Watershed 263
Management Plan
Final Report

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Submitted to:

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Introduction

This report presents a Watershed Management Plan for Watershed 263 (WS 263) in the City of Baltimore (the City). This plan provides recommendations for water quality BMPs to treat 20 percent of the impervious area in the watershed, meeting the requirements of the City's stormwater NPDES permit (MS-BC-1999-013). The permit conditions require the City to investigate its watersheds and develop plans to reduce pollution from stormwater runoff.

This project was undertaken in part to meet Baltimore City's obligation under the Clean Water Act to prepare water quality restoration plans required by the Federal and State government to improve the water quality of urban run-off flowing into the Chesapeake Bay.

However, water quality is only one facet of the improvements for Watershed 263 which the City is working towards. The work described in this report has been conducted in partnership with several other stakeholders and agencies which are conducting a long-term hydrologic and ecological study designed to improve the quality of life in this highly urbanized area. The project partners include:

- Baltimore Ecosystem Study (BES)
- Center for Urban Environmental Research and Education (CUERE)
- The Parks and People Foundation
- U.S. Forest Service (USFS)
- US Geological Survey (USGS)

Project Goals

The Watershed Management Plan for Watershed 263 is unique in that it combines goals that improve both water quality and quality of life for watershed residents. This is a function of the watershed's unique characteristics. Typically, a watershed plan will call for improvements in water quality, reduction of flooding and stream erosion, and protection of high-quality habitat. Watershed 263 does not have any natural stream channels or aquatic habitat, thus the only watershed-related goals that apply are improvements in water quality at the outfall to Baltimore Harbor.

The watershed's location provides an opportunity to meet quality of life goals which are being pursued by other watershed partners, primarily focusing on revitalizing the urban community through greening or urban forestry projects such as planting trees; cleaning and greening vacant lots; reducing litter; cleaning streets and alleys; creating community gardens, improving city parks and greening schoolyards where asphalt has been removed.

These goals have been incorporated into the plan by incorporating them in the process of evaluating and priortizing watershed improvements.

Project Description

This report describes the work in the second phase of a project to develop a watershed management plan for WS 263. The first phase of the project resulted in a report on the existing conditions and development of a SWMM model for the watershed (KCI, 2004). As part of the first phase, the watershed was subdivided into 36 subwatersheds, two of which, 263-F and 263-O, were modeled in more detail as part of a paired subwatershed study to compare different management approaches to watershed improvement. The Center for Watershed Protection developed stormwater management strategies for 263-O through a grant from the Chesapeake Bay Trust. (CWP 2005)

During the course of this phase of the project, the approach to watershed restoration and water quality improvement was refined. Watershed recommendations were separated into short-term and long-term projects.

- Short-term projects (within ten years) are designed to meet the City's NPDES permit requirements, by providing water quality treatment for runoff from 20% of the impervious area in the watershed. These projects would be sized to treat the water quality volume (WQv) calculated according to the Maryland Department of the Environment (MDE) Stormwater Management regulations. Whenever possible, they should include quality-of-life benefits related to pavement removal, landscaping vacant lots, creating playgrounds, and better trash removal and sanitation.

- Long-term projects (typically described as "greening") are designed to reduce impervious surface and provide more green space. These are projects that can be institutionalized across City agencies and implemented over generations when City infrastructure is reconstructed. Examples could be green roofs, permeable pavement for parking, or reduction of impervious area from streets and sidewalks.

Short-term projects were further subdivided into four types:

- Non-structural practices - These practices include source control and housekeeping measures, such as street sweeping, that are best implemented across the watershed.

- Regional facilities - These projects would seek to treat stormwater runoff from relatively large areas, within each neighborhood, and possibly from multiple subwatersheds.

- Small-scale facilities - City. These are smaller projects to be built by the City on City-owned property to supplement treatment by regional facilities.

- Small-scale facilities - Private. These are small projects that could be undertaken by citizen groups or property owners on private property, such as concrete removal from backyards or landscaping.

This report presents the strategies for short-term projects for non-structural, regional and small-scale City-constructed facilities. Other project partners are developing proposals for projects to be constructed by community volunteers or other privately financed groups.

The report provides information on the type, locations, size, and cost of recommended structural water quality improvements and also gives the results of stormwater management modeling quantiying improvements in stormwater flow and water quality that will result from these recommendations. The stormwater management facilities recommended in this report have been preliminarily sized using the design criteria from the 2000 Maryland Stormwater Design Manual (CWP et al., 2000)

Watershed Characteristics

General Characteristics

Watershed 263 occupies 930.4 acres of the western portion of the Middle Branch Patapsco River watershed in southwest Baltimore (Figure 1). The Middle Branch watershed is part of the Baltimore Harbor drainage basin (MDE Code 02130903).

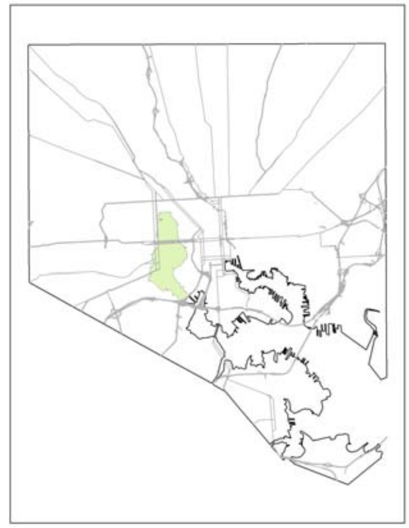


Figure 1 Watershed 263 Location

WS 263 is approximately 2.6 miles long from Presstman Street to the Middle Branch outlet; however the longest flow path is approximately 2.8 miles long. The longest flow path is considered the longest length of storm drain that water would flow from the watershed divide to the outlet. The average watershed slope is 0.012 ft/ft.

The approximate watershed boundaries are Presstman Street to the north, Middle Branch to the south, Freemont and Arlington Avenue and Bush and Poppleton Streets to the east, and Fulton Avenue and North Payson and South Payson Streets to the west. WS 263 incorporates all or portions of the following neighborhoods: Sandtown-Winchester, Harlem Park, Franklin Square, Poppleton, Union Square, Hollins Market, New Carrollton Ridge, Southwest /Mount Clare, Carroll Park, and Carroll-Camden Industrial Area (Fig. 2).

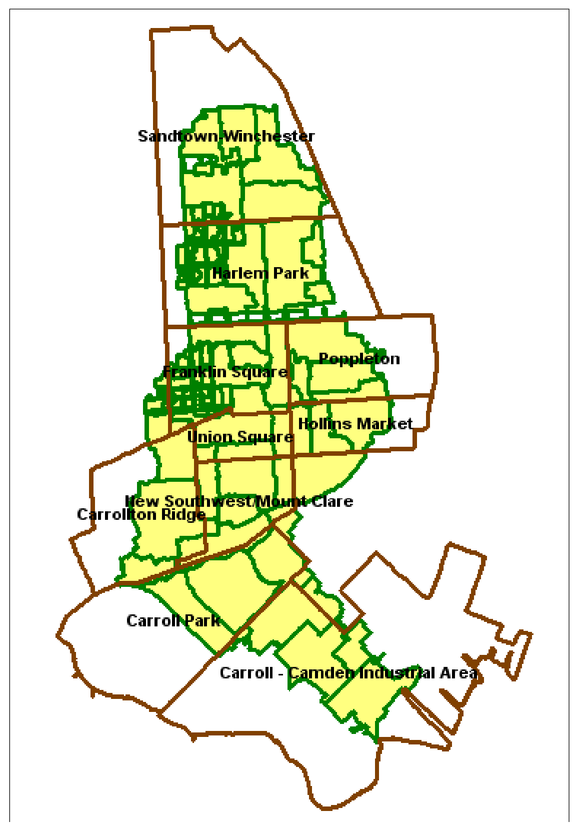


Figure 2 Neighborhoods in Watershed 263

WS 263 is considered an ultra-urban area with impervious surfaces covering over 80 percent of the land. No surface aquatic resources (i.e., streams and wetlands) are present in the watershed, and a complex system of storm drains conveys storm water runoff to the watershed outlet in Middle Branch immediately south of Russell Street. The most common land use is high density residential in the form of rowhouses. Eleven schools are located in WS 263, as well as 6 parks including Carroll Park. Additionally, south of Washington Boulevard, the land use is primarily industrial, except at the old Montgomery Wards building, which is now the Maryland Department of the Environment headquarters. The Baltimore & Ohio Railroad Museum is also located in WS 263 immediately south of Pratt Street along the eastern watershed boundary.

Subwatershed and Catchment Delineation

Watershed 263 was subdivided into 36 subwatersheds, identified with letters A through GG. Boundaries were delineated using topographic, planimetric, street edge and storm drain mapping provided by the City, then verified in the field. For all of the watershed except 263-F and 263-O, drainage area outlets points that drain approximately 10 to 40 acres.

For 263-F and -O, drainage areas were delineated to each inlet identified in the GIS data. As a result, 48 catchments were delineated for 263-F and 58 catchments were delineated for 263-O. Figure 3 presents the final subwatershed boundaries and the detailed catchment boundaries used in developing the SWMM model. A review of Figure 3 indicates that certain areas were excluded from the WS 263 drainage. The northernmost areas represent a depressed railroad bed. Runoff in this area bypasses WS 263. The southern areas represent US Route 40, which is a depressed roadway through WS 263. Runoff from US Route 40 enters a dedicated storm drain that bypasses WS 263 and is conveyed outside the watershed.

