CIVE 4750 Civil Engineering Senior Design
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Final Report

Stormwater West Mitigation Design

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Department of Civil Engineering
Senior Design Project
Executive Summary

Stormwater Treatment and Mitigation

Fall Semester 2011

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Problem Statement

The Ottawa River has problems with stormwater runoff adding pollution and excess flow to the river. Solutions to these problems on UT's main campus between the Carlson Library Bridge and the western edge of campus at Secor Road are the subject of the project. A short term solution will be suggested for the continuous discharge from an outfall located at the CPA Bridge. Long term solutions will be designed to help mitigate and treat flows being discharged into the river due to rain events. The solutions will not take away from the aesthetics of the river or affect parking on campus.

Project Constraints

- Available area for construction
- Storm sewer flows and capacity
- Runoff pollutant content
- Existing parking lot grades and storm sewer location
- Existing soil type
- Existing water table level
- Feasibility
- Cost of construction

Field Verification

Four field verifications during dry conditions were performed to investigate the source and effects of a discharge entering the Ottawa River through a stormwater outfall at the CPA bridge. One of the field visits was performed during wet conditions to provide data for regular stormwater. Through data collection and verification a few different conclusions were made including:

- Dry Conditions
  - The flow varies between 0.5 and 1.5 cubic feet per minute.
  - The discharge is 10˚F warmer than the Ottawa River.
  - The discharge is not a greatly polluted water source.
  - The origin of the unknown flow is from with Wolfe Hall or Bowman-Oddy buildings on campus.
- Wet Conditions
  - The flow varies between 2.5 and 3.5 cubic feet per minute.
  - The discharge is a combination of stormwater and unknown source from Wolfe Hall or Bowman-Oddy buildings on campus.
  - The discharge is 10-15˚F warmer than the Ottawa River.

Proposed Solutions

- Wolfe Hall Outfall
  - Connect sump directly to sanitary sewer
- Parking Lot Runoff (Identify High Flow Areas)
  - Catch basin filters
  - Porous Pavement
  - Infiltration planters

Economics

- Each alternative selected will be evaluated for cost

Conclusions

The summary of results with figures and tables will be included after design is completed.

Problem Statement and Constraints

Problem Statement

The Ottawa River runs 45 miles from Fulton County to Western Lake Erie. The portion of the river that cuts across UT's campus is 3700 feet long with an average width ranging from 60 to 70 feet. While the river adds to the aesthetics of the campus, there have historically been issues with water quality. The foremost problem with the river is pollution, and cleaning up the river has been a high priority of the City of Toledo. Currently, the University is working to improve the health of the Ottawa River by habitat restoration and mitigation of pollution.

There are many factors that contribute to the pollution of the river including contaminants being discharged into the river via huge runoff flows during storm events with the watershed. The West portion of the river from the pedestrian bridge by Carlson Library to the edge of campus by Secor is the focus of this study. A stormwater outfall located near Wolfe Hall on campus continuously discharges flow into the river. To solve this issue, a field investigation of the problem was performed to determine short term solutions for the continuous flow.

The other main issue being investigated is the amount of flow contributed by stormwater runoff on campus during average or major rain event. The Ottawa River's flow volume increases drastically during a storm event due to stormwater runoff coming from upstream as well as from the UT campus.

Even though the flows on campus are small in comparison to the overall flow of the Ottawa River, stormwater mitigation on the campus remains an important issue. These stormwater discharges can carry many different pollutants and deposit them into the river. The goal is to design long term solutions for stormwater flow mitigation and treatment. Solutions to these major issues were designed based on the given constraints particular to each individual problem location. Sustainability and innovation were also considered when choosing solutions.

Project Constraints

There are several constraints that influenced the design of this project. Available area for construction contributed to the determination of which alternatives were most feasible. Stormwater runoff flow quantities played a large part in the selection of an alternative for design. Existing parking lot grades and storm sewer locations ultimately determined the location of the selected alternative. The type of in-situ soil and depth of water table were also important for the design alternatives. The feasibility of design and construction as well as costs associated with the project were taken into consideration for this project.

CPA Bridge Outfall

<u>CPA Bridge Outfall</u>

To come up with a solution to the constant discharge at the outfall near the CPA bridge, four field visits were conducted. A summary of these investigations is given below. The field investigations described in greater detail can be seen in Appendix B.

The first field visit took place on September 1st, 2011. It yielded samples and temperature readings during dry weather from the outfall which were tested for coliform, BOD_5, and conductivity. The methods and procedures that were used for testing the water sample are included in the appendix. Temperatures were taken from the outfall and from the Ottawa River upstream of the outfall. Test results concluded that there were not major concerns regarding coliform, BOD_5, and conductivity; however there was a concern with temperature pollution because of a near 10 degree Fahrenheit temperature difference.

The second field visit took place on September 6th, 2011. It yielded an average flow quantity during dry weather. One of the major findings was fluctuation of the continuous flow at the CPA bridge. The main objective during this visit was to trace back the flow to the source. After opening up manholes leading to the outfall, the discovery of the source of the flow was made near Wolfe Hall. At this point, the fluctuation of the flow was very evident at two to four minute intervals.

During the third field visit, on September 7th, 2011, temperature, flow and a dye test to verify the source was carried out. During the dye test, dye was added to the flow coming out of Wolfe Hall and traced to each manhole leading to the CPA bridge outfall. This confirmed the source. A second sample from the flow was also taken on this field visit. This visit also consisted of recording temperatures of the discharge as well as temperatures upstream and downstream of the outfall. Once again, coliform, BOD_5, and conductivity were tested for and yielded only minor concerns. The same methods and procedures were used as before.

The last field visit took place on September 11th, 2011. It consisted of an in-depth investigation of Wolfe Hall with the assistance of a facilities worker to find the source within Wolfe Hall of the outfall. The investigation led to the mechanical room where sump pumps were found to be pumping into the stormwater pipe that was located just outside of Wolfe Hall. This was further confirmation of the source of the flow of the CPA bridge outfall.

Addressing CPA Bridge Discharge

The constant flow of water entering the Ottawa River from the outfall next to the CPA Bridge needed to be addressed. After conducting the four field investigations, it was determined that the sump pump in the Wolfe Hall basement was the source of the water. To rectify this problem and to be in compliance with the Ohio EPA, it is recommended that the sump discharge be redirected to the sanitary sewer. It is against stormwater regulations to have floor drains and steam condensation being discharged to a stormwater system.

Considered Alternatives

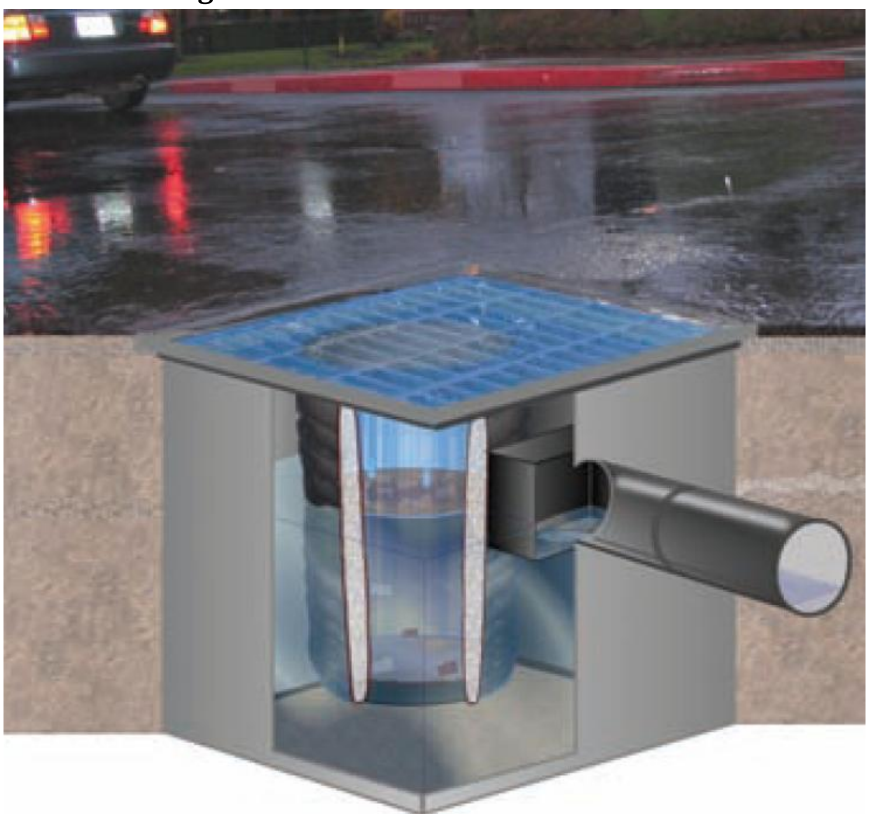
Considered Alternatives

Based on the different constraints of the project, several possible solutions were considered to mitigate the stormwater problems on campus. The following solutions focused on reducing the amount of stormwater runoff and reducing pollutants from The University of Toledo campus entering the Ottawa River.

A. Catch Basins Filters

Catch basin filters are a simple and easy short term solution to parking lot runoff pollution. These filters come in sizes to fit any catch basin or curb drain. It is as simple as taking the existing grate casting off the catch basin and dropping in an insert that holds a removable filter. There are several companies that make these types of filtration systems but one of the better styles that were found is made by CleanWay. Figure 1 below shows the basic way a CleanWay catch basin filter works.

Figure 1: Catch Basin Filter Schematic



CleanWay catch basin filtration inserts meet the NPDES Phase II storm water regulations and comply with the Clean Water Act. These filtration systems are recognized by the government as a BMP (best management practice). Benefits of this include removing suspended solids, pollutants such as oil, and heavy metals.

B. Retention Basins

A retention basin is an artificial pond that is designed to temporarily store and treat stormwater flows while releasing a small, controlled flow to the storm sewer system. Retention basins are effective in both limiting flooding and removing pollutants from stormwater.

Retention basins are useful for large areas of impermeable surfaces because they provide area for runoff to drain to that would otherwise absorb into soils. Flooding can be limited with the use of retention ponds because they hold a controlled amount of water and can absorb large storm flows. Retention ponds, unlike detention ponds, always hold water and are designed with an overflow pipe to prevent water levels from rising too high.

While retention ponds effectively reduce flooding, they also collect runoff pollutants and allow them to settle to the bottom of the basin. Retention ponds also allow pollutants to be biologically removed via plant species that can be planted in and around the pond area. Pollutants that are treated include oils and other petroleum products, nutrients from fertilizers, sediment, bacteria, metals, and other suspended solids. Pollutants settle and come to rest at the bottom of the basin, which should be routinely cleaned.

Retention basins can also be aesthetically pleasing, implementing fountains or other ornamental devices. These devices can also serve the purpose of increasing aeration throughout the pond. Natural bacteria that are present in the ponds need oxygen to break down pollutants. Aerating fountains are capable of increasing the dissolved oxygen in the pond. Dissolved oxygen is also important for fish, frogs and other various aquatic life that may reside in a retention pond. Figure 2 on the following page shows a retention pond with an aerator.

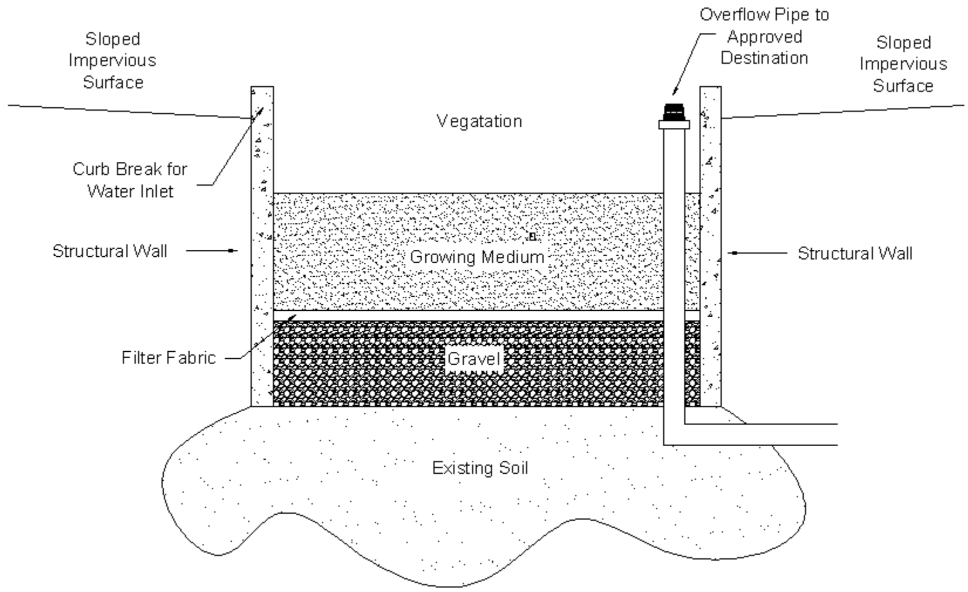
Figure 2: Retention Pond with Aerator

A negative aspect of retention ponds is the size required to hold storm flows. On the University of Toledo's main campus, space is very limited. Two possible locations for a retention pond are the "Flatlands," a very low-lying, large green space adjacent to the Ottawa River. This area could be utilized to treat stormwater from the south side of campus. Another possible area, in which a retention pond could be built, is the recently vacated space in front of Wolfe Hall, where the Student Annex and steam plant used to be located.

C. Infiltration Planters

An infiltration planter is a sustainable design structure which allows stormwater to slowly infiltrate into existing soil. The runoff from impervious surfaces is directed into the planter. As the stormwater flows into the planter, the structure allows the water to pool temporarily before infiltrating into the soil. After entering the planter, the stormwater flows through a growing medium, a filter fabric, a gravel base and then into the existing soil. The growing medium provides an area for vegetation to grow. This growth will be beneficial to the treatment of possible pollutants that may runoff from the impervious surfaces. The vegetation will also contribute to overall aesthetics of the campus. By allowing the stormwater to infiltrate into existing soil, the total stormwater and any pollutants associated with runoff would no longer be contributed to the pollution of the Ottawa River. On the following page is a conceptual design of an infiltration planter in Figure 3.

Figure 3: Infiltration Planter (Conceptual Design)



Economically the use of infiltration planters over the normal stormwater system is more financially efficient. Although, depending on constraints such as parking lot size or location, the average cost may vary between the two designs. The main costs for the planters involve structure construction, design, and maintenance. Maintenance for the infiltration planters may involve two to three years of gardening and watering. Design must consider proper state or local coding. EPA regulations may apply to application or treatment of designed structure to treat possibly environmentally harmful pollutants.

Before considering infiltration planters as a feasible design option, certain constraints must be addressed. These constraints particular to the design project include:

C. ***Soil Type*** – The existing soil below the planter must allow the stormwater to be infiltrated back into the groundwater. If the soil is unable to be infiltrated, flow through planters may be a better solution.
D. ***Water Table Location*** – The water table must be located at a distance great enough to allow the stormwater to infiltrate into the groundwater.

After the two above constraints are considered, other factors that must be taken into account for the design of the structure include: economics, available space, location, flow quantities, vegetation and climate. Another major factor for the design is the slope of the impervious surface which will contribute to the planter. If the surface is to be reconstructed, the grade can be sloped towards the planter. Otherwise, the planter location is determined by existing grades. The planter will be designed to not heavily decrease the number of parking lot spaces while still promoting efficient or total capture and infiltration of stormwater runoff. The use of infiltration planters would be considered for a few of the different parking lots and roadways on campus.

