BAE 231 --- Pond Eutrophication
Final Report

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I. Executive Summary

Bruce and Theresa Meyer have blue-green algae growing in their pond, due to eutrophication, preventing the pond from being used for recreational activities. Potential reasons for the nutrient imbalance is water runoff from surrounding farm areas draining into the pond. Currently, their solution is to use chemicals to harden the water, removing the algae. This is a temporary treatment and more expensive than the Meyer's would prefer. They have requested a solution that offers a more permanent result while also being less expensive than the current chemical treatment.

To identify the benefits and constraints of possible design alternatives to the chemical treatments, a design matrix was used to analyze each design possibility. The implemented design must be less expensive than the current chemical treatment, have a low environmental impact, and be easy to maintain. These design constraints and several others were included in the matrix analysis to identify the most effective design options. From the design matrix, it was concluded that the vegetative buffer strip and the floating garden were the top two designs that could provide a solution to the Meyer's eutrophication problem. The vegetative buffer strips are not only used to filter stormwater runoff which could reduce the growth of the blue-green algae, and also be effective in the ability to control soil erosion while providing a clean habitat for species in and around the pond. The floating garden design has the potential to provide an in-pond solution to reduce excess nutrients, but requires more maintenance and recurring costs. Well-planned buffer strips have a higher chance of providing a long term solution compared to the floating garden which would have to be maintained and reinstalled yearly. Correctly sized and installed buffer strips have the highest potential to restore the pond.

The design of the vegetative buffer strip includes grass left to grow naturally along the east side of the pond where the excess nutrients are suspected to be entering the pond. This strip of grass would be 6-10 ft. wide, and would be composed of grasses native to the area, such as Big Bluestem, Little Bluestem, Yellow Indian, Switch and Cord. A key component to the design is time, which is required for the formation of a root structure. The roots of the grasses will grow within the soil that can filter more of the excess nutrients out of the water. The only upkeep required to maintain this design would be a 2-3 year cycle of burning/grazing the grass.

Based on the design matrix analysis for each of the possible designs, it is recommended that the Meyer's family install the vegetative buffer strips to remediate the effect of eutrophication in their pond. The strip design offers a natural solution which reduces the effects of eutrophication, provides a clean habitat for many wildlife species within and outside of the pond, and assists in stabilize surrounding water sources. The design can be ineffective in filtering during periods of intense storms (high water runoff) and plant health is susceptible to harsh weather conditions and invasive species. Testing measures can be taken throughout the lifetime of the strip to make the design more compatible with the Meyer's location. Compared to the other design options, the vegetative strips meet all of the Meyer's needs, as well as providing an effective solution to the eutrophication problem.

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III. Introduction

Over the last 5 years Bruce and Theresa Meyer's pond near Palmer, KS has begun to show signs of eutrophication. Within the last two years, the pond has experienced an outbreak of blue-green algae. With large amounts of algae, the pond has the potential to be hazardous to the environment and those that encounter it. Currently Bruce and Theresa are treating their pond with chemicals to kill the algae, but these chemicals come at a cost. The Meyers are in need of a more cost effective and long term solution to this problem.

IV. Design Objectives

The design objective is to provide a less cost-effective and easy to maintain solution to meet clients specifications. The purpose of this design is to reverse the effects of eutrophication occurring within the Meyers' pond while conforming to various constraints. The Meyers requested that the design be less expensive than their current chemical treatment of Copper Triethanolamine and for the design to be long term, as opposed to the chemical treatment which requires routine application. In order for the design to be the most effective, the design team applied more constraints that included environmental impacts, maintenance, and weather impacts. The design should not change the conditions of the environment outside the affected areas. The clients will be responsible for maintenance after it is implemented so a design that is simple to maintain will help to ensure a long service life for the design. With the varying weather conditions of Kansas, an effective design should not be largely impacted by any weather conditions that it may have to endure. A design that meets each of these constraints and is effective at reversing the effects of eutrophication is the goal for this project.

V. Background Research

A. Bruce and Theresa Meyer

Bruce and Theresa Meyer have a manmade pond that is about 10-12 years old located near Palmer, Kansas. The Meyer's have been experiencing eutrophication in their pond for the past five years and have had an outbreak of blue-green algae for the past two years. There is about 200 acres of land that drain into the pond from surrounding farm lands. The Meyers know of a dairy farm that is near the location of the pond and believe that to be a cause to their nutrient imbalance (Bruce Meyer, Client, personal communication, 19 Sept 2017).

