South Florida Water Management District Comments on STA-1E Periphyton Stormwater Treatment Area Final Report

Provided December 28, 2011

This document is a compilation of four items:

1. A letter dated December 22, 2011 from Ernie Barnett, Director of Everglades Policy and Coordination at the South Florida Water Management District (SFWMD) to Eric Bush, Deputy Chief of the Planning and Policy Division of the United States Army Corps of Engineers regarding the *STA-1E Periphyton Stormwater Treatment Area (PSTA) Final Report* by Wetland Solutions, Inc. and Anamar Environmental Consulting, Inc.

2. A list of SFWMD comments on the abovementioned report.

3. The *STA 3/4 PSTA Cell Modifications* presentation made at the November 15, 2011, Long Term Plan (LTP) Quarterly Communications Meeting by David Unsell, P.E., Section Administrator for Water Quality Treatment Technologies at the SFWMD.

4. The *STA 3/4 PSTA Research Plan* presentation made at the November 15, 2011, LTP Quarterly Communications Meeting by Tom DeBusk of DB Environmental, Inc.

Provided by:
Garth Redfield

South Florida Water Management District
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SOUTH FLORIDA WATER MANAGEMENT DISTRICT

December 22, 2011

Mr. Eric Bush
Deputy Chief
Planning and Policy Division
U.S. Army Corps of Engineers
701 San Marco Blvd.
CESAJ-PD-R
Jacksonville, FL 32207

Dear Mr. Bush:

Subject: *STA-1E Periphyton Stormwater Treatment Area (PSTA) Final Report*

The South Florida Water Management District has reviewed the document *STA-1E Periphyton Stormwater Treatment Area (PSTA) Final Report (W912-EP-09-E-0013).* We understand that this report was prepared at your direction by Wetland Solutions, Inc. and ANAMAR Environmental Consulting, Inc. Our comments are attached as a separate document to this letter.

We appreciate the opportunity to review this report and believe that it is well written and will assist in our investigation and analysis of the water quality treatment technology known as Periphyton-based Stormwater Treatment Areas.

We look forward to a continuing productive relationship. If questions should arise, please direct them to David Unsell, Administrator, Water Quality Treatment Technologies Section, at 561-682-6888 or dunsell@sfwmd.gov.

Sincerely,

Ernie Barnett
Director, Everglades Policy & Coordination

EB/du
Enclosure

c: David Unsell

SFWMD comments on STA-1E Periphyton Stormwater Treatment Area (PSTA) Final Report
(*W912-EP-09-E-0013) by Wetland Solutions, Inc. and Anamar Environmental Consulting, Inc.*

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Summary of technical comments

1. The Report is generally thorough and sound in its approach to analyzing data available on PSTA projects at the Flying Cow Road Test Facility (FCRTF) and STA-1AE Field Scale Demonstration (FSD). The Report's overall goal of providing an evaluation of available PSTA data at STA-1E has been met. Detailed technical and editorial comments are provided below for use in improving the overall quality of the Final report.
2. The Report documented multiple and pervasive problems with project data quality, completeness, period of record and other project measurements. Unfortunately, these deficiencies preclude the use of resulting data for the design and implementation of large scale PSTA treatment projects for Everglades Restoration.
3. The Report is correct in concluding that "the results from the FSD PSTA cells are insufficient to independently support full-scale PSTA design." In other words, the performance of the FSD project provided very little information usable for predicting future long-term performance of large-scale PSTA systems.
4. Unfortunately, the compiled information does not provide strong support for the Report's suggestion that decommissioning the STA-1E FSD platform might be postponed. It is doubtful that useful data can be collected by continuing data collection with the FSD PSTA platform and operating the system in an uncontrolled mode. Likewise, the STA-1E projects reviewed in the Report do not provide a basis or justification to move forward with a larger-scale or full implementation of a PSTA facility.
5. Instead, the Report's compilation points towards initiating a genuine feasibility study utilizing the STA-3/4 PSTA project. Fortunately, the Long-Term Plan provides an adaptive management process for continuing evaluation of PSTA in the SFWMD's PSTA project in STA-3/4.

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Detailed technical and editorial comments:

1. Page ES-4, Table ES-2: Statistical measure whether there is significant difference between mean inflow and mean outflow TP concentrations need to be used to derive conclusions from the experimental results. The overall statistical evaluation needs to be included in the Summary. Results from Figures 5-16, 5-18 and 5-20 clearly show that there is no statistically significant difference between the means of inflow and outflow TP concentrations. Flow-weighted concentrations are the applicable concentrations for such analysis. Mean inflow and outflow concentrations shown in Table ES-2 should match what is shown in Figures 5-16, 5-18 and 5-20.
2. Page ES-4: See suggested underlined text:

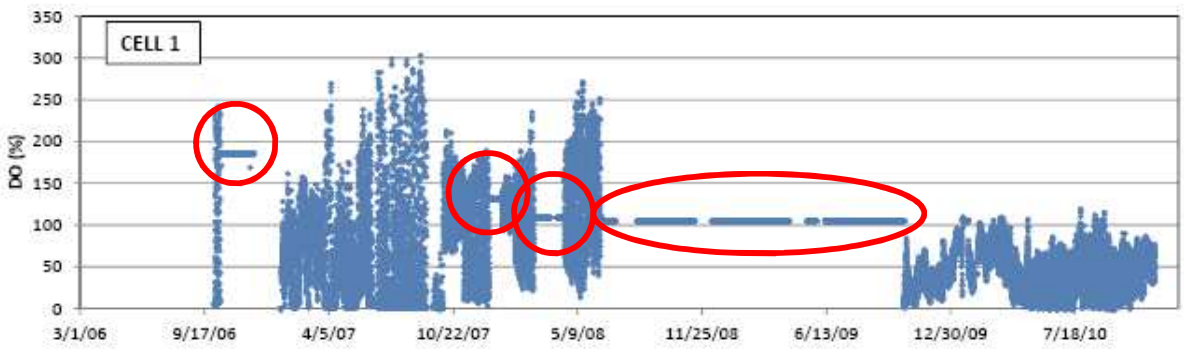
   Further, the addition of a storage reservoir and/or expansion of STA area in the eastern EAA, transfers of water from other basins to the C-51 basin, or other system-wide modifications will affect future flows and loads delivered to STA-1E (Walker 2010). <u>Any such system-wide modifications or changes in the flows and loads to be delivered to STA-1E will affect the projected PSTA full-scale area requirements contained in this report.</u>
3. Page ES-5: Regarding the use of k=31.0 m/yr value from STA-3/4 PSTA, the SFWMD continues to analyze the STA-3/4 PSTA data and use of this data to derive design criteria such as a settling rate should include appropriate caveats.

