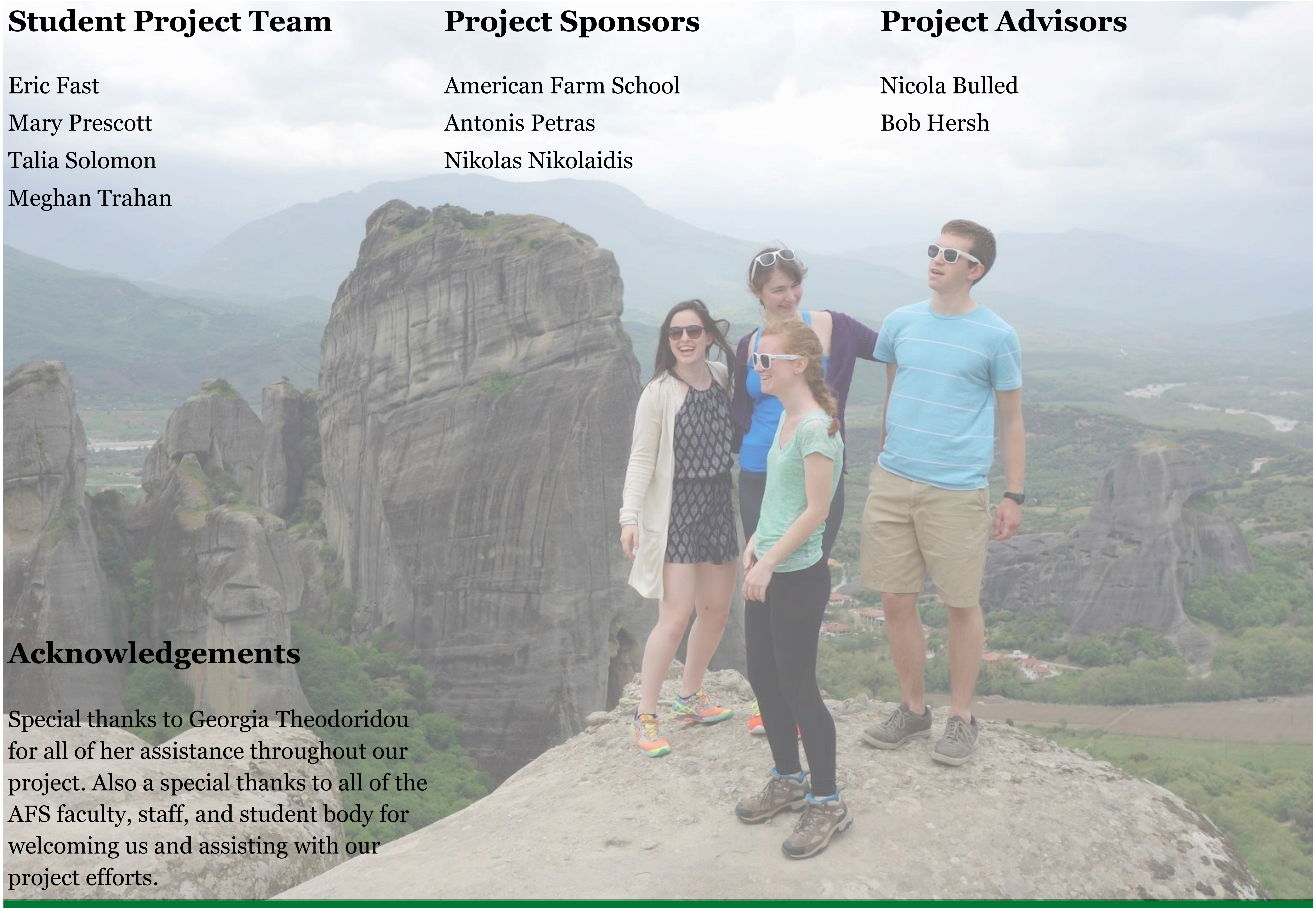
Alternative Water Treatment:

Designing a floating island that integrates social & technical elements at the American Farm School, Thessaloniki, Greece



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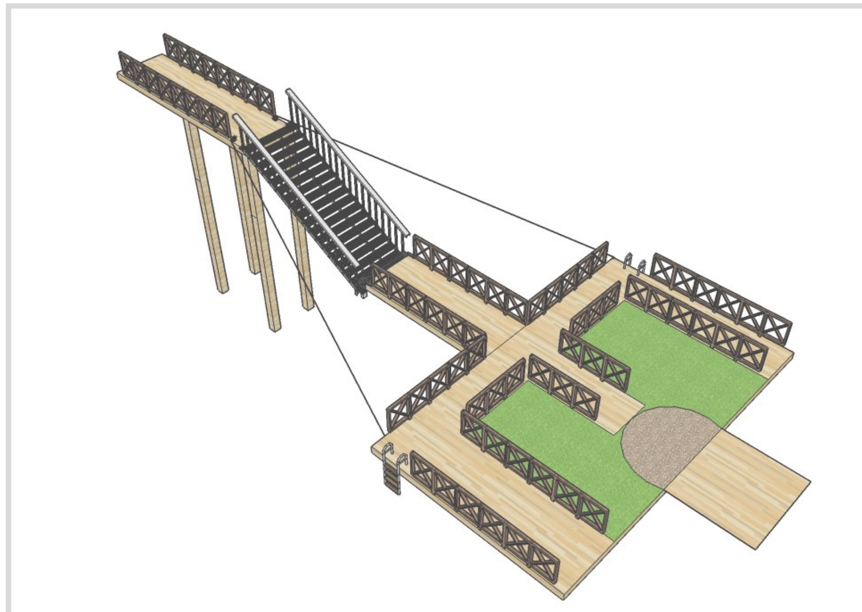


Introduction

Crop irrigation is one of the biggest water consumers in Greece, where 86% of freshwater consumption is dedicated to agriculture (Ilias et. al, 2014; Adamantopoulou, 2014). This large consumption takes place while 83% of Greece is facing desertification*[1] (United Nations, 2002). Furthermore, there is a consensus from the European Environmental Agency and the Intergovernmental Panel on Climate Change that Southern Europe will face water shortage in the future (EEA, 2016; IPCC, 2007). The combination of these factors means that the water available for agricultural purposes will become limited.

This has spurred water reuse projects around the country. In Thessaloniki, wastewater effluent is used to irrigate 2,500 hectares of agricultural land. However, this water must be treated prior to use to reduce pollutants in order to avoid health risks. Point and nonpoint sources, such as liquid wastes from livestock farming and agricultural runoff, can bring harmful pollutants into water bodies. For example, E. coli contributes to health problems of the digestive tract and lungs, and pesticides pose a carcinogenic risk if ingested (Vymazal et al., 2015).

[1]* indicates defined in Appendix A

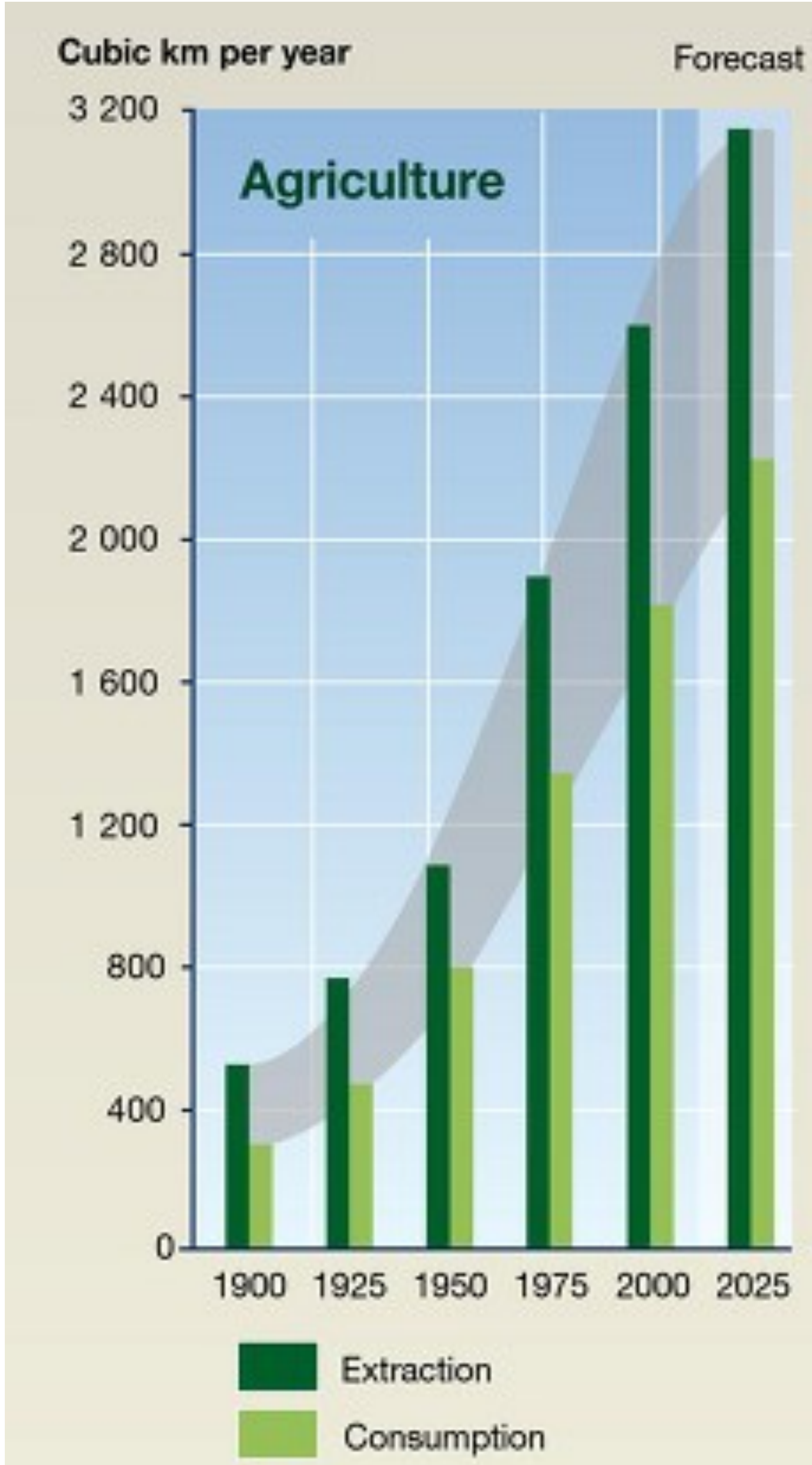


Figure 1: Global Agriculture Water Usage - *Projected growth of extraction and consumption of water for agriculture*

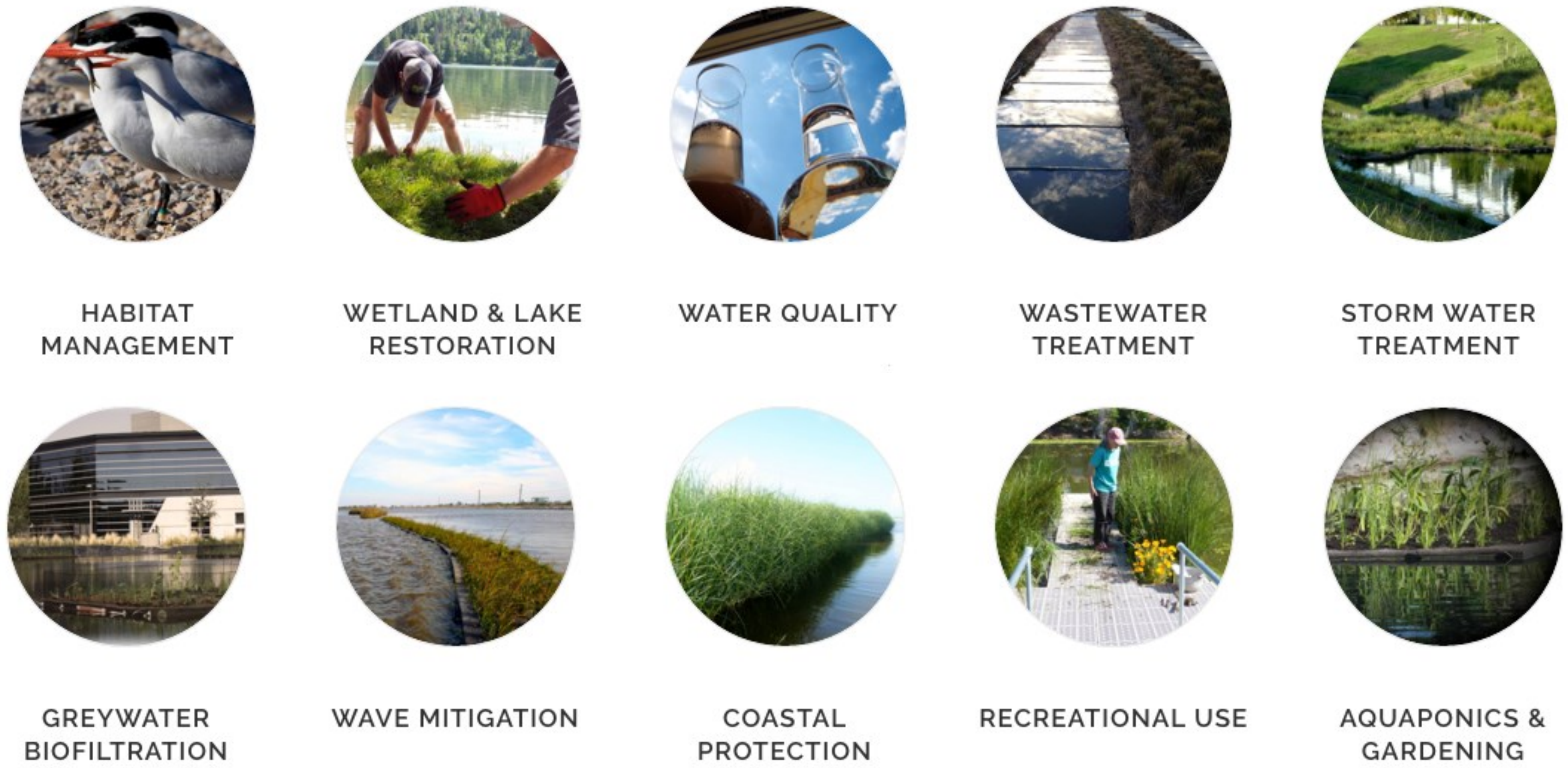


Figure 2: Floating Island Applications - *Outline of the various applications of floating island technology*

Problems associated with agricultural pollution can be alleviated using natural water treatment methods. Artificial floating islands (AFIs) are recognized as a low cost, sustainable practice for pollution mitigation. Although the technology has been around since the 1950's, it is now being sold commercially to naturally treat water, reduce algae growth, establish habitats for wildlife, produce food, and create aesthetically pleasing environments (Floating Islands West, LLC, 2014).

The islands can be constructed of floating mats, floating aquatic plants, and sediment-rooted emergent wetland plants. These structures host related ecological communities like algae, biofilms, zooplankton, and small invertebrates. (Yeh et al., 2015). The plants are seeded onto a base -- often a mat made of natural materials that form a matrix -- and the roots grow through into the water. The roots uptake various pollutants, while the biofilm, which grows on the mat matrix, mostly consumes nutrients.

The attractiveness of utilizing AFIs rather than conventional water treatment lies mainly in the effectiveness, cost, and sustainability benefits. Numerous studies have shown that floating islands are capable of removing up to 90% nitrogen, 73% phosphorus, and more than 92% organic carbon (Kerepeczki et al., 2011). On average, AFIs also have lower initial capital investment as well as lower operational and maintenance costs than conventional treatment systems. In addition to water treatment, AFIs beautify areas that are otherwise lacking, allowing them to serve as a public amenity. Lastly, AFIs do not require the use of harmful and costly chemical additives, and therefore many are eligible for sustainability certificates and accolades (John Todd Ecological Design, [2007]).

There are, however, many limitations to the analysis of floating islands. Some are due to the fact that plant species on the island are very specific to their location and purpose. In addition, most studies regarding floating islands are on a relatively small scale, which leaves “little or no design basis available for sizing a floating treatment wetland system” (Lyon et al., 2009). There is also uncertainty when it comes to the removal efficiency of the floating islands. It has been observed in nearly all studies that removal rates of nutrients, metals, and pesticides are highly variable due to changes in temperature (Zhao et al., 2012). Higher temperatures cause biochemical reactions to occur faster. This means that floating islands will not produce consistent results depending on the season. A final uncertainty in floating island projects is the cost. Commercial floating islands can be very expensive; a 100 square foot island from BioHaven® would cost around $3,000 (Garbs, [2013]). However, it can be inexpensive to build an island in-house using materials such as PVC piping, metal pipes, and natural components.

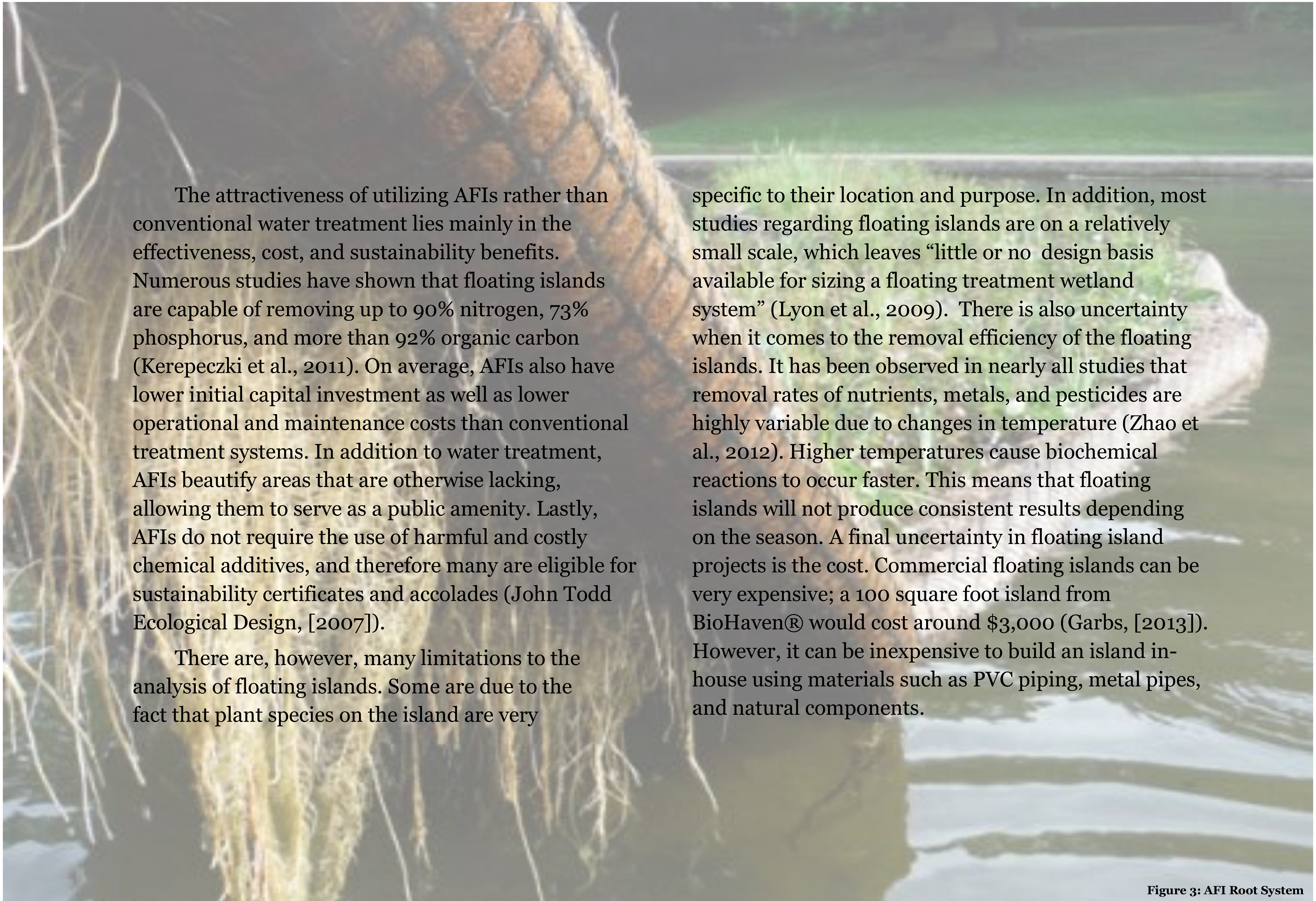


Figure 3: AFI Root System

Our project created a comprehensive recommendation for the design of a floating island at the American Farm School (AFS) that serves a three-fold purpose: improving water quality in the earthen lagoon; increasing opportunities for field-based learning at AFS; and creating an attractive, ecologically rich landscape feature. AFS is a private, non-profit educational institution located just outside Thessaloniki, Greece. The school educates youths and adults in sustainable agriculture, the environment, and life sciences to produce professionals in agriculture and agricultural tourism (AFS, [2014]). All of its programs utilize the large-scale, on-campus educational and demonstrative farm.

The school also operates its own wastewater treatment system involving two lagoons, one of which will be the home to the floating island. We collected community input through a variety of methods including photovoice, interviews, and design charrettes in order to create a model that was tailored to the needs and vision of members of AFS. We interviewed horticulturists at AFS in order to choose plants for the island that will be both effective at treatment and aesthetically pleasing. Our aim was to invigorate the lagoon through a tangible treatment system that creates a visually appealing environment to incorporate the area into the campus as a useful space for students and faculty alike.

Figure 4: Student Design Charrette - *Project Team discussion with Perrotis College students*

Context

Water Resources in Greece

Current water resources are predicted to shift in significant ways due to global climate change. To feed a world population of 7.4 billion people, 888 trillion cubic meters of water are required per year (Greywater Reuse Systems, 2007). Since only 2.5% of the world's water is fresh, of which only 30.1% is potable, alternative irrigation methods must be considered (U.S. Geological Survey, 2016b). Southern Europe is projected to face water shortage in the future. Both decreased rainfall and increased evapotranspiration* will lead to "a significant reduction of soil moisture" (Baltas & Mimikou, 2005). This reduction will spur stronger competition for water between agriculture, other industries, and residential areas as well as highlight the importance of water reuse (Čížková et al., 2011).

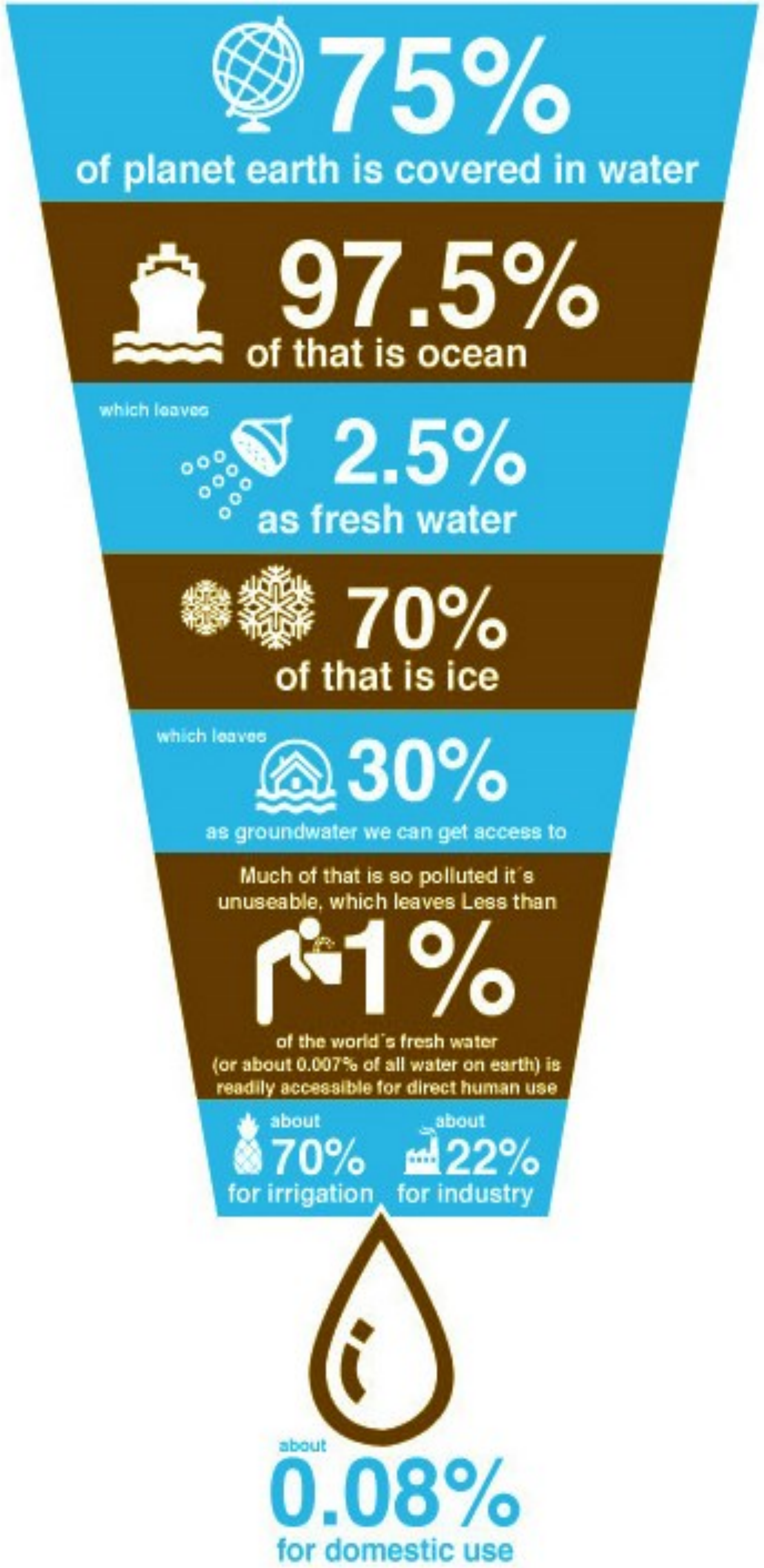


Figure 5: World Water Content - *Breakdown of water sources and use*


Figure 6: Soil Conditions at AFS - *Dry, cracked soil*

A surprising portion of water in Greece is used for agricultural purposes. Of the total fresh water consumed in Greece, 86% is used for this industry (Adamantopoulou, 2014). For comparison to another Southern European country, Spain uses only 19%. Agriculture accounts for 3.8% of Greece's GDP, while in Spain it accounts for 2.5% (FAO, 2016; The World Bank, 2016). This means that for one and a half times the agriculture, Greece uses four and a half times the water. Even more concerning, this large consumption takes place while Greece is facing desertification. The National Committee to Combat Desertification (NCCD) has found that 83% of the country is at a moderate to high risk (United Nations, 2002). Greece's National Report on Sustainable Development (2002) states that:

> "Greece's climatic conditions, with long, dry summers and high evapotranspiration rates, favour desertification in the driest areas of the country that are also suffering from water scarcity and droughts... The resulting loss of productive, arable land from soil erosion and salination, and the over-pumping of aquifers to compensate for water losses, are among the key factors posing a desertification risk for the country which is, subsequently, further intensified by raising global warming effects." (p. 28)

The high use of water for agriculture in Greece along with dry conditions is a driving factor for innovative technologies that conserve water.

Reusing domestic and industrial wastewater for farming can conserve a significant amount of freshwater. Table 1 shows current wastewater reuse projects in Greece as well as their capacity to assist in crop irrigation. Crop irrigation is one of the biggest water uses in Greece, as the demand occurs mostly in the dry summer months when resources are scarce. Fortunately, Thessaloniki is one of the largest agricultural areas in Greece and has the most substantial wastewater reuse for irrigation. Effluent from its wastewater treatment plant is mixed with fresh water from the Axios River in a 1:5 ratio to reduce salinity (Ilias et. al, 2014). Many other projects are taking place throughout Greece and it has even been discovered that ancient Greek civilizations likely reused wastewater for growing crops (Kretschmer et al., 2002).

