Powell Creek Algal Turf Scrubber® Pilot

Final Report

Dec 4, 2008 through Dec 10, 2009

Prepared for:

LEE COUNTY
SOUTHWEST FLORIDA

Lee County
1500 Monroe Street
Ft. Myers, FL 33902

Prepared by:

HydroMentia
WATER TREATMENT TECHNOLOGIES

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

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EXECUTIVE SUMMMARY

- An Algal Turf Scrubber® (ATS™) Pilot Facility was operated over the continuous period December 4, 2008 through December 10, 2009 for the purpose of determining the efficacy of the ATS™ technology in providing nutrient reduction and recovery from surface waters associated with the Powell Creek By-Pass Canal located in North Ft. Myers, Lee County, Florida. The water quality within this canal was influenced significantly by upstream runoff and tidal flows associated with the contiguous Caloosahatchee Estuary. Critical to this determination were the quantification of system performance over a full annual period and a wide range of seasonal conditions.

- Performance results included in this report are associated with the Start-up and Stabilization Phase for the Algal Turf Scrubber® pilot. During the Stabilization Phase the treatment vegetation (algal turf) is developing and system productivity and performance will generally be improving. As illustrated in Figure ES-1, algal net productivity continued to increase in Q4 winter conditions indicating that the system had not yet have achieved optimal performance.

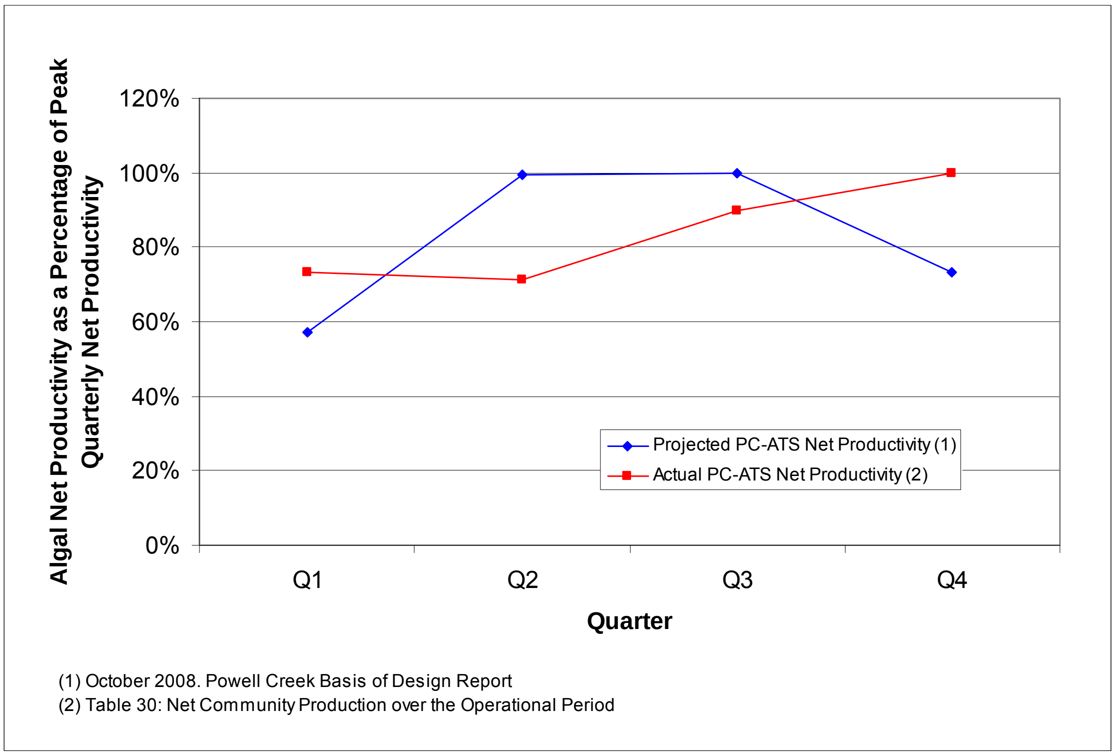

Figure ES-1: Comparison of Projected and Actual Net Algal Productivity as a Percentage of Peak Quarterly Productivity for the Powell Creek ATS™.

POLLUTANT LOAD REDUCTION OPTIMIZATION

- To optimize the Algal Turf Scrubber® system for phosphorus load reduction, the system was operated at a linear hydraulic loading rate of 18 gpm/lf; resulting in a mean flow rate of 25,728 gallons per day.

PHOSPHORUS TREATMENT PERFORMANCE

- The ATS™ technology is designed to offer high areal removal rates even at relatively low nutrient concentrations associated with urban and agricultural stormwater runoff. Areal removal rates are expressed as mass removal per unit process area per unit time. Typically areal removal rate has been expressed by water resource managers as grams of pollutant removed per square meter of process area over a year or g/m^2-yr. The higher the areal removal rate the smaller the required footprint for a common mass removal requirement. A system with a higher areal removal rate is particularly advantageous when land availability is limited.

- The average annual phosphorus areal removal rate of the Powell Creek ATS™ pilot study during the start-up and stabilization phase was 19.80 g/m^2-yr (177 lbs/acre-yr).

- The mean influent total phosphorus concentration during the project monitoring period was 139 ppb, with the mean effluent total phosphorus concentration at 110 ppb.

- Phosphorus removal dynamics over the course of the operational period for the Powell Creek ATS™ pilot study are noted in Table ES-1. When calculated using water quality and flow data, the pilot system provided an annual average total phosphorus areal removal rate of 19.80 g/m^2-yr (177 lbs/acre-yr). When calculations were done based upon the phosphorus recovered within the algal turf harvest, the annual average total phosphorus areal removal rate was calculated as 20.80 g/m^2-yr (186 lbs/acre-yr). The relative closeness of these two values indicates effective accountability of phosphorus.

- Of the total phosphorus pumped from the Powell Creek By-Pass Canal to the pilot facility over the operational period, 79.19% was as ortho phosphorus, the soluble form considered to be directly available for biological uptake. The remainder was as organic and polyphosphate, both forms which typically require enzymatic activity to render them available for biological uptake. The ortho phosphorus areal removal rate, not surprisingly, was higher than the total phosphorus areal removal rate, as noted in Table ES-1. Similarly, the percent mass removal of ortho phosphorus (27.17%) was higher than the percent mass removal of total phosphorus (19.28%), again as shown in Table ES-1.

Table ES-1: Phosphorus Removal Dynamics for the Powell Creek ATS™ Pilot Study Monitoring Period.

	PC-ATS Ortho Phosphorus Areal Removal Rate (g/m^2-yr)	**PC-ATS Ortho Phosphorus (% Mass Removal)**	**PC-ATS Total Phosphorus Areal Removal Rate (g/m^2-yr)**	**PC-ATS™ Total Phosphorus (% Mass Removal)**
Water Quality Based Calculation	22.60	27.17%	19.80	19.28%
Harvest Based Calculation	NC	NC	20.80	21.35%

NC = Not Calculated

NITROGEN TREATMENT PERFORMANCE

- The mean influent total nitrogen concentration to the ATS™ pilot during the project monitoring period was 0.95 mg/l, with the mean effluent total nitrogen concentration at 0.87 mg/l.

- Nitrogen removal dynamics over the course of the operational period for the Powell Creek ATS™ are presented in Table ES-2. Note that total nitrogen is the sum of nitrate + nitrite nitrogen; ammonia nitrogen and organic nitrogen. When calculated using water quality and flow data, the pilot system provided an annual average total nitrogen areal removal rate of 46.75 g/m^2-yr (417 lbs/acre-yr). When calculations were done based upon the nitrogen recovered within the algal turf harvest, the annual average total nitrogen areal removal rate was 71.37 g/m^2-yr (637 lbs/acre-yr). The disparity between these two values suggests there are external sources of nitrogen, probably as nitrogen fixation of atmospheric nitrogen, contributed to the incoming nitrogen load.

- Of the total nitrogen pumped from the Powell Creek By-Pass Canal to the facility over the operational period, 5.49% was as nitrate and nitrite nitrogen, and 6.70% was as ammonia nitrogen, the two forms considered to be directly available for biological uptake. The remaining 87.81% was as organic nitrogen. Not surprisingly, even though the respective concentrations were lower than that of the organic nitrogen, the percent mass removal of nitrate and nitrite nitrogen (34.12%) and ammonia nitrogen (53.92%) was higher than the percent mass removal of organic nitrogen (1.83%), again as shown in Table ES-2. This is rather clear evidence of the preferential uptake of these available forms of nitrogen by the algal turf, and that nitrogen dynamics related to the ATS™ operated under the environmental conditions associated with the Powell Creek By-Pass Canal and the contiguous Caloosahatchee Estuary, are influenced significantly by the relative abundance of nitrate + nitrite and ammonia nitrogen.

Table ES-2: Nitrogen Removal Dynamics for the Powell Creek ATS™ Pilot Study Monitoring Period

	PC-ATS™ Nitrate + Nitrite-N Areal Removal Rate (g/m^2-yr)	PC-ATS™ Nitrate + Nitrite-N (% Mass Removal)	PC-ATS™ Ammonia-N Areal Removal Rate (g/m^2-yr)	PC-ATS™ Ammonia-N (% Mass Removal)	PC-ATS™ Organic Nitrogen Areal Removal Rate (g/m^2-yr)	PC-ATS™ Organic Nitrogen (% Mass Removal)	PC-ATS™ Total Nitrogen Areal Removal Rate (g/m^2-yr)	PC-ATS™ Total Nitrogen (% Mass Removal)
Water Quality Based Calculation	12.53	34.12%	24.71	53.92%	11.92	1.83%	46.75	6.67%
Harvest Based Calculation	NC	NC	NC	NC	NC	NC	71.37	10.74%

NC = Not Calculated

ALGAL BIOMASS

- The Powell Creek By-Pass Canal is influenced significantly by the tidal fluctuations associated with the contiguous Caloosahatchee Estuary, and accordingly, salinity levels (as measured by conductivity) varied widely over the operational period. While performance of the ATS™ did fluctuate somewhat during the operational period as projected in the Basis of Design, there was no clear evidence that performance was deleteriously impacted by modulations in conductivity.

- During the operational period Lee County applied the herbicide glyphosate on several occasions within the Powell Creek watershed. While it is known that algal development can be impacted by certain herbicides and pesticides, there was no evidence that these applications significantly influenced algal turf productivity during the operational period. As with any biological treatment system, it is recommended that County forces communicate with operators of any future full-scale system when scheduling of herbicide applications within the vicinity of the treatment system's pump intake. These communications allow system adjustments to be made to prevent impacts to treatment performance.

- Over the operational period, the algal turf associated with the ATS™ Floway was harvested on 28 occasions. The total wet harvest weight was 5,078 pounds, with the percent solids at about 8%. The dry harvest weight was 411 pounds. System productivity, based upon the dry harvest, averaged 11.05 dry g/m^2-day, with a specific growth rate of 0.0071/hr and an average standing crop of 58.92 dry g/m^2.

- The nutrient content of the biomass that was harvested averaged 0.55% phosphorus and 1.90% nitrogen on a dry weight basis.

ALGAL TURF SCRUBBER® FULL-SCALE SYSTEM PERFORMANCE PROJECTIONS

- Water quality, flow, temperature and harvest data collected during the operational period were used to establish values for critical model constants associated with the ATSDEM model, a design and operational model developed around first order kinetics, as applied specifically to the algal turf community productivity and its rate of nutrient uptake.

- Adjustments to the critical model parameters were made during model calibration applied to data collected from the first half of the operational period. The model was then verified by applying the critical model constants to verified data collected from the second half of the operational period.

- The ATSDEM model projections for the water quality and environmental conditions during the operational period tracked the actual field conditions closely, and were found through ANOVA to be statistically indistinguishable.

- The ATSDEM model was assessed as being an effective tool for projecting ATS™ performance within the range of environmental conditions attendant with the Powell Creek By-Pass Canal and its association with the Caloosahatchee Estuary

- Prior to initiation of the Powell Creek ATS™ Pilot Study, HydroMentia had developed and submitted within a Basis of Design Report[1] an expected range of performance for a 6.2-acre full-scale ATS™ facility which would be located on contiguous property owned by Lee County. These projections were based upon historical average monthly water quality conditions. The ATSDEM model when applied to the same set of historical conditions used in the Basis of Design Report, using the verified critical constants established from the pilot data, provided projections in terms of pounds of nitrogen and phosphorus removed annually within the ranges developed within the Basis of Design Report.

[1] Powell Creek Basis of Design Algal Turf Scrubber® (ATS™) Basis of Design Final report revised 12/28/08 Prepared by HydroMentia, Inc. Ocala, Florida for Lee County, Florida. p 21-26.

- Based on ATSDEM Model projections, a 6.2-acre Algal Turf Scrubber® treatment facility located on property owned by Lee County and contiguous to the Powell Creek Bypass Canal would provide an annual removal of 1,118 pounds of phosphorus and 4,125 pounds of nitrogen from Powell Creek/Caloosahatchee River,

- It is proposed that initially the harvested biomass associated with a full scale system be windrow composted. The algal turf compost has been, and continues to be evaluated by the USDA, and has been found to be of high quality.[2] In the future it is possible that the harvested biomass could be used in developing other products, including biogas, biofuel, and livestock feed.

- Algal biomass harvest from the 6.2-acre facility would total 1,218 wet-tons per year, with a projected annual yield of 122 tons of compost.

[2] Work conducted and continuing by Dr. Joseph Albano, USDA-Agricultural Research Service, USHRL 200 S. Rock Road, Ft. Pierce, Fla 34945

SECTION 1. PROJECT BACKGROUND

INTENT

This Algal Turf Scrubber® (ATS™) Pilot Final Report (Final Report) has been prepared as a required element (Task 3) of Contract #4256 between Lee County, Florida and HydroMentia, Inc. entitled Powell Creek Algal Turf Scrubber® (PC-ATS™) Pilot Unit and System Design. This Final Report includes detailed review and analyses of data collected during one year's continuous operation of a 500 foot long, 1 foot wide ATS™ Mobile Pilot Unit. The pilot operation was developed with the intent of reducing nitrogen and phosphorus within the Powell Creek By-Pass Canal located in Lee County, and tributary to the Caloosahatchee River/Estuary. Accordingly, the review and analysis of this data serves as the foundation for establishing specific design and operational conditions for a proposed full scale ATS™ which would target flows associated with the Powell Creek/Caloosahatchee River/Estuary surface water network. Included in this Final Report is an assessment of process performance in terms of unit area removal rates of targeted nutrients; a review of harvesting and biomass processing needs; a discussion of sampling and analytical procedures and results of split sampling efforts; and development of performance projections using HydroMentia's ATS™ Design Model or ATSDEM to include the comparison of modeling results based upon field data with earlier projections included in the Basis of Design Report[3]. The specific intent of a full scale Powell Creek ATS™ facility is to:

a. Reduce nutrient loads associated with Powell Creek/Caloosahatchee River/Estuary surface water network.

b. Recover a significant portion of removed nitrogen and phosphorus as useable and marketable biomass.

c. To provide general information about the potential for pollutant load reduction to the Caloosahatchee River/Estuary using ATS™ for stormwater treatment.

FACILITY DESCRIPTION

The Powell Creek ATS™ Pilot facility was located on the west bank of the Powell Creek By-Pass canal on the Lee County right of way (ROW) about 2,000 feet from the confluence of the Caloosahatchee River/Estuary, in North Ft. Myers, Lee County, Florida. The ATS™ floway associated with this facility is an aluminum Mobile Pilot Unit (MPU) ATS™ Floway, which is 500 feet long and 1 foot wide, sloped at 1%--photographs are included as Appendix A. The MPU offers a reasonable similitude of a full scale ATS™ facility. Influent flow was delivered by a Godwin submersible pump located within the by-pass canal. The influent was discharged at a rate of up to 30 gpm, to a delivery surger at the front of the MPU. Flow adjustments were accommodated by the use of by-pass valving and piping. The surger, which is an automatic siphon device, delivers water to the floway in pulses, cycled in the range of 30-60 seconds. The pulsed flow emulates oscillatory wave action, which has been shown to solicit enhanced algal productivity. An image of the pilot under operation is shown in Figure 1. A schematic of the pilot layout is noted in Figure 2.

[3] "Powell Creek Algal Turf Scrubber® (ATS™) Basis of Design Report" October, 2008. Prepared for Lee County, Florida by HydroMentia, Inc. to complete Task 4 of referenced contract. Included in the Basis of Design Report was a range of ATSDEM based performance projections.

Figure 1: Powell Creek ATS™ (PC-ATS**)** Mobile Pilot Unit in Operation

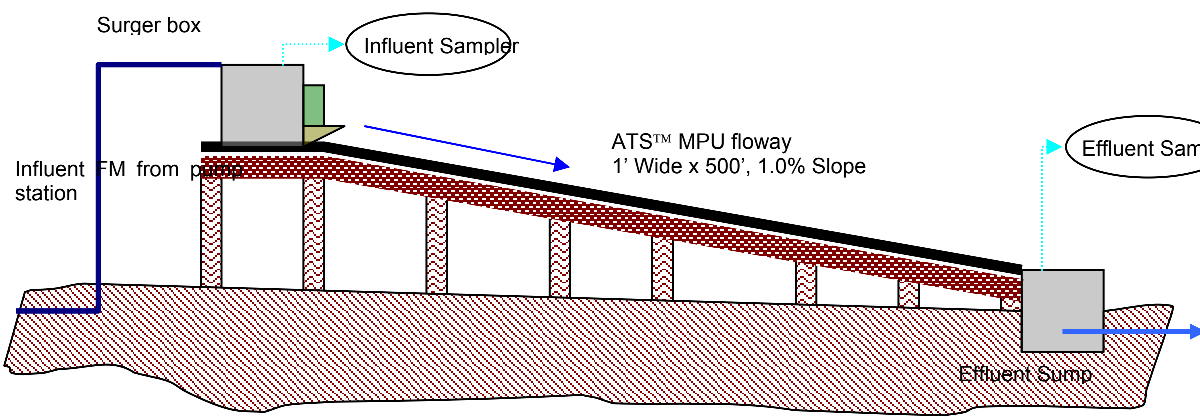

Figure 2: Schematic of Pilot Floway Cross Section

SAMPLING REVIEW

The Powell Creek ATS™ Pilot was operated for a period of 12 consecutive months—from December 4, 2008 to December 10, 2009. For reporting purposes, the project has been defined in terms of four quarters, as shown in Table 1. This Final Report covers the entire operational period.

Table 1. Date Ranges for Quarterly Reporting Periods for the Powell Creek ATS™ Pilot.

Quarter	Begin Date	End Date
Q1	December 4, 2008	March 12, 2009
Q2	March 13, 2009	June 11, 2009
Q3	June 12, 2009	September 10, 2009
Q4	September 11, 2009	December 10, 2009

Composite water samples were taken from both the influent and effluent by two Sigma 900 MAX refrigerated autosamplers. Composite sampling was done on a timed basis, with a 100 ml sample taken every three hours. These samples were collected in a 10 liter bottle and recovered weekly. No preservative was added to the refrigerated samples during the collection period. At the time of recovery of the composite samples (typically at 9:00 AM every Thursday), samples were taken both by HydroMentia staff and by staff from Lee County. Preservatives were added as appropriate at this time to the individual samples. These weekly composite samples were analyzed for total phosphorus (TP), Total Kjeldahl Nitrogen (TKN), nitrate+nitrite nitrogen and total suspended solids (TSS) by Pace Laboratories of Ormond Beach, Florida. Lee County conducted similar analyses on the composite samples, and included ammonia nitrogen.

Grab samples of influent and effluent were taken once weekly at the time of composite sample recovery. These grab samples were analyzed for Ortho-phosphorus by HydroMentia. Lee County also split grab samples with HydroMentia. Their grab sample analysis included, in addition to ortho-phosphorus, total phosphorus (after 6/11/09), nitrate nitrogen, nitrite nitrogen, TKN and ammonia nitrogen.

At the onset of operations an influent sample was taken for a series of heavy metals (Cu, Cr, B, Zn, As, Se, Cd, Pb, and Hg). In addition, once monthly the influent and effluent composite samples were analyzed for Ca, Mg, Fe, TOC and alkalinity. During each weekly visit pH, dissolved oxygen (DO), temperature and specific conductivity were determined for both influent and effluent. In addition alkalinity was estimated using field test strips.

Rainfall was recorded weekly from an on-site rain gauge. Influent flow was measured initially using a propeller type meter. However, this proved ineffective because of fouling from solids. Consequently this meter was replaced early into the operational period by a magnetic flow meter, which proved reliable. Totalized and instantaneous flows were recorded at each weekly visit.

In addition to monitoring conductivity once weekly, because it was expected that there may be significant variability in conductivity because of the close proximity of estuarine waters, both on a seasonal basis and diurnally, a Unidata in-situ data logger was installed. This unit performed relatively well, although some software problems resulted in periods of non-performance.

SYSTEM START-UP AND PHASES OF OPERATION

When operation of the Algal Turf Scrubber® is initiated and the system is being managed to optimize treatment performance, some time will be required for development and maturation of the algal turf. During this development period, system performance is dependent on the establishment of this developing biomass.

For the Algal Turf Scrubber®, the system proceeds through two operational phases, each with different levels of performance. Definitions that distinguish the Start-up & Stabilization Phase from the Fully Operational Phase are provided below.

Algal Turf Scrubber® Operational Phases:

(*1)* *Start-up & Stabilization Phase:* *System start-up is initiated with the introduction of continuous flow to the Algal Turf Scrubber® Floway. During the start-up and stabilization phase, the algal turf community proceeds through ecological succession toward a sustained algal turf community.*

The system operator shall define the stabilization phase complete and the system as fully operational when the following conditions are met:

- *A sustained algal turf community is present over 90% of the floway surface area*
- *A sustained algal turf is established and maintained for a minimum period of 120 days with (i) minimal variation of the dominant algal turf species and (ii) minimal changes in algal productivity; except those changes that are consistent with changes in inflow water quality and ambient conditions.*

(2) Fully Operational Phase: *Algal Turf Scrubber® system is fully operational when a sustained algal turf community is established and maintained in conjunction with routine biomass recovery on the floway. Algal turf of the fully-operational phase is a complex community of algae, bacteria, diatoms and micro and macro invertebrates and detritus. Predominant attached algae species for the sustained algal turf will vary dependent on water quality, season and geographical location.*

The algal turf community is developed from fragments of periphytic algae found within the source water. During the Start-up and Stabilization Phase, the algal turf community goes through natural succession like other ecological communities. During the Stabilization Phase the treatment vegetation (algal turf) will be maturing and system performance will generally be improving.

Duration of the Start-up and Stabilization Phase is difficult to predict, and the duration will vary according to water quality and ambient environmental conditions.

This start-up and stabilization period is similar to other autotrophic water treatment systems, where optimal performance is achieved only after the initial start-up and stabilization phases[4]. As noted by the SFWMD and FDEP, it is anticipated that the treatment vegetation in a treatment wetland will require one to three years after flow-through operations begin for the affected cells to achieve optimal performance; and overall performance of the treatment wetland system is extremely difficult to evaluate and predict during the start-up and stabilization period. While the start-up and stabilization period for the ATS™ is expected to be of shorter duration than a treatment wetland, performance during the initial 12 months of operation should not be considered optimal for the Algal Turf Scrubber® system.

The Algal Turf Scrubber® may enter a post initial system start-up Stabilization Phase after the following events: (1) system shut-down and dry-out in conjunction with loss of system flow; (2) system shut-down and algal die-off in conjunction with freezing temperatures; (3) planned/unplanned maintenance activities which result in die-off of the algal turf; or (3) algal die-off due to the presence of toxins in the source water. Duration of the stabilization phase following these events is typically shorter than the initial start-up and stabilization phase.

OPERATIONAL SUMMARY

Operational events were documented on a weekly basis. These notes are included as Appendix B. Throughout most of the operational period, the system operated without disruption of flow or malfunctioning of composite samplers. The few disruptions which were documented were attributable to impacts of vandalism, operator error, and line blockage.

[4] 2008. Florida Department of Environmental Protection and South Florida Water management District. Fact Sheet for FDEP Industrial Wastewater Permit No. F10300195

During the initial start-up period and the early weeks of the operation, the facility was disrupted by comparatively minor acts of vandalism—which included switching valves, removing liner, and damaging an electrical control panel (See Table 2). After a video camera was installed, and the Sheriff's Department was notified, major vandalism ceased after March 26, 2009.

Table 2. Summary of Documented Vandalism Powell Creek ATS™ Pilot.

Date	Nature of Vandalism	Impact
10/25/08 (Start-up)	Liner pulled from a portion of the floway. Influent line pulled from Surger	Loss of flow, minor erosion, loss of algal turf
11/2/08 (Start-up)	Electrical Box damaged, valves manipulated	Loss of flow, loss of algal turf
1/2/09	Valves adjusted	Loss of flow, damage to algal turf
1/22/09	Valves adjusted	Reduction of flow to floway
2/5/09	Intake sampler strainer removed from riser	Loss of influent composite sample
3/26/09	Liner removed, valves manipulated	Loss of floway, damage to algal turf, loss of composite samples

On June 25, 2009, the operator failed to reset the influent composite sampler, resulting in the necessary use of grab samples for the week in assessing total phosphorus and nitrogen levels. On October 1, 2009 the effluent sampling line was found to be blocked with an accumulation of small clams, which resulted in the failure to collect an effluent composite sample. A backwash system was installed to allow periodic flushing of the line. On October 8, 2009 sloughed algae blocked the effluent sampling line, resulting in failure to collect composite samples. A screen was placed within the effluent box to prevent this from happening in the future.

In summary of the 52 weeks of operation, composite samples had to be replaced with grab samples on five occasions - 1/5/09, 2/5/09, 6/25/09, 10/1/09 and 10/8/09 - and on one occasion disruption from vandalism was so severe that no sampling could be done, this being on 3/26/09. Of these six events, three were attributable to vandalism, one to operator error and two to sample line blockage.

On a few occasions Lee County sprayed the canal with glyphosate for the purpose of controlling aquatic vegetation. On each occasion, they informed HydroMentia of their schedule, as there was some concern related to potential deleterious impact on the algal turf. The dates around which spraying occurred during the operational period were 1/13/09; 4/29/09; 5/29/09; 6/30/09 and 8/21/09

SECTION 2. DATA REVIEW

FLOW

Influent flow was monitored through an in-line flow meter. During the initial weeks, the selected flow meter was a propeller type, which proved to be problematic because of clogging by solids. On five occasions this meter failed to record totalized flow, so weekly flow had to be estimated from instantaneous flow readings. The propeller meter was replaced on 2/19/09 by a Seametrics magnetic flow meter (www.seametrics.com/flow_meter/agAG.html), which proved reliable throughout the remaining operational period.

During the operational period, some variation was noted in influent flow rates—with the average rate at 18.0 gpm with a standard deviation of 3.2 gpm. This variation was attributed to 1) tidal fluctuations in water levels within the by-pass canal, which changes the total dynamic head on the pumping system; 2) periodic clogging of the intake strainers associated with the submersible pump; and 3) biofouling (e.g. mollusks and barnacles) within the piping network. While some fluctuation in flow is expected, if it is desired to stabilize flow rate within a full scale system, a variable flow pumping system would need to be installed. During the operational period, the pump intake and the piping network were periodically cleaned.

Effluent flow was estimated as the influent flow plus the influence of rainfall, minus the influence of evaporation. Rainfall was measured on site using a standard rain gauge, while evaporation losses were estimated based on historical data[5] - see Table 3. The system design flow was initially set at 20 gpm, or 20 gpm per linear foot of floway width - which had been found in other ATS™ studies and operations to be an effective linear hydraulic loading rate (LHLR). The flows were adjusted somewhat during the study period in an effort to optimize performance. As noted, the average influent flow rate was 18.0 gpm with a standard deviation of 3.2 gpm. Flows for the operational period are noted in Table 4. Effluent flows were calculated as the influent flow minus evaporation losses over 500 sf of floway plus rainfall gains over 500 sf of floway.

Table 3: Historical Pan Evaporation for Lee County, Florida Region

Month	Historical Pan Evaporation[2] inches/day
Jan	0.106
Feb	0.141
Mar	0.188
Apr	0.218
May	0.299
June	0.207
July	0.202
Aug	0.194
Sept	0.194
Oct	0.183
Nov	0.122
Dec	0.099

5 IFAS Bulletin 840. Dec 1984 65pp. NOAA 1930-1985

Table 4. Influent Totalized and Flow Rates and Estimated Effluent Rates

Week Ending	Period	Days in period	Influent Total Flow gallons	Influent Flow Rate gpm	ET rate inches/period	Rainfall inches/period	Estimated Effluent Total Flow gallons	Estimated Effluent Flow Rate gpm
12/11/2008	1	5	142,549	20.4	0.50	ND	142,395	20.3
12/18/2008	2	7	210,053	20.9	0.69	ND	209,838	20.9
12/29/2008	3	11	310,516	19.6	1.09	ND	310,176	19.6
1/5/2009	4	7	136,355	13.6	0.74	0.00	136,125	13.6
1/12/2009	5A	7	172,358	17.1	0.74	0.00	172,126	17.0
1/15/2009	5B	3	60,678	14.9	0.32	0.10	60,610	14.9
1/22/2009	6	7	102,999	10.2	0.74	0.00	102,768	10.2
1/29/2009	7	7	102,816	10.2	0.74	0.00	102,585	10.2
2/5/2009	8	7	185,658	19.4	0.99	0.30	185,444	19.4
2/12/2009	9	7	191,235	19.0	0.99	0.00	190,928	19.0
2/19/2009	10	7	159,075	15.8	0.99	0.00	158,767	15.7
2/25/2009	11+	6	142,500	17.3	0.85	0.00	142,237	17.2
3/5/2009	12	8	221,400	19.2	1.50	0.00	220,931	19.2
3/12/2009	13	7	179,700	17.8	1.32	0.00	179,289	17.8
3/19/2009	14	7	183,600	18.2	1.32	0.10	183,220	18.2
3/26/2009	15	7	177,400	17.6	1.32	0.00	176,989	17.5
4/2/2009	16	7	161,700	16.1	1.52	0.40	161,349	16.0
4/8/2009	17	6	138,600	16.0	1.31	0.00	138,192	16.0
4/16/2009	18	8	263,400	22.9	1.74	0.60	263,043	22.8
4/23/2009	19	7	232,800	23.2	1.52	0.00	232,326	23.1
4/30/2009	20	7	211,900	21.0	1.53	0.00	211,423	20.9
5/7/2009	21	7	210,600	20.9	2.09	0.00	209,948	20.9
5/14/2009	22	7	187,100	18.6	2.09	2.50	187,228	18.6
5/21/2009	23	7	213,100	21.1	2.09	2.50	213,227	21.2
5/28/2009	24	7	162,700	16.1	2.10	2.00	162,669	16.1
6/4/2009	25	7	169,800	16.8	1.45	1.50	169,816	16.8
6/11/2009	26	7	171,900	17.1	1.45	1.75	171,994	17.1
6/18/2009	27	7	171,500	17.0	1.45	0.30	171,142	17.0
6/25/2009	28	7	159,200	15.8	1.45	1.30	159,154	15.8
7/2/2009	29	7	177,100	17.6	1.42	3.50	177,750	17.6
7/9/2009	30	7	192,100	19.1	1.41	0.00	191,659	19.0
7/16/2009	31	7	175,000	17.4	1.41	0.40	174,684	17.3
7/23/2009	32	7	169,500	16.8	1.41	0.80	169,309	16.8
7/30/2009	33	7	145,700	14.5	1.41	0.50	145,416	14.5
8/6/2009	34	7	191,000	18.9	1.36	1.30	190,981	18.9
8/13/2009	35	7	178,300	17.7	1.36	3.00	178,812	17.7
8/20/2009	36	7	162,900	16.2	1.36	2.90	163,381	16.2
8/27/2009	37	7	149,100	14.8	1.36	6.00	150,547	14.9
9/3/2009	38	7	128,200	12.7	1.36	4.00	129,024	12.8
9/10/2009	39	7	203,700	20.2	1.36	1.00	203,587	20.1
9/17/2009	40	7	187,900	18.6	1.36	2.35	188,209	18.7
9/24/2009	41	7	149,000	14.8	1.36	0.30	148,670	14.7
10/1/2009	42	7	258,800	25.7	1.28	0.30	258,494	25.6
10/8/2009	43	7	202,900	20.1	1.28	0.00	202,501	20.1
10/15/2009	44	7	195,400	19.4	1.28	0.00	195,001	19.3
10/22/2009	45	7	183,600	18.2	1.28	0.00	183,201	18.2
10/29/2009	46	7	171,400	17.0	1.28	0.00	171,001	17.0
11/5/2009	47	7	159,100	15.8	0.85	0.00	158,834	15.8
11/12/2009	48	7	267,600	26.5	0.85	0.60	267,521	26.5
11/19/2009	49	7	237,600	23.6	0.85	0.00	237,334	23.5
11/24/2009	50	5	136,600	19.0	0.61	0.20	136,472	18.9
12/3/2009	51	9	201,200	15.5	0.89	0.75	201,156	15.5
12/10/2009	52	7	188,300	18.7	0.69	2.80	188,957	18.7
TOTALS		**369**	**9,545,192**		**65.72**	**44.05**	**9,538,439**	
AVERAGE			**180,098**	**18.0**			**179,971**	**18.0**
Q1 Average			**165,564**	**16.8**			**165,301**	**16.8**
Q2 Average			**191,123**	**18.9**			**190,879**	**18.9**
Q3 Average			**169,485**	**16.8**			**169,650**	**16.8**
Q4 Average			**195,338**	**19.5**			**195,181**	**19.4**

WATER QUALITY

Phosphorus

Phosphorus analyses were done using approved methods by NELAC certified laboratories. Initially, Jupiter Environmental Laboratories of Jupiter, Florida and later (after 1/12/09) Pace Laboratories of Ormond Beach, Florida conducted analysis for HydroMentia. Both laboratories were approved by Lee County and South Florida Water Management District (SFWMD). In addition split samples were analyzed by Lee County's environmental laboratory. Total phosphorus samples were kept refrigerated through the entire custody period, and were taken from weekly composite samples, unfiltered, and preserved with sulfuric acid. In addition, after 6/11/09 Lee County analyzed weekly unfiltered, preserved grab samples for total phosphorus.

Ortho-phosphorus, which is the ionized form PO_4^{3-} , is a component of what is referenced as total phosphorus - which also includes polyphosphates and organically bound phosphorus. Typically ortho-phosphorus is soluble and is considered the form readily available for biological uptake. Other forms of phosphorus require additional chemical action to convert them to available ortho-phosphorus. Therefore, the concentration of ortho-phosphorus provides some insight into the ability of a water to support active biological activity. Ortho-phosphorus needs to be analyzed within 24 hours of sample collection. Consequently, grab samples were used in determining ortho-phosphorus. Samples taken for analysis of ortho-phosphorus were filtered at 0.48 microns, and then refrigerated without addition of preservative. HydroMentia and Lee County split weekly grab samples for ortho-phosphorus determination.

Influent and effluent total phosphorus, including split results are noted in Table 5 and Figure 3. Influent and effluent ortho-phosphorus results, including split results are noted in Table 6 and Figure 4. Included in Table 6, is the estimated percentage of total phosphorus as ortho-phosphorus[6].

Nitrogen

Nitrogen analyses were conducted under the same guidelines and by the same laboratories as with phosphorus. Refrigerated weekly composite samples were used to determine Total Kjeldahl Nitrogen (TKN) and nitrate + nitrite nitrogen. In addition, the County analyzed the composite samples for ammonia nitrogen.

Total nitrogen is the sum of TKN, nitrate and nitrite nitrogen. TKN is considered to be the sum of organically bound nitrogen and ammonia nitrogen. Nitrogen in the form of nitrate, nitrite and ammonia are generally considered to be biologically available. Enzymatic degradation of organic nitrogen typically must occur before its nitrogen become biologically accessible. Noted in Table 7 and Figure 5 are nitrogen results over the course of the operational period based upon sampling and testing through HydroMentia, with composite ammonia-N results included. Shown in Table 8 are summaries of the composite sample ammonia and total nitrogen analyses conducted by Lee County.

Nitrogen to Phosphorus Ratio (N:P)

The ratio of nitrogen and phosphorus concentrations within a surface water can provide some insight into the nature of the biological dynamics associated with that water. When the ratio is between 5-10, the system can be expected to be rather balanced in terms of relative availability of each nutrient. When the ratio falls below 5 the system is more likely to become limited by nitrogen, particularly when initial concentrations are comparatively low. When nitrogen limitation occurs, a condition is established that gives an advantage to organisms that can utilize atmospheric nitrogen. Within aquatic, estuarine and marine environments *Cyanobacteria,* known as blue-green "algae" are often the most efficient nitrogen fixers.

Conversely, ratios above 8 may become limited by phosphorus availability. When phosphorus becomes limiting, organisms which produce enzymes such as phospho-diesterase, capable of hydrolyzing organically bound phosphate, may have a noticeable advantage.

[6] In some cases in Table 6 ortho phosphorus is noted to be higher than total phosphorus—hence the percentage as ortho phosphorus >100%. This normally could not be the case, as ortho phosphorus is a component of total phosphorus. However, the percentages are calculated as ortho phosphorus from a grab sample and total phosphorus from a composite sample.

Table 5. Influent and Effluent Total Phosphorus

Week Ending	HydroMentia Weekly Composite Total Phosphorus µg/L (Note 4) INFLUENT	HydroMentia Weekly Composite Total Phosphorus µg/L (Note 4) EFFLUENT	Lee County Weekly Composite Total Phosphorus µg/L INFLUENT	Lee County Weekly Composite Total Phosphorus µg/L EFFLUENT	Lee County Weekly Grab Total Phosphorus µg/L INFLUENT	Lee County Weekly Grab Total Phosphorus µg/L EFFLUENT
12/11/08	96	59	98	66	Note 3	Note 3
12/18/08	150	60	95	63	Note 3	Note 3
12/29/08	97	62	90	60	Note 3	Note 3
1/5/09	92	43	Note 1	Note 1	Note 3	Note 3
1/12/09	105	84	120	90	Note 3	Note 3
1/15/09	355	124	Note 1	Note 1	Note 3	Note 3
1/22/09	73	44	76	44	Note 3	Note 3
1/29/09	75	39	77	42	Note 3	Note 3
2/5/09	43	29	46	61	Note 3	Note 3
2/12/09	62	42	62	42	Note 3	Note 3
2/19/09	74	61	66	48	Note 3	Note 3
2/25/09	80	50	71	39	Note 3	Note 3
3/5/09	74	49	70	43	Note 3	Note 3
3/12/09	79	68	70	39	Note 3	Note 3
3/19/09	94	60	82	49	Note 3	Note 3
3/26/09	Note 2	Note 2	Note 2	Note 2	Note 3	Note 3
4/2/09	135	100	140	100	Note 3	Note 3
4/8/09	174	121	160	130	Note 3	Note 3
4/16/09	149	138	150	150	Note 3	Note 3
4/23/09	166	190	160	190	Note 3	Note 3
4/30/09	137	147	110	140	Note 3	Note 3
5/7/09	163	156	160	150	Note 3	Note 3
5/14/09	147	137	130	130	Note 3	Note 3
5/21/09	223	215	210	210	Note 3	Note 3
5/28/09	154	141	150	140	Note 3	Note 3
6/4/09	265	236	240	220	Note 3	Note 3
6/11/09	259	244	240	210	290	280
6/18/09	391	370	346	320	440	370
6/25/09	310	295	270	260	270	260
7/2/09	268	262	250	240	160	150
7/9/09	151	130	110	140	180	180
7/16/09	204	149	170	140	190	140
7/23/09	149	121	140	110	270	140
7/30/09	140	111	140	110	170	66
8/6/09	149	95	150	86	160	100
8/13/09	126	94	120	88	170	86
8/20/09	72	70	62	36	95	62
8/27/09	90	74	73	49	83	37
9/3/09	86	48	62	29	75	16
9/10/09	91	56	73	35	61	36
9/17/09	89	57	74	41	66	27
9/24/09	110	110	85	85	110	69
10/1/09	130	58	130	52	130	52
10/8/09	130	84	120	78	120	78
10/15/09	95	78	86	70	110	74
10/22/09	100	86	88	72	100	85
10/29/09	107	83	97	76	120	87
11/5/09	117	104	120	110	160	110
11/12/09	114	101	110	97	120	100
11/19/09	105	99	110	99	130	92
11/24/09	94	78	110	86	140	82
12/3/09	139	76	150	85	140	43
12/10/09	143	119	140	130	140	130
AVERAGES	**139**	**110**	**125**	**104**	**156**	**109**
St. Dev.	**73**	**70**	**61**	**66**	**82**	**82**
Q1 Average	**104**	**58**	**78**	**53**	**-**	**-**
Q2 Average	**172**	**157**	**161**	**152**	**-**	**-**
Q3 Average	**171**	**144**	**151**	**126**	**179**	**126**
Q4 Average	**113**	**87**	**109**	**83**	**122**	**79**

Note 1: County Staff did not take samples

Note 2: No sampling due to vandalism damage

Note 3: County analysis of grab samples for total phosphorus begun on 6/11/09

Note 4: Grab samples used 1/5/09;2/5/09;6/25/09;10/1/09;10/8/09

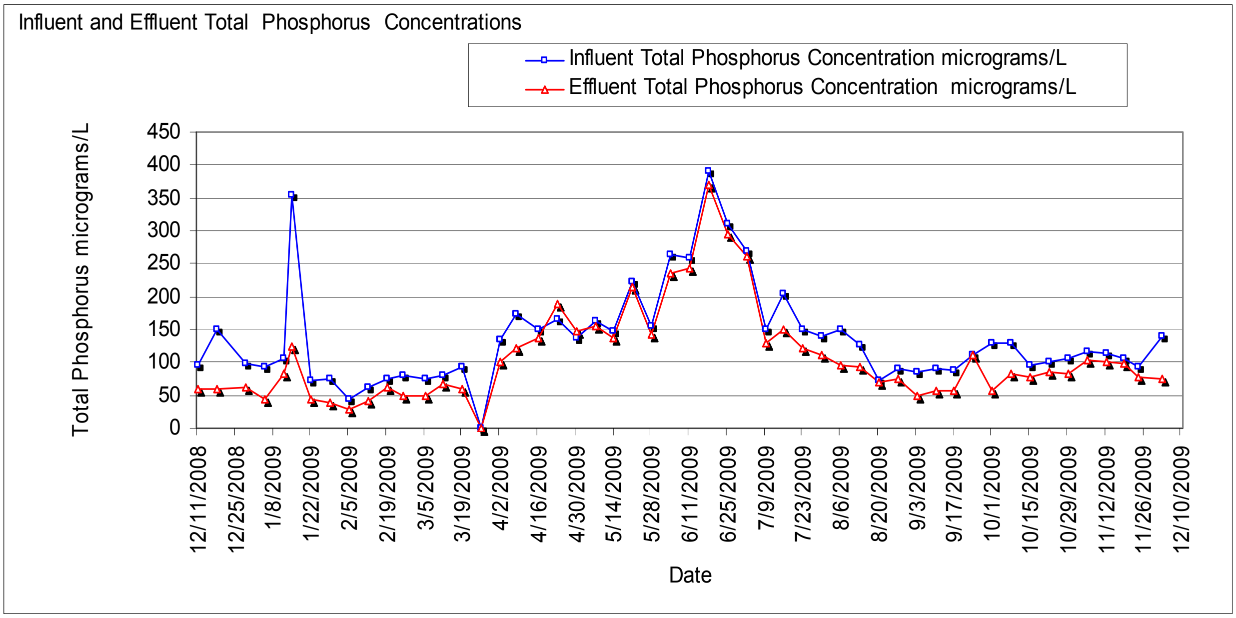

Figure 3: Influent and Effluent Total Phosphorus ATS™ Pilot Powell Creek By-Pass Canal

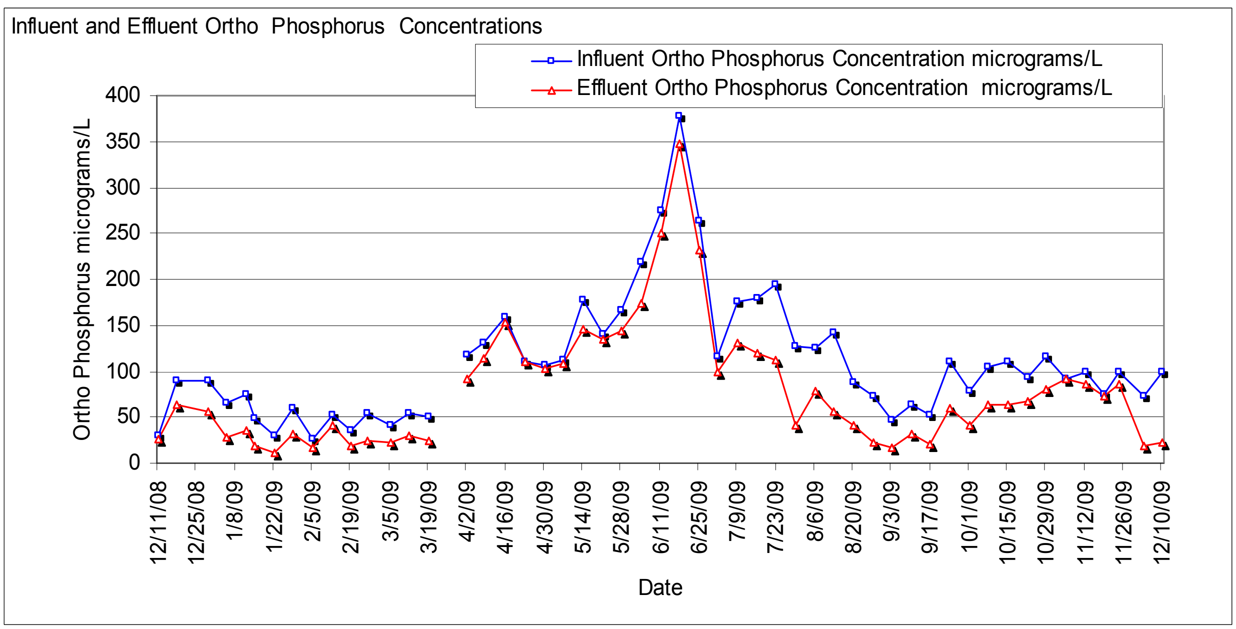

Figure 4: Influent and Effluent Ortho Phosphorus ATS™ Pilot Powell Creek By-Pass Canal

Table 6. Influent and Effluent Ortho Phosphorus

	HydroMentia Weekly Grab Ortho Phosphorus µg/L	HydroMentia Weekly Grab Ortho Phosphorus µg/L	HydroMentia Estimate % of Total Phosphorus as Ortho-Phosphorus	HydroMentia Estimate % of Total Phosphorus as Ortho-Phosphorus	Lee County Weekly Grab Ortho Phosphorus µg/L	Lee County Weekly Grab Ortho Phosphorus µg/L	Lee County Estimate % of Total Phosphorus as Ortho-Phosphorus	Lee County Estimate % of Total Phosphorus as Ortho-Phosphorus
Ending	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**
12/11/08	29	26	30.21%	44.07%	25	22	25.51%	33.33%
12/18/08	90	63	60.00%	105.00%	57	43	60.00%	68.25%
12/29/08	89	57	91.75%	91.94%	48	37	53.33%	61.67%
1/5/09	66	28	71.74%	65.12%	Note 2	Note 2	Note 2	Note 2
1/12/09	74	36	70.48%	42.86%	55	20	45.83%	22.22%
1/15/09	48	18	13.52%	14.52%	Note 2	Note 2	Note 2	Note 2
1/22/09	30	12	41.10%	27.27%	17	7	22.37%	15.91%
1/29/09	60	31	80.00%	79.49%	43	12	55.84%	28.57%
2/5/09	26	16	60.47%	55.17%	10	6	21.74%	9.84%
2/12/09	52	42	83.87%	100.00%	44	28	70.97%	66.67%
2/19/09	36	19	48.65%	31.15%	26	11	39.39%	22.92%
2/25/09	55	25	68.75%	50.00%	49	18	69.01%	46.15%
3/5/09	42	23	56.76%	46.94%	34	15	48.57%	34.88%
3/12/09	54	29	68.35%	42.65%	44	25	62.86%	64.10%
3/19/09	51	24	54.26%	40.00%	45	16	54.88%	32.65%
3/26/09	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1
4/2/09	118	91	87.41%	91.00%	113	80	80.71%	80.00%
4/8/09	131	114	75.29%	94.21%	123	105	76.88%	80.77%
4/16/09	159	154	106.71%	111.59%	144	140	96.00%	93.33%
4/23/09	110	110	66.27%	57.89%	97	101	60.63%	53.16%
4/30/09	106	102	77.37%	69.39%	94	86	85.45%	61.43%
5/7/09	112	109	68.71%	69.87%	103	96	64.38%	64.00%
5/14/09	178	146	121.09%	106.57%	168	142	129.23%	109.23%
5/21/09	141	135	63.23%	62.79%	132	124	62.86%	59.05%
5/28/09	166	144	107.79%	102.13%	153	129	102.00%	92.14%
6/4/09	219	174	82.64%	73.73%	200	181	83.33%	82.27%
6/11/09	275	250	106.18%	102.46%	257	229	107.08%	109.05%
6/18/09	377	348	96.42%	94.05%	346	317	100.00%	99.06%
6/25/09	263	231	84.84%	78.31%	242	208	89.63%	80.00%
7/2/09	116	100	43.28%	38.17%	104	83	41.60%	34.58%
7/9/09	175	130	115.89%	100.00%	154	106	140.00%	75.71%
7/16/09	180	120	88.24%	80.54%	158	100	92.94%	71.43%
7/23/09	194	113	130.20%	93.39%	191	102	136.43%	92.73%
7/30/09	128	41	91.43%	36.94%	129	31	92.14%	28.18%
8/6/09	126	79	84.56%	83.16%	123	72	82.00%	83.72%
8/13/09	142	57	112.70%	60.64%	138	50	115.00%	56.82%
8/20/09	88	42	122.22%	60.00%	59	30	95.16%	83.33%
8/27/09	72	22	80.00%	29.73%	58	7	79.45%	14.29%
9/3/09	46	17	53.49%	35.42%	42	17	67.74%	58.62%
9/10/09	63	32	69.23%	57.14%	56	26	76.71%	74.29%
9/17/09	53	20	59.55%	35.09%	45	11	60.81%	26.83%
9/24/09	110	60	100.00%	54.55%	92	46	108.24%	54.12%
10/1/09	79	42	60.77%	72.41%	69	30	53.08%	57.69%
10/8/09	105	63	80.77%	75.00%	90	50	75.00%	64.10%
10/15/09	110	63	115.79%	80.77%	93	41	108.14%	58.57%
10/22/09	94	67	94.00%	77.91%	81	55	92.05%	76.39%
10/29/09	116	81	108.41%	97.59%	105	67	108.25%	88.16%
11/5/09	92	91	78.63%	87.50%	139	82	115.83%	74.55%
11/12/09	99	86	86.84%	85.15%	85	71	77.27%	73.20%
11/19/09	74	73	70.48%	73.74%	72	72	65.45%	72.73%
11/24/09	99	86	105.32%	110.26%	103	51	93.64%	59.30%
12/3/09	73	19	52.52%	25.00%	73	9	48.67%	10.59%
12/10/09	100	23	69.93%	19.33%	108	24	77.14%	18.46%
AVERAGES	**109**	**79**	**79.19%**	**67.68%**	**101**	**69**	**77.42%**	**59.58%**
St. Dev.	**68**	**66**	**24.62%**	**26.68%**	**66**	**64**	**27.80%**	**26.50%**
Q1 Average	**54**	**30**	**60.40%**	**56.87%**	**38**	**20**	**47.95%**	**39.54%**
Q2 Average	**147**	**129**	**84.74%**	**81.80%**	**136**	**119**	**83.62%**	**76.42%**
Q3 Average	**152**	**102**	**90.19%**	**65.19%**	**138**	**88**	**92.99%**	**65.60%**
Q4 Average	**93**	**60**	**83.31%**	**68.79%**	**89**	**47**	**83.35%**	**56.51%**

Note 1: No sampling due to vandalism damage
Note 2: County Staff did not take samples

Table 7. Influent and Effluent TKN, Nitrate+Nitrite Nitrogen, and Total Nitrogen through HydroMentia, Inc with Ammonia-N by Lee County.

	HydroMentia Weekly Composite Total Kjeldahl Nitrogen mg/L (Note 3)	HydroMentia Weekly Composite Total Kjeldahl Nitrogen mg/L (Note 3)	HydroMentia Weekly Composite Nitrate + Nitrite Nitrogen mg/L (Note 3)	HydroMentia Weekly Composite Nitrate + Nitrite Nitrogen mg/L (Note 3)	Lee County Weekly Composite Ammonia Nitrogen mg/L (Note 3)	Lee County Weekly Composite Ammonia Nitrogen mg/L (Note 3)	HydroMentia Weekly Composite Total Nitrogen mg/L (Note 3)	HydroMentia Weekly Composite Total Nitrogen mg/L (Note 3)
Week Ending	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
12/11/08	0.44	0.36	0.01	0.01	0.03	0.01	0.45	0.37
12/18/08	0.76	0.56	0.01	0.01	0.02	0.01	0.77	0.57
12/29/08	1.10	1.20	0.01	0.01	0.03	0.01	1.11	1.21
1/5/09	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1
1/12/09	1.07	0.99	0.03	0.03	0.13	0.01	1.10	1.02
1/15/09	1.77	0.82	0.26	0.03	Note 4	Note 4	2.03	0.85
1/22/09	0.67	0.60	0.01	0.01	0.13	0.01	0.68	0.61
1/29/09	0.79	0.77	0.03	0.01	0.08	0.05	0.82	0.78
2/5/09	0.70	0.65	0.01	0.01	0.02	0.01	0.71	0.66
2/12/09	0.74	0.68	0.01	0.01	0.11	0.02	0.75	0.69
2/19/09	0.92	0.85	0.01	0.01	0.07	0.01	0.93	0.86
2/25/09	0.99	0.86	0.01	0.01	0.03	0.01	1.00	0.87
3/5/09	0.95	0.90	0.01	0.01	0.06	0.03	0.96	0.91
3/12/09	0.97	0.88	0.04	0.01	0.03	0.01	1.01	0.89
3/19/09	0.93	0.89	0.03	0.03	0.10	0.04	0.96	0.92
3/26/09	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
4/2/09	1.08	0.92	0.03	0.03	0.11	0.07	1.11	0.95
4/8/09	1.04	0.94	0.03	0.03	0.07	0.06	1.07	0.97
4/16/09	1.13	1.10	0.03	0.03	0.03	0.02	1.16	1.13
4/23/09	1.10	1.20	0.03	0.03	0.02	0.07	1.13	1.23
4/30/09	1.20	1.21	0.04	0.03	0.04	0.03	1.24	1.24
5/7/09	0.99	1.17	0.03	0.03	0.04	0.05	1.02	1.20
5/14/09	0.94	1.09	0.03	0.03	0.11	0.20	0.97	1.12
5/21/09	1.06	1.30	0.03	0.03	0.09	0.05	1.09	1.33
5/28/09	0.85	0.98	0.03	0.03	0.01	0.01	0.88	1.01
6/4/09	0.96	0.95	0.03	0.03	0.04	0.01	0.99	0.98
6/11/09	0.87	0.86	0.03	0.03	0.09	0.01	0.90	0.89
6/18/09	0.99	1.05	0.03	0.03	0.01	0.02	1.02	1.08
6/25/09	0.94	0.96	0.07	0.03	0.07	0.02	1.01	0.99
7/2/09	1.15	0.86	0.12	0.06	0.11	0.03	0.80	0.95
7/9/09	0.77	0.90	0.03	0.05	0.02	0.01	0.80	0.95
7/16/09	1.11	1.05	0.07	0.07	0.01	0.01	1.18	1.12
7/23/09	1.43	0.89	0.03	0.03	0.24	0.01	1.46	0.92
7/30/09	0.85	0.87	0.08	0.06	0.01	0.01	0.93	0.93
8/6/09	1.08	0.92	0.07	0.03	0.08	0.01	1.15	0.95
8/13/09	1.00	0.96	0.05	0.03	0.02	0.01	1.05	0.99
8/20/09	0.55	0.57	0.03	0.03	0.01	0.01	0.58	0.60
8/27/09	0.87	0.64	0.05	0.03	0.01	0.02	0.92	0.67
9/3/09	0.75	0.71	0.05	0.04	0.07	0.03	0.80	0.75
9/10/09	0.69	0.55	0.09	0.03	0.09	0.02	0.78	0.58
9/17/09	0.70	0.76	0.09	0.05	0.08	0.02	0.79	0.81
9/24/09	0.89	0.89	0.12	0.08	0.06	0.08	1.01	0.97
10/1/09	0.75	0.62	0.06	0.04	0.05	0.01	0.81	0.66
10/8/09	0.90	0.74	0.05	0.03	0.02	0.01	0.95	0.77
10/15/09	0.75	0.73	0.08	0.03	0.01	0.01	0.83	0.76
10/22/09	0.71	0.71	0.08	0.03	0.01	0.01	0.79	0.74
10/29/09	0.70	0.68	0.08	0.03	0.04	0.04	0.78	0.71
11/5/09	0.69	0.63	0.06	0.05	0.04	0.01	0.75	0.68
11/12/09	0.86	0.68	0.07	0.03	0.05	0.02	0.93	0.71
11/19/09	0.81	0.71	0.04	0.03	0.09	0.07	0.88	0.74
11/24/09	0.71	0.64	0.03	0.03	0.11	0.03	0.74	0.67
12/3/09	0.78	0.57	0.15	0.05	0.15	0.01	0.93	0.62
12/10/09	0.84	0.76	0.16	0.14	0.25	0.01	1.00	0.90
AVERAGES	**0.91**	**0.84**	**0.05**	**0.03**	**0.06**	**0.03**	**0.95**	**0.87**
St. Dev.	**0.22**	**0.20**	**0.05**	**0.02**	**0.05**	**0.03**	**0.23**	**0.20**
Q1 Average	**0.91**	**0.78**	**0.03**	**0.01**	**0.06**	**0.02**	**0.95**	**0.79**
Q2 Average	**1.01**	**1.05**	**0.03**	**0.03**	**0.06**	**0.05**	**1.04**	**1.08**
Q3 Average	**0.94**	**0.84**	**0.06**	**0.04**	**0.06**	**0.02**	**0.96**	**0.88**
Q4 Average	**0.78**	**0.70**	**0.08**	**0.05**	**0.07**	**0.03**	**0.86**	**0.75**

Note 1: No samples taken for nitrogen
Note 2: No sampling due to vandalism damage
Note 3: Grab samples used 2/5/09;6/25/09;10/1/09;10/8/09
Note 4: No sampling by County Staff

Table 8. Influent and Effluent Ammonia Nitrogen and Total Nitrogen through Lee County

	Lee County Weekly Composite Ammonia Nitrogen mg/L (Note 3)	Lee County Weekly Composite Ammonia Nitrogen mg/L (Note 3)	Lee County Weekly Composite Total Nitrogen mg/L (Note 3)	Lee County Weekly Composite Total Nitrogen mg/L (Note 3)
Week Ending	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**
12/11/08	0.03	0.01	0.64	0.36
12/18/08	0.02	0.01	0.50	0.56
12/29/08	0.03	0.01	0.91	1.20
1/5/09	Note 1	Note 1	Note 1	Note 1
1/12/09	0.13	0.01	0.96	0.99
1/15/09	Note 1	Note 1	Note 1	Note 1
1/22/09	0.13	0.01	0.50	0.60
1/29/09	0.08	0.05	0.82	0.77
2/5/09	0.02	0.01	0.65	0.65
2/12/09	0.11	0.02	0.77	0.68
2/19/09	0.07	0.01	0.99	0.85
2/25/09	0.03	0.01	1.10	0.86
3/5/09	0.06	0.03	0.82	0.90
3/12/09	0.03	0.01	1.00	0.88
3/19/09	0.10	0.04	0.68	0.89
3/26/09	Note 2	Note 2	Note 2	Note 2
4/2/09	0.11	0.07	0.81	0.92
4/8/09	0.07	0.06	0.76	0.94
4/16/09	0.03	0.02	0.95	1.10
4/23/09	0.02	0.07	0.95	1.20
4/30/09	0.04	0.03	1.10	1.21
5/7/09	0.04	0.05	1.20	1.17
5/14/09	0.11	0.20	1.10	1.09
5/21/09	0.09	0.05	1.00	1.30
5/28/09	0.01	0.01	0.53	0.98
6/4/09	0.04	0.01	0.77	0.95
6/11/09	0.09	0.01	1.10	0.86
6/18/09	0.01	0.02	1.20	1.05
6/25/09	0.07	0.02	1.10	0.96
7/2/09	0.11	0.03	1.10	0.86
7/9/09	0.02	0.01	0.82	0.90
7/16/09	0.01	0.01	1.70	1.05
7/23/09	0.24	0.01	1.80	0.89
7/30/09	0.01	0.01	0.91	0.87
8/6/09	0.08	0.01	1.20	0.92
8/13/09	0.02	0.01	0.98	0.96
8/20/09	0.01	0.01	0.91	0.57
8/27/09	0.01	0.02	1.10	0.64
9/3/09	0.07	0.03	0.75	0.71
9/10/09	0.09	0.02	0.75	0.55
9/17/09	0.08	0.02	0.78	0.76
9/24/09	0.06	0.08	1.20	0.89
10/1/09	0.05	0.01	0.80	0.62
10/8/09	0.02	0.01	0.65	0.74
10/15/09	0.01	0.01	0.81	0.73
10/22/09	0.01	0.01	1.10	0.71
10/29/09	0.04	0.04	1.10	0.68
11/5/09	0.04	0.01	1.10	0.63
11/12/09	0.05	0.02	0.94	0.68
11/19/09	0.09	0.07	0.52	0.73
11/24/09	0.11	0.03	0.87	0.72
12/3/09	0.15	0.01	0.84	0.91
12/10/09	0.25	0.01	1.00	1.10
AVERAGES	**0.06**	**0.03**	**0.93**	**0.85**
St. Dev.	**0.05**	**0.03**	**0.26**	**0.20**
Q1 Average	**0.06**	**0.02**	**0.81**	**0.78**
Q2 Average	**0.06**	**0.05**	**0.91**	**1.05**
Q3 Average	**0.06**	**0.02**	**1.10**	**0.84**
Q4 Average	**0.07**	**0.03**	**0.90**	**0.76**

Note 1: No sampling by County Staff

Note 2: No sampling due to vandalism damage

Note 3: Grab samples used 2/5/09;6/25/09;10/1/09;10/8/09

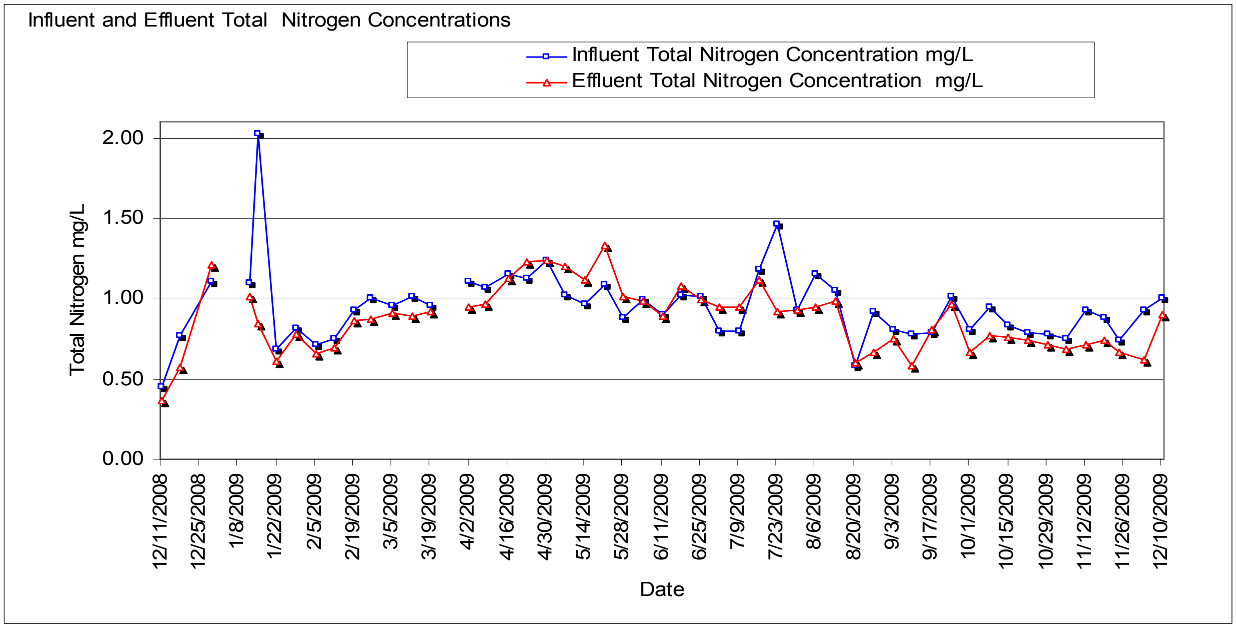

Figure 5: Influent and Effluent Total Nitrogen ATS™ Pilot Powell Creek By-Pass Canal

When assessing the N:P ratio, it is important to not only consider the ratio of total nitrogen to total phosphorus, but also the ratios of available forms. These ratios for the operational period are noted in Table 9, Table R9 and Figure 6. As shown, the ratio of total nitrogen to total phosphorus is generally within the range of 5-8 (average influent 7.9), and increases slightly within the effluent. However, when only available forms are considered, the ratio is well below this range (average influent 1.3), with little change in the effluent ratio. This is suggestive of a situation in which nitrogen could control productivity, and nitrogen fixation could be solicited. This is discussed in more detail in the System Analysis section.

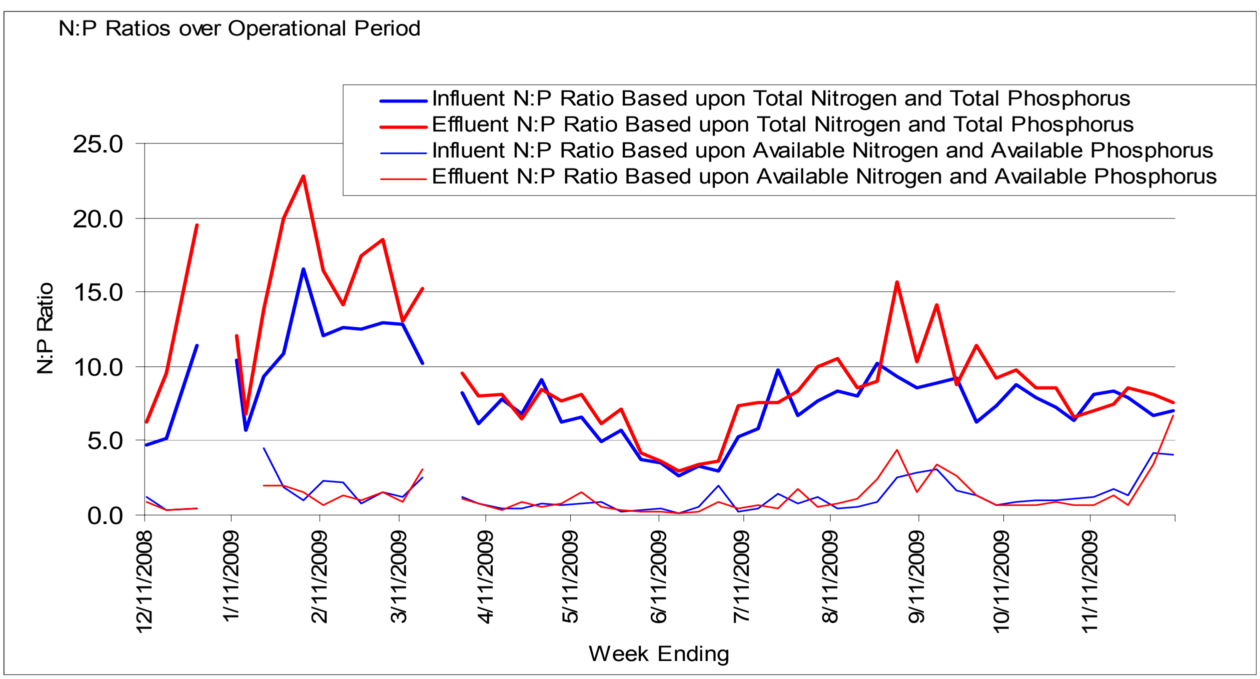

Figure 6: Nitrogen to Phosphorus Ratios (N:P) Through the Operational Period

Conductivity and Water Temperature

The pilot unit is designed to receive water from the Powell Creek By-Pass Canal, which is located about 1,000 feet upstream of the Caloosahatchee River/Estuary. The Caloosahatchee River at this point is about 14 miles from San Carlos Bay and the Gulf of Mexico. Tidal influence is quite evident at the point of water intake for the pilot study, and it was anticipated that salinity (hence conductivity) would fluctuate both seasonally and diurnally.