4. Page 1: Regarding the following text in the **Introduction** section, suggest either revising (with legal input) or omitting the following discussion as it appears to incorrectly co-mingle the requirements of the TP criterion and the STA permit effluent limits. For example, the "four-part test" included in Rule 62-302.540 of the Florida Administrative Code (F.A.C.), is the *Four-Part Test for Determining Achievement of the 10 ppb Criterion in the Everglades Protection Area. The Four-Part Test* uses data collected in the Water Conservation Areas and is separate from the compliance test associated with the STA permit effluent limits which are still being revised by the regulatory agencies. Following is some suggested revised text, however legal input is still suggested:

   The Everglades Forever Act (EFA) and Settlement Agreement (U.S. v. SFWMD, 88-1886-Civ-Moreno) require that water discharged to the WCAs and ENP meet a long-term geometric mean concentration of 10 ppb (µg/L) TP. Compliance with the long-term geometric mean concentration of 10 ppb is determined by a "four-part test" that is defined and codified under Florida Statutes. The "four-part test" was developed to enable ~~STA operators and~~ regulatory agencies to gauge compliance with the 10 ppb criterion in the Everglades Protection Area. ~~a long term criterion with shorter-term data. Operationally, the 10 ppb long-term geometric mean has been determined to be equivalent with a long-term flow-weighted mean of 12 ppb. Other shorter term requirements also apply.~~ For the purposes of this report, references to <u>the</u> ~~a~~ 10 ppb <u>criterion</u> ~~standard~~ refer to the long-term geometric mean.
5. Page 2: The 1st paragraph in Section 1.2, about calcareous periphyton "dominant in areas of the Everglades with short hydroperiods": What is the reference for this statement? Page 6 –Figure 1-4 is missing.
6. Page 10: Suggest providing reference for the information contained in Section 1.4.1.
7. Page 10: Text states: *After the problems with macrophyte growth on the organic substrate in Cell 3 during the initial testing in 2003, Cell 3 was reconstructed in March 2005 with 6 inches of* ***sand (high organic content****) overlaid by 6 inches of onsite limerock.*
   Suggest revising this sentence, since sand, such as what's in most of STA-1E, will generally have very low organic matter content.
8. Page 16 - 17: It is stated that no determination could be made whether the acceptance criteria were met for DO and specific conductance because temperatures were not recorded on data sheets. Further, acceptance criteria for pH were not met on many occasions. In addition, the FCRTF project did not have any field calibration reports. Therefore, it is not clear if there is any value in analyzing and summarizing the data.
9. Page 17 (bulleted items): While using a data screening protocol can be useful to eliminate potential outliers in the data set, it is important to justify the use of these protocols. For instance, values for pH were limited to 4-14. This would suggest that there were pH values outside this range. If so, it would be important to summarize the number of observations that were outside the set protocol. Also, the authors need to provide justification why the data range was selected to screen the pH data. It is unclear why specific conductance values less than 250 µS/cm were presumed to be erroneous. Levels below 250 µS/cm could easily occur after substantial amounts of rainfall. These types of dilutions should not be construed as unnatural or resulting values to be presumed erroneous. The protocol for water temperature does not address seasonal errors. For instance, water temperatures of 10-15°C recorded in the months of May through October would meet the criterion of being between 0-40°C. However, these temperatures are unrealistic for the time of year. In general, the authors do not report how many data points were presumed erroneous and removed from the statistical summarization and presentation of the PSTA data set. It is suggested that this information be provided in the final report.
10. Page 19 and beyond: The page header (title) needs to be changed from "STA-1E Recommendations for Performance Enhancement" to "STA-1E PSTA Final Report".

11. Page 19: Section 3.2: References are made to structures in STA-1E as S361-S. A map showing structures in STA-1E needs to be added for the report to be of use for readers who are not familiar with STA-1E. Also a separate schematic drawing of the Field Scale Demonstration should be shown similar to the Flying Cow experiment schematics with structures included.
12. Page 24: On Figure 3-8, what is the reference for water level on the Y-axis? It is not ft NGVD 29. What does the zero line mean?
13. Page 27: How did the authors determine that subsurface outflows were used for the FCRTF PSTA Cells? Further explanation about the subsurface outflows is needed.
14. Page 30: Walden and Kadlec (2010) cited on this page is not listed in the References.
15. Page 30, EQ 2: Equation variable definition; Q (free discharge flow per EQ 1) should be Q*.
16. Table 3-3 and Table 3-4 "Δ Storage" column, the "ft" column has negative and the "m^3" column has positive numbers.
17. Page 32: Balancing water budgets by setting seepage equal to the residual includes error in all the other water budget term along with the "true" seepage volume. While this approach would have had little impact on the FCRTF water budgets (because these cells had relatively small residuals), seepage was potentially overestimated for the FSD cells, due to their much larger residuals.
18. Page 42: Section 4.0 Water Quality Parameters: This section could have been organized differently for better clarity. For instance, the time series plots (for physical parameters, i.e., specific conductance, water temperature, pH and DO) should have been moved to the appendices and box and whisker plots should have been used to make comparisons. Because these parameters had more than adequate number of data points collected, a statistical comparison between inflows and outflows should have been provided. Another observation regarding the time series plots is that specific conductance, DO (mg/L and %Sat) and pH plots for the FCRTF exhibit constant values for periods when water temperature was not recorded (see Figures 4-3, 4-4, 4-8, and 4-11). Below are two plots that demonstrate this:

Both plots show measurements in CELL 1 (Top Temp, Bottom DO%). The gap in water temperature is shown to have a DO% of ≥100%. Were these data removed from the data summarization or were



they included?

Physical data collected at Cell B of the FSD facility appears to be problematic. Dissolved oxygen data appears to be lower in the outflow than in the inflow for part of the monitoring period. In addition, the variability of the outflow data is substantially greater than that measured in the inflow. Water pH for this same cell is distinctly higher in the outflow than the inflow (while still exhibiting the same high variability). Typically, higher pH values are associated with high photosynthetic activity resulting in higher DO concentrations.

Several parameters (SpCond, Color, Ca, TDS, SO_4, Cl, etc.) exhibited a decrease in concentration (or level) from inflow to outflow. The observed difference for SpCond is attributed to dilution but no source of dilution is identified. Based on the information provided in Table 10-1, it appears that there was a net loss of water in the PSTA. Loss of water would not explain how mineral content within the Cells was diluted. One possible explanation would be rainfall although dilution caused by rainfall would be seasonal. This explanation is used to describe the observed differences in color levels for the FCRT and FSD projects. However, inflow color levels are consistently higher than those measured at the outflows. It is not believed that this difference is only a result "dilution by rainfall rather than another removal mechanism".

