DEPARTMENT OF CIVIL ENGINEERING
SENIOR DESIGN PROJECT
FALL 2012

Campus RainWorks Challenge

A Green Infrastructure Design Challenge for Colleges and Universities, US EPA Office of Water

CAMPUS FLATLANDS,
THE UNIVERSITY OF TOLEDO,
TOLEDO, OHIO

THOMAS BACHMAYER, ELIZABETH BUSSING, ERIC FINGER, JOSEPH PERCHINSKE, DANIEL TORIS, ALEXANDER WELFLE

Background

The Ottawa River/Ten Mile Creek Watershed, located in Northwest Ohio and Southeast Michigan is Hydrologic Unit 04100001 020180. The Ottawa River/Ten Mile Creek is 45 miles long with a drainage basin of approximately 221 square miles. The river begins in northeastern Fulton County, where it is known as Ten Mile Creek, and flows east through Lucas County and empties into Lake Erie. The middle reach of the river passes through the University of Toledo's Main Campus located in Toledo, Ohio.

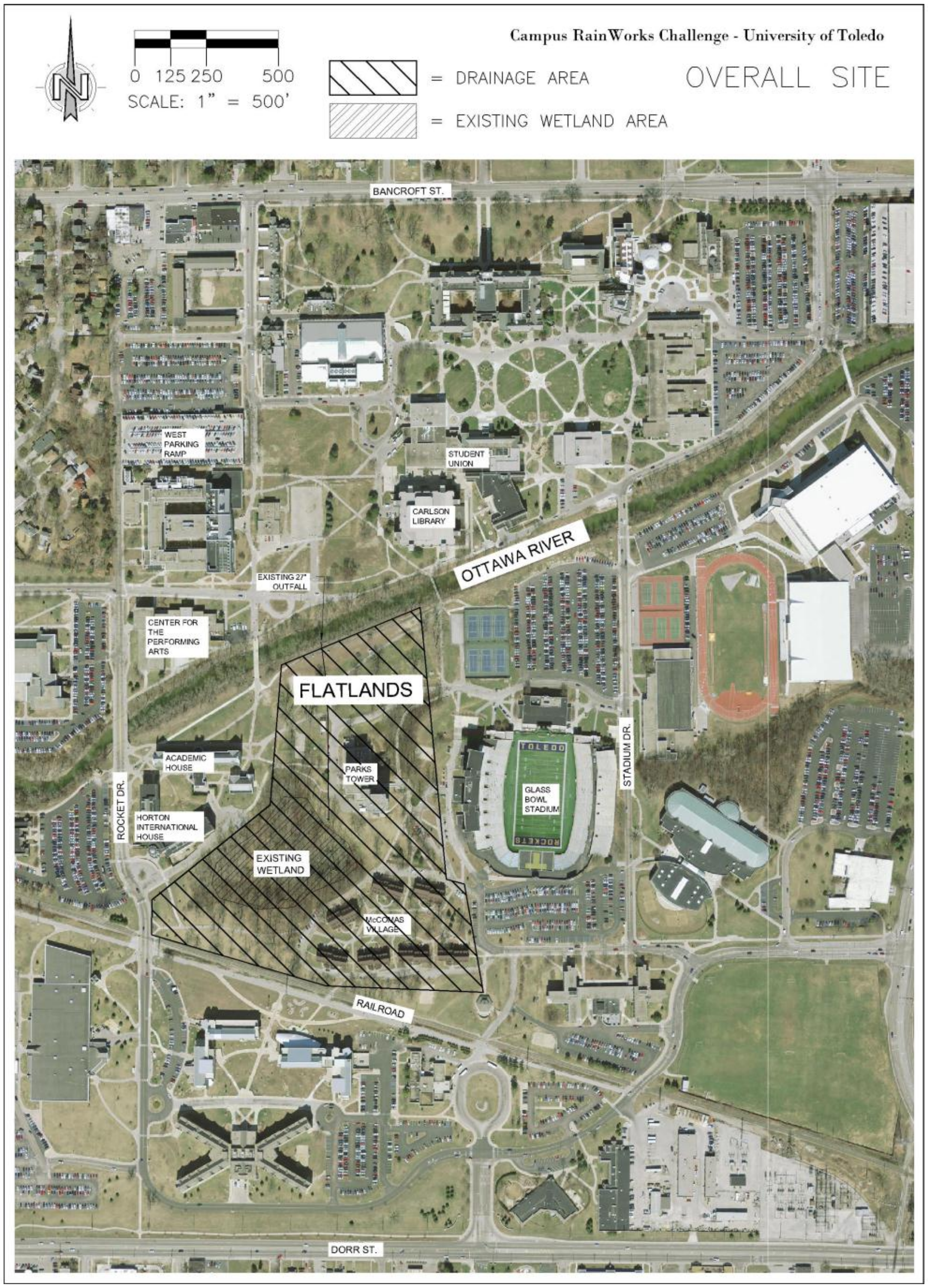

Figure 1: Overall Site
Image: Courtesy of University of Toledo Student Team

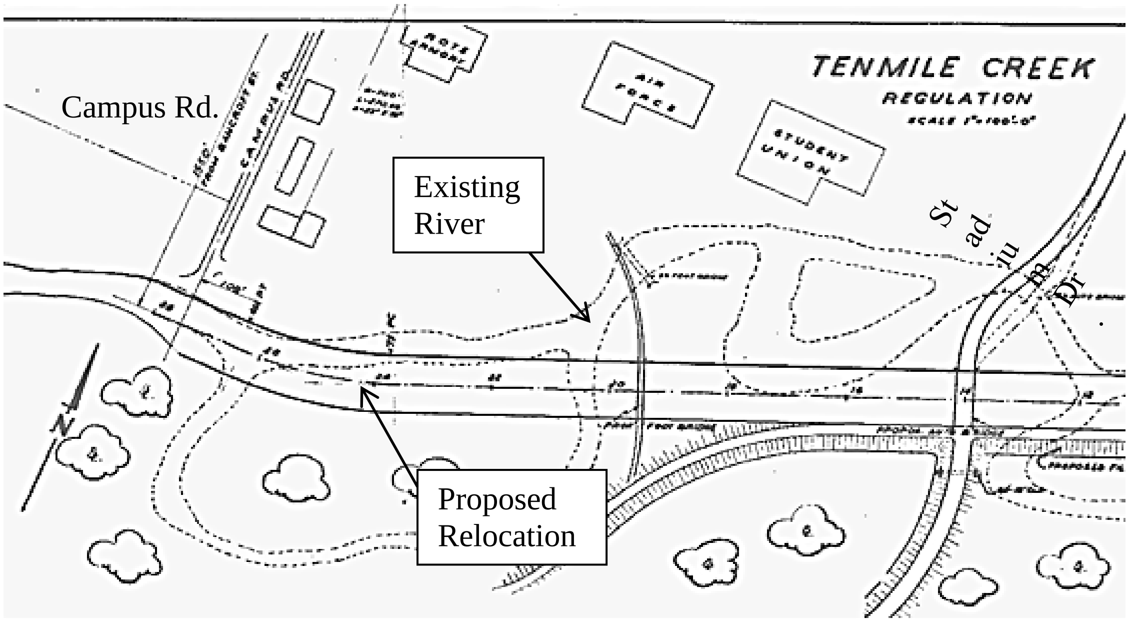

Figure 2: Ten Mile Creek Relocation
Image: Courtesy of University of Toledo – Plant

Historical Conditions. In 1960, the section of the Ottawa River that runs through campus was straightened, widened, deepened, and levees were added to the banks of the river (Figure 2). This was done to accommodate growth of campus infrastructure. So, the natural position and shape of The River was changed and is maintained by the addition of the levees as well as a few pump stations located on its southern bank. These modifications were intended to assist with flood control during peak flow conditions ("Ottawa River [Lake Erie]"), (*The Presidents Commission on the River*). On The University's campus, the depth of the Ottawa River varies widely from several inches during dry weather to over 15 feet during heavy rainfalls. The drastic increase in the water level, attributed to an abundance of impervious surfaces nearby, can result in damaging floods and the discharge of stormwater contaminants to the river. In Figure 3 below, you can see the drastic change in water levels.

Figure 3: Comparison of The Change In Water Levels
Image: Courtesy of The University of Toledo, Commission of the River

Water Quality. The Ottawa River is contained in the Maumee Area of Concern, which identified 10 of 14 beneficial use impairments in 1990. The downstream section of Ottawa River in the City of Toledo has been the focus of many efforts and research studies to address industrial discharges, contaminated sediments, and river dredging. River and stormwater discharge sampling on UT campus over the past several years have indicated that the levels of dissolved solids, suspended solids and nutrients can be high and have significant temporal variation. Also, fecal coliform levels are generally higher than the standard for recreational use. The river has poor water quality mainly due to its structure and slow flow, especially within the University of Toledo campus. The deepening of The River and the addition of the levees has resulted in a channelized river. On Main Campus, warning signs were once posted by direct order of the Ohio EPA along the river stating “Due to water pollution, fish in this area may be contaminated and unsafe to eat” but these have recently been removed. Since the river drains into the Maumee Bay, it has become known as one of the major sources of pollution into Lake Erie. Harmful algal blooms are a major problem within Lake Erie and species of these harmful algae include, Microcystis and Anabaena. These can produce toxins such as microcystins, which can poison the water and possibly cause kidney failure in cases of exposure. Surrounding tributaries and rivers supply Lake Erie’s Maumee Bay with phosphorus runoff from the watershed. This phosphorus runoff is the main contributor to the size of these blooms and can be seen in Figure 4 below.

