

## ABSTRACT

Title of Document: ADDRESSING NEW STORMWATER  
POLICIES IN THE REDESIGN OF THE  
NATIONAL GROVE OF STATE TREES AT  
THE UNITED STATES NATIONAL  
ARBORETUM

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The National Grove of State Trees at the United States National Arboretum is in need of redesign to meet ecological and social needs. The Grove serves as a scientific and cultural landscape and can be repurposed to serve the public as an ecological demonstration for contemporary environmental issues. In an intensive effort to clean up the local rivers of the District of Columbia and the Chesapeake Bay, the two agencies of the District Department of the Environment and DC Water have enacted stormwater runoff fees, based on impervious surface fees, on all property owners located in the District of Columbia. The redesign of the Grove is compounded by the Arboretum's need to add more parking to the area where the Grove is currently located. The objective of this thesis is to reimagine the design and interpretation of the Grove as well as address the impervious area charge assessments.

ADDRESSING NEW STORMWATER POLICIES IN THE REDESIGN OF THE  
NATIONAL GROVE OF STATE TREES AT THE UNITED STATES NATIONAL  
ARBORETUM

By

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2012

## Dedication

This thesis would not have been possible without the incredible guidance and help I received throughout the thesis process. I have been extremely blessed and grateful to have had support and encouragement from David Myers, Jack Leonard, Steve Cohan, Scott Aker, Allison Palmer-Jenson, John Palmer, Caren Yglesias, Vikki Chanse, Rosy Mora-Montenegro, Chris Myers, Sarah Watling, Kim Wharton and my family.

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## Acronyms

Arboretum	United States National Arboretum
Blue Plains	Blue Plains Advanced Wastewater Treatment Plant
BMP	Best Management Program
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
DCWASA	DC Water
DDOE	District Department of the Environment
EPA	Environmental Protection Agency
ERU	Equivalent Residential Unit (equal to 1,000 sq. ft. impervious surface)
G3	Green Streets, Green Jobs, Green Towns Program
GAO	Government Accountability Office
GIS	Geographic Information System
IAC	Impervious Area Charge
LID	Low Impact Development
LTCP	Long Term Control Plan
MS4	Municipal Separate Storm Sewer System
NASF	National Association of State Foresters
NGST	National Grove of State Trees
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point source (pollution)
PAH	Polycyclic Aromatic Hydrocarbons
PICP	Permeable Interlocking Concrete Pavements
Separate	Municipal Separate Storm Sewer System
SRC	Stormwater Retention Credit
SWMP	Stormwater Management Program
The District	District of Columbia
USDA	United States Department of Agriculture

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## Chapter 1: Introduction

The National Grove of State Trees (NGST) is located at the United States National Arboretum (the Arboretum) and serves as a scientific and cultural landscape. The current design is perceived as not fully meeting its mission and a redesign of the NGST is assumed to provide a landscape setting that better serves the public as an ecological demonstration for contemporary environmental issues. This thesis explores and uses the redesign of the NGST at the Arboretum to demonstrate the ability to incorporate both the need for a redesigned grove but additional contemporary stormwater issues. The NGST is one section of the Arboretum that the arboretum officials would like to improve for the public. The existing trees in the NGST are native to their own state but many are in decline or have not survived. The overall feel of the grove itself is not one of energy or liveliness and the Grove lacks a clear landscape identity. Additional requirements for 480 parking spaces and 8 bus parking space were also needed. One of the issues of creating additional parking lots, concerns the impervious area fees associated with the new stormwater policies that the District of Columbia (the District) has recently been allowed to charge for federal properties. In summary, addressing stormwater fees, adding additional parking capacity and the need to create a successful public space and thriving grove are all considerations in creating the final design as part of this thesis.

## **Chapter 2: Literature Review**

The following literature review provides a brief overview of the District's new stormwater policies and how they might influence parking options at the National Arboretum in Washington, DC. This literature review is organized into three sections. The first section pertains to the District's stormwater policies and codes. The second section pertains to the different types of porous pavement and the advantages and disadvantages of each type including approximate investment costs and maintenance requirements. Finally, the last section pertains to selected precedence studies concerning other arboretums and towns that are engaged in retrofitting their property to handle stormwater concerns.

### **District of Columbia Stormwater Policies and Regulations**

The following section is a literature review based on the District's stormwater policies and regulations. It documents how recent federal government rulings shape the issue of stormwater among District residents, businesses, and federal agencies.

### **Federal Government Financial Responsibility**

On January 4, 2011, President Barak Obama signed bill S. 3481 into public law 111-378. This law amends the 1972 Federal Water Pollution Control Act to clarify the federal government's responsibility for stormwater pollution. The law requires federal agencies to pay local governments for the federally mandated stormwater fees that are required to reduce polluted stormwater runoff.

Public Law 111-378 of the 111<sup>th</sup> Congress states;

“Section 313 of the Federal Water Pollution Control Act (33 U.S.C. 1323) is amended by adding at the end the following:

‘© Reasonable Service Charges-

‘(1) IN GENERAL- For the purposes of this Act, reasonable service charges described in subsection (a) include any reasonable nondiscriminatory fee, charge, or assessment that is—

‘(A) based on some fair approximation of the proportionate contribution of the property or facility to stormwater pollution (in terms of quantities of pollutants, or volume or rate of stormwater discharge or runoff from the property or facility); and

‘(B) used to pay or reimburse the costs associated with any stormwater management program (whether associated with a separate storm sewer system or a sewer system that manages a combination of stormwater and sanitary waste), including the full range of programmatic and structural costs attributable to collecting stormwater, reducing pollutants in stormwater, and reducing the volume and rate of stormwater discharge, regardless of whether that reasonable fee, charge, or assessment is denominated a tax.’<sup>1</sup>

Due to this law, and federal government properties accounting for 20% of the District’s impervious surface, the District Department of the Environment (DDOE) will collect an additional \$2.6 million in stormwater fees annually from the federal government. Prior to the law being signed, the federal government had been paying DDOE for the stormwater fee since 2001. However, these payments were stopped in 2009 when the Government Accountability Office (GAO) determined that the stormwater fees were actually a tax and declared the federal government could not be taxed due to sovereign immunity.

In January 2011, U.S. Senator Benjamin Cardin, D-Maryland stated:

“Polluters, including the federal government, should be financially responsible for the pollution they cause. From Washington, DC, to Washington State, the failure of the federal government to pay localities for reasonable costs associated with the control and

abatement of pollution that originated on its properties has taken its toll.”<sup>2</sup>

In the District, the actions of the federal government that have historically led to water degradation have included deforestation, weapons manufacturing, installation of combined sewer systems, historic dredge and fill activities and stream channelization which have severely polluted local waters such as the Anacostia River<sup>3</sup>. The issue of polluted stormwater runoff has become a major topic of concern as it is the fastest growing source of non-point source (NPS) pollution to the Chesapeake Bay as well as national waters in the United States. NPS pollution accounts for 40% of water pollution in the United States and is now considered the main cause of impairment to water quality.<sup>4</sup> Therefore, bill S.3481 , signed into law amending the 1972 Federal Water Pollution Control Act, had strong support not only from Cardin, but also; Senators James Inhofe, R-Oklahoma, Patty Murray, D-Washington, Maria Cantwell, D-Washington, and George Voinovich, R-Ohio as well as Delegate Eleanor Holmes Norton, D-District of Columbia. The legislation was also supported by the National Governors Association, the International City/County Management Association, U.S. Conference of Mayors, National League of Cities, National Association of Counties, Council of State Governments, and the National Conference of State Legislatures.

### **Non-Point Source Pollutants**

NPS pollution is defined by the Environmental Protection Agency (EPA) as coming “from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries

away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters.”<sup>5</sup> Impervious surfaces such as roadways and parking lots do not allow for rainwater to soak into the soil, therefore it quickly races off the land, transporting debris, oil, pesticides, fertilizers and other pollutants into our waterways [fig. 3]. Stormwater runoff from impervious surfaces is the main pollutant to the Anacostia Watershed, the watershed in which the Grove is located. It impairs the natural hydrologic system of stormwater being filtered through soil and



Source: EPA<sup>6</sup>

Fig. 1. Oil and Synthetics

vegetation. These pollutants not only smother stream life, but the force and velocity of the runoff and the volume of water erodes stream banks and triggers local floods. However, due to its sluggish nature, the Anacostia retains 85% of the sediments it receives via.<sup>7</sup>

### **Clean Water Act**

The federal Clean Water Act of 1972 set pollution control obligations for all U.S. cities and municipalities. The new law (PL 111-378) signed by President Obama in 2011, requiring the federal government to pay stormwater fees, “ensures that stormwater management costs will be fairly shared among federal and local governments, residents and private enterprise” and also allows for DDOE to have sufficient funding to meet Clean Water Act goals.<sup>8</sup> Since 2011, the District has been

aggressive in its approach in reducing and treating the flow of stormwater due to requirements set forth by the EPA for the city's National Pollutant Discharge Elimination System (NPDES) permit requirements of their Municipal Separate Storm Sewer Systems (MS4s).

The DC Water (formerly operated as DCWASA) operates a wastewater collection system that includes both a "separate" (MS4s) and a combined sewer system (CSS). Separate wastewater systems have two piping systems [fig. 2]. One system is for sewage from homes and businesses and the other is for stormwater. About two-thirds of the District is served by MS4s. The remainder is served by an antiquated CSS, which carries both raw sewage and stormwater runoff and was built before 1900.<sup>9</sup> When a storm event occurs, the excess mixture of sewage and stormwater is known as a combined sewer overflow (CSO), instead of flowing to the water treatment plant, it overflows into surrounding waters [fig. 3].

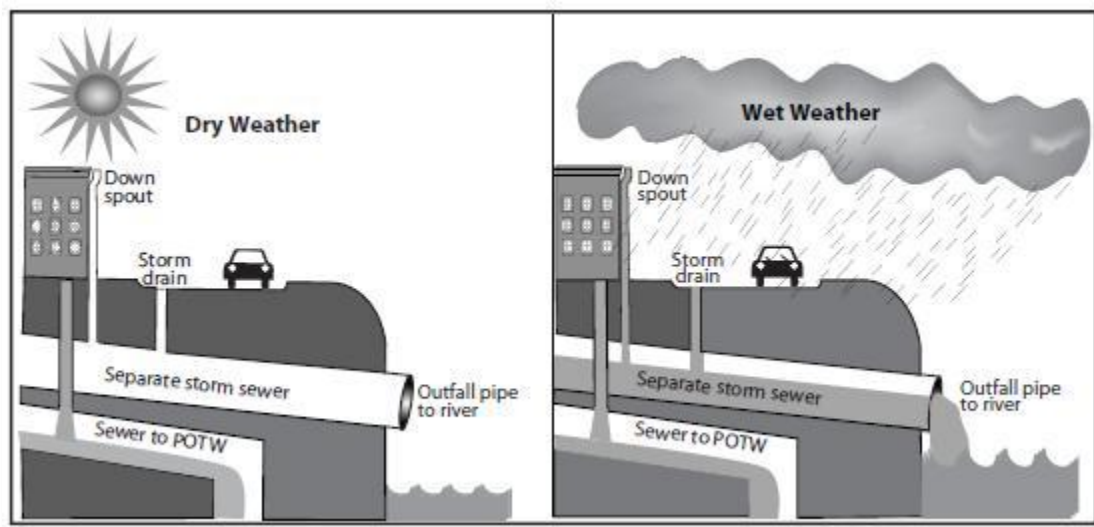


Image: EPA<sup>10</sup>

Fig. 2. Municipal Separate Storm Sewer Systems (MS4s) Diagram



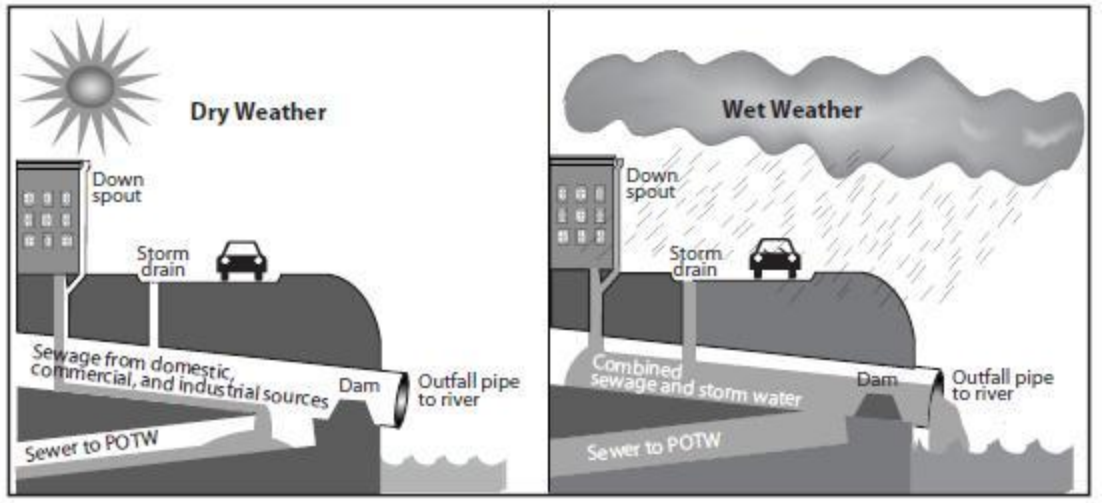


Image: EPA<sup>11</sup>

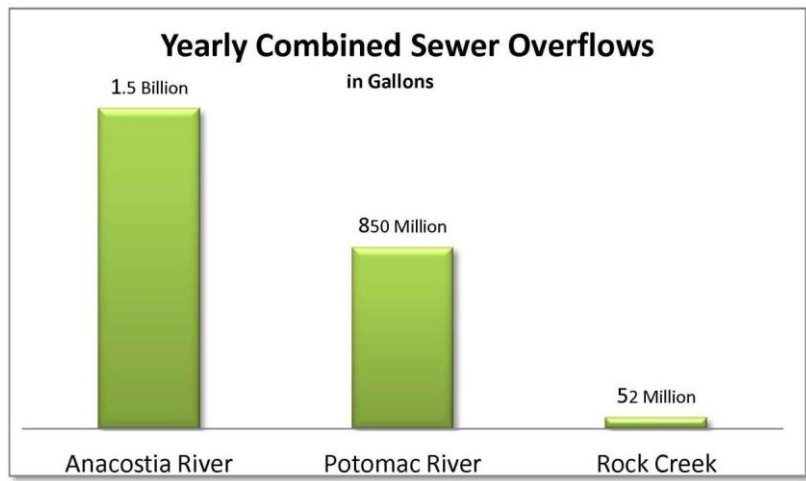
Fig. 3. Combined Sewer System and Combined Sewer Overflow (CSS, CSO)

DC Water has the responsibility of providing service to 725 square miles in the District, Montgomery and Prince George’s Counties in Maryland, and Fairfax and Loudon Counties in Virginia. This independent authority of the District government manages the Blue Plains Advanced Wastewater Treatment Plant, the largest advanced wastewater treatment facility of its type in the world, located on the Potomac River. It is capable of treating 330 million gallons of water a day. During a storm event, the water requiring treatment exceeds Blue Plains capacity, resulting in sewage being forced through CSOs to surrounding waters. DC Water’s cost of maintaining and replacing their aging infrastructure and replacing CSO’s has led to the District’s construction of a network of retention tunnels to capture stormwater and sewage.

### **Clean Rivers Project**

“In 2005, DC Water entered into a consent decree that established a judicially enforceable schedule for implementation of a long term control plan (LTCP) to reduce combined sewer overflows.”<sup>12</sup> The LTCP requires DC Water to build three large, underground storage tunnels to provide additional capacity to the combined

sewer system for stormwater. The Anacostia River Tunnel System is projected for completion in 2018, with the entire project for the Potomac and Rock Creek tunnel systems projected completion date set for 2025. This construction project is known as the Clean Rivers Project. Chicago and Milwaukee have also created similar stormwater tunnel networks. The 2011 cost estimate of the Clean Rivers Project was \$2.6 billion. The project “aims to eliminate combined sewer overflows to the Anacostia River, Potomac River and Rock Creek, ultimately improving the health of the Chesapeake Bay.”<sup>13</sup> Currently stormwater and raw sewage flow together in CSS’s, which accounts for one third of the District’s sewer system. When Blue Plains cannot accommodate all of the combined sewage flowing to the plant during a storm event, an “estimated 1.5 billion gallons of CSO’s are discharged into the Anacostia River, 850 million gallons into the Potomac River and 52 million gallons flow into Rock Creek each year” [fig. 4].<sup>14</sup>



Adapted From: National Resources Defense Council<sup>15</sup>

Fig. 4

The Anacostia River has 15 outfall locations along its 6.6 miles located within the District and it receives about 60% of the CSO discharges making it one of the most polluted rivers in the country. Once the new tunnels are constructed, they will

retain the combined sewage until the storm event subsides and Blue Plains is able to treat the sewage.

**Clean Rivers IAC Fee**

The Clean Rivers Impervious Area Charge (IAC) is a fee which DC Water collects from commercial and residential customers of the District. Based on the amount of impervious surface on each property, these funds subsidize the tunnel network. The Clean Rivers IAC is separate from DDOE’s stormwater fee entitled “DC Government Stormwater Fee,” which is also based on the amount of impervious surface on a property. The Clean Rivers IAC takes into account the impermeable surfaces of a property that contribute to stormwater runoff that their properties deposit onto streets and thus contribute to CSO’s.<sup>16</sup> The impervious surface square footage of a property is based on the District’s Geographic Information System (GIS) files that are used to calculate this information. The impervious surface is measured in Equivalent Residential Units or ERU’s. One ERU is equivalent to 1,000 square feet of impervious surface.

Each month for the 2012 billing year, DC Water charges \$6.64 and DDOE charges \$2.67 for each ERU [fig. 6]. DC Water will be using the fees they collect to build the Clean Rivers Tunnel Project. DDOE’s collected fees go towards mitigation projects and administrative costs [fig. 5].

<b>Monthly Fee</b>	<b><u>DC Water</u></b> \$2.67/month Per *ERU	<b><u>DDOE</u></b> \$6.64/month Per *ERU
<b>Allocation of Fees</b>	Stormwater Mitigation Practices and Administration	Construction of Clean Rivers Tunnel Project
*1 ERU = 1,000 sq. ft. Impervious Surface		

Fig. 5. DC Water and DDOE Impervious Surface Fee Comparison



Service Address  
Washington, DC 20011-4232

Account Number [REDACTED]  
Square/Suffix/Lot 2649/ /0052  
Impervious Surface Square Footage 2500

Customer Service / Servicio Al Cliente: (202) 354-3600  
Emergencies / Emergencia: (202) 612-3400

Bill Summary

Billing Date 01/25/12  
Previous Balance \$81.79  
Payments as of 01/24/12 - Thank you \$81.79 CR  
Late Fees From Prior Balance \$0.00  
Outstanding Amount Due \$0.00  
Total Current Bill \$50.43  
Total Amount Due - Please Pay by 02/21/12 \$50.43

Meter Number	Prior Read Date	Current Read Date	Number Of Days	Prior Read	Current Read	Usage (CCF)	Usage (Gallons)	Read Type
[REDACTED]	12/20/11	01/22/12	33	1131	1134	3	2,244	ACTUAL

CURRENT WATER AND SEWER CHARGES - RESIDENTIAL		IMPORTANT MESSAGES	
Metering Fee	\$4.56		
Water Services 3 CCF x \$ 3.24	\$9.72		
Sewer Services 3 CCF x \$ 3.96	\$11.88		
Clean Rivers IAC 2.40 ERU x \$ 6.64	\$15.94		
<b>CURRENT CHARGES AND CREDITS</b>			
DC Government PILOT Fee 3 CCF x \$ .49	\$1.47		
DC Government Right of Way Fee 3 CCF x \$ .15	\$0.45		
DC Govt Stormwater Fee 2.40 ERU x \$ 2.67	\$6.41		
<b>TOTAL CURRENT CHARGES</b>	\$50.43		
<b>TOTAL CURRENT BILL</b>	\$50.43		

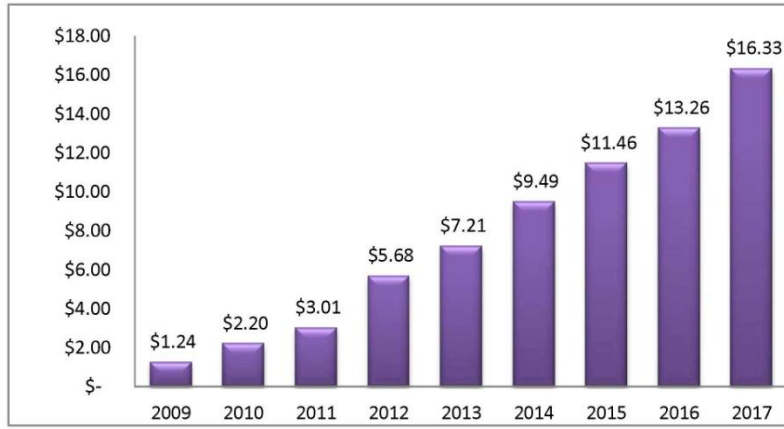
  

Please return the portion below with your payment to ensure proper credit to your account. For payment options, see reverse.

Source: Permission granted by homeowner, e-mail March 19, 2012.