The discussion regarding Ca suggests that decreasing levels between inflows and outflows were indicative of a potential P removal pathway. The results indicate that inflow concentrations of Ca were generally higher than measured at outflows. No conclusion is provided for this apparent difference. A decrease in concentration as a result of potential dilution (as was discussed for SpCond and color) is not offered as a possible cause. TDS also exhibited a decreasing trend between inflows and outflows. The observed decrease is only attributed to rainfall. However, time series data suggest that outflow measurements of mineral content (SpCond) were consistently lower than at the inflow. Therefore, rainfall may not be the only cause of the lower mineral content of the PSTA water. It is suggested that a better review of data associated with more conservative parameters (Cl, SpCond, TDS, SO_4, Alk) be reviewed and discussed. It seems that some contradictions exist. Both SO_4 and Cl appear not to exhibit any observable trend with respect to inflows and outflows. This is especially interesting with regards to Cl since it is a conservative parameter. Dilution (as a result of rainfall) was identified as a possible reason for the observed differences between inflows and outflows as discussed for color, SpCond and TDS. However, these trends were not observed for Alk, SO_4 and Cl. This brings into question the overall quality of the surface water quality data.

19. Page 42: The maximum temperature of 42.1 °C listed on this page is an obvious outlier (see the point in the Cell B plot, Fig. 4-2) and is suspect.
20. Page 45: It is not likely that the reported dissolved oxygen saturation values in a shallow open-water system that approach, let alone exceed, 300% are real.
21. Page 45: The extreme pH values are highly questionable (in excess of 12) and likely due to instrument malfunction.
22. Page 68: Plants use CO_2 or HCO_3 as a carbon source and not TOC. The authors need to provide a rational for using TOC concentration as a measure of carbon availability.
23. Page 78: Tables 4-15 and 4-16, Al concentrations for PSTA Cell 1, 2, 3 and 4 are all 6.95 µg/L. Were Al concentrations measured for these cells reported as below the MDL or <6.95? While it is possible to get the same identical concentration at several locations, it is not probable. Neither of the tables identify if concentrations were below MDL for any of the metals. In Table 4-16, As concentrations are all 2.4 µg/L. Probably, all concentrations should be reported as below MDL.

24. Page 84: Regarding section 4.2.10.2

    It's highly likely that seepage also affected the outcome in the APA analysis. The following two statements seem to contradict each other. *"Outflow APA was higher than inflow APA suggesting that available phosphorus had been stripped from the water column in the upper portion of each cell. When inflow phosphorus concentrations declined later in the year, both inflow and outflow APA measurements decreased in response."*
    The first statement indicates that APA increased as a result of reduction in P in the water column, while the second statement says APA decreased with the decrease in P concentration in both the inflow and outflow water.

25. Page 88: It is expected that the time-series data from this project, including the monthly FWM concentrations, are temporally autocorrelated. If so, the individual data points are not independent from each other; this violates one of the basic assumptions of inferential statistics, i.e., the data are independent. If temporal autocorrelation is present, the authors should consider using a repeated measures design for their analysis.

26. Page 88: A Student's t-test was used to compare mean TP concentrations for individual samples and monthly flow-weighted mean concentrations (at inflows and outflows). This test assumes that the residuals follow a normal distribution. The document does not provide any discussion whether the data were tested to determine if the distribution assumptions of the test were met. Distributional assumptions need to be tested to validate use of parametric statistics and to determine which measure of central tendency (mean, median) should be compared to determine differences between locations. In addition, there are basically two Student's t-tests that can be used to compare data sets: unpaired and paired two-sample t-tests. It is not explicitly stated which of the tests was being used to compare data. Based on the apparent unevenness of the data, it is assumed that an unpaired two-sample t-test was used.
    The analyses presented do not provide the reader with sufficient information regarding the data sets that are being tested. While the tables containing the comparison information do contain some data summarization, there are a few important variables that are missing. The tables do not provide any of the following information: (1) the number of TP concentrations that are being compared in each data set, (2) no standard deviations are provided for the data sets being compared, and (3) probability values (p-values) from the comparisons are not provided.
27. Page 91 - 92: There are two Fig. 5-2s in the document.
28. Page 97: TP concentrations are compared across Cells however, in order to perform these comparisons, the authors should use an analysis of variance (ANOVA). One of the assumptions of this test is that the residuals do not significantly deviate from a normal distribution. This assumption does not appear to have been tested. As was stated above, the summary tables where more than two cells are being compared do not have the following information provided: (1) the number of TP concentrations that are being compared for each cell, (2) no standard deviations are provided for the data from each cell, and (3) probability values (p-values) from the comparisons are not provided.
29. Page 104-105: It is important to note that any of the tests used to compare the data sets determine if a statistically significant difference exists (at a selected level of significance, α). Author should refrain from using the phrases "statistically the same" or "statistically similar" unless an equivalence test of the central tendency has been performed. The phrase "statistically the same" appears at the top of page 104 and "statistically similar" appears at the top of page 105. The Student's t-test is a test of statistical difference. Statistical equivalence is not determined when a

difference is not statistically significant. Just because the p-value for a comparison is greater than the level of significance, it does not imply that the two data sets are statistically the same or similar. The only conclusion that can be drawn is that the data sets maybe different but the difference is not statistically significant. It is suggested that the comparisons in this document be repeated using the appropriate test based on distributional assumptions. Since environmental data appears to follow a log-normal distribution, it is suggested that the data be log-transformed and tested for normality prior to application of a t-test or ANOVA. However, a more simple approach would be to test these comparison using equivalent non-parametric tests. Non-parametric tests are not affected by the distribution of the data. Instead of using the unpaired two-sample t-test, it is suggested that the authors use a Mann-Whitney test to compare the data sets. The Kruskal-Wallis test should be used to compare more than two data sets. In either case, it is extremely important to report the p-values. The results from the non-parametric analyses may change conclusions regarding the observed significant differences between inflows and outflows and Cells. Since the tests are comparing median values, results for Figures 5-20, 5-23 and 5-24 (for example) could change because the mean values (used in parametric comparisons) are influenced by extreme data values. For example, Figure 5-23 (page 105) shows that Cells A and B and Cells A and C are not statistically different. However, Cells B and C are. The results of a non-parametric test may indicate that Cells A and B and Cells B and C are not statistically different while Cells A and C are statistically different.

