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Creating the West Gate Entrance: Erosion and Water Quality Solutions for the University of Massachusetts – Amherst Campus

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CREATING THE WEST GATE ENTRANCE: EROSION AND WATER QUALITY SOLUTIONS FOR THE UNIVERSITY OF MASSACHUSETTS AMHERST CAMPUS

A Master's Project Presented by:

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ABSTRACT

CREATING THE WEST GATE ENTRANCE: EROSION AND WATER QUALITY SOLUTIONS FOR THE UNIVERSITY OF MASSACHUSETTS AMHERST CAMPUS

The impacts of development have degraded the Tan Brook to the point that water pollution and flooding issues are affecting residents and the University of Massachusetts Amherst campus as well as the adjacent Mill River Watershed. Water quality measurements indicate high levels of conductivity possibly due to winter salting. This proposed design solution includes a vegetated swale that integrates sand filters and bioretention basins. These applications within the design could reduce erosion issues and improve water quality while providing students, faculty, and staff a location for educational purposes, recreation, and respite. By embracing innovative and aesthetic solutions, the West Gate entrance could become a functional stormwater destination and identity marker that showcases the ecological stewardship founded in the roots of the land grant of the University of Massachusetts Amherst.

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INTRODUCTION

Stormwater management is an essential element of a healthy community. Improper stormwater management can have negative impacts on drinking supply and aquatic ecosystems. Within Amherst, Massachusetts these issues can be observed within the 512 acre Tan Brook Watershed. The impacts of development have degraded the Tan Brook to the point that water quality and flooding is impacting residents and the University of Massachusetts Amherst campus as well as the adjacent Mill River Watershed. Due to the lack of proper stormwater management upstream of the University of Massachusetts Amherst campus this Masters Project proposes water quality solutions through green infrastructure design to mitigate flooding and water quality issues along the southwestern entrance of the campus where the Tan Brook overflow leaves Amherst and enters the town of Hadley and the Mill River Watershed. This location is critical because of the adjacency to the Mill River Watershed. When the Mill River floods the Tan Brook becomes backed up and flooding occurs at the southwest entrance as well as the visitor center parking lot.

The Tan Brook originates from a spring near Strong Street and traverses Wildwood Cemetery before entering a culvert in downtown Amherst. The brook is day lighted for a brief period while it flows through a neighborhood before being sent into a culvert once again at the edge of the University. The water entering the campus is directed to the campus pond and any excess overflow is diverted through a pipe to the southwest edge of the campus. An EPA Campus RainWorks project from 2014 included water quality measurements of the campus pond, which indicated high levels of conductivity suggesting pollution from winter salting. Multiple challenges exist with the current layout and function of the Tan Brook. The increased impervious and pollutant load entering the system has become an issue for residents and ecosystem functions. The process of water traveling through a concrete pipe increases the speed causing flooding. The combination of these issues creates a situation that needs to be addressed utilizing federal and local regulations to improve water quality and ecosystem functions not only locally but also for regional watershed degradation.

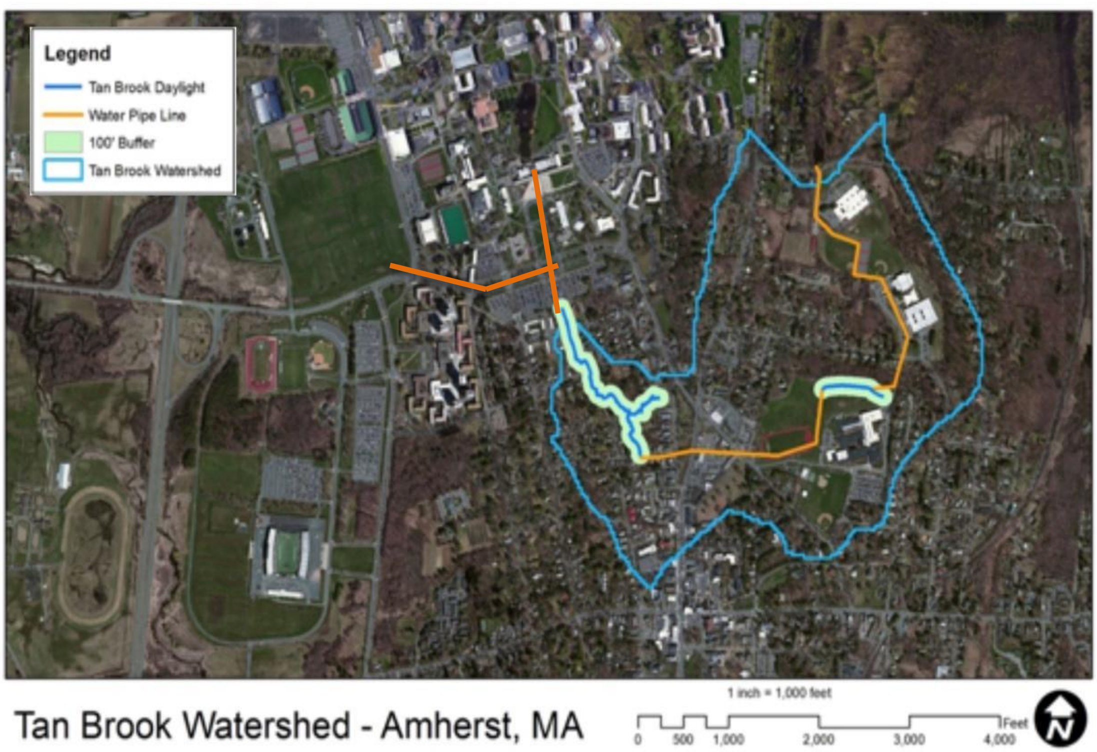


Figure 1.1: This map shows the portion of the Tan Brook Watershed that is piped on the University of Massachusetts Amherst campus *(Data Source: Mass GIS)*.

In 1970 the Environmental Protection Agency was created to address water quality issues. The town of Amherst has had a proactive approach in regards to watershed management since the 1940s. It was then that the town decided to protect the areas surrounding the drinking water sources. In 1941, the town purchased Amherst Water Company and began purchasing land for conservation around all of the reservoirs. Currently, Amherst has over 2,600 acres in watershed holdings. These holdings are located in Shutesbury, Pelham, Belchertown, and South Amherst. Amherst purchases as much land surrounding the water source as possible, creates boundary lines, preserves the forest cover, maintains tributaries, and monitors wildlife (Ziomek, D, 2013).

This method of watershed management does not adequately account for the impacts of development and automobile contamination. The increase in impervious land cover as well as automobile-related fluids contaminating the waterways leads to a variety of ecosystem failures. Residents have complained of flooding issues along with strong petroleum contamination along Fearing Street before the water flow enters the University of Massachusetts campus (Landeck, 2011). The Tan Brook collects contaminants from the downtown area and flows to adjacent watersheds without any mitigation attempts. Once the Tan Brook enters the University of Massachusetts campus it flows into a catch basin that diverts the water into two pipes. The first and most prominent pipe brings water to the campus pond where the functions of the pond help to treat contaminants through sediment control and vegetation. The second, an overflow pipe, allows water to flow to the western entrance of campus as shown in Figure 1.2. Once the water exits this three foot diameter pipe, it has reached a speed and quantity that has caused erosion problems. The University Physical Plant has been placing orange caution snow fencing around the pipe outflow and at the lower end of the swale. This does not combat the problems causing the erosion and serves only to limit access to the eroded areas.

This master's project will address the latter location and create a design along with construction documents to mitigate erosion problems while improving water quality and overall ecosystem functions. To achieve this, thorough green infrastructure research and best management practices and local, state, and national regulations on stormwater requirements will be applied. Understanding the regulations as well as the techniques to address stormwater will be the foundation of the design solution. Additionally, issues related to campus design must be considered. Pedestrian and automotive circulation along with aesthetics and opportunities for learning will be interfused within the stormwater improvements. Once this design is completed and implemented it could help to mitigate erosion problems while improving water quality and provide the campus with a multifaceted educational opportunity to engage students as well as visitors.

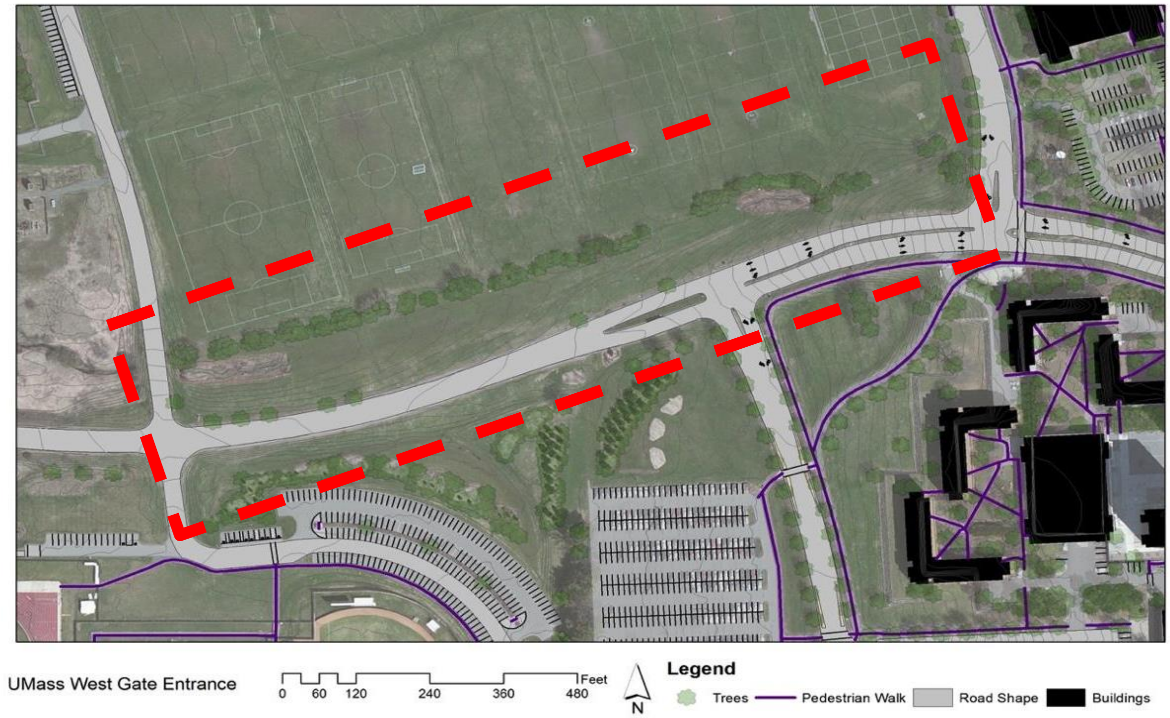


Figure 2.2: The study site is located at the West Gate Entrance to the University of Massachusetts Amherst campus and follows along University Drive *(Data Source: Mass GIS)*

LITERATURE REVIEW

This project focuses on the implementation of stormwater management. The literature review will provide a basic understanding of the hydrological cycle, watersheds, and soils. These elements are administered by the Environmental Protection Agency and have been used to further the studies of Green Infrastructure, Low Impact Development, and the Sustainable Sites Initiative. Case studies of various design approaches that illustrate the methodology utilized to determine the best solution for the Tan Brook will also be examined.

Hydrology

Historically, developments have been located around water bodies to be used for irrigation, transportation, and drinking supply. Figure 2.1 shows how towns grew, water turned from a resource to a nuisance when storm events would cause flooding. Because of this, stormwater has been a problem for people since cities have existed. There are examples of people addressing these issues dating back to 3,000 BC within ancient Roman and post- Roman development.

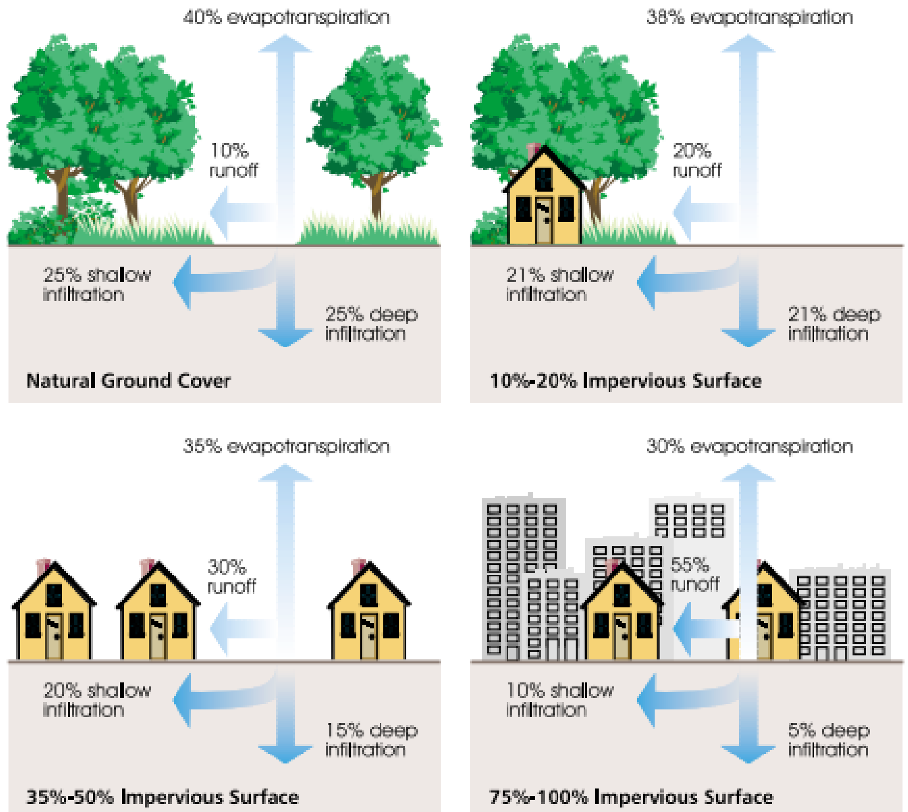


Figure 2.1: Increased development is in direct correlation with increased stormwater run off (U.S. Environmental Protection Agency, 1999).

Watershed

The U.S. EPA defines a watershed as the area of land in which all water drains to the same location as shown in Figure 2.2. Due to all the variables that come into play with landform and water flow, watersheds can come in different shapes and sizes. Within the continental United States there are approximately 2,100 watersheds (U.S. Environmental Protection Agency, 2012).

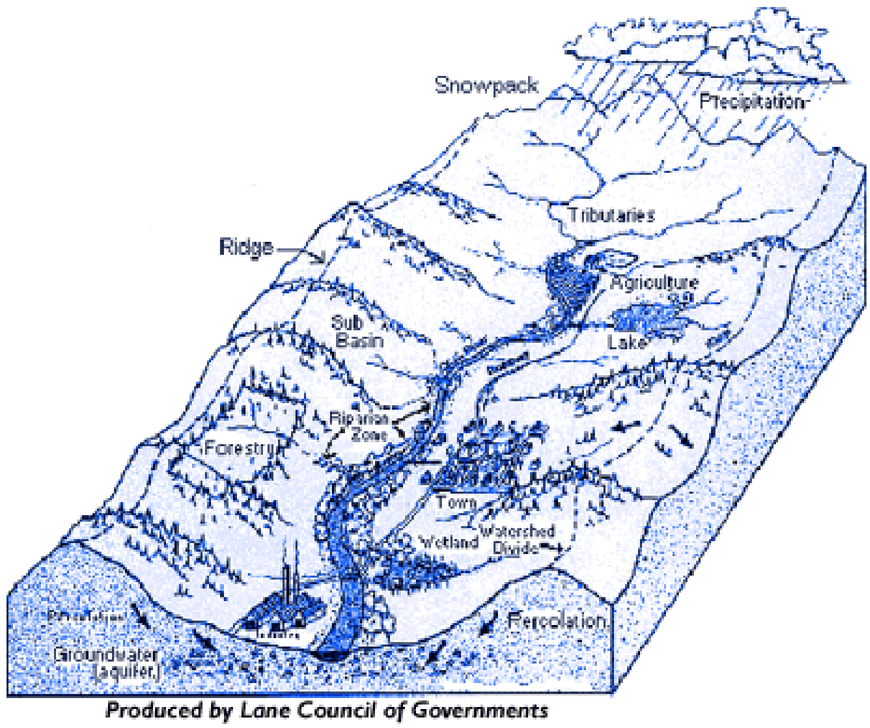


Figure 2.2: A watershed is contained within a topographical region and all precipitation flows to the same location (U.S. Environmental Protection Agency, 2012).

Hydrologic and Energy Cycle

Water moving through a watershed is known as the *water balance* or *budget* and is best explained through the factors of the hydrologic cycle. This cycle is presented as:

$$P - Et - Q \pm \Delta S \pm L = 0$$

P represents precipitation, which accounts for rain, snow, or a mixture thereof. *Et* represents evapotranspiration, which accounts for evaporation, transpiration and interception. *Q* is water yield, which accounts for streamflow and groundwater recharge. *S* is storage, which is represented as a change in amount. *L* is leakage of water in or out of the watershed (Cretaz & Barten, 2007) (Healy, Winter, LaBaugh, & Franke, 2007). The concept behind the water balance is that no matter the degree of variation within the components, the algebraic sum will always be equal as proven by the law of conservation of mass.

Because water is always moving through the system it is directly linked to the energy balance. The process of water changing from or to a gas, liquid, or solid requires energy that is either absorbed or released. The energy balance is represented as:

$$Rn + Hs + LE + G + M = 0$$

Rn represents net radiation, which is the solar or terrestrial energy. *Hs* is the sensible heat exchanged within the atmosphere. *LE* is the latent heat exchanged within the atmosphere. *G* is the heat exchanged within the ground or vegetation. *M* is the metabolic heat of photosynthesis or respiration. This balance becomes important because the flow of water through the hydrologic cycle requires energy input both for plants as well as human use. Understanding the balance and creating a system that functions with minimum additional energy inputs is critical for successful, sustainable systems (Cretaz & Barten, 2007) (Healy, Winter, LaBaugh, & Franke, 2007).

Soil Physics

Soil Physics, a subdivision of Soil Science, studies the physical properties and behavior of the soil. It provides an understanding of how water will respond and move through this phase of the hydrologic cycle (Hillel, 2003). This is important to understand that the dynamics of soil can be very different below the surface and it is necessary to have a proper profile of the types of soil present on a site. A breakdown of the types of soil present on a site is known as a soil profile. The United States Department of Agriculture's Natural Resources Conservation Service created a tool known as the Web Soil Survey (WSS), which provides data and information by the National Cooperative Soil Survey. These surveys can be used for general farm, local, and wider area planning.

Typical soil profiles consist of multiple layers known as *horizons* labeled 0, A, B, and C. The O horizon is the organic material located on the surface as shown in Figure 2.3. The thickness of this layer is directly related to the type of vegetation covering the soil. The A horizon is a critical layer due to its rich fertility. It is in the A horizon that most plant and animal interactions occur which assists in the breaking down of organic matter and continuing the fertilization of the enriched growing zone. The A horizon is typically 10 to 30 cm in thickness. The B horizon is where materials that leached from the A horizon collect. This layer is typically thicker and compacted from the pressure of the above horizons reducing the porosity of the soil, which is the ability of water to travel through the soil. The C horizon is most closely related to the parent material of the soil formation and is the least affected by the soil forming process (Cretaz & Barten, 2007) (Hillel, 2003).

