Egret Marsh Stormwater Park Algal Turf Scrubber® 319(h) Grant

Quarterly Performance Report
Quarter Four
Final Report
September 2011

Contract # G0143

Prepared for:

Indian River County and
Florida Department of Environmental Protection

Prepared by:

HydroMentia
WATER TREATMENT TECHNOLOGIES

HydroMentia, Inc.
3233 SW 33rd Road, Suite 201
Ocala, FL 34474

October, 2011







TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Egret Marsh Stormwater Park (EMSP), which is owned and operated by Indian River County, Florida, encompasses about 35 acres of land in the central part of the county. Built upon an old Construction Debris Landfill, the park includes a stormwater treatment train composed of 4.6 acres of Algal Turf Scrubber® (ATS™) followed by 14.4 acres of receiving ponds/wetlands. The source water is taken from the Lateral D Canal, which is a tributary to the Main Canal Network which drains agricultural and urban lands within Central and Western Indian River County.

The EMSP was designed with the intent of 1) providing effective, long term, sustainable nutrient removal and recovery from a constant flow (circa 10 MGD) of enriched water from the Main Canal Network, and 2) establishing a restored habitat amenable to the development and sustenance of diverse ecosystems, which would serve as feeding, roosting and breeding habitat for native plants, birds, fish and other wildlife, including threatened species such as the wood stork. Strategically, the stormwater treatment train associated with EMSP was developed primarily to facilitate both removal and recovery of soluble nutrients, and to work in concert with the County's downstream Main Canal screening facility which was designed to remove particulate nutrients associated with larger solids, such as floating and submerged aquatic vegetation, and miscellaneous debris. In combination, these two facilities substantially contribute to the protection and restoration of the receiving waters of the Indian River Lagoon, and accordingly are significant contributors to the County's plan to comply with existing and anticipated pollutant load removal requirements, such as those attendant with Total Maximum Daily Load (TMDL) allocations[1].

One continuous year of monitoring of the EMSP treatment train commenced on August 16, 2010. High level monitoring requirements are provisions delineated within the 319(h) grant per the Federal Clean Water Act (CWA), as issued to Indian River County, and administered by the Florida Department of Environmental Protection (FDEP)—DEP Agreement G0143. During the one year monitoring period the system functioned in general conformity with expectations, demonstrating the ability to reduce nutrients at high rates of areal removal, while facilitating recovery through periodic harvesting (28 harvest events during the period) and accordingly, generation of a viable product (compost), thereby allowing high level of nutrient accountability and reuse.

This final report includes review and analysis of data compiled from the monitoring period Quarter 1 (Q1) through Quarter 4 (Q4). Monitoring was conducted between the commencement date of August 16, 2010 through August 29, 2011. As noted within the main body of this report, recorded historical nutrient levels for the monitoring period are considerably higher than those actually documented during the four quarter period, particularly as related to total phosphorus. Nutrient levels were noted to increase during the final three weeks of the monitoring period, commensurate with increased rainfall and runoff/seepage. The lower than expected influent nutrient loads are likely related to the

[1] The Total Maximum Daily Load program finds genesis from section 303(d) of the Clean Water Act or CWA (PL92-500). It refers to the maximum loading allowable of determined specific pollutants, such as nutrients, that would not result in water quality degradation of impaired water bodies as designated and listed by appropriate authorized institutional entity.

lower than anticipated rainfall for the monitoring period, which was 51% below historical levels.[2]

- Nutrient load reduction associated with the EMSP stormwater treatment train is displayed in Table ES-1. Removals through Q1 was 339 pounds (49.0%) of total phosphorus and 940 pounds (15.8%) of total nitrogen; through Q2 was 96 pounds (33.4%) of total phosphorus and 1,247 pounds (22.9 %) of total nitrogen; through Q3 was 112 pounds (37.8%) of total phosphorus and 313 pounds (7.1%) of total nitrogen; and through Q4 was 930 pounds (54.1%) of total phosphorus and 2,778 pounds (21.3 %) of total nitrogen. For the full year's monitoring period there was a total reduction of 1,477 pounds (49.4%) of total phosphorus and 5,278 pounds (18.3%) of total nitrogen.

- Also as noted in Table ES-1, the average total phosphorus influent concentrations for Q1 was 0.100 mg/L; the average total phosphorus influent concentration for Q2 was 0.042 mg/L; the average total phosphorus influent concentration for Q3 was 0.043 mg/L; and the average total phosphorus influent concentration for Q4 was 0.173 mg/L The average total phosphorus effluent concentration for Q1 was 0.051 mg/L: the average total phosphorus effluent concentration for Q2 was 0.027 mg/L; the average total phosphorus effluent concentration for Q3 was 0.027 mg/L; the average total phosphorus effluent concentration for Q4 was 0.085 mg/L. For the full year's monitoring period the average total phosphorus influent was 0.101 mg/L and the average total phosphorus effluent was 0.053 mg/L.

- Also as noted in Table ES-1, the average total nitrogen influent concentrations for Q1 was 0.86 mg/L; the average total nitrogen influent concentration for Q2 was 0.80 mg/L; the average total nitrogen influent concentration for Q3 was 0.65 mg/L; and the average total nitrogen influent concentration for Q4 was 1.26 mg/L The average total nitrogen effluent concentration for Q1 was 0.74 mg/L; the average total nitrogen effluent concentration for Q2 was 0.61 mg/L; the average total nitrogen effluent concentration for Q3 was 0.61 mg/L; and the average total nitrogen effluent concentration for Q4 was 1.04 mg/L. For the full year's monitoring period the average total nitrogen influent was 0.95 mg/L and the average total nitrogen effluent was 0.79 mg/L.

- The lower phosphorus and nitrogen reductions noted through Q2 and Q3 when compared to Q1 is attributable to both lower nutrient concentrations within the influent and lower water temperatures (which impacts algal turf production). During Q4, with the return of higher temperatures and higher nutrient concentrations, higher phosphorus and nitrogen reductions were documented.

[2] Drought conditions during the Q3 period were defined as "Extreme" by the US Drought Monitor http://drought.unl.edu/dm/archive.html

- In addition, during the latter stages of Q1 and throughout Q2 and Q3, and during the early weeks of Q4, water was impounded within the Lateral D Canal, resulting in recycling of water through the EMSP treatment train. Through the retreatment of this recycled water, the levels of available nutrients were reduced to the extent that algal turf production and nutrient mass removals were substantially reduced. When these waters were released during the final weeks of Q4, the nutrient levels increased and the system responded with higher levels of performance.

- During the four quarter period, the ATS™ removed 739 pounds of the total phosphorus removal of 1,477 pounds by the system, or 50.0% of the total phosphorus removed.

- During the four quarter period, the ATS™ removed 2,770 pounds of the total nitrogen removal of 5,278 pounds by the system, or 52.5% of the total nitrogen removed.

- Essentially all of the nitrogen and phosphorus removed by the ATS™, as calculated from water quality and flow data was accounted for within the 148,765 dry pounds of algal turf biomass recovered during 28 harvests over Q1 through Q4.

- The EMSP treatment train provided substantial removal during the four quarter period of ammonia-N at 2,086 pounds (70.7%), of which the ATS™ provided removal of 1,399 pounds (47.4%) and the pond system 687 pounds (23.3%). (Table ES-2).

- The EMSP treatment train provided substantial percentage removal during the four quarter period of nitrate + nitrite-N at 44.6% or 989 pounds. The ATS™ during the fourth quarter however contributed 448 pounds of nitrate-N through active nitrification, and therefore provided over the monitoring period a minimal net nitrate + nitrite-N removal of 50 pounds, or 2.3% removal. The pond/wetland system provided the majority of the nitrate + nitrite-N removal at 939 pounds (42.3%). (Table ES-2)

- The EMSP treatment train provided modest percentage removal during the four quarter period of organic-N at 9.2% or 2,200 pounds. The ATS™ provided 1,319 pounds (5.5%) of organic-N removal while the pond/wetland system provided 881 pounds (3.7%) of organic-N removal. (Table ES-2)

Table ES-1: Q1 through Q4 Total Phosphorus and Total Nitrogen Concentrations and Mass Removals Egret Marsh Stormwater Park

Sampling Period Ending	Average Total Phosphorus Concentrations (mg/L)			Average Total Nitrogen Concentrations (mg/L)		
	Influent	ATS™ Effluent	Ponds Effluent	Influent	ATS™ Effluent	Ponds Effluent
9/13/2010	0.170	0.121	0.083	1.15	0.94	0.91
10/11/2010	0.081	0.052	0.043	0.89	0.59	0.69
11/8/2010	0.049	0.027	0.026	0.54	0.63	0.62
Q1 Mean	**0.100**	**0.067**	**0.051**	**0.86**	**0.72**	**0.74**
12/6/2010	0.026	0.033	0.018	0.83	0.89	0.79
1/3/2011	0.041	0.038	0.035	0.80	0.60	0.50
1/28/2011	0.059	0.048	0.029	0.76	0.69	0.55
Q2 Mean	**0.042**	**0.040**	**0.027**	**0.80**	**0.73**	**0.61**
2/28/11	0.043	0.030	0.024	0.68	0.55	0.56
3/28/11	0.042	0.026	0.027	0.78	0.68	0.68
4/25/11	0.045	0.037	0.029	0.55	0.61	0.58
Q3 Mean	**0.043**	**0.031**	**0.027**	**0.65**	**0.61**	**0.61**
5/23/11	0.051	0.036	0.025	0.70	0.59	0.68
6/20/11	0.069	0.048	0.043	0.80	0.90	0.58
7/18/11	0.344	0.294	0.137	1.56	1.41	1.07
8/22/11	0.167	0.125	0.065	1.70	1.63	1.36
Final week 8/29/11	0.234	0.193	0.153	1.56	1.68	1.47
Q4 Mean	**0.173**	**0.139**	**0.085**	**1.26**	**1.24**	**1.04**
Q1 through Q4 Mean	**0.101**	**0.079**	**0.053**	**0.95**	**0.88**	**0.79**

Sampling Period Ending	Total Phosphorus Mass Removal (lbs)			Total Nitrogen Mass Removal (lbs)		
	ATS™	Ponds	Total Treatment Train	ATS™	Ponds	Total Treatment Train
9/13/2010	119	78	197	541	44	585
10/11/2010	67	19	86	697	-198	499
11/8/2010	53	3	56	-160	16	-144
Q1 Cumulative	**239**	**100**	**339**	**1,078**	**-138**	**940**
12/6/2010	-16	32	16	-127	221	94
1/3/2011	8	6	14	472	213	685
1/31/2011	26	40	66	175	293	468
Q2 Cumulative	**18**	**78**	**96**	**520**	**727**	**1,247**
2/28/11	31	13	44	132	-7	125
3/28/11	35	-2	34	263	-15	248
4/25/11	17	18	34	-139	78	-60
Q3 Cumulative	**83**	**29**	**112**	**256**	**56**	**313**
5/23/11	35	22	57	243	51	293
6/20/11	52	11	63	-167	320	153
7/18/11	140	318	458	450	688	1,138
8/22/11	140	157	297	411	683	1,094
Final week 8/29/11	32	23	55	-21	121	100
Q4 Cumulative	**399**	**531**	**930**	**916**	**1,863**	**2,778**
Q1 through Q4	**739**	**738**	**1,477**	**2,770**	**2,508**	**5,278**

Table ES-2: Q1 through Q4 Ammonia-N, Nitrate-Nitrite-N and Organic-N Dynamics -- Egret Marsh Stormwater Park

	Sampling Period				
Sampling Period Ending	**Q1**	**Q2**	**Q3**	**Q4**	**Total Period**
Influent Ammonia-N(mg/L)	0.12	0.07	0.01	0.18	0.11
ATS™ Effluent Ammonia-N (mg/l)	0.05	0.04	0.00	0.10	0.06
Pond Effluent Ammonia-N (mg/l)	0.03	0.01	0.00	0.06	0.03
ATS™ Ammonia-N removal lb (% removal)	488 (59.1%)	215 (44.1%)	46 (66.7%)	651 (41.4%	1,399 (57.4%)
Pond Ammonia-N removal lb (% removal)	124 (15.1%)	209 (42.8%)	21 (30.4%)	333 (21.2%)	687 (23.3%)
System Ammonia-N removal lb (%removal)	612 (74.2%)	423 (86.9%)	67 (97.1%)	984 (62.6%)	2,086 (70.7%)
Influent Nitrate + Nitrite -N (mg/L)	0.08	0.09	0.03	0.09	0.08
ATS™ Effluent Nitrate + Nitrite-N (mg/l)	0.04	0.07	0.02	0.16	0.08
Pond Effluent Nitrate + Nitrite-N (mg/l)	0.02	0.02	0.01	0.12	0.05
ATS™ Nitrate + Nitrite-N removal lb (% removal)	254 (46.4%)	159 (26.0%)	86 (44.6%)	-448 (-51.4%)	50 (2.3%)
Pond Nitrate + Nitrite-N removal lb (% removal)	165 (30.1%)	277 (44.5%)	49 (25.4%)	454 (52.1%)	939 (42.3%)
System Nitrate + Nitrite-N removal lb (%removal)	419 (76.5%)	432 (70.5%)	135 (70.0%)	6 (0.7%)	989 (44.6%)
Influent Organic-N (mg/L)	0.66	0.64	0.61	0.99	0.76
ATS™ Effluent Organic-N (mg/l)	0.63	0.62	0.59	0.98	0.74
Pond Effluent Organic-N (mg/l)	0.70	0.58	0.60	0.87	0.71
ATS™ Organic-N removal lb (% removal)	335 (7.4%)	146 (3.3%)	125 (2.9%)	713 (3.0%)	1,319 (5.5%)
Pond Organic-N removal lb (% removal)	-427 (-9.4%)	245 (5.7%)	-12 (-0.2%)	1,075 (4.5%)	881 (3.7%)
System Organic-N removal lb (%removal)	-92 (-2.0%)	391 (9.0%)	113 (2.7%)	1,788 (7.5%)	2,200 (9.2%)

- The ATS™ increased daytime dissolved oxygen (DO) within the Lateral D source water during Q1 through Q4 from an average 7.29 mg/L to 12.67 mg/L, or a contribution of 161,410 pounds of DO.

- Daytime dissolved oxygen levels during Q1 through Q4 within the pond/wetland system were sustained at an average of 8.58 mg/L

- The ATS™ increased daytime pH during Q1 through Q4 within the Lateral D source water from and average of 7.75 to 8.33, with the pond system modulating daytime pH to an average of 8.06.

- The ATS™ increased daytime water temperature during Q1 through Q4 within the Lateral D source water from an average of 24.7° C to 26.5° C, with the pond system modulating daytime water temperature to an average of 24.9° C.

- During Q1 through Q4 the pond system provided valuable habitat to native birds, wildlife, plants and fish, establishing a valuable ecostructure which supported roosting, breeding and feeding activity for several native species, with one section of the system purposely developed to promote use by the threatened wood stork.

- The four quarter period was characterized by below normal rainfall (historical average of 57.9 inches Vs. actual 29.4 inches for the monitoring period). Flow into the system averaged 9.86 MGD. Water temperatures over the four quarters were near historical levels. These trends are noted in Table ES-3.

- For Q1 through Q4, the influent total phosphorus was 53.5% below the historical average for the period—(0.217 mg/L Vs. 0.101 mg/L); while the influent nitrogen level was 24.6% below the historical average for this same period. (1.26 mg/L Vs 0.95 mg/l). System effluent total phosphorus levels were also well below projected levels[3] --Table ES-4-- (0.107 mg/L Vs. 0.053 mg/L). Projected and actual total nitrogen effluent levels were similar at 0.78 mg/L Vs. 0.79 mg/L.

- For Q1 through Q4 the average effluent total nitrogen concentration of 0.79 mg/L was lower (hence of higher quality) than the preliminary TMDL water quality target nitrogen levels of 0.98 mg/l for the estuarine segments of the Indian River Lagoon[4], while the Q1 through Q4 average effluent total phosphorus concentration of 0.053 mg/L was close to the preliminary TMDL target phosphorus levels of 0.050 mg/l for the estuarine segments of the Indian River Lagoon.

- The ATS™ provided a total phosphorus areal removal rate of 17.46 g/m^2-yr for

[3] "Egret Marsh 10 MGD Algal Turf Scrubber® Final Basis of Design Report" July, 2005. Prepared for Indian River County by HydroMentia, Inc.
[4] Note that the influent total nitrogen averaged only 0.95 mg/L which was also below the TMDL target of 0.98 mg/L.

Q1 through Q4, as compared to 5.55 g/m^2-yr for the pond/wetland system and 8.42 g/m^2-yr for the entire treatment train for the same period. These results are summarized in Table ES-5

- The ATS™ provided a total nitrogen areal removal rate of 65.47 g/m^2-yr for the Q1 through Q4, as compared to 18.86 g/m^2-yr for the pond system and 30.11 g/m^2-yr for the entire treatment train. These results are summarized in Table ES-6.

- The EMSP system provided substantial reduction of color during the last weeks of Q4, when influent color from 7/18/11 to 8/22/11 averaged 350 pcu, and was reduced to 175 pcu within the ATS™ effluent and further reduced to 125 pcu within the final effluent. Reduction of color is important in protecting the photic zone associated with seagrass beds within the Indian River Lagoon,

- Most of the harvested biomass was wet processed, by blending with mulch and windrow composted. It is estimated that well over 100 tons of compost was generated.

- Several thousand dry pounds of the harvested algal turf material was converted to a fuel oil, to be analyzed by Statoil, a Norwegian energy company. Several gallons of algae-oil was produced from this algal turf biomass and delivered to Statoil for analysis.

- About 100 dry pounds of the harvested algal turf material was evaluated by one of the nation's leading paper producers for use in paper production.

- System design and operations were effective in the reliable reduction of nutrients and the general improvement of water quality. Based upon the one year's experience, a few design and operational adjustments are recommended for future projects, including consideration of different materials for floway surface, modifications to distribution system design to facilitate more efficient cleaning and control, and revisions to the Duperon Rake mechanism to enhance the rate and efficiency of removal of harvested algae.

- The data was applied to the ATS™ Design Model (ATSDEM) to determine the reliability of projecting treatment effectiveness of a range of environmental conditions. The model was calibrated and verified, showing a high degree of reliability.

- Based upon the model refinements, future projections under historical conditions were adjusted for the system to circa 2,000 lb/year total phosphorus and 7,000 lb/yr total nitrogen.

Table ES-3: Q1 through Q4 Flows, Rainfall, and Water Temperature Historical as Compared to Actual-- Egret Marsh Stormwater Park

Sampling Period Ending	Average Daily Flow (MGD)	Historical Rainfall (inches)	Actual Rainfall (inches)	Historical Average Influent Water Temperature (°C)	Actual Average Influent Water Temperature (°C)
9/13/10	9.88	6.7	5.3	28.6	29.6
10/11/10	9.75	6.4	2.0	26.9	27.5
11/8/10	9.88	4.4	0.5	24.7	23.6
Q1	**9.84**	**17.5**	**7.8**	**26.7**	**26.9**
12/6/10	9.68	2.2	0.3	23.5	20.4
1/3/11	9.87	1.9	2.0	18.9	15.9
1/31/11	9.74	2.2	1.5	19.1	16.7
Q2	**9.76**	**6.3**	**3.8**	**20.5**	**17.8**
2/28/11	9.79	2.5	1.5	19.9	21.0
3/28/11	9.90	3.6	2.0	22.6	22.3
4/25/11	9.90	3.4	0.3	24.3	25.3
Q3	**9.77**	**9.5**	**3.8**	**22.3**	**22.9**
5/23/11	9.69	4.4	2.2	27.6	26.9
6/20/11	9.96	7.6	3.3	28.4	28.7
7/18/11	10.00	7.1	3.0	29.4	28.8
8/22/11	10.04	-	4.6	29.1	29.9
8/29/11	10.97	7.3	1.0	29.1	30.9
Q4	**9.98**	**57.9**	**14.1**	**28.8**	**28.8**
Total Period	**9.86**	**57.9**	**29.4**	**25.2**	**24.7**

Table ES-4: Q1through Q4 Influent and Effluent Total Phosphorus and Total Nitrogen Concentrations Historical and Projected as Compared to Actual-- EMSP

Sampling Period Ending	Historical Influent Total Phosphorus (mg/L)	Actual Influent Total Phosphorus (mg/L)	Projected ATS™ Total Phosphorus Effluent (mg/L)	Actual ATS™ Total Phosphorus Effluent (mg/L)	Actual Pond Total Phosphorus Effluent (mg/L)
9/13/10	0.340	0.170	0.164	0.121	0.083
10/11/10	0.305	0.081	0.160	0.052	0.043
11/8/10	0.225	0.049	0.121	0.027	0.026
Q1	**0.290**	**0.100**	**0.148**	**0.067**	**0.051**
12/6/11	0.190	0.026	0.096	0.033	0.018
1/3/11	0.120	0.041	0.084	0.038	0.035
1/31/11	0.110	0.059	0.075	0.048	0.029
Q2	**0.140**	**0.042**	**0.085**	**0.040**	**0.027**
2/28/11	0.140	0.043	0.082	0.030	0.024
3/28/11	0.140	0.042	0.071	0.026	0.027
4/25/11	0.140	0.045	0.057	0.037	0.029
Q3	**0.140**	**0.043**	**0.070**	**0.031**	**0.027**
5/23/11	0.180	0051	0.072	0.036	0.025
6/20/11	0.310	0.068	0.134	0.048	0.043
7/18/11	0.310	0.334	0.137	0.294	0.137
8/22/11	0.330	0.167	0.158	0.125	0.065
8/29/11	0.330	0.234	0.158	0.193	0.153
Q4	**0.283**	**0.166**	**0.135**	**0.139**	**0.085**
Total Period	**0.217**	**0.101**	**0.107**	**0.079**	**0.053**

Sampling Period Ending	Historical Influent Total Nitrogen (mg/L)	Actual Influent Total Nitrogen (mg/L)	Projected ATS™ Total Nitrogen Effluent (mg/L)	Actual ATS™ Total Nitrogen Effluent (mg/L)	Actual Pond Total Nitrogen Effluent (mg/L)
9/13/10	1.48	1.15	0.70	0.94	0.91
10/11/10	1.62	0.89	0.82	0.59	0.69
11/8/10	1.49	0.54	0.94	0.63	0.62
Q1	**1.53**	**0.86**	**0.82**	**0.72**	**0.74**
12/6/11	0.98	0.83	0.70	0.89	0.79
1/3/11	0.90	0.80	0.71	0.60	0.50
1/31/11	1.04	0.76	0.86	0.69	0.55
Q2	**0.97**	**0.80**	**0.76**	**0.73**	**0.61**
2/28/11	1.02	0.61	0.72	0.55	0.56
3/28/11	1.24	0.78	0.88	0.67	0.68
4/25/11	0.92	0.55	0.70	0.61	0.58
Q3	**1.06**	**0.65**	**0.77**	**0.61**	**0.61**
5/23/11	1.04	0.70	0.81	0.59	0.58
6/20/11	1.64	0.80	0.77	0.90	0.75
7/18/11	1.59	1.56	0.70	1.41	1.07
8/22/11	1.48	1.70	0.81	1.63	1.36
8/29/11	1.48	1.56	0.81	1.68	1.47
Q4	**1.44**	**1.26**	**0.78**	**1.24**	**1.04**
Q1 through Q4	**1.26**	**0.95**	**0.78**	**0.88**	**0.79**

Table ES-5: Q1 through Q4 Total Phosphorus Areal Removal Rates and Percent Mass Removals--Egret Marsh Stormwater Park

	Total Phosphorus Areal Removal Rate (g/m^2-day)			Total Phosphorus Percent Mass Removal (%)		
Sampling Period Ending	**ATS™**	**Ponds**	**Total Treatment Train**	**ATS™**	**Ponds**	**Total Treatment Train**
9/13/10	37.80	7.94	15.19	30.3%	20.0%	50.3%
10/11/10	21.48	1.93	6.63	36.4%	10.3%	46.7%
11/8/10	16.75	0.24	4.23	46.3%	2.1%	48.5%
Q1	**25.36**	**3.37**	**13.02**	**34.6%**	**14.4%**	**49.0%**
12/6/11	-4.99	3.27	1.28	-26.6%	54.9%	28.3%
1/3/11	2.35	0.52	1.06	7.8%	6.8%	14.6%
1/31/11	8.38	4.05	5.06	19.4%	29.6%	49.0%
Q2	**1.90**	**2.65**	**2.47**	**6.2%**	**27.2%**	**33.4%**
2/28/11	9.91	1.30	3.38	31.4%	13.0%	44.5%
3/28/11	11.27	-0.18	2.59	36.8%	-1.8%	35.0%
4/25/11	5.33	1.74	2.64	16.5%	17.4%	33.9%
Q3	**8.84**	**0.97**	**2.87**	**28.1%**	**9.7%**	**37.8%**
5/23/11	11.08	2.26	4.39	30.2%	19.3%	49.5%
6/20/11	16.60	1.11	4.86	32.5%	6.8%	39.3%
7/18/11	44.50	32.24	35.24	17.4%	39.6%	56.9%
8/22/11	44.50	15.85	18.29	28.6%	32.0%	60.6%
8/29/11	36.64	9.54	17.15	21.5%	15.7%	37.1%
Q4	**28.30**	**11.98**	**15.92**	**23.2%**	**30.9%**	**54.1%**
Q1 through Q4	**17.46**	**5.55**	**8.42**	**24.7%**	**24.7%**	**49.4%**

Table ES-6: Q1 through Q4 Total Nitrogen Areal Removal Rates and Percent Mass Removals-Egret Marsh Stormwater Park

	Total Nitrogen Areal Removal Rate (g/m^2-day)			**Total Nitrogen Percent Mass (Removal (%)**		
Sampling Period Ending	**ATS™**	**Ponds**	**Total Treatment Train**	**ATS™**	**Ponds**	**Total Treatment Train**
9/13/10	171.99	4.43	44.87	20.4%	1.7%	22.1%
10/11/10	223.32	-20.15	38.61	34.3%	-9.7%	24.6%
11/8/10	-51.19	1.61	-11.13	-12.9%	1.3%	-11.6%
Q1	**114.11**	**-4.67**	**24.00**	**18.1%**	**-2.3%**	**15.8%**
12/6/11	-40.42	22.47	7.29	-6.8%	11.8%	5.0%
1/3/11	120.20	21.53	52.58	25.4%	11.5%	36.9%
1/31/11	56.08	29.88	36.20	10.1%	16.9%	27.0%
Q2	**54.94**	**24.69**	**32.00**	**9.5%**	**13.4%**	**22.9%**
2/28/11	42.14	-0.71	9.63	9.5%	-0.50%	9.0%
3/28/11	83.67	-1.49	19.06	14.6%	-0.81%	13.7%
4/25/11	-44.28	7.97	-4.64	-11.1%	6.3%	-4.8%
Q3	**26.70**	**2.09**	**8.04**	**5.7%**	**1.4%**	**7.1%**
5/23/11	77.43	5.13	22.57	15.3%	3.1%	18.4%
6/20/11	-53.24	32.47	11.79	-9.0%	17.2%	8.2%
7/18/11	143.55	69.77	87.58	12.4%	18.9%	31.3%
8/22/11	130.60	55.34	83.88	8.3%	13.7%	22.0%
8/29/11	-26.76	49.21	31.33	-2.1%	12.1%	10.0%
Q4	**64.97**	**42.05**	**47.56**	**7.0%**	**14.3%**	**21.3%**
Q1 through Q4	**65.47**	**18.86**	**30.11**	**9.6%**	**8.7%**	**18.3%**

SECTION 1. PROJECT BACKGROUND

In an effort to establish a program which facilitates effective removal and recovery of nutrient pollutants associated with stormwater runoff attendant with the network of canals managed and operated by the Indian River Farms Water Control District (IRFWCD), Indian River County, Florida (County) has actively pursued application of technologies which incorporate innovative mechanical and biological features into an integrated process train. One such facility, Egret Marsh Stormwater Park (EMSP), has been constructed in the central region of the county, just south of SR60 and east of I-95. The central nutrient control unit associated with the EMSP is a 4.6 acre Algal Turf Scrubber® (ATS™).

To assist in the funding and documentation of this project, the County pursued and secured a grant through EPA's 319(h) program, per the Clean Water Act, as administered by the Florida Department of Environmental Protection (FDEP). The terms of this grant are delineated within an agreement between the County and FDEP—DEP Agreement G0143. Included in these terms are requirements to monitor and analyze performance data, submit quarterly progress reports; and prepare a draft and final annual report. The County has prepared and submitted, through a contract with HydroMentia, Inc. of Ocala, Florida, a Quality Assurance Program Plan (QAPP), which includes a Monitoring Plan and Schedule; protocols for sampling and handling samples; procedures for field monitoring; Quality Assurance requirements for Laboratory(ies) conducting the analytical work; and a strategy for data compilation and documentation.

As part of their contracted responsibilities, HydroMentia in coordination with the County's staff has implemented the QAPP and Monitoring Program. All data used in developing this quarterly report[5], which covers the four quarter period beginning August 16, 2010 and ending August 29, 2011 was generated in conformance with applicable sections of the Quality Assurance Program Plan and the Monitoring Plan.

Quarter Period	Beginning Date	Ending Date	Days
1	8/16/10	11/8/10	84
2	11/8/10	1/31/11	84
3	1/31/11	4/25/11	84
4	4/25/11	8/29/11	126
TOTAL	**8/16/10**	**8/29/11**	**378**

[5] Quarters for purposes of this project are 12 week periods for the first three periods, this allowing 3 -28 day data collection periods per quarter. The final quarter is 18 weeks.

SECTION 2. FACILITY LOCATION AND DESCRIPTION

Indian River County is located on the Atlantic (eastern) coast of south central Florida, contiguous to and between Brevard County to the north, St. Lucie County to the south, and Okeechobee and Osceola Counties to the west (Illustrations 1 and 2). Hydrologically, lands in western Indian River County served historically as a divide between the upper St. Johns River, which originated from Blue Cypress Lake and its associated wetlands, and the Kissimmee River Basin to the south (Illustration 2). These hydrological units were separated to some extent from the coastal regions and the barrier islands by a north-south coastal ridge[6], although during the summer rainy season, waters were distributed to the coast from these western reaches through seepage and through natural surface conduits, such as the Sebastian and St. Lucie Rivers. Hydrological communication between inland and coastal units therefore was maintained through these diffuse connections. It was this methodical and cyclical allocation of inland waters to the coastal regions that sustained both the estuarine characteristics of the estuarine/mangrove forests of the Indian River Lagoon and the wet prairie, lacustrine, hammock island and freshwater marsh ecosystems of the upper St. John's basin.

In an effort to reduce flooding impacts and render the western lands amenable to agricultural and residential development, institutional mechanisms were established (circa 1913) to allow formation of water control districts in Florida through Chapter 298 of the Florida Statutes. Consequently, a number of "298" water control districts were established within Indian River County, including the IRFWCD. Through the use of a network of canals, control structures and water storage areas, the IRFWCD manages surface water distribution within the central portion of Indian River County to ensure protection from flooding, and water availability for irrigation (Illustration 3).

With changes in the scheduling, water quality and magnitude of flows from inland areas to the Indian River Lagoon, as facilitated by the water control districts, combined with agricultural, urban, suburban and industrial development along the coast, there have been documented notable ecological disruptions within the lagoon, which in turn have had deleterious impacts upon fisheries, water quality, and ecological stability. The comparatively heavy nutrient and solids loads associated with the canal systems contribute significantly to these impacts.

Presently, the surface waters transported through the Main Canal system, including those within Lateral D may be characterized as moderately mineralized, tannin colored, moderately hard, nutrient enriched freshwaters, with no indication of substantial industrial type pollutants, except, on occasion, slightly elevated mercury levels[7]. Pre-design water quality analysis by HydroMentia showed no evidence of organochloride or organophosphorus type pesticides/herbicides, or any heavy metals levels above FDEP drinking water standards, except for lead, which on one occasion was noted to be at 25 ppb, which is higher than the standard of 15 ppb[8]. The principal pollutant concern is

[6] This coastal ridge represents relict shorelines, and is located approximately along the I-95 corridor.
[7] The presence of mercury within Florida's freshwaters has been associated with atmospheric sources related to Power Station emissions
[8] Other than one case of elevated lead levels noted by HydroMentia, no history of elevated lead were found.

associated with the nutrients nitrogen and phosphorus and, during periods of heavy rainfall and runoff/seepage, with color, suspended solids and at times dissolved oxygen.

The Egret Marsh Stormwater Park (EMSP), located at the southeast corner of the intersection of 74th avenue and 4th street, east of I-95 and south of SR60 (Illustration 4) was designed with the intent of using available land owned by the County to enhance water quality and optimize nutrient reduction from agricultural and urban runoff collected within the Lateral D Canal, which is part of the IRFWCD Main Canal system that ultimately discharges into the Indian River Lagoon (Illustration 3). Lateral D drains water from the inland (west central) regions of Indian River County, which is predominantly agricultural (primarily citrus).

The County identified the need for water quality improvement within these surface waters to satisfy possible regulatory requirements associated with the EPA/FDEP Total Maximum Daily Load (TMDL) Program[9], and to enhance water quality and overall value of the Indian River Lagoon, which stands as a central contributor to the region's economy and quality of life.

The Egret Marsh Stormwater Park was also designed to provide important habitat for native fish and wildlife, as well as an educational (both teaching and research) and a recreational resource. The facility is built upon an old construction debris landfill and borrow site of about 35 acres (Illustration 5). There are four major components associated with the EMSP (Illustrations 6 and 7). In the Treatment Train sequence they are:

1. Pumping System at Lateral D.
2. A 4.58 acre Algal Turf Scrubber® or ATS™ which serves as the primary water treatment system
3. A series of ponds and associated littoral zones which serve to further polish the effluent from the ATS™.
4. A final wetland/pond arrangement hydraulically connected to the other ponds, which is designed to entice use by the wood stork, a threatened species in Florida, while providing additional polishing of the pond effluent. The combined area of the ponds and the Wood Stork Habitat is about 14.4 acres. Noted in Illustration 8 are a group of wood storks within this designed habitat.

Effluent from the Wood Stork Habitat wetland/pond is released back into the networks of IRFWCD Canal via Lateral C Canal, which is also a tributary to the Main Canal. There are three composite water quality monitoring stations associated with the approved Monitoring Plan (Illustration 9)—these being:

- Station 01: Influent from Lateral D pump station to ATS™ Headworks

[9] Total Maximum Daily Load for North and Central Indian River Lagoon and the Banana River, Lagoon, Florida, April, 2007. Region 4, USEPA, Atlanta, Georgia. Note that these load limits are still under review, and recent assessments include suggested TMDL changes to reflect expressed conclusions that water clarity has improved to the extent that conditions are amenable to support and expansion of sea grasses.

- Station 02: ATS™ Effluent at ATS™ Effluent and Harvest Diversion Box
- Station 03: Final Effluent control structure after polishing through the pond system.

In addition, composite samples are taken from the water directed into the Diverted Harvest Flow Solids Settling Ponds during harvest (Station 04). Algal Turf tissue samples are taken monthly as composited grab samples with each harvest. A general schematic of the monitoring strategy is noted in Figure 1.

The historical ranges of key water quality constituents within the Main Canal system are noted in Table 1. Also included in Table 1 and Table 2, are the average concentrations associated with the period Q1 through Q4 compared to the historical concentrations. As shown, during the monitoring period, influent nutrient levels were substantially lower than average historical levels. This had a noticeable impact upon algal turf production and the level of nutrient reduction, as discussed throughout the text.

During the monitoring period, rainfall totaled only 29.4 inches, or only 51% of the historical average annual rainfall of 57.9 inches. The drought conditions during much of this monitoring period were severe, and during the Q3 period were defined as “Extreme” by the US Drought Monitor (Figure 2). It was not until July of 2011 (Q4) that the rainfall resumed to near normal rates.

Because of the drought conditions, during much of the monitoring period the IRFWCD retained the water within the Lateral D canal, largely to accommodate upstream agricultural irrigation needs. During this period of retention, effluent from the facility which was discharged to Lateral C could not proceed into the Main canal, but rather became incorporated with the impounded Lateral D waters. This resulted in recirculation of flows through the EMSP facility, and the commensurate lowering of available nutrients and color during the drought period. This retention/recirculation period extended approximately from September 2010 to late June 2011. The impacts are noted in Table 1 under the “Q1 to early Q4” heading, and in Table 2, where nutrient levels are noted to be substantially lower than the historical average—particularly in the case of total phosphorus. In addition, color within the canal was also reduced to well below historical averages, and even below the historical minimum. During this drought period, runoff was minimal, and the base flows into the canal were presumed to be mostly deeper groundwaters, which tend to show higher conductivities, high alkalinities, and higher pH levels than surface runoff or shallow groundwater.

The ATS™ during the retention/recirculation period, in spite of low concentrations, continued to provide notable reduction of both nitrogen and phosphorus, although as expected because of the low concentrations, algal turf production was comparatively low. During the drought period, the pond/wetland system which received the ATS™ effluent prior to final discharge, provided some further water quality polishing, but was outpaced in terms of aerial removal rate (ARR) and mass removal by the ATS™. The pond/wetland system however, provided high quality aquatic habitat for a diverse population of native fish and invertebrates, as well as birds and wildlife, and served to modulate pH and water temperature fluctuations associated with the ATS™ effluent.

Beginning in early July, 2011, wet season rainfall ended the severe drought period, and established a new dynamic within the canal network and within the EMSP facility. As runoff and shallow groundwater seepage began to move into the Lateral D canal, it became necessary for IRFWCD to release the impounded waters to the Main Canal, and eventually to the Indian River Lagoon. This resulted in elimination of the high quality impounded water, temporary lowering of canal levels and eventual refilling with higher nutrient, higher color water into the Lateral D canal. It also ended the long period of effluent recirculation, as Lateral C was now allowed hydraulic communication with the downstream Main Canal. As noted under the heading “Late Q4” in Table 1, rather dramatic increases were documented with total phosphorus and color, with noticeable upward shifts in total nitrogen and suspended solids. During this period of renewed rainfall/runoff, the ATS™ responded with higher levels of nutrient reduction and algal turf productivity. In addition, likely because of both runoff/seepage associate pollutants, and movement into the canal of stored groundwater with the lowering of canal levels as a result of the releases to the Main Canal, both dissolved oxygen levels and pH decreased, and there was noted an abundance of colloidal particles, which caused an sizable increase in color levels and silt deposition.

The increase in color and solids, along with the higher levels of biological activity, resulted in some release of solids within the ATS™ effluent. Many of these solids were noted to be biologically active as either algae fragments or micro-invertebrates. Consequently, the receiving polishing ponds/wetlands became more influential in nutrient reduction, as they served to eliminate the solids and associated nutrients within the ATS™ effluent through settling and through grazing/predation.

The system design showed an ability to adjust to substantial seasonal fluctuations in water quality and environmental conditions, with the polishing ponds/wetlands providing a more important treatment role during periods of heavy nutrient loading through management of residual biological solids and inorganic silts associated with the ATS™ effluent. During periods of low nutrient loading, treatment through the ATS™ was clearly predominant.

In addition to providing substantial nutrient management and recovery, the EMSP facility provides important reduction of color during the heavy loading periods—reduction from 243 pcu to 127 pcu during the late Q4 period per Table 1. Reduction of color is helpful in assuring adequate light penetration to the sea grass beds within the Indian River Lagoon, and is an element of importance in determining total maximum daily load (TMDL) allocations

Table 1: Historical Water Quality Characteristics Water Quality Characteristics Main Canal, IRFWCD Comparison with Monitoring Period (Q1 through Q4) Water Quality Characteristics Main Canal, IRFWCD and Process Effluents

	Average EMSP Influent levels			Average ATS™ Effluent levels			Average EMSP Effluent levels			HISTORICAL Lateral D Canal (Influent)		
Parameter	**Q1 to early Q4**	**Late Q4**	**Total Period**	**Q1 to early Q4**	**late Q4**	**Total Period**	**Q1 to earl y Q4**	**late Q4**	**Total Period**	**Average**	**Min**	**Max**
Rainfall (inches)	**15.3**	**14.1**	**29.4**	**-**	**-**	**-**	**-**	**-**	**-**	**57.9**	**-**	**-**
pH	7.83	7.49	7.75	8.40	8.12	8.34	8.21	7.61	8.07	7.36	6.28	8.61
Conductivity (MicroS/cm)	2,129	1,934	2,084	2,170	1,939	2,118	2,08	1,868	2,038	1,338	360	8,446
Total Phosphorus (mg/L)	0.061	0.225	0.101	0.045	0.198	0.079	0.03	0.115	0.053	0.210	0.030	0.730
Total Nitrogen (mg/L)	0.76	1.35	0.95	0.67	1.32	0.88	0.65	1.06	0.79	1.20	0.37	3.59
Total Suspended Solids (mg/L)	5.8	7.4	6.1	3.2	8.0	4.3	4.7	2.5	4.2	9	0	188
Volatile Suspended Solids (mg/L)	-	-	-	-	-	-	-	-	-	4	0	18
Alkalinity (mg/L as $CaCO_3$)	175	152	169	167	142	161	167	143	162	138	40	185
Hardness (mg/L as $CaCO_3$)	-	-	-	-	-	-	-	-	-	253	9	355
Calcium (mg/L)	-	-	-	-	-	-	-	-	-	59	3.8	420
Iron (mg/L)	-	-	-	-	-	-	-	-	-	0.73	0.19	1.30
Color (pcu)	49	243	99	44	127	64	44	97	55	125	80	180

Table 2: Nutrient Level Comparisons--Design Influent (Historical) vs. Actual Concentrations

Sampling Period Ending	Historical Influent Total Phosphorus (mg/L)	Actual Influent Total Phosphorus (mg/L)	Historical Influent Total Nitrogen (mg/L)	Actual Influent Total Nitrogen (mg/L)
9/13/10	0.340	0.170	1.48	1.15
10/11/10	0.305	0.081	1.62	0.89
11/8/10	0.225	0.049	1.49	0.54
Q1	**0.290**	**0.100**	**1.53**	**0.86**
12/6/11	0.190	0.026	0.98	0.83
1/3/11	0.120	0.041	0.90	0.80
1/31/11	0.110	0.059	1.04	0.76
Q2	**0.140**	**0.042**	**0.97**	**0.80**
2/28/11	0.140	0.043	1.02	0.61
3/28/11	0.140	0.042	1.24	0.78
4/25/11	0.140	0.045	0.92	0.55
Q3	**0.140**	**0.043**	**1.06**	**0.65**
5/23/11	0.180	0.051	1.04	0.70
6/20/11	0.310	0.069	1.64	0.80
7/18/11	0.310	0.344	1.59	1.56
8/22/11 and 8/29/11	0.330	0.167 / 0.234	1.48	1.70 / 1.56
Q4	**0.283**	**0.166**	**1.44**	**1.26**
Total Period	**0.217**	**0.101**	**1.26**	**0.95**

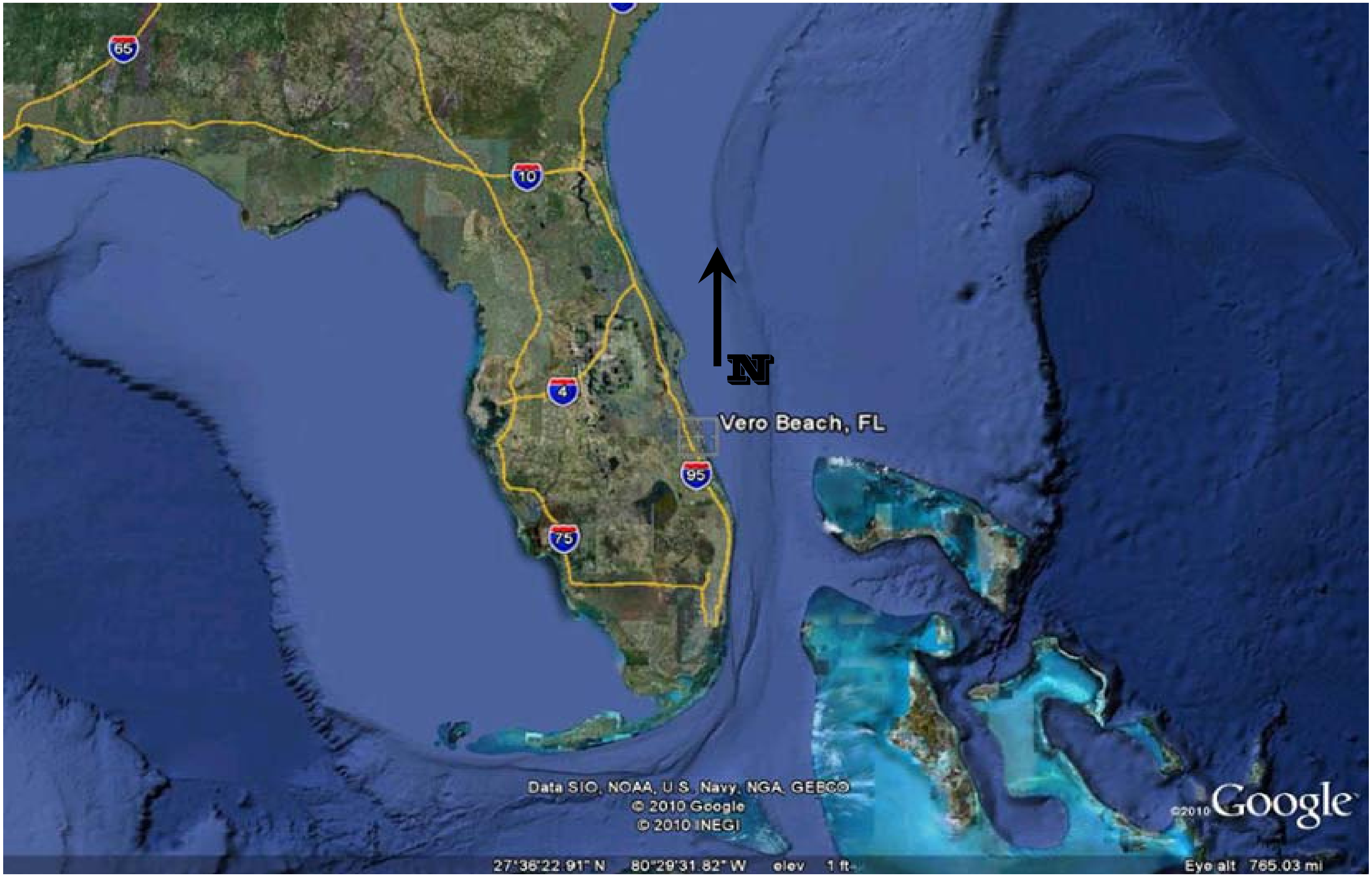


Illustration 1: Location Vero Beach, Florida

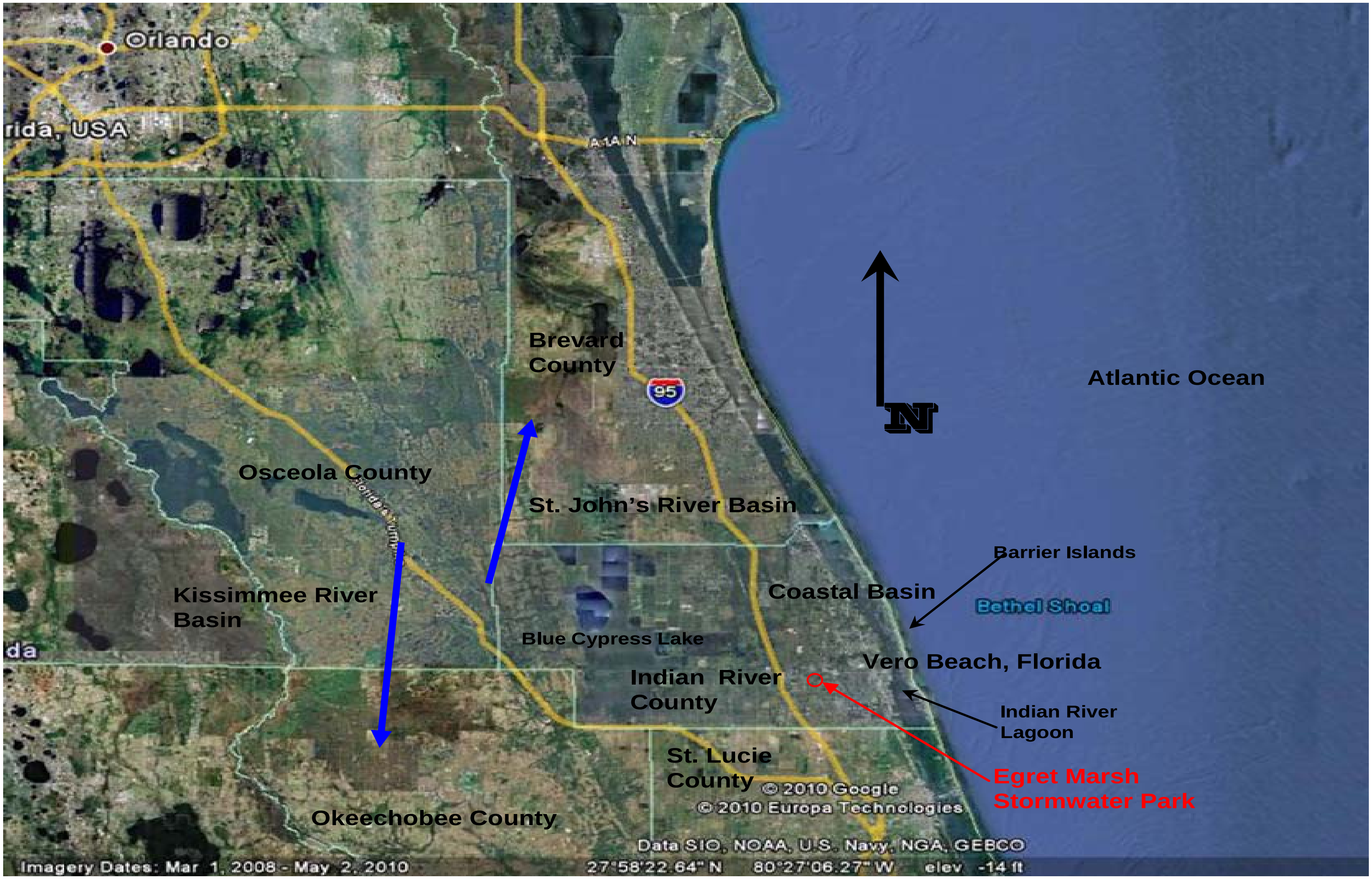


Illustration 2: Location Indian River County, Florida

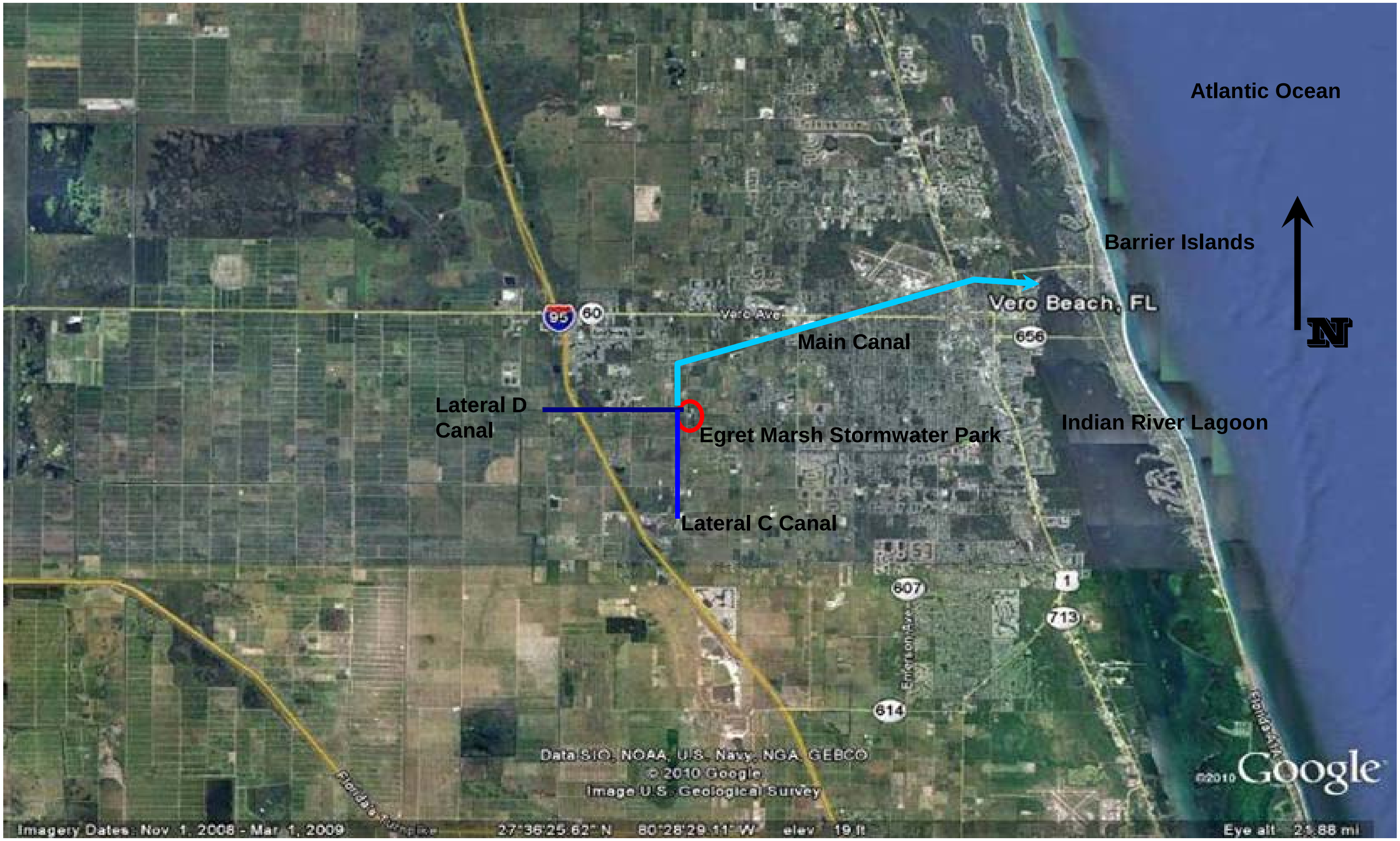


Illustration 3: Location Egret Marsh Stormwater Park and associated IRFWCD Main Canal System

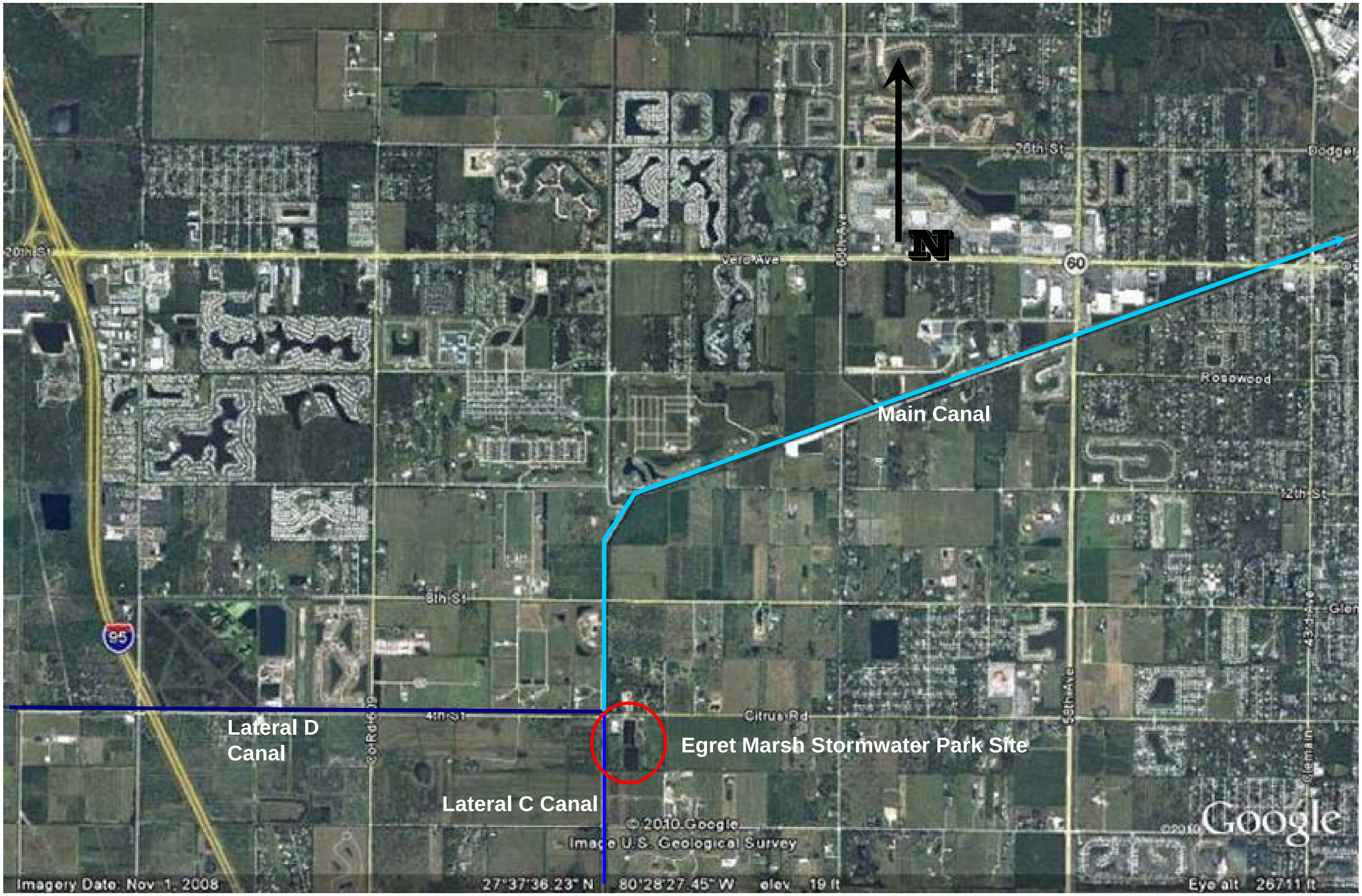


Illustration 4: Location Egret Marsh Stormwater Park (preconstruction)

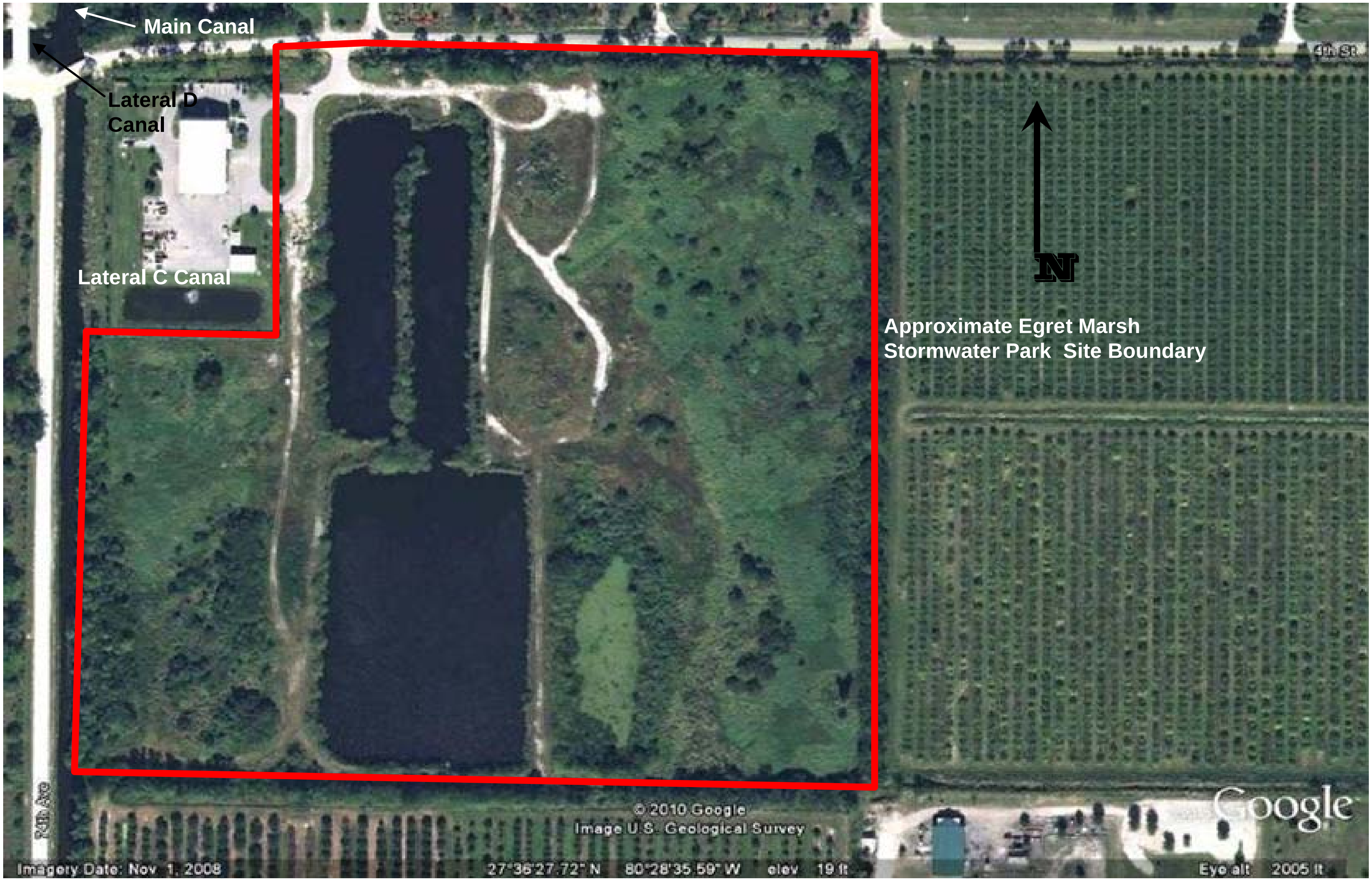


Illustration 5: Egret Marsh Stormwater Park Site Prior to Construction

Illustration 6: Egret Marsh Stormwater Park Site Following Construction—Dec 2010

Illustration 7: Egret Marsh Stormwater Park at Process Start-Up

Illustration 8: Egret Marsh Stormwater Park Woodstork Habitat with Visitation

(a) Monitoring Station 01
(Looking North)

(b) Monitoring Station 02
(Looking South)

(c) Monitoring Station 03
(Looking East)

Illustration 9: Egret Marsh Stormwater Park Monitoring Station

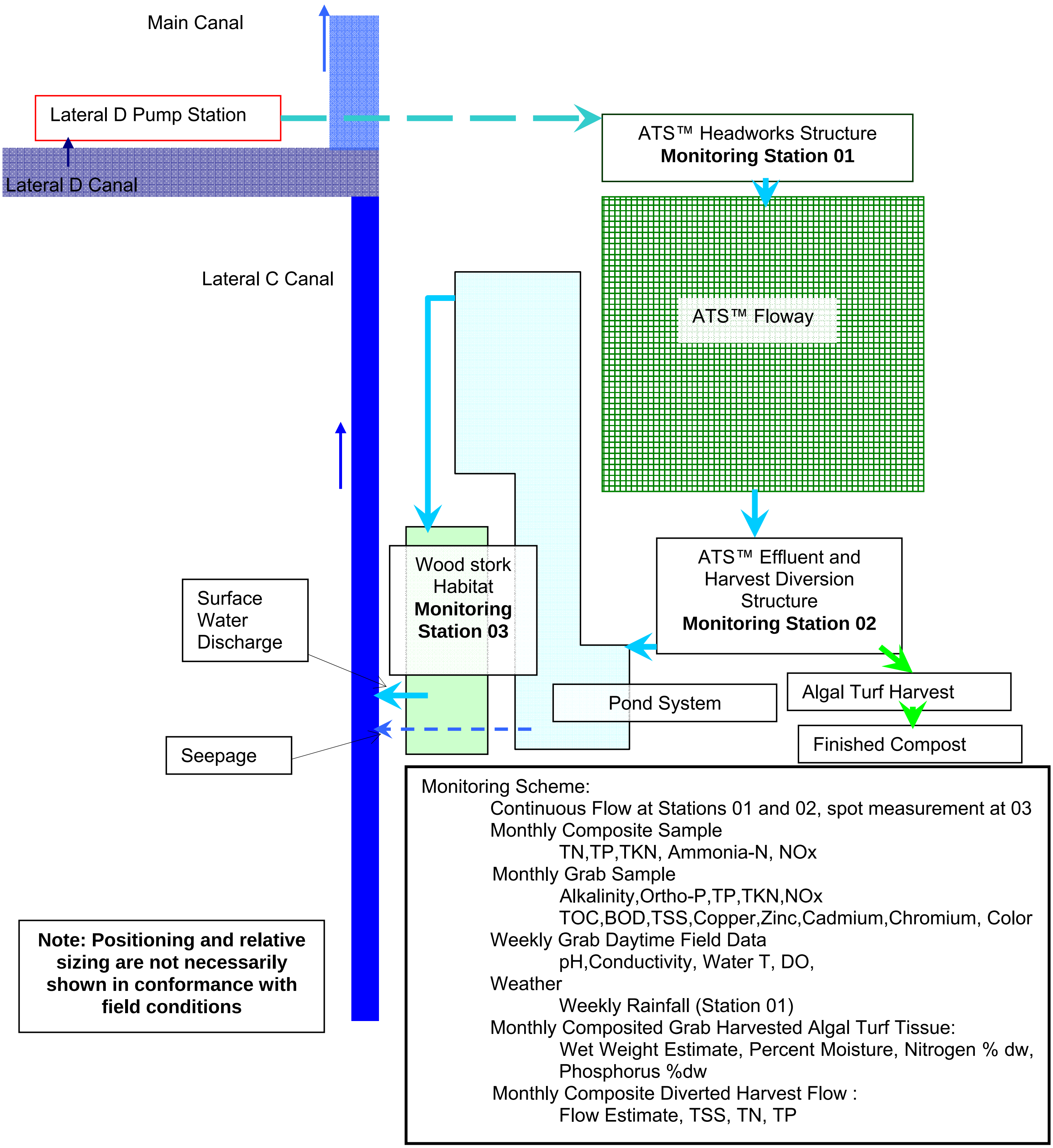
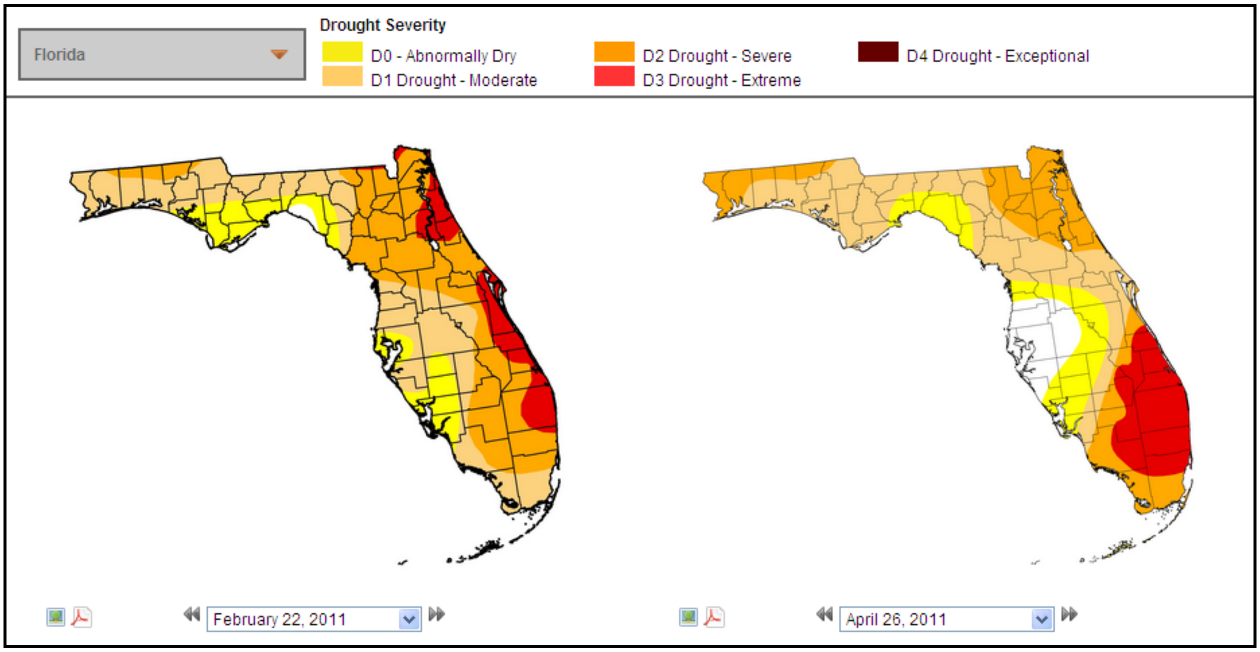


Figure 1: Monitoring Strategy Schematic Egret Marsh Stormwater Park



Source: http://drought.unl.edu/dm/archive.html

Figure 2: Regional Drought Conditions for February 22, 2011 and April 25, 2011 as Reported by US Drought Monitor

SECTION 3. DATA COLLECTION COMPILATION AND ASSESSMENT STRATEGY

For a one continuous year's monitoring period, critical water and tissue quality and quantity parameters were collected with the intent of facilitating: 1) assessment of the efficacy of the EMSP and its component processes in reducing total nitrogen and phosphorus loads from the Lateral D canal surface water, and in the transformation of nitrogen and phosphorus forms; 2) assessment of the overall impacts of the EMSP processes upon other water quality components (e.g. color, dissolved oxygen) important to sustaining ecological integrity; 3) determination to the extent practical of the fate of the removed nitrogen and phosphorus, particularly as related to direct capture as harvested material associated with the ATS™ and 4) insight into the operational and maintenance demands of the EMSP and identification of design features which may be modified to improve system durability and effectiveness. To enhance further understanding of the system, additional analyses were included beyond those required per the 319(h) Agreement and the approved QAPP. Specifically these included:

- Quantification of flows diverted during harvest
- Estimation of seepage flows and quality associated with the internal pond system and Wood Stork Habitat
- Solids and nutrient assessment of harvest diverted flows
- Nutrient and mineral assessment of harvested algal turf materials captured by the Flexrake during harvest[10].

Flows into the EMSP are measured through a Sigma bubbler system measuring height over an 8ft wide rectangular weir. An identical arrangement is provided at the ATS™ effluent structure[11]. The difference between the influent and effluent totalized flows represents an estimate of the net contributions of evapotranspiration, rainfall and incidental losses such as seepage. Final surface effluent flows from the Wood Stork Habitat are estimated from measured height over a five foot rectangular weir at the time of sample collection. The evapotranspirational losses through the pond/wetland system are assumed to equal pan evaporation. The difference of the surface outflow flow minus evapotranspiration plus rainfall to the ATS™ effluent flow is the seepage estimate through the pond bottom into the canal network.

Performance assessment is expressed in terms of four parameters:

- Mass Removal
- Areal Removal Rate
- Percent Removal
- Effluent Concentration

Mass removal is helpful in assessing the overall system contribution towards some

[10] Tissue analysis is conducted by Midwest Laboratories of Omaha, Nebraska. www.midwestlabs.com
[11] During the first quarter and portions of the second quarter the effluent flow meter malfunctioned and was sent back to the manufacturer for repair. Therefore effluent flows were estimated from hand measurements at the effluent weir. (see section 4)

assigned load allocation, such as may be associated with a TMDL determination. Areal Removal Rate (ARR), typically expressed by water resource managers as grams of targeted nutrient removal (total nitrogen or total phosphorus in the case of EMSP) per square meter of process area over a year or g/m^2-yr, serves as an indicator of system efficiency in terms of process sizing --the higher the ARR, the smaller the footprint for a set mass removal requirement. A biological system with a higher ARR is likely to be more cost effective than biological systems with lower rates because of the reduced land requirement. A high ARR is particularly advantageous when land availability is limited or land costs are very high.[12]

Percent removal is often misleading, as it does not necessarily relate to system efficiency. Rather it relates to proportional changes in influent and effluent loads without consideration of the magnitude of either mass removal or ARR. Therefore a system could have a very high percentage removal, but low mass removal and low ARR. For example, suppose a 100 acre marsh system is used to treat 1 million gallons of flow daily (MGD). If the incoming total phosphorus concentration is 200 µg/L and the effluent phosphorus concentration is 50 µg/L, then the percent removal is about 75%. However, the mass removal is only 456 pounds per year, and the ARR only 0.51 g/m^2-yr—assuming influent and effluent flows are nearly equal. In such a case percent removal as an indicator of cost effectiveness is somewhat misleading. For example, suppose that same water source is applied at the rate of 2 MGD to a 1 acre ATS™ floway, and the reduction is from 200 µg/L to 100 µg/L. In this case percent removal is only 50%--less than the marsh system percent removal. However, the mass removal is increased to 609 pound per year, and the ARR to 34.13 g/m^2-yr. Percent removal is offered then only as a general indicator of system contribution. Mass removal and ARR are considered much more valuable indicators of system performance when the intent is to minimize unit cost per mass removed.

