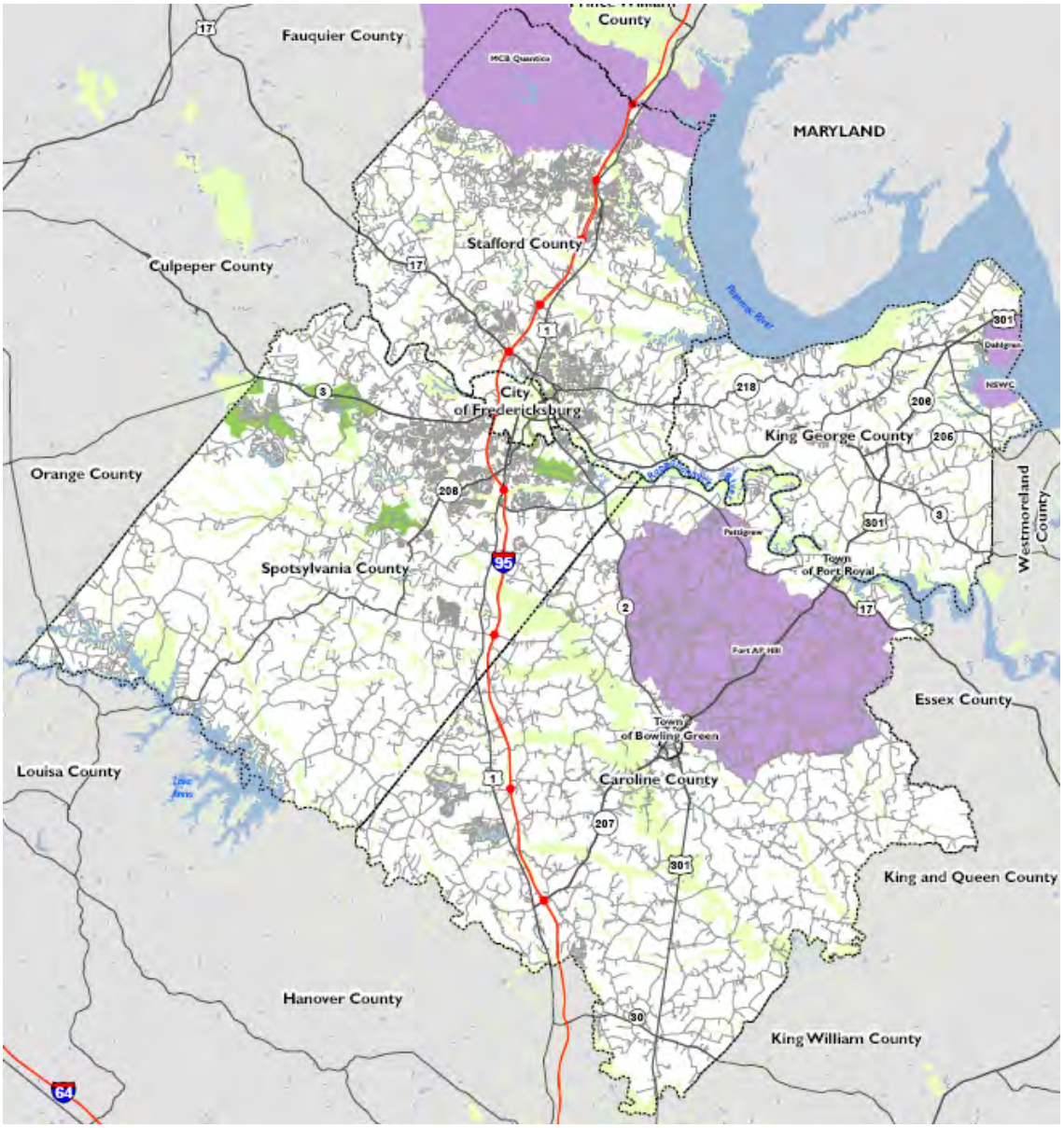
Urban Ecosystem Analysis for

the George Washington Region (PD 16)

Calculating the Value of Nature



GEORGE WASHINGTON REGIONAL COMMISSION

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

Virginia Coastal Zone MANAGEMENT PROGRAM

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Executive Summary

Trees are important indicators of the health of a community's urban ecosystem. Healthy trees provide valuable environmental benefits through the biological functions performed by their roots and leaves. These functions can be measured in terms of ecosystem services including reducing stormwater runoff, increasing atmospheric carbon sequestration and storage, improving air and water quality. The greater the tree cover and the less the impervious surface area in a community, the more ecosystem services are produced and the greater the community benefit from the existing tree cover.

The George Washington Regional Commission (GWRC) worked with American Forests, a non-profit organization, to obtain 2009 30-meter LANDSAT imagery to extend the time-series (1996, 2001, and 2006) of classified imagery available through NOAA's Coastal Change Analysis Program (C-CAP). With this data, GWRC staff used American Forest's CITYgreen® spatial analysis tool to analyze the land cover of Virginia Planning District 16, including the City of Fredericksburg and the Counties of Caroline, King George, Spotsylvania and Stafford and to calculate a variety of ecosystem service benefits of the region's tree canopy. The tool also analyzed land cover in the three major watersheds in the Region, the ecological cores of the Region, Resource Protection Areas, and two local reservoirs. The goal of the study was to provide information on general land cover trends throughout the 13 year period for the Region and the associated monetary value of the ecological services provided by the tree canopy.

The resulting "Urban Ecosystem Analysis" (UEA) report of the George Washington Region is the first of its kind and is based on well-accepted environmental research sponsored by the U.S. Forest Service and the U.S. Department of Agriculture's Natural Resources Conservation Service. The study can be used to educate local government staff, planning commissioners and elected officials on the monetary value of the tree canopy and the associated indirect ecosystem costs of new development. This information can be used by community planners to help the Region grow in a more sustainable manner. In the future with adequate funding support, GWRC staff hope to take this analysis to the next level and perform a more detailed high resolution analysis to estimate "current" land cover acreages with higher precision for the region, local governments, watersheds and other spatial units of interest.

Study Findings

An analysis of 1996-2009 data to identify land cover change trends over the 13 year period found that the GW Region (i.e. Planning District 16) lost 4.17% of its tree canopy, while gaining 2.80% of urban bare area, 8.68% of open space, and 43.46% of impervious surface area. These changes resulted in the loss of the tree canopy's ability to naturally manage 222.98 million cubic feet of stormwater, valued at $1.06 billion using a local engineering cost of $4.75 per cubic foot for man-made stormwater retention facilities. The Region's "green infrastructure" also lost the ability to remove approximately 2.89 million lbs. of air pollutants annually, valued at $7.74 million per year, 1.24 million lbs. of carbon stored in trees' wood, and 9,616 lbs. of annual carbon sequestration.

With differing levels of tree canopy and urbanization among local governments, local loss of tree canopy over this 13 year period varied considerably, from a low of 2.36% in King George County to a high of 27.64% in the City of Fredericksburg. At the same time, changes in the amount of impervious surface area over this period reflected the rapid population and development pressure experienced throughout the Region, with the highest increases in Stafford (48.93%) and Spotsylvania (46.78%) Counties, followed by King George Co. (41.91%), Caroline Co (32.85%) and the City of Fredericksburg (25.19 %).

Study Recommendations

Based on the project results, GWRC staff recommend that:

1. GWRC pursue grant opportunities for the financial support to acquire higher resolution 1-meter classified satellite imagery to provide more accurate and consistent estimates of land cover throughout the Region.

2. Local planners and elected officials use this regional study to understand the monetary value of undeveloped tree-covered areas and the ecosystem loss if land development is approved which allows the removal of trees without replacement. Public officials should use the CITYgreen® software to model land cover modifications and consider the program's results in site plan review and proffer discussions with development prospects.

3. The George Washington Region and its local governments should set a tree canopy goal of a 5% increase to sustain a regional level of 70% to 75%, thereby regaining the tree canopy lost over the last 13 years of development. The Region should work toward collective achievement of this goal through more careful rezoning impact analysis, development proposal review, and tree planting initiatives.

4. Environmental groups should use the report to encourage and promote tree conservation and planting initiatives along green corridors, adjoining rivers and streams and public reservoir and other bodies of water.

5. Local government officials should use the report to demonstrate to the public the benefits of tree cover in managing stormwater and cleaning the air. CITYgreen® software can also be used in classrooms to teach practical applications of technology and environmental stewardship.

6. In the event that the Region (or portions thereof) are designated as "non-attainment areas" for the 8-hour ozone standard, local governments should pursue State enabling legislation to amend § 15.2-961.1.B of the Code of Virginia to include local governments in Planning District 16, thereby allowing local governments authority to enact local ordinances to conserve trees during the land development process.

A. Introduction and Project Overview

Trees are important indicators of the health of a community's urban ecosystem. When trees are large and healthy, the ecological systems that support them are also healthy. Healthy trees provide valuable environmental benefits through the biological functions of their roots and leaves. These can be measured in terms of ecosystem services including reducing stormwater runoff, increasing carbon storage, and improving air and water quality. The greater the tree cover and the less the impervious surface in a community, the more ecosystem services are produced.

American Forests assesses the health and benefits of urban ecosystems through a process called Urban Ecosystem Analysis (UEA). The George Washington Regional Commission (GWRC) retained American Forests to reclassify 2009 30-meter LANDSAT imagery to extend the time-series of classified imagery available through NOAA's Coastal Change Analysis Program (C-CAP) to provide GWRC with a time-series of consistent imagery for 1996, 2001, 2006 and 2009 (for more information see the "Data Used" discussion on pg. 21). This imagery was analyzed by GWRC using American Forest's CITYgreen® spatial analysis tool to calculate a variety of ecosystem service benefits of the region's tree canopy, a detailed explanation about how the formulas for the analysis were developed begin on pg. 22 under "Analysis Formulas". This Urban Ecosystem Analysis of the George Washington Region is the first of its kind, but is patterned after similar studies and reports developed by American Forests for the Washington D.C. Metropolitan area (2002), Charlottesville (2002), Roanoke (2002) and Charlotte, N.C (2010).

The continued conversion of natural areas into urban areas contributes to increased environmental management costs to preserve quality of life for a community's residents. GWRC, through planning work funded through Virginia's Coastal Zone Management program, is attempting to develop a regional blue and green infrastructure plan which recognizes the importance of natural landscapes, viewsheds, habitat corridors and ecological "cores" and other features to preserve the Region's quality of life and the sensitive environment of the coastal zone. Consequently, GWRC commissioned American Forests to perform the imagery classification, provide user training on the CITYgreen® tool and provide reports on the changes that have occurred and trends that are emerging in the regional land cover over the 13 year period from 1996 through 2009. The project was made possible, in part, through a generous grant from the Urban and Community Forestry program from the Virginia Department of Forestry.

This UEA study used satellite imagery, GIS technology and American Forests' CITYgreen® software, to analyze land cover of Virginia Planning District 16, including the City of Fredericksburg and the Counties of Caroline, King George, Spotsylvania and Stafford. The first analysis, a trend analysis, utilized moderate-resolution 30-meter LANDSAT-based C-CAP imagery acquired in 1996, 2001, 2006 and 2009 to quantify land cover changes that occurred during this 13 year time period. In the future, GWRC hopes to take this analysis to the next level and perform a much more detailed high resolution analysis, using National Agricultural Imagery Program (NAIP) data from 2009 one-meter pixel resolution digital imagery to determine current land cover for the region, local governments, watersheds and other spatial units of interest. The first of these studies will be performed on the City of Fredericksburg through classified NAIP imagery provided by the Virginia Department of Forestry.

The project's objectives are threefold: 1) To provide detailed information regarding land cover trends and their ecological implications relevant to the region as a whole and its member localities; 2) to educate local planners, environmental managers to current data sources and analytical tools that can support better environmental management and policy formulation to best preserve tree canopy, target tree planting and reforestation efforts and to enhance riparian vegetation corridors, all of which are vital to protecting the area's environmental assets; and 3) to provide tools to enable local decision makers to more effectively plan for and manage growth throughout the Region. These tools, if used in accordance with recommendations in this report, will help the community improve air and water quality and minimize degradation of the area's tree canopy, stream network and remaining open space.

