COLLEGE OF
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Department of Plant Science and Landscape Architecture

Algae in Carroll Creek: Green Infrastructure and Community Greening Approaches

Landscape Architecture 452: Green Infrastructure & Community Greening
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Executive Summary

This report describes green infrastructure and community greening approaches to address excess algae in Carroll Creek in The City of Frederick. This report was written as partial fulfillment of course requirements for LARC 452: Green Infrastructure and Community Greening. Addressing excess algae in Carroll Creek is a complex problem that merits multifaceted approaches. The students in the class also recognized previous efforts that have been in part successful in documenting and reducing some of the algae in Carroll Creek. The report is organized into five sections: 1) a review of selected watershed reports; 2) a case study of the San Antonio Riverwalk; 3) approaches that address the symptoms of algae; 4) approaches that address the root course of excess nutrients; and 5) establishing a Carroll Creek watershed advocacy group.

Selected Watershed Reports

The report begins (Chapter 1) with an overview of selected watershed reports that pertain to the Carroll Creek Watershed. An overall understanding of Carroll Creek watershed is essential. The 2000 *Rock and Carroll Creek Stream Corridor Assessment Survey* document provides critical assessment of identified potential problems in the watershed. The 2003 *Lower Monocacy River Watershed Characterization* report provides an understanding of land use characteristics including Carroll Creek. The 2008 *Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement* provides a blueprint for action. The 2010 *Water Resources Element for Frederick County, Maryland* presents, among other information, the percent impervious of the Carroll Creek watershed relative to other watersheds in Frederick County. Last, the recent 2014 *A* Guide to Local Government Policy Changes to Implement Environmental Site Design to the Maximum Extent Practicable: Maryland & Washington, D.C. provides an evaluation of codes and ordinances related to the implementation of Environmental Site Design (ESD) requirements. This chapter provides a quick overview of information helpful to understand addressing excess algae in Carroll Creek.

Case Study: San Antonio Riverwalk

A case study of the San Antonio Riverwalk (Chapter 2) provides watershed management lessons for the City of Frederick. Like Carrol Creek, the River Walk area is a major economic and cultural driver for the entire region. One proposal is for the City of Frederick to explore the requirements for awards like the Thiess International Riverprize. The ideas and approaches learned in this

process may be useful in developing an approach that becomes an exemplary practice of watershed management.

Addressing the Symptoms of Algae

Algaecides (Chapter 3), Algal Turf Scrubbers (ATS) (Chapter 4), *Floating Treatment Wetlands (FTW) and Stargrass* (Chapter 5) are approaches that are proposed that address the symptoms of the algae problem. The use of algaecide chemicals is a viable and relatively inexpensive option for eradicating and controlling the algae in Carroll Creek. There is some question, however, whether the best possible algaecide will be effective during extreme events. Algal Turf Scrubbers (ATS) are water-filtering devices in which light is used to grow algae, and in the process *remove excess nutrients from the water.* ATS may be limited by budget, physical space, available land, and required nutrient reduction to control algal growth. However, they might provide an effective solution to the ongoing problem if implemented correctly. Preliminary data collection using a pilot ATS is the most reliable option. Floating Treatment Wetlands (FTWs) are structures floating where emergent wetland plants are grown hydroponically. Like ATS, the plants in a FTW remove excess nutrients from the water. The data supports that FTWs carry out functions similar to natural wetlands. Their advantages include modular construction and low maintenance. Water stargrass also may be useful as a tool in appropriate locations to uptake nutrients.

Addressing the Root Causes of Excess Nutrients

A series of approaches are proposed that deal with the root causes of excess nutrients flowing into the Carroll Creek Watershed. Chapter 6, Green Street Principles and Best Practices for Improving Infiltration in Highly Impervious Environments, examines methods and green street applications in the urban and residential environments. A few of these include Permeable Pavement Systems, Stormwater Planters, Stormwater Bump-outs, Stormwater Trees, Green Gutters, Stormwater Tree Trench and Stormwater Drainage Wells. This section also summarizes three Inner City Case Studies and three Residential Case Studies. In a more focused application chapter, Green Streets: Applications for The City of Frederick, MD (Chapter 7) proposes implementation of green street practices in The City of Frederick centers around three main action items involving the downtown, the Golden Mile, and the Comprehensive Plan. Implementation of these proposed projects is supported by the goals in the Comprehensive Plan

Exemplary Parking: Designs for Minimizing Runoff (Chapter 8) is a report on case studies of selected parking lots that incorporate strategies to reduce runoff and impervious surfaces. Redesigning and retrofitting parking lots is an effective strategy for reducing stormwater runoff. Implementing bioswales, rain gardens, cisterns and pervious paving systems is shown to collect and treat stormwater on-site. In the long run, reducing the amount of runoff will improve water quality in nearby water bodies. The retail area along Frederick's Golden Mile provides ample opportunities for retrofits.

Improving Infiltration through Bioretention Systems in High Impervious Landscapes (Chapter 9) investigates how bioretention systems can be implemented in numerous ways and designs. Bioretention has become an essential tool for improving local water bodies and water quality. The chapter on Reducing Nutrients via Source Reduction: Lawn Education Practices (Chapter 10) outlines best practices of lawn management and fertilizer reduction can be used by The City of Frederick to restore the health of the water system. The last chapter for approaches to treat the root cause of excess nutrients is titled Riparian Forest Buffers: Implementation on Residential and Public Park Land (Chapter 11). A review of the data shows that, just for addressing nutrient interception, a buffer width up to 164 feet may be necessary. Wider buffer widths would be necessary for the riparian forest to successfully offer a full spectrum of ecosystem services. Potential sites for future riparian reforestation on City parkland are presented.

Establishing a Carroll Creek Watershed Advocacy Group

Chapter 12, Establishing a Carroll Creek Watershed Advocacy Group discusses the creation of an advocacy group that could promote better stewardship and environmental responsibility. Using social media is an effective way to reach beyond The City of Frederick and reaching a younger audience. The establishment of an advocacy group would be a good first action step and could promote collaborations between city and county residents, build awareness of water quality issues and build private –public partnerships.

Summary

The report suggests that using multiple approaches addressing both the symptoms of the problem and the root causes of excess nutrients in the Carroll Creek Watershed are useful. Through the implementation of appropriate approaches and promoting stewardship and education, the Carroll Creek water system will be much healthier and sustainable to provide continued ecological, aesthetic and economic benefits.

Chapter 1: Review of Watershed Reports

Vincent Yi

Abstract

This chapter is an overview of Carroll Creek issues and a summary of existing Carroll Creek and Lower Monocacy River Watershed reports. It provides background information on water quality issues pertaining to land use and impervious cover from the early 2000s to the present. A review of these reports is useful in understanding water issues in the Carroll Creek Watershed.

Introduction

The Carroll Creek Linear Park in the City's downtown historic district is a 1.3-mile mixed-use urban park that runs along the length of the canal. The idea to reconstruct the Creek as a canal originated as a flood control device after flooding in 1972 and a historic flood in 1976 that resulted in millions of dollars in property loss. Construction of the canal began in 1983, and the $60 million project was completed in 1993 (City of Frederick 2011).

With the Carroll Creek Master Plan prepared by Jacobson Wallace Associated (JWA) in 1991, the vision of a multifunctional Carroll Creek Park came into being. The idea of a creekside park running through the historic City called for commercial, residential, cultural and recreational development (City of Frederick 2011).

Today, the park plays a vital role restoring the historic district's economic prosperity while serving as a recreational and cultural focal point for the City that has generated more than $150 million in private investment in existing or planned construction, infill development and historic renovation. The City estimates that the park has created more than 1,500 new jobs and added over $2.5 million in local property taxes annually (City of Frederick 2011).

The Algae in Carroll Creek Canal

Every spring and summer, people gather in Carroll Creek Park for food, music and art. Unfortunately, the warm weather and visitors are also joined by algae blooms in the canal. The unwelcome algae has become such a persistent problem that Marcia A. Hall, a member of the City's Carroll Creek Task Force called the algae "a fact of life." (Martin 2008). However, the algae poses an environmental challenge and is a problem City officials are working to solve.

The algae in the canal also poses an economic problem for the City. The sight and odor of the algae in the canal can distract the attention of tourists from attractions like the public arts displayed throughout the linear park and may even deter visitors with its unpleasant smell. From an economic, tourism and residential standpoint, the ultimate goal is to keep the canal as clean and attractive as possible.

City officials and Hood College students have partnered in an effort to solve the algae problem. In their research, the students found that the key factors to algae growth are water flow, nutrients and light, and that long term solutions would have to include increasing the water flow and reducing the amount of stormwater runoff, which carries excess nutrients into the creek. They also discovered that the source of the algae problem extends into the rest of Carroll Creek Watershed (McCarthy 2012).

Excess Nutrients in Streams

The Carroll Creek watershed is a subwatershed of the Lower Monocacy River Watershed, and since 1996, the watershed has been listed by the Maryland Department of the Environment as impaired by nutrients (MDDNR 2003). Nutrients, phosphorous and nitrogen are essential to support aquatic life, but excess nutrients, when coupled with slow water flow, can lead to problems like extensive algal growth. When algae grows to excessive levels, it can prevent sunlight from penetrating the water and crowd out other aquatic species. Eventually, the algae blooms die and decompose, and the decomposition process consumes dissolved oxygen, which can then lead to dead zones in the water.

It is in reaction to the increasing area of dead zones and the declining water quality that the Total Maximum Daily Load (TMDL) for the Chesapeake Bay was created in 2010. The TMDL specifies the amount of pollutants a water body can assimilate and still accommodate its designated use. This requires allocating maximum pollutant load, including nutrients like phosphorous and nitrogen, to specific sources (EPA 2014a).

When allocating pollutants, it is important to distinguish between point and nonpoint sources. Discharges from pipes or other “discrete conveyances” are identified as point sources (EPA 2011). Nonpoint sources do not have a specific source and come from many diffuse sources. Nonpoint sources can result from rainfall or snowmelt moving through the ground, picking up natural and manmade pollutants, and depositing them in waterways (EPA 2104b).

This distinction is significant because point sources are regulated under the National Pollutant Discharge Elimination System (NPDES) and are legally bound to be limited to the permitted amount. This permitting process has led to reduction in point sources of nutrient pollution, such as wastewater treatment plants (EPA 2014c). However, water quality issues persist because the primary sources of nutrient pollution come from nonpoint sources, which are difficult to detect and regulate.

Factors Influencing Nonpoint Sources of Nutrients

There are several factors that influence the amount of nonpoint source nutrient pollution. These include changes in land use, the amount of riparian forest buffers, and the prevalence of impervious surfaces in a watershed.

Changes in land use are a key factor influencing the amount of nonpoint source nutrient runoff into waterways. The conversion of naturally vegetated lands in a watershed can result in serious impacts to streams and the associated ecosystems. Conversion of forested space into development has played a crucial role in the increase of nonpoint source nutrient runoff.

Riparian (streamside) forest buffers are crucial to the health of streams for several reasons. Trees and other vegetation provide essential ecosystem functions such as stream bank stabilization and erosion reduction. They also provide shade that cools the water, which is particularly important when reducing warm season water temperature. Riparian forests also act as a filter, reducing amount of nutrients, sediments, and other pollutants that reach the streams. A loss of these streamside forests can result in increased overland flow and an increase in the amount of nonpoint source nutrients reaching the stream (Rice and Yetman 2000).

Changes in land use may lead to increases in impervious surfaces, which is another important factor that influences nonpoint source pollution. Impervious surfaces are roads, parking lots, sidewalks, rooftops, and any other hard surfaces that do not allow for the infiltration of water. Impervious surface prevents nutrients from seeping into the ground and causes an increase in the rate of overland flow, carrying pollutants like excess nutrients, into the stream.

In studies, imperviousness in a watershed has been linked to negative impacts on stream health and water quality. Research shows that when watershed imperviousness reaches 10 percent, sensitive stream elements are impacted. At 25 to 30 percent imperviousness, streams deteriorate to a poor condition

with “severe impact from erosion, channel instability, severe habitat degradation and decreasing biological integrity.”

Review of Watershed Reports

2000 Rock and Carroll Creek Stream Corridor Assessment Survey

Nineteen miles of streams in the Rock Creek and Carroll Creek Watersheds were surveyed to determine the locations of potential environmental problems. A total of 191 environmental problems were identified as a result of this survey; inadequate stream buffer was the most common environmental problem (Table 1.1).

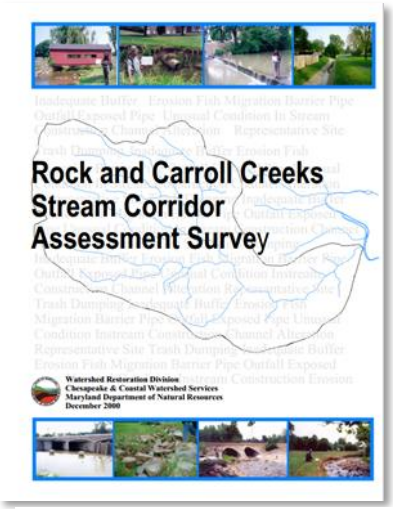


Figure 1.1. 2000 Rock and Carroll Creeks Stream Corridor Assessment Survey (Rice and Yetman 2000)

Other problems identified that contribute to excess nutrients in the streams are pipe outfalls, exposed pipes, unrestricted livestock access to streams, and new construction (Rice and Yetman 2000).

Identified Problems	Number of Sites
Channel Alterations	16
Inadequate Buffers	56
Erosion Site	37
Exposed Pipe	9
Fish Barrier	22
Pipe Outfalls	40
Unusual Conditions	5
Livestock	5
Near Stream Construction	1
Total	**191**
Representative Sites	42

Table 1:1. Identified Environmental Problems (Rice and Yetman 2000)

According to the survey, 56 sites had inadequate stream buffers, which were defined as forest buffers less than 50 feet wide, with a total of seven miles of inadequate buffers in the Rock Creek and Carroll Creek Watersheds. Thirty-one sites had no buffer at all on one or both sides of the stream (Rice and Yetman 2000).

The second most common problem identified in this report was pipe outfalls. Forty pipe outfalls, defined as “any pipes or small man made channels that discharge into the stream,” were discovered. A significant number of these pipe outfalls were located in Baker Park, which is not surprising because the surrounding area is heavily urbanized and these pipes discharge stormwater straight into the stream (Rice and Yetman 2000). These pipe outfalls can present a serious challenge to water quality

as nutrients and other pollutants are channeled directly into streams during storm events.

Livestock were also seen in the stream during this survey (Rice and Yetman 2000). Unrestricted livestock access to the stream could contribute to stream bank erosion, sedimentation, and nutrient pollution.

Lower Monocacy River Watershed Characterization, October 2003

This report of the Lower Monocacy River Watershed reviews land use and trends within the watershed. In 2000, agriculture was the dominant land use type at 46.7 percent while urban cover was 21.9 percent (MDDNR 2003).

In comparison, land use cover within the Carroll Creek Watershed was significantly different from the Lower Monocacy River Watershed. The Carroll Creek Watershed had a much greater ratio of developed area because of the City of Frederick. The Carroll Creek Watershed was 21 percent agricultural, 14 percent forested, and 65 percent developed, with less than 0.1 percent of wetland cover. Development has been concentrated in Carroll Creek Watershed and in 2003; impervious cover in the Carroll Creek watershed was 18.6 percent. Land use trends suggest this number will increase (MDDNR 2003).

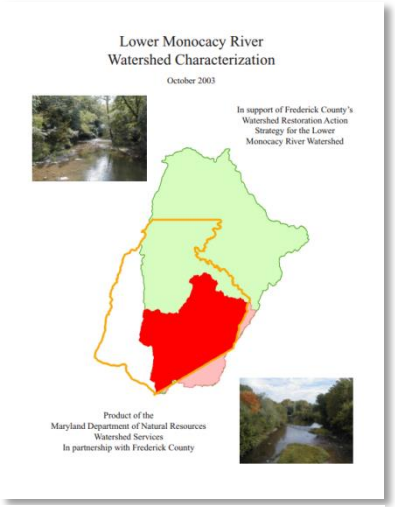
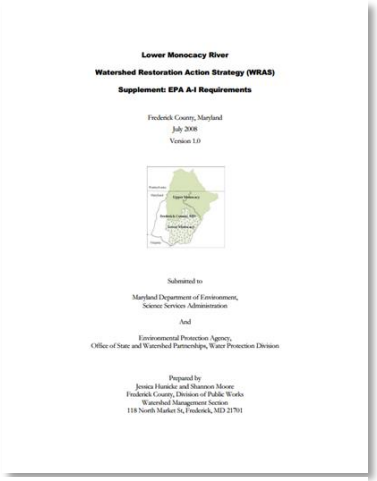


Figure 1.2. 2003 Lower Monocacy River Watershed Characterization

Looking at the Lower Monocacy River Watershed as a whole, 65 percent of its streams were not buffered with trees in 1998 and nearly 11,799 acres of wetlands have been lost. Based on these figures, the Lower Monocacy has lost more buffering and protection than similar Maryland watersheds. These figures were larger when compared to other similar Maryland watersheds (MDDNR 2003).

Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement, July 2008

The Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement updated the original May 2004 Lower Monocacy River WRAS. Its most significant findings related to the nutrient pollution problem are data on land use and the amount of nutrient loading associated with specific types of land use (Tables 1.2 and 1.3).



Lower Monocacy River

Watershed Restoration Action Strategy (WRAS)

Supplement: EPA A-I Requirements

Frederick County, Maryland
July 2008
Version 1.0

Submitted to

Maryland Department of Environment,
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And

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Figure 1.3. Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement 2008

According to the land use data, the Lower Monocacy River Watershed makes up 39.61 percent of Frederick County. However, within that watershed is 51.16 percent of the County's pasture land, 83.5 percent of its high-density residential area, and 62.53 percent of its medium-density residential area. These types of land uses all have relatively high loading rate coefficients. Pastures have the highest phosphorus loading rate coefficient at 3.123 lbs. /ac/yr. and the third highest nitrogen loading rate coefficient at 8.031 lbs. /ac/yr. High-density residential land use had the second highest phosphorus loading rate coefficient at 1.182 lbs./ac/yr. (Table 1.2). Other land use types worth noting are croplands, forests, and water/wetlands. The Lower Monocacy River watershed had a lower ratio of croplands when compared to the rest of Frederick County, but this land use type still makes up 37.7 percent of the watershed and had the highest nitrogen loading rate coefficient at 14.724 lbs. /ac/yr. (Hunicke and Moore 2008).

	Loading Rate Coefficients			
Land Use Type	Phosphorus (lbs/ac/yr)	Nitrogen (lbs/ac/yr)	Sediment (tons/ac/yr)	Imperviousness
Commercial/Industrial	0.669	5.8	0.10229	0.8
Cropland	1.606	14.724	0.24556	0.019
Forest	0.026	1.874	0.024	0.015
HDR*	1.182	4.462	0.15	0.28
LDR*	0.687	1.339	0.02859	0.09
MDR*	0.984	1.428	0.0587	0.21
Open Urban	0.535	8.924	0.0818	0.086
Pasture	3.123	8.031	0.4775	0.019
Water/Wetlands	-0.223	0.0000001	-0.034	1

Table 1.2: Loading Rates Coefficients by Land Use (Hunicke and Moore 2008)

Water Resources Element for Frederick County, Maryland, September 2010

One of the major challenges specified in this report is the County's population increase. From 2010 to 2030, there is a projected increase to 96,300 people, which will require the construction of 36,300 new dwellings (based

on the projected household size of 2.65) (Frederick County Division of Planning 2010).

This significant increase will put pressure on existing water resources, and the new development associated with this increase in population will lead to the conversion of forests and agricultural land to rooftops, roads, and driveways. This will only increase the Carroll Creek Watershed's already high impervious cover of 25.9 percent and put further stress on the Creek's water quality (Table 1.4).

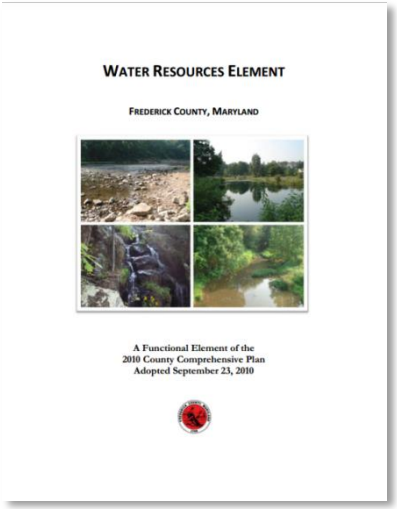

Figure 1.4. Water Resources Element (Frederick County Division of Planning 2010)

Land Use Type	Acres in Frederick County	Acres in Lower Monocacy	Lower Monocacy Percentage
Barren	56.91	49.87	87.63%
Commercial/Industrial	14,743.96	9,537.24	64.69%
Cropland	178,158.99	63,793.1	35.81%
Forest	145,432.63	48,616.04	33.43%
HDR	800.6	668.48	83.50%
LDR	35,907.33	18,497.22	51.51%
MDR	13,498.47	8,440.58	62.53%
Open Urban	6,233.53	3,968.18	63.66%
Pasture	28,965.65	14,817.7	51.16%
Water/Wetlands	3,297.2	804.49	24.40%
Total	**427,095.27**	**169,192.9**	**39.61%**

***HDR = High-density residential**
***MDR = Medium-density residential**
***LDR = Low-density residential**

Table 1.3. Forest and water/wetlands are also worth noting because the Lower Monocacy River Watershed had a lower ratio of these land use types when compared to the rest of Frederick County. These two land use types had the lowest nutrient loading rate coefficients (Hunicke and Moore 2008).

Watershed	% Impervious	Watershed	% Impervious
Ballenger Creek	16.7	Lower Bush	7.6
Bennett Creek	5.1	Lower Linganore	7.5
Carroll Creek	25.9	Middle Creek	3.6
Catoctin Creek	5.9	Monocacy Direct	9.4
Fishing Creek	4.1	Potomac Direct	6.4
Glade Creek	6.6	Owens Creek	4.1
Hunting Creek	4.6	Toms Creek	4.5
Israel Creek	7.2	Tuscarora Creek	8.2
Little Catoctin	8.2	Upper Bush Creek	9.8
Little Pipe	5.3	Upper Linganore Creek	5.6

Table 1.4. Percent Impervious (Frederick County Division of Planning 2010)

A Guide to Local Government Policy Changes to Implement Environmental Site Design to the Maximum Extent Practicable: Maryland & Washington, D.C.

The principles of Environmental Site Design (ESD) have three goals: reduce the amount of impervious cover, increase natural lands set aside for conservation, and use pervious areas for more effective stormwater management. Through the process of attaining these three goals, the hope is to reduce impact on waterways, incur savings in infrastructure costs, and improve quality of life for residents (Potomac Conservancy 2014).

This report reviews the codes and ordinances worksheets (COW) in Maryland and Washington, D.C. to identify the opportunities and challenges to implementing ESD practices. The Frederick County worksheet scored 68 percent, which is fourth in the State. However, this score is expected to lower since proposed changes to the County's codes and ordinances pose a greater barrier to environmental site design (Potomac Conservancy 2014).

According to the report, Frederick County's high population growth rate has led to the development of a mixed landscape of urban, suburban, and rural land. Coupled with a moderate level of existing development, The Potomac Conservancy has classified Frederick County as a highly vulnerable suburban jurisdiction with the main challenge being the creation of unnecessary impervious surface (Potomac Conservancy 2014).

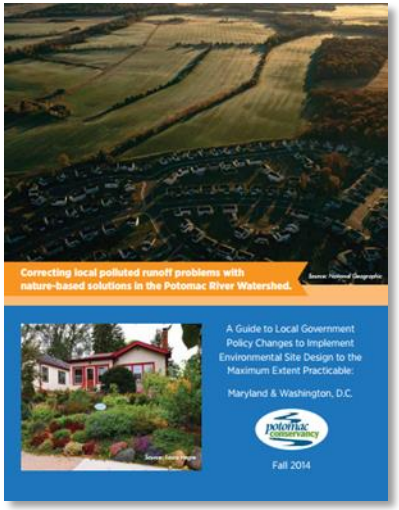

Figure 1.5. Codes and ordinances worksheets report (Potomac Conservancy 2014)

Summary

This chapter provides a summary of existing Carroll Creek and Lower Monocacy River Watershed reports.

An understanding of this background information on water quality issues pertaining to land use and impervious cover is useful in useful in understanding water issues in the Carroll Creek Watershed.

Chapter 2: Upper San Antonio River and the River Loop/River Walk—San Antonio, Texas

Seth Fleming

Abstract

An investigation into environments similar to Carroll Creek may be helpful in providing ideas and approaches to help with the algae issue. It is our understanding that City of Frederick officials have investigated the San Antonio Riverwalk. This chapter provides an update and focuses on two areas; the "Museum Reach – Urban Segment," which is upstream from the River Walk area, and the "Downtown Reach," which includes the River Walk.

Introduction

For more than a decade, many communities surrounding the San Antonio River and stakeholders throughout the watershed have been working toward a comprehensive and holistic approach to improve water quality within the San Antonio River. Comprehensively, this effort is often known formally as the San Antonio River Improvements Project (SARIP), and one major focus has been improving water quality in the downtown River Walk area. The River Walk area is a major economic and cultural driver for the entire region. Efforts have been made to address significant environmental problems in the River such as the causes of excess algae in the aquatic ecosystem, yet these problems continue (Jerstad 2013). A comprehensive and long-term strategy will be necessary; particularly to address problems in the urban corridor, where significant impervious surfaces and other non-point sources join various point sources as contributors to water quality impairments.

Progress to date has been achieved through a combination of ecosystem restoration, redesign and modification of legacy flood risk reduction projects (especially downstream), improved land management to reduce pollution from non-point source runoff, infrastructure improvements, and other community-based efforts. Also, partial solutions have been proposed and/or implemented both in upper portions of the watershed and at the site-scale in the area around the River Walk**.**

The Problem

Pollutants upstream in the main stem of the San Antonio River contribute to excess algae and other imbalances in the River Walk area's ecosystem. For example, bacterial contamination, erosion, invasive species, loss of habitat, and excess nutrients from land use in the upper San

Antonio River watershed contribute to impairments both upstream and in the River Walk area.

Also, factors in the River Walk area contribute to the impairments, including urban stormwater runoff from impervious surfaces, as well as aging, leaking, and inadequate wastewater infrastructure. Additional factors in the River Walk area include improper practices by adjacent property owners, including businesses, and a lack of ecological awareness by community members who unknowingly cause adverse impacts to San Antonio River water quality.

The Stakeholders

Participants in improving water quality in the San Antonio River reflect a broad and diverse coalition. Collaborative efforts came into focus in 1998, with the creation of the San Antonio River Oversight Committee (SAROC) (San Antonio River Authority 2014). The Committee brings together diverse interests and allows for an open process involving the public. Ultimately, extensive partnerships have formed, involving multiple collaborations between the federal, state, and local governments, as well as private entities. Partners include Bexar County, the City of San Antonio, the U.S. Army Corps of Engineers, the San Antonio River Foundation, SAROC, numerous individual property owners, and the San Antonio River Authority (SARA), which is a political subdivision of the State of Texas, along with many others. Major partners and stakeholders include business entities, as well as cultural organizations like the Witte Museum, the San Antonio Museum of Arts, and the San Antonio Zoo.

The Solution

In the upstream reaches of the San Antonio River, a multifaceted approach to water quality issues is underway. Ecosystem restoration is vital to restoring the river to a more natural flow, which enables natural processes to more effectively manage excess nutrients. The restoration of more natural elements in the river enhances the ability of the natural ecosystem to achieve balance. While the community has understandably insisted that no solution should increase the flood risk posed by the river, using more modern flood risk reduction techniques enables the community to restore the river to more natural conditions without elevating the flood risk.

Project designers are “creating designated wildlife habitat areas, and the river will be lined with natural cobblestones to create a healthier environment for fish and other aquatic organisms” (San Antonio River Authority 2014b). In particular, native fish communities such as bluegill, channel catfish, sunfish, and shad are

expected to thrive in a more balanced and restored river environment.

Another major component in the upper reaches of the San Antonio River is a successful effort to improve water quality through the use of constructed wetlands. For example, constructed wetlands will be installed and related enhancements will be made to the historic Acequia Madre agricultural irrigation canal in the area around the Witte Museum (San Antonio River Authority 2014c).

Figure 2.1. Native Vegetation along the San Antonio (Aivaliotis 2013)

Reintroducing native vegetation—such as pecan, redbud, cedar, elm, sideoats grama, maximillian sunflower, Texas bluebonnets, and scarlet sage—is also helping to establish sustainable riparian buffers alongside the river (San Antonio River Authority. 2014c). Riparian buffers also contribute to erosion prevention, which is vital to avoiding excess turbidity within the river. Another significant benefit of riparian buffers is that they can both filter excess nutrients, particularly nitrogen, and provide shade to the water, which will likely reduce harmful algae growth (Gilliam, et al 1997).

Designed wildlife habitats, for in-stream fish and aquatic species, amphibious species, and out-of-stream species, enhance the river's ecosystem and water quality. For example, the construction of tree overhangs along the river creates fish habitat, and low ponding areas provide refuge for species during in-stream maintenance, particularly in the highly-managed segments, such as the "River Loop" in downtown San Antonio (SWA Group et al 2001).

Some benefits of habitat restoration accumulate through indirect impacts. For example, the value of the river system is enhanced by providing opportunities for the community to enjoy recreation and benefit from wildlife along the river. This creates an incentive for individuals to

take steps to improve water quality or to support the efforts others are taking to address water quality challenges, even when those steps involve increased costs.

Site-scale solutions are also being implemented in the River Walk area, in downtown San Antonio. These solutions include enhanced water supply and flow. Much of this water is recycled water provided by the San Antonio Water System (SAWS) through the “largest direct recycled water delivery system in the nation.” According to SAWS, “more than 110 miles of pipeline delivers high-quality recycled water” for a variety of uses including “San Antonio’s famous River Walk” (San Antonio Water System 2014). Recycled water provides an alternative to pumping water from the region’s aquifer, as had been done previously with little regard to long-term sustainability.

The San Antonio River Authority (SARA) and other partners carry out a continuous and extensive water quality monitoring program, with sites up and down the river, and makes these data publicly available on its website (San Antonio River Authority 2014d). Improved water quality monitoring throughout the rivers also enables scientists, community leaders, and other stakeholders to promptly identify water quality impairments. Timely identification of pollution spikes or incidents increases the likelihood that the immediate cause of water quality impairments will be identified and then either completely addressed or partially mitigated.

