THE GREEN TAILGATE

Alternative Approach to Stormwater Management at Sports Venues

by

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Abstract

Sports venues require large amounts of parking to facilitate the number of spectators attending an event. The parking, mostly surface, is underutilized when compared to traditional parking lots accommodating daily use. Large parking surfaces alter the natural hydrological cycle by generating large volumes of runoff. Over time, pollutants build up on a parking surface and are discharged into a stormwater drainage system during a rain event. The intent of the research is to investigate the use of Best Management Practices that ultimately reduce the pollutant loads created by stormwater runoff while creating amenities for spectators that could potentially generate revenue.

The focus of the study will be on a 400 acre sports venue in Kansas City, Missouri, the Truman Sports Complex. To understand retrofitting stormwater management practices, one must understand how large parking lots are constructed and understand successful examples. Through the use of archival research, interviews and analysis of two parking lot case studies, Northgate Mall in Seattle, Washington and US Cellular Field in Chicago, Illinois, the research analyzed how retrofitting design solutions are utilized to reduce stormwater pollutant loads.

Each case study documents a distinct type of retrofitting strategy; bioswales at Northgate Mall and permeable concrete pavers at US Cellular Field. Using the Design Point Method developed by the Center for Watershed Protection, the research analyzes each case study retrofit design solution - conceptually and post construction. The Design Point Method allowed the research to measure the success of retrofitting strategies and informed the research to as to how the strategies could be implemented at the Truman Sports Complex.

The conclusion of the project is a retrofit design solution of a surface parking lot at the Truman Sports Complex. Using the Design Point Method as an analysis tool, the final study provides compelling evidence that retrofitting existing surface parking lots at sports venues using Best Management Practices provides a sustainable solution to reducing pollutant loads while creating the potential for enhancing the tailgate experience for the sports fan.

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Acknowledgements

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I would also like to thank all the committee members that challenged me along my academic journey. Attempting to finish my project from a distance was extremely challenging, but ultimately the guidance and knowledge I received allowed me to mold the project into something meaningful. I would also like to thank all the professionals that provided me guidance and time throughout the project. Without the exchange of ideas the research would not have been possible.

Finally I would like to thank my Mom and Dad. Your gentle reminders that I really needed to complete this chapter in my life were always helpful. While you never expressed your frustrations with my lack of progress, you provided me with the additional motivation to complete the project and move on with my life.

CHAPTER 1 - Introduction

Gameday

From a fans perspective, there is nothing better than firing up the grill and enjoying the beautiful day that is known as "Game Day" (Figure 1-1). But what if that day isn't so beautiful? It is the end of another long summer and the start of football season. You just pulled your car into the stall at the stadium and you are greeted by asphalt that has been heating up all day long in the 100-degree heat. Scanning the vast sea of cars, you find no relief from the heat, just row after row of automobiles parked continuously on asphalt pavement.

Figure 1-1 Gameday KSU Stadium

(**http://www.k-state.edu/photo/spirit/tailgaters-SI2013_003.jpg**, 2004)

One of the goals for the modern sports venue is to maximize revenue. Accompanying the fan on the journey to the suites, clubs, and box seats is the automobile. The majority of sporting venues that have been built in the last 30 years rely on the availability of some type of parking relatively close to the venue. How close the average fan eventually parks to the venue depends upon how much money they want to spend. Most venues offer mass transit opportunities, but mass transit does not resonate with the American love affair of the automobile. Most venues create as much parking as economically possible to capitalize on game day revenue. The cheapest solution for sports venues is the asphalt parking lot.

Forget green islands, landscape buffers, or grass medians. Most cities and communities want a new franchise, or upgraded collegiate facilities. Time and money are spent where the benefits for the fans are the greatest. Creating the “Super Suite”, the “Party Suite”, or increasing the number of restrooms and concessions are high on the list of where the money goes when a new venue is built. Upgrading all these amenities allows for higher ticket prices and increased revenue. So why should the average fan care about parking, one might ask? Shouldn’t the area where people spend a majority of their time, the tailgate (Figure 1-2), be taken into consideration when analyzing how to potentially create added revenue for a sports venue? What if enhancing the parking lot, or more importantly the tailgating experience, was a way to increase revenue?

Figure 1-2 Tailgating at Truman Sports Complex, (http://www.americaswonderlands.com/images/KC/ChiefsTailgating-web.jpg, 2003)

There are many ways to enhance the tailgate experience, but there is only one way to enhance the experience that also ties to sustainable methods for planning and design. Using Low Impact Development (LID) to manage stormwater with the use of natural systems, rather than the typical end of pipe methods, is a way to create the "Green Tailgate." LID is a sustainable design method of stormwater management and is modeled after nature and uses these materials and methods to reduce the impact to the existing hydrologic systems.

The intent of the research is to investigate the use of Best Management Practices that ultimately reduce the pollutant loads created by stormwater runoff while creating amenities for spectators that could potentially generate revenue. The Truman Sports Complex (Figure 1-3), located in Kansas City, Missouri, is an example of an existing sport facility built in the early 1970's using traditional stormwater management practices. The research will explore new approaches to stormwater management and apply the lessons learned into a design solution. The final outcome will be a proposed design solution that demonstrates how retrofitting an existing surface parking lot at the Truman Sports Complex can reduce stormwater pollutant loads.

Figure 1-3 Truman Sports Complex (Google Earth, 2008)

CHAPTER 2 - BACKGROUND

History of Large Scale Parking Lots at Sports Venues

Modern stadia built in the 1960's and 70's focused on the idea of building a multi-purpose event space. The singular stadiums for professional sports teams were being replaced with multipurpose stadiums like Qalcomm Stadium in San Diego (Figure 2-1). The advantage to a multi-purpose stadium was that cities could fund a singular project to serve two sports franchises. Land, infrastructure, public transportation, parking and the overall building costs were combined to save money. (In most cases, this money was often public.) Unlike stadiums of the past, which were generally built near the urban core, most multi-purpose stadiums were built with convenience of the fans in mind. Most were carved out of large chunks of land near freeways or highways, with large, expansive parking lots surrounding the stadium.

Figure 2-1 Qalcomm Stadium, San Diego (Google Earth, 2009)

The purpose of the research is to change the way sporting venues design, manage, and use surface parking. Across the United States there are roughly 1,795 stadiums that have a seating capacity of over a 1,000 (E40Projects, 2008). If we were to break down seating capacity further, there are roughly 298 stadiums with a seating capacity of over 20,000 in the United States. Each of these stadiums (Figure 2-2) would typically have one parking space for every three fans, which would equal roughly 6,666 parking spaces per venue. If one averages the parking requirements for a typical stadium, that would equal about 1,986,468 parking spaces across the country dedicated to sporting venues. Traditionally a ratio of 100 cars per acre is used in the early planning stages to determine how much land is required for parking. Taking that into consideration, roughly 66 acres are required for parking at each of these venues. Each venue would require 2,874,960 square feet of parking to function.

Figure 2-2 Ralph Wilson Stadium, Buffalo (Google Earth, 2009).

All of this land is not dedicated strictly to parking, because most cities have open space ordinances that dictate the design of parking areas. Even if we throw out twenty percent for open space, there still would be approximately 15,750 acres (686,070,000 square feet) dedicated to parking for sports venues. Most of these surfaces are impermeable asphalt or concrete, creating runoff to traditional stormwater management practices. So why are sports venues different from any other urban area that uses traditional impervious surfaces for parking lot design? The answer lies with the use of these facilities.

Typically, most sporting venues are rarely used year around. Smaller multipurpose facilities typically have more events, but the bigger, more traditional stadiums (Figure 2-3), have no more than 80 events a year. The biggest stadiums involving football and racing have even fewer. Looking at those schedules, why build a traditional parking surface for an event that only occurs 80 times a year or less? Would it not make more sense to leave the parking surfaces closer to a natural state which allows the lot to function more like green space throughout the year?

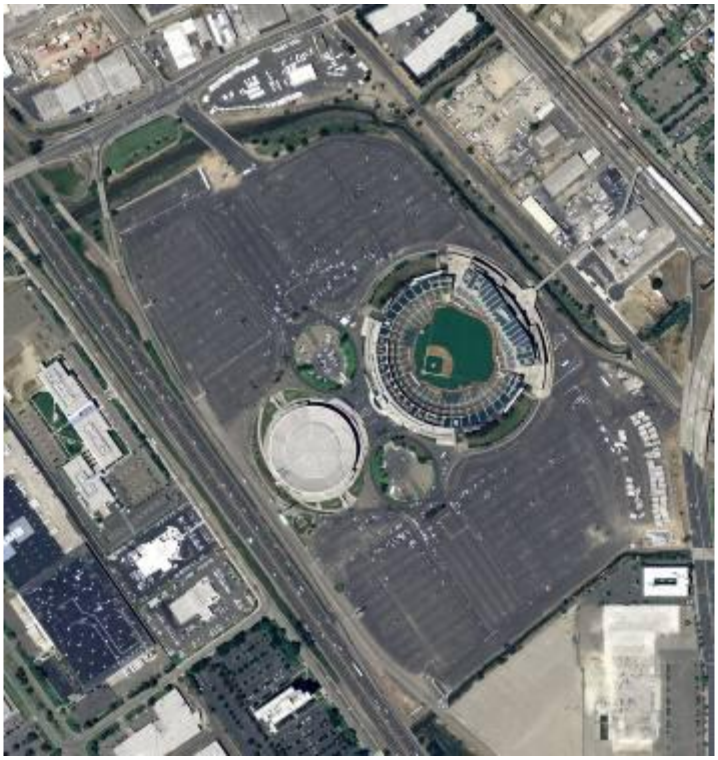


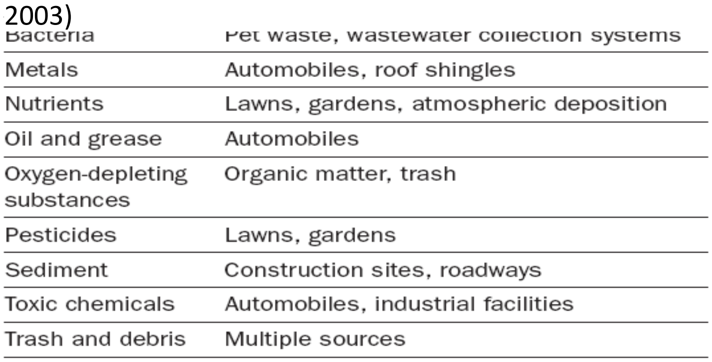
Figure 2-3 McAfee Coliseum – Oakland, California (Google Earth, 2009)

All of the stadiums with seating capacities over 20,000 have surface parking greater than 10 acres. Most of sports facilities use some type of traditional stormwater management practices. Some have adopted different types of Best Management

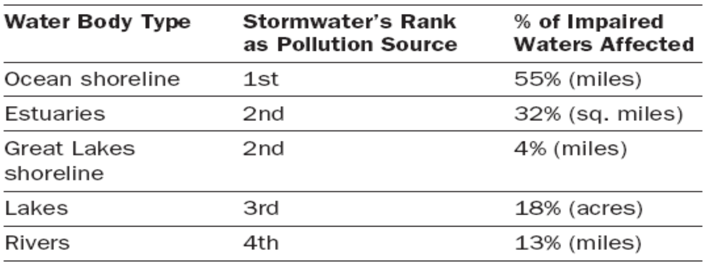
Practices (BPM’s), but for the most part, traditional stormwater management practices have been designed. All the facilities contribute to the problem of urban stormwater pollution. Pollution in our drinking water, beaches, lakes and streams are primarily caused by rainwater washing over impervious pavements

Urban Stormwater Pollution – The Problem

Table 2-1 Stormwater Pollutant Types and Source, (NRDC, http://www.nrdc.org/water/pollution/storm/stoinx.asp, 2003)



Bacteria	Pet waste, wastewater collection systems
Metals	Automobiles, roof shingles
Nutrients	Lawns, gardens, atmospheric deposition
Oil and grease	Automobiles
Oxygen-depleting substances	Organic matter, trash
Pesticides	Lawns, gardens
Sediment	Construction sites, roadways
Toxic chemicals	Automobiles, industrial facilities
Trash and debris	Multiple sources



Water Body Type	Stormwater’s Rank as Pollution Source	% of Impaired Waters Affected
Ocean shoreline	1st	55% (miles)
Estuaries	2nd	32% (sq. miles)
Great Lakes shoreline	2nd	4% (miles)
Lakes	3rd	18% (acres)
Rivers	4th	13% (miles)

According to the National Resources Defense Council, polluted runoff rivals or exceeds sewage treatment plant and factories as the number one source of water contamination as seen in Table 2-1. As development has occurred over time, more natural surface area has been covered by impervious surfaces such as buildings and pavement. The Center for Watershed Protection (CWP) estimates that 1.5 million square feet of land development is converted from a natural state to some type of impervious cover every year (1998). Impervious surfaces do not allow the natural systems to absorb or filter stormwater runoff. Instead, stormwater lands on an impervious surface, like an asphalt parking lot, and runs to the nearest stormwater drainage system. According to the Environmental Protection Agency (EPA), "adding as little as 10 percent additional impervious cover in a watershed can result in stream degradation" (EPA, 2005).

The biggest problem with creating large amounts of impervious surface are the pollutants carried in the stormwater as the surface drains. As stormwater flows over the impervious surfaces, it picks up numerous pollutants that lie on top of the surface (Figure 2-4). Examples of these pollutants include:

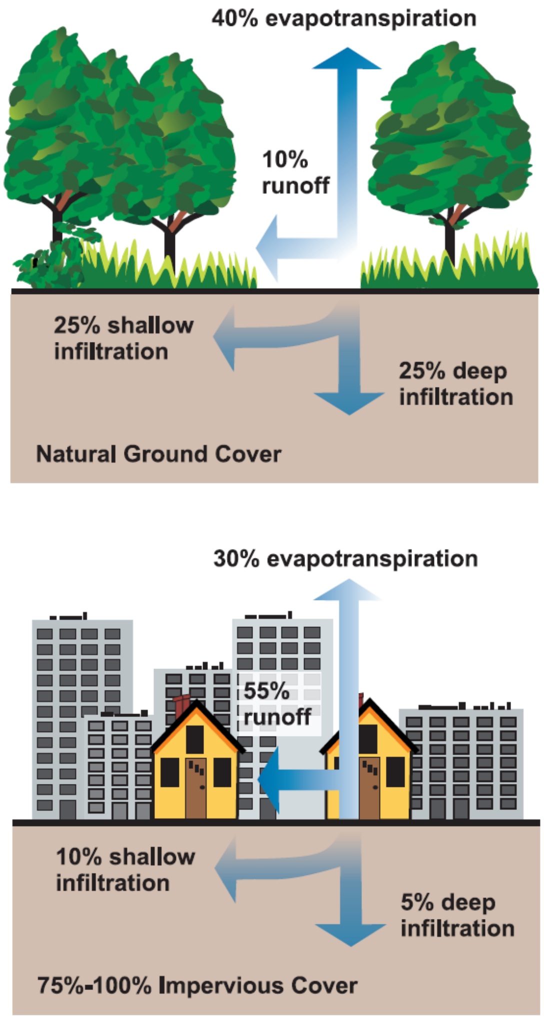


Figure 2-4 Relationship Between Impervious Cover and Surface Runoff, (http://www.epa.gov/nps/urban_facts.html), 2003)

- Sediment
- Oil, grease, and toxic chemicals from motor vehicles
- Pesticides and nutrients from lawns and gardens
- Viruses, bacteria, and nutrients from pet waste and failing septic systems
- Road Salts
- Heavy metals from roof shingles, motor vehicles, and other sources
- Thermal pollution from dark impervious surfaces such as streets.

If impervious pavement was eliminated or reduced, the natural systems would be able to help filter the pollutants by allowing them to process through the natural soil profile, thus reducing the amount of pollutants that end up in our rivers and streams.

"Green Parking" – Sustainability – The Solution

In the world of sustainability, everyone uses the term "Green." So what does "Green" really mean in the conversation about sustainability and a "Green Earth" (Figure 2-5)? For most people, the internet is the first place people go to research new or unfamiliar information. Many search engines churn out millions of web sites that try to define what green truly means. Some sites talk about the green party while others lead you to a discount beverage store. But, in reality, most people think of green as a color, so why does society instantly relate green to sustainability?

Figure 2-5 "Green Earth"

(http://www.23hq.com/qasimkhan/photo/2320121/standard - 2008)

To define green, one must truly understand the meaning of the word. The Oxford New English dictionary defines green as:

- (Green) concerned with or supporting protection of the environment.

From the definition, the meaning of "Green" and in the context of the study is more about a solution or strategy rather than the color.

When thinking about stormwater, green solutions are strategies that result in on-the-ground projects which are designed to reduce stormwater runoff, reduce water pollution, create recreational amenities that protect our natural resources through the use of “green infrastructure” (also referred to as “natural systems”) such as rain gardens, bio-retention facilities, stream restoration, stream buffers and other scientifically proven methods (KCMO, 2008).

In 1987, Gro Harlem Brundtland, then Prime Minister of Norway, directed a commission on Environment and Development to the United Nations. The report, “Our Common Future,” defined sustainability as “development that meets the needs of the present without compromising the ability of future nations” (Sustainable Sites, 2008). Gro Harlem Brundtlan had defined the term “sustainable development”, even though it was not the first time people had thought about sustainability.

Looking at history, architects have found ways to design buildings to take advantage of the natural systems surrounding their new creations. As modern buildings took shape during the Industrial Age, more and more raw materials were being consumed by their construction. Climate controlled buildings, glass skyscrapers, and the seemingly endless supply of fossil fuels created a world without limits. Anything seemed possible, and for mainstream society, there was not really a concern as to what human nature was doing to the natural systems that made our lives possible.

As time passed, more people became concerned with our planets natural systems; the ozone, forests, air pollution, and more importantly, water. Water makes up roughly 70-75 percent of the Earth's surface, and it is in a constant state of motion called the "The Water Cycle" (Figure, 2-6). Without water, and its continuous state of motion, our planet would be very different. The main reason for the alarming concern with our natural water systems is the current state of declining water quality facing our population.

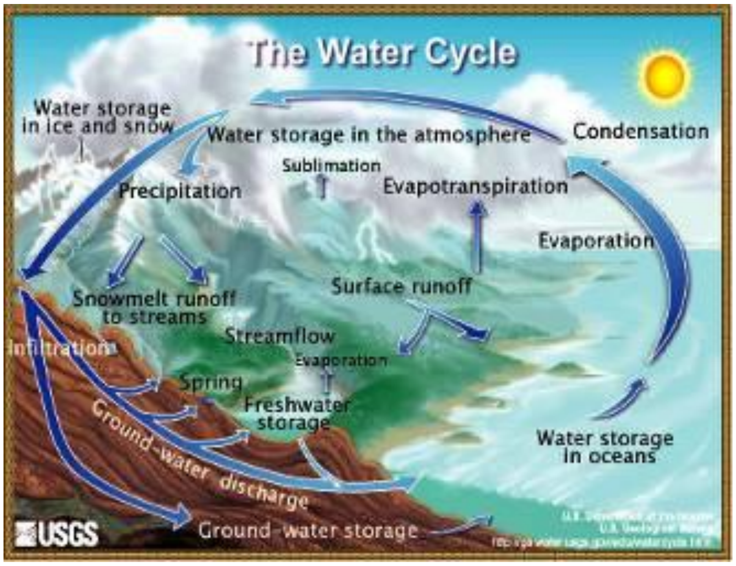


Figure 2-6, The Water Cycle

(USGS, http://ga.water.usgs.gov/edu/watercycle.html, 2008)

In an urban setting, The Water Cycle is disturbed. When undisturbed land is covered with forests and meadows, nearly all rainwater percolates into the ground, fills wetlands and ponds, or is taken up by plant material. Once the land is covered with impervious roads and buildings, water runs off and forms urban stormwater. Urban stormwater runoff collects pollutants from impervious surfaces, finally discharging them into ditches, pipes, and creeks.

In 1972, the Clean Water Act was passed by Congress "to address serious pollution problems affecting the Nations rivers, lakes, and coastal waters. The central objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters" (EPA, 2000, p. 1). Several guidelines and programs were established as a way to control pollutants into our Nations "Water Cycle." By 1972, our Nations Rivers, lakes, and waterways had degraded so much that only one third were deemed acceptable for swimming or fishing (EPA, 2000, p. 1). The outcome of the Clean Water Act was to create a permit system that required anyone discharging pollutants into our nation's waters to register with the National Pollutant Discharge Elimination System (NPDES).

The NPDES was the "cornerstone" of the Clean Water Act and it "regulates the discharge of pollutants into the waters of the U.S." (EPA, 2000, p. 1). The permit process allowed the quality of water in the U.S. to increase dramatically. By 2001, nearly two thirds of the Nations rivers, lakes, and waterways were deemed acceptable for swimming or fishing (EPA, 2000, 1). The permit process was expanded in 1987 and by 2003 the program had expanded its stormwater requirements. By expanding the requirements, they "have resulted in the removal of billions of pounds of conventional pollutants and millions of pounds of toxic pollutants annually" (EPA, 2000, p. 1).

Because of The Clean Water Act these point sources are regulated by the NPDES:

- Municipal Wastewater Systems
- Municipal and Industrial Storm Water Systems
- Industries and Commercial Facilities
- Concentrated Animal Feeding Operations

All the facilities are all required to have an NPDES permit which has played a key role in restoring the Nation's waterways for future generations.

"Green" Parking Defined

Green parking can be interpreted many different ways. For the purpose of this study green parking is defined as

> "several techniques that applied together reduce the contribution of parking lots to total impervious cover. From a stormwater perspective, green parking techniques applied in the right combination can dramatically reduce impervious cover and, consequently, reduce the amount of stormwater runoff" (EPA, 2006, p. 1).

Figure 2-7 Green Parking Island, (IEC, 2004)

As seen in Figure 2-7, several stormwater techniques fit the definition above, but the focus of this study is how stormwater techniques can influence the environmental impacts of parking lots. The purpose of this study is to understand how to control/manage stormwater runoff by applying different stormwater management strategies. According to the USGS, the main environmental impacts created by introducing impervious parking lots are:

- Hydrologic Cycle
- Pollutants
- Heat Island Effect
- Waste Impact
- Plant & Animal Disturbance

- Decrease in Green Space
- Urban Sprawl

Parking Economics

One of the core issues facing sustainable design is cost. Alternative stormwater management design strategies that deal with retrofitting parking lots are no different. To persuade a city, municipality, or private client to do something different or new is always challenging. Case studies and previous design experience help to validate new design solutions/strategies, but ultimately a client's choice usually revolves around cost. If a new strategy costs more than some "known" solution, then ultimately the implementation of a new solution/strategy becomes challenging. The evolution of BMP's to stormwater management is no different. Planning/design professionals and venue operators are familiar with drainage infrastructure and how it functions. The challenge then is prove how traditional stormwater management techniques have become outdated and ultimately cost more. According to Eileen Pannetier of CEI Engineering (2007, p. 25), typical retrofit costs can be compared to standard infrastructure costs. The retrofit cost issues deal with eleven objectives that focus on:

1. Public infrastructure costs are higher when a development is built within the context of urban sprawl, as compared to smart growth patterns that conserve land.
2. At the site level, significant cost savings can be achieved from clustering, including costs for clearing and grading, stormwater and transportation infrastructure, and utilities.

3. Installation costs can be between $4,400 and $8,850 cheaper per acre for natural landscaping than for turf grass approaches.

4. Maintenance cost savings range between $3,950 and $4,583 per acre per year over ten years for native landscaping approaches.

5. Better site design can reduce paving costs.

6. While conventional paving materials are less expensive than conservation alternatives, porous materials can help total development costs go down, sometimes as much as 30%, by reducing conveyance and detention needs.

7. Swale conveyance is cheaper than pipe, systems, by some claims as much as 80%.

8. The literature is not clear enough to resolve the cost differences between discrete detention and retention tools by themselves.

9. Costs of retention or detention cannot be examined in isolation, but must instead be analyzed in combination with conveyance costs, at which point conservation methods generally have a cost advantage.

10. Green Roofs are currently more expensive to install than standard roofs. Yet costs are highly variable and going down. Green roofs also have significant cost advantages when looking at life-cycle costs.

11. Several specific conservation tools can actually have multiple positive economic effects by themselves, both directly and indirectly.

The cost issues associated with retrofitting then must be considered when retrofitting a surface parking lot with any type of BMP.

Best Management Practices

According to the American Public Works Association, “Best Management Practices (BMP’s) are practical control measures (including technological, economic, and institutional considerations) that have been demonstrated to effectively minimize water quality impacts” (MARC, 2008, p. 5). As discussed previously, as the amount of development increases, the amount of imperious surface supporting the development also increases. Once natural surfaces disappear, the amount of degradation to existing watersheds also increases. According to the EPA, “during the past two decades the rate of land development across the country has been more than two times greater than the rate of population growth” (EPA, 2006). The only way to control the sources of pollutants from development is to attempt to manage them. The use of BMP’s is “the most appropriate method of controlling nonpoint sources of pollution because BMP’s prevent or minimize pollution rather than retrospectively respond to the problem” (MARC, 2008, p. 2). Below is the EPA’s classification of Best Management Practices (BMP’s) that are applied to stormwater management.

Non-Structural BMP’s

> **Planning Procedures**. Runoff problems can be addressed efficiently with sound planning procedures. Local master plans, comprehensive plans, and zoning ordinances can promote improved water quality in many ways, such as guiding the growth of a community away from sensitive areas to areas that can support it without compromising water quality.

> **Site-Based BMP's**. These BMP's can include buffer strip and Riparian Zone preservation, minimization of disturbance and imperviousness, and maximization of open space.
>
> **Structural BMP's**
>
> **Stormwater Retention/Detention BMP's.** Retention or detention BMPs control stormwater by gathering runoff in wet ponds, dry basins, or multi-chamber catch basins and slowly releasing it to receiving waters or drainage systems. These practices can be designed to both control stormwater volume and settle out particulates for pollutant removal.
>
> **Infiltration BMP's**. Infiltration BMP's are designed to facilitate the percolation of runoff through the soil to ground water, and, thereby, result in reduced stormwater runoff quantity and reduced mobilization of pollutants. Examples include infiltration basins/trenches, dry wells, and porous pavement.
>
> **Vegetative BMP's**. Vegetative BMP's are landscaping features that, with optimal design and good soil conditions, remove pollutants, and facilitate percolation of runoff, thereby maintaining natural site hydrology, promoting healthier habitats, and increasing aesthetic appeal. Examples include grassy swales, filter strips, artificial wetlands, and rain gardens. (EPA, 2000, p. 2)

Low Impact Development (LID)

In the late 1980's and early 1990's, stormwater management began to address water quality problems while also focusing on how to control costs. In the 1980's, Japan, Germany, and France were "interested in applying distributed, integrated management techniques to reducing stormwater quantity which would alleviate problems with combined sewer overflow" (Hager, 2003). Failure of the bioretention areas that were thought to effectively filter out pollutants created a new thought process focusing on water quality.

By 1988, Larry Coffman, then associate director of Programs and Planning, Environmental Resources in Prince George's County, MD began to explore ways to remove pollutants from bioretention through a plants biomass. By using the existing characteristics of a plants root structure, Coffman and various collaborators created a "plant-soil microbe filter modeled after a terrestrial forest complex" (Hager, 2003, p. 3). Using plants to remove pollutants was not a totally new way of thinking, but it further progressed into the idea of restoring the ecological function of a site. The end result was still the same in that traditional stormwater methods still conveyed the natural systems on site into an infrastructure system. According to Coffman, the key elements of Low Impact Development (Figure 2-8) allow LID to eliminate the traditional infrastructure and replace that with a living site that functions without infrastructure (Hager, 2003).

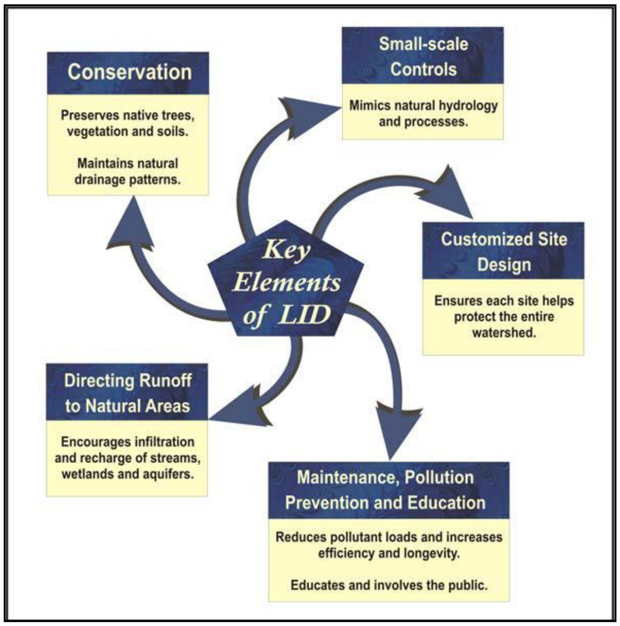


Figure 2-8, Key LID Elements,
(UFC, 2004, p.1)

The roots of Low Impact Development were born and the process was implemented in various test projects. Most of LID projects were in Maryland or the East Coast of the United States. In 1999, the EPA and Prince George's County published: Low-Impact Development Strategies: An Integrated Design Approach. This manual became the "National" manual for LID techniques and practices. In the manual, LID is defined as "hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality" (EPA, 1999, p. 1-1). Also contained in the manual was a set of core goals that became the focus of Low Impact Development (Fig 2-8).

The core goals were defined as:

1. Provide an improved technology for environmental protection of receiving waters.
2. Provide economic incentives that encourage environmentally sensitive development.
3. Develop the full potential of environmentally sensitive site planning and design.
4. Encourage public education and participation in environmental protection.
5. Help build communities based on environmental stewardship.
6. Reduce construction and maintenance costs of the stormwater infrastructure.
7. Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multifunctional landscape features (bioretention areas, swales, and conservation areas); mimic or replicate hydrologic functions; and maintain the ecological/biological integrity of receiving streams.
8. Encourage flexibility in regulations that allows innovative engineering and site planning to promote smart growth principles.
9. Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

The practices of LID have grown over the last 15 years and have fostered further study and created additional guidelines for communities and design professionals alike.

CHAPTER 3 - Methodology

Introduction

A major goal for redeveloping existing parking lots with effective stormwater management is to improve the water quality of the watershed. The intent of this study is to improve water quality, while also improving spectator comfort at sports venues. The focus will be on existing facilities, and how retrofitting existing stormwater management systems can be utilized to achieve this goal. The end result will take the shape of a revenue generating stormwater management system.

According to the CWP, large parking lots are an ideal retrofit because "they generate more stormwater runoff and pollutants on a unit area basis than any other land use in a subwatershed" (CWP, 2007, p. 89). By implementing different types of stormwater retrofit techniques, the factors that have disrupted/degraded the watershed over time can be remediated. Retrofitting parking lots with BMP's is not a new process. Large-scale parking lot retrofits have been completed across the county, but limited examples of retrofitting sporting venues have been completed. By analyzing alternative methods of stormwater management and applying those techniques to a hypothetical design study, one can begin to understand the impact of retrofitting large parking lots at sporting venues.

The design study will be performed on a surface parking lot at a sports venue. By understanding how to control or effectively manage the impacts stormwater has on existing parking lots, one can create a set of design strategies for the future. By applying different structural and non-structural retrofit strategies to an existing surface the study will try to understand how to deal with stormwater pollution from large impervious surfaces.

While examples of structural and non-structural BMP's exist in the Kansas City area, no large scale parking lots have implemented retrofitting techniques using BMP's. The lots constructed in the Kansas City area are relatively small (under 100 parking stalls) and parking lots utilizing BMP's have been designed in conjunction with new construction. Due to its age, the Truman Sports Complex has over 20,000 parking spaces on impervious asphalt using traditional stormwater management.

Research Design

The research will focus on four stages of design and implementation. The first step will be to understand the existing planning and design strategies of retrofitting an existing impervious parking surface. By conducting a literature review of planning policies, design, economics, and construction methods, one will be able to understand the standards used to retrofit an impervious parking surface. Secondly, the study will conduct interviews of design professionals and identify the design standards and objectives related to retrofit stormwater strategies. Taking the information gathered from the background, the study will begin to shape and mold the analysis strategies.

Next, the study will use two comparative case studies. The focus of the case study research will be to compare a newly constructed lot versus a lot that has been retrofitted with BMP techniques. The two case studies will have the requirement of being larger-scale parking lots that used retrofitting techniques to reduce and manage the impact of stormwater runoff. By using larger-scale parking lot it will allow one to understand the design standards and objectives of a new lot verses that of a facility that was retrofitted to improve the water quality of the watershed. At the same time, the study will focus on how to create a better environment for spectators of the venue. Unfortunately, a local case study does not exist in the Kansas City metropolitan area, so one will not have the benefit of studying the effects of regional factors in the Midwest.

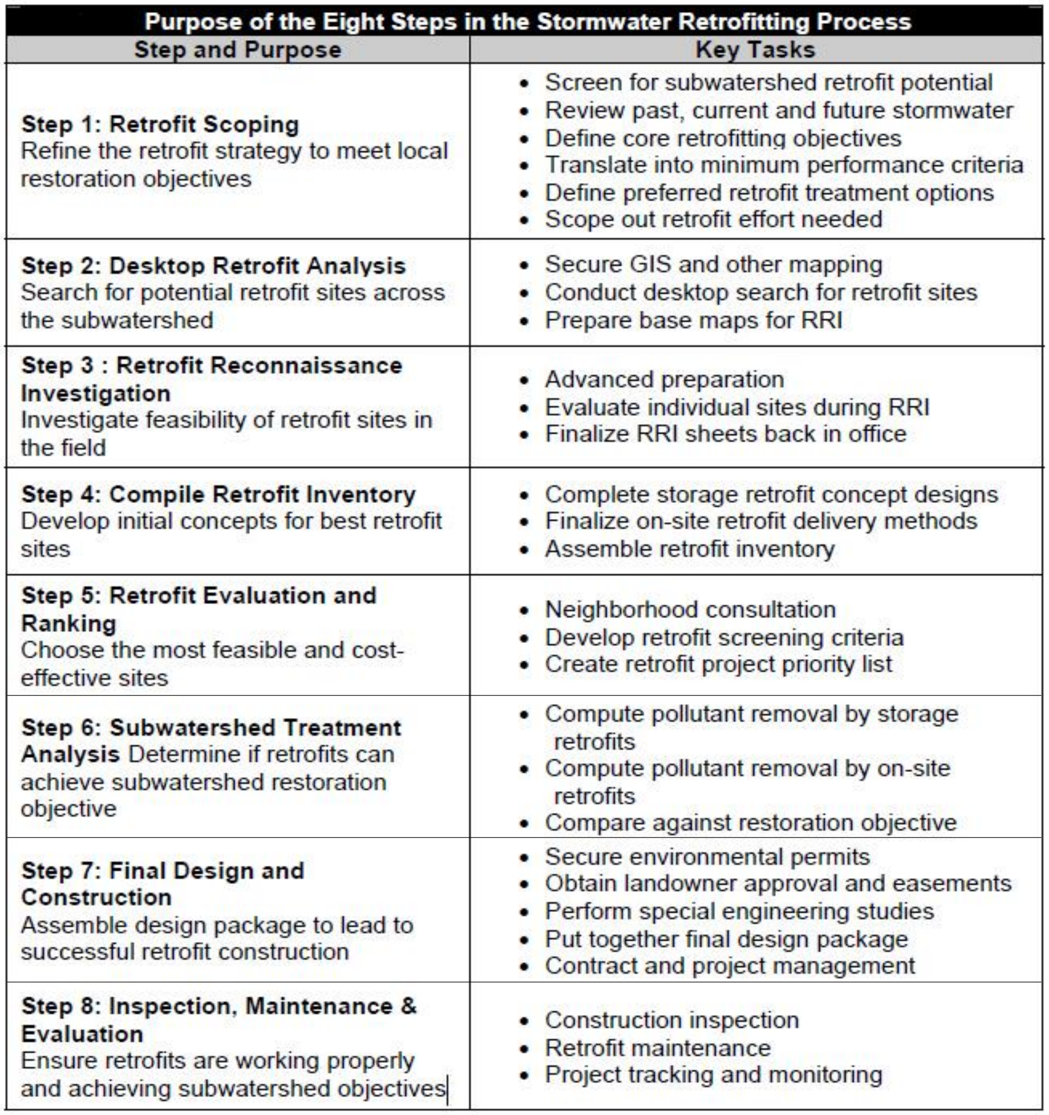
By gaining knowledge through interviews with design professionals that worked on the case study projects, one can understand the retrofit design strategies for the completed project and compare that to new construction. Using a set of analysis tools developed by the CWP, (Table 3-1), the retrofit design strategies will focus on:

1. Site Context
2. Design Opportunities
3. Economics
4. Installations and Maintenance

Finally, the study will take the analysis tools and conduct a comparative analysis of the case studies using a modified version of the *Eight Step Process for Stormwater Retrofitting* (Figure 3-1) defined by the CWP's *Urban Subwatershed Restoration Manual #3*. The stormwater retrofitting process will allow the author to evaluate the proposed design solution's effectiveness of improving water quality. The first three steps in the process deal with information gathering and for this study will be combined into one step, creating a six step process for analysis and evaluation.

Table 3-1, Eight Steps in the Stormwater Retrofitting Process

(CWP, 2007, p. 192)



Purpose of the Eight Steps in the Stormwater Retrofitting Process

Step and Purpose	Key Tasks
Step 1: Retrofit Scoping Refine the retrofit strategy to meet local restoration objectives	• Screen for subwatershed retrofit potential • Review past, current and future stormwater • Define core retrofitting objectives • Translate into minimum performance criteria • Define preferred retrofit treatment options • Scope out retrofit effort needed
Step 2: Desktop Retrofit Analysis Search for potential retrofit sites across the subwatershed	• Secure GIS and other mapping • Conduct desktop search for retrofit sites • Prepare base maps for RRI
Step 3 : Retrofit Reconnaissance Investigation Investigate feasibility of retrofit sites in the field	• Advanced preparation • Evaluate individual sites during RRI • Finalize RRI sheets back in office
Step 4: Compile Retrofit Inventory Develop initial concepts for best retrofit sites	• Complete storage retrofit concept designs • Finalize on-site retrofit delivery methods • Assemble retrofit inventory
Step 5: Retrofit Evaluation and Ranking Choose the most feasible and cost-effective sites	• Neighborhood consultation • Develop retrofit screening criteria • Create retrofit project priority list
Step 6: Subwatershed Treatment Analysis Determine if retrofits can achieve subwatershed restoration objective	• Compute pollutant removal by storage retrofits • Compute pollutant removal by on-site retrofits • Compare against restoration objective
Step 7: Final Design and Construction Assemble design package to lead to successful retrofit construction	• Secure environmental permits • Obtain landowner approval and easements • Perform special engineering studies • Put together final design package • Contract and project management
Step 8: Inspection, Maintenance & Evaluation Ensure retrofits are working properly and achieving subwatershed objectives	• Construction inspection • Retrofit maintenance • Project tracking and monitoring

CWP's manuals represent over two decades of work and provide a sampling of 25 urban watershed retrofits (CWP, 2007). The techniques and process represented in the manual where chosen for its simplistic nature. CWP's Manual #3 defines the retrofitting process and provides the methods necessary to analyze a conceptual retrofit and measure the intended results. Even thought other methods may be appropriate, CWP's six step process was chosen for its in-depth background and focus on retrofitting urban watersheds. By using the analysis method described by the CWP, one can define and understand the relationships between a theoretical retrofit of the Truman Sports Complex and retrofits of a similar nature that have been built.

The end result will be to apply the lessons learned to the study area using the "Design Point Method" to determine retrofit pollutant removal efficiency (CWP, 2007). By using the *Six Step Process for Calculating Pollutant Loads and Pollutant Load Reduction* defined by the CWP's *Urban Subwatershed Restoration Manual #3,* the analysis can evaluate and measure the potential success of a design solution. For comparative purposes, the study will use nine steps to compare the pollutant loads of existing sites versus pollutant loads of a conceptual design solution.

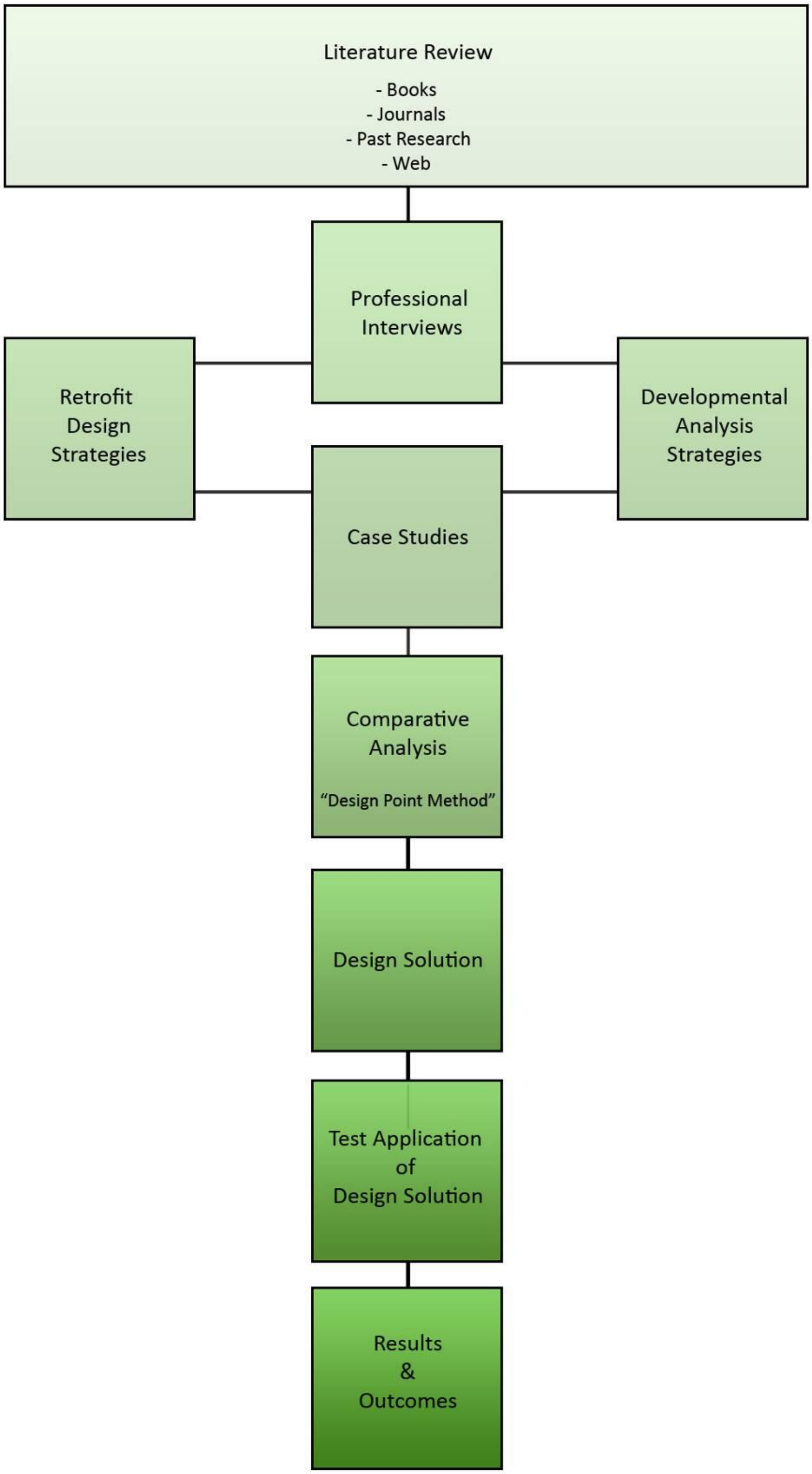


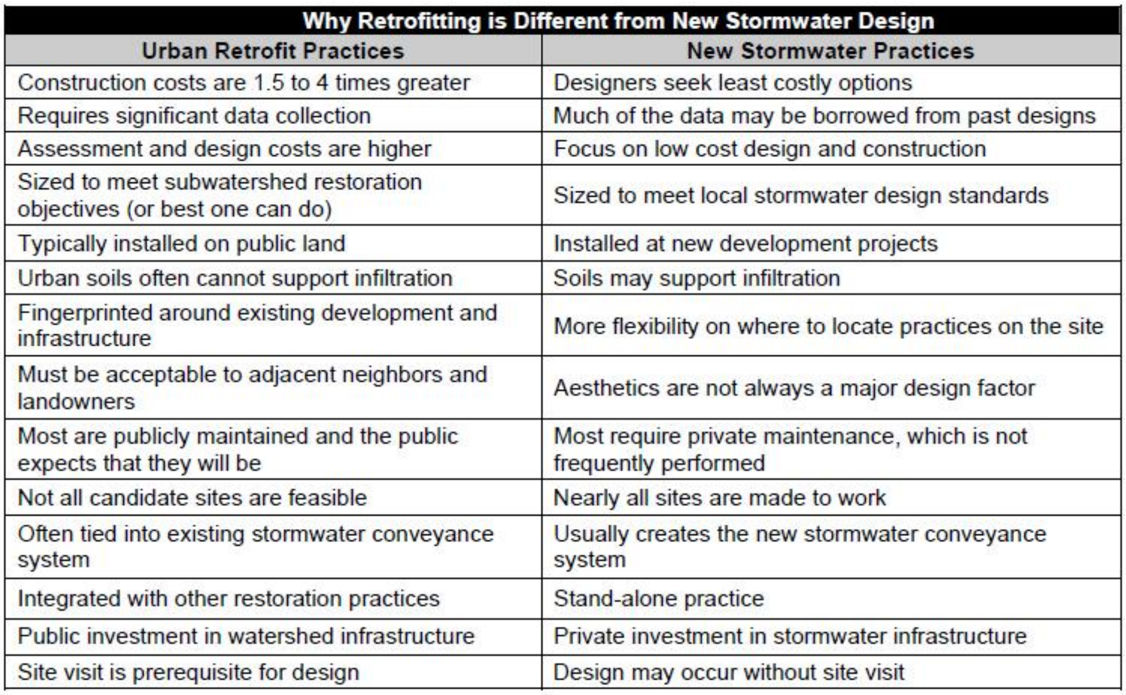
Figure 3-1, Methodology Diagram

Retrofitting Purpose

The ideal scenario of any new facility would be to recreate the natural drainage patterns that existed on site before development. As the knowledge base has grown for stormwater management, LID strategies have become the norm, but time has not stood still over the last 100 years as seen in Figure 3-2. There has been substantial development in the management of stormwater in the urban environment. New developments have fostered the need to created strategies for stormwater management that meets the expectations of a new "green" society. Unfortunately, the creation of "green" development also means that decades of stormwater infrastructure exists that does not meet the current standards of our new "green" society. But what happens to existing facilities? Ideally, existing facilities would be eliminated but cost, timing, and a basic understanding of how stormwater infrastructure works doesn't make elimination plausible. Stormwater retrofitting becomes so critical to the reduction of stormwater pollution and improvement of water quality. Table 3-2 outlines the core differences between constructing new stormwater infrastructure verses that of urban retrofit practices.

Figure 3-2, Channelized Stormwater Management (http://www.greatlakes.org/Page.aspx?pid=1027, 2010)

Table 3-2 Why Retrofitting is Different from New Stormwater Design, (CWP, 2007, p. 3)



Why Retrofitting is Different from New Stormwater Design

Urban Retrofit Practices	New Stormwater Practices
Construction costs are 1.5 to 4 times greater	Designers seek least costly options
Requires significant data collection	Much of the data may be borrowed from past designs
Assessment and design costs are higher	Focus on low cost design and construction
Sized to meet subwatershed restoration objectives (or best one can do)	Sized to meet local stormwater design standards
Typically installed on public land	Installed at new development projects
Urban soils often cannot support infiltration	Soils may support infiltration
Fingerprinted around existing development and infrastructure	More flexibility on where to locate practices on the site
Must be acceptable to adjacent neighbors and landowners	Aesthetics are not always a major design factor
Most are publicly maintained and the public expects that they will be	Most require private maintenance, which is not frequently performed
Not all candidate sites are feasible	Nearly all sites are made to work
Often tied into existing stormwater conveyance system	Usually creates the new stormwater conveyance system
Integrated with other restoration practices	Stand-alone practice
Public investment in watershed infrastructure	Private investment in stormwater infrastructure
Site visit is prerequisite for design	Design may occur without site visit

The biggest problem facing most municipalities is that "stormwater treatment systems were built long before federal and state water quality regulations became more stringent" (Rafter, 2008, p. 1). Most communities just ran stormwater into the closest body of water without even a thought towards treatment. NPDES regulations have improved the way stormwater is treated on site and the permit process for new development. NPDES regulations force new developments to treat stormwater on site, but, unfortunately, the regulations don't totally solve the treatment problems of older developments.

