Department of Civil Engineering

Senior Design Project

Fall 2011

Final Report for

Ottawa River East Storm Water Remediation Project

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COLLEGE OF ENGINEERING
THE UNIVERSITY OF TOLEDO

Department of Civil Engineering
Senior Project

Executive Summary Report

Main Campus – Storm Water East

Fall Semester 2011

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Problem Statement

The University of Toledo has asked for an evaluation of the section of the Ottawa River running though main campus, with regards to present contaminants. Additionally, there have been concerns that the university contributes large flows during heavy rainfall. The Ohio EPA has previously been on campus and noted discharge points belonging to the university as areas of concern. Our group has been tasked with determining potential eco-hazards and large flow concentrations discharged by the university, as well as developing solutions for any problems encountered.

Objectives

- Examine the university's storm water discharge into the Ottawa River for major health and ecosystem hazards.
- Determine areas of campus that contribute to heavy storm water flow and look to reduce.
- Trace outfalls from the river back to source(s).
- Evaluate possible solutions to reduce pollution and storm water flows into the Ottawa River.
- Establish a plan to put solutions into effect with limited installation and continued maintenance costs.

Constraints

- Funding by the University of Toledo and supporting agencies
- Available space on campus for proposed solutions
- Preservation of animal habitats along the river
- Maintaining the aesthetic appeal of the University's campus
- Ease of construction
- Sustainability and reliability of low maintenance costs

Solution Approach

It is very important that the concerns about volume and quality of water discharged by the university be addressed and corrected. Solutions will be evaluated based on:

- Initial capital involved with installation
- Aesthetic appeal to the university
- Maintenance costs and possible LEED certifications
- Design creativity
- Ability of design to change based on future needs

Schedule

Proposal submittal and presentation to the GEPL delivered October 7, 2011. Final presentation to Geological Department Chair and interested member of the university community will be delivered the week of December 5, 2011. The design project will be showcased in the University of Toledo Senior Design Expo December 9, 2011 with a final report being turned in December 9, 2011.

Economics

Estimate for construction materials and installation will be delivered with final report.

Implementation Potential

Each solution will be evaluated on the basis of constructability within the campus limits, feasibility, and sustainability. A strategy for implementation will be delivered with the final report.

Conclusions and Recommendations

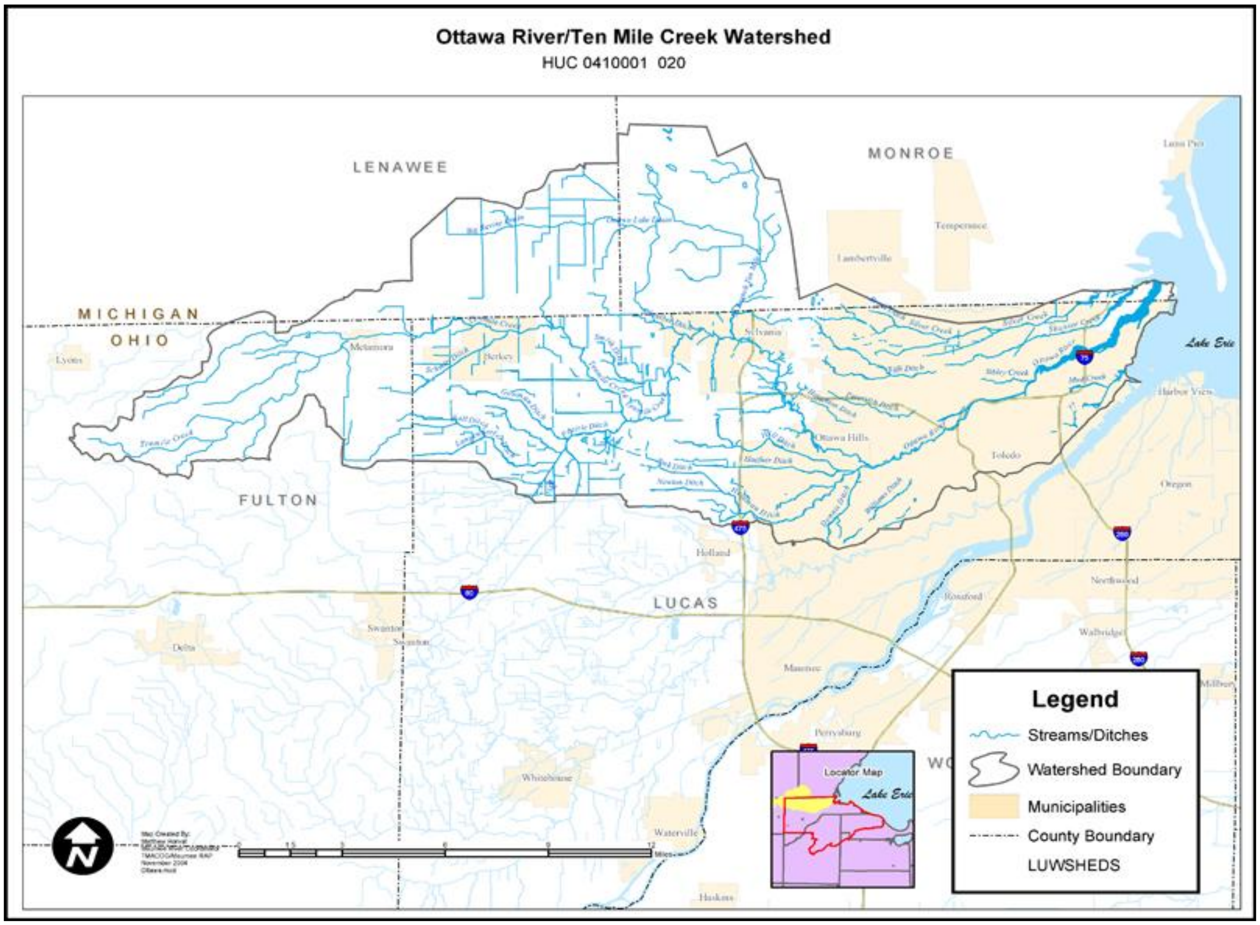
Summary of design project will be included after final design.

- Overall design of flow reduction and contaminant treatment system
- Area of impact associated with construction
- Estimated costs associated with project implementation
- Benefits from installing designed system

Ottawa River Background Information

Located in the center of The University of Toledo's main campus is the Ottawa River; originating in Fulton County and running through Lucas County to eventually draining into Maumee Bay and Lake Erie. The Ottawa River was established with the connection of two creeks; North Ten Mile Creek and Ten Mile Creek. Roughly 48 miles in length, with 220 square miles of drainage basin and an average slope of four feet per mile, the Ottawa River is home to approximately 40 species of fish. Figure 1 below shows a map of the Ottawa River and Ten Mile Creek watershed

Figure 1: Ottawa River/Ten Mile Creek watershed map



Unfortunately, signs are posted through The University of Toledo's campus stating "Due to water pollution this area of the river is unsafe for swimming, skiing, other water activities and fishing. Fish caught in this area may be contaminated and unsafe to eat" as seen in Figure 2. Maintenance of the river is done primarily by the cities and municipalities through which the river passes. (Restoring The Ottawa River.)

Figure 2: Picture of Ottawa River warning sign

The river has been the center of cleanup dating back to the 1990's and heightened after the publication of the Ottawa River Risk Assessment in 2001 by the Ohio EPA. This document declared the river a risk due to high concentrations of metals, PCBs (polychlorinated biphenyl), as well as DDT (dichlorodiphenyltrichloroethane). PCBs are typically used as dielectrics and coolants for refrigerated systems. DDT was a commonly used pesticide until it was banned from use in agriculture between 1970 and 1980. These contaminants had heavy concentrations in sections of the river downstream of The University of Toledo. Pollution is still a concern through the length of the Ottawa River due to land use and human activities; slow flow and runoff from contaminated sources such as landfills and sewers are major factors in the river's poor water quality. Because the river drains into Maumee Bay, it is seen as one of the major causes of Lake Erie's pollution problems. (Restoring The Ottawa River.)

The responsibility of cleaning and maintaining the Ottawa River stands as a responsibility for all the surrounding cities within its watershed. The University has been, and will continue to focus on, efforts to maintain or improve water quality through campus. Banks rise 18 feet on average above the water surface and are very unstable. The river through campus also has extreme variations in water level; the water level can be seen as low as one-to-two feet in some areas during dry weather and suddenly spike to 15 feet in depth during heavy rain falls. This increase in water level can cause flooding in areas of the campus such as the "Flat-lands" located between the tennis courts and the river as well as the low lying area near Savage Hall and McMaster Hall. The University of Toledo is interested in addressing the quality of the Ottawa River, especially in regards to storm water runoff, as well as improving the aesthetic appeal of the campus. (Restoring The Ottawa River.)

Problem Statement and Constraints

Problem Statement

The water quality of the Ottawa River has been a concern for the University of Toledo for many years. High levels of contamination such as dissolved solids, oils and greases, and nutrients have been a large concern along with the suspicion of E. coli being present. The Environmental Protection Agency (EPA), combined with The University of Toledo, has flagged a few areas of storm water concern. To address these concerns, two cases need to be addressed: short term solutions (in-situ treatment of current storm water) and long term (ways to reduce quantity of flow into the Ottawa River) solutions.

Short term solutions to the contaminants in the water involve finding a way to reduce contaminants into the Ottawa River given the current rate of flow of storm water into the river. During various site visits, the Storm Water East Senior Design Group identified three areas of concern along the banks of the Ottawa River. Through testing of samples collected from each of the three sites, The Senior Design Group determined that the following water quality benchmarks need to be addressed:

- Conductivity
- Coliform presence
- Dissolved oxygen (DO)
- Biochemical Oxygen Demand
- pH

Currently, storm water is collected from various parts of campus, and is drained into outlets along the river. Certain university outfalls are of concern because the source of flow and potential pollutants are unknown. Even during periods of little to no rain fall, these outfalls still exhibit steady flow. Some of these outlets also have raised levels of solids and dissolved solids, suggesting that there may be sanitary sewer issues as well.

Long term solutions to the storm water issue involve finding a way to reduce the amount of storm water runoff that is being drained into the Ottawa River on campus. As stated above, most storm water collected on campus is drained into the Ottawa River. By reducing the amount of flow, you in turn reduce the amount of contaminants in the water.

Constraints

Limiting factors for our design proposal have been established as:

- Funding by the University of Toledo and supporting agencies
- Available space on campus for proposed solutions
- Sustainability and relatively low maintenance costs
- Preservation of animal habitats along the river
- Maintaining the aesthetic appeal of the University's campus
- Ease of construction

It is important that the proposed solution meets all environmental standards set by the EPA and the University of Toledo. Construction needs to be simple and easy to install without interrupting the everyday flow of the campus.

Location

Figure 3: Aerial view of University of Toledo identifying areas of concern

Site Information

Figure 3 shows an aerial view of the three locations selected on The University of Toledo campus. More detailed pictures of each location can be seen in Figures 4-12.

Location A (Figures 4-6)
(35' between Location A and B)
18" diameter pipe, 27' from river
Flow rate = approximately 8 gal/min (wet)

Location B (Figures 7-9)
(35' between Location A and B)
21" diameter concrete pipe, 34' from river
Flow Rate = approximately 4 gal/min (wet)

Location C (Figures 10-12)
21" diameter red clay pipe with flapper, 32' from river
Flow rate = approximately 5.5 gal/min (wet)

Site Identification

Figure 4: Location A

Figure 5: River to Location A

Figure 6: Location A to river

Figure 7: Location B

Figure 8: River to location B

Figure 9: Location B to river

Figure 10: Location C

Figure 11: River to location C

Figure 12: Location C to river

Water Quality

Testing samples from the three outfalls of concern will provide a benchmark to determine the quality of water discharging into the river. Additionally, water testing will also indicate where the water is originating allowing for more treatment options to be explored. Both the University of Toledo and the Ohio EPA have suspected high levels of contaminates being released from the identified points. During dry weather, flow from these outlet points is still present, raising question of both where it's coming from and what it contains.

Multiple samples were taken from September 2011-October 2011 at each location during wet and dry weather to ensure that the full spectrum of potential hazards could be identified. During winter months higher levels of conductivity is to be expected due to the addition of road salts. During times of heavy rainfall, higher levels of suspended soils along with oils and greases will be flushed from the parking lots into the river.

