Multipurpose Wetland Creation and Restoration to Improve Water Quality and Wildlife Habitat in Coastal Urban Bayous

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University of Houston of Clear Lake
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Acknowledgements

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• KBA Consulting – Dr. Margaret Forbes

• Armand Bayou Nature Center - planting

• Master Naturalists - planting

• Students – monitoring, planting and “weed” removal

• EIH staff – monitoring, planting etc.

• UHCL administration – support for project
Outline

1. Background
2. Project Goals
3. Pre-construction
4. Construction
5. Post-construction
6. Monitoring Results
7. Conclusions
Background
Armand Bayou Watershed

• The Armand Bayou Watershed is situated in the 4,238 square-mile Lower Galveston Bay Watershed.

• Armand Bayou is listed as impaired in the 2012 Texas Integrated Report 303(d) List (TCEQ 2013) due to elevated levels of bacteria and depressed levels of dissolved oxygen.

• The bayou is currently being evaluated to determine if a bacteria TMDL is warranted from an initial listing in 1998 (HGAC 2013).
Armand Bayou Watershed

• A dissolved oxygen study was initiated in 1998 following an impairment listing in 1996, but it could not be if the suppressed dissolved oxygen was from pollutant loadings or a naturally occurring hydrologic problem.

• Grant from TCEQ/EPA – Galveston Bay Estuary Program: Armand Bayou Water Quality Improvement Project - UHCL Created Stormwater Treatment Wetland
1943 – Project Area
* Meandering Stream
* Oxbow wetlands
* Riparian Corridor
1978
Loss of meanders
Loss of riparian forest
Disconnected oxbows and wetlands
Project Goals

1. Improve water quality running off the campus to Horsepen Bayou
   a) Reduction in nutrient (N & P) loading
   b) Reduction in sediment loading
   c) Reduction in Indicator Bacteria

2. Provide Wildlife Habitat

3. Provide Research Opportunities

4. Provide Teaching Opportunities
Location

• Project located adjacent to Horsepen Bayou, a major tributary of the Armand Bayou Watershed (59 square miles), located in southeast Harris County, Texas.

• Primarily suburban neighborhoods with mixed light industrial use.

• Listed as impaired due to elevated levels of bacteria and suppressed levels of dissolved oxygen.
Approach

• Project incorporated two components:
• 1) Constructed wetland to treat stormwater runoff from part of the UHCL campus
• 2) Pilot feasibility study of a solar water pump wetland system that will be used to treat water withdrawn from the adjacent impaired water body, provide water during droughts.
Approach

• Runoff from approximately 21.5 acres of university property including:
  – Heavily used parking lots, roads and university buildings
  – Remaining Forested land (numerous wildlife)

• Discharge was routed through a newly constructed wetland.
Pre-Construction

2010- Spring 2011
Pre-construction Conditions

• Original pond was fairly deep, extending down to approximately 8 feet in the center, with steeply sloping sides.
• Little habitat for wading birds, shoreline fishes, and emergent vegetation.
• Fish populations were limited due to low amounts of habitat and cover in the receiving pond.
• Frequent algal blooms
Construction

Summer 2011
Treatment = Biological and mechanical
Planting

How Wetlands Improve Water Quality

- Sedimentation: Check dams in the upper wetland can help reduce the amount of sediment that enters the water. These structures trap sediment and reduce erosion.

- Phytoplankton: These are underwater plants that produce oxygen during photosynthesis. They help to aerate the water and remove excess nutrients.

- Phytoplankton Degradation: These organisms can break down organic matter, which helps to reduce nutrient levels in the water.

- Microbial Degradation: Microorganisms, such as bacteria and fungi, can break down organic matter and nutrients in the water.