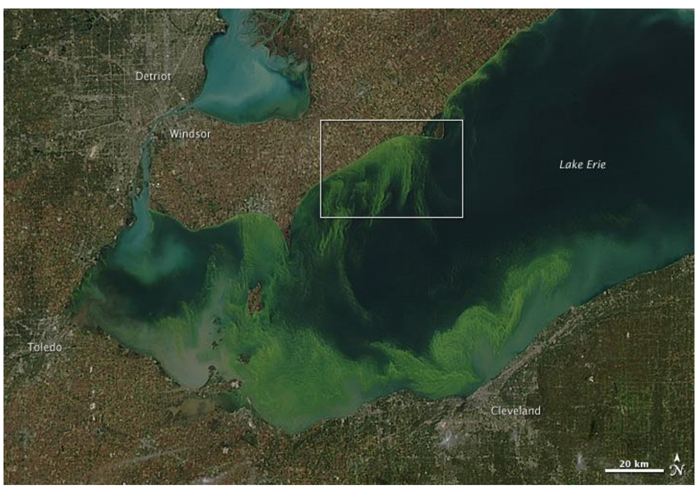

Figure 4: Harmful Algal Blooms in Lake Erie
Image: Courtesy of "Schamltz”

According to the National Pollutant Discharge Elimination System (NPDES), polluted stormwater runoff is the lead contributor to nearly 40 percent of the water bodies that do not meet the water quality standards. To protect the environment, the Clean Water Act was created to address the sources of stormwater discharges that directly affect our waters. This program uses permits that require the control devices to remove harmful pollutants and prevent them from being washed by stormwater runoff into their local bodies of water. In 1995, the U.S. EPA developed a set of regulations for Phase II of the NPDES permit that sought to preserve, protect, and improve the water resources from polluted stormwater runoff (Stormwater Phase II). This phase is intended to insure that the water quality and habitats of the surrounding area do not affect the environment in a negative way when the stormwater discharges into the water body. In order to follow the regulations of this program, the University of Toledo has been asked by the U.S. EPA to submit and develop a Stormwater Runoff Management Plan.

Existing Conditions. Like many campuses, the University of Toledo has many parking lots and buildings that increase the amount of runoff entering the Ottawa River. All the water collected within these impervious areas flow through a pipe network and is discharged from one of twelve outfalls into the river. With numerous outfalls, the river is forced to receive large amounts of stormwater over a short period of time, which causes the water level to rise and occasionally flood. The quantity of water that goes into the river during a storm could be drastically reduced by simply retaining the water with the addition of green infrastructure.

In 2005, the President's Commission on the River was established to improve the environmental features and quality of the Ottawa River. The Commission recommended a set of plans that included: developing a series of boardwalks that would cross through the meadows, incorporating a series of rain gardens, stabilizing the river banks, and creating riffles and other stream habitat restoration. This plan revolves around the opinion of the students and residents near the campus whose main goal was to increase the beauty of the river as well as campus itself. As a campus, The University of Toledo has made great strides toward cleaning up the Ottawa River with events such as Clean Your Streams, in which students, faculty, staff, and community members physically remove garbage from the river. The University of Toledo is interested in correcting the areas that discharge into the Ottawa River throughout the campus. This is done by reducing the amount of flow and contaminants that enter The River directly through conventional stormwater infrastructure without prior treatment or retention.