Table 1: Major Greek Water Reuse Sites

Project	Region	Capacity (m^3/day)	Irrigated area (ha)	Crops
Thessaloniki	Central Macedonia	165,000	2,500	Corn, sugar beet, rice, etc.
Iraklion	Crete	9,500	570	Grapes, olive
Levadia	Central Greece	3,500		Cotton, corn
Amfissa	Central Greece	400		Olive trees
Nea Kalikratia	Central Macedonia	800	150	Olive trees
Chersonissos	Crete	4,500	270	Olive trees
Malia	Crete	2,500	150	
Archanes	Crete	550	33	Grapes, olive
Kos	North, Aegean	3,500	210	Olive trees, citrus, etc.
Others		10,000		Various

While water reuse can reduce stress on resources, insufficient treatment exposes the public to pathogens and pollutants that degrade the quality of soil and groundwater (Bournaris et al., 2014; Maimon et al., 2014). This risk has led to the need for governments to provide suggestions for the proper handling of wastewater. In April of 2013, Thessaloniki, Greece held the first EWaS-MED International Conference on Improving Efficiency of Water Systems in a Changing Natural and Financial Environment.

This conference stressed that water quality improvements needed to be made in Greece under Directive 2000/60/EC of the European Parliament (European Parliament, 2000). Also known as the Water Framework Directive, this document recommends parameters for pollutants that affect surface waters such as heavy metals and pesticides. The Nitrates Directive, a subset of the Water Framework Directive, specifically targets nitrogen runoff from farming practices.

Figure 7: Thessaloniki Wastewater Treatment Plant

Our project took place at the American Farm School (AFS) in Thessaloniki, which seeks to bring innovation to farming. As its mission statement says, the school aims to "educate youth and adults to become professionally accomplished in the latest aspects of agriculture, ecology and the life sciences, and to make Greece and its neighbors a better place" (AFS, [2014]). The core of AFS's educational philosophy is a "learn-by-doing" curriculum that encourages students to interact with the many resources available on campus. In addition to classrooms, the 50-acre grounds boast an educational and demonstrative farm that includes 220 cattle, 22,000 chickens, and 22,000 turkeys (Willis et al., 2005; Petras et al., 2013). To support the animal populations, wheat and corn are grown in the winter and summer respectively to be used as feed.

Figure 8: AFS Student-Farmers - *The farm provides hands on learning for AFS students*

With its range of programs, the American Farm School creates several different types of wastewater. This includes: human waste, animal waste, and agricultural runoff, as well as industrial waste from milk, olive, and wine processing facilities. Residential waste from the campus is passed on to the municipal sewage system. To conserve water, all of the effluent generated by the farm is treated and reused to irrigate the school's crops. Treatment occurs in three independent tracks, as seen in Figure 3 (Petras et al., 2013).

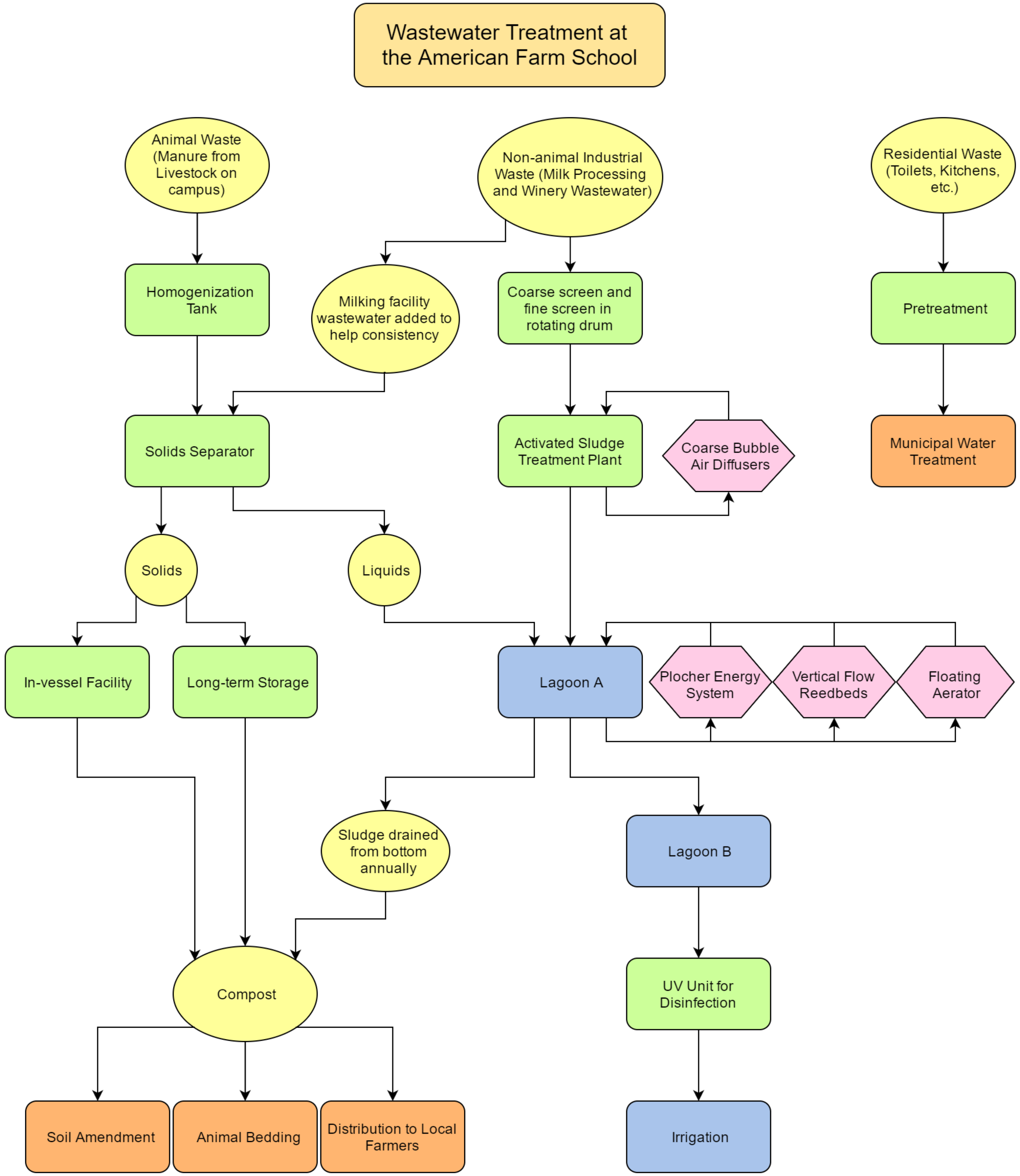


Figure 9: AFS Water Treatment System Diagram - *Full layout of the wastewater treatment and reuse system*

Figure 10: Earthen Lagoon

Non-animal industrial waste is put through several layers of processing: passing through screens, activated sludge*, and vertical flow reed beds*. It ultimately resides in the first of two holding lagoons on the campus, the concrete lagoon. Water in this lagoon is treated with quartz and calcium carbonate as part of the Plocher Energy System, a process that greatly reduces the foul smell of stagnant sewage (Willis et al., 2005). Surface water from the concrete lagoon eventually moves to the larger, adjacent earthen lagoon for storage. Both lagoons experience rainwater runoff inflow from the nearby school farmlands (Petras et al., 2013). Water in the earthen lagoon is used for irrigation during the dry season. Animal waste (from the resident cows, chickens, and turkeys) is separated into liquids and solids, with the liquids joining non-animal wastes in the first lagoon. Solid waste is matured into compost, some through an in-vessel* facility on campus and the rest spread on an asphalt mat to mature over the course of a year. The compost is used both at AFS and distributed to farmers in the wider Thessaloniki area.

AFS routinely measures pollutant levels in both the earthen and concrete lagoons. These measurements include, but are not limited to: nutrients, biochemical oxygen demand (BOD), pH, Escherichia coli (E. coli), and solids. The most common nutrients are nitrogen and phosphorus, which are the main ingredients in fertilizer. The lagoon contains high levels of nutrients due to adjacent agricultural practices. Although they are essential for plant growth, high levels can cause eutrophication, a process by which algae grows and is rapidly decayed by aerobic bacteria (Sharpley et al., 1981). This process decreases ecological health of water bodies by reducing oxygen levels and sunlight exposure. High levels of BOD in water sources indicates pollution from sewage (Bashir et al., 2014). When this water is applied to crops, BOD can deplete the oxygen in the soil pores, as well as indirectly decrease soil porosity and degrade soil quality over time. When high BOD water is utilized over a long period of time, soil quality degrades, which is undesired by AFS. Varying pH indicates that water is changing chemically, and thereby measurements can demonstrate the presence of pollutants. pH also determines the solubility and biological availability for aquatic life of potential pollutants. For example, heavy metals are more soluble in water at higher pH levels. Furthermore, plants require a certain pH for optimal growth therefore water in the lagoon could not be used for irrigation if it is too basic or too acidic. E. coli comes from the intestines of animals and people. It serves as an indicator organism, which is usually harmless but can signal the presence of bacteria and viruses from fecal matter. Some strains of E. coli can lead to urinary tract infections, respiratory illness, and pneumonia (Center for Disease Control and Prevention, 2016). Similarly, solids in water bodies can have adverse health effects. In order to reuse the water at AFS, these parameters must be treated to a level where they no longer pose a substantial risk.

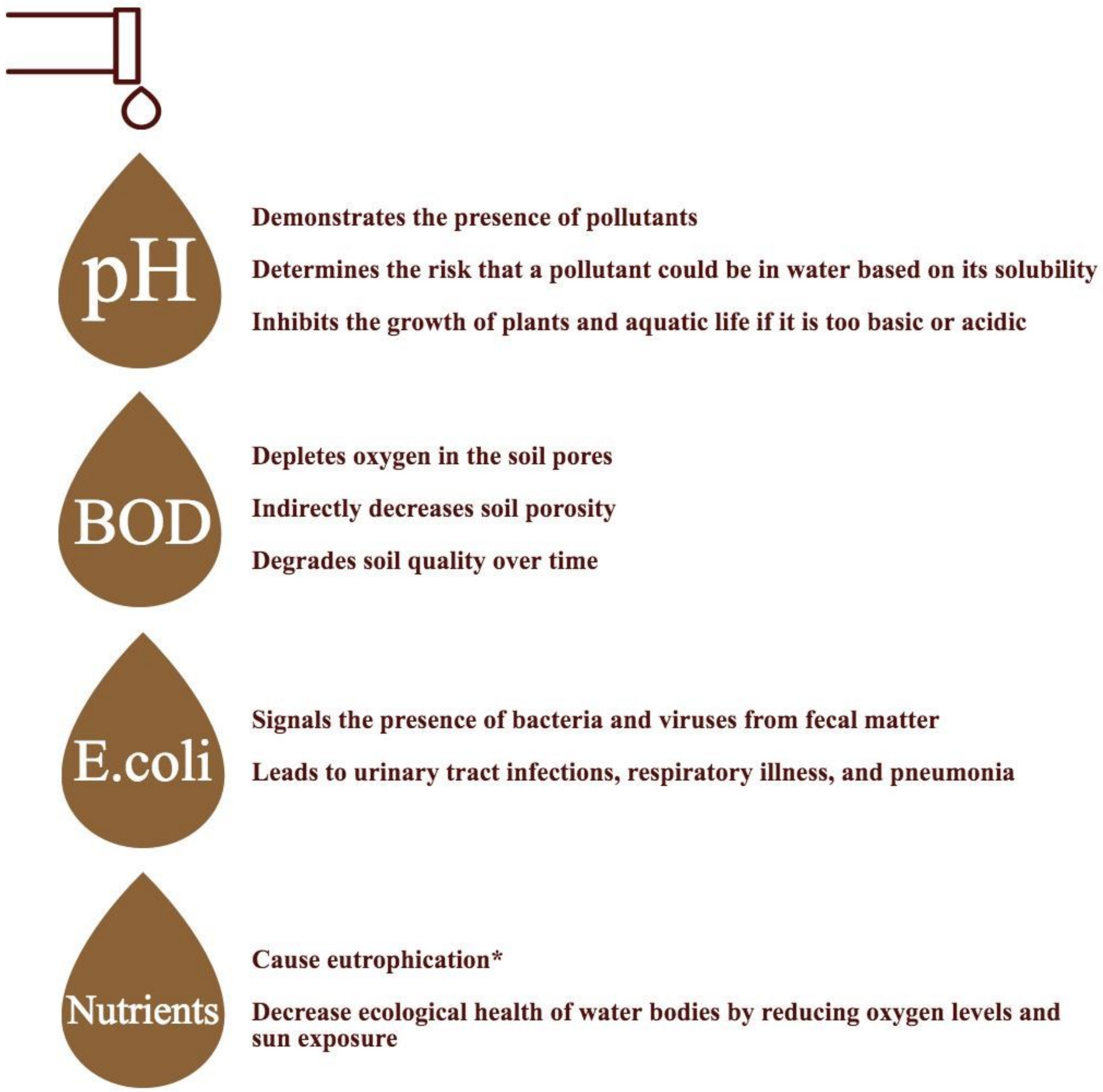


Figure 11: Negative Effects of Pollutants - *Many common pollutants found in water can have harmful effects*

While AFS currently meets water treatment requirements set by the Greek Ministry of the Environment, the school strives to stay “five years ahead of the game” in the face of increasingly strict regulations (N. Nikolaidis, personal communication, February 2, 2016). In line with its philosophy, the school would like to do so in an ecologically responsible way. AFS seeks to reduce contaminant levels in the lagoon through natural water treatment while also promoting environmental awareness and creating a space that combines science with art.

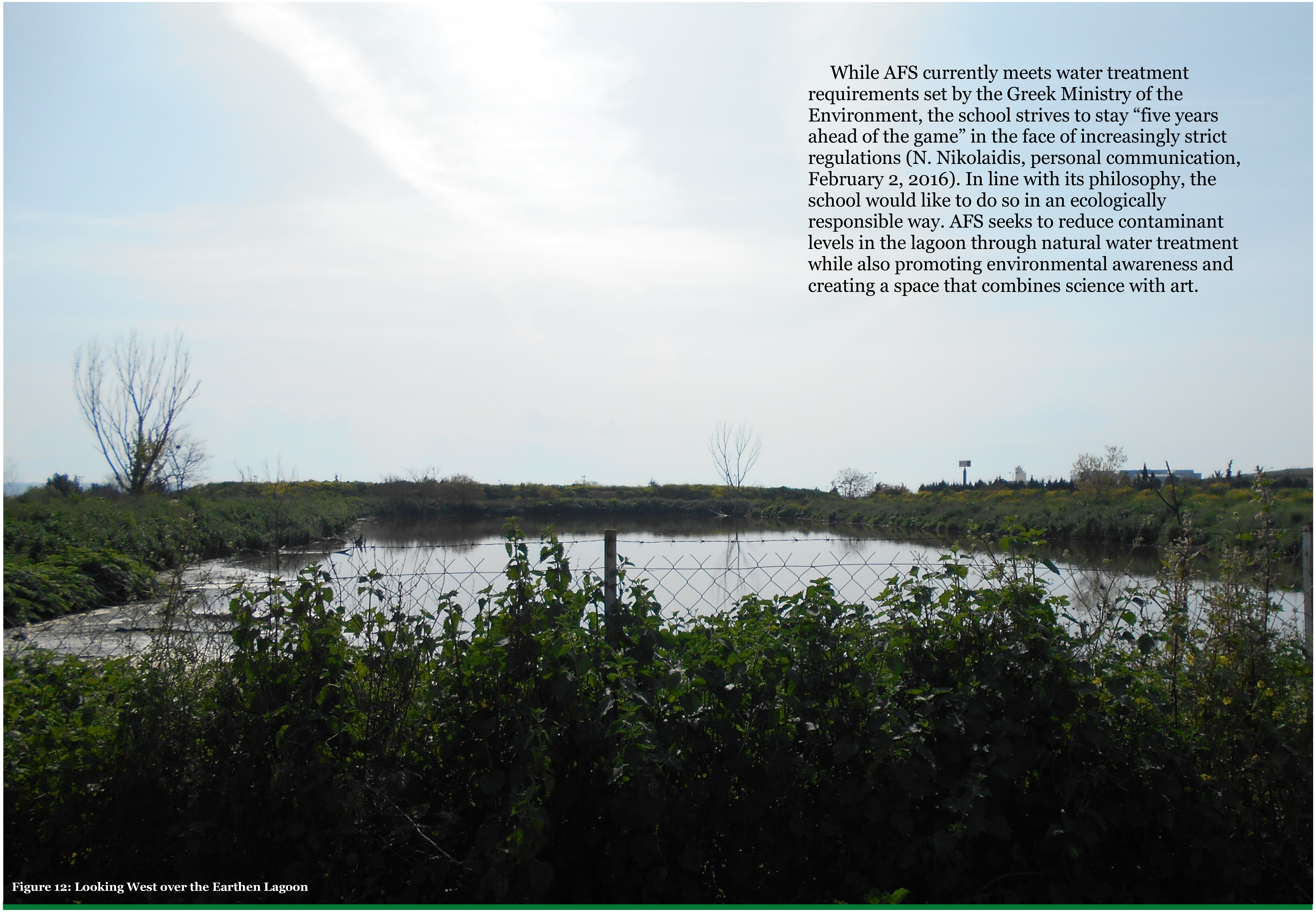


Figure 12: Looking West over the Earthen Lagoon

Natural Water Treatment

Natural water treatment techniques have been in place for decades. Some common technologies include filter strips, vegetative barriers, grassed waterways, and riparian wetlands (Vymazal & Březinová, 2015). Filter strips, vegetative barriers, and grassed waterways all involve the planting of native flora to form a barrier between the body of water and the source of pollution, which is frequently an agricultural operation. These buffer zones filter, slow, and infiltrate stormwater to lessen pollution levels in adjacent waters. They have been proven to capture solids, prevent sediment deposits, and reduce nutrients, chemicals, and metals. This is made possible through sedimentation, adsorption, biological uptake, and microbial activity (DEP, 2006).

Figure 13: Grassed Waterway

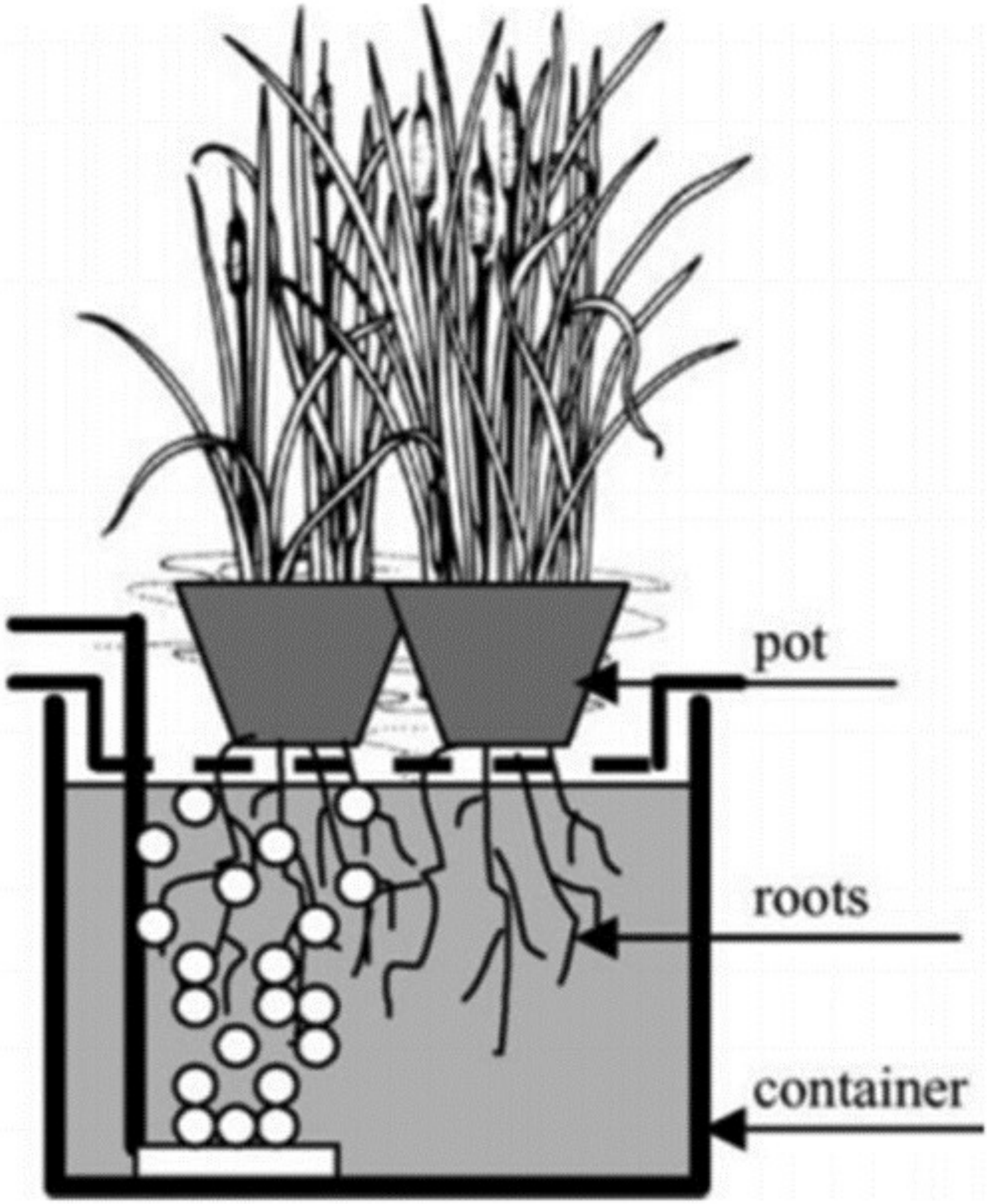


Figure 14: Contaminant Uptake by Plants - *Floating islands can remove pollutants through roots and microorganisms*

Riparian wetlands are vegetated areas highly saturated with ground or surface water. Although similar to those mentioned previously, this treatment system is located within the water body and purifies by dispersing high inflow rates, which allows for the filtration of sediments as the water moves through (University of Idaho, 2016). The power of all of these environmentally-friendly solutions lies within phytoremediation.

Phytoremediation – stemming from the Greek word for plant, phyto – is the use of living plants to remove, degrade, or contain contaminants in soils and water bodies through a variety of mechanisms (Erakhrumen, 2007). Biofilms on the roots of plants demonstrate this process by collecting suspended solids; a form of water pollution composed of organic material and metal particulates that do not settle due to gravity alone. They will uptake suspended solids as long as anaerobic conditions are maintained (Floating Islands West, LLC, 2014). Other means of decontaminating include extracellular enzyme release, contaminant settling and binding, and suspended matter flocculation enhancement (Yeh et al., 2015). Emergent macrophytes, plants that grow in water but pierce the surface so that they are partially in the air, are most optimal for phytoremediation. Not only can these plants grow in an oversaturated environment, but also often produce an aerial flower stimulating reproduction (Floating Islands West, LCC, 2014). Emergent plants can be a potent resource for environmental cleanup.

In recent years floating islands have emerged as an innovative agricultural runoff management practice. These soilless plantings are engineered systems that utilize phytoremediation and exploit the properties of wetland vegetation and their microbial assemblages to improve water quality (Vymazal & Březinová, 2015). Other functions include shading to reduce water temperature and algae growth, wildlife habitat, and food production (Floating Islands West, LLC, 2014). They are constructed of floating mats, floating aquatic plants, sediment-rooted emergent wetland plants and related ecological communities like algae, biofilms, zooplankton, and small invertebrates (Yeh et al., 2015).

Figure 15: Floating Island in Hicklin Lake, Washington - *Example of the use of a floating island in the U.S.*

The technology is becoming ever more popular such that floating mats are now commercially available through companies such as BioHaven® and BeeMats (Lynch et al., 2015). Floating islands purchased from BioHaven® are typically comprised of eight-inch thick recycled plastic bound to marine foam, otherwise known as polyurethane, with organic matter seated on top (Clemson University, 2015).

Figure 16: BioHaven® Floating Island Base - *Modular floating island bases are available from BioHaven®*

BeeMats sells puzzle cut mats, about one half-inch thick of buoyant material, held together by nylon connectors. After the mats are assembled, plants in perforated pots are inserted into the precut holes (BeeMats, n.d.).

Figure 17: BeeMats Floating Islands - *BeeMats floating islands can be purchased in pieces and put together*

Modular wetlands use a closed cell foam base in combination with a recycled plastic biomatrix foam and coir inserts to create a base for the plants (Charleston Aquatic Nurseries, 2013). These can be purchased from both the Charleston and Maryland Aquatic Nursery, Inc.

Figure 18: Rectangular Coir Insert (top) & Modular Wetlands (bottom) - *Various modular floating island options*

The treatment process of a floating island is quite simple. Emergent native plants are seeded on the mats and submerged within the existing ecosystem. These mats are made of natural materials that form a matrix, similar to those found in ordinary wetlands. While the roots of the plants grow through the mat, a biofilm forms on the matrix.

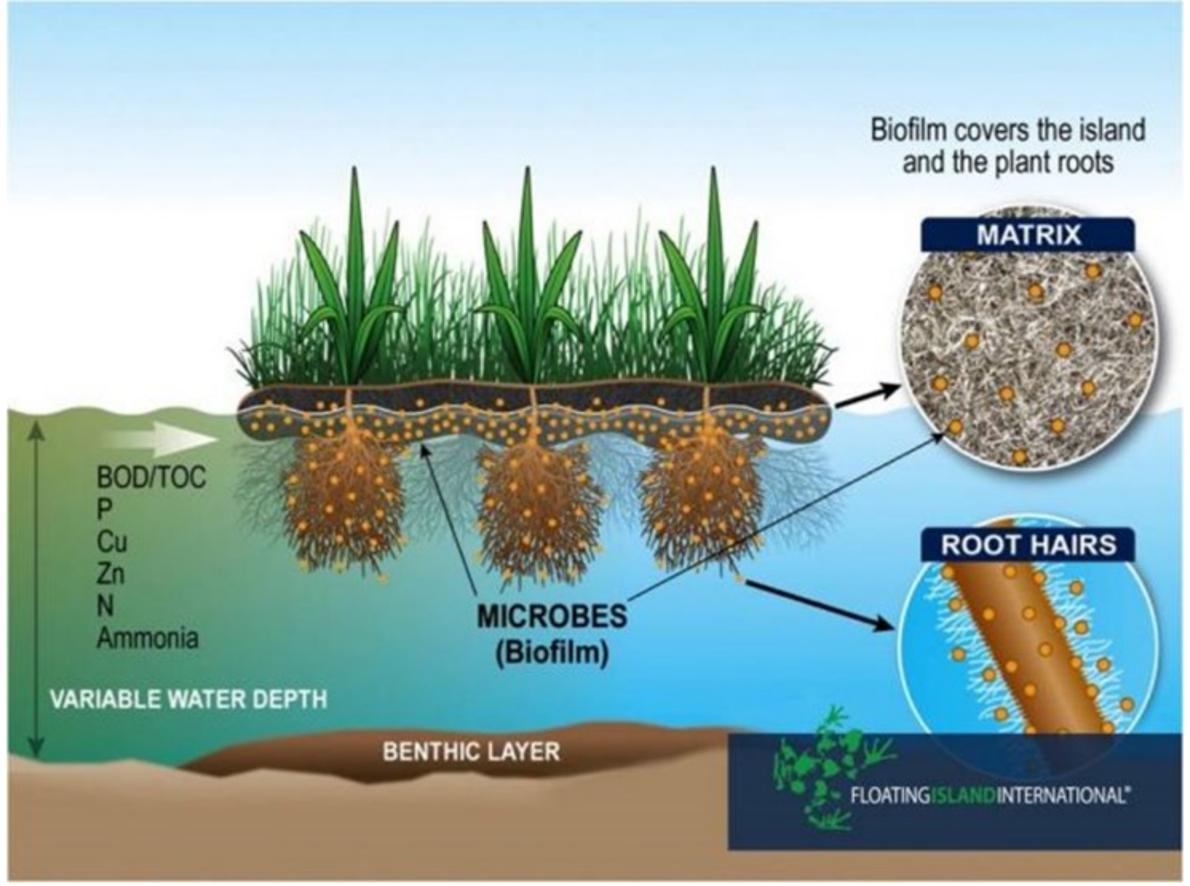


Figure 19: Floating Island Schematic - *Floating islands can remove various pollutants via microbes on the biomatrix and roots*

The treatment is then twofold: while nutrients circling in the water are consumed when they come into contact with the biofilm, plant roots uptake additional pollutants (Midwest Floating Islands, 2014). This unique process can be beneficial in a variety of applications.