D. Porous Pavements

Porous pavements are permeable surfaces consisting of coarse aggregate which allow stormwater to penetrate the pavement and temporarily be stored in a reservoir base of crushed aggregate. These pavements can be either asphalt or concrete and are very similar to traditional pavements. Porous pavements, however, do not have fine aggregates allowing for more air voids for precipitation to pass through.

The important element of the porous pavement system is the base. The aggregate base directly below the pavement acts as a temporary storage medium for the stormwater that collects. Once the stormwater seeps through the pavement, the underlying stone bed controls the flow, ensuring the water does not rise to the pavement level. Because of this, the pavement must be placed over soils that drain well such as gravelly or loamy sand; otherwise issues of standing water will occur.

Unlike conventional pavement, which is impervious, heat absorbing, and collects stormwater, porous pavements allow water to filter into the soil and return the water into its natural cycle. This process is very similar to an infiltration basin. By using porous pavement, stormwater is not channeled off of the structure through pipes, transporting it directly to the nearest body of water, the Ottawa River. This way, the water is treated in a better way before it is returned into the soil.

One significant disadvantage to using a porous pavement is the maintenance required to keep an effective system operating. The lack of proper maintenance for a system like this results in the system acting like conventional pavement; without the typical system of piping and gutters to control runoff. Regular maintenance can include power washing and vacuuming of the porous pavement to prevent the voids from clogging. This practice is usually done a minimum of 2 to 4 times a year. In general, this system is more delicate than the conventional system involving a conventional parking lot.

The use of porous pavement has been implemented on the campus of The University of Toledo already. On the Northwest corner of Lot 10 in the center of campus near the Glass Bowl, a patch of porous pavement the size of two parking spots has been paved. However, due to poor maintenance, the porous parking spaces now function like impermeable pavement. Despite this, porous pavement should not be ignored completely. There are other ways to implement it throughout campus.

E. Underground Detention with Manufactured Best Management Practice (BMP)

Underground detention systems are normally used in areas where space is limited. These include areas such as parking lots and roads. A system of large underground pipes with a minimum diameter of 36 inches or an underground reinforced concrete box is used to extend the detention time of stormwater runoff. All underground detentions require an outlet structure, emergency spillway or bypass and an access for maintenance. The maximum drainage area underground detention can handle is 25 acres. Implementing an underground detention system would greatly reduce the discharge flow rate during a rain event. Underground dentition only solves the flow rate problem. In order to treat the water, it needs to be used alongside a BMP. Figure 4 on the following page shows the installation of an underground detention system.

Figure 4: Underground Detention Pipe System

Advantages:

- Useful in areas with limited space
- Long design life
- Not dependent on soil type
- Does not create safety hazard
- Does not ruin the aesthetics of the surrounding area

Disadvantages:

- Only beneficial in limited spaces
- Require frequent maintenance due to trash and sediment buildup
- Only reduces flow rate
- BMP need to treat water pollutants
- More expensive and involved than similar above ground options

The manufactured BMP that would be used alongside underground detention to treat the stormwater are VortSentry® manholes. VortSentry® manholes use vortex settling to treat the stormwater. As the stormwater circulates, the pollutants settle in the center where the velocity is the slowest. This process removes sediment, traps debris and separates oil and grease from the water. Similarly to underground detention systems, Vortsentry® manholes are best used in areas with limited space. This solution would be feasible in any of the lots in the project area because it would not interfere with parking. Figure 5 on the following page shows a schematic of a VortSentry® structure. Table 1 on the following page compares different models.

Figure 5: VortSentry® Schematic

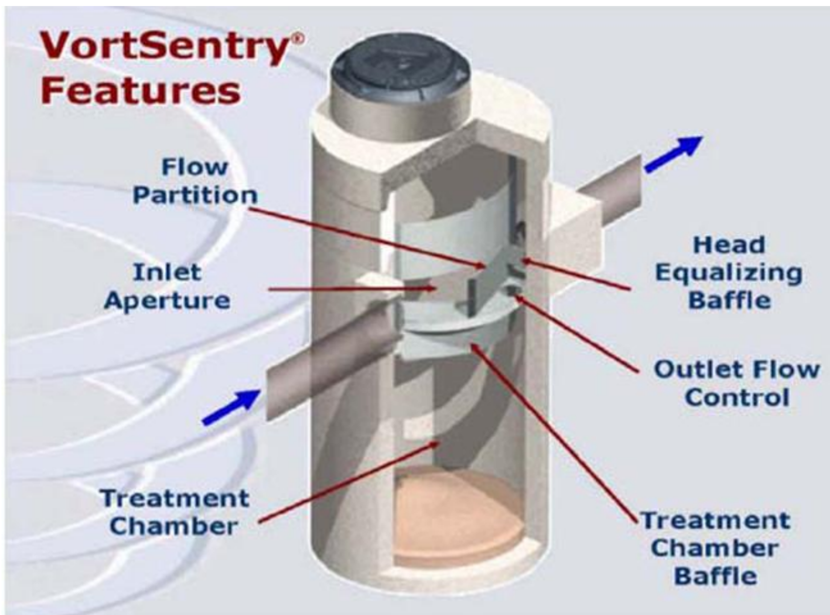


Table 1: VortSentry® Treatment Flows

Model Number	Diameter (ft)	Treatment Volume (ft^3)	Treatment Flow		Operating Rate	
			(cfs)	(gpm)	(cfs/ft^3)	(gpm/ft^3)
VS30	3	21	0.46	207	0.022	9.8
VS40	4	50	1.10	494	0.022	9.8
VS50	5	98	2.15	965	0.022	9.8
VS60	6	170	3.71	1665	0.022	9.8
VS70	7	269	5.90	2648	0.022	9.8
VS80	8	402	8.80	3950	0.022	9.8
VS100	10	785	17.19	7715	0.022	9.8
VS120	12	1357	29.70	13330	0.022	9.8

Advantages:

- Useful in areas with limited space
- Retrofitted to existing manholes
- Includes overflow bypass
- Easy maintenance

Disadvantages:

- Expensive
- Requires frequent maintenance
- Standing water accumulates in the bottom chamber

Design Solutions

Design Solutions

After taking in to account the project constraints, catch basin filters, porous pavement and infiltration planters were chosen as being the most feasible in reducing both stormwater runoff and pollutants in the stormwater.

A. Catch Basins Filters

Due to the effectiveness of removing runoff pollutants and their ease of installation, catch basin filters were chosen as one of the solutions. Removing pollutants is done in 3 stages of filtration. Primary filtration (stage 1) simply includes a strainer to remove large solids. Secondary filtration (stage 2) uses an absorption media called Adsorb-it to filter out smaller solids and oils. Site-specific media (stage 3) called MetalZorb filters out heavy metals. Table 2 and Table 3 below show the general specifications of the filters and Figure 6 shows the 3 stages of filtration.

Table 2: Primary Filter (stage 1 & 2)

Primary Filtration - Strainer	
Solids Total	1.0 ft^3
Total Surface Area	4.8 ft^2
Sieve Size	1/8 inch
Flow Rate	>100 gpm

Table 3: Filter Media (stage 3)

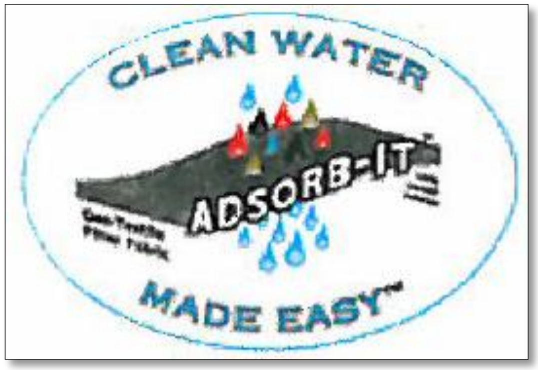
Secondary Filtration - Absorption Media	
Volume	1.5 ft^3
Surface Area	6.4 ft^2
Design Flow Rate	40 gpm
Max Flow Rate	80 gpm

Figure 6: Filtration Stages

Stage 1 filtration is just the rigid filter basket with a non-woven fabric filter. This removes all the larger solids and debris that would normally be washed down the catch basin and out to the river.

Stage 2 filtration includes the adsorption media call Adsorb-it which removes oil, oil sheen, and oil-borne contaminants, seen in Figure 7. It is simply an oil absorbent fabric that separates oil from water, such as when it was used in the Gulf oil spill clean-up. CleanWay buys this media from a company called Eco-Tec-Inc. which specializes in oil absorbent products. This material is made in the USA and manufactured from 100% recycled materials. (eco-tec-inc)

Figure 7: Adsorb-it



Stage 3 type filtration for these filters consists of MetalZorb media, seen in Figure 8. The only difference between the 2nd and 3rd stage filters is that the 3rd stage filters contain site-specific media to capture specific pollutants. This media reduces and removes heavy metals such as zinc, copper, lead, and many others. When the metal-saturated media is used up, it can easily be disposed of as solid waste (cleanwayusa). The selective pollutant removal can be altered whenever the conditions change to satisfy specific needs.

Figure 8: MetalZorb Media

For the purpose of this application, only stage 1 and 2 will be used due to the cost. We didn't measure for heavy metals coming off the parking lots but we don't expect them to be an issue, however the catch basin filters can be modified to address them if needed. MetalZorb is used more in applications where there are problems with heavy metal pollutants. In the case of applications around campus, heavy metal pollutants are not a known problem so the use of the catch basin filters with Adsorb-it in them will treat the pollutants from parking lots. There is also a cost advantage with not using MetalZorb unless it is necessary. With MetalZorb each catch basin filter unit would cost around $1,200 and without it the cost is around $760 per unit (Moulton, 2011).

Maintenance of these filters simply includes removing the old filter element and discarding it, then replacing it with a new filter. The time interval at which this would have to be done depends on how much flow that catch basin receives and how concentrated the pollution contaminates are.
This would work great for various places around campus as a short term solution to storm water pollution problems. The most attractive aspect of this solution is that it is simple, fast, and easy to install. With this solution there is no space constraint concerns so these can be placed anywhere on campus. These are also very feasible because there will not be any expensive construction costs associated with this modification.

The filters would be most effective in any area where there is direct pavement runoff such as curb drains and catch basins in the road. These filters wouldn't serve as much purpose in grassy areas where the grass is already filtering out pollutants before the water gets to the catch basin. A place that would be good to put these is in lot 12 and 26 since there is not any spare room to build filtration trenches in these lots. Here the catch basin filters can be easily installed and effective.

B. Porous Pavements

In order to help mitigate and treat flow, it was decided to go with porous concrete pavement gutters which were suggested by Director of Facilities and Construction, Doug Collins. Porous gutter lanes are a practical solution to use in areas where porous pavement on a large scale is not feasible. It costs less, maintained easier and easy to retrofit.

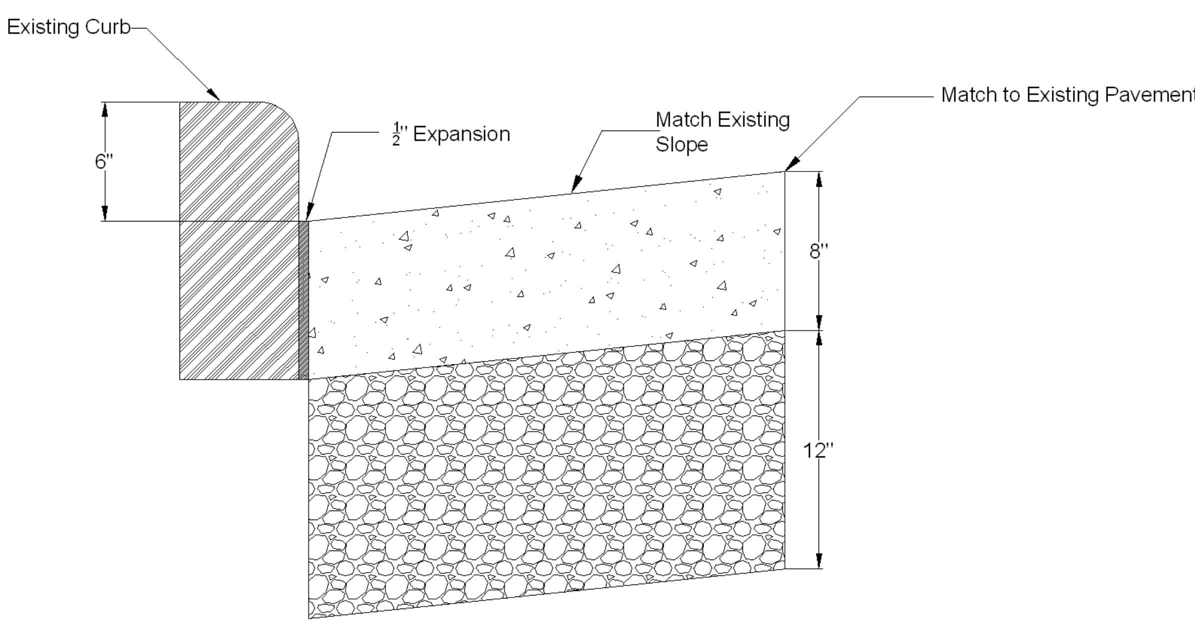
There are three proposed locations for the gutter lanes on the University of Toledo campus are Stadium Drive, West Rocket Drive and North Towerview Boulevard. These spots were chosen due to their location near the river. Even though only three locations were chosen, the porous pavement gutters can be implemented anywhere on campus.

The design of the gutters was done using a porous pavement mix design from the Kuhlman Concrete plant in Toledo, Ohio. Using this design, the porous pavement can infiltrate 360 rain in/hr. The gutter consists of a layer of porous pavement, a sub-base made up of No. 57 stones and a geotextile material between the sub-base and the soil subgrade. Porous concrete can be as strong and durable and impermeable concrete.

For the design of the gutters, the layer of porous pavement and layer of the No. 57 stone sub-base are given in ranges. Ranges are given because the design of porous pavement relies on the soil quality below the pavement. The available soil boring samples were not adequate enough to determine the exact strength of permeability of the soil. If the soil is not permeable, it does not matter how much water the pavement or sub-base can infiltrate. If the water cannot per permeate the soil, it will come back up through the pavement rendering it ineffective. In order to be feasible, the underlying soil needs to have an infiltration rate of 0.5 in/hr or greater. The water table needs to be more than 2 feet below the pavement as well.

The porous pavement thickness is in a range of 6 – 8 inches due to it being in the roadway. However, the gutter lanes should receive a lower amount of traffic since it is closer to the side of the road. The No. 57 stone base ranges from 8 - 12 inches thick to create storage capacity while the stormwater infiltrates the soil below. The width of the gutter lane is 2 feet. When installing the gutter lane, it will be matched to the existing roadway pavement and sloped to create a 6 inch curb. Expansion material ½" in thickness is placed between the curb and porous pavement, and construction joints will be cut every 20 feet. Figure 9 below shows the typical cross section of the porous gutter lane with 8 inch pavement and 12 inch sub-base.

Figure 9 – Porous Concrete Gutter Lane Typical Section



The curb inlets and undertrains in the current stormwater management system will remain in place. This will serve as a backup to the porous gutter lanes if they are unable to handle the flow due to a rain event larger than the designed 25 year storm. If the gutter lanes become clogged due to poor maintenance, they will function as impermeable pavement and runoff will be able to go through the existing system. Table 4 below shows the design length of each gutter lane and the drainage area for each location.

