

North Relief Canal Project: Status Update



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Project Basics

Three Stages (Field Work)

Stage 1: Preliminary Water Quality Investigation, Feasibility Study, Pilot Site Development

Stage 2: Comparative Testing of Two Systems

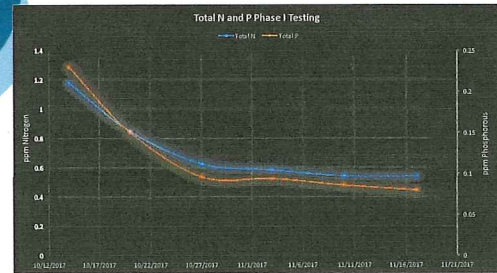
- Attached Algae System
- Low Energy Aquatic Plant System (LEAPS): Water Lettuce, Algae Flowway, and Emergent Aquatic Plants

Stage 3: Downselection of system and focused testing

Stage 1: Water Quality 10/14-11/17

Parameter	Sample Size (N)	Statistics		
		Average (Mean) (mg/L)	Standard Deviation (σ)	% of Total
Total Nitrogen	7	0.698	0.24	
Total Kjeldahl Nitrogen	7	0.604	0.19	86.6%
Organic Nitrogen	2	0.690	0.21	78.1%
Nitrate-Nitrogen	3	0.139	0.05	
Nitrite-Nitrogen	3	U		
Total-NOx Nitrogen	7	0.094	0.05	13.4%
Ammonia-Nitrogen	2	0.075	0.11	8.5%
Total Phosphorous	7	0.123	0.06	
Ortho-Phosphorous	2	0.116	0.05	70.9%
Org-Phosphorous	2	0.048	0.05	29.1%
Total Suspended Solids	2	5.25	7.42	
Total Volatile Suspended Solids	2	3.00	4.24	57.1%
Total Organic Carbon	2	14.40	2.40	

Stage 1 Water Quality Trends



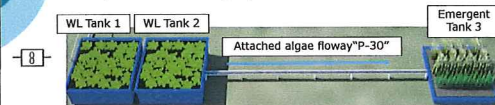
Stage 1 Water Quality Findings 10/14 – 11/17

- Steady decrease in both Nitrogen and Phosphorous following Hurricane Matthew impacts
- Majority of Nitrogen is organic form 78.1% (difficult for plants to utilize)
- Majority of Phosphorous is in Ortho-P state, which is readily available to plants
- Low Nitrogen levels and dominance of Organic Nitrogen suggests Nitrogen deficient conditions exist at site during the period
- Suspended solids are low at site and were only detectable immediately after Hurricane Matthew

Stage 2: Comparison of LEAPS to attached algae system 1/22/2017 – 3/28/2017

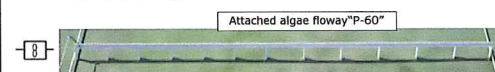
System 1: LEAPS

- Two 725 gallon Water Lettuce Tanks
- 30 foot attached algae flowway
- 725 gallon tank with emergent plants



System 2: P-60

- 60 foot attached algae flowway



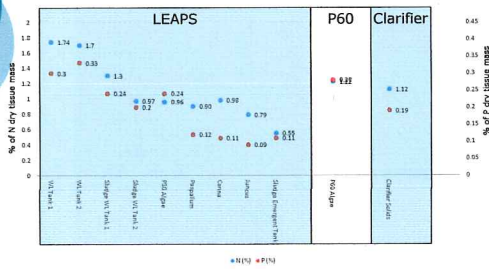
Stage 2 Objectives

- Compare plant/algae yields between systems and measure levels of N and P in tissue
- Calculate Areal Removal Rate (ARR) = amount of N and P in harvested plants/algae removed from systems divided by system area over a time period.
 - Overall ARR = (Tank 1 area)(% of Total area represented by Tank 1) + (Tank 2 area)(% of Total area represented by Tank 2) + ... + (Tank N area)(% of Total area represented by Tank N).
 - ARR typically expressed as g/m²/year
- Confirm ARRs and nutrient removal performance by measuring N and P concentrations in system influents versus effluents based on composite water samples

Site Pictures



Stage 2 Composite Tissue Sample Analysis



Performance Comparisons: LEAPS versus P-60 Attached Algae Floway

LEAPS showed superior areal removal rates (ARRs) to the P60 throughout Stage 2 and into early phases of Stage 3

System	Stage	Harvest Based Removals	
		Nitrogen Areal Removal (g/m ² /year)	Phosphorus Areal Removal (g/m ² /year)
LEAPS	Stage 2/3 ^a	52.19	9.74
P-60	Stage 2/3 ^a	33.31	7.65

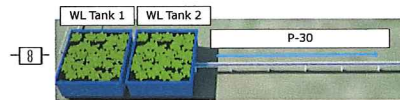
^aComparative areal removal rates for Stage2/3 were calculated from harvest data from 1/23/2017 to 6/18/2017, as we discontinued the operation of the stand-alone algae system on 6/18. Stage 2 composite tissue data was used to estimate Nitrogen and Phosphorus levels in biomass between systems in Stage 3, as we are awaiting lab results on Stage 3 tissue.