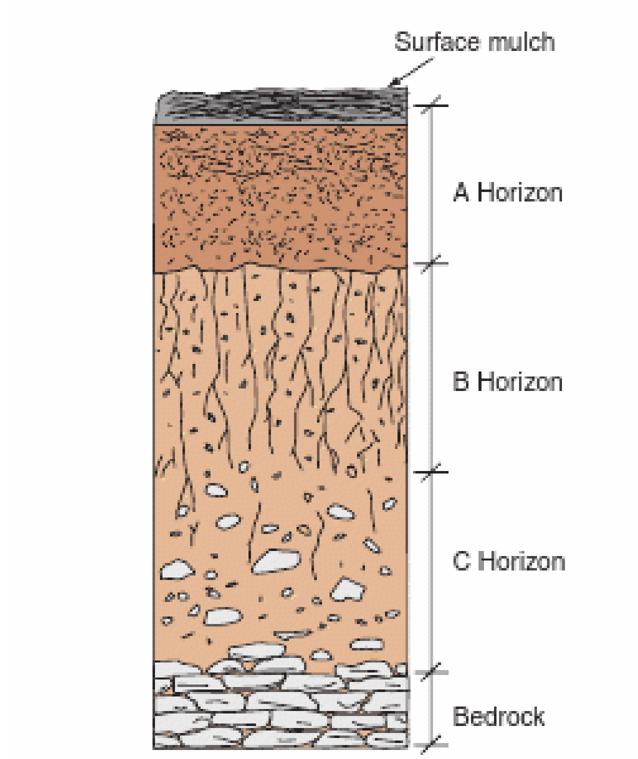


Figure 2.3: A soil profile illustrates the type of soils present and the depth at which they occur. This is critical in understanding what types of plants will survive in the area as well as the hydrologic potential (Hillel, 2003).

Soil is created from erosion of parent material, so the type of soil formed and depths will vary by the climatic zone they are located within. Because soils are the primary location where water infiltrates during rain events it is a critical component to the water cycle. The physical properties of soil contain water, air, mineral matter, and organic matter. Typically, mineral matter and organic matter make up 50% of the soil while water and air constitute the remaining amount. Water and air are in constant movement within the soil and this space is described as the soil's *porosity* (Hillel, 2003). Pore space is important in soil because it controls the water-holding potential for the soil as well as the ability for roots to grow.

Environmental Protection Agency

Within the United States, the understanding of environmental and water quality reached a critical breaking point in the middle of the 20th century with massive housing developments and unregulated pesticide applications. The U.S. Environmental Protection Agency (EPA) was created in 1970 with the mission to protect human health, specifically directed towards environmental issues. The EPA responded to the critical water issues facing the U.S. by creating the Clean Water Act in 1972, which established "the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (U.S. Environmental Protection Agency, 2012)."

The goals and objectives charged to the EPA were critical in a movement to acknowledge and address environmental issues facing the U.S. Many credit Rachel Carson's book, *Silent Spring*, for alerting the nation of the environmental and human dangers that had been caused by massive use of pesticides. *Silent Spring* would start an environmental revolution that is still surging today. The environmentalist movement helped solidify the environment as a valuable resource that the government and community must protect. Because these ideas and principles are becoming commonly understood and respected within the U.S. it is often overlooked that in order to have a sound environment and water quality, a great deal of planning and protections need to be in place. This movement continues today and is supported by landscape architects and planners within urban areas through the idea of green infrastructure.

Green Infrastructure

The EPA defines green infrastructure as "an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. Unlike single-purpose gray stormwater infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more (U.S. Environmental Protection Agency, 2012)." Another definition more applied to landscape design is "an inter-network of green open spaces that provide a range of ecosystem services – from clean air and water to wildlife habitat and carbon sinks (Green, 2013)." Combining these two definitions allows the application of green infrastructure to both small scale as well are larger regional planning.

The EPA divides green infrastructure into five categories: air, water, community, energy, and habitat. Water is where the majority of green infrastructure is focused. The issues created by stormwater within urban areas contribute to large amounts of pollutants entering streams, lakes, and beaches. Green infrastructure can help reduce stormwater and treat the pollutants in a natural method thus reducing potential ecological damages. The process if harvesting and recycling rainwater increases the efficiency of a community's water supply.

There are ten reoccurring principles within green infrastructure projects (Benedict, 2006).

1. *Connectivity is key*

The ability to create connections is vital for both natural landscapes and open space but also for people and programs. It has been shown that organisms, just like water, need to have linkage to function properly. This can be done through planning measures to ensure that conservation and green open spaces are laid out in a network allowing connections to occur.

2. *Context matters*

Understanding and designing with context in mind is almost universal in design. Green infrastructure needs to be integrated into the existing landscape and be responsive of the local resources and needs.

3. *Green infrastructure should be grounded in sound science and land-use planning theory and practice.*

The application of green infrastructure is multidisciplinary. Utilizing the strengths of the various scientific fields associated with ecological functions allows the design to be more holistic. Fields such as landscape ecology, biology, regional planning, landscape architecture, and civil engineering all play critical roles in the function of people and ecosystems. Applying the knowledge base of all of these fields will lead to a design that meets the needs of both sound ecological function and human lifestyles.

4. Green infrastructure can and should function as the framework for conservation and development.

The need for green infrastructure stemmed from the effects of sprawl on ecosystems. It can serve as the method to control and direct new development while providing a framework of unified conservation ideas.

5. Green infrastructure should be planned and protected before development.

To properly combat the impacts that development has already created, the implementation of green infrastructure and the restoration of a healthy ecosystem should have priority over new development.

6. *Green infrastructure is a critical public investment that should be funded up front.*

Funding is an important aspect to the success of any project. Because green infrastructure is a necessary element for a successfully balanced relationship with society and nature it is important to ensure that funding is available up front. Just as transportation, electricity, and telecommunication networks are essential, publicly financed elements, green infrastructure is rehabilitating and enhancing the impacts for future generations to come.

7. Green infrastructure affords benefits to nature and people.

Properly applied green infrastructure provides benefits to people, wildlife, and ecosystem functions. Because green infrastructure helps regulate hydrologic flows, municipalities can reduce the needed for added gray infrastructure elements and reallocate funding for other community needs.

8. Green infrastructure respects the needs and desires of landowners and other stakeholders.

Successful green infrastructure for communities needs to recognize the needs and wants of stakeholders and work through collaborative measures to ensure that the projects are for the best interest of the area. This does not require all of the area to be in public ownership but for owners and stewards to work with farmers and other owners willing to conserve and utilize practices to reduce and improve development-caused impacts.

9. Green infrastructure requires making connections to activities within and beyond the community.

The programs of design of green infrastructure should provide connections and engagement opportunities throughout the area. Many of these can occur alongside development and smart growth practices. Providing connections and programs enhances the visibility of the elements and allows stakeholders to be aware of the benefits of the infrastructure created.

10. Green infrastructure requires long-term commitment.

The long-term commitment to the program will ensure that all elements are properly established and the long-term benefits are allowed to come to fruition. Many of the management practices and elements will take time to be established and the impacts of this change may not be apparent immediately but over the course of time impacts of impervious areas and over development can be combated.

For the success of green infrastructure projects, it is important to address these ten reoccurring principles within already successful green infrastructure projects. Applying these principles to areas of degradation in urban areas could provide solutions to negative impacts created by over development. Additionally, utilizing natural processes provides opportunity for designs that are aesthetically pleasing and provide amenities to ensure a successful community.

Low Impact Development

The concept of Low Impact Development (LID) was first coined in Prince George County, Maryland. The focus of LID is primarily on the hydrologic affects of development. To combat these affects LID seeks to replicate natural management of stormwater as much as possible (Clar, 2008). This process combines hydrologic functions and alternative infiltration methods to treat and prevent pollution and combat the negative impacts on the environment that traditional development practices cause (Prince George's County, 1999).

The Prince George County Programs and Planning Division created the first manual to assist in creating LID projects. The primary goals of LID are:

- Provide an improved technology for environmental protection of receiving waters.
- Provide economic incentives that encourage environmentally sensitive development.

- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Help build communities based on environmental stewardship.
- Reduce construction and maintenance costs of the stormwater infrastructure.
- Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multi-functional landscape features (bioretention areas, swales, and conservation areas); mimic or replicate hydrologic functions; and maintain the ecological/biological integrity of receiving streams.
- Encourage flexibility in regulations that allows innovative engineering and site planning to promote smart growth principles.
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches (Prince George's County, 1999).

These goals address and focus on hydrologic functions and ensure that the projects are beneficial to the site and community. The principals of LID are outlined in Figure 2.4 as the suggested process of approaching an LID project. This approach begins with collecting the data for the site and deciding what storm event is desired for holding. A storm event is measured by the probability of occurrence, i.e. a 1 in a 100-year probability is a 100-year storm event. Selecting the storm event is important because the larger the storm event the more storage and higher volume of stormwater will occur. Once the storm event is selected, calculations and design decisions must be made to determine the amount of water to be held and the areas to store the water. To achieve these goals the selection of Best Management Practices (BMPs) must be done.

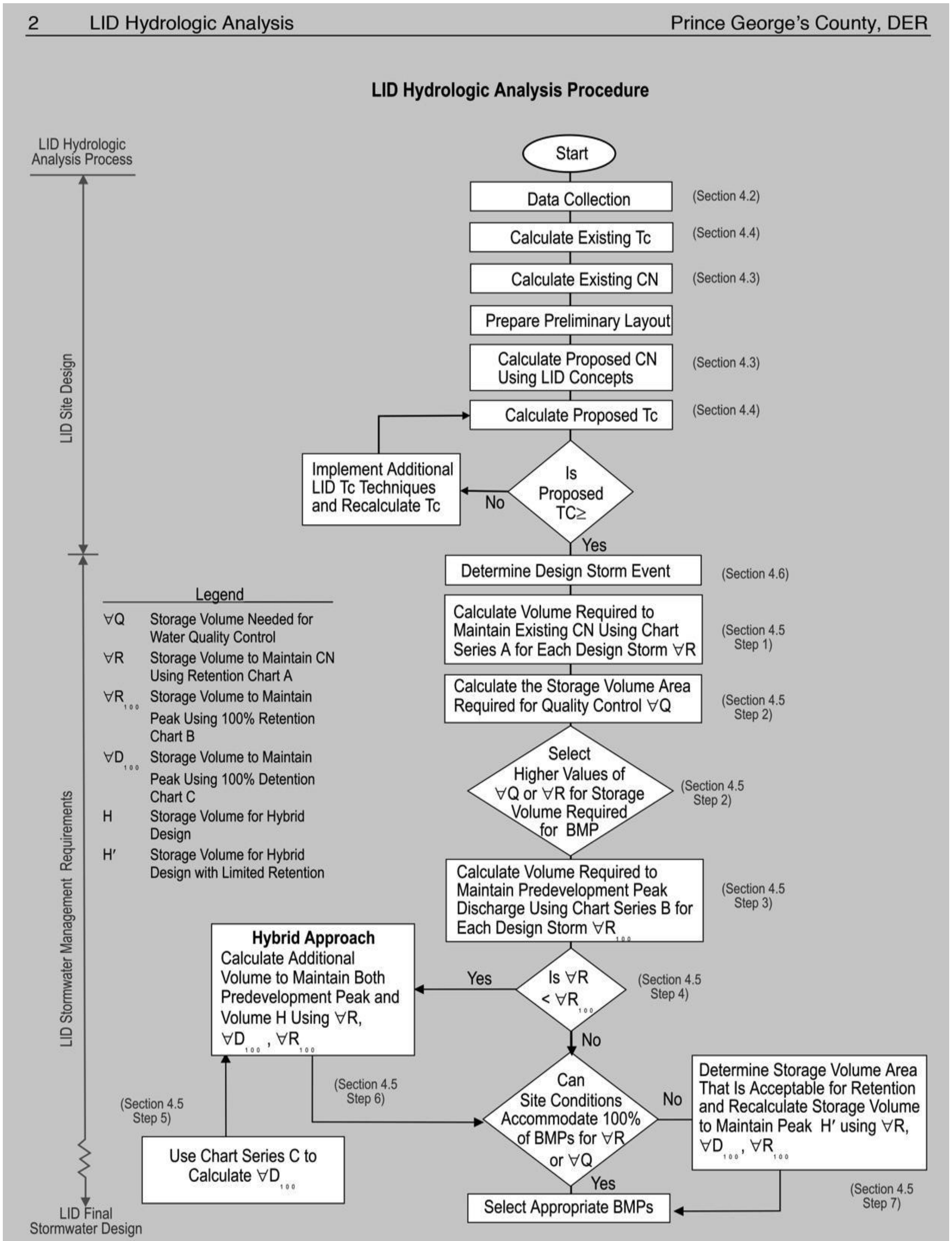


Figure 1.1. Low-impact development analysis procedure

Figure 2.4: Low Impact Development hydrological analysis procedure and approach to stormwater management (Prince George's County, 1999).

Best Management Practices

Best management practices (BMPs) are the primary tool within green infrastructure planning. These tools come in a variety of sizes and methods of approach. For the purpose of this master's project, relevant BMPs were researched to understand the potential opportunity they could provide to the final design. Several structural BMPs were selected for research and potential implementation. These BMPs are: infiltration systems, retention systems, constructed wetlands, filtration systems, and vegetated systems. Non-application BMPs for this project include structural BMPs such as detention ponds, porous pavements, and water quality inlets.

It is important in the design of these BMPs that they are able to retain and store water during storm events. This will reduce erosion and flood caused by storm events that the piped infrastructure is unable to handle. Additionally, these BMPs need to be able to improve the water quality. The important water quality elements that will be considered for this report are: total suspended solids (TSS), total phosphorus (TP), soluble phosphorus (Sol P), total nitrogen (TN), nitrogen as nitrate (NOx), copper (Cu), zinc (Zn), and bacteriological indicators such as fecal matter and E.coli (Bacteria).

Infiltration basins, also known as bioretention basins or rain gardens, are impoundment areas designed to capture stormwater during storm events. These areas allow the water to be stored and infiltrate into the ground over a set period of time. The typical design as shown in Figure 2.6 has water enter these systems through a stormwater pipe or sheet flow. Once the water has entered the designed area, the vegetation within the basin allows for water to be taken up by roots of plants as well as the soil. The root system of the vegetation creates cracks in the soil, which allow better soil uptake. The use of sand and vegetation help mitigate contaminates in the water as shown in Figure 2.5. The vegetation also serves to reduce soil erosion during large storm events and stabilizes banks to prevent system failure. These systems are designed to hold a determined amount of water. Typically, if a storm event creates more water than the system can handle, an overflow pipe allows any remaining water to flow back into a piped sewer system or another designated area for water retention (Metropolitan Council Environmental Services, 2001).

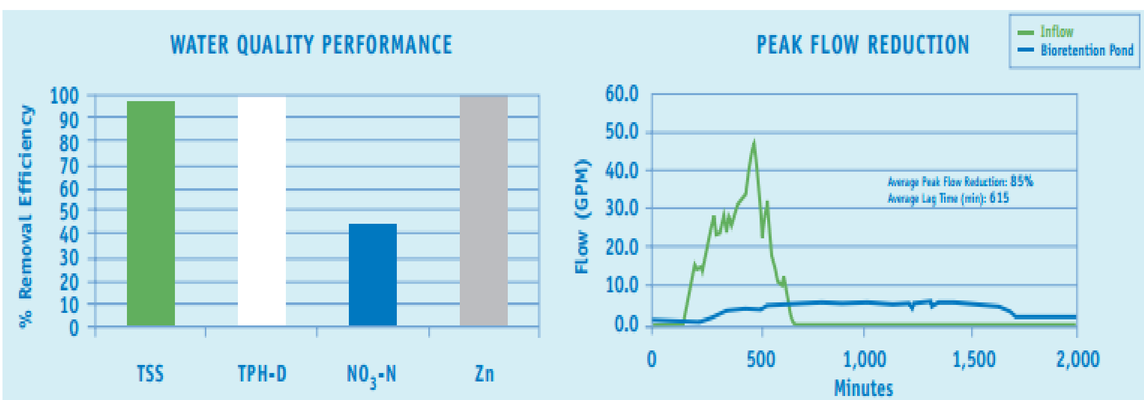


Figure 2.5: The effectiveness of detention basins as a water quality enhancement and peak flow reduction (UNH, 2005).

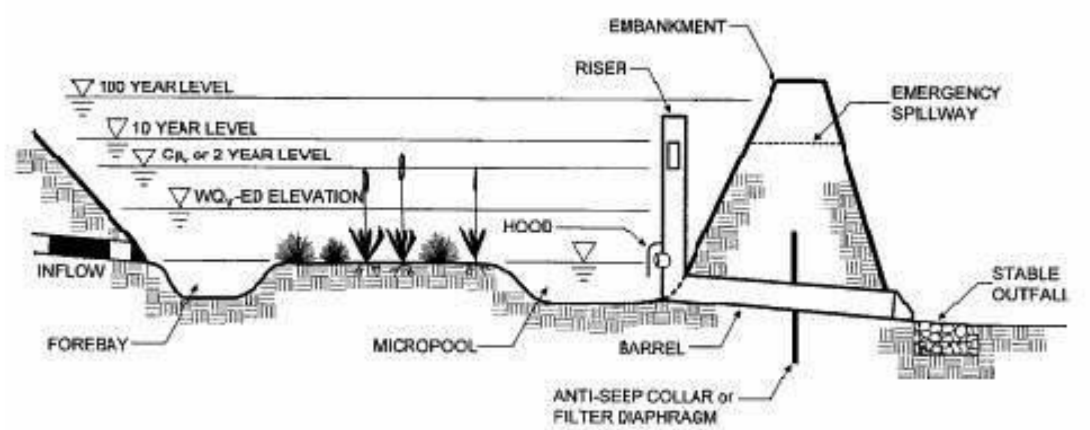


Figure 2.6: A bioretention basin shows how the system is able to hold a variety of storm events when properly designed ((U.S. Environmental Protection Agency, 2014).

Infiltration trenches, or swales, are subgrade channels typically three to twelve feet deep and lined with a geotextile material and filled with stone as shown in Figure 2.8. The design allows for an increased porous space where stormwater can rush during storm events. The water entering these trenches is allowed to flow through the stone and eventually filter through the geotextile and into the existing soil material. This BMP method allows for water infiltration to take place over a matter of days and reduces risk associated with open water. This differs from infiltration basins that typically require the entire space to be designated for water and is not useable during storm events because of the presence of water (Metropolitan Council Environmental Services, 2001). Infiltration trenches are advantageous because they can reduce the amount of runoff and, when properly designed, can remove sediments, trace metals, nutrients, bacteria, and oxygen-demanding substances as shown in Figure 2.7. They can be utilized in smaller sites therein reducing the downstream impacts of flooding and the need for larger stormwater catchments.

However, because they are small they have a higher chance of failure during larger storm events. The system depends on the infiltration opportunities of the subsoil, which may not provide for infiltration in certain areas. Without proper maintenance and upkeep the system is susceptible to failure due to the clogging of sediments (Metropolitan Council Environmental Services, 2001).