Table 4 – Gutter Lane Lengths

	Gutter Lengths (ft)		Drainage Area (ft^2)
Stadium Drive	**East**	**West**	12810
	391.92	399.67	
W. Rocket Drive	**East**	**West**	22396
	282.5	372	
North Towerview Blvd.	**North**	**South**	20553
	721	879.58	

The flow rates of runoff entering the porous pavement gutters were calculated using the NRCS TR-55 method as shown below. The gutters were designed for a 25 year storm. Example calculations using the data for Stadium Drive can be seen in Appendix A. The result for all three locations can be seen in Table 5 below.

Table 5 – Flow and Flow Capacities

25 Year Storm			
Location	**Q (cfs)**	**Pavement Flow Capacity (cfs)**	**Soil Flow Capacity (cfs)**
Stadium Drive	0.4711	107	0.5931
W. Rocket Drive	0.8236	187	1.0368
Towerview	0.7558	171	0.9515

The porous pavements can easily handle all of the stormwater runoff. To know if the gutters are feasible the runoff has to be compared to the flow capacity of the soil. As seen in Table 5, the soil flow capacity is greater than the runoff flow. Therefore, the porous gutters would work in each proposed location.

The installation of porous concrete is not difficult, but there are some differences compared to installing impermeable pavement. The subgrade soil must not be compacted. If it was compacted, the soil would become impermeable. A nonwoven geotextile fabric must be place between the soil and aggregate sub-base to prevent fines from the soil seeping into the sub-base.

Porous pavement cannot be poured if the temperature is below 35 °F or if the subgrade has been soften by rain. The water content of the porous pavement is a crucial for it to function as designed. In order to maintain the correct water to cement ratio, the sub-base must be properly wetted.

Porous concrete should be poured in a uniform layer in order for it to be properly compacted. It cannot be finished using floats. Doing so would close the surface voids causing it to be impermeable. The pavement is finished during the compaction phase. A steel roller is used which both compacts the pavement and finished the surface. Compaction is done within 30 minutes of the pavement being poured. Construction joints are placed 20 feet apart. Finally, curing is done by placing opaque polyethylene sheets over the pavement for a minimum of 3 days. For each cure day the temperature drops below 40 °F, another day of cure needs to be added.

Maintenance on the gutter lanes should be done between 2 – 4 times per year, with 4 times being more ideal. This can be done by using a street sweeper with a vacuum to remove material in the pavement voids. The porous areas are small enough that the sweeper can be rented for the day. This will save money due to not having to buy a vehicle. Proper installation and maintenance will help improve the functionality of the porous pavement.

Porous gutter lanes are an experimental idea; therefore it is unknown how effectively it will mitigate stormwater runoff. It is recommended that gutter be tested in one area before installing them in all locations. The preferable site to do this is the Stadium Drive location. Stadium Drive is a smaller area than Towerview and had more water ponding when it rained than the two other locations.

C. Infiltration Planters

Infiltration planters were selected for design because of their ability to reduce stormwater flows and treat pollutants. They are easily retrofitted in areas of limited space such as roadsides and parking lots. In addition to the functionality, infiltration planters bring aesthetic qualities that other stormwater mitigation designs cannot.

West Rocket Drive – Infiltration Planters 1 – 4 Design

Four infiltration planters were designed for West Rocket Drive between the Law Center and the Performing Arts Building on campus. The general location is shown in Figure 10 below.

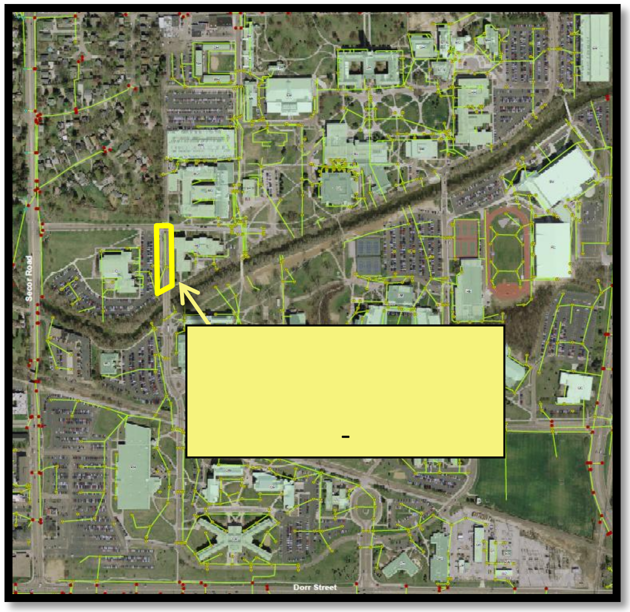


Figure 10: Location Map of West Rocket Drive Infiltration Planters

Design parameters for the infiltration planters were taken from the City of Portland's Design Manual for stormwater management. The Simplified Approach as described by the manual was used for the design of infiltration planters 1 – 4 along West Rocket Drive. A soil infiltration rate of two inches per hour or soil types of NRCS classifications A or B are required for the location of the planters. Using a soil boring report from 2009 on campus, the soil type predicted around the planters was either A-3a. Therefore the infiltration rate was considered sufficient for infiltration planters. The design manual specifies that the water table must be located approximately three feet below the bottom of the planter. Using a USGS water table location map (Appendix B, Figure 28), the water table along West Rocket Drive was determined to be greater than 200 cm. Being that the planter bottom would be located 49 inches below ground surface, it was determined that the water table would be approximately two and half to three feet below the bottom of the planter. As outlined by the Simplified Approach, the drainage areas which would contribute stormwater to each planter was estimated. After determining the drainage areas, a sizing factor of 0.06 was multiplied to the drainage area to calculate the area needed for the infiltration planter. An example calculation for the size of infiltration planter 1 is in Appendix A.

For infiltration planters 1 – 4, the different available areas were less than the calculated area of each planter. The different layers of the infiltration planters were obtained by minimum distances outlined by the design manual. For the growing medium, a minimum depth of 18 inches was used for planters 1 – 4. The growing medium will be a local topsoil mixture. A gravel layer of 12 inches will be used for the planters. The gravel type was specified by the Design Manual as 3/8" to 5/8" stone. A non-woven geotextile filter fabric was designed to be placed between the growing medium and gravel layers as specified by the Design Manual.

Overflow pipes were designed for planters 1 and 3. The existing inlets at 2 and 4 will act as the overflows for those planters. Landscaping for the planters was designed as specified by the Design Manual. For every 100 square foot of planter, 4 large shrubs and 6 medium sedges were to be planted in the planter. Smaller sedges were to be placed on a one plant per twelve inch spacing (triangular spacing). Figure 11 below shows the location of the four different planters which were designed.

Figure 11: Plan View West Rocket Drive

Lot 10 Infiltration Planter Design (Infiltration Planters 5 – 16)

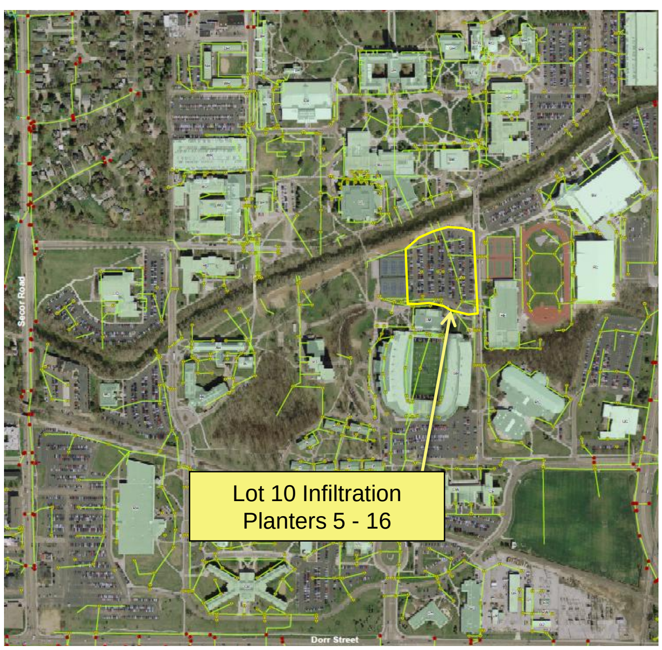


Figure 12: Lot 10 Location

When selecting areas for implementation of infiltration planters, the University of Toledo's Lot 10 located near the Glass Bowl Stadium (see Figure 12 above), was found to be a feasible location based on existing drainage. Currently, a majority of runoff drains to catch basins in the center of the parking rows. By using existing parking lot slopes, planters could be designed to fit in between parking rows with minimal loss of space. Figure 13 below shows the design concept behind the Lot 10 infiltration planters. The existing catch basins can also be implemented as overflows for the proposed infiltration planters.

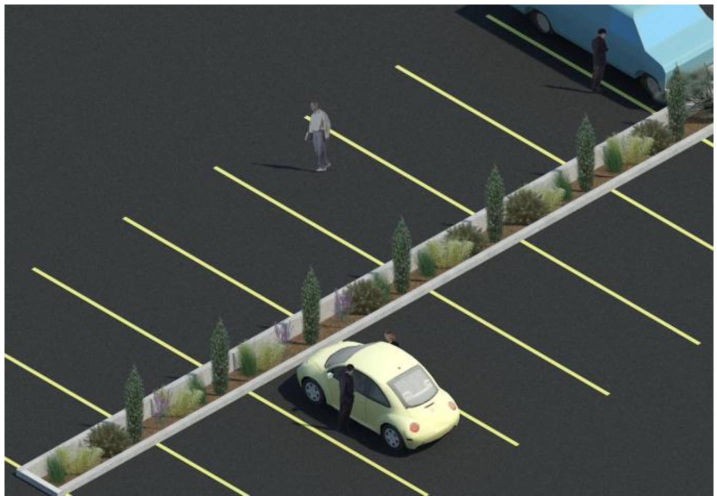


Figure 13: Parking Lot Infiltration Planter Design Concept

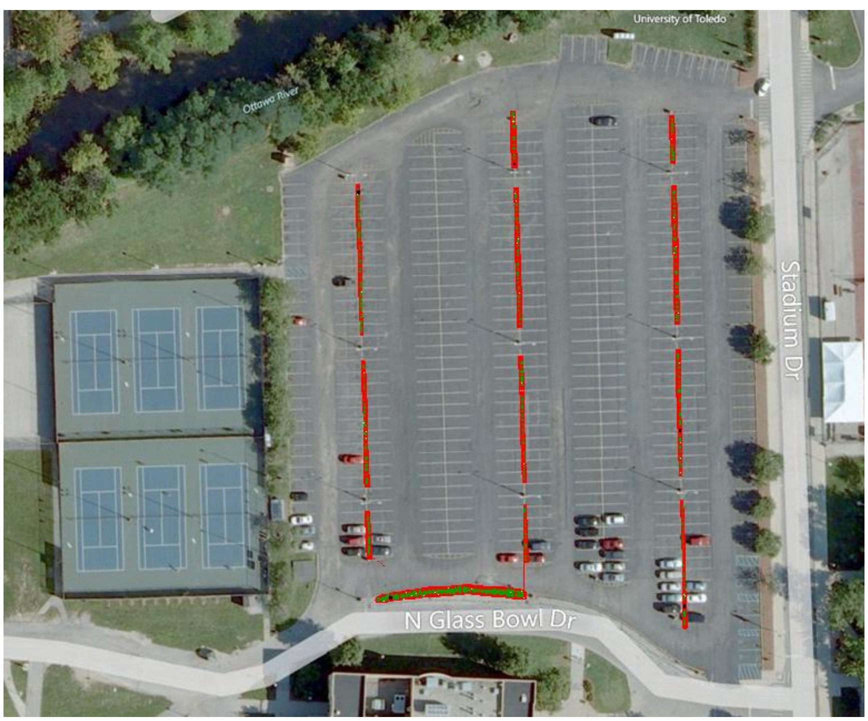


Figure 14: Lot 10 Infiltration Planter Locations

Figure 14 above shows the locations of the proposed Lot 10 infiltration planters. It was determined that there were 12 feasible locations for the design based on the slope of the parking lot and the existing catch basins. These locations were numbered 5 thru 16 (see project plans for individual planter numbers and locations), continuing with the numbering system used on West Rocket Drive. The total drainage area for Lot 10 is approximately 150,000 square feet (3.44 acres). The flow rate of runoff entering Infiltration Planters 5 thru 16 was calculated using the NRCS TR-55 method as shown in Appendix A. The planters were designed for a 25 year storm.

The infiltration planters were designed using the City of Portland's Stormwater Facility Design Manual. Because the planters were designed utilizing all available space, the sizing factor of 0.06 was not used. The minimum planter bed width of 30 inches was used in the design in order to have minimum impact on parking space length. The existing parking spaces are 9 feet wide by 18 feet long with approximately 22 feet of driving lane in between rows. By implementing 30 inch wide planters with 6 inch wide structure sides, the parking spaces adjacent to infiltration planters will be decreased by 1.75 feet in length. The structural walls of the planters also serve as a curb to prevent cars from pulling into the 12 inch deep planters. The curb height is designed to be 6 inches high, allowing the front of the car chassis to hang over, thus minimizing the effect of the reduction in parking space length.

In order to allow for adequate watering of the plants in the structures, curb cuts were designed and are specified in the project plans. Splash protection is required below all curb cuts to prevent erosion. The growing media was designed to be 1.5 feet deep comprising of topsoil. As specified for the West Rocket Drive infiltration planters, a non-woven geotextile filter fabric must be placed below the growing media, which sits on a 1 foot deep bed of gravel. The gravel is specified to be 3/8 inch to 5/8 inch in diameter. Spacing and plant selection are specified in the project plans.

The overflows for each planter were designed using existing catch basins and 3 inch overflow pipes. Catch basins are specified to be adjusted to grade or removed and installed to grade specified in the project plans. Catch basins were designed to be adjusted to a grade of 6 inches above the planter bed. This allows for adequate function and infiltration, while still giving excess flow an outlet during extremely large rain events. In planters without catch basins, 3 inch overflow pipes were designed to allow excess flows to exit the planters. The overflow pipes are specified to be routed to the nearest storm sewer facility in the project plans.

Plant Selection

All plants selected for infiltration planters were native species to Ohio. Selected plants were divided into Large Shrubs/Small Trees (3-gallon container) and Shrubs/Large Grass-Like Plants (1 gallon container) categories.

Large Shrubs/Small Trees

Figure 15: Red Twigged Dogwood (Cornus Sericea)

Cornus Sericea (shown in Figure 15 above) or Red Twigged Dogwood is a native shrub to the northern and western North America. The shrub can survive in full to low sunlight and in dry to heavily moist soils. The branches are dark to bright red and are aesthetically pleasing in the winter months. In the summer and spring months the leaves are a dark green while in the fall they change to a dark red. The Red Twigged Dogwood is recommended for rain gardens by Lucas County and is also a suggested plant for infiltration planters by the City of Portland.

Figure 16: Black Chokeberry (Aronia Melanocarpa)

Aronia Melanocarpa (shown in Figure 16 above) is a deciduous shrub that is native to eastern North America. It is found in wet forests and coniferous swamps and can survive in moist to dry soil. The shrub can survive in full to partial sun, and it most often blooms in the month of May. It has a moderate salt tolerance. The black chokeberry gets its name from the inedible berries that grow from its branches.