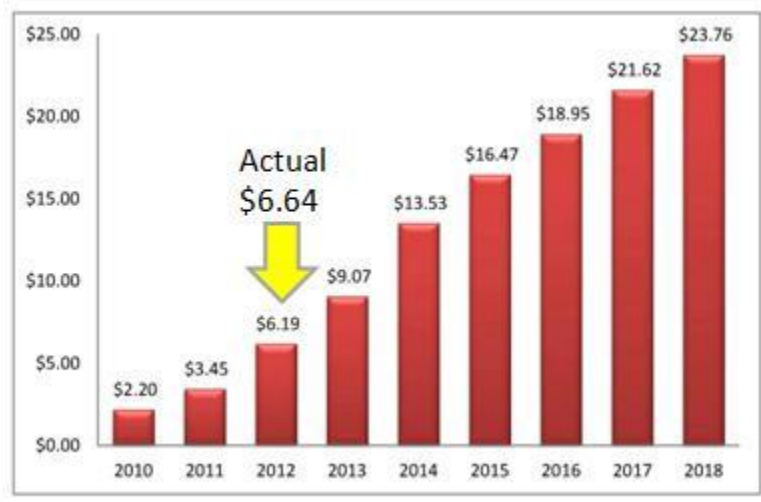
Fig. 6. Example of a 2012 monthly bill from DC Water reflecting the Clean Rivers IAC charge and DDOE (listed as DC Government Stormwater Fee) charge for the property owners impervious surface.

At present date, there does not seem to be a possibility of a large increase for DDOE’s fee of \$2.67 per ERU. However, DC Water’s IAC is expected to greatly increase as the tunnel building progresses (see appendix 2). In 2010, DC Water was charging \$2.20 per ERU [fig. 7]. In 2011, the fee was \$3.45, however estimates given in March 2011, expected the IAC to increase to \$6.19 per ERU for the 2012 billing year with increases of up to \$23.76 per ERU by 2018 [fig. 8]. The actual fee for 2012 ended up being \$6.64. The annual IAC for the average single family



Adapted From: DC Water, Stormwater Around the Bay Conference<sup>17</sup>  
 Graph: Author

Fig. 7. DC Water Estimated Impervious Surface Fees, October 2010



Adapted From: DC Water LID Summit<sup>18</sup>  
 Graph: Author

Fig. 8. DC Water Estimated Impervious Surface Fees, March 2011

homeowner will increase from \$41.40 in FY2011 to \$357.12 in FY 2019. In order to implement the Anacostia portion of the LTCP by 2018, as scheduled, DC ratepayers must bear the increases in DC Water’s IAC.<sup>19</sup> As of January 2012, DC Water is in the process of partnering with DDOE on a plan for creating a stormwater mitigation practice guide that ratepayers may participate in, in an effort to reduce their bill. DDOE estimates that the maximum discount a rate payer could receive is 55%,

however DC Water has not yet stated what the maximum discount a ratepayer could be eligible to receive.

The Clean Rivers Project broke ground on its 20 year construction process in October 2011. Upon completion, the three tunnels will reduce combined sewer overflows to the Anacostia River by 98% and to all three waterways – Rock Creek and the Anacostia and Potomac Rivers – by 96 percent. The predicted cost of the project, as of October 2011 is \$2.6 billion. The Anacostia River tunnel should be operational by 2018 and the Rock Creek and Potomac River tunnels are expected to be functional in 2025.<sup>20</sup>

### **National Pollutant Discharge Elimination System (NPDES)**

The EPA is responsible for the NPDES permits where the discharge of pollutants is regulated. The District has been proactive in trying to gain control of their polluted waters. Their NPDES permit was recently renewed by the EPA. This indicates that the DDOE's Storm Water Management Administration meets or exceeds the requirements of the EPA's NPDES. The District received their NPDES, permit no. DC0000221, giving authorization "to discharge from all portions of the MS4s" to the receiving waters of the Potomac and Anacostia River's, Rock Creek and tributaries to each water body effective October 7, 2011, expiring on October 7, 2016.<sup>21</sup> Polluted stormwater runoff is commonly transported through MS4s, from which it is often discharged untreated into local water bodies. MS4's are not combined sewers, but in order to reduce contaminated stormwater runoff, prohibit illicit discharges, and to prevent harmful pollutants from being washed or dumped

into an MS4, operators must obtain a NPDES permit and develop a stormwater management plan (SWMP).<sup>22</sup>

### **DDOE's Impervious Surface Fees and Mitigation**

In addition to meeting requirements for the NPDES, the District has also worked on increasing tree canopy, installing green roofs and encouraging other best management practices (BMPs) through low impact development (LID) techniques, in an effort to absorb rainwater where it falls.<sup>23</sup> These BMPs are paid for through the stormwater fee that DDOE collects. Stormwater fees are required for the District to implement BMPs to reduce pollutants from entering streams and rivers as required by the MS4 permit. Similar to the Clean Rivers IAC, the DDOE fee is based upon the square footage of impervious surface on a property. This fee can be reduced by property owners who implement BMPs such as replacing paved surfaces with pervious pavers, bioretention techniques and vegetation in the combined effort of capturing rainwater where it lands. As mentioned earlier, customers are charged for their ERU. Each ERU is \$2.67 per month as of November 1, 2010.<sup>24</sup>

In 2012, DDOE plans to implement a Stormwater Retention Credit (SRC) Trading Program. Regulated properties would be allowed to purchase SRC's after retaining a minimum volume of stormwater on site for a net of 1.2 inches of retention. By creating a market for stormwater LID retrofit practices in the District, the:

“SRC Trading Program has the potential to leverage the water quality benefit accompanying regulated development under the retention standard while maximizing flexibility for regulated sites. To achieve these benefits, DDOE must implement its SRC Trading Program in a way that ensures environmental outcomes.”<sup>25</sup>

To minimize administrative costs and to benefit from tested field practices and methods, DDOE's program will review plans, perform inspections and follow enforcement procedures. Since the District is the first jurisdiction in the United States to implement such a program, DDOE is anticipating the need to evaluate impacts and be prepared to make mid-course corrections.

Increasing stormwater retention is necessary to achieve the District's required pollutant reductions under the Clean Water Act. Discounts of up to 55% of the stormwater fee will be available to both residential and non-residential properties that install stormwater retention strategies such as green roofs, permeable pavements, rain gardens, and other stormwater practices and techniques. Properties will contribute less runoff to the storm sewer system and property owner will benefit from reduced stormwater fees.

DDOE has produced differential approaches for administering and calculating discounts for both residential and non-residential properties. This has been done to encourage participation and avoid making participation burdensome, particularly for residential properties. The District will face challenges as the first city in the U.S. to establish discounts implementing these programs and coordinating them with DC Water. To successfully "achieve the maximum benefit for stormwater retention in the District, these efforts will also need to coordinate with and complement other District stormwater programs, such as stormwater retention requirements for new development, stormwater retention credit trading program, and the District's Riversmart incentive programs."<sup>26</sup>



## **Porous Pavement and Low Impact Development**

The following section pertains to the ecological effects of impervious pavement and porous pavement. It is organized into several areas of research that examine both the options for pervious materials, as well as the effects of impervious materials on the environment e.g.; groundwater recharge, decrease in vegetation, non-point source pollution, stormwater velocity and heat island effect.

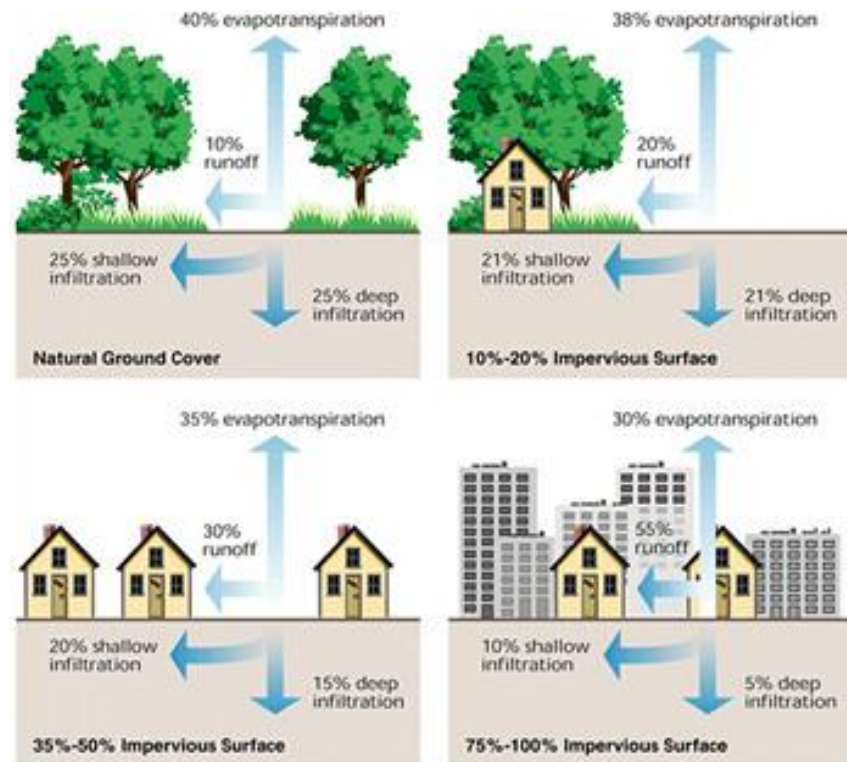
## **Issue of Imperviousness**

Parking lots are a typical sight in today's landscape. The familiarity of them may be why the environmental impact and cost of parking lots are often publically disregarded. The majority of parking lots are constructed of asphalt, concrete, including aggregates of sand, gravel or crushed stone. This pavement is impervious, which means it prohibits the infiltration of the natural water cycle to take place. One of the problems that occurs is that stormwater runoff has not been allowed to filter through the soil in order for pollutants to be mitigated. "Unlike natural conditions where rainwater filters into the ground, impervious surfaces halt this process, inhibiting a watershed's natural hydrological cycle and preventing groundwater recharge. As a result, water tables are lowered, reducing stream flow during dry periods, depleting water supplies, and exacerbating the negative impacts of droughts."<sup>27</sup> As stormwater travels over impervious pavement, it collects pollutants such as pesticides, fertilizers, petroleum residues and other contaminants and deposits them in nearby water bodies. The unnaturally high rate of these toxins and the volume of water both serve as a severe detriment to the local ecosystem. "Hence, parking lots degrade water quality, strain stormwater management systems, consume large amounts of land and resources and enable urban sprawl."<sup>28</sup>

The EPA defines impervious surfaces “as any material that prevents the infiltration of water into the soil.”<sup>29</sup> These surfaces include roofs, buildings, roads, sidewalks, patios, driveways and compacted soils. However, in the last 100 years, in correlation with the invention of the automobile; roads, highways, parking lots, and driveways have come to be an important landscape feature. In 1904, 93% of the roads in the United States were unpaved. The mid-20<sup>th</sup> century’s, massive construction effort of the interstate highway system served to both stimulate and facilitate the growth of suburbia which lead to more imperviousness.<sup>30</sup> The speed at which these roads and other impervious surfaces were constructed severely altered our ecosystems which served as a major shock to the environment which is now beginning to be understood.

As land becomes more urbanized, compacted, and paved, several things impact the hydrologic cycle leading to degraded water resources [fig. 9]. During a storm event, the stormwater runoff is not able to infiltrate the soil which leads to increases in velocity and volume. Due to these issues, society has responded by installing pipes, gutters, dams, stream diversion, and channel straightening which has led to severe flooding as well as “flashiness” of peak discharges resulting in wider and straighter stream channels. The other concern with water infiltration is that groundwater is not recharged resulting in aquifers attenuating and affecting the quality and supply of our drinking water. This same water feeds streams and due to the decrease in groundwater, base flow in streams is reduced and sometimes eliminated.

“About 39 percent of the entire District was covered with impervious surfaces as of 2008, with the amount of imperviousness varying by neighborhood or ward from 30 to 60 percent. Development and urbanization have taken a toll on the natural features within Washington, DC. Over the past 30 years the District has lost 64 percent of its areas with heavy tree cover and experienced a 34 percent increase in stormwater runoff.”<sup>31</sup>



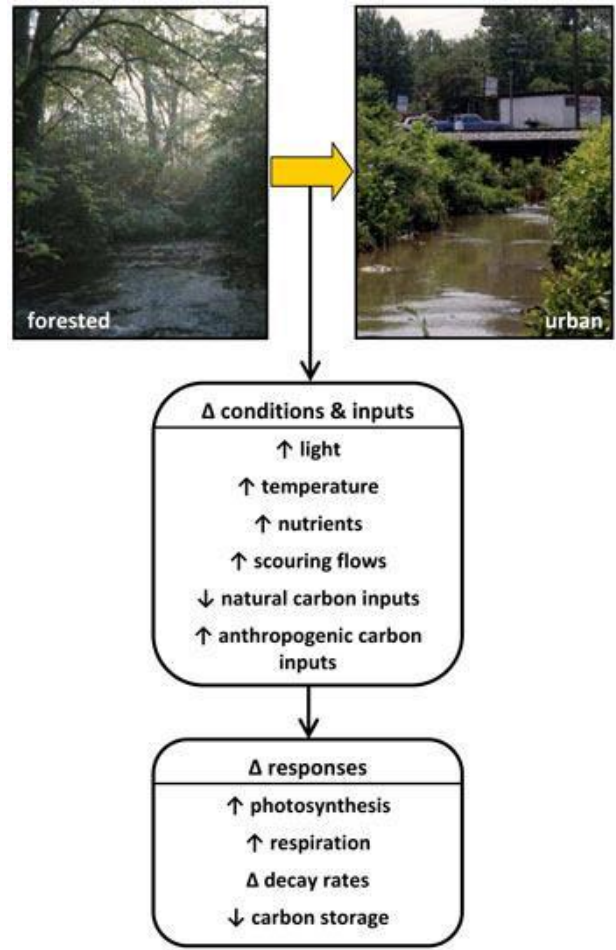
32

Fig. 9. Increase in impervious surfaces result in less stormwater infiltration. During a storm event, the stormwater runoff is not able to infiltrate into the soil, leading to increases in stormwater velocity and volume.<sup>33</sup>

### Decrease in Vegetation

Other factors of urbanization are the removal of trees from areas such as the banks of waterways or riparian zones. Trees and shrubs stabilize banks by reducing the impact of erosion through their strong root systems. Riparian zones also filter and trap pollutants such as sediments, nutrients and chemicals from stormwater runoff before reaching the water body. These riparian buffers provide food and protection to fish and wildlife. Impacts of urbanization on streams result in a lack of riparian

vegetation which leads to waterways becoming more polluted, warmer in the summer, colder in the winter and fish and wildlife disappear from the area [fig. 10].



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Fig. 10. Stream Changes Due to Urbanization

**Source of Pollution (NPS)**

Impervious pavements have gravely diminished our water quality as they are the main contributor of non-point source (NPS) pollution to waterways. The contaminants that can be found in this NPS pollution come from several sources including polycyclic aromatic hydrocarbons (PAHs) found in pavement sealants.<sup>35</sup> Cars also leave large amounts of pollutants on parking surfaces including grease, nitrous oxide from car exhaust, brake system debris, rubber particles from tires, oil,

antifreeze, hydrocarbons, and metals from brake linings. These NPS pollutants are known carcinogens that have detrimental effects on fish and wildlife. Studies conducted on brown bullhead catfish collected from the Anacostia River, found that 50 percent had cancerous liver tumors and about 25 percent had cancerous skin tumors.<sup>36</sup>

### **Stormwater Velocity**

Another impact of impervious surfaces is the increased velocity and force of the runoff produced. Contemporary parking lots typically channel water through drains, pipes and gutters quickly into the nearest receiving waters. “According to the U.S. Geological Survey, an impervious, man-made surface will generate two to six times more runoff than a natural surface.”<sup>37</sup> The volume of all this water increases the risk of flooding as well as overwhelms the stormwater system which causes them to overflow. CSS’s burdened during storm events end up discharging CSO’s. These incidents pose human health risks and cause algae blooms to form, which leads to depletion of aquatic oxygen levels and eventually altering the habitat of that waterway. Fast moving water created during storm events is also responsible for erosion of stream banks. The sediments deposited into the water results in turbidity, which disrupts aquatic ecosystems by diminishing light transmission, reducing plant growth, altering food supplies, interfering with navigation, decreasing spawning habitat, and reducing shelter.<sup>38</sup> Impervious surfaces can also have the opposite effect by creating streams that have an unnaturally low stream flow as a result of decreased infiltration reducing deep water and swift flowing habitats. “The decreased water quality and increase volume and velocity of runoff can lead to habitat loss, stress

aquatic species, and have an overall negative effect on biological diversity” in adjacent areas.<sup>39</sup>

### **Heat Island Effect**

“Heat island” describes urban areas that are hotter than rural areas. The dark, heat absorbing material in asphalt parking lots and roadways are also responsible for contributing to the heat island effect. “Research indicates that urban areas are 2° to 8° hotter in summer due to this increased absorbed heat.”<sup>40</sup> The EPA reports these temperatures can be as much as 22° warmer at night.<sup>41</sup> The heat affects local waterways when water flows quickly over the hot surface, rising in temperatures discharging into a nearby water body, and warming the receiving waters ultimately affecting fish and other aquatic life. The materials found in asphalt are not the only factors warming the property. Clearing land of trees and other natural vegetation promotes an unnaturally hot area as it removes shade and evaporative process that the vegetation once provided. A heat island effect not only impairs water quality, it contributes to increased air pollution, greenhouse gas emission, heat related illness and increases demands on energy for air conditioning.<sup>42</sup>

### **Green Parking Lot Overview**

The best method to address the lack of infiltration in parking lot is the use of low impact design (LID) techniques. LID can be considered a best management practices (BMP) focused on improving hydrological functioning in built landscapes. “Stormwater best management practices (BMPs) include structural controls and bioengineering techniques designed to facilitate natural water cycling processes (i.e. evaporation, transpiration, and groundwater recharge) by capturing, filtering,

infiltrating and/or storing stormwater.”<sup>43</sup> As stated earlier, some examples of BMPs include: swales, filter strips/vegetated buffer strips, riparian buffers, detention basins, and bioretention areas. These techniques minimize the impact on the environment caused by stormwater runoff and often lower site development costs while also increasing aesthetics. When used together, these stormwater treatment trains (STT) become even more ecologically valuable. Creative planning and design can considerably mitigate the adverse effects of parking lots. “Green parking lots” describe designs that incorporate a variety of “environmentally preferable features, including minimized footprint and/or impervious surfaces, use of stormwater BMPs, and use of recycled materials.”<sup>44</sup> These designs can also provide several beneficial functions such as groundwater recharge, decreasing the rates of stormwater runoff, and filtering out NPS pollution. They can also decrease imperviousness, protect water quality, decrease stormwater management and maintenance costs, and be more visually attractive. Green parking lot techniques include on-site stormwater management, material selection, recycling and reuse techniques. To reiterate, the purpose of on-site stormwater management is to capture water where it falls and allow it to filter into the ground and eventually the aquifer instead of flowing off into local waterways such as the Anacostia River.

### **Permeable Pavements Overview**

Due to the traditional impervious materials that are typically used in parking lot construction and the rise of stormwater issues related to parking lots, the construction industry has responded with numerous materials that are intended to address infiltration issues. Permeable materials are becoming more popular and are an

improved alternative in many jurisdictions. Some examples of permeable and semi-permeable alternative pavements include gravel, cobble, concrete, wood mulch, brick, open-jointed pavers, turf blocks, natural stone, and pervious concrete.<sup>45</sup> Porous pavements are successful in low traffic areas, such as parking lots and sidewalks. The most successful installations of these alternative pavements are found in coastal areas with sandy soils and flatter slopes. Permeable pavements allow stormwater to infiltrate into underlying soils promoting pollutant treatment and groundwater recharge, as opposed to producing large volumes of rainfall runoff requiring conveyance and treatment.<sup>46</sup> Permeable Interlocking Concrete Pavements (PICP) are recognized by the EPA as a BMP to reduce runoff and water pollution. Unlike conventional stormwater management solutions that concentrate and dispose of stormwater, PICP widely distribute runoff through “infiltration, detention, filtering and treatment.”<sup>47</sup> PICP filter water through small-sized aggregates that are extremely permeable. Permeable joints allow water to flow into the “crushed stone, open graded aggregate bedding course.”<sup>48</sup> By using PICP to control stormwater runoff volumes, rates and pollution reductions, municipalities are able to meet regulatory water quality criteria.<sup>49</sup> Porous concrete is capable of filtering 3-8 gallons of water a minute through open cell structures that form due to a mix of coarse aggregate, cement, water and almost no sand. “The open cell structure of pervious concrete provides a medium for aerobic bacteria that break down many of the pollutants that leak from parked cars. It also enhances air quality by lowering atmospheric heating through lighter color and lower density decreasing the impact of heat island effects.”<sup>50</sup> By using PICP



to control stormwater runoff volumes, rates and pollution reductions, municipalities are able to meet regulatory water quality criteria.<sup>51</sup>

Ferguson organizes types of porous paving into nine families.<sup>52</sup> Information gathered from Ferguson's literature was organized into tables for each paving family. The table provides the definition, advantages and disadvantages, as well as cost (if available) and maintenance requirements. The nine porous paving families are as follows:

1. Porous Aggregate
2. Porous Turf
3. Plastic Geocells
4. Open-Jointed Paving Blocks
5. Open Celled Paving Grids
6. Porous Concrete
7. Porous Asphalt
8. Soft Paving Materials
9. Timber Decks

**Table 1. Porous Aggregate Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
<p>“Porous aggregate is any mass of particulate material such as gravel, crushed stone, crushed recycled brick, or decomposed granite. Single-size particles create an aggregate mass with 30 to 40 percent void space; such ‘open graded’ material can be extremely permeable to air and water.”<sup>53</sup></p>	<p>It works best in areas such as driveways or parking lots. Aggregate is useful in freezing zones where it is not noticeably effected by heaving soils. And it is typically used when restoring hydrology in watersheds. Aggregate is flexible for tree root spread.<sup>54</sup></p>	<p>Aggregate can be easily displaced by traffic unless used with a grid structure.</p>	<p>Aggregate is the most common and least expensive pavement material.</p>	<ol style="list-style-type: none"> <li>1. Periodic leveling and replacing displaced stone.</li> <li>2. Compacted tracks may occur.</li> <li>3. Treatment of weeds or spreading lawn grasses sprouting in the gaps between the aggregates.</li> </ol>



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Fig. 11. Example of porous aggregate

**Table 2. Porous Turf Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Maintenance</u>
Porous turf is a green open space that supports pedestrian or vehicular traffic. It can also be used for overflow parking and remains permeable as long as it does not become compacted by excessive traffic.	Porous turf is a good material to use in areas where swelling soil or frost heave may occur. It can be used as a walkway or parking with frequencies of once weekly. Reinforcement with geocells, adds a green space look and flexible surface to settings with heavier or more frequent loads. <sup>56</sup>	It is easily damaged if placed where topsoil is clay, since wheels and heels can dig into turf in wet weather.	Regular mowing, once yearly fertilizing, periodic top dressing and irrigation. Because of maintenance, use should be predictable such as at an office, church or event parking.