The Meyer's are currently expecting to pay around $1000 for the chemical treatment, but are willing to pay the same amount if the solution is more long term. In the spring of 2017, the Meyers purchased Copper Triethanolamine, once with the brand name "Mizzen" and again with the brand name "Algae Defense." The Mizzen was bought and used first to clear the moss and algae in the pond. After the effects of the Mizzen wore off, the Meyers purchased the Algae Defense (Bruce Meyer, Client, personal communication, 20 Sept 2017).

Dr. Bailey Sullivan states that the construction on the pond was finished about 10 years ago and that there were no problems until 5 years ago when the eutrophication and algae started to appear. Sullivan says that the pond was stocked with catfish and possibly bass. The Meyer's fed the fish initially until the fish could survive on their own. The source of the pond is a natural creek that has been dammed. Sullivan states that the surrounding area is rural and used for agricultural purposes. The surrounding lands irrigate using water from the nearby dairy farm. Additionally, there is tension between the owner of the dairy farm and the Meyer's and that cooperation with the dairy farm owner is highly unlikely. The Meyer's have not made any modifications to their land and do not manually supply water to the pond (Nicholas Young, Design Team, Young-Sullivan Meeting, 21 Sept 2017).

B. Eutrophication

Eutrophication is the biological effect of an increase in the concentration of plant nutrients. Most frequently from nitrogen, phosphorus, potassium and manganese. Eutrophication is the process where an accumulation of nutrients in bodies of water lead to rapid growth of photosynthetic plants (Nixon, 2005). These nutrients come from a particular source and have flooded into a lake or other body of water. For example, eutrophication can occur after farmers fertilize their fields and rain washes the phosphorus and nitrogen from the fertilizer into a nearby lake. All the substances which plants need to grow are dissolved in the water which results in cyanobacteria and phytoplankton growth inside the lake and coverage of the entire lake with a large sheet of green sludge which prevents sunlight from getting into the lake. In other words, plants that are already on the bottom of the lake die because they are not getting any sunlight. When these plants decompose they consume oxygen and a state of "hypoxia" results and ultimately becomes "anoxia" in which no oxygen at all is dissolved inside the lake. At the same time, all living creatures in the lake will be affected by this lack of oxygen (Lapointe et al, 2012)

i. Causes of Eutrophication and Its Impact

When agricultural procedures are not managed correctly, agricultural runoff may occur. Agricultural runoff can lead to an imbalance of nutrients in local water sources, such as a pond, causing eutrophication. This happens when water from precipitation, irrigation, or other sources washes over soil that has accumulated too many nutrients from agricultural sources, such as from fertilizer or manure, and drains into nearby ponds or groundwater sources (US EPA, 2013).

Agricultural runoff, also called agricultural nonpoint source (NPS) pollution, highly affects the quality of surrounding surface and groundwater. A nonpoint source (NPS) is a source that has many points of origins or a large area that acts as the source of the pollution

(US EPA, 2005). Farm lands are an example of NPS while industrial or sewage treatment plants are examples of point sources. Agricultural processes that are done incorrectly can cause NPS pollution which can cause an excess of nutrients, metals, salts, and other byproducts of agricultural processes to be washed away into water sources such as ponds, rivers, and lakes. The largest contributor to water pollution is soil particles that get washed away with rain or irrigation water and flow into a water source. This can cause that water to become hazy, limiting the amount of sunlight that can reach plants in the water. The soil can also harm any fish that may live there. (US EPA, 2005)

Nutrient imbalances can come from more sources than just agriculture, such as fertilizers applied to golf courses and suburban lawns, the deposition of nitrogen from the atmosphere, erosion of soil which contains nutrients or sewage treatment plant discharges. Eutrophication is not only a human made problem, but can also be influenced by the biological state of its rivers and lakes (Carmichael, 1991). Thus, the impact of eutrophication can be related to all aspects of life and nature. For example, the enrichment of nutrients to an ecosystem can lead to a massive growth of microalgae which can inhibit or prevent access to waterways, and also decrease the use for water sports such as swimming and fishing. Eutrophication can also change the availability of sunlight and certain nutrients to an ecosystem which could reduce the biodiversity overtime. More realistically, harmful algal bloom species have the capacity to produce toxins which are dangerous to humans (Edmondson, 1995).

ii. Eutrophication in Kansas

Eutrophication in Kansas has been an ongoing problem. Both natural and man-made imbalances of nutrients in Kansas waters have occurred for a long time. These imbalances can sometimes lead to what are known as fish kills. A fish kill is a mass die-off of fish or aquatic life in a specific area. According to the U.S. Geological Survey (2016) these fish kills occur when there is not enough dissolved oxygen the water for the fish to use. These imbalances in oxygen levels can both be man-made or occur naturally (U.S. Geological Survey, 2016).

