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# Comprehensive Stormwater Management Plans on University Campuses: Challenges and Opportunities

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# Comprehensive Stormwater Management Plans on University Campuses: Challenges and Opportunities

## **Abstract**

Under the Clean Water Act, Philadelphia is required to reduce its Combined Sewer Overflow volume by 85% (PWD, 2009). Other cities have constructed massive underground storage tunnels to capture overflows, but the Philadelphia Water Department has proposed a plan that places a fee on impervious cover and relies heavily on green infrastructure. There is an opportunity for the University of Pennsylvania to become a model institution for stormwater management and also to save money on Philadelphia's stormwater charge. Sporadic green infrastructure projects will have some effect, but in order to be as efficient as possible in meeting the two aforementioned goals, it is necessary to coordinate green infrastructure projects through a stormwater management plan. The University of Pennsylvania is in the process of developing such a plan. This study describes the current stormwater management efforts being made at the University of Pennsylvania and examines the efforts of other universities in developing their own stormwater management plans, with the goal of gleaning innovative practices that can be recreated at other universities. While it is too early to determine which stormwater plans have achieved long-term success, a survey given to nine universities reveals common themes between plans. A common framework for a campus stormwater management plan was found to take inventory of existing infrastructure and campus conditions, develop a list of acceptable best management practices, develop an educational and outreach component, and develop an operation and maintenance v schedule for green infrastructure technologies. The most innovative plan in the study belongs to the Georgia Institute of Technology, which creates an Eco-Commons corridor on the most ecologically sensitive parts of campus, in which development is severely limited. Stormwater goals are met by using a regional approach, as opposed to a project-by-project approach, increasing the flexibility of new development on campus. Villanova University has also developed an excellent BMP research park, which also serves as an outreach component. The University of Pennsylvania should develop a plan that considers emulating these innovative practices and adding them to the common framework.

## **Disciplines**

Environmental Sciences | Physical Sciences and Mathematics

## **Comments**

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Master of Environmental Studies 2011.

**COMPREHENSIVE STORMWATER MANAGEMENT  
PLANS ON UNIVERSITY CAMPUSES: CHALLENGES  
AND OPPORTUNITIES**

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Steven R. Gillard

Spring 2011

Primary Reader: Professor John C. Keene

Secondary Reader: Howard Neukrug, Philadelphia Water Department Commissioner

## **DEDICATION**

I would like to dedicate this Capstone Project to my immediate and extended family. I am blessed to have been shaped by such a good and loving group of people.

## ACKNOWLEDGEMENTS

Many people helped me during the process of writing this capstone thesis that I would like to acknowledge. First, I would like to acknowledge Professor John Keene and Howard Neukrug, my capstone readers. Mr. Neukrug has added depth throughout the semester to my understanding of how green infrastructure can influence larger social and environmental issues. Professor Keene has shown genuine interest in helping me produce the best paper possible, and I appreciate his constructive comments.

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Finally, I would like to thank my family and friends for being a constant source of encouragement and joy.

# **ABSTRACT**

## **COMPREHENSIVE STORMWATER MANAGEMENT PLANS ON UNIVERSITY CAMPUSES: CHALLENGES AND OPPORTUNITIES**

Steven R. Gillard

Primary Reader: Professor John C. Keene

Under the Clean Water Act, Philadelphia is required to reduce its Combined Sewer Overflow volume by 85% (PWD, 2009). Other cities have constructed massive underground storage tunnels to capture overflows, but the Philadelphia Water Department has proposed a plan that places a fee on impervious cover and relies heavily on green infrastructure. There is an opportunity for the University of Pennsylvania to become a model institution for stormwater management and also to save money on Philadelphia's stormwater charge. Sporadic green infrastructure projects will have some effect, but in order to be as efficient as possible in meeting the two aforementioned goals, it is necessary to coordinate green infrastructure projects through a stormwater management plan. The University of Pennsylvania is in the process of developing such a plan. This study describes the current stormwater management efforts being made at the University of Pennsylvania and examines the efforts of other universities in developing their own stormwater management plans, with the goal of gleaned innovative practices that can be recreated at other universities. While it is too early to determine which stormwater plans have achieved long-term success, a survey given to nine universities reveals common themes between plans. A common framework for a campus stormwater management plan was found to take inventory of existing infrastructure and campus conditions, develop a list of acceptable best management practices, develop an educational and outreach component, and develop an operation and maintenance

schedule for green infrastructure technologies. The most innovative plan in the study belongs to the Georgia Institute of Technology, which creates an Eco-Commons corridor on the most ecologically sensitive parts of campus, in which development is severely limited. Stormwater goals are met by using a regional approach, as opposed to a project-by-project approach, increasing the flexibility of new development on campus. Villanova University has also developed an excellent BMP research park, which also serves as an outreach component. The University of Pennsylvania should develop a plan that considers emulating these innovative practices and adding them to the common framework.

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## DEFINITION OF TERMS

**Campus Stormwater Management Plan:** a document that outlines the short, medium, and long-term stormwater management project priorities for a college or university and defines a strategy to coordinate stormwater management projects for maximum diversion of stormwater runoff from the combined sewer system.

**Combined Sewer Overflow (CSO):** during moderate to heavy rainfall events, the system will reach capacity, overflow, and discharge a mixture of sewage and stormwater directly to our streams and rivers from the 164 permitted CSO outfalls within the City (Philadelphia Water Department, 2009).

**Combined Sewer System (CSS):** a single sewer system that carries both sewage and stormwater to a water pollution control plant for treatment before being released to a waterway (Philadelphia Water Department, 2009).

**Greened Acre:** an acre within the combined sewer service area that has at least the first inch of runoff managed by stormwater infrastructure. This includes the area of the stormwater management feature itself and the area that drains to it. One acre receives one million gallons of rainfall each year. Today, if the land is impervious, it all runs off into the sewer and becomes polluted. A Greened Acre will stop 80-90% of this pollution from occurring (Philadelphia Water Department, 2009).

**Green Infrastructure:** a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some cases release a portion of it slowly back into the sewer system (Philadelphia Water Department, 2009).

**Impervious Area:** the total square feet of any plane hard surface area, including buildings, any attached or detached structures, paved or hard-scaped areas, and compacted dirt and gravel that either prevents or restricts the absorption of water into the soil and thereby causes water to runoff the surface (PWD, 2010).

**Stormwater Runoff:** the runoff from roofs, streets, and other impermeable and permeable surfaces that flows into the Philadelphia sewer system, combined and separate.

**University of Pennsylvania Campus:** The approximately 280 acres of the University of Pennsylvania located in West Philadelphia, excluding the Morris Arboretum and the New Bolton Center.

## **Introduction to the Paper**

The purpose of this study is to examine various stormwater management plans and projects on university campuses. The ultimate goal is to help the University of Pennsylvania develop a comprehensive stormwater management plan, within the context of Philadelphia's stormwater management regulatory framework. This paper will examine the historic context of Philadelphia's sewer system, and the environmental, social, and financial challenges presented by stormwater runoff. Descriptions of the federal, state, and local regulations that guide stormwater management will follow. The paper will then examine conventional methods used by cities to control stormwater runoff and Philadelphia's innovative efforts, which rely heavily on green infrastructure. With this background, the paper then explains the stormwater management efforts and plans of the University of Pennsylvania, in addition to other universities, and finds common elements between them. The paper ends with recommendations to the University of Pennsylvania for a stormwater management plan framework, including descriptions of the innovative practices at other universities that should be emulated.

There is an opportunity for the University of Pennsylvania to become a model institution for stormwater management and also to save money on the new stormwater program. Sporadic green infrastructure projects will have some effect, but in order to be as efficient as possible in meeting the two aforementioned goals, it is necessary to direct green infrastructure projects through a stormwater management plan.

## **Study Methods**

In order to compare stormwater management approaches it is important to examine the stormwater management efforts of other Ivy League institutions, universities with well known stormwater management practices, and other institutions in Philadelphia, such as Villanova University. It is also important to comprehensively understand how the University of Pennsylvania is addressing the issue. This was accomplished by asking facilities staff workers at other institutions a standardized set of interview questions. Interviewing facilities staff was informative, since this involved gathering information from the people who manage the university facilities and implement many of the environmental policies. The interview questions appear in Appendix A.

Four research questions guided the study:

1. What campus efforts are currently being made to manage stormwater runoff?
2. What progress have other universities made in developing stormwater management plans?
3. What are the main components in an effective stormwater management plan?
4. What are the innovative practices in other university stormwater management programs that the University of Pennsylvania can emulate?

## **Related Research**

When dealing with the topic of stormwater management, most papers have focused on individual green infrastructure projects (Grehl & Kauffman, 2007), or have broadly outlined the associated environmental issues (Kloss & Calarusse, 2006). While these studies have value, it is also important to study how individual green infrastructure

projects interact with one another, according to Damodaram, Giacomoni, Prakash Khedun, Holmes, Ryan, Saour, and Zechman (2010). This is especially relevant for university campuses, since each typically consists of many buildings spread over a large area. Even on an urban campus such as the University of Pennsylvania, the buildings are spread across 280 acres on the main campus. A comprehensive stormwater management plan could more effectively direct green infrastructure projects on campus, so that they could have the largest overall effect possible. In their overview of stormwater management issues and practices, Kloss and Calarusse (2006) briefly compare the stormwater management efforts that are happening in various major cities across the United States, though the use of green infrastructure to reduce the volume of runoff entering the sewer is rarely a major component.

The Philadelphia Water Department has started implementing a progressive program to provide incentives for the construction of green infrastructure around the city. Instead of being based on the diameter of the pipe at the water meter, the new stormwater charge is based on the amount of impervious cover on a land parcel, which is more accurate in indicating how much stormwater the parcel of land contributes to the sewer system (Philadelphia Water Department, 2009). Blossom (2004) points out that advances in satellite imaging and Geographic Information Systems (GIS) technologies have allowed water departments to maintain an updated database of the impervious cover of land parcels.

Cook (2007) and the Philadelphia Water Department (2009) both outline various green infrastructure measures, including rain gardens, green roofs, pervious pavement, flow-through planters, stormwater wetlands, and rain harvesting barrels among other

strategies. In their case study, Grehl and Kauffman (2007) try to implement one of these strategies, a rain garden, on the University of Delaware campus. Constructing a rain garden is a fairly straightforward activity in theory, but this case study makes it clear that there can be unintended consequences associated with some of the simplest projects. The authors suggest placing the rain garden near an existing stormwater inlet, in order to catch overflow. The authors also experienced issues with erosion and the rate at which water percolated into the soil. These difficulties are consistent with Cook's (2007) assertion that drainage through green infrastructure is most effective if a site's natural systems are first studied and understood.

Though individual green infrastructure projects can have a positive impact, Niu, Clark, Zhou, and Adriaens (2010) have described novel benefits of green roof construction that emerge at the city-wide level, which are not observed at the building level. Urban heat island effect reductions, emissions reductions, and a reduction in the need for sewer infrastructure capacity can be observed when a critical mass of green roofs is achieved in the city. While it is true that green infrastructure will produce emergent benefits at a certain scale, it is also important to understand that the combination and spatial distribution of green infrastructure projects will most likely influence the level of benefits observed (Damodaram et al., 2010)

Brabec, Schulte, and Richards (2002) reject the notion that there is a single threshold for the percentage of impervious cover that determines when waterways will be negatively affected. The types of pervious surfaces in the area under consideration and the location of impervious surfaces within the watershed can greatly influence the impact of stormwater runoff. Similarly, Stone (2004) points out that stormwater management



research has traditionally focused on the physical connections between impervious surfaces and water quality degradation in waterways. Research rarely focuses on the land use policies that lead to the conditions in which impervious surfaces arise. Stone also asserts that while it is important to attack stormwater runoff issues from the level of the watershed, at a pragmatic level, it makes more sense to consider land parcels. Land parcels, not watersheds, are the legal units of land use regulation.

One clear message from the available literature is that green infrastructure projects are influenced by factors that are site-specific. Each campus would need to study the hydrology and the characteristics of the impervious and pervious surfaces on campus in order to develop a rational stormwater management plan.

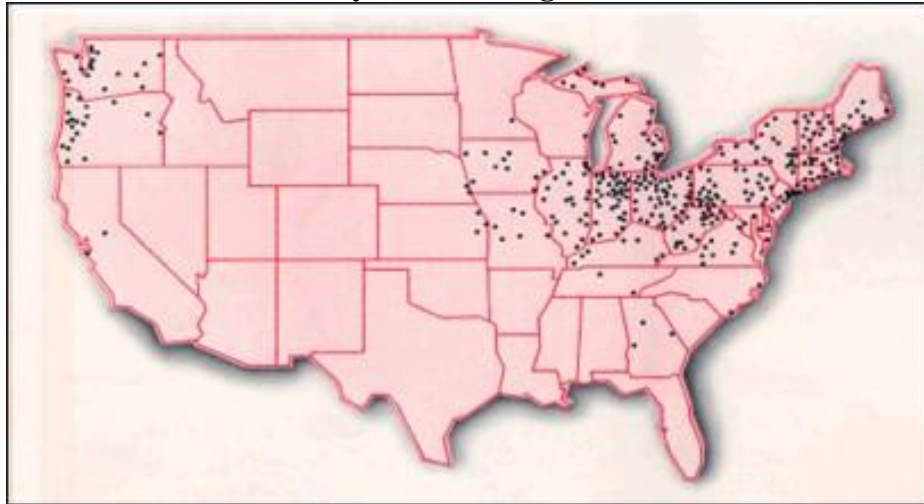
### **Stormwater History and Context**

Between 1982 and 1997 the population in the contiguous United States grew by fifteen percent. During the same time period, the area of developed land grew by thirty four percent, meaning that urbanization has outpaced population growth by more than two fold. Of the 107 million acres of developed land in the United States 25 million acres are impervious surfaces, which do not allow water to percolate through them. In urban areas, it is common for impervious surfaces to make up forty five percent of the landscape, and much more in large cities (Kloss & Calarusse, 2006). The United States is a vast 2.3 billion acres in total, which makes the 25 million acres of impervious area seem small (Lubowski, Vesterby, Bucholtz, Baez, & Roberts, 2006). However, one must also consider that these impervious surfaces tend to be congregated together on land that is near waterways and on the coasts.