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Fig. 12. Example of porous turf

**Table 3. Plastic Geocells Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Maintenance</u>
Plastic geocells are “manufactured lattice-like products that hold aggregate or topsoil in their cells, inhibiting displacement and compaction.” <sup>58</sup> Geocells work well in areas of aggregate and turf where demanding traffic would not allow them to act successfully on their own.	Plastic geocells are flexible which allows them to move with the swelling and heaving of the land due to frost.	Geocells may require a firm base depending on the soil and traffic loads.	Depending on whether angular gravel or sod is installed over the geocells, the geocell units may require irrigation, reseeding, or top dressing. If a cell becomes loose, it may need to be anchored or firmly interlocked, panel to panel. According to Ferguson’s <i>Porous Pavements</i> , if the geocell is installed with a sandy medium, it resists compaction. <sup>59</sup>



Fig. 13. Example of plastic geocells

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**Table 4. Open-jointed Paving Blocks Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
“Paving blocks are solid units of concrete, brick or stone laid side by side to bear traffic loads. The models that can be used to make porous pavements are shaped to produce open joints between adjacent units.” <sup>61</sup>	Many blocks are durable to the point of being able to bear heavy traffic. These pavements can be very permeable with the correct open-graded aggregate in the joints or through the use of open-grade block.	They also require a thick base course to avoid movement from heaving due to frost. This action may prevent infiltration through the block. Also, joint fill may become clogged and therefore porosity decreases.	Prices vary, however, block pavements are expensive.	Depending on the amount of use the parking area or driveway receives determines how often cleaning, vacuuming or replacement of joint fill occurs. Open grade pavers may only require periodic blowing or vacuuming of the joints if they become clogged due to leaf debris.



Source: Author

Fig. 14. Example of open jointed paving blocks

**Table 5. Open-celled Paving Grids Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
<p>“Open-celled paving grids are units of concrete or brick, which are designed with open cells that can be filled with porous aggregate or turf. The units are laid side by side like blocks. The resulting surface is a grid work of solid ribs or pedestals commonly an inch or more side, alternating with cells of aggregate or grass.”<sup>62</sup></p>	<p>If traffic is infrequent and the area is maintained well, it will give the impression of a lawn like look, suitable for walking. This material is long lived and can bear the loads of heavy materials for such areas as emergency lanes.</p>	<p>This pavement is best suited for lightly used parking stalls or infrequent traffic such as emergency access lanes.</p>	<p>Paving grids require fairly expensive paving materials in order for it to remain a valuable surface.</p>	<p>If the grass is poorly maintained or the cells are filled with aggregate, the irregular surface will make it difficult to walk across. It also will require mowing, fertilizing, top dressing and removal of thatch. This paving option should not be used in areas where the soil heaves or swells.</p>

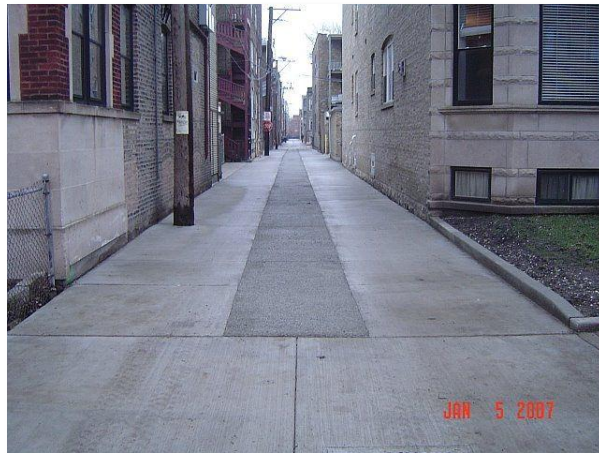


63

Fig. 15. Example of open-celled paving grids

**Table 6. Porous Concrete Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
<p>“Porous concrete is made of single size aggregate bound together by Portland cement, cast in place to form a rigid pavement slab. It is a subtle variation of conventional dense concrete, requiring a special specification and an experienced installer.”<sup>64</sup></p>	<p>Porous concrete has quite a long life as long as the concrete is properly installed. It also does extremely well in walkways and driveways where there is moderate traffic and it can handle heavy traffic loads.</p>	<p>It is also susceptible to cracking due to heaving and being incorrectly mixed, which should be considered when used in colder climates.</p>	<p>Although porous concrete costs more than dense concrete, due to its porosity, extra land is not required for retention ponds that may be required for stormwater control requirements.</p>	<p>Little routine maintenance is required if installed correctly. Periodic vacuuming or pressure washing may be necessary if material becomes clogged. Studies done by Cleveland State University found “two possible sources of clogging were identified: landscape soil washing onto the pavement, and adjacent deteriorated asphalt pavements.”<sup>65</sup></p>



66

Fig. 16. Example of porous concrete

**Table 7. Porous Asphalt Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
“Porous asphalt is made of single-size aggregate bound together by bituminous asphalt binder.” <sup>67</sup>	Porous asphalt can be highly permeable. Once asphalt reaches the end of its life, it can be recycled on site and reused with the same infiltration as new asphalt.	Although the permeability can be high, the binder can sometimes clog this benefit within the pavement structure and therefore must be installed correctly. Pollution from chemical binding agents in asphalt makes its way into waterways.	Porous asphalt can cost less due to its porosity, extra stormwater control requirements may not be necessary.	Seal coating cannot be done as it will clog pores, as will winter sanding. Brushing, pressure washing and vacuuming depends on the amount of sediment tracked onto the pavement.



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Fig. 17. Example of porous asphalt



**Table 8. Soft Paving Materials Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
“Soft paving materials include any granular material from an organic or recycled source such as bark, mulch, crushed shells, or rubber granules.” <sup>69</sup>	This material works well in naturalistic, historic or informal settings where very light traffic (i.e. pedestrian walkways) occurs. It can “bring gentle beauty and integration with the organic life of the soil.” <sup>70</sup> It can also act as a traffic calming device where pedestrian traffic comingles with vehicular traffic. <sup>71</sup>	Soft paving materials can easily become compacted or displaced under excessive traffic or in windy areas or areas where concentrated surface runoff occurs.	Low	Soft porous surfacing materials should be laid approximately 12” thick if impact attenuation is desired and edge restraints should be installed. Also, a bed of open aggregate placed on the bottom will help with drainage. Periodic replenishing, leveling and weeding is necessary.



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Fig. 18. Example of soft paving materials

**Table 9. Timber Deck Analysis**

<u>Definition</u>	<u>Advantages</u>	<u>Disadvantages</u>	<u>Cost</u>	<u>Maintenance</u>
“Decks and boardwalks are surrogates for pavements. They are bridge-like structures built on footings that suspend them over the soil surface. They leave the soil below almost entirely free for rooting and water infiltration. They are completely permeable to air and water as long as their decking components are perforated or spaced apart from each other.” <sup>73</sup>	Underlying soil does not compact under decks and they are suitable to freezing and swelling due to frost. Some desks are also suitable for vehicular traffic. Decks also allow for tree roots and soils to remain protected.	Cost	The cost can be quite high depending on the wood, foundation and other materials used.	Timber structures have a history of longevity. If good materials are used, rusting metal or rotting wood should be minimal.



Source: Author

Fig. 19. Example of timber decks

## **Precedent Projects**

The following selection provides an overview of selected precedent studies of other arboretums and towns that have undertaken porous pavement projects. Five precedent sites were reviewed and stormwater BMPs related to parking lots were noted. The five sites include 1) Morton Arboretum in Lisle, Illinois; 2) North Carolina Arboretum in Asheville, North Carolina; 3) Bladensburg Town Hall in Bladensburg, Maryland; 4) Autumn Trails Subdivision in Moline, Illinois; and, 5) Gotts Court and Visitor Center Parking Lot in Annapolis, Maryland.

### **The Morton Arboretum, Lisle, Illinois**

Since its founding in 1922, the Morton Arboretum has demonstrated sustainable practices benefiting the environment and the community. As an advocate of greener environments and the conservation of resources, the Morton Arboretum has been conducting five different pilot tests of new commercial products designed to protect trees and the environment. These studies include the following materials:

1. Filtercrete, a pervious concrete
2. FilterPave, made of crushed recycled beer bottles, as well as a polyurethane binder to make a permeable walking surface.
3. Aqua-Bric Paveloc, permeable pavers
4. Eco-Optiloc Unilock, permeable pavers



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Fig. 20. Morton Arboretum Permeable Paver Parking Lot

The main parking lot for the Morton Arboretum filters stormwater runoff before it reaches the ecosystem of Meadow Lake, habitat to plants, fish, birds, and amphibians [fig. 20]. Meadow Lake watershed drains into the DuPage River, which drains into the Des Plaines River, continues into the Mississippi River, and ultimately empties into the Gulf of Mexico. The filtration through the parking lot occurs when rainwater and melting snow passes through layers of interlocking permeable pavers, fine gravel placed in between the paver gaps, followed by a four foot deep layer of gravel found beneath the pavers. This process not only cleans and cools the water, it slows it down instead of forcing it into a sewer grate, taking with it oil, and other fluids from cars as well as tar and other pollutants typically carried by stormwater.<sup>75</sup>

As a pervious pavement and with use and wear over time, permeable pavements become blocked with sediment from soil, leaves or sediment, which slows infiltration. Although these surfaces require periodic cleaning for proper infiltration, the pavers at the Morton Arboretum proved to need little maintenance as it was sufficiently infiltrating water seven years after installation.

By 2009, the Morton Arboretum PICP parking lot had received considerable car and bus traffic, as well as sand and deicing materials in the winter. The surface of the parking lot had not been cleaned since its construction in 2002. To determine if cleaning was necessary and how the system had performed over a seven year period, pavers and jointing material were removed, in a heavily trafficked area, to observe the path and penetration of sediments in the joints. It was found that much of the sediment was trapped in the first ½ inch of the openings. When the pavers and jointing material were removed and there was no sediment visible on the bedding material or in the ASTM no. 57 stone base. This demonstrated the capability of PICP installation in trapping the surface sediment.

Due to PICP trapping sediment in the jointing aggregates, some cases with low infiltration will require removal of the jointing aggregates and replacement.

“This procedure was demonstrated at the Morton Arboretum parking lot using a vacuum machine capable of removing the aggregate and sediment captured in the joints. The vacuum was adjusted so that only the top inch of aggregates and sediment were removed. This cleaning process substantially increased the surface infiltration rate based on observing differences in the rate of water poured on and penetrating undisturbed and restored surfaces. After the surface was cleaned by removing aggregate and sediment, new aggregate was spread and swept into the openings there by refilling them to their original condition.”<sup>76</sup>

PICP cannot have sand spread on them in the winter months when this process of street treatment occurs. Instead, the Arboretum uses a rubber tip, metal blade,

sweeper or deicing agent to keep the pavements clear, which is used conservatively to protect plant life and water quality.<sup>77</sup>

### **FilterPave Project**

FilterPave is a product that mixes recycled, crushed beer bottles that have been processed to round the edges with a syrup-like polyurethane resulting in the texture of a Rice Krispy bar and laid like a concrete path. Due to its highly permeable surface, it allows water to quickly pass back into the ground water. The other benefit is reducing the heat island effect due to its lighter color than asphalt.

This product has been tested for the past 16 years and tests results indicate that FilterPave can handle freeze and thaws well. Although it is susceptible to damage by winter plow blades, it allows water to quickly drain preventing ice build-up. This product is similar in cost to permeable pavers as it costs approximately \$10 to \$12 per square foot installed.<sup>78</sup>

### **The North Carolina Arboretum, Asheville, North Carolina**

The North Carolina Arboretum installed its permeable parking lot so that it could retain a 10-year storm. The permeable pavers are set on 18 inches of washed gravel which acts as a temporary reservoir for the stormwater while slowing the momentum of the water and cooling it before it is released into local waterways. This permeable parking lot accommodates heavy traffic and receives annual maintenance in order to remove debris that clogs the permeability of the pavers.<sup>79</sup>

## The Town of Bladensburg, Maryland



Source: Author

Fig. 21 Bladensburg, MD Town Hall PaveDrain Parking Lot



Source: Author

Fig 22 Bladensburg, MD

The EPA and the Federal Highway Administration organized the Green Highways Partnership in 2005 and recently began the Green Streets, Green Jobs, Green Towns, program (G3), piloted in the Anacostia Watershed with the town of Bladensburg, Maryland.

“The G3 Initiative unites a town's green vision with tools needed to accelerate local greening efforts. The result is greater watershed protection, community livability and new green economic opportunities. The purpose of the G3 Academy, comprised of technical, financial, planning and design assistance providers, is to bring the information and technology to the local town in a meaningful way. By tapping into the Academy, local governments and communities protect environmental resources by implementing best management practices and create new green jobs through these greening projects.”<sup>80</sup>

Bladensburg installed an open grade concrete block system in the town hall parking lot that has been tested to handle a 7.6” per hour rain event without runoff [fig. 21 and

22]. The town administrator, John Moss, stated that after 13 months, the pavement system has not required vacuuming, needs less surface treatments during snow or ice events, and infiltrates 100% of the direct rainfall as well as all of the runoff from the roof of their building.<sup>81</sup>

**Autumn Trails Subdivision of Moline, Illinois**

PICP has proven to be cost effective in new development and redevelopment. One example of such cost savings on residential roads is located in the Autumn Trails subdivision of Moline, Illinois. About 39,000 square feet of permeable pavers were installed to eliminate the need for storm sewer inlets and pipes. According to developer estimates, using permeable pavers, without storm sewer drainage, was cost-competitive with conventional pavements using standard drainage systems (2006 prices). Cost comparison studies done included conventional pavements and curbing for all pavements as well as appropriate base materials and thicknesses [fig. 23].

<b>Pavement System</b>	<b>PICP <u>no sewers</u></b>	<b>Concrete <u>w/sewers</u></b>	<b>Asphalt <u>w/sewers</u></b>
<b>Cost/sf (m<sup>2</sup>)</b>	\$10.95 (\$117.82)	\$15.00 (\$161.40)	\$11.50 (\$123.74)

Adapted From: Permeable Interlocking Concrete Pavements<sup>82</sup>

Fig. 23. Cost Analysis of Autumn Trails PICP vs. Conventional Pavements



## Gotts Court and the Annapolis Visitor Center Parking Lot



Source: Author  
Fig. 24. Parking Lot



Source: Author  
Fig. 25. Raingarden and Walkway

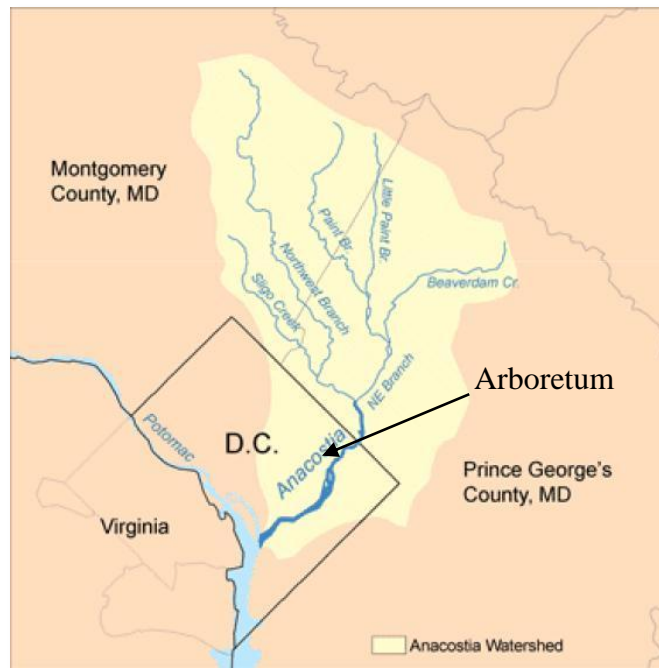
Gotts Court and the Annapolis Visitor Center parking lot were redeveloped in the Fall of 2009 by the O’Doherty Group Landscape Architecture firm [fig. 24]. The 10,000 square foot site includes permeable paving to increase infiltration of stormwater runoff, six raingardens that capture water from the parking area providing for, 27 parking spaces; and recycled paving materials that accent the design and increase its sustainability. It has been referred to as a “parking garden”.

The design directs all stormwater runoff from the parking area into the six raingardens and if needed, to an overflow pipe [fig. 25]. In September 2011, Hurricane Lee soaked Annapolis with 8.11” of rain water. Even with that amount of water, the overflow pipe had an insignificant amount of water trickling out of it. “The rain naturally flowed in between the spaces between the pavers to an underground system of aggregates.”<sup>83</sup> Whereas traditional impervious parking lot design would have allowed the water to sheet flow across the impervious pavement, collecting pollutants and distributing them into local waters.

## Chapter 3: Design Project

The methods for this design included inventory and analysis of the site as well as design exploration. The inventory included research into the location and history of the NGST and well as a photo documentation of the site. The analysis of the NGST includes document of the topography and vegetation. The design exploration focused heavily on pedestrian and vehicular circulation and the relationship between the proposed new Grove and the proposed parking.

### Location and History



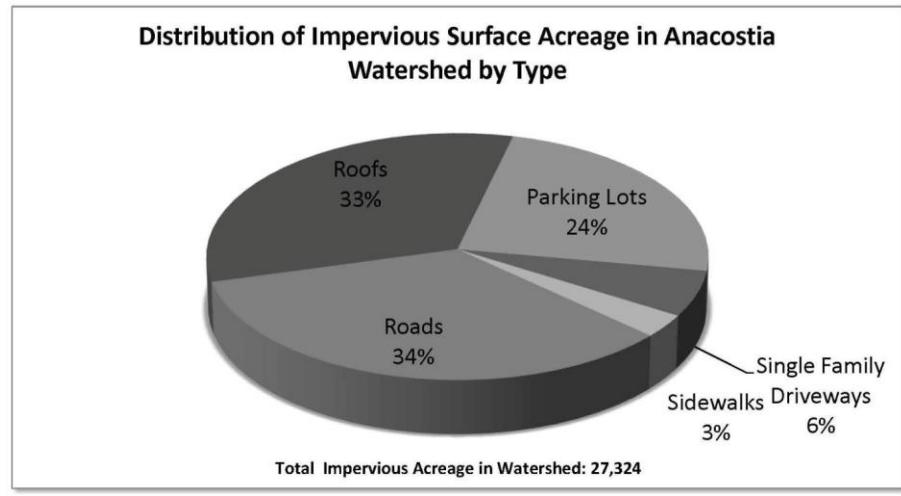
Source: EPA<sup>84</sup>

Fig. 26. Location of United States National Arboretum within the Anacostia Watershed

The United States National Arboretum is located within the Anacostia watershed [fig. 26]. Home to over 800,000 people, the Anacostia watershed has the highest population density of all areas within the Chesapeake Bay watershed.<sup>85</sup>

Seventy percent of the Anacostia watershed is developed and covered with

approximately 43 square miles of impervious surfaces such as driveways, roads, parking lots, roofs, and sidewalks equaling 20 million cubic yards of concrete [fig. 27].<sup>86</sup>



Adapted From: DC Appleseed<sup>87</sup>  
Graph: Author  
Fig. 27

of development within the watershed occurred without systems in place to manage stormwater runoff and pollutants that combine with the stormwater and flow into the Anacostia River.<sup>88</sup> The Anacostia River is a shallow tidal estuary that is fairly slow moving. It can take as many as 30 days for an object to move from the head of the estuary near Bladensburg, to the mouth of the River near Hains Point.<sup>89</sup> Therefore it is unable to perform a natural cleaning process due to the inability to move trash, pollutants or sediments downstream as well as not being able to re-aerate itself which contributes to low dissolved oxygen.<sup>90</sup> At one time the Anacostia River was deep enough that ocean-going vessels were able to navigate it. Historical accounts describe the river as having “extensive marshes, dense with wild rice, cattails, and reeds, lining

a deep-water channel” [fig. 28].<sup>91</sup> This changed due to Maryland’s profitable farming industry. Plantations such as Montpelier in Prince George’s County alone cleared

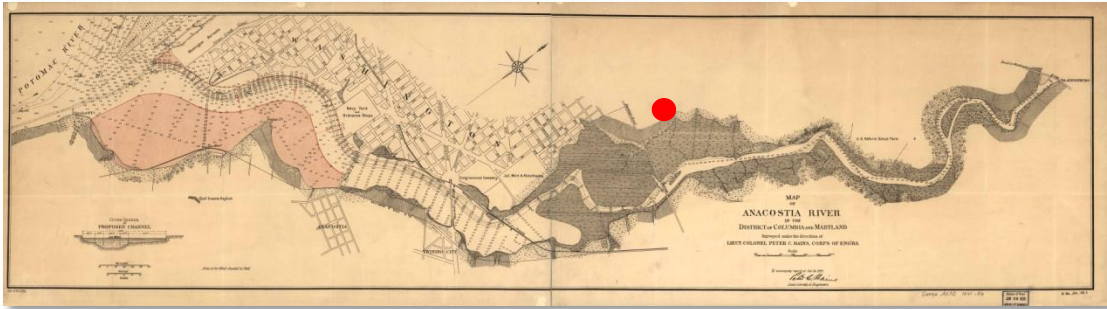
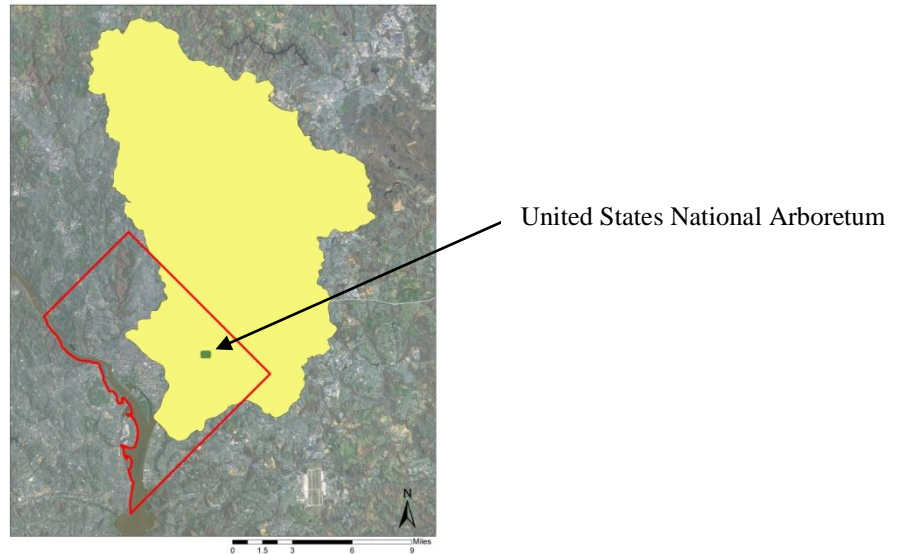


Fig. 28. The grey hatching around the Anacostia River shows the amount of marshes that once populated the river as shown in this map dated 1891. The current location of the United States National Arboretum is noted by the red dot. *Map of Anacostia River in the District of Columbia and Maryland, surveyed under the direction of Lieut. Colonel Peter C. Hains, Corps of Eng'rs, October 24, 1891*<sup>92</sup>

9,000 acres of forestland for tobacco fields. This clearing practice resulted in severe silting of the Anacostia River. Siltation followed by dredging, destroyed much of the ecologically beneficial marshes that filtered the polluted waters. Further damages resulted from expanding industry and unregulated dumping of sanitary sewage. Between 1920 and 1940, the U.S. Army Corps of Engineers removed any remaining marshes in an effort to control malaria outbreaks.<sup>93</sup> Today, the Anacostia River is mainly surrounded by non-vegetated and subsequently non-filtering mudflats.