One key question regarding pilot performance was the capability of the system to sustain treatment efficiency under such euryhaline conditions. Consequently, it was decided to place an in-situ conductivity logger within the influent flow so time active changes in conductivity could be monitored. A Model 6536D Unidata MicroLogger was installed at the onset of the project. During the course of the year some difficulty was encountered with this unit's software, so there were periods in which continuous conductivity was not monitored. Nonetheless, sufficient data was recovered to reveal general seasonal and diurnal trends. In addition to the in-situ datalogger, conductivity readings were taken weekly with a handheld YSI unit.

Not unexpectedly, conductivity did vary both with tidal fluctuations and seasonal changes. This is noted in the datalogger results noted in Figures 7 through 9.

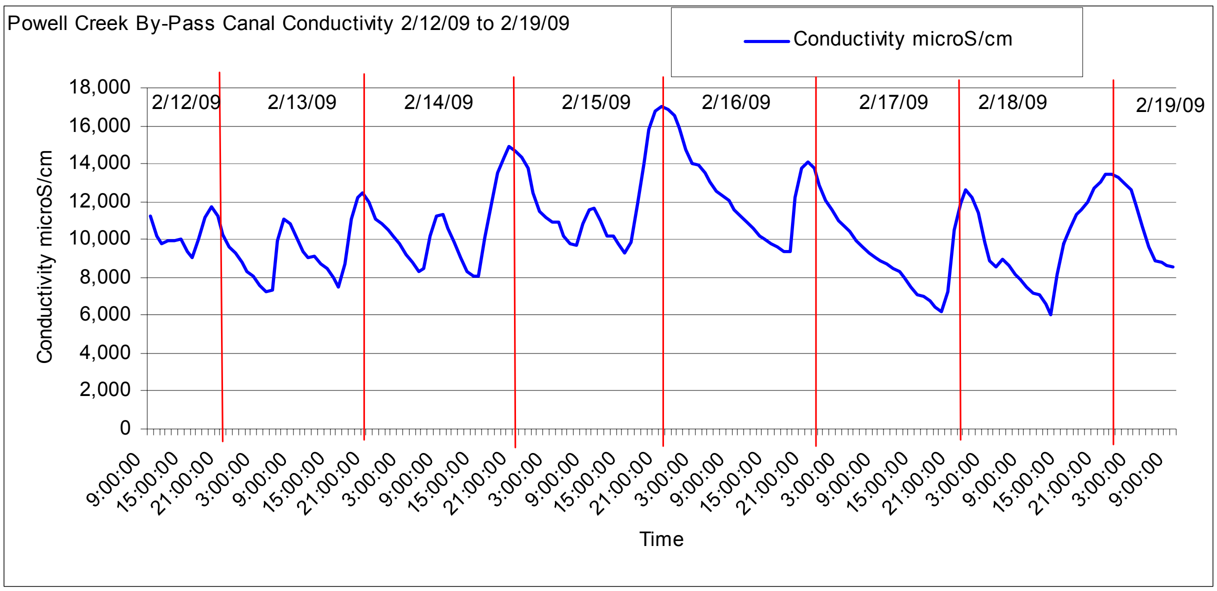

Figure 7: Diurnal Conductivity Patterns Powell Creek By-Pass Canal 2/12/09 through 2/19/09

As noted from these figures, during the dry season (approximately October through May) the conductivity increases with low rainfall and runoff rates. This can be clearly seen from Table 10 and Figure 10 in which are shown the weekly influent conductivity[7] through the operational period. Weekly rainfall during the monitoring period is provided in Figure 10a.The relationship between specific conductance and the classification of waters based on the Venice Classification System is provided in Image 1 During the rainy season, conductivity levels drop, and the extent of percent fluctuation in conductivity increases in response to runoff loads. This is clearly seen in Figure 8, in which is shown a week in which there was 4" of rain. On 8/29/09 for example, conductivity dropped from 2,000 microS/cm to 1,300 microS/cm in about 1 hour. By November (Figure 9) the conductivity had risen considerably in response to reduced runoff.

[7] Most of the data points in Table 10 represent the weekly average taken from the in-situ data logger. On weeks the datalogger was not functioning, the field influent reading taken at the time of sampling was used.

Because of the complexity of the dynamics associated with the movement and mixing of upstream and tidal waters, particularly when the impact of upstream control structures within the Caloosahatchee is considered, it is difficult to project anything other than general seasonal patterns. However, it is clear that the water quality in the region in terms of conductivity (salinity) is significantly influenced by tidal flow and upstream runoff, and this needs to be seriously considered during design of any proposed full scale system which would serve this area. Further discussion regarding the possible influence of conductivity fluctuation upon system performance is included within the System Analysis Section.

Weekly field sampling using the YSI 556 hand held unit included monitoring of influent and effluent conductivity at the time of sampling. Results are noted in Table 11. As would be expected there is little difference over the operational period between influent and effluent conductivity, but there is wide seasonal variability in conductivity in both the influent and effluent as noted by the large standard deviation.

Water temperature changes from influent to effluent averaged an increase of 1.69 ° C over the year. It needs to be recognized that these are daytime readings, and that during the night there is often a drop in water temperature from influent to effluent. Similar fluctuations have been observed in other ATS™ operations, and it can be expected that during the warmer months the influent flow may increase by 2-4° C during the daytime, and show a reverse trend at night.

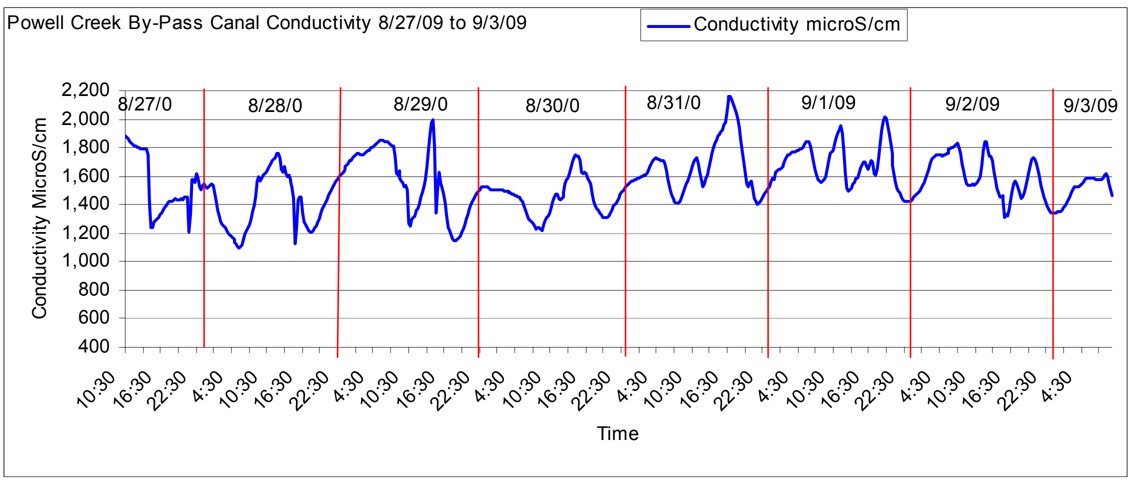

Figure 8: Diurnal Conductivity Patterns Powell Creek By-Pass Canal 8/27/09 through 9/3/09

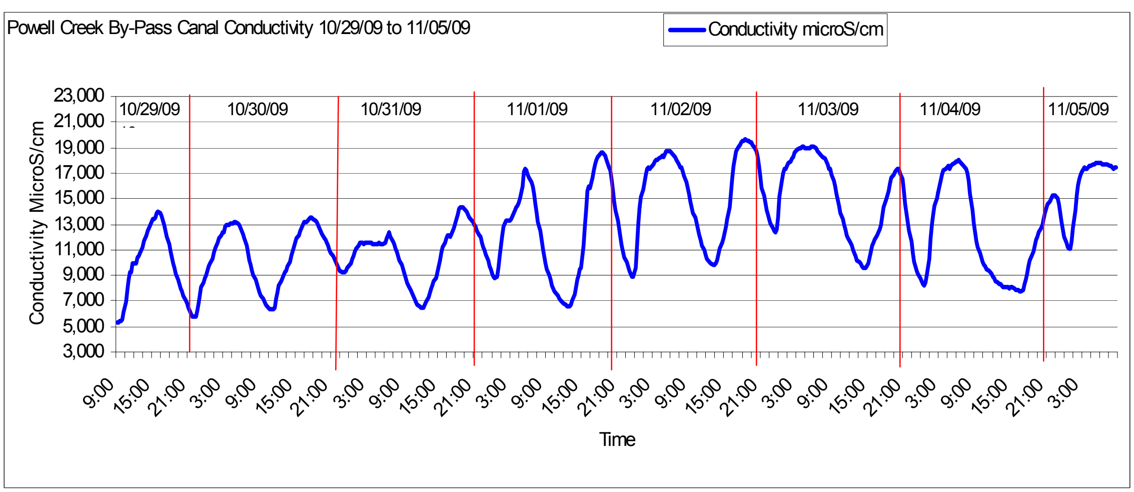

Figure 9: Diurnal Conductivity Patterns Powell Creek By-Pass Canal 10/29/09 through 11/05/09

Table 9. Influent and Effluent Nitrogen to Phosphorus Ratio

	N:P Ratio Based upon Total Nitrogen and Total Phosphorus (Note 3)	N:P Ratio Based upon Total Nitrogen and Total Phosphorus (Note 3)	N:P Ratio Based upon Available Nitrogen and Available Phosphorus (Note 3)	N:P Ratio Based upon Available Nitrogen and Available Phosphorus (Note 3)
Week Ending	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
12/11/08	4.7	6.3	1.2	0.9
12/18/08	5.1	9.5	0.3	0.4
12/29/08	11.4	19.5	0.4	0.4
1/5/09	Note 1	Note 1	Note 1	Note 1
1/12/09	10.4	12.1	2.1	1.2
1/15/09	5.7	6.8	Note 2	Note 2
1/22/09	9.3	13.9	4.5	2.0
1/29/09	10.9	20.0	1.9	2.0
2/5/09	16.5	22.8	1.0	1.5
2/12/09	12.1	16.4	2.3	0.7
2/19/09	12.6	14.1	2.2	1.3
2/25/09	12.5	17.4	0.8	1.0
3/5/09	13.0	18.6	1.5	1.5
3/12/09	12.8	13.1	1.3	0.8
3/19/09	10.2	15.3	2.5	3.1
3/26/09	Note 1	Note 1	Note 1	Note 1
4/2/09	8.2	9.5	1.2	1.1
4/8/09	6.1	8.0	0.7	0.8
4/16/09	7.8	8.2	0.4	0.4
4/23/09	6.8	6.4	0.5	0.9
4/30/09	9.1	8.4	0.7	0.5
5/7/09	6.3	7.7	0.6	0.7
5/14/09	6.6	8.1	0.8	1.5
5/21/09	4.9	6.2	0.8	0.6
5/28/09	5.7	7.2	0.3	0.3
6/4/09	3.7	4.2	0.3	0.3
6/11/09	3.5	3.6	0.5	0.2
6/18/09	2.6	2.9	0.1	0.1
6/25/09	3.3	3.4	0.5	0.2
7/2/09	3.0	3.6	2.0	0.9
7/9/09	5.3	7.3	0.3	0.5
7/16/09	5.8	7.5	0.5	0.7
7/23/09	9.8	7.6	1.4	0.4
7/30/09	6.6	8.4	0.7	1.8
8/6/09	7.7	10.0	1.2	0.6
8/13/09	8.3	10.5	0.5	0.8
8/20/09	8.0	8.5	0.5	1.0
8/27/09	10.2	9.0	0.9	2.4
9/3/09	9.3	15.7	2.5	4.4
9/10/09	8.6	10.4	2.9	1.5
9/17/09	8.9	14.1	3.1	3.5
9/24/09	9.2	8.8	1.6	2.6
10/1/09	6.2	11.4	1.4	1.3
10/8/09	7.3	9.2	0.7	0.7
10/15/09	8.7	9.7	0.9	0.7
10/22/09	7.9	8.6	1.0	0.7
10/29/09	7.3	8.6	1.0	0.9
11/5/09	6.4	6.5	1.0	0.7
11/12/09	8.2	7.0	1.3	0.6
11/19/09	8.4	7.5	1.8	1.4
11/24/09	7.9	8.6	1.4	0.7
12/3/09	6.7	8.2	4.1	3.4
12/10/09	7.0	7.6	4.1	6.7
AVERAGES	**7.9**	**9.9**	**1.3**	**1.3**
St. Dev.	**2.9**	**4.5**	**1.0**	**1.2**
Q1 Average	**10.54**	**14.65**	**1.62**	**1.14**
Q2 Average	**6.56**	**7.73**	**0.77**	**0.86**
Q3 Average	**6.81**	**8.05**	**1.08**	**1.17**
Q4 Average	**7.69**	**8.91**	**1.79**	**1.83**

Note 1: No sampling due to vandalism damage
Note 2: County Staff did not take samples
Note 3: Grab samples used for 2/5/09;6/25/09;10/1/09;10/8/09.
HydroMentia data used in calculations , except for ammonia nitrogen

Table R9: Percentage of Total Phosphorus as Ortho Phosphorus from Lee County Grab Samples.

	Lee County Weekly Grab Total Phosphorus µg/L		Lee County Weekly Grab Ortho Phosphorus µg/L		Lee County Estimate % of Total Phosphorus as Ortho-Phosphorus per Grab Samples	
Week Ending	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**
6/11/2009	290	280	257	229	88.62%	81.79%
6/18/2009	440	370	346	317	78.64%	85.68%
6/25/2009	270	260	242	208	89.63%	80.00%
7/2/2009	160	150	104	83	65.00%	55.33%
7/9/2009	180	180	154	106	85.56%	58.89%
7/16/2009	190	140	158	100	83.16%	71.43%
7/23/2009	270	140	191	102	70.74%	72.86%
7/30/2009	170	66	129	31	75.88%	46.97%
8/6/2009	160	100	123	72	76.88%	72.00%
8/13/2009	170	86	138	50	81.18%	58.14%
8/20/2009	95	62	59	30	62.11%	48.39%
8/27/2009	83	37	58	7	69.88%	18.92%
9/3/2009	75	16	42	17	56.00%	106.25%
9/10/2009	61	36	56	26	91.80%	72.22%
9/17/2009	66	27	45	11	68.18%	40.74%
9/24/2009	110	69	92	46	83.64%	66.67%
10/1/2009	130	52	69	30	53.08%	57.69%
10/8/2009	120	78	90	50	75.00%	64.10%
10/15/2009	110	74	93	41	84.55%	55.41%
10/22/2009	100	85	81	55	81.00%	64.71%
10/29/2009	120	87	105	67	87.50%	77.01%
11/5/2009	160	110	139	82	86.88%	74.55%
11/12/2009	120	100	85	71	70.83%	71.00%
11/19/2009	130	92	72	72	55.38%	78.26%
11/24/2009	140	82	103	51	73.57%	62.20%
12/3/2009	140	43	73	9	52.14%	20.93%
12/10/2009	140	130	108	24	77.14%	18.46%
AVERAGES	**156**	**109**	**119**	**74**	**74.96%**	**62.24%**
St. Dev.	**82**	**82**	**71**	**72**	**11.46%**	**20.04%**

Table 10. Average Weekly Conductivity and Rainfall

Week Ending	Weekly Rainfall inches	Cumulative Rainfall inches	Weekly Conductivity microS/cm
12/11/08	0.50	0.50	5,652
12/18/08	1.00	1.50	5,679
12/29/08	0.00	1.50	6,533
1/5/09	0.00	1.50	7,000
1/12/09	0.00	1.50	9,200
1/15/09	0.10	1.60	10,542
1/22/09	0.00	1.60	3,457
1/29/09	0.00	1.60	12,000
2/5/09	0.30	1.90	5,398
2/12/09	0.00	1.90	6,649
2/19/09	0.00	1.90	9,490
2/25/09	0.00	1.90	9,000
3/5/09	0.00	1.90	9,700
3/12/09	0.00	1.90	16,200
3/19/09	0.10	2.00	28,000
3/26/09	0.00	2.00	36,200
4/2/09	0.40	2.40	36,500
4/8/09	0.00	2.40	37,000
4/16/09	0.60	3.00	15,100
4/23/09	0.00	3.00	35,000
4/30/09	0.00	3.00	41,500
5/7/09	0.00	3.00	49,500
5/14/09	2.50	5.50	11,000
5/21/09	2.50	8.00	18,500
5/28/09	2.00	10.00	7,750
6/4/09	1.50	11.50	1,750
6/11/09	1.75	13.25	3,400
6/18/09	0.30	13.55	
6/25/09	1.30	14.85	2,930
7/2/09	3.50	18.35	500
7/9/09	0.00	18.35	1,100
7/16/09	0.40	18.75	1,300
7/23/09	0.80	19.55	900
7/30/09	0.50	20.05	980
8/6/09	1.30	21.35	1,100
8/13/09	3.00	24.35	1,000
8/20/09	2.90	27.25	1,400
8/27/09	6.00	33.25	1,558
9/3/09	4.00	37.25	1,286
9/10/09	1.00	38.25	1,286
9/17/09	2.35	40.60	1,000
9/24/09	0.30	40.90	1,141
10/1/09	0.30	41.20	1,998
10/8/09	0.00	41.20	2,138
10/15/09	0.00	41.20	2,250
10/22/09	0.00	41.20	4,613
10/29/09	0.00	41.20	9,078
11/5/09	0.00	41.20	12,609
11/12/09	0.60	41.80	12,389
11/19/09	0.00	41.80	18,730
11/24/09	0.20	42.00	
12/3/09	0.75	42.75	
12/10/09	2.80	45.55	8,415
Total Q1	**1.90**	**Average Q1**	**8,321**
Total Q2	**11.35**	**Average Q2**	**24,708**
Total Q3	**25.00**	**Average Q3**	**1,278**
Total Q4	**7.30**	**Average Q4**	**6,304**

Table 11. Weekly Grab Sample Influent and Effluent Conductivity and Water Temperature

	Specific Conductivity (µS/cm)		Temp (°C)	
Date	Influent	Effluent	Influent	Effluent
12/11/08	5,652	3,404	21.57	19.55
12/18/08	8,679	8,821	22.60	23.50
12/29/08	7,308	7,164	22.39	24.45
1/5/09	4,151	4,339	21.05	23.14
1/12/09	9,854	10,321	22.23	22.90
1/15/09	1,898	1,918	14.14	13.68
1/22/09	3,092	3,031	9.70	13.30
1/29/09	11,867	14,011	21.43	22.45
2/5/09	5,508	5,527	8.54	9.37
2/12/09	14,732	15,909	21.28	22.10
2/19/09	12,326	12,687	20.51	22.69
2/25/09	6,969	6,863	19.62	20.32
3/5/09	9,707	9,708	19.15	21.19
3/12/09	16,050	16,533	22.37	22.69
3/19/09	28,142	28,693	22.16	27.01
3/26/09	36,212	36,699	20.62	22.52
4/2/09	36,100	35,900	22.31	22.85
4/8/09	37,166	36,966	20.91	25.11
4/16/09	15,162	15,130	21.51	21.58
4/23/09	34,761	35,026	23.49	26.10
4/30/09	41,474	41,670	24.64	26.96
5/7/09	49,312	49,658	27.06	29.01
5/14/09	11,027	10,601	24.81	26.62
5/21/09	18,074	18,917	26.39	26.42
5/28/09	7,510	8,086	31.94	34.47
6/4/09	1,525	2,062	26.51	27.66
6/11/09	3,475	3,431	28.92	30.04
6/25/09	2,945	2,933	30.40	34.82
7/2/09	527	480	27.26	30.61
7/9/09	890	861	28.98	31.65
7/20/09	958	867	28.93	30.81
7/26/09	815	805	27.49	27.73
7/30/09	876	881	29.23	30.83
8/8/09	877	814	30.14	36.42
8/13/09	1,127	988	29.94	31.55
8/27/09	1,295	1,072	30.67	31.29
9/3/09	1,222	1,147	27.68	32.00
9/10/09	968	1003	31.06	30.47
9/17/09	1,015	1,008	28.89	31.47
9/24/09	1,138	929	29.61	32.05
10/1/09	1,456	1,385	24.38	27.73
10/8/09	1,530	1,577	29.40	31.37
10/15/09				
10/22/09	7,056	7,474	24.43	25.22
10/29/09	6,886	5,374	26.48	27.50
11/5/09	8,035	8,145	26.66	28.66
11/12/09	18,786	13,642	22.77	21.18
11/19/09	13,769	13,957	21.65	22.90
11/24/09				
12/3/09				
12/10/09	9,128	7,702	23.90	24.80
AVERAGE	**10,813**	**10,752**	**24.33**	**26.02**
STANDARD DEVIATION	**12,485**	**12,577**	**5.05**	**5.56**
Average Q1	**8,414**	**8,588**	**19.04**	**20.10**
Average Q2	**24,611**	**24,834**	**24.71**	**26.64**
Average Q3	**1,136**	**1,077**	**29.25**	**31.65**
Average Q4	**6,880**	**6,119**	**25.82**	**27.29**

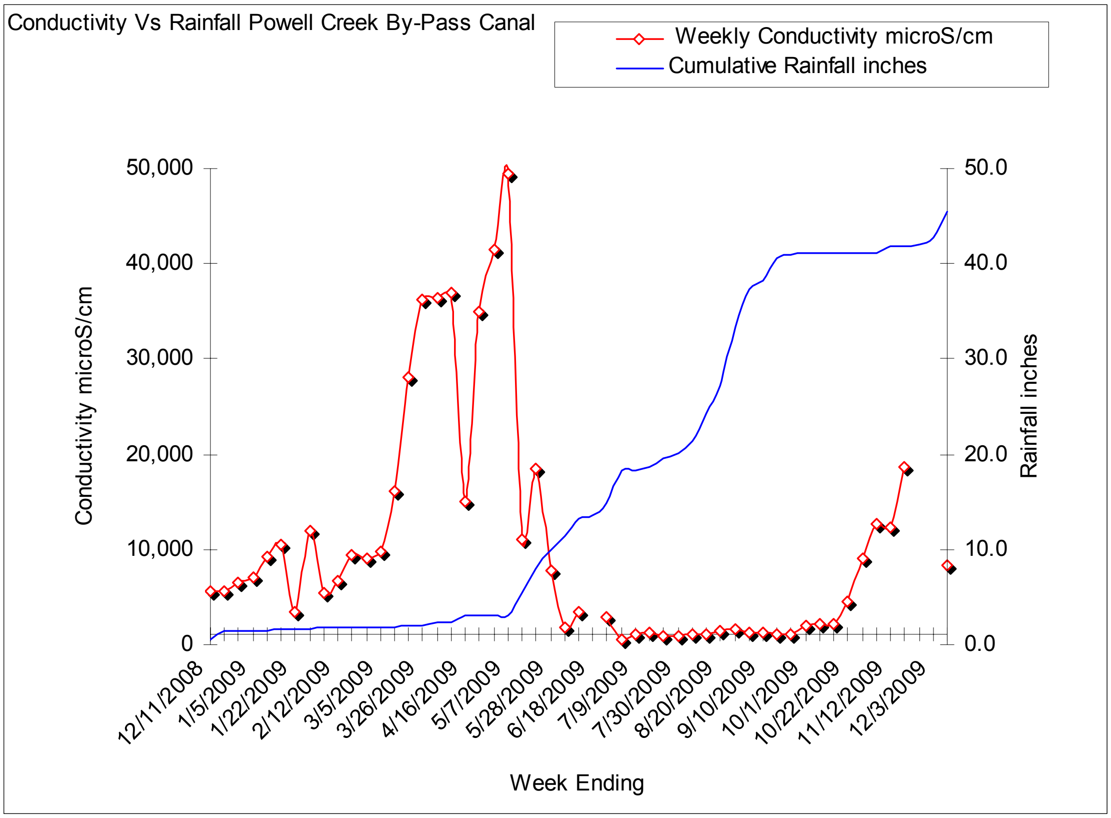

Figure 10: Rainfall and Conductivity Patterns Powell Creek By-Pass Canal

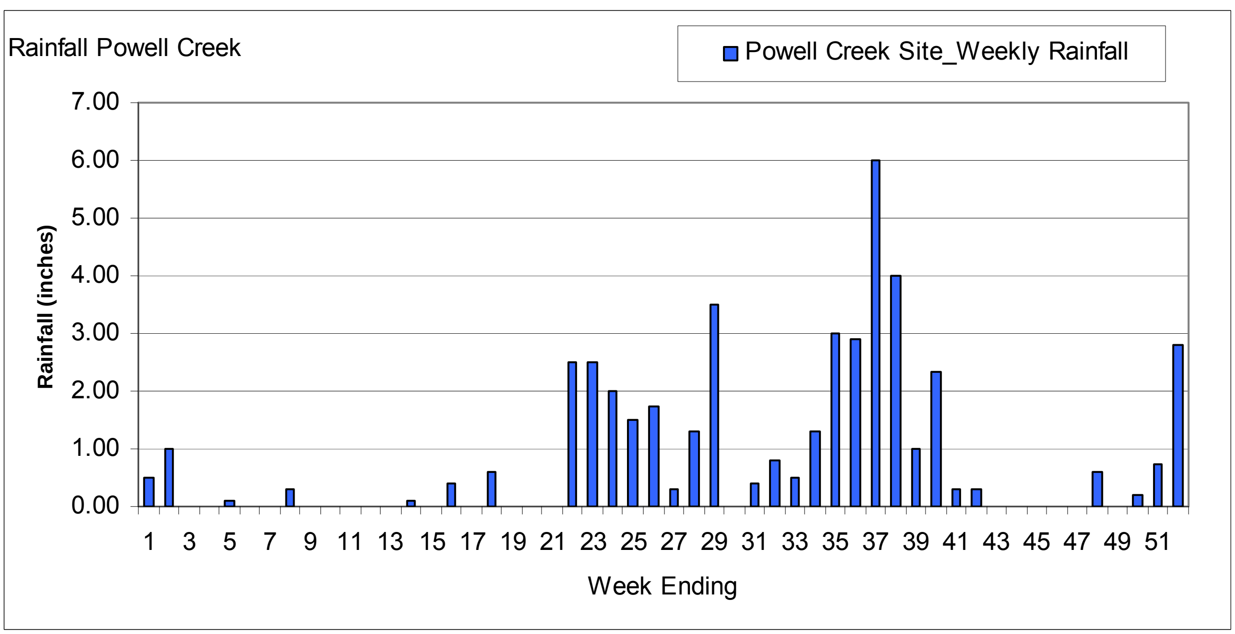

Figure 10a: Weekly Rainfall at Powell Creek By-Pass Canal for Project Monitoring Period

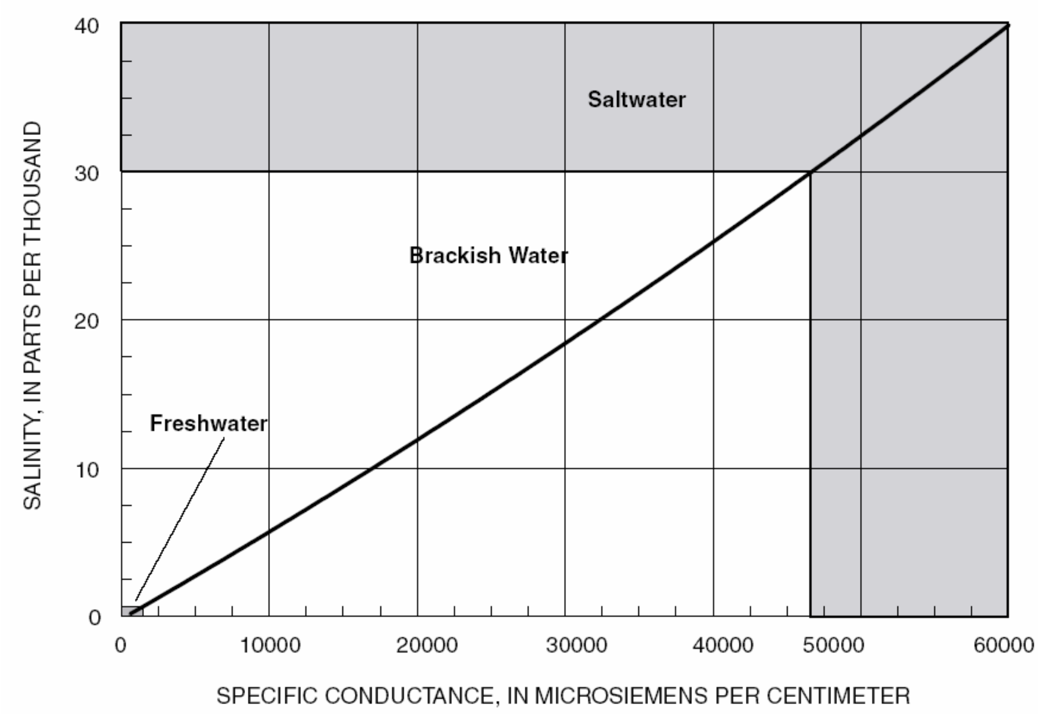

Illustration 1: Variation in Specific Conductance with Salinity

pH and Alkalinity

Alkalinity and pH were documented for the influent and effluent at the time of sampling each week. The alkalinity of the canal water was comparatively high—between 180-240 mg/L as CaCO3. Typically a high alkalinity indicates adequate amounts of available carbon for photosynthesis. With an active ATS™ unit pH usually is considerably higher in the effluent than the influent, because of the consumption of carbon dioxide, bicarbonate and carbonate by the algae during photosynthesis. The high alkalinity levels serve to prevent excessive pH increases. Alkalinity and pH values for the operational period are noted in Table 12. pH trends are noted in Figure 11. These are daytime values. At night, because of the absence of photosynthesis, there is a tendency for the pH trend to reverse, with respirational CO2 soliciting a reduction in pH.[8]

Dissolved Oxygen

Dissolved oxygen (DO) levels were documented for the influent and effluent at the time of sampling each week. Typical of ATS™ operations, daytime DO levels were noted to be higher in the effluent than the influent. This is attributable to the generation of oxygen during photosynthesis. The extent of the difference in DO between influent and effluent can serve as a general indicator of algal turf productivity—with a higher differential indicating higher levels of production. Dissolved oxygen trends for the operational period are noted in Table 13 and Figure 12.

Total Suspended Solids

Total suspended solids (TSS) can be of concern if the concentrations within the incoming flows are such that they settle and interfere with algal development, either by obscuring available sunlight, or by

[8] A detailed review of the relationship between available carbon, pH and Alkalinity, and the diurnal pH trends typical of an ATS™ operation is included in "S-154 Pilot ATS™-WHS™ Aquatic Plant Treatment System Final Report 2005" pp 77-80;129-134. Prepared for South Florida Water Management District by HydroMentia, Inc. Contract C-13933.

smothering developing algal turf, and thereby restricting transfer of nutrients and gases. Typically, concentrations need to be well over 25 mg/L before TSS has any influence on productivity. High TSS in the effluent is indicative of extensive sloughing of the algal turf, which can happen as a result of too infrequent harvesting, or loss of turf viability. During the operational period, both influent and effluent TSS concentrations remained comparatively low, as shown in Table 14.

Other Water Quality Data

In addition to nutrients, TSS, pH, DO, conductivity and water temperature, additional analyses were included for heavy metals, organic carbon and the key cations--calcium, magnesium and iron. These results are included in Table 15. The heavy metals tested were well below applicable State and Federal standards. As expected, cation concentrations appear to be directly related to conductivity. Based upon this data, it is not expected that any of these elements would be growth limiting. Total organic carbon was comparatively low in both the influent and effluent.

Table 12. Weekly Diurnal Grab Sample Influent and Effluent pH and Alkalinity

	pH		Alkalinity (mg/L as $CaCO_3$)	
Effluent	Influent	Effluent	Influent	Effluent
12/11/08	7.57	7.74		
12/18/08	7.51	8.18		
12/29/08	7.53	8.32		
1/5/09	7.6	8.43		
1/12/09	7.66	8.24	240	240
1/15/09	7.86	8.41	200	200
1/22/09	8.12	8.5	180	180
1/29/09	7.58	8.3	240	240
2/5/09	7.97	8.29	240	240
2/12/09	7.65	8.37	240	240
2/19/09	7.95	8.37	240	240
2/25/09	7.98	8.51	240	240
3/5/09	7.99	8.78	140	140
3/12/09	7.7	8.01	240	240
3/19/09	7.77	8.73	240	240
3/26/09	7.61	8.02	240	240
4/2/09	7.43	8.05	240	240
4/8/09	8.04	8.45	240	240
4/16/09	7.44	8.01	180	180
4/23/09	8.31	8.58	200	200
4/30/09	7.91	8.51	200	200
5/7/09	8.25	8.66	240	240
5/14/09	7.78	8.56	120	120
5/21/09	6.95	7.53	180	180
5/28/09	8.78	9.26		
6/4/09	8.55	9.03	240	240
6/11/09	7.26	7.72	240	240
6/25/09	7.51	8.4	240	240
7/2/09	8.05	9.77	180	240
7/9/09	7.98	8.3	240	200
7/20/09	7.75	8.26	180	180
7/26/09	8.41	8.75	200	200
7/30/09	8.15	8.64	200	200
8/8/09	8.04	8.98	240	240
8/13/09	8.09	8.74	200	200
8/27/09	7.87	8.22	240	240
9/3/09	7.78	8.53	180	180
9/10/09	7.57	8.02	204	195
9/17/09	7.56	8.20	240	240
9/24/09	7.33	10.17	180	180
10/1/09	6.53	8.02	240	240
10/8/09	7.29	8.00	180	180
10/15/09				
10/22/09	7.16	7.39	200	200
10/29/09	6.93	7.15	240	240
11/5/09	7.00	7.99	200	200
11/12/09	6.95	7.24	200	200
11/19/09	7.64	7.74	240	240
11/24/09				
12/3/09				
12/10/09	7.70	9.87		
AVERAGE	**7.71**	**8.37**	**214**	**214**
STANDARD DEVIATION	**0.44**	**0.60**	**31**	**31**
Average Q1	**7.76**	**8.32**	**220**	**220**
Average Q2	**7.85**	**8.39**	**213**	**213**
Average Q3	**7.93**	**8.60**	**209**	**210**
Average Q4	**7.21**	**8.18**	**213**	**213**

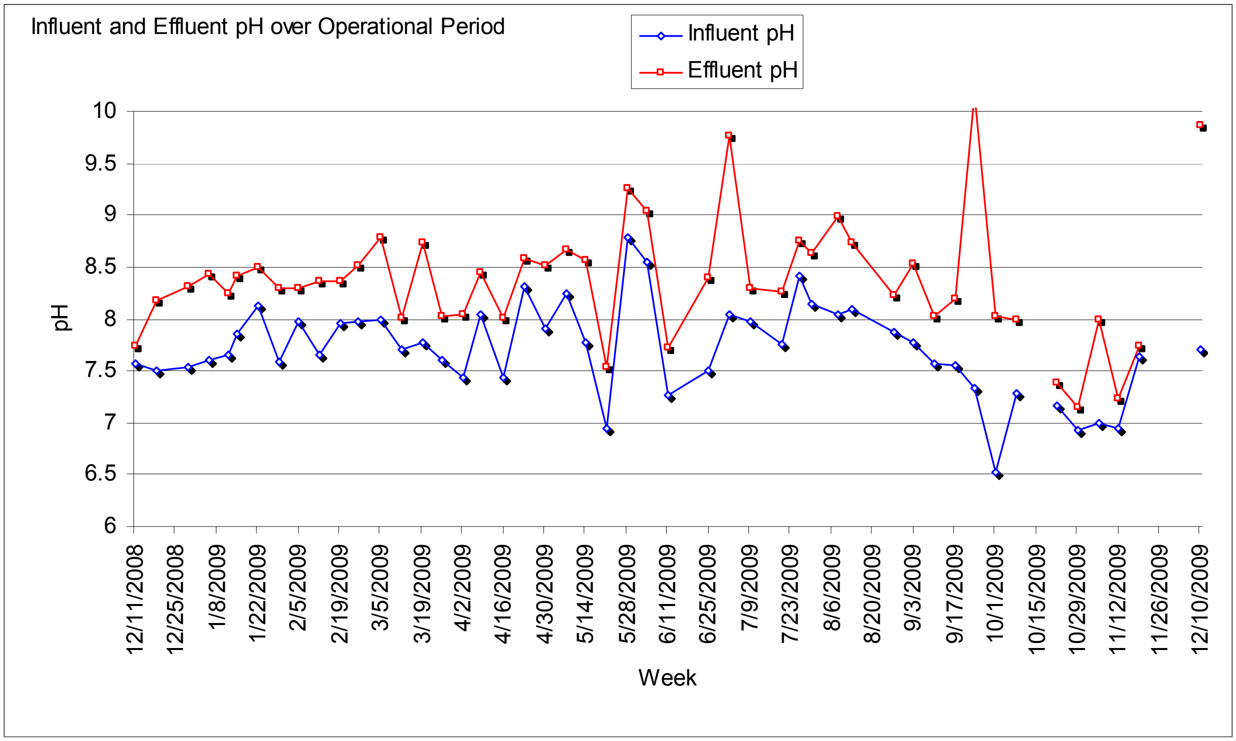

Figure 11: Influent and Effluent Diurnal pH Patterns over operational period ATS™ Pilot Powell Creek By-Pass Canal

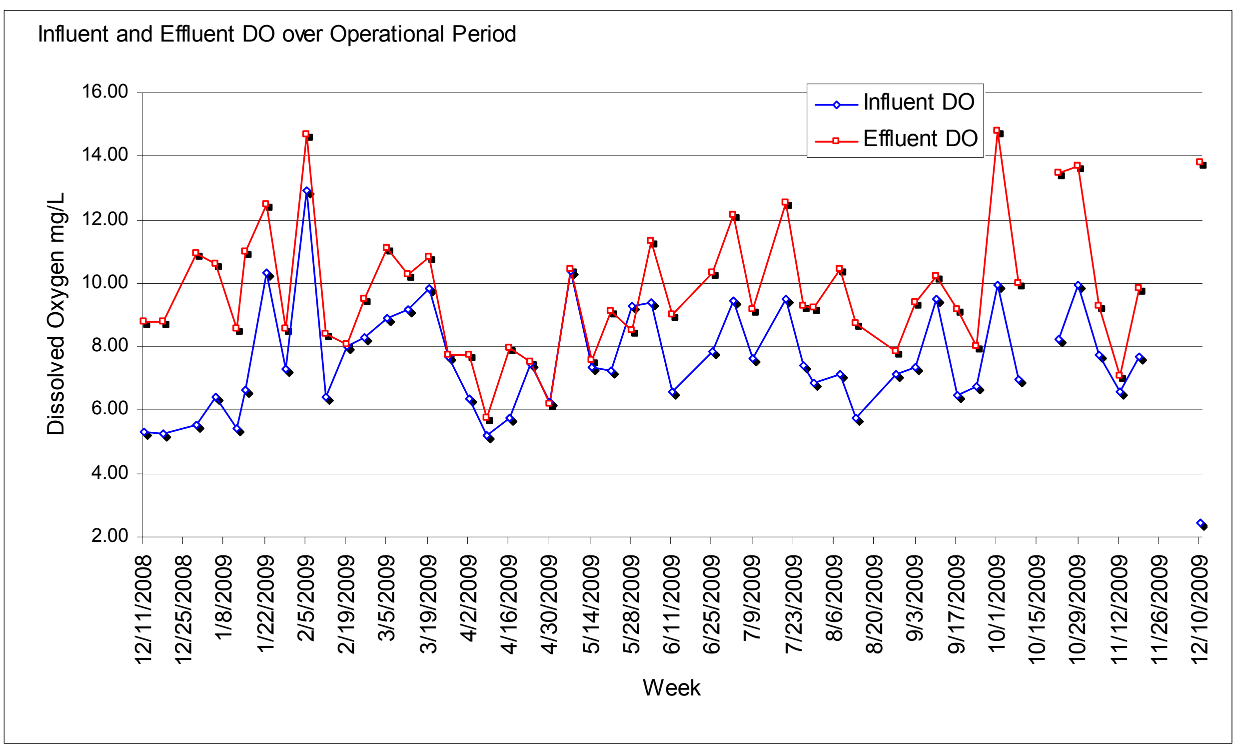

Figure 12: Influent and Effluent Diurnal Dissolved Oxygen Patterns ATS™ Pilot Powell Creek By-Pass Canal

Table 13. Weekly Diurnal Grab Sample Influent and Effluent Dissolved Oxygen

	Dissolved Oxygen mg/L	
Date	Influent	Effluent
12/11/08	5.30	8.78
12/18/08	5.26	8.76
12/29/08	5.53	10.94
1/5/09	6.39	10.59
1/12/09	5.43	8.58
1/15/09	6.65	11.00
1/22/09	10.35	12.46
1/29/09	7.31	8.56
2/5/09	12.92	14.70
2/12/09	6.42	8.40
2/19/09	8.00	8.05
2/25/09	8.29	9.49
3/5/09	8.91	11.08
3/12/09	9.15	10.25
3/19/09	9.85	10.82
3/26/09	7.70	7.75
4/2/09	6.36	7.71
4/8/09	5.19	5.75
4/16/09	5.73	7.97
4/23/09	7.46	7.51
4/30/09	6.24	6.18
5/7/09	10.37	10.45
5/14/09	7.32	7.59
5/21/09	7.26	9.13
5/28/09	9.30	8.51
6/4/09	9.36	11.29
6/11/09	6.58	9.00
6/25/09	7.84	10.30
7/2/09	9.42	12.12
7/9/09	7.60	9.14
7/20/09	9.48	12.52
7/26/09	7.39	9.26
7/30/09	6.84	9.20
8/8/09	7.11	10.41
8/13/09	5.74	8.71
8/27/09	7.12	7.82
9/3/09	7.34	9.38
9/10/09	9.49	10.21
9/17/09	6.46	9.18
9/24/09	6.74	8.00
10/1/09	9.96	14.76
10/8/09	6.97	9.98
10/15/09		
10/22/09	8.21	13.48
10/29/09	9.94	13.66
11/5/09	7.74	9.30
11/12/09	6.58	7.06
11/19/09	7.68	9.83
11/24/09		
12/3/09		
12/10/09	2.44	13.78
AVERAGE	**7.56**	**9.78**
STANDARD DEVIATION	**1.81**	**2.09**
Average Q1	**7.57**	**10.12**
Average Q2	**7.59**	**8.44**
Average Q3	**7.76**	**9.92**
Average Q4	**7.27**	**10.90**

Table 14. Weekly Influent and Effluent Composite Total Suspended Solids

	Total Suspended Solids mg/L	
Date	Influent	Effluent
12/11/08	11	5
12/18/08	10	4
12/29/08	7	3
1/5/09	7	35
1/12/09	16	9
1/15/09	42	15
1/22/09	5	5
1/29/09	5	5
2/5/09	5	6
2/12/09	5	5
2/19/09	5	5
2/25/09	5	5
3/5/09	5	5
3/12/09	5	5
3/19/09	8	5
3/26/09		
4/2/09	5	5
4/8/09	6	5
4/16/09	5	7
4/23/09	8	5
4/30/09	8	5
5/7/09	5	5
5/14/09	5	5
5/21/09	5	5
5/28/09	6	5
6/4/09	5	5
6/11/09	5	5
6/18/09	5	5
6/25/09	5	5
7/2/09	5	5
7/9/09	5	5
7/16/09	7	5
7/23/09	6	5
7/30/09	5	5
8/6/09	5	5
8/13/09	5	5
8/20/09	10	10
8/27/09	10	10
9/3/09	5	5
9/10/09	7	5
9/17/09	5	5
9/24/09		
10/1/09	5	5
10/8/09	5	5
10/15/09	5	5
10/22/09	5	5
10/29/09	5	5
11/5/09	5	5
11/12/09	5	5
11/19/09	5	5
11/24/09	5	5
12/3/09	7	14
12/10/09	9	9
AVERAGE	**7**	**6**
STANDARD DEVIATION	**5**	**5**
Average Q1	**10**	**8**
Average Q2	**6**	**5**
Average Q3	**6**	**6**
Average Q4	**5**	**6**

Table 15. Other Water Quality Parameters

	12/11/2008		1/12/2009		3/5/2009		4/23/2009		6/11/2009		7/30/2009		9/10/2009		10/8/2009		11/5/2009	
Date	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Ca mg/L			130		110	110	160		77	78	62	61	88	86	82	83	116	115
Mg mg/L			240	240	220	220	400		78	79	20	20	22	22	39	40	230	228
Fe mg/L			0.49		0.03	0.14	0.09		0.12	0.08	0.20	0.13	0.24	0.07	0.09	0.17	0.12	0.02
TOC mg/L			16	18	18	19	19	21	17	19	20	20	15	15	23	1	19	19
B µg/L	0.64																	
Cd µg/L	U																	
Cr µg/L	1.0																	
Se µg/L	20.0																	
Hg µg/L	U																	
Pb µg/L	1.3																	
Zn µg/L	39.0																	
Cu µg/L	3.7																	
As µg/L	6.9																	

U = Undetected

ALGAL TURF BIOMASS

General Observations

Upon initiation of continuous flows on 11/14/08, the algal turf developed quickly. By the first sampling period on 12/11/08, a significant turf had developed, with a predominance of filamentous green algae and diatoms. A series of pictures taken on 12/18/09 as included in Appendix C, show heavy green filamentous growth near the surger, with diatom growth dominant further down the floway. A conductivity level at this time was about 5,600 µS/cm.

By February 2009, the conductivity had increased to nearly 9,000 µS/cm, and a noticeable shift of dominant algae to filamentous green and diatoms. (See Appendix C). Included as Appendix D is an algal identification analysis completed in February, 2009. As noted, diatoms by far made up the greatest numbers, although green algae (*Chlorophycae*), because of their greater size, may have made up a greater mass.

During March 2009 the conductivity continued to rise, being over 16,000 µS/cm by March 12, 2009. The algal turf at this time was well developed, with filamentous green algae and diatoms noted.

By early May, 2009, conductivity had increased to over 40,000 µS/cm, which is close to being classified as marine (saltwater). The invertebrates associated with the turf had become more marine/estuarine, with a predominance of mollusks and certain crustaceans, such as barnacles. The algae also appeared more marine, with large "ulva" like green filaments noted—e.g. *Ulothrix sp.* During April, algal development was noticeably sparse. It is not known if this decline was related to the fluctuating conductivity, nutrient or mineral limitation, runoff associated toxins or inhibiting agents, or herbicide spraying activity within the watershed at that time. By mid May, rainfall had increased, conductivity had dropped to about 11,000 µS/cm, and the algal turf production had improved.

From May 2009, through the summer, the algal turf remained healthy, with filamentous greens, blue greens, and diatoms being dominant. The summer rains brought a dramatic drop in conductivity, eventually dropping to about 1,000 µS/cm by late summer.

By late October, 2009 the conductivity again began to increase, and the water again became more estuarine. The algal turf appeared to support a greater number of *Cyanophyceae* (blue-green"algae") along the first 200-300 feet of the floway, after which filamentous green algae became dominant.

Harvested Biomass

Over the operational period, algae turf was removed, collected, wet and dry weight determined, and dry samples composited for tissue analysis. Tissue analysis was done monthly on the composited dry samples. The frequency of harvesting was determined by subjective assessment by the operator. It is desirable to allow the turf biomass to establish a density which is high enough to ensure significant mass uptake of nutrients, but not to become so dense that necrosis and sloughing interfere with the benefits of direct nutrient uptake. This is discussed in further detail in the section entitled ATSDEM Modeling.

By measuring the harvest in this manner, it is possible to establish a harvest based nutrient quantification, which can be compared to nutrient quantification based upon water quality data. In addition, net productivity can be reasonably estimated, as well as specific growth rate and average standing crop. These parameters are important in assessing the general nutrient uptake and growth dynamics of the system. Noted in Table 16 is the harvest record for the operational period. The harvest trends are also noted in Figures 13 and 14. As shown, the harvesting amounts from 0-250 feet track those from 250-500 feet rather closely. This indicates that there is no significant change in limiting growth factors influencing biomass production.

It should also be noted that dry biomass harvest continued to increase from 111 pounds in Q3 to 121 pounds in Q4. This increase in recovered biomass occurred even though water temperatures, solar radiation, and nutrient levels were lower, which should have produced lower levels of production. This increase in production in Q4 indicates that the algal turf system may still be in the Stabilization Phase and the system is not Fully-Operational.

Table 16. Measured Harvest over the Operational Period

		0-250 ft			**250-500 ft**			**Total Floway**		
Date of Harvest	Days Between Harvests	wet harvest lbs	Percent Solids	dry harvest lbs	wet harvest lbs	Percent Solids	dry harvest lbs	wet harvest lbs	Percent Solids	dry harvest lbs
12/18/08	34	85.3	6.10%	5.20	63.4	6.85%	4.34	148.7	6.47%	9.54
1/5/09	18	65.4	7.80%	5.10	155.1	12.90%	20.01	220.5	10.35%	25.11
1/12/09	7	85.9	8.05%	6.91	72.1	8.20%	5.91	158.0	8.13%	12.83
1/29/09	17	97.3	5.20%	5.06	20.3	12.15%	2.47	117.6	8.68%	7.53
2/12/09	14	163.7	7.20%	11.78	63.4	6.44%	4.08	227.1	6.83%	15.86
2/25/09	13	176.6	4.85%	8.57	50.6	6.35%	3.21	227.2	5.60%	11.78
3/12/09	15	94.6	7.40%	7.00	134.7	6.15%	8.28	229.3	6.78%	15.28
3/26/09	14	137.8	8.60%	11.85	56.1	7.80%	4.38	193.9	8.20%	16.23
4/2/09	7	78.3	7.95%	6.22	41.5	11.25%	4.67	119.8	9.60%	10.89
4/23/09	21	12.0	10.40%	1.25	24.5	13.80%	3.38	36.5	12.10%	4.63
5/7/09	14	26.0	12.95%	3.37	1.8	10.60%	0.19	27.8	11.78%	3.56
5/21/09	14	90.6	10.55%	9.56	67.7	11.50%	7.79	158.3	11.03%	17.3
6/4/09	14	164.1	11.80%	19.36	78.3	5.65%	4.42	242.4	8.73%	23.8
6/11/09	7	59.5	7.95%	4.73				59.5	7.95%	4.7
6/25/09	14	110.2	4.65%	5.12				110.2	4.65%	5.12
6/25/09	21				89.7	5.15%	4.62	89.7	5.15%	4.62
7/9/090	14	111.2	5.65%	6.28	107.2	6.00%	6.43	218.4	5.83%	12.71
7/23/090	14	125.2	6.45%	8.08	68.6	5.05%	3.46	193.8	5.75%	11.54
8/6/09	14	194.7	6.45%	12.56	84.3	5.05%	4.26	279.0	5.75%	16.82
8/13/09	7	102.3	5.20%	5.32	84.0	4.40%	3.70	186.3	4.80%	9.02
8/27/09	14	147.3	9.95%	14.66	123.4	10.65%	13.14	270.7	10.30%	27.80
9/10/09	14	102.1	12.60%	12.86	115.0	9.00%	10.35	217.1	10.80%	23.21
9/24/09	14	88.5	8.85%	7.83	122.9	10.05%	12.35	211.4	9.45%	20.18
10/8/09	14	103.4	7.90%	8.17	107.2	9.65%	10.34	210.6	8.78%	18.51
10/22/09	14	84.1	9.95%	8.37	151.2	10.80%	16.33	235.3	10.38%	24.70
11/5/09	14	50.7	7.75%	3.93	228.6	9.05%	20.69	279.3	8.40%	24.62
11/19/09	14	50.9	6.60%	3.36	104.4	8.70%	9.08	155.3	7.65%	12.44
12/10/09	21	110.1	9.55%	10.51	134.0	7.85%	10.52	244.1	8.70%	21.03
Totals		**2,717.8**		**213.02**	**2,350.0**		**198.41**	**5,067.8**		**411.43**
Averages		**100.7**	**8.09%**	**7.89**	**90.4**	**8.50%**	**7.63**	**181.0**	**8.16%**	**14.69**
Standard Deviation		**43.8**	**2.30%**	**4.02**	**48.8**	**2.69%**	**5.32**	**70.4**	**2.16%**	**7.22**
Total Q1		**768.8**		**49.62**	**559.6**		**48.31**	**1,328.4**		**97.93**
Total Q2		**568.3**		**56.34**	**269.9**		**24.83**	**838.2**		**81.17**
Total Q3		**893.0**		**64.88**	**672.2**		**45.96**	**1,565.2**		**110.84**
Total Q4		**487.7**		**42.17**	**848.3**		**79.32**	**1,336.0**		**121.49**

Tissue Analyses

As noted, over the course of the operational period, samples of the harvested biomass were collected and dried. Samples were taken from each harvest, at 0-250 feet and 250-500 feet. Once a month these dried samples were composited and thoroughly mixed, and delivered to Mid West Laboratories in Nebraska, for analysis. These results allow comparison of algae quality down the floway over the operational period. Of primary interest is phosphorus and nitrogen content, for these allow reasonable estimation of nutrient mass removed through harvest, as the product of nutrient content and dry weight harvested. Tissue analyses are shown in Table 17. Monthly nitrogen and phosphorus tissue data are shown in Figures 15 and 16. As a general observation, nutrient content appears to be somewhat lower within tissue associated with the final 250 feet of the floway. This is understandable because of the drop in nutrient concentration. There is also a noticeable increase in chloride levels within the tissue during periods of higher conductivity. In addition, both iron and manganese show a high percentage drop in concentrations within the final 250 feet. There are likely several factors which contribute to this, such as precipitation, in response to pH and temperature changes.

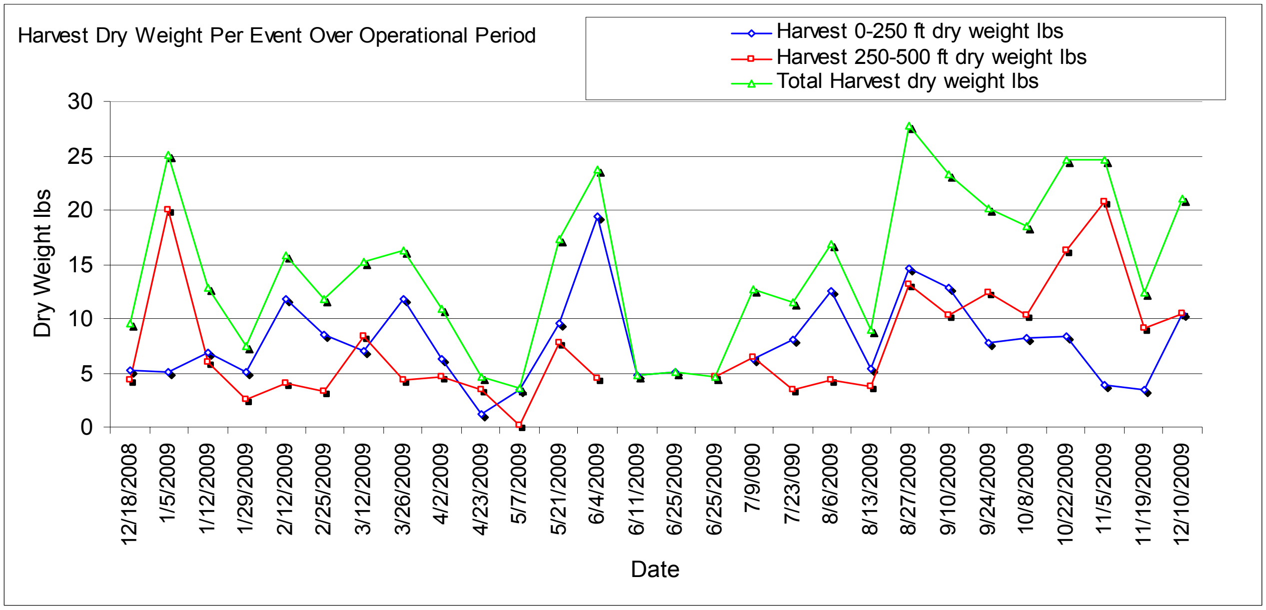

Figure 13: Dry Weight Harvest Patterns ATS™ Pilot Powell Creek By-Pass Canal

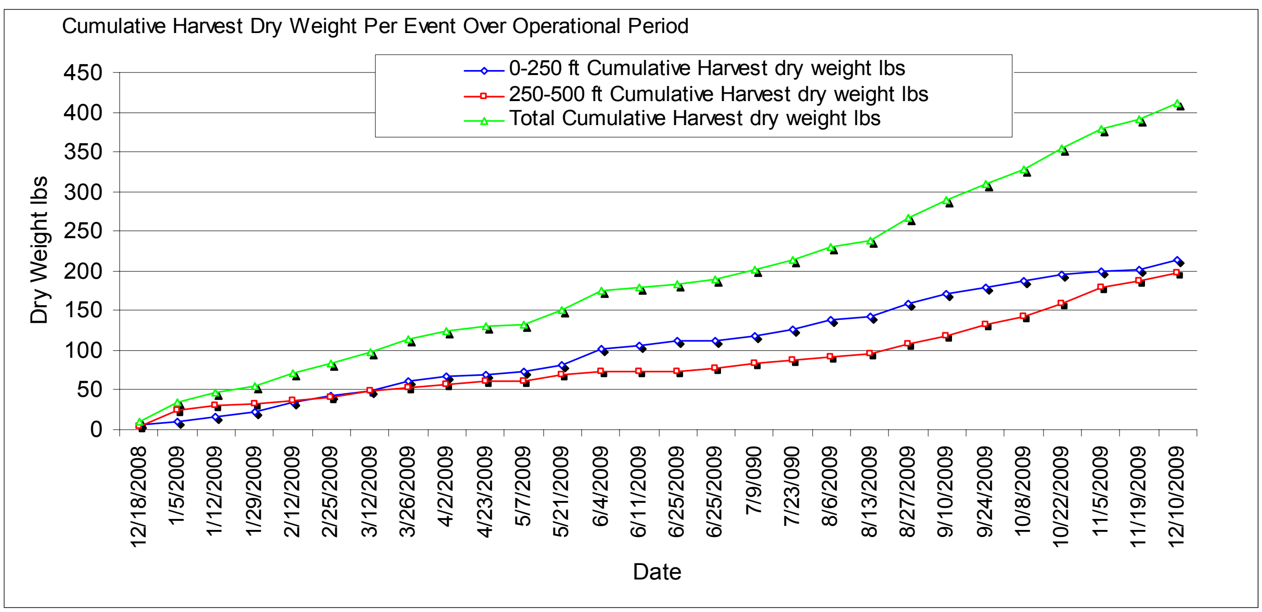

Figure 14: Cumulative Dry Weight Harvest Patterns ATS™ Pilot Powell Creek By-Pass Canal

Table 17. Tissue Analyses of Harvested Biomass over the Operational Period

		12/08	1/09	2/09	3/09	4/09	5/09	6/09	7/09	8/09	9/09	10/09	11/09	12/09	Average	St Dev
Phosphorus % dry weight	0-250 ft	0.54%	0.72%	0.69%	0.68%	0.64%	0.66%	0.90%	0.39%	0.48%	0.49%	0.60%	0.65%	0.80%	0.63%	0.14%
	250-500 ft	0.32%	0.28%	0.47%	0.63%	0.55%	0.49%	0.58%	0.39%	0.68%	0.38%	0.47%	0.48%	0.73%	0.50%	0.14%
Nitrogen % dry weight	0-250 ft	1.72%	1.57%	2.15%	2.06%	2.08%	2.58%	2.59%	2.05%	2.52%	1.87%	2.01%	2.21%	2.60%	2.15%	0.34%
	250-500 ft	1.26%	0.72%	1.83%	2.46%	1.79%	1.42%	2.97%	2.06%	1.89%	1.37%	1.48%	1.92%	2.73%	1.84%	0.62%
Nitrate % dry weight	0-250 ft	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
	250-500 ft	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
Ammonia % dry weight	0-250 ft	0.04%	nd	0.12%	0.10%	0.03%	0.03%	nd	nd	0.01%	0.04%	nd	0.01%	0.11%	0.05%	0.04%
	250-500 ft	0.35%	nd	0.06%	0.19%	0.06%	0.05%	nd	0.01%	0.01%	0.02%	nd	0.01%	0.09%	0.09%	0.11%
Organic N% dry weight	0-250 ft	1.68%	1.57%	2.04%	1.95%	2.05%	2.54%	2.59%	2.05%	2.51%	1.83%	2.01%	2.20%	2.49%	2.12%	0.33%
	250-500 ft	-	0.70%	1.78%	2.26%	1.71%	1.37%	2.97%	2.06%	1.88%	1.35%	1.48%	1.91%	2.63%	1.84%	0.61%
K_2O % dry weight	0-250 ft	0.53%	1.62%	1.04%	1.55%	2.20%	1.50%	0.78%	0.71%	4.33%	0.51%	0.95%	1.85%	1.64%	1.48%	1.01%
	250-500 ft	0.66%	0.35%	0.50%	-	0.83%	1.31%	0.86%	0.64%	1.04%	1.00%	0.98%	1.24%	1.44%	0.90%	0.33%
Calcium, % dry weight	0-250 ft	6.28%	2.97%	4.31%	2.01%	3.52%	2.47%	]	14.94%	5.76%	18.18%	9.34%	3.48%	2.60%	6.32%	5.25%
	250-500 ft	3.54%	5.58%	5.83%	1.73%	2.56%	3.06%	2.42%	15.62%	5.34%		12.11%	5.82%	4.94%	5.71%	4.14%
Magnesium % dry weight	0-250 ft	1.26%	0.90%	1.02%	1.42%	1.28%	1.50%	0.85%	0.78%	0.51%	0.46%	0.91%	1.06%	0.74%	0.98%	0.32%
	250-500 ft	0.73%	0.75%	0.93%	1.40%	1.45%	1.31%	0.85%	0.86%	0.45%	0.43%	0.66%	0.89%	0.85%	0.89%	0.32%
Sodium % dry weight	0-250 ft	1.44%	2.57%	1.67%	5.33%	4.70%	5.53%	1.42%		0.53%	0.24%	1.95%	3.70%	2.46%	2.63%	1.80%
	250-500 ft	0.93%	1.56%	1.80%	4.61%	4.58%	3.94%	0.73%		0.44%	0.23%	1.24%	2.84%	3.21%	2.18%	1.60%
Total Carbon % dry weight	0-250 ft	16.57%	18.13%	19.06%	20.09%	19.77%	23.92%	21.86%	23.66%	26.59%	18.45%	18.80%	20.45%	16.34%	20.28%	3.00%
	250-500 ft	11.13%	9.05%	16.59%	19.82%	15.31%	16.93%	24.67%	24.15%	18.54%	19.03%	16.02%	17.55%	19.00%	17.52%	4.35%
Chloride % dry weight	0-250 ft	1.91%	2.53%	3.11%	7.76%	7.84%	7.71%	2.34%	0.67%	2.03%	0.31%	1.35%	2.57%	2.04%	3.24%	2.69%
	250-500 ft	1.14%	1.03%	3.82%	7.47%	6.51%	4.61%	4.96%	0.50%	0.61%	0.51%	1.76%	3.01%	4.37%	3.10%	2.38%
Sulfur % dry weight	0-250 ft	0.83%	1.53%	1.33%	1.40%	1.65%	1.68%	1.16%	0.53%	1.44%	0.45%	0.60%	1.15%	0.86%	1.12%	0.43%
	250-500 ft	0.50%	0.40%	0.85%	1.25%	0.97%	1.29%	0.97%	0.53%	0.58%	0.57%	0.48%	0.71%	0.90%	0.77%	0.29%
Manganese ppm dry weight	0-250 ft	1,167	922	979	1,956	-	7,967	28,236	3,227	2,276	3,806	1,914	2,425	4,858	4,978	7,590
	250-500 ft	674	611	799	1,077	2,225	2,165	5,216	1,876	2,843	1,756	1,400	2,849	2,580	2,005	1,245
Iron ppm dry weight	0-250 ft	18,803	15,882	17,687	14,785	14,715	16,475	26,232	6,880	7,144	11,322	9,747	9,349	16,265	14,253	5,369
	250-500 ft	768	6,646	11,711	10,450	16,394	10,582	15,057	4,693	8,543	6,710	5,632	10,098	9,227	8,962	4,215
Zinc ppm dry weight	0-250 ft	699	1,483	1,187	979	601	586	633	329	283	378	317	373	307	627	377
	250-500 ft	465	374	797	573	598	325	524	236	263	257	208	376	273	405	176
Copper ppm dry weight	0-250 ft	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
	250-500 ft	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-

nd = not detected

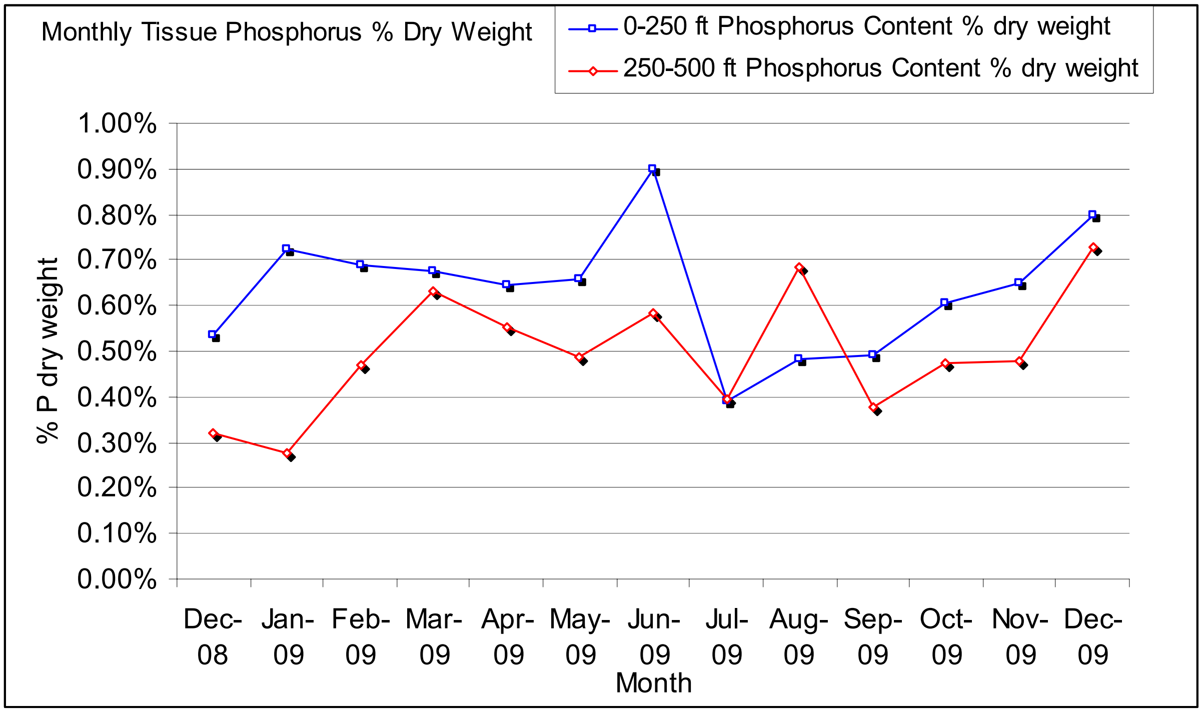

Figure 15: Monthly Trends in Tissue Phosphorus Levels within Harvested Biomass from ATS™ Floway Powell Creek By-Pass Canal

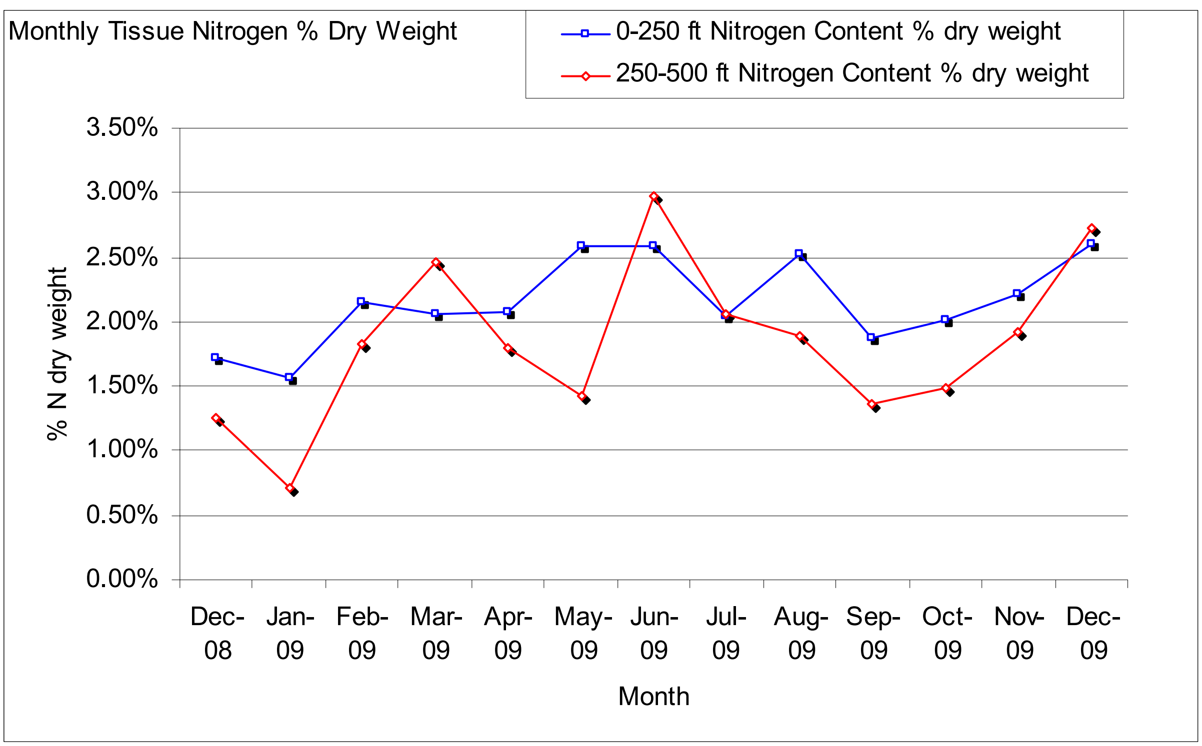

Figure 16: Monthly Trends in Tissue Nitrogen Levels within Harvested Biomass from ATS™ Floway Powell Creek By-Pass Canal

SECTION 3. SYSTEM ANALYSIS

PHOSPHORUS DYNAMICS

Areal Removal Rates and Mass Removal

The ATS™ System is designed and operated to accommodate effective nutrient uptake by an active algal turf community. This uptake may be through incorporation into algal tissue, or the tissue of any participating organism; through precipitation as salts with comparatively low solubility; through adsorption; or through processes which allow certain nutrients (e.g. nitrogen and carbon) to escape as a gas into the atmosphere. With nitrogen and carbon, it also needs to be recognized that the algal turf community can capture and fix atmospheric stores, through nitrogen fixation and through photosynthesis.