The design layout for these swales have several key components including longitudinal slope, bottom width, depth, length residence time, and water velocity. The longitudinal slope is optimally in the range of 1-2% to allow water flow travel at a low velocity with optimal treatment to the water and limited potential for erosion. Because of this, infiltration trenches are not recommended in steep and hilly locations. The bottom of the swale should be wide to allow for pollutant removal and easier maintenance. The depth of the swale should be designed to ensure that at peak flow the water is not overflowing the sides and impacting adjacent walkways and drives. The length of the swale from the inlet pipe to the outlet impacts the time that water spends within the stormwater treatment system, known as residence time. Swales should be designed to be as long as possible to ensure the most amount of time for pollutant treatment. Swales should be designed to allow for at least five minutes of residence time (Richman, Lichten, Worth, & Ferguson, 1998).

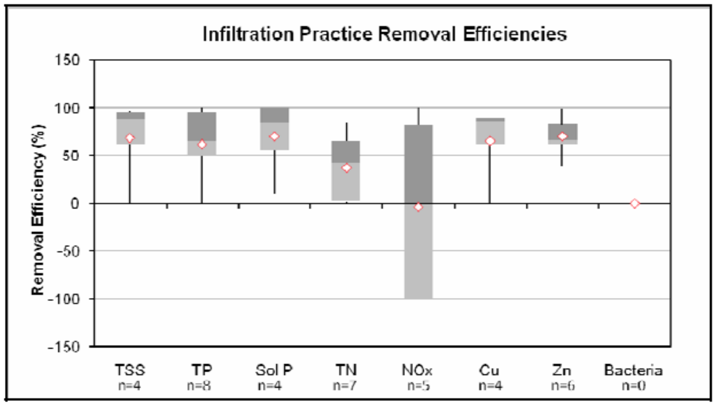


Figure 6. Infiltration Practice Removal Efficiencies

Table 6. Infiltration Practice Removal Efficiency Statistics								
	TSS	**TP**	**Sol P**	**TN**	**NO_x**	**Cu**	**Zn**	**Bacteria**
Median	89	65	85	42	0	86	66	N/A
Min	0	0	10	0	-100	0	39	N/A
Max	97	100	100	85	100	89	99	N/A
Q1	62	50	55	2	-100	62	63	N/A
Q3	96	96	100	65	82	89	83	N/A
Number	4	8	4	7	5	4	6	0

Figure 2.7: Effectiveness of infiltration trenches in removal of contaminants (Center for Watershed Protection, 2007).

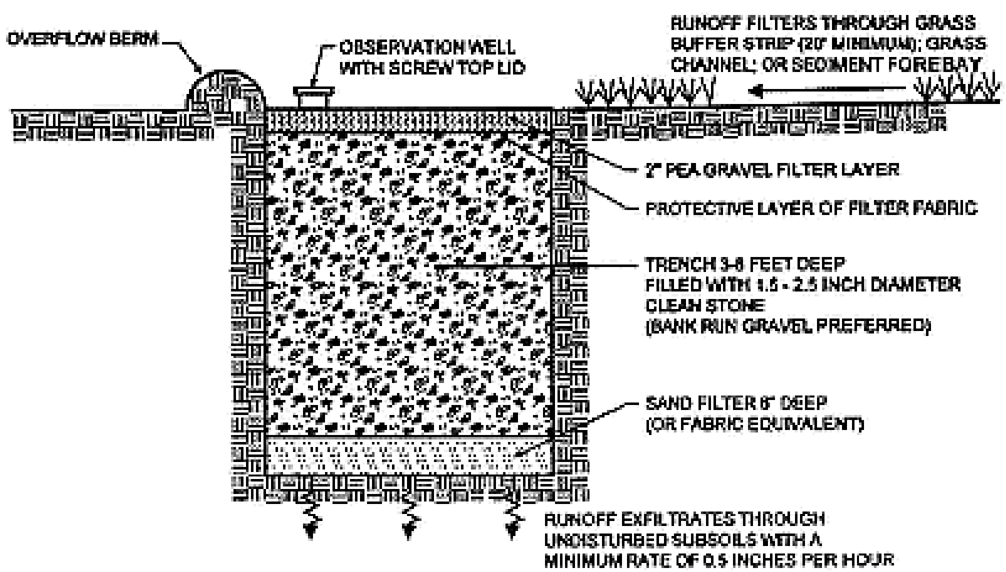


Figure 2.8: A typical construction of an infiltration trench (U.S. Environmental Protection Agency, 2014).

Filter strips are planted or grass areas that allow water to sheet flow over and percolate through the soil as shown in Figure 2.9. In the process, the filter strips flow runoff, trap sediment and contaminants, and allow for infiltration as shown in Figure 2.10. Filter strips are able to be adapted for the specific needs and requirements of a site. They are visual barriers as well as open recreational areas. However, they are limited to the layout of the site. A hilly site will produce high-velocity runoff that filter strips may not be able to handle. Because they require a large amount of space for the water to travel over they may not be applicable in very tight spaces (Metropolitan Council Environmental Services, 2001).

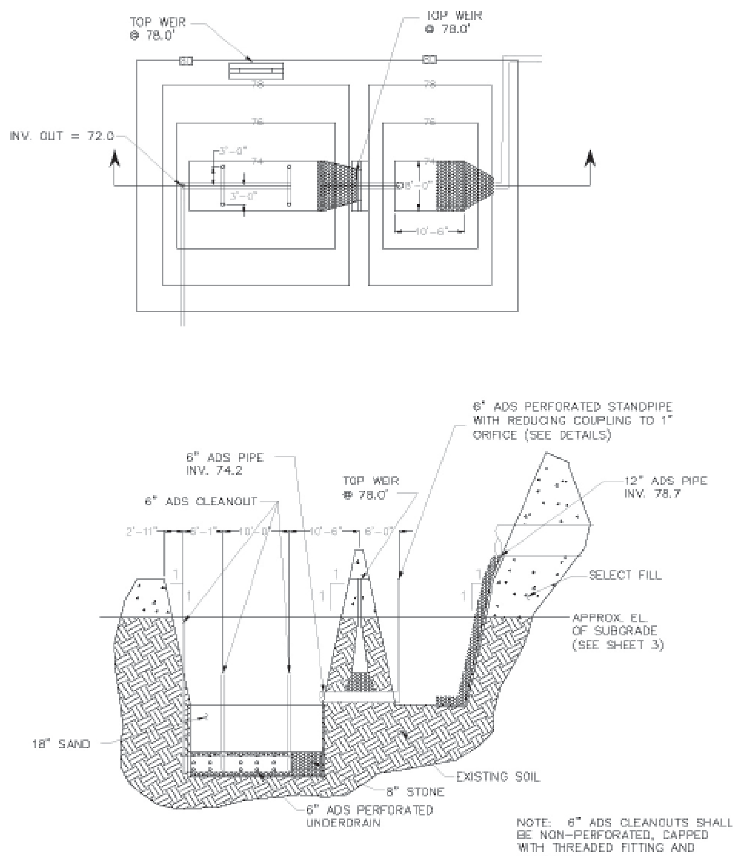


Figure 2.9: Details of sand filter construction (UNH, 2005).

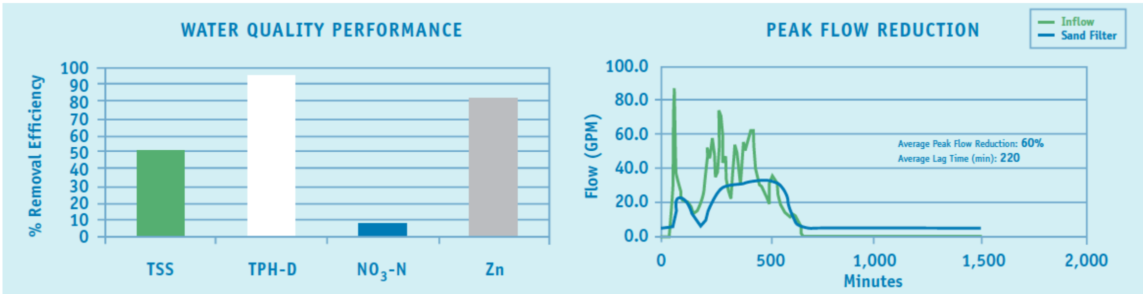


Figure 2.10: The effectiveness of sand filters as a water quality enhancement and peak flow reduction (UNH, 2005).

Cost Benefits of Green Infrastructure

In the spring of 2012 the American Society of Landscape Architects released a study addressing the cost of green infrastructure to communities. *Banking on Green* introduces the concepts of green infrastructure and the importance of incorporating these within communities to improve stormwater conditions (Odefey, 2012). The argument is made that these management strategies are financially beneficial in four critical aspects: lower construction and maintenance costs, energy efficiency, reduced economic impacts associated with flooding events, and reduction in illness-related costs.

Addressing these four areas, along with proper planning, can help reduce the overall money spent on maintenance and increase capacity of facilities. By doing this, the facilities that handle the discharge would have smaller and more manageable surges of stormwater. This would eliminate the need to build larger facilities and fund the continued maintenance associated with running those facilities.

The report collected over 450 case studies provided by professionals that addressed green infrastructure and the cost benefits associated with them. The reoccurring results within all of these case studies were reduction of costs related to construction and operation, land acquisitions, repair and maintenance, and infrastructure replacement. The incorporation of these costs compared with green infrastructure helps support the case for a change in existing trends and an emphasis on more environmentally sound alternatives.

The report concludes with three critical points: (1) green infrastructure construction can cost less than conventional methods, (2) continued costs of conventional infrastructure outweighs costs of green infrastructure, and (3) benefits of green infrastructure can extend beyond stormwater for total project cost-effectiveness. These savings have occurred in the majority of projects collected and can potentially show the elimination or strong reduction of costly traditional infrastructure approaches. The approaches offered through green infrastructure allow for natural systems to occur and manage stormwater.

These same results are found in New York City's green infrastructure plan released in 2009. New York City Mayor Michael Bloomberg and Commissioner Cas Holloway released a report that discusses the city's plan to improve water quality through green infrastructure improvements over a 20-year span at a cost of $1.5 billion. The Department of Environmental Protection conducted modeling to show how these green infrastructure elements could reduce combined sewer overflows and reduce the water treatment costs to the city. The plan is to create areas where water can infiltrate or be held during storm events to reduce surges into water treatment facilities. The models indicate that with a sound green infrastructure for the city that approximately 12.1 billion gallons a year will be removed from the current system. These reductions reduce wear and tear as well as size demands on the current infrastructure (Bloomberg & Holloway).

Sustainable Sites Initiative

In 2005, the Lady Bird Johnson Center and the American Society of Landscape Architects held the first Sustainable Sites Summit in Austin, Texas. This meeting laid the groundwork for what would become the Sustainable Sites Initiative (SITES), the landscape version of the U.S. Green Building LEED Certification program. In 2006, SITES and LEED joined forces to address development practices for buildings as well as landscapes (American Society of Landscape Architects, 2009).

The goal of SITES is to create and promote sustainable land development and management practices. To achieve this goal, SITES created a handbook for built environment projects that provide a point system for degrees of sustainable applications. This took can be utilized to combat growing global issues associated with climate change, ecosystem degradation, and resource depletion. The desired users are planners, landscape architects, engineers, developers, builders, maintenance crews, horticulturalists, governments, land stewards, and organizations that oversee building standards.

The guidelines addressed site selection, pre-design assessment and planning, water, soil and vegetation, materials selection, human health and wellbeing, construction, operations and maintenance, monitoring, and innovation. There are benchmarks outlined under prerequisites and under credits for each section. Prerequisites must be met in order to receive any points for that section. Although the benchmarks are optional, a certain amount must be met in order to receive points.

The 2009 rating system is the pilot phase for SITES and is currently reviewing and evaluating projects submitted for SITES status. The rating system ranged from one star to four stars with the latter being most accomplished. To achieve these ratings, a project must receive between 100 and 200 points out of a possible 250.

With an understanding of watersheds and how the hydrologic cycle and soils impact the flow of water it is important to apply the recommended low impact and green infrastructure practices provided from the Environmental Protect Agency. Based on the research and recommendations of BMPs, for sites with gradual, small slopes and larger surface area, bioretention basins and filter strips are recommended to address the total amount of soils and contaminants that enter the system. These applications are proven, cost-effect solutions for municipalities. The American Society of Landscape Architects through SITES is currently evaluating projects that utilize BMPs and the University of Massachusetts gateway entrance could be submitted as a pilot study.

Case Studies

Chagrin River Watershed, Ohio

The Chagrin River Watershed in Ohio was the location for a development project of 87 acres completed by a landscape architecture firm called Biohabitats. The site had been used as a landscape nursery with compacted soils, gravel, and a large amount of impervious cover. To the southwest of the property is a large wooded lot with steep slopes. The Eastern Stream creates the property edge on the northern, eastern and southern edges. There are two smaller streams that flow across the site from east to west as well as the Northern Stream, which is intermittent, and the entire drainage area is held within the property. The Northern and Southern Streams are in good condition; however, the riparian vegetation is fragmented and often minimal. They are both entrenched and disconnected from their floodplains (Chagrin River Watershed Partners, Inc., 2009).

The design had 29 residential lots with a minimum size of 1.5 acres, road right-of-way of sixty feet, a minimum building footprint of 1,000 square feet, and at least 40% open space as shown in the site plan Figure 2.11. To meet these requirements, the principles of open space design were utilized. Lots were clustered and a variety of open space was preserved surrounding them. Stormwater was a critical component and the site design included treatment of water quality and volume control. They system was designed to control a 24-hour storm, which would be expected about once a year (Chagrin River Watershed Partners, Inc., 2009).

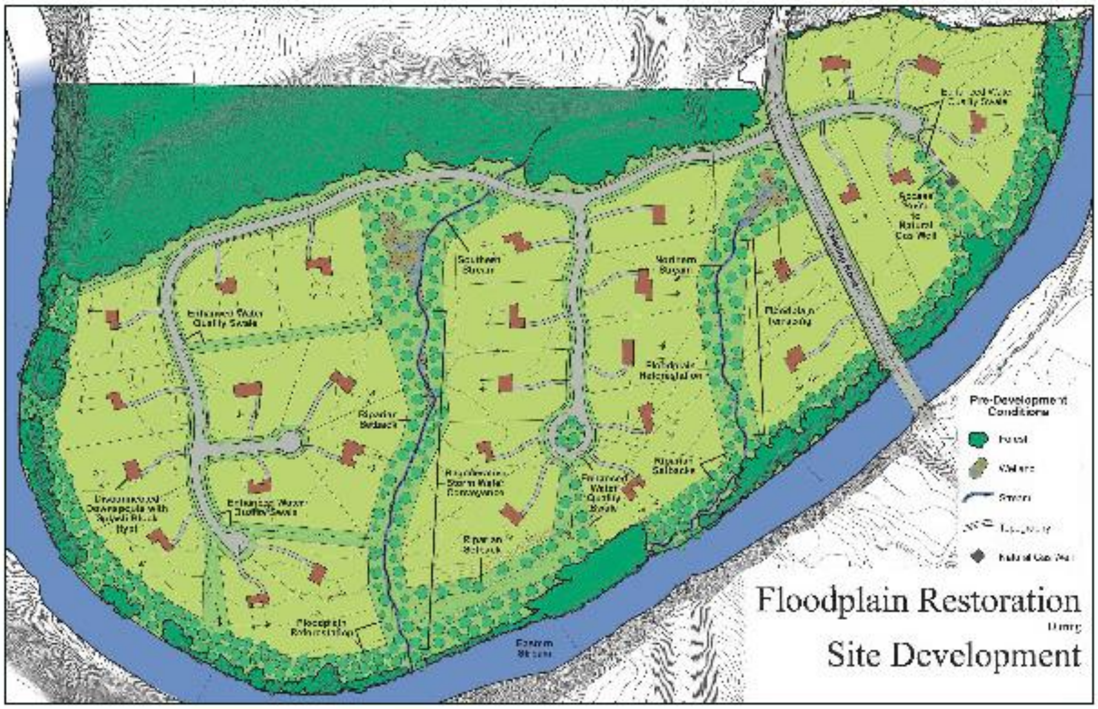


Figure 2.11: Biohabitats site plan for the Chagrin River Watershed and enhancement of the wetlands (Chagrin River Watershed Partners, Inc., 2009).

The primary method of controlling stormwater was through the floodplains along the streams. The stream banks were reforested with trees and other plants as shown in Figure 2.12. These plants provide stormwater quality treatments of runoff sheet flow. Additionally, several swales were included along roads and through the open spaces to enhance water quality throughout the entire project. The Northern and Southern Streams were reconnected with their floodplain and, through terracing, the floodplain was enhanced to protect against flooding (Chagrin River Watershed Partners, Inc., 2009).

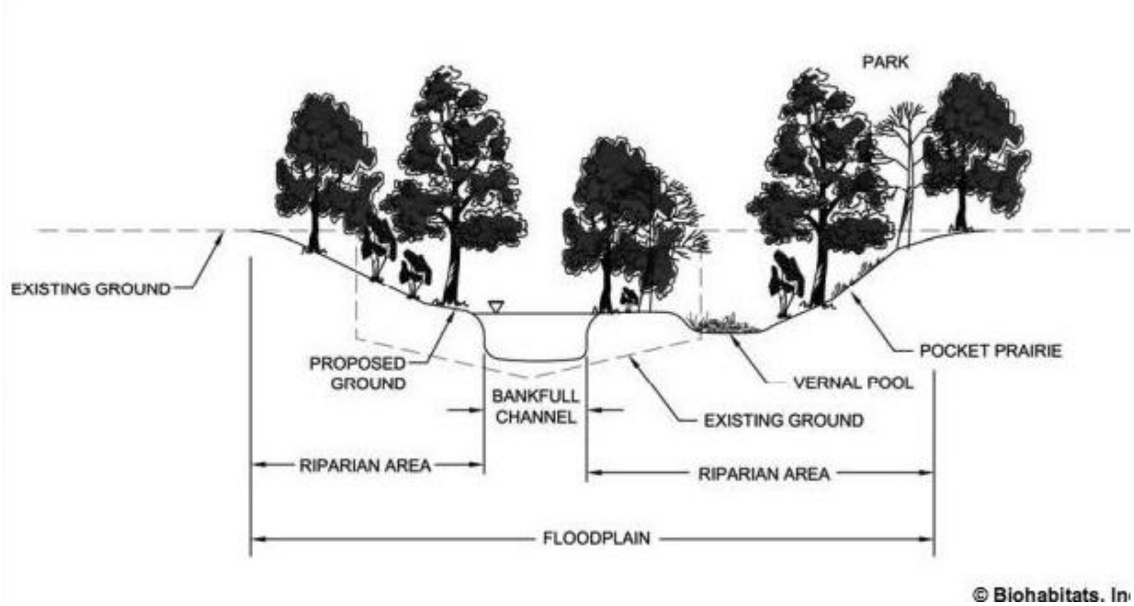


Figure 2.12: Biohabitats design of the Northern Stream riparian corridor (Chagrin River Watershed Partners, Inc., 2009).

IFAW World Headquarters, Yarmouth Port, Massachusetts

The World Headquarters for the International Fund for Animal Welfare (IFAW) is located in Yarmouth Port, MA. The landscape architect and architect team that developed the building and site plans for the project had to adhere to the mission of IFAW, which is to provide a cohesive habitat for animals and people. To do this, the development project had to utilize sustainable practices on both the building and landscape as shown in Figure 2.13 (Bioengineering Group, 2013).