Fish kills due to imbalances in pond nutrients have been documented for some time. Back in 1978, 34 fish kills were reported to the state of Kansas. Of the 34 fish kills that were reported that year, 11 were determined to be of natural causes. The other 23 were suspected of being caused from pollution of runoff from municipalities, industries, and agriculture. Of all the human caused fish kills, agriculture was identified as the largest killer in Kansas. Feedlot runoff and other agricultural activities were identified as the cause for more than 70% of the fish killed that year. While this data may be dated, it demonstrates that pollution of Kansas ecosystems has been an issue for some time (Haslouer,1979).

C. Blue Green Algae and its Hazards

Blue Green Algae, which is also known as "Cyanobacteria", is often referred to as "pond scum" because it is a mass of algae forming a green film on the surface of ponds, lakes and slow moving streams. When the amount of pond scum reaches a large sum, it can form floating mats and scum layers known as a "Blue Green Algae bloom" (Harper, 1992). Blue-green algae is mostly found in blue and green color, but can also be purple, red, or brown. Blue-green algae can reproduce very quickly in suitable environmental conditions where there is still or slow-flowing water, abundant sunlight and sufficient levels of nutrients, especially nitrogen and phosphorus. The living conditions for blue-green algae are very different based on location, season, and the dominant species (Carmichael, 1991).

Eutrophic lakes are typically characterized by shifts towards dominance of the phytoplankton by blue-green algae, some of which produce compounds that are more toxic than cobra venom. Poor water quality and the potential for toxicity means that blue-green algae can cause problems such as disrupting drinking water supplies, recreational activities and water-dependent industries. Additionally, poor water quality could lead to significant economic losses to coastal communities and commercial fisheries as well as pose a risk to livestock, wildlife, and humans. Some of the concerns which are associated with human health include illness due to direct or indirect contact with eutrophic water and exposure to neurotoxins that can lead to muscle spasms, convulsions, weakness and paralysis. Additionally, death can also occur due to paralysis of the muscles used for breathing. People who are exposed to contaminated water while swimming, boating or skiing often develop skin rashes, eye irritation and respiratory symptoms (Skulberg et al., 1984).

D. Surrounding Area

Bruce and Teresa Meyers' Farm is located two miles southeast of Palmer, KS. The town of Palmer is located north of Manhattan in Washington County, along the Nebraska border. Washington County is a very rural county that is sparsely populated, and reliant on natural resources. With over 700 farms in Washington County, the economy is heavily dependent on agriculture. In 2012 alone, $135.9 million was sold from crop and livestock (Kansas Department of Agriculture, 2017).

The Meyers' farm is located in the Lower Republican watershed. A watershed is an area of land of any size where all water flows to a common source. The Lower Republican watershed starts near Mankato, KS in the Northwest and drains to Milford Lake in the Southeast. There is a Watershed District located in the Lower Republican watershed, but it does not encompass the Meyers' property (U.S. Environmental Protection Agency, 2017).

E. Soil

The characteristics of soil and the natural processes that act upon it could provide useful information about the source of the eutrophication that is occurring at Bruce and Theresa Meyers' property. Soil is broken down into three different categories based on the size of particles in the soil. The three categories of particle size from largest to smallest are sand, silt, and clay. Different soils have different percentages of sand, silt, and clay, which cause water and other natural processes to behave differently when acting upon it. By using the U.S. Department of Agriculture's Soil Survey, the soil composition of the Meyers' property and the surrounding area can be determined (Hons, n.d.).

The soil that immediately surrounds the pond is classified as Lancaster-Hedville complex. Due to the percent composition of sand, silt, and clay, this soil is classified as a high runoff area. Soil that is classified as high runoff will tend to drain most precipitation into nearby ditches and ponds rather than soaking the water into the ground. The next soil classification that immediately surrounds the Lancaster-Hedville soil is Lancaster Loam. This soil is classified as medium runoff (Web Soil Survey, 2017).