The substantial urbanization in the United States over the past century has

brought many environmental challenges along with it. One of the challenges, which has been given considerable attention in recent years, is mitigating stormwater runoff that results from the high percentage of impervious surfaces in urbanized areas. Water that cannot percolate through impervious surfaces, such as concrete and asphalt, needs to flow somewhere in order to avoid flooding when it rains. These impervious surfaces alter the hydrological cycles of the landscape. Contaminants, such as oil, fertilizer, and pesticides, are spilled onto roads and other impervious surfaces and are either washed directly into streams and rivers, or more frequently into storm drains (Kloss & Calarusse, 2006). These drains will dump directly into local waterways, if they belong to a Separate Sewer System, or flow to a wastewater treatment plant, if they belong to a Combined Sewer System. The Combined Sewer System in Philadelphia, and many other cities, often overflows during rain events, dumping a mix of stormwater runoff and untreated sewage directly into local waterways (Philadelphia Water Department, 2009c). According to the EPA there are over 770 communities in the United States that are served by Combined Sewer Systems. Each Combined System is represented by a black dot on Map 1 below. As you can see, these communities are heavily concentrated in the Mid-Atlantic states, New England, and the Midwest. Approximately 40 million people live in the communities served by these sewer systems. It is estimated that about 850 billion gallons of stormwater runoff contaminated with untreated sewage flow into streams and rivers each year from Combined Sewer Overflows (U.S. Environmental Protection Agency, 2004).

**Map 1.**  
**Combined Sewer Systems Throughout the United States**



Source: U.S. Environmental Protection Agency, Office of Watershed Management website

It is also estimated that Combined Sewer Overflows are composed of fifteen to twenty percent sewage, and eighty to eighty five percent stormwater runoff, meaning that approximately 125 billion to 170 billion gallons of untreated sewage flow into our waterways from Combined Sewer Overflows annually. Additionally, even if stormwater is discharged from a Separate Sewer System, in which there is no untreated sewage, there are often many contaminants in the runoff that are picked up as rain water runs over roofs, streets, and lawns on en route to the street drain (Kloss & Calarusse, 2006).

### **Negative Effects of Combined Sewer Overflows**

There are health and environmental concerns associated with contaminated stormwater runoff overflowing into waterways. The main stormwater pollutants can be characterized in several categories: bacteria, metals, nutrients, oil and grease, oxygen-depleting substances, pesticides, sediments, toxic chemicals, and trash and debris (Kloss & Calarusse, 2006). Some pollutants contaminate wildlife in the waterways,

increasing the health risks of eating local fish. Residents may be wary of using the streams and rivers for swimming or other recreation as well. The perception that the rivers are polluted can also lower property values along the waterfront. These are the main social and economic impacts of Combined Sewer Overflows (Philadelphia Water Department, 2009c).

If stormwater runs off and does not percolate into the ground, there is less water to recharge the groundwater. Groundwater allows streams to have a base flow when there is no rain to flow directly into the streams. In Philadelphia and other urban areas a large percentage of stormwater is channeled directly to the streams and rivers, which creates short periods of flash floods in the streams. These flash floods increase the peak flow of rivers and streams, beyond levels that would normally be seen under natural hydrological conditions. During times of drought, there is not enough groundwater to keep the streams flowing at their normal level. This dramatic shift from low levels of water to flash floods degrades the habitat for wildlife in streams. During rain events the intensity of the flash floods in the streams causes erosion of the stream banks. The United States Environmental Protection Agency (EPA) has identified stormwater runoff as the largest source of pollution in the nation's waterways today (Philadelphia Water Department, 2010b).

### **The Philadelphia Sewer System**

Philadelphia has one of the oldest sewer systems in the United States. It was built in the second half of the nineteenth century. Originally, there were numerous streams running through the landscape. Over time these streams were placed inside large sewers, which were then covered over. The two maps below compare the historic

streams of Philadelphia with the remaining streams and the streams that have been covered over. Map 2 shows the historic streams in blue. Most of these historic streams have been placed in sewers, which are depicted with the red lines in Map 3 on the following page (Levine, 2008b).

According to Adam Levine, a historical consultant to the Philadelphia Water Department, streams were encased and buried for two main reasons. It made sense to use stream beds sewer locations, since they were already at low points and were gravity fed. Since streams were used as sewers, it became a matter of public health to cover these sewers so that people were not directly exposed to the sewage. Secondly, it was much easier to divide land into parcels and develop it once the streams were buried. This also avoided the cost of having to build bridges over streams (Levine, 2008a).

**Map 2.**  
**Historic Streams in Philadelphia**



Source: Adam Levine, Philadelphia Water Department

**Map 3.  
Remaining Streams in Philadelphia**

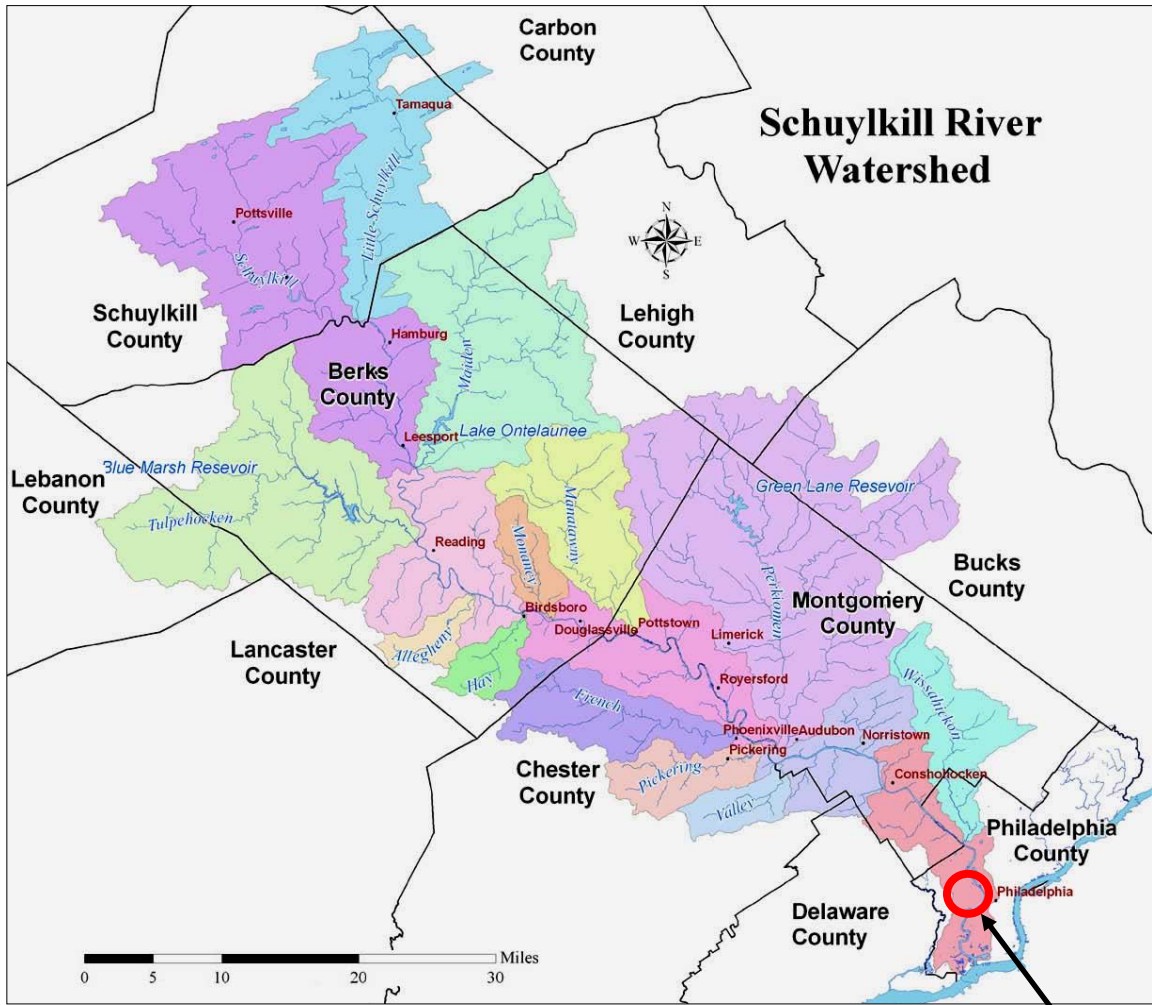


Source: Adam Levine, Philadelphia Water Department

A sixty four square mile area within Philadelphia drains into a Combined Sewer System (CSS) (Philadelphia Water Department, 2009). Sanitary sewage from buildings combines with runoff from the streets in a CSS. Forty percent of Philadelphia's sewers have separate pipes for sewage and stormwater runoff, which means that sixty percent are CSSs (Philadelphia Water Department, 2009). When CSSs are loaded beyond capacity, excess stormwater and raw sewage is released through one hundred and sixty four outflows into local streams and the Schuylkill and Delaware Rivers in a Combined Sewer Overflow (CSO). In recent years, approximately fifty billion gallons of untreated CSO have been released into Philadelphia's waterways annually (Neukrug, 2010). There are four main watersheds in Philadelphia that receive CSOs: Tookany/Tacony-Frankford Creek, Cobbs Creek, the Delaware River, and the Schuylkill River (Philadelphia Water Department, 2009). The map on the following page shows that Philadelphia is at the bottom of all the watersheds that drain to it. This means that when pollutants are dumped into the streams further up in the watershed, they can travel downstream to Philadelphia. Even if Philadelphia contributed no pollution to the waterways, there would still be pollution coming from development and industries upstream, potentially at a level that would violate the water quality standards set by the Clean Water Act. This implies that a collaborative effort among all municipalities in the watershed will be required to achieve clean water in the Schuylkill and Delaware Rivers (Levine, 2008b).



**Map 4.**  
**Philadelphia within the Schuylkill River Watershed**



Source: Philadelphia Water Department, Office of Watersheds website

University of Pennsylvania

## **Regulatory Framework**

### *The Clean Water Act*

The Federal Water Pollution Control Act is the major law that has required Philadelphia to develop a stormwater management plan that greatly reduces Combined Sewer Overflows. Originally enacted in 1972, it was amended in 1977 and renamed the Clean Water Act (Moya & Fono, 2010). The main purpose of the Clean Water Act is to protect the navigable waters of the United States from pollution. Navigable waters do not include groundwater, though there are other laws that protect groundwater quality. Concerns over water quality were heightened after the Cuyahoga River in Ohio caught fire in 1969. This was a potent illustration of the pollution in our nation's waterways and it spurred significant environmental legislation to prevent further pollution. Under the Clean Water Act, the Environmental Protection Agency (EPA) established effluent limitations for point sources of pollution to meet water quality standards for the designated use of that waterway. If effluent standards are not stringent enough to meet water quality standards, under section 303 states must set Total Maximum Daily Loads (TMDLs), which are the maximum quantities of pollutants that a waterway can absorb and still meet water quality standards in impaired waterways. The Clean Water Act established several different programs to reduce pollution in the waterways of the United States (Moya & Fono, 2010).

*National Pollution Discharge Elimination System Permits Program:* Section 402 of the Clean Water Act requires any person to have a permit in order to discharge pollutants into the navigable waters in the United States from a point source. Point source pollution is defined as pollution that comes from a specific source, such as a

pipe that discharges the effluent, or waste products from a given land use. It is easy to pinpoint these sources and regulate releases from them. These permits, which last for five years, are issued through the National Pollutant Discharge Elimination System (NPDES) permit program. NPDES permits have minimum technology requirements and effluent limitations that are necessary to obtain the water quality standards that were set by the Clean Water Act. The entity that holds the NPDES permit must monitor its discharges and the water quality of the waters receiving discharges. States were delegated the authority to administer the NPDES program (Moya & Fono, 2010).

*Wetlands Protection and the Dredge and Fill Permit Program:* Section 404 requires a person to obtain a permit to dredge in wetlands or dump fill materials into navigable waterways or wetlands. This section recognizes that dumping dredge or fill materials in aquatic areas is potentially harmful to the navigable waters of the United States. Fill material is used to replace aquatic areas with dry land and dredge material is the material that is excavated from the floor of a body of water. Both of these materials are classified as “pollutants” under the Clean Water Act, and the corresponding permit program is administered by the Army Corps of Engineers. There are several exemptions, most of which involve farming activities (Moya & Fono, 2010).

*Oil Spill Prevention, Control, and Countermeasure Program:* Section 311 regulates the discharge of quantities of oil into the navigable waters of the United States that violate water quality standards or develop a sheen on the water. This program recognizes that oil spills pose a threat to tourism, recreation, fishermen, and aquatic wildlife. The EPA is authorized to run studies and to issue regulations to ensure that the “no discharge” policy is followed. Under this program, facility owners are liable

for the costs associated with cleaning oil spills, even if the spill has not been shown to be their fault. The Oil Pollution Act works in conjunction with section 311 to assign liability to facility owners and exact financial penalties (Moya & Fono, 2010).