Unlike nitrogen and carbon, phosphorus dynamics are not complicated by atmospheric transactions (except for atmospheric fallout and that associated with direct rainfall, both of which are considered to be comparatively negligible), so accountability is typically easier. By accountability is meant the reconciliation between phosphorus removed as calculated by changes in influent and effluent phosphorus concentrations (Water Quality Based), and phosphorus removed as calculated by harvest loads (Harvest Based).

From an operational and economic perspective, the most meaningful parameter related to nutrient removal is areal removal rate—the amount of nutrient removed per unit process area per unit time. This rate is particularly important if the management goal is to maximize mass removal of the targeted nutrient—e.g. phosphorus. Such is typically the case with Total Maximum Daily Load[9] (TMDL) allocations, although in some situations, such as with the Everglades, there may also be included a target concentration.

In consideration of the need for mass removal, it is reasonable that there would be an advantage to maximizing the amount of removal per unit of process area. The South Florida Water Management District (SFWMD) often relates areal removal rates in terms of grams of nutrients removed per square meter of process area per year when assessing their Stormwater Treatment Areas (STA). Because TMDL's are often stated in pounds or tons, it is often helpful to express areal removal rate as pounds per process acreage per year. For shorter term evaluations, the areal removal rate may be expressed in terms of days, weeks or months. However, the annual value is generally accepted as the standard, and expressing performance on an annual basis provides clarity when making comparisons to other systems.

For the Powell Creek ATS™ Pilot, the mass removals and areal removal rates calculated from water quality data for total and ortho phosphorus for the operational period are shown in Tables 18 and 19. Percent mass removals are noted in Tables 20 and 21 and Figures 17. Shown in Table 22 are the mass removal and areal removal rates calculated from harvest data.

Mass removal based upon harvested biomass is calculated as:

$P_{mh} = (sH_w)p$

Where P_{mh} = mass of 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

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[9] Total Maximum Daily Load (TMDL) relates to Section 303(d) of the Federal Clean Water Act (PL92-500) and the subsidiary Chapter 99-223 of the Florida Statute. TMDL is a scientifically developed assessment of the maximum amount of a critical pollutant which a selected "impaired" water body can receive to render it "unimpaired". Consequently, there is typically a set amount of the identified pollutant which represents the exceedance, which is targeted for removal. Quite often in Florida this pollutant is either nitrogen or phosphorus or both.

Mass removal based upon water quality is calculated as:

$P_{mw} = I_p Q_I – E_p Q_E$
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

Phosphorus Areal Removal Rates therefore are calculated using harvest data as:

$R_{AP} = 365 *(P_{mh}/A\ t)$
Where R_{AP} = Harvest Based Areal Removal Rate as mass removed per unit process area over a year
P_{mh} = mass of phosphorus removed through harvesting
A = Process Area
t = days since last harvest or sampling

Phosphorus Areal Removal Rates therefore are calculated using water quality data as:

$R_{AW} = 365 *(P_{mw}/A\ t)$
Where R_{AW} = Water Quality Based Areal Removal Rate as mass removed per unit process area over a year
P_{mw} = mass of phosphorus removed through harvesting
A = Process Area
t = days since last harvest or sampling

Based upon data noted in Tables 18, 19 and 22, it is possible to generate a comparative graph for both cumulative and weekly mass removal (Figures 18 and 19) and collective areal removal rate (Figure 20). As noted from these graphs, the harvest and water quality based total phosphorus mass removal and collective areal removal rates track very closely. The total mass removal for total phosphorus for the harvest based and water quality based calculations are respectively 2.280 lbs and 2.058 lbs, or the difference being 10% of the mean of the two values. This is considered very close, recognizing that the method for determining the harvest mass removal is based upon sampling a heterogeneous matrix, and accordingly would be expected to be more susceptible to error. The collective areal removal rates also track closely, with the final areal removal rate for total phosphorus for the harvest based and water quality based calculations at 20.80 g/m^2-yr and 19.80 g/m^2-yr respectively, or the difference being about 5% of the mean of the two values.

When areal removal rates are estimated on a monthly basis for both water quality and harvest data, as noted in Table 23 and Figure 21, there is noted some divergence between the two, although they appear to be oscillating around similar means.

It is noteworthy that the mass removal and areal removal rate for ortho-phosphorus both are greater than the water quality based values for total phosphorus[10]—2.349 lb as compared to 2.058 lb for mass removal and 22.60 g/m^2-yr as compared to 19.80 g/m^2-yr respectively. This is suggestive not only of a preference for ortho-phosphorus uptake by the algal turf, but also that there is little interaction associated with the algal turf and the incoming organic phosphorus.[11]

Because ortho phosphorus was analyzed as grab samples, and total phosphorus as composite samples, it is inappropriate to place too much confidence in any assessment made from review of this data regarding the nature of the dynamics of ortho and organic phosphorus as it relates to the algal turf. However, as noted previously, Lee County did conduct both total and ortho phosphorus on grab samples beginning 6/11/09 (see Table 5). This allows a more reliable review of the comparative dynamics related

[10] The ortho phosphorus removal is based upon grab samples, while total phosphorus removal is based upon composite samples. Therefore it is possible that the ortho phosphorus Mass Removal can be calculated as greater than total phosphorus Mass Removal

[11] In this evaluation, organic phosphorus is considered to be the difference between total phosphorus and ortho phosphorus. It is recognized that within the organic component may be included polyphosphates.

to algal turf uptake rates of ortho and organic phosphorus. Shown in Tables 24 is the weekly and annual percentage removal of total, ortho and organic phosphorus based upon weekly grab samples taken by Lee County from June 11, 2009 through December 10, 2009. It is evident that net organic phosphorus removal is negligible, and subsequently it would appear that there would be little enzymatic activity associated with removing phosphate from complex organic or inorganic polyphosphate compounds in the Powell Creek system. Because of this, there is a notable decrease in the percentage of the total phosphorus as ortho phosphorus from influent to effluent (from 76% to 67% respectively based upon Lee County grab samples), and an increase in the percentage organic phosphorus (from 24% to 33% respectively, based upon Lee County grab samples). This shift could influence the dynamics of primary production within a receiving water, by reducing directly available phosphorus, and perhaps forcing primary producers such as algae to rely upon enzymes (e.g. phospho-diesterase) to secure phosphate from organic and polyphosphate sources. This dynamic of preferential uptake of available phosphorus (ortho phosphorus) by the algal turf community is often not replicated within extensive large scale wetland treatment systems in which accretion rather than uptake and removal through a sustained crop is the primary removal mechanism, for within the stored materials in these wetlands, organic, not ortho phosphorus is quite often the predominant form.

Response to Fluctuations in Conductivity

The modeling used to assess ATS™ dynamics and system performance (ATSDEM), as presented in Section 4 is based upon the general dynamics of the production associated with a standing crop of algal turf as influenced by the concentration of phosphorus; water temperature; alkalinity and pH; and linear hydraulic loading rate. It is recognized that other factors, such as conductivity (salinity) shifts; invertebrate grazing; toxic and inhibitory agents; N:P ratios; and mineral concentrations have the potential to be influential. Therefore it is necessary to examine the data to determine the extent of influence, if any, of such factors.

Prior to initiation of the PC-ATS™ Pilot Study, it was recognized that the Powell Creek By-Pass Canal would be influenced by tidal flow, and accordingly would experience wide fluctuations in diurnal and seasonal conductivity (see Figure 10). One of the principal objectives of the project therefore was to determine if these fluctuations would have any noticeable influence upon system performance. A linear regression analysis conducted with conductivity as the independent variable and total phosphorus mass removal (based upon water quality) as the dependent variable, shows a very weak inverse correlation ($r^2 = 0.08$), as noted in Figure 22. This is suggestive that performance in terms of phosphorus removal is not significantly impacted by conductivity. However, when weekly mass removal of total phosphorus is plotted with the weekly average conductivity (Figure 23), it is noted that during the second quarter (Q2), for the week from April 8, 2009 to April 16, 2009, there was a rather abrupt drop in conductivity, which was tracked by a commensurate drop in total phosphorus mass removal. Algal turf development productivity during this period was also low, and this was the only period in which effluent total phosphorus concentration was higher than the influent concentration—suggestive of internal release of phosphorus stores, either as held within the algae itself or associated subsidiary organisms. However, during other periods when the conductivity changed rather abruptly, there is no evidence that the mass removal of phosphorus was impacted. Considering the lack of any meaningful correlation, it appears that conductivity itself may not be significantly influential upon system performance, but that substantial, rather abrupt changes in conductivity may be indicative of other water quality or ecological changes which may be influential. These could include die-off of invertebrate populations (e.g. mollusks); changes in nutrient or mineral availability; or influx via runoff surges of toxic or inhibitory substances (e.g. herbicides, pesticides).

Response to N:P Ratio Based upon Available N and P

During Q2, the ratio of available nitrogen to available phosphorus was substantially lower than the other quarters (see Table 9). It is also the quarter in which system performance in terms of mass removal and areal removal rate were the poorest (see Table 18) and when algal turf harvest was the lowest (see Table 16). However, when a linear regression was conducted on the N:P ratio (based upon available N and P) and total phosphorus mass removal, as shown in Figure 24, the correlation throughout the operational period does not appear to be strong ($r^2 = 0.07$), even though during Q2 when the N:P initially fell rather abruptly, both the conductivity and the mass removal of total phosphorus also fell as noted in Figure 25.

Considering the poor correlation between N:P ratio and conductivity to total phosphorus mass removal over the operational period, it would appear that the events associated with Q2 are likely aligned more with perturbations that are unique to this one period, and that there is no particular trend indicating total phosphorus Mass Removal throughout the operational period is dictated solely by one factor, such as N:P or conductivity.

When N:P based upon available N and P is plotted with conductivity, as shown in Figure 26, the N:P ratio does drop with the April decline in conductivity, but for the remainder of the operational period, the ratio shows no trend which would indicate any discernible relationship between N:P and conductivity. This is noted also with the linear regression analysis noted in Figure 27, which reveals only a very week inverse relationship (r^2 = 0.02).

Response to Herbicide Applications within the Powell Creek Watershed

As mentioned previously, Lee County sprayed herbicides (glyphosate) in the waterways associated with the Powell Creek Watershed on several occasions during the study period - including the Powell Creek-By-Pass Canal. Before spraying the By-Pass Canal, the County personnel would call with notification. Based upon these notifications, the scheduling of these spraying events can be compared to total phosphorus mass removal, as shown in Figure 28. The plot does not reveal any clear trend which would indicate the County's spraying efforts within the Powell Creek By-Pass canal had significant influence upon total phosphorus mass removal. However, the scheduling of both Lee County's program and the use of herbicides for private use in other reaches of the watershed were not considered, and it must be considered possible that such applications could impose upon the quality of runoff—particularly that associated with a first flush. In looking at the conductivity/rainfall patterns associated with early April (see Figure 10), and in reviewing the operational summary (Appendix B), a 0.6 inch rainfall occurred during the week of April 8-16, 2009. This was the first significant rainfall following a dry winter period, and considering the magnitude of the drop in conductivity, it must have resulted in a sizable flush of runoff.

Summary

Performance results included in this report are associated with the start-up and stabilization phase. During the stabilization phase the treatment vegetation (algal turf) is developing and system productivity and performance will generally be improving. While a sustained algal turf community was established on the floway throughout the operational period, increasing algal productivity in Q4 during a period of reduced water temperatures and nutrient concentrations indicate that the algal turf community may not have achieved optimal performance.

For the 12-month monitoring period, total phosphorus was reduced by 19.28% based upon mass removals calculated from water quality data, with the influent total phosphorus averaging 139 µg/L and the average effluent total phosphorus averaging 110 µg/L. For the monitoring period the ortho phosphorus was reduced by 27.24% based upon mass removal calculated from water quality data, with the influent ortho phosphorus averaging 109 µg/L and the average effluent ortho phosphorus averaging 79 µg/L. Total phosphorus accountability was excellent, with the mass removal calculated by harvest closely tracking the mass removal calculated by water quality.

Lower levels of system performance in terms of phosphorus removal were associated with Q2. Regardless of the cause of this Q2 drop in performance, the overall impact may be considered comparatively minor in terms of overall phosphorus dynamics. Over the full operational period, the ATS™ system sustained a viable algal turf, which consistently provided total phosphorus areal removal rates of 19.80 g/m^2-yr, with the large majority of the phosphorus removed being ortho phosphorus. The ortho phosphorus removal rate based upon grab sample analysis was 22.60 g/m^2-yr.

These phosphorus areal removal rates are significantly higher than typical wetland treatment systems which generally offer from 0.5 to 3.0 g/m^2-yr.

Lee County maintained a split sample program during the operational period for both phosphorus and nitrogen. A comparison of split sample analyses between HydroMentia's contracted laboratory and Lee County, as presented in Appendix E, shows reasonably close tracking of results.

Table 18. Water Quality Based Calculations for Total Phosphorus Mass Removals and Areal Removal Rates over the Operational Period

	Days Between Sampling	Cumulative Days Between Sampling	Water Quality Based Mass Removal Total Phosphorus gm	Water Quality Based Mass Removal Total Phosphorus lbs	Cumulative Water Quality Based Mass Removal Total Phosphorus lbs	Water Quality Based Areal Removal Rate Total Phosphorus g/m^2-day	Water Quality Based Areal Removal Rate Total Phosphorus g/m^2-yr	Water Quality Based Areal Removal Rate Total Phosphorus lb/acre-yr	Collective Water Quality Based Areal Removal Rate Total Phosphorus g/m^2-yr
12/11/2008	7	7	20.0	0.044	0.044	0.061	22.42	200.0	22.42
12/18/2008	7	14	71.6	0.158	0.202	0.220	80.29	716.0	51.36
12/29/2008	11	25	41.2	0.091	0.292	0.081	29.39	262.1	41.69
1/5/2009	7	32	25.3	0.056	0.348	0.078	28.54	254.5	38.82
1/12/2009	7	39	13.8	0.030	0.379	0.045	16.26	145.0	34.94
1/15/2009	3	42	53.2	0.117	0.496	0.381	139.20	1241.3	42.45
1/22/2009	7	49	11.3	0.025	0.521	0.035	12.73	113.6	38.17
1/29/2009	7	56	14.0	0.031	0.552	0.043	15.76	140.6	35.35
2/5/2009	7	63	9.9	0.022	0.573	0.030	11.07	98.7	32.64
2/12/2009	7	70	14.5	0.032	0.605	0.045	16.30	145.4	31.00
2/19/2009	7	77	7.9	0.017	0.623	0.024	8.87	79.1	28.98
2/25/2009	6	83	16.3	0.036	0.659	0.058	21.28	189.7	28.42
3/5/2009	8	91	21.0	0.046	0.705	0.057	20.66	184.3	27.73
3/12/2009	7	98	7.6	0.017	0.722	0.023	8.52	75.9	26.35
3/19/2009	7	105	23.7	0.052	0.774	0.073	26.62	237.4	26.37
3/26/2009	7	112			0.774				24.72
4/2/2009	7	119	21.6	0.047	0.821	0.066	24.19	215.8	24.69
4/8/2009	6	125	28.0	0.062	0.883	0.100	36.66	326.9	25.26
4/16/2009	8	133	11.2	0.025	0.908	0.030	10.95	97.7	24.40
4/23/2009	7	140	-20.8	-0.046	0.862	-0.064	-23.35	-208.3	22.01
4/30/2009	7	147	-7.8	-0.017	0.845	-0.024	-8.71	-77.6	20.54
5/7/2009	7	154	6.0	0.013	0.858	0.018	6.70	59.7	19.91
5/14/2009	7	161	7.0	0.015	0.873	0.022	7.88	70.2	19.39
5/21/2009	7	168	6.4	0.014	0.887	0.020	7.13	63.6	18.87
5/28/2009	7	175	8.0	0.018	0.905	0.025	9.00	80.3	18.48
6/4/2009	7	182	18.6	0.041	0.946	0.057	20.90	186.4	18.57
6/11/2009	7	189	9.7	0.021	0.967	0.030	10.86	96.8	18.29
6/18/2009	7	196	14.1	0.031	0.998	0.043	15.86	141.5	18.20
6/25/2009	7	203	9.1	0.020	1.018	0.028	10.20	91.0	17.92
7/2/2009	7	210	3.4	0.007	1.026	0.010	3.79	33.8	17.45
7/9/2009	7	217	15.5	0.034	1.060	0.048	17.38	155.0	17.45
7/16/2009	7	224	36.6	0.081	1.141	0.113	41.09	366.5	18.19
7/23/2009	7	231	18.1	0.040	1.180	0.056	20.26	180.7	18.25
7/30/2009	7	238	16.1	0.036	1.216	0.050	18.09	161.3	18.25
8/6/2009	7	245	39.1	0.086	1.302	0.120	43.83	390.8	18.98
8/13/2009	7	252	21.4	0.047	1.349	0.066	24.04	214.3	19.12
8/20/2009	7	259	1.1	0.002	1.352	0.003	1.24	11.1	18.64
8/27/2009	7	266	8.6	0.019	1.371	0.027	9.68	86.3	18.40
9/3/2009	7	273	18.3	0.040	1.411	0.056	20.53	183.1	18.45
9/10/2009	7	280	27.0	0.060	1.470	0.083	30.32	270.4	18.75
9/17/2009	7	287	22.7	0.050	1.520	0.070	25.47	227.1	18.92
9/24/2009	7	294	0.1	0.000	1.521	0.000	0.15	1.4	18.47
10/1/2009	7	301	70.6	0.156	1.676	0.217	79.24	706.7	19.88
10/8/2009	7	308	35.5	0.078	1.754	0.109	39.80	354.9	20.34
10/15/2009	7	315	12.7	0.028	1.782	0.039	14.25	127.0	20.20
10/22/2009	7	322	9.9	0.022	1.804	0.030	11.07	98.7	20.00
10/29/2009	7	329	15.7	0.035	1.839	0.048	17.62	157.1	19.95
11/5/2009	7	336	7.9	0.017	1.856	0.024	8.90	79.4	19.72
11/12/2009	7	343	13.2	0.029	1.885	0.041	14.81	132.1	19.62
11/19/2009	7	350	5.5	0.012	1.897	0.017	6.17	55.0	19.35
11/24/2009	5	355	8.3	0.018	1.916	0.036	13.09	116.8	19.26
12/3/2009	9	364	48.0	0.106	2.021	0.115	41.88	373.5	19.82
12/10/2009	7	371	16.7	0.037	2.058	0.051	18.76	167.3	19.80
		Total Q1	**327.6**	**0.722**	**Average Q1**	**0.084**	**30.81**	**274.7**	
		Total Q2	**111.5**	**0.246**	**Average Q2**	**0.029**	**10.74**	**95.7**	
		Total Q3	**228.4**	**0.503**	**Average Q3**	**0.054**	**19.72**	**175.8**	
		Total Q4	**266.9**	**0.588**	**Average Q4**	**0.061**	**22.40**	**199.8**	

Table 19. Water Quality Based Calculations for Ortho Phosphorus Mass Removals and Areal Removal Rates over the Operational Period

	Days Between Sampling	Cumulative Days Between Sampling	Water Quality Based Mass Removal Ortho Phosphorus gm	Water Quality Based Mass Removal Ortho Phosphorus lbs	Cumulative Water Quality Based Mass Removal Ortho Phosphorus lbs	Water Quality Based Areal Removal Rate Ortho Phosphorus g/m^2-day	Water Quality Based Areal Removal Rate Ortho Phosphorus g/m^2-yr	Water Quality Based Areal Removal Rate Ortho Phosphorus lb/acre-yr	Collective Water Quality Based Areal Removal Rate Ortho Phosphorus g/m^2-yr
12/11/08	7	7	1.6	0.004	0.004	0.005	1.82	16.2	1.82
12/18/08	7	14	21.5	0.047	0.051	0.066	24.10	214.9	12.96
12/29/08	11	25	37.6	0.083	0.134	0.074	26.84	239.4	19.07
1/5/09	7	32	19.6	0.043	0.177	0.061	22.10	197.1	19.73
1/12/09	7	39	24.8	0.055	0.232	0.080	29.27	261.0	21.37
1/15/09	3	42	6.9	0.015	0.247	0.049	18.05	160.9	21.13
1/22/09	7	49	7.0	0.015	0.262	0.022	7.88	70.2	19.22
1/29/09	7	56	11.3	0.025	0.287	0.035	12.67	113.0	18.40
2/5/09	7	63	7.0	0.015	0.303	0.022	7.89	70.3	17.23
2/12/09	7	70	7.2	0.016	0.319	0.022	8.12	72.5	16.31
2/19/09	7	77	10.2	0.023	0.341	0.031	11.49	102.5	15.87
2/25/09	6	83	16.2	0.036	0.377	0.058	21.19	189.0	16.26
3/5/09	8	91	15.9	0.035	0.412	0.043	15.64	139.5	16.20
3/12/09	7	98	17.0	0.037	0.449	0.052	19.09	170.2	16.41
3/19/09	7	105	18.8	0.041	0.491	0.058	21.06	187.8	16.72
3/26/09	7	112			0.491				15.67
4/2/09	7	119	16.5	0.036	0.527	0.051	18.55	165.4	15.84
4/8/09	6	125	8.9	0.020	0.547	0.032	11.68	104.1	15.64
4/16/09	8	133	5.0	0.011	0.558	0.013	4.90	43.7	14.99
4/23/09	7	140	0.0	0.000	0.558	0.000	0.00	0.0	14.24
4/30/09	7	147	3.2	0.007	0.565	0.010	3.60	32.1	13.73
5/7/09	7	154	2.4	0.005	0.570	0.007	2.68	23.9	13.23
5/14/09	7	161	22.7	0.050	0.620	0.070	25.44	226.8	13.76
5/21/09	7	168	4.8	0.011	0.631	0.015	5.43	48.4	13.41
5/28/09	7	175	13.6	0.030	0.660	0.042	15.21	135.6	13.49
6/4/09	7	182	28.9	0.064	0.724	0.089	32.46	289.5	14.22
6/11/09	7	189	16.3	0.036	0.760	0.050	18.26	162.8	14.37
6/18/09	7	196	18.8	0.041	0.801	0.058	21.13	188.4	14.61
6/25/09	7	203	19.3	0.042	0.844	0.059	21.64	193.0	14.85
7/2/09	7	210	10.7	0.024	0.868	0.033	12.04	107.4	14.76
7/9/09	7	217	32.7	0.072	0.940	0.101	36.73	327.5	15.47
7/16/09	7	224	39.8	0.088	1.027	0.122	44.61	397.8	16.38
7/23/09	7	231	52.0	0.115	1.142	0.160	58.33	520.2	17.65
7/30/09	7	238	48.0	0.106	1.248	0.148	53.85	480.3	18.72
8/6/09	7	245	34.0	0.075	1.322	0.104	38.14	340.1	19.28
8/13/09	7	252	57.4	0.126	1.449	0.176	64.39	574.2	20.53
8/20/09	7	259	28.4	0.062	1.511	0.087	31.84	283.9	20.84
8/27/09	7	266	28.2	0.062	1.573	0.087	31.67	282.5	21.12
9/3/09	7	273	14.1	0.031	1.604	0.043	15.80	140.9	20.99
9/10/09	7	280	23.9	0.053	1.657	0.074	26.83	239.2	21.13
9/17/09	7	287	23.5	0.052	1.709	0.072	26.34	234.9	21.26
9/24/09	7	294	28.2	0.062	1.771	0.087	31.65	282.3	21.51
10/1/09	7	301	36.3	0.080	1.851	0.111	40.68	362.8	21.95
10/8/09	7	308	32.3	0.071	1.922	0.099	36.21	322.9	22.28
10/15/09	7	315	34.8	0.077	1.998	0.107	39.02	348.0	22.65
10/22/09	7	322	18.8	0.041	2.040	0.058	21.06	187.8	22.62
10/29/09	7	329	22.7	0.050	2.090	0.070	25.49	227.3	22.68
11/5/09	7	336	0.6	0.001	2.091	0.002	0.68	6.0	22.22
11/12/09	7	343	13.2	0.029	2.120	0.040	14.78	131.8	22.07
11/19/09	7	350	0.9	0.002	2.122	0.003	1.01	9.0	21.64
11/24/09	5	355	6.7	0.015	2.137	0.029	10.56	94.2	21.49
12/3/09	9	364	41.1	0.091	2.228	0.098	35.90	320.2	21.84
12/10/09	7	371	54.9	0.121	2.349	0.169	61.60	549.3	22.60
		Total Q1	**204.0**	**0.449**	**Average Q1**	**0.044**	**16.15**	**144.0**	
		Total Q2	**141.1**	**0.311**	**Average Q2**	**0.036**	**13.27**	**118.4**	
		Total Q3	**407.3**	**0.897**	**Average Q3**	**0.096**	**35.15**	**313.5**	
		Total Q4	**313.9**	**0.691**	**Average Q4**	**0.073**	**26.54**	**236.6**	

Table 20. Water Quality Based Calculations for Total Phosphorus Percent Mass Removal over the Operational Period

	Influent Total Phosphorus Load lb	Effluent Total Phosphorus Load lb	Total Phosphorus Removed lb	Cumulative Total Phosphorus Removed lb	Percent Total Phosphorus Removed	Cumulative Percent Total Phosphorus Removed
12/11/08	0.11	0.07	0.04	0.04	38.61%	38.61%
12/18/08	0.26	0.11	0.16	0.20	60.04%	53.55%
12/29/08	0.25	0.16	0.09	0.29	36.15%	46.59%
1/5/09	0.10	0.05	0.06	0.35	53.34%	47.56%
1/12/09	0.15	0.12	0.03	0.38	20.11%	42.87%
1/15/09	0.18	0.06	0.12	0.50	65.11%	46.63%
1/22/09	0.06	0.04	0.02	0.52	39.86%	46.25%
1/29/09	0.06	0.03	0.03	0.55	48.12%	46.35%
2/5/09	0.07	0.04	0.02	0.57	32.64%	45.62%
2/12/09	0.10	0.07	0.03	0.61	32.37%	44.66%
2/19/09	0.10	0.08	0.02	0.62	17.73%	42.84%
2/25/09	0.10	0.06	0.04	0.66	37.62%	42.52%
3/5/09	0.14	0.09	0.05	0.70	33.92%	41.82%
3/12/09	0.12	0.10	0.02	0.72	14.12%	40.00%
3/19/09	0.14	0.09	0.05	0.77	36.30%	39.73%
3/26/09				0.77		39.73%
4/2/09	0.18	0.13	0.05	0.82	26.09%	38.56%
4/8/09	0.20	0.14	0.06	0.88	30.66%	37.88%
4/16/09	0.33	0.30	0.02	0.91	7.51%	34.14%
4/23/09	0.32	0.37	-0.05	0.86	-14.22%	28.91%
4/30/09	0.24	0.26	-0.02	0.84	-7.06%	26.21%
5/7/09	0.29	0.27	0.01	0.86	4.59%	24.45%
5/14/09	0.23	0.21	0.02	0.87	6.74%	23.36%
5/21/09	0.40	0.38	0.01	0.89	3.53%	21.46%
5/28/09	0.21	0.19	0.02	0.91	8.46%	20.83%
6/4/09	0.38	0.33	0.04	0.95	10.94%	20.05%
6/11/09	0.37	0.35	0.02	0.97	5.74%	19.00%
6/18/09	0.56	0.53	0.03	1.00	5.57%	17.67%
6/25/09	0.41	0.39	0.02	1.02	4.87%	16.80%
7/2/09	0.40	0.39	0.01	1.03	1.88%	15.89%
7/9/09	0.24	0.21	0.03	1.06	14.10%	15.82%
7/16/09	0.30	0.22	0.08	1.14	27.09%	16.30%
7/23/09	0.21	0.17	0.04	1.18	18.88%	16.38%
7/30/09	0.17	0.13	0.04	1.22	20.87%	16.48%
8/6/09	0.24	0.15	0.09	1.30	36.25%	17.10%
8/13/09	0.19	0.14	0.05	1.35	25.18%	17.29%
8/20/09	0.10	0.10	0.00	1.35	2.49%	17.11%
8/27/09	0.11	0.09	0.02	1.37	16.98%	17.11%
9/3/09	0.09	0.05	0.04	1.41	43.83%	17.41%
9/10/09	0.15	0.10	0.06	1.47	38.50%	17.81%
9/17/09	0.14	0.09	0.05	1.52	35.85%	18.11%
9/24/09	0.14	0.14	0.00	1.52	0.22%	17.82%
10/1/09	0.28	0.13	0.16	1.68	55.44%	19.02%
10/8/09	0.22	0.14	0.08	1.75	35.51%	19.42%
10/15/09	0.15	0.13	0.03	1.78	18.06%	19.40%
10/22/09	0.15	0.13	0.02	1.80	14.19%	19.31%
10/29/09	0.15	0.12	0.03	1.84	22.61%	19.36%
11/5/09	0.16	0.14	0.02	1.86	11.26%	19.23%
11/12/09	0.25	0.23	0.03	1.89	11.43%	19.03%
11/19/09	0.21	0.20	0.01	1.90	5.82%	18.76%
11/24/09	0.11	0.09	0.02	1.92	17.10%	18.74%
12/3/09	0.23	0.13	0.11	2.02	45.34%	19.34%
12/10/09	0.22	0.19	0.04	2.06	16.49%	19.28%
Total Q1	**1.80**	**1.08**	**0.72**	**% Removed Q1**	**40.00%**	
Total Q2	**3.29**	**3.04**	**0.25**	**% Removed Q2**	**7.48%**	
Total Q3	**3.17**	**2.66**	**0.50**	**% Removed Q3**	**15.88%**	
Total Q4	**2.42**	**1.83**	**0.59**	**% Removed Q4**	**24.30%**	

Table 21. Water Quality Based Calculations for Ortho Phosphorus Percent Mass Removal over the Operational Period

	Influent Ortho Phosphorus Load lb	Effluent Ortho Phosphorus Load lb	Ortho Phosphrus Removed lb	Cumulative Ortho Phosphorus Removed lb	Percent Ortho Phosphorus Removed	Cumulative Percent Ortho Phosphorus Removed
12/11/08	0.03	0.03	0.00	0.00	10.44%	10.44%
12/18/08	0.16	0.11	0.05	0.05	30.07%	26.55%
12/29/08	0.23	0.15	0.08	0.13	36.03%	31.72%
1/5/09	0.08	0.03	0.04	0.18	57.65%	35.63%
1/12/09	0.11	0.05	0.05	0.23	51.42%	38.41%
1/15/09	0.02	0.01	0.02	0.25	62.54%	39.34%
1/22/09	0.03	0.01	0.02	0.26	60.09%	40.16%
1/29/09	0.05	0.03	0.02	0.29	48.45%	40.76%
2/5/09	0.04	0.02	0.02	0.30	38.53%	40.64%
2/12/09	0.08	0.07	0.02	0.32	19.36%	38.51%
2/19/09	0.05	0.03	0.02	0.34	47.32%	38.99%
2/25/09	0.07	0.03	0.04	0.38	54.63%	40.08%
3/5/09	0.08	0.04	0.04	0.41	45.35%	40.48%
3/12/09	0.08	0.04	0.04	0.45	46.42%	40.92%
3/19/09	0.08	0.04	0.04	0.49	53.04%	41.72%
3/26/09				0.49		41.72%
4/2/09	0.16	0.12	0.04	0.53	23.05%	39.50%
4/8/09	0.15	0.13	0.02	0.55	13.23%	36.83%
4/16/09	0.35	0.34	0.01	0.56	3.28%	30.45%
4/23/09	0.21	0.21	0.00	0.56	0.20%	27.30%
4/30/09	0.19	0.18	0.01	0.57	3.99%	25.35%
5/7/09	0.20	0.19	0.01	0.57	2.98%	23.55%
5/14/09	0.28	0.23	0.05	0.62	17.92%	22.97%
5/21/09	0.25	0.24	0.01	0.63	4.20%	21.38%
5/28/09	0.23	0.20	0.03	0.66	13.27%	20.81%
6/4/09	0.31	0.25	0.06	0.73	20.54%	20.79%
6/11/09	0.39	0.36	0.04	0.76	9.04%	19.60%
6/18/09	0.54	0.50	0.04	0.81	7.89%	18.17%
6/25/09	0.35	0.31	0.04	0.85	12.19%	17.74%
7/2/09	0.17	0.15	0.02	0.87	13.48%	17.59%
7/9/09	0.28	0.21	0.07	0.94	25.88%	18.03%
7/16/09	0.26	0.17	0.09	1.03	33.45%	18.77%
7/23/09	0.27	0.16	0.11	1.15	41.82%	19.87%
7/30/09	0.16	0.05	0.11	1.25	68.03%	21.13%
8/6/09	0.20	0.13	0.07	1.33	37.31%	21.66%
8/13/09	0.21	0.09	0.13	1.45	59.74%	22.93%
8/20/09	0.12	0.06	0.06	1.52	52.13%	23.47%
8/27/09	0.09	0.03	0.06	1.58	69.15%	24.09%
9/3/09	0.05	0.02	0.03	1.61	62.81%	24.38%
9/10/09	0.11	0.05	0.05	1.66	49.23%	24.78%
9/17/09	0.08	0.03	0.05	1.71	62.20%	25.24%
9/24/09	0.14	0.07	0.06	1.78	45.58%	25.64%
10/1/09	0.17	0.09	0.08	1.86	46.90%	26.15%
10/8/09	0.18	0.11	0.07	1.93	40.12%	26.49%
10/15/09	0.18	0.10	0.08	2.00	42.84%	26.88%
10/22/09	0.14	0.10	0.04	2.04	28.88%	26.92%
10/29/09	0.17	0.12	0.05	2.09	30.34%	27.00%
11/5/09	0.12	0.12	0.00	2.10	1.25%	26.60%
11/12/09	0.22	0.19	0.03	2.13	13.16%	26.23%
11/19/09	0.15	0.14	0.00	2.13	1.46%	25.79%
11/24/09	0.11	0.10	0.01	2.14	13.21%	25.62%
12/3/09	0.12	0.03	0.09	2.23	73.98%	26.32%
12/10/09	0.16	0.04	0.12	2.35	76.92%	27.24%
Total Q1	**1.10**	**0.65**	**0.45**	**% Removed Q1**	**40.92%**	
Total Q2	**2.79**	**2.48**	**0.31**	**% Removed Q2**	**11.20%**	
Total Q3	**2.81**	**1.91**	**0.90**	**% Removed Q3**	**31.96%**	
Total Q4	**1.94**	**1.25**	**0.69**	**% Removed Q4**	**35.74%**	

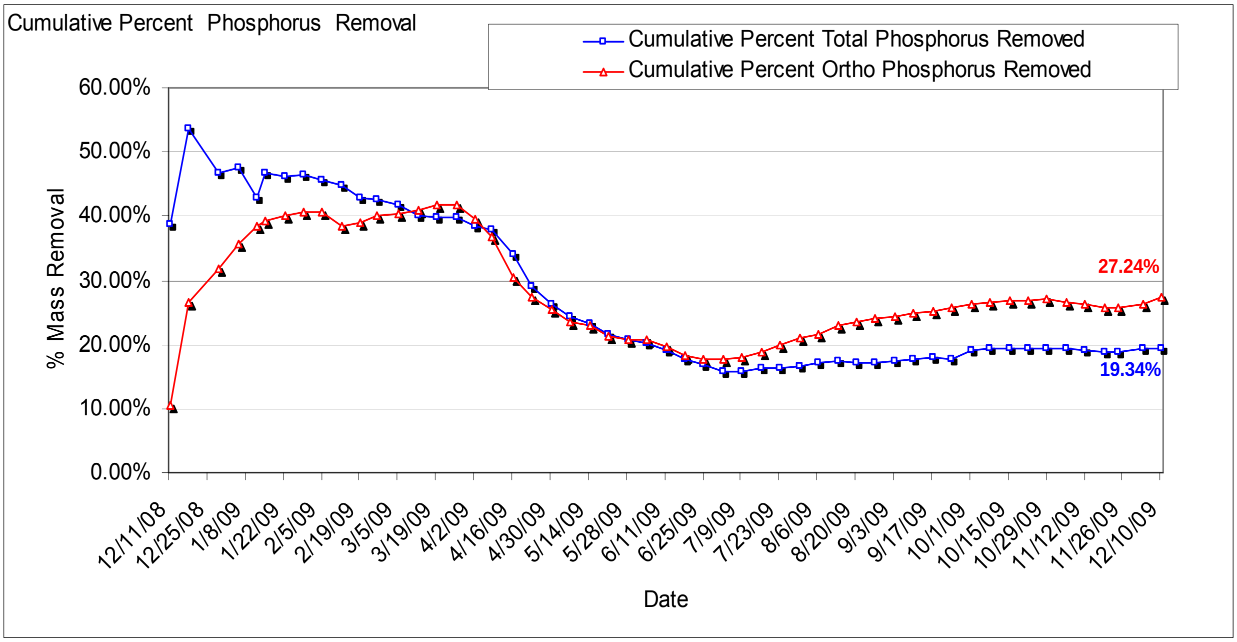


Figure 17: Percent Cumulative Mass Removal of Phosphorus for ATS™ Floway Powell Creek By-Pass \Canal

Table 22. Harvest Based Calculations for Total Phosphorus Mass Removals and Areal Removal Rates over the Operational Period

	Days Between Harvest	Cumulative Days	Harvest Based Mass Removal Total Phosphorus gm	Harvest Based Mass Removal Total Phosphorus lbs	Cumulative Harvest Based Mass Removal Total Phosphorus lbs	Harvest Based Areal Removal Rate Total Phosphorus g/m^2 day	Harvest Based Areal Removal Rate Total Phosphorus g/m^2-yr	Harvest Based Areal Removal Rate Total Phosphorus lb/acre-yr	Collective Harvest Based Areal Removal Rate Total Phosphorus g/m^2-yr
12/18/08	34	34	19.0	0.042	0.042	0.012	4.39	39.1	4.39
1/5/09	18	52	41.8	0.092	0.134	0.050	18.23	162.5	9.18
1/12/09	7	59	30.1	0.066	0.200	0.093	33.79	301.3	12.10
1/29/09	17	76	19.7	0.043	0.244	0.025	9.11	81.2	11.43
2/12/09	14	90	45.6	0.100	0.344	0.070	25.59	228.2	13.63
2/25/09	13	103	33.7	0.074	0.418	0.056	20.35	181.5	14.48
3/12/09	15	118	45.3	0.100	0.518	0.065	23.74	211.7	15.66
3/26/09	14	132	49.0	0.108	0.626	0.075	27.50	245.2	16.91
4/2/09	7	139	29.8	0.066	0.692	0.092	33.49	298.6	17.75
4/23/09	21	160	12.1	0.027	0.718	0.012	4.52	40.3	16.01
5/7/09	14	174	10.5	0.023	0.742	0.016	5.88	52.4	15.20
5/21/09	14	188	45.8	0.101	0.842	0.070	25.67	228.9	15.98
6/4/09	14	202	91.0	0.200	1.043	0.140	51.04	455.2	18.41
6/11/09	7	209	19.4	0.043	1.085	0.060	21.72	193.7	18.52
6/25/09	14	223	33.2	0.073	1.159	0.051	18.64	166.2	18.53
7/9/090	14	237	22.6	0.050	1.208	0.035	12.70	113.3	18.18
7/23/090	14	251	20.5	0.045	1.254	0.032	11.50	102.5	17.81
8/6/09	14	265	40.7	0.090	1.343	0.063	22.82	203.5	18.07
8/13/09	7	272	23.1	0.051	1.394	0.071	25.91	231.1	18.28
8/27/09	14	286	72.8	0.160	1.554	0.112	40.84	364.2	19.38
9/10/09	14	300	46.4	0.102	1.656	0.071	26.01	232.0	19.69
9/24/09	14	314	21.0	0.046	1.703	0.032	11.80	105.2	19.34
10/8/09	14	328	44.9	0.099	1.802	0.069	25.22	224.9	19.59
10/22/09	14	342	58.5	0.129	1.931	0.090	32.84	292.9	20.13
11/5/09	14	356	56.4	0.124	2.055	0.087	31.64	282.2	20.58
11/19/09	14	370	29.6	0.065	2.120	0.045	16.59	147.9	20.43
12/10/09	21	391	72.8	0.160	2.280	0.075	27.23	242.8	20.80
		Total Q1	235.2	0.518	Average Q1	0.053	19.31	172.2	
		Total Q2	257.5	0.567	Average Q2	0.066	24.26	216.3	
		Total Q3	259.3	0.571	Average Q3	0.062	22.63	201.8	
		Total Q4	283.3	0.624	Average Q4	0.066	24.22	216.0	

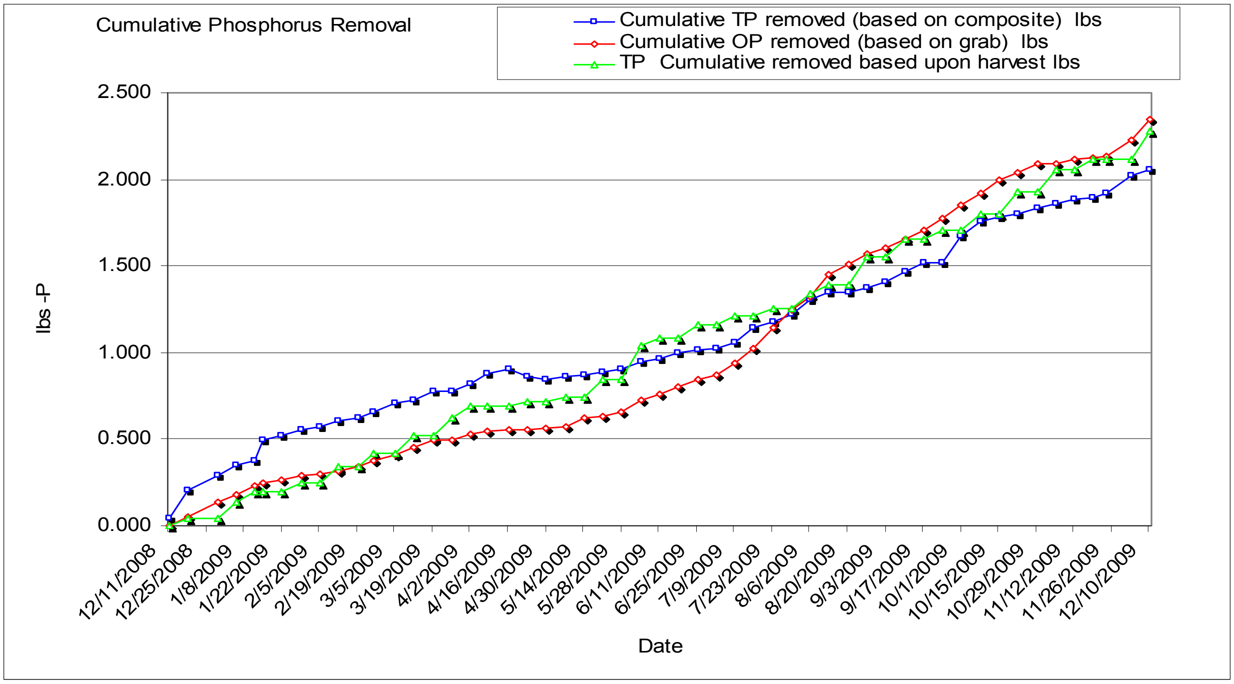


Figure 18: Comparative Cumulative Mass Removals for Phosphorus over Operational Period Based upon Water Quality and Harvest Calculations ATS™ Floway Powell Creek By-Pass Canal

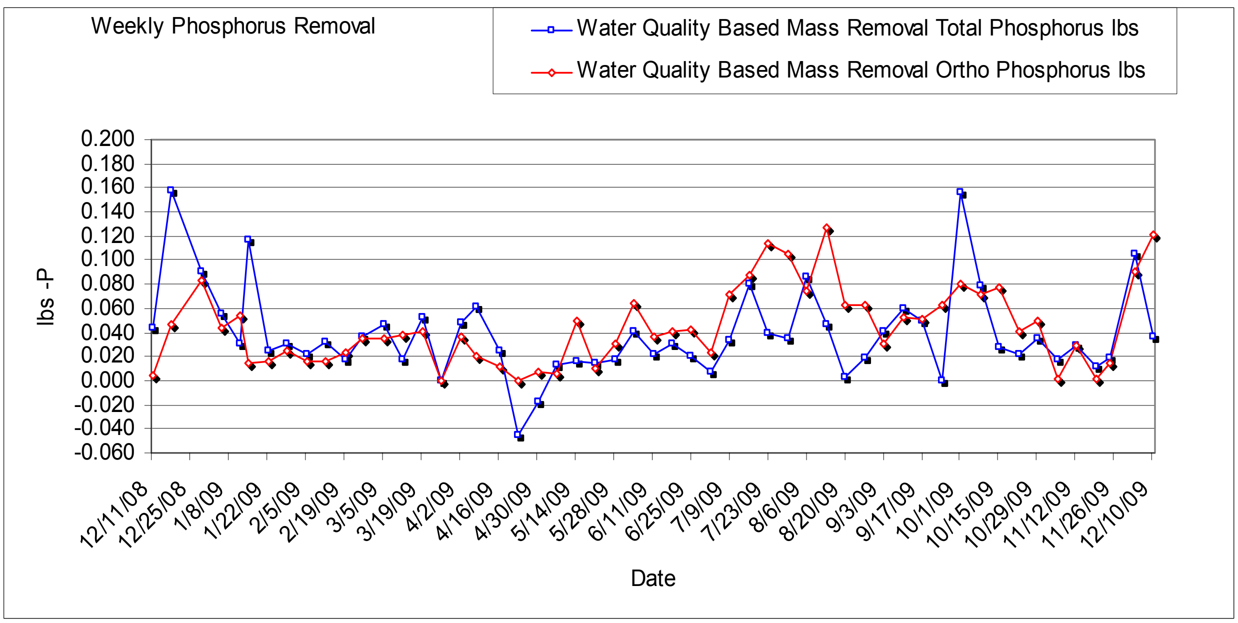


Figure 19: Weekly Mass Removals for Phosphorus over operational Period Based upon Water Quality ATS™ Floway Powell Creek By-Pass Canal

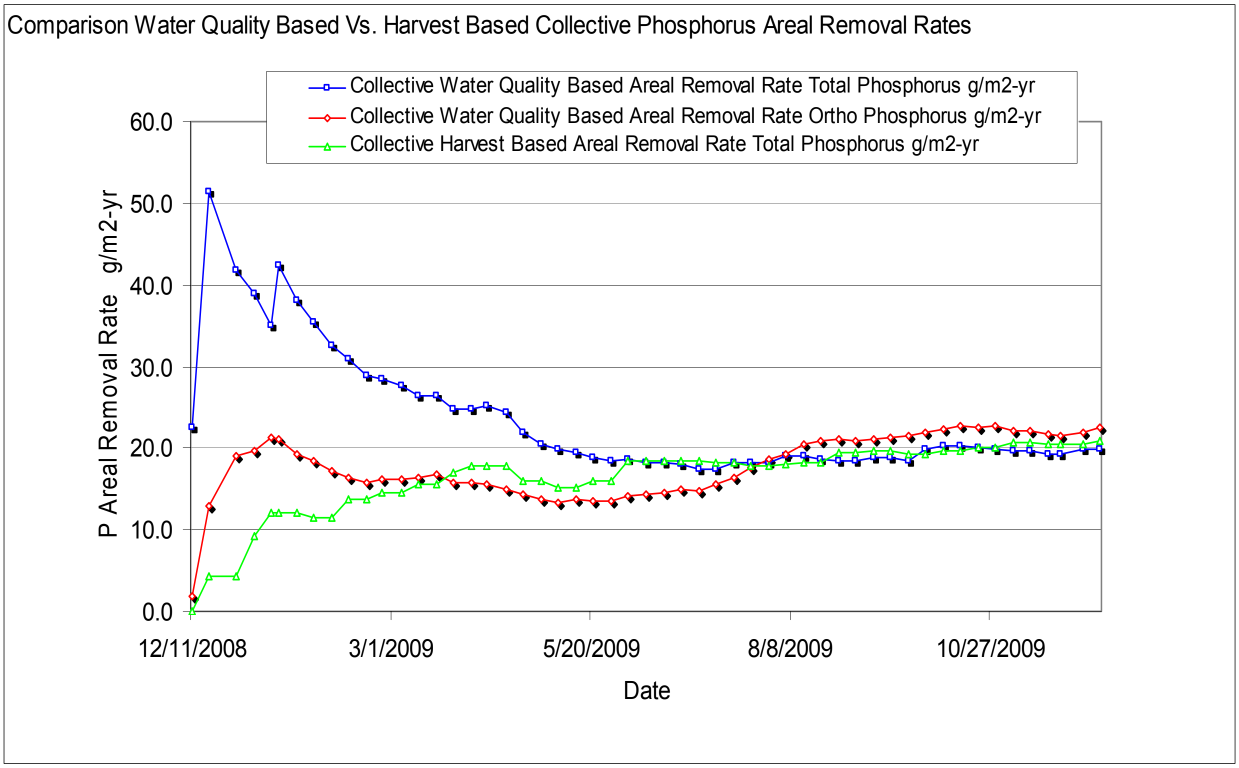


Figure 20: Comparative Collective Areal Removal Rates for Phosphorus over Operational Period based upon Water Quality and Harvest Calculations ATS™ Floway Powell Creek By-Pass Canal

Table 23: Water Quality Based and Harvest Based Calculations for Monthly Total Phosphorus Areal Removals Rates over the Operational Period

Month	Water Quality Based Areal Removal Rate Total Phosphorus g/m^2-month	Harvest Based Areal Removal Rate Total Phosphorus g/m^2-month
Dec-08	3.10	0.78
Jan-09	2.57	1.38
Feb-09	1.08	1.77
Mar-09	0.98	2.17
Apr-09	0.20	0.97
May-09	0.65	1.34
Jun-09	1.01	2.65
Jul-09	2.06	1.03
Aug-09	1.67	2.60
Sep-09	2.56	1.55
Oct-09	1.76	2.47
Nov-09	0.87	1.98
Dec-09	4.32	2.31

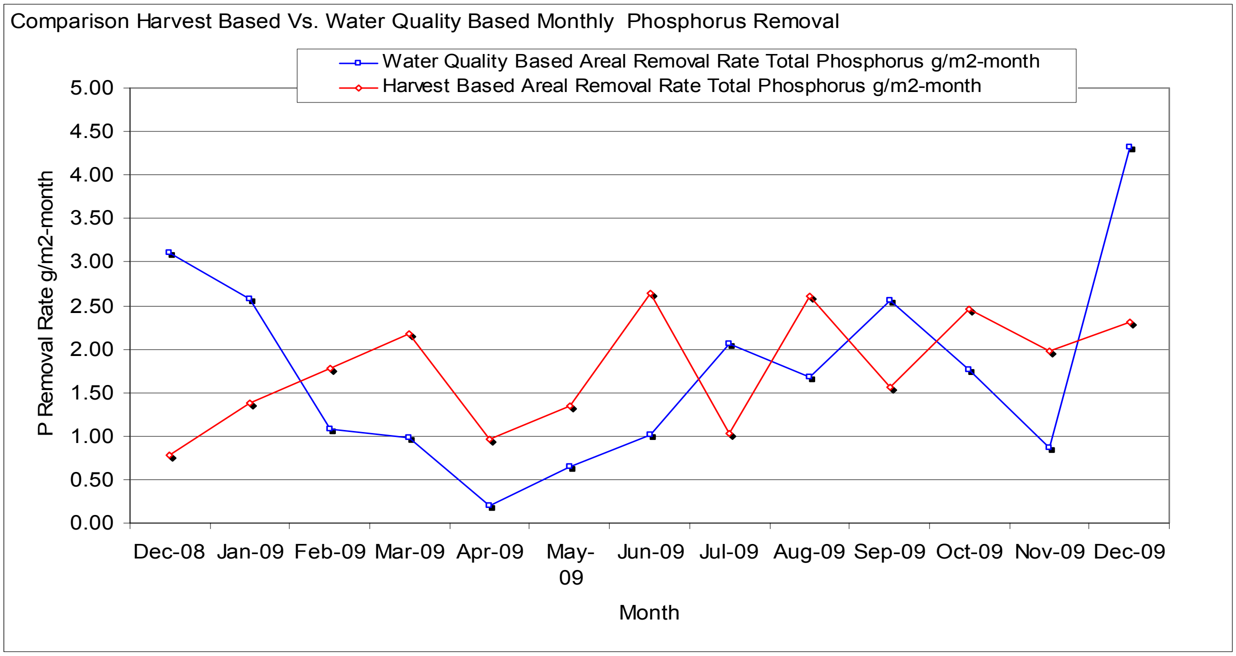


Figure 21: Comparative Collective Areal Removal Rates for Phosphorus over Operational Period Based upon Water Quality and Harvest Calculations ATS™ Floway Powell Creek By-Pass Canal

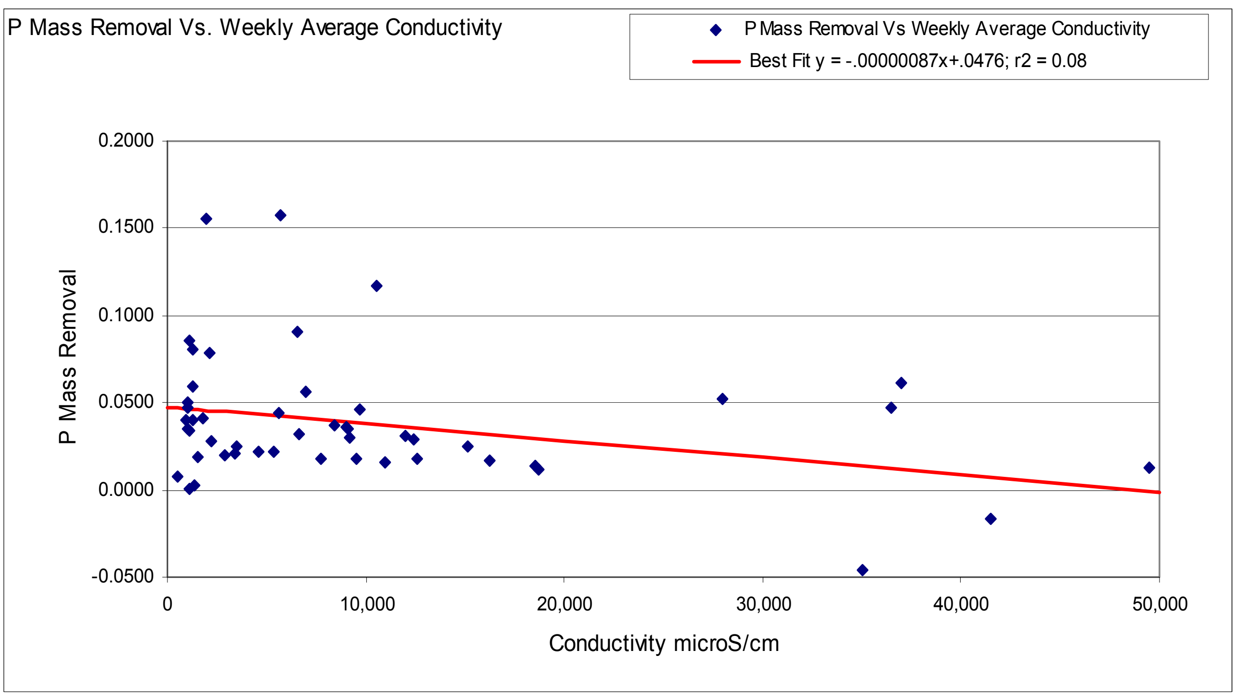


Figure 22: Linear Regression Analysis Conductivity Versus Total Phosphorus Mass Removal over Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 24. Water Quality Based Calculations for Comparative Percent Removal of Total, Ortho and Organic Phosphorus from Lee County Weekly Grab Samples Taken from 6/11/09 through 12/10/09

	Influent Total Phosphorus lb	Influent Ortho Phosphorus lb	Influent Organic Phosphorus lb	Effluent Total Phosphorus lb	Effluent Ortho Phosphorus lb	Effluent Organic Phosphorus lb	% of Influent as Ortho Phosphorus	% of Effluent as Ortho Phosphorus	% of Influent as Organic Phosphorus	% of Effluent as Organic Phosphorus	% Total Phosphorus Reduction	% Ortho Phosphorus Reduction	% Organic Phosphorus Reduction
6/11/09	0.42	0.37	0.05	0.40	0.33	0.07	88.62%	81.79%	11.38%	18.21%	3.40%	10.85%	-54.63%
6/18/09	0.63	0.49	0.13	0.53	0.45	0.08	78.64%	85.68%	21.36%	14.32%	16.08%	8.57%	43.73%
6/25/09	0.36	0.32	0.04	0.35	0.28	0.07	89.63%	80.00%	10.37%	20.00%	3.73%	14.07%	-85.66%
7/2/09	0.24	0.15	0.08	0.22	0.12	0.10	65.00%	55.33%	35.00%	44.67%	5.91%	19.90%	-20.08%
7/9/09	0.29	0.25	0.04	0.29	0.17	0.12	85.56%	58.89%	14.44%	41.11%	0.23%	31.33%	-183.96%
7/16/09	0.28	0.23	0.05	0.20	0.15	0.06	83.16%	71.43%	16.84%	28.57%	26.45%	36.82%	-24.77%
7/23/09	0.38	0.27	0.11	0.20	0.14	0.05	70.74%	72.86%	29.26%	27.14%	48.21%	46.66%	51.95%
7/30/09	0.21	0.16	0.05	0.08	0.04	0.04	75.88%	46.97%	24.12%	53.03%	61.25%	76.02%	14.80%
8/6/09	0.25	0.20	0.06	0.16	0.11	0.04	76.88%	72.00%	23.13%	28.00%	37.51%	41.47%	24.33%
8/13/09	0.25	0.21	0.05	0.13	0.07	0.05	81.18%	58.14%	18.82%	41.86%	49.27%	63.66%	-12.82%
8/20/09	0.13	0.08	0.05	0.08	0.04	0.04	62.11%	48.39%	37.89%	51.61%	34.54%	49.00%	10.85%
8/27/09	0.10	0.07	0.03	0.05	0.01	0.04	69.88%	18.92%	30.12%	81.08%	54.99%	87.81%	-21.16%
9/3/09	0.08	0.04	0.04	0.02	0.02	0.00	56.00%	106.25%	44.00%	-6.25%	78.53%	59.26%	103.05%
9/10/09	0.10	0.10	0.01	0.06	0.04	0.02	91.80%	72.22%	8.20%	27.78%	41.02%	53.60%	-99.89%
9/17/09	0.10	0.07	0.03	0.04	0.02	0.03	68.18%	40.74%	31.82%	59.26%	59.02%	75.52%	23.68%
9/24/09	0.14	0.11	0.02	0.09	0.06	0.03	83.64%	66.67%	16.36%	33.33%	37.41%	50.11%	-27.49%
10/1/09	0.28	0.15	0.13	0.11	0.06	0.05	53.08%	57.69%	46.92%	42.31%	60.05%	56.57%	63.98%
10/8/09	0.20	0.15	0.05	0.13	0.08	0.05	75.00%	64.10%	25.00%	35.90%	35.13%	44.55%	6.85%
10/15/09	0.18	0.15	0.03	0.12	0.07	0.05	84.55%	55.41%	15.45%	44.59%	32.86%	56.00%	-93.72%
10/22/09	0.15	0.12	0.03	0.13	0.08	0.05	81.00%	64.71%	19.00%	35.29%	15.18%	32.25%	-57.55%
10/29/09	0.17	0.15	0.02	0.12	0.10	0.03	87.50%	77.01%	12.50%	22.99%	27.67%	36.34%	-33.02%
11/5/09	0.21	0.18	0.03	0.15	0.11	0.04	86.88%	74.55%	13.13%	25.45%	31.36%	41.11%	-33.11%
11/12/09	0.27	0.19	0.08	0.22	0.16	0.06	70.83%	71.00%	29.17%	29.00%	16.69%	16.50%	17.17%
11/19/09	0.26	0.14	0.11	0.18	0.14	0.04	55.38%	78.26%	44.62%	21.74%	29.31%	0.11%	65.56%
11/24/09	0.16	0.12	0.04	0.09	0.06	0.04	73.57%	62.20%	26.43%	37.80%	41.48%	50.53%	16.29%
12/3/09	0.23	0.12	0.11	0.07	0.02	0.06	52.14%	20.93%	47.86%	79.07%	69.29%	87.67%	49.26%
12/10/09	0.22	0.17	0.05	0.20	0.04	0.17	77.14%	18.46%	22.86%	81.54%	6.82%	77.70%	-232.41%
Totals	**6.30**	**4.77**	**1.52**	**4.43**	**2.97**	**1.46**	**75.81%**	**66.99%**	**24.19%**	**33.01%**	**29.64%**	**37.82%**	**4.01%**

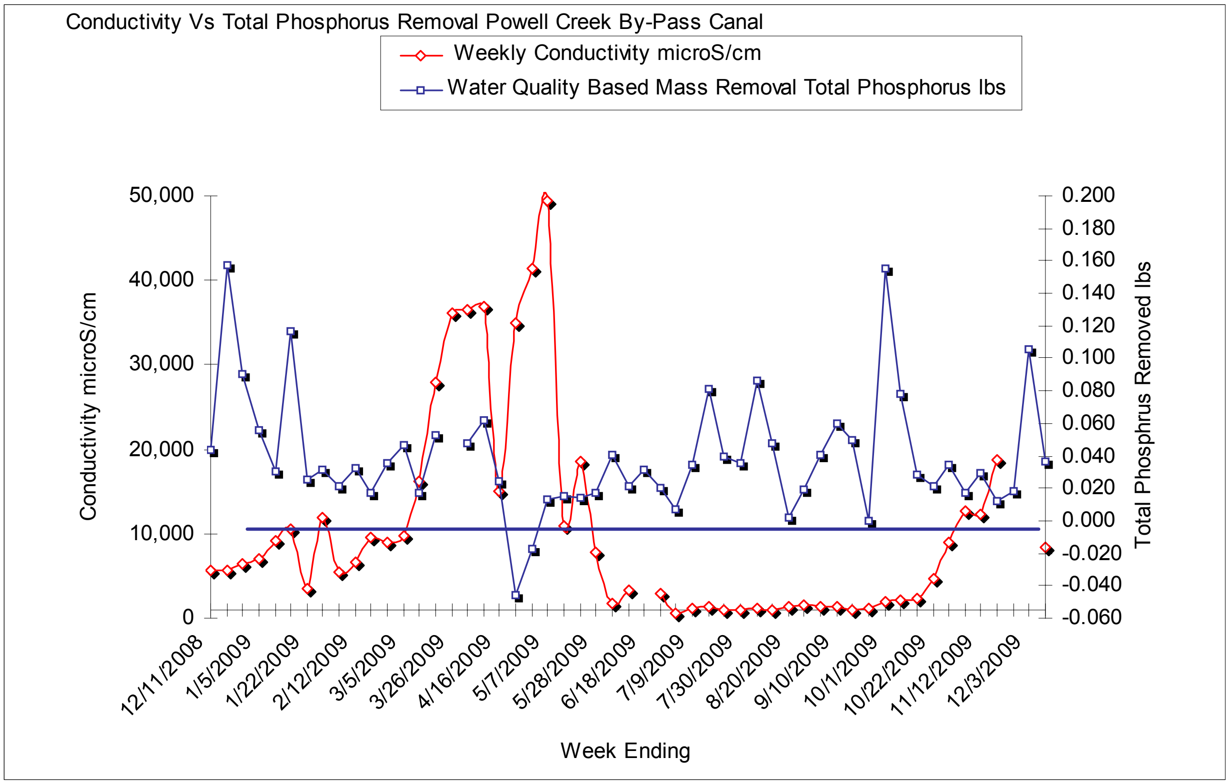


Figure 23: Weekly Average Conductivity Versus Total Phosphorus Mass Removal over Operational Period ATS™ Floway Powell Creek By-Pass Canal