The project was located on a brownfield adjacent to Cape Cod so managing water was critical. To do this, soil was amended and retained on site to help create bioswales, rain gardens, bio-infiltration basins, and wet meadows as shown in Figure 2.14. The implementation of these elements allowed conventional water infrastructure to be reduced significantly and allowed the overall five-acre site design to create 75% open space. Within this open space a variety of wildlife habitat, biodiversity, and native plantings were included to attempt to restore the ecosystem as much as possible. The final project incorporated a pedestrian bridge to allow interaction with the wetlands as shown in Figure 2.15. Once completed, the project achieved LEED Gold status (American Society of Landscape Architects, 2013).

Figure 2.13: Stimson Associates' Low Impact Development project plan, diagram, and sections show swale design and locations (AIA, 2013).

Figure 2.14: Stimson Associates' Low Impact Development project plan, diagram, and sections show swale design and locations (AIA, 2013).

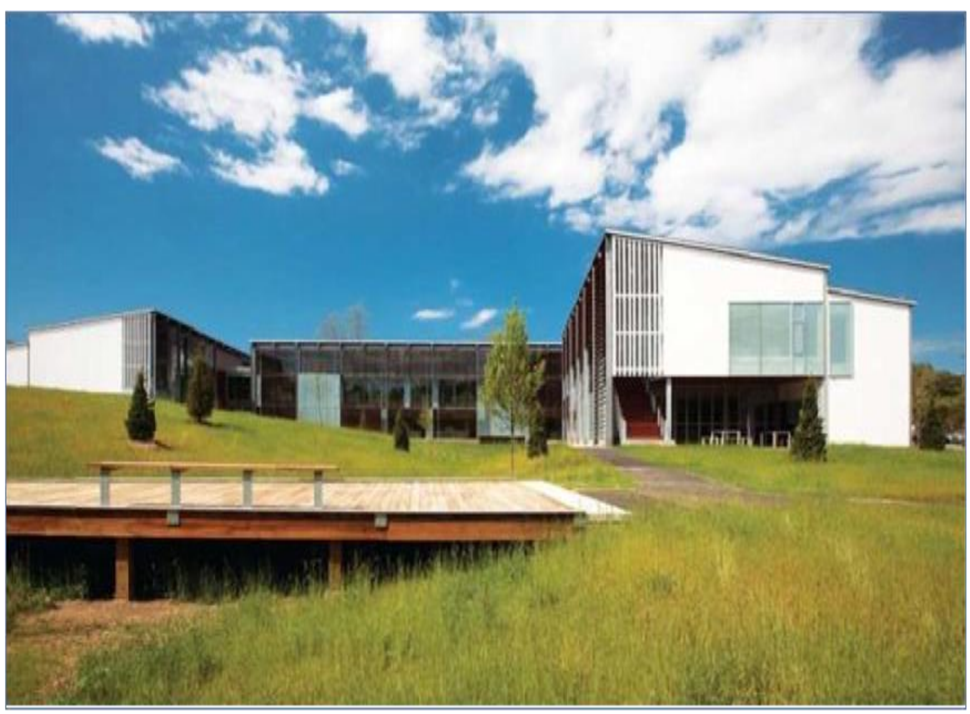


Figure 2.15: A pedestrian bridge over a vegetated swale within the naturalistic landscape surrounding the IFAW National Headquarters (Vanderwarker, P, 2008).

Bishan Park, Singapore, Kallang River

Bishan Park by Atelier Dreiseitl was completed in 2012 as a much-needed upgrade to help improve the capacity of the Kallang channel. The previous channel had been a utilitarian concrete channel that inhibited infiltration and increased water velocity. The design solution was to transform the concrete channel into a naturalized river utilizing the BMP vegetated swale. The project is part of Singapore's Active, Beautiful, Clean Waters (ABC Waters) program to create long-term solutions to transform the country's water bodies into successfully functioning drainage and water supplies while also incorporating community engagement (Atelier Dreiseitl, 2015).

The project encompassed 155 acres and removed a concrete channel that was over 1.5 miles long. In its place was created a naturalized river that is almost two miles long and meanders throughout the park. The design incorporated a dynamic hydrologic approach that allowed the river system to have fluctuating water levels that protect certain areas of the park for community use including playgrounds, restaurants and overlooks (Atelier Dreiseitl, 2015).

Figure 2.16: Before photo (left) of the utilitarian concrete channel in contrast with an after photo (right) of the naturalized stream with lush vegetation and resources for community engagement (Atelier Dreiseitl, 2015).

Figure 2.17: The photo on the left shows slope stabilizers with riprap stone, vegetation and gabion baskets. The photo on the right shows a pedestrian bridge that allows greater circulation while provided lookouts of the ecological processes below (Atelier Dreiseitl, 2015).

Penn State University - Centre County Visitor Center, State College, PA

In 1999 the Penn State University/Centre County Visitor Center in State College was constructed with a variety of stormwater infiltration techniques. The design sought to mimic the natural hydrologic systems that had been occurring on the site prior to the development of the center. These applications included porous asphalt parking lots, porous concrete sidewalks, infiltration trenches, vegetated infiltration beds, and several bioretention areas.

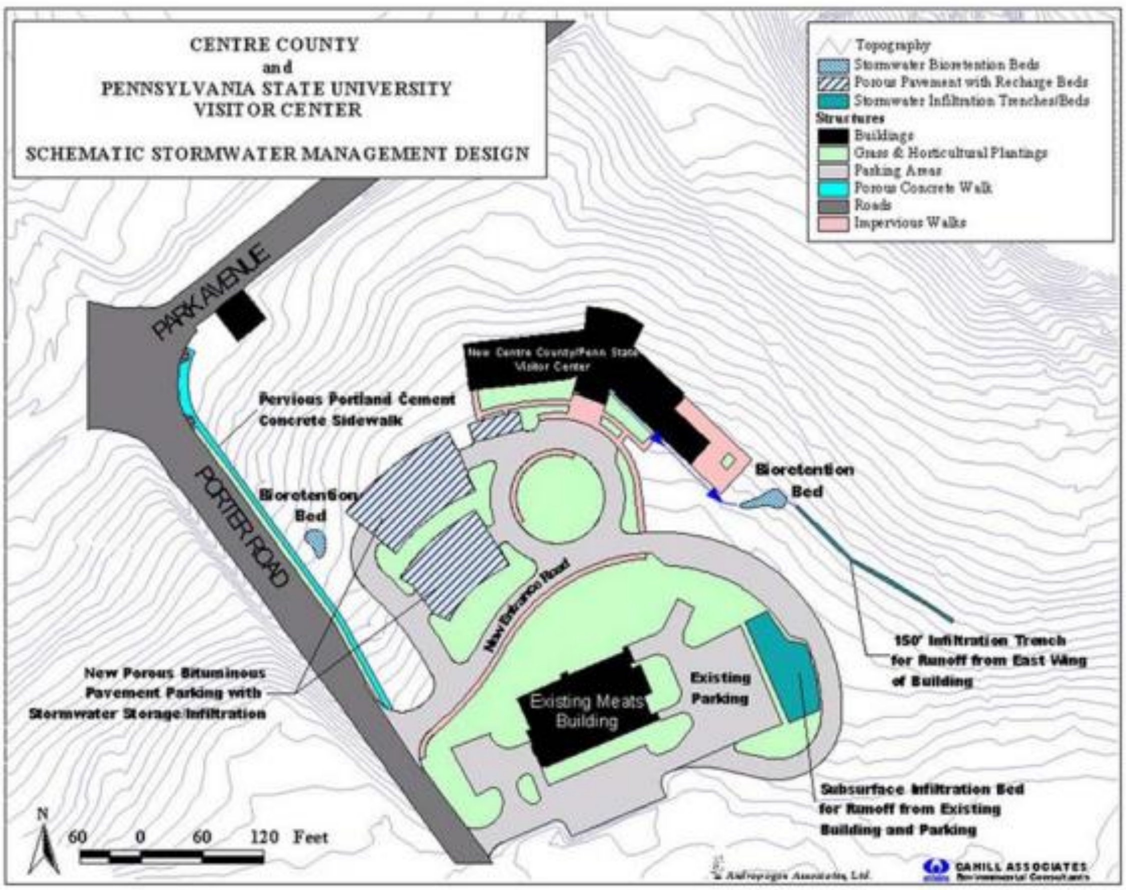


Figure 2.18: Centre Visitor Center and the layout and location of the various stormwater management applications (Department of Environmental Protection, 2006).

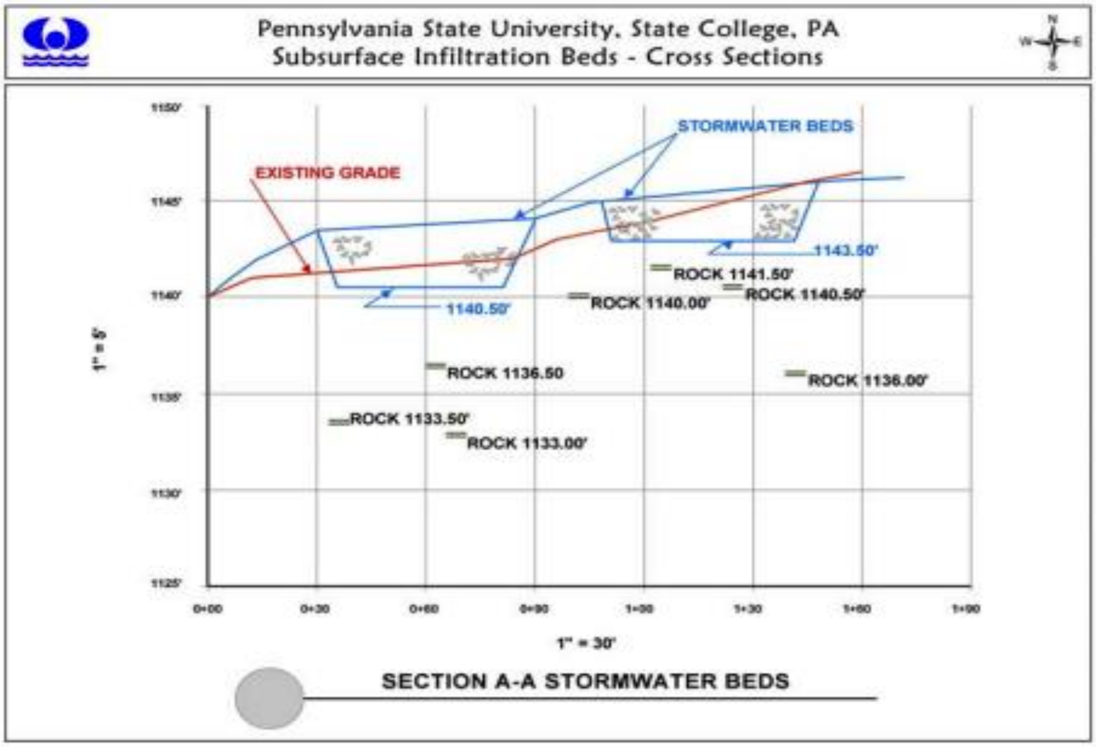


Figure 2.19: Centre Visitor Center's tiered stormwater bed system that allows one bed to fill up before water enters the next bed (Department of Environmental Protection, 2006).

These stormwater beds were "fit" into the site within the parking bays and were required to step down in elevation allowing the water to be stored and held along the slope of the site.

Figure 2.20: The Centre Visitor Center vegetated bioretention area (Department of Environmental Protection, 2006).

Several constraints were stated within the project including shallow soils in areas with bedrock throughout the site. This required a lot of the site to be built up over the bedrock and resulted in elevated parking lots that needed step down stormwater beds.

The final design maintained the pre-development balance for loading rate. The project photos show plants are thriving but appear to be not aesthetically pleasing or appropriate in an area that will be highly visible and serve as a showpiece for a college campus.

Flying J. Truck Plaza - Middlesex Township, Pennsylvania

The Flying J Truck Plaza was a development project proposed in 1993 that incorporated subsurface infiltration beds, perimeter trench drain, wetlands, vegetated infiltration filters and curb cuts with filter strips. The town has a municipal open space mandate that this project must meet. The mandate requires an amount of volume that conventional stormwater systems cannot achieve.

Because the site can see as many as 1,5000 heavy trucks per day, it was essential to design a system that could handle the potential water quality issues associated with that volume of pollutants. A two-stage pretreatment system was incorporated that allows a sediment settling and vegetated filtration for first flush pollutants from runoff.

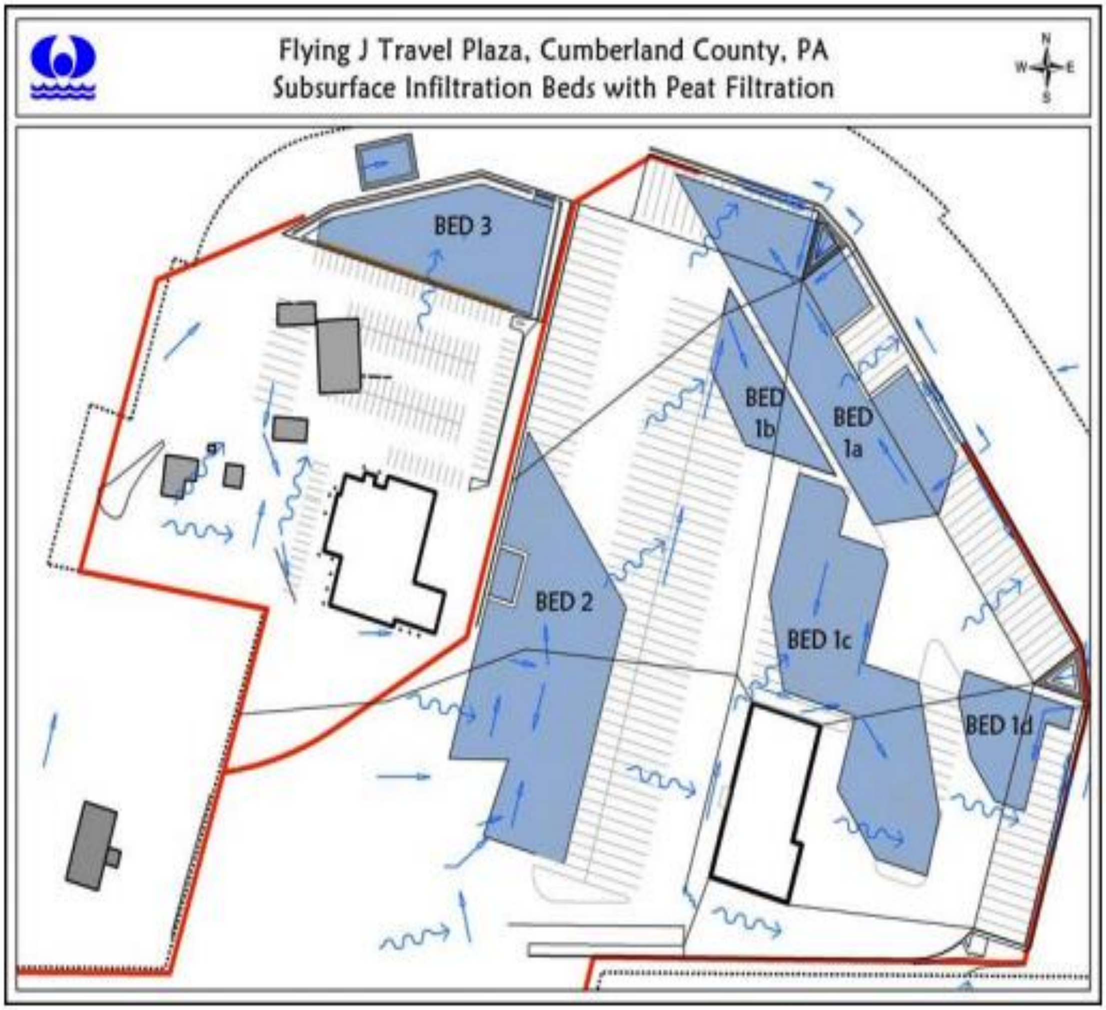


Figure 2.21: The Flying J Travel Plaza plan shows how the drainage for a large impervious surface is directed to a variety of BMPs for treatment (Department of Environmental Protection, 2006).

Figure 2.22: This photo shows the initial settling drain and vegetated filter strip used to treat the first flush during storm events (Department of Environmental Protection, 2006).

The photos show a large amount of concrete infrastructure within the treatment of the first flush settling drains. This type of construction is needed for this project due to the large quantity of trucks utilizing the space. The potential for spills and contaminates from those vehicles necessitate this infrastructure. Reviewing the details for these elements show sand filters incorporated into the structures. Water enters a concrete chamber with a sand filter and the water settles to the bottom and exits through a pipe at the bottom of the structure, which has an access point at the top that allows for maintenance and cleanout when the system becomes clogged.

Figure 2.23: Water enters through an inflow pipe, settles through the sand, and exits the structure through a pipe at the bottom (Department of Environmental Protection, 2006).

The perimeter channel, which allows water to enter through curb cuts and treats the first flush, is a concrete channel that allows water to exit into a concrete conveyance channel. This structure then allows water to drain into peat infiltration bed where a peat mix and plants are able to treat any remaining contaminants within the stormwater.

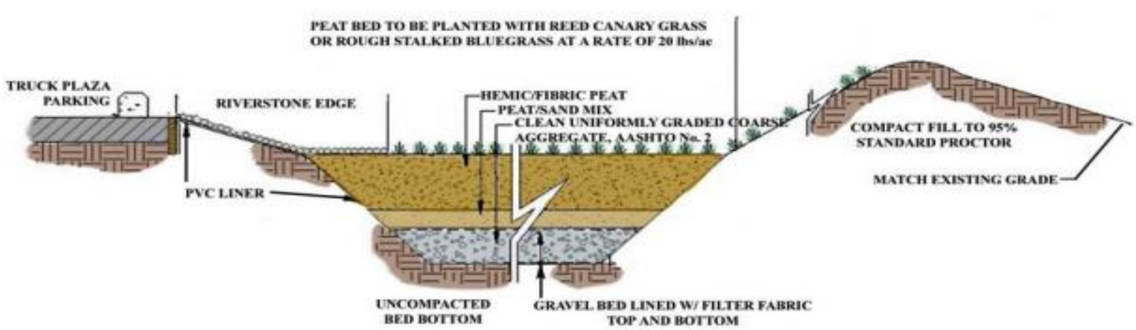


Figure 2.24: Water is able to enter and drain through the peat mix and plants to allow a final level of treatment before infiltration into the ground water in a peat infiltration system (Department of Environmental Protection, 2006).

Figure 2.25: In a vegetated infiltration bed, little maintenance is required for the area and a more naturalistic look is achieved with no visible water (Department of Environmental Protection, 2006).

Case Study Conclusion

These case studies illustrate how various approaches to stormwater management have been applied for decades and can provide ecological, social, and economic benefits. The largest argument against these approaches is typically that they are not aesthetically pleasing and can have higher maintenance requirements. However, as these projects demonstrate, they can be accomplished in a way that reduces very costly concrete and piped infrastructure and include aesthetically pleasing grasses, perennials, shrubs and trees. With the reduced costs of installation compared to conventional methods the additional funding could go towards long term maintenance. This could be the solution for the argument against increased maintenance costs for these approaches.

