Lake LaVerne Watershed Project: Project Number 1415-007
Final Report
June 30, 2016

Financial Accountability

Grant Agreement Budget Line Item	Total WIRB Funds Approved ($)	Total WIRB Funds Expended ($)	Total ISU Match Approved($)	Total ISU Funds Contributed ($)	Available Funds ($)
Vegetated Floating Island	7,680	6,493.43			1,186.57
Salary and Benefits	28,748	29,965.16	30,026	30,026	(1,217.16)
Water and Vegetation Monitoring	3,888	3,280.46			607.54
Travel	346.00	299.60			46.40
Information and Outreach	1,318.00	707.68			610.32
Totals	41,980.00	40,746.33	30,026.00	30,026.00	1,233.67
Difference					1,233.67

Project costs were slightly under-budget for all elements with the exception of salary and benefits. In each case, the costs were estimates and the actual costs, while very close, were slightly less than our estimate. Actual costs for salary and benefits were 4% higher than anticipated. This was due to a discrepancy between the actual ISU accounting of salaries and our grant budget. A balance of $1,233.69, remains unspent in the project. The total WIRB contribution is the same as anticipated at the start of the project.

Watershed Improvement Fund contribution:
Approved Application Budget = 58%
Actual = 58%

Environmental Accountability

As per the WIRB agreement, three vegetated floating islands (VFIs), for a total of 170 square feet, were fabricated and installed in Lake LaVerne on the Iowa State University campus in May 2015. Lake LaVerne is adjacent to the ISU Memorial Union which is a highly visible location on campus. The lake is encircled by heavily used sidewalks and streets. The islands were removed in late September 2015 following the end of the growing season and public education activities.

This project was a "proof of concept" effort. We fabricated the islands and conducted research on their performance in order to verify that conditions similar to those described in peer-reviewed research would also occur in this climate. It was recognized prior to beginning the project that the VFIs installed on Lake LaVerne would not cover enough of the surface area of the lake to affect water quality. VFIs must cover 15% +/- of a pond surface in order to demonstrate water quality improvements. ISU would allow only 170 square feet of islands installed on the lake. Due to aesthetic reasons, the university also restricted us from using some of the most effective plant species for removal of P and N from the water such as cattails. Two types of laboratory analysis were planned and conducted: vegetative tissue sampling and water quality sampling.

Water Quality Research

Water quality samples were extracted from under the center island as well as from a control location across the lake on a biweekly basis between May and September. Samples were analyzed for total phosphorus (TP), total nitrogen (TN), and dissolved organic carbon (DOC) by the ISU Limnology Lab. As stated above, we did not expect to see a difference in TP and TN conditions between water from under the islands compared to a control location and this was the result. Samples collected under vs. away from the islands were not significantly different for TP or TN, but samples collected under the island were significant higher in DOC compared to samples collected away from the island. Because of mixing potential in Lake LaVerne, we were not surprised that nutrient concentrations were similar under and away from the islands, despite the fact that the plants were removing nutrients from the water column. A complete summary of water chemistry data and analysis are included in Appendix A.

Vegetative Tissue Analysis

Tissue sampling occurred at the end of the growing season in early October. Vegetative matter from each island was collected separately and processed by the ISU Agronomy Lab. Shoot and root matter was combined / not kept separate. Root matter had grown throughout the biofilter webbing as intended. However, this made it very difficult to extract the tissue for analysis. Above-ground and roots were harvested for each VFI as a single sample. Root matter was completely or nearly completely removed from only one island due to the difficulty of extracting it from the filter material. The 3 layers of biofilter were torn apart to obtain as much biomass as possible. Only the shoots and the roots protruding from the filter material were collected from the remaining two islands. All matter from each island was cleaned, oven dried and chopped; two samples were extracted per island and utilized to measure P, total carbon (TC) and TN. Concentrations of these nutrients were then multiplied by the relative dry weight of the total matter for each island to obtain the quantity of each in grams. Moisture accounted for between 78% - 86% of the total weight of each sample.

In order to compare our results with data from other researchers we were required to convert the amount of P, TC and TN present per square meter of each VFI and by the number of growing days it was in place (g/sq. m./day). The VFI with total plant matter analysis accumulated a total of 0.04 g of TN, 0.0027 g of P and 1.28 g of TC/sq. m./day. Results for the two remaining islands were very close. These results are consistent with the findings of accumulations from other researchers in the U.S. and internationally. Each VFI was 4.7 sq. meters in size so total accumulations per VFI were 6.5 g TN, 0.42 P and 196.4 TC. A full report of vegetative tissue analysis is included in Appendix B.

Public Education

Two formal public outreach and education events were held during the growing season. Each event was moderately well attended. The May event was the launch date for the first VFI. Approximately 40 participants installed plants on the island and, together with research staff, pushed it off shore. The VFI was towed to its home location in the center of the lake by a canoe and anchored. The fall event attracted approximately 35 people. All 3 VFIs were pulled near the shore and one was elevated so people could inspect and touch the root mats underneath. We assembled test kits with nitrogen test strips for property owners to take home to test their own pond or small lake (instructions are included in Appendix C). Additionally, we created a brochure for use at the September event (Appendix D).

The informal educational value of this project, however, was likely more important than the formal events. The signage placed around the lakeshore was incredibly effective. We overheard students talking about the islands as they walked by each time we were at the lake with water sampling or maintenance activities. It was also common to hear students explain the project to their visiting parents as they walked by on the sidewalk. When we drove by the lake, there were nearly always people stopped at the lakeshore looking at the VFIs. Our rough estimate is that 30,600 people viewed the VFIs (VFIs were installed on the lake for 153 days and 150 people walking by per day); this is probably low. The lighted sculpture on the VFIs was also incredibly popular with students, particularly that it lit up at dusk.

We also operated a Facebook page for the VFIs as well as a separate webpage (http://laverne-islands.weebly.com/). The Facebook page was "liked" by 229 people and the webpage had 2,320 visitors.

Two of the three VFIs were donated to Story County Conservation. The CCB replanted them and have placed the islands on the McFarland Park Lake.

Practices and Activities Summary

Practice	Unit	Approved Goal	Accomplished	Percent Completion
Vegetated Floating Island (VFI)	Square feet	170	170	100%
Public Events	Each	2	2	100%

Program Accountability

The goals established in this project proposal are stated below as well as a summary of the outcomes related to each.

1. *Determine the effectiveness of vegetated floating islands to remove excess nutrients (nitrogen and phosphorus) in Iowa ponds and small lakes through the quantification of lab sample analysis, biomass calculations and extrapolation; we expect an 80% reduction in phosphorus and a 70% reduction in nitrogen from the water surrounding the VFI system*. We determined that the plants on the VFIs we used did accumulate the percentages of phosphorus and nitrogen achieved by other research. Therefore we believe that the use of VFIs, when sized and designed to meet specifications, would effectively impact water quality conditions.