Unfortunately, this UEA reports that the Region has been consistently losing tree canopy and gaining impervious surface area. However, the good news is that the tools used to complete this analysis also offer feasible solutions. GWRC and its member localities can use the tools and new data provided as part of this project to change this trend and maintain a healthy, sustainable tree canopy and maximize its ecosystem services benefits. With this goal in mind GWRC recommends that the community:

1) Integrate these new land cover data into its planning processes so that impacts from future growth and development can be anticipated and managed to preserve canopy wherever possible;

2) invest in the classification of 1-meter imagery for the remainder of the region to provide more accurate baseline data for each local government, watersheds and subwatersheds and other areas of interest

3) Use the integrated data to support Scenario Planning exercises and additional, more detailed analysis of the community's natural assets using CITYgreen® software with consideration of the community's land use plans, zoning categories, transportation plans, etc.;

4) Guided by this additional analysis, establish tree canopy goals that can be attained within various zoning categories and key watershed areas as it continues to develop; and

5) Preserve and plant trees throughout the Region on a continuing basis to obtain and sustain a suitable level of tree canopy.

B. Major Findings Summary

An analysis of LANDSAT/C-CAP data, used to identify land cover change trends, found:

- Between 1996 and 2009 Planning District 16, or the GW Region, lost 4.17% of its tree canopy, while gaining 2.80% of urban bare area, 8.68% of open space, and 43.46% of impervious surface area (Table 1, page 9). These changes resulted in the loss of the tree canopy's ability to naturally manage 222.98 million cubic feet of stormwater, valued at $1.06 billion using a local engineering cost of $4.75 per cubic foot.[2] The Region's green infrastructure[3] also lost the ability to remove approximately 2.89 million lbs. of air pollutants annually, valued at $7.74 million per year, 1.24 million lbs. of carbon stored in trees' wood, and 9,616 lbs. of annual carbon sequestration—the rate at which carbon is stored.

- Between 1996 and 2009, the City of Fredericksburg, with 0.74% of the regional land area, lost 27.64% of its tree canopy and 17.24% of its urban bare area while gaining 13.33% of open space and 25.19 % of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, Caroline County, with 37.77% of the regional land area, lost 2.75% of its tree canopy while gaining 7.11% of urban bare area, 10.06% of open space, and 32.85% of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, King George County, with 13.16% of the regional land area, lost 2.36% of its tree canopy and 1.30% of its urban bare area while gaining 1.87% of open space and 41.91% of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, Spotsylvania County, with 28.90% of the regional land area, lost 5.10% of its tree canopy and 2.92% of its urban bare area while gaining 10.39% of open space and 46.78% of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, Stafford County, with 19.58% of the regional land area, lost 6.40% of its tree canopy while gaining 5.28% of urban bare area, 9.30% of open space, and 48.93% of impervious surface area (Table 1, page 9).

The GW region is sub-divided into three major watersheds: i.e. for the Lower Potomac, the Rappahannock and the York Rivers, respectively. Within the Planning District 16 regional portion of each watershed, the following trends were found:

- Between 1996 and 2009, the Lower Potomac watershed, with 21.36% of the regional land area, lost 4.52% of its tree canopy while gaining 4.55% of urban area, 9.02% of open space, and 43.84% of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, the Rappahannock River watershed, with 26.38% of the regional land area, lost 5.73% of its tree canopy while gaining 13.51% of urban bare area, 4.43% of open space, and 43.17% of impervious surface area (Table 1, page 9).

- Between 1996 and 2009, the York River watershed, with 51.77% of the regional land area, lost 3.33% of its tree canopy and 8.22% of its urban bare area, while gaining 11.14% of open space and 43.73% of impervious surface area (Table 1, page 9).

An analysis of recent moderate resolution data,[1] providing a snapshot in time and estimating what major environmental benefits the Region's current green infrastructure is to the community, found:

- As of 2009, the GW Region had a 72.19% tree canopy cover, which provided 5.09 billion cubic feet of stormwater detention services, valued at $24.17 billion. It removed 66.40 million lbs. of air pollutants at a value of $177.80 million per year, stored 28.37 million tons of carbon in trees' wood, and sequestered 220.86 thousand tons of carbon annually (Table 4, page 13).

- As of 2009, the City of Fredericksburg had an estimated 31.42% tree canopy that provided 18.38 million cubic feet of stormwater detention services, valued at $87.32 million. It removed 212.90 thousand lbs. of air pollutants at a value of $570.03 thousand per year, stored 90.95 thousand tons of carbon in trees' wood, and sequestered 708 tons of carbon annually (Table 4, page 13). More accurate estimates, based on detailed 1-meter resolution imagery, are available from a separate report on the City's tree canopy developed by the Virginia Department of Forestry

- As of 2009, Caroline County had an estimated 78.05% tree canopy that provided 2.14 billion cubic feet of stormwater detention services, valued at $10.19 billion. It removed 27.12 million lbs. of air pollutants at a value of $72.60 million per year, stored 11.58 million tons of carbon in trees' wood, and sequestered 90,186 tons of carbon annually (Table 4, page 13). A significant share (21.68%) of the County's tree canopy is outside local control, residing under federal jurisdiction being located on the property of the US Army's Fort A.P. Hill.

- As of 2009, King George County had an estimated 66.91% tree canopy that provided 616.55 million cubic feet of stormwater detention services, valued at $ 2.93 billion. It removed 8.10 million lbs. of air pollutants at a value of $21.68 million per year, stored 3.46 million tons of carbon in trees' wood, and sequestered 26,936 tons of carbon annually (Table 4, page 13).

- As of 2009, Spotsylvania County had an estimated 70.47% tree canopy that provided 1.35 billion cubic feet of stormwater detention services, valued at $6.43 billion. It removed 18.74 million lbs. of air pollutants at a value of $50.17 million per year, stored 8.00 million tons of carbon in trees' wood, and sequestered 62,317 tons of carbon annually (Table 4, page 13).

- As of 2009, Stafford County had an estimated 68.02% tree canopy that provided 934.82 million cubic feet of stormwater detention services, valued at $4.44 billion. It removed 12.25 million lbs. of air pollutants at a value of $32.80 million per year, stored 5.23 million tons of carbon in trees' wood, and sequestered 40,744 tons of carbon annually (Table 4, page 13). A significant share (18.42%) of the County's tree canopy is outside local control, residing under federal jurisdiction being located on the property of the US Marine Corps' Quantico Base.

Within each watershed, the respective estimated benefits derived from the 2009 tree canopy are:

- The Lower Potomac River watershed had an estimated 74.26% tree canopy that provided 111.57 million cubic feet of stormwater detention services, valued at $529.95 million. It removed 14.59 million lbs. of air pollutants at a value of $39.07 million per year, stored 6.23 million tons of carbon in trees' wood, and sequestered 48,533 tons of carbon annually (Table 4, page 13).

- The Rappahannock River watershed had an estimated 64.68% tree canopy that provided 1.23 billion cubic feet of stormwater detention services, valued at $5.85 billion. It removed 15.69 million lbs. of air pollutants at a value of $42.02 million per year, stored 6.70 million tons of carbon in trees' wood, and sequestered 52,193 tons of carbon annually (Table 4, page 13).

- The York River watershed in the Region had an estimated 75.88% tree canopy that provided 2.73 billion cubic feet of stormwater detention services, valued at $12.96 billion. It removed 36.14 million lbs. of air pollutants at a value of $96.76 million per year, stored 15.44 million tons of carbon in trees' wood, and sequestered 120,187 tons of carbon annually (Table 4, page 13).

In 2009, GWRC staff, working with local government environmental staff and community environmental interest groups that serve on the GWRC's Green Government Commission Green Earth Sub-Committee, worked with the Virginia Conservation Lands Needs Assessment (VCLNA) and Natural Heritage data sets supplied by the Virginia Department of Conservation and Recreation to locally "customize" the "ecological cores" and conservation corridors identified through the statewide effort. This work is summarized in GWRC's report "2009 Green Infrastructure and Conservation Corridors Maps", published under a grant from the Virginia coastal zone management program. GWRC staff applied the CITYgreen® tool to quantify the ecosystem service benefit value of the remaining "natural" area which might be considered the "backbone" of the Region's green infrastructure. As of 2009, the Region's remaining ecological core areas and potential conservation corridors that inter-connect these prime natural habitat areas represented 52.82% of the Region's land area. The identified areas (see Figure 1) had an estimated 92.60% tree canopy that provided 3.58 billion cubic feet of stormwater detention services, valued at $17.00 billion. This "green infrastructure" system removed 44.99 million lbs. of air pollutants at a value of $120.47 million per year, stored 19.22 million tons of carbon in trees' wood and sequestered 149,645 tons of carbon annually (Table 4, page 13).

Figure 1. Ecological Corridor Areas of the GW Region

The region's tree cover has declined for the last 13 years and new policies and practices will be needed to reverse this trend. The Region is blessed with a tree canopy that far exceeds many other larger urban areas. With this natural advantage the Region has the opportunity to set a course for environmental quality for decades to come. The data and tools provided with this UEA offer decision support tools to help the region's communities maintain the recommended levels of tree canopy as they continue to grow. These tools will also allow local leaders and staff to calculate the positive contributions of not only halting decline, but enhancing green infrastructure. For example, by increasing the regional tree canopy 5% from its current 72.2% to 77.2% (and thereby exceeding the amount of tree canopy lost over the last 13 years), the Region would gain an additional 4.61 million lbs. of air pollution removal annually, valued at $12.35 million. Carbon storage would increase by 1.97 million tons and carbon sequestration would increase by 15,338 tons per year. If the increased tree cover replaced open space, then stormwater runoff would decrease by 543.99 million cubic feet, valued at $2.58 billion. However, if 20% of the additional replacement tree canopy was produced by replacing impermeable surfaces with tree cover, and the additional 80% increase in tree canopy came from existing open space (through reforestation efforts) then stormwater runoff would decrease by 589.06 million cubic feet, valued at $2.80 billion (Table 6).

The UEA process involves a technical analysis of a community's land cover data taken from satellite imagery and aerial photography, computer technology called Geographic Information Systems (GIS), and the application of scientific and engineering models developed by experts to quantify environmental benefits. In short, the UEA calculates the benefits the studied community derives from ecosystem services provided by its natural assets.

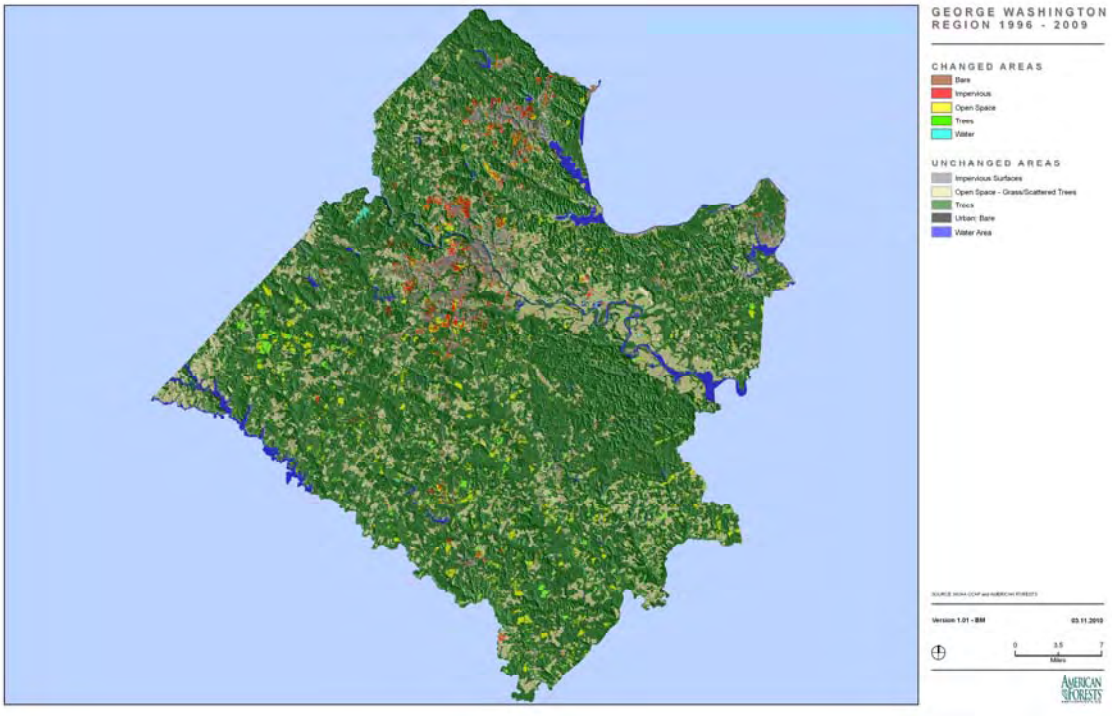
Upon completion of an UEA, the community receives data that accurately depict and quantify the community's land cover by type (trees, open space, urban area, and water) and detailed information about the ecosystem services and associated financial benefits. American Forests also provides CITYgreen® software to the community's planners and managers which enable them to integrate data about the natural assets into growth and development planning and management endeavors. This in turn enables the community to design and adopt effective measures to protect and preserve the community's trees and other natural assets.