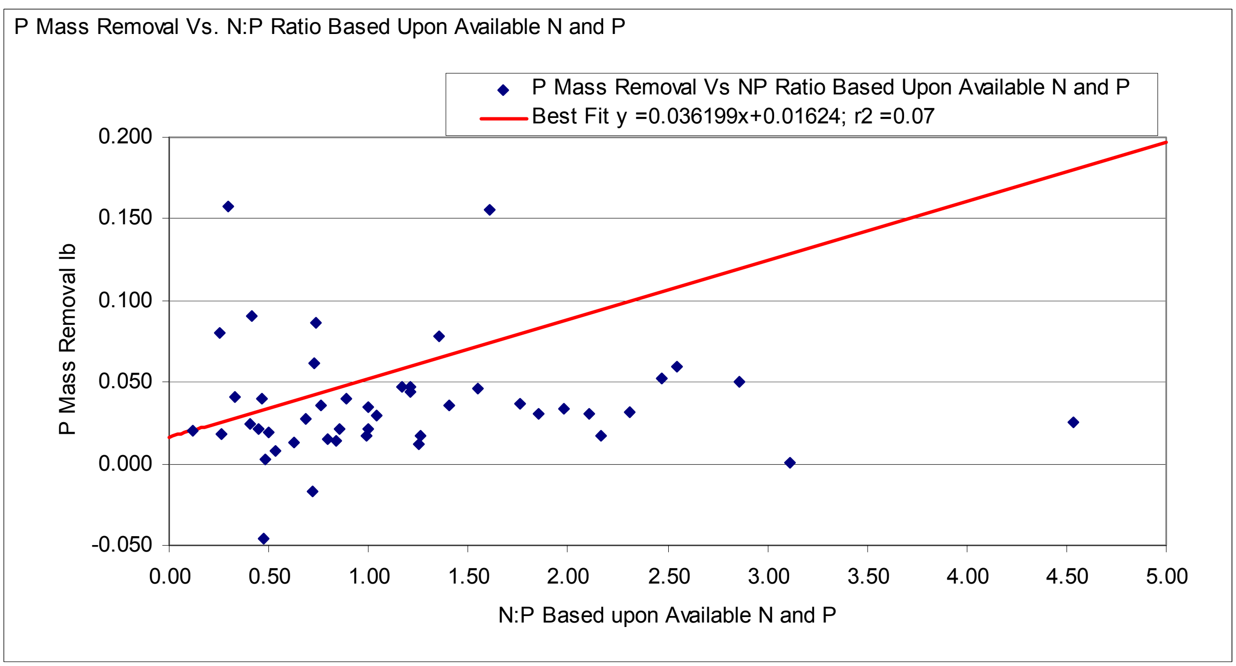


Figure 24: Water Quality Based Total Phosphorus Removal Versus N:P Ratio Based upon Available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

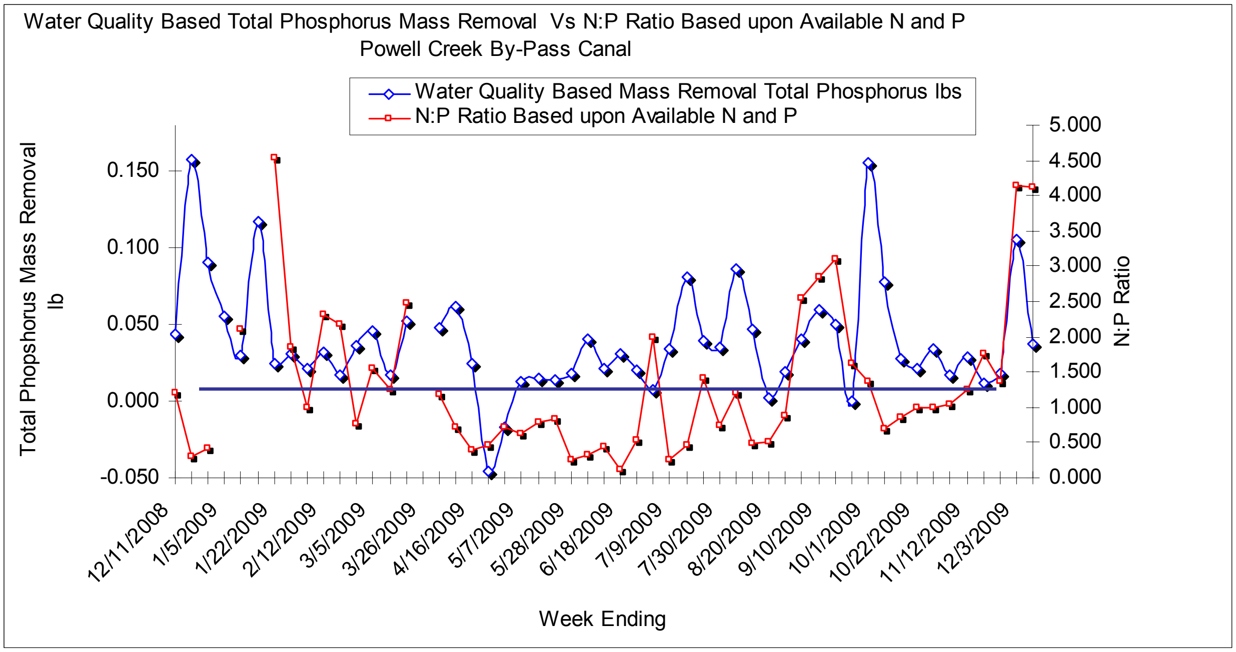


Figure 25: Water Quality Based Total Phosphorus Mass Removal Versus N:P Ratio Based upon Available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

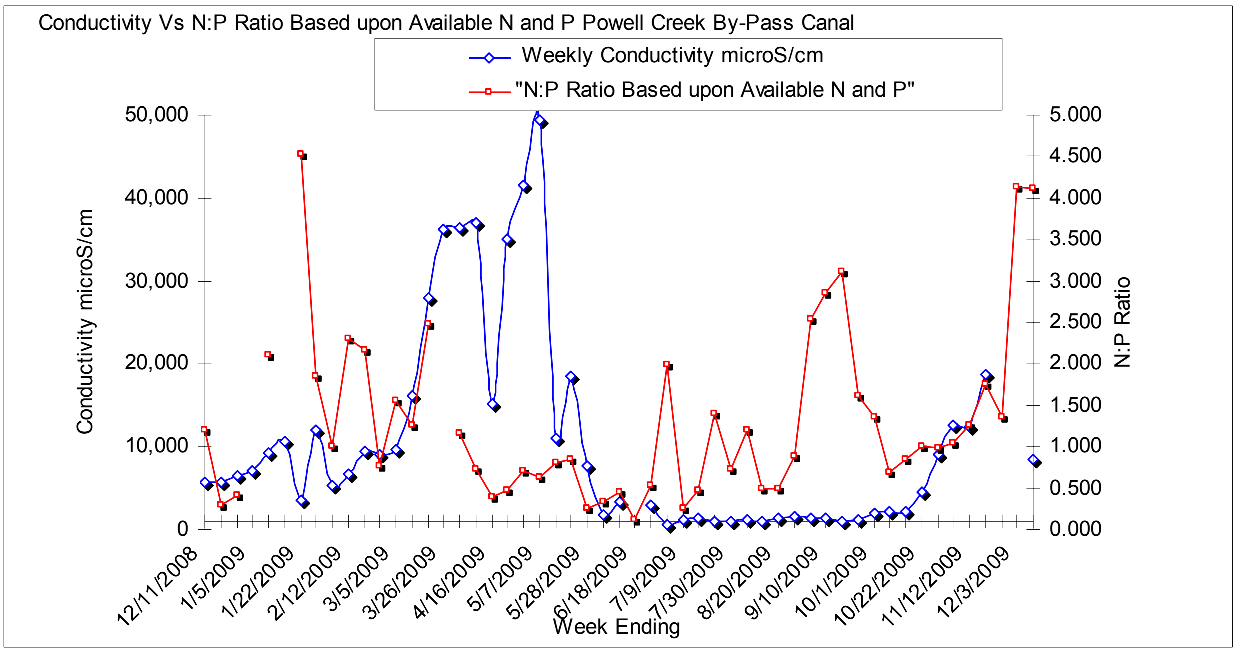


Figure 26: Weekly Average Conductivity Compared to N:P Ratio based upon available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

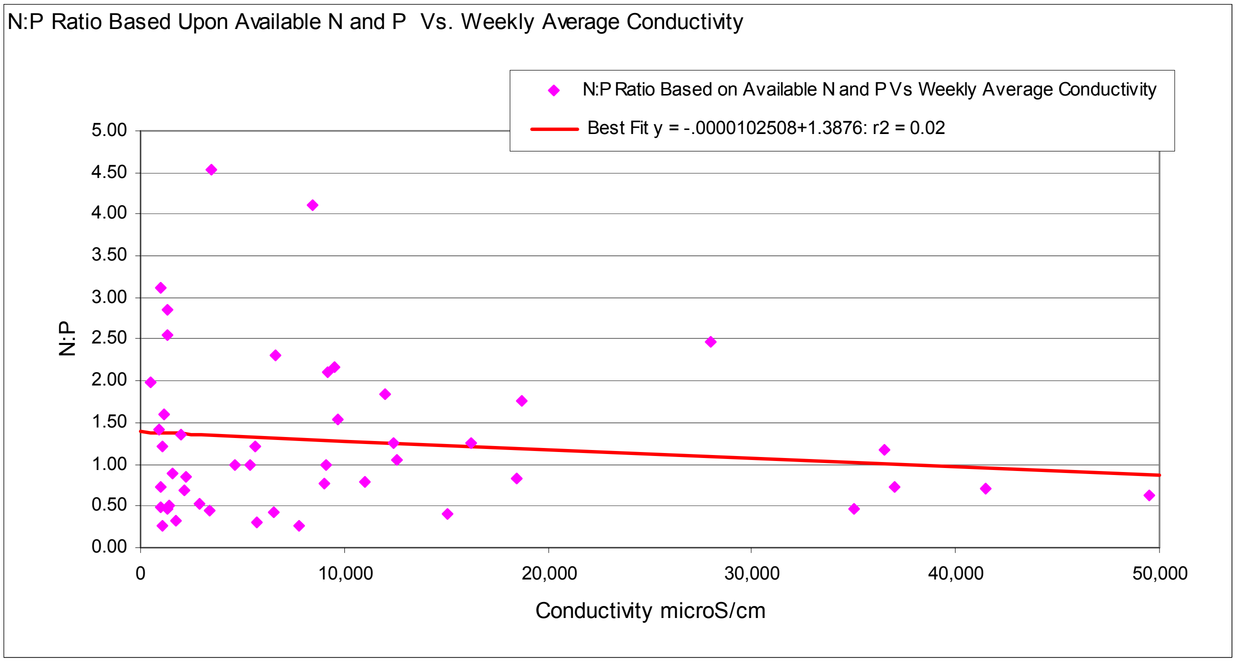


Figure 27: Conductivity Versus N:P Ratio Based upon Available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

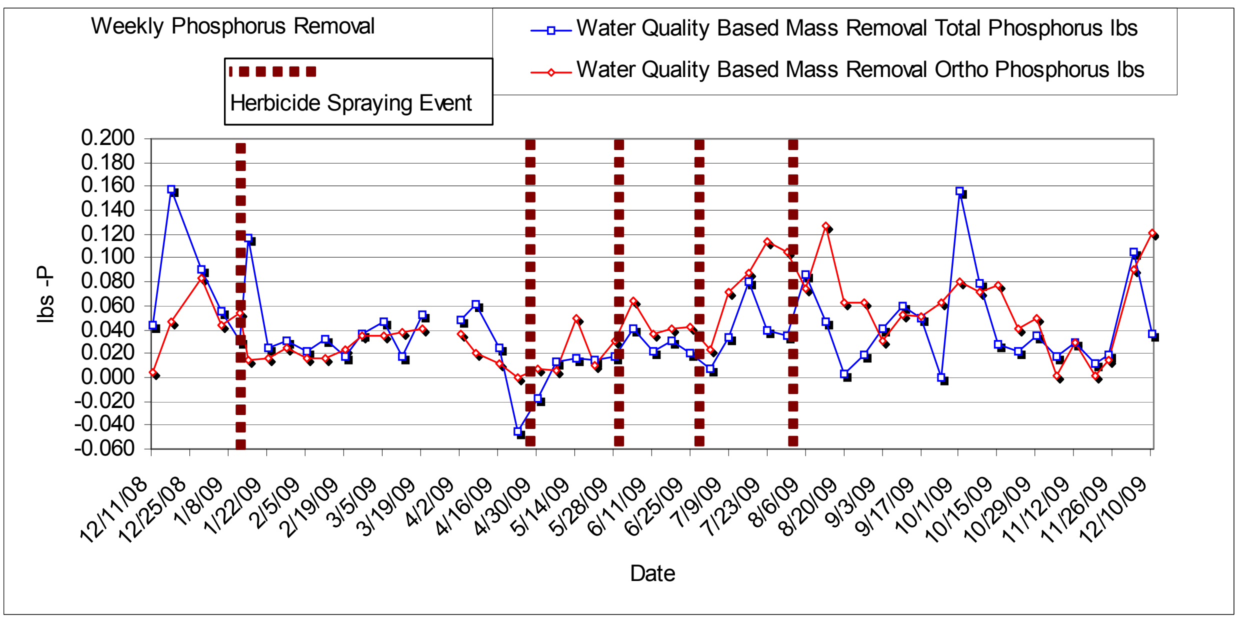


Figure 28: Water Quality Based Total Phosphorus Mass Removal Versus Herbicide Spraying Schedule over Operational Period ATS™ Floway Powell Creek By-Pass Canal

NITROGEN DYNAMICS

Areal Removal Rates and Mass Removal

Nitrogen dynamics associated with ATS™ can become somewhat more complex than phosphorus dynamics, largely because of the potential interaction with atmospheric nitrogen. While ATS™ nitrogen removal is typically targeted toward direct nitrogen uptake by the tissue from the existing loads within the influent water; there is the possibility of significant external influences associated with atmospheric gains related to nitrogen fixation and atmospheric losses through ammonia volatilization and denitrification. This can confuse efforts to establish nitrogen accountability.

Total nitrogen coming into the floway from the by-pass canal, as noted in Table 25, averaged 5.49% as nitrate and nitrite nitrogen, 6.26% ammonium and 87.82% organic nitrogen for the operational period. This shifted within the effluent as 3.76% nitrite and nitrate nitrogen, 3.30% ammonium and 92.94% organic nitrogen. The total nitrogen levels in this water was low compared to what has been observed in many Florida waters, averaging only 0.95 mg/L over the study period within the influent.

- Mean effluent nitrate-nitrite nitrogen was 0.03 mg/l reflecting a 33.3% mass reduction over the operational period
- Mean effluent ammonia nitrogen was 0.03 mg/l reflecting a 50.18% mass reduction over the operational period
- Mean organic nitrogen was 0.81 mg/L reflecting a 1.64% mass reduction over the operational period
- Mean effluent TN was 0.87 mg/L reflecting a 6.7% mass reduction over the operational period.

It is evident from this analysis that the algal turf preferentially targeted the available forms (nitrate + nitrite and ammonia) for uptake. Of the total nitrogen reduction over the operational period of 0.08 mg/L, about 0.05 mg/L (or 62.5% of the removal) is attributable to this available nitrogen, even though their relative concentrations were low (0.05 and 0.06 mg/L respectively for nitrate + nitrite and ammonia nitrogen). The organic nitrogen, while comprising the majority of the total nitrogen at 0.81 mg/L, was reduced by only 1.64%. The implication is that little enzymatic activity targeting the hydrolysis of organic nitrogen was associated with the PC-ATS™, and that when a paucity of available nitrogen occurred, the system appeared to resort to nitrogen fixation rather than the application of deaminase type enzymes that would extract ammonia from organic nitrogen.

The suspicion that nitrogen fixation may have been involved at certain time over the study period is based upon a review of nitrogen mass removal and areal removal rates, and the evaluation of nitrogen accountability. Noted in Table 26 is the water quality based nitrogen mass removal and areal removal rates for the operational period. Weekly water quality based mass removal is shown in Figure 29. Cumulative water quality based percent mass removals are noted in Table 27 and Figure 30.

While there was, based upon water quality, a net removal over the operational period of 4.9 pounds of nitrogen, with an areal removal rate of 46.75 g/m^2-yr, there were several weeks in which the system showed a net gain in nitrogen. This was most noticeable during the second quarter when there was a gain of 0.875 pounds of nitrogen. It is not unreasonable to assign this gain to nitrogen fixation, although sloughing and possibly invertebrate die-off from the algal turf community could certainly be contributing factors as well. The fact that the second quarter was represented by the lowest available nitrogen to available phosphorus ratio for the operational period (0.77 as compared to 1.3 as the average over the operational period), further strengthen the argument regarding the involvement of nitrogen fixation.

The harvest based nitrogen mass removal and areal removal rates are shown in Table 28. A comparison of water quality based cumulative mass removals and collective areal removal rates and harvest based cumulative mass removals and collective areal removal rates are shown in Figures 31 and 32. Unlike phosphorus, nitrogen accountability is not as clearly demonstrated by comparison of water quality and harvest based determinations. Nitrogen removal based upon harvest data was calculated as 7.83 pounds (10.7% removal) over the operational period, while the nitrogen removal based upon water quality data was calculated as 4.86 pounds (6.7% removal) over the operational period. The difference of 2.97 pounds, assuming no major sampling or laboratory error, represents nitrogen that could logically be attributed to sources other than the influent flow—and the most likely suspect would be nitrogen fixation.

Areal removal rates estimated on a monthly basis for both water quality and harvest data, as noted in Table 29 and Figure 33, indicates some divergence between the two, with the harvest data sustained at a rather constant rate throughout the operational period, while the water quality data reflects the periods when there was a net gain in nitrogen.

Based upon the trends noted in Figures 29 and 30, the period from early April 2009 to mid July 2009 showed effluent nitrogen levels higher than influent levels, suggestive of a net gain. This would be a period when high activity of nitrogen fixation would be suspected. Typically, it would be expected that nitrogen fixation could be solicited by a relative paucity of available nitrogen in the presence of a comparative abundance of phosphorus—in other words when the ratio of available nitrogen to available phosphorus was low.

Response to Fluctuations in Conductivity

When the total nitrogen mass removal is compared with conductivity, as shown in Figure 34, again as with phosphorus, there is a very weak correlation ($r^2 = 0.05$) of an inverse relationship. Noted in Figure 35, is the weekly comparison of total nitrogen mass removal and conductivity. As with phosphorus, there is a noticeable decline in performance during the Q2 period, when conductivities were high, and fluctuations rather severe, particularly during early to mid April. However, the lower performance, as indicated by periods of gain of nitrogen, persists well into the summertime, when conductivity had dropped to what are considered freshwater levels and the dramatic conductivity fluctuations had subsided. Performance recovered by late August and was sustained through the remainder of the operational period, even as conductivity levels began to rise again during Q4. As with phosphorus, over the operational period, the total nitrogen mass removal trends appear to be associated with factors other than just conductivity fluctuations, and there is no evidence that overall system performance is significantly influenced by conductivity shifts.

Response to N:P Ratio Based upon Available N and P

Shown in Figure 36, is a plot of the N:P ratio (developed from available N and P) and total nitrogen mass removal (based on water quality). It appears from this plot that there is a correlation between N:P ratio and nitrogen mass removal during the Q2 period, although this correlation appears to weaken during the remainder of the operational period. It is noted that in all cases when total nitrogen mass removal based upon water quality is negative, the N:P ratio is below 1.0. These negative removals are suggestive of active nitrogen fixation. However, the linear regression analysis shown in Figure 37 indicates a weak correlation ($r^2 = 0.07$) of a direct relationship between nitrogen mass removal and N:P ratio, indicating the dynamics associated with nitrogen removal and nitrogen fixation is not driven solely by the N:P ratio. It does seem reasonable that as mentioned previously, that a low N:P ratio based upon available N and P would have influence upon the extent of nitrogen fixation, and certainly this is supported by the fact that negative total nitrogen mass removal is attended by N:P based upon available N and P below 1.0. There is little question however, that other factors also have significant influence, and that the dynamics are much more complex than a simple direct linear relationship between N:P and total nitrogen mass removal.

Response to Herbicide Applications within the Powell Creek Watershed

The scheduling of the County's spraying events can be compared to total nitrogen mass removal, as shown in Figure 38. The plot does reveal a general extended decline in mass nitrogen removal following the April spraying event. The trend is much more discernible than the response patterns noted for total phosphorus (see Figure 28). For subsequent events, this pattern is not as obvious. While not conclusive, the possibility that the County's spraying efforts within the Powell Creek By-Pass canal had significant influence upon total nitrogen mass removal can not be totally dismissed. Considering this possibility, it will be important to include as part of any full scale design as means of internally recycling flow during periods of herbicide spraying within the designated water source, or its tributaries.

Summary

For the monitoring period total nitrogen was reduced by 6.7% based upon mass removals calculated from water quality data, with the influent total nitrogen averaging 0.95 mg/L and the average effluent total nitrogen averaging 0.85 mg/L. Ammonia nitrogen and nitrate+nitrite nitrogen were preferentially targeted for uptake by the algal turf community, and consequently accounted for a significant percentage of the total uptake (62.5%), even though their concentrations were low when compared to organic nitrogen. There appeared to be little enzymatic activity targeted towards hydrolysis of organic nitrogen, and the system appeared to prefer accessing any additional nitrogen through nitrogen fixation—likely through the actions of *Cyanobacteria.*

In evaluating total nitrogen accountability, it was found that nitrogen mass removal calculated by harvest was considerably higher than the mass removal calculated by water quality - 7.83 lbs and 4.86 lbs, respectively. The difference of 2.97 lbs could well represent a net gain aligned with contributions from nitrogen fixation.

Periods in which the system appears to gain nitrogen, which indicates there is a possibility of influence by nitrogen fixation, reduced the overall total nitrogen mass removal and areal removal rate. However, over the operational period the system still provided a total nitrogen areal removal rate of 46.75 g/m^2-yr, which may be considered substantial, and more than competitive with typical wetland treatment systems.

Table 25. Nitrogen Influent and Effluent Load Characteristics

	Total Nitrogen mg/L		Nitrate + Nitrite Nitrogen mg/L		Ammonia Nitrogen mg/L		Organic Nitrogen (TKN) mg/L		Total Kjeldahl Nitrogen (TKN) mg/L	
	INFLUENT	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**
Quarter 1	0.95	0.79	0.03	0.01	0.06	0.02	0.85	0.76	0.91	0.78
Quarter 2	1.04	1.08	0.03	0.03	0.06	0.05	0.95	1.00	1.01	1.05
Quarter 3	0.96	0.88	0.06	0.04	0.06	0.02	0.88	0.82	0.94	0.84
Quarter 4	0.86	0.75	0.08	0.05	0.07	0.03	0.70	0.67	0.78	0.70
Total	0.95	0.87	0.05	0.03	0.06	0.03	0.84	0.81	0.91	0.84

	Nitrate + Nitrite Nitrogen % of Total Nitrogen		Ammonia Nitrogen % of Total Nitrogen		Organic Nitrogen (TKN) % of Total Nitrogen		Total Kjeldahl Nitrogen (TKN) % of total Nitrogen	
	INFLUENT	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**	**INFLUENT**	**EFFLUENT**
Quarter 1	3.66%	1.65%	6.26%	2.33%	90.09%	96.02%	96.34%	98.35%
Quarter 2	2.96%	2.78%	6.02%	4.82%	91.02%	92.40%	97.04%	97.22%
Quarter 3	6.17%	4.53%	6.14%	2.06%	87.69%	93.41%	93.83%	95.47%
Quarter 4	9.57%	6.37%	8.51%	3.68%	81.92%	89.95%	90.43%	93.63%
Total	5.49%	3.76%	6.70%	3.30%	87.82%	92.94%	94.51%	96.24%

Table 26. Water Quality Based Calculations for Total Nitrogen Mass Removals and Areal Removal Rates over the Operational Period

	Days Between Sampling	Cumulative Days Between Sampling	Water Quality Based Mass Removal Total Nitrogen gm	Water Quality Based Mass Removal Total Nitrogen lbs	Cumulative Water Quality Based Mass Removal Total Nitrogen lbs	Water Quality Based Areal Removal Rate Total Nitrogen g/m^2-day	Water Quality Based Areal Removal Rate Total Nitrogen g/m^2-yr	Water Quality Based Areal Removal Rate Total Nitrogen lb/acre-yr	Collective Water Quality Based Areal Removal Rate Total Nitrogen g/m^2-yr
12/11/08	7	7	43.3	0.095	0.095	0.133	48.55	432.9	48.55
12/18/08	7	14	158.9	0.350	0.445	0.488	178.25	1,589.6	113.40
12/29/08	11	25	-116.6	-0.257	0.188	-0.228	-83.17	-741.7	26.87
1/5/09	7	32	0.0	0.000	0.188	0.000	0.00	0.0	21.01
1/12/09	7	39	53.1	0.117	0.305	0.172	62.66	558.8	28.18
1/15/09	3	42	272.0	0.599	0.904	1.951	712.07	6,350.0	77.46
1/22/09	7	49	27.8	0.061	0.966	0.086	31.23	278.5	70.80
1/29/09	7	56	15.5	0.034	1.000	0.048	17.37	154.9	64.08
2/5/09	7	63	35.7	0.079	1.078	0.110	40.04	357.1	61.39
2/12/09	7	70	44.2	0.097	1.176	0.136	49.65	442.8	60.21
2/19/09	7	77	43.2	0.095	1.271	0.133	48.43	431.9	59.14
2/25/09	6	83	71.3	0.157	1.428	0.256	93.34	832.4	61.62
3/5/09	8	91	43.5	0.096	1.524	0.117	42.74	381.1	59.95
3/12/09	7	98	83.0	0.183	1.707	0.255	93.17	830.8	62.34
3/19/09	7	105	29.1	0.064	1.771	0.090	32.68	291.4	60.35
3/26/09	7	112			1.771				56.57
4/2/09	7	119	99.2	0.219	1.989	0.305	111.34	992.9	59.80
4/8/09	6	125	54.0	0.119	2.108	0.194	70.65	630.0	60.32
4/16/09	8	133	31.4	0.069	2.178	0.085	30.87	275.3	58.54
4/23/09	7	140	-85.9	-0.189	1.988	-0.264	-96.43	-859.9	50.78
4/30/09	7	147	2.2	0.005	1.993	0.007	2.51	22.3	48.47
5/7/09	7	154	-140.6	-0.310	1.684	-0.432	-157.73	-1,406.6	39.08
5/14/09	7	161	-106.8	-0.235	1.448	-0.328	-119.84	-1,068.7	32.15
5/21/09	7	168	-194.3	-0.428	1.020	-0.597	-218.01	-1,944.1	21.71
5/28/09	7	175	-80.0	-0.176	0.844	-0.246	-89.74	-800.2	17.24
6/4/09	7	182	6.4	0.014	0.858	0.020	7.15	63.7	16.85
6/11/09	7	189	6.2	0.014	0.872	0.019	6.95	62.0	16.48
6/18/09	7	196	-37.5	-0.083	0.789	-0.115	-42.07	-375.2	14.39
6/25/09	7	203	12.2	0.027	0.816	0.038	13.72	122.4	14.36
7/2/09	7	210	-102.9	-0.227	0.590	-0.316	-115.49	-1,029.9	10.03
7/9/09	7	217	-107.5	-0.237	0.353	-0.331	-120.64	-1,075.9	5.81
7/16/09	7	224	41.1	0.091	0.443	0.126	46.11	411.2	7.07
7/23/09	7	231	347.2	0.765	1.208	1.067	389.62	3,474.5	18.68
7/30/09	7	238	1.0	0.002	1.210	0.003	1.13	10.0	18.16
8/6/09	7	245	144.7	0.319	1.529	0.445	162.37	1,447.9	22.29
8/13/09	7	252	43.3	0.095	1.624	0.133	48.61	433.5	23.02
8/20/09	7	259	-11.2	-0.025	1.600	-0.034	-12.57	-112.1	22.06
8/27/09	7	266	139.5	0.307	1.907	0.429	156.56	1,396.1	25.60
9/3/09	7	273	21.9	0.048	1.955	0.067	24.60	219.4	25.58
9/10/09	7	280	154.5	0.340	2.296	0.475	173.36	1,546.0	29.28
9/17/09	7	287	-12.3	-0.027	2.269	-0.038	-13.83	-123.3	28.22
9/24/09	7	294	26.6	0.059	2.327	0.082	29.84	266.1	28.26
10/1/09	7	301	140.9	0.310	2.637	0.433	158.10	1,409.8	31.28
10/8/09	7	308	139.4	0.307	2.945	0.429	156.47	1,395.4	34.13
10/15/09	7	315	52.9	0.117	3.061	0.163	59.40	529.7	34.69
10/22/09	7	322	35.9	0.079	3.140	0.110	40.26	359.0	34.82
10/29/09	7	329	46.5	0.102	3.243	0.143	52.18	465.3	35.19
11/5/09	7	336	42.9	0.094	3.337	0.132	48.09	428.8	35.45
11/12/09	7	343	223.1	0.491	3.829	0.686	250.36	2,232.6	39.85
11/19/09	7	350	126.7	0.279	4.108	0.389	142.16	1,267.7	41.89
11/24/09	5	355	36.7	0.081	4.189	0.158	57.69	514.4	42.12
12/3/09	9	364	236.1	0.520	4.709	0.565	206.07	1,837.7	46.17
12/10/09	7	371	68.3	0.150	4.859	0.210	76.66	683.7	46.75
		Total Q1	**774.9**	**1.707**	**Average Q1**	**0.261**	**95.31**	**849.9**	
		Total Q2	**-379.0**	**-0.835**	**Average Q2**	**-0.096**	**-34.97**	**-311.8**	
		Total Q3	**646.4**	**1.424**	**Average Q3**	**0.153**	**55.79**	**497.5**	
		Total Q4	**1163.8**	**2.563**	**Average Q4**	**0.266**	**97.19**	**866.7**	

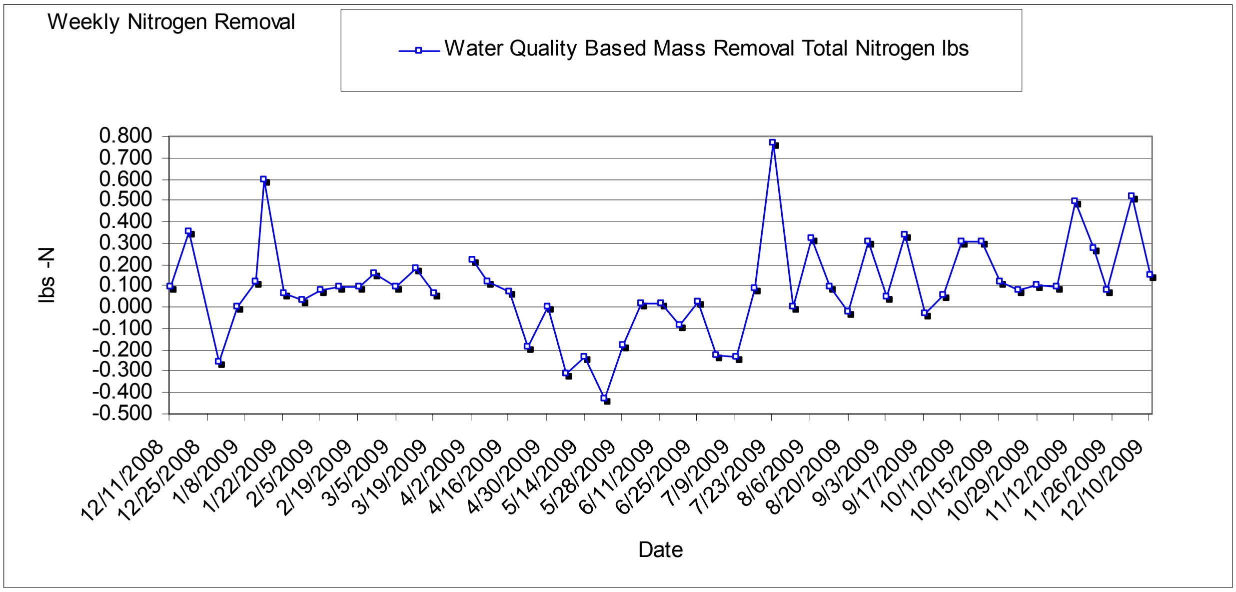


Figure 29: Weekly Water Quality Based Mass Removal Total Nitrogen over Operational Period ATS™ Floway Powell Creek By-Pass Canal

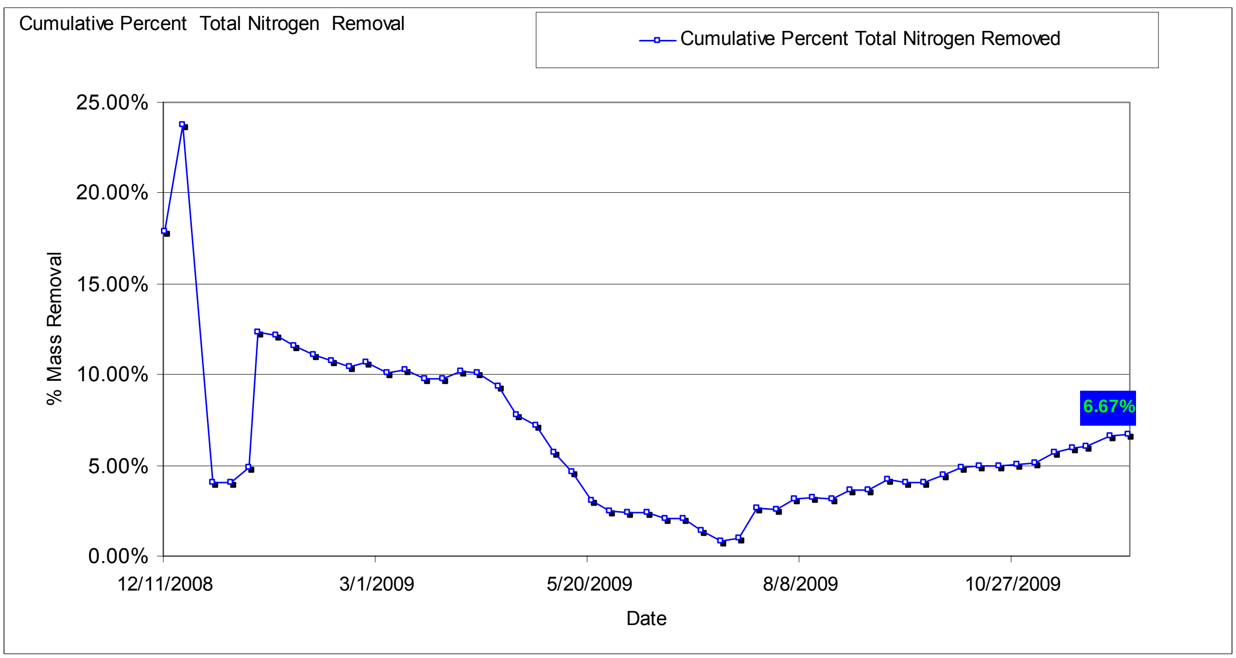


Figure 30: Cumulative Water Quality Based Percent Mass Removal Total Nitrogen over Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 27. Water Quality Based Calculations for Total Nitrogen Percent Mass Removal over the Operational Period

	Influent Total Nitrogen Load lb	Effluent Total Nitrogen Load lb	Total Nitrogen Removed lb	Cumulative Total Nitrogen Removed lb	Percent Total Nitrogen Removed	Cumulative Percent Total Nitrogen Removed
12/11/08	0.53	0.44	0.10	0.10	17.87%	17.87%
12/18/08	1.35	1.00	0.35	0.45	26.05%	23.73%
12/29/08	2.87	3.13	-0.26	0.19	-8.89%	4.02%
1/5/09				0.19		4.02%
1/12/09	1.57	1.46	0.12	0.31	7.43%	4.87%
1/15/09	1.03	0.43	0.60	0.91	58.34%	12.32%
1/22/09	0.58	0.52	0.06	0.97	10.50%	12.19%
1/29/09	0.70	0.67	0.03	1.00	4.86%	11.59%
2/5/09	1.10	1.02	0.08	1.08	7.15%	11.09%
2/12/09	1.20	1.10	0.10	1.18	8.15%	10.77%
2/19/09	1.23	1.14	0.10	1.27	7.71%	10.46%
2/25/09	1.19	1.03	0.16	1.43	13.16%	10.70%
3/5/09	1.77	1.68	0.10	1.53	5.41%	10.08%
3/12/09	1.51	1.33	0.18	1.71	12.08%	10.26%
3/19/09	1.46	1.40	0.06	1.77	4.39%	9.79%
3/26/09				1.77		9.79%
4/2/09	1.50	1.28	0.22	1.99	14.60%	10.15%
4/8/09	1.23	1.11	0.12	2.11	9.65%	10.12%
4/16/09	2.54	2.47	0.07	2.18	2.73%	9.32%
4/23/09	2.19	2.37	-0.19	1.99	-8.66%	7.78%
4/30/09	2.19	2.19	0.00	1.99	0.23%	7.19%
5/7/09	1.79	2.10	-0.31	1.69	-17.28%	5.70%
5/14/09	1.51	1.74	-0.24	1.45	-15.62%	4.67%
5/21/09	1.94	2.37	-0.43	1.02	-22.09%	3.10%
5/28/09	1.19	1.37	-0.18	0.85	-14.75%	2.47%
6/4/09	1.40	1.39	0.01	0.86	1.00%	2.42%
6/11/09	1.29	1.28	0.01	0.87	1.06%	2.37%
6/18/09	1.46	1.54	-0.08	0.79	-5.66%	2.06%
6/25/09	1.34	1.31	0.03	0.82	2.01%	2.06%
7/2/09	1.18	1.41	-0.23	0.59	-19.19%	1.45%
7/9/09	1.28	1.52	-0.24	0.35	-18.48%	0.84%
7/16/09	1.72	1.63	0.09	0.44	5.26%	1.01%
7/23/09	2.06	1.30	0.76	1.21	37.06%	2.63%
7/30/09	1.13	1.13	0.00	1.21	0.19%	2.58%
8/6/09	1.83	1.51	0.32	1.53	17.40%	3.13%
8/13/09	1.56	1.47	0.10	1.63	6.10%	3.22%
8/20/09	0.79	0.81	-0.02	1.60	-3.14%	3.13%
8/27/09	1.14	0.84	0.31	1.91	26.89%	3.64%
9/3/09	0.86	0.81	0.05	1.96	5.63%	3.68%
9/10/09	1.33	0.98	0.34	2.30	25.68%	4.21%
9/17/09	1.24	1.26	-0.03	2.27	-2.20%	4.07%
9/24/09	1.26	1.20	0.06	2.33	4.67%	4.08%
10/1/09	1.74	1.43	0.31	2.64	17.82%	4.49%
10/8/09	1.61	1.30	0.31	2.95	19.11%	4.88%
10/15/09	1.35	1.24	0.12	3.06	8.62%	4.96%
10/22/09	1.21	1.13	0.08	3.14	6.53%	4.99%
10/29/09	1.11	1.01	0.10	3.24	9.19%	5.06%
11/5/09	1.00	0.90	0.09	3.34	9.48%	5.13%
11/12/09	2.08	1.58	0.49	3.83	23.68%	5.70%
11/19/09	1.74	1.46	0.28	4.11	16.00%	5.96%
11/24/09	0.84	0.76	0.08	4.19	9.54%	6.01%
12/3/09	1.56	1.04	0.52	4.71	33.35%	6.61%
12/10/09	1.57	1.42	0.15	4.86	9.69%	6.67%
Total Q1	**16.65**	**14.94**	**1.71**	**% Removed Q1**	**10.26%**	
Total Q2	**20.23**	**21.06**	**-0.83**	**% Removed Q2**	**-4.13%**	
Total Q3	**17.69**	**16.26**	**1.42**	**% Removed Q3**	**8.05%**	
Total Q4	**18.31**	**15.74**	**2.56**	**% Removed Q4**	**14.01%**	

Table 28. Harvest Based Calculations for Total Nitrogen Mass Removal and Areal Removal Rates over the Operational Period

	Days Between Harvest	Cumulative Days	Harvest Based Mass Removal Total Nitrogen gm	Harvest Based Mass Removal Total Nitrogen lbs	Cumulative Harvest Based Mass Removal Total Nitrogen lbs	Harvest Based Areal Removal Rate Total Nitrogen g/m^2-day	Harvest Based Areal Removal Rate Total Nitrogen g/m^2-yr	Harvest Based Areal Removal Rate Total Nitrogen lb/acre-yr	Collective Harvest Based Areal Removal Rate Total Nitrogen g/m^2-yr
12/18/08	34	34	65.4	0.144	0.144	0.041	15.11	134.7	15.11
1/5/09	18	52	101.8	0.224	0.368	0.122	44.41	396.0	25.25
1/12/09	7	59	68.6	0.151	0.519	0.211	76.99	686.6	31.39
1/29/09	17	76	44.1	0.097	0.617	0.056	20.39	181.8	28.93
2/12/09	14	90	148.9	0.328	0.945	0.229	83.55	745.0	37.42
2/25/09	13	103	110.3	0.243	1.187	0.183	66.64	594.3	41.11
3/12/09	15	118	158.0	0.348	1.535	0.227	82.73	737.8	46.40
3/26/09	14	132	159.7	0.352	1.887	0.245	89.60	799.0	50.98
4/2/09	7	139	96.7	0.213	2.100	0.297	108.53	967.8	53.88
4/23/09	21	160	39.3	0.086	2.187	0.040	14.68	131.0	48.74
5/7/09	14	174	40.7	0.090	2.276	0.063	22.82	203.5	46.65
5/21/09	14	188	162.1	0.357	2.633	0.249	90.97	811.3	49.95
6/4/09	14	202	287.3	0.633	3.266	0.442	161.21	1437.6	57.66
6/11/09	7	209	55.6	0.123	3.389	0.171	62.41	556.6	57.82
6/25/09	14	223	122.5	0.270	3.659	0.188	68.75	613.1	58.51
7/9/090	14	237	118.6	0.261	3.920	0.182	66.56	593.5	58.98
7/23/090	14	251	107.6	0.237	4.157	0.165	60.34	538.1	59.06
8/6/09	14	265	180.2	0.397	4.554	0.277	101.10	901.6	61.28
8/13/09	7	272	92.6	0.204	4.758	0.285	103.88	926.3	62.38
8/27/09	14	286	280.4	0.618	5.376	0.431	157.34	1403.1	67.03
9/10/09	14	300	173.6	0.382	5.758	0.267	97.39	868.5	68.44
9/24/09	14	314	143.3	0.316	6.074	0.220	80.41	717.0	68.98
10/8/09	14	328	96.7	0.213	6.287	0.149	54.27	484.0	68.35
10/22/09	14	342	111.4	0.245	6.532	0.171	62.50	557.3	68.11
11/5/09	14	356	219.8	0.484	7.016	0.338	123.29	1099.5	70.28
11/19/09	14	370	112.9	0.249	7.265	0.174	63.33	564.8	70.02
12/10/09	21	391	254.5	0.561	7.825	0.261	95.19	848.8	71.37
		Total Q1	**697.1**	**1.535**	**Average Q1**	**0.153**	**55.69**	**496.6**	
		Total Q2	**841.5**	**1.853**	**Average Q2**	**0.215**	**78.60**	**701.0**	
		Total Q3	**1,075.5**	**2.369**	**Average Q3**	**0.257**	**93.62**	**834.9**	
		Total Q4	**938.6**	**2.067**	**Average Q4**	**0.219**	**79.83**	**711.9**	

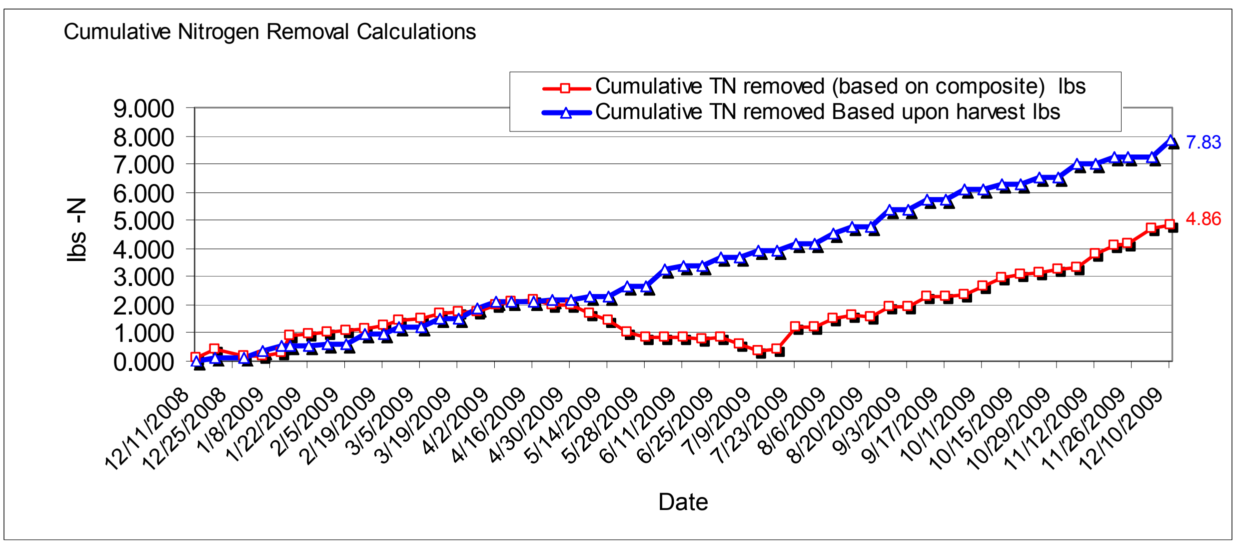


Figure 31: Cumulative Nitrogen Mass Removal Comparison Water Quality Versus Harvest Based over Operational Period ATS™ Floway Powell Creek By-Pass Canal

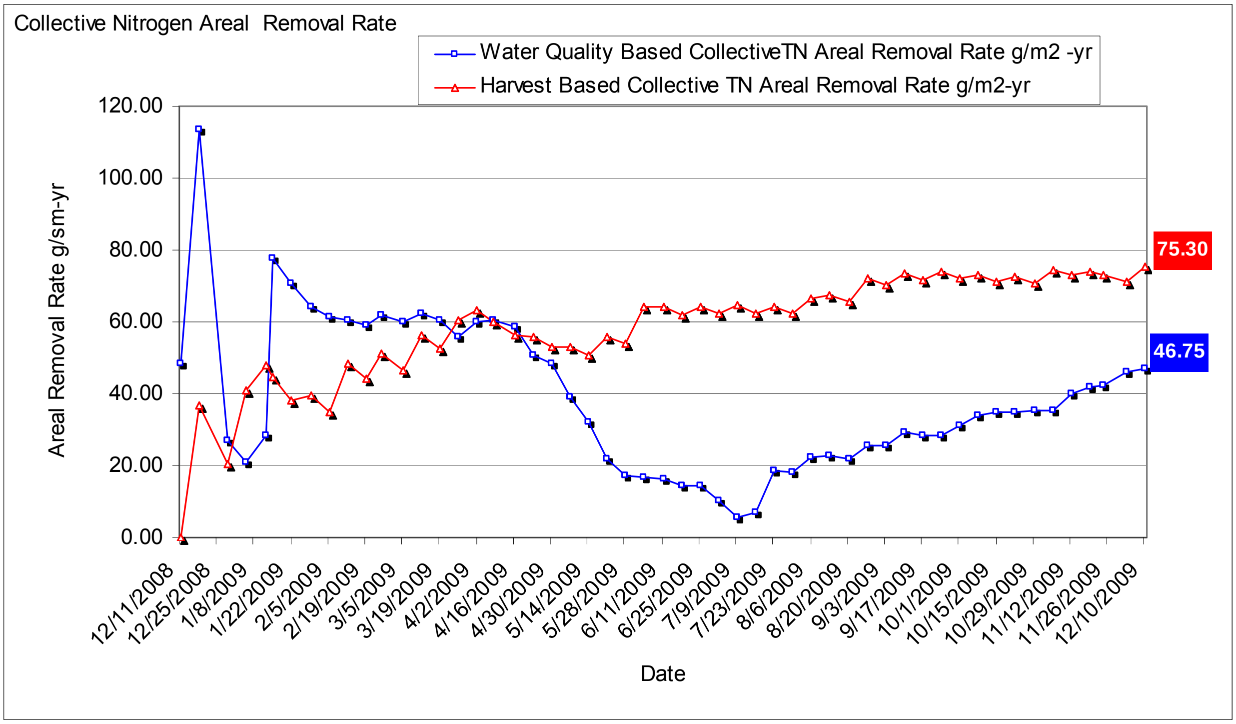


Figure 32: Cumulative Nitrogen Areal Removal Rate Comparison Water Quality Versus Harvest Based over Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 29: Water Quality Based and Harvest Based Calculations for Monthly Total Nitrogen Areal Removals Rates over the Operational Period

Month	Water Quality Based Areal Removal Rate Total Nitrogen g/m^2-month	Harvest Based Areal Removal Rate Total Nitrogen g/m^2-month
Dec-08	1.68	2.14
Jan-09	10.24	3.13
Feb-09	4.34	5.78
Mar-09	3.92	7.31
Apr-09	0.32	3.14
May-09	-12.43	4.83
Jun-09	-2.13	8.59
Jul-09	6.71	5.39
Aug-09	7.54	10.54
Sep-09	6.12	7.31
Oct-09	6.55	4.96
Nov-09	10.66	7.67
Dec-09	20.31	8.08

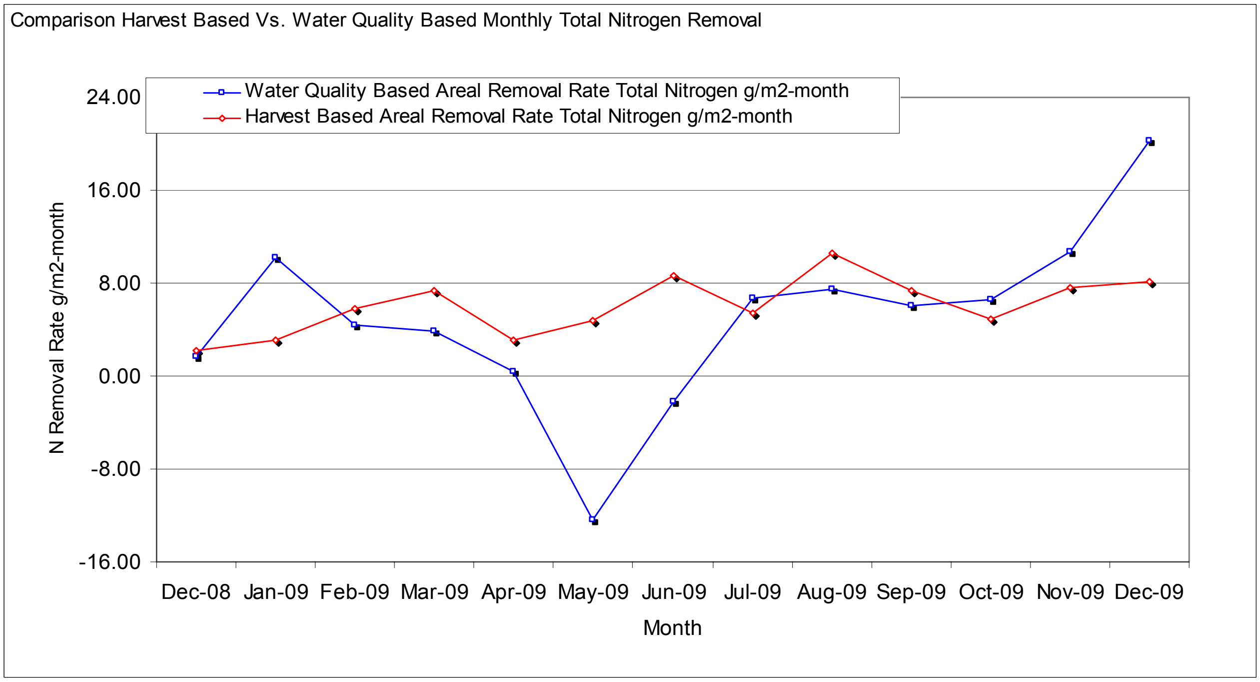


Figure 33: Comparative Collective Areal Removal Rates for Nitrogen over Operational Period Based upon Water Quality and Harvest Calculations ATS™ Floway Powell Creek By-Pass Canal

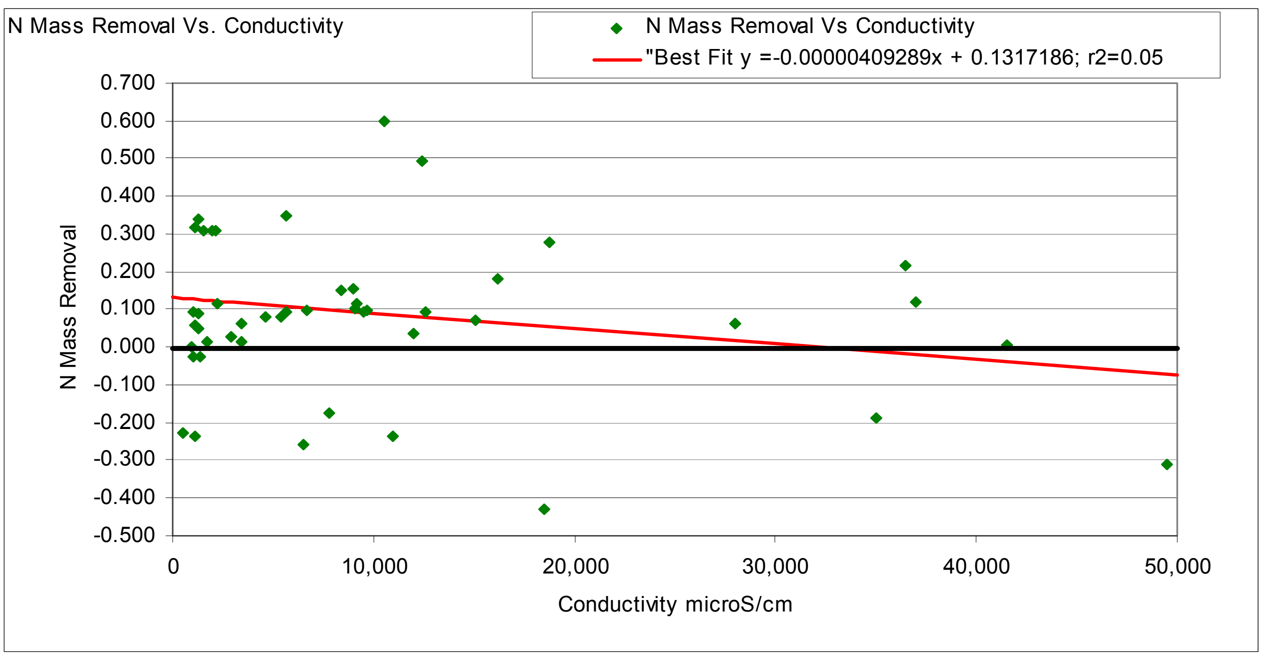


Figure 34: Linear Regression Analysis Conductivity Versus Total Nitrogen Mass Removal over Operational Period ATS™ Floway Powell Creek By-Pass Canal

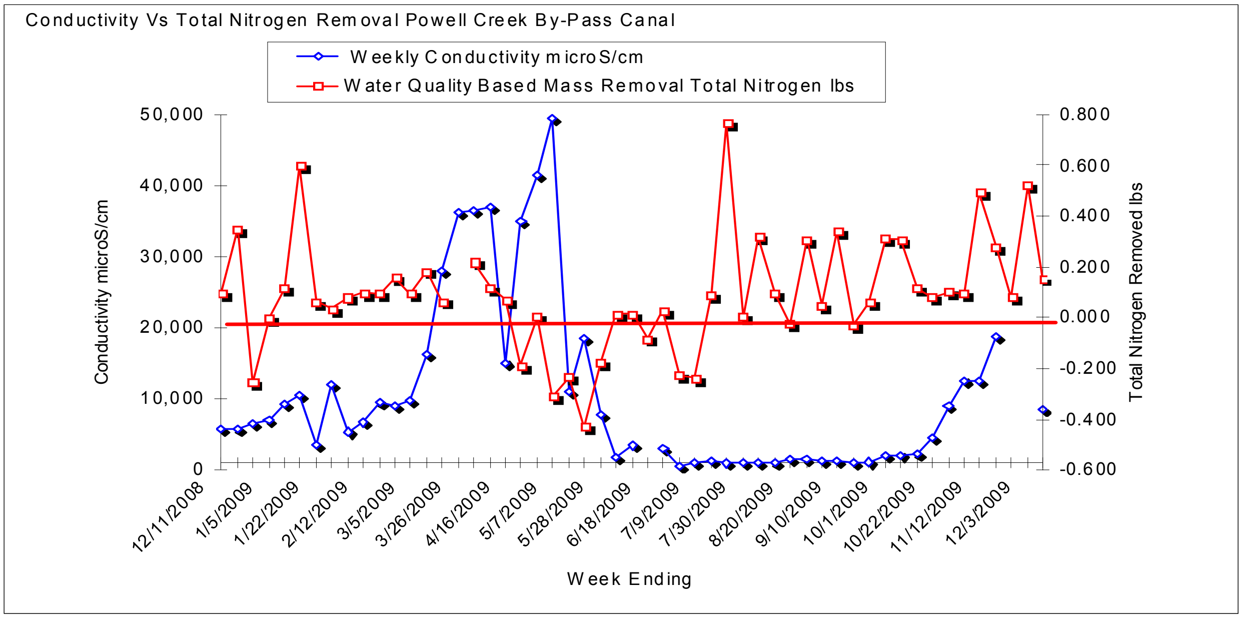


Figure 35: Weekly Average Conductivity Versus Total Nitrogen Mass Removal over Operational Period ATS™ Floway Powell Creek By-Pass Canal

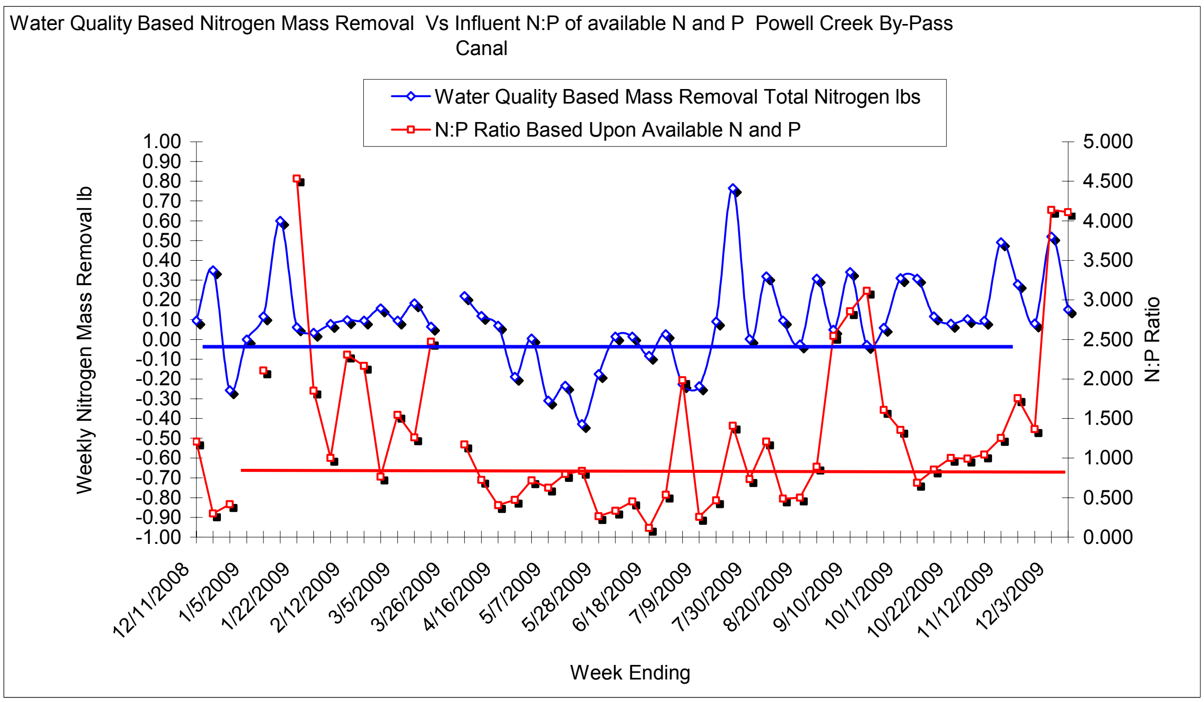


Figure 36: Weekly Nitrogen Mass Removal Based upon Water Quality Compared to N:P Ratio based upon available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

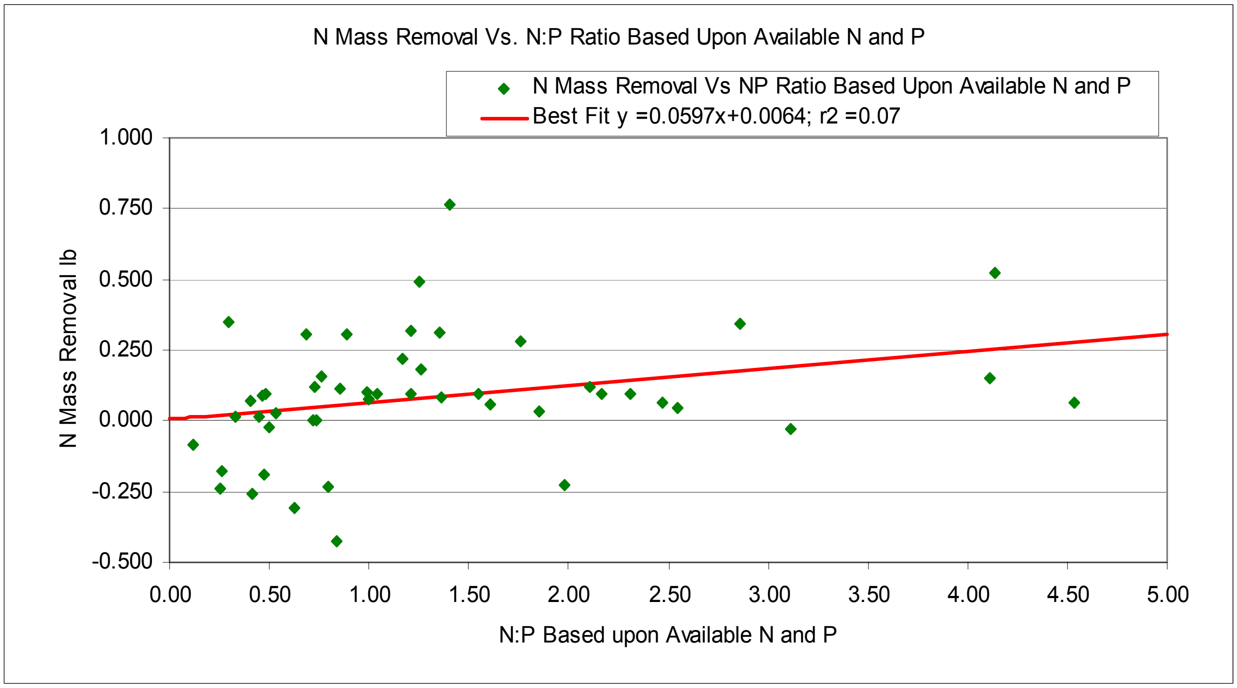


Figure 37: Water Quality Based Total Nitrogen Mass Removal Versus N:P Ratio Based upon Available N and P over Operational Period ATS™ Floway Powell Creek By-Pass Canal

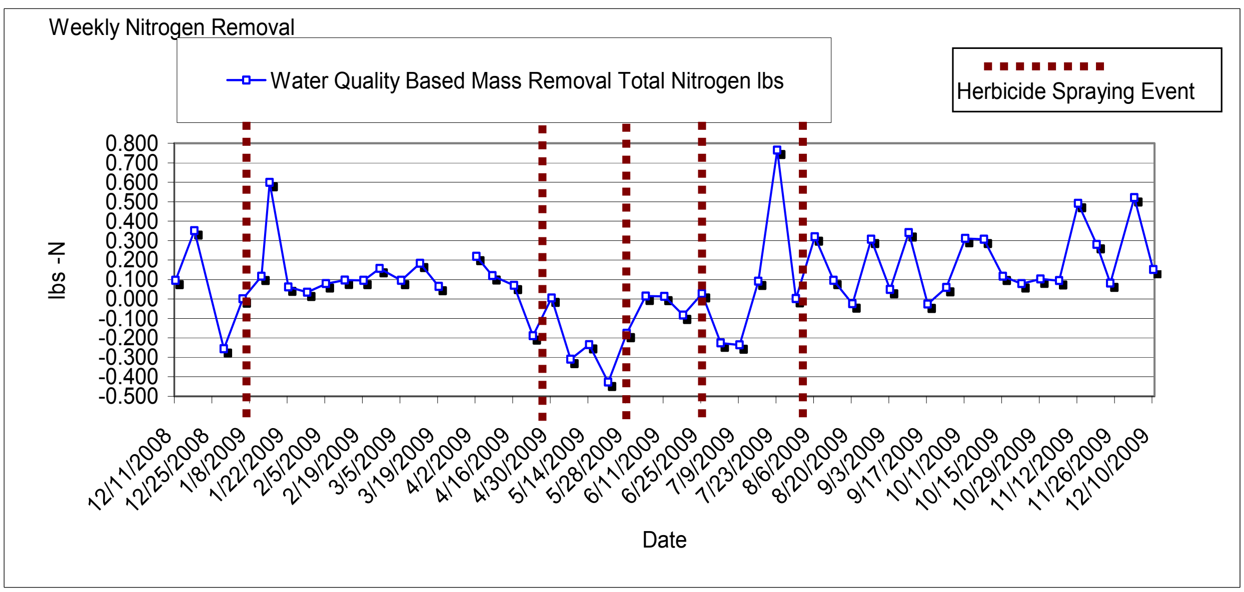


Figure 38: Water Quality Based Total Nitrogen Mass Removal Versus Herbicide Spraying Schedule over Operational Period ATS™ Floway Powell Creek By-Pass Canal

ALGAL TURF GROWTH AND PRODUCTION DYNAMICS

Assessment of Net Community Production

Material harvested from an ATS™ consists not only of algae tissue, but tissue of subsidiary organisms, such as protists, macroinvertebrates, and insect larvae. In addition, included with the harvest are any residual organic detritus, and inorganic materials, such as precipitated salts and settled silts and sand. The harvest then is an agglomeration of net productivity and inorganic and organic residuals. The principal driving reaction associated with this diverse accumulation is photosynthesis associated with photoautotrophic organisms—largely algae and to some extent bacteria, including *Cyanobacteria*.

The harvest then may be viewed as net community production, and contained within the harvest is a sizable amount of nitrogen and phosphorus. Most of this nitrogen and phosphorus is the result of direct uptake from the water source by the photoautotrophic (primary production) community, although some may be associated with precipitation, settling and atmospheric fixation in the case of nitrogen. When such uptake occurs, a portion of the incoming nitrogen and phosphorus mass associated with the water source is removed and sequestered as a readily harvested form, known as algal turf.

The net community productivity can be determined with each harvest as the dry mass removed divided by the number of days since the previous harvest. If this production is divided by the process area harvested, then the net community production is expressed as dry weight per unit area per day. This value represents the mean production over the harvest period. Therefore:

$P_{NC} = (454sH)/(A\ t)$

Where P_{NC} = Net Community Production as dry weight in grams per square meter per day (g/m^2-day).

H = mass of phosphorus removed through harvesting in lbs

s = percent solids of wet harvest

A = Process Area in m^2

t = days since last harvest

While this is a rather straightforward and reliable method of assessing net community productivity, it is qualified by the assumption that the algal turf mass at the beginning of the harvest period—the harvest period being the period in days between harvests—and the algal turf mass immediately after the harvest are equal. In other words the calculation is based upon the assumption that there is no net storage gain of algal turf mass on the floway.