Partnerships with property owners are another vital component of ongoing site-scale solutions. The implementation of best management practices (BMPs) by adjacent property owners, such as business operators along the River Walk, is vital to the success of overall efforts. Improving practices can significantly reduce non-point source pollution and runoff.

Periodic debris and trash removal is also important to water quality in the River Walk area. This is especially true since the restricted and controlled flow through this segment limits the ability of natural processes to dilute pollutants and/or remove debris and other contaminants. This segment, known as the “River Loop,” was the historic and natural river channel, but it was isolated from most natural flow by the construction of a “cutoff channel” constructed in 1929 (Eckhardt 2014). The operation of structures where the cutoff channel diverges from the River Loop controls the flow of water. As a result, periodic debris and trash removal is required.

Improved wildlife management in the River Walk area also contributes to enhanced water quality along the River Walk. Animal waste from wildlife has been considered a contributing factor in the accumulation of excess nutrients, particularly in the River Walk area. Redesigning infrastructure and habitat to reduce the deposits of animal waste into the river is underway.

The City of San Antonio is modernizing wastewater infrastructure near the River Walk. As is common in communities with older sewer systems, overflows and leaks have the potential to contribute significant excess nutrients into the San Antonio River. Prioritizing wastewater infrastructure improvements is vital to preventing the environmental damage caused by excess nutrients.

One example of a project that will improve infrastructure in the vicinity of the River is the South Alamo Capital Improvement Project (City of San Antonio 2014a). This multifaceted project will improve stormwater management and includes the replacement of a 36-inch sewer line under the San Antonio River. Despite the costs, projects like this one provide significant long-term environmental benefits to the aquatic ecosystem by preventing leaks of untreated sewage.

The City of San Antonio's Transportation and Capital Improvements division is also undertaking a "Storm Water Utility Fee Comprehensive Study" to investigate the viability of "migrating the existing Storm Water Utility Fee from one based upon land use and parcel size to one based upon impervious cover" (City of San Antonio. 2014c). According to the City, this funding is vital to stormwater pollution reduction efforts, such as street sweeping, infrastructure maintenance, and channel restoration. While the use of collected revenue may not change, a restructured fee would create additional incentives for land uses that minimize harmful runoff. At the same time, City officials will be considering a variety of fee and revenue proposals (based on impervious cover or other factors) to determine which ones can sustain public support for watershed protection efforts.

The San Antonio River Authority encourages citizen efforts to monitor pollution, such as illegal dumping and spills, as well as symptoms of pollution, such as fish kills. SARA also recruits volunteers to participate in water quality monitoring (San Antonio River Authority 2014f). For many members of the public, pollutants transported to the river via stormwater runoff remains the most concerning water quality challenge (Horne 2014). Of course, this problem also remains a significant contributor to the algae problem. One way that SARA

proposes to address stormwater runoff is through updated best management practices (BMPs) that would be developed through an updated Watershed Protection Plan. According to SARA:

> In an effort to enhance the urban reaches of the … River and improve and protect water quality …SARA is proposing to update, revise and begin implementing the 2006 Upper San Antonio River Watershed Protection Plan (WPP). The revised WPP will identify and propose water quality… BMPs that would serve to abate or control non-point source pollution of fecal coliform bacteria, sediments and excess nutrients (nitrogen and phosphorous). The water quality goals of the project are to develop a plan for implementation of approved BMPs that would aid in reducing E. coli bacteria non-point source (NPS) loads to segment 1911 of the San Antonio River (Bexar Regional Watershed Management 2006).

While an updated Watershed Protection Plan could prove extremely beneficial, the existing WPP (2006) has already been highly useful in identifying major contributors of pollution and proposing realistic solutions. For example, it identified discharges from the San Antonio Zoo as one of the most significant contributors of high coliform bacteria to the river, especially during dry weather. Bacteria concentrations have been so high that the State of Texas recommends against “contact recreation” in segments of the River. However, based on the WPP’s recommendations, in June 2014, the San Antonio Zoo began treating its discharge with an ultraviolet disinfection facility, which is highly effective at killing bacteria (Eckhardt 2014).

Additionally, SARA promotes and provides informational resources for low impact development and has developed and implemented an education and outreach program known as “Be Watershed Wise.” This program encourages individuals to be involved in protecting the watershed through efforts such as “picking up your pet waste, proper lawn care and vehicle maintenance techniques,” and so on (San Antonio River Authority 2014f).

Increasing public awareness of water quality concerns and pollution sources through improved access and an extended River Walk is essential to achieving community “buy in” and support for improvements. In fact, the San Antonio Parks and Recreation Department has worked to turn maintenance of the River Walk section of the San

Antonio River into a community event (Wise 2014), known as the Riverwalk Mud Festival (KSAT 2006). The River Loop will not need to be drained for maintenance in 2015, as workers completed the removal of over 2,300 tons of sediment during 2014 (White 2014). At the same time, the volume of silt and debris removed in 2014 illustrates the scope of continuing needs for improvement.

Ongoing efforts to improve water quality in the upper reaches of the San Antonio River and along the River Loop in the River Walk area are starting to show some benefits, but much work remains. Excess algae and high concentrations of bacteria remain two indicators that pollution from multiple sources continues to be a serious and ongoing problem. Progress to date has been achieved through a combination of ecosystem restoration, redesign, and modification of legacy flood risk reduction projects (especially downstream); improved land management to reduce pollution from non-point source runoff; investments by adjacent land owners and partners like the San Antonio Zoo to reduce the impact of their operations; infrastructure improvements—particularly sewer infrastructure improvements—such as those carried out by the City of San Antonio; improved public awareness and education; and other community-based efforts.

This is not a comprehensive overview of the many efforts that are underway, but it does demonstrate the broad scope and extensive collaborative efforts that have been undertaken. The scope and extent of these efforts have been recognized globally. On December 17, 2014, the *San Antonio Business Journal* reported that “the San Antonio River was named one of four finalists for the prestigious Thiess International Riverprize, a global award that is given to communities who have developed and implemented outstanding, visionary and sustainable programs in river management” (Aldridge 2014). As the only watershed in the United States to receive this honor in 2014, the San Antonio River and all partners can be very proud of their efforts to date and find renewed motivation to continue making improvements in the coming years.

Summary

A review of efforts for the San Antonio Riverwalk may be useful for The City of Frederick. One proposal is for the City of Frederick to explore the requirements for awards like the Thiess International Riverprize. The ideas and approaches learned in this process may be useful in developing an approach that becomes an exemplary practice of watershed management.

Chapter 3: Algaecides

Jesse Clark

Abstract

This chapter considers the use of algaecide as a method of eliminating and controlling algae in Carroll Creek. Benefits and disadvantages will be compared and a conclusion will be drawn on whether algaecide should be accepted or considered as a worthwhile approach.

Algae and Algaecide

Algae are autotrophic, meaning they can transform inorganic material into energy-containing molecules using basic energy sources for consumption and sustenance (Nave 2012). Because algae can thrive on so little, it can grow and reproduce exponentially, if left unchecked, with very little help. Algae can infest an area using only sunlight as fuel, and if left alone for an extended period of time, it will become a very serious problem, as it has become in Carroll Creek. There are numerous ways to combat it. The most direct is algaecide.

In a case study in Deer Lake (an 807-acre drainage lake), Wisconsin, liquid algaecide was applied to kill and control annual noxious algae blooms. It was a risky venture, as Deer Lake is used commercially for fishing and recreationally for swimming and boating. Polluting the water with a chemical agent could result in serious environmental and financial losses.

The objective was to maintain aesthetic and recreational value using aquatic herbicide treatments applied with a precision Aquatic Pesticide Application System (APAS). Two chemicals were used: granular copper sulfate algaecide slurry and liquid Cutrine Plus. They were applied per pound (copper sulfate) or per gallon (Cutrine Plus) using the process described in the case study.

“Six treatments occurred during 2003; June 18th, July 1st, 8th, 21st, August 22nd and 26th were the treatment dates. The “as-applied” APAS prescription for the June 18th treatment date called for a constant application rate of 10 pounds (4.5 kg) of granular copper sulfate algaecide slurry per acre, over the 7.0 acres of the lake where algae was identified and the average depth was 4 feet, an “as applied” swath width of 15 feet (4.6 m) at 7 mph (11.3 kph) yielding a total product amount of 70 pounds (31.8 kg). The “as-applied” APAS prescription for the July 1 treatment date called for a constant application rate of 0.5 gallons (1.9 L) of liquid Cutrine Plus algaecide per surface acre, over the 12.4 acres of the lake where algae was identified and the average depth was 4 feet, an “as applied” swath width of 15 feet (4.6 m) at 7 mph

(11.3 kph) yielding a total product amount of 24.8 gallons (93.9 L). The “as-applied” APAS prescription for the treatments on July 8th, 21st, August 22nd, and 26th called for a constant application rate of 0.5 gallons (1.9 L) of liquid Cutrine Plus algaecide per acre-foot over 6.0, 10.5, 5.5, and 6.9 acres, respectively. An “as applied” swath width of 15 feet (4.6 m) at 7 mph (11.3 kph) with and average depth of 4’yielded a total product amount of 12.0, 21.0, 11.0, 13.8 gallons, respectively.”

A follow-up review of the lake showed nearly 100 percent algae control (The Natural Resource Company 2004). Based on the fact that a chemical algaecide treatment was successful in a publicly accessible lake, algaecide may be a practical, successful method of treating and controlling algae in Carroll Creek.

Algaecide, by definition, is a biocide, a chemical designed to destroy, render harmless, prevent the action of, or otherwise exert a controlling effect on any harmful organism by chemical or biological means (European Union 2009). More specifically, it is a pesticide; as algae is defined as a pest, the pesticide is applied in various ways at various dosages to kill algae and prevent it from growing back. Algaecides have been used for years commercially and privately to clean ponds, pools, spas and Jacuzzis, with mixed results. It generally falls into one of two categories: natural and synthetic.

Natural Algaecide

Natural algaecide comes in the form of barley straw, which is the most well-known and, interestingly enough, most controversial. It first came into popular use in England in the 1990s as a natural solution for algae in bodies of water of any size, including canals. It was believed that fungi attacked the barley straw, causing a chemical to be released that stopped algae from growing. The straw is stuffed into netted bags and left floating on the surface, tethered to the shore or anchored to the bottom of the water body, to keep them from floating away. The barley is able to interact with the water without spreading out of reach.

As of now, the chemical(s) has not been isolated, nor has the method of algae inhibition been observed. It is borderline folk remedy and, though experiments have been performed in both England and America on the actual effectiveness of barley straw, the results are inconclusive. A field study (Lembi 2002) investigated the effectiveness of barley straw. They isolated a lake infested with phytoplankton (blue-green algae) as a test. Barley straw was applied and the lake was monitored for five months, ending in September 2000. Unfortunately,

the water quality failed to improve. The nets were removed and the water was monitored for two more years, yet the lake was in no better health than it was initially.

All that is known for certain is that barley straw does not actually kill algae; rather, it inhibits its growth and causes it to stop reproducing. It also works only on certain species of algae and even then doesn't begin its work for several months, if at all. Therefore, barley straw is not technically an algaecide. If synthetic algaecides prove ineffective barley straw can be a back-up plan. If other methods are successful in killing the algae, barley straw could be a useful means of keeping it from returning. However, the City should judge whether it is a worthwhile investment, considering the lack of data.

Synthetic Algaecide

Synthetic algaecides are chemical-based compounds designed to kill algae. They are all different combinations and dilutions of chemical compounds. The three most known successful compounds are copper sulfate ($CuSO_4$), sodium percarbonate ($2Na_2CO_3$), and Polyquat.

Copper sulfate is a unique compound that, when added to water, is absorbed by algae. The algae dies from the ingested copper and dissipates. However, after killing the algae, the copper will be released back into the water. It is safe around most fish, but the idea of having a vast amount of aqueous copper in a creek running near and through a suburban area is less than ideal. Copper is a heavy metal and, according to the National Library of Medicine, is poisonous. Ingestion of pure copper can cause severe health problems (Heller 2014). Granted, it will be diluted by water and in the correct parts per million is considered safe, but it is still unwise. Furthermore, copper cannot be simply filtered out of a body of water. It can only be removed through use of water changes (impossible in a moving body of water) or through application of EDTA (Ethylenediaminetetraacetic acid) to chelate it from the water (Aukes 2006).

EDTA is widely-used and has shown up in multiple different markets, including cosmetics and medicine. It has been tested and exhibits low acute toxicity (Hart 2005), so ingestion is not a concern. In fact, it is not a contact irritant (in other words, EDTA does not affect the human body negatively through skin contact), and can even make contact with the human eye without consequences. A 0.01M neutral solution of EDTA can safely touch a human eye without ill effect (Cosmetic Ingredient Expert Review Panel 2002). However, EDTA degrades very slowly, to the point that it may be a persistent organic pollutant, and it does so in an abiotic

way in the presence of sunlight (Bucheli-Witschel and Egli 2001). This characteristic supports using copper sulfate, since EDTA could be used to chelate the copper and would in time degrade in the creek. Unfortunately, it would be much more expensive, and chemical residue in a creek neighboring a suburban zone is, again, less than ideal.

Sodium percarbonate is considerably different. Many common cleaning agents, such as Oxo Bright and OxiClean, are composed of sodium percarbonate. It is initially a powdery substance that releases hydrogen peroxide. It is incredibly powerful, to the extent that in specific doses it can kill algae in minutes. The hydrogen peroxide damages the cell wall of algae, causing it to degrade rapidly. The powder is soluble and dissipates in minutes, and the resulting hydrogen peroxide adds oxygen to the water, increasing its health and improving the quality of animal life (KLM Solutions 2014). Downsides include potential health concerns, but unlike copper sulfide this substance causes much less severe irritation, though medical procedures must be followed if it is exposed to the skin, eyes, or throat. This is not unexpected; all algaecides (and chemicals in general) should be handled carefully and with appropriate safety equipment.

Polyquat, which is chemically called “poly [oxyethylene (dimethyliminio) ethylene (dimethyliminio) ethylene dichloride],” is a unique algaecide produced by Buckman Laboratories in Memphis. It is considered to be an agent that creates clean pools and hot tubs with no real side effects, even at high doses. The best version of polyquat is 60-percent concentration, often abbreviated as “algaecide 60,” depending on the company distributing it (while polyquat is made by only one company, several other companies, such as Kem-Tek and Nava, repackage and sell it. If it has the chemical name on the label, it is polyquat [Powell 2011]). As of now, though, polyquat has only been tested in swimming pools and spas. The effectiveness of it in a creek is undetermined.

Plan of Action

Considering all the algaecide options, the best plan of action will involve sodium percarbonate. Copper sulfate is effective but dangerous and cannot be naturally removed from the water. It must be dealt with by using EDTAs, which increases the expense of the project. (Even Cutrine from the Deer Lake case study is basic copper carbonate.) Polyquat has had positive results, but they aren’t as common or well-documented as sodium percarbonate. Polyquat is sold almost exclusively in one-quart bottles. Carroll Creek has hundreds of gallons of water running through it daily. The amount of manpower

and time needed to apply an algaecide by the quart makes such an option impractical.

The most practical algaecide, based on content and size available, would be Algae-Off Algaecide, which is 50 percent sodium percarbonate. It is sold in up to 25 pound tubs in granular form (since it is a granular compound), making transportation and deployment that much easier; one 25 pound tub is far easier to move than 400 one-ounce tubs of polyquat. To best dispense the algaecide through the 8.3-mile creek, an area could be isolated just past the Frederick suburban area, depending on how far the algae has moved. At that location the creek could be measured bank-to-bank and the distance recorded. The site could be a square patch of the creek; whatever the distance is, that would be one side of the square. The location could be marked off and the depth of the creek calculated.

Algae-Off is applied in units of “scoops” where one scoop equals one ounce and is dispersed per square foot of pond, hence the need for a square area of Carroll Creek. It is distributed differently for “light debris” and “heavy debris.” Considering the current state of Carroll Creek, the ratio for heavy debris will be used.

For pond sizes up to:

- 50 square feet, four “scoops” should be applied
- 51 to 100 square feet, eight scoops should be applied
- 101 to 150 square feet, 12 scoops should be applied
- 151 to 200 square feet, 16 scoops should be applied
- 201 to 250 square feet, 20 scoops should be applied (KLM Solutions 2014).

In the City, Carroll Creek is an average of 20 feet wide, creating a test area of around 400 square feet. Calculating up (and rounding up) from the given ratio of square feet to number of scoops, the site would require 40 scoops, or 2.5 pounds, of algaecide. Doctors Foster and Smith, a veterinarian website, sells Algae-Off in 2.5 pound containers for $15.99, so one tub could be purchased for the test area.

A period of one week could be allotted to judge how quickly and effectively Algae-Off performs. If it eliminates the algae in that span of time, a larger, full-size operation could begin. If not, the site could be observed weekly to see how long Algae-Off takes to eliminate the algae. Scheduling will be based on the weeks it takes for the algaecide to either kill the algae in the test area or cease to work. That amount of time will be used as a baseline for applying Algae-Off on the rest of the creek. Ideally, the creek could be treated in 400-square-foot units, since

400 square feet had been successfully cleaned. The units could be treated one at a time until all the algae is eradicated. If an application fails, the dosage will be tried a second time under the same conditions.

After a successful algaecide application, netted bags of barley straw could be placed and anchored near the Monocacy River, where Carroll Creek begins. The creek can be used as a case study to see how effective, if at all, barley straw is. Considering its unreliability and the lack of solid data, this could be a good chance to test its capabilities. After the barley straw is placed, the site could be observed under the same conditions used in the 2000 University of Nebraska case study. It is known that barley straw is an inhibitor, not an algaecide, so placing it in an area recently purged of algae could be an excellent safety method; if algae appears again, barley straw could have been proven ineffective at controlling algae.

Expected Results

Considering that Algae-Off has not yet been used at this level or dosage, the results are hard to predict. Mathematically, if algaecide can treat a specific size with a specific dosage, that ratio should continue to apply regardless of how high the numbers go, but logically it is unlikely that algaecide will be able to kill algae the larger the area grows. The Carroll Creek application would be double the highest dosage on the label, so it is entirely possible that the algaecide will not be able to handle the amount of algae in the creek. It is very likely that the algaecide will attack and kill some of the algae, but not all of it.

Summary

Algaecide is a viable option for eradicating and controlling the algae in Carroll Creek. The question is whether the best possible algaecide will be good enough. Considering that sodium percarbonate is a very low-risk substance, that it comes in a container the exact size of the test area, that it can easily be transported and that it would take very little work to distribute it (a team of two wearing waders would be able to distribute the algae in less than an hour if they divided the algaecide up and distributed 20 scoops each to the area), it is recommended that Algae-Off Algaecide be tried. The worst-case scenario is that 16 dollars and one day's labor would be wasted. Plus, useful data on the effectiveness of barley straw will be made available, regardless of whether it is successful or not, since both outcomes would lead to better recommendations to farmers and landowners with algae-infested bodies of water.

Chapter 4: Algal Turf Scrubbers in Carroll Creek

Josh Gaimaro
Luke Petrusic

Abstract

Algal Turf Scrubbers (ATS) control algal growth to improve water quality by removing algae, nutrients, and sediment from polluted waterways. This technology can be used to mitigate damages from uncontrolled algae growth and enhance the economic, social, and environmental conditions of the canal and park.

Introduction: Case Studies and Methods

The City's Carroll Creek Park began as a flood control project in the late 1970s that ultimately removed the downtown from the 100 year floodplain (City of Frederick 2014). Unfortunately this public works and civil engineering project has been impaired by the development of algae growth. This algae might be mitigated through the use of ATS. To better understand how this technology can be used to help remediate the algae in Carroll Creek we must first look at the history of this technology.

An ATS is a water-filtering device in which light is used to grow algae, and in the process undesirable chemicals and nuisance algae are removed from the water. This is essentially natural filtration in the form of primary production. These ATS were pioneered by Dr. Walter Adey who was the Director of the Marine Systems Laboratory at the National Museum of Natural History. He built several versions of the scrubbers for aquariums at the Smithsonian. The reasons these systems are called algae 'turf' scrubbers is because at the time it was thought that "turf" algae was the best type of algae to grow in the scrubber (Wiki 2014).

Contemporary ATS are a simple waterfall driven by gravity or a piping system directing water down a plastic knitting screen that is roughed up to allow algae to attach. Providing a controlled place for the algae to grow and be harvested, reduces the amount of nuisance algae in the water, something that could be very advantageous for Carroll Creek. In almost every case where scrubbers are used, they have reduced nutrients to very low levels as well as eliminating all nuisance algae problems (Wiki 2014).

Once the ATS system has collected the algae from a body of water, it must be harvested or removed from the harvester periodically. This removal of algae also has the

effect of removing undesirable nutrients from the water because the algae uses the nutrients to grow (Wiki 2014). It is recommended that these scrubbers have to be cleaned every seven to 21 days depending on the rate of growth. Cleaning the scrubbers varies based on configuration. To clean the previously mentioned waterfall scrubber the screen must be removed and then the algae must be removed from the screen. To clean the floating surface type, the algae has to be removed from the surface of the designated growing area. If the screen is not cleaned periodically, then the algae will die and “let go,” which results in nutrients being re-introduced into the water.

Regardless of the type of ATS system used, one will not be able to identify the most efficient means of algae harvesting without first understanding the various causes of algal growth and how to remediate this growth.

How are the nutrients entering the canal in the first place? Many homeowners have a social obligation to keep a healthy, green lawn, using fertilizers. Farmers are responsible for crop production, which requires fertilizers and other chemicals as well. However, lawns and farms are not the only thing getting greener. More often than not, fertilizers are improperly applied to lawns. Soil can only hold a small amount of fertilizer. The next rainy day, excess fertilizer is washed away and carried to the closest waterway or storm drain, providing the essential nutrients for algal growth. Furthermore, agricultural chemicals, metals, and phosphorus are absorbed and carried into waterways by positively charged silt and clay particles found in sediment. Nutrients carried by sediment can stimulate the growth of blue-green algae, which is toxic to humans (Mid-America Regional Council 2006)

The increase in urban development has accelerated erosion processes including sedimentation and sediment pollution. Roads, concrete, and asphalt are all impervious surfaces that impede soil-water infiltration. Impervious surfaces allow water to gain speed and volume, which transports sediment, nutrients, and other pollutants into our waterways.

ATS have been shown to be an effective treatment option to improve water quality by controlling algal growth. The uncontrolled algal growth in the canal has economic, ecological, and social impacts.

The City uses the canal to attract potential customers and generate profit. Algal blooms can produce noxious odors that may deter people from the canal, therefore, inducing a loss of potential customers. Similar to the ecological impacts, economic impacts may extend to the

Chesapeake Bay. The decrease in dissolved oxygen, food supply, and habitat for aquatic species in the Bay means lower population sizes that fisheries rely on for their income. The decreases are due to the influx of pollutants into the Chesapeake Bay Watershed.

Toxins and bacteria pose a greater risk of fish, shellfish, and groundwater contamination in regions with high nitrogen and phosphorous concentrations. In addition to the risk of consuming contaminated fish and shellfish, overexposure to algae has been linked to health risks (Ongley 1996).

ATS could provide an educational component to the canal. Signs along the canal could present educational information. Flyers or pamphlets could be mailed to nearby residents to engage the community and pique interest while raising environmental awareness. Furthermore, flyers can be used to attract customers to City and the ATS project through coupons from local restaurants and an organized event. Guest speakers and/or local environmental groups could supply information that connects the potential health risks from algal blooms with the nutrient pollution coming from their lawns, and encourage proper, less frequent fertilizer application. Moreover, the ATS will eliminate the noxious odor and health risk associated with the algal blooms, which may have deterred potential customers in the past.

The ecological impacts of nutrient loading in the canal extend downstream. Water flowing through the canal transports nutrients and sediments all the way to the Chesapeake Bay. EPA water quality criteria state that to control algal growth, phosphates should not exceed 0.1 milligram per liter in streams or flowing water. Nutrients, particularly nitrogen and phosphorous, are considered pollutants at high concentrations. Nutrient pollution increases algal growth, toxins, and bacteria, while simultaneously decreasing oxygen levels, food supply, and habitat (EPA 2014).

Case Studies

To better understand the benefits of ATS systems as well as possible best practices, the following case studies extrapolate data findings relevant to potential implementation in Carroll Creek. Mulbry et. al. 2010 evaluated the implementation of ATS systems in an effort to restore the biological and ecological health of the Chesapeake Bay.

For this study, small-scale fiberglass ATS units were operated for a five to 10-month period starting in April 2007 through April 2008. Each consisted of a 1 meter by

1m growing area where water moved from a submerged pump into a trough then onto nylon netting on top of a fiberglass tray. They were placed on three of the Bay's tributaries: Bush River, the Patapsco River, and the Patuxent River. They were located in sunny areas, a condition similar to Carroll Creek. After documenting the results of these ATS systems in the different tributaries, there was a considerable amount of nutrient removal of nitrogen and phosphorus from all sites, varying only with the water's salinity. This means that any sort of ATS system used in Carroll Creek would more than likely remove the nitrogen and phosphorus that is contributing to the algal growth.

These ATS systems that were effective in the Chesapeake Bay were agricultural in scale in order to have any discernable impact on nutrient treatment of pollution sources. This limits them to areas where land prices are relatively low. Even with this constraint, a modified version of the ATS system might be useful in Frederick.

Mulbry, W., et al 2010 used ATS systems to recover nitrogen and phosphorus using pilot-scale algal turf scrubbers. This study was carried out in the light of Chesapeake Bay restoration. The study argues that, "restoration of the bay poses significant challenges because of increasing population pressure, conversion of farmland to urban/suburban development and the expense of infrastructure needed to achieve significant and sustained nutrient reductions from agricultural and urban sources" (Chesapeake Bay Foundation 2004). Although the study was at a larger scale than Carroll Creek, its issues and the lessons learned could be applied to those in Carroll Creek. The large amounts of agricultural land in the Carroll Creek catchment are most likely adding additional nitrogen and phosphorus that contribute to the canal's algae problem.

The types of ATS systems documented in Mulbry, W., et al 2010 were small scale fiberglass ATS units, four 30 foot raceways were constructed, each consisting of a 1x30m section of landfill liner covered with 6mm mesh nylon netting, and a 3700L underground concrete sump at the base of the raceway leading to the top.

Using this ATS system the percentage recovery value of phosphorus and nitrogen in the biomass increased as loading rate increased and vice versa. The study concluded that total recovery of input manure effluent nitrogen and phosphorus in the outdoor raceways was 60-90 percent (treatment). If applied to the Carroll Creek catchment to treat farm animal manure instead of allowing it to go untreated into the stream system, these

raceway ATS systems could reduce nitrogen and phosphorus (treatment) by 90 percent.

A cost analysis indicates that implementing this system at the agricultural scale versus upgrading existing water treatment plants would be significantly less, based on a dollar per kilogram of nitrogen removed from the water supply (Treatment). Also, the sale of the dried algal biomass, which can be used as an organic fertilizer, could offset some of the costs of implementing the raceway ATS system. Additional arguments for the use of ATS systems are presented by Adey W.H., et al 2011. "There is a growing need for low-cost technologies to improve water quality in degraded aquatic ecosystems" (p. 434).

To solve the problem of algal growth, there are other methods besides ATS systems, including treatment wetlands and bioengineered vegetation commonly used for erosion control. However, both require large areas of land, making them most effective in rural settings and unsuitable for urban environments such as Carroll Creek Park.

Although larger scale ATS systems may not be appropriate for use in City of Frederick, they may be effectively integrated farther upstream to treat the water before it enters Carroll Creek Park, preventing algal growth downstream. This larger "landscape-scale" ATS system began in the mid-1990s in California. Later, in 2002, HydroMentia (2005) began building 18-110 million liters per day ATS units to scrub nutrient pollution of non-point source waste water systems. These systems have a "removal capability is roughly two orders of magnitude greater than that of the managed wetlands in the same region" (Adey, W.H., et al 2011, p 437) proving that ATS systems are more efficient than treatment wetlands and bioengineered vegetation.

ATS systems have advanced to the point where they can now effectively treat entire river systems. 11 billion liters per day engineering plan has been created to clean the entire Suwanee River in Florida of excess nutrients. One could imagine that the cost for such a system would be quite high. However, this was not the case as shown by Sano, D. et al 2005. For a test plant of a 23-hectare facility over a 50-year operation; they determined that an ATS system could remove phosphorous for $24 per kilogram (Adey, W.H., et al 2011), which is one-third of the least expensive equivalent constructed wetland. This approach could prove useful for Carroll Creek by removing undesired algae while producing useable biofuel.

Another benefit of ATS is the conversion of the algal biomass into biodiesel. The cost to do this is relatively inexpensive compared to other methods of biofuel production. “ATS algae provide a much larger potential for bioenergy supply than the corn and soy because of their high productivity” (Adey, W.H., et al 2011, p 440). The article also discusses how, “the value in the nutrient removal process, given as credits or bankable dollars, would cover the cost of construction, operations, and maintenance, and still leave a significant profit margin.” This suggests the possible practicality of incorporating an ATS system in Carroll Creek. This type of system might not only solve the algae problem, but also offers the potential to produce revenue for the City.