When regulations set a concentration limit for an impaired surface water, such as 10 µg/L total phosphorus as determined for the Everglades, then final effluent concentration can become more important. With numerical nutrient standards being proposed for Florida, there will be an increased need to monitor total nitrogen and total phosphorus concentrations within designated impaired waters.

With the ATS™ process it is possible to maintain nutrient accountability by calculating and comparing removals based upon water quality and flow data to those based upon harvested material. As the ATS™ relies largely upon direct uptake, precipitation and filtration as the means of nutrient removal, then it would be reasonable to expect the total phosphorus and total nitrogen removed to be similar when calculated by both methods. However, water quality based calculation is considered a more accurate measurement because of the homogeneity of the matrix (water), and the normally higher level of reliability of applied laboratory methods.

[12] A high ARR, while indicative of potential cost savings, does not always equate to optimal cost effectiveness, if capital costs are particularly high and/or annual operating expenses are exceptionally high. A long term (e.g. 50 year) present worth analysis is recommended when conducting comparative engineering analyses.

Mass total phosphorus removal (also applicable to other nutrients) based upon harvested biomass is calculated as:

$P_{mh} = (sH_w)p$

Where P_{mh} = mass of total phosphorus removed through harvesting
s = solids content as fraction of wet harvest
H_w = mass of wet harvest
(sH_w) = mass of dry harvest
p = tissue phosphorus content as fraction of dry harvest

Mass removal based upon water quality is calculated as[13]:

$P_{mw} = I_p Q_I – E_p Q_E$

Where P_{mw} = mass of phosphorus removed based upon water quality
I_p = Influent total phosphorus concentration
E_p = Effluent total phosphorus concentration
Q_I = Influent totalized flow
Q_E = Effluent totalized flow

As noted, it would typically be expected that the harvest based removals would be similar to the water quality based removals. The extent of similarity of these two calculations provides some insight into system dynamics and the following may be indicated:

A. If the harvest based total nitrogen removal estimate is similar to the water quality based total nitrogen removal calculation, then direct biological uptake by the algal turf community may be considered the principal means of nitrogen removal.

B. If the harvest based total nitrogen removal estimate is considerably lower than the water quality based total nitrogen removal calculation, then
    1. Either the analytical methods or field sampling methods are not sufficiently reliable, or
    2. Extensive nitrogen loss is attributable to denitrification, ammonia volatilization, or emigration (e.g. emerging insects from pupae stage, and/or external grazing/ predation) or
    3. A combination of these.

C. If the harvest based total nitrogen removal estimate is considerably higher than the water quality based nitrogen removal calculation, then;
    1. Either the analytical methods or field sampling methods are not sufficiently reliable, or
    2. There is a net immigration from external sources (e.g. deposits from birds, or wind blown material) or

[13] While rainfall can contribute some nitrogen and phosphorus to the system, it is considered negligible and not included in these calculations.

3. Fixation of atmospheric nitrogen may be indicated or
4. A combination of these

D. If the harvest based total phosphorus removal estimate is similar to the water quality based total phosphorus removal calculation, then direct plant uptake may be considered the principal means of phosphorus removal.

E. If the harvest based total phosphorus removal estimate is considerably lower than the water quality based total phosphorus removal calculation, then
   1. Either the analytical methods or field sampling methods are not sufficiently reliable, or
   2. Extensive phosphorus loss is attributable to emigration (e.g. emerging insects from pupae stage, or external grazing/ predation) or
   3. A combination of these.

F. If the harvest based total phosphorus removal estimate is considerably higher than the water quality based phosphorus removal calculation, then;
   1. Either the analytical methods or field sampling methods are not sufficiently reliable, or
   2. There is a net immigration from external sources (e.g. deposits from birds, or wind blown material) or
   3. A combination of these

To evaluate system performance in terms of the four indicator parameters, monthly composite samples were collected using three time-sequenced Sigma 900Max automatic samplers[14].

As noted in Figure 1, composite samples were analyzed for TKN, Nitrate + Nitrite-N or NOx-N, Ammonia-N, Total Nitrogen or TN (as calculated as sum of TKN and NOx-N), Organic-N (as calculated as TKN minus ammonia-N) and total phosphorus or TP. In addition, monthly grab samples are taken at the monitoring stations for TP, TKN, NOx-N, ortho-P, BOD, TOC, TSS, color, copper, zinc, cadmium, chromium, and alkalinity. At the time of sample collection (weekly), field data is taken for pH, DO, water temperature and conductivity. Rainfall is monitored weekly. Data as delivered by the laboratory (Test America, Inc.) is transferred to operational spreadsheets, which have been developed to provide monthly and cumulative Mass Removal, ARR[15], Percent Removal and Effluent Concentrations for the ATS™ process; the pond system/wood stork habitat process; and the combined system. These operational spreadsheets are in Microsoft Excel format, and are attached as a CD to this report as Appendix 1.

[14] The details of the sampling scheduling and collection procedures are included in Section B2.1.6 of the QAPP
[15] Mass Removal and ARR calculations are included for both water quality based and harvest based methods as applied to the ATS™.

SECTION 4. DATA REVIEW AND SYSTEM PERFORMANCE ASSESSMENT

FLOW DYNAMICS

Influent and effluent flow was monitored continuously using an 8-ft rectangular, confined non-submerged weir, and a Sigma bubbler supported flowmeter. During the Q1 and portions of Q2 period, the effluent flow meter malfunctioned and was sent to the manufacturer for repair. Therefore, during these periods, flows were estimated at the effluent by hand measurement at the height of water over the weir during the weekly sample collection. The repaired effluent meter was installed during Q3. The height over the weir was applied to the classical Kindsvater-Carter Equation[16]

$$Q = (2/3)C_e(2g)^{0.5}(b + K_b)(h + K_h)^{1.5}$$

Where Q is flow rate
C_e is the weir coefficient which is a function of the ratio of height over the weir (h) and channel depth below the weir (P)
b is weir length
h is height of water above weir taken at a reasonable distance upstream.
K_b and K_h constants with value of -.003 inches and 0.04 inches when h is in inches, respectively.

The weir at Station 03 was typically submerged, so adjustments to the equation had to be made considering height in front of (H_1) and behind the weir (H_2).

$$Q_s = (Q_1)[\ 1-(H_2/H_1)^{1.5}]^{0.385}$$

Where Q_1= flow at H_1 if the weir were not submerged (apply Kindsvater-Carter Equation)

A more detailed presentation of flow determination methods are presented in the Planning Review Audit as Appendix 2. Also included as part of Appendix 2 is Laboratory QA results, including planning audits, blanks, replicates and split samples.

For both Q1 and Q2, while the influent flows may be considered reasonably accurate, the hand measured ATS™ effluent flows and the Station 03 flows represent engineering estimates based upon spot field measurements extended over a week. For Q3 the repaired effluent flow meter was reinstalled, but the unit could not hold the battery charge for a full week. Therefore, through the quarter, effluent flows were calculated from partial week data. At the end of Q3, the effluent meter arrangement was upgraded by including a weather proof enclosure and a continuous charger system. This allowed Q4 measurements to be more reliable, which facilitated more accurate assessment of water losses across the

16 www.lmnoeng.com/weirs/RectangularWeir.htm

ATS™ Floway. However, the inherent accuracy limitations of this flow measurement method[17], and the possibility of some incidental losses from seepage, reduces confidence that calculated water loss values are true representations of evapotranspiration rates across the ATS™.

The assumption that evaporation losses associated with the pond system are equal to documented pan evaporation for the region[18] is perhaps somewhat conservative, as surface evaporation is often lower than pan evaporation by 20-30%. However, because of the higher water temperatures associated with the ATS™ effluent entering the pond system, it is not unreasonable to expect somewhat higher evaporative losses.

Flows documented for the Q1 through Q4 period are noted in Tables 3 and 4. Total influent flow for the full monitoring period was 3,725.66 million gallons, with the average flow rate of 9.86 MGD—just below the design rate of 10 MGD. Water losses across the ATS™ were estimated to average 1.24 inches per day over 4.58 acres, or over the monitoring period 58.36 million gallons or about 1.57% of the influent flow. Water losses across the ATS™ floway were highly variable as illustrated in Figure 3, and as noted can not be considered an accurate reflection of evapotranspirational losses across the floway surface. Based upon this data, it appears that water losses through evaporation across the ATS™ could be substantially higher than pan evaporation during the warmer months, and it is not unreasonable to suspect that shallow flow across a heated surface could well increase the rate of evaporation. However, while perhaps somewhat indicative, this data is not conclusive, largely because of the accuracy limitations of the flow measurement method (see footnote 14). More exact measurement, conducted and replicated through a more controlled research arrangement is needed to firmly establish the dynamics of evaporation associated with the ATS™ technology. Such investigations are beyond the contracted scope of this project.

Effluent flows from the ATS™ for the four quarter period were estimated at 3,671.17 million gallons, including flows contributed through direct rainfall. This also represents influent flows to the 14.4 acre pond/wetland system, which includes the Woodstork Habitat. There was noted considerable seepage through the pond/wetland system. It would be expected that this seepage would migrate towards the lower water surface elevations within the Lateral C Canal, and therefore is considered part of system discharge to the canal. Seepage estimates for Q1 through Q4 amount to 695.45 million gallons or about 19.1% of the total discharge estimate of 3,645.04 million gallons. Flow patterns for Q1 through Q4 are shown in Figure 4.

---

[17] The bubbler flow depth unit (Hach) has a stated accuracy of 0.01 ft +/-, or 0.12 inches, which correlates with about 0.24 MGD at the design flow of about 10 MGD or 2.4% +/_, or about 2"/day across the ATS™. This range exceeds what would be considered the typical evaporational losses, and impedes the ability to adequately assess evaporation across the ATS™.

[18] (1) Pan evaporation data recorded at SFWMD Station S65C_ E from 1976 - 1989 (Unpublished data)

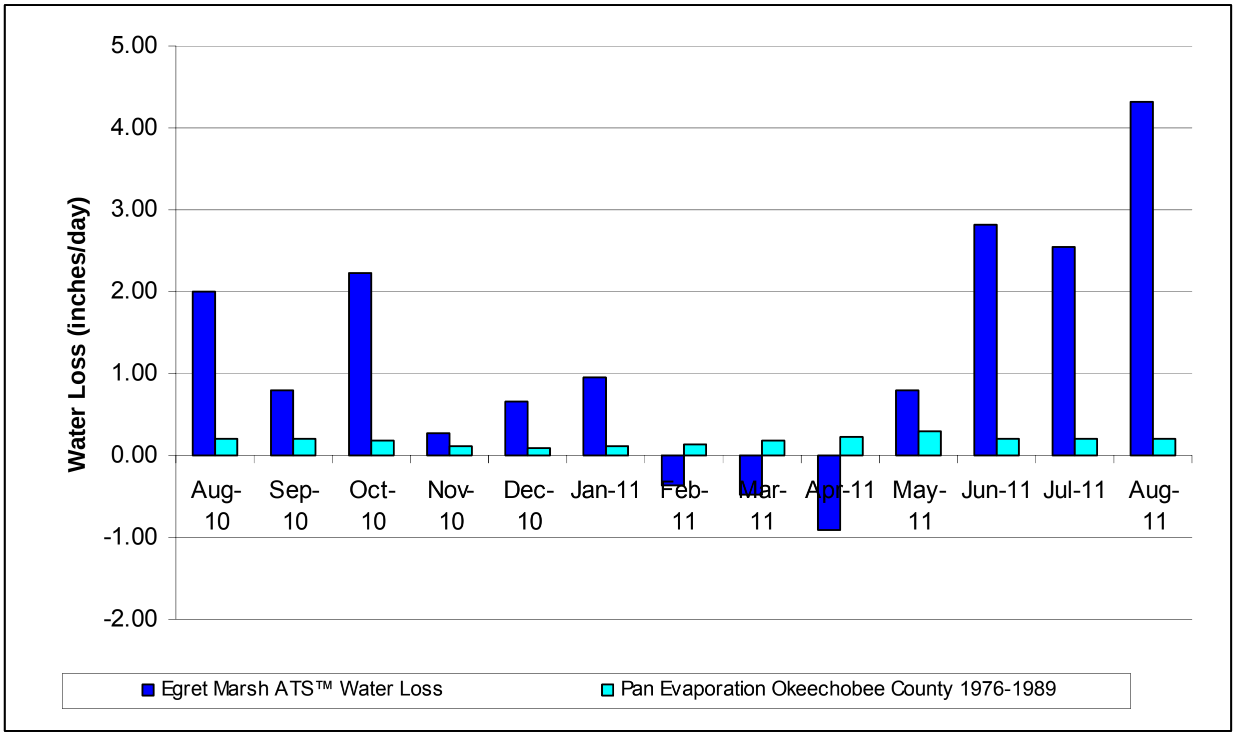


Figure 3: Calculated Q1 through Q4 ATS™ Water Loss at Egret Marsh ATS™ Versus Pan Evaporation Rates for the Period 1976 to 1989 in Okeechobee County, Florida

Table 3: Quarters 1 through 4 ATS™ Flow Dynamics (4.58 acres)

Sampling Period Ending	ATS™ Influent Flow Volume (Million Gallons)	ATS™ Effluent Flow Volume (Million Gallons)	Rainfall (inches)	ATS™ Rainfall Flow Volume (Million Gallons)	ATS™ Water Loss Volume (Million Gallons)	Average ATS™ Water Loss (inches/day)
9/13/10	276.77	270.50	5.25	0.69	6.93	1.98
10/11/10	272.94	270.44	2.00	0.26	2.74	0.79
11/8/10	276.65	268.95	0.50	0.07	7.76	2.23
12/6/10	270.99	270.09	0.25	0.03	0.98	0.27
1/3/11	276.24	274.73	2.00	0.26	2.27	0.65
1/31/11	272.72	270.02	1.55	0.20	3.29	0.95
2/28/11	274.24	275.35	1.50	0.20	-1.23	-0.37
3/28/11	277.07	277.94	2.00	0.26	-1.60	-0.47
4/25/11	269.48	271.54	0.25	0.03	-3.11	-0.91
5/23/11	271.40	271.73	2.20	0.29	2.81	0.81
6/20/11	278.79	270.68	3.30	0.43	9.81	2.82
7/18/11	280.08	270.79	3.00	0.40	8.83	2.54
8/22/11	351.50	335.28	4.60	0.61	15.07	4.33
8/29/11	76.80	73.13	1.00	0.13	3.80	4.43
TOTAL (378 day period)	**3,725.66 (9.86 MGD)**	**3,671.17 (9.71 MGD)**	**29.40**	**3.87 (0.010 MGD)**	**58.36 (0.15 MGD)**	**1.24**

Table 4: Quarter 1 through 4 Pond System Flow Dynamics (14.44 acres)

28 day Sampling Period Ending	ATS™ Effluent Flow Volume into Pond System (Million Gallons)	Pond System Rainfall Flow Volume (Million Gallons)	Pond System Evaporation Volume (Million Gallons)	Pond System Surface Discharge Flow Volume (Million Gallons)	Pond System Seepage Flow Volume (Million Gallons)	Pond System Total Release to Lateral C Canal (Million Gallons)
9/13/10	270.50	2.05	2.12	223.38	47.05	270.43
10/11/10	270.44	0.78	2.06	220.41	48.75	269.16
11/8/10	268.95	0.20	1.67	223.77	43.71	267.47
12/6/10	270.09	0.10	1.34	240.08	28.77	268.86
1/3/11	274.73	0.78	1.37	218.91	55.13	274.04
1/31/11	270.02	0.61	1.26	229.87	39.95	269.86
2/28/11	275.35	0.59	1.67	227.50	46.61	274.10
3/28/11	277.94	0.78	2.14	220.29	56.27	276.56
4/25/11	271.54	0.10	2.61	225.98	43.56	269.54
5/23/11	271.73	0.86	3.27	220.91	48.04	268.95
6/20/11	270.68	1.29	2.24	219.77	48.95	268.73
7/18/11	270.79	1.17	2.21	215.05	55.82	270.87
8/22/11	335.28	1.80	2.12	258.20	76.30	334.50
8/29/11	73.13	0.39	0.53	66.47	6.51	72.99
TOTAL (378 day period)	**3,671.17 (9.71 MGD)**	**11.50 (0.03 MGD)**	**26.63 (0.070 MGD)**	**3,010.59 (7.96 MGD)**	**645.45 (1.71 MGD)**	**3,656.04 (9.67 MGD)**

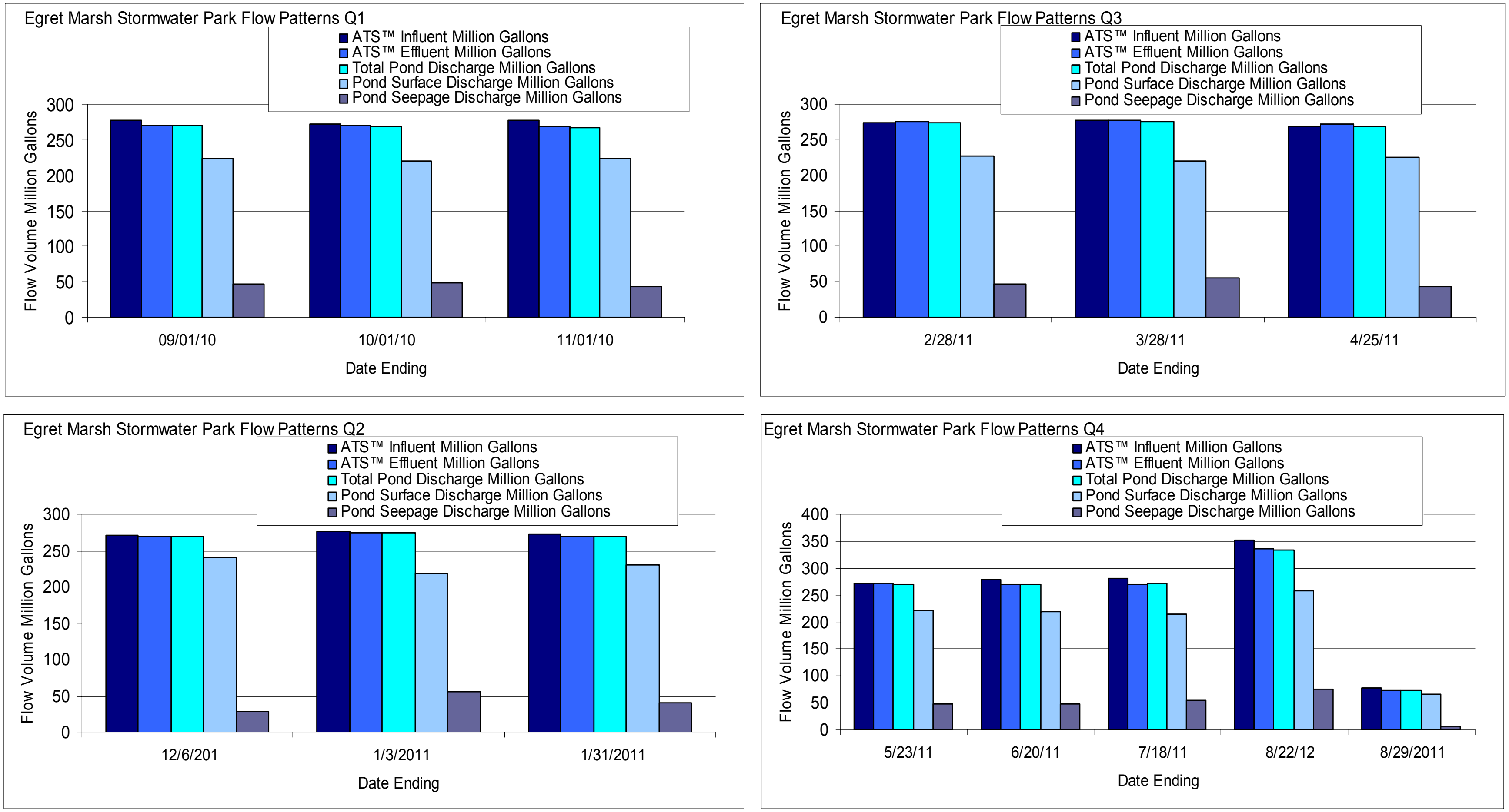


Figure 4: Quarter 1 through Quarter 4 Flow Patterns

ALGAL TURF PRODUCTION AND HARVEST BASED PERFORMANCE

Net Algal Turf Community Productivity

Net algal turf community productivity is typically expressed as dry-g/m^2-day. The net community productivity is estimated from actual harvested quantity. The algal turf is harvested periodically to ensure sustainability and community viability. Harvesting is done using a conventional tractor with a custom blade designed to protect the floway liner and grid (Illustration 10). The tractor dislodges the excess algal turf and eventually moves it into the effluent flume, which moves the harvest and the associated flow to the harvesting rake (Illustration 11). One half of the floway is harvested with each harvesting event. Through the use of gates and by-pass weirs incorporated into the effluent and harvest diversion structure, the non-harvested half of the floway can continue operation, while flows from the harvested side are diverted towards a ¼" automatic Flexrake (Illustration 12). The Flexrake captures algal filaments and other solids up to ¼", with the remaining solids being diverted to two settling ponds (Illustration 13). The solids in these ponds are eventually removed and recovered. All solids are windrow composted, and the final compost material is retained by the County for use with landscaping projects (parks, medians etc.) (Illustration 14).

The harvest that is captured by the Flexrake is measured for volume and average wet density to determine harvest mass. Three composite samples are then analyzed on-site for percent solids. Once monthly, the dried samples are composited and delivered to Midwest Laboratories in Omaha, Nebraska for nutrient and mineral analysis[19]. The diverted solids which pass the rake are measured as total suspended solids within the diverted flow after it passes through the Flexrake. Total nitrogen and total phosphorus are also analyzed from this diverted flow. Volume of the diverted flow is measured using the difference over the harvest time of influent flow and flow measured over the effluent weir, which represents the non-harvested half of the floway. Total solids, nitrogen and phosphorus recovered during a harvest are the sum of the rake harvest and the diverted solids. A typical harvest worksheet is noted as Figure 5. During the one year monitoring period, the ATS™ was harvested on twenty eight different occasions. The collection of harvest worksheets are on the CD included in Appendix 1.

The harvested algal turf material represents net community productivity, and includes not only plant and animal tissue, but also residuals associated with organic detritus, sedimentation of inorganic residuals, and extra-cellular chemical reactions. It is important to recognize that net community productivity is not the same as net primary productivity, which is a measurement of photoautotrophic based carbon fixation and retained organic matter production, after consumption of a portion of such production through respiration by the involved photoautotrophic organisms.

As mentioned previously, the harvesting process results in two harvest streams—the filaments captured upon a ¼" Flexrake (Rake Harvest), and the diverted flow (Diverted Harvest) that passes through the rake and is collected in settling ponds. The diverted flow typically contains single celled epiphytic organisms as well as small invertebrates, organic detritus and inorganic sediment.

[19] www.midwestlabs.com

The net community productivity therefore is calculated as:

[(Wet Rake Harvest x percent solids of wet harvest + Diverted Flow Volume x Total Suspended Solids Concentration in Diverted Volume)] ÷ area of floway harvested ÷ time between harvesting.

The progression of algal turf production, at least during a comparatively short time period when space and resources are readily available, is exponential, controlled by a specific rate of growth (**μ**)[20]:

$$Z_t = Z_o e^{\mu t}$$

Where Z_t is the standing crop in dry-g/m^2 at time t in hours
Z_o is the standing crop in dry-g/m^2 at initiation[21] (t =0) or 10 dry-g/m^2
μ is the specific growth rate at 1/hr.
or
$\mu = [\ln(Z_t / Z_o)]/t$

Illustration 10: Harvesting ATS™ Floway at Headworks

[20] Specific Growth Rate has been shown to be a function of water temperature, concentration of critical nutrients and a hydraulic loading factor related to velocity. Reasonably projecting Specific Growth Rate is a critical component of system modeling.
[21] It is a defendable assumption that the amount of algal turf remaining on that portion of the floway that is harvested, is nearly the same after each harvesting. Based upon past experiences with a number of ATS™ units, setting a post harvest standing crop of 10 dry-g/m^2 is reasonable.

Illustration 11: Deposition of Harvested Material into Effluent Flume for Delivery to Flexrake and Diversion Ponds

Illustration 12: Removal of Filaments and Larger Particles by the Automatic Flexrake

Illustration 13: Solids Settling Ponds which Receive Diverted Harvest Flows Containing Solids which Pass through the Flexrake

Illustration 14: Windrow Composting Process for Harvested Algal Turf

EGRET MARSH ALGAL TURF SCRUBBER HARVEST DOCUMENTATION

Note: Blue represents data to be input. Black represents calculated values.

Date of Harvest	**09/01/10**		
Side Harvested	**West**	**Side Area m^2**	**9,271.6**
Days Since Side Last Harvest	14		
Weather : Hot, partly cloudy, low wind			
Begin Harvest Time	9:30		
End Harvest Time	1:30		
Harvest Time hrs	4.00		
FLOWS			
Begin Influent Totalizer gal	18,638,000		
End Infuent Totalizer gal	20,289,000		
Harvest Influent Flow Volume gal	1,651,000		
Begin Effluent Totalizer gal	NA		
End Effluent Totalizer gal	NA		
Harvest Effluent Flow Volume gal (per field measurement via height over weir)	685,000		
Diverted Flow gal	966,000		
Rake Harvest		**Diverted Harvest**	
Buckets Harvested	32.0	Flow Diverted gal	966,000
Volume per bucket cy	0.80	TSS mg/l	403
First Density Measurement lb/5 gallons *	24.80	TP mg/L	2.37
Second Density Measurement lb/5 gallons *	22.40	TKN mg/L	7.36
Third Density Measurement lb/5 gallons *	28.20	Nitrate-Nitrite -N mg/l	0.09
Total Weight Measured 5 gallon Buckets lb	75	Diverted Harvest dry lb	3,246.75
Total Volume Measured gallon Buckets cy	0.07	Diverted Phosphorus lb	19.09
Calculated Wet Density lb/cy	1,015.3	Diverted Nitrogen lb	60.02
Rake Harvest Volume cy	25.7	Solids TP %	0.59%
Rake Harvest Wet Weight	**26,072**	Solids TN %	1.85%

Figure 5: Typical Harvest Worksheet

Dry Solids Determinations Rake Harvest						
	Container wt gm	Wet Sample + Container gm	Wet Sample gm	Dry Sample + Container gm	Dry Sample gm	% solids
Sample 1	7.20	207.20	200.00	28.30	21.10	10.55%
Sample 2	7.20	207.20	200.00	28.50	21.30	10.65%
Sample 3	7.20	207.20	200.00	34.40	27.20	13.60%
Total & Average	**21.60**	**621.60**	**600.00**	**91.20**	**69.60**	**11.60%**

TOTAL HARVEST	
Rake Harvest Dry Harvest lb	3,024.4
Diverted Dry Harvest lb	3,246.7
Dry Tissue TP Rake Harvest %	0.62%
Dry Tissue TN Rake Harvest %	3.71%
TOTAL HARVEST DRY SOLIDS lb	**6,271.1**
TOTAL NET COMMUNITY PRODUCTIVITY dry g/m^2-day	**21.93**
TP Removed Rake Harvest lb	18.62
TP Removed Diverted Harvest lb	19.09
TOTAL TP REMOVED HARVEST lb	**37.72**
TP AREAL REMOVAL RATE VIA HARVEST g/m^2-yr	**48.15**
TN Removed Rake Harvest lb	112.21
TN Removed Diverted Harvest lb	60.02
TOTAL TN REMOVED HARVEST lb	**172.23**
TN AREAL REMOVAL RATE VIA HARVEST g/m^2-yr	**219.87**

COMMENTS: Final density 330 g/sm

* Samples for solids determination to be taken from density buckets at time of density determination

Figure 5: Typical Harvest Worksheet (Continued)

Similarly the average standing crop over the period T =0 to T= n in days, where the n^{th} day is the day of harvest, is calculated as:

$$Z_{ave} = \left(\sum_{T=0}^{T=n} Z_T e^{24\mu}\right) / n$$

Review of Algal Turf Development and Harvest Events

Shown in Table 5 are the dry harvest, calculated productivity, specific growth rates, average standing crop, and percentages of rake and diverted harvests for each month of Q1 through Q4. The productivity trends are shown graphically in Figure 6 through 9. Over the monitoring period 148,765 dry pounds of algal turf were harvested from the Egret Marsh ATS™ floway, which maintained an average standing crop of 86 g/m^2 and an average specific growth rate of 0.0080/hr.

For the first quarter (Q1), there were nine harvesting events, four for the first month, three for the second month and two for the last month. Productivity dropped considerably during the last month of the quarter, largely because of the paucity of available nutrients within the Lateral D Canal water. Reduction in water temperature also contributed to lower productivity.

During Q1, there was a notable shift, both quantitatively and qualitatively in the algal turf community during the last month of the quarter. During the first two months the predominant algal species were two green filamentous algae---*Cladophora sp.* and *Rhizoclonium sp.* These formed a thick mat across much of the floway, and demonstrated high levels of productivity. During harvest of this community, a significant percentage (nearly 60%) of the harvest was captured on the Flexrake. During these first two months, because of significant rainfall in the watershed, the Lateral D Canal contained comparatively high nutrient levels, averaging 0.126 mg/L as total phosphorus and 1.02 mg/L total nitrogen. By the third month of the quarter, however, because of negligible rainfall, and the closure of the downstream release gate, the Lateral D Canal became an impoundment, meaning the EMSP was recirculating treated water, which resulted in significant decreases in Lateral D nutrient levels. For the third month, total phosphorus within Lateral D was reduced to 0.049 mg/L and the total nitrogen to 0.54 mg/L. In addition, average daytime water temperatures within Lateral D had decreased from 28.6 °C to 22.9 °C. As a consequence, the algal turf productivity declined noticeably during the third month.

During the latter part of Q1, the algal turf community shifted away from *Cladophora/Rhizoclonium* dominance, to filamentous diatoms, represented by a dominance of the species *Melosira sp.* Filamentous diatoms are not as structurally sturdy as the green algae, and tend to fragment during harvest, resulting in a substantial mass passing through the Flexrake. Consequently, during the third month of Q1, less than 50% of the harvest was captured by the Flexrake, and on the final harvest on 11/3/10, only 30% of the harvest was captured by the Flexrake.

For the second quarter (Q2), there were only three harvesting events, two for month four, zero for month five and one for month six. Productivity continued to drop during Q2 as compared to Q1, because of reduced water temperatures and substantial reductions in available nutrient concentrations. The nutrient reductions were attributable to both a paucity of nutrient enriched runoff/seepage because of low rainfall, and the fact that the impounded water within lateral D continued to be recycled through the EMSP treatment regime, resulting in retreatment of water, and exhaustion of available nutrients. Comparatively, the average influent water temperature for Q2 was 17.8° C and 26.9 ° C for Q1 (a 34% reduction); the average influent total phosphorus for Q2 was 0.042 mg/L and 0.100 mg/L for Q1 (a 58% reduction); and the average influent total nitrogen for Q2 was 0.80 mg/L and 0.86 mg/L for Q1 (a 7.0% reduction).

During Q2 the trends attendant with the last month of Q1 continued, with algal turf production decreasing substantially in response to lower water temperatures and lower levels of available nutrients. Low rainfall during Q2 and Q3, as well as the first two months of Q4, resulted in extended periods of impoundment within Lateral D, and accordingly a higher level of recycling and retreatment. This resulted in total phosphorus influent levels falling to an average of 0.042 mg/L and total nitrogen levels falling to an average of 0.82 mg/L for Q2 and 0.043 mg/L total influent phosphorus and 0.65 mg/L influent total nitrogen for Q3.

However, even though the nutrient levels were similar for Q2 and Q3, the net algal turf productivity during Q3 was notably higher--11.10 g/m^2-day for Q3 compared to 2.36 g/m^2-day for Q2. This is likely attributable to the substantial increase in influent water temperature—average 17.8 °C for Q2 compared to 22.8 °C for Q3. During Q3, the filamentous green algae density increased, with about 60% of the harvest being recovered on the rake.

For the third quarter (Q3), there were seven harvesting events, two for month seven, three for month eight and two for month nine. As noted, productivity increased during Q3 as compared to Q2, most likely in response to increased water temperatures. However, nutrient levels during Q3 remained comparatively low, and were similar to Q2. As with Q2, the low nutrient levels were attributable to both a paucity of nutrient enriched runoff/seepage, and the fact that the impounded water within lateral D was being recycled through the EMSP treatment regime, resulting in retreatment of water, and exhaustion of available nutrients.

For the fourth quarter (Q4), there were nine harvesting events, two for month ten, two for month eleven, two for month twelve, and three for month thirteen. Productivity increased somewhat during Q4 as compared to Q3, and was substantially higher during the final month of Q4, in response to increased water temperatures and nutrient levels. Nutrient levels during Q4 remained comparatively low during the first few weeks, but increased substantially during the last two months (July and August 2011), in response to increased rainfall and a cessation of effluent recycling through the Lateral D canal. The average influent water temperature for Q4 was 28.8° C and 22.7° C for Q3 (a 27% increase); the average influent total phosphorus for Q4 was 0.158 mg/L and 0.043 mg/L for Q3 (a 267% increase); and the average influent total nitrogen for Q4 was 1.19 mg/L and 0.65 mg/L for

Q3, (an 83% increase).

During Q4, the trends noted during Q3 continued until early July, when heavy rains and the resultant runoff caused substantial increases in nitrogen and phosphorus. During the first two months of Q4, influent total phosphorus averaged 0.060 mg/L and the influent total nitrogen averaged 0.75 mg/L. During the last months of Q4 these averages increased to 0.248 mg/L total phosphorus and 1.61 mg/L total nitrogen. This increase combined with higher water temperatures generated an increase in both algal turf production and in system performance. The algal turf community during Q4 was a mix of filamentous green algae and an abundance of associated epiphytic diatoms. About 46% of the harvest was captured on the rake, with the remainder incorporated within the diverted harvest flow delivered to the settling ponds.

Review of Algal Turf Tissue Quality and Tissue Nutrients to Nutrient Water Concentrations Relationships

Seasonal shifts in algal community and water quality within an ATS™ facility are not unexpected. However, as noted previously (see Tables 1 and 2), nutrient levels within Lateral D during much of the monitoring period were substantially lower than what has been recorded historically, and this most likely contributed to the extent of variability in the rate and nature of these shifts.

Nutrient and mineral content of the algal turf tissue over the monitoring period also varied considerably with seasonal fluctuations in water quality and productivity rates. Shown in Table 6 is the tissue quality of the rake harvest. The diverted harvest and combined harvest nutrient content are noted in Table 7. Based upon general indicators of nutrient and mineral sufficiency levels as shown in Table 8, and based upon field observations, no serious deficiencies occurred during the monitoring period, even though potassium levels and at times phosphorus levels appeared to be near or below the lower limits as listed in Table 8[22].

The scattergrams shown in Figure 10 display the relationships between nitrogen and phosphorus tissue content with influent total nitrogen and total phosphorus concentrations. Included in Figure 10 are the results of linear regression analyses of each of these relationships. These analyses provide indication that total phosphorus concentration is more closely related to both nitrogen and phosphorus tissue levels than total nitrogen concentrations (r^2 of 0.40 and 0.41 respectively). This is a pattern which has been observed with other ATS™ units. The linear equations developed from these analyses will be applied to the modeling effort detailed in later sections of this text.

[22] The general sufficiency levels listed in Table 8are offered as guidelines , and are taken from information related to hydroponic systems, and may not always be specifically applicable for diverse algal turf communities.

Table 5: Summary of Q1 through Q4 Algal Turf Productivity Parameters by Monthly Period

Harvest Date	Total Dry Harvest (lbs)	Productivity (dry-g/m^2-day)	Specific Growth Rate (1/day)	Average Standing Crop (dry-g/m^2)	Harvest Percent as Rake Harvest	Harvest Percent as Diverted Harvest
8/18/2010	6,483	22.67	0.0104	103	73.1%	26.9%
8/25/2010	6,163	21.56	0.0102	99	62.4%	37.6%
9/1/2010	6,271	21.93	0.0103	100	48.2%	51.8%
9/8/2010	5,123	17.92	0.0097	86	53.7%	46.3%
Total Month 1	24,040					
Month 1 Average		21.02	0.0102	97	59.7%	40.3%
9/15/10	7,743	27.08	0.0109	118	39.4%	50.6%
9/21/10	7,025	26.46	0.0114	110	66.8%	33.2%
10/610	6,370	14.85	0.0069	97	68.2%	31.8%
Total Month 2	21,138					
Month 2 Average		18.48	0.0097	108	57.2%	42.8%
10/13/10	5,178	11.53	0.0062	83	67.7%	32.3%
11/3/10	2,742	4.80	0.0040	53	30.3%	69.7%
Total Month 3	7,920					
Month 3 Average		6.93	0.0051	68	54.7%	45.3%
Total Q1	**53,098**					
Q1 Cumulative		**15.48**	**0.0089**	**94**	**57.9%**	**42.1%**
11/18/10	2,642	3.59	0.0030	51	42.8%	67.2%
12/1/2010	1,921	3.73	0.0036	45	8.9%	91.1%
Total Month 4	4,563					
Month 4 Average		3.99	0.0033	48	28.5%	71.5%
1/5/11	2,817	2.46	0.0019	30	21.5%	79.5%
Total Month 6	2,817					
Month 6 Average		2.46	0.0019	30	21.5%	79.5%
Total Q2	**7,380**					
Q2 Cumulative		**2.15**	**0.0028**	**39**	**25.8%**	**74.2%**

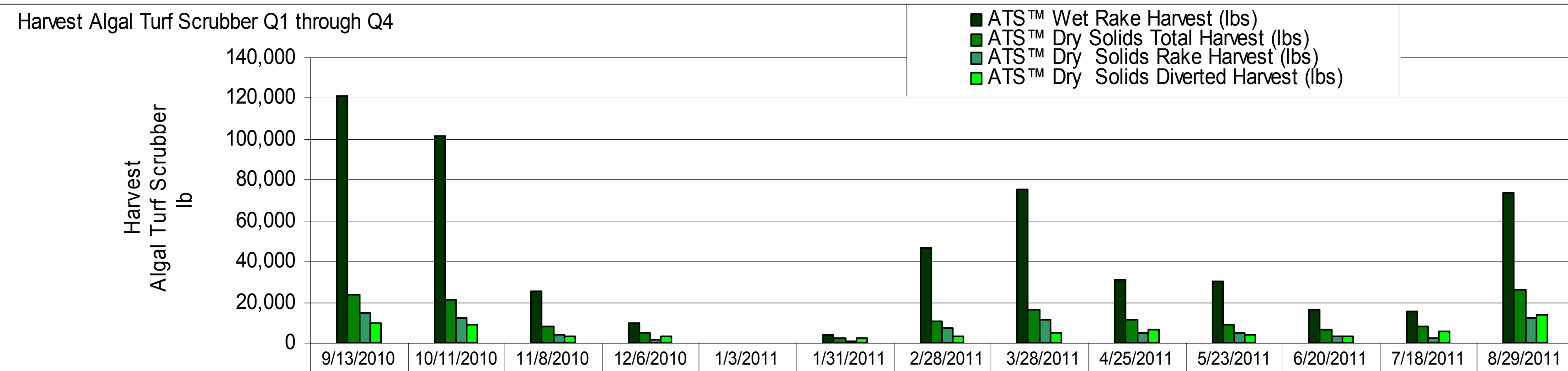
Table 5: Summary of Q1 through Q4 Algal Turf Productivity Parameters by Monthly Period (Continued)

Harvest Date	Total Dry Harvest (lbs)	Productivity (dry-g/m^2-day)	Specific Growth Rate (1/day)	Average Standing Crop (dry-g/m^2)	Harvest Percent as Rake Harvest	Harvest Percent as Diverted Harvest
2/11/11	6.305	4.37	0.0032	53	61.5%	39.5%
2/24/11	4.361	18.25	0.0103	83	71.3%	28.7%
Total Month 7	10,666					
Month 7 Average		9.33	0.0067	68	65.5%	34.5%
3/3/11	7,895	21.48	0.0079	125	75.0%	25.0%
3/10/11	3,921	15.24	0.0092	77	57.7%	42.3%
3/24/11	4,385	11.36	0.0064	80	69.6%	30.4%
Total Month 8	16,201					
Month 8 Average		14.17	0.0078	94	69.3%	30.7%
3/31/11	4,415	11.44	0.0064	80	65.9%	34.1%
4/14/11	6,783	17.57	0.0108	115	24.9%	75.1%
Total Month 9	11,198					
Month 9 Average		9.79	0.0086	98	41.1%	58.9%
Total Q3	**38,065**					
Q3 Cumulative		**11.10**	**0.0077**	**88**	**60.0%**	**40.0%**
4/28/11	5,161	10.03	0.0100	94	70.1%	29.9%
5/12/11	3,911	7.60	0.0092	76	35.9%	64.1%
Total Month 10	9,072					
Month 10 Average		7.93	0.0096	85	55.4%	44.6%
5/26/11	3,906	7.59	0.0092	76	47.1%	52.9%
6/9/11	2,341	4.55	0.0078	53	51.8%	48.2%
Total Month 11	6,247					
Month 11 Average		5.46	0.0085	65	48.9%	51.1%
6/23/11	2,182	4.24	0.0076	51	50.9%	49.1%
7/14/11	6,266	9.74	0.0071	104	23.5%	76.5%
Total Month 12	8,448					
Month 12 Average		7.39	0.0074	78	30.5%	69.5%
7/21/11	6,590	12.81	0.0215	127	62.2%	37.8%
8/11/11	10,476	20.36	0.0081	154	37.1%	62.9%
9/1/11	9,389	12.17	0.0078	142	44.6%	53.4%
Total Month 13	26,455					
Month 13 Average		15.42	0.0125	141	46.0%	54.0%
Total Q4	**50,222**					
Q4 Cumulative		**12.55**	**0.0098**	**97**	**45.4%**	**54.6%**
Cumulative Q1 through Q4 Monitoring Period	**148,765**	**9.64**	**0.0080**	**86**	**52.7%**	**47.3%**

Comparative Review of Harvest Based System Performance to Water Quality Based System Performance

Once nitrogen and phosphorus content of the harvested material (both Rake and Diverted Harvest) is determined, it is possible to estimate the nutrient performance parameters, mass removal and Areal Removal Rates (ARR), based upon harvest. These estimates, as shown in Table 9 for Q1 through Q4, can be compared to the values for the same parameters based upon water quality[23] and flow data. These performance parameters as shown in Figures 11 through 14 for total phosphorus and total nitrogen track rather closely for the two methods of calculation[24], indicating that mass removal based upon the harvest method and the water quality method are reliable, and that most of the nutrients removed through the ATS™ are incorporated directly into the algal turf. Such mass balance comparisons using two independent methods of calculation serve both as a means of quality assurance for data and sampling methods, and as a diagnostic useful for assessment of the nature of nutrient dynamics across the ATS™ floway (see discussion included at the end of Section 3).

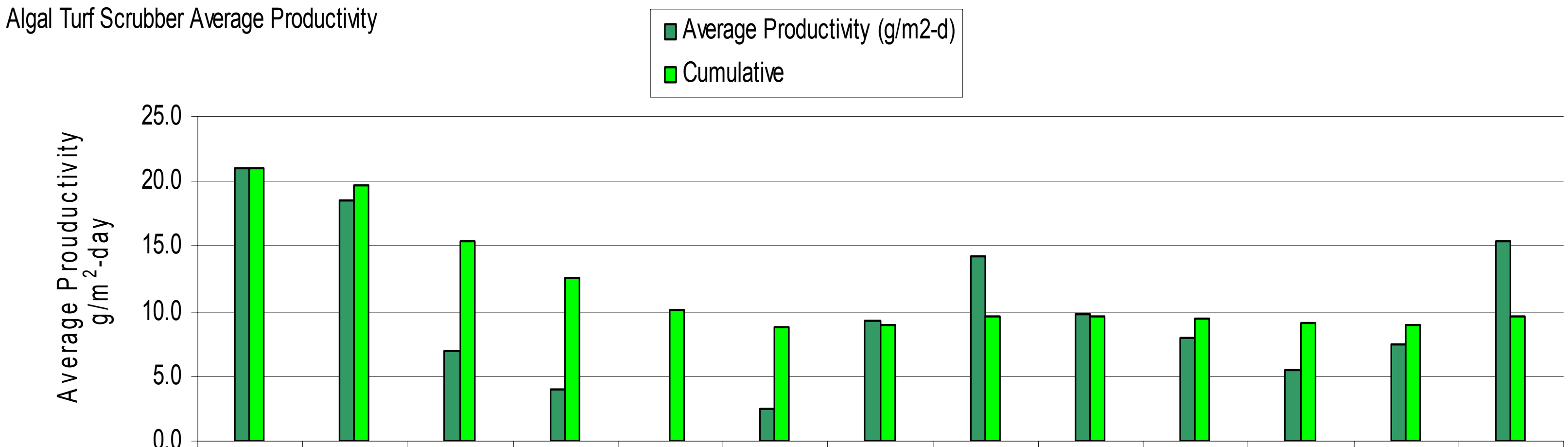
[23] The water quality based calculations are discussed in detail in following sections of this text.
[24] The mass removal relative percent difference (RPD%) for the two methods was only 6% and 9% for P and N respectively.



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
ATS™ Wet Rake Harvest (lbs)	121,037	101,750	25,285	9,470		4,075	46,364	75,494	31,171	29,985	16,056	15,815	73,988
ATS™ Dry Solids Total Harvest (lbs)	24,040	21,138	7,920	4,563		2,817	10,666	16,201	11,199	9,072	6,247	8,447	26,456
ATS™ Dry Solids Rake Harvest (lbs)	14,357	12,087	4,334	1,300		606	6,991	11,234	4,597	5,021	3,054	2,581	12,167
ATS™ Dry Solids Diverted Harvest (lbs)	9,683	9,051	3,587	3,262		2,211	3,676	4,967	6,601	4,050	3,194	5,867	14,289

Date Ending

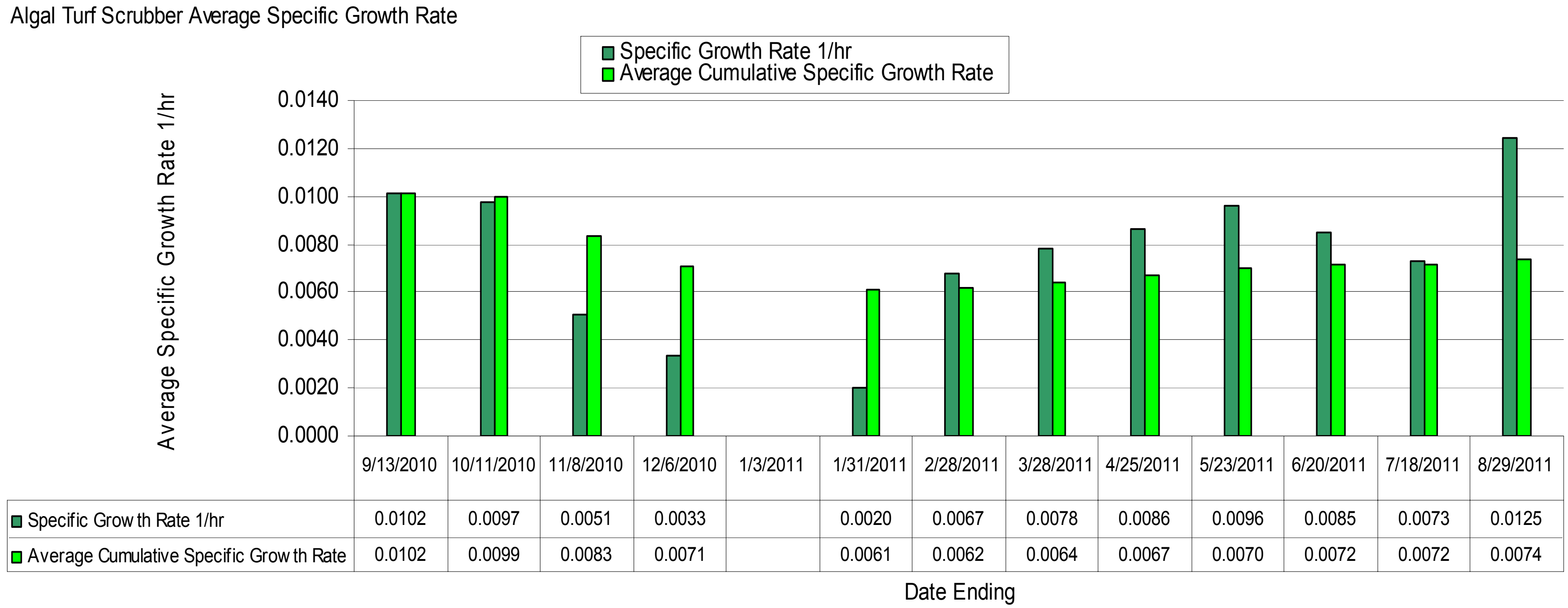
Figure 6: Q1 through Q4 Monthly Harvest Egret Marsh Algal Turf Scrubber®



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Average Productivity (g/m2-d)	21.02	18.48	6.93	3.99		2.46	9.33	14.17	9.79	7.93	5.46	7.39	15.42
Cumulative	21.02	19.75	15.48	12.60	10.08	8.81	8.89	9.55	9.57	9.41	9.05	8.91	9.64

Date Ending

Figure 7: Q1 through Q4 Monthly Algal Turf Net Productivity Egret Marsh Algal Turf Scrubber®



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Specific Growth Rate 1/hr	0.0102	0.0097	0.0051	0.0033		0.0020	0.0067	0.0078	0.0086	0.0096	0.0085	0.0073	0.0125
Average Cumulative Specific Growth Rate	0.0102	0.0099	0.0083	0.0071		0.0061	0.0062	0.0064	0.0067	0.0070	0.0072	0.0072	0.0074

Figure 8: Q1 through Q4 Monthly Specific Growth Rates Egret Marsh Algal Turf Scrubber®

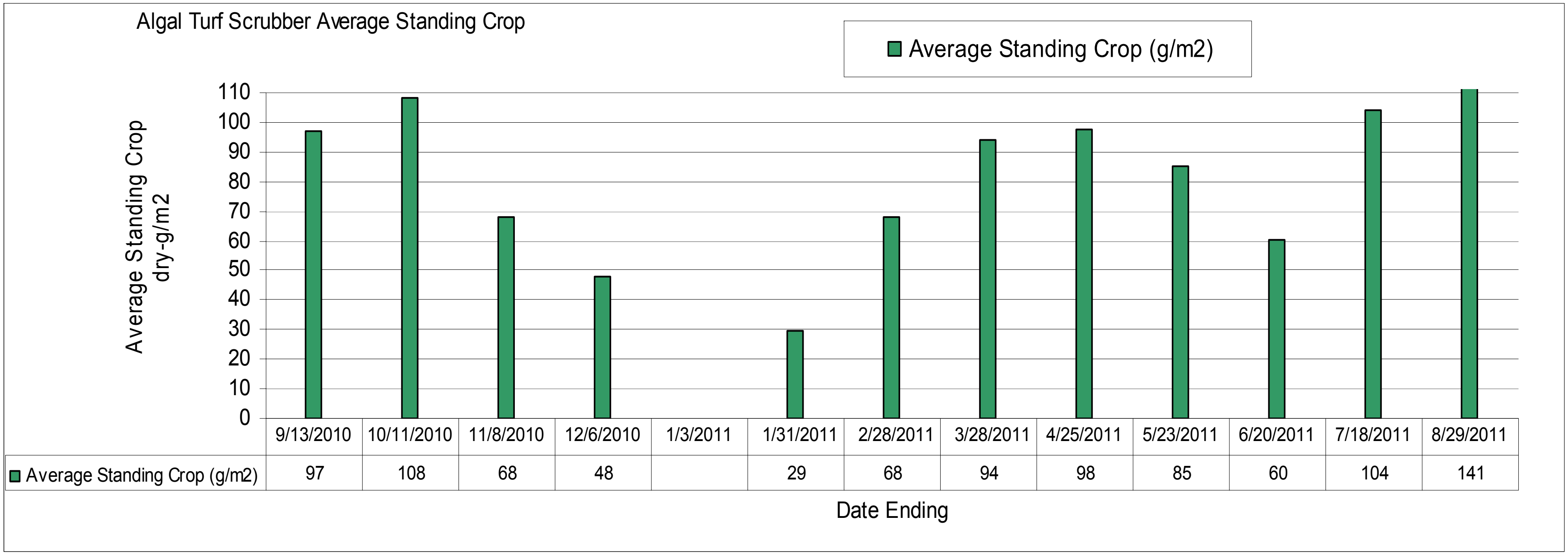


Figure 9: Q1 through Q4 Monthly Average Standing Crop Egret Marsh Algal Turf Scrubber®

Table 6: Q1 through Q4 Algal Turf Tissue Quality by Monthly Period—Rake Harvest

Parameter (units as % of dry weight unless noted otherwise)	Period Ending 9/13/10	Period Ending 10/11/10	Period Ending 11/8/10	Period Ending 12/6/10	Period Ending 1/31/11	Period Ending 2/28/11	Period Ending 3/28/11	Period Ending 4/25/11	Period Ending 5/23/11	Period Ending 6/20/11	Period Ending 7/18/11	Period Ending 8/29/11
TN	3.72	2.63	1.98	1.56	1.98	2.37	2.08	1.50	2.00	2.21	2.65	3.24
Ammonia-N	0.03	0.03	0.01	0.02	0.05	0.02	0.01	0.01	0.02	0.05	0.01	0.08
Organic-N	3.46	2.54	1.95	1.53	1.88	2.28	2.04	1.47	1.97	2.15	2.59	3.11
Nitrate-N	0.22	0.16	0.02	0.01	0.04	0.06	0.03	0.02	0.01	nd	0.05	0.05
P_2O_5	1.41	1.01	1.01	0.56	0.68	1.34	0.66	0.56	0.46	0.73	0.82	0.87
P	0.62	0.44	0.44	0.24	0.30	0.58	0.29	0.24	0.20	0.32	0.49	0.52
K_2O	2.96	1.80	2.08	0.76	0.68	0.71	2.00	1.51	0.53	0.76	1.02	1.23
S	1.04	0.82	0.88	0.47	0.75	0.70	1.08	0.94	2.13	0.57	0.61	0.89
Ca	9.06	12.40	15.59	15.72	12.46	9.18	11.25	10.87	21.31	15.18	14.41	14.80
Mg	0.43	0.43	0.53	0.50	0.45	0.33	0.40	0.42	0.65	0.47	0.45	0.48
Na	0.07	0.23	0.23	0.23	0.37	0.26	0.43	0.30	0.30	0.20	0.21	0.19
Cu (ppm)	52	57	50	28	51	67	67	34	Nd	31	64	85
Fe (ppm)	23,187	17,300	13,915	8,918	15,236	16,279	12,900	12,614	8,355	8,279	13,035	15,436
Mn (ppm)	2,510	1,330	1,057	993	1,884	1,913	15,160	1,590	1,145	1,550	1,929	2,210
Zn (ppm)	121	97	100	73	172	143	99	-	84	85	125	131
pH (units)	6.90	7.50	7.70	7.90	7.60	7.10	7.10	7.70	7.60	7.70	7.30	7.20
Total Carbon	26.59	18.08	15.98	15.29	13.92	13.30	20.75	20.03	18.04	18.38	20.85	24.71
Ash	-	56.80	-	-	-	-	60.00	-	-	-	-	56.46
Cl	1.04	0.80	1.11	0.25	0.51	0.45	1.35	0.65	0.22	0.38	0.29	0.38

Table 7: Q1 through Q4 Algal Turf Tissue Nutrient Content by Monthly Period—Diverted and Combined Harvest

Month	Diverted Flow Total Phosphorus mg/L	Diverted Flow Total Nitrogen mg/L	Diverted Flow Total Solids mg/L	% P Diverted Solids	% N Diverted Solids	% P Combined Harvest Solids	% N Combined Harvest Solids
Sep 2010	2.370	7.45	403	0.59%	1.85%	0.61%	2.92%
Oct 2010	1.670	5.29	338	0.49%	1.56%	0.41%	1.88%
Nov 2010	2.140	7.94	358	0.60%	2.22%	0.51%	2.09%
Dec 2010	1.410	6.27	558	0.25%	1.12%	0.41%	1.71%
Jan 2011	0.974	4.82	321	0.30%	1.50%	0.26%	1.31%
Feb 2011	0.970	7.02	391	0.25%	1.80%	0.49%	2.10%
Mar 2011	2.010	7.28	838	0.24%	0.87%	0.48%	1.92%
Apr 2011	1.540	9.63	830	0.19%	1.16%	0.30%	1.35%
May 2011	1.230	5.97	388	0.32%	1.54%	0.19%	1.51%
Jun 2011	6.370	16.93	952	0.67%	1.78%	0.32%	1.89%
July 2011	5.730	17.84	807	0.71%	2.21%	0.59%	2.18%
Aug 2011	5.120	6.26	1200	0.43%	0.52%	0.55%	2.09 %
Average	**2.628**	**8.41**	**606**	**0.42%**	**1.51%**	**0.47%**	**2.04%**

Table 8: Summary of Q1 through Q4 Algal Turf Scrubber® Tissue Sufficiency Levels

Element	Unit	Egret Marsh Stormwater Park ATS™ (Q1)	Egret Marsh Stormwater Park ATS™ (Q2)	Egret Marsh Stormwater Park ATS™ (Q3)	Egret Marsh Stormwater Park ATS™ (Q4)	General Sufficiency Levels*
Calcium	% dry weight	9.06-15.59	12.46-15.76	9.18-11.25	14.41-21.31	1.9-2.5
Magnesium	% dry weight	0.43-0.53	0.45-0.50	0.33-0.42	0.45-0.65	0.35-0.50
Iron	mg/kg	13,915-23,187	8,918-15,236	12,614-16,279	8,355-15,436	50-150
Potassium	% dry weight	1.80-2.96	0.68-0.76	0.71-2.00	0.53-1.23	2.0-3.0
Manganese	mg/kg	1,057-2,510	993-1,884	1,590-15,160	1,145-2,210	30-100
Nitrogen	% dry weight	1.98-3.71	1.56-1.98	1.50-2.37	2.00-3.24	-
Phosphorus	% dry weight	0.44-0.62	0.24-0.30	0.24-0.58	0.20-0.52	0.25-0.40

*These levels are general guidelines applied to hydroponic systems, and may not always be applicable for certain algae groups.

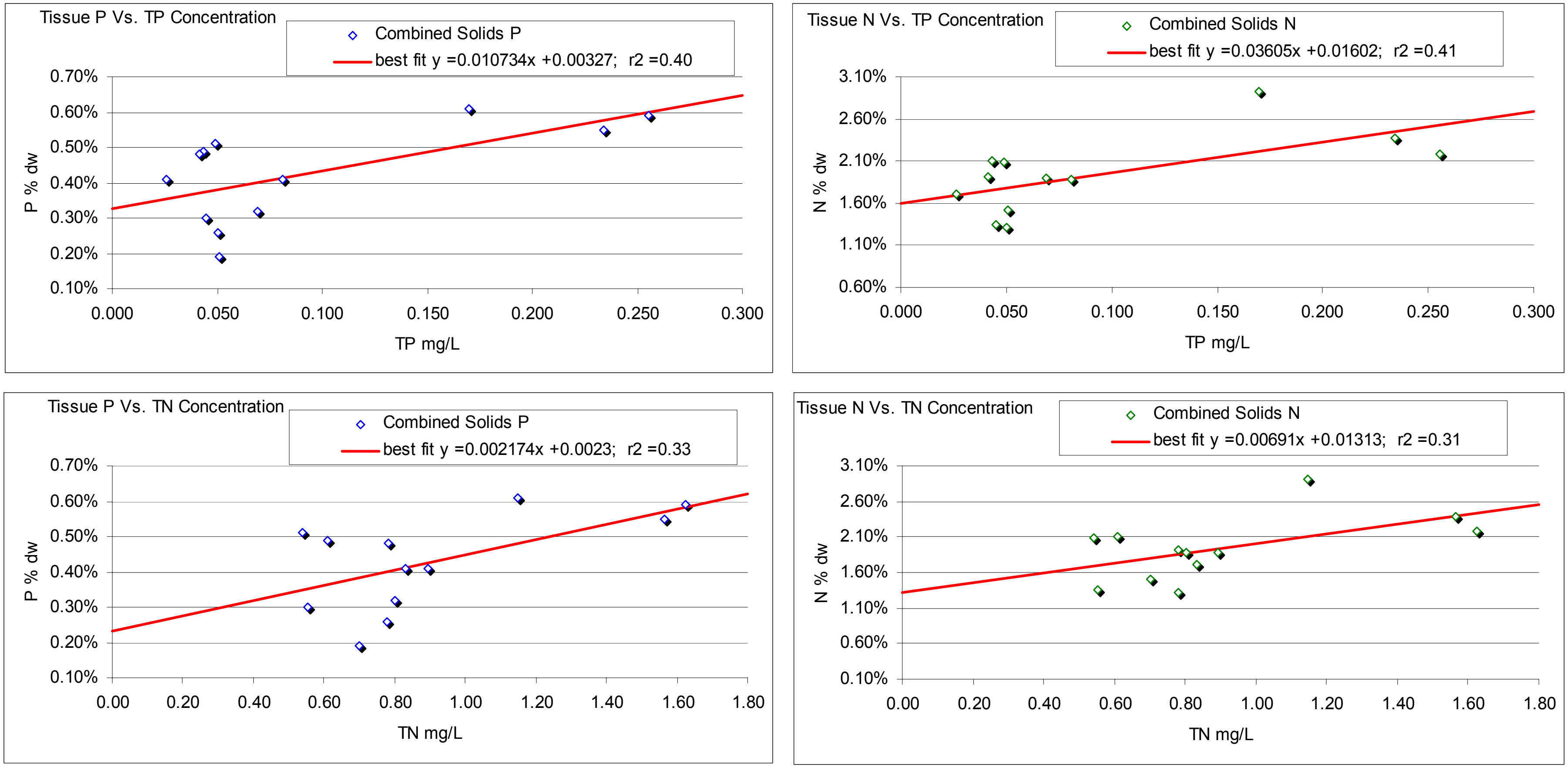
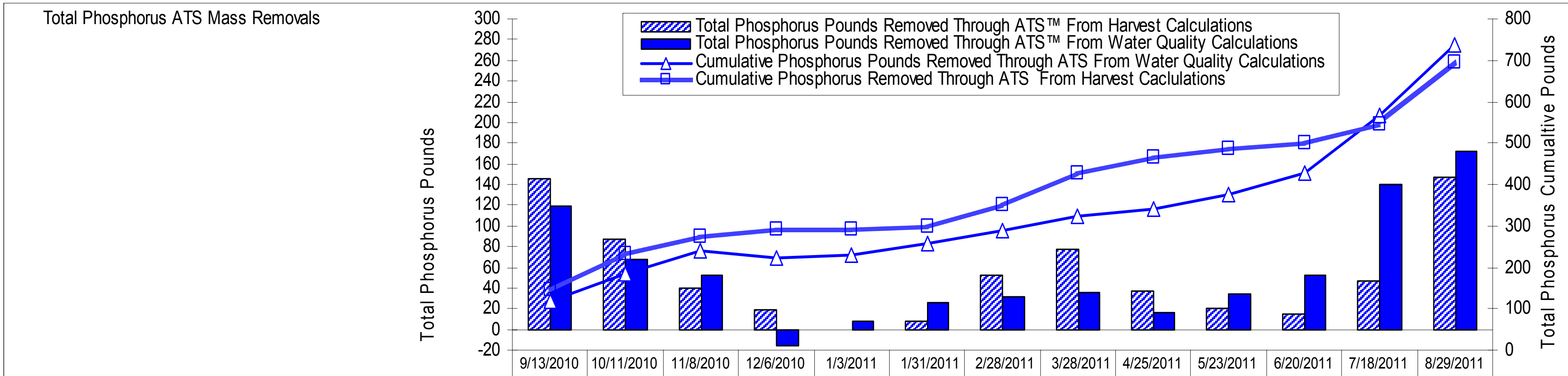


Figure 10: Linear Regression Analysis of Nutrient Concentrations vs. Nutrient Tissue Content Egret Marsh Algal Turf Scrubber®

Table 9: Summary of Q1 through Q4 Algal Turf Scrubber® Harvest Based Nutrient Performance Parameters

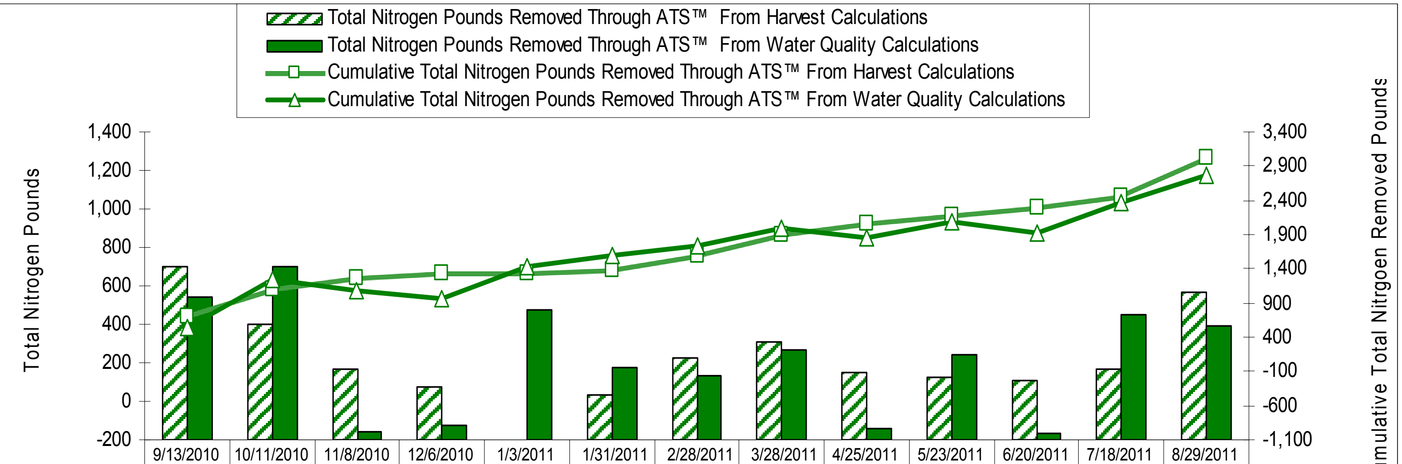
	Mass Removal via Harvest (lbs)		Harvest Based Areal Removal Rate (g/m^2-yr)	
Sampling Period Ending Date	**Total Phosphorus**	**Total Nitrogen**	**Total Phosphorus**	**Total Nitrogen**
9/13/2010	146	698	46.49	222.78
10/11/2010	87	397	27.78	126.72
11/8/2010	40	165	12.88	52.48
Q1 Cumulative	**273**	**1,260**	**30.89**	**142.58**
12/6/2010	19	78	6.00	24.96
1/3/2011	-	-	-	-
1/31/2011	7	37	2.36	11.75
Q2 Cumulative	**26**	**115**	**2.79**	**12.24**
2/28/11	52	224	16.74	71.42
3/28/11	78	311	24.76	99.12
4/25/11	37	154	11.80	49.15
Q3 Cumulative	**167**	**689**	**20.73**	**85.43**
5/23/11	20	125	6.39	39.84
6/20/11	15	105	4.79	33.51
7/18/11	46	167	14.78	53.29
8/29/11	147	568	31.20	120.90
Q4 Cumulative	**228**	**965**	**13.23**	**56.01**
Q1 through Q4	**694**	**3,029**	**16.41**	**71.61**



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Total Phosphorus Pounds Removed Through ATS™ From Harvest Calculations	146	87	40	19		7	52	78	37	20	15	46	147
Total Phosphorus Pounds Removed Through ATS™ From Water Quality Calculations	119	67	53	-16	7	26	31	35	17	35	52	140	172
Cumulative Phosphorus Pounds Removed Through ATS From Water Quality Calculations	119	186	238	223	230	256	287	323	339	374	426	566	738
Cumulative Phosphorus Removed Through ATS From Harvest Caclulations	146	233	273	292	292	299	352	429	466	486	501	548	694

Date Ending

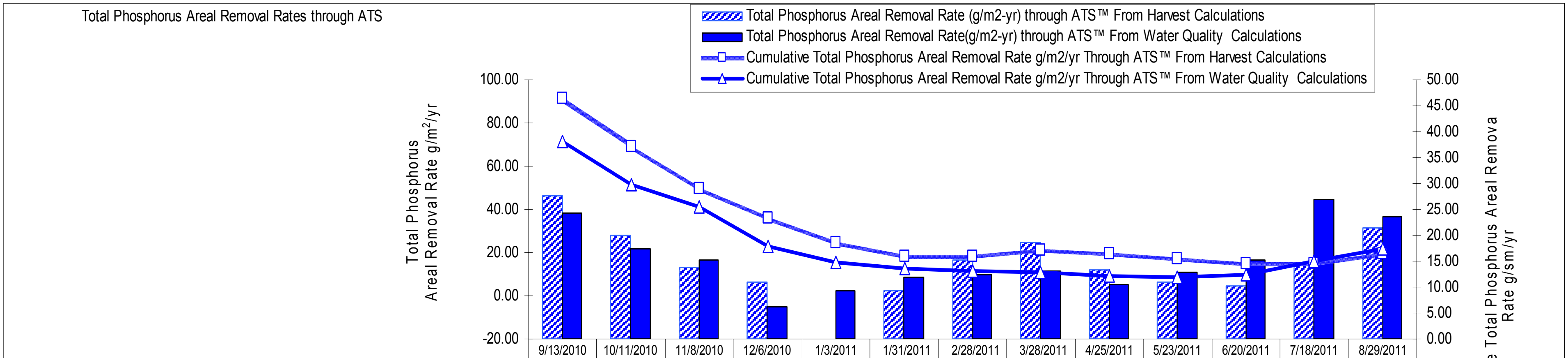
Figure 11: Mass P Removal Comparison Harvest Based vs. Water Quality Based Calculations Egret Marsh Algal Turf Scrubber®



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Total Nitrogen Pounds Removed Through ATS™ From Harvest Calculations	698	397	165	78		37	224	311	154	125	105	167	568
Total Nitrogen Pounds Removed Through ATS™ From Water Quality Calculations	541	697	-160	-127	472	175	132	263	-139	243	-167	450	390
Cumulative Total Nitrogen Pounds Removed Through ATS™ From Harvest Calculations	698	1,095	1,260	1,339	1,339	1,375	1,599	1,910	2,064	2,189	2,294	2,461	3,029
Cumulative Total Nitrogen Pounds Removed Through ATS™ From Water Quality Calculations	541	1,238	1,078	951	1,422	1,597	1,729	1,992	1,854	2,096	1,929	2,380	2,770

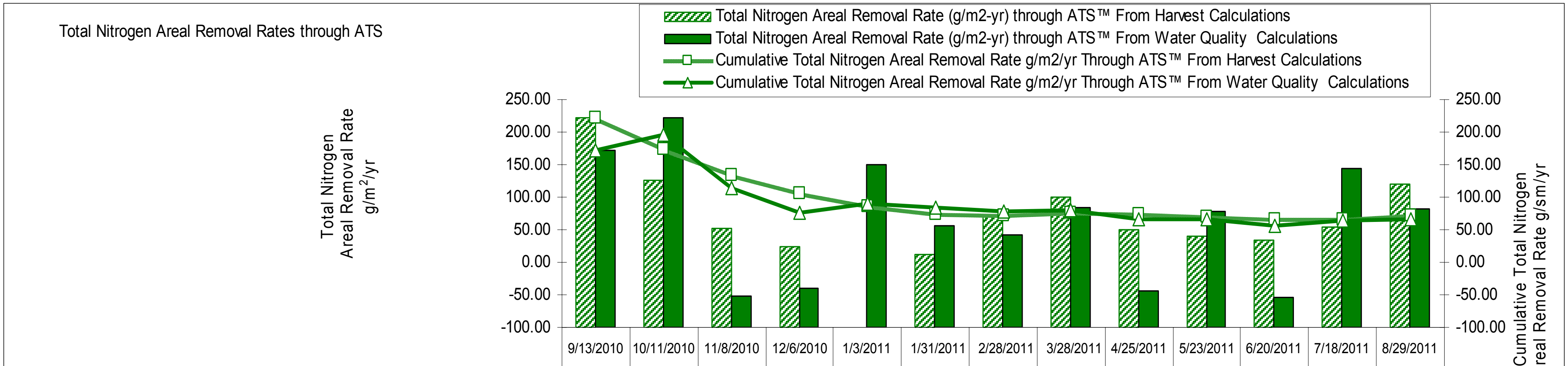
Date Ending

Figure 12: Mass N Removal Comparison Harvest Based vs. Water Quality Based Calculations Egret Marsh Algal Turf Scrubber®



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Total Phosphorus Areal Removal Rate (g/m2-yr) through ATS™ From Harvest Calculations	46.49	27.78	12.88	6.00		2.36	16.74	24.76	11.80	6.39	4.79	14.78	31.20
Total Phosphorus Areal Removal Rate(g/m2-yr) through ATS™ From Water Quality Calculations	38.00	21.48	16.75	-4.99	2.35	8.38	9.91	11.27	5.33	11.08	16.60	44.50	36.64
Cumulative Total Phosphorus Areal Removal Rate g/m2/yr Through ATS™ From Harvest Calculations	46.49	37.13	29.05	23.29	18.63	15.92	16.04	17.13	16.53	15.52	14.54	14.56	16.41
Cumulative Total Phosphorus Areal Removal Rate g/m2/yr Through ATS™ From Water Quality Calculations	38.00	29.77	25.43	17.82	14.72	13.67	13.13	12.90	12.06	11.96	12.38	15.06	17.46

Figure 13: ARR P Removal Comparison Harvest Based vs. Water Quality Based Calculations Egret Marsh Algal Turf Scrubber®



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/29/2011
Total Nitrogen Areal Removal Rate (g/m2-yr) through ATS™ From Harvest Calculations	222.78	126.72	52.78	24.96		11.75	71.42	99.12	49.15	39.84	33.51	53.29	120.90
Total Nitrogen Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	172.54	222.62	-51.21	-40.44	150.51	55.77	42.17	83.86	-44.23	77.49	-53.31	143.72	82.99
Cumulative Total Nitrogen Areal Removal Rate g/m2/yr Through ATS™ From Harvest Calculations	222.78	174.75	134.09	106.81	85.45	73.17	72.92	76.19	73.19	69.85	66.55	65.44	71.61
Cumulative Total Nitrogen Areal Removal Rate g/m2/yr Through ATS™ From Water Quality Calculations	172.54	196.80	114.11	75.47	90.44	85.00	78.87	79.47	65.74	66.91	55.97	63.28	65.47

Month

Figure 14: ARR N Removal Comparison Harvest Based vs. Water Quality Based Calculations Egret Marsh Algal Turf Scrubber®

WATER QUALITY – ASSESSMENT OF PHOSPHORUS AND NITROGEN DYNAMICS

Total Phosphorus

Total Phosphorus is the sum of inorganic phosphate, also known as Ortho phosphorus (PO_4^{-3}), organic phosphorus and polyphosphate phosphorus, both in soluble and particulate forms. Ortho Phosphorus is the inorganic ionic form and accordingly is soluble. It is comparatively labile, and therefore is collected as a filtered grab sample with a 24 hr laboratory holding time. Ortho phosphorus is often called Soluble Reactive Phosphorus or SRP, although SRP could include other forms, such as certain polyphosphates, that could under certain circumstances, become readily available. For purposes of this study, the Ortho phosphorus determined from the filtered grab samples represents that portion of the total phosphorus that is readily available for direct plant uptake. Other forms, both soluble and particulate, may be rendered available through enzymatic action (e.g. phospho-diesterase) or through changes in the physical environment (e.g. pH, redox potential, temperature).