According to Jim Lenhart, Chief Technology Officer with Contech Stormwater Solutions, "there is no reason to have a stormwater treatment system if they don't do the job either because of aging or because they weren't installed properly in the first place" (Rafter, 2008, p. 3). In essence, without retrofitting or substantially improving the existing stormwater infrastructure, the benefits of building new systems will not be fully utilized because the problems just keep moving from one location to the next. There has to be a unified treatment plan that considers old infrastructure along with the new pieces so a holistic solution to stormwater treatment can be formed. Stormwater retrofitting will only become more critical as our existing infrastructure continues to age and our population increases.

Urban Stormwater Retrofit Manual

The CWP has established itself as a leader in defining the standards for protecting and restoring watersheds across the county. For the past 22 years, the organization has worked "to protect, restore, and enhance our streams, rivers, lakes, wetlands, and bays" (CWP, 1998). CWP's goal is to "create viable solutions and partnerships for responsible land and water management so that every community has clean water and healthy natural resources to sustain diverse life" (CWP, 1998).

In the last ten years, CWP has worked in conjunction with the EPA's Office of Wastewater Management to produce a series of 11 Manuals that "describe the techniques to restore small urban watersheds" (CWP, 2007, p. i). *Manual 3, Urban Stormwater Retrofit Practices*, deals with urban stormwater retrofits applied to the subwatershed level. The key to restoring subwatersheds is to create stormwater treatment locations in areas where they did not exist or were ineffective (CWP, 2007). Creating stormwater treatment locations will help restore subwatersheds since they can "remove pollutants, promote more natural hydrology and minimize stream channel erosion" (CWP, 2007, p. 2). The basic retrofit objectives of this manual are to:

- Correct Past Mistakes
- Reduce Flood Damage
- Educate & Demonstrate
- Trap Trash & Floatables
- Reduce Flows to Combined Sewer
- Renovate Stream Corridor
- Remove Pollutant of Concern
- Reduce Bank Erosion
- Support Stream Repair
- Restore Entire Watersheds

The intent of the research is to investigate the use of BMP's that allow for a stormwater retrofit of an existing parking lot at a sports venue.

In addition to the watershed diagnosis, the study seeks to understand the relationship between rainfall and runoff. The rainfall frequency spectrum (Figure 3-3) is used to "define target runoff volumes for retrofitting" a particular site (CWP, 2007, p. 6). This spectrum "describes the average frequency of the depth of rainfall events that occur during a normal year, adjusted for snowfall" (CWP, 2007, p.6).

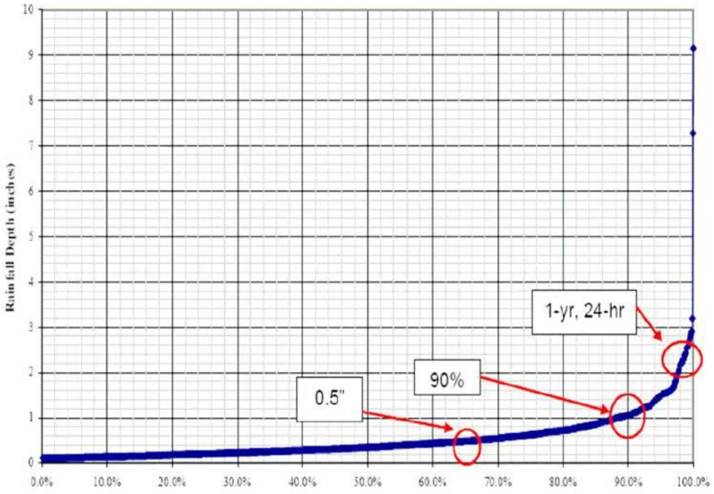


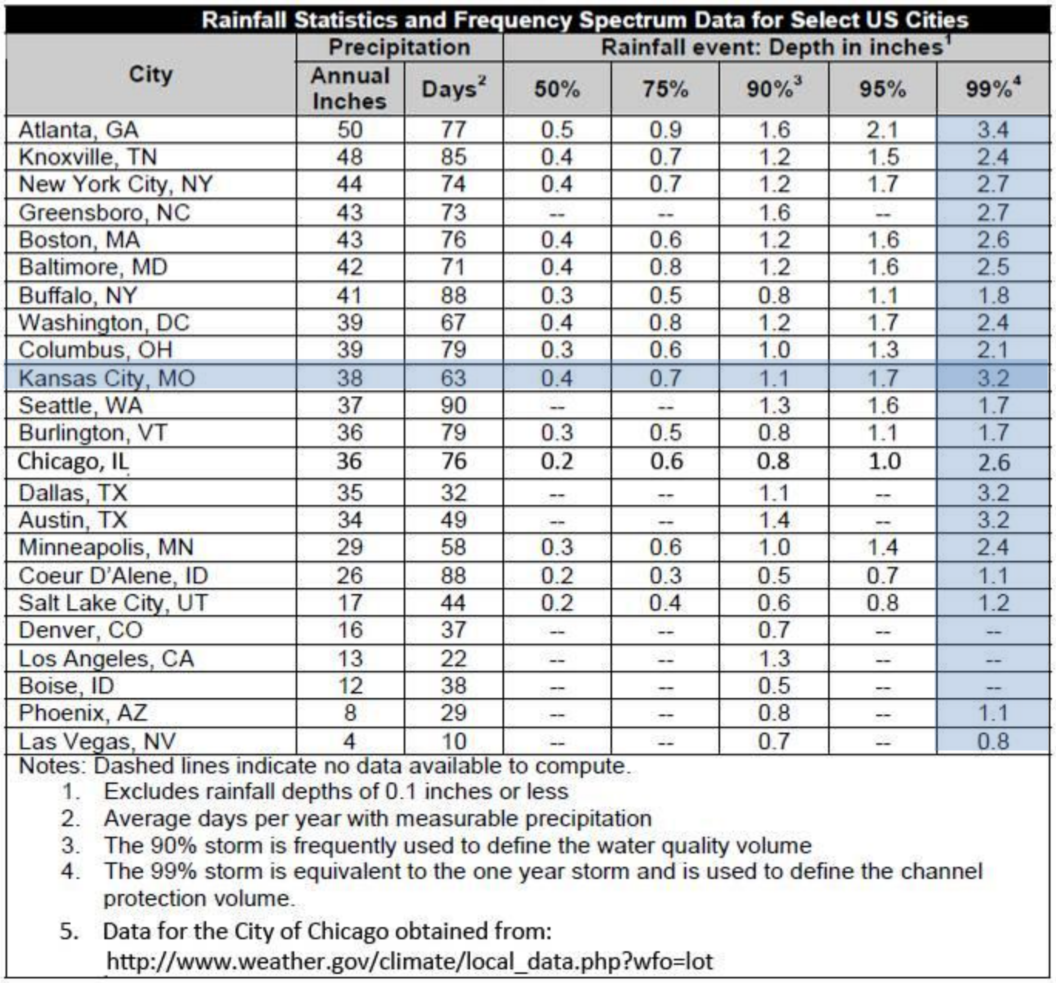
Figure 3-3, Rainfall Frequency Spectrum Example

(CWP, 2007, p. 6)

According to the CWP, the rainfall spectrum“defines the percent of rainfall events that are equal to or less than the indicated rainfall depth” (CWP, 2007, p.7). As we can see from Table 3-3, 90% of the storm events in the Kansas City Area produce about one inch of rainfall. Typically, across the country, 0.8 to 1.21 inches of rain fall annually 90 percent of the time (CWP, 2007). Table 3-3 defines this 90 percent rain event for selected US cities. It is also relatively easy to create a rainfall frequency spectrum for any city using the guidelines provided by the Center for Watershed Protection.

Table 3-3 Rainfall Statistic and Frequency Spectrum Data

(CWP, 2007, p. 7)



Rainfall Statistics and Frequency Spectrum Data for Select US Cities

City	Precipitation		Rainfall event: Depth in inches[1]				
	Annual Inches	Days[2]	50%	75%	90%[3]	95%	99%[4]
Atlanta, GA	50	77	0.5	0.9	1.6	2.1	3.4
Knoxville, TN	48	85	0.4	0.7	1.2	1.5	2.4
New York City, NY	44	74	0.4	0.7	1.2	1.7	2.7
Greensboro, NC	43	73	--	--	1.6	--	2.7
Boston, MA	43	76	0.4	0.6	1.2	1.6	2.6
Baltimore, MD	42	71	0.4	0.8	1.2	1.6	2.5
Buffalo, NY	41	88	0.3	0.5	0.8	1.1	1.8
Washington, DC	39	67	0.4	0.8	1.2	1.7	2.4
Columbus, OH	39	79	0.3	0.6	1.0	1.3	2.1
Kansas City, MO	38	63	0.4	0.7	1.1	1.7	3.2
Seattle, WA	37	90	--	--	1.3	1.6	1.7
Burlington, VT	36	79	0.3	0.5	0.8	1.1	1.7
Chicago, IL	36	76	0.2	0.6	0.8	1.0	2.6
Dallas, TX	35	32	--	--	1.1	--	3.2
Austin, TX	34	49	--	--	1.4	--	3.2
Minneapolis, MN	29	58	0.3	0.6	1.0	1.4	2.4
Coeur D’Alene, ID	26	88	0.2	0.3	0.5	0.7	1.1
Salt Lake City, UT	17	44	0.2	0.4	0.6	0.8	1.2
Denver, CO	16	37	--	--	0.7	--	--
Los Angeles, CA	13	22	--	--	1.3	--	--
Boise, ID	12	38	--	--	0.5	--	--
Phoenix, AZ	8	29	--	--	0.8	--	1.1
Las Vegas, NV	4	10	--	--	0.7	--	0.8

Notes: Dashed lines indicate no data available to compute.

1. Excludes rainfall depths of 0.1 inches or less
2. Average days per year with measurable precipitation
3. The 90% storm is frequently used to define the water quality volume
4. The 99% storm is equivalent to the one year storm and is used to define the channel protection volume.
5. Data for the City of Chicago obtained from: http://www.weather.gov/climate/local_data.php?wfo=lot

The importance of the Rainfall Frequeny Spectrum to the study is that a rain event that occurs 90 percent of the time is used to define water quality volume, while a one year storm (99% storm) is typically used to define channel protection volume (CWP, 2007). It is important to focus on the fact that “surface pollutants are carried off by the first ½-inch to 1-inch of rainfall, or first flush” (Kevern, 2009, p. 11). Highly urbanized land developments typically have large amounts of impervious areas. By focusing on the “first flush” the study will be able to outline potential treatment volumes for water quality.

After the target storm event has been established, one of the biggest challenges is establishing the optimization point for retrofit treatment. Figure 3-4 diagrams the optimal point for retrofit treatment. In essence, the larger the treatment volume, the less likely the site can support the number of retrofit opportunities on site. The optimization point occurs when there are

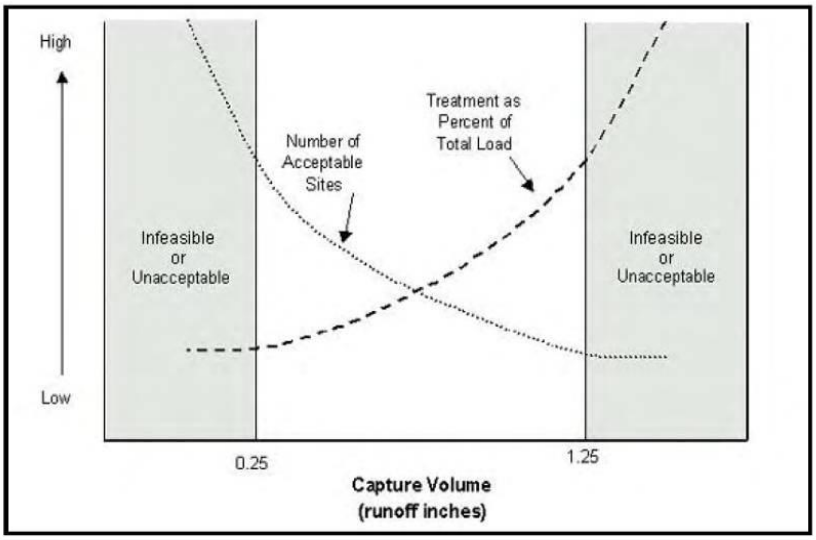


Figure 3-4, Optimization Point for Retrofit Treatment
(CWP, 2007, p. 8)

just enough acceptable retrofit sites to treat the accepted water quality treatment volume. The estimate of water quality volume targets is based on a subwatershed's imperviousness.

Retrofitting Design Strategies

As stated previously, the retrofit design strategies will focus on five issues critical to analyzing the success or failure of implementing a stormwater retrofit to an existing site. The retrofit design strategies will focus on:

1. Site Context
2. Design Opportunities
3. Economics
4. Installation and Maintenance

With the help of Manual 3, *Urban Stormwater Retrofit Practices*, the retrofit strategies define and measure the success of the retrofit practices using the analysis tool, *The Design Point Method*, developed by the CWP.

Site Context - The study explores the site context, what exists on site and defines the parameters of the watershed by its history. By focusing on the diagnosis of a watershed, the study will:

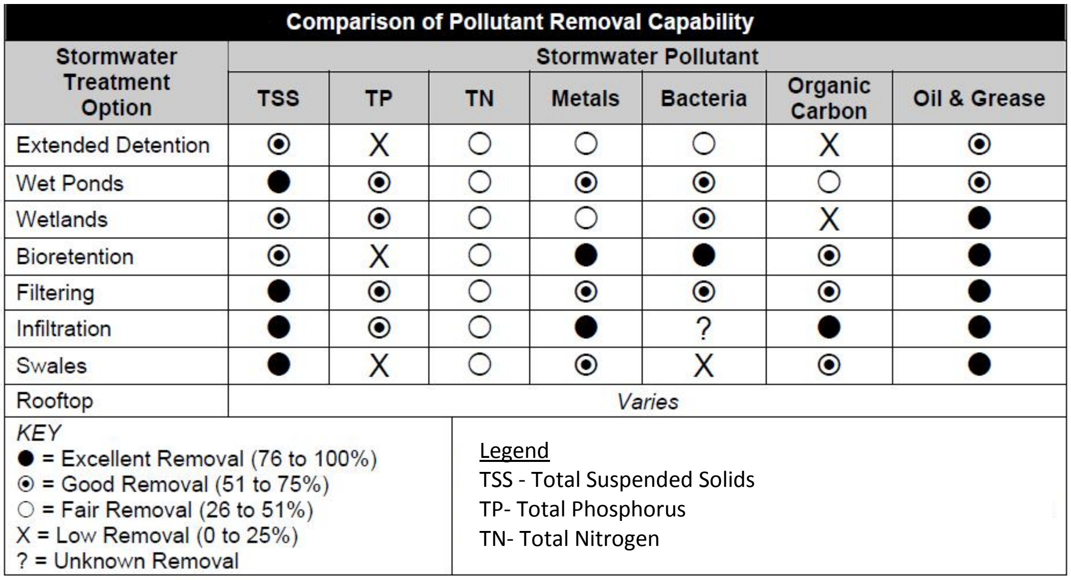
1. Review Past, Current and Future Stormwater Management
2. Define Core Retrofitting Objectives for Subwatershed
3. Translate Objectives into Minimum Retrofit Treatment Performance Criteria
4. Define the Preferred Methods of Retrofit Treatment
5. Estimate Retrofitting Effort Needed in the Subwatershed

Design Opportunities – There are many different ways to redevelop existing surface parking lots through the use of stormwater retrofit techniques. The critical decisions that the study will explore will be to understand what treatment options were used and how the site functions after the established design parameters were implemented. According to the *Urban Subwatershed Restoration Manual* 3, the core retrofitting design strategies for subwatersheds are:

- Extended Detention
- Wet Ponds
- Wetlands
- Bio-retention
- Filters
- Infiltration
- Swales

Once design strategies are defined, they can be analyzed in terms of pollutant load reduction using the information in Table 3-4. The design can focus on the Best Management Practices that would allow the stormwater retrofit to have the greatest possible success from the standpoint of form and function.

Table 3-4 Pollutant Removal Capability, (CWP, 2007, p. 158)



Comparison of Pollutant Removal Capability

Stormwater Treatment Option	Stormwater Pollutant						
	TSS	TP	TN	Metals	Bacteria	Organic Carbon	Oil & Grease
Extended Detention	⦿	X	○	○	○	X	⦿
Wet Ponds	●	⦿	○	⦿	⦿	○	⦿
Wetlands	⦿	⦿	○	○	⦿	X	●
Bioretention	⦿	X	○	●	●	⦿	●
Filtering	●	⦿	○	⦿	⦿	⦿	●
Infiltration	●	⦿	○	●	?	●	●
Swales	●	X	○	⦿	X	⦿	●
Rooftop	*Varies*						

KEY
● = Excellent Removal (76 to 100%)
⦿ = Good Removal (51 to 75%)
○ = Fair Removal (26 to 51%)
X = Low Removal (0 to 25%)
? = Unknown Removal

Legend
TSS - Total Suspended Solids
TP- Total Phosphorus
TN- Total Nitrogen

Economics – New products, technologies, or ideas that have evolved over a period of time create opportunities for new design solutions. The biggest problem new ideas face is a perception of cost. With anything new there is a lack of understanding of how a unique product or technique is applied. Because of this learning curve, there will always be the initial reaction by the construction industry to say, "that costs more." Representative case studies exist that prove nontraditional methods of stormwater management can be done cost effectively, but an economic analysis using comparative cost analysis must be done on any theoretical design to understand the cost impacts of proposed design solution. The economic analysis focuses on comparing the retrofit construction costs to the cost of new construction.

1. Comparative Cost Models
2. Preliminary Cost Estimate
3. Life Cycle Costs

Installation and Maintenance - Installation practices and the maintenance of a project will ultimately shape the success of a project. Ideas are great, but if the design cannot deliver the client expectations, the project will be deemed a failure. The practicality of the design from an installation and maintenance perspective must be assessed by two core goals:

1. Can the proposed design be efficiently and effectively built?
2. How will maintenance be handled to ensure that the proposed design will meet the project goals?

The two core goals will be analyzed against the traditional methods of installation and maintenance and define the success of a project.

Analysis of Stormwater Management

Once the design issues are understood, the analysis or modeling of a proposed stormwater management solution can begin. The site has been defined, the design parameters understood, cost data has been reviewed, and the installation and maintenance procedures have been established. The result is a finalized design solution that reduces pollutant load and improves water quality while enhancing spectator comfort. The only way to thoroughly test a design solution is to put the design through an analysis process that will test the proposed design against the existing conditions using a desktop retrofit analysis as defined in Manual 3. The only modifications to this process will be steps 5 and 6, which will evaluate the design and not a constructed project. The study will not end with physical construction of the intended design, rather hypothetical design that is analyzed.

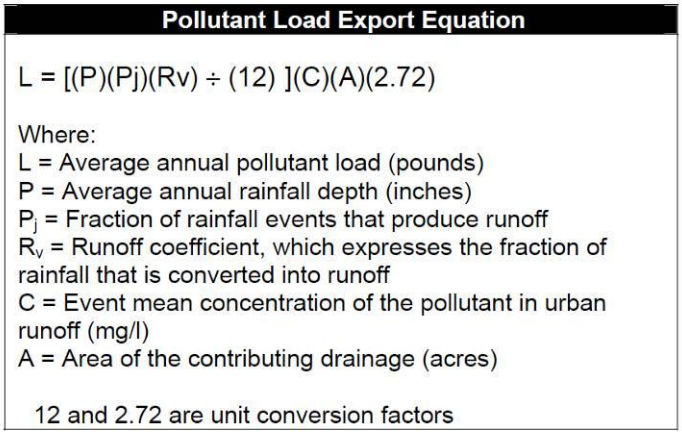
Stormwater Retrofitting Analysis Steps:

1. Retrofit Reconnaissance Investigation
2. Compile Retrofit Inventory
3. Retrofit Evaluation and Ranking
4. Subwatershed Treatment Analysis
5. Final Design
6. Evaluation

While hypothetical in nature, analysis modeling provides a critical step in the development of any proposed design solution. By understanding what has been done in the past, and what could potentially be done to an existing site, one can make informed design decisions. The end result is a set of design criteria that suggests the benefits of the applied design solution.

Design Analysis – "The Design Point Method"

One of the main goals of redeveloping existing parking lots with stormwater management is to improve the water quality of the watershed. Impervious surfaces have disturbed the hydrologic cycle of the watershed and its ability to function naturally. The first step in the Design Point Method is to use the basic principles of the Simple Method. The Simple Method (Figure 3-5) estimates "the annual pollutant load exported in stormwater runoff from small urban catchments" (CWP, 2007). While the manual acknowledges that the Simple Method as an analysis tool sacrifices accuracy due to the fact that it does not use local stormwater quality monitoring data. It does however provide an accurate way to calculate the reduction of pollutant loads on individual stormwater retrofits (CWP, 2007). Figure 3-5, defines how to "calculate the annual pollutant loads exported in pounds per year from the contributing drainage area to a retrofit" (CWP, 2007, p. B-1). It is also important to recognize the Simple method is used to calculate individual retrofits less than one square mile in size. If a watershed is larger than one square mile, a more comprehensive modeling analysis



Pollutant Load Export Equation

$$L = [(P)(Pj)(Rv) \div (12)](C)(A)(2.72)$$

Where:
L = Average annual pollutant load (pounds)
P = Average annual rainfall depth (inches)
P_j = Fraction of rainfall events that produce runoff
R_v = Runoff coefficient, which expresses the fraction of rainfall that is converted into runoff
C = Event mean concentration of the pollutant in urban runoff (mg/l)
A = Area of the contributing drainage (acres)

12 and 2.72 are unit conversion factors

Figure 3-5, Pollutant Removal Capability – "The Simple Method", (CWP, 2007, p. B-1) should take place (CWP, 2007). The study site, Truman Sports Complex has a watershed area of 400 acres (0.625 square miles).

Process – Calculating Pollutant Loads

The Design Point Method uses nine basic steps to calculate pollutant loads before and after a retrofit. The basic steps are:

1. Calculate Site Imperviousness of the Existing Site
2. Calculate the Pre-Retrofit Pollutant Load of the Existing Site
3. Identify the Stormwater Retrofit
4. Calculate Site Imperviousness of the Proposed Design
5. Calculate the Pre-Retrofit Pollutant Load of the Proposed Design
6. Determine the Retrofit Pollutant Removal Efficiency
7. Adjust the Removal Rates
8. Calculate the Post-Retrofit Pollutant Load
9. Calculate the Pollutant Load Reduction of the Retrofit

Calculate Site Imperviousness – Using a simple GIS base map or aerial photography of the study site, a desktop analysis can take place to calculate the sites imperviousness. The CWP defines impervious cover as:

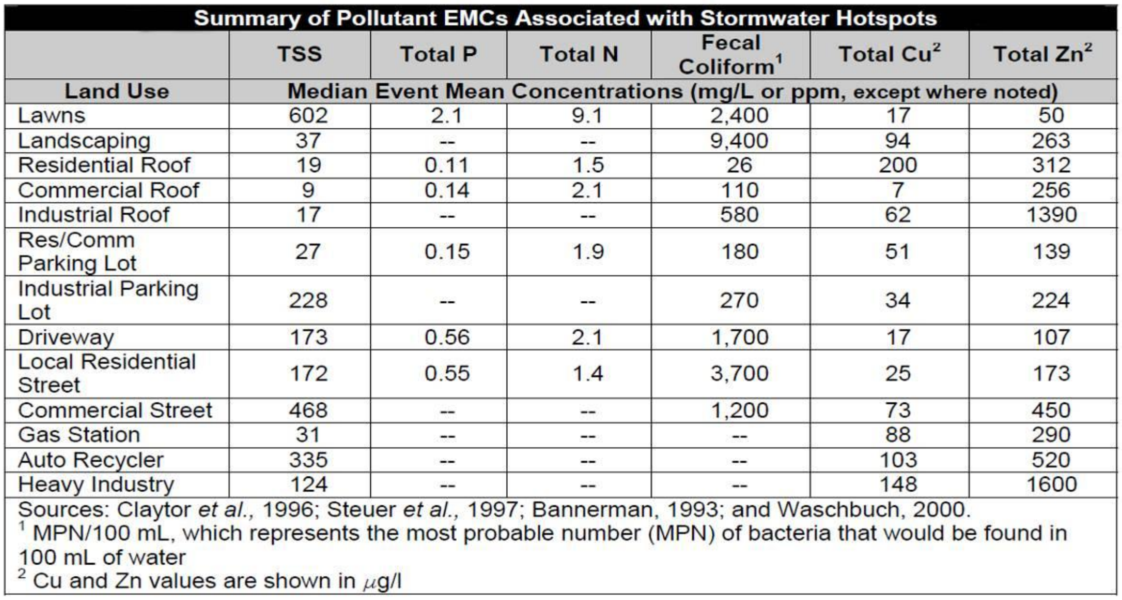
> "any hard surface in the catchment that cannot infiltrate rainfall, such as rooftops, roads, sidewalks, driveways and any other compacted gravel or dirt surfaces. As a general rule, man-made surfaces that are not vegetated should be considered impervious" (CWP, 2007, p. B-4).

It is important to realize that unless impervious cover is removed, a sites imperviousness will remain the same after a retrofit is complete.

Calculate the Pre-Retrofit Pollutant Load - The next step is to identify the pollutant load that currently exists on site. Using the Simple Method (Figure 3-5) the average annual pollutant load prior to retrofitting options can be calculated. The Simple Method allows one to understand what types of pollutants are typically found on site based on its land use characteristics.

The greatest factor in the pollutant load calculations are the pollutant concentrations (C) represented in the equation. Looking at Table 3-5, the method provides an estimated mean concentration of the stormwater pollutant of concern. It is important to note that the concentration values have been derived from a collection of samples from the National Stormwater Quality Database (NSQD). The concentration values can obviously be more accurate if testing results from monitoring wells can be utilized. For this project, it is not feasible to use monitoring wells due to the conceptual nature of the study, so the values in Table 3-5 will be utilized for the calculations.

Table 3-5, Summary of Pollutant Event Mean Concentrations Associated with Stormwater, (CWP, 2007, p. B-4)



Summary of Pollutant EMCs Associated with Stormwater Hotspots

	TSS	Total P	Total N	Fecal Coliform[1]	Total Cu[2]	Total Zn[2]
Land Use	**Median Event Mean Concentrations (mg/L or ppm, except where noted)**					
Lawns	602	2.1	9.1	2,400	17	50
Landscaping	37	--	--	9,400	94	263
Residential Roof	19	0.11	1.5	26	200	312
Commercial Roof	9	0.14	2.1	110	7	256
Industrial Roof	17	--	--	580	62	1390
Res/Comm Parking Lot	27	0.15	1.9	180	51	139
Industrial Parking Lot	228	--	--	270	34	224
Driveway	173	0.56	2.1	1,700	17	107
Local Residential Street	172	0.55	1.4	3,700	25	173
Commercial Street	468	--	--	1,200	73	450
Gas Station	31	--	--	--	88	290
Auto Recycler	335	--	--	--	103	520
Heavy Industry	124	--	--	--	148	1600

Sources: Claytor *et al.*, 1996; Steuer *et al.*, 1997; Bannerman, 1993; and Waschbuch, 2000.

[1] MPN/100 mL, which represents the most probable number (MPN) of bacteria that would be found in 100 mL of water

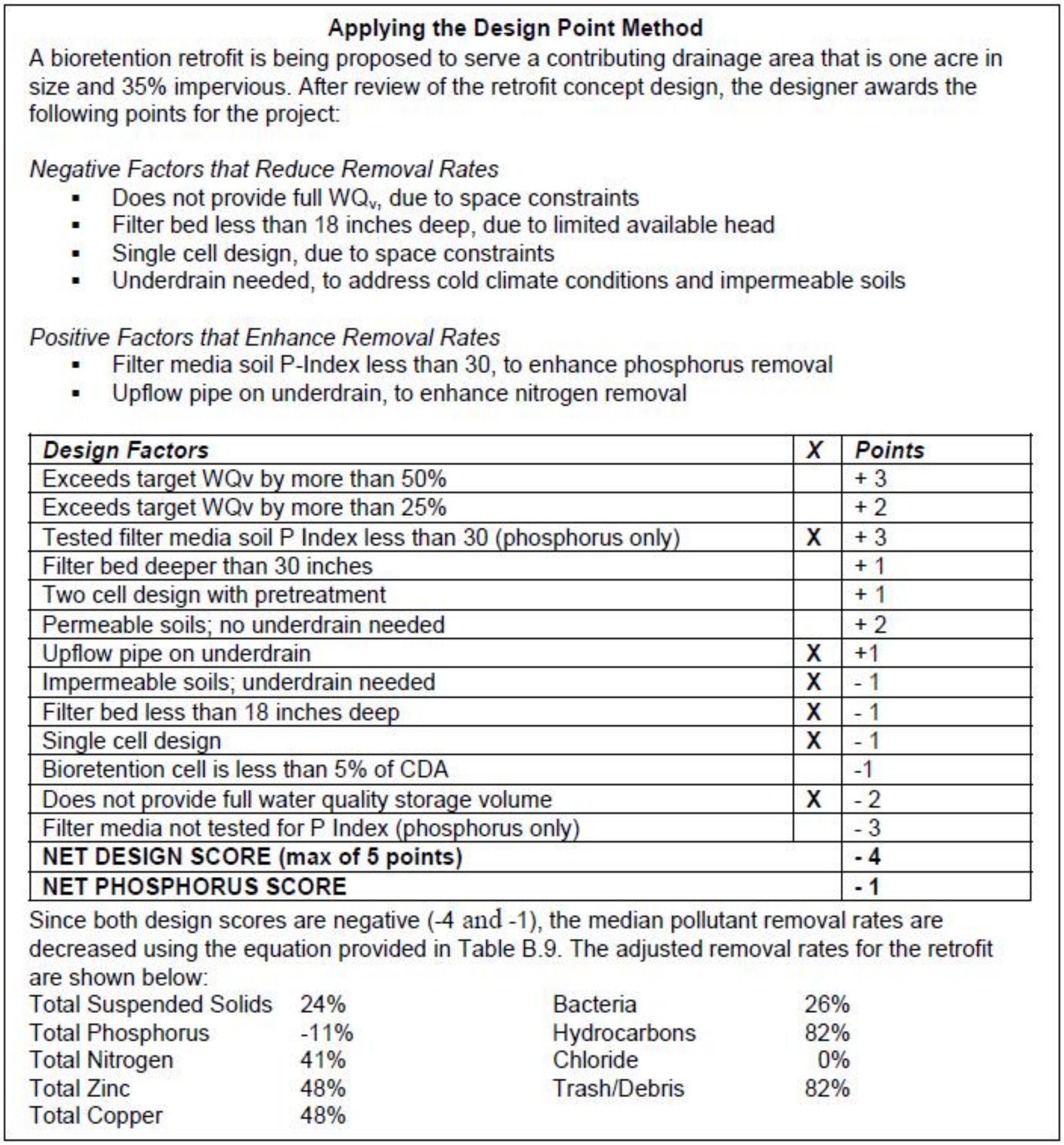
[2] Cu and Zn values are shown in μg/l

Identify the Stormwater Retrofit – The next step in the retrofitting practice is to choose the stormwater treatment option. Using the information gathered by the CWP, there is a range of eight treatment types that can be utilized as retrofitting design strategies (CWP, 2007).

1. Extended Detention
2. Wet Ponds
3. Grass Swales
4. Wetlands
5. Bioretention
6. Filtration
7. Infiltration
8. Swales
9. Other (Green Roofs, Rain Barrels,

Each of the options "differs greatly in its pollutant removal capability, stormwater benefits and retrofit suitability" (CWP, 2007, p. 155). By conducting an analysis of the Truman Sports Complex one can focus on the retrofit strategies and decisions can be made on which type(s) of retrofit to use on the proposed design solution

Determine the Retrofit Pollutant Removal Efficiency - The CWP defines "median pollutant removal rates for each stormwater treatment option" (CWP, 2007, p. 7). Determining retrofit pollutant removal efficiency is the core of the Design Point Method. The biggest influences on pollutant removal rates are the site-specific factors that enhance or reduce the overall effectiveness of the treatment option (CWP, 2007). The basic strategy behind the Design Point Method is to use a predefined series of tables that award points based on certain site specific conditions and design factors that are represented on a retrofit site. By selecting the appropriate treatment technique, the designer can assign a point table(s) based on that score. From that point table the designer can apply the point data into the design point tables (Figure 3-6) and perform the calculations. The design point tables used to establish the point rankings for the stormwater treatment options are shown in Appendix B.



Applying the Design Point Method

A bioretention retrofit is being proposed to serve a contributing drainage area that is one acre in size and 35% impervious. After review of the retrofit concept design, the designer awards the following points for the project:

Negative Factors that Reduce Removal Rates

- Does not provide full WQ_v, due to space constraints
- Filter bed less than 18 inches deep, due to limited available head
- Single cell design, due to space constraints
- Underdrain needed, to address cold climate conditions and impermeable soils

Positive Factors that Enhance Removal Rates

- Filter media soil P-Index less than 30, to enhance phosphorus removal
- Upflow pipe on underdrain, to enhance nitrogen removal

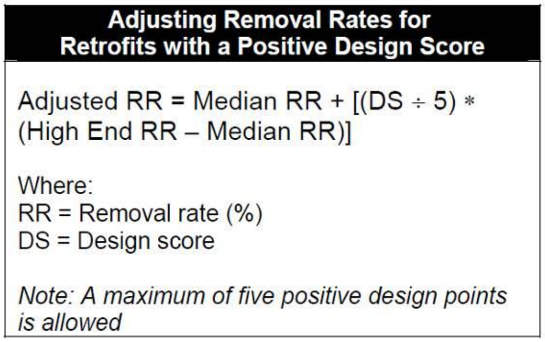
Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested filter media soil P Index less than 30 (phosphorus only)	**X**	+ 3
Filter bed deeper than 30 inches		+ 1
Two cell design with pretreatment		+ 1
Permeable soils; no underdrain needed		+ 2
Upflow pipe on underdrain	**X**	+1
Impermeable soils; underdrain needed	**X**	- 1
Filter bed less than 18 inches deep	**X**	- 1
Single cell design	**X**	- 1
Bioretention cell is less than 5% of CDA		-1
Does not provide full water quality storage volume	**X**	- 2
Filter media not tested for P Index (phosphorus only)		- 3
NET DESIGN SCORE (max of 5 points)		**- 4**
NET PHOSPHORUS SCORE		**- 1**

Since both design scores are negative (-4 and -1), the median pollutant removal rates are decreased using the equation provided in Table B.9. The adjusted removal rates for the retrofit are shown below:

Total Suspended Solids	24%	Bacteria	26%
Total Phosphorus	-11%	Hydrocarbons	82%
Total Nitrogen	41%	Chloride	0%
Total Zinc	48%	Trash/Debris	82%
Total Copper	48%		

Figure 3-6, Sample Design Point Table, (CWP, 2007, B-6)

Adjusting the Removal Rates - If the design score is positive, the equation shown in Figure 3-7 is used to increase the removal rate for the pollutant of concern. If the design score is negative, the equation shown in Figure 3-8 is used to decrease the removal rate for the pollutant of concern.



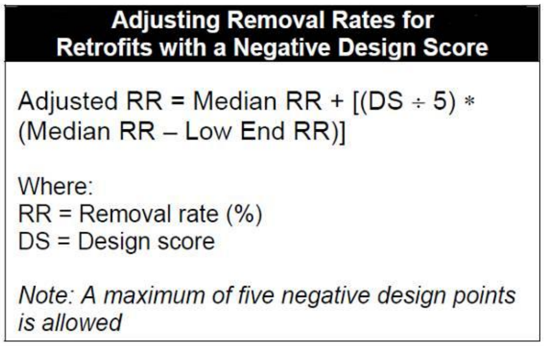
Adjusting Removal Rates for Retrofits with a Positive Design Score

Adjusted RR = Median RR + [(DS ÷ 5) * (High End RR – Median RR)]

Where:
RR = Removal rate (%)
DS = Design score

Note: A maximum of five positive design points is allowed

Figure 3-7, Adjusting Removal Rates for Retrofits with a Positive Design Score (CWP, 2007, p. B-6)



Adjusting Removal Rates for Retrofits with a Negative Design Score

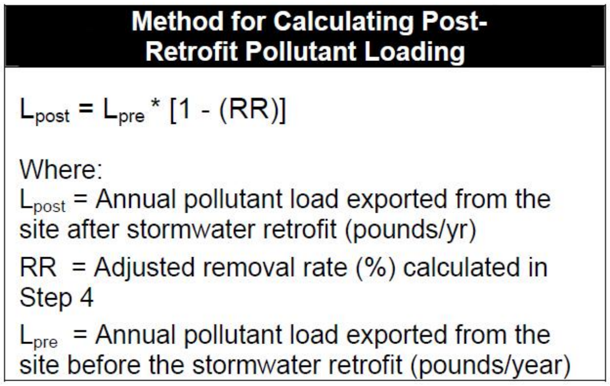
Adjusted RR = Median RR + [(DS ÷ 5) * (Median RR – Low End RR)]

Where:
RR = Removal rate (%)
DS = Design score

Note: A maximum of five negative design points is allowed

Figure 3-8, Adjusting Removal Rates for Retrofits with a Negative Design Score (CWP, 2007, p. B-6)

Calculate the Post-Retrofit Pollutant Load – The fifth step in the design point method is to calculate the post-retrofit pollutant load exported from the drainage area. The drainage area that is contributing to the retrofit and the equation determines annual amount of pollutant load that can be expected once the retrofit is complete (CWP, 2007). Figure 3-9 defines the equation for calculating the post retrofit pollutant load.



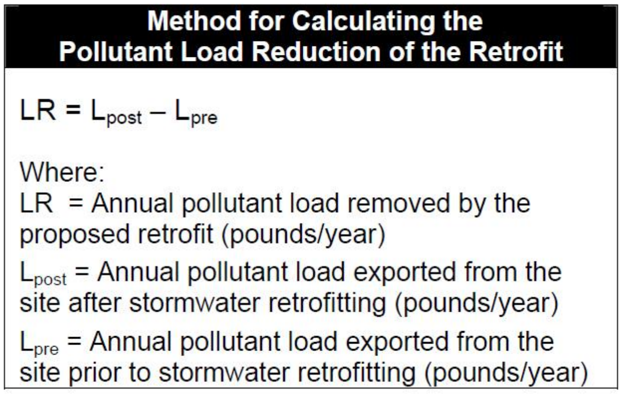
Method for Calculating Post-Retrofit Pollutant Loading

$L_{post} = L_{pre} * [1 - (RR)]$

Where:
L_{post} = Annual pollutant load exported from the site after stormwater retrofit (pounds/yr)
RR = Adjusted removal rate (%) calculated in Step 4
L_{pre} = Annual pollutant load exported from the site before the stormwater retrofit (pounds/year)

Figure 3-9, Calculating Post-Retrofit Pollutant Loading, (CWP, 2007, p. B-7)

Calculate the Pollutant Load reduction of the Retrofit – The final step in the process is to calculate how effective the retrofit was in reducing the pollutant load. Using Figure 3-10, the design simply subtracts the predetermined pollutant load before the retrofit process from the post retrofit pollutant load. The outcome is the annual pollutant load removed by the proposed retrofit (CWP, 2007). It is important to note that the analysis process determines the possible treatment types for the proposed design. Any retrofit strategy will have to test the different treatment types to determine the best overall retrofit solution.



Method for Calculating the Pollutant Load Reduction of the Retrofit

$LR = L_{post} – L_{pre}$

Where:
LR = Annual pollutant load removed by the proposed retrofit (pounds/year)
L_{post} = Annual pollutant load exported from the site after stormwater retrofitting (pounds/year)
L_{pre} = Annual pollutant load exported from the site prior to stormwater retrofitting (pounds/year)

Figure 3-10, Calculating Pollutant Load Reduction of the Retrofit (CWP, 2007, p. B-7)

Case Study Research

Case Study 1 – "Retrofitted Lot" - Northgate Mall, Seattle Washington

Site Context - The parking lot design for Northgate Mall in Seattle, Washington is like many of the malls you would see across the country, except for the parking lot on the west side of the mall. This 20-acre parking lot retrofit is an example of how private development can meet the needs of sustainable design. Northgate Mall is located north of downtown Seattle, Washington (Figure 3-11 & Figure 3-12) in the area of Seattle commonly known as 'Northgate District.' Today, roughly 75,000 people live in Thornton Creek watershed that ultimately drains into Lake Washington.

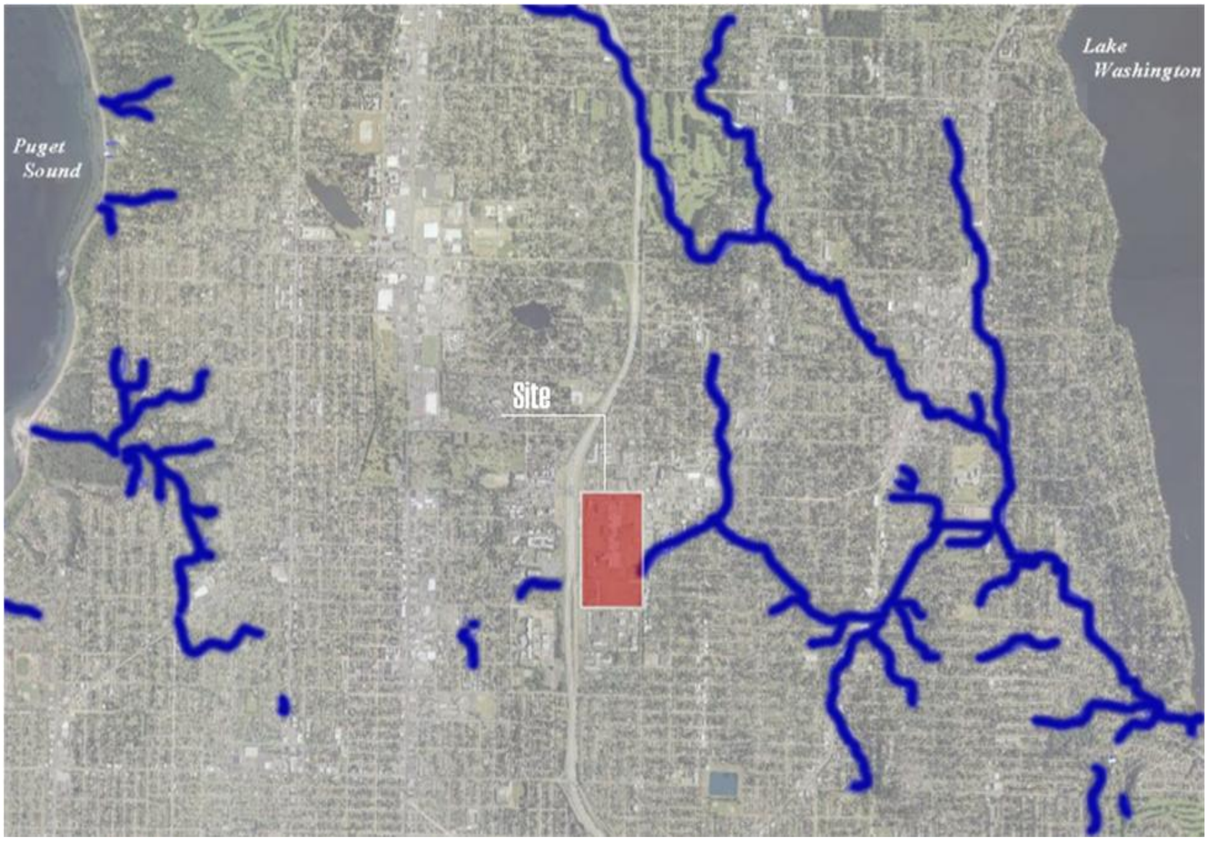


Figure 3-11, Northgate Mall Site Location (Google Earth, 2010, Adapted by Author)

Figure 3-12, Aerial of Northgate Mall & Thornton Creek Water Quality Channel,

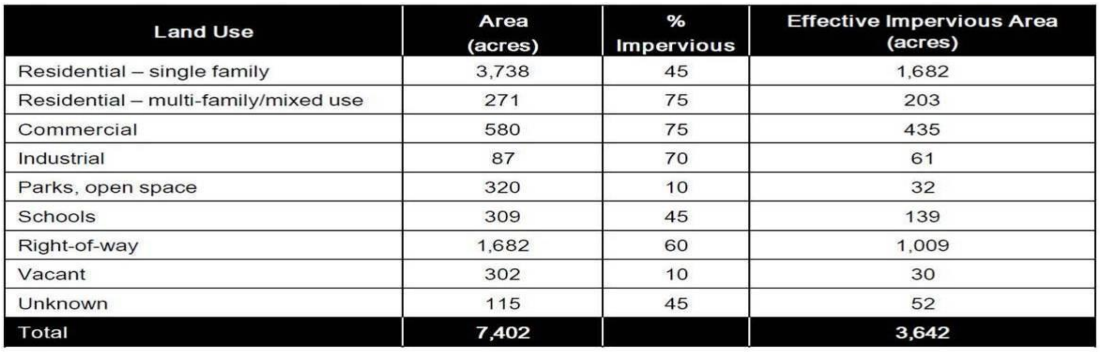
(Google Earth, 2009, Adapted by Author)

Built in 1950, the mall was hyped as the first mall in the United States (Cheek, 2007). Originally an 'outdoor' mall open to the sky, the current version has since been enclosed and has the typical mix of large anchor stores intermixed with smaller 'boutique' style retail. As the mall grew so did the surrounding suburban area and it expanded into one of Seattle's largest watersheds, Thornton Creek Watershed.

In the 1950's people did not really think about the environmental impacts of paving over a creek with a parking lot. It was the perfect solution to solving the Northgate Mall drainage problems. Why build detention or retention areas when there is perfectly good stream to drain the mall parking lots. What was "once a bog that settlers mined for peat well into the 1900's" had now become a part of Seattle's largest remaining open channel streams (Holt, 2006). Thus, the entire 64-acre mall site was draining into Thornton Creek.

The Thornton Creek Watershed is made up of roughly 7,402 acres of highly developed urban land (SPU, 2000). Of these 7,402 acres, 3,642 acres, or nearly half of the watershed is covered by impervious surfaces (Table 3-6). The mall site itself sits on the north branch of Thornton Creek in a subwatershed of roughly 640 acres.

Table 3-6, Amounts of Impervious Surface in Thornton Creek Watershed (by Land Use)
(Seattle Public Utilities, 2000, p. 3-44)



Land Use	Area (acres)	% Impervious	Effective Impervious Area (acres)
Residential – single family	3,738	45	1,682
Residential – multi-family/mixed use	271	75	203
Commercial	580	75	435
Industrial	87	70	61
Parks, open space	320	10	32
Schools	309	45	139
Right-of-way	1,682	60	1,009
Vacant	302	10	30
Unknown	115	45	52
Total	7,402		3,642

The main source of pollution to Thornton Creek is urban runoff. Although population has increased, the watershed is almost completely built out, and land use has not changed significantly in the last 13 years (Tackett, personal comm., 2009).
The City's stormwater utility, the Drainage and Wastewater Utility, was formed in 1987. The utility's responsibility is to regulate stormwater, manage the existing conveyance system, alleviate flooding, and mitigate water pollution (SPU, 2000).

In 1997, Thornton Creek was one of 22 Puget Sound lowland streams studied by the University of Washington to assess the cumulative effects of urbanization on streams. Researchers examined instream characteristics, riparian conditions, physio-chemical water quality, and biological attributes. Thornton Creek represented the watershed with the highest level of urbanization, measured by percentage of impervious surface area within watershed boundaries (SPU, 2000).