Considering this, the calculated net community production over the operational period is noted in Table 30 and Figure 39. Productivity for the operational period for the total floway length averaged 11.05 g/m^2-day, with the production being only slightly higher from 0-250 ft down the floway (11.75 g/m^2-day) when compared to 250-500 ft (10.67 g/m^2-day). The production for the total floway was lowest during Q2, averaging 9.50 g/m^2-day. However, a wide disparity between 0-250 ft (13.34 g/m^2-day) and 250-500 ft (6.60 g/m^2-day) was observed during Q2. The lowest productivity was noted during the period from April 2-23, 2009 (2.16 g/m^2-day). This is the same period noted previously as having comparatively poor system performance.

During Q4, a period in which temperatures and nutrient concentrations were lower than Q3, productivity for the total floway was the highest of any quarter at an average 13.31 g/m^2-day. As noted in the Powell Creek Basis of Design Report, net productivity in Q4 is projected to be lower than peak productivity levels in Q2 and Q3. This increase in net productivity in Q4 indicates that the algal turf community may not yet have fully matured and thus the system may not have yet achieved optimal performance.

Interestingly, during Q4, unlike any other quarterly period, the productivity was higher from 250-500 ft (17.63 g/m^2-day) than for 0-250 ft (8.99 g/m^2-day). It is not clear why this reversal was observed. It was noted that during Q4, there was a discernible difference in the algal turf community, with filamentous green algae more prevalent from 250-500 ft. This pattern would suggest the possibility that some type of inhibitory influence within the incoming flow is attenuated as the flow moves down the system. It is also possible that chemical and biological changes down the system resulted in improved availability of a critical nutrient(s). This could include the fixation of nitrogen or enzymatic action upon organic compounds containing bound nutrients.

Assessment of Specific Growth Rate

The specific growth rate (**μ**) expressed as time^{-1}, represents the fraction increase in the mass of any standing crop over time. It should not be mistaken with productivity, because it does not imply any specific mass—it is simply a rate function. The specific growth rate relates to work completed by Michaelis and Menten[12] and expanded upon by Monod[13]. While typically applied to the rate of enzymatic reactions or to the growth of a single species, engineering practitioners have applied the concept of specific growth rate to working communities, such as activated sludges, fixed films, or fermentation reactions. The value of any specific growth rate is typically a function of temperature, the genetic capabilities of the target organism or community, and the relative abundance of one or more controlling factors, e.g. nutrient concentration.

Over any period of time, therefore the biomass of any targeted biological entity may be expressed as:

$$Z_t = Z_0 e^{\mu t}$$

Where Z_t = dry biomass at time t
Z_0 = Initial dry biomass at time zero
μ = specific growth rate 1/t

Solving for specific growth rate therefore:

$$\mu = [\ln(Z_t / Z_0)]/t$$

It is easy to see how specific growth rate relates to productivity as:

$$P_{NC} = (454sH)/(A\ t)$$

noting that sH = dry harvest = $Z_t - Z_0 = Z_0(e^{\mu t}-1)$

then when Z is in pounds,

$$P_{NC} = \{454\ [Z_0(e^{\mu t}-1)]\}/(At)$$

Development of equations for **μ** is discussed further in Section 4 - ATSDEM Modeling. Harvest data can be applied to the specific growth rate equation to estimate field specific growth rates. The growth rates as calculated are noted in Table 31 and Figure 40. In calculating these rates, it is necessary to assume an initial standing crop, as it is very difficult to measure standing crop remaining on the floway after harvest. It is assumed that harvesting results in 90% removal and that the initial standing crop for the next harvest period is 11.1% of the harvest—remembering that the harvest represents only 90% of the standing crop before harvest.

Assessment of Average Standing Crop

As can be seen by comparing Table 29 and 30 a higher specific growth rate does not necessarily correlate with higher productivity. Productivity is significantly dependent upon initial standing crop, and the time between harvests.

If the specific growth rate were to remain constant with increasing standing crop, then it would be advisable to harvest infrequently, and let the standing crop grow exponentially. Obviously this is not practical, for as the turf community grows, it also begins to slough tissue, and to accumulate non-productive, necrotic tissue. Therefore, while it may appear the standing crop is high, the viable crop

[12] Michaelis, L. and M. L. Menten,(1913) *Biochem.Z.*,**49**, 333
[13] Monod, J. (1942) *Recherches sur la Croissance ds Cultures Bacteriennes,* Herman et Cie, Paris

component may be comparatively small. At some point then, the system begins to approach senescence, when tissue and nutrient loss is greater than tissue production and nutrient uptake. Consequently the specific growth rate will fluctuate, and generally decline, at some critical standing crop density. With each community then there is a range of standing crop densities in which the specific growth rate remains comparatively constant, and there is consequently an upper limit in standing crop density above which nutrient removal efficiency begins to decline significantly.

In modeling the dynamics of an ATS™ floway, it is important that the range of effective standing crop densities be identified during pilot studies. A convenient and reasonable approach is to identify an average standing crop over the period between harvests. This average standing crop is calculated as:

$$Z_{ave} = \left(\sum_{t=0}^{t=h} Z_0 e^{\mu t} \right) \Big/ h$$

The average standing crop densities calculated for each harvesting event over the operational period are shown in Table 32 and Figure 41. The average standing crop for the operational period is calculated as 58.92 g/m^2, based upon the assumption as stated previously, that during harvest 90% of the biomass is removed. The lowest average standing crops are noted for Q1 and Q2 (47.64 g/m^2 and 50.84 g/m^2, respectively), with the highest being during Q4 (80.36 g/m^2). As with the other critical parameters as reviewed in this section, there is noted a substantial decline in average standing crop value during April-May, 2009.

Table 30: Net Community Production over the Operational Period

		0-250 ft		250-500 ft		Total Floway	
Date of Harvest	Days Between Harvests	dry harvest lbs	Net Community Productivity g/m^2 day	dry harvest lbs	Net Community Productivity g/m^2-day	dry harvest lbs	Net Community Productivity g/m^2-day
12/18/2008	34	5.20	2.99	4.34	2.50	9.54	2.74
1/5/2009	18	5.10	5.54	20.01	21.72	25.11	13.63
1/12/2009	7	6.91	19.30	5.91	16.50	12.83	17.90
1/29/2009	17	5.06	5.82	2.47	2.83	7.53	4.33
2/12/2009	14	11.78	16.44	4.08	5.70	15.86	11.07
2/25/2009	13	8.57	12.87	3.21	4.83	11.78	8.85
3/12/2009	15	7.00	9.12	8.28	10.79	15.28	9.96
3/26/2009	14	11.85	16.54	4.38	6.11	16.23	11.32
4/2/2009	7	6.22	17.38	4.67	13.03	10.89	15.20
4/23/2009	21	1.25	1.16	3.38	3.15	4.63	2.15
5/7/2009	14	3.37	4.70	0.19	0.27	3.56	2.48
5/21/2009	14	9.56	13.34	7.79	10.87	17.34	12.10
6/4/2009	14	19.36	27.03	4.42	6.17	23.79	16.60
6/11/2009	7	4.73	13.20			4.73	6.60
6/25/2009	14	5.12	7.15	4.62	4.30	9.74	6.80
7/9/090	14	6.28	8.77	6.43	8.98	12.71	8.87
7/23/090	14	8.08	11.27	3.46	4.84	11.54	8.05
8/6/2009	14	12.56	17.53	4.26	5.94	16.82	11.73
8/13/2009	7	5.32	14.85	3.70	10.32	9.02	12.58
8/27/2009	14	14.66	20.46	13.14	18.34	27.80	19.40
9/10/2009	14	12.86	17.96	10.35	14.45	23.21	16.20
9/24/2009	14	7.83	10.93	12.35	17.24	20.18	14.09
10/8/2009	14	8.17	11.40	10.34	14.44	18.51	12.92
10/22/2009	14	8.37	11.68	16.33	22.79	24.70	17.24
11/5/2009	14	3.93	5.48	20.69	28.88	24.62	17.18
11/19/2009	14	3.36	4.69	9.08	12.68	12.44	8.68
12/10/2009	21	10.51	9.78	10.52	9.79	21.03	9.79
Totals		**213.02**		**198.41**		**411.43**	
Averages		**7.89**	**11.75**	**7.63**	**10.67**	**15.24**	**11.05**
Standard Deviation		**4.02**	**6.12**	**5.32**	**7.12**	**6.88**	**4.89**
Total Q1		**49.62**		**48.31**		**97.93**	
Total Q2		**56.34**		**24.83**		**81.17**	
Total Q3		**64.88**		**45.96**		**110.84**	
Total Q4		**42.17**		**79.32**		**121.49**	
Average Q1			**10.30**		**9.27**		**9.78**
Average Q2			**13.34**		**6.60**		**9.50**
Average Q3			**14.00**		**9.59**		**11.95**
Average Q4			**8.99**		**17.63**		**13.31**

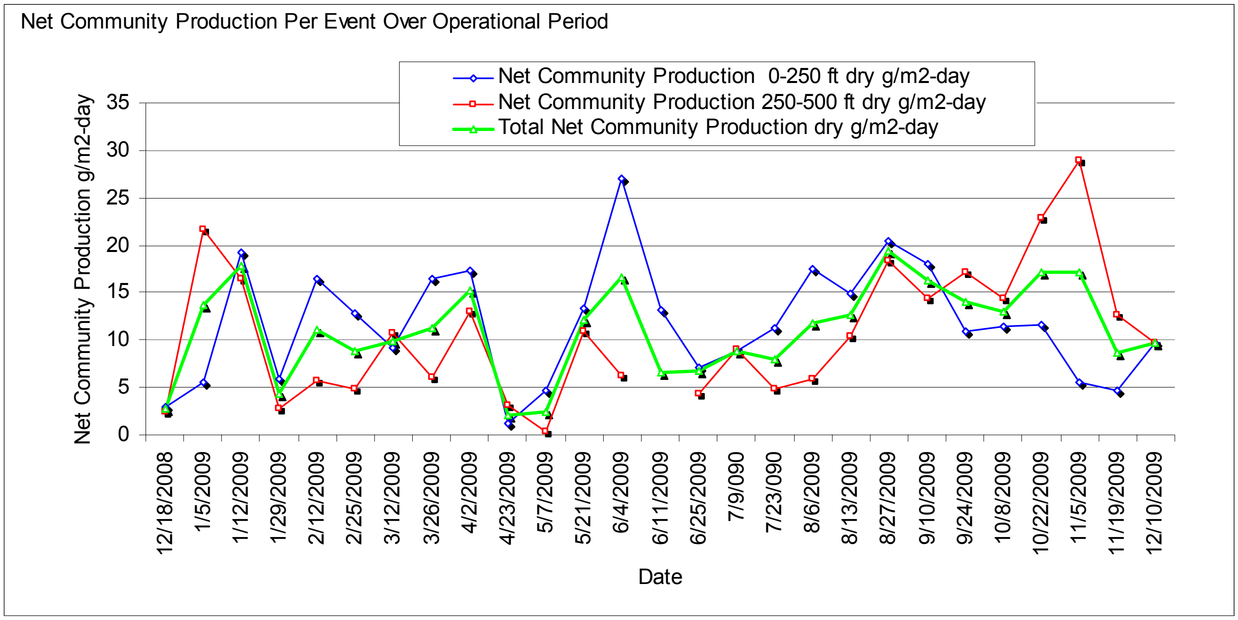


Figure 39: Net Community Production over Operational Period ATS™ Floway Powell Creek By-Pass Canal

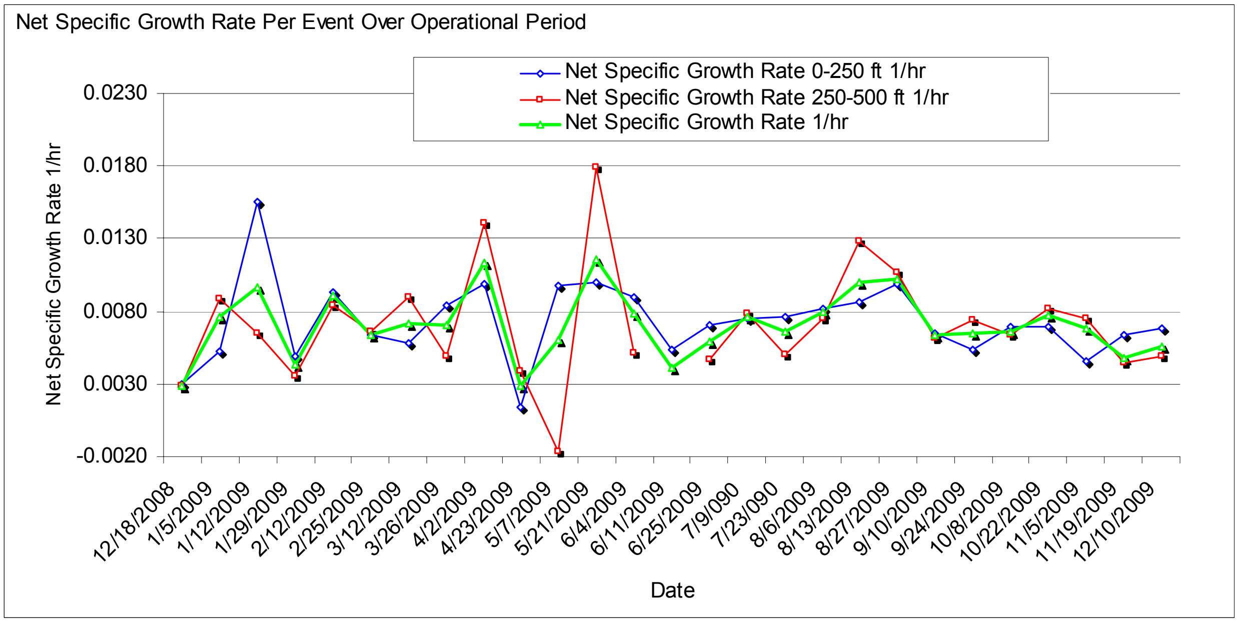


Figure 40: Net Specific Growth Rate over Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 31: Net Specific Growth Rate over the Operational Period

Date of Harvest	Days Between Harvests	0-250 ft Initial Standing Crop dry lbs	0-250 ft Standing Crop at Harvest lbs	0-250 ft Specific Growth Rate 1/hr	250-500 ft Initial Standing Crop dry lbs	250-500 ft Standing Crop at Harvest lbs	250-500 ft Specific Growth Rate 1/hr	Total Floway Initial Standing Crop dry lbs	Total Floway Standing Crop at Harvest lbs	Total Floway Specific Growth Rate 1/hr
12/18/2008	34	0.58	5.78	0.0028	0.48	4.83	0.0028	1.06	10.60	0.0028
1/5/2009	18	0.58	5.67	0.0053	0.48	22.23	0.0089	1.06	27.90	0.0076
1/12/2009	7	0.57	7.68	0.0155	2.22	6.57	0.0064	2.79	14.25	0.0097
1/29/2009	17	0.77	5.62	0.0049	0.66	2.74	0.0035	1.43	8.36	0.0043
2/12/2009	14	0.56	13.09	0.0094	0.27	4.54	0.0084	0.84	17.63	0.0091
2/25/2009	13	1.31	9.52	0.0064	0.45	3.57	0.0066	1.76	13.09	0.0064
3/12/2009	15	0.95	7.78	0.0058	0.36	9.20	0.0090	1.31	16.98	0.0071
3/26/2009	14	0.78	13.17	0.0084	0.92	4.86	0.0050	1.70	18.03	0.0070
4/2/2009	7	1.32	6.92	0.0099	0.49	5.19	0.0141	1.80	12.10	0.0113
4/23/2009	21	0.69	1.39	0.0014	0.52	3.76	0.0039	1.21	5.14	0.0029
5/7/2009	14	0.14	3.74	0.0098	0.38	0.21	-0.0017	0.51	3.95	0.0061
5/21/2009	14	0.37	10.62	0.0100	0.02	8.65	0.0179	0.40	19.27	0.0116
6/4/2009	14	1.06	21.52	0.0090	0.87	4.92	0.0052	1.93	26.43	0.0078
6/11/2009	7	2.15	5.26	0.0053	0.49			2.64	5.26	0.0041
6/25/2009	14	0.53	5.69	0.0071	0.49	5.13	0.0047	0.53	10.83	0.0059
7/9/090	14	0.57	6.98	0.0075	0.51	7.15	0.0078	1.08	14.13	0.0076
7/23/090	14	0.70	8.97	0.0076	0.71	3.85	0.0050	1.41	12.82	0.0066
8/6/2009	14	0.90	13.95	0.0082	0.38	4.73	0.0075	1.28	18.68	0.0080
8/13/2009	7	1.40	5.91	0.0086	0.47	4.11	0.0129	1.87	10.02	0.0100
8/27/2009	14	0.59	16.28	0.0099	0.41	14.60	0.0106	1.00	30.89	0.0102
9/10/2009	14	1.63	14.29	0.0065	1.46	11.50	0.0061	3.09	25.79	0.0063
9/24/2009	14	1.43	8.70	0.0054	1.15	13.72	0.0074	2.58	22.43	0.0064
10/8/2009	14	0.87	9.08	0.0070	1.37	11.49	0.0063	2.24	20.57	0.0066
10/22/2009	14	0.91	9.30	0.0069	1.15	18.14	0.0082	2.06	27.44	0.0077
11/5/2009	14	0.93	4.37	0.0046	1.81	22.99	0.0076	2.74	27.35	0.0068
11/19/2009	14	0.44	3.73	0.0064	2.30	10.09	0.0044	2.74	13.82	0.0048
12/10/2009	21	0.37	11.68	0.0068	1.01	11.69	0.0049	1.38	23.37	0.0056
Average		**0.85**	**8.77**	**0.0073**	**0.81**	**8.48**	**0.0071**	**1.65**	**16.93**	**0.0071**
Standard Deviation		**0.45**	**4.47**	**0.0027**	**0.58**	**5.91**	**0.0039**	**0.76**	**7.65**	**0.0023**
Average Q1		**0.76**	**7.88**	**0.0072**	**0.70**	**7.67**	**0.0065**	**1.46**	**15.54**	**0.0067**
Average Q2		**0.93**	**8.94**	**0.0077**	**0.53**	**4.60**	**0.0074**	**1.46**	**12.88**	**0.0073**
Average Q3		**0.97**	**10.10**	**0.0076**	**0.70**	**8.10**	**0.0077**	**1.61**	**18.20**	**0.0076**
Average Q4		**0.70**	**7.63**	**0.0063**	**1.53**	**14.88**	**0.0063**	**2.23**	**22.51**	**0.0063**

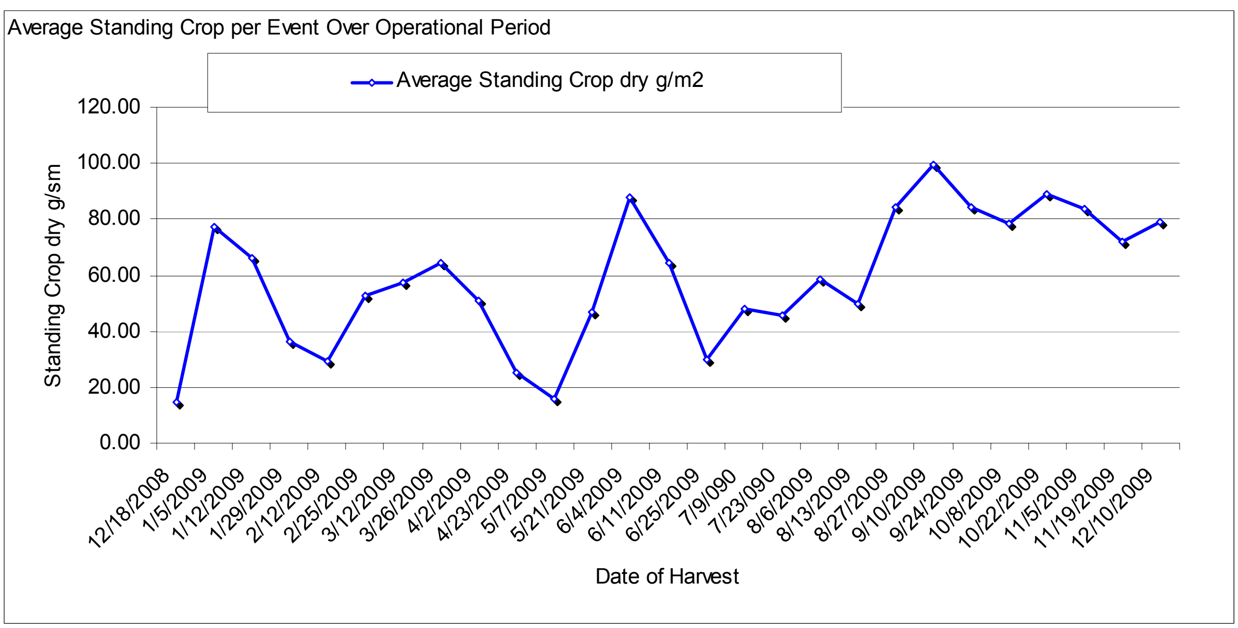


Figure 41: Average Standing Crop over Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 32: Average Standing Crop over the Operational Period

Date of Harvest	Days Between Harvests	Average Standing Crop dry g/m ^{2}
12/18/2008	34	14.61
1/5/2009	18	77.25
1/12/2009	7	66.00
1/29/2009	17	36.29
2/12/2009	14	29.43
2/25/2009	13	52.65
3/12/2009	15	57.27
3/26/2009	14	64.66
4/2/2009	7	51.20
4/23/2009	21	25.07
5/7/2009	14	15.70
5/21/2009	14	46.90
6/4/2009	14	87.91
6/11/2009	7	64.43
6/25/2009	14	30.05
7/9/090	14	47.71
7/23/090	14	45.49
8/6/2009	14	58.82
8/13/2009	7	49.53
8/27/2009	14	84.21
9/10/2009	14	99.41
9/24/2009	14	84.43
10/8/2009	14	78.18
10/22/2009	14	88.92
11/5/2009	14	83.96
11/19/2009	14	71.83
12/10/2009	21	78.90
Average		**58.92**
Standard Deviation		**23.63**
Average Q1		**47.64**
Average Q2		**50.84**
Average Q3		**62.46**
Average Q4		**80.36**

SECTION 4. ATSDEM MODELING

INTRODUCTION

When field data is applied in the model set-up, the modeling effort can facilitate refinement of critical input parameters, and subsequent comparison of actual to projected performance. Once the model is calibrated and verified with existing data, it can then serve to make reasonable performance and sizing projections of a proposed large scale, commercial level, facility. The model used is based upon the first order growth kinetics, arranged specifically for the ATS™ process. The model named ATSDEM was developed by HydroMentia. It can serve both as a design and operational model. Derivation of the algorithms associated with ATSDEM is presented in Appendix F.

The critical model parameters established during the modeling efforts include:

1. Best-fit relationship between tissue nitrogen and phosphorus levels and nitrogen and phosphorus water concentrations.
2. Average standing crop specifically applicable to the pilot study
3. Maximum Net Growth Rate (μ_{max}) (1/hr) for the Turf Community applicable to the specific field conditions encountered.
4. V'ant Hoff Arrhenius coefficient theta (θ) applied in establishing the relationship between growth rate and water temperature.

5. Water temperature when growth rate is highest for the other conditions given.
6. Half rate concentration of total phosphorus (K_{sp})--i.e. the concentration at which the net growth rate is half of the maximum net growth rate.
7. Half rate linear for linear hydraulic loading rate (LHLR) (K_{sh}).

MODEL SET-UP

At the end of Q1-Q2, the data collected through 6/11/09 was used to estimate initial modeling parameters, and to calibrate and verify the model based upon the Q1-Q2 data set. This assessment was done as part of the Q2 Report[14] . The Q1-Q2 modeling was conducted on each week's data. The parameters developed during the entire operational period are noted in Table 32. The modeling effort included in this final report has been refined, with the discreet model runs applied to individual harvesting events. The critical parameters developed to this latest modeling are also noted in Table 32. These values are somewhat more conservative than those developed from Q1-Q2 modeling.

Equations for projecting nitrogen and phosphorus tissue values were developed from linear regression analysis. The equations and the associated plots are shown in Figures 42 and 43. Note that there is a weak correlation between tissue phosphorus and phosphorus concentration (r^2= 0.07). The fit between nitrogen tissue levels and phosphorus concentration was better (r^2=0.22), and was also better than the correlation between nitrogen tissue content and nitrogen concentration (r^2 = 0.02). A number of possible linear correlations were examined regarding nutrient tissue levels. The results of the regression analyses are presented in Table 33

Modeling harvest periods allows the model set-up to include the same initial standing crop as that applied to field conditions, and to consider average water quality and flow conditions during each period. This approach facilitates a meaningful, direct comparison of projected and actual performance. Shown in Table 34 is the model set-up for each harvest event. The input data represents averages of weekly data over each harvest event. Table 35 is a typical ATSDEM modeling summary spreadsheet.

Table 32: Model Calibrated Critical Model Parameters

Parameter	Description	Q1-Q2 Values	Q1-Q4Adjusted Values
K_{sp}	Half Rate Concentration of total phosphorus	25 µg/L	75 µg/L
K_{sh}	Half Rate Value of Linear Hydraulic Loading Rate	20.0 gpm/lf	30.0 gpm/lf
μ_{max}	Maximum net growth rate potential of Algal Turf Community	0.040/hr	0.038/hr
Θ	V'ant Hoff Arrhenius Coefficient	1.05	1.10
T_{opt}	Optimal Temperature	30.0 ° C	30.0 ° C
Tissue P	Percent dry weight Tissue Phosphorus Levels	$1.79 \times 10^{-5}P + 4.13 \times 10^{-3}$ where P is total phosphorus concentration in µg/L	$7.41 \times 10^{-6}P + 4.71 \times 10^{-3}$ where P is total phosphorus concentration in µg/L
Tissue N	Percent dry weight Tissue Nitrogen Levels	1.83%	$3.89 \times 10^{-5}P + 0.0149$
Z_{ave}	Maximum Average Standing Crop over Harvest Period	(Q1 and Q2) 50.33 g/m^2	Q1 47.64 g/m^2 Q2 50.84 g/m^2 Q3 62.46 g/m^2 Q4 80.36 g/m^2

[14] Powell Creek Algal Turf Scrubber® Pilot Quarterly Operational Report; Dec 11, 2008 through June 11, 2009. August 13, 2009. Prepared for Lee County, Florida by HydroMentia, Inc. of Ocala, Fl.

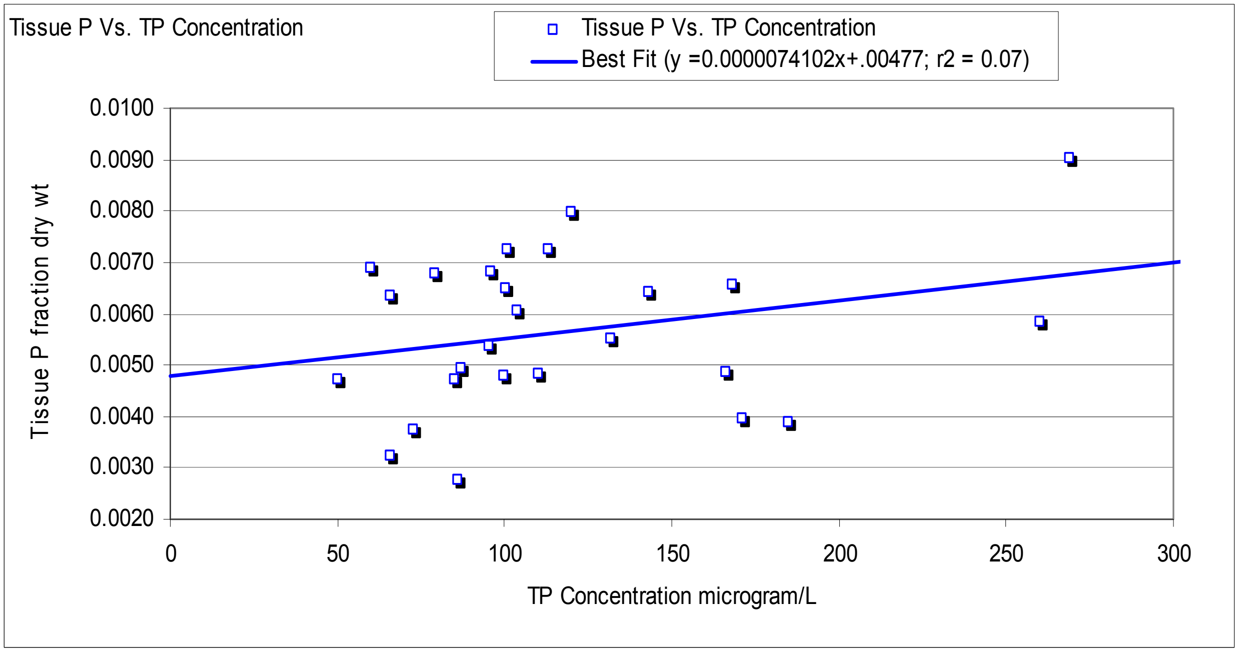


Figure 42: Total Phosphorus Concentration Versus Fraction Tissue Phosphorus Operational Period ATS™ Floway Powell Creek By-Pass Canal

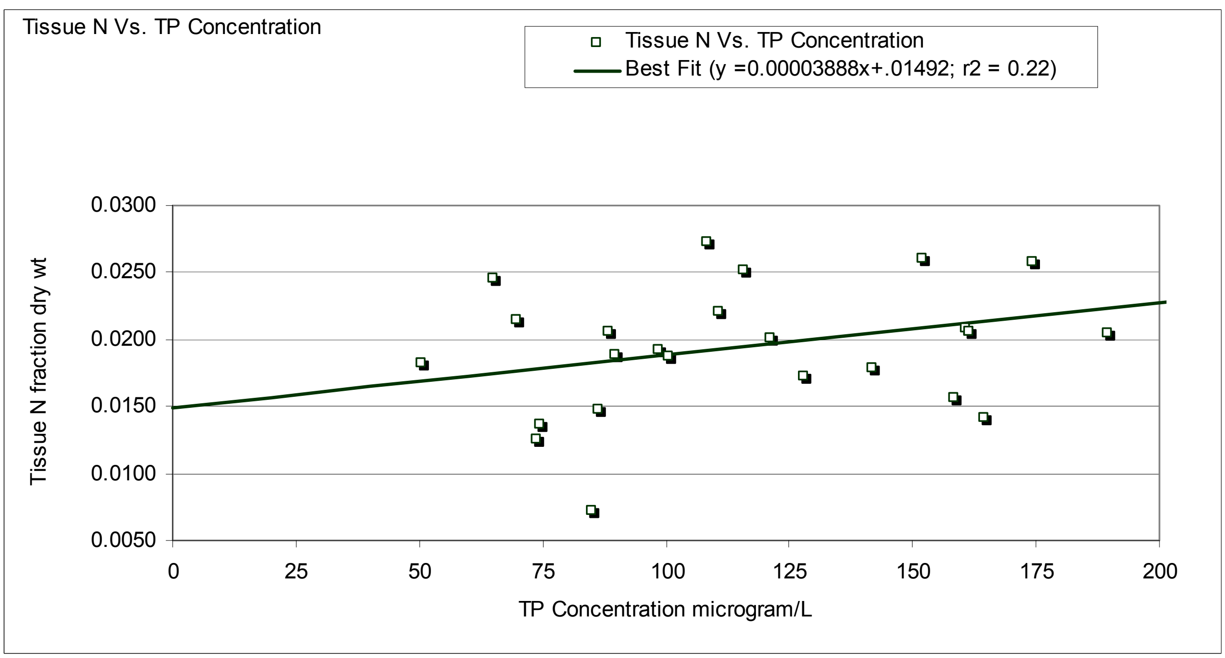


Figure 43: Total Phosphorus Concentration Versus Fraction Tissue Nitrogen Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 33: Summary Linear Regression Analysis Related to Tissue Nutrient Levels

X	Y	a	B	r^2
TP Concentration µg/L	Fraction Tissue P	7.41×10^{-6}	4.79×10^{-3}	0.07
Conductivity µS/cm	Fraction Tissue P	1.83×10^{-8}	5.49×10^{-3}	0.04
Available N:P	Fraction Tissue P	5.36×10^{-4}	5.11×10^{-3}	0.06
TN Concentration mg/L	Fraction Tissue P	2.86×10^{-3}	3.07×10^{-3}	0.05
TN Concentration mg/L	Fraction Tissue N	5.86×10^{-3}	1.45×10^{-2}	0.02
TP Concentration µg/L	Fraction Tissue N	3.89×10^{-5}	1.49×10^{-2}	0.22
Conductivity µS/cm	Fraction Tissue N	-1.30×10^{-7}	1.92×10^{-2}	0.01
Available N:P	Fraction Tissue N	5.64×10^{-4}	2.02×10^{-2}	0.06

Table 34: ATSDEM Model Set-Up Data for Full Operational Period

Date	Days Between Harvest	Influent Flow MGD	Effluent Flow MGD	Influent T ° C	Influent TP Load lb	Effluent TP Load lb	Removed TP Load lb	Influent TP µg/L	Effluent TP µg/L	TP Areal Removal Rate g/m^2 yr	Influent N Load lb	Effluent TN Load lb	Removed N Load lb	Influent TN mg/L	Effluent TN mg/L	TN Areal Removal Rate g/m^2 yr
12/18/2008	34	0.029	0.029	22.09	0.377	0.175	0.202	110	51	21.15	1.884	1.439	0.445	0.55	0.42	113.40
1/5/2009	18	0.025	0.025	23.80	0.356	0.209	0.147	95	56	29.04	2.875	3.131	-0.257	1.26	1.38	-50.87
1/12/2009	7	0.025	0.025	22.23	0.151	0.121	0.030	105	84	15.46	1.574	1.457	0.117	1.10	1.02	59.58
1/29/2009	17	0.012	0.012	15.09	0.307	0.134	0.173	179	78	36.30	2.311	1.616	0.694	1.35	0.94	145.68
2/12/2009	14	0.027	0.027	14.91	0.165	0.112	0.054	53	36	13.69	2.296	2.119	0.176	0.73	0.68	44.85
2/25/2009	13	0.023	0.023	20.07	0.193	0.140	0.053	77	56	14.59	2.422	2.170	0.252	0.96	0.86	69.16
3/12/2009	15	0.027	0.027	20.76	0.255	0.192	0.063	76	58	14.99	3.286	3.008	0.279	0.98	0.90	66.27
3/26/2009	14	0.026	0.026	22.27	0.144	0.092	0.052	96	61	26.62	1.462	1.398	0.064	0.97	0.93	16.34
4/2/2009	7	0.023	0.023	22.31	0.182	0.135	0.047	135	100	24.19	1.497	1.278	0.219	1.11	0.95	111.34
4/23/2009	21	0.030	0.030	21.21	0.851	0.810	0.040	161	153	6.86	5.955	5.956	-0.001	1.12	1.13	-0.20
5/7/2009	14	0.030	0.030	24.07	0.528	0.532	-0.004	150	151	-1.01	3.983	4.288	-0.305	1.13	1.22	-77.61
5/21/2009	14	0.029	0.029	25.94	0.626	0.596	0.029	187	179	7.50	3.444	4.107	-0.663	1.03	1.23	-168.93
6/4/2009	14	0.024	0.024	29.17	0.584	0.526	0.059	211	190	14.95	2.596	2.758	-0.162	0.94	0.99	-41.30
6/11/2009	7	0.025	0.025	26.51	0.371	0.350	0.021	259	244	10.86	1.290	1.277	0.014	0.90	0.89	6.95
6/25/2009	14	0.024	0.024	29.66	0.971	0.920	0.051	352	334	13.03	2.800	2.856	-0.056	1.02	1.04	-14.18
7/9/090	14	0.026	0.026	28.12	0.638	0.596	0.042	207	194	10.59	2.463	2.927	-0.464	0.80	0.95	-118.07
7/23/090	14	0.025	0.025	28.21	0.508	0.388	0.120	177	135	30.68	3.786	2.931	0.855	1.32	1.02	217.87
8/6/2009	14	0.024	0.024	29.69	0.407	0.286	0.122	145	102	30.96	2.962	2.641	0.321	1.05	0.94	81.75
8/13/2009	7	0.025	0.026	29.94	0.187	0.140	0.047	126	94	24.04	1.564	1.469	0.095	1.05	0.99	48.61
8/27/2009	14	0.022	0.022	29.18	0.210	0.188	0.021	81	72	5.46	1.929	1.647	0.283	0.74	0.63	72.00
9/10/2009	14	0.024	0.024	29.98	0.247	0.147	0.100	89	53	25.42	2.183	1.794	0.389	0.79	0.65	98.99
9/24/2009	14	0.024	0.024	27.00	0.276	0.226	0.050	98	80	12.81	2.492	2.460	0.031	0.89	0.88	8.00
10/8/2009	14	0.033	0.033	29.40	0.501	0.267	0.234	130	69	59.52	3.349	2.732	0.618	0.87	0.71	157.29
10/22/2009	14	0.027	0.027	25.46	0.308	0.258	0.050	97	82	12.66	2.562	2.367	0.196	0.81	0.75	49.83
11/5/2009	14	0.024	0.024	24.72	0.308	0.256	0.052	112	93	13.26	2.110	1.913	0.197	0.77	0.70	50.13
11/19/2009	14	0.036	0.036	21.65	0.462	0.421	0.041	110	100	10.49	3.819	3.049	0.771	0.91	0.72	196.27
12/10/2009	21	0.025	0.025	24.11	0.565	0.404	0.161	129	92	27.32	3.974	3.223	0.751	0.91	0.73	127.61

Table 35: ATSDEM Model Typical Printout

ATSDEM ANALYSIS

Week 14 3/12/2009 Powell Creek ATS Pilot

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	0.0078532	0.0078532	18.57	0.041	1.188	0.06	0.73	0.73

Panel B Process Conditions

Water T[1] °C	Optimal T °C	∠	Θ pb	K_{sh} as LHLR gpm/ft	net ∠max 1/hr	μmax 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 Nitrogen mg/l
20.8	30.0	1.10	75.00	30.00	0.038	76	15	23.83	12.79	8	0.98	0.30

Panel C Performance

Control Time Seconds	Control Volume liter	Final Total P S_f ppb	Total Flow Time seconds	Total P % 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
1	1.188	72	689	5.41%	500	61	541	3.28	29.24	1.71	0.067	0.97

Panel D System Design

Total Flow mgd	Floway Width ft	Floway Area acres	Total P removed lb/period	Moisture % wet harvest	Moisture % compost	Period Dry Harvest lbs/period	Period Wet Harvest lbs	Period Compost Production lbs	Performance Period days	∠net 1/hr	μnet l N ved lb/period	Total N % Removal
0.0267	1.0	0.01	0.01	5%	40%	1	25	2	7	0.0030	0.02	1.40%

Panel E pH Dynamics

Influent pH	Influent Alkalinity mg/l as $CaCO_3$	Influent Available Carbon mg/l	Diurnal Effluent pH	Algae Tissue Carbon % dw
7.70	240	66.22	7.73	30%

1. Do not enter water temperatures higher than optimum Temperature

Note: Inputs in Blue Print

MODELING RESULTS

The modeling results for the 27 harvest events are summarized in Tables 36 and 37. Shown in Figures 44 and 45 are comparisons of model projections with actual data for total phosphorus and total nitrogen concentrations. The model values track field data rather closely, particularly with projections related to phosphorus. Nitrogen projections of areal removal rate reflect the suggested influence of nitrogen fixation, with the model projections much closer to the harvest based values.

Shown as part of these two figures are the best fit linear regression plots. With phosphorus there is a high level of correlation between model and actual values ($r = 0.95$; $r^2 = 0.90$), with the model projecting field conditions very closely between the values of 50 to 180 µg/L. The best fit and 100% correlation lines begin to diverge somewhat when values exceed 200 µg/L. These are only 2 data points however that exceeded 200 µg/L as average effluent values per harvest session during the operational period. A one way ANOVA analysis of the model and field data show the values to be statistically indistinguishable, with $P = 0.92$, $F_{critical} = 4.03$ and $F = 0.009$. The ATSDEM model is shown to be a reliable tool for projecting system phosphorus reduction performance under Powell Creek environmental conditions.

With respect to nitrogen removal, the best fit linear regression plot shows a good correlation between model and actual values ($r = 0.72$; $r^2 = 0.51$), although not as strong as with phosphorus removal. The model projections of field conditions are sustained rather well between the values of 0.50 to 1.50 mg/L as total nitrogen. There are some data points noted below the two lines (model projections are optimistic when compared to field values) around the value of 100 mg/L. These likely represent the influence of nitrogen fixation. A one way ANOVA analysis of the model and field data show the values to be statistically indistinguishable, with $P = 0.34$, $F_{critical} = 4.02$ and $F = 0.930$. The ATSDEM model is shown to be a reliable tool for projecting system nitrogen reduction performance under Powell Creek environmental conditions.

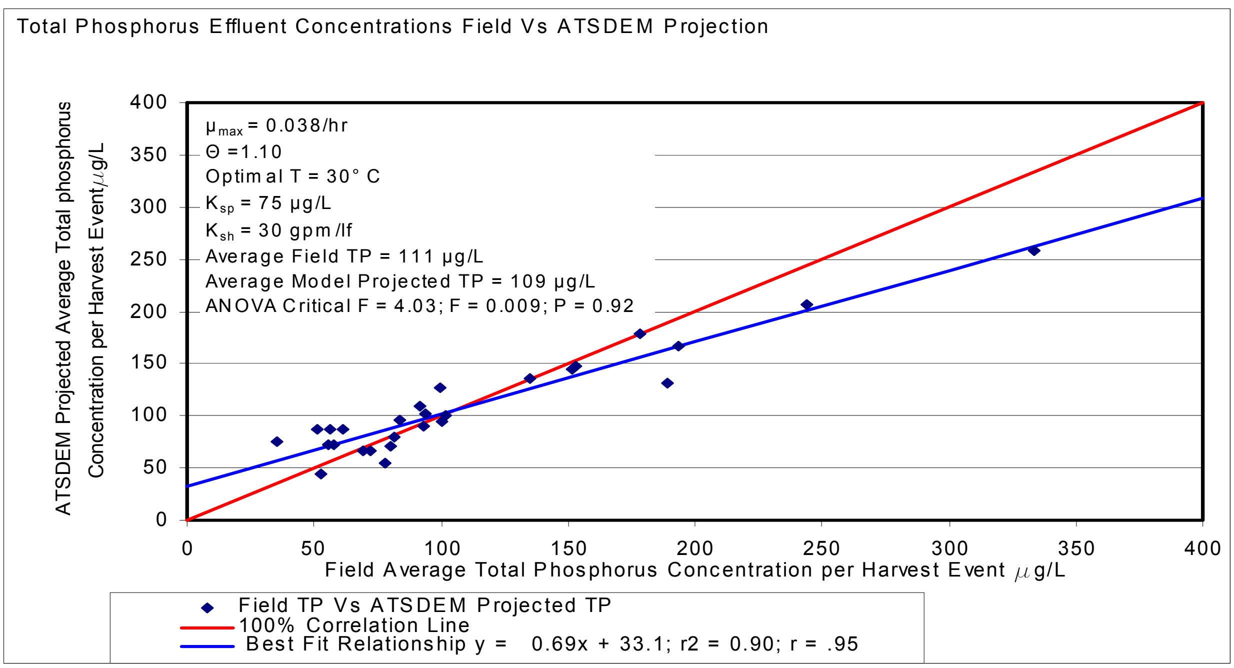


Figure 44: Total Phosphorus Concentration Field Versus ATSDEM Model Projections through Operational Period ATS™ Floway Powell Creek By-Pass Canal

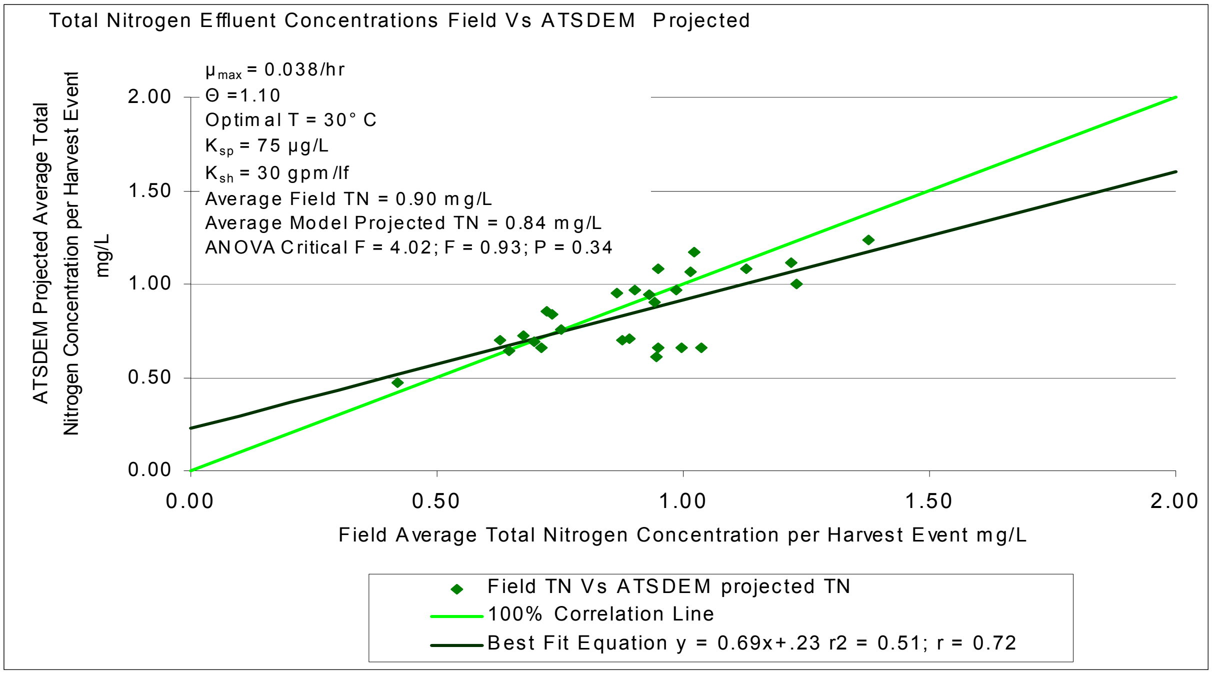


Figure 45: Total Nitrogen Concentration Field Versus ATSDEM Model Projections through Operational Period ATS™ Floway Powell Creek By-Pass Canal

Table 36: ATSDEM Model Projections Comparison with Field Data for Individual Harvest Events

	calibration	Influent Phosphorus µg/L	Effluent Total Phosphorus µg/L		Influent Nitrogen mg/l	Effluent Total Nitrogen µg/L		Specific Growth Rate 1/hr		Water Quality Based TP Areal Removal Rate g/m^2-yr		Water Quality Based TN Areal Removal Rate g/m^2-yr		Net Productivity dry- g/m^2-day	
Date	Harvest Event	Field	Field	Model	Field	Field	Model	Field	Model	Field	Model	Field	Model	Field	Model
12/18/2008	1	110	51	87	0.55	0.42	0.47	0.0084	0.0041	21.15	20.14	113.40	178.25	2.74	10.17
1/5/2009	2	95	56	87	1.26	1.38	1.23	0.0073	0.0042	29.04	6.14	-50.87	20.79	13.63	3.13
1/12/2009	3	105	84	95	1.10	1.02	1.06	0.0091	0.0038	15.46	7.05	59.58	24.27	17.90	3.59
1/29/2009	4	179	78	55	1.35	0.94	0.61	0.0041	0.0036	36.30	7.96	145.68	27.63	4.33	4.20
2/12/2009	5	53	36	75	0.73	0.68	0.73	0.0088	0.0017	13.69	0.90	44.85	3.04	11.07	0.47
2/25/2009	6	77	56	72	0.96	0.86	0.95	0.0061	0.0026	14.59	3.21	69.16	10.73	8.85	1.68
3/12/2009	7	76	58	72	0.98	0.90	0.97	0.0068	0.0030	14.99	3.28	66.27	10.96	9.96	1.71
3/26/2009	8	96	61	88	0.97	0.93	0.94	0.0067	0.0037	26.62	6.10	16.34	20.67	10.14	3.11
4/2/2009	9	135	100	127	1.11	0.95	1.08	0.0107	0.0040	24.19	5.30	111.34	18.45	11.32	2.56
4/23/2009	10	161	153	148	1.12	1.13	1.08	0.0027	0.0046	6.86	11.31	-0.20	39.94	15.20	5.31
5/7/2009	11	150	151	144	1.13	1.22	1.11	0.0058	0.0059	-1.01	5.04	-77.61	17.73	2.15	2.39
5/21/2009	12	187	179	179	1.03	1.23	1.00	0.0113	0.0073	7.50	7.02	-168.93	25.21	2.48	3.18
6/4/2009	13	211	190	132	0.94	0.99	0.65	0.0075	0.0086	14.95	55.74	-41.30	198.87	12.10	25.70
6/11/2009	14	259	244	206	0.90	0.89	0.71	0.0047	0.0075	10.86	38.40	6.95	141.46	16.60	16.42
	Average	**135**	**107**	**112**	**1.01**	**0.97**	**0.90**	**0.0071**	**0.0046**	**16.80**	**12.69**	**21.05**	**52.71**	**9.89**	**5.97**
	St Dev	**59**	**65**	**45**	**0.20**	**0.24**	**0.23**	**0.0024**	**0.0020**	**9.85**	**15.63**	**85.12**	**66.66**	**5.25**	**7.02**

	verification	Influent Phosphorus µg/L	Effluent Total Phosphorus µg/L		Influent Nitrogen mg/l	Effluent Total Nitrogen µg/L		Specific Growth Rate 1/hr		Water Quality Based TP Areal Removal Rate g/m^2-yr		Water Quality Based TN Areal Removal Rate g/m^2-yr		Net Productivity dry- g/m^2-day	
Date	Harvest Event	Field	Field	Model	Field	Field	Model	Field	Model	Field	Model	Field	Model	Field	Model
6/25/2009	15	352	334	259	1.02	1.04	0.66	0.0056	0.0104	13.03	65.65	-14.18	249.63	6.60	25.94
7/9/090	16	207	194	167	0.80	0.95	0.66	0.0073	0.0086	10.59	31.40	-118.07	112.98	6.80	14.16
7/23/090	17	177	135	136	1.32	1.02	1.17	0.0060	0.0078	30.68	30.03	217.87	106.14	8.87	14.06
8/6/2009	18	145	102	100	1.05	0.94	0.90	0.0075	0.0081	30.96	32.29	81.75	111.79	8.05	15.80
8/13/2009	19	126	94	102	1.05	0.99	0.97	0.0101	0.0084	24.04	18.25	48.61	62.77	11.73	9.02
8/27/2009	20	81	72	67	0.74	0.63	0.70	0.0099	0.0059	5.46	9.13	72.00	30.48	12.58	4.77
9/10/2009	21	89	53	44	0.79	0.65	0.64	0.0060	0.0062	25.42	31.64	98.99	105.00	19.40	16.69
9/24/2009	22	98	80	71	0.89	0.88	0.70	0.0061	0.0054	12.81	19.22	8.00	64.72	16.20	9.88
10/8/2009	23	130	69	67	0.87	0.71	0.65	0.0063	0.0087	59.52	62.03	157.29	210.94	14.09	31.33
10/22/2009	24	97	82	80	0.81	0.75	0.75	0.0073	0.0051	12.66	13.81	49.83	46.64	12.92	7.06
11/5/2009	25	112	93	90	0.77	0.70	0.69	0.0058	0.0046	13.26	15.18	50.13	51.73	17.24	7.64
11/19/2009	26	110	100	94	0.91	0.72	0.85	0.0051	0.0045	10.49	14.14	196.27	48.23	17.18	7.10
12/10/2009	27	129	92	109	0.91	0.73	0.84	0.0056	0.0049	27.32	14.83	127.61	49.31	8.68	7.29
	Average	**143**	**115**	**107**	**0.92**	**0.82**	**0.78**	**0.0068**	**0.0068**	**21.25**	**27.51**	**75.09**	**96.18**	**12.33**	**13.13**
	St Dev	**72**	**74**	**56**	**0.16**	**0.15**	**0.16**	**0.0016**	**0.0019**	**14.33**	**17.98**	**89.89**	**66.31**	**4.31**	**7.91**

Operational Period Average	**139**	**111**	**109**	**0.96**	**0.90**	**0.84**	**0.0070**	**0.0057**	**18.94**	**19.82**	**47.07**	**73.64**	**11.07**	**9.42**
Operational Period St Dev	**64**	**68**	**49**	**0.19**	**0.21**	**0.20**	**0.0020**	**0.0022**	**12.18**	**18.12**	**90.05**	**68.86**	**4.89**	**8.18**

Table 37: Summary of ATSDEM Modeling over Operational Period

Parameter	Units	Average Over Operational Period*	Average of Model Projections	Standard Deviation
Total Phosphorus Effluent Concentration	µg/L	111	109	68 Field 49 Model
Total Nitrogen Effluent Concentration	mg/L	0.90	0.84	0.21 Field 0.20 Model
Phosphorus Areal Removal Rate	g/m^2-yr	18.94 Water Quality Based 20.80 Harvest Based	19.82	12.18 Water Quality 11.10 Harvest 18.12 Model
Nitrogen Areal Removal Rate	g/m^2-yr	47.07 Water Quality Based 71.37 Harvest Based	73.64	90.05 Water Quality 37.10 Harvest 68.86 Model
Specific Growth Rate	1/hr	0.0070	0.0057	0.0020 Field 0.0022 Model
Net Productivity	dry g/m^2-day	11.07	9.42	4.89 Field 8.18 Model

***** Averages represent values for each harvest event and may vary slightly from average of weekly values as shown in previous sections

SECTION 5. ATSDEM BASED PERFORMANCE ESTIMATION OF FULL SCALE SYSTEM

NUTRIENT REMOVAL PROJECTIONS

In the Basis of Design Report submitted 10/28/09 (prior to pilot study initiation) to Lee County[15], a range of ATSDEM based performance projections were presented for a 13 MGD, 600 foot long, 451 foot wide ATS™ Floway (6.2 acres) considering historical water quality and climatic conditions. The performance data assumed that the system was post-start-up and stabilization phase. A series of tables were included, absent the projections based upon the pilot work. The tables are replicated within this review as Table 38 through 41, to include the pilot data and the resulting ATSDEM development for the full monitoring period of the pilot study. As noted, the performance projections based upon the modeling, are between the conservative and optimistic projections, being closer to the conservative projections.

Total phosphorus removal for a fully-operational ATS™ was projected by ATSDEM at 18.3% based upon an average annual influent concentration of 153 µg/L and an average annual effluent concentration of 125 µg/L, with a mass removal of 1,118 lb/yr at an average annual phosphorus areal removal rate of 20 g/m^2-yr. Total nitrogen removal is projected by ATSDEM at 9.7% based upon an average annual influent concentration of 1.03 mg/L and an average annual effluent concentration of 0.93 mg/L, with a mass removal of 4,125 lb/yr at an average annual areal removal rate of 74 g/m^2-yr. The pilot investigation provides indication that the ATS™ technology can support high rates of nutrient reduction within the Powell creek basin, and that demonstrated performance is consistent with ranges projected within the referenced Basis of Design report.

[15] Powell Creek Basis of Design Algal Turf Scrubber® (ATS™) Basis of Design Final report revised 12/28/08 Prepared by HydroMentia, Inc. Ocala, Florida for Lee County, Florida. p 21-26.

Biomass Production and Management

It is recommended that initially biomass management be through windrow processing. This is a reliable and low cost method of converting the harvested biomass into a valuable product. Recent tests completed by USDA[16] show the algal turf biomass when composted yields a superb product. Biomass and compost yields projected through the ATSDEM application are shown in Table 42. Assuming wet harvested biomass is 8% solids, which is typical for algal turf after harvest, and completed compost is 40% moisture, which has also been typical from experience with other ATS™ operations, it is projected that the full scale 6.2 acre unit would yield 1,218 tons of wet harvest annually at 8% moisture, and nearly 122 tons of compost at 40% moisture. The processing of this material could be done on-site on an asphalt pad of no more than one acre using a small skid loader and a compost mixing attachment.

Table 38: ATSDEM Critical Parameters with Data through the Operational Period Powell Creek ATS™ Pilot Study

Parameter	Optimistic	Conservative	Model Projection Based Upon Pilot Study Data
Maximum Specific Growth Rate 1/hr	0.04	0.03	0.038
Optimal Average Crop Density dry g/sm	150	75	Q1 47.64 g/m^2 Q2 50.84 g/m^2 Q3 62.46 g/m^2 Q4 80.36 g/m^2
V'ant Hoff-Arrhenius Constant	1.10	1.05	1.10
Half Rate Concentration TP µg/L	37	75	75
Half Rate LHLR gpm/lf	9.3	15.0	30
Tissue Nitrogen % dry weight to Nitrogen Concentration	[N]2.87×10^{-3} +0.0273	[N]2.87×10^{-3} +0.0180	[P]3.89×10^{-5} + 0.0149
Tissue Phosphorus % dry weight to Phosphorus Concentration	[P]5.9×10^{-6}+0.0052	[P]5.9×10^{-6}+0.0025	[P]7.41×10^{-6}+ 4.71×10^{-3}

[16] Work conducted and continuing by Dr. Joseph Albano, USDA-Agricultural Research Service, USHRL 200 S. Rock Road, Ft. Pierce, Fla 34945

Table 39: ATSDEM TP Performance Ranges from Basis of Design Compared to Model Projections Based Upon Field Data through Operational Period Powell Creek ATS™ Pilot Study

	Historical TP Influent µg/L	Effluent TP (µg/L)			P Mass Removal (lbs)		
		Opt	Con	Model Projection Based Upon Pilot Study Data	Opt	Con	Model Projection Based Upon Pilot Study Data
January	79	29	69	69	175	33	35
February	103	36	99	92	205	38	33
March	109	26	96	95	281	42	49
April	345	219	312	315	410	106	99
May	247	122	227	217	420	67	100
June	207	61	188	164	476	62	141
July	152	31	138	110	405	48	142
August	166	27	149	121	467	56	152
September	110	14	97	79	311	41	102
October	108	14	94	77	314	46	87
November	108	23	94	81	276	44	72
December	102	26	90	81	256	34	112
AVERAGE	153	52	138	125	-	-	-
TOTAL	-	-	-	-	3,966	617	1,118

Opt = Optimistic Projection from Basis of Design
Con= Conservative Projection from Basis of Design

Table 40: ATSDEM TN Performance Ranges from Basis of Design Compared to Model Projections Based Upon Field Data through Operational Period Powell Creek ATS™ Pilot Study

	Historical TN Influent mg/l	Effluent TN mg/l			N Removal lbs		
		Opt	Con	Model Projection Based Upon Pilot Study Data	Opt	Con	Model Projection Based Upon Pilot Study Data
January	0.93	0.65	0.86	0.90	937	228	116
February	1.08	0.72	0.95	1.04	1,091	258	111
March	1.34	0.89	1.25	1.29	1,529	295	166
April	1.11	0.56	0.96	0.99	1,775	500	380
May	1.23	0.63	1.12	1.12	2,002	369	369
June	1.46	0.72	1.35	1.30	2,421	373	506
July	0.86	0.25	0.77	0.64	2,040	288	730
August	0.74	0.20	0.64	0.58	1,815	325	533
September	0.74	0.25	0.66	0.63	1,605	266	351
October	0.58	0.20	0.49	0.47	1,277	289	362
November	1.21	0.75	1.12	1.12	1,487	304	300
December	1.13	0.72	1.05	1.07	1,378	271	200
AVERAGE	1.03	0.55	0.94	0.93	-	-	-
TOTAL	-	-	-	-	19,357	3,766	4,125

Opt = Optimistic Projection from Basis of Design
Con= Conservative Projection from Basis of Design

Table 41: ATSDEM Nutrient Areal Removal Rate and Productivity Performance Ranges from Basis of Design Compared to Model Projection Based Upon Field Data Through Operational Period Powell Creek ATS™ Pilot Study

	P areal removal rate g/m²-yr (lb/acre-yr)			N areal removal rate g/m²-yr (lb/acre-yr)			Net Productivity dry-g/m²-yr		
	OPT	**CON**	**Field***	**OPT**	**CON**	**Field***	**OPT**	**CON**	**Field***
January	37 (331)	7 (62)	7 (66)	199 (1,773)	48 (431)	25 (219)	19	7	4
February	48 (429)	9 (79)	8 (69)	256 (2,286)	61 (541)	26 (234)	24	8	4
March	60 (531)	9 (80)	10 (92)	325 (2,894)	63 (559)	35 (315)	30	8	5
April	90 (801)	23 (207)	22 (194)	389 (3,471)	110 (977)	83 (744)	36	15	8
May	89 (794)	14 (127)	21 (189)	425 (3,789)	78 (698)	78 (698)	39	10	9
June	104 (931)	14 (121)	31 (275)	531 (4,735)	82 (729)	111 (990)	49	10	14
July	86 (767)	10 (90)	30 (269)	433 (3,862)	61 (546)	155 (1,383)	42	8	15
August	99 (883)	12 (106)	32 (288)	385 (3,435)	69 (615)	113 (1,009)	48	10	15
September	68 (608)	9 (81)	22 (200)	352 (3,140)	58 (521)	77 (686)	34	8	12
October	67 (595)	10 (87)	22 (200)	271 (2,417)	61 (547)	77 (886)	33	9	12
November	60 (539)	10 (86)	19 (171)	326 (2,909)	67 (595)	66 (586)	30	9	10
December	54 (485)	8 (25)	15 (136)	292 (2,608)	58 (514)	42 (378)	27	8	8
AVERAGE	72 (644)	11 (101)	20 (179)	348 (3,121)	68 (609)	74 (661)	34	9	10

OPT = Optimistic Projection
CON= Conservative Projection
*Field = Model Projection Based Upon Pilot Study Field Data

Table 42: ATSDEM Wet Harvest and Compost Production Projections

Month	ATSDEM Projected Wet Biomass Harvest at 8% Solids (tons)	Compost ATSDEM Projected Production at 40% Moisture (tons)
January	41	4.13
February	38	3.78
March	56	5.59
April	87	8.70
May	98	9.77
June	145	14.52
July	157	15.72
August	165	16.51
September	120	11.98
October	124	12.43
November	102	10.23
December	85	8.47
TOTAL	1,218	121.83

SECTION 6. GENERAL DISCUSSION AND OBSERVATIONS

During the one year monitoring period, the Powell Creek Pilot ATS™ Floway provided performance through a rather wide variation in environmental conditions. Aside from the normal variation associated with seasonal effects, the interaction with estuarine waters resulted in significant fluctuations in conductivity (salinity). These conductivity changes at times were somewhat abrupt, and noticeable changes were observed not only in the algal composition of the algae community, but also in the invertebrate community. During times of elevated conductivity, invertebrates such as barnacles, bivalve mollusks, and polychaete annelids were dominant. As conductivity fell during the wet season, the invertebrate community changed somewhat, although some of the bivalve mollusks appeared to sustain their populations.

It seems reasonable that with time there will be established upon the floway a stable euryhaline population. However, it is possible that with prolonged exposure to rather consistently high (quasi-marine) salinity levels some species will become established which have a narrower range of salinity tolerance. Consequently, with an abrupt change, such as would be associated with heavy rain and runoff, a die-off period may be experienced. It is quite possible that such an event was associated with the comparatively poor performance period in April, 2009[17].

It is encouraging, that in spite of these abrupt changes in conductivity, the system maintained satisfactory performance levels over the operational period. These performance levels were within the initially established range of expectations noted in the Basis of Design report. With design of a full scale system, therefore, it is not necessary to make any special adjustments in control of Floway or hydraulic dynamics. However, it will be necessary to be aware that any full scale design should be developed to accommodate the management of potential biofouling often associated with marine and estuarine environments, and to avoid establishing conditions in which the impacts of invertebrate die-offs could

[17] It is also possible that the poor performance as noted may not have been actual poor performance of the Floway but rather a sampling perturbation associated with invertebrate die-offs within the effluent sampling line during periods in which flow was disrupted and dissolved oxygen levels in the sampling line was below the tolerance limits of the involved organisms.

impact system performance. This would include ensuring relatively easy access to pump intakes, sampling equipment, piping and open channel systems, and associated sumps and boxes.

In summary, the ATS™ technology, based upon the results from the Powell Creek pilot study, appears to be well suited to provide levels of nutrient removal at an areal removal rate considerably higher than extensive wetland systems (e.g. STA or Filter Marsh systems). In addition the ATS™ technology facilitates direct removal and recovery of captured nutrients, and is well suited to provide organic substrate for processes, which would yield valuable products such as biofuels, composts and organic fertilizers, or livestock feeds. By including harvesting and recovery of biomass, the technology offers the advantage of sustainability, and is less vulnerable to changes in long term performance, or future maintenance demands associated with systems which rely upon large scale internal storage of organic material; or economic impacts associated with unpredictable fluctuations in chemical costs associated with systems which rely upon chemical additions to facilitate nutrient removal.

APPENDIX A. MPU PHOTOS

APPENDIX A
Powell Creek MPU (Mobile Pilot Unit) Pictures

Picture 1. Powell Creek Influent, Surger and Floway
(picture taken via security camera)

Picture 2. Powell Creek Influent line and view of floway

Picture 3. Powell Creek Lab/Control Room and Surger

Picture 4. Powell Creek – View of the floway

Picture 5. Powell Creek – Effluent

APPENDIX B. OPERATIONAL NOTES/SUMMARY

APPENDIX B
Powell Creek Operational Notes

START UP Powell Creek By-Pass Canal

Site Visit: Time 11:43 AM
Started 1:47 PM 10/23/08

The system was vandalized sometime in the evening 10/25/08 or early morning 10/26/08. Liner and grid pulled first 75 feet, influent riser pulled from surger box. Flows directed away from Floway. System repaired and back in operation 11:00 AM 10/26/08

Sample collection interruption. Samples do not represent normal operation.

Finish sample prep 12:31 PM 10/30/08

Influent (12:45 PM)	Effluent (12:45 PM)
pH = 7.80	pH = 8.27
DO 11.46 mg/l	DO = 9.01 mg/l
WT = 22.3 C	WT = 18.5 C
Conductivity 1001 MicroS/cm	Conductivity 1019 MicroS/cm
Salinity = 0.49 ppt	Salinity = 0.51 ppt

Vandalism again on 11/2/08 (Sunday). System off, electrical box destroyed, Dirt in floway. Sampling and operation terminated until Video Camera in Place and Box repaired. Sheriff's deputy called on site. Lee County notified. Pumps reactivated 11/14/08.
System in full start-up on 12/6/08
Instantaneous Flow 23.7 gpm.
Weather sunny, warm, light breeze. Will sample Thursday 12/11/08 @9:00 AM.
Algal turf developing well since pumps reactivated 11/14/08. Turf appears as brown filaments with occasional green filamentous strands, which are more prevalent near surger. Surger cycle about 30 secs.

WEEK 1: Thursday 12/11/08 arrive on site 9:00 AM
Anura and Sue Fite from Lee County arrived about 9:30 AM. Robinson Bazurto arrived about 9:45 AM.

Weather cloudy, moderate to heavy rain throughout sampling period. Air T about 19 C.

Flow totalizer reading @ 9:10 AM 142,549 gallons. Noted the paddlewheel not registering. Flow meter removed and cleaned, and paddlewheel rendered operable. Reset totalizer at 9:10 AM. Algae production good, and turf develop extensive down entire floway. Surge cycle about 30 seconds.

Canal level comparatively low, and tidal waters do appear to be mixing with the upstream run-off—as confirmed by the comparatively high conductivity (circa 5,000 microS/cm). The lower conductivity in the effluent is a result of rain dilution, as it was raining heavily at the time of the measurement.