- Organics: Wetlands can help detoxify organic materials, making them less harmful to the environment.
Table 16. List of the plant species planted at the UHCL wetland immediately following construction on 8/27/2011.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Number Planted</th>
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<tbody>
<tr>
<td>Brasenia schreberi</td>
<td>Watershield</td>
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<tr>
<td>Eleocharis montevidensis</td>
<td>Sand spikerush</td>
<td>25</td>
</tr>
<tr>
<td>Eleocharis quadrangulata</td>
<td>Squarestem spikerush</td>
<td>52</td>
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<td>Iris virginica</td>
<td>Virginia iris</td>
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<tr>
<td>Nymphaea sp.</td>
<td>Water Lily</td>
<td>44</td>
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<tr>
<td>Panicum hemitomon</td>
<td>Maidencane</td>
<td>115</td>
</tr>
<tr>
<td>Polygonum hydropiperoides</td>
<td>Swamp Smartweed</td>
<td>26</td>
</tr>
<tr>
<td>Pontederia cordata</td>
<td>Pickerelweed</td>
<td>105</td>
</tr>
<tr>
<td>Sagittaria sp.</td>
<td>Arrowhead</td>
<td>59</td>
</tr>
<tr>
<td>Schoenoplectus californicus</td>
<td>Bullrush</td>
<td>132</td>
</tr>
</tbody>
</table>
Figure 13. Time-series photographs of the secondary wetland complex showing pre-construction, during construction, and post-construction conditions.
Post Construction
2011-2013
Setbacks
Maintenance
Enhancements
Overflowed berm during peak rainstorm (also minor leaks later)

Response:
1) Install overflow notch to bayou
2) Used polyurethane sealant later for minor leaks

Figure 10. Photo of the Levee breach and erosion experienced by an extreme rain event post-construction at the UHCL wetland into Alligator Pond during September 2011.
Figure 116. Conductivity (Low Range uS/cm) measured every 30 minutes by HOBO deployed at the Solar Pump Intake in Horsepen Bayou.

Figure 117. EIH Staff removing debris from around the solar pump intake.
Figure 11. V-notched weir installed at the most upstream point of the secondary wetland, UHCL created wetland site. The weir is used to monitor water flow.
Plant and Animal Community

• One year later additional plants, mostly trees plants (tupelo, cypress) planted in wetland and in receiving pond
• One and two years later “weedy species” e.g. cattails, physically removed by volunteers
• Stocking of fish into pond for “kid” fishing opportunities
Monitoring Highlights
Plant Community

• Both species composition and richness changed, with a total of 41 species observed during preconstruction sampling, and a total of 122 species observed one year post construction.

• One year later additional plants, mostly trees plants (tupelo, cypress) in wetland and pond

• A total of 113 of the 122 species (92%) of plants observed one year post construction, naturally recruited to the site.

• One and two years later “weedy species” e.g. cattails removed by volunteers
### Table 2. Laboratory parameters sampled as part of the UHCL wetland study.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>TSS</td>
<td>SM 2540 D</td>
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<tr>
<td></td>
<td>VSS</td>
<td>EPA 160.4</td>
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<tr>
<td></td>
<td>TDS</td>
<td>SM 2540C</td>
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<td></td>
<td>Sulfate</td>
<td>ASTM D516</td>
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<tr>
<td></td>
<td>Chloride</td>
<td>SM 4500 Cl⁺ C</td>
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<td></td>
<td>Alkalinity</td>
<td>SM 2320 B</td>
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<td></td>
<td>Chlorophyll-a</td>
<td>EPA 446.0</td>
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<td></td>
<td><em>E. coli</em> IDEXX</td>
<td>SM 9223-B</td>
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<tr>
<td></td>
<td><em>Enterococcus</em> IDEXX</td>
<td>ASTM D-6503-99</td>
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<tr>
<td></td>
<td>TKN</td>
<td>SM 4500 C</td>
</tr>
<tr>
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<td>Ammonia N, Total</td>
<td>SM 4500 NH₃-G</td>
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<tr>
<td></td>
<td>Nitrate, Nitrite Total</td>
<td>SM 4500-NO₃ F</td>
</tr>
<tr>
<td></td>
<td>Total P</td>
<td>SM 4500-P E</td>
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<tr>
<td></td>
<td>O-Phosphate-P, field filtered</td>
<td>SM 4500-P E</td>
</tr>
<tr>
<td></td>
<td>CBOD (Matching BOD done at UHCL) -3</td>
<td>SM 5210B</td>
</tr>
<tr>
<td></td>
<td>TOC</td>
<td>SM 5310 C</td>
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<tr>
<td>Sediment</td>
<td>Total Organic Carbon</td>
<td>EPA 9060</td>
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<tr>
<td></td>
<td>Grain Size</td>
<td>Standard sieve</td>
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<tr>
<td></td>
<td>Nitrate, Nitrite Total</td>
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<tr>
<td></td>
<td>Total Phosphorus</td>
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<tr>
<td></td>
<td>TKN</td>
<td>EPA 351.2</td>
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<tr>
<td></td>
<td>Total Mercury</td>
<td>SW846 7471</td>
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<tr>
<td></td>
<td>Total Lead</td>
<td>SW846 6010</td>
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<tr>
<td></td>
<td>Total Cadmium</td>
<td>SW846 6010</td>
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<tr>
<td>Rainfall and Dry Deposition</td>
<td>Ammonia N, Total</td>
<td>SM 4500 NH₃-G</td>
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<td>Nitrate, Nitrite Total</td>
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<td></td>
<td>Sulfate</td>
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<td>Plant Tissue</td>
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<tr>
<td></td>
<td>Total Cadmium</td>
<td>EPA 6020A</td>
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</tbody>
</table>