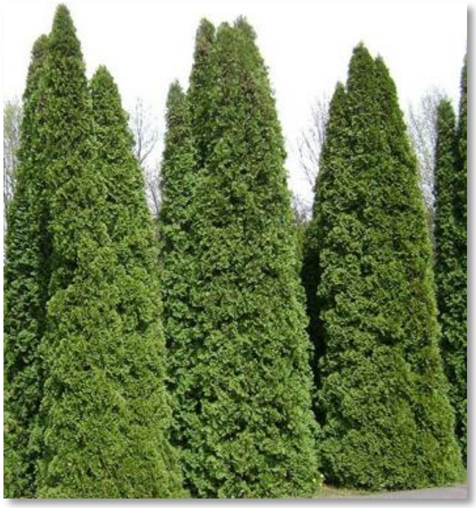


Figure 17: Eastern Arborvitae (Thuja Occidentalis)

Thuja Occidentalis (shown in Figure 17 above) is an evergreen coniferous tree from the Cypress family. It is native to much of the North America including Ohio. The Eastern Arborvitae is found in wet forests and coniferous swamps and prefers moist to saturated wet soil. The tree is tall and slender making it an ideal candidate for infiltration planters of limited width. It has moderate salt tolerance.

Shrubs/Large Grass-Like Plants

Figure 18: Soft Rush (Juncus Effusus)

Juncus Effusus (shown in Figure 18 above) is native to most continents and grows in saturated to wet areas. The plant prefers full to partial sun and grows to approximately 4-5 feet tall. In the fall the soft rush may need to be harvested in order to promote new and healthy growth in the spring. In the spring and summer, soft rush may be a bright green to slightly brownish color towards the end of summer. The soft rush is recommended for rain gardens by Lucas County and is also recommended for infiltration planters by the City of Portland.

Figure 19: Little Bluestem (Schizachyrium Scoparium)

Schizachyrium Scoparium (shown in Figure 19 above) is a perennial prairie grass native to North America. Little bluestem prefers well-drained sunny sites. It grows 2-3 feet tall and has culms that are tan or reddish brown with light green or light blue sheaths. This grass has high drought tolerance, therefore would be ideal for infiltration planters during hot and dry summer months.

Figure 20: Ohio Spiderwort (Tradescantia Ohiensis)

Tradescantia Ohiensis (shown in Figure 20 above) is a native plant to the eastern United States. The Ohio Spiderwort prefers full to partial sun and wet to dry soil conditions. It grows 2-4 feet tall and produces a purple- blue flower which blooms from May to July. It is recommended for rain gardens by Lucas County.

Volume Reduction

Volume reduction analysis was estimated to determine the benefits of the infiltration planters. The average rainfall in Toledo in the month of June (rainiest month) was divided by the number of rain events within the month of June. This determines the amount of rainfall per rain event in the wettest month of the year. The drainage area supported by the infiltration planters was then multiplied by this value to determine the volume of runoff during a rain event. The calculation in Appendix A determines the volume of runoff.

The volume of the infiltration planters which will immediately hold the volume of runoff is approximately 20,000 gallons. The percent reduction of runoff would be 45 % and is calculated using the formula in Appendix A.

Economics

Economics

The senior design group has researched several ways to improve water quality of storm water runoff entering the Ottawa River on the west side of the UT campus. While designing these different concepts, the economics and feasibility were prime concerns.

The budget and cost of this project is unknown due to the highly variable costs associated with materials and size constraints. Nevertheless, in an effort to make the designs more appealing, the cost of construction and maintenance were kept to a minimum without compromise to the quality of the project.

Each of the long term storm water solutions has high longevity designs. This will enable the University to move forward with other maintenance problems and not have to reinvest money to fix the same storm water issues again.

Design solution A, Catch basin filters, for this application would cost about $760 per filter (Moulton, 2011). With 7 catch basins in lot 12 and 3 in lot 26, the total cost of materials for installing these in those locations will be $7,600. There shouldn't be much cost associated with installation though because they are a drop-in installation.

The catch basin filtration systems will need maintenance at regular intervals. Maintenance includes using a Vactor truck to suck the debris out of the filter and replacement of the filter elements. The service fee associated with a Vactor truck runs between $75 and $125 per catch basin (Moulton, 2011). Replacement elements that will need to be changed during this time cost approximately $45 each (Moulton, 2011). In addition there is also the cost of labor to change the filter element. However, this should not be very high since the filters are so easy to change and should only need maintenance once or twice a year. Total cost per maintenance interval would be $1,595 for all 11 catch basins.

Design solution B, porous concrete gutters, is estimated to cost quite a bit more than catch basin filters. A list of labor and materials was estimated: No. 57 gravel sub-base, expansion joint material, geotextile fabric, saw cutting, pavement removal, laborers, and operators. Table 6 below shows the total cost for all of the porous pavement gutters. Tables 15–17 in the Appendix C show the breakdown of the costs associated with each proposed design location: Stadium Drive, West Rocket Drive, and North Towerview Boulevard respectively. Each unit price either came from an over-the-phone quote from local suppliers, calculations, and internet sources.

Table 6: Cost Summary for Porous Pavement Gutters

Location	Total Cost
Stadium Drive	$12,875.56
W. Rocket Drive	$11,161.49
Towerview Blvd.	$23,397.94

Maintenance of the porous concrete gutters will need to be performed 2 – 4 times per year using a street sweeper. The price associated with this was estimated by using $250 per day to rent a street sweeper unit. This equates to $500 - $1000 per year for maintenance.

The main costs of design solution C, infiltration planters, are construction materials and vegetation. Excavation, concrete and labor are the main construction costs oriented with the planters. As seen in the cost analysis Tables 18 – 32 in the Appendix C, the total costs of all 16 infiltration planters is approximately $140,000. The different cost breakdowns for the each planter are located in the Appendix C as well. The average cost of the sixteen planters is approximately $9,000. The City of Seattle suggests that infiltration planters cost approximately $8 per cubic feet of infiltration planter. Using this suggestion, the average cost of planter is approximately $7500. Therefore the cost analysis done for this report seems to be a little conservative. The total cost for each infiltration planter can be seen in Table 7 below.

Table 7: Total Cost for Infiltration Planters

Infiltration Planters Cost Estimate				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	691.4	$30.00	$20,742.00
Concrete - Infiltration Planter Structure	CY	187.4	$135.00	$25,299.00
Concrete - New 6" Standard Curb	FT	98.3	$12.00	$1,179.60
3" PVC Pipe	FT	96.5	$0.94	$90.71
Pavers	SF	337.0	$17.50	$5,897.50
Decorative Metal Grates	SF	86.2	$15.00	$1,293.00
Growing Media	CY	215.1	$16.00	$3,441.60
Sign Removal and Replacement	EA	2.0	$200.00	$400.00
Filter Fabric	SF	387.4	$0.30	$116.22
Gravel Base	CY	143.4	$25.00	$3,585.00
Splash Protection Rock	CY	2.0	$48.00	$94.08
Drain Cover and Elbow	EA	3.0	$6.07	$18.21
Curb Removed	FT	30.8	$5.00	$154.00
Vegetation	LS	1.0	$26,050.00	$26,050.00
Labor	LS	1.0	$39,360.00	$39,360.00
Catch Basin Removed	EA	5.0	$500.00	$2,500.00
Catch Basin Installed	EA	5.0	$1,000.00	$5,000.00
Catch Basin Adjusted to Grad	EA	5.0	$750.00	$3,750.00
12" PVC Pipe	FT	30.0	21.28	$638.40
FERNCO Fitting	EA	13.0	$17.75	$230.75
			Total Cost Estimate	**$139,840.07**

The city of Seattle also suggests that there is a $400 to $500 maintenance costs per year per planter. For existing rain gardens on campus, maintenance is done by volunteer groups. It is suggested that the infiltration planters are also maintained by volunteer groups. With regards to infiltration planters 1 – 4, pavers are used for aesthetics and serve no purpose in the management of the stormwater. To reduce the costs of these four planters, it is suggested to replace pavers with flowerbeds which will at to the aesthetics of the planters also.

Conclusion

Conclusion

Catch basin filters, porous pavement gutter lanes and infiltration planters are the most feasible design choices that can be implemented around the University of Toledo campus to mitigate stormwater runoff and its pollutants entering the Ottawa River. They are effective, sustainable and on average, cost effective solutions. Catch basin filters will treat stormwater runoff pollution for parking lots that do not have room for infiltration planters. Porous pavement is used to treat stormwater runoff in roadways that do not have room for infiltration planters.

There are numerous ways to treat stormwater runoff including in parking lots and roadways. Many of those entail tearing up the entire existing parking lots and re-grading them. However, with the designs we have suggested, it allows the existing parking lots to be retrofitted with these designs at a minimum cost.

Contacts

Contacts

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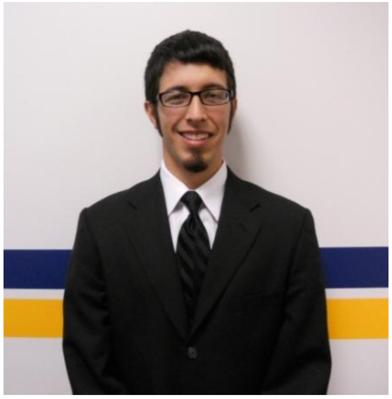
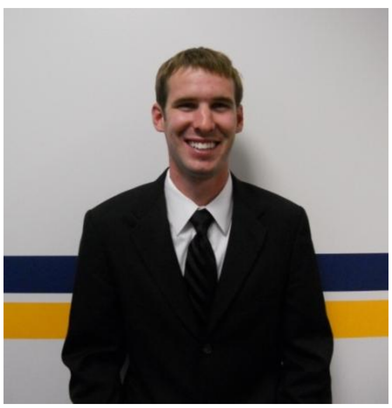
Statement of Qualifications

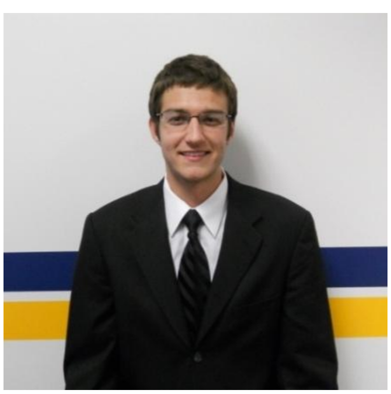
Biographies and Résumés



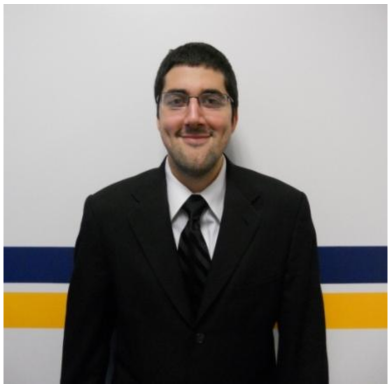
Giovanni Furio is a senior at The University of Toledo working on his last semester in the Civil Engineering Program. Giovanni has worked with Jones and Henry Engineers and the Ohio Department of Transportation, District 12, during his college career. He has interacted and coordinated with engineers on multiple projects with Jones and Henry and ODOT, however his main focus is in the construction field dealing with Transportation Engineering. With the experience ODOT has offered, Giovanni has had many disciplines covered during his Co-op experiences, including bridge construction and deconstruction, pile driving, and quantity calculations for various aspects of the projects. With graduation approaching at the end of the Fall 2011 semester, Giovanni hopes to start his career with ODOT and gain more knowledge towards his Transportation Engineering focus.



Andrew Hodges is a senior at The University of Toledo with an anticipated degree in Civil Engineering. During Andrew's time in the Civil Engineering program, he has completed 5 co-op terms with a heavy highway construction company, E. S. Wagner. Andrew gained experience ranging from skills of a laborer up to supervising field operations. He was involved in shop organization, field surveying, the bidding process (including plan take-offs and quantity verification), supervising small field operations, and organizing material delivery's. Andrew plans to take full time position with E. S. Wagner upon graduation this December as a Heavy Equipment Manager Assistant.



Clinton Kuenzli is in his final semester of the Civil Engineering program at The University of Toledo. Clinton has completed four semesters of co-op with the City of Oregon Public Service Department and has worked there part-time during school semesters. He has gained valuable experience from his time with Oregon inspecting construction sites, storm and sanitary sewers, and erosion control practices. While with the City of Oregon, he also estimated construction quantities and costs. Experience gained in surveying and GIS/GPS is also valuable in Clinton's career as a Civil Engineer. Clinton plans to attend graduate school for Landscape Architecture or Environmental Engineering.



Joe Simeone is currently a senior in the Civil Engineering program at the University of Toledo. He has worked at the Ohio Department of Transportation four different times throughout his college career. Joe’s main focus during his time at ODOT was in the field of construction. During his first two Co-ops, Joe worked on a new bridge being built over five train tracks. His last two Co-ops involved working on both a swing bridge and lift bridge being renovated. Joe gained valuable experience from working with the engineers at ODOT as well dealing with contractors. His communication skills and ability to work with people from different disciplines has vastly improved due to his time spent at ODOT. His knowledge of transportation and construction has come from both his work experience as well as the courses he has taken throughout college.

Brad Brocker is a senior at The University of Toledo for a Bachelor’s degree in Civil Engineering. He has complete four co-ops with two different companies. Starting his first co-op with the Ohio Department of Transportation, Brad gained valuable knowledge of the regulatory control of transportation construction. For the next three co-ops, Brad worked with Great Lakes Dredge and Dock Co. Working on primarily four different beach/berm construction projects, Brad learned the basics to land and hydro surveying practices. Besides the surveying aspects of the three co-ops with GLDD, Brad gained valuable people skills, file management, and adaptability. After graduating in December of 2011, Brad hopes to start his career with an environmental firm located near his hometown of Youngstown, Ohio.

GIOVANNI FURIO

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OBJECTIVE

To secure a cooperative education position in the Civil Engineering field in order to enhance my knowledge through practical experiences and applications.

EDUCATION
August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering
Anticipated graduation: December of 2011

EXPERIENCE
August 2004-September 2004
August 2005-September 2005
August 2007-September 2007

Konstruction King, Inc., Brunswick, Ohio

- Observed the cutting and removal of concrete
- Cleared road of concrete slurry and debris
- Operated machinery (forklifts, excavation machinery)
- Painted (interior/exterior)
- Landscaped

January 2010-May 2010

Jones & Henry Engineers, Ltd., Toledo, Ohio

- Processed shop drawings
- Coordinated with Engineers & Project Managers on multiple projects
- Organized project set-up for Construction Services

September 2010-December 2010
June 2011-August 2011

Ohio Department of Transportation-District 12, Garfield Hts., Ohio

- Inspected bridge construction and deconstruction
  - Reinforcing steel layout on bridge decks
  - Concrete placement
  - Bridge demolition
  - Pile driving
- Calculated cost quantities for wall surface treatments
- Inspected noise wall installation

SPECIAL SKILLS & INTERESTS

- Excellent ability to interact with others
- Enjoy challenges and take extreme pride in my work
- Well-developed oral communication skills
- Above average Microsoft Word & Excel knowledge

HONORS & AWARDS

Scholarships

- UT Pride
- Dr. Lancelot Thompson
- Rocket Success Award

REFERENCES

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ANDREW DAVID HODGES

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OBJECTIVE

To secure a full time position in the Civil Engineering field that will complement my academic endeavors with engineering experience.