In the Thornton Creek watershed there are many sources of non-point pollution. The most problematic is urban runoff that carries pollutants from roads, buildings, parking lots, parks, and other areas (SPU, 2000). The three main elements that create pollutant sources for the mall parking lot are:

> ***Street and Parking Lot Deposition*** - In urban areas, street and parking lot deposition frequently is a major source and collector of urban runoff pollution. Such deposited materials may include street dirt and litter. Pollutants frequently bind to dirt particles. Street dirt may arise from traffic, road deterioration, vegetative residue, and decomposed litter. Litter includes cans, glass, paper, cigarette butts, and garbage. Vegetation, animal excrement, dead animals, automotive fluids, and spilled or improper disposal of solid and liquid wastes generated from household or commercial activities onto the streets are picked up when it rains and contribute to polluted or contaminated runoff (SPU, 2000, p.9-2).

> ***Vehicles -*** Internal combustion engine exhaust emits primarily dust-sized particles containing hydrocarbons. Many other pollutants are deposited into the environment by automobiles and trucks. Fluids such as oil and antifreeze leak onto roadways, worn metals and brake pads deposit toxic mineral dusts onto roads, tires wear and deposit rubber particles, poorly maintained vehicles drip oils and other automotive fluids onto street surfaces, and various solids and fluids are rinsed from vehicles and the loads they transport. These fluids and solids are rinsed from roadways and other impervious areas when precipitation falls, which results in polluted creeks and tributaries. Residential car washing also contributes soap and other chemicals to the storm system and Thornton Creek (SPU, 2000, p.9-2).
>
> ***Excessive Storm Flows -*** High levels of impervious surface contribute to high storm flows in the stream. Stream banks and beds and ditches also erode due to increased stream velocities during periods of heavy rainfall. Turbidity and sediment problems are caused (SPU, 2000, p.9-2).

According to Tracy Tackett (personal communication, 2009), Green Stormwater Infrastructure Program Manager for the City, the four main municipal laws and regulations affecting water quality and habitat in the Thornton Creek watershed are:

- Stormwater, Grading and Drainage Control Ordinance and related best management practices
- Permit Review Process/Seattle’s Land Use Code
- State Environmental Policy Act (SEPA)
- Environmentally Critical Areas (ECA) Ordinance

The biggest hurdle came in the spring of 1998 when the mall’s real estate developer created a master plan to expand Northgate Mall’s footprint and add more impervious surfaces to the development. The community was not in favor of the mall expansion. With the creek passing through many residential areas in the neighborhood, the community wanted to put a halt to the mall dumping its stormwater directly into the creek (Figure 3-13) that caused damaging floods to many of the surrounding properties (Tackett, personal comm., 2009).

In 1993, Northgate residents published a plan to redevelop Northgate Mall and the surrounding development as a "pedestrian-friendly urban center" (Boyer, 2005). The plan was deemed the "Northgate Area Comprehensive Plan", and the City as the future for the Northgate development eventually adopted it. Six years later, Simon Properties Inc., submitted a developmental master plan to the City of Seattle for the one million square foot expansion of the mall over the next 15 years. The plan included:

Figure 3-13, Storm Drain, Northgate Mall (Boyer, http://seattletimes.nwsource.com/ABPub/zoom/html/2002280398.html, 2005)

- A Hotel
- 30 Screen Cinema
- Office Space
- Retail
- Transit Plaza
- 450 Residential Apartments.
- 3 New Structured Parking Garages
-

The community members were appalled by the proposed plan. The two core issues that violated the Northgate Area Comprehensive Plan were:

1. The automobile-centric nature of the Simon development plan.

2. The potential rerouting of Thornton Creek's, which now flows under the south parking lot of the mall.

The lack of “pedestrian-friendly” spaces created by the redevelopment plan was frustrating to the neighborhood because there were already large asphalt lots surrounding the development. The new development was just adding more impervious surface to the watershed and not taking steps to improve the stormwater management on site. The proposal to reroute a section of stormwater pipe around the proposed development would only lead to more flooding downstream and not solve any of the community issues (Nabbefeld, 1999).

Since the pipe was actually a leg of Thornton Creek that had been channelized, it became problematic for the developer to ‘technically’ move the creek to a new location because of city requirements. The developers sought a variance from the city and that outraged the community even more due to the salmon run reestablishment project planned in the lower portions of Thornton Creek (Boyer, 2005). Lawsuits and petitions would follow and the legal process created a 10-year debate on the future of Northgate Mall (Nabbefeld, 1999). The neighborhood, developer and city were at an impasse.

Finally in 2003, things turned around when the Mayor and the City Council struck the deal to try to revive Northgate's development (Boyer, 2005). The city was committed to build a new library and community center north of the Mall, so they sought developers' commitments to build housing and make the area more pedestrian-friendly. By streamlining the Northgate building-permit process and setting up “an advisory panel of neighborhood groups, environmentalists, developers and property owners,” the City helped to shape the plans to meet the neighborhoods needs (Boyer, 2005).

The core retrofitting objectives that were specifically addressed dealt with two points of contention for the community: the lack of pedestrian connections, and the channelization of Thornton Creek. To address the concerns, the Mall Developer sold off part of the development property to the City of Seattle. The City became the prime developer for the residential mixed-use development (Boyer, 2005). In exchange the City would use the former parking lot site to create a residential mixed used development that would center on a green space. That green space would become the Thornton Creek Channel and the surrounding stormwater management system that was developed in conjunction with the expansion of the Northgate Shopping Mall would help to transform the Thornton Creek Watershed (Boyer, 2005).

The City felt that if they could fix the stormwater management problems on site by creating the Thornton Creek Chanel (Figure 3-14, 3-15). Creating the chanel would also solve the stormwater management problems for the lower branch of the Thornton Creek at no cost to the Northgate Mall developer. Seattle Public Utilities was then charged with the task to build the Thornton Creek Channel on 2.7 acres of land that cuts diagonally through the Residential Development.

Figure 3-14, Thornton Creek Channel
(Seattle Public Utilities, 2009, p. 6)

The project will divert stormwater from Northgate Mall through channelized landscape with soil and native plants to filter the water and slow it down before it reaches Thornton Creek. Surrounding surface lots from the Northgate Mall expansion would also flow from the stormwater connection points to the channel (Tackett, personal comm., 2009). But the city felt like it needed to do more to treat the large amount of impervious parking lot surface with a stormwater management system that would treat the lots before going to the drainage channel.

Figure 3-15, Thornton Creek Channel

(Seattle Public Utilities, 2009, p. 16)

According to Tracy Tackett, the sheer volume of the surface lots themselves created a need to slow down the water before it reached Thornton Creek Channel. "ninety-eight percent of Seattle's rainfall occurs at the one year storm event," and that according to Tackett has a large impact on downstream aquatic life (Tackett, personal comm., 2009). With the focus on the one-year storm, the City of Seattle established the Natural Drainage Systems Program Goals. These goals were defined as:

- Control small storms to protect aquatic biota.
- Control one to two year storms to prevent channel erosion.
- Improve Water Quality by Reducing:

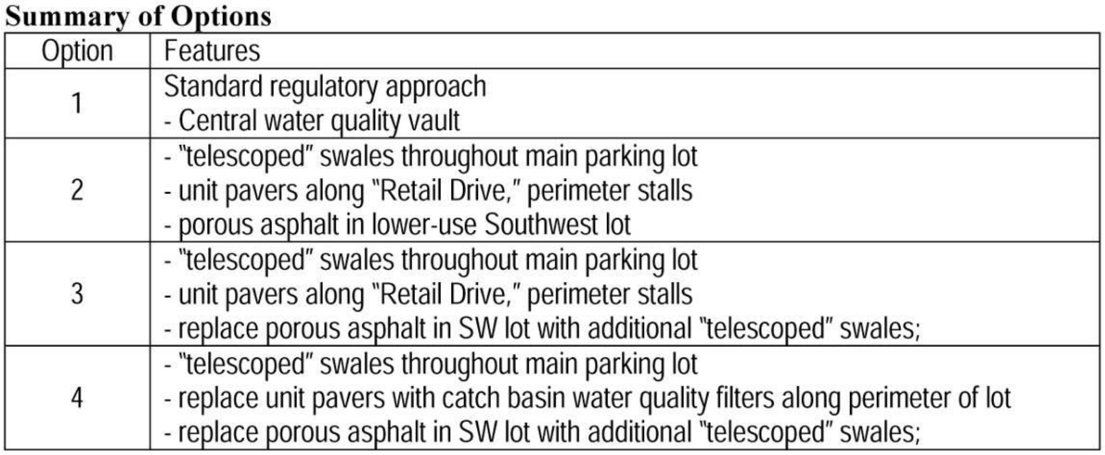
  Petroleum Hydrocarbons,
  Metals (copper, lead, zinc),
  Fecal Coliform,
  Pesticides & Herbicides
  Nitrogen
  Water Temperature,
  pH

With such a huge pushback from the community over the salmon runs, the City wanted to make sure all the new development functioned as one cohesive plan from a stormwater management perspective. At the center of this plan was a 63-acre mall development staring the city directly in the face. The mall developer and the city had come to an agreement that the mall would not lose one space from the proposed original agreement. The City went back to the drawing board and analyzed their options (Table 3-6) on how they could best create a system within an existing parking lot that would treat stormwater on site and not lose one single parking space.

The engineering firm of KPFF was hired by the city to perform an analysis of options for the city. The options in Table 3-7 represent a summary of KPFF's findings. According to David Schwartz, it wasn't until they put the economics of the analysis with the summary of the options that it became clear to everyone involved that treating the lots with a non-traditional approach to stormwater management provided better design and drainage benefits. The other substantial benefit was that it also proved to be very cost effective (Schwartz, personal comm., 2009).

Table 3-7, Summary of Northgate Mall Design Options

(City of Seattle, 2005, p. 2)



Summary of Options

Option	Features
1	Standard regulatory approach - Central water quality vault
2	- "telescoped" swales throughout main parking lot - unit pavers along "Retail Drive," perimeter stalls - porous asphalt in lower-use Southwest lot
3	- "telescoped" swales throughout main parking lot - unit pavers along "Retail Drive," perimeter stalls - replace porous asphalt in SW lot with additional "telescoped" swales;
4	- "telescoped" swales throughout main parking lot - replace unit pavers with catch basin water quality filters along perimeter of lot - replace porous asphalt in SW lot with additional "telescoped" swales;

Design Strategies - The central retrofitting objective for the project was the creation of the "Telescoping" swales (Fig 3-16). The idea behind the swales came from an analysis of how a mall parking lot functions on a daily basis. For most of the year a mall parking lot will never reach capacity. Only a portion of the parking lot will be used

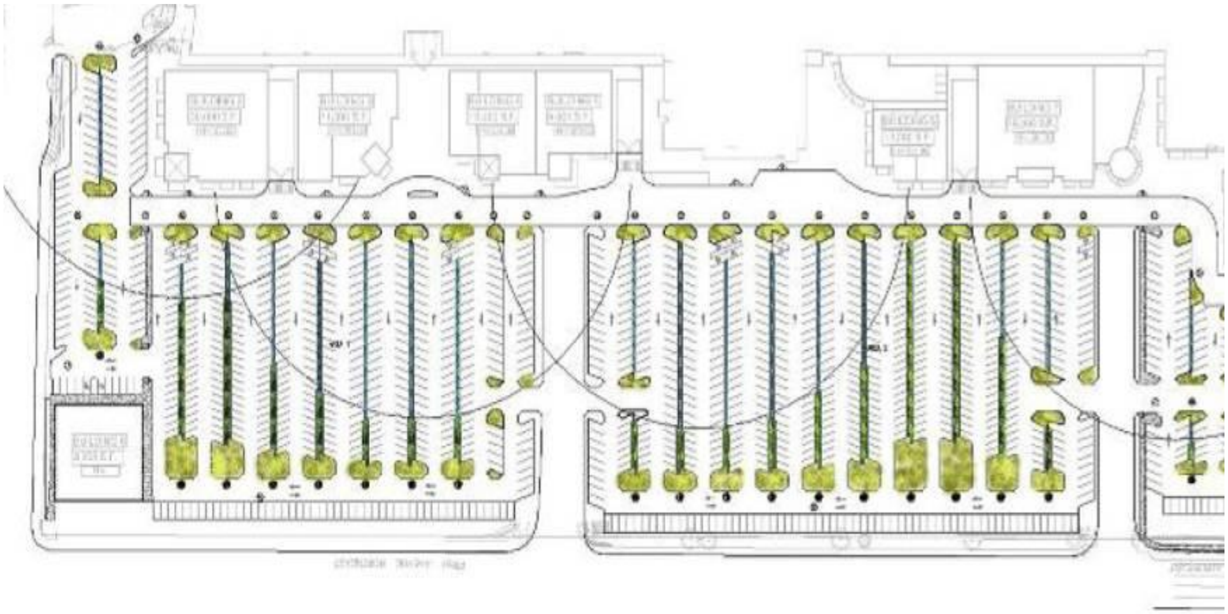


Figure 3-16, Plan of Northgate Mall, Design solution utilized a 250 radius to establish parking relationships to mall entry points.

(SVR Design, http://www.svrdesign.com/docs/MontgomeryCo%20-%20Planning%20and%20Design%20-%20Applied%20LID%20Techniques.pdf, 2005).

while the rest of the lot will remain empty. Only during peak shopping events will the lot be full.

Using the analysis of use as a guide, designers came up with a radial pattern that provided more space for traditional shoppers on a daily basis, while taking space away from areas of the lot that were used less frequently.   The swale design (Figure 3-17 & 3-18) was then formulated around that idea and with the use of four basic retrofit concepts the City was able to meet their stormwater management goals.

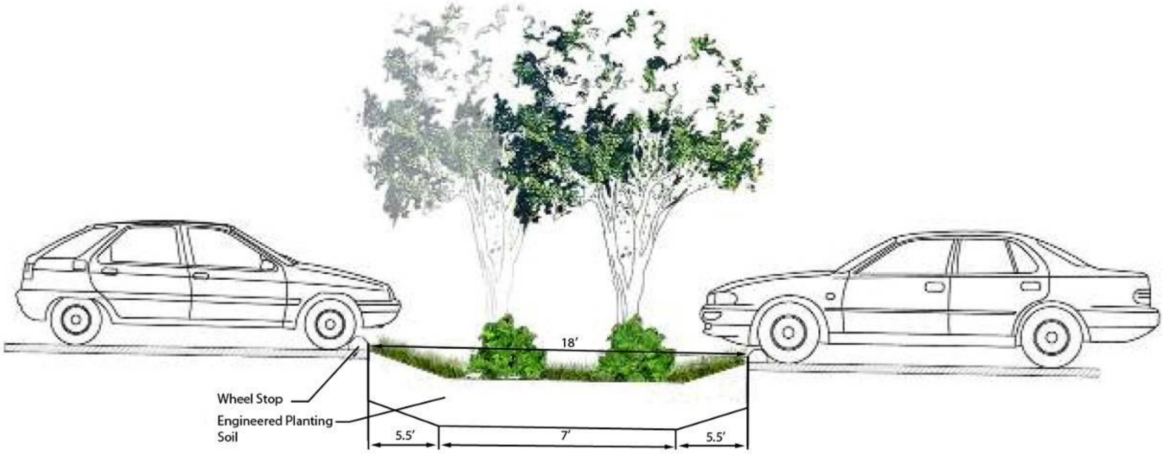


Figure 3-17, Section of "Telescoping Swale"
(SVR Design, http://www.svrdesign.com/docs/MontgomeryCo%20-%20Planning%20and%20Design%20-%20Applied%20LID%20Techniques.pdf, 2005).

The components of the project were:

1. Telescoping Vegetated Swales - A series of increasingly larger landscape cells (i.e. bioswales, strands) for filtration, infiltration and sedimentation prior to discharge
2. Biofiltration Planters - Vegetated open channels or swales that infiltrate and transport runoff water

3. Clarification pond/Raingarden - Ponds that supplement storage and pollutant removal

The construction techniques for the swale consisted of a "slope towards a mid point and consists of soil, vegetation, rocks and trees" Tackett, personal comm., 2009). The green space nearest the mall processes water, but most of the treatment happens in the larger sections. The curb cuts in the parking lot also allow water to flow from the parking surface into the swales for filtration. Soil medium in the swales then "naturally treats any oil cars have left, on the pavement. The water eventually filters into the ground and into the Thornton Creek Channel" (Tackett, personal comm., 2009). The whole system was a process that allowed the development to creatively manage its stormwater treatment system in a complex urban watershed.

Figure 3-18, "Telescoping Swale", (Tracy Tackett, 2009).

Economics - The total cost of the project was roughly six million dollars. While there were skeptics at first, the Seattle Public Utilities staff determined that

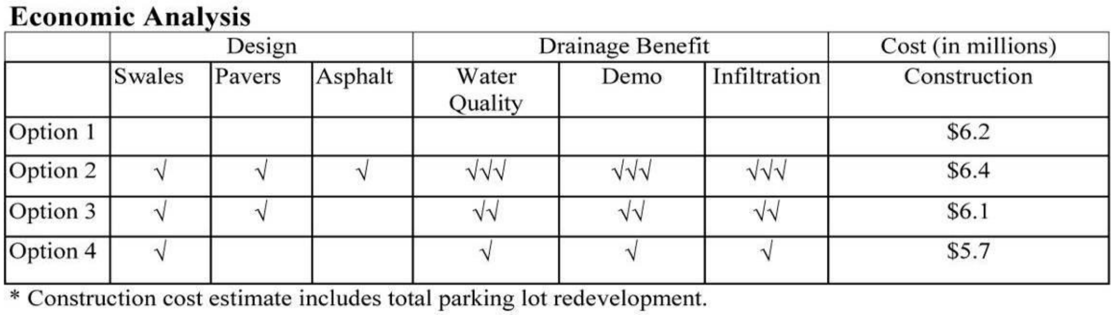
> "a natural drainage approach is not only feasible in parking lot redevelopment, but can provide additional drainage and aesthetic benefits not realized by a traditional code compliance approach. In addition, the team determined that if a project has water quality requirements, a natural drainage approach can be about 12% less

> expensive. The team concluded that swales are generally less cost per acre than porous pavement. The use of porous pavement reduces total impervious surface on the site and, in the case of unit pavers, can offer other benefits such as improved aesthetics, pedestrian way-finding, and traffic calming" (City of Seattle, 2005).

The use of a natural drainage approach was critical for the client to understand from a cost benefit analysis. According to Tackett, the swales also meet their stormwater management goals when it came to capacities, so they were also able to save money by not having to introduce large areas of other stormwater management techniques like porous pavement, or some type of unit paving. Looking at Table 3-8, it became relatively obvious that constructing the swales (Figure 3-19) would offer the best opportunity for improving water quality for the site.

Table 3-8, Economic Analysis of Northgate Mall Design Options,

(City of Seattle, 2005, p. 2)



Economic Analysis

	Design			Drainage Benefit			Cost (in millions)
	Swales	Pavers	Asphalt	Water Quality	Demo	Infiltration	Construction
Option 1							$6.2
Option 2	√	√	√	√√√	√√√	√√√	$6.4
Option 3	√	√		√√	√√	√√	$6.1
Option 4	√			√	√	√	$5.7

* Construction cost estimate includes total parking lot redevelopment.

Figure 3-19, Aerial Oblique "Telescoping Swale"

(Microsoft Visual Earth, 2009)

Another benefit according to Tackett was the life cycle costs. Traditional asphalt has to be periodically repaired and replaced. Eliminating areas of traditional asphalt and replacing the areas with native plant material (Figure 3-20) will save on the yearly maintenance costs for the lot. The use of permeable concrete pavers was also considered and its use would have added to the life cycle of the lot. Ultimately permeable concrete pavers were never used because it was proven that the swales could treat the parking lot independently of any other stormwater management technique, thus saving the project money. Another step in the analysis process that must be weighed before carrying out the intended design is to determine the feasibility of installation and maintenance.

Figure 3-20, "Telescoping Swale"
(Tracy Tackett, 2009)

Installation/Maintenance – Like any facility, maintenance will always serve as a critical control measure for a project's success. Can the project physically be built on site as designed and provide the intended treatment functions? If a facility is poorly maintained, the original design intent will never be achieved. After a design has been carried out, the long-term success will be judged on how well the facility functions with the intended design program. Maintenance usually has a lot to do with how successful any facility meets the expectations of a client.

The biggest ongoing maintenance issue for Northgate Mall will be maintaining the swales themselves (Figure 3-21) to ensure that they function properly. The stormwater treatment capacity is directly related to having living plant material in the swales. According to Tackett, the project used the Washington State Department of Ecology's guidelines for a standard biofiltration swale installation. By specifying grasses that are 4-6 inches in height the design was able to meet its target water quality treatment flow depth of 2-3 feet (SPU, 2000). Native plant materials by nature take care of themselves, but according to Tackett the initial installation is critical and has to be monitored correctly to insure that plants become established. Once the plant material is established, yearly maintenance of trimming back the native plant material is all that is required.

Figure 3-21, Aerial View 'Telescoping Swale" (Google Earth, 2009).

Lessons Learned – According to Tackett, there were three major lessons that the City learned during the construction phase and through post occupancy evaluation. These were:

- A curb system needs to have structural integrity to act as a wheel stop or have sufficient soil behind the curb to act as a structural member. Wheel stops were 'value engineered' out of the project, but nothing was replaced from a design standpoint that replaced the wheel stops.

- The lack of walking paths or sidewalks next to the bio-swale. The thought through the design process was that people would walk down the drive aisles towards the shopping center. That didn't entirely happen every time and as a result that plant material in the bio-swale has suffered from constant pedestrian traffic.

- The construction techniques of retrofitting an existing lot needs to be monitored and areas where existing conditions meet renovated conditions have to be detailed correctly. The construction sequence was not properly thought through and the bio-swales were built at the end of the project. This created some steep slopes in the swale itself but also undermined the existing asphalt lot. Settlement then created some undesirable low points in the parking lot that didn't allow the drainage to work correctly.

Analysis – Retrofitting large parking lots for the enhanced treatment of stormwater is not new. The design and implementation can be applied too most existing conditions creating a practical yet effective stormwater management system. According to Tackett, retrofits in the Seattle area are:

- Practical
- Demonstrated results
- Installed examples now common place
- Accepted practice with many jurisdictions
- Accepted treatment by the public
- Value added

The master plan for the "Urban Center" for the community of Northgate represents how a number of different stormwater treatment practices can come together and influence the way projects treat stormwater. Ultimately, most projects are not that complex, but the ideas and practices learned with this re-development can be applied to about any parking lot. Fortunately, the City, developer, and community all came together to create something that benefited everyone.

Northgate Mall Case Study Calculations

Step 1 – Calculate Site Imperviousness of the Existing Site – The existing mall site (Figure 3-22) is made up of roughly 841,142 square feet (19.31 acres) of area (Table 3-9). Of this area, 777,546 square feet was defined as impervious surface area primarily made up of buildings, asphalt parking lots and concrete sidewalks. The mall, as expected, had very little permeable surface. Of the 63,598 square feet (1.46 acres) of pervious surface, none of this area was used for stormwater treatment. The design of the parking lots themselves was a traditional mix of asphalt with high and low points that directed surface runoff to the catch basins located throughout the site. The interior lots were made up of asphalt.

Table 3-9, Northgate Mall Existing Site Imperviousness,
(Authors Calculations, 2010)

Step 1: Calculate Site Imperviousness				
Using a base map (Figure 3-23) calculate the areas below				
Site Size	19.31 AC	841,144	Sq. Ft.	Percentage of Total Site Area
Impervious Area	17.85 Ac	777,546	Sq. Ft.	92.47%
Pervious Services	1.46 Ac	63,598	Sq. Ft.	7.56%
Total Area	19.31 Ac	841,144	Sq. Ft.	100%

Looking at calculations, the mall site before retrofitting was made up of 92.47 percent of impervious area. The pervious surface, which made up only 7.56 percent of the total, was mostly landscape parking islands. While the pervious surface does not look like it would have a huge impact on the site, it is critical to understand the special relationships between pervious and impervious surfaces and how they impact the storage potential on site.   With a limited amount of pervious area, the design team had to develop creative solutions to deal with storage locations.

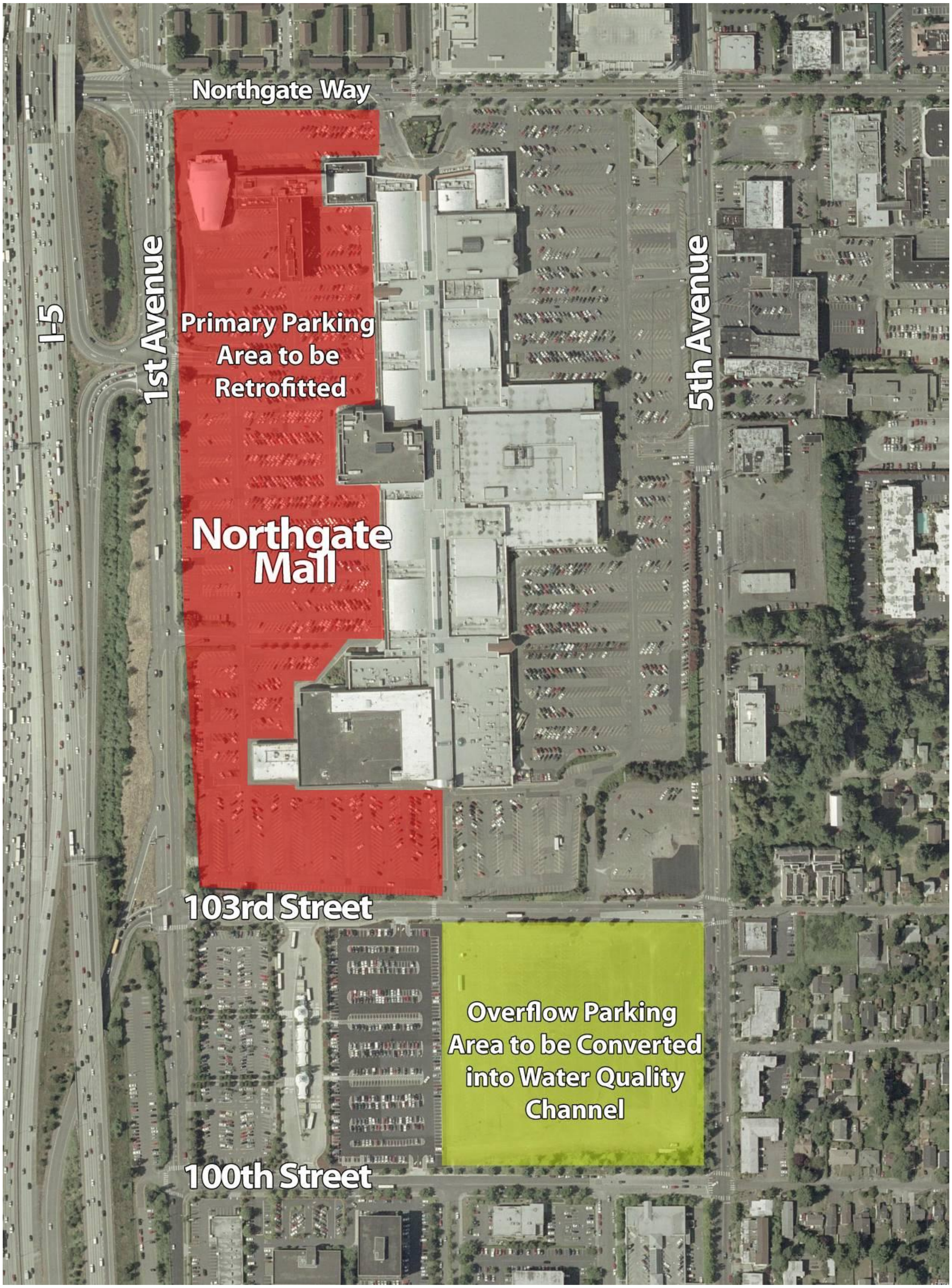


Figure 3-22, Northgate Mall before Retrofit – Seattle, WA. Photo shows existing parking lot on the west side of the mall and overflow lot to the south of mall. (Google Earth, 2009).

Figure 3-23, Northgate Mall after Retrofit – Seattle, WA. Photo shows the two parking lot retrofit projects that were constructed. (Google Earth, 2009).

Step 2 – Calculate Pre-Retrofit Pollutant Load of the Existing Site - Using the Pollutant Load Export Equation, (Figure 3-6) the average annual pollutant load prior to retrofitting can be calculated. The first step in the process is to define the values for the Pollutant Load Export Equation for each pollutant type. By defining values to the equation allows the analysis to understand what types of pollutants are typically found on-site based on its land use characteristics. According to the CWP and the EPA (CWP, 2007, p.4) the pollutants of concern for large parking lots are:

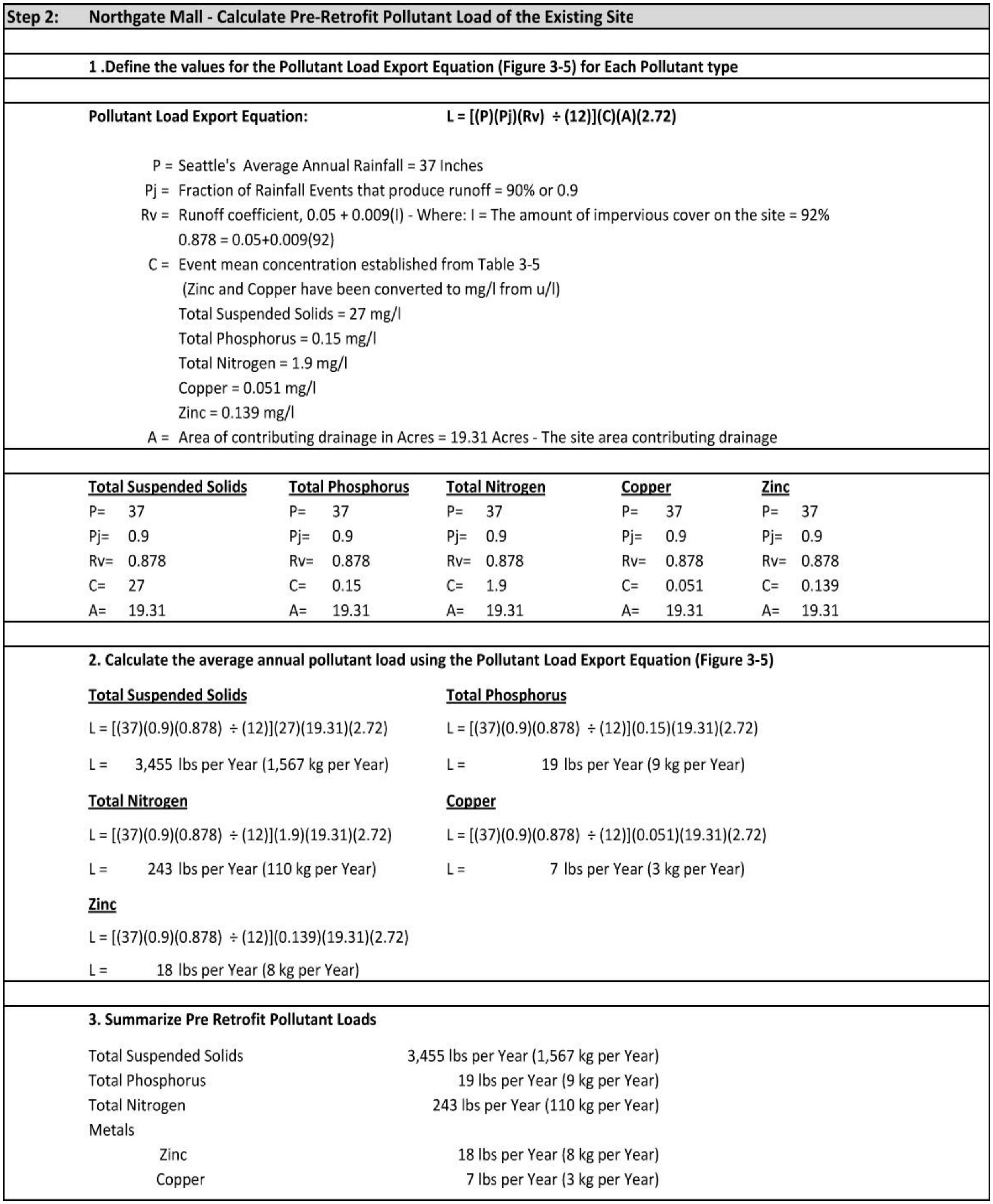
1. Total Suspended Solids
2. Total Phosphorus
3. Total Nitrogen
4. Metals (Zinc & Copper)

It is important to understand that other pollutants, such as hydrocarbons (petroleum such as oil) and trash/debris, typically have the same removal rates as Total Suspended Solids. In most circumstances, hydrocarbons either quickly stick to sediments or they are suspended in stormwater runoff and would have the same removal rates as Total Suspended Solids (CWP, 2007).

Due to the fact that most parking lot retrofits deal with a large amount of impervious surface, it is important to understand what is feasible due to the conceptual nature of the intended research. The maximum treatment area is often constrained by the amount of impervious cover defined on any particular site. Table 3-10 illustrates the process for calculating the pollutant load exported for each pollutant type prior to the retrofit.

Table 3-10, Northgate Mall – Pre-Retrofit Pollutant Load Calculations

(Authors Calculations, 2010)



Step 2: Northgate Mall - Calculate Pre-Retrofit Pollutant Load of the Existing Site

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: **L = [(P)(Pj)(Rv) ÷ (12)](C)(A)(2.72)**

P = Seattle's Average Annual Rainfall = 37 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious cover on the site = 92%
0.878 = 0.05+0.009(92)
C = Event mean concentration established from Table 3-5
(Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 19.31 Acres - The site area contributing drainage

Total Suspended Solids		**Total Phosphorus**		**Total Nitrogen**		**Copper**		**Zinc**	
P=	37	P=	37	P=	37	P=	37	P=	37
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.878	Rv=	0.878	Rv=	0.878	Rv=	0.878	Rv=	0.878
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	19.31	A=	19.31	A=	19.31	A=	19.31	A=	19.31

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

L = [(37)(0.9)(0.878) ÷ (12)](27)(19.31)(2.72)

L = 3,455 lbs per Year (1,567 kg per Year)

Total Phosphorus

L = [(37)(0.9)(0.878) ÷ (12)](0.15)(19.31)(2.72)

L = 19 lbs per Year (9 kg per Year)

Total Nitrogen

L = [(37)(0.9)(0.878) ÷ (12)](1.9)(19.31)(2.72)

L = 243 lbs per Year (110 kg per Year)

Copper

L = [(37)(0.9)(0.878) ÷ (12)](0.051)(19.31)(2.72)

L = 7 lbs per Year (3 kg per Year)

Zinc

L = [(37)(0.9)(0.878) ÷ (12)](0.139)(19.31)(2.72)

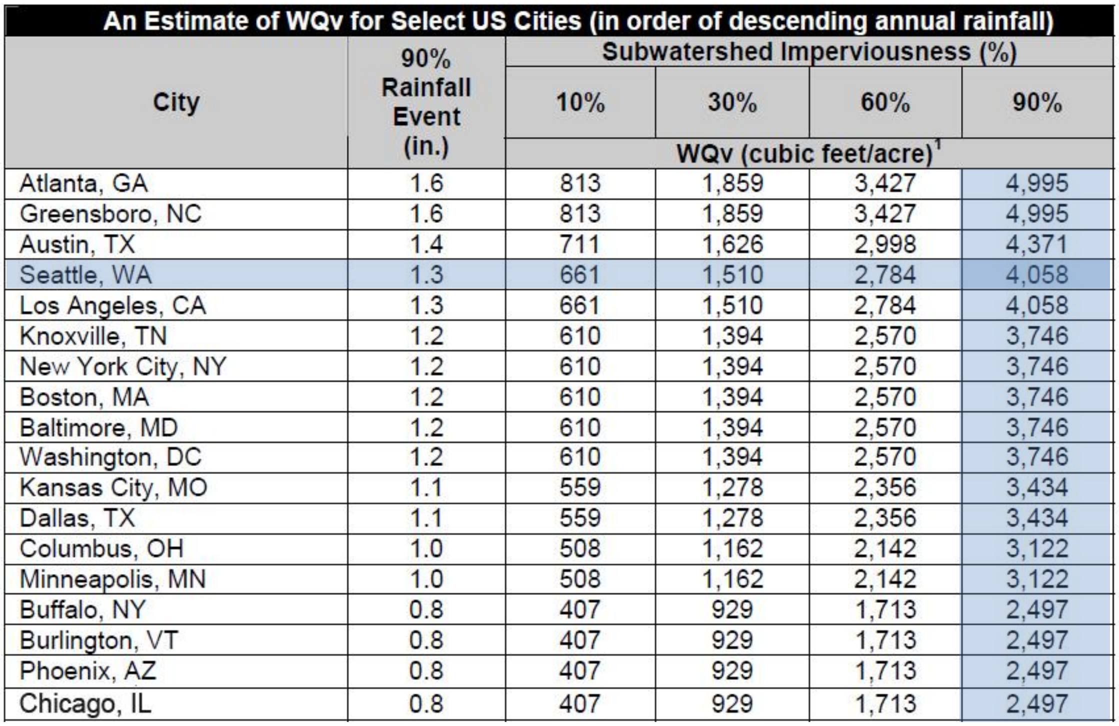
L = 18 lbs per Year (8 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

Total Suspended Solids	3,455 lbs per Year (1,567 kg per Year)
Total Phosphorus	19 lbs per Year (9 kg per Year)
Total Nitrogen	243 lbs per Year (110 kg per Year)
Metals	
Zinc	18 lbs per Year (8 kg per Year)
Copper	7 lbs per Year (3 kg per Year)

In most subwatersheds, it is hard to find enough feasible storage retrofits to treat more than 50 percent of subwatershed area (CWP, 2000). To achieve a higher level of treatment, often onsite retrofits will have to be explored. Because of the high level of impervious surfaces typically found in large parking lots, the focus of the study will be onsite retrofits. Table 3-11 is used to estimate the aggregate Water Quality Volume (WQv) storage needed. The Northgate Mall is in the city of Seattle, Washington, so with an impervious area of around 90 percent, the site would need to treat 4,058 cubic feet of water per acre. At 19.31 acres, the site would have to treat 78,360 cubic feet of stormwater for every 1.3 inches of rain.

Table 3-11, Estimate of WQv for US Cities
(CWP, 2007. p. 7)



An Estimate of WQv for Select US Cities (in order of descending annual rainfall)

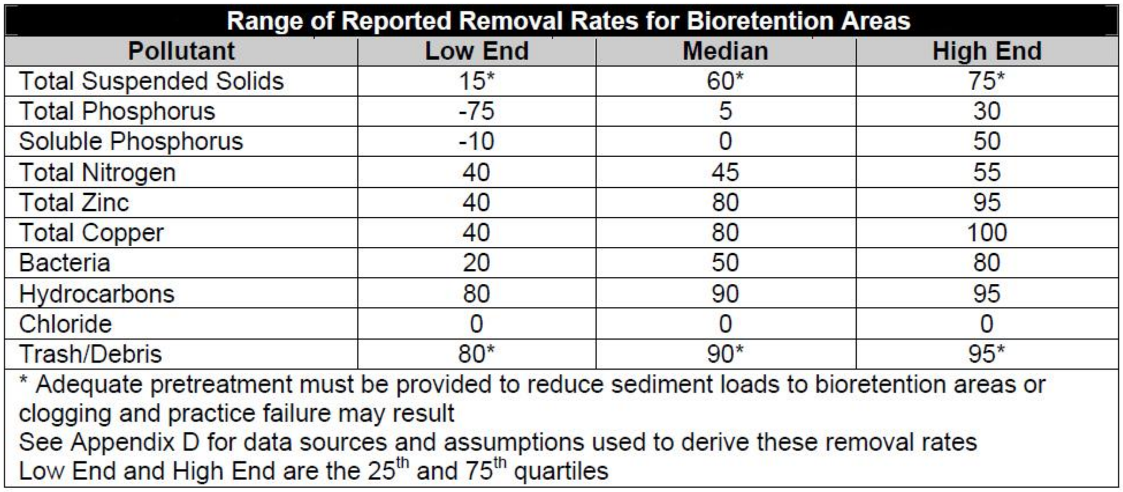
City	90% Rainfall Event (in.)	Subwatershed Imperviousness (%)			
		10%	30%	60%	90%
		WQv (cubic feet/acre)[1]			
Atlanta, GA	1.6	813	1,859	3,427	4,995
Greensboro, NC	1.6	813	1,859	3,427	4,995
Austin, TX	1.4	711	1,626	2,998	4,371
Seattle, WA	1.3	661	1,510	2,784	4,058
Los Angeles, CA	1.3	661	1,510	2,784	4,058
Knoxville, TN	1.2	610	1,394	2,570	3,746
New York City, NY	1.2	610	1,394	2,570	3,746
Boston, MA	1.2	610	1,394	2,570	3,746
Baltimore, MD	1.2	610	1,394	2,570	3,746
Washington, DC	1.2	610	1,394	2,570	3,746
Kansas City, MO	1.1	559	1,278	2,356	3,434
Dallas, TX	1.1	559	1,278	2,356	3,434
Columbus, OH	1.0	508	1,162	2,142	3,122
Minneapolis, MN	1.0	508	1,162	2,142	3,122
Buffalo, NY	0.8	407	929	1,713	2,497
Burlington, VT	0.8	407	929	1,713	2,497
Phoenix, AZ	0.8	407	929	1,713	2,497
Chicago, IL	0.8	407	929	1,713	2,497

According to the CWP, the "standard measure for target storage volume for runoff reduction ranges from 20 to 50 percent of the target WQv" (CWP, 2000, p. 5). Using the standard measure for target storage, the mall site would have to find an onsite storage area between 4-10 acres to treat the volume required. The desire to keep the number of existing parking spaces onsite limited the amount of potential impervious area, so the criteria for onsite storage area was not achieved with an impervious area of 2.83 acres. For most parking lots, meeting this requirement becomes challenging because of space limitations. To achieve this goal, the focus of onsite retrofit techniques becomes important.

Step 3 – Identify the Stormwater Treatment Option – As previously described, the Northgate Mall used bioretention in the form of an onsite drainage swale to treat stormwater. The onsite drainage swales treated stormwater for the 20-acre asphalt parking lot.   The range of pollutant removal rates for bioretention areas is defined in Table 3-12.

Table 3-12, Bioretention Removal Rates

(CWP, 2007, B-9)



Range of Reported Removal Rates for Bioretention Areas			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	15*	60*	75*
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	0	50
Total Nitrogen	40	45	55
Total Zinc	40	80	95
Total Copper	40	80	100
Bacteria	20	50	80
Hydrocarbons	80	90	95
Chloride	0	0	0
Trash/Debris	80*	90*	95*

* Adequate pretreatment must be provided to reduce sediment loads to bioretention areas or clogging and practice failure may result

See Appendix D for data sources and assumptions used to derive these removal rates

Low End and High End are the 25th and 75th quartiles

Step 4 – Calculate Site Imperviousness of Design – Using figure 3-23, the study can calculate the sites imperviousness of the installed design. If the design was not built, a conceptual design solution would be utilized to understand the imperviousness of a potential solution.

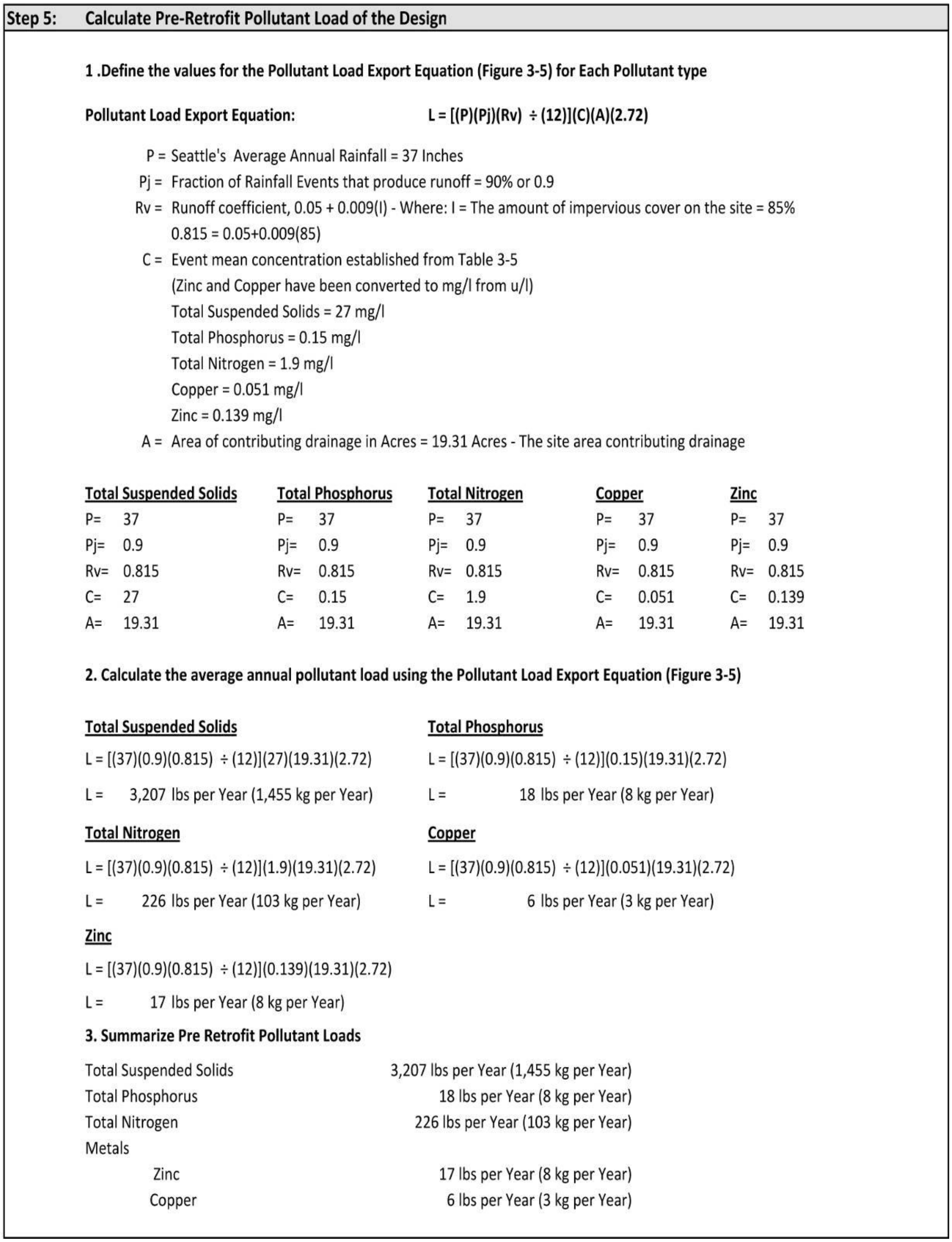
Table 3-13, Northgate Mall – Calculations of Site Impervious Area of the Design
(Authors Calculations, 2010)

Step 4: Calculate Site Imperviousness of Design				
Using a base map (Figure 3-23) calculate the areas below				
Site Size	19.31 AC	841,144	Sq. Ft.	Percentage of Total Area
Impervious Area	16.48 Ac	717,896	Sq. Ft.	85.34%
Pervious Services	2.83 Ac	123,275	Sq. Ft.	14.66%
Total Area	19.31 Ac	841,144	Sq. Ft.	100%

Step 5 – Calculate Pre-Retrofit Pollutant Load of the Design – Since the design is installed and the areas have been defined in step 4, the pre-retrofit pollutant load can be calculated using the same process as defined in step 1. This calculation defines the conceptual pre-retrofit pollutant loads of the intended design. Table 3-14 outlines the steps to calculate these loads. Again, the event mean concentration (C) is based on the values defined in Table 3-5, as monitoring well samples were not available for this study. The pollutant load results will then be adjusted up or down using site-specific factors in the design point method.