American Forests has conducted UEAs within 40 different urban areas across the country and documented a disturbing trend--urban areas are losing trees at an alarming rate while urban land cover like roads and buildings, has been increasing rapidly. This trend is harming local environmental assets and quality of life in significant ways and is also costing communities billions of dollars because ecosystem services are lost when trees are removed.

C. LAND COVER CHANGE TRENDS: LANDSAT/C-CAP 1996-2009

Using moderate resolution satellite data from LANDSAT imagery acquired in 1996 and 2009, American Forests measured changes in four distinct land cover types: tree canopy, urban, open space, and water within the George Washington Region. This moderate resolution data identifies land cover change trends between these years. The analysis quantified the impacts these changes had on stormwater management, air and water quality, and carbon sequestration and storage.

Figure 2. Land Cover Change from 1996 – 2009 for the George Washington Region



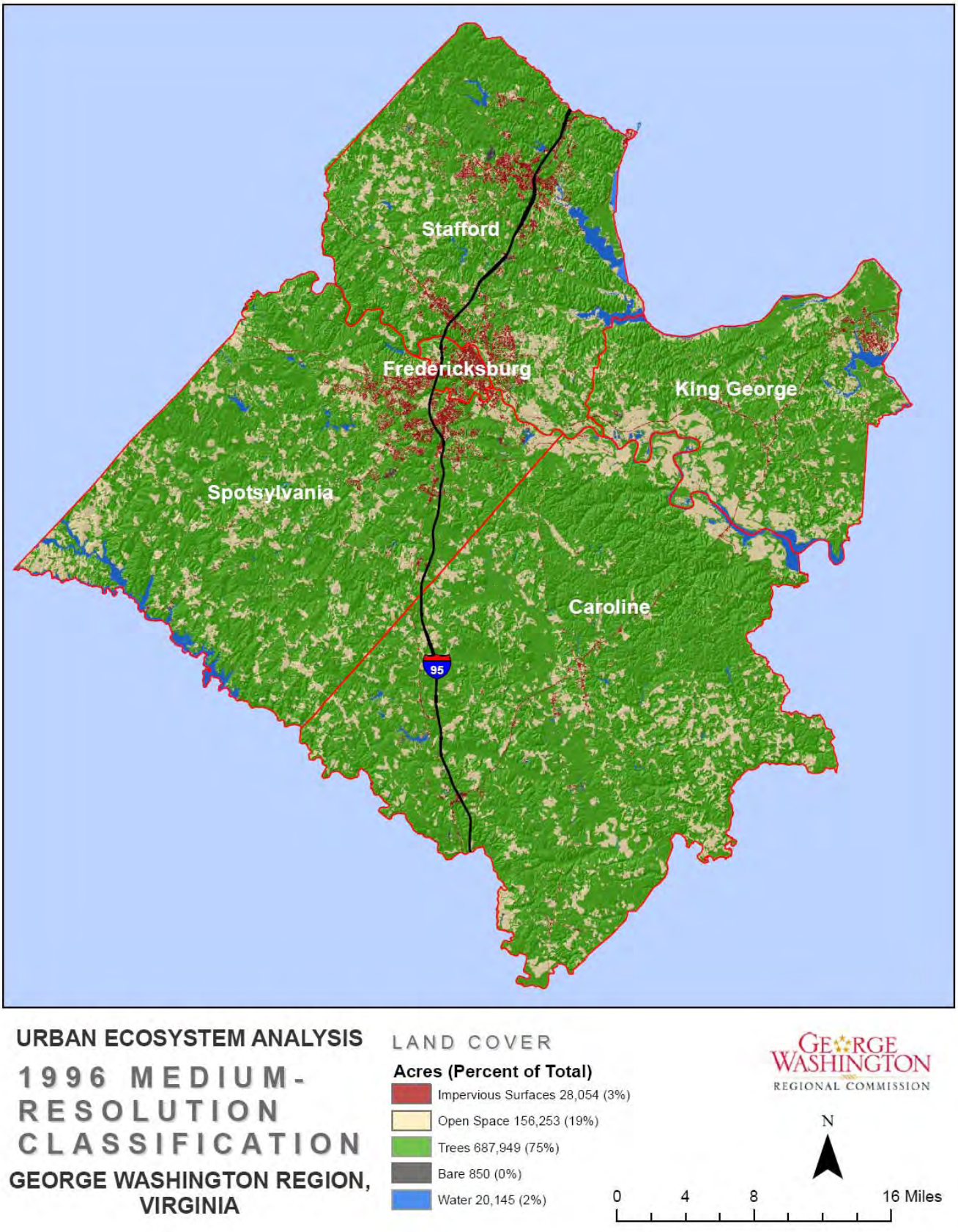
It is important to note that LANDSAT data are valuable for identifying general trends and comparing land cover from one period of time to another in large areas, but these data are not used to determine where trees, open space and urban area are located due to its coarse scale. In contrast, the high resolution dataset available from the US Dept of Agriculture (NAIP) provides an accurate spatial location of land cover and is the appropriate resolution to use to determine land cover existing in smaller parcels. High resolution data are used for planning and management functions involved in achieving tree canopy and open space goals, etc. **Because of the difference in resolution, LANDSAT/C-CAP data and high resolution data should not be compared to one another.**

Land cover change trends from this study document tree canopy decline throughout the Region. Between 1996 and 2009, the Region lost 4.17% tree canopy, while gaining 2.80% of urban bare area, 8.68% of open space, and 43.46% of impervious surface area (Table 1). In the same time period, the City of Fredericksburg lost 27.64% of its tree canopy and 17.24% of its urban bare area while gaining 13.33% of open space and 25.19 % of impervious surface area. Caroline County lost 2.75% of its tree canopy while gaining 7.11% of urban bare area 10.06% of open space and 32.85% of impervious surface area. King George County lost 2.36% of its tree canopy and 1.30% of its urban bare area while gaining 1.87% of open space and 41.91% of impervious surface area. Spotsylvania County lost 5.10% of its tree canopy and 2.92% of its urban bare area while gaining 10.39% of open space and 46.78% of impervious surface area. Similarly, Stafford County lost 6.40% of its tree canopy while gaining 5.28% of urban bare area 9.30% of open space and 48.93% of impervious surface area.

Table 1. LANDSAT Land Cover Percent Change Trends

Land Cover	1996-2009																	
	GW Region		Caroline		Fredericksburg		King George		Spotsylvania		Stafford		Lower Potomac		Rappahannock		York	
	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%	Area (mi^2)	%
Trees	-44.85	-4.17	-11.91	-2.75	-1.26	-27.64	-3.03	-2.36	-15.61	-5.10	-13	-6.40	-10.73	-4.52	-14.80	-5.73	-19.31	-3.33
Urban Bare Area	0.04	2.80	0.01	7.11	0	-17.24	0.00	-1.30	-0.01	-2.92	0.04	5.28	0.03	4.55	0.04	13.51	-0.03	-8.22
Open Space	23.91	8.68	9.54	10.06	0.25	13.33	0.87	1.87	8.51	10.39	4.68	9.30	4.55	9.02	3.77	4.43	15.54	11.14
Impervious Surface	19.05	43.46	1.81	32.85	1.01	25.19	1.69	41.91	6.49	46.78	8.08	48.93	5.94	43.84	9.79	43.17	3.33	43.73

Figure 3. 1996 Planning District 16 Land Cover



See Appendix for related Detailed CITYgreen®analysis for Planning District 16.

Figure 4. 2009 Planning District 16 Land Cover

See Appendix for related detailed CITYgreen®analysis for Planning District 16.

As the Region with the fastest growing population in Virginia for more than the last 20 years, the resulting rapid urbanizing and suburbanizing development pattern has transformed the natural landscape as well. Over the 13 years of the analysis period, the Region's population has grown by 48.6 percent (see Table 2); while impervious surface area has grown by 43.4 percent and tree canopy has declined by 4.17%.

To determine land cover change trends over the 13 year study period, GWRC compared the 1996 moderate resolution data with comparable 2001, 2006, and 2009 data. The 13 year period shows that tree canopy continued to decline throughout the Region. Fredericksburg lost an estimated 807.50 acres of trees, a 27.64% decline; Stafford County lost 8,321.30 acres of trees, a 6.40% decline; Spotsylvania County lost 9,991.90 acres of trees, a 5.10% decline; Caroline County lost 7,624.60 acres of trees, a 2.75% decline; and King George County lost 1,939.70 acres of trees, a 3.03% decline (Figure 5, page 14).

Figure 5. Tree Canopy Decline in the George Washington Region

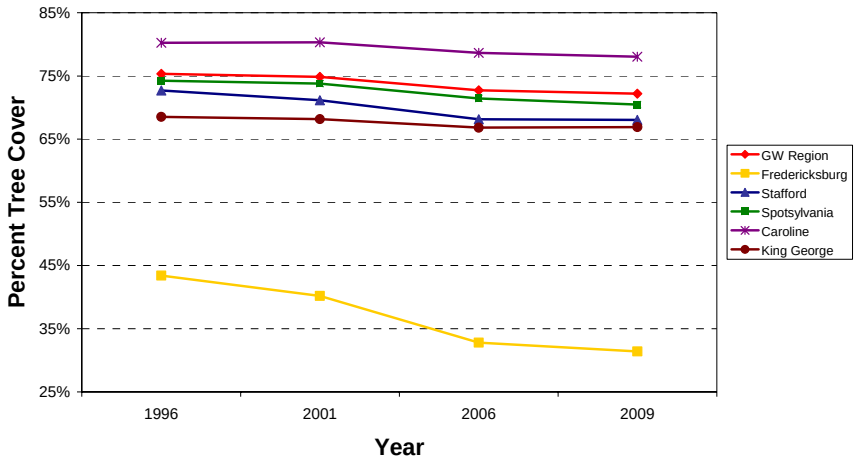


Table 2. Land Cover, Tree Canopy, Impervious Surface Area and Population Growth Comparisons: 1996 - 2009

Area	1996 Acres				2009 Acres				1996 - 2009 Net Change (%)		
	Total Acres	Canopy Area (Acreage)	Impervious Surfaces (Acreage)	Population	Total Acres	Canopy Area (Acreage)	Impervious Surfaces (Acreage)	Population	Canopy Area (Acreage)	Impervious Surfaces (Acreage)	Population
GW Region	913,250.70	687,948.50	28,123.3	217,100	913,250.70	659,245.40	40,336.5	322,739	-4.17%	43.43%	48.66%
Caroline	344,932.40	276,828.20	3,523.1	21,400	344,932.40	269,203.60	4,680.6	28,245	-2.75%	32.85%	31.99%
Fredericksburg	6,727.80	2,921.10	2,559.0	21,000	6,727.80	2,113.60	3,203.7	22,902	-27.64%	25.19%	9.06%
King George	120,161.30	82,341.90	2,579.7	15,800	120,161.30	80,402.20	3,660.9	23,891	-2.36%	41.91%	51.21%
Spotsylvania	263,971.50	196,006.10	8,873.7	75,400	263,971.50	186,014.20	13,025.0	121,809	-5.10%	46.78%	61.55%
Stafford	178,788.90	129,940.70	10,565.8	83,500	178,788.90	121,619.40	15,736.1	125,892	-6.40%	48.93%	50.77%

D. ECOSYSTEM SERVICE BENEFITS

There are ecological consequences when there is a loss of pervious land cover, such as tree canopy, open space and other vegetated areas, which define an area's green infrastructure. There are also ecosystem impacts associated with an increase in urban impervious and bare areas. The 13-year trend data for the Region shows that the loss of green infrastructure adversely affected the Region's natural environment's ability to provide ecosystem services which include air pollutant removal, stormwater management, carbon storage and sequestration, water pollutant removal (Table 3).