Critical components from these case studies could be incorporated within the final design include sediment bays and filter strips along the areas where water first enters the system. This will allow the majority of TSS to be removed and reduce the chances of the system becoming clogged and failing. Additionally, vegetating swales are utilized throughout all of the applications and appear to be one of the most successful treatments for stormwater management and erosion stabilization as implemented in Bisham Park and IFAW Headquarters. Both of these projects approached slope stabilization by mimicking a natural riparian zone. The Penn State Visitors Center and Flying J Travel Center both implemented BMPs in areas where the site's had major space restrictions. These design approaches were vastly different. The implementation at Flying J included a significant amount of concrete infrastructure that requires regular clean out and maintenance. Penn State used a terrace system that allows the natural treatment of water without extensive concrete infrastructure. The combination of these two elements may be required within the final design implementation and it is important to keep in mind the ability for maintenance crews to properly keep up with requirements of a design solution.

INVENTORY AND ANALYSIS

The methods utilized for this master's project are based on Thomas Russ' *Site Planning and Design Handbook*. This approach was selected because of the direct focus on landscape restoration, stormwater strategies, and impact minimization.

1. Regional Analysis

This entails understanding the current population, and potential population growth anticipated global climate change, land use, materials, and how these aspects relate to the particular site.

2. Site Inventory and Analysis

This process requires gathering site data including topography, plant hardiness, FEMA map information, vegetation, current aerial, historical information, soil information, hydrology, and existing infrastructure. This information can be assessed for issues and opportunities that will set the groundwork for design.

3. Site Design

The design will require engaging pedestrians, vehicles, and hydrology through the site. This process entails creating design concepts and a preferred design.

Each of these steps will require multiple iterations due to the fact the design process are not linear. Within this process, meetings were conducted the University of Massachusetts Planning Department to assess the progress and potential for installation of this project.

Regional Analysis

According to data from the U.S. Census, the town of Amherst, MA had a population of 37,819 in 2010. This was an 8.4% increase since 2000. The population growth in Amherst from 1950 to 2010 shows an increase of almost 10 times as shown in Figure 3.1. In 2010, the Amherst Planning Board adopted a new Master Plan that had been in the works for four years. The prior version of the master plan was dated 1969 when the town had a population of roughly 4,000 people. A new master plan was needed to ensure that future development is done with a logical framework to ensure economic and environmental improvements for the town. The plan is considered a "blueprint" for the town's future and provides a broad set of policy for decision making for future growth and development.

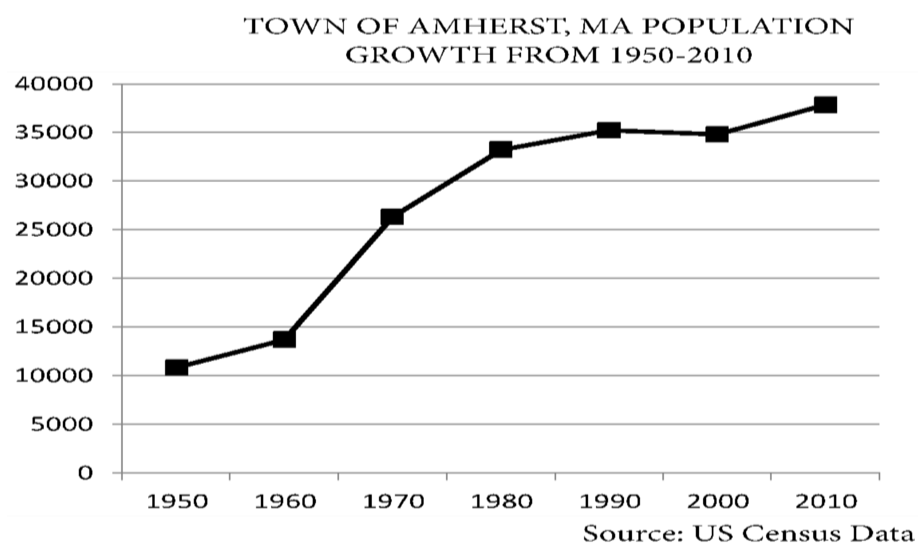


Figure 3.1: Town of Amherst, MA population growth from 1950-2010 (U.S. Census Data.

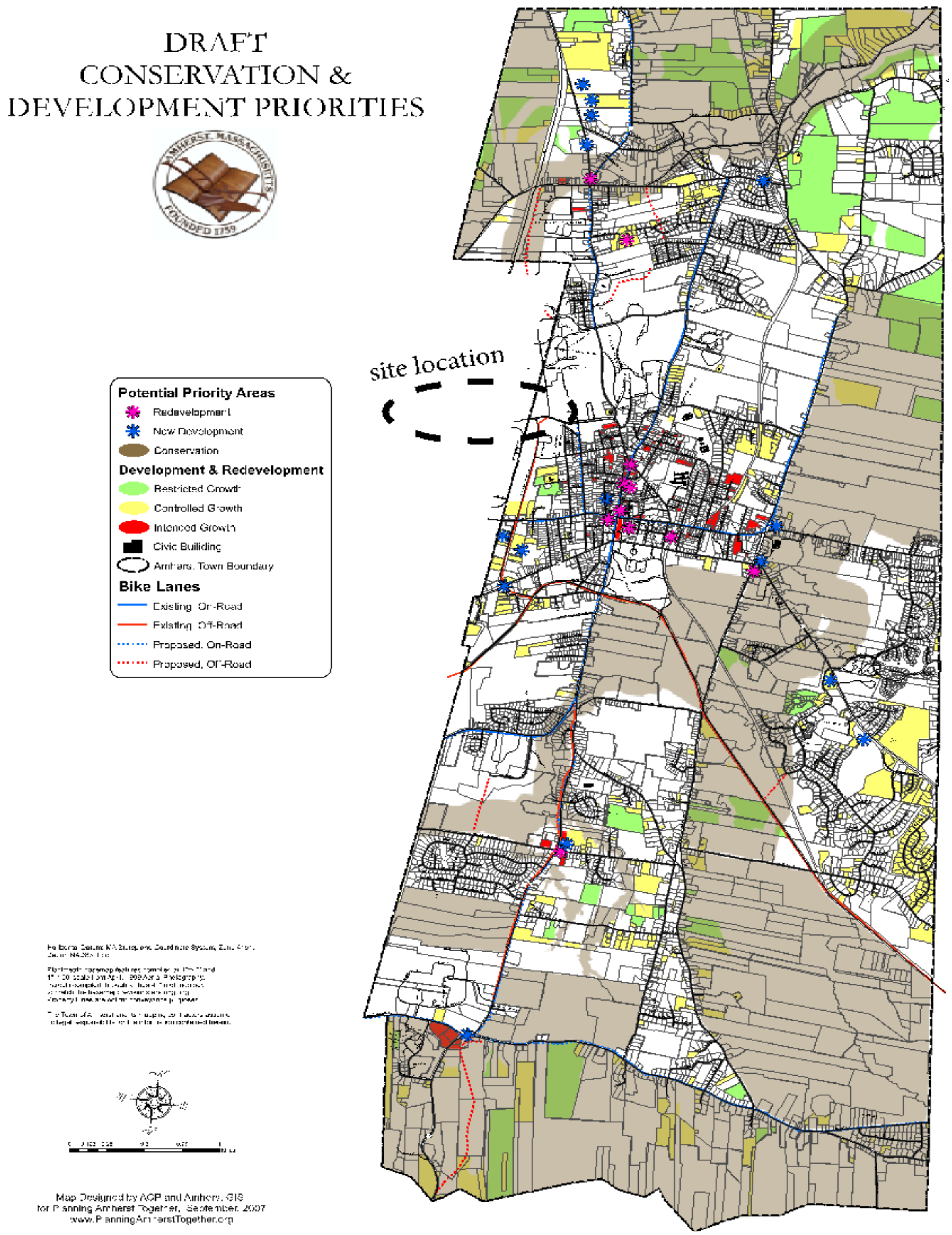


Figure 3.2: Town of Amherst, MA planning department draft of Conservation & Development Priorities in relation to the master's project design site (Amherst GIS, 2013).

Utilizing the information provided from the Amherst Planning Board, it is possible to understand where development is occurring and where it may increase. Based on the Conservation and Development Priorities Draft as shown in Figure 3.2, there is significant acreage of conservation lands through the town. This map also indicates that the majority of the intended growth is within the downtown area. This is a smart growth principal that increases centralized density while preserving farmlands. However, this increased development often means increased impervious surfaces and higher stormwater runoff. On positive side, the town has recognized this and in the Master Plan addresses it by requiring the additional housing and development to minimize impacts on the environment. One method is to increase upper floors for residential areas, which helps reduce the impervious infrastructure associated with added structures.

Even with a smart approach there will most likely be increased impervious surfaces that will impact stormwater. This increase in stormwater runoff is most impactful for downstream sites where the increased stormwater can have a major effective in erosion and sediment deposit.

The Tan Brook Watershed that handles the majority of downtown Amherst will bear the brunt of increased stormwater. The site this project focuses on is within the Tan Brook watershed and downstream from downtown Amherst. As the Tan Brook Watershed map (Figure 3.3) illustrates, there is both an open stream and piped portions within the watershed. The piped portions of the stream inhibit infiltration and channelize the water into a higher velocity and quantity when reaching the UMass campus.

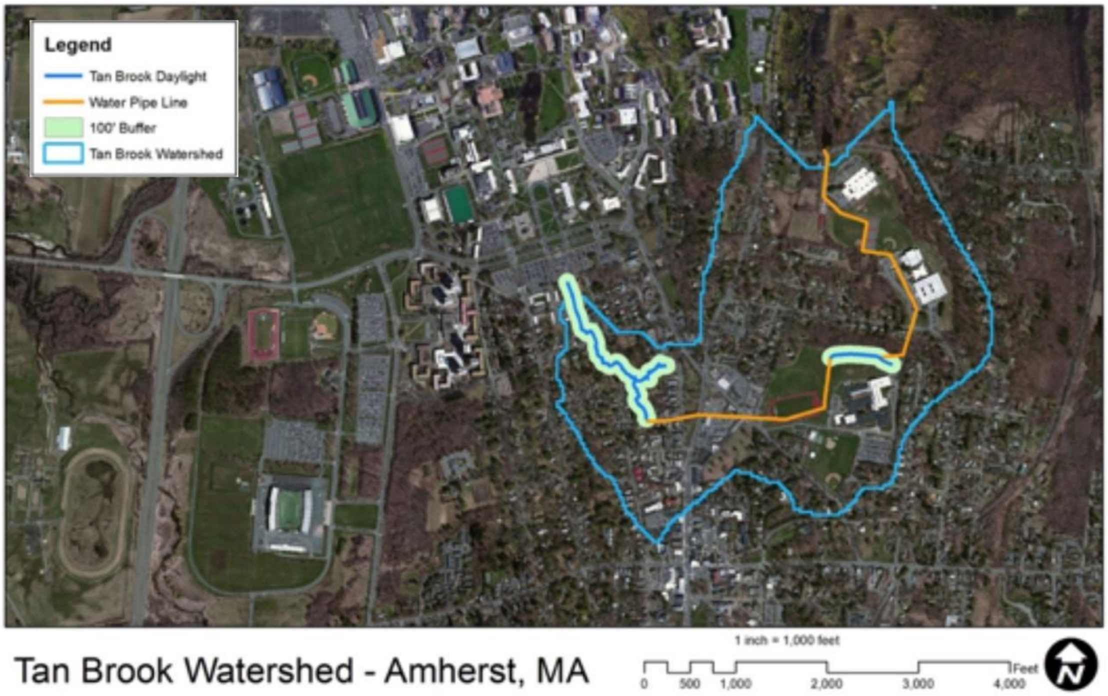


Figure 3.3: A map of the Tan Brook watershed indicating areas that are open stream and areas that are piped sections (Data Source: Mass GIS) (Amherst GIS, 2013).

Understanding the characteristics of the brook outside of the study area is important. However, the solutions sought in this project are to mitigate the impacts within the designated area of UMass Amherst campus. It is important to understand the UMass Amherst plans for the campus and how any changes to this area would impact those plans. For this step the UMass master plan was reviewed with the Planning Department.

Figure 3.4: UMass Amherst Campus Master Plan Draft in 2011 indicates the long-term goals for the campus development (UMass Amherst Campus Planning Division, 2011).

Based on the campus master plan as shown in Figure 3.4, there are two roundabouts planned for areas directly adjacent to the project site. This will impact the site by making it more direct views into the site while vehicles are traveling through the roundabouts. Aside from the roundabouts and the addition of street trees in this area it does not appear that there are any long-term plans for addressing issues in this part of campus.

Understanding of how the regional development and campus development may change over the coming years will serve as a foundation to help better design the area to meet these goals. In order to create a design for the area it is important to do a site inventory and analysis on the existing conditions within the project site (UMass Amherst Campus Planning Division, 2011).

Site Analysis and Inventory

The first step in the site analysis and inventory process was to conduct a site visit and document the existing conditions. This site visit was conducted during a heavy rain event that provided the opportunity to analyze how both the site and maintenance crews handled these storms.

The first location visited was the UMass Visitor's Center parking lot where the Tan Brook first enters the UMass campus. While visiting this area the campus maintenance crew's were working to remove branches and sediment that was inhibiting flow into the pipe as shown in Figure 3.5. When approached, the crews indicated that this is a common issue with heavy storm events.

Figure 3.5: UMass Physical Plant teams work to clean out debris and sediment blocking the inlet drain at the Visitor's Center parking lot (photo credit: Nathan Frazee).

The second location was the outlet pipe within the project site. There was a second maintenance crew in this location that was working to dislodge additional sediment and branches that had migrated past the first location as shown in Figure 3.6. The crews indicated the importance of removing this sediment to ensure the overflow system is utilized and that the amount of water entering the campus pond does not exceed the holding capacity.

Figure 3.6: A second UMass Physical Plant team works to clean out debris and sediment blocking the outlet pipe at the west gate entrance to campus (photo credit: Nathan Frazee).

The entire site was assessed and documented during this visit. The orange snow fencing placed to keep people away from the potential hazard was observed to be falling down due to high volumes of water and debris as shown in Figure 3.7. Once outside of the eroded area at the outlet pipe the water became channelized and flowed in a stream the entire length of the site.

Figure 3.7: View looking east of a flowing stream and orange snow fence collapsing around the outlet pipe (photo credit: Nathan Frazee).

Along the middle of the site, there is a slight elevation change between sports fields to the north and a road to the south as shown in Figure 3.8. Within this slight elevation change, the water was flowing constantly, which makes crossing the site dangerous. This area would most likely stay highly saturated creating adverse conditions on the field.

Figure 3.8: View looking north of a flowing stream through the site during a heavy rain event (photo credit: Nathan Frazee).

At the western end of the site a similar eroded area was observed with additional orange snow fencing collapsing as shown in Figure 3.9. In this area there was also previous snow fencing observed within the overgrowth that had been damaged during a previous storm. These conditions, along with rill and gully erosion cracks observed, indicate that erosion problems have been reoccurring and that no successful, permanent solution has been implemented.

Figure 3.9: View looking east as the flowing stream enters the eroded edge of the site. Gully and rill cracks were observed indicating additional erosion would take place (photo credit: Nathan Frazee).

The next phase of the inventory and analysis process was to collect information about vehicular and pedestrian circulation, any climate conditions that impact the site, and natural features of the site including hydrology, slopes, vegetation and soils. The approach to collecting this information included using observations recorded during the site visit as well as creating a geographical information system map with data files provided by the UMass Planning Department.

Circulation

The three modes of circulation on campus are by vehicles, pedestrians, and bicycles as shown in Figure 3.10. Within this site, there is no infrastructure for pedestrian access. There are crosswalks and sidewalks on the opposite side of the busy North Hadley Road, which becomes Massachusetts Ave at the intersection adjacent to the project site. Bicyclists could potentially share this road but there currently are no markers or painted lanes indicating their use.

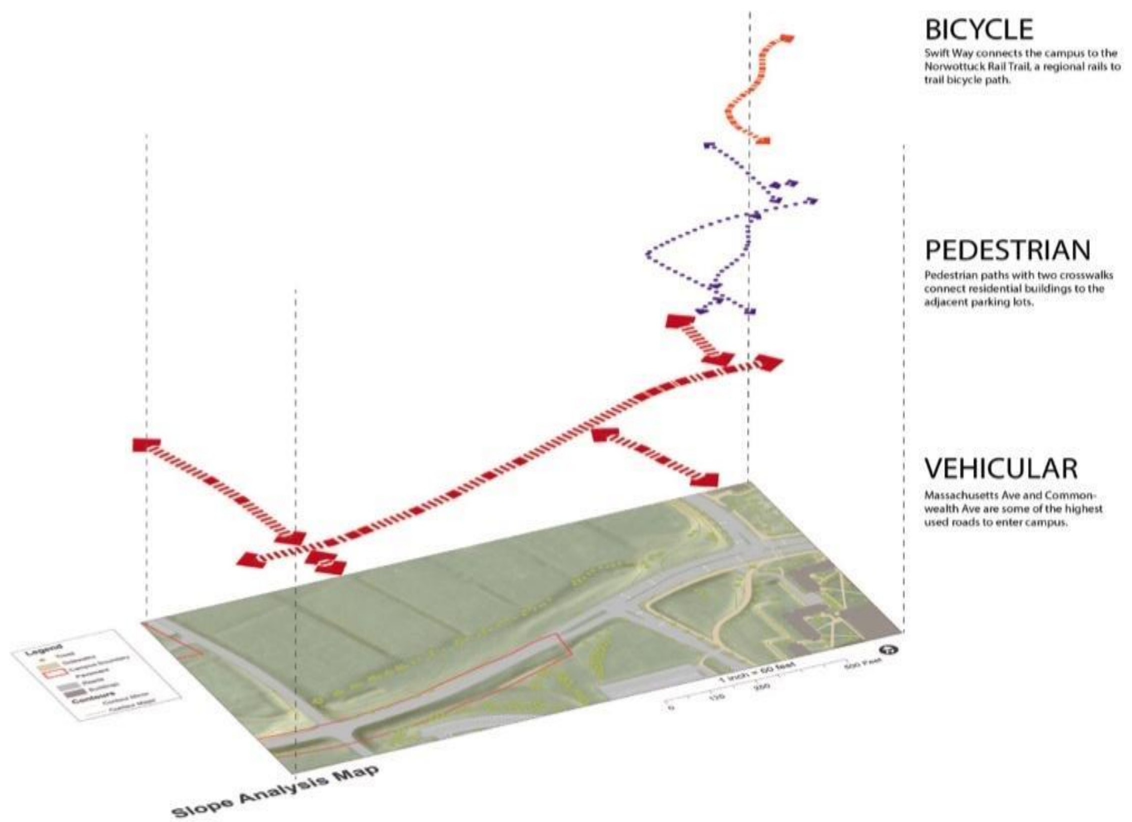


Figure 3.10: Site inventory showing bicycle, pedestrian and vehicular circulation.

The majority of bicycle traffic occurs on the Swift Connector Path that runs parallel to North University Drive and connects to the very popular regional Mass Central

Rail Trail – Norwottuck Branch as shown in Figure 3.11, which goes from Northampton to Belchertown and serves students who travel from those areas from bicycles.