Total phosphorus is measured after digestion converts all forms to Ortho phosphorus. The difference between total phosphorus and Ortho phosphorus (determined without digestion) may be considered the sum of organic and polyphosphate phosphorus. Because Ortho phosphorus is collected as a grab sample, while total phosphorus is typically collected as a composite sample, any comparison or calculations involving the two may be considered somewhat indicative, but not conclusive. Fortunately, as noted in the following subsection, total phosphorus was analyzed for many of the grab samples used for Ortho phosphorus determination.

It is expected that the ATS™ on an annual basis would provide a higher total phosphorus Areal Removal Rate (ARR) than the pond/wetland system, for not only is the ATS™ the first process within the EMSP treatment train to encounter the incoming flow, allowing it to access the most available phosphorus, but also the ATS™ is an active process, with effective nutrient recovery and accountability through direct biological uptake and harvesting, designed to optimize and sustain uptake of nutrients, while the pond/wetland system is a passive system which relies largely upon sediment accretion for removal of phosphorus from the water column[25].

[25] The relative long term value of active treatment systems such as the ATS™ is associated not only with a comparatively high ARR, but also with the fact that they are sustained by harvest and recovery of nutrients, and establish and maintain nutrient accountability. Passive systems, such as ponds and Stormwater Treatment Area (STA) type wetlands do not typically provide active nutrient recovery and accountability, and often serve more as nutrient storage facilities than nutrient removal and recovery facilities. Passive pond and wetland systems however, when used to receive effluent from an active system such as an ATS™ serve to provide some additional phosphorus reduction from a high quality water, while attenuating the fluctuations of such factors as pH and water temperature associated with ATS™ effluent. As important, pond/wetland systems such as those incorporated into the Egret Marsh Stormwater Park, provide a valuable ecological function as fish and wildlife habitat. An extended discussion of this design strategy is presented in the later sections of this text.

Total phosphorus reduction through the EMSP is shown in Table 10. Over the monitoring period, the average total phosphorus concentration reduction through the ATS™ was 0.022 mg/L, from an average influent concentration of 0.101 mg/L to an average effluent concentration of 0.079 mg/L, with the highest reduction occurring as expected during Q1 and Q4 when influent concentrations were the highest. The pond/wetland system provided an additional average reduction[26] over the monitoring period of 0.026 mg/L, from 0.079 mg/L to 0.053 mg/L. By far the greatest contribution from the pond/wetland system was during Q4 (0.053 mg/L reduction) when biological activity was the highest on the ATS™ floway. This was the only quarter in which the pond/wetland removals were higher than those associated with the ATS™. This high level of removal within the pond/wetland system is most likely related to the higher sloughing of viable biological solids across the ATS™, such as epiphytic algae and small invertebrates which were not captured by the Flex rake. During Q4, rainfall was much higher that any other quarter, and during heavy rains sloughing down the ATS™ can be increased, particularly when much of the algal turf community is represented by epiphytic organisms and heavy populations of invertebrates (e.g. amphipods). Active fish populations observed during Q4 near the ATS™ effluent discharge into the pond/wetland system provided indication that much of the viable biological solids were being removed through aggressive grazing and predation.

It became clear over the monitoring period that during the rainy season, the receiving ponds/wetlands serve the important function of polishing the ATS™ effluent through the reduction of any residual solids and small organisms, and in buffering pH and temperature fluctuations. They also served as important habitat for fish, birds, and attendant fauna.

System performance[27] in terms of total phosphorus mass removals, Areal Removal Rates and Percent Removal are summarized within Table 11, and Figures 15 through 18. Total phosphorus removal was, as would be expected, much higher when influent total phosphorus concentrations were the highest. The ATS™ provided the highest overall Areal Removal Rate with an average of 17.46 g/m^2-yr (156 lb/acre-yr), which was expected. Mass total phosphorus removals by the ATS™ and the pond/wetland system based upon the composite samples over the monitoring period were essentially equal (739 lb and 738 lb respectively). As mentioned previously, it is likely that much of the total phosphorus removal through the pond/wetland system was through reduction of particulate phosphorus associated with the incoming ATS™ influent. Overall the EMSP removed 49.4% of the incoming total phosphorus.

---

[26] Based upon surface water discharge from pond/wetland structure without consideration of concentrations within seepage water.

[27] In calculating the mass removal of nutrients from the pond system, loads associated with both the surface water discharge and the seepage flow must be considered. Because determination of the quality of the seepage water is not included in the monitoring plan, it is assumed that its quality is the average of the concentrations of the influent flow to the ponds and the surface water discharge. Therefore mass removal (applies to any nutrient component) from the pond system is calculated as:

$$M_{pp} = Q_{AE} P_{AE} - (Q_{PD} P_{PD} + Q_{PS}[(P_{AE} + P_{PD})/2]$$

Where M_{pp} = Total Phosphorus Mass Removal through pond system
Q_{AE} = Effluent Flow Volume from ATS™ to pond system
P_{AE} = ATS™ Effluent Total Phosphorus concentration
Q_{PD} = Surface Discharge Flow Volume from pond system
Q_{PS} = Seepage Flow Volume associated with pond system
P_{PD} = Total Phosphorus concentration in Surface water discharge from pond system

Ortho Phosphorus and Organic and Polyphosphate Phosphorus

Reviewing changes in Ortho phosphorus and organic/polyphosphate phosphorus through the EMSP process train can provide some helpful insight into the nature of the incoming total phosphorus and the dynamics involved in the uptake and manipulation of phosphorus within the two unit processes--ATS™ and the pond/wetland system. Because Ortho phosphorus is collected as a grab sample, it is most appropriate to collect total phosphorus from the same grab sample to facilitate a more accurate assessment of the relative percentage of total phosphorus as Ortho phosphorus. The difference between the total phosphorus and Ortho phosphorus is considered to be the organic/polyphosphate fraction. In making such assessments it needs to be recognized that there is a bidirectional flux between Ortho and organic/polyphosphate phosphorus (Figure 19). Consequently changes have to be reviewed both in terms of changes in percentage of total phosphorus and in mass removals.

Fortunately, early in the monitoring period (following week 4) it was decided to evaluate the grab sample for total phosphorus. However, with some of the grab samples, particularly during the last months of Q4, the Ortho phosphorus concentration was reported as higher than total phosphorus, implying organic/ polyphosphate levels were less than zero, which is nonsensical.[28] In such cases, for purposes of establishing mass removals, the total phosphorus was considered to be composed entirely of Ortho phosphorus, and the organic/polyphosphate accordingly, was set at zero. The percentages of grab sample total phosphorus as Ortho phosphorus and organic/polyphosphate are shown in Table 12 and Figure 20. The comparative concentrations of Ortho and organic/polyphosphate phosphorus are presented as Figure 21.

The influent total phosphorus to the EMSP was estimated to average 62.1% Ortho phosphorus over the monitoring period. However this percentage varied considerably, with a standard deviation of 25.6% and a range of 9.9% to 96.2%. The percentage of total phosphorus as Ortho phosphorus increased noticeably during the last two months of Q4, when both influent color and total phosphorus increased in response to rainfall and to the release of impounded water within the Lateral D canal. The lower percentage of Ortho phosphorus during late Q1 through early Q4 is largely attributable to the fact that water was being recirculation through the impounded Lateral D during this period, and Ortho phosphorus was being continually reduced through retreatment through the EMSP—remembering that there is a preferential uptake of Ortho phosphorus within biological systems, such as the ATS™.

The fact that the more soluble form of phosphorus (Ortho-P) increased as a greater percentage of total phosphorus with the onset of the 2011 wet season (latter months of Q4) is suggestive that the associated influent flows may largely be associated with groundwater

[28] In reality it is not possible for Ortho phosphorus to be higher than total phosphorus. However the accuracy of the analytical procedures are of a range that when the majority of the total phosphorus is as Ortho phosphorus the accuracy ranges of the two can overlap, and in such cases Ortho phosphorus is often reported as the higher of the two values.

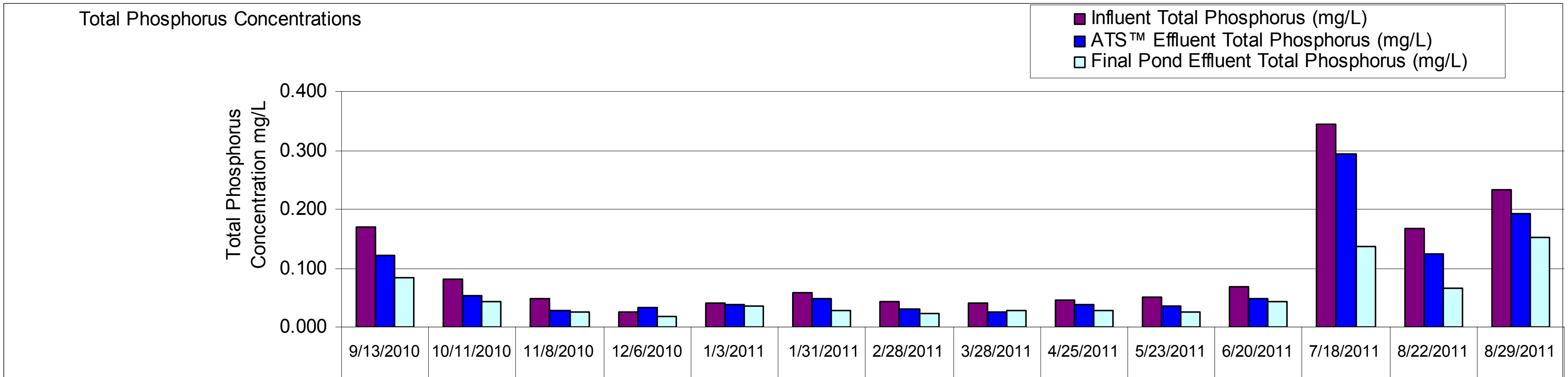
Table 10: Q1 through Q4 Composite Total Phosphorus Concentrations through Egret Marsh Stormwater Park

Sampling Period Ending Date	Influent Total Phosphorus (Station 01)	ATS™ Effluent Total Phosphorus (Station 02)		Final Total Phosphorus System Effluent from Pond System (Station 03)[A]	
	mg/L	mg/L	mg/L reduction concentration	mg/L	mg/L reduction concentration
9/13/2010	0.170	0.121	*0.049*	0.083	*0.038*
10/11/2010	0.081	0.052	*0.029*	0.043	*0.009*
11/8/2010	0.049	0.027	*0.022*	0.026	*0.001*
Q1 Mean	**0.100**	**0.067**	***0.033***	**0.051**	***0.016***
12/6/2010	0.026	0.033	*-0.007*	0.018	*0.015*
1/3/2011	0.041	0.038	*0.003*	0.035[B]	*0.003*
1/28/2011	0.059	0.048	*0.009*	0.029	*0.019*
Q2 Mean	**0.042**	**0.040**	***0.002***	**0.027**	***0.013***
2/28/11	0.043	0.030	*0.013*	0.024	*0.006*
3/28/11	0.042	0.026	*0.016*	0.027	*0.001*
4/25/11	0.045	0.037	*0.008*	0.029	*0.008*
Q3 Mean	**0.043**	**0.031**	***0.012***	**0.027**	***0.004***
5/23/11	0.051	0.036	*0.015*	0.025	*0.011*
6/20/11	0.069	0.048	*0.021*	0.043	*0.005*
7/18/11[B]	0.344	0.294	*0.051*	0.137	*0.157*
8/22/11[B]	0.167	0.125	*0.042*	0.065	*0.060*
Final week 8/29/11	0.234	0.193	*0.041*	0.153	*0.040*
Q4 Mean	**0.173**	**0.139**	***0.034***	**0.085**	***0.054***
Q1 through Q4 Mean	**0.101**	**0.079**	***0.022***	**0.053**	***0.026***

A. Concentration for surface water overflow at pond/wetland discharge structure. Does not include estimated concentration of seepage water.
B. Grab Samples

Table 11: Q1 through Q4 Total Phosphorus Water Quality Calculations Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

	Total Phosphorus Mass Removal (lbs)			Total Phosphorus Areal Removal Rate (g/m^2-yr)			Total Phosphorus Percent (%) of Influent Load Removed		
Sampling Period Ending Date	**ATS™**	**Ponds**	**Total System**	**ATS™**	**Ponds**	**Total System**	**ATS™**	**Ponds**	**Total System**
9/13/2010	119	78	197	37.80	7.94	15.19	30.3%	20.0%	50.3%
10/11/2010	67	19	86	21.48	1.93	6.63	36.4%	10.3%	46.7%
11/8/2010	53	3	56	16.75	0.24	4.23	46.3%	2.1%	48.5%
Q1	**239**	**100**	**339**	**25.36**	**3.37**	**13.02**	**34.6%**	**14.4%**	**49.0%**
12/6/2010	-16	32	16	-4.99	3.27	1.28	-26.6%	54.9%	28.3%
1/3/2011	8	6	14	2.35	0.52	1.06	7.8%	6.8%	14.6%
1/31/2011	26	40	66	8.38	4.05	5.06	19.4%	29.6%	49.0%
Q2	**18**	**78**	**96**	**1.90**	**2.65**	**2.47**	**6.2%**	**27.2%**	**33.4%**
2/28/11	31	13	44	9.91	1.30	3.38	31.4%	13.0%	44.5%
3/28/11	35	-2	34	11.27	-0.18	2.59	36.8%	-1.8%	35.0%
4/25/11	17	18	34	5.33	1.74	2.64	16.5%	17.4%	33.9%
Q3	**83**	**29**	**112**	**8.84**	**0.97**	**2.87**	**28.1%**	**9.7%**	**37.8%**
5/23/11	35	22	57	11.08	2.26	4.39	30.2%	19.3%	49.5%
6/20/11	52	11	63	16.60	1.11	4.86	32.5%	6.8%	39.3%
7/18/11*	140	318	458	44.50	32.24	35.24	17.4%	39.6%	56.9%
8/22/11*	140	157	297	44.50	15.85	18.29	28.6%	32.0%	60.6%
Final week 8/29/11	32	23	55	36.64	9.54	17.15	21.5%	15.7%	37.1%
Q4	**399**	**531**	**930**	**28.30**	**11.98**	**15.92**	**23.2%**	**30.9%**	**54.1%**
Q1 through Q4	**739**	**738**	**1,477**	**17.46**	**5.55**	**8.42**	**24.7%**	**24.7%**	**49.4%**

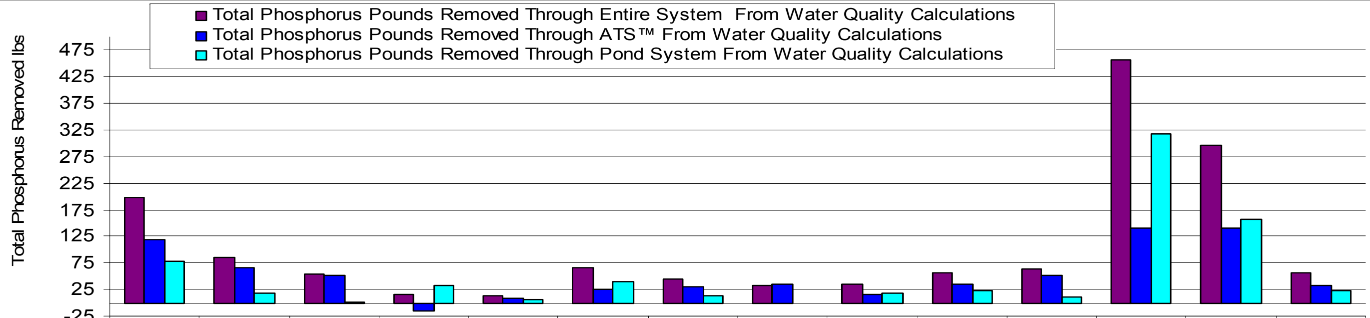


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Total Phosphorus (mg/L)	0.170	0.081	0.049	0.026	0.041	0.059	0.043	0.042	0.045	0.051	0.069	0.344	0.167	0.234
ATS™ Effluent Total Phosphorus (mg/L)	0.121	0.052	0.027	0.033	0.038	0.048	0.030	0.026	0.037	0.036	0.048	0.294	0.125	0.193
Final Pond Effluent Total Phosphorus (mg/L)	0.083	0.043	0.026	0.018	0.035	0.029	0.024	0.027	0.029	0.025	0.043	0.137	0.065	0.153

Date Ending

Figure 15: Q1 through Q4 Composite Samples Total Phosphorus Concentrations through Egret Marsh Stormwater Park

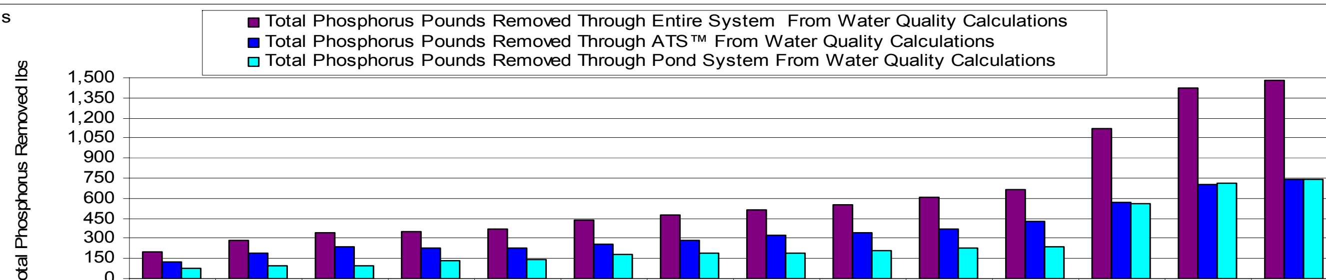
Total Phosphorus Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Pounds Removed Through Entire System From Water Quality Calculations	198	86	55	17	14	66	44	34	34	57	63	458	297	56
Total Phosphorus Pounds Removed Through ATS™ From Water Quality Calculations	119	67	52	-16	7	26	31	35	17	35	52	140	140	32
Total Phosphorus Pounds Removed Through Pond System From Water Quality Calculations	78	19	2	32	6	40	13	-2	18	22	11	318	157	23

Date Ending

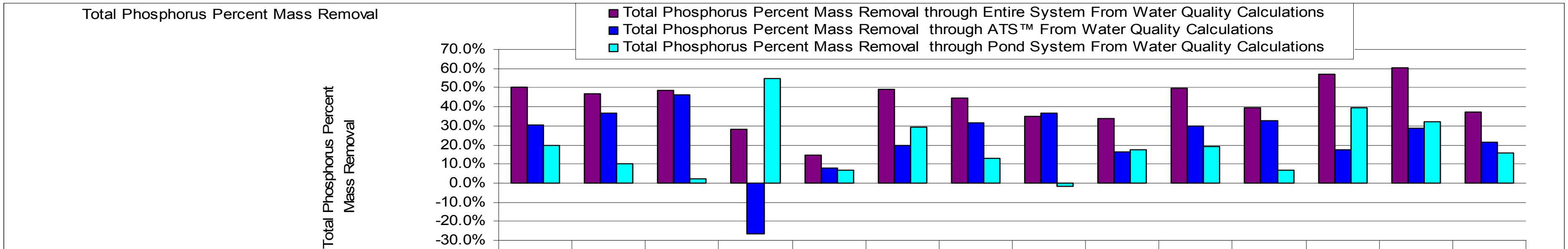
Cumulative Total Phosphorus Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Pounds Removed Through Entire System From Water Quality Calculations	198	284	339	355	369	435	479	512	547	604	667	1,124	1,421	1,477
Total Phosphorus Pounds Removed Through ATS™ From Water Quality Calculations	119	187	239	223	231	257	288	323	340	375	427	566	706	739
Total Phosphorus Pounds Removed Through Pond System From Water Quality Calculations	78	97	100	132	138	178	191	189	207	229	240	558	715	738

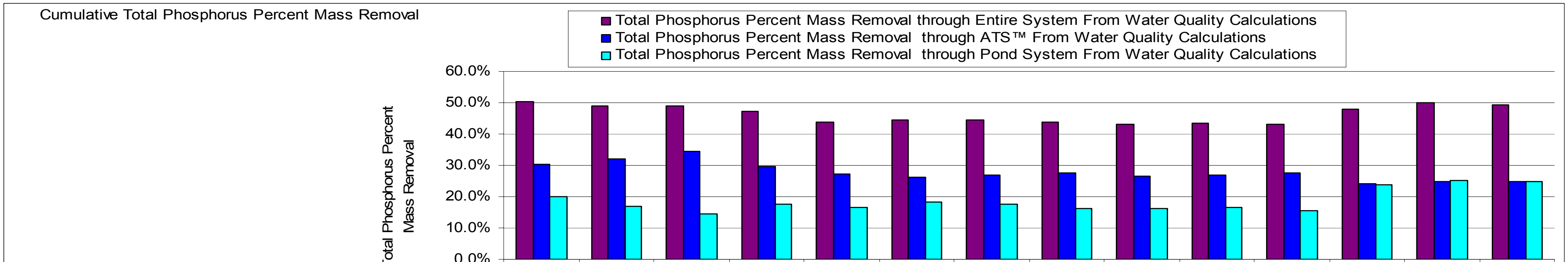
Date Ending

Figure 16: Q1 through Q4 Total Phosphorus Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Percent Mass Removal through Entire System From Water Quality Calculations	50.3%	46.7%	48.5%	28.3%	14.6%	49.0%	44.4%	35.0%	33.9%	49.5%	39.3%	56.9%	60.6%	37.1%
Total Phosphorus Percent Mass Removal through ATS™ From Water Quality Calculations	30.3%	36.4%	46.4%	-26.6%	7.8%	19.4%	31.4%	36.8%	16.5%	30.2%	32.5%	17.4%	28.6%	21.5%
Total Phosphorus Percent Mass Removal through Pond System From Water Quality Calculations	20.0%	10.3%	2.1%	54.9%	6.8%	29.6%	13.0%	-1.8%	17.4%	19.3%	6.8%	39.6%	32.0%	15.7%

Date Ending

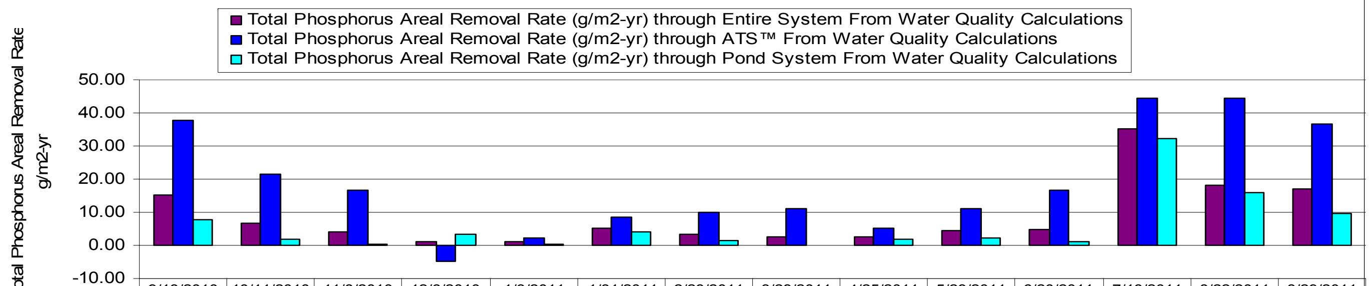


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Percent Mass Removal through Entire System From Water Quality Calculations	50.3%	49.1%	49.0%	47.4%	43.7%	44.4%	44.5%	43.7%	42.9%	43.5%	43.0%	47.8%	50.0%	49.4%
Total Phosphorus Percent Mass Removal through ATS™ From Water Quality Calculations	30.3%	32.2%	34.6%	29.8%	27.3%	26.2%	26.8%	27.6%	26.7%	27.0%	27.6%	24.1%	24.9%	24.7%
Total Phosphorus Percent Mass Removal through Pond System From Water Quality Calculations	20.0%	16.9%	14.5%	17.6%	16.4%	18.2%	17.7%	16.1%	16.2%	16.5%	15.5%	23.7%	25.1%	24.7%

Date Ending

Figure 17: Q1 through Q4 Total Phosphorus Percent Mass Removals through Egret Marsh Stormwater Park

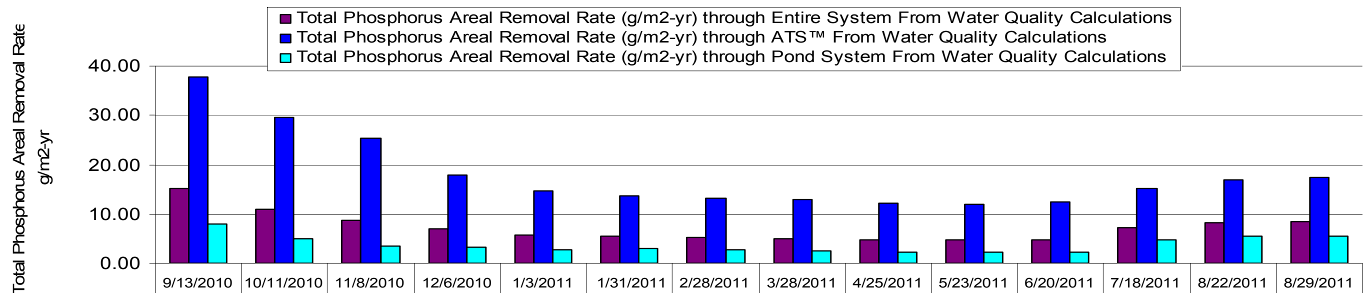
Total Phosphorus Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	15.23	6.63	4.23	1.28	1.06	5.06	3.38	2.59	2.64	4.39	4.86	35.24	18.29	17.15
Total Phosphorus Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	37.80	21.48	16.75	-4.99	2.35	8.38	9.91	11.27	5.33	11.08	16.60	44.50	44.50	36.64
Total Phosphorus Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	7.93	1.93	0.24	3.27	0.52	4.05	1.30	-0.18	1.79	2.26	1.11	32.24	15.85	9.54

Date Ending

Cumulative Total Phosphorus Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Phosphorus Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	15.23	10.93	8.69	6.84	5.68	5.58	5.27	4.93	4.68	4.65	4.67	7.22	8.26	8.42
Total Phosphorus Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	37.80	29.67	25.36	17.77	14.68	13.64	13.13	12.90	12.06	11.96	12.38	15.06	17.01	17.46
Total Phosphorus Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	7.93	4.94	3.37	3.35	2.81	3.01	2.77	2.40	2.33	2.32	2.21	4.72	5.47	5.55

Date Ending

Figure 18: Q1 through Q4 Total Phosphorus Areal Removal Rate through Egret Marsh Stormwater Park

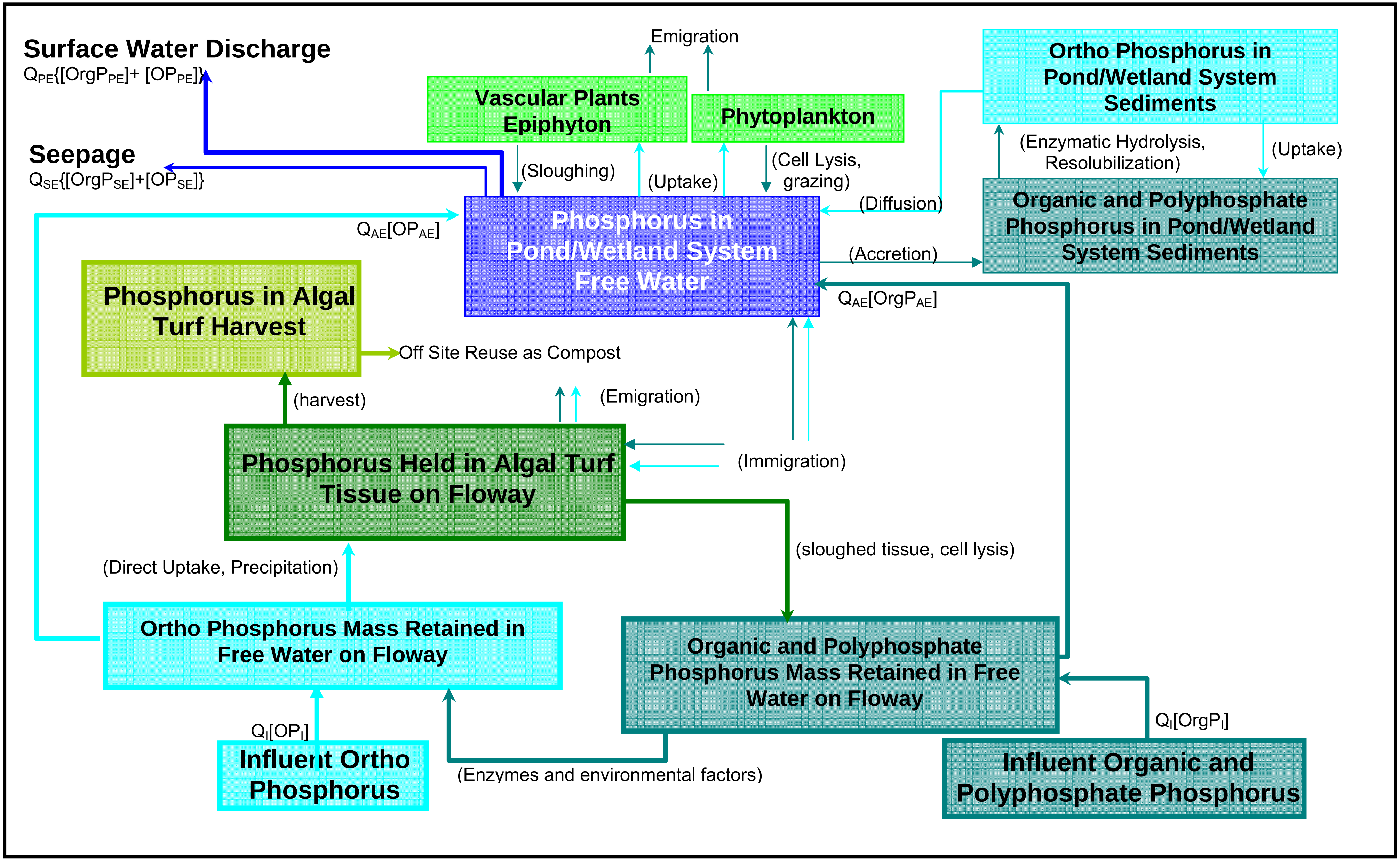
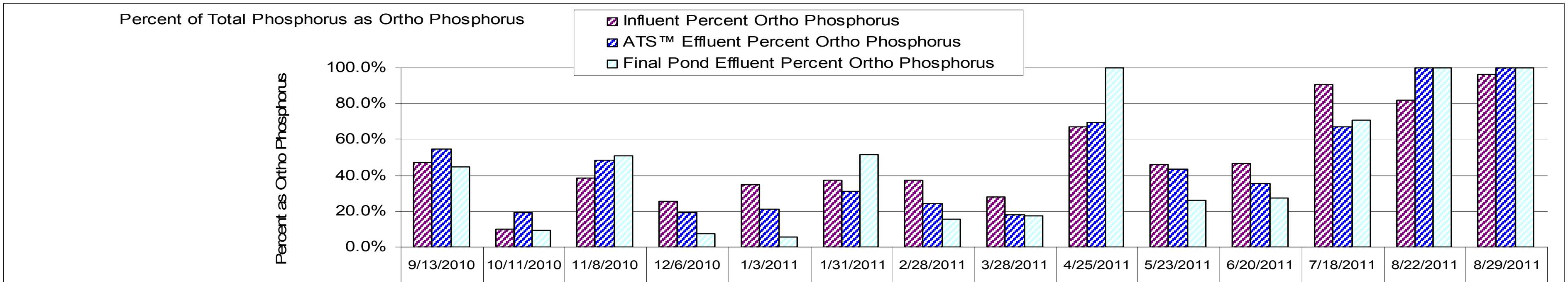


Figure 19: Generalized Schematic of Phosphorus Dynamics through Egret Marsh Stormwater Park

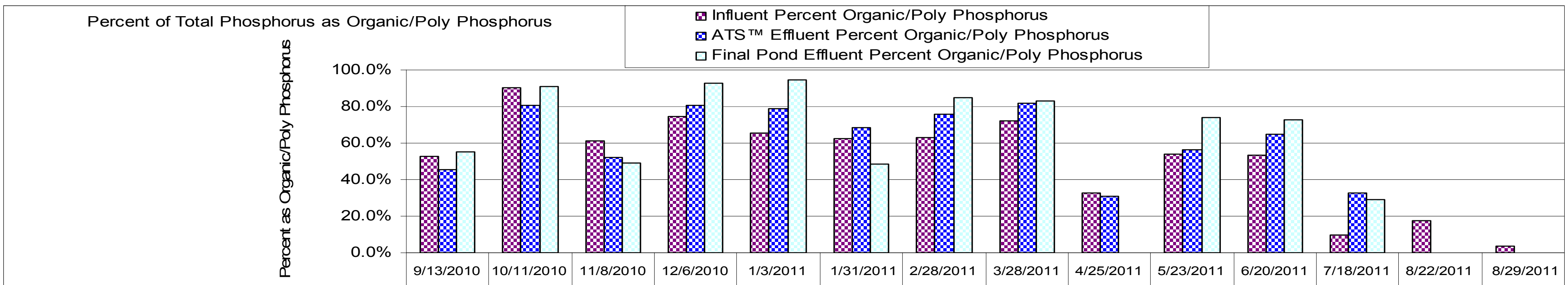
Table 12: Q1 through Q4 Total Phosphorus Components through Egret Marsh Stormwater Park

Period Ending Date	Influent Phosphorus[A] (Station 01)				ATS™ Effluent Phosphorus[A] (Station 02)				Final Phosphorus[A] System Effluent from Pond System (Station 03)			
	Total P (mg/L)	Ortho P (mg/L)	% Ortho P	% Poly and Org P	Total P (mg/L)	Ortho P (mg/L)	% Ortho P	% Poly and Org P	Total P (mg/L)	Ortho P (mg/L)	% Ortho P	% Poly and Org P
9/13/10	0.170	0.080	47.1%	52.9%	0.121	0.066	54.5%	45.5%	0.083	0.037	44.6%	55.4%
10/11/10	0.081	0.008	9.9%	89.1%	0.052	0.010	19.2%	80.8%	0.043	0.004	9.3%	90.7%
11/8/10	0.049	0.019	38.8%	61.2%	0.027	0.013	48.1%	51.9%	0.026	B	B	B
Q1	**0.100**	**0.036**	**36.0%**	**64.3%**	**0.067**	**0.030**	**44.5%**	**55.5%**	**0.051**	**0.021**	**29.0%**	**71.0%**
12/6/10	0.047	0.012	25.4%	74.6%	0.052	0.010	30.3%	69.7%	0.054	0.004	22.4%	87.6%
1/3/11	0.041	0.014	34.5%	65.5%	0.038	0.008	21.1%	88.9%	0.035	0.002	5.7%	94.3%
1/31/11	0.059	0.022	37.3%	62.7%	0.048	0.015	31.3%	69.7%	0.029	0.018	62.1%	37.9%
Q2	**0.049**	**0.016**	**32.7%**	**67.3%**	**0.046**	**0.011**	**27.7%**	**72.3%**	**0.039**	**0.008**	**18.4%**	**81.6%**
2/28/11	0.047	0.018	37.0%	63.0%	0.028	0.007	23.3%	76.7%	0.026	0.004	16.7%	83.3%
3/28/11	0.047	0.013	27.8%	72.2%	0.029	0.005	19.2%	80.8%	0.028	0.005	18.5%	81.5%
4/25/11	0.055	0.037	67.3%	32.7%	0.035	0.024	64.9%	35.1%	0.019	0.019[C]	100%	0.0%
Q3	**0.050**	**0.023**	**46.0%**	**64.0%**	**0.030**	**0.012**	**38.7%**	**61.3%**	**0.024**	**0.009**	**37.9%**	**62.1%**
5/23/11	0.052	0.024	46.2%	52.9%	0.039	0.017	47.2%	52.8%	0.025	0.007	28.0%	72.0%
6/20/11	0.069	0.032	46.4%	53.6%	0.048	0.017	35.4%	64.6%	0.043	0.012	27.9%	72.1%
7/18/11	0.344	0.311	90.4%	9.6%	0.294	0.198	67.3%	32.7%	0.137	0.097	70.8%	29.2%
8/22/11	0.359	0.295	82.2%	17.8%	0.212	0.212[C]	100%	0.0%	0.217	0.217[C]	100%	0.0%
Final week 8/29/11	0.234	0.225	96.2%	3.8%	0.193	0.193[C]	100%	0.0%	0.153	0.153[C]	100%	0.0%
Q4	**0.212**	**0.177**	**81.6%**	**19.4%**	**0.157**	**0.127**	**78.6%**	**21.4%**	**0.115**	**0.097**	**82.0%**	**18.0%**
Q1 through Q4	**0.118**	**0.079**	**65.1%**	**34.9%**	**0.087**	**0.057**	**62.6%**	**37.4%**	**0.066**	**0.044**	**60.3%**	**39.7%**

[A] All but first three months and final week are TP grab Samples
[B] Outlier Value Not Included [C] Ortho P reported as slightly greater than TP, reported here as equal to TP

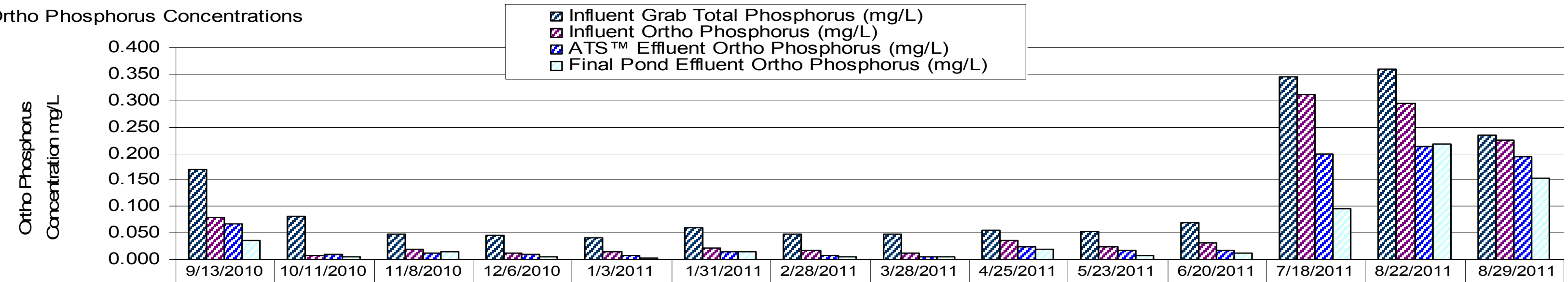


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Percent Ortho Phosphorus	47.1%	9.9%	38.8%	25.4%	34.5%	37.3%	37.0%	27.8%	67.2%	46.2%	46.4%	90.4%	82.2%	96.2%
ATS™ Effluent Percent Ortho Phosphorus	54.5%	19.2%	48.1%	19.2%	21.1%	31.3%	24.2%	18.2%	69.4%	43.4%	35.4%	67.3%	100.0%	100.0%
Final Pond Effluent Percent Ortho Phosphorus	44.6%	9.3%	51.0%	7.5%	5.7%	51.7%	15.4%	17.3%	100.0%	26.2%	27.3%	70.8%	100.0%	100.0%



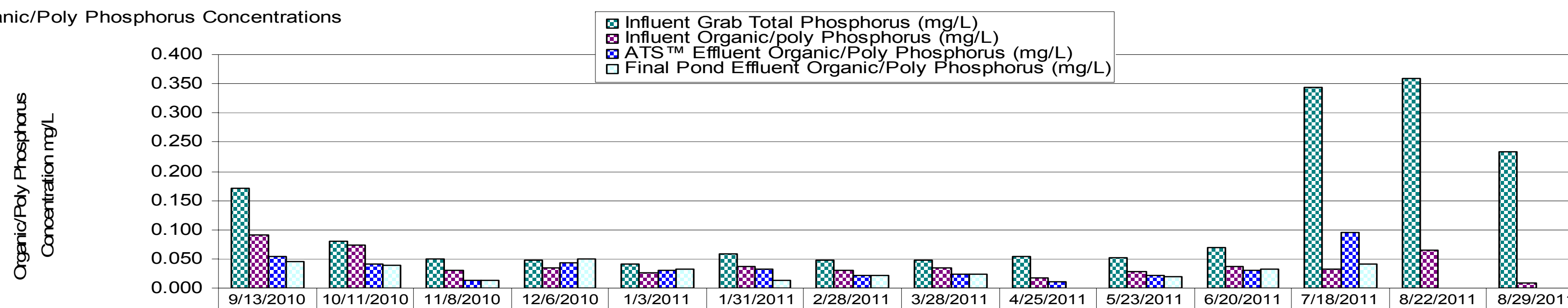
	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Percent Organic/Poly Phosphorus	52.9%	90.1%	61.2%	74.6%	65.5%	62.7%	63.0%	72.2%	32.8%	53.8%	53.6%	9.6%	17.8%	3.8%
ATS™ Effluent Percent Organic/Poly Phosphorus	45.5%	80.8%	51.9%	80.8%	78.9%	68.8%	75.8%	81.8%	30.6%	56.6%	64.6%	32.7%	0.0%	0.0%
Final Pond Effluent Percent Organic/Poly Phosphorus	55.4%	90.7%	49.0%	92.5%	94.3%	48.3%	84.6%	82.8%	0.0%	73.8%	72.7%	29.2%	0.0%	0.0%

Figure 20: Q1 through Q4 Percent of Total Phosphorus as Ortho and Organic/Polyphosphate Phosphorus through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Grab Total Phosphorus (mg/L)	0.170	0.081	0.049	0.047	0.041	0.059	0.047	0.047	0.055	0.052	0.069	0.344	0.359	0.234
Influent Ortho Phosphorus (mg/L)	0.080	0.008	0.019	0.012	0.014	0.022	0.018	0.013	0.037	0.024	0.032	0.311	0.295	0.225
ATS™ Effluent Ortho Phosphorus (mg/L)	0.066	0.010	0.013	0.010	0.008	0.015	0.007	0.005	0.024	0.017	0.017	0.198	0.212	0.193
Final Pond Effluent Ortho Phosphorus (mg/L)	0.037	0.004	0.014	0.004	0.002	0.015	0.004	0.005	0.019	0.007	0.012	0.097	0.217	0.153

Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Grab Total Phosphorus (mg/L)	0.170	0.081	0.049	0.047	0.041	0.059	0.047	0.047	0.055	0.052	0.069	0.344	0.359	0.234
Influent Organic/poly Phosphorus (mg/L)	0.090	0.073	0.030	0.035	0.027	0.037	0.030	0.034	0.018	0.028	0.037	0.033	0.064	0.009
ATS™ Effluent Organic/Poly Phosphorus (mg/L)	0.055	0.042	0.014	0.042	0.030	0.033	0.021	0.023	0.011	0.022	0.031	0.096	0.000	0.000
Final Pond Effluent Organic/Poly Phosphorus (mg/L)	0.046	0.039	0.012	0.050	0.033	0.014	0.022	0.023	0.000	0.018	0.032	0.040	0.000	0.000

Date Ending

Figure 21: Q1 through Q4 Ortho and Organic/Polyphosphate Grab Samples Phosphorus Concentration through Egret Marsh Stormwater Park

rather than direct surface runoff[29]. Recognizing that color also increased substantially during this period, it is reasonable to suspect that the underlying "hardpan" soil layer[30] perched the shallow seepage water within the attendant watershed during the drought period when canal levels were kept artificially high through impoundment. These seepage waters were then released during the wet weather discharge of Lateral D impounded waters and the commensurate temporary lowering of water level within Lateral D. This implication is supported by the linear relationship between color and both total and Ortho phosphorus as shown in Figure 22. This relationship is not observed with organic/polyphosphate as also noted in Figure 22.

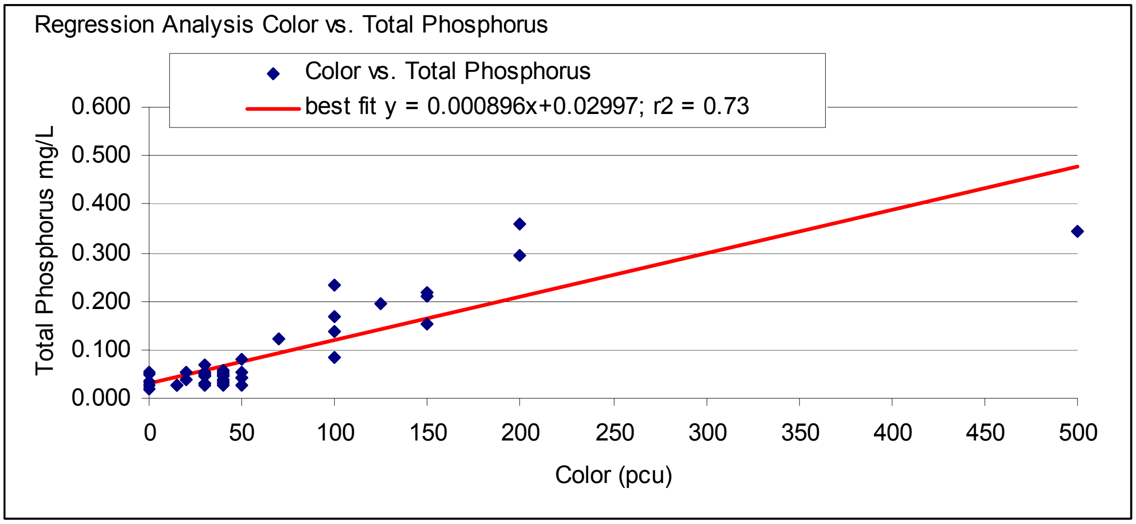
In support of this suspected trend of seepage water domination within Lateral D, the total suspended solids (TSS) within the influent flow did not increase noticeably with the wet weather flows of Q4, and remained comparatively low throughout the monitoring period, averaging 6.15 mg/L during the monitoring period, with a maximum concentration of 9.60 mg/L. Unlike color, TSS did not show a clear linear relationship with phosphorus concentrations, as shown in Figure 23. This is indicative that particulate phosphorus associated with suspended solids was not typically a significant source of loading to the EMSP during the monitoring period.

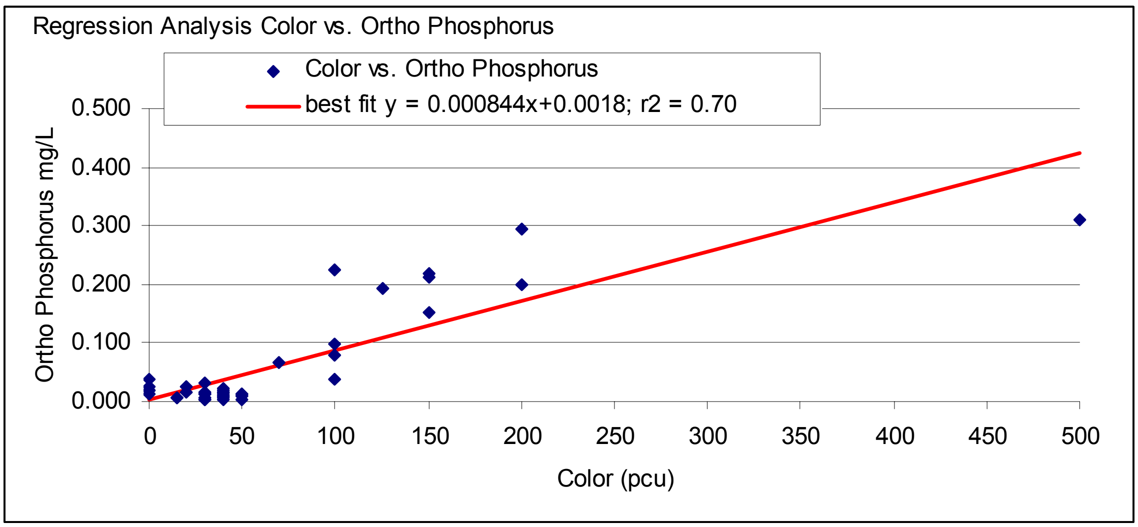
Because there was substantial reduction of color through the EMSP during the latter months of Q4, and there was a commensurate reduction of Ortho phosphorus, it is suggested that Ortho phosphorus may be adsorbed onto, or in some other manner closely aligned with, the colloids associated with color. Considering this possibility, it would seem reasonable to pursue and develop a watershed management program that facilitated the periodic draining of the stored seepage water into the Lateral D canal during the dry season. This could be accomplished by establishing an up gradient storage reservoir, hydraulic connected to the Lateral D canal through control gates, with this reservoir serving to periodically receive Lateral D impounded water. This arrangement would resemble a batch flow treatment approach, and would likely provide the EMSP the opportunity to improve phosphorus reduction, and accordingly, substantially attenuate mass phosphorus loading associated with wet season releases to the Main Canal and the Indian River Lagoon.

Regarding comparative removals of Ortho and organic/polyphosphate phosphorus, there was noted a rather modest reduction in the percentage of total phosphorus as Ortho phosphorus in both the ATS™ effluent (62.6%) and the pond/wetland effluent (60.3%) when compared to the influent percentage (65.1%) as noted in Table 12 and Figure 20. This is not unexpected, considering the normal fluctuations between Ortho and organic/polyphosphate phosphorus (Figure 19).

[29] Phosphorus associated with direct surface runoff is more likely to be high in particulate phosphorus and accordingly, total suspended solids. Organic and to some extent, polyphosphates, are more likely to be incorporated into particulate phosphorus than is Ortho phosphorus, although it needs to be recognized that some organic and polyphosphate phosphorus can be soluble, and that in some cases a portion of Ortho phosphorus can be associated with suspended solids through adsorption and precipitation.

[30] Hardpan in Florida is a layer of cemented soils with the presence of organic matter that is often associated with pine and palmetto flatwoods—a common eco-type in the vicinity of the EMSP. This hardpan is dark brown in color, and because of its low permeability, tends to support a perched layer of seepage water, which can inherit the dark color of the hardpan and can hold accumulated nutrients and other pollutants.





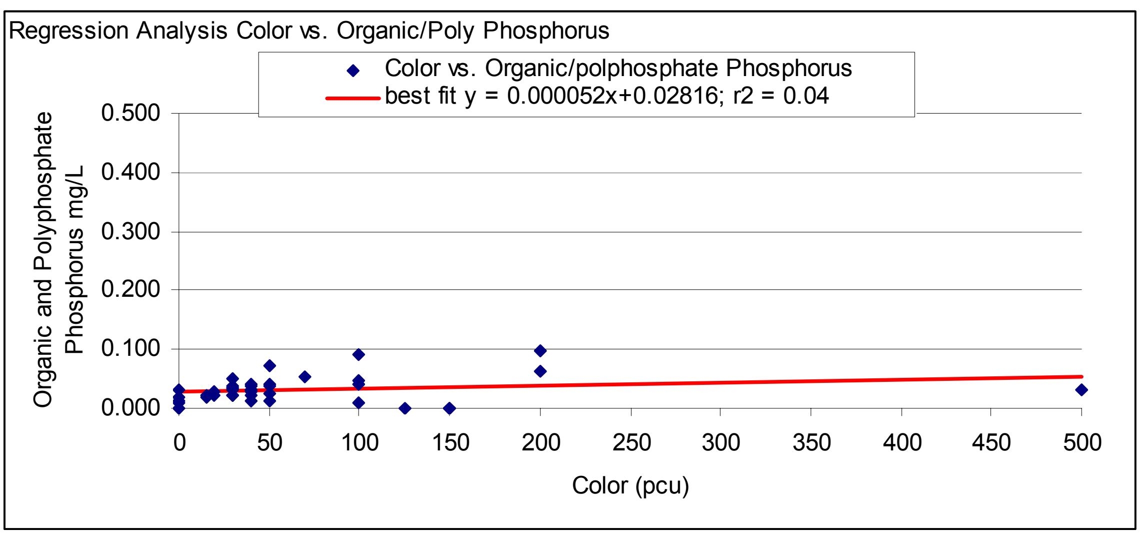


Figure 22: Q1 through Q4 Regression Analysis Color vs. Phosphorus Concentrations through Egret Marsh Stormwater Park

More revealing is the comparative mass removals, both in term of the two fractions of phosphorus and within the two unit processes, as noted in Table 13, and shown in Figures 24 and 25. There are a few trends associated with this mass removal data that are worth noting. First, as might be anticipated, because the ATS™ was provided the initial opportunity to assimilate the most readily available nutrients, and because the ATS™ is sustained at comparatively high productivity levels through frequent harvesting, the mass removal of Ortho phosphorus was dominated by the ATS™, which contributed removal of 781 pounds of Ortho phosphorus over the monitoring period or 67% of the total EMSP removal of 1,171 lbs. The ATS™ also provided the larger percentage of organic/polyphosphate phosphorus reduction over the monitoring period—60% or 321 lbs as compared to 214 lbs removed by the pond/wetland system. Overall, based upon the grab sample data and the assumptions as listed previously, the ATS™ overall provided removal of 1,105 lbs or 67% of the 1,709 lbs of phosphorus removed. Over 63% of the total phosphorus reduction and 75% of the Ortho phosphorus reduction occurred during Q4, particularly after the rainy season began in mid July, 2011. However, only 38% of the organic/polyphosphate phosphorus reduction occurred during Q4.

As noted, organic/polyphosphate phosphorus represented about 35% of the incoming phosphorus, and accordingly accounted for about 32% of the total phosphorus removed. This is suggestive that much of the organic/polyphosphate fraction was biologically labile, and perhaps vulnerable to enzymatic hydrolysis, particularly on the ATS™. Also, sedimentation or direct consumption through grazing and predation could have been an active removal mechanisms for organic/polyphosphate phosphorus, being most likely associated with the pond/wetland system. It was quite evident, based upon the observed active feeding of the fish populations in the vicinity of the ATS™ effluent discharge into the pond/wetland system, that small organisms and organic residuals associated with the ATS™ effluent discharge were being quickly consumed.

Much of the influent Ortho phosphorus was being converted through direct uptake by photoautotrophs (e.g. algae) on the ATS™ into organic phosphorus. While much of this organic phosphorus was harvested, it is inevitable that small amounts would periodically escape into the pond/wetland system. This would be most noticeable during periods of extensive hydraulic flushing such as during heavy rainfall events; during periods following harvest or temporary shut downs; or even as a diurnal pattern of fluctuation, with higher releases perhaps occurring during the nighttime when there is no photosynthetic induced uptake. This periodic release is indicated by comparative differences in total phosphorus reduction contributions of the ATS™ and the pond/wetland system considering calculations based upon composite samples and grab samples, as presented in Table 14. As seen, calculations supported by grab samples indicate the ATS™ contribution to total phosphorus removal is substantially greater than that associated with the pond/wetland system (1,102 lb vs.604 lb), while the two processes provide equal contributions when composite samples are used in developing the calculations (739 lb vs. 738 lb). Also, the total system removal is somewhat higher (~16%) when grab samples are applied (1,477 lb vs. 1,709 lb). These trends are, as suggested, indicative of periodic fluctuations in phosphorus release rates to the ATS™ effluent, which would be less likely to be documented through a single grab sample.

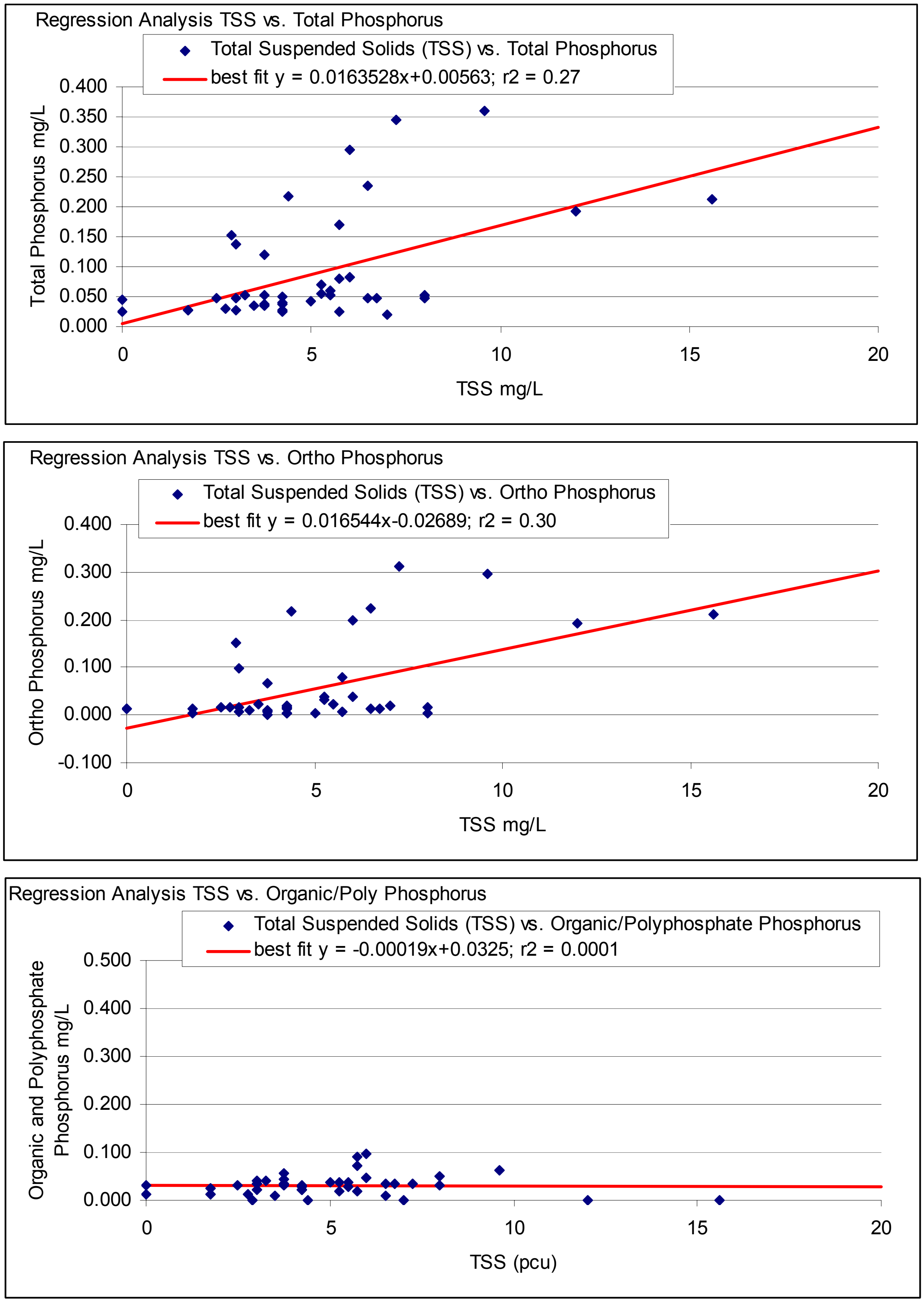


Figure 23: Q1 through Q4 Regression Analysis Total Suspended Solids vs. Phosphorus Concentrations through Egret Marsh Stormwater Park

In summary, over the course of the monitoring period, the percentage of total phosphorus as Ortho phosphorus within the Lateral D canal showed a tendency to increase as the total phosphorus concentration increased. The highest percentage of over 80% was noted during the latter months of Q4 when total phosphorus levels increased to well over 0.200 mg/L in response to the onset of the summer rainy season. During previous quarters, when most of the Lateral D total phosphorus levels were well under 0.075 mg/L, Ortho phosphorus represented less than 50% of the total phosphorus. A direct linear correlation was documented between Ortho phosphorus and color, suggestive that the source of the canal water was largely stored seepage water perched above a ubiquitous dark hardpan layer. There was little indication that TSS and phosphorus were so correlated, with the implication that particulate phosphorus levels within the canal were minimal.

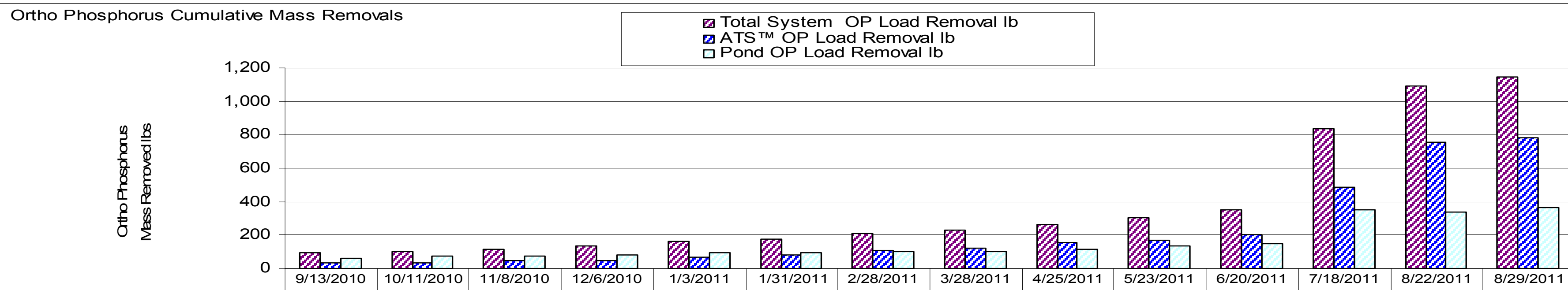
During Q2 and Q3, the last month of Q1 and the first 2 months of Q4, the region experienced severe drought conditions. In an effort to conserve water, downstream gates were closed by IRFWCD so upstream flows could be impounded within the Lateral D canal. This established a dynamic of extensive recirculation and retreatment of waters through the EMSP, which resulted in the disproportionate removal of Ortho phosphorus, and a subsequent reduction of Ortho phosphorus as a percentage of total phosphorus. During this impoundment period total phosphorus levels were kept at concentrations well below 0.075 mg/L.

Based upon grab sample data, the ATS™ showed a preferential uptake of Ortho phosphorus, as would be expected with a biological system. However, it also was effective in some reduction of organic/polyphosphate phosphorus, indicating an ability to accommodate enzymatic hydrolysis. The pond/wetland system provided further reduction of both Ortho phosphorus and organic/polyphosphate phosphorus at rates somewhat lower than the ATS™. The pond/wetland system relied not only upon direct photoautotrophic uptake of Ortho phosphorus, but also from grazing and predation of biotic solids, which included small organisms associated with the ATS™ effluent, and upon accretion within the sediments.

It is noteworthy that when the dynamics of phosphorus reduction are compared between the set of composite sample data and the grab sample data, that the grab sample calculations indicate the ATS™ offers a greater phosphorus mass removal when compared to the pond/wetland system. The composite sample based calculations indicate the ATS™ and the pond/wetland system provide the same level of phosphorus mass removal. It is likely this difference relates to periodic releases of phosphorus in response to certain disruptive events such as heavy rainfall which can induce increased sloughing of algal turf tissue and harvesting, or to normal loss of photosynthesis associated with nighttime periods. Based upon this pattern as observed, it is recommended that ATS™ units designed for stormwater management include unit processes which facilitate removal of any residual solids, and the attendant nutrients, from the ATS™ effluent. This can be accomplished through the use of downstream ponds/wetlands such as applied at the EMSP, or if land availability is an issue, through micro-screening or filtration.

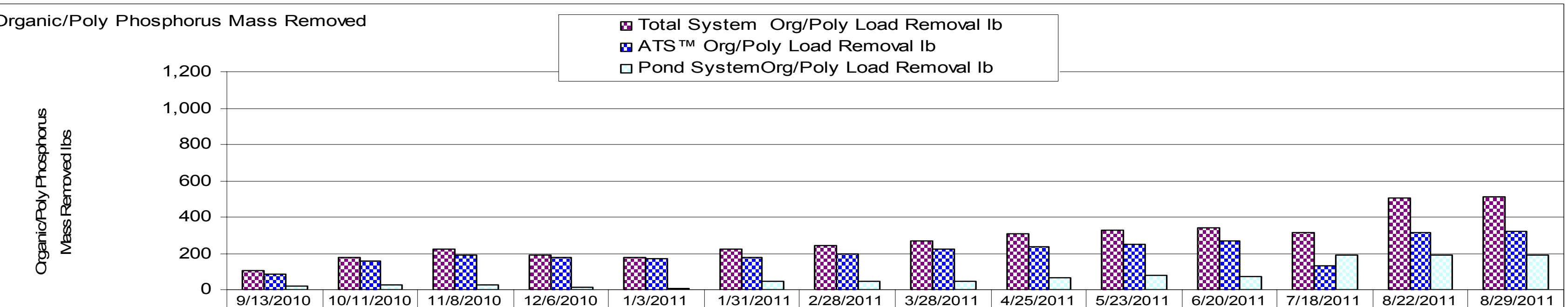
Table 13: Q1 through Q4 Ortho Phosphorus and Organic/Poly Phosphorus Mass Removals and Percent Removals Based upon Grab Samples through Egret Marsh Stormwater Park

	Ortho Phosphorus Mass Removal (lbs)			Organic/Poly Phosphorus Mass Removal (lbs)			Ortho Phosphorus Percent (%) of Influent Load Removed			Organic/Poly Phosphorus (%) of Influent Load Removed		
Sampling Period	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System
9/13/2010	36	60	96	84	19	103	19.4%	32.4%	51.8%	40.3%	8.9%	49.2%
10/11/2010	-4	12	8	71	7	79	-23.9%	67.9%	44.0%	43.0%	4.0%	47.0%
11/8/2010	15	27	42	38	29	67	33.5%	-	-	54.6%	-	-
Q1	**47**	**99**	**146**	**193**	**55**	**248**	**16.7%**	**40.1%**	**56.8%**	**43.5%**	**6.7%**	**50.2%**
	4	13	17	-17	-15	-32	15.5%	48.1%	63.6%	-21.2%	-19.2	-40.4%
1/3/2011	14	12	26	-7	-6	-13	43.2%	38.4%	81.6%	-12.2%	-9.8%	-22.0%
1/31/2011	16	0	16	10	40	50	32.5%	0.0%	32.5%	11.7%	47.1%	58.8%
Q2	**34**	**25**	**59**	**-14**	**19**	**5**	**31.5%**	**23.2%**	**54.7%**	**-6.4%**	**8.3%**	**1.9%**
2/28/11	25	6	31	20	-2	18	61.3%	14.5%	75.8%	28.7%	-2.3%	26.4%
3/28/11	18	1	19	24	1	25	59.7%	2.9%	62.6%	30.3%	1.2%	31.5%
4/25/11	29	11	40	17	22	39	34.6%	12.9%	47.5%	41.0%	54.3%	95.3%
Q3	**72**	**18**	**90**	**61**	**21**	**82**	**46.5%**	**11.4%**	**57.9%**	**32.1%**	**11.5%**	**43.6%**
5/23/11	16	21	37	14	8	22	29.9%	39.3%	59.2%	21.7%	11.9%	33.6%
6/20/11	35	10	45	16	-2	14	48.4%	14.1%	62.5%	18.7%	-1.8%	16.9%
7/18/11	279	205	484	-140	113	-27	38.4%	28.2%	66.6%	-181.3%	147.1%	-34.2%
8/22/11	272	-11	261	188	0	188	31.5%	-1.3%	30.2%	100%	0.0%	100%
Final week 8/29/11	26	23	49	6	0	6	18.3%	16.3%	34.6%	100%	0.0%	100%
Q4	**628**	**248**	**876**	**84**	**119**	**203**	**33.8%**	**13.3%**	**47.1%**	**19.9%**	**28.4%**	**48.3%**
Q1 thr Q4	**781**	**420**	**1,171**	**324**	**214**	**538**	**32.9%**	**16.5%**	**49.4%**	**25.3%**	**15.3%**	**40.6%**



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total System OP Load Removal lb	96	104	117	134	161	177	207	226	266	303	350	834	1,095	1,144
ATS™ OP Load Removal lb	36	31	46	50	64	80	105	123	152	168	204	483	755	782
Pond OP Load Removal lb	60	72	71	84	96	97	102	103	114	135	146	350	339	363

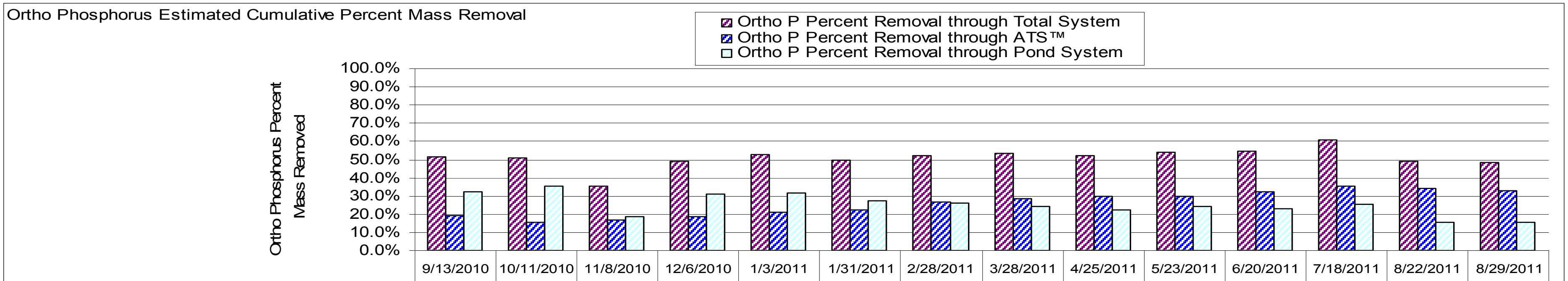
Date Ending



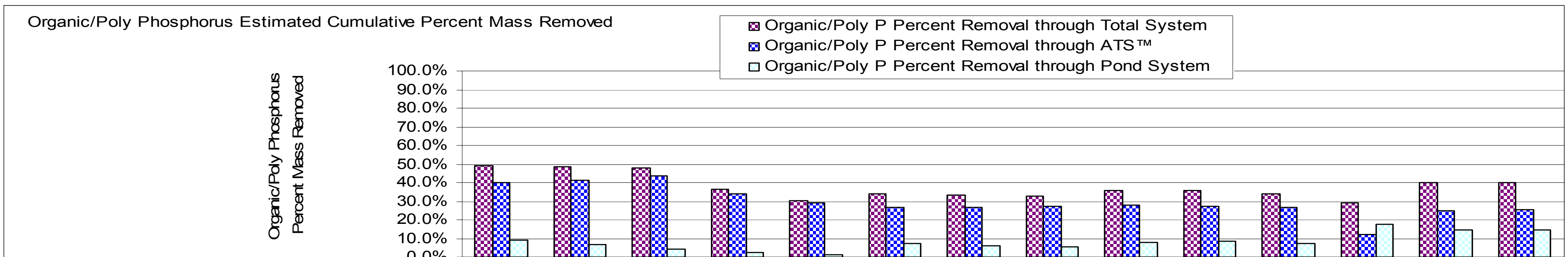
	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total System Org/Poly Load Removal lb	102	180	221	190	176	226	244	268	307	328	343	317	504	510
ATS™ Org/Poly Load Removal lb	84	155	193	176	169	179	198	222	239	252	268	129	316	322
Pond SystemOrg/Poly Load Removal lb	19	25	29	13	7	47	46	46	69	76	75	188	188	188

Date Ending

Figure 24: Q1 through Q4 Ortho and Organic/Polyphosphate Phosphorus Cumulative Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ortho P Percent Removal through Total System	51.7%	51.0%	35.2%	49.1%	52.6%	49.7%	52.4%	53.1%	52.2%	53.8%	54.8%	61.1%	49.1%	48.2%
Ortho P Percent Removal through ATS™	19.4%	15.5%	16.7%	18.4%	21.0%	22.6%	26.5%	28.9%	29.8%	29.8%	32.0%	35.4%	33.9%	32.9%
Ortho P Percent Removal through Pond System	32.4%	35.5%	18.6%	30.8%	31.6%	27.1%	25.9%	24.2%	22.4%	24.0%	22.9%	25.7%	15.2%	15.3%



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic/Poly P Percent Removal through Total System	49.21%	48.21%	47.77%	36.39%	30.25%	33.85%	33.17%	33.01%	35.97%	35.81%	34.18%	29.31%	39.77%	40.04%
Organic/Poly P Percent Removal through ATS™	40.27%	41.5%	43.5%	33.8%	29.0%	26.8%	27.0%	27.3%	27.9%	27.5%	26.8%	11.9%	24.9%	25.3%
Organic/Poly P Percent Removal through Pond System	8.9%	6.7%	4.2%	2.6%	1.3%	7.1%	6.2%	5.7%	8.0%	8.3%	7.4%	17.4%	14.8%	14.8%

Figure 25: Q1 through Q4 Ortho and Organic/Polyphosphate Phosphorus Cumulative Percent Mass Removals through Egret Marsh Stormwater Park

Table 14: Q1 through Q4 Ortho Phosphorus and Organic/Poly Phosphorus Mass Removal Comparison of Composite and Grab Sample Based Calculation through the Egret Marsh Stormwater Park

Sampling Period	Calculated Total Phosphorus Removed lbs						
	ATS™ per harvest	ATS™ per composite samples	ATS™ per grab samples	Pond/Wetland System per composite samples	Pond/Wetland System per grab samples	Total System per composite samples	Total System per grab samples
Q1	273	239	240	100	154	339	394
Q2	26	18	20	78	44	96	64
Q3	167	83	133	29	39	112	172
Q4	228	399	712	531	367	830	1,079
Total	**694**	**739**	**1,105**	**738**	**604**	**1,477**	**1,709**

Total Nitrogen

Total nitrogen is the sum of Total Kjeldahl Nitrogen (TKN) and nitrate+nitrite-N (or NOx-N). TKN is the sum of organic nitrogen and ammonia (NH_3-N) nitrogen. Typically, ammonia and nitrate+nitrite are considered the available forms of nitrogen, readily accessible for direct plant uptake. More labile forms of organic nitrogen can be converted to ammonia nitrogen through enzymatic activity (e.g. deaminase) or through changes in the physical environment (e.g. pH, light, redox, water temperature). Experience with past ATS™ facilities has shown that some transformation of organic nitrogen to ammonia nitrogen can occur across the floway. Transformation dynamics of nitrogen through an active biological system is even more complex than phosphorus, as there is an open association with the atmospheric sink of elemental nitrogen through nitrogen fixation, denitrification and ammonia volatilization—see Figure 26.