*Nonpoint Source Pollution:* Nonpoint sources of pollution cannot be traced back to a single point. An example of this would be runoff from a suburban development that flows directly into a body of water. It is difficult to prove that fertilizer dissolved in stormwater runoff that flows over the land to a body of water came from a specific yard. There is no single pipe that can be regulated, and there are many possible origins of the pollution. This is a complicated definition, however, because in a 1987 amendment to the Clean Water Act, Congress classified stormwater runoff from industrial and municipal storm sewer systems as a point source. Additionally, runoff from agriculture is exempt from being defined as a point source. Though the main focus of the Clean Water Act is on controlling point source pollution, the Act also addresses nonpoint sources of pollution, since they cause a significant amount of the pollution in streams, lakes, and estuaries. The states are mainly responsible for setting up nonpoint source controls, under sections 319 and 208 of the Clean Water Act. Section 319 requires states to identify waters that cannot meet the goals of the Clean Water Act without controls on nonpoint source pollution, and to develop a management program to address the problem. Section 208 authorizes the EPA to develop guidelines to identify waterways that are heavily polluted from urban and industrial activities. The states should then designate local government officials to develop a management plan (Moya & Fono, 2010).

*Publicly Owned Treatment Works Grant Program:* The Clean Water Act also introduced a requirement for POTWs to submit wastewater to at least secondary treatment levels. This means that in addition to removing floatable solids and solids that are able to settle out, POTWs must also treat wastewater with microbes and oxygen. This process removes approximately ninety percent of the oxygen-depleting substances and suspended solids from the wastewater (Moya & Fono, 2010).

### ***EPA's Combined Sewer Overflow Control Policy***

In 1994 the EPA developed a framework for controlling Combined Sewer Overflows under the NPDES permit program. The purpose of this guidance is to give municipalities as much flexibility as possible to comply with the Clean Water Act's pollution reduction requirements in a cost-effective way (Horres, Gray, & Cook, 2006). In Philadelphia, it is especially important that there is flexibility built into this policy that takes the financial capability of a community into consideration in developing a plan. This guidance document lists four fundamental principles:

1. Clear levels of control to meet health and environmental objectives
2. Flexibility to consider the site-specific nature of Combined Sewer Overflows and to find the most cost-effective way to control them
3. Phased implementation of Combined Sewer Overflow controls to accommodate a community's financial capability
4. Review and revision of water quality standards during development of Combined Sewer Overflow control plans to reflect site-specific wet weather impacts of Combined Sewer Overflows (U.S. Environmental Protection Agency, 1994)

This guidance also introduces the Nine Minimum Controls, which are controls that are not anticipated to require major engineering or construction efforts to implement. In a way these controls can be viewed as the low-hanging fruit – steps that maximize the

efficiency of the Combined Sewer System, without making any fundamental changes.

These nine minimum controls are:

1. Proper operation and regular maintenance programs for the sewer system and the Combined Sewer Overflows
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to assure Combined Sewer Overflow impacts are minimized
4. Maximization of flow to the publicly owned treatment works for treatment
5. Prohibition of Combined Sewer Overflows during dry weather
6. Control of solid and floatable materials in Combined Sewer Overflows
7. Pollution prevention
8. Public notification to ensure that the public receives adequate notification of Combined Sewer Overflows occurrences and impacts
9. Monitoring to effectively characterize Combined Sewer Overflow impacts and the efficacy of controls (U.S. Environmental Protection Agency, 1995)

Municipalities with Combined Sewer Systems are also expected to develop long-term Combined Sewer Overflow control plans, which lay out long-term paths to attain the water quality standards set forth in the Clean Water Act. Municipalities are at different stages of forming their long-term control plans, which consist of the following elements:

1. Characterization, monitoring, and modeling of the Combined Sewer System
2. Public participation
3. Consideration of sensitive areas
4. Evaluation of alternatives to meet CWA requirements using either the "presumption approach" (facilities are designed to limit CSOs to no more than four per year, or to eliminate at least eighty five percent of CSO volume in wet weather) or the "demonstration approach" (showing that a program meets water

quality standards, reduces pollution as much as reasonably possible, and can be cost-effectively adapted if water quality standards change)

5. Cost/performance considerations
6. Operational plan
7. Maximizing treatment at the existing POTW treatment plant
8. Implementation schedule
9. Post-construction compliance monitoring program

Though this policy takes the financial capability of communities into consideration in developing a suitable long-term control plan, there is also the expectation that communities will pursue reductions in Combined Sewer Overflows as aggressively as possible, utilizing the State Revolving Fund program for financial help when needed. If a municipality is able to capture and treat at least eighty five percent of the Combined Sewer Overflow volume, as an annual average of the entire Combined Sewer System, the control plan would be presumed to attain the water quality standards set forth in the Clean Water Act (U.S. Environmental Protection Agency, 1994).

### **Pennsylvania Stormwater Regulations**

In 1978 Pennsylvania passed the Storm Water Management Act, also known as Act 167. This was passed after the recognition that increased development was leading to accelerated stormwater runoff, which caused stream bank erosion and downstream flooding. The Act requires that the PA DEP divide up the state into major watersheds. Each major watershed is required to develop a stormwater management plan, specifically for that watershed. Watersheds cross municipal and county boundaries and the DEP is able to require counties to develop joint stormwater management plans, which fostered cooperation. The goal of the Act is to minimize the effect of construction on the rate, volume and quality of stormwater runoff.

After a stormwater management plan is approved, any new construction in that watershed is required to follow the stormwater management measures in the plan. Also, each municipality in that watershed is required to adopt ordinances that are compatible with the watershed stormwater management plan, including zoning, subdivision and development, erosion control, and building codes. Under Act 167, the PA DEP pays for up to seventy five percent of the costs incurred by counties to develop and implement stormwater management plans (McGinty, 2007).

The legislation requires that each watershed stormwater management plan incorporate the following elements at least:

1. A survey of existing runoff characteristics in small as well as large storms, including the impact of soils, slopes, vegetation and existing development;
2. A survey of existing significant obstructions and their capabilities;
3. An assessment of projected and alternative land development patterns in the watershed, and the potential impact of runoff quantity, velocity, and quality;
4. An analysis of present and projected development in flood hazard areas, and its sensitivity to damages from future flooding or increased runoff;
5. A survey of existing drainage problems and proposed solutions;
6. A review of existing and proposed stormwater collection systems and their impacts;
7. An assessment of alternative runoff control techniques and their efficiency in the particular watershed;
8. An identification of existing and proposed State, Federal and local flood control projects located in the watershed and their design capabilities;
9. A designation of those areas to be served by stormwater collection and control facilities within a ten year period...
10. An identification of flood plains within the watershed;
11. Criteria and standards for the control of stormwater runoff from existing and new development...



12. Priorities for implementation of action within each plan; and
13. Provisions for periodically reviewing, revising and updating the plan.

(McGinty, 2007)

There are a few common elements between the Nine Minimum Controls, the Long Term Control Plan requirements, and the watershed plans required by Act 167. Each of these lists requires the municipality to characterize the stormwater collection system, with the goal of maximizing its efficiency. The Nine Minimum Controls and the Long Term Control Plan also require an element of public participation and a plan to maximize the flow of wastewater to the POTWs.

### **Conventional Methods of Mitigating Combined Sewer Overflows**

Many cities with older sewer infrastructures are opting to meet this requirement by increasing the capacity of their Combined Sewer Systems, which is also known as a grey infrastructure solution. Grey infrastructure is designed with the goal of removing water from an urban area as efficiently as possible. In several cities this has taken the form of constructing enormous underground tunnels to hold the excess capacity that cannot be processed by the POTW. The excess stormwater mixed with sewage will be pumped back into the sewer system after the rain event is over and there is extra capacity at the POTW. This method of Combined Sewer Overflow control allows cities to comply with the Clean Water Act, but it is very expensive, does not provide any extra positive externalities to the city residents, and does not start providing benefits to the city until after construction is complete, which can be many years. An extreme example can be found in Chicago, in which an 18 billion gallon capacity tunnel is being constructed to contain excess stormwater from the Combined Sewer System. This tunnel will cost \$3.4 billion to construct, has been under construction since the mid-1970's and will not be completed until later this decade (Kloss & Calarusse, 2006).

A recent example of this technique can be seen in Portland, Oregon, which has

taken a twenty year project to build two of these underground storage tunnels to control the vast majority of the nearly 6 billion gallons of Combined Sewer Overflows from the city's fifty five outfalls. The larger of the two tunnels is twenty-two feet in diameter and runs for 5.5 miles underground. Pictured is one of the cutting heads that was used to bore through the ground rock to create the tunnel (Horres et al., 2006).

**Figure 1.**  
**Cutting Head for Portland's CSO Storage Tunnel Project**



Source: Horres, R., Parsons Brinckerhoff, PB Network

The Philadelphia Water Department (PWD) estimates that if Philadelphia were to take a similar approach to reducing Combined Sewer Overflows to come into compliance with the Clean Water Act, the project would cost nearly \$10 billion. This is not a feasible cost for an economically disadvantaged city such as Philadelphia. In light of this realization Philadelphia developed an innovative plan that will achieve similar reductions in Combined Sewer Overflows, while being much more cost effective and providing other benefits to the residents of the city beyond stormwater management.

## **Philadelphia's *Green City, Clean Waters Plan***

In 1995 PWD submitted documentation to the PA Department of Environmental Protection (DEP) that described the city's efforts to implement the Nine Minimum Controls required by the EPA's Combined Sewer Overflow Control Policy (Philadelphia Water Department, 2009a). To date \$200 million has been committed to attaining the Nine Minimum Controls, capital improvement projects, and developing integrated watershed plans, which do not require significant engineering studies and are part of the 1997 Long Term Control Plan. In 2007 this plan was updated to create the CSO Long Term Control Plan Update, otherwise known as *Green City, Clean Waters* (Philadelphia Water Department, 2009c).

This new plan takes an alternative approach to managing Combined Sewer Overflows that does not involve constructing enormous underground tunnels, which treat the symptom of Combined Sewer Overflows, but not the cause. The main mechanism for controlling stormwater runoff in this new plan is to build green infrastructure to prevent the runoff from flowing into the sewer system in the first place. The stated goal of the plan is to "minimize stormwater overflows and nurture healthy, beautiful watersheds (Philadelphia Water Department, 2009c)." This goal goes beyond complying with the requirements of the Clean Water Act and considers the ways that green infrastructure can help move the city back towards its natural hydrological cycles, through groundwater recharge. It also considers the benefits that green infrastructure can provide the residents of Philadelphia, such as additional green space and cleaner air.

More specifically this plan sets a goal of "greening" one third of Philadelphia's impervious surfaces over the next twenty years, using 2006 as the baseline. In this plan,

a “greened acre” is defined as an acre of land in the combined sewer area that manages the first inch of runoff from a rain event. This concept is further explained below. One million gallons of water will fall on an average acre of land in Philadelphia each year, almost all of which will flow into the sewer if the land is completely covered with impervious surface. A greened acre will stop eighty to ninety percent of the runoff from reaching the sewer during the storm. Most storms produce less than one inch of rain.

Studies have shown that there are positive externalities associated with green infrastructure, beyond the value of preventing Combined Sewer Overflows (Jaffe, 2010). However, a recent study suggests that green infrastructure is often more cost-effective when compared with grey infrastructure. This was found to be true, even if the positive externalities are not taken into consideration. The study goes as far as to say that it may be better to only compare the direct costs, since considering the value of indirect benefits is often complex and controversial in public policy-making, and can even cause proponents of green infrastructure to lose credibility (Jaffe, 2010).

No other city has relied so heavily on green infrastructure to prevent Combined Sewer Overflows, making this plan the first of its kind in the United States. It would be possible to use the rest of this paper to discuss the specifics of *Green City, Clean Waters*, since it is more than seven hundred pages in length, but for the purposes of this paper it is important to focus on the broad themes and main regulations that serve as the plan’s foundation (Philadelphia Water Department, 2009b).

## **Stormwater Fee**

Until July of 2010, PWD based the stormwater fee on the diameter of the pipe leading to a land parcel's water meter. The larger the pipe diameter, the greater the stormwater charge included on the monthly bill from PWD, despite the fact that there is no connection between the pipe diameter at the water meter and the amount of stormwater runoff that a property contributes to the sewer system (Philadelphia Water Department, 2010c). This method of calculating a stormwater fee meant that tall residential buildings paid much more to manage their stormwater than land uses that did not have much plumbing, even if this land use was spread out horizontally over a large swath of land. If a land parcel was a large parking lot, the owners would pay only a small stormwater fee, even though the impervious surface of the parking lot contributed a large volume of runoff to the sewer system during rain storms. Conversely, the owner of a thirty story apartment complex that did not take up much acreage, would have to pay much more for their property's stormwater, even though it contributed less runoff to the sewer system during a rain storm.

To make the stormwater fee more closely related to the amount of stormwater runoff contributed to the sewers, PWD decided to base the fee largely on the amount of impervious area on a land parcel. The impervious area is defined as "the total square feet of any plane hard surface area, including buildings, any attached or detached structures, paved or hard-scaped areas, and compacted dirt and gravel that either prevent or restrict the absorption of water into the soil and thereby causes water to runoff the surface (Philadelphia Water Department, 2010a)." Some landowners will have to pay more under this new system, but others will pay less each month.

The formula for calculating the charge is as follows:

**Monthly fee = (Gross Area rate x Gross Area of property) + (Impervious Area rate x Impervious Area of property),**

where the Gross Area rate is \$0.526/500 square feet and the Impervious Area rate is \$4.145/500 square feet. Because the Impervious Area rate is much greater than the Gross Area rate, the Impervious Area is weighted much more heavily than the Gross Area in calculating the fee.