FIELD PARAMETERS

Parameter	Influent	Effluent
Time	10:43 AM	10:55 AM
pH	7.57	7.74
DO mg/l	5.30	8.78
SC micros/cm	5,652	3,403
T degC	21.57	19.55

WEEK 2: Thursday 12/18/08 arrive on site 8:30 AM

Sue Fite and Beth Loewer from Lee County arrived about 8:50 AM.

Weather clear, light southerly breeze at 10:00, air T about 20.5C

Flow totalizer reading @ 210,053 gallons at 8:41 AM . Flow meter functioning properly. Reset totalizer at 8:45. Sampling completed at 9:50 AM. Left site around 11:00 AM for lunch and to acquire supplies. Back on site at 12:20 PM. Pictures taken every 100 feet..

Canal level comparatively low, and tidal waters do appear to be mixing with the upstream run-off—as confirmed by the comparatively high conductivity (circa 8,000 microS/cm). The pH shows an expected increase from influent to effluent, but the high mineral content, and expected attendant high alkalinity serves to buffer pH. DO increase is notable, but comparatively modest when compared to other ATS™ units. Algae production appears good, but needs to be harvested today. Filamentous green algae at the first fifty feet give way to what appear to be a mix of diatoms and perhaps red or brown algae downstream. These have a gelatinous sheen, and capture oxygen bubbles, which causes some grid flotation. The turf peels rather easily from the grid, and it looks as though the algae community may be associated with high polysaccharide content, considering the gelatinous appearance. This would need to be verified from laboratory tissue analysis. Surge cycle remains at about 30 seconds

FIELD PARAMETERS

Parameter	Influent	Effluent
Time	10:10 AM	10:05 AM
pH	7.51	8.18
DO mg/l	5.26	8.76
SC micros/cm	8,679	8,821
T degC	22.6	23.5

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	85.3	63.4	148.7
Sample Size wet g	201.8	201.4	-
Sample Size dry g	12.3	13.8	-
% Solids	6.10%	6.85%	-
Algae (dry lbs)	5.20	4.34	9.54

The system pump was stopped at 1:05 PM, and the bottom 250 feet scraped and collected. At 2:05 the pump was re-started to accommodate observation of the surger and the floway dynamic by Anura Karuna-Muni and several visitors from Lee County and the local SFWMD office. The system was again shut down at 2:38 PM and harvested completed at 3:15 PM. Wet harvest weight was 85.3 lbs for 0-250 feet and 63.4 lbs for 250-500 feet. Samples were taken and sent to HydroMentia facilities in Okeechobee for solids determination. Dried samples will be sent to Midwest Laboratory for tissue analysis. Water samples were delivered to FedEx for delivery to Jupiter Laboratory at 4:45 PM.

Mark Zivojnovich was on site from 2:45 PM to 5:20 PM, working on the video camera set-up. He was not able to complete installation of the second camera, and decided it would require two people several hours to properly install the system. This will be done after the holidays. In the interim, the system will continue to be monitored by one camera. The system was secured and both Mark and Allen Stewart left by 5:30 PM. Both samplers were running and influent and effluent sample stations were functioning properly, as was the floway.

WEEK 3: Monday 12/29/08: Arrive on site 8:45 AM

Sue Fite from Lee County arrived about 8:50 AM.

Weather clear, light southerly breeze at 10:00 AM, air T about 22 C. No measured rain previous week.

Flow totalizer reading @ 310,516 gallons at 8:55 AM . Instantaneous flow at 20.8 gpm. Flow meter functioning properly. Reset totalizer at 8:55 AM. Sampling completed at 9:50 AM. Field data taken. Pictures taken every 100 feet. The system was secured by 12:45 PM. Both samplers were running and influent and effluent sample stations were functioning properly, as was the floway. Water samples were delivered to FedEx for delivery to Jupiter Laboratory at 1:15 PM.

Canal levels were comparatively low, and tidal waters continue to appear to be mixing with the upstream run-off—as confirmed by the comparatively high conductivity (circa 7,500 microS/cm). The pH shows the expected increase from influent to effluent, even at the high alkalinity measured at about 240 mg/l as $CaCO_3$. DO increase is notable, with greater differential as compared to sampling on 12/18/08. Algae production following harvesting on 12/18/08 is luxuriant. We will harvest next week. Some filamentous green algae at the first fifty feet gives way to what appear to be a mix of diatoms and perhaps red or brown algae downstream. Surge cycle remains at about 30 seconds.

The continuous conductivity meter (Unidata) which had been set in place the previous week, failed to register with the downloading software. We will troubleshoot the problem with the manufacturer next week.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:16 AM	10:26 AM
pH	7.53	8.32
DO mg/l	5.53	10.94
SC micros/cm	7,308	7,164
T degC	22.39	24.45

INTERIM VISIT: January 1, 2009 9:15 AM

System operating, with luxuriant algal turf. Set conductivity meter after fixing software glitch earlier the previous day. Left the site at 10:45 AM.

INTERIM VISIT: January 2, 2009 9:00 AM

Visited the site after noticing at 8:00 AM that the floway was not receiving flow. Found the influent by-pass valve fully opened, as well as the effluent by-pass valve. Turf moist but much sloughing. System retarted at 20 gpm at 9:45 AM. Much sloughed algae in the effluent. Also noted the grid and liner had been vandalized at the terminus. The system was quickly repaired—no permanent damage done, but turf community damaged, which could impact water quality for the week (week #4). Vandalism reported to Ocala office. Mark to attempt to review back video to see when vandalism occurred.

WEEK 4: Monday 1/5/09: Arrive on site 8:05 AM

No representatives from Lee County.

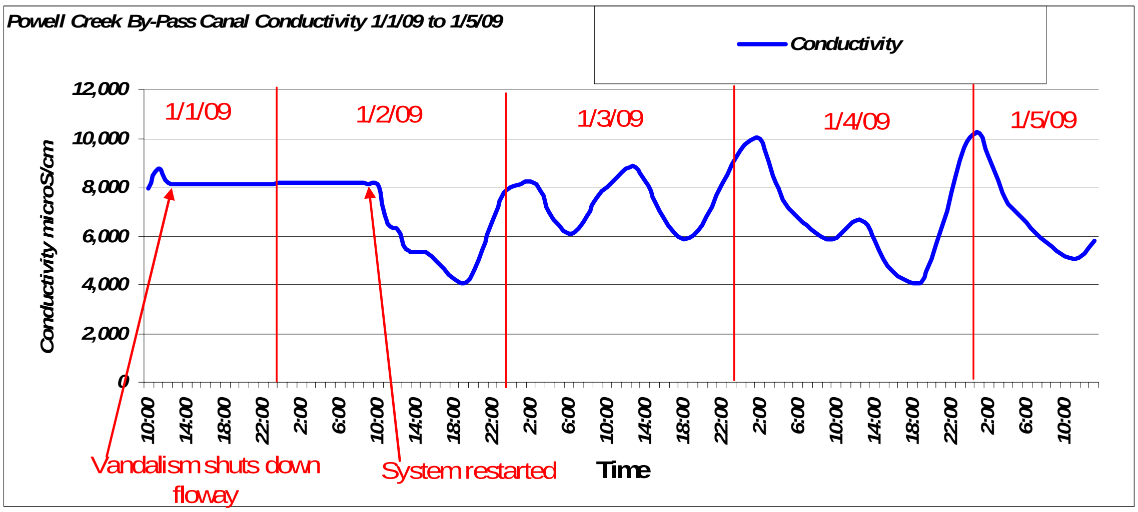
Weather clear, only slight breeze at 10:00 AM, air T about 19 C. No measured rain previous week.

Flow totalizer reading @ 136,355 gallons at 8:15 AM. Instantaneous flow at 16.1 gpm. Flow meter functioning properly. Reset totalizer at 8:16 AM. Sampling completed at 9:50 AM. Field data taken. The system was shut down at 10:00 AM for harvesting. While there was considerable biomass on the floway, there would have been much more if it had not been lost during the shut down caused by vandals on 1/1/09 (see above interim visits). Harvesting was completed and the system returned to normal operation on 12:25 PM. Both samplers were set to run and influent and effluent sample stations were functioning properly, as was the floway. Flow was adjusted to about 20 gpm. The harvest was weighed and samples taken for determination of moisture content. The harvest was mixed with mulch for composting on site. The conductivity unit data was downloaded (see curve below). Water samples were delivered to FedEx for delivery to ELAB (Pace) Laboratory at 2:00 PM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:00 AM	10:00 AM
pH	7.60	8.43
DO mg/l	6.39	10.59
SC micros/cm	4,151	4,339
T deg C	21.05	23.14
Alkalinity mg/l as $CaCO_3$	240	240

CONDUCTIVITY



HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	65.1	155.1	220.2
Sample Size wet g	200	200	400
Sample Size dry g	15.6	25.8	41.4
% Solids	7.80%	12.90%	10.35%
Algae (dry lbs)	5.10	20.01	25.11

Tidal influences are noted by the diurnal fluctuation in conductivity. It continues to appear that estuarine water is mixing with the upstream run-off—as supported by the comparatively high conductivity. The pH shows the expected increase from influent to effluent, even at the high alkalinity measured at about 240 mg/l as $CaCO_3$. DO increase is notable, with effluent levels at super-saturation. Algae production appears good. Small bivalve mollusks noted. Surge cycle remains at about 30 seconds. Next sampling on January 15, 2008. After that, sampling will be every Thursday.

WEEK 5A: Monday 1/12/09: Arrive on site 8:45 AM

On Thursday 1/8/09, we were informed that Lee County DOT would be spraying herbicide (glyphosate) within the Powell Creek By-Pass south of Bayshore Blvd on Tuesday 1/13/09. It was decided consequently to sample and harvest on Monday, 1/12/09 prior to the spraying, and then sample again on Thursday 1/15/09, thereby allowing more reliable assessment of the impact of spraying. The County was notified of this adjustment. Susan Fites and Beth Loewer arrived on site to split samples about 9:15 AM.

The weather was cool and calm, with fog. The air temperature was 20 C. No rain was measured during the previous week. The floway was functioning well, with heavy turf development throughout the floway. The first 200 feet was dominated by filamentous green algae, the final 300 feet showed a predominance of non-filamentous turf—likely diatoms and perhaps brown algae. The flowmeter was not registering flow. Inspection of the flow meter propeller showed clogging. It was cleaned and reset, showing a flow rate of 18.0 gpm. The totalizer read 83,018, which represents only portion of the week's flow. Flow estimates for the week will be based upon instantaneous flow measurements. It appears it will be necessary to clean the propeller each week to prevent clogging.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:30 AM	10:00 AM
pH	7.66	8.24
DO mg/l	5.43	8.58
SC micros/cm	9,854	10,321
T deg C	22.23	22.29
Alkalinity mg/l as $CaCO_3$	>240	>240

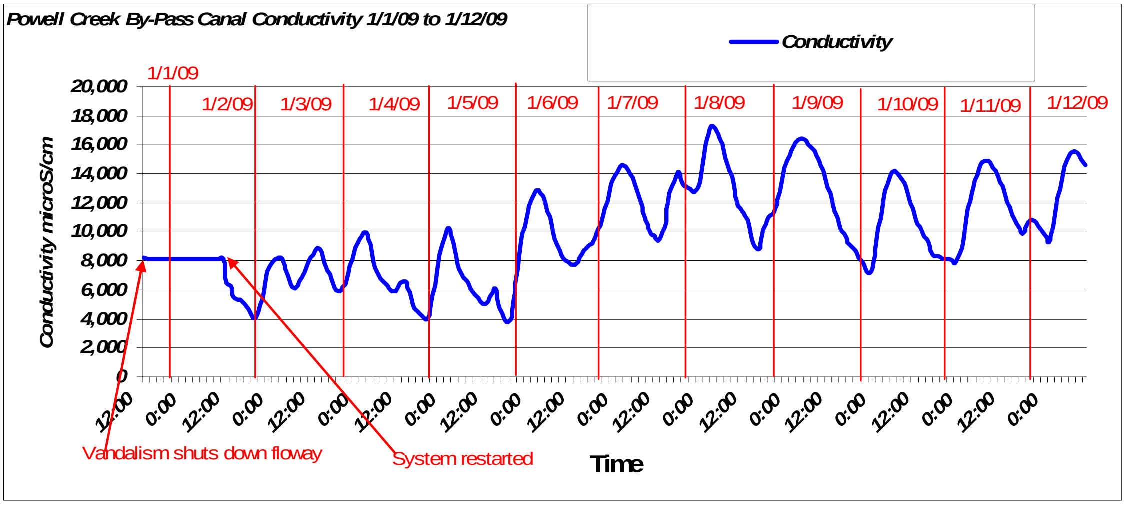
Sampling was completed by 10:30. The sample period was designated week 5A. After sample collection, both intake strainers were cleaned. Both had accumulated solids, and several small mollusks had found refuge within the strainer body. Smaller strainer holes may be required to prevent sample contamination. At 10:45 the pump was shut down, and the system harvested. Harvesting was completed by 1:00PM. The pump was restarted and the flowmeter reset to zero. Samplers set on run at 2:00 PM. Conductivity probe data unloaded. Trends as noted in graph, show increasing conductivity, implying increased influence of coastal waters.

Site secured. Water samples delivered to Fedex for delivery to PACE Lab by 2:30 PM.

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	85.9	72.1	158.0
Sample Size wet g	200	200	400
Sample Size dry g	16.1	16.4	32.5
% Solids	8.05%	8.20%	8.13%
Algae (dry lbs)	6.91	5.91	12.82

CONDUCTIVITY



WEEK 5B: Thursday 1/15/09: Arrive on site 8:41 AM

The weather was cold, calm, and overcast. It was low tide. The air temperature was 10 C. Less than 0.1 inches of rain was measured. The floway was functioning well, with good turf recovery development throughout the floway. There was no evidence of impact from herbicide spraying on Tuesday. The first 300 feet of the floway was dominated by filamentous algae, the final 200 feet showed a mix of diatoms, filamentous algae and patches of blue-green bacteria (algae). The flowmeter was registering 18.4 gpm. The flowmeter was cleaned was cleaned and reset, showing a flow rate of 19.0 gpm. The totalizer read 60,678 gallons.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:30 AM	10:21 AM
pH	7.86	8.41
DO mg/l	6.65	11.00
SC micros/cm	1,898	1,918
T deg C	14.14	13.68
Alkalinity mg/l as $CaCO_3$	200	200

Field data indicates conductivity has dropped considerably, likely due to some rain, and the very low tide, which isolates the intake area from direct contact with the Caloosahatchee River. Sampling was completed by 11:00 AM. The sample period was designated week 5B. After sample collection, both intake strainers were cleaned. The in-situ conductivity probe data was not unloaded this period.

Site secured. Water samples delivered to Fedex for delivery to PACE Lab by 1:30 PM.

HARVEST

No Harvest this period

CONDUCTIVITY

Conductivity data will be unloaded on 1/22/09.

WEEK 6: Thursday 1/22/09: Arrive on site 8:40 AM

The weather was very cold, calm, and clear. The tide was very low. The air temperature was 5 C. No rain was measured for the week. The floway was functioning well, with good turf recovery development throughout the floway. However, someone had moved the sampling valve on the influent line, which reduced flow to the floway to about 10 gpm. The algal turf however remained wet, and there was no evidence of sloughing or lysis. As with week 5B, the first 300 feet of the floway was dominated by filamentous algae, both green and diatoms. The final 200 feet showed a mix of diatoms, filamentous green algae and patches of blue-green bacteria (algae). The standing crop was heavier than the previous week, but sloughing was negligible. It was decided to not harvest until next week (1/29/09). The flowmeter was registering 9.3 gpm. The totalizer read 102,999. As noted the low flow was attributable partly to the disturbance to the sampling valve. Also contributing was the increased lift associated with the very low water levels. The flowmeter was cleaned and reset, and the sampling valve adjusted and re-buried. The instantaneous flow rate was noted at 16.0 gpm.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:35 AM	10:25 AM
pH	8.12	8.50
DO mg/l	10.35	12.46
SC micros/cm	3,092	3,031
T deg C	9.70	13.30
Alkalinity mg/l as $CaCO_3$	180	180

Field data was taken after calibration of YSI unit. Data indicates conductivity remains below weeks 1 through 5A, but somewhat higher than the previous week. The low tide continues to maintain isolation of the intake area from direct contact with the Caloosahatchee River. pH levels within the influent are higher than the previous week, as are DO levels. The DO would be expected to be higher because of the cold weather. There was still a substantial increase in DO (above saturation) within the effluent, indicating active photosynthesis. All sampling was completed by 10:40 AM. After sample collection, both intake strainers were cleaned.

An attempt was made to unload the in-situ conductivity probe data, but was unsuccessful. After over an hour troubleshooting with the factory, the problem was not resolved. We will try to resolve during the upcoming week.

Site secured. Water samples delivered to Fedex for delivery to PACE Lab by 12:30 PM.

HARVEST

No Harvest this period

CONDUCTIVITY

Unable to unload data, as noted previously.

WEEK 7: Thursday 1/29/09: Arrive on site 8:35 AM

The weather was warm and clear. The tide was higher than the previous week, and water was being exchanged with the Caloosahatchee. The air temperature was 22.5 C. No rain was measured for the week. The floway was functioning well, with good turf recovery development throughout the floway. However, flow was reduced, and it was decided to exchange the pump, as it was suspected that the pump was partially clogged. When the pump was pulled, it was found to be fouled with barnacles and small clams. The new pump was installed, which took about two hours, as the cable had to be pulled through the existing conduit. Flow was renewed to about 20 gpm. Growth on the floway had expanded, with the first 300 feet of the floway dominated by filamentous green algae. The final 200 feet continued to show a mix of diatoms, filamentous green algae and patches of blue-green bacteria (algae). Sloughing was negligible. The flowmeter at 8:40 AM had quit registering, and when cleaned it read 10.2 gpm (this is before the pump replacement). Totalized flow was not registered, and will need to be estimated. The existing flow meter will be replaced by a mag meter next week. The flowmeter was cleaned and reset at 5:00 PM after pump replacement and harvesting. The instantaneous flow was 20.3 gpm.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:05AM	10:00 AM
pH	7.58	8.30
DO mg/l	7.31	8.56
SC micros/cm	11,867	14,011
T deg C	21.43	22.45
Alkalinity mg/l as $CaCO_3$	240	240

Field data was taken after calibration of YSI unit. Data indicates conductivity has returned to estuarine levels. The low tide continues to maintain isolation of the intake area from direct contact with the Caloosahatchee River. pH levels within the influent are higher than the previous week, as are DO levels.

Sampling commenced at 9:00 AM. Lee County on site at 9:00 AM. All sampling was completed by 10:00 AM. After sample collection, both intake strainers were replaced, and the sampling stations flushed.

The in-situ conductivity probe was set-up on 1/24/09. It will be unloaded next week.

Photos taken prior to harvest. Water samples delivered to Fedex for delivery to PACE Lab by 2:30 PM. Site secured at 5:15 PM.

HARVEST

Harvesting commenced at 12:40 PM, completed at 2:00 PM. Samples taken for tissue analysis and moisture determination.

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	97.3	20.3	117.3
Sample Size wet g	200	200	400
Sample Size dry g	10.4	24.3	34.7
% Solids	5.20%	12.15%	8.68%
Algae (dry lbs)	5.06	2.47	7.53

CONDUCTIVITY

Logger repaired and reinstated on 1/24/09. Data to be unloaded next week.

WEEK 8: Thursday 2/5/09: Arrive on site 8:30 AM

The weather was cold, clear , with a slight westerly breeze. The tide was very low, with no surface exchange with the Caloosahatchee River. The air temperature was 4º C. Rain was measured at 0.35 inches for the week. The floway was functioning well, with good turf recovery development throughout the floway. Instantaneous flow rate was 19.4 gpm, indicating the pump is functioning well. The totalizer had malfunctioned during the week, and totalized flow will be estimated from the instantaneous flow. The totalizer was reset and appeared to be functioning properly. When the samplers were inspected, it was found the influent sampler had only taken a few samples. Upon inspection it was found the sampler strainer was not submerged, apparently having been tampered with. Grab samples will need to be used for the nutrient review for this week. The samplers were reset and sampling tested to be certain samples were delivered. Growth on the floway has recovered well following last weeks harvesting, in spite of unseasonably cold weather. The first 300 feet of the floway continue to be dominated by filamentous green algae, with the final 200 feet continuing to show a mix of diatoms, filamentous green algae. The patches of blue-green growth has disappeared. Sloughing was negligible. As noted, the existing flow meter will be replaced by a mag meter. However, we are awaiting delivery of a battery pack, which is expected to arrive next week.. The flowmeter was cleaned was cleaned and reset at 8:40 AM. The instantaneous flow was 19.4 gpm.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:05AM	10:00 AM
pH	7.97	8.29
DO mg/l	12.92	14.70
SC micros/cm	5,508	5,527
T deg C	8.54	9.37
Alkalinity mg/l as $CaCO_3$	240	240

Field data was taken after calibration of YSI unit. Data indicates conductivity is lower than the previous week, but are still at estuarine levels. The low tide continues to maintain isolation of the intake area from direct contact with the Caloosahatchee River. pH levels within the influent are higher than the previous week, as are DO levels.

Sampling commenced at 9:00 AM. Lee County on site at 9:00 AM. All sampling was completed by 10:00 AM. After sample collection, both intake strainers were cleaned.

The in-situ conductivity probe was unloaded and remained in service.

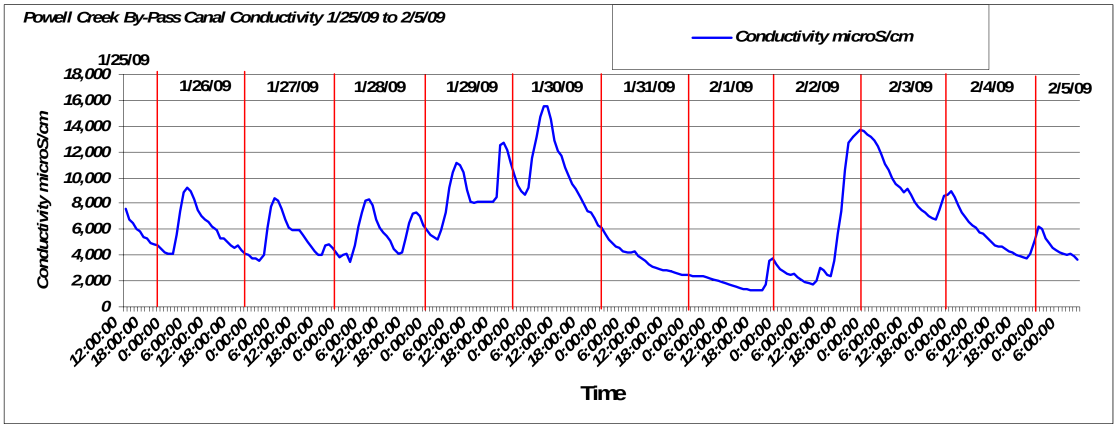
Photos taken at 11:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 12:00 noon.

HARVEST

No harvest this week.

CONDUCTIVITY

Logger unloaded. Trends noted in graph below. Tidal influence is noted as before. The influence of rainfall is noted towards the end of the week, with a drop in conductivity.



WEEK 9: Thursday 2/12/09: Arrive on site 8:15 AM

The weather was calm, clear , with moderate temperature . The tide was high, with surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 20º C. No rain was measured for the week. The floway was functioning well, with very good turf recovery development throughout the floway. Instantaneous flow rate was 18.8 gpm, indicating the pump is functioning well. The totalizer had again malfunctioned during the week, and totalized flow will be estimated from the instantaneous flow. The totalizer was reset and appeared to be functioning properly. The new flow meter will be installed next week. Samplers functioned properly this week. Growth on the floway has been very high following last week's cool weather. The first 300 feet of the floway continue to be dominated by a thick lawn of filamentous green algae, with the final 200 feet continuing to show a mix of diatoms, filamentous green algae. Sloughing was negligible. The system was harvested, which was completed by 12:30 PM. Algae samples were collected for taxonomic analysis. The flowmeter was cleaned was cleaned and reset at 12:45 PM. The instantaneous flow was 18.9 gpm.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:00AM	10:00 AM
pH	7.65	8.37
DO mg/l	6.42	8.40
SC micros/cm	14,732	15,909
T deg C	21.28	22.21
Alkalinity mg/l as $CaCO_3$	240	240

Field data was taken after calibration of YSI unit. Data indicates conductivity is higher than the previous week. The high tide allow the intake area to be in direct contact with the Caloosahatchee River.

Sampling commenced at 9:00 AM. Lee County on site at 9:00 AM. All sampling was completed by 10:00 AM. After sample collection, both intake strainers were cleaned.

The in-situ conductivity probe was unloaded and remained in service.

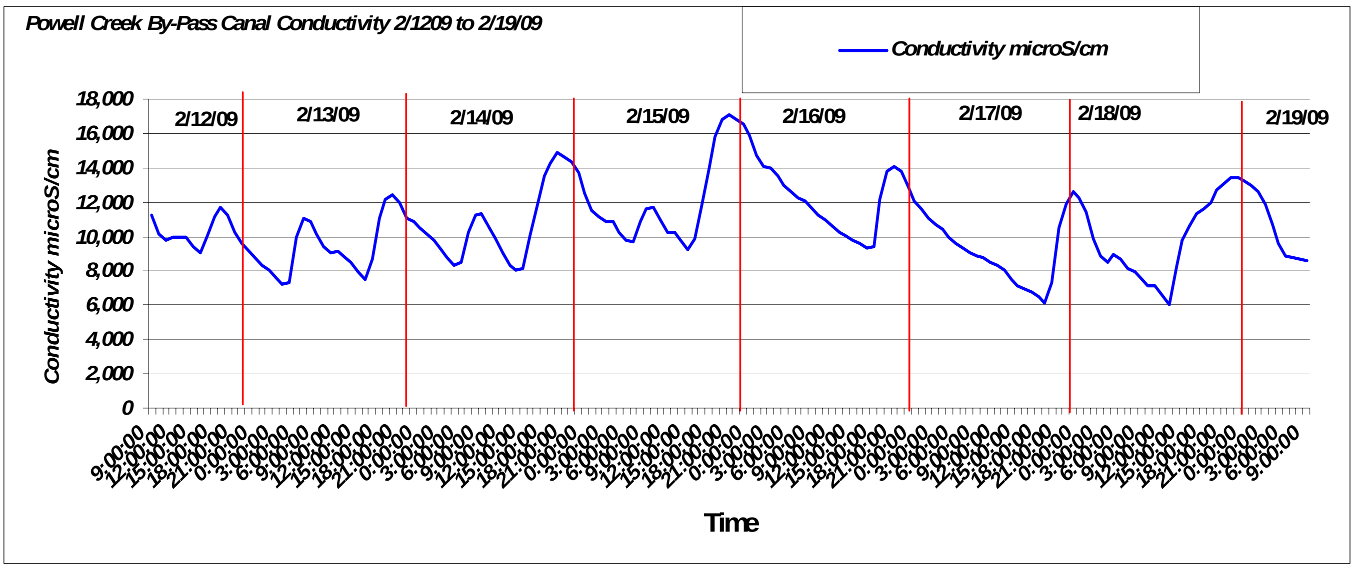
Water samples delivered to Fedex for delivery to PACE Lab by 3:00 PM. Site secured at 2:30 PM.

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	163.7	63.4	227.1
Sample Size wet g	200.1	200.3	400.4
Sample Size dry g	14.4	12.9	27.3
% Solids	7.20%	6.44%	6.83%
Algae (dry lbs)	11.78	4.08	15.86

CONDUCTIVITY

Logger unloaded. Trends noted in graph below. Tidal influence is noted as before. The lack of runoff results in higher conductivities



WEEK 10: Thursday 2/19/09: Arrive on site 8:35 AM

The weather was calm, clear , with moderate temperature . The tide was high, with surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 23º C. No rain was measured for the week. The floway was functioning well, with very good turf recovery development throughout the floway. Instantaneous flow rate was 12.5 gpm, indicating the pump intake is beginning the become occluded. The totalizer had again malfunctioned during the week, and totalized flow will be estimated from the instantaneous flow. The existing flowmeter was replaced with a Mag Meter at 3:00 PM. Flow was set at 19 gpm, with the totalizer at 1,223,300. The new meter appeared to be functioning properly. Samplers functioned properly this week. The algal turf is very productive, and it is expected weekly harvesting may become necessary very shortly. The first 300 feet of the floway continue to be dominated by a thick lawn of filamentous green algae, with the final 200 feet continuing to show a mix of diatoms, filamentous green algae. Sloughing was negligible. The system was not harvested this week. The intake strainers were replaced. It was noted during the installation of the Mag Meter, that clams and barnacles are beginning to grow in the 2” force Main piping. The pump was removed and cleaned. Bio-fouling will be a design and operational challenge for any full scale system. Replacement of the force main may become necessary before the pilot is completed.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:00AM	10:00 AM
pH	7.95	8.37
DO mg/l	8.00	8.05
SC micros/cm	12,326	12,687
T deg C	20.51	22.69
Alkalinity mg/l as $CaCO_3$	240	240

Field data was taken after calibration of YSI unit. Data indicates conductivity remains high. The high tide allows the intake area to be in direct contact with the Caloosahatchee River.

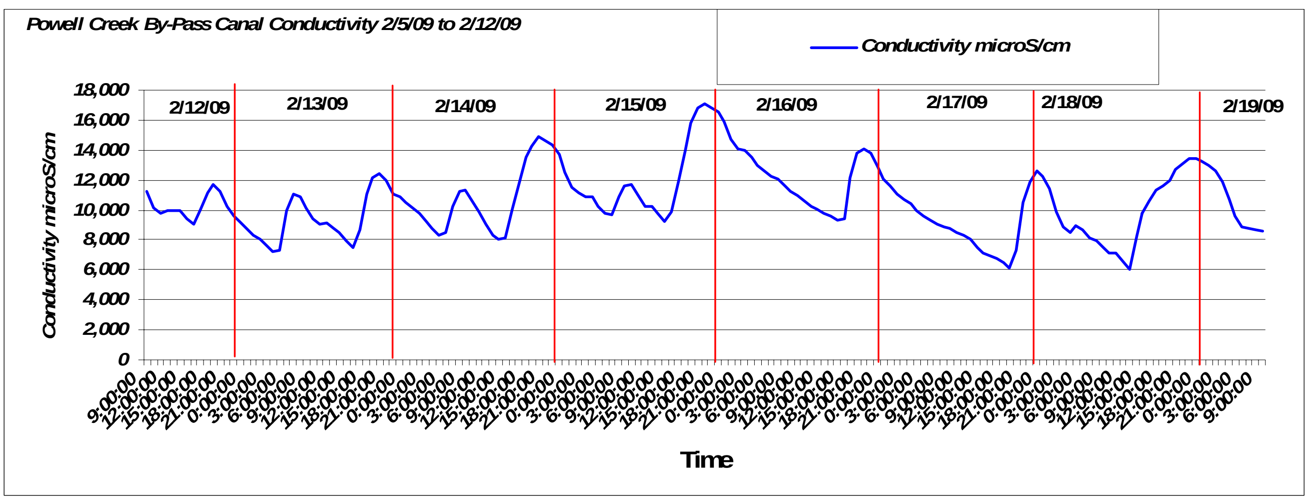
Sampling commenced at 9:00 AM. Lee County on site at 9:00 AM. All sampling was completed by 10:00 AM. After sample collection, both intake strainers were replaced

The in-situ conductivity probe was unloaded and remained in service. Pictures were taken of the floway.

Water samples delivered to Fedex for delivery to PACE Lab by 3:00 PM. Site secured at 2:30 PM.

HARVEST
No harvest this week

CONDUCTIVITY
Logger unloaded. Trends noted in graph below, indicate higher trends than previous week. Tidal influence is noted as before. The lack of runoff results in higher conductivities.



WEEK 11: Wednesday 2/25/09: Arrive on site 8:20 AM

(NOTE: This is a short week—6 days—because of scheduling conflicts.)

The weather was calm, clear , with moderate temperature . The tide was low, with no surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 19º C. No rain was measured for the week. The floway was functioning well, and the new Mag Meter was working, showing 17 gpm. Totalized flow was 142,500 gallons, or about 17.3 gpm average for the week. There was noted very good turf recovery development throughout the floway. Flow was reset at 19 gpm at 12:30 PM after harvesting. Samplers functioned properly this week. The algal turf has been very productive, and harvesting was done today. It is expected weekly harvesting will soon become necessary. The decision to harvest next week will be made on site on 3/5/09. The first 400 feet of the floway is now dominated by a thick lawn of filamentous green algae, with the final 100 feet continuing to show a mix of diatoms, filamentous green algae.

Sloughing was negligible. The intake strainers were cleaned but not replaced. The in-situ conductivity probe was unloaded and remained in service. Lee County (Susan Fites) on site at 9:00 AM. Sampling completed by 9:45 AM. Pictures taken at 10:00 AM.

Water samples delivered to Fedex for delivery to PACE Lab by 1:30 PM. Site secured at 1:00 PM.
Field data was taken after calibration of YSI unit. DO probe not as responsive as expected. This will be addressed during the next week. Data indicates conductivity has fallen some, perhaps because of the separation from the Caloosahatchee River.

FIELD PARAMETERS

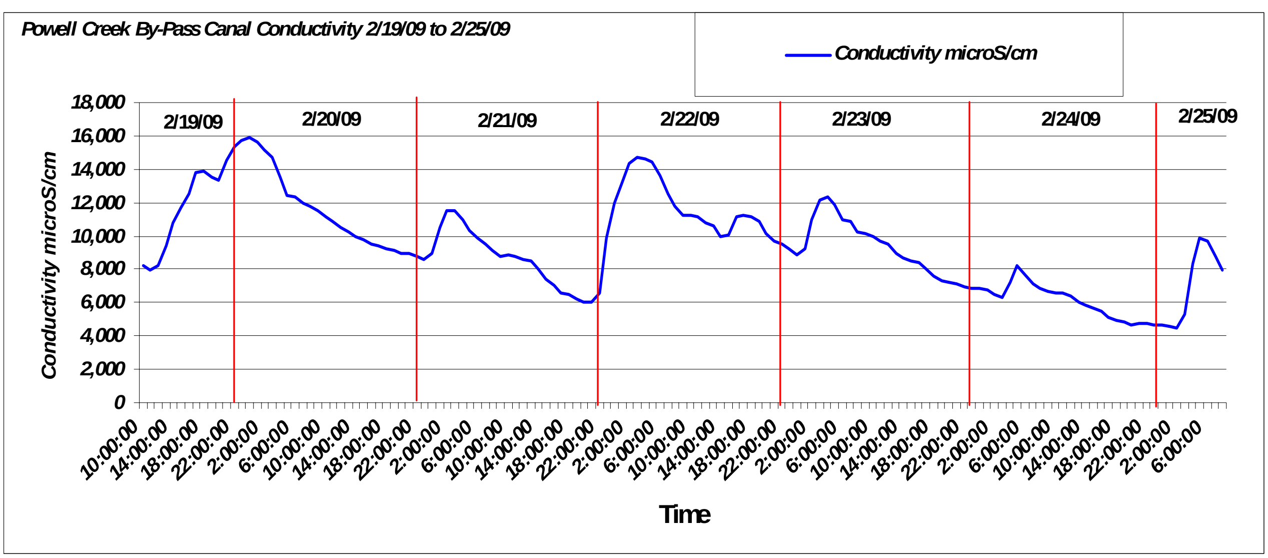
Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	9:45AM	9:45 AM
pH	7.98	8.51
DO mg/l	8.29	9.49
SC micros/cm	6,969	6,863
T deg C	19.62	20.32
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST
Harvest commenced at 10:30 AM, completed at 12:30 PM.

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	176.6	50.6	227.2
Sample Size wet g	200	200	400
Sample Size dry g	9.7	12.7	22.4
% Solids	4.85	6.35	5.60
Algae (dry lbs)	8.57	3.21	11.78

CONDUCTIVITY

Logger unloaded. Trends noted in graph below, indicate slightly lower trends than previous week. Tidal influence is noted as before. There has been no noticeable runoff, but the north canal has been surface isolated fro the Caloosahatchee to the south by the existing culverts.



WEEK 12: Thursday 3/5/09: Arrive on site 8:30 AM

(NOTE: This is a long week—8days—because of scheduling conflicts.)

The weather was calm, clear , with moderate temperature . The tide was low, with no surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 19º C. No rain was measured for the week. The floway was functioning well, and the new Mag Meter was working, showing 19 gpm. Totalized flow was 221,400 gallons, or about 19.32 gpm average for the week. There was noted very good turf recovery development throughout the floway.   Flow was kept at 19 gpm. Samplers functioned properly this week. The algal turf has been very productive, but will wait until next week to harvest. The first 400 feet of the floway is now dominated by a thick lawn of filamentous green algae, with some filamentous diatom (e.g. Melosira sp.). The final 100 feet continuing to show a mix of diatoms, filamentous green algae. Sloughing was negligible. The intake strainers were cleaned but not replaced. The in-situ conductivity probe could not be unloaded. The manufacturer will be contacted to determine the problem. Lee County on site at 9:00 AM. Sampling completed by 10:00 AM.

Water samples delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 12:00 PM. Returned to site to mow the site, and to make minor adjustments to floway.

Field data was taken at 10:15 AM after calibration of YSI unit. DO probe is functioning properly. Data indicates conductivity still comparatively high.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:15AM	10:15 AM
pH	7.99	8.78
DO mg/l	8.91	11.08
SC micros/cm	9,707	9,708
T deg C	19.15	21.19
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

No harvest this week.

CONDUCTIVITY

Logger not functioning.

WEEK 13: Thursday 3/12/09: Arrive on site 8:30 AM

The weather was calm, clear , with moderate temperature . The tide was low, with no surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 18º C. No rain was measured for the week. The floway was functioning well, and the new Mag Meter was working, showing 20 gpm. Totalized flow was 179,700 gallons, or about 17.8 gpm average for the week. There was noted heavy algal turf growth on the floway, with some indication of sloughing, and partial blockage of the floway causing some minor overflow leakage. Harvesting will need to be done weekly to avoid sloughing and overflow in the future. Flow was kept at 19 gpm. Samplers functioned properly this week. Some green filamentous algae noted to 400 feet, with thick growth in the first 100 feet. Sloughing was negligible. The intake strainers were cleaned but not replaced. The in-situ conductivity probe could not be repaired last week, and has been sent back to the manufacturer. It will be down for at least two more weeks. Lee County on site at 9:00 AM. Sampling completed by 9:45 AM.

It was noted that the County is cleaning out the canal and mowing the banks. Some suspended solids were noted in the influent grab sample. Water samples delivered to Fedex for delivery to PACE Lab by 2:30 PM. Site secured at 1:30 PM.

Field data was taken at 9:45 AM after calibration of YSI unit. DO probe appears to be functioning properly. Data indicates conductivity still comparatively high. Pictures taken down the floway.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	9:45AM	9:45AM
pH	7.70	8.01
DO mg/l	9.15	10.25
SC micros/cm	16,050	16,533
T deg C	22.37	22.69
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Harvesting commenced at 10:15 AM completed at 12:18 PM.

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	94.6	134.7	229.3
Sample Size wet g	200.1	200.2	400.3
Sample Size dry g	14.8	12.3	27.1
% Solids	7.40	6.14	6.78
Algae (dry lbs)	7.00	8.28	15.28

CONDUCTIVITY

Logger being repaired.

WEEK 14: Thursday 3/19/09: Arrive on site 9:00 AM

The weather was calm, clear , with moderate temperature . The tide was low, with no surface exchange with the Caloosahatchee River through the existing culverts. The air temperature was 20.5º C. Rain was measured for the week at 0.1 inches. The floway was functioning well, and the new Mag Meter continues to work well, showing 18 gpm. Totalized flow was 183,600 gallons, or about 18.2 gpm average for the week. There was noted healthy algal turf development on the floway following last week's harvesting. It was decided not to harvest this week. Samplers functioned properly this week. Tubing and strainers were replaced, and field and equipment blank samples taken. County crews still working on the canal. The in-situ conductivity probe has been sent back to the manufacturer. Lee County on site at 9:00 AM. Sampling completed by 10:30 AM. Water samples delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 12:00 PM.

Field data was taken at 11:00 AM after calibration of YSI unit. Data indicates conductivity has increased to over 28,000 microS/cm. Pictures taken down the floway.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	11:00AM	11:00AM
pH	7.77	8.73
DO mg/l	9.85	10.82
SC micros/cm	28,142	28,693
T deg C	22.16	27.01
Alkalinity mg/l as $CaCO_3$	>240	>240

HARVEST

No harvest this week

CONDUCTIVITY

Logger being repaired.

WEEK 15: Thursday 3/26/09: Arrive on site 9:00 AM

Note: At 8:15 AM Jim Green of Lee County Parks called to note that someone had vandalized the floway, probably during Wednesday evening. I arrived on site at 9:00 AM to find the liner and grid removed from the floway on the last 100 feet. In addition the effluent by-pass valve had been opened fully, and the influent sample valve had been closed, meaning both samplers were denied flow. Because flow could not reach the effluent box, it was overflowing onto the canal berm, and caused some erosion, and settling of some of the support legs. After sampling, the Lee County Sheriff's Department was called. Kayla Fewox of the Department arrived about noon. A statement affidavit was completed by Allen Stewart, and a case number was assigned (09-125711). The vandalized section was repaired, and the system returned to normal operation by 4:00 PM. Later that day, Mark Zivojnovich, upon reviewing the video record, found two persons on bicycles had been on site about 6:00 PM Wednesday. The Sheriff's Department was notified of the photos of these two person, and copies were submitted to the County.

At 9:00 AM the weather was cool, clear and windy. The tide was very high, with the Caloosahatchee River extending well upstream into the by-pass canal. The conductivity was noted to be about 36,000 microS/cm indicating dominance of marine waters, which would be expected considering the low rainfall amount during the past two months. The air temperature was 17º C. No rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 177,400 gallons, or about 17.6 gpm average for the week. There was noted healthy algal turf development on the floway, with some build-up at about 100 feet causing minor overflow. The floway was harvested this week, recognizing that about 100 foot of production had been lost, because of the vandalism. Samplers functioned properly this week, but the lack of flow caused disruption of the sampling, with low total volumes. In addition, the long lapse of no-flow within the effluent line, had caused die-off of aerobic organisms within the accumulated stagnant water, which was noted from the smell of the sampled effluent water. Because the composite samples were rendered unusable, grab samples for nutrients and solids were taken, after the effluent line had been flushed. It needs to be recognized that even the effluent grab sample might be impacted by the necrotic material in the line, if flushing was not adequate, so this week's water samples need to be reviewed carefully, and may in fact not be usable. It was noted that County crews were no longer working on the canal. The in-situ conductivity probe remains down, and we continue to wait for information from the manufacturer. Lee County was on site at 9:00 AM, and witnessed the results of the vandalism. Sampling was completed by 10:30 AM. Water samples delivered to Fedex for delivery to PACE Lab by 4:45 PM. Site secured at 4:10 PM.

Field data was taken at 11:00 AM after calibration of the YSI unit. Data indicates conductivity has increased to over 36,000 microS/cm. The system was harvested, which was completed by 1:00 PM. The floway and effluent lines were thoroughly flushed before the sampling sequence was initiated. The samplers were set on "run" at 4:00 PM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	11:00AM	11:00AM
pH	7.61	8.02
DO mg/l	7.70	7.75
SC micros/cm	36,212	36,699
T deg C	20.62	22.52
Alkalinity mg/l as $CaCO_3$	>240	>240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	137.8	56.1	193.9
Sample Size wet g	200	200	400
Sample Size dry g	17.2	15.6	32.8
% Solids	8.6	7.8	16.4
Algae (dry lbs)	11.85	4.38	16.23

CONDUCTIVITY
Logger being repaired.

WEEK 16: Thursday 4/2/09: Arrive on site 9:00 AM

Arrived on site at 9:00 AM. System was running normally. The weather was overcast, warm and calm. The tide was high, with the Caloosahatchee River extending well upstream into the by-pass canal. The conductivity was noted to remain at about 36,000 microS/cm indicating dominance of marine waters, which would be expected considering the low rainfall amount during the past two months. The air temperature was 21º C. 0.4 inches of rain was measured for the week. The Mag Meter continues to work well, showing 16 gpm instantaneous flow. Totalized flow was 161,700 gallons, or about 16.1 gpm average for the week. There was noted healthy algal turf development on the floway. The floway was harvested this week. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM.

Robinson Bazurto and Jesus Hernandez were on site to assist in changing oil in the pump, cleaning the pump, weed whacking the site, adjusting floway panels and repairing erosion. Harvest was completed and samples sent to Western Michigan University for analysis and processing for energy products. Water samples delivered to Fedex for delivery to PACE Lab by 4:00 PM. Site secured at 3:15 PM.

Field data was taken at 10:00 AM after calibration of the YSI unit. Data indicates conductivity remains over 36,000 microS/cm (about 22 ppt salinity). The system was harvested, which was completed by 12:20 PM. The floway and effluent lines were thoroughly flushed before the sampling sequence was initiated. The samplers were set on “run” at 3:00 PM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:00AM	10:00AM
pH	7.43	8.05
DO mg/l	6.36	7.71
SC micros/cm	36,100	35,900
T deg C	22.31	22.85
Alkalinity mg/l as $CaCO_3$	>240	>240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	78.3	41.5	119.8
Sample Size wet g	200	200	400
Sample Size dry g	15.9	22.5	38.4
% Solids	7.95%	11.25%	9.60%
Algae (dry lbs)	6.22	4.67	10.89

CONDUCTIVITY
Logger being repaired.

WEEK 17: Wednesday 4/8/09: Arrive on site 8:55 AM

Note: This is a 6 day week, because of scheduling requirements. Arrived on site at 8:55 AM. System was running normally. The weather was cool, clear, slight breeze. The tide was low, and the intake was surface isolated from the Caloosahatchee River. However, the conductivity was noted to remain at about 36,000 microS/cm indicating continued dominance of marine water. The air temperature was 15º C. at 9:00 AM, but warmed to about 25º C later in the day. No rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 138,600 gallons, or about 16 gpm average for the week. There was noted healthy algal turf development on the floway. The floway was not harvested this week. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 11:30 AM. Site secured at 11:15 AM.

Field data was taken at 11:00 AM after calibration of the YSI unit. Data indicates conductivity remains over 36,000 microS/cm (about 22 ppt salinity). The floway and effluent lines were thoroughly flushed before the sampling sequence was initiated. The samplers were set on “run” at 11:00 AM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	11:00AM	11:00AM
pH	8.04	8.45
DO mg/l	5.19	5.75
SC micros/cm	37,166	36,966
T deg C	20.91	25.11
Alkalinity mg/l as $CaCO_3$	>240	>240

HARVEST
Not Harvest

CONDUCTIVITY
Logger being repaired.

WEEK 18: Thursday 4/16/09: Arrive on site 8:55 AM

Note: This is a 8 day week, because of scheduling requirements. Arrived on site at 9:00 AM. System was running normally. The weather was warm, clear. Rainfall for the week 0.6 ". The conductivity was lower than the previous week, dropping about 15,000 microS/cm indicating influence of rainfall and attendant runoff. The Mag Meter continues to work well, showing 24 gpm instantaneous flow. Totalized flow was 263,400 gallons, or about 23 gpm average for the week. There was noted healthy but sparse algal turf development on the floway. The floway was not harvested this week. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair. Lee County was on site at 9:05 AM. Sampling was completed by 10:30 AM. Water samples delivered to Fedex for delivery to PACE Lab.

Field data was taken. Data indicates conductivity dropped to about 15,000 microS/cm . The floway and effluent lines were thoroughly flushed before the sampling sequence was initiated. The samplers were set on "run" at 11:00 AM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10:30AM	10:30AM
pH	7.44	8.01
DO mg/l	5.73	7.97
SC micros/cm	15,162	15,130
T deg C	21.51	21.58
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST
No Harvest

CONDUCTIVITY
Logger being repaired.
WEEK 19: Thursday 4/23/09: Arrive on site 8:35 AM

Arrived on site at 8:55 AM. System was running normally. The weather was warm, clear, calm. The tide was low, and the intake was surface isolated from the Caloosahatchee River. However, the conductivity was noted to have increased from the previous week to about 35,000 microS/cm indicating dominance of marine water. The air temperature was 18º C. at 9:00 AM, but warmed to about 25º C later in the day. No rain was measured for the week. The Mag Meter continues to work well, showing 22 gpm instantaneous flow. Totalized flow was 232,800 gallons, or about 23 gpm average for the week. While there was healthy algal turf development on the first 100 feet of the floway, it was noted that a species shift has occurred, with a marine type algae being abundant—this algae appears similar to Ulva sp. –with a wet "lettuce" appearance. Pictures were taken. Down the remaining floway, growth was notably sparse. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair, and will be returned shortly. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 2:00 PM. Site secured at 1:15 PM.

Field data was taken at 11:00 AM after calibration of the YSI unit. Data indicates conductivity has returned to about 35,000 microS/cm (about 22 ppt salinity). The floway and effluent lines were thoroughly flushed before the sampling sequence was initiated. The samplers were set on “run” at 1:00 PM following harvest.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	11:00AM	11:00AM
pH	8.31	8.58
DO mg/l	7.46	7.51
SC micros/cm	34,761	35,026
T deg C	23.49	26.10
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

Harvest commenced at 11:00 and was completed at 12:30 PM. As noted, the first 200 feet was represented by a healthy turf, of lower density when compared to previous weeks—with the dominant algae being an Ulva type green algae. The last 250 feet had little real turf development, rather having accumulations of diatoms and organic debris, and a very high density of amphipods. Small mollusks and occasional barnacle were noted growing on the floway liner.

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	12.0	24.5	36.5
Sample Size wet g	200	200	400
Sample Size dry g	20.8	27.6	48.4
% Solids	10.4%	13.5%	12.1%
Algae (dry lbs)	1.25	3.38	4.63

CONDUCTIVITY
Logger being repaired.

WEEK 20: Thursday 4/30/09: Arrive on site 9:00 AM

Arrived on site at 9:00 AM. System was running normally. The weather was warm, clear, calm. The tide was moderately high, and the intake was surface connected to the Caloosahatchee River. The conductivity has increased from the previous week to about 41,000 microS/cm indicating continued dominance of marine water. The air temperature was 26º C. at 9:00 AM, but warmed to about 30º C later in the day. No rain was measured for the week. The Mag Meter continues to work well, showing 21 gpm instantaneous flow. Totalized flow was 211,900 gallons, or about 21 gpm average for the week. While we were notified that the County sprayed herbicides in the canal yesterday, the algal turf community appeared very healthy, and had expanded noticeably from last week. The algal density was high to about 100 feet, then the density diminished noticeably downstream, but what was present appeared healthy. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair, and will be returned shortly. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 12:00 noon. Site secured at 11:30 PM.

Field data was taken at 10:30 AM after calibration of the YSI unit. Data indicates conductivity has increased to about 41,000 microS/cm (about 26 ppt salinity). The floway and effluent lines were thoroughly flushed and the strainers cleaned. The samplers were set on “run” at 10:00 AM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	10:30AM	10:30AM
pH	7.91	8.51
DO mg/l	6.24	6.18
SC micros/cm	41,474	41,670
T deg C	24.64	26.96
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

No harvest this week.

CONDUCTIVITY
Logger being repaired.

WEEK 21: Thursday 5/7/09: Arrive on site 8:47 AM

Arrived on site at 8:47 AM. System was running normally. The weather was warm, clear, slightly breezy. The tide was moderately high, and the intake was surface connected to the Caloosahatchee River. The conductivity has increased from the previous week to about 49,700 microS/cm indicating continued dominance of marine water. The air temperature was 25º C. at 9:00 AM, but warmed to over 30º C later in the day. No rain was measured for the week. The Mag Meter continues to work well, showing 20 gpm instantaneous flow. Totalized flow was 210,600 gallons, or just below 21 gpm average for the week. The algal density was high to about 100 feet, then the density diminished noticeably downstream, but what was present, appeared healthy. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair, and will be returned shortly. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 2:00 PM. Site secured at 1:30 PM.

Field data was taken at 10:30 AM after calibration of the YSI unit. Data indicates conductivity has increased to about 49,700 microS/cm (about 29 ppt salinity). The floway and effluent lines were thoroughly flushed and the strainers cleaned. The samplers were set on “run” after harvesting at 12:30 PM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	10:30AM	10:30AM
pH	8.25	8.66
DO mg/l	10.37	10.45
SC micros/cm	49,312	49,658
T deg C	27.06	29.01
Alkalinity mg/l as $CaCO_3$	>240	>240

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	26.0	1.8	27.8
Sample Size wet g	200	200	400
Sample Size dry g	25.9	21.2	27.8
% Solids	12.95%	10.60%	11.78%
Algae (dry lbs)	3.37	0.19	3.56

CONDUCTIVITY
Logger being repaired.

WEEK 22: Thursday 5/14/09: Arrive on site 8:35 AM

Arrived on site at 8:35 AM. System was running normally. The weather was cool, clear, slightly breezy. The tide was moderately high, and the intake was surface connected to the Caloosahatchee River. The conductivity has decreased from the previous week to about 11,000 microS/cm , a result of extensive rainfall. The air temperature was 22º C. at 9:00 AM, but warmed to over 30º C later in the day. 2.5" of rain was measured for the week. The Mag Meter continues to work well, showing 19 gpm instantaneous flow. Totalized flow was 187,100 gallons, or just below 19 gpm average for the week. The algal density had increased to about 300 feet. The density diminished noticeably the last 100 feet, but what was present, appeared healthy. The in-situ conductivity probe remains down, and we have been notified by the manufacturer that it remains under repair, and will be returned shortly. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 11:00 AM. Site secured at 10:45 AM. Pictures taken

Field data was taken at 10:30 AM after calibration of the YSI unit. Data indicates conductivity has decreased to about 11,000 microS/cm (about 8 ppt salinity). The sampling strainers were cleaned. The samplers were set on "run" at 10:30 PM.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	10:30AM	10:30AM
pH	7.78	8.56
DO mg/l	7.32	7.59
SC micros/cm	11,027	10,601
T deg C	24.81	26.62
Alkalinity mg/l as $CaCO_3$	120	120

HARVEST

No Harvest this week.

CONDUCTIVITY
Logger being repaired.

WEEK 23: Thursday 5/21/09: Arrive on site 8:35 AM

Arrived on site at 8:35 AM. System was running normally, however, slough algae had blocked the floway at about 300 feet, and some overflow was occurring. Minimal flow was entering the effluent box. It appears this sloughing occurred recently, as there was no indication of necrosis or stagnation within the effluent line. The effluent composite sample was clear. The lab results should provide indication if contamination occurred. The algae was removed, and the floway returned to normal flow. The weather was cool, overcast, slightly breezy, with a few showers. The tide was moderately high, and rising quickly. The intake was surface connected to the Caloosahatchee River. The conductivity has increased from the previous week to about 18,000 microS/cm , even though there was extensive rain. This is probably attributable to rising levels in the Caloosahatchee. We still do not have the in-situ conductivity meter in place. The manufacturer has been late in returning the unit. This matter should be resolved shortly. The air temperature was 22º C. at 9:00 AM, and remained cool throughout the day. Another 2.5” of rain was measured for the week. The Mag Meter continues to work well, showing 22 gpm instantaneous flow. Totalized flow was 213,100 gallons, or just below 22 gpm average for the week. The algal density had increased significantly throughout the floway, and appears healthy. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water samples delivered to Fedex for delivery to PACE Lab by 1:00 AM. Site secured at 12:00 noon.

Field data was taken at 10:15 AM after calibration of the YSI unit. Data indicates conductivity has increased to about 18,000 microS/cm. The sampling strainers were cleaned. The samplers were set on “run” at 11:45 PM, after harvesting . Harvest completed in about one hour.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	10:15AM	10:15AM
pH	6.95	7.53
DO mg/l	7.26	9.13
SC micros/cm	18,074	18,917
T deg C	26.39	26.42
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	90.6	67.7	158.3
Sample Size wet g	200	200	400
Sample Size dry g	21.1	23.0	44.1
% Solids	10.55%	11.50%	11.03%
Algae (dry lbs)	9.56	7.79	17.34

CONDUCTIVITY
Logger being repaired.

WEEK 24: Thursday 5/28/09: Arrive on site 9:00 AM. Sample collection by Cesar Peralta

Note: Notified by Lee County DOT that they would be herbicide spraying in the area on Friday, 5/29/09.
Arrived on site at 9:00 AM. System was running normally. The air temperature was 22º C. at 9:00 AM. Another 2.0” of rain was measured for the week. The Mag Meter continues to work well, showing 16 gpm instantaneous flow. Totalized flow was 162,700 gallons, or just above 16 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 1:00 AM. Site secured at 12:00 noon.

Allen Stewart visit the site Monday, June 1, 2009 at 3:00 PM. The algae density was high down the entire floway, with minimal sloughing. Flow was at 16 gpm. No rain noted. Field data was taken at 3:15 PM after calibration of the YSI unit. Data indicates conductivity has decreased to about 8,000 microS/cm.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	6/1/09 3:15PM	6/1/09 3:15PM
pH	8.78	9.26
DO mg/l	9.30	8.51
SC micros/cm	7,510	8,086
T deg C	31.94	34.47
Alkalinity mg/l as $CaCO_3$	-	-

HARVEST
No harvest this week

CONDUCTIVITY
Logger being repaired.

WEEK 25: Thursday 6/4/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The air temperature was 19º C. at 9:00 AM. Another 1.5" of rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 169,800 gallons, or just below 17 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 1:00 PM. Site secured at 12:30 PM.

Conductivity was noted to have dropped considerably compared to previous weeks. About 2,000 microS/cm, which is equivalent to a mineralized freshwater. Abundant algae growth in canal, and algal production on the floway was dense and healthy, with filamentous greens appearing dominant. There appears to have been an ecological shift toward more filamentous algae with the influx of freshwater. The system was harvested. Water quality was clear, with slight color.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	6/4/09 10:00AM	6/4/09 10:00 AM
pH	8.55	9.03
DO mg/l	9.36	11.29
SC micros/cm	1,525	2,062
T deg C	26.51	27.66
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	164.1	78.3	242.4
Sample Size wet g	200	200	400
Sample Size dry g	23.6	11.3	34.9
% Solids	11.80%	5.65%	8.73%
Algae (dry lbs)	19.36	4.42	23.79

CONDUCTIVITY
Logger being repaired.

WEEK 26: Thursday 6/11/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The air temperature was 25º C. at 9:00 AM. 1.75" of rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 171,900 gallons, or just above 17 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 12:30 pm

Conductivity was noted to be similar to the previous week at about 3,500 microS/cm, which is equivalent to a mineralized freshwater. Algae growth on the floway was dense and healthy, with filamentous greens continuing to show dominant. The first 250 feet of the system was harvested. Water quality was clear, with perhaps a bit more color than the previous week.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	6/11/09 10:00AM	6/11/09 10:00 AM
pH	7.29	7.72
DO mg/l	6.58	9.00
SC micros/cm	3,475	3,431
T deg C	28.92	30.04
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**		**TOTAL**
Algae (wet lbs)	59.5		59.5
Sample Size wet g	200		200
Sample Size dry g	15.9		15.9
% Solids	7.95%		7.95%
Algae (dry lbs)	4.73		4.73

CONDUCTIVITY
Repaired logger has arrived and is being programmed.

WEEK 27: Thursday 6/18/09: Arrive on site 9:00 AM.

Sampling by Cesar Peralta. Arrived on site at 9:00 AM. System was running normally. 0.75" of rain was measured for the week. The Mag Meter continues to work well, showing 16 gpm instantaneous flow. Totalized flow was 171,500 gallons, or just above 17 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 12:30 pm

FIELD PARAMETERS

No Field Parameters Taken

HARVEST

No Harvest

CONDUCTIVITY
Repaired logger has arrived and is being programmed.

WEEK 28: Thursday 6/25/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The air temperature was 27º C. at 9:00 AM. 1.30” of rain was measured for the week. The Mag Meter continues to work well, showing 14 gpm instantaneous flow. Totalized flow was 159,900 gallons, or 15.8 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Site secured at 1:45 pm

Conductivity was noted to be similar to previous week 26 at about 2,900 microS/cm, which is equivalent to a mineralized freshwater. Algae growth on the floway was dense and healthy, with filamentous greens continuing to show dominant. Some accumulated algae near the end of the floway. The entire system was harvested. Water quality was clear. The pump station was serviced and cleaned, and new tubing and sampling strainers installed. Field and tubing blanks taken.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	6/25/09 10:00AM	6/25/09 10:00 AM
pH	7.51	8.40
DO mg/l	7.84	10.30
SC micros/cm	2,945	2,933
T deg C	30.40	34.82
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	110.2	89.7	199.7
Sample Size wet g	200	200	200
Sample Size dry g	9.3	10.3	19.6
% Solids	4.65	5.15	4.90
Algae (dry lbs)	5.12	4.62	9.74

CONDUCTIVITY
Repaired logger has arrived, having difficulty with logger communications with computer.

WEEK 29: Thursday 7/2/09: Arrive on site 9:05 AM.

Arrived on site at 9:05 AM. System was running normally. The air temperature was 27º C. at 9:05 AM. The sky was overcast, with some rain later in the day. 3.5” of rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 177,100 gallons, or 17.6 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 9:45 AM. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Sampling line was repaired, as it had become clogged with mussels. Also the sampling riser was replaced, allowing incoming water to enter from above, thereby preventing solids accumulation.

Conductivity was noted to be much lower than the previous week, at about 500 microS/cm, which is a freshwater. Algae growth on the floway was healthy, with filamentous greens continuing to show dominance in the first 150 feet, with blue green algae becoming noticeable over the last 350 feet. Some accumulated algae near the end of the floway. The thought is that the blue-greens are indicative of nitrogen fixation, and a low N:P ratio—both of which have been observed in recent weeks. The floway is clearly making an adjustment to freshwater conditions. Effluent quality is clear, and high in dissolved oxygen, indicating good algae production. Note the County Sprayed the Canal on 6/30/09.

FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	7/2/09 10:00AM	7/2/09 10:00 AM
pH	8.05	9.77
DO mg/l	9.42	12.12
SC micros/cm	527	480
T deg C	27.26	30.61
Alkalinity mg/l as $CaCO_3$	180	240

HARVEST

No harvest for the week.

CONDUCTIVITY

Repaired logger has been programmed, and unit set in place in the field.

WEEK 30: Thursday 7/9/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The air temperature was 30º C. at 9:05 AM. The sky was clear, sunny. No rain was measured for the week. The Mag Meter continues to work well, showing 18 gpm instantaneous flow. Totalized flow was 192,100 gallons, or 19.1 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. It was noted that the new influent sampling riser resulted in the strainer being above water level part of the week, so several influent composite samples were missed. This was corrected. Water delivered to Fedex for delivery to PACE Lab by 12:00 noon.

Conductivity was noted to be similar but higher than the previous week, at about 1100 microS/cm, which is a freshwater. Algae growth on the floway was healthy, with filamentous greens continuing to show dominance in the first 150 feet, with blue green algae becoming very noticeable over the last 350 feet. Effluent quality is clear, and high in dissolved oxygen, indicating good algae production.

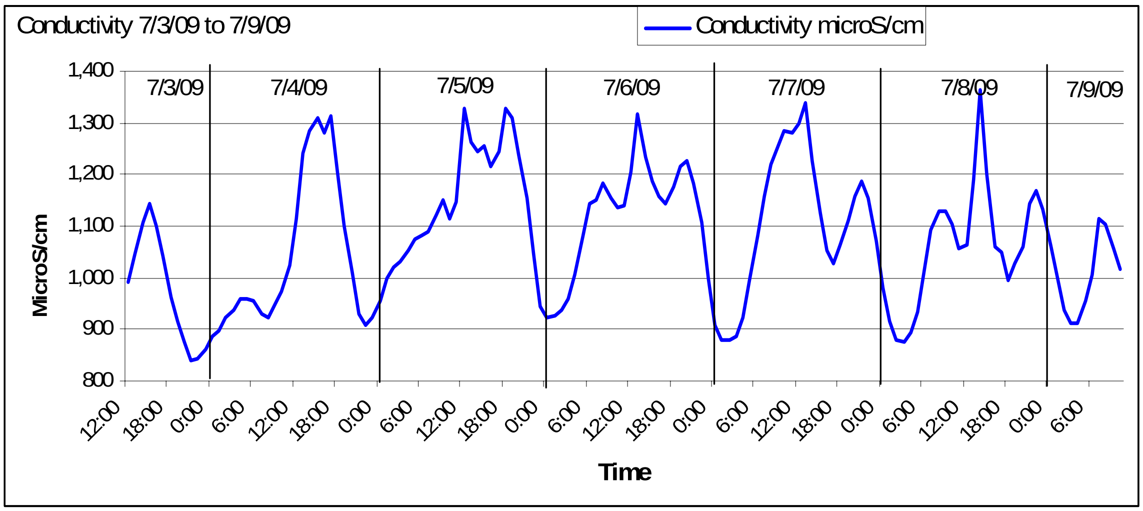
FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	7/9/09 10:00AM	7/9/09 10:00 AM
pH	7.98	8.30
DO mg/l	7.60	9.14
SC micros/cm	890	861
T deg C	28.98	31.65
Alkalinity mg/l as $CaCO_3$	240	200

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	111.2	107.2	218.4
Sample Size wet g	200	200	200
Sample Size dry g	11.3	12.0	23.3
% Solids	5.65%	6.00%	5.83%
Algae (dry lbs)	6.23	5.38	11.61

CONDUCTIVITY



WEEK 31: Thursday 7/16/09: Arrive on site 9:00 AM.

Sampling by Cesar Peralta. Arrived on site at 9:00 AM. System was running normally. The sky was clear, sunny. 0.4 “ of rain was measured for the week. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 175,000 gallons, or 17.4 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 12:00 noon.

Conductivity on 7/20/09 was noted to be slightly lower than the previous week, at about 900 microS/cm, which is still freshwater. Algae growth on the floway was healthy, with filamentous greens continuing to show dominance in the first 150 feet, with blue green algae becoming dominant over the last 350 feet. The blue-green growth has caused the grid to be lifted from the liner, resulting in flows beneath the top of the algal turf. The blue-green development is possibly stimulated by a low N/P ratio, with the blue-green turf likely fixing nitrogen to some extent. Effluent quality is clear. Conductivity probe was unloaded by Allen Stewart on Saturday 7/18/09. Field parameters were taken Monday 7/20/09. On Saturday the influent riser was reconfigured to ensure the strainer is always submerged.

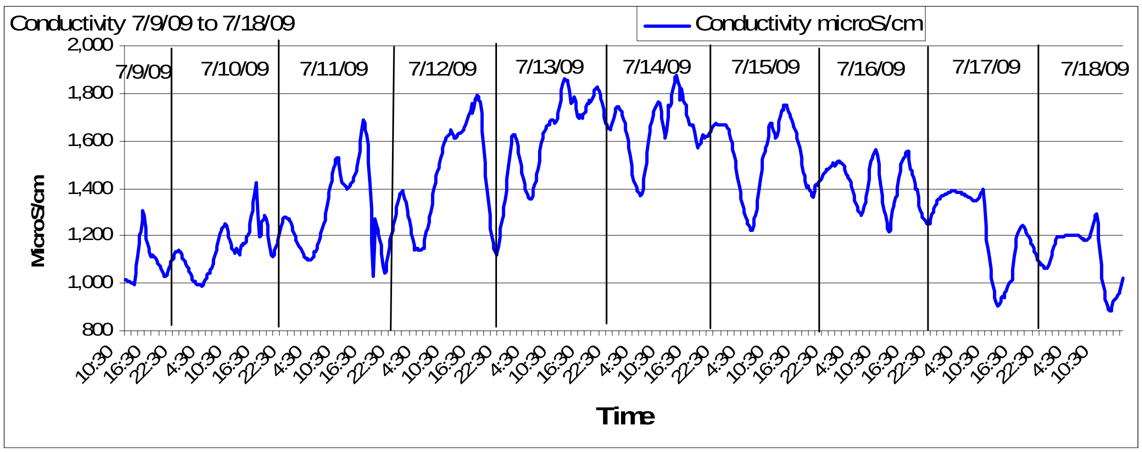
FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	7/20/09 3:00PM	7/20/09 3:00 PM
pH	7.75	8.26
DO mg/l	9.48	12.52
SC micros/cm	958	867
T deg C	28.93	30.81
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

No Harvest

CONDUCTIVITY



WEEK 32: Thursday 7/23/09: Arrive on site 9:00 AM.