ATS systems are an up-and-coming best management practice that provides a cost effective solution to improve water quality. The recent enforcement of the Total Maximum Daily Load (TMDL) regulations encouraged the Port of Baltimore to install 200 square meters of ATS to their TMDL requirements. If the extended ATS provides a sufficient load reduction in the Port, it will be considered as a Best Management Practice. On average, their ATS accumulates 100 pounds of dried algae every week. The algal biomass typically contains 3-5 percent nitrogen and 0.3-0.5 percent phosphorous (Kangas, P., et al 2010). The canal’s algal growth can be controlled by

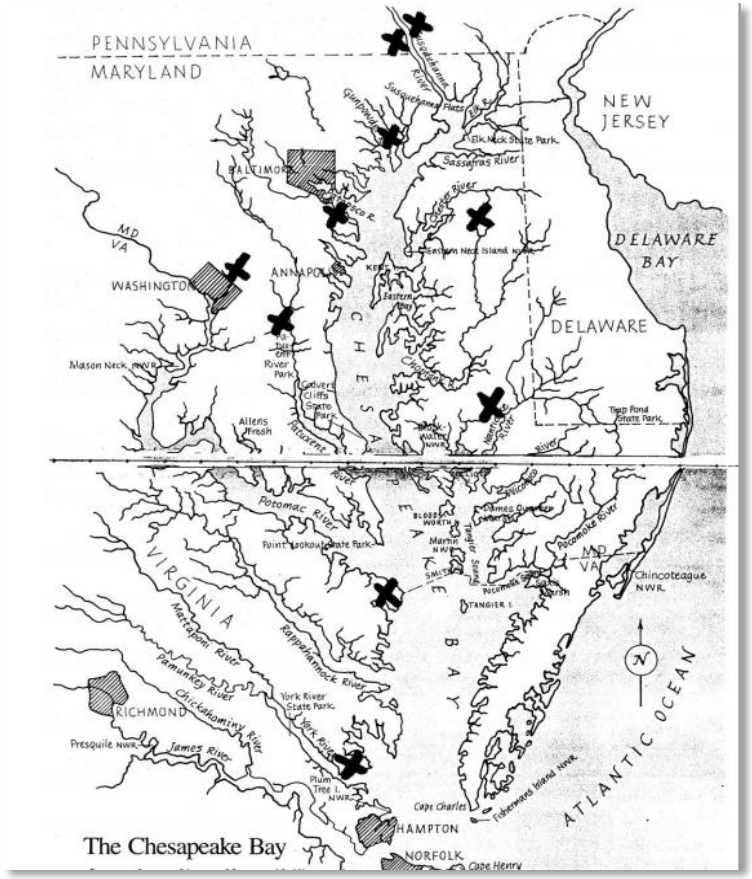

Figure 4.1. Pilot ATS along the Chesapeake Bay (Kangas, P., et al 2010)

implementing an ATS that considers design, size, location, and maintenance. Other considerations include the aesthetics, budget, and opportunities. What information is crucial to ensure the success of ATS systems? What is the current and optimal nutrient concentration of the canal? What volume of water must enter the ATS to obtain the optimal nutrient concentration in the canal? Determining the appropriate size for an ATS requires data. Data has been collected for many ATS systems, including roughly 12 in Maryland. Kangas, P., et al 2010 conducted an annual study on 12 pilot ATS along the Chesapeake Bay (Figure 4.1). Results illustrate the effectiveness of ATS in improving water quality. That nutrient reductions varied among the sites can be attributed to the different water types, inputs, surrounding areas, and algal communities, among other conditions. Ultimately, the size of the ATS is dependent on many environmental factors particular to each site. Data on nutrient removal rates gathered by a small scale ATS could be used to determine the appropriate size to control the algal growth. The nutrient removal rate (in grams nutrients/m^2/day) of the algae is calculated using the following equation:

> Biomass Production Rate (grams dry weight/m^2/day) multiplied by Nutrient Content of Biomass (grams nutrients/grams dry weight)

Using a small scale ATS, the biomass production rate and nutrient content can be calculated and applied to determine the size of an effective system for the canal. This strategy requires data collection, creation of a small scale ATS, and calculations. The small scale ATS could be extended rather than discarded.

Next, Maryland Department of the Environment's (MDE) watershed loading estimates can be used to calculate the total nitrogen, total phosphorus, and total suspended solid loading into the canal. The watershed loading estimates are illustrated below in Table 4.1.

	Total Nitrogen (lb./ac/yr.)	Total Phosphorous (lb./ac/yr.)	Total Suspended Solids (lb./ac/yr.)
Urban Impervious	10.85	2.4	0.46
Forest	3.16	0.13	0.003

Table 4.1. Watershed-loading estimates Maryland (Department of the Environment 2014).

The EPA criteria state that phosphates in flowing water should not exceed 0.1 mg/l to control algal growth. The

difference between the loading estimate and EPA's recommended phosphate concentration can be used to determine the necessary load reduction to control algal growth in the canal.

As previously stated, data is required to determine the appropriate size for an ATS in the canal. Within Maryland, natural systems are very dynamic and the data gathered from an ATS in the Chesapeake Bay may not produce the same results in the canal. Moreover, the objective for each ATS is subject to change. A farmer could use an ATS to treat agricultural run-off, while others are using it to meet TMDL requirements. Data from a pilot ATS for the canal will provide the most reliable data to determine its appropriate, effective size.

There are many factors to consider when locating an ATS in the City and based on location, its design may change. In general, ATS include but are not limited to waterfall, glass attached, floating-surface, drop-in, and raceway designs. Larger ATS are most often a raceway or trough design, which use pumps and valves to transport water to and from the canal and ATS. Figure 4.2 illustrate each proposed ATS design.

Ideally, the location is close enough to accommodate a water pump extending from the canal to the ATS raceway. The plot of land dedicated to the ATS may exceed an acre. The water being pumped into the ATS must be upstream of the outflow. The elevation of the design must compensate for the topography of the landscape so water can flow from the input to the output of the ATS. The system pulls in water, which then flows gently down the ATS to the output pipe while simultaneously removing nutrients and sediment.

The trough-like design could be implemented along the canal or upstream of the canal depending on the depth of the water. Trough designs function very similar to the raceway design. The major difference is the trough designs pump water into a bucket that empties into the trough once it is filled. The elevation, depth, length, width, and pipes regulate the flow rate and quantity of water moving through the system. The flow rate and quantity of water must correspond to the algae nutrient removal rate to obtain the optimal load reduction. In other words, the optimal water flow rate is dependent on the nutrient concentration of the water and the rate algae uptakes these nutrients. The effectiveness of the ATS is dependent on the slope of the ATS, as well as the size. Exelon's Muddy Run hydroelectric facility experimented with different three different ATS. The aluminum ATS with a 2 percent slope had the highest nutrient reduction

with a higher productivity than natural ecosystems (Kangas, P., et al 2010).
The surface designs have many advantages over submerged and floating designs. Surface designs are limited only by the plot of land rather than the width and length of the canal. They can also be extended or modified. Maintenance and harvesting is easier for raceways and troughs than submerged and floating designs. However, surface designs have disadvantages as well. They require land and energy for the water pumps.

Floating-surface and waterfall designs are composed of screens and pipes that regulate water flow. Screens can lie horizontally at water level, before the canal, or hang vertically from the “waterfall” structure at the beginning of the canal. However, for this to work the waterfall structure must have full sun exposure. There are many limitations for these smaller designs, which rely heavily on the calculated nutrient reduction. Many screens are required if the nutrient reduction is high and maintaining multiple screens is more challenging and time consuming than maintaining one ATS raceway or trough.

ATS systems require maintenance to be successful. The screens on ATS have algal biomass attached to them, which absorbs sunlight to grow while simultaneously removing nutrients from the water. An alga generally completes its lifecycle in one to three weeks. After its life

Trough Design (Kanga, P. et al 2010)

Raceway (Perry, A, 2010)

Floating-Surface 1(Adey, Walter. 2015)

Waterfall (Mullins, C. 2012)

Figure 4.2. Designs are not limited to those illustrated in the photographs; these are general examples of ATS designs

cycle is complete the algae detaches from the ATS screen or netting, and begins to decompose. Therefore, weekly algae harvest is recommended to avoid the reintroduction of algae into the canal.

Harvesting is usually done by draining the ATS, then vacuuming the algal biomass using a Shop-Vac or similar device. The easiest option is to pay a maintenance crew to harvest and dispose of the algae. This cost can be eliminated by recruiting volunteers. Similarly, involving a stakeholder in the project could provide financial, maintenance, and data collection assistance. For instance, Hood College's environmental courses may be interested in studying and harvesting the algae.

ATS operate about 270 days out of the year. They are usually turned off from mid-December through mid-March. The colder temperatures decrease algal production. Maintenance visits will be less frequent, but are still important during the winter. In addition to collection and disposal, regular functional assessments are necessary to make sure everything is working properly. Monitoring is important when dealing with an outdoor system. The canal is a complex and dynamic ecosystem. The concentration of nutrients and canal's water level are two inconsistent variables in the canal ecosystem. To deal with this dynamic system, the ATS might have to be modified. For instance, an increase in nutrient loading, may require that the ATS be extended so more water could be treated. Figure 4.3 characterizes the mechanisms and financial opportunities for the City in implementing an ATS.

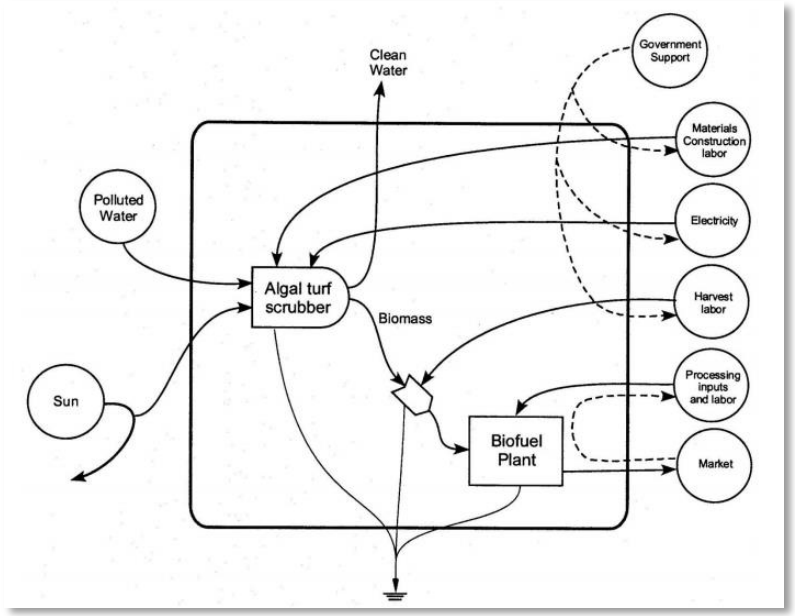

Figure 4.3. This is a systems diagram. The circles to the left represent the inputs and the ones to the right are the outputs. Solid arrows indicate positive energy flows, while the dotted arrows are negative energy flows. For the purpose of this figure energy can be characterized as any of the text within the

circle and the flows can represent the transfer of energy. (Kangas, P. et al 2010, p. 7)

Algal biomass can be used as a feedstock for biofuels. The disposal cost (or the tipping fee for waste pickup services) can be avoided if the algal biomass is used to synthesize biofuels. Furthermore, once the biomass is converted into biofuel it can be sold to generate revenue for the City. Eventually, the ATS will pay for itself if biofuel production is implemented correctly. There are different types of biofuels that can be produced by algae. The method of synthesis (i.e. pyrolysis, anaerobic digestion, fermentation, etc.) determines what biofuel is produced. For instance, producing ethanol from algae requires a complicated two-step process that would require employees with laboratory experience. However, some of the methods are relatively simple and not labor intensive, such as the anaerobic digestion of algal biomass. Moreover, the Port of Baltimore plans to implement a biofuel plant using their ATS and could provide a reliable model for the canal (if and when they successfully complete their biofuel plant). Dr. Peter May, a senior ecologist at Biohabitats and professor at the University of Maryland, College Park, has worked on various ATS systems including the 300-foot ATS at the Port of Baltimore with Dr. Kangas. After receiving a brief explanation of the issue impacting the canal, Dr. May estimated the material and construction cost for an ATS in the City of Frederick based on costs for other ATS projects. He estimated the cost to be less than $10,000 for materials and installation. Typically, ATS systems are constructed using reused or recycled materials to cut costs. However, materials can be chosen to create a more visually appealing ATS. Harvest labor requirements and costs were discussed above, which leaves the electricity source to power the ATS water pumps. It's common practice to use solar panels to power the water pumps. Other options may be challenging depending on the system's location. Smaller designs don't require electricity, but may not be large enough to remediate the canal's algae.

Summary

The City's algal issue impacts the environment, economy, and society. The ATS options illustrated in this chapter may be limited by budget, physical space, available land, and required nutrient reduction to control algal growth. However, they might provide an effective solution to the ongoing problem if implemented correctly. Preliminary data collection using a pilot ATS is the most reliable option. Following the pilot ATS, a raceway or trough ATS are the most practical in terms of design flexibility and modifications to optimize nutrient reduction.

Chapter 5: Floating Treatment Wetlands (FTWs) and Stargrass

Adam Spensieri

Abstract

This chapter focuses on biotic approaches to address the negative water quality conditions in the Carroll Creek Watershed. The patented Floating Treatment Wetlands (FTWs) system is reviewed for its applicability and effectiveness in improving water quality in the downtown section of Carroll Creek that flows through The City of Frederick. In addition, the possibilities of using the submerged aquatic vegetative species water stargrass, Heteranthera dubia, in Carroll Creek is explored.

Introduction

The Carroll Creek watershed has been experiencing high levels of pollution from the overload of nitrogen and phosphorus nutrients. Ultimately, this results in a process called eutrophication. Photosynthetic algae use these nutrients as an abundant food source and propagate quickly, reducing the oxygen levels in the water. As a result, fish, crab, and many other species populations decline in the affected region, and in severe cases, the aquatic ecosystem could be deemed a dead zone. Often, these dead zones are found near agricultural systems that over-fertilize their land, or near highly developed urban areas, such as harbors to cities. Some aquatic systems, such as the Carroll Creek Watershed in this case study, are affected by both types of nutrient pollution. This is becoming more common because watersheds can include diverse landscapes that support both urban development and agricultural practices. As a result, watersheds have been exploited for the provisioning and regulating services they provide. To keep benefiting from these services, it will be necessary to restore, or construct and maintain the functions of the various watershed features.

An important feature in all watersheds is the presence of wetlands and their ability to sequester nitrogen and phosphorus nutrients in the soil. Many of the wetlands that served as filters for Carroll Creek have been degraded or destroyed due to the urban development in Frederick. Restoring and even reconstructing wetlands can reduce pollution but in some locations this may be impossible due to the grey infrastructure that surrounds the polluted water body. Grey infrastructure includes nearby buildings, sidewalks, and streets, which are well developed in the City (Figure 5.1).

Figure 5.1. Carroll Creek through The City of Frederick, downtown (Google Maps 2014a).

A site visit led to the conclusion that this portion of the creek was highly affected by nutrient pollution, evident from the blooms of algae that were present.

Furthermore, this section of the creek not only has a cement streambed, but has at least five meters of cement buffer that eventually connects to the adjacent, parallel commercial development. It's clear that constructing a wetland in this location is unlikely and unfavorable given the deconstruction that would be necessary.

Fortunately, it is possible to mimic wetland structure and function in areas that can't support a natural wetland ecosystem by using a patented product called, "floating islands," developed by Floating Island International. They are categorized as Floating Treatment Wetlands (FTWs) and function as tiny wetlands that float on top of water surfaces, improving the water quality. Before applying FTWs, it is appropriate to discuss wetlands, including:

- How do you define a wetland?
- What is wetland structure?
- What are wetland functions?
- How do humans benefit from wetlands?
- How can humans use these functions?
- What practices can we learn from?
- What is the next step?

With these questions explored, the lessons learned will form suggestions for the use and implementation of FTWs in Carroll Creek.

Wetlands
Definition, Structure and Function

A wetland, under the Clean Water Act, means, "those areas that are inundated or saturated by surface groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (Environmental Protection Agency 2013)." At first thought, some people may think of huge swamps and marshes, but small-scale areas that are only flooded occasionally can still be considered. Regardless of size, these areas provide crucial

ecosystem services that sustain a livable environment for humans.

Most critically, they serve as natural water filtration systems for polluted stormwater run-off. Their vegetation "filters and absorbs nutrients, suspended sediments, and chemical contaminants before they reach nearby waterways," such as Carroll Creek. Its downtown location may need a wetland system (not necessarily a constructed wetland) because urban development increases the rate and volume of polluted stormwater run-off (Chesapeake Bay Program 2014). Nevertheless, all natural, constructed or floating wetlands have the ability to improve water quality. In turn, healthier water should support a healthier ecosystem with a larger suitable habitat for a diverse wildlife.

Additionally, wetlands serve as a natural erosion control system by holding mass amounts of water during flooding events, then slowly releasing it, allowing suspended sediments to settle before traveling too far (Chesapeake Bay Program 2014). Currently, the only feature retaining sediment and water flow in Carroll Creek is the constructed dam, which actually hinders natural functions further. The Creek's downtown lacks any natural soil buffer to serve as an erosion control system (Figure 5.1), which could be improved with the implementation of FTWs.

Humans and Wetlands

Wetlands have long been valuable to human society, even if their value often goes unrecognized. We enjoy the outdoor activities they provide, such as hunting, bird watching, and boating but also enjoy the protection they provide—a protection growing smaller as we continually degrade and destroy it. Those protective functions historically have been greatly under-valued by society, as no one paid for wetlands as we did for roads. However, scientists have brought light upon wetlands, and many restoration practices are underway.

Wetlands are associated with some pest species and even diseases, making them unattractive in densely populated urban settings. These concerns must be flipped in order to allow and facilitate nature's processes that ultimately sustain the world we can live in. Currently, the natural cycle is broken by man-made pollution and degradation. The cycle is repairable, if communities accept the necessity to protect naturally occurring systems and processes. Innovative development and infrastructure that consider more sustainable design are a step in that direction.

Treatment Wetlands

Treatment wetlands are an excellent example of how humans can study and use sustainable natural processes instead of energy-intensive practices. Kadlec and Wallace (2009) define modern treatment wetlands as, “man-made systems that have been designed to emphasize specific characteristics of wetland ecosystems for improved treatment capacity.” These wetlands can provide nutrient sequestration, sedimentation, and chemical contaminant absorption to improve water quality. They include three types of widely used treatment wetland systems: free water surface (FWS), horizontal subsurface flow (HSSF), and vertical flow (VF). The conceptual models are illustrated in the figures below.

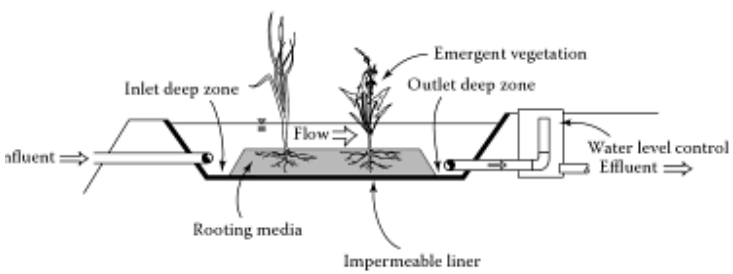

Figure 5.2. FWS treatment wetland (Kadlec and Wallace 2009)

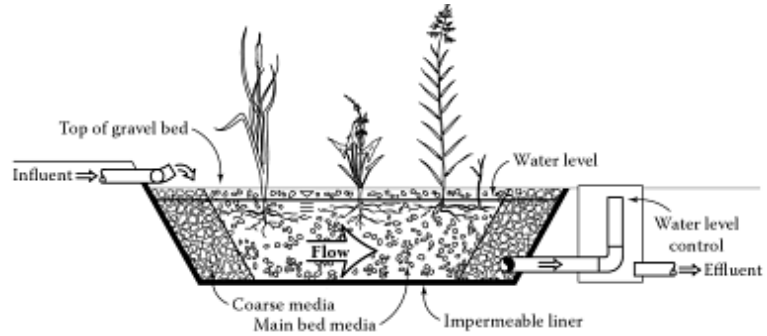

Figure 5.3. HSSF treatment wetland (Kadlec and Wallace 2009).

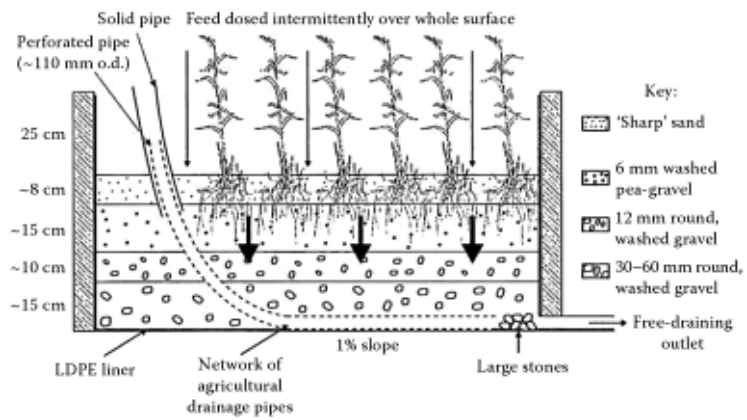

Figure 5.4. VF treatment wetland (Kadlec and Wallace 2009).

All three models share a similar characteristic with floating treatment wetlands. Their vegetation is dominated by hydrophytes. Typically these plants are emergent, meaning the stems grow out from the water; however, submersed aquatic vegetation (SAV) is sometimes seen, but causes varying effects. The exact species may not be the same from system to system—in fact, they shouldn't be—because each system harvests the species that are most effective at its specific goal e.g. denitrification. In further description, the only other treatment wetland system that shares a commonality with FTWs is the free water surface (FWS) system. The FWS treatment wetland maintains areas of open water; the others do not (Figure 5.2). Instead, they have flexible designs to control water flow underneath the substrate, rather than allowing more natural hydrological flows. This may be acceptable for these systems, because they carry out biogeochemical processes that require specific conditions of oxygen availability.

The main difference between these three systems and floating treatment wetlands is that a FWS involves a flotation device that relieves the need for a substrate to secure the vegetation in place. This innovation allows modularity, among other benefits that will be explained. However, the development of this new system does not imply that it should replace other systems that have been developed. In fact, the proposal for Carroll Creek involves concepts that were determined through studying conventional treatment wetland systems.

The main concept is that each site has a specific problem and requires a system designed to treat its particular conditions. In treatment wetlands, a succession of various systems is most effective in treating wastewater with each responsible for different treatment levels. For Carroll Creek, treatment wetlands may only be part of the solution, among many other management practices. Nevertheless, treatment wetlands serve as an innovative companion to FTWs and exemplify the progress towards sustainable design.

Floating Treatment Wetlands (FTWs)

"Floating Treatment Wetlands (FTWs) are an emerging variant of constructed wetland technology which consists of emergent wetland plants growing hydroponically on structures floating on the surface of a pond-like basin" (Headley and Tanner 2008). There are many specifics of this system (Figure 5.5) that are essential to the success of its structure and function.

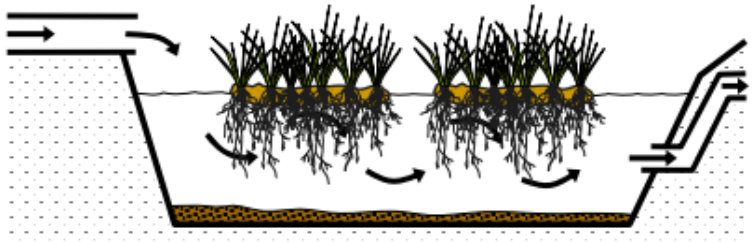

Figure 5.5. Cross-sectional view of a typical FTW (Headley and Tanner 2008)

Structure and Function

FTWs mimic wetlands and ponds, which serve to improve stormwater quality. A pond is simply a shallow open body of water, while a wetland typically has abundant vegetative cover. FTWs can support both, mainly because of their physical structure. The frame of the FTW must be buoyant and able to support a mat, net, or mesh that serves as the substrate on which the plants grow. The emergent vegetation grows through the mat, with stems above the water surface and roots underneath the mat, suspended in the water column, as hydroponics suggests. This enables the plants to receive the nutrients directly from the polluted water via the roots, rhizomes and biofilms that are associated with the physical and biogeochemical processes of filtering sediment and transforming nutrients (Headley and Tanner 2008).

Figure 5.6. Integral Buoyancy Feature (Headley and Tanner 2008)

Establishing a low-maintenance FTW requires initial innovative technologies and designs that keep the system afloat and allow proper vegetative growth. A polyester floating mat is injected with patches or marine polystyrene (Figure 5.6) and stabilizing cables extend above the water surface for early plant growth (Figure 5.7). These features facilitate the plant growth until the system can be buoyant from its own structure. Once the root system is fully developed, the chemical activity releases gaseous bubbles underneath the mat, keeping the FTW afloat (along with the hollow, buoyant

frame). Figure 5.8 below depicts a fully-functioning FTW system.

Figure 5.7. Integral Buoyancy Feature (Headley and Tanner 2008).

Advantages

FTWs have several advantages compared to natural wetlands or the conventional treatment wetlands described above. First and foremost is their tolerance of deep water because they float. When the water level rises, so does the FTW; when the water level lowers, the FTW does as well. In a more natural environment, the FTW faces a threat when the water level lowers because the root system could stabilize itself in the stream bed if water levels are low for a long time. Carroll Creek has a cemented streambed and thus rooting into the streambed is not a concern. Another benefit of FTWs is that they are modular, durable, and require little maintenance over time.

Furthermore, the FTW's structure plays a role in retaining the water based on its frame and depth. The water sets inside the frame longer, allowing longer chemical/ biological reactions to take place, further improving water quality. Another related advantage is that the biological activity is taking place in the water column rather than in the soil beneath. Floating Island International tested the effectiveness of FTW designs compared to traditional constructed treatment wetlands and determined that

Figure 5.8. Integral Buoyancy Feature (Headley and Tanner 2008).

having the root system in the water column, FTW improved water quality much better than roots in the soil. Their results showed a 46 percent removal of biological oxygen demand, 40 percent removal of total nitrogen, and 89 percent removal of total suspended solids for a 288 m^2 FTW. By comparison, an 872m^2 treatment wetland (proportionally much larger) only removed 33 percent biological oxygen demand, 33 percent total nitrogen, and 55 percent total suspended solids (Floating Island International 2014). This demonstrates that a FTW uses less space to improve water quality more effectively than constructed treatment wetlands. Overall, FTWs have proven to be a great management practice for wastewater and stormwater quality measures.

Water Stargrass

Water stargrass (Google 2014b), *Heteranthera dubia*, was reviewed and its potential is discussed in the proposal below. However, it is necessary to understand its characteristics as a freshwater species before any suggestions can be made. In comparison to the vegetation that is typically used in FTWs, water stargrass is a submerged species, the entire plant is in the water column, naturally stabilized in the streambed. The only emergent feature of water stargrass is the bright yellow flowers that serve as its reproductive and pollinating feature (Maryland Department of Natural Resources 2014). Additionally, water stargrass serves to uptake nutrients and as a food source for various waterfowl.

Figure 5.9. Heteranthera dubia (Google 2014b)

Proposal/Suggestions

FTWs appear to be an appropriate biological solution to the pollution problem faced in Carroll Creek, which has been experiencing heavy loads of nitrogen and phosphorus nutrients. While there are many best management practices to control this pollution, FTWs are an emergent technology that suits this case. Their advantages demonstrate that they should be considered for implementation in Carroll Creek. Their exact design is discussed below, beginning with the most appropriate location.

Location

One of the disadvantages of FTWs is that when water levels are low, they are susceptible to rooting themselves in the streambed. Fortunately, the downtown portion of Carroll Creek has a channelized cement bed (Figure 5.1), which makes it a prime location for FTWs.

Furthermore, FTWs are not restricted by number or to a percentage of surface area because the emergent vegetation allows some sunlight to enter the system (even though this isn't really favorable because less sunlight means less photosynthetic algae causing eutrophication). Thus, the entire portion of this creek section could be covered with FTWs. Since there aren't any known negative effects, to the City should consider implementing as many as possible to yield the greatest effects. Because this section of Carroll Creek is surrounded by urban development and grey infrastructure, the stormwater run-off entering the creek is likely highly polluted. FTWs in this location would serve as an initial filter for that run-off, as well as for the water upstream.

Summary

There are recent innovations and new BMPs to address nutrients in water bodies. While this chapter reviews many methods, any site would require a specific design solution for the most effective results. For Carroll Creek, FTWs are one strategy, among many, that have been proven to carry out functions similar to natural wetlands.

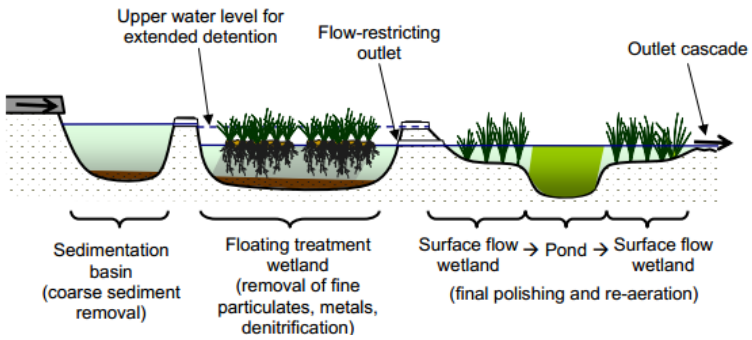

Figure 5.10. Conceptual Diagram (Headley and Tanner 2008)

Their advantages include modular construction and low maintenance. For best results, the FTWs should be installed to avoid the threat of the wetlands being anchored in the soil. Consultations with companies like Floating Island International may be necessary to ensure professional results.

Overall, FTWs and Water Stargrass seem to be promising strategies to improve the water quality of Carroll Creek.

Chapter 6: Green Street Principles and Best Practices for Improving Infiltration in Highly Impervious Environments

Timothy McCartney
Rochelle Samuel

Abstract

This section examines methods and green street applications in the urban and residential environments. These technologies might be applicable throughout street systems in the Carroll Creek Watershed.

Introduction

Urban environments tend to have large percentages of impervious cover, which lead to high stormwater flows directly affecting the hydrology of the natural environment. These surfaces increase the amount and rate of overland flow, or stormwater runoff, into the hydrologic system. The high water volume and rate does not allow for infiltration of the water into the soil and eventually groundwater. This decreases the overall base flow within the system and increases amount of water runoff into nearby streams, including any pollutants that travel with that runoff. The increase in amount of flow leads to an increase in the peak flow and a decrease in the lag time to reach that peak flow. The system does not have enough time to adapt to the high load, which leads to increased flash flooding and standing water. The impervious surfaces also allow for increased sediment loading into the systems. Impervious surfaces hold trash and pollutants of the urban environment that are then washed into the system after a storm event. Impervious surfaces not only affect stormwater flow, but also affect overall community health. Nutrient loading in creeks and streams affect the plant life and species, water quality and aesthetics of the environment. The flash flooding and standing water can increase water damage within the urban environment.

Frederick's impervious surfaces and lack of stormwater management practices have contributed to the amount of sediment and nutrients entering Carroll Creek, contributing to the algae growth issue. The construction of Carroll Creek Park was an innovative solution to address the City's flooding problem. However it did not fix the underlying issue of a high percentage of impervious surface cover, one of the causes of both the flooding and nutrient loading in the creek. A solution would be to convert areas previously covered by impervious surface to pervious surface. Pervious surfaces allow infiltration of water and capture harmful nutrients or sediment. These

practices are known as complete street, or particularly, green street policies. Complete street and green street technologies can decrease the effects of impervious surfaces, particularly nutrient loading, on the Carroll Creek Watershed.