Based on information provided in Section 4 of the report, it appears that one of the factors driving a decrease in concentrations from inflows to outflows is dilution (i.e., SpCond, color, etc.). How is potential dilution accounted for in the statistical evaluation comparing the inflow and outflow TP concentrations?

The transect plots (especially for the FSD project) seem to contradict the comparisons made for inflows and outflows. Cell B (Figure 5-17) shows that the inflow and outflow TP concentrations are not statistically different. However, the transect data for Cell B (Figure 5-30) suggest that a statistically significant difference may exist between inflow and outflow TP concentrations. Seventy-five (75) percent of the data at distance 0 feet in Figure 5-30 ranges between 10 and 22 ppb while the TP concentrations at 3816 feet from the inlet are all below 10 ppb. Based on the box and whisker plots presented, the 95% confidence intervals around the median values would not overlap (ergo statistically different).

30. Page 118:

    "Periphyton total phosphorus concentrations did not follow a clear trend from inlet to outlet in any cell. Under higher loading conditions, it would be expected that the concentration of phosphorus in the periphyton would decline from inlet to outlet, but considering that water column concentrations were low, it is reasonable that there was no apparent gradient."

    The preceding paragraph said there were no periphyton samples collected during the operational phase, so it is not clear why a gradient is discussed.

31. Page 121: Why don't the algal relative abundance values for each location in Table 7-5 total to 1? Shouldn't the "other" group include all taxa other than blue-greens, diatoms, dinoflagellates and greens?

32. Page 123: Section 8.1.2

    "Mass balances were not prepared for the SAV cell due to incomplete inflow and outflow concentration records and undocumented inflow rates. Mass balances were prepared for three months of operation in 2008 and 10 months of operation in 2010 for the FSD PSTA cells. For all three cells, inflow loads were dominated by the inflow from the upstream SAV cell. Rainfall and

seepage input loads were minimal. Outflow loads were variably proportioned between surface discharge and seepage, depending on the cell."

Earlier in the document, the authors indicated concerns about lack of a more accurate estimation of seepage. In Section 8.1.2, however, the authors indicate that seepage contribution is minimal.

33. Page 124 – 130: The left side of these tables is missing.
34. Page 138: For the statement in the 1st paragraph of Section 10.1, "…. This applied research has concluded that a periphyton-dominated wetland ecosystem is likely the only natural technology capable of achieving 10 ppb geometric mean on a long-term, sustainable basis. …".
    i. "… the only natural technology…" statement was not proper, as the USACE projects didn't examine other types of natural system in addition to periphyton.
    ii. The limited data and results presented do not provide sufficient evidence to support the conclusion of the long-term P removal performance for PSTA. Hence the "long-term sustainable performance" of the PSTA remains unresolved.
35. Page 141: The area of the STA-3/4 PSTA Cell in Table 10-1 is incorrect. It should be 404,685 m^2.
36. Page 141: The number of months that the STA-3/4 PSTA system operated up through WY2010 was 24 months not 12 months.
37. Page 141: Please point out database and references used to calculate Table 10-1. Author should cite Table 10-1 in the text of Section 10.2, so that the project names in the text (p. 138-139) match with those in Table 10-1. Some of the numbers in the text don't match those in Table 10-1. For example, was "Porta-PSTA" in Section 10.2.1 equal to the 1st case project in Table 10-1? In the text on p. 139, inflows average was 23-27 ppb, but Table 10-1 shows "20 ppb".
38. Page 142: The text states that there is evidence that pretreatment will reduce internal P loading in treatment wetlands. It would be helpful to provide some reference to support this statement.
39. Page 142: Regarding "Inflow TP Concentrations": moderate to low (<20ppb): It is not clear where the <20 ppb came from. Again, it would be helpful to provide a reference to support this statement.
40. Page 142:

    "Source Water Dissolved Calcium *– The presence of dissolved calcium at adequate concentrations (above 50 mg/L) is utilized in the co-precipitation process with TP and periphyton. As algae strip carbon dioxide from the water column for photosynthesis, calcium carbonate is precipitated. Some P is incorporated in this precipitated calcium carbonate and assumed to be* ***recalcitrant*** *and effectively removed from the internal nutrient cycle."*

    Ca-P can be considered stable, but not recalcitrant.
41. Page 146: It is agreed that having the calcium-based substrate will be beneficial; however, it will not be feasible to conduct a sound comparison of this area versus the adjoining bypass cell, unless they are brought to the same ground elevation and the contribution of seepage is either controlled or accurately estimated. Also, with the current soil condition in STA-1E, this expense does not appear to be warranted. There is very little TP stored in the sediment, therefore, the flux potential is small.

