Algae Based Water Treatment Systems – Cost-Effective Nutrient Pollution Control and for Point and Nonpoint Source Applications

February 16, 2010
Presenter: Mark J. Zivojnovich, VP Project Development
Presentation Outline

1. Algal Turf Scrubber® Technology
   • Early Development
   • Function and Design
2. Algal Turf Scrubber® Project History and Timeline
3. Research Partners
4. Algal Biomass Products
5. Technology Advantages
   • Treatment Costs
6. Santa Fe Algal Turf Scrubber® Pilot
7. The Next Step
Algal Turf Scrubber®
Early Stage Development
1970s – 1980s
What is an Algal Turf Scrubber®?

• A culture unit for attached algae
• The algae remove nitrogen and phosphorus from the water
• The algae is regularly recovered and processed
• Recovery of algal biomass maintains the culture units in an accelerated growth phase
• And provides sustainability as nutrients are continuously recovered and removed from the treatment unit
Algal Turf Scrubber® Design
System Inflow

Water is surged down the sloped floway in a pulsing motion. The pulsing surge stimulates algal growth.
The algal turf biomass is recovered on a 7-14 day cycle using HydroMentia’s proprietary harvest design. The recovered algal biomass contains excess nutrients removed from the water.
Algal Turf Scrubber® Design
Biomass Production

Algal turf or dense mats of simple algae are cultivated on the surface of the floway. As the algae grow, they remove nutrient pollutants (phosphorous and nitrogen) from the water.
Algal Turf Scrubber® Design
Centralized Biomass Recovery

Harvested algae is conveyed by the water via a concrete flume to a centralized recovery facility.
Algal Turf Scrubber® Design
Centralized Biomass Recovery System
The harvested algae is removed from the water with a Flex Rake.
Algal Turf Scrubber® Systems
Pilot and Full Scale Locations
Patterson ATS™
Stanislaus County, CA
0.2 MGD x 500’
HMI Aquaculture ATS™
(2000-2002)
Okeechobee County, FL
30 MGD x 220’
S-154 ATS™ with WHS Pre-Treatment (2003-2004)
Okeechobee County, FL
1-6 MGD x 300’
Taylor Creek ATS™ (2007-2009) Okeechobee County, FL 15 MGD x 300’
STA-IW ATS™
(2009)
Palm Beach County, FL Pilot
Powell Creek ATS™
(2009)
Lee County, FL
Pilot
Santa Fe ATS™
(2009)
Alachua County, FL
Pilot
Egret Marsh ATS™
(2010)
Indian River County, FL
10 MGD x 575’
Research Partners
Algal Turf Scrubber® Research

- US Department of Agriculture
- University of Florida
- Statoilhydro
- William and Mary
- Virginia Institute of Marine Science
- University of Maryland
- Western Michigan
- University of Arkansas
- University of Georgia
- Kimberly Clark
Algal Biomass Products
Algal Biomass Products

Biofuel Production

Compost/Organic Fertilizer

Livestock Feed
Algal Turf Scrubber®
Technology Advantages
Phosphorus and Nitrogen Control Treatment Options

NON POINT SOURCES

• Best Management Practices
• Regional Treatment Systems
  • Treatment Wetlands
  • Managed Aquatic Plant Systems
    • Algal Turf Scrubber®
  • Chemical Treatment

POINT SOURCES

• Treatment Plant Upgrades
  • Biological Nutrient Removal (BNR)
  • Algal Turf Scrubber®
Lake Okeechobee BMP Performance

• In 1987, the PLRG developed for Lake Okeechobee mandated a 40% reduction in total phosphorus loads to Lake Okeechobee from 531 Mtons to 360 Mtons. The PLRG was to be achieved by 1992.

• Following nearly $160 million in direct costs and lost income resulting from BMPs and other programs, the programs implemented failed to meet the 1992 360 Mton SWIM PLRG objective.