Complete streets are designed and operated to enable safe access for all users regardless of age, accessibility, or mode of transportation, including pedestrians, bicyclists, public transit users, and drivers. Any specific complete street is unique, and depends on the community in which it is applied. In general, complete streets components can include wider sidewalks, bike lanes, and special public transit bus lanes, curb extensions, narrower car lanes and marked crosswalks. All of these components contribute to environmental sustainability, and complete streets are a natural complement to sustainability efforts (Smart Growth America 2014). Making streets safe and accessible for pedestrians, bikers, and public transit, decreases the potential for people to drive cars, further decreasing the emission of harmful pollutants to the air and environment, including nitrous oxides. The Chesapeake Bay has a similar, albeit more severe, issue with algal blooms, and studies have shown that "roughly one third of nitrogen pollution comes from the air" (Chesapeake Bay Foundation 2010). The Foundation recommends driving less as a means to reduce airborne nitrogen loads, which complete streets policies can encourage.

The environmentally sustainable elements of complete streets are known as green streets, a low-impact development design practice. Green street technology captures stormwater runoff in an area that lets the water soak into the ground while the plants and soil filter out the pollutants. Emphasis on pavement types, landscaping and climate are important to the green street approach. Pervious pavement systems not only reduce/control water runoff, but "maximize pavement albedo (reflectivity) to reduce the urban heat island effect, improve air quality, increase pavement durability, and improve nighttime illumination," added benefits that make the policy more economical (Smart Growth America 2014). Landscaping is essential to capturing stormwater runoff and also adds to the aesthetics of the street. These green elements also help to calm traffic and make the street safer for pedestrians. Green streets and complete streets promote climate health because of their support of mass transit and alternatives to car travel.

Green Street Toolbox

The principal green street technologies used to reduce and filter stormwater runoff are landscaped bioretention areas and pervious pavement systems. These elements

are integrated into complete streets to form sustainable complete streets. Pervious elements applied to the urban environment include boardwalk elements in the pedestrian right of way, pervious pavers, porous concrete and asphalt, and pervious driveways and alleys. Bioretention elements include stormwater tree trenches, bump outs, drainage wells, planters, green gutters, rain gardens and bioswales that help capture stormwater. Other elements in the built environment such as stormwater canopies, planters, and green walls and roofs also help capture water and reduce the amount of water introduced into the system.

Permeable Pavement Systems

These systems provide stormwater management while maintaining paved and other hardscape surfaces. In most cases they can be implemented instead of traditional pavement replacement projects. These systems are composed of material that allows the water to flow freely through the surface and penetrate into the ground. These pavement systems have a ratio of impervious untreated per unit area to treated per unit area of 1 to 8 (Philadelphia Water Department 2014).

Figure 6.1. Permeable Pavement (Philadelphia Water Department 2014)

Stormwater Planters

This system is a bioretention element integrated within the streetscape. The planting media within the planter is lower than the streets' gutter system, allowing for stormwater filling the planter and slowly penetrating into the ground. The planting soil helps to filter the water, thereby improving the water quality (Philadelphia Water Department 2014). The planter also helps create a physical boundary between the pedestrian and the roadway making a safer urban environment. These elements can be sized to fit the streetscape and have an impervious area manage per unit area of 10 to 20, depending on their makeup and size (Philadelphia Water Department 2014)

Figure 6.2. Stormwater Planter (Philadelphia Water Department 2014)

Stormwater Bump-out

Stormwater bump-outs are landscaped curb extensions, using existing parallel parking spaces or other street space to create a bioretention area (Philadelphia Water Department). Similar to the stormwater planters, the planting media is lower than street level, which improves water quality, creates a pedestrian buffer and makes a better street environment. These elements have an impervious area managed per unit area of 10 to 20 (Philadelphia Water Department 2014). Bump-outs don't encroach on the sidewalk. Their encroachment into the street narrows the path of vehicular traffic causing slower speeds.

Figure 6.2. Stormwater Bump-Out on Corner and within Streetscape (Philadelphia Water Department 2014)

Stormwater Trees

This element involves a tree planted into a specialized tree pit installed within the sidewalk with the planters and bump-outs, the planting media lower than the street, improving water quality and creating a pedestrian buffer (Philadelphia Water Department 2014). Stormwater trees have a small footprint, allowing them to integrate easily within the sidewalk and can accommodate topography changes.

Figure 6.3. Stormwater Tree (Philadelphia Water Department 2014)

Green Gutters

Green gutters are a narrow and shallow landscaped strip along a street's curb line (Philadelphia Water Department 2014). The planting media is lower than the street level and the stormwater from the sidewalk and the street can flow directly into the system. The system encroaches onto the street and not the sidewalk and creates a buffer for the pedestrian, as well as a safer and greener streetscape.

Figure 6.4. Green Gutter (Philadelphia Water Department 2014)

Stormwater Tree Trench

A subsurface trench is installed in the sidewalk that includes a series of street trees. The trench is connected to one or more inlets and the runoff is stored within the empty spaces between the stones or other storage media within the trench (Philadelphia Water Department 2014). The trees capture stormwater and aid in the infiltration of water stored within the trench. This system allows for large amounts of stormwater storage and improves infiltration, while creating an engaging and safer streetscape. The tree trench allows for an impervious area manage per unit area of 10 to 20.

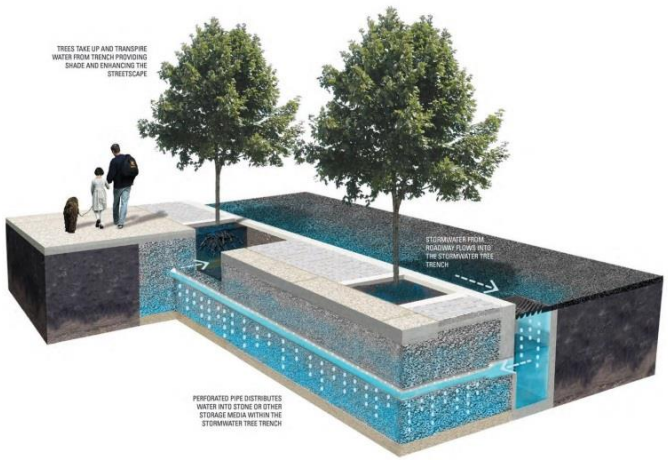

Figure 6.5. Stormwater Tree Trench (Philadelphia Water Department 2014)

Stormwater Drainage Well

This system is solely based on capturing stormwater and does not add to the streetscape. It works by "receiving stormwater from upstream collection areas and pretreatment systems then discharging the stormwater into surrounding soils through perforations in the manhole" (Philadelphia Water Department 2014). The creation of a storage drum, integrated into a manhole, with penetration allows for large volumes of stored water to release slowly into the ground. This element emphasizes water storing and slowing infiltration back into the ground.

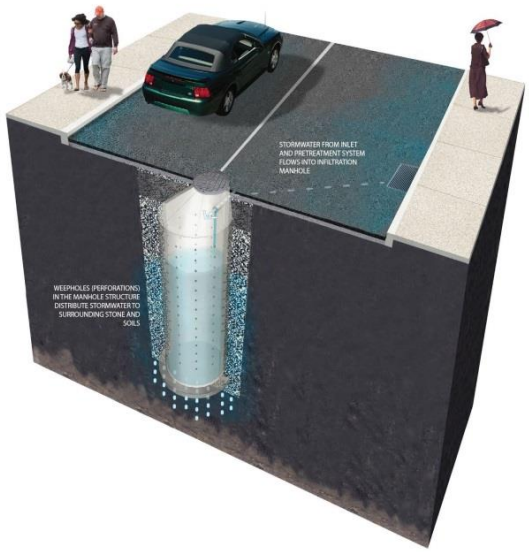

Figure 6.6. Stormwater Drainage Well (Philadelphia Water Department 2014)

Case Study Applications

Case studies on different aspects of the environment can help assess the impact of green street principles on Frederick. The six case studies here implemented green street principles on impervious surfaces, within dense inner city and residential areas of the urban environment.

Inner City Case Studies

SW Montgomery Green Street in Portland, Oregon

This project proposes renovations to nine city blocks along Montgomery Street in Portland, Oregon. The nine-block study area, from SW 11th Avenue to SW 2nd Avenue, "demonstrates how in even the most urban conditions, downtown streets can be retrofitted not only to fully manage stormwater runoff but to create and integrate vibrant pedestrian spaces" (Nevue Ngan Associates 2009). One of the project's major goals is to use water as a recurring element that is a teaching tool and beautifying part of the streetscape. The project emphasizes using stormwater features to create a pedestrian-friendly environment and unique conditions that respond to each block. Finally, the project strives to integrate stormwater management to enhance and develop models for sustainable practices, while enhancing Portland's sustainable reputation.

Figure 6.7. Extent of SW Montgomery Green Street (Nevue Ngan Associates 2009)

The main green street element is a five-foot wide stormwater spine along one side and is integrated into each block along the street. This spine is a continuous stormwater planter with a depth of four to six inches to hold stormwater and is filled with plants and street trees to help aid in water retention (Nevue Ngan Associates 2009). The street is designed with no curbs leaving the green street elements to separate vehicular from pedestrian traffic. This spine is integrated within the horizontal plane to capture the runoff from the streets, sidewalks and buildings. Boardwalks or pervious systems are included to allow for pedestrian movement over the system.

Figure 6.8. Stormwater Spine (Nevue Ngan Associates2009)

The area between SW 11th and SW 10th Streets use features such as green roofs and green walls to help capture stormwater off the buildings. Integrated circular stormwater planters, filled with plants, collect rainwater from buildings and the street. The percentage of landscape to impervious area is about 21 percent. The planter can capture and retain the stormwater from the site's 4,000 square feet of impervious surface and still have the ability to take on an additional 5,700 square feet of surface (Nevue Ngan Associates 2009).

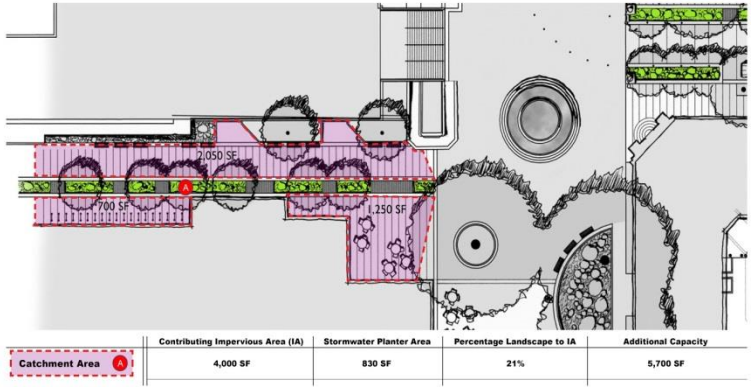

Figure 6.9. SW 11th to SW 10th Stormwater Data (Nevue Ngan Associates 2009)

Another block, the Urban Center Plaza, integrates stormwater planters into the circulation from one level of the plaza to the next. The runoff from the Portland State University Recreation Center is integrated and captured by a large stormwater planter, while stormwater from the entry terrace is funneled through terraced planters along the stairs (Nevue Ngan Associates 2009). The planter adds to the tree cover and aesthetic appeal of the plaza.

Figure 6.10. Stormwater Planters Built into Stairs (Nevue Ngan Associates 2009)

Each block along the SW Montgomery Green is retrofitted with new green street elements to help capture stormwater. The system is capturing the majority of runoff produced by impervious surfaces and still has capacity to capture more. This developing green street is a model of sustainability that demonstrates how a city can integrate these principles into the existing fabric.

NE Holladay Street in Portland, Oregon

Northeast Holladay Street is a primary pedestrian and transit spine in the Lloyd District in Portland, Oregon that runs east and west though the district's center" (The City of Portland Oregon. NE Holladay). The project's main goal is to improve stormwater management along the street and mass transit corridors. The concept plan integrates green infrastructure into all transportation modes. A unified green street along NE Holladay Street "will serve to meet stormwater management and watershed health goals as well as catalyze sustainable development in the district" (City of Portland 2012).

This project uses a variety of elements to capture stormwater in the street's pedestrian and vehicular zones. Curb extensions or stormwater bumpouts extend into the street calming traffic, separating movement systems and capturing stormwater while bridging the pedestrian space. They also create space that can support more trees to help capture stormwater. Integrating the bump-outs with a subsurface infiltration zone (stormwater tree trenches) allows the site to capture, store, and clean the water (City of Portland 2012). Permeable pavement in the parallel parking spaces, above the subsurface storage zone, and in the sidewalk zone help improve infiltration.

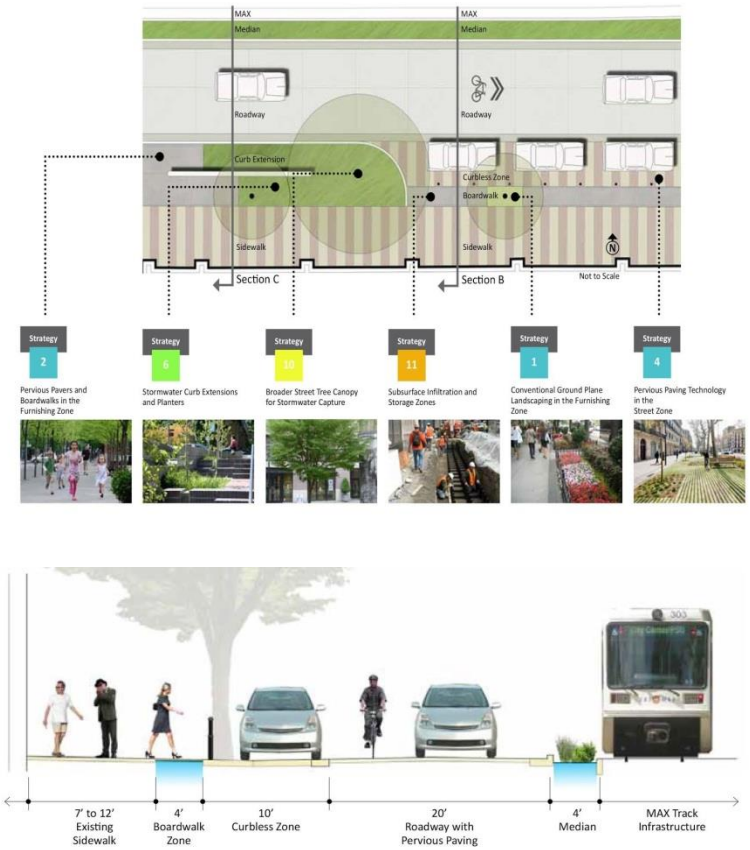

Figure 6.11. Plan and Section through Street (City of Portland 2012)

Within the mass transit zone, the street includes elements such as green gutters and green track technology to help improve/capture the sediment and stormwater coming of the tracks. The green gutters separate mass transit and vehicular traffic, while adding to the street's aesthetic appeal. The bus stops and mass transit buildings have been fitted with green roofs and stormwater canopies designed to capture stormwater.

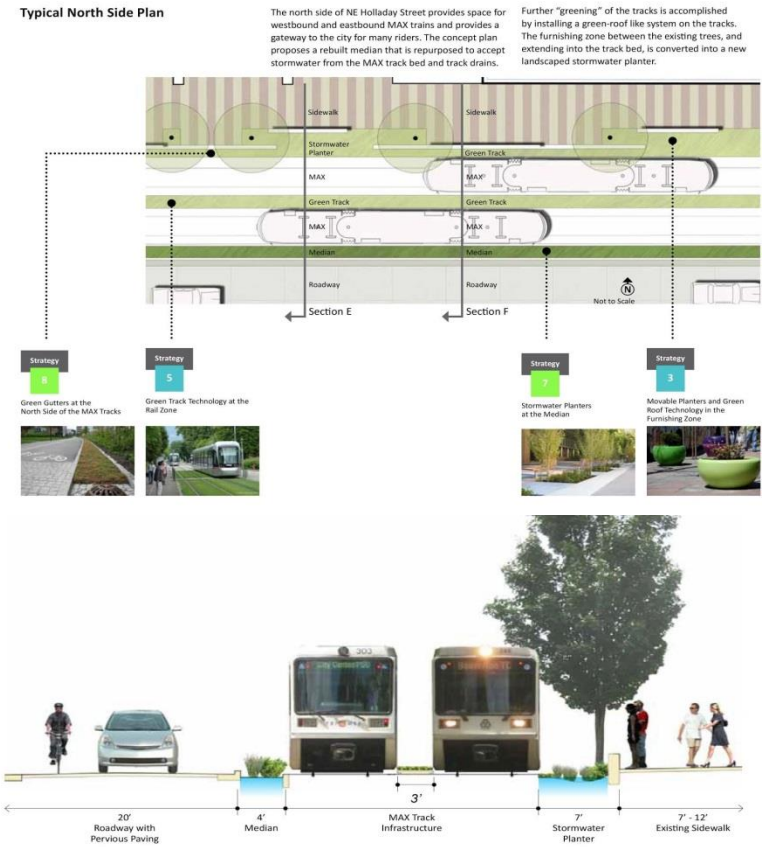

Figure 6.12. Plan and Section through Max Train (City of Portland 2012)

“Illustrating the combination of stormwater management with placemaking along the most constrained street in the district “shows how this toolbox would be useful on other streets throughout the Lloyd EcoDistrict to create green infrastructure” (City of Portland 2012). North East Holladay Street uses six green street elements to help capture stormwater from impervious surfaces of the built environment.

Bagby Street Reconstruction in Houston, Texas

The Bagby Street Reconstruction project focuses on transforming three transit centers, between downtown Houston and the Texas Medical Center, into a walkable mixed-use community (Design Workshop 2014). This reconstruction seeks to make a 10-block area more sustainable, decrease the heat island effect and capture stormwater from the highly impervious area, while increasing the neighborhood’s aesthetic appeal and safety.

Figure 6.13. View of Rain Gardens and New Retail Along Street (Design Workshop 2014)

The major stormwater element is a 60-inch conveyance line. It was installed 28 feet below the surface and serves the drainage needs of the local watershed (Greenroads 2014). This conveyance line helps alleviate drainage pressure by capturing more stormwater.

Figure 6.14. Bioretention Area along Bagby Street (Design Workshop 2014)

Integrating rain gardens into the existing street has allowed for the capture and treatment of one-third of the stormwater that falls within the right-of-way. These stormwater planters are removing five percent of the bacteria, 73 percent of the phosphorus, 93 percent of the oil and grease, 43 percent of the nitrogen, and 85 percent of the total suspended solids. (Houston Midtown 2013) The gardens are populated with native and adapted vegetation that provides additional shading and increases the number of street trees. These efforts have led to a 14 percent decrease in surface temperature, increased shade on sidewalks by 42 percent, increased the amount of tree canopy from 32 to 70 percent and increased tree growth area by 42 percent (Houston Midtown 2013).

Figure 6.15. Bioretention Area with facts about stormwater along Bagby Street (Design Workshop 2014)

This project has become only the eighth complete and certified Greenroads project in the world (Greenroads 2014). The green street elements have helped alleviate stormwater problems, reduce the heat island effect, and transform the aesthetic appeal of the street. This case study shows that green street elements provide a large advantage in capturing stormwater, but also provide other benefits dealing with heat, shade, safety and aesthetic appeal.

Residential Case Studies

Forest Estates in Montgomery County, Maryland

This project is part of a County-wide effort to reduce runoff, erosion, and pollution by capturing, holding, and treating stormwater close to where it falls. Montgomery County was issued the National Pollutant Discharge Elimination System (NPDES) permit in 2010 and its requirements include stormwater management for 20 percent of the existing impervious surface area, identifying pollution sources and improving water quality, and increasing the use of Environmental Site Design (ESD) practices.

The goals of the Forest Estates project are to maximize stormwater management to improve conditions in the Wheaton tributary and Sligo Creek, improve water quality treatment practices, encourage infiltration from parking lots and other impervious surfaces, and fulfill the requirements of the NPDES permit (Montgomery County, MD 2012). To accomplish these goals, the project used the following green street elements: rain gardens, bioretention gardens, grass bioswales, tree box filters (stormwater trees), pervious sidewalks, and through pavement removal.

Figure 6.16. Forest Estates Proposed LID Locations (Montgomery County, MD 2012)

Forest Estates is a residential area with surrounding land uses that includes other residential, commercial, institutional, and forested areas. A January 2011 field assessment gauged 40 potential sites based on available space within the right-of-way, utility or vegetation conflicts, proximity to existing storm drain systems, existing drainage patterns, and property ownership. The project team identified 24 sites without any major utility conflicts or critical tree root zone impacts (Montgomery County, MD 2011) that would be appropriate for green elements. To narrow down the types of Low Impact

Development (LID) features to implement, a topographic survey, utility designations, soil borings, and infiltration tests were completed. Proposed trees were eliminated from the project due to concerns about installing them under utility lines. Pervious sidewalks were eliminated because of construction constraints, and pavement removal was not included because of conflict with the parking configuration in the cul-de-sac and utility conflicts. Ultimately, the County decided to implement three green street elements: bioretention gardens, rain gardens, and grass bioswales.

Bioretention gardens were proposed in areas near an existing storm drain inlet or pipe, because the under-drain system eventually runs to the storm drain. Rain gardens were proposed in areas where a storm drain was not available or too shallow to tie a bioretention garden's underdrain. Bioswales were proposed in areas where the existing roadway slope was too steep to install bioretention or rain gardens, which need to be on a flat surface (Montgomery County, MD 2011).

Figure 6.17. Bioretention Garden in Forest Estates (Montgomery County, MD 2012)

Figure 6.18. Department of Environmental Protection Stormwater Controls Field Walk for Forest Estates (Montgomery County, MD 2012)

The 24 green street element sites provided 4,878 cubic feet of stormwater management treatment volume within the County right-of-way before it reaches Sligo Creek (Montgomery County, MD 2011). However, several of the proposed sites have large drainage areas comprising mostly residential backyards or non-roadway areas (Figure 6.14). In these cases, the County recommends that private owners use its RainScapes program. The Department of Environmental program incentivizes green street elements by offering rebates to private property owners who install “RainScapes” techniques, which include all green street elements such as rain gardens, rain barrels, and pervious pavement (Department of Environmental Protection 2012). Rainscapes elements located on private property in Forest Estates could create an additional 13,718 cubic feet volume of treatment (Montgomery County, MD 2011). To encourage homeowners, Montgomery County holds public meetings and neighborhood walks to tell people how green streets LID features provide environmental benefits and improve property aesthetics. This case study demonstrates the importance of involving private owners in stormwater management practices, especially in residential areas, to help projects reach their full potential.

8th Avenue NW in Puyallup, Washington

This project is a unique neighborhood and City collaboration to implement residential rain gardens on 8th Avenue NW, known as the “Street of Green.” The City found that 75 percent of the toxins measured in the Puget Sound came from runoff from roofs, driveways, and roadways, which most community members didn’t realize. Therefore, a major part of this project was

educating the community on stormwater management practices and how they can affect water quality.

After the success of a sustainably-built City Hall, which included multiple green street and LID elements such as rain gardens, green roofs, and a cistern in 2009, sustainability efforts were expanded with the help of a local non-profit organization, Stewardship Partners, that worked with the City to target areas for implementing residential rain gardens. The City held a workshop on rain gardens, and seven homeowners on 8th Street NW volunteered their yards. Community efforts, including local stores such as Lowe's donating the planting materials, along with the neighborhood providing free labor, significantly cut installation costs. A local radio host covered the rain garden installation live to spread awareness (Rain Dog Designs 2014).

As a result, in 2012, 8th Avenue NW's traditional asphalt roadway was transformed into a green street that filters polluted water, provides attractive landscaping, creates a curved road alignment to slow down traffic, and protects the local Puyallup River and ultimately the Puget Sound (Rain Dog Designs 2014).

Figure 6.19. 8th Ave NW Rain Garden Showcasing Community Aesthetics (Rain Dog Designs 2014)

Figure 6.20. 8th Avenue NW Rain Garden Installation Sites (Rain Dog Designs 2014)

Figure 6.22. Sign on 8th Ave NW Rain Garden Explaining Technology to Community (Rain Dog Designs 2014)

Because of the initial push from the local government and the following positive media coverage and education, 8th Avenue NW residents decided to install 13 more rain gardens on their own.

The success of these rain gardens prompted homeowners to lobby the City to apply for a Washington Department of Ecology grant for creative rainwater solutions, which was approved. This construction project included:

- a 630-foot long pervious asphalt roadway that infiltrates 100 percent of the rainfall
- a curved linear road realignment that slows vehicle traffic
- 11 attractive roadside rain gardens in the rights-of-way on both sides of the street
- a 620-foot long permeable paver and pervious concrete sidewalk on both sides of the street that is attractive and filters all the rain that falls on them

(Rain Dog Designs 2014)

Figure 6.23. 8th Ave NW Roadside Rain Gardens (Rain Dog Designs 2014)

Figure 6.24. Community Involvement in Installing the Rain Garden (Rain Dog Designs 2014)

The success of this project can easily be attributed to the initial government investment in installing free rain gardens for homeowners. Then, exposing and educating the public led to them taking the initiative. A similar approach can be adopted in Carroll Creek's residential areas.

Ecorse Road/Morton Taylor Road in Wayne County, Michigan

This project was funded by the Environmental Protection Agency Great Lakes Restoration Initiative to establish native plant grow zones within the road right-of-way to reduce long-term maintenance and runoff volume and improve water quality. "Native plant grow zone" is actually a term coined by Wayne County as they began converting large-scale park areas to native planting areas in order to improve water quality, habitat, and reduce stormwater runoff volumes (SEMCOG 2013). These zones can be in any green street element, including rain gardens and bioswales, as long as they use native vegetation's significant root systems that promote stormwater runoff infiltration and uptake. The Southeast Michigan Council of Governments (SEMCOG) published an LID Manual and Structural Best Management Practices guidebook through the grant (SEMCOG 2013).

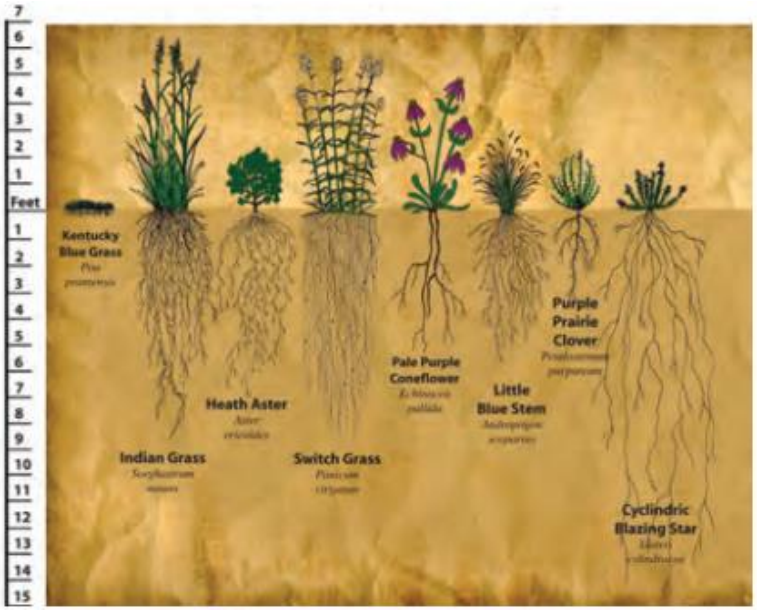

Figure 6.25. Native Plant Root System Depths and Heights in Wayne County, MI (SEMCOG 2013)

Native plant grow zones work best adjacent to roadways where roadway runoff is in sheet flow. This includes large open areas traditionally managed as turf grass, cloverleaf areas around on and off ramps of highways, large highway medians, and in linear vegetated areas adjacent to roadway impervious surfaces (SEMCOG 2013). Because these are native plants, once installed they require very little maintenance.

Wayne County sees opportunities to implement these grow zones at community parks, municipal buildings, commercial developments, and in private owners' yards as a means to improve water quality in the Rouge Watershed and provide the added benefit of improving wildlife habitat. This project is an expansion of the multi-year growth zone initiative that aims to convert turf to native plant grow zones in strategic locations. The County has constructed over 47 acres of grow zones that have led to improved water quality and wildlife habitat in the Rouge Watershed and its tributaries (SEMCOG 2013).

Figure 6.26. Native Plant Growth Zone in Wayne County, Michigan (SEMCOG 2013)

The intersection of Ecorse and Morton Taylor Roads is in a rural residential area, with a small pond adjacent to it. The project began in October 2010 and ended in November 2013 with a total budget of $100,000. Approximately seven acres of mowed turf grass were converted to deep-rooted native grasses, wildflowers, and shrubs to reduce and filter polluted stormwater runoff. Stormwater catch basins were also added to increase filtration and reduce the volume of water entering the open pond during small storm events (Alliance of Rouge Communities 2013). The zone covers a drainage area of 19 acres and reduces runoff by 38,000 cubic feet. The project team also measured the annual pollutant loading reduction to be 4,400 pounds of suspended solids, 6 pounds of phosphorous, and 20 pounds of nitrogen reduction.

Although the Rouge Watershed initiative targets sediment and thermal pollution, its approach can still be implemented in Carroll Creek since the project also reduced nutrient loading (Annis Water Resources Institute 2000).

Summary

This section has examined methods and green street applications in the urban and residential environments. A variety of best management practices were reviewed that contribute to a Green Street Toolbox. A few of these include Permeable Pavement Systems, Stormwater Planters, Stormwater Bump-outs, Stormwater Trees, Green Gutters, Stormwater Tree Trench and Stormwater Drainage Wells. This section also summarized three Inner City Case Studies and three Residential Case Studies. Lesson learned from these case studies may be useful in addressing issues throughout similar built environments in the Carroll Creek Watershed.

Chapter 7: Green Streets: Applications for The City of Frederick, MD

Dylan Reilly

Abstract

The chapter discusses the potential benefits of applying green street principles in The City of Frederick. The discussion focuses on two proposed green street sites: one in the downtown and one in the Golden Mile. Throughout, elements from the Comprehensive Plan are noted help to make green streets relevant for The City. The downtown site centers on changes made to sidewalks, while the Golden Mile application will address the stormwater challenges posed by parking lots. Suggested changes to the Comprehensive Plan draw on manuals and plans from other cities. Green streets are fundamentally about managing stormwater with visible, attractive, biological infrastructure as opposed to hidden grey infrastructure. They are not a panacea, but their transparency helps educate the public on the design and environmental challenges posed by stormwater and our increasingly impervious environment.