Table 3. George Washington Region: Net Change in Ecosystem Services (Landsat Data 1996-2009)

Tree Canopy Change	Loss of Air Pollution Removal	Loss in Removal Value	Loss in Stormwater Value	Loss in Stormwater Value @ $4.75/cu ft.	Loss of Carbon Stored	Carbon Sequestered
%	lbs./year	dollar value	cu ft.	dollar value	tons	tons
-4.17%	-2,891,237	-7,741,206	-222,978,298	-1,059,146,916	-1,235,134	-9,616

Over this time period, the Region lost the ability to naturally manage 222.98 million cubic feet of stormwater (see "TR-55 for Stormwater Runoff" on pg. 23 for an explanation on how this was developed). The average cost of an engineered stormwater management system, based on input of local urban stormwater managers and private consulting engineers, is

estimated to be $4.75[1] per cubic foot of retained stormwater. The value of the remaining regional tree canopy to perform this service is $1.06 billion. The Region's land cover also lost $7,741,206 in annual air pollution removal benefits, 1.24 million pounds of carbon storage, and 9,616 pounds of carbon sequestration annually. Tree roots absorb water pollutants for which nine measures are available: Biological Oxygen Demand, Cadmium, Chromium, Chemical Oxygen Demand, Lead, Nitrogen, Phosphorus, Suspended Solids, and Zinc. Throughout the Region, the amount of these contaminants entering streams and lakes worsened in the past 13 years. This chronological analysis provides valuable public policy information regarding the continual loss trends in tree canopy cover and associated ecosystem impacts.

For this UEA, American Forests used the U.S. Geological Survey's (USGS) 2001 National Land Cover Data (NLCD) as the baseline to update land cover change.[5] The USGS data, considered the gold-standard for land cover change analysis, was classified from 30-meter LANDSAT data acquired in 2001. American Forests utilized this dataset as the basis to compare land cover change from 1996 to 2009.

The CITYgreen®model provides estimates of the ecosystem service benefits value of the remaining tree canopy. These estimates are summarized in Table 4.

Table 4. 2009 Tree Canopy and Ecosystem Services from Medium-Resolution Data (30-meter pixel resolution)

Area		2009 Tree	Air Pollution	Air Pollution	Stormwater	Stormwater Value	Carbon	Carbon
	Area	Canopy	Removal	Removal Value	Value	at $4.75 per cu. ft.	Stored	Sequestered
	acres	acres	lbs./yr	dollar value	cu. ft.	dollar value	tons	tons
GW Region	913,250.7	659,245.4	66,405,329	$177,798,410	5,089,465,747	$24,174,962,298	28,368,309	220,855
Caroline	344,932.4	269,203.6	27,116,693	$72,604,185	2,144,370,474	$10,185,759,752	11,584,231	90,186
Fredericksburg	6,727.8	2,113.6	212,898	$570,028	18,383,653	$87,322,352	90,950	708
King George	120,161.3	80,402.2	8,098,860	$21,684,468	616,548,105	$2,928,603,499	3,459,827	26,936
Spotsylvania	263,971.5	186,014.2	18,737,082	$50,168,014	1,354,668,770	$6,434,676,658	8,004,468	62,317
Stafford	178,788.9	121,619.4	12,250,640	$32,800,742	934,817,624	$4,440,383,714	5,233,464	40,744
Lower Potomac	195,075.6	144,870.4	14,592,695	$39,071,535	111,568,123	$529,948,584	6,233,989	48,533
Rappahannock	240,875.1	155,795.2	15,693,139	$42,017,940	1,231,702,933	$5,850,588,932	6,704,098	52,193
York	472,782.9	358,756.0	36,137,236	$96,756,438	2,728,516,714	$12,960,454,392	15,437,801	120,187
Resource Protection Areas (RPAs)	85,794.9	60,967.4	6,141,202	$16,442,895	518,833,790	$2,464,460,503	2,623,517	20,425
Motts Run	13,246.7	9,722.1	979,299	$2,622,047	73,820,369	$350,646,750	418,356	3,257
Rocky Point Run (after construction)	11,687.5	8,073.5	813,242	$2,177,432	63,783,115	$302,969,795	347,416	2,705

Air Quality Benefits

Air quality is of particular concern in the George Washington region because the Environmental Protection Agency (EPA) has proposed stricter air quality standards which could change the regional air quality status (for ozone standard attainment) from "maintenance" to a "non-attainment" area for ozone.[6] Sunlight and hot weather can cause ground- level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. For this reason, the months of April through October often are referred to as the "ozone season". The air quality ecosystem services provided by trees are a big plus for any heavily urban or urbanizing region (such as the Northern Virginia portion of the Washington D.C. PMSA). Tree canopy cools the air by evaporating water and by direct shading of buildings and pavement. This lowers the ambient temperature in cities (known as urban heat islands), reducing ground level ozone production and related smog conditions. While trees also emit hydro-carbons that contribute to smog ozone, research shows that because of trees cooling effects, they provide a net benefit in reducing air pollution.[7] As a result of these benefits, local environmental planners and tree conservationists in the GWRC region would like to see the authority to conserve trees in the land development process granted by the Virginia General Assembly under § 15.2-961.1 of the Code of Virginia to local governments of Virginia's Planning District 8 (Northern Virginia) extended to localities in Planning District 16.

[1] The average value of $4.75 per cubic foot of retained stormwater is based on local feedback from local public and private environmental engineers and a small sampling of private site development projects in the George Washington Region. The national default value used by the CITYgreen model is a conservative $2.00 per cubic foot. Local experience around the United States in the use of the CITYgreen model has shown this value to range has high as $6-$8 per cubic foot in some areas. However, GWRC staff emphasize that actual site development costs will vary based on local economic and market conditions, physical site conditions (i.e. geology, hydrology, slope, tree cover, etc), and State and local ordinance requirements for stormwater management.

The ecological value of air quality ecosystem services is based on the UFORE model developed by the U.S. Forest Service (see "UFORE Model for Air Pollution", pg. 23). The dollar value is calculated based on externality costs to society (such as public health-related respiratory costs) due to the additional air pollution. Externality values are established by State Public Service Commissions. The Planning District's urban forest removes 66.40 million lbs. of air pollutants annually, valued at almost $177.80 million per year (Table 5). Fredericksburg's urban forest removes 212.90 thousand lbs. of air pollutants annually, valued at almost $570.03 thousand per year, while Caroline's forest removes 27.12 million lbs. of air pollutants annually, valued at almost $72.60 million per year. King George County's urban forest removes 8.10 million lbs. of air pollutants annually, valued at almost $21.68 million per year. Spotsylvania County's urban forest removes 18.74 million lbs. of air pollutants annually, valued at almost $50.17 million per year and Stafford County's urban forest removes 12.25 million lbs. of air pollutants annually, valued at almost $32.80 million per year.

Table 5. Urban Forest Air Pollutant Removal Benefits

Air Pollutant	GW Region		Caroline		Fredericksburg		King George		Spotsylvania		Stafford	
	Lbs. Removed per yr.	$ Value per yr.	Lbs. Removed per yr.	$ Value per yr.	Lbs. Removed per yr.	$ Value per yr.	Lbs. Removed per yr.	$ Value per yr.	Lbs. Removed per yr.	$ Value per yr.	Lbs. Removed per yr.	$ Value per yr.
Carbon Monoxide	2,938,289	$1,442,036	1,199,854	$588,857	9,420	$4,623	358,357	$175,872	829,074	$406,888	542,064	$266,031
Nitrogen Dioxide	22,918,653	$80,972,764	9,358,858	$33,065,321	73,478	$259,602	2,795,182	$9,875,518	6,466,781	$22,847,464	4,228,097	$14,938,079
Ozone	11,753,156	$41,524,494	4,799,415	$16,956,575	37,681	$133,129	1,433,426	$5,064,368	3,316,298	$11,716,648	2,168,255	$7,660,554
Particulate Matter	19,392,707	$45,744,443	7,919,034	$18,679,796	62,174	$146,658	2,365,154	$5,579,037	5,471,891	$12,907,359	3,577,620	$8,439,061
Sulfur Dioxide	9,402,524	$8,114,673	3,839,532	$3,313,636	30,145	$26,016	1,146,741	$989,673	2,653,038	$2,289,655	1,734,604	$1,497,017
Totals	66,405,329	177,798,410	27,116,693	$72,604,185	212,898	$570,028	8,098,860	$21,684,468	18,737,082	$50,168,014	12,250,640	$32,800,742

Stormwater Benefits

Trees reduce the volume of stormwater runoff by capturing some rain on their leaves and branches, which then evaporates back into the atmosphere. Other water is absorbed by the tree roots or infiltrates into the soil rather than running off the land. As a result, less runoff must be managed by man-made infrastructure. In 2009, Planning District 16 had a 72.19% coverage in tree canopy, which managed 5.089 billion cubic feet of stormwater, valued at $24.175 billion using a $4.75 per cubic foot value based on local costs (see "TR-55 for Stormwater Runoff", pg. 23). In 2009, Fredericksburg's 31.42% tree canopy provided 18.384 million cubic feet of stormwater management, valued at $87.322 million. At this same time Caroline County's 78.05% tree canopy provided 2.144 billion cubic feet of stormwater management, valued at $10.186 billion, and King George County's 66.91% tree canopy provided 616.548 million cubic feet of stormwater management, valued at $2.928 billion. In 2009, Spotsylvania County's 70.47% tree canopy provided 1.355 billion cubic feet of stormwater management, valued at $6.435 billion. Stafford County's 68.02% tree canopy provided 934.818 million cubic feet of stormwater management, valued at $4.440 billion.

In 2009, The City of Fredericksburg passed a low-impact development (LID) ordinance which changes stormwater management practices associated with development and requires on-site retention, absorption or infiltration of the first ½ inch of stormwater runoff to reduce off-site impact. This requirement should encourage developers to seek ways to preserve or plant trees on the property to comply with stormwater management requirements. Similar actions are called for by new State stormwater management regulations promulgated and adopted by the State Soil and Water Conservation Board. The effective date of these regulations was deferred by the 2010 Virginia General Assembly until 2012.

Carbon Storage and Sequestration Benefits

Trees have a direct impact on the carbon footprint—the amount of atmospheric carbon a community produces that contributes to global warming. Trees provide a carbon sink by storing and sequestering atmospheric carbon in their wood. Both the total storage and the rate at which carbon is stored (known as sequestration) can be measured. The Region's tree canopy stores 28.37 million tons of carbon and sequesters 220,855 tons of carbon annually. Planting new trees and maintaining existing trees provide opportunities for the public and private sector to reduce their community's carbon footprint.

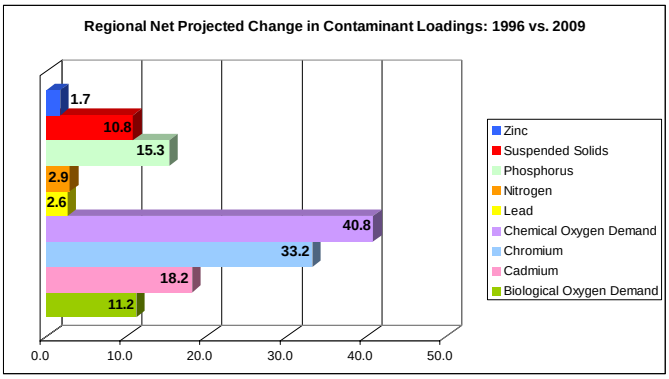
Water Quality Benefits

Trees provide very valuable water quality ecosystem services. Tree roots absorb water pollutants, ten of which measures are readily available: Biological Oxygen Demand, Cadmium, Chromium, Chemical Oxygen Demand, Lead, Nitrogen, Phosphorus, Suspended Solids, and Zinc. The CITYgreen® model looks at the "worst-case" scenario of the water quality impact resulting from the loss of all the remaining tree canopy. GWRC and local government staff view this as a highly unlikely scenario. Consequently, for this report, GWRC staff have tried to show what the water quality impact has been from the loss of tree canopy over the past 13 years.

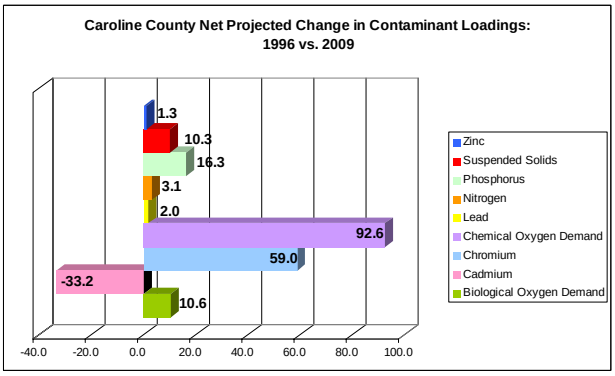
For Planning District 16, water pollution resulting from the 13 year change in tree canopy can be indirectly measured from the CITYgreen® analysis in the net difference in the projected pollutant loadings in 1996 (if all trees were lost) versus 2009 (if all remaining trees were lost) (see Figure 6). Over this time, the net difference in projected pollutant loadings shows a pollution increase, anywhere from 1.7% for Zinc up to 40.8% for Chemical Oxygen Demand, as a result of the historic loss of tree canopy. For the City of Fredericksburg, water pollution from tree canopy loss has increased, from 4.7% for Zinc up to 26.0% for Chemical Oxygen Demand. For Caroline County, the predicted change in water pollutant loading in 1996 vs. 2009 resulting from the loss of tree canopy shows a pollution increase, from 1.3 % for Lead up to 92.6% for Chemical Oxygen Demand and a 33% reduction in Cadmium. In King George County the water pollution has worsened somewhat, from .9% for Zinc up to 24.2% for Chemical Oxygen Demand. The net loss in tree cover in Spotsylvania County contributed to water pollution, from 1.9% for Zinc up to 27.5% for Chemical Oxygen Demand. Likewise, in Stafford County the decline in tree canopy contributed to water quality declines from increased pollution from 1.4% for Lead up to 34.2% for Chemical Oxygen Demand, and a 7.7% improvement in zinc loadings (see "L-THIA for Water Quality", pg. 23).