In order to give property owners time to adjust to this new way of calculating the stormwater fee, PWD will be moving to the new system in phases over the next four years. For instance, in 2010 the stormwater fee was based seventy five percent on the old system and twenty five percent on the new formula. In 2011, the charge will be split evenly between the old method and new method. In 2012 the charge will be 25 percent based on the old system and 75 percent on the new formula. By 2013, the fee will be base completely on the new formula (Philadelphia Water Department, 2010c).

This new method of calculating the stormwater fee gives property owners an incentive to minimize the area of their land that is covered with impervious surface. There is a stormwater credit system, in which property owners can make efforts to manage the first inch of rainwater on their property. These credits lower that property owner's monthly stormwater fee. Currently, this credit system is only applicable to non-residential properties. Residential properties are currently charged a flat stormwater fee. PWD was able to calculate the amount of impervious area on each non-residential land parcel in the city by developing shapefiles for each land parcel using Geographic Information Systems (GIS) software (Philadelphia Water Department, 2010c). This is

essentially a digital aerial photograph of each land parcel. PWD has the capability to map out the impervious surfaces in this photograph and calculate the impervious area and gross area of the land parcel using the GIS software. Pictured below is the land parcel for Stouffer College House, a dormitory at the University of Pennsylvania. The land parcel is outlined in red, impervious surfaces are yellow and purple, and the gross and impervious areas are listed below. The stormwater fee is substantially reduced as the new method is phased in.

**Figure 2.**  
**Stouffer College House: Impervious Surfaces**



<b>Parcel Area (square feet)</b>	<b>Gross Area</b>	<b>Impervious Area</b>
Total:	71,812	Total: 59,998
Credit:	0	Credit: 0

Source: Philadelphia Water Department

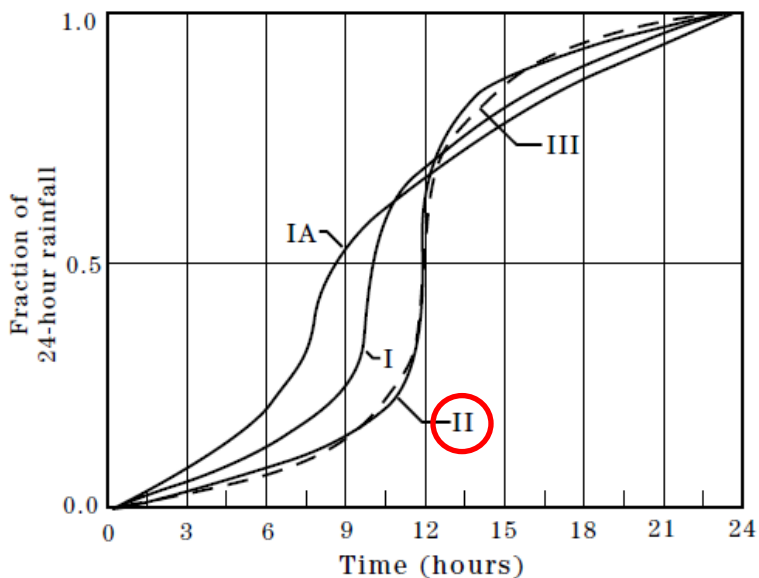
<u>FY 2010</u>	<u>FY 2011</u>	<u>FY 2012</u>	<u>FY 2013</u>	<u>FY 2014</u>
\$1,364.70	\$1,206.54	\$1,017.17	\$799.39	\$581.61

## **New Development and Major Renovation Regulations**

The second foundational component of this plan involves requiring all new construction and major renovation projects in Philadelphia to manage the first inch of rain that falls on the property. A major renovation project is currently defined as one that disturbs at least a 15,000 square foot area, though PWD is considering lowering it to 5,000 square feet. It is important to understand what is meant by managing the first inch of rain, since rain falls at different rates and runoff behaves differently based on the type of surface. A project must first attempt to infiltrate the first inch of rainfall from the Directly Connected Impervious Area (DCIA), which is an impervious surface that is directly connected to the drainage system (Philadelphia Water Department, 2006). If infiltration is not possible, the builder must provide storage capacity equal to the volume of the one inch spread over the DCIA. When this requirement is met, the PWD tests the project design to make sure that it will function properly under the conditions of a one inch Soil Conservation Service Type II 24 hour design rainfall distribution, which is displayed in Figure 3. This distribution was calculated by the U.S. Department of Agriculture to characterize a typical rain storm in this region of the country. When evaluating runoff from projects, PWD considers the time distribution of rainfall, the volume of rain retained in depressions, and the changing infiltration rate of the soil as it becomes saturated (Philadelphia Water Department, 2006). The requirement to control the first inch of runoff will not have a major immediate influence on the stormwater management of Philadelphia, but will have a large cumulative effect over time.



**Figure 3.**  
SCS 24-hour rainfall distributions



Source: Natural Resources Conservation Service

### **Best Management Practices (BMPs)**

The PA DEP's Stormwater BMP Manual breaks BMPs into two main categories: non-structural and structural. Non-structural BMPs are those that are not “brick and mortar” techniques. In other words these BMPs do not focus on installing tanks or swales, for example, to manage stormwater. These practices focus on development policies and management practices. Structural BMPs are more specific to a certain location. Structural BMPs include constructing green roofs, rain gardens, retention ponds, and other site-specific projects (PA Bureau of Watershed Management, 2006).

The goal of implementing BMPs is to follow the ten principles of stormwater management, which are listed in the BMP Manual:

1. Managing stormwater as a resource;
2. Preserving and utilizing existing natural features and systems;
3. Managing stormwater as close to the source as possible;

4. Sustaining the hydrologic balance of surface and ground water;
5. Disconnecting, decentralizing and distributing sources and discharges;
6. Slowing runoff down, and not speeding it up;
7. Preventing potential water quality and quantity problems;
8. Minimizing problems that cannot be avoided;
9. Integrating stormwater management into the initial site design process; and
10. Inspecting and maintaining all BMPs (PA Bureau of Watershed Management, 2006).

Non-Structural BMPs: To describe each specific BMP is beyond the scope of this paper, since there are many variations. It is useful, however, to describe several categories, each with broad goals, into which non-structural BMPs can be placed.

1. Protect Sensitive/Special Value Features: This can be accomplished by avoiding development in areas that perform valuable natural stormwater management services, such as filtering runoff and water percolation. This also includes avoiding development on areas, such as steep slopes, that would have a greater impact on stormwater runoff quality if developed. The practice of building riparian buffers is also included. These are areas of trees and shrubs surrounding the banks of streams or rivers that help prevent erosion on the bank, and filter runoff as it flows toward the water. In order to effectively meet the goals of this category, it is necessary to take inventory of the natural services provided by the land.
2. Cluster and Concentrate: Essentially, this is decreasing lot sizes and moving development closer together. This will decrease the amount of impervious

surface necessary to connect development and the amount of infrastructure needed. This must be considered when development is first being planned.

3. Minimize Disturbance and Minimize Maintenance: This group of practices aims at reducing the grading necessary in construction by fitting construction to the existing topography of a site. Another goal is to minimize the disturbance of native vegetation on site and to minimize the compaction of soils during construction. This can be achieved by clearly marking traffic lanes for heavy equipment and storage pile zones on the construction site while building. Compacted soils lose the ability to absorb and filter water, and the ability to support a healthy environment for root systems, animals, and microbes. If there will be landscaping on the development site, it is best to use native vegetation that will not require fertilizers or pesticides, which would contaminate runoff from the site.
4. Reduce Impervious Cover: This may seem like an obvious BMP, but it is specifically aimed at reducing impervious cover by systematically minimizing street width and length and creating more compact or pervious parking areas. Developers would need to ensure they are meeting local fire code and access requirements.
5. Disconnect/Distribute/Decentralize: One of the main techniques in this group of practices is to disconnect roof leaders and redirect runoff into vegetated areas or other non-vegetated catchments. Streets can also be disconnected from the sewer system. The runoff can be directed into vegetated swales, infiltrating runoff on site, instead of piping it offsite through the sewer system.

6. Source Control: The main practice in this group is to develop a regular street sweeping program to remove particles and debris from streets that would have clogged stormwater infrastructure and further polluted runoff (PA Bureau of Watershed Management, 2006).

*Selected Structural BMPs*: These practices are grouped into five categories in the BMP Manual. These practices involve site-specific projects, and most work by reducing the peak rate of runoff flowing into the sewers, even if the practices do not directly infiltrate the runoff into the ground. There are too many specific BMPs to have a comprehensive description of each, but representative BMPs are described below.

1. Volume/Peak Rate Reduction by Infiltration: This is the largest group of structural BMPs, most of which rely on infiltration beds. One of the main practices in this group is to construct permeable pavement on top of an infiltration bed. Pervious pavement is functionally similar to impervious pavement, except that it does not include the fine particles in impervious pavement, allowing water to be absorbed through it. Water flows into the infiltration bed, usually composed of gravel, and is slowly absorbed into the underlying soil. Pervious pavement is currently 10-20% more expensive than conventional pavement. The infiltration bed adds significant cost, though it also often eliminates the need for water inlets and pipes to the sewer system.

These infiltration beds can take various forms. Infiltration basins are little more than shallow basin dug into permeable soils, with an overflow to a conventional inlet. Infiltration beds can also be placed beneath sports fields

or gardens. The vegetation in the garden would aid in evapotranspiration.

A bioretention bed can take the form of a rain garden, which is simply a depression in the soil that is planted with native vegetation that will treat and capture runoff. This practice can also enhance aesthetic quality and provide habitat for wildlife. A vegetated swale is similar to a rain garden in that it is an impression that is planted with heavy vegetation. They act as broad channels, however, and are meant to filter contaminants out of runoff.

A dry well is another variation on this theme, in which a roof leader is directed into an underground pit that is filled with gravel, allowing roof runoff to slowly seep into the soil.

2. Volume Peak Rate Reduction: These are similar to the BMPs described above, except they do not facilitate infiltration. One of the main examples is a vegetated roof cover, more commonly known as a green roof. Green roofs can be either extensive or intensive. Extensive green roofs are two to six inches thick and are often planted with sedum, though other kinds of plants also work. Extensive green roofs have thicker soil and are often planted with larger plants, such as shrubs. Green roofs absorb a portion of the rain that falls on them, preventing runoff from flowing into the downspouts. Green roofs also provide a measure of insulation and energy efficiency for the building, in addition to improved aesthetic quality.

Even if a roof does not have vegetation, the runoff can still be captured in tanks and reused for irrigation or to flush toilets. Runoff captured from rooftops is less likely to contain contaminants that would be present if it were

captured from the streets. In a CSS there is still a stormwater management benefit if the water that is captured is not reused, but is slowly released into the sewer system after the rain has stopped.

3. Runoff Quality/Peak Rate: This group contains practices that improve the water quality of runoff, while simultaneously reducing the rate of peak flow into the sewers or streams. An example is a constructed wetland. These wetlands contain vegetation that aids in filtering runoff that enters. The wetlands also slow the flow of the runoff, promoting precipitation of sediments and reducing the peak flow of runoff into sewers or streams. Another BMP in this group involves installing water quality filters or hydrodynamic devices, which are installed in the runoff conveyance system. These can take the form of a mesh bag that filters debris out of runoff flowing into an inlet on the street. This can also be a box with an inlet on one side and an outlet into the sewer about half way up the inside of the box. This allows for sediments to settle out and debris to get trapped before flowing into the sewer pipes. Regular maintenance is crucial for this BMP, in order to remove the sediment and debris (PA Bureau of Watershed Management, 2006).

### **Stormwater Tax versus Stormwater Fee**

The difference between a tax and a fee may seem semantic, but it is actually a very important distinction for reasons that go beyond mere politics. The most important distinction is that nonprofit entities are required to pay utility fees, but are exempt from taxes. The University of Pennsylvania is a nonprofit institution, meaning that the