The project site at the NGST, which is located in the District and falls within the Anacostia Watershed. The Anacostia Watershed encompasses territory in Prince George’s County, Maryland, Montgomery County, Maryland and the District of Columbia [fig. 29]. The total amount of land that falls within the project site is 35 acres [fig. 30]. It is a combination of woodland, parking lot, streets, picnic areas and the NGST itself.

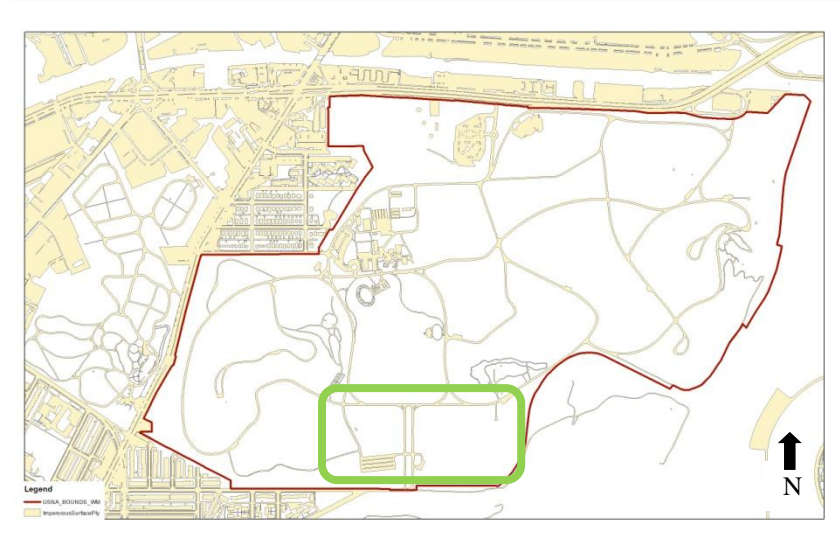


Data Source: District of Columbia GIS  
 Fig. 29. Anacostia Watershed and District of Columbia Boundary



Data Source: District of Columbia GIS  
 Fig. 30. 35-Acre Thesis Boundary encompassing the National Grove of State Trees located on the southern boundary of the Arboretum

The NGST is located within the southern portion of the United States National Arboretum [fig. 31]. It was first envisioned in 1989 by the National Association of State

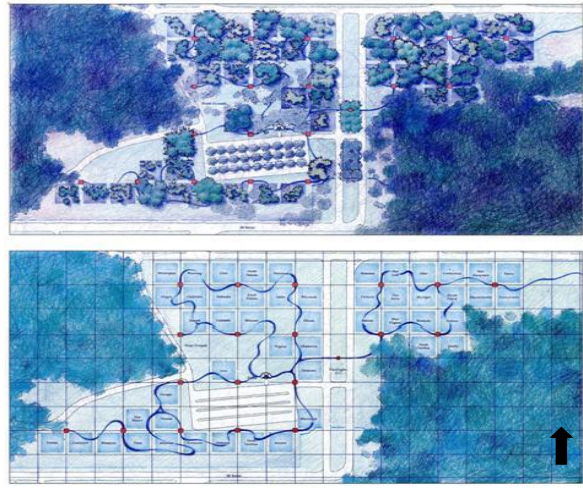


Data Source: District of Columbia GIS

Fig. 31 United States National Arboretum, Washington D.C.  
Roads, property boundary and design site.

Foresters (NASF). With the cooperation of the Arboretum, the American Forestry Council and the USDA Forest Service, the NGST was developed and implemented. The NGST was originally sponsored by the late Jeanne Yeutter, wife of the former Secretary of Agriculture, Clayton Yeutter. Mrs. Yeutter's platform focus concerned the encouragement of tree planting and reforestation across America. She felt that school children were her most important audience. In 1990, Mrs. Yeutter stated "we have to start thinking about global warming now. We can't wait until it's a huge problem."<sup>94</sup>

The original design for the NGST was done by HOH Associates [fig. 32]. Trees were installed in the NGST during the growing seasons of 1991-1993. Each State Forestry agency supplied trees from their home state, and planted them in the NGST. Each planting was followed by a commemorative ceremony. The goal was to include a trail with interpretive signs throughout, which would explain information about each of the trees. Unfortunately, this trail and interpretive signs were never



95

Fig. 32. HOH Associates original plan drawing, including trails and interpretive sign nodes, of the National Grove of State Trees

completed and there are no visible remains of the trail today. The NGST was originally intended as a “demonstration of the various environmental benefits of trees” and “enhance our understanding and awareness of the natural environment” as well as act as a “living monument to America’s natural environment.”<sup>96</sup>



Photo: author

Fig. 33. Image shows Wyoming state trees in a failing state



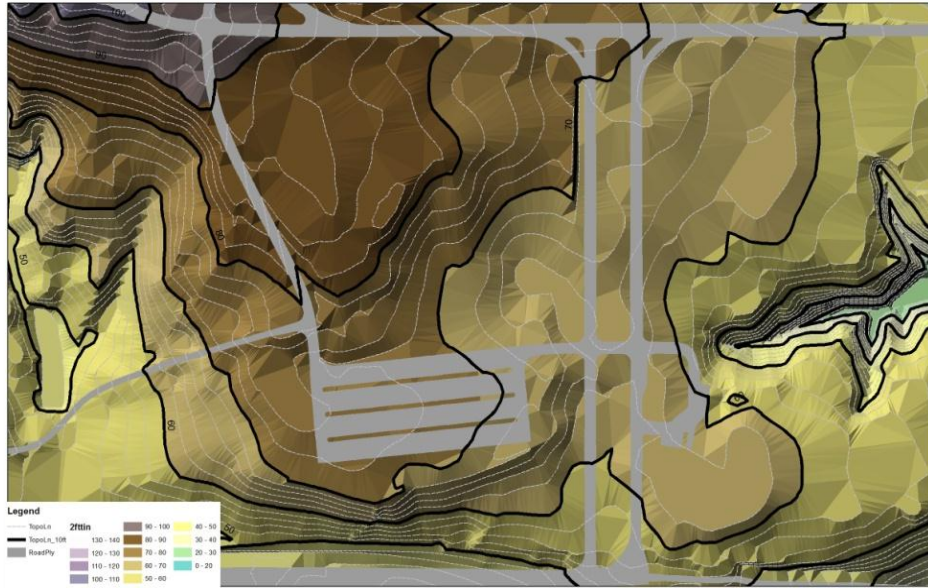
Photo: author

Fig. 34. Image shows remains of a tree left in the NGST

Unfortunately, many of these trees have either died or are in decline and therefore the NGST has open areas and is in need of a re-design [fig. 33 and fig. 34 and appendix 1].

## Topography

The current topography of the site varies considerably and has an overall grade change of 86 feet from its highest point to lowest point [fig. 35].

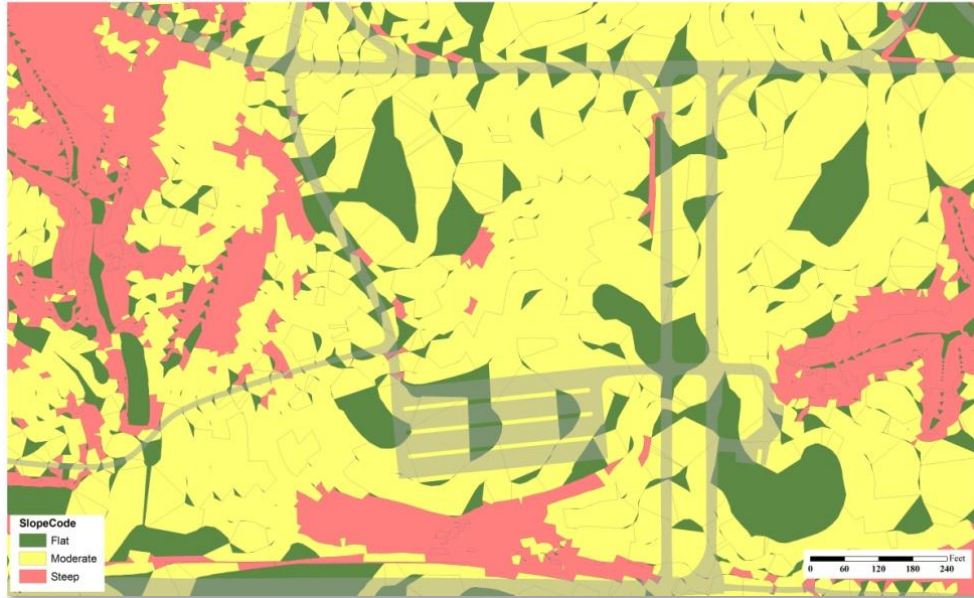


Data Source: District of Columbia GIS

Fig. 35. Relief Map

Much of the site has a moderate slope of 8% to 15% (yellow sections of the slope map fig. 36). However, the next largest category of slope is the steep slopes of 15% or more (red sections of the slope map) with the remainder of the areas being fairly flat at a slope of 8% or less (green sections on the slope map).



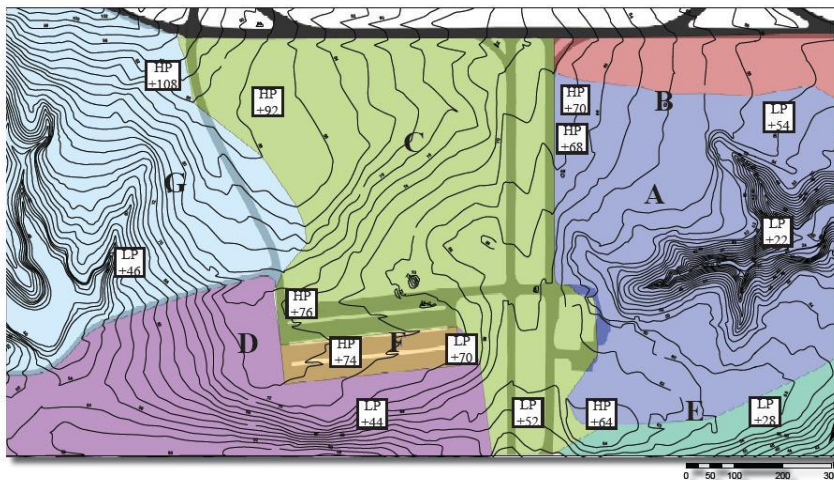


Data Source: District of Columbia GIS

Fig. 36. Map illustrating the slope surrounding the site

## Hydrology

The NGST has seven main catchments on the property [fig. 37]. These catchments end up flowing to one of two main ravines that eventually lead out to the Anacostia River. The characteristics, acreage, high point and low point of each catchment are noted [fig. 37 – 39].



Data Source: District of Columbia GIS

Fig. 37. Catchment Map

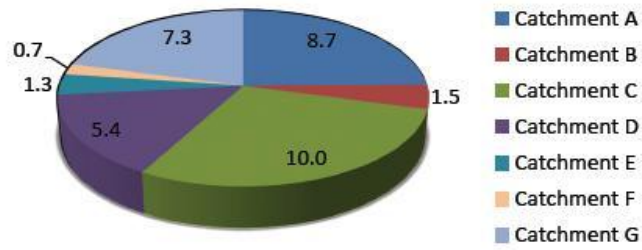


Fig. 38. NGST Catchment Acreage

Catchment	% of Total Land Area	Catchment Characteristics
A	24.8%	Combination of dispersed tree collection and heavily wooded steep ravines surrounded by oaks and sycamores
B	4.4%	Fairly flat with dispersed tree collection
C	28.8%	Gentle slopes for most of the area with dispersed tree collection mixed with existing pre-National Grove of State Trees existing
D	15.4%	Steep Sloping area with dispersed tree collection
E	3.8%	Heavily wooded area that is not typically used by the public
F	1.9%	Flat asphalt paved parking lot
G	20.8%	Steep sloping woodland of Oaks and sycamores

Fig. 39. Catchment Table Characteristics

## Vegetation

Existing vegetation within the site boundary varies. As a broad categorization, the site has been divided into four sections to describe the characteristics of the vegetation [fig. 40].



Data Source: District of Columbia GIS

Fig. 40. Existing Vegetation

Section A is a woodland containing oaks and sycamores. Section B is the largest containing the NGST and 317 trees of varying species [see appendix 8]. Section C is almost completely wooded with oaks, sycamores and few maples except for the former location of a building where asphalt pavement still exists from an old parking lot. Section D has a couple of trees, however it is main lawn and therefore mostly turf.

The 317 trees within the NGST collectively have approximately seven acres of tree canopy with nine acres of turf, two acres of road and one acre of parking lot [fig. 41 and fig. 42].

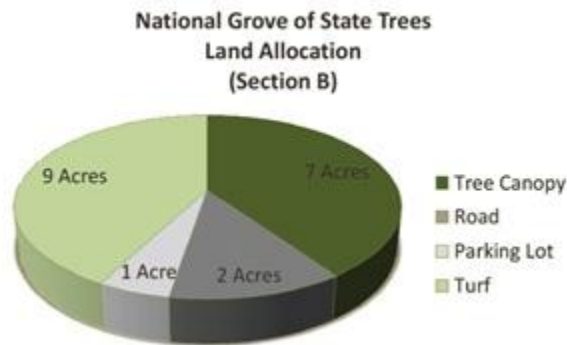


Fig. 41. National Grove of State Trees Existing Vegetation Graph

Area	Square Foot	Acreage	Trees	Grass	Impervious Surface
A	304,920	7	95%	5%	-
B	827,640	19	43%	47%	10%
C	261,360	6	99%	-	1%
D	130,680	3	3%	67%	30%

Fig. 42 Thesis Site Vegetation Table

## Site Master Plans

The current master plan for the Arboretum includes 149 parking spaces on the existing site. It also indicates the permanently closed M Street entrance, which still reflects a type of grandness with the double road leading into the Arboretum.



Source: United States National Arboretum  
Fig. 43 Existing Master Plan and Thesis Focus Area

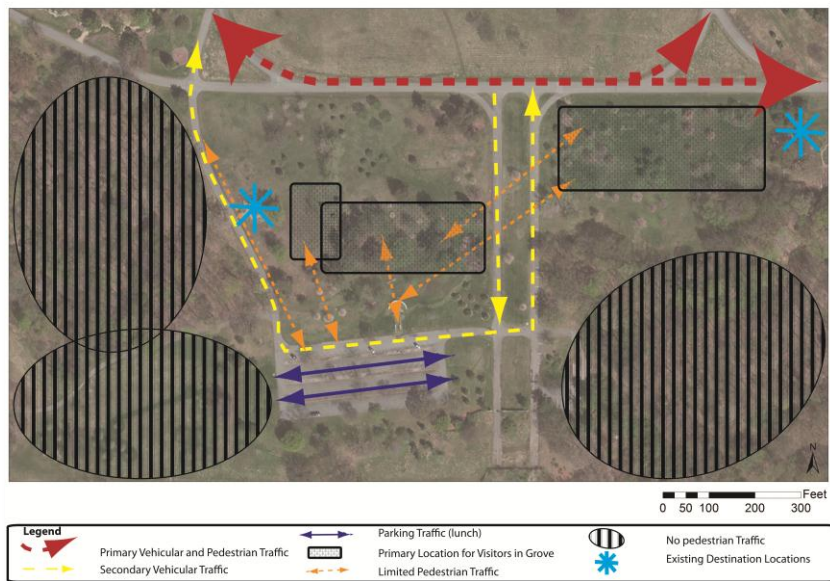
The 2000 proposed master plan by Marshall Taylor Rausch LLC [fig. 43] and the revised 2007 master plan by Rhodeside & Harwell, Inc. [fig. 44] reflects a plan with 980 parking spaces.



Source: United States National Arboretum  
 Fig. 44. 2000/2007 Proposed Master Plan and Thesis Focus

### Site Uses

Traffic patterns in and around the site suggests that the NGST is underutilized [fig. 45]. On one busy spring 2012 weekend site visit, most pedestrian and vehicular traffic was passing the NGST by way of Ellipse Road on the north side of the site [fig. 46 and fig. 48]. If cars did come onto the site, they continued to drive through. Other drivers were seen venturing onto the site but realized they have made a wrong turn as they were attempting to go through the closed M Street entrance and were forced to drive in reverse to turn around as there is not even an area for drivers to turn around [fig. 47]. Others were seen to park in the existing lot but did not leave their cars [fig. 49].



Source: Author's Personal Observations  
 Fig. 45. Vehicular and Pedestrian Traffic



Source: Author  
 Fig. 46. Vehicular Traffic Bypassing Site



Source: Author  
 Fig. 47. Vehicle Attempting to through Closed Gate



Source: Author  
 Fig. 48. Pedestrian Traffic Bypassing



Source: Author  
 Fig. 49. Parked vehicles and drivers

When the NGST was actively being used, it was typically due to children playing kickball, climbing some of the tree stumps lying around. Most commonly, families use the site for picnicking. The NGST is a very successful picnic area and this activity is a desired part of the redesign program. Picnicking is one of the current activities that draw people into the site [fig. 50].



Source: Author

Fig. 50. Family picnicking

### **Existing Stormwater Treatment**

The state of the current stormwater measures within the site is very poor. They are mostly in need of being rebuilt as many stormwater inlets and grates are buried under years of eroded soils, paved over, or are not functioning in the way originally intended [fig. 51, 52, and 54]. Stormwater rushing down the hill to the outfall has severely disintegrated the pipe and eroded the ravine that the water is directed to [fig. 53].



Source: Author  
Fig. 51. Existing Sewer Grate



Source: Author  
Fig. 52. Existing Sewer Inlet



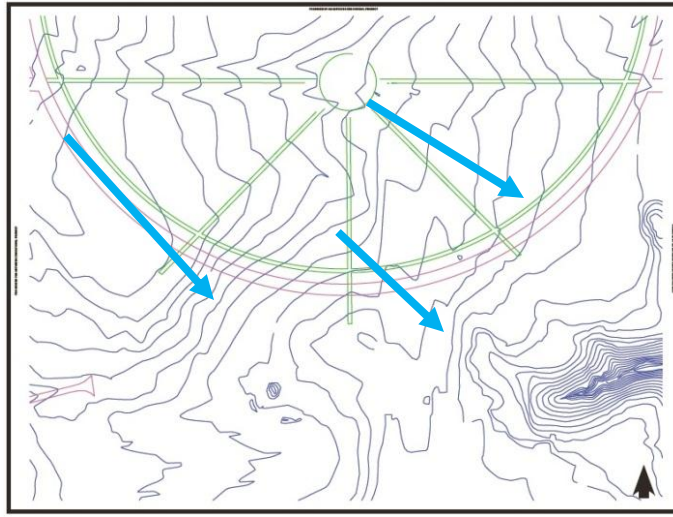
Source: Author  
Fig. 53. Damaged outfall



Source: Author  
Fig. 54. Buried Grate

The hydrology of the site has water flowing from the highest point on the west side, crossing east towards the ravine that eventually flows out to the Anacostia River. Due to the impervious surface fees instituted by District government, it is important that all water remain where it lands. Figure 65 shows the original topography as well as the proposed path and street design that will be discussed later.