Shown in Table 15 are the various percentages of these different components of TKN through the process train over the monitoring period. Of note is that a higher percentage of the organic nitrogen appears recalcitrant than with the organic phosphorus and polyphosphate, even through the ATS™ floway. This recalcitrant organic nitrogen, sometimes referenced as refractory dissolved organic nitrogen (RDON), may be associated with complex organic structures such as naturally occurring humic compounds, or with anthropogenic molecules, which may involve aliphatic and aromatic components.

It is also noteworthy that during Q4, unlike the previous quarters, the ATS™ supported an observable level of nitrification. This resulted in higher NOx-N levels in the ATS™ effluent than the influent.

As with total phosphorus, influent total nitrogen levels increased substantially in response to the heavy rainfall during the last months of Q4. Also, during this period, the pond/wetland system provided a greater percentage of the total nitrogen removal, likely due to periodic algal turf sloughing associated with the ATS™ floway.

Total nitrogen influent and effluent concentrations through the ATS™ and through the Pond System for the monitoring period are shown in Table 16 and Figure 27. Monthly and cumulative Mass removal, ARR, and percent reduction through the ATS™ and through the pond/wetland system for the monitoring period are shown in Table 17 and Figures 28 through 30.

Over the monitoring period, the average total nitrogen concentration reduction through the ATS™ was 0.07 mg/L, from an average influent concentration of 0.95 mg/L to an average effluent concentration of 0.88 mg/L, with the highest reduction of 0.30 mg/L occurring during the second month of Q1. The pond/wetland system provided an additional average reduction[31] over the monitoring period of 0.08 mg/L, from 0.88 mg/L to 0.79 mg/L. By far the greatest contribution from the pond/wetland system was during Q4 (0.20 mg/L reduction for the quarter) when biological activity was the highest on the ATS™ floway. As with phosphorus, this high level of removal within the pond/wetland system during Q4 is

[31] Based upon surface water discharge from pond/wetland structure without consideration of concentrations within seepage water.

most likely related to the higher sloughing of biological (biotic) solids across the ATS™.

Total nitrogen removal through the system was highest when influent total nitrogen concentrations were the highest during Q4. During Q4, 2,778 lb of nitrogen was removed, or 52.7% of the total removal of 5,278 lb over the monitoring period. Of this 2,778 lb, the pond/wetland system was responsible for removal of 1,863 lb or 67%.

For the entire monitoring period, of the 5,278 lb of total nitrogen removed, 2,770 lb was removed through the ATS™, or about 52.5%. The pond wetland system removed 2,508 lb over the monitoring period (47.5%). As with phosphorus, the pond/wetland system provides an important function in polishing the ATS™ effluent through removal of residual nitrogen, particularly that associated with periodic releases of biotic solids.

As expected, the ATS™ provided the highest overall total nitrogen Areal Removal Rate with an average of 65.47 g/m^2-yr (583 lb/acre-yr). Mass total nitrogen removals by the ATS™ and the pond/wetland system based upon the composite samples over the monitoring period as noted were similar at 2,770 lb and 2,508lb respectively. Overall the EMSP removed 18.3% of the incoming total nitrogen.

Through the ATS™ there was a high level of accountability for nitrogen between harvest and water quality based calculations (see Figures 12 and 14), indicating that fixation of atmospheric nitrogen was not a factor. Also, because the flows associated with the ATS™ were highly oxygenated, denitrification activity also was likely negligible. During Q4, however, with increased ammonia levels, there was some evidence of active nitrification across the ATS™.

Using the pond/wetland systems as the second stage of a treatment train which receives pretreatment from an active system such as the ATS™, reduces the burden imposed upon the pond/wetland from heavy nutrient loads often attendant with designs in which pond/wetlands are used as the sole treatment component. Acting as a secondary rather than a primary treatment process effectively prolongs the pond/wetland system's ability to provide long term performance in terms of water quality polishing and extends its period of effective performance, while enhancing the system's value as fish and wildlife habitat. This dual process train with a viable pond/wetland system following an ATS™ is an important strategy shift in regards to the application of ponds/wetlands for nitrogen control, which have often been used as a stand-alone, primary treatment mechanism. Recently, the involved institutional and engineering community has expressed serious concerns regarding the long term nitrogen reduction effectiveness of pond/wetland systems used as the sole stormwater treatment unit, particularly when considering the expected imposition of higher regulatory demands and standards related to TMDL and nutrient numeric standards.[32]

[32] During a 2010 seminar offered by the Florida Engineering Society (FES) in Lake Mary, Florida entitled "Understanding Florida's New Stormwater Quality Criteria" leaders in the design and regulation of stormwater Best Management Practices (BMP's) discussed the need for more effective nitrogen removal methods that offer capabilities that extend beyond what is provided by conventional pond and wetland technologies.

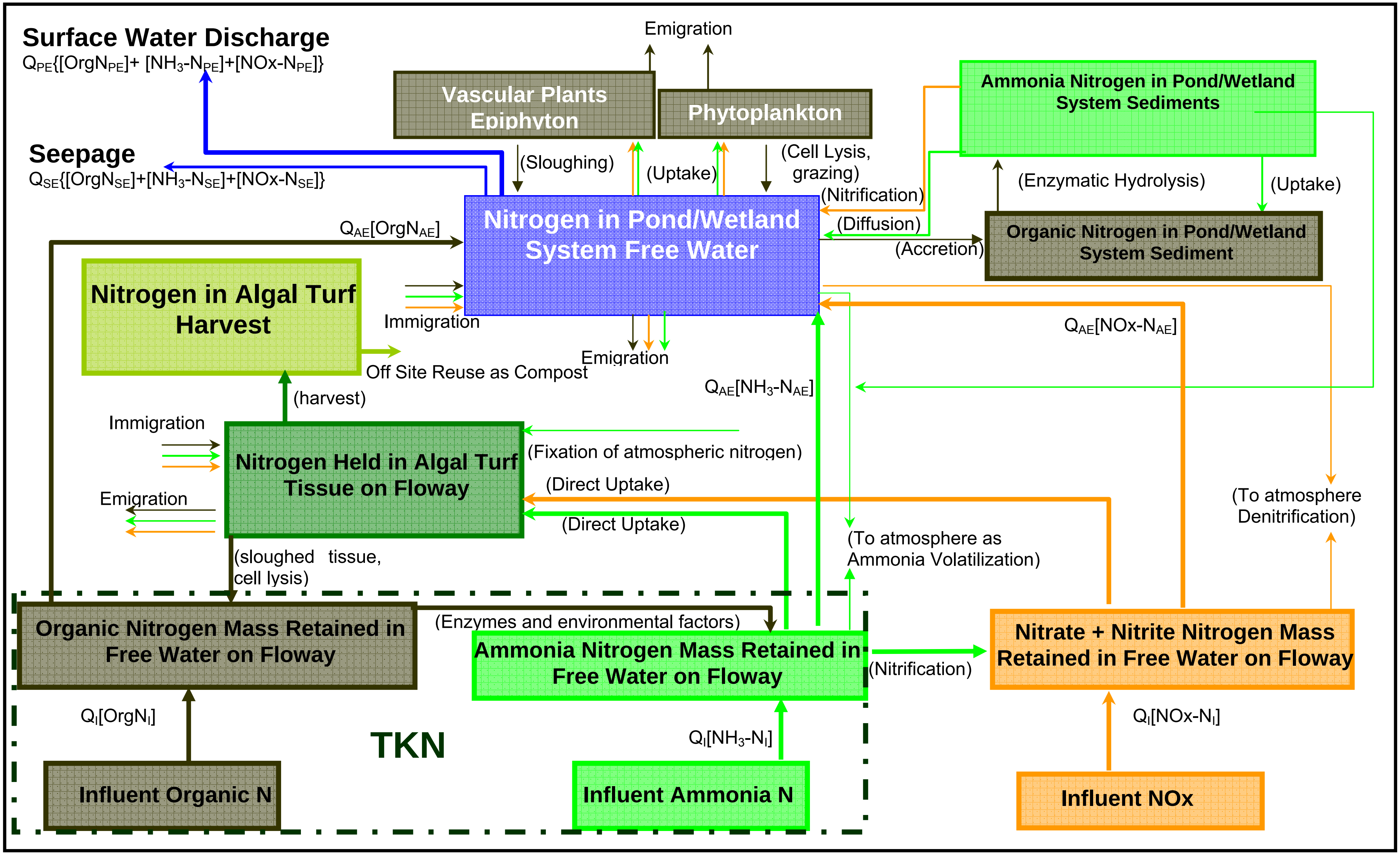


Figure 26: Generalized Schematic of Nitrogen Dynamics through Egret Marsh Stormwater Park

Table 15: Q1 through Q4 Estimates of Total Nitrogen Composition through Egret Marsh Stormwater Park

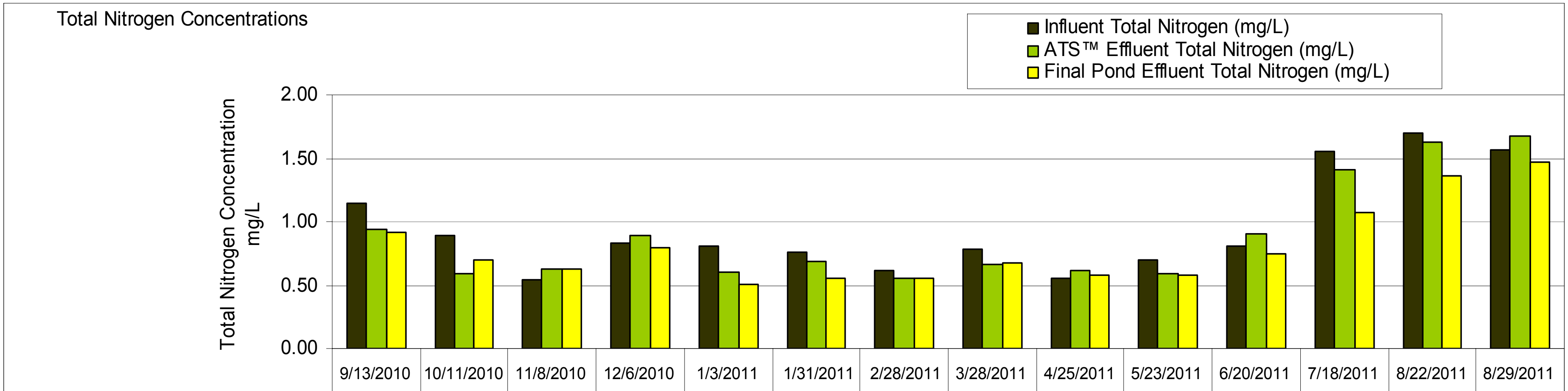
	Influent Nitrogen (Station 01)				ATS™ Effluent Nitrogen (Station 02)				Final Nitrogen System Effluent from Pond System (Station 03)			
Period Ending Date	**9/13/1**	**10/11/1**	**11/8/1**	**Q1 Ave**	**9/13/1**	**10/11/1**	**11/8/10**	**Q1 Ave**	**9/13/1**	**10/11/1**	**11/8/10**	**Q1 Ave**
Total N (mg/L)	1.15	0.89	0.54	**0.86**	0.94	0.59	0.63	**0.72**	0.91	0.69	0.62	**0.74**
Ammonia N (mg/L)	0.11	0.17	0.08	**0.12**	0.02	0.06	0.07	**0.05**	0.02	0.03	0.04	**0.03**
Ammonia % of TN	9.6%	19.1%	14.8%	**14.0%**	2.1%	10.2%	11.1%	**6.9%**	2.2%	4.3%	6.5%	**4.1%**
Nitrate+ Nitrite N (mg/L)	0.11	0.07	0.04	**0.08**	0.07	0.04	0.02	**0.04**	0.04	0.01	0.00	**0.02**
Nitrate+ Nitrite % of TN	9.6%	7.9%	7.4%	**9.3%**	7.4%	6.7%	3.2%	**5.5%**	4.4%	1.5%	0.0%	**2.7%**
Organic N (mg/L)	0.93	0.65	0.40	**0.66**	0.85	0.49	0.54	**0.63**	0.85	0.65	0.58	**0.70**
Organic N % of TN	80.9%	73.0%	74.1%	**76.7%**	90.4%	83.1%	85.7%	**87.5%**	93.4%	94.2%	93.5%	**94.6%**
TKN (mg/L)	1.04	0.82	0.48	**0.78**	0.87	0.55	0.61	**0.68**	0.87	0.68	0.62	**0.73**
TKN % of TN	90.0%	92.1%	88.9%	**90.7%**	92.6%	93.2%	96.8%	**94.4%**	95.6%	98.6%	100%	**98.6%**
Period Ending Date	**12/6/1**	**1/3/11**	**1/31/1**	**Q2 Ave**	**12/6/1**	**1/3/11**	**11/8/11**	**Q2 Ave**	**12/6/1**	**1/3/11**	**1/31/11**	**Q2 Ave**
Total N (mg/L)	0.83	0.80	0.76	**0.80**	0.89	0.60	0.69	**0.73**	0.79	0.50	0.55	**0.61**
Ammonia N (mg/L)	0.00	0.09	0.12	**0.07**	0.00	0.08	0.04	**0.04**	0.00	0.02	0.00	**0.01**
Ammonia % of TN	0.0%	11.3%	15.8%	**8.8%**	0.0%	13.3%	5.8%	**5.7%**	0.0%	4.0%	0.0%	**1.0%**
Nitrate+ Nitrite N (mg/L)	0.06	0.09	0.12	**0.09**	0.04	0.06	0.10	**0.07**	0.02	0.01	0.04	**0.02**
Nitrate+ Nitrite % of TN	7.2%	11.3%	15.8%	**11.3%**	4.5%	10.0%	14.5%	**9.6%**	2.5%	2.0%	7.3%	**3.3%**
Organic N (mg/L)	0.77	0.63	0.52	**0.64**	0.85	0.46	0.55	**0.62**	0.77	0.47	0.47	**0.58**
Organic N % of TN	92.8%	78.8%	68.4%	**80.0%**	95.5%	76.7%	79.7%	**84.9%**	97.5%	94.0%	85.5%	**95.1%**
TKN (mg/L)	0.77	0.72	0.64	**0.71**	0.85	0.54	0.59	**0.66**	0.77	0.49	0.51	**0.59**
TKN % of TN	92.8%	90.0%	84.2%	**88.9%**	95.5%	90.0%	85.5%	**90.4%**	97.5%	98.0%	92.7%	**96.7%**
Period Ending Date	**2/28/1**	**3/28/11**	**4/25/1**	**Q3 Ave**	**2/28/1**	**3/28/11**	**4/25/11**	**Q3 Ave**	**2/28/1**	**3/28/11**	**4/25/11**	**Q3 Ave**
Total N (mg/L)	0.61	0.78	0.55	**0.65**	0.55	0.68	0.61	**0.61**	0.56	0.68	0.58	**0.61**
Ammonia N (mg/L)	0.03	0.01	0.00	**0.01**	0.01	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**
Ammonia % of TN	4.9%	1.3%	0.0%	**1.5%**	1.8%	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%	**0.0%**
Nitrate+ Nitrite N (mg/L)	0.05	0.01	0.02	**0.03**	0.03	0.01	0.01	**0.02**	0.02	0.01	0.00	**0.01**
Nitrate+ Nitrite % of TN	8.2%	1.3%	3.6%	**4.6%**	5.5%	1.8%	1.6%	**3.3%**	3.6%	1.8%	0.0%	**1.6%**
Organic N (mg/L)	0.53	0.76	0.53	**0.61**	0.51	0.66	0.60	**0.59**	0.54	0.67	0.58	**0.60**
Organic N % of TN	86.9%	97.4%	96.4%	**93.8%**	92.7%	97.1%	98.4%	**96.7%**	96.4%	98.5%	100%	**98.4%**
TKN (mg/L)	0.56	0.77	0.53	**0.62**	0.52	0.66	0.60	**0.59**	0.54	0.67	0.58	**0.60**
TKN % of TN	91.8	98.7	96.4	**95.4%**	94.4%	97.1%	98.4%	**96.7%**	96.4%	98.5%	100%	**98.4%**

Table 15 (continued): Q1 through Q4 Estimates of Total Nitrogen Composition through Egret Marsh Stormwater Park

	Influent Nitrogen (Station 01)				**ATS™ Effluent Nitrogen (Station 02)**				**Final Nitrogen System Effluent from Pond System (Station 03)**			
Period Ending Date	**5/23/11**	**6/20/11**	**7/18/11**	**8/22/11**	**5/23/11**	**6/20/11**	**7/18/11**	**8/22/11**	**5/23/11**	**6/20/11**	**7/18/11**	**8/22/11**
Total N (mg/L)	0.70	0.80	1.56	1.70	0.59	0.90	1.41	1.63	0.58	0.75	1.07	1.36
Ammonia N (mg/L)	0.03	0.09	0.24	0.17	0.02	0.09	0.14	0.10	0.01	0.01	0.08	0.09
Ammonia % of TN	4.3%	11.3%	15.4%	10.0%	3.4%	10.0%	10.0%	6.1%	1.7%	1.3%	7.5%	6.6%
Nitrate+ Nitrite N (mg/L)	0.02	0.00	0.13	0.15	0.00	0.06	0.14	0.19	0.00	0.01	0.10	0.13
Nitrate+ Nitrite % of TN	2.9%	0.0%	8.3%	8.8%	0.0%	6.7%	10.0%	11.7%	0.0%	1.3%	9.3%	9.6%
Organic N (mg/L)	0.65	0.71	1.19	1.38	0.58	0.75	1.08	1.34	0.57	0.75	0.89	1.14
Organic N % of TN	92.9%	88.7%	76.3%	81.2%	96.6%	83.3%	80.0%	82.2%	98.3%	97.4%	83.2%	83.8%
TKN (mg/L)	0.68	0.80	1.33	1.55	0.59	0.84	1.22	1.44	0.58	0.76	0.99	1.23
TKN % of TN	97.2%	100.0%	91.7%	91.2%	100.0%	93.3%	90.0%	88.3%	100.0%	98.7%	90.7%	90.4%
Period Ending Date	**8/29/11**	**Q4 Ave**	**Q1 through Q4**		**8/29/11**	**Q4 Ave**	**Q1 through Q4**		**8/29/11**	**Q4 Ave**	**Q1 through Q4**	
Total N (mg/L)	1.56	**1.26**	**0.95**		1.68	**1.24**	**0.88**		1.47	**1.04**	**0.75**	
Ammonia N (mg/L)	0.38	**0.18**	**0.11**		0.15	**0.10**	**0.06**		0.13	**0.06**	**0.03**	
Ammonia % of TN	24.4%	**14.3%**	**11.6%**		8.9%	**8.1%**	**6.8%**		8.8%	**5.7%**	**4.0%**	
Nitrate+ Nitrite N (mg/L)	0.17	**0.09**	**0.08**		0.37	**0.16**	**0.08**		0.34	**0.12**	**0.05**	
Nitrate+ Nitrite % of TN	10.9%	**7.1%**	**8.4%**		22.0%	**12.9%**	**9.1%**		23.1%	**11.5%**	**6.7%**	
Organic N (mg/L)	1.01	**0.99**	**0.76**		1.16	**0.98**	**0.74**		1.00	**0.87**	**0.71**	
Organic N % of TN	64.7%	**78.6%**	**80.0%**		69.1%	**79.0%**	**84.3%**		68.1%	**83.8%**	**89.3%**	
TKN (mg/L)	1.39	**0.97**	**0.87**		1.31	**0.88**	**0.80**		1.13	**0.78**	**0.74**	
TKN % of TN	89.1%	**92.9%**	**91.6%**		78.0%	**87.1%**	**91.1%**		76.9%	**88.5%**	**93.3%**	

Table 16: Q1 through Q4 Composite Total Nitrogen Concentrations through Egret Marsh Stormwater Park

Sampling Period Ending Date	Influent Total Nitrogen (Station 01) (mg/L)	ATS™ Effluent Total Nitrogen (Station 02) (mg/L)	Final Total Nitrogen System Effluent from Pond System (Station 03) (mg/L)
9/13/2010	1.15	0.94	0.91
10/11/2010	0.89	0.59	0.69
11/8/2010	0.54	0.63	0.62
Q1 Average	**0.86**	**0.72**	**0.74**
12/6/201	0.83	0.89	0.79
1/3/2011	0.80	0.60	0.50
1/31/2011	0.76	0.69	0.55
Q2 Average	**0.80**	**0.73**	**0.61**
2/28/11	0.68	0.55	0.56
3/28/11	0.78	0.68	0.68
4/25/11	0.55	0.61	0.58
Q3 Average	**0.65**	**0.61**	**0.61**
5/23/11	0.70	0.59	0.68
6/20/11	0.80	0.90	0.58
7/18/11	1.56	1.41	1.07
8/22/11	1.70	1.63	1.36
8/29/11	1.56	1.68	1.47
Q4 Average	**1.26**	**1.24**	**1.04**
Q1 through Q4	**0.95**	**0.88**	**0.79**

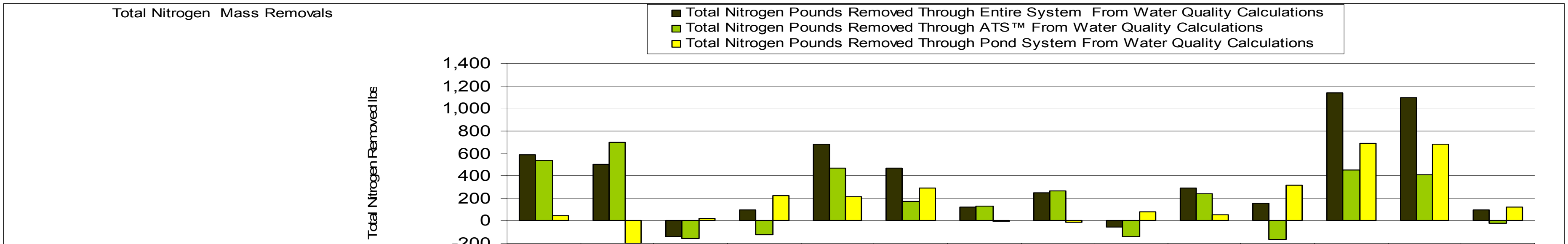


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Total Nitrogen (mg/L)	1.15	0.89	0.54	0.83	0.80	0.76	0.61	0.78	0.55	0.70	0.80	1.56	1.70	1.56
ATS™ Effluent Total Nitrogen (mg/L)	0.94	0.59	0.63	0.89	0.60	0.69	0.55	0.67	0.61	0.59	0.90	1.41	1.63	1.68
Final Pond Effluent Total Nitrogen (mg/L)	0.91	0.69	0.62	0.79	0.50	0.55	0.56	0.68	0.58	0.58	0.75	1.07	1.36	1.47

Figure 27: Q1 through Q4 Composite Samples Total Nitrogen Concentrations through Egret Marsh Stormwater Park

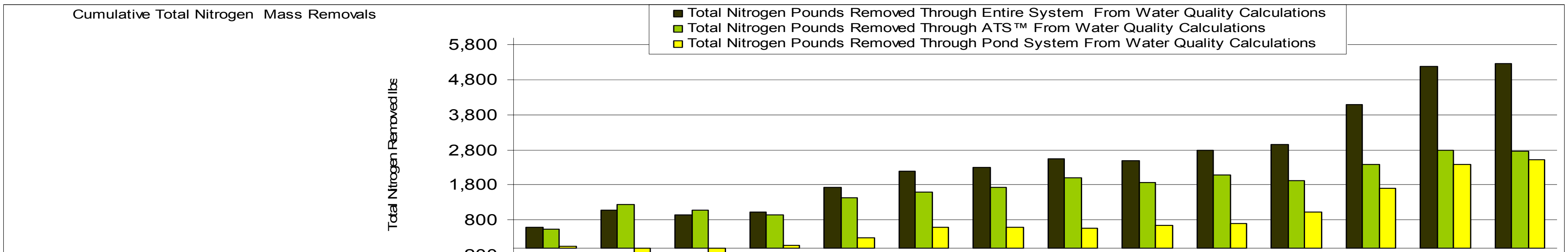
Table 17: Q1 through Q4 Total Nitrogen Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

	Total Nitrogen Mass Removal (lbs)			Total Nitrogen Areal Removal Rate (g/m^2-yr)			Total Nitrogen Percent (%) of Influent Load Removed		
Sampling Period Ending Date	**ATS™**	**Ponds**	**Total System**	**ATS™**	**Ponds**	**Total System**	**ATS™**	**Ponds**	**Total System**
9/13/2010	541	44	585	171.99	4.43	44.87	20.4%	1.7%	22.1%
10/11/2010	697	-198	499	223.32	-20.15	38.61	34.3%	-9.7%	24.6%
11/8/2010	-160	16	-144	-51.19	1.61	-11.13	-12.9%	1.3%	-11.6%
Q1 Cumulative	**1,078**	**-138**	**940**	**114.11**	**-4.67**	**24.00**	**18.1%**	**-2.3%**	**15.8%**
12/6/2010	-127	221	94	-40.42	22.47	7.29	-6.8%	11.8%	5.0%
1/3/2010	472	213	685	120.20	21.53	52.58	25.4%	11.5%	36.9%
1/31/2011	175	293	468	56.08	29.88	36.20	10.1%	16.9%	27.0%
Q2 Cumulative	**520**	**727**	**1,247**	**54.94**	**24.69**	**32.00**	**9.5%**	**13.4%**	**22.9%**
2/28/11	132	-7	125	42.14	-0.71	9.63	9.5%	-0.50%	9.0%
3/28/11	263	-15	248	83.67	-1.49	19.06	14.6%	-0.81%	13.7%
4/25/11	-139	78	-60	-44.28	7.97	-4.64	-11.1%	6.3%	-4.8%
Q3 Cumulative	**256**	**56**	**313**	**26.70**	**2.09**	**8.04**	**5.7%**	**1.4%**	**7.1%**
5/23/11	243	51	293	77.43	5.13	22.57	15.3%	3.1%	18.4%
6/20/11	-167	320	153	-53.24	32.47	11.79	-9.0%	17.2%	8.2%
7/18/11	450	688	1,138	143.55	69.77	87.58	12.4%	18.9%	31.3%
8/22/11	411	683	1,094	130.60	55.34	83.88	8.3%	13.7%	22.0%
8/29/11	-21	121	100	-26.76	49.21	31.33	-2.1%	12.1%	10.0%
Q4 Cumulative	**916**	**1,863**	**2,778**	**64.97**	**42.05**	**47.56**	**7.0%**	**14.3%**	**21.3%**
Q1 through Q4	**2,770**	**2,508**	**5,278**	**65.47**	**18.86**	**30.11**	**9.6%**	**8.7%**	**18.3%**



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Pounds Removed Through Entire System From Water Quality Calculations	584	500	-145	95	684	467	125	248	-60	293	153	1,138	1,094	100
Total Nitrogen Pounds Removed Through ATS™ From Water Quality Calculations	541	697	-160	-127	472	175	132	263	-139	243	-167	450	411	-21
Total Nitrogen Pounds Removed Through Pond System From Water Quality Calculations	44	-198	16	221	213	293	-7	-15	78	51	320	688	683	121

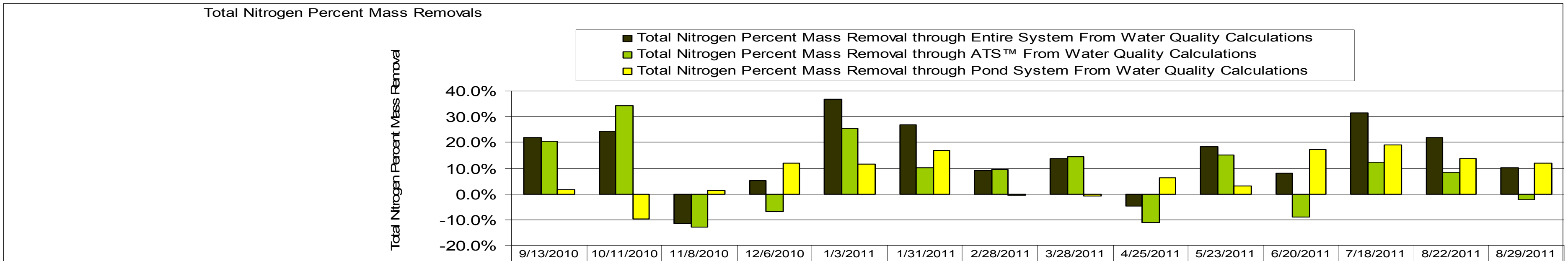
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Pounds Removed Through Entire System From Water Quality Calculations	584	1,084	940	1,034	1,718	2,186	2,311	2,559	2,499	2,792	2,945	4,084	5,178	5,278
Total Nitrogen Pounds Removed Through ATS™ From Water Quality Calculations	541	1,238	1,078	951	1,422	1,597	1,729	1,992	1,854	2,096	1,929	2,380	2,791	2,770
Total Nitrogen Pounds Removed Through Pond System From Water Quality Calculations	44	-154	-138	83	296	589	582	567	645	696	1,016	1,704	2,387	2,508

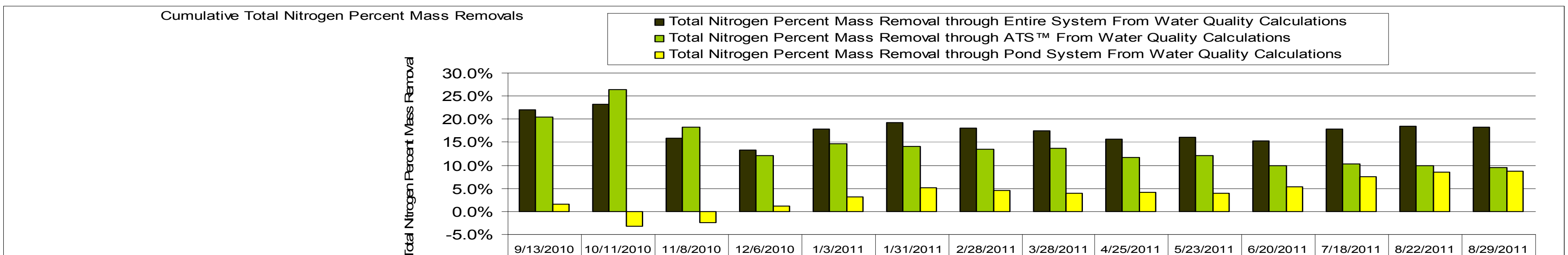
Date Ending

Figure 28: Q1 through Q4 Total Nitrogen Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Percent Mass Removal through Entire System From Water Quality Calculations	22.05%	24.55%	-11.60%	5.04%	36.91%	27.04%	8.97%	13.74%	-4.84%	18.49%	8.22%	31.32%	22.01%	10.01%
Total Nitrogen Percent Mass Removal through ATS™ From Water Quality Calculations	20.40%	34.28%	-12.88%	-6.75%	25.44%	10.11%	9.47%	14.55%	-11.13%	15.30%	-8.96%	12.39%	8.27%	-2.09%
Total Nitrogen Percent Mass Removal through Pond System From Water Quality Calculations	1.65%	-9.72%	1.28%	11.79%	11.47%	16.93%	-0.50%	-0.81%	6.29%	3.19%	17.17%	18.93%	13.74%	12.10%

Date Ending

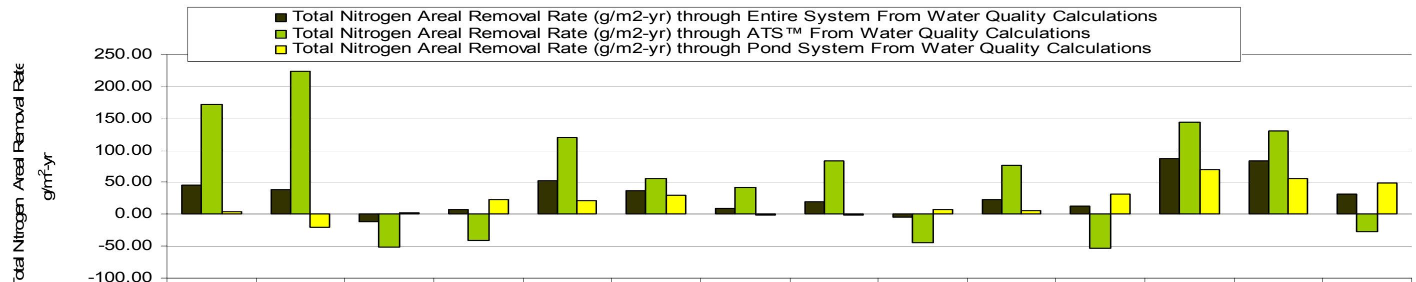


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Percent Mass Removal through Entire System From Water Quality Calculations	22.05%	23.14%	15.84%	13.24%	17.78%	19.19%	18.07%	17.54%	15.78%	16.02%	15.27%	17.81%	18.56%	18.27%
Total Nitrogen Percent Mass Removal through ATS™ From Water Quality Calculations	20.40%	26.43%	18.17%	12.18%	14.72%	14.02%	13.53%	13.65%	11.70%	12.03%	10.00%	10.38%	10.00%	9.59%
Total Nitrogen Percent Mass Removal through Pond System From Water Quality Calculations	1.65%	-3.29%	-2.33%	1.07%	3.06%	5.17%	4.55%	3.88%	4.07%	3.99%	5.27%	7.43%	8.56%	8.68%

Date Ending

Figure 29: Q1 through Q4 Total Nitrogen Percent Mass Removal through Egret Marsh Stormwater Park

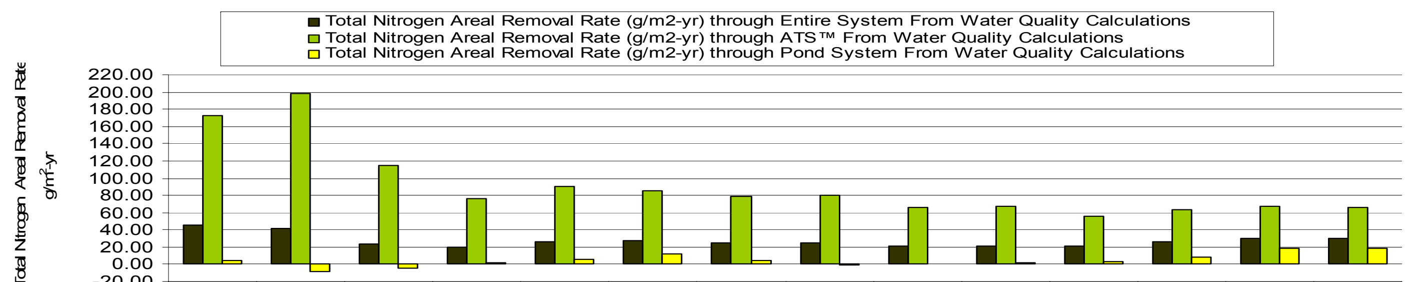
Total Nitrogen Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	44.87	38.61	-11.13	7.29	52.58	36.20	9.63	19.06	-4.64	22.57	11.79	87.58	83.88	31.33
Total Nitrogen Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	171.99	223.32	-51.19	-40.42	120.20	56.08	42.14	83.67	-44.28	77.43	-53.24	143.55	130.60	-26.76
Total Nitrogen Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	4.43	-20.15	1.61	22.47	21.53	29.88	-0.71	-1.49	7.97	5.13	32.47	69.77	55.34	49.21

Date Ending

Cumulative Total Nitrogen Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Total Nitrogen Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	44.87	41.75	24.12	19.91	26.45	28.07	25.43	24.64	21.39	21.50	20.62	26.21	30.08	30.11
Total Nitrogen Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	171.99	197.57	114.63	75.86	90.75	85.00	78.87	79.47	65.74	66.91	55.97	63.28	67.19	65.47
Total Nitrogen Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	4.43	-7.82	-4.67	2.11	6.00	12.30	4.14	-0.28	0.72	1.31	3.42	8.53	18.28	18.86

Date Ending

Figure 30: Q1 through Q4 Total Nitrogen Areal Removal Rates through Egret Marsh Stormwater Park

Total Kjeldahl, Organic and Ammonia-Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of organically bound nitrogen (organic nitrogen) and ammonia nitrogen. Organic nitrogen is typically determined in the laboratory through digestion and subsequent conversion to ammonia nitrogen. The difference between the ammonia concentration before and after digestion is considered organic nitrogen. Ammonia-N is of concern as a pollutant, not only because it can contribute to eutrophication, but also because under high pH and high water temperature conditions, it can be toxic to aquatic animals.

The form of organic nitrogen can range from readily hydrolyzed forms such as urea, to recalcitrant or refractory organic complexes, or RDON. The availability of nitrogen bound to these organic molecules depends upon the vulnerability of the molecule to enzymatic hydrolysis or to changes within the physical environment (e.g. light, temperature, pH). Once the amine group is stripped from an organic molecule, it becomes available for direct ammonia uptake by plants. Typically bacteria are associated with deaminase type enzymes, but these enzymes can also be produced and applied by certain algae species. Regardless of the origin of the enzymatic activity, algal turfs have displayed an ability to access some of the organic nitrogen attendant with surface waters in Florida, even when the concentrations are low.

The trends in TKN, organic-N and ammonia-N concentration changes are noted within Table 18 and Figure 31. Mass removal, cumulative mass removals, ARR, and percent reduction through the ATS™ and through the pond system for the monitoring period are shown in Tables 19 through 21 and Figures 32 through 40.

During the monitoring period, the total influent TKN load to the EMSP was calculated at 26,670 lb of which 23,703 lb was as organic nitrogen (89%) and 2,953 lb was as ammonia nitrogen. Through the ATS™, the TKN load was reduced by 2,719 lb (10.2%) to 23,951 lb; the organic nitrogen was reduced by 1,319 lb (5.6%) to 22,384 lb; and the ammonia nitrogen was reduced by 1,399 lb (47.4%) to 1,554 lb. Through the pond/wetland system the TKN was reduced an additional 1,568 lb (5.9%) to 22,383; the organic nitrogen was reduced by 881 lb (3.7%) to 21,503 lb; and the ammonia nitrogen was reduced by 687 lb(23.3%) to 867 lb. Through the entire system, 4,286 lb of TKN was removed or 16.1% of the total influent. Of this, 2,200 lb was as organic nitrogen or 9.22% of the total influent organic nitrogen; and 2,086 lb was as ammonia nitrogen or 70.7% of the total influent ammonia nitrogen. Considering this data, it is evident that there is, as would be expected, a preferential targeting of ammonia nitrogen, and that over 90% of the influent organic nitrogen may be as RDON, and particularly resistant to enzymatic hydrolysis.

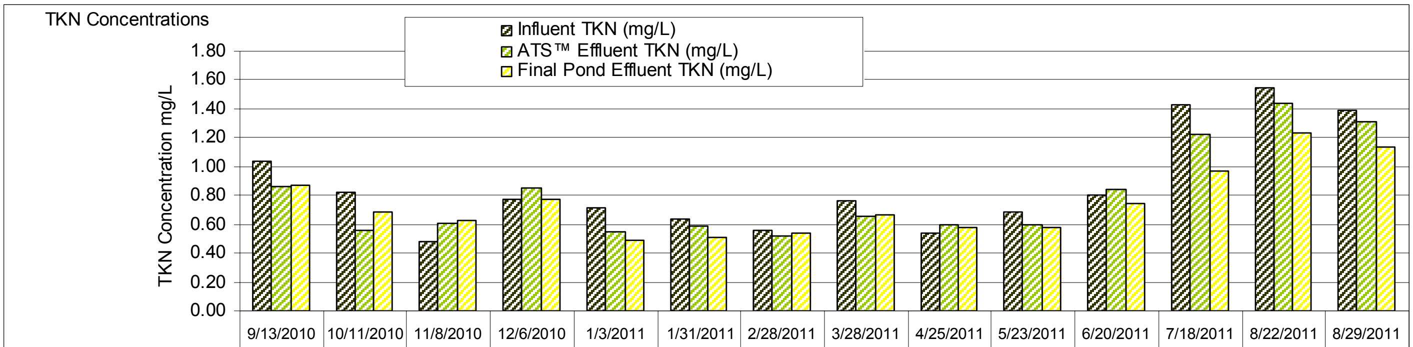
There are some notable trends associated with TKN dynamics during Q1 through Q4. Through the monitoring period, the ATS™ provided the greatest mass removal and areal removal rates for TKN, ammonia-N and organic-N. Through the first three quarters, the pond/wetland system did not provide even minimal TKN reduction, and actually contributed organic nitrogen to the system. This likely was associated with conversion of available forms of nitrogen to organic nitrogen through phytoplankton uptake. However, during Q4, particularly during the final two months, when nitrogen loads increased substantially, the pond/wetland system was a significant contributor to organic nitrogen reduction—removing

1,075 lb as compared to 713 lb by the ATS™ over the same period. This shift in nitrogen dynamics, as with phosphorus, is most likely associated with the periodic sloughing of algal turf tissue into the pond/wetland system, and the attendant grazing, predation and settling of this tissue within the pond/wetland system.

The reduction of total nitrogen through the EMSP was such that the predominant fraction within the final effluent was not readily available for direct uptake. It is reasonable to surmise that this substantially reduces the threat of eutrophication within the final receiving waters of the Indian River Lagoon.

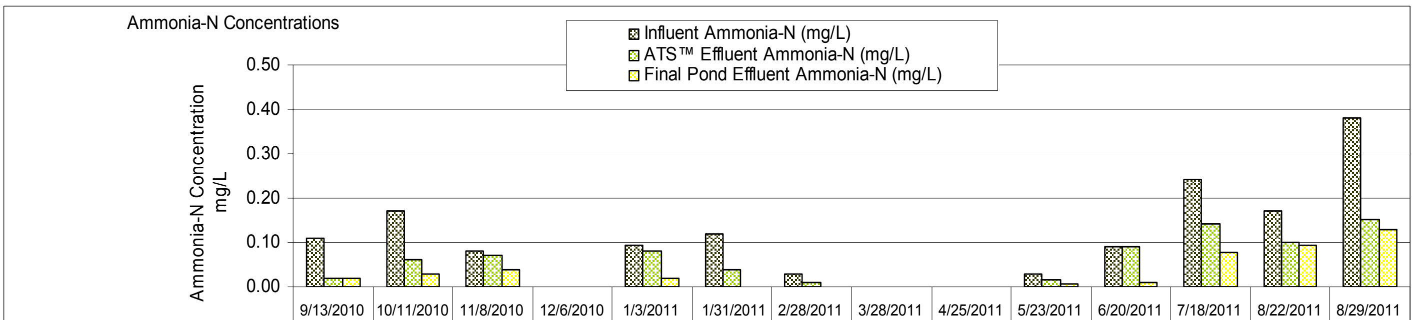
Table 18: Q1 through Q4 Composite TKN, Organic-N and Ammonia-N Concentrations through Egret Marsh Stormwater Park

Sampling Period Ending Date	Influent (Station 01) (mg/L)			ATS™ Effluent (Station 02) (mg/L)			Final System Effluent from Pond System (Station 03) (mg/L)		
	TKN	Am-N	Org-N	TKN	Am-N	Org-N	TKN	Am-N	Org-N
9/13/2010	1.04	0.11	0.93	0.87	0.02	0.85	0.87	0.02	0.85
10/11/2010	0.82	0.17	0.65	0.55	0.06	0.49	0.68	0.03	0.65
I11/8/2010	0.48	0.08	0.40	0.61	0.07	0.54	0.62	0.04	0.58
Q1 Average	**0.78**	**0.12**	**0.66**	**0.68**	**0.05**	**0.63**	**0.73**	**0.03**	**0.70**
12/6/2010	0.77	0.00	0.77	0.85	0.00	0.85	0.77	0.00	0.77
1/3/2011	0.72	0.09	0.63	0.54	0.08	0.46	0.49	0.02	0.47
1/31/2011	0.64	0.12	0.52	0.59	0.04	0.55	0.51	0.00	0.51
Q2 Average	**0.71**	**0.07**	**0.64**	**0.66**	**0.04**	**0.62**	**0.59**	**0.01**	**0.58**
2/28/11	0.56	0.03	0.53	0.52	0.01	0.51	0.54	0.00	0.54
3/28/11	0.77	0.00	0.77	0.66	0.00	0.66	0.67	0.00	0.67
4/25/11	0.53	0.00	0.53	0.60	0.00	0.60	0.58	0.00	0.58
Q3 Average	**0.62**	**0.01**	**0.61**	**0.59**	**0.00**	**0.59**	**0.60**	**0.00**	**0.60**
5/23/11	0.68	0.03	0.65	0.59	0.02	0.58	0.58	0.01	0.57
6/20/11	0.80	0.09	0.71	0.84	0.09	0.75	0.74	0.01	0.73
7/18/11	1.43	0.24	1.19	1.22	0.14	1.08	0.97	0.08	0.89
8/22/11	1.55	0.17	1.38	1.44	0.10	1.34	1.23	0.09	1.14
8/29/11	1.39	0.38	1.01	1.31	0.15	1.16	1.13	0.13	1.00
Q4 Average	**1.06**	**0.18**	**0.99**	**1.00**	**0.10**	**0.98**	**0.87**	**0.06**	**0.87**
Q1 through Q4 Average	**0.87**	**0.11**	**0.76**	**0.80**	**0.06**	**0.74**	**0.74**	**0.03**	**0.71**



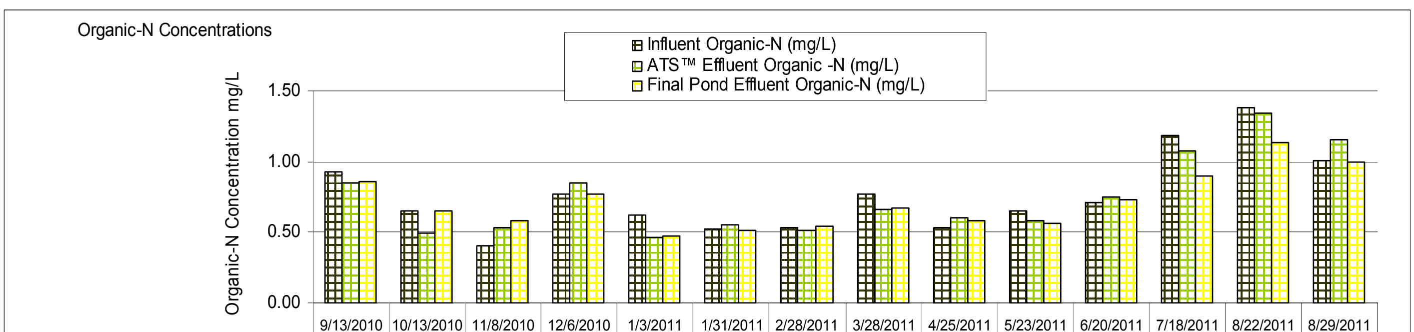
	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent TKN (mg/L)	1.04	0.82	0.48	0.77	0.72	0.64	0.56	0.77	0.53	0.68	0.80	1.43	1.55	1.39
ATS™ Effluent TKN (mg/L)	0.87	0.55	0.61	0.85	0.54	0.59	0.52	0.66	0.60	0.59	0.84	1.22	1.44	1.31
Final Pond Effluent TKN (mg/L)	0.87	0.68	0.62	0.77	0.49	0.51	0.54	0.67	0.58	0.58	0.74	0.97	1.23	1.13

Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Ammonia-N (mg/L)	0.11	0.17	0.08	0.00	0.09	0.12	0.03	0.00	0.00	0.03	0.09	0.24	0.17	0.38
ATS™ Effluent Ammonia-N (mg/L)	0.02	0.06	0.07	0.00	0.08	0.04	0.01	0.00	0.00	0.02	0.09	0.14	0.10	0.15
Final Pond Effluent Ammonia-N (mg/L)	0.02	0.03	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.09	0.13

Date Ending



	9/13/2010	10/13/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent Organic-N (mg/L)	0.93	0.65	0.40	0.77	0.62	0.52	0.53	0.77	0.53	0.65	0.71	1.19	1.38	1.01
ATS™ Effluent Organic -N (mg/L)	0.85	0.49	0.54	0.85	0.46	0.55	0.51	0.66	0.60	0.58	0.75	1.08	1.34	1.16
Final Pond Effluent Organic-N (mg/L)	0.85	0.65	0.58	0.77	0.47	0.51	0.54	0.67	0.58	0.57	0.73	0.89	1.14	1.00

Date Ending

Figure 31: Q1 through Q4 Composite Samples TKN, Ammonia-N and Organic-N Concentrations through Egret Marsh Stormwater Park

Table 19: Q1 through Q4 TKN Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

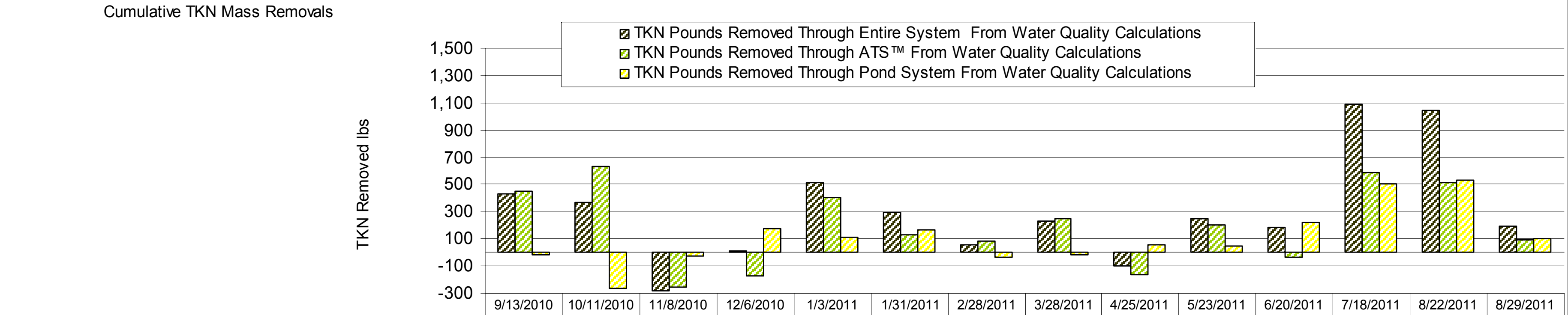
TKN	Mass Removal (lb)			ARR (g/m^2-yr)			% Removal		
Ending Date	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System
9/13/2010	449	-18	430	142.90	-1.82	33.11	18.7%	-0.8%	17.8%
10/11/2010	628	-259	369	201.19	-26.43	28.50	33.5%	-13.8%	19.7%
11/8/2010	-254	-25	-279	-81.05	-2.57	-21.51	-22.9%	-2.3%	-25.2%
Q1 Cumulative	**823**	**-302**	**520**	**87.55**	**-10.25**	**13.37**	**15.3%**	**-5.6%**	**9.6%**
12/6/2010	-172	179	6	-54.93	18.12	0.49	-9.9%	10.3%	0.4%
1/3/2011	405	108	513	103.33	10.94	39.45	24.6%	6.6%	31.1%
1/31/2011	127	170	295	39.95	17.36	22.81	8.6%	11.7%	20.2%
Q2 Cumulative	**357**	**457**	**814**	**38.05**	**15.45**	**20.90**	**7.4%**	**9.4%**	**16.8%**
2/28/2011	83	-30	52	26.37	-3.08	4.03	6.5%	-2.4%	4.1%
3/28/2011	242	-12	230	76.97	-1.23	17.64	13.6%	-0.7%	13.0%
4/25/2011	-159	55	-103	-50.65	5.61	-7.97	-13.2%	4.6%	-8.6%
Q3 Cumulative	**166**	**13**	**179**	**17.66**	**0.44**	**4.60**	**3.9%**	**0.3%**	**4.2%**
5/23/2011	202	51	253	64.43	5.13	19.44	13.1%	3.3%	16.3%
6/20/2011	-32	217	186	-10.06	20.04	14.29	-1.7%	11.7%	10.0%
7/18/2011	585	506	1,091	186.52	51.29	83.42	17.5%	15.1%	32.7%
8/22/2011	517	528	1,046	164.36	42.82	80.18	11.4%	11.6%	23.0%
8/29/2011	91	106	198	116.72	43.76	61.78	10.3%	11.9%	22.2%
Q4 Cumulative	**1,364**	**1,408**	**2,773**	**96.75**	**31.76**	**47.46**	**11.2%**	**11.6%**	**22.8%**
Q1 through Q4 Cumulative	**2,719**	**1,568**	**4,286**	**64.26**	**11.79**	**24.45**	**10.2%**	**5.9%**	**16.1%**

Table 20: Q1 through Q4 Organic-N Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

Organic-N	**Mass Removal (lb)**			**ARR (g/m^2-yr)**			**% Removal**		
Ending Date	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System
9/13/2010	240	-18	222	76.49	-1.82	17.08	11.2%	-0.8%	10.4%
10/11/2010	377	-321	55	120.24	-32.73	4.28	25.3%	-21.6%	3.7%
11/8/2010	-282	-88	-369	-89.84	-8.89	-28.43	-30.5%	-9.5%	-40.0%
Q1 Cumulative	**335**	**-427**	**-92**	**35.69**	**-14.45**	**-2.35**	**7.4%**	**-9.4%**	**-2.0%**
12/6/2010	-172	179	6	-54.93	18.12	0.49	-9.9%	10.3%	0.4%
1/3/2011	374	-17	356	95.20	-1.73	27.40	26.0%	-1.2%	24.8%
1/31/2011	-56	84	28	-17.93	8.59	2.19	-4.7%	7.1%	2.4%
Q2 Cumulative	**146**	**245**	**390**	**13.30**	**8.39**	**10.01**	**3.3%**	**5.7%**	**8.8%**
2/28/2011	41	-55	-14	1.87	-5.61	-1.10	3.4%	-4.6	-1.2%
3/28/2011	245	-15	230	77.95	-1.54	17.64	13.8%	-0.9%	13.0%
4/25/2011	-161	58	-103	-51.41	5.85	-7.97	-13.4%	4.8%	-8.6%
Q3 Cumulative	**125**	**-13**	**113**	**13.30**	**-0.23**	**2.91**	**2.9%**	**-0.2%**	**2.7%**
5/23/2011	172	35	207	54.99	3.52	15.94	11.6%	2.3%	14.0%
6/20/2011	-38	53	15	-12.00	5.37	1.18	-2.3%	3.2%	0.9%
7/18/2011	337	372	704	107.43	37.74	54.56	12.2%	13.4%	25.6%
8/22/2011	294	516	811	93.52	41.85	62.17	7.3%	12.8%	20.0%
8/29/2011	-53	99	46	77.31	38.18	10.03	-9.4%	14.4%	5.0%
Q4 Cumulative	**713**	**1,075**	**1,788**	**50.59**	**24.25**	**30.60**	**3.0%**	**4.5%**	**7.5%**
Q1 through Q4 Cumulative	**1,319**	**881**	**2,200**	**31.00**	**6.57**	**12.47**	**5.5%**	**3.7%**	**9.2%**

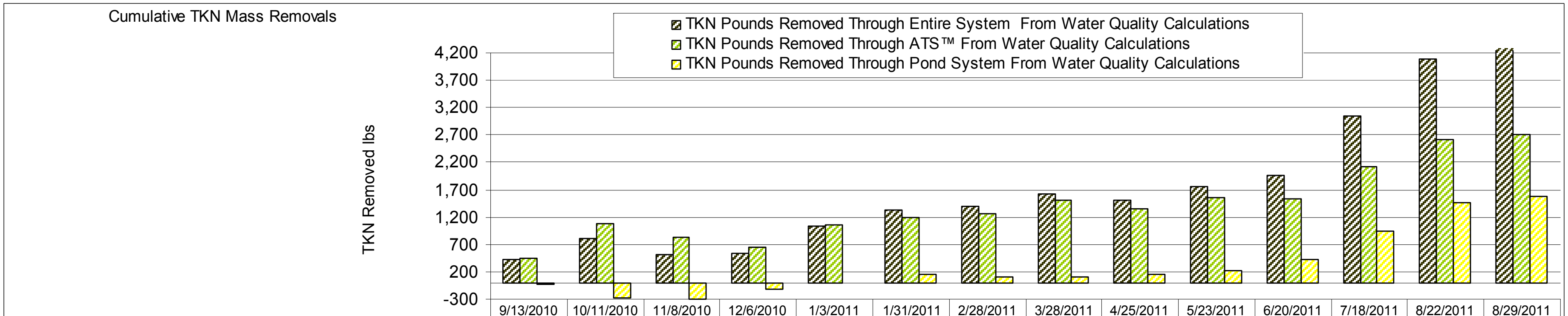
Table 21: Q1 through Q4 Ammonia-N Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

Ammonia-N	**Mass Removal (lb)**			**ARR (g/m^2-yr)**			**% Removal**		
Ending Date	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System
9/13/2010	209	0	209	66.43	0.00	16.03	82.2%	0.00%	82.2%
10/11/2010	252	62	314	80.57	6.30	24.22	65.0%	16.0%	81.0%
11/8/2010	28	62	90	8.79	6.32	6.92	14.9%	33.8%	48.7%
Q1 Cumulative	**489**	**124**	**612**	**51.90**	**4.20**	**15.71**	**59.1%**	**15.1%**	**74.2%**
12/6/2010	0	0	0	0.00	0.00	0.00	0.0%	-	-
1/3/2011	32	125	157	8.12	12.67	12.06	14.9%	58.4%	73.2%
1/31/2011	183	84	266	58.63	8.53	20.62	66.9%	30.6%	97.6%
Q2 Cumulative	**215**	**209**	**423**	**22.83**	**7.06**	**10.86**	**44.1%**	**42.8%**	**86.9%**
2/28/2011	46	21	67	14.5	2.14	5.13	66.4%	30.8%	97.2%
3/28/2011	0	0	0	0.00	0.00	0.00	-	-	-
4/25/2011	0	0	0	0.00	0.00	0.00	-	-	-
Q3 Cumulative	**46**	**21**	**67**	**2.29**	**0.71**	**1.72**	**66.4%**	**30.8%**	**97.2%**
5/23/2011	30	16	45	9.44	1.61	3.50	46.1%	24.6%	70.7%
6/20/2011	6	164	171	1.94	16.67	13.12	2.9%	78.6%	81.5%
7/18/2011	248	134	382	79.09	13.55	29.37	43.6%	23.5%	67.1%
8/22/2011	223	12	235	70.84	0.97	18.02	44.7%	2.4%	47.1%
8/29/2011	145	7	152	184.50	2.93	47.40	62.6%	3.1%	65.7%
Q4 Cumulative	**651**	**333**	**984**	**46.17**	**7.51**	**16.84**	**41.4%**	**21.2%**	**62.6%**
Q1 through Q4 Cumulative	**1,399**	**687**	**2,086**	**33.08**	**5.16**	**11.90**	**47.4%**	**23.3%**	**70.7%**



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Pounds Removed Through Entire System From Water Quality Calculations	431	369	-279	6	513	295	52	230	-103	253	186	1,091	1,046	198
TKN Pounds Removed Through ATS™ From Water Quality Calculations	449	628	-254	-172	405	127	87	245	-161	202	-32	585	517	91
TKN Pounds Removed Through Pond System From Water Quality Calculations	-18	-259	-25	179	108	168	-34	-15	58	51	217	506	528	106

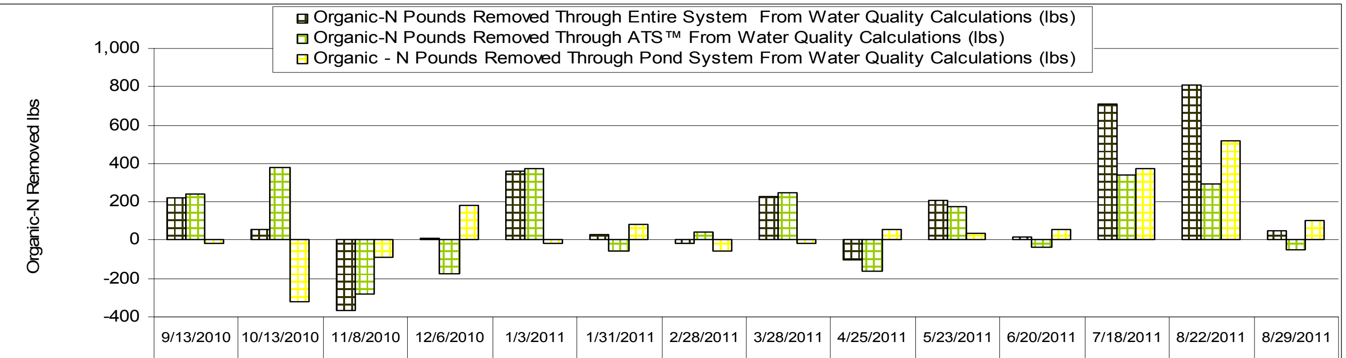
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Pounds Removed Through Entire System From Water Quality Calculations	431	800	521	527	1,040	1,335	1,387	1,617	1,514	1,766	1,952	3,043	4,088	4,286
TKN Pounds Removed Through ATS™ From Water Quality Calculations	449	1,078	824	651	1,057	1,184	1,270	1,515	1,354	1,556	1,525	2,110	2,627	2,719
TKN Pounds Removed Through Pond System From Water Quality Calculations	-18	-278	-303	-124	-16	151	117	102	159	210	427	933	1,461	1,568

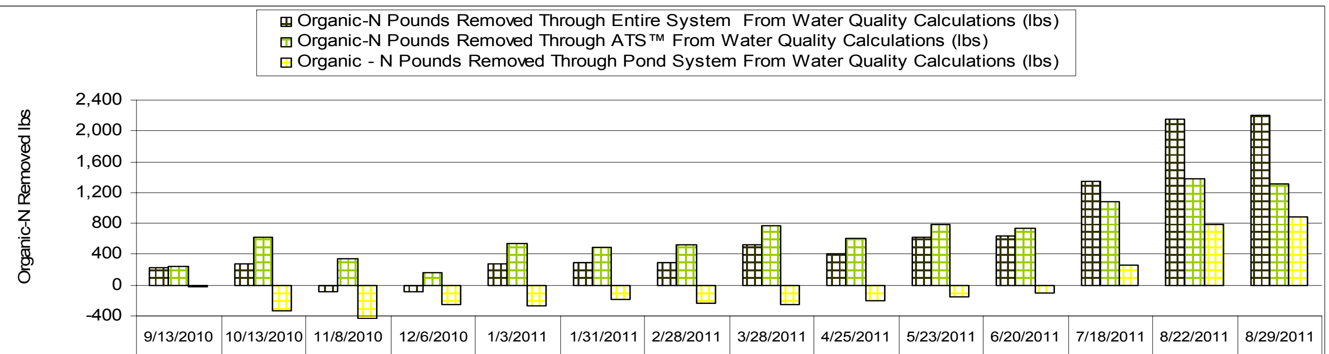
Date Ending

Figure 32: Q1 through Q4 TKN Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/13/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Pounds Removed Through Entire System From Water Quality Calculations (lbs)	222	55	-369	6	356	28	-14	230	-103	207	15	709	811	46
Organic-N Pounds Removed Through ATS™ From Water Quality Calculations (lbs)	240	377	-282	-172	374	-56	41	245	-161	172	-38	337	294	-53
Organic - N Pounds Removed Through Pond System From Water Quality Calculations (lbs)	-18	-321	-88	179	-17	84	-55	-15	58	35	53	372	516	99

Date Ending

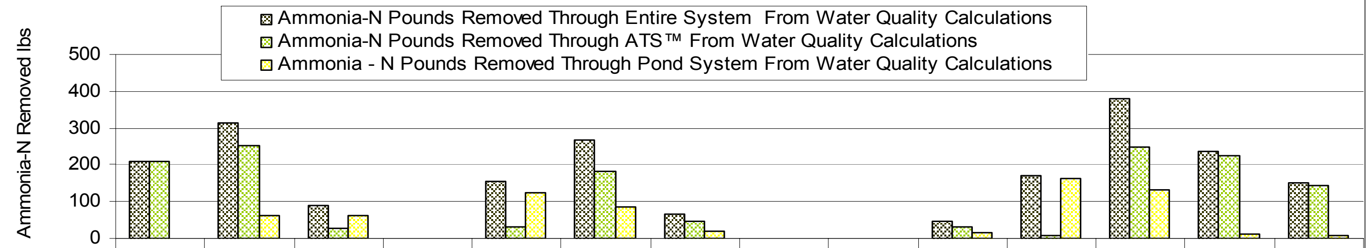


	9/13/2010	10/13/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Pounds Removed Through Entire System From Water Quality Calculations (lbs)	222	278	-91	-85	271	300	285	515	411	619	634	1,343	2,154	2,200
Organic-N Pounds Removed Through ATS™ From Water Quality Calculations (lbs)	240	617	336	163	537	481	522	767	606	779	741	1,078	1,372	1,319
Organic - N Pounds Removed Through Pond System From Water Quality Calculations (lbs)	-18	-339	-427	-248	-266	-182	-237	-252	-195	-160	-107	265	782	881

Date Ending

Figure 33: Q1 through Q4 Organic-N Mass Removals through Egret Marsh Stormwater Park

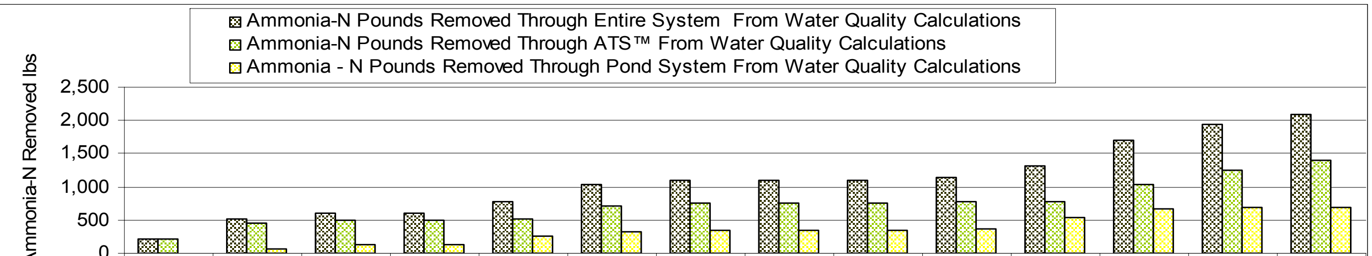
Ammonia-N Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Pounds Removed Through Entire System From Water Quality Calculations	209	314	90	0	157	266	67	0	0	45	171	382	235	152
Ammonia-N Pounds Removed Through ATS™ From Water Quality Calculations	209	252	28	0	32	183	46	0	0	30	6	248	223	145
Ammonia - N Pounds Removed Through Pond System From Water Quality Calculations	0	62	62	0	125	84	21	0	0	16	164	134	12	7

Date Ending

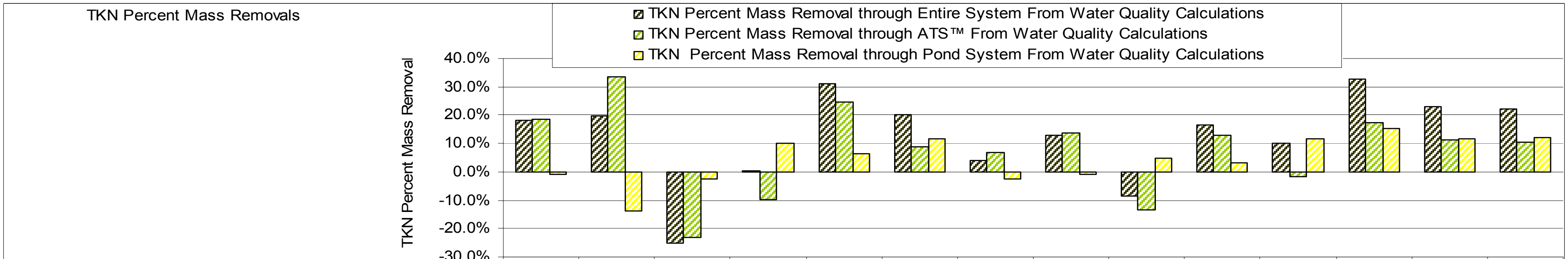
Ammonia-N Cumulative Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Pounds Removed Through Entire System From Water Quality Calculations	209	522	612	612	769	1,035	1,102	1,102	1,102	1,147	1,318	1,700	1,935	2,086
Ammonia-N Pounds Removed Through ATS™ From Water Quality Calculations	209	460	488	488	520	703	748	748	748	778	784	1,032	1,255	1,399
Ammonia - N Pounds Removed Through Pond System From Water Quality Calculations	0	62	124	124	249	333	354	354	354	370	534	668	680	687