Table 3-14, Northgate Mall – Calculations of Pre-Retrofit Pollutant Load of the Design

(Authors Calculations, 2010)



Step 5: Calculate Pre-Retrofit Pollutant Load of the Design

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: $L = [(P)(Pj)(Rv) \div (12)](C)(A)(2.72)$

P = Seattle's Average Annual Rainfall = 37 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious cover on the site = 85%
0.815 = 0.05+0.009(85)
C = Event mean concentration established from Table 3-5
(Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 19.31 Acres - The site area contributing drainage

Total Suspended Solids		**Total Phosphorus**		**Total Nitrogen**		**Copper**		**Zinc**	
P=	37	P=	37	P=	37	P=	37	P=	37
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.815	Rv=	0.815	Rv=	0.815	Rv=	0.815	Rv=	0.815
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	19.31	A=	19.31	A=	19.31	A=	19.31	A=	19.31

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

L = [(37)(0.9)(0.815) ÷ (12)](27)(19.31)(2.72)

L = 3,207 lbs per Year (1,455 kg per Year)

Total Phosphorus

L = [(37)(0.9)(0.815) ÷ (12)](0.15)(19.31)(2.72)

L = 18 lbs per Year (8 kg per Year)

Total Nitrogen

L = [(37)(0.9)(0.815) ÷ (12)](1.9)(19.31)(2.72)

L = 226 lbs per Year (103 kg per Year)

Copper

L = [(37)(0.9)(0.815) ÷ (12)](0.051)(19.31)(2.72)

L = 6 lbs per Year (3 kg per Year)

Zinc

L = [(37)(0.9)(0.815) ÷ (12)](0.139)(19.31)(2.72)

L = 17 lbs per Year (8 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

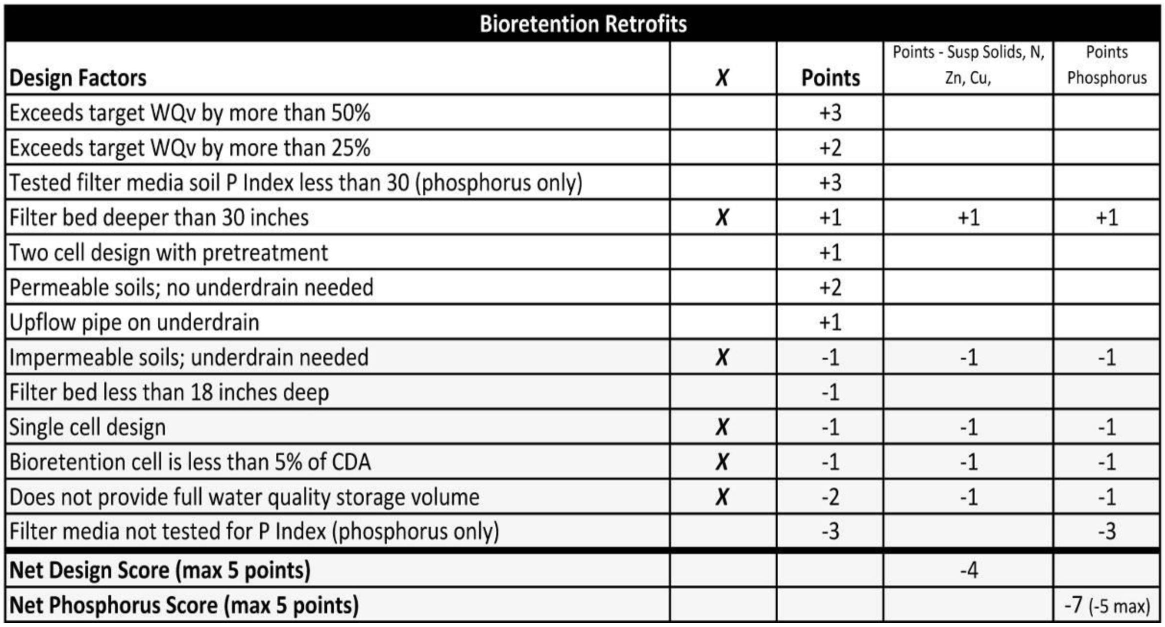
Total Suspended Solids	3,207 lbs per Year (1,455 kg per Year)
Total Phosphorus	18 lbs per Year (8 kg per Year)
Total Nitrogen	226 lbs per Year (103 kg per Year)
Metals	
Zinc	17 lbs per Year (8 kg per Year)
Copper	6 lbs per Year (3 kg per Year)

Step 6- Pollutant Removal Efficiency – Using the Design Point Method, the site was scored and ranked using table 3-15. The negative factors for the design were:

1. The design does not provide the full WQv (4-10 acres) due to the space requirements on site. The mall site had only 1.45 acres of impervious area available out of 19.31 acres, so the criteria for onsite storage area was not achieved due to the developers desire not to eliminate parking spaces.
2. Single Cell Design – Space Requirements. The use of an additional treatment cell, or drainage body, was not used due to the size of the parking lot. While the swales occur throughout the parking lot, they treat the same pollutant sources without the added benefit of draining into another stormwater treatment type.
3. Underdrainage was needed due to the impermeable soils on-site.

After the method was implemented, a negative design score was derived.

Table 3-15, Bioretention Design Sheet - Northgate Mall, Red points indicate the points to total. (Author's Calculations, 2010)

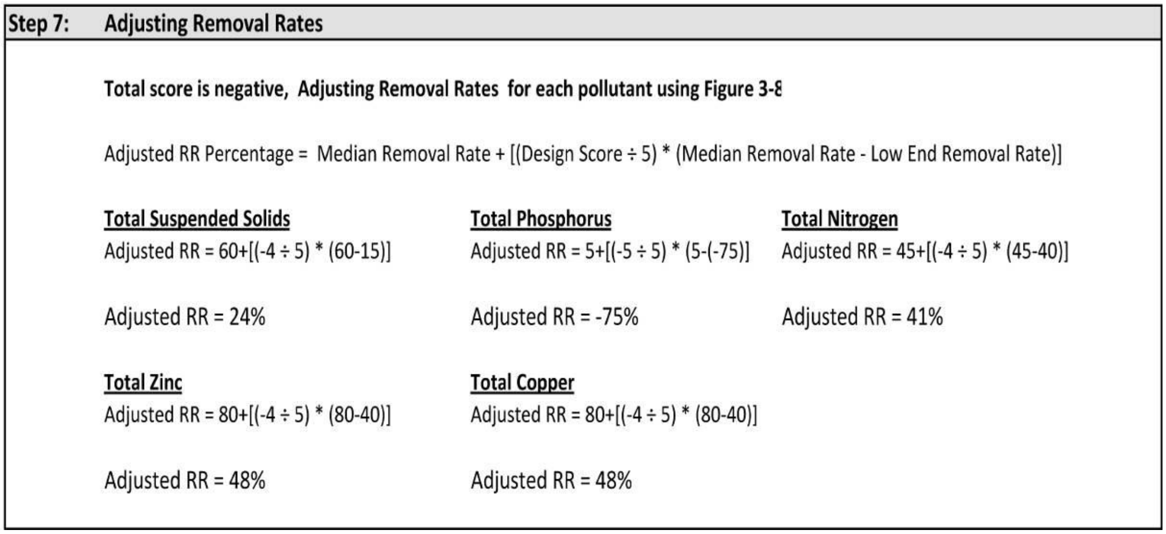


Bioretention Retrofits				
Design Factors	***X***	**Points**	Points - Susp Solids, N, Zn, Cu,	Points Phosphorus
Exceeds target WQv by more than 50%		+3		
Exceeds target WQv by more than 25%		+2		
Tested filter media soil P Index less than 30 (phosphorus only)		+3		
Filter bed deeper than 30 inches	***X***	+1	+1	+1
Two cell design with pretreatment		+1		
Permeable soils; no underdrain needed		+2		
Upflow pipe on underdrain		+1		
Impermeable soils; underdrain needed	***X***	-1	-1	-1
Filter bed less than 18 inches deep		-1		
Single cell design	***X***	-1	-1	-1
Bioretention cell is less than 5% of CDA	***X***	-1	-1	-1
Does not provide full water quality storage volume	***X***	-2	-1	-1
Filter media not tested for P Index (phosphorus only)		-3		-3
Net Design Score (max 5 points)			-4	
Net Phosphorus Score (max 5 points)				-7 (-5 max)

Step 7 - Adjusting Removal Rates for Each Pollutant Type – By adding up the points in Table 3-15, the total score is negative four out of a possible five (positive or negative). The removal rates then are adjusted negatively using equation shown in Table 3-8. The calculations are shown in Table 3-16.

Table 3-16, Northgate Mall – Calculations of Adjusted Removal Rates

(Author's Calculations, 2010)



Step 7: Adjusting Removal Rates

Total score is negative, Adjusting Removal Rates for each pollutant using Figure 3-8

Adjusted RR Percentage = Median Removal Rate + [(Design Score ÷ 5) * (Median Removal Rate - Low End Removal Rate)]

Total Suspended Solids
Adjusted RR = 60+[(-4 ÷ 5) * (60-15)]
Adjusted RR = 24%

Total Phosphorus
Adjusted RR = 5+[(-5 ÷ 5) * (5-(-75)]
Adjusted RR = -75%

Total Nitrogen
Adjusted RR = 45+[(-4 ÷ 5) * (45-40)]
Adjusted RR = 41%

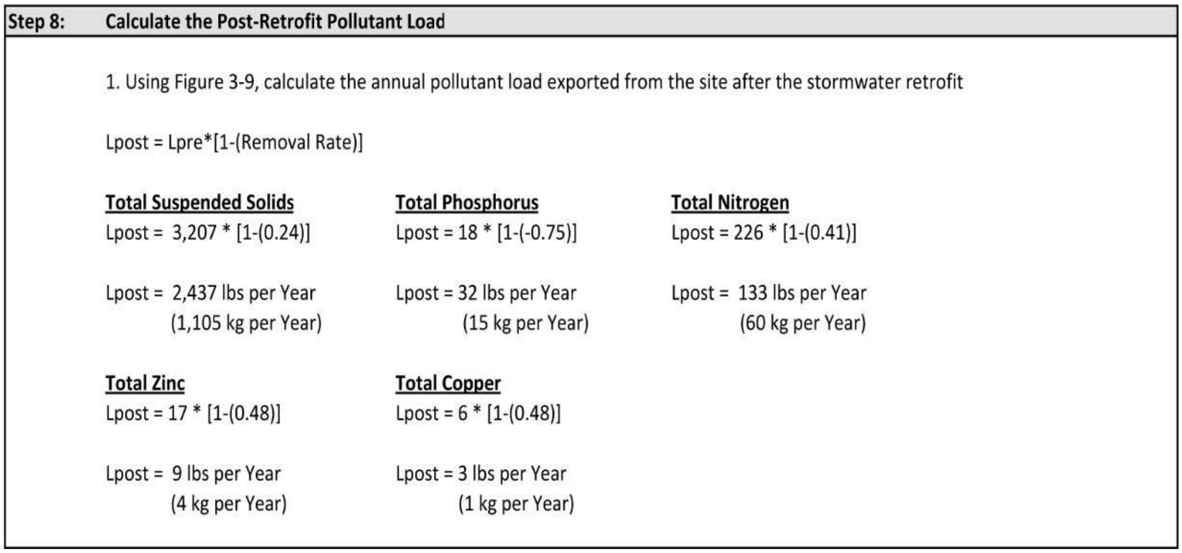
Total Zinc
Adjusted RR = 80+[(-4 ÷ 5) * (80-40)]
Adjusted RR = 48%

Total Copper
Adjusted RR = 80+[(-4 ÷ 5) * (80-40)]
Adjusted RR = 48%

Step 8 – Post-Retrofit Pollutant Load – The eighth step in the process is to calculate the post-retrofit pollutant load. Using Figure 3-9, the post-retrofit pollutant loads are adjusted. Using the adjusted removal rates, based on the site-specific factors in the point tables, the actual pollutant loads are reduced. The results are shown in Table 3-17.

Table 3-17, Northgate Mall – Calculations of Post-Retrofit Pollutant Load

(Author's Calculations, 2010)



Step 8: **Calculate the Post-Retrofit Pollutant Load**

1. Using Figure 3-9, calculate the annual pollutant load exported from the site after the stormwater retrofit

Lpost = Lpre*[1-(Removal Rate)]

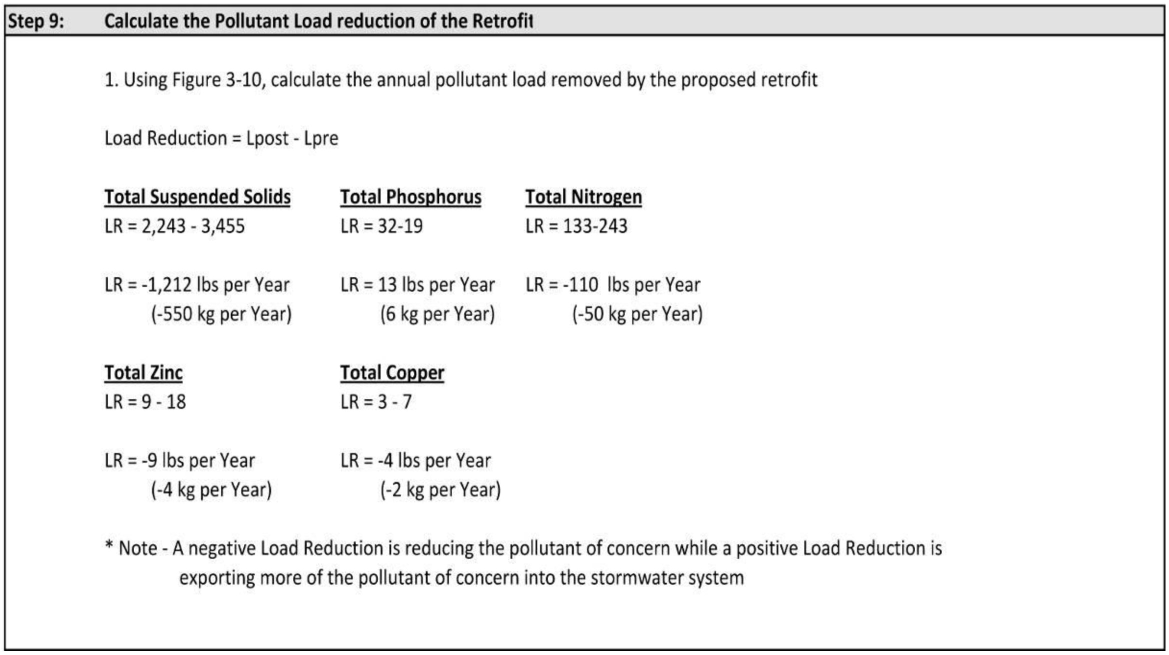
Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
Lpost = 3,207 * [1-(0.24)]	Lpost = 18 * [1-(-0.75)]	Lpost = 226 * [1-(0.41)]
Lpost = 2,437 lbs per Year (1,105 kg per Year)	Lpost = 32 lbs per Year (15 kg per Year)	Lpost = 133 lbs per Year (60 kg per Year)

Total Zinc	**Total Copper**
Lpost = 17 * [1-(0.48)]	Lpost = 6 * [1-(0.48)]
Lpost = 9 lbs per Year (4 kg per Year)	Lpost = 3 lbs per Year (1 kg per Year)

Step 9 - Pollutant Load Reduction of the Retrofit – The final step in the process is to calculate the pollutant load reduction of the retrofit. Using Figure 3-10, the pollutant load reduction of the retrofit can be calculated. The results are shown in Table 3-18.

Table 3-18, Northgate Mall – Calculations of Pollutant Load Reduction of the Retrofit

(Author's Calculations, 2010)



Step 9: **Calculate the Pollutant Load reduction of the Retrofit**

1. Using Figure 3-10, calculate the annual pollutant load removed by the proposed retrofit

Load Reduction = Lpost - Lpre

Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
LR = 2,243 - 3,455	LR = 32-19	LR = 133-243
LR = -1,212 lbs per Year (-550 kg per Year)	LR = 13 lbs per Year (6 kg per Year)	LR = -110 lbs per Year (-50 kg per Year)

Total Zinc	**Total Copper**
LR = 9 - 18	LR = 3 - 7
LR = -9 lbs per Year (-4 kg per Year)	LR = -4 lbs per Year (-2 kg per Year)

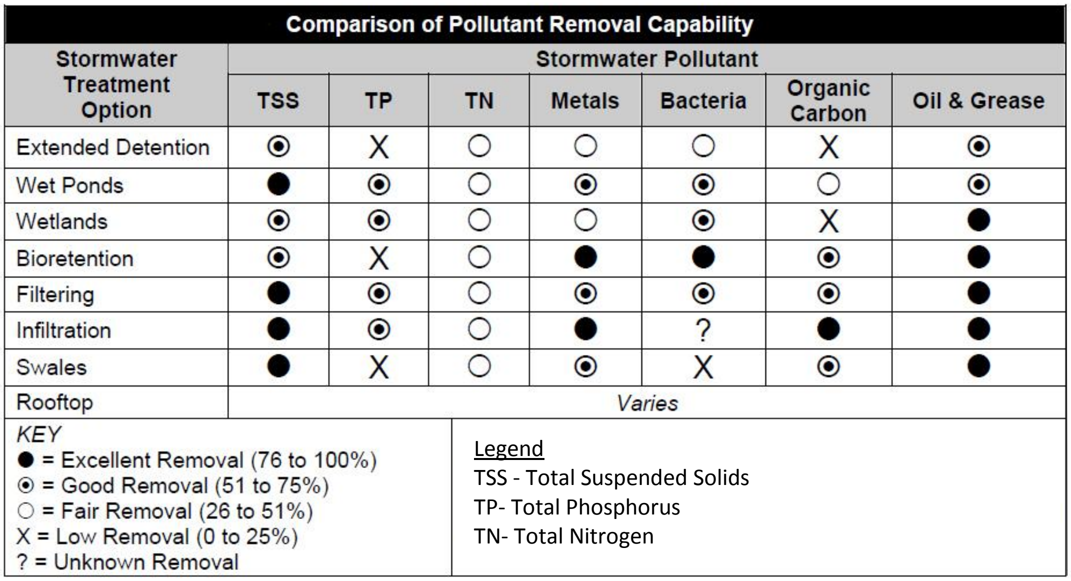
* Note - A negative Load Reduction is reducing the pollutant of concern while a positive Load Reduction is exporting more of the pollutant of concern into the stormwater system

Since the final design solution has already been constructed, the hypothetical results based off the existing aerial photography can be compared to the actual built solution. As a hypothetical way to calculate pollutant load reductions, the Design Point Method does not always deal with every site-specific factor. From the numbers, the Design Point Method suggested removal rates that were greater than those actually achieved by the built solution. An analysis of the calculations (Table 3-18) reveals that all the pollutants, except for Total Phosphorus, were reduced by the retrofit.

Table 3-19, also defines bioretention as a poor way to remove total phosphorus, so that would explain why the actual built solution is exporting phosphorus (the positive number in Table 3-18) out of the stormwater treatment solution rather than removing this pollutant. As a hypothetical measurement, it suggests to the designer that soil testing should take place prior to specifying the appropriate soil type to implement.

Table 3-19, Comparison of Pollutant Removal Capability

(CWP, 2007, p. 158, modified by Author)



Comparison of Pollutant Removal Capability

Stormwater Treatment Option	Stormwater Pollutant						
	TSS	TP	TN	Metals	Bacteria	Organic Carbon	Oil & Grease
Extended Detention	⦿	X	○	○	○	X	⦿
Wet Ponds	●	⦿	○	⦿	⦿	○	⦿
Wetlands	⦿	⦿	○	○	⦿	X	●
Bioretention	⦿	X	○	●	●	⦿	●
Filtering	●	⦿	○	⦿	⦿	⦿	●
Infiltration	●	⦿	○	●	?	●	●
Swales	●	X	○	⦿	X	⦿	●
Rooftop	*Varies*						

KEY
● = Excellent Removal (76 to 100%)
⦿ = Good Removal (51 to 75%)
○ = Fair Removal (26 to 51%)
X = Low Removal (0 to 25%)
? = Unknown Removal

Legend
TSS - Total Suspended Solids
TP- Total Phosphorus
TN- Total Nitrogen

Site-specific factors can enhance or reduce the overall effectiveness of a treatment option. The results of the Design Point Method can provide the designer a fair idea as to the effectiveness of each treatment option. For the Northgate Mall site, the design reduced the impervious surface by roughly eight percent. In doing so, it kept the number of parking spaces while reducing the amount of pollutants that are typically seen in large parking lots.

With the City of Seattle's focus on the one-year storm, the design met the City's Natural Drainage Systems Program Goals of improving water quality by reducing:

Petroleum Hydrocarbons,
Metals (copper, lead, zinc),
Nitrogen

Ultimately, the City deemed the project a success because it laid the groundwork for parking lot retrofits in the greater Seattle area.

Case Study 2 – "New" Parking Lot - US Cellular Field, Chicago, Illinois

Site Context - US Cellular Field is home to the Chicago White Sox, a professional baseball team, and is located in the 'South Side' of Chicago, Illinois (Figure 3-24). Built in 1991, US Cellular Field was billed as the "New Home" of the Chicago White Sox. The previous facility, Comiskey Park, had become outdated and was replaced 200 feet away by a new facility. The surrounding site (Figure 3-25) is made up of eight parking lots with roughly 6,500 spaces on site.

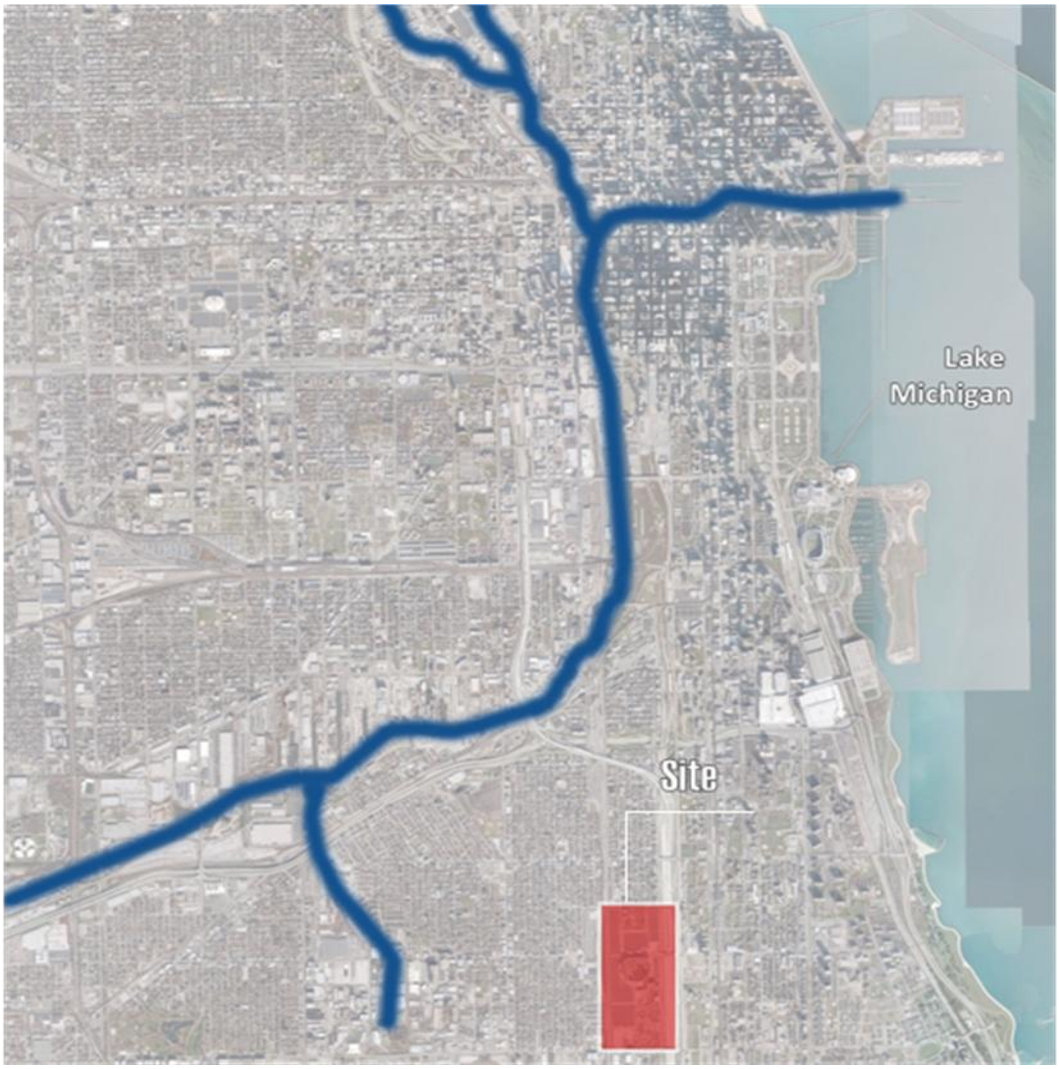


Figure 3-24, US Cellular Field Site Location, Chicago, Illinois

(Google Earth, 2009, Adapted by Author)

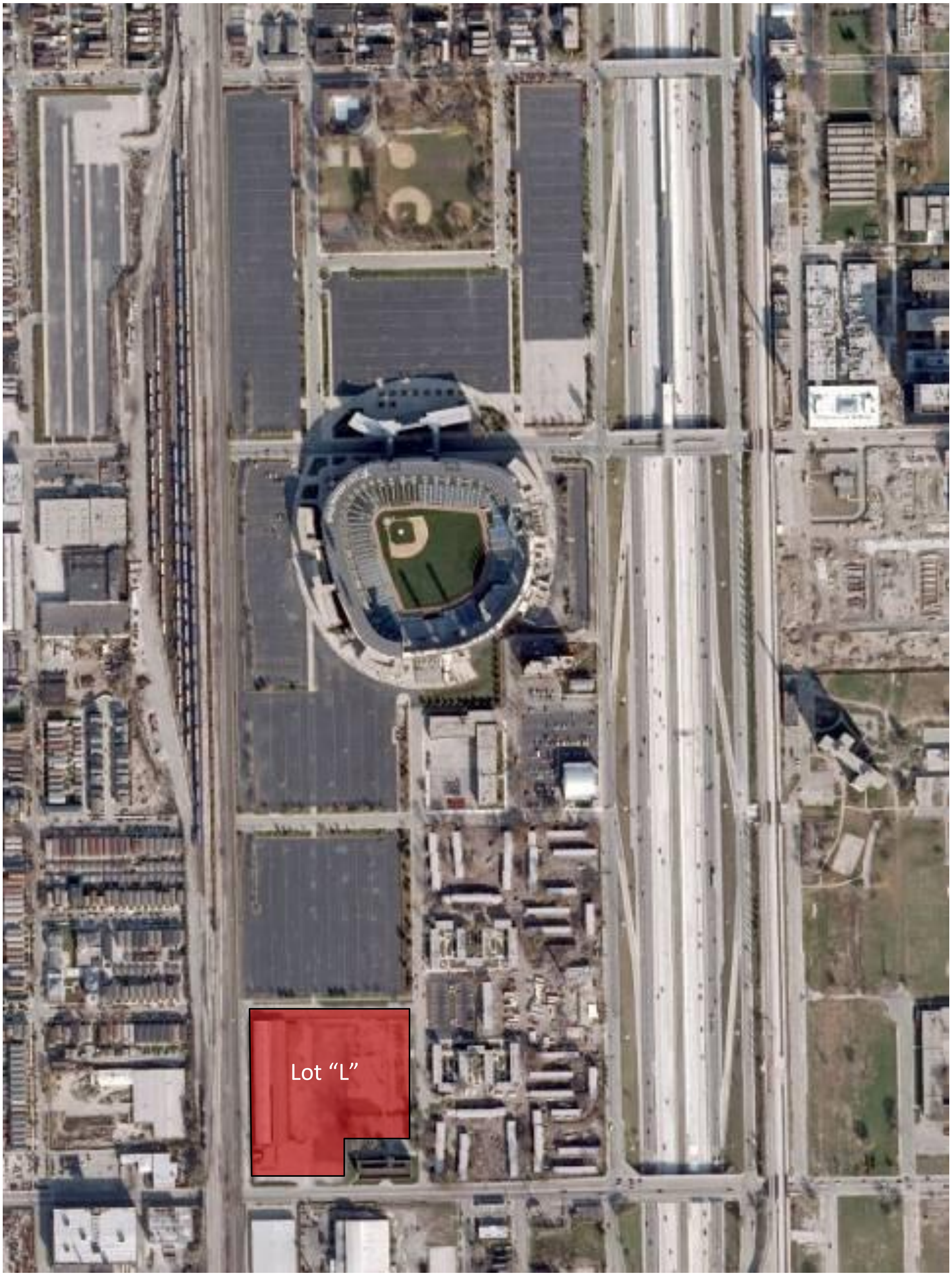


Figure 3-25, Aerial Photograph of US Cellular Field, Lot L

(Google Earth, 2009, Adapted by Author)

The study site, Lot ‘L’ (Figure 3-26), is a redesigned 7.0 acre (304,920 sq. ft.) parking lot located in the southern portion of the complex. The existing parking surface of concrete & gravel was redesigned to accommodate roughly 100 event dates during a typical ‘event’ season. The events include primarily professional baseball games but the facility is also used for concerts, trade shows, and various smaller events throughout the season. The Illinois Sports Facilities Authority converted this former industrial brownfield into a temporary parking lot. While mass transit serves the facility, fans primarily access the site across the Chicago region via their cars. A new surface was needed to replace the old concrete and gravel lot that had the look and feel of a temporary facility.

Figure 3-26, Aerial Photograph of US Cellular Field, Lot L
(Google Earth, 2009, Adapted by Author)

With the growing demand for more parking at the ballpark, the Illinois Sports Facilities Authority looked to acquire surrounding properties within the immediate ontext of the ballpark to appeal to the increased parking demand. According to Ernest Wong of Site Design Group, the landscape architect on the project, the site between West 38th Street and West Pershing Road was already being used to accommodate the 600 parking spaces. The authority was looking to upgrade the facility and the temporary lot was an obvious location (Wong, personal comm., 2009).

As the project was going through the conceptual design phase in early 2007 (Figure 3-27), one of the initial realizations was that a new Stormwater Management Ordinance was to take effect in 2008. The new ordinance "is designed to promote programs that minimize stormwater runoff and erosion control impacts of new development and redevelopment" (ISFA, 2008, p. 1).

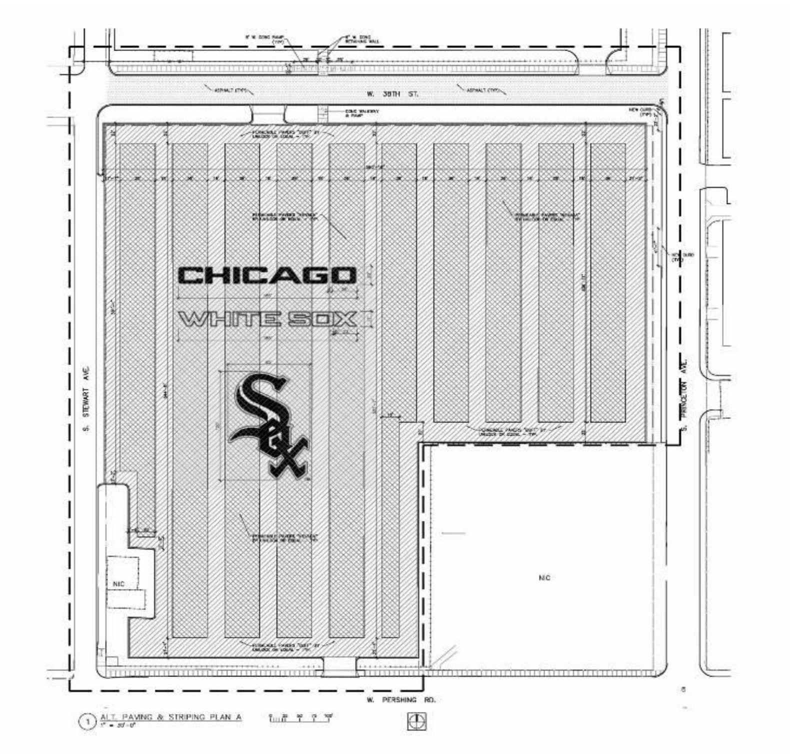


Figure 3-27, Proposed Plan of Lot 'L' – US Cellular Field (Ernest Wong, 2009)

The Sports Authority and the City felt Lot 'L' was ideal for serving as a model for how parking lots, which traditionally have a tremendous amount of impervious surface, could be designed to follow the guidelines within the new ordinance. The ordinance in the City Stormwater Manual includes the following requirements related to volume control that had the greatest impact on the design:

> *Stormwater drainage systems shall reduce the volume of runoff from a Regulated Development by one of the following measures:*
>
> > *(A) Capture one-half inch of runoff from all impervious surfaces in accordance with volume control BMPs; or*
> >
> > *(B) For Developments that do not directly discharge to Waters or to a municipal separate storm sewer system, achieve a fifteen-percent reduction in impervious surfaces from existing conditions.*
> >
> > (Friends of Chicago River, 2007, p.13)

Design - According to Wong, design challenges became readily apparent due to the size limitations of the site (Wong, personal comm., 2009). Obviously, the Sports Authority wanted to maximize the amount of parking on site. Sacrificing space for stormwater management was not going to provide the Sports Authority with a workable solution, while still meeting the requirements of the city.

One of the major objectives for the City of Chicago is stormwater management since all the fresh drinking water for the city comes from Lake Michigan. While the flow of water in the Chicago River was reversed in 1900 to combat pollution, the amount of stormwater runoff has become a highly sensitive subject. The ‘Green Alleys’ program and the Stormwater Ordinance of 2008 have established Chicago as one of the leaders in sustainable design. Chicago markets themselves as the “Greenest City on Earth.”

While the shift in focus for how stormwater was going to be treated onsite for Lot ‘L’ created some design challenges, it also created some opportunities for Ernest Wong and his firm, Site Design Group. One of the firm's specializations is environmental projects and their understanding of adaptive reuse of brownfields, landfills and other environmentally challenged sites lead them in the design process (Wong, personal comm., 2009).

The design objectives for the parking lot shifted to a retrofitting technique that could be used to treat stormwater, the focus narrowed to permeable pavement. Wong and Civil Engineer Robert Giurato, of Environmental Design International (EDI), began exploring the use of permeable material. While EDI was committed to sustainable initiatives, this was their first project associated with permeable pavement. In the end, it was the ISSA's desire to maximize the number of parking spaces that steered the project toward permeable pavers. Since the team currently charges 23 dollars a space for game day parking, it became readily apparent that other methods for stormwater retrofitting would not be possible due to the space concerns.

The final selection of interlocking permeable concrete pavement as the permeable surface dealt with three core issues: material durability, cost, and an understanding of the material. The reinforcements in permeable concrete and the binders in permeable asphalt have the tendency to break down in northern climates. *CH2M HILL,* a leader in the field of sustainable stormwater management, describes the need for a fabric binder to hold the porous materials together. As Dan Wible, with CH2M Hill, explained;

> "Probably the biggest lesson we have learned in the past decade is that, depending on the application and expected traffic load, the durability of porous pavement can be greatly enhanced with the addition of polymers

> and/or fibers. Without them, the material has a tendency to break down and performance suffers” (Wible, personal comm., 2009).

Because of durability issues, expected traffic loads, and the comfort level with the material being specified, the final decision was to go with interlocking ‘porous’ concrete pavers.

The Unilock L-shaped Eco-Optiloc pavers ultimately were specified. The paver system, according to Wong, “allows water to infiltrate and collect below the paving surface, substantially reducing or eliminating the amount of water entering the stormwater system.” (Wong, personal comm., 2009). The detail, Figure 3-28, shows the 100-mm-thick Eco-Optiloc pavers are molded with edge notches that create approximately half-inch voids between each stone; a 1.5 inch deep setting bed of quarter-inch crushed aggregate enables water to flow through to the 14-inch-deep subbase, comprising 3-inch diameter recycled concrete and 3/4- to 1-inch limestone rock, (Figure 3-29) capable of retaining 600,000 gallons of water on site (Wong, personal comm., 2009). According to Wong, that amount of water is equivalent to a 100-year rain event. The detained water is

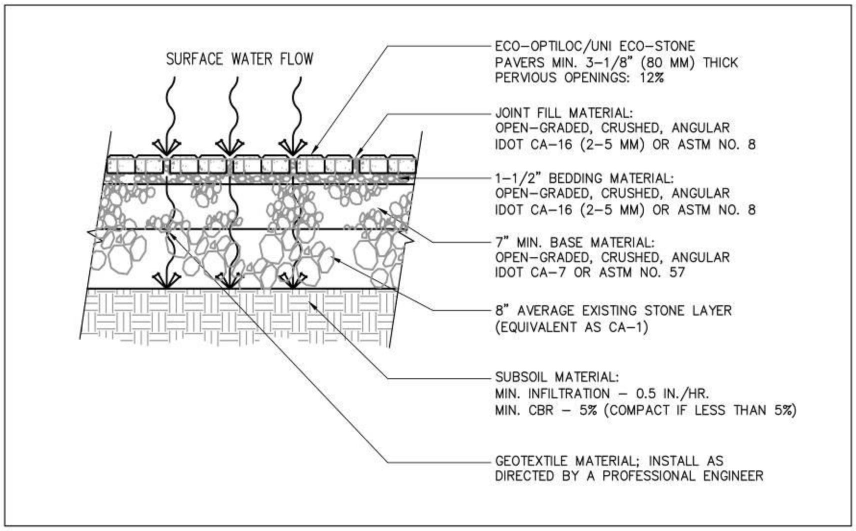


Figure 3-28, Section of Permeable Concrete Pavers

(Robert Giurato, 2009)

eventually absorbed into the subgrade below the surface and released naturally back into the environment, filtering out most contaminants.

Figure 3-29, Construction Photograph – Lot 'L' US Cellular Field,
(Site Design Group, Ltd., 2009).

Economics – As previously discussed, traditional "impervious" pavement is currently a less expensive solution when comparing the square foot cost of the material to a material that is permeable. For US Cellular Field, that was also the case. While the new stormwater ordinance forced the design towards a "greener" solution, the decision made about the type of pavement to use eventually saved the project money. Charles Sample, Project Manager for the facility, explains, "a project using the permeable paving system, typically costs less, lasts twice as long, requires less maintenance and is more durable than traditional bituminous asphalt projects." Additionally, the system uses recycled materials, helps recharge the groundwater — improving water quality — and reduces urban heat island effect (ISFA, 2009).

According to the Illinois Sports Facilities Authority, the overall cost of Lot ‘L’ was $3.5 million dollars (ISFA, 2008). This netted a cost of $13.21 per square foot for the overall project. By using interlocking concrete pavers, and creating the permeable surface, Lot ‘L’ was able to eliminate the typical storm drainage structures and additional materials associated with traditional drainage systems.

The initial short-term savings was $400,000 dollars to the project. The savings will be magnified over the life of the project because the pavers themselves will last over 40 years. While traditional asphalt pavement costs less than pavers, (roughly five dollars less per square feet) it still needs to be sealed and resurfaced over the life of the project. The critical cost savings component for this project is the drainage infrastructure. The finished design at US Cellular Field (Figure 3-30) does not require

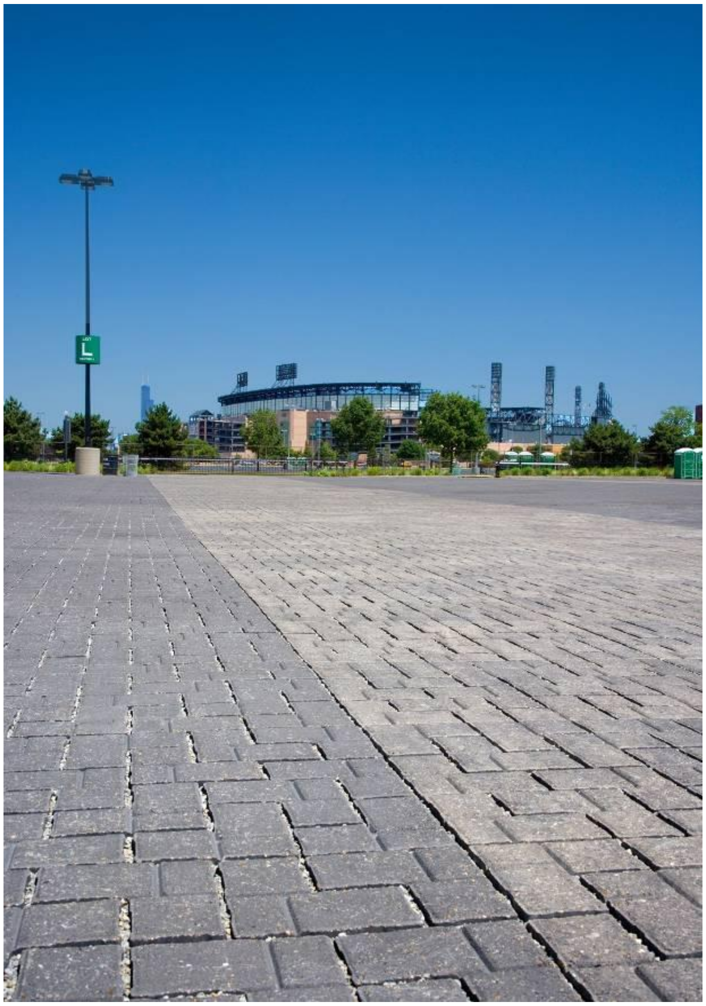


Figure 3-30, Concrete Pavers, US Cellular Field

(Site Design Group, Ltd., 2009)

stormwater infrastructure, while asphalt or other types of permeable surfaces would require stormwater infrastructure. According to Wong, by factoring the overall project cost of both treatment types, the cost was roughly the same between permeable concrete pavers and asphalt pavement with stormwater infrastructure (Wong, personal comm., 2009). The biggest negative for permeable pavement of any type is that it requires an annual vacuuming to insure the porous surface does not become clogged.

Installation was the other cost benefit to the project. The type of permeable concrete pavers used, Unilock L-shaped Eco-Optiloc Nabbefeld, were designed to be installed with an automated machine (Figure 3-31) that places a pallet of pavers on the ground at one time. With the assistance of one worker, the pavers are set in a matter of minutes. According to Mike Shereck of Rose Paving, using this machine, pavers can be installed at an average of 20,000 square feet per day. A typical manual installation with a crew of workers would only be able to install 7,000 square feet per day (ISFA, 2009).

Figure 3-31, Installation of Permeable Pavers

(Site Design Group, Ltd., 2009).

Installation/Maintenance - The biggest challenge for installing the proposed design (Figure 3-32) is the maintenance involved with the permeable pavement surface. The challenge permeable concrete pavers face is keeping the "pores" or voids between the pavers porous. While this might sound ridiculous, in most "northern" climates the weather has the biggest impact on permeable pavers. The most common way to treat ice and snow on any type of pavement is with salt and sand.

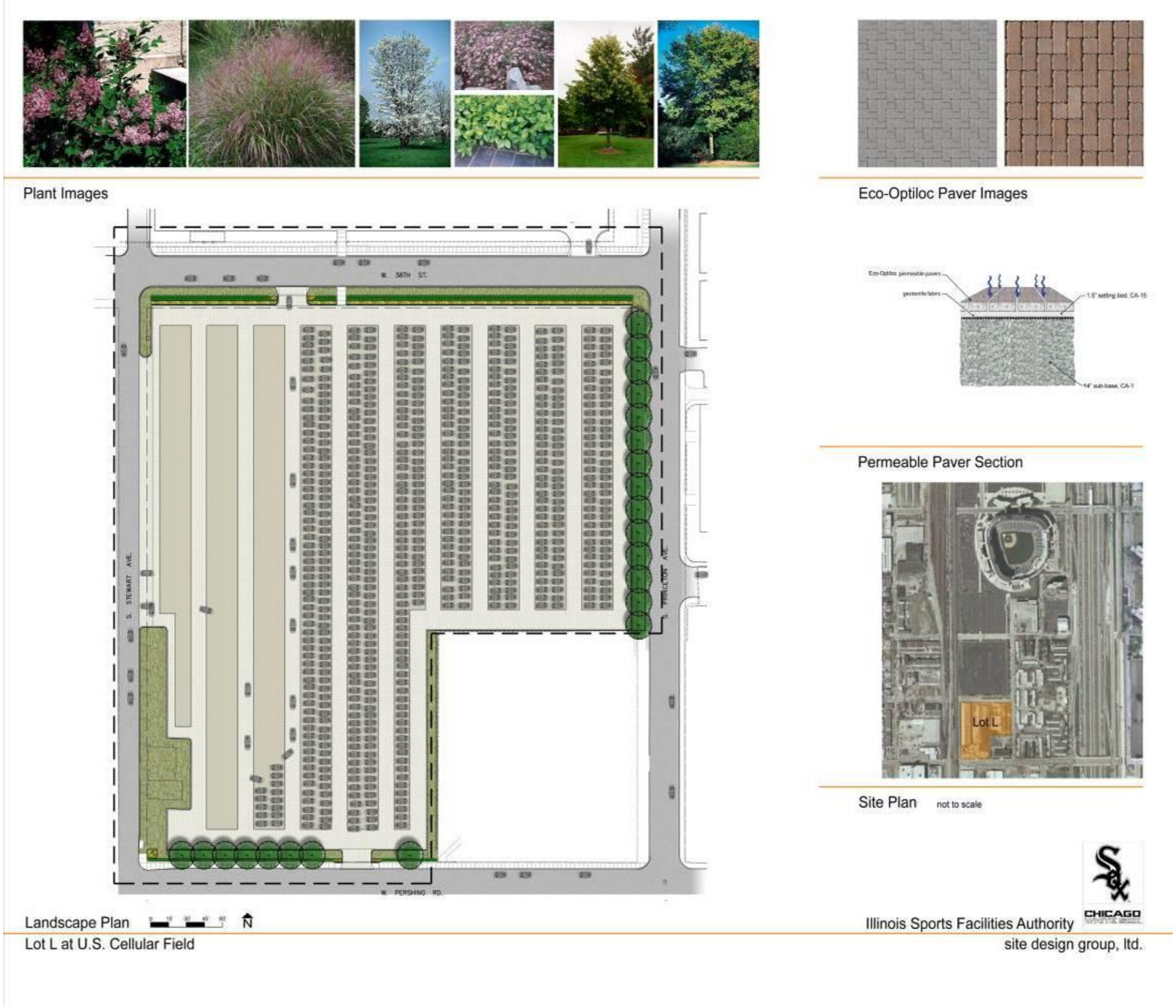


Figure 3-32, Proposed Site Plan Concept – Lot 'L' US Cellular Field.

(Site Design Group, Ltd., 2009)

The use of ice melting treatments, along with other sediments that typically accumulate on pavement, is ultimately the biggest enemy for the pores of porous pavement. The sediments eventually break down and clog the pores, making the once porous surface impervious. Fortunately, for lots of this size, it is not an issue because these lots are traditionally plowed before an event. Additionally, annual vacuuming of the pavements surface to clean out the pores and proper maintenance techniques are simple ways to solve common maintenance issues, but should be taken into consideration when choosing the type of permeable parking solution.

Lessons Learned – While the parking lot at US Cellular Field is still rather new, the feedback from the design professionals interviewed was very positive. The spring after the pavers were installed was uncommonly 'wet' for Chicago. The drainage system handled the rain events and performed as intended. There was so much positive feedback from the success of the lot that the firms involved have used the project to spur other types of sustainable projects. Site Design Group has taken some of the knowledge learned on Lot 'L' and is now implementing similar solutions on 'Park & Ride' facilities across the Chicago metropolitan area.

The project also had the benefit of 'very' sandy soils. Sandy soils allowed the project to save even more money by eliminating secondary drainage that is sometimes required due to low percolation rates in other soil types. Both Earnest Wong and Robert Giurato were very adamant about the importance of the soil conditions and the ability to recycle materials on site. Nearly 1/3 of the site was an old concrete building slab. The project was able to achieve a greater savings because the slab was ground up on site and used as a crushed aggregate subbase for the pavers.

It is important to note that the most important factor for the success of permeability is soil. “Soils can support adequate infiltration, since past grading, filling, disturbance and compaction can greatly alter their original infiltration qualities” (CWP, 2000, p. 181). While most people would assume that permeable pavers only can be successful when soils have high infiltration rates, they are much more versatile, because they “rely less on soil infiltration as compared to surface storage to provide runoff treatment” (CWP, 2000, p. 181).