Due to the flows observed during dry weather, the Ohio EPA has suggested that a cross connection between storm water and wastewater lines could be present; such a connection would result in wastewater E. coli contamination of the discharging waters.

To ensure the most infallible collection of water discharge, the sample was taken directly from the pipe outlet point without contacting any outside sources such as soil or surrounding river water. Each sample bottle was filled and flushed with outfall water prior to sample collection. Each bottle was accurately labeled, sealed, and stored until tests were conducted.

The following tests were conducted on each sample:

- Dissolved Oxygen (DO)
- pH
- Total Organic Carbon (TOC)
- Turbidity
- Escherichia coli (E. coli)
- Biochemical Oxygen Demand (BOD)
- Conductivity
- Total Suspended Solids (TSS)
- Chlorine (only on Location C)
- Nitrates
- Phosphorus

Procedures for each test can be found in Appendix A.

An example of what the US EPA considers healthy levels is provided below:

(Based on USEPA Gold Book – standards are safe for fish habitats and human contact)

- DO: 0.5 mg/L
- pH: 6.5-8.2
- TOC: 300 µg/L
- Turbidity: 5 NTU safe for human swimming
  80 NTU shown to cause death to microscopic invertebrates
  5000 NTU shown to directly cause fish deaths
- Coliform: Less than 235 colony forming units 235 CFU/100 mL
- BOD_5: 2-8 mg/L
- Conductivity: Expected levels of 300-700µs/cm
- TSS: ≤ 1000 mg/L expected for ecosystems containing mixed cultures of fish
- Chlorine: >0 begins to affect aquatic life
- Nitrates: >0.5 mg/L begins to impact aquatic life
- Phosphorus: 0.1 mg/L is recommended maximum for rivers and streams

These characteristics are what an ideal river should contain and what we are trying to create in the Ottawa River. As evident through sample collection, the three outlet points in this study are not main contributors to all the water quality issues present in the river. While the three outfall points do show some signs of water contamination, E. coli was not identified at any of the locations. Figure 13 below shows the E. coli test for Location A, B, and C along with a sample taken from the river.

Figure 13: E.Coli Results from Dry (1) and Wet (2) Samples

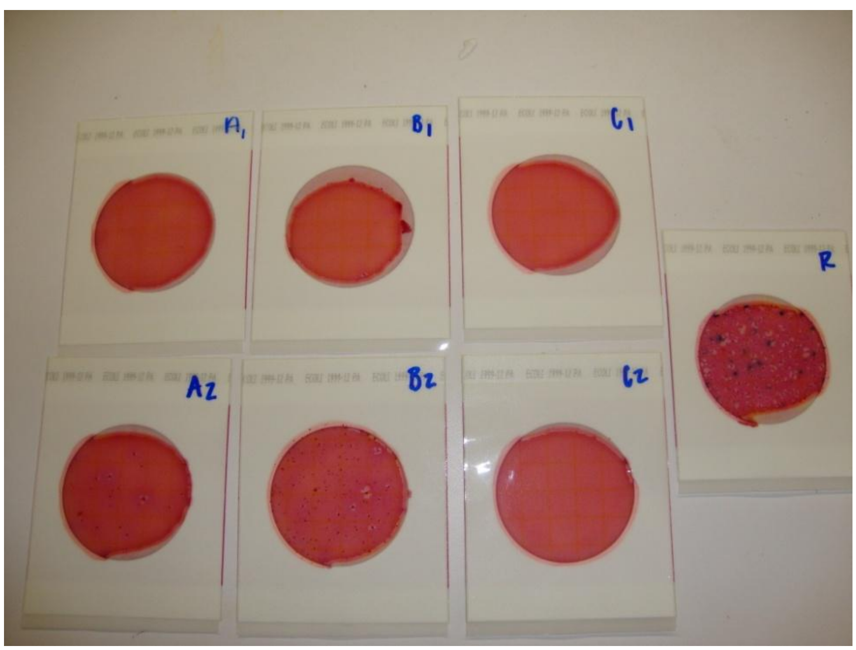


Figure 14: River Sample Showing E.coli

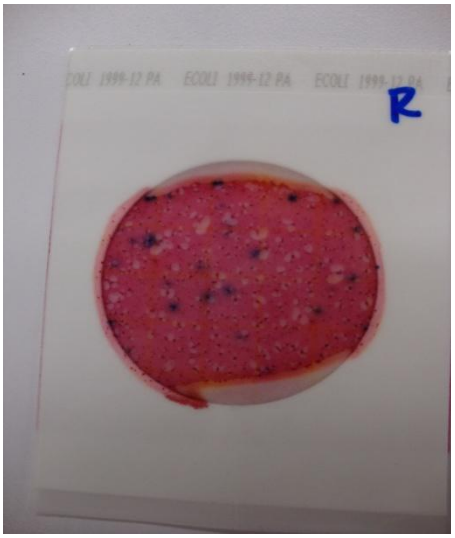
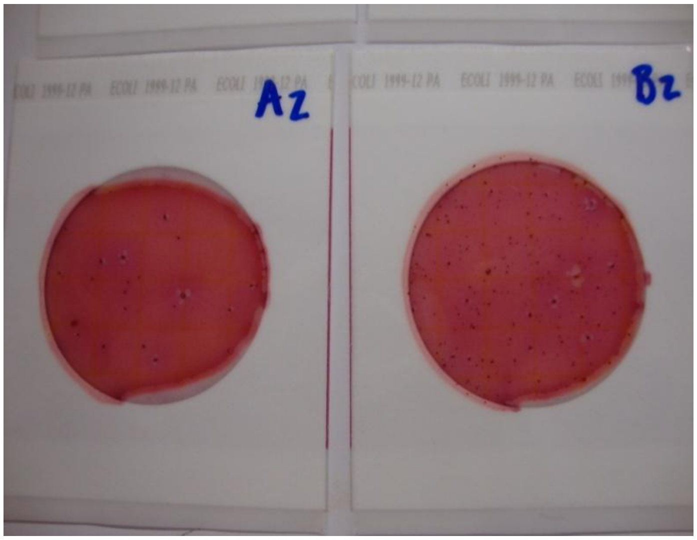


Figure 15: Location A & B wet samples showing Coliform



The blue colonies associated with entrapped gas are confirmed E. coli as seen in Figure 14 above whereas the red colonies associated with gas bubbles are confirmed coliform (Figure 15), but not counted as E.coli. E.coli presence can indicate that human or animal waste is polluting the water, and although normally benign, some E.coli strains may be deadly. The river sample was collected downstream of locations A, B, and C, indicating that further testing of the river water upstream is needed. NOTE: More sample pictures are posted in Appendix B.

It has been speculated that septic systems in the Ottawa Hills residential neighborhood are in disrepair and could be a source for sanitary system water seeping into the groundwater or river, eventually making way to the Ottawa River. Ottawa Hills is located to the west of the University of Toledo's campus approximately two miles upstream.

The problems that are evident in the outfall at **Location A** include:

- Conductivity (dissolved ions) – 1640 μs/cm, more than twice the normal level
- Coliform present
- Nutrients present

The problems that are evident in the outfall at **Location B** include:

- Total Organic Carbon (TOC) – 29.7 mg/L, about 10 mg/L above normal level
- Conductivity (dissolved ions) – 1948 μs/cm, almost 3 times normal level
- Biochemical Oxygen Demand (BOD) – 2 mg/L
- Coliform present
- Nutrients present

The problems that are evident in the outfall at **Location C** include:

- Chlorine present - 0.4 mg/L (at 0.25mg/L only the hardiest fish can survive)

Figure 16 below shows the chlorine test conducted on sample taken on 10/11/11 at Location C. The sample the far left is deionized water, middle sample is tap water, and far right is the sample from Location C. The darker the shade of pink in the sample the higher the chlorine level present.

Figure 16: Chlorine test; deionized, tap water, sample 10/11/11 Location C

Tables with test results from each sample and location can be seen in Appendix C.

Knowing the contaminants in the sample will help pinpoint the unknown sources of flow. Tracing back the storm water lines will help confirm the test results and reveal ideas to minimize storm water runoff to prevent the pollution at the source.

Field verifications of each outfall needed to be performed to better identify why particular contaminants were present. During the field verification, each of the three outflow sources was traced back to the place of pipe origin.

The field verification of **Pipe A** yielded the following:

- The catch basin leading directly to the river contained a 4" overflow pipe, hinting the location has experienced heavy flows at certain times
- Upon verifying the final catch basin in the system, it was determined that Pipe A was responsible for draining much of Centennial Mall, located on the North side of The University of Toledo
- Much of the storm water from Centennial Mall is collected from one of two sources: roof drains or catch basins located along walkways and parking areas near Centennial Mall
- Based on the verification of storm lines, it was concluded that sanitary system lines did not intersect the storm water system for Pipe A

Field verification of **Pipe B** yielded the following:

- A 4" overflow pipe is tied into Pipe B from Location A
- Location B was traced back under the Health and Human Services building, and could not be verified as to where the pipe goes

Field verification of **Pipe C** yielded the following:

- Location C is fed primarily from roof drains off of McMaster Hall, as well as catch basins near parking areas around McMaster Hall
- Location C was found to have flow at random times. This is due to a storm water sump pump located in McMaster Hall
- No sanitary systems seemed to be tied into the storm water system, and this has been confirmed based on our water quality tests

Based on the water quality data, as well as field verification of each pipe location, short-term and long-term solutions can be researched. The following solutions are all viable solutions to address the problem(s) at hand.

Possible Solutions

As part of the design process, the group has developed six different solution alternatives to the given water quality issues. Solution types have been broken down into in-situ (in stream) and out of stream. In-situ solutions are to treat the current water quality issues at the pipe outfall before entering the river, whereas the out of stream solutions are treating the water at or closer to the source. The in-situ solutions are more immediate and short term options, and the out of stream solutions are more long term and sustainable. The six solutions options our group has identified are outline here and detailed further in the following pages.

In stream:

- Wetland biofilter
- Activated carbon filter system

Out of Stream:

- Biological screening system
- Permeable pavement
- Storm chambers
- Rainwater harvesting

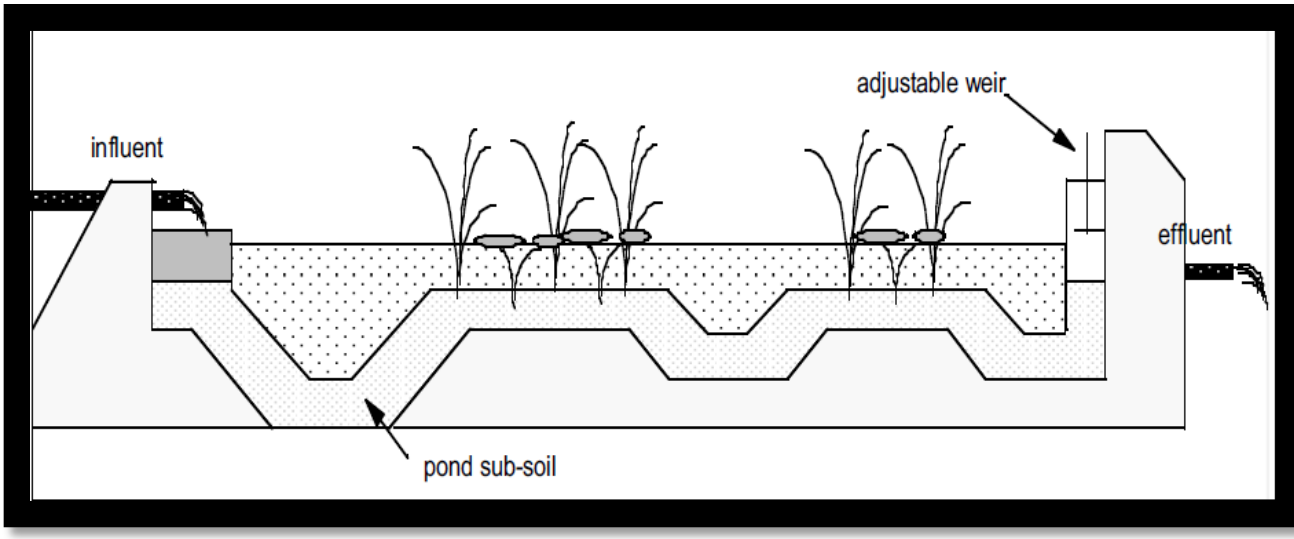
In Stream Solutions

In-situ solutions offer the benefit of immediate treatment for contaminants being released into the river, without needing to identify the contaminant origin. This would allow for a stronger ecosystem to develop within the Ottawa River quickly. The high river banks would reduce visibility of any installed systems, allowing for water treatment without detracting from the aesthetic appeal of the surroundings.