Figure 6. Net Change in Projected Pollutant Loadings between 1996 and 2009 Tree Canopy Loss Scenarios: GWRC & Localities

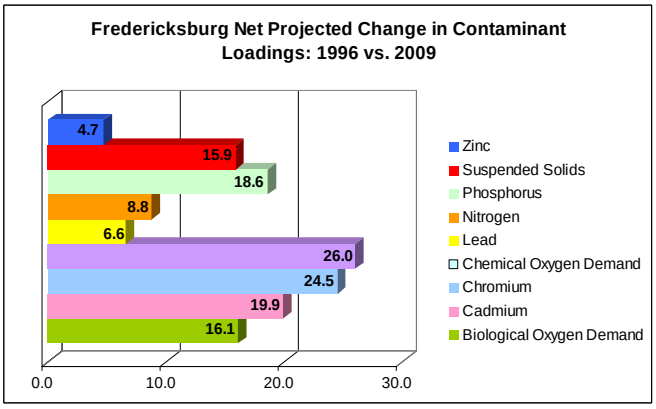
George Washington Region



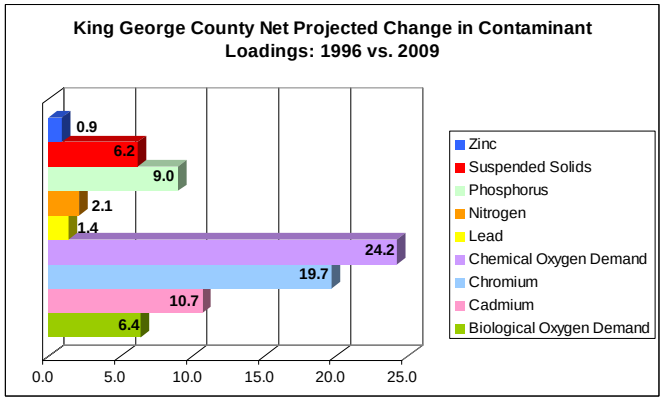
Caroline County



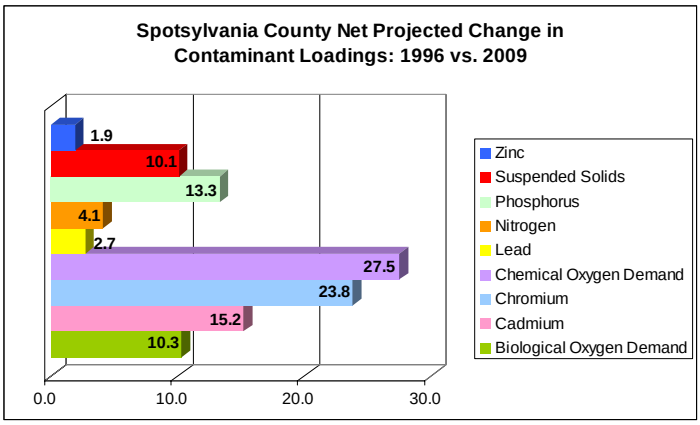
Fredericksburg City

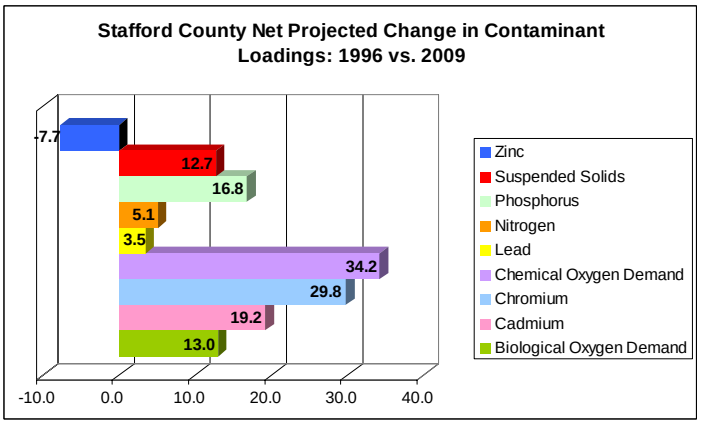


King George County



Spotsylvania County **Stafford County**

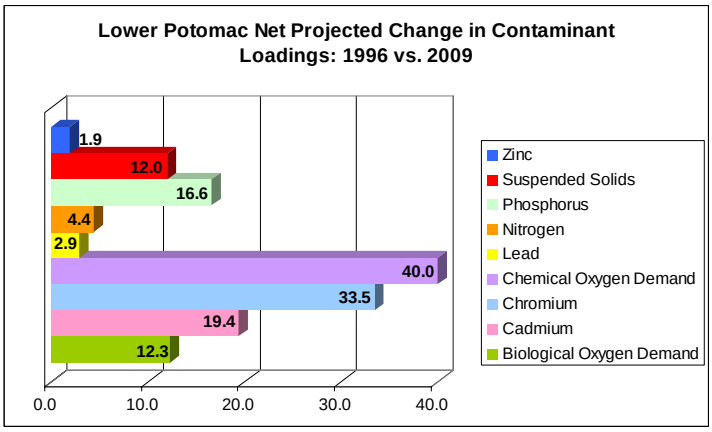




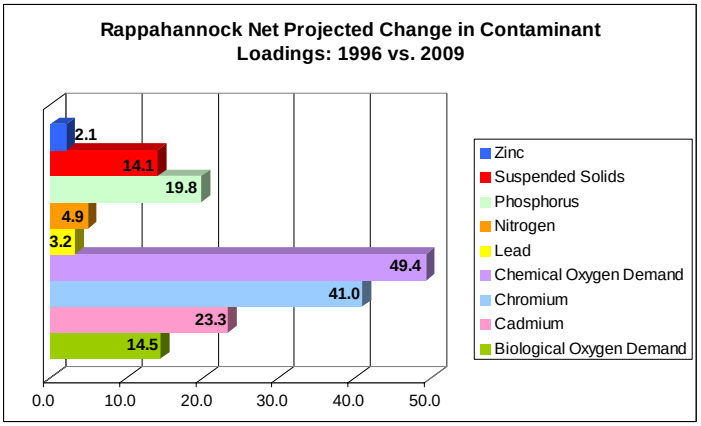
Similar results would be experienced within the three major watersheds of the Region (see Figure 7). For the Lower Potomac Watershed area, water pollution, as measured in percent change in pollutant loading resulting from the projected loss of all tress in 1996 versus the loss of all remaining trees in 2009, has increased, from 1.9% for Zinc to 40.0% for Chemical Oxygen Demand. The Rappahannock watershed has experienced an increase in water pollution of 2.1% for Zinc up to 49.4% for Chemical Oxygen Demand. Likewise, within the York River watershed water pollution has increased over the last 13 years, from 1.4% for Zinc up to 34.1% for Chemical Oxygen Demand.

Figure 7. 2009 Percent Change in Pollutant Loading for the Lower Potomac, Rappahannock, and York Watersheds (within Planning District 16)

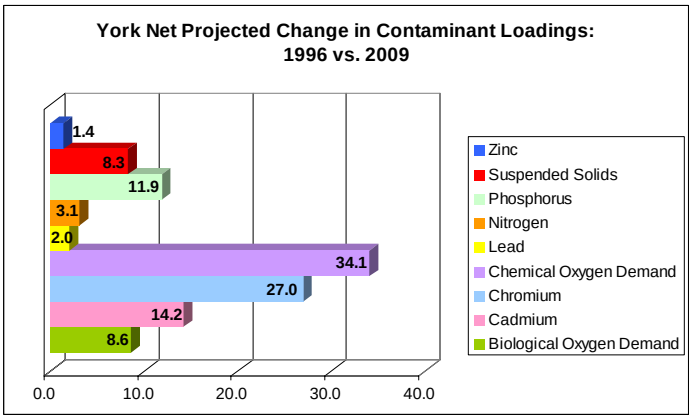
A. Lower Potomac



B. Rappahannock



C. York River



E. Modeling Ecosystem Benefits of Increased Tree Canopy

As mentioned earlier, the Region continues to lose tree canopy land cover. Fortunately, the City of Fredericksburg's Clean and Green Commission is already using similar data from a related urban forestry study and could further use the data set produced by this UEA (and the forthcoming study results to be produced under the regional CZM grant in the 4th quarter of 2010) for land use planning (see Implementation Recommendations, pg. 18) and to implement watershed management practices. To illustrate how the Region might go about reversing the trend of canopy loss and leverage the benefits that tree canopy provides, GWRC modeled a 5% increase in the Region's tree canopy from its current 72.2% to 77.2% and calculated the additional ecosystem service benefits this resource would provide in helping the community achieve its water and air quality goals.

If the Region increased its canopy cover by 5% overall (or a little more than the amount lost over the last 13 years), the ecosystem services would provide an additional $4.61 million in annual air pollutant removal value, an additional 1,970,156 tons of stored carbon and an annual 15,338 tons of sequestered carbon, as well as potentially 589.06 million cubic feet of additional managed stormwater, valued at $2.80 billion. Table 6 details these increased benefits. Of course the Region would also realize other benefits in the form of increased property value, increased tax revenue, reduced energy consumption, etc., not detailed in this report. Local planners can use the data set delivered with this project to establish overall tree canopy goals and also to stratify goals by land use. Staff can look for opportunities within public and private land development initiatives to increase tree canopy cover which will improve overall environmental benefits. Tree planting and ongoing care engages all sectors of the community, where everyone has the opportunity and responsibility to contribute.

Table 6. Modeled Ecosystem Benefit from Increasing George Washington Region's Tree Cover

GW Region Scenario	2009 Tree Canopy	Modeled Tree Canopy	Additional Air Pollution Removal	Additional Air Pollution Removal Value	Additional Stormwater Mgmt Reduced	Additional Stormwater Value at $4.75 per cu. ft.	Additional Carbon Stored	Additional Carbon Sequestered
	percent	percent	lbs./yr	dollar value	cu. ft.	dollar value	tons	tons
5% of Open Space Converted to Tree Cover	72.20%	77.20%	4,611,797	$12,347,959	543,989,280	$2,583,949,079	1,970,156	15,338
4% of Open Space and 1% of Impervious Surface Converted to Tree Cover	72.20%	77.20%	4,611,797	$12,347,959	589,059,907	$2,798,034,558	1,970,156	15,338

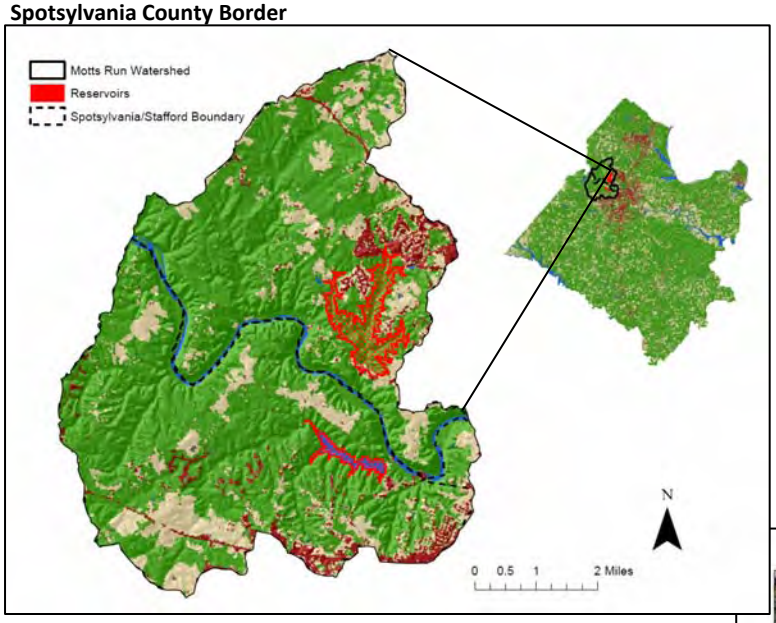
A community's pervious land cover serves as its *green infrastructure*; its protection and enhancement provides direct benefits to the taxpayer and improved environmental quality (including slowing stormwater runoff) improving water and air quality, protecting soil from erosion, and storing atmospheric carbon. Green infrastructure includes vegetation and their complex interactions with soil, air and water systems. As defined in this project, green infrastructure includes tree canopy, open space, and water. GWRC used CITYgreen® software to analyze the environmental and dollar value of each benefit. For more details and formulas used in each assessment visit:

http://www.americanforests.org/resources/urbanforests/naturevalue.php

F. Protecting Watershed Scale Tree Canopy for Water Quality

One of the major pollution problems plaguing the Chesapeake Bay is non point source pollution. Consequently, increasing tree cover and decreasing impermeable surface area is one of the most effective ways of dealing with this type of pollution. American Forests conducted an ecosystem analysis of the Chesapeake Bay Region, using GIS technologies, in order to help assess the landuse trends of this region over time. They found in 1973 that dense forest was the dominant land cover type. However, by 1997 over half the region had land cover that was sparsely forested, if at all. This trend was exaggerated in the Southeast with tree cover declining from 51% of the region to 37%. Areas without tree cover increased from 31% to 49%.[9]