Within the four square miles that surrounds the Meyers' property nearly 40% of the soil is classified as high runoff, and another 56% is classified as medium runoff. With medium to high runoff surrounding the Meyers' pond, it is likely that a good portion of the pond's water comes from runoff from the surrounding area. It is possible that this runoff water is being contaminated from practices in the surrounding area and plays a part in the imbalance of nutrients causing eutrophication of the pond (Web Soil Survey, 2017).

F. Environmental Standards

The Harmful Algal Bloom (HAB) refers to cyanobacterial blooms that are formed by toxin-producing bacteria. When these HAB blooms are detected, the water poses health risks to both humans and animals. The potential contamination in drinking water and in waters of recreational areas poses the greatest risk to public welfare. The most common route of human exposure in recreational activities is through the direct contact with the bloom or through accidental uptake of water. Other potential exposures include drinking contaminated water and the use of untreated water sources for irrigation. As more and more water sources are becoming affected by HAB, there is an increase for risks of exposure to and the potential for adverse health effects. Thus, agencies both federal and state must be able to respond to sites, mainly in recreational areas, that pose a risk. To effectively respond to these situations, guidelines and procedures have been set forth and developed from established scientific and medical research studies. To be prepared for a future HAB event, bodies of water are prioritized by risk or likelihood of a HAB event (Baker, 2002).

A response and monitoring plan, treatment plan, and communication methods are then established by local and state governments. Once alerted of a potential harmful bloom, a sample from the affected body of water will be taken and then tested for cyanobacteria. In Kansas, The Kansas Department of Health and Environment (KDHE) perform the sampling in recreational bodies of water. If HAB is detected a public health watch or warning will be released determined by concentration of bacteria and risk associated with the specific body of water. It is of utmost importance to determine the concentration of the toxin correctly to alert the public in order to protect their health and safety. The continued nutrient monitoring and long-term treatment plant will help to mitigate future algae blooms (Moiser, 2015).

G. Methods for Analysis

Eutrophication can be caused by both natural and unnatural changes to the ecosystem. Eutrophication is the biological response of water to over-enrichment by plant nutrients, particularly nitrogen and phosphorus (Pitois et al., 2001). Bodies of water that experience eutrophication can experience an increase in phosphates, nitrogen, and sediments. This nutrient pollution can arise from a number of sources including, agricultural runoff, wastewater, and lawn fertilizers (Pitois et al., 2001). The increase and excess amounts of these nutrients can spur the growth of blue green algae. Once these algae blooms begin growing, it becomes more difficult to analyze which nutrient is causing the problem directly from the water (Pitois et al., 2001). The algae feed off the excess nutrients and, thus, the nutrients become part of the algae itself.

Due to the difficulty of determining the most abundant and problematic nutrient from the water, soil testing can be utilized to determine the source of the nutrient imbalance occurring in the pond. If excessive amounts of phosphorous or nitrogen are found in the soil at a site, there is a greater chance that these nutrients might move off the site and cause pollution (Robotham et al., 2004). Certain soil types and landscape characteristics can also lead to the potential of nitrogen or phosphorous accumulation in bodies of water. Nitrogen leaching and runoff potential is highest in sandy soils, thin organic soils, shallow soils, and excessive application of fertilizer or manure followed by hard rain (Robotham et al., 2004). The situations for when sampling for environmental purposes is appropriate are often high-risk situations which are areas where landscape, soil, or climatic characteristics make pollution more likely. These areas include steep slopes, shallow soils or soils with bedrock or a hardpan near the surface, sandy soils, soils with a high water table, fields located near streams or other water bodies, locations with a history of intensive agriculture, and high-rainfall areas or areas that are extensively irrigated (Robotham et al., 2004).

H. Remediation Strategies

The chemical treatment previously used could be replaced with runoff control or other nature-based treatment solution, such as utilizing plants and animals that would help to stabilize the pond ecosystem. Sources of runoff water are high in nutrients causing eutrophication and installing water control structures in drainage ditches can be beneficial in reducing the total amounts of nitrogen and phosphorous in the water (Bohlen and Villapando, 2011). During a four-year study conducted by Bohlen and Villapando, pasture water retention significantly reduced annual total nitrogen (TN) loads, which were 11.28 kg ha^{-1} and 6.28 kg ha^{-1} in pastures with unobstructed and reduced flow, respectively. Total phosphorus (TP) loads were 27% lower in pastures with reduced flow than in pastures with unobstructed flow (Bohlen and Villapando, 2011).