Wetland Biofilter

One potential solution is to install a bio-filtration area enclosing Locations A and B and the area up to the edge of river bank. In the design below (see Figure 17) water from the outfalls at Locations A and B would flow into the wetland filtration system, be treated, and the flow out into the river. The river banks will also keep the treatment systems hidden from view, providing protection for the system.

Figure 17: Wetlands surface flow filtration design



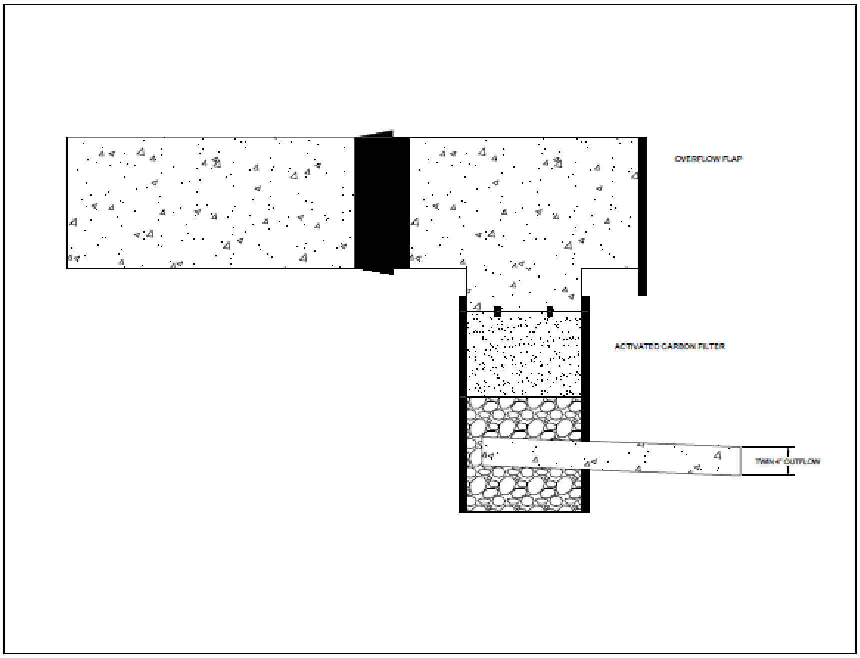
The area between locations A and B would serve as a good location to install a surface wetland, collecting water from both outfalls. Water would then be filtered through the installed media and allowed to clarify for a duration of time before being dispelled into the Ottawa River. The base layer of the surface wetland could be constructed with a variation of pervious pavement covered with several layers of biofilter media and plants. This would also aid in the reduction of erosion for the surrounding area, preventing soil movement during heavy rain falls. In the event of a heavy rain (5 year storm or greater), excess water would travel over the top of the wetland (not absorbed into the filter media) and flow directly into the river, thus reducing a backflow or pooling of water.

One disadvantage to this system would be the constructability. Because the base of the surface wetland is a man-made material, it would require more labor than installing strictly plant/filter based solutions; this would also increase the overall cost of the solution. Materials to construct the base, retaining sides, and headwalls of the structure would require the use of some heavy machinery. Compared to the other in situ solutions described in this report, the wetland biofilter will contain the most amounts of inorganic materials.

Activated Carbon Filter System

Another in-situ solution is a media filter design with the main treatment material of activated carbon. A circular filter with media would be placed outside the end of each out flow pipe connected by a T-pipe. The water would flow out of the outflow pipe, into the bottom of the T, through the filter and gravel bed, finally being discharged into the river via corrugated pipe. When a flow is reached that the filter cannot handle, the water would flow out the open end of the T as the overflow exit. Figure 18 shows an example of what an activated carbon filter system would look like.

Figure 18: Activated carbon filter system drawing



An activated carbon filter design would consist of activated carbon, sand, gravel and other filter media. This filter would clip onto the T-pipe and have a hinge connected to the outflow pipe allowing easy access to the filter for maintenance. Once the carbon has run its life cycle, the filter will be removed and replaced quickly and simply. Figure 18 above is an example of what an activated carbon filter looks like.

To minimize erosion, a product from Proesto Geo systems can be placed along the steep banks and filled with soil or rock and topped with SubmergeSeed and other plantings that will grow vegetation that can sure shoreline habitats and also treat overflow water from containments.

Out of Stream Solutions

Preventing the entry of contaminants into a water system is much more cost effective and efficient than treating the flow after contamination. Source control is the first step in keeping pollutants out of the system and eventually out of the river. Capturing the contaminants close to the point of origin and minimizing the runoff flow is the main goal of any source control design.

Biological Screening System

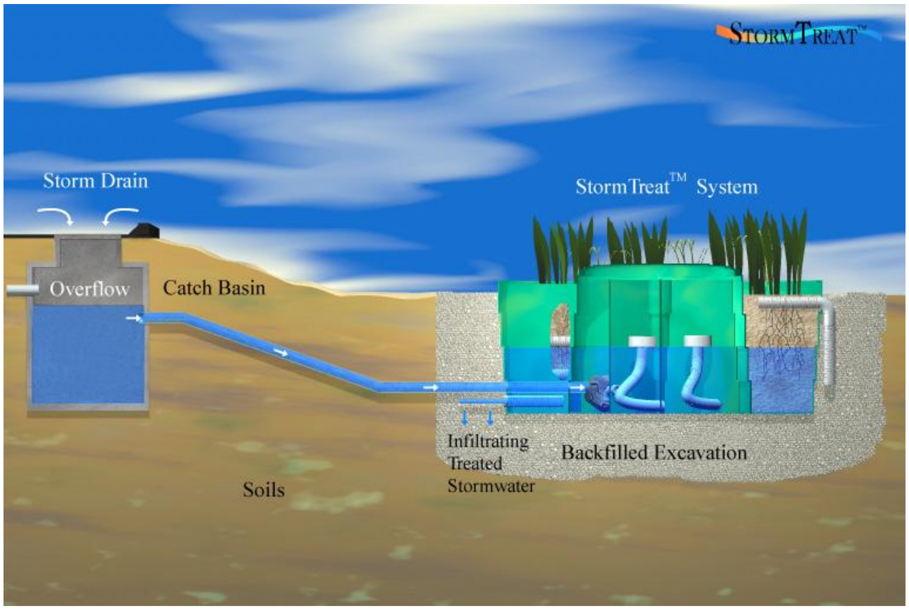
One possible solution to reduce the flow and increase the quality of run-off water into the Ottawa River is a biological screening system. There are several types that are established on the market known as Stormceptor, Stormtreat, Vortechnics, and HIL Downstream Defender. These systems are different primarily in patent right but similar in overall layout. The systems consist of influent piping, a retention area, metal filters, biological filters, and regulated effluent piping.

These systems can be installed to remove:

- Grit
- Suspended solids
- Biological Oxygen Demand (BOD)
- Petroleum Products (oil and fuel from paved areas)
- Hydrocarbons
- Metals
- Nitrogen
- Phosphorus
- Bacteria (Coliforms)

Two kinds of units are typically installed, recharge and closed. A recharge unit is used to cleanse run-off water and allow it to reenter the environment through soil absorption. Closed units are installed as a portion of an entire loop of water treatment. The best choice for University of Toledo's needs would be the recharge unit, which would be used to treat and release water to be absorbed in surrounding soils, gardens, or runoff into the Ottawa River. Figure 19 shows a profile schematic of what an installed biological screening system.

Figure 19: Typical schematic of bio retention/filtering system



This system would be beneficial to the university because it is easily installed in small areas. Each Unit measures roughly 9.5' in diameter and 4' deep. The units are installed in groups and are connected in parallel to new or existing manholes or drain runoffs. The biological filter itself consists of gravel, soil, and plant life. The plant life would add to the benefits of the system in that the University could still maintain its aesthetic appeal, as seen in Figure 20 below.

Figure 20: Outside view of biological retention/filtering system

System maintenance consists of:

- Vacuuming out solid buildups (Typical every 3 years)
- Maintaining installed plant life and replanting new species when they lose their absorbing ability or die (Plants lose the ability to absorb contaminants over time, namely phosphorus.)
- Physical removal of objects in grit screen (Done easily through central access)
- Establish a maintenance record to establish regularly cleaning methods for specific system
- Inspect all hoses, screens, and pipes for damage at least once a year and replace as needed

Applicable areas of installation:

- To collect runoff from parking lots and garages known to contain oils and greases as well as high concentrations of salt in the winter months.
- To control flow from large roof areas that drains into the main storm sewer lines.
- To collect large quantities of runoff water and treat it for storage and use as grey water.

Permeable Pavement

Permeable pavement is a road surface option that allows storm water to run through the pavement, acting as an initial filter before the storm water re-enters the ground water. This type of pavement is constructed with air voids throughout the surface, allowing water to run freely through the pavement, as seen in Figure 21. Figure 22 on the following page provides a breakdown of the general composition of permeable pavement.

Figure 21: Water flow through permeable pavement

Advantages of permeable pavement:

- Large reduction of storm water flow into the Ottawa River
- Considered a “green” technology, allowing for potential LEED certification
- Storm water runoff filtered as the water runs through the permeable layer

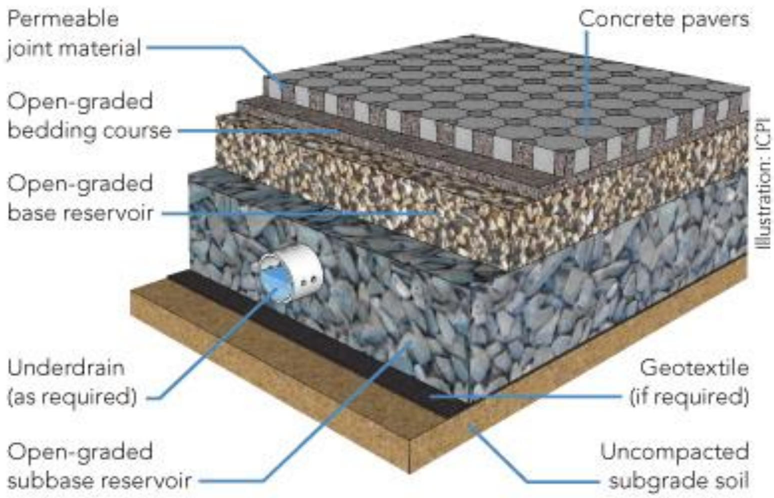
Disadvantages of permeable pavement:

- The freeze/thaw cycle Toledo experiences could be detrimental to the quality of length of life for the pavement
- Not durable enough to stand up to heavy traffic (i.e. trucks, heavy loads, etc.)

Some recommended areas of application:

- Savage Arena parking areas
- Centennial Mall, connecting most of the walkways students use between classes

Figure 22: Example of permeable pavement used for walkway surfaces



Storm Chambers

Another out of stream solution for dealing with water quality issues involves the idea of underground detention ponds. A company called StormChamber has developed a system that collects storm water underground. This system helps treat storm water where other systems are lackluster. Storm chambers help with retention, detention, and storm water reuse such as gray water. These systems are successful at removing nutrients and other contaminants by taking advantage of the soil properties on site. The system contains a "sediment trap," eliminating the need for a pre-treatment system can be seen in Figures 23 and 24.