Successes and Challenges of Floating Islands

Numerous studies have been conducted regarding the efficiency of artificial floating islands (AFIs) to remove harmful or unwanted pollutants such as nitrogen, phosphorus, and Escherichia coli (E. coli). Overall, floating islands and constructed wetlands have yielded striking results with removal of up to 90% nitrogen, 73% phosphorus, and more than 92% organic carbon (Kerepeczki et al., 2011). CWs have been used since the 1950s, however they have only recently been implemented worldwide (Vymazal et al., 2015). CWs and AFIs have now become a popular tactic for mitigating nonpoint source pollution, including pesticides, in many countries around the globe. Refer to Appendix B for a full list of analyzed projects.

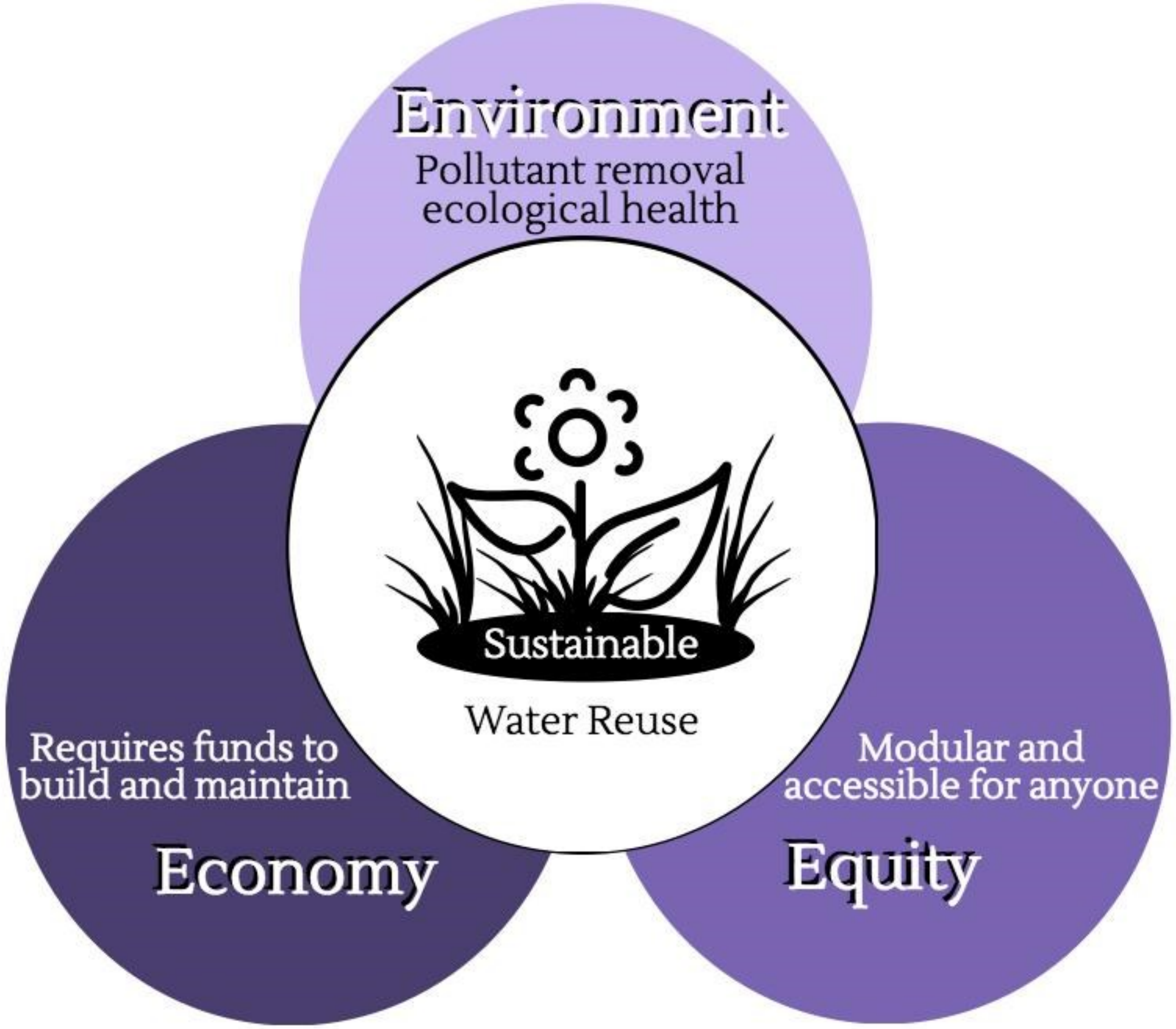


Figure 20: Sustainable Water Reuse Through Floating Islands

The popularity of CWs and AFIs is due to their low cost, use of natural mechanisms, and and achievements in sustainable water reuse. A 2011 project by Floating Island International in New Zealand showed that CWs could be used instead of aerators to reduce BOD by 81% and save $150,000 annually. This is not a standalone outcome. On average, AFIs have lower initial capital investment as well as lower operational and maintenance costs than their conventional counterparts (Kerepeczki et al., 2011). AFIs do not need costly additives since they rely solely on biological reactions, while many conventional processes require chlorine, ozone, or other chemicals. In many cases, biological methods have proven to be the most effective and environmentally-friendly option for nitrogen removal (Cao et al., 2016). Floating island projects from John Todd Ecological Design all meet Leadership in Energy and Environmental Design certification, Living Building Challenge guidelines, and Net Zero energy goals (John Todd Ecological Design, [2007]).

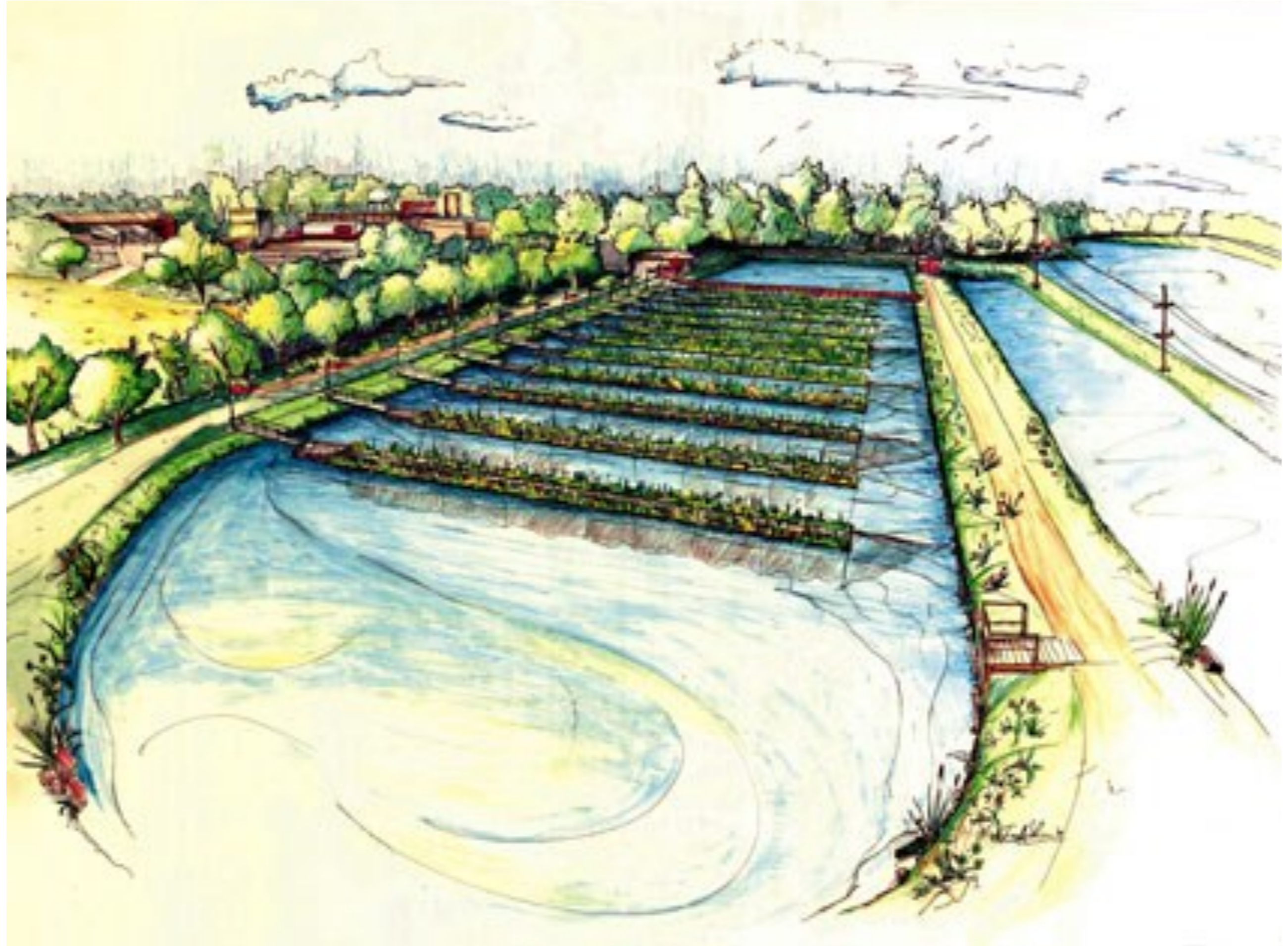


Figure 22: John Todd Ecological Design Drawing

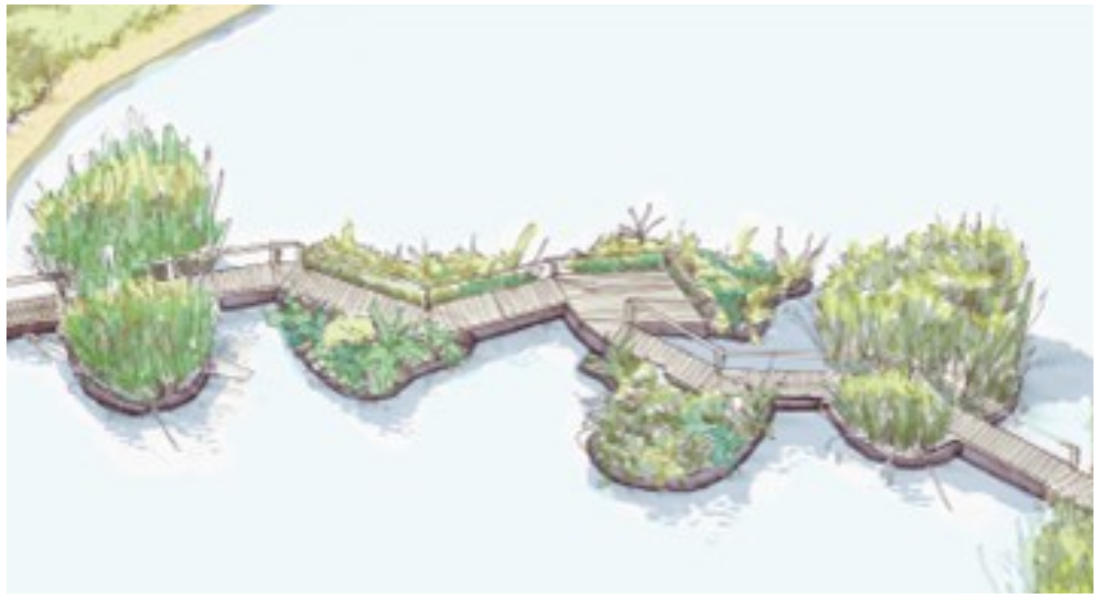
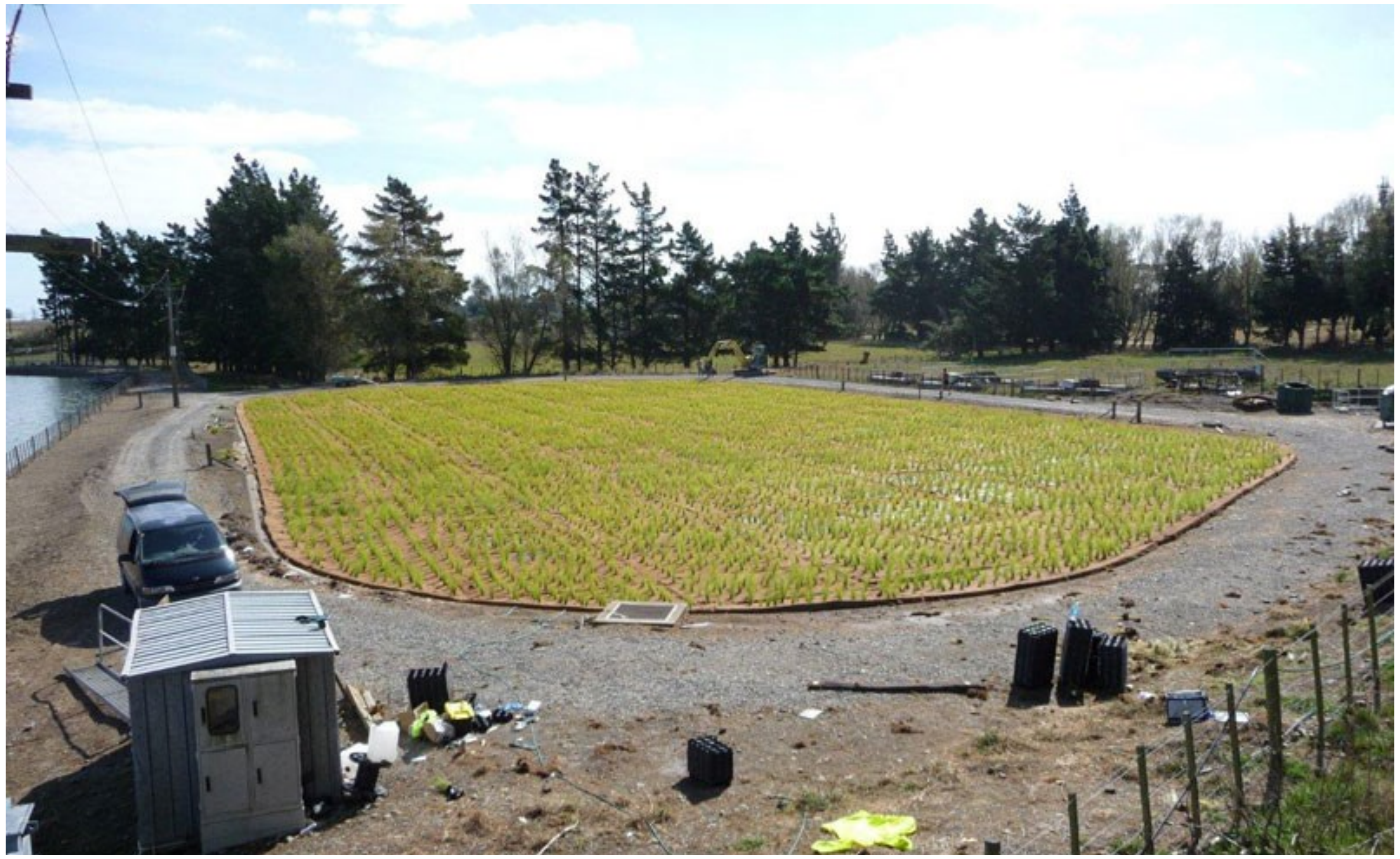


Figure 21: John Todd Ecological Design Living Walkway - *Projects from John Todd Ecological Design are often aesthetically pleasing and LEED certified*

This allows the AFIs to act not only as a treatment method, but as an innovative way to attract attention to sustainability. In a Chinese study, spinach was used as an emergent macrophyte to remove both nitrogen and phosphorus as well as providing a food source (Zhang et al., 2014). Spinach plants themselves uptake phosphorus while microorganisms grow on the roots of the plant and consume nitrogen. This provides a unique opportunity to use the treatment system as either a food or income source (Kerepeczki et al., 2011).

Nonetheless, there are still uncertainties about their design, cost, and reliability. Until now, many case studies and implementations have been done on a small test scale. Stephen Lyon et al. (2009, p. 2) claim that there is “little or no design basis available for sizing a floating treatment wetland system.” The use of CWs for agricultural effluent is still relatively new, which accounts for the limited knowledge on the subject (Kerepeczki et al., 2011). Another problem that has been observed in nearly all studies of CWs and AFIs is that removal rates of nutrients, metals, and pesticides are highly variable due to changes in plant temperature (Zhao et al., 2012). At higher temperatures, biochemical reactions happen faster while the opposite is true at low temperatures.



In a New Zealand implementation, there was no statistical difference in contaminant levels during winter months between a control group and a CW (Borne et al., 2013). Finally, upfront cost may be a prohibiting factor in some projects. The cost to purchase an AFI from a commercial company can be rather expensive depending on the size of the project. From BioHaven®, a 100 square foot AFI would cost around $3,000 (Garbs, [2013]). This cost to build an AFI is rather inexpensive as it can be constructed with PVC piping, metal pipes, and natural materials. Due to these variations, cost is an uncertainty as it is highly dependent on the budget and skill of those running the project.

Figure 23: Floating Island in New Zealand - *A project in Marton, NZ saw highly successful results*

Aesthetic and Ecological Enhancement

Another advantage of AFIs is that they have the potential to be aesthetically pleasing or to provide an area for animal habitat. In 2011, Walt Disney World featured floating islands at the 16th annual EPCOT International Flower and Garden Festival in Orlando, Florida. The attraction became so popular that in 2014 the festival included over 210 islands (Indiana Public Media, 2014).

Figure 24: EPCOT International Flower & Garden Festival - *Floating islands can be used for purely aesthetic purposes*

In New York City, a local initiative was started to clean up the Gowanus Canal (Gardner, 2015). With the help of local citizens, the company Balmori constructed an AFI that helped to not only clean up the canal but also provided a nice aesthetic habitat for bees and local birds. The island was built out of metal culvert pipes, plastic bottles, and a layered structure of biomass material including materials such as bamboo, water hyacinth rope, and coconut matting. The island is home to more than 30 plant species, which provides a beautiful piece of natural art in the middle of a highly polluted superfund site. This island also looks to desalinate and recycle water from the canal to water some of the plants.

Figure 25: Floating Island in Gowanus Canal, NYC - *Islands can be multipurpose: providing water treatment as well as habitat and aesthetics*

Floating islands have also been implemented with the purpose to increase animal populations in an area and to improve breeding rates. One such project was implemented in Sheepy Lake in California as part of the Caspian Tern Management Project (Floating Island International, 2010). This island was built to provide a breeding ground for the Caspian terns of the area as their populations were struggling. This floating island was covered with a gravely mixture of crushed stone, pumice, and a rhyolite mix to provide suitable nesting grounds for the terns. Attractive wetland plants such as bulrush, red-twigged dogwood, and sand willows were planted along the edge of the island for wind protection. This project has been incredibly successful in bringing bird species back to an area and/or introducing new species. Other projects, like those completed by John Todd Ecological Design, have also seen success in returning amphibians and turtles to aquatic habitats by cleaning up the body of water (John Todd Ecological Design, [2007]). A floating island implementation in Woods Hole, MA by John Todd saw very positive results in treatment of a canal contaminated with petroleum products. The AFI was able to reduce petroleum hydrocarbons by up to 90% which allowed the aquatic wildlife to return to the canal.

Figure 26: Caspian Tern (top) & Floating Island Caspian Tern Habitat (bottom) - *Floating islands have been used to reinvigorate animal populations*

Figure 27: Floating Islands in Lake Kasumigaura, Japan - *Floating islands can serve multiple purposes*

There are also successful cases of projects whose main purpose is to provide aesthetics and habitat at the same time. Near the Tsuchiura Port on Lake Kasumigaura, Japan, a floating island was constructed in order to create a habitat for insects, spiders, and aquatic species via a reef constructed below the island. The island also looked to provide a piece of beauty in contrast to the otherwise bleak port as pictured below (Nakamura et al., 1997). This installation is a series of small floating islands of approximately 20 square meters that are constructed in and around the port. They increased fish and prawn species as well as the biodiversity in and around the island (Nakamura et al., 2015).

Predominantly, floating islands have been extremely successful in reinvigorating animal populations and providing natural beauty in areas that are otherwise lacking. In recent years, Antonis Petras, the Technical Works and Environment Director, alongside two students from Arizona State University, developed a Trail Master Plan for AFS. This plan outlines various trails that will be constructed in order to make the campus more interconnected and accessible. It involves revamping the area surrounding the lagoon to allow for visitors to easily walk around the site and enjoy the scenery.

Figure 28: Excerpt from AFS Trail Master Plan - *This excerpt from the trail plan shows the future of the earthen lagoon area*

Approach

How does the community perceive its campus?

The first step in understanding how the community sees the campus was to gain perspective from the largest demographic of the school, its students. In order to do so, the team employed photovoice, a research method in which community members are given the opportunity to express their experiences through photographs (Wang & Burris, 1997). To recruit student participants, the team held a cookie social with Perrotis College students at which the project was introduced to the community. Nine students signed up, however only two students participated. Each student took five to seven photos of their favorite places on campus, and then discussed their significance with the team. Discussion points included what the location was, why it was important to them, and how it gives them a sense of place on campus. This method delivered highly descriptive information regarding each location, which was then analyzed through categorical aggregation*. Through this process we began to understand what contributes to students feeling a sense of belonging and place on the campus. Both participants are highly active members of the AFS community and, therefore, their opinions may not be representative of the larger student community.

Figure 29: Photovoice Submission 1 - *AFS rooftop garden*

“I’m not a designer or something, but the house really describes the president and his wife.”
- Student

Figure 30: Photovoice Submission 2 - *AFS President’s House*

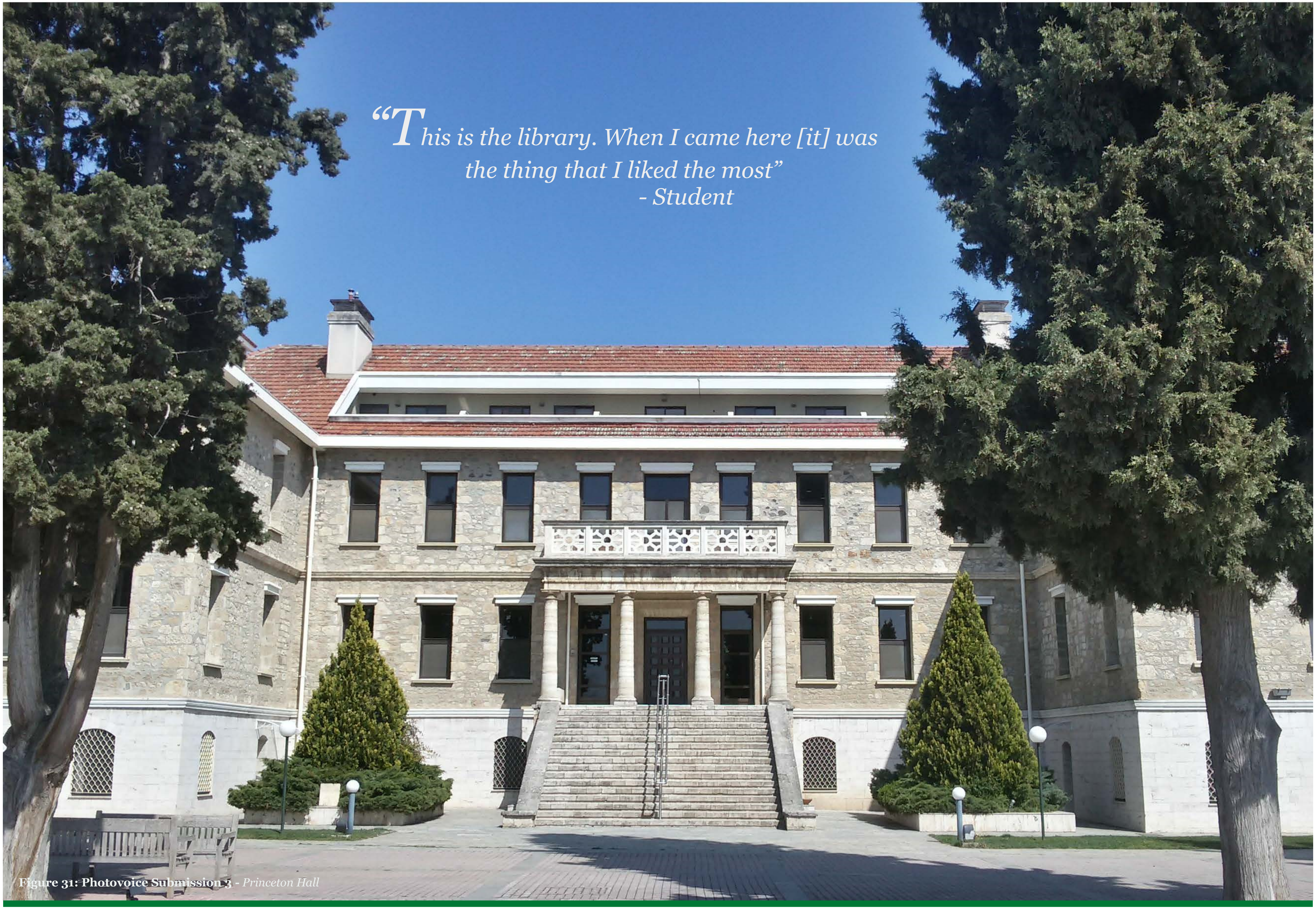


Figure 31: Photovoice Submission 3 - *Princeton Hall*

Figure 32: Design Charrette Setup

Next, a broader subset of the AFS community was asked to give their ideas. The team conducted multiple design charrettes -- one with Perrotis College students and smaller charrettes with faculty. Six students signed up to participate, four attended. Three faculty participated as well, individually and in a group of two. Each charrette began with a brief explanation of the project and its goals, as well as an outline of the expectations for the charrette. Participants were also shown pictures of floating island projects that were obtained from case studies and company websites. Each person was provided with a writing utensil and a piece of paper with a rectangle on it representing the earthen lagoon. Participants were then asked to draw or write their ideas via step-by-step instruction from the team. After the design phase was completed, the team led a discussion to gather their thoughts and gain a deeper insight into their particular design choices. Participants were asked to list or draw additional thoughts and ideas that arose during the conversation on the reverse side of the paper. Through analysis of the drawings and discussion transcriptions, all charrettes provided community preferences for designs, layouts, and landscaping.

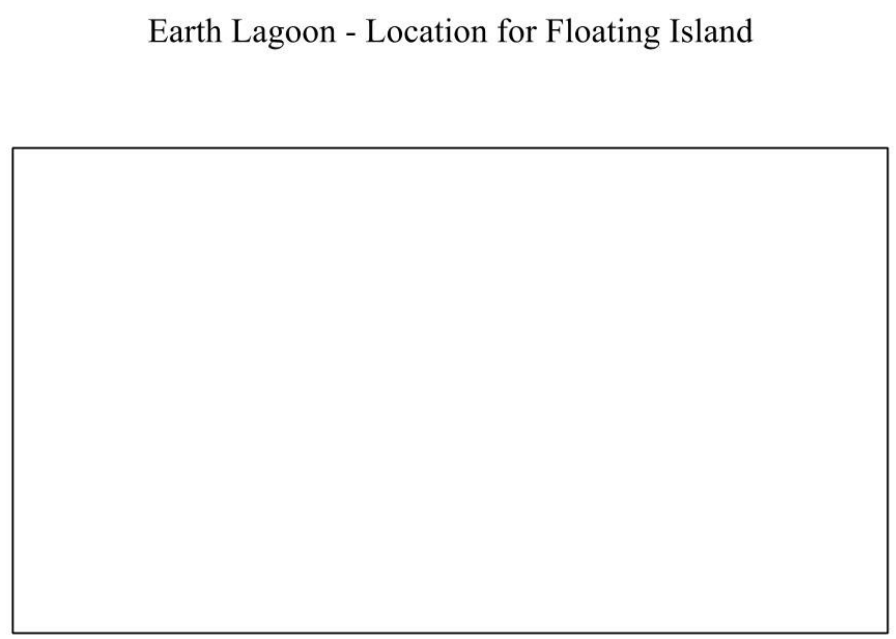


Figure 33: Design Charrette Drawing Template - *The team provided participants with an outline of the lagoon area*

What are the current operations of the water treatment system?