2. *Fine tune the percent of cover needed for a vegetated floating island in Iowa to effectively remove excess nitrogen and phosphorus in ponds and small lakes.* The research literature indicates a specific plant density for VFIs which equates to a plant spacing of 6" center-to-center. Additional research would be needed to determine if fewer plants could achieve the same impact.

3. *Utilize public art principles to create a VFI system that will be visually interesting and communicate educational information about water quality.* The public art sculptures we created were very large arrows pointing at the pond surface. Neon orange LED lights on the arrows (powered by solar collectors on each VFI) illuminated each evening at sunset. We know from anecdotal information that people saw them as landmarks in the neighborhood and they were immensely popular. The educational signage placed on the banks of the pond described the significance of the arrow shape from a watershed perspective.

4. *Utilize what is learned about the Lake LaVerne vegetated floating island system to develop design guidelines to allow landowners and institutions either to construct or purchase appropriate systems of their own.* We have successfully completed these specifications and they are included in the appendix for this report (Appendix E)

5. *Construct local leadership to adopt the concept of vegetated floating islands in regional municipalities, counties and other institutions with public ponds and small lakes.* Our project got the attention of City of Ames Public Works staff as well as fisheries biologists from Iowa DNR. Both are interested in using VFIs for their own applications.

6. *Educate the public, especially agricultural pond owners, about eutrophic ponds and small lakes and the importance of enhancing water quality in the region.* We reached a number of property owners through our outreach events, first-hand observation of the VFIs and likely the publicity surrounding the project. We were unable to connect directly with farm pond owners specifically though and this was a disappointment. We were unable to obtain the names of Story County farmers with ponds from USDA-NRCS.

In all respects, and probably with all projects everywhere, planning ahead would always be good. With more time and insight, we would have sought alternative ways of reaching farm pond owners. Beacon property records could be utilized to identify ponds within a certain distance of Lake LaVerne and those landowners contacted with a mailing. We could also have prepared more information about VFIs (not as much as the specifications, but more than was available on the website) for pond owners and mailed them. A field day (for a future project) where a VFI was built would also be successful in generating interest and educating people.

Further research in this area must work with property owners willing to allow a VFI installed to the specified coverage percentage. Then, impacted water quality conditions can be assessed. Also important would be a pond owner willing to allow cattails, rushes and other known beneficial vegetation to be included on the island. Lastly, we learned many small things about the design and fabrication of VFIs. These elements are included in the specification. Some examples include positioning the island in full sun throughout the day on the pond (strongly effects plant growth) and the use of adequate flotation for the mature weight of the VFI including moss and algae that will accumulate (rather than the initial weight).

This view shows the people attaching the steel frame for the lighted sculpture to the VFI. Small, individual pours of marine foam (the white substance in this photo) was used to hold the 3 layers of biofilter material together.

A solar panel and battery was installed on each VFI to collect energy. Orange neon lights, powered by the solar energy, lit the sculpture each evening at sunset for several hours.

The summer public event allowed visitors to inspect the islands first-hand One of two lead researchers, Austin Stewart, is shown in the blue shirt answering participant questions.

This view shows late summer plant growth on one VFI as well as a close up of the sculpture—a watershed drainage arrow pointing at the surface of the pond.

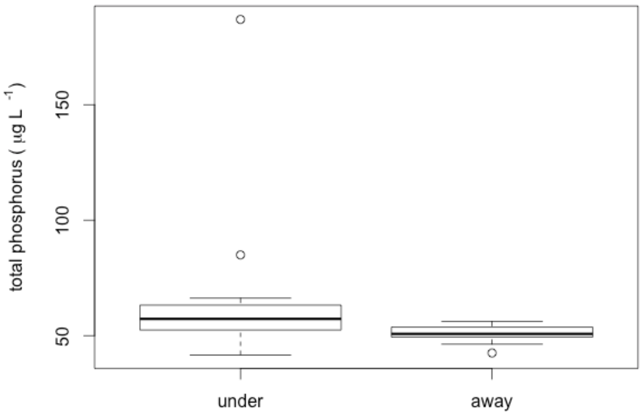
Extensive root growth through all 3 layers of biofilter was visible six weeks after the VFIs were launched onto the pond.

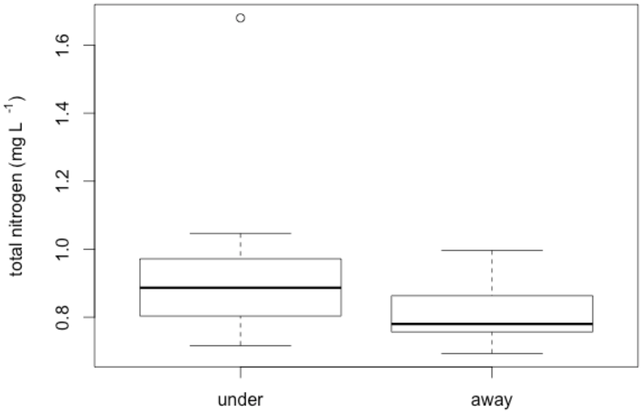
One VFI was disassembled to remove as much vegetative root tissue as possible for lab analysis. This view shows workers removing tissue.

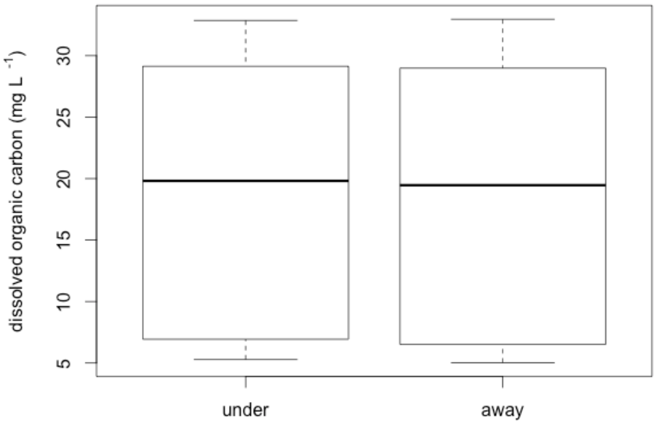
This photo shows all vegetative tissue harvested from one VFI prior to delivering it to the Agronomy Lab. This sample weighed twenty-five pounds (wet weight).

APPENDIX A: ISU Limnology Lab Analysis Notes for Water Quality Monitoring

When comparing concentrations based on their proximity to the island (irrespective of date), there were not statistically significant differences in total phosphorus (TP), total nitrogen (TN), or dissolved organic carbon (DOC) concentrations for samples collected under the island versus samples collected away from the island. Median TP concentrations were 57.3 µg L^{-1} (range: 41.6 – 186.9 µg L^{-1}) and 50.8 µg L^{-1} (range: 42.5 – 56.2 µg L^{-1}) for samples collected under and away from the island, respectively. Median TN concentrations were 0.89 mg L^{-1} (range: 0.72 – 1.68 mg L^{-1}) and 0.78 mg L^{-1} (range: 0.69 – 1.00 mg L^{-1}) for samples collected under and away from the island, respectively. Median DOC concentrations were 19.81 mg L^{-1} (range: 5.28 – 32.86 mg L^{-1}) and 19.46 mg L^{-1} (range: 5.03 – 32.96 mg L^{-1}) for samples collected under and away from the island, respectively.