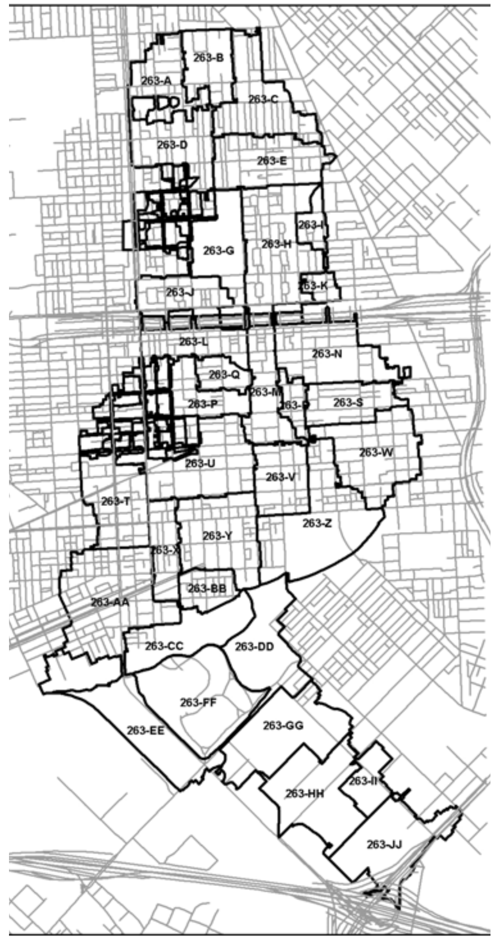


Figure 3: Subwatersheds

Geology

The geology of WS 263 was reviewed to gain an understanding of the environmental setting and the potential behavior of groundwater flow. WS 263 lies within the Piedmont and Atlantic Coastal Plain physiographic provinces. Separating these provinces is a linear feature known as the Fall Line that trends northeast to southwest though most of the east coast of the United States. The area at or near the Fall Line is where crystalline Piedmont rocks dip below younger alluvial, lacustrine, or deltaic sediments forming a wedge that extends to the Continental Shelf. Although the Fall Line is not a precisely surveyed linear feature, the documented location appears to cross WS 263 near Route 40 in the northern half of the watershed.

According to the Geologic Map of Baltimore County (MGS, 1968), Atlantic Coastal Plain geologic units in WS 263 include the Patuxent Formation and Quaternary lowland deposits, and Piedmont rock includes the Relay Quartz Diorite, Baltimore Gabbro Complex, and Baltimore Gneiss. The Cretaceous Age Patuxent Formation consists of white or light gray to orange-brown, moderately sorted, cross-bedded, argillaceous, angular sands and subrounded quartz gravels; silts and clays subordinate, predominately pale gray. Patuxent sediments are underlain by crystalline basement rock likely belonging to the Baltimore Gabbro Complex. Quaternary lowland deposits consist of gravel, sand, silt and clay.

WS 263 is in a recharge area for the Patuxent Formation, which forms a confined aquifer downgradient. The Patuxent Aquifer is a prolific water-bearing unit providing large supplies of drinking and industrial water in Anne Arundel and Prince George's County.

Soils

After imperviousness, soil characteristics have the largest influence on runoff and groundwater recharge. The 1998 soil survey of Baltimore City (USDA, 1998) was used to obtain information on the types of soils and their extent within WS 263. Table 1 shows the result.

Table 1: Watershed 263 Soils

Soil Unit	Description	Area (ac)	Percent of Watershed
9UB	Elkton - Urban Land Complex	1.74	0.2%
13UB	Joppa - Urban Land Complex	5.30	0.6%
14UB	Urban Land - Joppa Complex	29.08	3.1%
15B	Keyport - Urban Land Complex	11.31	1.2%
29B	Sassafras, Gravelly Loam	15.68	1.7%
29C	Sassafras, Gravelly Loam	2.31	0.2%
29UB	Sassafras - Urban Land Complex	20.54	2.2%
30B	Sassafras - Joppa Complex	8.15	0.9%
31UB	Urban Land - Sassafras Complex	278.82	29.9%
40C	Udorthents, loamy, very deep	21.54	2.3%
42E	Udorthents, smoothed	86.63	9.3%
43U	Urban Land - Udorthents Complex	1.79	0.2%
44UC	Urban Land	430.34	46.2%
45UB	Woodstown - Urban Land Complex	17.97	1.9%

The survey showed that there was very little undisturbed soil in WS 263. Urban Land, Udorthents, and Urban Land complexes with other soils make up 97 percent of the area of soils in the watershed. Urban soils consist of areas which have been cut or graded or which are covered by structures or pavement. Soil characteristics, including runoff characteristics, are highly variable and may not reflect the conditions of the native undisturbed soils. Urban soils tend to be less permeable when cut due to removal of topsoil and exposure of subsoil, and also less permeable when filled, due to compaction.

Land Use / Land Cover and Imperviousness

Two data sources were used to develop the land cover mapping.

- Existing planimetric data generated from Project 831 was used to obtain information on impervious surfaces including roads, driveways, alleyways, buildings, and medians.

- Orthophotography obtained from Project 831 was used to digitize pervious surfaces, which included approximately 1,000 pervious area polygons classified as demolished buildings, grass, dirt, and trees.

For this project, an additional 1,600 polygons identified as "MISC" or "NON" in the Project 831 database were reattributed using the orthophotographs to determine the actual land cover. "NON" and "MISC" polygons were placed into one of the pervious or impervious land cover categories discussed above. This data was considered representative of the year 2000, and was used for the modeling and analysis for this report.

The watershed as a whole is about 75% impervious. The largest land use areas are Buildings, which are 100% impervious, and Grass, which is entirely pervious.

Table 2: Land Use and Imperviousness

LU Code	Land Use	Area (ac)	Percent of Watershed	Percent Impervious	Impervious Area (ac)
ALYPVD	Alley pavement	44.6	4.8	85	37.9
BLDNG	Buildings	248.3	26.7	100	248.3
BLDOBS	Buildings	1.5	0.2	100	1.5
BLDRUN	Buildings	0.3	0.0	100	0.3
CTYARD	Courtyard	1.4	0.2	75	1.1
DEMOLISHED_BLDG	Demolished bldg	18.5	2.0	20	3.7
DIRT	Dirt	31.6	3.4	30	9.5
DWPVD	Driveway, paved	2.3	0.2	95	2.2
GARDEN	Garden	0.1	0.0	95	0.1
GRASS	Grass	162.9	17.5	10	16.3
GRASS-GARDEN	Grass / gardens	0.5	0.1	10	0.1
MEDPVD	Paved median	0.6	0.1	80	0.5
MEDUPD	Unpaved median	0.2	0.0	80	0.1
MISC	Miscellaneous	0.1	0.0	80	0.0
PRKNG	Parking lots	91.1	9.8	95	86.6
RDINT	Road intersections	23.3	2.5	95	22.1
RDPVD	Road pavement	129.2	13.9	95	122.7
STRTNK	Storage tanks	0.1	0.0	100	0.1
SWALK	Sidewalks	142.0	15.3	90	127.8
TREES	Trees	31.8	3.4	40	12.7
	TOTAL	930.3	100.0	74.5%	693.5

During the summer of 2003, the Parks and People Foundation conducted a vacant land survey to identify vacant parcels and assess vacant parcel conditions. Generally, parcels become vacant by demolishing abandoned or dilapidated homes. Because home demolition increases pervious cover, KCI reviewed the survey data to determine if it would have a significant effect on runoff and model results. The review indicated that incorporating the vacant lot data reduced the percentage of buildings land cover area by 1.91 percent and increased the amount of demolished building area by 1.1 percent. Although these are relatively small numbers over the entire watershed, locally the increased pervious surface area could have a significant impact on runoff.

For purposes of modeling, the impervious area was modified with an estimate of the amount of disconnected impervious surfaces in each subwatershed. Connectivity surveys were conducted by visual inspection of specific areas to note if rooftop runoff entered storm drains directly or flowed over a pervious surface or area of excessively broken pavement first. Examples of ground surfaces that could intercept runoff are shown in Photos 1 and 2.

Two areas of the watershed were inspected in more detail to investigate whether all the impervious area was directly connected to the storm drain system or whether some storm water flowed over pervious areas before reaching an inlet. For these areas (subwatersheds

263-F and 263-O) each block was inspected to identify those buildings that were disconnected. These inspections indicated that the amount of disconnected impervious surface varies significantly from block to block.

To model the change in imperviousness, the total area of disconnected buildings was subtracted from the building land cover and added to the grass land cover producing a net decrease in building area. Imperviousness was then recalculated, and a reduction factor for imperviousness was generated and added to the RUNOFF block as a default/ratio line.

Photo 1: Broken concrete walk

Photo 2: Vegetated backyard

Connectivity was determined for the remaining subwatersheds by inspecting a random set of 20 blocks out of approximately 180 that are north of Washington Boulevard. Because of the highly impervious land cover, the industrial areas south of Washington Boulevard were assumed to be 100 percent connected; therefore, these areas were not included in the sample population.

Sampling results of the selected blocks indicated that the total disconnected area is 2.81 acres out of a total of 200.4 acres examined. This area was subtracted from the buildings land cover and placed in the grass land cover and the percent impervious was recalculated. Results indicated that the watershed-wide reduction factor for imperviousness is 0.984, which was entered as an impervious reduction factor in the default/ratio lines for the remaining 34 subwatersheds.

Storm Drains and Stormwater Management

Watershed 263 is drained by a network consisting of 225,543 LF (43 miles) of storm drains, discharging through a single outlet, an 11 ft x 14 ft box culvert to the Middle Branch of the Patapsco River adjacent to the BRESCO recycling plant. For the WS 263 project, storm drain data served two purposes: for delineating subwatersheds and for developing a drainage network for modeling.

Regional and Small-Scale Facilities

There were no existing SWM facilities identified in the watershed. Development of the area predates the City's SWM regulations.