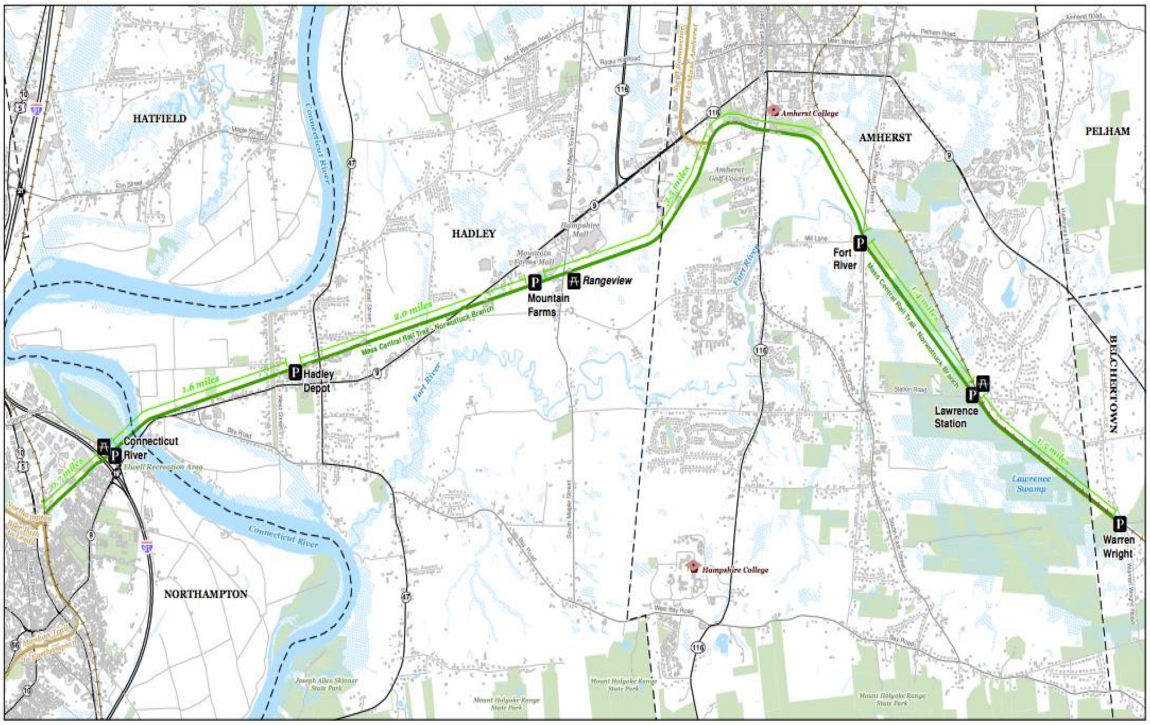


Figure 3.11: The Norwottuck Branch of the Mass Central Rail Trail which connects to the UMass campus (Department of Conservation and Recreation, 2015).

These circulation patterns appear to ignore the site's potential completely. Aside from, the site's parallel layout with the North Hadley/Massachusetts Avenue there is no indication that pedestrians or cyclists would engage the site other than going past it on the roads. This, however, is in contradiction of the fact that sporting events take place at these fields that serve the students of UMass as well as visitors during summer camps. Without proper sidewalks or paths, these user groups are forced to forge their own paths to the sporting fields, which could potentially be saturated and unsafe if water is present.

The 2011 UMass Campus Plan Draft indicates the future addition of two roundabouts adjacent to this site as shown in Figure 3.12. The red dashed lines indicate roads that are proposed to become complete streets with enhanced pedestrian, bicycle, and vehicular connections. The addition of these elements means increased visibility of campus across the site and the locations for visitors utilizing the parking across North Hadley Road that are attending sporting events at the site.

Figure 3.12: The Campus Master Plan shows the long term planning for additional roads and intersections (UMass Amherst Campus Planning Division, 2011).

The enhancement of Commonwealth Ave throughout campus from a four lane road to a 2 lane road with pedestrian, bicycle and vehicular circulation is indicated in the section and plan view proposed by Campus Planning in Figure 3.13. This change will help create a road that is properly scaled for the campus. The road entering site will two lanes and when getting closer to the core of campus will be a turning lane. Introducing roads that complement these changes around the site will help ensure the roads are used safely for pedestrians, bicyclists and motorists.

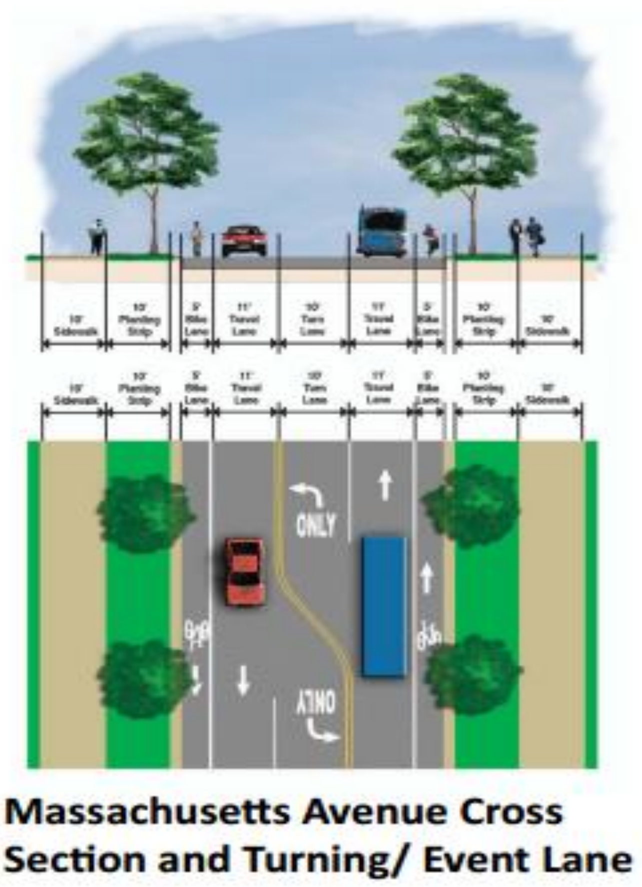


Figure 3.13: The Campus Master Plan shows new road layouts for Massachusetts Ave (UMass Amherst Campus Planning Division, 2011).

The potential for this site being a major gateway is further emphasized in the identification by Campus Planning as this being "The Gateway" in the master plan as shown in Figure 3.14. The enhancement of this area could provide a great site of campus to visitors entering from the west.

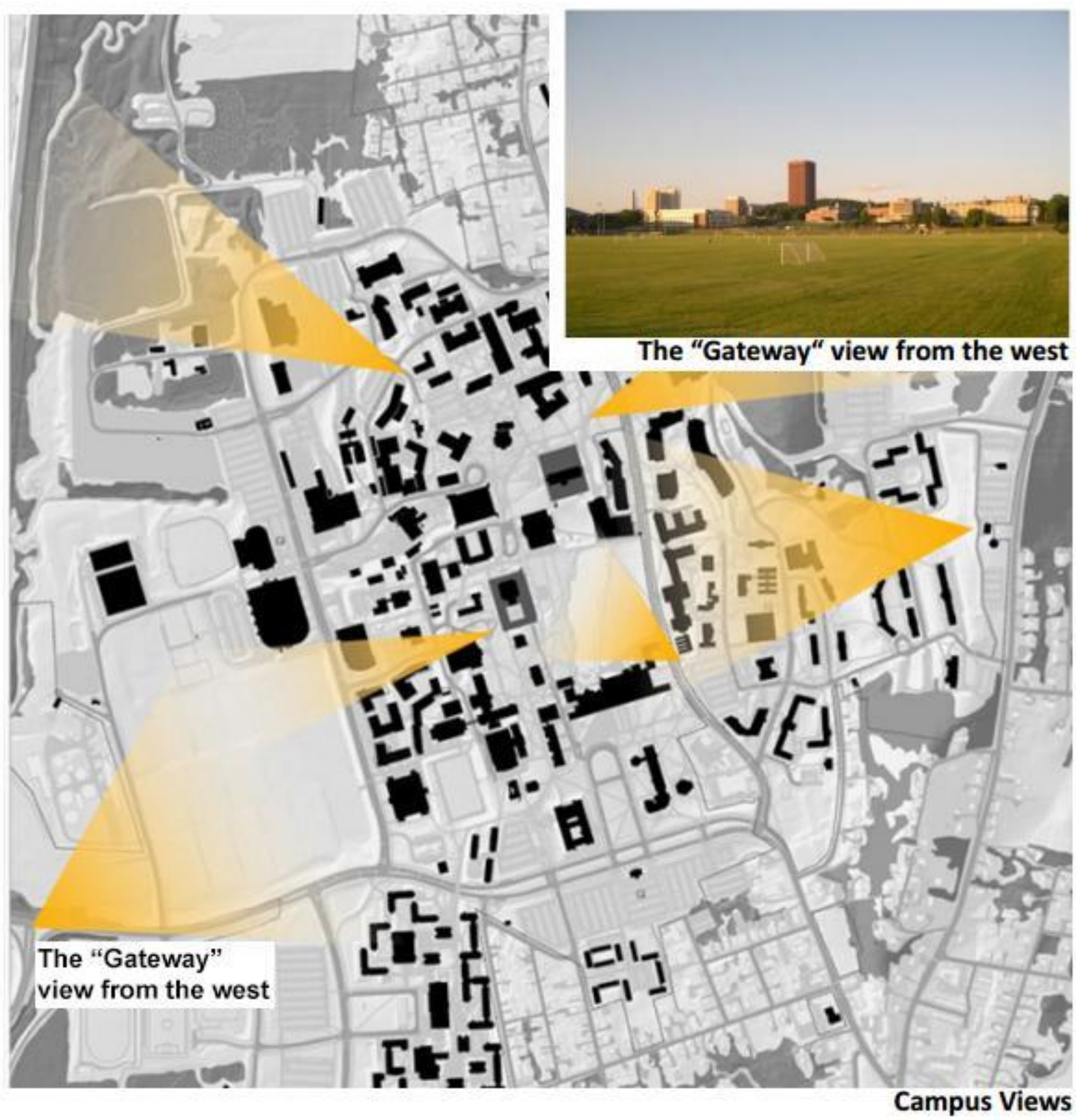


Figure 3.14: The Campus Master Plan shows the major views into campus and the west gateway view crosses over the study site (UMass Amherst Campus Planning Division, 2011).

Climate

Analyses for climate conditions include solar orientation, summer and winter wind patterns, and annual precipitation trends. The solar orientation shows the path of the sun over the site. During the winter months the sun is lower in the sky and in the summer the sun is higher in the sky with more direct light into the site.

The solar orientation and wind patterns were mapped for this site in Figure 3.15. This information will help to understand where potential shaded areas will be as well as any major season winds. Due to the trees being small ornamental trees and no large buildings near the site, shadows and wind tunnels are not a major issue for the potential design.

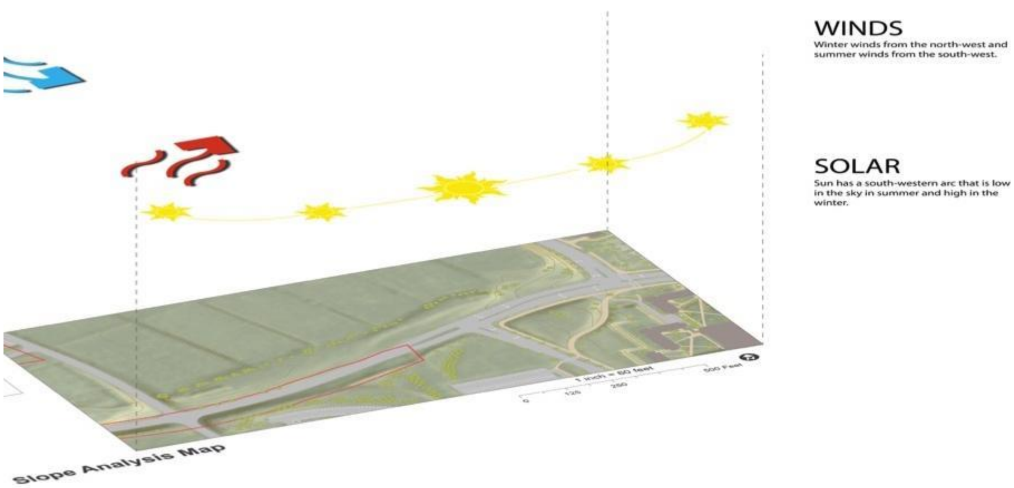


Figure 3.15: Site inventory showing winds and solar orientation.

The average temperature and precipitation plays an important role in understanding when the majority of the water will be flowing through this site and what the environmental conditions will be. For this the average high and low temperatures along with the average precipitations, in inches, were recorded. Figure 3.16 shows that the temperatures and average precipitation are lower from December to March. The growing season, where plants and microbes will be most active, has both a higher temperature and higher average precipitation. This plays well into the use of vegetated swales as it will allow the optimal plant and microbes use for treating the water entering the site.

Temperature - Precipitation C | F

	Jan	Feb	March	April	May	June
Average high in °F	33	36	46	58	70	78
Average low in °F	11	13	24	34	45	54
Av. precipitation - inch	3.78	2.83	3.58	3.82	4.09	3.82

	July	Aug	Sep	Oct	Nov	Dec
Average high in °F	83	81	73	62	49	38
Average low in °F	59	57	49	36	28	18
Av. precipitation - inch	3.94	4.09	4.06	3.98	3.94	3.62

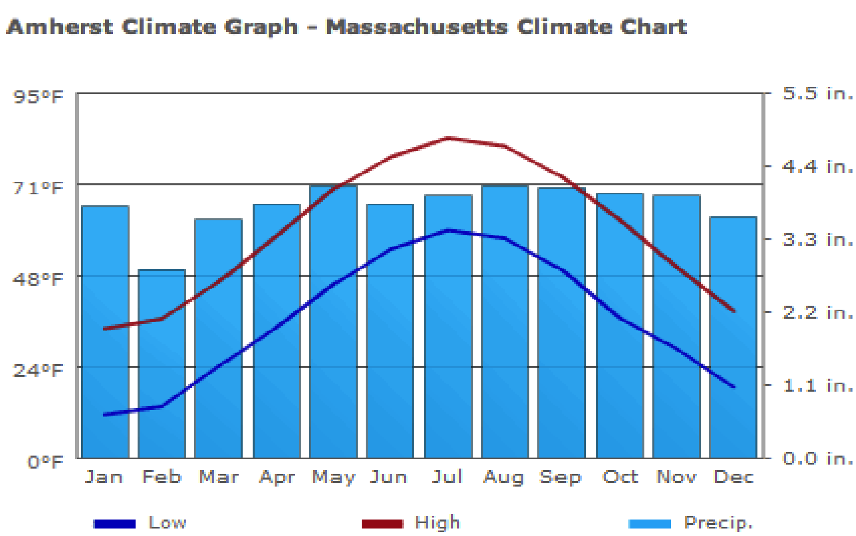
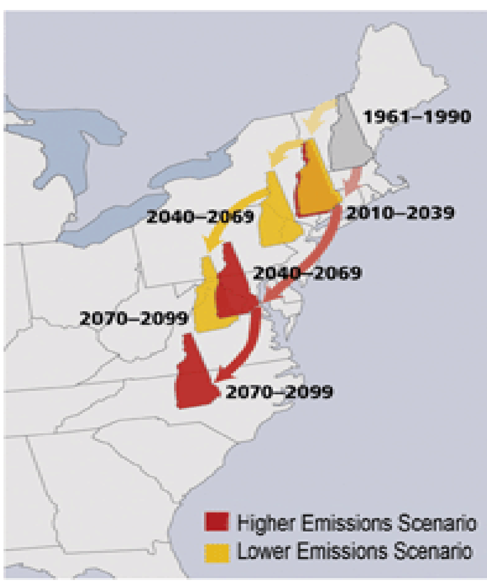


Figure 3.16: The average rainfall and temperature for Amherst, MA over the course of a full year. The peak temperatures correlate with the higher amount of average rainfall (U.S Climate Data, 2015).

It is important to consider the climate change models to understand the long-term conditions the site will be facing. Do to the proximity of sea levels there is no need to include those impacts in this report. However, temperature and precipitation shifts could have an impact on the site. According to the EPA, the current average temperatures within the Northeast have already begun to increase and are mimicking those of New York City as shown in Figure 3.17. This slight change will not have a great impact. However, the long term modeling shows that the average temperatures could be closer to the current ones of North Carolina as soon as 2070-2099. This would mean almost six times more days over 90 degrees. This will have a major impact on plant species, the growing season, insect and diseases, and precipitation (Karl, 2009).



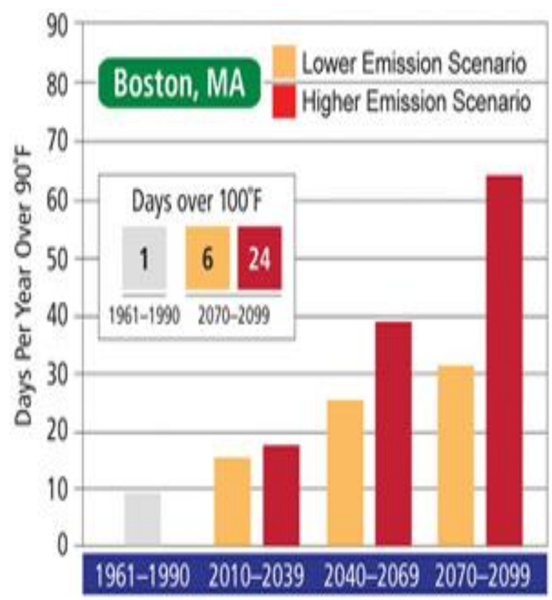


Figure 3.17: The projected average temperature for the Northeast could be similar to the existing conditions of North Carolina as early as 2070 (Karl, 2009).

Natural Resources

The natural resources of the site that were examined include hydrologic patters, topography, vegetation and. To obtain hydrology and topography inventory, data provided by Campus Planning will be used. The vegetation will be recorded by observation during site visits. The existing soils will be recorded by utilizing the United States Department of Agriculture (USDA) and the National Cooperative Soil Survey.

According to the 2011 UMass Amherst Campus Plan Draft, the study area is designated as an area for stormwater management as shown in Figure 3.18. With the current conditions, the area primarily serves as conveyance of water from the overflow pipe to the adjacent wetlands off of campus. However, if the long term planning for this area is for storage, a design will need to be implemented that slows the conveyance of water off of the site allowing the wetlands to receive the flow without any backflow. This notion of storage will need to be incorporated in any design solutions.

Figure 3.18: The Campus Master Plan shows that the long-term planning for the site is to continue to serve as a conveyance of stormwater off campus (UMass Amherst Campus Planning Division, 2011).

The hydrological function of this site is done predominately through a 60” concrete pipe that daylight at the head of a swale. This pipe is the primary cause of erosion due to high volumes of water that flow into an area not reinforced to withstand these volumes. To understand how much water can potentially flow into the site from this pipe the flow rate must be calculated as shown in Figure 19

UMass West Gate Pipe Calculations	
Pipe Diameter	60”
Manning Coefficent	0.012
Pipe Slope	5%
Percent of flow depth	50%
Flow	315cfs
Velocity	32ft/sec

Figure 3.19: This pipe flow chart shows that with the pipe flowing at 50% capacity, its highest level without hydraulic pressure, the flow rate would be 315cfs.