Data Source: Arboretum

Fig. 55. Original Topography with Proposed Trails and Road

### Enhancement Opportunities

The NGST has several opportunities for enhancement. Current views, improvements, education and using the existing plant structure are all design opportunities. Views of the site include the stately Capitol Columns viewed to the north of the Grove which can be seen from anywhere around Ellipse Road or the historic gate from the former M Street entrance. The tranquility and seasonal colors offered by the existing vegetation also create viewshed opportunities [fig. 56].



Photo Source: Author

Fig. 56. Various Views of the Arboretum from the Grove

Enhancement potentials for the site include rebuilding or modernizing the restrooms as well as creating inviting picnic grounds on a mulch base, which would avoid worn out and bare dirt conditions [fig. 57]. The redesign of the road system

could also bring additional people into the site rather than encouraging them to bypass the Grove which is what happens with the current road layout. Another enhancement opportunity is the consideration of other options to display state trees in a way that is educational, beautiful, and low maintenance.



Photo Source: Author

Fig. 57. Various Enhancement Possibilities within the Grove

The redesign of the NGST offers many educational possibilities. Providing more prominent, eye appealing, signage or place identification could draw people to the site [fig. 58]. Displaying signs that inform the visitor about the plant species but also how it benefits the environment would be helpful in the educational experience. Also of value would be signage about Jeanne Yeutter’s role in the NGST and the importance of stormwater in the District.



Photo Source: Author

Fig. 58. Various Educational Possibilities within the Grove

The features on the site include trees that can be used to provide shady picnic areas, educational opportunities, and beauty [fig. 59]. One way to handle the declining trees is to mulch them to recycle when they need to be removed. They can also be used in creating new play areas for children for climbing. It is important to

maintain as many healthy trees as possible and allow for the natural decline of non-native trees for potential replacement or open area.



Photo Source: Author

Fig. 59. Natural Features on the Site

The impervious surface fees that DDOE and DC Water has enacted upon the federal government is another factor that needs to be considered in the new redesign of the NGST. The Arboretum will pay a total of \$16,164.60 in impervious surface fees this year for the current 145 ERU’s within this project site unless a redesign of pervious pavement and stormwater mitigation is completed [fig. 60].

				<b><u>FY 2012 Fees</u></b>
<b><u>DC Water</u></b>		<b><u>DDOE</u></b>		
\$11,571.00	+	\$4,593.60	=	\$16,164.60

Fig. 60. Estimated 2012 NGST Impervious Surface Fees Paid

Based on the actual 2012 fee and the projected increases, the NGST’s 145 ERU’s is costing approximately \$964.25 per month and should it remain in its current design state, cost projections from March 2011 predictions estimate that the monthly fee for the NGST will be \$3,445.20 [fig. 61].



Adapted From: DC Water LID Summit, March 2011  
Graph: Author

Fig. 61. Estimated NGST Monthly Fees to DC Water

## **Chapter 4: Design Results**

The design program requirements include two primary elements. The first major element is the redesigned grove. The second major design element is the requested parking for 480 cars plus eight buses that serve both the Grove and serves as temporary parking for buses and cars for all areas of the Arboretum. Three major street layouts were created and used as the basis for the initial spatial diagramming which focuses on circulation as the initial organizing aspect for the two primary site elements in the program [fig. 62]. Three overall vehicular circulation layouts were created. 1.) “intersect”, which followed the topography of the site, 2.) “ellipse”, which followed in a circular manner into the southern area of the site, and 3.) “bypass”, which represents the existing circulation layout. The next consideration for these circulation designs was the size and arrangement of the parking lots in various schemes for each of the three circulation layouts.

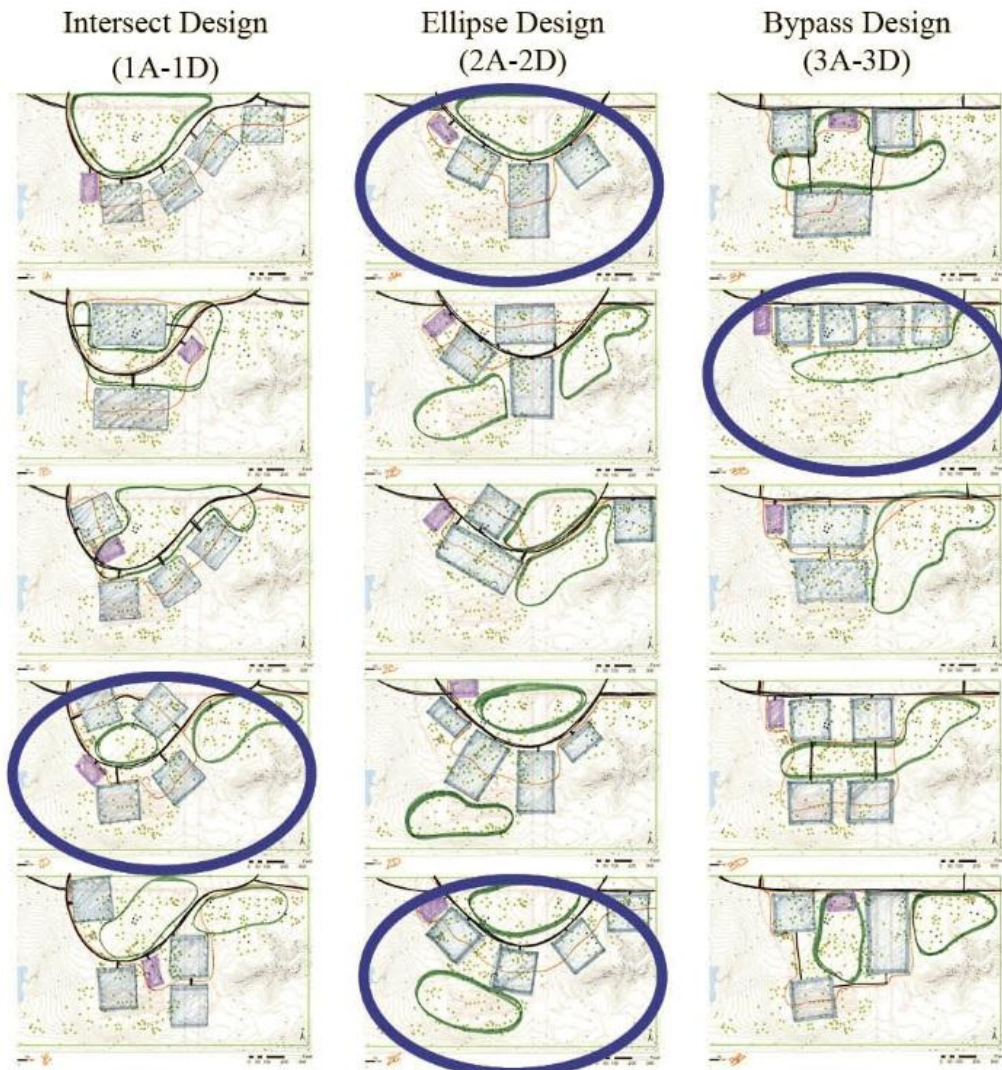
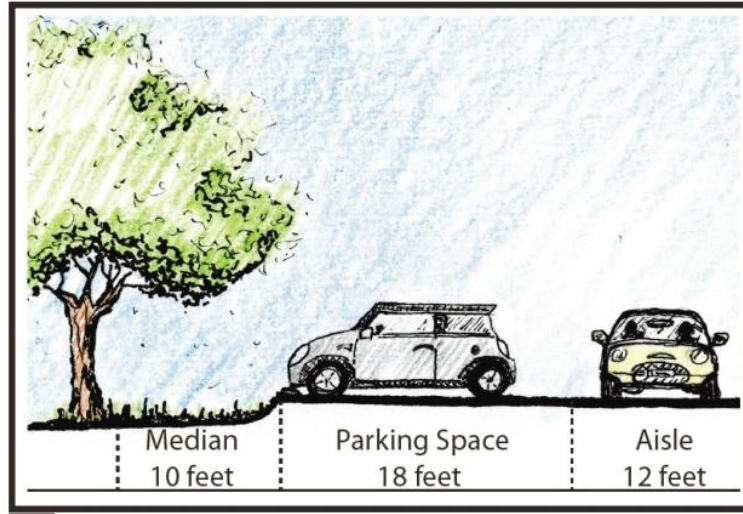


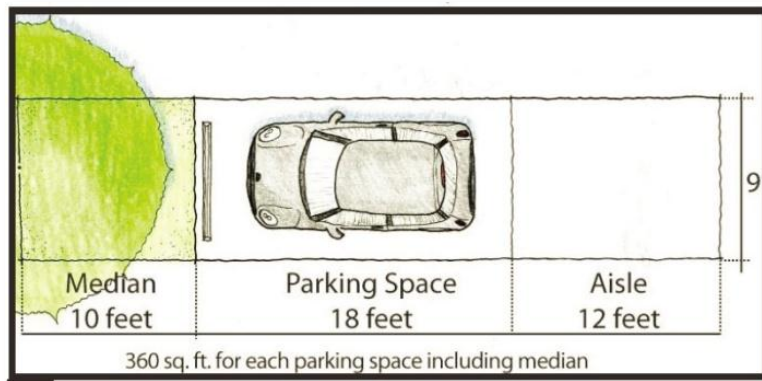
Fig. 62 Spatial Diagramming Using Three Street Layouts.

A template, of 360 square feet was used for each parking space, which was used to estimate the size requirements needs for each parking lot [fig. 63 and 64]. Using the parking template and the three base street designs, five diagrams were created and a design matrix was used to determine the merits of each of the circulation layouts.



Source: Author

Fig. 63. Parking Template, Section View



Source: Author

Fig. 64. Parking Template, Plan View

Each layout was further looked at critically and advantages and disadvantages were noted. After scoring all fifteen designs and evaluating them with the design matrix [appendix 4], four designs were selected that provide the most benefits, [circled in figure 62 and were then further developed in appendix 4]. A final layout was selected that provided the best overall benefits [appendix 5]. This layout was used for further design development [fig. 65a].

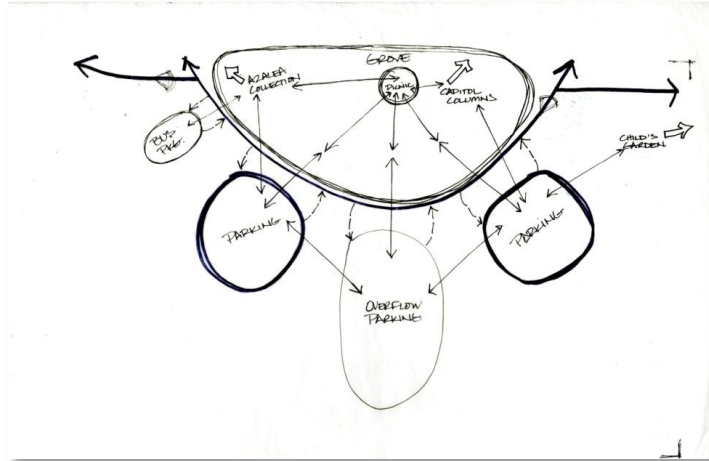
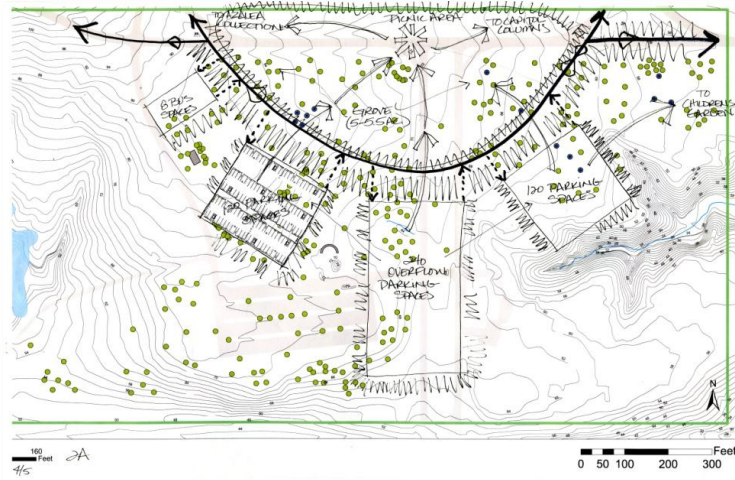


Fig. 65a



Source: Author

Fig. 65b. Final Design Spatial Diagramming

The final design resulted in three main elements in the proposed concept master plan (Figure 65b). These elements included; the National Oak Grove, the State Trees Plaza and the National Oak Grove Parking Area. Each area also included further elements and a site program. The overall design layout was driven by the arrangement between the vehicular circulation, selecting a more prominent and central location for the Grove. Other considerations included ways to keep pedestrians safe and providing a clear identity to the Grove to encourage more visitation.



## National Oak Grove Master Plan

Based on the selected circulation scheme and the analysis of the site, a more specific illustrative plan (fig. 64) was created to convey the site elements. The illustrative plan shows the three main elements of the master plan, which includes the National Oak Grove, the parking areas, and the State Trees Plaza and Meadow. Each of the primary elements includes an in-depth program of elements. The first primary element is the National Oak Grove.



Source: Author

Fig. 64. National Oak Grove, State Tree Plaza and Parking Area Master Plan

## Oak Grove

The existing NGST includes trees that are not native to the District and therefore labor intensive and unable to survive in the District without significant cost.

The Grove is proposed to be converted into the National Oak Grove as the oak

became the national tree through an act of Congress in 2004. Although the existing trees will remain intermingled with the oaks, they will be allowed to decline until they are removed and replaced with an oak of any cultivar or left as an open area. (See appendix 12 for a list of state trees currently existing in the site.)

## **Paths**

The National Oak Grove and paths were designed on axis with the Arboretum visitor center, Capitol Columns, and Capital. The linear layout of the National Oak Grove was chosen as it has a formal design style to accent the already formal setting of the existing site design. To draw people to the site, various elements were chosen for the Grove. The layout of the paths are direct and lead visitors from the parking lots through the Grove and directly to the State Trees Plaza. A path parallel to Ellipse Road on the north side of the street was included so that pedestrians and vehicles are not sharing the same curved road where visibility may be dangerous for drivers. Also, raised crosswalks are being proposed for pedestrians to cross Ellipse Road from the parking lots into the grove. Raised crosswalks are best suited in areas where a significant number of pedestrians cross the road. This design does not detract from aesthetics and can be made with complimentary materials such as brick. They provide easy maneuverability for bicyclists, whereas other types of vehicle calming devices, such as chokers and neckdowns, may be dangerous for bicyclists since they would have to share tighter traffic lanes with vehicles. [A matrix was created to determine how this pedestrian crossing was determined. Appendix 6 and 7.]

## **Recreation**

Another element includes a passive recreation lawn where people can throw a Frisbee, children can kick a soccer ball to each other or people can simply lay out a blanket for a picnic. However, this is not the only place for people to gather for a picnic. Throughout the grove, picnic tables are proposed. The picnic tables in the existing NGST site are used so extensively that the turf has been worn away.

Therefore, tables should be placed randomly throughout the site. However, they should be a fairly permanent fixture set on top of a mulch base where the turf cannot be worn away to bare soil. A children's play area is also being proposed. The vision for this play area includes natural elements such as tree trunks for climbing, jumping, sitting, balancing, and hiding. As the existing trees in the NGST decline or other trees in the arboretum need to be removed, the wood from these resources can be used for mulching or creating climbing elements. These elements could include 5" to 12" high stumps secured in a row on the ground where children could hop on them like stepping stones. Also, long logs secured on the ground where children could use them like a balance beam. Large trees could be used in their entirety where small, weak limbs should be removed and thicker branches that are weight bearing are left. The tree can then be laid on the ground where children can climb on it similar to a jungle gym.

## **Parking**

Overflow parking for 240 cars is also proposed. This lot will be located in the large center parking area [fig. 64]. This curb less overflow parking lot is designed using pervious concrete grids in the aisles and flexible paving in all non-handicapped parking spaces. The overflow parking lot is only needed a couple times a year for special events. During off-times, this lot should be closed to traffic to allow the paving materials to remain viable for infiltration of water

Parking for eight buses is located on the edge of all pedestrian crossings. This was done in an attempt to bring buses in from the visitor center, past the Capital and to the bus parking lot so to keep buses as far away from main pedestrian movements as possible. Pervious open grade block is proposed for this area [fig. 24 and 25].

## State Trees Plaza and Meadow Master Plan and Program

The second primary element is the State Trees Plaza and Meadow [fig. 67].

Circulation continued to be a driving force in the master plan of the State Trees Plaza and Meadow. The three main elements of the State Trees Plaza and Meadow include 1) the Overlook Terrace, 2) the meadow, and 3) the canopied pergola and State Trees Wall.



Source: Author

Fig. 67. State Trees Plaza

### Overlook Terrace

The terrace is the central element of the design as it overlooks one of the most prominent features of the Arboretum, the Capitol Columns as well as the great lawn and hill to the azalea collection [fig. 68]. This terrace also doubles as a stage for outdoor concerts, allowing for a beautiful backdrop of the Capitol Columns. The

other element for the terrace includes an U.S. flag on a flag pole approximately 70 to 100 feet tall. This element was chosen due to signify the relationship between the National Grove and the United States Arboretum. This element will also provide a landmark which will be visible from areas that are on the north side of the great lawn. The flag will also share a location with the proposed new Jeanne Yeutter memorial. Mrs. Yeutter was the wife of the Secretary of Agriculture (1989-1991), Clayton Yeutter. As the sponsor for the original grove, this memorial will honor her and explain her love of trees and their importance.



Source: Author

Fig. 68. Birds-eye view of Plaza looking North

## **Meadow**

The meadow serves as the central open space framed by the overlook terrace on the north and the Canopied Pergola and State Trees Wall on the south. A five foot mow strip is proposed around the perimeter of the meadow as well as the north side of Overlook Terrace to maintain a clear edge to help reinforce the open space. The meadow provides a location for outdoor concert attendees to picnic while enjoying

any type of outdoor performance. It can also serve as an area where plant sales can take place or tents can be set up for various types of fairs or markets. The meadow will be planted with a native wildflower and grass mix and will be allowed to grow naturally, unless it is needed to be moved for an event. The topography of the meadow has been modified to create a low spot that is underdrained into a raingarden outside of the plaza meadow [fig. 69]. Yearly prescribed burns are recommended to keep the meadow healthy. A five-foot mow strip is also proposed around the perimeter of the meadow as well as the north side of Overlook Terrace.



Source: Author  
Fig. 69. Meadow Section

### **Canopied Pergola and State Trees Wall**

This area consists of two pergolas, ladies and men’s restrooms, and the State Trees Wall [fig. 70]. Two pergolas on the west and east side of the plaza are proposed



Source: Author

Fig. 70. Perspective of meadow and State Tree Interpretative Wall

for seating or meeting locations for large groups or the general public [fig. 72]. Rows of benches should be placed there so that school groups visiting the Arboretum have a place to congregate and use as an outdoor classroom. Beside the west pergola is the ladies restroom and the east pergola is the men's restroom [fig. 71]. The area between the two restrooms, on the south side of the plaza is the State Trees Wall. The program





Source: Author

Fig. 71. Perspective across Meadow looking towards Crabtree Road



Source: Author

Fig. 72. Perspective of Secondary Trails Around Plaza and Pergolas

envisioned for the State Trees Wall includes elements that complement the sandstone Capitol Columns and allow for the opportunity for learning about the State Trees. A six foot tall wall including a two foot tall sandstone base with a three and a half foot tall glass panel and a six inch sandstone cap set atop the glass will contain the

interpretive panels for the State Trees (fig. 73). The glass will include a three dimensional sculpture of each state tree visible from either side of the wall as well as information concerning the environmental benefits and other information of each tree in its natural setting.

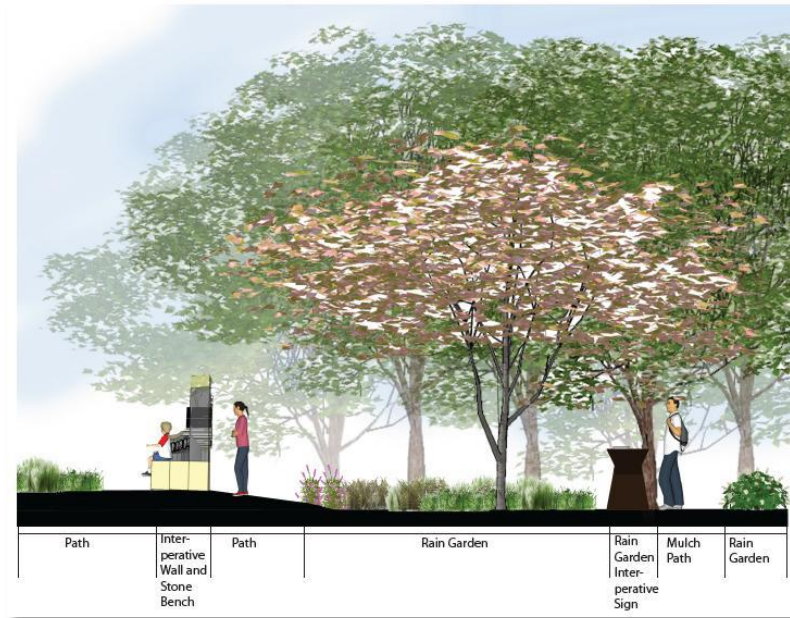


Source: Author

Fig. 73. Perspective of State Tree Interpretative Wall

To provide for further opportunities for public education, a raingarden including interpretive signs, regarding stormwater mitigation practices is proposed to the southeast side of the State Trees Wall [fig. 74]. This will demonstrate to the public the importance of rainwater and hydrology and how the Arboretum is protecting this resource through mitigation. Further educational opportunities concerning permeable pavers and their influence on stormwater will be provided through interpretative signage. Due to the impervious surface fees charged by the District, permeable paving is recommended for all of the paths throughout the site. Mitigation is being included where possible, which would allow for future discounts

by the District. Should the paving be 100% pervious, the District does not charge any impervious surface fees.