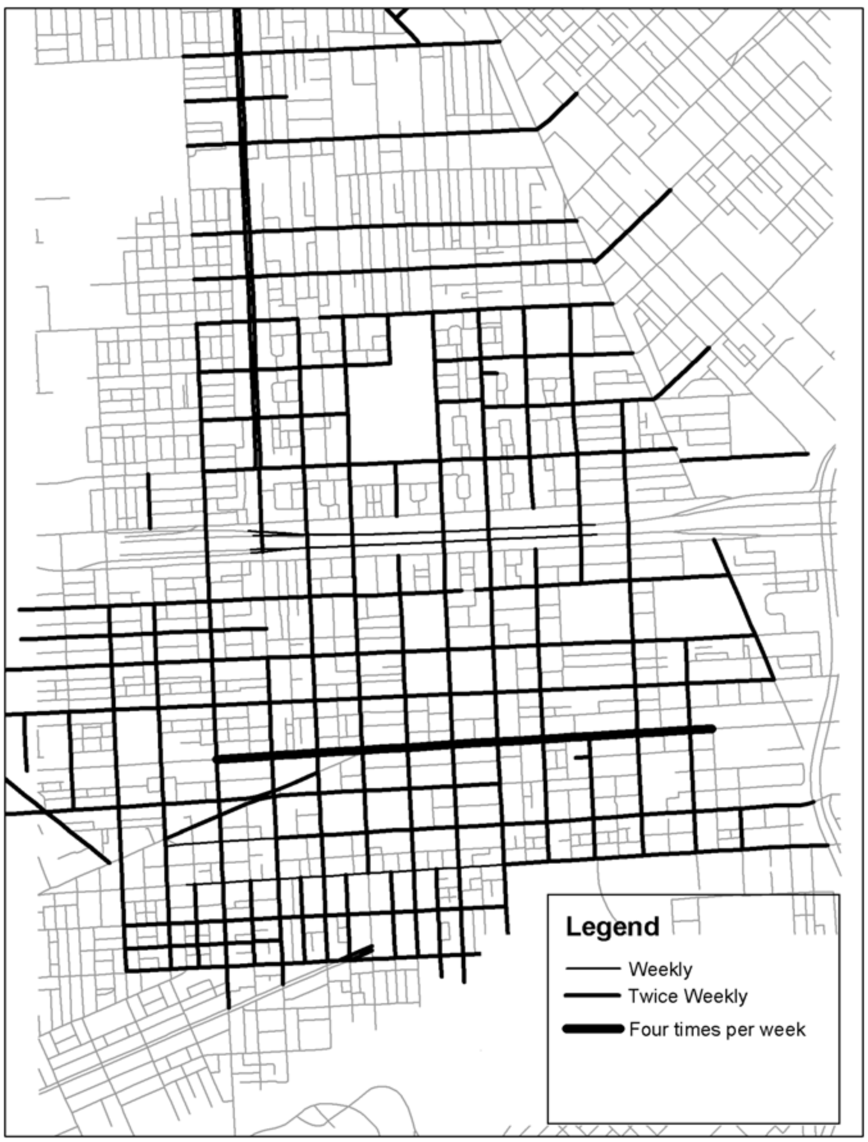
Non-Structural Practices

The City maintains a street sweeping program which covers many of the streets within and adjacent to Watershed 263, shown in Figure 3.

Five routes which cover 33.4 miles are swept twice a week. There are two gateway routes covering 3.0 miles of Pratt Street, Lombard Street, and US 40 which are swept weekly. The 0.8 mile portion of Baltimore Street is swept four times per week.

Overall, at these frequencies, 3,800 miles of streets and 7,600 curb miles are swept annually in the watershed. One sweeper and crew can sweep approximately 8,000 curb miles annually (Strassler et al., 1999), so one sweeper would be required to continue the current level of service.

Figure 4: Current Street Sweeping Routes



Water Quality

Regulatory Background

Watershed 263 is part of the Baltimore Harbor drainage basin, which is one of the waterbodies monitored by the Maryland Department of the Environment for water quality impairments. An impairment is identified when water quality monitoring data suggest that a waterbody does not meet water quality standards.

Waterbodies that are impaired are officially identified on Maryland's 2002 303(d) list (MDE 2002) shown in Table 3, which describes the location and type of impairment. The Middle Branch, which is the portion of the Baltimore Harbor basin which WS 263 drains to, has been listed as follows:

Table 3: Water Quality Impairments Downstream of WS 263

Date	Impairment	Potential Source
1998	PCBs - Fish Tissue	Unknown
1998	PCBs - Sediment	Unknown
1998	Zinc - Sediments	Point, nonpoint, legacy
1996	Nutrients	Point, nonpoint, natural
1996	Sediments	Point, nonpoint, natural

The listing shows that the key pollutants that need to be monitored and reduced in WS 263 are nutrients (nitrogen and phosphorus) and sediment. Poly-chlorinated biphenyls (PCBs) were used in electrical equipment and are no longer manufactured or used and are unlikely to be found in any discharge from WS 263.

There are no point sources of pollutants such as industrial discharges identified in WS 263. The only type of source expected is nonpoint sources. These include stormwater runoff and illicit discharges such as dumping, sewage leaks, or cross-connections between sanitary sewers and storm drains.

Sampling and Monitoring Data

Stormflow and baseflow samples have been collected at Subwatershed F and O monitoring stations since September 28, 2004 as part of the study of Watershed 263 existing conditions. The purpose of the water quality field monitoring program is to measure concentrations of pollutants for a set of limited parameters.

The water quality monitoring stations have been built and are being maintained by Baltimore City Department of Public Works (DPW) with some assistance by the U.S Forest Service (USFS) and the University of Maryland at Baltimore County (UMBC). Once a week the stations are accessed to check equipment operation, change batteries and bottles, draw dry weather flow samples and evaluate flow and flow obstructions.

A summary of the data collected through May 2005 is presented in Table 4. The values listed are Event Mean Concentration (EMC) values and are based upon sample sizes of 4 to 6 stormflow events and 12 to 14 baseflow grab samples. Median storm water EMCs for commercial land use from Maryland NPDES permits (Maryland Storm EMC) and average

EMCs from all land uses from national data (National Storm EMC) are provided in the table as a means for comparison.

Table 4: Stormflow Sample Results

Parameter	Units	Subwatershed O	Subwatershed F	Maryland Storm EMC	National Storm EMC
TSS	mg/l	93.0	52.0	N/A	58.0
TP	mg/l	0.33	0.30	0.32	0.27
TN	mg/l	3.20	2.11	2.74	2.0
FC	MPN/ 100 ml	94,081	58,204	2,309	5,081
Cu	ug/l	46	17	23	16
Pb	ug/l	90	34	14	16
Zn	mg/l	140	88	93	116
BOD-5	mg/l	31	21	N/A	9

The monitoring results show that Total Suspended Solids (TSS), Total Phosphorus (TP), Total Nitrogen (TN), and Zinc (Zn) found in storm samples are reasonably consistent with statewide and national averages. All the other parameters are higher in WS 263, and in the case of fecal coliform, they are higher by more than an order of magnitude.

There were also high fluoride and ammonia levels (not shown) in the baseflow samples, suggesting that drinking water or sewage discharges may be part of the baseflow. The sampling data are inconsistent, however, because the fecal coliform data are low and lead to the conclusion that domestic wastewater is not a big contributor. Also, since there is a lower concentration of bacteria in the baseflow, it appears the source is from runoff and not from illicit discharges from sanitary sewers. Table 5 shows the results of baseflow sampling in WS263.

Table 5: Baseflow Sample Results

Parameter	Units	Subwatershed O	Subwatershed F
TSS	mg/l	3.0	9.0
TP	mg/l	0.40	0.07
TN	mg/l	5.62	2.60
FC	MPN/ 100 ml	357	532
Cu	ug/l	24	3
Pb	ug/l	5	5
Zn	mg/l	24	31
BOD-5	mg/l	2	2

Pollutant Loads

Pollutant loads were estimated using the SWMM model described in the Existing Conditions report (KCI 2004). Loads were modeled using a continuous simulation of two years of rainfall, which included both pollutants washed off from the land surface and those transported through groundwater. Tables 6 and 7 show the annual load of each pollutant in pounds/year from WS 263 by subwatershed, and the annual load normalized by watershed area in pounds/acre/year.

Table 6: Annual Loads, Conventional Pollutants

	TSS	TP	TN	TKN	NOx	BOD5	Fecals (Qty in MPN)
lb/yr	214,979	1,341	24,739	12,512	10,420	39,369	92,654,475
lb/ac/yr	231	1.4	26.6	13.4	11.2	42.3	99,587

Table 7: Annual Loads, Toxic Pollutants

	Cd	Cu	Zn	Pb	TPH	Phenol	OilGrease
lb/yr	1.2	112.6	765.8	2.6	2.0	0.8	13,150
lb/ac/yr	0.00	0.12	0.82	0.00	0.00	0.00	14.13

These values are within the range expected in urban areas. As a check, a Simple Method calculation was made for six of the parameters: TSS, TP, TN, BOD-5, Cu, and Zn. The results were almost identical for TP, within a factor of 2 for TN, Zn and Cu, and within a factor of 3 for BOD-5. Given the completely different computational methods of the two models, these results appear reasonable.

Analysis and Recommendations

Watershed Impairments

Natural Resources and Land Cover

From an ecological perspective, the primary impairment found in Watershed 263 is the loss of streams due to urbanization, which occurred decades ago as the city was constructed. As a result, impairments related to stream condition which are a large part of other watershed assessments are not discussed in this report.

About 30 percent of the watershed is open space, defined as areas that lack structures. Open space is not necessarily pervious -- it may consist of parks, vacant or abandoned lots, paved backyards, or asphalt play areas at school. Terrestrial habitat in the form of trees and ground cover are heavily impaired in Watershed 263. Gardens and lawns made up 17.6 percent of the land cover in 2003, and trees made up another 3.4 percent. The lack of habitat is best expressed by the amount of impervious cover in the watershed, which is about 75%.

The greening strategies which are being undertaken by watershed partner organizations are focused on improving watershed conditions and addressing these impairments by removing excess impervious cover, improving soil conditions, and planting trees. These strategies are being addressed in other projects.

Water Quality

Water quality impairments in WS 263 are evident from both the sampling and modeling results. As shown in Table 4, storm sampling showed higher concentrations for most of the pollutants measured than averages for state or national sampling programs. The comparison with baseflow loads showed that with the exception of TP and TN, the highest concentration of pollutants is from stormwater runoff.

Potential Restoration Alternatives

This section describes the restoration practices and non-structural measures which were identified as potential feasible improvements to be used in Watershed 263. They fall into three categories: regional facilities, small-scale facilities, and non-structural practices. Regional facilities and non-structural practices are best suited to implementation across one or more subwatersheds. Small-scale facilities are recommended within a single subwatershed. Some may be suitable for construction by property owners or volunteer groups.