Proposed Plan. In working with interested stakeholders on The University of Toledo's campus including Facilities and Maintenance, The President's Commission on the River, several faculty members and students from across campus, this project was developed in an effort to establish a stormwater treatment demonstration site to educate our campus community and to contribute to ongoing efforts to beautify campus and to improve the conditions of the Ottawa River. We identified a site on campus appropriate for a stormwater BMP. The Flatlands, as shown in Figure 1, is approximately a 3.5-acre area on campus that mainly consists of grass, trees, and some walkways. This area is located directly south of the Ottawa River and is within its flood plain, as shown in Figure 5 below (Earley, Keith G).

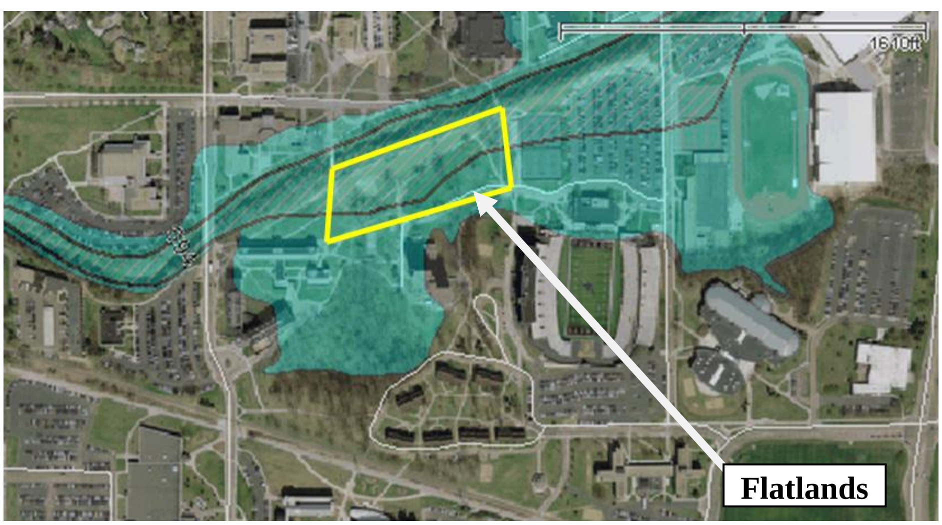

Figure 5: The Floodplain through Campus Image: Courtesy of "Engineer's Flood Plain."

The Flatlands is a low point in the area that will retain water when it rains. Because the Flatlands are undeveloped, both the University and students take advantage of the area for community and recreational activities. The green infrastructure will replace some of this open area, but with the occasional campus activity, the green infrastructure can be used as an educational attraction for the university, as well as serving its purpose to treat stormwater and direct it for groundwater recharge.

A stormwater outfall passes through the Flatlands, which can be seen in Figure 1. The flow from this outfall will be collected and treated at this location using a stormwater best management practice (BMP). The potential stormwater drainage area consists of 22 acres that is drained by a single outfall into the river. This land consists of eight campus buildings, sidewalks, wooded areas and open grass. The impermeable area consists of buildings that occupy just about 50,000 ft^2 of the total area as well as sidewalks and drives that take up nearly 105,000 ft^2. The remaining 805,000 ft^2 of the land is the grass and wooded areas.

When the weather is dry, there is little to no flow through the outfall. Tests were run on the river and standing water found within the stormwater system. There were no signs of phosphorous or nitrogen within the river water at this time, while the water collected from a manhole revealed both of these nutrients. According to the United States EPA Gold Book, there should be no more than 10 mg/L of nitrate nitrogen. From the sample we collected, test results revealed a value of 0.35 mg/L of nitrate nitrogen, meaning this nutrient is within EPA standards for stormwater discharge. In the case of phosphorous, the EPA requires a value of 0.1 mg/L while the water tested from the manhole resulted in a value of 0.06 mg/L. Throughout the year, these numbers could increase, such as when the lawns get fertilized. Two tests were run to determine the amount of total suspended solids for the stormwater. Both samples showed that very few solids were present in the water during the fall season. However, our design will be able to remove the solids if they are present during other times of the year. Another important determinant for treatment design is the presence of bacteria such as E. coli and fecal coliform. The standard established by the EPA for coliform must be less than 235 fecal coliform colonies per 100 mL and E. coli must be less than 126 colonies per 100 mL. Based on the results, the biggest concern for pollutants from this outfall is the bacteria content (US EPA Gold Book).

The northwest part of Ohio was once known as The Great Black Swamp, which was essentially a giant wetland. It consisted of a wide variety of vegetation and was difficult to develop. Today, several cities have been constructed over this once historic landmark and have taken away the beauty. Instead of adding grey infrastructure, the use of green infrastructure will once again naturally highlight and embellish the history of this area.

Decision Analysis. We hope to create positive environmental impacts through recognizing the technical and economic potential our plan could bring to the Ottawa River site. In doing this, we sought to minimize negative environmental impacts through making our infrastructure proposal as green as possible. Design constraints were developed by listing all of the issues that we thought would have an impact on the project design, are shown in Table 1, and discussed in the following.

Functionality includes project location on campus, size, arrangement, existing infrastructure, and flow information. There are few locations on campus with enough unused area to implement a project of this type. Detailed knowledge of existing infrastructure and flow information will be needed to determine the best possible solution to our problem. Life-cycle constraints include operation and maintenance through an established lifetime of the project. Economic constraints consist of development costs and resources. The University of Toledo, as well as most universities, delegates certain funds for campus projects. Cost and resources required must be kept low to increase acceptance of the project and its likelihood to be built. Ecological constraints include stormwater, environmental impact, climate/region, and materials to be used. Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. To accomplish this, we must know what types of contaminants are in the stormwater, take advantage of native plant species in our region, and make use of various “green” materials. Quality constraints include quality assurance with respect to regulations, standards, and codes, and design life. Legal/Ethical constraints include regulations and ethics. The design needs to conform to all US EPA regulations and must be ethical with respect to public safety, health, welfare, and integrity. Aesthetic constraints include campus life, user appeal, and value to campus. Human safety constraints are particularly important. The design of this project must take into account safety precautions to prevent physical injury. Many of these constraints were identified and considered in an effort to increase the likelihood of project implementation.