According to the light detection and ranging (LIDAR) topography map provided by Campus Planning the site has several different slopes on site. The west and east side of the site has step slopes between 8% and >15%. These areas are where the adjacent roads slope down to the inlet and outlet pipes on the site. The side slopes of the swale along the athletic field range from 0-8% and is comprised of grass slopes. The side slopes along the road range from 0-15% and also is comprised of grass slopes. The bottom of the swale is a consistent 2% along the entire site. This will be the primary path of water flowing through the site. A 2% slope means water will be traveling relatively slowly during small events.

The vegetation on the site is largely comprised of turf and a variety of apple trees buffering the sports fields. A massing of evergreen trees and street trees can be found on adjacent streets. At each of the washout areas at the end of the site are a variety of weeds and invasive plants. These plants do not provide the stabilization or water treatment needed for this site. It will be important to additional plants be incorporated into a design that protections from erosion, dissipates the velocity of water and serves to treat the various pollutants in the water. The crab apple trees are not close enough to the channel area and they should not be impacted by any proposed design for the area.

According to the USDA and the National Cooperative Soil Survey, the entire site is comprised of Amostown-Windsor silty substratum-urban land complex soil as shown in Figure 3.20. This type of soil is comprised of 35% Amostown soils, 25% Urban land, 25% Windsor silty substratum, and 15% other minor components. This soil has a depth to water table of 18-36" and is classified as moderately well drained and is typically formed by outwash plains and down slopes (Natural Resources Conservation Service, 2013). The shallow depth to the water table will impact the type of BMPs that are possible to implement. Although this soil is listed as well drained, for implementing sand filters and bioretention areas custom soils will be recommended for the majority of the channel.

Water Features– Hampshire County, Massachusetts, Central Part								
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding		
				Upper limit	Lower limit	Surface depth	Duration	Frequency
				Ft	*Ft*	*Ft*		
741A—Amostown-Windsor silty substratum-Urban land complex, 0 to 3 percent slopes								
Amostown	C	Low	January	1.5-3.0	>6.0	—	—	None
	C	Low	February	1.5-3.0	>6.0	—	—	None
	C	Low	March	1.5-3.0	>6.0	—	—	None
	C	Low	April	1.5-3.0	>6.0	—	—	None
	C	Low	December	1.5-3.0	>6.0	—	—	None
Urban land	D	Very high	Jan-Dec	—	—	—	—	None
Windsor, silty substratum	A	Very low	Jan-Dec	—	—	—	—	None
Enosburg	—	—	January	0.0-1.0	>6.0	—	—	None
	—	—	February	0.0-1.0	>6.0	—	—	None
	—	—	March	0.0-1.0	>6.0	—	—	None
	—	—	April	0.0-1.0	>6.0	—	—	None
	—	—	May	0.0-1.0	>6.0	—	—	None
	—	—	November	0.0-1.0	>6.0	—	—	None
	—	—	December	0.0-1.0	>6.0	—	—	None
Maybid	—	—	January	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	February	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	March	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	April	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	May	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	June	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	July	0.0	>6.0	0.0-1.0	Long	Frequent
				Ft	*Ft*	*Ft*		
	—	—	August	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	October	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	November	0.0	>6.0	0.0-1.0	Long	Frequent
	—	—	December	0.0	>6.0	0.0-1.0	Long	Frequent

Figure 3.20: This chart from the soil survey report indicates the depth to water table is between 1’-6’ in depth (Department of Conservation and Recreation, 2015).

The natural resources of hydrology, topography, vegetation and soils are overlapped in this graphic to provide an understanding of how these elements interact on the site as shown in Figure 3.21. The hydrologic function follows the topography of the site with the addition of piped inlets and outlets. The vegetation and soils have impacts erosion control and ability for water infiltration.

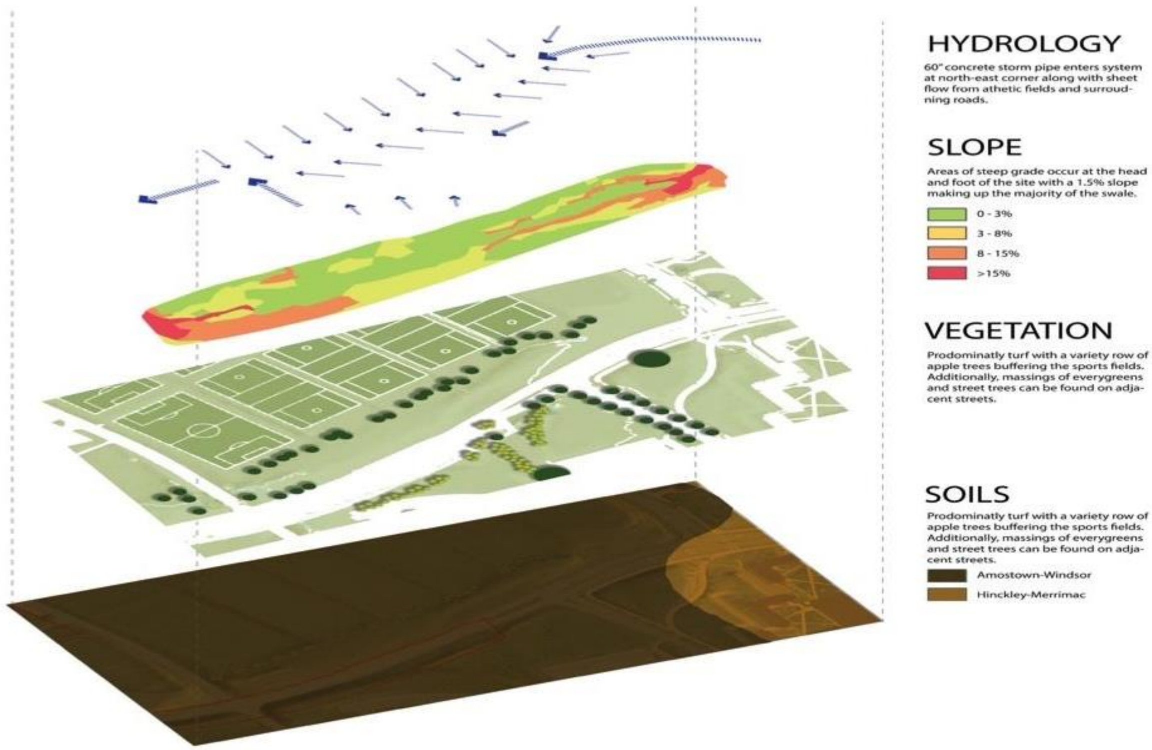


Figure 3.21: Site inventory showing bicycle, pedestrian and vehicular circulation.

The analysis of regional and site specific issues and opportunities will serve as the foundation for design solutions that are best suited for this specific area. This information will be utilized in the preliminary design phase that will entail schematic design solutions based on the BMPs stated in the Literature Review of this master's project. These implementations, along with aesthetics and preliminary cost estimates, will be reviewed with Campus Planning to best ensure this project is feasible for potential installation.

Site Analysis and Inventory Conclusion

By observing the site several times both when it was inundated with water and dry, a thorough understanding of the existing conditions were achieved. While the site is flowing with stormwater, it is not safe to cross the site and the flowing water becomes a large barrier between the fields and the parking lot. The amount of water that exits the pipe has caused significant erosion problems and deposited sediments and invasive plants. At the other end of the swale those conditions are also observed and the Physical Plant is currently blocking the space off with snow fences until a permanent solution can be implemented.

The circulation throughout the site is impacted both when water is flowing and after until the area is able to thoroughly dry out. This circulation would be primarily by pedestrians while bicyclists would most likely continue to travel on the already established regional bike path connector. Motorists will also observe the site as they enter the campus and serve as their first introduction to campus- an important entrance for the University and its guests. Currently, the views of eroded swales with overgrown invasive plants are neither safe nor aesthetically pleasing. Addressing these issues while handling the large amount of water will be critical to the project.

To properly understand the amount of water entering the site through the pipe, calculations were done with the understanding that the pipe will at most be able to flow at 50% without hydraulic backpressure. With these numbers calculated it was concluded that the pipe has the capacity to flow at 315cfs. That is a very large amount of water flowing and in those conditions it will be critical to install a system that will continue to allow water to flow through the site while providing as much treatment as possible without creating a flooding condition in the adjacent areas.

The natural features of hydrology, slope, vegetation, and soils are important to know in or to determine what the site will allow for BMPs. With water entering the site from a source point of the pipe and exiting through another pipe, the only other water would be adjacent run country grading runoff from the roads and athletic fields. The slopes, vegetation and soils dictate the way water moves across the site. The gradual slopes along with turf areas between these spaces prevent any major concentration of flow from these areas.

The full understanding of existing conditions, circulation patterns, climate conditions both current and in the future, and the natural features of the site will provide the foundation for concept options presented to the UMass Campus Planning for selection and further development.

DESIGN CONCEPT AND APPLICATION

Several design concepts based on the analysis of the site conditions and a final design solution were developed with the objectives to mitigate stormwater issues of erosion and water quality while providing an aesthetic West Gate Entrance. The design will showcase the fact that the University Massachusetts Amherst is a land grant university with innovative solutions grounded in ecological stewardship. This will include addressing all three pillars of sustainability: economic, social, and environmental as shown in Figure 4.1.

Enhancing the aesthetic of the entrance as well as cost of maintenance in this area will help attract potential students and allow the physical plant to redirect resources. By providing a quality space for students, faculty, and staff to gather for recreation and/or outdoor classroom space will provide a social aspect that the site was unable to offer previously. Mitigating the stormwater issues of contaminants and erosion will begin to address the environmental issues that the Tan Brook passes on the University campus onto this site as well as impacts of those issues further down stream.

Figure 4.1: All three pillars of sustainability are addressed within the site design.

The site analysis showed a very gradual slope of 2% along the entire site. This slope along with the large amount of water that enters the site through the five-foot water pipe will dictate which of the BMPs are best suited for installation. Due to the fact that the site is not large enough to hold the water for large storm events, an infiltration trench is the best BMP. The implementation of an infiltration will allow water to continue to flow through the site on the gradual slope while addressing water quality issues of a high volume that will continue to flow through the site.

Schematic Concepts

Three concepts were created with very different design layouts and applications. **Concept 1** – Stream, as shown in Figure 4.2, is a curvilinear design that allows the water to travel through the site similar to the behavior of a naturally occurring, meandering stream. Pockets of vegetation would be located at the bends of the stream and the water would be primarily located at the bottom of the swale. The curves of the swale would slow the water down and openings in the vegetation pockets would allow for views across the field, providing glimpses of buildings as drivers enter campus. However, by having the swale continue throughout the site without any weirs or dams, the water would continue to flow even during small storms and no storage is provided.

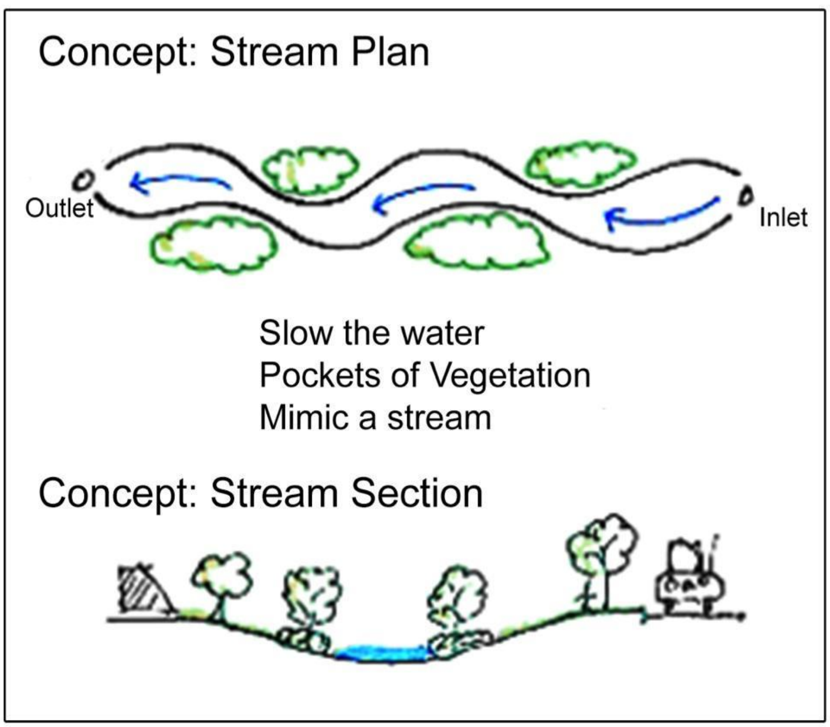


Figure 4.2: Stream Concept diagram and section shows a curvilinear design mimicking a naturally occurring stream flowing through the site.

Concept 2 – Pools, as shown in Figure 4.3, is a rectilinear design that has a series of connected pools that could move water through the site by filling one pool and overflowing into the next pool. This distinctive design feature would provide an immediate visual cue to visitors that they are entering campus. The design has plantings scattered within the space between pools, which with water flowing through the space would provide dramatic views into campus. The pools would serve to store some water while still allowing the water to continue to flow during large storm events. This design has the highest potential of becoming clogged during large storm events and could become the most costly in regards to long-term maintenance.

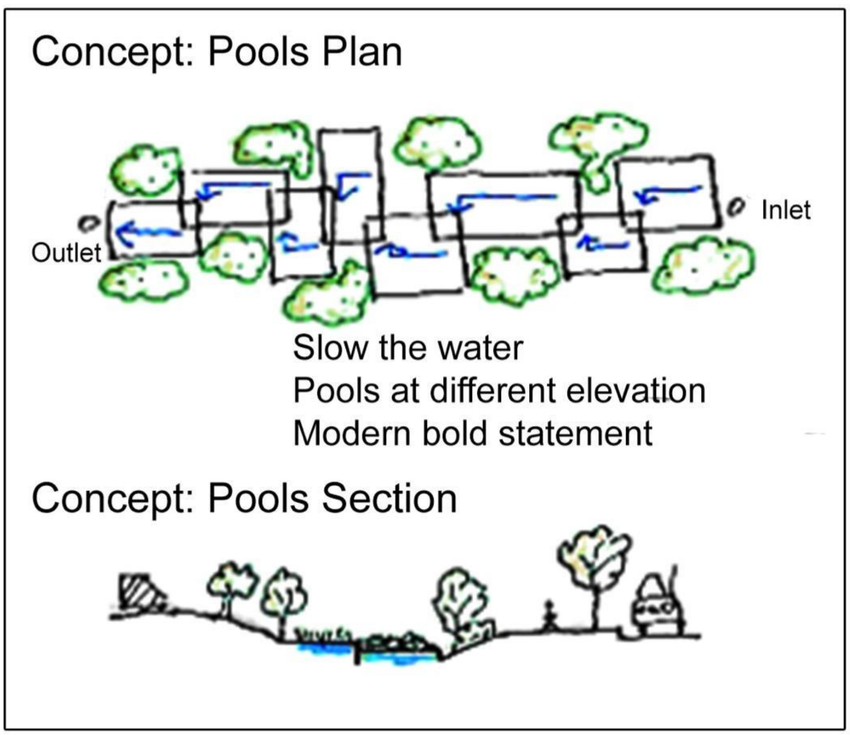


Figure 4.3: Pools Concept shows a rectilinear design with a series of pools that cascade water from one pool to another as it flows through the site.

Concept 3 – Cascade, as shown in Figure 4.4, has a series of weirs throughout the site that create foot bridges where visitors to the site will be able to cross and have access to the sports fields. Two steps along the sides of the swale will allow for storage of water during storm events while still allowing water to continue to flow during the larger storm events, reducing the chances of any flooding into the field space. This plan has plantings along the majority of the site with gaps where the weirs are located.

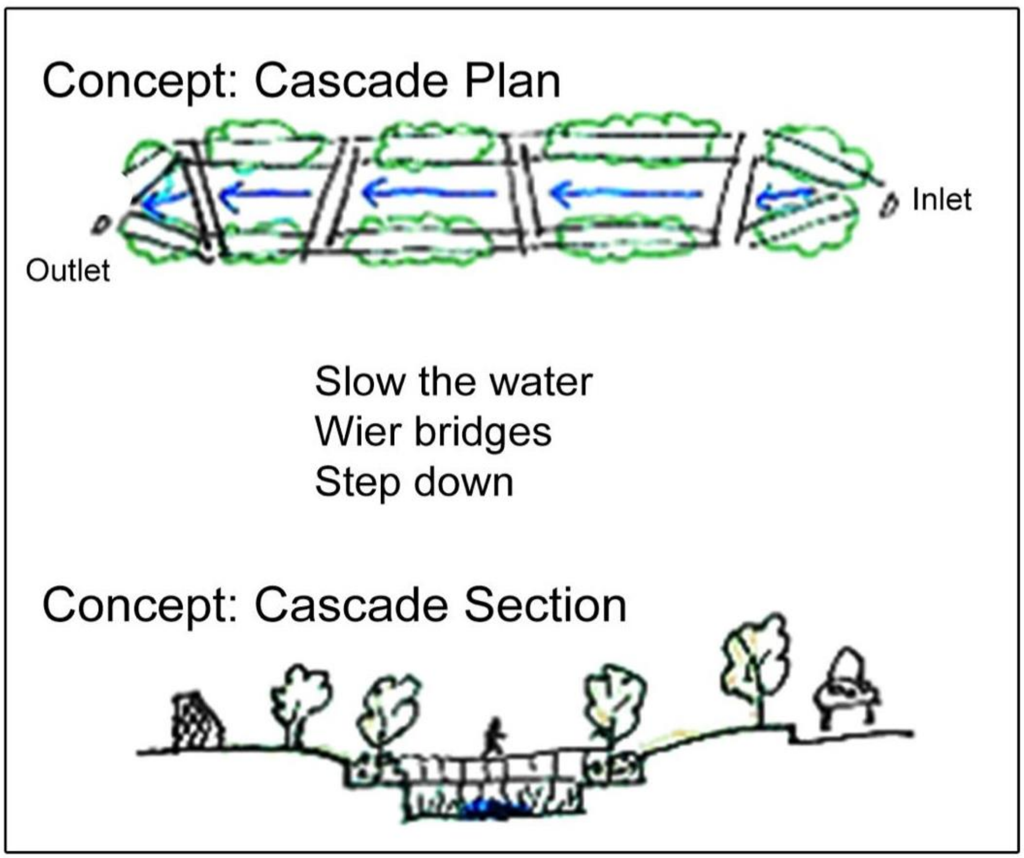


Figure 4.4: Cascade Concept and section show how the water would fill each area and cascade over several weirs throughout the site.

Through design critiques with Campus Planning the side levels of Concept 3- Cascade were discussed in depth and to expand on how the steps would be created, an additional sketch was done shown in Figure 4.5. This sketch shows how gabion baskets filled with stone and faced to look like a natural stonewall which would play into the local character of natural stonewalls. This would also allow sidewall infiltration opportunities. The areas within the steps and at the bottom of the swale utilize sand filters to help treat water as it flows through the site and increase infiltration levels.

Figure 4.5: Section showing the gabion baskets and sand filters stabilizing the slopes and creating a pedestrian crossing.