Strategies utilizing fish and aquatic plants, or biomanipulation strategies, to avoid cyanobacterial blooms in shallow lakes and large ponds are multiple and aim first to control eutrophication and, secondly, the enhancement of functional biodiversity in each compartment (Triest et al., 2016). Using plants and animals to remove pollution from water is a sustainable method that is gaining popularity (Triest et al., 2016). Many of these strategies use aquatic plants known as macrophytes.

Macrophytes grow in aquatic environments, are well adapted to their surroundings, and have the potential to eliminate excessive nutrients via their root systems and, hence, function as biofilters (Lone et al., 2014). These plants also stabilize the surface and provide good conditions for physical filtration. Macrophytes have effective root systems that help them take up nutrients from their surroundings and produce large amounts of biomass (Lone et al., 2014). A number of emergent, free-floating, and submerged macrophytes can take up large amounts of nitrogen and phosphorous and this amount can be easily removed if the biomass is harvested (Lone et al., 2014).

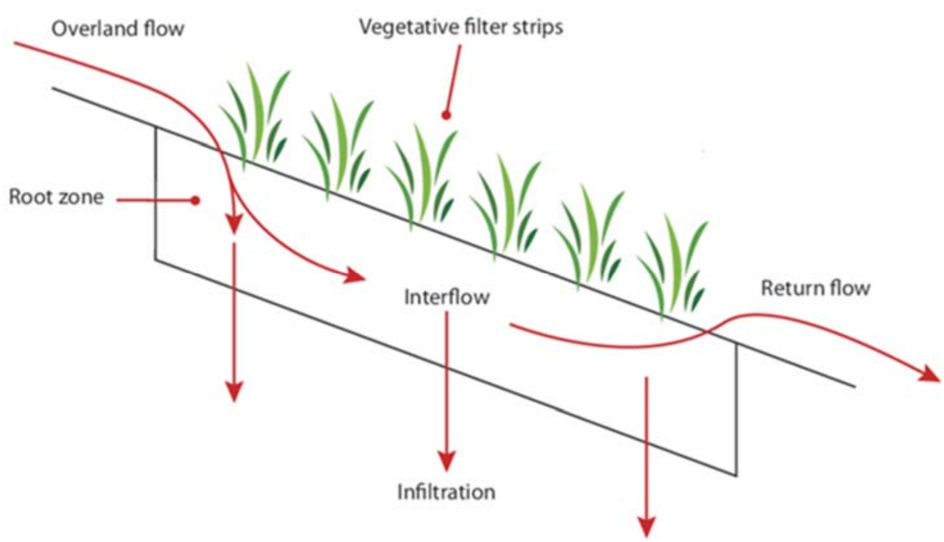
There are several macrophytes that are suitable for Kansas including cattail, coontail, potamogeton, water naiad, lotus, and water lilies (BGA, 2017). Many plants, such as marsh milkweed, blue-flag iris, swamp hibiscus, *Justicia americana*, and Sagittaria, can also be utilized on the shoreline to create a buffer to reduce runoff and increase the uptake of nutrients from the water (BGA, 2017). An interesting and cost-effective means of reducing eutrophication is a floating garden. Floating gardens are planted, floating platforms that have roots dangling in the water and function as a biofilter in the same way as other macrophytes. The floating gardens provide a habitat for many other organisms, as well as providing a potential for growing hydroponic vegetables (BGA, 2017).

VI. Alternatives Considered

To attempt to reduce the amount of unwanted nutrients that is washed into the Meyer's pond, it was determined that implementing a vegetative filter strip would be a viable solution to the problem. The design involves creating a strip of naturally growing native grass with a width of about 6-10 feet along the southern edge of the pond where it is assumed the excess nutrients are coming from. (Figure 1) Specific native grasses to implement are Big Bluestem, Little Bluestem, Yellow Indian, Switch, and Cord grasses. These grasses are both effective filters of nutrients as well as likely to flourish due to their native roots. As these grasses grow over a few years their roots will grow deeper and deeper into the soil, becoming more effective at filtering the water as time goes on. The implementation of this design is as simple as plowing the area clear of current vegetation, and planting a mixture of the native grasses. To maintain the buffer strip design, the grass would need to be grazed or burned every 2-3 years.