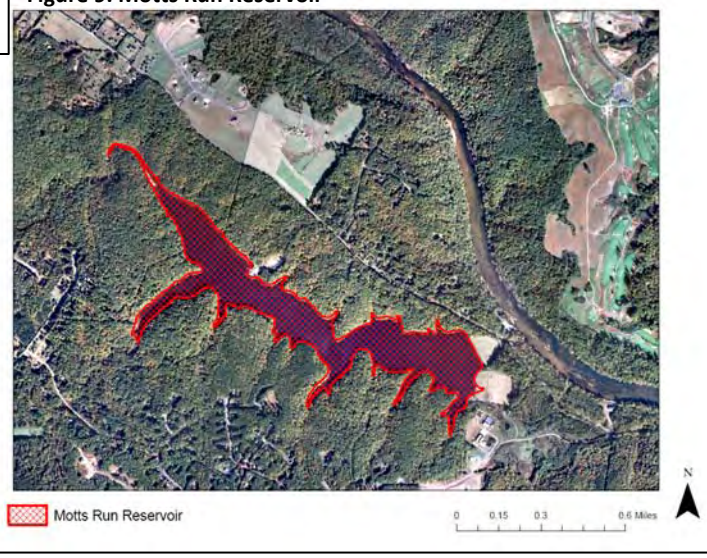
Figure 8. Location of the Motts Run Watershed, Stafford & Spotsylvania County Border



The results of that earlier study highlights the fact that, especially in the Southeastern section of the Chesapeake watershed, tree cover is decreasing significantly as impermeable surface area increases. This could be one of the reasons the water quality of the Chesapeake Bay has not improved.

The magnitude and relevance of these findings are best illustrated at the watershed scale—where the importance of protecting urban forests for a water supply affects everyone. For the City of Fredericksburg, Spotsylvania County, and Stafford County, two of the most important man-made landmarks are the large reservoirs created and under construction on Motts Run and Rocky Pen Run, respectively, in Spotsylvania and Stafford County. These two projects will demonstrate how these important public facilities impact the Region's environment this might be best shown with case studies on the effects of increased development around the Motts Run and the Rocky Pen Run Reservoirs.

Figure 9. Motts Run Reservoir



City of Fredericksburg's Motts Run Reservoir

Motts Run Reservoir is on the Motts Run River in Spotsylvania County and is used for drinking water for both the County and the City as well as for flood control purposes. Construction of the Reservoir was completed in 1971. At normal levels, it has a surface area of 160 acres. It is owned by the City of Fredericksburg.

Motts Run Reservoir Dam is of earthen construction. Its height is 96 feet and is 660 feet long. Its holding capacity is 6,906 acre feet, but normal storage is 4,119 acre feet. It drains an area of 10.3 square miles.

Over the time period from 1996 to 2009 there has been a significant amount of development in the watershed area of the Motts Run Reservoir. As development increases the tree cover decreases, which proportionally decreases the natural management capacity of the environment. From 1996 to 2009, the Spotsylvania portion of the Motts Run Watershed lost 4.2% of its tree cover. This land cover change led to a decrease in air pollution removal capacity of 55,430 lbs. per year, or $148,564. It also caused a decrease in carbon storage capacity of 23,704 tons which translates into 185 tons of carbon

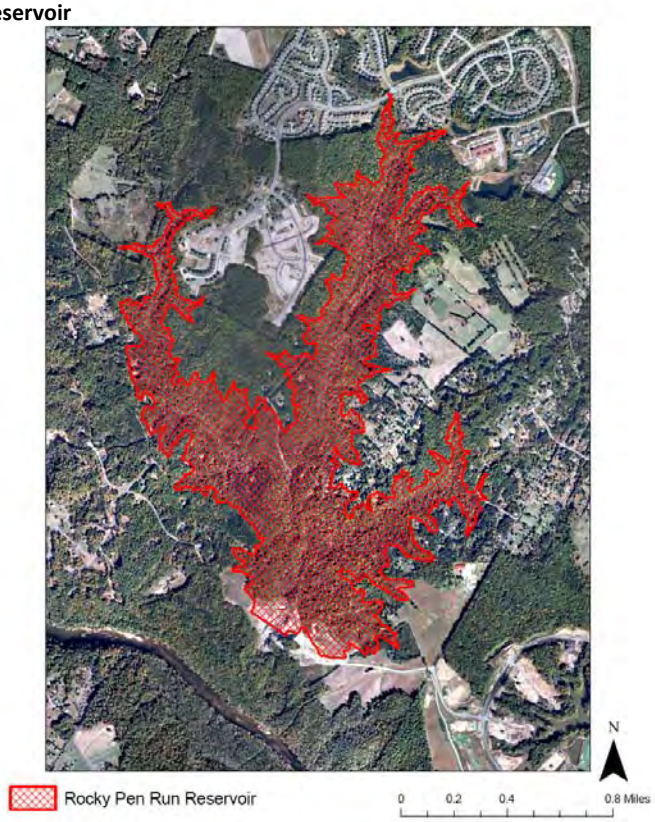
sequestration less per year. It also caused a $19,047,645 value loss due to 4,010,030 cubic feet less of natural stormwater remediation capacity (Table 7). These are significant losses for a relatively small area, especially one so critical in supplying clean drinking water to Spotsylvania and Fredericksburg.

Rocky Pen Run Reservoir

Selected by the Stafford County Board of Supervisors in 1992 as the County's long-term water source, Rocky Pen Run Reservoir is being constructed by the County 2,000 feet upstream at the mouth of Rocky Pen Run in Stafford County. The Reservoir will have a surface area of 503 acres and will hold 5.3 billion gallons of water. The reservoir and surrounding facilities will be the third water source for Stafford County and provide an additional 12 million gallons per day safe yield for the growing population.[8]

The Rocky Pen Run Reservoir is part of the same watershed as Motts Run, so protecting this watershed is of great importance because it impacts two regional water resources. From 1996 to 2009, the Stafford portion of the Motts Run Watershed has seen changes, mainly with tree loss, which have affected both the water and air quality. No land use cover was seen between 1996 through 2001, but the area has experienced continued residential development and population growth.

Figure 10. Proposed Inundation Area of the Rocky Pen Run Reservoir



Since 2001, the watershed has seen both a decrease in forested area and an increase in impervious surfaces and open land. Impervious surface area has increased an estimated 3.4% from 2001 to 2009. This has led to the direct loss of tree canopy from 79% coverage in 2001 to only 74% in 2009. This remaining canopy will drop below 70% with the completion of Rocky Pen Run (Table 7, page 19).

With the loss in tree cover there has been a direct decline in value of the watershed's storm water management ability. Increasing impervious surfaces and lowering the amount of tree canopy increases the amount of storm runoff that does not get managed naturally. As a result the amount of water that must be treated will increase. Valued at $337,229,533 in 2001, the watershed lost $18,545,565 of natural stormwater management services by 2009. Acting now in the Rocky Pen Run Reservoir's portion of the watershed will serve to lower the cost ultimately necessary to treat stormwater and ensure the quality of the water in the future.

Environmental Impacts

With the building of the new Rocky Pen Run Reservoir, the surrounding Motts Run watershed will start to see some of the negative environmental impacts associated with a loss of tree cover related to the inundation of the reservoir water area. The building of the new reservoir will remove an estimated 4.9% of the tree cover from the watershed. This will cause the area to experience a loss of $15,714,173 of stormwater management capacity as well as the loss of numerous other services such as carbon sequestration and air quality control (Table 7, page 19). Of particular concern is the trend of decreased water quality associated with a loss of tree canopy. Since Fredericksburg City, Spotsylvania County, and Stafford County will all rely upon water from this watershed and its 2 reservoirs, maintaining water quality is extremely important. The loss of tree cover during the construction of the Rocky Pen Run Reservoir, and the decrease in overall water quality associated with that loss, should be given consideration in all subsequent land use planning within the watershed.

The ecological impacts of losing tree canopy cover in this critical area will increase future storm water runoff and contribute to water pollutants flowing into both reservoirs which could increase the costs of providing drinking water to all three localities. For example, a 5% change from tree canopy to urban land cover in the Spotsylvania portion of the watershed effecting Motts Run Reservoir will decrease the ability to naturally manage 5,672,571 million cubic feet of storm water, valued at $26,944,712 million in storm water management alone. For Stafford County a 5% change in tree canopy to urban land cover will decrease the ability to naturally manage 4,127,329 million cubic feet of storm water, valued at $19,604,815 million in storm water management. Preserving or increasing the tree cover in critical places, like planting trees to buffer the streams that feed the reservoirs is a high priority task. The natural water management of area land is going to see a decline in quality due to the building of the new reservoir; protecting and working to increase remaining tree cover and working to increase cover is of great importance to the people of the region. The green infrastructure layer provided as part of this project will allow the local officials to identify the critical places for organizing replanting efforts and/or implementing a tree protection strategy.

Table 7. Tree Canopy and Ecosystem Services Loss in the Watershed due to Rocky Pen Run Reservoir

1996 – 2009 Loss	2009 Tree Canopy	Tree Canopy Percent	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Value	Stormwater Value at $4.75 per cu. ft.
	acres	percent	lbs./yr	dollar value	tons	tons	cu. ft.	dollar value
Motts Run Watershed Analysis	550.8	4.2%	55,430	$148,564	23,704	185	4,010,030	$19,047,645
Rocky Pen Run Watershed Analysis: Land Area	588.5	5%	59,272	$158,701	25,321	197	3,904,329	$18,545,565
Rocky Pen Run Watershed Analysis: After Construction	573.1	4.9%	57,727	$154,562	24,661	192	3,308,247	$15,714,173

Stream Buffers

All of the George Washington Region lies within the Chesapeake Bay watershed. Consequently, local governments are subject to compliance with the Chesapeake Bay Preservation Act passed by the Virginia General Assembly as part of Virginia's part in cleaning up and preserving the Chesapeake Bay. Local governments have designated all perennial streams within their jurisdiction and defined a riparian buffer along these streams to reduce surface run-off and erosion that contributed to the pollution of the Bay and its tributaries.

The George Washington Region has 85,794.9 acres of land in locally-designated "Resource Protection Areas" ("RPAs") where development is prohibited or severely restricted (Figure 11). Within the regional RPA system, there is an estimated 60,967.4 acres in tree canopy or 71.1%. This extensive network currently provides 518.83 million cubic feet of stormwater management, valued at $2.46 billion (Table 4, page 13).

If reforestation efforts are undertaken, RPAs are critical areas on which to focus. Hypothetically, if 9.7% of open space and .3% of impervious surface were converted to tree canopy, the canopy would increase to 69,579.7 acres. The ecosystem services would provide an additional $2.32 million in annual air pollutant removal value, an additional 370,598 tons of stored carbon and an annual 2,885 tons of sequestered carbon, as well as potentially 69.69 million cubic feet of additional managed stormwater, valued at $298 million. Table 8, page 20 details these increased benefits.