Table 1: Total P Loads (in Mtons) to Lake Okeechobee 1991-2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Measured Load</th>
<th>Long-term Load (5-yr moving average)</th>
<th>Long-term Over-target Load (5-yr moving average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>445</td>
<td>415</td>
<td>275</td>
</tr>
<tr>
<td>1992</td>
<td>388</td>
<td>393</td>
<td>253</td>
</tr>
<tr>
<td>1993</td>
<td>296</td>
<td>375</td>
<td>235</td>
</tr>
<tr>
<td>1994</td>
<td>580</td>
<td>421</td>
<td>281</td>
</tr>
<tr>
<td>1995</td>
<td>683</td>
<td>478</td>
<td>338</td>
</tr>
<tr>
<td>1996</td>
<td>200</td>
<td>430</td>
<td>290</td>
</tr>
<tr>
<td>1997</td>
<td>470</td>
<td>446</td>
<td>306</td>
</tr>
<tr>
<td>1998</td>
<td>780</td>
<td>543</td>
<td>403</td>
</tr>
<tr>
<td>1999</td>
<td>670</td>
<td>561</td>
<td>421</td>
</tr>
<tr>
<td>2000c</td>
<td>169</td>
<td>458</td>
<td>318</td>
</tr>
<tr>
<td>2001</td>
<td>607</td>
<td>539</td>
<td>399</td>
</tr>
<tr>
<td>2002</td>
<td>543</td>
<td>554</td>
<td>414</td>
</tr>
<tr>
<td>2003</td>
<td>187d</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

a: Includes an atmospheric load of 35 Mtons per year based on the Lake Okeechobee TMDL (FDEP 2001)
b: Target is the Lake Okeechobee TMDL of 140 Mtons (FDEP 2001) compared to a five-year moving average. Period of record for baseline load estimate in LOPP is 1991-2000 (see page 11).
c: Year 2003 data reported is through June 2003 and includes half of the annual atmospheric load. The QA/QC process for the data for the complete year will not be completed until March 2004.
Lake Okeechobee BMP Performance

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Algal Turf Scrubber® Water Treatment
Strategic Advantages:

• High Level Treatment Capabilities – Restoration to Background Levels
• Lower Treatment Costs
• Reduced Land Requirements
• Revenue Generating Byproducts
Lower Treatment Costs
Typical Nitrogen Reduction Unit Costs to Comply with TMDLs in the Lower St Johns River Watershed

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Average ($/lb N/yr)</th>
<th>Typical Range ($/lb N/yr)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater Treatment</td>
<td>26</td>
<td>23–28</td>
<td>Size of facility and ultimate level of treatment affect unit cost.</td>
</tr>
<tr>
<td>Residential Reclaimed Water (Reuse)</td>
<td>78</td>
<td>27–190</td>
<td>Does not include household hookups or irrigation systems. Quality of effluent and service territory specific characteristics affect unit cost (better effluent, high unit costs).</td>
</tr>
<tr>
<td>Stormwater Treatment Systems</td>
<td>475</td>
<td>150–500</td>
<td>Land availability is a major implementation constraint in older urban settings. Mean is for retrofitting older urban areas, and low range is for relatively easy projects. These projects may not completely meet nutrient reduction requirements for MS4 permit holders.</td>
</tr>
<tr>
<td>Regional Land Application (Recharge)</td>
<td>60</td>
<td>25–250</td>
<td>Very high initial capital costs for a regional project.</td>
</tr>
</tbody>
</table>

Source: CH2MHiIl, 2007. LSJR Main Stream Nutrient TMDL

Lower Treatment Costs - Nitrogen

Algal Turf Scrubber®

<table>
<thead>
<tr>
<th>Average ($/lb N/yr)</th>
<th>Typical Range ($/lb N/yr)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>15-60</td>
<td>Assumes direct treatment of impaired surface water or Ultra-AWT treatment of wastewater</td>
</tr>
</tbody>
</table>

Source: HydroMentia, Inc.
2006 PRELIMINARY ENGINEERING ASSESSMENT
Nitrate-N Concentration FW1 - Q1 to Q3

Nitrate-N Concentrations FW1

- Nitrate-N Influent FW1 mg/l
- Nitrate-N Effluent FW1 mg/l

Week Ending

0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30
Nitrate-N mg/l

Nitrate-N Percent Removal

Figure ES-5: Comparative System Performance Nitrate + Nitrite Nitrogen Percent Removal

<table>
<thead>
<tr>
<th></th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Monitoring Period YTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floway SF1</td>
<td>61.9%</td>
<td>55.0%</td>
<td>57.6%</td>
</tr>
<tr>
<td>Floway SF2</td>
<td>59.2%</td>
<td>57.6%</td>
<td>58.2%</td>
</tr>
</tbody>
</table>
Nitrate-N Areal Removal Rate

Figure ES-4: Comparative System Performance Nitrate + Nitrite Nitrogen Areal Removal Rates