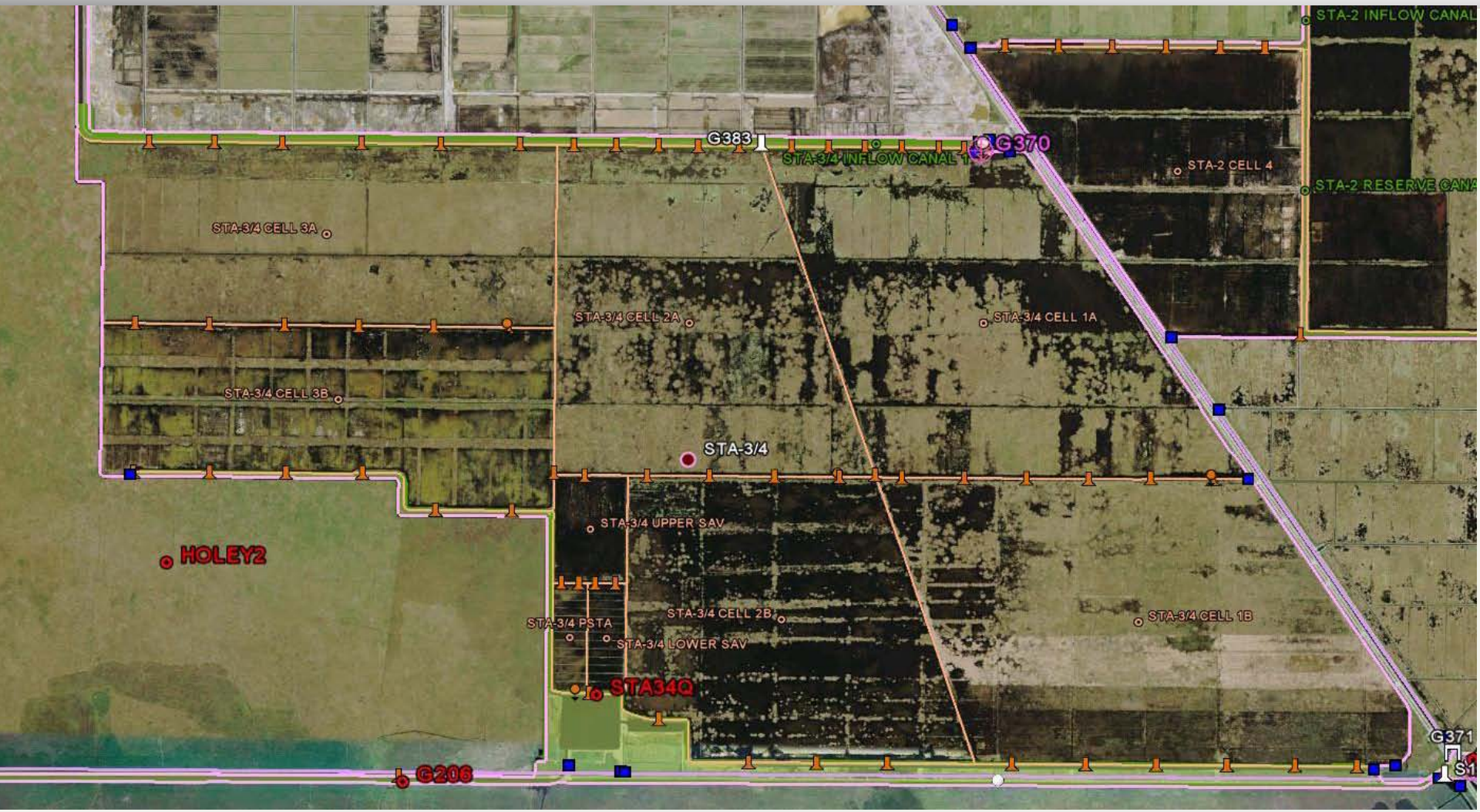
STA 3/4
PSTA Cell Modifications

Long Term Plan Quarterly Communications Meeting
November 15, 2011

David Unsell, P.E.

Section Administrator
Water Quality Treatment Technologies

PSTA Cell Improvements




G390B
G390A
G389B
G389A
STA-3/4 PSTA
STA-3/4 LOWER SAV
G388
G379E
STA34Q

G-390B Modification

G-390B Modification

G-388 Modifications

STA 3/4 PSTA Cell Modifications

- Objective: Flow/load measurement improvements
- Modify G-390B to improve flow measurements
- Modify one pump at G-388 to reduce pump flow rate
- Resurvey all stage sensors in the flow path in a single loop
- Utilize existing wells/piezometers on east and west levees
- Other future work to include is improved gauging at S378 and S389 structures

PSTA Modifications
Start Up Options

- Start using existing flow/stage criteria
- Plan to move to higher stage and/or flow rates after vegetation has stabilized/recovered from dry down

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Transition to Science Plan

STA 3/4 PSTA Research Plan

Prepared for the
Long Term Plan Communications Meeting
November 15, 2011

Tom DeBusk
DB Environmental, Inc.

Background: PSTA Concept

- The PSTA "concept" generally refers to:
  - Treatment wetland with a lime rock (LR) substrate, achieved either through muck removal or LR cover placed over muck
  - Deployed as a "back end" STA community
  - Low inflow P concentrations/loadings desired
  - Subsequent colonization with calcareous periphyton may occur, but it is not always the dominant plant type

Background: Prevailing theory as to how PSTA achieves outflow TP levels of ~10 ug/L

- The lime rock provides a stable substrate, and therefore minimizes potential sediment P contribution to water column via diffusive flux, bioturbation and/or macrophyte mining
- Vegetation that develops/persists is adapted to low P conditions, and can support microbial communities that contribute to removal of relatively recalcitrant P forms (e.g., dissolved organic P [DOP])

PSTA: Potential constraints to scale-up

- Only a small subset of the PSTA projects performed in past 12 years have attained the 10 ug/L TP target
- High cost of muck removal or lime rock placement
- Presumed requirement of operating at very shallow water depths
- Water balance of many prior PSTA projects potentially compromised by undocumented seepage
- Considerable speculation about additional requisite PSTA design and operational features
  - Certain LR types superior to others?
  - Routine drydown needed to obtain best performance from calcareous periphyton communities?

Example PSTA Projects that did not achieve the 10 ug/L TP target

STA-2 Field Scale Facility

- ~2’ LR over soils; or muck scraped
- Unit sizes of 0.5 ha

STA-1W Test Cell Facility

- ~1’ LR over soils
- Unit sizes of 0.22 ha

Despite a poorly characterized water balance, the STA 3/4 PSTA facility has provided key information on the technology

- The 40 ha STA 3/4 PSTA cell is the largest individual platform deployed in 12 years of PSTA research
- Achieved the mean 10 ug/L TP target for several years in succession
- Successfully operated at a water depth comparable to “typical” SAV cells, with no drydown until summer 2011

STA 3/4 PSTA Cell: TP loading and inflow/outflow TP concentrations for WYs 2008 - 2011