Small-scale and non-structural practices include twenty-one treatment alternatives that were described in the Visual Glossary developed by KCI and the Parks and People Foundation for the Watershed 263 Community Forum in February 2004. The Visual Glossary has been included within Appendix A of this report.

Regional Facilities

> <u>Extended Detention Wet Ponds</u> Ponds help reduce the impacts of stormwater runoff by storing the water in a permanent pool (wet pond) and by providing additional

temporary storage (extended detention), reducing the amount of runoff and the rate of flow. Ponds also improve water quality by allowing pollutants to settle.

Extended Detention Wetlands Wetland provide many of the same benefits as ponds, by providing both temporary and permanent storage. They have additional benefits from landscaping with wetland plants, which include aesthetics, pollutant removal, and educational opportunities. However, because they are more shallow, they require more space for the same treatment volume.

Non-Structural Practices

Other Non-structural Techniques These techniques intercept or detain runoff, thereby preventing or limiting the runoff of pollutants. These techniques minimize pollution at the source, thereby reducing the amount that needs to be removed by subsequent treatment and structural controls. They include methods of managing land use and educating the public, such as tree planting, vacant lot treatments, informational outreach, demonstration projects, and signs.

A number of these techniques have been proposed by the watershed partners as part of the greening initiative.

Housekeeping Practices These are municipal operation and maintenance measures that prevent or reduce pollutant runoff that collects on streets, parking lots, and open spaces, and is discharged into local waterways and storm drain systems. Practices proposed for this plan include:

- Street sweeping
- Storm drain cleaning

Small-Scale Facilities - City

Vegetative Filter Practices Filter practices are designed to provide runoff filtration and retention of conventional pollutants. A vegetative filter is an area of vegetation located between a pollutant source (such as a parking lot) and a stream, storm drain system, or other waterbody. They include swales, rain gardens, graded street gardens, and filter strips. Specific practices proposed for this project include:

- Rain garden
- Filter strips

Infiltration Systems Infiltration is designed to detain and filter stormwater runoff, which may be collected and returned to the storm drain system or allowed to percolate into the soil. They are generally used for larger areas, and include infiltration trenches, infiltration basins, porous pavement, sand filters, downstream filtration devices, and bioretention facilities. For this project, the following infiltration systems have been proposed:

- GrassPave
- GravelPave
- Infiltration Basin
- Inlet bioretention
- Corner bioretention

- Courtyard bioretention
- Sidewalk bioretention

Small-Scale Facilities - Private

On-Lot Treatments These practices filter and reduce quantity of runoff from individual lots. The primary purpose of most on-lot practices is to manage rooftop, driveway, and sidewalk runoff. On-lot treatments proposed for this project include dry wells, rain barrels, rain tanks, planter boxes, and green roofs.

Except for green roofs, these are intended to be constructed by volunteers and residents throughout the watershed.

Watershed Restoration Survey

Field work was conducted in the Fall of 2004 to assess watershed conditions and identify locations for proposed improvements. The process of selecting alternatives for particular sites was carried out keeping both water quality and quality of life goals in mind. The first step was to identify feasible water quality improvements for each subwatershed.

Field surveys were performed by walking each site to determine if there were any site constraints which would prevent certain types of improvements from being implemented, or opportunities that would make others more likely to be successful. The following were key considerations:

- Topography
- Utility conflicts
- Land availability and ownership
- Soil type
- Environmental impacts
- Public acceptability
- Cost

More than any other constraint, watershed topography dictates where potential BMPs may be feasible. Sites must be downstream of runoff and pollutant sources, and should have a large enough drainage area to function properly.

To the extent they were known, BMPs were sited to avoid construction conflicts with other existing utilities. Another important consideration was making sure that existing storm drains were in the right location and elevation to receive outflow from proposed BMPs.

Land availability and ownership are also major constraints when siting facilities. It is more feasible to construct facilities on land owned by the City, either lots or right-of-way, than privately-owned land. The small size of available land also dictates the use of small-scale BMPs in most of the watershed rather than regional facilities.

Soil type is the key constraint for infiltration BMPs, which require well-drained soils. Since Watershed 263 is a highly urbanized area, it was assumed that most soils are compacted and not well suited to infiltration. These types of BMPs have been proposed in areas where soils can be remediated if necessary.

Environmental impacts were a minor constraint in this watershed, where there are no natural watercourses or wetlands and no permitting is anticipated.

Public acceptability has been an important factor in selecting alternatives. Impacts to adjacent properties were one of the constraints to siting infiltration BMPs near houses, to avoid the potential for wet basements. Safety considerations were important in siting the proposed regional pond facilities at a distance from residential neighborhoods.

During the BMP selection process, cost was not a primary consideration. For example, sidewalk bioretention is the most expensive alternative proposed, but it brings aesthetic benefits to the neighborhood as well as water quality improvements. Costs are discussed in more detail in the Prioritization section of the report which follows.

Regional Facilities

Site visits were made to the watershed to identify potential locations for regional facilities, specifically wet ponds or wetlands. Potential sites had to meet the following criteria:

- Publicly-owned land.
- Storm drain inverts within 4 feet of ground surface so water can be diverted into and out of the facility.
- Reasonably far from residences for safety reasons.

Three sites in the watershed met these criteria:

- An area of Carroll Park adjacent to Bayard Street
- The grassy area between the depressed section of US 40 and Franklin Street between Fulton Street and Arlington Avenue, which could accomodate three separate facilities
- An area on or adjacent to the BRESCO property southeast of Russell Street.

Preliminary designs were made for all the facilities using the 2000 Stormwater Design Manual procedures. They were designed to treat the water quality volume only. Because downstream drainage is entirely conveyed by storm drains, there was no need to provide channel protection volume.

Carroll Park ED Wetland

This site is in an area where several tennis courts and basketball courts were recently taken up and replaced with grass. There is evidence of surface water flow and sedimentation on the site, and the revegetation is only in fair condition. There is approximately 1.5 acres of surface area available for wetland creation.

Along with water quality improvements, this facility would offer opportunities for beautification and public education and awareness.
The main design constraint is to ensure the facility is safe. It is adjacent to a playground so the maximum water depth should be no more than 2 feet.

Two potential sources of stormwater are available for treatment. From the northeast the main trunk storm drain from Watershed 263 enters the park, with a drainage area of 585.7 acres and 77.0% imperviousness to the site. From the west, a smaller 78-inch diameter pipe reaches the site, draining subwatersheds 263T, 263X, 263AA, 263BB, and 263CC, an area of 137.5 acres and 74.3% impervious.

WQv to be treated for these two drainage areas is 36.2 acre-ft and 8.2 acre-ft, respectively. The site is too small to feasibly treat the larger area. It has the potential to treat a portion of the WQv from the smaller drainage area, but is too small to treat the entire volume. A preliminary design was made to calculate the amount of storage available on the site:

Table 8: ED Wetland Design Characteristics- Carroll Park

Wetland Zone	Percent of Area	Surface Area (ac)	Average Depth (in)	Volume (ac-ft)
High Marsh	35	0.53	6	0.21
Low Marsh	30	0.45	18	0.66
Pool	35	0.53	24	1.03
Total	100	1.50		1.90

The available volume of 1.9 ac-ft is 23% of the volume needed to treat the WQv from the 137.5 acre west drainage area, which shows that the site is too small to provide full water quality benefits and is not recommended for this use. It is feasible to design a diversion structure to send a limited flow of the first flush to the wetland, or to design it for treatment of local drainage, which would provide some water quality benefit while providing community benefits.

In this case, the impervious area that could be treated can be back calculated from the wetland volume. Assuming the WQv is equal to the pond volume, and that the drainage area has an average imperviousness of 75%, there is sufficient surface area with this design to treat the equivalent of a 32-acre drainage area, or about 24 impervious acres.

US 40 Wet Pond 1

This site is one of three potential pond sites in the grass strip north of the depressed section of Route 40. It is located in the block between Mount Street and Gilmore Street. There are approximately 0.5 acres of open space available at the site.

Along with water quality improvements, the facility would offer opportunities for beautification and public education.

Safety issues could be a constraint. The site is adjacent to residential areas, although it could be easily fenced to prevent accidental falls into the marsh areas or pools. It is separated from the residential areas by Franklin Street, which provides an element of safety.

The source of stormwater to be treated is the southwestern portion of subwatershed 263-J. Stormwater would be diverted from the storm drain running under Franklin Street. Outflow from the pond would be sent to the manhole at the intersection of Franklin and Gilmore Street. The drainage area to be served measures approximately 5.7 acres and is 75% impervious.

WQv to be treated is 0.35 ac-ft. A preliminary design was made to determine the size of the facility needed. A facility with a surface area of 0.20 acres provides 0.40 ac-ft of storage, sufficient to treat the entire WQv.

Table 9:Pond Design Characteristics- US 40 Pond 1

Pond Zone	Percent of Area	Surface Area (ac)	Average Depth (in)	Volume (ac-ft)
High Marsh	35	0.07	6	0.04
Low Marsh	35	0.07	18	0.11
Pool	30	0.06	48	0.25
Total	100	0.20		0.40

US 40 Wet Pond 2

This site is one of three potential pond sites in the grass strip north of the depressed section of Route 40. It is located between Strickler Street and Calhoun Street. Including both grassy areas on either side of Strickler Street, there is approximately 1.5 acres of open space available. Along with water quality improvements, the facility would offer opportunities for beautification and public education.

Safety issues could be a constraint. The site is adjacent to residential areas, although it could be easily fenced to prevent accidental falls into the marshes or pools. It is separated from the residential areas by Franklin Street, which provides an element of safety.

The source of stormwater to be treated is the remainder of subwatershed 263-J which is not treated by Wetland 1, along with the small part of 263-G which includes the site. Stormwater would be diverted from the storm drain running under Franklin Street. Outflow from the pond would be sent to the manhole at the intersection of Franklin and Calhoun Street. The drainage area to be served measures approximately 13.5 acres and is 85% impervious.