Analysis - While Lot ‘L’ benefitted from the fact that pavement material selected had strong support from the client and was in a city that is on the cutting edge of sustainable practices. Lot ‘L’ at US Cellular Field proved that public projects can go outside the ‘norm’ and use BMP’s on a tight budget. While the parking lot uses porous concrete pavers and does a tremendous job from a stormwater management standpoint, the lack of landscape throughout the project is disappointing. The lack of green space ties directly to the relationship between sports and revenue. Maximizing income will almost always trump most decisions in the sports industry. The team and the Sports Facilities Authority wanted to maximize the number of spaces. Ultimately, there has to be a source of revenue, a monetary benefit, or some type of regulation for a project like this to justify the use of sustainable design initiatives.

Site Imperviousness – The existing site (Figure 3-33) is made up of roughly 304,920 square feet (7 acres) of area. Of this area, 223,206 square feet was defined as impervious surface area primarily made up concrete pavement for parking and concrete sidewalks. An existing building was leveled to create a temporary lot for parking. The pervious service, 81,714 square feet, was primarily made up of gravel and landscape.

Figure 3-33, Existing Lot L - US Cellular Field
(Google Earth, 2009, Adapted by Author)

Looking at Table 3-15, the site before retrofitting was made up of 73.20 percent of impervious area. The post-retrofit numbers (Calculations shown in Step 1, Appendix C) show a substantial reduction of impervious area (71.63 percent) due to the impact of replacing almost all the impervious surface with permeable concrete pavers. Permeable concrete pavers, when applied to the right site conditions, can have a huge impact on the site permeability. With that in mind, it is critical to understand the relationships between permeability and pollutant load reduction.

Table 3-20, Pre /Post Site Impermeability
(Author's Calculations, 2010)

US Cellular Field - (Pre)			US Cellular Field - (Post)	
Site Size	7 AC 304,920 Sq. Ft.	Percentage of Total Area	7 AC 304,920 Sq. Ft.	Percentage of Total Area
Impervious Area	5.12 Ac 223,206 Sq. Ft.	73.20%	0.11 Ac 4,792 Sq. Ft.	1.57%
Pervious Services	1.88 Ac 81,714 Sq. Ft.	26.80%	6.89 Ac 300,128 Sq. Ft.	98.43%
Total Area	7 Ac 304,920 Sq. Ft.	100%	7 Ac 304,920 Sq. Ft.	100%

Pre-Retrofit Pollutant Load - As with the Northgate Mall case study, the next step is to identify the pollutant load that currently exists onsite. Using the Simple Method, the average annual pollutant load prior to retrofitting options can be calculated. As noted before, the pollutants of concern for large parking lots are:

1. Total Suspended Solids
2. Total Phosphorus
3. Total Nitrogen
4. Metals (Zinc & Copper)

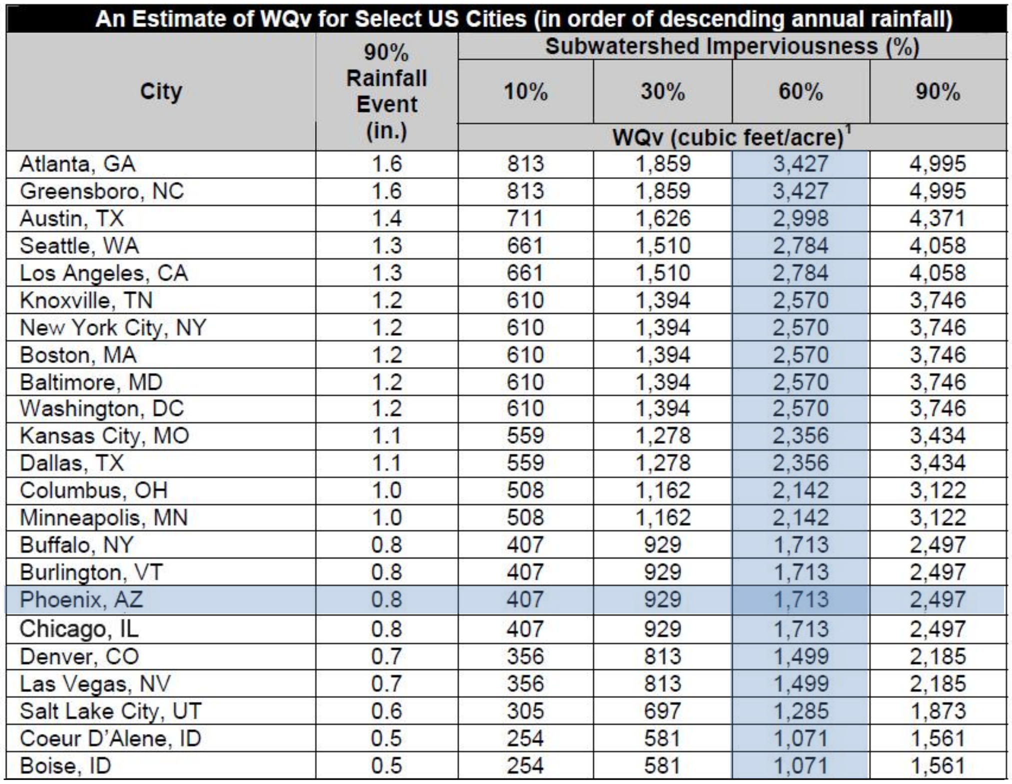
It is important to understand that other pollutants, such as hydrocarbons (petroleum such as oil) and trash/debris, typically have the same removal rates as Total Suspended Solids. In most circumstances these particles either quickly stick to sediments or they are suspended in stormwater runoff and would have the same removal rates as Total Suspended Solids (CWP, 2007).

Using Figure 3-6, the pre-retrofit pollutant load for Lot 'L' was calculated using the Pre Pollutant Load Export Equation (Step 2, Appendix C). Due to the fact that most parking lot retrofits deal with large amount of impervious surface, it is important to understand what is feasible due to the conceptual nature of the research. The maximum treatment area is often constrained by the amount of impervious cover defined on any particular site. In most subwatersheds, it is hard to find enough feasible storage retrofits to treat more than 50 percent of subwatershed area (CWP, 2007). In this case, almost the entire parking lot was transformed into a pervious surface using permeable pavers.

To get to a higher level of treatment, often onsite retrofits will have to be explored. Because of the high level of impervious surfaces typically found in large parking lots, the study will focus on onsite retrofits. Table 3-21 is used to estimate the aggregate Water Quality Volume (WQv) storage needed. Lot L, at US Cellular Field, is in the city of Chicago, so with an impervious area of around 60 percent, the site would need to treat 1,713 cubic feet of water per acre. At seven acres, the site would have to treat 11,991 cubic feet of stormwater for every 0.8 inches of rain.

Table 3-21, Estimate of WQv for US Cities

(CWP, 2007, p. 9)

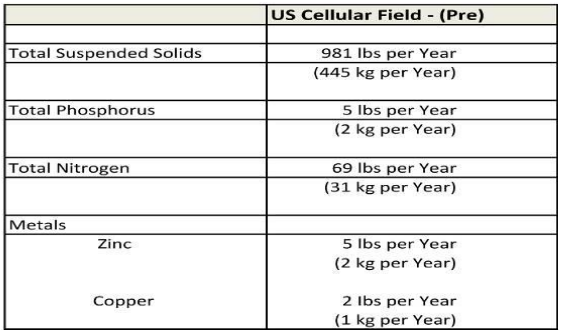


An Estimate of WQv for Select US Cities (in order of descending annual rainfall)

City	90% Rainfall Event (in.)	Subwatershed Imperviousness (%)			
		10%	30%	60%	90%
		WQv (cubic feet/acre)[1]			
Atlanta, GA	1.6	813	1,859	3,427	4,995
Greensboro, NC	1.6	813	1,859	3,427	4,995
Austin, TX	1.4	711	1,626	2,998	4,371
Seattle, WA	1.3	661	1,510	2,784	4,058
Los Angeles, CA	1.3	661	1,510	2,784	4,058
Knoxville, TN	1.2	610	1,394	2,570	3,746
New York City, NY	1.2	610	1,394	2,570	3,746
Boston, MA	1.2	610	1,394	2,570	3,746
Baltimore, MD	1.2	610	1,394	2,570	3,746
Washington, DC	1.2	610	1,394	2,570	3,746
Kansas City, MO	1.1	559	1,278	2,356	3,434
Dallas, TX	1.1	559	1,278	2,356	3,434
Columbus, OH	1.0	508	1,162	2,142	3,122
Minneapolis, MN	1.0	508	1,162	2,142	3,122
Buffalo, NY	0.8	407	929	1,713	2,497
Burlington, VT	0.8	407	929	1,713	2,497
Phoenix, AZ	0.8	407	929	1,713	2,497
Chicago, IL	0.8	407	929	1,713	2,497
Denver, CO	0.7	356	813	1,499	2,185
Las Vegas, NV	0.7	356	813	1,499	2,185
Salt Lake City, UT	0.6	305	697	1,285	1,873
Coeur D'Alene, ID	0.5	254	581	1,071	1,561
Boise, ID	0.5	254	581	1,071	1,561

According to the CWP, the "standard measure for target storage volume for runoff reduction ranges from 20 to 50% of the target WQv" (CWP, 2007, p. 5). Using that analysis, Lot 'L' would have to find an offsite storage area between 1.4-3.5 acres to treat the volume required. For Lot ‘L’, it became even more challenging because of space limitations. To achieve the goal of storage the focus of onsite retrofit techniques becomes important. The results for the four types of pollutants treated on site are defined in Table 3-22 and the calculations are shown in Appendix C, Step 2.

Table 3-22, Lot L, US Cellular Field Pre-Retrofit Pollutant Loads, (Author’s Calculations, 2010)

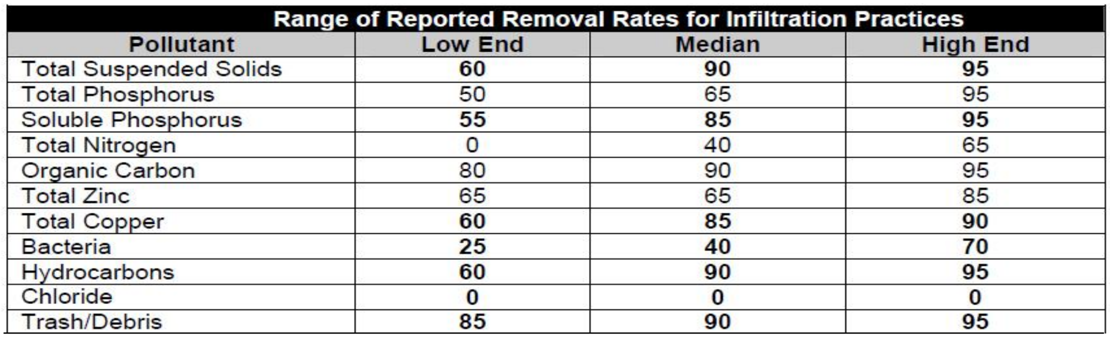


	US Cellular Field - (Pre)
Total Suspended Solids	981 lbs per Year
	(445 kg per Year)
Total Phosphorus	5 lbs per Year
	(2 kg per Year)
Total Nitrogen	69 lbs per Year
	(31 kg per Year)
Metals	
Zinc	5 lbs per Year (2 kg per Year)
Copper	2 lbs per Year (1 kg per Year)

Stormwater Treatment Option – As previously described, Lot L, at US Cellular Field, used permeable concrete pavers to treat stormwater on the 7-acre asphalt parking lot (Step 3, Appendix C). Permeable pavers have similar drainage capacities to that of infiltration trenches or French drain. The range of pollutant removal rates for in areas is defined in Table 3-23.

Table 3-23, Infiltration Removal Rates

(CWP, 2007, p. D-4)



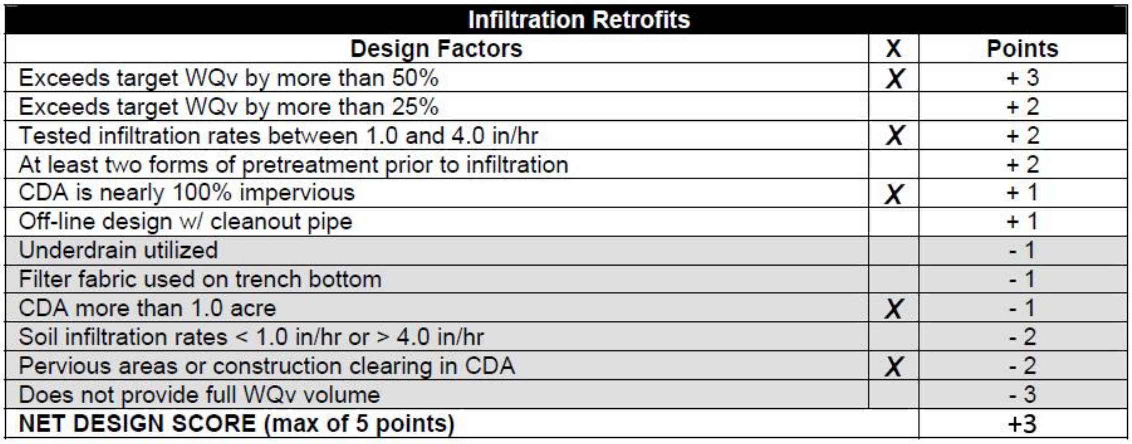
Range of Reported Removal Rates for Infiltration Practices			
Pollutant	Low End	Median	High End
Total Suspended Solids	60	90	95
Total Phosphorus	50	65	95
Soluble Phosphorus	55	85	95
Total Nitrogen	0	40	65
Organic Carbon	80	90	95
Total Zinc	65	65	85
Total Copper	60	85	90
Bacteria	25	40	70
Hydrocarbons	60	90	95
Chloride	0	0	0
Trash/Debris	85	90	95

Pollutant Removal *Efficiency* – Using the Design Point Method, Lot 'L' was scored and ranked (Steps 4, 5 & 6, Appendix C) using available data (Table 3-24). The positive factors for the design were:

1. Exceed target WQv by more than 50% due to the transformation of the entire site to permeability.
2. High infiltration rates on site.
3. Contributing Drainage Area is nearly 100% impervious.

Table 3-24, Infiltration Design Sheet- Lot L, US Cellular Field

(Author's Calculation, 2007)



Infiltration Retrofits		
Design Factors	**X**	**Points**
Exceeds target WQv by more than 50%	X	+ 3
Exceeds target WQv by more than 25%		+ 2
Tested infiltration rates between 1.0 and 4.0 in/hr	X	+ 2
At least two forms of pretreatment prior to infiltration		+ 2
CDA is nearly 100% impervious	X	+ 1
Off-line design w/ cleanout pipe		+ 1
Underdrain utilized		- 1
Filter fabric used on trench bottom		- 1
CDA more than 1.0 acre	X	- 1
Soil infiltration rates < 1.0 in/hr or > 4.0 in/hr		- 2
Pervious areas or construction clearing in CDA	X	- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		+3

After the Design Point Method was implemented, a positive design score was derived. By adjusting the removal rates, with the calculations shown in step 7 of Appendix C, the pollutant removal rates were then adjusted to the following percentages:

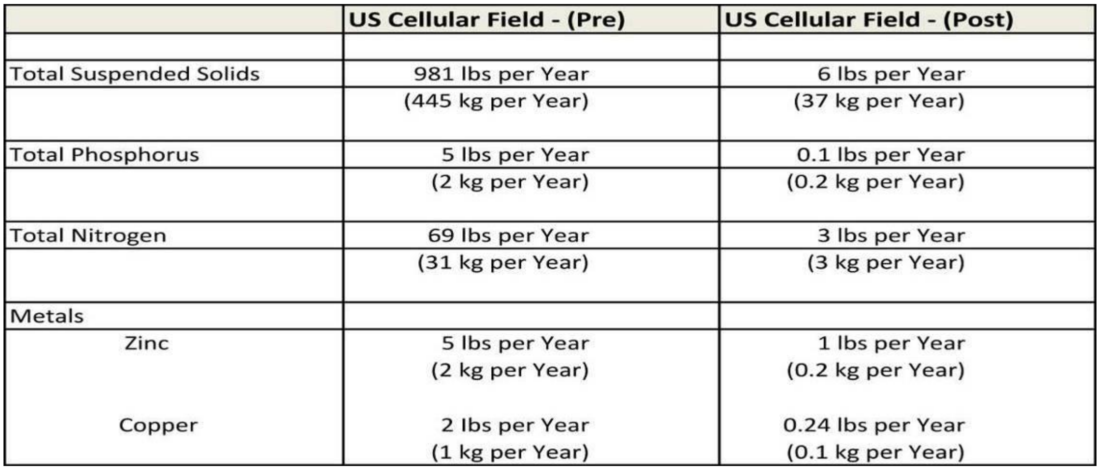
Total Suspended Solids	93%
Total Phosphorus	83%
Total Nitrogen	55%
Total Zinc	77%
Total Copper	88%

Post –Retrofit Pollutant Load – The next step is to calculate the post retrofit pollutant load. By using the adjusted percentages, the analysis can calculate the adjusted percentage (Step 8, Appendix C) based on site factors and get a more accurate analysis of the removal rate for the concept design. Since the final design solution has already been constructed, the hypothetical results can be compared to the actual built solution. The results are shown in Table 3-25.

Pollutant Load Reduction of the Retrofit – The final step (Step 9, Appendix C) is to calculate the pollutant load reduction of the retrofit. Looking at Table 3-25, it reveals some interesting results. The built solution reduces the pollution level dramatically for the pollutants of concern. According to the CWP, this range in pollutant load reduction is typical with this type of stormwater retrofit. The biggest challenge any design faces when using permeable pavers is cost. Permeable pavers are one of the most expensive stormwater retrofit options at an average price of $120 per cubic foot of stormwater treated (Table 4-8). The high cost is due primarily to the fact that most stormwater infrastructure is already in place at an existing site. The savings for permeable pavers is not realized because the traditional stormwater infrastructure cost cannot be offset due to the fact that it is already in place.

Table 3-25, Post-Retrofit Pollutant Loading Comparison

(Author's Calculations, 2010)



	US Cellular Field - (Pre)	US Cellular Field - (Post)
Total Suspended Solids	981 lbs per Year	6 lbs per Year
	(445 kg per Year)	(37 kg per Year)
Total Phosphorus	5 lbs per Year	0.1 lbs per Year
	(2 kg per Year)	(0.2 kg per Year)
Total Nitrogen	69 lbs per Year	3 lbs per Year
	(31 kg per Year)	(3 kg per Year)
Metals		
Zinc	5 lbs per Year	1 lbs per Year
	(2 kg per Year)	(0.2 kg per Year)
Copper	2 Ibs per Year	0.24 lbs per Year
	(1 kg per Year)	(0.1 kg per Year)

Another measure of the success of an infiltration retrofit was that this treatment type meets the City goals for controlling runoff. As previously stated the goals established by the city of Chicago were to:

> 1. Capture one-half inch of runoff from all impervious surfaces in accordance with volume control BMPs; or
>
> 2. For Developments that do not directly discharge to Waters or to a municipal separate storm sewer system, achieve a fifteen-percent reduction in impervious surfaces from existing conditions.
>
> (Friends of Chicago River, 2007, p.13)

The permeable design solution retrofit meets both those stated goals, and even took the project a step further by creating the largest permeable parking lot of its kind in the world today.

Finally, the success of this retrofit that cannot be measured with numbers is the social aspect of how tailgating functions in the lot itself. While the research is not intended to analyze all the social functions of tailgating, the perception and reaction to the parking lot has been outstanding (Wong, personal comm., 2009). Fans no longer have to walk through the mud next to a razor wire fence on their way to the game (Figure 3-34, 3-35). While the Lot ‘L’ lacks shade or any type of formal green space, it provides an upgrade to a parking lot that the average fan can enjoy. In the end, the Lot ‘L’ is deemed successful because it created a lot specifically for tailgating and did it without impacting the city’s stormwater treatment system.

Figure 3-34, Lot L - US Cellular Field, Before Retrofit

(Google Earth, 2009)

Figure 3-35, Lot L - US Cellular Field, After Retrofit

(Google Earth, 2009)

CHAPTER 4 - DESIGN IMPLEMENTATION & RESULTS

The Project Site – Truman Sports Complex

The development of the Truman Sports Complex was a revolutionary event in the world of sports architecture. The idea of designing and constructing two purpose-built stadiums was revolutionary in an era of multi-purpose venues. Original plans for the complex didn't start out to be the same sort of revolution. In fact, the vision was to duplicate the Houston Astrodome, but ultimately, one trip to Houston would have a dramatic effect on the development of the Truman Sports Complex.

In the early months of 1968, a spirited debate began on whether to build the stadium downtown, or at a remote location in Eastern Jackson County. When city planners started looking to replace Municipal Stadium, they laid out two possible sites: one in a wide-open field southeast of downtown near Leeds Road, and one in the Central Business District, just south of what is now Bartle Hall (Lewis, 1977). Both sites had their challenges, but the city knew one thing, this facility was going to be "first class."

After a trip to Houston to visit the newly completed Astrodome, community leaders felt the need to do something to put Kansas City on the map. Tired of being considered a "Cowtown," community leaders wanted to make Kansas City's new facility "first class" (Lewis, 1977). Most community leaders didn't really know what that meant in relationship to building a sports facility, but they knew one thing; Kansas City needed something better than Houston and the community leadership wanted to make the project better than the Astrodome.

In the end, three problems with the Astrodome changed the development patterns for the future Kansas City. Traffic concerns, energy costs with building a domed stadium, and less than optimal sight lines for football got community leaders thinking about something different for Kansas City (Lewis, 1977). Solving these problems on either site would be a difficult task. Fearful of the same traffic nightmares Houston faced and a growing number of business leaders threatening to relocate to Kansas due to land acquisition requirements, city leaders grew more favorable of the Leeds site. Eventually, it was a greater understanding of costs associated with building the sports complex that would lead to building two stadiums away from downtown.

Wary of the $98 million price tag of a downtown domed stadium, the city chose the wide-open field near Leeds for the site of the Harry S. Truman Sports Complex. Remarkably for $54.5 million City Leaders found they could build both a football and a baseball stadium (Figure 4-1) at the Leeds site (Lewis, 1977). The choice for community leaders seemed easy enough and when the Chiefs agreed to sign a 35-year lease for a football only facility the downtown site was dead.

Figure 4-1, Construction Photograph, Truman Sports Complex
(Lewis, 1977, p. 81)

Ecoregion

Truman Sports complex is located in the Blue River watershed of greater Kansas City, Missouri. This watershed is made up of 270 square miles and composed of 12 major streams. The stream that lies directly below the complex (Figure 4-2) is Round Grove Creek. This creek is classified as a third order stream in the watershed and the majority of the stormwater generated from the complex ends up in the Round Grove Creek (MDFG, 2005). Impervious surfaces on site that generate stormwater runoff include the stadiums, parking lots, and other outlying areas that surface flow to drainage structures located around the site.

Figure 4-2, Truman Sports Complex Stream Location Map

(Google Earth, Adapted by Author)

The Blue River then flows into the Missouri River, which is located in the Central Lowland of Missouri. The lowland areas of Missouri are divided into subdivisions, of which the Blue River is located primarily in the Western Glaciated Plains. The Western Glaciated Plains are then a subsection of the dissected Tilled Plains (MDNR, 1986).

Topographically the Truman Sports Complex is characterized by ridgelines with moderate slopes that lay between the Little Blue River to the east and the Blue River to the west.   The dominant visual features of the complex are the bluffs, ravines, tree cover, and highly visible views of the Kansas City Downtown skyline (KCMO, 2008).

Site Geology

The most significant impact on the Truman Sports Complex ability to deal with stormwater using non-traditional methods is the geology of a site.   How water interacts with the subsurface composition will impact the permeability of the site. Ignoring the subsurface layers and its characteristics will create conditions that will hinder the design and implementation of any natural drainage solutions. Understanding the soil conditions on at the complex is critical to establish what retrofit solution to implement due to drainage characteristics of any given soil type.

Soils

From field observations, the soil conditions at Truman Sports Complex represent a mixture of clay, shale and limestone. Because the site at one time was made up of rolling terrain and then manipulated by earthwork operations to construct the stadiums, there are many visual clues that allow a basic understanding of the soil strata. According to the United States Department of Agriculture, the primary soil types along the Blue

River are Kennebec silt loam, Colo silty clay loam and Bremer silt loam. Up the bank where the site is located are the soil types that include Menfro silt loam, Knox silt loam, and several other miscellaneous soil types. Underlying the sports complex development is a layer of fill, which is primarily clay. These soils contribute to very rapid surface water runoff especially in heavily developed areas of the watershed (U.S. Department of Agriculture Natural Resources Conservation Service, 1984).

Climate

There is an old saying about the weather in Missouri, “if you don’t like it, just wait a day and it will change.” This local anecdote is a perfect analogy of the weather patterns in the Kansas City area, which vary greatly according to the Mid America Regional Council (2004). Vast temperature changes throughout the season are due to physiographic features of the area. There are no large mountain ranges or large bodies of water nearby that moderate the temperatures. Throughout all four seasons there are usually dramatic temperature swings. The scientific classification for the region is “a Modified Continental Climate” (MARC, 2004, p. 21).

Precipitation in the region is primarily greatest during the spring and average rainfall for the area, Northwest Prairie Climatological Region, is approximately 36 inches per year (Clements, 53). During the winter months the average mean temperature is around 30.4 degrees while the warmer months can swing from just above freezing in the fall.

Truman Sports Complex Site Context

Kansas City is not unlike any other city in the United States that was developed during a time period when people did not give much thought to how a cities infrastructure was created. Most of the stormwater and sewage treatment operations were hastily constructed because no one ever saw or cared about the finished product. The only time anyone paid attention was when the sewer system failed. Due to the fact that sewer failures were becoming common, the City began to pay attention. Initially, the flooding concerns surrounding Brush Creek and the retail development, commonly referred to the as Country Club Plaza, took center stage because of the amount of damage that was created in 1977. As time passed on, the City began to look to the future.

In 2004, the City set out to develop the *KC-One Stormwater Management Plan*; a comprehensive citywide stormwater management plan (KCMO, 2008). The focus of the plan was to recommend that the City adopt new drainage design standards and to implement a stream buffer ordinance to protect the City's streams. The comprehensive plan included recommendations to the following areas:

- **Policy**: proposes best management practices (BMPs), stream protection, land use planning, development plan approval, floodplain management and permit compliance.
- **Administration**: recommends roles and responsibilities of City departments, staffing needs, operations and maintenance.

- **Stormwater Master Plan Review**: combines watershed master plans into coherent and usable access system, creating centrally organized geographic information system.

- **Capital Improvement Program**: re-prioritizes improvements in 35 watersheds after applying "Green" multi-purpose solutions while complementing the overflow control program (OCP) and improving Municipal Separate Storm Sewer Systems MS4 permit compliance.

- **Public Involvement**: lays the foundation for expanded stormwater management and the use of green solutions.

- **Funding**: identifies approaches and options to address capital, administrative, and operational needs.

- **Implementation**: formulates a comprehensive plan to achieve results. (KCMO, 2008, p 8).

Since the *KC-One Stormwater Management Plan* is focused on improving water quality, the City's recommendations for improving water quality were:

- Floodplain management criteria should be based upon the 100-year flood;

- Stormwater facility designs should be based upon the American Public Works Association (APWA) Section 5600 design standards

- Stormwater facility design should also be based on the APWA BMP manual, which requires new development to manage both quality and quantity of runoff.
  (KCMO, 2008, p. 19).

For this study, it was then critical to understand how the City/Community perceived stormwater management at the Truman Sports Complex.

In 2003, the Kansas City Planning Commission in conjunction with the Mid American Regional Council produced the Kansas City Stream Asset Inventory. The report focused on gaining an understanding of how natural resources could be incorporated into development and stormwater management into KCMO's planning and development guidelines. The end goal was for the City to incorporate natural resource planning with the same weight as infrastructure planning into development process (KCMO, 2003).

Within the KCMO study was an analysis of existing streams and watersheds. Round Grove Creek was an obvious focus due to the lack stormwater drainage management at the Truman Sports Complex. According the report:

> “The Stadium/Park East Planning Area is mostly developed, providing minimal opportunity for new development but at the same time providing opportunities for improvement at the time of redevelopment. Recommendations for this study area place the greatest emphasis on protecting the buffer areas along Round Grove Creek and reducing the amount of impervious surfaces (roads, parking lots, roof tops) as appropriate during redevelopment. The parking lots at the Truman Sports Complex (the Stadiums) and Blue Ridge Mall are two prime areas for implementing Best Management Practices (BMPs) to demonstrate the value of these practices in reducing stormwater runoff from the site while providing additional functional value in the form of shade and aesthetics” (MARC, 2004, p. 81).

By including natural resources within the redevelopment process, the City could gain “a balance between the economic, social, and environmental aspects of growth management” (KCMO, 2008, p21).

Diagnosis of Watershed - As stated previously, the Blue River Watershed is one of the largest in the greater Kansas City Metropolitan area (Figure 4-3). According to the MARC, the primary pollutant generators contributing to the subwatershed of the Truman Sports Complex are:

- Trash and other man-made waste, including oil and grease.
- Nutrient rich overland runoff entering the stream unfiltered.
- Combined sewer outflows (CSO).
- Riparian corridors dominated by non-native vegetation.
  (MARC, 2004, p.38)

The primary pollutant generators align with parking lots previously studied and allow the study to focus on the reducing the impact of the following pollutants:

- Total Suspended Solids
- Total Phosphorus
- Total Nitrogen
- Metals (Zinc & Copper)

For this study, the relationship between the removal rates of hydrocarbons (petroleum such as oil) and trash/debris typically has a direct correlation to removal rates

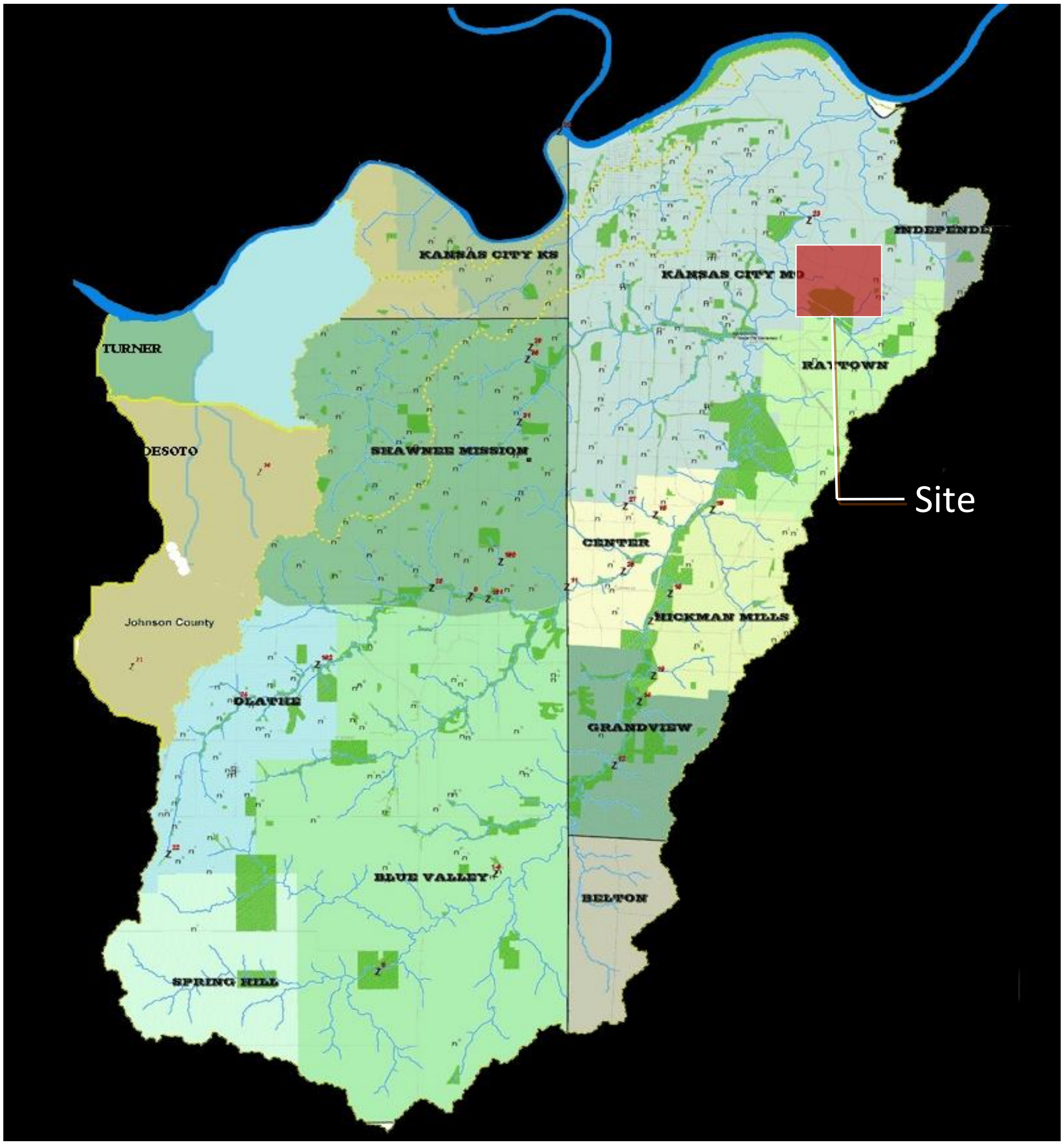


Figure 4-3, Blue River Watershed

(http://mdc.mo.gov/fish/watershed/blue/location/23bloflo.htm) as Total Suspended Solids. In most circumstances these particles either quickly stick to sediments or they are suspended in stormwater runoff and would have the same removal rates as Total Suspended Solids (CWP, 2007).

The study site, the Truman Sports complex, located in Jackson County, Missouri, comprises roughly 400 acres of manmade development (Figure 4-4). The primary site condition is a two-stadium complex serving profession football and professional baseball. These two sports specific stadiums create the hub of professional sports for the greater Kansas City metropolitan area. The five components or features affecting permeability on the site are:

1. Asphalt Surface Parking
2. Stadium Footprints
3. Concrete/Asphalt Walks
4. Greens space – Grading Transitions/Landscape
5. Asphalt Roads

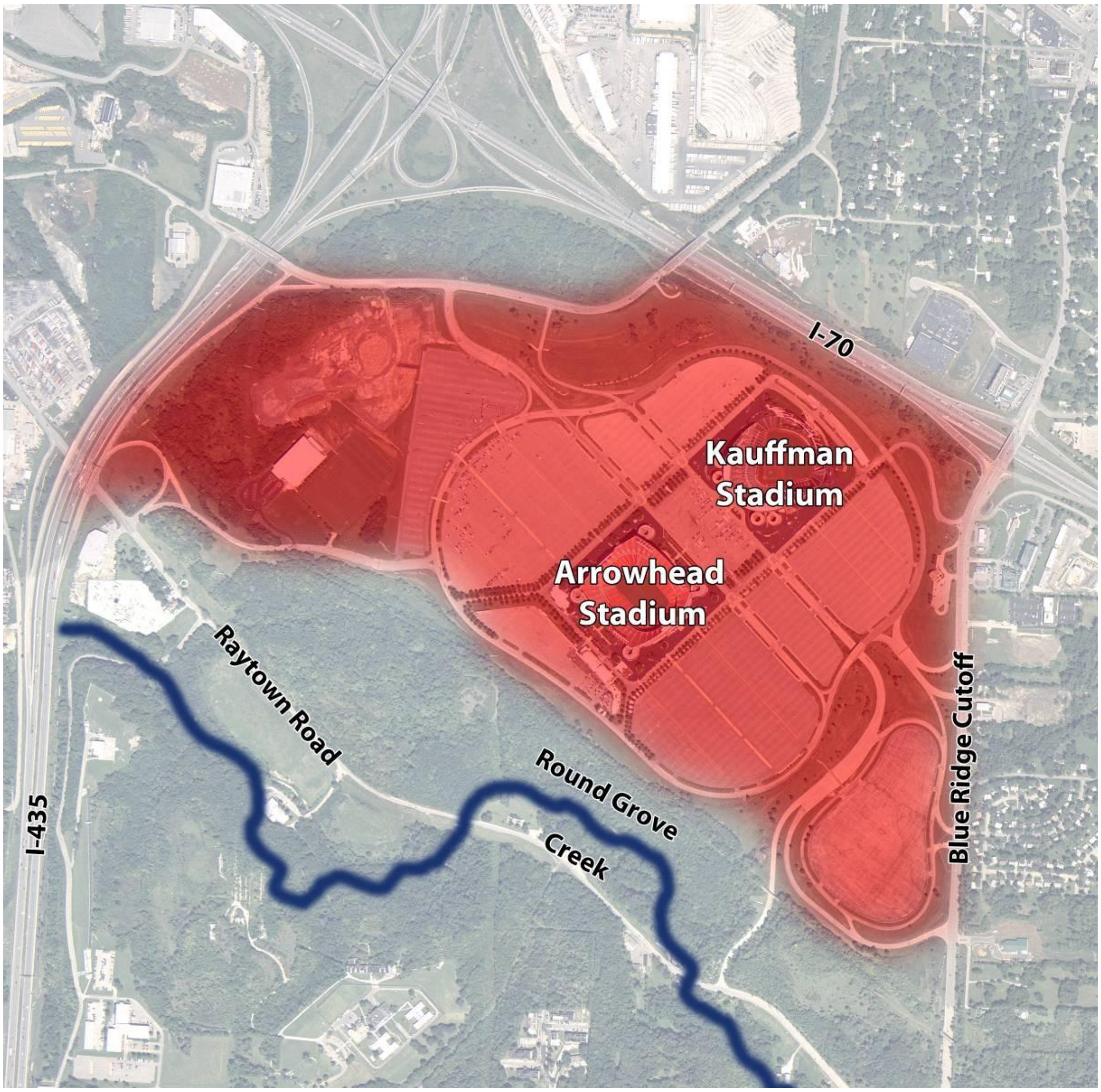
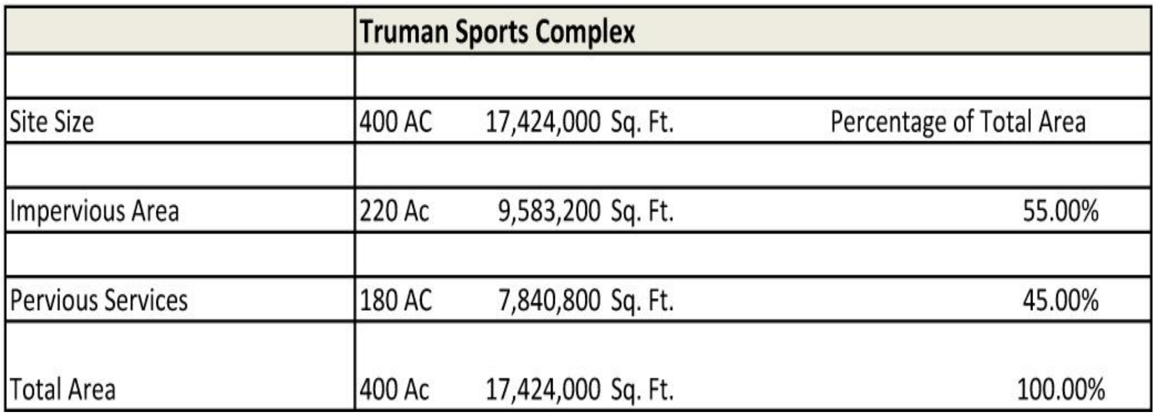


Figure 4-4, Truman Sports Complex Site Location,
(Google Earth, 2007, Adapted by Author)

The primary impervious surface is existing parking surface and road network that surrounds the stadium complex. The impervious surfaces are made up of asphalt and they accommodate roughly 100 event dates during a typical ‘event’ season. The events include professional baseball games, professional football games, college sporting events, and various concerts throughout the year. While mass transit serves the facility, fans primarily access the site across the Midwest via the automobile.

The amount of impervious surface is defined in Table 4-1. From the table, the sports complex impervious surface is calculated at roughly 55 percent. The biggest misconception the numbers reveal is the amount of impervious area throughout the whole complex. While moderate percentage of impervious surface would suggest opportunity for onsite storage retrofits, a simple analysis of the topography (Figure 4-5) suggests that the green space surrounding the site cannot support storage retrofits due to the elevation surrounding the surface parking.

Table 4-1, Truman Sports Complex – Percentage of Impervious Area
(Author's Calculations)



	Truman Sports Complex			
Site Size	400 AC	17,424,000	Sq. Ft.	Percentage of Total Area
Impervious Area	220 Ac	9,583,200	Sq. Ft.	55.00%
Pervious Services	180 AC	7,840,800	Sq. Ft.	45.00%
Total Area	400 Ac	17,424,000	Sq. Ft.	100.00%

As the site looks to storage potential, it is imperative to understand the characteristics of the site and how the site functions from a hydrological standpoint. As seen in Figure 4-5, the site has a ridgeline that bisects the centerline of the two stadiums. The ridge serves as a high point and directs water from the stadiums to the two roads flanking the stadiums, Red Coat Lane and Lancer Lane. The surrounding surface parking, roughly 174 acres, also drains to this common low point into a 6'x6' concrete box culvert under the green space that flanks the roadways. Once inside this channelized culvert, the water is directed to the southwest location of the sports complex where it is discharged into Round Grove Creek and eventually to the Blue River.

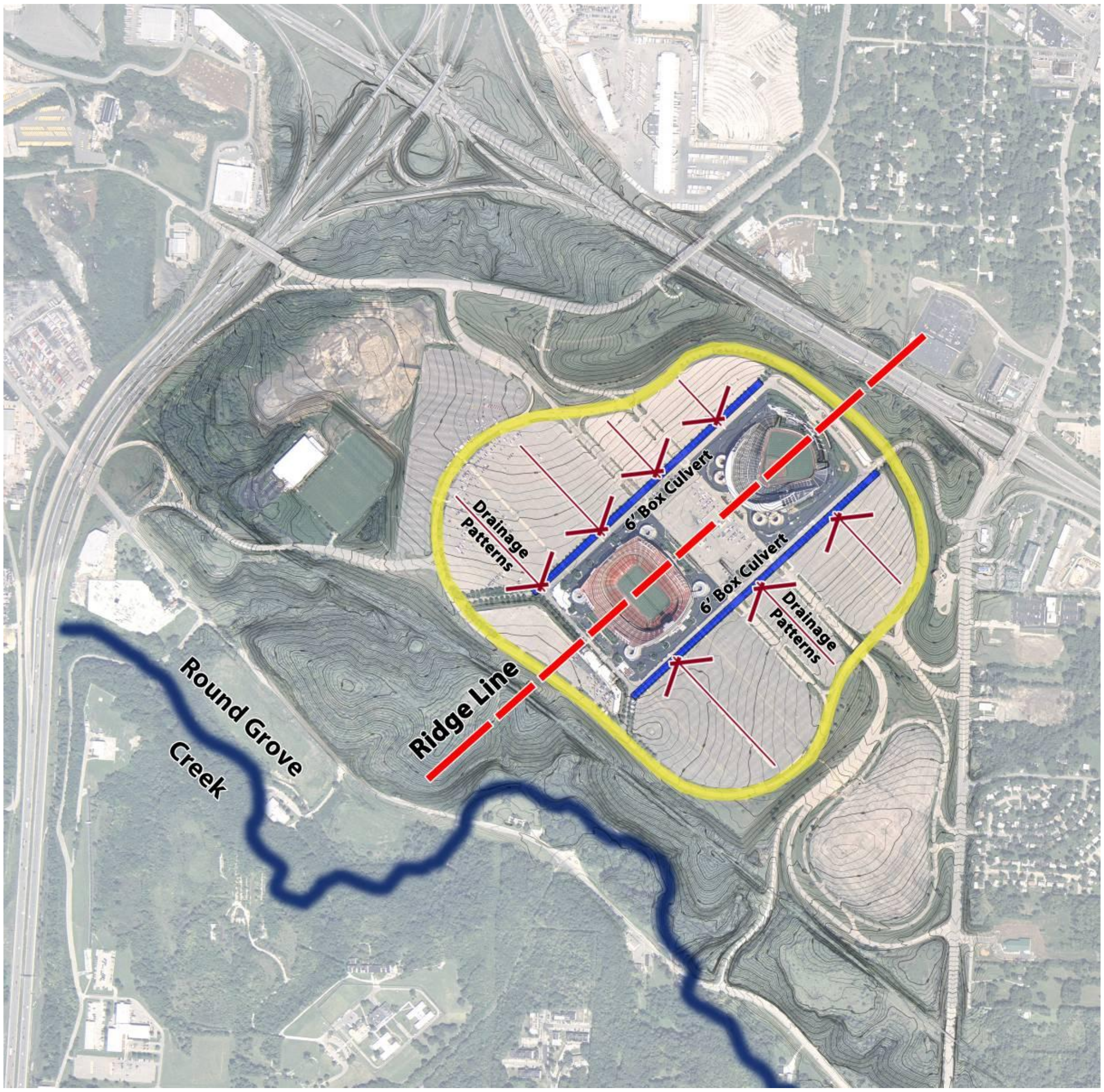
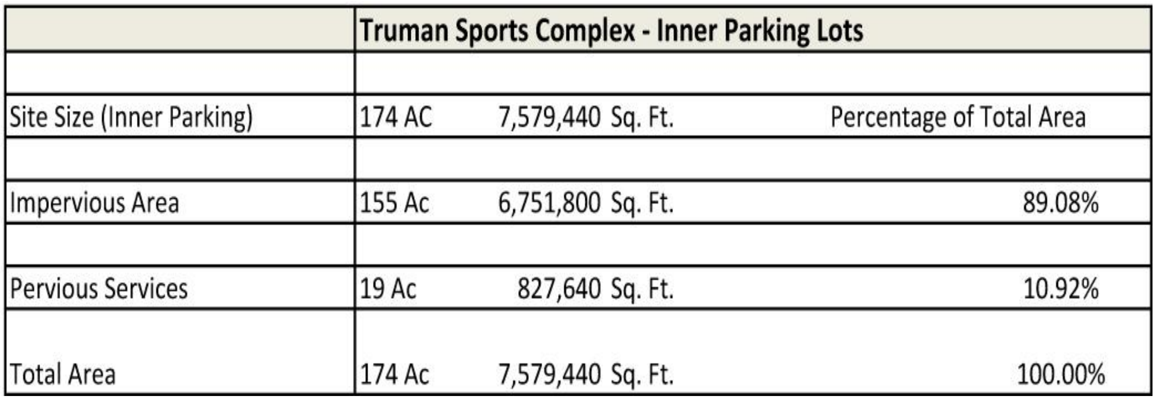


Figure 4-5, Truman Sports Complex Site – Drainage Patterns, Yellow boundary outlines the boundaries of the inner parking lots. (Google Earth, 2007, Adapted by Author)

The importance of site characteristic is how a perceived stormwater retrofit can actually function on site. As shown in Table 4-2, the inner parking is highly impervious at 89.16 percent. The inner parking lots subwatershed generates a large volume of pollutants to the overall system due to its high level of impermeability. The sports complex design and elevations direct the drainage towards both stadiums and away from the common green areas. The existing site factors leave the designer but one choice; onsite treatment options.