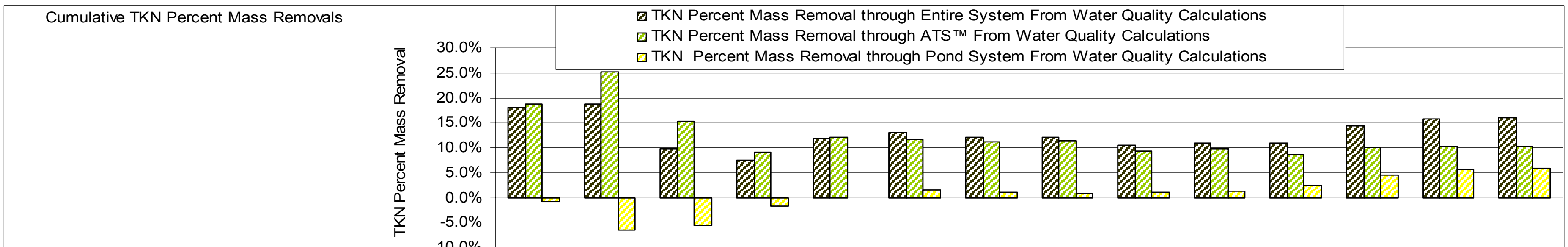
Date Ending

Figure 34: Q1 through Q4 Ammonia-N Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Percent Mass Removal through Entire System From Water Quality Calculations	17.96%	19.67%	-25.22%	0.36%	31.12%	20.23%	4.09%	12.95%	-8.61%	16.34%	9.97%	32.66%	23.01%	22.20%
TKN Percent Mass Removal through ATS™ From Water Quality Calculations	18.71%	33.50%	-22.94%	-9.88%	24.58%	8.72%	6.77%	13.81%	-13.40%	13.07%	-1.69%	17.52%	11.38%	10.27%
TKN Percent Mass Removal through Pond System From Water Quality Calculations	-0.75%	-13.83%	-2.29%	10.25%	6.55%	11.51%	-2.68%	-0.86%	4.79%	3.27%	11.66%	15.14%	11.63%	11.93%

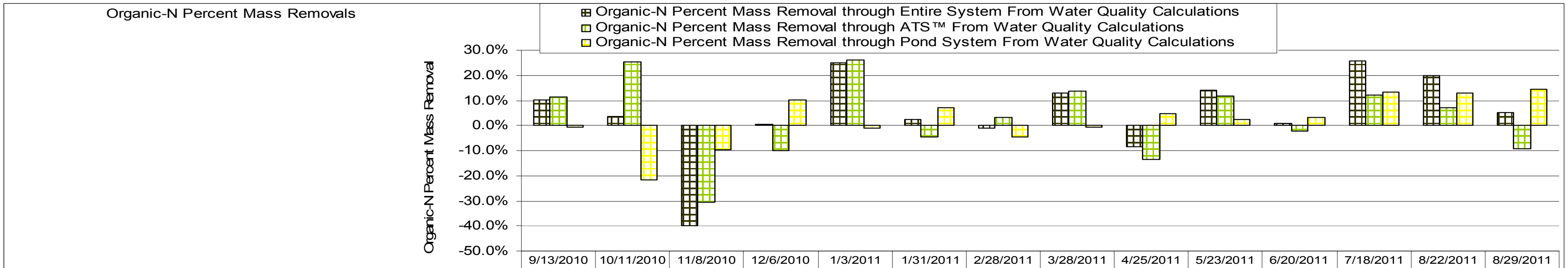
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Percent Mass Removal through Entire System From Water Quality Calculations	17.96%	18.71%	9.67%	7.40%	11.86%	13.05%	12.05%	12.17%	10.45%	11.02%	10.91%	14.33%	15.86%	16.07%
TKN Percent Mass Removal through ATS™ From Water Quality Calculations	18.71%	25.20%	15.30%	9.14%	12.04%	11.57%	11.04%	11.41%	9.35%	9.71%	8.52%	9.94%	10.19%	10.19%
TKN Percent Mass Removal through Pond System From Water Quality Calculations	-0.75%	-6.49%	-5.62%	-1.74%	-0.19%	1.48%	1.02%	0.77%	1.10%	1.31%	2.39%	4.39%	5.67%	5.88%

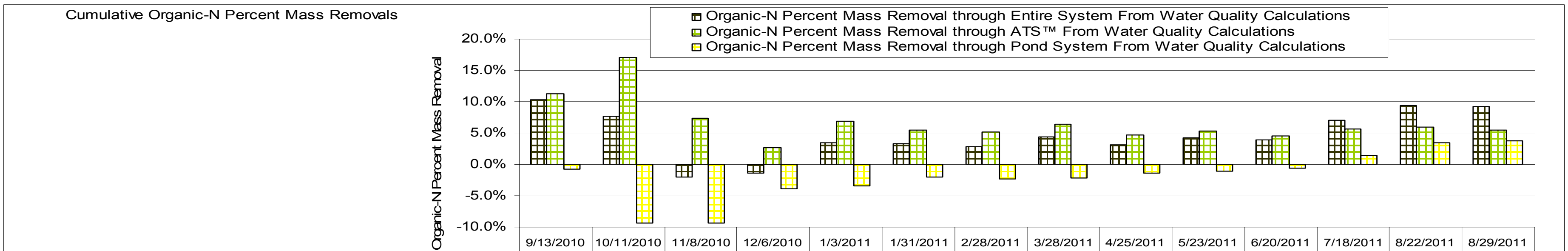
Date Ending

Figure 35: Q1 through Q4 TKN Percent Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Percent Mass Removal through Entire System From Water Quality Calculations	10.36%	3.72%	-40.01%	0.36%	24.84%	2.39%	-1.18%	12.95%	-8.61%	13.98%	0.93%	25.59%	20.04%	4.97%
Organic-N Percent Mass Removal through ATS™ From Water Quality Calculations	11.20%	25.31%	-30.51%	-9.88%	26.02%	-4.72%	3.38%	13.81%	-13.40%	11.64%	-2.27%	12.16%	7.27%	-9.38%
Organic-N Percent Mass Removal through Pond System From Water Quality Calculations	-0.84%	-21.59%	-9.49%	10.25%	-1.19%	7.11%	-4.57%	-0.86%	4.79%	2.34%	3.20%	13.43%	12.76%	14.35%

Date Ending

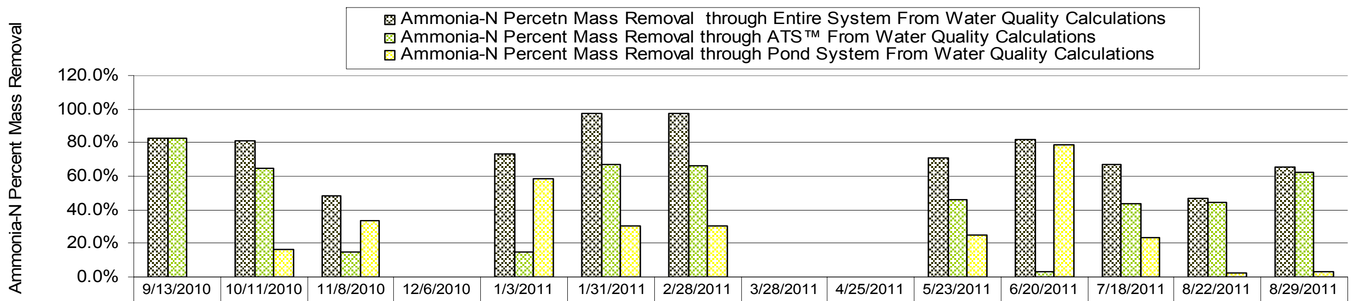


	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Percent Mass Removal through Entire System From Water Quality Calculations	10.36%	7.64%	-2.01%	-1.35%	3.51%	3.36%	2.82%	4.33%	3.14%	4.24%	3.90%	7.06%	9.34%	9.22%
Organic-N Percent Mass Removal through ATS™ From Water Quality Calculations	11.20%	16.98%	7.36%	2.59%	6.94%	5.39%	5.15%	6.44%	4.62%	5.34%	4.56%	5.67%	5.95%	5.53%
Organic-N Percent Mass Removal through Pond System From Water Quality Calculations	-0.84%	-9.34%	-9.37%	-3.94%	-3.43%	-2.03%	-2.34%	-2.12%	-1.48%	-1.10%	-0.66%	1.40%	3.39%	3.69%

Date Ending

Figure 36: Q1 through Q4 Organic-N Percent Mass Removals through Egret Marsh Stormwater Park

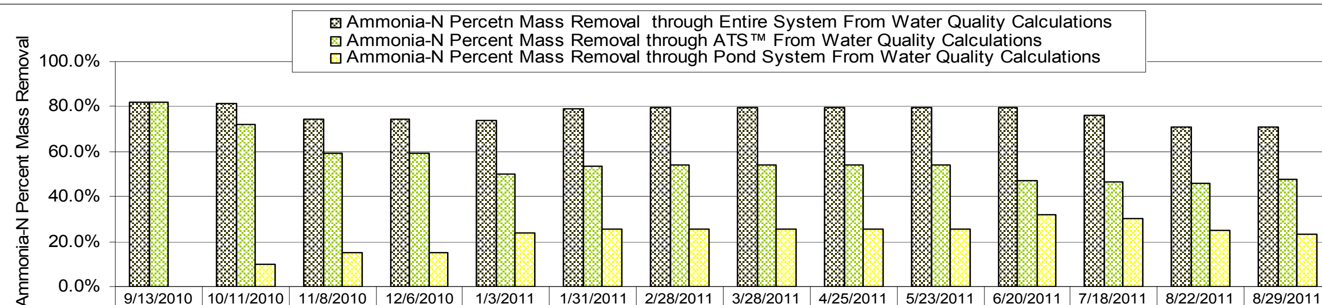
Ammonia-N Percent Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Percetn Mass Removal through Entire System From Water Quality Calculations	82.24%	81.02%	48.70%	0.00%	73.23%	97.56%	97.17%			70.70%	81.49%	67.11%	47.14%	65.70%
Ammonia-N Percent Mass Removal through ATS™ From Water Quality Calculations	82.23%	65.03%	14.94%	0.00%	14.88%	66.93%	66.42%			46.06%	2.91%	43.62%	44.73%	62.62%
Ammonia-N Percent Mass Removal through Pond System From Water Quality Calculations	0.00%	15.99%	33.76%	0.00%	58.36%	30.62%	30.75%			24.64%	78.58%	23.50%	2.41%	3.08%

Date Ending

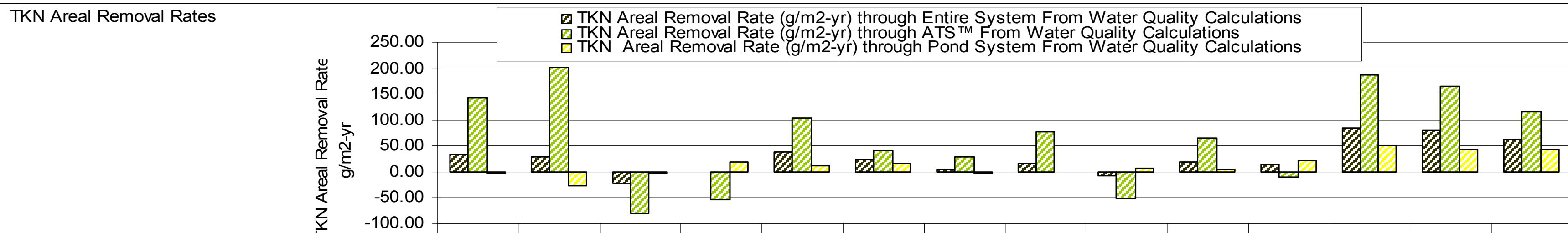
Cumulative Ammonia-N Percent Mass Removals



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Percetn Mass Removal through Entire System From Water Quality Calculations	82.24%	81.50%	74.17%	74.17%	73.97%	78.88%	79.79%	79.79%	79.79%	79.38%	79.65%	76.44%	71.08%	70.66%
Ammonia-N Percent Mass Removal through ATS™ From Water Quality Calculations	82.23%	71.84%	59.12%	59.12%	50.00%	53.52%	54.16%	54.16%	54.16%	53.82%	47.38%	46.42%	46.11%	47.40%
Ammonia-N Percent Mass Removal through Pond System From Water Quality Calculations	0.00%	9.66%	15.05%	15.05%	23.97%	25.35%	25.62%	25.62%	25.62%	25.56%	32.27%	30.02%	24.97%	23.26%

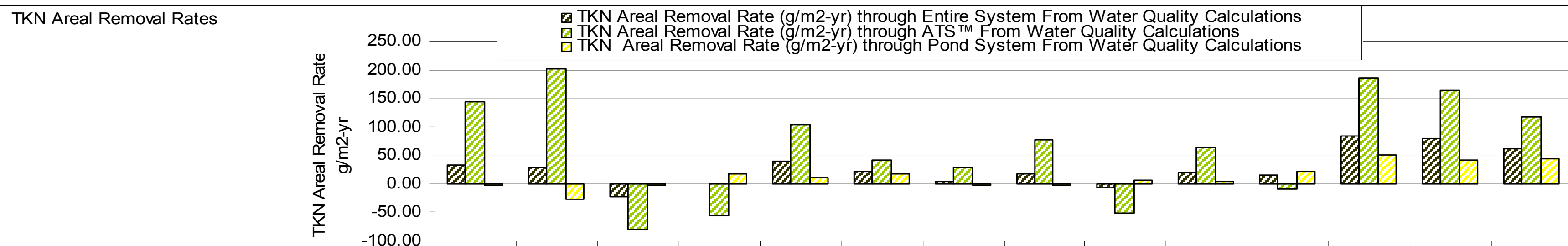
Date Ending

Figure 37: Q1 through Q4 Ammonia-N Percent Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	33.11	28.50	-21.51	0.49	39.45	22.81	4.03	17.64	-7.97	19.44	14.29	83.92	80.18	61.78
TKN Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	142.92	201.19	-81.05	-54.93	103.33	40.76	27.64	77.95	-51.41	64.43	-10.06	186.52	164.36	116.72
TKN Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	-1.82	-26.43	-2.57	18.12	10.94	17.10	-3.48	-1.54	5.85	5.13	22.04	51.29	42.82	43.76

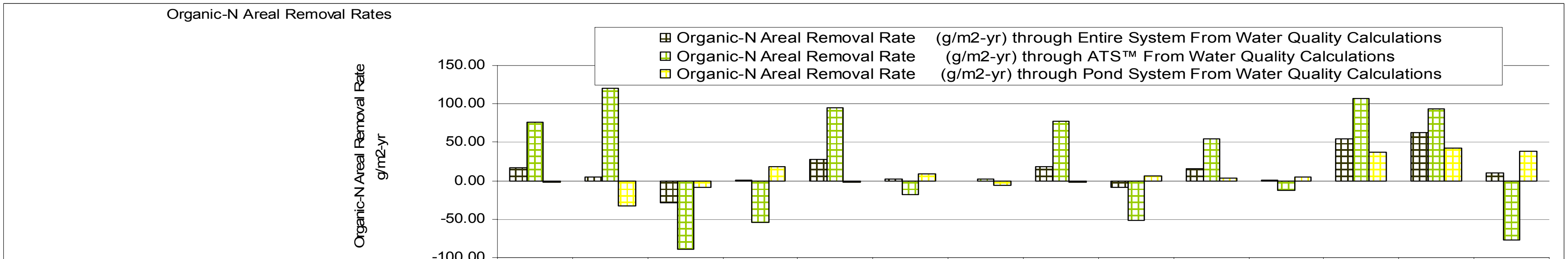
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
TKN Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	33.11	28.50	-21.51	0.49	39.45	22.81	4.03	17.64	-7.97	19.44	14.29	83.92	80.18	61.78
TKN Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	142.92	201.19	-81.05	-54.93	103.33	40.76	27.64	77.95	-51.41	64.43	-10.06	186.52	164.36	116.72
TKN Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	-1.82	-26.43	-2.57	18.12	10.94	17.10	-3.48	-1.54	5.85	5.13	22.04	51.29	42.82	43.76

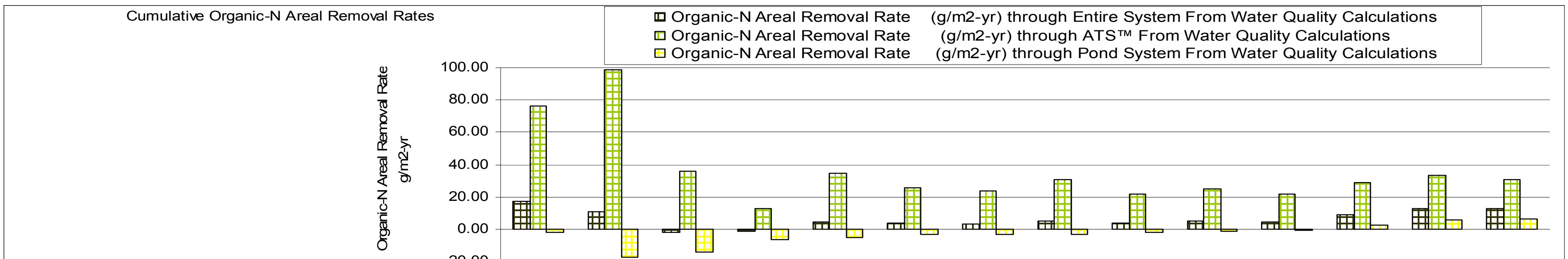
Date Ending

Figure 38: Q1 through Q4 TKN Areal Removal Rates through Egret Marsh Stormwater Park



	9/13/2010	10/13/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	17.08	4.28	-28.43	0.49	27.40	2.19	-1.10	17.64	-7.97	15.94	1.18	54.56	62.17	10.03
Organic-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	76.49	120.62	-89.84	-54.93	95.20	-17.93	1.87	77.95	-51.41	54.99	-12.00	107.43	93.52	-77.31
Organic-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	-1.82	-32.73	-8.89	18.12	-1.73	8.59	-5.61	-1.54	5.85	3.52	5.37	37.74	41.85	38.18

Date Ending

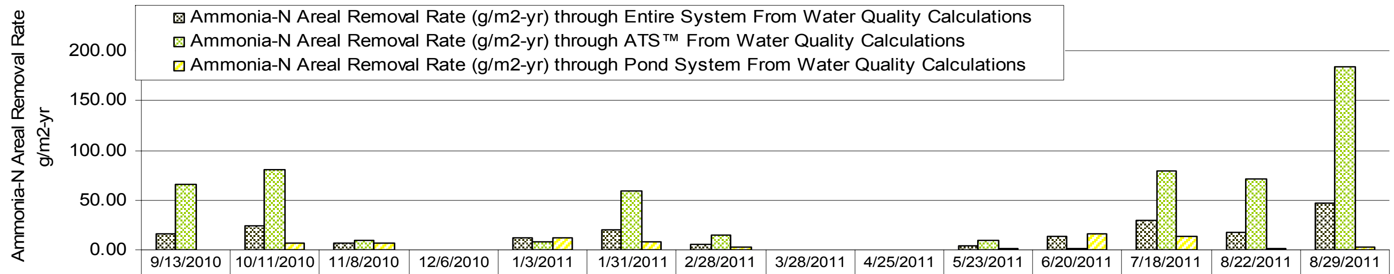


	9/13/2010	10/13/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Organic-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	17.08	10.70	-2.35	-1.64	4.18	3.85	3.14	4.96	3.52	4.76	4.44	8.62	12.51	12.47
Organic-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	76.49	98.49	35.69	13.03	34.25	25.60	23.81	30.59	21.49	24.84	21.49	28.66	33.04	31.00
Organic-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	-1.82	-17.23	-14.45	-6.30	-5.39	-3.07	-3.43	-3.20	-2.19	-1.62	-0.99	2.24	5.99	6.57

Date Ending

Figure 39: Q1 through Q4 Organic-N Areal Removal Rates through Egret Marsh Stormwater Park

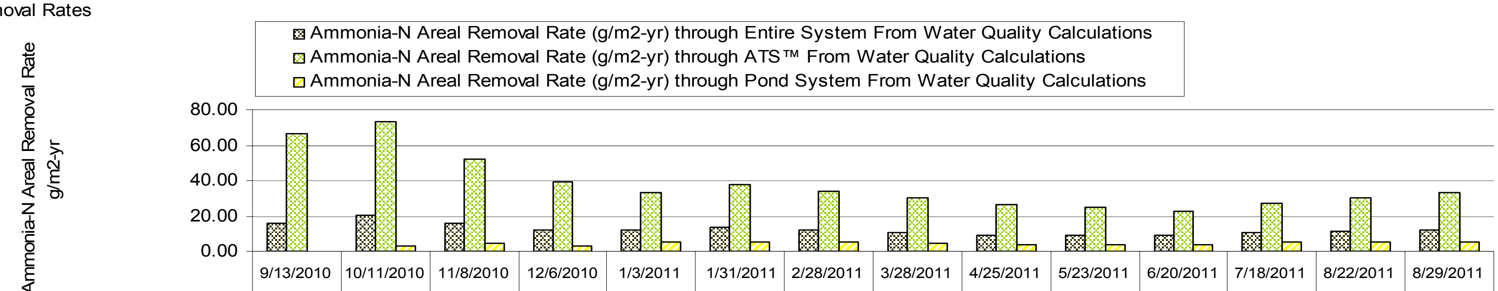
Ammonia-N Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	16.03	24.22	6.92	0.00	12.06	20.62	5.13	0.00	0.00	3.50	13.12	29.37	18.02	47.40
Ammonia-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	66.43	80.57	8.79	0.00	8.12	58.63	14.54	0.00	0.00	9.44	1.94	79.09	70.84	184.50
Ammonia-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	0.00	6.30	6.32	0.00	12.67	8.53	2.14	0.00	0.00	1.61	16.67	13.55	0.97	2.93

Date Ending

Cumulative Ammonia-N Areal Removal Rates



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Ammonia-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	16.03	20.12	15.72	11.79	11.84	13.30	12.13	10.61	9.43	8.84	9.23	10.91	11.24	11.90
Ammonia-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	66.43	73.48	51.91	38.93	33.16	37.39	34.12	29.84	26.53	24.83	22.75	27.45	30.22	33.08
Ammonia-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	0.00	3.14	4.20	3.15	5.06	5.63	5.13	4.49	3.99	3.75	3.75	5.65	5.20	5.16

Date Ending

Figure 40: Q1 through Q4 Ammonia-N Areal Removal Rates through Egret Marsh Stormwater Park

Nitrate + Nitrite-Nitrogen

Nitrate emerged as a serious nutrient pollutant in Florida with the use of inorganic fertilizers containing nitrate, such as ammonium nitrate, or potassium nitrate. Because nitrate is very soluble, much of it can escape direct uptake or adsorption, and enter into the groundwater system. When groundwater nitrate concentrations reach 10 mg/L, it becomes a drinking water hazard, as it can cause serious health problems, especially in infants, by interfering with the normal function of hemoglobin. At much lower concentrations, nitrate can contribute to eutrophication of surface waters.

Nitrate fertilizers are likely the primary source of the NOx-N noted in the influent from the Lateral D canal. Compared to other regions in the state, such as the Karst areas in northern Florida[33], the Lateral D concentrations however were low—averaging just 0.08 mg/L over the monitoring period. Like ammonia-N, nitrate and nitrite-N[34] is typically available for direct uptake by algae. Therefore, its removal is readily accommodated by biological systems such as the ATS™ or a passive pond/wetland system.

Within surface waters, both nitrate and nitrite can be generated by the oxidation of ammonia-N, through a process known as nitrification. When ammonia levels and oxygen levels are high enough the rate of nitrification can outpace the rate of direct uptake, and as a result, effluent levels can exceed influent levels. For nitrification to occur within biological systems such as the ATS™, two chemoautotrophic bacteria - *Nitrosomonas* and *Nitrobacter* - are required, along with an abundance of available oxygen and ammonia. Conversely, nitrate can be removed from the water column either through direct plant uptake, or through a process known as denitrification, which involves the action of facultative bacteria under anaerobic or microaerophilic conditions and sufficient quantities of available organic carbon. A generalized schematic of Nitrate and Nitrite dynamics within the EMSP is included as part of Figure 26. A review of NOx-N concentrations through the EMSP are presented in Table 22.

Nitrification has been observed under certain conditions across ATS™ floways, but it is not a common occurrence when ammonia-N levels are comparatively low. During Q1 through Q3 there was no evidence of net nitrification, as there was noted a decrease in NOx-N concentrations across the ATS™ from 0.07 mg/L to 0.04 mg/L. During this period, ammonia levels averaged only 0.07 mg/L. However, during Q4, ammonia levels increased to an average of 0.18 mg/L, reaching a high of 0.38 mg/L on 8/29/11(see Table 18). This ammonia increase apparently stimulated nitrification across the ATS™, resulting in an increase in NOX-N concentration from a Q4 average of 0.09 mg/L in the influent to 0.16 mg/L in the ATS™ effluent. The largest NOx-N increase was for the week ending 8/29/11, from 0.17 mg/L to 0.37 mg/L. This was also the period of the highest ammonia-N levels (see Figure 18). There was no evidence of net nitrification through the pond/wetland system.

Extensive denitrification has not been observed on an ATS™ system, largely because the system is highly charged with oxygen and typically low in organic carbon, both conditions inhibiting the denitrification process. Based upon the nitrogen accountability developed from a

[33] In the artesian flows associated with the springs in north Florida, nitrate levels are often seen above 1 mg/L, helping to stimulate in certain situations extensive blooms of the cyanobacteria species *Lyngbia sp.,* and the subsequent loss of submerged vascular plants such as eel grass (*Vallisneria sp)*
[34] The sum of nitrate and nitrite is often expressed as NOx-N

comparison of harvested nitrogen and nitrogen removal calculated from water quality and flows, as presented in Figure 12, there was no evidence of extensive nitrogen loss to the atmosphere through the ATS™, suggestive that denitrification was not a factor in ATS™ nitrogen dynamics. It is possible that denitrification could occur within the pond/wetland system, but it is unlikely to have been of any significance during the monitoring period because, like the ATS™, the pond/wetland system was high in oxygen content, as contributed by the ATS™ effluent, and low in organic carbon. If denitrification did occur within the pond/wetland systems it would be because of oxygen deficiencies within the benthic zone, or within an isolated hypolimnion[35]. Within the total EMSP process therefore, transformation of nitrate and nitrite are likely to be mostly associated with direct uptake and to a lesser degree, during periods of elevated ammonia nitrogen, with nitrification. Denitrification could possibly contribute at times within the pond system, and may well increase in importance as organic sediments develop over time. However, considering the high levels of oxygen and the low nutrient and organic loading rates, the rate of accretion within the pond/wetland system should be minimal.

Nitrite is less stable than nitrate under conditions rich in oxygen, and typically is not present in any substantial quantities in the abundance of dissolved oxygen. Under low oxygen conditions, nitrite can accumulate to levels potentially toxic to aquatic organisms. Nitrite toxicity is not considered a serious issue within the EMSP, because of the high oxygen levels and the comparatively low concentrations of nitrate and nitrite.

During Q1 through Q3, influent nitrate + nitrite-N concentrations averaged 0.07 mg/L, and did not exceed 0.12 mg/L. What nitrate+nitrite-N that was present was readily removed, probably through direct plant uptake, by both the ATS™ and the pond/wetland system, with minimal likelihood of any substantial denitrification within the pond/wetland system. The ATS™ and the pond/wetland system contributed about equally in the removal of nitrate + nitrite-N during this period. Overall mass removal of nitrate+nitrite-N for Q1 through Q3 was 985 lb or 72.8% of the influent load, with the average final effluent concentration of 0.02 mg/L, which is near the limits of detection.

The NOx-N dynamic changed during Q4 when net nitrification became evident across the ATS™. During Q4, a net of 448 pounds of NOx-N was generated via nitrification across the ATS™. All of this was removed through the pond wetland system, presumably through direct uptake by phytoplankton and littoral vegetation and by grazing/predation. As long as nitrate levels do not increase to high levels, active nitrification is generally considered advantageous, as it serves to reduce ammonia levels and is indicative of highly oxygenated conditions.

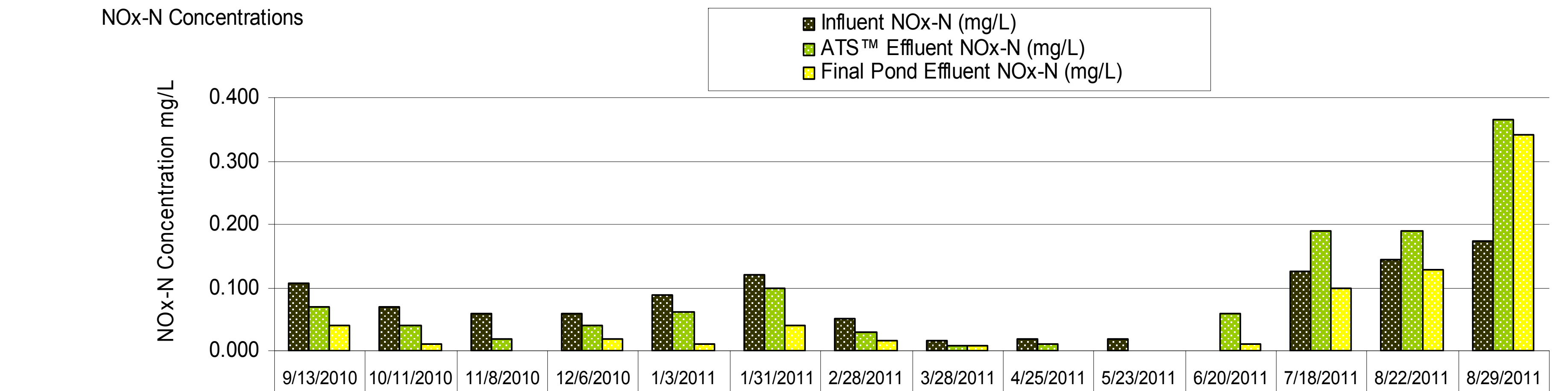
---

[35] The hypolimnion is a region of water associated with a lake bottom which becomes isolated from the upper region of water known as the epilimnion. This isolation or stratification, is typically associated with temperature differentials, and is a common occurrence in deeper temperate northern lakes. Lakes within Florida are generally shallow, subtropical systems, which rarely develop a permanent hypolimnion. However, it has been observed that in some lakes in Florida, particularly artificial lakes, such stratification may occur on a short term basis, and it is possible that low oxygen levels can develop in the water near the bottom during such periods, particularly if there is considerable nutrient and organic enrichment. In such situations, denitrification could become prevalent.

The trends in nitrate+nitrite-N concentration changes are noted within Table 22 and Figure 41. Monthly and cumulative mass removal, ARR, and percent reduction through the ATS™ and through the pond system for Q1 through Q3 are shown in Table 23 and Figures 42 - 44. Net NOx-N removal over the monitoring period was dominated by the pond/wetland system, largely because of the active nitrification associated with the ATS™ during Q4. The role of the pond/wetland system in polishing the ATS™ in regards to NOx-N management, as with other nutrient components, during periods of heavy nutrient loading, proved important over the course of the monitoring period

Table 22: Q1 through Q4 Composite Nitrate + Nitrite-N Concentrations through Egret Marsh Stormwater Park

Sampling Period Ending Date	Influent Total Nitrate+Nitrite-N (Station 01) (mg/L)	ATS™ Effluent Total Nitrate+Nitrite-N (Station 02) (mg/L)	Final Nitrate + Nitrite-N System Effluent from Pond System (Station 03) (mg/L)
9/13/2010	0.11	0.07	0.04
10/11/2010	0.07	0.04	0.01
I11/8/2010	0.06	0.02	0.00
Q1 Average	**0.08**	**0.04**	**0.02**
12/6/2010	0.06	0.04	0.02
1/3/2011	0.09	0.06	0.01
1/31/2011	0.12	0.10	0.04
Q2 Average	**0.09**	**0.06**	**0.02**
2/28/2011	0.05	0.03	0.02
3/28/2011	0.01	0.01	0.01
4/25/2011	0.02	0.01	0.00
Q3 Average	**0.03**	**0.02**	**0.01**
5/23/2011	0.02	0.00	0.00
6/20/2011	0.00	0.06	0.01
7/18/2011	0.13	0.19	0.10
8/22/2011	0.15	0.19	0.13
8/29/2011	0.17	0.37	0.34
Q4 Average	**0.09**	**0.16**	**0.12**
Q1 through Q4 Average	**0.08**	**0.08**	**0.05**



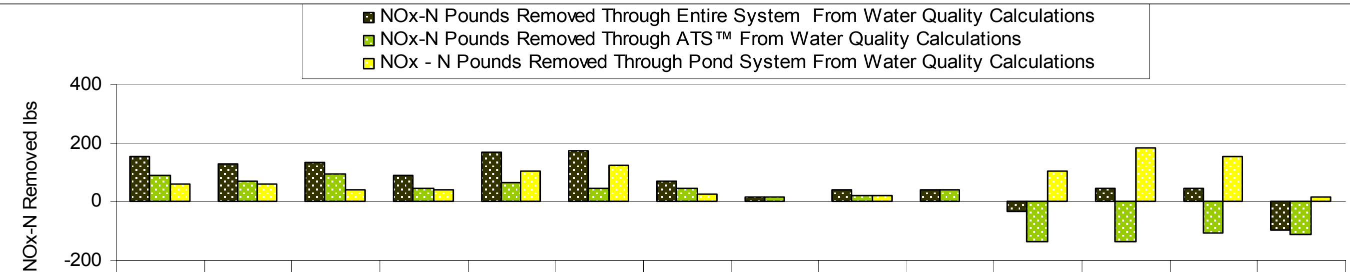
	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent NOx-N (mg/L)	0.11	0.07	0.06	0.06	0.09	0.12	0.05	0.01	0.02	0.02	0.00	0.13	0.15	0.17
ATS™ Effluent NOx-N (mg/L)	0.07	0.04	0.02	0.04	0.06	0.10	0.03	0.01	0.01	0.00	0.06	0.19	0.19	0.37
Final Pond Effluent NOx-N (mg/L)	0.04	0.01	0.00	0.02	0.01	0.04	0.02	0.01	0.00	0.00	0.01	0.10	0.13	0.34

Date Ending

Figure 41: Q1 through Q4 Composite Samples Nitrate + Nitrite-N Concentrations through Egret Marsh Stormwater Park

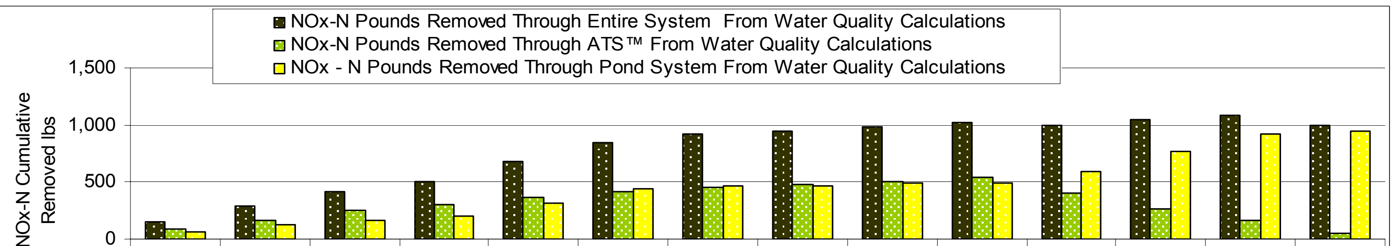
Table 23: Q1 through Q4 Nitrate+Nitrite-N Mass Removals, Areal Removal Rates and Percent Removal through Egret Marsh Stormwater Park

	Nitrate+Nitrite-N Mass Removal (lb)			Nitrate + Nitrite-N Areal Removal Rate (g/m^2-yr)			Nitrate+Nitrite-N Percent (%) of Influent Load Removed		
Sampling Period Ending Date	ATS™	Ponds	Total System	ATS™	Ponds	Total System	ATS™	Ponds	Total System
9/13/2010	91	62	153	29.07	6.26	11.76	36.7%	24.8%	61.5%
10/11/2010	69	62	131	22.13	6.28	10.11	43.4%	38.7%	82.1%
11/8/2010	94	41	135	29.85	4.18	10.38	67.6%	29.8%	97.4%
Q1 Cumulative	**254**	**165**	**419**	**27.03**	**5.58**	**10.75**	**46.4%**	**30.1%**	**76.6%**
12/6/2010	45	43	88	14.51	4.35	6.80	33.6%	31.6%	65.2%
1/3/2011	66	105	171	16.87	10.59	13.12	32.4%	51.2%	83.6%
1/31/2011	48	125	173	15.32	12.78	13.39	17.5%	45.9%	63.4%
Q2 Cumulative	**159**	**273**	**432**	**16.96**	**9.23**	**11.09**	**26.0%**	**44.5%**	**70.5%**
2/28/2011	45	25	70	14.50	2.77	5.60	39.8%	23.9%	63.6%
3/28/2011	18	1	19	5.72	0.06	1.42	52.9%	1.7%	54.5%
4/25/2011	22	21	43	7.13	2.12	3.33	49.6%	46.3%	96.0%
Q3 Cumulative	**85**	**47**	**132**	**9.07**	**1.65**	**3.45**	**44.4%**	**25.4%**	**69.8%**
5/23/2011	41	0	41	12.99	0.00	3.14	100.0%	0.0%	100.0%
6/20/2011	-135	103	-33	-43.17	10.43	-2.51		0.0%	0.0%
7/18/2011	-135	182	47	-42.96	18.48	3.65	-45.8%	61.9%	16.1%
8/22/2011	-106	154	48	-33.75	12.52	3.70	-25.0%	36.3%	11.4%
8/29/2100	-112	15	-97	-	6.17	-30.46	-101.4%	13.5%	-87.9%
Q4 Cumulative	**-448**	**454**	**6**	**-31.80**	**10.24**	**0.10**	**-51.4%**	**52.1%**	**0.7%**
Q1 through Q4 Cumulative	**50**	**939**	**989**	**1.21**	**7.07**	**5.66**	**2.3%**	**42.3%**	**44.6%**



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Pounds Removed Through Entire System From Water Quality Calculations	153	131	135	88	171	173	73	19	43	41	-33	47	48	-97
NOx-N Pounds Removed Through ATS™ From Water Quality Calculations	91	69	94	45	66	48	45	18	22	41	-135	-135	-106	-112
NOx - N Pounds Removed Through Pond System From Water Quality Calculations	62	62	41	43	105	125	27	1	21	0	103	182	154	15

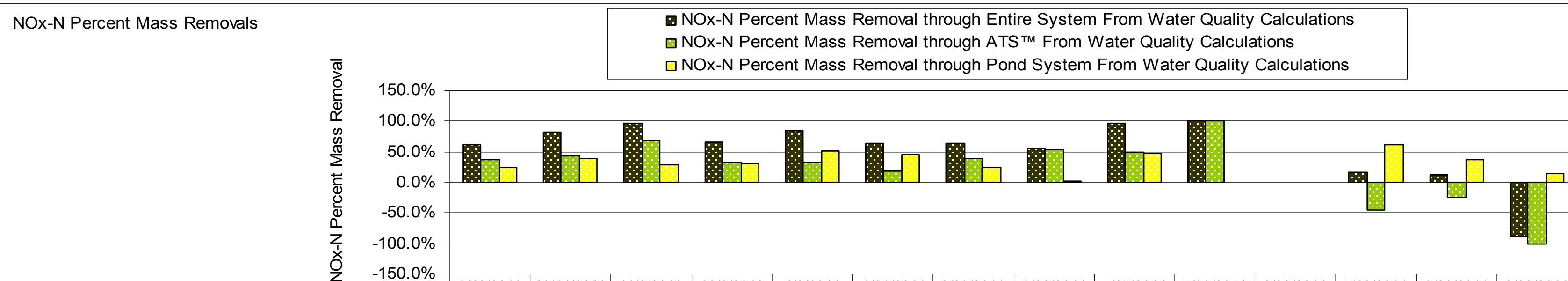
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Pounds Removed Through Entire System From Water Quality Calculations	153	284	419	507	678	851	924	942	985	1,026	993	1,041	1,089	992
NOx-N Pounds Removed Through ATS™ From Water Quality Calculations	91	160	254	300	366	413	459	477	499	540	405	270	164	51
NOx - N Pounds Removed Through Pond System From Water Quality Calculations	62	123	165	208	312	437	465	465	486	486	589	771	926	941

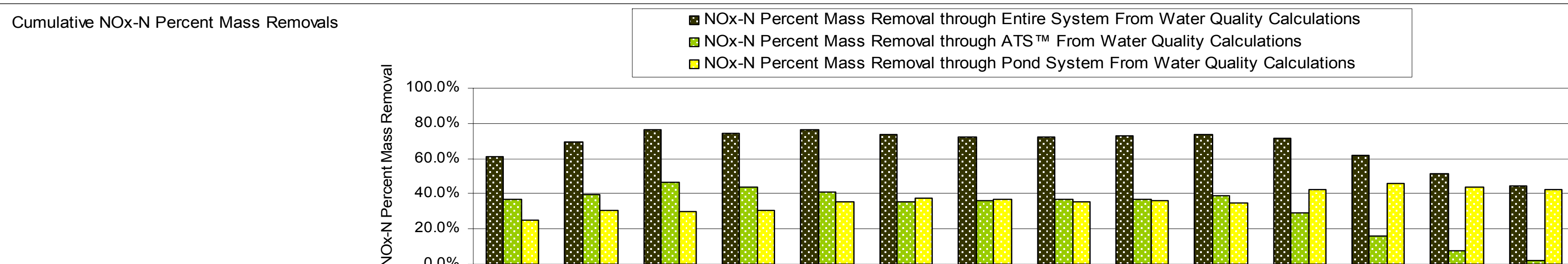
Date Ending

Figure 42: Q1 through Q4 Nitrate+Nitrite-N Mass Removals through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Percent Mass Removal through Entire System From Water Quality Calculations	61.45%	82.08%	97.37%	65.16%	83.66%	63.35%	63.62%	54.54%	95.96%	100.00%	0.00%	16.13%	11.35%	-87.92%
NOx-N Percent Mass Removal through ATS™ From Water Quality Calculations	36.65%	43.38%	67.59%	33.55%	32.42%	17.49%	39.76%	52.85%	49.62%	100.00%		-45.79%	-24.99%	-101.43%
NOx-N Percent Mass Removal through Pond System From Water Quality Calculations	24.80%	38.70%	29.77%	31.61%	51.24%	45.86%	23.87%	1.70%	46.34%	0.00%	0.00%	61.92%	36.34%	13.51%

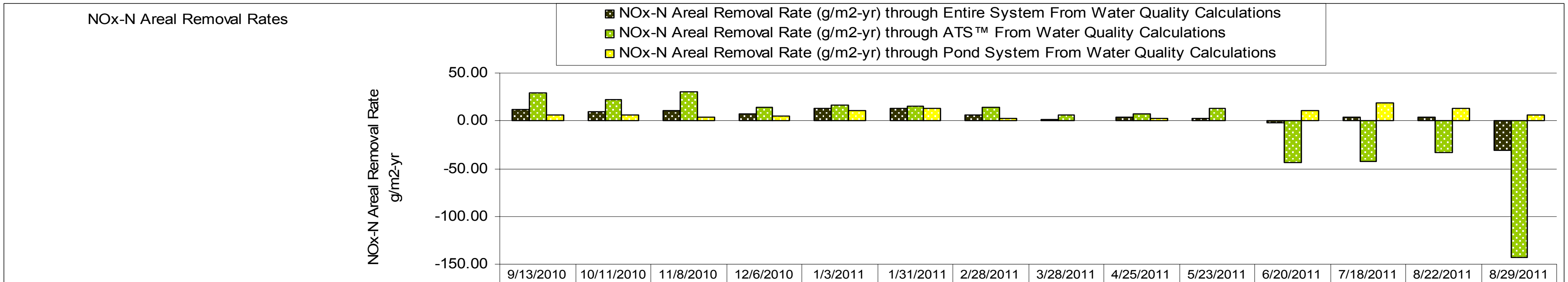
Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Percent Mass Removal through Entire System From Water Quality Calculations	61.45%	69.50%	76.55%	74.29%	76.45%	73.36%	72.49%	72.02%	72.82%	73.61%	71.27%	61.66%	51.54%	44.59%
NOx-N Percent Mass Removal through ATS™ From Water Quality Calculations	36.65%	39.28%	46.44%	43.88%	41.25%	35.65%	36.02%	36.46%	36.90%	38.74%	29.02%	15.98%	7.74%	2.30%
NOx-N Percent Mass Removal through Pond System From Water Quality Calculations	24.80%	30.22%	30.11%	30.40%	35.20%	37.71%	36.47%	35.56%	35.92%	34.87%	42.25%	45.68%	43.80%	42.29%

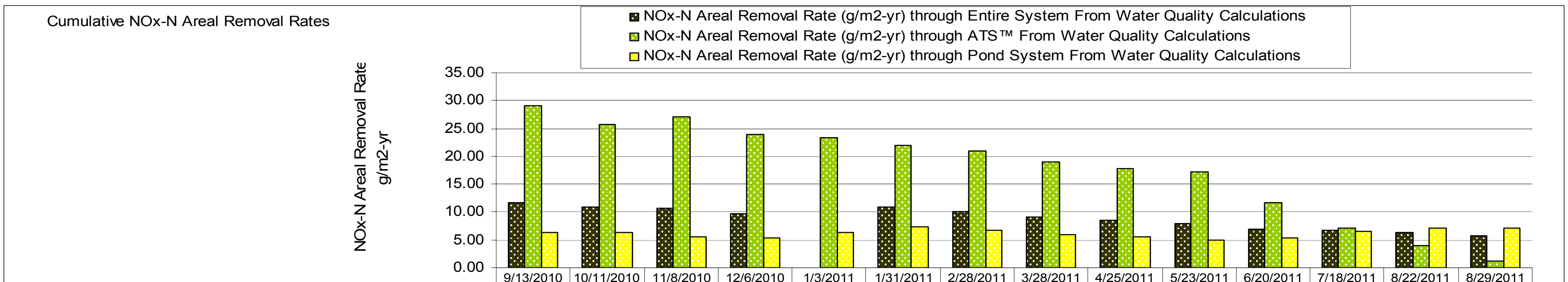
Date Ending

Figure 43: Q1 through Q4 Nitrate+Nitrite-N Percent Mass Removal through Egret Marsh Stormwater Park



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	11.76	10.11	10.38	6.80	13.12	13.39	5.60	1.42	3.33	3.14	-2.51	3.65	3.70	-30.46
NOx-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	29.07	22.13	29.85	14.51	16.87	15.32	14.50	5.72	7.13	12.99	-43.17	-42.96	-33.75	-143.49
NOx-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	6.26	6.28	4.18	4.35	10.59	12.78	2.77	0.06	2.12	0.00	10.43	18.48	12.52	6.17

Date Ending



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
NOx-N Areal Removal Rate (g/m2-yr) through Entire System From Water Quality Calculations	11.76	10.94	10.75	9.76	0.00	10.93	10.16	9.07	8.43	7.90	6.95	6.68	6.33	5.66
NOx-N Areal Removal Rate (g/m2-yr) through ATS™ From Water Quality Calculations	29.07	25.61	27.03	23.90	23.33	22.00	20.93	19.02	17.70	17.23	11.74	7.17	3.94	1.21
NOx-N Areal Removal Rate (g/m2-yr) through Pond System From Water Quality Calculations	6.26	6.27	5.57	5.27	6.33	7.40	6.74	5.90	5.48	4.93	5.43	6.52	7.09	7.07

Date Ending

Figure 44: Q1through Q4 Nitrate+Nitrite-N Areal Removal Rates through Egret Marsh Stormwater Park

WATER QUALITY – ASSESSMENT OF OTHER PARAMETERS

General Comments

Grab samples were taken for those parameters which demand immediate analysis because of short hold-times, and those which are not used in determining system performance in terms of total nutrient removal, but can be indicative of general shifts in water quality and process dynamics. The parameters evaluated as grab sample or determined in the field at time of sample collection for the EMSP monitoring program are:

- Ortho Phosphorus
- Total Phosphorus
- Total Organic Carbon
- TKN-N
- NOx-N
- Five Day Biochemical Oxygen Demand
- Alkalinity
- Total Suspended Solids
- Color
- Copper
- Zinc
- Cadmium
- Chromium
- Daytime pH (in-situ)
- Daytime Water T (in-situ)
- Daytime Dissolved Oxygen (in-situ)
- Daytime Specific Conductivity (in-situ)

Grab samples are typically taken using the manual sampling option within the automatic samplers. This means the sampling location is the same as with the composite samples. Grab samples are taken monthly for analysis, at the time of composite sample recovery. In-situ field samples, taken with a properly calibrated YSI unit, are taken weekly during mid morning. Q1 through Q4 values for the grab sample parameters analyzed within the laboratory are shown in Table 24. Q1 through Q4 values for in-situ parameters are shown in Table 25. (The dynamics of Ortho phosphorus, TKN and NOx-N are presented in previous subsections).

Table 24: Q1 through Q4 Grab Sample Results through Egret Marsh Stormwater Park

		Influent Station O1						ATS™ Effluent Station 02						Pond Effluent Station 03					
Parameter	**Units**	9/13 2010	10/11 2010	11/8 2010	12/6 2010	1/3 2011	1/31 2011	9/13 2010	10/11 2010	11/8 2010	12/6 2010	1/3 2011	1/31 2011	9/13 2010	10/11 2010	11/8 2010	12/6 2010	1/3 2011	1/31 2011
TSS	mg/L	5.75	5.75	4.25	6.75	4.25	5.50	3.75	3.25	1.75	3.75	3.75	3.00	6.00	5.00	U	8.00	3.75	2.75
Color	pcu	100	50	U	30	50	40	70	50	U	50	40	40	100	50	U	40	40	40
Alkalinity	mg/L as $CaCO_3$	182	164	150	183	186	170	167	156	146	179	180	167	159	160	149	181	185	156
BOD_5	mg/L	2.1	2.0	U	1.6	1.8	6.4	1.6	1.7	U	1.6	1.6	2.1	2.3	2.3	U	1.5	1.9	1.5
TOC	mg/L	13.80	9.70	5.40	7.04	7.12	11.50	13.90	10.0	5.50	7.50	7.31	10.50	14.50	10.30	5.80	7.71	6.67	8.96
Zinc	µg/L	4.47	12.80	4.61	5.74	10.90	8.33	U	5.35	3.74	3.62	9.04	6.43	3.56	3.97	13.3	3.12	6.70	6.32
Chromium	µg/L	U	U	U	U	U	U	U	U	1.05	U	U	U	U	U	1.07	U	U	U
Cadmium	µg/L	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0.06	U	U	U
Copper	µg/L	5.82	7.59	8.86	6.22	4.79	23.60	5.88	7.29	11.20	5.99	4.43	20.80	7.84	6.93	5.52	4.21	4.63	10.40

U = Undetectable

Table 24 (continued): Q1 through Q4 Grab Sample Results through Egret Marsh Stormwater Park

		Influent Station O1						ATS™ Effluent Station 02						Pond Effluent Station 03					
Parameter	**Units**	2/28 2011	3/28 2011	4/25 2011	5/23 2011	6/20 2011	7/18 2011	2/28 2011	3/28 2011	4/25 2011	5/23 2011	6/20 2011	7/18 2011	2/28 2011	3/28 2011	4/25 2011	5/23 2011	6/20 2011	7/18 2011
TSS	mg/L	8.00	6.50	5.25	5.50	5.25	7.25	3.00	1.75	3.50	4.25	2.50	6.00	4.25	4.25	7.00	5.75	0.00	3.00
Color	pcu	40	40	-	20	30	500	30	30	-	20	30	200	30	15	-	15	40	100
Alkalinity	mg/L as $CaCO_3$	191	178	169	174	141	155	184	176	153	161	131	149	183	174	166	158	146	163
BOD_5	mg/L	U	1.5	1.9	5.1	2.2	2.3	U	U	1.6	2.6	U	2.2	U	U	1.7	2.4	1.7	1.9
TOC	mg/L	8.56	8.80	9.23	8.18	10.40	27.00	8.26	9.01	9.40	8.17	10.70	10.30	9.00	9.00	8.54	7.40	10.30	20.00
TOC/ BOD_5	-	-	5.87	4.86	1.60	4.72	11.7	-	-	5.88	3.14	-	4.68	-	-	5.02	3.08	6.05	10.5
Zinc	µg/L	4.94	5.09	3.34	3.70	3.33	10.70	5.29	4.17	3.51	3.17	U	7.41	4.20	3.51	2.71	3.57	3.33	6.97
Chromium	µg/L	U	U	U	U	U	1.07	U	U	U	U	U	1.03	U	U	U	U	U	U
Cadmium	µg/L	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	µg/L	10.80	8.33	2.73	6.22	4.79	23.60	8.30	7.08	2.67	5.99	4.43	20.80	4.31	7.24	2.71	4.21	4.63	10.40

Table 24 (continued): Q1 through Q4 Grab Sample Results through Egret Marsh Stormwater Park

		Influent Station O1			ATS™ Effluent Station 02			Pond Effluent Station 03		
Parameter	**Units**	8/22 2011	8/29 2011	**Q1-Q4 Average**	8/22 2011	8/29 2011	**Q1-Q4 Average**	8/22 2011	8/29 2011	**Q1-Q4 Average**
TSS	mg/L	9.60	6.50	**6.15**	15.60	12.00	**4.85**	4.40	2.90	**4.08**
Color	pcu	200	100	**99**	150	125	**70**	150	125	**61**
Alkalinity	mg/L as $CaCO_3$	160	184	**171**	146	179	**162**	120	169	**162**
BOD_5	mg/L	2.6	2.6	**2.5**	2.7	2.3	**2.0**	2.9	1.7	**2.0**
TOC	mg/L	26.40	14.30	**11.97**	26.30	14.20	**11.91**	27.40	15.00	**11.48**
TOC/ BOD_5	-	10.15	5.5	**4.79**	9.74	6.17	**5.96**	9.45	8.82	**5.74**
Zinc	µg/L	9.45	U	**6.11**	11.20	5.26	**4.94**	8.34	U	**4.94**
Chromium	µg/L	1.55	U	**U**	1.42	U	**U**	1.43	U	**U**
Cadmium	µg/L	U	0.58	**U**	U	U	**U**	U	U	**U**
Copper	µg/L	25.70	5.67	9.47	35.80	9.24	9.92	39.80	8.53	8.67

Table 25: Q1 through Q4 In-Situ Results through Egret Marsh Stormwater Park Sampling taken mid-morning

	Influent Station O1				ATS™ Effluent Station 02				Pond Effluent Station 03			
Week Ending	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)
8/23/10	7.65	5.02	29.21	1,558	9.08	13.95	31.38	1,533	8.20	5.98	31.02	1,489
8/30/10	7.84	4.91	29.17	1,860	8.87	8.05	30.54	1,877	8.15	5.60	29.65	1,569
9/6/10	7.65	5.49	29.46	1,882	7.85	6.00	28.66\	1,843	8.06	5.37	29.44	1,742
9/13/10	7.66	7.37	30.57	1,742	9.04	11.60	32.83	1,387	8.42	7.55	31.61	1,674
9/20/10	7.67	6.59	28.79	1,964	8.84	15.54	31.01	2,009	8.34	8.69	28.96	1,753
9/27/10	8.01	5.19	29.62	1,970	8.87	12.21	30.81	1,986	8.39	7.45	29.38	1,828
10/4/10	7.60	6.12	26.50	1,775	8.73	14.71	28.45	1,802	8.14	8.74	26.70	1,768
10/11/10	7.93	7.82	25.18	1,811	8.53	13.50	28.16	1,894	8.23	9.81	25.50	1,786
10/18/10	8.22	9.34	23.72	1,877	8.69	15.38	26.33	1,960	8.32	10.59	24.72	1,879
10/25/10	7.52	4.94	25.52	2,382	7.95	9.35	29.32	2,410	7.97	6.94	25.78	2,238
11/1/10	7.78	4.39	24.48	2,380	8.38	11.29	27.73	2,501	8.06	6.67	25.62	2,361
11/8/10	7.98	8.24	17.78	2,069	8.43	17.75	19.59	2,136	8.16	11.35	19.34	2,130
Q1 Ave	**7.79**	**6.29**	**26.67**	**1,939**	**8.61**	**12.44**	**28.73**	**1,944**	**8.20**	**7.90**	**27.31**	**1,851**
11/15/10	7.72	4.94	20.75	2,339	8.49	13.56	23.12	2,428	8.27	13.60	20.92	2,173
11/22/10	8.12	8.86	21.56	2,152	8.23	10.63	24.36	2,152	8.33	12.99	22.08	2,213
11/29/10	7.88	9.24	22.85	2,256	8.46	14.88	24.03	2,256	8.10	8.92	22.43	2,239
12/6/10	7.89	8.15	16.45	1,933	8.06	13.25	18.66	1,933	7.89	11.10	17.50	2,011
12/13/10	7.71	11.61	15.23	1,857	8.28	18.06	15.27	1,857	7.63	15.31	14.91	1,859
12/20/10	7.06	10.61	14.16	1,921	8.04	18.48	16.12	1,921	8.07	14.90	14.10	1,955
1/3/11	7.70	9.50	17.39	2,130	8.24	12.28	18.66	2,130	7.89	7.53	17.94	2,163
1/10/11	7.96	7.72	16.91	1,926	8.47	13.51	19.22	1,926	8.60	9.57	16.76	1,950
1/17/11	7.96	9.59	16.12	1,933	8.38	14.28	18.30	1,933	8.10	10.81	16.23	1,946
1/24/11	7.78	7.92	16.73	1,978	8.33	13.93	19.25	1,978	8.14	9.77	16.65	1,947
1/31/11	7.66	9.73	17.17	2,068	8.06	15.61	17.30	2,068	8.22	12.11	16.93	2,012
Q2 Ave	**7.77**	**8.90**	**17.76**	**2,045**	**8.28**	**14.41**	**19.48**	**2,098**	**8.11**	**11.51**	**17.86**	**2,043**

Table 25 (continued): Q1 through Q4 In-Situ Results through Egret Marsh Stormwater Park

	Influent Station O1				ATS™ Effluent Station 02				Pond Effluent Station 03			
Week Ending	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)	pH	DO (mg/L)	Water T° C	Conductivity (microS/cm)
2/7/11	7.91	6.71	22.17	2,082	8.43	14.21	23.86	2,183	8.35	9.09	21.94	2,023
2/14/11	7.97	8.02	17.14	2,217	8.40	14.35	19.16	2,203	8.39	9.24	17.24	2,200
2/21/11	7.85	8.12	21.45	2,107	8.39	10.98	23.66	2,184	8.21	9.17	21.24	2,063
2/28/11	7.75	6.68	23.28	2,282	8.22	11.33	24.29	2,354	8.14	8.45	23.06	2,123
3/7/11	7.93	9.23	21.29	2,105	8.46	15.29	24.46	2,233	8.35	10.96	21.94	2,179
3/14/11	7.97	10.50	20.70	2,175	8.48	14.59	23.38	2,286	8.58	11.42	20.54	2,125
3/21/11	7.82	8.04	23.00	2,263	8.02	12.25	24.45	2,310	7.87	8.75	22.74	2,343
3/28/11	8.14	6.89	24.08	2,408	8.16	8.30	23.32	2,332	8.33	8.04	23.28	2,328
4/4/11	7.84	7.56	25.05	2,315	8.31	11.89	26.65	2,374	8.21	8.10	25.12	2,306
4/11/11	7.78	7.80	27.08	2,339	8.25	13.23	29.36	2,422	7.89	8.08	27.04	2,313
4/18/11	8.23	8.55	26.34	2,176	8.56	11.71	28.39	2,295	8.34	9.62	26.52	2,260
4/25/11	-	-	-	-	-	-	-	-	-	-	-	-
Q3 Ave	**7.93**	**8.01**	**22.87**	**2,225**	**8.33**	**12.56**	**24.63**	**2,289**	**8.24**	**9.17**	**22.79**	**2,206**
5/2/11	7.97	8.51	26.38	2,487	8.52	15.24	29.05	2,593	8.22	9.48	26.50	2,434
5/9/11	7.88	7.44	26.79	2,635	8.38	12.05	28.34	2,716	8.04	8.13	26.88	2,621
5/16/11	7.86	7.02	25.95	2,601	8.38	13.16	27.37	2,653	8.52	8.83	26.80	2,497
5/23/11	7.88	7.18	28.55	2,779	8.33	11.82	29.96	2,827	8.74	9.68	28.74	2,703
5/30/11	7.67	6.20	27.88	2,356	8.12	11.77	27.54	2,323	8.45	9.36	27.64	2,337
6/6/11	7.77	7.31	28.81	2,546	8.37	13.96	31.23	2,625	8.09	7.31	28.93	2,510
6/13/11	7.86	7.11	29.11	2,510	8.42	9.05	31.10	2,587	8.26	8.33	29.27	2,517
6/20/11	7.69	6.90	29.14	2,481	8.43	7.14	31.81	2,582	7.78	6.91	29.61	2,525
6/27/11	7.74	7.37	28.73	2,163	8.44	16.53	29.92	2,129	8.03	6.29	28.87	2,218
7/5/11	7.56	4.96	27.85	1,728	8.13	14.70	30.56	1,805	7.78	5.68	29.43	1,718
7/11/11	7.60	5.57	28.75	1,805	8.42	15.45	32.58	1,903	7.76	4.68	29.81	1,837
7/18/11	7.41	-	29.66	1,645	8.36	-	32.12	1,722	7.90	-	29.68	1,622
7/25/11	7.40	6.41	30.38	1,817	7.94	12.80	31.03	1,814	7.72	7.48	30.82	1,844
8/1/11	7.32	6.50	30.65	2,088	7.84	13.97	31.45	2,088	7.10	1.92	30.48	1,852
8/8/11	7.31	5.34	29.90	1,723	7.64	8.49	30.10	1,709	7.58	6.96	30.24	1,849
8/15/11	7.61	5.02	29.18	1,484	7.92	7.19	29.93	1,003	6.93	4.69	29.60	953
8/22/11	6.63	5.52	29.59	1,229	7.57	8.47	34.03	1,299	6.40	3.80	29.79	972
8/29/11	7.41	5.99	30.89	2,099	7.99	12.78	31.65	2.107	7.28	4.65	30.78	1,954
Q4 Average	**7.59**	**6.47**	**28.79**	**2,121**	**8.18**	**12.03**	**30.54**	**2,138**	**7.81**	**6.72**	**29.10**	**2,054**
Q1-Q4 Ave	**7.75**	**7.29**	**24.67**	**2,087**	**8.33**	**12.67**	**26.50**	**2,117**	**8.06**	**8.58**	**24.93**	**2,037**

Total Suspended Solids

Total suspended solids (TSS) within Lateral D and throughout the EMSP treatment train for Q1 through Q4, were comparatively low, averaging 6.15 mg/L at the influent, 4.85 mg/L at the ATS™ effluent and 4.08 mg/L at the final effluent. Through the monitoring period a slight reduction of TSS was documented through the ATS™ and the pond/wetland system, as shown in Figure 46 and Table 26. However, during Q4 a noticeable increase in TSS through the ATS™ was observed. This is consistent with the suggestion that heavy rainfall and nutrient loading resulting in higher sloughing of algal turf tissue. The pond/wetland system served to reduce the TSS loads coming from the ATS™ during this Q4 period.

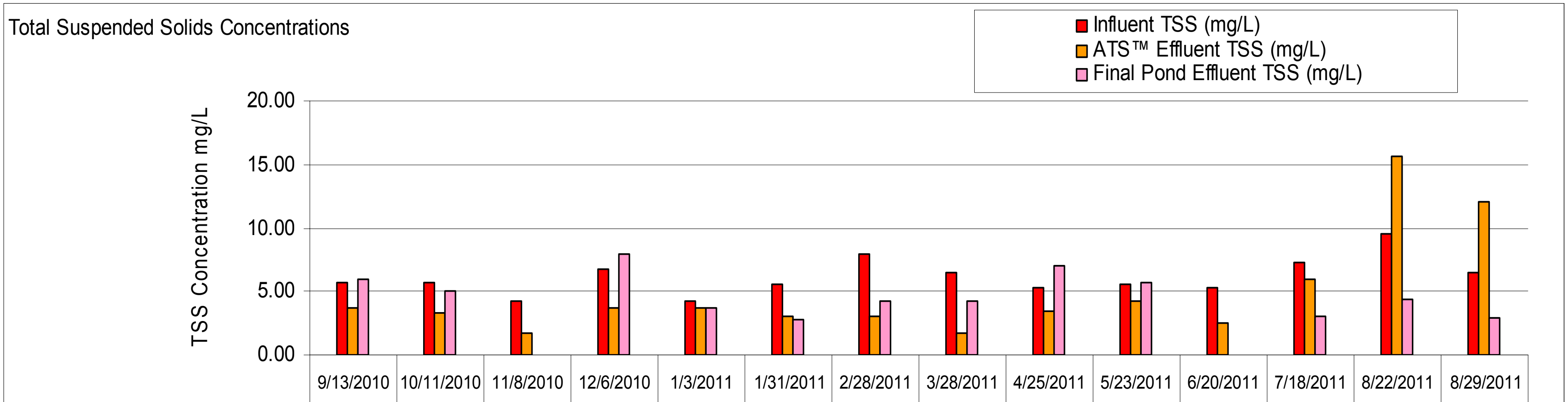
Volatile suspended solids (VSS) analyses were not conducted on the TSS, so it is not possible to discern the organic from the inorganic fraction. It is suspected that the TSS from Lateral D includes a higher percentage of inorganic solids (e.g. silts, sand etc.) than the TSS associated with the ATS™ and pond effluents—these likely being sloughed periphytic and epiphytic algal fragments, small invertebrates and/or phytoplankton.

A general increase in TSS is noted from the ATS™ through the pond system for the first three quarters, which is likely a result of phytoplankton productivity within the ponds. The TSS however, at the levels shown within the pond system (0-8 mg/L) is comparatively low, indicating that phytoplankton activity was not at eutrophic levels. As noted, this dynamic changed during Q4, with the pond serving to attenuate TSS loads from the ATS™.

Because TSS is comparatively low throughout the process, it is likely that particulate nutrient levels represent a smaller percentage of the total nutrient levels than dissolved nutrients. Estimates of particulate nutrients as noted in Table 27, based upon the assumption that solids P and N content are as the percentages found in the solids within the diverted ATS™ harvest. As noted, particulate phosphorus is sustained from influent through the ATS™ at 25.6% of the total phosphorus, increasing somewhat during the Q4 period. Particulate nitrogen represent a somewhat lower percentage, being 9.8% within the influent, and slightly lower at 8.3% within the ATS™ effluent. The final effluent shows a higher percentage of total phosphorus as particulate phosphorus at 32.1%. This particulate phosphorus is most likely associated with phytoplankton within the pond/wetland system. However, particulate nitrogen associated with the pond/wetland effluent is basically unchanged at 7.3% of the total nitrogen. The low levels of particulate nitrogen is suggestive that dissolved organic nitrogen is a substantial component of the recalcitrant nitrogen—i.e. RDON.

Total Organic Carbon and Biochemical Oxygen Demand

Levels of total organic carbon (TOC) and five-day biochemical oxygen demand (BOD_5) throughQ1 through Q4 were low throughout the treatment train (Table 22). While there was no significant change in concentrations of BOD_5 throughout the EMSP process over the monitoring period, the TOC did increase substantially during the final two months of Q4. As noted from Table 24 the ratio of TOC: BOD_5 increased during the onset of the rainy season in July from values around 5-6 to over 10, indicating the TOC load had increased in recalcitrance, and the contributing compounds were likely high molecular weight complexes such as lignins and humic acids, which are associated with soil hardpans. It is probably not coincidental that during this period, increased TOC was attendant with increases in color.



	9/13/2010	10/11/2010	11/8/2010	12/6/2010	1/3/2011	1/31/2011	2/28/2011	3/28/2011	4/25/2011	5/23/2011	6/20/2011	7/18/2011	8/22/2011	8/29/2011
Influent TSS (mg/L)	5.75	5.75	4.25	6.75	4.25	5.50	8.00	6.50	5.25	5.50	5.25	7.25	9.60	6.50
ATS™ Effluent TSS (mg/L)	3.75	3.25	1.75	3.75	3.75	3.00	3.00	1.75	3.50	4.25	2.50	6.00	15.60	12.00
Final Pond Effluent TSS (mg/L)	6.00	5.00	0.00	8.00	3.75	2.75	4.25	4.25	7.00	5.75	0.00	3.00	4.40	2.90

Figure 45: Q1 through Q3 Grab Total Suspended Solids (TSS) Concentrations through Egret Marsh Stormwater Park

Table 26: Estimates of Particulate Nutrient Dynamics through EMSP Treatment Train

Suspended Solids at 0.30% TP And 2.00% TN	**ATS™ Influent (Station 01)**					**ATS™ Effluent (Station 02)**					**Pond Effluent (Station 03)**				
Period Ending Date	Q1	Q2	Q3	Q4	**Q1-Q4**	Q1	Q2	Q3	Q4	**Q1-Q4**	Q1	Q2	Q3	Q4	**Q1-Q4**
TSS (mg/L)	5.25	5.50	6.58	6.82	**6.15**	2.91	3.50	2.75	8.07	**4.85**	3.67	4.83	5.17	3.21	**4.08**
Total P (TP) (mg/L)	0.100	0.042	0.043	0.173	**0.101**	0.067	0.040	0.031	0.139	**0.079**	0.051	0.027	0.027	0.085	**0.053**
Estimated Solids %P	0.56%	0.28%	0.24%	0.46%	**0.42%**	0.56%	0.28%	0.24%	0.46%	**0.42%**	0.56%	0.28%	0.24%	0.46%	**0.42%**
Estimated Particulate P (mg/L)	0.029	0.015	0.016	0.031	**0.026**	0.016	0.010	0.007	0.037	**0.020**	0.021	0.014	0.013	0.015	**0.017**
Estimated Particulate P as % of TP	29.4%	36.7%	36.7%	18.1%	**25.6%**	24.3%	25.0%	21.3%	26.7%	**25.6%**	40.3%	51.9%	46.0%	17.4%	**32.1%**
Total N (TN) (mg/L)	0.86	0.80	0.65	1.26	**0.95**	0.72	0.73	0.61	1.24	**0.88**	0.74	0.61	0.61	1.04	**0.79**
Estimated Solids %N	1.88%	1.31%	1.33%	1.44%	**1.51%**	1.88%	1.31%	1.33%	1.44%	**1.51%**	1.88%	1.31%	1.33%	1.44%	**1.51%**
Estimated Particulate N (mg/L)	0.10	0.07	0.09	0.10	**0.09**	0.05	0.05	0.04	0.12	**0.07**	0.07	0.06	0.07	0.05	**0.06**
Estimated Particulate N as % of TN	11.6%	9.0%	13.5%	7.8%	**9.8%**	6.9%	6.2%	6.0%	9.4%	**8.3%**	9.3%	10.3%	11.3%	4.4%	**7.8%**

The overall low values of both parameters indicate that there was no heavy organic loading associated with the Lateral D Canal system, and there are no significant organic carbon contributions to the water column from either the ATS™ or the pond system.

Color

Within Lateral D there was a decline during Q1 in color from the first to the third sampling periods (Table 24). By the third sampling period, color was undetectable. By the first sampling period of Q2, color increased to about 30 pcu, and increased to 40-50 pcu during the remainder of Q2. During Q3, the color was 30-40 pcu, with some decline noted through the ATS™. It is not clear whether this drop in color relates to the fact that the waters were being re-treated through the EMSP, or that it was a manifestation of the paucity of up-gradient seepage and surface runoff during the drought period.

For the first three quarters, when color levels were relatively low, there was little evidence that either the ATS™ or the pond system had dramatic influence on color, although during the first sampling period, Color did drop from 100 pcu to 70 pcu through the ATS™, and some reduction of color was noted during Q3. Over the first three month period, color averaged 49, 44 and 44 pcu within the influent, the ATS™ effluent, and the pond effluent respectively.

During Q4, the dynamics of water color changed rather dramatically with the onset of the rainy season and the influx of seepage water which had been stored during the drought season above the hardpan soil horizon. For the period from July 18, 2011 to the end of the monitoring period on August 29, 2011 influent color ranged from 100 to 500 pcu, averaging 267 pcu. For the same period, the color within the ATS™ decreased to an average of 158 pcu, and declined further to an average of 125 pcu through the pond/wetland system. This trend provides indication that during periods of high color levels associated with the rainy season flows that the EMSP system, and particularly the ATS™, contribute significantly to color reduction. It is beyond the scope of this investigation to evaluate the exact nature of the colloidal particles associated with these high color levels, or the exact mechanism involved in their reduction. However, it appears quite likely that the hardpan soil horizon is largely responsible for the increased color, and that colloidal particles which impose this color may coalesce or agglomerate through the ATS™ in a manner that their removal is facilitated—either through settling or adsorption. This capability of an EMSP type facility to reduce color during periods of heavy color development within the canal networks is important, as color reduction helps ensure adequate light reaches the seagrass beds within the receiving waters of the Indian River Lagoon. It is suggested, when practical, to continue with more detailed investigations related to this issue.