Figure 34: First Site Visit

Visits to the earthen lagoon were conducted on three different occasions on various days of the week and at different times. Two formal visits took place on 16 March and 5 April and another informal visit on 22 March 2016. Refer to Appendix C for site visit data. Although visiting the lagoon was a necessary and informative step of the process, site characteristics vary from day to day as well as seasonally. Time to explore the area was limited to the seven-week project duration during the months of March and April The collected data is therefore only representative of specific conditions during a short time frame, not a full year at AFS.

Table 2: Site Visit Weather Data

Day	Time of Day	Temperature (°C)	Humidity	Wind Speed (km/h)	Wind Direction	Sunlight Intensity (W/m^2)
16-Mar-16	12:00-12:30	8.7	77%	8.6	W	158.7
22-Mar-16	13:00-13:30	19.8	59%	5.7	SW	727.4
5-Apr-16	16:00-16:30	23.2	58%	13.4	SSW	575.8

In parallel, horticulturists, landscapers, and project sponsors were interviewed. They were asked questions regarding how maintenance is conducted on the campus: Who does this work? What areas of campus do they focus on? What maintenance is done specifically at the lagoon? And how could this evolve once a floating island is implemented? This provided information on logistics surrounding the potential operation and maintenance of the floating island.

Figure 35: AFS Landscape & Horticulture Equipment -

Examples of various equipment used for maintenance and work at AFS

How can a floating island improve the water quality in the earthen lagoon?

AFS water quality data provided a wide base of knowledge for the project. School records gave insight to water quality at the lagoon and the government regulations AFS operates under. Using this information, the team determined what parameters needed to be improved and the best techniques to accomplish this.

Figure 37: Earthen Lagoon Flowers - *A variety of wild flowers currently grow around the earthen lagoon*

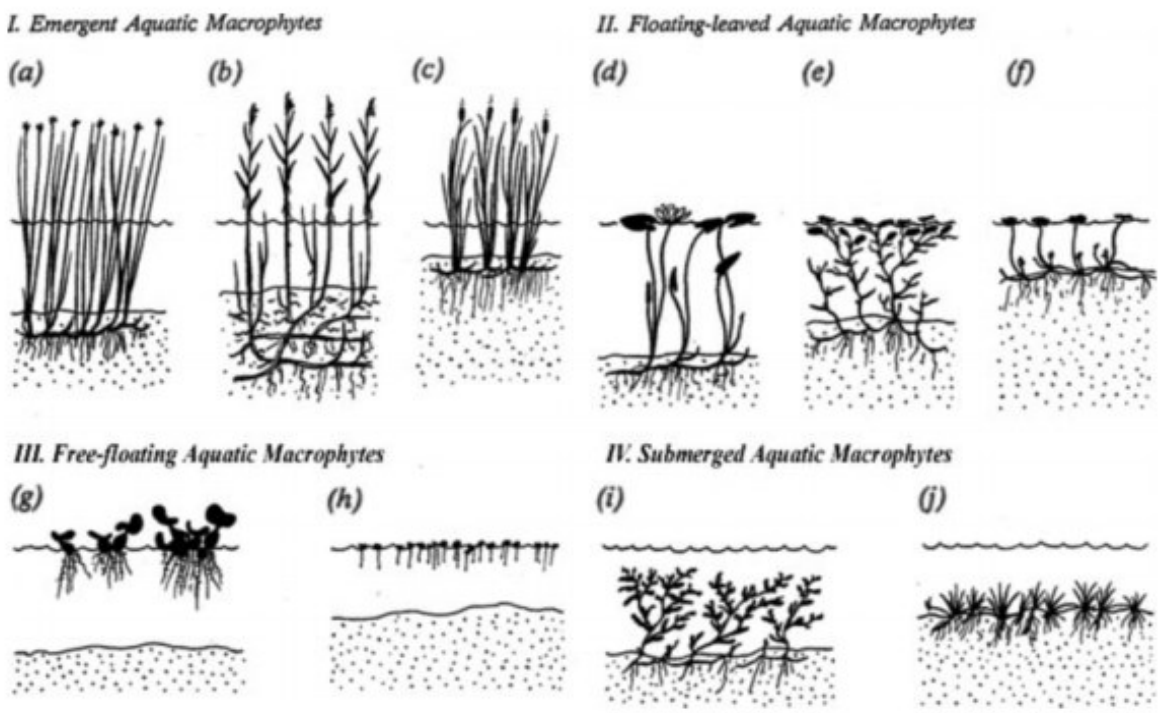


Figure 36: Macrophyte Categorization - *Plants used for floating islands can be sorted into four categories*

Plants to include on the floating island were determined using scholarly case studies and online research. Each plant was categorized as either an agricultural product, a colorful plant, or a reed/grass. The team marked yes or no on attributes that were non-negotiable for use on a floating island. The plants had to be able to grow on a raft structure in an oversaturated environment, native to Greece, non-toxic, non-invasive, and effective at treating treat water. Non-toxic plants are safe to handle; safe for humans to expose to the skin, mouth, eyes, and nose; and safe for wildlife to consume. For those that fulfilled all these requirement, a qualitative look at each plant's resiliency and maintenance needs informed the final selection. Plants that are more resilient are more likely to survive throughout a variety of weather conditions, therefore they will be more effective in cleaning the water on a year-round basis. Simultaneously, plants that require less maintenance are preferable since interviews exposed that the school has limited resources to tend to them.

What are the educational opportunities provided by a floating island?

Figure 38: AFS Primary School Students - *AFS students have a heavily STEM based education, including emergent plant observation*

Additional interviews with faculty provided an understanding of how this natural water treatment system could fit into the curriculum. Individual, semi-structured interviews were conducted with faculty members from all levels of schooling offered at AFS. Specifically, the principals of the primary school and both high schools, as well as four professors from Perrotis College and the STEM Fellow. Questions explored what topics are being taught to which age groups, how often faculty bring students outside of the classroom for lessons, and how and why they utilize the AFS campus to teach their students.

What other benefits can the floating island provide?

The Trail Master Plan was reviewed to understand what improvements will take place at the lagoon and surrounding area. In addition to reviewing the trail plan, discussions with the project sponsor, Mr. Petras, were held in order to better understand the future plans and resource constraints of these operations.

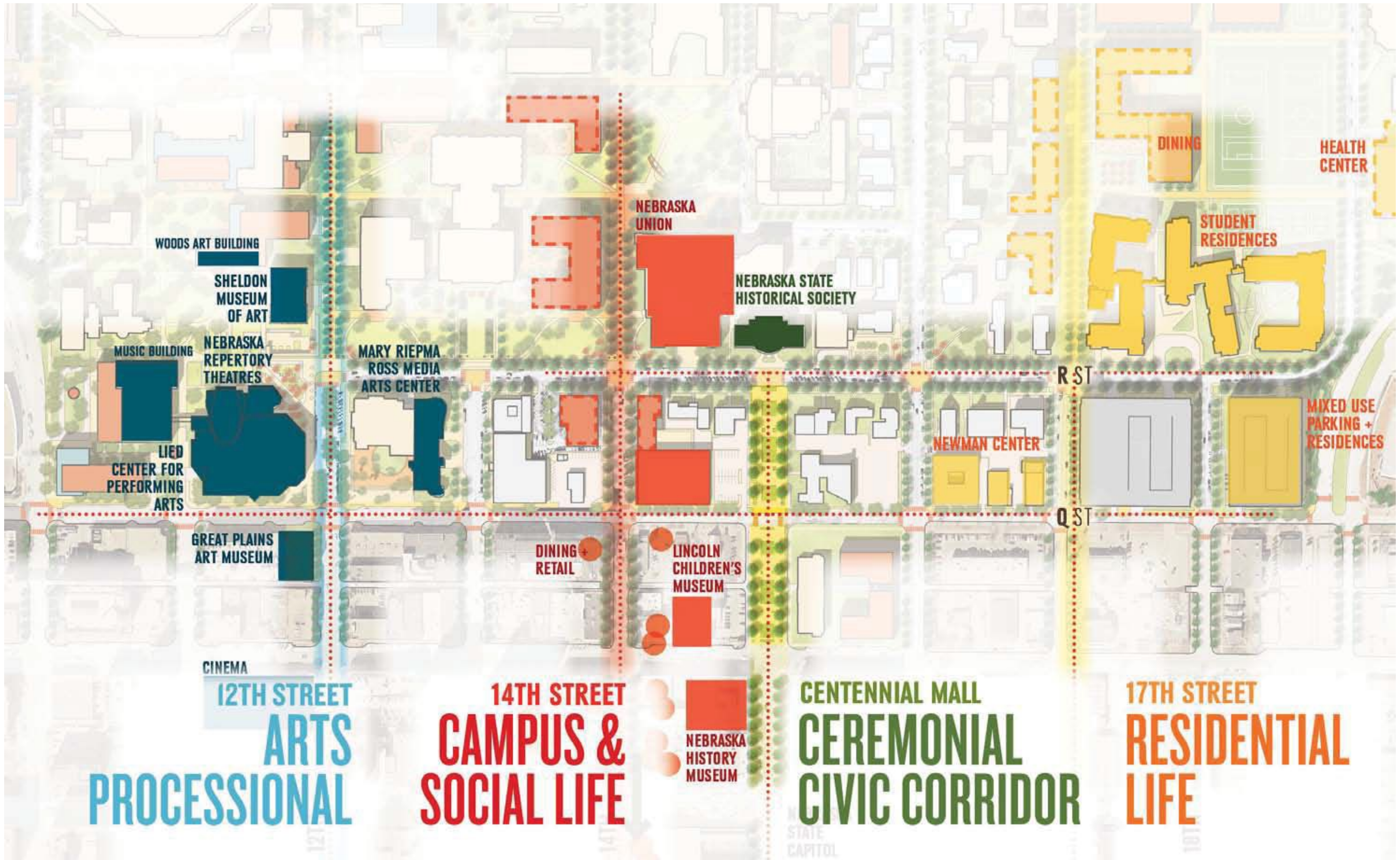


Figure 39: UNL Landscape Master Plan Case Study - *Other campuses master plans were used in the AFS Trail Master Plan as a model*

How can social research be incorporated into a technical design?

During interviews, photovoice, and design charettes, the team recorded participants to keep their identities confidential. Recordings were later transcribed to create physical data. Once the transcripts were completed, they were compiled and coded using a modified version of grounded theory (Bulawa, 2014; Glaser & Strauss, 2016). “Data coding” refers to taking a piece of text and assigning to it a short qualitative description, often one word or phrase, that captures the essence of what the interviewee said. These codes were then sorted into categories to condense the data and identify important topics. These categories encompassed both facts about the school and desires of the community. The latter were separated and further condensed into concrete desires that could be incorporated into the design of a floating island. A frequency distribution was used to weigh desires by counting the number of community members that expressed each of them. The team then considered the feasibility of each through information from both research and interviews.

The team drew technical layouts of the proposed island design in a 3D model using Google SketchUp, AutoCAD Civil 3D, and Revit. The final design attempts to address all of the community desires that are also found to be feasible. Lastly, the team conducted online research to estimate the cost of the design.

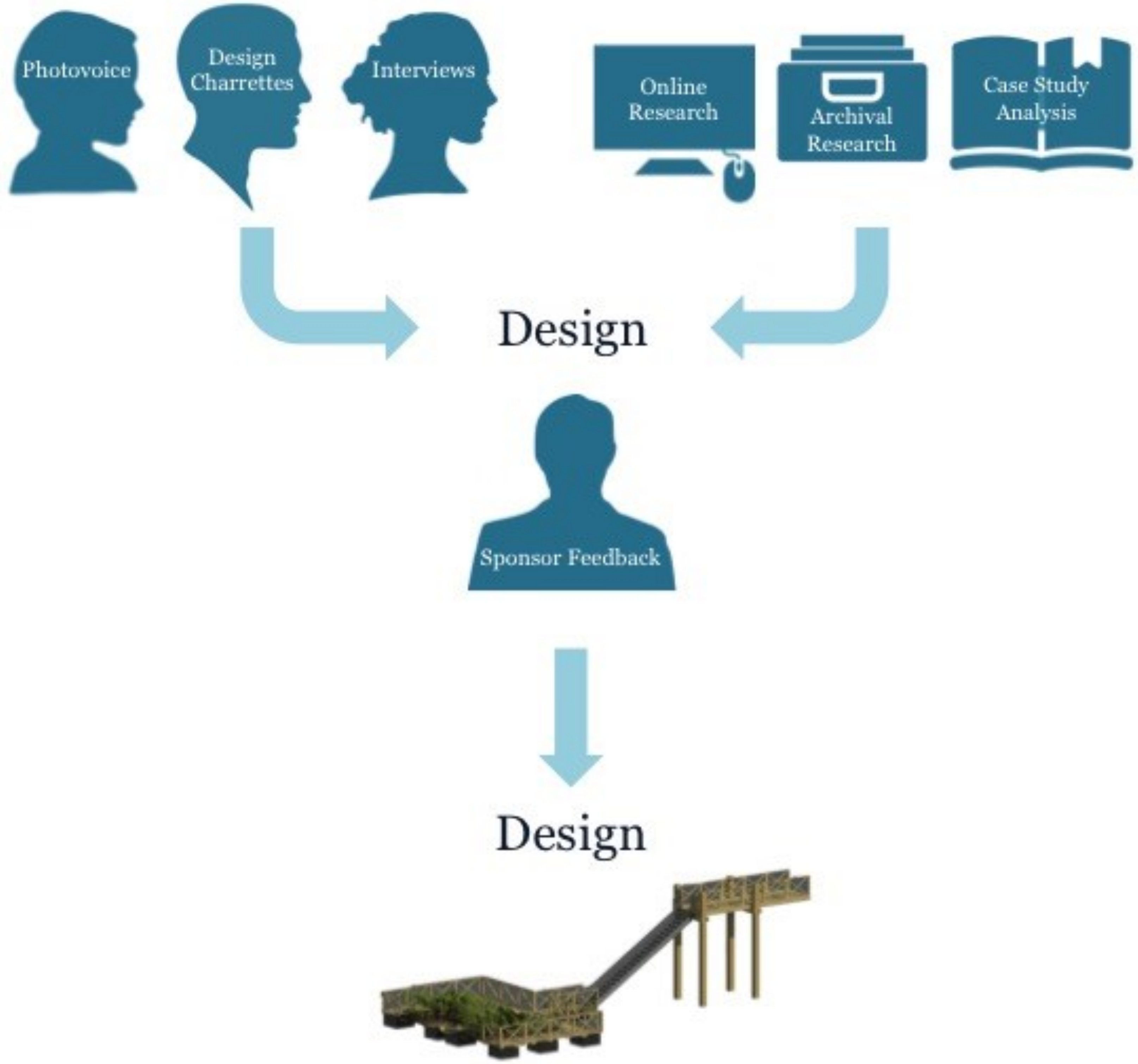
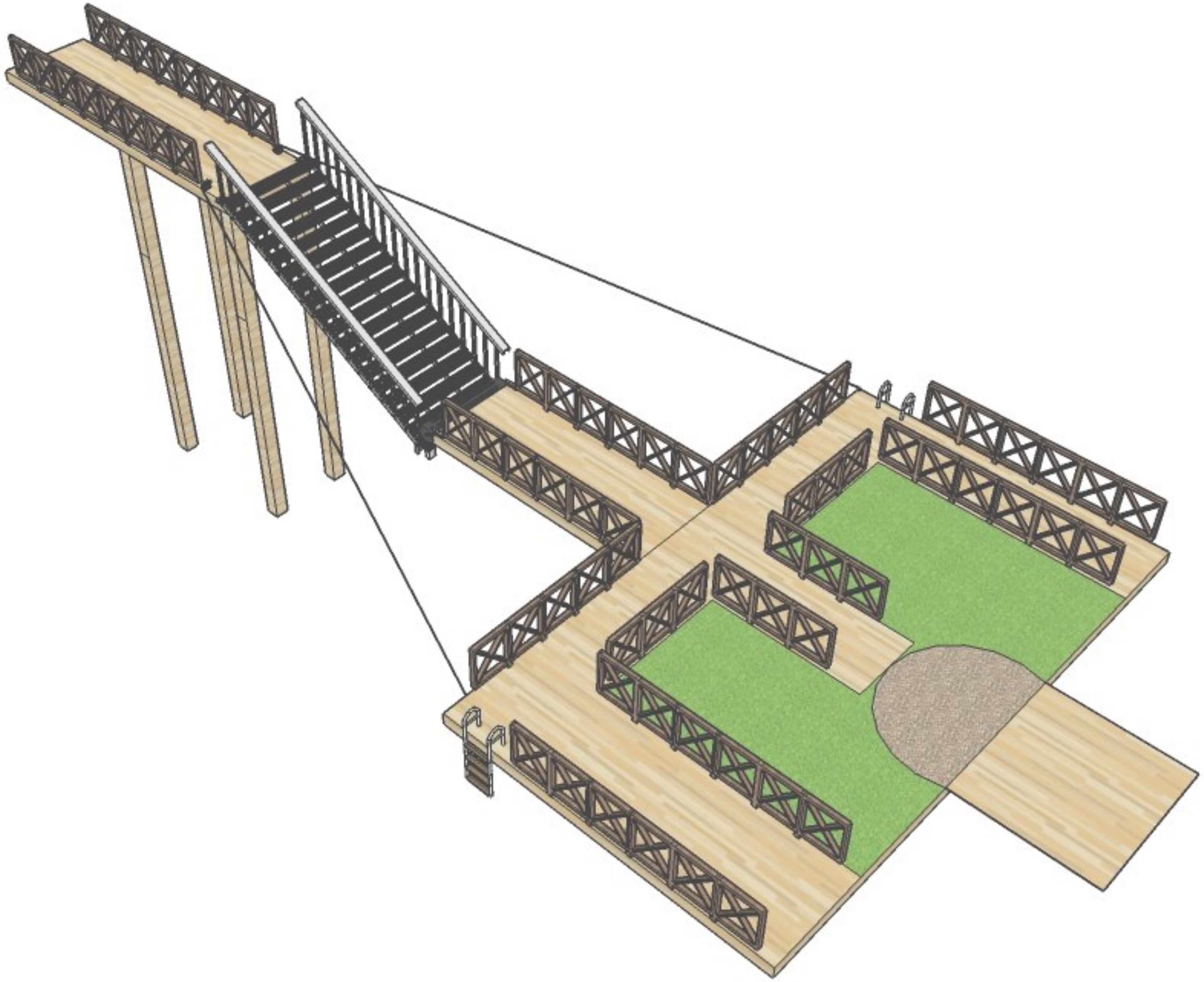


Figure 40: Summary of Methods



Design

The Site

March 16, 2016

The lagoon is located far from the main part of campus, and to reach it, visitors must pass by the school's cow barns and composting station. These can sometimes stink, making a visit unpleasant. The pathway surrounding the lagoon is very porous, and it retained much of the water from heavy rainfall, making the existing pathway quite muddy.

Bordering vegetation creates a barrier to the lagoon. Without signage, it is difficult to establish the correct and safe way to proceed when the path in the western corner diverged. Last, there was no human or vehicular traffic on the site that day.

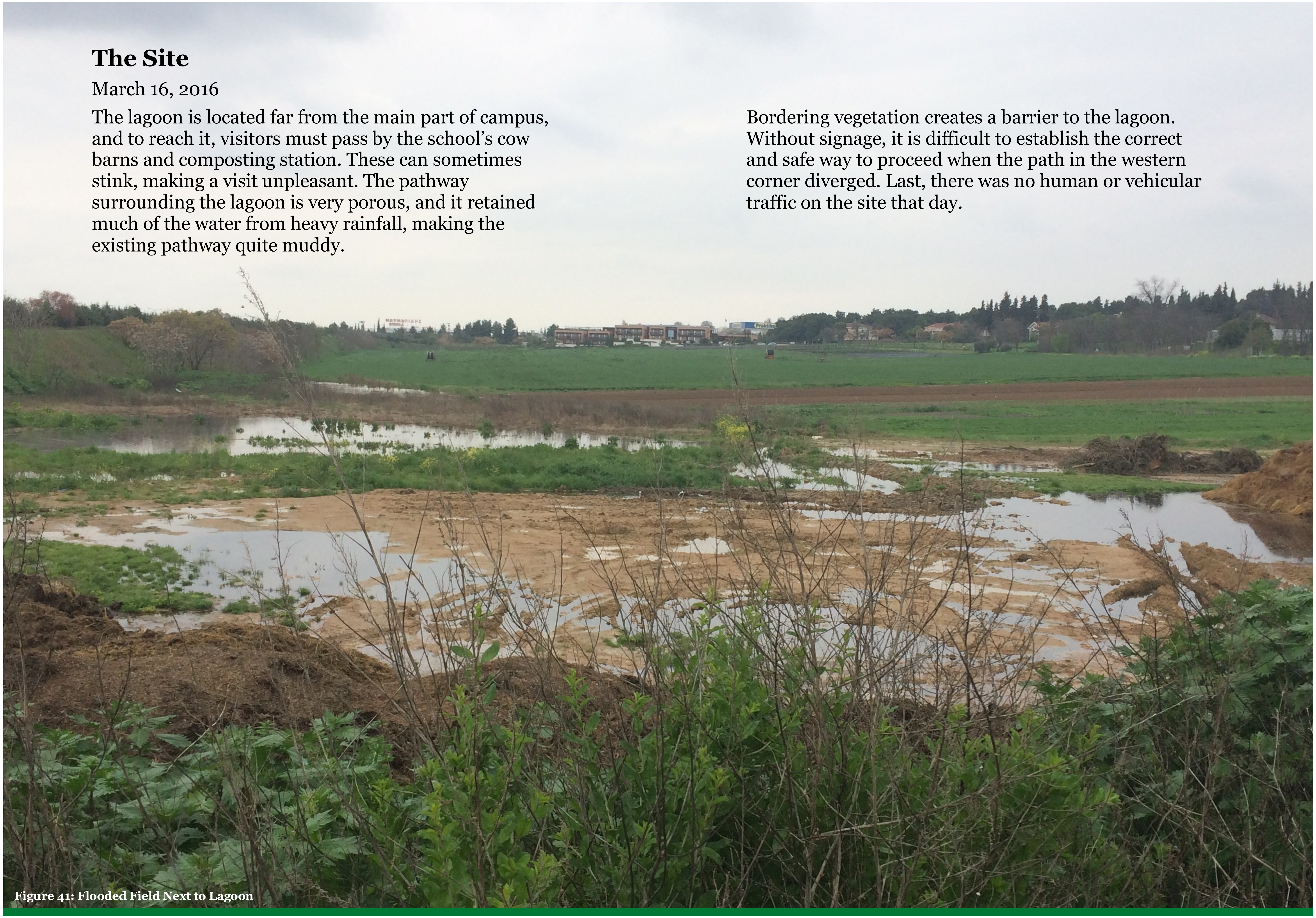


Figure 41: Flooded Field Next to Lagoon

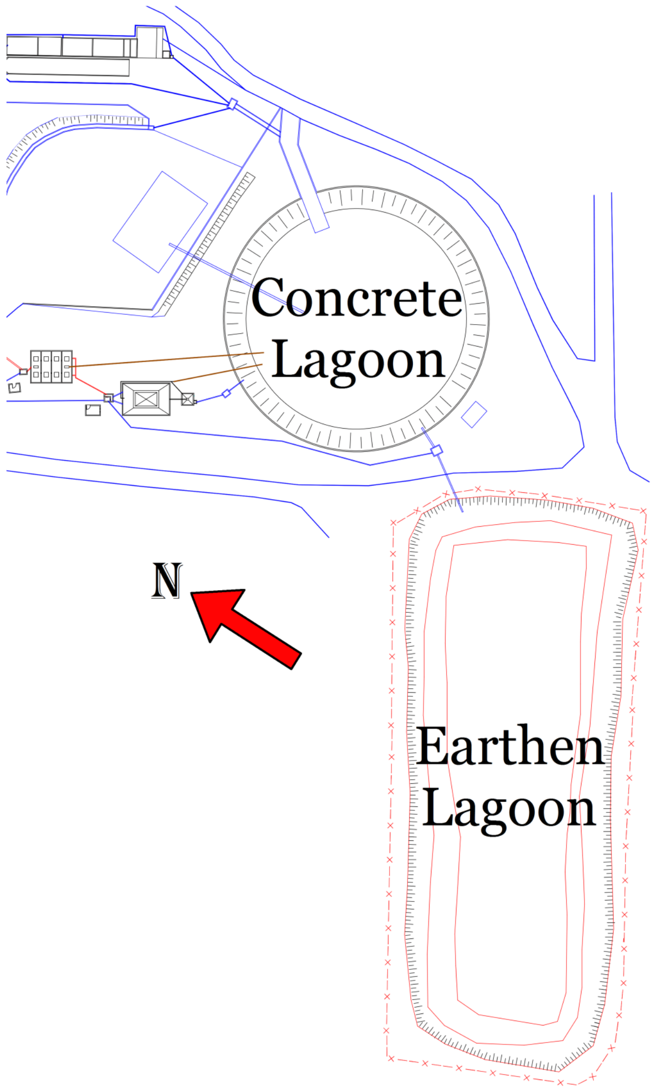


Figure 42 AFS Treatment Lagoons Layout -
The informal visit explained the relationship between the lagoons and the rest of the system

Informal Visit: March 22, 2016

The school's system primarily handles its industrial waste, while domestic waste is sieved on campus and then sent to the municipality for further processing. Project sponsors conveyed that the treatment system as it now stands differs from its original construction, having been altered on an irregular basis. One example was the reed bed system surrounding the concrete lagoon, which was added in two separate phases as money was received from an outside donor. The first implementation was an experiment and its success was the reason the second phase was funded. This financial model informs the budget for the floating island project, which will likely be built in phases and used as an experimental treatment system. If it is successful, additional islands may be constructed.

Figure 43: AFS Wastewater Treatment Plant Tour -
The team observed the many processes that wastewater goes through at AFS

Community Voices

What opportunities does a floating island present?

"For us, it's going to be another area in which we could do great things."
-Interviewee

After talking with teachers, administrators, and Perrotis College students, there were several common desires. After consideration, the final design of the floating island will include the following community ideas: clean the water, student interaction, sustainable reuse, visual appeal, animal habitat, natural design, and color. These components were chosen because they are also feasible based on research and talks with the Technical Works Department.