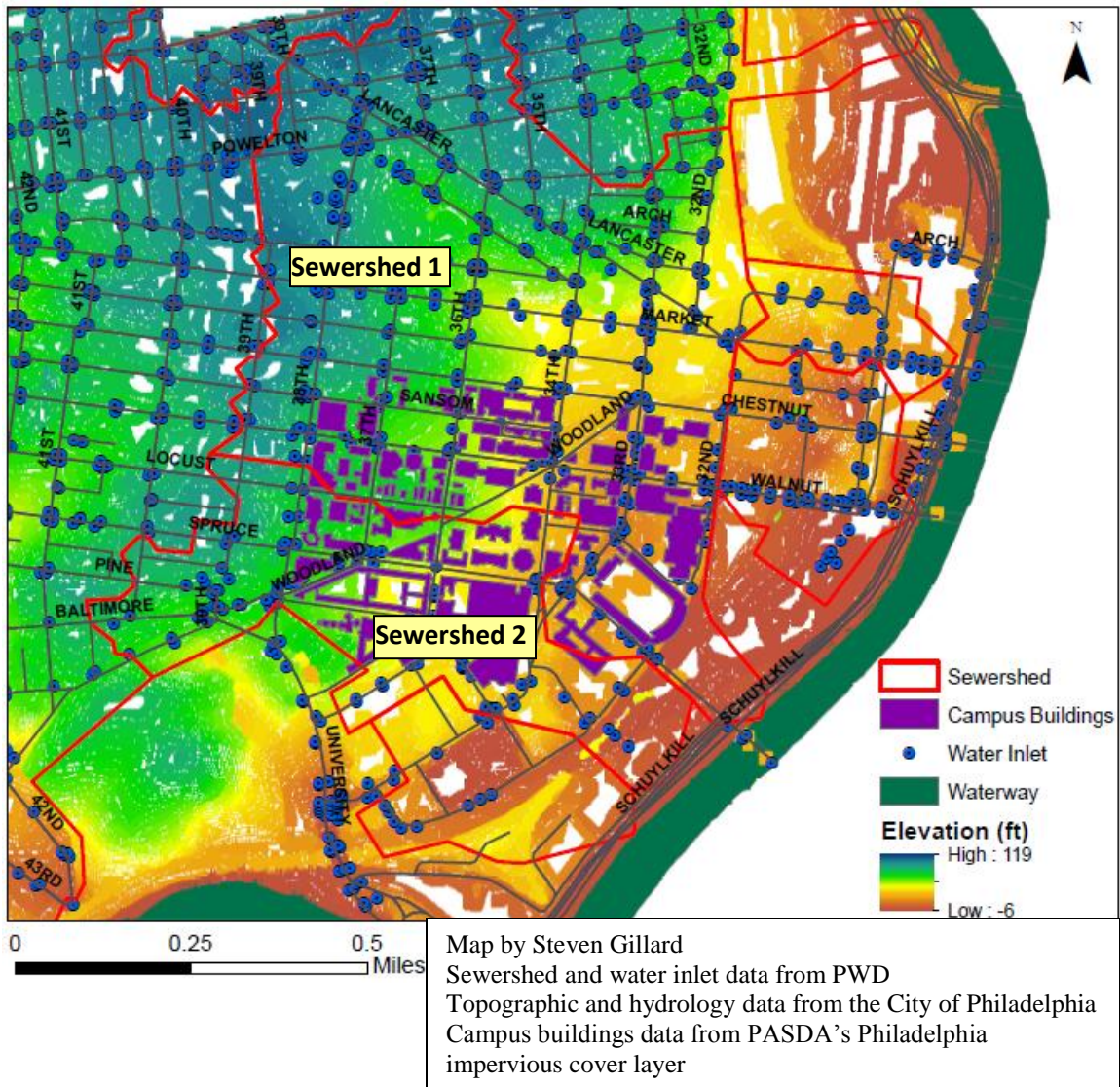
campus must pay the stormwater fee, whereas it would have been exempt if the charge were classified as a tax. PWD views the stormwater fee the same as any other utility bill. An electricity bill is based on the amount of electricity consumed by a resident. In the same way, since the new stormwater charge is based on the amount of impervious cover, each land owner is paying for the amount of stormwater passed into the storm sewer system.

The conflict between the classification of a stormwater charge as a fee or a tax was recently illustrated in Washington, DC. The City has a similar stormwater fee structure as Philadelphia. The Government Accountability Office determined that the stormwater charge did not apply to federal buildings, since it interpreted the stormwater fee as a local tax, which would violate the sovereign immunity of the federal government. This would be an issue in any city, but especially in Washington, approximately twenty percent of which is federal property. If twenty percent of the landowners exempt from paying the charge, this would mean a serious loss in expected revenue for the water department. Congress recognized this issue and acted to amend the Clean Water Act to ensure that federal property is not exempt from reasonable fees charged by localities in efforts to control their stormwater runoff. Now, even if a stormwater fee is interpreted to be a tax, federally-owned property is not exempt from paying it (O'Connell, 2010).

The EPA has yet to give final approval to Philadelphia for its *Green City, Clean Waters* program. The PWD estimates that the plan will ultimately reduce the volume of CSOs by eighty percent, which is five percent shy of what is required by the Clean Water Act (Philadelphia Water Department, 2009c). If approved, Philadelphia will be

the first city to use green infrastructure as the primary means to comply with the Combined Sewer Overflow reduction requirements set up in the Clean Water Act.

**Map 5.**  
Sewersheds and Topography of University City





## **Stormwater Management on the University of Pennsylvania Campus**

Map 5 shows the sewersheds within the watersheds on the campus of the University of Pennsylvania. The pink sections are at the lowest elevation and the blue sections are the highest elevations. The campus is divided between two main sewersheds, meaning there are two main outfalls through which runoff flows from campus during CSOs. These sewersheds are both part of the historic Beaver Creek Watershed. The blue dots represent water inlets, meaning that even though the campus is at the bottom of a large sewershed, most of the off-campus runoff flows into water inlets before reaching campus. The location of campus within this large sewershed does, however, mean that the southeastern portion of campus is an ideal location for a regional stormwater treatment facility. Such a facility would most likely drastically reduce the CSO volume from the corresponding outfall.

As the new method of calculating the Philadelphia stormwater fee is phased in gradually over the next few years, the University of Pennsylvania has a great opportunity to lower the amount of money owed to PWD each month by managing the first inch of rainfall on campus and earning credits. The University is actually one of the winners under the new system. Once the new charge is fully phased in, the University will owe approximately half as much each month as it did under the previous method of calculating the charge, because the campus has many buildings with large pipe diameters at the water meters, such as dormitories, laboratories, and dining halls. There is also less impervious cover than in the surrounding neighborhoods. Despite the fact that the University's stormwater fee will automatically be lowered under the new system, the monthly fee is still sizeable, and there is plenty of room for further

reductions. Additionally, as an institution of higher learning the University ought to go beyond financial incentives, and consider environmental and educational motivations.

There are several reasons why Penn should prioritize the issue of stormwater management on campus. Energy expenditures are by far the largest component of the University's utility bill, so that emissions reduction and energy efficiency will most likely be the top environmental priority for the University (Lundgren & Weide, 2010). However, because the campus is in the middle of a highly impervious city, the campus has a major opportunity to more effectively manage its stormwater runoff and save money on the stormwater charge as a result. Even though the campus has more pervious surfaces than the average land parcel in this part of Philadelphia, the West Philadelphia campus still covers two hundred and eighty acres, and will receive significant stormwater (Lundgren & Weide, 2010). Proximity to the Schuylkill River is another reason why stormwater management should be a priority. There is an outfall by Franklin Field that drains directly into the river. The University has recognized that water issues have come into the spotlight by declaring 2010-2011 *The Year of Water*. Though simply a theme that is not binding on school policy, this year's theme partially reflects the idea that urbanization and development are having an impact on our waterways.

### **Current and Planned Stormwater Management Efforts**

The University has made admirable efforts to control its stormwater runoff even before the stormwater charge existed. In the fall of 2009 the University unveiled its Climate Action Plan. This plan is heavily dominated with initiatives to lower our energy use and our carbon emissions in general, but there are still some sections that

deal with stormwater management on campus. Before the creation of the Climate Action Plan, the trustees approved the *Design Guidelines and Review of Campus Projects*, which outlines the standards for design, review of design, and construction. One of the tenets of the guidelines is to “Us[e] landscape design to create healthy and ecologically appropriate spaces, provide pleasant outdoor environments, reduce exterior lighting demand and minimize stormwater runoff (Penn Green Campus Partnership, 2009).”

**Figure 4.**  
**Stormwater Projects at the University of Pennsylvania**

<i>Project</i>	<i>Description</i>
Green Roofs	There are five green roofs throughout campus
Penn Park (planned)	24 acres; 365,000 gallon collection tank; native plants
Shoemaker Green (planned)	Cistern; 3 rain gardens; porous pavers
Penn Alexander School	Porous pavement playground; rain garden; infiltration bed beneath playing field
UC Green	Have planted over 1,000 trees in University City
Brick Walkways (in progress)	3700 block of Woodland Walk, Hamilton Walk, Locust Walk
New College House on Hill Field (planned)	Possible green roof; porous pavement; rain garden; capture and reuse
Radian Apartments	Curb cutouts along sidewalk; pervious pavers in main courtyard; cistern; green roof on City Tap House
Morris Arboretum	2 green roofs; cisterns; porous parking lot
Stormwater Management Plan (planned)	RFP drafted to create a plan to coordinate stormwater management projects
Penn Civic House	Recycled pavers; native plants in rain garden

In 1999 the University joined with other local organizations to form UC Green, an organization that has since been responsible for planting over one thousand trees in University City. The trees serve to beautify the area, but also have the effect of absorbing stormwater runoff. The University has also repaved several walkways with

pervious bricks or with pervious pavement (Penn Green Campus Partnership, 2009). There are plans to redo the 3600 block between 38<sup>th</sup> and 40<sup>th</sup> Streets, on Locust Walk with pervious pavers. The walkway outside of Stouffer College House also redirects excess runoff onto a new grassy area (Lundgren & Weide, 2010). According to the Climate Action Plan, “pilot projects to test the feasibility of below-grade water retention and recharge large impervious areas are underway, with the intent of decreasing both installation costs and the impact of the University’s runoff on Philadelphia’s wastewater infrastructure (Penn Green Campus Partnership, 2009).” At this point the University has installed five green roofs around campus. These are located at the Vet School’s Hill Pavilion, a plaza in Wharton’s Huntsman Hall, Nursing’s Claire Fagin Hall courtyard, Kings Court College House, and a portion of the roof of The Radian apartment complex (Penn Green Campus Partnership, 2009).

Away from the main campus, the University has constructed a couple progressive stormwater management projects. For example, a five thousand square foot porous pavement playground, a fourteen hundred square foot rain garden, and an infiltration bed were incorporated into the design of the Penn Alexander Elementary School. This allowed the roof leaders of the school to be disconnected from the sewer system and redirected into the infiltration bed or the rain garden. This project was successful enough that the EPA used it as a case study of a successful National Pollutant Discharge Elimination System green infrastructure project (U.S. Environmental Protection Agency, 2009). The Morris Arboretum has also undertaken some major initiatives to manage stormwater. These efforts include: two new green roofs, a porous parking lot, and large cisterns for stormwater storage (Penn Green

Campus Partnership, 2009).

The University also has future plans to add green infrastructure to its campus. The main part of this effort, Penn Park, is already underway, and is scheduled to be completed by August of 2011 (Penn Green Campus Partnership, 2009). The land that will constitute Penn Park previously belonged to the United States Postal Service and was mainly a large parking lot. The park will add twenty four acres of open space to the campus, and will also incorporate a 365,000 gallon underground stormwater storage facility (Lundgren & Weide, 2010). These features are especially important on this site since Penn Park will be right next to the Schuylkill River. The park will also incorporate native plantings, and the irrigation water will be drawn from the underground storage of stormwater. Once Penn Park, pictured below, is built, the existing tennis courts will be demolished and turned into a green space.

**Figure 5.**



**A Depiction of Penn Park**

Source: University of Pennsylvania Facilities and Real Estate Services

There is currently a project, still in the design phase, to construct a large underground storage tank under the new Shoemaker Green, which will be where the campus tennis courts are currently located. This tank will be able to contain stormwater from the downspouts of the Palestra, Hutchinson Gymnasium, and the David Rittenhouse Laboratories. The Shoemaker Green project is expected to be completed in Fall 2012 (Penn Green Campus Partnership, 2009).

Another project that is still in the early planning stages is to build a college house on the northwest part of Hill Field. The current plan is still subject to changes as the project progresses, but it currently involves a green roof on the college house and a pervious brick walkway. This would also be an ideal location for some kind of bio-filtration system, such as a large rain garden. Currently, even when it has not rained for several days, Hill Field is perpetually muddy (Lundgren & Weide, 2010).

### **Effective Management Techniques**

Bob Lundgren, the Landscape Architect at the University, and Becky Weide, a Landscape Planner with Facilities and Real Estate Services, agree that the easiest and most successful stormwater management initiatives on campus involve using porous pavement, building underground stormwater storage tanks, and building rain gardens. In a campus setting, rain barrels typically do not have enough capacity to make a meaningful impact. Additionally, green roofs can be very effective, but they can be difficult to retrofit onto existing buildings, and they are typically not as cost effective as other stormwater management methods (Lundgren & Weide, 2010).

## **Education**

Many management techniques are designed to serve a function without being noticeable to the general public. In the case of stormwater prevention on a university campus, however, it may be beneficial to draw attention to the benefits and features of the green infrastructure initiatives on campus. It would most likely be difficult to accomplish this educational component when dealing with underground storage tanks, or even green roofs that are not accessible or visible to students. Rain gardens, on the other hand, are a great opportunity to serve a management purpose while being visible and attractive enough to serve an educational function. This could possibly be done with signage near the rain gardens explaining the stormwater benefits associated with rain gardens and the way that they work

One way that the University can improve its own stormwater management practices is to collaborate with other universities. For instance, Bob Lundgren mentioned collaborating with other universities at landscape architecture conferences. The Ivy League schools have their own collaboration, named Ivy Plus, in which various Ivy League schools will share information and ideas. A recent topic of discussion has been considering sustainable athletic fields that are able to percolate water more easily, or that have underlying infiltration beds to store stormwater (Lundgren & Weide, 2010). Conditions vary from campus to campus and make each stormwater management strategy different. Many campuses are in more rural settings than the University of Pennsylvania, or are in cities that do not have a Combined Sewer System. Even if a campus is in a city with a Combined Sewer System, there are few cities that have a stormwater charge that is based on the area of impervious

cover on each parcel of non-residential land.

## **Metrics**

Linda Aarismaa, who works with Cornell's Environmental Compliance Programs, described many impressive stormwater management efforts on her campus. Despite these efforts, stormwater management efforts can be improved.

*"We do not have a program to really track or monitor performance, except for doing periodic inspections to ensure they are maintained – even then there are questions as to what those needs are, what actions and how often (Aarismaa, 2010)."*

When asked about the metrics used to measure the influence of green infrastructure projects, Ms. Aarismaa said that quantitative metrics had not been clearly defined. Her office has discussed this matter, but they have not come to any final conclusions yet, and would be interested to hear what metrics other universities settle on to monitor green infrastructure projects (Aarismaa, 2010).

A common theme that comes up when talking with professionals in the field is that it is extremely difficult to identify reliable, practical metrics to measure the progress or success of stormwater management efforts on a university campus. Howard Neukrug, Commissioner of the Philadelphia Water Department, defines a metric as "a measure for quantitatively assessing progress of a given parameter as implementation occurs (Neukrug, 2010)." The first step to developing metrics is to comprehensively account for the characteristics and conditions on the campus. Even if there is a grassy area, the soil may not be able to absorb water at a very high rate, which would add extra challenges to creating stormwater wetlands or a rain garden (Lundgren & Weide, 2010).