EDUCATION
August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering
Anticipated graduation: December of 2011

EXPERIENCE
June 2005-Present

E.S. Wagner Company, Oregon, OH.
Co-op – 5 Terms
- Surveying
- GPS/ ATS systems
- AutoCAD/ Terramodel
- Read, interpret, and design plans
- Supervise field operations
- Organize material delivery

General labor
- Deliver parts, materials, etc. to job sites
- Perform engine/ mechanic work
- Prepare equipment and material orders for field job sites
- Power wash machinery
- Maintain shop cleanliness

SPECIAL SKILLS & INTERESTS

- Takes tremendous pride in work
- Good ability to learn new skills quickly
- Possesses a very logical thought process
- Very mechanically inclined

HONORS & AWARDS

University of Toledo Tower Prestige Scholarship

REFERENCES

Available upon request

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OBJECTIVE

To secure a full time position in the Civil Engineering field that will challenge me and give me valuable experience.

EDUCATION
August 2007-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering
Anticipated graduation: December of 2011

EXPERIENCE
May 2009 – Present
4 full time semesters,
4 part-time semesters

City of Oregon Public Service Dept., Oregon, Ohio

- Assisted engineers in engineering duties
- Construction project inspection
- Storm/sanitary sewer inspection (I&I)
- Rainwater BMP and erosion control inspection
- GIS/GPS
- Surveying
- Utility location

May 2004-May 2009

Wyandot Tractor & Implement Co., Upper Sandusky, Ohio

- Organized incoming stock orders
- Updated existing parts inventory on computer system
- Filled customers' orders

INTERESTS

- Partners for Clean Streams, Clean Your Streams Event (Sept. 2010)
- Tau Beta Pi Engineering Scholarship Society (Nov. 2009)
- Chi Epsilon Civil Engineering Scholarship Society (Nov. 2009)
- Youthworks Mission Trip in Juarez, Mexico (June, 2007)
- American Legion Buckeye Boys State, County Engineer (June, 2006)

COMPUTER SKILLS

- AutoCAD
- Microsoft Office Suite
- EPANET 2
- ArcMap GIS/GPS Software

REFERENCES

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OBJECTIVE	To secure a full-time position in the field of Civil Engineering.
EDUCATION August 2007-Present	**The University of Toledo,** Toledo, Ohio *Bachelor of Science, Civil Engineering* *Anticipated graduation: December of 2011*
EXPERIENCE June 2011-August 2011 August 2010-December 2010 January 2010-May 2010 May 2010-August 2009	**Ohio Department of Transportation-District 12,** Garfield Hts., Ohio • Inspected work done on lift bridge and swing bridge • Read and interpreted plans • Inspected concrete, reinforcing steel, pile driving • Inspected concrete, MSE walls, pile driving • Performed calculations for pay items • Checked plan calculations and final pay quantities
May 2006-August 2006	**North East Ohio Regional Sewer District,** Cleveland, Ohio • Shadowed Engineers in the field • Surveyed beaches and sampled sand • Organized data and databases
COMPUTER SKILLS	• Microsoft Office 2007 • AutoCAD
ACTIVITIES	• Intramural Football • First Year Rocket Engineer
HONORS & AWARDS	• Tower Prestige Scholarship
REFERENCES	**Available upon request**

BRAD BROCKER

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OBJECTIVE

To secure a full time position in the Civil Engineering field that will complement my academic endeavors and satisfy my drive to excel within my profession.

EDUCATION
June 2008-Present

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

- Anticipated Graduation Date: December 2011
- Grade Point Average: 3.787

COMPUTER SKILLS

- Auto CAD
- Microsoft Office Suite

EXPERIENCE
January 2009- Present

Ohio Department of Transportation
(May 2009 to August 2009)

- Worked on MAH-62-19.69 and MAH-62-19.81 (Two Bridge Project)
- Inspected Work of Contractors to the State of Ohio's Speculations
- Aided in the Completion of Daily Reports

Learning Enhancement Center
(January 2009 to April 2009, August 2009 to December 2009, January . 2011 to May 2011)

- Tutored Mathematics
- Developed Oral Communication

Great Lakes Dredge and Dock Co.
(January 2010 to May 2010, August 2010 to December 2010, May 2011 to August 2011)

- Performed Beach Surveys and Daily Hydro Surveys
- Interpreted Data to Create Beneficial Reports for Beach Construction

RELEVANT COURSEWORK

- Elementary Surveying
- Structural Analysis, Transportation 1, and Water Supply

HONORS & AWARDS

- Tower Prestige Scholarship
- Dean's List

COLLEGIATE ACTIVITIES

- Editor of Chi Epsilon (Honor's Society for Civil Engineers)

REFERENCES

Available upon request

Appendix A

Sample Calculations for Porous Gutter Lanes

$Q = ciA$
$c{:}\, Runoff\ Coefficient = 0.7\ to\ 0.95\ for\ asphalt\ (used\ value\ of\ 0.90\ for\ calculations$
$i{:}\, Rainfall\ Intensity\ \ varies\ with\ duration\ of\ rain\ event$
$= 1.78\ for\ 25\ year\ storm\ with\ duration\ of\ 20\ minutes$

$A\ (Stadium\ Dr.) = 0.2941\ acres$
$Q = 0.90 \times 1.78 \times 0.2941 = \boldsymbol{0.4711\ ft^3/sec}$

$$Pavement\ Flow\ Capacity = \frac{360in}{hr}\ X\ \frac{\frac{3630ft^3}{acres}}{in}\ X\ 0.2941acres\ X\ \frac{1hr}{3600s} = \boldsymbol{107ft^3/sec}$$

$$Soil\ Flow\ Capacity = \frac{2in}{hr}\ X\ \frac{\frac{3630ft^3}{acres}}{in}\ X\ 0.2941acres\ X\ \frac{1hr}{3600s} = \boldsymbol{0.5391ft^3/sec}$$

Sample Calculations for Infiltration Planters

Area of Infiltration Planter 1

$2436.90\ ft^2\ \ drainage\ area\ \ \times 0.06 = 146.21\ ft^2\ (area\ of\ planter)$

Flow Entering Parking Lot Infiltration Planters

$Q = ciA$

$c{:}\, Runoff\ Coefficient = 0.7\ to\ 0.95\ for\ asphalt\ (used\ value\ of\ 0.90\ for\ calculations)$

$i{:}\, Rainfall\ Intensity\ \ varies\ with\ duration\ of\ rain\ event$
$= 1.78\ for\ 25\ year\ storm\ with\ duration\ of\ 20\ minutes$

$A = 3.44\ acres$

$Q = 0.90 \times 1.78 \times 3.44 = \boldsymbol{5.5\ ft^3/sec}$

Volume Reduction of Infiltration Planters

$$165876\ ft^2\ \ drainage\ area\ \ * 0.0368\ ft\ \ rainfall\ \ * 7.48\frac{gal}{ft^3}$$
$$= 45659.7\ gal\ (total\ volume\ of\ runoff)$$

$$Percen\ Runoff\ Reduction = \frac{20000\ gal\ (volume\ of\ IP)}{46000\ gal\ (volume\ of\ runoff)} * 100 \approx 45\%$$

Appendix B

Field Measurements and Verifications

Field Visit 1:
Date: September 1, 2011
Time: 12:45 p.m.
Weather: Sunny, 86˚F
Location: Outfall near Wolfe Hall
Equipment: Thermometer, Liter Sample Bottle

For this first field visit, a sample and temperatures were taken from the CPA bridge outfall. Being that it had not rained for a couple of days, using data from the USGS station on campus, the Ottawa River was low with a discharge of approximately four to five cubic feet per second. Even with the low amount of rain, the discharge in question still had a steady flow. The sample would be tested for coliform, BOD_5, and Conductivity. The different methods and procedures used for testing the water sample are included at the end of Appendix B. Below in Table 8 are the lab results of the dry sample analysis.

Table 8: Dry Water Sample Analysis	
BOD_5	Conductivity
1.16 mg/L	711 µs

As seen in Figure 21 & 22 below, a petri dish was used to determine levels of coliform within the sample. After 1 day to allow the bacteria to grow, the petri dish was found to have low levels of colonized growth. From the water analysis, it was concluded that there were no major problems with coliform, BOD, or Conductivity.

Figure 21: Coliform Test 1 - Initial

Initial petri dish for coliform testing. 0.5 mL of Sample #1 was added to the petri dish.

Figure 22: Coliform Test 1 - Final

Final petri dish for coliform testing. After 1 day, there were insignificant amounts of coliform growth found in the dish.

The discharge temperature and upstream temperatures were observed and are displayed in Table 9 below:

Table 9: Temperature Measurement 1	
Discharge Temperature	84.2˚F
Upstream Temperature	73.4˚F

From these two temperature observations, it was determined that a temperature pollution would need to be considered in design solutions. Although temperature pollution would be considered, the downstream temperature also should have been taken to determine if there were any effects on the temperature of the river. A note was made to take both upstream and downstream temperatures in future measurements.

Field Visit 2:
Date: September 6, 2011
Time: 1:00 p.m.
Weather: Partly Cloudy, 59˚F
Location: Outfall near Wolfe Hall
Equipment: 500 mL Graduated Cylinder, Bucket (measured for 4000 mL), Stopwatch, Manhole Hook

The two field measurements taken on Field Visit 2 were both flow quantities. As with the first field visit, the second visit was in between rains. Therefore, the flow quantities would represent that of the steady questionable trickle. For the first test, a stopwatch and 500 mL graduated cylinder were used. The first test's results are shown below in Table 10.

Table 10: Flow Quantity1

Test	Time (s)	Volume (mL)	Flow (L/s)	Flow (ft^3/min)
1	2.8	500	0.18	0.38
2	2.5	480	0.19	0.41
3	2.8	490	0.18	0.37
4	2.8	500	0.18	0.38
5	2.7	490	0.18	0.38
6	2.9	520	0.18	0.38
7	2.9	500	0.17	0.37
8	3.0	490	0.16	0.35
9	1.2	430	0.36	0.76
10	0.7	530	0.76	1.60

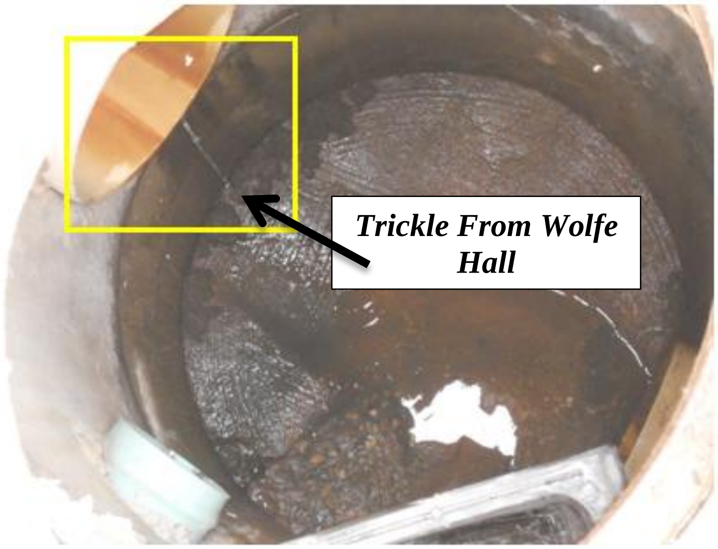
After performing the first test with the graduated cylinder, it was determined that the flow was too quick to use the 500 mL graduated cylinder for an accurate reading. Using the 500 mL graduated cylinder, a bucket was measured for 4000 mL or 4 L. The results from the second test, using the measured bucket, are displayed in Table 11 on the following page.

Table 11: Flow Quantity2				
Test	Time (s)	Volume (L)	Flow (L/s)	Flow (ft^3/min)
1	12.0	4	0.33	0.71
2	12.0	4	0.33	0.71
3	13.1	4	0.30	0.65
4	13.7	4	0.29	0.62
5	14.7	4	0.27	0.58
6	16.2	4	0.25	0.52
7	7.3	4	0.55	1.16
8	5.7	4	0.70	1.48
9	5.9	4	0.67	1.43
10	6.5	4	0.62	1.31

One major finding of Field Visit 2 was that the flow of the continuous trickle fluctuates. The flow varied one cubic foot for two of the tests. Although both of these tests may not be extremely accurate they are useful for an approximate flow being discharge into the Ottawa River.

Along with flow quantities, field verification was performed on Field Visit 2. The main objective was to follow the flow of the steady trickle back to its source. As seen in Figure 27 in the Appendix C, the flow was followed back through the following manholes (in order from outfall to source): PST-8336, PST-8337, PST-8339, and PST-8340. The final manhole uncovered was PST-8340 which is located right next Wolfe Hall. Inside the manhole located near Wolfe Hall (PST-8340), a slow trickle was found flowing from a white pipe directed towards Wolfe Hall. Figure 23 on the following page shows the trickle coming from Wolfe Hall.

Figure 23: Manhole PST-8340



The PVC pipe boxed in the upper left hand corner of the picture is from Wolfe Hall. It can be seen that a slow trickle is flowing from the building.

In intervals of approximately two to four minutes, a pump would turn on and the flow would increase. On this field visit, the flow was not traced back into the building due to the absence of facilities personnel. An investigation inside Wolfe Hall would be performed on a later field visit.

Field Visit 3:
Date: September 7, 2011
Time: 2:15 p.m.
Weather: Cloudy/Rainy, 65˚F
Location: Outfall near Wolfe Hall
Equipment: Thermometer, Manhole Hook, Bucket, Stopwatch, Dye, Liter Sample Bottle

For the third field visit, temperature, flow, and verification/dye test were all performed, and a second water sample was taken. Unlike the first two field visits, it was raining and had rained in the days before the field visit. Therefore, measurements would be representative of regular stormwater along with the unknown source. First the temperature of the discharge, upstream, and downstream waters were taken. These temperatures are displayed in Table 12 below:

Table 12: Temperature Measurement 2	
Discharge Temperature	77˚F
Upstream Temperature	64.4˚F
Downstream Temperature	64.4˚F

Compared to the first temperature measurement, there was an increase in the difference between the discharge and the river temperature. This is most likely due to the addition of rainwater to the river which would have lowered the overall temperature of the river. Also for this test, the downstream temperature was equal to the upstream temperature. This may suggest that the temperature of the discharge may not have a great effect on the river temperature.

The next test performed on Field Visit 3 was another flow measurement. Below, in Table 13 are the results to the measurements. An increase in flow was expected due to the weather conditions. As before with the previous tests, there was a change in flow as the measurements were taken.

Table 13: Flow Quantity 3

Test	Time (s)	Volume (L)	Flow (L/s)	Flow (ft^3/min)
1	2.9	4	1.38	2.92
2	3.0	4	1.33	2.83
3	3.1	4	1.29	2.73
4	3.2	4	1.25	2.65
5	3.1	4	1.29	2.73
6	2.9	4	1.38	2.92
7	3.0	4	1.33	2.83
8	3.0	4	1.33	2.83
9	2.5	4	1.60	3.39
10	2.6	4	1.54	3.26

The final part of Field Visit 3 was a dye test to confirm the field verification of Field Visit 2. The following manholes, as seen in Figure 27 in the Appendix C, were uncovered: PST-8336, PST-8337, PST-8339, and PST-8340. Dye was added to PST-8340. A different team member was stationed at each manhole to wait for the recognition of the dye flowing through the stormwater system. The flow was confirmed by the dye at each manhole and finally the outfall. The dye can be seen flowing into the river from the outfall in Figure 24 on the following page.