The method of treatment our team chose was ultimately based on functionality as we determined previously in our constraint ratings. Initially, our group examined pervious pavement and green roof ideas in addition to sand filters and a pocket wetland. However, the amount of imperious area that these alternatives would utilize was minimal, and we decided not to include them in our project. A treatment train was chosen as the best alternative because we can include multiple treatment methods to educate the public on their specific uses. A surface sand filter and a pocket wetland were chosen as the best methods of treatment. Rain gardens, swales, and bio-filters were other Best Management Practices (BMP’s) considered to be included in the treatment train. However, after considering the removal efficiencies, required area, costs, and volume capabilities of these alternatives, they were excluded from being incorporated into the design. Unlike a rain garden, sand and organic filters or a pocket wetland have not been implemented on campus, making the concept more appealing. This is where our group began to envision a solution to raising the water quality in the Ottawa River in hopes this solution would also lead to other positive environmental factors.

Table 1: Decision Table	**Sand and Organic Filters**	**Pocket Wetland**
Functional	Sufficient area and Minimal impact to infrastructure	Sufficient area and Minimal impact to infrastructure
Life-Cycle	Biannual-annual maintenance	>20 years, Annual maintenance

Table 1: Decision Table	Sand and Organic Filters	Pocket Wetland
Economical	$185,000-$434,000	$57,000 for a one Acre facility
Ecological	Removes suspended solids, phosphorous, nitrates, and metals and reduces stormwater flow	Removes suspended solids, phosphorous, nitrates, and metals and reduces stormwater flow
Quality of Design	Yes	Yes
Legal/Ethical	Yes	Yes
Aesthetically Pleasing	Yes	Yes
Safe	Yes	Yes

Table 2: Decision Table

A treatment train was chosen as the best alternative because we can include multiple treatment methods to educate the public on their specific uses.

Preservation of Natural Features

A treatment train is a series of processes designed to treat stormwater and increase the quality of water. In our case, it would treat water before being discharged into the Ottawa River. Essentially, a treatment train is a conglomerate of many Best Management Practices (BMPs) or Integrated Management Practices (IMPs) that work in a progressive fashion to treat the stormwater runoff. For the EPA Campus RainWorks Challenge, our group would like to design a treatment train that will treat and retain the stormwater and also serve as an educational opportunity. The two processes we chose are a passive filter and a pocket wetland. These two BMP's in series will comprise our treatment train. The sand filter will act as a pre-filter to remove larger particulates that might impede flow through the pocket wetland.

Sand Filter. Filtration involves the removal of the solids through physical straining. Many contaminants including phosphorous, metals, and coliform bacteria adhere to particles present in stormwater that can be removed via filtration. An example of a surface sand filter is provided in Figure 6.

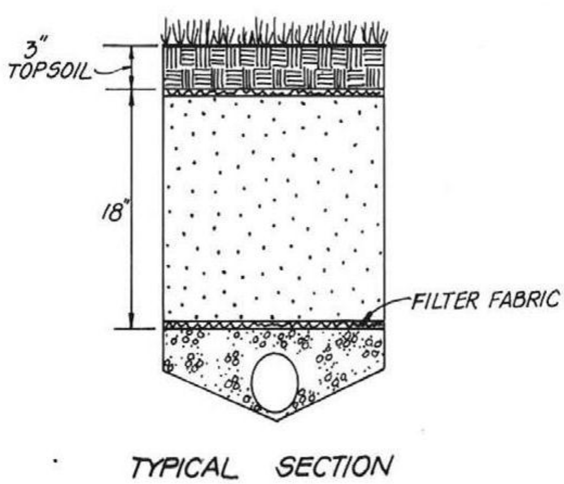

Figure 6: Typical Surface Sand Filter Design
Image: Courtesy of Claytor and Schueler.

There are different types of filters that can be used for stormwater treatment including surface filters, perimeter filters, and underground filters. Each filter type essentially works in the same manner. "Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter) (*Stormwater Menu of BMPs*)." Filters are relatively low maintenance and need checked only annually or semiannually for clogging of filter media and deterioration of the filtration bed itself. For our treatment train, we chose the surface sand filter as it will be visible to the campus community and also because it has removal capabilities suitable for our purposes.

The type of media used in the filter and its grain size distribution determine the size of particle that can be removed. Sand is commonly used as the filter media. Coarser sands have larger pore spaces that have high flow-through rates but pass larger suspended particles. Very fine sand, or other fine media, has small pore spaces with slow flow-through rates and filter out smaller suspended solids particles. In addition, we plan to incorporate mixed media, such as peat-sand or sand-iron mix, to provide ionic adhesion or exchange for some dissolved constituents (e.g., phosphorous, organic carbon), which further enhances effluent stormwater quality.
Design considerations for the filter included location of the filter, filter surface area, media type, and media depth. It is beneficial to locate the sand filter at or below the frost line. Another design criterion is the fact that The University of Toledo is a somewhat ultra-urban area; therefore it was necessary to size the filter so as to save space on campus. Therefore, we calculated the expected water quality volume in watershed inches that would result from a one inch storm event, given the impervious area. From this number, we were able to follow the Shortcut Method and determine the approximate volume of water that would exist after such a storm event. With this information, the surface area of the filter bed was found. The calculations for the sizing of the filter can be found in the appendix. Typically a sand filter should be kept at least 2 feet above the ground water table so as to prevent ground water contamination and structural damage to the filter.

"Pocket wetlands are constructed shallow marsh systems designed and placed to control stormwater volume and facilitate pollutant removal" (*Pocket Wetlands*). A pocket wetland is an eco-friendly way to remove stormwater contaminants using only native plants and resources. The main goal of a pocket wetland is to remove total suspended solids, heavier organic materials, E. coli, fecal coliform, oils/grease, and biochemical oxygen demand (BOD). The secondary purposes for a pocket wetland are to treat phosphorous, nitrogen, heavy metals, and floating debris. Naturally occurring native plants are commonly found in these constructed pocket wetlands, since non-native species are invasive and typically aren't ideal considering the wetland will be a prominent educational site. The flow path of a wetland can be seen in Figure 7.