Zinc, Copper, Chromium and Cadmium

The concentrations of these four metals in all instances during Q1 through Q4 (Table 24) were well below the maximum allowable concentrations per the Florida regulations as listed in Ch 62-302.53 F.A.C., except for one cadmium sample (8/29/11) within the influent of 0.58 µg/L, and copper samples for 8/22/11, when levels were 25.70, 35.80 and 39.80 µg/L for the influent, ATS™ effluent and pond/wetland effluent respectively. It is suggested that these elevations were associated with the seepage water attendant with the onset of the rainy season. The maximum allowable limits per Ch 62-302.53 F.A.C, are 20.6 µg/L; 0.5 µg/L; 46.9 µg/L and 44.9 µg/L for copper (Cu), cadmium (Cd), total chromium (Cr) and zinc (Zn), respectively[36]. There was no indication that these metals were reduced substantially through the EMSP treatment train.

Alkalinity, pH and Available Carbon

Typically, when algal turf productivity is active and available carbon is consumed, an upward daytime shift in pH is noted from influent to effluent. (This phenomenon is seen as well in any aquatic system which supports substantial rates of photosynthesis).The extent of this pH shift is largely dependent upon the initial pH and alkalinity, as well as the productivity level. The higher the alkalinity and the lower the initial pH, the greater the level of available carbon, and the more attenuated the pH differential. During the nighttime, when respiration dominates, CO_2 levels recover, and pH shifts downward. These patterns result in diurnal pH fluctuations which are typical of ATS™ dynamics, or for any photosynthetically active aquatic system (Figure 46).

During Q1through Q4, pH was taken during the daytime (usually 9:00 -10:00 AM) at the three monitoring stations. The upward pH shift during Q1 from an average Lateral D influent pH of 7.79 to an average ATS™ effluent pH of 8.61 reflects the consumption of carbon dioxide and bicarbonate and carbonate alkalinity, and the generation of hydroxyl alkalinity. The same shift was noted during Q2 and Q3, although somewhat attenuated when compared to Q1, with the average lateral D influent pH at 7.77 and 7.93 for Q2 and Q3 respectively, and the average ATS™ effluent pH of 8.28 and 8.33 for Q2 and Q3 respectively. This decline in effluent pH is indicative of the lower productivity associated with Q2 and Q3. During Q4, influent pH levels dropped to 7.60 in response to the onset of the rainy season and attendant increases in seepage and runoff flows. The ATS™ effluent pH averaged 8.19 during Q4.

Through the pond/wetland system, the pH shifted downward to an average of 8.20 during Q1, 8.11 during Q2, 8.24 during Q3 and 7.84 during Q4. These declines are a result of lower levels of productivity within the pond/wetland when compared to the ATS™, as well as an extended hydraulic residence period through the ponds (about 4-5 days), during which the flow encounters several cycles of production and respiration. The daytime pH trends for Q1 through Q4 are shown in Figure 47. It is noteworthy that the pond/wetland system serves to modulate pH fluctuations across the ATS™ prior to release to the receiving surface water, and that during the latter month of Q4, the pH levels declined noticeably in the influent, indicating the upstream seepage and runoff waters are, as might be expected somewhat more acidic than the impounded waters associated with Q1 through Q3.

The relationship of pH and alkalinity to available carbon for algal photosynthesis was investigated by Saunders et al. [37] The available carbon was expressed as a percentage of total alkalinity, as noted in Figure 48. Using this relationship, the amount of carbon consumed through the ATS™ can be estimated (Table 27). This carbon roughly correlates to

[36] The limits are based upon formulae that include total hardness. The average total hardness (Table1) for the Main Canal has been documented at 253 mg/L as $CaCO_3$.

[37] Saunders, G.W., F.B. Trama, and R.W. Bachman. 1962. Evaluation of a modified C14 technique for shipboard estimation of photosynthesis in large lakes. Great Lakes Research Division, Institute of Science and Technology, University of Michigan, Ann Arbor, Michigan, USA.

the carbon used in producing organic compounds through photosynthesis, which is expressed as gross productivity. A portion of this gross production is used as an energy source for normal cellular function, and is oxidized into CO_2. The remaining production then is stored and used in the construction of new tissue, which in turn may be consumed by grazers, and indirectly, by other trophic levels. This remaining carbon, which is incorporated in both plant and animal tissue, as well as detrital solids, is recovered as harvested biomass, and generally represents net community productivity. The ratio of net community productivity as estimated from harvest, to gross productivity, as estimated through pH and alkalinity changes, provides some insight into the extent of grazing and other factors which contribute to the ecological dynamics of the algal turf. This comparison is presented in Table 28.

As seen within Table 28, the gross productivity declines from a high of 3,247 g-C/m^2-yr during Q1 to 1,019 g-C/m^2-yr during Q2, and increasing during Q3 to 1,756 g-C/m^2-yr, and to 1,936 g-C/m^2-yr for Q4.The Q2 value is related largely to the commensurate decline in available nitrogen and phosphorus, as well as to lower water temperatures. The recoveries during Q3 relates to increased water temperatures as compared to Q2, even though nutrient levels remained comparatively unchanged. The additional increase during Q4 relates to both increased water temperature and increased nutrient levels associated with the onset of the rainy season. The net community productivity for Q4 was likely higher the calculated 1,936 g-C/m^2-yr , as a portion of the production was released during intermittent sloughing to the pond/wetland system.

The Lateral D water appears to have maintained adequate levels of available carbon through the four quarter period (40-43 mg/L), and the alkalinity levels did not fluctuate substantially throughout the four quarters. The Q1 and Q4 levels of gross productivity are similar to levels which might be seen in highly eutrophic ponds[38], and moderately productive ponds during Q2 and Q3, which indicates that the ATS™ is capable of soliciting high levels of productivity, even when nutrient levels are suppressed.

The percentage of gross productivity which was net community productivity (based upon carbon consumed and carbon recovered as harvest) declined from 38.8% for Q1 to 11.6% for Q2, recovering during Q3 to 34.6% and during Q4 to 39.3%.These percentages are within the ranges which might be expected, with the lower Q2 level suggestive that greater energy expenditures are needed to maintain tissue under conditions of cooler water and lower nutrients, and that involvement by grazers and secondary consumers (including transient predators such as birds) may be more extensive.

[38] Noriega-Curtis, P 1979, “Primary Productivity and related fish yields in intensely manured ponds” ***Aquaculture*** 17:335-344

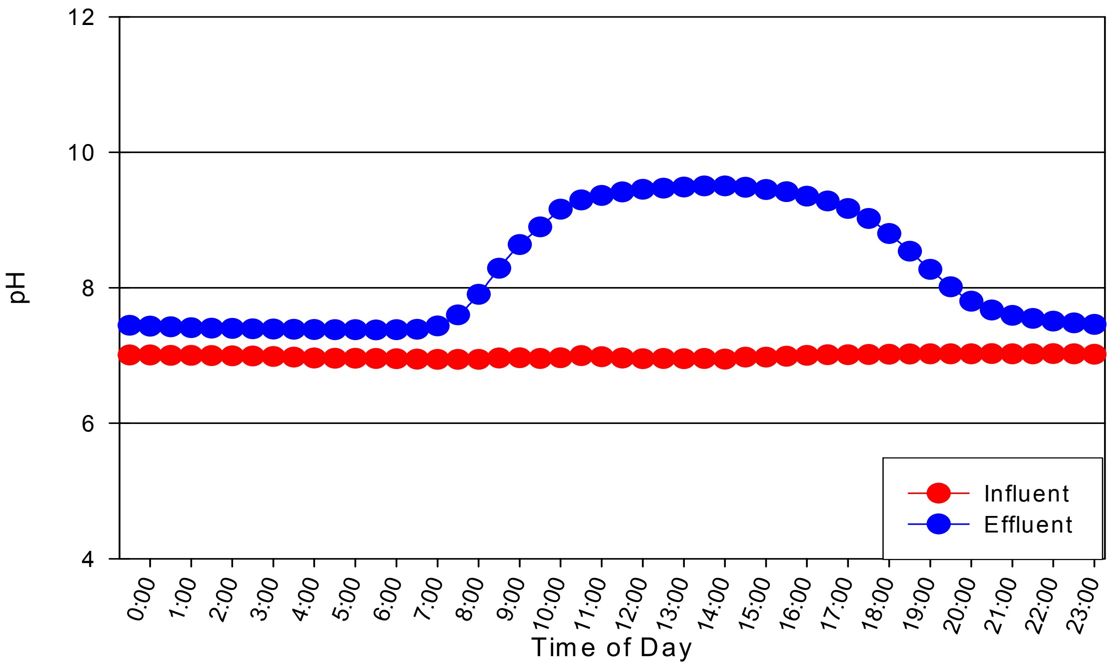


Figure 46: Typical Diurnal pH Trends Across an Active ATS™ floway [39]

---

[39] Taken from HydroMentia (2005) "S-154 Pilot ATS^{TM}-WHS^{TM} Aquatic Plant Treatment System Final Report" for SFWMD Contract C-13933

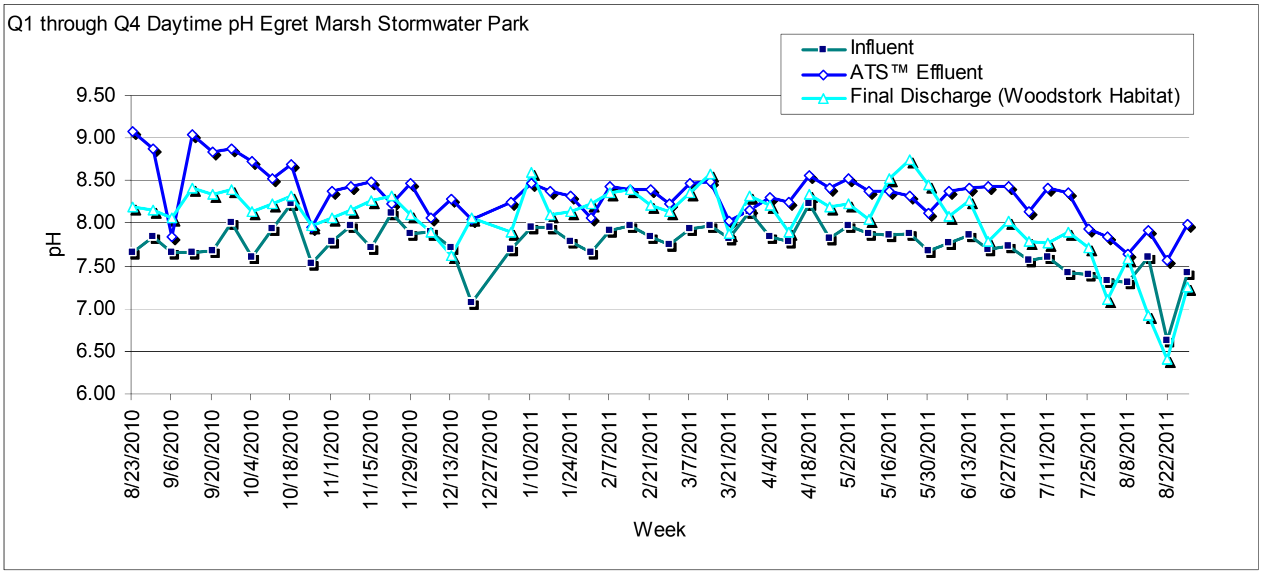


Figure 47: Q1 through Q4 Daytime pH Trends Egret Marsh Stormwater Park

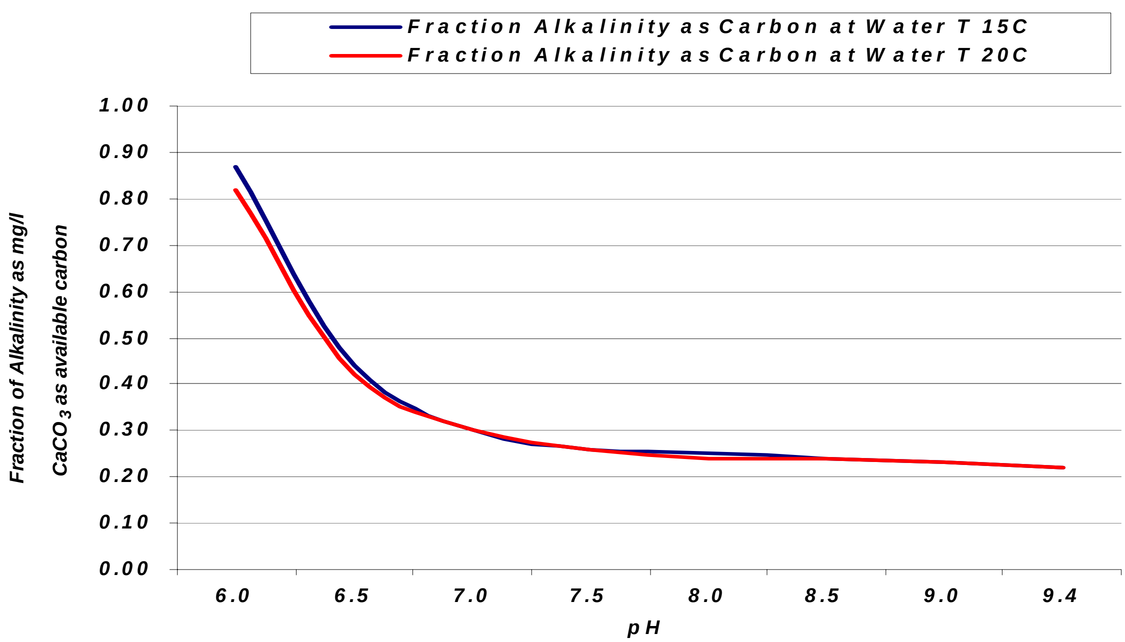


Figure 48: Available Carbon, Alkalinity, pH relationship per Saunders et. al.[22]

Table 27: Q1 through Q4 Estimates of Gross and Net Community Productivity through EMSP ATS™

	ATS™ Influent (Station 01)					ATS™ Effluent (Station 02)				
Parameter	Q1	Q2	Q3	Q4	Total Project Period	Q1	Q2	Q3	Q4	Total Project Period
Alkalinity mg/L as $CaCO_3$	173	177	177	163	171	156	174	170	153	162
Average pH	7.79	7.77	7.93	7.59	7.75	8.61	8.74	8.33	8.18	8.33
Available Carbon (mg/L)	43	43	42	40	42	34	40	37	35	35
Available Carbon Uptake (mg/L)						9	3	5	5	7
Percentage of Day Photoperiod						50.2%	47.0%	48.0%	52.0%	49.3%
Available Carbon Uptake Gross Productivity (lbs)						30,517	9,582	16,510	27,291	83,900
Available Carbon Uptake Rate (g-C/m^2 –yr)						3,247	1,019	1,756	1,936	7,958
Dry Harvest (lbs)						53,099	7,379	31,761	50,222	148,766
Tissue Percent Carbon						22.3%	15.1%	18.0%	21.3%	19.8%
Carbon as Net Community Productivity (lbs)						11,841	1,114	5,712	10,719	29,386
Percentage of Gross Productivity as Net Community Productivity						38.8%	11.6%	34.6%	39.3%	35.0%

Dissolved Oxygen

Oxygen is a product of photosynthesis. During the daytime when photosynthesis rates are typically high, enough oxygen is generated by the ATS™ that levels in the effluent can exceed saturation. It is not unusual for dissolved oxygen (DO) levels to approach or even exceed 14 mg/L, even during the summer when saturation concentrations can be as low as 5-7 mg/L. At night, while there is no photosynthetic DO contributed to the floway, the shallow flow associated with the ATS™ process facilitates comparatively high reaeration rates, thereby avoiding the severe DO “sag” often associated with highly productive systems. Therefore, while there is a drop in DO levels at night, they typically remain higher than the influent levels, and above 5 mg/L. A typical diurnal pattern for DO is noted in Figure 49.

Daytime DO levels across the ATS™ during the monitoring period showed this typical pattern, with effluent levels normally above saturation (See Figure 50). Some drop in DO was noted through the pond system, which was as expected; because of the lower production and the extended hydraulic residence time. With the onset of the rainy season during the latter part of Q4, some lower DO levels were observed within the pond/wetland effluent. During this period, water levels within the wood stork habitat wetland were lowered on several occasions, which may have impacted DO dynamics within the wetland. Monitoring DO provides a general indication of productivity levels across the ATS™, and to the overall health of the algal turf community.

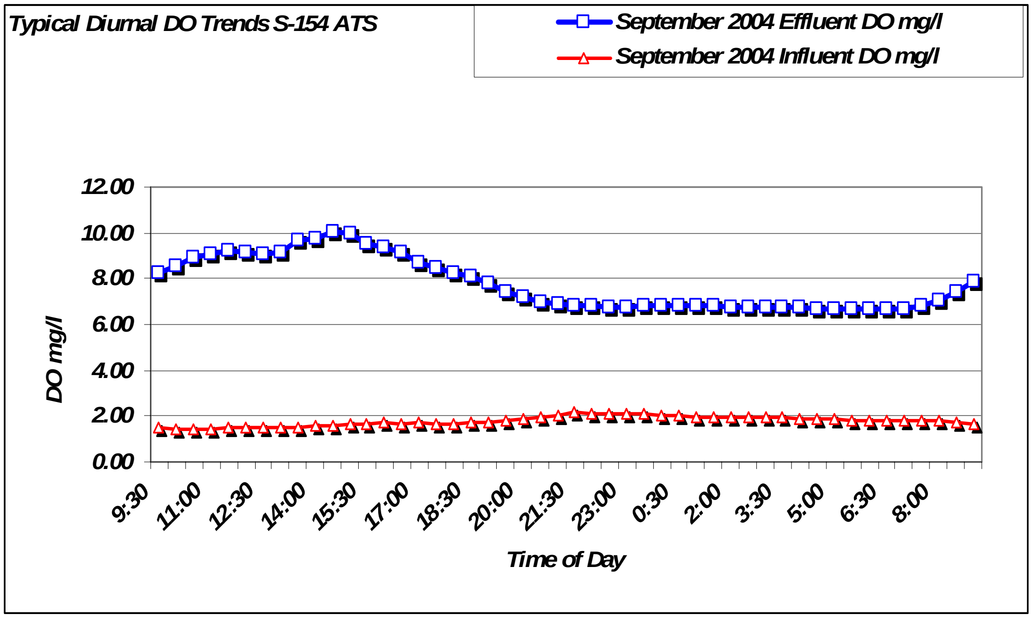


Figure 49: Typical Diurnal DO Trends Across an Active ATS™ Floway[40]

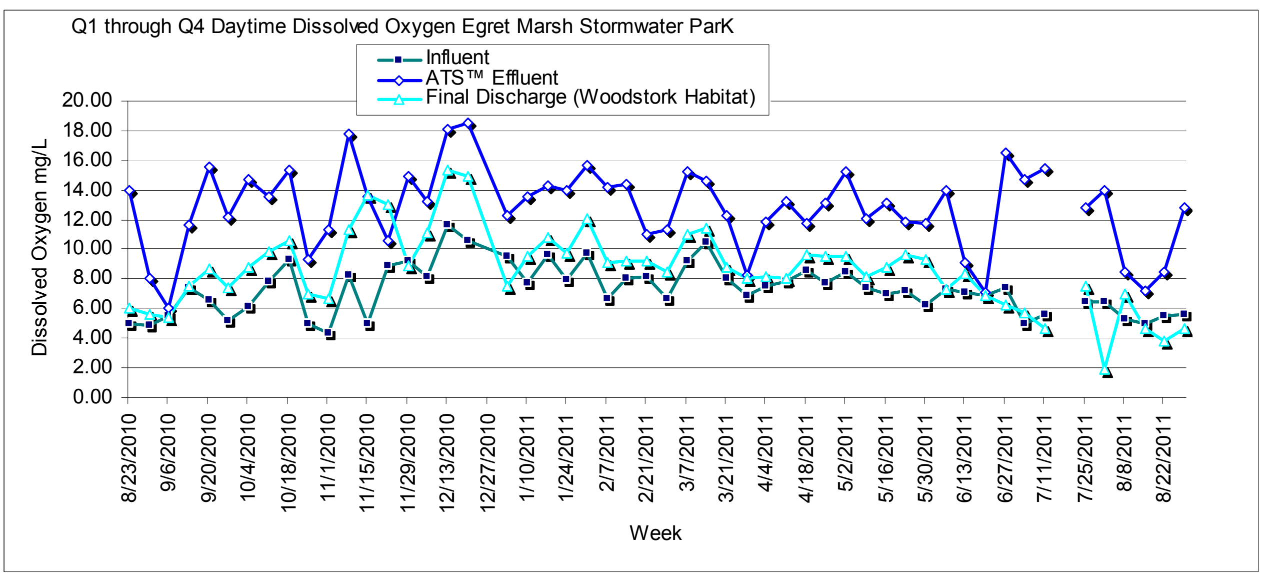


Figure 50: Q1 through Q4 Daytime DO Trends Egret Marsh Stormwater Park

[40] Taken from HydroMentia (2005) "S-154 Pilot ATS^{TM}-WHS^{TM} Aquatic Plant Treatment System Final Report" for SFWMD Contract C-13933

Water Temperature

Water temperature changes from influent to effluent across an ATS™ floway depend upon the differential between air temperature and water temperature. A typical pattern for Florida when the daytime air temperature is normally higher than the water temperature is for the water to gain heat down the ATS™ floway during the day time, and then release heat at night (Figure 51). The daytime water temperature changes for Q1 through Q4 indicate a 3-4 degree daytime increase across the ATS™ is typical, with downward modulation of temperature through the pond system (Figure 52). There is noted a significant decline in water temperature during Q2, which contributed to substantially lower productivity during this period. Water temperatures increased during Q3, which appeared to contribute to improved productivity. During Q4 the water temperatures continued to increase, as did productivity. The temperature differential from influent to ATS™ effluent was not as great as with the previous quarters, due largely to the modulating effects of the heavy rainfall events.

As expected, increased water temperature normally solicits increased algal productivity, although prolonged temperatures above 40° C have the potential of challenging the physiology of certain algal communities. Even during peak summer periods of Q4, the ATS™ effluent water temperature did not reach 40° C.

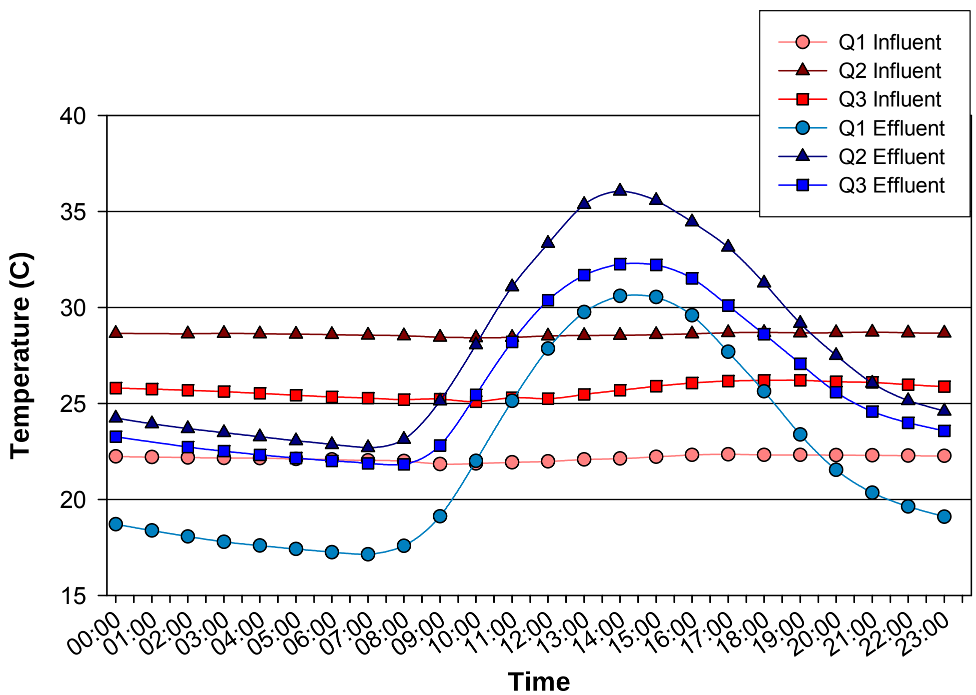


Figure 51: Typical Diurnal Water Temperature Trends Across an Active ATS™ floway[41]

[41] Taken from HydroMentia (2005) "S-154 Pilot ATS™-WHS™ Aquatic Plant Treatment System Final Report" for SFWMD Contract C-13933

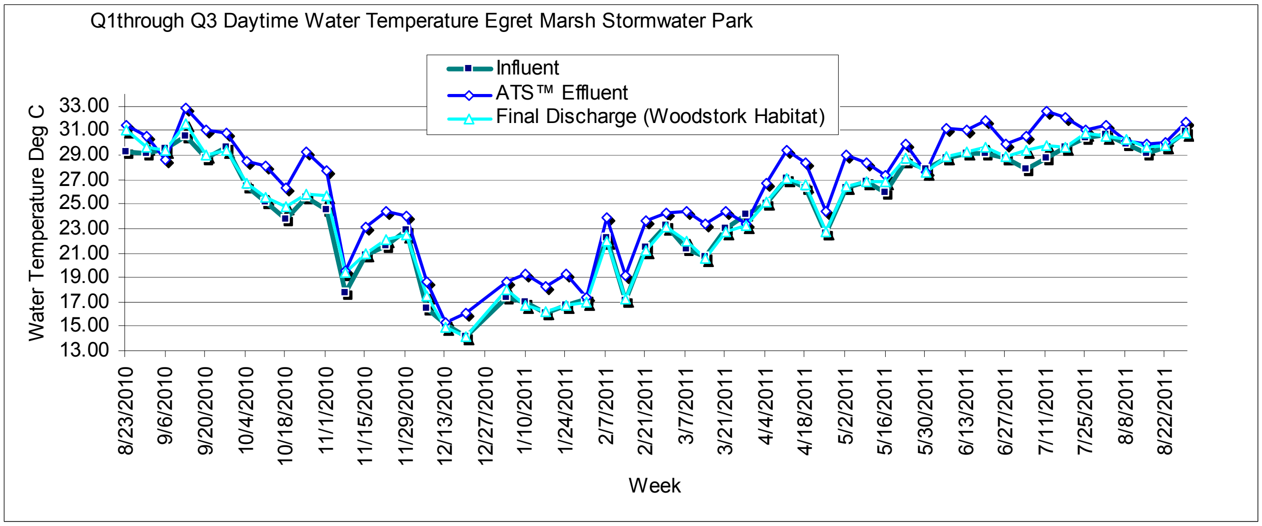


Figure 52: Q1 through Q4 Daytime Water Temperature Trends Egret Marsh Stormwater Park

Conductivity

The Lateral D water is freshwater with moderate ionic activity, characterized during Q1 through Q4 by a conductivity of 1,229-2,779 microS/cm. When flows move across an ATS™ floway, there normally is very little shift in conductivity from influent to effluent. The changes that are noted are typically attributable to temperature changes, with the effluent normally having somewhat higher conductivity levels during the warm daytime period (Figure 53). During Q1through Q2 the influent, ATS™ effluent, and pond conductivities were very similar (Figure 54), with the pond showing a slightly lower conductivity, which probably relates to the greater rainfall capture area. It was noted that there was an increase in conductivity from sampling period Q1 to Q2 and Q3. This is likely due to the growing influence of ground waters as the runoff volumes declined. With the heavy rainfall associated with Q4, the conductivity levels decreased.

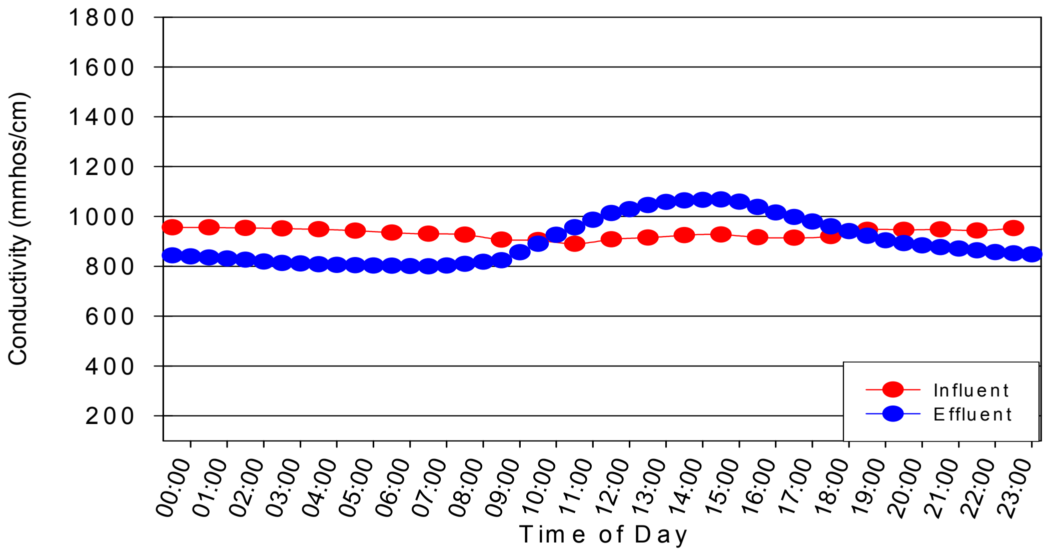


Figure 53: Typical Diurnal Conductivity Trends Across an Active ATS™ floway[42]

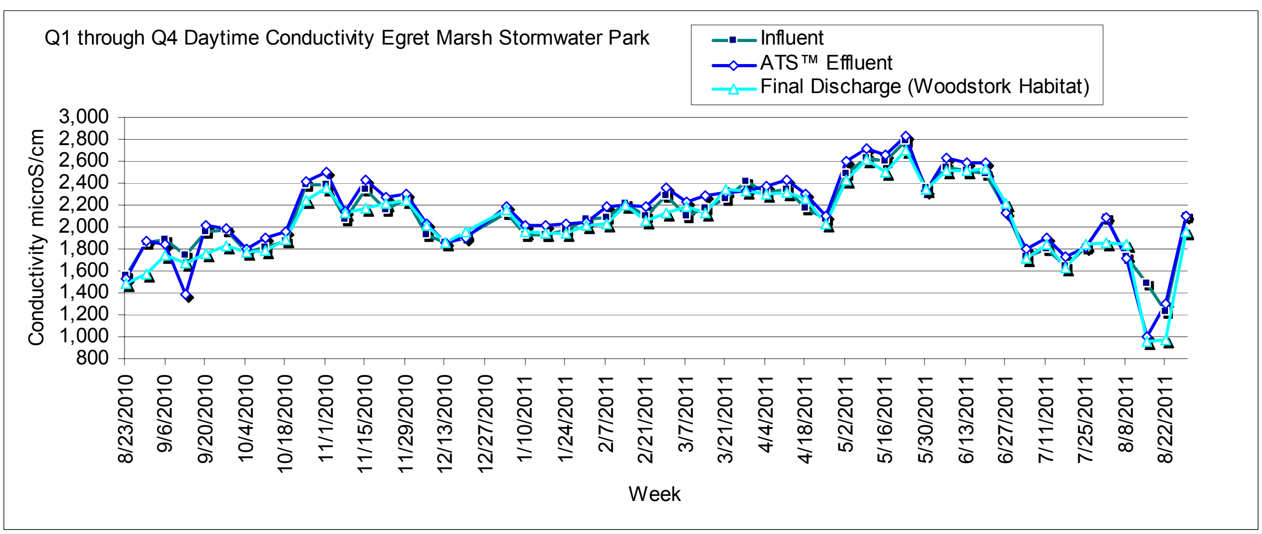


Figure 54: Q1 through Q4 Daytime Conductivity Trends Egret Marsh Stormwater Park

[42] Taken from HydroMentia (2005) "S-154 Pilot ATS^{TM}-WHS^{TM} Aquatic Plant Treatment System Final Report" for SFWMD Contract C-13933

SECTION 5: ATS™ MODEL (ATSDEM) REFINEMENT

Statistical Review of Nutrient Data

Because the level of reliability of the laboratory analyses for nutrients is about 20% Relative Percent Difference (RPD), the influent and effluent data needs to be evaluated to determine if the differences noted between influent and effluent nutrient levels are statistically indicative of removal. To do this a one tailed t-Test was completed on the difference of paired influent and effluent concentrations for TP, OP, Organic and polyphosphate P, TN, TKN, NH_3-N, NOx-N and organic N with the null hypothesis being that the paired differences between influent and effluent concentrations are less than or equal to zero. This is a one-tailed hypothesis, with the critical level set at 95%. The results are noted in Table 28. Several things are particularly noteworthy regarding this analysis.

- There is >95% confidence that the effluent TP concentration is less than the influent TP concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that a net removal occurs through both unit processes. The p-value for the ATS™ is very low (<0.001) indicating a very high level of confidence of net removal of TP through the ATS™.
- There is >95% confidence that the effluent Ortho P concentration is less than the influent Ortho P concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that a net removal occurs through both unit processes. The p-value for the ATS™ is very low (0.006) indicating a very high level of confidence of net removal of Ortho P through the ATS™.
- There is no statistical support for 95% confidence that the effluent organic/polyphosphate P concentration is less than the influent organic/polyphosphate P concentration through both the ATS™ and the pond/wetland, and consequently there is not high degree of statistical support that there is a net removal through both unit processes. The p-value for the ATS™ at 0.115 indicates a lower probability of organic/polyphosphate removal than with the pond/wetland system with a p-value of 0.059. The bidirectional movement between the organic/polyphosphate phosphorus compartment and the Ortho phosphorus compartment may account for the uncertainty related to net removal of organic/polyphosphate phosphorus.
- There is >95% confidence that the effluent TN concentration is less than the influent TN concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that a net removal occurs through both unit processes. The p-value for the ATS™ is comparatively high at 0.038 when compared to the pond/wetland system with a p-value of 0.003.
- There is >95% confidence that the effluent TKN concentration is less than the influent TKN concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that a net removal occurs through both unit processes. The p-values for the ATS™ and the pond/wetland system are similar (0.011 and 0.017 respectively) indicating a high level of confidence of net removal of TKN through both unit processes.
- There is >95% confidence that the effluent ammonia-N concentration is less than the influent ammonia-N concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that a net removal occurs through both unit processes. The p-values for the ATS™ and the pond/wetland system are similar

(0.001 and 0.0005 respectively) indicating a high level of confidence of net removal of ammonia-N through both unit processes.

- There is no statistical support for a 95% confidence that the effluent organic N concentration is less than the influent organic N concentration through both the ATS™ and the pond/wetland, and consequently there is statistical support that there may not be a net removal through either unit process. The p-value for the ATS™ at 0.255 indicates a lower probability of organic N removal than with the pond/wetland system with a p-value of 0.106. The bidirectional movement between the organic N phosphorus compartment and the ammonia and NOx nitrogen compartments may account for the uncertainty related to net removal of organic nitrogen as well as the recalcitrance of RDON.
- There is no statistical support for a 95% confidence that the effluent NOx-N concentration is less than the influent NOx-N concentration through the ATS™ (p-value = -0.2912) but there is statistical support for >95% NOx-N removal through the pond/wetland (p-value = 0.0002). The statistical indication is that there is in fact a likelihood of net NOx-N gain through the ATS™. This is attributable to the development of nitrification capabilities upon the ATS™ in response to increased ammonia-N, particularly during Q4. The pond/wetland system showed no sign of nitrification, and accordingly showed statistical evidence of net NOX-N removal.

Table 28: One tailed t-Test analysis of paired differences influent and effluent nutrient data.

Parameter/Floway Degree of Freedom = 12 Null Hypothesis: Paired differences are less than or equal to zero	**Critical value at 0.05 significance one-tailed**	**t- value**	**p-value**	**Comment**
Total P influent through ATS™	1.78	4.77	0.0001	Null Hypothesis rejected
Total P influent through pond/wetland system	1.78	2.39	0.008	Null Hypothesis rejected
Ortho P influent through ATS™	1.78	2.51	0.006	Null Hypothesis rejected
Ortho P influent through pond/wetland system	1.78	1.99	0.023	Null Hypothesis rejected
Organic/Polyphosphate P influent through ATS™	1.78	1.20	0.115	Null Hypothesis accepted
Organic/Polyphosphate P influent through pond/wetland system	1.78	1.56	0.059	Null Hypothesis accepted
Total N influent through ATS™	1.78	1.78	0.038	Null Hypothesis rejected
Total N influent through pond/wetland system	1.78	2.79	0.003	Null Hypothesis rejected
TKN influent through ATS™	1.78	2.28	0.011	Null Hypothesis rejected
TKN influent through pond/wetland system	1.78	2.11	0.017	Null Hypothesis rejected
NH_3-N influent through ATS™	1.78	2.99	0.001	Null Hypothesis rejected
NH_3-N influent through pond/wetland system	1.78	3.44	0.0005	Null Hypothesis rejected
Org-N influent through ATS™	1.78	0.66	0.255	Null Hypothesis accepted
Org-N influent through pond/wetland system	1.78	1.25	0.106	Null Hypothesis accepted
NOx-N influent through ATS™	1.78	-0.55	-0.291	Null Hypothesis accepted
NOx-N influent through pond/wetland system	1.78	4.70	0.0001	Null Hypothesis rejected

Model Review

Critical Input Parameters

The ATS™ Design Model (ATSDEM) was developed by HydroMentia to establish a means of developing initial assessments of system performance, and for sizing facilities during preliminary engineering efforts. The model can also be used during operations for establishing harvesting regimens and projecting influence of adjustments to hydraulic loading. The model is based upon the Monod[43] relationship and first order dynamics applied to a community, such as is done with other commercial biological process (e.g. activated sludge), rather than an isolated enzyme or an individual species. The Monod relationship is expressed as:

$$\mu = \mu_{max} S/(K_s + S)$$

Where μ_{max} is the maximum potential growth rate of the community and K_s is the half-rate constant for growth limited by **S**, or the value of **S** when $\mu = ½\ \mu_{max}$.

A review of how the ATSDEM model was initially developed is included as Appendix 3. To effectively apply the Monod relationship to the ATSDEM model, certain critical parameters need to be quantified. These include:

- **a.** Water Temperature
- **b.** Linear hydraulic loading rate (LHLR)
- **c.** Relationship between tissue nutrient content and nutrient water levels
- **d.** Total Phosphorus concentration
- **e.** Total Nitrogen Concentration
- **f.** Initial crop density
- **g.** Average crop density between harvests
- **h.** Harvest frequency
- **i.** Alkalinity
- **j.** pH
- **k.** Maximum Net Community Specific Growth rate--μ_{max} (1/hr)
- **l.** Half Rate Concentration (S_N) of Limiting Nutrient
- **m.** Half Rate Concentration of LHLR (S_H)
- **n.** V'ant Hoff-Arrhenius Constant (for adjusting growth rate to temperature)

For applications within most freshwater systems, phosphorus, hydraulic loading and water temperature have been used as key parameters (**S**) for estimating specific growth rate. However, in some cases nitrogen and carbon can be more influential in limiting production. Carbon limitation is not an issue at the EMSP because of the high alkalinities and near neutral pH levels within the influent. While it does appear that, at times, some nitrogen fractions, such as ammonia, could influence the rate of productivity to a certain extent, phosphorus does appear the more influential nutrient, as discussed further in the text.

[43] Monod J. (1942) *Recherches sur la Croissance ds Cultures Bacteriennes,* Herman et Cie, Paris

Temperature Adjusted Field Estimates of Specific Growth Rate

During the course of the monitoring period, specific growth rate was calculated with each harvest. This rate expresses in the case of the ATS™ a net community growth rate, and is used to project net productivity through the first order equation:

$$Z_t = Z_0 e^{\mu t} \quad \text{or } \mu = [\ln(Z_t/Z_0)]/t$$

Where **Z** is the dry biomass weight, **t** is the time interval between harvests, $\mathbf{Z_0}$ is the initial standing crop and **μ** is the net community specific growth rate (1/time)

Specific growth rates can be adjusted for temperature by using the V'ant Hoff-Arrhenius equation:

$$\mu_2 / \mu_1 = \Theta^{(T2-T1)} \quad \text{or} \quad \mu_1 = \mu_2 / \Theta^{(T2-T1)}$$

Where μ_2 is the growth rate for given **S** at an optimal growing temperature ^oC, T_2, and μ_1 is the growth rate for the same given **S** at some temperature ^oC, T_1, when $T_1 < T_2$, and Θ is an empirical constant ranging from 1.03 to 1.10.

As noted, the algal turf harvested calculations during the monitoring period balanced very well with the water quality calculations (Figures 11 and 12). Therefore the specific growth values developed from the harvest data appeared to correlate well with the nutrient levels or with removal rates. The specific growth rates were calculated assuming a constant initial standing crop (Z_0) of 10 g/m^2 which represents the residual biomass left after the previous harvest. Typically Θ as applied to ATS™ has been found to be about 1.03. Using these two values for Z_0 and Θ and T_2 = 30° C, the values for **μ** can be adjusted as shown in Table 29.

Assessment of Nutrient Influence on Growth Rate

There are several methods which have been developed to calculate the Monod parameters of maximum specific growth rate (μ_{max}) and half rate concentration K_S. The one which was used in developing the ATSDEM model is the Hanes[44] method as described by Brezonik[45]. The Hanes equation as developed from the Monod relationship is:

$$[S]/\mu = K_S/(\mu_{max}) + (1/(\mu_{max}) [S]$$

When plotted, the slope is $1/\mu_{max}$, and y-intercept is K_S/μ_{max}. A Hanes plot was conducted for **S** using all of the phosphorus and nitrogen fractions as **S.** A linear regression analysis was completed for each of the nutrient fractions, as shown in Table 30.

The plots of total and Ortho phosphorus, which reveal the highest correlation (r^2 of 0.91 and 0.84 respectively), are shown as Figure 55. Note that ammonia nitrogen also showed a

[44] Hanes, C.S. (1942) *Biochem. J.* , 26, 1406
[45] Brezonik, P.L. (1993) Chemical Kinetics and Process Dynamics in Aquatic Systems Lewis Publishers, Boca Raton, Fl pp 421-427 ISBN 0-87371-431-8

comparatively high regression coefficient of 0.62. It is suggested the values associated with TP be used in the modeling, as these are based upon composite sampling, not grab samples as with Ortho phosphorus, and may be considered more representative of actual field trends and conditions. The two plots are similar in terms of μ_{max} and half rate concentration K_S. The value for μ_{max} at 0.0085/hr and K_S of 0.005 mg/L Total Phosphorus is comparatively lower than values typical applied to ATS™ units. This may be related to the long period of low levels of available phosphorus during the impoundment period within Lateral D during the drought periods of much of Q1 and Q4 and all of Q2 and Q3, and possibly some influence from low ammonia nitrogen levels during this same period.

The relationship might be better illustrated if a larger number of higher concentrations (>0.150 mg/L TP) had been observed during the monitoring period. Nonetheless for purposes of modeling the trends associated with this period, the values appear suitable, and probably will result in the development of sufficiently conservative projections for future operational periods.

Table 29: Temperature adjusted field net community specific growth rates Egret Marsh Stormwater Park.

Month $\Theta = 1.03$ $T_2 = 30°$ C $Z_0 = 10$ g/m^2	Calculated Field Net Community Growth Rate 1/hr	T adjusted Field Net Community Growth Rate 1/hr	Water T °C
9/13/2010	0.0102	0.0103	29.60
10/11/2010	0.0097	0.0105	27.52
11/8/2010	0.0051	0.0063	22.88
12/6/2010	0.0033	0.0051	15.59
1/31/2011	0.0020	0.0031	16.09
2/28/2011	0.0067	0.0088	21.01
3/28/2011	0.0078	0.0098	22.27
4/25/2011	0.0086	0.0099	25.26
5/23/2011	0.0096	0.0106	26.92
6/20/2011	0.0085	0.0088	28.74
7/18/2011	0.0073	0.0076	28.75
8/29/2011	0.0125	0.0124	30.10

Assessment of Nutrient Concentrations Influence on Tissue Nutrient Levels

The influence of nutrient concentrations upon nutrient tissue levels was discussed previously in Section 4—see Figure 10. The two equations developed for use in the model were:

$$P_{\%dw} = 0.010734[TP] + 0.00327$$
$$N_{\%dw} = 0.03605[TP] + 0.01602$$

Where $P_{\%dw}$ is the dry weight percentage of phosphorus in the harvested tissue
$N_{\%dw}$ is the dry weight percentage of nitrogen in the harvested tissue

[TP] is total phosphorus concentration in water as mg/L

Linear Hydraulic Loading Rate Influence on Specific Growth Rate

In the development of ATSDEM (see Appendix 3), the hydraulic loading to the ATS™ across the width measured as gpm/ft, was shown to influent productivity, with the **K_{LHLR}** typically about 9.0 gpm/lf. This value will be adjusted during model calibration to optimize model precision and used at this same value during verification.

Table 30: Summary of Hanes' plots for various nutrient fractions Egret Marsh Stormwater Park

Nutrient Fraction $\Theta = 1.03$ $T_2 = 30°$ C $Z_0 = 10$ g/m^2	"a" Slope	"b" y-intercept	r^2 Regression Coefficient	μ_{max} 1/hr	K_N mg/L
Total Phosphorus	117.37	0.58	0.84	0.0085	0.005
Ortho Phosphorus	104.93	0.61	0.91	0.0095	0.006
Organic/Poly Phosphorus	68.97	2.44	0.27	0.0145	0.035
Total Nitrogen	79.00	42.90	0.23	0.0127	0.54
TKN	67.10	50.20	0.20	0.0149	0.75
Ammonia Nitrogen	124.68	0.90	0.62	0.0080	0.01
Organic Nitrogen	59.42	50.09	0.17	0.0168	0.84
Nitrate + Nitrite Nitrogen	153.07	-0.002	0.50	0.0065	0.00

Average Crop Density

The average crop density over the monitoring period was presented in Section 4, Table 5. The monthly values shown in this table will be applied to the calibration and verification model runs. As noted previously, the initial crop density, that is the density immediately following harvest, is set at 10 dry g/m^2.

Harvesting Frequency

For modeling purposes the harvest frequency is established based upon the time required to achieve the average crop density. This is explained in the tutorial within the ATSDEM spreadsheet.

Model Calibration and Verification

The ATSDEM model is calibrated by applying the model to the first two quarters (6 months) of the monitoring period. The results as noted in Table 31, indicate that the model as developed is effective at projecting effluent total phosphorus and nitrogen levels.
The calibrated ATSDEM was applied to the final months of the monitoring period in an effort

to verify the model. The results as noted in Table 32, indicate that the model as developed can effectively be applied to varying conditions associated with the Lateral D watershed. Scattergrams for both phosphorus and nitrogen showing actual versus projections for both phosphorus and nitrogen over the monitoring period are presented in Figure 56. A typical ATSDEM summary sheet is shown as Figure 57.

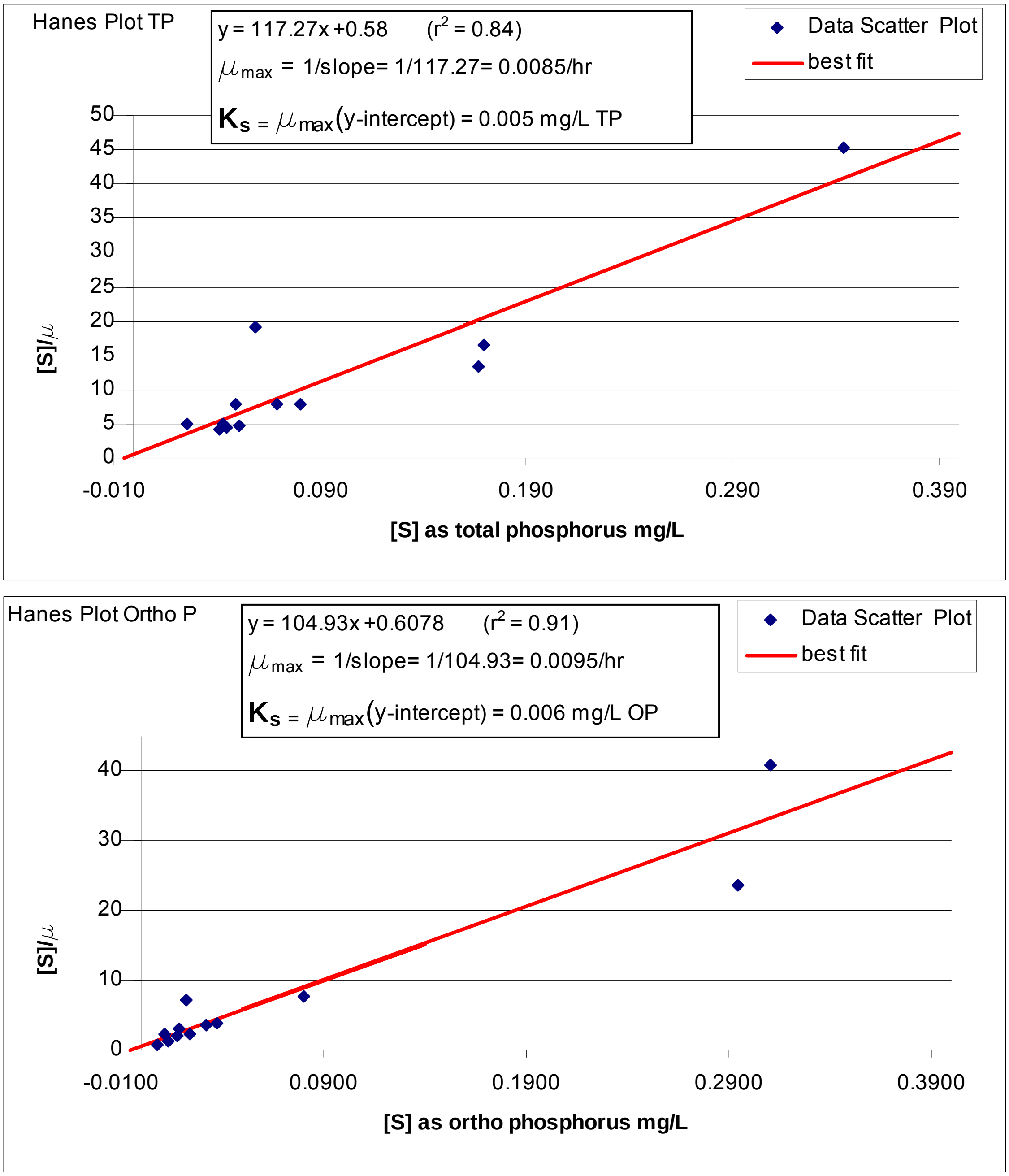


Figure 55: Hanes' Plots Total and Ortho Phosphorus Egret Marsh Stormwater Park

Table 31: ATSDEM Calibration Run Months 1 through 6 Egret Marsh Stormwater Park

K_{lhlr} = 9 gpm/lf
Kp = 0.005 mg/L
µmax = 0.0085/hr
Topt = 30 C
Zo = 10 g/sm
Θ = 1.03

Month Ending	Flow MGD	Water T °C	Influent TP mg/L	Influent TN mg/L	Zave g/sm	Effluent TP mg/L	Projected Effluent TP mg/L	TP Difference mg/L	Effluent TN mg/L	Projected Effluent TN mg/L	TN Difference mg/L
9/13/10	9.88	29.6	0.170	1.15	101	0.121	0.135	-0.014	0.94	1.00	-0.06
10/11/10	9.75	27.5	0.081	0.89	101	0.052	0.055	-0.003	0.59	0.77	-0.18
11/8/10	9.88	22.9	0.049	0.54	104	0.027	0.027	0.000	0.63	0.79	-0.16
12/6/10	9.68	20.4	0.026	0.83	68	0.033	0.016	0.017	0.89	0.78	0.11
1/3/11	9.89	15.6	0.041	0.80	48	0.038	0.035	0.003	0.60	0.57	0.03
1/31/11	9.74	16.7	0.059	0.76	48	0.048	0.050	-0.002	0.69	0.72	-0.03

	TP		TN
Mean Difference	**0.000**	**Mean Difference**	**-0.049**
Standard Error	**0.010**	**Standard Error**	**0.109**
two tail t-test Critical Value*	**2.57**	**two tail t-test Critical Value***	**2.57**
sensitivity	**0.05**	**sensitivity**	**0.05**
t-value	**-0.05**	**t-value**	**-0.62**
Accept null hypothesis		**Accept null hypothesis**	

* Null hypothesis that the difference between actual and projected is equivalent to zero at 95% confidence level

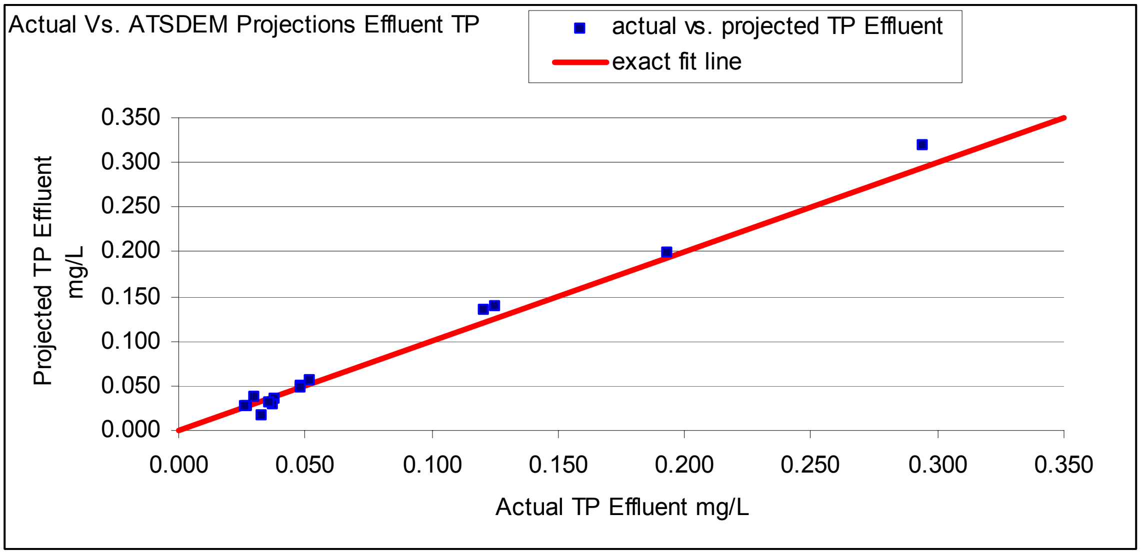
Table 32: ATSDEM Verification Run Months 7 through 14 Egret Marsh Stormwater Park

K_{lhlr} = 9 gpm/lf
Kp = 0.005 mg/L
µmax = 0.0085/hr
Topt = 30 C
Zo = 10 g/sm
Θ = 1.03

Month Ending	Flow MGD	Water T °C	Influent TP mg/L	Influent TN mg/L	Zave g/sm	Effluent TP mg/L	*Projected Effluent TP mg/L*	TP Difference mg/L	Effluent TN mg/L	*Projected Effluent TN mg/L*	TN Difference mg/L
2/28/11	9.74	21.0	0.043	0.61	29	0.030	***0.038***	-0.008	0.55	***0.58***	-0.03
3/28/11	9.90	22.3	0.042	0.78	87	0.026	***0.026***	0.000	0.67	***0.71***	-0.04
4/25/11	9.62	25.3	0.045	0.55	78	0.037	***0.030***	0.007	0.61	***0.48***	0.13
5/23/11	9.69	26.9	0.051	0.70	98	0.036	***0.031***	0.005	0.59	***0.60***	-0.01
6/20/11	9.96	28.7	0.069	0.80	82	0.048	***0.048***	0.000	0.90	***0.70***	0.20
7/18/11	10.00	28.8	0.344	1.56	53	0.294	***0.318***	-0.024	1.41	***1.45***	-0.04
8/22/11	10.04	29.9	0.167	1.70	94	0.125	***0.139***	-0.014	1.63	***1.58***	0.05
8/29/11	10.97	30.9	0.234	1.56	94	0.193	***0.199***	-0.006	1.68	***1.41***	0.27

Mean Difference	**-0.005**	**Mean Difference**	**0.065**
Standard Error	**0.010**	**Standard Error**	**0.120**
two tail t-test		**two tail t-test**	
Critical Value*	**2.57**	**Critical Value***	**2.57**
sensitivity	**0.05**	**sensitivity**	**0.05**
t-value	**-1.35**	**t-value**	**1.83**
Accept null hypothesis		**Accept null hypothesis**	

* Null hypothesis that the difference between actual and projected is equivalent to zero at 95% confidence level



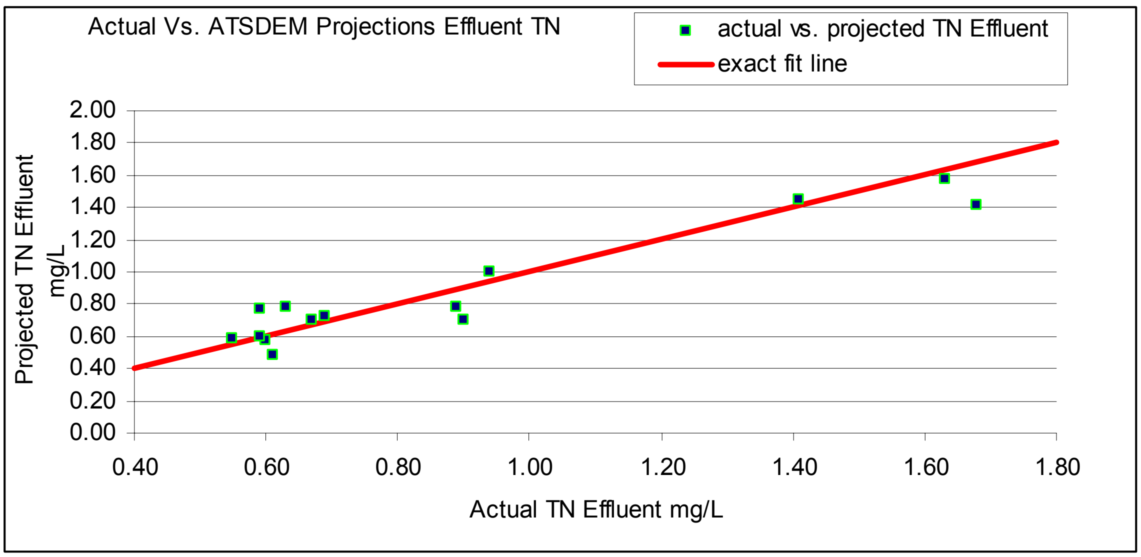


Figure 56: ATSDEM Projection Scattergrams for Effluent Nitrogen and Phosphorus Egret Marsh Stormwater Park

Egret Marsh Verification
Month 8-- 3/28/11

Panel A Velocity Conditions

Floway slope (s)	Manning n	Manning Factor (1)	Manning Factor (2) Match	LHLR gpm/lf	LHLR cfs/lf	LHLR liters/sec-lf	Average flow depth (d) ft	Velocity fps	Flow length interval ft
0.005	0.02	0.00838	0.00838	19.81	0.044	1.268	0.06	0.74	0.74

Panel B Process Conditions

Water T °C	Optimal T °C	Θ	K_{sp} as ppb TP	K_{sh} as LHLR gpm/ft	μ_{max} 1/hr	S_o ppb Total P	Harvest Cycle days	Z_{ave} dry-g/m^2	Z_0 dry-g/m^2	S^*_p Total Phosphorus ppb	N_o mg/l Total N	N* Total Phosphorus mg/l
22.3	30.0	1.03	5	9.0	0.0085	42	35	91.06	10.00	10	0.78	0.30

Panel C Performance

Control Time Seconds	Control Volume liter	Final Total P S_f ppb	Total Flow Time seconds	Total P percent removal	Floway Length ft	Areal Loading Rate TP g/m2-yr	Areal Loading Rate TP lb/acre-year	Areal Removal Rate TP g/m2-yr	Areal Removal Rate TP lb/acre-yr	Average Production dry-g/m^2-day	Area per time sequence m^2	Final Total N N_f mg/l	Areal Loading Rate TN g/m2-yr	Areal Loading Rate TN lb/acre-year	Areal Removal Rate TN g/m2-yr	Areal Removal Rate TN lb/acre-yr
1	1.268	26	774	37.36%	575	31	276	12	103	8.84	0.069	0.71	575	5,131	55	490

Panel D System Design

Total Flow mgd	Floway Width ft	Floway Area acres	Total P removed ton/period	Moisture % wet harvest	Moisture % compost	Period Wet Harvest tons	Period Dry Harvest tons	Period Compost Production wet tons	Performance Period days	μ_{ave} 1/hr	Total N removed ton/period	% N Removal
9.9	347	4.58	0.02	15%	40%	37	6	7	31	0.0040	0.10	9.54%

Panel E pH Dynamics

Influent pH	Influent Alkalinity mg/l as $CaCO_3$	Influent Available Carbon mg/l	Effluent pH	Algae Tissue Carbon % dw
7.98	191	50.93	8.74	25%

Figure 57: Typical ATSDEM Summary Sheet (Month 8) Egret Marsh Stormwater Park

Revised Projections from Historical Data

In July, 2005, prior to the construction and operation of the Egret Marsh ATS™ Unit, ATSDEM projections were made regarding nitrogen and phosphorus reductions based upon historical influent concentrations associated with the Lateral D Canal. As noted, these influent concentrations were considerably higher than those encountered during the 2010-2011 monitoring period. The critical parameters applied to the 2005 ATSDEM projections also varied widely from those developed from the 2010-2011 monitoring period data. In an effort to more precisely project nutrient reductions in the future, the adjusted critical parameters were used in revising ATSDEM projections for historical conditions.

The revised projections are shown in comparison with the 2005 projections in Table 33. Load reduction projections as revised—1,032 lb TP and 4.409 lb TN-- amount to just about 1/3 of the 2005 projections. While these revisions are offered as a more defendable series of projections, it is quite possible that during years when there is no significant impounding of waters within Lateral D and influent nutrient levels are increased, removals may exceed these projections. Should this be observed, another review of the ATSDEM parameters would be suggested.

Not included in the load reduction projections are the impact of the pond/wetland system. The 14.4 acres of the pond/wetland system provided an average TP-ARR of 5.55 g/m^2-yr and TN-ARR 18.86 g/m^2-yr, which is considerably higher than what has been historically recorded for wetland type systems, such as the Stormwater Treatment Areas (STA's) in South Florida.[46] This higher than expected performance is likely related to the removal of labile nutrients associated with the ATS™ effluent through grazing, predation and settling. It is not unreasonable to expect the pond/wetland will consistently provide removals similar to that noted during the 2010-2011 monitoring period—738 lb TP and 2,508 lb TN. Considering these additional load reductions, it is not unreasonable to expect the EMSP to remove perhaps as much as 2,000 lb/yr TP and 7,000 lb/yr TN. Over 50% of this would be expected to be recovered through harvest of the ATS™.

[46] In the 2007 South Florida Environmental Report prepared by the South Florida Water Management District (Pietro, K; R. Bearzatti; M. Chimney; G. Germain; N. Iricann; T. Piccone) reported an average TP ARR for all of their STA's at 1.32 gm/m^2-yr

Table 33: ATSDEM Revised 2010-2011 Historical Nutrient Load Reductions Egret Marsh Stormwater Park

K_{lhlr} = 9 gpm/lf
K_p = 0.005 mg/L
μmax = 0.0085/hr
Topt = 30 C
Zo = 10 g/sm
Θ = 1.03

Month	Flow MGD	Water T °C	Historical Influent TP mg/L	2005 Projected Effluent TP mg/L	2005 Projected TP Removal lbs	2010-11 Projections Effluent TP	2010-11 Projected TP Removal lbs	Historical Influent TN mg/L	2005 Projected Effluent TN mg/L	2005 Projected TN Removal lbs	2010-11 Projections Effluent TN	2010-11 Projected TN Removal lbs
January	10.00	19.1	0.110	0.075	90	0.089	54	1.04	0.86	465	0.95	245
February	10.00	19.9	0.140	0.082	135	0.116	55	1.02	0.72	776	0.91	246
March	10.00	22.6	0.140	0.071	178	0.115	65	1.24	0.88	931	1.13	290
April	10.00	24.3	0.140	0.057	208	0.114	64	0.94	0.70	620	0.83	286
May	10.00	27.6	0.180	0.072	279	0.145	90	1.04	0.70	879	0.89	391
June	10.00	28.4	0.310	0.134	440	0.264	115	1.64	0.81	2,146	1.45	476
July	10.00	29.2	0.310	0.137	447	0.265	117	1.59	0.77	2,120	1.40	487
August	10.00	29.1	0.330	0.158	445	0.283	120	1.48	0.70	2,017	1.29	497
September	10.00	28.0	0.350	0.175	438	0.303	122	1.62	0.82	2,068	1.43	499
October	10.00	25.8	0.260	0.145	297	0.222	97	1.49	0.94	1,422	1.33	411
November	10.00	23.5	0.190	0.096	235	0.160	77	0.98	0.70	724	0.85	332
December	10.00	18.9	0.120	0.084	93	0.099	55	0.90	0.71	491	0.80	248
Average	10.00	24.7	0.215	0.107		0.181		1.25	0.78		1.10	
Total					**3,287**		***1,032***			**14,659**		***4,409***

SECTION 6. DISCUSSIONS AND RECOMMENDATIONS

Project Summary

The Egret Marsh Stormwater Park (EMSP) was designed with the intent of 1) providing effective, long term, sustainable nutrient removal and recovery from a constant flow (circa 10 MGD) of enriched water from the Main Canal Network, and 2) establishing a restored habitat amenable to the development and sustenance of diverse ecosystems, which would serve as feeding, roosting and breeding habitat for native fish and wildlife, including threatened species such as the wood stork. Strategically, the stormwater treatment train associated with EMSP was developed primarily to facilitate both removal and recovery of soluble nutrients, and accordingly, to work in concert with the County's downstream Main Canal screening facility which was designed to remove particulate nutrients associated with larger solids, such as floating and submerged aquatic vegetation, and miscellaneous debris. It is intended that in combination, these two facilities will facilitate the protection and restoration of the receiving waters of the Indian River Lagoon, and consequently will significantly contribute to the County's long range plan to comply with existing and anticipated pollutant load removal requirements, such as those attendant with TMDL allocations.

The stormwater treatment train associated with the EMSP is a two stage system, which includes a 4.6 acre Algal Turf Scrubber®, or ATS™, as the first treatment unit, followed by 14.4 acres of a pond/wetland system. About 5 acres of the pond/wetland system is a designed wetland, which was developed as a habitat for the threatened species, the wood stork (see Illustration 8). This wood stork habitat serves as the final unit prior to release of effluent into the Lateral C canal.

This two stage system allows the ATS™, with its greater removal efficiencies, to initially access incoming nutrients and incorporate them into a biomass known as algal turf. These nutrients are then recovered through periodic harvesting of the algal turf, and conversion into usable, and potentially marketable products. During the monitoring period the bulk of the harvested algal turf (148,765 lbs of dry solids) was blended with mulch provided by the County, and processed through windrow compost, with an estimated 100-200 tons of compost being generated. This compost is being used by the County for their landscaping needs, and will help reduce the application of inorganic fertilizers through the reuse of "lost" nutrients, while also sequestering nearly twenty tons of carbon. The value of this compost is currently being investigated by USDA. Early findings provide indication this product could be developed as a valuable potting soil for certain foliage plants.

In addition to compost production, a few thousand pounds of dry harvested algal turf was used to generate a test sample of over 17 liters of fuel oil through a contract between VEN Consulting Group of Melbourne, and StatOil, a Norwegian energy company. In addition, about 100 dry pounds of harvested algal turf was delivered to a major paper company to support investigations into the feasibility of producing algae based paper products. With continued system operation, interest has grown in the development of products from the recovered biomass, providing opportunities for County partnerships with corporations, academic and governmental institutions, and others interested in full scale development of algae-based products.

As noted, following the ATS™ process, treated effluent is delivered to a 14.4 acre pond/wetland system. This pond/wetland system is intended to further condition the treated water by modulating pH levels and temperature, while providing some additional nutrient reduction and transformation. In addition, the pond system was designed to provide habitat amenable to native fish and wildlife, through the establishment of littoral zones along the shoreline and the shallow edges of the ponds; the maintenance of high dissolved oxygen levels associated with the incoming ATS™ effluent ; the use of islands to encourage roosting and breeding of wading birds; the development of shallow marsh areas to encourage feeding by the threatened wood stork; and the ability to adjust water levels in emulation of historical seasonal patterns.

Over the monitoring period breeding activity of the black bellied whistling duck and the black-necked stilt was observed within the borders of EMSP. In addition, roosting and possibly breeding activity was noted on the created islands by cattle egret and tri-colored heron. In the spring a pair of sandhill cranes set up a nest within the wetland area, and hatched one chick (see Illustration 15). During the early summer a larger number of black-necked stilts and killdeer established nests in and around the ATS™ unit, and throughout the EMSP site.

Numerous other bird species use the ATS™ and the ponds/wood stork habitat as a feeding platform, including wood stork (see Illustration 8), osprey, bald eagle, little green heron, lesser sandpipers, roseate spoonbills (see Illustration 16), white ibis, glossy Ibis, American egret, snowy egret, great blue heron, little green heron, swifts, yellow-legs, cormorant, anhinga, mottled duck, moorhens, kingfishers and others. The ponds also supported an abundance of native fish, including a healthy population of largemouth bass and several species of “panfish” (see Illustration 17), as well as native minnows, and a group of “landlocked” tarpon. A number of native mammals, reptiles and amphibians were also observed, including American alligator, southern soft-shelled turtle, leopard frog, red bellied slider, banded water snake, otter and raccoon.

The general development and implementation philosophy applied to the EMSP was somewhat of a deviation from what has been the typical approach to stormwater treatment, in which runoff is captured on an intermittent basis and treated through single treatment train facilities as low rate, passive, extensive systems such as created wetlands and detention ponds, which typically exclude reliable nutrient accountability or recovery, and often are only presumed to provide treatment. Unlike these passive approaches, the ATS™ operation facilitates nutrient accountability as well as nutrient recovery and reuse through the harvesting of algal turf, and supportable documentation of system performance. The ATS™ therefore is a sustainable technology which provides the advantage of high rates of nutrient removal attendant with long term reliability[47].

With the ATS™ assuming the major burden of nutrient reduction, the pond/wetland system then is relieved of the burden of handling heavy nutrient loads, allowing it to function less as a nutrient storage facility and more as a healthy lacustrine/freshwater marsh system, thereby

[47] During the monitoring period for example, the ATS™ provided an average total phosphorus areal removal rate of about 17.5 g/m^2-yr, while extensive, passive systems such as Stormwater Treatment Areas (STA’s) used by the South Florida Water Management District (SFWMD), as previously noted per footnote 6, typically provide phosphorus areal removal rates around 1.0 to 1.5 g/m^2-day.

allowing avoidance of excessive phytoplankton blooms, severe dissolved oxygen sags within the pond bodies, or rapid sediment accumulation of nutrients and organic detritus. To summarize, the advantages of this philosophy include 1) valid documentation of sustainable, high rates of nutrient removal 2) substantial accountability of nutrient removal through recovery and reuse of these nutrients; 3) conversion of nutrients and captured carbon into viable by-products; 4) enhanced environmental benefits associated with high quality water delivered to a receiving pond/wetland system; 5) extension of the effective life of the receiving ponds and marsh by the initial elimination of heavy nutrient loads by the ATS™; and 6) coordinating the benefits of soluble nutrient control provided by EMSP with particulate removal through a downstream (Main Canal), off site screening facility .

Review and Critique of Design, Operational and Maintenance Strategy

Pump Station

The pump station was designed as a single submersible pump station located at the Lateral D canal about 300 feet west of the EMSP site. Water was delivered directly to the ATS™ headworks surger box at a rate of about 10 MGD. The inlet of the station was protected by a Duperon Flex rake, which removed particles of less than 2". This rake functioned automatically, and was effective in protecting the pump from clogging from oversized solids. This primary station was backed up by a secondary station located on site. This secondary station was used to recycle water from the pond/wetland system through the ATS™ in situations in which the primary pumped failed or was intentionally shut down for maintenance or during periods of herbicide spraying in the Lateral D canal.[48] The two stations communicated through a telemetry system.

During the monitoring period the pump station generally performed well. There were some initial issues with the pump control systems. Further into the monitoring period, biological fouling, primarily by freshwater Bryozoans, created some problems with the pump cooling system. These had to be cleaned periodically. Also the Asian Clam (*Corbicula sp.*) created some problems as they accumulated within the wet well, including impeding the full closure of the check valve (along with the Bryozoans). Power outages occurred on several occasions, forcing visitation to manually restart the primary pumps.

For future pump stations which service systems such as the EMSP, it is suggested that dual systems be implemented, and that maintenance programs be established to check for biofouling. The wet well design may need to be refined to better accommodate removal of solids, Control and alarm/annunciation systems may also need to undergo design refinements.

When the total dynamic head is under 20 feet, and the water source is contiguous to the facility, and readily accessed, more efficient low head, high flow pumps such as

[48] Glyphosate and other herbicides which are commonly used to control aquatic vegetation in the ponds are toxic to algae, and during spraying events the primary station was shut down to prevent loss of the Algal Turf. It was previously found that only a 24 hour wait time was needed for the natural degradation of these herbicides.