Figure 23: Group installation of storm chamber

Figure 24: Sediment trap for storm chamber

The system is extremely lightweight, as well as high in strength, withstanding up to three times the AASHTO H-20 load rating. Other advantages of StormChamber can be seen below:

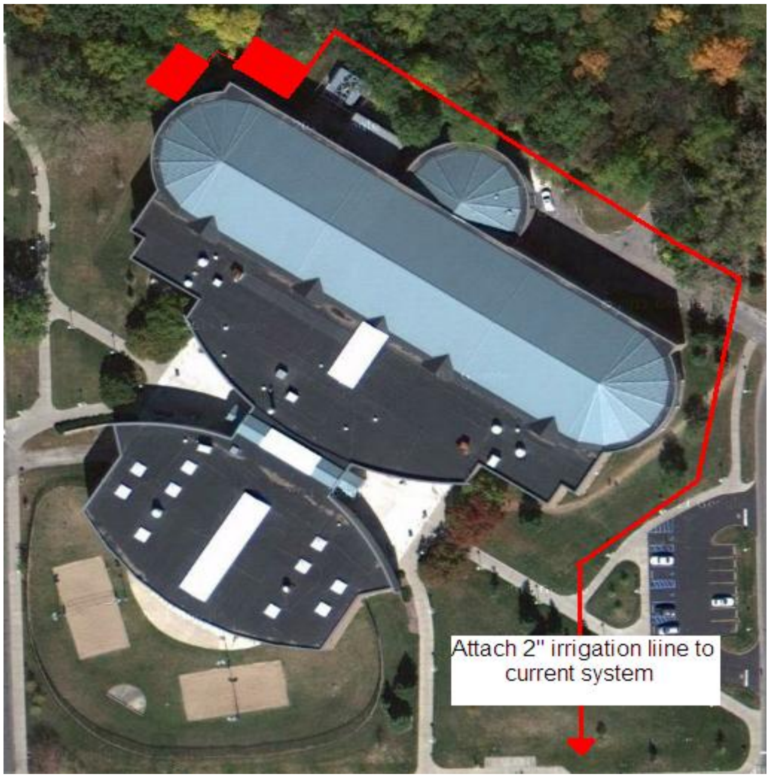
- Extremely cost effective in regards to removing sediment (i.e. from parking lots)
- Easy and inexpensive to install

- Effectively removes high levels of pollutants through soil filtration and bio-remediation
- Green technology, capable of up to 18 LEED points
- Effective under or around parking areas, due to high strength of the system

Rainwater Harvesting

To reduce flow on the South East part of campus a rainwater collection system can be placed on the Student Recreation Center and attached the holding take to the Carter field Irrigation system, as seen in Figure 25. Currently The University of Toledo is using ground water to water Carter Field and the proposed systems would complement that water use.

Figure 25: Placement of rainwater collection tanks at the UT Recreation Center



A similar system can be used in Carter Hall which to reduce storm water flow further in this area of campus.

Benefits of rainwater harvesting:

- Potential LEED points on each building
- Reduction in storm water flows into the Ottawa River
- Reduce the smell of sulfur by using rain water instead of ground water

Selected Solution Design

After reviewing all potential solutions, the group determined to move forward with two in-stream solutions and two out-of-stream solutions. The in-stream solutions included the wetland biofilter and activated carbon filter designs. Out-of-stream solutions included the rainwater harvesting system for The University of Toledo recreation center and installation of permeable pavement. Detailed designed of each of the selected solutions can be seen in the following section.

Rainwater Harvesting:

Because rainwater harvesting was one of the solutions of interest to the client the group wanted to highlight the works of another group in the Senior Design class working solely on rainwater harvesting at the University of Toledo campus. The group has currently developed plans to harvest rainwater at the University of Toledo Law Center and Rocket Hall. These same designs could be expanded to incorporate the areas around University of Toledo Recreation Center.

Wetland Biofilter:

Design:

There will be 1" diameter reinforcing dowels driven into the aggregate base at two foot intervals along the biofilter to strengthen the filter, and three 4" diameter perforated pipe placed at the bottom of the filter will facilitate drainage. At a flow rate of 12 gpm the tank will not overflow. Overflow can be expected in the case of heavy rainfall. The filter will simply overflow the top of the system. By driving dowels and placing 304 erosion control aggregate, system overflows will not damage the structural integrity of the system. Figure 26 provides an example of a wetland biofilter profile.

Figure 26: Example of a Wetland Biofilter

Drawings/Specifications:

NOT TO SCALE

Figure 27: Wetland biofilter section view

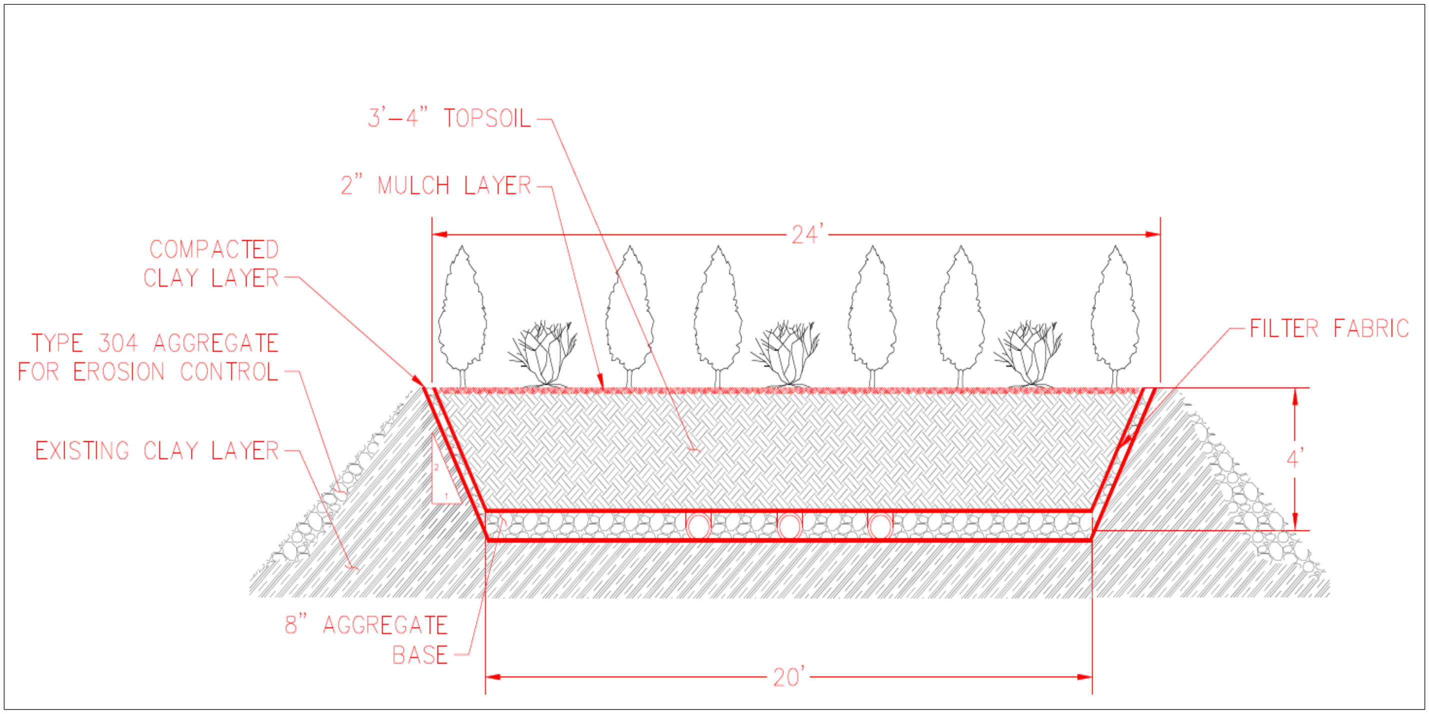
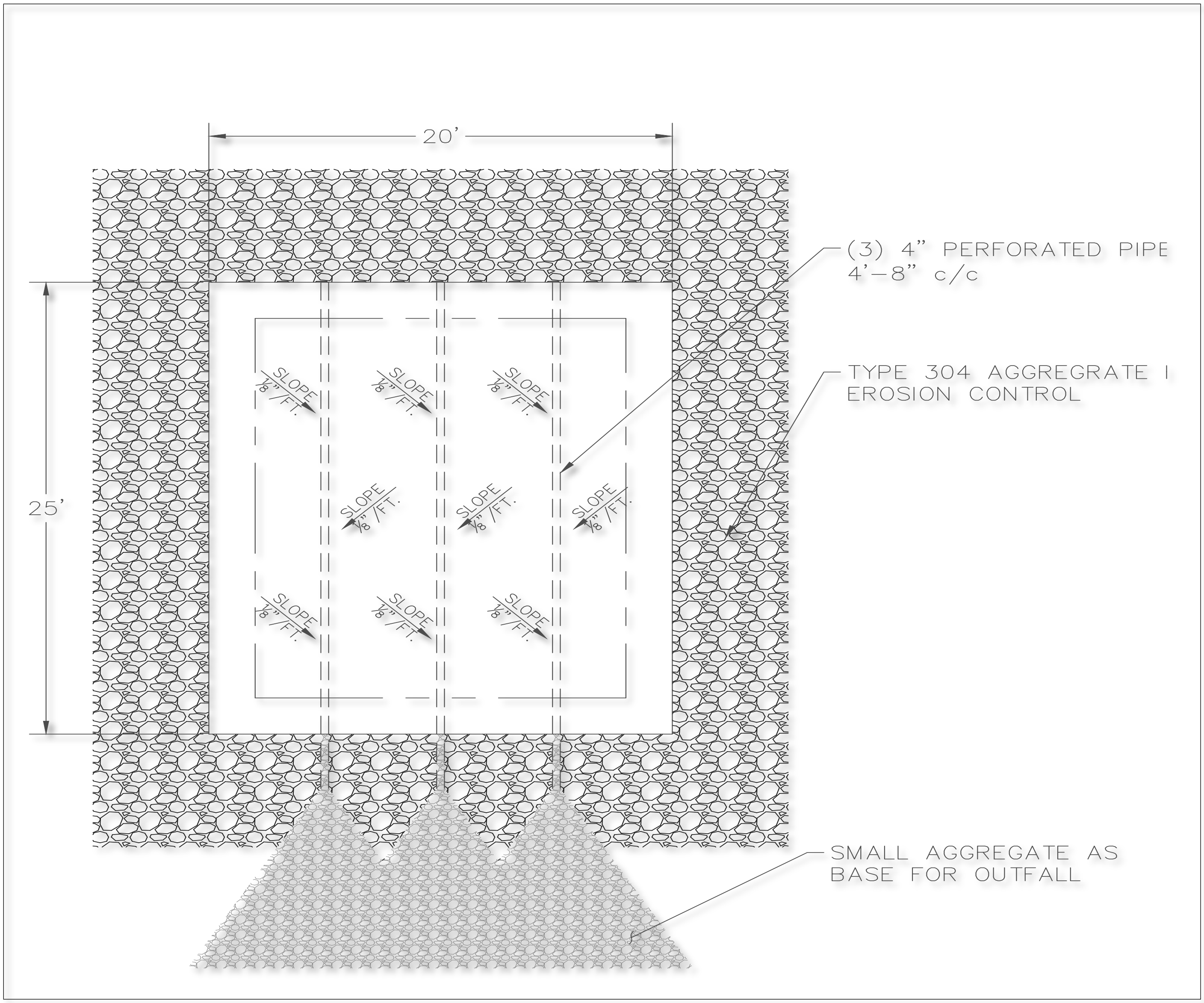


Figure 27 is a section view of the wetland biofilter designed. Figure 28 on the following page is a plan view of the designed wetland biofilter. The layers and thickness of the filter material will be, from bottom to top:

- 2" Clay Underlay (compacted to size to prevent seepage)
- 8" No. 25 Aggregate
- Filter Fabric (Minimum 120# tensile strength)
- 3'-4" Sandy Loam Soil (k value = 0.50 min)
- 2" Mulch Overly

Figure 28: Wetland biofilter plan view



Flooding is a major concern that was taken into account for the design of the filter system. The system will sit within the river bank and will be constructed at an elevation that can be expected to flood in the event of substantial rainfall. The bio retention filter was designed to withstand the pressures of flooding through reinforcement. Filter fabric, vertical reinforcing dowels, and exterior erosion control aggregate will together reinforce the structure. One possible alternative that could reduce the risk of flooding and washout would be to install the filter system above the riverbank.

Installing the system above the river bank rather than in river bed would require different construction methods. The outfall pipe would have to be demolished back to accommodate an acceptable elevation, and the filter system would need an additional outfall height of roughly ten feet. This would require a significant amount of demolition and additional excavation. We are unaware of the exact slope of the pipe, but visual inspection shows a very shallow slope. It appears that excavating back along the pipe would not increase the elevation enough for a significant change to the filter position. The only way to determine if this is a feasible option would be to physically trace the storm system and determine actual elevations of the pipes. Installing the filter system above the river bank would reduce the risk for flooding and remove any costs associated with reinforcement of the system but would increase the excavation costs as well as add costs for pipe tracing and demolition. It is in the best interest of the funding agencies to build the system in the river, reinforce it according to plans, and plant species of vegetation that can handle the increased water levels.