These concepts were presented in a meeting with Campus Planning in the spring of 2013 and with the potential of increase circulation as well as highest rate of storage and infiltration, Concept 3- Cascade was selected as the most preferred design solution for the site. This design will be further developed in the following section.

Preferred Design

The Cascade Concept was selected because of the ability to address the hydrologic and circulation issues while creating an educational and aesthetic entrance to the campus. The design uses a series of weirs that slow the water down during storm events and create pools where water can infiltrate. If the storm event is larger than the pools can hold the water will flow over the weirs into the next pool. In the event that a storm is larger than the entire system can handle the water will flow through the entire site. This allows water to be treated when applicable and during large events the entire system simply conveys water through the site safely.

Further development of the Cascade Concept entails applying the design over a survey of the site as shown in Figure 4.6. This will allow more precise calculations on the amount of materials needed for implementation as well as the quantity of water that could be stored during storm events. This process will allow the design to evolve to a state where Campus Planning could seek the creation of construction documents for installation.

Preliminary Design Plan View

Preliminary Design Axonometric

Figure 4.6: Design layout and sketches presented to Campus Planning to further develop the concept plan.

In a follow-up meeting with the Campus Planning Department, these design layouts within the space were shown along with sketches and character images of possible materials within the design. Feedback from the previous meeting requested very preliminary costs on gabion baskets required for this design layout. Based on these preliminary design layouts it was calculated that there would be roughly one thousand gabion baskets with a cost of $45.00 each for a total of $45,000. Within the baskets there would need to be roughly 670 cubic yards of stone. The faces of these baskets could be filled with local stone to give the impression of a natural stone wall while being backfilled with gravel and recycled stone materials as shown in Figure 4.7. This would reduce the cost while maintaining the appearance of a natural stonewalls from a distance.

Figure 4.7: Design layout and sketches presented to Campus Planning to further develop the concept plan.

Presented to the Campus Planning were boards that showed the character of the bioretention swale in various states as shown in Figure 4.8. One of the images showed water flowing through a central low point in the swale, another fully vegetated so water is not visible, and one with weirs that show pools similar to the proposal for this site. All of these character images were well received and the only issue revolved around the level of maintenance that would be required. Additionally, images of fountains were shown with the potential for a light/water feature that could provide a vibrant element and enhance the entrance to campus. Campus Planning felt this component would be too expensive to purchase and maintain and requested these features left out of the proposed design.

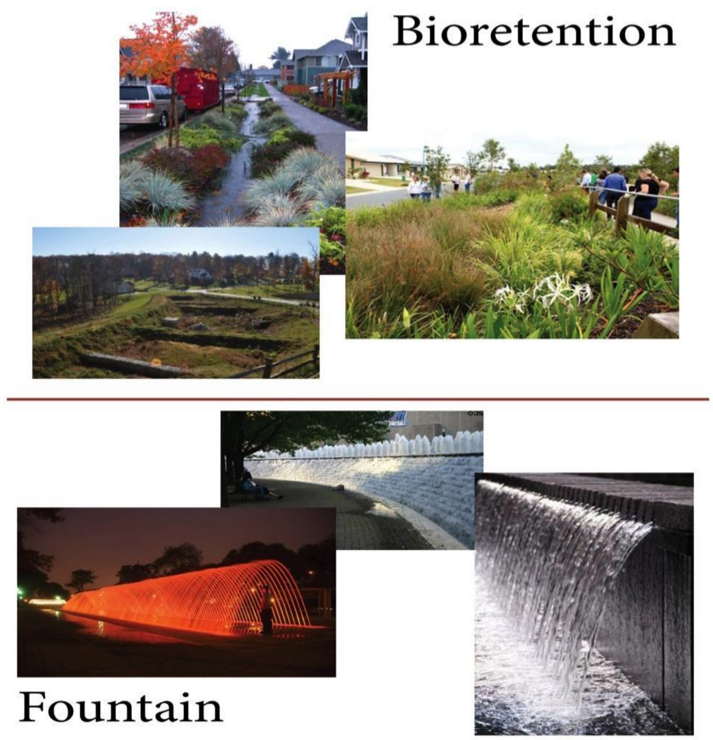


Figure 4.8: Design layout and sketches presented to Campus Planning to further develop the concept plan.

With this feedback, the weir and gabion basket concept was modeled to provide a better understanding of what the constructed product would look like and how the water would flow through the site as shown in Figure 4.9. The bottom of the swale is proposed to have wet-loving plants and be more grasses that could be mowed to keep maintenance requirements to a minimum in response to the concerns from Campus Planning. Because these plants are wet-loving plants they will be able to tolerate both large and small storm events. The second level will contain wooded shrubs and trees. When the water levels rise during larger events these plants could potentially become inundated by water so careful selection of these plants will be critical to ensure they are able to handle such conditions.

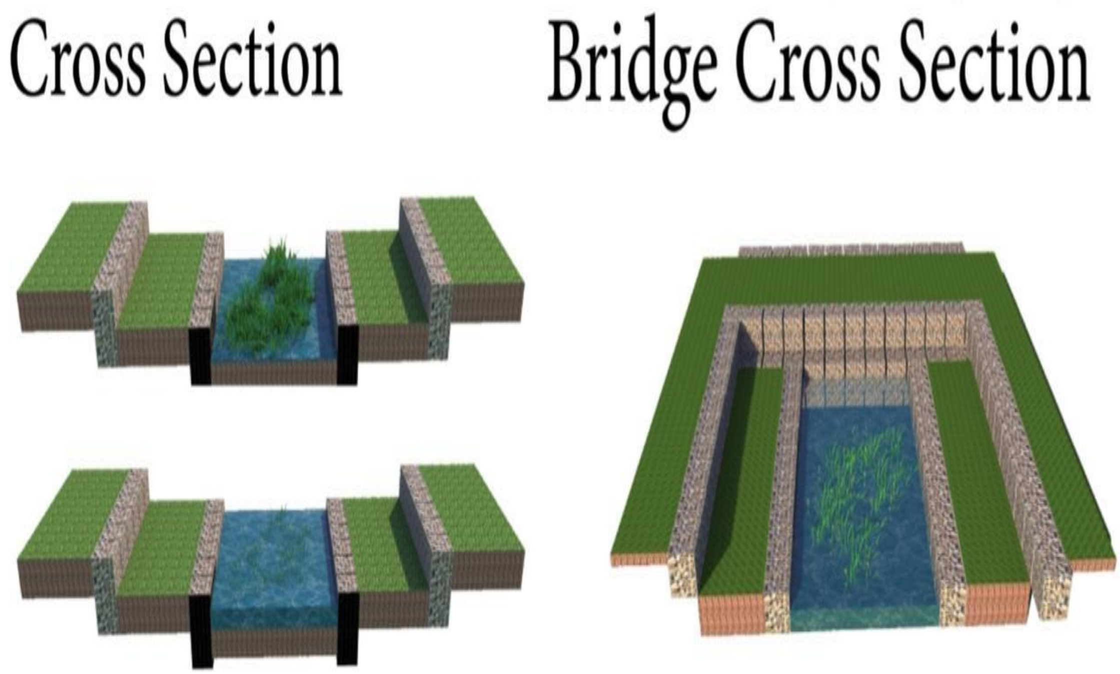


Figure 4.9: Design layout and sketches presented to Campus Planning to further develop the concept plan.

During this meeting, an addition of a recycled lenticular bridge was recommended in place of one of the weir crossings. The bridge is stored adjacent to the athletic fields close to the proposed site. Dr. Lutenegger of the Civil Engineering Department salvaged the historic bridge and it is one of the last lenticular bridges in existence.

The installation of this bridge in this location would allow the site to be utilized for civil engineering students and teachers and serve as an iconic element for campus. The bridge proposed for this location is 76’ wide, made of wrought iron, and was constructed in 1885. It was manufactured by Berlin Iron Bridge Company and installed in Lee, MA on Golden Hill Road spanning the Housatonic River as shown in Figure 4.10.

Figure 4.10: This lenticular bridge is proposed for the site and being stored adjacent to the site (Photo provided by Dr. Lutenegger).

For the final design and renderings, this bridge along with the recommendation of allowing additional views through the site will be incorporated. A list of plants suitable for the various conditions in the proposal will be provided along with a plan and various sections throughout the site. These elements will serve as the final schematic design elements that Campus Planning will be provided with to assemble construction documents.

Plant Lists

For the final design the following plants are proposed within each location. These plants were selected because of their ability to tolerate wet conditions and serve as sustainable, low-maintenance plants. A variety of trees, shrubs, and grasses were selected that could be utilized throughout the design as shown in Figure 4.11 along with images to convey character of plants.

Trees	
Acer rubrum	Red Maple
Alnus incana	Speckled alder
Betula alleghaniensis	Yellow birch
Nyssa sylvatica	Tupalo
Salix nigra	Black willow

Shrubs	
Aronia melanocarpa	Black chokeberry
Cornus sericea	Redtwig dogwood
Ilex verticillata	Winterberry

Seed Mixes from NEWP
New England Wetmix
New England Erosion Control
New England Wildflower Mix

Figure 4.11: Plant lists for trees, shrubs and seed mixes along with images to convey characteristics.

Additionally, specific perennials were selected that would be best suited for the lower level, middle level, and upper level of the stepped design as shown in Figure 4.12. The lower plants are suited for consistently wet conditions, where the middle level can tolerate both wet and dry conditions. The plants on the upper level are primarily for dry conditions.

Lower Level perennials	
Astilbe biternata	False goat's beard
Carex grayi	Gray's sedge
Chelone glabra	White turtlehead
Iris cardinalis	Blue flag iris
Lobelia cardinalis	Cardinal flower
Lobelia siphilitica	Great blue lobelia
Panicum virgatum 'Dallas blues'	Panic grass 'Dallas Blues'

Mid Level perennials	
Coreopsis rosea	Pink tickseed
Iris cristata	Crested iris
Iris setosa v. Nana	Dwarf arctic blue flag
Phlox glaberrima	Smooth phlox

Upper Level perennials	
Asarum caudatum	Western wild ginger
Carex platyphylla	Broad leaf sedge
Spigelia marilandica	Indian pink
Viola labradorica	Labrador violet
Waldsteinia lobata	Piedmont strawberry

Figure 4.12: Plant lists for trees, shrubs and seed mixes along with images to convey characteristics.

Final Rendering

Figure 4.13: The final site plan rendering, showing three large bays with a swale at the bottom and sand filter planting areas

The final design utilizes these plants and their ability to tolerate a variety of conditions as well as treat contaminated soils that entire the site. The final design has a meandering low point in the swale and, if planted with a single plant such as cardinal flower or panicum grass, could provide a strong aesthetic interest of a naturalistic stream traversing a clearly manmade stormwater management system.

The final design incorporates a sediment/settlement basin directly outside of the outlet pipe. This will serve to dissipate the energy of water flowing from the pipe and eliminate the erosion issues that are currently occurring in this location. This area has concrete floors that can be accessed by excavation equipment as needed to remove sediment when build-up occurs. This area has smaller stone/concrete weirs that will have water cascade over onto a riprap area and across vegetation for treatment.

Moving further down the swale, directly adjacent to the location of the proposed roundabout, the lenticular bridge is placed. This location is highly visible for vehicles and direct path for pedestrians entering the site from campus' South West Dormitories, and the parking lot across Massachusetts Avenue. The first gabion basket weir is placed directly up swale from the bridge so that visitors to the site will be able to see water traveling through and over the weirs during storm events.

The bridge spans one of three proposed holding areas that will continue to let water flow during small events but, during larger events, will hold a certain amount of water for infiltration while allowing anything over that holding capacity to exit the site at the end of the swale. The bottom of the swale is two steps down from a buffer strip along Massachusetts Avenue and the athletic fields. Each of these steps is 30" to eliminate the requirement of any railings by Massachusetts Code 780 CMS 5312-Guards. Each of these steps are gabion basket retaining walls that allow for planting on the high side while allowing side-wall infiltration when water is flowing. The lower step is curvilinear with larger areas for the middle range plants creating pockets with visual interest. These curves will also slow water from smaller storm events by forcing water to go a longer distance throughout the swale.

The final basin in this design is highly vegetated to ensure erosion problems are resolved. The final weir is placed close to the outlet pipe, which will help in erosion control as a final energy dissipater before the water becomes bottlenecked at the outlet pipe.

Sediment Bay		
1366sf	2.5’	3415cf
2839sf	2.5’	7098cf
3156sf	2.5’	7890cf
11539sf	2.5’	28848cf
Bay 1		
24978sf	2.5’	62445cf
9750sf	2.5’	24375cf
Bay 2		
28811sf	2.5’	72028cf
11215sf	2.5’	28038cf
Bay 3		
22488sf	2.5’	56220cf
8499sf	2.5’	21248cf
End Bay		
5419sf	2.5’	13548
2128sf	2.5’	5320cf
Total Storage		330470cf
Time to Fill		18 min.

Figure 4.14: Plant lists for trees, shrubs and seed mixes along with images to convey characteristics.

These basins combine for a total holding capacity of 330,470 cubic feet as shown in Figure 4.14. Based on the maximum flow from the inlet pipe it would take eighteen minutes to fill the entire site. The holding capacity will only be achieved when the sidewall capillary action is maximized and all remaining water entering the site will continue to flow through the site to the outlet and into the wetlands and Mill River to the west.

Section perspectives as shown in Figure 4.15 were rendered showing the critical locations to provide a framework for potential construction documents. Section A-A’ shows the sediment bay area and how a concrete floor along with a set of weirs would allow water to flow into this area and sediment to settle to the floor while the water flows over the weirs. Section B-B' shows how an extensive planting around the outlet pipe could help to stabilize the slopes. Section C-C' shows how a lenticular bridge could be incorporated in the steps of the side slope and how pedestrians would traverse the swale. Section D-D' shows a cross section of the weirs constructed with the same gabion baskets as the side slopes. This application could slow water flow during larger events while continue to allow a steady flow of water through the weirs.

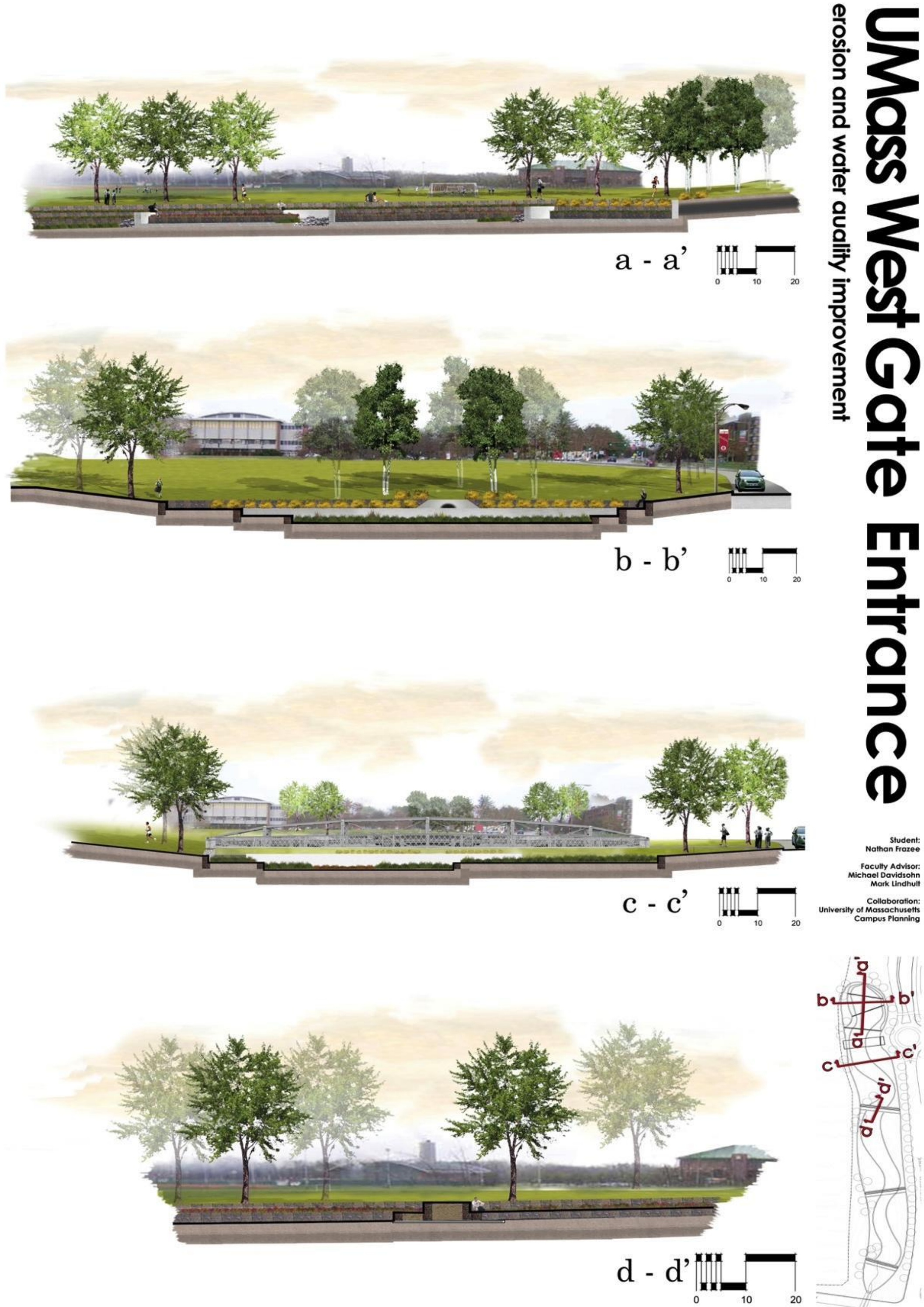


Figure 4.15: Section perspective views how the design would look in the landscape and how users would travel through the site.

CONCLUSION

The concept of addressing stormwater with a natural systems approach and allowing infiltration is a growing trend that will help reduce the impacts of low water quality and erosion issues created by the concentration of water flow. This approach, when applicable, enhances the ecological processes and is important for addressing stormwater sustainably.

This project addresses an area where a piped portion of the Tan Brook in Amherst, MA, is day lighted without a properly designed outlet so that the pipe has created erosion and water quality issues. The University of Massachusetts has yet to address the source of the problems and have continued to place fencing around the space to discourage pedestrians from entering this dangerous area.

To successfully develop a solution for this problem an extensive literature review provided the framework and understanding of the hydrologic process and how current sustainable trends can be applied through low impact design and best management practices (BMPs). To ensure the correct BMPs are selected for this project, a series of case studies that have similar issues and site conditions were studied and evaluated for their ability to achieve the desired result.

Based on those case studies and through a series of meetings with UMass Campus Planning Department, the proposed solutions include a vegetated swale that integrates sand filters and bioretention basins. These applications could allow the space to serve the highest volume of water possible and reduces any flooding issues that could arise with slowing the water flow in this area. With the installation of these BMPs, the UMass Physical Plant could implement a maintenance plan that would only require mowing the perennial beds once a year and cleaning out the sediment bays as needed. With proper maintenance and installation this design could reduce erosion issues and improve water quality while providing students, faculty, and staff a location for educational purposes, recreation, and respite. By embracing innovative and aesthetic solutions, the West Gate entrance could become a functional stormwater destination and identity marker that showcases the ecological stewardship founded in the roots of the land grant of the University of Massachusetts Amherst.

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