Illustration 15: Nesting pair of Sandhill Cranes with chick in Wood Stork Habitat Wetlands - Egret Marsh Stormwater Park

Illustration 16: Pair of Sandhill Cranes and Roseate Spoonbills on the ATS™ Floway - Egret Marsh Stormwater Park

Archimedes Pumps, might be considered as a way of reducing power costs. Also variable speed pumps may be helpful in some situations. .

Illustration 17: Typical Healthy Native “Panfish” from Pond/Wetland System-Egret Marsh Stormwater Park

ATS™

Surger Box, Influent Flow metering, Distribution Box

The influent receiving unit, of cast-in-place concrete construction, located at the headworks of the ATS™ (see Illustration 9a) includes a receiving box, an 8 ft rectangular weir, a surge box, an aluminum surger and a distribution box. Access is via aluminum stairs and grating, with aluminum handrails. A bubbler type level meter is used to measure the height over the 8ft weir, with instantaneous and totalized flow being recorded.

This combined receiving unit performed well during the course of the monitoring period. Initially the pressurized flow caused some splash over at the receiving box. This was corrected by placing energy dissipaters within the flow path. It was also noted that there was some level fluctuation in the approach channel to the weir. This could be corrected by increasing the length of the approach channel. It is suggested that when budget allows, a Parshall Flume would be a more reliable flow measurement device.

The aluminum surger functioned as intended and after being adjusted to provide the desired surge cycle, did not require any maintenance during the monitoring period. The distribution box also functioned as intended without any significant maintenance. Solid did accumulated within the surger box, and were removed via vacuum truck on at least two occasions. Much of this sediment was composed of the Asian clam shells.

Flow Distribution System

The flow distribution system includes two identical manifolds, one servicing the eastern half of the Floway and the other the western half. Flow to these manifolds emanates from the Distribution Box, which receives flow through the Surger. The Surger is an automatic siphon which facilitates pulsing of flows to the Floway, as an emulation to oscillatory waves. Such wave action has been shown to stimulate algal production, probably through boundary layer disruption and the consistent replacement of nutrients.

The flow distribution manifold is of HDPE water tight gravity pipe, which is telescoped in size from 42” at the distribution box to 8 “at the distal terminus. The telescoping assures velocities are high enough through most of the pipe to ensure solids are maintained in suspension, and do not settle in the manifold. Vertical laterals (see Illustration 18) are located about every four feet, and range in diameter from 4” to 12”. Flow from the laterals is controlled by a low pressure PVC knife gate valves.

Illustration 18: ATS™ Flow Distribution Laterals Egret Marsh Stormwater Park

The Flow Distribution System functioned as expected and provided adequate flow control capabilities over the monitoring period. Several operational and maintenance issues however were noted, as listed below:

- The proliferation of Asian clams and bryozoans resulted in their accumulating at the distal reaches of the distribution manifold, where velocities slowed to below 2 fps. This required the system be flushed with a greater frequency than anticipated.
- When the manifold was flushed there was no mechanism to collect the clams, so many remained on the floway, interfering with algal turf development.
- The knife gate valves accumulated algal strands, and had to be cleaned fairly frequently. In addition, accumulated sand and clam shells collected around the o-ring associated with the valves, which caused the o-rings to wear over time, meaning the seal when the valves were closed were not totally water-tight.
- The actuator stems of the knife gate valves after time often lost the clip holding the horizontal handle, making it difficult to open and close the valve.
- Over time, sand associated with the influent flow began to accumulate on the floway.
- The hydraulic drop from the knife gate invert to the floway surface was about 12", which created some stress on the floway liner.

Design and operational adjustments suggested for future projects related to the distribution system are as listed below

- Consider a distribution manifold as an open channel rather than a telescoping buried pipe system. The channel would include a cleanout sump which would allow easier removal of accumulated solids.
- Reduce the discharge distance from distribution system to floway surface to 0-2 inches.
- Consider weir mechanisms rather than knife gate valves for flow distribution control.
- Retain a supply of clips for the knife gate actuator handles.
- Include a sand and fine particle removal system prior to flows entering the headworks box and flow distribution systems.
- Establish a more aggressive clean-out schedule for the entire headworks unit, including the flow distribution system.

Floway

The ATS™ Floway it 347 feet wide and 575 feet long, with an area of 4.58 acres. The Floway is sloped at 0.5% or 2.875 feet elevation change from headworks to the effluent flume. The Floway is constructed of 40 mil HDPE geomembrane, fusion welded as appropriate at each panel, and extrusion welded at the headworks and effluent flume to an HDPE imbed strip. The geomembrane is placed upon a flat compacted soil subbase, the top 6" of which are clean medium sand. The side and effluent end slopes of the Floway are also HDPE and are set at 3:1 to an elevation which ensures rainfall from a 100 year storm is sufficiently contained within the Floway footprint.

On top of the geomembrane is a woven grid material of polypropylene. This grid is attached to the headworks with aluminum battens and at the sides the grid is sewed into HDPE strips which are extrusion welded to the toe of the Floway. The grid is not attached to the geomembrane at the effluent end of the Floway.

During the course of the monitoring period the Floway generally performed hydraulically as expected, and the grid material effectively supported algal turf development. However several challenges presented themselves, as summarized in the following bullet points.

- The Floway sub-base was not properly graded during construction, which left high zones, predominantly in the center and the west side of the Floway. These high spots did remain moist, but generally did not receive substantial rates of flow. This resulted in higher flows in other parts of the Floway. Note in Illustration 19 is a December 2010 Google Earth View of the EMSP. The high areas are clearly shown, and are marked in hatched red on the Illustration. These areas amount to about 16% of the total Floway Area.
- Because the Floway is built over an old C&D landfill, generated gases developed at a rate in certain places such that they did not dissipate effectively through the final sand sub-base. Consequently, these gases caused areas of the geomembrane to form “bubbles”, particularly in the high zones. PVC vents were installed which resolved this problem effectively, but these vents became hindrances during harvest.
- The grid connections on the sides were easily snagged by the harvesting tractor scraper blade, resulting in rips to the grid. In other parts of the Floway the grid also was damaged during the course of the monitoring period.
- The larvae of the Asian clam which are only 1mm in size, would settle on the Floway between the grid and the geomembrane, resulting in a substantial clam population under the grid, which were largely inaccessible to harvest. The shells have the potential of damaging the geomembrane, and the expanding population can experience die-offs which can impact nutrient levels within the water column.
- In addition to the clam population, sediments from the distribution system accumulated on the geomembrane near the headworks. This solicited the establishment of certain submerged aquatic vegetation, such as Southern Naiad, and to a lesser degree, Hydrilla. These vascular plants are generally not as effective as periphytic algae in nutrient removal, so their presence can impose upon system effectiveness.

Considering these issues, several design and operational adjustments should be seriously reviewed for future systems. These include:

- A more formidable Floway construction strategy, such as the use of fibermesh concrete. This would not only provide durability regarding maintenance of grading consistency, but also will permit grades to be more precisely set during construction, thereby avoiding high zones and excessive flow diversion.
- Review the feasibility of eliminating the grid layer, thereby relying upon the concrete surface to directly support algal turf development and maintenance. Saw-cutting the surface may help to facilitate algal attachment. Elimination of the grid will allow easier removal of accumulated sediments and bio-fouling.
- If HDPE with grid is found to be a lower cost approach than concrete, and budgetary restraints do not allow the additional expenditure, then the Floway could be

segmented into discreet channels of 30-40ft width, separated by concrete curbs. The individual channels would facilitate easier and more precise geomembrane placement, and would provide a mechanical connection of the grid material which would facilitate removal, repair and replacement, and less interference during harvesting.

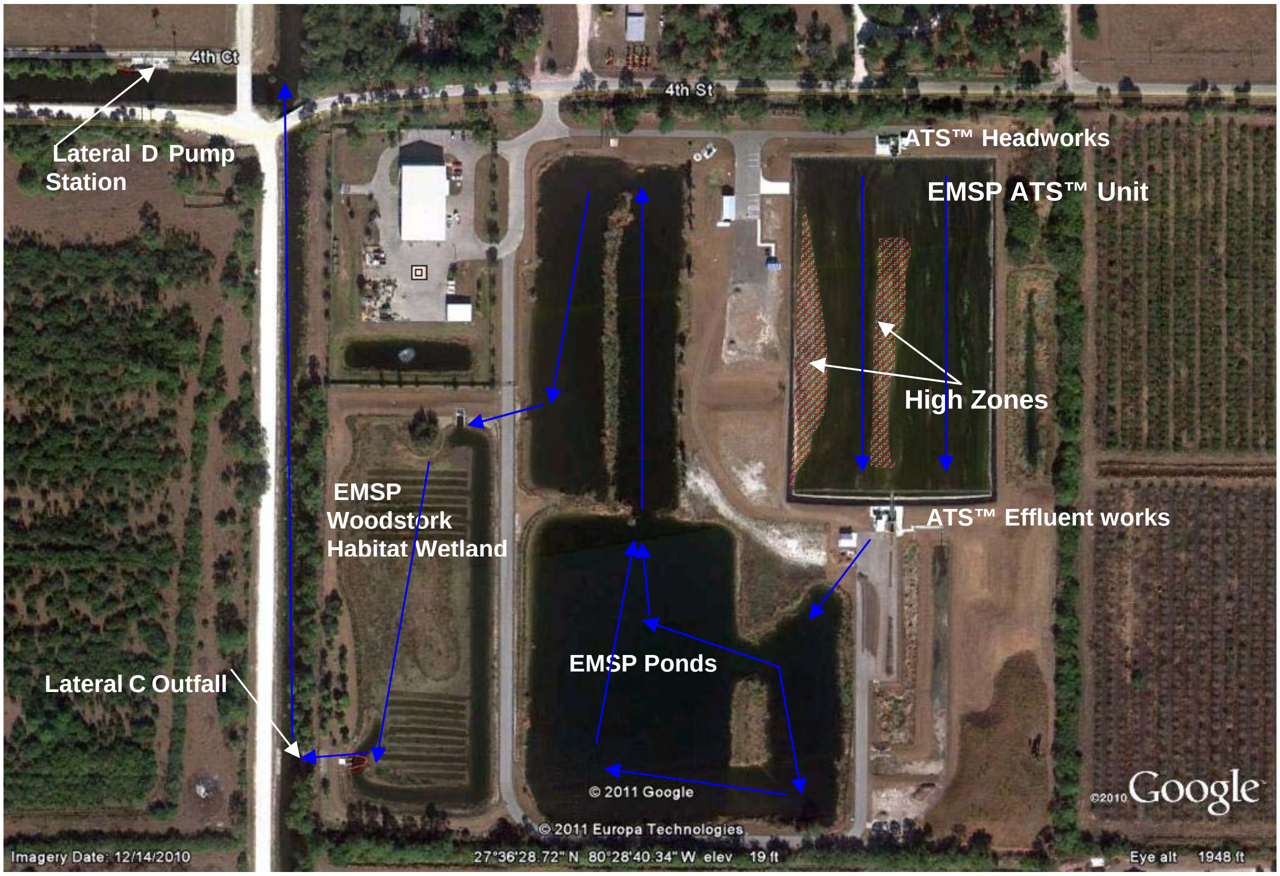


Illustration 19: Egret Marsh Stormwater Park Dec 2010 with Delineated ATS™ High Zones—General Flow Lines in blue.

- More aggressive gas relief and venting systems need to be included as part of system design, particularly when the system is constructed over closed landfills.
- Scraper mechanisms used on the harvest tractors need to be capable of an expanded range of articulation, which would allow the mechanism to adjust to irregularities in the harvested surface.
- As noted, mechanisms which facilitate reduction of fine solids (which could include larvae of the Asian Clam) prior to distribution of influent water to the Floway, would help reduce sediment accumulations on the Floway.
- Based upon the first year's experience, it is suggested that at least once annually, the Floway be taken out of service, harvested and cleaned. This would best be done in the winter (dry) period, when incoming nutrients are minimal, and rainfall less frequent.

Algal Turf Harvesting, Processing and Flow Diversion, and Cost Effectiveness Review

The ATS™ system was designed to function as two independent halves, with an effluent harvest channel on the east side and the west side, each delivering flow and sloughed/ harvested material to two hydraulically isolated center effluent channels. During normal operation, these flows confluence at a common rake box, where flows pass through a Duperon Automatic Flexrake, with ¼" bar screen. The screened flow then is directed to a common approach channel and an 8 foot rectangular weir, where flow is measured before being released to the pond/wetland system.

During harvest four slide gates are used to isolate flows from each side during harvest. The non-harvested flow is isolated by one of these gates from the harvested flow. The non-harvested flow is directed over a diversion weir, and eventually to the approach channel and rectangular weir, and the pond/wetland system outfall. The flow associated with the harvest is allowed to move into the rake box and the harvested algal turf over ¼" removed by the Duperon Rake. Water that passes through the rake is diverted to the east, to two solids settling ponds, which act as clarifiers. The flow after settling within these ponds, is released into the pond/wetland system.

This arrangement, including the effluent flumes, functioned well, and the flow rate within the effluent flume and the effluent channels was sufficient to move the harvest into the rake box area. The biggest issue with this dynamic was the performance of the Duperon Rake during harvest. The speed of the chain which moves the cleaning bars across the stationary rake was often insufficient to clear the screen quickly enough during heavy loading. This often resulting in binding at the toe of the screen, causing the bars to be pushed above the impinged biomass, which resulted in more accumulation until the entire screen was blinded. This forced water to back-up into the effluent channel, eventually forcing it over the diversion weir, and therefore mixing with the clean water from the non-harvested side.

In addition, when the algal turf was largely long filamentous green algae, the long strands would not clear from the rake, and would be carried back into the rake box. This also resulted in blinding and the attendant by-pass over the diversion weir. To correct for these concerns, it is recommended that adjustments be made to the rake and ancillary harvesting systems which include:

- A forced water or air (or both) manifold be placed under and in front of the toe of the rake screen within the rake box. This will allow the operator to force the impinged algae from the screen to prevent blinding.
- Increase rake speed to at least 1 fps during harvest.
- Establish a design which is more amenable to clean-out of accumulated solids within the rake box, as well as portions of the effluent channel.
- Provide a cutting system on the rake that will shear long filaments, thereby preventing their recycling through the rake mechanism.
- One design adjustment which is being considered is the use of a central harvest flume which runs parallel to the system flow. This would facilitate pushing the harvested material a shorter distance, and may well decrease harvest time.

The actual harvesting process proved effective, although the issue associated with grid damage as mentioned previously was somewhat problematic. Excluding the labor required to complete the 319(h) monitoring requirements, harvesting was completed in an average 2.54 hours. While there was some excess personnel time associated with the early harvests, it was clear that by the end of the monitoring period, two persons could complete the harvest, if there were no issues with the Duperon Rake. Considering 28 harvests/year, this amounts to a projected man-hour requirement of 142 man-hours/year. The set-up time, the compost processing, and clean-up require an additional 18 hours per week of one operator, excluding major upsets or breakdowns. The total normal operational and maintenance time therefore could reasonably be expected to involve about 1,078 hours per year, or about 0.73 man-hours per pound of phosphorus removed and 0.20 man-hours per pound of nitrogen removed. At $37/hr this amounts to labor costs of $27.01/lb-P removed and $7.40/lb-N removed.

Other expenses such as ground maintenance, monitoring and reporting, replacement parts, repairs, fuel, lubricants etc would need to be added to this amount. Fuel consumption is related to the small harvest tractors and the skid loader used to process the compost, and would be comparatively small. Monitoring and reporting requirements vary, and would have some impact upon overall costs. These other expenses, once the system operation and maintenance demands are stabilized, might amount to $25,000/yr, or $16.93/lb-P removed and $4.74/lb-N removed.

The largest expenditure is electrical fees associated with the pumping units, amounting to perhaps as much as $59,000/year, or $39.95/lb-P removed and $11.17/lb-N removed. This is why attention during design to TDH requirements and pump selection are so important. At some point in the future, application of alternate energy sources such as solar, or biogas might results in some long term energy cost savings.

With an efficiently operated system, it is quite possible that phosphorus reduction costs could be kept between $85-95/lb, and nitrogen reduction costs between $25-35/lb. These do not include amortization costs for capital expenditures. The cost efficiency could be improved considerably with 1) higher removal rates which might be facilitated by more effective operational and water management strategies (as discussed later in this section of this text), and 2) return value from sale of algal turf based products such as, but not restricted to, compost, fuel, fiber products, biogas, and livestock feed.

The on-site composting operation functioned smoothly, and resulted in the production of an estimated 100-200 tons of high quality compost from the rake harvest, and a similar amount from the diverted harvest solids. Movement and mixing of the material was facilitated by a small skid loader, with a Brown Bear mixing attachment. The wet rake harvest was typically mixed with mulch generated at the County landfill. This mulch material was laden with large sticks and other debris, which reduced the compost quality. At some point the fresh harvest was mixed with finished product during windrowing, which improved the quality somewhat.

Initial testing by USDA of the compost provided some indication that it might well be a valuable product for the foliage industry. If the product value were found to be $100-200/ton, then the gross return from sales would be estimated at $10,000 to $30,000, or $6.77 to $20.31/lb-P removed. This would not cover all of the costs but could reduce operational costs by perhaps 8% to as much as 24%.

Pond/Wetland System and Landscaping

Very little operational attention was required for the pond/wetland system. The only design concern which may need to be considered in future systems is not to place the outfall at the end of the wetland unit, as on occasions, as noted during the final month of Q4, dissolved oxygen levels can be reduced, which is not atypical of wetland systems.

Also, the use of traditional grass cover on the berms and open areas can make ground maintenance more costly if it is desirable to keep the grass cut. The use of native clump grasses, such as Muhly grass, sand cord grass, or lop-sided Indian grass would be more attractive to bird and wildlife utilization, and would require cutting only once or twice annually, with the cuttings left on the ground as mulch material. In up-gradient sandy areas, native vegetation such as blazing star, blue-eyed grass, coreopsis, palmetto, gall berry and rusty lyonia can be tolerant of drought conditions, and provide good wildlife and bird habitat. During start-up it is important to control cattail proliferation within the wetland and littoral areas so more desirable aquatic plants can get established.

Water Management Considerations

The IRFWCD has responsibility of managing the movement, storage and distribution of surface waters throughout the Main Canal watershed, which stretches from the large citrus farming areas west of I-95 through the suburban and urban areas of Vero Beach, and ending at the connection with the Indian River Lagoon. Historically the management of these waters was conducted in a manner that accommodated the irrigation concerns of agriculture while providing flood protection to all within the watershed. Scheduling of water movement into the Indian River Lagoon (IRL) from the Main Canal was established around these two concerns, with little, if any, initial consideration given to the environmental impacts upon the IRL.

With time it has become evident that by substantially changing the movement and quality of water from the upland regions into the IRL, the ecological dynamics of the IRL has also been changed. Consequently a need has arisen to protect the IRL from extensive degradation, and as a result, Federal, State and local programs and regulations have been promulgated which address the issue of reducing impacts upon the quality of critical impaired waters such as IRL-- hence, the establishment of programs such as the National Estuary Program (NEP), the Indian River Lagoon SWIM plan, and the TMDL component of the Clean Water Act (CWA—PL92-500).

As would be expected, these programs with their directives targeted at protecting the IRL are often seen as conflicted with the irrigation and flood protection responsibilities of the IRFWCD and other “298” Districts. Central to resolution to this perception of what appears to be conflicting mandates, is the objective assessment of long term economic impacts of any proposed actions—including the “no action” alternative.

The established pattern of “298” type management is important to sustaining the existing economic dynamic related to agriculture and a consumer population. However, continued degradation of the IRL has the potential of imposing upon the vitality of the tourism industry and an important fishery associated with the IRL. It is not particularly difficult to assess the importance of the flow of money attendant with citrus farming and the sustenance of the existing consumer market. It is not as easy to project the economic benefits which might result from restoration of the estuarine ecostructure of the IRL. What can not be denied is that if indeed the IRL could be restored such that the fishery improved substantially, property values increased, and the water quality was more amenable to attracting tourism associated with both passive and active water recreation, there would be a positive economic impact. The quantification and timing of such economic enhancement and the determination of the extent IRL restoration is achievable, and what the associated cost might be, are of course critical questions. Answering these question will require a long term comprehensive and objective economic review, and is well beyond the scope of this study.

From a technical perspective however, it is not difficult to envision a refined water management scenario which might well accommodate both the agricultural and flooding concerns and the need to make real progress regarding the restoration of the IRL. Such a scenario must include both the issue of scheduling of flows to the IRL, and the quality of water which finds its way to the IRL. Presently, in simplified terms, canal networks such as the Main Canal system, are managed by retaining water through the use of gates during the dry season, and expediting the release of flood water during the wet season. As noted, this can result in long periods of impoundment during which water treatment systems such as EMSP are forced to re-treat the same water. This results in very high quality water within the impounded canal, but prevents the treatment systems access to the retained seepage water. If during the dry season, water could be stored in an up-gradient reservoir, then periodic lowering of the canal water level would be possible, and access to these sequestered seepage waters and their associated nutrients would be more likely.

A scenario such as shown in the schematic presented as Figure 58(b), might well facilitate enhanced reduction of nutrients by allowing release of impounded seepage water during the dry season, while retaining water through the use of up-gradient reservoirs which can be used for irrigation either from direct extraction, or through release back into the canal network. If an EMSP type facility is used to continually treat the water retained within the reservoir system, even further nutrient reduction will be facilitated, and the reservoirs themselves can be maintained with high quality water, making them valuable fish and wildlife areas.

The third component of this approach is the potential development of valuable products from the harvested ATS™ algal turf biomass. As noted, while present assessments show the product value will not in the near future cover all of the operating costs, it could be a significant percentage. And as new products are researched and developed, values can be expected to increase. Among products which have this potential are livestock feed ingredients, biogas, fiber sources for paper and plastic manufacturing, high quality compost and soil amendment, and specialty products which may have value in the food, pharmaceutical or cosmetics industries.

This approach of using reservoirs to compensate for loss of historical water storage areas such as marshes and floodplains is being pursued throughout south Florida, with particular attention now being directed to the Kissimmee River, Lake Okeechobee and the Everglades. It certainly has potential application in east coastal counties such as Indian River, St. Lucie, Martin and Brevard Counties, as well as west coast counties such as Charlotte, Sarasota, Lee and Collier Counties. To develop and assess the technical and economic feasibility of such a plan applied to the Main Canal watershed would require extensive study, with recognition that impositions on certain parts of society, such as conventional agriculture, could be off-set by new paradigms which would include the coalition of water quality treatment and water quantity management interests and new agricultural endeavors, i.e. algal turf production. In addition, long term economic benefits associated with projected improvements within the IRL would have to receive detailed and objective evaluation.

If such a study shows there is an economic value to making such adjustments, then it becomes reasonable to explore funding sources and to develop the institutional mechanisms for allocating ownership and operational responsibility as well as rights to initial production and to development, marketing and sale of final products.

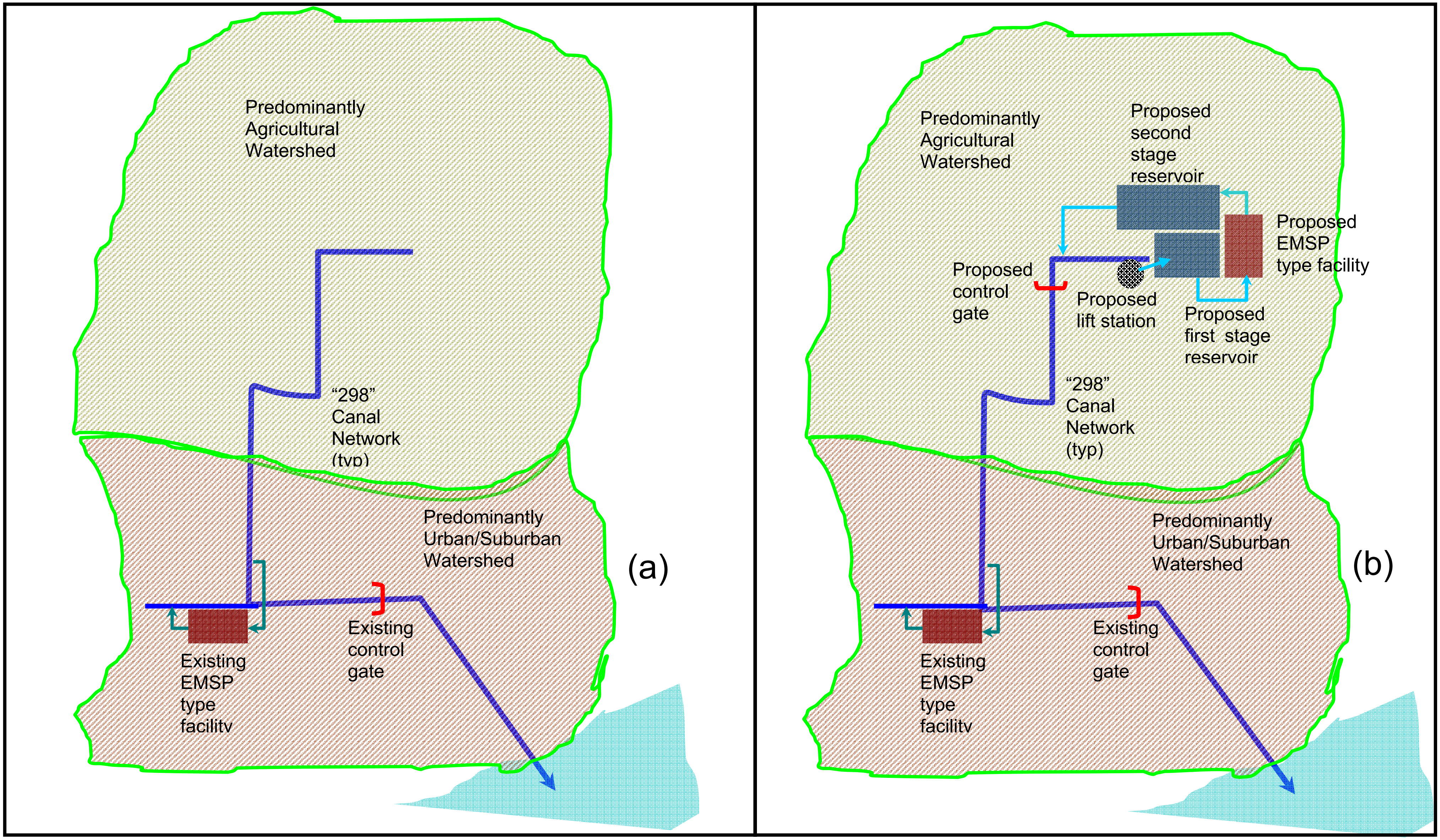


Figure 57: Generalized Schematic of a typical "298" network existing a) and proposed refinements of water management approach (b)

APPENDIX 1
MONITORING SPREADSHEETS

Harvest Summary Sheets
Monthly Summary Sheet
pH, DO, Conductivity, Water T Sheet
Operational spreadsheet

(Submitted on enclosed CD)

APPENDIX 2
PLANNING REVIEW AUDITS
QA/QC DATA

Planning Review Audit
Egret Marsh Stormwater Park
Indian River County, Florida
319(h) Contract G0143

September, 2010
Revised November 2011

INTRODUCTION

In accordance with Section 5 of Attachment H of Contract G0143, as executed April 19, 2005 between The Florida Department of Environmental Protection (FDEP) and Indian River County, Florida (COUNTY), a Planning Review Audit has been completed, and is submitted as specified within Addendum 1, of the abovementioned Attachment, within thirty days of collection of the initial water samples associated with the monitoring of the Egret Marsh Stormwater Park. The monitoring plan for this project is delineated within the approved Quality Assurance Project Plan (QAPP) of June 8, 2010 entitled:

QUALITYASSURANCE PROJECT PLAN
EGRET MARSH AREA STORMWATER IMPROVEMENT PROJECT

Project sampling was initiated upon acceptance in early August of the QAPP document by FDEP. The first monthly sample was retrieved and delivered to the selected Laboratory, Test America, Inc. on September 13, 2010. This Planning Audit Review was completed after discussions and meeting between the involved COUNTY staff and HydroMentia, Inc., who has been contracted by the COUNTY to help implement the 319(h) monitoring program. Individuals involved in developing this Planning Review Audit were Keith McCully P.E. Project Manager for the COUNTY; Todd Tardiff, QA Manager for the COUNTY; Allen Stewart P.E., Project Manager HydroMentia, and Robinson Bazurto, Operations Manager HydroMentia.

ISSUES OF DISCUSSION AND RESOLUTION

All parties involved in the Planning Review Process are familiar with the QAPP and with the dynamics of the system operation. The sessions were held after the first set of sample results had been received.

1) Field Sampling and Monitoring
   a) Automatic Samplers
      i) Battery units need to be supported on a pedestal to keep them from discharging to ground.
      ii) Intake strainer at station 02 placed in free flow in front of effluent discharge weir at 12” depth, and must be far enough upstream to ensure it does not overflow the weir
      iii) Intake strainers shall be cleaned thoroughly using DI water at each sample recovery
      iv) The sampler shell that holds the bottle shall be kept clean, and tightly closed to ensure insects can not access the space.
      v) It was decided to place an open bottle of DI water within the sampler shell at stations 01 and 02 to test (Field Blank) for TKN and ammonia-N to verify that the activity on site, including harvesting and the windrow composting, is not impacting sample integrity.

b) Flow Meters
   i) The ATS™ effluent (sta 02) flow meter failed on 9/6/10 (would not register readout) The unit was recovered for repair. Return time not known.
   ii) Flow at 02 will be determined from hand measurements taken at sampling time of height over weir, until the unit is returned. (see Attachment 1)
   iii) Flow at station 03 (effluent discharge and seepage at wood stork pond structure (WS) is estimated from rainfall and measured height over a 5 ft rectangular weir, and the downstream submergence. (see Attachment 2)

c) YSI Unit (pH, DO, Conductivity, T)
   i) Readings to be taken between 10:00 and 11:30 AM on day of sample retrieval.
   ii) Copy of Calibration Log to be kept in Operations Building

d) Pump Cycling
   i) Records will be kept by Todd of the times the internal In-Lake recycling pump is on. This pump is used when the main pump at lateral D is being serviced and /or rested (about 6 hrs/week). The In-Lake pump will also be used in situations in which herbicides are being used in Lateral D canal.

2) Laboratory Data
   a) Pollutant load removal through the ATS™ is to be calculated as the influent flow volume at sta 01 times concentration at sta 01 minus the effluent flow at sta 02 times concentration at sta 02. Seepage is not an issue with the ATS™ system because of the geomembrane liner which forms an impermeable floway subbase.
   b) Pollutant load removal through the pond system is to be calculated as the ATS™ effluent (sta 02) flow volume (which is the pond influent) times the concentration at sta 02 minus the estimated flow volume at sta 03 plus estimated rainfall volume times the concentration at sta 03 minus the estimated seepage flow times the average concentration between sta 02 and sta 03. Seepage through the pond system into the shallow groundwater has been estimated during the first month to amount to about 18% of the total flow into the pond system. While the quality of this seepage water into the groundwater is not known, it appears reasonable that it could represent an average between the incoming concentrations (sta 02) and the concentration at the surface water discharge (sta 03). Direct rainfall pollutant loads are assumed to be negligible. (see Attachment 2)
   c) Initial data show favorable results, with areal removal rates within the ATS™ at 37.70 g/m^2-yr for total phosphorus and 172.38 g/m^2-yr for total nitrogen and within the pond system 7.80 g/m^2-yr for total phosphorus and 2.86 g/m^2-yr for total nitrogen. A total of 195.5 lb of phosphorus was removed for the first 28 day period, much of which was recovered as harvested algae, which was windrow composted on site. Of this total, 118.5 lb was attributable to the ATS™, and 77.0 lb was attributable to the pond system. A total of 569.9 lb of nitrogen was removed, again with most of it being recovered through algae harvest. Of this total, 541.7 lb was attributable to the ATS™ while 28.2 lb was attributable to the pond system.
   d) The influent total phosphorus concentration was 0.170 mg/L at the influent (sta 01); 0.121 at the ATS™ effluent (sta 02), and 0.083 mg/L at the pond discharge (sta 03). Total phosphorus mass reduction was 49.8%.
   e) The influent total nitrogen concentration was 1.15 mg/L at the influent (sta 01); 0.94 at the ATS™ effluent (sta 02), and 0.91 mg/L at the pond discharge (sta 03). Total nitrogen mass reduction was 21.44%.
   f) Ammonia nitrogen with an influent concentration (sta 01) of 0.11 mg/L was reduced to below detectable limits (0.02 mg/L) through the ATS™ (sta 02), and remained below detectable limits through the pond system (sta 0.03). Mass removal was over 82%.
   g) Nitrate+ Nitrite (NOx) nitrogen with an influent concentration (sta 01) of 0.11 mg/L was reduced to 0.07 mg/L through the ATS™ (sta 02), and reduced further to 0.04 mg/L through the pond system (sta 0.03). Mass removal was 61.1%.

h) Equipment Blanks taken at all three stations showed undetectable levels or values between MDL and PQL. The samples that were between the MDL and PQL were Ortho-P for sta 02; TKN for all three stations; and zinc for sta 02 and sta 03. (See Attachment 3).
i) Samples were split with Pace Laboratories of Ormond Beach, and results for all parameters were within set %RPD limits, with the exception of OP for 01G-EM-1and TSS for 02G-EM-1. The OP was retested for 01G-EM-1, and found to be at same concentration (0.034 mg/L). The replicate OP 01GR-EM-1 for OP was within %RPD with split (0.080 mg/l and 0.065 mg/L respectively. This replicate was used in place of the primary sample within the data spreadsheet. The TSS levels were very low and the difference with splits is considered inconsequential. Even though the labs used the same method, they listed different reporting limits. As a result of an oversight, Test America did not conduct Ammonia testing, although Ammonia was tested by Pace. Splits for Ammonia will be included in the next sample run (see Attachment 4).
j) Pace Labs and Test America used different methods for the four metals (Cr, Cd, Zn, and Cu). The results for both methods were low, being near or below MDL. (all Cd and Cr values were below MDL for both labs) For the next split sample we will attempt to have Pace use the methods used by Test America.
k) Replicate samples were within set % RPD except for 01G-EM-1/01GR-EM-1 for OP and BOD and 02G-EM-1/02GR-EM-1 for TSS, Cu and BOD. The BOD, Cu and TSS values were very low, near detectable limits, and the differences are considered inconsequential. The OP disparity is as discussed, with the value of 0.034 mg/L appearing to be an outlier. (see Attachment 5)

SUMMARY

Other than the need for continued vigilance in regards to sampling equipment maintenance and sample handling, the monitoring program and protocols appear to be effective, and data reliability is acceptable. For the next split sample session, corrections will be made regarding lab methods applied.

The close correlation of TN and TP reduction as calculated from water quality/flow and harvest provide indication that overall the laboratory values are reliable and usable.

ADDENDUM Quarter 2

1) Field Blanks analyzed for all three sampling stations on 12/6/10 show some elevations in TKN, Ammonia-N and Nitrate-N. It was suspected he deionized water might be contaminated, so source was changed. A retest of TKN and Ammonia-N on 1/26/2011showed more reasonable levels, close to or below PQL. The results of Q2 blanks are noted in Attachment 3.
2) Split samples for Q2 are included in Attachment 4. All parameters noted below %RPD limit except Ammonia-N for Station 01 (0.12 m/L Vs. 0.07 mg/L), and copper for Station 02 (5.08 µg/L Vs 6.23 µg/L)
3) The effluent flow meter continued to provide only intermittent service. It was returned again to the manufacturer, but upon return still continued to exhaust batteries within 1-2 days. Will request the County purchase a plug-in transformer to ensure power is maintained. Data extrapolated from partial week data to

estimate effluent flow.

ADDENDUM Quarters 3 & 4

1) Field Blanks and equipment blanks done for Q3/Q4 analyzed for all three sampling stations show either undetectable levels or levels low enough to be inconsequential.
2) Replicate samples show consistency with the laboratory analyses with the exception of total phosphorus from 8/29/11, with the value of 0.380 mg/L appearing as an outlier. This sample was retested and the value verified, which suggests possible contamination during field sampling.
3) Split samples taken on 8/29/11 show some inconsistencies with total phosphorus. Both laboratories were asked to rerun the results. Pace (the split lab) showed no difference in results. Test America found some dilution problems. However, even with adjustment, the %RPD were still above limits. It is not quite clear why such a discrepancy occurred at this time, although it appears the digestion process may be involved, as OP splits were within limits, and the OP from Test America was higher than the TP. The closeness of the phosphorus removal calculated by water quality/flows and by harvest over the ATS™ provides confidence that overall TP values were sufficiently reliable.
4) The effluent flow meter was placed upon a charger system and enclosed in waterproof box During Q3, and performed well during Q4.
5) For the months ending 6/20/11 and 7/18/11 grab samples were used in place of composite samples for TP and TKN, as the composite sampler was interrupted on numerous occasions during hand harvesting and washing of algal turf collected for generating oil and dry product for the VEN contract with StatOil. The intensity and frequency of this harvesting activity during the daylight hours skewed the quality of the ATS™ effluent.

ATTACHMENT 1
Method of Flow Volume Calculation Station 02 (ATS™ Effluent) During Flow Meter Downtime

For both station 01(Influent) and station 02 (ATS™ Effluent), a Sigma bubbler type flow meter has been installed in association with a suppressed 8 ft rectangular weir. Measuring flows at these two stations not only facilitates more reliable calculation of load removals, but also provides insight into the dynamics of evaporation associated with an ATS™ floway, recognizing that water temperatures during the warm season can increase by about 1.5-2.0° C down the floway.

Upon project initiation, the bubbler systems were calibrated, and totalized flows documented on a weekly basis. By the third week however, the Flow Meter at Sta 02 failed, and is now under repair. The length of time before repair is completed is unknown at this time.

In the interim period, flows will be estimated at station 02 through hand measurements of the upstream water level above the set weir, taken at the time of sample recovery (each Monday at about 10:00 AM). The measurement will be converted to a flow rate using the same equation incorporated into the Flow Meter, the Kindsvater-Carter Equation

$$Q = (2/3)C_e(2g)^{0.5}(b + K_b)(h + K_h)^{1.5}$$

Where Q is flow rate

C_e is the weir coefficient which is a function of the ratio of height over the weir(h) and channel depth below the weir (P)

b is weir length

h is height of water above weir taken at a reasonable distance upstream.

K_b and K_h constants with value of -0.003 ft and 0.04 inches when h is in inches, respectively.

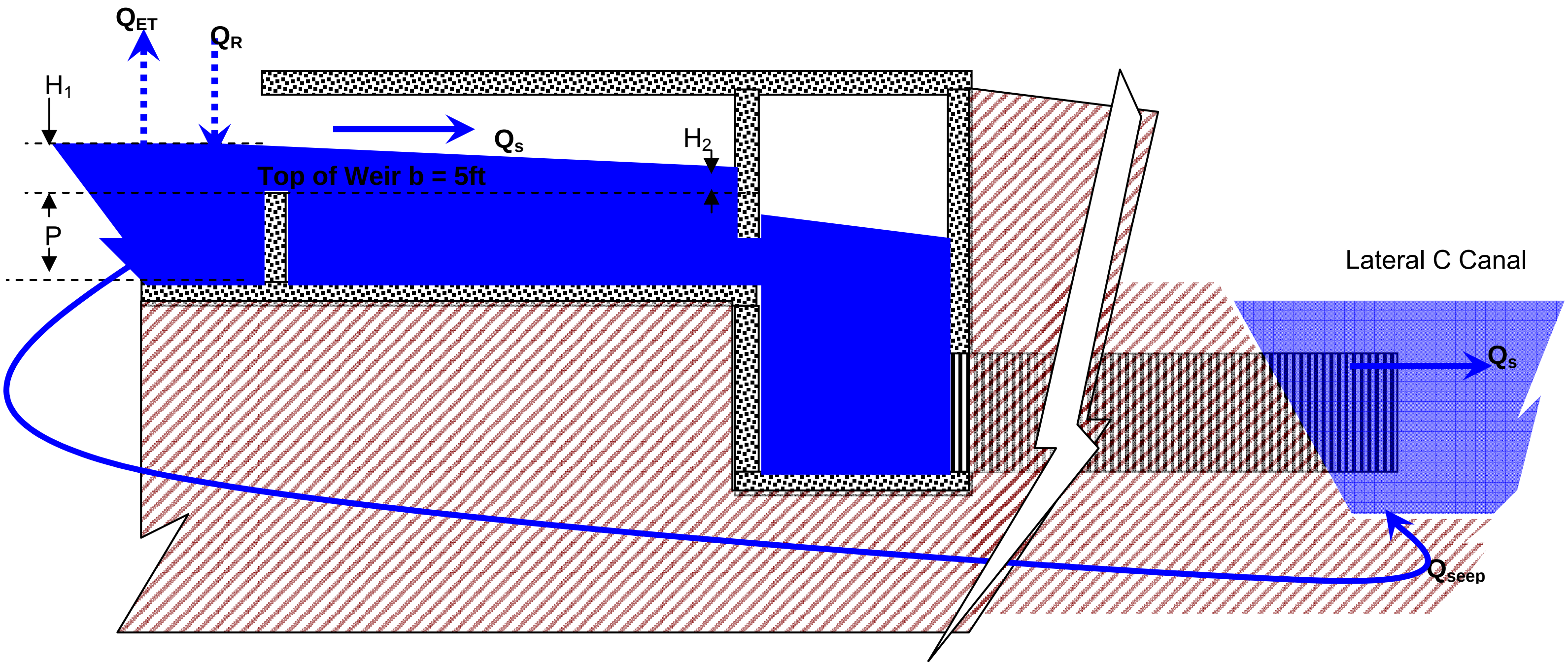
Once the flow rate is established, this is multiplied by the time period, and then the volume attributable to rainfall is added.

Example: Suppose over the week 2 inches of rainfall was reported, and at sample retrieval it was not raining, and the height over the weir was 8.25 inches. The total volume estimate would be 69.54 MG over the week.

Weir Description	Type	Weir Length ft	Height Over Weir inches	P ft	h/P (Hydraulic Radius)	Weir Coefficient C	Flow gpm	Flow MGD
Effluent Diversion Weir	Rectangular	8.00	8.25	6.00	0.11	0.61	6,874	9.90

Time lapse minutes	10,080
Rainfall inches	2.00
Rain Volume in gallons over 4.6 acres	249,835
Total Effluent Volume	69,542,187

ATTACHMENT 2
Method of Flow Volume Calculation Station 03 (Wood Stork Habitat Discharge))



The above illustration represents conditions at Station 03, with a five foot weir, submerged via a downstream baffle (this is not an exact representation). The flow under submerged condition (Q_s) can be estimated by[49]:

$$Q_s = (Q_1)[\ 1-(H_2/H_1)^{1.5}]^{0.385}$$

Where
Q_1= flow at H_1
if the weir were
not submerged

(apply Kindsvater-Carter Equation)

[49] Brater, Ernest F. and Horace Williams King, 1976 " Handbook of Hydraulics" Mcgraw-Hill, New York

Weir Description	Type	Weir Length ft	Height Over Weir inches	P ft	h/P (Hydraulic Radius)	Weir Coefficient C	Q1 Flow gpm	Q1Flow MGD	H_2 inches	Qs Flow gpm	QsFlow MGD
Effluent Diversion Weir	Rectangular	5.00	9.60	4.50	0.18	0.62	5,470	7.88	2.30	5,214	7.51
	Time lapse minutes	10,080									
	Rainfall inches	2.00									
	Rain Volume in gallons over 14.4 acres	782,094									
	Total Effluent Volume	55,924,419									

This exercise provides a reasonable estimate of surface water discharge from sta 03. However, to complete the hydraulic balance both seepage (Q_{seep}) and evapotranspiration (Q_{et}) need to be considered as well as rainfall. This balance is expressed by:

$$Q_{ATS} + Q_r = Q_s + Q_{seep} + Q_{ET}$$

or

$$Q_s + Q_{seep} = Q_{ATS} + Q_r - Q_{ET}$$

Where Q_{ATS} is the ATS™ effluent flow volume which is the influent to the pond system
Q_r is the rainfall flow volume
Q_{seep} is the volume seeping from the pond bottom into the shallow groundwater and eventually seeping into the canal system.
Q_{ET} is the volume losses through evaporation and transpiration over the pond system surface

As the pond area is about 14.4 acres, the Q_r in gallons = 14.4 acres x 43560 sf/acre x (rainfall inches/12) ft x 7.48 gallons/cf. Rainfall is measured on site weekly.

The evaporational losses from a water surface typically approaches the pan evaporation for the area, usually being somewhat less. Pan Evaporation for this general region of Florida has been documented by the South Florida Water Management District. To be conservative, evaporation losses are assumed to equal pan evaporation.

Pan Evap Belle Glade Month	Pan Evaporation SFWMD Station S65C_E 1976 - 1989 (in/mnth) (1)
Jan	3.6
Feb	4.2
Mar	5.8
Apr	7.2
May	7.9
Jun	6.9
Jul	6.2
Aug	6.0
Sep	5.8
Oct	5.7
Nov	4.2
Dec	3.6
	67.2

(1) Pan evaporation data recorded at SFWMD Station S65C_ E from 1976 - 1989 (Unpublished data)

Example: Over a week in September, the rainfall was 2.0 inches, and the flow volume from the ATS™ was 69.75 million gallons; the estimated volume from the sta 03 submerged weir was 57.50 million gallons; the rainfall volume is calculated as 0.78 million gallons, and the ET loss is calculated as 0.52 million gallons. The total seepage volume then is calculated as 12.51 million gallons.

To estimate the pollutant load leaving the pond system (P_{03}), it is assumed that the quality of water within the seepage is the mean between the concentration of the incoming ATS™ effluent and the surface water discharge at sta 03, or

$$P_{03} = (C_{o3})(Q_s) + [(C_{02} + C_{03})/2](Q_{seep})$$

If, in the example above C_{02} is 0.121 mg/L total phosphorus, and C_{03} is 0.081 mg/L, then P_{03} is calculated as {(57.50)(0.081) + [(0.121 + 0.081)/2] (12.51)}8.34 or 5.92 lbs . Note that 8.34 is a conversion factor from (million gallons-mg)/L to pounds.[50]

[50] Note that these calculations do not include any phosphorus carried by rain. Work by the South Florida Water Management District reveal the TP concentration in rainfall at about 0.030 mg/L, therefore for this example the P contributed by rainfall would be about 0.02 pounds, or 0.33% of the total calculated load.

ATTACHMENT 3
Review of Equipment and Field Blank Results Q1 through Q4

Egret Marsh 319(h) Contract G0143--Equipment Blanks
Test America 9/13/10

Station 01

Note	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.133 (I)	E351.2
	NOx	mg/L	U	E353.2
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	U	SM2320B

Station 02

Note	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.130 (I)	E351.2
	NOx	mg/L	U	E353.2
	TP	mg/L	U	E365.3
Note 2	OP	mg/L	0.004 (I)	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
Note 3	Zinc	µg/L	2.87 (I)	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	U	SM2320B

Station 03

Note	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.142 (I)	E351.2
	NOx	mg/L	U	E353.2
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
Note 3	Zinc	µg/L	3.90 (I)	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	U	SM2320B

Note 1: I--value falls between MDL of 0.04 mg/L and PQL of 0.20 mg/L
Note 2: I--value falls betwee MDL of 0.001 mg/L and 0.05 mg/L
Note 3: I--value falls between MDL of 2.80 microg/L and PQL of 20 microg/L

Equipment Blanks

Station 01 **Test America 7/18/11**

Note 1

Parameter	Units	Value	Method
TKN	mg/L	0.11(I)	E351.2
NOx	mg/L	U	E353.2
NH3	mg/L	0.01(I)	E350.1
TP	mg/L	U	E365.3
OP	mg/L	U	E365.2
TSS	mg/L	U	SM2540D
Color	pcu	U	SM2120B
Zinc	µg/L	9.13(I)	200.8
Copper	µg/L	U	200.8
Chromium	µg/L	U	200.8
Cadmium	µg/L	U	200.8
TOC	mg/L	0.9(I)	SM5310B
Alkalinity	mg/L	0.43(I)	SM2320B

Station 02

Note	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.09(I)	E351.2
	NOx	mg/L	0.01(I)	E353.2
	NH3	mg/L	U	E350.1
	TP	mg/L	U	E365.3
Note 2	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
Note 3	Zinc	µg/L	9.14(I)	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	0.6(I)	SM5310B
	Alkalinity	mg/L	U	SM2320B

Station 03

Note	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.09(I)	E351.2
	NOx	mg/L	0.01(I)	E353.2
	NH3	mg/L	U	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
Note 3	Zinc	µg/L	8.74(I)	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	0.5(I)	SM5310B
	Alkalinity	mg/L	0.60(I)	SM2320B

Note 1: I--value falls between MDL of 0.04 mg/L and PQL of 0.20 mg/L
Note 2: I--value falls betwee MDL of 0.001 mg/L and 0.05 mg/L
Note 3: I--value falls between MDL of 2.80 microg/L and PQL of 20 microg/L

Equipment Blanks

Composite all Stations **Test America 8/29/11**

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.07(I)	E351.2
	NOx	mg/L	U	E353.2
	NH3	mg/L	U	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	0.63(I)	SM2320B

Egret Marsh 319(h) Contract G0143--Field Blanks

Station 01 **Test America 12/6/10**

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.19	E351.2
	NOx	mg/L	U	E353.2
Note 2	NH3	mg/L	0.07	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	.465(I)	SM2320B

Station 02

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.14 (I)	E351.2
Note 3	NOx	mg/L	0.03	E353.2
Note 2	NH3	mg/L	0.03	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	.587(I)	SM2320B

Station 03

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.13 (I)	E351.2
Note 3	NOx	mg/L	0.01	E353.2
Note 2	NH3	mg/L	0.01	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	U	SM2320B

Note 1: I--TKN above PQL in 01, values for 02 and 03 fall between MDL of 0.04 mg/L and PQL of 0.20 mg/L
Note 2:Ammonia levels above PQL
Note 3: I--Nox values above PQL

Egret Marsh 319(h) Contract G0143--Field I
Test America 12/6/10

Station 01

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.19(I)	E351.2
	NOx	mg/L	U	E353.2
Note 2	NH3	mg/L	0.07	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	.465(I)	SM2320B

Station 02

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.14 (I)	E351.2
Note 3	NOx	mg/L	0.03	E353.2
Note 2	NH3	mg/L	0.03	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	.587(I)	SM2320B

Station 03

	Parameter	Units	Value	Method
Note 1	TKN	mg/L	0.13 (I)	E351.2
Note 3	NOx	mg/L	0.01	E353.2
Note 2	NH3	mg/L	0.01(I)	E350.1
	TP	mg/L	U	E365.3
	OP	mg/L	U	E365.2
	TSS	mg/L	U	SM2540D
	Color	pcu	U	SM2120B
	Zinc	µg/L	U	200.8
	Copper	µg/L	U	200.8
	Chromium	µg/L	U	200.8
	Cadmium	µg/L	U	200.8
	TOC	mg/L	U	SM5310B
	Alkalinity	mg/L	U	SM2320B

Note 1: I--TKN above PQL in 01, values for 02 and 03 fall between MDL of 0.04 mg/L and PQL of 0.20 mg/L
Note 2: I--Ammonia levels above MDL of 0.004mg/L but below 0.02 mg/L PQL for 03, just above PQL in 01 and 02
Note 3: I--NOx values above PQL of 0.01 mg/L

Egret Marsh 319(h) Contract G0143--Field Blanks
Test America 1/26/11

Station 01

Parameter	Units	Value	Method
TKN	mg/L	0.064(I)	E351.2

Station 02

Parameter	Units	Value	Method
TKN	mg/L	0.140(I)	E351.2
NH3	mg/L	0.0095 (I)	E350.1

Station 03

Parameter	Units	Value	Method
TKN	mg/L	0.270(I)	E351.2
NH3	mg/L	0.036	E350.1

Egret Marsh 319(h) Contract G0143--Field Blanks
Test America 8/29/11

Station 01

Note 1

Parameter	Units	Value	Method
TKN	mg/L	0.07(I)	E351.2
NOx	mg/L	U	E353.2
NH3	mg/L	U	E350.1
TP	mg/L	U	E365.3
OP	mg/L	U	E365.2
TSS	mg/L	U	SM2540D
Color	pcu	U	SM2120B
Zinc	µg/L	U	200.8
Copper	µg/L	U	200.8
Chromium	µg/L	U	200.8
Cadmium	µg/L	U	200.8
TOC	mg/L	U	SM5310B
Alkalinity	mg/L	U	SM2320B

Station 02

Note 1

Parameter	Units	Value	Method
TKN	mg/L	0.10 (I)	E351.2
NOx	mg/L	U	E353.2
NH3	mg/L	U	E350.1
TP	mg/L	U	E365.3
OP	mg/L	U	E365.2
TSS	mg/L	U	SM2540D
Color	pcu	U	SM2120B
Zinc	µg/L	U	200.8
Copper	µg/L	U	200.8
Chromium	µg/L	U	200.8
Cadmium	µg/L	U	200.8
TOC	mg/L	U	SM5310B
Alkalinity	mg/L	U	SM2320B

Station 03

Note 1

Parameter	Units	Value	Method
TKN	mg/L	0.10(I)	E351.2
NOx	mg/L	U	E353.2
NH3	mg/L	U	E350.1
TP	mg/L	U	E365.3
OP	mg/L	0.001(I)	E365.2
TSS	mg/L	U	SM2540D
Color	pcu	U	SM2120B
Zinc	µg/L	U	200.8
Copper	µg/L	U	200.8
Chromium	µg/L	U	200.8
Cadmium	µg/L	U	200.8
TOC	mg/L	U	SM5310B
Alkalinity	mg/L	U	SM2320B

Note 1: I--TKN above PQL in 01, values for 02 and 03 fall between MDL of 0.04 mg/L and PQL of 0.20 mg/L

ATTACHMENT 4
Review of Split Sample Results Q1through Q4

Egret Marsh 319(h) Contract G0143--Split Samples
Test America and Pace Labs 9/13/10

Station 01

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.80	E351.2	1.04	E351.2	26.09%	0-30
	NOx	mg/L	0.11	E353.2	0.11	E353.2	0.00%	0-30
	TP	mg/L	0.157	E365.3	0.170	E365.3	7.95%	0-30
Note 2	OP	mg/L	0.066	E365.1	0.034	E365.2	64.00%	0-30
Note 2	OP (rep)	mg/L	0.066	E365.1	0.080	E365.2	19.18%	0-30
	TSS	mg/L	5.00	SM2540D	5.75	SM2540D	13.95%	0-25
	Color	pcu	70	SM2120B	100	SM2120B	35.29%	0-40
Note 1	Zinc	µg/L	U	200.7	U	200.8	NA	0-20
Note 1	Copper	µg/L	3.96	200.7	5.82	200.8	NA	0-20
Note 1	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 1	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	13.50	SM5310B	13.80	SM5310B	2.20%	0-25
	BOD	mg/L	2.20	SM5201B	2.10	SM5201B	4.65%	0-30
	Alkalinity	mg/L	168	SM2320B	180	SM2320B	6.90%	0-30

Station 02

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.73	E351.2	0.87	E351.2	17.34%	0-30
	NOx	mg/L	0.08	E353.2	0.08	E353.2	0.00%	0-30
	TP	mg/L	0.135	E365.3	0.121	E365.3	10.94%	0-30
	OP	mg/L	0.056	E365.1	0.066	E365.2	16.39%	0-30
Note 3	TSS	mg/L	5.00	SM2540D	3.75	SM2540D	28.57%	0-25
	Color	pcu	90	SM2120B	70	SM2120B	25.00%	0-40
Note 1	Zinc	µg/L	U	200.7	U	200.8	NA	0-20
Note 1	Copper	µg/L	4.17	200.7	5.82	200.8	NA	0-20
Note 1	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 1	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	13.60	SM5310B	13.90	SM5310B	2.18%	0-25
	BOD	mg/L	U	SM5201B	U	SM5201B	-	0-30
	Alkalinity	mg/L	159	SM2320B	167	SM2320B	4.91%	0-30

Station 03

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.66	E351.2	0.87	E351.2	28.65%	0-30
	NOx	mg/L	0.04	E353.2	0.04	E353.2	20.00%	0-30
	TP	mg/L	0.081	E365.3	0.086	E365.3	5.99%	0-30
	OP	mg/L	0.029	E365.1	0.037	E365.2	24.24%	0-30
	TSS	mg/L	5.50	SM2540D	6.00	SM2540D	8.70%	0-25
	Color	pcu	90	SM2120B	100	SM2120B	10.53%	0-40
Note 1	Zinc	µg/L	U	200.7	3.56	200.8	NA	0-20
Note 1	Copper	µg/L	6.20	200.7	7.84	200.8	NA	0-20
Note 1	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 1	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	14.60	SM5310B	14.50	SM5310B	0.69%	0-25
	BOD	mg/L	2.40	SM5201B	2.30	SM5201B	4.26%	0-30
	Alkalinity	mg/L	153	SM2320B	159	SM2320B	3.85%	0-30

Note 1: The two Labs used two different methods for metals 200.7 Pace; 200.8 Test America.
Values low in both cases
Note 2: The OP was out of %RPD range for the first Test America sample, but within limits for replicate. The replicate was used in data spreadsheet calculations.
Note 3: The values of TSS are low, near or below PQL. The difference noted here is considered inconsequential
Even though the labs used same method (SM2540D) they listed different reporting limits (5.0 for Pace; 2.5 for TA)

Egret Marsh 319(h) Contract G0143--Split Samples
Test America and Pace Labs 1/31/11

Station 01

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.48	E351.2	0.52	E351.2	8.00%	0-30
	Ammonia-N	mg/L	0.07	E350.1	0.12	E350.1	52.63%	0-30
	NOx	mg/L	0.11	E353.2	0.12	E353.2	8.70%	0-30
	TP	mg/L	0.060	E365.3	0.059	E365.3	1.68%	0-30
	OP	mg/L	0.018	E365.1	0.022	E365.2	20.00%	0-30
Note 1	TSS	mg/L	5.00	SM2540D	5.00	SM2540D	0.00%	0-25
	Color	pcu	U	SM2120B	U	SM2120B	NA	0-40
Note 2	Zinc	µg/L	U	200.7	U	200.8	NA	0-20
Note 2	Copper	µg/L	6.20	200.7	5.89	200.8	5.13%	0-20
Note 2	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 2	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	8.90	SM5310B	11.50	SM5310B	25.49%	0-25
	BOD	mg/L	U	SM5201B	6.80	SM5201B	NA	0-30
	Alkalinity	mg/L	163	SM2320B	170	SM2320B	4.20%	0-30

Station 02

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.48	E351.2	0.49	E351.2	2.06%	0-30
	Ammonia-N	mg/L	0.03	E350.1	0.04	E350.1	28.57%	0-30
	NOx	mg/L	0.10	E353.2	0.10	E353.2	0.00%	0-30
	TP	mg/L	0.048	E365.3	0.048	E365.3	0.00%	0-30
	OP	mg/L	0.014	E365.1	0.015	E365.2	6.90%	0-30
Note 1	TSS	mg/L	U	SM2540D	3.00	SM2540D	NA	0-25
	Color	pcu	U	SM2120B	U	SM2120B	NA	0-40
Note 2	Zinc	µg/L	U	200.7	6.43	200.8	NA	0-20
Note 2	Copper	µg/L	5.08	200.7	6.33	200.8	21.91%	0-20
Note 2	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 2	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	8.70	SM5310B	10.50	SM5310B	18.75%	0-25
	BOD	mg/L	U	SM5201B	2.10	SM5201B	-	0-30
	Alkalinity	mg/L	155	SM2320B	167	SM2320B	7.45%	0-30

Station 03

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	0.44	E351.2	0.47	E351.2	6.59%	0-30
	Ammonia-N	mg/L	U	E350.1	U	E350.1	NA	0-30
	NOx	mg/L	0.04	E353.2	0.04	E353.2	0.00%	0-30
	TP	mg/L	0.027	E365.3	0.024	E365.3	11.76%	0-30
	OP	mg/L	0.017	E365.1	0.017	E365.2	0.00%	0-30
Note 1	TSS	mg/L	U	SM2540D	2.71	SM2540D	NA	0-25
	Color	pcu	U	SM2120B	U	SM2120B	NA	0-40
Note 2	Zinc	µg/L	U	200.7	6.32	200.8	NA	0-20
Note 2	Copper	µg/L	5.89	200.7	7.16	200.8	19.46%	0-20
Note 2	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
Note 2	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	8.90	SM5310B	9.00	SM5310B	1.12%	0-25
	BOD	mg/L	U	SM5201B	1.50	SM5201B	NA	0-30
	Alkalinity	mg/L	150	SM2320B	156	SM2320B	3.92%	0-30

Note 1: The values of TSS are low, near or below PQL. The difference noted here is considered inconsequential
Even though the labs used same method (SM2540D) they listed different reporting limits (5.0 for Pace; 2.5 for TA)
Note 2: The two Labs used two different methods for metals 200.7 Pace; 200.8 Test America.

Egret Marsh 319(h) Contract G0143--Split Samples
Test America and Pace Labs 8/22/11

Station 01

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	1.39	E351.2	1.55	E351.2	10.88%	0-30
	Ammonia-N	mg/L						
	NOx	mg/L	0.13	E353.2	0.15	E353.2	14.81%	0-30
Note 1	TP	mg/L	0.262	E365.3	0.189	E365.3	32.37%	0-30
	OP	mg/L	0.230	E365.1	0.295	E365.2	24.76%	0-30
Note 2	TSS	mg/L	7.00	SM2540D	9.60	SM2540D	31.33%	0-25
	Color	pcu	250	SM2120B	200	SM2120B	22.22%	0-40
	Zinc	µg/L	10.70	200.7	9.45	200.8	12.41%	0-20
	Copper	µg/L	25.00	200.7	25.70	200.8	2.76%	0-20
	Chromium	µg/L	U	200.7	U	200.8	NA	0-20
	Cadmium	µg/L	<2.5	200.7	<1.5	200.8	NA	0-20
	TOC	mg/L	23.50	SM5310B	26.40	SM5310B	11.62%	0-25
	BOD	mg/L	U	SM5201B	2.60	SM5201B	-	0-30
	Alkalinity	mg/L	151	SM2320B	160	SM2320B	5.79%	0-30

Station 02

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	1.16	E351.2	1.44	E351.2	21.54%	0-30
	Ammonia-N	mg/L		E350.1		E350.1		0-30
	NOx	mg/L	0.26	E353.2	0.19	E353.2	27.17%	0-30
Note 1	TP	mg/L	0.251	E365.3	0.159	E365.3	44.88%	0-30
	OP	mg/L	0.204	E365.1	0.245	E365.2	18.26%	0-30
	TSS	mg/L	15.50	SM2540D	15.80	SM2540D	NA	0-25
	Color	pcu	250	SM2120B	150	SM2120B	50.00%	0-40
	Zinc	µg/L	12.70	200.7	11.2	200.8	12.55%	0-20
	Copper	µg/L	30.60	200.7	35.8	200.8	15.66%	0-20
	Chromium	µg/L	2.55	200.7	1.42	200.8	56.93%	0-20
	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	24.60	SM5310B	26.30	SM5310B	6.68%	0-25
	BOD	mg/L	U	SM5201B	2.70	SM5201B	-	0-30
	Alkalinity	mg/L	140	SM2320B	146	SM2320B	4.20%	0-30

Station 03

	Parameter	Units	Pace	Method	Test America	Method	% RPD	limit % RPD
	TKN	mg/L	1.16	E351.2	1.23	E351.2	5.86%	0-30
	Ammonia-N	mg/L		E350.1		E350.1		0-30
	NOx	mg/L	0.14	E353.2	0.13	E353.2	11.07%	0-30
Note 1	TP	mg/L	0.164	E365.3	0.078	E365.3	71.64%	0-30
	OP	mg/L	0.228	E365.1	0.243	E365.2	6.37%	0-30
	TSS	mg/L	<5	SM2540D	4.40	SM2540D	-	0-25
	Color	pcu	300	SM2120B	150	SM2120B	66.67%	0-40
	Zinc	µg/L	10.10	200.7	8.34	200.8	19.09%	0-20
	Copper	µg/L	37.80	200.7	39.8	200.8	5.15%	0-20
	Chromium	µg/L	U	200.7	1.43	200.8	-	0-20
	Cadmium	µg/L	U	200.7	U	200.8	NA	0-20
	TOC	mg/L	25.90	SM5310B	27.40	SM5310B	5.63%	0-25
	BOD	mg/L	2.30	SM5201B	2.90	SM5201B	23.08%	0-30
	Alkalinity	mg/L	116	SM2320B	120	SM2320B	3.39%	0-30

Note 1: Disparity with total phosphorus investigated, not resolved. Concerned that digestion process with TestAmerica may not be complete.
Note 2: The values of TSS are low, near or below PQL. The difference noted here is considered inconsequential

ATTACHMENT 5
Review of Replicate Sample Results Month 1

Egret Marsh 319(h) Contract G0143--Replicate Samples
Test America 9/13/10

Station 01

	Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
	TKN	mg/L	1.04	1.13	E351.2	8.29%	0-30
	NOx	mg/L	0.11	0.11	E353.2	0.00%	0-30
	TP	mg/L	0.170	0.167	E365.3	1.78%	0-30
Note 1	OP	mg/L	0.034	0.080	E365.2	80.70%	0-30
	TSS	mg/L	5.75	7.00	SM2540D	19.61%	0-25
	Color	pcu	100	70	SM2120B	35.29%	0-40
	Zinc	µg/L	4.47	5.06	200.8	12.38%	0-20
	Copper	µg/L	5.82	5.75	200.8	1.21%	0-20
	Chromium	µg/L	U	U	200.8	NA	0-20
	Cadmium	µg/L	U	U	200.8	NA	0-20
	TOC	mg/L	13.80	14.00	SM5310B	1.44%	0-25
Note 2	BOD	mg/L	2.10	1.50	SM5201B	33.33%	0-30
	Alkalinity	mg/L	182	180	SM2320B	1.10%	0-30

Station 02

	Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
	TKN	mg/L	0.87	1.12	E351.2	25.69%	0-30
	NOx	mg/L	0.08	0.07	E353.2	13.33%	0-30
	TP	mg/L	0.121	0.128	E365.3	5.62%	0-30
	OP	mg/L	0.066	0.066	E365.2	0.00%	0-30
Note 3	TSS	mg/L	3.75	2.75	SM2540D	30.77%	0-25
	Color	pcu	70	70	SM2120B	0.00%	0-40
	Zinc	µg/L	U	U	200.8	NA	0-20
Note 4	Copper	µg/L	4.17	5.88	200.8	34.03%	0-20
	Chromium	µg/L	U	U	200.8	NA	0-20
	Cadmium	µg/L	U	U	200.8	NA	0-20
	TOC	mg/L	13.60	13.90	SM5310B	2.18%	0-25
Note 2	BOD	mg/L	3.00	1.60	SM5201B	60.87%	0-30
	Alkalinity	mg/L	167	167	SM2320B	0.00%	0-30

Station 03

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	0.87	0.90	E351.2	2.37%	0-30
NOx	mg/L	0.04	0.04	E353.2	5.41%	0-30
TP	mg/L	0.083	0.086	E365.3	3.55%	0-30
OP	mg/L	0.037	0.037	E365.2	0.00%	0-30
TSS	mg/L	5.50	6.00	SM2540D	8.70%	0-25
Color	pcu	90	100	SM2120B	10.53%	0-40
Zinc	µg/L	U	3.56	200.8	NA	0-20
Copper	µg/L	6.20	7.84	200.8	NA	0-20
Chromium	µg/L	U	U	200.8	NA	0-20
Cadmium	µg/L	U	U	200.8	NA	0-20
TOC	mg/L	14.60	14.50	SM5310B	0.69%	0-25
BOD	mg/L	2.40	2.30	SM5201B	4.26%	0-30
Alkalinity	mg/L	153	159	SM2320B	3.85%	0-30

Note 1: The first sample was retested, and agreed with original value of 0.034 mg/L OP. The replicate was in line with split.
The first sample considered and outlier and discarded.
Note 2: BOD values very close to reporting limit. These differences considered inconsequential
Note 3: As with Note 2
Note 4: As with Note 2

Egret Marsh 319(h) Contract G0143--Replicate Samples
Test America 8/22/11

Station 01

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.55	1.57	E351.2	1.28%	0-30
NH3	mg/L	0.16	0.17	E350.1	6.06%	0-30
NOx	mg/L	0.15	0.15	E353.2	0.00%	0-30
TP	mg/L	0.167	0.189	E365.3	12.36%	0-30
OP	mg/L			E365.2	NA	0-30
TSS	mg/L			SM2540D	NA	0-25
Color	pcu			SM2120B	NA	0-40
Zinc	µg/L			200.8	NA	0-20
Copper	µg/L			200.8	NA	0-20
Chromium	µg/L			200.8	NA	0-20
Cadmium	µg/L			200.8	NA	0-20
TOC	mg/L			SM5310B	NA	0-25
BOD	mg/L			SM5201B	NA	0-30
Alkalinity	mg/L			SM2320B	NA	0-30

Station 02

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.44	1.22	E351.2	16.54%	0-30
NH3	mg/L	0.1	0.17	E350.1	51.85%	0-30
NOx	mg/L	0.15	0.15	E353.2	0.00%	0-30
TP	mg/L	0.167	0.189	E365.3	12.36%	0-30
TSS	mg/L			SM2540D	NA	0-25
Color	pcu			SM2120B	NA	0-40
Zinc	µg/L			200.8	NA	0-20
Copper	µg/L			200.8	NA	0-20
Chromium	µg/L			200.8	NA	0-20
Cadmium	µg/L			200.8	NA	0-20
TOC	mg/L			SM5310B	NA	0-25
BOD	mg/L			SM5201B	NA	0-30
Alkalinity	mg/L			SM2320B	NA	0-30

Station 03

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.23	1.03	E351.2	17.70%	0-30
NH3	mg/L	0.09	0.09	E350.1	0.00%	0-30
NOx	mg/L	0.13	0.13	E353.2	0.00%	0-30
TP	mg/L	0.065	0.088	E365.3	30.07%	0-30
TSS	mg/L			SM2540D	NA	0-25
Color	pcu			SM2120B	NA	0-40
Zinc	µg/L			200.8	NA	0-20
Copper	µg/L			200.8	NA	0-20
Chromium	µg/L			200.8	NA	0-20
Cadmium	µg/L			200.8	NA	0-20
TOC	mg/L			SM5310B	NA	0-25
BOD	mg/L			SM5201B	NA	0-30
Alkalinity	mg/L			SM2320B	NA	0-30

Egret Marsh 319(h) Contract G0143--Replicate Samples
Test America 8/29/11

Station 01

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.39	1.47	E351.2	5.59%	0-30
NH3	mg/L	0.382	0.373	E350.1	2.38%	0-30
NOx	mg/L	0.173	0.18	E353.2	3.97%	0-30
TP	mg/L	0.234	0.225	E365.3	3.92%	0-30
OP	mg/L	0.225	0.214	E365.2	5.01%	0-30
TSS	mg/L	6.5	7.5	SM2540D	14.29%	0-25
Color	pcu	100	100	SM2120B	0.00%	0-40
Zinc	µg/L	U	U	200.8	NA	0-20
Copper	µg/L	U	U	200.8	NA	0-20
Chromium	µg/L	U	U	200.8	NA	0-20
Cadmium	µg/L	U	U	200.8	NA	0-20
TOC	mg/L	14.30	14.40	SM5310B	0.70%	0-25
BOD	mg/L	2.60	2.60	SM5201B	0.00	0-30
Alkalinity	mg/L	184	184	SM2320B	0.00%	0-30

Station 02

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.31	1.25	E351.2	4.69%	0-30
NOx	mg/L	0.37	0.37	E353.2	0.00%	0-30
TP	mg/L	0.193	0.380	E365.3	65.27%	0-30
OP	mg/L	0.205	0.206	E365.2	0.49%	0-30
TSS	mg/L	12.00	12	SM2540D	0.00%	0-25
Color	pcu	125	125	SM2120B	0.00%	0-40
Zinc	µg/L	U	U	200.8	NA	0-20
Copper	µg/L	9.78	9.24	200.8	5.68%	0-20
Chromium	µg/L	U	U	200.8	NA	0-20
Cadmium	µg/L	U	U	200.8	NA	0-20
TOC	mg/L	14.40	14.30	SM5310B	0.70%	0-25
BOD	mg/L			SM5201B	#DIV/0!	0-30
Alkalinity	mg/L	179	180	SM2320B	0.56%	0-30

Station 03

Parameter	Units	Value	Replicate Value	Method	% RPD	limit % RPD
TKN	mg/L	1.13	1.12	E351.2	0.89%	0-30
NOx	mg/L	0.34	0.34	E353.2	0.00%	0-30
TP	mg/L	0.153	0.194	E365.3	23.63%	0-30
OP	mg/L	0.180	0.189	E365.2	4.88%	0-30
TSS	mg/L	6.00	5.00	SM2540D	18.18%	0-25
Color	pcu	125	125	SM2120B	0.00%	0-40
Zinc	µg/L	4.73	5.26	200.8	10.61%	0-20
Copper	µg/L	8.96	8.53	200.8	NA	0-20
Chromium	µg/L	U	U	200.8	NA	0-20
Cadmium	µg/L	U	U	200.8	NA	0-20
TOC	mg/L	15.00	15.00	SM5310B	0.00%	0-25
BOD	mg/L			SM5201B	NA	0-30
Alkalinity	mg/L	164	169	SM2320B	3.00%	0-30

APPENDIX 3
ATSDEM DEVELOPMENT REVIEW

From HydroMentia (2005) "S-154 Single Stage Algal Turf Scrubber® - Final Report"
pg 53-74 for SFWMD Contract C-13933

DEVELOPMENT OF AN ATS™ DESIGN MODEL (ATSDEM)

Technical Rationale and Parameter Determination

Modeling of complex, expansive biological processes requires recognition that system behavior is a composite of a number of physical, chemical and biological reactions, and that each has the capability of exerting influence over the other. Within most biological treatment systems, the dominant reactions revolve around enzymatic conversion. These enzymatic reactions will influence both tissue creation and tissue reduction. The more expansive the biological system, the more difficult it becomes to identify and project the dynamics of specific reactions. For example, Walker[1], in modeling treatment wetlands, known as Stormwater Treatment Areas or STA, utilized the resultant, documented removal of phosphorus to establish a general first order equation in which removal is projected, but the mechanisms involved are not individually assessed. This model, Dynamic Model for STA, or DMSTA, while quite reliable over a set period of time, projects only the rate at which phosphorus is accumulated through sediment accretion. Admittedly, it does not include efforts to model or optimize plant productivity, as noted by Walker[21] –"*The model makes no attempt to represent specific mechanisms, only their net consequences, as reflected by long-term average phosphorus budget of a given wetland segment.*"

The principle weakness of the DMSTA approach is that it presumes, and requires storage (peat accumulation), or **$dA/dt > 0$,** with **A** the accreted peat, and **t** is time, while assuming that there is no change in the rate factor, **K_e ,** also know as the effective velocity, or **$dK_e /dt = 0$.** This relationship is incongruous with the present understanding of ecological succession, as it assumes no relationship between the collection of complex ecological processes and the accumulated stores within the ecosystem. This presumption does not eliminate the inevitability that ultimately there will be a changed ecostructure in which the mechanisms and rates of phosphorus management will change. The need recently to remove accumulated peat within an STA near the City of Orlando[2] has validated this suspected vulnerability.