Table 4-2, Truman Sports Complex Inner Parking Lots – Percentage of Impervious Area
(Author's Calculations)

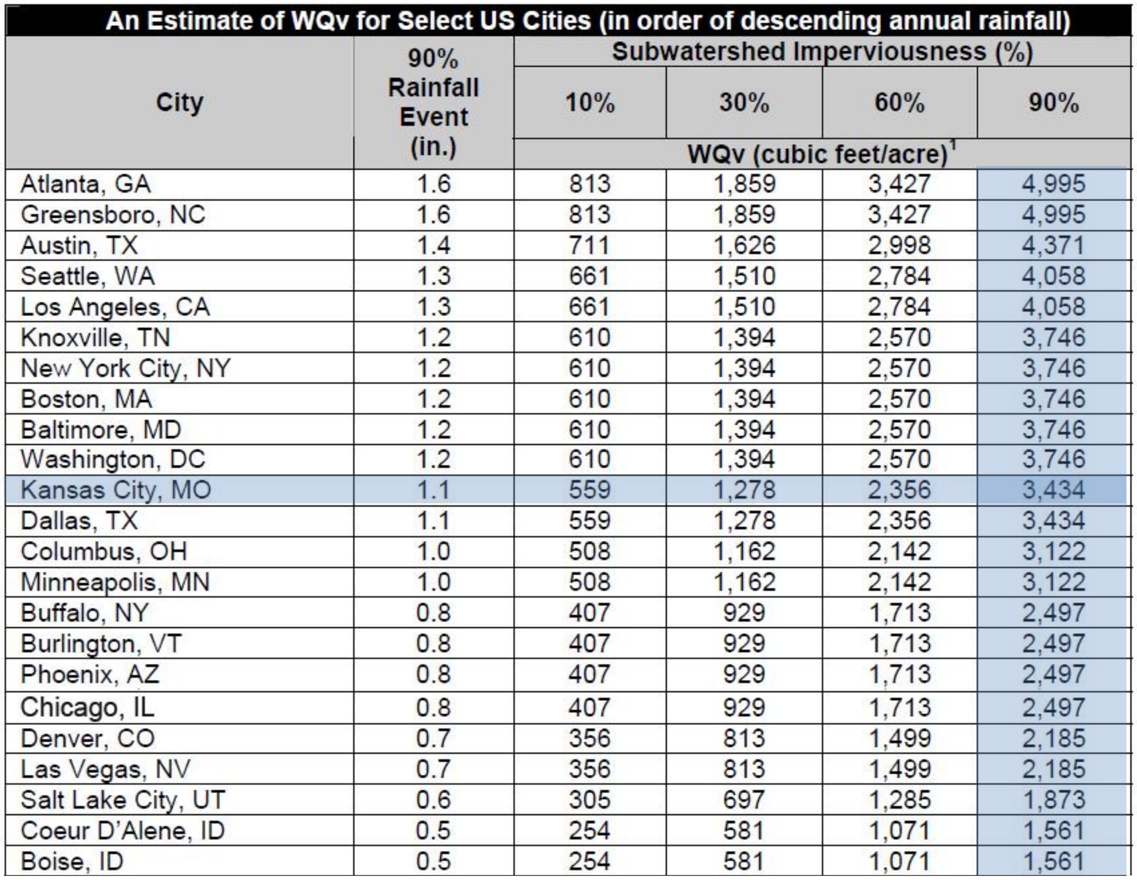


	Truman Sports Complex - Inner Parking Lots			
Site Size (Inner Parking)	174 AC	7,579,440	Sq. Ft.	Percentage of Total Area
Impervious Area	155 Ac	6,751,800	Sq. Ft.	89.08%
Pervious Services	19 Ac	827,640	Sq. Ft.	10.92%
Total Area	174 Ac	7,579,440	Sq. Ft.	100.00%

As previously examined during the case study analysis, the estimate for Water Quality Volume, Table 4-3, can determine the aggregate Water Quality Volume (WQv) storage needed for a retrofit site. In most subwatersheds, it is hard to find enough feasible storage retrofits to treat more than 50 percent of subwatershed area (CWP, 2000). To get to a higher level of pollutant reduction onsite retrofits must be explored. Because of the high level of impervious surfaces typically found in large parking lots, the study focuses on onsite retrofits.

Table 4-3, Estimate of WQv for US Cities

(CWP, 2007, p. 9)



An Estimate of WQv for Select US Cities (in order of descending annual rainfall)

City	90% Rainfall Event (in.)	Subwatershed Imperviousness (%)			
		10%	30%	60%	90%
		WQv (cubic feet/acre)[1]			
Atlanta, GA	1.6	813	1,859	3,427	4,995
Greensboro, NC	1.6	813	1,859	3,427	4,995
Austin, TX	1.4	711	1,626	2,998	4,371
Seattle, WA	1.3	661	1,510	2,784	4,058
Los Angeles, CA	1.3	661	1,510	2,784	4,058
Knoxville, TN	1.2	610	1,394	2,570	3,746
New York City, NY	1.2	610	1,394	2,570	3,746
Boston, MA	1.2	610	1,394	2,570	3,746
Baltimore, MD	1.2	610	1,394	2,570	3,746
Washington, DC	1.2	610	1,394	2,570	3,746
Kansas City, MO	1.1	559	1,278	2,356	3,434
Dallas, TX	1.1	559	1,278	2,356	3,434
Columbus, OH	1.0	508	1,162	2,142	3,122
Minneapolis, MN	1.0	508	1,162	2,142	3,122
Buffalo, NY	0.8	407	929	1,713	2,497
Burlington, VT	0.8	407	929	1,713	2,497
Phoenix, AZ	0.8	407	929	1,713	2,497
Chicago, IL	0.8	407	929	1,713	2,497
Denver, CO	0.7	356	813	1,499	2,185
Las Vegas, NV	0.7	356	813	1,499	2,185
Salt Lake City, UT	0.6	305	697	1,285	1,873
Coeur D'Alene, ID	0.5	254	581	1,071	1,561
Boise, ID	0.5	254	581	1,071	1,561

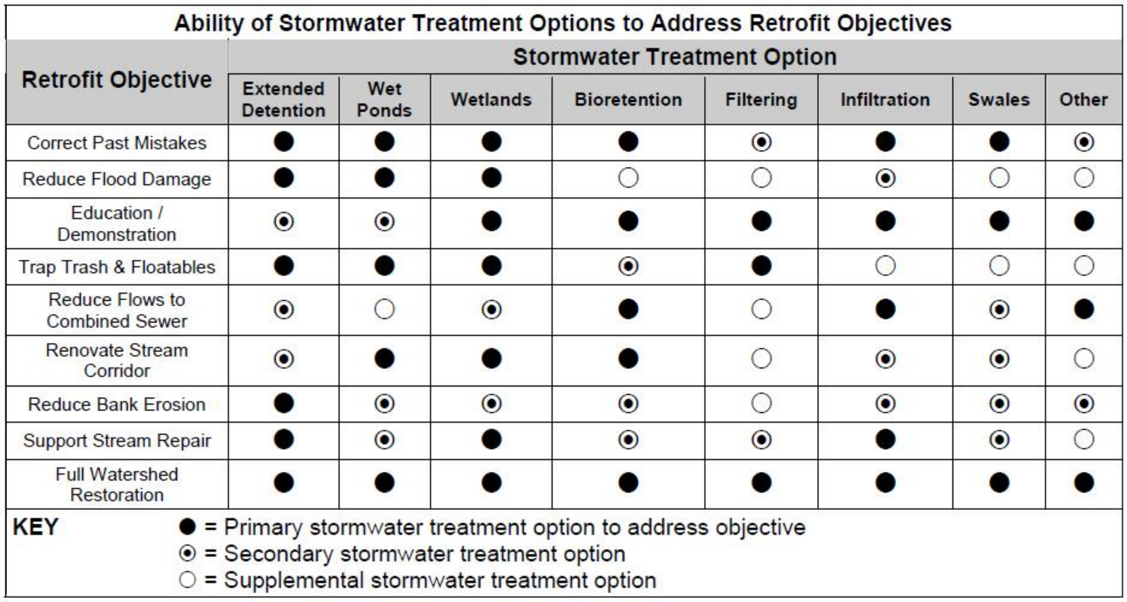
The Truman Sports Complex inner parking area has an impervious area of around 90 percent. As such, the site would need to treat 3,434 cubic feet of water per acre. At 174 acres, the parking lot sites would have to treat 597,516 cubic feet of stormwater for every 1.1 inches of rain. According to the CWP, the standard measure for target storage volume for runoff reduction ranges from 20 to 50% of the target WQv" (CWP, 2000). Using that analysis, the sports complex would have to find an offsite storage area between 35-87 acres to treat the volume required. For this site, this requirement became even more challenging because of space limitations. With only 19 acres of green space, it becomes apparent that the focus should center on onsite retrofit techniques.

Retrofit Objectives – By understating the site characteristics, the design can then define the core retrofit objectives for the watershed. The objectives are listed below:

- Correct past mistakes
- Removing pollutants of concern

According to the CWP these objectives can be realized by utilizing the retrofit techniques defined in Table 4-4 below.

Table 4-4, Treatment Options to Address Retrofit Objectives, The asterisks indicates the core retrofit objectives of the intended design solution (CWP, 2007, p. 158)



Ability of Stormwater Treatment Options to Address Retrofit Objectives

	Retrofit Objective	Stormwater Treatment Option							
		Extended Detention	Wet Ponds	Wetlands	Bioretention	Filtering	Infiltration	Swales	Other
*	Correct Past Mistakes	●	●	●	●	◉	●	●	◉
	Reduce Flood Damage	●	●	●	○	○	◉	○	○
	Education / Demonstration	◉	◉	●	●	●	●	●	●
*	Trap Trash & Floatables	●	●	●	◉	●	○	○	○
	Reduce Flows to Combined Sewer	◉	○	◉	●	○	●	◉	●
	Renovate Stream Corridor	◉	●	●	●	○	◉	◉	○
	Reduce Bank Erosion	●	◉	◉	◉	○	◉	◉	◉
	Support Stream Repair	●	◉	●	◉	◉	●	◉	○
	Full Watershed Restoration	●	●	●	●	●	●	●	●

KEY
● = Primary stormwater treatment option to address objective
◉ = Secondary stormwater treatment option
○ = Supplemental stormwater treatment option

Truman Sports Complex Design Implementation Strategies

Using Table 4-4, the design strategies are narrowed to the primary treatment options that address the outlined retrofit objectives. Based on the site characteristics and restraints for this site, this study focuses on the following treatment options:

1. Bioretention
2. Infiltration
3. Swales

Before the treatment options can be implemented, it is important for the retrofit to understand how the specific treatments could potentially function on the selected site.

Bioretention – The use of bioretention as an onsite stormwater retrofit technique can help this site significantly impact water quality by treating runoff from impervious surfaces, such as rooftops and parking lots (MARC, 2008). The CWP defines bioretention as: “a landscaping feature adapted to treat stormwater runoff at retrofit sites” (2007, p. 171). Figure 4-6 is a representative section of a bioretention area. Typically, effective

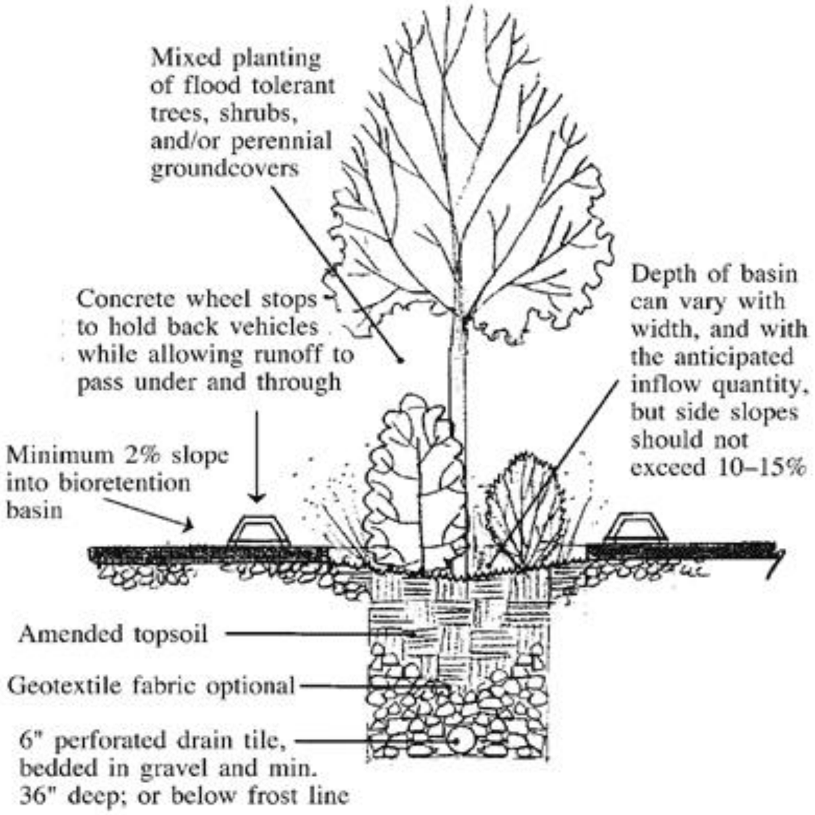


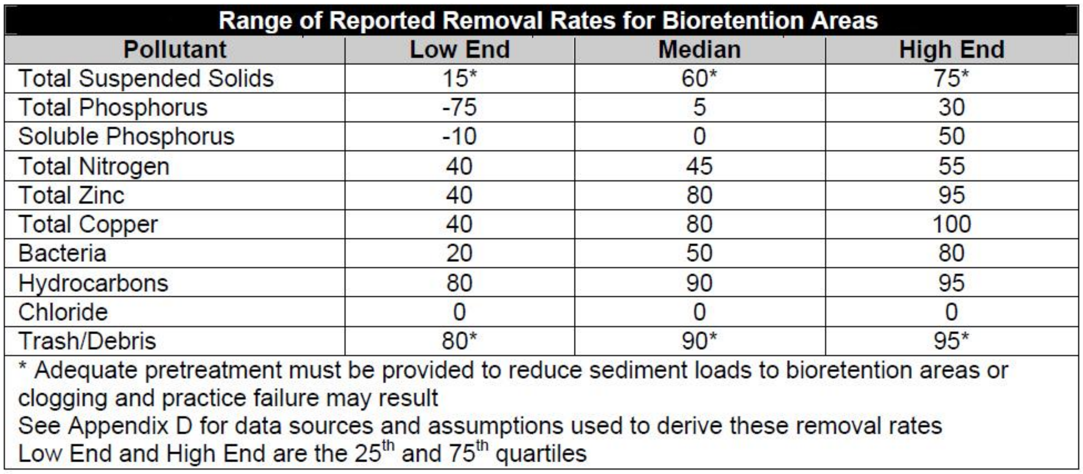
Figure 4-6, Bioretention Section,

(University of Illinois, http://urbanext.illinois.edu/lcr/landscaping.cfm, 2005) bioretention provides these common benefits:

- Requires only about five percent of the total impervious area.
- Easily designed and can be part of the site's required open space.
- Easy to maintain/reduces maintenance costs

Another benefit of this treatment strategy on the selected site is the effectiveness in removing a large number of pollutants as a result of sedimentation. Bioretention has been shown to reduce runoff volume by 35 to 50 percent through evapotranspiration and infiltration of runoff (CWP, 2007). Table 4-5 describes the removal rates for bioretention areas. It is also very important to factor in the soil types for the treatment area. With highly permeable soil, the bioretention area can potentially eliminate the need for an underdrain and achieve higher pollutant removal rates (CWP, 2007). For the Truman Sport Complex, the extra benefit from permeable soils is not a factor due to the high clay content present in the soil, but it still gives the design a viable treatment option.

Table 4-5, Removal Rates for Bioretention Areas.
(CWP, 2007, p. D-3)



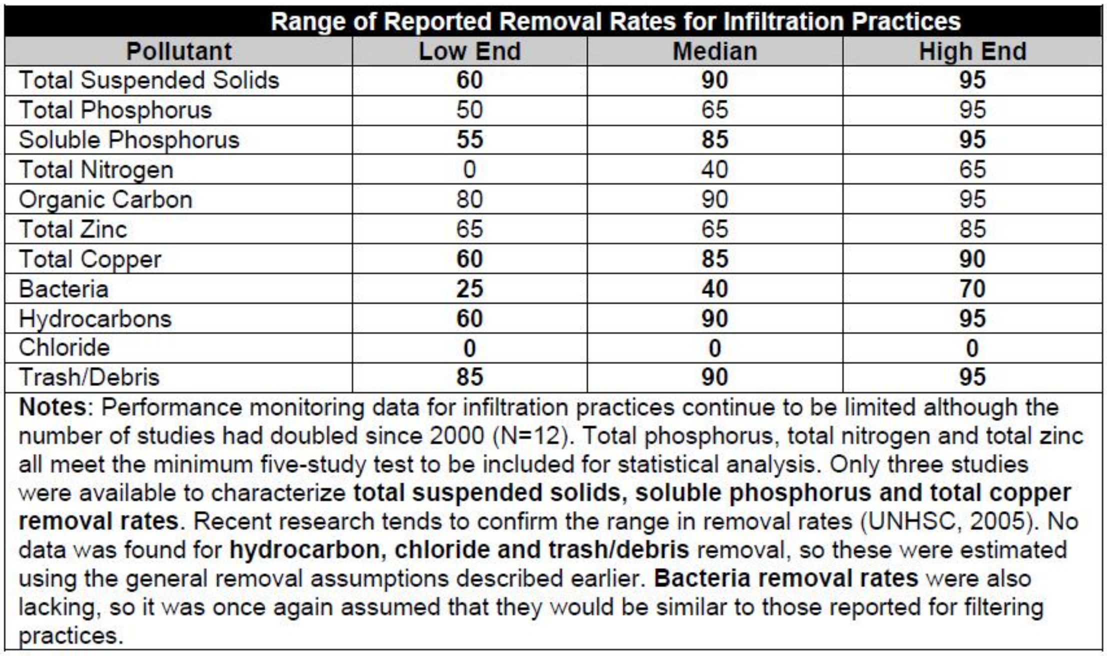
Range of Reported Removal Rates for Bioretention Areas

Pollutant	Low End	Median	High End
Total Suspended Solids	15*	60*	75*
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	0	50
Total Nitrogen	40	45	55
Total Zinc	40	80	95
Total Copper	40	80	100
Bacteria	20	50	80
Hydrocarbons	80	90	95
Chloride	0	0	0
Trash/Debris	80*	90*	95*

* Adequate pretreatment must be provided to reduce sediment loads to bioretention areas or clogging and practice failure may result
See Appendix D for data sources and assumptions used to derive these removal rates
Low End and High End are the 25th and 75th quartiles

Infiltration – The biggest difference between bioretention and infiltration treatment strategies deals with how the water is stored and when the water is treated. Most infiltration practices store water before they treat the pollutants present. Infiltration uses the soil and other nature systems to absorb and treat the pollutants existing on site. Infiltration, as a retrofit strategy, typically only addresses the treatment of water quality (CWP, 2007). Table 4-6 represents the range of removal rates for infiltration practices.

Table 4-6, Removal Rates for Infiltration Practices.
(CWP, 2007, p. D-4)



Range of Reported Removal Rates for Infiltration Practices

Pollutant	Low End	Median	High End
Total Suspended Solids	**60**	**90**	**95**
Total Phosphorus	50	65	95
Soluble Phosphorus	**55**	**85**	**95**
Total Nitrogen	0	40	65
Organic Carbon	80	90	95
Total Zinc	65	65	85
Total Copper	**60**	**85**	**90**
Bacteria	**25**	**40**	**70**
Hydrocarbons	**60**	**90**	**95**
Chloride	**0**	**0**	**0**
Trash/Debris	**85**	**90**	**95**

Notes: Performance monitoring data for infiltration practices continue to be limited although the number of studies had doubled since 2000 (N=12). Total phosphorus, total nitrogen and total zinc all meet the minimum five-study test to be included for statistical analysis. Only three studies were available to characterize **total suspended solids, soluble phosphorus and total copper removal rates**. Recent research tends to confirm the range in removal rates (UNHSC, 2005). No data was found for **hydrocarbon, chloride and trash/debris** removal, so these were estimated using the general removal assumptions described earlier. **Bacteria removal rates** were also lacking, so it was once again assumed that they would be similar to those reported for filtering practices.

For an infiltration system to be highly effective from the stormwater management and cost perspectives, it must be utilized on sites with highly permeable soils. Sites with a low level of permeability can still use infiltration as a treatment type, but the costs to create storage usually outweigh the benefits for using a storage treatment type. As stated previously, the soil types present at the Truman Sports Complex would make an infiltration solution difficult to achieve due to the cost benefit analysis. It is important to note that infiltration retrofits are not intended to treat sites with high sediment or trash/debris loads, as they could cause the infiltration retrofit to clog and fail.

Typically, infiltration design is nothing more than a gravel-lined trench (Figure 4-7) that allows water to collect between the gravel and then percolate into the soil. With the introduction of permeable pavements, the type of retrofit technique has expanded to applications such as Permeable Pavers (Figure 4-8). For the Truman Sports complex, the soil conditions and the amount of use the parking receives make an infiltration retrofit treatment practical.

Figure 4-7, Infiltration Trench,

(CWP, 2007

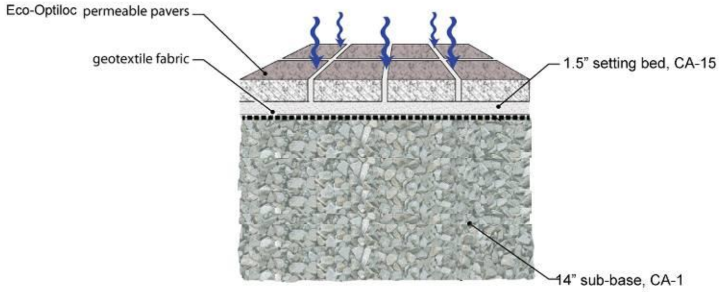


Figure 4-8, Permeable Pavers- Section,

(CWP, 2000)

Swales – Swales are utilized to provide treatment in either storage or on-site retrofit applications by using the stormwater conveyance system. With their moderate pollutant removal capability, swales can reduce runoff volume and increase groundwater recharge (CWP, 2007). The three common design types are:

Dry Swale - Are a linear soil filter system that temporarily stores and then filters the desired WQv. Dry swales are similar to bioretention areas in that they rely on a fabricated soil bed on the bottom of the channel. Existing soils are replaced with a sand/soil mix that meets minimum permeability requirements (CWP, 2007, p.185).

Wet swale - Are linear wetland cells that intercept shallow groundwater to maintain a wetland plant community. Saturated soils support wetland vegetation, which provides an ideal environment for gravitational settling, biological uptake, and microbial activity (CWP, 2007, p.185).

Grass channel - are open channels that provide limited water quality treatment using rate-based design criteria (Figure 4-9 & 10). Grass channels reduce flow velocities and increase filtration capacity. Grass channels generally cannot provide the same degree of pollutant removal as dry or wet swales (CWP, 2007, p. 185).

Figure 4-9, Dry Swale - Grass Channel

(CWP, 2007, p. 185)

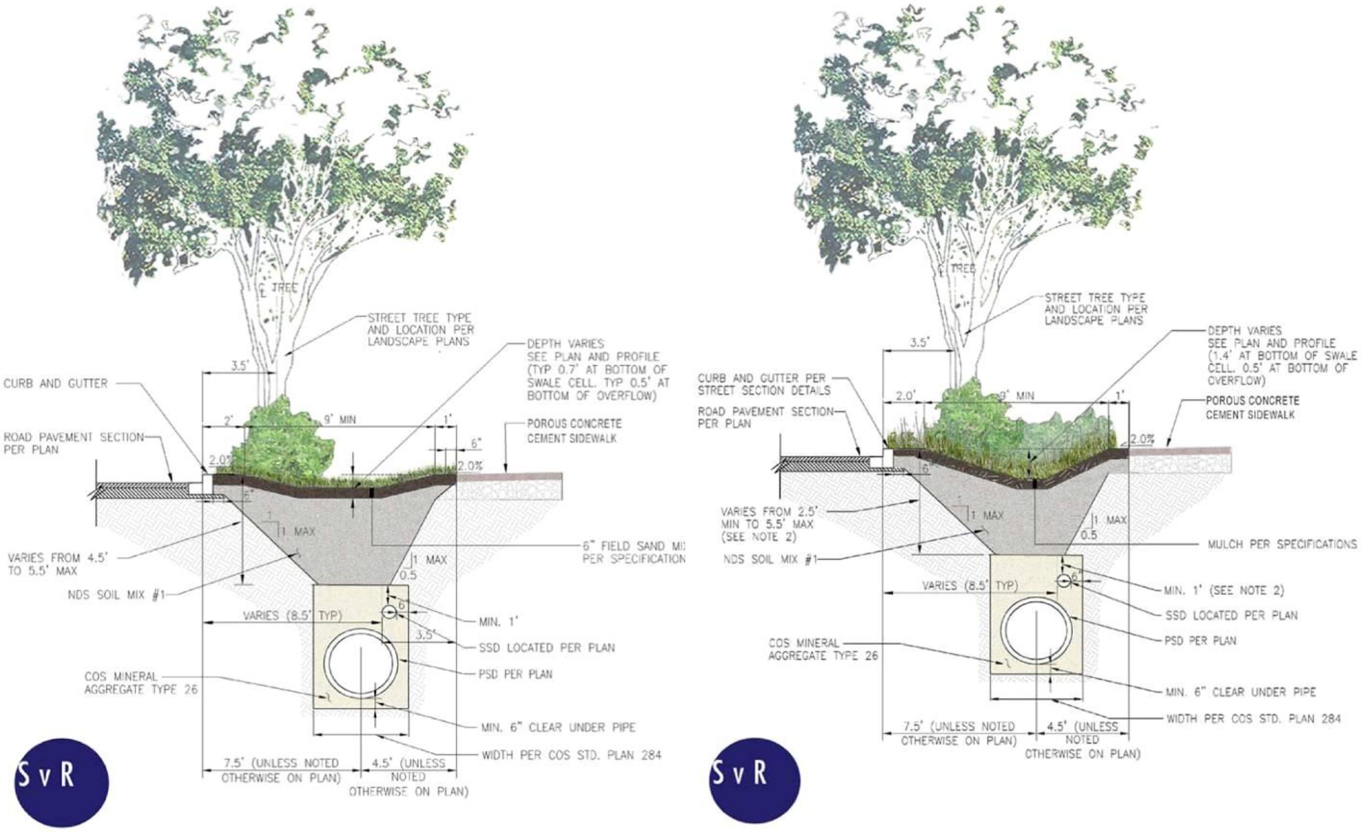


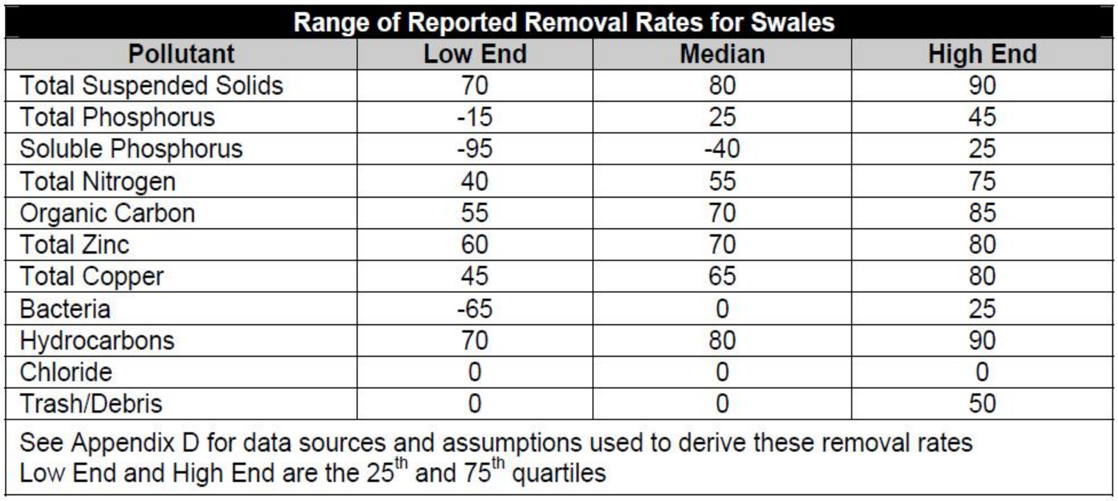
Figure 4-10, Swale Sections - Grass Channel & Vegetative Channel

(SVR Design, http://www.svrdesign.com/docs/MontgomeryCo%20-%20Planning%20and%20Design%20-%20Applied%20LID%20Techniques.pdf, 2005).

The primary concern with using swales in any retrofit application is the variability of removal rates in pollutant types. Swale design and plant selection create the biggest variation in removal rates for the treatment solution. For the Truman Sports Complex design solution it is important to know that a grass lined swale needs to cut the median pollutant removal rates (Table 4-7) in half and adjust the high and low end numbers accordingly (CWP, 2007).

Table 4-7, Removal Rates for Infiltration Practices.

(CWP, 20107, p. D-5)



Range of Reported Removal Rates for Swales			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	70	80	90
Total Phosphorus	-15	25	45
Soluble Phosphorus	-95	-40	25
Total Nitrogen	40	55	75
Organic Carbon	55	70	85
Total Zinc	60	70	80
Total Copper	45	65	80
Bacteria	-65	0	25
Hydrocarbons	70	80	90
Chloride	0	0	0
Trash/Debris	0	0	50

See Appendix D for data sources and assumptions used to derive these removal rates
Low End and High End are the 25th and 75th quartiles

Economics of Retrofitting the Truman Sports Complex

As stated earlier, new products, technologies, or ideas have evolved over a period of time creating opportunities for new design solutions. The biggest problem new solutions face is a perception of cost. For the Truman Sports Complex, it is important to understand the unit costs per cubic foot of runoff treated for the treatment solutions. Table 4-8 defines the unit costs per treatment type.

From Table 4-8, the three treatment types, large bioretention retrofits, water quality swale retrofits and permeable pavers show a wide swing in cost. Bioretention retrofits and swales have the lowest treatment cost per cubic foot of runoff treated, while permeable pavers have one of the higher treatments costs. Based off the cost data it would suggest that permeable pavers not be used in the retrofit of the Truman Sports Complex due to the high cost.

Table 4-8, Removal Rates for Infiltration Practices. The asterisks indicate the retrofit techniques applied to the intended design solution (CWP, 2007, p. E-3)

Range of Retrofit Costs (2006 $ per cubic foot of runoff treated)		
Retrofit Technique	**Median Cost**	**Range**
Pond Retrofits	$ 3.00	$ 1.00 to 10.00
Rain Gardens	$ 4.00	$ 3.00 to 5.00
New Storage Retrofits	$ 5.00	$ 2.50 to 9.00
* Larger Bioretention Retrofits	$ 10.50	$ 7.50 to 17.25
* Water Quality Swale Retrofit	$ 12.50	$ 7.00 to 22.00
Cisterns	$ 15.00	$ 6.00 to 25.00
French Drain/Dry Well	$ 12.00	$ 10.50 to 13.50
Infiltration Retrofits	$ 15.00	$ 10.00 to 23.00
Rain Barrels	$ 25.00	$ 12.50 to 40.00
Structural Sand Filter	$ 20.00	$ 16.00 to 22.00
Impervious Cover Conversion	$ 20.00	$ 18.50 to 21.50
Stormwater Planter	$ 27.00	$ 18.00 to 36.00
Small Bioretention Retrofits	$ 30.00	$ 25.00 to 40.00
Underground Sand Filter	$ 65.00	$ 28.00 to 75.00
Stormwater Tree Pits	$ 70.00	$ 58.00 to 83.00
* Permeable Pavers	$ 120.00	$ 96.00 to 144.00
Extensive Green Rooftops	$ 225.00	$ 144.00 to 300.00
Intensive Green Rooftops	$ 360.00	$ 300.00 to 420.00
Note: Costs shown are base construction costs and do not include additional D&E costs, which can range from 5 to 40%		

Installation and Maintenance

As previously discussed, the installation and maintenance practices of a project will ultimately define whether or not the project is a success in the mind of any client. The biggest constraint for any sports venue is an ongoing maintenance cost to keep the facility up and running. With a limited number of operational dates, it is imperative to the operators of sports facilities to keep everything functioning to generate revenue. A parking lot is the last place any operator wants to spend a great deal of maintenance and operational costs. Parking spaces need to function by themselves with little or no daily maintenance.

When deciding which design solution to implement, it is important to understand the maintenance concerns. The biggest two concerns with the treatment types identified are:

1. Bioretention/Swales – The plant material that is used to help reduce the pollutant load has to be able to survive a series of rain events with little or no recovery time.
2. Permeable Pavers – The venue operator has to sweep and/or vacuum the pavers on a regular basis to keep the surface performing at pollutant removal levels per the intended design.

With the maintenance factors in mind, the design can take the implementation strategies and move into the final design phase.

Treatment Types - Selection

Site Imperviousness – By narrowing the study to a specific parking area, the study will be able to focus in on the intended design solution (Step 1, Appendix D). Parking lots C & D (Figure 4-11) are made up of roughly 1,335,974 square feet (30.67 acres) of area. Of this area, 1,228,066 square feet (28.19 acres) is defined as impervious surface area primarily made up of asphalt pavement for parking walkways. The pervious surface, 107,908 square feet, (2.5 acres) is primarily made up of gravel and landscape.

Figure 4-11, Existing Lot C & D – Truman Sports Complex

(Microsoft Visual Earth, 2009, Adapted by Author)

Pre-Retrofit Pollutant Load - As noted before, understanding the types of pollutants typically found on site based on a sites land use characteristics is critical to the selection of the proposed retrofit solution. The final design solution will focus on these pollutants of concern:

- Total Suspended Solids
- Total Phosphorus
- Total Nitrogen
- Metals (Zinc & Copper)

It is important to understand that other pollutants such as hydrocarbons (petroleum such as oil) and trash/debris typically have the same removal rates as Total Suspended Solids. In most circumstances, pollutant particles either stick to sediments or they are suspended in stormwater runoff. Therefore, hydrocarbons would have the same removal rates as Total Suspended Solids (CWP, 2007). Using Table 3-6, the pre-retrofit pollutant load for Lots C & D was calculated (Step 2, Appendix D) and the results for the three treatment types are defined in Table 4-9.

Table 4-9, Truman Sports Complex, Lot C & D Pre-Retrofit Pollutant Loads,
(Author's Calculations, 2010)

Truman Sports Complex - Lot C & D	
Pre-Retrofit Pollutant Load	
Total Suspended Solids	5,636 lbs per Year (2,556 kg per Year)
Total Phosphorus	31 lbs per Year (14 kg per Year)
Total Nitrogen	397 lbs per Year (180 kg per Year)
Metals	
Zinc	29 lbs per Year (13 kg per Year)
Copper	11 lbs per Year (5 kg per Year)

Stormwater Treatment Option – Based on the analysis of the potential treatment types, the final design solution will use a combination of bioretention and grass lined swales for stormwater treatment. The combination of bioretention and grass lined swales as treatment option was selected because it allowed the design to respond to the site-specific factors for retrofitting this site. The site factors that will have the biggest impact on the design are:

- Maintaining the Existing Parking Count of Lot C & D (4,278 parking spaces).
- Creating a fan amenity for tailgating.
- Parking lot circulation
- Limited site area.

These factors then formed the basis for selecting the treatment options.

The biggest concern with a sports facility is the volume of spectators that use the parking areas during an event. The viability of the plant material to perform and function as a stormwater treatment option is what allows bioretention to function. Figure 4-12 shows a vegetative bioretention area that could only be used on a site in areas where heavy pedestrian traffic will not occur. The use of low lying plant material, such as buffalo grass for its deep root growth, will be critical in high traffic areas.

Figure 4-12, Vegetative Swale Example

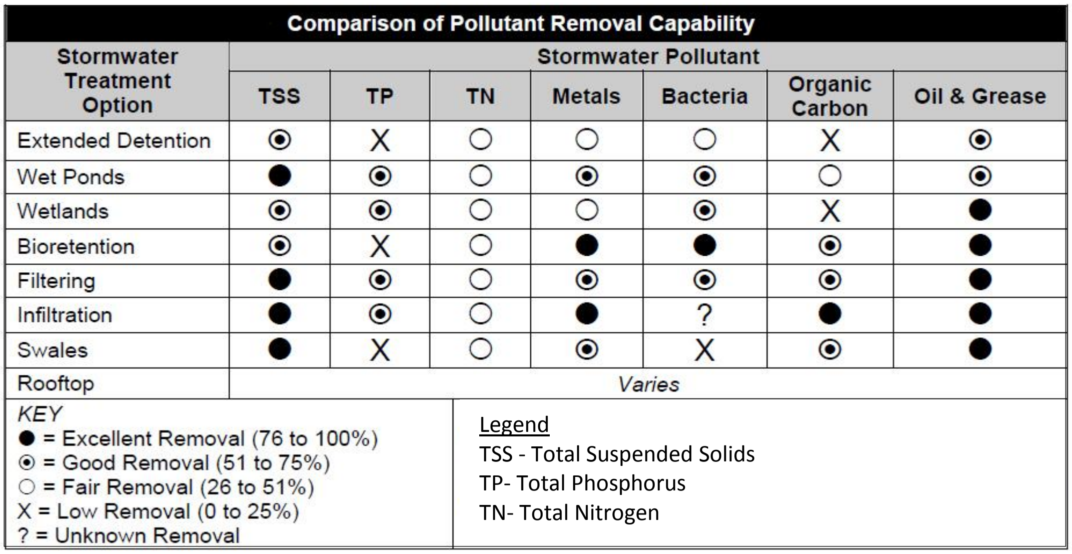
(Microsoft Visual Earth, 2009,)

As mentioned previously, the Truman Sports Complex climate and soil conditions have the greatest impact on plant material. Summer heat and lack of rainfall during the summer months will create the requirement for irrigation. Keeping the plant material irrigated is the only hope to maintaining healthy plant material during the summer months. The soil conditions used in bioretention are another challenge.

Primarily made up of clay, the existing soils contribute to rapid surface water runoff that generally does not allow water to percolate through the soil structure. An engineered soil that promotes drainage will have to be imported onto the site to allow the bioretention and grass lined swales the ability to treat stormwater. The challenge will be to keep the plant material alive. With such a well-drained soil, the irrigation component will become critical during the dry season to keep the plants alive. Table 4-10 defines how various treatment types deal with the pollutants of concern and their removal capacity associated with implementation.

Table 4-10, Comparison of Pollutant Removal Capability

(CWP, 2007, p. 158, modified by Author)



Comparison of Pollutant Removal Capability							
Stormwater Treatment Option	Stormwater Pollutant						
	TSS	TP	TN	Metals	Bacteria	Organic Carbon	Oil & Grease
Extended Detention	⦿	X	○	○	○	X	⦿
Wet Ponds	●	⦿	○	⦿	⦿	○	⦿
Wetlands	⦿	⦿	○	○	⦿	X	●
Bioretention	⦿	X	○	●	●	⦿	●
Filtering	●	⦿	○	⦿	⦿	⦿	●
Infiltration	●	⦿	○	●	?	●	●
Swales	●	X	○	⦿	X	⦿	●
Rooftop	*Varies*						

KEY
● = Excellent Removal (76 to 100%)
⦿ = Good Removal (51 to 75%)
○ = Fair Removal (26 to 51%)
X = Low Removal (0 to 25%)
? = Unknown Removal

Legend
TSS - Total Suspended Solids
TP- Total Phosphorus
TN- Total Nitrogen

Final Design Solution

Retrofitting goals – The final design solution will then take the objectives of the site analysis and apply them to the design (Figure 4-13). The goals for the final design solution will be to:

1. Recharge Watershed
2. Improve Water Quality
3. Improve Spectator Comfort
4. Provide Amenities

Figure 4-13, Aerial - Truman Sports Complex

(Google Earth, 2010, Adapted by Author)

Design Theory – Looking at the parking areas surrounding the stadiums (Figure 4-5) at the Truman Sports Complex, it is apparent that all the parking lots have the same basic drainage patterns and characteristics. Parking Lot C and D (Figure 4-13) at the Truman Sports Complex comprise 30.67 acres. By focusing the solution on a specific lot, the design can identify a detailed design solution, which could hypothetically be applied to all the lots surrounding the sports complex. This hypothetical implementation would be calculated to achieve the maximum treatment outcome.

Arrival – The basis for the design solution will take cues from the design of the Northgate Mall (Case Study 1) as means for implementation. Understanding how fans arrive and utilize the parking area is critical to creating a usable space that treats stormwater, improves the fan experience and provides amenities during an event. This all has to happen simultaneously to create a dynamic fan experience.

Typically, at any venue, the arrival times for fans will vary greatly. People that enjoy the tailgate atmosphere will arrive early and stay late, while other fans arrive late and leave early to avoid traffic. Using arrival time as the first guiding principle for the design, an analysis diagram can be created that reflects the arrival patterns for most fans at any given lot. (Figure 4-11). In this diagram, a set distance, roughly 1/3 of the parking lot defines the space that will be developed for the fan that has a passion for the tailgate experience.

Tailgating – Space is the defining factor for any tailgate experience and the average fan always wants more. The second guiding design principal is similar in theory to the usage requirements at Northgate Mall. At Northgate Mall, the telescoping swale design took cues from the fact that everyday use was greater than that of holiday traffic. In theory people that came to the mall everyday would want more space to park their cars than that of the casual holiday shopper. In the case of the sports venue the pattern is reversed. The hardcore fan that loves to tailgate wants as much available space as possible around their cars to create their own event. Even more important to the experience is open space.

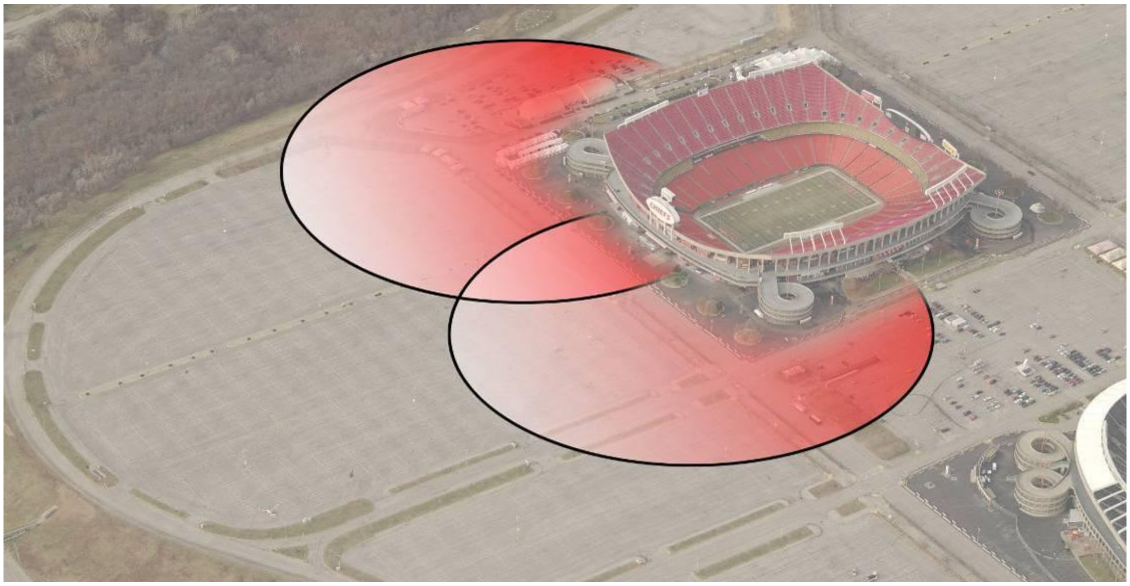


Figure 4-14, Lot C & D – Arrival Areas

(Microsoft Visual Earth, 2010, Adapted by Author)

Solving the open space requirement then is fairly straightforward. By providing more open space for the fans that arrive early and tailgate allows the venue to enhance the spectator experience while providing the special requirements to treating stormwater. The obvious question then is how the design deals with reducing the number of existing parking spaces in a place where parking is at a premium due to the revenue generation it produces. The final guiding design principle deals with the last event before any game - getting to the gate.

Pedestrian Movement – Once the tailgate is over and the fans are heading into an event, the stormwater treatment option has to take into consideration how pedestrians will move around a given treatment solution. The existing parking configuration at the Truman Sports Complex is rather odd considering how pedestrians travel to and from a vehicle. The current orientation of the parking lots surrounding the stadiums runs perpendicular to the direction of travel for most pedestrians (Figure 4-15, 16, 17). Large pedestrian walkways, defined by breaks in parked vehicles, are intended to gather people and direct them to the stadium. The walkways are relatively ineffective and most fans end up walking through the cars not knowing the walkways exist. The vehicular orientation becomes problematic for any type of bioretention application due to the amount of pedestrian traffic that would be walking through these areas.

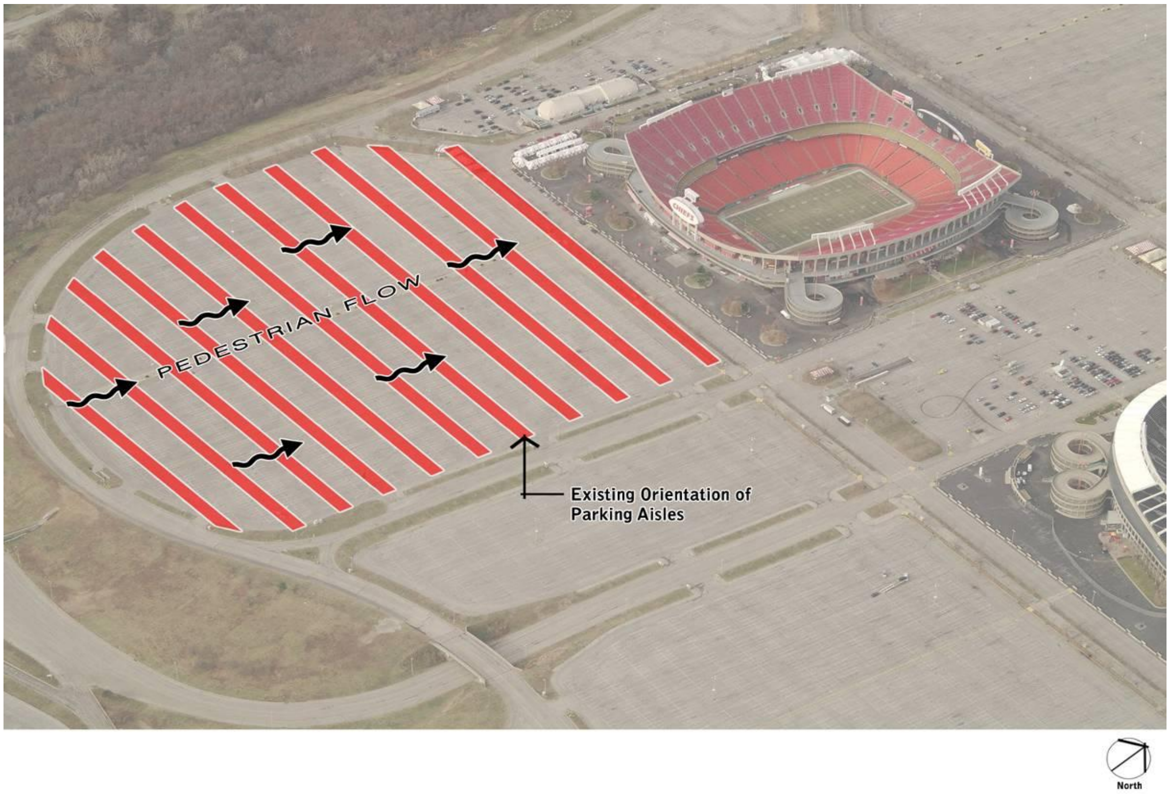


Figure 4-15, Parking Lot C & D – Existing Orientation of Parking Drive Aisles

(Microsoft Visual Earth, 2010, Adapted by Author)

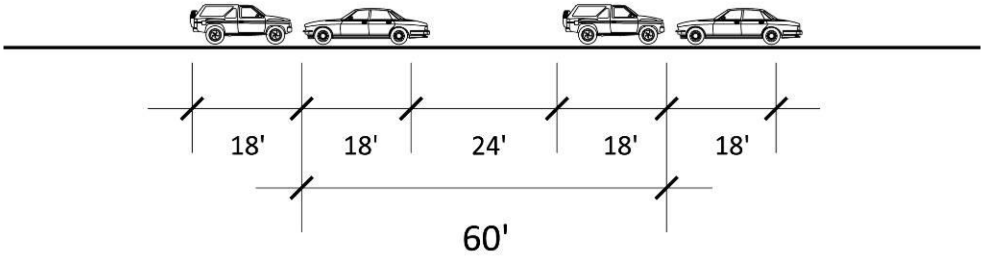


Figure 4-16, Parking Lot C & D – Section of Typical Parking Bay – Existing Conditions

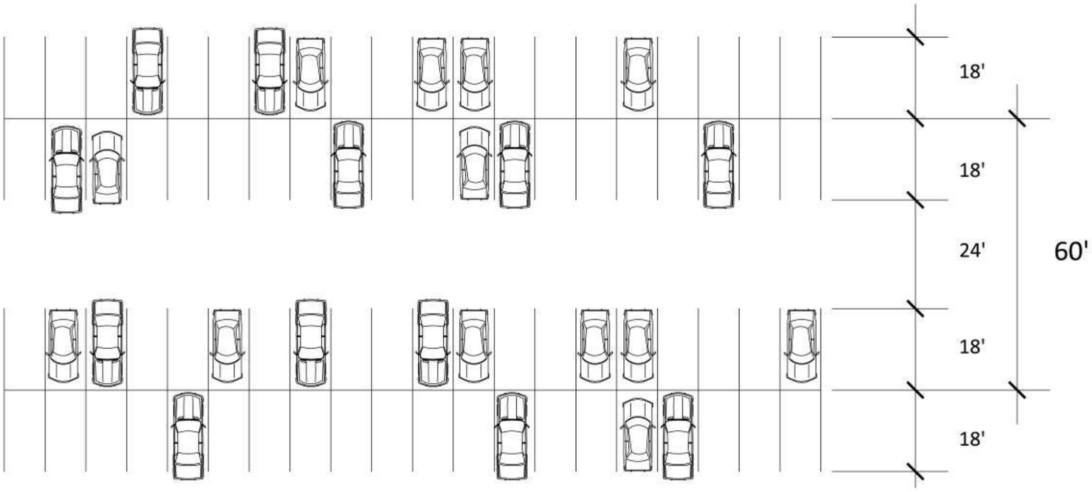


Figure 4-17, Parking Lot C & D – Plan of Typical Parking Bay – Existing Conditions

To solve the pedestrian flow issue, the design would focus on a reorientation of the existing parking lot by 90 degrees to allow pedestrians to flow through the drive isles towards the stadium (Figure 4-18). To further make up for the potential of parking reduction the design will vary the parking bay size from the standard 60 feet to that of 56 feet (Figure 19 & 20) allowing the retrofit to pick up valuable space for the implementation of the stormwater treatment areas while trying to maintain the existing parking count.