**Figure 17.** Dry deposition and precipitation samplers deployed in the field near the N.O.A. building on the UHCL campus.

**Figure 18.** Rhodamine Dye release at the top of the primary wetland complex (Site 4).
Hydrology and Nutrient Reduction Experiment

- Controlled water releases of lawn irrigation water from wastewater treatment
- Monitored flow, time of travel, nutrients
- Using estimated time of travel data from dye studies we were able to track a “slug” of water to evaluate nutrient removal.
Figure 21. EIH staff sampling sediment using a petite ponar at the primary wetland site 4.

Figure 23. EIH staff completing post-construction vegetation survey at the secondary wetland complex.
Figure 24. EIH staff sampling for nekton using a backpack electroshocker in the Secondary Wetland complex at the UHCL created wetlands.

Figure 25. EIH staff pulling a zooplankton tow at Duck Pond (Site 2), UHCL campus.

Figure 26. Locations and areas of visibility for game cameras set up at north alligator pond (red), south alligator pond (yellow), and the arbor (green).
Figure 27. Daily precipitation recorded at the HCFCD rain gage in adjacent Horsepen Bayou at Bay Area Blvd. Dry and wet weather sampling events are denoted. Post construction period started July 20, 2011.
Automated Sondes
Turbidity in
Receiving Pond =
Alligator Pond

Figure 33. Results of automated continuous monitoring of surface turbidity at the Alligator Pond prior to and after wetland construction.

Figure 34. Boxplot and 95% confidence interval of median (red box) turbidity at the Alligator Pond prior to and after construction of the wetland.
Automated Sondes
Dissolved Oxygen

Figure 40. Results of automated continuous monitoring of surface dissolved oxygen at the Alligator Pond prior to and after wetland construction.

Figure 41. Boxplot and 95% confidence interval of median (red box) dissolved oxygen at the Alligator Pond prior to and after construction of the wetland.
Automated Sondes
Chlorophyll-a

Figure 38. Results of automated continuous monitoring of surface relative fluorescence (RFU) in equivalent chlorophyll-α (µg/L) at the Alligator Pond prior to and after wetland construction.

Figure 39. Boxplot and 95% confidence interval of median (red box) relative fluorescence (RFU) in µg/L chlorophyll-α at the Alligator Pond prior to and after construction of the wetland.
No. of Instantaneous Grab Samples at

1) Wetland Pond = Alligator Pond = AP

2) Control = Duck Pond = DP

3) Horsepen Bayou = HB
No. of Instantaneous Grab Samples at Sites

1) AP
2) DP
3) HB

Period
Pre = 1; Post = 2

Rainfall
Wet
Dry
No. of Instantaneous Grab Samples at Sites

1) AP
2) DP
3) HB

Period
Pre = 1; Post = 2

Rainfall
Wet
Dry
Figure 80. Boxplot of nitrate plus nitrite nitrogen measured during dry weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.

Figure 81. Boxplot of nitrate plus nitrite nitrogen measured during wet weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.
Figure 88. Boxplot of total phosphorus measured during dry weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.