Stage 3: Testing of LEAPS

- Focus testing on LEAPS system based on its superior performance relative to a stand-alone algae system
 - Harvest and plant tissue based monitoring
 - Continue and focus water quality testing

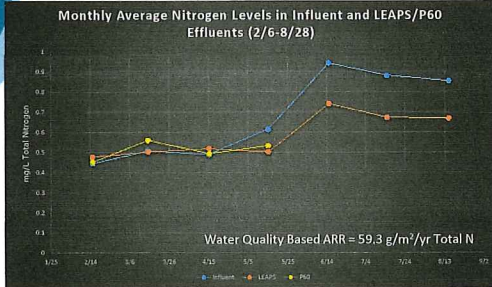
Stage 3: LEAPS Module Specific ARRs (based on harvested biomass 1/23/2017-8/14/2017)

- ARRs of LEAPS as of 8/14/17: N = 71.1 and P = 13.3 g/m²/yr; this value exceeds ARRs of Egret Marsh Stormwater Treatment Park
- ARRs of individual modules of the LEAPS system were also determined (presented below)
- WL tank 1 exhibits very high ARRs (best removal based on footprint): N=98.1 g/m²/yr and P= 17.3 g/m²/yr

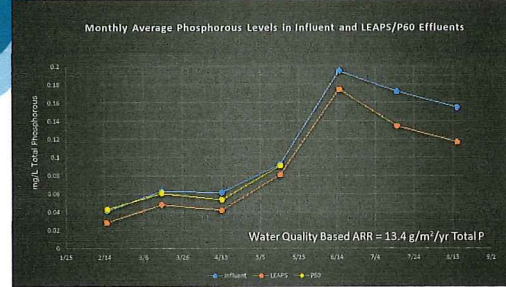


	WL Tank 1	WL Tank 2	P-30
N Areal Removal Rate (g/m ² /yr)	98.10	58.44	28.69
P Areal Removal Rate (g/m ² /yr)	17.30	11.60	7.42

Water Quality Data Stage 2/3 Monthly Average Total Nitrogen (2/1/2017 to 8/28/2017)

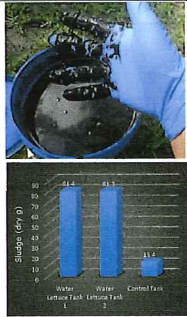


Water Quality Data Stage 2/3 Monthly Average Total Phosphorous (2/1/2017 to 8/28/2017)



A surprising finding...

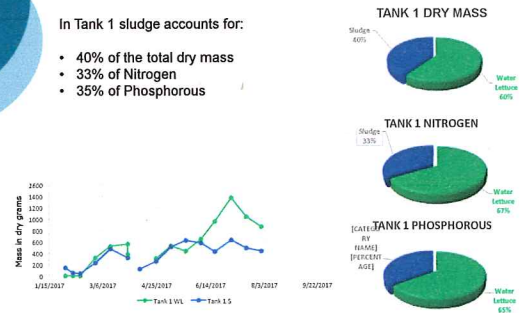
- High levels of sludge accumulation in Water Lettuce tanks - precipitating dissolved solids?
- Not explained by simple suspended solids settling
 - Preliminary side-by-side experiment with identical tank without Water Lettuce
 - < 17% of sludge could be explained by settling solids from canal
- Tissue analysis indicates:
 - ~ 1.0 % Nitrogen
 - > 0.2% Phosphorous
- A lucrative target for N and P removal



Water Lettuce Tank 1 Sludge Analysis

In Tank 1 sludge accounts for:

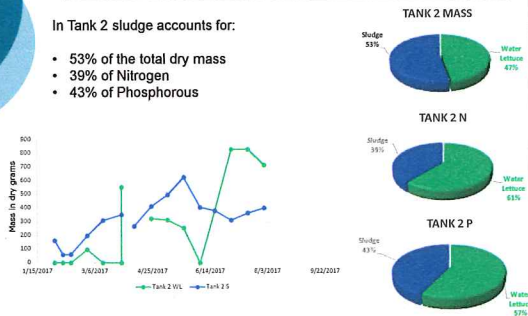
- 40% of the total dry mass
- 33% of Nitrogen
- 35% of Phosphorous



Water Lettuce Tank 2 Sludge Analysis

In Tank 2 sludge accounts for:

- 53% of the total dry mass
- 39% of Nitrogen
- 43% of Phosphorous



Summary

- Stage 1: Nutrient levels in the NRC exhibit a seasonal degree of nitrogen limitation/deficiency, but WQ parameters are sufficient to support algae/WL growth
- Stage 2: Comparative testing demonstrated LEAPS has superior N and P removal versus a stand-alone attached algae system
- Preliminary Stage 3 testing findings:
 - Biomass-based ARRs compare favorably to and can exceed large-scale systems (Eg., the Egret Marsh Algal Turf Scrubber - Wetland System)
 - Water quality data based ARRs highly similar to biomass-based ARRs
 - The first Water Lettuce tank exhibited the highest ARRs; data can be leverage for full-scale build to maximize footprint/removal
 - A full-scale LEAPS system should incorporate a sludge capture and handling system
- Major advantages of the LEAPS:
 - No loss of crop during power outages and flow interruptions
 - Option for daytime only pumping to reduce OPEX