Figure 11. Resource Protection Areas in the George Washington Region

Table 8: PD 16 RPA Riparian Buffer Network

GW Region Stream Buffer Scenario	2009 Tree Canopy	Additional Air Pollution Removal	Additional Air Pollution Removal Value	Additional Stormwater Mgmt Reduced	Additional Stormwater Value at $4.75 per cu. ft.	Additional Carbon Stored	Additional Carbon Sequestered
	percent	lbs./yr	dollar value	cu. ft.	dollar value	tons	tons
Current 2009 Conditions	71.1%	6,141,202	$16,442,895	518,833,790	$2,464,460,503	2,623,517	20,425
9.7% of Open Space and .3% of Impervious Surface Converted to Tree Cover	81.1%	7,008,709	$18,765,623	581,527,941	$2,762,257,720	2,994,115	23,310

The Region has measured the pollutant removal benefits that riparian buffers naturally achieve by diffusing stormwater runoff--specifically removing 30% Nitrogen, 30% Phosphorus, and 85% of Suspended Solids (Diffuse Flow Requirement 15A NCAC 2B.0233(5)). Additional land cover analyses of sub-watersheds throughout the Region, like those completed here for the Rocky Pen Run and Motts Run Reservoirs' watersheds can support local efforts to protect the entire stream network. Reforestation can reduce stormwater runoff into the streams, reduce pollutant loading now occurring in the streams, improve air quality and provide habitat for wildlife. County and citizen tree planting partnerships can significantly reduce the cost of reforestation and enhance this valuable resource that contributes to water quality without costly constructed infrastructure (see Implementation Recommendations pg. 21).

G. Implementation Recommendations

The digital data set included in this project is packaged into GIS interactive data layers compatible with existing GIS data so that GWRC and local government staff can advise and local leaders can use it to make well-informed planning decisions. GWRC staff recommends the following actions to better integrate green infrastructure into local decision making.

1) Use the green infrastructure data and CITYgreen® software to calculate the ecosystem services provided by existing tree programs

- Share the green infrastructure data layer provided with this project among local departments and environmental non-profit organizations concerned with ecosystem services.

- Test the impacts of changing tree canopy, impervious surfaces, and other land covers under different development scenarios. Using high resolution data, analyses can be conducted on a neighborhood, sub-watershed, or sub-jurisdictional scale.

2) Plan and establish tree canopy goals

GWRC's Green Government Commission's Green Earth Sub-Committee recommends that the Region and localities adopt an overall 70%-75% tree canopy goal. This goal recognizes the historical decline of regional tree canopy, especially in critical sub-watershed areas. Increasing canopy to the higher end of this range in key areas will have the most beneficial impact. Since the loss of tree canopy has been most pronounced in the City of Fredericksburg and suburbanizing areas of Spotsylvania and Stafford Counties, the Region recommends developing no net loss of canopy strategies for future development. This can be accomplished if local jurisdictions will:

- Integrate these new land cover data into local government's planning and stormwater management processes (e.g. MS-4 programs) so that impacts from future growth and development can be anticipated and managed to preserve canopy wherever possible. Where this is not possible, establish a tree replacement fee (if allowed under Code of Virginia) to plant trees elsewhere in the jurisdiction.

- Work through GWRC to conduct additional and more detailed analysis of the community's natural assets using CITYgreen® software with consideration of the community's land use plans, zoning categories, transportation plans, etc.

- Use such additional analysis to guide the community in establishing tree canopy goals that can be attained within various zoning categories and key watershed areas as it continues to develop.

- Advocate amendment of § 15.2-961.1 of the Code of Virginia to enable Planning District 16 localities to conserve trees in the land development process.

- Budget adequately to both maintain existing canopy and to plant trees throughout the George Washington Region on a continuing basis until a suitable and sustainable level of tree canopy is achieved.

3) Use green infrastructure data to identify critical areas for reforestation

- Conduct additional UEAs to focus reforestation efforts on critical areas such as riparian stream buffers that tie in to the Rocky Pen Run and Motts Run Reservoirs

4) Use the findings from the Urban Ecosystem Analysis to increase awareness of the relationship between trees and environmental quality and to engage citizens in environmental improvement efforts like tree planting and trailway development so that the public gains wider appreciation for and understanding of the ecological systems impacted by urban development.

- Communicate UEA study findings to media.

- Incorporate findings from the UEA into active citizen environmental education programs:

  - Friends of Stafford Creeks- is actively promoting the recognition of the importance of improving stream water quality by reducing urban stormwater runoff and preserving riparian buffers through the use of conservation easements, purchase of development right and transfer of development right programs.

  - Spotsylvania Greenway Initiative (SGI) – using community volunteers, SGI is building a pilot nature trail to raise community awareness of the value of the natural environment and the opportunity and positive benefits to be derived from establishing a County- and Region-wide interconnected system of trails.

  - Fredericksburg Clean and Green Commission' urban reforestation/tree planting programs

  - Tri-County/City Soil and Water Conservation District tree planting and environmental education programs.

- Incorporate CITYgreen® schools program into public schools to increase awareness of environmental issues, by teaching practical applications of GIS, math, science and geography. The Curriculum is available through American Forests' Urban Ecosystem Center and a laboratory education license was donated by American Forests to the University of Mary Washington as a result of the University's hosting the CITYgreen® training class at a discounted lab rental rate.

H. Urban Ecosystem Analysis Methodology

The American Forests' Urban Ecosystem Analysis methodology is based on the assessment of "ecological structures"—unique combinations of land use and land cover patterns. Each combination performs ecological functions differently and is therefore assigned a different value. For example, a site with greater tree canopy provides more stormwater reduction benefits than one with less tree canopy and more impervious surface.

Data Used

LANDSAT (30 meter pixel resolution) Imagery: To keep current with rapidly changing Geographic Information Systems (GIS) technology, American Forests calibrated land cover change for this UEA report based on the US Geological Survey (USGS) 2001 National Land cover Dataset (NLCD). The USGS's NLCD data set is now the standard for LANDSAT-derived land cover change analysis and was used to classify the imagery of the George Washington Region for 1996, 2001, 2006 and 2009. This

enabled very accurate comparison trends of the land cover data for these years to determine changes that occurred. Imagery from these dates also aligned almost perfectly, further increasing the accuracy of land cover change calculations. This approach also enables comparisons of this data to data collected in the future more reliable.

Land Cover Classification and Other Definitions

The LANDSAT images were classified into five categories: impervious surface, open space/grass scattered trees, trees, urban bare, and water. The classifications are based on NOAA's C-CAP Land Cover Classification Scheme, which can be downloaded from the website: http://www.csc.noaa.gov/digitalcoast/data/ccapregional/support.html . Impervious surfaces includes high, medium, and low intensity development. The open space classification includes cultivated land, developed open space, estuarine emergent wetland, grassland, palustrine emergent wetland, pasture/hay, and tundra. Urban bare land is classified as bare, and all other land area that is not water (estuarine aquatic bed, unconsolidated shore, and water) is classified as trees.

"Carbon storage" refers to the amount of atmospheric carbon dioxide absorbed by plant matter (trees) and "stored" in the cell structure of a plant or tree.

"Carbon sequestration" refers to the active absorption of atmospheric carbon dioxide in the growth of plant matter.

NAIP High Resolution (1 meter pixel resolution) Imagery: The City of Fredericksburg received a report from the Virginia Department of Forestry which documents more accurately the "current" (2009) City tree canopy.

Analysis Formulas

Urban Ecosystem Analyses were conducted using American Forests' CITYgreen® software®. CITYgreen® for ArcGIS calculates the value of green infrastructure. Data inputs include rainfall, soil types and remotely sensed imagery. These data are used to populate scientific and engineering formulas so calculations of ecosystem services can be performed.

TR-55 for Stormwater Runoff: The CITYgreen® stormwater analysis estimates the amount of stormwater that runs off a land area during a major storm. The stormwater runoff calculations incorporate volume of runoff formulas from the Urban Hydrology of Small Watersheds model (TR-55) developed by the U.S. Natural Resources Conservation Service (NRCS), formerly known as the U.S. Soil Conservation Service. Don Woodward, P.E., a hydrologic engineer with NRCS, customized the formulas to determine the benefits of trees and other urban vegetation with respect to stormwater management. To provide accuracy to the estimates calculated by the CITYgreen® program, GWRC staff surveyed local government development review personnel and consulted with private land planning and environmental engineering firms to establish a local cost range for urban stormwater runoff retention facilities. From all the input received, the final average cost of $4.75 per cubic foot of retained stormwater was the cost multiplier developed for this study.

L-THIA for Water Quality: Using values from the U.S. Environmental Protection Agency (EPA) and Purdue University's Long-Term Hydrological Impact Assessment (L-THIA) spreadsheet water quality model, the Natural Resources Conservation Service (NRCS) developed the CITYgreen® water quality model. This model estimates the change in the concentration of the pollutants in runoff during a typical storm event given the change in the land cover from existing trees to a no tree condition. This model estimates the event mean concentrations of nitrogen, phosphorus, suspended solids, zinc, lead, cadmium, chromium, chemical oxygen demand (COD), and biological oxygen demand (BOD). Pollutant values are shown as a percentage of change.

UFORE Model for Air Pollution: CITYgreen® uses formulas from a model developed by David Nowak, PhD, of the USDA Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, and carbon monoxide and particulate matter less than 10 microns are absorbed and filtered by tree canopies. The urban forest effects (UFORE) model is based on data collected in 55 U.S. cities. Dollar values for air pollutants are based on averaging the externality costs set by the State Public Service Commission in each state. Externality costs are the indirect costs to society, such as rising health care expenditures as a result of air pollutants' detrimental effects on human health. The UFORE model also estimates the carbon storage capacity and the annual amount of carbon sequestered by the tree canopy in a given area.

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GWRC Green Government Commission Green Earth Sub-Committee, including:

- Kevin Utt, Site Development Manager, City of Fredericksburg Dept of Building and Development Services (Chair)
- Patricia Kurpiel, Friends of Stafford Creeks
- Chris Folger, Chair, Spotsylvania Greenway Initiative
- Jacob Pastwick, Planner, Spotsylvania County Planning Department
- David Nunnally, Senior Environmental Planner, Caroline Co Planning and Community Development
- Paula Chow, Sierra Club and Fredericksburg Clean & Green Commission
- Amber Forestier, Environmental Planner, Stafford County Planning Dept.

Other Contributors:
Dave King, City Arborist & Deputy Director of Public Works, City of Fredericksburg
Heather Straughan, Planning/Zoning Enforcement Officer, Planning and Community Development, King George County
Richard Street & Doug Morgan, Environmental Engineer, Chesapeake Bay Division of the Code Compliance Dept., Spotsylvania County
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Diane Beyer, District Manager, Tri-County/City Soil & Water Conservation District
Mac Saphir, Caroline County Cooperative Extension & Hanover-Caroline Soil & Water Conservation District
Jenn Allen, Deputy Director, Friends of the Rappahannock
Michael Blake, Welford Engineering

I. Endnotes

1. UEA reports are available for download at: http://www.americanforests.org/resources/urbanforests/analysis.php

2. Source of unit cost: City of Fredericksburg

3. Green infrastructure is defined by pervious land cover, such as tree canopy, open space and other vegetated areas.

4. High resolution data (1-meter pixel resolution) is used for day to day management decisions of smaller land areas such as subwatersheds, zoning categories, and stream buffers.

5. Due to an update of land cover classification methodologies set by the Multi Resolution Land (MLRC) consortium and adopted as the national standard, land cover changes from previous Urban Ecosystem Analyses can not be compared with this one (see Data Used pg 15 for more information.)

6. Environmental Protection Agency, Virginia, Fredericksburg http://epa.gov/airquality/greenbk/gmstate.html

7. "Urban smog control: A new role for trees?" http://findarticles.com/p/articles/mi_m1200/is_n1_v138/ai_9177813/pg_2/?tag=content;col1 2008

8. Source: http://stafford.va.us/Departments/Utilities/Construction/Current_Projects/Rocky_Pen_Run_Reservoir.shtml

9. Source: http://www.americanforests.org/downloads/rea/AF_Chesapeake.pdf pg 2.

Information About American Forests

American Forests, founded in 1875, is the oldest national nonprofit citizen conservation organization. American Forests (AF) is a world leader in planting trees for environmental restoration, a pioneer in the science and practice of urban forestry, and a primary communicator of the benefits of trees and forests. American Forests (www.americanforests.org) is the nation's oldest nonprofit citizens' conservation organization. Citizens concerned about the waste and abuse or the nation's forests founded American Forests in 1875. The organization is proud of its historic roots in the development of America's conservation movement and proud of the new approaches the organization has developed to help people improve the environment in the 21st Century. American Forests' Ecosystem Restoration and Maintenance Agenda presents their core values and seeks to build support for our policy goals. These goals focus on assisting communities in planning and implementing tree and forest actions to restore and maintain healthy ecosystems and communities. AF also works with community-based forestry partners in both urban and rural areas to help them participate in national forest policy discussions. American Forests seeks to broaden awareness of the interdependence of communities and forests through our policy and communication activities with local partners.