Figure 24: Dye Test Confirmation

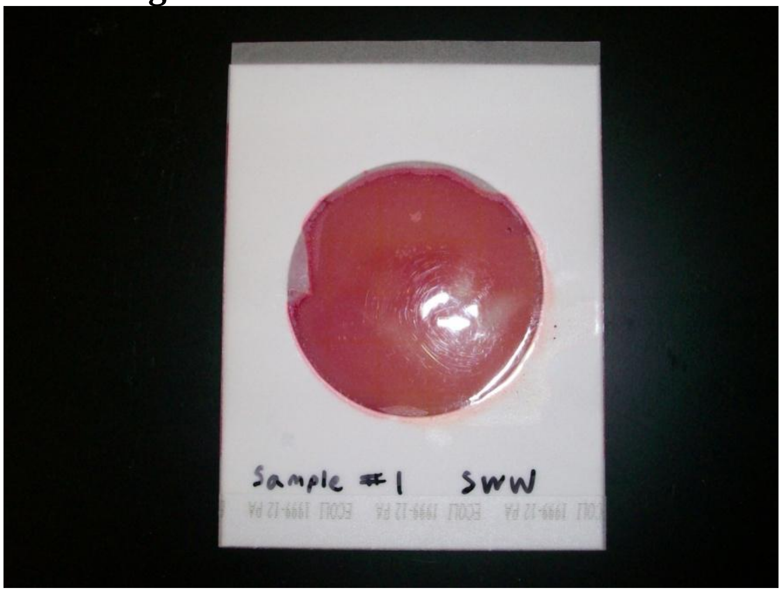
The green dye can be seen flowing out of the outfall in question.

Another part of the field verification was the collection of a water sample to represent the properties of the increased discharge due to wet weather flows. The sample was tested for coliform, BOD_5, and Conductivity. The different methods and procedures used for testing the water sample are included at the end of Appendix B. Below in Table 14 are the lab results of the wet sample analysis.

Table 14: Wet Water Sample Analysis	
BOD_5	Conductivity
1.39 mg/L	564 µs

As seen in Figure 25 & 26 below, a petri dish was used to determine the levels of coliform within the sample. In Figure 26, the petri dish displays low amounts of coliform growth. From the second water analysis, it was concluded that there were no major problems with coliform, BOD, or Conductivity.

Figure 25: Coliform Test 2 - Initial



Initial petri dish for coliform testing. 0.5 mL of Sample #2 was added to the petri dish.

Figure 26: Coliform Test 2 - Final

Final petri dish for coliform testing. After 1 day, there were insignificant amounts of coliform growth found in the dish.

Field Visit 4:
<u>Date:</u> September 11, 2011
<u>Time:</u> 2:15 p.m.
<u>Location:</u> Inside Wolfe Hall

Field Visit 4 was spent touring the basement of Wolfe Hall and Bowman-Oddy on September 11th. With the assistance of a facilities worker, the mechanical room where the stormwater pipe ran into Wolfe Hall was investigated. A floor drain/trench was found to run through the entire room where steam condensation overflows and pipe leaks drain. This drain was traced back to a 4' diameter crock where there are twin 3" sump pumps, which pump directly into the storm sewer main. Further investigation was done to see if any other notable sources drained to the storm sewer main. After tracing it back out of the mechanical room deeper into Wolfe Hall the pipe continued towards Bowman-Oddy but could not be found after it left Wolfe Hall. During the investigation of the pipe location, no other source of flow could be found. It was verified however that just one of the 3" sump pumps was capable of producing the flow in the manhole which was observed earlier just outside Wolfe Hall. In conclusion, on the day that the investigation was performed the source of hot/ warm water exiting Wolfe Hall could not be found. This could have been because steam production is reduced on the weekends, but this could not be confirmed.

Methods and Procedures for Water Analysis:

BIOCHEMICAL OXYGEN DEMAND (BOD)

INTRODUCTION

The BOD test originated from Great Britain where no flowing river reaches the ocean in more than five days. Thusly, it was standardized as the measurement of oxygen utilized in the stabilization of organic matter over a five-day period. One reference describes in quantified terms what is typically happening in the five days that a BOD sample is incubating. Such quantification is not to suggest that these numbers happen every time in a BOD test, but simply to give a rational picture of what is happening. The text that follows is that picture.

Day One

In fresh domestic sewage with 240 mg/L BOD_5 and 100,000 bacteria per milliliter, a 1:40 dilution would be the lowest used for the BOD test. This dilution would give about 3,000 bacteria per milliliter and 9 mg/L ultimate BOD. This would relate to a high F/M ratio where initially there is unlimited food and bacterial growth will be unrestricted. The bacteria begin reproducing exponentially. The bacteria will continue to grow in numbers in this log phase until food becomes a limiting factor. Approximated 50 percent of the original available food will be stabilized at the end of that log growth phase usually within about 24 hours. Stabilization of this fraction of the organic matter should exert approximately 1.8 mg/L of oxygen demand and will produce approximately 10,000,000 bacteria per milliliter. At the end of this phase the lack of food slow down bacteria growth, but a second inhibiting factor also develops. Protozoa have started to develop, which use the substrate bacteria as their food source. It takes approximately 100,000 bacteria to produce a protozoa and protozoan growth will lag bacterial growth by this relationship. There is little change in the protozoan population within the first 24-hour period.

Day Two

In the second day, the substrate bacteria are beginning to be held back by food limitations as well the developing protozoan predators. All the original food is removed with the production of an additional 6,000,000 million bacteria per milliliter and an exertion of 2.7 mg/L of oxygen demand. The protozoan population then grows from 1 or 2 per milliliter to over thirty per milliliter and consumes 3,000,000 bacteria per milliliter. This growth exerts an oxygen demand of 0.3 mg/L. At the end of two days, the bacteria population remains at 13,000,000 and the protozoan population at 30 per milliliter. The total oxygen spent will be 4.8 mg/L.

Day Three

The third day finds the bacteria in endogenous metabolism and declining growth resulting from exponential protozoan growth. Endogenous metabolism essentially derives its energy from cytoplasm. As a normal food source becomes limited, less likely substances are made available for food. Bacteria cells begin burning up their own excess cellular materials. The bacteria eventually die and their intracellular materials are released as food for other bacteria to survive. During this third day, the protozoan population probably reaches about 100 per mL, which puts a further limiting factor on the substrate bacteria population. Bacterial population most likely reduces to about 4,000,000 per mL. The protozoa exert an oxygen demand of 0.7 mg/L while the bacteria now exert an oxygen demand of only about 0.5 mg/L. The net effect is that by the end of the third day, 5.5 mg/L of oxygen has been used.

Day Four

On the fourth day, the protozoan population probably maintains at 100 per mL, which requires 6,000,000 bacteria per mL. Oxygen uptake by the end of the fourth day is about 5.8 mg/L.

Day Five

The fifth day finds all microorganisms decreasing in number. The protozoans drop to approximately 50 per mL while the bacteria drop to about 500,000 to 1,000,000 per mL. The total oxygen uptake rises to about 6.0 mg/L or 67 percent of the ultimate BOD.

After Day Five

Endogenous metabolism will continue until around the twentieth day when near total oxidation of all food matter has taken place.

The Biochemical Oxygen Demand (BOD) test is an empirical test that is used to determine the relative oxygen requirements of wastewater and polluted waters. The test has its widest application in measuring waste loadings to wastewater treatment plants, designing wastewater treatment plants, and in evaluating the treatment efficiency of such systems. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material (carbonaceous oxygen demand), and the oxygen used to oxidize inorganic material such as sulfides and ferrous ion. The BOD test may also be used to measure the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented using an inhibitor during the test procedure.

The most common BOD test is the 5-day BOD (BOD_5), which has a total incubation period of five days. Longer and shorter tests can be performed depending on the purpose of study. In this lab, a 7-day BOD test (BOD_7) will be performed. The lab includes a study of the BOD equation and first order reactions. Using the BOD equation given in this handout, the measured BOD_7 will be converted to ultimate BOD (BOD_u) and BOD_5.

Biological Oxidation of Organic Matter

The BOD test is a bioassay test in which the rate (and extent) of the aerobic degradation of organic matter is assessed in terms of the amount of the oxygen consumed in its degradation. The biological reactions occurring can be summarized as follows:

Organic matter + Microorganisms + $O_2 \Rightarrow$ More microorganisms + CO_2 + H_2O + Residual organic matter

The BOD test measures the amount of oxygen depleted during the test, which is a direct correlation of the amount of biodegradable organic matter in the sample. Many of the parameters employed in the design and operation of wastewater treatment plants utilize BOD concentrations of wastewater. Among these parameters, the influent BOD loading rate and the amount of food provided to the bacteria in the aeration tank (food to microorganism or F/M ratio) are common as design and operational parameters.

BOD Equation

The rate of oxidation of carbonaceous organic matter in the BOD test can be approximated by a first order reaction:

$$1.)\ BOD_t = BOD_u\left(1 - 10^{-kt}\right)$$

where **BOD_t** = amount of DO consumed at time t (BOD_t), in mg/L
BOD_u = ultimate amount of DO consumed (BOD_u), in mg/L
t = time, days
k = pseudo first order rate constant, in days^{-1}

The solution to this equation is complicated since usually both BOD_u and k are unknown. Appropriate methods are available to determine these constants if data is available. Typical values of k will be assumed in this lab for converting the BOD values (i.e., BOD_7, BOD_5, BOD_u). Consider the following case as an example: Assume that the ultimate BOD allowed in a wastewater effluent discharge to a river is 30 mg/L, with a reaction rate constant of 0.23 day^{-1}. You can calculate the BOD_5 of this wastewater as follows:

$$BOD_5 = 30\left(1 - 10^{-0.23*5}\right) = 27.9 \text{ mg/L}$$

Note that the BOD_u is greater than BOD_7, which is greater than BOD_5.

Carbonaceous versus Nitrogenous BOD

Oxidation of reduced forms of carbon, mediated by microorganisms exerts a *carbonaceous demand*. Oxidation of reduced forms of nitrogen, mediated by microorganisms exerts a *nitrogenous demand*. If a nitrification inhibition chemical is not used, the BOD measured is a combination of carbonaceous and nitrogenous BOD. Nitrogenous demand is directly related to the amount of ammonia nitrogen in the water sample. Nitrogenous demand (i.e., *nitrification*) can be summarized using the following equations:

$$\mathbf{2NH_3 + 3O_2 \Rightarrow 2NO_2^- + 2H^+ + 2H_2O} \quad \textbf{in the presence of } \textbf{\textit{Nitrosomonas}}$$
$$\mathbf{2NO_2^- + O_2 \Rightarrow 2\ NO_3^-} \quad \textbf{in the presence of } \textbf{\textit{Nitrobacteria}}$$

The extent of oxidation of nitrogenous compounds during the 5-day incubation period depends on the presence of microorganisms capable of carrying out this nitrification reaction. If the test is seeded with activated sludge samples from a wastewater treatment plant, it seed contains sufficient amount of nitrifying bacteria, and ammonia oxidation will occur. However, if the seed does not contain large populations of these microorganisms, then nitrification is unlikely to occur during a 5-day BOD test. Nitrifies grow relatively slowly and do not develop a significant population in five days. Such organisms are usually not present in the raw sewage or primary effluent in sufficient numbers to oxidize significant quantities of reduced nitrogen, but exist in sufficient amounts in the activated sludge samples from nitrifying wastewater treatment plants.

Dilution Requirements

The BOD concentration in most wastewaters exceeds the concentration of dissolved oxygen (DO) available in an air-saturated sample. Therefore, it is necessary to dilute the samples before incubation to bring the oxygen demand and supply into an appropriate balance. Because bacterial growth requires nutrients such as nitrogen, phosphorus, and trace metals, these are added to the dilution water, which is buffered to ensure that the pH of the incubated sample remains in a range suitable for bacterial growth. Complete stabilization of a sample may require a period of incubation too long for practical purposes; therefore five days has been accepted as the standard incubation period. If the dilution water is of poor quality, it will appear as sample BOD. Therefore, it is necessary to perform a dilution water check. The DO uptake observed in the dilution water check in five days at 20^oC should not be more than 0.2 mg/L, and preferably not more than 0.1 mg/L.

PROCEDURE

Part A: Determination of BOD

Principle

Microorganisms consume dissolved oxygen (DO) to maintain their growth and activities while biodegrading the organic matter in a sample at 20^{o}C and for a designated time period. The consumption of DO is directly related to the amount of organic matter in the water sample. DO is measured before and after the incubation period and the BOD is computed from the difference between initial and final DO measurements.

Apparatus and Supplies

Glass-stoppered 300 mL BOD bottles
Incubator at 20^{o}C
DO meter and probe
Graduated cylinders
Aerated dilution water (prepared by the TA)
Aerated PolySeed Solution (prepared by the TA)
Aluminum foil
Water sample

Procedure

1. Each group will prepare TWO sets of BOD bottles. 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). Mark the group number on each bottle and the record the bottle number for each sample appropriately.
2. If you are testing something other than wastewater, you will need to add PolySeed Solution which will add the needed microorganisms to calculate decay. This solution should be added to all sample bottles for consistency prior to incubation.

The instructor and TA will suggest dilution levels that are appropriate. Based on these levels, determine the volume of dilution water and sample that need to be added to teach bottle.

3. Day 0 Bottles:
   (i) Pipet the correct amount of sample into each BOD bottle. Fill the remaining volume with aerated dilution water. Fill the BOD bottles with aerated dilution water halfway into the neck. Make sure there are no bubbles in the bottle.
   (ii) Fill the blank BOD bottle with aerated dilution water halfway into the neck. Make sure there are no bubbles in the bottle.
   (iii) Measure and record the initial DO readings in each bottle, using the procedure described under Part B.
   (iv) Discard the sample and wash all the glassware.

4. Day 7 Bottles:
   (i) Pipet the correct amount of sample into each BOD bottle. Pipet 10 mL of polyseed solution. Fill the remaining volume with aerated dilution water. Fill the BOD bottles

(ii) with aerated dilution water halfway into the neck. Make sure there are no bubbles in the bottle.

(iii) Fill the blank BOD bottle with aerated dilution water halfway into the neck, so that insertion of the glass stopper will displace all air, leaving no bubbles in the bottle.

(iv) Pour a small amount of dilution water onto the stopper to form a seal. This water seal will form a precaution against drawing air into the bottles during incubation period. Place foil over the flared mouth of the bottles to reduce evaporation of the water seal during incubation.

(v) Place the bottles in the incubator for one week. Make sure the incubator does not receive excessive amount of light to induce photosynthesis in the bottles.

(vi) After one week, remove the sample bottles from the incubator and measure the final DO as described under Part B.

(vii) Discard the samples and wash all the glassware.

Part B: Measurement of Dissolved Oxygen (DO)

<u>Principle</u>

The DO content of a water sample can be measured using a DO probe, which has an oxygen-permeable membrane. Under steady-state conditions, the current produced is directly proportional to the DO concentration. Membrane electrodes exhibit a relatively high temperature coefficient largely due to changes in membrane permeability.