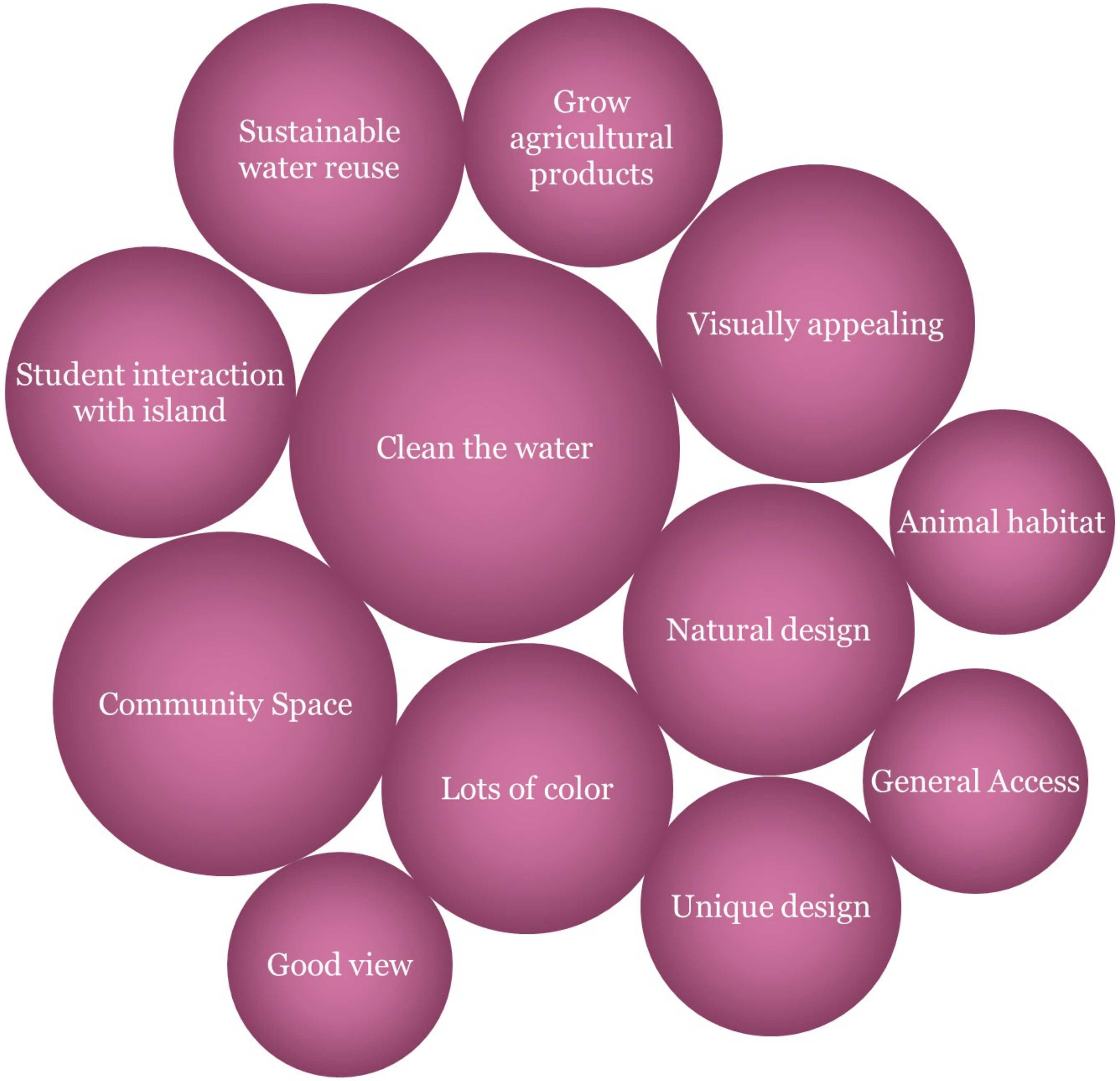


Figure 44: Community Desires Bubble Chart - *Community desires were collected and evaluated by the project team*

Understanding Community Attitudes

Base

Figure 45: Photovoice Submission 4 - *Walkway on campus*

Community members have a strong appreciation for areas that provide a combination of natural and built environments on their campus. Students spend the most time at places that provide a relaxing environment and opportunities for both quiet solitude and community gatherings. Alternatively, faculty view the campus as a place of learning wherein all aspects of the farm are interactive and incorporated into the curriculum. Both students and faculty alike were excited at the concept of having a floating island, and were interested in being involved in the design process and learning more about the technology.

Figure 46: Photovoice Submission 5 - Walkway to secondary school

What do you like about AFS?

"The thing that's good on this campus is the nature"

- Student

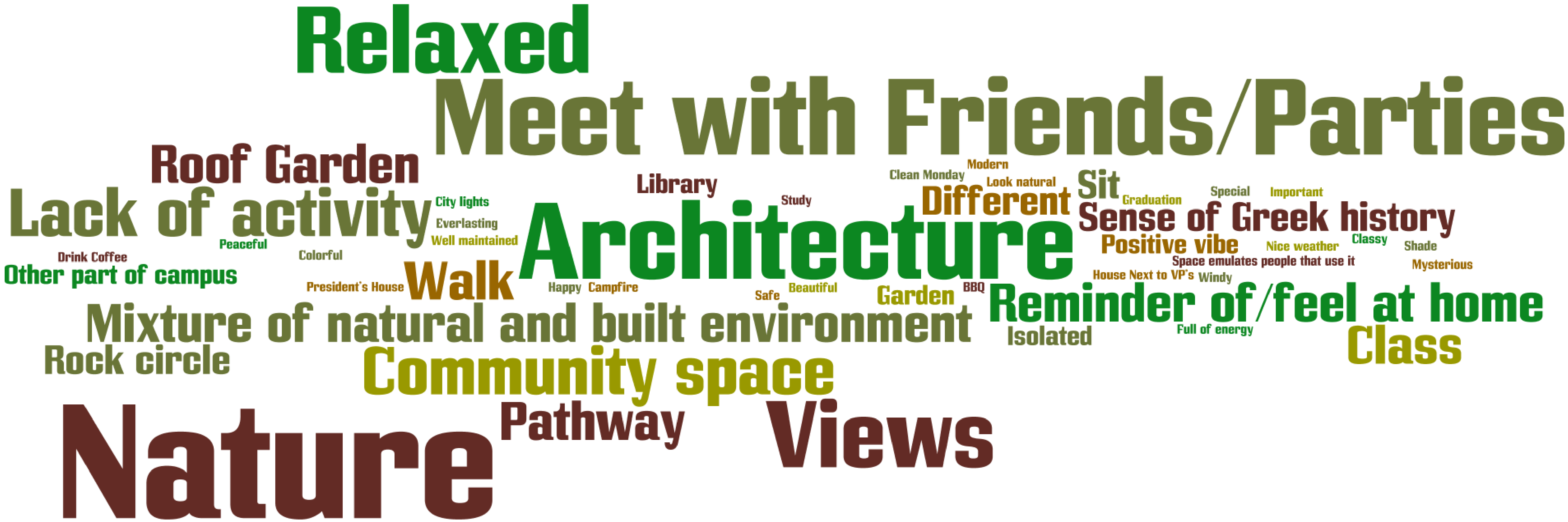
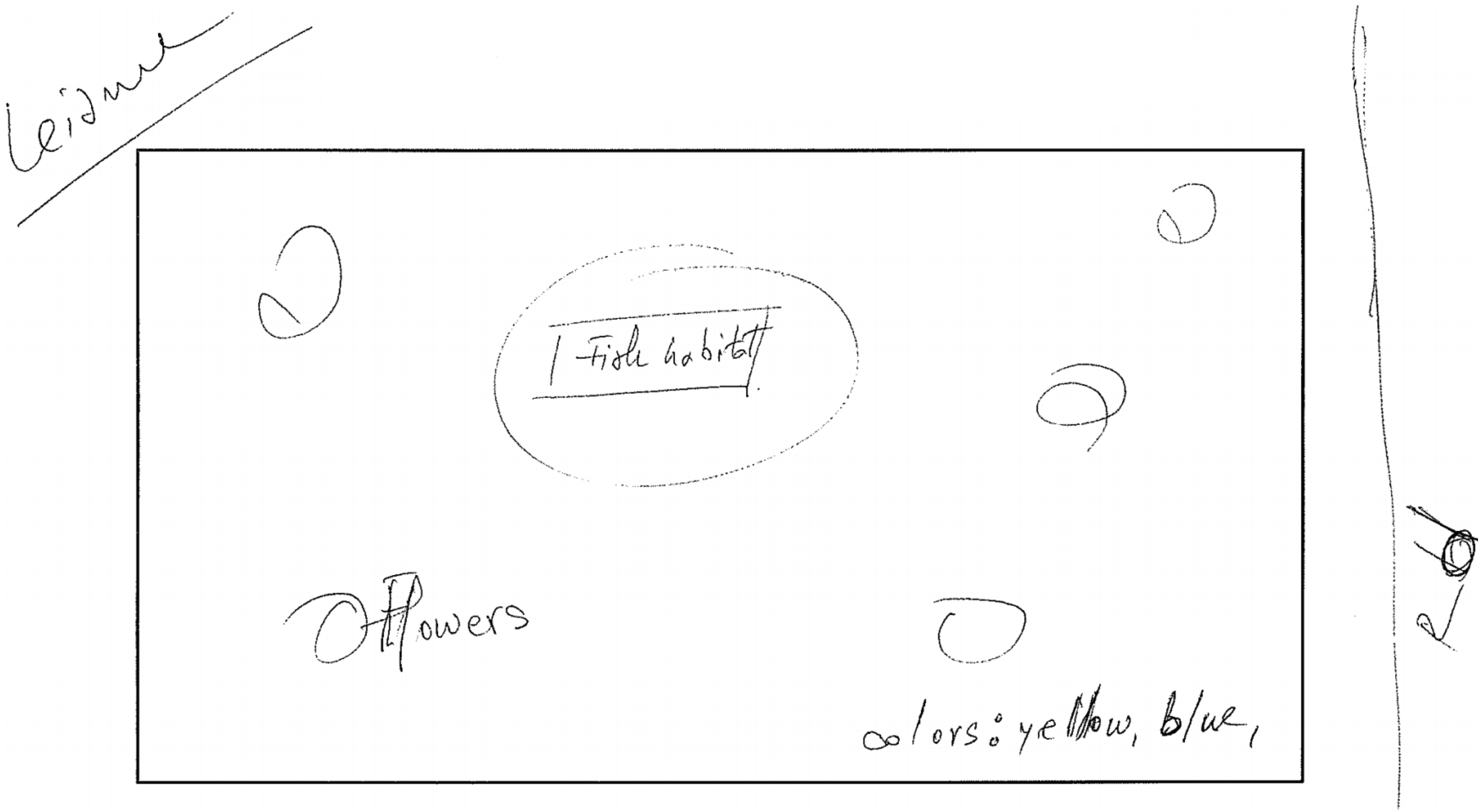


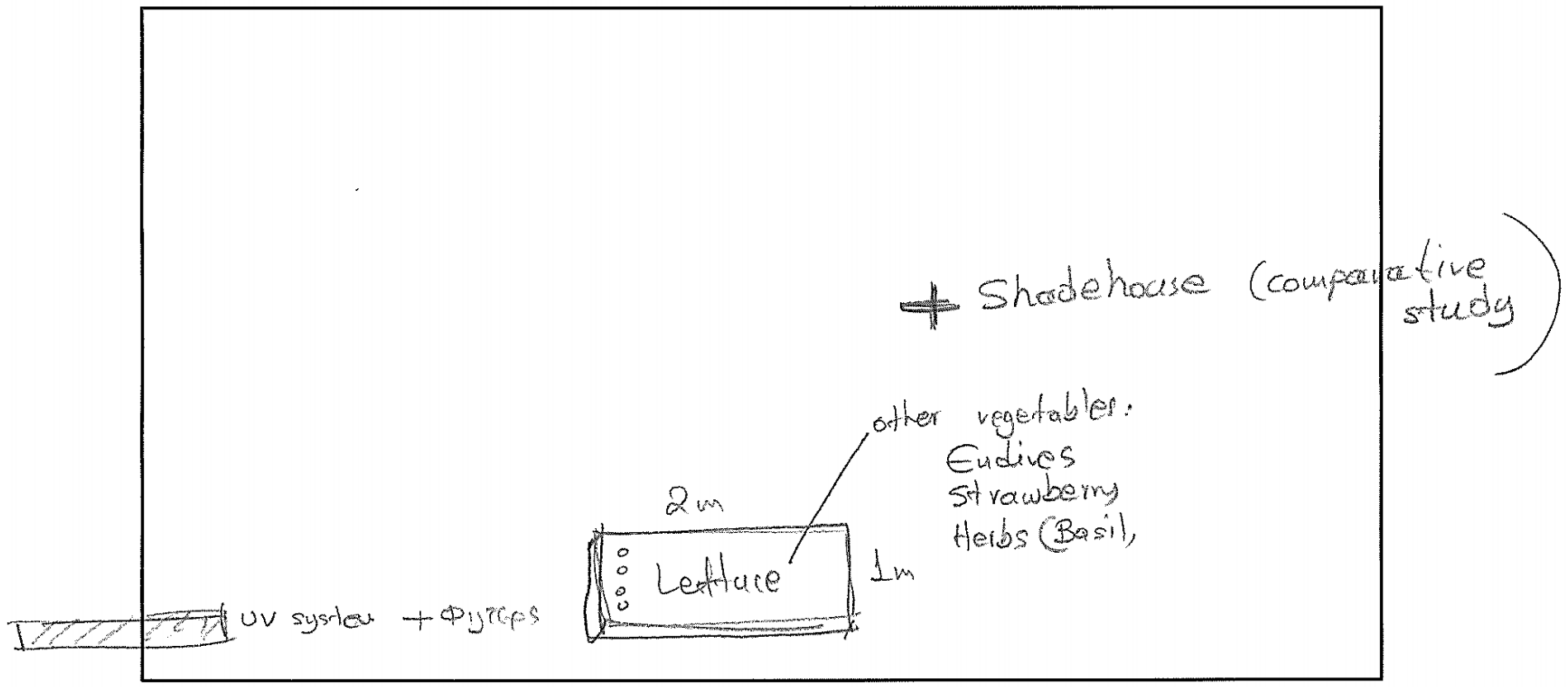
Figure 47: Photovoice Word Cloud - *Many words and terms were used frequently during photovoice sessions and displayed here*

During photovoice sessions, the team learned that students are fond of nature and the environment. It was clear that students enjoy multipurpose spaces that provide the opportunity to relax and spend time alone as well as gather together with friends. Views of the nearby city, the ocean, and beautiful landscapes on campus were also appreciated.

Design Charrette Example Drawings



All design charrette participants expressed a desire for students to be able to interact with the floating island. The ability for the island to clean the water was important to both faculty and students as well, making it clear that this should be a key output of the project. It was observed that students had a desire for a floating island with a unique design, while it was more important to teachers that the floating island could be used for agricultural production. For illustrations from the charrettes, see the next page.



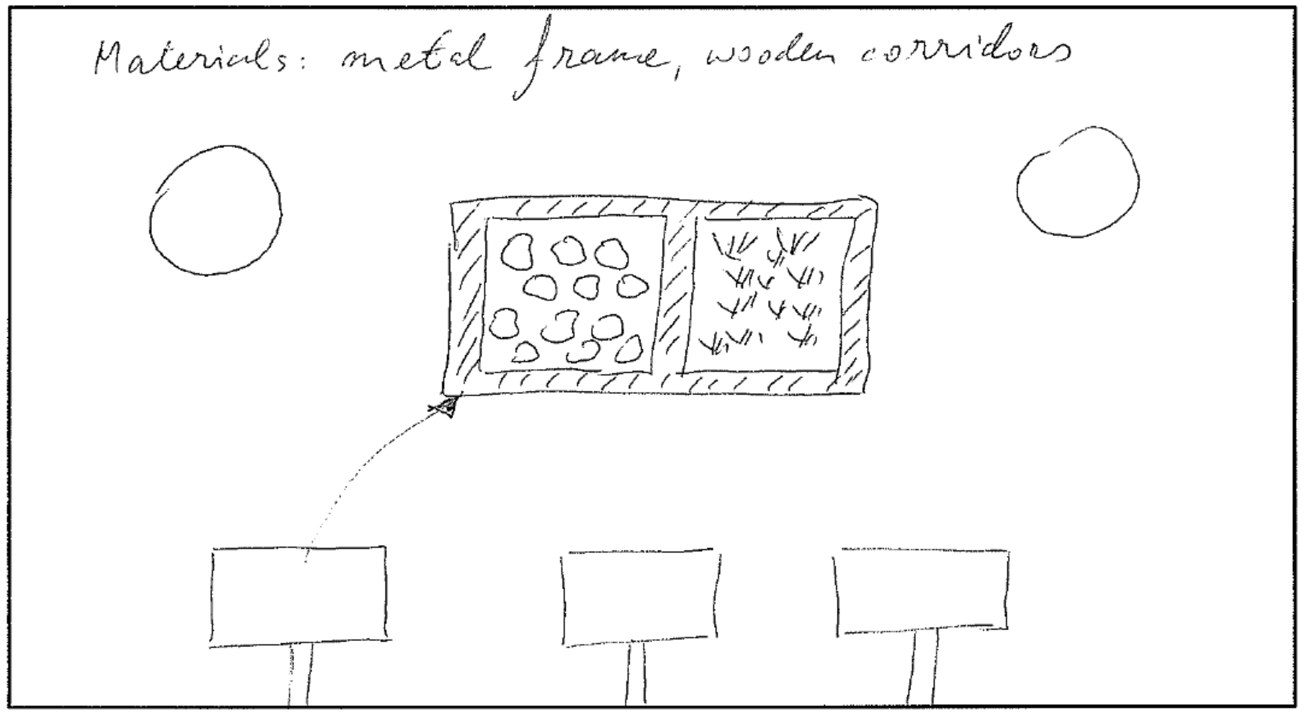
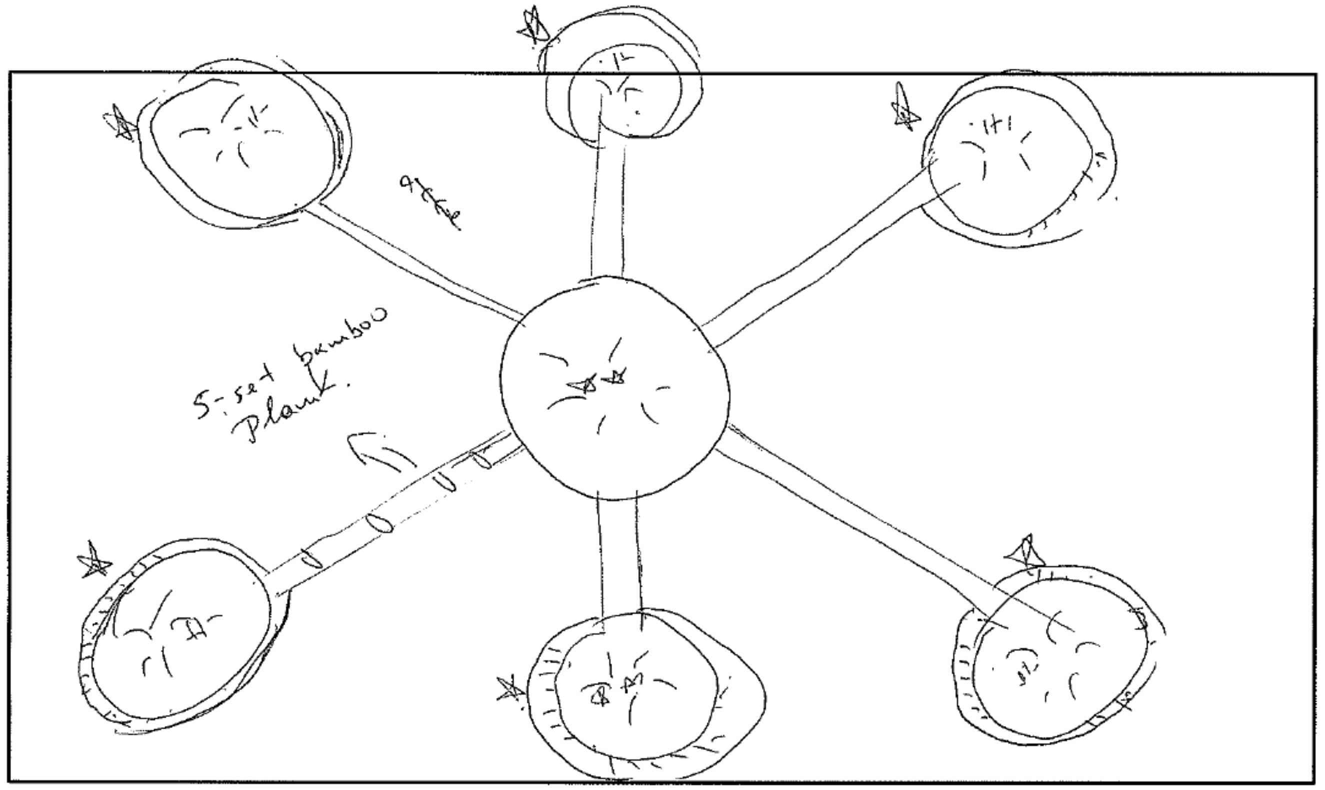
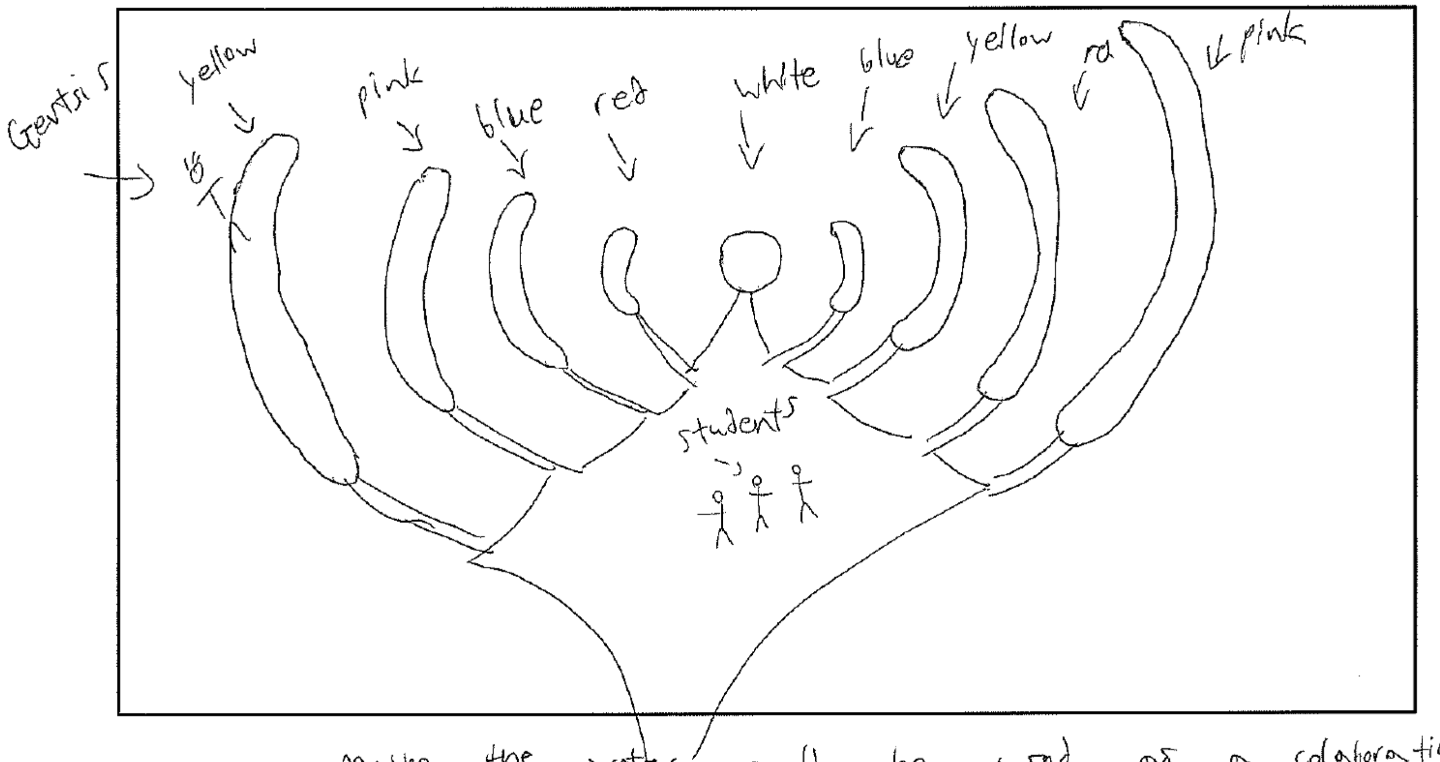


Figure 48: Student & Faculty Design Charrette Drawings - *Students tended to appreciate a very unique design while faculty had expectations for educational use*

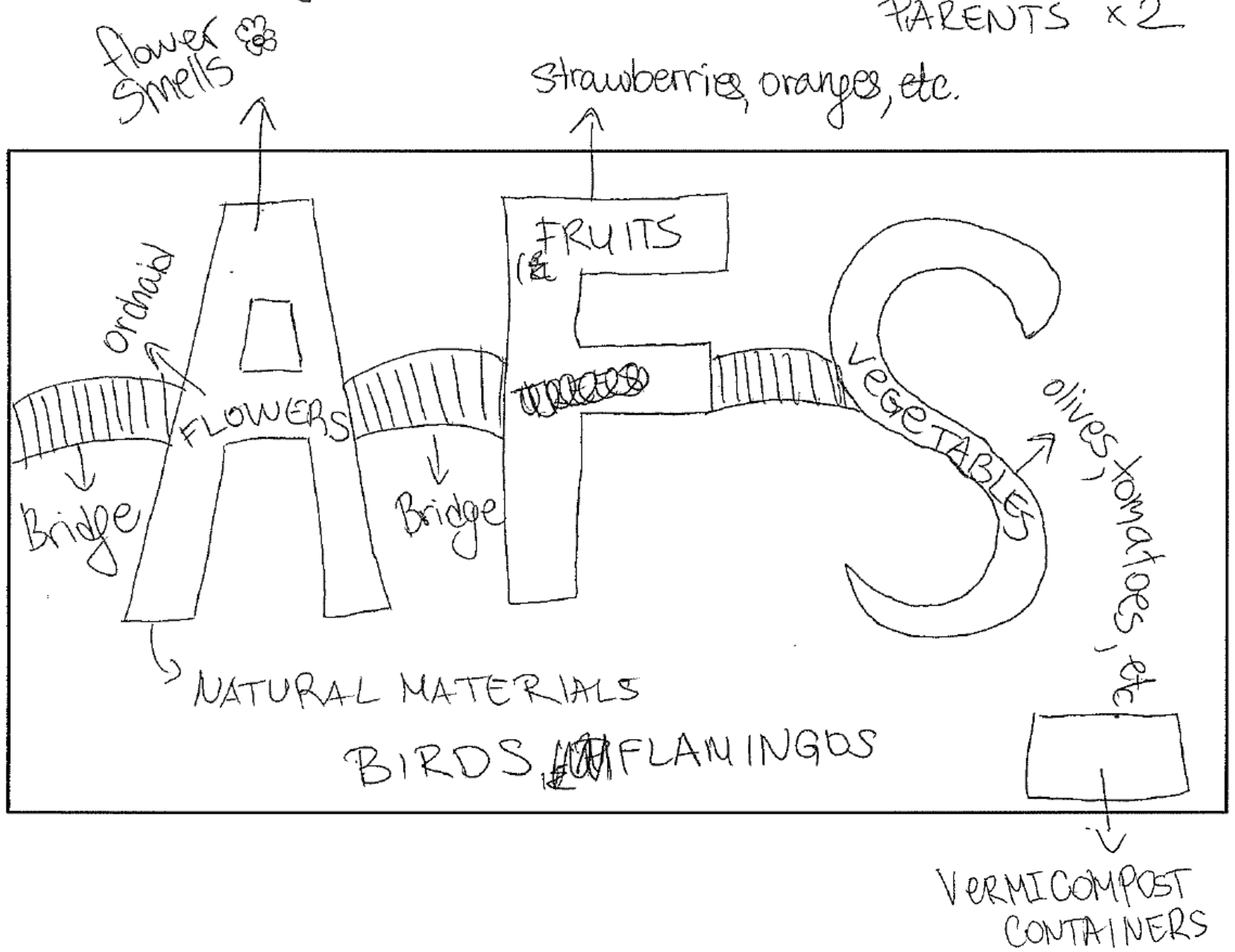


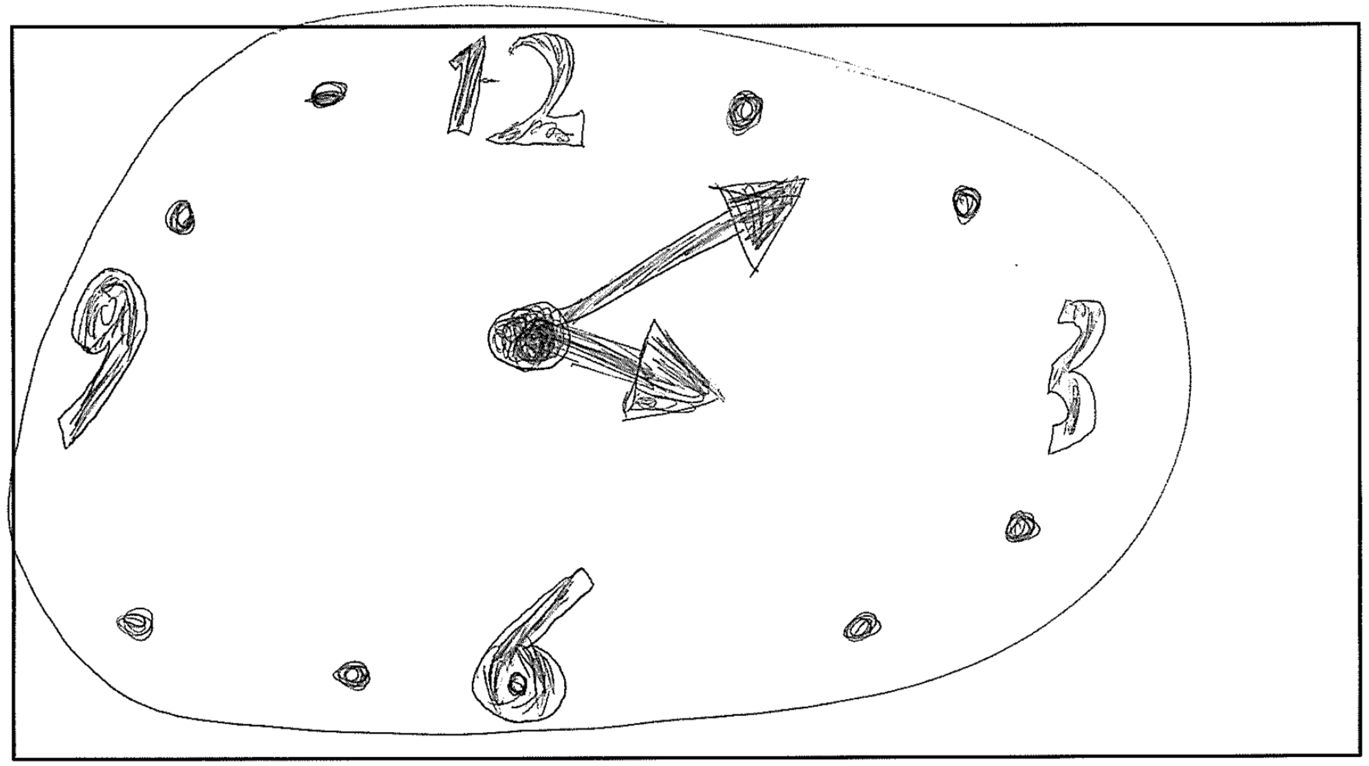
☆ solar energy sensory.
☆☆ beauty. flowers
☆☆☆ flowers smell.
☆☆☆☆ kindergarden