Downtown

An almost two-fold increase in population since 1980 (The City of Frederick 2010) validates The City's efforts to preserve historic character and spur economic prosperity. People want to visit and live in Frederick, especially the downtown, whether they are working there or commuting to Washington, DC on the MARC train. The challenge for the City is to preserve character while meeting the challenges that this growth presents. The Comprehensive Plan responds with, "several approaches intended to preserve and enhance neighborhood character, maintain a vibrant and growing economy, and promote sustainability" (The City of Frederick 2010, p10). The green street proposals presented are in the context of achieving these three goals.

In the City's historic guidelines, landscapes are "planted and… provide relief from building and street fabric" (Historic Preservation Commission 2009, p116). In the historic district, green streets infrastructure should be thought of as landscapes as well as a stormwater management strategy. Historically two park landscapes, the courthouse and a campus, along with many smaller landscapes, cemeteries and churchyards, provided relief to City residents. "The number of cemeteries has dwindled" in the Historic District (Historic Preservation Commission 2009, p116), which presents an opportunity

to apply green street practices in a way that mimics the small-scale landscapes provided by historic cemeteries. One principle of green streets is to create spaces with distinct character. “Placemaking uses pedestrian amenities such as parklets to encourage people to linger and generate a strong connection to a place” (Conway School 2014, p11). A historic model is the Olmstead-designed Emerald Necklace which provides green spaces to Boston residents. The Frederick proposal would be at a smaller scale, as a series of parklets in a ring of interconnected green spaces - a type of greenway- around the Historic District, designed with a historic character and stormwater mitigation. In this way the Historic District’s character can be “preserved and enhanced” (The City of Frederick 2010, p10), while addressing the challenges of stormwater and providing green spaces for The City’s growing population.

Development of such a greenway should coordinate with redevelopment and infill development of high-density residential and mixed-use in the downtown. This strategy matches the goals of the Housing Element, Policy 5 of The City’s Comprehensive Plan to “encourage the development of compact residential neighborhoods” (The City of Frederick. 2010, p162). One possible area for such development is on the east side of the downtown, which abruptly shifts from historic townhouses to large parking lots, warehouses, and other industrial uses. Encouraging redevelopment as high-density residential and mixed-use properties adjacent to existing townhome neighborhoods would also fulfill the “compatible with surrounding land uses” (The City of Frederick 2010, p163) stipulation. Many of these properties are currently zoned Office/Industrial (The City of Frederick 2010). Zoning that encourages redevelopment should be given to projects that include greenway and green streets elements. This process can act as an economic engine, while accomplishing landscape and stormwater goals. The greenway section on the City’s east side would also provide new and current residents pleasant walking access to the MARC station, fulfilling the goals of the Housing Element, Policy 4 to “promote higher-density residential and pedestrian-friendly development within walking distance (a 10-minute walk) of existing and planned public transit routes (including the MARC station)” (The City of Frederick 2010, p161).

The character of existing parks will be key to designing and implementing appropriate green streets elements. By taking themes from existing green spaces and the City’s historic character, the greenway will be able to knit seamlessly into them. Harmon Field Playground, the Amtrak Station, Third Street Park, Staley Park, Max Kenne Memorial Park, Carroll Creek Path, Maryvale

Park, McCurdy Field, South End Park, and Carver Park would act as touchstones for the greenway as it loops around the City. Carroll Creek Linear Park would be connected via a greenway from both the east and west, making the retail space that is concentrated there more accessible to pedestrians from the City and from the Amtrak station.

The next step is to determine which green street elements would be most effective in the greenway plan. Curb bump-outs or extensions are already part of the City's streetscape, implemented successfully in the downtown at East Patrick Street's intersections with North Court Street, and South Market Street. These bump-outs help define on-street parking, while improving walkability with a shorter curb-to-curb crosswalk (Bureau of Environmental Services 2008).

Stormwater bump-outs offer the same design benefits while managing stormwater with vegetation on top and aggregate-based water retention below to transpire, infiltrate, and slow water flow to the stormwater management system (Cutler and Neukrug 2014). These systems can be designed to overflow into existing stormwater infrastructure by the street or by integrating a drain. During a storm event, water enters the extension through a curb cut, filtering through the vegetation and into the aggregate below. This filtering process improves stormwater quality (Cutler and Neukrug 2014) while decreasing volume through infiltration and evapotranspiration. Though design plays a huge role in how much stormwater these features can mitigate, The City of Portland estimated that three extensions at SE 12th Avenue and Clay Street would manage 74,000 gallons annually (Bureau of Environmental Services. 2008). Routine maintenance includes removing litter, weeding, watering during droughts, and cleaning pipes (Cutler and Neukrug 2014). Stormwater bump-outs also increase walkability by visually buffering the street from the sidewalk with vegetation (Conway School 2014).

Street trees are an integral part of downtown's character. Trees are so important that the Historic "Commission may require street tree plantings… in the context of new construction or where changes are being made to the streetscape" (Historic Preservation Commission 2009.). Stormwater trees are planters with a curb cut that allows water to enter the planter and filter through the soil into aggregate below (Cutler and Neukrug 2014). The water can then be piped into the existing stormwater infrastructure or allowed to infiltrate into the soil. Unlike for regular street trees, the soil surface for stormwater planters is a few inches below street-grade, allowing stormwater to collect (Cutler and Neukrug 2014).

Stormwater trees would mesh well with the existing character of the downtown and their minimal footprint makes them a versatile technique in crowded areas.

Permeable pavement is another green streets strategy that is best implemented on pedestrian surfaces, not surfaces used heavily by vehicular traffic (Conway School 2014). Permeable pavement allows stormwater to infiltrate to an aggregate layer and then to the soil (Cutler and Neukrug 2014). There are three major types: permeable pavers, porous asphalt, and pervious concrete. Permeable pavers allow water to infiltrate around each paver, while permeable concrete and asphalt allow water to infiltrate through the entire surface.

The City should also look beyond downtown to apply green streets. Parking lots and big box commercial development often present impervious surface and stormwater runoff challenges. Assuming 100 percent runoff in a one-year storm event (2.7 inches), one acre of parking lot produces 0.23 acre-feet or 75,000 gallons of stormwater runoff. In the case of Carroll Creek, the streams channel has been heavily incised in a section dominated by strip development. Due to the quantity of stormwater runoff that these areas produce, they are ideal places to implement green street principles.

The Golden Mile

The US 40 corridor, known as the Golden Mile, is planned for commercial development. One of the Plan's goals for the Golden Mile is to "provide a more coherent and attractive commercial environment" by stipulating that "future redevelopment along these corridors should be integrated with surrounding businesses and neighborhoods" (The City of Frederick 2010, p27). One of the benefits of that integration would be "more organized pedestrian and vehicular movement" (The City of Frederick 2010, p27). To address this Plan goal a green streets policy should be implemented in the Golden Mile, perhaps via a handbook of practices to create a unified character that meshes with surrounding neighborhoods. This would help to address the issues of "inconsistent streetscape" and the "lack of pedestrian or vehicular connectivity between retail centers" (The City of Frederick 2009, p6).

In 2009, the Golden Mile contained over 2.6 million square feet of commercial space and had only 10 percent vacancy by area (The City of Frederick 2009). "Many of the vacant buildings are not conducive to reuse; new construction is the best option" (The City of Frederick 2009, p2). This new construction is an opportunity to implement green streets from the beginning of the design process.

Some funding could come from the State's Transportation Enhancement Program; a Golden Mile green street program would fulfill three of 12 qualifying categories including: "Provision of facilities for pedestrians and bicycles," "Landscaping and other scenic beautification," and "to address water pollution due to highway runoff" (The City of Frederick 2009, p21). Another funding method could be the establishment of "Capital Improvement Projects to improve the City's waterways" as outlined in the Comprehensive plan (The City of Frederick 2010, p105).

Any Golden Mile redevelopment should include a mixed-use path with a pedestrian bridge across Route 40, as residents have requested (The City of Frederick 2009), to improve pedestrian connectivity.

San Mateo County, California created a guidebook for green street practices and, in particular, applying them to parking lots (San Mateo County 2009). The guidebook notes that it is crucial that stormwater management shift from the "out of sight, out of mind" design approach to treating "rainfall runoff as a valuable resource" (San Mateo County. 2009, p12).

The first step in redeveloping the Golden Mile will be to address site layout by maximizing landscape and minimizing impervious surface (San Mateo County 2009). This is critical because "The City is approximately 45 percent impervious today, with additional impervious surfaces planned as infill, redevelopment, and expansion occur" (The City of Frederick 2010, p105). Incorporating maximum pervious landscape into the redevelopment of existing impervious surface the City can address the quality of its waterway, because "until the existing impervious areas in the City are addressed for storm water management measures, the quality of the City's streams and rivers will not improve" (The City of Frederick 2010, p105).

Reduce impervious surface in parking lots faces two obstacles: "Sometimes local planning and design codes require more surface parking than is actually necessary for a particular business or use to thrive" and "parking lots are also often designed with oversized parking stalls and travel/back-up aisles" (San Mateo County 2009, p36). By decreasing the area required for parking, space can be opened up for stormwater features.

The next step in redeveloping the Golden Mile is to incorporate alternative transportation (San Mateo County 2009). A mixed-use path, emphasizing existing bus routes, and shelters and pedestrian access, go a long way to supporting transit users.

The final step comes in reviewing redevelopment and choosing which stormwater practices to implement (San Mateo County 2009). Unlike in downtown streets, stormwater features in the Golden Mile could be larger, incorporating rain gardens and constructed wetlands. Decreasing parking stall length from 18 to 15 feet (6, p36) creates room for vegetated swales that support trees and mesh well with the City's character. Vegetated swales are linear rain gardens that allow water to infiltrate in the soil. The level of the soil in the center of the swale is below the grade of the parking lot; curb cuts allow stormwater runoff to enter. The Plan should include a toolkit of stormwater facilities, such as San Mateo County's, to allow developers to choose what works best for their project.

The plant palette for stormwater features in the Golden Mile could encompass diverse shrubs, grasses, and trees, however it is critical that the plants can handle the inevitable wet/dry cycles and require minimal maintenance. "The correct selection of plants is an important aspect of stormwater management" (Portland Development Commission 2009, p14). Vegetation can also provide habitat and food for wildlife, like birds, insects, and squirrels. A short list of potential grasses includes *Andropogon virginicus, Carex stricta,* and *Panicum virgatum.* Shrubs could include *Ilex verticillata, Itea virginica,* and *Myrica pensylvanica.* Trees could be matched to existing species in the downtown to extend the character of the downtown. Possible trees include *Betula nigra* and *Quercus phellos.*

Summary

This proposed implementation of green street practices in The City of Frederick centers around three main action items involving the downtown, the Golden Mile, and the Comprehensive Plan.

A new greenway encircling the downtown would connect existing parks and act as a pedestrian route to the Amtrak station. It would be developed in a multi-phase process employing stormwater bump-outs, stormwater tree planters, and permeable pavement to transition existing sidewalks into a cohesive greenway.

A new mixed-use path running through the Golden Mile, a pedestrian bridge across route 40, and San Mateo-style parking lot design could attract needed capital investment.

Implementation of these projects is supported by the goals in the Comprehensive Plan. Green street practices have the potential to manage stormwater and address challenges faced by The City.

Chapter 8: Exemplary Parking: Designs for Minimizing Runoff

Matthew Doeller

Abstract

This section provides case studies of parking lots that incorporate strategies to reduce runoff and impervious surfaces. Reducing runoff and impervious surfaces will allow stormwater to infiltrate into the ground closer to the source, which results in fewer non-point source pollutants from entering Carroll Creek.

Introduction

Stormwater runoff is a major contributing factor to the issues with algae in Carroll Creek in the Linear Park area. Stormwater runoff is when precipitation from rain or snow event flows over the ground, as opposed to soaking into the ground (EPA 2014). This is especially an issue in areas of highly impervious surfaces, such as the Golden Mile region of Frederick. “Impervious surfaces are areas covered in material that impedes the infiltration of water into the soil. Examples of impervious surfaces are buildings, pavement, concrete and severely compacted soils” (University of New Hampshire 2007). Stormwater runoff is an issue because it picks up debris, chemicals, sediment and other pollutants that are deposited directly into water bodies like Carroll Creek.

Current Situation on the Golden Mile

Frederick’s Golden Mile is known for its stretch of retail. High concentrations of pollutants in stormwater are associated with large areas of impervious parking lots. Stormwater from the parking lots along the Golden Mile drains directly into Carroll Creek, which runs just north of the retail area. During major rain events, the immediate and drastic change in the amount of water has caused significant erosion of the banks. Furthermore, the volume of water coming off of the parking lots carries high concentrations of pollutants, which are contributing to algae growth and other environmental issues in Carroll Creek.

Case Study 1: San Mateo County, California

San Mateo County is a thriving area south of San Francisco, California. In response to a statewide initiative to mitigate the environmental impacts associated with vehicles, the County established a Sustainable Green Streets and Parking Lots Design Guidebook.

“The guidebook provides designers, builders, municipal staff, and other interested groups practical and state-of-the-art information on creating low-impact development

roadways and parking lots within San Mateo County. Roads and parking lots provide important opportunities for managing stormwater…" (Nevue Ngan Associates and Sherwood Design Engineers 2009).

Low-impact development roadways and parking lots are designed to capture stormwater where it falls and allow it to infiltrate into the ground. To achieve this, the County established principles for sustainable stormwater design. The first is to manage stormwater on the surface at its source. This means that when rainfall lands on streets or parking lots it either infiltrates directly into the ground or the surface flow is directed to nearby landscaping. The second principle is to use plants and soils to absorb, slow, and filter stormwater runoff. This allows the natural environment to do the job more efficiently, and with reduced costs, than conventional stormwater management systems. The third principle is to design stormwater management facilities that are simple, cost effective and aesthetically pleasing.

The guidebook established design concepts for the construction of new parking lots as well as retrofitting existing ones. One of the most successful methods is to reduce the size of parking stalls to 15 feet deep and the driving/backup lanes to 22 feet wide. San Mateo County has found that these dimensions are large enough to accommodate SUVs while allowing more space for vegetation (Figure 8.1). (Nevue Ngan Associates and Sherwood Design Engineers 2009).

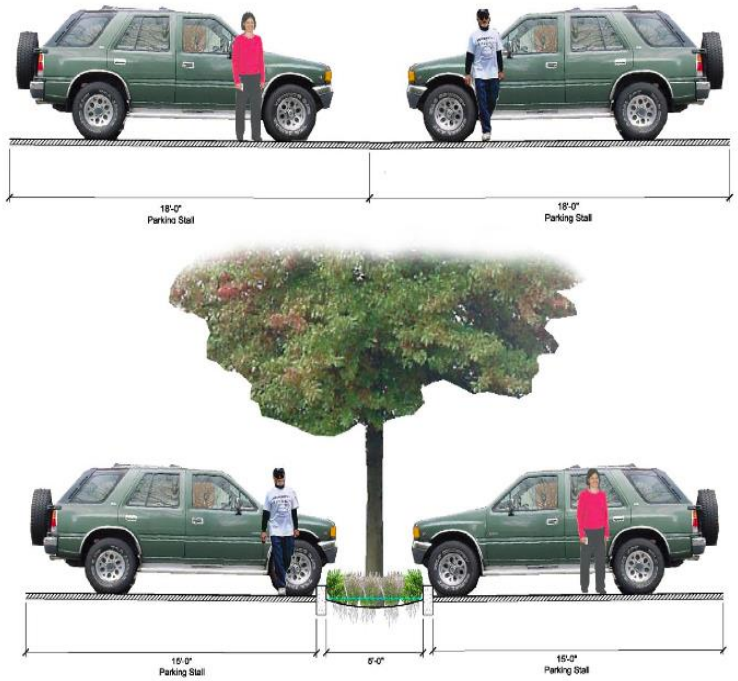

Figure 8.1. Reduced Parking Stall Size: Without changing the overall dimension of the space, a vegetative median can be added (Nevue Ngan Associates and Sherwood Design Engineers 2009, modified by author.

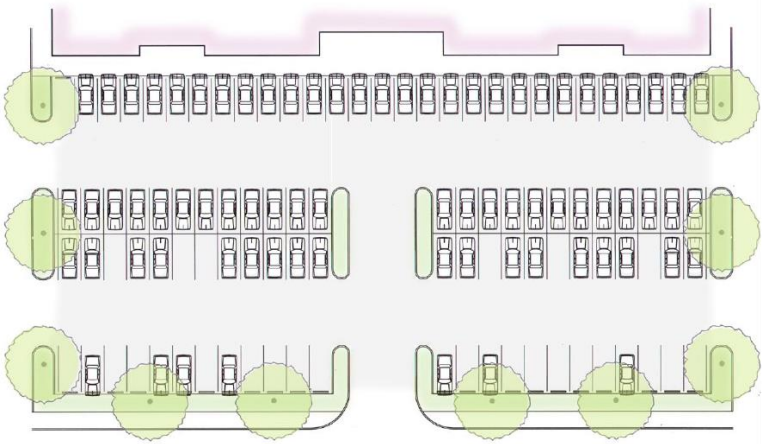

Figure 8.2. Typical Parking Lot Layout: 101 Parking Stalls (Nevue Ngan Associates and Sherwood Design Engineers 2009)

Figure 8.3. Proposed Parking Lot Layout: 78 Parking Stalls with Vegetative Medians and Pedestrian Paths (Nevue Ngan Associates and Sherwood Design Engineers 2009)

Establishing parking lots that increase infiltration can reduce the number of parking spaces. Although this may seem like an issue, most large-scale retail establishments have more parking than necessary. This is the result of regulations and methods for calculating the required number of parking stalls. Most calculate parking for the maximum expected amount as opposed to the average. Figures 8.2 and 8.3 show a typical parking lot plan and one that includes areas for vegetation and improved pedestrian circulation. It is important to note that there is a reduction of 23 parking spaces between the concepts. San Mateo County believes that this is acceptable for several reasons. The first is that there are still enough parking spaces for the average day. Another is that with increased County iniatives to support biking and mass transit systems, there will be a decreased dependency on individual cars. Furthermore, studies have shown that improving the pedestrian realm of streets and parking lots with vegetation increases community pride and brings people to businesses (Nevue Ngan Associates and Sherwood Design Engineers 2009).

These views on growth are similar to those of The City of Frederick, as indicated in its Golden Mile Small Area Plan. In that plan, the City illustrates the desire for more pedestrianized streets that include bike lanes as well as

maintaining or increasing the frequency of buses through the area (The City of Frederick 2013).

In its guidebook, San Mateo County recognized that there are best practices for designing these vegetative areas. The best designs are more than grass and trees. For instance, vegetative swales provide aesthetically pleasing plantings while maximizing the amount of stormwater that can be collected, filtered, and infiltrated into the soil. Figure 8.4 shows a section of the County's recommendations for vegetative swales.

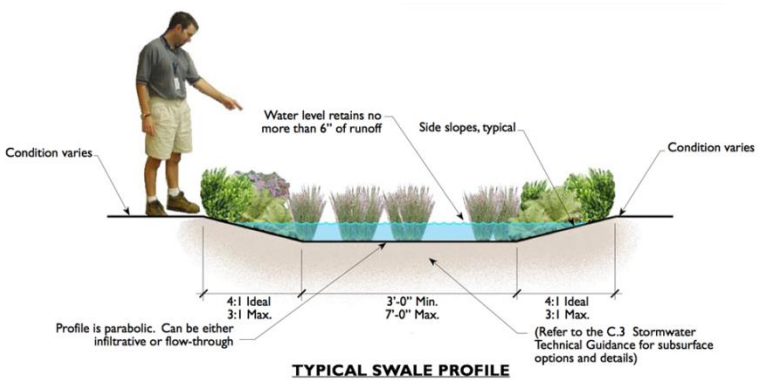

Figure 8.4: Typical Swale Section (Nevue Ngan Associates and Sherwood Design Engineers 2009)

These swales can be incorporated into the space between parking stalls or the residual space associated with angled parking. For narrower spaces, San Mateo County sees the benefits of infiltration and flow-through planters. These planters require as little as a three feet total width, making them easier to place in existing parking lots, as shown in Figure 8.5.

The San Mateo County guidebook is a great resource for the City of Frederick to use for future parking lot development as well as retrofitting existing ones. The Golden Mile Small Area Plan could be a useful means of incorportating the principles addressed in the guidebook (Nevue Ngan Associates and Sherwood Design Engineers 2009).

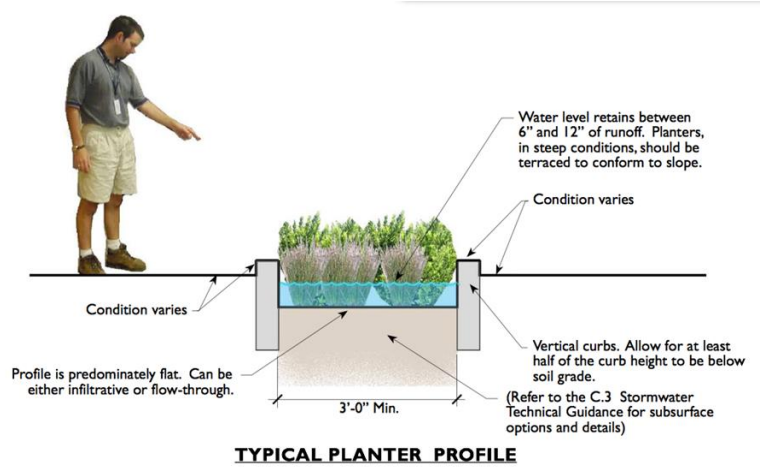

Figure 8.5: Typical Planter Section (Nevue Ngan Associates and Sherwood Design Engineers 2009)

Figure 8.6: Heifer International's Park

Case Study 2: Heifer International's World Headquarters

Heifer International is a non-profit organization that is working to eliminate world hunger and poverty. When Heifer International located their headquarters to Little Rock, Arkansas, the organization wanted to be as environmentally sustainable as possible. The result is a LEED Platinum project that uses 52 percent less energy than conventional office buildings of similar size (About Heifer International). The world headquarters is located on a formerly contaminated industrial site adjacent to the Arkansas River. The project was part of an EPA pilot program aimed "to test innovative approaches with the potential to realize environmental improvements and public health protection" (Industrial Economics 2007). As part of that goal, a green parking lot and urban wetland were included. The stormwater management system is slightly larger than four acres and the parking lot has 337 stalls (Industrial Economics 2007).

The parking lot is designed to minimize environmental damage while maintaining the ability to accommodate

large amounts of traffic. To achieve this goal, it uses several strategies including minimizing the amount of impervious surface, reducing runoff, reducing potable water use and incorporating recycled materials. By incorporating bioswales and a gravel pavement system, the parking lot reduced the amount of impervious surface by 30 percent. An added sustainable effort includes the gravel pavement system, which was constructed using 100 percent recycled materials (Industrial Economics). To reduce the heat island effect, the lot's drive aisles are made of concrete in a lighter color that helps reflect light, as opposed to absorbing it (McClelland Consulting Engineers 2014).

The parking lot is also designed to manage stormwater more efficiently than a conventional parking lot. Conventional design would channel stormwater runoff directly into the Arkansas River, bringing pollutants along with it. Instead, this stormwater management system creates a closed loop that collects the water and ultimately diverts it to the wetlands. The first step guides stormwater into the open space median and bioswales located throughout the parking lot. There are five bioswales constructed of three foot deep sand filtration basins. Any water that does not infiltrate into adjacent soils is drained via underground piping into a retention basin capable of holding two months' worth of rainwater, approximately three million gallons. The final step releases the water from the retention basin into the constructed wetlands surrounding the building. The wetlands can store 750,000 gallons of water, which is filtered and cleaned by native plant species. Water level in the wetlands is designed to mimic the natural cycle, with fluctuations throughout the year. Any on-site irrigation is fulfilled using water in the retention basin and the wetlands (Industrial Economics 2007).

The design of the parking lot and stormwater management system are vast improvements from the standard asphalt parking lot. As part of the EPA's pilot program, calculations were done to show the amount of pollutants that don't go into the Arkansas River as a result of the closed loop stormwater management system. An estimated 180 pounds of nitrogen and over two and a half pounds of phosphorus are prevented from entering the river over a ten-year period (Industrial Economics 2007). High volumes of these same pollutants are leading causes of algae growth within the Linear Park area of Carroll Creek.

There are many costs associated with the construction and maintenance of the parking lot and the stormwater management system. For instance, the project's initial cost was slightly under $2.5 million, with annual

maintenance costs close to $48,000 (Industrial Economics 2007).

The stormwater management system at the Heifer headquarters works exceptionally well, allowing 100 percent of the stormwater to infiltrate on-site. This is incredibly uncommon. Most sustainable parking lots implement several strategies to reduce, not eliminate, stormwater runoff since they can't accommodate constructed wetlands. But the including bioswales and pervious paving would considerably decrease the amount of pervious surface and increase the amount of on-site infiltration.

Case Study 3: Los Angeles Zoo

As part of a larger effort to remove pollutants and trash from water bodies around Los Angeles, the Zoo's main parking lot was extensively renovated in 2010. Prior to renovations, the parking lot covered 33 acres of impervious surface. It was prone to flooding and stormwater runoff brought pollutants directly into the Los Angeles River.

Improvements to the parking lot include bioswales, native plants, several permeable pavement systems and educational signage (Los Angeles Sanitation 2014).

The renovated lot drastically improved the site's ability to mitigate and treat stormwater. Figure 8.7 shows the

Figure 8.7. Bioswale Median [Gonzalez 2011]

bioswales that were introduced between many parking stalls (Los Angeles Sanitation 2014).

Bioretention cells surround most of the parking lot (Gonzalez 2011) and 11 percent of the surface area was converted into pervious surfaces using permeable pavers and pervious concrete. To use these strategies, the Los Angeles Zoo accepted a 10 percent reduction in parking stalls. However, improved traffic patterns and stormwater management were worth more to the Zoo Los Angeles Sanitation 2014). The design and construction of the 33-

acre site was around $14 million (Los Angeles Sanitation 2014).

The Los Angeles Zoo sets a great precedent for Frederick. It was a large, impervious surface as is the Golden Mile. Furthermore, it was a retrofit project that maintained existing boundaries while altering portions within the lot. It also provided educational opportunities, an interesting strategy that can be beneficial in the long term. A community that is educated on the issues is more likely to induce changes among themselves.

Case Study 4: Duke University's Sand Parking Garage

In 2010, Duke University opened the first LEED certified, stand-alone parking structure. The seven-story parking garage accommodates 2,000 cars and replaced a surface parking lot (Duke University). Given the proposed density of development in scenario three of the Golden Mile Small Area Plan, a parking garage seems plausible for the area (The City of Frederick 2013).

The garage (Figure 8.8) conserves energy and manages stormwater in a variety of ways. For example, the remaining 82 percent of land that used to be surface parking reforested and protected from future development. This drastically reduces the amount of impervious surface. The garage also manages stormwater in two 10,000-gallon cisterns that store rainwater until it can be used in the drip irrigation system for the vegetative trellises on the garage's walls and roof. At the base of the garage, rain gardens capture any remaining stormwater and manage it on-site (Duke University 2014).

Figure 8.8: Sands Parking Garage (Ratio Architects 2014)

Summary

Redesigning and retrofitting parking lots is an effective strategy for reducing stormwater runoff. Implementing bioswales, rain gardens, cisterns and pervious paving systems is shown to collect and treat stormwater on-site. In the long run, reducing the amount of runoff will improve water quality in nearby water bodies.

The retail area along Frederick's Golden Mile provides ample opportunities for retrofits. Carroll Creek, running just north of the area, is an ideal location to reduce the amount of impervious surfaces.

Chapter 9: Improving Infiltration through Bioretention Systems in High Impervious Landscapes

Nicholas Gilbert

Abstract

This section discusses the principles of bioretention systems, case studies, and how to use bioretention systems in the City of Frederick.

Introduction

Storm events can wreak havoc in an urban environment. Specifically, stormwater runoff, the excess water from a storm event that does not infiltrate into the soil, leads to a host of different water quality issues. It is particularly problematic in urban areas where water tends to carry significant levels of pollutants into local water bodies and moves at a high velocity that causes stream erosion, which in turn causes further reduced water quality. In addition, this erosion tends to reduce meanders in the stream, which causes the water to move even more quickly, further reducing local water quality.

These issues build on themselves as reduced water quality and erosive forces reduce or eliminate the vegetation along the streambed. This vegetation helps filter the water before it reaches the stream and keep the soil of the streambed in place. There are numerous ways to combat this cycle of water and ecosystem degradation in an urban environment, one of the most effective are bioretention systems.

Bioretention systems are areas that utilize certain vegetation (woody and herbaceous) and certain soils to slow down and remove pollutants from stormwater. They generally consist of vegetative (usually grass) strips around a graded ponding area, with a depressed center, that has woody and/or herbaceous plants on its surface. The ponding area profile consists of, from top to bottom, a small layer of mulch or organic material, a large layer of planting soil, and a sand bed to promote infiltration (Figure 9.1) (EPA 1999).

Bioretention areas are designed to maximize pollutant removal and reduce peak flow. Specifically, the design allows for increased retention time of the stormwater to facilitate pollutant removal using three mechanisms: soil adsorption, filtration, and biological uptake by vegetation and microorganisms. In addition, bioretention systems are designed to be effective at reducing erosion downstream, which would further increase pollution in the water body with excess nutrients and suspended solids.