When accounting for date, paired samples t-tests indicated that samples collected under versus away from the island were not significantly different for TP ($t(10) = 1.42$, $p > 0.10$) or TN ($t(10) = 1.57$, $p > 0.10$), but were significantly different for DOC ($t(10) = 2.66$, $p < 0.05$). On average, samples collected under the island were significantly higher by 0.25 mg L^{-1} DOC compared to samples collected away from the island (although this difference is not visible in the box plot).

APPENDIX B: Vegetative Tissue Analysis Notes

VFI	Data from Agronomy Lab					
	FRESH BIOMASS WEIGHT, g	DRY WEIGHT, g	MOISTURE CONTENT %	TN %	P (mg/kg)	TOTAL C %
CENTRAL VFI (1)	11221.6	2284.9	79.64	1.336	863	39.4
CENTRAL VFI (2)				1.368	840	40.4
WEST VFI (1)	6789	987.6	85.45	1.5669	903	39.8
WEST VFI (2)				1.598	903	39.7
EAST VFI (1)	6758.88	1797.9	77.84	1.307	965	41.5
EAST VFI (2)				1.337	903	41.5

VFI	concentration x dry weight				nutrient/sq m (each island = 4.7 sq m)		
	TN g	P mg	P g	TOTAL C g	TN g	P g	C g
CENTRAL VFI (1)	30.52626	1971.869	1.971869	900.2506	6.49495	0.419547	191.5427
CENTRAL VFI (2)	31.25743	1919.316	1.919316	923.0996	6.650517	0.408365	196.4042
WEST VFI (1)	15.4747	891.8028		393.0648	3.29249	189.7453	83.63081
WEST VFI (2)	15.77691	891.8028		392.0772	3.356789	189.7453	83.42068
EAST VFI (1)	23.49855	1734.974		746.1285	4.999692	369.1433	158.7507
EAST VFI (2)	24.03073	1623.504		746.1285	5.112922	345.4263	158.7507

VFI	growing days			nutrient/sq m/day		
	launched	harvested	days on lake	TN g	P g	C g
CENTRAL VFI (1)	5/2/2016	10/2/2016	153	0.04	0.0027	1.25
			153	0.04	0.0027	1.28
CENTRAL VFI (2)						
WEST VFI (1)	5/28/2016	10/4/2016	130	0.03	1.46	0.64
			130	0.03	1.46	0.64
WEST VFI (2)						
EAST VFI (1)	5/28/2016	10/9/2016	135	0.04	2.73	1.18
			135	0.04	2.56	1.18
EAST VFI (2)						

LAKE LAVERNE FLOATING ISLANDS

STORY COUNTY SOIL AND WATER CONSERVATION DISTRICT IN PARTNERSHIP WITH
SUSTAINABLE ENVIRONMENTS PROGRAM | COLLEGE OF DESIGN | IOWA STATE UNIVERSITY
FUNDED BY A GRANT FROM THE WATERSHED IMPROVEMENT REVIEW BOARD

INSTRUCTIONS FOR USING TEST STRIP

DIRECTIONS:

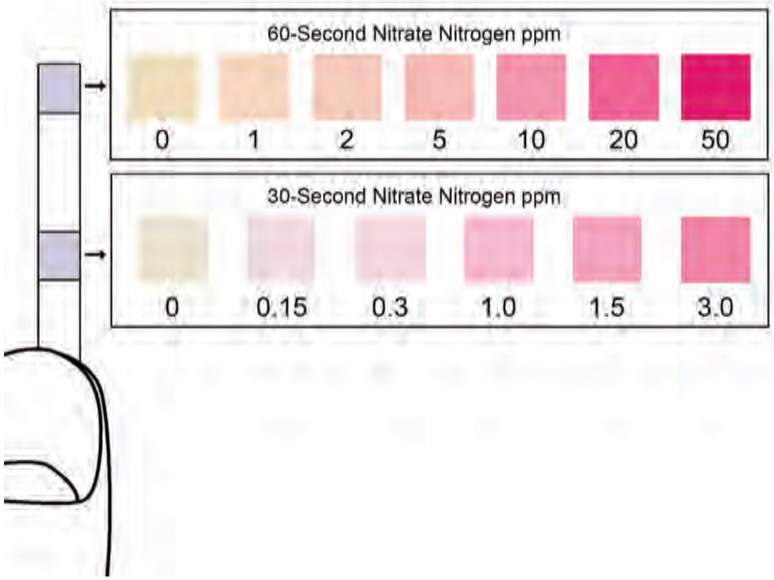
1. Dip a strip into water for **1 second** (or pass under gentle water stream) and remove. **Do not shake** excess water from the test strip.
2. Hold the strip level, with pad side up, for **30 seconds**. Compare the NITRITE test pad (bottom pad) to the color chart above.
3. At **60 seconds**, compare the NITRATE test pad (top pad) to the color chart. Estimate results if the color on the test pad falls between two color blocks.
4. Record nitrate and nitrite resding.
5. Email us at laverne_islands@iastate.edu with the following information or mail to: 146 College of Design, Iowa State University, Ames, IA 50011-3091

Please include the info below in your email:

- Pond Address/GPS
- Is the Pond Public or Private?
- Park Name if applicable
- County
- Owner/Manager of Pond
- Nitrate Level
- Nitrite Level

Email us: **laverne_islands@iastate.edu**
website: www.laverne-islands.com
Like us on Facebook! **Lavereneisland**
Like us on Twitter! **Lavereneisland**

Test Strip PPM Color Code:



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WATER QUALITY IN IOWA PONDS

There are four indicators that determine the “water quality” condition of a water body such as a pond. The first and most obvious indicator is chemical—the concentration of pollutants and oxygen as well as pH. The second is the quality of the biological community living in it including bacteria and viruses. Third are the physical characteristics—smell, taste, and appearance. Radiological characteristics include impacts from mining or the use of radio-active materials. The Environmental Protection Agency (EPA) indicates that the top three pollutants in Iowa are sediment, bacteria, and nutrients (EPA, 2012). Iowa DNR indicates that excess algae is the primary source of pollution in Iowa lakes and ponds (Iowa DNR, 2010). From a realistic standpoint, poor water quality in a pond or small lake impacts the quality of fish able to live there as well as the appearance and smell of the water.

By sheer volume, non-point source pollution, pollutants that run off of the land is Iowa’s largest and most threatening water quality problem (EPA). Non-point pollution is created when rainfall, or snowmelt runs over or through the ground and picks up contaminants, depositing them into streams, lakes, ponds rivers, or groundwater. The most common non-point pollutants are soil (sediment) and nutrients that are picked up and deposited elsewhere through stormwater runoff. Other common pollutants include pesticides, pathogens (bacteria and viruses), salts, oil and grease.