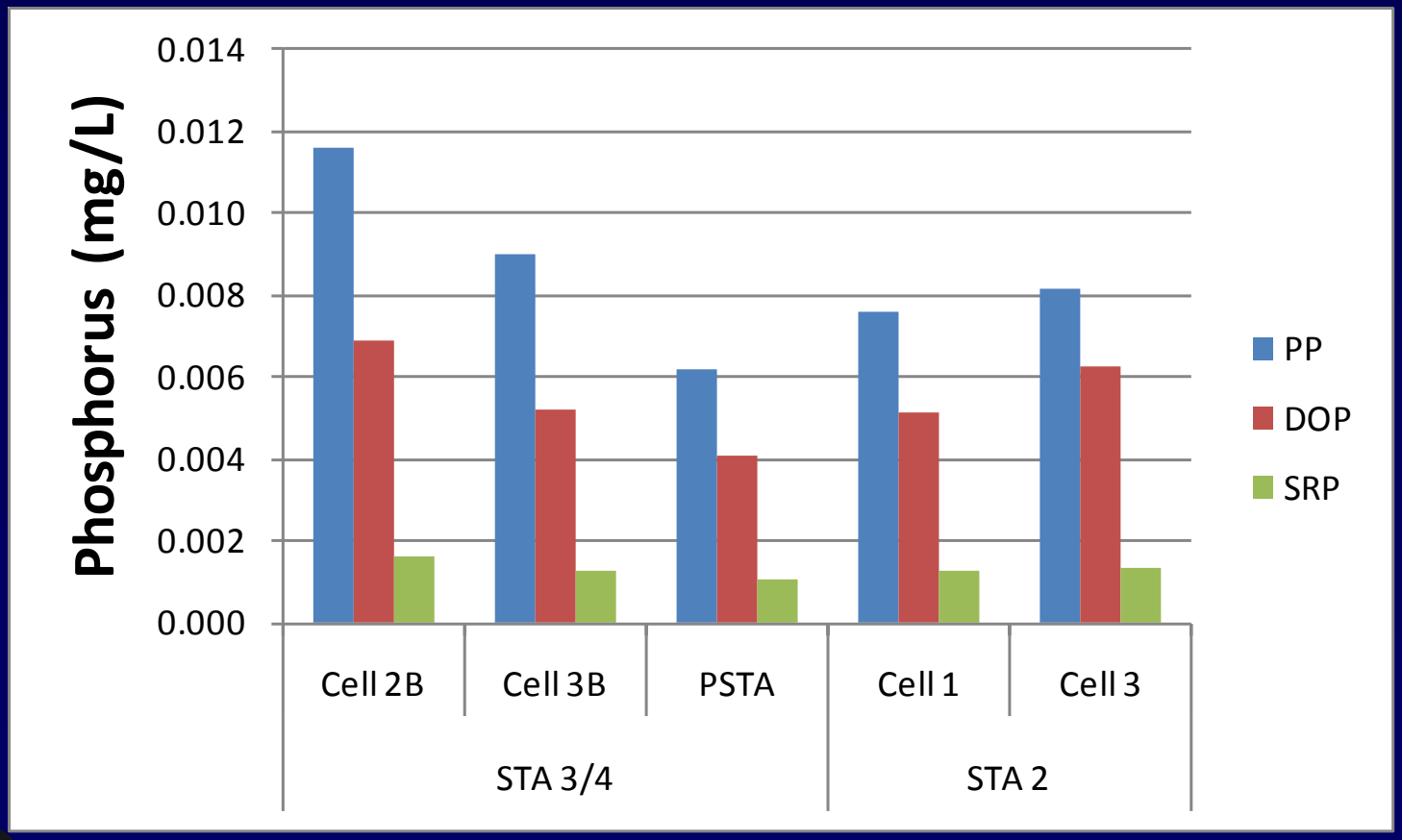
	Days of Operation	HLR (cm/day)	TP Load (g P/m^2/yr)	TP Inflow (µg/L)	TP Outflow (µg/L)
WY2008	161	6.3	0.63	28	12
WY2009	168	7.1	0.37	14	8
WY2010	341	7.1	0.52	20	10
WY2011	159	7.4	0.52	20	11

Values from draft SFER 2012

The STA-3/4 PSTA cell offers a useful platform for evaluating critical questions that should be addressed prior to scale-up

- What characteristics of the PSTA wetland facilitate low-level outflow P concentrations?
- Are the P removal processes sustainable, or will system performance decline as new sediments accumulate over time?
- Under what P loading and inflow P levels does PSTA remain sustainable?
- How critical is the scraping of muck (or addition of a LR soil cover) to support these key processes, and to achieve low outflow TP levels?
- Are there less expensive alternatives to achieving low P levels than muck scraping or LR addition?

Outflow chemistry comparisons among well-performing STA flow paths provides insight into the unique characteristics of PSTA cell discharges

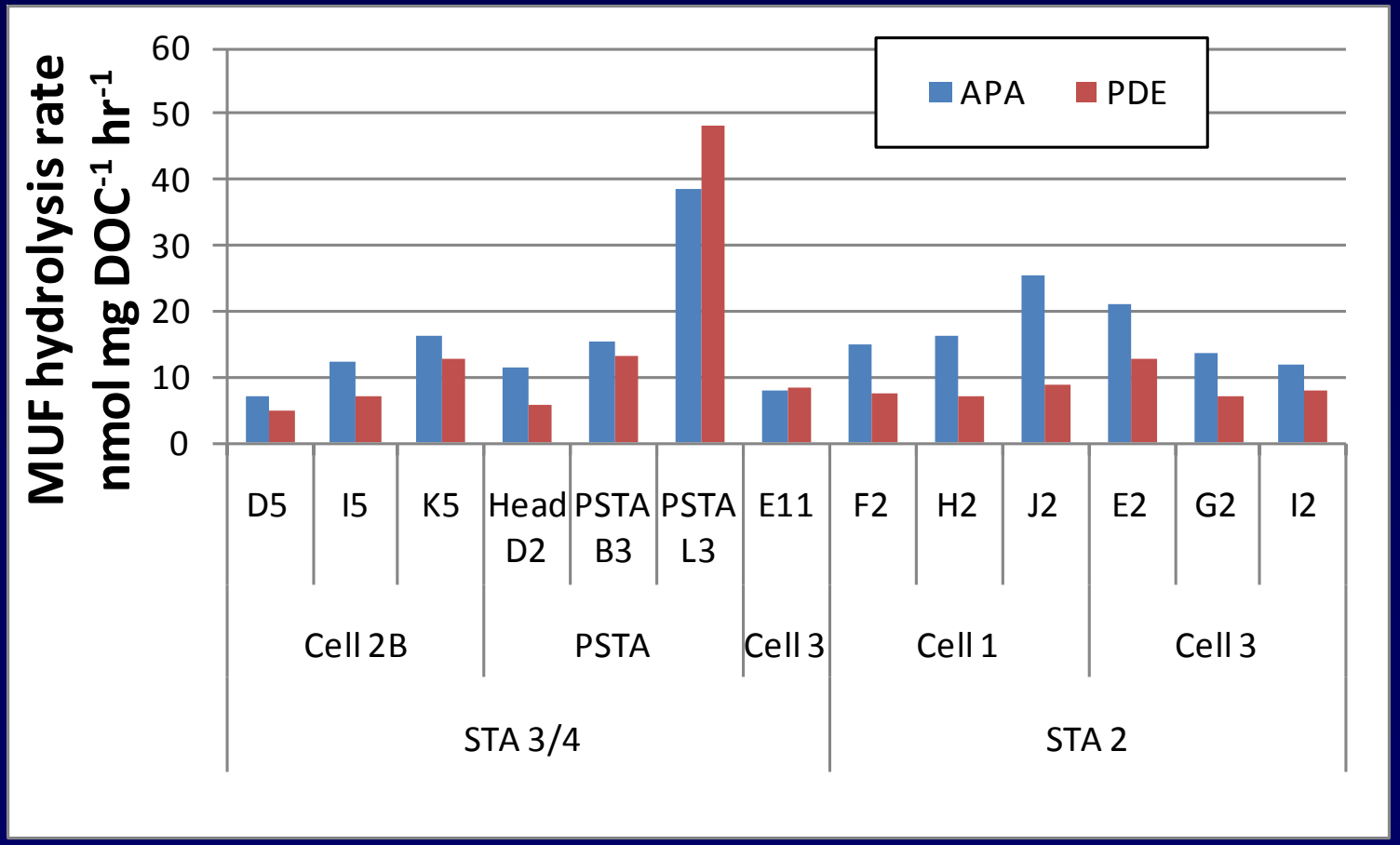


Mean values, Sept 2009 – Aug 2010

Phosphatase enzymes probably play a key role in the PSTA cell's low outflow P concentrations