Sampling by Cesar Peralta. Arrived on site at 9:00 AM. System was running normally. The sky was clear, sunny. 0.8 " of rain was measured for the week. The Mag Meter continues to work well, showing 16 gpm instantaneous flow. Totalized flow was 169,500 gallons, or 16.8 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

Conductivity was noted to be similar to previous week, at about 900 microS/cm. Algae growth on the floway was healthy, with filamentous greens continuing to show dominance in the first 150 feet, with blue green algae becoming dominant very over the last 350 feet. Effluent quality is clear. Conductivity probe was unloaded by Allen Stewart. Field parameters were taken Sunday 7/26/09.

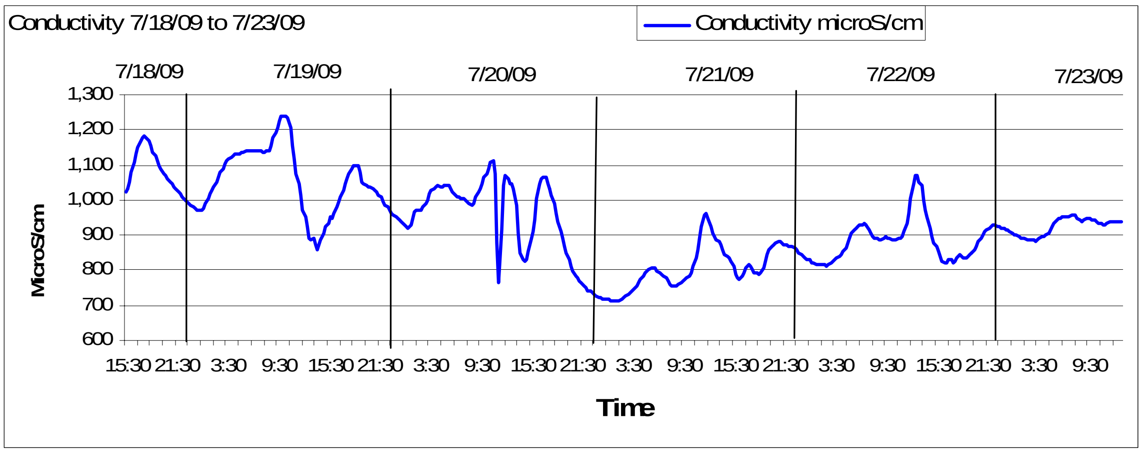
FIELD PARAMETERS

Parameter	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	7/26/09 12:00noon Note: Overcast, light rain	7/26/09 12:00 noon
pH	8.41	8.75
DO mg/l	7.39	9.26
SC micros/cm	815	805
T deg C	27.49	27.73
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	125.2	68.6	203.8
Sample Size wet g	200	200	200
Sample Size dry g	12.9	10.1	23.0
% Solids	6.45	5.05	5.75
Algae (dry lbs)	8.08	3.46	11.54

CONDUCTIVITY



WEEK 33: Thursday 7/30/09: Arrive on site 8:45 AM.

Arrived on site at 8:45 AM. System was running normally. The sky was clear, warm, sunny. 0.5 " of rain was measured for the week. The Mag Meter continues to work well, showing 14 gpm instantaneous flow. Totalized flow was 145,700 gallons, or 14. gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

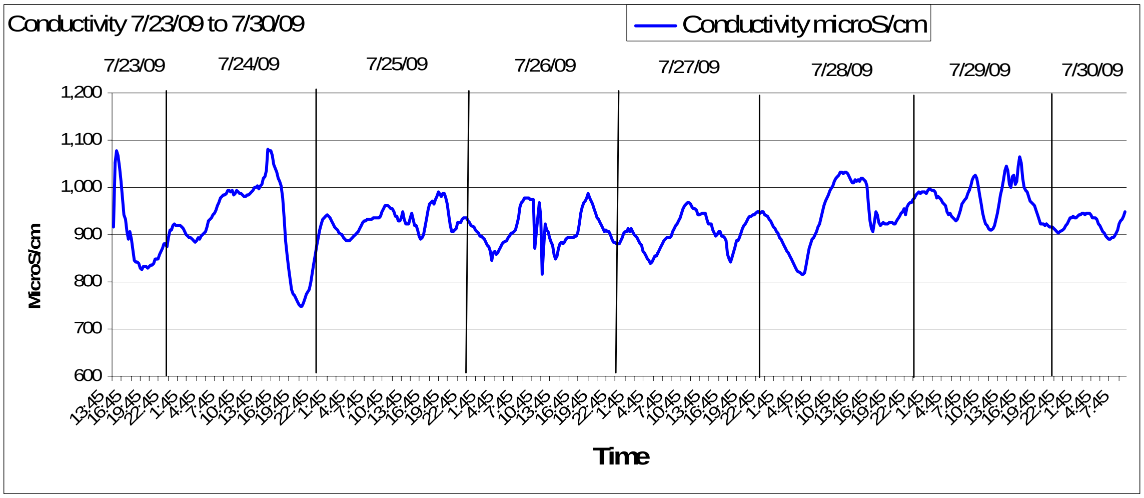
Conductivity was noted to be similar to previous week, at about 900 microS/cm. Algae growth on the floway was healthy, with filamentous greens now showing dominance all the way down the floway. Blue-greens were scarce. Effluent quality is clear. Conductivity probe was unloaded by Allen Stewart. Pump was pulled and intake cleaned. Flow returned to about 20 gpm.

FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent riser)
Time	7/30/09 10:00 AM	7/30/09 10:00 AM
pH	8.15	8.64
DO mg/l	6.84	9.20
SC micros/cm	876	881
T deg C	29.23	30.83
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST
No Harvest

CONDUCTIVITY



WEEK 34: Thursday 8/6/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The sky was overcast, warm, 1.3 " of rain was measured for the week. Rain began today after sampling completed. Lawn mowed. The Mag Meter continues to work well, showing 17 gpm instantaneous flow. Totalized flow was 191,000 gallons, or 18.9 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

Field sampling done on Saturday, 8/8/09. Conductivity was noted to be similar to previous week, at about 900 microS/cm. Algae growth on the floway remains healthy, with filamentous greens showing dominance all the way down the floway. Blue-greens remain scarce. Effluent quality is clear. Conductivity probe was unloaded by Allen Stewart.

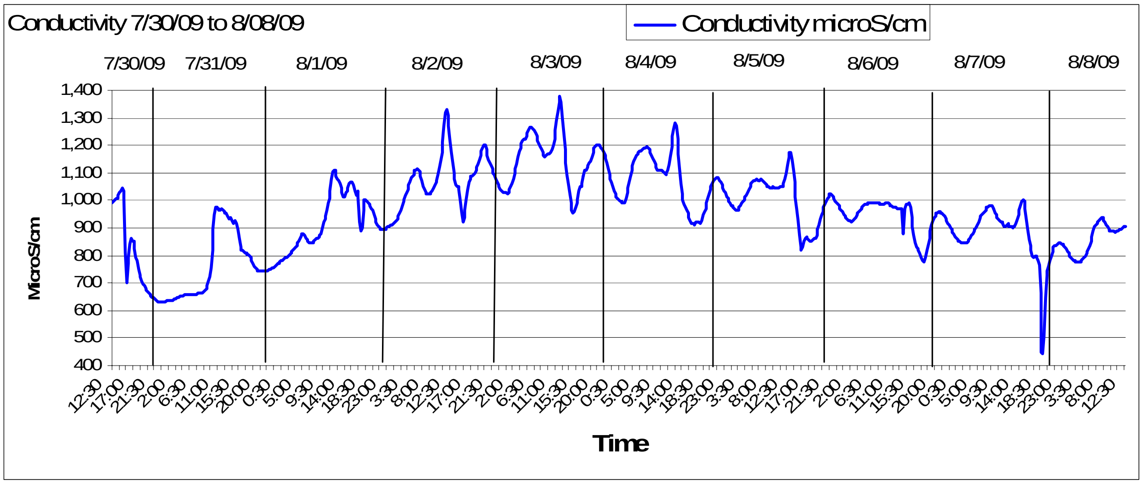
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent box)
Time	8/8/09 12:00 noon	8/8/09 12:00 noon
pH	8.04	8.98
DO mg/l	7.11	10.41
SC micros/cm	877	814
T deg C	30.14	36.42
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	194.7	84.3	279.0
Sample Size wet g	200	200	200
Sample Size dry g	12.9	10.1	23.0
% Solids	6.45	5.05	5.75
Algae (dry lbs)	12.56	4.26	16.82

CONDUCTIVITY



WEEK 35: Thursday 8/13/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. The sky was clear, warm, 3 " of rain was measured for the week. The Mag Meter continues to work well, showing 18 gpm instantaneous flow. Totalized flow was 178,300 gallons, or 17.7 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

Conductivity was noted to be similar, but slightly higher than previous week, at about 1,000 microS/cm. Algae growth on the floway remains healthy, with filamentous greens showing dominance all the way down the floway. Blue-greens remain scarce. Effluent quality is clear. Conductivity probe was unloaded by Allen Stewart. System was harvested.

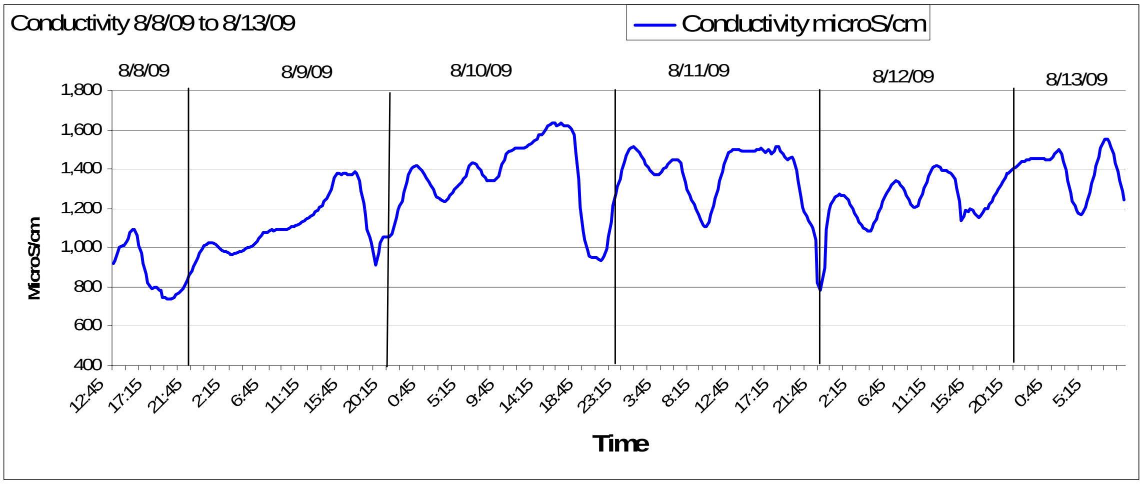
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent riser)
Time	8/13/09 10:30 AM	8/13/09 10:30 AM
pH	8.09	8.74
DO mg/l	5.74	8.71
SC micros/cm	1,127	988
T deg C	29.94	31.55
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	102.3	84.3	186.6
Sample Size wet g	200	200	200
Sample Size dry g	10.4	8.8	19.2
% Solids	5.2	4.4	4.8
Algae (dry lbs)	5.32	3.70	9.02

CONDUCTIVITY



WEEK 36: Thursday 8/20/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally. Cesar Peralta doing sampling. There was 2.9 " of rain measured for the week. The Mag Meter continues to work well, showing 16 gpm instantaneous flow. Totalized flow was 178,300 gallons, or 17.7 gpm average for the week. Lee County was on site at 9:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

FIELD PARAMETERS

No field parameters run this week

HARVEST

No harvest this week

CONDUCTIVITY

Conductivity will be down loaded next week

WEEK 37: Thursday 8/27/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, although the pump station was surrounded by a grass island.. The County had sprayed herbicides in the canal the previous Friday. Also noted was a minor overflow area where algae growth had accumulated about 50 feet down the floway There was also heavy rain for the week---6". In combination, these two factors probably caused the movement of these islands. The pump was only delivering 12 gpm. Later in the day it was cleared somewhat and returned to about 19 gpm. Flow for the week was 149,100 gallons or 14.8 gpm. The sky was partly cloudy, warm, about 35 C at 9:30 AM. As noted 6 " of rain was measured for the week. Lee County was on site at 9:00 AM. Two other representatives visited the site about 9:30 AM to view the facility. They left about 10:00 AM. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 PM.

Conductivity was noted to be similar to the week of 8/13/09, but higher than previous week, at about 1,200 microS/cm. In spite of the herbicide application, algae growth on the floway appeared healthy, with filamentous greens showing dominance all the way down the floway. Blue-greens remain scarce. Effluent quality is clear, although likely because of the heavy rains for the week, and perhaps because of the spraying, there were some small filaments noted in the effluent composite sample. Conductivity probe was unloaded by Allen Stewart. System was harvested.

FIELD PARAMETERS

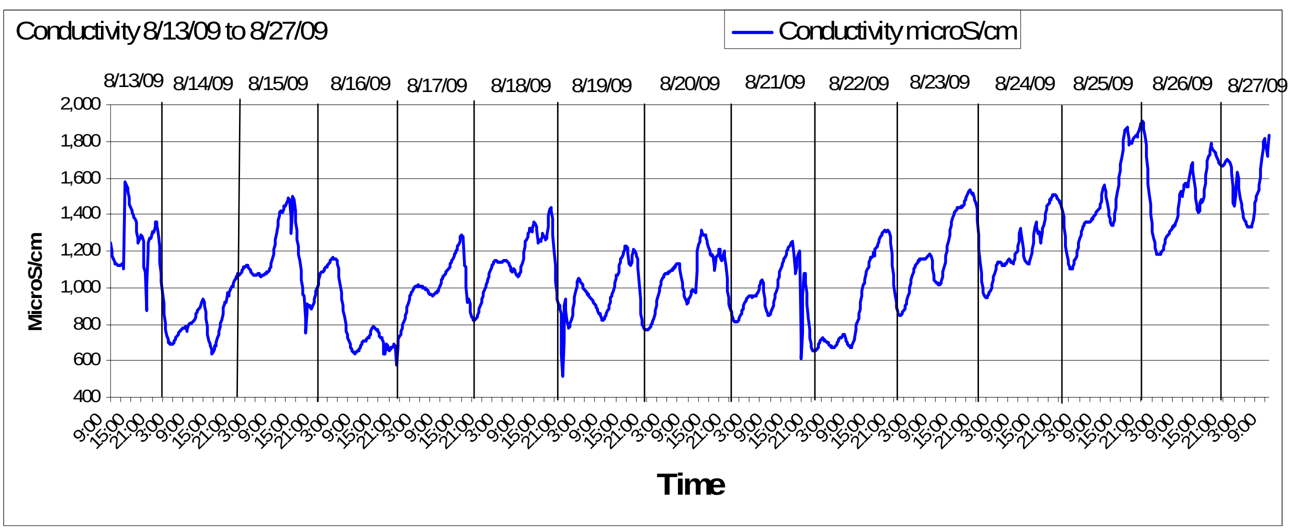
	Influent (at Surge Spout)	Effluent (At Effluent box)
Time	8/27/09 2:00 PM after harvest	8/27/09 2:00 PM after harvest
pH	7.87	8.22
DO mg/l	7.12	7.82
SC micros/cm	1,295	1,072
T deg C	30.67	31.29
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	147.2	123.4	270.7
Sample Size wet g	200	200	200
Sample Size dry g	19.9	21.3	41.2
% Solids	9.95	10.65	10.30
Algae (dry lbs)	14.66	13.14	27.80

CONDUCTIVITY

In-situ graph shown below shows the influence of two heavy rain events—one early AM 8/19/09 and one late evening 8/21/09. There is a slight upward trend towards the end of the week.



WEEK 38: Thursday 9/3/09: Arrive on site 8:50 AM.

Arrived on site at 8:50 AM. System was running normally, although the flow was reduced to 12 gpm. Algal turf appeared healthy. There was heavy rain for the week---4". Sky clear, warm. Low tide. Flow for the week was 128,200 gallons or 12.7 gpm. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 12:00 noon.

Conductivity was noted to be slightly higher than the previous week, at about 1,600 microS/cm. Algae growth on the floway appeared healthy, but the growth was somewhat lower over the week. This may relate to the herbicide spraying the previous week. Filamentous greens showing dominance all the way down the floway. Blue-greens remain scarce. Effluent quality is clear. The pump intake screen was cleaned, which increased output. Pump rate reset at about 17 gpm.

FIELD PARAMETERS

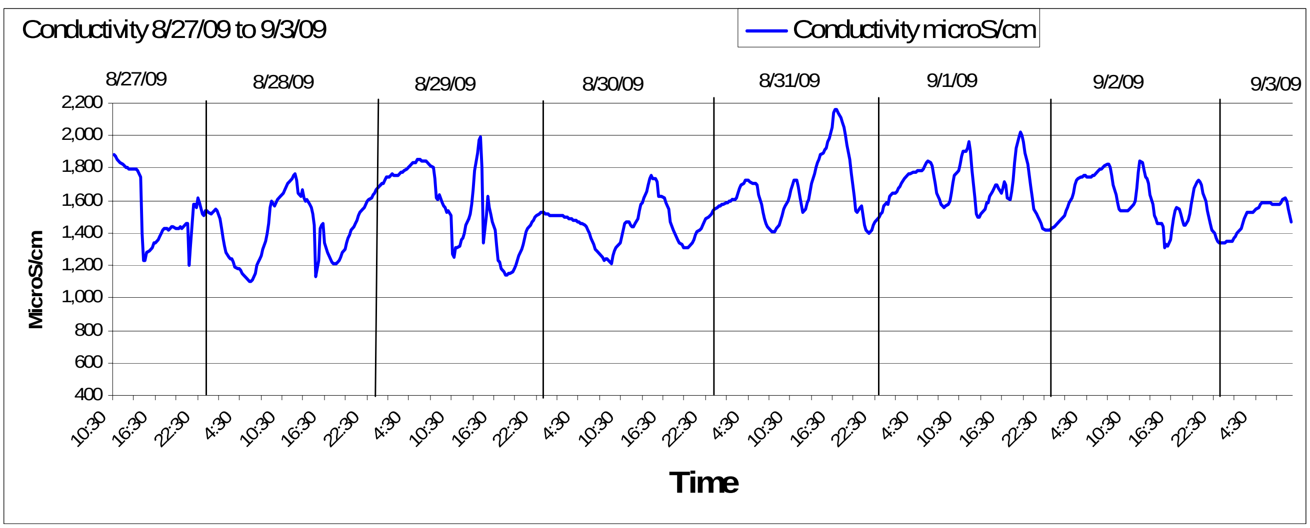
	Influent (at Surge Spout)	Effluent (At Effluent sample riser)
Time	9/4/09 10:30 AM	9/4/09 10:30 AM
pH	7.78	8.53
DO mg/l	7.34	9.38
SC micros/cm	1,222	1,147
T deg C	27.68	32.00
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

No Harvest

CONDUCTIVITY

In-situ graph shown below shows upward movement of conductivity, with major rain events well marked at late 8/27/09; about 2:00 pm 8/28/09 and 2:00 PM 8/29/09.



WEEK 39: Thursday 9/10/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, the flow was 20 gpm. Algal turf appeared healthy. There was 1” of rain for the week. Sky clear, warm. High tide. Flow for the week was 203,700 gallons or 20.1 gpm. Field duplicates and blanks sampled, and tubing changed. Sampling was completed by 11:00 AM. Water delivered to Fedex for delivery to PACE Lab by 1:30 pm.

Conductivity was noted to be about the same as the previous week, maybe a bit lower, at about 1,300 microS/cm. Algae growth on the floway appeared healthy. Filamentous greens showing dominance in the lower half of the floway. A mixture of greens and blue-greens were noted in the first half. Effluent quality is clear. The pump intake screen was cleaned, which increased output. Pump rate reset at about 20 gpm.

FIELD PARAMETERS

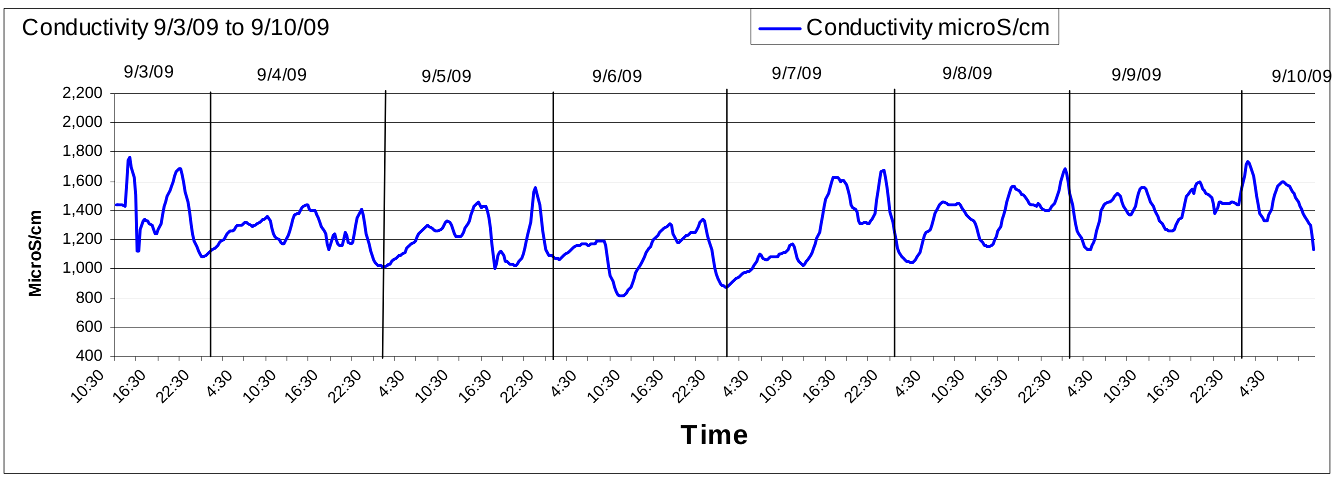
	Influent (at Surge Spout)	Effluent (At Effluent sample riser)
Time	9/11/09 @3:00 PM	9/11/09 @3:00 PM
pH	7.57	8.02
DO mg/l	9.49	10.21
SC micros/cm	968	1,003
T deg C	31.06	30.47
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	102.1	115.0	217.1
Sample Size wet g	200	200	400
Sample Size dry g	25.2	18.0	43.2
% Solids	12.60	9.00	10.8
Algae (dry lbs)	12.86	10.35	23.21

CONDUCTIVITY

In-situ graph shown below shows a slight downward movement of conductivity compared to previous week. No major rain events noted.



WEEK 40: Thursday 9/17/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, the flow was 17 gpm. Algal turf appeared healthy. There was 2.35” of rain for the week. Sky overcast, warm. Low tide. Flow for the week was 187,900 gallons or 18.6 gpm. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm.

Conductivity was noted to be somewhat lower than the previous week, averaging 1,055 microS/cm. Algae growth on the floway appeared healthy. Filamentous greens showing dominance in the floway. Effluent quality is clear. The pump intake screen was cleaned, which increased output. Pump rate reset at about 17 gpm.

FIELD PARAMETERS

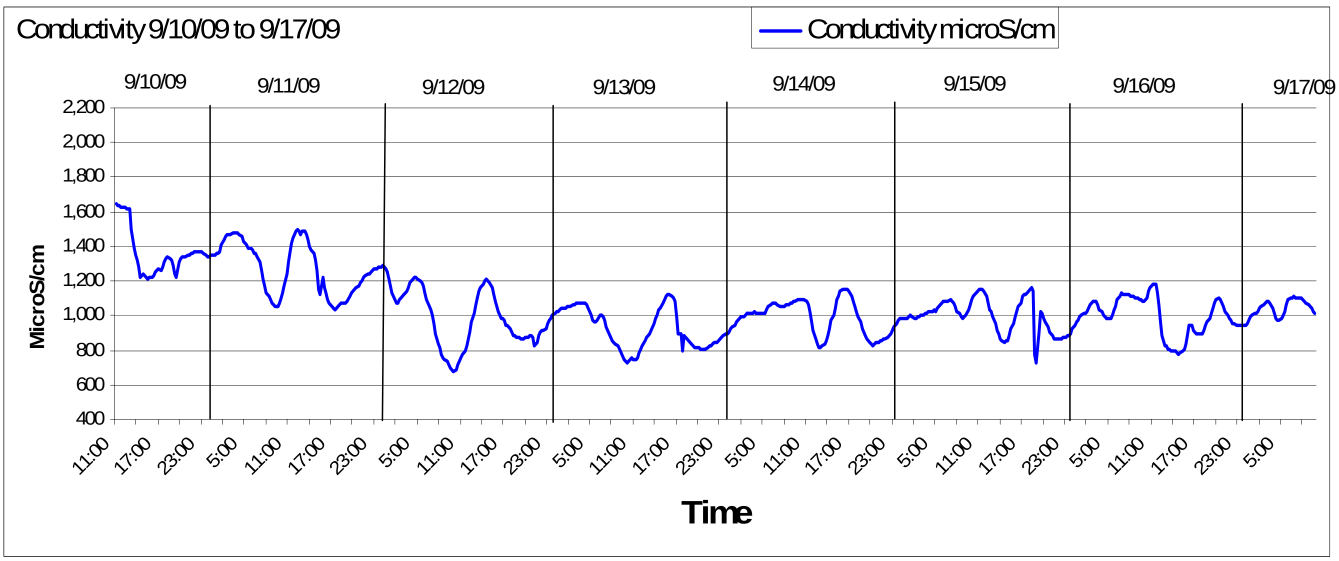
	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	9/17/09 @12:00 noon	9/17/09 @12:00 noon
pH	7.56	8.20
DO mg/l	6.46	9.18
SC micros/cm	1015	1,008
T deg C	28.89	31.21
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

No harvest

CONDUCTIVITY

In-situ graph shown below shows a slight downward movement of conductivity compared to previous week. Rain events noted 9/15 evening and 9/12 morning, and possibly 9/16/09 afternoon.



WEEK 41: Thursday 9/24/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, the flow was 12 gpm. The 3" sampling line appeared to be clogged, and minimal flow was entering the sampling riser. It is possible this may impact effluent sample quality. Algal turf appeared healthy. There was 0.30" of rain for the week. Sky clear, warm. high tide. Flow for the week was 149,200 gallons or 14.8 gpm. Pump intake cleaned, and rate reset at 20 gpm. System harvested. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm.

Returned to site to flush effluent sampling line. Failed to get complete clearance. Will return tomorrow.

Conductivity was noted to be similar to the previous week, averaging 1,144 microS/cm. Algae growth on the floway appeared healthy. Blue-greens noted in first 250 feet, filamentous greens showing dominance in the last 250 feet. Effluent quality is clear.

FIELD PARAMETERS

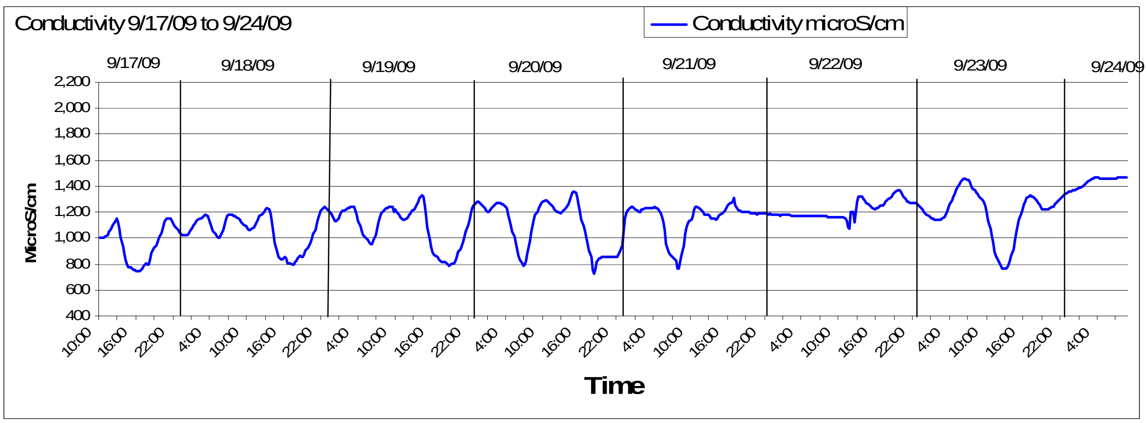
	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	9/24/09 @10:00 AM	9/24/09 @10:00 AM
pH	7.33	10.17
DO mg/l	6.74	8.00
SC micros/cm	1138	929
T deg C	29.61	32.05
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	88.5	112.9	201.4
Sample Size wet g	200	200	400
Sample Size dry g	17.7	20.1	37.8
% Solids	8.85%	10.05%	9.45%
Algae (dry lbs)	7.83	12.35	20.18

CONDUCTIVITY

In-situ graph shown below shows steady conductivity, until 9/21/09. This appears to be when the effluent line became blocked.



WEEK 42 : Thursday 10/1/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running, however the effluent sampling line remained clogged, making the composite samples invalid. Grab samples were taken. A backwash system was set-up, and the line was cleared. The blockage appeared to be from an accumulation of small clams which resembled corbicula. Flow was 23 gpm, totalized flow for the week was 258,700 or 25.7 gpm. Algal turf appeared healthy. There was 0.30" of rain for the week. Sky clear, cooler, low tide. Sampling was completed by 10:00 AM. Water delivered to Fedex for delivery to PACE Lab by 3:00 pm.

Conductivity was noted to be similar to the previous week. The in-situ readings reflect the influence of the effluent line being clogged on 9/28/09. Algae growth on the floway appeared healthy. Blue-greens diminishing.

FIELD PARAMETERS

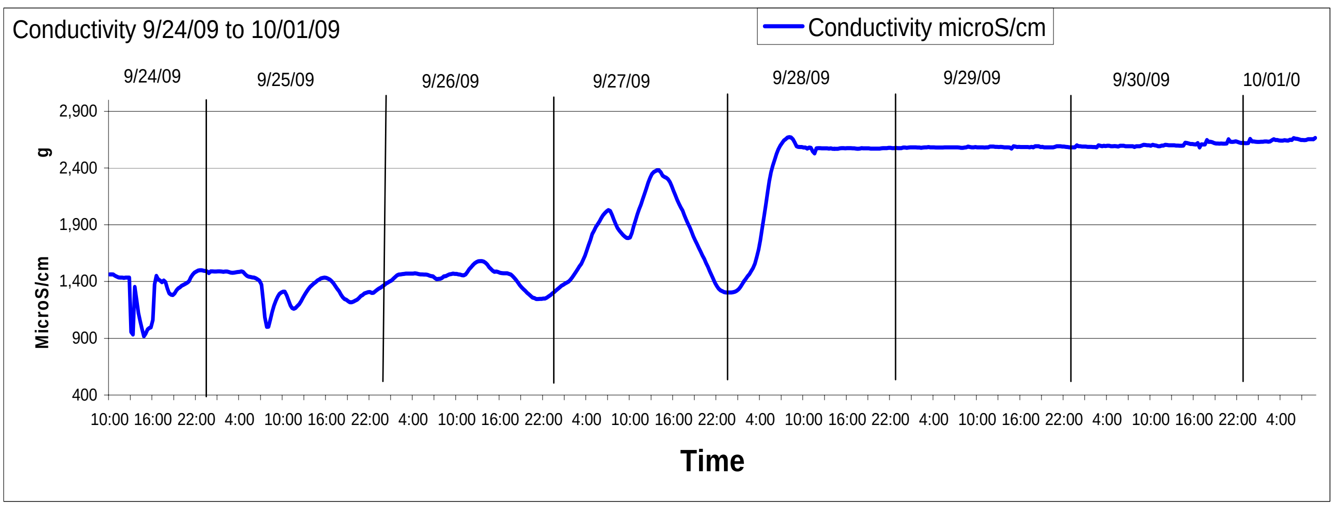
	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10/1/09 @10:30 AM	10/1/09 @10:30 AM
pH	6.53	8.02
DO mg/l	9.96	14.76
SC micros/cm	1456	1385
T deg C	24.38	27.73
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

No harvest

CONDUCTIVITY

In-situ graph shown below shows typical conductivity patterns, until 9/28/09. This appears to be when the effluent line became blocked.



WEEK 43: Thursday 10/8/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, effluent line clogged with sloughed algae, contaminating the effluent composite sample. A screen was placed in front of the effluent outlet to prevent future clogging. Composite samples drawn, but also grab samples taken. The flow was 22 gpm. Totalized flow was 202,900 or 20.5 gpm or 20.1 gpm. . Algal turf appeared healthy. There was no rain for the week. Sky clear, warm. high tide. Sampling was completed by 10:00 AM. Effluent line flushed, new plumbing allows line flushing. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm.

Conductivity was noted to average 2,138 microS/cm, somewhat higher than the previous week. Algae growth on the floway appeared healthy. Filamentous greens showing dominance in the floway. Effluent quality is clear. Pump rate reset at about 19 gpm.

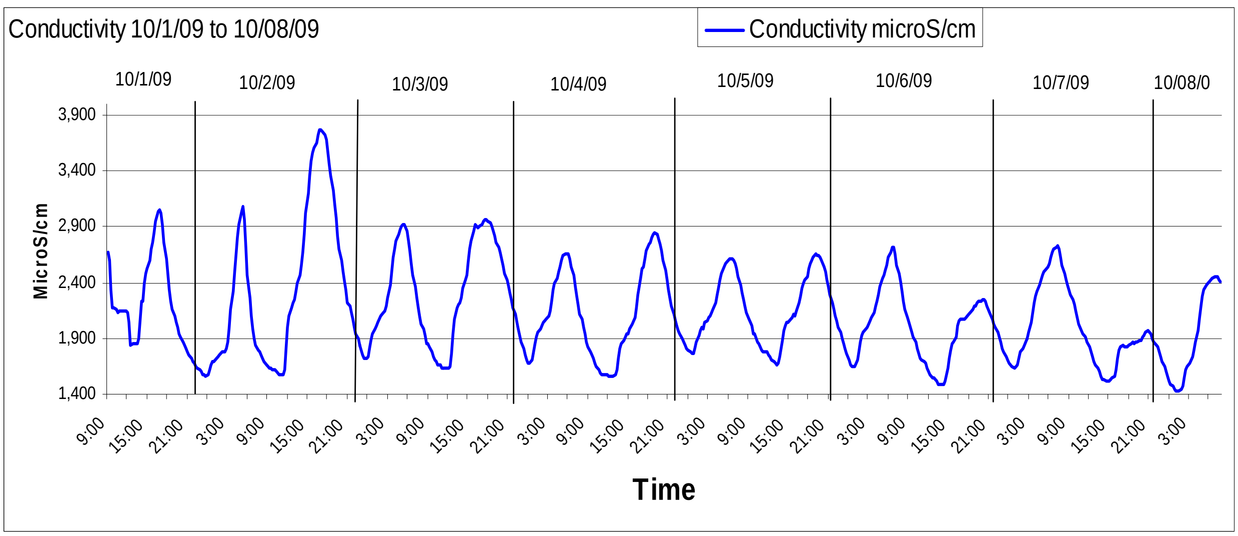
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10/8/09 @10:00 noon	10/8/09 @10:00 noon
pH	7.29	8.00
DO mg/l	6.97	9.98
SC micros/cm	1530	1577
T deg C	29.4	31.37
Alkalinity mg/l as $CaCO_3$	180	180

HARVEST

Distance (ft)	0-250	250-500	TOTAL
Algae (wet lbs)	103.4	107.2	210.6
Sample Size wet g	200	200	400
Sample Size dry g	15.8	19.3	35.1
% Solids	7.9	9.65	8.78
Algae (dry lbs)	8.17	10.34	18.51

CONDUCTIVITY



WEEK 44: Thursday 10/15/09: Arrive on site 9:00 AM.

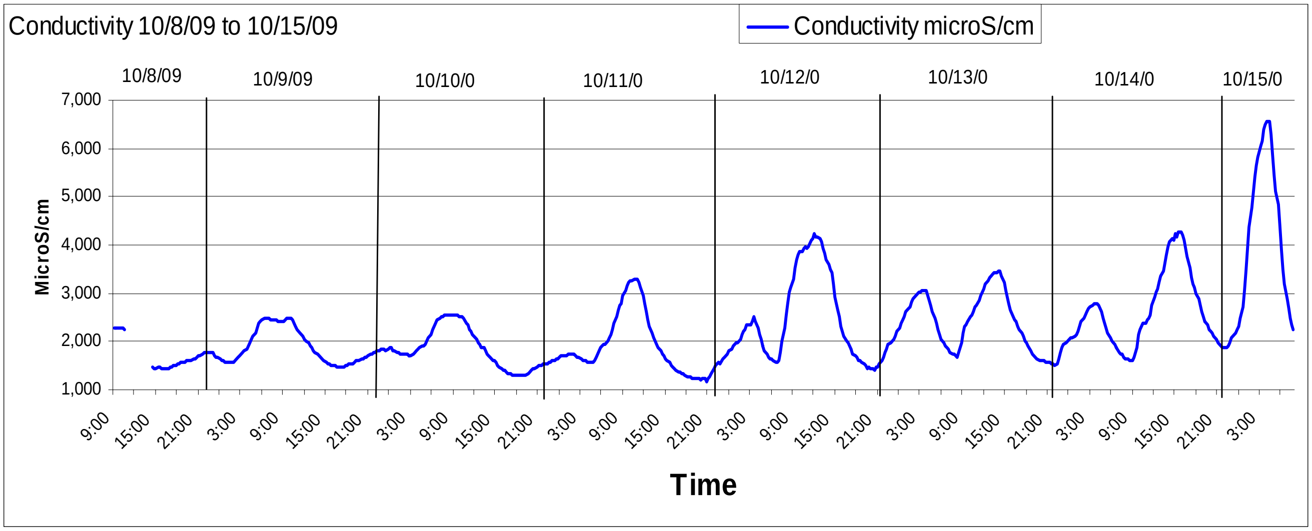
Sampling by Cesar Peralta. Arrived on site at 9:00 AM. System was running normally, effluent screen cleaned.   The flow was 20 gpm. Totalized flow was 195,400 or 19.4 gpm. Algal turf appeared healthy. There was no rain for the week. Sky clear, warm. high tide. Sampling was completed by 10:00 AM. Effluent line flushed, new plumbing allows line flushing. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm.

At 2,250 microS/cm the conductivity was slightly higher on average than the previous week. A notable increase was noted at the end of the week.

FIELD PARAMETERS
No parameters taken

HARVEST
No harvest

CONDUCTIVITY



WEEK 45: Thursday 10/22/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, effluent screen cleaned.   The flow was 17 gpm. Totalized flow was 183,600 or 18.2 gpm. Algal turf appeared healthy. Filamentous seen for last 100 feet. O-400 feet mix of filamentous green, blue-green, and diatoms. There was no rain for the week. Sky clear, cool. high tide. Sampling was completed by 10:00 AM. Effluent and influent lines flushed. Flow reset to 20 gpm. System harvested. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm. Conductivity increased substantially to an average of 4,613 microS/cm, indicating influence from onset of dry season. Tidal influence is also very noticeable.

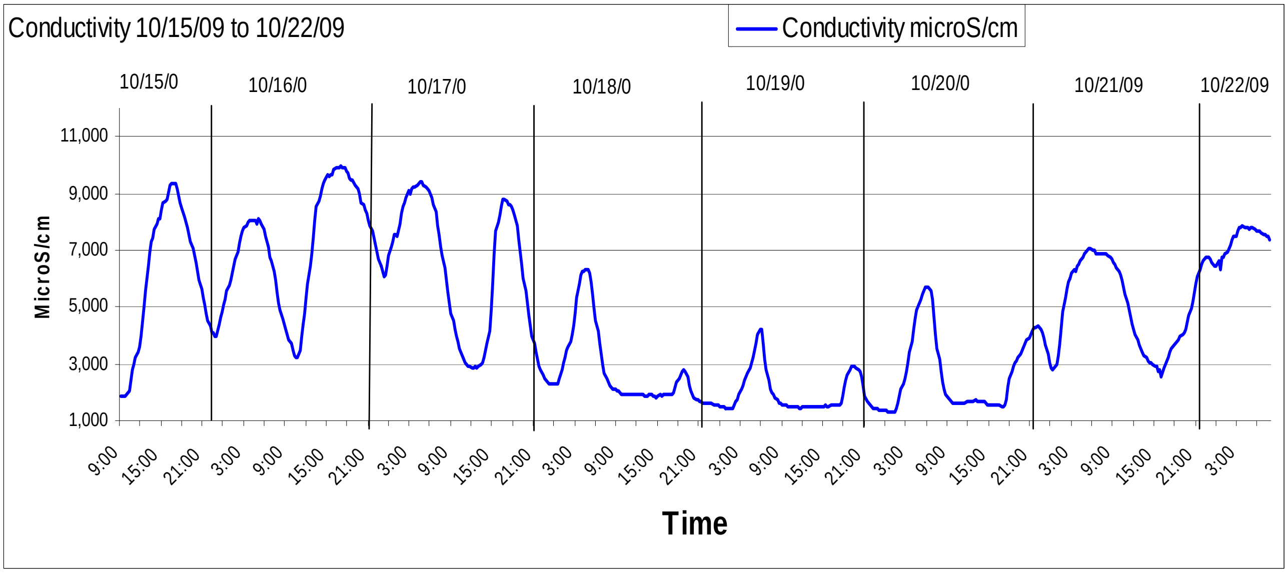
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent Box)
Time	10/22/09 @10:00 AM	1022/09 @10:00 AM
pH	7.16	7.39
DO mg/l	8.21	13.48
SC micros/cm	7056	7474
T deg C	24.43	25.22
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	84.1	151.2	235.3
Sample Size wet g	200	200	400
Sample Size dry g	19.9	21.6	41.5
% Solids	9.95	10.80	10.38
Algae (dry lbs)	8.37	16.73	24.70

CONDUCTIVITY



WEEK 46: Thursday 10/29/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, effluent screen cleaned. The flow was 17 gpm. Totalized flow was 171,400 or 17.0 gpm. Algal turf appeared healthy. Filamentous seen for last 100 feet. O-400 feet mix of filamentous green, blue-green, and diatoms. There was no rain for the week. Sky clear, cool. low tide. Sampling was completed by 10:00 AM. Effluent and influent lines flushed. Flow reset to 18 gpm. System not harvested. Water delivered to Fedex for delivery to PACE Lab by 1:00 pm. Video camera reset via ATT. Conductivity increased substantially again to an average of 9.078 microS/cm, indicating continued influence from onset of dry season. Tidal influence is also very noticeable.

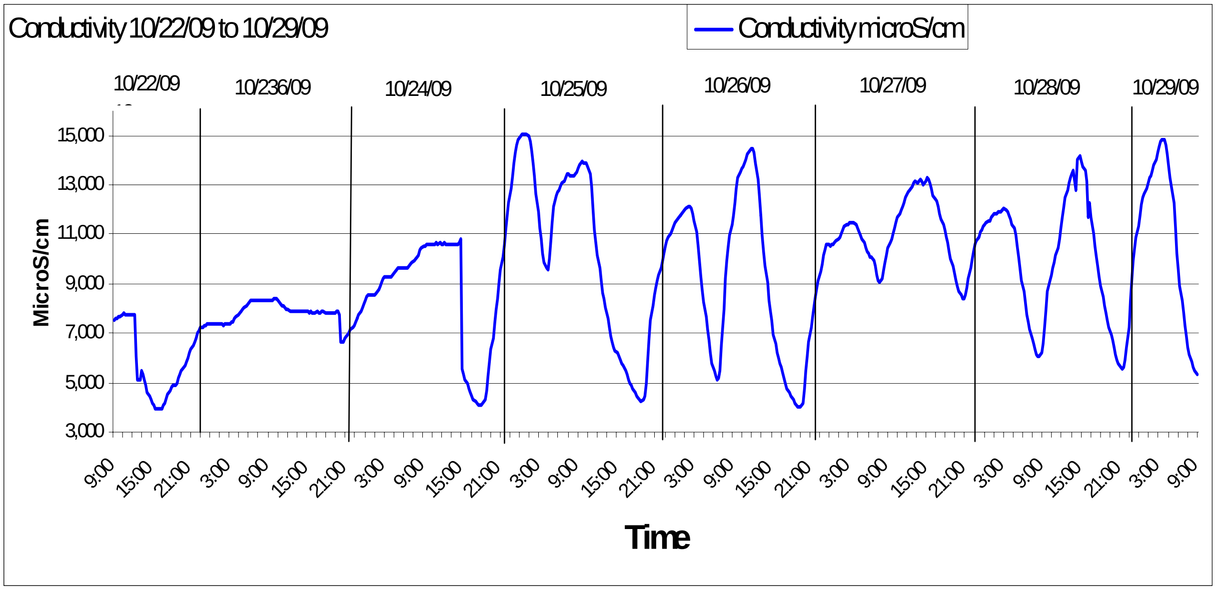
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent Riser)
Time	10/29/09 @10:00 AM	10/29/09 @10:00 AM
pH	6.93	7.15
DO mg/l	9.94	13.66
SC micros/cm	6886	5347
T deg C	26.48	27.50
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

No Harvest

CONDUCTIVITY



WEEK 47: Thursday 11/05/09: Arrive on site 8:45 AM.

Arrived on site at 8:45 AM. System was running normally, effluent screen cleaned. A large number of clams had accumulated on the screen. The flow was 14 gpm. Totalized flow was 159,100 or 15.8 gpm. Algal turf appeared healthy. Heavy filamentous production seen for last 100 feet. O-400 feet mix of filamentous green, blue-green, and diatoms. There was no rain for the week. Sky cloudy, breezy, cool, low tide. Pictures Taken. Sampling was completed by 10:00 AM. Effluent and influent lines flushed. Pump cleaned. Flow reset to 20 gpm. System harvested. Water delivered to Fedex for delivery to PACE Lab by 1:30 pm. Video camera functional. Conductivity increased substantially again to an average of 12,609 microS/cm, indicating continued influence from onset of dry season. Tidal influence is also very noticeable.

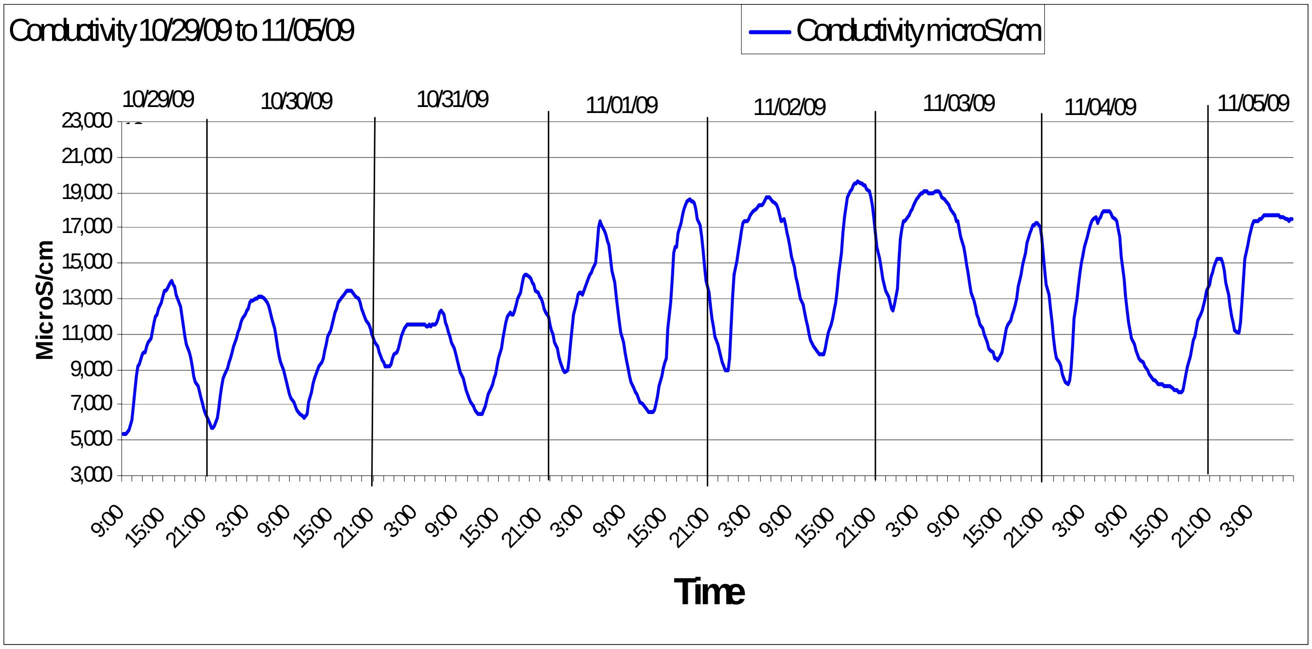
FIELD PARAMETERS

	Influent (at Surge Spout After Harvest)	Effluent (At Effluent Box After Harvest)
Time	11/05/09 @11:30 AM	11/05/09 @11:30 AM
pH	7.00	7.99
DO mg/l	7.74	9.30
SC micros/cm	8,035	8,145
T deg C	26.66	28.66
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	50.7	228.6	279.3
Sample Size wet g	200	200	400
Sample Size dry g	15.5	18.1	33.6
% Solids	7.75	9.05	8.40
Algae (dry lbs)	3.93	20.69	24.62

CONDUCTIVITY



WEEK 48: Thursday 11/12/09: Arrive on site 8:45 AM.

Arrived on site at 8:45 AM. System was running normally, effluent screen cleaned. A large number of clams had accumulated on the screen. The flow was 26 gpm. Totalized flow was 267,600 or 26.5 gpm. Algal turf appeared healthy. Heavy filamentous production seen for last 100 feet. O-400 feet mix of filamentous green, blue-green, and diatoms. There was 0.6" of rain for the week. Sky cloudy, breezy, cool, low tide. Sampling was completed by 10:00 AM. Effluent and influent lines flushed. Flow reset to 20 gpm. Water delivered to Fedex for delivery to PACE Lab by 12:00 noon. Video camera functional. Conductivity similar to last week with an average of 12,389 microS/cm. Tidal influence is also very noticeable.

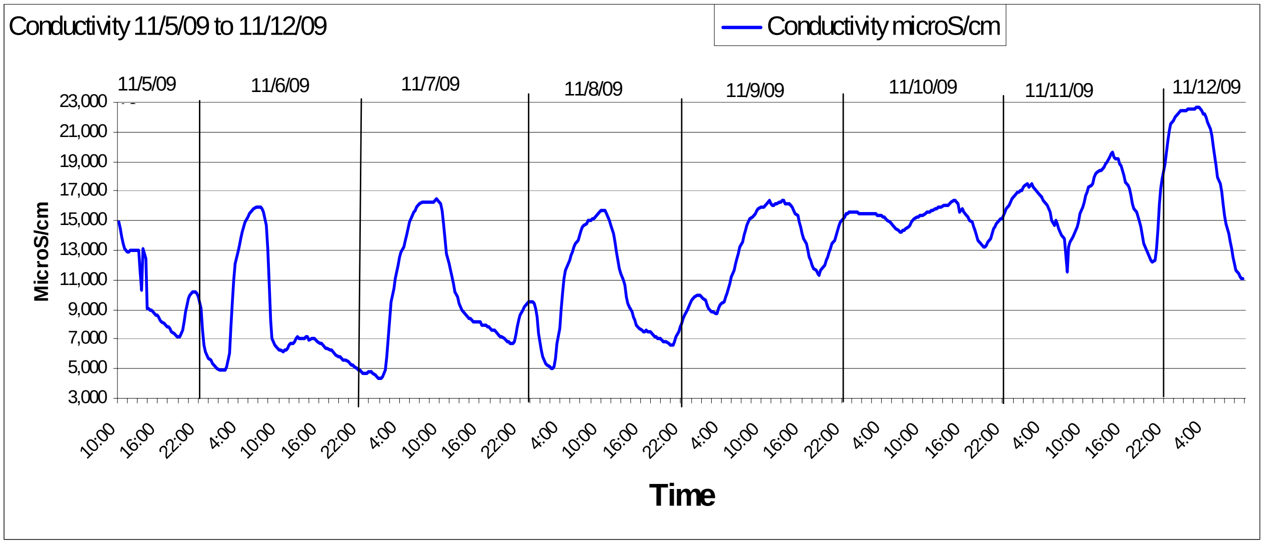
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent Box After Harvest)
Time	11/12/09 @10:00 AM	11/05/09 @11:30 AM
pH	6.95	7.24
DO mg/l	6.58	7.06
SC micros/cm	15,786	13,642
T deg C	22.77	21.18
Alkalinity mg/l as $CaCO_3$	200	200

HARVEST

No harvest

CONDUCTIVITY



WEEK 49: Thursday 11/19/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. System was running normally, effluent screen cleaned. A large number of clams had accumulated on the screen, and a great deal of sloughed algae The flow was 22 gpm. Totalized flow was 237,600 or 23.6 gpm. Algal turf appeared healthy. There appeared to be some shift in communities, with heavy filamentous green algae now in the first 50 feet. Blue-greens dominated from 100-400 feet, with the last 100 feet in filamentous diatoms and a few green filaments. Shift likely in response to salinity shifts. There was no rain for the week. Sky foggy, calm, cool, warming up as the fog cleared later in the day. Low tide. Sampling was completed by 10:00 AM. Effluent and influent lines flushed. Flow reset to 19 gpm. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Video camera functional. Conductivity much higher than previous week with an average of 18,730 microS/cm. Tidal influence is also very noticeable.

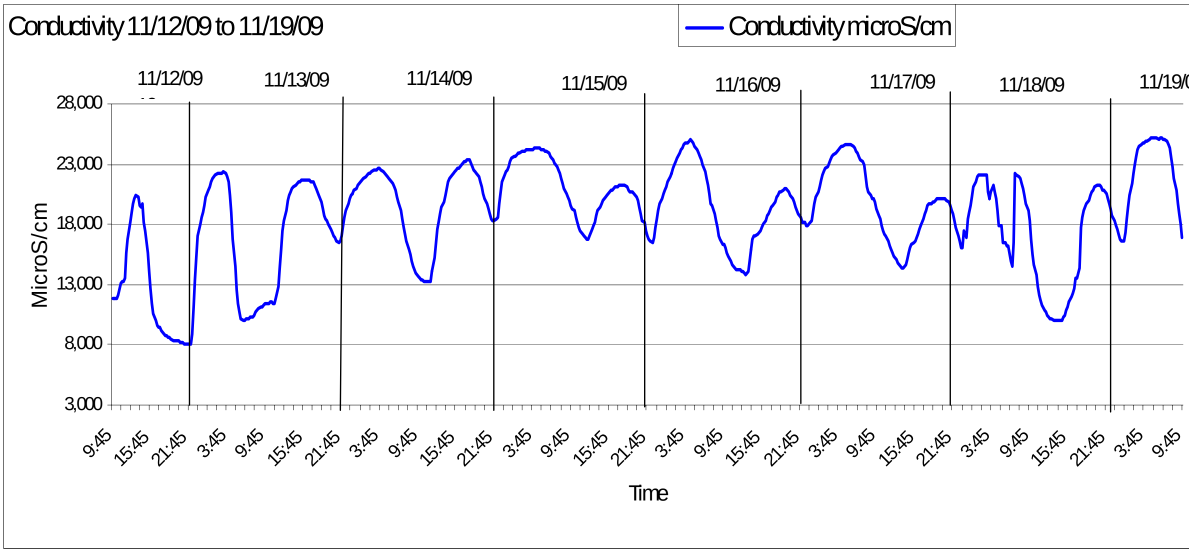
FIELD PARAMETERS

	Influent (at Surge Spout)	Effluent (At Effluent Box After Harvest)
Time	11/12/09 @10:00 AM	11/05/09 @11:30 AM
pH	7.67	7.74
DO mg/l	7.68	9.83
SC micros/cm	13,769	13,957
T deg C	21.65	22.90
Alkalinity mg/l as $CaCO_3$	240	240

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	50.9	104.4	155.3
Sample Size wet g	200	200	400
Sample Size dry g	13.2	17.4	30.6
% Solids	6.60%	8.70%	7.65%
Algae (dry lbs)	3.36	9.08	12.44

CONDUCTIVITY



WEEK 50: Tuesday 11/24/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. Cesar Peralta conducting sampling. County on site. This was a short week because of Thanksgiving (five days). System was running normally, effluent screen cleaned. The flow was 19 gpm. Totalized flow was 136,600 or 19.0 gpm. Algal turf appeared healthy. There was 0.2" rain for the week. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Video camera functional. No field parameters or harvesting this week. Conductivity data could not be downloaded from datalogger.

WEEK 51: Thursday 12/3/09: Arrive on site 9:00 AM.

Arrived on site at 9:00 AM. County on site. System was running normally,but pump was delivering only about 12 gpm. The effluent screen was cleaned. The flow was 12 gpm. Totalized flow was 201,200 or 15.5 gpm. Algal turf appeared healthy. There was 0.75" rain for the week. Pump screen cleaned. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. Video camera functional. No field parameters or harvesting this week. Conductivity data could not be downloaded from datalogger.

WEEK 52: Thursday 12/10/09: Arrive on site 9:00 AM.

Final week of sampling. Sampling by Robinson Bazurto. Arrived on site at 9:00 AM. Pump was running fine. Water was overflowing at the effluent box due to the algal screen was clogged by a significant amount of algae. Effluent auto sampler bottle had a substantial amount of filamentous algae on the bottom.

Algal growth in the system was strong along the floway. Brown filamentous algae was present from 0 ft until 500 ft; the brown filamentous could be green filamentous algae covered by different species of diatoms. There were also a few spots that show green slime algae that may be blue green filamentous algae. There were 2.8" of rain for the period. The flow was 22 gpm. Totalized flow was 188,300 or 18.7 gpm for the period. System Harvested. Water delivered to Fedex for delivery to PACE Lab by 12:30 PM. (Note: In-situ Conductivity Monitor not functional after Week 49). Conductivity data could not be downloaded from datalogger.

FIELD PARAMETERS

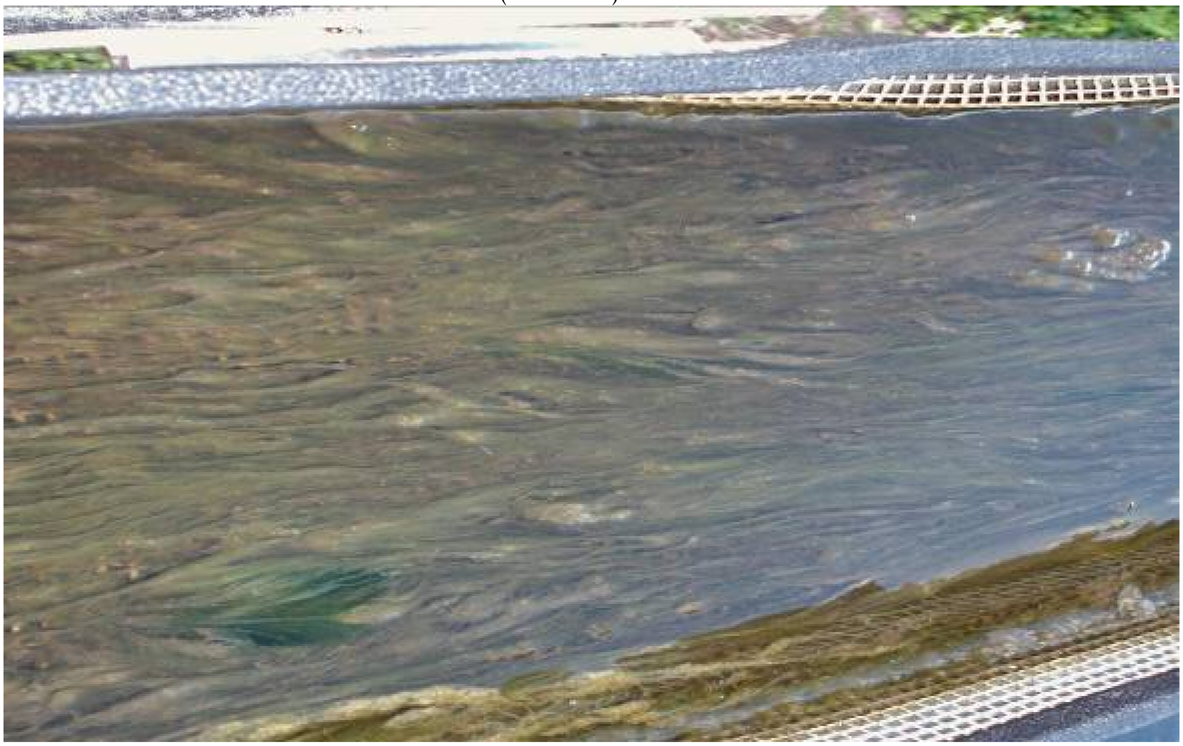
	Influent	Effluent
Time	9:00 AM	9:30 AM
pH	7.70	8.97
DO mg/l	2.44	13.78
SC micros/cm	9,128	7,702
T deg C	23.9	24.8

HARVEST

Distance (ft)	**0-250**	**250-500**	**TOTAL**
Algae (wet lbs)	110	134.4	155.3
Sample Size wet g	200	200	400
Sample Size dry g	19.1	15.7	34.8
% Solids	9.55%	7.85%	8.70%
Algae (dry lbs)	10.51	10.52	21.03

APPENDIX C. FEBRUARY 2009 SHIFT OF DOMINANT ALGAE

POWELL CREEK ATS™ PILOT 12/18/08 (WEEK 2)



AT SURGER

100 feet

200 feet

300 feet


400 feet

500 feet

POWELL CREEK ATS™ PILOT 12/29/08 (WEEK 3) TEN DAYS FOLLOWING HARVEST

AT SURGER

100 feet


200 feet


300 feet


400 feet


500 feet

POWELL CREEK ATS™ PILOT 1/22/09 (WEEK 6) TEN DAYS FOLLOWING HARVEST

AT SURGER PRE-SURGE

AT SURGER DURING SURGE

100 feet


200 feet


300 feet

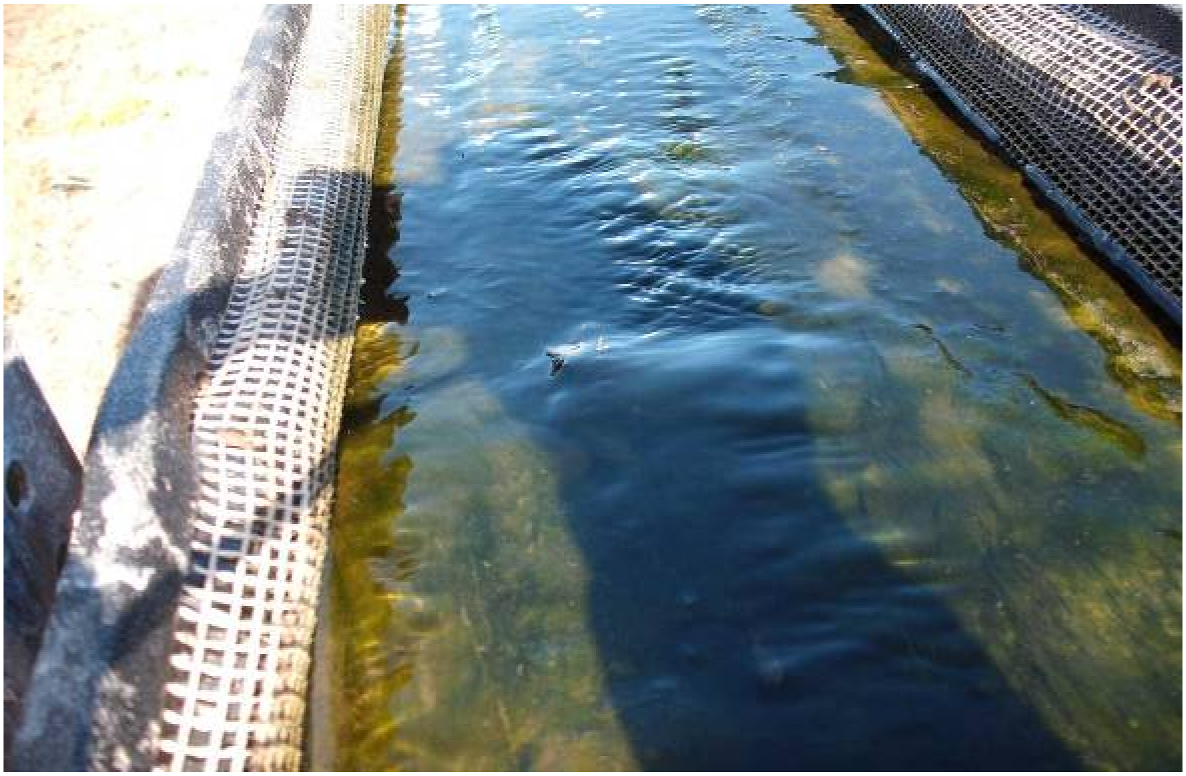

400 feet


500 feet

POWELL CREEK ATS™ PILOT 1/29/09 (WEEK 7) SEVENTEEN DAYS FOLLOWING HARVEST

AT SURGER DURING SURGE

100 feet


200 feet


300 feet

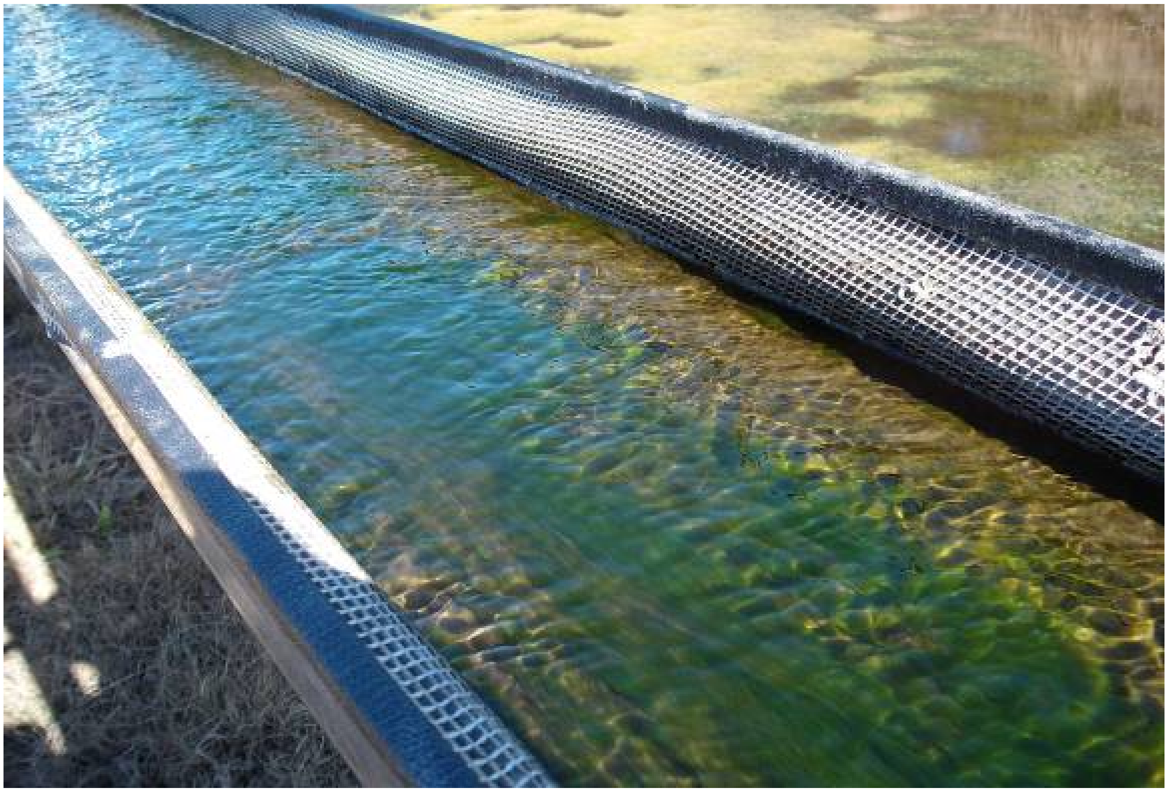

400 feet


500 feet

POWELL CREEK ATS™ PILOT 2/5/09 (WEEK 8) SEVEN DAYS FOLLOWING HARVEST

AT SURGER

100 feet


200 feet


300 feet


400 feet


500 feet

POWELL CREEK ATS™ PILOT 2/19/09 (WEEK 10) SEVEN DAYS FOLLOWING HARVEST


AT SURGER


100 feet


200 feet


300 feet


400 feet


500 feet

POWELL CREEK ATS™ PILOT 2/19/09 (WEEK 10) and 2/25/09 (WEEK 11) 7 AND 13 DAYS FOLLOWING HARVEST

2/19/09 AT SURGER

2/25/09 AT SURGER

2/19/09 100 feet

2/25/09 100 feet

2/19/09 200 feet

2/25/09 200 feet


2/19/09 300 feet


2/25/09 300 feet


2/19/09 400 feet


2/25/09 400 feet


2/19/09 500 feet


2/25/09 500 feet

POWELL CREEK ATS™ PILOT 3/12/09 (WEEK 13) 14 DAYS FOLLOWING HARVEST

3/12/09 AT SURGER

3/12/09 100 feet


3/12/09 200 feet

3/12/09 300 feet


3/12/09 400 feet

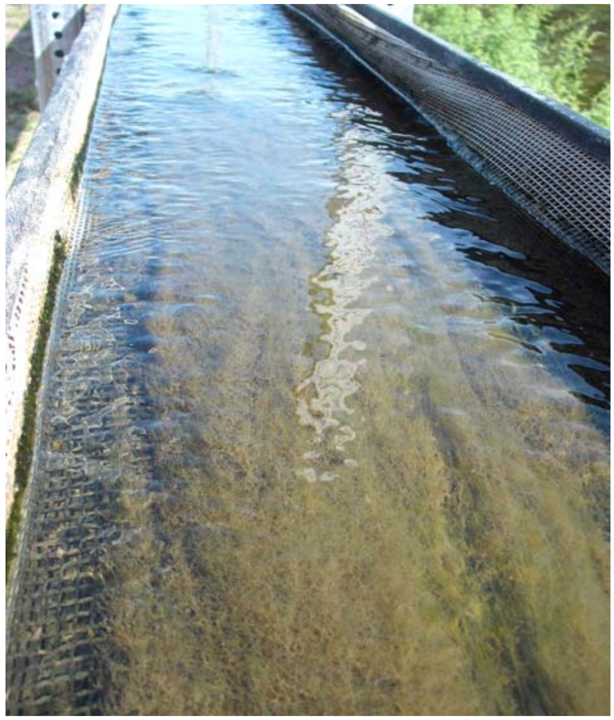

3/12/09 500 feet

POWELL CREEK ATS™ PILOT 5/14/09 (WEEK 22) 7 DAYS FOLLOWING HARVEST, ONE DAY PAST 2.5" RAINSTORM

5/14/09 AT SURGER

5/14/09 100 feet

5/14/09 200 feet



5/14/09 300 feet

5/14/09 400 feet

5/14/09 500 feet

Powell Creek 6/2/09 Conductivity at 2,000 microS/cm
Photos taken after 14 days production

Surger

100 ft


200 ft


300 ft


400 ft

Powell Creek ATS™ Floway 8/10/09

Surger

100 ft


200 ft

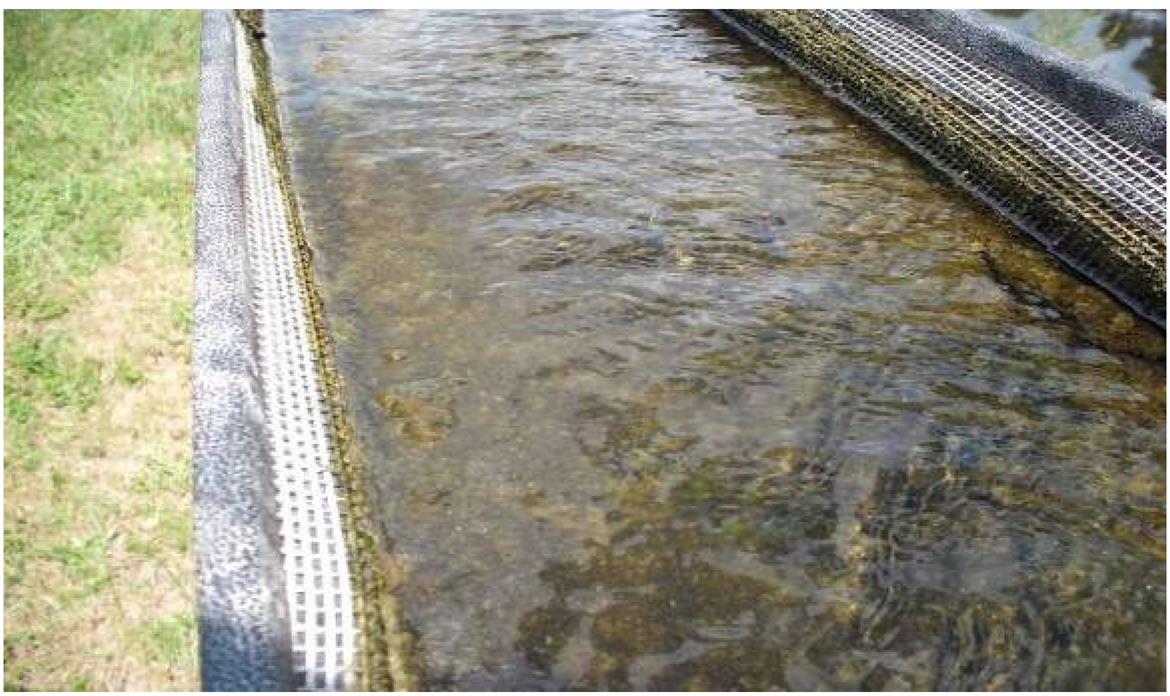

300 ft


400 ft


500 ft

Powell Creek ATS™ Floway 9/7/09

Surger



100 ft


200 ft


300 ft


400 ft


500 ft

POWELL CREEK ATS™ PILOT 11/5/09/09 (WEEK 47) 14 DAYS FOLLOWING HARVEST

11/5/09 AT SURGER

11/5/09 100 feet


11/5/09 200 feet

11/5/09 300 feet


3/12/09 400 feet

11/5/09 500 feet

APPENDIX D. FEBRUARY 2009 ALGAE IDENTIFICATION ANALYSIS

APPENDIX D Algae ID
Powell Creek

By the species composition, it is noted that there is a slightly elevated salt content (brackish water) in the system (ex: *Enteromorpha* sp., *Melosira nummoloides*, *Gyrosigma* sp., etc.). At the top portion (0-120 ft.) of the system, Chlorophyceae (*Enteromorpha* sp. and *Microspora* sp.) was dominant, due to their size in comparison to the others however, several species of diatoms and a *Phormidium* sp. were still abundant. As the analysis continued down the system, it was noticed that there was a shift to a more diatom dominant system, with both chlorophytes and cyanobacteria rare to frequent.