Figure 89. Boxplot of total phosphorus measured during wet weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.
TSS
Dry

TSS increased?

Disturbed sediments?

Wet

Pond sediments still eroding?
Enterococci

Dry

Figure 96. Boxplot of most probable number of Enterococci bacteria measured during dry weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.

Wet

Figure 97. Boxplot of most probable number of Enterococci bacteria measured during wet weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DP – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.
Figure 98. Boxplot of most probable number of *E. coli* bacteria measured during dry weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DF – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.

Figure 99. Boxplot of most probable number of *E. coli* bacteria measured during wet weather conditions at outfall from each pond system (AP – alligator pond downstream from wetland; DF – Duck Pond; HB – Horsepen Bayou at Bay Area Blvd; 1 = pre-construction and 2 = post construction wetland). Red bar denotes 95% confidence interval of median.
Figure 109. Nutrient level water samples from controlled reclaimed water releases, values averaged from three events, triplicate samples taken at each site during each event, n=9.
Sediment Level

2 = control pond

4 = upper wetlands

10 = downstream wetlands

N – loss
P – gain
(wetland)
TOC – loss/gain

Figure 114. Nutrient concentrations measured in the top 3 cm of the sediment at the UHCL wetland complex. Values represent averages from replicates collected at each site.
Numerous species of wildlife was seen at the wetland complex using the camera traps. These included:

- **Turtle**
  - Red eared slider
  - Possibly spiny softshell
- **Duck**
  - Black-bellied whistling duck
- **Raptor**
  - Red-tailed hawk
  - Red-shouldered hawk
- **Wading birds**
  - Black crowned night heron
  - Cattle/Snowy egret
  - Great blue heron
  - Great egret
  - Green heron
  - Little blue heron (breeding and non)
  - Reddish egret (?)
  - Roseate spoonbill
  - White ibis (juvenile and adult)
  - Yellow crowned night heron
- **Bird, other**
  - Belted (?) kingfisher
Conclusions
Water Quality

• By all measures the UHCL created wetland has been an overwhelming success.
• The plant community established itself rapidly.
• Levels of phosphorus declined leading to reduced frequency of algal blooms (chlorophyll-a).
• Overall level of dissolved oxygen (24 hour cycle) increased.
• Sediment nitrogen declined through time, but phosphorus levels increased suggesting that the wetland was sequestering phosphorus.
Water Quality

• Decreases in nutrient concentrations were observed and in some cases by 3 orders of magnitude – wastewater experiment

• Enterococci and *E. coli* bacteria showed significant declines in density during dry weather. This pattern did not occur during all wet weather events.

• The wetland was effective in reducing levels from 100-880 MPN/100 ml down to less than 50 MPN/100 of *E. coli and/or Enterococci* bacteria.
Wildlife and Human Use

- The wetland site has attracted numerous terrestrial and aquatic wildlife species.
- Over 1000 people have been documented visiting the site.
- More than 300 students have used the wetland as a natural classroom.
Solar Pump Test

• Failed!

• Approach did not appear to be logistically feasible in the long term due to:
  – Natural salinity of Horsepen Bayou during dry periods.
  – Intake frequently became clogged by floating vegetation

• Should be viable in non-tidal streams but maintenance will be needed.
Project Goals Achieved?

1. Improve water quality running off the campus to Horsepen Bayou
   a) Reduction in nutrient (N & P) loading - **YES**
   b) Reduction in sediment loading – **Not yet**
   c) Reduction in Indicator Bacteria – **YES but not always**

2. Provide Wildlife Habitat - **YES**

3. Provide Research Opportunities - **YES**

4. Provide Teaching Opportunities - **YES**
Future

• The water which discharges from campus to Horsepen Bayou is now cleaner due to the wetland system
• As the wetland continues to mature, additional plant growth will stabilize bottom sediments and lead to increased nitrogen, phosphorus, TSS, and bacteria removal.
• Wetland supports new wildlife
• Wetland is positive amenity and/or teaching tool for students, teachers and community.
• Exploring new sites on campus and reconnecting oxbows naturally as well – challenge.
Questions?