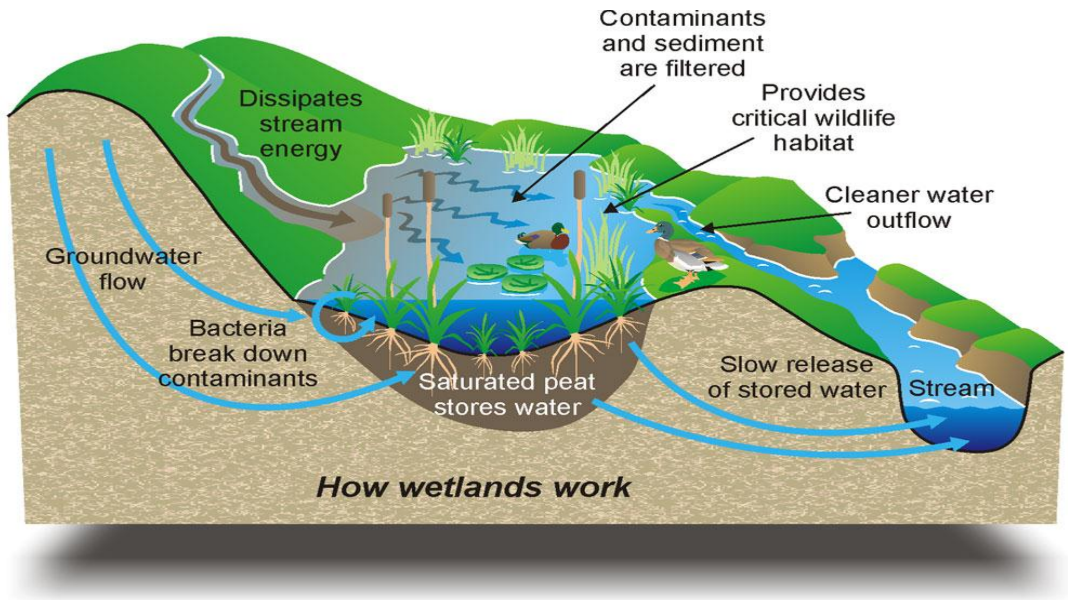

Figure 7: Wetland Flow Path
Image: Courtesy of "Aerial Snapshots of the Past: Beachwood, 1939"

A pocket wetland seems like an unlikely and rudimentary choice when choosing treatment processes for stormwater runoff. But, in reality, a pocket wetland is very effective when treating stormwater runoff. This is due to the fact that a constructed stormwater wetland varies greatly from an existing pond/ marsh wetland. "Stormwater wetlands are designed specifically for the purpose of treating stormwater runoff, and typically have less biodiversity than natural wetlands in terms of both plant and animal life" (*USEPA*).

The constructed wetland would receive flow from the sand filter. The filtration system would remove sediments and trash that would normally build up in the wetland. With the filter system in place, the need to dredge the wetland is no longer necessary. Once the water flows into the wetland, the depth will begin varying to help encourage settling. The *USEPA* says "Effective wetland design displays 'complex microtopography.' In other words, wetlands should include zones of both very shallow (< 6 inches) and moderately shallow (< 18 inches) water, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling, and it provides two depth zones to encourage plant diversity." Also, it has been shown that the wetland should be longer than it is wide to better promote downstream flow. The normal ratio is roughly 1.5:1 to ensure the water can't bypass any treatment zone. The last major design consideration is that the surface area of the wetland must be roughly 2-4% of the total drainage area to be treated.
Plants chosen for the wetland is another design consideration that has to be taken into account. Native plants are encouraged to be used versus using non-native plants that are found in most common marshes and wetlands. The University of Toledo could benefit from having a constructed wetland for an educational site, and native plants are a must to have an accurate portrayal of a local wetland. But, it must be made clear if the plants chosen are capable of biological uptake of the nutrients flowing through the wetland. "Vegetation in a wetland provides a substrate (roots, stems, and leaves) upon which microorganisms can grow as they break down organic materials. This community of microorganisms is known as the periphyton.

The periphyton and natural chemical processes are responsible for approximately 90 percent of pollutant removal and waste breakdown" (*Constructed Wetland*).

In conclusion, we feel that these two processes will work in cohesion to reduce contaminants reaching the Ottawa River, as well as slow the runoff flow and avoid excessive flooding in the Flatlands. The two processes are designed specifically to treat E. coli, coliform, and phosphorous that we have found in our runoff. They will also help to address the filtration needs through sand filters and sedimentation in the pocket wetland. The filter bed and pocket wetland will also serve a dual purpose on The University of Toledo's campus as a quality educational site to demonstrate green practices for stormwater runoff, as well as fulfill our requirements for the EPA Campus RainWorks Challenge.

Through the design we investigated, preservation was a top priority. Determined not to negatively impact the existing wetlands as shown in Figure 1, we chose a site more northerly to the river in hopes of avoiding the existing wetland on campus and develop a green stormwater infrastructure on the campus.

As shown on Figure 1, note that the existing wetlands are a distance that will prevent impact from our newly-designed system. By attacking water flooding and overflow in this manner, we can improve flood control, whereby the water quality will improve. Another benefit of this location is stabilization in terms of soil and erosion issues along with preserving the habitat that exists in these wetlands. In addition, by creating a new wetland, the existing wetland habitat will be expanded.

Integrated Water Management

Through the innovative designing of our infrastructure, the water that passes through the processes will also serve an additional purpose by adding to the natural elements found on campus. This water is known as "gray water" and is recycled and reused to water plants and other green features on campus at no additional cost. By collecting this water, we have the opportunity to attract more native species and pollinators to the area. The most crucial reuse of this water is within the wetland itself, keeping the plants alive. Gravity will control the flow of the water through the filter and into the drainage pipes located below the filter media. From there, the water will be directed into the wetland where it will meander through the selected plant life until it eventually reaches the micro pool. Here, the water will gain head and eventually flow up a reverse pipe until it reaches the standpipe. The standpipe directs the water through the final pipe down the slope and into the river. A flapper backwater valve will be located at the end of this pipe in order to prevent any backflow in times of flooding in the river. With this design, no pumps or additional equipment will be needed to keep the filter and wetland operational, as shown in Figure 8.