Plants:

Below (Figures 29-33) are the selected Ohio plants to be used in the filtration process. Each plant selected lives well in wet soils and/or standing water along with drought for 3-4 days. They can be found in many rain gardens in the Ohio area.

Figure 29: Cardinal Flower

Cardinal Flower (Lobelia cardinalis)

- Herbaceour perennial 5-15cm tall
- Produces red, two-lipped flowers
- Easy to grow, capsules captured in the fall
- To harvest, cut two node stem cuttings (4-6 inches) before flowers open, remove lower leaf and half of upper leaf
- Hummingbirds are attracted to the nectar

Figure 30: Eastern Purple Coneflower

Eastern Purple Coneflower (Echinacea pirpirea)

- Perennial herb 0.5-2 feet tall
- Rough hairy stems, mostly unbranched
- Flowers are heads similar to sunflowers, redish purple to lavender in color
- Takes three to four years for roots to reach harvestable size

Silky Dogwood (Cornus amomum)

- Primarily used as wildlife boarders or windbreaks and streambank stabilization
- Large shrub, 6-10 feet in height
- Lives very well in Great Lake states
- Should be examined each spring after heavy runoff period has ended

Figure 31: Silky Dogwood

Swamp Rose (Rosa palustris)

- Fruits eaten by wildlife
- Stems are tall, around three feet in height
- Flowers are pale pink, and berries are red
- Common in marshes and swamps
- Pruning should be done to remove blossoms

Figure 32: Swamp Rose

White Turtlehead (Chelone glabra)

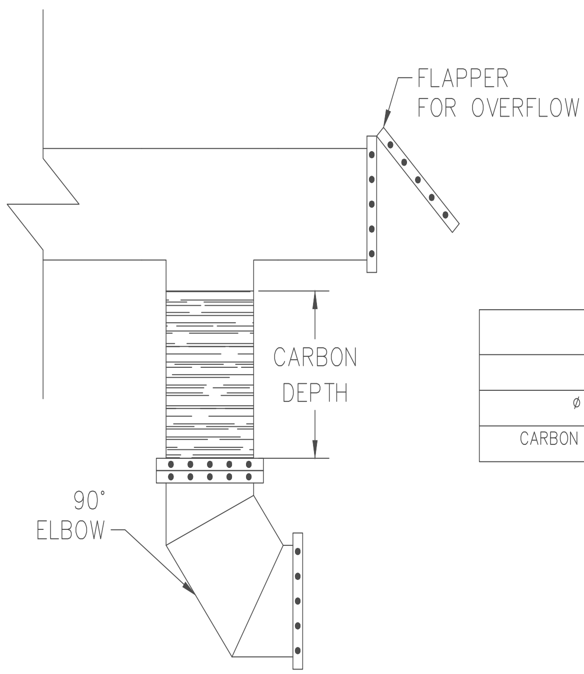
- 2-3' tall
- Wet to moist conditions
- Fertile soil containing some organic matter
- Temporary flooding is tolerated
- The flowers are pollinated by bumblebees; sometimes they also attract the Ruby-Throated Hummingbird
- Blooming period occurs from late summer to fall and lasts about 1½ months

Figure 33: White Turtlehead

Activated Carbon Filter:

Granular activated carbon has the capabilities to remove most of the containments that have been found in the storm water at each outfall location. To design the depth of the filter carbon absorption must be determined. In order to determine specific carbon absorption a Methylene-Green Dye test is completed and the data is used to determine the amount of carbon needed to remove contaminants. See Appendix E for additional information regarding the Methylene Green Dye test. Figure 34 is a section view of designed carbon filter along with activated carbon filter schedule.

Figure 34: Carbon Filter section view



ACTIVATED CARBON FILTER SCHEDULE

	LOCATION A	LOCATION B	LOCATION C
Ø	1'–6"	1'–9"	1'–9"
CARBON DEPTH	2'–10"	1'–4"	1'–4"

In order to supply sufficient carbon to treat the outflow water, the above design was selected. If carbon were to be placed along the bottom of the pipe the filter would need to be nearly 20 feet long and become a challenge to replace and handle. With the design selected the filter will be easily maintain and accessible for replacement. It will also allow for a filter design that uses the entire cross-sectional area of the pipe.

Each filter is designed for constant wet flows, in Toledo over a sixth month period there are 52 wet days. This creates a safety factor of 3.5 which insures that the filter will still be functioning at full capacity at end of its sixth month life expectancy.

Table 1: Carbon filter design

Location	Pipe Diameter	Depth of Carbon
A	18”	34”
B	21”	16”
C	21”	16”

Table 1 above shows the pipe diameter, and carbon depth required at each outfall location. Minimal maintenance will be needed at each filter because debris will be able to flow over the filter and out the overflow flap. The filters will be bolted down to surrounding concrete structures so the filter will not move or become dislodged with heavy river or outfall flows.

Granular activated carbon has the ability to effectively target:

- Chlorine
  - The EPA does not recognize GAC as a removal media for chlorine, but after many laboratory tests GAC is proving to be the best media for removal.
- BOD
  - Laboratory testing has proven GAC to effectively remove BOD at a rate of up to 70% depending on flow rate and concentration.
- TOC
  - GAC can remove any organic or ionized compound, and is incredibly effective at removing carbon based containments.

Other additives such as phosphorus will be needed to remove nitrates in the storm event outflows. Special GAC formulations can be made to remove nutrients, but that could become extremely costly to design and test for the correct formulation.

Permeable Pavement:

Permeable pavement provides a valuable storm water management tool under requirements of the EPA Storm Water Phase II Final Rule by reducing the overall runoff and level of runoff contamination for the designed area. Unlike traditional pavement, permeable pavement allows water to flow through and drain into the aggregate and soil beneath. Because permeable pavement is most typically used in areas of low-volume pavements, parking lots, residential roads, sidewalks, and pathways the Centennial Mall of the University of Toledo's main campus was chosen for pavement replacement based on the low vehicular traffic and high foot traffic.

The main benefit would be runoff reduction because few oils and/or greases will be accumulating from pedestrian traffic. Figure 35 is an aerial view of the Centennial Mall area on the Main Campus of The University of Toledo including the surrounding roadways to be included in the permeable pavement design. Figure 36 is an image of the current section of pavement in the area. This proves as a good example of the lack of uniformity and need for overall improvement.

Figure 35: Photo of Centennial Mall area

Figure 36: Current pavement in Centennial Mall

Increased air voids in permeable pavement reduce the harmful effects of the freeze-thaw process during the winter months. Fewer water droplets would remain on the pavement surface, when frozen the concrete can expand into the gaps between the aggregate. Reduced damage from freeze-thaw will increase the overall life of the pavement. Icing will also be significantly limited for the permeable pavement sections which will increase safety of individuals walking during the winter months, and limiting the amount of road salt that will be needed to keep the area clear. To enhance the efficiently of the permeable pavement, a steam line has been designed into the aggregate base of the pavement to be installed. This will additionally aid the necessity for deicing or snow removal during the winter.

Installation of the permeable pavement requires less intensive labor techniques compared to traditional pavement. Because additional compaction is not warranted during the installation of permeable pavement fewer pieces of machinery are required for installation. Maintenance of permeable pavement requires a sweeper-vacuum system. This would need to be used on the pavement at least four times a year (approximately once per season) to insure the pavement is working to the highest effectiveness.

Design

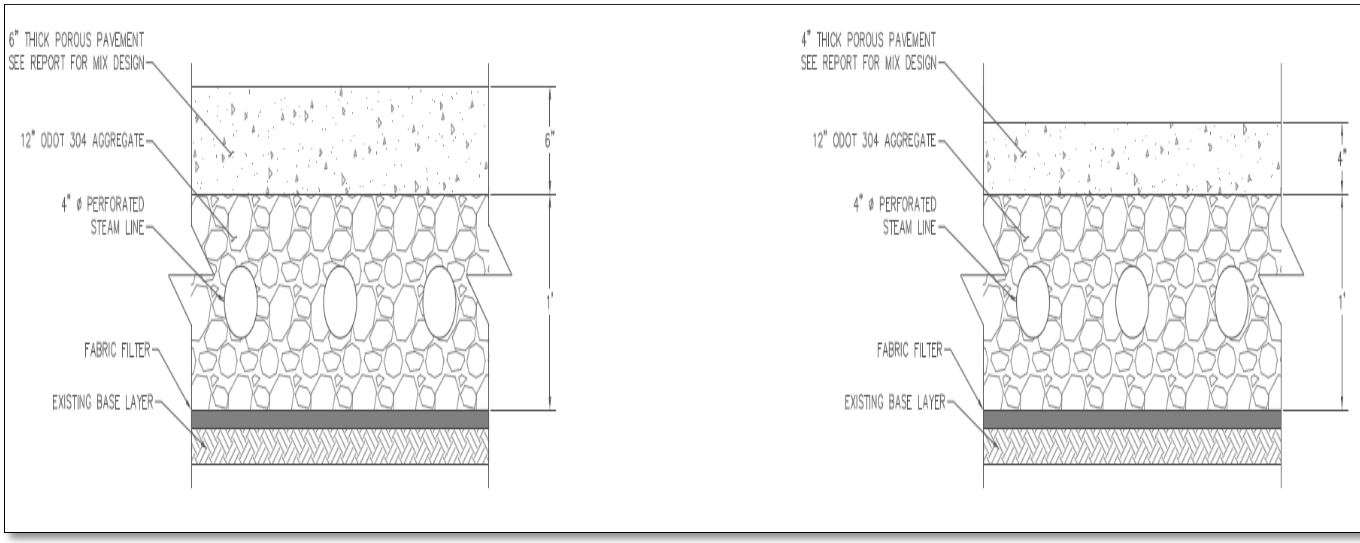
Pavement design was completed using the ODOT Rigid Pavement Design Charts (302-2 & 302-3) see Appendix D for detailed design chart used.

Design of the permeable pavement to be used was based on a 20 year design life and an average of 15 ESAL trucks per day. Typical pervious pavement design parameters were used (given by Kuhlman Concrete) and are as follows:

Depth of stone = 12" (used 12 inches for allow for pooling in heavy rain event)
ESAL's/20 years = 109.200 trucks
E_{STONE} = 30,000 psi
$E_{CONCRETE}$ = 5,000,000 psi
S'_C = 700 psi
J = 3.2
C_d = 1.0

Upon completion of the design procedure, it was determined that the thickness of the pervious concrete shall be 6” for the roadway surfaces, and 4” for the walkway surfaces. A 12” aggregate base has been included (instead of the typical 6-9” base used in most pervious concrete designs) to account for pooling in an extra heavy rain event due to the high levels of clay in the soil in the Centennial Mall area. Below the aggregate base is a layer of filter fabric which will lie on top of the existing, non-compacted soil. This filter fabric will help hold the system together, keeping the aggregate base from entering into the existing soil. A cross section of the pavement design can be seen in Figure 37.

Figure 37: Permeable pavement cross section



Economics and Schedule

Economics

An economic breakdown for the wetland biofilter can be seen in Table 2 below along with a breakdown for the plant cost in Table 3. Tables 4 and 5 are economic breakdowns for the activated carbon and permeable pavement designs respectively.