Figure 1. Map of Meyer's pond showing proposed site of buffer strip. (Adapted from Google, 2017)

Vegetative filter strips (VFS) work to reduce eutrophication by absorbing nutrients from the water as it passes through and by impeding water flow. The VFS are placed perpendicular to the water flow. This allows the water and excess nutrients to run across the greatest area of the VFS. The water and excess nutrients are absorbed into the root zone of the VFS, where the plants absorb the nutrients that would have otherwise flowed into the pond. The water either continues to infiltrate deeper into the soil or it starts to flow parallel to the surface and becomes interflow (Grismer et al., 2006). Some of the water won't be absorbed into the soil and flows across the surface through the VFS, which helps to remove any sediment that has accumulated in the runoff. This process is depicted in Figure 2. There are multiple factors that impact the effectiveness of VFS from the properties of the soil to the



plants used to the climate.

Figure 2. Cross-section of the patterns of water flow through hillside vegetative filter strips (Grismer et al., 2006).

The design matrix seen below in Table 1, allowed for general design solutions to be narrowed down to choose the best solution to the pond eutrophication problem. The design matrix includes the designs described above as well as several other possible designs, Design constraints such as low cost, low environmental effects, high potential effectiveness, high client's safety, ease of maintenance and low weather impact were all used to rate the designs. Then each constraint was paired with a corresponding importance factor that was used to score each design. The final score of each design option was calculated and the highest scoring design was the buffer strip design. The mobile aquaponics (floating garden) design was calculated to be the second best design.

Objective/Design Constraints →	Low Cost	Low Environ-Mental Impact	Effectiveness	Safety of Clients	Ease of Maintenance	Low Impact By Weather	Total
Importance Factor → Design Options ↓	10	6	5	6	4	1	Final Score
Mobile Aquaponics	6 60	9 54	9 45	8 48	5 20	5 5	232
Buffer Plants/Strips	7 70	7 42	9 45	9 54	8 32	5 5	248
Filter Fish	7 70	6 36	5 25	9 54	9 36	3 3	224
Pool Source Water	5 50	6 36	4 20	9 54	7 28	6 6	194
Natural Pond Filter	4 40	8 48	9 45	9 54	4 16	5 5	208
Detour Run-off Water	5 50	5 30	4 20	8 48	7 28	6 6	182

Table 1. Matrix Analysis Chart used to determine best method to use.

The design matrix provided a solid basis for narrowing down the design options and aiding in the decision of the final design. However, before making the final decision of selecting our design, the buffer strip design's advantages and disadvantages were considered. The second best design, floating garden, was also evaluated based on the advantages and disadvantages to determine which design would be more effective.

The buffer strip design has many advantages in the biological aspect and for the client. Buffer strips and plants are effective in the ability to control soil erosion by both wind and water. The strips have the ability to improve water and soil quality by removing sediments, fertilizer, pesticides, pathogens and other contaminants by slowing and filtering the water before reaching the final pooling source. Thus, removing these contaminants and excess nutrients results in enhanced fish and wildlife habitats and assist in conserving biodiversity both in the water source and on land. The buffer strips and plants can be used as a source of food, nesting cover, and shelter for many wildlife species. Buffers also provide connecting corridors that enable wildlife to move safely from one habitat area to another. The buffers also help stabilize streams and reduce its water temperature.

The buffer strip also has many benefits for the client. Well-planned buffers can improve the appearance of a farm or ranch. If used as part of a comprehensive conservation system, buffers can be a better option for areas that should not be used for crop ground. Depending on the plants used in the buffer strips, the cost of implementation is a relatively low comparative to the cost of implementing and maintenance of other designs.

The buffer strip design also has some potential disadvantages. Depending on the area where the buffer strip is to be implemented, the buffer strips could divide the client's personal property and also could take away from effective farming ground. Another disadvantage to the buffer strip design is its effectiveness during flooding and high runoff periods. This depends highly on the area where the buffer strip is implemented and the likelihood of the area to flood. Finally, buffer strips and the plants used are susceptible to the effects of weather and invasive species. The selection of plants to be used in the buffer strips must be made carefully. Plants should be native species to the area, in order to grow effectively and have some resistance to invasive plant species. If not selected carefully, the buffer strip can become more susceptible to the weather effects.