WQv to be treated is 0.92 ac-ft. A preliminary design was made to determine the size of the facility needed. A facility with a surface area of 0.60 acres provides 1.14 ac-ft of storage, sufficient to treat the entire WQv.

Table 10: Pond Design Characteristics- US 40 Pond 2

Pond Zone	Percent of Area	Surface Area (ac)	Average Depth (in)	Volume (ac-ft)
High Marsh	35	0.21	6	0.10
Low Marsh	35	0.21	18	0.32
Pool	30	0.18	48	0.72
Total	100	0.60		1.14

US 40 Wet Pond 4

This site is the third of three potential pond sites in the grass strip north of the depressed section of Route 40. It is located between Carey Street and Carrollton Avenue. Including both grassy areas on either side of Carey Street, there is approximately 1.5 acres of open space available. Along with water quality improvements, the facility would offer opportunities for beautification and public education.

Safety issues could be a constraint. The site is adjacent to residential areas, although it could be easily fenced to prevent accidental falls into the facility. It is separated from the residential areas by Franklin Street, which provides an element of safety.

The source of stormwater to be treated includes all of Subwatersheds 263-I and 263-K. For 263-I, stormwater would be diverted from the storm drain running under Franklin Street. Drainage from 263-K would have to be diverted from the Franklin Street storm drain and rerouted directly into the treatment facility. Outflow from the pond would be sent to the manhole at the intersection of Franklin and Carey Street. The drainage area to be served measures approximately 13.1 acres and is 75% impervious.

WQv to be treated is 0.80 ac-ft. A preliminary design was made to determine the size of the facility needed. A facility with a surface area of 0.65 acres provides 1.24 ac-ft of storage, sufficient to treat the entire WQv.

Table 11: Pond Design Characteristics- US 40 Pond 4

Pond Zone	Percent of Area	Surface Area (ac)	Average Depth (in)	Volume (ac-ft)
High Marsh	35	0.23	6	0.11
Low Marsh	35	0.23	18	0.35
Pool	30	0.19	48	0.78
Total	100	0.65		1.24

BRESCO Wet Pond

This site is on the northern corner of the BRESCO site southeast of Russell Street, adjacent to the outfall from Watershed 263. There is approximately 0.6 acres of open space available. The facility would be placed in an area which is not accessible to the public, and as a result would offer fewer opportunities for beautification and public awareness than the other sites. It is designed solely for water quality improvements. Because it is located in industrial areas, safety issues are not a constraint.

The source of stormwater to be treated is a portion of subwatershed 263-JJ. Stormwater would be diverted from the storm drain running under Russell Street. Outflow from the wetland would be sent to the Patapsco River. The drainage area to be served measures approximately 28.7 acres and is 75% impervious.

WQv to be treated is 1.73 ac-ft. A preliminary design was made to determine the size of the facility needed. A facility with a surface area of 0.55 acres provides 1.86 ac-ft of storage, sufficient to treat the entire WQv.

Table 12: Pond Design Characteristics- BRESCO Pond

Pond Zone	Percent of Area	Surface Area (ac)	Average Depth (in)	Volume (ac-ft)
High Marsh	0	0	6	0
Low Marsh (Bench)	25	0.14	18	0.21
Pool	75	0.41	48	1.65
Total	100	0.60		1.86

Non-Structural Practices

Street Sweeping

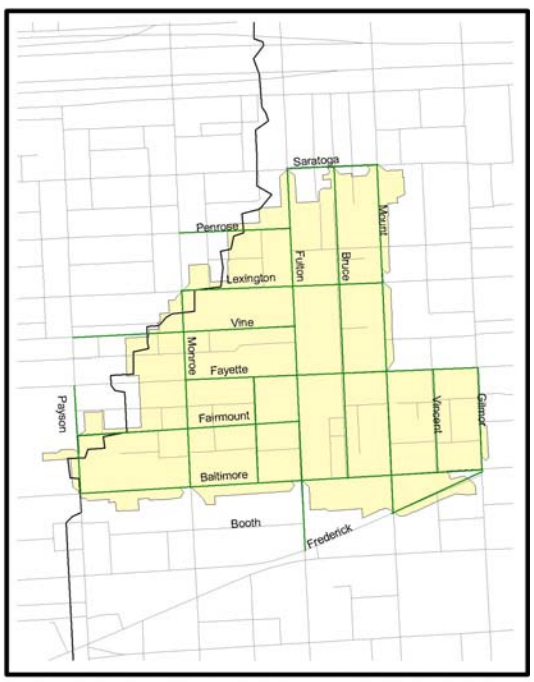
As a BMP, street sweeping is well suited to ultra-urban environments where retrofits of structural controls may be difficult or expensive. It should be given primary consideration in commercial or industrial districts, where sweeping of parking lots is a reasonably inexpensive addition to other pollution prevention procedures.

Street sweeping also provides aesthetic quality-of-life benefits by improving the overall cleanliness and sanitation of an area. It should be considered for the residential parts of Watershed 263 for this reason as well. In areas where structural BMPs have been installed, street sweeping could extend the maintenance interval by removing sediment that contributes to clogging or failure. This would be particularly important where infiltration BMPs are placed.

Vacuum-assisted sweepers are the most efficient type of equipment for removing fine sediments, which often bind a higher proportion of heavy metals than other sediments. They are extremely effective at removing respirable particulates less than 10 microns, which can help meet National Ambient Air Quality Standards.

Capital costs are incurred for equipment, and annual costs are incurred for maintenance and staff. Vacuum-assisted sweepers can cost on the order of \$150,000 to \$200,000 each and have a useful life of about eight years. Operation and maintenance costs have been reported at \$15 to \$20 per curb mile. (Strassler et al., 1999)

Figure 5: Proposed Street Sweeping Routes, 263-O



A more extensive street sweeping program has been proposed for Subwatershed O as part of a study by the Center for Watershed Protection (CWP, 2005). The proposed sweeping is shown in Figure 4. The protocol will result in a addition of 35,448 LF (6.7 curb miles) to be swept twice a week, increasing the current amount 152% from 23,364 LF to 58,812 LF. The annual increased sweeping works out to about 700 miles.

Storm Drain Cleaning

Routine storm drain cleaning reduces the amount of trash, debris, and pollutants in the storm drains and receiving waters. This practice is particularly useful in areas of flat grades or low flows where stormwater rarely achieves sufficient velocity for flushing.

Cleaning is carried out by flushing the storm drain, then collecting and treating the resulting wastewater. Efficiency decreases in pipes larger than 35 inches in diameter and storm drains longer than 700 feet. For this reason, it is most appropriate in headwater areas of each subwatershed which are drained by smaller, shorter pipes. Costs have been cited at

\$1.00 to \$2.00 per linear foot (1997 dollars), which includes a Vactor truck, crew, and disposal of wastewater. (Strassler, et al., 1999)

As part of the Catchment O study, after 6 months of monitoring street sweeping, storm drain cleanout operations will begin. These operations will include extensive cleaning of stormwater inlets. The sample inlets have not been defined, but will be selected from a total of 71 stormwater inlets and 42 storm drain manholes.

Outreach, Education, and Stewardship

No specific outreach projects or programs have been developed as part of the short-term water quality improvement work described in this report. Several activities have been identified by other watershed partners during the course of this project, including pollution prevention techniques for businesses, trash management education, vacant lot greening, downspout disconnection, tree planting, and pet waste management.

Small-Scale Practices

Watershed 263 was divided into 36 subwatersheds and specific BMP's were then sited for each subwatershed, with a goal to treat 20% of the existing impervious area. Due to site constraints the actual percent impervious area treated varies from as low as zero for four of the subwatersheds to 100 for four other subwatersheds.

The treated area, treated runoff volume, and size of facilities are summarized in Table 13. They have been sized as follows:

Bioretention

Sidewalk, corner, and courtyard bioretention, and rain gardens used calculations for infiltration trenches from the 2000 Stormwater Design Manual with the following assumptions.

$$A_f = WQv \times d_f / 9[k \times (h_f + d_f)t_f$$

where

A_f	= infiltration area (SY)	
WQv	= water quality volume (cf)	
d_f	= filter bed depth (ft)	use 2.5
k	= coefficient of permeability (ft/day)	use 0.5
h_f	= height of water above filter bed (ft)	use 0.5
t_f	= drain time (days)	use 2.0

Infiltration

Grasspave, Gravelpave, and infiltration basin facilities were sized using calculations from the Maryland Stormwater Manual

$$A_f = WQv / 9(nd_t + fT)$$

where

A_f	= infiltration area (SY)
WQv	= water quality volume (cf)

n	= porosity of stone reservoir	use 0.4
d_t	= trench depth (ft)	use 3.0
f	= infiltration rate (in/hr)	use 0.5
T	= maximum storage time (hr)	use 48

Inlet Bioretention

Filterra systems were sized using information from the manufacturer, which stated that one unit can treat 0.25 impervious acres.