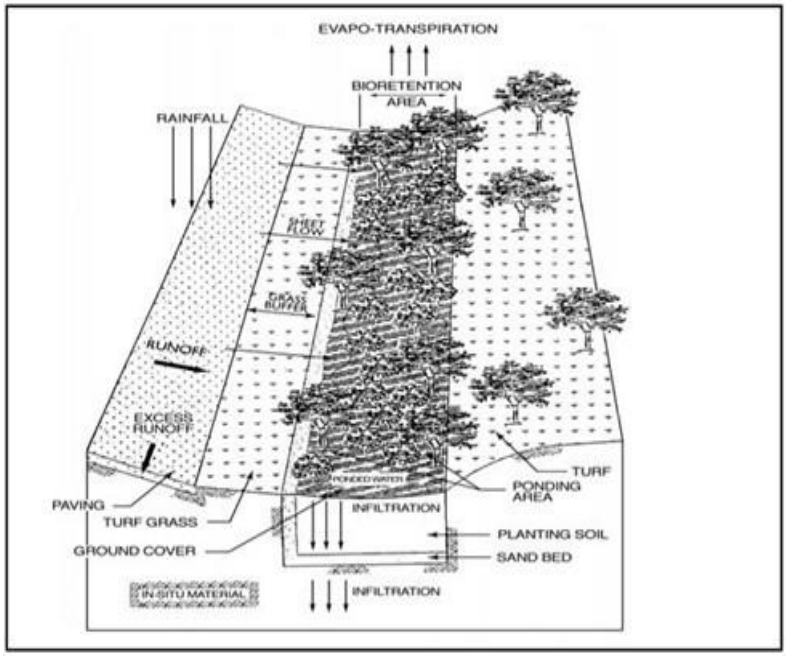

Figure 9.1. Diagram of simple bioretention system (EPA 1999)

There are many kinds of bioretention systems used for different functions and site considerations. Functionally defined systems fall into four major categories. The first include infiltration/recharge facilities (Figure 9.2), which are ideal for areas where significant groundwater recharge would be possible and beneficial. The in situ soils need to have a high infiltration rate as there is no underdrain and at least 2.5 feet of filter media to allow

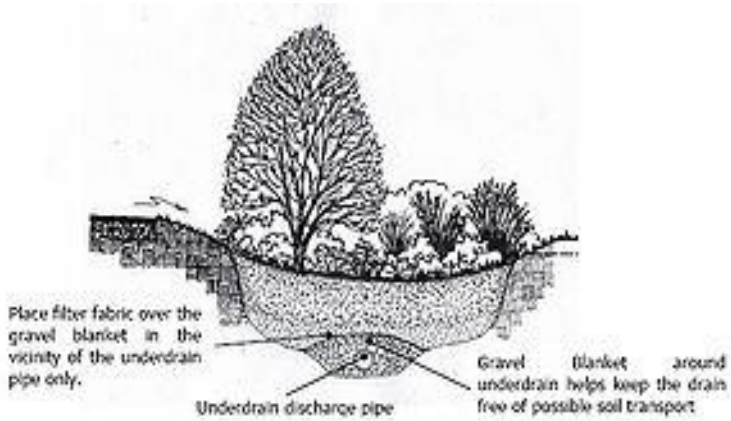

Figure 9.2. Infiltration/Recharge Facilities (MPCA 2014)

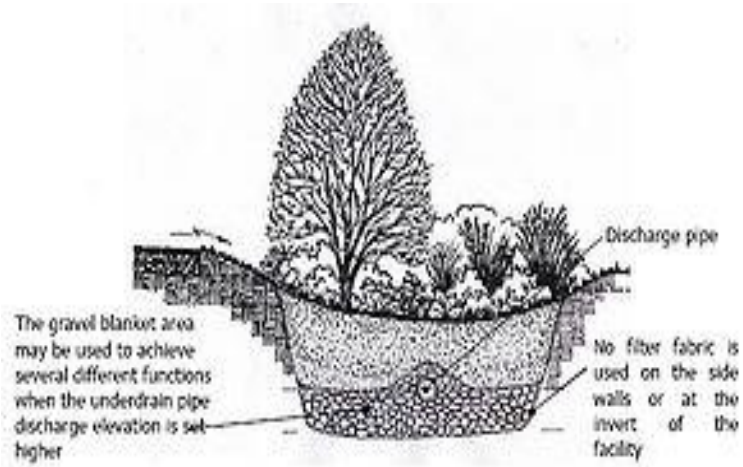

Figure 9.3. Filtration/partial recharge Facilities (MPCA 2014)

adequate filtration. This type of system is suitable for areas expected to generate nutrient runoff that can be infiltrated and captured by the facility. Next are the filtration/partial recharge facilities (Figure 9.3), which are ideal for areas where high infiltration and partial runoff recharge would be beneficial.

This design includes an underdrain in the planting soil mix and also is shallow (2.5 feet). This facility is recommended for areas with tight impermeable soils where infiltration is limited and with land uses expected to generate significant nutrient and metal loadings. Infiltration/filtration/recharge facilities (Figure 9.4) are intended for areas where higher nutrient loading is expected, especially for nitrate treatment. They include a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe to promote de-nitrification. Consequently, these facilities are recommended for residential communities and other areas high in nitrate loading.

Finally, filtration-only facilities (Figure 9.5) are ideal for stormwater hot spots such as gas stations, transfer sites, and transportation depots. They include an impervious liner designed to greatly reduce, if not eliminate, the possibility of groundwater contamination. This design also allows for blocking the underdrain and the siphoning materials through an observation well in the event of an accidental spill, an important for the sites where these facilities will likely be located (MDCA 2014).

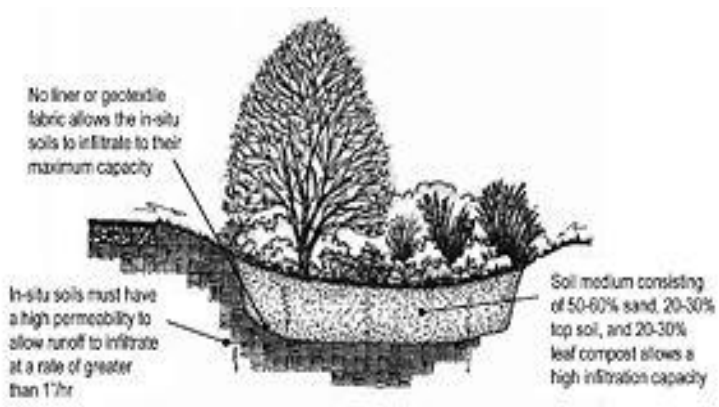

Figure 9.4. Infiltration/Filtration/Recharge Facilities (MPCA 2014)

In addition to considering bioretention systems by function, they can be categorized by their site location. First and foremost, are the simple on-lot bioretention systems designed to capture and treat runoff on-site, however they are very site dependent in their design. More importantly, there are other more urban-specific locations, including parking lot islands without curbs, and parking islands that are curb cut. In both cases, the parking lot must be relatively low in grade change while ideally guiding water toward the islands. In the curbless

islands, pre-cast car-stops should be installed along the pavement to protect the bioretention area. In locations with curbs, intentional cuts must be made into the curb and water directed into these cuts using an inlet deflector block. Their design should also consider erosion control and pre-treatment (Figure 9.6). It is also important to address “frost heave” in road medians and traffic islands by implementing a buffer along the outside curb perimeter. Alternatively, the installation of a geotextile filter fabric “curtain wall” along the perimeter will achieve the same effect.

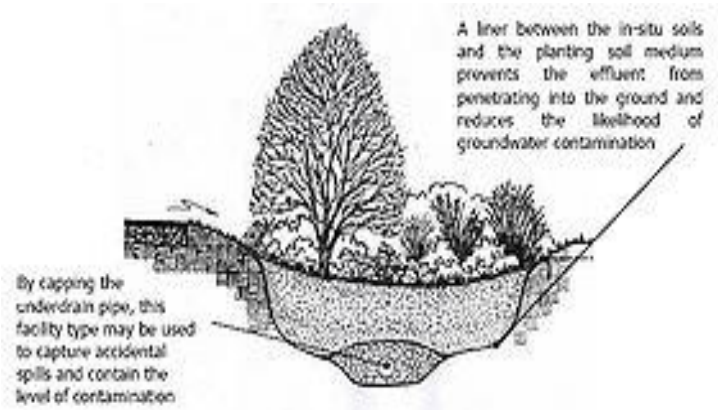

Figure 9.5. Filtration Only Facilities (MPCA 2014)

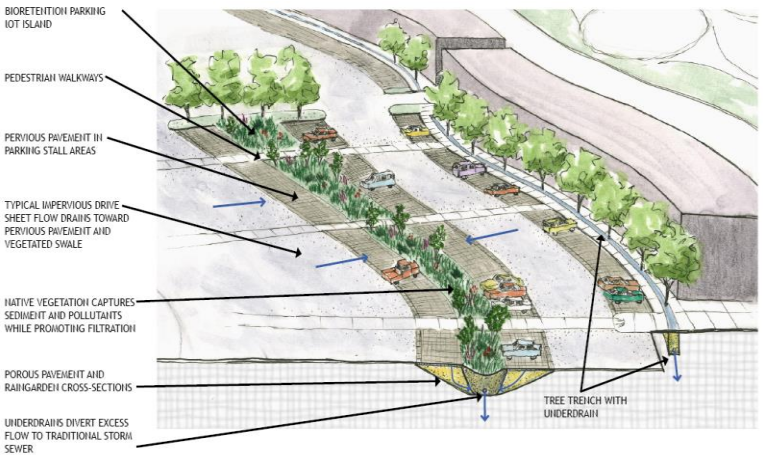

Figure 9.6. A bioretention parking lot island (MPCA 2014)

Finally, there is a range of tree pits and tree box filters (Figure 9.7), which can be for local drainage capture and retention, or can capture and treat runoff in highly urbanized streetscapes. Tree pit design consists of a depressed (at least 2-3 inches) mulch base around a tree that extends to the dripline. Tree box filters, are bioretention areas installed beneath trees and comprise a soil mixture, a mulch layer, under-drain system, and a shrub or a tree. The vegetation and soil remove some pollutants from the runoff before it enters a catch basin. The treated water flows out of the system through an underdrain connected to a storm drainpipe or it into the surrounding soil (MDCA 2014).

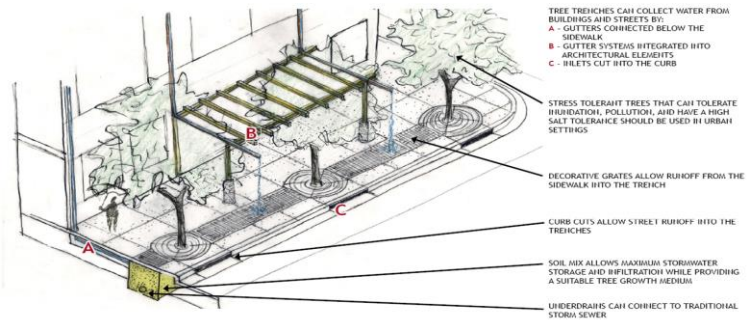

Figure 9.7. A tree box filter (MPCA 2014)

Case Studies

Charlotte, N.C.

This study compared nutrient and metal removal rates reported in current bioretention literature with a bioretention cell treating an institutional parking lot in an urban environment to determine how well the cell reduced the concentrations of fecal coliform and *E. coli.* and to examine how much peak flow was reduced by the cell. The study site was the Hal Marshal bioretention cell (HMBC) which is a retrofit BMP next to an asphalt parking area in Charlotte, North Carolina. The drainage area was 0.92 acres of an aging asphalt parking lot, which consistently appeared to be almost 100 percent used.

The HMBC was located between the parking area and an abandoned railroad line, with a steep gradient in between the cell and the railroad line. The bioretention area was constructed in winter 2003 and monitoring began in 2004, after the fill soil was replaced and a forebay and a single inlet chute with a weir were installed. In addition, the mulch and vegetation were replaced before monitoring took place. Charlotte's weather is, on average, warm and humid, with an average temperature of 61.4°F and an average annual precipitation of 43.64 inches.

This study measured storm events from February 2004 to March 2006, a total of 23 separate events. Water quality samples were taken from the stormwater's inflow into the cell and from the outflow.

The study found that the cell was very effective at reducing all parameters: bacteria levels, mitigating peak flows, and removing nitrogen and phosphorous species. The only area where the cell could have been improved was the inclusion of an internal water storage feature. As shown in studies conducted in 2005 and 2006, including this feature has helped remove nitrate-nitrite, the cell's only ineffective area (Hunt et. al 2008).

Greenbelt, MD

This study investigated and evaluated the removal of heavy metals in bioretention cells by evaluating the performance of existing field cells in Greenbelt, Maryland. Their performance was compared to created laboratory cells as a basis for understanding how effective the field cells truly were.

The laboratory bioretention cells were created first by filling both a smaller and a larger bioretention box with sandy loam soil and topped with a mulch layer of about 2.5 cm. Both boxes were filled with creeping juniper plants of six inches and 24 inches respectively, and both were built with polyvinyl chloride pipes at designated depths for water quality analysis.

In both the field and laboratory cells, a synthetic runoff was applied at the same rate for six hours at a time to determine their relative effectiveness. Flow rates out of the cells and their varying water qualities were measured at determined intervals.

The study found that these bioretention cells, both in field and in the laboratory, were very effective at removing metals from stormwater, although this effectiveness decreased if the cell is too shallow (<30cm). The metal removal rates were consistent throughout all cells despite variations in runoff pH, duration, intensity, and pollutant concentrations. However, the authors mentioned that for the health of the larger landscape, runoff bypassing the bioretention treatment cells must be minimized. The cells must be also maintained to avoid long-term accumulation of metals that compromise the cell's effectiveness (Davis 2003).

Tampa, FL

This study examined the effects small alterations to a parking lot on runoff water quality. The study targeted the Florida Aquarium parking lot in Tampa, Florida, which was altered to have asphalt areas with no swale (its original form), asphalt areas with a swale, cement areas with a swale, and pervious pavement with a swale.

For the study, the parking lot was redesigned with eight catch basins, two for each of the four different treatment options. Inflow water for each option was measured and compared to the outflow in the catch basins. Specifically, the amount of water and pollutants in it were measured before and after treatment.

The results showed numerous findings, most notably, that sectors with swales reduced runoff by about 30 percent compared to those without. Also, pervious pavement with a swale reduced runoff by about 50 percent compared to the lot's original form and 32 percent compared to the other areas with swales. Pervious pavement was also significantly more effective at removing metals and suspended solids than the original lot design. Nevertheless, pervious pavement with swales are not nearly as effective for larger storm events (when compared with the results from smaller storm events) and maintenance is important to limit sedimentation that accumulates relatively quickly and reduces overall effectiveness (Rushton 2001).

Summary

Bioretention cells have a relatively short history but have been proven as effective best management practice to reduce pollution and retain stormwater, particularly in urban environments.

Bioretention cells are consistently able to reduce nitrogen, phosphorous, metals, suspended solids from urban stormwater runoff. In addition, they provide temporary water storage in precipitation events, helping alleviate stress on local water bodies from high levels of nearby impervious surfaces. Bioretention systems can be implemented in numerous ways and designs, and have become an essential tool for improving local water bodies and water quality.

The City of Frederick could implement bioretention cells, particularly along the Golden Mile, to improve local water quality and reduce stream erosion.

Chapter 10: Reducing Nutrients via Source Reduction: Lawn Education Practices

Stephanie Treacy

Abstract

The overall health of the Carroll Creek water system is vital to The City of Frederick and its residents. With a 10-foot wide shared use path being discussed, reducing nutrient input into the system has taken on a new urgency. Transforming the Creek system and its environment starts by understanding a variety of behavioral issues including lawn installation and management. Through education, the Carroll Creek water system will be much healthier.

This section's proposals on best practices of lawn management and fertilizer reduction can be used by The City of Frederick to restore the health of the water system.

Fertilization

Fertilizers are a combination of nutrients that plants need to grow, primarily nitrogen, phosphorus, and potassium. Due to improper fertilization, these nutrients flow into water systems and pollute the water. For example, the Chesapeake Bay is vital to Maryland's economy and environment, but it has suffered a severe drop in water quality since the 1950s for a variety of reasons, but a key factor is the excess nutrients entering the water from fertilizer runoff (Felton 2013).

Although fertilizer runoff may not seem detrimental, these nutrients are coming from farm fields, public parks, golf courses, athletic fields, businesses and hundreds of thousands of urban and suburban lawns (Felton 2013). It adds up to about one million acres of land compared to the total 1.2 million acres of cultivated farmland in Maryland (Maryland Department of Agriculture 2013). This pollution in the water system is harmful on many levels. Fertilizers are designed to help plants grow; once in waterways they trigger the associated algae growth problems present in Carroll Creek. As more algae grows and spreads, it becomes harmful to the other aquatic life by consuming oxygen that other aquatic plants and animals need. Felton (2013) states that "the basic concept of timing is that fertilizer should not be applied unless either the shoots or the roots of the turf are actively growing." This means that fertilizer should not be applied in winter when the grass is dormant and in

summer if heat and lack of precipitation have combined to make the cool-season turf go dormant" (Felton 2013).

Inorganic Sources	Organic Sources
Ammonium nitrate	Alfalfa meal
Ammonium sulfate	Blood meal
Ammonium phosphate	Chilean nitrate
Diammonium phosphate (DAP)	Compost
Dimethylenetriurea (DMTU)	Cottonseed meal
Discyanodiamide (DCD)	Crab meal
Isobutylidene diurea (IBDU)	Gluten
Methylene Urea	Grass clippings
Methylenediurea (MDU)	Feather meal
Monoammonium phosphate (MAP)	Fish meal
Potassium nitrate	Manure
UAN (a solution of urea and ammonium nitrate)	Milorganite®
Urea	Soybean meal
Ureaform	
Urea-formaldehyde	

Figure 10.1. Common Sources of Nitrogen in Fertilizer (Felton 2013, p.23)

Maryland's Fertilizer Use Act

Maryland's Fertilizer Use Act of 2011, effective October 2013, is a vital strategy for reducing water pollution in the Bay, and by extension, all watershed systems in Maryland. Since 2001, restrictions have been enforced for farmers and larger farm care companies, but the State thought more extensive measures would improve the Bay's water quality (Maryland Department of Agriculture 2014). The Maryland Department of Agriculture (MDA) notes that 44 percent of the fertilizer sold in the State is lawn fertilizer, justifying the need for stricter controls on fertilizer. The new regulations stem from the U.S. Environmental Protection Agency's Watershed Implementation Plan that aims to stabilize and restore the Bay by 2025. The Plan highlights the Bay's Total Maximum Daily Load (the maximum amount of pollution that the Bay can intake and still meet the water quality standards) and created new nutrient and sediment reduction caps. The Fertilizer Use Act establishes new restrictions for fertilizer manufacturers and distributors, lawn care professionals, as well as individual homeowners. Professionals must go through the MDA's training program to be certified and licensed to practice. Because fertilizer use reaches beyond professionals for hire, individuals responsible for public parks, airports, athletic fields, businesses, cemeteries, golf courses and nonagricultural properties must also abide by these standards and be certified by MDA (Maryland Department of Agriculture 2013). To better communicate the expectations of homeowners, the law has set mandatory restrictions:

- Fertilizer that lands on sidewalks or driveways must be swept back onto the grass or cleaned up.
- Lawn fertilizer applications must be kept 10 to 15 feet from waterways.

- Fertilizer may not be used to de-ice walkways and driveways.
- Lawn fertilizer applications are banned between November 15 and March 1 and when heavy rain is predicted.
- Phosphorus may only be applied to lawns if soil test results indicate it is needed or when establishing, patching or renovating a lawn (Maryland Department of Agriculture 2013).

In addition to the professional standards required by the Fertilizer Use Act, there are requirements for the production of fertilizer. Product labels must include directions for proper use and an environmental use statement. Phosphorus is no longer permitted in fertilizer products unless specifically labeled as a starter fertilizer or an organic fertilizer product (Maryland Department of Agriculture 2013). The nitrogen in a product cannot be more than 0.9 pound of total nitrogen over a 1,000 square foot area. Some of this nitrogen must be in slow release form (Maryland Department of Agriculture 2013*Room*). The chart below shows main ways to reduce nitrogen in lawns, which will in turn reduce the amount of nutrients in waterways for better water quality.

- Correct soil pH, P, and K according to soil tests
- When establishing turf, improve soil conditions with the incorporation of organic matter
- Use recommended turfgrass species and cultivars
- Don't mow turfgrass too short
- Return clippings when mowing
- Don't try to grow turfgrass where it is not adapted, such as heavy shade or where there is severe tree root competition. Applying N will not help turf on these locations.
- Promote healthy root system through proper cultural practices.
- Established turf that is older than 10 years may require 30 to 50% less N fertilizer than younger turf.

Figure 10.2. Key Points for Long-term Reductions in Total Annual N Applications (Felton 2013, p.63)

Lawn Care Practices

Liming

"Liming" a lawn is the addition of pulverized limestone or chalk (Burke 2014). Liming acidic soils can raise pH, enhance the availability of necessary plant nutrients, supply calcium and magnesium for plant consumption, and lower the toxicity of substances in soil that restrict root growth, improve soil structure, and promote the growth of beneficial soil microorganisms (Felon 2013). Soil pH should not be raised above 6.8 to avoid negative effects. The MDA states that "Soils with different textures, but the same initial pH value, usually require different rates of lime applications. For example, a sandy loam soil with a pH of 5.5 may need 65 pounds of lime per 1,000 square feet, whereas a silt loam soil may need 150

pounds of lime" (Maryland Department of Agriculture 2014).

Nitrogen fertilizers add to the soil's acidity, so liming helps to balance the pH of soils. Just as different soils need different amounts of fertilizer and lime, they also hold onto the lime differently. Sandy soils have a balanced pH for about two to three years after initial liming, whereas soils with a finer texture maintain their pH soils for about three to four years. Since soils absorb the effects of liming for multiple years, it is excessive to apply lime yearly. The soil nutrients can be depleted and the lawn is more susceptible to root-infecting diseases. Soils must be tested prior to application to find the appropriate amount of lime needed (Burke 2014).

Mowing

"Low and infrequent mowing are perhaps the major causes of lawn deterioration" (Felton 2013). Mowing grass below three inches can have negative consequences on performance, health and appearance. When grass is cut too short, the plant puts stress on itself to create more top growth. This causes its roots to become less dense and too shallow, allowing more weeds to emerge. The MDA gives lawn owners advice on keeping healthy grass, stating:

> "When mowing, never remove more than 1/3 of the leaf surface at any time. For example, if the desired mowing height is 2.0 inches, do not allow turf to grow higher than 3.0 inches before mowing. By mowing to a height of 3.0 to 3.5 inches, broadleaf weeds can be reduced by 50 to 80 percent compared to turf mowed at a 2.0- inch height. Taller turf results in roots that are healthier and turf that is cooler. Finally, taller turf stays greener in the summer" (Maryland Department of Agriculture 2014).

Figure 10.3 shows the ideal mowing heights for grass in the Maryland area.

Turf Type	Spring and Summer (inches)	Autumn and Winter (inches)
Kentucky bluegrass	2.5 - 3.0	2.0
Perennial ryegrass	2.5 - 3.0	2.0
Tall fescue	2.5 - 3.0	3.0
Fine-leaf fescue	3.0 - 4.0	3.0
Zoysiagrass	0.5 - 1.0	0.5 - 1.5

Figure 10.3. Mowing height for Maryland turf (Felton 2013, p.28)

Grass Clippings

Grass clipping management is one of the easiest ways to maintain soil nutrients. Many people prefer the look of a "clean" lawn with the clippings removed, but residents must be informed of the benefits to their own lawns as well as to overall water quality by returning their grass clippings to the lawn. Areas where grass clippings were returned had more vigorous growth with about a 60 percent higher daily growth rate than areas with clippings removed. Nitrogen levels were greater in the soil with the clippings returned compared to the areas where the clippings were removed (Felton 2013).

Reducing Lawn Cover by Using Native Plants

The Natural Resources Defense Council is one of many organizations that stress the importance of native plants in lawns. "Native plants need less water, are more tolerant of drought conditions, cost less to maintain and provide habitat for birds and butterflies" (Natural Resources Defense Council 2012).

A benefit of using native plants is the reduced need of fertilizer. Native plants are naturally chemically balanced with the existing soils, so they don't need fertilizer, which reduces costs homeowners and stops nutrients from unnecessarily entering the waterways. In addition, native plants require fewer pesticides than lawn cover. The U.S. Environmental Protection Agency claims that "Nationally, over 70 million pounds of pesticides are applied to lawns each year. Pesticides run off lawns and can contaminate rivers and lakes. People and pets in contact with chemically treated lawns can be exposed to pesticides" (EPA 2013). The EPA goes on to show the significance of native plants by stating "The modern lawn requires significant amounts of water to thrive. In urban areas, lawn irrigation uses as much as 30 percent of the water consumption on the East Coast and up to 60 percent on the West Coast. Native plants can significantly reduce water runoff and, consequently, flooding" (Natural Resources Defense Council 2012). Native plants should be chosen over non-native plants in lawns, and should reduce the overall lawn cover.

Summary

This section outlines some of the principles regarding the implementation of Maryland's new fertilizer law. In addition, this section also suggests best practices for the proper fertilization of lawns.

Chapter 11: Riparian Forest Buffers: Implementation on Residential and Public Park Land

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Abstract

This chapter examines the role of riparian forests in addressing the eutrophication of Carroll Creek along with the potential for implementing riparian forests on residential and public parkland, and case studies from outside jurisdictions. Potential sites for future riparian reforestation on City parkland will also be presented.

Introduction

Enhanced forest riparian buffers represent an optimal, long-term approach to reducing the quantity of algae in Carroll Creek because both are due to be mandated by both The City of Frederick and Frederick County. The City's 2010 Comprehensive Plan Update refers to a balance between development and environmental resources, emphasizing several policies relevant to riparian forest buffers, including remediation of degraded areas, urban forest management and monitoring for BMP implementation (The City of Frederick 2010). Riparian buffers are also specifically mentioned in The City's codes and regulations (The City of Frederick 2014). Furthermore, Frederick County's 2012 Land Preservation, Parks and Recreation Plan highlights a comprehensive approach, including watershed protections and restoration (Frederick County 2012). Because they are already being considered in the long-term plans of The City and County, riparian forest buffers represent a practical approach to removing excess algae from Carroll Creek.

The History and Function of Buffers

Before extensive land development, forests covered 95 percent of the land in the State of Maryland (MDDNR 2014). Settlement, agricultural use and forest products harvesting have cleared much of that land several times over. Riparian forests were typically cut first in order to provide access to fresh water (Sweeney and Blaine 2007). Currently forests cover approximately 40 percent of the land in Maryland (MDDNR 2014). Nationwide, it is estimated that 19 percent of streams lack appropriate riparian vegetation (Sweeney and Blaine 2007). As for the Carroll Creek Watershed, the percentage of riparian buffer in poor condition will be discussed later in this chapter.

Until the 1980s, riparian buffers consisting of low-lying vegetation and grasses were considered sufficient to protect streams, based on studies showing that grass buffers could intercept between 10-85 percent of sediment and nutrients flowing into the streams (Wenger 1999). The problem with grass buffers, however, is that despite their ability to intercept nutrients, they lack some of the more important features a forested riparian area has in fostering a healthy ecosystem.

Ecosystem Services

In addition to nutrient interception and processing, riparian forests contribute a variety of ecosystem services that benefit the streams, wildlife, and ultimately humans. These benefits include their ability to intercept non-point pollution. Among the sources of pollution are excess nitrogen, phosphorus and sediments. A fully functioning forested ecosystem can support "sheet flow," spreading out the flow of polluted stormwater, thus increasing the potential for it to infiltrate. This is preferable channelized stormwater, when rain, unable to infiltrate an impervious surface, flows with high velocity and energy leading to surface and stream bank erosion. Forests, in addition to stabilizing soils with their extensive root structure, provide another benefit by minimizing surface runoff. Forests also help modify stream temperature fluctuations (Horner 2014). Trees along the stream provide shade, helping reduce high temperature extremes in summer (Allan and Castillo 2007). Wildlife, including macroinvertebrates sensitive to temperature fluctuations, benefit from the modifying effect of trees. For these small organisms, and much of wildlife in general, riparian forests provide food and habitat. Simply put, the more biological activity that a stream can support, the greater the processing and cycling of nutrients (Sweeney, et al. 2004).

Buffer Effectiveness

The ability of riparian buffers, in particular riparian forest buffers, to effectively slow runoff and absorb nutrients before entering the stream depends on a few variables: slope, soil type and existing vegetation. The degree to which the land slopes down to the stream can influence how fast water flows. The steeper the slope, the faster the flow, necessitating a larger buffer width to process the nutrients. Buffer effectiveness is also influenced by soil type. More porous soils can infiltrate runoff more effectively. Soils that don't infiltrate water as readily will require a wider buffer zone. Finally, the type of vegetation that exists on the slope can influence runoff interception. All of these variables directly influence how wide a buffer must be to successfully intercept nutrients.

In addition to intercepting nutrients, riparian forests can positively affect the stream ecology by offering a variety

of ecosystem services. While buffer widths of approximately 100 feet have been shown to effectively retain nutrients, larger widths would be required to control sediment and provide habitat corridors for wildlife.

Providing habitat for a diverse array of wildlife is just as important for stream quality as intercepting nutrients before they reach the stream. Higher biodiversity and the presence of organisms found within the stream system are associated with greater nutrient processing within the stream (Sweeney, et al. 2004). Studies have also shown that riparian forest buffers act to shorten the nutrient uptake length within a stream. In other words, they prevent nutrients from traveling farther downstream before they are processed by slowing down water flow and increasing retention (Weigelhofer et.al. 2012). “When riparian buffers are forested, the adjacent water body’s aquatic community processes and consumes watershed “stuff” – detritus that includes nutrients, sediment, organic matter, and other material that washes in from the watershed” (Horner 2014). A buffer’s width not only affects how many nutrients are intercepted before reaching the stream, but how well nutrients are processed within the stream itself.

While the width of a riparian forest buffer can directly affect the nutrient input into a stream, as well as the processing of those nutrients, buffer widths should also be considered in relation to stream order type within the whole watershed. Nationwide, it is estimated that the headwaters of a watershed, where smaller, first order streams begin as the capillaries of the river system, make up approximately 80 percent of the stream network (Meyer, et al., 2003). It is here that the interaction between stream and land plays an essential role in ecological processes that protect the waters downstream (Horner, 2014). By processing nutrients and preventing sediments upstream, appropriately buffered small streams of the headwaters prevent the concentration and accumulation of such pollutants downstream. In fact, “buffering low order streams (1st, 2nd and 3rd) has greater positive influence on water quality than wider buffers on portions of larger order streams already carrying polluted water” (Hawes and Smith 2005). Within the Carroll Creek Watershed, it should be expected that implementing riparian forests along much of the headwaters will mitigate eutrophication within Carroll Creek Linear Park.

Buffers are most effective when four conditions are met. First, they must be protected from encroaching development. Nearby impervious surfaces, by increasing and subsequently channelizing surface flow, interfere with the buffer’s ability to effectively intercept runoff.