Another common theme surrounding metrics is a dislike of the term “metrics.” This may reflect a sense that metrics can be arbitrary and may not effectively describe all the important factors. For instance, the metric of reduction in the number of CSOs annually may appear impressive but not actually help to solve the root problem of why CSOs happen in the first place.

According to the assessment done by the Philadelphia Water Department, the University of Pennsylvania campus has a gross area of 7.8 million square feet and an impervious area of 5.5 million square feet, within the individual land parcels. This works out to being a little over seventy percent impervious. The amount of impervious cover on the campus is the most obvious and straight forward metric that can be measured and reduction would indicate progress in stormwater management. It would be easy to keep track of some other metrics, such as changes in the stormwater charge and the number of credits obtained from the Philadelphia Water Department to lower this charge. It would also be useful to track the maintenance costs of green infrastructure projects. For instance, a green roof requires maintenance to care for the plants, and pervious asphalt requires that sediment is vacuumed out of the voided spaces on a fairly regular basis. Monitoring these costs would give the campus a more complete view of the total costs and benefits of various green infrastructure projects (Lundgren & Weide, 2010).

### **Potential Barriers for the University of Pennsylvania**

There are some potential barriers to implementing green infrastructure projects at the University of Pennsylvania. Because Philadelphia is an old city some plots of land have been developed and used for different purposes over time. For instance,

Hill Field used to have rowhouses on it. The rowhouses are no longer standing, but the debris from their foundations and demolition is buried under a pile of fill on the site. This changes the character of the soil by not allowing water to percolate nearly as quickly as it would have otherwise. A second barrier is financial. Green infrastructure measures can be included in the plans early in the design phase, but as a project progresses it is common for more costly measures to be value engineered out of the project. Since many green technologies are still in their infancy there is also uncertainty about what maintenance procedures will be for a project and how much maintenance will cost (Lundgren & Weide, 2010).

There are also some legal barriers. Some streets have been converted into pedestrian walkways, such as Hamilton and Locust Walk. These are now considered to be part of the campus, but there are still utility lines running underneath and are they still considered rights-of-way. The University does not have to pay the stormwater charge for other streets, such as 38<sup>th</sup> Street, that split the campus, since these are rights-of-way. If the University were to construct a green infrastructure project on one of these walkways, and the City then needed to do some work on a sewer line or other utility lines, it is not clear who would be responsible for redoing the green infrastructure. If there is a possibility that a project on a right-of-way on campus will be ripped out, the University is less likely to undertake such a project (Lundgren & Weide, 2010).

## **Request for Proposals**

In addition to specific projects that are planned, the Facilities and Real Estate Services (FRES) at the University has drafted a Request for Proposals (RFP), in order to hire a consulting firm to help develop a campus stormwater management plan. At the time of this writing a consultant has not yet been chosen, and FRES will not make the actual RFP public until after the bidders are evaluated. In conversations with FRES, however, I have found out about some of the components of the RFP.

The consultant chosen for the job will characterize the impervious surfaces on campus and take an inventory of existing infrastructure and future development plans. Philadelphia has a long history of development, which means that a network of underground infrastructure has developed over time. Existing infrastructure lines would need to be taken into consideration when proposing stormwater management projects. The consultant will also check the GIS files from the PWD in order to make sure the calculated charge is accurate and up to date. Even in the example GIS screen shot of Stouffer College House used above, the landscape has changed since the aerial photograph was taken. Some of the impervious surfaces have been removed and replaced with a grass lawn, which means the charge currently listed is too high. The University is hoping that the data collected by the consultant will help create goals to work towards and metrics by which success and progress can be measured. The consultants will also help determine which regulations the campus needs to follow and the cost of doing so. This comprehensive stormwater management plan will be completely separate from the Climate Action Plan (Lundgren & Weide, 2010).

## **Survey Results**

Figure 6 summarizes the responses from the survey, which can be found in Appendix A, and was administered to nine universities: the University of Delaware, Georgia Tech, Harvard, Johns Hopkins, the University of Maryland – Baltimore County, the University of Michigan, Princeton, Villanova, and Yale. More in depth discussion of these interviews can be found after the table. The survey questions are intended to understand the hydrological characteristics of each campus, current and future stormwater management efforts, the main motivations for managing stormwater, and the main barriers to such projects. Each survey took approximately an hour to administer, and were usually conducted via telephone. The staff members in charge of stormwater management differed from campus to campus. For instance, some interviews were given by landscape architects, while others were given by utilities managers. Each interview was recorded with a digital voice recorder. If stormwater management plans were posted online, additional research beyond the interview was conducted. Princeton has a Campus Master Plan posted online, as is the Landscape Master Plan for Georgia Tech.

**Figure 6.**  
**Summary of Survey Responses from Universities**

Campuses on Combined Sewer Systems (CSS)	5 have at least some sewage and runoff going into a CSS
Campuses with Combined Sewer Overflows (CSOs)	4 reported issues with CSOs
Stormwater charges and calculation methods	8 respondents reported no land-parcel based stormwater charges; 2 reported charges based on impervious cover. 3 anticipated that an impervious cover charge may be imposed in the near future
Common green infrastructure efforts	Retention ponds, rain gardens, and bio-swales. Green roofs/pervious pavement are less common
Low-hanging fruit on campuses	5 universities mentioned opportunities to disconnect roof leaders and direct the runoff onto pervious surfaces
Prioritization of stormwater management	4 cited stormwater control as being as important as other environmental issues
Drivers in developing stormwater plan	8 mentioned regulatory compliance; also campus sustainability goals
Major barriers to stormwater projects	8 mentioned high capital costs; 3 mentioned lack of guidance from regulators; 2 mentioned a lack of space
Common Stormwater Plan Components	Mapping and inventory of campus infrastructure and physical conditions; Best Management Practice lists; Education
Innovative stormwater plan elements	Divide campus into ecological-sensitivity zones; mimic natural hydrology

## **Interviews**

### *Johns Hopkins University – Homewood Campus*

There were two interviews that took place with Johns Hopkins University; one with the Facilities Architect, Anne Roderer, and another with Shandor Szalay from AKRF, which is the consulting firm that is producing a comprehensive stormwater management plan. It was valuable to speak with a person from both the consulting and campus facilities perspectives. AKRF has worked closely with the facilities staff while developing the stormwater management plan. A steering committee was formed, headed by the University Architect, which facilitated periodic meetings between consultants and university staff.

The Homewood Campus is 160 acres and is in a suburban setting north of downtown Baltimore. The campus is completely on a Separate Sewer System, most of which drains to a creek, called Stoney Run. Mr. Szalay cited the adoption of the Chesapeake Bay TMDL as the major regulatory driver in developing a stormwater management plan. Just as important, however, is an emphasis on developing a robust sustainability program on campus, with the intention of eventually expanding the campus. Ms. Roderer mentioned that, currently, there is no land parcel-based stormwater fee, but one is anticipated in the future.

This plan has not been finalized, but Mr. Szalay was able to describe the main parts of it to me. AKRF did not conduct many infiltration studies on the soils around campus. The focus of the plan is to give the university as much flexibility as possible for future development, while developing six or seven management zones that will allow the university to meet its stormwater management goals. Many of these goals are

broad and include targets such as enhancing habitat on campus, reducing flooding, enhancing aesthetics, and improving downstream water quality. The easiest opportunity to improve stormwater management on campus is to disconnect roof leaders and redirect them to dozens of small turf areas on campus that are currently not being utilized for any other purpose (Roderer, 2011) (Szalay, 2011).

*University of Maryland – Baltimore County*

Philip Cho, a Landscape Architect at UMBC, gave this interview. UMBC is also a suburban campus near Baltimore, Maryland, though the runoff from campus flows into a mixture of combined and separate sewer systems. Mr. Cho said that there are rarely issues with CSOs, but the combined systems do get clogged and require improved maintenance. The stormwater fee is based on the quantity of water consumed. The main stormwater management practice on campus is to build microbioretention ponds for each drainage area on campus.

Mr. Cho did not feel that stormwater management was a high priority, compared with other environmental issues on campus. He cited higher capital costs as one of the main barriers to completing stormwater management projects. Another main barrier was a lack of guidance from state regulators on how to achieve compliance with state stormwater management regulations (Cho, 2011).

*University of Michigan*

Timothy Cullen, the Manager of the University of Michigan's Occupational Safety and Environ Department, gave this interview. Ann Arbor has a stormwater fee that is based on the area of impervious surface of a land parcel, though they are completely on a separate sewer system. The plan was first adopted in 1996 as a

requirement of the University's NPDES Stormwater Discharge Permit, because of discharges into the Huron River. This permit requires the following elements to be included in the plan:

- Public education and outreach program(s) on storm water impacts
- Public involvement and participation
- Illicit discharge elimination program for the campus
- Post-construction storm water management program for new development and redevelopment projects
- Construction storm water runoff control
- Pollution prevention and good housekeeping practices for University Operations
- Total Maximum Daily Loads

The main motivation for this plan is compliance with the Clean Water Act (Cullen, 2011).

#### *University of Delaware*

Jennifer Pyle, an Occupational Health and Safety Specialist at the University of Delaware, gave this interview. There is no combined sewer system or issue with CSOs associated with the University. There is no stormwater charge based on impervious surface, yet the University still has a stormwater management plan. This is mainly to comply with the City of Newark's NPDES permit. The elements of the stormwater management plan are, therefore, the same as those in the University of Michigan's plan. Ms. Pyle recognized roof leader disconnections as the easiest way for the University to reduce stormwater runoff at low cost. She also said that there is moral support for green infrastructure, but there are few funds to implement it (Pyle, 2011).

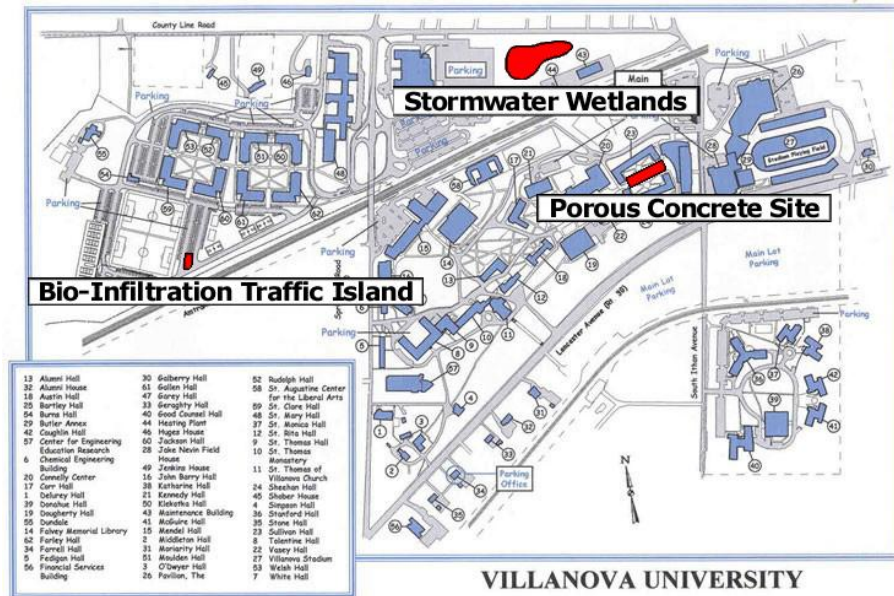


## *Villanova University*

Dr. Robert Traver, a professor in the Department of Civil Engineering, gave this interview. Dr. Traver is well-known for his research on stormwater BMPs. Villanova University is in Villanova, which is near Philadelphia, but is not under the same stormwater regulations. The sewers are separate, there are no issues with CSOs, there is no stormwater charge, and stormwater management is not a high priority for the university, yet there is robust research to improve and understand stormwater BMPs on campus. Dr. Traver identified the disconnection of roof leaders as the easiest way to lower the impact of the campus on stormwater runoff.

Villanova is a leader in developing Best Management Practices (BMPs) for stormwater management techniques. Professor Traver, in the Civil Engineering department, has completed extensive work to try and understand how various stormwater management techniques operate and how they can be made more efficient. As part of this effort, Villanova worked with the PA DEP to develop the Stormwater BMP Park (Traver, 2010). This park consists of three stormwater management sites, which serve as an educational tool and a research lab at the same time. Currently the park has stormwater wetlands, a bio-infiltration traffic island, and a porous concrete site, pictured below. Dr. Traver is working to measure the performance of various methods and to provide insights on how to improve the construction of these measures (Traver, 2010).

**Map 6.  
Villanova University Stormwater BMP Research Park**



Source: Villanova Urban Stormwater Partnership

Stormwater is currently being addressed in a short section in the University Master Plan, but Dr. Traver would prefer to have a plan that is completely separate. Currently most of the stormwater practices on campus are integral to the NPDES permit for new construction, which is issued by the Radnor Township. In order to change the local stormwater regulations, dozens of townships would need to coordinate and agree, which is very unlikely. Philadelphia has more autonomy in setting local regulations (Traver, 2011).

*Harvard University*

Brian Culver, Harvard’s Utilities Coordinator, and Dr. Gary Alpert, a professor of Biology, gave this interview. Cambridge is a very old city and has brick combined sewers that have outfalls flowing into the Charles River. Mr. Culver identified roof leader disconnection as the easiest way to improve stormwater management practices. Dr. Alpert noted that the placement of dumpsters on campus could greatly improve the

quality of runoff. Dumpsters are currently placed over water inlets and the plugs are almost always missing in the bottom of the dumpsters. As a result, contaminated runoff from the dumpsters flows directly into the water inlets.