<u>Apparatus</u>

DO meter
DO meter probe
Deionized water
Samples to be tested

<u>Procedure</u>

1. Insert the probe in the sample BOD bottle, turn on the stirrer, and press the **“meas”** button. Record the measurement when the reading is stable (it will beep when stable). Turn off the stirrer before removing the probe from the bottle.
2. Rinse the probe with deionized water after each measurement.
3. Measure the DO of all three bottles in the same manner and record the readings.

DATA ANALYSIS

1. Calculate the BOD_7 of each sample using the equation below: DO_7

$$BOD = \frac{DO_i - DO_f \; - SCF}{P}$$

Where **DO$_i$** = initial DO of the diluted sample before incubation (day 0), mg/L

DO$_f$ = final DO of the diluted sample after incubation (day 7), mg/L

P = decimal volumetric fraction of sample used. For example, if the sample volume was 10 mL, P = 10 mL/300 mL=0.0333 since the total volume of the BOD bottles is 300 mL.

SCF = Seed correction factor (calculated by the TA)

2. Calculate the ultimate BOD (BOD_u) for each sample using the **BOD equation 1** given earlier. Assume that the reaction rate **k** is -0.46 day^{-1} for raw water at 20^{o}C and **t** is 7 days.
3. Convert the BOD_u to BOD_5 for each sample using the **BOD equation 1** given earlier. Assume that the reaction rate **k** is -0.46 day^{-1} for raw water at 20^{o}C and **t** is 5 days.

Note: The dilution water should have a D.O. depletion of 0.2 mg/L or less after incubation. If it does not, a correction must be made in the test results. The dilution water D.O. depletion must be subtracted from the D.O. depletion of each sample after incubation. The net D.O. results are then used to determine the BOD of each sample.

Example BOD calculations are attached to the end of this lab. Use the examples to determine the BOD_5, BOD_u of the samples.

REFERENCES

AEESP, (2001). Association of Environmental Engineering Professors Environmental Engineering Processes Laboratory Manual.

APHA, AWWA, WEF, (1992). Standard Methods for the Examination of Water and Wastewater. Editors Greenberg, A. E., Clesceri, L. S., Eaton, A. D. American Public Health Association, American Water Works Association, Water Environment Federation. 18th ed, Washington, DC.

Viessman, W., Jr. and Hammer, M. (1998). Water Supply and Pollution Control. Sixth edition. Addison Wesley Longman Inc., California.

Conductivity

What is conductivity and why is it important?

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C).

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.

Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity.

The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Sampling and equipment Considerations

Conductivity is useful as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered a stream.

Conductivity is measured with a probe and a meter. Voltage is applied between two electrodes in a probe immersed in the sample water. The drop in voltage caused by the resistance of the water is used to calculate the conductivity per centimeter. The meter converts the probe measurement to micromhos per centimeter and displays the result for the user. NOTE: Some conductivity meters can also be used to test for total dissolved solids and salinity. The total dissolved solids concentration in milligrams per liter (mg/L) can also be calculated by multiplying the conductivity result by a factor between 0.55 and 0.9, which is empirically determined (see Standard Methods #2510, APHA 1992).

Suitable conductivity meters cost about $350. Meters in this price range should also measure temperature and automatically compensate for temperature in the conductivity reading. Conductivity can be measured in the field or the lab. In most cases, it is probably better if the samples are collected in the field and taken to a lab for testing. In this way several teams of volunteers can collect samples simultaneously. If it is important to test in the field, meters designed for field use can be obtained for around the same cost mentioned above.

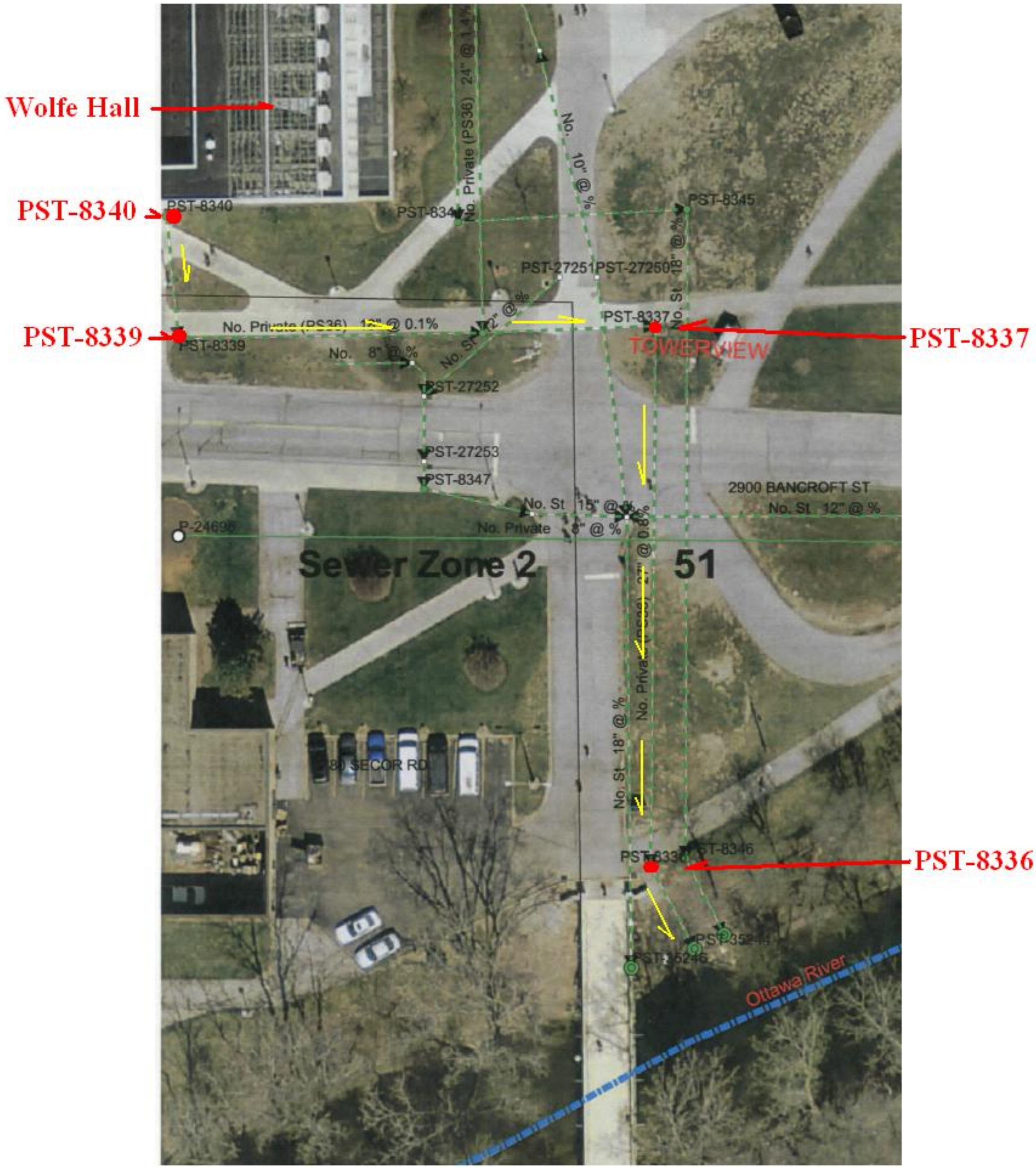
If samples will be collected in the field for later measurement, the sample bottle should be a glass or polyethylene bottle that has been washed in phosphate-free detergent and rinsed thoroughly with both tap and distilled water. Factory-prepared Whirl-pak® bags may be used.

Source:

US Environmental Protection Agency @ www.water.epa.gov . September 14, 2011.

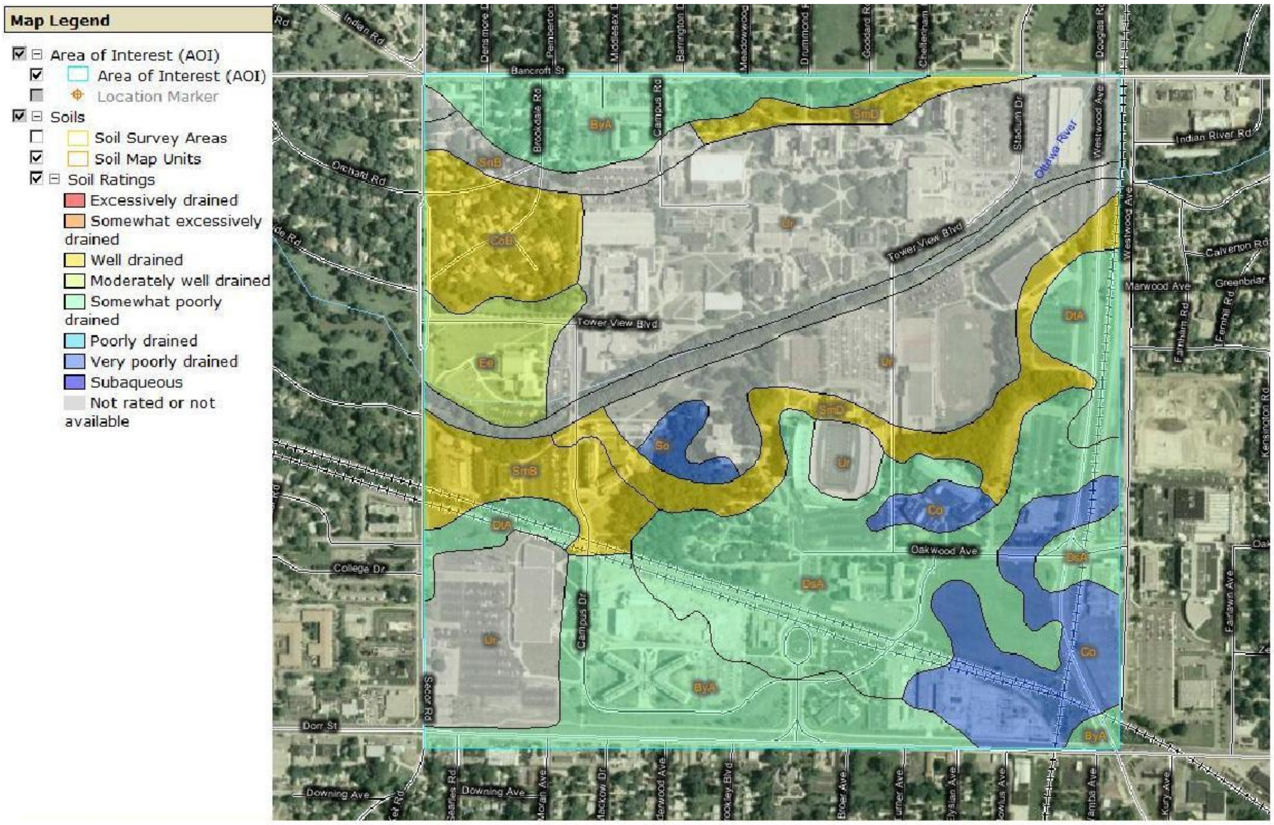
Appendix C

Figure 27: Manhole Location



The different manholes (PST-8340, PST-8339, PST-8338, PST 8337, and PST-8336) which were monitored during the dye test and for other field verifications are boxed in yellow. The Ottawa River and Wolfe Hall are also labeled. The stormwater lines are labeled as green dotted lines while the lines in question are labeled with yellow arrows.

Figure 28: Soil Survey - Drainage Class Map



Summary by Map Unit — Lucas County, Ohio (OH095)

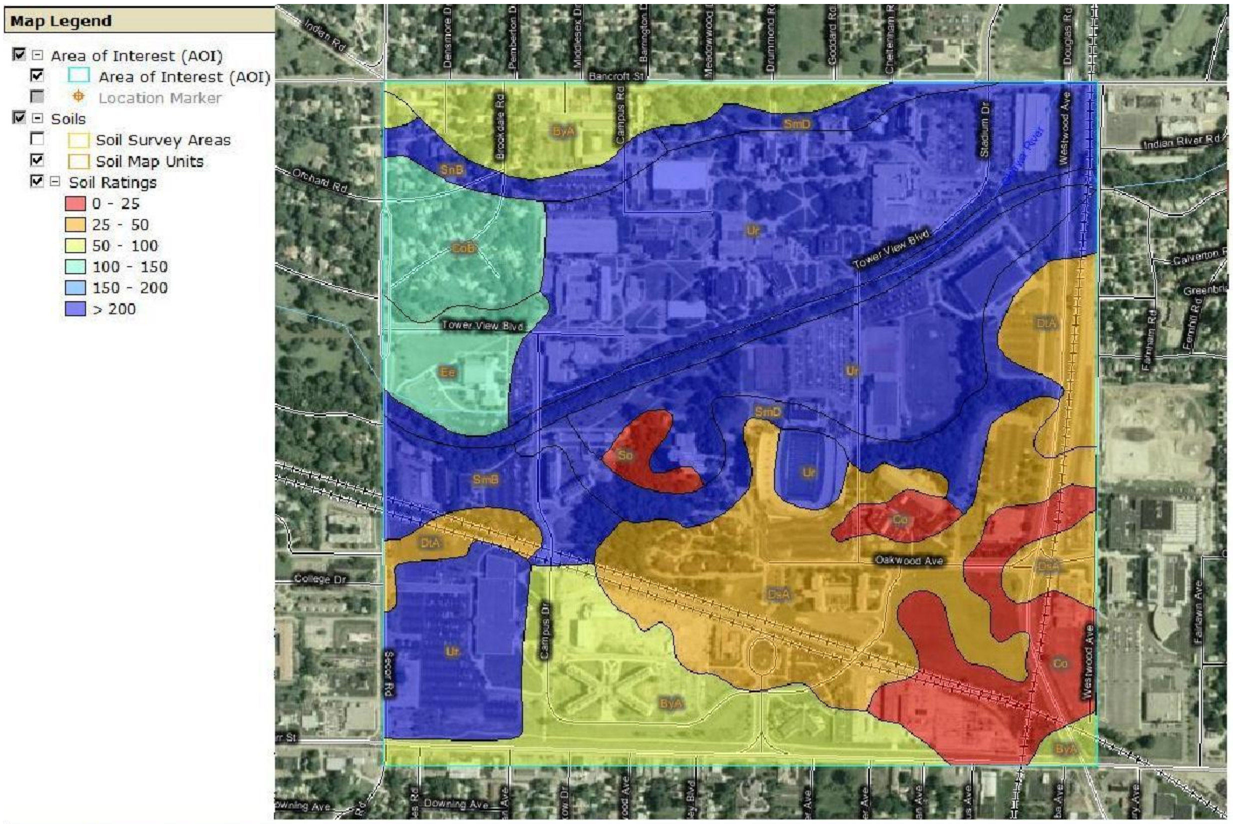
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
ByA	Bixler-Urban land complex, 0 to 3 percent slopes	Somewhat poorly drained	50.1	15.1%
Co	Colwood loam	Very poorly drained	24.0	7.2%
CoB	Colonie fine sand, 1 to 6 percent slopes	Well drained	13.9	4.2%
DsA	Dixboro fine sandy loam, 0 to 2 percent slopes	Somewhat poorly drained	51.4	15.5%
DtA	Dixboro-Urban land complex, 0 to 2 percent slopes	Somewhat poorly drained	12.2	3.7%
Ee	Eel loam, occasionally flooded	Moderately well drained	10.7	3.2%
OuB	Ottokee-Urban land complex, 0 to 6 percent slopes		0.5	0.2%
SmB	Sisson loam, 2 to 6 percent slopes	Well drained	12.5	3.8%
SmD	Sisson loam, 12 to 18 percent slopes	Well drained	23.2	7.0%
SnB	Sisson-Urban land complex, 2 to 12 percent slopes		5.8	1.8%
So	Sloan loam, occasionally flooded	Very poorly drained	2.9	0.9%
Ur	Urban land		115.8	34.9%
W	Water		9.0	2.7%
Totals for Area of Interest			**332.1**	**100.0%**

Description — Drainage Class

"Drainage class (natural)" refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized-excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. These classes are defined in the "Soil Survey Manual."