Its three centers— Global ReLeaf, Urban Ecosystem Center, and Forest Policy Center—mobilize people to improve the environment by planting and caring for trees. American Forests' CITYgreen® software provides individuals, organizations, and agencies with a powerful tool to evaluate development and restoration strategies and impacts on urban ecosystems. American Forests offers regional training, teacher workshops and technical support for CITYgreen® and is a certified ESRI developer and reseller of ArcGIS products.

American Forests, Web: www.americanforests.org, P.O. Box 2000, Washington D.C. 20013

Phone: 202/737-1944; Fax: 202/737-2457

APPENDICES

A) CITYgreen®Analysis for George Washington Region (PD 16): 1996

B) CITYgreen®Analysis for George Washington Region (PD 16): 2001

C) CITYgreen®Analysis for George Washington Region (PD 16): 2006

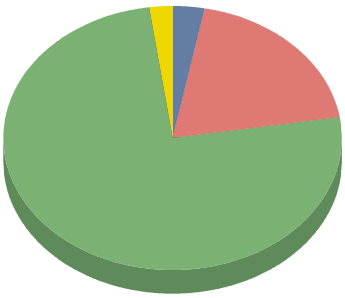
D) CITYgreen®Analysis for George Washington Region (PD 16): 2009

Other reports available for:

- Major Watersheds (Lower Potomac, Rappahannock & York Rivers)
- PD 16 Local Governments:

  - City of Fredericksburg
  - Caroline, King George, Spotsylvania & Stafford Counties

Analysis Report
for
George Washington Region 1996



Land cover in acres and percentages

Impervious Surfaces	28,054.1	3.1%
Open Space - Grass/Scattered Trees	176,253.4	19.3%
Trees	687,948.5	75.3%
Urban: Bare	850.0	0.1%
Water Area	20,144.7	2.2%
Total:	913,250.7	100.0%

Tree Canopy: 687,948.5 acres (75.3%)

Air Pollution Removal

Nearest air quality reference city: ***Washington DC***

	Lbs. Removed/yr	Dollar Value/yr.
Carbon Monoxide:	3,066,220	$1,504,821
Ozone:	23,916,514	$84,498,256
Nitrogen Dioxide:	12,264,879	$43,332,439
Particulate Matter:	20,237,050	$47,736,121
Sulfur Dioxide:	9,811,903	$8,467,979
Totals:	**69,296,566**	**$185,539,616**

Dollar values are based on 2009 dollars

Carbon Storage and Sequestration

Tons Stored **(Total)**:	**29,603,443**
Tons Sequestered **(Annually)**:	**230,471**

Stormwater Management

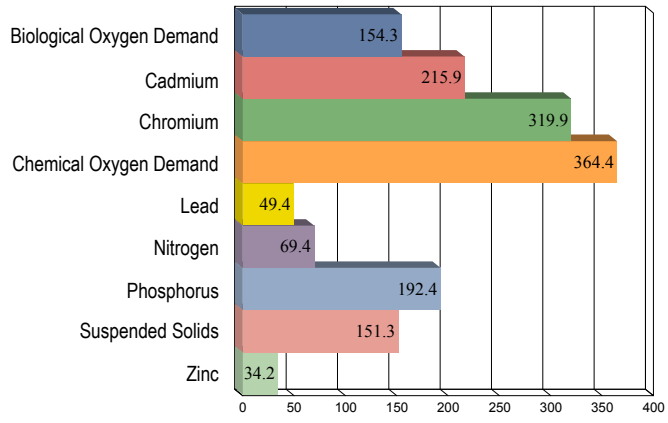
Water Quantity (Runoff Volume)

2-yr, 24-hr Rainfall in inches:	3.25
Curve Number reflecting existing conditions:	71
Curve Number of replacement land cover:	93
Dominant Soil Type: **B**	
Replacement land cover type: (existing condition)	
Impervious Surfaces: Buildings/ structures	
Additional cu. ft. storage needed:	**5,312,444,045**
Construction cost per cu. ft.:	$4.75
Total Stormwater Value:	**$25,234,109,213**
Annual Stormwater Value:	**$2,200,024,632**

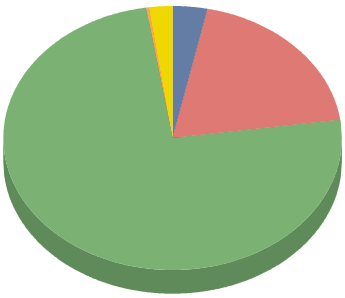
(based on 20-year financing at 6% interest)

Water Quality (Contaminant Loading)

Percent change in contaminant loadings



Analysis Report
for
George Washington Region 2001



Land cover in acres and percentages

Impervious Surfaces	30,266.9	3.3%
Open Space - Grass/Scattered Trees	176,900.8	19.4%
Trees	683,514.3	74.8%
Urban: Bare	2,057.5	0.2%
Water Area	20,511.2	2.2%
Total:	913,250.7	100.0%

Tree Canopy: 683,514.3 acres (74.8%)

Air Pollution Removal

Nearest air quality reference city: ***Washington DC***

	Lbs. Removed/yr	Dollar Value/yr.
Carbon Monoxide:	3,046,456	$1,495,122
Ozone:	23,762,360	$83,953,622
Nitrogen Dioxide:	12,185,826	$43,053,139
Particulate Matter:	20,106,612	$47,428,438
Sulfur Dioxide:	9,748,660	$8,413,399
Totals:	**68,849,914**	**$184,343,720**

Dollar values are based on 2009 dollars

Carbon Storage and Sequestration

Tons Stored **(Total)**:	**29,412,634**
Tons Sequestered **(Annually)**:	**228,985**

Stormwater Management

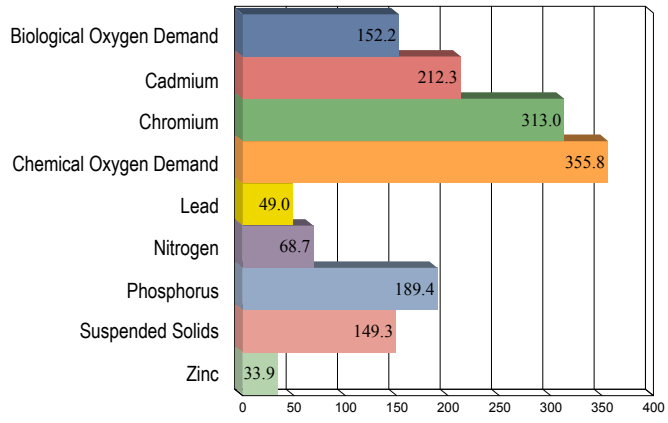
Water Quantity (Runoff Volume)

2-yr, 24-hr Rainfall in inches:	3.25
Curve Number reflecting existing conditions:	71
Curve Number of replacement land cover:	93
Dominant Soil Type: **B**	
Replacement land cover type: (existing condition)	
Impervious Surfaces: Buildings/ structures	
Additional cu. ft. storage needed:	**5,281,750,993**
Construction cost per cu. ft.:	$4.75
Total Stormwater Value:	**$25,088,317,218**
Annual Stormwater Value:	**$2,187,313,822**

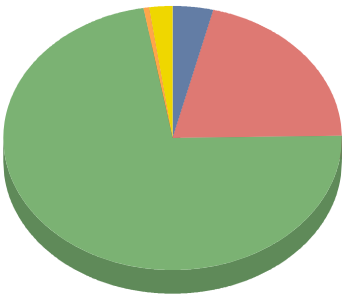
(based on 20-year financing at 6% interest)

Water Quality (Contaminant Loading)

Percent change in contaminant loadings



Analysis Report
for
George Washington Region 2006



Land cover in acres and percentages

Impervious Surfaces	35,701.6	3.9%
Open Space - Grass/Scattered Trees	189,332.0	20.7%
Trees	663,979.2	72.7%
Urban: Bare	2,884.1	0.3%
Water Area	21,353.8	2.3%
Total:	913,250.7	100.0%

Tree Canopy: 663,979.2 acres (72.7%)

Air Pollution Removal

Nearest air quality reference city: ***Washington DC***

	Lbs. Removed/yr	Dollar Value/yr.
Carbon Monoxide:	2,959,387	$1,452,390
Ozone:	23,083,221	$81,554,191
Nitrogen Dioxide:	11,837,549	$41,822,662
Particulate Matter:	19,531,956	$46,072,912
Sulfur Dioxide:	9,470,039	$8,172,940
Totals:	**66,882,154**	**$179,075,096**

Dollar values are based on 2009 dollars

Carbon Storage and Sequestration

Tons Stored **(Total)**:	**28,572,008**
Tons Sequestered **(Annually)**:	**222,441**

Stormwater Management

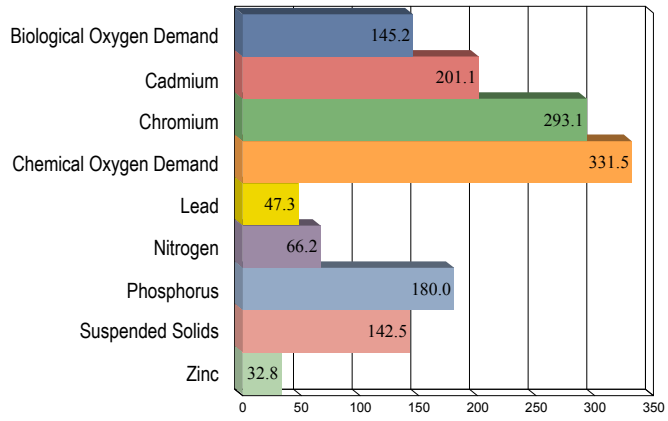
Water Quantity (Runoff Volume)

2-yr, 24-hr Rainfall in inches:	3.25
Curve Number reflecting existing conditions:	71
Curve Number of replacement land cover:	93
Dominant Soil Type: **B**	
Replacement land cover type: (existing condition)	
Impervious Surfaces: Buildings/ structures	
Additional cu. ft. storage needed:	**5,122,280,820**
Construction cost per cu. ft.:	$4.75
Total Stormwater Value:	**$24,330,833,896**
Annual Stormwater Value:	**$2,121,272,974**

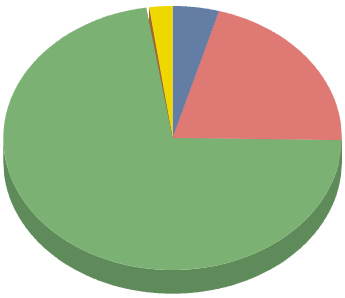
(based on 20-year financing at 6% interest)

Water Quality (Contaminant Loading)

Percent change in contaminant loadings



Analysis Report
for
George Washington Region 2009



Land cover in acres and percentages

Impervious Surfaces	40,246.9	4.4%
Open Space - Grass/Scattered Trees	191,554.1	21.0%
Trees	659,245.4	72.2%
Urban: Bare	873.8	0.1%
Water Area	21,330.5	2.3%
Total:	913,250.7	100.0%

Tree Canopy: 659,245.4 acres (72.2%)

Air Pollution Removal

Nearest air quality reference city: ***Washington DC***

	Lbs. Removed/yr	Dollar Value/yr.
Carbon Monoxide:	2,938,289	$1,442,036
Ozone:	22,918,653	$80,972,764
Nitrogen Dioxide:	11,753,156	$41,524,494
Particulate Matter:	19,392,707	$45,744,443
Sulfur Dioxide:	9,402,524	$8,114,673
Totals:	**66,405,329**	**$177,798,410**

Dollar values are based on 2009 dollars

Carbon Storage and Sequestration

Tons Stored **(Total)**:	**28,368,309**
Tons Sequestered **(Annually)**:	**220,855**

Stormwater Management

Water Quantity (Runoff Volume)

2-yr, 24-hr Rainfall in inches:	3.25
Curve Number reflecting existing conditions:	71
Curve Number of replacement land cover:	93
Dominant Soil Type: **B**	
Replacement land cover type: (existing condition)	
Impervious Surfaces: Buildings/ structures	
Additional cu. ft. storage needed:	**5,089,465,747**
Construction cost per cu. ft.:	$4.75
Total Stormwater Value:	**$24,174,962,300**
Annual Stormwater Value:	**$2,107,683,378**

(based on 20-year financing at 6% interest)

Water Quality (Contaminant Loading)

Percent change in contaminant loadings