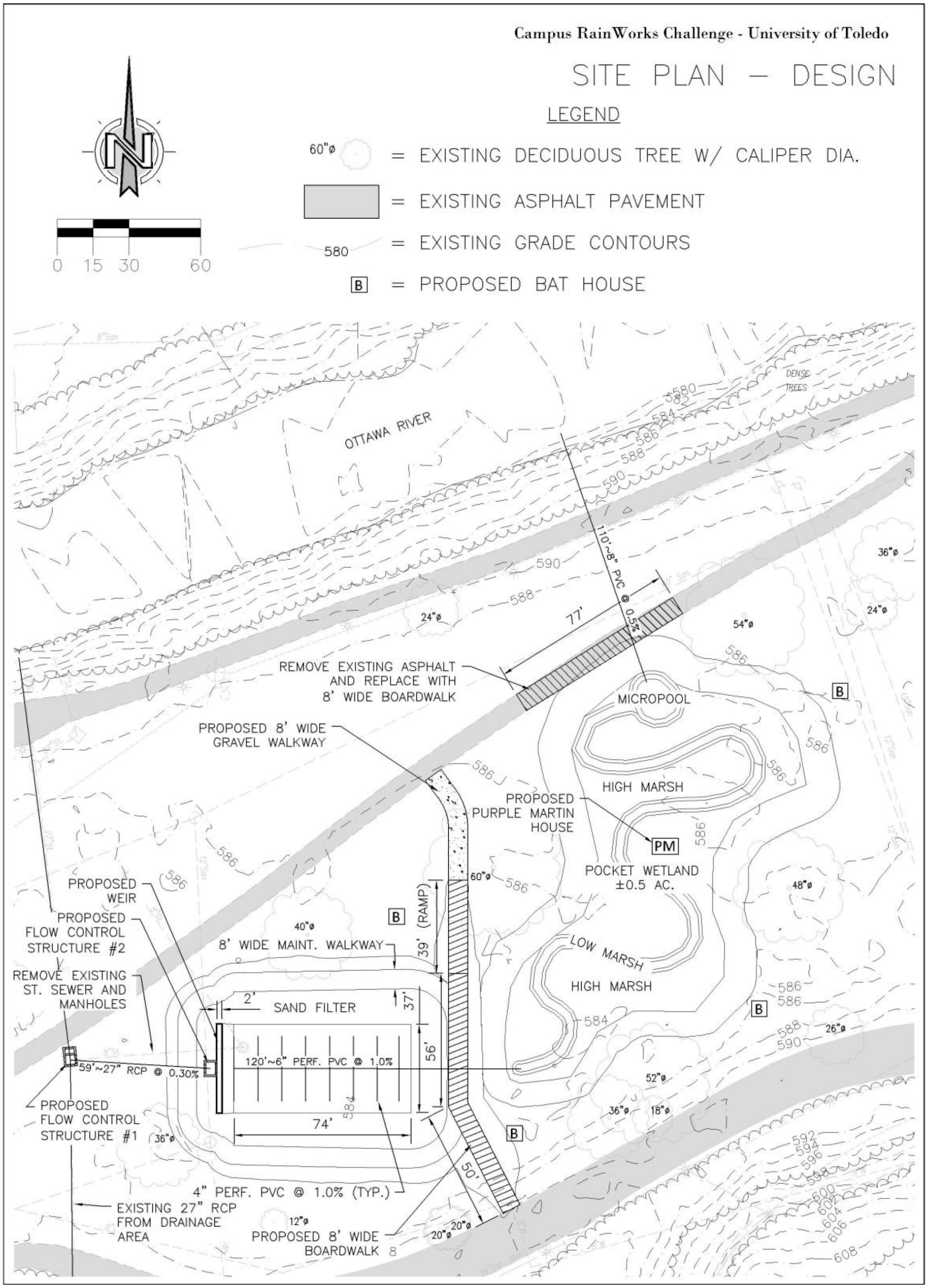

Figure 8: Site Plan - Design
Image: Courtesy of Courtesy of University of Toledo

The proposed design of a filter followed by a pocket wetland will reduce the impervious area by a total of 3.52 acres, or 153,331.2 square feet. The city of Toledo's annual rainfall averages at 33.21 in/year. The change in annual runoff depth from the existing and natural conditions in the drainage area where we are placing our design would be equivalent to 5.31 in/year of change.

Our stormwater collected at the site contained a significant amount of E. coli and coliform found in the water. With our new design, we will be able to remove a significant amount of the pollutants from the water prior to the water flowing into the river. Samples were taken from standing water in a manhole near the river and also from the river itself. The sand filter will be able to remove up to 80% of the bacteria, 85% of the total phosphorous, and 47% of the total nitrogen that enter. The pocket wetland will remove up to 78% of the bacteria, 56% of the total phosphorous, and 19% of the total nitrogen that remain following the sand filter. Estimated removal amounts of the bacteria are shown below in Table 2.

Table 2: Removal Efficiency		
Sand Filter Removal	**Coliform Removal Range (cfu/100mL)**	**E. Coli Removal Range (cfu/100mL)**
Tested from manhole	127,968	53,320
Tested from river	10,344	1,386
Pocket Wetland	**Coliform Removal Range (cfu/100mL)**	**E. Coli Removal Range (cfu/100mL)**
Tested from manhole	24,954	10,397
Tested from river	2,017	270

Table 2: Removal Efficiency

The existing peak flow for a 1 year, 24 hour storm comes out to 0.3553 ft^3/sec (Huff).

Soil and Vegetation Management

Nonpoint source pollution is considered the nation's leading source of surface and ground water quality contamination. Wetlands, including constructed systems, can intercept runoff and help mitigate nonpoint source pollutants like sediment, nutrients, and heavy metals without being damaged. Also, wetlands can keep stream channels intact by storing and slowing storm runoff (EPA 2012).

Microbial communities are an essential part of constructed wetlands. Microbes help maximize transformation and removal of pollutants by recycling nutrients. Microbial communities recycle nitrogen through nitrification and denitrification. These communities also contribute to sulfate reductions in the system through sulfate reducing bacteria and sulfur oxidation (Faulwetter et al. 2009). Aerobic heterotrophic microbes can remove phosphorus from the water by storing orthophosphates, these are also known as phosphate-accumulating organisms (EPA 2007).

Critical to the design of a constructed wetland system is the careful selection of featured vegetation. The uptake of heavy metals and nutrients by plants may be significant, and vegetation largely contributes to a wetland's aesthetic and habitat values (Bonilla-Warford 2002). In addition, increase in plant diversity will attract a wide variety of pollinators.

Plants chosen for the pocket wetland system are presented in Table 3. All plants are native to Ohio and included on the Ohio Department of Natural Resources' "Selected Ohio Native Plants For Landscape and Restoration Use" list (ODNR 2007). The chosen plants are relatively easy to maintain, thrive in moist soil conditions but can withstand inundations and arid periods, and are aesthetically pleasing, encouraging "school spirit" with blue and gold flowers to reflect the University of Toledo's official colors.