Source: Author

Fig. 74. State Tree Wall and Raingarden Section

## The National Grove Parking Lot and Program

Stormwater education, site disturbance and the need for a total of 480 parking spaces were the main factors that determined the parking area locations. A concept plan for a 120 car-space parking was created to illustrate how typical hydrological interventions are incorporated into the space [fig. 75]. This concept plan includes five handicapped parking spaces and eight motorcycle parking spaces. The plan has three main elements including parking lots, bioretention, and the ravine overlook.



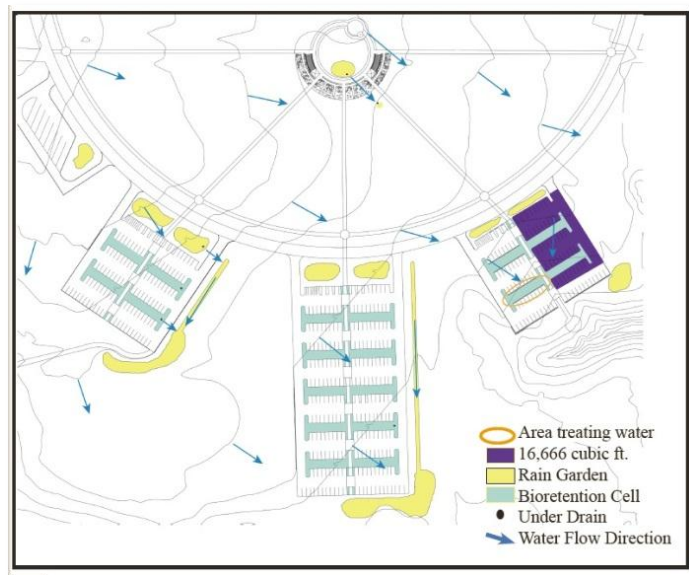
Source: Author

Fig. 75. Concept Plan of Daily Use Parking Lot

## Parking Lots

The daily parking lots will include curbing around the perimeter of the parking lots in order to keep cars from driving into surrounding turf. Pervious open grade block [see fig. 24 and fig. 25] is proposed for these regularly used parking lots as this type of block requires limited maintenance other than using a leaf blower periodically as there is no aggregate between the block. Timber decks are proposed in the design for vehicle crossings at all bio-retention cells so that hydrological process is not interrupted.

The topography has been altered from its original state for the programming of the thesis in order to retain stormwater on site. Several rain gardens, underdrains, swales and bioretention cells have been proposed for the site. The hydrology for the Parking areas were altered to direct stormwater into the bioretention areas [fig. 76].



Source: Author

Fig. 76. Redesigned Site Hydrology

Should there be overflow, there are bioretention swales and raingardens located around the south/east perimeter of each parking area. The Maryland Dept. of the

Environment *Environmentally Sensitive Design Guidelines* (July 2010) was used to determine catchment and rain garden calculations. It was determined that one bioretention cell (circled in orange, fig. 76) is capable of capturing 16,666 cubic feet of rainfall from a 1.2” storm (equivalent to the area outlined in purple in fig. 76).

### **Bioretention Medians and Boardwalk**

The overall size and connectivity of the bioretention medians will allow for median trees to spread and intermingle, producing a stronger root structure and tree. These areas are proposed to be 6” deep and without curbs to allow for better water infiltration. Parking spaces will include a parking block to keep cars from rolling into these sensitive areas.

This boardwalk will go through the center of the parking lots and will have interpretative signs that will teach visitors about the bioretention cells, raingardens, pervious pavement and how they all effect stormwater [fig. 77].



Source: Author

Fig. 77. Bioretention Boardwalk Section

## **Ravine Overlook**

This overlook will extend over the ravine on the southeast side of the site.

This ravine currently receives most of the stormwater flow, which due to its velocity, has damaged the ravine [fig. 78]. This overlook is proposed to have interpretive signs that explain the damaging effects of stormwater velocity and how the Arboretum is restoring the ravine.



Source: Author

Fig. 78. Photo Collage of Eroded Ravine on Southeast Side of Site

## **Chapter 5: Conclusions**

The objective of this thesis was to explore and use the redesign of the NGST to demonstrate the ability to incorporate both the need for a redesigned grove as well as addressing contemporary stormwater issues. This objective was met through consideration of circulation, parking needs, removing the least amount of existing trees as possible as well as creating a unique way to inform the public about the state trees.

The National Oak Grove was determined to be a logical choice for replacing the NGST as many types of oaks are able to survive in the District and very few of the state trees are able to thrive in the Districts climate. Instead of trying to keep the state trees alive, the State Trees Wall was proposed as an alternative where visitors could still learn about these trees and see them in a realistic manner.

The layout of the streets, paths, and parking lots were determined through evaluating how visitors would move through the site. The final design leads visitors into the National Grove rather than allowing them to bypass the site as is the existing design. By moving Ellipse Road so that it circles around the south end of the National Grove and places the parking lots on the south side of Ellipse Road, visitors are successfully encouraged into the site. They are then directed to cross Ellipse Road and walk into the site to move to other locations. However, by completing this process, the site was also given elements that visitors would find appealing and possibly draw their curiosity.



The National Grove has been designed in a way that will provide for social needs. Picnic areas are proposed throughout as well as a children's play area, a passive recreation lawn, and a State Trees Plaza and Meadow.

The concerns over stormwater runoff and impervious surface fees were addressed through analyzing the hydrologic flow of the site. Raingardens, underdrains, bioretention cells, and swales are located throughout the redesigned site. These BMPs offer the Arboretum the opportunity to educate the public about rainwater and trees. Through the design of these BMP techniques, the Arboretum's impervious surface fees should be greatly decreased if not negligible.

Future research should include how the public interacts with this design. Also, research about stormwater mitigation practices and how the public can reduce their own impervious surface fees could be demonstrated at the new National Grove.

In summary, the growing trend for jurisdictions to charge for stormwater fees gives the opportunity for organizations, such as arboretums, to use this incentive to incorporate BMPs as an educational tool. The result will lead to a better informed public who views rainwater as a sustainable resource that needs to be fostered and protected.

# Appendices

## Appendix 1 Photos of Current Appearance



Picnic Grounds



Nevada's *Pinus monophylla*



Location of Alaska's *Picea sitchensis*  
and South Carolina's *Sabal palmetto*



Bike Rack



3 of 8 originally planted District of  
Columbia's *Quercus coccinea*



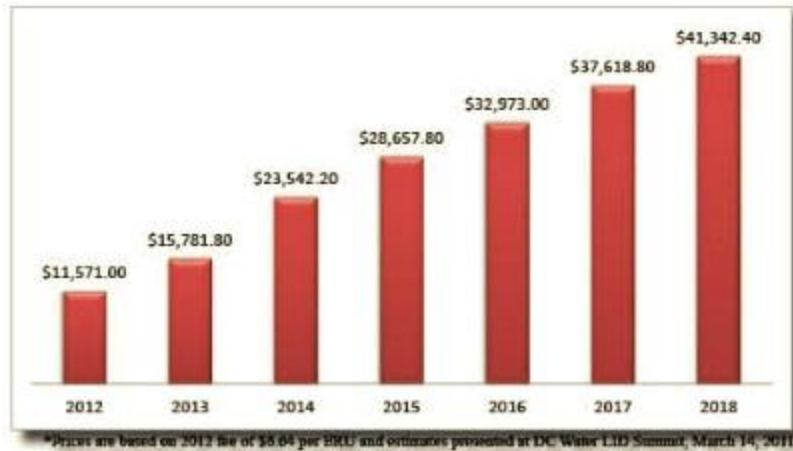
Georgia's *Quercus virginiana*

### Current Appearance

HOH Associates designed the National Grove of State Trees in 1991. An interpretive trail with informational signs was also incorporated in the design but never built. Existing conditions show many unhealthy or missing trees.

Source: Author

## Appendix 2. National Grove of State Trees Yearly Fees to DC Water



Adapted From: DC Water LID Summit, March 2011

Graph: Author

The March 2011 estimates for the yearly Clean Rivers Impervious Area Charge show that the yearly fees for the 145 ERU's within the project scope will more than triple in the next five years.

### Appendix 3. Spacial Diagram Matrix

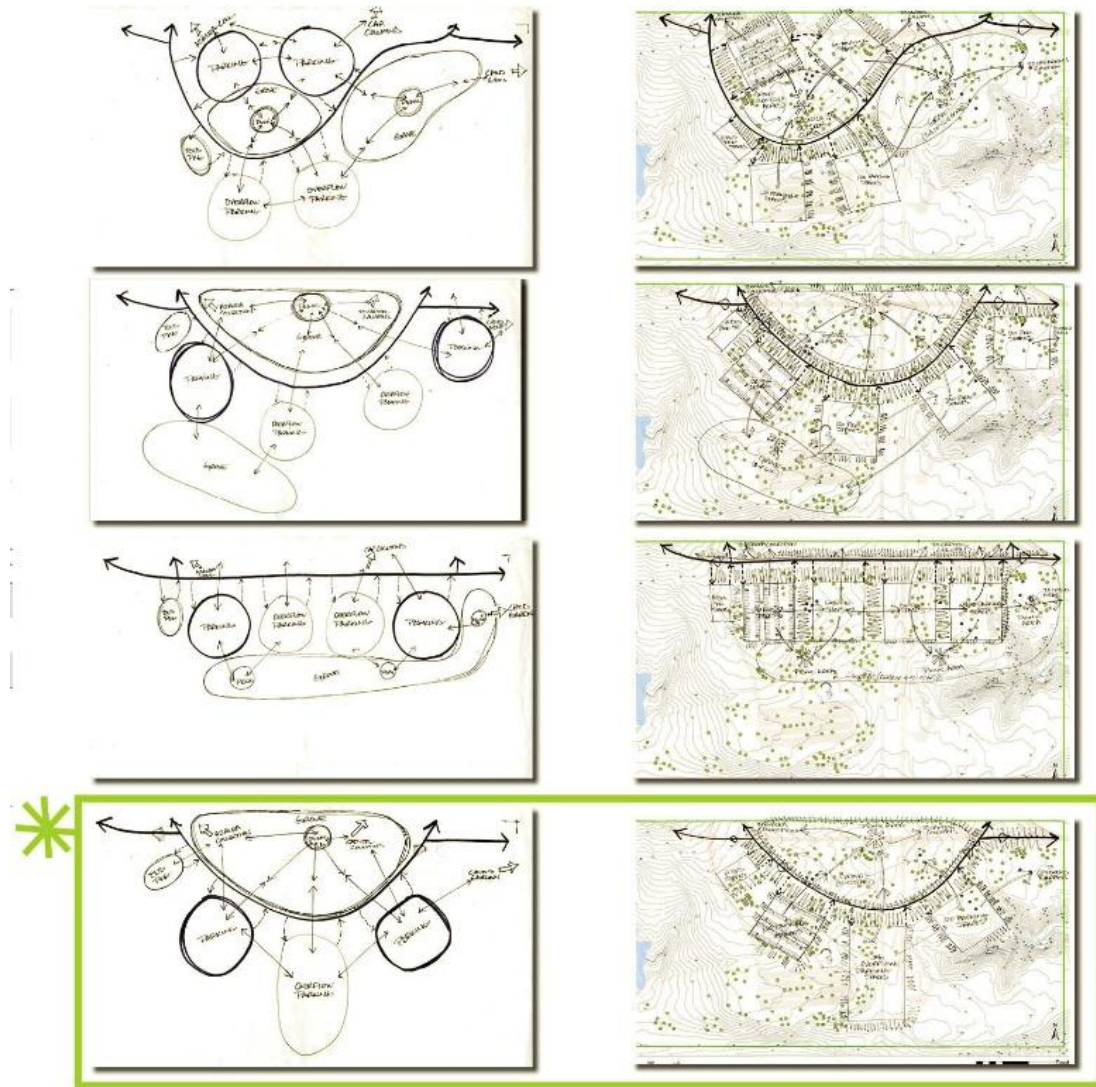
	Design Groups	Visitors Bypass Site	Grove Dissected	Vast Parking Lot	Existing Trees Removed	Paths unsuccessfully Exhibit Stormwater	Minimal Drives	Bus Pkg Far From Restrms	Comments	Total
Intersect Design	1A	1	1	2	3	1	1	1	wood apply to show diversity of treatments.	10
	1B	1	1	3	3	2	3	3	Not enough exhibit variety.	16
	1C	1	1	2	2	2	1	1	Poor layout, due to alignment, sides of the road.	10
	1D	1	2	1	2	1	1	1	wood apply to show diversity of treatments, grove split though.	9
	1E	1	1	1	2	2	3	1	2	Poor layout, different sides of the road.
Ellipse Design	2A	1	1	3	2	2	1	1	Site layout, due to large lot, would be a great overflow lot, closed most of the year.	11
	2B	1	3	2	2	2	1	1	Poor layout, different sides of the road.	12
	2C	1	1	3	3	2	1	1	Poor layout, different sides of the road.	12
	2D	1	3	3	3	1	1	2	Grove Split.	14
	2E	1	3	3	1	3	1	1	wood apply to show diversity of treatments, grove split though.	11
Bypass Design	3A	3	1	2	2	3	3	3	Excessive imperviousness due to entrance drives.	17
	3B	3	1	1	3	1	1	2	Potential bypass of stormwater exhibits and Grove, resulting in failed project.	12
	3C	3	3	3	3	3	2	1	Not enough exhibit space and separation in size.	18
	3D	3	1	1	2	2	3	1	Excessive imperviousness due to entrance drives.	13
	3E	3	1	2	2	3	3	3	Excessive imperviousness due to entrance drives.	17

Scoring	Points
No	1
Somewhat	2
Yes	3

**\*Lowest Score Desired**

This matrix was completed in order to score the spatial diagrams completed early on in the design process to determine which design would be best for the site. The lowest scores were the most desirable. The four designs that scored the lowest were analyzed closer and redrawn more to scale.

## Appendix 4. Second Set of Designs



The four remaining designs were drawn more to scale with an accompanying relationship diagram. They were evaluated by a simple pros and cons list to make a final determination. See chapter 4, page 57-58 for more information.

## Appendix 5. Second Design Matrix

### Spacial Diagram 1D

	Advantages	Disadvantages
1	Street and parking lots will bring people into the site	Parking will be visible from the columns, which will detract from the site
2		The Grove is split, which creates a disconnect or diminished experience.
3		The smaller section of the Grove is only 2.3 acres which will allow for limited plaza space.

### Spacial Diagram 2A

	Advantages	Disadvantages
1	Noise from traffic should not be audible from the plaza or azalea collection	Visitors must cross the road to get to most destinations (however, the culture of the location is such that people are already using the road as a foot path and traffic is slow)
2	The parking area and road bring people into the site rather than allowing for them to bypass the Grove as is the current environment	
3	The plaza is on axis from the visitor center, Capitol Columns and capital (column top)	
4	Overflow lot allows for it to be closed most of the year and therefore allows for a healthy flexible pavement such as turf.	
5	Less trees are removed than other designs (63 total)	

### Spacial Diagram 2E








	Advantages	Disadvantages
1	Parking will be close to children's garden and within proximity of Capitol Columns	More trees are removed (96 total) due to the two separate lots
2	Bus parking near azalea collection	The split Grove creates an unused part of the Grove or a section that may quickly become obsolete
3	Parking area and road pull people into the site rather than allow for bypassing	Two overflow parking lots create significant distance in daily use lots.
4	Two overflow lots can be closed for most of the year	

### Spacial Diagram 3D

	Advantages	Disadvantages
1	Existing street does not require modification	The Grove is behind the lots and will likely end up being overlooked or bypassed by visitors
2		Multiple picnic areas in the grove are not easily visible due to being behind the lots and below street grade
3		Parking lots act as a wall cutting off USNA property from parking to M Street wall or about 16.5 acres

The pros and cons list for the final 4 designs resulted in Diagram 2A being the basis for the resulting design.

# Appendix 6. Traffic Calming/Crosswalk Design Options

Traffic Calming Options					
Treatment	Description	Advantages	Disadvantages	Cost	Image
Speed Hump	Rounded, raised areas placed across the roadway, generally 10 to 14 feet long	Relatively inexpensive, fairly easy for bicycles to cross, effective in slowing travel speeds	Can cause severe pain for people with certain skeletal disabilities, increase noise and air pollution, questionable aesthetics	\$2,000	
Speed Tables	Flat-topped speed humps often constructed with brick or other textured materials on the flat section, typically long enough for the entire wheelbase of a passenger car to rest on the flat section, long flat fields give speed tables higher design speeds than speed humps	They are smoother than speed humps on large vehicles (such as buses) and effective in reducing speeds, though not to the extent of speed humps	Questionable aesthetics, if textured materials are not used; Textured materials can be expensive; may increase noise and air pollution.	\$2,000	
Raised Crosswalks	Speed Tables outfitted with crosswalk markings and signage to channelize pedestrian crossings, raising the level of the crossing allows pedestrians to be more visible to approaching motorists, good for locations where pedestrian crossings occur at haphazard locations	Improve safety for pedestrians, can have positive aesthetic value, effective in reducing speeds (not to the extent of speed humps)	Textured materials, if used, can be expensive, impacts on drainage needs to be considered, may increase noise and air pollution	\$4,000	
Textured Pavement	Stamped pavement or alternate paving materials creating an uneven surface, emphasizing pedestrian crossing, good for substantial pedestrian activity where noise is not a concern.	Reduce vehicle speeds over an extended length, can have positive aesthetic value.	Generally expensive due to materials used, can make crosswalks more difficult for wheelchair users and the visually impaired, noise	Varied due to materials and area	
Chicanes	Chicanes are curb extensions that alternate from one side of the street to the other, forming S-shaped curves.	Discourage high speeds by forcing horizontal deflection, easily negotiable by large vehicles (such as buses)	Design carefully to discourage drivers from deviating out of the appropriate lane	\$14,000	
Neckdowns	Curb extensions that reduce the roadway width, "pedestrianize" intersections by shortening crossing distances for pedestrians and drawing attention to pedestrians via raised peninsulas, good for areas of substantial pedestrian activity and areas with noise considerations	Improves pedestrian circulation, easily negotiable by large vehicles, reduce speeds	May require bicyclists to briefly merge with vehicular traffic, effectiveness limited by the absence of vertical or horizontal deflection, questionable aesthetics	\$40,000	
Center-Island Narrowings	Often combined with textured pavement, they are called "gateway islands," with a gap allows pedestrians to walk through at a crosswalk, called "pedestrian refuges"	Increase pedestrian safety, can have positive aesthetic value	Speed-reduction effect is somewhat limited by the absence of any vertical or horizontal deflection	\$5,000 to \$15,000	

## Appendix 7. Traffic Calming/Crosswalk Matrix

### Traffic Calming Design Options Scoring

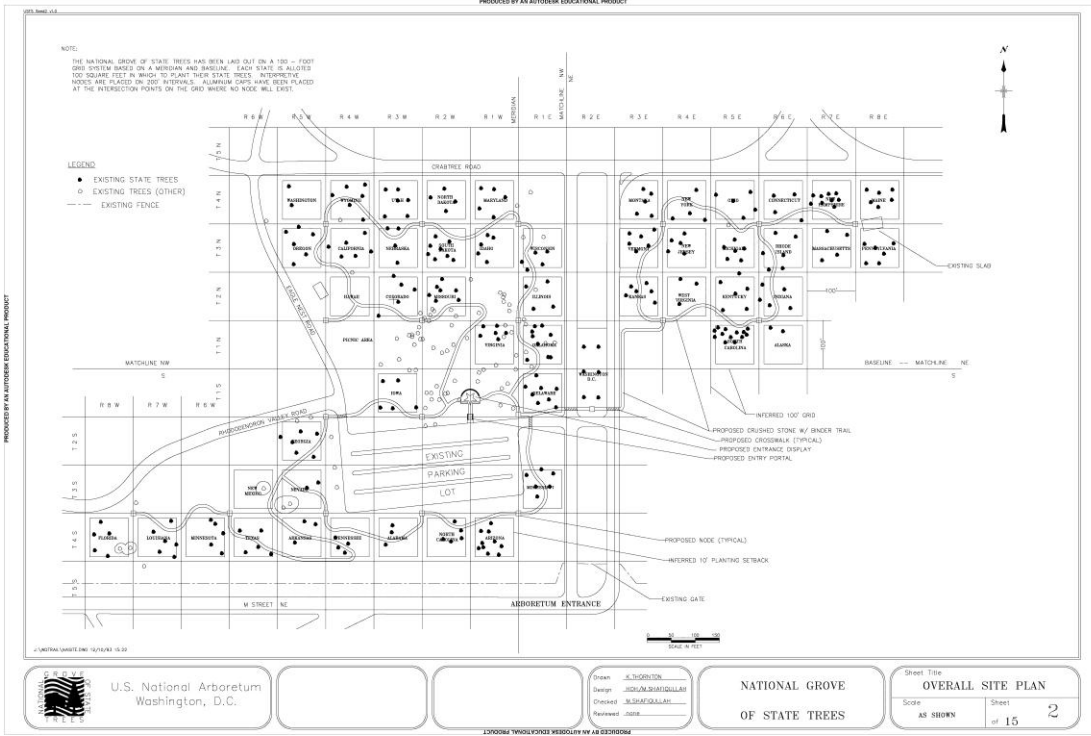
Treatment	Advantages +	Disadvantages -	Score
Speed Hump		Pain to disabled pedestrians, questionable aesthetics, noise	-3
Speed Tables		Noise, questionable aesthetics	-2
Raised Crosswalks	Pro-pedestrian, good aesthetics	Noise	1
Textured Pavement	Good aesthetics	Noise	0
Chicanes		Possible distraction for driver from pedestrians when focusing on maneuvering	-1
Neckdowns	Pro-pedestrian	Questionable aesthetics	0
Center-Island Narrowings	Pro-pedestrian, good aesthetics		2
Chokers	Pro-pedestrian, good aesthetics		2

\*Scoring was based on whether the design option protected pedestrians, was aesthetically pleasing to its environment and if noise would be a factor. Each advantage or disadvantage was given a +1 or a -1 depending on the category.