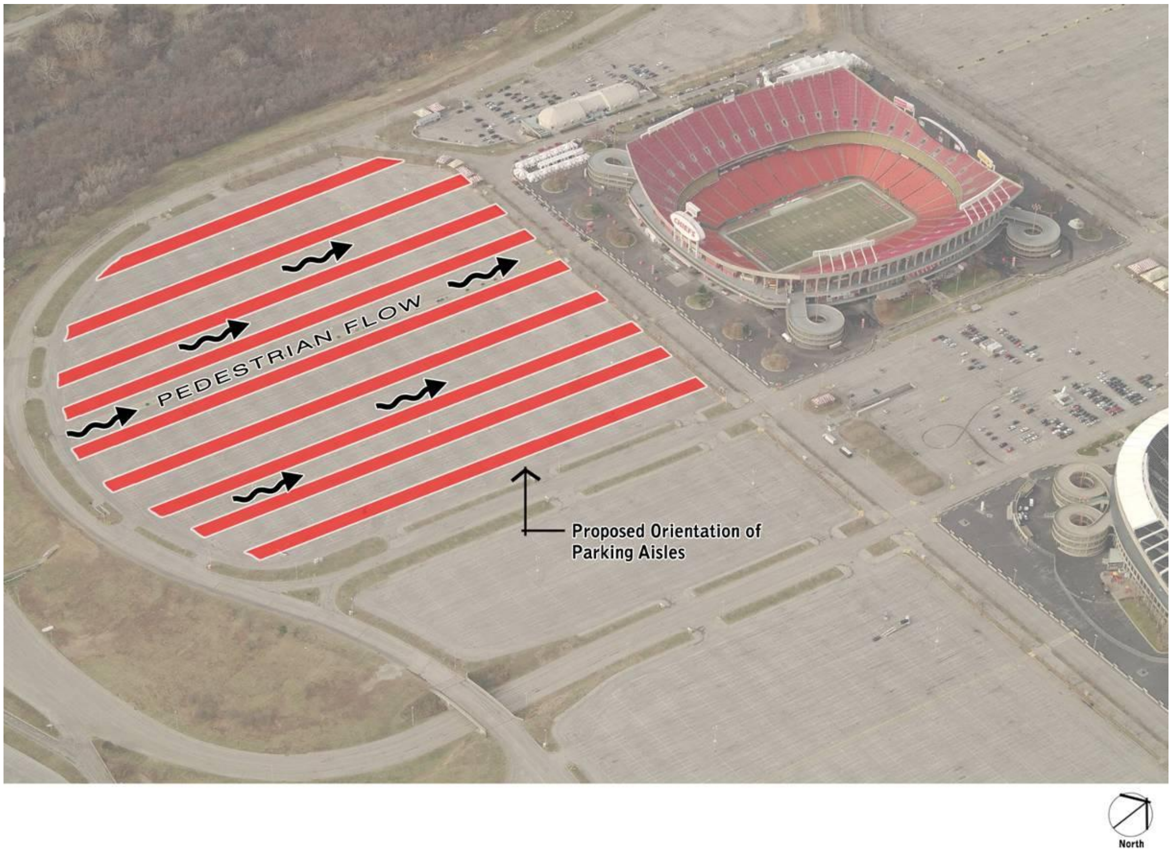


Figure 4-18, Lot C & D Parking Rotation,

(Microsoft Visaual Earth, 2010, Adapted by Author)

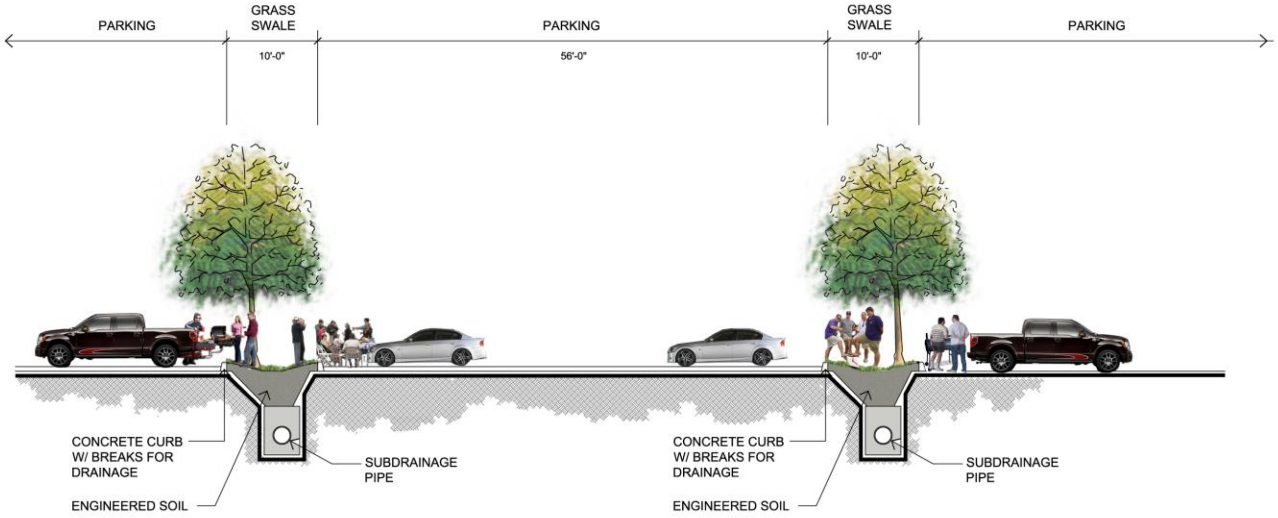


Figure 4-19, Parking Lot C & D – section of 56’ Parking Bay – Proposed Space Saving Parking Bay

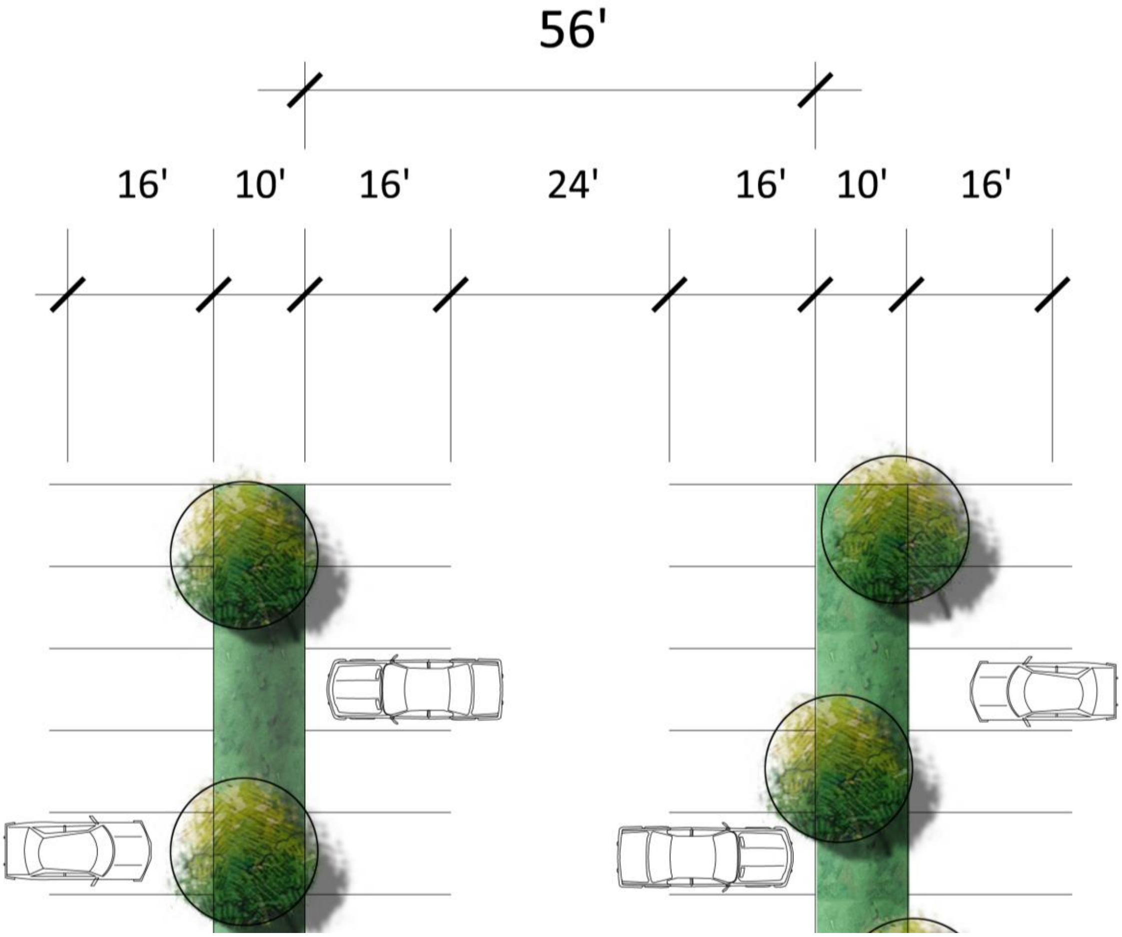


Figure 4-20, Parking Lot C & D – Plan of 56’ Parking Bay – Proposed Space Saving Parking Bay

Design Solution

The plan for Lot C & D implements a series of green spaces combining grass lined swales and bioretention areas that run parallel to the parking bays (Figure 4-21 & 22). The ten-foot areas represent a green space for tailgating and stormwater treatment. The ten-foot areas also use subdrainage (Figure 23 & 24) as an additional means to drain the grass lined swales and provide a useable space for tailgating.

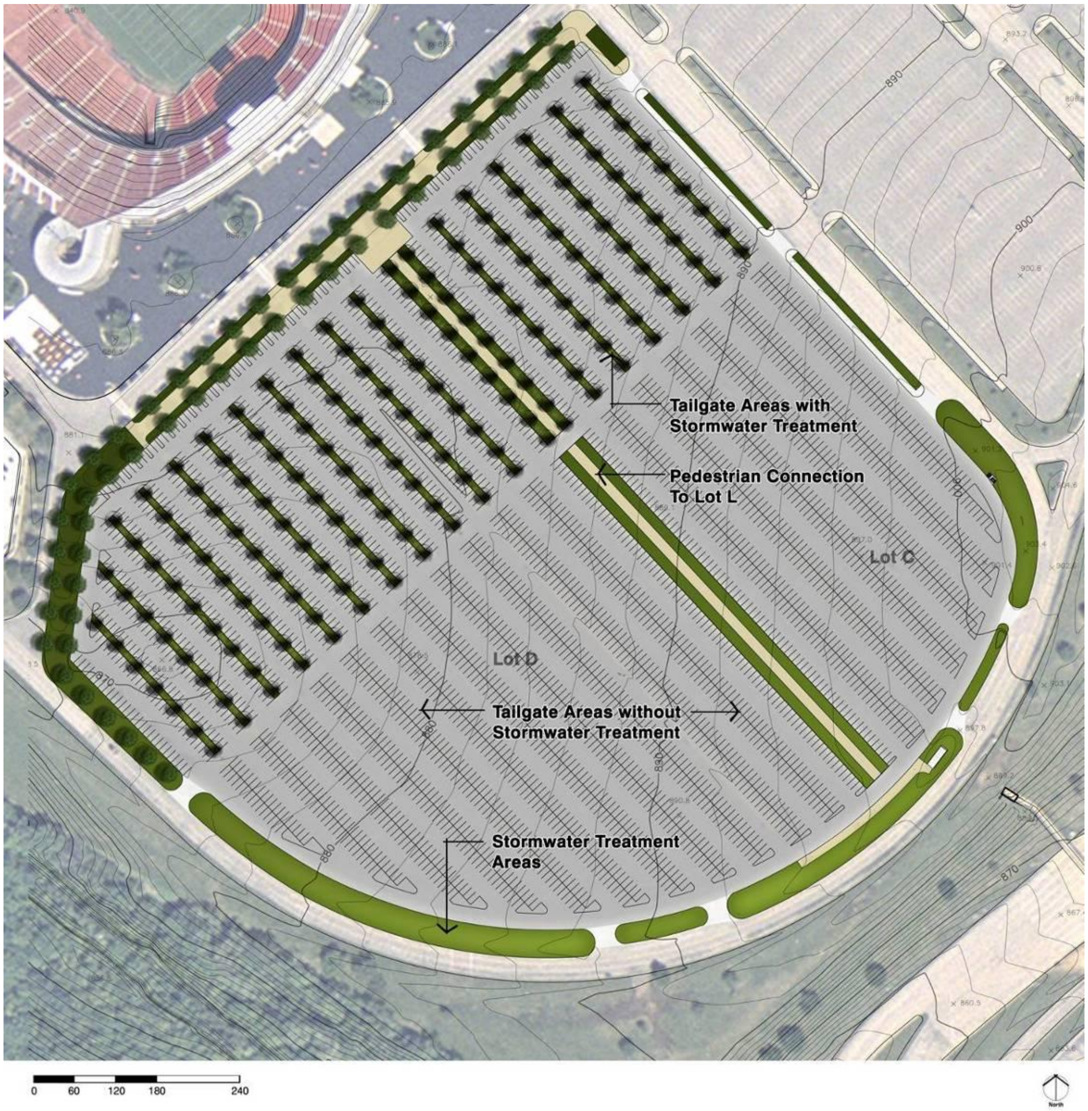


Figure 4-21, Truman Sports Complex, Lot C & D Parking Lot Design

Figure 4-22, Enlarged Concept Plan of Lot C & D, Truman Sports Complex

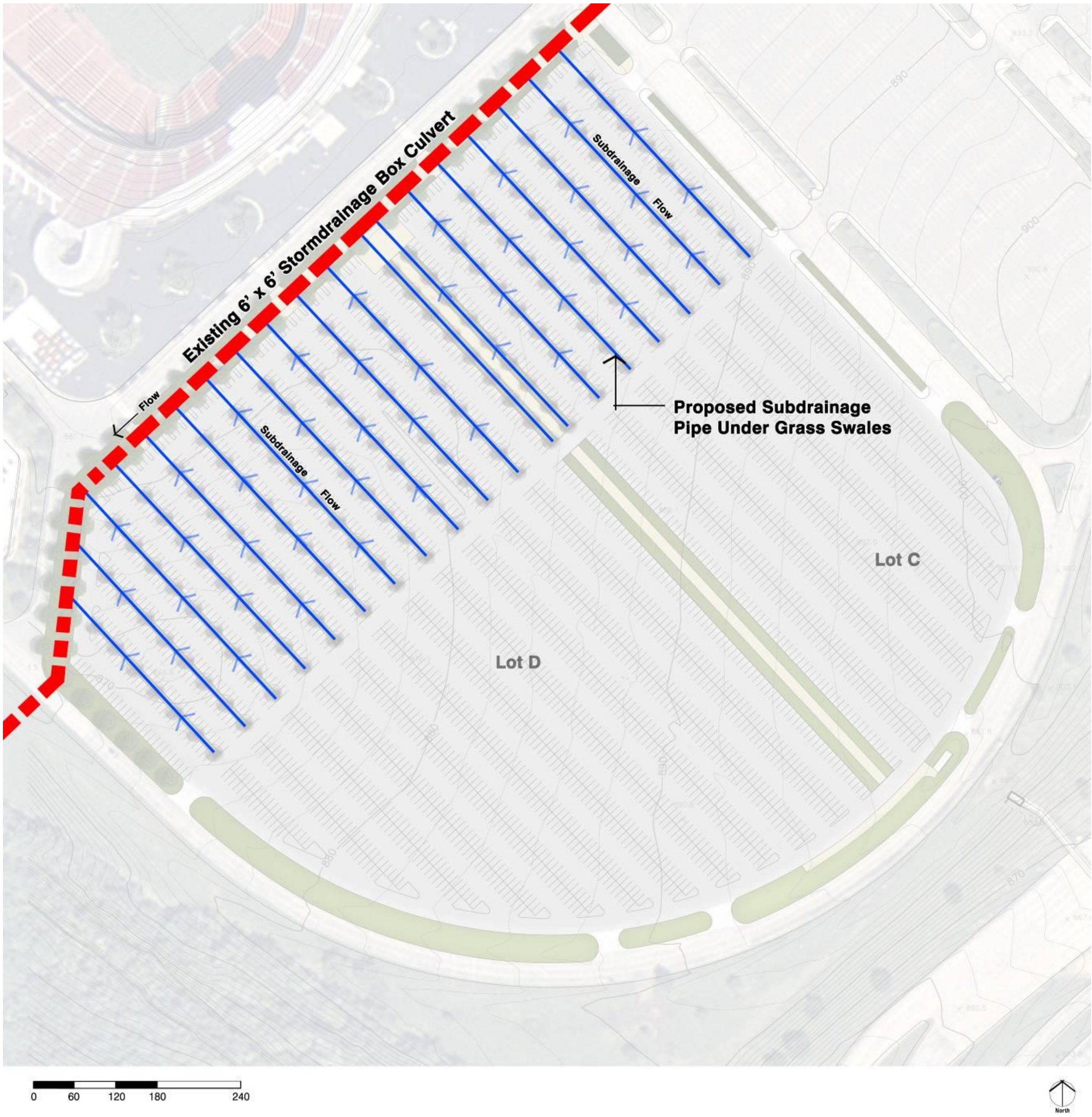


Figure 4-23, Truman Sports Complex, Lot C & D Parking Lot Design – Proposed Subdrainage

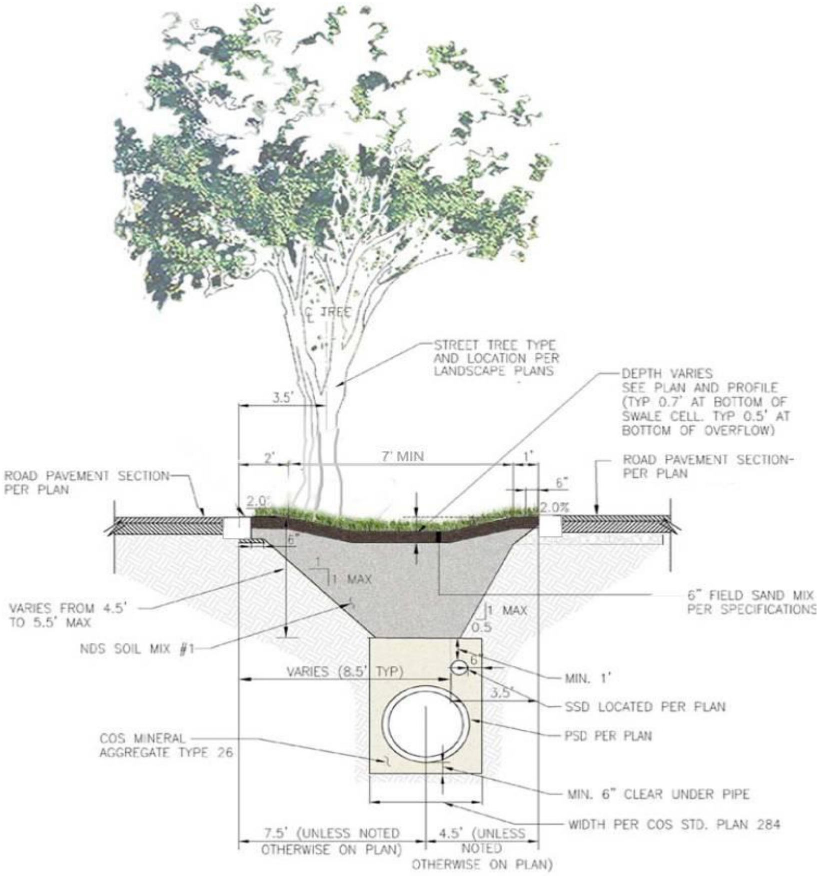


Figure 4-24, Concept Design Swale Section Example

(SVR Design, http://www.svrdesign.com/docs/MontgomeryCo%20-%20Planning%20and%20Design%20-%20Applied%20LID%20Techniques.pdf, Adapted By Author, 2010).

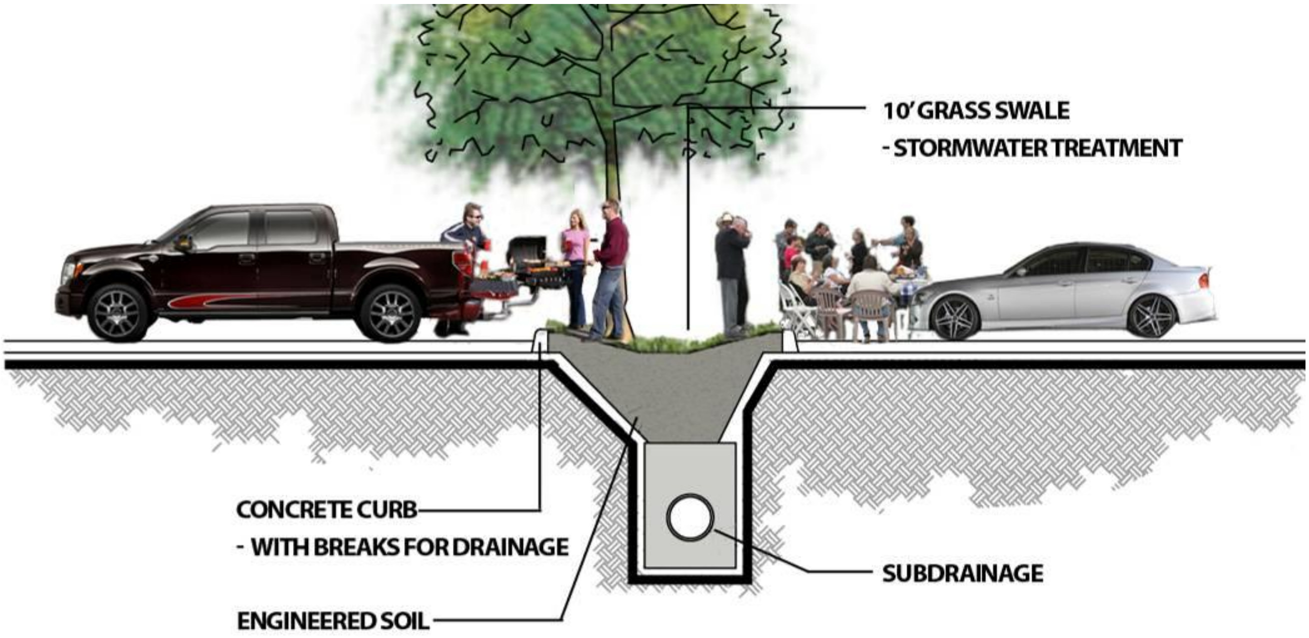
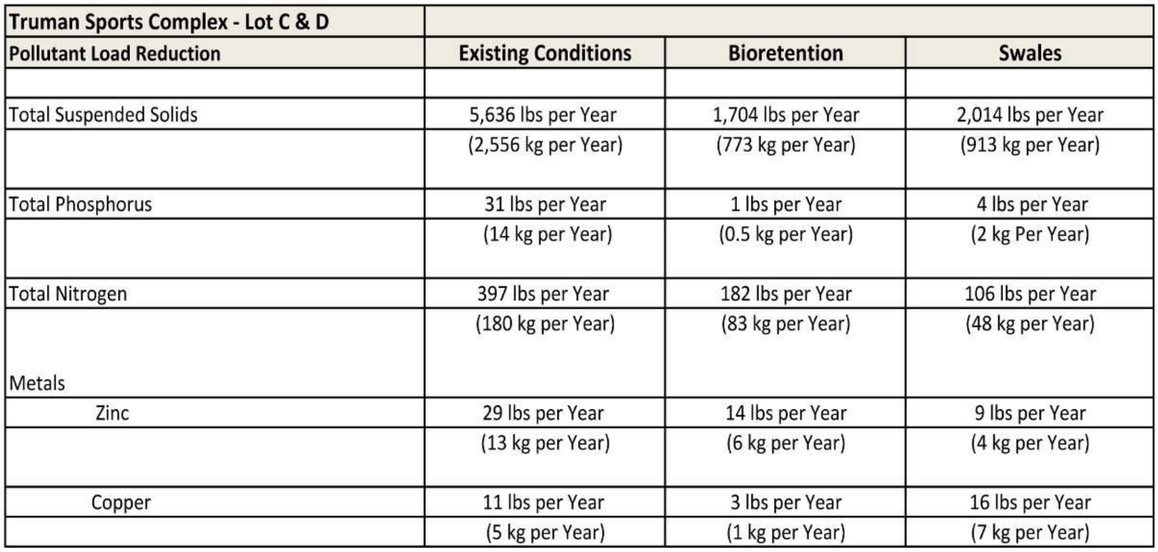


Figure 4-25, Concept Design Swale Section

(Adapted By Author 2010)

Analysis of Pollutant Load Reduction – An analysis of Table 4-11, shows the results of the pollutant load reduction calculated for the retrofit. As shown in the calculation steps 3-9 of Appendix D, the design itself produces a reduction in impervious area of roughly eight percent. While the proposed design solution does not seem like a tremendous reduction in surface area, it does provide a load reduction between 30 to 50 percent for the pollutants of concern. The proposed design represents a substantial reduction to the pollutant loads while only removing eight percent of the total impervious area.

Table 4-11, Post-Retrofit Pollutant Loading Reduction Comparison
(Personal Calculations, 2010)



Truman Sports Complex - Lot C & D			
Pollutant Load Reduction	**Existing Conditions**	**Bioretention**	**Swales**
Total Suspended Solids	5,636 lbs per Year	1,704 lbs per Year	2,014 lbs per Year
	(2,556 kg per Year)	(773 kg per Year)	(913 kg per Year)
Total Phosphorus	31 lbs per Year	1 lbs per Year	4 lbs per Year
	(14 kg per Year)	(0.5 kg per Year)	(2 kg Per Year)
Total Nitrogen	397 lbs per Year	182 lbs per Year	106 lbs per Year
Metals	(180 kg per Year)	(83 kg per Year)	(48 kg per Year)
Zinc	29 lbs per Year	14 lbs per Year	9 lbs per Year
	(13 kg per Year)	(6 kg per Year)	(4 kg per Year)
Copper	11 lbs per Year	3 lbs per Year	16 lbs per Year
	(5 kg per Year)	(1 kg per Year)	(7 kg per Year)

After hypothetically applying the results to the rest of the inner parking lots, one could see how this treatment technique could similarly reduce the pollutant loads by 30 to 50 percent of the rest of the inner parking lots. Applying the treatment solution to the remainder of the lots would create a beneficial reduction in pollution loads to the overall stormwater system and the Blue River watershed. One critical factor that would have to be studied in detail would be the effect of the topography on the intended design solution. The general nature of the site is to slope towards the stadium (Figure 4-5), but each lot surrounding the stadium is slightly different and the topography would have an impact on how much water ends up in each treatment area. For the sake of simplicity, the design study of parking lots C & D treated each parking lot the same and did not try to model the subwatersheds to depict the amount of runoff to each specific treatment area.

As a hypothetical way to calculate pollutant load reductions, the Design Point Method gives the design some merit as to its success or failure of pollutant load removal. Because of the negative site factors represented on site, the Design Point Method suggests that this design solution would be the low end of pollutant load reductions. The reality of the numbers suggests that scale has the biggest impact on a retrofit at a sports venue.

Due to the sheer volume of surface area that could be treated by a retrofit solution, a slight reduction in impervious area would create substantial benefits to the pollutant loads that currently pollute the watersheds of the Truman Sports Complex. Looking at Table 4-2, the inner parking lots at Truman Sports Complex have an impervious area of 89.09 percent. By hypothetically applying the design solution to all the lots with a similar retrofit approach, the overall reduction to impervious area would reduce the impervious area to 81.09 percent.

Reducing the overall imperious area would yield a reduction to the pollutants of concern similar to results shown in Table 4-11. By implementing the design solution, the reductions could provide a decrease in pollutants between 30 to 50 percent of the pollutants flowing out of the inner parking lots an into the Blue River watershed. The pollutant reductions would ultimately improve the water quality of the existing watershed and provide the basis for further study.

CHAPTER 5 - CONCLUSION

Design Challenges

The challenges facing the implementation of the proposed solution as it relates to the treatment of water quality were:

- Maintaining the Existing Parking Counts – 4,278 parking spaces.
- Size limitations for Grass Swales/Bioretention Areas
- Space limitations for Canopy Trees
- Soil Conditions and Climate

The first challenge creates the biggest impact on the spatial requirements for the intended design. If parking was not in such a high demand, the number of spaces could be significantly reduced and the amount of surface area available for any potential retrofit could be increased. For some venues increasing the availability of public transportation and reducing the number of cars on any given site could be a viable solution. For the Truman Sports Complex that is not feasible in the short term due to the culture of the fans in the Midwest. However, it is worth exploring ways to increase public transportation to and from the sports complex. As it stands, the proposed solution achieves the primary goal of maintaining the existing number of parking spaces.

Other design challenges deal specifically with the space limitation of the stormwater treatment type. The space requirements for surface parking could be solved by reducing the number of parking spaces and creating more space for treatment.

Charging more for the opportunity to tailgate next to a shaded open space then could make up the reductions in revenue. Limiting the design to a ten-foot wide stormwater treatment channel, limits the amount of stormwater that can be treated as well as the size of trees that can be grown within the stormwater collection areas.

Using Table 4-3 outlined previously, the proposed treatment area would only treat about 9,684 cubic feet of stormwater. In order to treat the first 1.1 inches of runoff as defined by the 90 percent storm, the retrofit would be required to treat 113,332 cubic feet of water. With a low percentage (8.5%) of treated stormwater, one would have to consider the cost of treatment area needed to make up the difference and the benefit of the installation.

Based on guidelines from the CWP (Table 4-8), the 2.82 acres of treatment area would cost roughly \$101,680 – \$121,050 at \$10.50-12.50 per cubic foot of stormwater runoff. If one assumed the remaining lots surrounding the stadium were treated in a similar fashion, the overall cost for this type of project would be roughly \$610,000 – \$726,300 to treat roughly eight and half percent of the stormwater runoff for each lot. With this analysis it becomes even more apparent that future studies would require the elimination of parking on site to create a larger treatment areas.

To create larger treatment areas, one potential solution would be to make the parking stalls themselves permeable with the use of a permeable pavement. Using permeable pavement would allow the stormwater treatment channels to grow by 34 feet (two 17 foot parking stalls) to an overall treatment width of 44 feet. The downfall to expansion is the cost of the pavement itself compared to that of traditional asphalt. As we learned from US Cellular field the cost is up to five times as much that of traditional asphalt. To offset some of the additional cost, the construction could be potentially phased so that stormwater retrofit is built at the end of the parking lots life cycle. Additionally, the added revenue from the increased tailgate experience could also provide another source of funding. With over three times the treatment area, one can see how big an impact the use of permeable concrete pavers would actually create.

Other Successful Examples

Looking at history (Figure 5-1) one can see that the original intent of the design for the site was to create green space throughout the parking lots. Also present in the original concept was a pedestrian connection to the rail corridor that lies just to the

Figure 5-1, Truman Sports Complex, Conceptual Site Plan Rendering.

(http://baseballmusings.com/?p=11522, 2009) south of the sports complex. The use of open space and enhanced transportation opportunities leads one to believe that the designers of this site were forward thinking in terms of how they saw venues of this type functioning into the 21st century. So the real question; could the Truman Sports Complex and its traditional stormwater infrastructure be recreated in today's sustainable world?

In Kansas City the answer to that question would unfortunately be yes based on the stormwater requirements that exist in Kansas City. In Kansas City, the existing stormwater regulations only requirement is for any developer/owner to pay the stormwater fees that are assessed for the amount of runoff leaving the site. To truly solve this problem one has to go to other cities in the United States that have a successful history of stormwater management. Cites such as the two case studies, Seattle, Washington and Chicago, Illinois have substantially upgraded their stormwater management regulations to force developers and landowners to search out alternative stormwater treatment types. From the case studies presented, it is possible that sustainable design solutions are possible and economically feasible for urban developments, but more importantly for sports venues.

For sports venues there exists some progressive examples of stormwater management, such as Dolphin Stadium in Miami, Florida (Figure 5-2). The parking lot design approach for Dolphin Stadium has proven successful for treating stormwater in parking lots in the coastal regions of the United States. The use of grass parking to manage stormwater allows the reduction in impervious surface while also reducing the stormwater that leaves the site by allowing stormwater to infiltrate naturally into the soil structure . This infiltration is critical to the success of the design because it attempts to recreate the natural drainage characteristics of the site prior to the parking lots being constructed.

Figure 5-2, Dolphin Stadium - Miami Florida.
(http://z.about.com/d/architecture/1/0/h/i/DolphinStadium.jpg, 2009)

There are also examples of progressive stormwater management in the Midwest can be related to the region of the study site. For example, the recent construction of TCF Bank Stadium (Figure 5-3) in Minneapolis provides us with an example of how sustainable construction can be achieved. The stadium was constructed on a compact urban site that brought football back to the campus setting. Site constraints and the progressive nature of stormwater management for the city created stormwater design challenges for the project.

Figure 5-3, TCF Bank Stadium - Minneapolis, Minnesota.
(http://stadium.gophersports.com/multi_photo_gallery.html , 2009)

The biggest stormwater management challenge for the proposed design was to reduce the amount of stormwater runoff from the site. The core goal for the stormwater ordinance for the city of Minneapolis is to reduce the amount of stormwater runoff on development projects greater than one acre because that size of development has a direct impact on runoff into the Mississippi River (City of Minneapolis, 2009). How the design controlled and managed stormwater runoff became the greatest challenge to the stormwater design for TCF Bank Stadium.

To reduce the amount of runoff emanating from an urban site would mean that the design solution would require stormwater storage somewhere on site. For the TCF Bank Stadium, the success of the project was its ability to eliminate a stormwater detention pond. The design used a patented stormwater treatment system, the EPIC System™ by Rehbein Environmental Solutions (Figure 5-4), that allowed the plaza and landscape space to be doubled. The EPIC system "removes pollutants from stormwater by filtering runoff through the plants roots and sandy soil" (RESI, p. 7, 2009). At TCF Bank Stadium, the EPIC System has the potential to remove over 85 percent of phosphorous pollutants in the water (RESI, 2009). The final design will prevent downstream water bodies from having excessive algae growth and maintain the health of the Mississippi River.

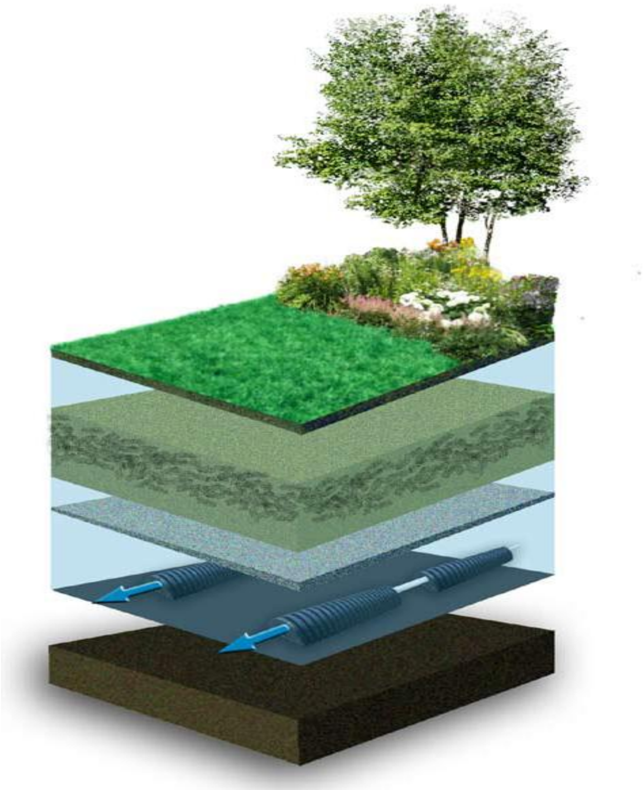


Figure 5-4, TCF Bank Stadium - Minneapolis, Minnesota. Section of EPIC System (**http://www.rehbeinsolutions.com/files/RESI%20Sustainable%20Parks%20and%20Fields.pdf.pdf**, 2009)

The Enhanced Fan Experience

For the average fan, the benefit that makes the proposed stormwater design solution for Truman Sports Complex successful is its ability to enhance the tailgating experience. With virtually no open space on the existing site, the primary benefit to fans would be the aesthetic improvements to the sea of asphalt that the average fan experiences on any given Sunday (Figure 5-5). The proposed use of shade trees, increased open space, and the ability to provide fans with upgraded amenities will untimely improve the fan experience.

Figure 5-5, Truman Sports Complex – A Vision for a Green Tailgate on a Game Day (http://farm1.static.flickr.com/116/285761752_235139d0b8.jpg, 2009**)**

In addition to the shade created by canopy trees, the grass lined swales would provide open space for fans. While the ten foot dimension provides a small addition spatially, the grass lined swales would create gathering areas for fans to use in their tailgating actives. While the proposed design is not meant to analyze the physiological aspects of open space, it is important to understand the impact the additional open space might have on the fans and their enjoyment of the experience.

According to a report conducted by the University of Miami, Ohio, public open spaces and gardens have an important impact on human emotions such as security, happiness and creative aspects of behavior (Rodrigues, 2005). Creating the additional open space then could have an impact of adding pleasure to the fan experience. This added emotional experience could lead to the desire for fans to come back and recreate the experience at each event, thus adding value to the new tailgating areas.

While the space is small, the additional open space also provides the operators of the venue the ability to create upgraded or premium amenities. The upgraded amenities could be as simple as power, water or satellite connections that could enhance the tailgating experience. The upgraded experience then could be marketed and sold to the fan and become another source of income for operators. Ultimately, the proposed design solution benefits fans that attend these events, but more importantly the watershed and everything that lives in that watershed.

Recommendations for Further Research

The best opportunity to further this research would be to explore the other analysis models that have been developed to evaluate stormwater treatment options. Two such stormwater analysis models that have potential for use are:

- **Watershed Assessment Model** - WAM is a tool that has been shown to be useful in the assessment of watershed-related properties. WAM was developed to allow engineers and planners to assess the water quality of both surface water and groundwater based on land use, soils, climate, and other factors. The model simulates the primary physical processes important for watershed hydrologic and pollutant transport (EPA, 2009, 29).

- **System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN).** Developed by the EPA, this is a fully integrated framework for the selection and placement of stormwater BMPs at strategic locations in urban or developing watersheds (EPA, 2009, p. 29).

By gaining an understanding of how a particular analysis model works, the research could compare and contrast the modeling types, allowing a designer to evaluate which modeling solution derives the best hypothetic results for a proposed design solution. The research could then explore the ideas presented in the final design and input that information into a computer model. Computer modeling software could potentially break down the design solution into a detailed simulation of the proposed retrofit option prior to documenting the intended design.

By using computer simulation, the required treatment areas are sized to achieve the greatest benefit from stormwater management goals and objectives. Detailed analysis modeling would also allow the design to directly and to accurately factor cost. With interactive cost information, the designer and client can evaluate and select a design solution with increased confidence in not only the treatment effectiveness, but the costs as well. Finally, it is important to understand there are several theories about stormwater management and effective treatment for water quality. Ultimately, by identifying specific goals of the project and utilizing viable analysis tools for the evaluation of stormwater management, the intended outcome will yield better results for stormwater management and pollutant load reductions, as well as create a "Green Tailgate".

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Appendix A - COMUNICATION with PROFESSIONALS

CASE STUDY 1 – Northgate Mall, Seattle, WA

Tracy Tackett, PE, Green Stormwater Infrastructure Program Manager, Seattle Public Utilities

Phone Interview with Tracy Tackett - August 11, 2009

Questions Regarding the Design of Northgate Mall – Seattle, WA.

1. How did Seattle get involved with "Green" movement as it relates to stormwater management?

    - Are there any specific projects that allowed the city to evolve the knowledge base?

    "Part of the requirements for the city is the development of regional design standards as it relates to stormwater. Because of the amount of rainfall we receive every year the amount the spatial requirements for detention areas are significant. One of the desires by many people in the Seattle community was to create something that was more astatically pleasing than your standard detention areas, thus the focus towards aesthetically pleasing drainage systems." Landscape elements and other forms of aesthetically pleasing drainage was a critical component to successfully achieve our goals of creating desirable spaces in an urban environment that also function from a stormwater management standpoint.

2. Background of the redevelopment of the Northgate Mall/Thornton Creek watershed

    http://www.seattle.gov/transportation/rowmanual/manual/6_4.asp

    http://www.seattle.gov/dpd/static/Volume_III_Draft_LatestReleased_DPDS015879.pdf

    see section 4.4.1

    http://www.seattlepi.com/business/243553_greenwood06.html

3. Green Parking Retrofit? - What drove the expansion/renovation?

    "The existing site was a sea of asphalt. The Thornton Creek Watershed as a whole was being redeveloped and there was a desire by the client to use green space to make the shopping 'experience' better. The use of permeable pavers was not acceptable to the client because they didn't like the look and ultimately felt that adding a landscape element to deal with stormwater was the most desirable option. The biggest design challenge from the client dealt with parking spaces. The redeveloped lot could not lose one space once the renovation was complete.

4. The Telescoping Swale. Describe the design process from the conceptual stages through build construction.

> "Originally the design intent was to study ways to use permeable pavement on site to deal with the stormwater management issues. We were basically creating the standards for a project of this type in the city so once we ran the stormwater calculations. Were able to accomplish our goals

5. Soil – How big a role did the existing site conditions have on the final outcome?

> "The soil conditions in the lot were so compact that there was basically no permeably within the existing soil structure. That focused our redevelopment efforts of the site to focus on ways to detain/retain water on site. The cost of going to a permeable system didn't make sense in this case because we were able to obtain our stormwater management goals through the sense of the bio-swale."

6. Are there any long-term concerns/lessons learned with the lot post construction?

> "There were three major lessons that we learned during the construction phase and through post occupancy evaluation.
>
> - Curb and Gutter system needs to have structural integrity to act as a well stop or have sufficient soil behind the curb to act as a structural member. Well stops were 'value engineered' out of the project, but nothing was replaced from a design standpoint that replaced the wheel stops.

1. Walking areas next to the bio-swale. The thought all along was that people would walk down the aisles towards the shopping center. That didn't entirely happen every time and as a result that plant material in the bio-swale has suffered from constant pedestrian traffic.

2. The construction techniques of retrofitting an existing lot needs to be monitored and areas where existing conditions meet renovated conditions have to be detailed correctly. The construction sequence was not properly thought through and the bio-swales were built at the end of the project. This created some weird slopes in the swale itself but also undermined the existing asphalt lot. Settlement than created some undesirable low points in the parking lot that didn't allow the drainage to work correctly.

7. Are there any other large scale permeable lots the city has worked on before Northgate Mall that allowed you to avoid past project pitfalls? What were the problems that were avoided?

> "No this was the 1st of this scale that was constructed within the city. Some of the techniques had been used on other projects within the city, but that didn't stop us from exploring new ideas or learning from other projects in the city."

From: Jay Graber
Sent: Monday, May 10, 2010 4:29 AM
To: Tackett, Tracy
Subject: RE: Seattle resources

Tracy,

I have one final request. I need your permission to use the information (attached) you provided to me in my thesis. (I have attached the images for your reference). The final document is electronically posted to the Library's database, so it can be accessed from the web. Let me know if you are ok with me using this information when you have time.

Thanks again for all you time and assistance.

Jay

From: Tackett, Tracy
Sent: Monday, May 10, 2010 10:21 AM
To: Jay Graber
Subject: RE: Seattle resources

Sure.

Send me the link to your document when you get it all together.

Congradulations on getting it wrapped up,

tracy

David Schwartz, PE, KPFF, Consulting Engineers

Phone Interview with David Schwartz - October 16, 2009

Questions Regarding the Design of Northgate Mall – Seattle, WA.

1. Background of the redevelopment of the Northgate Mall/Thornton Creek Canal/Thornton Creek watershed

> "The Mall was redeveloping to get more square footage and as part of the expansion put in rain gardens and a large detention system to store water and release it at a controlled rate. The drainage basin in question is the Thornton Creek drainage which is an important drainage corridor in the area."

2. The Telescoping Swale - A brief explanation on what you know about the project and how the stormwater ultimately get's to Thornton Creek.

> "The storm water off the parking lot mostly drains to rain garden planter strips and is conveyed to a piped collection system and then to a detention tank under the parking lot before being released to the Creek. Runoff from the parking lot enters the rain garden swales through scuppers/cut outs in the parking curb."

3. Are there any long-term concerns/lessons learned with the lot post construction that you are aware of?

   - Are there any maintenance issues or operational concerns for example.

> "One lesson is that installation often doesn't match the plans. The intent was to have inlets that were set above grade to allow for some ponding. In most cases the landscape contractor filled the area in to bring the level of the soil up to the rim of the inlets rather than letting them sit above grade as intended."

4. Economics of the project.

   - Do you have any information on the scope of the project and the associated costs?

> "I do not."

5. Are there any other large scale permeable lots that have been built in the city?

> "The lot itself is not permeable and I don't know of any large lots that have been built in Seattle. We designed a medium sized lot with porous asphalt at the City of Sammamish City Hall. This project also included percocrete for the large plaza which is a permeable concrete product that is proprietary.

From: Jay Graber
Sent: Tuesday, May 11, 2010 7:27 PM
To: David Schwartz
Subject: RE: Northgate Mall Project.....

David,

You helped me out last fall with some questions regarding the Northgate Mall project. I am a Graduate Student doing research on how sporting venues design, manage, and use surface parking. You provided me with some answers to some questions below that I would like to use in my research. I need your permission to use the information you provided last fall in my project. If you have further questions or concerns please let me know.

Thanks again for your help.

Jay

From: David Schwartz
Sent: Friday, May 14, 2010 7:01 PM
To: Jay Graber
Subject: RE: Northgate Mall Project.....

I have no objection to you using my previous responses.

CASE STUDY 2 – US Cellular Field

Robert S. Giurato, PE Civil Engineering Department Head Environmental Design International inc. (EDI)

Phone Interview with Bob Giurato - February 25, 2009

Questions Regarding the Design of US Cellular Field.

1. How did your Firm get involved with "Green" movement as it relates to stormwater management?

   - Are there any specific projects that allowed the firm to evolve the practice?

   "This was our first project that dealt with any sort of permeable pavement. The local landscape architect brought us on as a consultant and our role was to assist with the engineering of the project."

2. Background of US Cellular Field Lot L installation.

   - Existing condition of the lot was a Brownfield industrial Site - What drove the expansion/addition?

   "Part of the site was an existing Brownfield, an old industrial building that had some environmental concerns. The condition of the existing slab drove some of the design decisions."

3. Why Permeable Concrete Pavers?

   - Where any other types of permeable surfaces considered such as asphalt or concrete?

   "Concrete pavers were chosen by the Landscape Architect. The decision was already made by the time we came on board, so we went with the design."