- Enzymes liberate phosphate from larger DOP molecules
  - Phosphate can pass through cell walls, membranes into bacteria, algae cells
  - Dissolved organic P compounds typically are too large for direct biological uptake
- Phosphatase activity increases P available for uptake, reduces DOP levels, and may also reduce PP concentrations

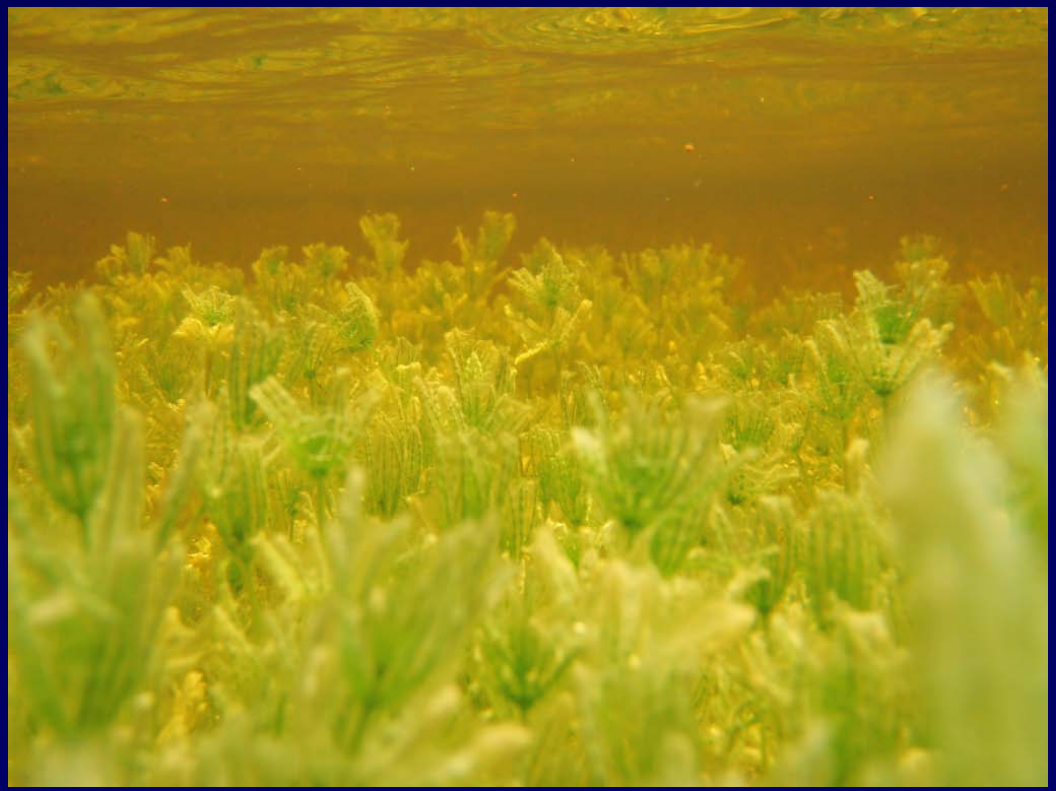
Our initial survey demonstrated enhanced phosphatase activity in portions of the PSTA cell



Samples collected late summer 2010;
APA – alkaline phosphatase, PDE – phospho-diesterase

UV radiation also may play a role in DOP breakdown. This process may be enhanced in regions of sparse vegetation, or in areas where SAV is not “topped out”. Conversely, high dissolved organic matter levels can inhibit this process by minimizing UV penetration into the water column.

Dense Chara meadow



PSTA Research Plan

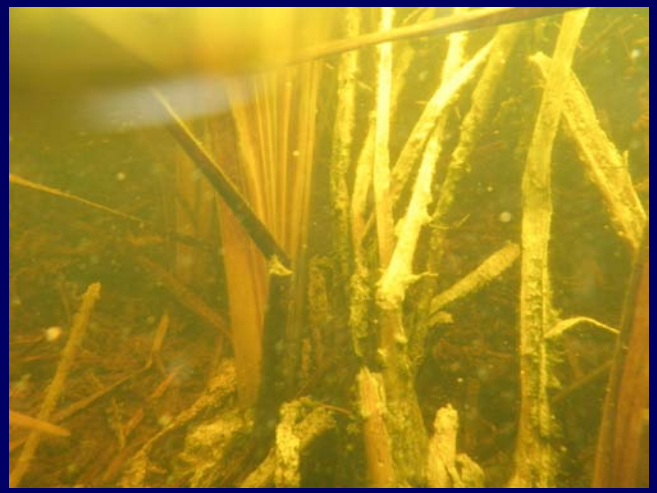
- Anticipated 2 – 3 year effort
- Flexible – we will modify activities over time as findings suggest
- Spatial and temporal internal transect sampling of surface waters
  - Perform under varying P loading rates and if possible, variable inflow P concentrations
  - Assess enzyme activity, P species, N species, DOC quantity and quality, + other analytes
  - Evaluate regions of particularly effective (or ineffective) treatment; relate to cell operational conditions and/or site-specific vegetation characteristics

PSTA Research Plan

- Spatial sediment characterization
  - survey accrued sediments: assess depth, enzyme activity, TP, TN, TC and Ca contents and size of P pools available for flux or macrophyte “mining”
- Sediment core or flask lab incubations to assess potential P release
  - comparisons to be made with underlying LR and with sediments from outflow regions of other well-performing STA cells
- These sediment analyses are critical to assess PSTA long-term sustainability
  - i.e., are sediments that accrue along the cell flow path as “P stable” as the original underlying LR?