Nonpoint source pollution can include:

- Excess fertilizers, herbicides and insecticides from agricultural lands and residential areas
- Oil, grease and toxic chemicals from urban runoff and energy production
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks
- Salt from irrigation practices and acid drainage from abandoned mines
- Bacteria and nutrients from livestock, pet wastes and faulty septic systems
- Atmospheric deposition and hydromodification

SIGNS AND SYMPTOMS

- Overgrowth of aquatic plants
- Turbid or cloudy water
- Fish kills
- Eroded soil accumulation in ponds.
- algal blooms
- Pond has a strong odor
- Loss of desirable fish species

EFFECTS

The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, we know that these pollutants have harmful effects on drinking water supplies, recreation, fisheries and wildlife.

Many rural and urban small ponds and lakes across Iowa and the region have eutrophic conditions with high levels of nutrients and low levels of oxygen. This is why we see algal blooms and why many lakes aren’t safe for drinking or recreation. Healthy lakes are important because they intercept pollution from their watershed and have the potential to improve water quality downstream.

WHAT YOU CAN DO TO PREVENT NPS POLLUTION

- Do not mow right up to the edge of a lake or pond.
- Limit or eliminate use pesticides and fertilizers.
- Apply Fertilizers or pesticides more than 24 hours before precipitation
- Limit the amount of impenetrable surfaces in your landscape. Use permeable paving surfaces such as wood decks, bricks, and concrete lattice to let water soak into the ground.
- Allow thick vegetation or buffer strips to grow along waterways to slow runoff and soak up pollutants. Plant trees, shrubs, and ground cover. They will absorb up to 14 times more rainwater than a grass lawn and don’t require fertilizer.
- Don’t hose down driveways or sidewalks. Dry sweeping paved areas, along with careful trash disposal, are simple, effective pollution reducers.
- Divert runoff from pavement to grassy, planted or wooded areas of your property, so stormwater can seep slowly into the ground.
- Compost grass clippings and leaves. Never allow them to wash into roadways where they will reach storm drains.
- Place litter, including cigarette butts, in trash receptacles. Never throw litter in streets or down storm drains.
- Clean up spilled brake fluid, oil, grease and antifreeze. Do not hose them into the street where they can eventually reach local streams and lakes.
- Purchase household detergents and cleaners that are low in phosphorous to reduce the amount of nutrients discharged into our lakes, and streams.
- Properly dispose of household hazardous wastes. Many common household products, (paint thinners, moth balls, drain and oven cleaners, etc.) contain toxic ingredients. When improperly used or discarded, these products are a threat to public health and the environment. Do not pour hazardous products down any drain or toilet. Do not discard with regular household trash. Learn about natural and less toxic alternatives and use them whenever possible. Contact your County Solid Waste Management Office for information regarding hazardous waste collection in your area.
- Manage animal waste to minimize contamination of surface water and ground water.
- Reduce soil erosion by using conservation practices and other applicable best management practices. (see below)
- Keep litter, pet wastes, leaves and debris out of street gutters and storm drains—these outlets drain directly to lake, streams, rivers and wetlands.

PRACTICES TO ENHANCE WATER QUALITY

Remedial (corrective) solution to water quality impairment:
Constructed Wetlands:
A constructed wetlands (CW) are artificial wetlands, generally built on uplands and outside floodplains or floodways in order to avoid damage from nonpoint source pollution to natural wetlands and other aquatic resources.

Buffer Strips
Buffers and filter strips are areas of permanent vegetation located within and between agricultural fields and the water courses to which they drain. These buffers are intended to intercept and slow runoff thereby providing water quality benefits.

Rain Gardens:
A rain garden is a planted depression or a hole that allows rainwater runoff from impervious urban areas, like roofs, driveways, walkways, parking lots, and compacted lawn areas, the opportunity to be absorbed. This reduces rain runoff by allowing stormwater to soak into the ground.

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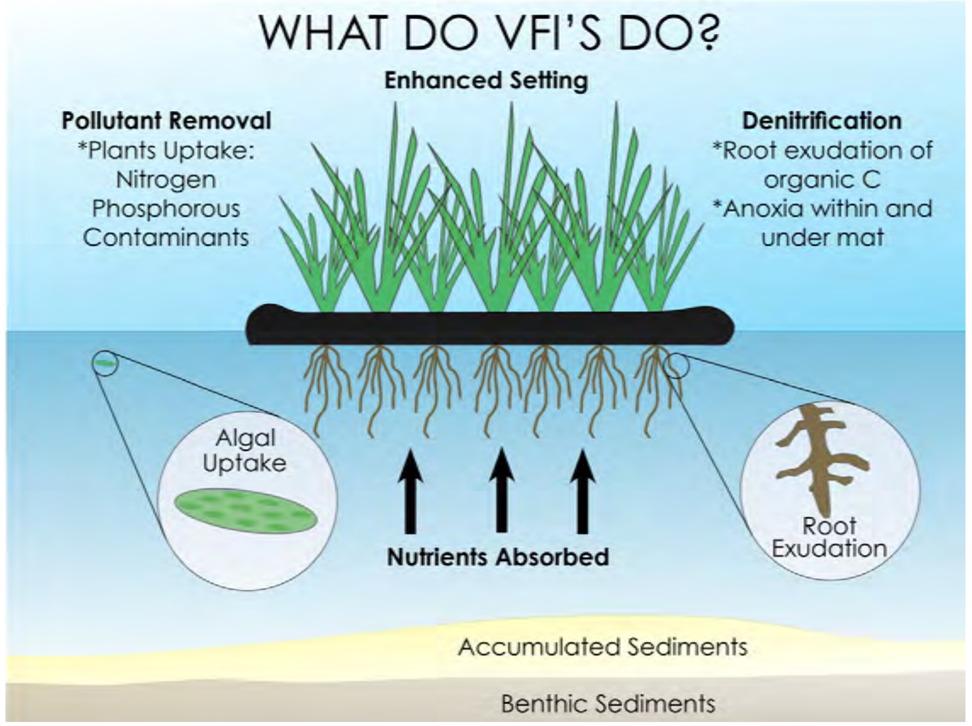
Bioswales:
Bioswales are landscape elements designed to remove silt and pollution from surface runoff water. They consist of a swale drainage course with gently sloped sides and filled with vegetation, compost and/or riprap. They function by slowing the flow of runoff.

Chemical Treatments:
Various chemical solutions are available to remove phosphorus and reduce turbidity. Alum (aluminum sulphate) is commonly used. It works by coagulating the solids in the water causing them to precipitate out of the water column.

Vegetated Floating Islands (VFIs):
VFIs increase the surface area of aquatic vegetation in a body of water, which allows for a larger bacterial population and therefore greater nutrient uptake (Stewart et al., 2008).

HOW DOES A VFI WORK?



WHAT ARE THE BENEFITS OF USING A VFI VERSUS OTHER METHODS?