Table 3: Plants Chosen for Wetlands

<table>
<tr><th>Common name</th><th>Scientific name</th><th>Type</th><th>Pollinators</th></tr>
<tr><td>Blue flag iris</td><td>Iris versicolor</td><td>Forb - perennial</td><td rowspan="12">Bees, Bumblebees, Flies, Skipper Butterflies, Moths, Hummingbirds, leaf beetles, wasps, tiphiid wasp, sand wasp, potter wasp, thread-waisted wasp, bald faced hornets, orchard mason bees, halictid bees, verbena bees, swallowtail butterflies, skippers, honey bees, mining bees</td></tr>
<tr><td>Blue lobelia</td><td>Lobelia siphilitica</td><td>Forb - perennial</td></tr>
<tr><td>Blue vervain</td><td>Verbena hastata</td><td>Forb - perennial</td></tr>
<tr><td>Boneset</td><td>Eupatorium perfoliatum</td><td>Forb - perennial</td></tr>
<tr><td>Dark green bulrush</td><td>Scirpus atrovirens</td><td>Graminoid</td></tr>
<tr><td>Marsh marigold</td><td>Caltha palustris</td><td>Forb - perennial</td></tr>
<tr><td>Nannyberry viburnum</td><td>Viburnum lentago</td><td>Deciduous - shrub</td></tr>
<tr><td>Silky dogwood</td><td>Cornus amomum</td><td>Deciduous - shrub</td></tr>
<tr><td>Soft rush</td><td>Juncus effusus</td><td>Graminoid</td></tr>
<tr><td>Swamp goldenrod</td><td>Solidago patula</td><td>Forb - perennial</td></tr>
<tr><td>Tussock sedge</td><td>Carex stricta</td><td>Graminoid</td></tr>
<tr><td>White turtlehead</td><td>Chelone glabra</td><td>Forb - perennial</td></tr>
</table>

Table 3: Plants Chosen for Wetlands

Routine maintenance on the wetland will be conducted by University of Toledo student volunteers from the Department of Environmental Sciences, the Department of Civil Engineering, and the Society for Environmental Education. As recommended by the EPA, routine maintenance shall include semi-annual removal of invasive plant species, annual inspections for sediment buildup and damage to embankments and inlet/outlet structures, monthly removal of litter and other debris, and removal of sediment buildup from the inlet/outlet areas once every five to seven years (EPA 2012).

The design of the constructed wetland will also include several educational aspects so that the University of Toledo community will be able to gain new insights to these systems and the benefits they provide. A boardwalk with benches will be constructed through the wetland to allow access and highlight the uses and benefits of green stormwater systems. The boardwalk will also feature educational signs, each one explaining a different feature of the wetland, to allow self-guided educational tours of the wetland system. Because the wetland will be constructed in a heavily populated area, the attraction of mosquitoes and other potential pests is of some concern. To combat this, several bat boxes and purple martin houses will be installed throughout the wetland. It is our hope that these habitats will encourage the presence of these two important insectivores that will help control the mosquito population.

Value to Campus

The design we came up with was based on a design that adds aesthetics, accessibility, and educational value to the campus of The University of Toledo. In recent years, The University of Toledo has gained attention for its efforts in green construction for projects such as the completed, certified green renovation of the Memorial Field House. This project would also add recognition to the University's efforts to form a green environment that will appeal to the greater public and serve as an example for other public entities and corporations to follow. The campus averages around 30,000 site users per year if you were to include the professors, students, friends and family of students, and fans. The plan for this particular design is located in such a spot that when students visit the University and attend orientation, they will be able to view this new, creative green design.

Likelihood of Implementation

In 2005, the UT President's Commission on the River was established, which resulted in fundraising (over $400,000). These funds are being applied toward several projects including restoration of the approximately 4000 square feet of river located on the UT main campus, which will be completed in August of 2013. To date, this work has focused on stream restoration and has not emphasized stormwater treatment and management. This project proposes the implementation of a stormwater best management practice (BMP) on UT campus adjacent to the Ottawa River as a synergistic project to the ongoing river restoration work.

Because of our use of existing features of the site, the likelihood of the implementation is high. This design would add more character to the site that is aesthetically pleasing as well as being located in a central area on the campus. This allows high accessibility for students, faculty, guests and the general public. The opportunity to educate these audiences on green infrastructure will be very convenient. The efficacy of the design speaks for itself in its use of existing space and structures.

After consulting with stakeholders, emphasis was put on solving the issue of water quality, which would benefit all users. In addition, this projects educational value is clear to the campus and to those interested in promoting green renovations and upgrades to inefficient sites such as the one that exists now.

Capital costs for this project would be approximately $270,000 to implement all parts of the design including preparation and construction for both the sand filter and the pocket wetland.

The lifecycle costs for this site, which includes operations and maintenance, would be roughly -$479,160 for the life of the sand filter and $46,000 for the life of the pocket wetland. There is no cost at this time for the existing site as no action is occurring there.

The University would have to gather funding sources or corporate partners to implement this design. Recently, the University of Toledo has introduced a Green Fund to move forward with the green initiatives put forth by the University. This particular fund is a collection of money that comes from the University's login website where the students opt-in, in order to donate $5.

Therefore, it is easy to see the high likelihood of implementation of our green infrastructure design. Other potential gifts and support could come from a variety of sources including multiple possibilities of monies available to green projects on the federal, state, and county levels which may include grants such as: The Clean Water Act 319, possible Green Grants allocated under the American Recovery and Reinvestment Act (ARRA), Surface Water Improvement Fund (SWIF), and the Great Lakes Restoration Initiative (GLRI). Other opportunities for funding may also be state construction grants for universities, federal grant funding, and possible alumni donations. The financing strategy for implementation of this design may be to introduce the idea to the rest of the University, its alumni, the city of Toledo, and corporate partners.