Restoration proposals for subwatershed 263-O have been prepared by the Center for Watershed Protection (CWP) under a separate project to develop a detailed restoration and monitoring plan. The CWP provided KCI with the recommended priority BMPs for subwatershed 263-O and KCI then modeled these recommended BMPs. (CWP, 2005)

Table 13: Small-Scale Facilities Design

Sub-watershed	BMP Drainage ID	Treatment Type	Treated Area (ac)	Impervious Area (ac)	WQv (cf)	BMP Size (SY)
A	263-A-1	Sidewalk Bioretention	2.37	1.99	6,930	642
A	263-A-2	Courtyard Bioretention	1.45	1.36	4,714	437
A	263-A-3	Corner Bioretention	0.32	0.30	1,041	96
B	263-B-1	Courtyard Bioretention	1.89	1.64	5,710	529
B	263-B-2	Infiltration	1.09	0.50	1,826	63
B	263-B-3	Courtyard Bioretention	2.75	1.31	4,785	443
C	263-C-1	Courtyard Bioretention	0.76	0.56	1,977	183
C	263-C-2	Courtyard Bioretention	0.75	0.48	1,701	158
C	263-C-3	GrassPave	1.04	0.99	3,439	119
C	263-C-4	GravelPave	0.76	0.41	1,475	51
C	263-C-5	GravelPave	0.75	0.41	1,474	51
C	263-C-6	GrassPave	2.13	1.15	4,131	143
C	263-C-7	GrassPave	0.92	0.78	2,703	94
C	263-C-8	GrassPave	2.62	1.38	4,992	173
D	263-D-1_2	Courtyard Bioretention	1.86	1.59	5,527	512
D	263-D-3	Courtyard Bioretention	0.24	0.23	785	73
D	263-D-3a	Courtyard Bioretention	1.79	1.22	4,320	400
E	263-E-1	Corner Bioretention	1.03	0.44	1,611	149
E	263-E-2	Corner Bioretention	1.20	0.77	2,738	253
E	263-E-3	Infiltration	1.41	0.90	3,194	111
E	263-E-5	Courtyard Bioretention	0.65	0.37	1,323	123
E	263-E-7	Infiltration	0.74	0.52	1,823	63
F	263-F-1	Corner Bioretention	1.59	1.48	5,122	474
F	263-F-10	Sidewalk Bioretention	0.34	0.32	1,106	102
F	263-F-11	Courtyard Bioretention	1.25	0.67	2,411	223
F	263-F-13	Courtyard Bioretention	1.48	1.16	4,045	375
F	263-F-14	Courtyard Bioretention	3.06	2.24	7,889	730
F	263-F-15	Courtyard Bioretention	0.66	0.55	1,929	179
F	263-F-16	Courtyard Bioretention	1.29	0.86	3,040	282
F	263-F-17	Courtyard Bioretention	0.40	0.25	903	84
F	263-F-2	Corner Bioretention	1.51	1.38	4,771	442

Sub-watershed	BMP Drainage ID	Treatment Type	Treated Area (ac)	Imper-vious Area (ac)	WQv (cf)	BMP Size (SY)
F	263-F-3	Courtyard Bioretention	0.61	0.24	882	82
F	263-F-4	Courtyard Bioretention	2.02	1.65	5,765	534
F	263-F-5	Courtyard Bioretention	0.52	0.27	983	91
F	263-F-6	Courtyard Bioretention	0.59	0.45	1,560	144
F	263-F-7	Courtyard Bioretention	1.05	0.78	2,746	254
F	263-F-8	Infiltration	0.48	0.33	1,162	40
F	263-F-9	Infiltration	0.70	0.53	1,874	65
G	263-G-1	GrassPave	2.08	1.64	5,724	199
G	263-G-2	Infiltration	2.22	0.90	3,331	116
G	263-G-3	Rain Garden	2.41	0.86	3,252	301
H	263-H-1	Infiltration	2.61	2.06	7,188	250
H	263-H-2	Courtyard Bioretention	1.07	0.32	1,241	115
I	263-I-1	Sidewalk Bioretention	0.77	0.42	1,514	140
I	263-I-2	Sidewalk Bioretention	0.43	0.20	740	68
I	263-I-3	Infiltration	0.67	0.48	1,680	58
I	263-I-4	Sidewalk Bioretention	0.82	0.77	2,676	248
I	263-I-6	Sidewalk Bioretention	2.44	2.15	7,453	690
J	263-J-1	GrassPave	0.59	0.41	1,433	50
J	263-J-2	GrassPave	1.02	0.70	2,469	86
J	263-J-4	Courtyard Bioretention	1.06	0.73	2,580	239
J	263-J-5	Inlet Bioretention	1.73	1.43	4,980	6
K	263-K-1	GrassPave	2.35	1.67	5,896	205
L	263-L-1	Corner Bioretention	0.98	0.77	2,683	248
L	263-L-2	Corner Bioretention	1.70	1.06	3,772	349
M	263-M-1	Courtyard Bioretention	1.31	1.14	3,951	366
M	263-M-2	Sidewalk Bioretention	1.07	0.51	1,859	172
M	263-M-3	Sidewalk Bioretention	0.97	0.53	1,899	176
M	263-M-4	Rain Garden	0.97	0.77	2,685	249
N	263-N-1	Infiltration	2.67	1.92	6,755	235
N	263-N-2	Courtyard Bioretention	2.80	1.26	4,636	429
P	263-P-1	Corner Bioretention	1.25	0.63	2,285	212
P	263-P-2	Corner Bioretention	1.18	0.91	3,174	294
Q	263-Q-1	GrassPave	1.17	1.14	3,953	137
Q	263-Q-2	Rain Garden	0.73	0.69	2,398	222
R	263-R-1	Corner Bioretention	2.63	1.94	6,828	632
S	263-S-1	GrassPave	0.64	0.50	1,734	60
S	263-S-2	Infiltration	3.17	1.76	6,337	220
T	263-T-1	Corner Bioretention	2.03	1.88	6,508	603
T	263-T-2	Corner Bioretention	1.56	1.19	4,180	387
T	263-T-3	Corner Bioretention	1.69	1.46	5,066	469
T	263-T-4	Corner Bioretention	0.17	0.13	470	44
T	263-T-5	Corner Bioretention	0.22	0.20	705	65
U	263-U-1	Filter Strip	0.82	0.60	2,107	195
U	263-U-2	Infiltration	1.38	1.14	3,990	139
V	263-V-1	GravelPave	0.40	0.38	1,310	46
V	263-V-2	GravelPave	0.68	0.65	2,245	78
V	263-V-3	Sidewalk Bioretention	0.39	0.37	1,268	117

Sub-watershed	BMP Drainage ID	Treatment Type	Treated Area (ac)	Imper-vious Area (ac)	WQv (cf)	BMP Size (SY)
V	263-V-4	Sidewalk Bioretention	0.72	0.68	2,348	217
W	263-W-1	Corner Bioretention	1.45	1.36	4,715	437
W	263-W-1_2	Courtyard Bioretention	1.92	1.17	4,158	385
X	263-X-1	Courtyard Bioretention	0.23	0.22	753	70
X	263-X-2	Inlet Bioretention	0.12	0.11	374	1
X	263-X-3	Corner Bioretention	0.34	0.32	1,121	104
X	263-X-4	Sidewalk Bioretention	1.57	1.45	5,035	466
X	263-X-5	Sidewalk Bioretention	1.50	1.43	4,959	459
X	263-X-6	Courtyard Bioretention	0.71	0.50	1,747	162
Y	263-Y-1	Corner Bioretention	0.83	0.74	2,577	239
Y	263-Y-2	Rain Garden	0.83	0.69	2,410	223
Y	263-Y-3	Corner Bioretention	0.22	0.14	501	46
Y	263-Y-4	Infiltration	0.52	0.47	1,626	56
Y	263-Y-5	Infiltration	0.41	0.37	1,289	45
Y	263-Y-6	Infiltration	0.12	0.11	381	13
Y	263-Y-7	Sidewalk Bioretention	1.40	0.87	3,102	287
Z	263-Z-1	Corner Bioretention	3.10	2.96	10,220	946
Z	263-Z-2	Corner Bioretention	0.28	0.21	730	68
Z	263-Z-3	Inlet Bioretention	1.02	0.84	2,922	4
Z	263-Z-4	Courtyard Bioretention	0.31	0.29	992	92
AA	263-AA-1	Corner Bioretention	0.18	0.17	575	53
AA	263-AA-2	Corner Bioretention	0.78	0.71	2,455	227
AA	263-AA-3	Corner Bioretention	1.01	0.90	3,119	289
AA	263-AA-4	Corner Bioretention	1.56	1.43	4,956	459
AA	263-AA-5	Corner Bioretention	0.33	0.32	1,098	102
AA	263-AA-6	Corner Bioretention	0.05	0.01	42	4
AA	263-AA-7	GrassPave	0.09	0.08	272	9
AA	263-AA-8	GrassPave	0.35	0.33	1,141	40
BB	263-BB-1	Corner Bioretention	3.53	3.23	11,180	1,035
BB	263-BB-2	Corner Bioretention	1.75	1.60	5,546	513
DD	263-DD-1	Courtyard Bioretention	0.58	0.55	1,899	176
DD	263-DD-2	Courtyard Bioretention	0.75	0.70	2,423	224
GG	263-GG-1	Corner Bioretention	0.63	0.60	2,061	191
GG	263-GG-2	Corner Bioretention	14.06	12.39	43,045	3,986

Model Results for Pollutant Load Reduction

Improvements in water quality are quantified through modeling of alternatives to show the amount of pollutant removed or the percent of reduction. For this study, the area draining to each proposed BMP was delineated and loads were estimated from existing conditions and with the proposed improvements in order to estimate the amount of pollutant removed by each BMP.

BMPs were modeled in SWMM by applying a percent removal for each pollutant for each BMP. They were sized to treat flows generated by rainfall events of 1 inch or less, corresponding to the runoff equal to the water quality volume (WQv). Removal efficiencies were derived from a number of literature sources (Young, 1996; Winer, 2000; Claytor, 2000;

Caraco, 2001) and are shown below in tables 14 and 15. The small-scale structural treatment systems proposed fell under the categorizations of bioretention, porous pavement, and infiltration basins, and the regional facilities were categorized as either extended detention wet ponds or wetlands.