Vegetated floating islands (VFIs) differ from conventional constructed wetlands in that the microbes and macrophytes (a member of the macroscopic plant life especially of a body of water) grow on and within floating platforms. The macrophytes extend roots into the water where they take up nutrients hydroponically. In contrast, the roots of conventional wetlands grow into pond-bottom soils and are therefore not in direct contact with nutrient-rich surface-flow water. The roots from floating wetland plants provide and additional submerged surface area to support the growth of microbes. As more roots grow, more surface area is created, thereby improving the effectiveness of the system as it matures (Stewart et al., 2008).

Effective: Ammonium (NH4) removal rates in conventional wetlands vary between 35% and 50%. VFIs have shown removal rates from 45% to 75% for NH4, and between 36% and 40% for total nitrogen (TN). Phosphorus (P) retention within different conventional wetlands range from 40%-60%, most of this due to setting, and associated processes such as accretion (a gradual process in which layers of a material are formed) and soil absorption. P removal from VFIs is usually higher due to additional filtering properties of the roots, occasionally reaching 81% (Dodkins et al., 2014)
Note: Water treatment through VFI's only produce temporary storage of P, so removal of pond/lake sediments is necessary to completely remove P from the water body.

NITROGEN AND PHOSPHORUS INFOMATION

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH3), nitrates (NO3), and nitrites (NO2). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.

Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

Reference:
Iowa Nutrient Reduction Strategy, a science and technology-based framework to assess and reduce nutrients to Iowa water and the Gulf of Mexico, 9/2014
What is Nonpoint Source Pollution? From EPA
Effects: http://laverne-islands.weebly.com/impaired-ponds--lakes.html
Symptoms: Brown Water, Green Weeds, Familiar Signs of Nonpoint Source Pollution I Michigan Department of Environmental Quality
Test strip: http://www.hach.com/test-strips/test-strips/family?productCategoryId=35547009709
Test Strip: https://preclaboratories.com/product/nitrite-nitrate-test-strip/
Phosphorus: http://water.epa.gov/type/rsl/monitoring/vms56.cfm
Nitrogen: http://water.epa.gov/type/rsl/monitoring/vms57.cfm
Practice to avoid: http://water.epa.gov/polwaste/nps/abc.cfm

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Email us: **laverne_islands@iastate.edu**

APPENDIX E:

IOWA STATE UNIVERSITY COLLEGE OF DESIGN
Associate Professor Mimi Wagner and Assistant Professor Austin Stewart
CONSTRUCTION SPECIFICATION
VEGETATED FLOATING ISLAND (VFI) FABRICATION FOR WATER QUALITY ENHANCEMENT
JUNE 2016

1. Scope

This specification consists of the design, material selection, fabrication process, deployment and maintenance to establish a Vegetated Floating Island (VFI) in Iowa. As their name implies, VFIs are artificial structures placed on open surface water that function as a floating vegetated mattress. The mattress supports the plants much like the soil does on land. Specific species of native perennial and annual plants known to utilize high concentrations of soluble nitrogen and phosphorus from surface water are established on the surface of the island. Plant roots grow downward and float freely into the water body. VFIs are effective because the plant roots and the biological filter material provide a large surface area for micro-organism activity including those that promote decomposition and denitrification.

2. VFI Design and Calculation

Identifying pollutants present. Water quality testing prior to installation of the VFI is recommended. The VFI detailed in this specification is focused most specifically on nitrogen and, to a lesser degree, phosphorus found in storm water runoff. Although VFIs are commonly used for tertiary treatment in wastewater systems, these specifications are not intended for treatment of that type.

Develop a water quality improvement strategy. For optimal performance ensure that legacy sediments are not present in the bottom of the water body prior to installing a VFI. VFIs are considered to be the last type of treatment employed in a drainage basin following upland treatment practices such as buffer strips, wetlands and sediment basins. Research indicates that properly sized and maintained VFIs typically result in between 2 and 55% increase in phosphorus removal and a 12 to 42% increase in nitrogen removal compared to a wetland with open water and no islands.

Size. Effective VFI treatment of high nitrogen concentrations in a water body require an appropriately scaled VFI system. The surface area of the VFI must equal between 10% and 20% of the total water surface area of the pond or small lake.

Water Body Specifics.

The minimum recommended water depth at VFI locations is 3 feet; effective nutrient removal from surface water requires that plant roots be free floating in the water body (roots cannot establish in the bottom sediment).

3. VFI Materials

Structural Frame. A structural frame is required to support the vegetated floating island unless a plastic pipe flotation system is used. Flotation materials attach directly to the frame and the frame distributes the flotation to the entire island. The structural frame extends along the entire outside edge of the VFI allowing posts to be erected on the corners to support the bird netting.

Frame materials should be lightweight and withstand frozen and submerging conditions. A square tube form of low-carbon steel with a wall thickness of 14ga is recommended. Joints are welded. Square tube allows for faster fabrication due to reduced cutting and fitting time compared to round tube. If properly treated, a steel frame is expected to last approximately 10 years in these conditions although this is difficult to estimate based on variables such as water pH and temperature fluctuations. Low-carbon steel is recommended due to its low cost, ease of fabrication and the relative temporary nature of the VFI. A lighter and more resilient option is aluminum. A heavy, corrosion resistant, and significantly more expensive option is stainless steel. Steel frame fabrication is illustrated in figure 1 below.

Size of the steel and the arrangement of the frame are based on a 56” (1.4 meter) square module; each module results in 9.3 square feet (0.86 square meters) of VFI. Multiple modules can be attached to create the total size required for the VFI application. The use of one inch square tube in a tic-tac pattern is recommended to support the weight of the VFI. Figure 1 illustrates the arrangement of the steel frame.

Proper treatment of the surface is important as steel readily corrodes in the presence of water. A marine grade oil-based paint is recommended to weatherproof the steel. Three coats of paint with no top coat are recommended. A clear coat of marine grade polyurethane could also be applied to increase UV resistance. Following proper application procedures are crucial. Making sure the surface is free from contaminants and applying a primer coat will ensure good adhesion. Frame coating alternatives by a third party include a spray-on truck bed lining (such as Rhino Lining), powder coating and galvanization.