Even though the buffer strip design appears to be the best solution for our clients, the floating garden alternative also proved to be a feasible alternative. The floating garden is a different approach to providing a solution for the clients. The design would be an in-pond system that could be designed to grow aquatic plants or crops. As shown in Figure 3, the plants are supported above the surface of the water by the frame of the garden and the plant roots dangle in the water.

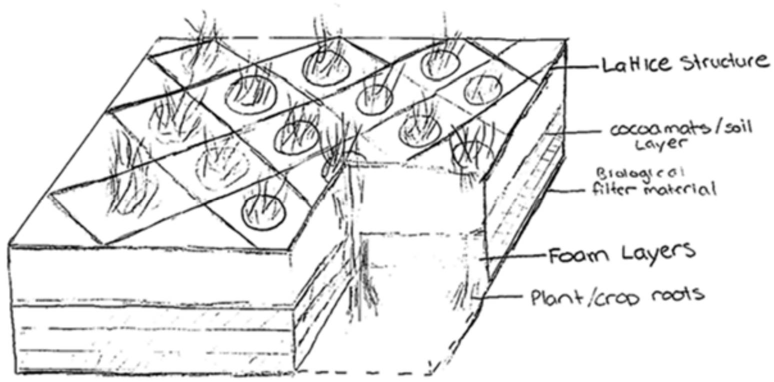


Figure 3. Floating garden main structure and interior view.

Over time as the plants grow the excess nutrients in the pond water will be absorbed and utilized by the plant materials and thus recycled out of the water. The floating garden can be designed to be mobile, docked, or anchored within the pond. One of the bigger disadvantages with the floating garden design is that as the growing season comes to an end the garden must be removed from the pond and the decaying plant material must be discarded and the system must be replaced for the next use. The decaying plant material allows for the nutrients to be recycled into another system to replenish nutrients naturally in areas such as, a lawn, compost pile or exposed soil that may already need a fertilizer treatment. This is an advantage biologically for the system as it can take many years for the nutrients in the water to be recycled out of nutrient saturated systems into biological systems lacking nutrients. The floating garden also provides habitats for both aquatic and terrestrial life as shown in Figure 4. However, the maintenance and cost factors that result in having to replace the system each season, was a major drawback of the floating garden design. Before making the final decision to determine which solution to implement, a visit was scheduled with the Meyer's to survey the site of their pond, and to get a better sense of the problem.

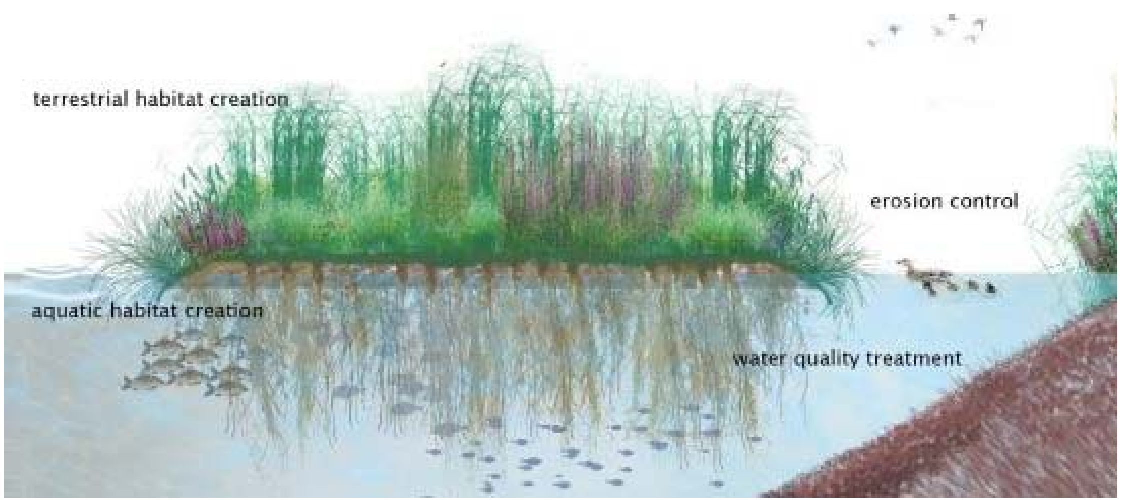
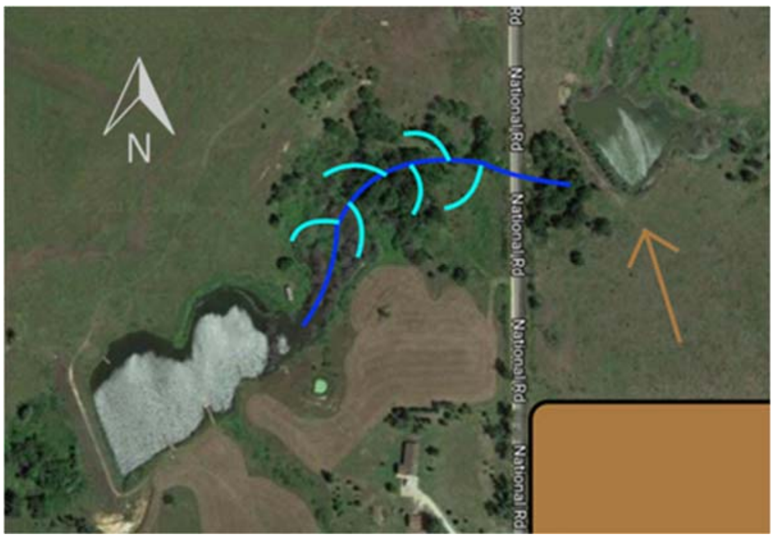