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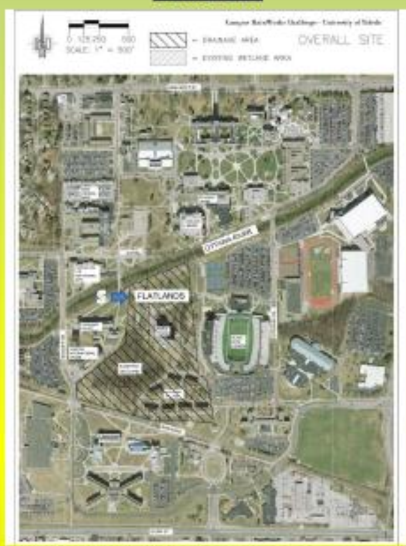
Campus RainWorks Challenge

A Green Infrastructure Design Challenge for Colleges and Universities, US EPA Office of Water

Campus Flatlands, The University Of Toledo - Toledo, Ohio

Thomas Bachmayer, Robert Bowser, Elizabeth Bussing, Eric Finger, Lauren Mccafferty, Courtney Mobilian, Joseph Perchinske, Daniel Toris, Alexander Welfle

Background



- University of Toledo Campus
- Drainage Area = 22 Acres
  - 16% Impervious (3.52 ac.)
- Ottawa River Cuts Through Campus
- Average annual rainfall (Toledo) = 33.21 in./year

Constraints

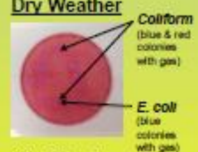
Decision Table	Sand and Organic Filters	Pocket Wetland
Functional	Sufficient area and minimal impact to infrastructure	Sufficient area and minimal impact to infrastructure
Life-Cycle	Biannual-annual maintenance	>20 years, annual maintenance
Economical	$100,000-$300,000	$80,000 for a one acre facility
Ecological	Removes suspended solids, phosphorous, nitrates, and metals and reduces stormwater flow	Removes suspended solids, phosphorous, nitrates, and metals and reduces stormwater flow and promotes natural habitat and diversity
Quality of Design	Yes	Yes
Legal/Ethical	Yes	Yes
Aesthetically Pleasing	Yes	Yes
Safe	Yes	Yes

Flatlands

Contaminants

Manhole — Dry Weather

River — Dry Weather



Manhole — Wet Weather

River — Wet Weather

Alternatives

Pocket Wetland

Pros:
- Economic
- Low maintenance
- Slows flow of stormwater runoff
- Promotes natural habitat and diversity

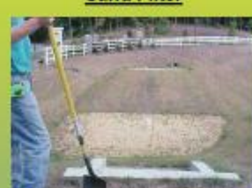
Cons:
- Can take up a large area
- Will freeze if not enough flow or depth

Sedum (Green) Roof

Pros:
- Reduces stormwater runoff
- Recharge groundwater
- Opportunity to reduce flooding

Cons:
- Reduced strength
- Higher installation cost than asphalt; however lower life cycle cost

Sand Filter



Pros:
- Economic
- Low Maintenance
- Filters large drainage areas
- Can be concealed underground

Cons:
- Can be destroyed by high water table
- Possibility of freezing in winter

Pervious Pavement

Pros:
- Reduces stormwater runoff
- Recharge groundwater
- Opportunity to reduce flooding

Cons:
- Reduced strength
- Higher installation cost than asphalt; however lower life cycle cost

Removal Efficiencies

TYPICAL POLLUTANT REMOVAL RATES (%)		
	Sand Filter	Pocket Wetland
TSS	< 90	< 71
TP	< 65	< 56
TN	< 47	< 19
Bacteria	< 80	< 78
(US EPA 2012)		

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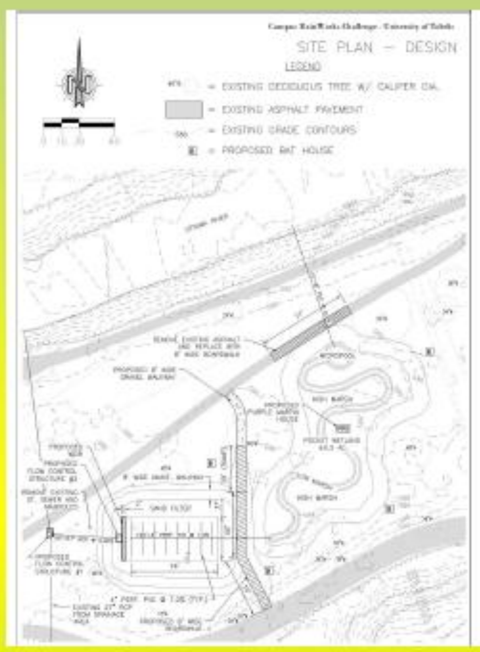
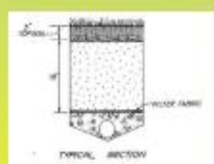
Design



Sand Filter



Pocket Wetland

Bat House

Purple Martin House

Plant Chosen for Wetland

Common name	Scientific name	Type	Pollinators
Blue flag iris	Iris versicolor	Forb - perennial	Bees, Bumblebees,
Blue lobella	Lobelia siphilitica	Forb - perennial	Flies, Skipper
Blue vervain	Verbena hastata	Forb - perennial	Butterflies, Moths,
Boneset	Eupatorium perfoliatum	Forb - perennial	Hummingbirds, leaf
Dark green bulrush	Scirpus atrovirens	Graminoid	beetles, wasps, tiphiid
Marsh marigold	Caltha palustris	Forb - perennial	wasp, sand wasp,
Nannyberry viburnum	Viburnum lentago	Deciduous - shrub	potter wasp, thread-waisted wasp, bald
Silky dogwood	Cornus amomum	Deciduous - shrub	faced hornets,
Soft rush	Juncus effusus	Graminoid	orchard mason bees,
Swamp goldenrod	Solidago patula	Forb - perennial	halictid bees, verbena
Tussock sedge	Carex stricta	Graminoid	bees, swallowtail
White turtlehead	Chelone glabra	Forb - perennial	butterflies, skippers, honey bees, mining bees

Cost

	Sand Filter	Pocket Wetland
Original Costs	$75,000 (in year 1994)	$57,000 (in year 1997)
Inflation Rate	3% (assumed)	3% (assumed)
Costs in 2012	$115,000	$80,000
Annual Maintenance	$5,750	$4,000
Lifecycle Maintenance (20 years)	$115,000	$80,000
(Weiss et al., 2005) (Schueler 1994)		

Potential Funding

- Clean Water Act 319
- Possible "Green Grants" Allocated Under The American Recovery And Reinvestment Act (ARRA)
- Surface Water Improvement Fund (SWIF)
- Great Lakes Restoration Initiative (GLRI)
- University of Toledo "Green Fund"
- State construction grants for universities, federal grant funding, and possible alumni donations