Table 14: Pollutant Removal Rate, Conventional Pollutants (%)

Practice	TSS	TP	TN	TKN	NOx	BOD	FC
Regional Facilities							
Wet ED Pond	80	50	35		60	45	70
ED Wetland	75	50	30		65	45	75
Non-Structural Practices							
Street Sweeping	60	40	40	50		50	
Storm Drain Cleaning							
Small-Scale Practices							
Rain gardens							
Filter strips							
Grasspave™ w/ infiltration (1)	90	65	85		80	80	90
Gravelpave™ w/ infiltration (1)	90	65	85		80	80	90
Infiltration basin	90	60	50		80	80	90
Inlet bioretention - Filterra (2)	80	60	40		15	65	35
Corner bioretention (2)	80	60	40		15	65	35
Courtyard bioretention (2)	80	60	40		15	65	35
Sidewalk bioretention (2)	80	60	40		15	65	35
NOTES (1) Use removals for porous pavement (2) Use removals for bioretention blank: No data available							

Table 15: Pollutant Removal Rate, Toxic Pollutants (%)

Practice	Cd	Cu	Zn	Pb	TPH	Phenol	O&G
Regional Facilities							
Wet ED Pond		55	70		80		
ED Wetland		40	40		85		
Non-Structural Practices							
Street Sweeping	50	50	40	50			
Storm Drain Cleaning							
Small-Scale Practices							
Rain gardens							
Filter strips							
Grasspave™ w/ infiltration (1)		70	95				
Gravelpave™ w/ infiltration (1)		70	95				
Infiltration basin		70	95				
Inlet bioretention - Filterra (2)		95	95		84		
Corner bioretention (2)		95	95		84		
Courtyard bioretention (2)		95	95		84		
Sidewalk bioretention (2)		95	95		84		
NOTES (1) Use removals for porous pavement (2) Use removals for bioretention blank: No data available							

For TKN, Cd, Pb, Phenols, and Oil and Grease, there were no data available for pollutant removal effectiveness for any BMPs. Tables 16 and 17 summarize the modeling results for each pollutant for the entire watershed. The first line shows the load from existing conditions and the next three lines summarize the reduction achieved by each management alternative. The last line shows the percent removal.

Table 16: Load Reduction, Conventional Pollutants

	Runoff	TSS	TP	TN	TKN	NOx	BOD5	Fecals
	(in)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	MPN/yr
Existing Load	11.5	214,979	1,341	24,739	12,512	10,420	39,369	92,654,475
Regional Reduction	-	3,520	15	195	-	76	473	1,112,600
Non-Structural Reduction	-	1,045	10	190	212	-	256	-
Small-Scale Reduction	-	34,915	161	2,197	-	650	5,434	9,368,372
Total Reduction	-	39,480	187	2,582	212	726	6,163	10,480,972
Total Percent	0.0%	18.4%	13.9%	10.4%	1.7%	7.0%	15.7%	11.3%

Table17:Load Reduction, Toxic Pollutants

	Cd	Cu	Zn	Pb	TPH	Phenol	OilGrease
	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
Existing Load	1.2	112.6	765.8	2.6	2.0	0.8	13,149.9
Regional Reduction	-	1.9	14.2	-	0.0	-	-
Non-Structural Reduction	0.0	0.3	2.1	0.0	-	-	-
Small-Scale Reduction	-	19.9	147.0	-	0.3	-	-
Total Reduction	0.0	22.1	163.3	0.0	0.4	-	-
Total Percent	0.4%	19.6%	21.3%	1.5%	18.1%	0.0%	0.0%

Prioritization

Introduction

This section of the report presents the analysis of benefits for proposed BMPs and a comparison with costs. A set of evaluation criteria have been developed to help quantify how well each proposed alternative meets the two watershed goals of improved water quality and a better quality of life.

Structural BMP Cost Estimates

Unit cost estimates were prepared for each type of BMP so that an estimate could be developed based on the size of the facility proposed. Table 19 at the end of this section provides information on how the costs were estimated for each type of practice. Initial costs include construction, design and permitting. Design and permitting costs were estimated to be 10% of the construction cost, and a 20% contingency was added to the total.

For wet ponds and wetlands, construction costs (C) for wet ponds and wetlands were estimated using an empirical equation developed by the Center for Watershed Protection (Schueler, 2000), based on cubic feet of storage, which assumed wetland costs were 25% more expensive than a wet pond. The equation was escalated by 14% to account for the years from 1997 to 2005 using the Consumer Price Index (CPI-W) published by the US Bureau of Labor Statistics.

Wet Pond $C = (1.14)\ 24.5\ V^{0.705}$
Wetland $C = (1.14)\ 30.6\ V^{0.705}$

For inlet bioretention, information was provided by manufacturers. An installed cost of $6,100 per unit was used, with a maintenance cost of $100 per year. For other structural BMPs, a unit cost was developed using current bid tabulations for construction, such as sidewalk removal, excavation, furnished soil, etc. Spreadsheets showing the calculations for unit cost, facility size, and construction cost are included in Appendix B.

Annual maintenance costs are an average of routine maintenance, such as cleanouts, and major maintenance, such as pond dredging or replacement of filter media, but do not include costs of substantially rebuilding or replacing facilities. They are derived as a percentage of construction costs (Strassler, et al., 1999). The percentages used in this plan are as follows:

Table 18: Maintenance Costs

Type of BMP	Annual Maintenance
Wet Pond	6%
Wetland	2%
Filter Strips	5%
Infiltration	5%
Bioretention	6%

Life cycle costs combine both capital and maintenance costs by annualizing maintenance using a Net Present Value (NPV) calculation based on the expected life of the facility and an assumed discount rate of 5% representing the time value of money.

The expected life of stormwater management facilities is the length of time they will function before complete reconstruction is needed. Expected life of SWM facilities is less certain than for other types of infrastructure. It is generally acknowledged that infiltration systems have a shorter life span than detention systems. Some of the newer systems, such as bioretention, have not been in place long enough to determine the life span.

For the purpose of this report, we have assumed a 20-year life for all facilities except infiltration, filter strips, planters, and filter bags, which are assumed to be 10 years. For these systems, the life cycle cost is calculated as the NPV of annual maintenance, plus twice the construction cost, which incorporates the need to reconstruct the facility after 10 years. Expected life and life cycle costs are shown in Table 19 below.

Non-Structural BMP Cost Estimates

Street sweeping costs were estimated based on information from Strassler, et al., 1999, which indicated that capital costs for a vacuum-assisted high-efficiency sweeper was approximately $150,000, and that annual operating and maintenance costs were $15 per curb mile. Costs for storm drain cleaning were not available.

These costs were annualized based on sweeping 8,000 curb-miles per year, and an expected sweeper life of 8 years. Operating and maintenance costs are estimated at $120,000 per year. With a discount rate of 5%, the NPV cost over 20 years is $1,570,239. Sweepers would have to be purchased in years 0, 8 and 16 over a 20-year period. The NPV cost of these purchases at 5% is $ $320,243.

It is possible to estimate the area directly treated by sweeping by multiplying the annual curb miles by the sweeper path of approximately 10 feet. Based on a weekly sweeping frequency, this works out to 93 acres per year, and a NPV cost of $20,275 per acre. This is a conservative estimate, because pollutants at the curb are generated from adjacent land uses, which cover a larger area than the street surface.

Table 19: Cost Estimate Basis

Practice	Unit Cost	Annual O & M Costs	Expected Life (years)	NPV O&M Cost
Regional Facilities				
Wet ED Pond	See text	6% of construction	20	
ED Wetland	See text	2% of construction	20	
Non-Structural Practices				
Street Sweeping	See text		4	
Storm Drain Cleaning	n/a	n/a	n/a	n/a
Small-Scale Practices				
Rain gardens	$128/SY	$7.67/SY	20	$96/SY
Filter strips	$26/SY	$1.58/SY	10	$12/SY
Grasspave™ w/ infiltration	$62/SY	$3.74/SY	10	$29/SY
Gravelpave™ w/ infiltration	$65/SY	$3.91/SY	10	$30/SY
Infiltration basin	$26/SY	$1.58/SY	10	$12/SY
Inlet bioretention - Filterra	$6,100/EA	$100 EA	20	$1,246 EA
Corner bioretention	$201SY	$12.08/SY	20	$150/SY
Courtyard bioretention	$128/SY	$7.67/SY	20	$96/SY
Sidewalk bioretention	$218/SY	$13.07/SY	20	$163/SY

Cost Comparison

Based on the sizing criteria and cost estimating procedures, it is possible to develop a cost for treating a unit of impervious acre with each of these alternatives. Except for the pond and wetland estimates, all of the costs vary linearly with WQv, and approximately linearly with impervious area. The pond and wetland estimates vary with a power function which applies economies of scale to their construction.

With the exception of street sweeping, the estimates below are based on the assumptions of 80% imperviousness and a drainage area of 5 acres, resulting in impervious area of 4.0 acres and WQv of 13,976 cf.

Table 20: BMP Costs per Impervious Acre

Practice	Capital Cost	NPV O&M Cost	Total	Total Cost per Impervious Acre
Regional Facilities				
Wet ED Pond	$30,841	$176	$31,017	$7,754
ED Wetland	$38,520	$201	$38,720	$9,680
Non-Structural Practices				
Street Sweeping	$320,243	$1,570,239	$1,890,481	$20,275
Storm Drain Cleaning	n/a	n/a	n/a	n/a
Small-Scale Practices				
Rain gardens	$218,640	$124,227	$342,866	$85,717
Filter strips	$44,411	$15,528	$59,940	$14,985
Grasspave™ w/ infiltration	$39,714	$14,073	$53,786	$13,447
Gravelpave™ w/ infiltration	$41,635	$14,558	$56,193	$14,048
Infiltration basin	$16,654	$5,823	$22,478	$5,619
Inlet bioretention - Filterra	$32,208	$129,403	$161,611	$40,403
Corner bioretention	$343,332	$194,104	$537,436	$134,359
Courtyard bioretention	$218,640	$124,227	$342,866	$85,717
Sidewalk bioretention	$372,369	$210,927	$583,296	$145,824

Represented as a cost per impervious acre, the bioretention systems are clearly the most costly. A review of the unit price estimate shows why. All the bioretention systems involve deeper excavation, construction of an underdrain, and landscaping with shrubs and trees. The landscaping alone adds about $45 per SY to the cost.

Evaluation Criteria

Water Quality

Several pollutants were modeled, but not all were chosen for evaluating benefits. The subset of water quality criteria below was chosen as a representative sample of improvements in hydrology and flow, improvements in nutrient loads to the harbor and the Chesapeake Bay, and improvements in toxic pollutant loading.