4. Where any other types of BMP's used on the project or considered?

   "The directive from the Sports Authority and White Sox's was to create as many parking spaces a physically possible. There are no green islands or an even a chance to create something different. Our role was to use the material given to us and engineer the parking lot.

5. Are there any Long term concerns with permeable concrete pavers or has there been any problems/lessons learned with the lot post construction?

> "The response has been great and especially this year with the amount of rain we have had there have been no concerns. Everyone from my knowledge is extremely happy with the project.

6. Was there any thought to the integration of green space into the parking lot with the use of other types of BMPs, or was maxing out the number of spaces the top priority?

> "Again, the Sports Authority and the Team wanted to maximize the number of spaces for revenue generating purposes, so the only choice the design team had was to maximize the number of parking spaces.

7. Are there any other large scale permeable lots that your firm worked on before US Cellular field that allowed you to avoid past project pitfalls? What were the problems that were avoided?

> "No, this was our 1st project that our firm dealt with permeable pavement."

From: Jay Graber
Sent: Tuesday, May 11, 2010 9:35 PM
To: 'Robert Giurato'
Subject: RE: US Cellular Field

Bob,

You helped me out last spring with some questions regarding US Cellular Field. I am a Graduate Student doing research on sporting venues design, manage, and use surface parking. You provided me with some answers to some questions and provided me with some site plans that I would like to use in my research. (attached is the information) I am trying to finish up my degree this spring and I need your permission to use the information you provided last spring in my project. If you have further questions or concerns please let me know.

Thanks again for your time and help.

Jay

From: Robert Giurato
Sent: Friday, May 14, 2009 7:13 AM
To: Jay Graber
Subject: RE: US Cellular Field

Sure. Have fun

Robert S. Giurato, PE
Civil Engineering Department Head
Environmental Design International inc. (EDI)
Civil, Survey, Environmental and Construction Inspection Services
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MBE/WBE

Ernest Wong, ASLA, APA - The founder and Principal of Site Design Group, Ltd.,

Phone Interview with Ernest Wong - June 26, 2009

Questions Regarding the Design of US Cellular Field.

1. How did your Firm get involved with "Green" movement as it relates to stormwater management?

    - Are there any specific projects that allowed the firm to evolve the practice?

    “Our firm has always had a strong interest in a sustainable practice. This was the largest lot we had ever worked on from a size standpoint, but the main goal was to meet the new stormwater requirements the City of Chicago had established in 2007. With the new requirements and the desire to maximize the parking spaces we had to turn to a permeable surface.”

2. Background of US Cellular Field Lot L installation.

    - Existing condition of the lot was a Brownfield industrial Site - What drove the expansion/addition?

    The Illinois Sports Authority and the White Sox’s drove the desire to develop a new lot at US Cellular Field. Yes, part of the site was an existing Brownfield and there were some environmental concerns, but ultimately the revisions to the stormwater requirements by the city drove the design decisions on how the stormwater would be handled on site.

    The use of permeable pavement allowed two big benefits to the Sports Authority and the White Sox. The obvious benefit was the creation of more area dedicated to surface parking. For the client that meant the area that would have been required for drainage structures could be used for parking spaces. Consequently they didn’t have to pay for the storm drainage infrastructure and the increased number of spaces generated more revenue.

3. Why Permeable Concrete Pavers?

    - Where any other types of permeable surfaces considered such as asphalt or concrete?

    “Concrete pavers were chosen because at the time we knew the most about the system. Permeable asphalt and concrete had been used but we were more comfortable with pavers so the decision was made to go with that material.”

4. Where any other types of BMP's used on the project or considered?

    “There were no landscape islands or green buffers of any kind on the project. We had to apply for a variance, but that wasn’t really a problem because of the client. With the majority of the project being a hard surface our only choice was to consider permeable materials.

5. Are there any Long term concerns with permeable concrete pavers or has there been any problems/lessons learned with the lot post construction?

> "The publicity on the project has been fantastic. The long term outcome is still obviously ongoing but with the amount of rain we have had the project had work well. We were fortunate enough to have sandy soils on the site so the peculation rates make this site drain well."

6. Was there any thought to the integration of green space into the parking lot with the use of other types of BMPs, or was maxing out the number of spaces the top priority?

> "The sports authority drove the number of spaces required to make the lot work from a financial standpoint for the team. Trust me the wanted as many spaces as we could jam into the lot."

7. Are there any other large scale permeable lots that your firm worked on before US Cellular field that allowed you to avoid past project pitfalls? What were the problems that were avoided?

> "We really hadn't worked on a lot that size before, but with the success of the project our firm has started studying the ways storm drainage systems are designed for large sale park and ride parking lots around greater Chicago. The idea is very similar to what you are testing with your thesis. Large scale lots that are primarily empty or take up a great deal of space that could easily accommodate some type of sustainable drainage modifications."

From: Jay Graber
Sent: Monday, May 10, 2010 6:35 AM
To: Ernest Wong
Cc: Bradley McCauley
Subject: RE: Lot L at US Cellular Field

Ernest/Brad,

I have one final request. I need your permission to use the images you sent to me in my report (I have attached the images for your reference). The final document is electronically posted to the Library's database, so it can be accessed from the web. Let me know if you are ok with these images being in the report when you have time.

Thanks again for all you time and assistance.

Jay

From: Bradley McCauley
Sent: Tuesday, May 11, 2010 6:21 PM
To: Jay Graber
Cc: Ernest Wong; Robert Sit
Subject: RE: Lot L at US Cellular Field

Jay,

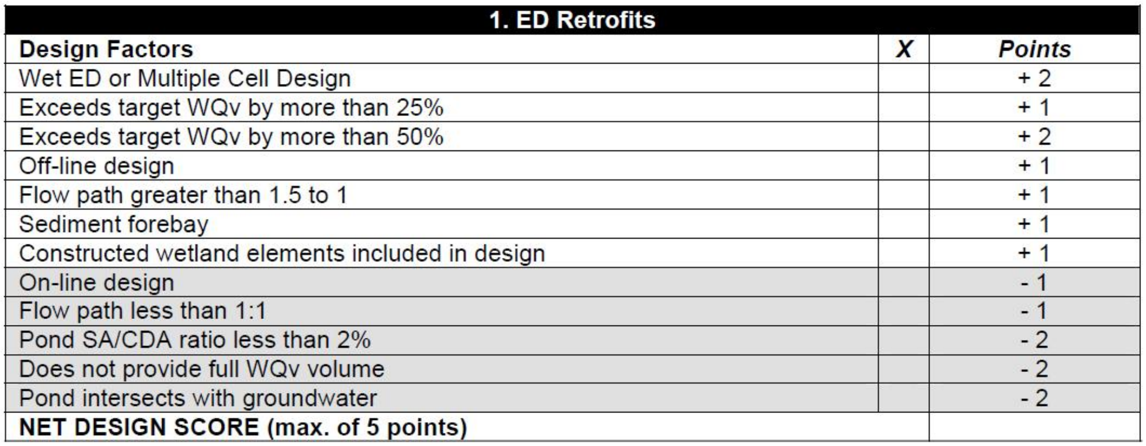
Please take this email as approval to use the information provided to you from Site Design Group, Ltd. for educational/research purposes. Please be sure to follow the appropriate documentation procedures when images/plans are used (i.e. photo courtesy of Site Design Group Ltd. etc.). If you have any questions or concerns please feel free to contact me.

Regards,

Brad McCauley
Associate ASLA, CSI, CDT
Site Design Group, Ltd.
888 South Michigan Avenue #1000
Chicago, IL 60605-2247
O: 312-427-7240 x 108
F: 312-427-7241

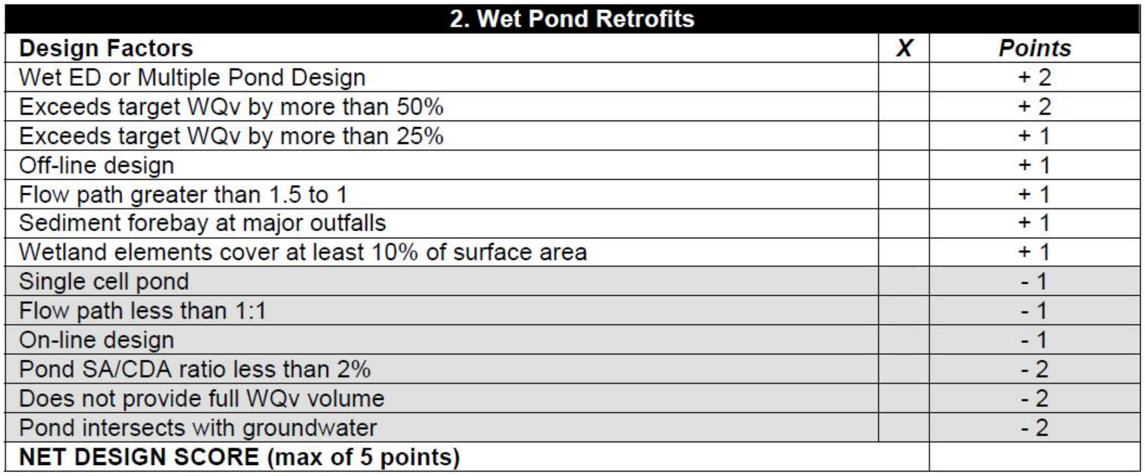
Appendix B - Design Point Tables

Design Point Tables taken from the CWP, Manual 3, Urban Subwatershed Restoration Manual Series, Urban Stormwater Retrofit Practices: Appendices, 2007, p B-8 – B-10.



1. ED Retrofits

Design Factors	***X***	***Points***
Wet ED or Multiple Cell Design		+ 2
Exceeds target WQv by more than 25%		+ 1
Exceeds target WQv by more than 50%		+ 2
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay		+ 1
Constructed wetland elements included in design		+ 1
On-line design		- 1
Flow path less than 1:1		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max. of 5 points)		



2. Wet Pond Retrofits

Design Factors	***X***	***Points***
Wet ED or Multiple Pond Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Exceeds target WQv by more than 25%		+ 1
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay at major outfalls		+ 1
Wetland elements cover at least 10% of surface area		+ 1
Single cell pond		- 1
Flow path less than 1:1		- 1
On-line design		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max of 5 points)		

3. Wetland Retrofits		
Design Factors	***X***	***Points***
Pond-Wetland or Multiple Cell Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Complex wetland microtopography		+ 2
Exceeds target WQv by more than 25%		+ 1
Flow path greater than 1.5 to 1		+ 1
Wooded wetland design		+ 1
Off-line design		+ 1
No forebay or pretreatment features		- 1
Wetland intersects with groundwater		- 1
Flow path is less than 1:1		- 1
No wetland planting plan specified		- 2
Wetland SA to CDA ratio is less than 1.5%		- 2
Does not provide full WQv volume		- 2
NET DESIGN SCORE (max of 5 points)		

4. Bioretention Retrofits		
Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested filter media soil P Index less than 30 (phosphorus only)		+ 3
Filter bed deeper than 30 inches		+ 1
Two cell design with pretreatment		+ 1
Permeable soils; no underdrain needed		+ 2
Upflow pipe on underdrain		+1
Impermeable soils; underdrain needed		- 1
Filter bed less than 18 inches deep		- 1
Single cell design		- 1
Bioretention cell is less than 5% of CDA		-1
Does not provide full water quality storage volume		- 2
Filter media not tested for P Index (phosphorus only)		- 3
NET DESIGN SCORE (max of 5 points)		
NET PHOSPHORUS SCORE (max of 5 points)		

5. Filtering Retrofits		
Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Site is a severe or confirmed hotspot		+ 2
Organic media used within filter bed (all pollutants except N/P)		+ 2
Two cells with at least 25% WQv allocated to pretreatment		+ 1
Filter bed SA is at least 2.5% of CDA		+ 1
Filter bed exposed to sunlight		+ 1
Off-line design w/ storm bypass		+ 1
Dry pretreatment		- 1
On-line design, w/o storm bypass		- 1
Underground design (except MCTT)		- 1
Filter design is hard to access for maintenance		- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		

6. Infiltration Retrofits

Design Factors	X	Points
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested infiltration rates between 1.0 and 4.0 in/hr		+ 2
At least two forms of pretreatment prior to infiltration		+ 2
CDA is nearly 100% impervious		+ 1
Off-line design w/ cleanout pipe		+ 1
Underdrain utilized		- 1
Filter fabric used on trench bottom		- 1
CDA more than 1.0 acre		- 1
Soil infiltration rates < 1.0 in/hr or > 4.0 in/hr		- 2
Pervious areas or construction clearing in CDA		- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		

7. Swale Retrofits

Design Factors	*X*	*Points*
Exceeds target WQv by more than 50%		+ 3
Dry or wet swale design		+ 2
Exceeds target WQv by more than 25%		+ 2
Longitudinal swale slope between 0.5 to 2.0%		+ 1
Velocity within swale < 1 fps during WQ storm		+ 1
Measured soil infiltration rates exceed 1.0 in/hr		+ 1
Multiple cells with pretreatment		+ 1
Off-line design w/ storm bypass		+ 1
Longitudinal swale slope < 0.5% or > 2%		- 1
Measured soil infiltration rates less than 1.0 in/hr		- 1
Swale sideslopes more than 5:1 h:v		- 1
Swale intersects groundwater (except wet swale)		- 1
No pretreatment to the swale or channel		- 1
Swales conveys stormflows up to 10 year storm		- 2
Does not provide full WQv volume		- 2
Grass channel		- 3
NET DESIGN SCORE (max of 5 points)		

Appendix C - Detailed Calculation for Case Study #2 – US Cellular Field - Design Point Method

Step 1:	**US Cellular Field - Calculate Site Imperviousness**			
	Using a base map calculate the areas below			
	Site Size	7.0 AC	304,920 Sq. Ft.	Percentage of Total Area
	Impervious Area	5.12 Acres	223,206 Sq. Ft.	73.20%
	Pervious Services	1.88 Acres	81,714 Sq. Ft.	26.80%
	Total Area	7.0 Acres	304,920 Sq. Ft.	100%

Step 2: Calculate Pre-Retrofit Pollutant Load

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: **L = [(P)(Pj)(Rv) ÷ (12)](C)(A)(2.72)**

P = Chicago's Average Annual Rainfall = 36 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious cover on the site = 73%
0.707 = 0.05 + 0.009(73)
C = Event mean concentration established from Table 3-4 (Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 7.0 Acres - The site area contributing drainage

Total Suspended Solids		Total Phosphorus		Total Nitrogen		Copper		Zinc	
P=	36	P=	36	P=	36	P=	36	P=	36
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.707	Rv=	0.707	Rv=	0.707	Rv=	0.707	Rv=	0.707
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	7	A=	7	A=	7	A=	7	A=	7

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

L = [(36)(0.9)(0.707) ÷ (12)](27)(7.0)(2.72)

L = 981 lbs per Year (445 kg per Year)

Total Phosphorus

L = [(36)(0.9)(0.707) ÷ (12)](0.15)(7.0)(2.72)

L = 5 lbs per Year (2 kg per Year)

Total Nitrogen

L = [(36)(0.9)(0.707) ÷ (12)](1.9)(7.0)(2.72)

L = 69 lbs per Year (31 kg per Year)

Copper

L = [(36)(0.9)(0.707) ÷ (12)](0.051)(7.0)(2.72)

L = 2 lbs per Year (1 kg per Year)

Zinc

L = [(36)(0.9)(0.707) ÷ (12)](139)(7)(2.72)

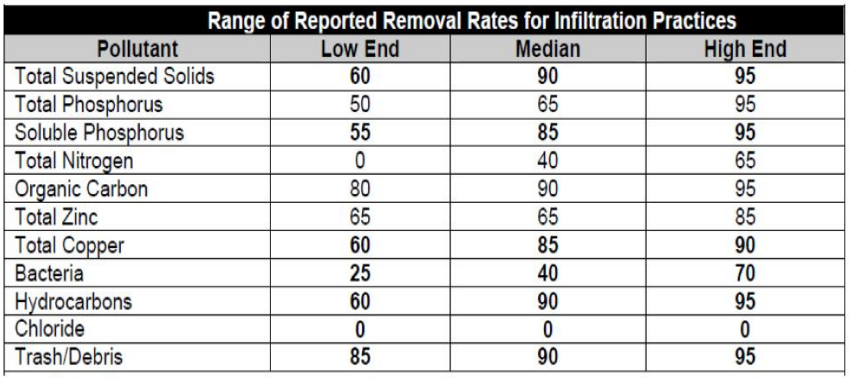
L = 5 lbs per Year (2 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

Total Suspended Solids	981 lbs per Year (445 kg per Year)
Total Phosphorus	5 lbs per Year (2 kg per Year)
Total Nitrogen	69 lbs per Year (31 kg per Year)
Metals	
Zinc	5 lbs per Year (2 kg per Year)
Copper	2 lbs per Year (1 kg per Year)

Step 3: **Identify the Stormwater Retrofit Design**

Case Study #2 US Cellular Field used Permeable Concrete Pavers (Infiltration) for the stormwater retrofit



Range of Reported Removal Rates for Infiltration Practices

Pollutant	Low End	Median	High End
Total Suspended Solids	**60**	**90**	**95**
Total Phosphorus	50	65	95
Soluble Phosphorus	**55**	**85**	**95**
Total Nitrogen	0	40	65
Organic Carbon	80	90	95
Total Zinc	65	65	85
Total Copper	**60**	**85**	**90**
Bacteria	**25**	**40**	**70**
Hydrocarbons	**60**	**90**	**95**
Chloride	**0**	**0**	**0**
Trash/Debris	**85**	**90**	**95**

Step 4: **Calculate Site Imperviousness of Design**

Using a base map calculate the areas below

Site Size	7.0 AC	304,920	Sq. Ft.
Impervious Area	0.11 Ac	4,792	Sq. Ft.
Pervious Services	6.89 Ac	300,128	Sq. Ft.
Total Area	7.0 Ac	304,920	Sq. Ft.
Percentage of Impervious Area		1.57%	Impervious Area ÷ Total Area

Step 5: Calculate Pre-Retrofit Pollutant Load of the Design

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: **$L = [(P)(Pj)(Rv) \div (12)](C)(A)(2.72)$**

P = Chicago's Average Annual Rainfall = 36 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious cover on the site = 1%
0.707 = 0.05 + 0.009(1)
C = Event mean concentration established from Table 3-4 (Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 7.0 Acres - The site area contributing drainage

Total Suspended Solids		**Total Phosphorus**		**Total Nitrogen**		**Copper**		**Zinc**	
P=	36	P=	36	P=	36	P=	36	P=	36
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.059	Rv=	0.059	Rv=	0.059	Rv=	0.059	Rv=	0.059
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	7	A=	7	A=	7	A=	7	A=	7

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

$L = [(36)(0.9)(0.059) \div (12)](27)(7.0)(2.72)$

L = 82 lbs per Year (37 kg per Year)

Total Phosphorus

$L = [(36)(0.9)(0.059) \div (12)](0.15)(7.0)(2.72)$

L = 0.5 lbs per Year (0.2 kg per Year)

Total Nitrogen

$L = [(36)(0.9)(0.059) \div (12)](1.9)(7.0)(2.72)$

L = 6 lbs per Year (3 kg per Year)

Copper

$L = [(36)(0.9)(0.059) \div (12)](0.051)(7.0)(2.72)$

L = 0.2 lbs per Year (0.1 kg per Year)

Zinc

$L = [(36)(0.9)(0.059) \div (12)](0.139)(7)(2.72)$

L = 0.4 lbs per Year (0.2 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

Total Suspended Solids	82 lbs per Year (37 kg per Year)
Total Phosphorus	0.5 lbs per Year (0.2 kg per Year)
Total Nitrogen	6 lbs per Year (3 kg per Year)
Metals	
Zinc	0.4 lbs per Year (0.2 kg per Year)
Copper	0.2 lbs per Year (0.1 kg per Year)

Step 6: **Determine the Retrofit Pollutant Removal Efficiency**

Using the Bioretention Design Sheet, score the proposed retrofit based on site conditions

Positive Design Factors

1. Exceed target WQv by more than 50% due to the transformation of the entire site to permeability.
2. High infiltration rates on site due to the exisitng sandy soils
3. Contributing Drainage Area is nearly 100% impervious.

Infiltration Retrofits		
Design Factors	**X**	**Points**
Exceeds target WQv by more than 50%	X	+ 3
Exceeds target WQv by more than 25%		+ 2
Tested infiltration rates between 1.0 and 4.0 in/hr	X	+ 2
At least two forms of pretreatment prior to infiltration		+ 2
CDA is nearly 100% impervious	X	+ 1
Off-line design w/ cleanout pipe		+ 1
Underdrain utilized		- 1
Filter fabric used on trench bottom		- 1
CDA more than 1.0 acre	X	- 1
Soil infiltration rates < 1.0 in/hr or > 4.0 in/hr		- 2
Pervious areas or construction clearing in CDA	X	- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE **(max of 5 points)**		+3

* Note: **X** designates design impact to the retrofit and the total score is derived from the total number of factors

Step 7: **Adjusting Removal Rates**

Total score is positive, Adjusting Removal Rates for each pollutant using Figure 3-7

Adjusted RR Percentage = Median Removal Rate + [(Design Score ÷ 5) * (High End Removal Rate - Median Removal Rate)]

Total Suspended Solids

Adjusted RR = 90+[(3 ÷ 5) * (95-90)]

Adjusted RR = 93%

Total Phosphorus

Adjusted RR = 65+[(3 ÷ 5) * (95-

Adjusted RR = 83%

Total Nitrogen

Adjusted RR = 40+[(3 ÷ 5) * (65-40)]

Adjusted RR = 55%

Total Zinc

Adjusted RR = 65+[(3 ÷ 5) * (85-65)]

Adjusted RR = 77%

Total Copper

Adjusted RR = 85+[(3 ÷ 5) * (90-85)]

Adjusted RR = 88%

Step 8: **Calculate the Post-Retrofit Pollutant Load**

1. Using Figure 3-9, calculate the annual pollutant load exported from the site after the stormwater retrofit

Lpost = Lpre*[1-(Removal Rate)]

Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
Lpost = 82 * [1-(0.93)]	Lpost = 0.5* [1-(0.83)]	Lpost = 6 * [1-(0.55)]
Lpost = 6 lbs per Year (3 kg per Year)	Lpost = 0.1 lbs per Year (0.05 kg per Year)	Lpost = 3 lbs per Year (1 kg per Year)

Total Zinc	**Total Copper**
Lpost = 5 * [1-(0.77)]	Lpost = 2 * [1-(0.88)]
Lpost = 1 lbs per Year (0.5 kg per Year)	Lpost = 0.24 lbs per Year (0.1 kg Year)

Step 9: **Calculate the Pollutant Load reduction of the Retrofit**

1. Using Figure 3-10, calculate the annual pollutant load removed by the proposed retrofit

Load Reduction = Lpost - Lpre

Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
LR = 6 - 981	LR = 0.1-5	LR = 3-69
LR = -975 lbs per Year (-442 kg per Year)	LR = -5 lbs per Year (-2 kg per Year)	LR = -66 lbs per Year (-30 kg per Year)

Total Zinc	**Total Copper**
LR = 1-5	LR = 0.24-2
LR = -4 lbs per Year (-2 kg per Year)	LR = -2 lbs per Year (-1 kg per Year)

* Note - A negative Load Reduction is reducing the pollutant of concern while a positive Load Reduction is exporting more of the pollutant of concern into the stormwater system

Appendix D - Detailed Calculations for Design Solution - Truman Sports Complex, Lots C & D

Step 1:	**Truman Sports Complex - Calculate Site Imperviousness**			
	Using a base map calculate the areas below			
	Site Size	30.67 Acres	1,335,974 Sq. Ft.	Percentage of Total Area
	Impervious Area	28.19 Acres	1,228,066 Sq. Ft.	91.92%
	Pervious Services	2.48 Acres	107,908 Sq. Ft.	8.08%
	Total Area	30.67 Acres	1,335,974 Sq. Ft.	100%

Step 2: **Calculate Pre-Retrofit Pollutant Load**

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: **L = [(P)(Pj)(Rv) ÷ (12)](C)(A)(2.72)**

P = Kansas City's Average Annual Rainfall = 38 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious area on the site = 92%
0.878 = 0.05+0.009(92)
C = Event mean concentration established from Table 3-4
(Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 30.67 Acres - The site area contributing drainage

Total Suspended Solids		**Total Phosphorus**		**Total Nitrogen**		**Copper**		**Zinc**	
P=	38	P=	38	P=	38	P=	38	P=	38
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.878	Rv=	0.878	Rv=	0.878	Rv=	0.878	Rv=	0.878
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	30.67	A=	30.67	A=	30.67	A=	30.67	A=	30.67

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

L = [(38)(0.9)(0.878) ÷ (12)](27)(30.67)(2.72)

L = 5,636 lbs per Year (2,556 kg per Year)

Total Phosphorus

L = [(38)(0.9)(0.878) ÷ (12)](0.15)(30.67)(2.72)

L = 31 lbs per Year (14 kg per Year)

Total Nitrogen

L = [(38)(0.9)(0.878) ÷ (12)](1.9)(30.67)(2.72)

L = 397 lbs per Year (180 kg per Year)

Copper

L = [(38)(0.9)(0.878) ÷ (12)](0.051)(30.67)(2.72)

L = 11 lbs per Year (5 kg per Year)

Zinc

L = [(38)(0.9)(0.878) ÷ (12)](0.139)(30.67)(2.72)

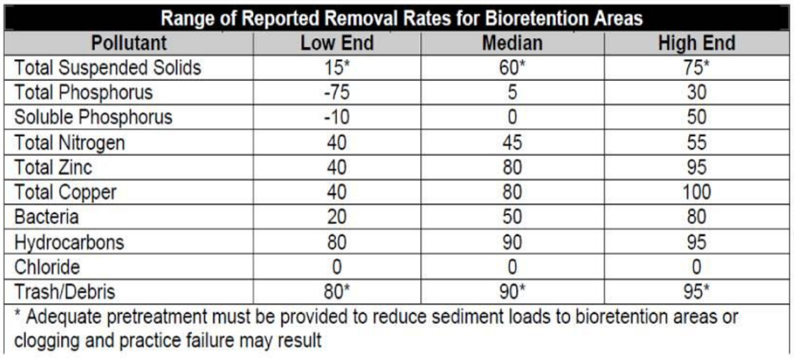
L = 29 lbs per Year (13 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

Total Suspended Solids	5,636 lbs per Year (2,556 kg per Year)
Total Phosphorus	31 lbs per Year (14 kg per Year)
Total Nitrogen	397 lbs per Year (180 kg per Year)
Metals	
Zinc	29 lbs per Year (13 kg per Year)
Copper	11 lbs per Year (5 kg per Year)

Step 3: **Identify the Stormwater Retrofit - Concept Design**

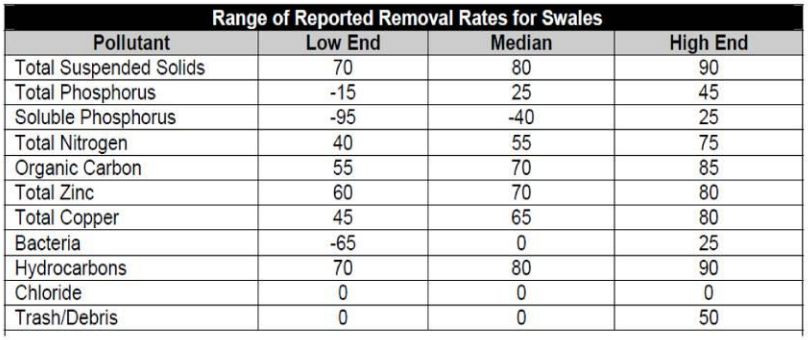
Design Solution will use Grass Swales and Bioretention for Stormwater Retrofit



Range of Reported Removal Rates for Bioretention Areas

Pollutant	Low End	Median	High End
Total Suspended Solids	15*	60*	75*
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	0	50
Total Nitrogen	40	45	55
Total Zinc	40	80	95
Total Copper	40	80	100
Bacteria	20	50	80
Hydrocarbons	80	90	95
Chloride	0	0	0
Trash/Debris	80*	90*	95*

* Adequate pretreatment must be provided to reduce sediment loads to bioretention areas or clogging and practice failure may result



Range of Reported Removal Rates for Swales

Pollutant	Low End	Median	High End
Total Suspended Solids	70	80	90
Total Phosphorus	-15	25	45
Soluble Phosphorus	-95	-40	25
Total Nitrogen	40	55	75
Organic Carbon	55	70	85
Total Zinc	60	70	80
Total Copper	45	65	80
Bacteria	-65	0	25
Hydrocarbons	70	80	90
Chloride	0	0	0
Trash/Debris	0	0	50

Step 4: **Calculate Site Imperviousness of Concept Design**

Using a base map calculate the areas below

Site Size	30.67 Acres	1,335,974 Sq. Ft.
Impervious Area	25.80 Acres	1,123,848 Sq. Ft.
Pervious Services	4.87 Acres	212,126 Sq. Ft.
Total Area	30.67 Acres	1,335,974 Sq. Ft.

Percentage of Impervious Area 84.12% Impervious Area ÷ Total Area

Step 5: Calculate Pre-Retrofit Pollutant Load

1 .Define the values for the Pollutant Load Export Equation (Figure 3-5) for Each Pollutant type

Pollutant Load Export Equation: **L = [(P)(Pj)(Rv) ÷ (12)](C)(A)(2.72)**

P = Kansas City's Average Annual Rainfall = 38 Inches
Pj = Fraction of Rainfall Events that produce runoff = 90% or 0.9
Rv = Runoff coefficient, 0.05 + 0.009(I) - Where: I = The amount of impervious area on the site = 84%
0.806 = 0.05+0.009(84)
C = Event mean concentration established from Table 3-4
(Zinc and Copper have been converted to mg/l from u/l)
Total Suspended Solids = 27 mg/l
Total Phosphorus = 0.15 mg/l
Total Nitrogen = 1.9 mg/l
Copper = 0.051 mg/l
Zinc = 0.139 mg/l
A = Area of contributing drainage in Acres = 30.67 Acres - The site area contributing drainage

Total Suspended Solids		**Total Phosphorus**		**Total Nitrogen**		**Copper**		**Zinc**	
P=	38	P=	38	P=	38	P=	38	P=	38
Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9	Pj=	0.9
Rv=	0.806	Rv=	0.806	Rv=	0.806	Rv=	0.806	Rv=	0.806
C=	27	C=	0.15	C=	1.9	C=	0.051	C=	0.139
A=	30.67	A=	30.67	A=	30.67	A=	30.67	A=	30.67

2. Calculate the average annual pollutant load using the Pollutant Load Export Equation (Figure 3-5)

Total Suspended Solids

L = [(38)(0.9)(0.806) ÷ (12)](27)(30.67)(2.72)

L = 5,174 lbs per Year (2,347 kg per Year)

Total Nitrogen

L = [(38)(0.9)(0.806) ÷ (12)](1.9)(30.67)(2.72)

L = 364 lbs per Year (165 kg per Year)

Zinc

L = [(38)(0.9)(0.806) ÷ (12)](0.139)(30.67)(2.72)

L = 27 lbs per Year (12 kg per Year)

Total Phosphorus

L = [(38)(0.9)(0.806) ÷ (12)](0.15)(30.67)(2.72)

L = 29 lbs per Year (13 kg per Year)

Copper

L = [(38)(0.9)(0.806) ÷ (12)](0.051)(30.67)(2.72)

L = 10 lbs per Year (5 kg per Year)

3. Summarize Pre Retrofit Pollutant Loads

Total Suspended Solids	5,174 lbs per Year (2,347 kg per Year)
Total Phosphorus	29 lbs per Year (13 kg per Year)
Total Nitrogen	364 lbs per Year (165 kg per Year)
Metals	
Zinc	29 lbs per Year (13 kg per Year)
Copper	10 lbs per Year (5 kg per Year)

Step 6: Determine the Retrofit Pollutant Removal Efficiency

Using the Bioretention Design Sheet, score the proposed retrofit based on site conditions

Design Impacts

- The design does provide the full WQv due to the space requirements on site.
- Single Cell Design – Space Requirements
- Underdrainage was need due to the impermeable soils.

Bioretention Retrofits				
Design Factors	***X***	**Points**	Points - Susp Solids, N, Zn, Cu,	Points Phosphorus
Exceeds target WQv by more than 50%		+3		
Exceeds target WQv by more than 25%		+2		
Tested filter media soil P Index less than 30 (phosphorus only)		+3		
Filter bed deeper than 30 inches	*X*	+1	+1	+1
Two cell design with pretreatment		+1		
Permeable soils; no underdrain needed		+2		
Upflow pipe on underdrain		+1		
Impermeable soils; underdrain needed	*X*	-1	-1	-1
Filter bed less than 18 inches deep		-1		
Single cell design	*X*	-1	-1	-1
Bioretention cell is less than 5% of CDA	*X*	-1	-1	-1
Does not provide full water quality storage volume	*X*	-2	-1	-1
Filter media not tested for P Index (phosphorus only)		-3		-3
Net Design Score (max 5 points)			-4	
Net Phosphorus Score (max 5 points)				-7 (-5 max)

Swale Retrofits		
Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Dry or wet swale design		+ 2
Exceeds target WQv by more than 25%		+ 2
Longitudinal swale slope between 0.5 to 2.0%	*X*	+ 1
Velocity within swale < 1 fps during WQ storm		+ 1
Measured soil infiltration rates exceed 1.0 in/hr		+ 1
Multiple cells with pretreatment		+ 1
Off-line design w/ storm bypass	*X*	+ 1
Longitudinal swale slope < 0.5% or > 2%		- 1
Measured soil infiltration rates less than 1.0 in/hr	*X*	- 1
Swale sideslopes more than 5:1 h:v	*X*	- 1
Swale intersects groundwater (except wet swale)	*X*	- 1
No pretreatment to the swale or channel	*X*	- 1
Swales conveys stormflows up to 10 year storm		- 2
Does not provide full WQv volume		- 2
Grass channel	*X*	- 3
NET DESIGN SCORE (max of 5 points)		-5

* Note: **X** designates design impact to the retrofit and the total score is derived from the total number of factors

Step 7: Adjusting Removal Rates

Total score is negative for both Bioretention and Swales, Adjusting Removal Rates for each pollutant using Figure 3-8

Adjusted RR Percentage = Median Removal Rate + [(Design Score ÷ 5) * (Median Removal Rate - Low End Removal Rate)]

Bioretention

<u>Total Suspended Solids</u>
Adjusted RR = 60+[(-4 ÷ 5) * (60-15)]

Adjusted RR = 24%

<u>Total Phosphorus</u>
Adjusted RR = 5+[(-5 ÷ 5) * (5-(-75)]

Adjusted RR = -11%

<u>Total Nitrogen</u>
Adjusted RR = 45+[(-4 ÷ 5) * (45-40)]

Adjusted RR = 41%

<u>Total Zinc</u>
Adjusted RR = 65+[(3 ÷ 5) * (85-65)]

Adjusted RR = 48%

<u>Total Copper</u>
Adjusted RR = 85+[(3 ÷ 5) * (90-85)]

Adjusted RR = 48%

Swales

<u>Total Suspended Solids</u>
Adjusted RR = 80+[(-5 ÷ 5) * (80-70)]

Adjusted RR = 30%

<u>Total Phosphorus</u>
Adjusted RR = 25+[(-5 ÷ 5) * (25-(-15)]

Adjusted RR = -20%

<u>Total Nitrogen</u>
Adjusted RR = 55+[(-5 ÷ 5) * (55-40)]

Adjusted RR = 20%

<u>Total Zinc</u>
Adjusted RR = 70+[(-5 ÷ 5) * (70-60)]

Adjusted RR = 30%

<u>Total Copper</u>
Adjusted RR = 65+[(-5 ÷ 5) * (65-45)]

Adjusted RR = 23%

Step 8: **Calculate the Post-Retrofit Pollutant Load**

1. Using Figure 3-9, calculate the annual pollutant load exported from the site after the stormwater retrofit

Lpost = Lpre*[1-(Removal Rate)]

Bioretention

Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
Lpost = 5,174 * [1-(0.24)]	Lpost = 29 * [1-(-0.11)]	Lpost = 364 * [1-(0.41)]
Lpost = 3,932 lbs per Year (1,784 kg per Year)	Lpost = 32 lbs per Year (15 kg per Year)	Lpost = 215 lbs per Year (98 kg per Year)

Total Zinc	**Total Copper**
Lpost = 29 * [1-(0.48)]	Lpost = 27 * [1-(0.48)]
Lpost = 15 lbs per Year (7 kg per Year)	Lpost = 14 lbs per Year (6 kg per Year)

Swales

Total Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
Lpost = 5,174 * [1-(0.30)]	Lpost = 29 * [1-(-0.20)]	Lpost = 364 * [1-(0.20)]
Lpost = 3,622 lbs per Year (1,643 kg per Year)	Lpost = 35 lbs per Year (16 kg per Year)	Lpost = 291 lbs per Year (132 kg per Year)

Total Zinc	**Total Copper**
Lpost = 29 * [1-(0.30)]	Lpost = 27 * [1-(0.23)]
Lpost = 20 lbs per Year (9 kg per Year)	Lpost = 21 lbs per Year (10 kg per Year)

Step 9: **Calculate the Pollutant Load reduction of the Retrofit**

1. Using Figure 3-10, calculate the annual pollutant load removed by the proposed retrofit

Load Reduction = Lpost - Lpre

Bioretention

Total Suspended Solids	Total Phosphorus	Total Nitrogen
LR = 3,932- 5,636	LR = 32-31	LR = 215-397
LR = -1,704 lbs per Year (773 kg per Year)	LR = 1 lbs per Year (0.5 kg per Year)	LR = -182 lbs per Year (83 kg per Year)

Total Zinc	Total Copper
LR = 15-29	LR =14-11
LR = -14 lbs per Year (6 kg per Year)	LR = 3 lbs per Year (1 kg per Year)

* Note - A negative Load Reduction is reducing the pollutant of concern while a positive Load Reduction is exporting more of the pollutant of concern into the stormwater system

Swales

Total Suspended Solids	Total Phosphorus	Total Nitrogen
LR = 3,622 - 5,636	LR = 35-31	LR = 291-397
LR = -2,014 lbs per Year (914 kg per Year)	LR = 4 lbs per Year (2 kg per Year)	LR = -106 lbs per Year (48 kg per Year)

Total Zinc	Total Copper
LR = 20 - 29	LR = 27 - 11
LR = -9 lbs per Year (4 kg per Year)	LR = 16 lbs per Year (7 kg per Year)

* Note - A negative Load Reduction is reducing the pollutant of concern while a positive Load Reduction is exporting more of the pollutant of concern into the stormwater system

Appendix E - Operational Definitions

The terms that follow were defined by the American Public Works BMP Manual for Stormwater Quality (MARC, 2008, p. 5-8) unless otherwise specified.

Antidegradation: Refers to regulations designed to maintain and protect high quality waters and existing water quality in other waters from unnecessary pollution (EPA, 2009).

Best Management Practice (BMP): A method, activity, maintenance procedure, or other management practice for reducing the amount of pollution entering a water body. The term originated from the rules and regulations developed pursuant to Section 208 of the Federal Clean Water Act (40 CFR 130).

Biofiltration: The use of plants to filter contaminants and sediment out of stormwater.

Catch Basin: Traps installed in the street between storm drain inlets and the drain pipes to catch litter and pollutants that either sink to the bottom of the catch basin or float to the top.
These captured materials are then removed periodically through City street maintenance activities. Catch basins serve to help keep storm drains clear and flowing properly, and help remove sediments and pollutants that would otherwise end up downstream.

Channelization: The process of making a channel or channels. A channel is the bed of a stream or river, or the hollow or course in which a stream flows.

Check Dam: A small dam designed to retard the flow of water and sediment in a channel, used especially for controlling soil erosion.

Clean Water Act: An Act passed by Congress in 1972 and amended in 1977 to restore all the nation's waters to "fishable and swimmable" condition. Originally, the focus of the Act was on point source pollution from sources such as pulp and paper mills and sewage treatment plants.
More recently the emphasis has shifted towards decreasing pollution from non-point sources such as run-off from yard and garden products, automobile fluids, and erosion stemming from development.

Combined Sewer Overflow (CSO): A pipe that discharges untreated wastewater during storms from a sewer system that carries both sanitary wastewater and stormwater. The overflow occurs because the system does not have the capacity to transport and treat the increased flow caused by stormwater runoff.

Combined Sewer System: A wastewater collection and treatment system in which domestic and industrial wastewater is combined with storm runoff. Although such a system does treat
stormwater, the overflow from major storms results in discharge of untreated wastewater.

Comprehensive Drainage Plan (CDP): City of Seattle document prepared to address citywide flooding and water quality problems.

Creek Restoration Project: Project designed to restore the natural function and appearance of
a creek. Examples include planting native vegetation in the riparian corridor, and instream improvements to create fish rearing habitat

Culvert: A drain, usually a concrete or metal pipe, crossing under a road or an embankment.

Detention: The process of collecting and holding back stormwater for later release to receiving waters.

Detention Ponds: Engineered basins placed along creeks to temporarily capture excess flows of stormwater and thereby reduce flooding in an area. Several detention ponds ranging from 50 to over 300 feet in diameter have been installed in several places along Thornton Creek by SPU to alleviate flooding problems exacerbated by development and impervious surface runoff.

Environmental Impact Statement (EIS): A document that discusses the likely significant impacts of a proposal, methods to lessen the impacts, and alternatives to the proposal. Projects may merit an EIS following requirements of the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA).

Erosion: Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical and chemical forces

Groundwater: Rainwater that soaks into the ground and flows downward until reaches an impermeable underground layer of the earth’s crust where it collects in aquifers. Groundwater then usually flows laterally toward a river or lake or the ocean. Wells tap the groundwater for human use. (See also aquifer.).

Habitat: Specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be free of harmful contaminants. Puget Sound habitats include beaches, marshes, rocky shores, the bottom sediments, mud flats, and the water itself.

Headwater: The source of a stream or creek. Within a watershed, the headwaters are the upper and outer edges of the watershed basin and sub-basins where individual creeks begin and flow down towards the main creek branch.

Hydrology: Refers to the way that water behaves from its origins as precipitation, through its movement on or beneath the surface of the earth, to its entry into sewers, streams, lakes, oceans and its eventual return to the atmosphere (Illinois EPA, 2009).

Impervious or Impermeable Surface: A surface that cannot be easily penetrated, for instance, rain does not readily penetrate asphalt or concrete surfaces.

Infiltration: The process of water permeating or soaking into a surface such as the ground.
Infiltration of stormwater into the earth recharges groundwater and feeds streams during dry periods.

Inflow and Infiltration (I&I): Excess water that enters a sewer system. Since a sewer system can only handle a certain amount of wastewater at one time, excess flows can trigger overflows of raw wastewater. Inflow refers to water that unnecessarily flows into the system, for example, from household roof drains. Infiltration is water that seeps into the system through cracks and gaps in the pipes.

Land Use: The way land is developed and used in terms of the types of activities allowed (agriculture, residences, industries, etc.) and the size of buildings and structures permitted.
Certain types of pollution problems are often associated with particular land use practices, such as sedimentation from construction activities.

Metals: Elements found in rocks and minerals that are naturally released to the environment by erosion, as well as generated by human activities. Certain metals, such as mercury, lead, nickel, zinc, and cadmium, are of environmental concern because they are released to the environment in excessive amounts by human activity. They are generally toxic to life at certain concentrations. Since metals are elements, they do not break down in the environment over time and can be incorporated into plant and animal tissue.

Monitor: To systematically and repeatedly measure conditions in order to track and assess changes. For example, dissolved oxygen in a bay might be monitored over a period of several years in order to identify any trends in its concentration.

National Pollutant Discharge Elimination System (NPDES): A federal Clean Water Act requirement for point source dischargers to obtain permits. These permits are also

required for stormwater and Combined Sewer Overflow (CSO) discharges. Commonly referred to as
NPDES permits, they are administered by the Washington State Department of Ecology.

Nonpoint Source Pollution: Pollution that enters water from dispersed and uncontrolled sources (such as surface runoff) rather than through pipes. Nonpoint sources (e.g., forest practices, agricultural practices, on-site sewage disposal, and recreational boats) may contribute pathogens, suspended solids, and toxicants. While individual sources may seem insignificant, the cumulative effects of nonpoint source pollution can be significant.

Nonpoint Sources: Dispersed sources of pollutants that accumulate in surface or ground water. Generally, individual sites are insignificant, but can add to a cumulative problem, with serious health or environmental consequences.

One-Year Storm Event: A storm with rainfall of an amount likely to occur on average once a year in a given area. A ten-year storm event would be likely to occur once in ten years.

Outfall: The downstream end of a pipe or ditch where the water joins a stream, lake, or other water body.

Permeable Surface: Surface, such as dirt, that allows some percolation or infiltration of water into the ground and ultimately the groundwater system. This is in contrast to impermeable surfaces, such as concrete, that allow water to run off without any infiltration.

Point Sources: A single point of discharge such as a pipe that contributes pollutants into a water body. For example, the outfall from a sewage treatment plant or a factory is a point source.

Pollutant: A substance that adversely alters the physical, chemical, or biological properties of the environment. The term includes coliforms, metals, oxygen-demanding materials, and all other potentially harmful substances. With reference to nonpoint sources, the term is sometimes used to apply to substances released in low concentrations from many activities that collectively degrade water quality. As defined in the federal Clean Water Act, pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Priority Pollutants: Substances listed by EPA under the Clean Water Act as toxic and having priority for regulatory controls. The list currently includes metals (13), inorganic compounds (cyanide and arsenic), and a broad range of both natural and artificial organic compounds (111).

Right-of-way: Publicly used land, including streets, sidewalks, ditches and road shoulders.
Includes publicly owned land and easements negotiated with private owners.

Sediment: Material suspended in or settling to the bottom of a liquid, such as the sand and mud that make up much of the shorelines and bottom of lakes. Sediment comes from natural sources, such as erosion of soils and weathering of rock, or human activities sources, such as forestry, agriculture, or construction. Certain contaminants tend to collect on and adhere to sediment particles. The sediments can also contain elevated levels of toxic contaminants.

Sedimentation: The process by which a river, lake, or other water body becomes increasingly filled with sediment. Sediment can clog gravel beds and prevent successful drainage.

Separated Sewer System: A wastewater collection and treatment system where domestic and industrial wastewater is separated from storm runoff. A separated system consists of independent sanitary wastewater and stormwater systems. The stormwater is discharged directly into open water and the sanitary wastewater goes to a treatment plant.

Side Sewer: A sewer that connects from a structure to the municipal sewer line. Side sewers are the responsibility of the property owner.

Storm Drain: A system of gutters, pipes, or ditches used to carry stormwater from surrounding lands to streams, lakes, or Puget Sound, and in practice, carrying a variety of substances such as oil and antifreeze which enter the system through runoff, deliberate dumping, or spills. This term also refers to the end of the pipe where the stormwater is discharged.

Stormwater: Water generated by rainfall and often routed into drain systems in order to prevent flooding.

Sub-basin: A smaller basin contained within a larger watershed. A large watershed is composed of many smaller sub-basins (see Watershed).

Suspended Solids: Organic or inorganic particles suspended in and carried by the water. The term includes sand, mud, and clay particles as well as solids in wastewater.

Swale: A broad, shallow, vegetated channel. A biofiltration swale is a vegetated drainage ditch that has been engineered to collect and transport stormwater in a way that allows the vegetation to filter sediments and pollutants. A swale can be any natural or constructed drainageway.

Total Suspended Solids (TSS): A measure of the weight of particles suspended in water. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles.

Tributary: A stream that flows into another stream or river.

Urban Runoff: Rainwater that flows over surfaces in a watershed and is not absorbed by the ground. Urban runoff can contain sediments and contaminants (nonpoint source pollution) that can add to water quality degradation in the watershed. Increases in impervious surface usually result in increased urban runoff.

Watershed: The geographic region from which water drains into a particular river or body of water. A watershed includes hills, lowlands, and the body of water into which the land drains.
Watershed boundaries are defined by the ridges that separate watersheds.

Weir: A low dam or fence built across a stream, primarily to control water level or to divert water into another facility.

Wetlands: Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes (water loving plants); (2) the substrate is predominantly under drained hydric soil; and (3) the substrate is not soil and is saturated with water or covered by shallow water at sometime during the growing seasons each year.