Harvard is in the process of developing a comprehensive stormwater management plan. The University views stormwater management as part of the mix of sustainability issues and does not prioritize it above or below other environmental issues. Mr. Culver identified a lack of space, poor soil percolation, competition with other land uses as major barriers that limit green infrastructure projects on campus.

Dr. Alpert discussed his ideas for short and medium term goals for a stormwater management program. The short-term goal would be to better understand the hydrology of the campus and to understand the sources of phosphorus flowing into local streams. In the medium-term, Dr. Alpert would map all the area drains on campus and install “do not dump” signage by these inlets. A maintenance program would also be formed to clean out oil-water separators, which are frequently ignored (Culver & Alpert, 2011).

#### *Yale University*

Whyndam Abrams, an Environmental Affairs Officer at Yale, gave this interview. The runoff from Yale’s campus in New Haven flows into combined and separate sewer systems. There has been an effort recently to separate more campus buildings from the combined system. There have been some issues with CSOs in New Haven in the past, though there is an EPA-approved plan to build underground tunnels to prevent CSOs from flowing through the outfalls.

Yale is currently trying to develop a stormwater management plan without the

assistance of a consultant. The main components of this plan will likely include mapping campus structural and non-structural BMPs, develop a stormwater quality testing and monitoring program, developing educational signs and outreach, determining runoff volumes, marking sewer inlets, and maintaining the aesthetics of campus. Their first priority is to map out all existing infrastructure. The second priority is to characterize the stormwater pollutant levels, and the third priority is to develop the inlet marking program (Abrams, 2011).

*Georgia Institute of Technology*

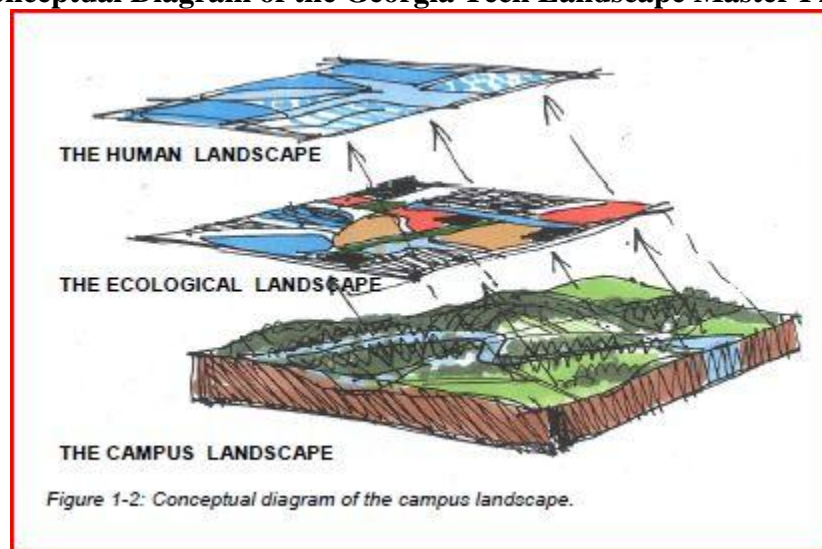
Robinson Fisher, of Robinson Fisher Associates, gave this interview. He heads the environmental planning and design firm that put together the landscape master plan, which acts as Georgia Tech's stormwater management plan. Georgia Tech is a 400 acre urban campus at the top of a watershed. Stormwater runoff flows into Atlanta's separate and combined sewer systems. There have been issues with CSOs in Atlanta, and the city is currently considering adopting a stormwater fee based on the amount of impervious cover on a land parcel, similar to Philadelphia's stormwater fee.

The stormwater plan that was developed sets the ambitious goal of reducing Georgia Tech's total discharge into the sewer system by fifty percent. Despite the extensive development on campus, this would lower the stormwater impact to pre-1950 levels, when there were fewer parking lots, buildings, and roads. One important element of the plan is that the Atlanta Department of Watershed Management agreed to review the runoff performance of the campus as a whole, as opposed to individual projects. This gives Georgia Tech greater flexibility in planning to meet stormwater regulations and attain their runoff reduction goals (Fisher, 2011).

This was the most innovative comprehensive university stormwater management plan examined in this study. Georgia Tech hired a consultant to come up with a Landscape Master Plan, of which stormwater management was a major element (Fisher, 2009). The plan developed several maps that could be overlaid to aid in decision-making: Existing Conditions, Tree Inventory, Existing Utilities, and a Corridor Map. This plan set three major goals:

1. Develop and integrated, ecologically-based landscape and open space system that helps Georgia Tech achieve its goal of environmental sustainability, specifically, a 50% reduction of current stormwater entering the Atlanta sewer system.
2. Develop a landscape that enhances the living, working, and learning environment of the Institute.
3. Develop a landscape that unifies the campus and gives it a distinct sense of place and express the identity of Georgia Tech.

**Figure 7.**  
**Conceptual Diagram of the Georgia Tech Landscape Master Plan**

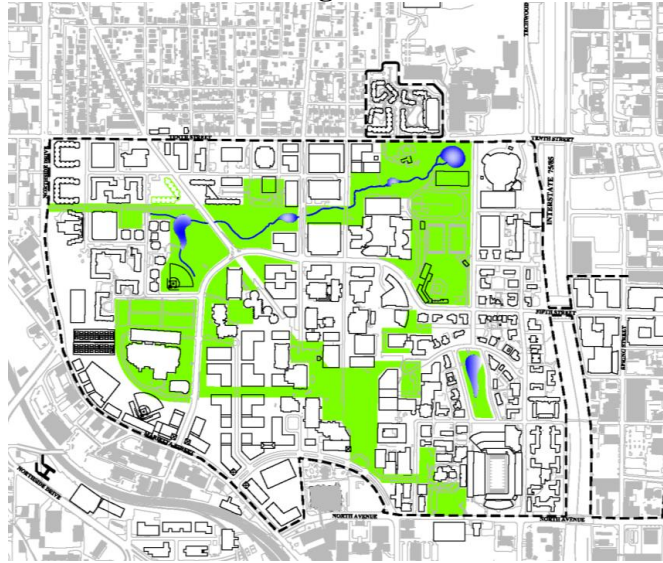


Source: Robinson Fisher Associates

***Campus Zones:*** These goals demonstrate the connection of stormwater management with larger campus goals. An innovative assumption made in the development of this plan was that the landscape of the campus is composed of any place that gets rained on. This allows the landscape to move beyond bushes and grass, including roofs and buildings as well to achieve a more holistic sustainability plan. The most important part of this plan, however, is that it divides the campus into several separate zones. Each zone is assigned performance standards that need to be achieved by new construction or renovations in that zone. The zones are based on the ecological sensitivity of the landscape on that part of campus. Performance standards in each zone consider: the maximum allowable runoff from the zone, the percentage of tree cover, percentage of impervious surface, and the total allowable area of development in the zone.

***Eco-Commons:*** The Eco-Commons is the foundation of the Landscape Master Plan. This is the most sensitive ecological zone on campus, which will perform the most ecological services. For example, this zone will receive and treat stormwater runoff from the entire rest of the campus. The Eco-Commons are displayed on Map 7 below.

## Map 7. The Georgia Tech Eco-Commons



Source: Robinson Fisher Associates

The Green Building Zone and Green Transfer Corridor are adjacent to the Eco-Commons. Development can happen in these zones, but must have high environmental standards. Most buildings on campus are contained in the Development Zone. These zones aim to mimic the same performance standards of various natural landscapes. For example, in the Eco-Commons a minimum of forty percent of the area is required to meet the same hydrological standards as a typical woodland area.

This plan has ambitious goals, but also manages to be flexible at the same time. It does not map out the exact locations or specifications of future development. By dividing the campus into zones and setting overall goals for those zones, the campus is able to meet these goals in numerous ways. There will certainly be standards for individual buildings as they are constructed, but the overall performance of each zone is the most important outcome. This plan also does not necessitate the immediate construction of projects. This is a long-term plan that will guide the evolution of the campus for decades to come. Regulators will need to be flexible with this type of plan,

and will need to be able to approve the performance of the campus as a whole, not just of individual buildings. This will also give the university more flexibility in complying with local and federal regulations.

*Princeton University*

Natalie Shivers, the Associate University Architect, and Sean Gallagher, an engineer at Princeton, gave this interview. Princeton has an interesting campus, since it gradually slopes downward from north to south, and all of the runoff drains into Lake Carnegie. CSOs are not a concern on this campus. Rather, protecting stream banks and water quality is the main concern behind stormwater management. There are four designated watersheds on campus, two of which flow to streams (which flow into the lake) and two of which flow to retention basins (which are piped into the lake).

In 2006 Princeton released a ten year Campus Master Plan, which contains a substantial amount of information on stormwater management plans. Additionally, consultants have been hired to restore the Washington Stream, which runs through campus, back to natural conditions. Ms. Shivers said that the easiest way for Princeton to improve their stormwater management is to remove soil that does not infiltrate well and replace it with new soil profiles. This is already a common practice on the campus. Energy efficiency was listed as the top environmental priority on campus, though there are provisions in the Campus Master Plan that direct new construction projects to take progressive measures in managing stormwater runoff. The planned projects on campus have proceeded more slowly than expected, due to difficult financial times, but the provisions in the Master Plan have still been followed. Other barriers mentioned include a lack of space on campus for new green infrastructure, and a lack of “regional



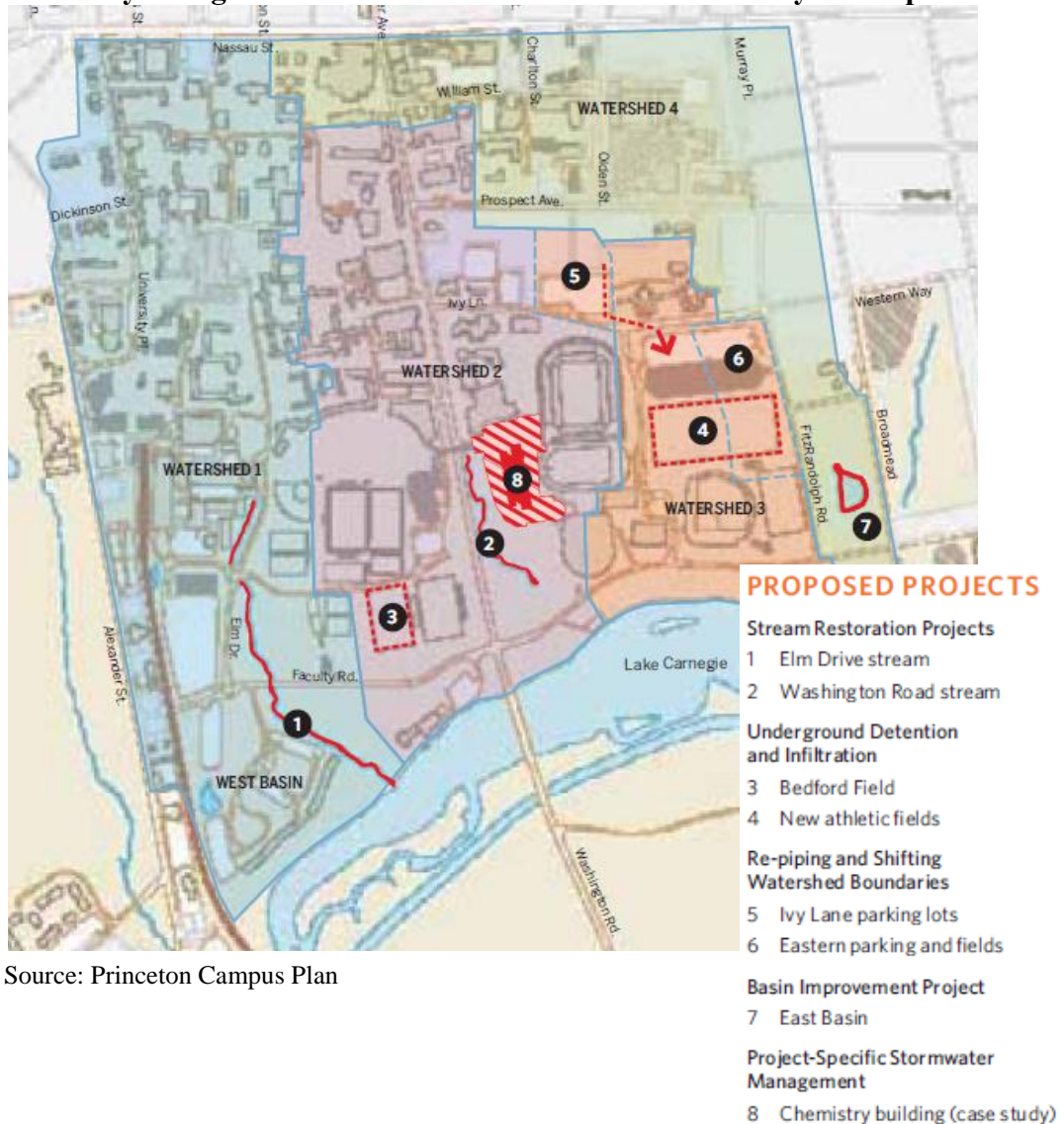
thinking” by project managers. In other words, project managers have an incentive to worry about the runoff and environmental impacts of their specific site, but have no incentive to coordinate efforts with surrounding project sites.