STUDENTS x 3
KIDS x 1
PARENTS x 2



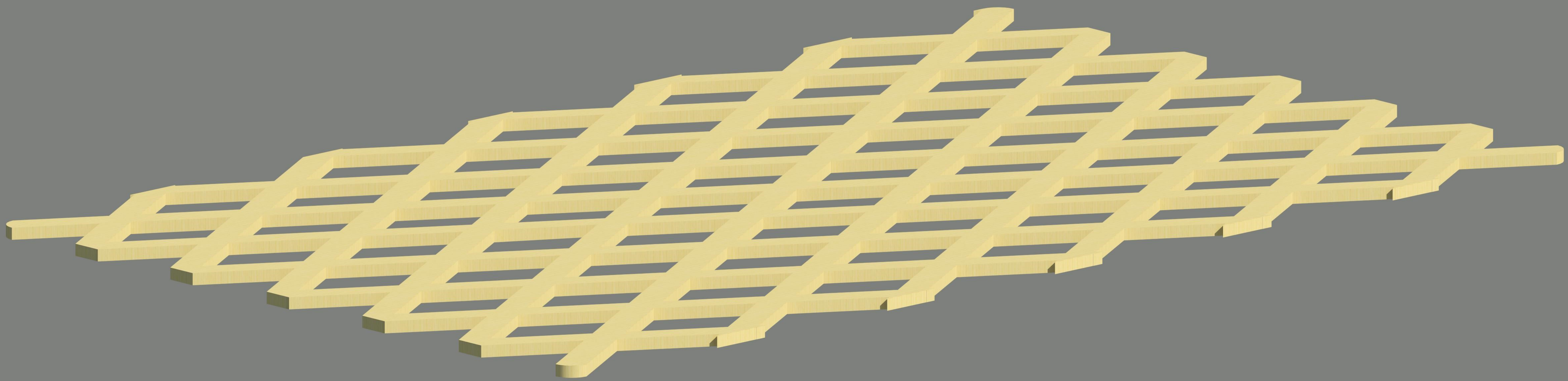
Maybe the water could be used as a colaboration with the team that makes the hydroponic system, or this water will be actually "clean" but at the same time container a lot of organic matter. So, you can try making a "free hydroponics system".





Base

To incorporate nature into our design, we chose to construct the island out of natural materials. The base will be a wooden lattice that has open space for plant roots to grow down into the water. This base will be 6.5 meters wide by 11 meters long. Typically in projects that take place near the water, pressure treated wood is used. However, this can leech chemicals into the water that could potentially harm the plants. Instead, the lattice will be made of chestnut wood, the sap of which naturally protects it from water degradation.



Supporting Current Operations

Structure

AFS has improved its wastewater system over the past decade with sustainable technologies such as reed beds, but few campus residents are aware of these changes. There is an interest in accessing the lagoon and the floating island, but many are skeptical that the area can be improved to their standards. Currently it is very difficult to safely and easily access the lagoon area, and possibilities for development are limited due to budgetary constraints within departments.

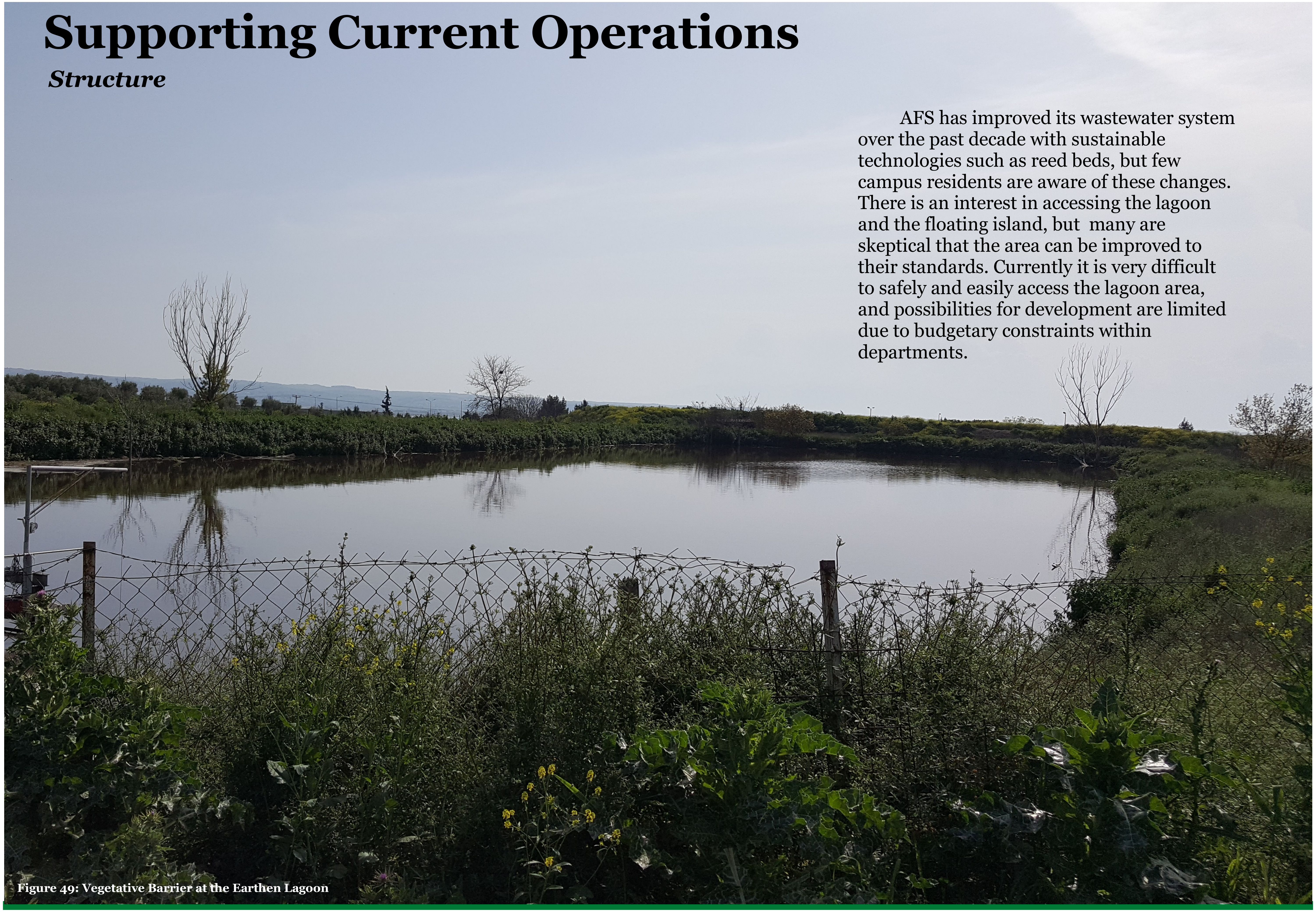


Figure 49: Vegetative Barrier at the Earthen Lagoon

Figure 50: Maintenance at Earthen Lagoon - *Between the first and second formal site visits, significant landscaping was completed around the lagoon*

During hotter weather, the soil near the lagoon took on clay like characteristics; it was dry and cracking, but completely solid to walk on. Sections of the surrounding vegetation had been cut back, and it was now possible to easily walk around the perimeter of the lagoon. No unpleasant odors were present, except for brief moments during times of high wind on the northwest side. This was attributed to adjacent farm operations, not the lagoon itself. It was clear that the odor is not always as pungent as community members perceive it to be. Hypotheses were confirmed from prior site observation that campus-lagoon interaction is minimal.

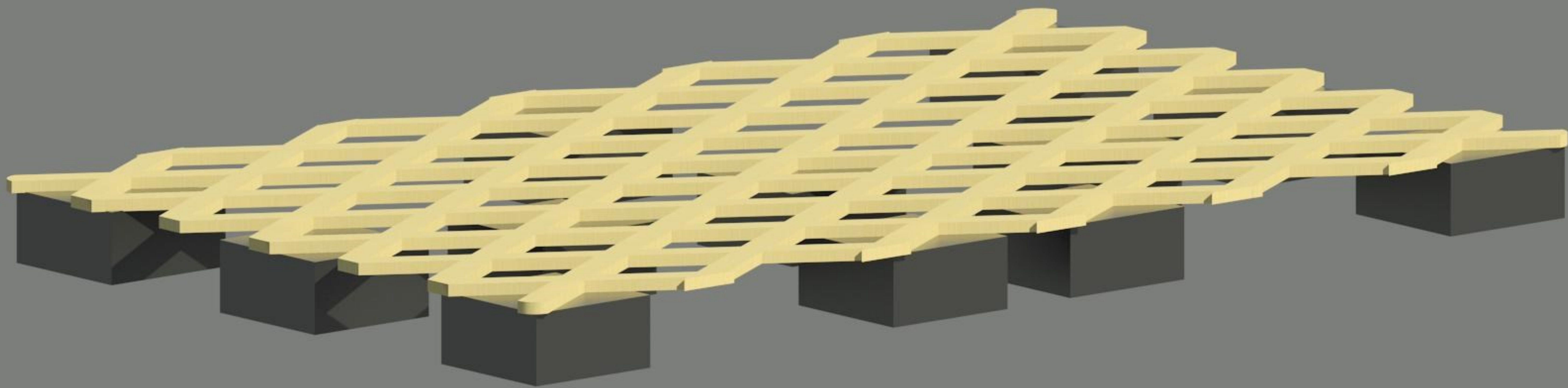
A significant amount of grounds work is completed by the Perrotis College students and then undertaken by temporary employees during the summer months. While the AFS has created and maintained a visually appealing campus, the lagoon is a hidden and undervalued space in its current its current state. Limited resources are available for landscaping. However, the team was ensured that if a floating island were to be installed it would make the lagoon a higher priority and it would be maintained. To allow for upkeep of the floating island, the team determined that extra flotation would be necessary.

"So it looks like this area has fallen down the list as a priority"

- Staff member

Structure

Large polyurethane floaters will provide flotation for the island. Twelve of these are capable of holding the anticipated weight of all the island's components as well as four people plus maintenance equipment at one time. Floaters were placed strategically in areas that we expect will need to hold the most weight. This allows for potential human interaction and maintenance to take place, keeping the island functional and beautiful.



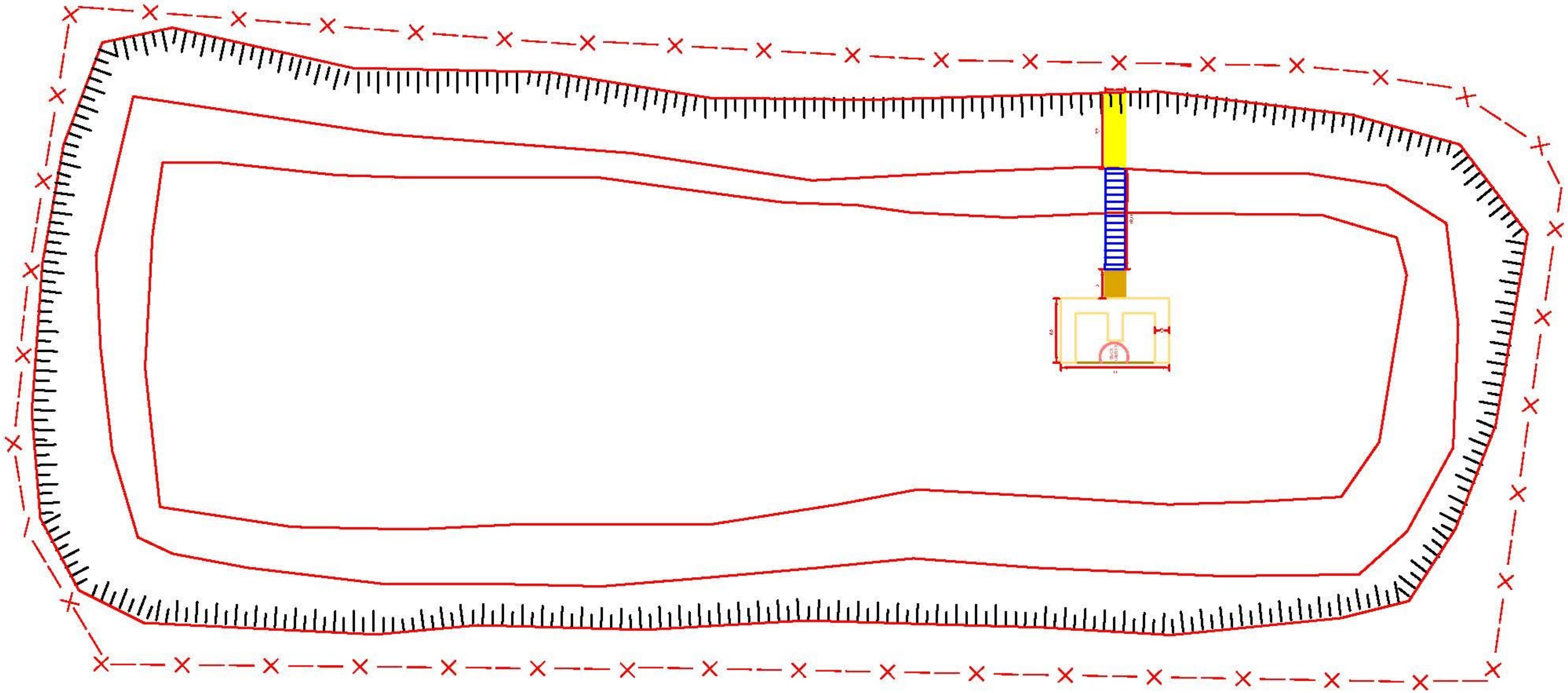


Figure 51: Floating Island Layout

The floating island will be located in the southern end of the earthen lagoon. It will reach halfway across to the middle of the lagoon, which is the deepest part. In an ideal world, the island would be very large, to treat the most water. However, the island could not be too big for a few reasons. A large island would be very expensive to construct and maintain. In addition, as the lagoon is drained for irrigation in the summer, the water level drops by several meters. Since there are concrete and metal structures at the bottom of the lagoon the island could be damaged if it were much larger or placed in a different spot. Therefore, the base will be 6.5 meters wide by 11 meters long. A rectangular shape was chosen for ease of construction.

Improving Water Quality

Plants

To determine the plants needed for the island, the team analyzed water quality data for both the concrete and earthen lagoons from June 2013 to August 2015.

Table 3: AFS Discharge Data

Water Quality Parameters	**Permit Discharge Level**	**Average Discharge Level From January 2013 to August 2015**	**Relative Standard Deviation**
E. Coli†	200 (CFU/100mL)	90626.5217	210.01 %
BOD_5	1200 (mg/L)	143.50	123.58 %
SS	4500 (mg/L)	212.25	176.50 %
Electric Conductivity†	0.7-3.0 (dS/m)	2.754348	15.86 %
Cl-	140-350 (mg/L)	331.96	70.68 %
pH	6.5-8.5	7.87	0.2743 %
Nitrogen†	92 (mg/L)	66.3913	53.44 %
Phosphorus†	20 (mg/L)	14.43913	73.72 %

†Only measured from May-September

Figure 52: Sludge in the Concrete Lagoon

Raw data showed both regulated discharge values as set by permits from the Greek government and measured discharge values from the past five years. Averages and relative standard deviations were calculated for each parameter, which show large inconsistencies in discharge levels through the years. However, not all parameters were measured for the entirety of the five year period, so a full data set was only available for the two year period described in the table.

There were striking disparities in many parameters, such as suspended solids, which had a relative standard deviation of over 176%. In 2014, suspended solids in the concrete lagoon peaked to a level of 3741 mg/L, while the measured level in the earthen lagoon decreased to 211 mg/L. This shows significant water quality improvement in the earthen lagoon despite inconsistent discharge levels.

Other parameters of high concern included BOD and E. Coli, which had relative standard deviations of over 100% as well. For these parameters, a distinct spike was observed in the concrete lagoon, but had little effect on the quality of the earthen lagoon. This is another indication that the earthen lagoon serves to improve water quality after passing through the concrete lagoon.

Levels of nitrogen and phosphorus are a main concern to the Technical Works and Environment Department due to their effect on plants when they remain in water used for irrigation. Although these inconsistencies were smaller than those of the pollutants previously described, they are not insignificant. Research shows these will be the easiest to address via floating island pollutant uptake.

Figure 53: Solids in the Earthen Lagoon

Water Quality Parameter Graphs

Figure 54: Suspended Solids in the Lagoons

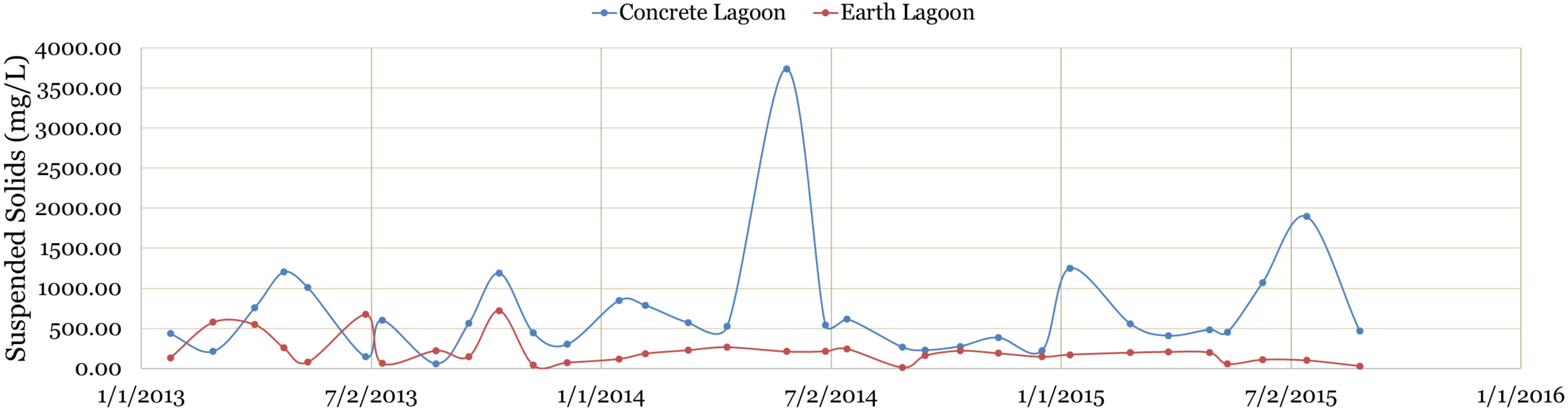
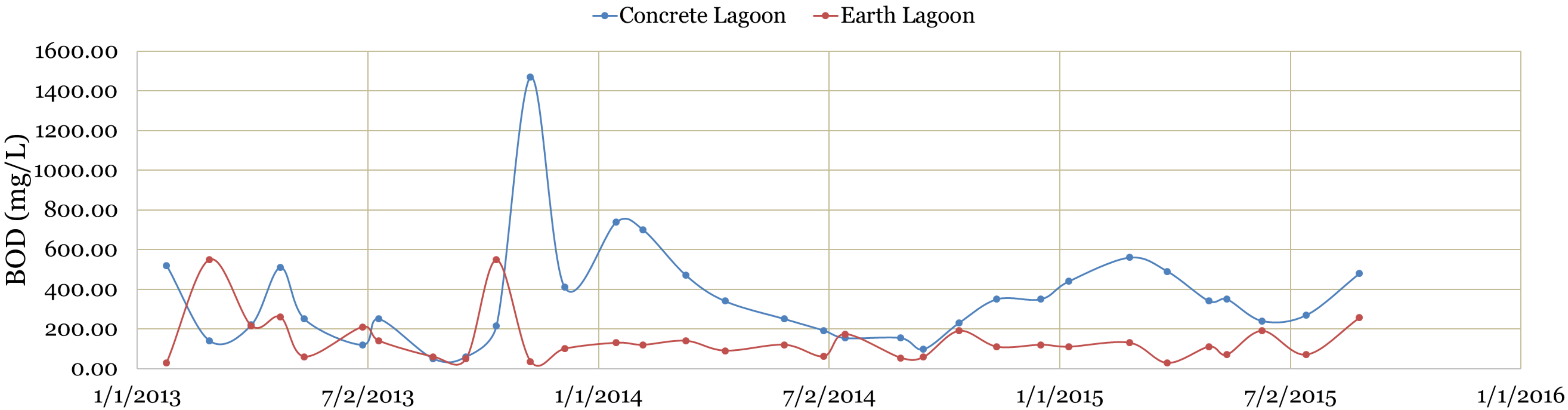


Figure 55: BOD in the Lagoons



Under current regulations, the school is required to renew its water treatment system permit every five to eight years. AFS would like to build a third lagoon, but there is insufficient space and money to construct one. For this reason, a floating island could be an important alternative. Project sponsors outlined plans to move most of the campus livestock to the school's secondary farm, which would improve both smells in the lagoon area and the water quality as there would be less inflow from livestock waste. However, they also expressed that even though these plans are in place, there is no timeline for their implementation and this project should proceed according to current data.

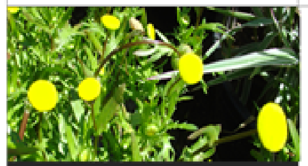
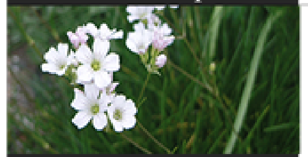
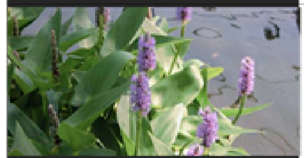
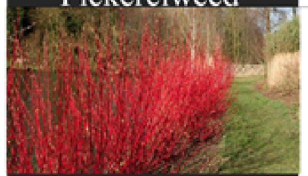
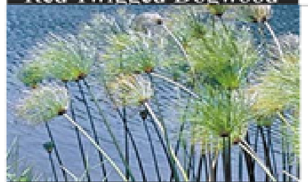
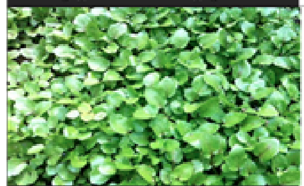
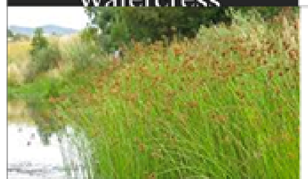
After review of over twenty scholarly case studies, there was overwhelming evidence that a floating island could improve a variety of water quality parameters. For more information, refer to the context section. Many of these studies also suggested plants that could be seeded onto a floating island. The team compiled these into a comprehensive plant checklist, as seen on the following page.

Figure 56: Effluent Contributors - *Waste enters the earthen lagoon from a variety of sources*

"Our final target is to make it like water from a well ... so we are reaching to find ways to make this seventy percent 100%."