Table 2: Wetland biofilter economic analysis

Quantity	Description	Daily Output	Unit	Material/Labor Total	Labor Hrs.
67	Excavating, trench or continuous footing, common earth, 3/4 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	270	B.C.Y.	$ 335.00	1.99
13	Aggregate, includes material only, for trucking 10 miles, add	78	C.Y.	$ 133.25	1.33
67	Soil preparation, mulching, aged barks, 3" deep, hand spread	100	S.Y.	$ 389.94	5.36
81	Geosynthetic soil stabilization, geotextile fabric, non-woven, 120 lb. tensile strength, includes scarifying and compaction	2500	S.Y.	$ 106.11	0.26
80	Subdrainage Piping, plastic, perforated PVC, pipe, 4" diameter, excludes excavation and backfill	314	L.F.	$ 703.20	2.04
3	Rip-rap and rock lining, random, broken stone, machine placed for slope protection	62	L.C.Y.	$ 157.68	0.39
38	1/2" Reinforcing Wood Dowels	50	E.A.	$ 163.40	6.08
5	Backfill, 6" layers, compaction in layers, roller compaction with operator walking, add to above	100	E.C.Y.	$ 34.20	0.40
66	Backfill, structural, sandy clay & loam, 50' haul, excludes compaction	1070	L.C.Y.	$ 59.40	0.49
	Selected Greenery, as described (Table 3)	36	E.A.	$ 252.00	8
	Total			**$2,334.00**	**26.34**

Table 3: Wetland biofilter plant economic breakdown

Plant	Quantity (#)	Unit Cost ($)	Total ($)
Cardinal Flower	4	4.00	16.00
Purple Coneflower	4	4.00	16.00
Silky Dogwood Bush	4	29.95	120.00
Swamp Rose	4	15.00	60.00
White Turtlehead	2	20.00 (1 gal pot)	40.00
TOTAL			**252.00**

Table 4: Activated carbon filter economic analysis

Location	A	B	C
Carbon	$ 816.20	$ 510.20	$ 510.20
Tee Fitting	$ 129.56	$ 899.90	$ 899.90
45˚ Fitting	$ 409.23	$ 702.22	$ 702.22
Pipe	$ 492.60	$ 576.60	$ 576.60
End Flap	$ 101.79	$ 143.79	$ 143.79
Metal Screens	$ 28.10	$ 28.10	$ 28.10
Total (per filter)	$ 1977.48	$ 2860.81	$ 2860.81

Table 5: Permeable pavement economic analysis

Item	Cost
Materials and Equipment	$1.50
Labor	$4.55
Aggregate Base Delivered to Site	$1.56
Filter Fabric	$0.10
Pervious Concrete Delivery Charge	$2.10
Total Cost per Square Foot	$9.81

Schedule

Fall 2011 Semester

Scope Presentation to Class – Thursday, October 6, 2011

Final Scope Due – Friday, October 7, 2011

Final Presentation to Client – Tuesday, November 29, 2011

Senior Design Expo – Friday, December 9, 2011

Final Report Due - Friday December 16, 2011

Conclusion

The Ottawa River has been flagged as a problem area by the Environmental Protection Agency for years. Recently, the University of Toledo has approached the Storm Water East Senior Design Group to analyze the water quality coming from the eastern portion of campus, which drains directly into the Ottawa River.

Once samples were collected from each of the three (3) sites the group has targeted, water quality tests were performed. The tests included items such as the BOD test, E. coli, and TOC. The results from these tests have allowed the Senior Design Group to start analyzing short and long-term solutions for dealing with the contaminants entering into the Ottawa River.

Considering an economical design, the Senior Design Group began the design phase of the project. Uneconomical solutions were eliminated, which left the group with four different solutions:

1. Rainwater harvesting
2. Wetland Biofilter
3. Carbon Filter
4. Permeable pavement

Rainwater harvesting has been analyzed by another senior design group, and should be referenced for further information. Taking economics, aesthetics, and creativity of design into account, the Senior Design Group has design a wetland biofilter to be placed at Location A, an Activated Carbon filtration system to be placed at all locations of interest. Finally, a permeable pavement system will be installed in all walkways and private drives in the Centennial Mall area. These solutions effectively reduce contaminants entering the river, as well as help reduce the quantity of flow into the river.

Upon conclusion of the design phase, the Senior Design Group has recommended and designed the most effective, cost minimizing solution to the water quality/flow quantity issue they were presented with.

Persons Contacted

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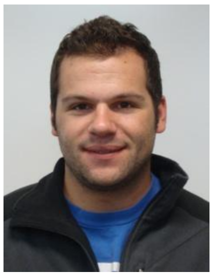
Qualifications of Group Members

Ashley Frey



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OBJECTIVE

To secure a challenging position in the field of Civil Engineering in order to enhance my knowledge and work experience.

EDUCATION

August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering; Business Admin. Minor

- Anticipated Graduation Date: December 2011
- Grade Point Average: 3.594

COMPUTER SKILLS

- Microsoft Office Suite 2003-2010
- Experience with AutoCAD 2007
- Microsoft Windows 95/98/XP/Vista/7

.
EXPERIENCE

May 2011-Present

The Toledo Zoo, Toledo, Ohio
- Customer Service/Cashier

May-August 2008-2010

Lake County Engineers, Painesville, Ohio
Engineering Co-op
- Worked on designs using AutoCAD and ARCMap
- Worked directly with professional engineers and surveyors
- Inspected roadway and storm water construction and repairs
- Conducted/analyzed traffic counts and speed studies

September 2006-August 2007

Dave's Cosmic Subs, Mentor, Ohio
- Receptionist/Cashier
- Restocked shelves

June 2005-August 2005

A.C.E Tennis Camp, Highland Heights, Ohio
Club Ultimate Fitness & Sports Club
- Tennis Instructor for children

COLLEGIATE ACTIVITIES & AWARDS

- University of Toledo Women's Varsity Tennis, Captain 2011
- Full Athletic Scholarship
- Tower Prestige Scholarship
- Presidents List 2008, 2011 Deans List 2008, 2010
- Student Athletic Advisory Committee

SPECIAL SKILLS & INTERESTS

- Well organized and effectively manages time
- Thrives on challenges and works well under pressure
- Motivated and dedicated to the task until completion
- Enjoys working with others and being team orientated

REFERENCES

Available upon request.

THOMAS HASSON

11221 Hampshire Ct.
North Royalton, OH 44133
440-590-3421
Thasson@rockets.utoledo.edu

OBJECTIVE

To secure a cooperative education position in the Civil Engineering field that will complement my academic endeavors with hands-on experience.

EDUCATION

August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering
Minor in Economics

- Anticipated Graduation Date: December 2011
- Grade Point Average: 3.098

EXPERIENCE

January 2011 - Present

AQUABLOK Ltd. (Hull & Associates Inc.)
Sales and Marketing Intern

- Target market research
- Marketing preparation for trade shows

May 2008- August 2008
May 2009- August 2009
May 2010- August 2010

Ohio Department of Transportation, District 12
Project Inspector/Internship

- Daily work reports
- Grade test/ Concrete tests
- Small individual projects

June 2005-August 2007

(Summers)

The City of Parma, Service Department Parma, Ohio
Summer Labor

- Cleaned buildings
- Cut grass
- Maintained streets

\COMPUTER SKILLS

Microsoft Office Suite
AutoCAD

HONORS & AWARDS

University of Toledo Tower and Prestige Scholarship
University of Toledo Shapiro Economics Scholarship

COLLEGIATE ACTIVITIES

Intramural flag football, basketball, softball and golf
Intramural referee
Volunteer Teaching Assistant
Student Advisory Board

Brandon M. Heaney

2363 Garden Creek Dr.
Maumee, Ohio 43537
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OBJECTIVE

To secure a full time position with a competitive, engineering base firm.

EDUCATION

June 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering

- Anticipated Graduation Date: December 2011
- Grade Point Average: 3.17

EXPERIENCE

August 2009 – December 2009,
March 2011 – May 2011

Ulliman Schutte Construction, Rockville, MD
Co-op Engineer (Estimator)

- Architectural take-off
- Coordinate with vendors and subcontractors
- Create and distribute architectural information packets pertaining to specific trades/materials
- Revise plans and specification based on addenda changes issued
- Maintain a high level of attention to detail while working to complete tasks in a timely fashion
- Maintain an up to date understanding of plans and specifications involved with current jobs
- Determine potential risks associated with upcoming job and create construction timelines

May 2010 – August 2010,
January 2011 – March 2011

Ulliman Schutte Construction, Washington, D.C & Savage, MD
Co-op Engineer (Project Engineer)

- Acquire materials and custom fabrications and coordinate deliveries on schedule
- Coordinate with vendors, subcontractors, construction managers, and design engineers
- Prepare and submit product submittals, temporary operation plans, and operation and maintenance manuals
- Develop and maintain a precise construction schedule

November 2006-Present

Minuteman Press Toledo, Toledo, Ohio
Bindery Worker

- Operate and maintain hydraulic cutter, folder, booklet maker, and mailing equipment
- Sort and pack mailings
- Box and deliver finished product to customers and maintain customer appreciation
- Work expeditiously to complete job within scheduled time frame
- Demonstrate a high level of attention to detail

HONORS & AWARDS

University of Toledo Pride Scholarship
University of Toledo College of Engineering Dean's List (Spring 2008)
University of Toledo College of Engineering Dean's List (Fall 2008)
North American Honor Consortium – Member with Honor

TARA MARIE NEMCIK

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Stryker, Ohio 43557

Current Address:
1131 North Byrne
Toledo, Ohio 43607

EDUCATION
August 2007-P`resent

The University of Toledo; Toledo, Ohio
Bachelor of Science, Civil Engineering; Minor, General Business Administration
- Anticipated Graduation Date: December 2011
- Cumulative Grade Point Average: 3.384

COMPUTER SKILLS
- AutoCAD 2007
- Microsoft Office Suite 2007-Excel, PowerPoint, Word
- C++

EXPERIENCE

August-December 2011 &
August- December 2008

The University of Toledo; Toledo, Ohio
Teaching Assistant-Introduction to Civil Engineering course
- Answered questions from students.
- Assisted the professor in preparing and conducting experiments.
- Provided expertise and assistance in class instruction

January 2011- May 2011

Marathon Petroleum Company; Findlay, Ohio
Major Projects-Woodhaven Facility Upgrade Co-op
- Provided assistance to project leaders with Woodhaven flare project.
- Lead and oversaw exploratory dig sub-project.
- Assisted with project documentation and organization of documentation.

May 2010- August 2010

Marathon Petroleum Company; Findlay, Ohio
Environmental Technical Services Engineering Co-op
- Coordinated soil remediation and demolition projects.
- Worked with the law and real estate departments to sell Marathon owned properties.
- Assisted in oversight of soil remediation and building demolition site work.

August 2009-
December 2009

Marathon Petroleum Company; Indianapolis, Indiana
Terminal Engineering Processes-Pipe Integrity Program Co-op
- Updated location drawings.
- Organized and interpreted collected data.
- Assisted in the oversight of terminal project site work.

January 2009-May 2009

Marathon Petroleum Company; Findlay, Ohio
Pipeline Engineering Co-op
- Closed projects for engineering project leaders, including required paperwork.
- Provided assistance to project leaders on various pipeline projects.
- Assisted in the oversight of pipeline project site work.

COLLEGIATE ACTIVITIES
- Order of Omega, Greek Leaders Honor Society (Spring 2010-Present)
- Society of Women in Engineering (Spring 2010-Present)
- Alpha Omicron Pi, Social Sorority (Fall 2009-Present)
- Carter Hall Activities Personnel, Vice President (Fall 2007-Spring 2008)

AWARDS & HONORS
- Recipient of the Tower Prestige Scholarship
- Recipient Ohio Environmental Science and Engineering Scholarship

CHRISTOPHER MICHAEL WANCATA

1535 Lourdes Drive
Parma, OH, 44134
216-571-0966
christopher.wancata@gmail.com

EDUCATION
August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering
- Anticipated Graduation Date: December 2011
- Grade Point Average: 3.658

Minor in Business Administration

COMPUTER SKILLS

- Microsoft Office Suite 2010
- AutoCAD 2010
- On-Screen Take Off
- Adobe CS 3 Master Collection

EXPERIENCE
May 2010-August 2010

Diamond Z Engineering Cleveland, OH
Pipelines and Logistics Co-op
- Inspected various BP refueling terminals along the east coast in order to update piping and instrumentation diagrams
- Upon completing on-site inspections, performed updates to P&IDs in AutoCAD
- Performed equipment list updates to all sites inspected after January 1, 2010

August 2009-
December 2009

Lucas Metropolitan Housing Authority Toledo, OH
Modernization Co-op
- Inspected 220+ homes for LMHA for structural/conditional issues
- Performed project take-offs and estimates for various modernization projects
- Assisted in environmental reviews for LMHA
- Assisted in creating a tree trimming/landscaping removal package, while providing site drawings in AutoCAD 2010

January 2009-May 2009

The Douglas Company
Project Coordinator Co-op
- Assisted in estimating projects in all phases of construction
- Acted as a liaison between clients and sub-contractors
- Discussed and implemented value engineering in all current projects and estimates

HONORS & AWARDS

University of Toledo Tower of Excellence Scholarship
Gretchen Koo Memorial Award – Fall 2010

COLLEGIATE ACTIVITIES

- **Part-Time Job with Northwood Industries**
- **Teaching Assistant for Civil Engineering Orientation - Fall 2008**
- **Teaching Assistant for Civil Engineering Professional Development – Spring 2011**
- **Cleveland Engineering Society Member**
- **University of Toledo Men's Club Lacrosse – Coach**
- **National Society of Collegiate Scholars Member**

SPECIAL SKILLS & INTERESTS

- Goal oriented person who takes pride in his work
- Enjoy challenging athletic situations
- Excellent listening skills with well-developed oral communication skills
- Excellent time-management skills; thrives with high responsibility projects/situations

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Appendices

Appendix A
Procedures for Water Quality Tests:

Dissolved Oxygen (DO):

1. Insert dissolved oxygen meter probe in the sample bottle, turn on stirrer, and press "**meas**" button. Record the measurement when the reading is stable (it will beep when stable). Turn off stirrer before removing the probe.
2. Rinse the probe with deionized water between measurements of different samples.

pH:

1. Calibrate the pH meter using pH 7 and pH 9 buffer solutions.
2. Every time you take the meter probe out of any solution, rinse the probe with deionized water and blot the probe with a Kim wipe.
3. Put the probe in the next solution.
4. When finished, leave the probe submerged in the deionized water.
5. Measure and record the pH of the samples using the pH meter.