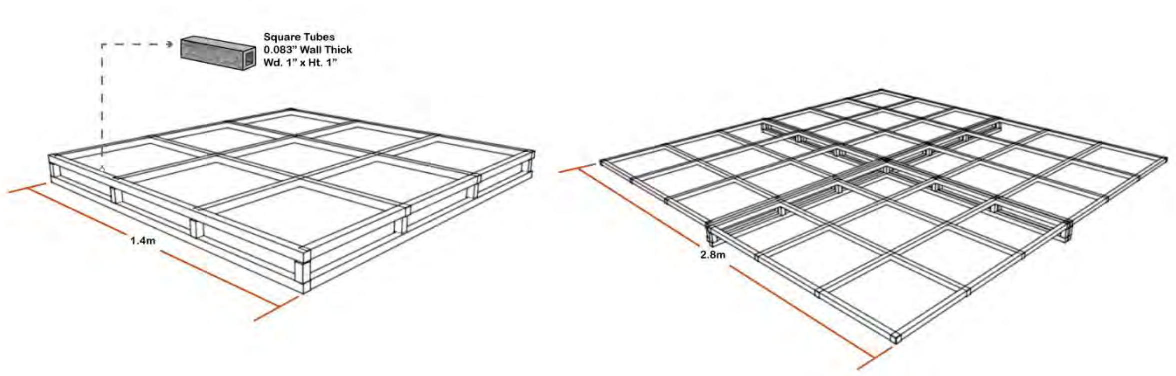

Figure 1 Steel Structural Frame Design Drawing. Use two layers of steel on the sides where one module will be attached to another module

Surface material. Three layers of non-woven biological filter media is recommended for the VFI surface material; each layer is 2” deep. Biological filter media is designed for use in ponds and skimmers with a high surface area for beneficial bacterial colonization, to be long lasting and UV resistant. Poly Flo is one well-known brand that is non-toxic to fish. This material is available in 56 inch (1.4 meters) wide rolls of various lengths. Layers of the filter media can be attached to each other using various options such as wire. Expanding marine polyurethane foam can be poured through the three layers at various points and will result in excellent bonding between the layers as well as add some floatation benefits. However, plant roots cannot grow through the foam and this form of “foam weld” should be planned for locations between plants.

Connection materials are required to attach the layers of biological filter material together and to connect them to the structural frame. It is also required to attach the floatation elements and anchor system to the frame. A strong rot-resistant 1/8” diameter nylon or plastic cord, such as paracord, is recommended.

Floatation material. The choice of floatation material is the first design decision. Once selected, it determines the additional materials needed as well as other aspects of the fabrication process. Three choices are recommended: polyethylene float structures, PVC pipes or recycled bottles. A structural frame is utilized for all floatation methods except for PVC pipes. However, any floatation material could be used as long as it is resistant to and non-toxic in water and with a specific gravity lower than water.

Polyethylene float structures are commonly used to support floating docks, bridges and walkways. The units are available in various widths, depths and lengths; the float material cannot be cut or resized in any way. Numerous brands are available. Float structures can be attached to the frame using hardware sold with the structures or with rot-resistant 1/8” diameter nylon or plastic cord such as paracord.

Plastic pipe systems are the most commonly used flotation system we found for do-it-yourself vegetated floating islands. This material serves as both the flotation and the structural frame for the island. Plastic pipe and joints are configured to serve as a frame with cross bracing for the vegetated floating island (Figure 2). The most commonly available plastic pipe is PVC which has a major limiting factor. PVC pipe material has an outdoor life span of less than 10 years because it is not resistant to the ultraviolet (UV) component of sunlight. PVC pipe can be protected against UV damage by either painting or using an insulation material. Any painting or pipe insulation utilized should be verified to be non-toxic in submerged aquatic settings. A more expensive alternative to typical PVC is UV protected (high modulus) PVC pipe. UV protected PVC pipe has an outdoor life span of 50-70 years.

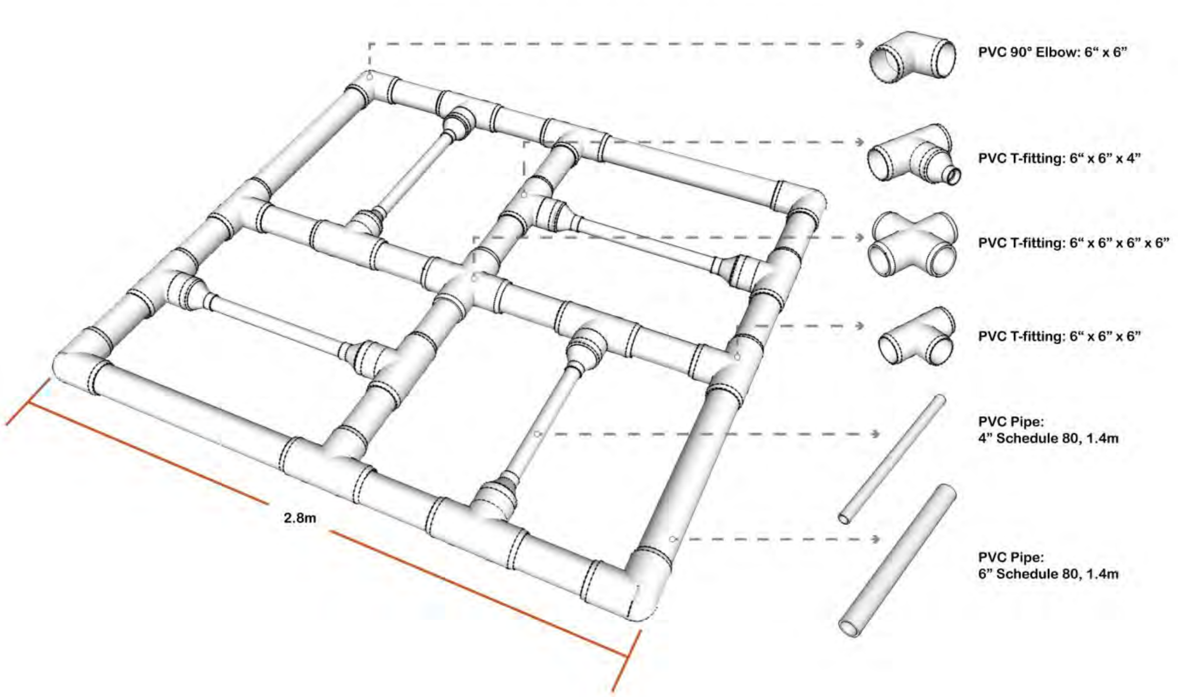

Figure 2. Plastic Pipe Frame Design Drawing. The selection of plastic pipe for the structural frame provides a portion of the floatation value required for the VFI.

Recycled bottles are the least expensive and short-lived flotation option. These bottles generally are not resistant to the ultraviolet (UV) component of sunlight. No information about the expected outdoor life span is available.

Expanding marine polyurethane foam can also be used as a form of floatation. Precise measurement of the two part liquid material is critical. Marine foam, on its own, is not sufficient to support a mature VFI module.

However, it can be used to supplement other floatation materials and also to attach the three layers of biofilter together.

Calculating the floatation required includes the estimated weight of all materials included on the VFI as well as a multiplier to account for biomass accumulation, saturated conditions and mature plant size. A multiplier of 300% is recommended as a starting point for the calculation. A standard module of 56” (1.4 meters) inches on each side is used as an example. The weight of a person is also included to allow for maintenance of the VFI. Table 1 illustrates the amount of floatation required based on frame material, the floatation system selected; calculations may need to be adjusted to compensate for the actual weight of the maintenance person. The type(s) of floatation utilized can be determined once the required amount of floatation is determined. Table 2 illustrates the floatation that one unit of each of the methods provides.

Table 1. This table summarizes the design weight requiring floatation for one 56” (1.4 meter) standard VFI module.