PSTA Research Plan

- Spatial vegetation assessments
  - characterize SAV and periphyton speciation, standing crop and whether or not plants are “topped out”; compare to plant characteristics in muck-based SAV flow path outflow regions
  - assess potential role of EAV on vegetated strips
  - measure enzyme activity and elemental composition of algae and macrophyte tissues

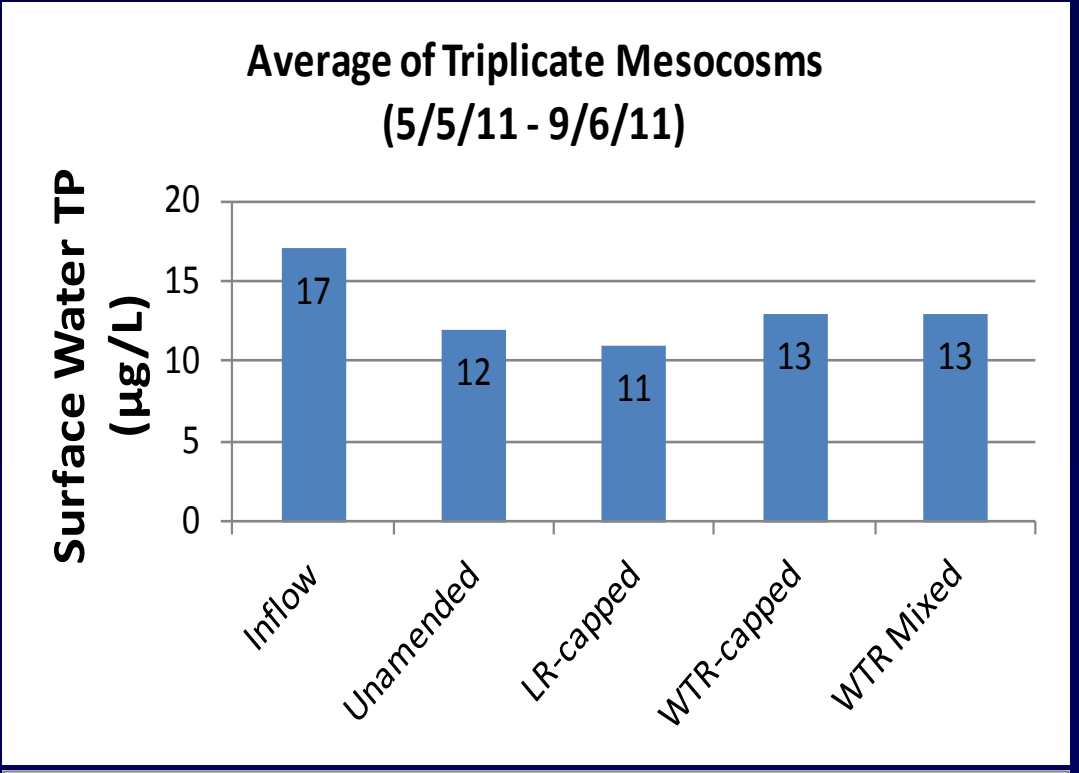


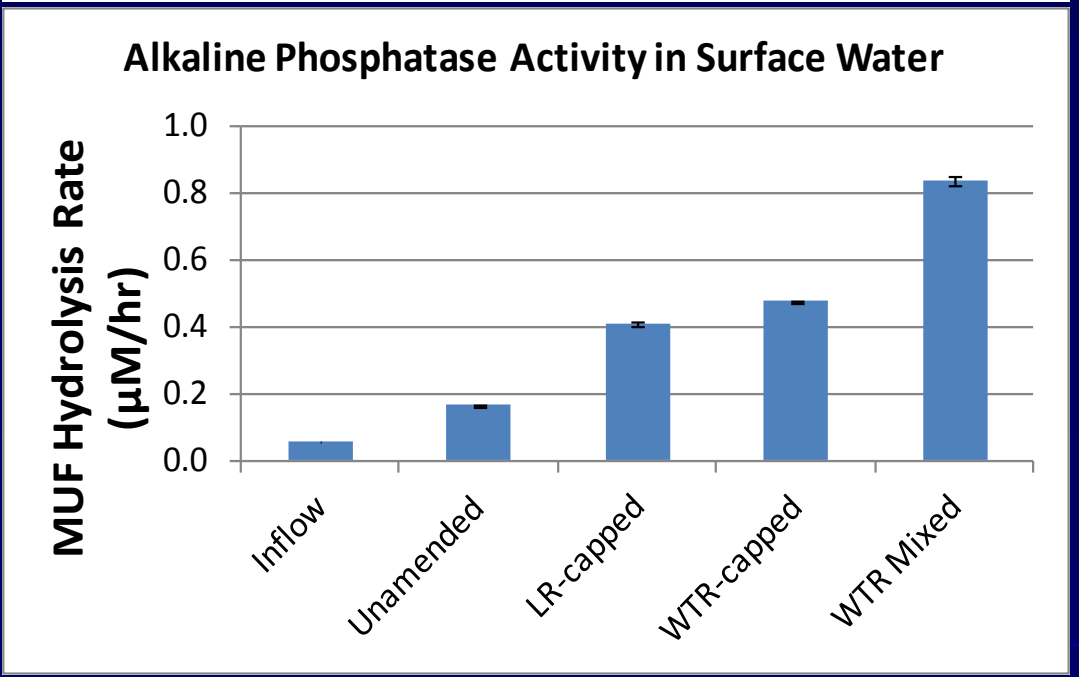
PSTA Research Plan

- Mesocosms and enclosures
  - mesocosms (containing soils/amendments and vegetation) will be used for selected studies to characterize vegetation – sediment interactions (e.g., P mining, enzyme activity)
  - Intact soil + vegetation + water “cylinder” studies, at scales ranging from intact cores to *in situ* enclosures, will be used to evaluate key processes
- Other assessments
  - Stable isotope analyses to determine sources of dissolved organic matter
  - Periodic sampling of levee wells for P species to help characterize potential contribution of seepage to the wetland P balance

Example mesocosm effort: current study at STA-1W outflow region, comparing LR substrate with another P-sorbing (but non-calcium) substrate

Lime rock and water treatment residual (WTR) amendments. Both were used as a 4 cm “cap” over muck to attenuate soil P release. The WTR also was blended in with top 4 cm of muck soil.





Initial P removal performance and phosphatase enzyme activity in unamended muck mesocosms and those amended with LR and a WTR

Summary

- Outflow data demonstrate that the STA-3/4 PSTA cell achieves slightly better reductions in both DOP and PP compared to well-performing SAV cells.
- Water column sampling has revealed high phosphatase enzyme activity in the PSTA cell.
- A multi-year research effort has been initiated to identify and optimize the key DOP and PP removal processes, and to better define operational boundaries
- This effort will include spatial and temporal water column, vegetation and sediment assessments
- Initial efforts will focusing on identifying regions (and substrates) with greatest phosphatase enzyme activity, and on characterizing stability of P in the accrued sediments.