<table>
<thead>
<tr>
<th></th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Monitoring Period YTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN Inflow</td>
<td>1.1 mg/l</td>
<td>1.3 mg/l</td>
<td>1.2 mg/l</td>
</tr>
<tr>
<td>NO3 Inflow</td>
<td>0.11 mg/l</td>
<td>0.17 mg/l</td>
<td>0.14 mg/l</td>
</tr>
<tr>
<td>TP Inflow</td>
<td>0.21 mg/l</td>
<td>0.300 mg/l</td>
<td>0.26 mg/l</td>
</tr>
<tr>
<td>Floway SF1</td>
<td>54.2</td>
<td>77.9</td>
<td>66.0</td>
</tr>
<tr>
<td>Floway SF2</td>
<td>52.0</td>
<td>81.7</td>
<td>66.8</td>
</tr>
</tbody>
</table>
Figure ES-3: Comparative System Performance Total Nitrogen Areal Removal Rates

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Floway SF1</th>
<th>Floway SF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter 1</td>
<td>70.5</td>
<td>32.3</td>
</tr>
<tr>
<td>TN Inflow</td>
<td>1.1 mg/l</td>
<td>1.3 mg/l</td>
</tr>
<tr>
<td>NO3 Inflow</td>
<td>0.11 mg/l</td>
<td>0.17 mg/l</td>
</tr>
<tr>
<td>TP Inflow</td>
<td>0.21 mg/l</td>
<td>0.300 mg/l</td>
</tr>
<tr>
<td>Monitoring Period YTD</td>
<td>197.8</td>
<td>130.1</td>
</tr>
<tr>
<td>TN Inflow</td>
<td>1.2 mg/l</td>
<td></td>
</tr>
<tr>
<td>NO3 Inflow</td>
<td>0.14 mg/l</td>
<td></td>
</tr>
<tr>
<td>TP Inflow</td>
<td>0.26 mg/l</td>
<td></td>
</tr>
</tbody>
</table>
Alkalinity Concentrations

Figure 2-22. Plot of mean alkalinity (mg/L as CaCO₃) in the five reaches of the Suwannee River in Florida.

Source: LSR MFL Final Report. 2006
## Relative Nitrate-N Concentrations

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean Discharge (MGD)</th>
<th>Nitrate-N (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suwannee River</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ellaville</td>
<td>2,482</td>
<td>0.35</td>
</tr>
<tr>
<td>Dowling Park</td>
<td>2,362</td>
<td>0.30</td>
</tr>
<tr>
<td>Luraville</td>
<td>2,554</td>
<td>0.40</td>
</tr>
<tr>
<td>Branford</td>
<td>2,863</td>
<td>0.64</td>
</tr>
<tr>
<td>Bell/Rock Bluff</td>
<td>3,645</td>
<td>0.63</td>
</tr>
<tr>
<td>Wilcox</td>
<td>3,691</td>
<td>0.61</td>
</tr>
<tr>
<td>Gopher River</td>
<td>4,106</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Springs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troy Springs</td>
<td>89</td>
<td>2.20</td>
</tr>
<tr>
<td>Fanning Springs</td>
<td>70</td>
<td>4.85</td>
</tr>
<tr>
<td>Manatee Springs</td>
<td>131</td>
<td>1.80</td>
</tr>
<tr>
<td><strong>Santa Fe River</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Santa Fe ATS™</td>
<td></td>
<td>0.13</td>
</tr>
</tbody>
</table>

1 Preliminary Engineering Assessment for ATS™, Sep 2006
2 Florida Springs Initiative Monitoring Report. Feb 2010

**Suwannee River Overall System Projections**

Total N Removal Rate = 310 g/m²/yr

**Santa Fe River ATS™ Pilot (Q1 - Q2)**

Total N Removal Rate = 130-198 g/m²/yr
N is the Areal Removal Rate (g m⁻² yr⁻¹)

S154 Single Stage (ATS-300', HLR=368 cm/d, CI=1.1 - 2.8 mg/l)

y = 5.2611x - 6378.2
R² = 0.5602
THE NEXT STEP
The Algal Turf Scrubber® is a proprietary technology available exclusively through HydroMentia, Inc. HydroMentia designs, builds and operates innovative, cost-effective, managed aquatic plant treatment systems for pollution control and water restoration in agricultural, industrial and urban applications. HydroMentia owns numerous patents and intellectual property. Its head office is in Ocala, Florida. For more information about HydroMentia, Inc., call 352.237.6145 or go to www.hydromentia.com.