Figure 4. Floating garden system showing possible benefits (Midwest Floating Island, 2017).

VII. Final Design Description

After visiting the site, it was determined that the original buffer strip idea would not be sufficient in stopping the excess nutrients from entering the pond. This was due to a few discoveries made while visiting the Meyers' pond. It was initially thought that the polluted water flowed from the south over the Meyers' field and into the pond (Figure 1). After visiting the site, the source of the polluted water was identified to be a small stream that originates from a pond located across the road to the east. The pollution is thought to come from the fields to the southeast of the pond. Lastly it was discovered that there was a large amount of vegetation already surrounding the pond.

After considering these factors and the new information gained from visiting the Meyers' property, it was determined that the best solution would be to alter the original buffer strip idea. The final design recommendation is to divert the water entering the pond across the existing vegetation (Figure 5). To do this, the water flowing into the pond will need to be channeled away from the current stream bed, and out across the vegetation. Along with this it was determined based off of the matrix analysis (Table 1) that the addition of a



floating garden would be beneficial in reducing the amount of excess nutrients in the water.

Figure 5: Map of Meyer's pond showing flow of pollution (brown) and the final design (light blue)

VIII. Testing Needs

There are aspects of the design that for which the specifics are unknown. To determine the information required there are multiple tests that can be conducted. Testing specific plants for their nutrient absorption rate can be done by running nutrient-rich water through each plant species in a closed system to determine which plant species would work best for the design. Determining how effective the design will be can be done by testing the nutrients in the water before and after the design is implemented and comparing the amount of nutrients that have been removed. Monitoring the growth rates of blue green algae blooms before and after the design is implemented will also assist in determining how effective the design is. Water testing kits, such as the Earth Force monitoring kit, can be used to identify and rank levels of specific nutrients, the amount of dissolved oxygen present, and pH levels of the water. This kit in particular uses test tablets and color diagrams to analyze the results, thus it would be easy for the Meyer's to sample and test the water throughout the design implementation process. Overall, it is important to make sure that the client is satisfied with the design and this can be accomplished through a survey asking various questions about how the design has affected them.

A secondary effect of the design is the effect on the surrounding wildlife. One way to monitor this is to set up a wildlife camera and observe the changes in wildlife activity by counting the number of animals that pass through the area. Since this is a secondary effect of the design the results won't impact the design significantly. Depending on how important the client feels about the surrounding wildlife there are steps that can be taken to help increase or decrease wildlife activity.

IX. Conclusion

Bruce and Theresa Meyer are seeking a cheaper and longer term solution to their problem of eutrophication in their pond. The eutrophication occurring in their pond has the potential to be very harmful to people and to the environment. The cause of the eutrophication is most likely pollution that comes from nearby agricultural runoff. To solve this problem it has been determined that the best solution would be to treat the water immediately before it enters the pond by diverting the flow of the water over the existing vegetation to filter out the excess nutrients from the water flowing into their pond. It is also recommended to install a floating garden to help supplement the design while the vegetative portion of the design is established.