Within more compact intensive processes, such as activated sludge and fermentation chambers, as well as MAPS programs, greater management effort is extended towards a specific product, and typically this product is targeted specifically within the modeling efforts. For example, with activated sludge, design and operation relies upon the rate of production of the diverse population of heterotrophic and chemoautotrophic microorganisms, which collectively generate the desired oxidation and consumption of organic debris. These processes are typically compatible with the principles of ecological succession, as the accumulated biomass is removed at frequent intervals, therefore, **$dA/dt = 0$.** This removal stabilizes the system's dynamic, and permits long-term reliability.

MAPS, which include ATS™, are such stabilized systems that rely upon photoautrophic (green plants and certain bacteria) production, and the subsequent removal (harvesting) of accumulated production to preserve relative predictable and reliable performance. Managed photoautotrophic production of course is the basis of much of established agriculture, and has been practiced for several thousands of years—therefore it is not a new concept, and it is understandable that certain aspects of ATS™ resemble conventional farming. The difference between an ATS™ and traditional farming is oriented more around purpose than technique, although to some extent purpose directs technique. With ATS™ and other MAPS it is the intent not to maximize production for the sole purpose of food or fiber cash product generation, but rather maximizing production for the principal purpose of removal of pollutant nutrients. With an ATS™, the resultant crop value is secondary—the larger and more valuable product is enhanced water quality. In other words, algae is not grown because it fixes carbon and thereby generates a valuable product, but because in its growth, supported by the fixation of carbon, it incorporates phosphorus and nitrogen in its tissue, and thereby provides an efficient mechanism for water treatment.

As with many biological water treatment processes, the dynamics associated with the ATS™ can be described as a first-order reaction, where the rate of reaction is proportional to the concentration of the substrate. This can be expressed through Equations 1 through 3.

$$dS/dt = -kS \qquad \textbf{Equation 1}$$

or

$$dS/S = -kdt \qquad \textbf{Equation 2}$$

Integrated between **t = 0** to **t = i** or

$$\ln(S_i/S_0) = -kt \text{ or } S_i = S_0e^{-kt} \qquad \textbf{Equation 3}$$

Where **S** is the nutrient concentration, **t** is time, and **k** is the rate constant

This general expression was initially applied to enzymatic reactions as described by Michaelis-Menten[19]. While the value **"k"** within the laboratory was in these vanguard studies applied to a specific substrate and a specific enzyme, the **"k"** value, as noted previously, has come to be identified within more complex biological treatment processes with the cumulative effect of a broad and fluctuating collection of reactions and organisms. While repetitive experimentation in such cases can strengthen confidence in establishing values for **"k"** on a short-term basis, it cannot, as noted previously, determine the rate of change in **"k"** as environmental conditions change within a system, such as a treatment wetland, which is not managed through tissue removal —i.e. as accretion begins to change to chemical and physical complexion of the process.

Within sustainable biological processes, in which biomass removal allows long-term stabilization of the chemical and physical environment, it is possible to orient the first-order reaction around the principal mechanism involved in nutrient removal—that being actual biomass productivity. In some cases, modeling of this productivity can target a dominant species, such as with the WHS™ technology. However, in most cases, the application of growth models is applied to a set community of involved organisms, such as with activated sludge, fixed film technology, fermentation and ATS™.

Managing a collection of organisms in this manner presents the design challenge of projecting performance of a functioning ecosystem and, in operations, manipulating parameters, to the extent practical, (e.g. hydraulic loading rate, chemical supplementation) such that the most efficient ecostructure in terms of removal of the targeted pollutant, is sustained, and thus provided a selective advantage.

When a biological unit process is oriented around sustainable community production, the first order kinetics are generally applied through the Monod[20] relationship.

$$\mathbf{Z_t = Z_0 e^{\mu t}} \qquad \textbf{Equation 4}$$

Where **Z** is the biomass weight and μ is the specific growth rate (1/time) when:

$$\mu = \mu_{max} S/(K_s+S) \qquad \textbf{Equation 5}$$

Where μ_{max} is the maximum potential growth rate and K_s is the half-saturation constant for growth limited by **S**, or the concentration of **S** when $\mu = ½\ \mu_{max}$.

Considering the flow dynamic of the ATS™, the system may be viewed as a plug flow system. Recognizing that the average biomass at any one time on the ATS™ is assumed stable **(Z_{ave})**, and relatively constant when harvesting is done frequently, and the reduction rate at steady state of **S** is also a function of the concentration of **S** within the tissue or S_t, then S_{y1} at a sufficiently small increment ***"y"*** down the ATS™ may be expressed as:

$$S_{y1} = S_{y0} - \{[S_t\{Z_{ave} e^{[\mu][(y1-y0)/v]} - Z_{ave}\}]/[q(y_1-y_0)/v]\} \qquad \textbf{Equation 6}$$

Where "**v**" is the flow velocity down the ATS™ at unit flow rate "**q**".

The conditions required for Equation 6 are that the temperature is optimal for growth, that solar intensity is relatively constant, that the process is irreversible, and that there is no inhibitory effects related to **S** within the ranges contemplated, and that the difference between S_{y1} and S_{y0} is sufficiently small down **"y"**, as to not influence μ**.** If temperature variations are expected, their impacts need to be considered using the classical V'ant Hoff-Arrhenius[3] equation (Equation 7), which may be incorporated into the relationship as noted in Equations 8.

$$\mu_{opt}/\mu_1 = \Theta^{(Topt-T1)} \quad \text{or} \quad \mu_1 = \mu_{opt}/\Theta^{(Topt-T1)} \qquad \textbf{Equation 7}$$

Where μ_{opt} is the growth rate for given **S** at the optimal growing temperature ^oC, T_{opt}, and μ_1 is the growth rate for the same given **S** at some temperature ^oC, T_1, when $T_1 < T_{opt}$, and Θ is an empirical constant ranging from 1.03 to 1.10.

$$S_{y1} = S_{y0} - \{[S_t\{Z_{ave} e^{[\mu(y1-y0)/v][1/\Theta^{(Topt-T1)}]} - Z_{ave}\}]/[q(y_1-y_0)/v]\} \qquad \textbf{Equation 8}$$

In more northern applications, adjustments might need to be made for light intensity as well. While there are seasonal fluctuations in Florida for both solar intensity and photoperiod, the impacts are assumed to be minimal when compared to temperature influences, and can be incorporated into the empirical determination of Θ.

Finally, if the right side of Equation 5 is included for μ, then the relationship for concentration of **S**, at the end of segment $\mathbf{y_1}$ becomes Equation 9.

$$\mathbf{S_{y1} = S_{y0} - \{[S_t\{Z_{ave}e^{[\mu maxSy0/(Ks+Sy0)][(y1-y0)/v][1/\Theta^{(Topt-T1)}]} - Z_{ave}\}]/[q(y_1-y_0)/v]\}} \quad \textbf{Equation 9}$$

Estimation of μ_{max} and $\mathbf{K_s}$ can be done by manipulation of the Monod[20] relationship, noted as Equation 5 to yield linear equations to which field data can be applied and plotted, as discussed by Brezonik[4]. Several techniques are discussed, including Lineweaver-Burke[5], Hanes[6] and Eadie-Hofstee[7]. It is suggested that of the three methods, the Hanes[25] method, which involves the plot of substrate concentrations **S**, as the independent variable, and the quotient of substrate concentration and growth rate, **[S]**$/\mu$, as the dependent variable is the preferred of the three. In such a plot, μ_{max} is represented as the inverse of the slope of the linear equation:

$$\mathbf{[S]/\mu = (K_s/\mu_{max}) + (1/\mu_{max})\,[S]} \quad \textbf{Equation 10}$$

Accordingly, K_s is the negative of the x-intercept, or K_s = -[S], when [S]$/\mu$= 0.

Plotting the single flow data set using the Hanes method is helpful at providing some indication of expected general range of μ_{max} and $\mathbf{K_s}$. The fact that data collection, particularly as related to growth, as noted earlier, is inherently vulnerable to error, and that there are undoubtedly other factors involved in determining production rate that must be considered when deciding how to apply a developed model, and in determining the extent of contingencies included in establishing sizing and operational strategy, non-linear regression analysis, a technique beyond the scope of this review, may result in a set of parameters that provide closer projections.

The data set used in establishing the Hanes plot as shown in Table 4-1, were created from field data incorporated with the following approach:

1. Data was used for that period identified as the adjusted POR, as inclusion of results impacted by the hurricane events, and the associated power outages represent unusual perturbations that would likely influence system performance. This POR was from May 17, 2004 to August 23, and October 23 to December 6, 2004.
2. Water loss was considered negligible down the ATS™.
3. Crop production was calculated as the mass of total phosphorus removed over the monitoring period divided by the tissue phosphorus content as % dry weight, with the tissue phosphorus content calculated using the equation note in Figure 3-7.

4. Growth rate is calculated by $\ln(Z_t/Z_0)/t = \mu$ with Z_0, the initial algal biomass assumed to be 10 g/m^2 on a dry weight basis, adjusted to optimal growing temperature. This value is based upon a reasonable harvest of 90-95% of standing crop.
5. Optimal growing temperature (water) is set at 30^o C, with $\Theta = 1.10$.
6. Substrate concentration is set as the mean between influent and effluent concentrations.
7. Available carbon concentration is calculated using the method described in Section 3-4.

Scattergrams of the total phosphorus, total nitrogen, available carbon, and linear hydraulic loading rate with calculated growth rate are noted in Figures 4-9 to 4-12. The patterns as seen provide indication that phosphorus influences upon growth rate are more dramatic at lower concentrations, with a “plateau” noted at high concentration indicating rather low values of K_s. Phosphorus appears to be more influential than nitrogen or available carbon. The LHLR however, as noted previously, appears to be quite influential. This may be related to the greater available mass of nutrients per unit time, or to the influences of increased flow velocity, as discussed in a later segment of this section.

Based upon literature review and field observations, it is possible that algae productivity and nutrient removal rates are impacted by more than one parameter, particularly at low concentrations. Brezonik[8] includes in his discussions related to Monod and diffusion algal growth dynamics the recognition that more than one controlling factor may be involved, and that the Monod relationship may need to reflect this within the model, as noted in the following equation form:

$$\mu = \mu_{max.} \{[P]/(K_p+[P])\} \{[N]/(K_n+[N])\} \{[CO_2]/(K_C+[CO_2])\}\ldots \qquad \textbf{Equation 11}$$

Noted in Table 4-2 are the results of Hanes plots for the four parameters considered. It is not surprising that total phosphorus shows good correlation with growth rate, as total phosphorus removal was used in calculating algae production. Nonetheless, it does appear reasonable that phosphorus is involved in growth rate determination, as noted in Figures 4-13 through 4-15. What is more difficult to explain are the negative values of K_S, most notable during the October to December period. Initially, this might be interpreted as indication of inhibition at high concentrations. However, at these concentrations (500-1,000ppb), there is no evidence within the literature that phosphorus inhibits algae production. Rather, it appears that what may be associated with this condition is the fact that growth calculated by phosphorus uptake during this period was an underestimate of actually measured growth—see Figures 3-5 and 3-6. The implication therefore is that during this time, the system drew its phosphorus from some source other than the water column—such as stores. As discussed previously, there is little space available for such stores within an ATS™, so it is suspected that the more likely explanation for these anomalies is data error.

The relationship over the adjusted POR between LHLR and growth rate appears rather clear, as noted in Figures 4-16 through 4-18, at least within the ranges studies. The correlations shown are reasonable, even with a few “outlier” data points. As noted, the relationships associated with nitrogen and carbon are not as clear.

Table 4-1: Data set for adjusted POR

	Week ending	Period days	Average Water T C	Total P Average Concentration ppb	Total N Average Concentration mg/l	Available Carbon Average Concentration mg/l	LHLR gallons/ minute-ft	Estimated Algae Production dry grams	Calculated growth rate 1/hr
South Floway	5/17/2004	6	27.2	171	1.30	13.83	6.20	13,194	0.021
	5/24/2004	7	27.8	190	1.40	13.83	6.09	18,351	0.020
	5/31/2004	7	28.4	218	2.01	19.14	5.60	28,746	0.021
	6/7/2004*	7	29.2	178	1.90	15.24	3.90	13,681	0.015
	6/14/2004	7	27.1	116	1.70	17.98	4.41	14,627	0.019
	6/21/2004	7	30.2	106	1.48	18.56	5.62	12,103	0.013
	6/28/2004	7	31.4	75	1.49	16.23	2.69	13,488	0.012
	7/5/2004	3	32.3	57	1.70	14.07	5.12	5,277	0.018
	7/12/2004	7	31.1	72	1.30	14.07	4.44	4,094	0.007
	7/19/2004	7	30.4	48	1.19	11.90	4.82	463	0.002
	7/26/2004	7	29.4	61	1.05	12.16	4.15	6,947	0.011
	8/2/2004	7	29.5	55	1.21	22.68	4.52	6,874	0.011
	8/9/2004	7	28.3	57	0.96	11.55	3.61	4,204	0.010
	8/16/2004	5	29.7	63	1.20	22.81	5.82	6,670	0.015
	8/23/2004	7	30.4	336	2.20	30.72	3.37	18,905	0.015
	10/25/2004	7	28.0	885	1.28	25.58	5.47	6,959	0.013
	11/1/2004	7	28.3	830	2.11	11.74	2.95	3,324	0.009
	11/8/2004	7	28.2	715	2.63	26.33	6.48	3,912	0.009
	11/15/2004	7	24.8	625	1.57	25.46	4.93	5,260	0.015
	11/22/2004	7	24.3	500	2.01	21.53	4.82	2,245	0.010
	11/29/2004	7	24.7	300	1.11	17.09	4.90	16,022	0.025
Central Floway	5/17/2004	6	26.7	186	1.25	11.81	22.84	30,193	0.030
	5/24/2004	7	27.3	190	1.50	11.81	22.98	71,964	0.030
	5/31/2004	7	28.0	223	2.24	14.11	22.60	110,742	0.032
	6/7/2004*	7	29.1	178	1.90	11.27	25.11	79,193	0.026
	6/14/2004	7	27.3	129	1.79	13.54	24.55	56,162	0.029
	6/21/2004	7	30.2	119	1.53	13.35	23.40	45,956	0.021
	6/28/2004	7	30.9	88	1.54	11.98	19.14	34,307	0.018
	7/5/2004	3	31.5	65	1.26	11.17	26.51	26,807	0.036
	7/12/2004	7	30.5	77	1.30	10.37	18.30	16,849	0.015
	7/19/2004	7	30.5	48	1.15	18.04	19.57	1,910	0.005
	7/26/2004	7	29.6	67	1.10	9.88	16.96	20,676	0.017
	8/2/2004	7	30.2	66	1.19	15.47	19.52	15,628	0.015
	8/9/2004	7	28.4	58	0.96	15.62	14.21	16,114	0.018
	8/16/2004	5	29.1	70	1.12	15.76	22.72	19,803	0.025
	8/23/2004	7	30.2	346	2.21	28.94	11.78	64,722	0.023
	10/25/2004	7	27.5	880	1.28	17.65	16.47	24,019	0.022
	11/1/2004	7	27.3	815	2.05	10.59	17.97	30,617	0.024
	11/8/2004	7	27.5	710	2.17	18.03	17.22	13,906	0.018
	11/15/2004	7	24.9	630	1.81	17.82	17.14	14,583	0.024
	11/22/2004	7	23.4	490	1.94	16.00	17.03	15,984	0.028
	11/29/2004	7	24.4	335	1.09	12.84	17.33	22,940	0.029
	12/5/2004	6	23.3	240	1.52	12.84	18.16	26,852	0.040
North Floway	5/17/2004	6	27.0	171	1.25	11.66	10.52	22,410	0.026
	5/24/2004	7	27.5	210	1.60	11.66	10.71	18,990	0.020
	5/31/2004	7	28.2	223	2.19	13.99	9.56	46,102	0.025
	6/7/2004*	7	29.1	193	2.00	11.17	9.36	23,893	0.019
	6/14/2004	7	27.1	119	1.62	13.72	9.10	26,433	0.024
	6/21/2004	7	30.2	110	1.58	13.37	9.41	23,294	0.017
	6/28/2004	7	31.0	83	1.54	12.09	8.78	16,184	0.014
	7/5/2004	3	32.1	58	1.22	11.07	19.10	15,493	0.028
	7/12/2004	7	31.1	68	1.25	10.04	4.70	10,084	0.011
	7/19/2004	7	30.8	41	1.11	17.55	9.56	5,363	0.009
	7/26/2004	7	30.1	59	1.05	9.80	9.40	14,860	0.015
	8/2/2004	7	29.6	55	1.16	14.86	8.09	13,400	0.015
	8/9/2004	7	28.3	53	0.96	15.31	8.10	9,813	0.015
	8/16/2004	5	29.7	81	1.20	15.76	6.66	3,035	0.010
	8/23/2004	7	30.4	326	2.10	29.99	2.23	11,409	0.013
	10/25/2004	7	27.8	630	1.28	18.05	7.99	16,982	0.019
	11/1/2004	7	27.8	582	2.23	10.86	8.79	17,389	0.019
	11/8/2004	7	28.0	524	2.26	18.47	7.22	13,229	0.017
	11/15/2004	7	24.5	468	1.58	17.95	9.01	17,174	0.026
	11/22/2004	7	24.9	398	1.85	16.01	9.11	18,348	0.026
	11/29/2004	7	24.6	325	1.08	12.60	9.24	17,264	0.026

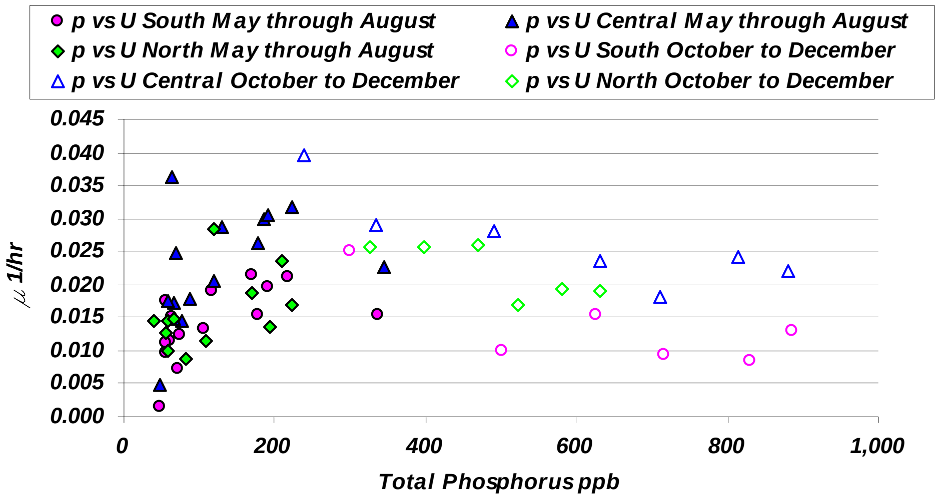


Figure 4-9: Total phosphorus Vs. calculated growth rate adjusted POR data set

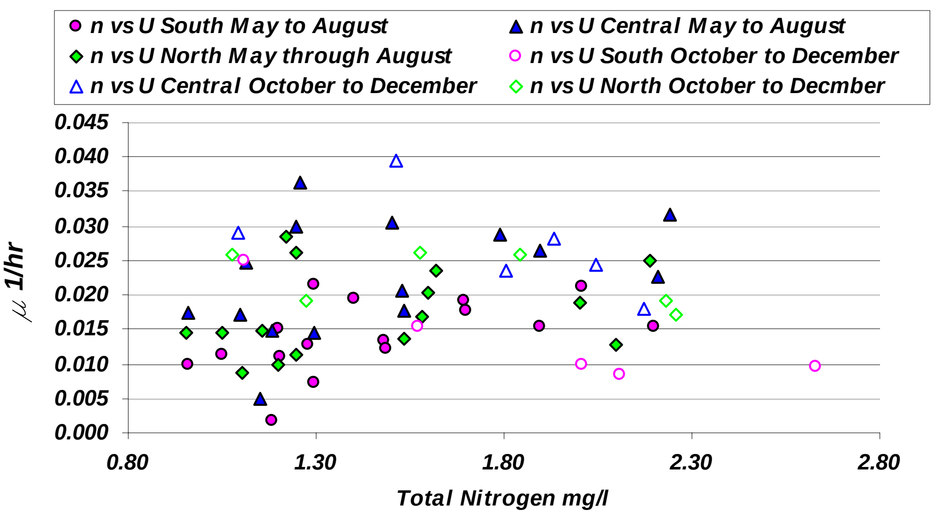


Figure 4-10: Total nitrogen Vs. calculated growth rate adjusted POR data set

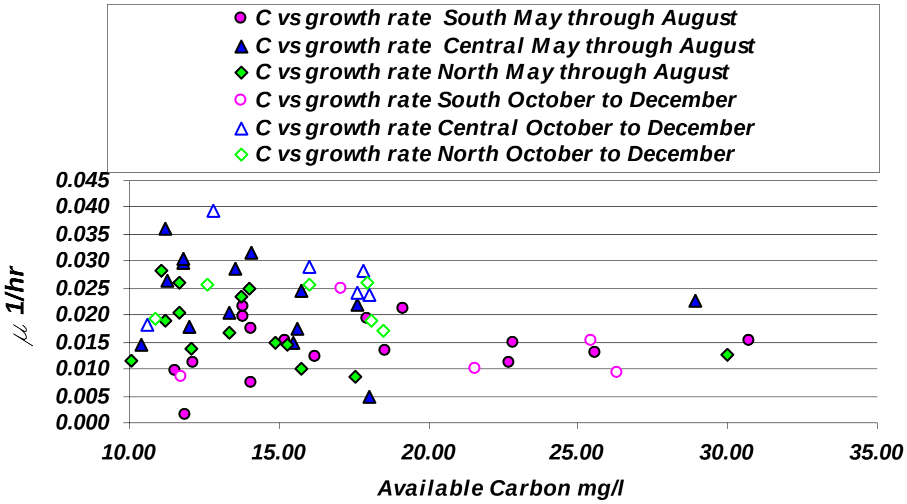


Figure 4-11: Available Carbon Vs. calculated growth rate adjusted POR data set

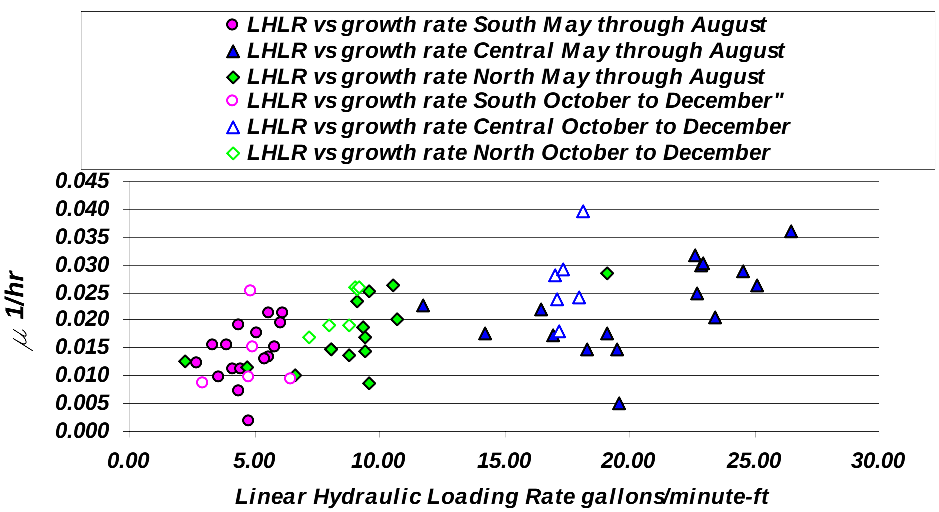


Figure 4-12: Linear Hydraulic Loading Rate Vs. calculated growth rate adjusted POR data set

Table 4-2: Results of Hanes analysis

Floway	Time Period	Parameter	r^2	μ_{max} 1/hr	K_s *
Combined	Total POR	TP	0.720	0.015	-15
Combined	May through August	TP	0.327	0.025	71
Combined	October to December	TP	0.740	0.015	-81
Combined	Total POR	TN	0.021	0.031	1.72
Combined	May through August	TN	0.002	-0.091	-11.04
Combined	October to December	TN	0.536	0.017	-0.32
Combined	Total POR	Available C	0.126	0.014	-0.27
Combined	May through August	Available C	0.078	0.016	3.16
Combined	October to December	Available C	0.590	0.013	-5.17
Combined	Total POR	LHLR	0.159	0.030	8.6
Combined	May through August	LHLR	0.147	0.029	9.5
Combined	October to December	LHLR	0.805	0.037	5.7

*** ppb for TP, mg/l for TC and Carbon, gpm/ft for LHLR**

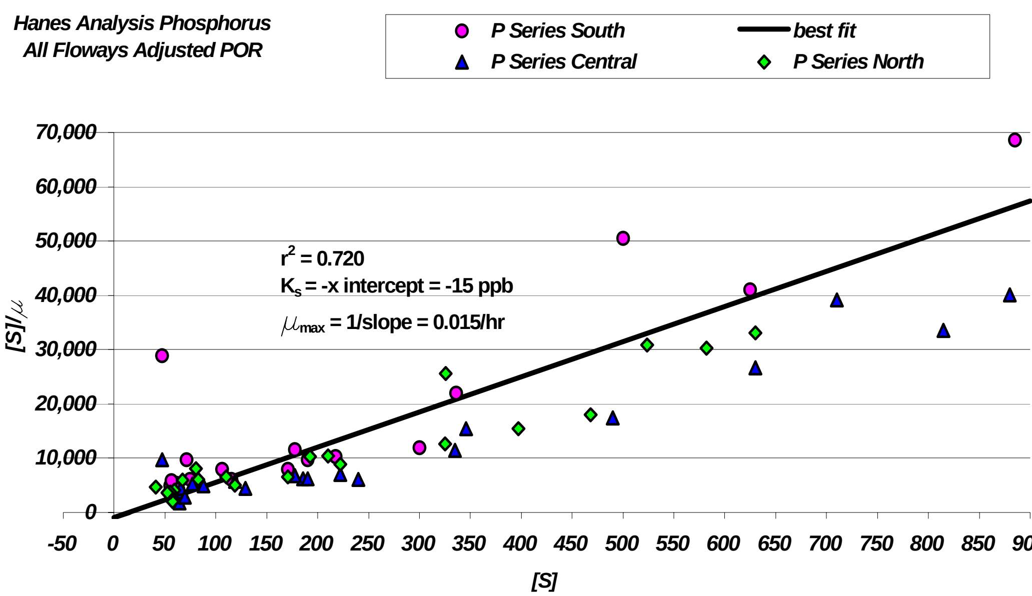


Figure 4-13: Hanes plot total phosphorus all floways over adjusted POR

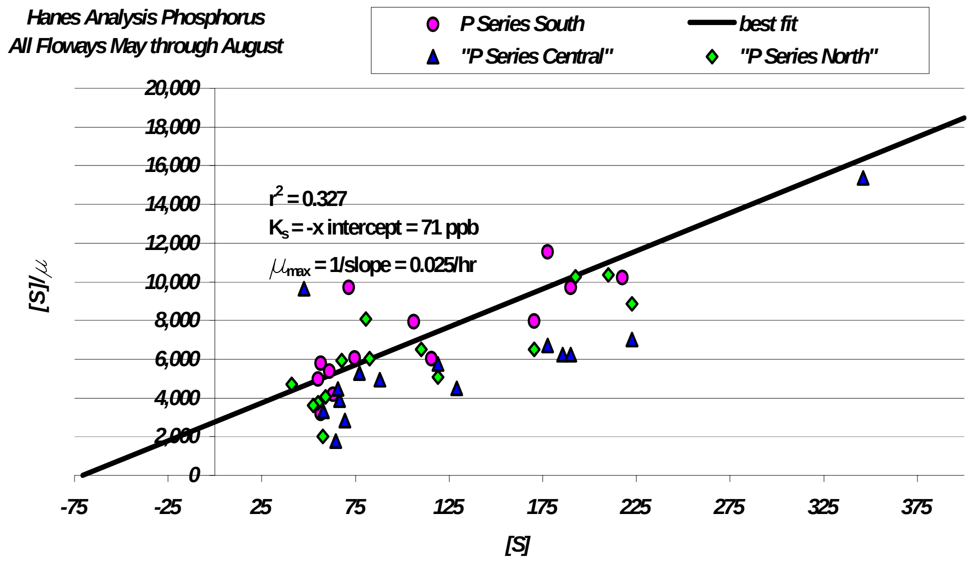


Figure 4-14: Hanes plot total phosphorus all floways May through August

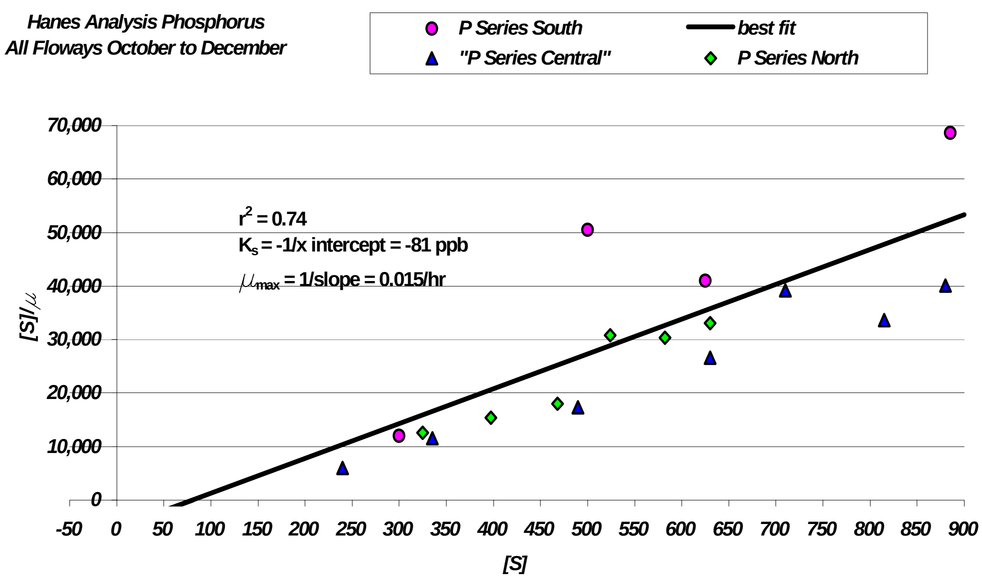


Figure 4-15: Hanes plot total phosphorus all floways October to December

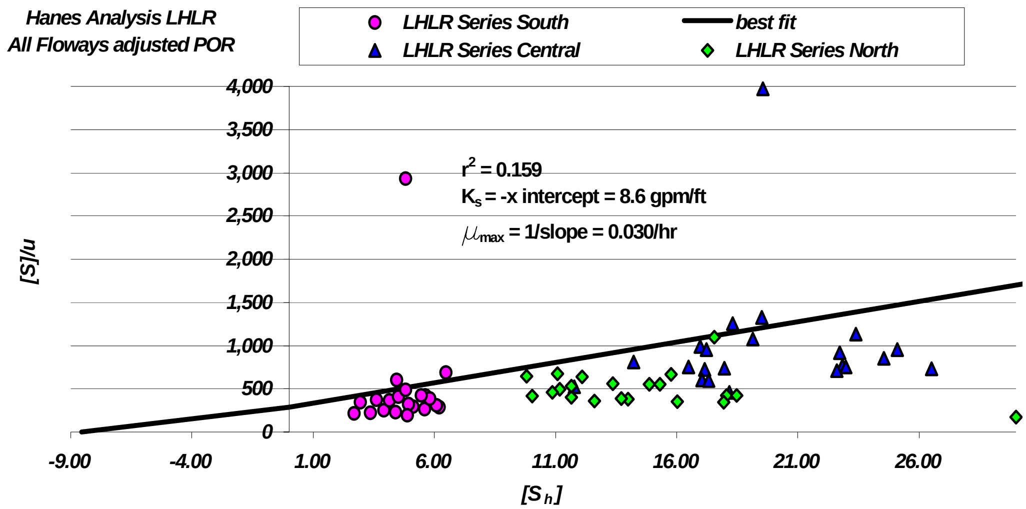


Figure 4-16: Hanes plot LHLR all floways over adjusted POR

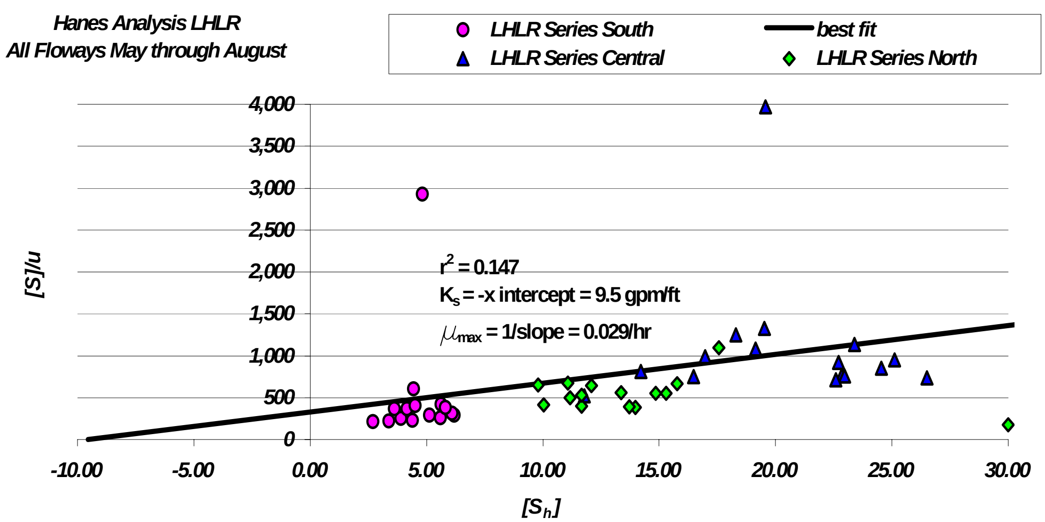


Figure 4-17: Hanes plot LHLR all floways May through August

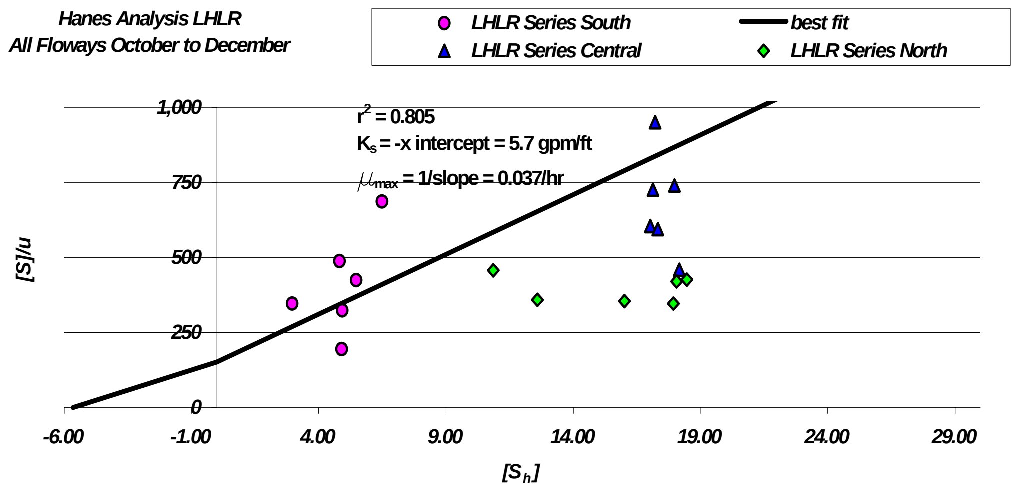


Figure 4-18: Hanes plot LHLR all floways October to December

The issue of the influence of flow rate and velocity upon algae growth rate has been extensively reviewed within the literature. Brezonik[9] in a detailed discussion regarding the relative role of nutrient uptake within algae as influenced by both Monod dynamics and boundary layer transport through molecular diffusion, presents work done on models that include consideration of both phenomena. He notes that at high substrate [S] concentrations, boundary-layer diffusion control over growth rate becomes negligible. At low concentrations, however, diffusion influences can overwhelm the Monod kinetics, and uptake projections based solely upon the Monod growth equations without inclusion of diffusion influence can be higher than observed. He identifies a factor **1/(1+P')** as representative of the proportion of the total resistance to nutrient uptake caused by diffusion resistance, where:

$$P' = a(14.4\pi D_s r_c K_s)/V \qquad \textbf{Equation 12}$$

When ***a*** = shape factor applied to algal cell shape

D_s = Fick's diffusion coefficient as substrate changes per unit area per unit time

r_c = algal cell radius

K_s = Substrate concentration when uptake rate ***v*** is ½ of maximum uptake rate ***V***

V = Michaelis-Menten substrate uptake rate mass per unit time

The Michaelis-Menten ***V*** may be seen in this case as analogous to the Monod maximum growth rate or μ_{max}, therefore it is reasonable to express the equation as:

$$P' = a(14.4\pi D_s r_c K_s)/\mu_{max}. \qquad \textbf{Equation 13}$$

Brezonik includes this P' into the Monod relationship at low concentrations of S, resulting in the equation:

$$\mu = \mu_{max.} [P'/(P'+1)]S/K_s$$ **Equation 14**

It is noted then, the smaller P' the greater the influence of growth.

Observations regarding velocity influences relate to the general thickness of the boundary layer around the cell wall. Carpenter et al.[16] discuss the influence water movement has upon the thickness of the boundary layer. This is consistent with discussions offered by Brezonik who notes that "*turbulence increases nutrient uptake rates at low concentrations where diffusion limitations can occur*". He generally observed that at low concentrations Monod dynamics can be influenced by boundary layer conditions, and uptake rates may be lower than predicted by Monod kinetics. This is relevant when discussing the use of periphytic algae for reduction of total phosphorus to low concentrations, because passive systems such as PSTA which rely upon extensive areas and very low velocities, would be expected to be much more restrained by boundary layer thickness at low concentrations, which as noted by both Carpenter et al. and Brezonik, is inversely related to the gradient through which diffusion occurs. The ATS™ system by adding the influence of flow and turbulence can substantially enhance the uptake rate and production of the algal turf.

Turbulence and water movement therefore serve to increase the rate of substrate transport, and hence decrease the importance of diffusion. This quite logically is why the use of high velocities and turbulence (e.g. oscillatory waves) enhances algal nutrient uptake. Brezonik notes that in low nutrient conditions there exists a minimum velocity (u_{min}) at which diffusion limitation of nutrient uptake is avoided. He defines this mathematically as:

$$u_{min} = (2D_s/r_c)\{(2/P')-1\}$$ **Equation 15**

This means that at P' = 2, u_{min} = 0, and u_{min} increases as P' decreases. Values for P' of some algae species are provided, ranging from 0.33 to 680, but there is no discussion offered for assessing the cumulative influence of an algal turf community upon the general role of diffusion or how u_{min} might be determined on the ecosystem level. Rather, empirical information such as that provided by Carpenter et al. and work such as that done on the single-stage ATS™ floways can provide insight into the reaction of algal communities to velocity changes.

It is noteworthy that at low nutrient concentrations, adapted algae species would likely be characterized by a low K_s value. This is validated by Brezonik, who notes the difficulty in determining the controlling influence of nutrients upon algae production at low nutrient levels, as "*K_s may be below analytical detection limits—making it difficult to define the μ vs. [S] curve*." He includes some of the documented K_s values for several algae species associated with low nutrients. Phosphate appears as a limiting nutrient in several cases, with K_s values as low as 0.03 μM as PO_4, or about 3 ppb as PO_4, or just less than 1 ppb as phosphorus. As K_s is directly proportional to P', then it would not be unexpected that at low nutrient levels, P' would be comparatively small, and hence u_{min} comparatively large—the implication being that elimination of diffusion influence becomes very important, and hence flow velocity becomes an important design parameter. As noted, Kadlec and Walker[9] made reference to the influence of flow velocity upon the efficacy of PSTA systems. With velocities orders of magnitude greater within ATS™ systems, it becomes an even more essential design component with ATS™. The inclusion of higher velocities and oscillatory motion within the ATS™ operational protocol allows contemplation of much higher phosphorus uptake rates, which has broad economic implications.

One practical way to include flow in an operational model, is to treat LHLR as a controlling parameter. It seems appropriate then to consider a growth model, as suggested by Brezonik, in which two factors are included in the Monod equation (see Equation 10). It seems reasonable to include both total phosphorus and LHLR in the case of this dataset. The parameters **K$_s$** and μ_{max} can then be approximated through convergence to the lowest standard error between actual and projected total phosphorus concentration. Once the parameters are so calibrated with the Central Floway data, then the model reliability can be tested with data from the North and South Floways. This was done, applying the following relationship, as modified from Equation 9:

$$S_{pp} = S_{pi} - \{[S_t\{Z_o e^{\mu max\,[\{Spa/(Ksp+Spa)]\,[(Lp/(Khp+Lp)][24t]\,[1/\Theta^{(Topt-T1)}} - Z_o\}]/V_p\}$$ **Equation 16**

Where S_{pp} = projected effluent total phosphorus concentration for sampling period

S_{pi} = Influent total phosphorus concentration for sampling period

Z_o = Initial algal standing crop at beginning of sampling period

S_{pa} = Mean total phosphorus concentration across ATS™ for sampling period

K_{sp} = Monod half-rate coefficient total phosphorus

L_p = Linear Hydraulic Loading Rate for sampling period

K_{hp} = Monod half-rate coefficient LHLR

t = sampling period time in days

V_p = Volume of flow during sampling period

The result of the calibration run for the Central floway is shown in Table 4-3 and Figure 4-19. The parameter set which resulted in the best projection (lowest standard error=40.61

ppb) was μ_{max} = 0.04/hr, $\mathbf{K_{sp}}$ = 37 ppb, $\mathbf{K_{hp}}$ = 9.3 gpm/ft, $\mathbf{T_{opt}}$ = 29.9 °C and Θ = 1.10, with an initial standing crop of 10 dry-g/m^2.Using these values, the model was applied to the other two floways, as noted in Figures 4-20 and 4-21.

Table 4-3: ATSDEM Projection effluent total phosphorus Central Floway

$Z_{0\ dry}$-g	1390
Θ	1.10
T_{opt} °C	29.9
K_{sp} ppb	37
K_{sh} gpm/ft	9.30
μ_{max} 1/hr	0.04

	Week ending	Period days	Average Water Temperature C	Period Flow gallons	Sp Average P ppb	Sh LHLR gpm/ft	Estimated P tissue Content	Field Calculated Growth Rate	Projected Growth Rate	Influent Total P ppb	Effluent Total P ppb	Projected Total P
Central	**5/17/2004**	**6**	26.7	986,787	186	22.8	0.63%	0.026	0.017	211	160	184
	5/24/2004	**7**	27.3	1,204,631	190	23.0	0.63%	0.028	0.019	240	140	197
	5/31/2004	**7**	28.0	1,157,989	223	22.6	0.65%	0.030	0.020	305	140	245
	6/7/2004	**7**	29.1	1,139,115	178	25.1	0.63%	0.028	0.022	235	120	151
	6/14/2004	**7**	27.3	1,265,598	129	24.6	0.60%	0.026	0.018	164	94	133
	6/21/2004	**7**	30.2	1,237,320	119	23.4	0.59%	0.025	0.022	148	90	74
	6/28/2004	**7**	30.9	1,179,360	88	19.1	0.57%	0.023	0.021	110	66	53
	7/5/2004	**3**	31.5	964,656	65	26.5	0.56%	0.051	0.022	85	44	77
	7/12/2004	**7**	30.5	572,540	77	18.3	0.57%	0.019	0.019	99	55	15
	7/19/2004	**7**	30.5	922,204	48	19.6	0.55%	0.008	0.016	49	46	19
	7/26/2004	**7**	29.6	986,135	67	17.0	0.56%	0.020	0.016	82	51	53
	8/2/2004	**7**	30.2	854,905	66	19.5	0.56%	0.019	0.018	79	52	34
	8/9/2004	**7**	28.4	983,700	58	14.2	0.55%	0.019	0.013	70	46	54
	8/16/2004	**5**	29.1	716,421	70	22.7	0.56%	0.028	0.017	90	49	70
	8/23/2004	**7**	30.2	817,852	346	11.8	0.73%	0.027	0.021	422	270	317
	10/25/2004	**7**	27.5	830,325	880	16.5	1.05%	0.021	0.020	920	840	801
	11/1/2004	**7**	27.3	905,817	815	18.0	1.01%	0.023	0.020	860	770	754
	11/8/2004	**7**	27.5	867,933	710	17.2	0.95%	0.018	0.020	730	690	626
	11/15/2004	**7**	24.9	864,060	630	17.1	0.90%	0.018	0.015	650	610	605
	11/22/2004	**7**	23.4	858,542	490	17.0	0.81%	0.019	0.013	510	470	483
	11/29/2004	**7**	24.4	873,224	335	17.3	0.72%	0.021	0.014	360	310	332
	12/5/2004	**6**	23.3	784,534	240	18.2	0.66%	0.026	0.012	270	210	255

Mean TP Effluent actual ppb	**242**
Mean TP Effluent projected ppb	**251**
Standard error of estimate ppb	**40.61**

The model displayed reasonable, and conservative projections, and may be considered applicable for initial sizing of proposed facilities. Depending upon the level of performance demand placed upon the facility, the design engineer may want to include a contingency factor to cover the standard error, which ranged from 17% to 35%. Considering that the difference between the actual and projected mean effluent concentrations for the POR were so close, it is concluded that for long-term projections, the ATSDEM model is suitable for ATS™ programs that fall within the general water quality and environmental ranges studied. In some cases, particularly if there are significant differences in conditions, or when performance tolerances are small, "bench" scale testing may be a recommended pre-design exercise.

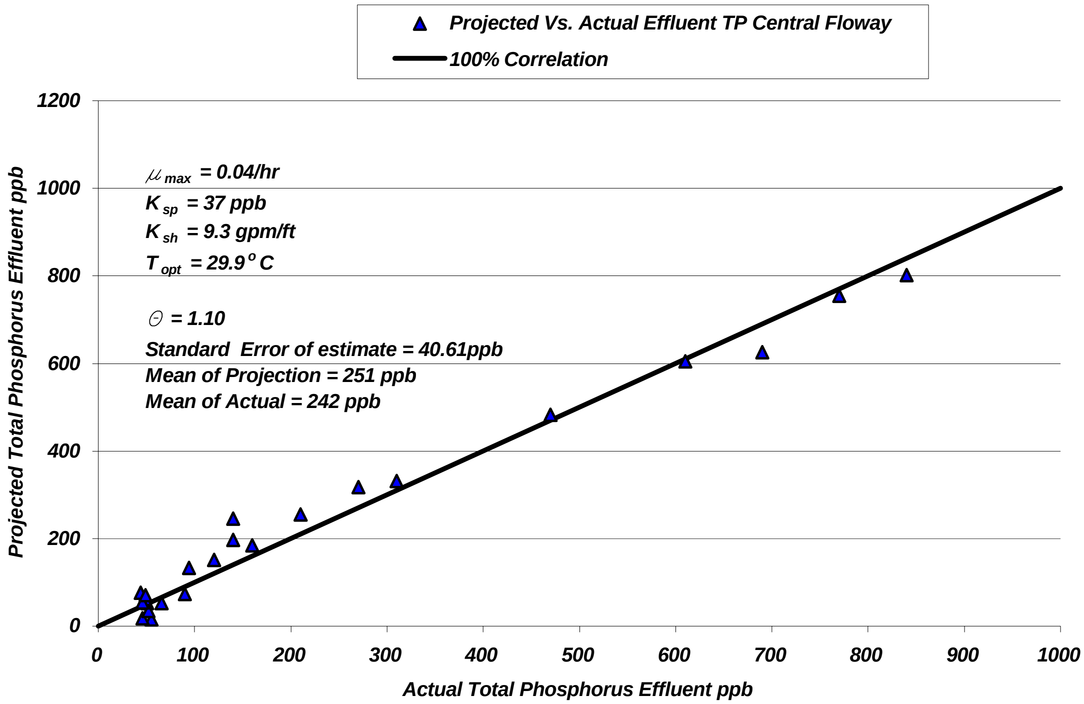


Figure 4-19: Actual vs. ATSDEM Projected total phosphorus effluent concentration Central Floway

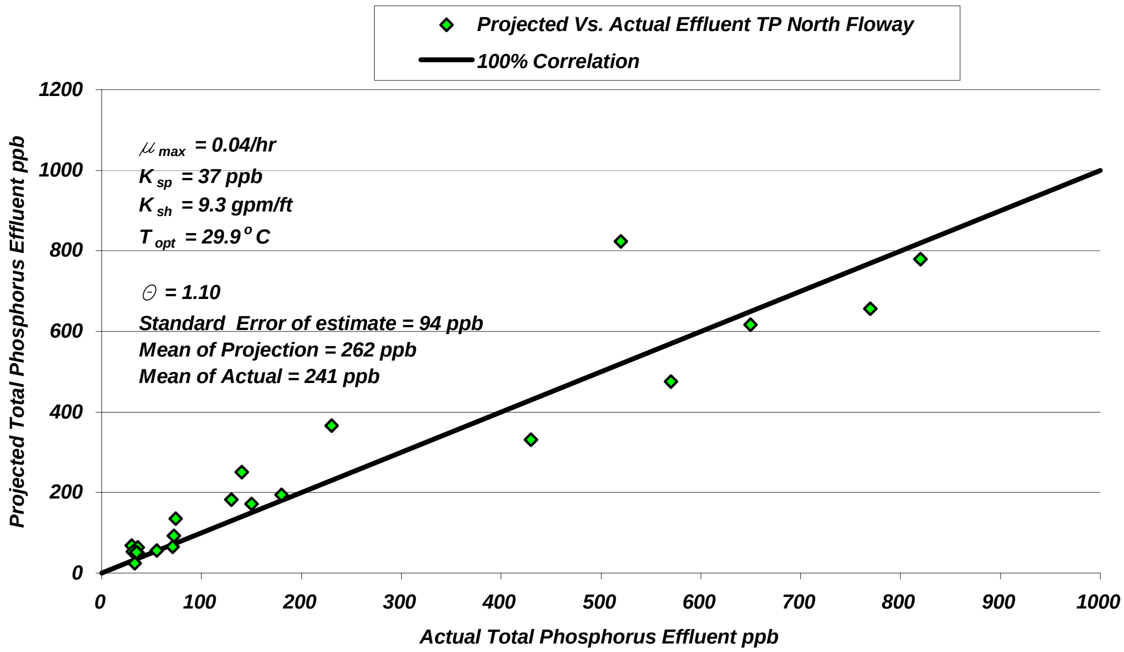


Figure 4-20: Actual Vs. ATSDEM Projected total phosphorus effluent concentration North Floway

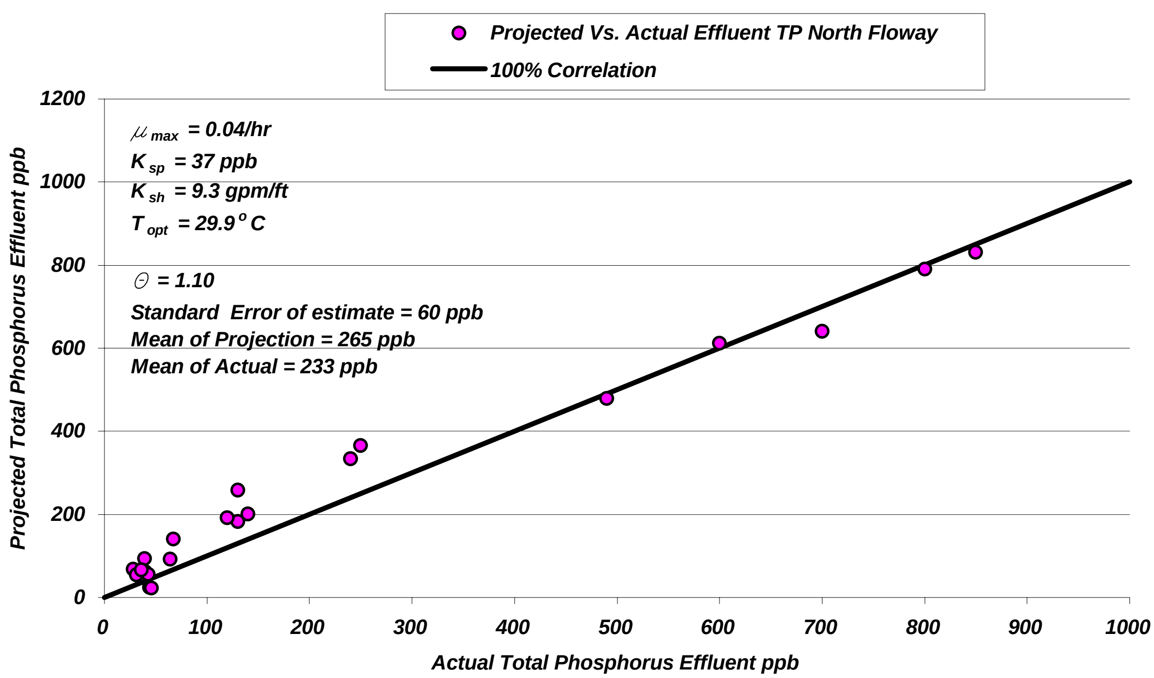


Figure 4-21: Actual Vs. ATSDEM Projected total phosphorus effluent concentration South Floway

While models such as ATSDEM are helpful in conducting conceptual level sizing of a proposed facility, and the various components associated with the proposed facility, and for projecting the rate of production and the harvesting needs, they assume that system operation is conducted such that the design provisions are sustained. As with most biological systems, the ultimate success and efficiency of a system relies heavily upon effective operational management, and the ability of a skilled operator to recognize, and sustain a healthy working biomass.

A Practical EXCEL Spreadsheet based ATSDEM

While very complex computer models could certainly be developed for sizing and designing ATS™ systems, a practical EXCEL spreadsheet model is often the most helpful to the engineer at the conceptual and preliminary engineering level, and may well be all that is required, as long as design conditions are relatively predictable, and within ranges for which the model is developed, and the engineer includes sufficient contingency provisions to allow operational flexibility. The general theory of function regarding ATS™ has already been described, with Monod growth kinetics, and diffusion boundary influences both incorporated into the basic algorithm. The basic premise for ATS™ is that 1) it is driven by photosynthesis, or primary productivity, and that sustaining high levels of productivity through frequent harvesting is essential and 2) the principal mechanism for removal of nutrients through an ATS™ is direct plant uptake, either through incorporation into tissue, luxury storage within cellular organelles, or precipitation/adsorption upon the cell wall.

Before proceeding with the refinement of a practical EXCEL based model, it is crucial that those involved in sizing and design, be even more sensitive to the importance of operational efficiency, as mentioned in the previous section. The modeling includes assumptions that the system is harvested effectively and completely, with biomass removal complete, and that the standing biomass is sustained at a density that prevents senescence or excessive necrosis. It has been observed that incomplete or too infrequent harvesting can interfere with performance. Harvesting at improper frequencies can also result in excessive densities and attendant poor performance. The general operational strategy is to maintain a consistent biomass range on the ATS™ at all times, and the modeling is based on the presumption that this is done. Senescent algae resulting from improper harvesting strategy will interfere and compete with the uptake of water column associated nutrients, as they become a rudimentary “soil” for new plant communities—such as aquatic vascular plants, and pioneer transitional plants (e.g. Primrose willow and cattails). This new ecostructure becomes less dependent upon the water column as its nutrient source, which accordingly will retard performance. It is a critical operational component then that harvesting be used to “pulse stabilize” the ecosystem, and thereby avoid successional pressures. This general strategy is the foundation of all MAPS technologies, as well as heterotrophic based systems, such as activated sludge.

It is typical that the harvesting frequency for an ATS™ in warm season conditions will be about every seven days, meaning that the entire ATS™ floway is completely harvested every seven days. In the cooler season, this frequency will typically increase to about a 14 days cycle. ATSDEM projections are based upon a composite average condition for the entire floway. For example a mean standing biomass, Z_{ave} represents the standing crop at anytime as dry-g/m^2 averaged over the whole ATS™ area. It is a function of the frequency of harvesting, and can be estimated through Equation 17.

$$Z_{ave} = \left(\sum_{m=1}^{n} Z_0 e^{24m\mu} \right) \Big/ n$$

Equation 17

Where **m** is the days since harvest, and **n** is the days between harvests. While setting the optimal value of Z_{ave} will ultimately be by the operator, it may be expected to be higher in warmer months, perhaps over 160 dry-g/m^2, while in the cooler months it may be difficult to establish a crop over 75 dry-g/m^2.

It is recognized that any one section of the ATS™ may be providing better or less treatment than the model projection, but as an average, the model effluent estimate and actual composite effluent can be expected to be similar. This applies to any time period during the operation. While photosynthesis occurs only during the daytime, productivity projections are based upon a 24-hour period. While there may be some concern that nocturnal performance is well below diurnal performance, experience indicates that nutrient uptake does continue with the loss of sunlight, even if carbon fixation is discontinued.

While the model is based upon the assumption that direct nutrient uptake within the plant biomass is the sole removal mechanism, under certain conditions other phenomenon may also contribute—including luxury uptake; adsorption; emigration through invertebrate pupae emergence and predation; and chemical precipitation, both within the water column directly, and upon the surface of the algal cell wall. Some evidence of these factors is noted with the change in tissue phosphorus concentration with change in water column total phosphorus concentration, as noted previously. By incorporating the change in phosphorus concentration within the tissue, it is presumed that ATSDEM incorporates the influence of these other phosphorus removal mechanisms.

In the case of an ATS™, the flow parameter is expressed as gal/minute-ft of ATS™ width, also known as the Linear Hydraulic Loading Rate or LHLR, as presented previously. The LHLR as discussed previously is incorporated into the ATSDEM equations. The LHLR converts to flow by multiplying by the ATS™ width. Width in this case does not refer to the short side of a rectangle, but rather the length of the influent headwall in which the flow is introduced to the ATS™. In actuality this "width" may well be larger than the ATS™ "length", which is the distance from the headwall to the effluent flume. Within the ATS™ velocity can be estimated using the Manning's Equation:

$$\mathbf{V = (1.49/n) r^{2/3} s^{1/2})}$$

Equation 18

Where **V** = velocity fps
n = Manning's friction coefficient
r = hydraulic radius = flow cross- section area/wetted perimeter

s = floway slope

However, the Manning's coefficient "**n"** will vary as the algal turf develops, and is harvested, and in addition, surging will create a predictable change in flow from nearly zero to something greater than u_{min} (Equation 15) during the siphon (surge) release. Actual velocity variations are best determined from field observations under different conditions (e.g. high standing biomass, pre-surge, post surge, etc.)

As applied to an ATS™, the Manning Equation can be simplified by first multiplying both sides of the equation by the flow area A, which is equal to the flow depth (d) in feet times the ATS™ width (w) in feet, or:

$$Q_{cfs}=Vdw = (1.49/n)dw)r^{2/3}s^{1/2} \qquad \textbf{Equation 19}$$

As the hydraulic radius r is flow area (A) over the wetted perimeter, then:

$$r = dw/(w+2d) \qquad \textbf{Equation 21}$$

Therefore:

$$Q_{cfs} = 0.00223(LHLR)w \qquad \textbf{Equation 22}$$

when **LHLR** is gallons/minute-ft. If **w** is set at 1 ft, then

$$LHLR = \{0.00332d^{5/3}s^{1/2}\}/[n(2d+1)^{2/3}] \qquad \textbf{Equation 23}$$

This allows for the flow depths to be established for specific Manning's "n" values and slopes, and accordingly, velocity can be estimated. These relationships are noted in Figure 4-21.

As noted, the higher the floway slope, the greater flexibility in terms of maintenance of a critical velocity—i.e. the velocity at which boundary layer disruption is complete. However, higher slopes require greater earthwork quantities and higher lifts.

Down a floway then, the change in phosphorus concentration (dS_p/dt) may be expressed as:

$$dS_p/dt = S_t(dZ/dt)/ q_t \qquad \textbf{Equation 24}$$

Where q_t=control volume over time increment

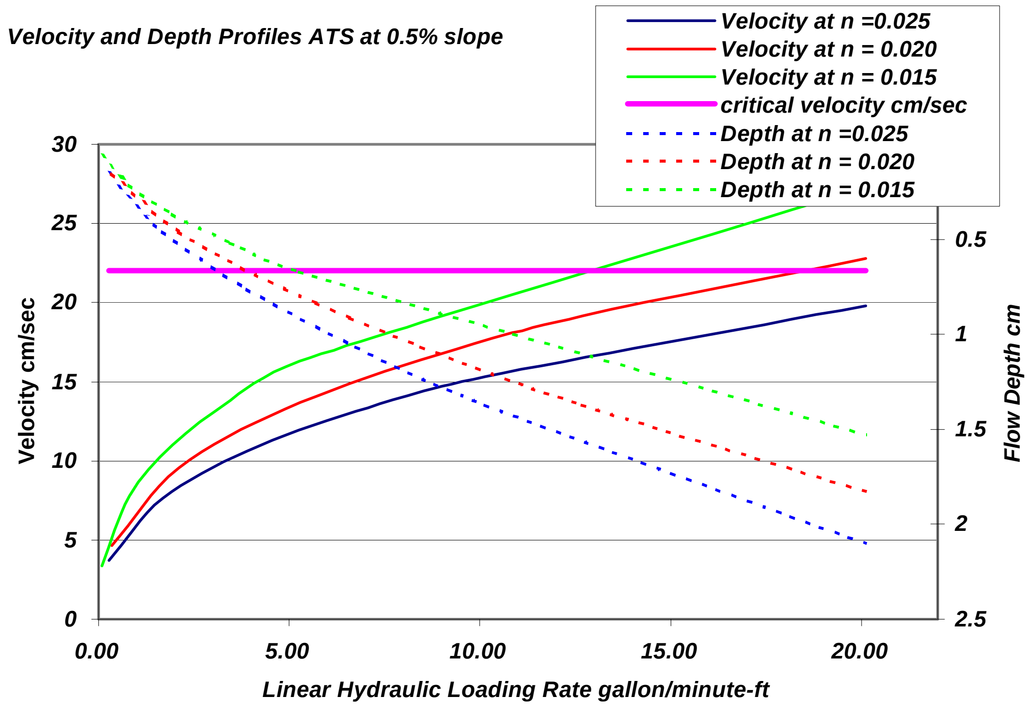
The change in floway length traversed by the control volume, with time, **dL/dt**, is expressed as:

dL/dt = vt **Equation 25**

These relationships hold for a relatively short time sequence when $\mathbf{S_{t0}} \sim \mathbf{S_{t1}}$, e.g. one second. This then can be put into a spreadsheet to facilitate assessment of ATS™ performance using Equation 8 adjusted per Equation 15, under established $\mathbf{K_s}$ and μ_{max} values. The Manning relationship is incorporated into the model to allow estimation of Velocity and average flow depth.

The actual format for the ATSDEM spreadsheet model includes a front-end tutorial sheet, followed by a Design Parameter and Summary Worksheet, followed by a Z_{AVE} worksheet, and finally the Model Run Worksheet. These are presented within Appendix A.

The example used for the model run is for a proposed 300 ft long ATS™ system located in the Lake Okeechobee Watershed with a flow of 25 MGD, a design LHLR of 20 gallons/minute-ft, requiring a width of 868 feet and a process area of 5.98 acres. At an incoming total phosphorus concentration of 150 ppb, and evaluating the proposed facility over four quarters, using water temperature from existing field data[10], the annual total phosphorus removal, as noted in Table 4-4, is 3,149 lbs/year, with an annual harvest of 4,140 wet tons, resulting in the generation of 561 cy of finished compost. A typical model summary printout is noted for Quarter 2 in Figure 4-22.



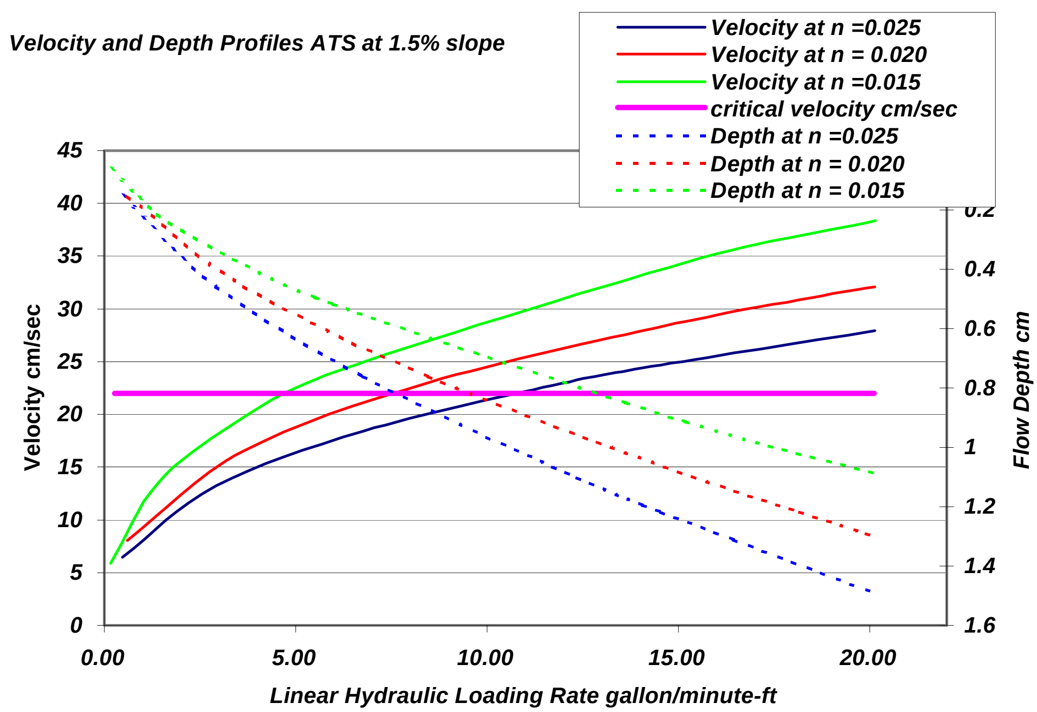


Figure 4-21: Velocity, LHLR and depth relationships as determined from Manning Equation

Table 4-4: ATSDEM summary 25 MGD Lake Okeechobee Watershed ATS™

Conditions:	
Flow MGD	25
Average Flow Velocity fps	0.93
Average Flow Depth inches	0.58
Average Flow-through time minutes	324
Influent TP	150
ATS length ft	300
ATS Headwall Width ft	868
ATS Acreage	5.98
ATS slope	1.00%

Parameter	Q1	Q2	Q3	Q4	Total Annual
Effluent Total Phosphorus ppb	133	109	74	118	109
Total Phosphorus Areal Removal Rate lb/acre-yr	212	524	970	401	527
Total Phosphorus Removed lb	317	783	1,450	599	3,149
Wet Harvest tons	532	83	2,510	1,015	4,140
Compost tons	33	83	157	63	337
Compost CY	55	139	261	106	561

Panel A Velocity Conditions

Floway slope (s)	Manning n	Manning Factor (1)	Manning Factor (2) Match	LHLR gpm/lf	LHLR cfs/lf	LHLR liters/sec-lf	Average flow depth (d) ft	Velocity fps	Flow length interval ft
0.01	0.02	0.005981	0.005981	20	0.045	1.280	0.05	0.93	0.93

Panel B Process Conditions

Water T °C	Optimal T °C	Θ	K_{sp} as ppb TP	K_{sh} as LHLR gpm/ft	μmax 1/hr	S_o ppb Total P	Harvest Cycle days	Z_{ave} dry-g/m²	Z_0 dry-g/m²	S^*_p Total Phosphorus ppb
27.44	29.9	1.10	37	9.3	0.04	150	7	105.74	10.00	30

Panel C Performance

Control Time Seconds	Control Volume liter	Final Total P S_f ppb	Total Flow Time seconds	Total P percent removal	Floway Length ft	Areal Loading Rate TP g/m2-yr	Areal Loading Rate TP lb/acre-year	Areal Removal Rate TP g/m2-yr	Areal Removal Rate TP lb/acre-yr	Average Production dry-g/m²-day	Area per time sequence m²
1	1.280	109	324	27%	300	214	1909.18	59	524.07	27.39	0.086

Panel D System Design

Total Flow mgd	Floway Width ft	Floway Area acres	Total P removed lb/period	Moisture % wet harvest	Moisture % compost	Period Wet Harvest tons	Period Dry Harvest tons	Period Compost Production wet tons	Performance Period days	μ_{ave} 1/hr
25	868	5.98	783.38	5%	40%	1,332	67	83	91.25	0.0168

Note: Inputs in Blue Print

Figure 4-22: Conceptual Design Parameter and Summary Worksheet Lake Okeechobee Watershed Quarter 2 ATS™ 25 MGD

---

[1] Walker, W.W. (1995) "Design basis for Everglades stormwater treatment areas" Water Resource Bulletin American Water Resources Association Vol 31 No. 4

[2] The City of Orlando just recently had to remove over 500,000 cubic yard of organic sediment after 15 years of operation of the Orlando Easterly Wetland.

[3] As described by Brezonik, P.L.(1994) *Chemical kinetics and process dynamics in aquatic systems,* CRC Press, Boca Raton, Fl pp 114-117

[4] Brezonik, P.L. (1993) Chemical Kinetics and Process Dynamics in Aquatic Systems Lewis Publishers, Boca Raton, Fl pp 421-427 ISBN 0-87371-431-8

[5] Lineweaver, H and D. Burke (1934) "The determination of enzyme dissociation constants" *J.Am.Chem.Soc.* **56,** 568

[6] Hanes, C.S. (1942) *Biochem. J.* , 26, 1406

[7] Eadie,G.S (1942) *J/ Biol. Chem.* 146,85 ; Hofstee, B.H.J. (1959) *Nature* 184, 1296

[8] Brezonik, P.L. (1993) Chemical Kinetics and Process Dynamics in Aquatic Systems Lewis Publishers, Boca Raton, Fl pp 507-509 ISBN 0-87371-431-8

[9] Brezonik, P.L. (1993) Chemical Kinetics and Process Dynamics in Aquatic Systems Lewis Publishers, Boca Raton, Fl pp 513-525 ISBN 0-87371-431-8

[10] White, J.R., K.R. Reddy, and T.A. DeBusk. 2001. Preliminary design of vegetation modifications and pilot development of sediment management protocols for the City of Orlando's Easterly Wetland's treatment system. A proposal for the City of Orlando.