For the Campus Master Plan, a consultant developed a hydrological model of campus and conducted sensitivity analyses to determine which areas of campus would be affected most by new development (Shivers, 2011). The stormwater management plan for Princeton is still being developed, but the Campus Master Plan has done a great job of creating a framework for a more in-depth stormwater plan in the future. As mentioned above, there are four subwatersheds on campus, all of which eventually drain south to Lake Carnegie (see Map 8). Protecting the streams and improving water quality are the main concerns of the plan. There is an east and a west drainage basin, and two streams that gather water in the subwatersheds. The basins were designed to mitigate runoff from future construction projects. Each basin has a certain stormwater capacity, so whenever a new building project occurred, the runoff from the impervious areas of the new development were subtracted from the capacity of each basin, acting like a bank account for stormwater runoff. Each basin is now reaching its stormwater capacity. Another issue with this system is the stormwater from these developments often did not flow directly into the basins, but directly into the two streams. The basic campus hydrology and a list of some proposed stormwater projects can be seen on Map 8 on the following page (Princeton University, 2008).

The entire campus has expanded to be over five times the size of the original historic campus, which has increased runoff and strained the streams that run through campus. The historic section of campus was previously separated by a wooded area

from the recreational section of campus, but as the campus has grown the two sections have met. Princeton's plan has the goal of managing stormwater, while logically tying these two divergent sections of campus together, giving the transition between the two sections character (Princeton University, 2008).

**Map 8.**  
**Hydrological Characteristics of Princeton University's Campus**



Source: Princeton Campus Plan

The stormwater strategy describes some campus-wide initiatives to improve quality and reduce quantity of runoff. These can broadly be categorized into four groups: restoration of the major natural streams on campus, detention and infiltration of stormwater under the new athletic fields, re-piping and shifting of runoff to watershed three, and improvements to the capacity of the East Basin. In addition, Princeton has developed a hydrological model of campus and conducted sensitivity analyses, in which future development plans are compared with the hydrological model of campus to determine which development will have the most significant impact on the watershed. This data can be used to guide future development projects. For example, it was determined that Watershed 2 (see Map 8) was already overloaded with runoff, making the addition of the Ivy Lane parking lots (proposed project 5) unacceptable. To remedy this issue, the runoff from these parking lots will be piped into a rock basin underneath the new athletic fields in Watershed 3 (Princeton University, 2008).

As Princeton has developed over the decades, woodland buffer areas have been removed, creating a fragmented woodland canopy and weakening the ecosystem. The Master Plan lays out the goal of reconstructing woodland buffer areas around the streams and in other areas to absorb runoff from new building projects. Another initiative describes efforts to engineer soils that will infiltrate water, and replace soils that do not have this quality. These two efforts demonstrate that Princeton's Master Plan sets the goal of taking a campus-wide approach to stormwater management (Princeton University, 2008).

Though the foundation of this stormwater management plan is strong, much work needs to be done to develop more specific goals, a list of BMPs, an educational

program, an operation and maintenance schedule, and more detail in general.

### **Challenges in Conducting the Survey**

There were some challenges in conducting this survey. The biggest challenge was finding time in the schedules of the facilities staffs to have a thirty to sixty minute conversation about their stormwater management efforts and plans. The employees working behind the scenes to help universities operate work very hard. Because there is no standardized method of putting together a stormwater management plan, universities have organized their efforts in different ways. This sometimes made it difficult to know which staff worker to interview. The employees interviewed tended to work in offices of sustainability, were landscape architects, or had more of an engineering background, and had different approaches to managing stormwater. Some universities organized their stormwater efforts in the office of environmental health and safety, while others viewed it as more of a planning issue. It might have been useful to interview several staff workers at each university to get a broader perspective on their approach to managing stormwater, but time and resources were limited.

Because stormwater management efforts are approached differently at various universities, it does not seem possible to develop a stormwater management plan that would work for every campus. Rather, it is better to develop a general framework from the common issues that each university should consider in developing their own plan.

### **The Components of a Comprehensive Stormwater Management Program**

***Campus Inventory:*** Most of the respondents that had developed stormwater management plans began with an inventory of the current campus conditions and the current infrastructure available, as well as a projection of planned future development.

It is a good idea to consolidate these data into a format that can easily be updated, such as a GIS file. This is exactly what AKRF, the consultant that developed Johns Hopkins' stormwater plan, put together. Campuses develop and change over time, so it makes sense to have a comprehensive digital map that can be updated easily. Mapping existing infrastructure and conditions is important because it allows the university to have a starting point from which progress can be measured. It is crucial to know where most of the runoff is coming from on campus and which sewer inlets the majority of runoff flows into. This would allow the university to focus its efforts on the areas that would make the biggest impact on lowering the amount of stormwater flowing into the sewer system.

***Best Management Practices:*** Another common element that should be included in a plan is a list of stormwater Best Management Practices (BMPs). These BMPs can be tailored to each set of conditions on different campuses. For example, a campus with hard clay soil in a dense urban setting may not be able to rely on detaching their roof leaders and letting the runoff flow onto the grass. However, this may be the best option for a rural campus with porous soil that allows water to percolate quickly into the water table. Each campus's list of BMPs could be incorporated into the new construction and major renovation procedures whenever development happens on campus.

***Education:*** Most of the respondents reported having some sort of education and outreach element. This is important because many stormwater management techniques are designed to be out of sight and out of mind. Universities must have the goal of developing well-rounded students. Part of this involves making students aware of the

environmental impacts of development, how the university is working to minimize those impacts, and how students can contribute to reducing runoff and lessening its pollution. Educational efforts could involve developing a signage program for green infrastructure, curriculum related to stormwater management, or the incorporation of green infrastructure efforts into campus tours given to prospective students.

***Maintenance Schedule:*** Green infrastructure technology is a new concept to many facilities departments and contractors. In order for green infrastructure to work as long and efficiently as possible, it is necessary to develop an operation and maintenance guide. For example, in order for porous pavement to work efficiently and consistently, it is necessary to remove sediment and other material that have accumulated in the pores of the pavement by vacuuming about twice a year. AKRF developed an especially comprehensive and user-friendly maintenance schedule for Johns Hopkins' stormwater management plan.

### **Common Barriers and Concerns**

Not surprisingly, many respondents cited financial concerns as a barrier to stormwater management projects, especially citing the recession as a reason for delayed projects. It was often noted, however, that it is much easier to get funding for a stormwater management project, when that project is part of a larger vision. For example, if stormwater management is one component of an effort to make a department more sustainable, alumni are more likely to be excited about donating for this purpose. Underground storage tanks and retention basins are not attractive projects on their own.

Georgia Tech also noted that it is difficult to get funding for stormwater projects

with integrative features. A project idea that illustrates this point well is a water tower into which harvested rainwater would be pumped. The tower would then feed water into a gravity-fed irrigation system. The benefits of this project would not be attributable to one department, but would be spread across many university departments. In this way, it is necessary to find a way to share project costs between departments, if those projects have regional benefits. Other universities, such as Princeton, mentioned that funding for stormwater management projects, which are part of renovation or redevelopment efforts, is not an issue. This is because a commitment to sustainability, which includes managing stormwater, was made in the campus master plan. Even if it costs more overall, the school administration has made a commitment and will follow through on it. Of course, Princeton has greater access to funding than many universities, but this is nevertheless an admirable effort.

### **Low-Hanging Fruit**

The most commonly mentioned low-hanging fruit to improve stormwater management on campus was to disconnect roof leaders and direct the water to a pervious surface, such as a patch of turf. Several universities mentioned this step, making use of unproductive patches of land that were not being used for recreational purposes. The Philadelphia plumbing code prohibits the disconnection of roof leaders. However, PWD has agreed to help anyone obtain the necessary variances to this part of the plumbing code, as long as the runoff is being directed to a pervious area large enough to absorb the runoff (Philadelphia Water Department, 2008). This is also not possible, or is unreasonably expensive, for some buildings at the University of Pennsylvania. Some buildings were built in such a way that the runoff from the roof

mixes with sewage from the building in the building interior, making it difficult or impossible to separate out the stormwater from the sewage. There are, however, some buildings on campus that have external roof leaders. If buildings are equipped with external roof leaders, disconnection is a cheap and effective way of keeping runoff out of the sewer system.

It is worth mentioning that Harvard recognized dumpster management as a low-hanging fruit in improving stormwater practices. Dr. Alpert pointed out that dumpsters are often placed over drains and the plugs in the dumpsters are often permanently absent. Cumulatively, the fluid from the dumpsters can add a lot of contamination to the stormwater runoff that runs into the storm drains. Improving dumpster management may not have an effect on the volume of stormwater entering the system, but it would influence the water quality of runoff, which is also important. It seems like it would be relatively easy to make sure that plugs are in place in the dumpsters. If liquid were emptied from the dumpsters it would be important to ensure that it is filtered in some way before entering the storm drain.

### **Innovative Efforts at Other Universities**

Besides the common stormwater management plan elements at various universities, it is useful to highlight some of the individual efforts at universities that are particularly innovative. Drexel University has installed a system called the Rain Bird irrigation system, which is able to monitor the moisture content of the soil. This creates a “smart” irrigation system that will only water the grass when necessary, which will ultimately save water and money.

Georgia Tech has the most innovative stormwater plan of the universities



examined. The concept of dividing the campus into zones based on ecological sensitivity and developing buildings standards in each of these zones will help the campus meet its stormwater goals, while allowing flexibility for future construction. Villanova's Stormwater BMP Research Park is a prime example of how to build green infrastructure projects on campus, while incorporating a strong research and educational component. Princeton is still in the beginning stages of developing a comprehensive stormwater management plan, but their Campus Master Plan has laid a good foundation. Building retention basins filled with crushed rock underneath athletic fields is a way for the campus to control runoff from construction projects, without taking up additional space. Princeton's plan also places an emphasis on restoring the streams on campus and rebuilding contiguous woodlands to provide riparian buffers and to add pervious space to absorb extra runoff. The sensitivity analyses performed around campus will help Princeton make informed decision about where to place new development.

### **Recommendations for the University of Pennsylvania**

The University of Pennsylvania should create a comprehensive stormwater management program framework with the common elements described above. An inventory of the existing infrastructure on campus, hydrological conditions, and planned development is a crucial piece of information to have when planning how to best manage stormwater. Ideally, this inventory would be in a format that is easy to update on a regular basis, such as a GIS file. Next, the plan should develop a list of structural and non-structural BMPs that work well with the campus. Having this list, and some guidance in deciding which BMPs to install, will save designers time and

effort. An educational and outreach element may not seem crucial, but is very important to help make green infrastructure a well-accepted practice. It is also important on a college campus, which has a duty to educate students about the environmental impacts of the campus and their possible contributions to reducing environmental pollution. This can take the form of curriculum, presentations, or signage around campus. The final crucial element in the stormwater plan skeleton is a BMP maintenance schedule. Many green infrastructure technologies are relatively new, so guidance and training need to be provided to maintenance workers in order to keep these projects working efficiently. For example, this schedule would ensure that permeable asphalt projects are vacuumed out at least twice a year.

In addition to the common elements, the University of Pennsylvania should emulate some of the more innovative practices from other universities. Georgia Tech's approach of designating an Eco-Commons in the most ecologically valuable land, is a great way to organize future development. If the campus were divided into several zones, which had to meet certain runoff and construction requirements, future development could take many forms while achieving the same improvements in stormwater runoff. The zoning approach guides development, but allows significant flexibility. This system allows the campus to be viewed as one entity, as opposed to a collection of various projects and buildings.

There are some easy ways for the University to make significant gains, such as developing a program to ensure that runoff from dumpsters does not flow directly into inlets, and disconnecting roof leaders and directing the runoff onto permeable surfaces. The University should also consider constructing some projects as demonstration

projects, or developing a research park, similar to the one at Villanova.

### **Further Study**

This study provides a broad overview of campus stormwater management plans. It may be useful to develop a series of in depth case studies of individual campus stormwater management plans that is based off of more than a survey and an interview with a facilities worker. After campus stormwater management plans have become more established and solid metrics to measure success have been developed, it would be useful to use these metrics to compare the performances of various universities. At this point it is not possible to measure the effectiveness of a plan, because the plans are relatively new.

## **Conclusion**

The degradation of the quality of our waterways can partially be attributed to contaminated stormwater runoff from impervious surfaces in urbanized areas. Penn is in an ideal geographic location, surrounded by impervious surfaces and next to a river, to take a leadership role in educating students about this environmental issue and leading by example with our stormwater management practices. A crucial step towards understanding how to effectively lower our impact will be to account for our impermeable and impermeable surfaces and to develop a comprehensive stormwater management plan to guide our efforts. Managing stormwater may not have large financial returns, but the educational benefits have the potential to be great.

There are several common elements that can be seen between various university stormwater management plans. It seems as though the plans that are able to coordinate the green infrastructure on campus for the maximum benefit, are the plans that take a Master Plan approach. This approach considers other campus needs, such as maintaining a traditional aesthetic quality, new development, and social and recreational use.

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## **APPENDIX A**

## Survey Questions

- 1) Does the stormwater runoff from your campus flow into a Combined Sewer System (CSS)?
- 2) If there is a CSS, are there issues with Combined Sewer Overflows (CSOs) in your city or town?
- 3) Is there a stormwater charge per land parcel? If so, how is this charge calculated?
- 4) Has the university made efforts to control stormwater runoff?
- 5) What are the “low-hanging fruit” in terms of stormwater management improvements on campus?
- 6) Where does stormwater management fall when prioritizing against other environmental issues on campus? What are the main reasons for this?
- 7) What are the main motivations/ incentives for changing stormwater management practices?
- 8) What are the main barriers to stormwater management projects?
- 9) Are there sufficient sources to fund green infrastructure projects on campus?
- 10) Has the university developed/ will they develop a stormwater management plan?
- 11) If so, was a consultant used? What was the main methodology?
- 12) If your campus has or will have a stormwater management plan, what are the main elements?
- 13) Has your university identified short, medium, and long-term stormwater management priorities? If so, can you summarize them?