USGS soil data for The University of Toledo.

Figure 29: Soil Survey – Depth to Water Table Map



Summary by Map Unit — Lucas County, Ohio (OH095)				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
ByA	Bixler-Urban land complex, 0 to 3 percent slopes	84	52.2	15.4%
Co	Colwood loam	15	25.2	7.4%
CoB	Colonie fine sand, 1 to 6 percent slopes	138	14.1	4.2%
DsA	Dixboro fine sandy loam, 0 to 2 percent slopes	46	52.4	15.4%
DtA	Dixboro-Urban land complex, 0 to 2 percent slopes	46	13.6	4.0%
Ee	Eel loam, occasionally flooded	137	10.8	3.2%
OuB	Ottokee-Urban land complex, 0 to 6 percent slopes	69	0.6	0.2%
SmB	Sisson loam, 2 to 6 percent slopes	>200	12.7	3.7%
SmD	Sisson loam, 12 to 18 percent slopes	>200	23.5	6.9%
SnB	Sisson-Urban land complex, 2 to 12 percent slopes	>200	5.9	1.7%
So	Sloan loam, occasionally flooded	8	2.9	0.9%
Ur	Urban land	>200	116.5	34.3%
W	Water	>200	9.2	2.7%
Totals for Area of Interest			**339.5**	**100.0%**

Description — Depth to Water Table

"Water table" refers to a saturated zone in the soil. It occurs during specified months. Estimates of the upper limit are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table.

This attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

USGS water table data for The University of Toledo.

Table 15: Stadium Drive Porous Gutter

Stadium Drive				
Item	Estimated Quantity	Unit	Unit Price	Estimated Cost
8" Porous Concrete Gutter	1583.16	SF	$3.09	$4,886.30
No. 57 Gravel Sub-base	791.58	LF	$1.31	$1,033.45
Expansion Material	36	EA	$12.70	$457.20
Geotextile Fabric	1	LS	$366	$366.00
Saw Cutting	798.58	LF	$1.50	$1,197.87
Pavement Removal	1583.16	SF	$1.50	$2,374.74
Labor	64	HR	$25	$1,600.00
Operator	32	HR	$30	$960.00
			Total Cost Estimate	**$12,875.56**

Table 16: West Rocket Drive Porous Gutter

West Rocket Drive				
Item	Estimated Quantity	Unit	Unit Price	Estimated Cost
8" Porous Concrete Gutter	1309	SF	$3.09	$4,040.12
No. 57 Gravel Sub-base	654.4	LF	$1.31	$857.26
Expansion Material	30	EA	$12.70	$381.00
Geotextile Fabric	1	LS	$366	$366.00
Saw Cutting	662.4	LF	$1.50	$993.60
Pavement Removal	1309	SF	$1.50	$1,963.50
Labor	64	HR	$25	$1,600.00
Operator	32	HR	$30	$960.00
			Total Cost Estimate	**$11,161.49**

Table 17: North Towerview Boulevard Porous Gutter

North Towerview Boulevard				
Item	Estimated Quantity	Unit	Unit Price	Estimated Cost
8" Porous Concrete Gutter	3201.17	SF	$3.09	$9,880.15
No. 57 Gravel Sub-base	1600.58	LF	$1.31	$2,096.76
Expansion Material	72	EA	$12.70	$914.40
Geotextile Fabric	2	LS	$366	$732.00
Saw Cutting	1608.58	LF	$1.50	$2,412.87
Pavement Removal	3201.17	SF	$1.50	$4,801.76
Labor	64	HR	$25	$1,600.00
Operator	32	HR	$30	$960.00
			Total Cost Estimate	**$23,397.94**

Table 18: Infiltration Planter 1

Infiltration Planter 1				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	33.0	$30.00	$990.60
Concrete - Infiltration Planter Structure	CY	5.2	$135.00	$697.95
Curb Constructed	FT	12.7	$12.00	$152.04
3" PVC Pipe	FT	2.8	$0.94	$2.66
Pavers	SF	44.6	$17.50	$779.98
Decorative Metal Grates	SF	8.2	$15.00	$123.60
Growing Media	CY	9.2	$16.00	$147.36
Sign Removal and Replacement	EA	1.0	$200.00	$200.00
Filter Fabric	SF	165.8	$0.30	$49.73
Gravel Base	CY	6.1	$25.00	$153.50
Splash Protection Rock	CY	0.1	$48.00	$4.32
Drain Cover and Elbow	EA	1.0	$6.07	$6.07
Curb Removed	FT	4.9	$5.00	$24.60
Vegetation	LS	1.0	$1,125.00	$1,125.00
Labor	LS	1.0	$2,400.00	$3,200.00
			Total Cost Estimate	**$7,657.41**

Table 19: Infiltration Planter 2

Infiltration Planter 2				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	57.6	$30.00	$1,726.80
Concrete - Infiltration Planter Structure	CY	8.3	$135.00	$1,119.15
Concrete - New 6" Standard Curb	FT	37.3	$12.00	$447.96
Pavers	SF	111.2	$17.50	$1,946.18
Decorative Metal Grates	SF	23.9	$15.00	$358.95
Growing Media	CY	16.2	$16.00	$259.68
Sign Removal and Replacement	EA	1.0	$200.00	$200.00
Filter Fabric	SF	292.2	$0.30	$87.66
Gravel Base	CY	10.8	$25.00	$270.50
Splash Protection Rock	CY	0.1	$48.00	$3.84
Curb Removed	FT	8.4	$5.00	$42.10
Vegetation	LS	1.0	$1,800.00	$1,800.00
Labor	LS	1.0	$2,400.00	$2,400.00
			Total Cost Estimate	**$10,662.81**

Table 20: Infiltration Planter 3

Infiltration Planter 3				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	49.1	$30.00	$1,471.50
	CY	9.6	$135.00	$1,301.40
Concrete - New 6" Standard Curb	FT	30.5	$12.00	$366.00
3" PVC Pipe	FT	38.7	$0.94	$36.35
Pavers	SF	86.7	$17.50	$1,516.55
Decorative Metal Grates	SF	46.0	$15.00	$690.30
Growing Media	CY	16.1	$16.00	$256.80
Filter Fabric	SF	288.9	$0.30	$86.68
Gravel Base	CY	10.7	$25.00	$267.50
Splash Protection Rock	CY	0.1	$48.00	$2.88
Drain Cover and Elbow	EA	2.0	$6.07	$12.14
Curb Removed	FT	12.5	$5.00	$62.50
Vegetation	LS	1.0	$1,900.00	$1,900.00
Labor	LS	1.0	$2,400.00	$2,400.00
			Total Cost Estimate	**$10,370.60**

Table 21: Infiltration Planter 4

Infiltration Planter 4				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	43.0	$30.00	$1,290.90
Concrete - Infiltration Planter Structure	CY	7.9	$135.00	$1,065.15
Concrete - New 6" Standard Curb	FT	17.8	$12.00	$213.00
Pavers	SF	94.5	$17.50	$1,654.28
Decorative Metal Grates	SF	8.0	$15.00	$120.00
Growing Media	CY	14.1	$16.00	$225.28
Filter Fabric	SF	253.4	$0.30	$76.01
Gravel Base	CY	9.4	$25.00	$234.50
Splash Protection Rock	CY	0.1	$48.00	$2.40
Curb Removed	FT	5.0	$5.00	$25.00
Vegetation	LS	1.0	$1,550.00	$1,550.00
Labor	LS	1.0	$2,400.00	$2,400.00
			Total Cost Estimate	**$8,856.51**

Table 22: Infiltration Planter 5

Infiltration Planter 5				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	53.3	$30.00	$1,599.00
Concrete - Infiltration Planter Structure	CY	17.8	$135.00	$2,407.05
Catch Basin Removed	EA	1	$500.00	$500.00
Catch Basin Installed	EA	1	$1,000.00	$1,000.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	5	$21.28	$106.40
FERNCO Fitting	EA	2	$17.75	$35.50
3" PVC Pipe	FT	0	$0.94	$0.00
Growing Media	CY	16.1	$16.00	$257.60
Filter Fabric	SF	290.7	$0.30	$87.21
Gravel Base	CY	10.7	$25.00	$267.50
Splash Protection Rock	CY	0.2	$48.00	$9.60
Vegetation	LS	1	$2,250.00	$2,250.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$10,919.86**

Table 23: Infiltration Planter 6

Infiltration Planter 6				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	45.3	$30.00	$1,359.00
Concrete - Infiltration Planter Structure	CY	15.1	$135.00	$2,038.50
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	1	$750.00	$750.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	13.7	$16.00	$219.20
Filter Fabric	SF	247.2	$0.30	$74.16
Gravel Base	CY	9.2	$25.00	$230.00
Splash Protection Rock	CY	0.1	$48.00	$4.80
Vegetation	LS	1	$1,650.00	$1,650.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$8,725.66**

Table 24: Infiltration Planter 7

Infiltration Planter 7				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	16.9	$30.00	$507.00
Concrete - Infiltration Planter Structure	CY	5.9	$135.00	$796.50
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	15.0	$0.94	$14.10
Growing Media	CY	5.0	$16.00	$80.00
Filter Fabric	SF	90.0	$0.30	$27.00
Gravel Base	CY	3.3	$25.00	$82.50
Splash Protection Rock	CY	0.1	$48.00	$4.80
Vegetation	LS	1	$850.00	$850.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$4,761.90**

Table 25: Infiltration Planter 8

Infiltration Planter 8				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	21.9	$30.00	$657.00
Concrete - Infiltration Planter Structure	CY	7.5	$135.00	$1,012.50
Catch Basin Removed	EA	1	$500.00	$500.00
Catch Basin Installed	EA	1	$1,000.00	$1,000.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	5	$21.28	$106.40
FERNCO Fitting	EA	3	$17.75	$53.25
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	6.5	$16.00	$104.00
Filter Fabric	SF	117.9	$0.30	$35.37
Gravel Base	CY	4.4	$25.00	$110.00
Splash Protection Rock	CY	0.1	$48.00	$4.80
Vegetation	LS	1	$825.00	$825.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$6,808.32**

Table 26: Infiltration Planter 9

Infiltration Planter 9				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	49.5	$30.00	$1,485.00
Concrete - Infiltration Planter Structure	CY	16.6	$135.00	$2,241.00
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	10.0	$0.94	$9.40
Growing Media	CY	15.0	$16.00	$240.00
Filter Fabric	SF	269.8	$0.30	$80.94
Gravel Base	CY	10.0	$25.00	$250.00
Splash Protection Rock	CY	0.1	$48.00	$6.24
Vegetation	LS	1	$1,800.00	$1,800.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$8,512.58**

Table 27: Infiltration Planter 10

Infiltration Planter 10				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	45.4	$30.00	$1,362.00
Concrete - Infiltration Planter Structure	CY	15.2	$135.00	$2,052.00
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	1	$750.00	$750.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	13.7	$16.00	$219.20
Filter Fabric	SF	247.2	$0.30	$74.16
Gravel Base	CY	9.2	$25.00	$230.00
Splash Protection Rock	CY	0.1	$48.00	$6.24
Vegetation	LS	1	$1,775.00	$1,775.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$8,868.60**

Table 28: Infiltration Planter 11

Infiltration Planter 11				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	20.8	$30.00	$624.00
Concrete - Infiltration Planter Structure	CY	7.1	$135.00	$958.50
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	30.0	$0.94	$28.20
Growing Media	CY	6.3	$16.00	$100.80
Filter Fabric	SF	112.5	$0.30	$33.75
Gravel Base	CY	4.2	$25.00	$105.00
Splash Protection Rock	CY	0.1	$48.00	$4.80
Vegetation	LS	1	$875.00	$875.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$5,130.05**

Table 29: Infiltration Planter 12

Infiltration Planter 12				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	16.8	$30.00	$504.00
Concrete - Infiltration Planter Structure	CY	5.9	$135.00	$796.50
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	1	$750.00	$750.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	5.0	$16.00	$80.00
Filter Fabric	SF	90.0	$0.30	$27.00
Gravel Base	CY	3.3	$25.00	$82.50
Splash Protection Rock	CY	0.1	$48.00	$4.80
Vegetation	LS	1	$600.00	$600.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$5,244.80**

Table 30: Infiltration Planter 13

Infiltration Planter 13				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	49.5	$30.00	$1,485.00
Concrete - Infiltration Planter Structure	CY	16.7	$135.00	$2,254.50
Catch Basin Removed	EA	0	$500.00	$0.00
Catch Basin Installed	EA	0	$1,000.00	$0.00
Catch Basin Adjusted to Grade	EA	1	$750.00	$750.00
12" PVC Pipe	FT	0	$21.28	$0.00
FERNCO Fitting	EA	0	$17.75	$0.00
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	15.0	$16.00	$240.00
Filter Fabric	SF	269.4	$0.30	$80.82
Gravel Base	CY	10.0	$25.00	$250.00
Splash Protection Rock	CY	0.2	$48.00	$9.60
Vegetation	LS	1	$1,725.00	$1,725.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$9,194.92**

Table 31: Infiltration Planter 14

Infiltration Planter 14				
Item	Unit	Estimated Quantity	Unit Price	Estimated Cost
Excavation	CY	45.4	$30.00	$1,362.00
Concrete - Infiltration Planter Structure	CY	15.1	$135.00	$2,038.50
Catch Basin Removed	EA	1	$500.00	$500.00
Catch Basin Installed	EA	1	$1,000.00	$1,000.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	5	$21.28	$106.40
FERNCO Fitting	EA	1	$17.75	$17.75
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	13.8	$16.00	$220.80
Filter Fabric	SF	248.2	$0.30	$74.46
Gravel Base	CY	9.2	$25.00	$230.00
Splash Protection Rock	CY	0.2	$48.00	$9.60
Vegetation	LS	1	$1,700.00	$1,700.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$9,659.51**

Table 32: Infiltration Planter 15

Infiltration Planter 15				
Item	**Unit**	**Estimated Quantity**	**Unit Price**	**Estimated Cost**
Excavation	CY	45.3	$30.00	$1,359.00
Concrete - Infiltration Planter Structure	CY	15.0	$135.00	$2,025.00
Catch Basin Removed	EA	1	$500.00	$500.00
Catch Basin Installed	EA	1	$1,000.00	$1,000.00
Catch Basin Adjusted to Grade	EA	0	$750.00	$0.00
12" PVC Pipe	FT	10	$21.28	$212.80
FERNCO Fitting	EA	4	$17.75	$71.00
3" PVC Pipe	FT	0.0	$0.94	$0.00
Growing Media	CY	13.8	$16.00	$220.80
Filter Fabric	SF	248.2	$0.30	$74.46
Gravel Base	CY	9.2	$25.00	$230.00
Splash Protection Rock	CY	0.2	$48.00	$9.60
Vegetation	LS	1	$1,725.00	$1,725.00
Labor	LS	1	$2,400.00	$2,400.00
			Total Cost Estimate	**$9,827.66**

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