Powell Creek
12-Feb-09

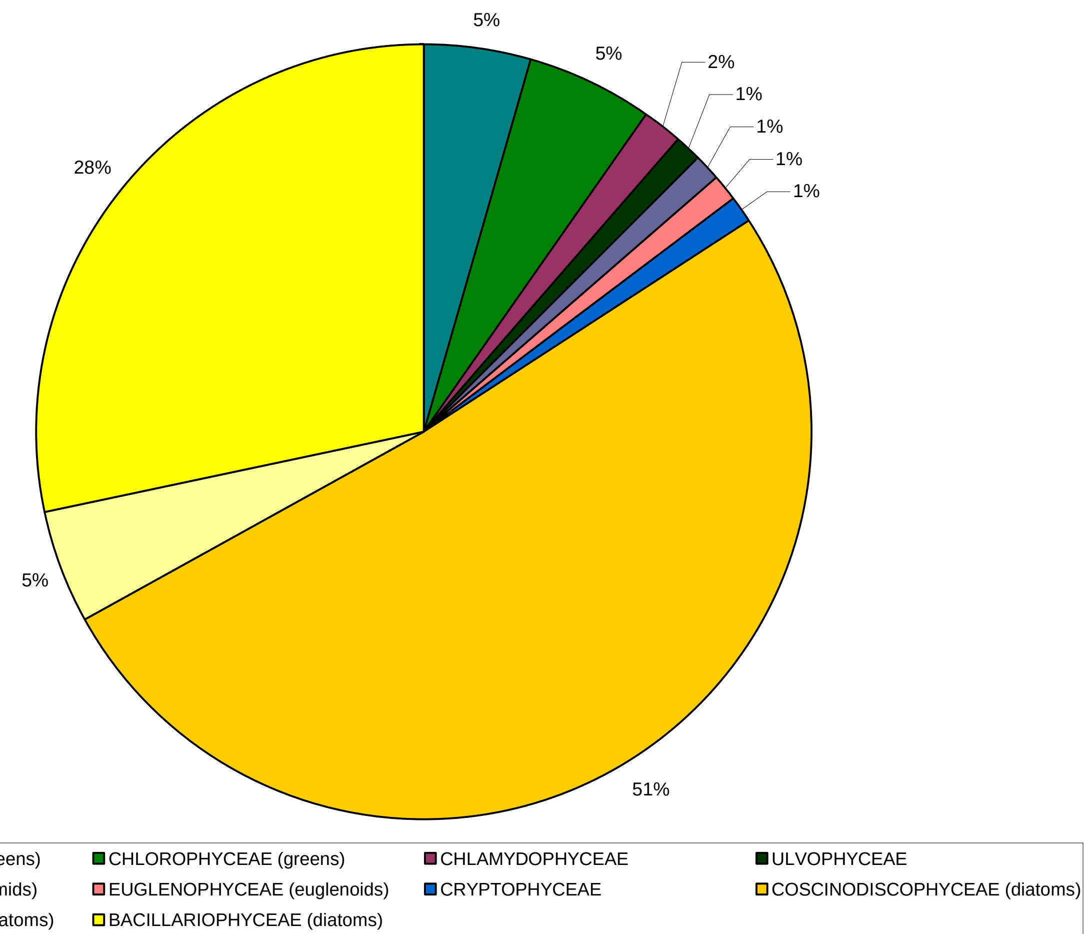
	0-120ft	120-240ft	240-360ft	360-480ft	Total	Ind per mL*	Ranking**
Fields of view counted	5	4	4	3	16		
CYANOPHYCEAE							
Anabaena sp.			2	3	5	10,523,546	
Aphanocapsa rivularis				1	1	2,104,709	
Chroococcus sp.		1		1	2	4,209,419	
Chroococcus cf. *submarinus*		4			4	8,418,837	
Cyanothece sp.			2		2	4,209,419	
Eucapsis carpatica	1				1	2,104,709	
Eucapsis sp.			1	2	3	6,314,128	
Gloeocapsa sp.		2	3		5	10,523,546	
Johannesbaptistia pellucida			1	1	2	4,209,419	
Lyngbya sp.				2	2	4,209,419	
Merismopedia tenuissima		1			1	2,104,709	
Microcisis cf. *irregularis*	2	4			6	12,628,256	
Oscillatoria sp.		1	2	4	7	14,732,965	
Phormidium sp.	15	1	1	2	19	39,989,476	8
Phormidium cf. *autumnale*	3				3	6,314,128	
Planktolynbya sp.			4		4	8,418,837	
Pseudanabaena sp.				1	1	2,104,709	
Pseudanabaena muscicola		2	3		5	10,523,546	
					0	-	
CHLOROPHYCEAE					0	-	
Cladophora sp.		3	8		11	23,151,802	10
Closteriopsis acicularis				1	1	2,104,709	
Enteromorpha sp.	6	1			7	14,732,965	
Microspora sp.	4	1			5	10,523,546	
Monoraphidium contortum	3	1			4	8,418,837	
Monoraphidium convolutus		3		1	4	8,418,837	
Monoraphidium minutum	4	3	3		10	21,047,093	
Palmella			6		6	12,628,256	
Scenedesmus linearis	1				1	2,104,709	
Sphaerocystis		4	1		5	10,523,546	
Stigeoclonium sp.			1		1	2,104,709	

Tetraedron sp.		1			1	2,104,709	
					0	-	
CHLAMYDOPHYCEAE					0	-	
Pleodorina sp.	1				1	2,104,709	
Pandorina sp		1	1		2	4,209,419	
					0		
ULVOPHYCEAE					0	-	
Ulothrix sp.				1	1	2,104,709	
					0	-	
ZYGNEMAPHYCEAE					0	-	
Cosmarium sp.			1		1	2,104,709	
					0	-	
EUGLENOPHYCEAE					0	-	
Trachelomonas sp.	1				1	2,104,709	
Trachelomonas cf. *armata*			1		1	2,104,709	
					0	-	
CRYPTOPHYCEAE					0	-	
Cryptomonas sp.			1		1	2,104,709	
					0	-	
COSCINODISCOPHYCEAE					0	-	
Camplyodiscus sp.			1		1	2,104,709	
Cyclotella sp.	3	6	5	4	18	37,884,767	9
Melosira nummoloides	2	43	65	40	150	315,706,393	2
Melosira varians	9	1	1	4	15	31,570,639	
					0	-	
FRAGILARIOPHYCEAE					0	-	
Fragilaria sp.				2	2	4,209,419	
Synedra acus	9				9	18,942,384	
Synedra sp.	5				5	10,523,546	
*Ulnaria ulna**			1		1	2,104,709	
					0	-	
BACILLARIOPHYCEAE					0	-	
Achnanthes sp.	5	11	1	9	26	54,722,441	6
Achnathidium sp.	3				3	6,314,128	
Amphora sp.	1	1			2	4,209,419	
Cocconeis cf. *placentula*	2				2	4,209,419	
Cocconeis sp.	5	10	4	5	24	50,513,023	
Denticula sp.	1				1	2,104,709	
Encyonema sp.		1			1	2,104,709	
Epithemia sp.				3	3	6,314,128	
Frustulia sp.	6	8	22		36	75,769,534	5
Gomphonema sp.	2	2	1		5	10,523,546	
Gyrosigma sp.	10	9	3	3	25	52,617,732	7
Hantzschia sp.*	22		9	10	41	86,293,081	4
Navicula cf. *gregaria*	1		2		3	6,314,128	
Navicula cf. *margalithi*	4				4	8,418,837	
Navicula cryptocephala	1				1	2,104,709	
Navicula sp.	38	20	22	52	132	277,821,626	3
Nitzschia cf. *amphibia*	7				7	14,732,965	
Nitzschia cf. *lanceolata*	15	24	14	5	58	122,073,139	4

Nitzschia palea	7				7	14,732,965	
Nitzschia sp.	113	26	35	45	219	460,931,334	1
Pinnularia sp.	1	2			3	6,314,128	
Rhoicosphenia sp.		2			2	4,209,419	
Rhopalodia sp.			1		1	2,104,709	
Surirella sp.		3	1	1	5	10,523,546	
Total	313	203	230	203	949	1,997,369,113	

* Utermohl Method
** modified Lobo (1984)
1-10 (abundance)

Powell Creek 2/12/09



APPENDIX E. SPLIT SAMPLE ANALYSIS

Appendix E

EVALUATION OF SPLIT SAMPLE RESULTS

Lee County conducted weekly split-sample analysis for the duration of the Powell Creek ATS™ Pilot Project (Figure E-1-Figure E-4). A review of data provided by Lee County vs. that provided by the Contract Laboratories for HydroMentia (Jupiter and PACE Laboratories) shows no significant difference in means for either influent or effluent total phosphorus or total nitrogen based upon one-way ANOVA. The relative percent difference between laboratory values for TP was greater than 20% on seven occasions of the 50 split samples taken during the operational period, while there was greater variability among TN values between labs. Pace Laboratories was notified about the disparity related to nitrogen, and both the contract laboratory and Lee County laboratory personnel agreed that analysis for total nitrogen is highly sensitive and the documented differences between laboratories are not atypical.

In terms of removal, data from Jupiter and PACE labs translates to a total of 838 grams total phosphorus and 2,158 grams total nitrogen; while data from Lee County translates to a total of 731grams total phosphorus and 2,629 grams total nitrogen (Figure E-5- Figure E-6).

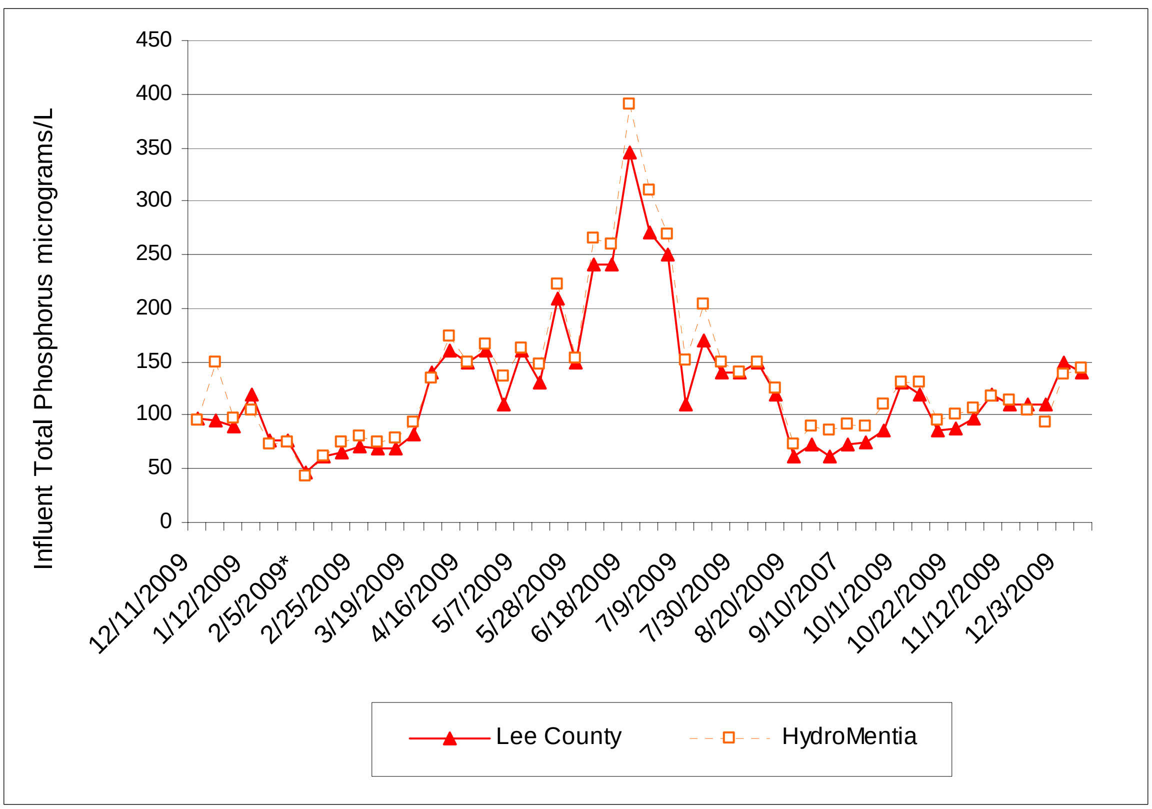


Figure E-1: Influent total phosphorus concentration based on analysis by Lee County and the HydroMentia Contract Laboratories (Jupiter and PACE)

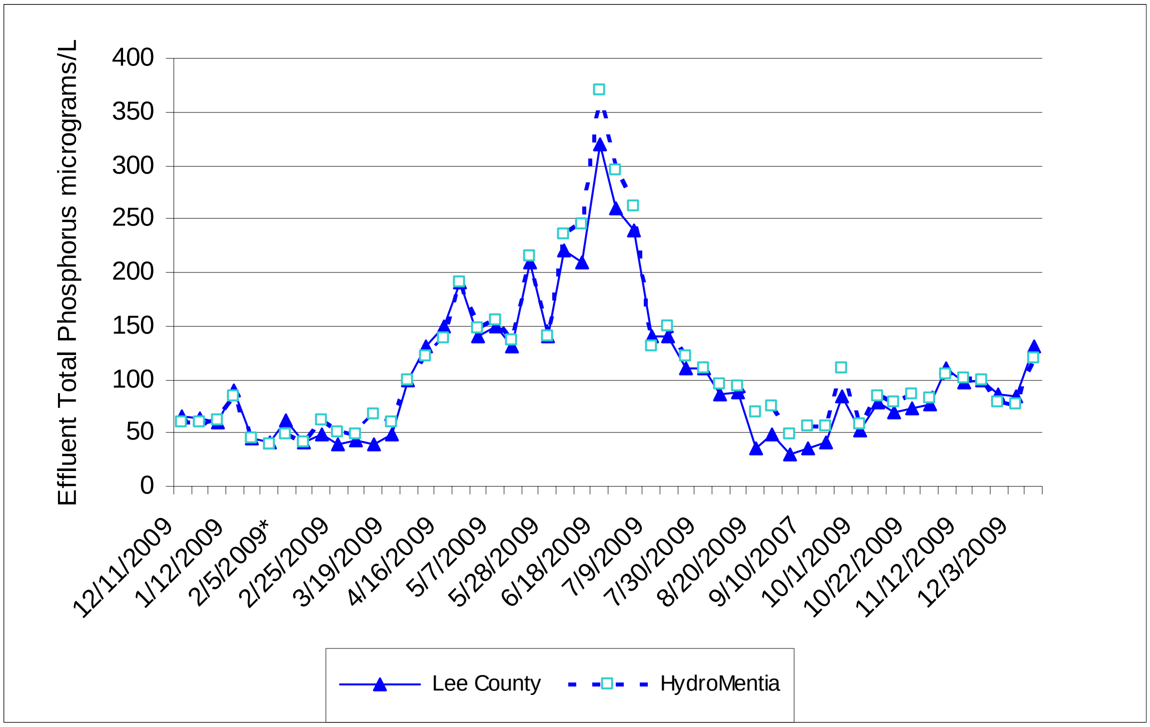


Figure E-2: Effluent total phosphorus concentration based on analysis by Lee County and the HydroMentia Contract Laboratories (Jupiter and PACE)

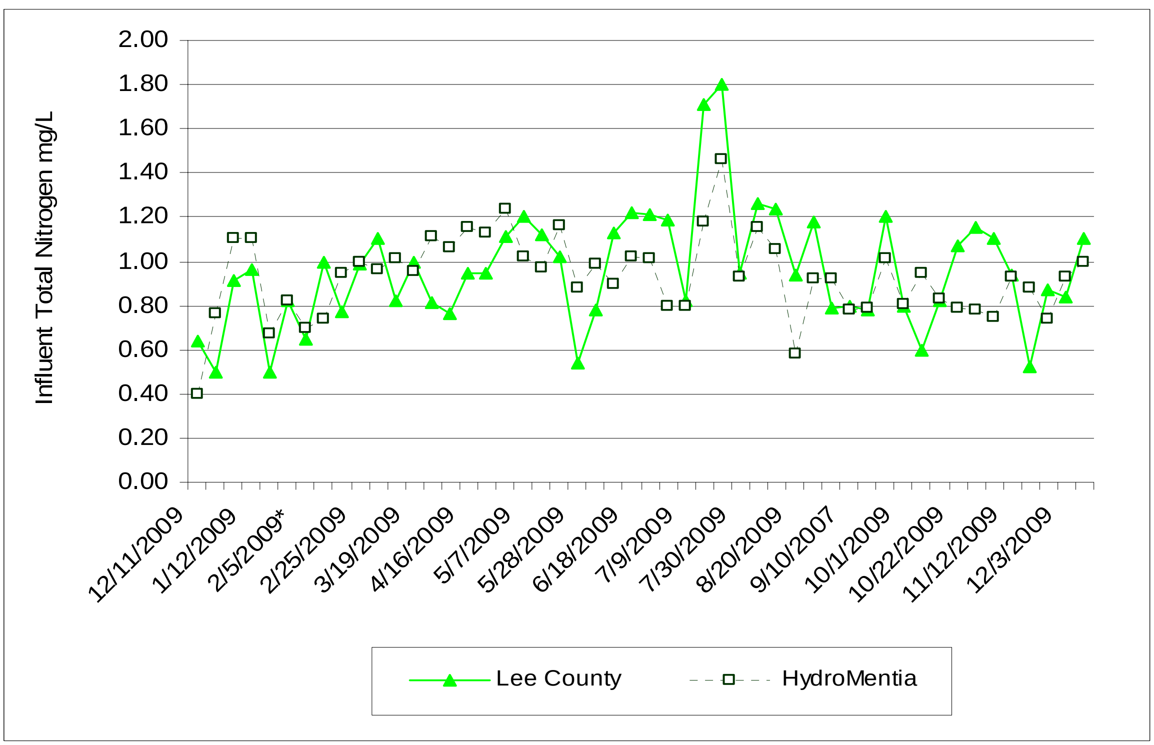


Figure E-3: Influent total nitrogen concentration based on analysis by Lee County and the HydroMentia Contract Laboratories (Jupiter and PACE)

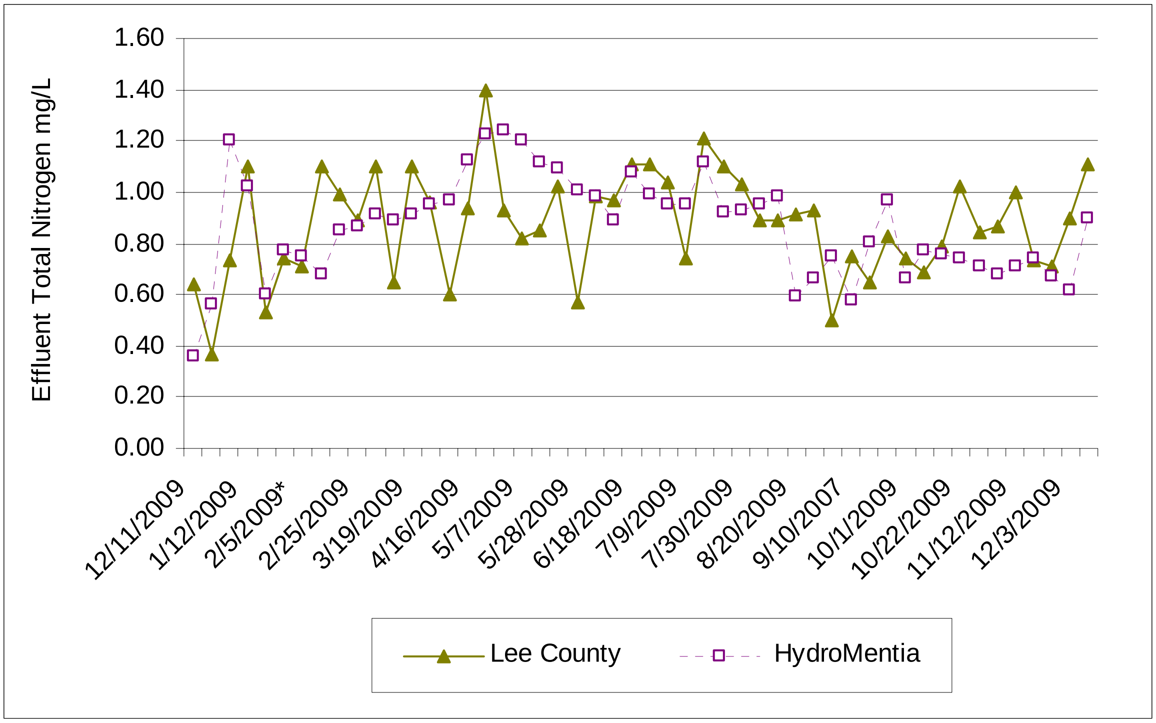


Figure E-4. Effluent total nitrogen concentration based on analysis by Lee County and the HydroMentia Contract Laboratory (Jupiter and PACE)

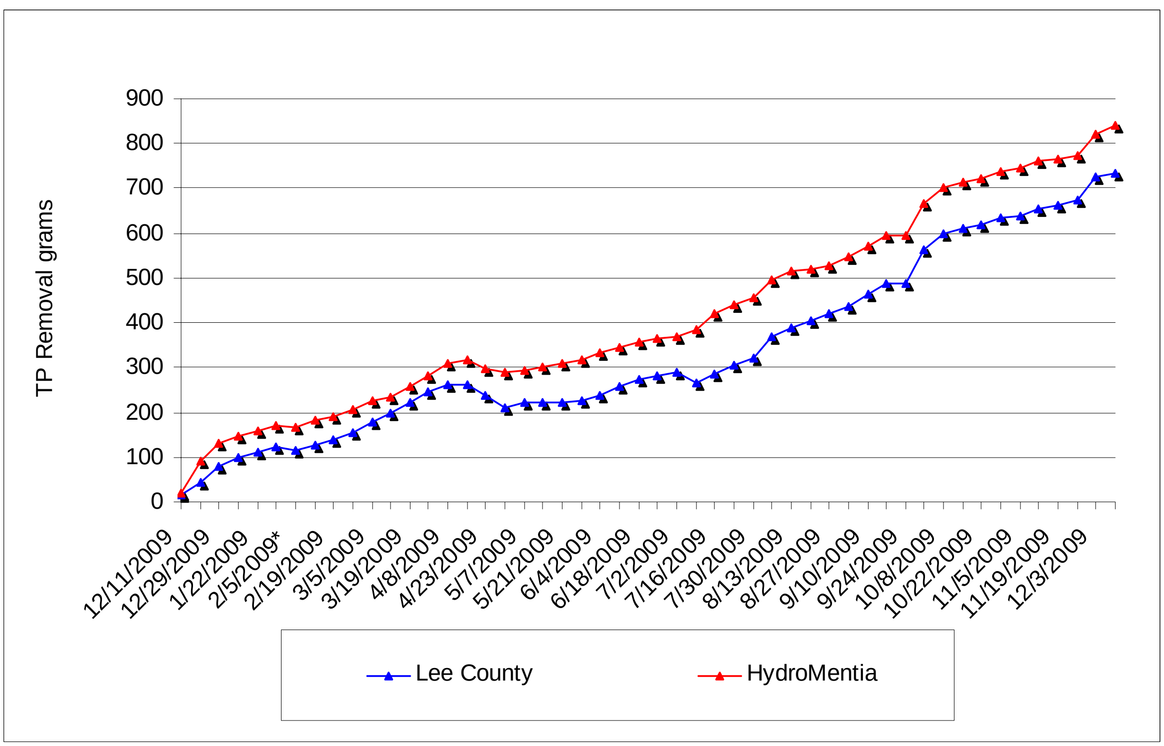


Figure E-5: Cumulative phosphorus load removed based on analysis by Lee County and the HydroMentia Contract Laboratory (PACE)

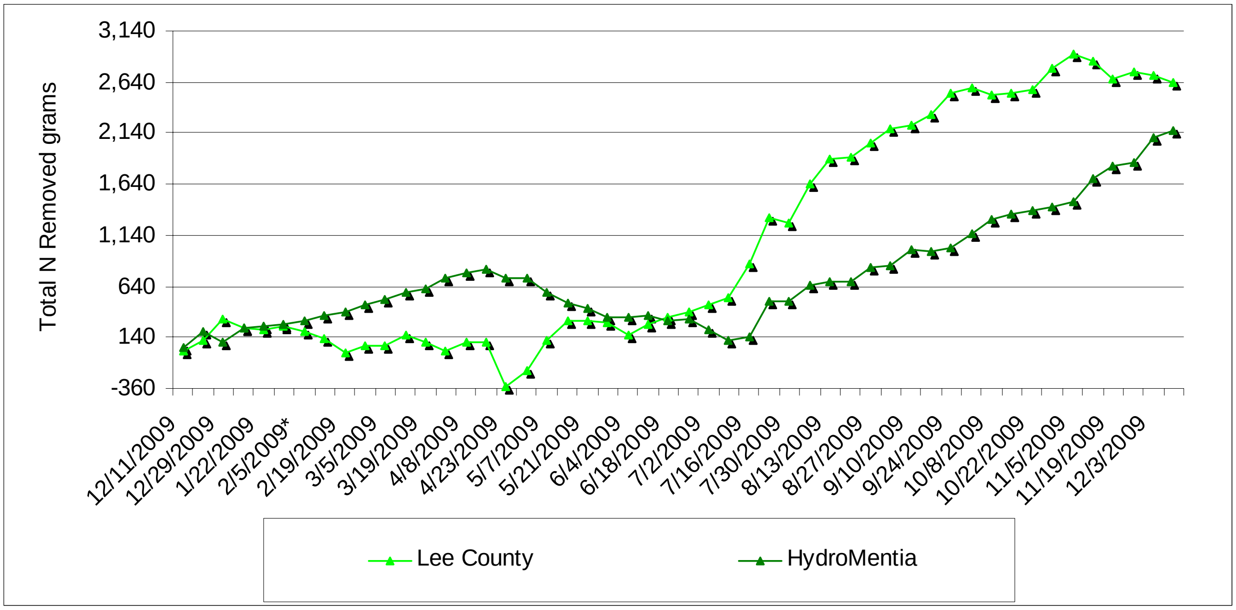


Figure E-6: Cumulative nitrogen load removed based on analysis by Lee County and the HydroMentia Contract Laboratory (PA

APPENDIX F. ATSDEM ALGORITHMS DERIVATION

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[i], 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[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[ii] 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.

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

or

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

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

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

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.

$$Z_t = Z_0e^{mt} \qquad \text{Equation 4}$$

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

$$m = m_{max}S/(K_s+S) \qquad \text{Equation 5}$$

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

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 $\mathbf{(Z_{ave})}$, 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 $\mathbf{S_t}$, then $\mathbf{S_{\mathit{y1}}}$ at a sufficiently small increment ***"y"*** down the ATS™ may be expressed as:

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

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 **m.** If temperature variations are expected, their impacts need to be considered using the classical V'ant Hoff-Arrhenius[iii] equation (Equation 7), which may be incorporated into the relationship as noted in Equations 8.

$$m_{opt}/m_1 = Q^{(T_{opt}-T_1)} \quad \text{or} \quad m_1 = m_{opt}/Q^{(T_{opt}-T_1)} \qquad \textbf{Equation 7}$$

Where m_{opt} is the growth rate for given **S** at the optimal growing temperature ^{o}C, T_{opt}, and m_1 is the growth rate for the same given **S** at some temperature ^{o}C, T_1, when $T_1 < T_{opt}$, and **Q** is an empirical constant ranging from 1.03 to 1.10.

$$S_{y1} = S_{y0} - \{[S_t\{Z_{ave}e^{[m(y1-y0)/v]\,[}1/Q^{(T_{opt}-T1)]} - Z_{ave}\}]/[q(y_1-y_0)/v]\} \qquad \textbf{Equation 8}$$

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 **Q.**

Finally, if the right side of Equation 5 is included for **m,** then the relationship for concentration of **S**, at the end of segment y_1 becomes Equation 9.

$$S_{y1} = S_{y0} - \{[S_t\{Z_{ave}e^{[m_{max}S_{y0}/(Ks+S_{y0})][(y_1-y_0)/v]\,[}1/Q^{(T_{opt}-T1)]} - Z_{ave}\}]/[q(y_1-y_0)/v]\} \quad \textbf{Equation 9}$$

Estimation of m_{max} and 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[iv]. Several techniques are discussed, including Lineweaver-Burke[v], Hanes[vi] and Eadie-Hofstee[vii]. 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]/m,** as the dependent variable is the preferred of the three. In such a plot, m_{max} is represented as the inverse of the slope of the linear equation:

$$[S]/m = (K_s/m_{max}) + (1/m_{max})\,[S] \qquad \textbf{Equation 10}$$

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

Plotting the single flow data set using the Hanes method is helpful at providing some indication of expected general range of m_{max} and 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 $\mathbf{ln(Z_t/Z_0)\ /t = m}$ with $\mathbf{Z_0}$**,** 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 **Q=** 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 $\mathbf{K_s}$**.** 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[viii] 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:

$$\mathbf{m = m_{max.}\ \{[P]/(K_p+[P])\}\ \{[N]/(K_n+[N])\}\ \{[CO_2]/(K_C+[\ CO_2])\}\ldots\ Equation\ 11}$$

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 $\mathbf{K_s}$, 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

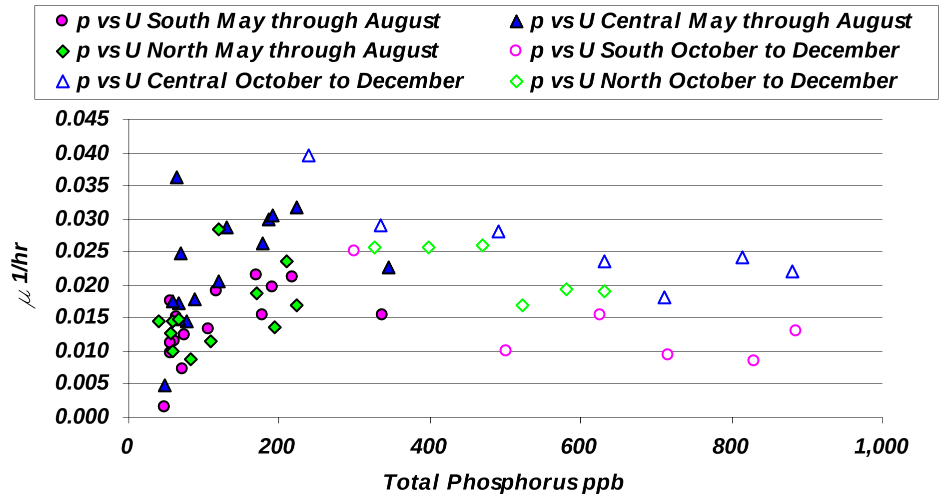


Figure 4-9: Total phosphorus Vs. calculated growth rate adjusted POR data set

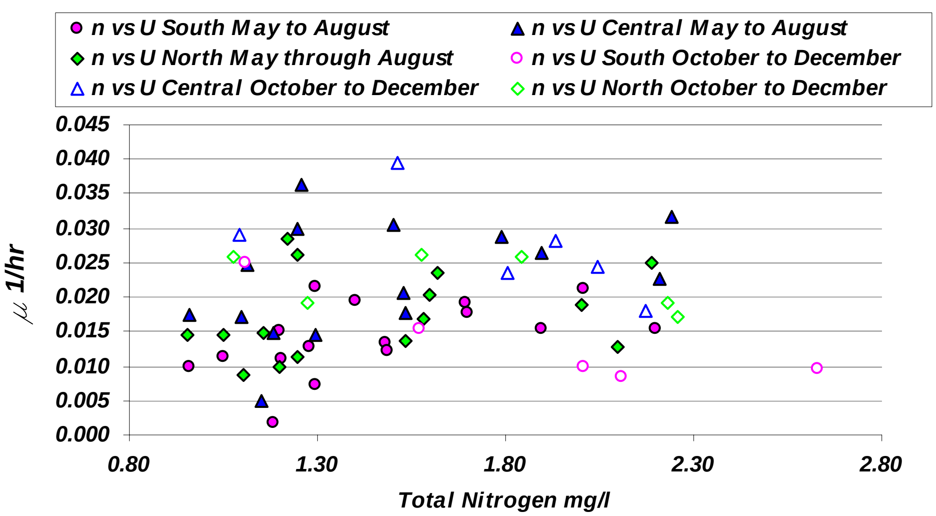


Figure 4-10: Total nitrogen Vs. calculated growth rate adjusted POR data set

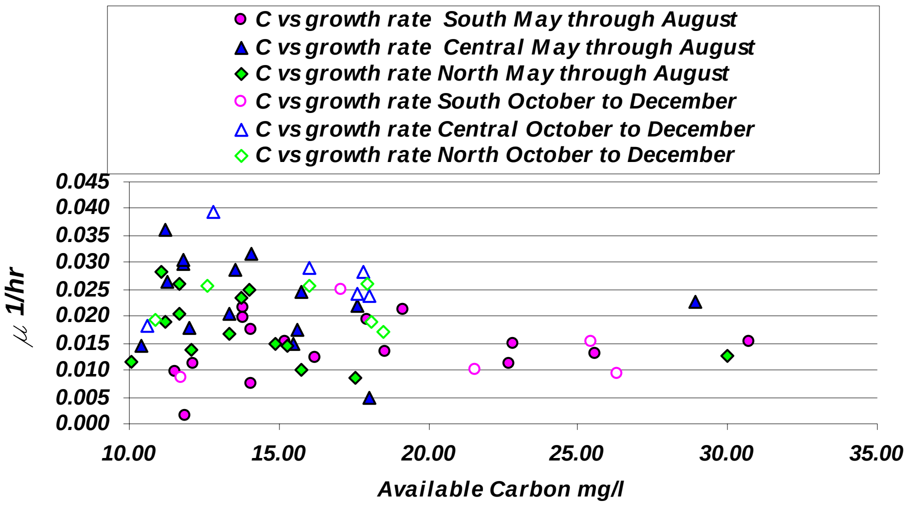


Figure 4-11: Available Carbon Vs. calculated growth rate adjusted POR data set

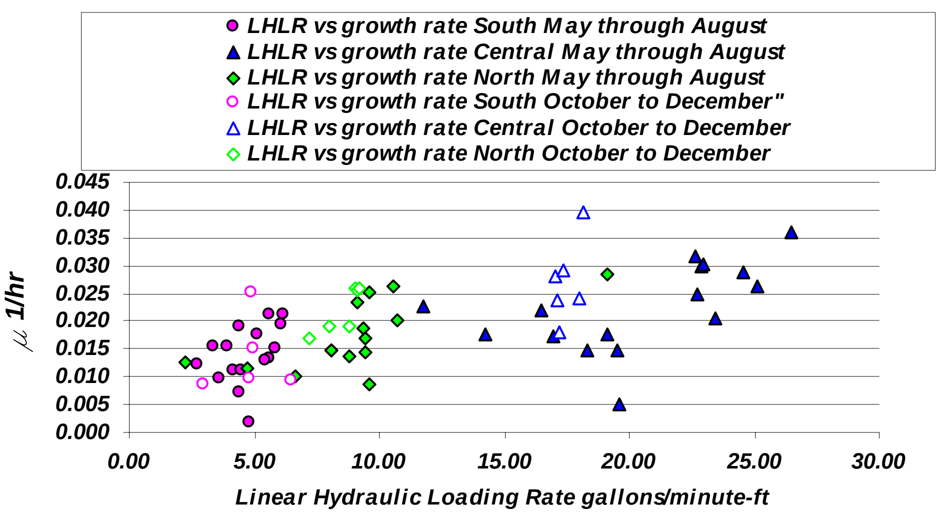


Figure 4-12: Linear Hydraulic Loading Rate Vs. calculated growth rate adjusted POR data set

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**

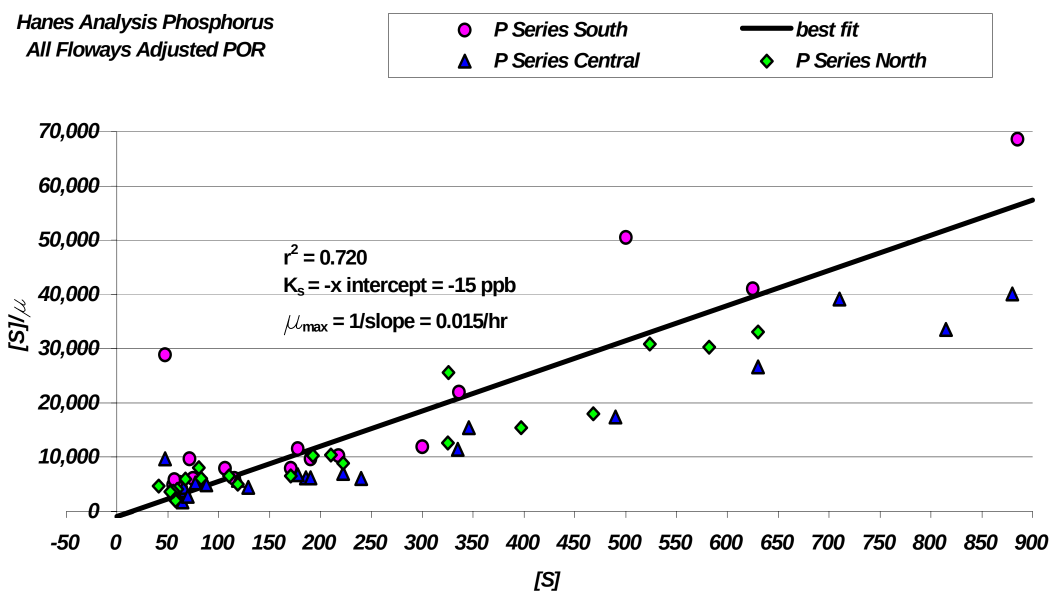


Figure 4-13: Hanes plot total phosphorus all floways over adjusted POR

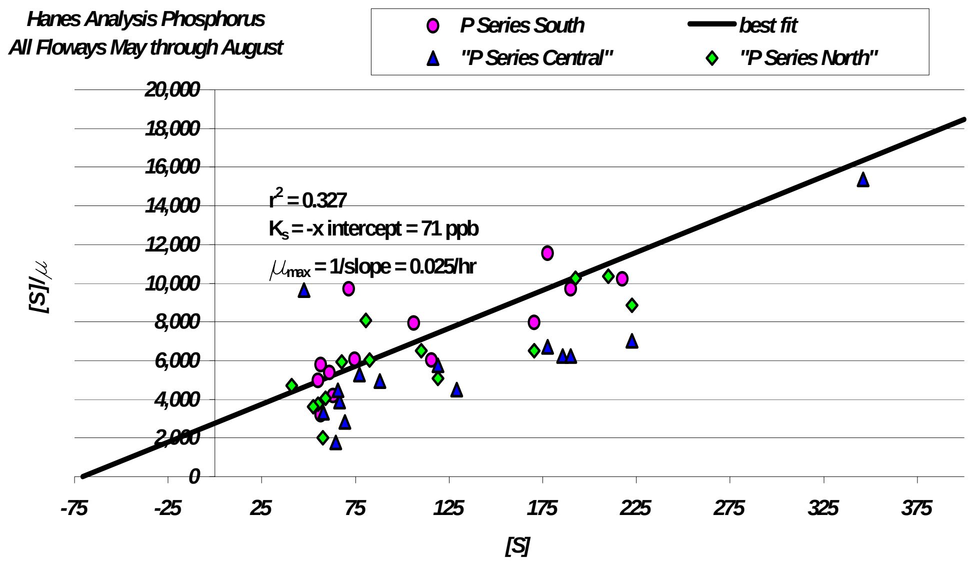


Figure 4-14: Hanes plot total phosphorus all floways May through August

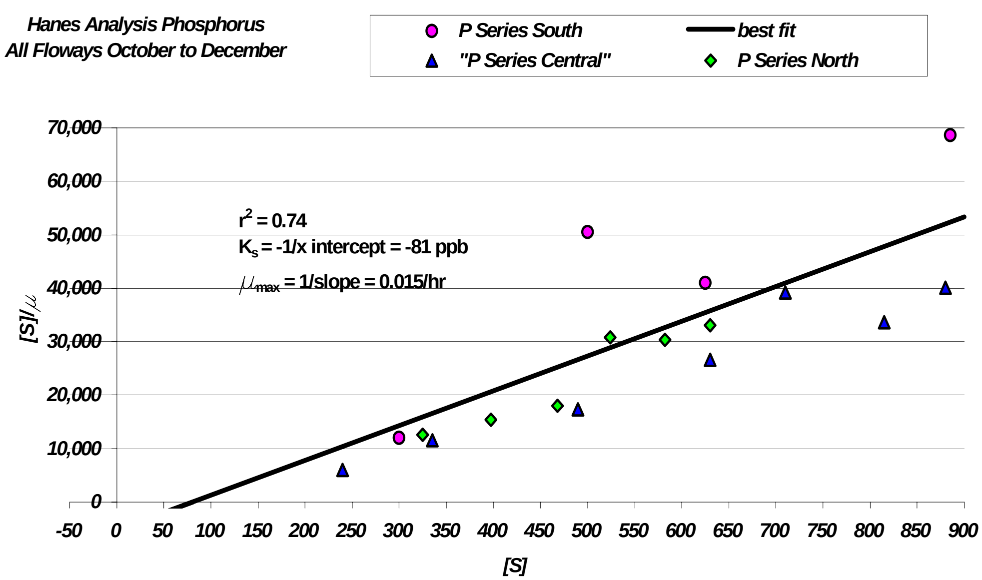


Figure 4-15: Hanes plot total phosphorus all floways October to December

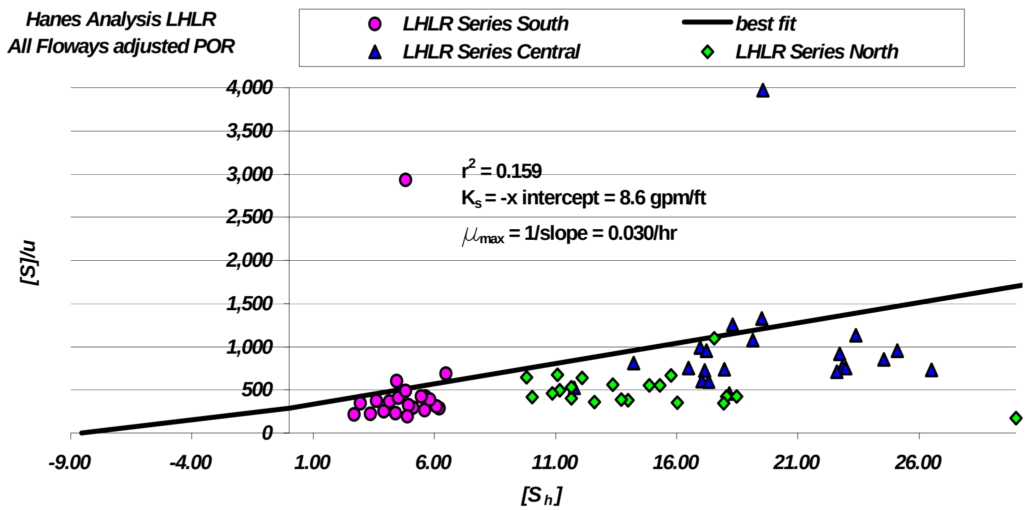


Figure 4-16: Hanes plot LHLR all floways over adjusted POR

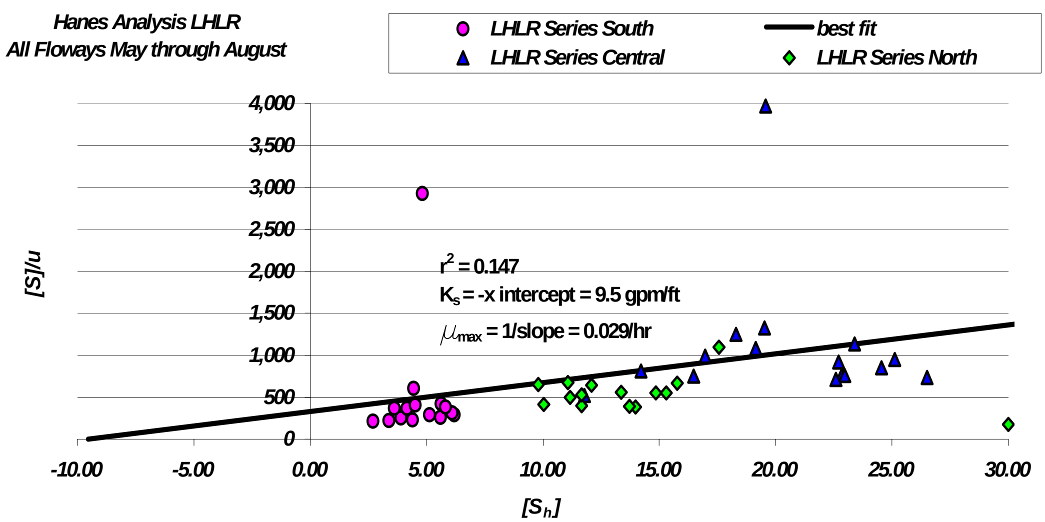


Figure 4-17: Hanes plot LHLR all floways May through August

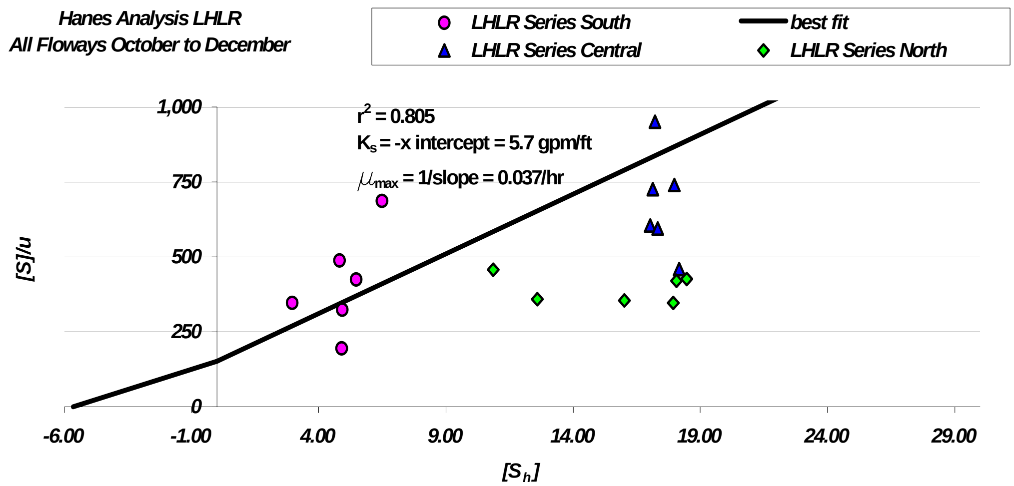


Figure 4-18: Hanes plot LHLR all floways October to December

The issue of the influence of flow rate and velocity upon algae growth rate has been extensively reviewed within the literature. Brezonik[ix] 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:

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

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 m_{max}, therefore it is reasonable to express the equation as:

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

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

$$m = m_{max.}\ [P'/(P'+1)]S/K_s \qquad \textbf{Equation 14}$$

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:

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

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 m 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 mM 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 $\mathbf{K_s}$ and $\boldsymbol{m_{max}}$ 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:

$$S_{pp} = S_{pi} - \{[S_t\{Z_o e^{m_{max}[\{S_{pa}/(Ksp+S_{pa})][(Lp/(Khp+Lp)][24t][} 1/Q^{(T_{opt}-T1)} - Z_o\}]/V_p\} \qquad \textbf{Equation 16}$$

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 $\mathbf{m_{max}}$ = 0.04/hr, $\mathbf{K_{sp}}$ = 37 ppb, $\mathbf{K_{hp}}$ = 9.3 gpm/ft, $\mathbf{T_{opt}}$ = 29.9 °C and **Q** = 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.

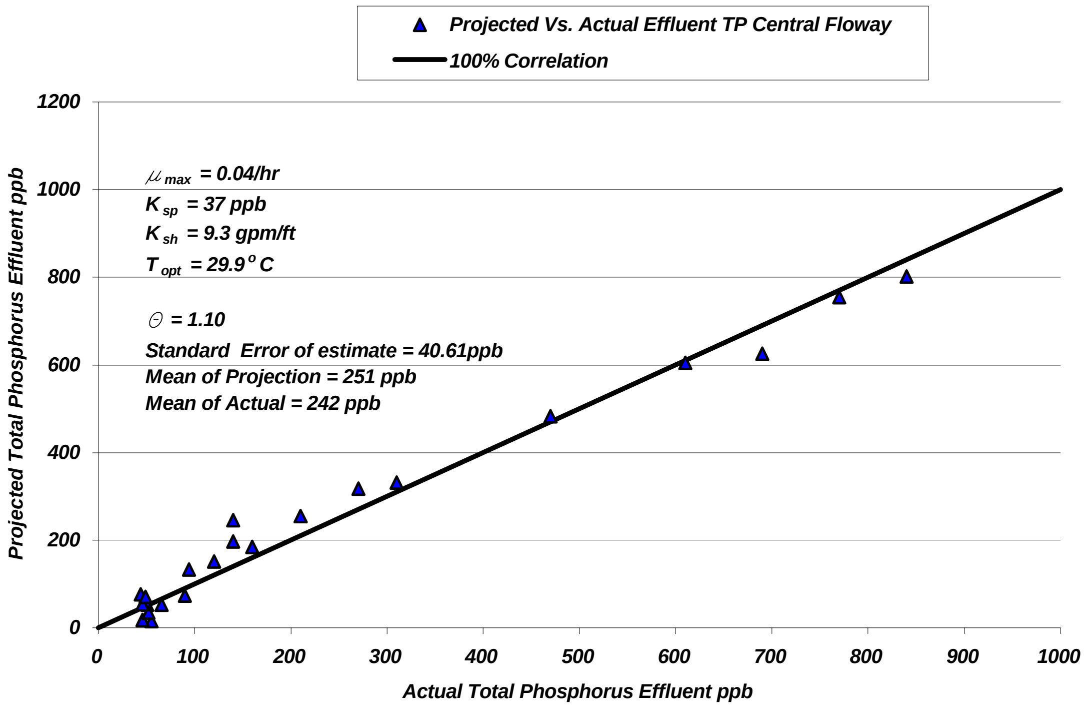


Figure 4-19: Actual Vs. ATSDEM Projected total phosphorus effluent concentration Central Floway

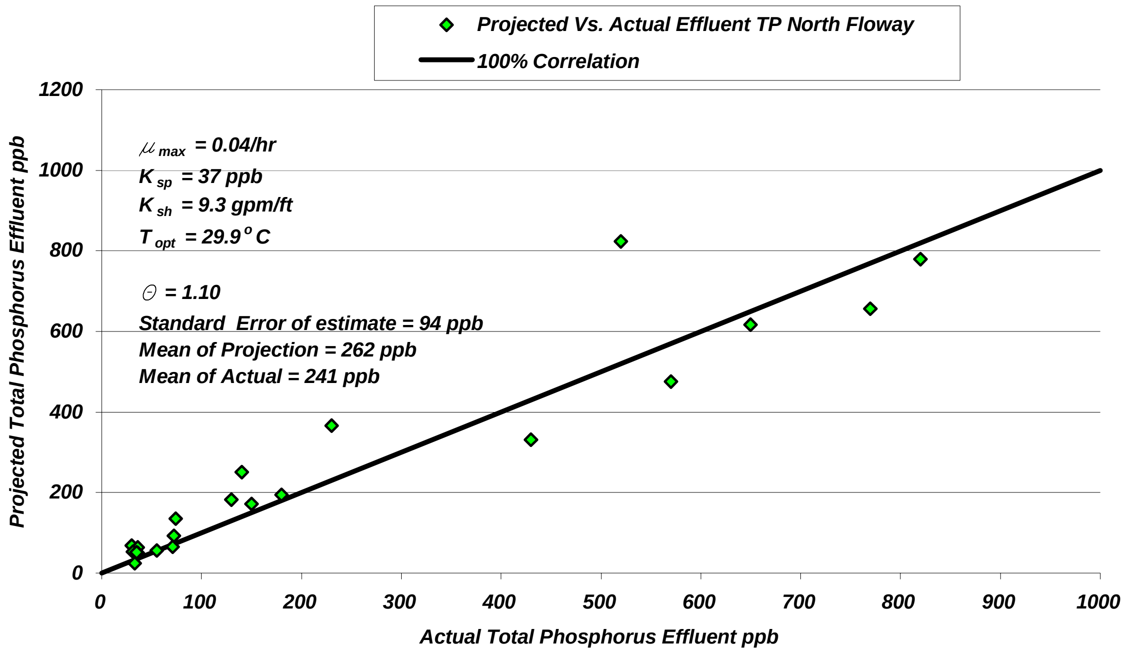


Figure 4-20: Actual Vs. ATSDEM Projected total phosphorus effluent concentration North Floway

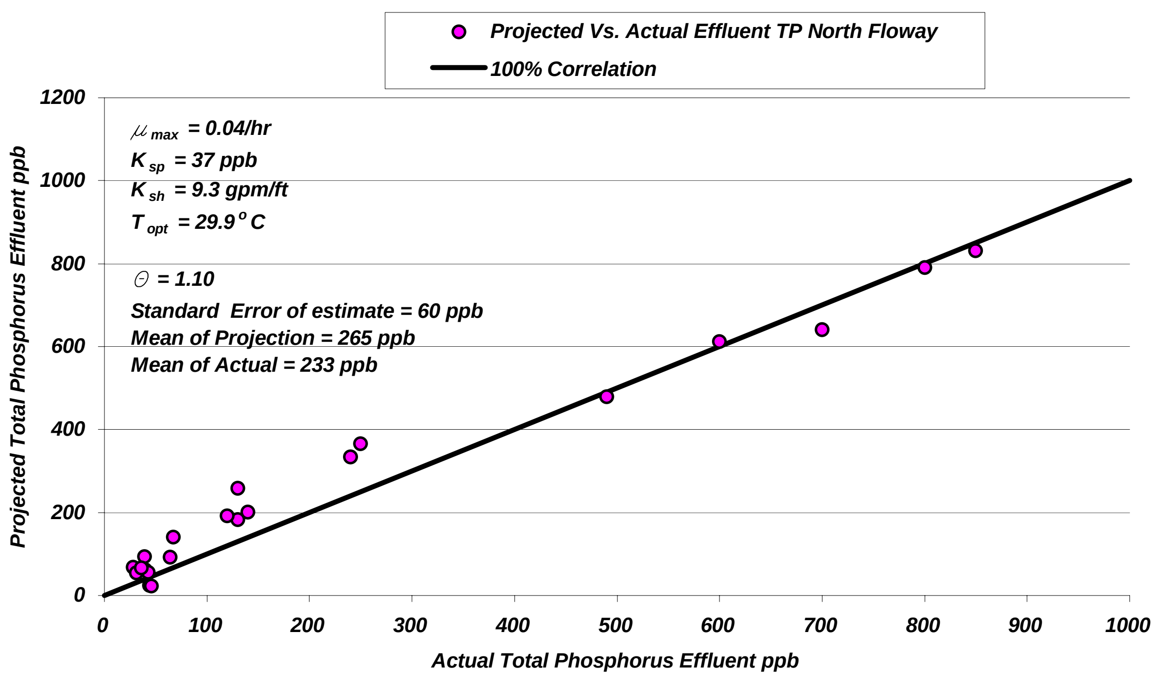


Figure 4-21: Actual Vs. ATSDEM Projected total phosphorus effluent concentration South Floway

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:

$$\mathbf{V = (1.49/n)r^{2/3}s^{1/2})} \qquad \textbf{Equation 18}$$

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:

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

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

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

Therefore:

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

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

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

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:

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

Where $\mathbf{q_t}$=control volume over time increment

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

$$\mathbf{dL/dt = vt} \qquad \textbf{Equation 25}$$

These relationships hold for a relatively short time sequence when $\mathbf{S_{t0} \sim S_{t1}}$, 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 $\boldsymbol{m_{max}}$ 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[x], 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.

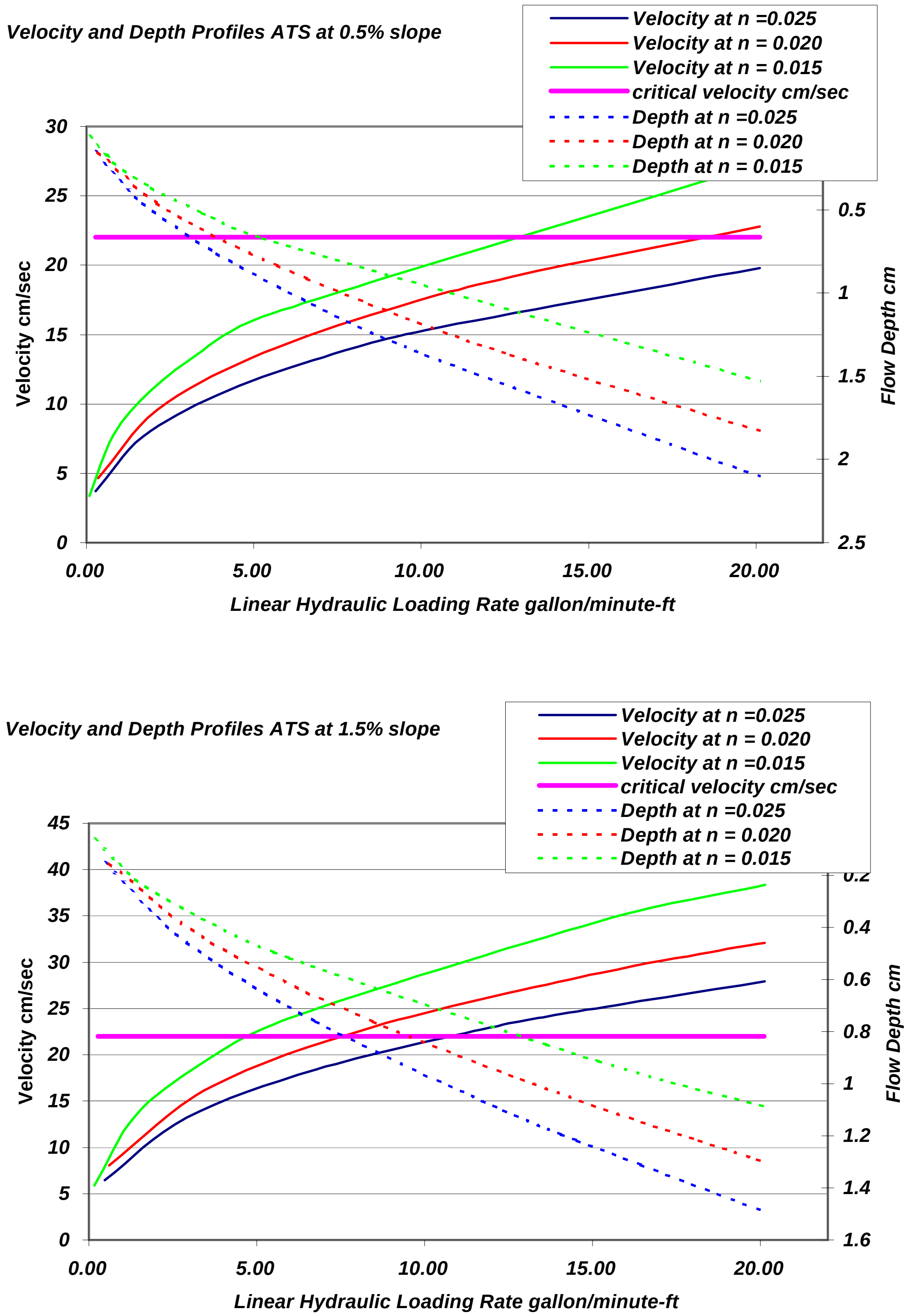


Figure 4-21: Velocity, LHLR and depth relationships as determined from Manning Equation

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/m^2	Z_0 dry-g/m^2	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/m^2-day	Area per time sequence m^2
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

[i] Walker, W.W. (1995) "Design basis for Everglades stormwater treatment areas" Water Resource Bulletin American Water Resources Association Vol 31 No. 4
[ii] 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.
[iii] As described by Brezonik, P.L.(1994) *Chemical kinetics and process dynamics in aquatic systems,* CRC Press, Boca Raton, Fl pp 114-117
[iv] 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
[v] Lineweaver, H and D. Burke (1934) "The determination of enzyme dissociation constants" *J.Am.Chem.Soc.* **56,** 568
[vi] Hanes, C.S. (1942) *Biochem. J.* , 26, 1406
[vii] Eadie,G.S (1942) *J/ Biol. Chem.* 146,85 ; Hofstee, B.H.J. (1959) *Nature* 184, 1296
[viii] 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
[ix] 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
[x] 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.