Frame Material	Frame weight (lbs.)	Biofilter, vegetation, biomass weight	Adult weight (lbs.) for maintenance	Total design weight	Weight / floatation needed per 1.4 meter module (lbs.)
Steel Tubing	51.2	375.03	150	576.23	576.23
6" PVC Pipe	82.99	375.03	150	608.02	502.02

Table 2. This table illustrates the floatation (weight supported by) the types of floatation materials included in the specification. Note that use of a PVC structural frame provides 106 lbs. of floatation in addition to its structural properties.

Floatation Material	Can support Weight/unit
2 - 2 Liter Plastic bottles	4.4
Dock Floatation Unit (24"x36"x12"size)	327
PVC pipe frame (1.4m module)	106
Marine foam (1 cu ft)	60

Coconut fiber liner fabric is recommended to cover the top surface of the VFI as seeds will readily establish on the surface. A 12” square piece of liner fabric is also recommended for each plant.

Bird netting is required to keep waterfowl from landing on and consuming vegetation on the VFI. A 3/4” polyethylene netting is recommended. The material must be attached under the surface of the island and extend at least 36” above the surface of the island. Commercial grade landscape staples are recommended to attach netting to the underside of the island. Some form of landscape stake or vertical extension of the structural frame is required to keep the netting in place. Zip ties or a similar attachment is recommended to attach netting to the vertical supports.

Anchoring is required to keep the VFI in the desired location. A single cinder block is usually adequate for every 50 square feet of VFI area. Paracord is recommended to attach the cinder block to the VFI. To calculate the amount of rope needed, multiply water body depth by number and add a few extra feet for attaching the island and cinder block(s).

Vegetation appropriate for use on a VFI includes any native perennial plant species known to uptake and hold higher amounts of nitrogen and phosphorus during the growing season. The mass accumulation of pollutants in VFI vegetation is positively correlated with the deployed environment. The number of plants required is based on the area of the VFI. Plants are planted on a 6” center to center grid, equaling approximately 52 plants per square meter (11 square feet). Table 3 illustrates the number of plants required based on the total surface area of the VFI.

Table 3. Optimum performing VFI’s establish plants at a 6” center-to-center spacing over the entire surface of the island. Plants may also be planted more closely depending on the species selected and owner preferences.

Area in Sq. Feet	Center-to-Center Plant Spacing
	6”
10	46
25	115
50	231
75	346
100	461
150	692
200	922

Plant species vary considerably on the amount of nitrogen and phosphorus they remove from water. Table 4 lists 13 plants that are native to and hardy in Iowa that have been researched for their utilization of nitrogen and phosphorus in a VFI setting. Color-coding and text are used to communicate the relative nutrient removal effectiveness from peer-reviewed literature. Quantitative utilization data for both pollutants may not be available for each species; cells with no shading indicate data was not available. Additional native and hardy herbaceous plants without a scientific basis for nutrient utilization but included in the ISU research VFIs are included at the bottom of the table. This specification includes only herbaceous plant material although VFI examples exist that have incorporated shrubs. An illustrated summary for each of these plants is located in the Appendix.

Standard 2” nursery pot-sized plants (or those with similarly sized root systems) are recommended because they have an already-developed root system and are able to establish themselves quickly in a VFI setting. In addition to individual plants, seeds of desirable species can also be sprinkled onto the surface of the coconut fabric liner at the time of deployment.

Table 4. Plant Species Known to be highly efficient at removing nitrogen and phosphorus from surface water in a VFI setting.

Plant Name	Mature Height (ft.)	Expected Nitrogen Removal Rate	Expected Phosphorus Removal Rate	Sun exposure
Native Plant Species With Published Research Documenting Nutrient Removal Effectiveness on VFI's				
Carex spp. (Sedges)	1 to 3		LOW	Full Sun, Part Shade
Glyceria grandis (American mannagrass)	4 to 5	HIGH		
Iris virginica var. shrevei (Southern Blue Flag Iris)	3	HIGH	LOW	Full Sun, Part Shade
Juncus effuses (Soft Rush)	2	LOW	LOW	Full sun
Panicum capillare, dichotomiflorum, flexile, or philadelphicum) Witchgrass or panicgrass; note this is an annual grass that reseeds itself	1 to 3	MODERATE	MODERATE	Full Sun
Penthorum sedoides (Ditch Stonecrop)	1.5		LOW	Full Sun, Part Sun
Pontederia cordata L. (Pickerelweed) Harvest in July or August, not later because it translocate nutrient tissue to roots in fall	3	HIGH	LOW	Full Sun, Part Shade
Rumex verticillatus (Swamp Dock)	3 to 5	MODERATE		Full Sun, Light Shade
Schoenoplectus tabernaemontani (Soft Stem Bulrush)	6	LOW	HIGH	Full Sun
Scirpus cyperinus (Wool Grass)	5	MODERATE	HIGH	Full Sun, Part Sun
Spartina pectinata (Prairie Cordgrass)	8	MODERATE	MODERATE	Full Sun, Part Shade
Typha latifolia (Cattail)	6	HIGH	HIGH	Full Sun
Native Plant Species Without Published Research Findings Documenting Nutrient Removal Effectiveness on VFI's; Utilized in ISU's 2015 Research VFI				
Asclepias incarnate (Swamp Milkweed)	4			Full Sun, Part Shade
Carex vulpinoidea (Brown Fox Sedge)	3.2			Full Sun, Part Sun
Lobelia cardinalis (Cardinal Flower)	4			Full Sun, Part Shade
Lobelia siphilitica (Great Blue Lobelia)	3			Full Sun, Part Shade
Rudbeckia laciniata (Cutleaf Coneflower)	7			Full Sun, Part Shade
Symphyotrichum novae-angliae (New England Aster)	5			Full sun, Part Shade

4. VFI Fabrication

A cross section of a constructed VFI is illustration in Figure A. Final assembly is recommended near the water's edge.