Second, when designing buffers, the wider the buffer, the greater the service it provides. The more riparian forest there is, the greater the ability of the buffer to regulate and prevent disturbances to the stream ecology.

A third point to consider is that riparian buffers must be forested, as opposed to being simply grass or low-lying vegetation. Riparian forests provide more ecosystem services to the stream compared to grass.

Finally, riparian forests are most effective in the headwaters of the watershed. Like capillaries in the human vascular system, first order streams are often the most extensive part of the watershed and are more sensitive to disturbances.

Riparian Buffers on Residential Land use

Much of the land use adjacent to Carroll Creek and its headwaters are low- to medium-density residential properties, meaning the City does not have direct access to it for tree planting. Therefore, any tree planting efforts on the riparian areas of these properties will need to involve the homeowners, who will be largely responsible for tree acquisition, planting and maintenance. In addition, the small size of these residential lots relative to large agricultural lots precludes certain approaches that require several acres of land. In spite of these challenges, it is crucial to watershed health to include private residential lands in riparian buffer restoration efforts and it is imperative to encourage the participation of urban residents.

Examples from other cities and counties throughout the country reinforce this notion, but also demonstrate how this challenge is really an opportunity to create a more sustainable riparian buffer restoration initiative. This section describes the methods The City of Frederick can use to enhance riparian forest buffers on residential property and provides several examples of their application. Using this information, The City, in collaboration with the County, can create opportunities for residents to be directly involved in restoring the health of Carroll Creek Watershed by planting trees on the riparian areas of their properties. Participation at this level will produce a more complete and lasting buffer restoration effort and generate more robust public support for future riparian reforestation projects.

The case studies use a variety of methods to generate public involvement in riparian tree planting. The methods fall on a continuum of municipal regulation, with tree planting and protection mandated, incentivized or

encouraged by the municipality. Any of these approaches can be successful if done properly.

Zoning Ordinances

In many cases, municipalities and counties have used riparian buffer zoning ordinances to protect riparian forest from development. Wenger and Fowler (2000) describe how to properly establish a riparian buffer zone based on a survey of communities that have adopted them. They describe two types of riparian buffer zones: independent zones and overlay zones. While several of their examples use independent zones, an overlay zone can be used without changing the overall zoning map. Rather, it creates an additional set of restrictions applied to the land. Overlay zones in Douglas, Fulton and Madison Counties in Georgia all include restrictions on future development, the placement of septic tanks and the building of impervious surfaces within a stated distance of the stream bank that ranges from 25 to 100 feet depending on the size of the stream (Wenger and Fowler 2000). The City of Frederick would need to adapt this approach to the smaller scale of residential properties, where there is unlikely to be major future development and where the streams in question are of low order and potentially ephemeral. Buffer zones would likely only need to extend 15 to 25 feet from each bank of the stream (Palone and Todd 1998). The overlay could impose basic restrictions such as mowing, tree removal and fertilizer prohibitions to allow a natural buffer to generate. Requiring tree plantings of a specific density on tree-less areas would enhance the function and aesthetics of the buffer. Wenger and Fowler (2000) recommend clear definitions of the buffer's area, its use restrictions and its vegetation requirements. It is crucial to avoid imposing unnecessarily harsh restrictions on residents, as curbing too much of the property and limiting economic use without just cause could be grounds for a takings lawsuit (Wenger and Fowler 2000). As a guide, Wenger and Fowler (2000) include a model riparian buffer ordinance written as an overlay zone.

Residents may not react favorably to restrictions on the use of their property. However, a buffer ordinance would ensure that established riparian buffers are maintained, even after properties are transferred to new owners. Additionally, Wenger and Fowler's survey results (2000) indicate that overall, riparian buffer ordinances are well accepted by residents especially when they are involved in the ordinance development process from the beginning. Establishing a relationship with the general public based on open communication is the foundation for any successful approach to riparian buffer establishment.

Financial Incentives

There are also numerous financial incentives that the City can use to encourage residents to create and maintain forest riparian buffers on their properties, rather than mandating it with an ordinance. Many states, including Maryland, offer tax incentives for landowners who establish or preserve riparian forests on their properties. The Maryland Department of Natural Resources Forest Service manages several of these programs. In the Forest Conservation and Management Program, the landowner agrees to a management plan prepared by Maryland DNR in exchange for a reduced or delayed property tax assessment. In the Income Tax Modification Program, landowners can deduct double the cost of timber stand improvement from their taxable income as long as the forest can be managed for timber production. In the Woodland Incentive Program, landowners can be reimbursed up to 65 percent of the cost of reforestation and forest management practices (Maryland DNR Forest Service 2014). All of these programs see strong participation each year, but they are limited to landowners with at least several acres of continuous forest on their properties. Another limitation is that they are nullified if the property is transferred to a new owner. Frederick could use these types of programs as a model for a smaller scale program that targets residential property owners, who do not have the space for acres of forest. If a forest buffer already exists, the homeowner could receive a reduced property tax assessment for agreeing to maintain it. If trees need to be planted, the City could share the cost of building the buffer, or could make those expenditures tax deductible. Incentives may be more attractive to residents than an ordinance, because it empowers them to protect the health of Carroll Creek. This approach has been shown to be highly effective in Baltimore County, where the Department of Environmental Protection and Resource Management (DEPRM) emphasized the importance of engaging and empowering the property owners.

Creating a Holistic View of Forest Management: Baltimore County Case Study

The foundation for success in Baltimore County is its adoption of the Montreal Process Criteria and Indicators, a structural framework that helped organize the diverse interests in forest resource management into a holistic view by forming a stakeholder committee comprising representatives of government agencies, businesses, environmental groups, academic institutions and private citizens. Together they drafted forest management strategy for the entire county (Hart and Coelho 2007).

This led to the implementation of two programs: the Rural Residential Stewardship Initiative and the Valleys

Reforestation Initiative. Both of these programs targeted rural residential property owners whose lands offered forest management opportunities. The key to the success of these programs is the personal attention each landowner received. Baltimore County DEPRM teamed up with local organizations like the Gunpowder Valley Conservancy and the Valleys Planning Council to request meetings with residents. They established group meetings with neighbors in their homes and conducted "walk and talk" meetings on the properties (Outen 2010). By personally engaging residents from the beginning, Baltimore County DEPRM reduced the stigma against government programs and put the power of forest conservation in the hands of the property owners. They also made sure to maintain the dialogue with residents by following up with them after trees were planted (Outen 2010). This type of partnership demonstrates the importance of empowering the public in forest conservation by educating them on opportunities and including them in the process. Like the tax examples, the projects in Baltimore County focus on larger properties where several acres of forest can be planted, but The City of Frederick can apply the core principles of open dialogue and resident empowerment to important lots along the tributaries to Carroll Creek. By focusing on smaller riparian areas, the costs of acquiring and planting trees might be much less than those in Baltimore County. However, like the Baltimore County DEPRM, The City of Frederick and Frederick County can apply for federal grant funding and use fee-in-lieu funds to sponsor planting projects (Outen 2010).

A similar effort is underway in The City of Vancouver, British Columbia, which is trying to become the greenest city in the world by the year 2020. The city's plan includes expanding urban green spaces by planting 150,000 new trees, including 54,000 on private property. To aid in implementation, The Vancouver Board of Parks and Recreation solicited the help of the Greenest City Scholars Program, a partnership between The City of Vancouver and The University of British Columbia. A subsequent report by a graduate student at the university summarized lessons learned from residential tree planting programs in New York, Portland, Toronto and Los Angeles (Hsieh 2012). Many of the recommendations parallel those from Baltimore County, namely, promoting community engagement using local organizations, door-to-door canvassing and community events. Other important considerations include acknowledging the socio-economic capabilities of residents, providing clear and accessible planting and maintenance instructions, providing multiple avenues for donor contributions and considering residents' preferences in tree types (i.e. native species and fruit

trees). He also recommends monitoring planting efforts to evaluate the success of any program.

The City of Frederick is already in the position to meet some of these criteria. There are existing programs in Maryland that offer free and discount trees to residents for the purpose of enhancing riparian forest buffers. The Backyard Buffers Program is sponsored by the Potomac Watershed Partnership in conjunction with the Maryland DNR Forest Service, Frederick County and the Monocacy and Catoctin Watershed Alliance. Each year the program accepts applications for a free "buffer in a bag" that are distributed in the spring. Each bag includes 20-30 native tree and shrub seedlings, along with fact sheets and instructions for proper planting and maintenance. To apply, residents of The City of Frederick should contact the Maryland DNR Forest Service (Maryland DNR Forest Service 2007). The State also offers the Marylanders Plant Trees Program, which provides a $25 coupon that can be used toward the purchase of a tree at participating nurseries in Maryland, including one in The City of Frederick (The State of Maryland 2014). The City can inform residents about these low cost opportunities, and again put the power of restoring the health of Carroll Creek Watershed in their hands.

Promoting the Benefits of Trees

To further encourage residents to plant trees on their properties, The City of Frederick should highlight the economic benefits of riparian buffer trees. Studies indicate that riparian buffers generally increase the value of nearby properties, although those properties directly affected by the buffer may see a slight decrease in value if the buffer reduces the amount of usable land (Wenger and Fowler 2000). However, Bin et al. (2008) found no evidence that implementing a mandatory buffer rule in North Carolina impacted property values. Studies on the impacts of urban trees on property values show that a planting a single tree on a residential property increases its value (Donovan and Butry 2010; 2011). This bodes well for residential properties in the City that are too small for agriculture, but are well suited for riparian tree plantings. Additionally, certain tree or shrub species can be planted that also produce nut or berry crops. These benefits are not insignificant. To promote them, the City should encourage its residents to use the Tree Benefit Calculator (http://trees.maryland.gov/calculate-your-benefits/), developed as part of the Marylanders Plant Trees Program. The calculator generates specific annual benefits based on property location, the number of trees and the size and species of the trees.

Encouraging Homeowner Participation through Competition

A more novel strategy that The City of Frederick could use to encourage its residents to plant trees on the riparian areas of their property is competition. People are naturally competitive with friends and neighbors over many issues, including home landscaping and gardening. The City could encourage residents to direct their competitive nature toward planting trees. A great example is the Texas Urban Forestry Council's 2013 Arbor Day Tree Planting Competition. Volunteer teams of eleven competed to record the fastest time for planting 100 trees. In total, 130 volunteers planted 1,300 trees in a Houston area stormwater detention basin in approximately two and a half hours (The Potpourri 2013). Organizing a community event centered on planting trees in needed areas would be an efficient, informative and fun way to restore the health of Carroll Creek.

The Philadelphia City Department of Recreation and Parks (PCDRP) created a more individualized competition in its TreePhilly Program. They solicited the community for short stories describing a personal experience with a tree, and the best story was awarded $300 gift card to a local garden center (PCDRP 2014). Although the stories weren't required to describe a tree planting experience, The City of Frederick could create a competition that does just that, by emphasizing the planting of trees in riparian areas. The TreePhilly program attracted over one hundred stories with just a modest prize, indicating that the competitive spirit of residents can be a significant motivator.

Implementing Buffers on Agricultural Land

Within the Carroll Creek Watershed, about 21 percent of the land use is made up of farms and agricultural land. Agricultural buffers are intended to provide space for typical farming practices to continue even when development occurs in or near farm operations. Strategically placed buffer strips in an agricultural landscape can effectively mitigate the movement of sediment, nutrients, and pesticides within farm fields and from farm fields. Balancing continued agricultural practices with the desire to develop land can be challenging, but open space buffers between active

	Effective Width of Buffer (in feet)							
Author	**Aqu**	**Terrestrial**	**Stream Tem**	**Litter/Debris**	**Nutri**	**Sediment**	**Bank Stabilization**	**Pesticci**
Wenger 1999		220-574 ft	33 – 98 ft.	50 ft.	50 – 100 ft.	82 – 328 ft	–	> 49 ft.
Army Corps 1991	98 ft.	30 – 656 ft.	33 – 66 ft.	66-102 ft.	52 – 164 ft.	33 – 148 ft.	49 – 98 ft.	49 – 328 ft.
Fisher and Fischenich 2000	> 98 ft.	98-1,640 ft.	–	10 – 33 ft.	16.4-98 ft.	30-200 ft.	30 -66 ft.	–
Broadmeadow and Nisbet 2004	33 – 164 ft.	–	49 – 230 ft.	82 – 328 ft.	16.4-98 ft.	49 – 213 ft.	–	–

Figure 11.1. Estimated buffer widths reviewed from the scientific literature (Hawes and Smith 2005).

agricultural areas and other uses can help reduce land use conflicts.

Buffers are generally imposed on residential developments, rather than on farming operations, since the farm was probably the initial land use. However, buffers should be sufficiently wide to protect children from farming operations and other conflicts but not so burdensome as to require excessive land commitments from residential property owners. Buffers are most effective if a "no-disturb" zone is provided between residential properties and farmland. This requirement should be tied to subdivision, site condominium development, planned unit development, and land division approval. Buffers must also be described in the property deed to alert potential buyers of the need to honor the no-disturb area.

In particular, conservation buffers offer social and environmental benefits in agricultural lands. Conservation buffers are small areas or strips of land in permanent vegetation, designed to intercept pollutants. A range of buffers (Figure 11.1) have been documented. Conservation buffers slow water runoff, trap sediment, and enhance infiltration within the buffer. They also trap fertilizers, pesticides, pathogens, and heavy metals. In addition, conservation buffers also help trap snow and cut down on blowing soil in areas with strong winds, and protect livestock and wildlife from harsh weather and protect buildings from wind damage.

If well placed and properly installed and maintained, buffers can to remove up to 50 percent or more of nutrients and pesticides, 60 percent or more of certain

pathogens and 75 percent or more of sediment in the stream. Conservation buffers help stabilize a stream and reduce its water temperature and also offer a setback distance for agricultural chemical use from water sources. When coupled with appropriate upland treatments, including crop residue management, nutrient management, integrated pest management, winter cover crops, and similar management practices and technologies, buffer strips should allow farmers to achieve a measure of economic and environmental sustainability in their operations. They can also enhance wildlife habitat and protect biodiversity.

Conservation buffers work economically with the help of financial incentives available through USDA conservation programs—the continuous Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentives Program (WHIP), Wetlands Reserve Program (WRP), and Conservation Stewardship Program (CSP).

Riparian Buffers on Public Parkland

This section is concerned with identifying potential buffer installations in public parkland. Case studies of successful riparian reforestation projects within public lands are also examined.

To identify possible sites for riparian forest buffers within the Carroll Creek Watershed, it was necessary to identify the most inadequately buffered sites. A 2000 Stream Corridor Assessment for Rock and Carroll Creeks was consulted. In it, the authors identified 56 sites with inadequate buffers along the stream system (Rice and Yetman 2000). These sites were then ordered according to land use type: residential, agricultural, and public parkland. The sites were imported into Google Maps, which allowed for navigability and ease of searching. Additional sites were investigated by desktop survey along the Carroll Creek Watershed.

The City of Frederick's Parks and Recreation Department is responsible for over 1,000 acres of open space, floodplains, and right-of-ways (The City of Frederick Planning Department 2010). It maintains over 670 acres of parks, of which a high percentage of the grass is mowed on a 7-10 day schedule to within a height of two to three inches (Parks Division 2014). This presents an opportunity to reconsider vegetation management in these areas, especially lands near riparian areas. Indeed, the City has already identified these sites as good candidates for riparian forest restoration: Clover Ridge, Waterford Park, Carroll Creek/Baker Park(I-III), Willowbrook, Old Camp Park, Rivermist, the Career and Technology Center, and the Fredericktowne Village Park

(The City of Frederick 2012). Some of these sites are already undergoing riparian reforestation.

Other Potential Sites

Whittier Lake Park is located in the headwaters of the Carroll Creek Watershed. It is classified as a recreational area and is surrounded on all sides by mowed turf. Not only is there no riparian forest, but the cultivation of the surrounding turf invites a resident population of Canada Geese. These geese contribute fecal waste and nutrients directly into the stream system. To effectively manage them, it is suggested that vegetative cover 30 inches in height be established in order to disrupt their sightlines (Smith, Craven, and Curtis 1999). Also, any tall trees surrounding the water's edge may disrupt their landing pattern, thus discouraging their use of the lake. Not only will tree cover discourage any geese from using the shorelines, but it will help to establish a successful riparian forest that can help mitigate nutrient runoff into the lake, as well as provide valuable services to human beings in the park, namely shade and enhanced greenery. As mentioned before, even tall grassy vegetation will provide buffering services while at the same time discouraging geese from nesting. Whittier Lake Park has the potential to be a showcase site of best management practices for riparian forest areas. It is highly visible and its amenity pond attracts dog walkers and pedestrians to its walking trails. If the quality of the waters feeding the pond are improved, it may even be suitable for water activities.

Stonegate Park is another can also potentially accommodate riparian forest restoration. The park's northeast side, adjacent to the baseball field, among other areas, has a narrowly vegetated strip of riparian forest that could be increased to at least the standard width of 100 feet.

Walnut Ridge Park has already been identified by the City as a potential site for buffer restoration. In fact, progress is underway to establish four acres of riparian forest in this parkland.

There is another section of city-owned parkland, six acres off of Rocky Springs Road (Department of Assessments and Taxation 2014). The site includes a large catchment that drains to the Creek. This catchment may be considered for an upgrade to a more highly forested and greener piece of infrastructure. Along the Creek presents an opportunity to reforest within the eastern part of the city-owned parcel.

Willowdale Park could also be considered for riparian forest buffer restoration. This parcel of city-owned

property starting at Key Parkway and moving northeast to the tennis court shows areas that lack canopy cover within 50 feet of Carroll Creek.

Case Studies

The following case studies demonstrate the types of riparian forest restoration projects other jurisdictions have undertaken.

The Temple-Villanova Sustainable Stormwater Initiative is a partnership between two universities to facilitate the study and implementation of best practices for stormwater management, developing sustainable initiatives, and improving public health. Under their sponsorship, local jurisdictions in Pennsylvania have been able to transform publicly owned land into more ecologically responsive landscapes.

In Montgomery County, Pennsylvania, the township of White Marsh worked in conjunction with the local school district and a consultant to restore a degraded creek within McCarthy Park. In addition to renovating the stream and clearing out non-native vegetation, they installed a riparian forest buffer. The project includes interpretive signage to educate the public about the project's environmental benefits. Over two acres of parkland were restored at a cost of approximately $60,000 (McCarthy Park Riparian Buffer Restoration 2009).

Miles Park, also located in White Marsh, is considered that township's premier park. A drainage ditch running through the park had caused significant erosion, so the White Marsh Environmental Advisory Board undertook efforts to restore it. This highly visible project was designed to manage stormwater and stabilize the stream bank. Members of the EAB completed the first phase of the project, including installing 2,500 native plants at a cost of $7,000 (Miles Park Riparian Buffer Restoration 2009).

Summary

The establishment of riparian forests represents an opportunity to address the excessive nutrient flow into the Carroll Creek Watershed, which has culminated in the algal blooms within the Carroll Creek Park. Given the ecological sensitivity and importance of the low order headwater streams, it may be a worthwhile option to establish overlay zones of increased buffer width to the maximum extent practicable along these headwater stream corridors. A review of the data shows that, just for addressing nutrient interception, a buffer width up to 164 feet may be necessary. Wider buffer widths would be necessary for the riparian forest to successfully offer a

full spectrum of ecosystem services. In addition to interception, an ecologically balanced stream can further process nutrients in-stream. Thus, to control sediments, modify stream temperatures, and support terrestrial life, buffer widths up to several hundred feet may be necessary.

The importance of buffers to the ecosystem in general, and to the potential remediation of eutrophication within the Carroll Creek Watershed, was considered. North American examples demonstrate how crucial it is to engage residents in any tree planting effort. Doing so in diverse and creative ways allows these residents to maximize their potential as stewards of riparian forest buffers. The establishment of riparian forest buffers on residential land and public parkland was also examined. A few city-owned properties were exhibited for potential suitability for buffer restoration.

Chapter 12: Establishing a Carroll Creek Watershed Advocacy Group

Yulithia Godley

Abstract

The creation of an advocacy group will promote better stewardship and responsibility within the community. The creation of an advocacy group will promote better stewardship and responsibility within the community Methods to begin an advocacy group, case studies of successful groups, and a proposal for the City are discussed.

Introduction

It's not surprising that the overall health of the Carroll Creek Canal system is important to the City of Frederick, its businesses, and residents. Involving the community in restoring and maintaining the water system will relieve the City of some of the burden of this task. Asking the community to be stewards of the Carroll Creek Canal system will give a sense of ownership and pride. The community will feel that the City is genuinely concerned about their input, which will foster a lasting relationship.

Given the planned construction of a 10-foot shared use route path, the implementation of a watershed and canal restoration and maintenance program takes on a new urgency. Beginning such a program now will ensure that the Carroll Creek Canal system is at its healthiest when the path opens. Providing a picturesque park setting along the shared use path and an improved canal appearance will help attract businesses, residents, and visitors, boosting the City's downtown economy.

Establishing an effective advocacy group depends on community involvement, well-defined roles, education programs, a solid budget with opportunities to increase funding, a thorough implementation program, a management program with benchmark dates, and a willingness to take advantage of social media to help carry the message of preserving the Carroll Creek Canal system.

Community Involvement

Community-based advocacy groups can work to restore and preserve the Carroll Creek Canal system. The development of a strong advocacy group is vital to restoring and protecting the Carroll Creek Canal system. Inviting the local homeowner, seasoned gardener, nursery owner, or landscaping company, etc. to have an input on how Carroll Creek should progress fosters a

sense of ownership. Much like the “Adopt A Highway” program, the City can ask residents to adopt the Carroll Creek Canal. Creating this community stewardship will benefit the canal’s overall health. Oftentimes the biggest challenge is how to go about creating and organizing the efforts to support an advocacy group.

Defined Roles

An effective advocacy group comes from the collaboration of people with diverse skills, reflecting a multitude of professional disciplines, and experiences to form the core team or committee. This team should include local government planners, engineers, wetland scientists, hydrologists, water quality experts, educators, private homeowners and gardeners, landscape architects, and consultants (Center for Watershed Protection 2005).

These individuals will play different roles in the planning process. Subcommittees may be developed to address the Canal’s issues.

For example, an important sub-committee for Carroll Creek would be one that examines Total Maximum Daily Load (TMDL).

Collaborating with other advocacy groups along the Monocacy River Watershed system, and groups outside the system, would allow for work sharing and assist with information to provide a basis for the recommendations in the Carroll Creek Canal system. Other team priorities that will need to be addressed are how often the team should meet to effectively set an agenda with attainable benchmarks.

Education

Education provides social benefits to individuals and to society as a large. Education provides a way for one to take better care of oneself, while providing a better environment and, ultimately, benefiting society (Kidwai 2014). A Carroll Creek education program should seek to overcome any misunderstandings or lack of information the community may have about pollution in the Creek. Keeping the community up to speed on the progress of the Carroll Creek Canal system will generate long-term community involvement.

One educational approach might be addressing the community’s awareness of pathogens that affect the health of the Carroll Creek Canal system, and the health of the community and its pets. This is a great way to get people to think about products they use in their homes. Building a strong constituency and awareness in the

community will assist the fundraising aspect of the advocacy group.

Fundraising and Budgeting

Advocacy groups are often plagued by a lack of funding for projects that meet benchmark dates. Costs include project development, consultant fees, and basic operations (e.g., rent, lights, etc.). Fundraising is necessary when donations fall short.

A solid fundraising strategy will help the Carroll Creak Canal Advocacy Group to achieve its purpose. A well thought out strategy will reduce financial risk and time wasted. Fundraising has benefits revenue generation. It bestows a sense of pride and ownership, thus giving a feeling of empowerment. Fundraising is also a great way to engage younger audiences, who are more likely to carry the message into adulthood. Another major benefit is creating self-esteem and self-worth in younger residents as a result of learning to help others or participate in a cause (AKG Media, LLC 2008). Another important factor, one that will ensure the advocacy's group longevity, is an effective budget plan. It is a vital tool in prioritizing and monitoring spending (Duke University 2014). A strong budget lessens stress, makes money flow predictable, and helps identify wasteful spending. From the beginning, the budget needs to reflect the group's mission, projects, and plan.

Implementation

Before implementation, a project size and time frame must be identified. One of the major contributors to project failure is taking on a task that is too large (FAO 2004). A project manager and team are essential to the successful outcome of a project (Richards 2014).

Getting started is simple when tasks are identified as manageable parts; identifying all the tasks required to meet the project's objective. This includes funding and budget requirements, risk analysis, human resources, training plans, and any software programs and hardware to assist with keeping on track (FAO 2004). Also, these tasks should be clearly assigned to individuals or groups, with a feasible time frame for completion (FAO 2004).

Social Media

"But one of the best things about social media is the way it can unite people behind causes and be a force for good. Its immediacy and accessibility has allowed it to contribute to everything from the Arab Spring to animal conservation." - Richard Branson (2014)

The far-reaching hand of social media has become essential to marketing success. But it requires commitment, strategizing, evolving insight, eye-catching content, and genuine engagement (Romeri2014). "Social media is here to stay." (Soskey 2013). Soskey (2013) highlights eighteen social media techniques and its marketing statistics.

These techniques are not just applied to for-profit businesses. An effective advocacy group will market when it comes to fundraising and recruiting. These techniques can be applied to the mission of the Carroll Creek Advocacy group and reach people beyond the City of Frederick boundaries.

Case Studies

Friends of Baker Park, Inc., Frederick, MD

Citizens of Frederick founded The Friends of Baker Park 75 years ago as a non-profit, volunteer-staffed group dedicated to preservation, restoration, use and maintenance of Baker Park (Friends of Baker Park 2014). Over the years, the group has successfully implemented programs for park benches, planting and weeding, public education, and holiday park decoration. New and upcoming projects are found under the "Events" tab on their website. Carroll Creek is near Baker Park and the Carroll Creek Canal Advocacy group can benefit from the experience and knowledge of Friends of Baker Park on establishing and maintaining a community based stewardship.

Spa Creek Conservancy, Annapolis, MD

Spa Creek Conservancy is a volunteer organization dedicated to the stewardship of the Spa Creek Watershed through education, preservation, mitigation, and restoration (Spa Creek Conservancy 2014). The Spa Creek Conservancy outlines its goals on its website: to clean up the headwaters of the Severn River, educate the public about the link between human lifestyles and the health of the creek, reduce erosion, stormwater runoff, and pollution, and provide and umbrella nonprofit 501(c)(3) status to obtain funding. In the past, they have invited the community out to assist with a retrofitting project of plantings in rain gardens and installing conservation landscaping around two local churches that were identified as contributors of stormwater runoff into the Spa Creek watershed. The conservancy constantly invites the community to become involved in efforts to preserve the Spa Creek system.

Weems Creek Conservancy, Annapolis, MD

Weems Creek Conservancy (2014) was formed in 1982 to preserve, restore, and improve the watershed serving both Annapolis and Anne Arundel County (Weems Creek Conservancy). Successful projects include a State Highway Agency sound barrier study, a walking trail and bioretention ponds, rain gardens, and several restoration programs. Information at "Take Action in Your Home" tab on their website includes non-point source pollution and its contribution of excess nutrients, sediments, and chemicals. The website includes a "Calculate Your Impervious Cover Rating" tool and a tutorial on how to build a rain garden. The site also includes Mark Burchick of Environmental System Analysis, Inc., discussing installing water bars on steep slopes and David Wallace of the Severn River Association, on how to build an infiltration system.

Potomac Conservancy, Silver Spring, MD

Founded in 1993, the Potomac Conversancy's mission is to safeguard the lands and waters of the Potomac River and its tributaries, and connect people to this national treasure (Potomac Conservancy 2014). Their goal is to improve local water quality by discovering fun opportunities to make a difference in the fight for clean water. The website provides annual reports and discussion of the fight for clean water. The website includes "River Quick Facts," a photo gallery, recreation and trail maps, and 2014 Milestones Assessments.

Proposal

The concept behind the "Adopt Carroll Creek Canal" program is similar to the "Adopt a Highway" program. The "Adopt a Highway" program encourages citizens to keep their adopted section free of litter, and in exchange, the citizen(s) receive a sign with their name on it. The "Adopt Carroll Creek Canal" could follow the same concept by encouraging residents to adopt parts of the canal. In exchange for keeping the canal debris free, lessening non-point runoff, and finding ways to improve the canal's overall health, they would receive a sign displaying their contribution.

Summary

Creating an advocacy group for the Carroll Creek Canal system will prove beneficial to the health of Carroll Creek Cana, which can be restored and improved through community involvement and collaboration with already established advocacy and conservancy groups.

A lot of components go into beginning and maintaining an advocacy group, such as establishing a core team, planning and implementing a plan based on the group's mission, fundraising and budgeting.

Taking full advantage of social media is an effective way to reach beyond the City of Frederick for contributions and support. Social media also offers the opportunity to reach a younger audience.

Presenting residents of the City of Frederick with the opportunity to adopt a section of the Carroll Creek Canal will assist in creating stewardship and ownership.

References

Chapter 1: Review of Watershed Reports

City of Frederick. 2011. Economic Development. Carroll Creek Park Overview. http://cityoffrederick.com/DocumentCenter/Home/View/1100. Retrieved December 18, 2014.

EPA. 2011. Point Source. http://www.epa.gov/region6/6en/w/ptsource.htm. Retrieved December 18, 2014.

EPA. 2014a. Chesapeake Bay TMDL. http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html. Retrieved December 18, 2014.

EPA. 2014b Polluted Runoff: Nonpoint Source Pollution. http://water.epa.gov/polwaste/nps/. Retrieved December 18, 2014.

EPA. 2014c. NPDES Home. http://water.epa.gov/polwaste/npdes/. Retrieved December 18, 2014.

Frederick County Division of Planning. 2010. Water Resources Element; Frederick County, Maryland. September 23, 2010. http://frederickcountymd.gov/4329/Water-Resource-Element. Retrieved December 18, 2014.

Hunicke, Jessica and Shannon Moore 2008. Lower Monocacy River Watershed Restoration Strategy (WRAS) Supplement. July 2008. http://www.dnr.state.md.us/watersheds/surf/proj/lmon_strategy.html. Retrieved December 18, 2014.

Martin, Keith L. 2008. City taking new approach to fight Carroll Creek's algae problems. Gazette.net. March 27, 2008. http://ww2.gazette.net/stories/032708/frednew62001_32355.shtml. Retrieved December 18, 2014.