\*A combination of the center-island narrowings and raised crosswalk or the choker and raised crosswalk should each be tested to determine which option would be best for the Arboretum.

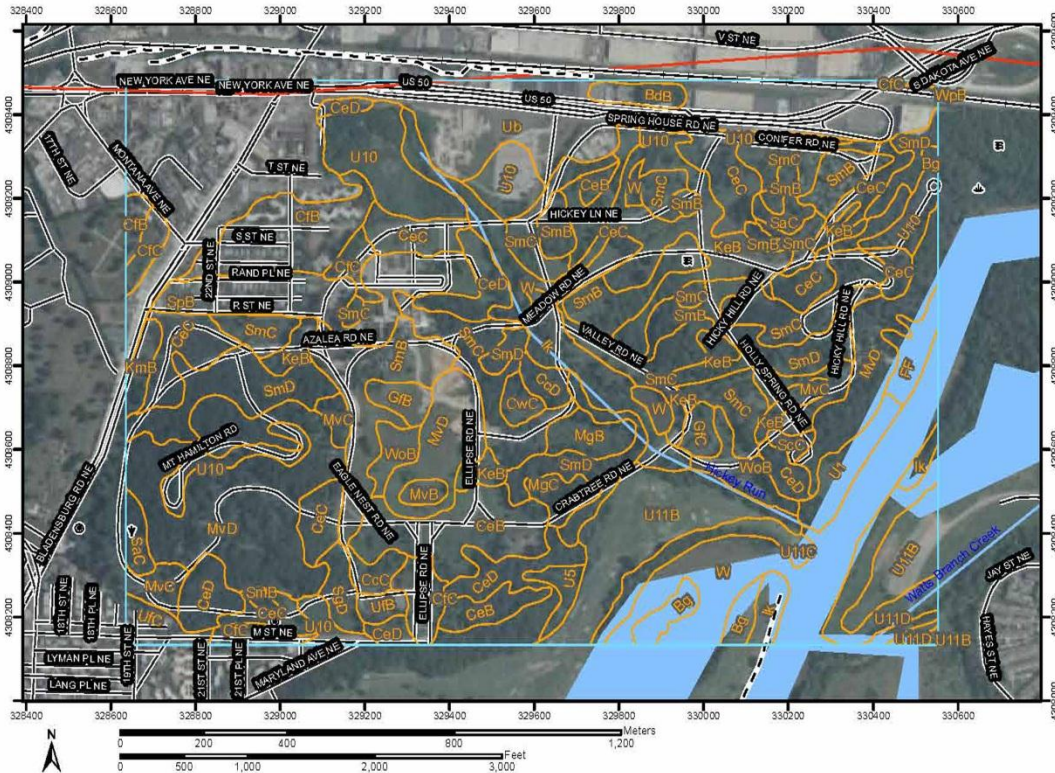


# Appendix 8. National Grove of State Trees Tree Inventory



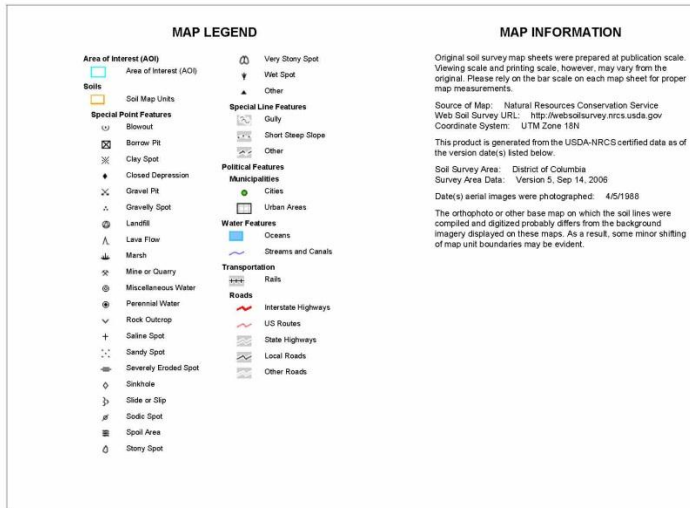
Source: United States National Arboretum

# Appendix 9 National Grove of State Trees Soil Map and Descriptions



Source: United States National Arboretum

Soil Map—District of Columbia



Source: United States National Arboretum

**Map Unit Legend**

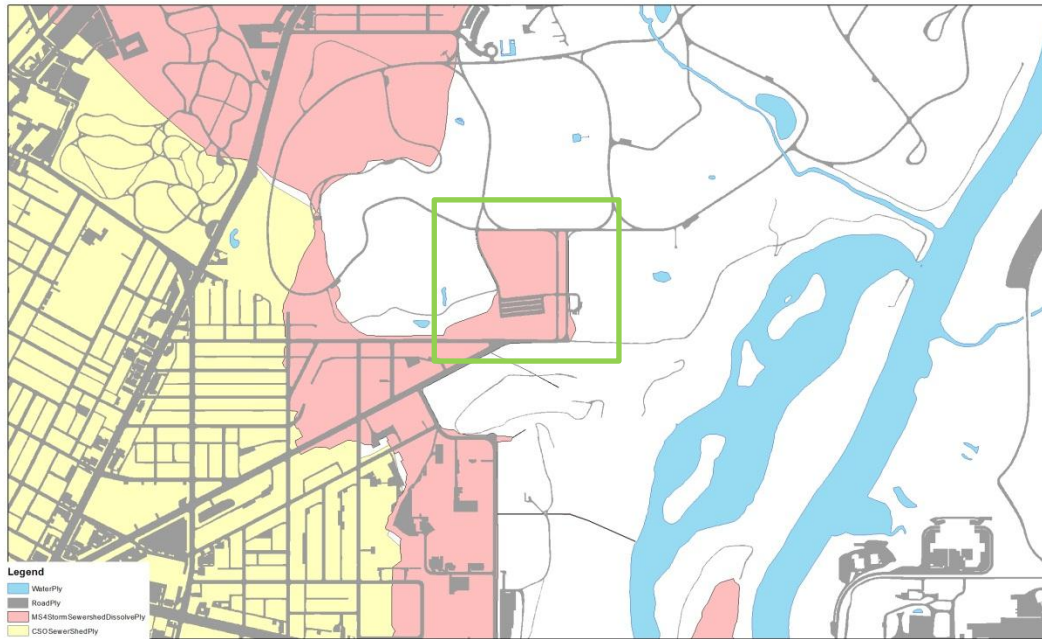
District of Columbia (DC001)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BdB	Beltsville silt loam, 0 to 8 percent slopes	2.9	0.4%
Bg	Bibb sandy loam	5.1	0.8%
CcC	Chillum silt loam, 8 to 15 percent slopes	2.5	0.4%
CcD	Chillum silt loam, 15 to 40 percent slopes	2.5	0.4%
CeB	Christiana silt loam, 0 to 8 percent slopes	20.8	3.2%
CeC	Christiana silt loam, 8 to 15 percent slopes	40.0	6.2%
CeD	Christiana silt loam, 15 to 40 percent slopes	25.0	3.9%
CIB	Christiana-Urban land complex, 0 to 8 percent slopes	16.3	2.5%
CIC	Christiana-Urban land complex, 8 to 15 percent slopes	11.8	1.8%
CwC	Croom very gravelly sandy loam, 8 to 15 percent slopes	2.1	0.3%
FF	Fluvioquent-Udfluvents complex, frequently flooded	4.2	0.6%
GB	Galestown and Rumford soils, 0 to 8 percent slopes	2.9	0.4%
GIC	Galestown and Rumford soils, 8 to 15 percent slopes	2.4	0.4%
Ik	Iuka sandy loam	21.1	3.3%
KeB	Krypot fine sandy loam, 0 to 8 percent slopes	30.1	4.6%
KmB	Krypot-Urban land complex, 0 to 8 percent slopes	2.7	0.4%
MgB	Matapeake silt loam, 0 to 8 percent slopes	4.4	0.7%
MgC	Matapeake silt loam, 8 to 15 percent slopes	3.3	0.5%
MvB	Murkirk variant complex, 0 to 8 percent slopes	1.4	0.2%
MvC	Murkirk variant complex, 8 to 15 percent slopes	9.2	1.4%
MvD	Murkirk variant complex, 15 to 40 percent slopes	62.1	9.6%
SaC	Sassafras sandy loam, 8 to 15 percent slopes	4.3	0.7%
ScC	Sassafras gravelly sandy loam, 8 to 15 percent slopes	1.3	0.2%

Source: United States National Arboretum

District of Columbia (DC001)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
SgD	Sassafras Urban land complex, 15 to 40 percent slopes	3.4	0.5%
SmB	Sunnyside fine sandy loam, 0 to 8 percent slopes	37.4	5.8%
SmC	Sunnyside fine sandy loam, 8 to 15 percent slopes	53.0	8.2%
SmD	Sunnyside fine sandy loam, 15 to 40 percent slopes	33.7	5.2%
SpB	Sunnyside-Urban land complex, 0 to 8 percent slopes	20.2	3.1%
U1	Udorthents	6.0	0.9%
U5	Udorthents, clayey	2.4	0.4%
U10	Udorthents, clayey, smoothed	30.1	4.6%
U11B	Udorthents, deep, 0 to 8 percent slopes	30.1	4.7%
U11C	Udorthents, deep, 8 to 15 percent slopes	6.5	1.0%
U11D	Udorthents, deep, 15 to 25 percent slopes	9.8	1.5%
Ub	Urban land	89.1	13.7%
URB	Urban land-Christiana complex, 0 to 8 percent slopes	1.9	0.3%
URC	Urban land-Christiana complex, 8 to 15 percent slopes	3.7	0.6%
W	Water	34.9	5.4%
WoB	Woodstown sandy loam, 0 to 8 percent slopes	7.8	1.2%
WpB	Woodstown-Urban land complex, 0 to 8 percent slopes	0.0	0.0%
Totals for Area of Interest (AOI)		648.2	100.0%

Source: United States National Arboretum

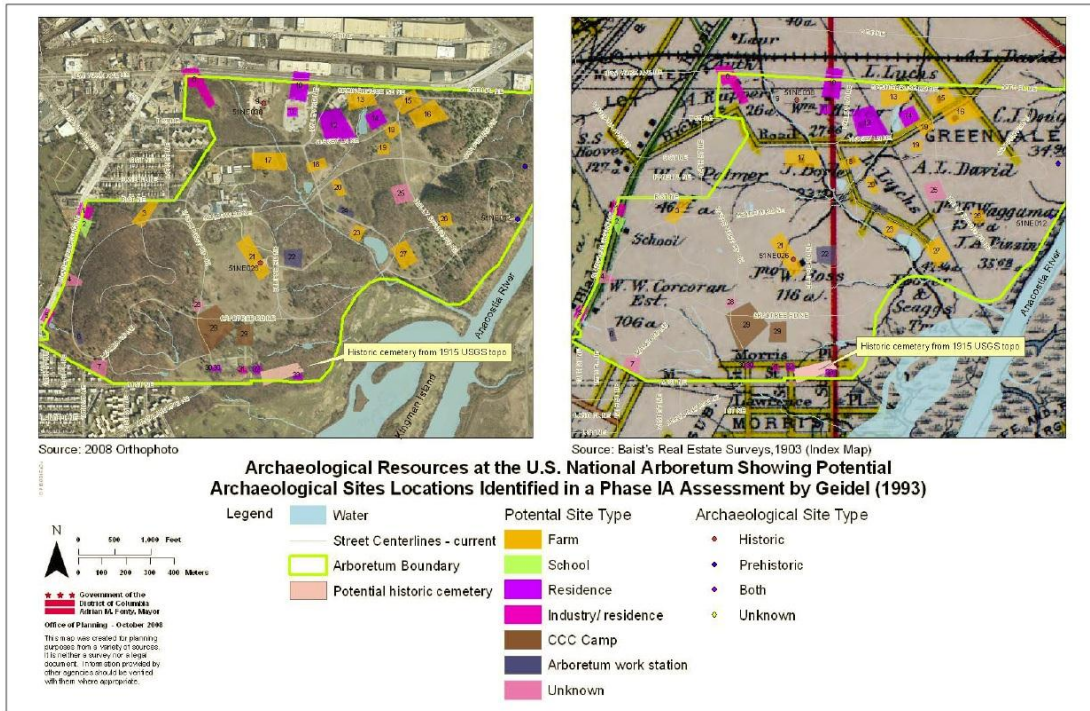
## Appendix 10 Sewersheds



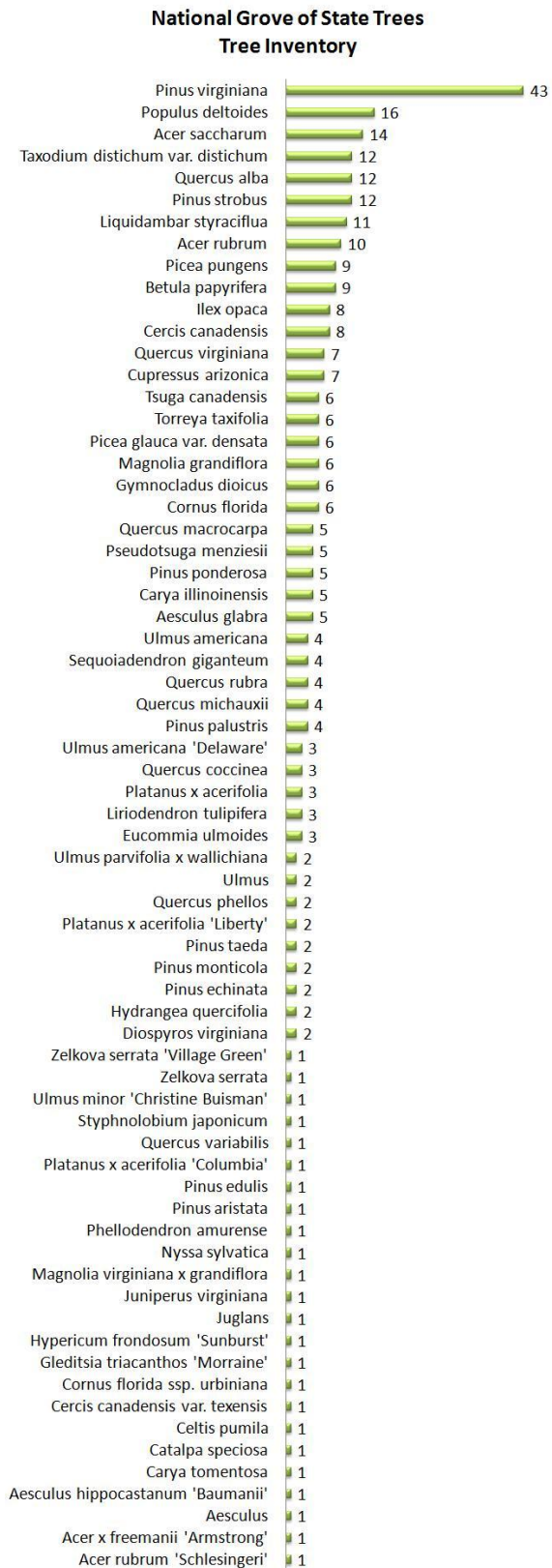
Source: District of Columbia GIS

The thesis site location is outlined in green.


# Appendix 11 Archaeological Site Map



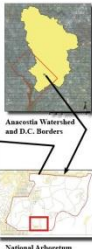
## Appendix 12 National Grove of State Trees Inventory Chart




# Appendix 14 Presentation Boards




**Aerial Photograph of National Grove of State Trees and project scope**



**Anasentia Watershed and D.C. Borders**



**National Arborescent Property and project scope**




**Existing Land Allocation on Aerial Photograph of Site**

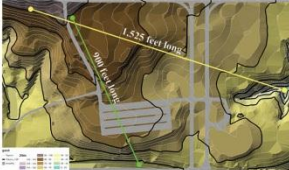
The site boundary is segmented into four sections that represent the basic land allocation. Section A is woods containing oaks and sycamores. Section B is the largest section containing the National Grove of State Trees which has 317 trees of varying species. Section C is almost completely wooded with oaks, sycamores and few maples, except for the former location of a building where asphalt pavement still exists. Only Section D has a couple trees and is mostly turf.

Area	Square Feet	Average Trees	Green	Tree Canopy	Hard	Parking Lot	Turf
A	304,920	7	95%	5%	-	-	-
B	827,640	13	43%	47%	20%	-	-
C	763,365	6	99%	-	1%	-	-
D	130,680	3	3%	67%	30%	-	-


**Existing Vegetation on Site**



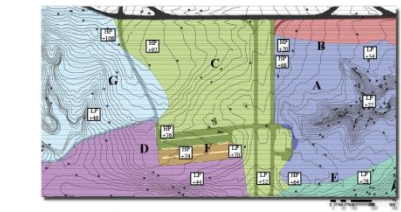
**Site Boundary Location**  
This collection of maps show where the United States National Arborescent is found within the Anasentia Watershed and the District of Columbia. It also shows where the National Grove of State Trees is found within the Arborescent as well as the original grid design created to categorize where each state tree would be placed.



**Relief Map of Site**  
The site has an overall grade change of 86 feet from top to bottom of the yellow line. The National Grove of State Trees has an overall grade change of 48 feet from top to bottom of the green line.



**Slope Map of Site**  
Much of the site has a moderate slope of 8% to 15%, whereas most of the sections have a slope of greater than 15% and are not typically accessed by the public.




**Plan Map of Site Catchment Areas**  
This map shows where each of the seven catchment lies within the site boundary as well as the high point and low point for each individual catchment. The varying sizes of the catchment areas are indicated in the pie chart.


Catchment	% of Total Land Area	Catchment Characteristics
A	24.8%	Combination of dispersed tree collection and heavily wooded steep slopes surrounded by oak and sycamores.
B	4.4%	Only turf with dispersed tree collection.
C	28.8%	Gentle slopes for most of the area with dispersed tree collection mixed with existing pre-National Grove of State Trees existing.
D	31.4%	Steep sloping area with dispersed tree collection.
E	1.0%	Heavily wooded area that is not typically used by the public.
F	1.0%	Flat asphalt paved parking lot.
G	21.8%	Steep sloping area of oak and sycamores.

## Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees


1  
Context and Site Boundary  
Key: Executive M.S. Thesis, April 2012  
University of Maryland



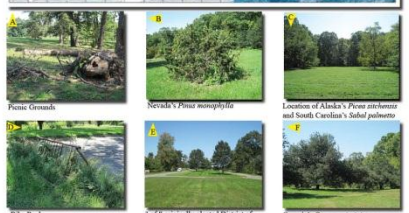
**Existing Master Plan**  
This map shows the existing roads and parking lot around the National Grove of State Trees. It also shows the permanently closed M Street entrance, which will reflect a type of grandness with the double road leading into the arborescent.



**2000/2007 Proposed Master Plan**  
Proposed United States National Arborescent plan designed by Marshall Taylor Rausch, LLC in 2000 and revised by Rhodeide & Harwell, Inc. in 2007. This design incorporates 980 parking spaces and alters the location of Ellipse Road to go through the existing National Grove of State Trees.



**Site Usage and Circulation**  
Motor vehicles and pedestrian trails bypass the National Grove of State Trees by way of Ellipse Road on the north side of the site. Most cars that come into the site continue to drive by. If the vehicle stops it is to park in the existing lot, however most visitors do not exit the vehicle. When visitors do enter the Grove, it has been to picnic, play soccer or walk over to the East section of the grove where most interest appears to take place.