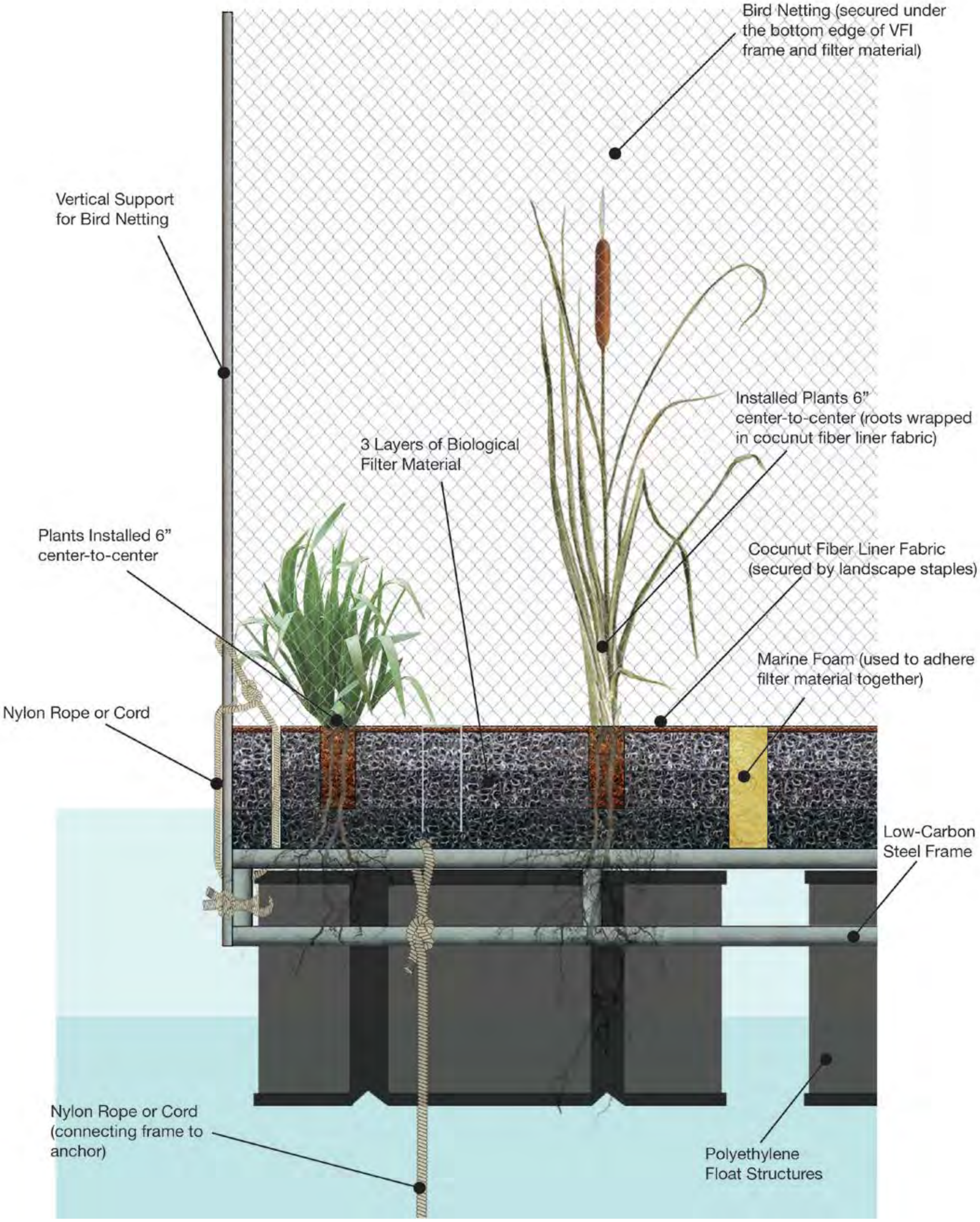

Figure 1. Cross section through Vegetated Floating Island

a. **Construct the frame modules** and attach them together and to the floatation system. Attach the anchor connection cord to the outside edge of the structural frame with 1/8" cord. Ensure this location is conveniently located and accessible from the water side of the deployed VFI as it may need to be disconnected from its anchor occasionally for maintenance or to move its location.

b. **Prepare the VFI surface.** Cut the three layers of biological filter media to fit the size of the module(s).
c. **Attach the three layers of filter media together** using rot-resistant 1/8” diameter nylon or plastic cord such as paracord. Use a ¾” hole saw to drill holes through the layers of filter media, approximately 2 inches from the outside edge, to route the cord through all layers of the material and secure them. Alternatively, expanding marine polyurethane foam can be used for this connection. Pour the 2-part foam through the three layers on an approximate 3’ center to center grid arrangement and allow curing; place a disposable tarp under the filter media to catch seepage.
d. **Mark the planting hole locations** on a 12” center to center grid arrangement, ensuring that approximately 52 plants are placed per 11 square feet of the VFI. Use a 2 inch hole saw to drill holes through the top 2 of the 3 layers and remove the hole cores.
e. **Final assembly.** Consider completing these final assembly and plant installation steps at the water’s edge to easily deploy the VFI.
    1. Attach the filter media deck to the structural frame. Use a ¾” hole saw to drill holes through all 3 layers of the filter media approximately 3’ apart around the entire outside edge. Secure filter media deck to structural frame using 1/8” cord.
    2. Place the coconut fiber liner fabric cover on the top surface of the secured filter media and attach it using commercial landscape staples. Using a scissors or craft knife cut an X on top of each drilled plant hole just large enough to be able to pull back the liner fabric exposing the entire planting hole.
    3. Install the plants. Remove plants from their pots and rinse the majority of soil off of the root surface. Removal of this soil is necessary because it contains high levels of nutrients which will further pollute the water body. Center each plant on a 12” square piece of coconut fiber fabric and place in a planting hole; align the existing soil surface of the potted plant to the top of the VFI filter media surface. Water each plant thoroughly before launching.

f. **Install bird netting** support stakes to the structural frame using 1/8” cord around the entire perimeter of the VFI. Wrap the netting around the entire perimeter allowing several feet of overlap at the location where the fabric joins. Ensure the netting extends 3’ above the surface of the VFI and also extends below the VFI filter material. Secure the netting to the support stakes with zip ties. Secure the netting to the underside of the VFI filter material with long landscape stakes or other similar material.
g. **Place the completed VFI onto the water surface**. A canoe, kayak or raft is recommended to shuttle the VFI to its designated location. Secure the anchor to its connection cord.

5. Plant Growth and Maintenance

Plant roots will begin growing toward the water surface immediately after launching. Ensure that plants have adequate water supply by watering manually until their roots are in contact with the water surface, particularly when initial conditions are hot and windy. Plants on the VFI can be expected to reach between 1/2 to full size during the first growing season. Taller species may take an additional growing season to reach mature size.

Plants will fill in the surface of the VFI as they mature. Plant roots will form a dense root mat under the surface of the island as well as within the biological filter material. In the fall, vegetative material must be trimmed and removed from the VFI. Clip all stems and leaves several inches above the VFI surface slightly before they begin to go dormant. If left to overwinter, the vegetation will decompose and release the removed and stored pollutants back to the water. The VFI remains on the water surface throughout the winter season. No additional work is required in the spring.

6. Fabrication Costs

The costs for all materials required to build a VFI (using 2015 costs) was approximately $38/square foot.

Appendix.
VFI Plant Illustrations

<table>
<tr><th colspan="2">Native Plant Species With Published Research Documenting Nutrient Removal Effectiveness on VFI's</th></tr>
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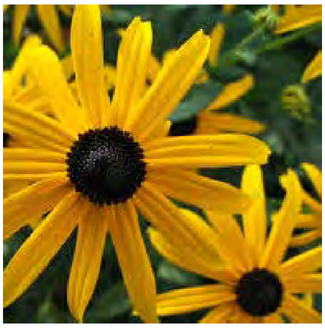
Rudbeckia laciniata (Cutleaf Coneflower)	
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