Maryland Department of Natural Resources Watershed Services (MDDNR). 2003. Lower Monocacy River Watershed Characterization. October 2003. http://www.dnr.state.md.us/watersheds/surf/proj/lmon_char.html. Retrieved December 18, 2014.

McCarthy, Pete. 2012. Hood Students Tackle Carroll Creek Algae. The Frederick News-Post. May 1, 2012. http://www.fredericknewspost.com/archive/hood-students-tackle-carroll-creek-algae/article_75845b3e-b79e-5ed8-be8c-c283c0558d1c.html. Retrieved December 18, 2014.

Potomac Conservancy. 2014. A Guide to Local Government Policy Changes to Implement Environmental Site Design to the Maximum Extent Practicable: Maryland & Washington, D.C. http://potomac.org/esdscorecard. Retrieved December 18, 2014.

Rice, Patricia and Ken Yetman. 2000. Rock and Carroll Creek Stream Corridor Assessment Survey. Maryland Department of Natural Resources. http://cfpub.epa.gov/ols/catalog/catalog_full_record.cfm?&FIELD1=AUTHOR&INPUT1=%20RICE%20AND%20PATRICIA.%20&TYPE1=ALL&COLL=&SORT_TYPE=YRDESC&item_count=1

Chapter 2: Upper San Antonio River and the River Loop/River Walk—San Antonio, Texas

Aldridge, James. “Global leaders give nod to San Antonio for river restoration project,” San Antonio Business Journal. http://www.bizjournals.com/sanantonio/blog/2014/12/global-leaders-give-nod-to-san-antonio-for-river.html?page=all. December 17, 2014. Web. Retrieved December 19, 2014.

Bexar Regional Watershed Management. 2006. “BRWM – Upper San Antonio River Watershed Protection Plan.” http://www.bexarfloodfacts.org/watershed_protection_plan/. Retrieved December 19, 2014.

Aivaliotis, Eva. 2013. San Antono's River Walk Expansion Leads Nation in Urban Ecosystem Restoration. http://media.visitsanantonio.com/News/English/San-Antono-s-River-Walk-Expansion-Leads-Nation-in Retrieved December 18, 2014.

City of San Antonio. 2014a. “South Alamo (About the Project)” http://www.sanantonio.gov/TCI/Projects/SouthAlamo.aspx#12953572-about-the-project. Retrieved December 18, 2014.

City of San Antonio. 2014b. South Alamo” (Work Updates), http://www.sanantonio.gov/TCI/Projects/SouthAlamo.aspx#12953572-about-the-project. Web. Retrieved December 18, 2014.

City of San Antonio. 2014c. “Storm Water Fee,” http://www.sanantonio.gov/TCI/Projects/StormWaterFee.aspx. Web. Retrieved December 18, 2014.

Eckhardt, Gregg. 2014. “The San Antonio River,” http://www.edwardsaquifer.net/sariver.html. Retrieved December 17, 2014.

Gilliam, J.W., D.L. Osmond, and R.O.Evans. 1997. “Riparian Buffers” in Selected Agricultural Best Management Practices to Control Nitrogen in the Neuse River Basin. North Carolina Agricultural Research Service Technical Bulletin 311, North Carolina State University, Raleigh, NC. http://www.soil.ncsu.edu/publications/BMPs/buffers.html. Retrieved December 18, 2014.

Horne, Justin. 2014. http://www.ksat.com/content/pns/ksat/news/2014/09/15/tags-placed-on-south-side-storm-drains-serve-as-a-reminder.html, Retrieved December 18, 2014.

Jerstad, 2013. http://www.mysanantonio.com/news/local/slideshow/More-to-explore-on-Mission-Reach-45413/photo-4405080.php. Web. Retrieved December 19, 2014.

KSAT. 2006. "River Walk Drained; Mud Party to Follow – Trash, Debris Removed from River Bed" (January 6, 2009), http://web.archive.org/web/20110611044054/http://www.ksat.com/travelgetaways/18420940/detail.html. Retrieved December 18, 2014.

San Antonio River Authority. 2014a. San Antonio River Improvements Project.. http://www.sanantonioriver.org/. Retrieved December 12, 2014.

San Antonio River Authority. 2014b. San Antonio River Improvements: Project Benefits. http://www.sanantonioriver.org/proj_benefits/benefits.php. Retrieved December 18, 2014.

San Antonio River Authority. 2014c. "San Antonio River Improvements Project (Museum Reach - Park Segment)." http://www.sanantonioriver.org/museum_reach/museum_reach.php. Retrieved December 18, 2014.

San Antonio River Authority 2014d. Monitoring Stations," http://gis.sara-tx.org/website/wqmapviewer/. Web. Retrieved December 18, 2014.

San Antonio River Authority. 2014f. "The San Antonio River," http://www.edwardsaquifer.net/sariver.html.

"San Antonio River Authority – Watershed Wise," http://www.sara-tx.org/education_outreach/watershed_wise/index.php. Retrieved December 17, 2014.

San Antonio Water System. 2014. "SAWS Water Recycling" http://www.saws.org/Your_Water/Recycling/. Retrieved December 18, 2014.

SWA Group, Biohabitats Inc., PBS&J, Economics Research Associates, Sprinkle Robey Architects, and Jaster-Quintanilla Inc. 2001. San Antonio River Improvements Project, Concept Design – Design Guidelines." July 2001.

White, Tyler. "River Walk will not be drained next year," San Antonio Express, December 18, 2014, http://www.mysanantonio.com/news/local/article/River-Walk-will-not-be-drained-next-year-5965763.php, Retrieved December 19, 2014.

Wise, Danno. 2014. San Antonio's Riverwalk Mud Festival. http://gotexas.about.com/od/enterta6/a/MudFest.htm. Retrieved December 19, 2014.

Chapter 3: Algaecides

Aukes, G. 2006. Fish Q&A Section: All About Copper. http://www.nationalfishpharm.com/Q&A/all_about_copper.html. Retrieved December 19, 2014.

Bucheli-Witschel, M. and T. Egli. 2001. DAB: Environmental Fate and Microbial Degradation of Aminopolycarboxylic Acids/ FEMS Microbiology Reviews 25: 69-106.

Cosmetic Ingredient Expert Review Panel. 2002. Final Report on the Safety Assessment of EDTA, Calcium, Disodium EDTA, Diammonium EDTA, Dipotassion EDTA, TEA-EDTA, Tetrasodium EDTA, Tripotassium EDTA, Trisodium EDTA, HEDTA, and Trisodium HEDTA. International Journal of Toxicology 21: 95-142.

European Union. 2009. Biocides: 1. What Are Biocides and How Widely Are They Used? http://ec.europa.eu/health/opinions/en/biocides-antibiotic-resistance/l-3/1-definition-antimicrobials.htm#1p0. Retrieved December 18, 2014.

Heller, J. 2014. Copper poisoning. http://www.nlm.nih.gov/medlineplus/ency/article/002496.htm.Retrieved December 19, 2014.

KLM Solutions. 2014. Algae off Algaecide. http://www.pondalgaesolutions.com/algae-off.html. Retrieved December 19, 2014.

Lembi. 2002. Aquatic Plant Management. http://www.btny.purdue.edu/pubs/apm/apm-1-w.pdf. Retrieved December 18, 2014.

The Natural Resource Company. 2004. Liquid Algaecide Case Study. http://thenrco.com/images/algae.pdf. Retrieved December 2, 2014.

Nave, R. 2012. Autotrophs and Heterotrophs. http://hyperphysics.phy-astr.gsu.edu/hbase/biology/autotroph.html . Retrieved December 18, 2014.

Powell, B. 2012. Polyquat algaecide for Swimming Pools. http://www.poolsolutions.com/gd/polyquat.html . Retrieved December 19, 2014.

Chapter 4: Algal Turf Scrubbers in Carroll Creek

Adey, Walter H., Patrick C. Kangas and Walter Mulbry. 2011. Algal Turf Scrubbing: Cleaning Surface Waters with Solar Energy while Producing a Biofuel. BioScience (2011) 61 (6): 434-441. http://bioscience.oxfordjournals.org/content/61/6/434.short. Retrieved December 12, 2014

Adey, Walter. 2015. http://www.algalturfscrubber.com/bio_mimicry.htm. Retrieved December 12, 2014

Chesapeake Bay Foundation. 2004. Manures impact on Rivers, Streams, and the Chesepeake Bay: Keeping Manure out of the water, p. 26 www.cfb.org/site/DocServer/0723manureport_noembargo_pdf?docID=2143. Retrieved December 12, 2014

City of Frederick. 2014. Carroll Creek Park. http://www.cityoffrederick.com/index.aspx?NID=169. Retrieved December 12, 2014.

EPA. 2014. The Problem. December 18, 2014. http://www2.epa.gov/nutrientpollution/problem . Retrieved December 12, 2014

Hydromentia Inc., 2005. S-154 Pilot Single Stage Algal Turf Scrubber Final Report. South Florida Water Management District Contract No. C-13933. http://www.hydromentia.com/Products-Services/Algal-Turf-Scrubber/Product-Documentation/Assets/2005_HMI_S1540-Single-Stage-ATS-Final-Report.pdf, 81 pp. Retrieved December 12,

Kangas, Patrick , Walter Adey , Walter Mulbry , Emmett Duffy. 2010. Algal Turf Scrubber Technology and Pilot Projects in The Region. http://www.chesapeake.org/stac/dev/stac/presentations/63_kangas.pdf. Retrieved December 18, 2014

Maryland Department of the Environment. 2014 http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/Accounting_For_Growth.aspx. Retrieved December 18, 2014

Mulbry, W., Kangas, P., & Kondrad, S. 2010. Toward scrubbing the bay: Nutrient removal using small algal turf scrubbers on Chesapeake Bay tributaries. Ecological Engineering, 36, 4, 536-541.

Mid-America Regional Council. 2006. What is a Watershed? http://cfpub.epa.gov/npstbx/files/ksmo_sediment.pdf. Retrieved December 12, 2014.

Mullins, Craig. 2012. Algae Turf Scrubbers – How To Remove Algae. http://mullinsfarms.com/misc/algae-turf-scrubbers/Retrieved December 12, 2014.

Ongley, Edwin D. 1996. Control of water pollution from agriculture. http://www.fao.org/docrep/w2598e/w2598e05.htm. Retrieved December 12, 2014

Perry, Ann. 2010. Algae, A Mean, Green Cleaning Machine. Agricultural Research. May-June 2010

Sano, D, Hodges A, Degner R. 2005. Economic analysis of water treatments for phosphorus removal in Florida. University of Florida, IFAS. edis.ifas.ufl.edu/pdffiles/FE/FE57600.pdf . Retrieved December 12, 2014

Wiki. 2014 http://en.wikipedia.org/wiki/Algae_scrubber. Retrieved December 12, 2014

Chapter 5: Floating Treatment Wetlands (FTWs) and Stargrass

Chesapeake Bay Program. 2014. Wetlands. http://www.chesapeakebay.net/issues/issue/wetlands#inline. Retrieved December 16, 2014.

Environmental Protection Agency. 2013 “Wetlands Definition.” 25 September 2013. http://water.epa.gov/lawsregs/guidance/wetlands/definitions.cfm. Retrieved December 16, 2014.

Floating Island International. 2014 http://www.floatingislandinternational.com/wp-content/plugins/fii/casestudies/3.pdf. Retrieved November 7, 2014.

Google Maps. 2014a. Frederick, MD Map. Retrieved December 12, 2014.

Google Maps. 2014b. Frederick, MD Map. Retrieved December 12, 2014.

Headley, T.R., and C.C. Tanner. 2008. "Floating Treatment Wetlands: An Innovative Option for Stormwater Quality Applications." (2008): 1101-1106. http://www.floatingislandinternational.com/wp-content/plugins/fii/research/8.pdf. Retrieved December 2, 2014.

Headley, Tom, and Chris Tanner. "Components of Floating Emergent Macrophyte Treatment Wetlands Influencing Removal of Stormwater Pollutants." Ecological Engineering37.3 (2011): 474-86. Science Direct. National Institute of Water and Atmospheric Research. Web. 10 Dec. 2014. http://www.sciencedirect.com.proxy-um.researchport.umd.edu/science/article/pii/S0925857410003472. Retrieved December 2, 2014.

Kadlec, Robert and Scott Wallace. 2009. "Introduction to Treatment Wetlands." in Treatment Wetlands. 2nd ed. Boca Raton: Taylor & Francis Group. pp. 3-30.

Maryland Department of Natural Resources. 2014. Water Stargrass Fact Sheet. Bay Grasses in Classes. http://www.dnr.maryland.gov/bay/sav/bgic/download/Water%20Stargrass%20F act%20Sheet.pdf. Retrieved December 2, 2014.

Chapter 6: Green Street Principles and Best Practices for Improving Infiltration in Highly Impervious Environments

Alliance of Rouge Communities. 2013. Great Lakes Restoration: Celebrating our Accomplishments and Celebrating the Future in Southeast Michigan. http://www.allianceofrougecommunities.com/PDFs/SmallFinalGLRbook.pdf. Retrieved December 12, 2014.

Annis Water Resources Institute. 2000. Rogue River Watershed Project. Rogue River Watershed Management Plan. ftp://148.61.56.205/ISCWebDocuments/Rogueplan2-02.pdf .Retrieved December 12, 2014.

Chesapeake Bay Foundation. 2010. About the Bay - The Issues - Dead Zones - Nitrogen & Phosphorous http://www.cbf.org/about-the-bay/issues/dead-zones/nitrogen-phosphorus. Retrieved November 20, 2014.

Nevue Ngan Associates. 2009. Southwest Montgomery Green Street: starting to connect the west hills with the river. https://www.portlandoregon.gov/bes/article/427079 . Retrieved November 25, 2014.

City of Portland. 2012. NE Holladay Green Street Corridor Plan: Achieving EcoDistrict Goals. https://www.portlandoregon.gov/bes/article/427078 Retrieved November 25, 2014.

Department of Environmental Protection. 2012. What are RainScapes? http://www.montgomerycountymd.gov/DEP/water/rainscapes.html. Retrieved November 20, 2014

Design Workshop. 2014. Bagby Street Reconstruction. http://www.designworkshop.com/projects/bagby.html Retrieved December 1, 2014.

Greenroads. 2014. Greenroads Certifies First Project in Texas. https://www.greenroads.org/files/2290.pdf Retrieved December 1, 2014.

Houston Midtown. 2013. Bagby Street Reconstruction: Greenroads Silver Certified Project. www.houstonmidtown.com/.../Bagby-Street-GreenRoads-whitepaper-12. Retrieved December 1, 2014

Montgomery County, MD. 2011. Stormwater Management Retrofit Report. http://www.montgomerycountymd.gov/DEP/Resources/Files/downloads/restoration/forest-estates/90-design-stormwater-management.pdf. Retrieved December 12, 2014.

Montgomery County, MD. 2012. Forest Estates Green Streets. Project Schedule and Documents. http://www.montgomerycountymd.gov/DEP/Restoration/forest-estates.html Accessed December 12, 2014.

Montgomery County, MD . 2012 Forest Estates. Green Streets in Your Neighborhood. Green Streets: Environmentally Friendly Landscapes for Healthy Watersheds. http://www.montgomerycountymd.gov/DEP/Resources/Files/downloads/restoration/forest-estates/Forest-estates-brochure.pdf Retrieved November 10, 2014.

Philadelphia Water Department. 2014. City of Philadelphia Green Streets Design Manual. http://www.phillywatersheds.org/img/GSDM/GSDM_FINAL_20140211.pdf. Retrieved November 25, 2014.

Rain Dog Designs. 2014. 8th Avenue NW – Street of Green http://raindogdesigns.com/wordpress/?page_id=1877 Retrieved December 1, 2014.

Smart Growth America. Green Streets. 2014. Green Streets http://www.smartgrowthamerica.org/complete-streets/implementation/factsheets/green-streets/ . Retrieved December 1, 2014

Southeast Michigan Council of Governments (SEMCOG). 2013. Great Lakes Green Streets Guidebook: A Compilation of Road Projects Using Green Infrastructure. http://www.semcog.org/uploadedFiles/Programs_and_Projects/Water/Stormwater/GLGI%20Guidebook_web.pdf Retrieved November 20, 2014.

Chapter 7: Green Streets: Applications for the City of Frederick, MD

Bureau of Environmental Services. 2008. Sustainable Stormwater Management for Clean Rivers SE 12th and Clay Green Street Project. https://www.portlandoregon.gov/bes/article/500774. Retrieved December 12, 2014.

Conway School. 2014. Green Streets Guidebook: for the City of Holyoke, Massachusetts. http://www.holyoke.org/wp-content/uploads/2012/10/Final-Cover-Page-LowRes-w-Cover.pdf. Retrieved December 12, 2014.

Cutler, Rina, and H. M. Neukrug, 2014. City of Philadelphia Green Streets Design Manual. http://www.phillywatersheds.org/img/GSDM/GSDM_FINAL_20140211.pdf. Retrieved December 12, 2014.

Historic Preservation Commission. 2009. Frederick Town Historic District Design Guidelines. http://www.cityoffrederick.com/DocumentCenter/Home/View/497. Retrieved December 12, 2014.

Portland Development Commission. 2009. Southwest Montgomery Green Street: starting to connect the west hills with the river. https://www.portlandoregon.gov/bes/article/427079. Retrieved December 12, 2014.

San Mateo County. 2009. San Mateo Countywide Water Pollution Prevention Program. San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook. http://www.flowstobay.org/files/greenstreets/FirstEdGuidebook2009-01-05.pdf. Retrieved December 12, 2014.

The City of Frederick. 2009. Golden Mile Retail Report. http://www.cityoffrederick.com/DocumentCenter/Home/View/809. Retrieved December 12, 2014.

The City of Frederick. 2010. City of Frederick 2010 Comprehensive Plan. http://www.cityoffrederick.com/DocumentCenter/Home/View/585. Retrieved December 12, 2014.

Chapter 8: Exemplary Parking: Designs for Minimizing Runoff

Duke University. 2014. Sands Parking Garage. http://sustainability.duke.edu/campus_initiatives/buildings/pg9.html. Retrieved December 12, 2014.

EPA. 2014. After the Storm. http://water.epa.gov/action/weatherchannel/stormwater.cfm. Retrieved December 12, 2014.

Gonzalez, Ciara. 2011 L.A. Zoo's New Watershed Friendly Parking Lot. https://lacreekfreak.wordpress.com/2011/05/21/. Retrieved December 12, 2014.

Industrial Economics. 2007. Green Parking Lot Case Study: Heifer International, Inc. http://www.epa.gov/region6/6sf/pdffiles/heiferparkingstudy.pdf. Retrieved December 12, 2014.

Los Angeles Sanitation. 2014. Los Angeles Zoo Parking Lot. http://lacitysan.org/wpd/Siteorg/LAPropo/sitefiles/LA_Zoo/zoointro.htm. Retrieved December 12, 2014.

McClelland Consulting Engineers. 2014. Heifer International World Headquarters. http://mcclelland-engrs.com/projects/heifer-international-world-headquarters/. Retrieved December 12, 2014.

Nevue Ngan Associates and Sherwood Design Engineers. 2009. San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook. http://www.flowstobay.org/documents/municipalities/sustainable%20streets/San%20Mateo%20Guidebook.pdf Retrieved December 12, 2014.

Ratio Architects. 2014 Duke University Sands Parking Garage. http://issuu.com/ratioarchitects/docs/2014_general_ratio_brochure_issuu. Retrieved December 12, 2014.

San Mateo County. 2009. San Mateo Countywide Water Pollution Prevention Program. San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook. http://www.flowstobay.org/files/greenstreets/FirstEdGuidebook2009-01-05.pdf. Retrieved December 12, 2014.

The City of Frederick. 2013. The Golden Mile Small Area Plan. http://www.cityoffrederick.com/DocumentCenter/Home/View/1143 Retrieved December 12, 2014.

University of New Hampshire.2007. The Impacts of Impervious Surfaces on Water Resources. The New Hampshire Estuaries Project, http://www.prep.unh.edu/resources/pdf/theimpactsof-nhep-04.pdf. Retrieved December 12, 2014.

Chapter 9: Improving Infiltration through Bioretention Systems in High Impervious Landscapes

Davis, Allen P. 2003. "Water Quality Improvement through Bioretention: Lead, Copper, and Zinc Removal." Water Environment Research 75.1: 73-82. Puget Sound Partnership Resource Center. Water Environment Federation, Jan.-Feb. 2003. Web. 16 Dec. 2014.

Hunt, W., J. Smith, S. Jadlocki, J. Hathaway, and P. Eubanks. 2008. ”Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban Charlotte, N.C..” Journal of Environmental Engineering, 134(5), 403–408.

Rushton, Betty T. 2001. "Low-Impact Parking Lot Design Reduces Runoff and Pollutant Loads." Water Resources Planning and Management: 172-79. http://sfrc.ifas.ufl.edu/urbanforestry/Resources/PDF%20downloads/Rushton_2001.pdf. Retrieved December 20, 2014.

EPA. 1999. Storm Water Technology Fact Sheet: Bioretention. http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_biortn.pdf. Retrieved December 15, 2014.

Minnesota Pollution Control Agency (MPCA). 2014. Types of Bioretention. http://stormwater.pca.state.mn.us/index.php/Types_of_bioretention. Retrieved December 20, 2014.

Chapter 10: Reducing Nutrients via Source Reduction: Lawn Education Practices

Burke, Kelly. 2014 Lime the Lawnhttp://lawncare.about.com/od/plantnutrition/a/lime.htm. Retrieved December 4, 2014.

Felton, Gary K. 2013 Maryland Professional Lawn Care Manual. University of Maryland, Maryland Department of Agriculture. http://mda.maryland.gov/siteassets/pages/fertilizer/mdaprolawncaremanual6.24.13.pdf. Retrieved December 4, 2014

EPA. 2013. Green Landscaping: Greenacres. Environmental Protection Agency. http://www.epa.gov/greenacres/nativeplants/factsht.html. Retrieved December 3, 2014.

Natural Resources Defense Council. 2012 . How to Clean Up Our Water. http://www.nrdc.org/water/pollution/gsteps.asp. Retrieved December 3, 2014.

Maryland Department of Agriculture. 2013. Maryland's New Lawn Fertilizer Law Takes Effect October 1." . http://news.maryland.gov/mda/press-release/2013/09/26/marylands-new-lawn-fertilizer-law-takes-effect-october-1/. Retrieved December 4, 2014.

Maryland Department of Agriculture 2014. MD's Lawn Fertilizer Law. http://mda.maryland.gov/pages/fertilizer.aspx Retrieved December 17, 2014.

Chapter 11: Riparian Forest Buffers: Implementation on Residential and Public Park Land

Allan, J. D.,and M. M. Castillo. 2007. Stream Ecology: Structure and Function of Running Waters (2nd ed.). AA Dordrecht, The Netherlands: Springer.

Bin, O., C. E. Landry, and G. F. Meyer. 2009. Riparian buffers and hedonic prices: a quasi-experimental analysis of residential property values in the Neuse River Basin. American Journal of Agricultural Economics 91: 1067-1079.

Department of Assessments and Taxation. 2014. http://sdat.resiusa.org/RealProperty/Pages/viewdetails.aspx?County=11&SearchType=ACCT&District=02&AccountNumber=466600. Retrieved Dec 9, 2014.

Donovan, G. H. and Butry. 2010. Trees in the city: valuing street tees in Portland, Oregon. Landscape and Urban Planning 94: 77-83.

Donovan, G. H. and D. T. Butry. 2011. The effect of urban trees on the rental price of single-family homes in Portland, Oregon. Urban Forestry and Urban Greening 10: 163-168.

Hart, M. and D. Coelho. 2007. Baltimore County Forest Sustainability Project. The Conservation Fund.

Hawes, E., and M. Smith. 2005. Riparian Buffer Zones: Function and Recommended Widths. Yale School of Forestry and Environmental Studies. Eightmile River Wild and Scenic Study Committee .

Hsieh, J. 2012. Residential tree planting programs: a review of best practices. Greenest City Scholars Program. Vancouver, British Columbia.

Horner, W. R. 2014. A Scientific Foundation for Shaping Riparian Buffer Protection Regulations. Harrisburg: Pennsylvania Land Trust Association and Brandywine Conservancy.

McCarthy Park Riparian Buffer Restoration. 2009. Temple-Villanova Sustainable Stormwater Inititative: http://www.csc.temple.edu/t-vssi/BMPSurvey/mccarthy_park.htm. Retrieved Nov 29, 2014.

MDDNR. 2014. Maryland's Updated Green Infrastructure Assessment. http://www.dnr.state.md.us/land/green_infra.asp Retrieved November 30, 2014.

Maryland DNR Forest Service. 2007. Backyard Buffers. http://www.potomacriver.org/wildlifedocs/BYBBrochure2007.pdf. Retrieved November 19, 2014.

Maryland DNR Forest Service. 2014. Forest Stewardship. http://www.dnr.maryland.gov/forests/programapps/stewcon.asp Retrieved December 4, 2014.

Meyer, J. L., Kaplan, L. A., Newbold, D., Strayer, D. L., Woltemade, C. J., Zedler, J. B., et al. 2003. Where Rivers are Born: The Scientific Imperative for Defending Small Streams and Wetlands. American Rivers and Sierra Club.

Miles Park Riparian Buffer Restoration. 2009. Temple-Villanova Sustainable Stormwater Initiative. http://www.csc.temple.edu/t-vssi/BMPSurvey/miles_park.htm. Retrieved November 29, 2014.

Outen, D. C. 2010. Restoring green infrastructure In D. G. Burke and J. E. Dunn (editors), A Sustainable Chesapeake: better models for conservation (pp. 99-106). Arlington, VA: The Conservation Fund.

Parks Division. 2014. The City of Frederick, Maryland. https://www.cityoffrederick.com/index.aspx?NID=268 Retrieved December 3, 2014.

PCDRP. 2014. Trees of Philly contest: tell us your tree story. http://treesofphillystories.com/. Retrieved December 8, 2014

Rice, P., & Yetman, K. (2000). Carroll and Rock Creeks: Stream Corridor Assessment Survey. Chesapeake & Coastal Watershed Services, Watershed Restoration Division. Annapolis: MD Department of Natural Resources..

Smith, A. E., Craven, S. R., & Curtis, P. D. (1999). Managing Canada Geese in Urban Environments. Ithaca: Jack Berryman Institute. http://wildlifecontrol.info/pubs/Documents/Goose/Managing%20Canada%20Geese.pdf. Retrieved December 10, 2014.

Sweeney, B. W., and J. G. Blaine. 2007. Resurrecting the In-Stream Side of Riparian Forests. Journal of Contemporary Water Research and Education (136), 17-27.

Sweeney, B. W., T. L. Bott, J. K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, et al. 2004. Riparian Deforestation, Stream Narrowing, and Loss of Stream Ecosystem Services. PNAS, 101(39), 14132–14137.

The City of Frederick. 2012. Park Planting Exhibits. Exhibit, Frederick.

The City of Frederick Planning Department. (2010). Urban Forestry Management Plan. https://www.cityoffrederick.com/DocumentCenter/Home/View/1413. Retrieved November 7, 2014.

The Potpourri. 2013. Volunteer teams compete to plant 1300 trees in 141 minutes. http://www.yourhoustonnews.com/tomball/news/volunteer-teams-compete-to-plant-trees-in-minutes/article_0b5ca4bc-762d-11e2-be55-001a4bcf887a.html. Retrieved December, 8 2014.

The State of Maryland. 2014. Marylanders Plant Trees. http://trees.maryland.gov/. Retrived November 19, 2014

Weigelhofer, G., Fuchsberger, J., Teufl, B., Welti, N., & Hein, T. 2012. Effects of Riparian Forest Buff ers on In-Stream Nutrient Retention. Journal of Environmental Quality, 41, 373-379.

Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation. University of Georgia, Institute of Ecology. Athens: Office of Public Service and Outreach.

Wenger, S. J. and L. Fowler. 2000. Protecting stream and river corridors: creating effective local riparian buffer ordinances. The University of Georgia: Carl Vinson Institute of Government. Athens, GA.

Chapter 12: Establishing a Carrol Creek Watershed Advocacy Group

AKG Media, LLC. 2008 Why Fundraising Is Important: Fundraising How-to's and Event Ideas RSS. http://www.fundraisingip.com/fundraising/why-fundraising-is-important/. Retrived December 18, 2014.

Branson, Richard. 2014. The Power of Social Media. http://www.virgin.com/richard-branson/the-power-of-social-media. Retrived December 18, 2014.

Center for Watershed Protection. 2005. A User's Guide to Watershed Planning in Maryland Center for Watershed Protection. http://www.dnr.state.md.us/irc/docs/00015710.pdf. Retrived November 18, 2014

Duke University. 2014. What is a budget and why is it important?http://www.personalfinance.duke.edu/manage-your-finances/budget/overview. Retrived November 18, 2014

FAO. 2004. Computerizing Agricultural Cooperatives: A Practical Guide. Economic and Social Development Department. http://www.fao.org/docrep/007/y5471e/y5471e00.htm#Contents. Retrived November 18, 2014

Friends of Baker Park. 2014. Friends of Baker Park. http://www.friendsofbakerpark.org/. Retrived December 18, 2014.

Kidwai, Anam. 2014. Top 15 Reasons Why Education Is Extremely Important. http://listovative.com/top-15-reasons-why-education-is-important/. Retrived December 16, 2014.

Potomac Conservancy. 2014. Home Page. Potomac Conservancy. http://potomac.org/. Retrived December 18, 2014.

Richards, Francine. "Components of a Project Implementation Plan." Brighthub Project Management. http://www.brighthubpm.com/project-planning/87423-putting-together-a-project-implementation-plan/. Retrived December 17, 2014.

Romeri, Monica Jade. 2013. New Statistics Highlight the Power of Social Media Marketing. http://www.socialmediatoday.com/content/new-statistics-highlight-power-social-media-marketing. Retrived December 18, 2014.

Soskey, Ginny. 18 Fresh Stats about the Current State of Social Media Marketing. Hub Spots Blogs, http://blog.hubspot.com/marketing/18-fresh-stats-about-social-media-marketing. Retrived December 19, 2014.

Spa Creek Conservancy. 2014. "Spa Creek Conservancy - Stewards of the Creek." - Stewards of the Creek. http://www.spacreek.org/. Retrived December 18, 2014.

Weems Creek Conservancy. 2014. http://weems-creek.org/. Retrived December 18, 2014.