Total Organic Carbon (TOC):

1. Open the TOC-Control V program on the computer and connect to the ASI-V machine.
2. Fill vials with the sample solution (10 mL minimum).
3. Place the vials into the Auto Sample ASI-V Machine (can handle 68 at one time).
4. Have the program table open on the computer and choose TOC Analysis.
5. Insert a sample name and the number of vials.
6. Begin the test.
7. Read the results from the results column.

Turbidity:

1. Calibrate the Nephelometer. Be careful not to adjust the calibration knobs, as this will require recalibration of the meter.
2. Measure the turbidity of the water samples by filling a sample vial at least 80% full with the solution to be measured, generally 25 mL.
3. Wipe any fingerprints from the vial.
4. Gently inserting the vial into the Nephelometer and recording the reading. (If no reading is displayed, the suspension is too concentrated. Dilute the samples as required).

E. coli:

1. Rinse the micrometer with the samples water, and collect 0.5mL of the sample.
2. Lift the top film of the petrifilm E. coli count plate and pipe the sample into the center of the plate

3. Slowly roll the top film down onto the samples to prevent entrapment of air bubbles
4. Using the plastic spreader (flat side down) press gently apply downward pressure on the center of the plate; do not slide the spreader across the film.
5. Repeat steps 1-4 for each sample collected.
6. Incubate the plates in a horizontal position with the clear sides up for 24±2 hours.
7. High concentrations of E. coli will cause the growth area to turn a bluish color while high concentrations of coliforms (non-E. coli) will cause the growth area to turn a dark reddish color. When this occurs, further dilution of the sample is required to obtain a more accurate count. Petrifilm E. coil count plates can be counted on a standard colony counter.

Biochemical Oxygen Demand (BOD):

1. For each sample, two sets of BOD bottles need to be prepared. One of the sets will be used in determining the initial BOD (Day 0), and the second set will be used in determining the final BOD (Day 7). *Note that the initial DO levels must be determined as soon as the bottles are prepared.
2. Fill a blank BOD bottle with aerated dilution water halfway into the neck. Make sure there are no bubbles in the bottle.
3. Day 0 Bottles: Measure and record the initial DO readings in each bottle, using the procedure for Dissolved Oxygen.
4. Discard the sample.
5. Day 7 Bottles: Insert a glass stopper to seal the samples and place bottles into the incubator for one week.
6. After one week, remove the sample bottles from the incubator and measure the final DO using the procedure for Dissolved Oxygen.
7. Discard the sample.
8. Calculate BOD_7.

Conductivity:

1. Calibrate the conductivity meter in deionized water.
2. Insert the meter in the sample and slowly stir the meter until a stable reading has been obtained.
3. Rinse the probe with deionized water before testing another sample.

TSS:

1. Total suspended solids were observed by visually observing the appearance of the water samples taken.

Chlorine:

1. Calibrate spectrophotometer with deionized water.
2. Fill sample vile with 10mL of sample solution.

3. Empty contents of DPD free chlorine reagent packet into sample vile.
4. Swirl until completely dissolved, will begin to turn pink if chlorine present.
5. Put vile into spectrophotometer and press "Test" button.
6. Record value projected on screen of spectrophotometer.

Appendix B

Water Quality Tests – E.coli Results:

Figure 38: E. coli results from location A and B (9/29/11) samples

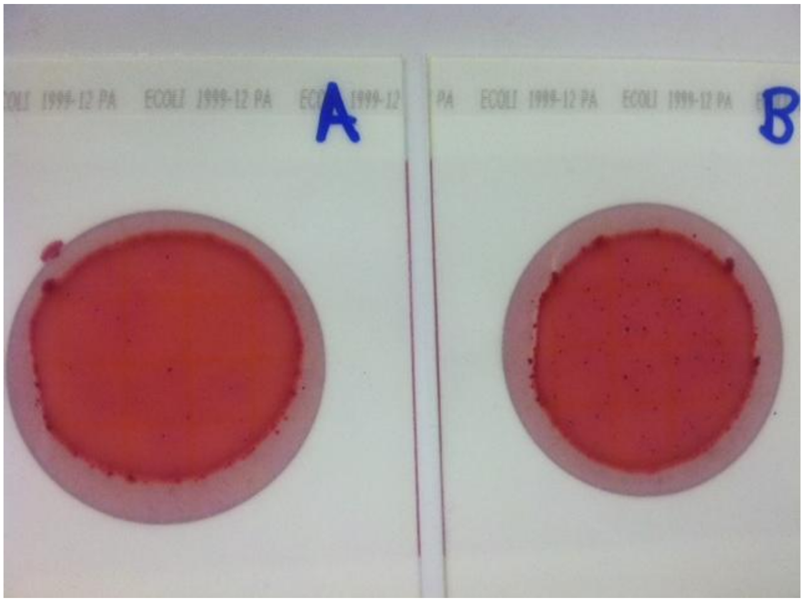


Figure 39: E.coli results from location C and the river (9/29/11) samples

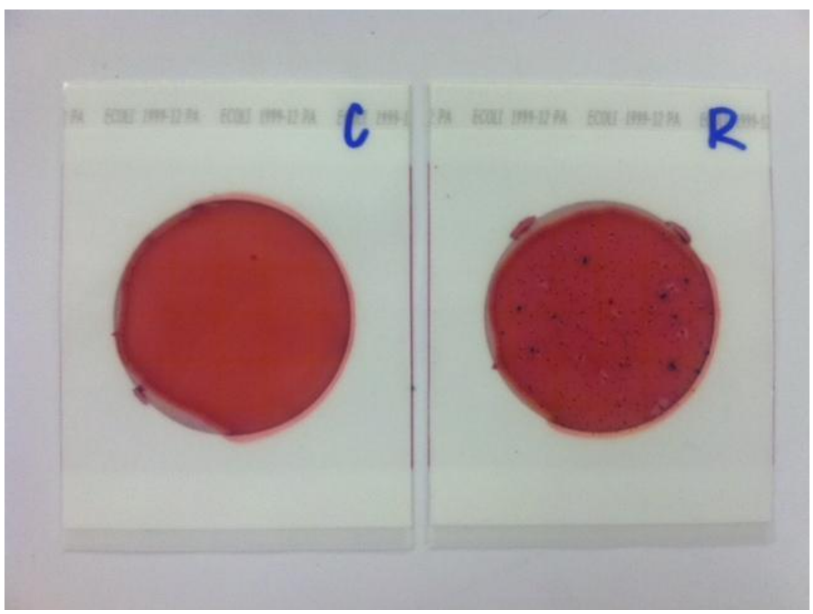


Figure 40: E.coli results from locations A, C, and the river (10/11/11) sample

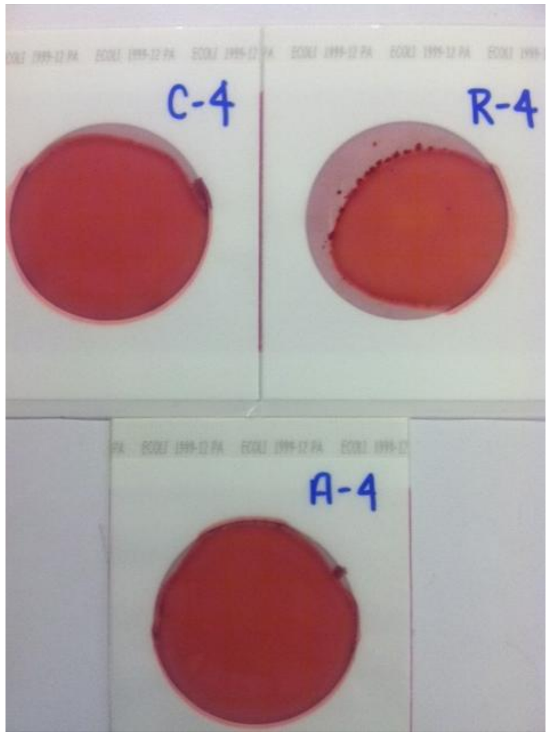
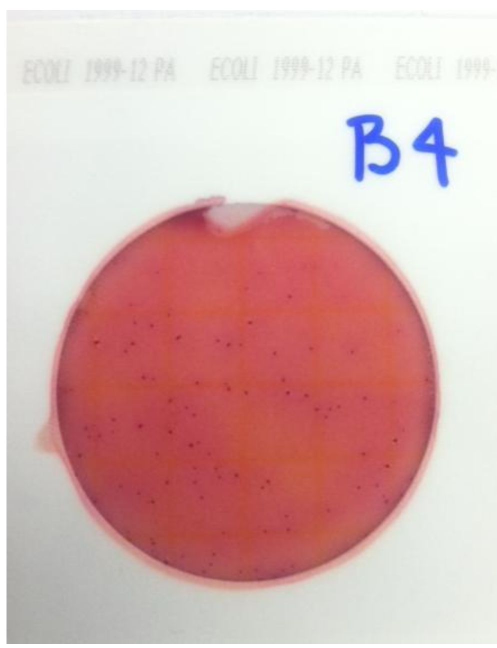


Figure 41: E.coli results from location B (10/11/11) sample



Appendix C
Water quality data tables

*BDL: below detection level

Table 6: Water quality data for location A

LOCATION A							
		Normal	9/6/2011	9/9/2011	9/29/2011	10/11/2011	
Weather Conditions			rain 2 days prior	raining	raining	dry	
CHARACTERISTIC	**Units**						
Dissolved Oxygen:							
(t_o)	mg/L	4-12	7.8	7.8	8.89	9	
(t_7)	mg/L	4-12	NA	7.05	6.57	7.04	
BOD	mg/L		NA	0.75	2.32	1.96	
pH		6.5-9	NA	6.95	7.53	7.41	
TOC	mg/L		NA	6.41	6.86		
Turbidity	NTU		NA	0.57	0.37		
E. Coli			None	Coliform	Coliform	Coliform	
Conductivity	μs/cm	300-700	925	1640	823	846	
Nitrate	mg/L		NA	NA	1.5	BDL	
Phosphorous	mg/L		NA	NA	6.0	1.0	

Table 7: Water quality data for location B

LOCATION B							
		Normal	9/6/2011	9/9/2011	9/29/2011	10/11/2011	
Weather Conditions			rain 2 days prior	raining	raining	dry	
CHARACTERISTIC	**Units**						
Dissolved Oxygen:							
(t_o)	mg/L	4-12	6.5	7.9	8.23	8.48	
(t_7)	mg/L	4-12	NA	6.6	5.69	6.39	
BOD	mg/L		NA	1.3	2.54	2.09	
pH		6.5-9	NA	6.85	7.78	7.88	
TOC	mg/L		NA	29.745	7.02		
Turbidity	NTU		NA	1.76	1.04		
E. Coli			NA	Coliform	Coliform	Coliform	
Conductivity	μs/cm	300-700	1264	1948	1655	1303	
Nitrate	mg/L		NA	NA	1.0	BDL	
Phosphorous	mg/L		NA	NA	7.0	BDL	