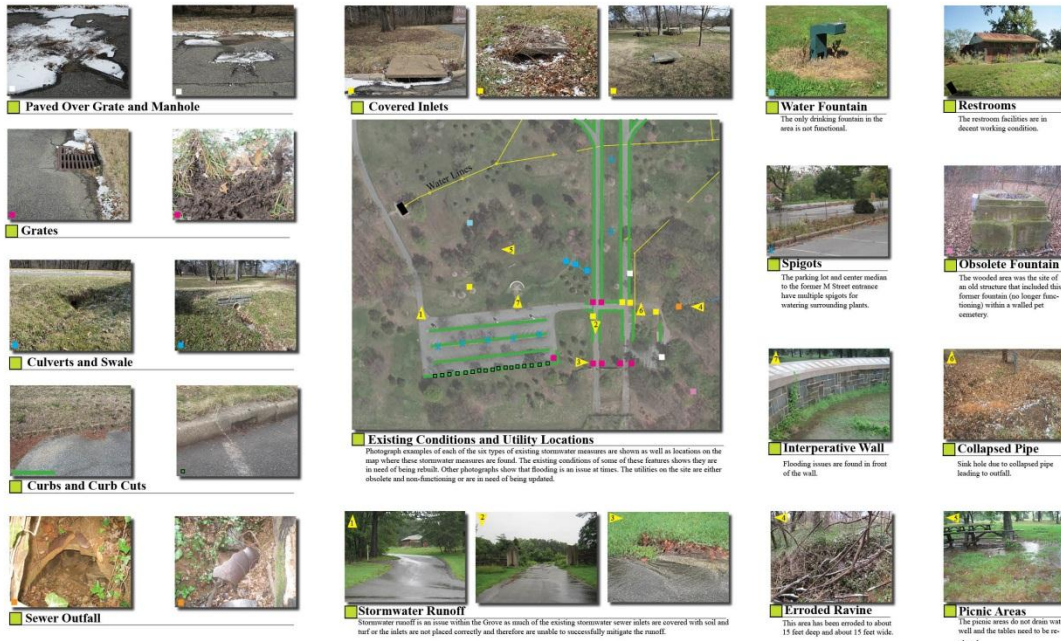


**Current Appearance**  
FHRI Associates designed the National Grove of State Trees in 1991. An interpretive trail with informational signs was also incorporated in the design but never built. Existing conditions show many subquality or missing trees.

- 3 of 8 originally planted District of Columbia's Quarter oaks
- Georgia's *Quercus virginiana*
- Florida's *Pinus mitis*
- Location of Alaska's *Pinus sibirica* and South Carolina's *Sabal palmetto*
- Pinet Grasslands
- Bike Rack

## Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees

2  
Conditions and Site Plans  
Key: Executive M.S. Thesis, April 2012  
University of Maryland



Addressing New Stormwater Policies  
in the Redesign of the National Grove of State Trees

3  
Cultural Attributes  
Key Dates: M.S. Thesis, April 2012  
University of Maryland

Views

- Stately Capitol Columns are a dominant viewshed around Ellipse Road
- Historic gates built by the Civilian Conservation Corps
- Peaceful solitude needed in the District of Columbia
- Seasonal changes in colors, beauty and wildlife



Enhancement Potential

- Construction of modern restrooms
- Creation of inviting picnic grounds that set on a mullch base to avoid worn out surfaces
- Redesign of road layout, which brings people into all areas of the site, rather than encouraging bypassing
- Considering other options to display state trees in a way that is educational, beautiful, and low maintenance



Educational Possibilities

- Providing more prominent, eye appealing, signage or place identification that draws people to the site
- Displaying plant species signs that also inform the viewer of the environmental benefits of the plant
- Creating a memorial to Jeanette Yontee, the sponsor of the Grove, and providing information on her love of trees
- Capturing Stormwater and educating the public why this precious resource needs to be captured



Existing Plant Structure

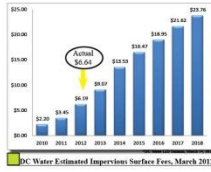
- Using the abundant resource of trees in every way possible through providing shady picnic areas, educational opportunities, and beauty. And when they need to be removed, matching them to recycle or creating new play areas for children to climb on.
- Maintaining as many healthy trees as possible, and allowing the natural decline of non-native trees for potential replacement or open areas.
- Attempt to be as gentle to the topography as possible without much disturbance



Addressing New Stormwater Policies  
in the Redesign of the National Grove of State Trees

4  
Opportunities and Constraints  
Key Dates: M.S. Thesis, April 2012  
University of Maryland





**Impervious Surface Fee for the National Grove of State Trees**

The United States National Arboretum is being charged an impervious surface fee for both DC Water and the District Department of the Environment (DDE). Each agency charges \$6.64 and \$2.07 (respectively) for each Equivalent Residential Unit (ERU) or 1,000 square feet of impervious surface.

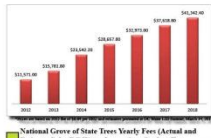
The Arboretum will pay the following impervious surface fees this year for the current state of imperviousness within the project scope unless a redesign of pavements is completed:

DC Water \$11,571.00 + DDOE \$4,593.00 = **\$16,164.00**



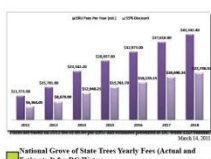
**National Grove of State Trees Monthly Fees to DC Water**

The monthly Clean Rivers Impervious Area Charge is currently over \$900.00 for 145 ERU's within the project scope. However, it is expected to increase dramatically over the next several years unless impervious surfaces become pavements or removed.



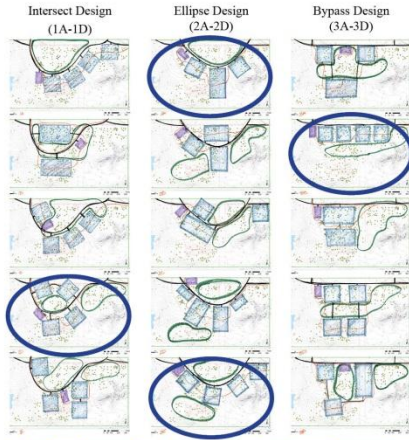
**National Grove of State Trees Yearly Fees to DC Water**

The March 2011 estimates for the yearly Clean Rivers Impervious Area Charge show that the yearly fees for the 145 ERU's within the project scope will more than triple in the next five years.



**Discounts**

Currently DC Water is not offering a discount program, however, they are in the process of working on a discount program with the District Department of the Environment (DDE) who is creating a discount program titled RiverSmart Rewards. DDE's program should be enacted in the Summer of 2012. The maximum discount possible for impervious surfaces is 55%.



Design Group	Walkway	Grass	Vegetation	Parking	Path	Material	Notes	Comments
1A	1	1	2	3	1	1		
1B	1	1	2	3	1	1		
1C	1	1	2	2	2	1		
1D	1	2	1	2	2	1		
1E	1	1	2	2	3	1		
2A	1	1	3	2	2	1		
2B	1	3	2	2	2	1		
2C	1	1	3	3	2	1		
2D	1	3	3	3	1	2		
2E	1	3	1	3	1	1		
3A	3	1	2	2	3	3		
3B	3	1	1	3	1	1		
3C	3	3	3	3	2	1		
3D	3	1	1	2	2	3		
3E	3	1	2	2	3	3		

**The National Grove of State Trees**

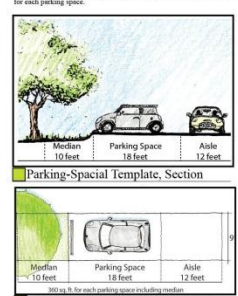
The Grove is approximately 30 acres and has trees from almost every state including the District of Columbia. Some states have the same state tree and therefore can be combined to use one tree to represent each state that shares the same tree. It is believed that four or five acres is the necessary space for all state trees, that can survive this climate, to be represented.

**Parking Requirements**

The National Arboretum currently has 149 parking spaces in this area. However, overflow parking is needed during special events. A total of 480 parking spaces and eight bus spaces are requested, while considering the financial burden of the impervious surface fees.

**Spatial Diagrams**

This study was done using the dimensions of a nine foot by 18 foot long wide parking space, including a 10 foot center median and 12 foot aisle for each parking space.



**Design Matrix**

Considerations for the design matrix included:

- How to get visitors into the site as most drive by or walk by on Ellipse Road (to the north of the site).
- The Arboretum requested this parking lot not resemble shopping mall parking with great spaces of asphalt.
- The impervious surface fees paid to DC Water and DDOE are a major factor.
- In order to make the Grove a place of interest and a destination location, it should not be visible.
- The Arboretum requested that as many existing trees remain and new design work around their root structure.
- The ultimate goal was for lower total scores.

## Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees

**Narrowing Down to a single design: Design Option 1D**

Advantages	Disadvantages
1 Street and parking lots will bring people into the site	Parking will be visible from the columns, which will detract from the site
2 The Grove is split, which creates a disconnect or diminished experience.	
3 The smaller section of the Grove is only 2.3 acres which will allow for limited plaza space.	

**Narrowing Down to a single design: Design Option 2E**

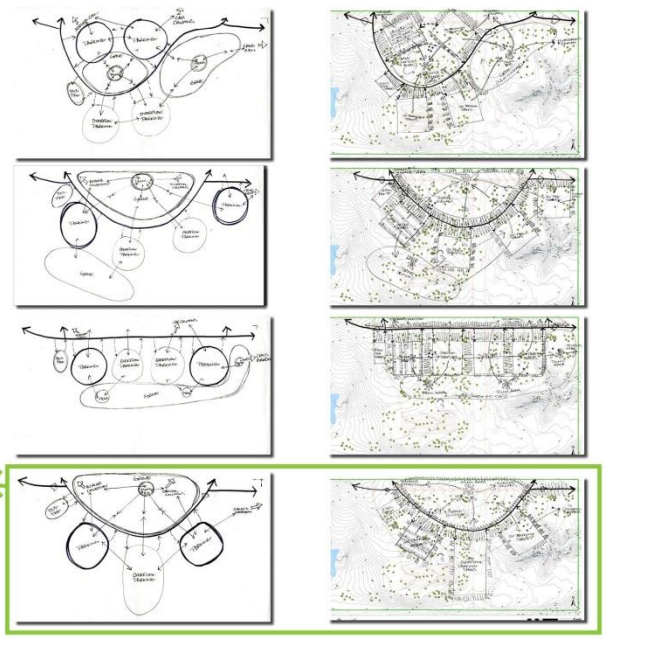
Advantages	Disadvantages
1 Parking will be close to children's garden and within proximity of Capitol Columns	More trees are removed (66 total) due to the two separate lots
2 Bus parking near azalea collection	The split Grove creates an unused part of the Grove or a section that may quickly become obsolete
3 Parking area and road pull people into the site rather than allow for bypassing	Two overflow parking lots create significant distance in daily use lots.
4 Two overflow lots can be closed for most of the year	

**Narrowing Down to a single design: Design Option 3D**

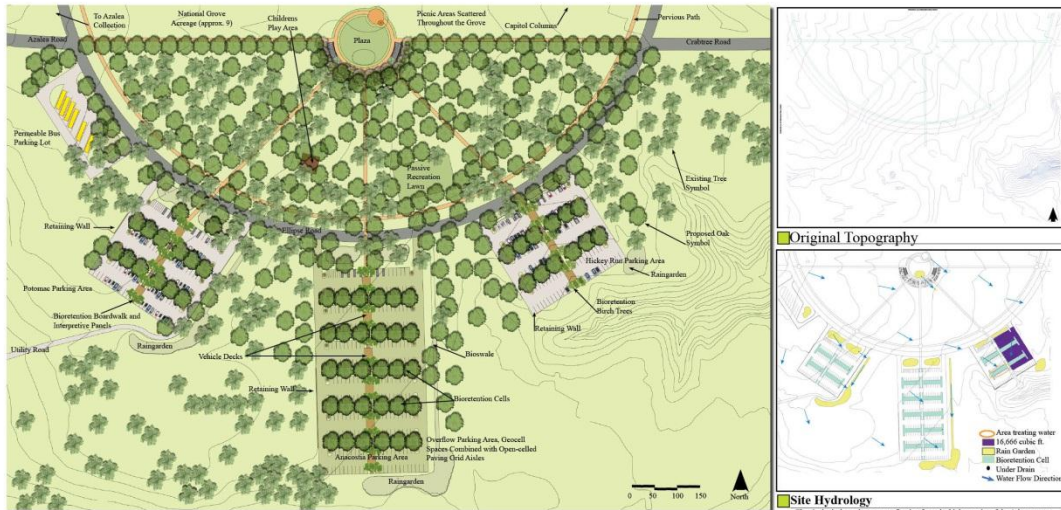
Advantages	Disadvantages
1 Existing street does not require modification	The Grove is behind the lots and will likely end up being overlooked or bypassed by visitors
2 Multiple picnic areas in the grove are not easily visible due to being behind the lots and below street grade	
3 Parking lots act as a wall cutting off ROMA property from parking to M Street walk or about 16.5 acres	

**Narrowing Down to a single design: Design Option 2A**

Advantages	Disadvantages
1 Noise from traffic should not be audible from the plaza or azalea collection	Visitors must cross the road to get to most destinations (However, the culture of the location is such that people are already using the road as a foot path and traffic is slow)
2 The parking area and road bring people into the site rather than allowing them to bypass the Grove as in the current environment	
3 The plaza is on axis from the visitor center, Capitol Columns and capital (azalea tree)	
4 Overflow lot allows for it to be closed most of the year and therefore allows for a healthy flexible pavement such as turf.	
5 Less trees are removed than other designs (63 total)	



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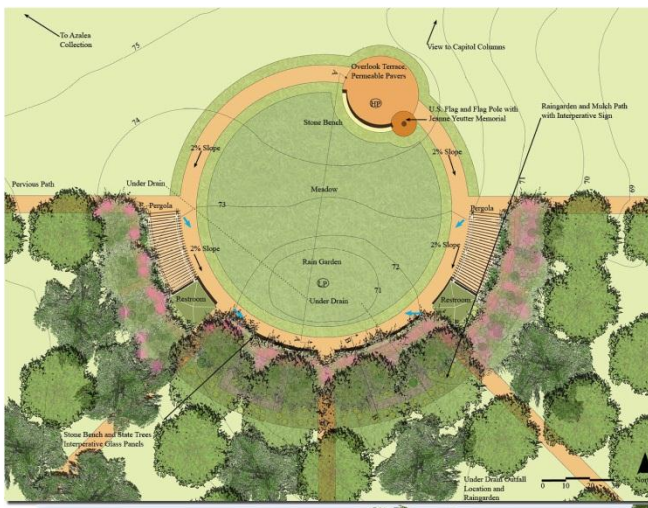


- Site Design Program**
- National Oak Grove: Many 100+ trees are labor intensive and unable to survive in the District without significant cost. The Grove is proposed to be converted into the National Oak Grove, one national tree.
  - Existing Trees: The existing trees will remain intermingled with the oaks. They will be allowed to decline until they are removed and replaced with an oak of any cultivar or left open.
  - National Wall of State Trees: An interpretive 3-dimensional glass and stone wall provide information regarding how each state tree benefits the natural environment with an emphasis on stomatocyst.
  - Passive Recreation Lawn: An open space has been allocated for passive recreation, play or simply laying in the grass.
  - View to the Columns: The view to the Capital Columns was important in the design as a main travel destination and the National Grove Plaza will be visible from that location.
  - Bus Parking: The location for bus parking was chosen as it is an area where buses could avoid driving through the heavy pedestrian area of the south side of the National Grove.
  - Overflow Parking Lot: This lot is only used during special occasions a few times a year. Due to the impervious area charges of \$6.64 and \$2.67 per EBI, should this \$2,700 square foot lot be paved, the Arboretum would pay \$9,150 (FY 2012). Therefore this lot should not be built with curb and gutter and should be a flexible pavement, which will allow for the area not to be assessed an impervious area charge.
  - Aids: The National Grove was set on axis with the Visitor Center, Capital Columns and Capital. Due to the formality of the Capital Columns, the State Grove Plaza was designed in a formal manner.
  - Children's Play Area: Children enjoy climbing. Large tree trunks, trimmed of their small branches, would serve as excellent natural playground.

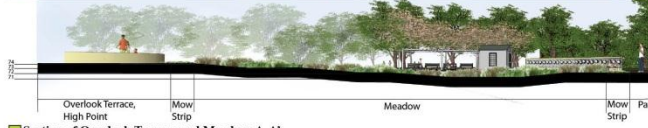
- Site Hydrology**
- The site hydrology shows water flowing from the highest point of the Arboretum towards the ravine that eventually flows out to the Anacosta River.
- Due to the impervious area charge instituted by District government, it is important that all water remains where it lands. Several rain gardens, underdrains, swales and bioretention cells have been installed on the site.
  - Using the Maryland Dept. of the Environment Environmentally Sensitive Design Guidelines (July 2010) for the catchment and rain garden calculations, it was determined that one bioretention cell is capable of capturing 10,666 cubic feet of rainfall from a 1.2" storm (equivalent to the area outlined in purple).

## Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees

National Oak Grove  
Key Events: 10/15/2010, 10/20/2010  
University of Maryland



- Overlook Terrace**  
The terrace is the central element of the design as it overlooks the most prominent feature of the Arboretum as well as the great meadow and hill to the south collection. This terrace could also double as a stage for outdoor concerts. Allowing for a beautiful backdrop.
- United States Flag**  
The U.S. flag has been included in this location due to it being the National Grove and the United States Arboretum. This flag is intended to be exceptionally large on a flag pole of approximately 70 to 100 feet tall.
- Jeanne Yeutter Memorial**  
Jeanne Yeutter was the Secretary of Agriculture, Clayton Yeutter's wife. She loved trees and was the sponsor of the original grove. This memorial will explain her love of trees and their importance.
- Pergola**  
Pergolas and seating are being proposed for outdoor meeting locations for large groups or the general public. They can also act as outdoor classrooms.
- Restrooms**  
A ladies room and men room are included.
- Meadow**  
The meadow is a perfect location for outdoor concert goers to picnic while enjoying any type of outdoor performance. The meadow will be native wildflower grasses mix and will be allowed to grow naturally, unless it is needed to be mowed for an outdoor performance. Mowing is recommended to keep it healthy. A 5' mow strip is also proposed around the perimeter of the meadow as well as the north side of Overlook Terrace and path.
- Permeable Paving**  
Due to the impervious surface charges by the District, permeable paving is recommended. Mitigation has also been included with a large rain garden, which would allow for future discounts by the District. Should the paving being 100% pervious, the District does not charge any impervious area fees.
- Rain Garden**  
A rain garden and interpretive signs regarding stormwater mitigation practices is proposed to the southeast side of the Meadow. Interpretive signs will help educate the public on the importance of keeping rainwater where it lands. Interpretive signs should also be included throughout the site, informing the public about this precious resource and how the Arboretum is protecting it through mitigation, and uptake and capture of water through trees.
- Wall of State Trees**  
The wall will include a 3-dimensional image of the state tree in a glass wall, including information regarding how the tree benefits the environment in its native state. This wall will have a stainless steel wall to match the Capital Columns, facing the direction of the meadow. It will also be capped by sandstone where each state name will be etched into the stone with the image of the tree below. The wall will be visible from both sides and stand about 6' tall with each state having a 1.5' wide panel to display their tree.
- Plaza Trees**  
The State Trees Plaza will be surrounded with proposed oaks and existing trees, as well as ocean cactuses to give it springtime interest. The diversity of oaks surrounding the locations will give provide fall color.
- Entrways**  
The entry ways from the parking lot give the visitor a feeling of arrival with entering into a clearing where there is such a beautiful view.
- Anacosta-Crabtree Path**  
This path was purposefully left straight so that vehicles traveling west on Crabtree Road and East on Anacosta Road, are able to see the strong linear line of trees leading the visitor to the vertical element of the U.S. flag and the plaza overlooking the Capital Columns. This path would also be a good location for interpretive benches for people to be able to sit and read a book, rest from a heavy morning dew resting in the low areas. I am able to come here for personal quiet time where I can sit on any of the many options provided for rest. The craziness of this day and age does not allow for such peace and coming to this location verifies my actions and when I need it most. This is a hidden gem in Washington D.C.



Section of Overlook Terrace and Meadow, A-A'

- Site Design Program**
- "My husband and I have come here at night to enjoy concerts under the stars. I have come here with my kids they love the new play area where they can climb over old tree trunks. The play area is always evolving as new trees are removed from the arboretum and placed there for climbing. And as a D.C. resident, the fees that everyone here is being charged is confusing. The education I have received from the Arboretum on stormwater runoff and mitigation practices has been helpful to our pocketbook.
- The other thing that is truly wonderful about this place, is the serenity especially early in the morning when there is a heavy morning dew resting in the low areas. I am able to come here for personal quiet time where I can sit on any of the many options provided for rest. The craziness of this day and age does not allow for such peace and coming to this location verifies my actions and when I need it most. This is a hidden gem in Washington D.C."
- User Narrative**  
-D.C. Mom of two

## Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees

State Trees Plaza  
Key Events: 10/15/2010, 10/20/2010  
University of Maryland



Section of State Tree Interpretive Wall and Rain Garden, B-B'



Scene Across the Meadow



Birds Eye View of the Plaza



View of Secondary Path System Alongside Pergolas



View of Path leading to State Tree Wall from Parking Areas



View of State Tree Interpretive Wall

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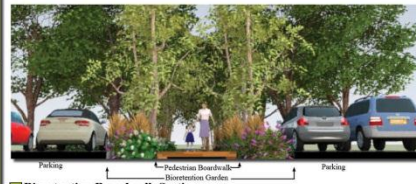
### 9 State Trees Plaza Perspectives

Kary Krenn, M.A. Thesis, April 2012  
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#### Bus Parking Precedence

Bus parking specifications require a parking space of 15' x 40' unless it has a wheelchair lift, in which case the space would need to be widened to 18'. However since this parking is not an area where passengers would be load and unload, the spaces were all created under the standard of 15' wide. Parking spaces must also be aligned at a 135 degree angle to the traffic lane with a minimum turning radius of 50'.



#### Bioretention Boardwalk Section



#### Paving Materials

Permeable open grade block is proposed for regularly used parking lots as they require limited maintenance other than using a leaf blower periodically as there is no aggregate between the block. Timber decks are used in the design for vehicle crossings at all bio-retention cells. The overflow parking lot is designed using permeable concrete grids in the aisle and flexible paving in all non-handicapped parking spaces. The overflow parking lot is only needed a couple times a year for special events. During off-times, the overflow lot should be closed to traffic to allow the paving materials to remain viable.

### Addressing New Stormwater Policies in the Redesign of the National Grove of State Trees

### 10 National Grove Parking

Kary Krenn, M.A. Thesis, April 2012  
University of Maryland

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