-Antonis Petras, AFS Director of Technical Works and Environment

Table 4: Plant Checklist

Plant	Cleans Water (Yes/No)	Works on Raft (Yes/No)	Local (Yes/No)	Non-Invasive (Yes/No)	Non-Toxic (Yes/No)	Resiliency	Maintenance Required
 Cotula Coronpifolia	Yes	Yes	Yes	Yes	Yes, but stinky	Short-lived, mostly just summer	Low maintenance
 Gypsophila sp.	Yes	Yes	Yes	Invasive in the Great Lakes region, not Europe	Yes, but considered noxious in the US	Lives year-round, in dry or wet environments	Prevent overgrowth with seasonal trimming
 Juncus Effusus	Yes	Yes	Yes	Yes	Yes	Prefers PH below 6, die in winter and regrow in the spring	Cut twice a year
 Pickerelweed	Yes	Yes	Yes	Yes	Yes	Symbiosis with ducks and aquatic life	Prevent overgrowth with monthly dividing
 Red Twigged Dogwood	Yes	Yes	Yes	Yes	Yes	Grows all year	Yearly trimming
 Cyperus Papyrus	Yes	Yes	Yes	Yes	Yes	Grows year-round, though much dies in the winter	Prune at the end of fall and throughout winter
 Watercress	Yes	Yes	Yes	Yes	Yes	Frost resistent, grows most of the year	Harvest when desired, weekly-monthly
 Schoenoplectus Tabernaemontani	Yes	Yes	Yes	Yes	Yes	Prefers salt water but grows in fresh water as well, tolerates winter, can be aggressive	Divide seasonally

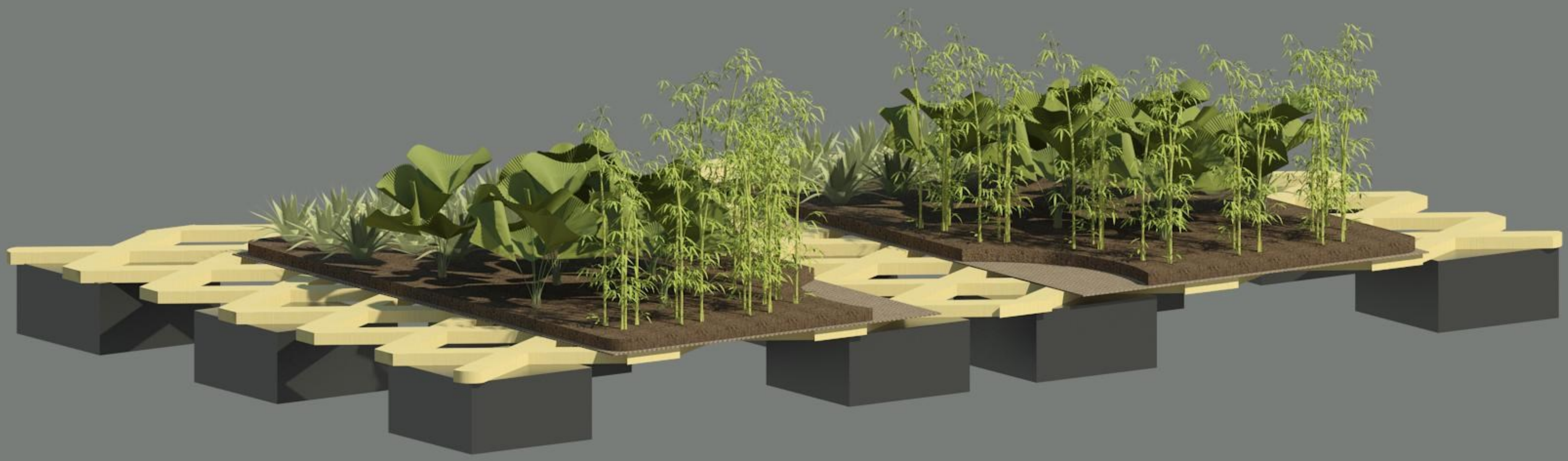
Final Plant Selection

Eight plants were chosen to be included on the island. All of these plants have been proven to remove pollutants from the water and received 'yes's in all categories on the checklist. Color was a community desire that could be incorporated into this area of the design. Fortunately, plants such as pickerelweed and cotula have colorful flowers. Pickerelweed, for example, was used on a floating island in China that removed nitrogen, phosphorus, and heavy metals. All of these attractive plants meet both needs, so no compromises had to be made. Reeds will be placed furthest from the entrance of the island, while flowers and other more beautiful plants will be featured towards the front. This drawing shows how we plan to incorporate each of the plant species we have chosen. The red zone is the tallest; reeds and grasses. The blue zone will feature medium height plants, and the purple zone will be composed of the shortest plants, such as watercress.

Figure 57: Plant Layout - *Location of chosen plant species by zone*

Plants

Although the software used to model the design did not have the chosen plants, this drawings shows the general schematic. The plants were strategically placed from short to tall, so that if when looking at the floating island all of the plants are visible at once. The plants will be seeded into a coconut fiber growth medium wrapped in netting with mulch mats underneath to keep the medium from falling through the lattice.



Exploring Educational Opportunities

Walkways

Hands-on learning is a large part of the AFS curriculum, and school administrators believe all aspects of the farm should be useful to the students. Environmental education is apparent throughout AFS, and students have taken special interest in sustainable practices through extracurricular activities such as the Environmental Club. There is excitement to incorporate the floating island into the curriculum at all levels of schooling, but it must not disrupt government mandated educational requirements.

Interviews with principals, faculty, and a STEM fellow revealed that younger students require fun yet critically-minded activities, while older students benefit more from labs and experiments. They also provided insight into what types of educational materials would be most beneficial to spark inspiration for floating island lessons.

Community Voices

"Here in Greece we have to follow, first off, the official state curriculum. It's something we can't avoid"
- AFS Administrator

Figure 58: Example Primary School Activity - *AFS students are provided with many hands-on activities including experiments*

All of the AFS and Perrotis College interviewees expressed interest in teaching their students about water reuse and treatment through floating island technology. Elementary school administrators spoke proudly of the exploration program, in which students complete hands-on activities, often outside of the classroom, in correlation with traditional education. The STEM Fellow, who creates these lesson plans, stressed the importance of pursuing the students' creative mindsets to learn the basics of science, technology, engineering, and mathematics. He explained that each topic is taught as a series of 'quests' where students are secret agents entrusted with a mission that allows them to discover nature. There is currently a plants mission, in which topics relating to phytoremediation* could be incorporated, but the program is flexible. The team collected examples of a typical mission-quest lesson plan as well as a class summary document, written by teachers post-activity, which details learning outcomes. The team filled out these templates to give faculty a brief overview on water treatment and reuse concepts, and suggest fun activities like field trips to the floating island.

ΟΜΙΛΟΣ ΣΧΟΛΕΙΩΝ ΒΙΩΜΑΤΙΚΗΣ ΜΑΘΗΣΗΣ ΘΕΣΣΑΛΟΝΙΚΗΣ
Δημοτικό Σχολείο
Νηπιαγωγείο
Στο χώρο της ΑΜΕΡΙΚΑΝΙΚΗΣ ΓΕΩΡΓΙΚΗΣ ΣΧΟΛΗΣ

Primary School
20xx.xx

Class __
Project "Water"
Calendar Actions and Activities

Date: xx.xx.20xx
Lesson: Experiential Zone
Actions/Activities: We introduced the experiential program "Water". Students were asked what they use water for in their everyday lives, from brushing their teeth to swimming in the ocean. A huge list was compiled as a class. Then we explored what happens to the water after it is used – where does it go? Can we use it again?
Remarks:

Date: xx.xx.20xx
Lesson: Experiential Zone
Actions/Activities: Students were taken on a tour of water on campus: the small pond near the green house and the two lagoons were visited. At the Earthen lagoon, the actions of the floating island were described, and the benefit of reusing water for farming was explained. Students made scientific drawings: What plants did they see? Were there butterflies? What did the water look like? After returning to the classroom, they colored their drawings and shared their findings with the class.
Remarks:

Date: xx.xx.20xx
Lesson: Water
Actions/Activities: The question was brought back: what happens to water after we use it? The basic steps of water treatment were described and shown in videos. Students were then given materials to conduct their own water treatment process in the classroom! https://thewaterproject.org/resources/water_pollution_filtration_experiments
Remarks:

Figure 59: Sample Lesson Plan - *The project team completed a lesson plan about floating islands for the primary school*

Figure 60: Floating Island Maintenance - *Floating islands require maintenance that could be incorporated as a lab*

Secondary school and college administrators explained that lab-based learning is a main component of the curriculum. There are already lessons that involve analysis of alternative technologies for food and plant production. Faculty who supervise this program expressed interest in creating a comparative study program with plants on the living walkway to compare their nutrient levels with those grown in a conventional environment. At the collegiate level, these comparative studies would be more analytically intensive and have the potential to turn into student dissertations, a graduation requirement completed in the final year of study. Interviews with Mr. Petras also shed light on the fact that AFS is proposing the addition of an environmental engineering program to Perrotis College, in which the wastewater treatment system, including the floating island, would be a laboratory. These suggestions do not lend themselves to the production of specific educational materials, but the team hopes that involving a large portion of the community in the design process will kindle excitement to pursue the opportunities that have been discussed.

Island Walkways

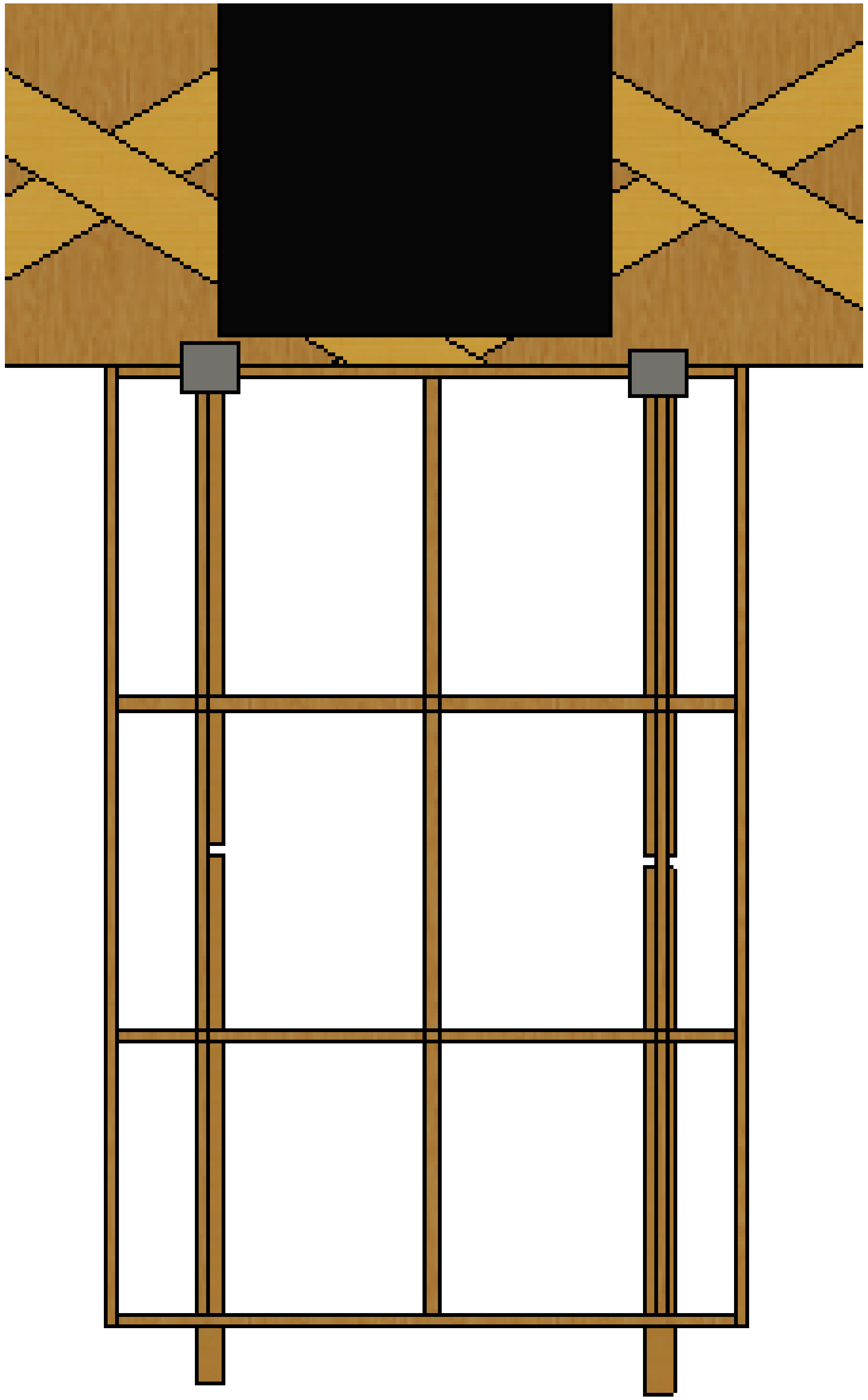
In order to make this a safe environment for potential student interaction, chestnut railings were added to all of the walkways. These walkways form an E-shape on the island to guarantee access to all of the plants.

Living Walkway

The island also includes a living walkway, which is a 3 by 2 meter floating dock with soilless plantings on either side that further help to clean the water. These plants are seeded in the same way as the plants on the island itself, using a coconut fiber growth medium wrapped in netting. The walkway is made out of chestnut wood boards, with a wooden frame underneath and two polyurethane floaters to support it. It will be attached to the island using hinge joints. Wooden railings will be placed on both sides as a safety feature.

Living Walkway Wooden Frame

Bottom View



Enhancing the Campus

Additional Features

At a cookie social, students gave open and honest perceptions about their campus. The team learned the various nicknames that students have given to the lagoon such as “the dirty pond,” “the smelly pond,” and “the gateway to hell”. They made it clear that it is not a place they intend to hang out at due to the smell and lackluster views. Although many supported improving the area, they did not believe it could happen anytime soon.

However, there are steps in place to improve the space. As a part of the school’s plan for developing the campus, the earthen lagoon will eventually become a wetland as part of an educational trail. Here, community members will be able to see the local wildlife and learn about the water recycling process. After initial visits to the site, the team was concerned about accessibility. The trail plan assured the team that progress is in place to make the area more accessible.

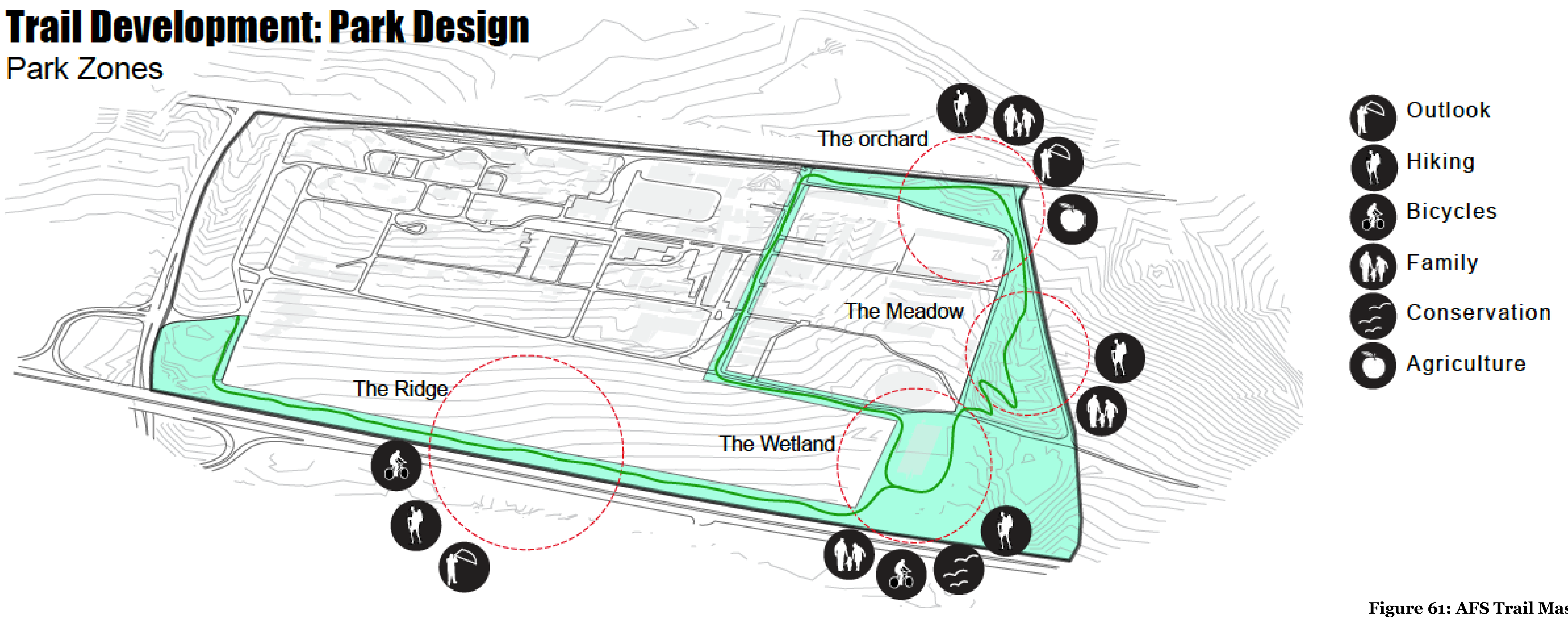
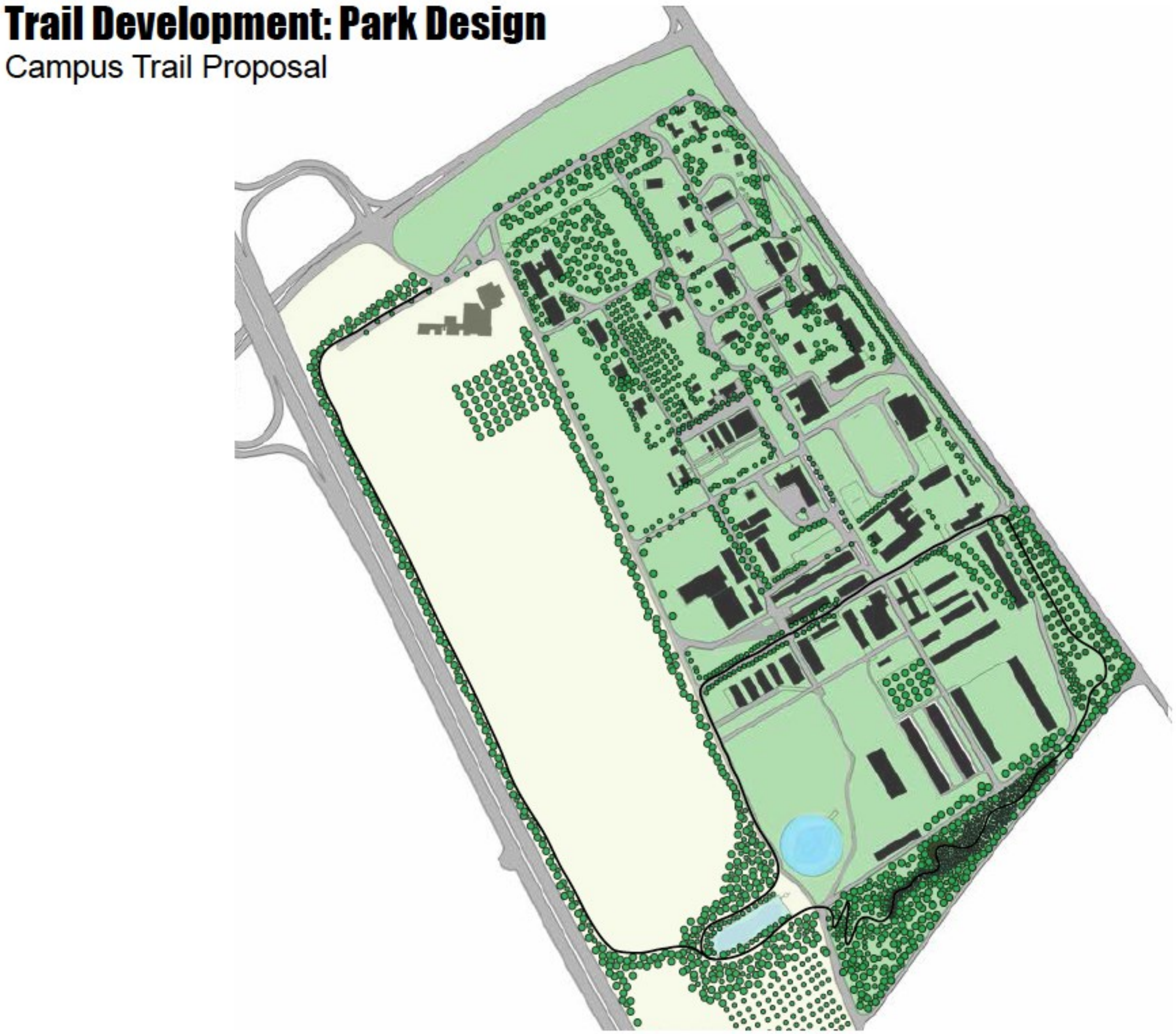


Figure 61: AFS Trail Master Plan Park Zones -
Various attractions around the campus



Interviews with Mr. Petras informed the team that there are also intentions to build a new dock at the perimeter of the earthen lagoon. The dock will open up the space and allow for the floating island to be used as an educational tool. It is incorporated as Phase Zero in this project to allow for flexible construction plans. For more detail, refer to the Next Steps section. Alongside the trail plan, the island will enhance the campus as a whole and create an accessible space for the community and visitors to enjoy.

The trail plan shows many drawings that depict a natural community space near the lagoon by removing the barbed wire fencing and planting more grass. This theme of invigorating the area with nature is a strong component of this project as well.

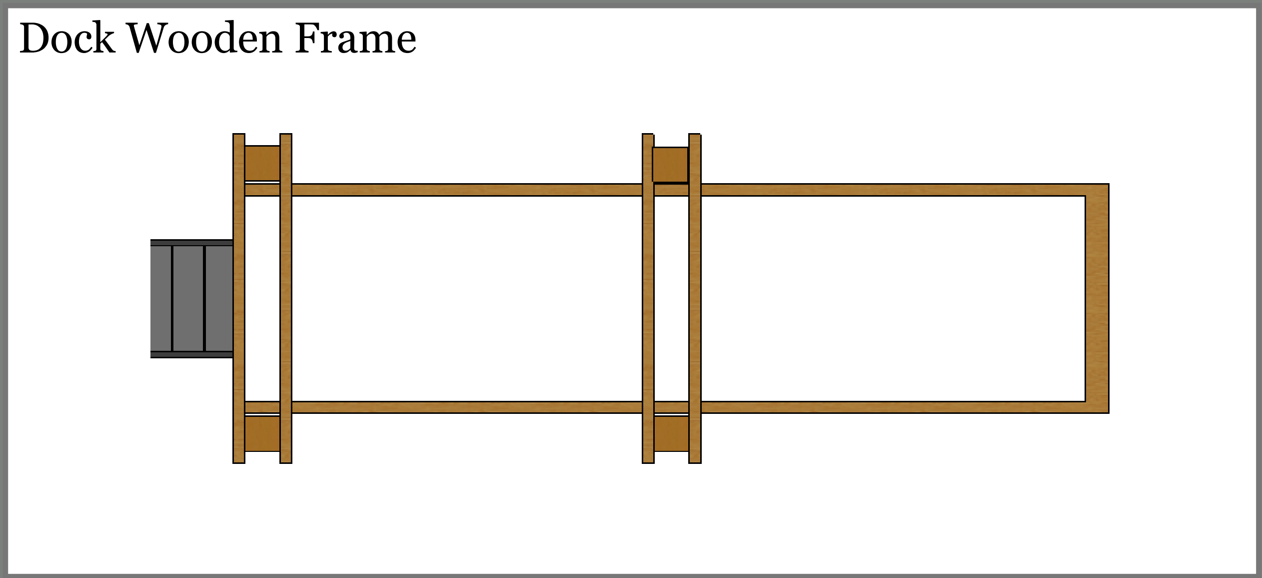
Figure 62: AFS Campus Trail Proposal

Wild Duck Habitat

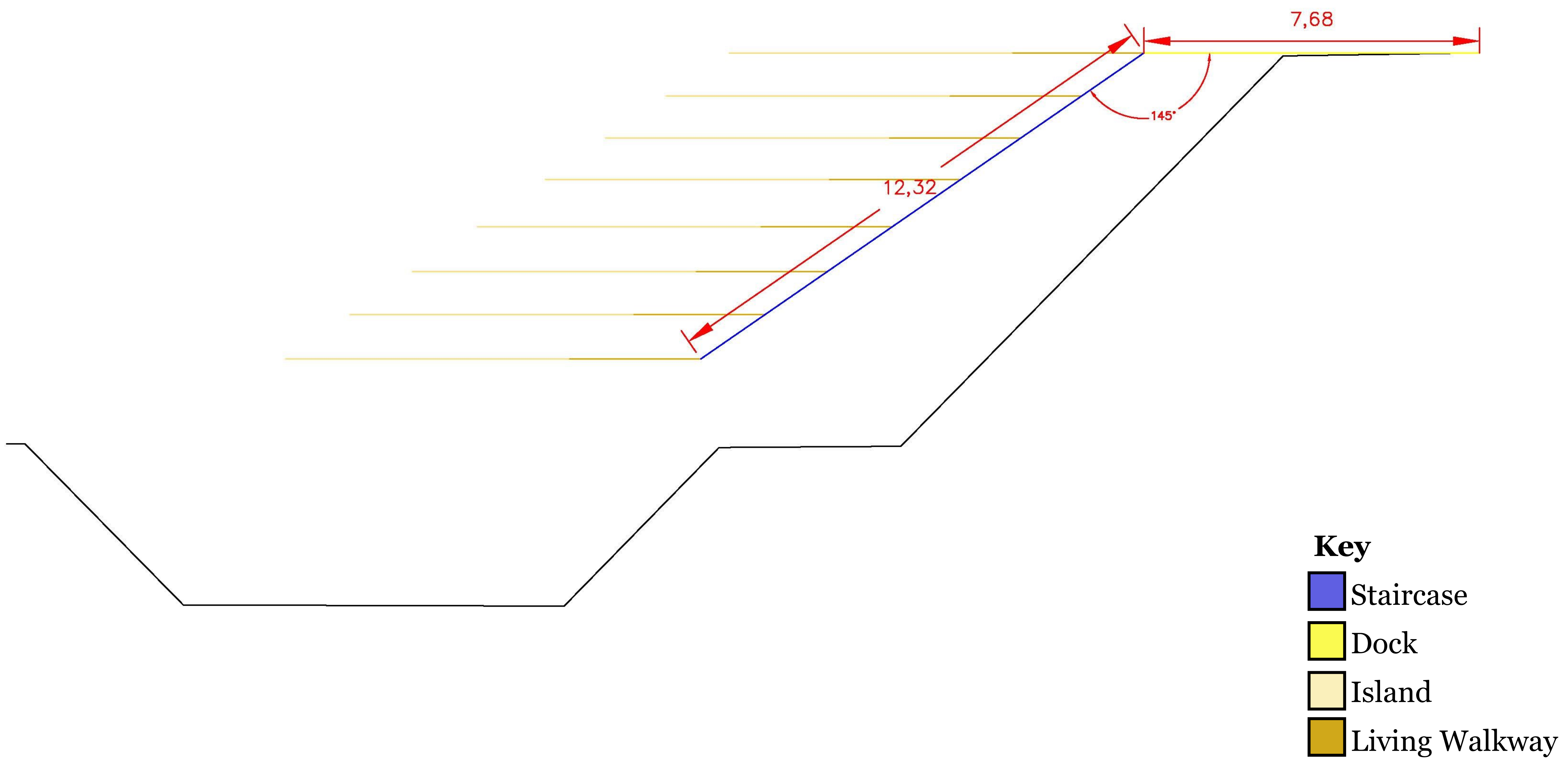
The floating island will incorporate a habitat to house the current duck population and ensure that the lagoon remains an ecologically rich area. The proposed duck habitat consists of five centimeters of gravel on top of a mulch mat surrounded by reeds and grasses. The gravel is a comfortable material for the ducks to build a nest on, and the mulch mat keeps the gravel from falling into the water. The tall reeds and grasses provide both food and shelter to the ducks, who typically enjoy privacy in their nesting habitat. The chestnut wood ramp gives the ducks easy access in and out of the water.