Table 8: Water quality data for location C

LOCATION C							
		Normal	9/6/2011	9/9/2011	9/29/2011	10/11/2011	
Weather Conditions			rain 2 days prior	raining	raining	dry	
CHARACTERISTIC	**Units**						
Dissolved Oxygen:							
(t_o)	mg/L	4-12	6.7	8	8.73	8.9	
(t_7)	mg/L	4-12	NA	4.27	2.4	6.05	
BOD	mg/L		NA	3.73	6.33	2.85	
pH		6.5-9	NA	7.02	7.35	8.24	
TOC	mg/L		NA	7.518	6.02		
Turbidity	NTU		NA	2.41	1.48		
E. Coli			None	None	None	None	
Conductivity	µs/cm	300-700	501	505	440	266	
Chlorine	mg/L	0.2-1	NA	NA	0.11	0.4	
Nitrate	mg/L		NA	NA	0.12	BDL	
Phosphorous	mg/L		NA	NA	6.0	10.0	

Table 9: Water quality data for the river

RIVER							
		Normal	9/6/2011	9/9/2011	9/29/2011	10/11/2011	
Weather Conditions			rain 2 days prior	raining	raining	dry	
CHARACTERISTIC	**Units**						
Dissolved Oxygen:							
(t_o)	mg/L	4-12	NA	7.9	8.67	9.13	
(t_7)	mg/L	4-12	NA		3.61	5.79	
BOD	mg/L		NA	7.9	5.06	3.34	
pH		6.5-9	NA		7.8	7.86	
TOC	mg/L		NA		11.01		
Turbidity	NTU		NA		14.6		
E. Coli			NA	E.coli	E. coli	E.coli	
Conductivity	µs/cm	300-700	NA	290	673	1231	
Nitrate	mg/L		NA	NA	0.75	0.4	
Phosphorous	mg/L		NA	NA	6.0	6.0	

Appendix D

Rigid Pavement Design Charts

Figure 42: Rigid pavement design chart 1

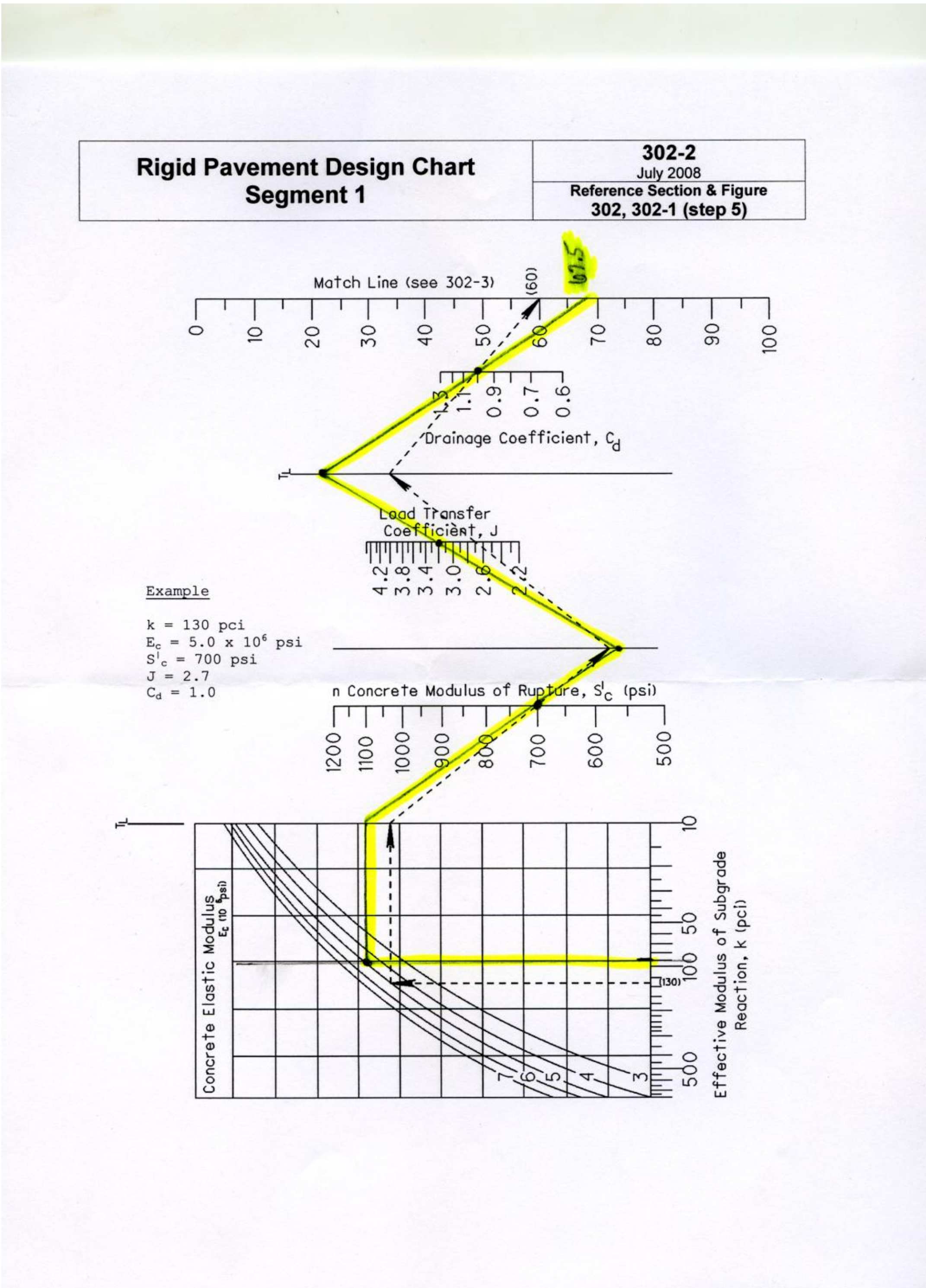
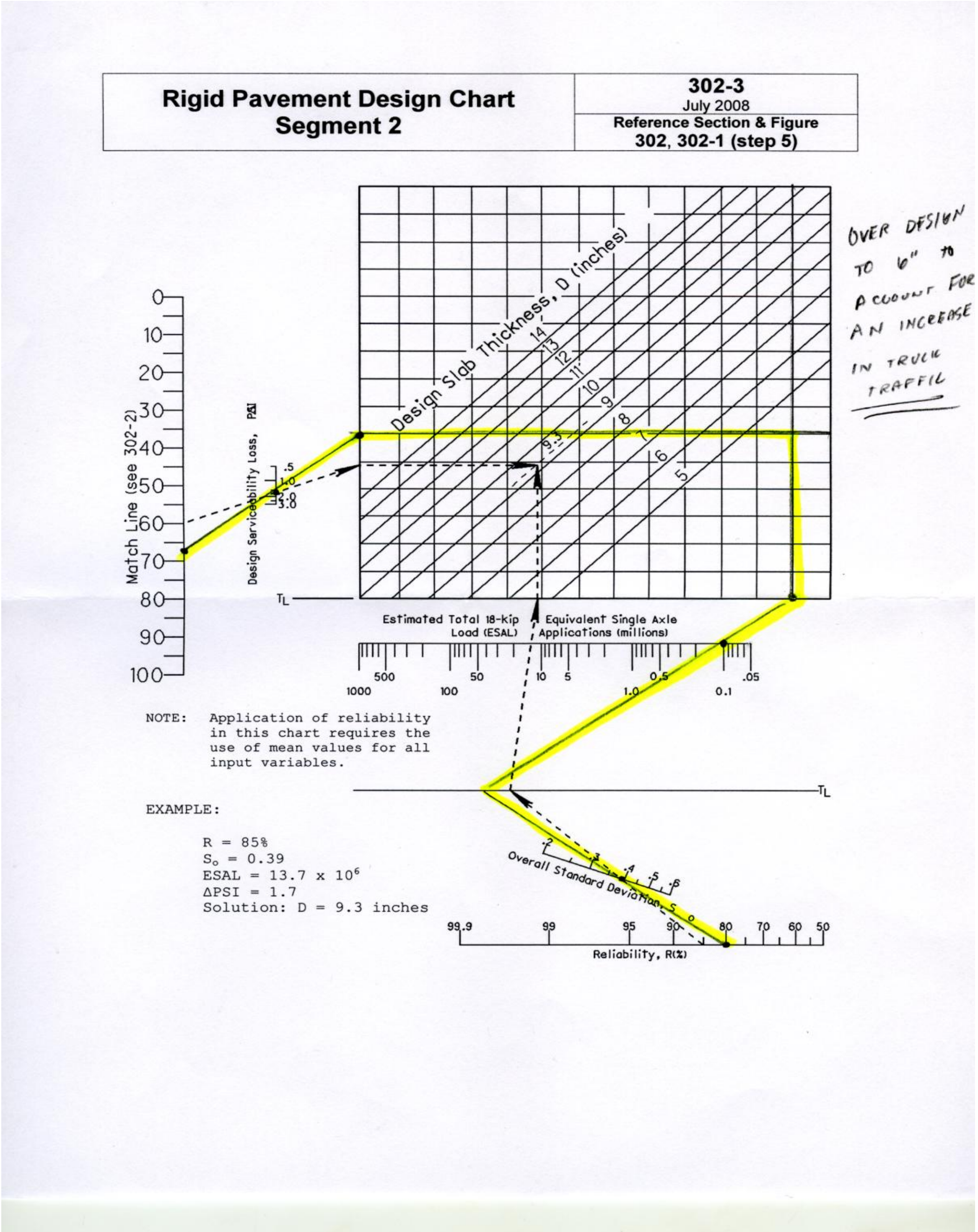


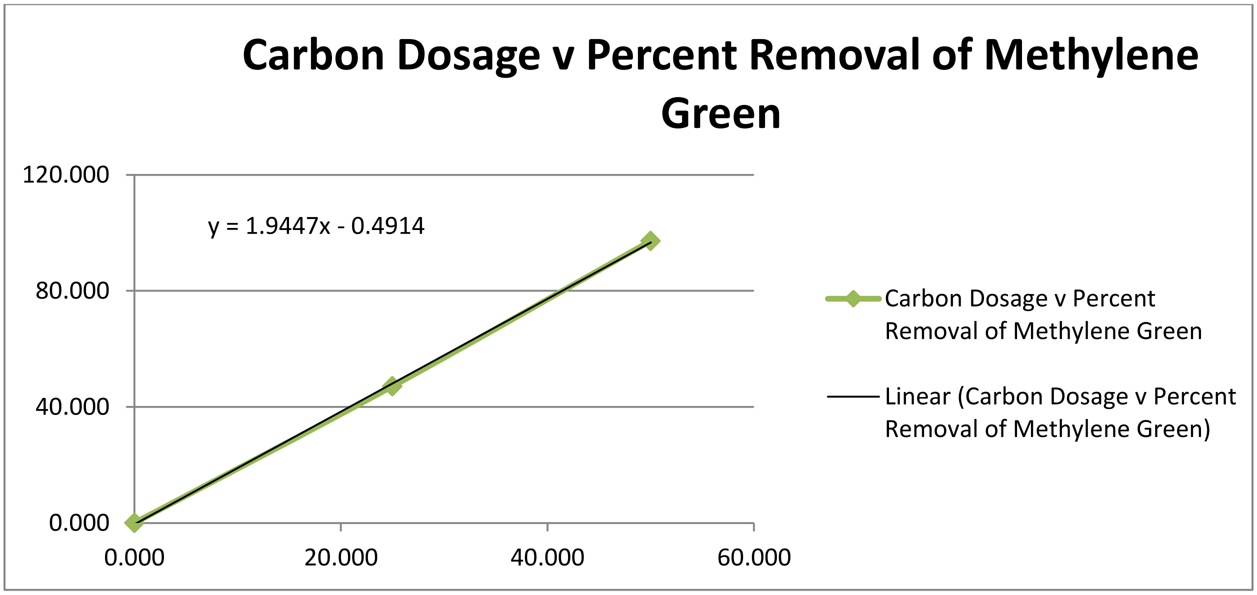
Figure 43: Rigid pavement design chart 2



Appendix E

Methylene Green Dye Test

Figure 44: Methylene green dye curve



A calibration curve was determined as given in Figure 44 for methylene green dye. The methylene green dye (or contaminant) concentration of an unknown solution can be determined using this curve if the sample absorbance value is determined using spectrophotometric analysis.

Because of their molecular structures, each contaminant absorbs light best at one particular wavelength. Measuring the absorption of a given sample at different wavelengths and select the wavelength that provided the highest absorbance is used to determine the wavelength most suitable for the preparation of a calibration curve. For methylene green dye, this wavelength is 6nanometers (nm).