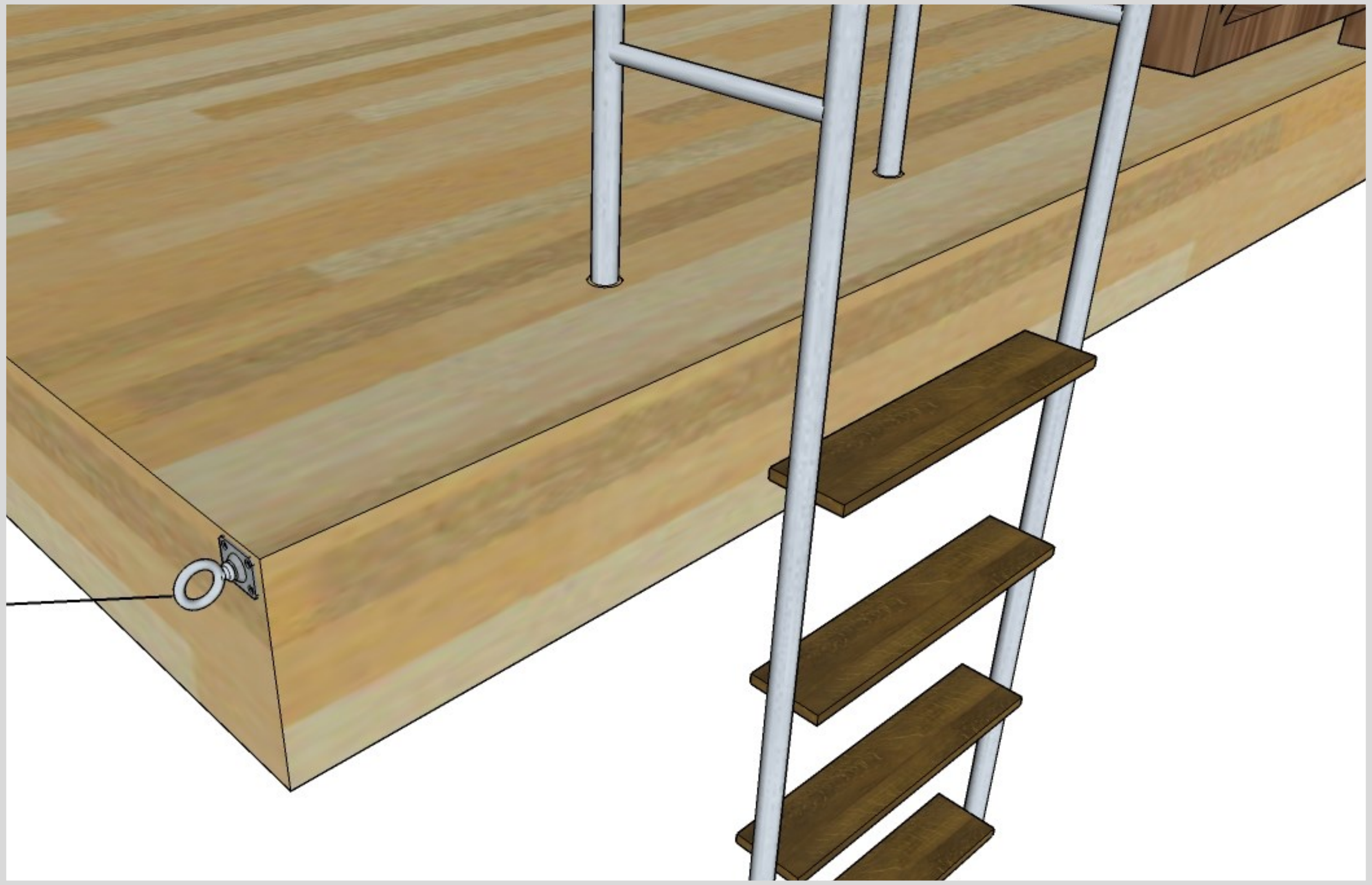
Dock and Staircase

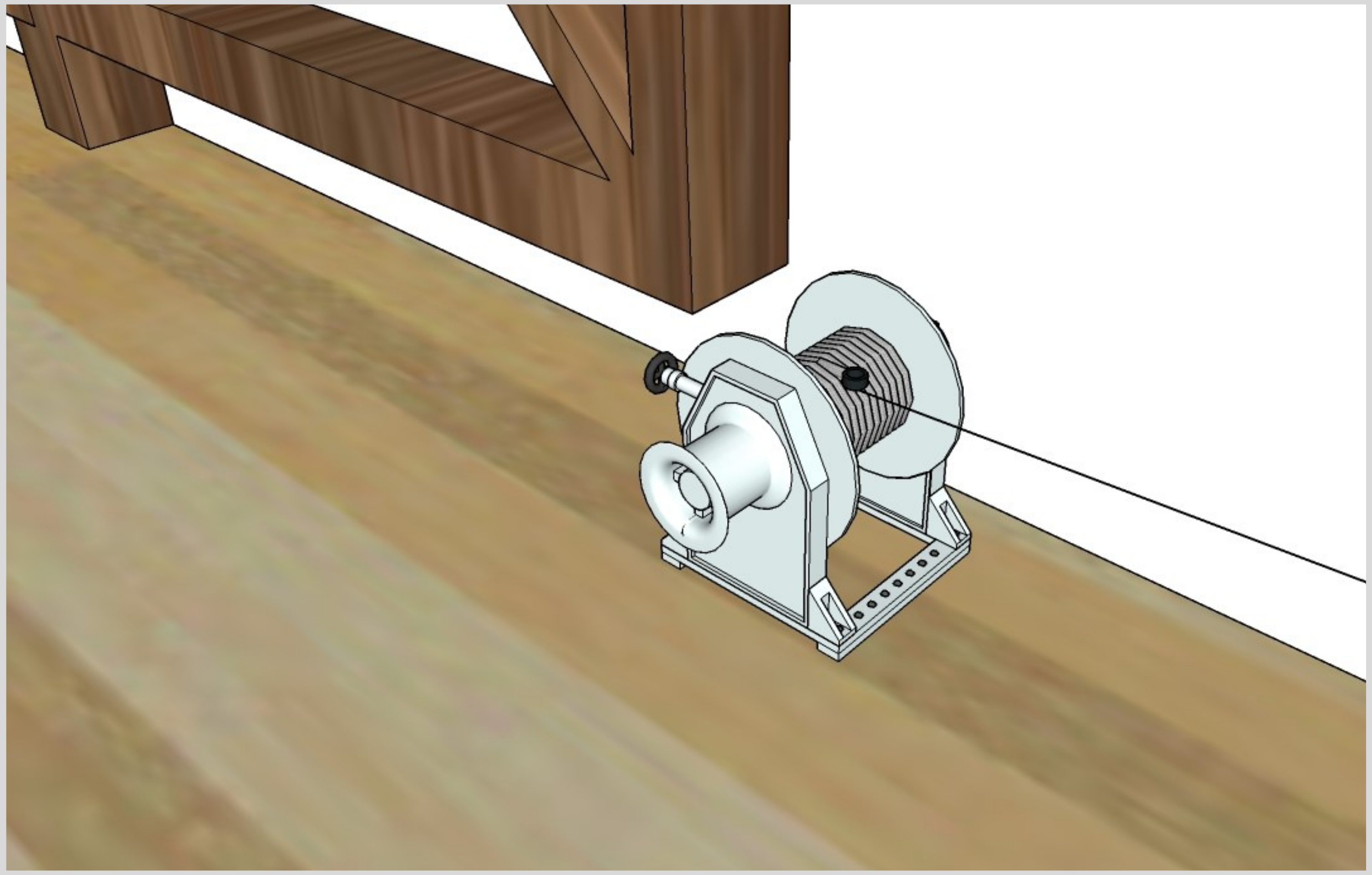
The design also includes a stationary dock fixed to the edge of the lagoon with a staircase to access the living walkway and island. Both the island and living walkway can slide along the stairs using a rope and cable system, making it easy to walk onto the island no matter the water level. A rubber fender will serve as a barrier between the living walkway and staircase. The 7.68 meter-dock will be constructed with chestnut wood and fixed in the ground with four pilings. The staircase is 12.32 meters long to ensure that the island is in the deepest part of the lagoon at the lowest water level. It is at a 45 degree angle in order to follow the slope of the lagoon walls. Stainless steel grated steps allow for easy cleaning and a better grip when walking.

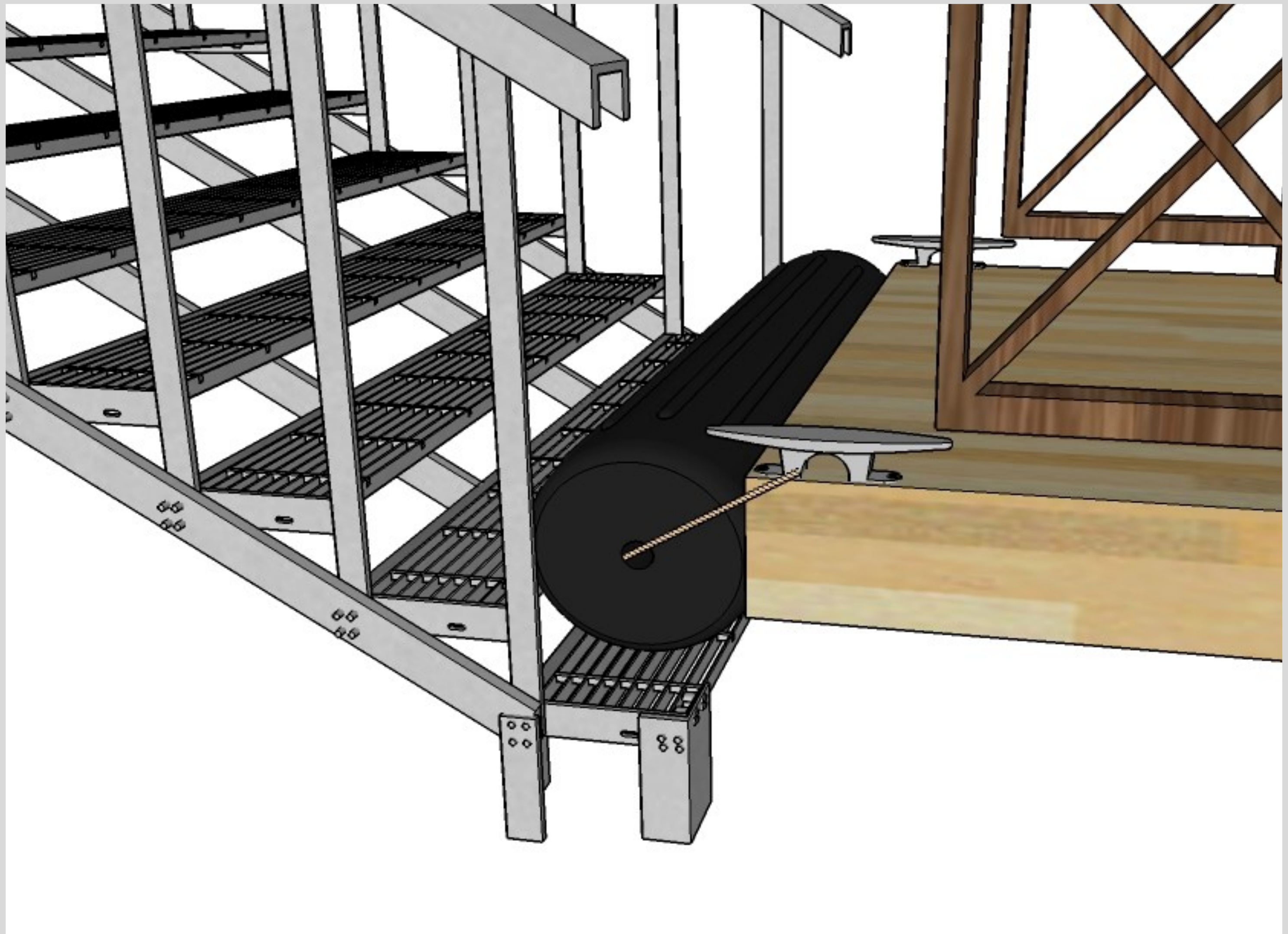


Island Design Section View

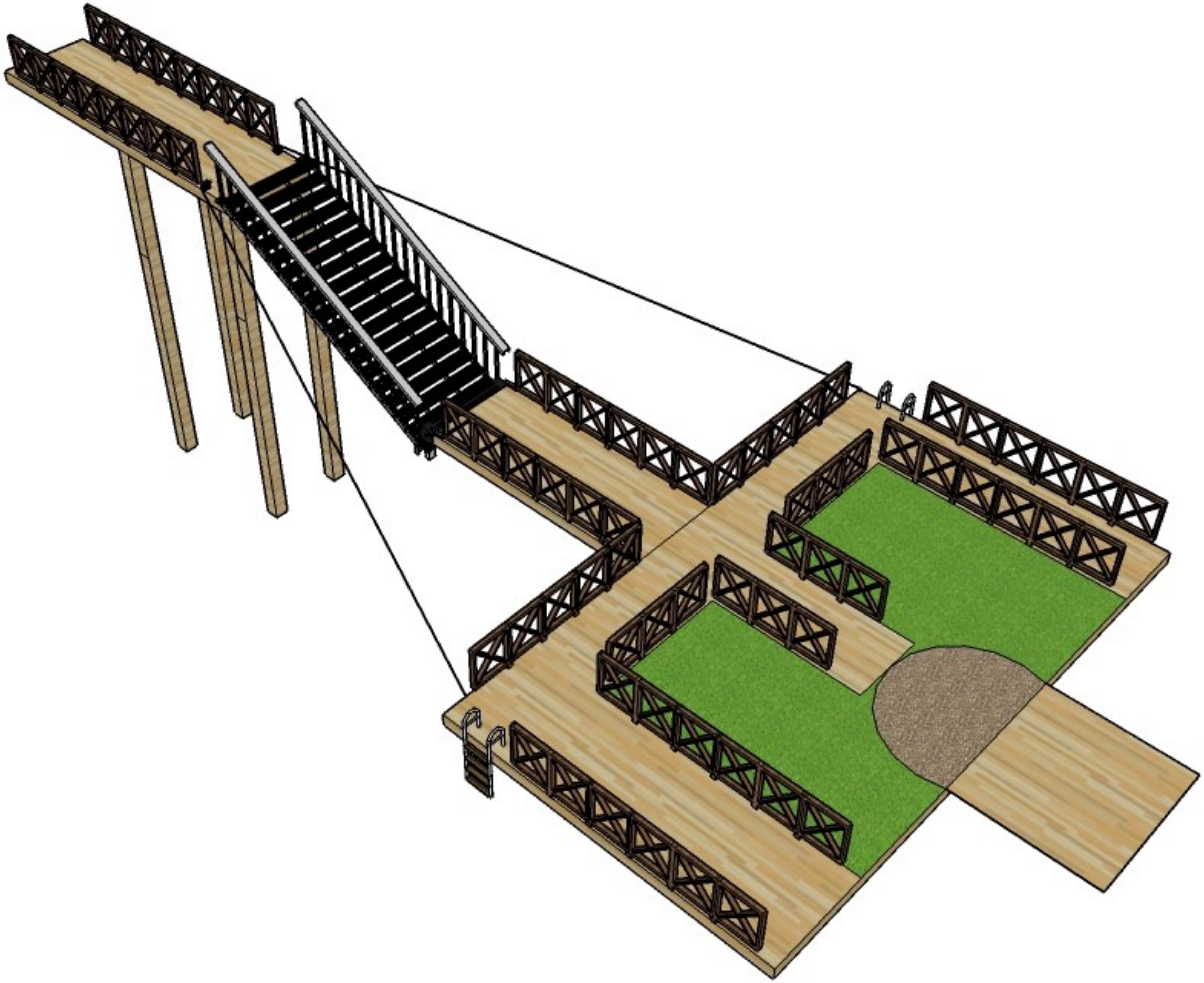








This island is anchored to the dock with two steel cables. To accommodate seasonal changes in water level, the cables can be tightened or loosened with a winch. The living walkway is separated from the staircase with a rubber fender, which moves with the walkway. Ladders on the island provide an extra measure of safety.



Next Steps

Cost Estimate

The floating island, living walkway, and dock are estimated to cost 30.228,48 euros to construct on-site. This is 4.544,02 euro cheaper than purchasing a pre-made island from a company such as Biohaven®. Neither estimate includes the cost of labor. The estimate is provided in phases so that the island can be constructed as resources become available. Phase zero, the dock, is a feature that AFS was already considering building, so this may or may not be constructed at the same time as the island.

Phase one is the living walkway and phase two is the island itself. The second phase can be further broken down into two stages: (1) one plant space and two walkways can be built then (2) the second plant space and final walkway can be added to complete the "E" shape of the island. Unfortunately, this cost estimate has limitations because the project team is not familiar with local businesses to purchase materials from. The team recommends that AFS contracts an external service to build the custom dock and staircase as the dimensions are atypical.

Table 5: Floating Island Cost

Phase #	Construction	To Make		To Buy	
Phase 0	Dock + staircase	€	12.685,00	€	12.685,00
Phase 1	Living walkway	€	1.710,18	€	1.710,00
Phase 2	Island	€	15.833,30	€	20.377,50
	Total	**€**	**30.228,48**	**€**	**34.772,50**

Maintenance

The island maintenance will depend on the needs of the plants. The plants should be added after the last frost in spring to ensure good growth throughout the first year. However, before being placed on the floating island, the plant roots need to be established. Plants can be purchased already grown and placed in the coconut fiber growth medium for a few weeks, or they can be seeded in the fiber and grown in a shadehouse prior to being put on the floating island. Once on the island, the plants require infrequent trimming, pruning, or dividing*. Refer to the plant checklist in the Design section for more maintenance details. In addition, the staircase leading to the island will need to be cleaned if particulates accumulate on it for safety reasons. Since the steps are graded, maintenance personnel will simply need to hose down the area.

Further Research

There are opportunities for further research regarding the phytoremediative properties of the plants that will be used on the floating island. Research-scale prototypes could be constructed by seeding the chosen plant species into the growth medium and placing them in lagoon water samples. Observation and testing will show how effective each plant is at cleaning the water in the environment-specific conditions that exist at AFS.

Figure 63: AFS Research - *Students conduct research together as part of a dissertation in the final year at AFS*

Appendices

Appendix A
Definitions

Activated Sludge Treatment: A water purification process in which clumps of microorganisms are suspended in wastewater to break-down organic material. The mixture is aerated and stirred. Sludge eventually settles out of the mixture, at which point it is returned to the beginning of the cycle as the cleaned water is pumped out (National Environmental Services Center, 2003).

Biofilm: a thin usually resistant layer of microorganisms (as bacteria) that form on and coat various surfaces (Merriam-Webster, 2016)

Categorical Aggregation: A series of techniques using labels, codes, and categories to organize qualitative data (Amsden et al., 2011).

Dividing: A term loosely applied to a number of propagation methods where a plant is split into two or more pieces all of which have roots attached… At its most vigorous it means driving a spade through the centre of a clump, pulling one half of the plant out of the ground and planting it somewhere else in the garden (Australian Native Plants Society, 2016).

Ecotoxicological: Pertaining to ecotoxicology, a scientific discipline combining the methods of ecology and toxicology in studying the effects of toxic substances and especially pollutants on the environment (Merriam-Webster 2015).

Evapotranspiration: The total amount of water lost to the air, both through evaporation and transpiration. Water spontaneously evaporates as part of a balance between liquid water and water vapor in the air. Water also transpires out of leaves as part of the chemical processes performed by living plants. Both are a net loss from liquid water sources (U.S. Geological Survey, 2016a).

Eutrophication: A process by which algae grows and is rapidly decayed by aerobic bacteria, decreasing the dissolved of a water body (Sharpley et al., 1981).

In-vessel Composting: A process in which organic material is composted in an enclosed, controlled space under ideal conditions (CalRecycle, 1995).

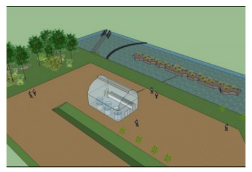
Non-point source pollution: Pollution discharged over a wide land area, not from one specific location. Typically occurs when rainfall, snowmelt, or irrigation washes off landscapes. As this runoff moves across surfaces it picks up soil particles and pollutants and deposits them in bodies of water (U.S. Geological Survey, 2015a).

Point source pollution: Pollution discharged from a single, concrete source (U.S. Geological Survey, 2015b).

Vertical Flow Wetlands: A water treatment system consisting of plants rooted in beds of sand-topped gravel. Wastewater is fed into the column intermittently, flooding the bed and slowing percolating down through the material. When the bed is not filled with water, air refills the space between the gravel, where the influx of oxygen provides more raw chemical material for the next time the bed is flooded (Vymazal, 2010).

Appendix B
Case Study Analysis

Location	Purpose	Design Principles	Key Plants	Outcomes
 Walt Disney World, Orlando, FL	Aesthetic - Flower and Garden Festival	Base made of polystyrene boards Drainage holes drilled into the side Tethered to concrete blocks in the bottom of the lake via nylon cords	54 inch annuals - pink impatiens and yellow marigolds	Popular attraction at the Festival
 Elephant Butte, NM	Bass Spawning Habitat	Plants provide nutrients for growth of young bass Root structure under islands and above spawning platforms acts as nursery for fry bass Spawning beds attract fish and provide protected environment Spawning beds filled with pea-sized gravel	-------	Increased spawning
  Sheepy Lake, CA	Caspian Tern Management Project	Sloped stone edges to provide water access for young birds Bullrush, red-twigged dogwood and sand willows were planted on the perimeter to protect island from wind Crushed stone, pumice, and rhyolite mix used for gravel on the island for nesting	Bullrush Red-twigged dogwood Sand willows	Increased colony activity on the island and increased breeding of caspian terns
 Gowanus Canal, Brooklyn, NY	To clean water through phytoremediation and irrigate plants through desalination	Metal culvert pipes and plastic bottles to hold plants Island structure consists of layered bamboo, woody plant material, water hyacinth rope, post-consumer shredded plastic, coconut matting, and oak cork Over 30 plant species used on the island	-------	Successful habitat for animals as well as providing some clean up (still monitoring success)

 Marton, New Zealand	To reduce odor and BOD in anaerobic wastewater pond	Intended to replace current pond aerators Specially fitted floating “blanket” to lay over pond Plants seeded in the blanket to remove desired parameters	*Carex virgata* - highly resilient	Extremely successful High removal rates of BOD and annual savings of $150,000
 Jiaxing City, Zhejiang Province, China	To remove nutrients and heavy metals Secondary, use crops grown for animal feed	Aquatic vegetation and adsorptive biofilms were used on the islands Island 1 used bamboo covered in plastic netting and island 2 used PVC pipes Five floating plants, one submerged plant and three emerged plants were placed inside the plastic netting	Water hyacinth Water lettuce Water dragon Pennywort Frogbit Parrot weather Pickerelweed Canna Alligator flag	~37% total nitrogen removal 17-43% total phosphorus removal Removed heavy metals
 Lake Kasumigaur, Japan	Purify water using wetland plants Improve on the ecological diversity Add aesthetics	9.5 x 92 meters braced by stainless steel with diagonal supports 10 centimeters thick special urethane cushion as a root base for vegetation Artificial reef constructed below the island	Common reed Water oat Cattail Roughseed bulrush Bur reed Yellow iris	Increased fish and shellfish populations COD and TS were reduced
  Woods Hole, MA	Process heavy metals and legacy contaminants (hazardous site) Use a low-cost, low-maintenance alternative Create a passive process	A greenhouse with solar aquatic tanks and a mycelial loop Floating plant raft anchored in the canal Sediment intake structure upstream Functions as an ecological incubator and chemostat		Treated over 300,000 gallons of petroleum contaminated waters and sediment Over a 90% reduction of Petroleum Hydrocarbons throughout most of the test period Return of amphibians and turtles to the canal

Case Study Analysis adapted from:

Floating Island International. (2011). "Eliminating Odors Using Bio-Haven® Technology." Retrieved from http://www.floatingislandinternational.com/

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Nakamura, K., Shimatani, Y., Suzuki, O., Oguri, S., & Yasumochi, T. (2015). *The ecosystem of Artificial Floating Island in Lake Kasumigaura [Scholarly project]. In ResearchGate. Retrieved February 19, 2016, from https://www.researchgate.net/publication/265228404_The_ecosystem_of_Artificial_Floating_Island_in_Lake_Kasumigaura*

Nakamura, K., Tsukidate, M., & Shimatani, Y. (1997). Characteristic of ecosystem of an artificial vegetated floating island. *Ecosystems and Sustainable Development, 171-181.*

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Zhao, F., Xi, S., Yang, W., Yang, X., Li, J., Gu, B., & He, Z. (2012). Purifying eutrophic river waters with integrated floating island systems. *Ecological Engineering, 40, 53-60. doi: 10.1016/j.ecoleng.2011.12.012*

Appendix C
Site Checklist

	Weather				Topography			Focal and Vantage Points	Current Access and Circulation		Inhabitants	
Site Visit	Temperature	Humidity	Sunlight Intensity	Wind	Slope	Visual Characteristics	Potential Construction Problems		Vehicular	Pedestrian	Flora	Fauna
16/3/16 12:00-12:30	8.7°C	77%	158.7 W/m^2	•Speed cannot be too high due to surrounding buildings and wildlife •Light breeze 8.6 km/h W	•Slopes down to lagoon (very gentle) from road	•Very unpleasant sights, sounds, and smells •Foreboding, not welcoming, ominous	•No roads, muddy dirt road exists and must remain for material transport •A fence surrounds both lagoons (barbed) •Very soft, silty soil. Overgrown with weeds •Walkway contraption at entrance exists for unknown purposes •Piles of trash and dumpsters	•Can walk perimeter •Hill at Southwest end	•Access dirt roads, removed from the lagoon seperated by vegtation •Full loop	•Dirt road, not very walkable	•Weeds, grasses, wild flowers	•Ducks, tracks from bird and unknown mammal •Worms and centipedes •Dog •Bone from unknown animal
5/4/16 16:00-16:30	23.2°C	58%	575.8 W/m^2	•Medium breeze 13.4 SSWkm/h	•Slopes down to lagoon (very gentle) from road	•Pleasant feeling of nature •Quiet, peaceful but ominous	•Dirt road exists and must remain for material transport •A fence surrounds both lagoons (barbed) •Hard, clay-like soil •Piles of trash and dumpsters	•Hill at Southwest end •Northeast end where lagoon will go	•Access dirt roads and loop •3 vehicles observed on main road	•Dirt road, easily walkable •3 students on main road walking toward far entrance of school	•Weeds, grasses, lots of wild flowers •Shrubs •Barren trees	•Ducks (at least 9) •Butterflies, ants, various insects •Dog

Drainage Channels			Immediate Surroundings					Additional Comments
Natural	Man-made	Pattern/Direction	Buildings	Shade/solar access	Noise from streets	Odors	Views	
•Slope induce runoff	•Influent from lagoon A •Concrete drainage channel between A and B	•Everywhere •Additional water collection West of lagoon	•Storage for equipment and trash •Road •Vegetation wall around perimeter	•No comment	•No traffic, not much noise	•Swampy, unpleasant	•Vegetation wall, fence, lagoon •Office buildings •Metro sign	•How to harvest and install floating island in light of poor access •How to address smell... Living wall? Especially from cows •The fence is very uninviting and dangerous. Are there regulations surrounding this? •Railing should be added •Viewing deck could be installed by reed beds •Walkways should be gravel or other material for accessibility •Shoes get caked in mud in rainy conditions •Maintenance would be necessary to maintain access
•Rainfall and runoff	•Influent from lagoon A •Concrete drainage channel between A and B	•Additional water collection West of lagoon	•Storage for equipment and trash •Road •Vegetation wall around perimeter	•Extremely high sun exposure, no shade available	•No noise	•Slight floral tones •Swampy smells when wind slows down •Dry dirt/ dust smell	•Vegatation wall immidiately around lagoon •Office buildings •Metro sign •Olive grove	•Area needs more shade to make it pleasant in the summer •Northeast area where lagoon will go is not visible from any point aside from the main road (more maintenance needs to be done) •Concrete pad observed at intersection of main road and Northeast side •Gate area could be incoporated into fence, but barbed wire shoudl be removed around this area

Appendix D
Citations

Figures

Cover Photo: Lagoon Aerial
Source: Google. N.d. "[American Farm School, Thessaloniki Greece; zoomed in view of lagoons]". *google.gr/maps. Retrieved 24 April 2016 from https://www.google.gr/maps/place/American+Farm+School,+Thessaloniki*

Introduction

Figure 1: Global Agriculture Water Usage
Source: UNEP. (1999). "Trends in Global Water use by Sector." *Unep.org. Retrieved 26 April 2016, from http://www.unep.org/dewa/vitalwater/rubrique16.html*

Figure 2: Floating Island Applications
Source: Floating Islands West, LLC. (2014). "Floating islands west...for solutions above & below the waterline." *Floatingislandswest.com. Retrieved from http://www.floatingislandswest.com/*

Figure 3: AFI Root System
Source: Canadianpond. (2016). "Biomatrix Floating Islands Treatment Wetlands." *Canadianpond.ca. Retrieved 26 April 2016, from https://canadianpond.ca/product/biomatrix-floating-islands-treatment-wetlands-ftw/*

Figure 4: Student Design Charrette
Source: Prescott, Mary. Personal Photography. (2016).

Context

Context Section Photo: AFS Campus
Source: American Farm School. (n.d.). *afs.edu.gr. Image retrieved 26 April 2016 from http://afs.edu.gr/files/02TemplatesImages/farm_home_02.png*

Figure 5: World Water Content
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Figure 9: AFS Water Treatment System Diagram
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Source: Adapted from Nikolaidis, N. (2016, February 2). Personal Communication.

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Tables

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