- Reduction in runoff volume
- Reduction in total suspended solids (TSS)
- Reduction in total nitrogen (TN)
- Reduction in total phosphorus (TP)
- Reduction in zinc (Zn)

Evaluation ratings are ranked from 1 (low) to 3 (high), and were selected as follows:

Runoff volume – Ratings are based on the effectiveness of each type of BMP at reducing the amount of runoff. Infiltration systems are the most effective, and were given a rating of 3. Bioretention, rain gardens, and wetlands are capable of reducing runoff through uptake by vegetation, and were given a rating of 2. Wet ponds, street sweeping, and filter strips have little or no effect on volume and were given a score of 1.

Water Quality (TSS, TP, TN, and Zn) -- Ratings are based on the pollutant removal efficiencies shown in Tables 14 and 15 above. BMPs with lower than 50% efficiency received a score of 1. Efficiencies between 50 and 80 received a score of 2, and those better than 80 received a score of 3.

While there were no data available from literature sources for rain gardens, these systems function similarly to bioretention systems and were assigned the same ratings.

There were also no data available for filter strips in an urban setting. Based on results for agricultural and open space areas, removals are expected to be below 50% for all pollutants, so a rating of 1 was assigned.

Table 21: Water Quality Benefits

Practice	Runoff Volume	TSS	TP	TN	ZN	Total
Regional Facilities						
Wet ED Pond	1	2	2	1	2	8
ED Wetland	2	2	2	1	1	8
Non-Structural Practices						
Street Sweeping	1	2	1	1	1	6
Storm Drain Cleaning	n/a	n/a	n/a	n/a	n/a	n/a
Small-Scale Practices						
Rain gardens	2	2	2	1	3	10
Filter strips	1	1	1	1	1	5
Grasspave™ w/o infiltration	3	3	2	3	3	14
Gravelpave™ w/o infiltration	3	3	2	3	3	14
Infiltration basin	3	3	2	2	3	13
Inlet bioretention - Filterra	2	2	2	1	3	10
Corner bioretention	2	2	2	1	3	10
Courtyard bioretention	2	2	2	1	3	10
Sidewalk bioretention	2	2	2	1	3	10

Using this ranking method, the most effective systems for pollutant removal are the infiltration BMPs, followed by bioretention, then the wet pond and wetland.

Quality of Life

Staff from watershed partners met with the community on two occasions to discuss goals for the neighborhoods which make up Watershed 263. At a Community Forum on February 28, 2004, a wide range of community concerns were discussed in order to help define what "quality of life" meant to watershed residents. A subsequent meeting was held on December 9, 2004 to develop indicators and vital signs and to discuss goals for greening the watershed.

KCI staff reviewed the meeting summaries and adapted the following quality of life criteria to be used in evaluating proposed alternatives. These are taken primarily from the ecological goals described in the Goals for Greening framework.

- Disconnect impervious cover from storm drains
- Increase tree canopy
- Improve ecology by adding habitat to schoolyards, parking lots, and vacant lots

Two additional criteria are adapted from the social goals:

- Improve environmental awareness
- Maintain public safety

In Table 22 below, evaluation ratings are ranked from 1 (low) to 3 (high).

Table 22: Quality of Life Benefits

Practice	Disconnection Strategies	Increase Tree Canopy	Improve Habitat	Environmental Awareness	Safety	Total
Regional Facilities						
Wet ED Pond	1	1	2	3	1	8
ED Wetland	1	2	3	3	2	11
Non-Structural Practices						
Street Sweeping Storm Drain Cleaning	1	1	1	1	3	7
Small-Scale Practices						
Rain gardens	2	2	3	2	3	12
Filter strips	2	1	2	1	3	9
Grasspave™ w/o infiltration	2	1	1	1	3	8
Gravelpave™ w/o infiltration	2	1	1	1	3	8
Infiltration basin	3	1	1	1	3	9
Inlet bioretention - Filterra	2	2	2	1	3	10
Corner bioretention	2	3	3	3	3	14
Courtyard bioretention	2	3	3	3	3	14
Sidewalk bioretention	2	3	3	2	3	13

Prioritization by BMP Types

As shown in tables 21 and 22, the proposed BMPs provide a range of effectiveness for pollutant removal and for quality of life benefits. Using the total cost per impervious area from Table 20, the benefit to cost ratio can be calculated. It is shown in Table 23 below.

Table 23: Cost / Benefit Ratio for BMP Types

Practice	Total Cost per Impervious Acre	Water Quality Benefits	Quality of Life Benefits	Total Benefits	Cost per Benefit Point	Rank
Regional Facilities						
Wet ED Pond	$7,754	8	8	16	$485	2
ED Wetland	$9,680	8	11	19	$509	3
Non-Structural Practices				0		
Street Sweeping	$20,275	6	7	13	$1,560	7
Storm Drain Cleaning		n/a				
Small-Scale Practices				0		
Rain gardens	$85,717	10	12	22	$3,896	10
Filter strips	$14,985	5	9	14	$1,070	6
Grasspave™ w/ infiltration	$13,447	14	8	22	$611	4
Gravelpave™ w/ infiltration	$14,048	14	8	22	$639	5
Infiltration basin	$5,619	13	9	22	$255	1
Inlet bioretention - Filterra	$40,403	10	10	20	$2,020	8
Corner bioretention	$134,359	10	14	24	$5,598	11
Courtyard bioretention	$85,717	10	14	24	$3,572	9
Sidewalk bioretention	$145,824	10	13	23	$6,340	12

The most cost effective structural BMP is the infiltration basin, largely because of its simplicity. It does not require much excavation or infrastructure, and is not landscaped. The two regional facilities, the wet pond and wetland, are ranked 2 and 3. While they offer lower benefits than most of the other BMPs, the economies of scale in construction reduce the cost enough to compensate.

Street sweeping falls in the middle range of cost effectiveness. This practice has a mid-range cost per impervious acre and provides both water quality and quality of life benefits; however, at a lower level than many of the other alternatives.

The two alternatives that are least cost effective are corner bioretention and sidewalk bioretention. The additional cost of construction or replacing a storm drain inlet with these systems make the cost significantly higher than the other bioretention BMPs.

Recommendations

Regional Facilities

Five regional facilities are proposed for the watershed restoration.

The entire treatment volume for the ED wetland proposed for Carroll Park has been included with Subwatershed 263-CC. The facility is undersized for the upstream drainage area, but would have the ability of treating the equivalent of 23.6 acres of impervious surface. Determination of how to divert the flow to the facility would be part of a preliminary engineering study.

Table 24: Costs for Regional Facilities

Recommendation	Location	Treated Area (ac)	Treated Impervious Area (ac)	Capital Cost	Life Cycle Cost
ED Wetland	Carroll Park	33.2	23.6	$139,336	$218,265
Wet Pond	US 40	5.7	4.3	$44,920	$70,368
Wet Pond	US 40	13.5	11.5	$94,162	$147,502
Wet Pond	US 40	13.1	9.9	$99,628	$156,065
Wet Pond	BRESCO	28.7	21.5	$106,314	$166,537
Total		94.2	70.8	$484,360	$758,736

Small-Scale Facilities

Table 25 at the end of this section shows the recommended small-scale watershed improvements. They include 102 infiltration and bioretention practices which will treat 132.4 acres, or about 14 percent of the impervious cover of the watershed. With the addition of the five recommended regional facilities, however, the recommended practices will treat 25% of the overall WS 263 impervious areas.

The regional facilities along US 40 will treat all of the area of subwatersheds I, J, and K. For this reason, the small-scale facility recommendations described elsewhere in this report are not found in this table and are not recommended.

Non-Structural Practices

The Urban Storm Water Work Group (USWG) of the Chesapeake Bay Program has begun a project to quantify the pollutant removal benefits of street sweeping in Watershed 263, in the paired subwatersheds of 263-F and 263-O.

The project will involve testing different street sweeping treatments (e.g., increase in effort, decrease in effort) concurrently to increase the chances of detecting change. Street sweeping practices are to be increased in Subwatershed O concurrently with a decrease in effort in subwatershed F, translating to a 48% increase in the number of curb miles swept in subwatershed O and an 85% decrease in curb miles swept in subwatershed F.

The total area to be swept in Subwatershed O is 58,812 LF, at a frequency of twice weekly. Using a 10-foot sweeping width, this works out to treatment of 13.5 impervious acres. The sweeping frequency gives a total of 1,158 curb-miles swept in this subwatershed, or about one-seventh the capability of a single sweeper and crew.

At an estimated cost of $20,275 per impervious acre, the NPV cost of sweeping Subwatershed O comes to $273,746.

Summary of Improvements

Table 25 summarizes the proposed improvements. The capital improvements proposed in this report and those for Subwatershed O proposed by the Center for Watershed Protection will treat 28% of the watershed's impervious area at total cost of approximately $10,992,827, or $56,974 per treated impervious acre. The improvements will exceed the goal of treating 20% of the watershed, which will allow for some variability if some projects can not be implemented.

Table 25: Summary of Improvements

Practice	Quantity	Treated Area (ac)	Treated Impervious Area (ac)	Capital Cost	Life Cycle Cost
Regional Facilities					
Wet ED Pond	4	60.9	47.2	$345,026	$540,471
ED Wetland	1	33.2	23.6	$139,336	$218,265
Non-Structural Practices					
Street Sweeping		13.5	13.5		$273,746
Storm Drain Cleaning					
Small-Scale Practices					
Rain gardens	4	4.9	3.0	$168,081	$263,582
Filter strips	1	0.8	0.6	$6,695	$9,036
Grasspave™ w/ infiltration	12	15.0	10.8	$107,661	$145,810
Gravelpave™ w/ infiltration	4	2.6	1.8	$19,382	$26,158
Infiltration basin	14	18.2	12.0	$50,593	$68,283
Inlet bioretention - Filterra	3	2.9	2.4	$24,156	$25,256
Corner bioretention	31	49.2	41.6	$3,559,586	$5,572,016
Courtyard bioretention	30	35.8	24.8	$1,366,955	$2,143,634
Sidewalk bioretention	13	14.8	11.7	$1,089,454	$1,706,570
TOTAL	117	251.7	192.9	$6,876,924	$10,992,827

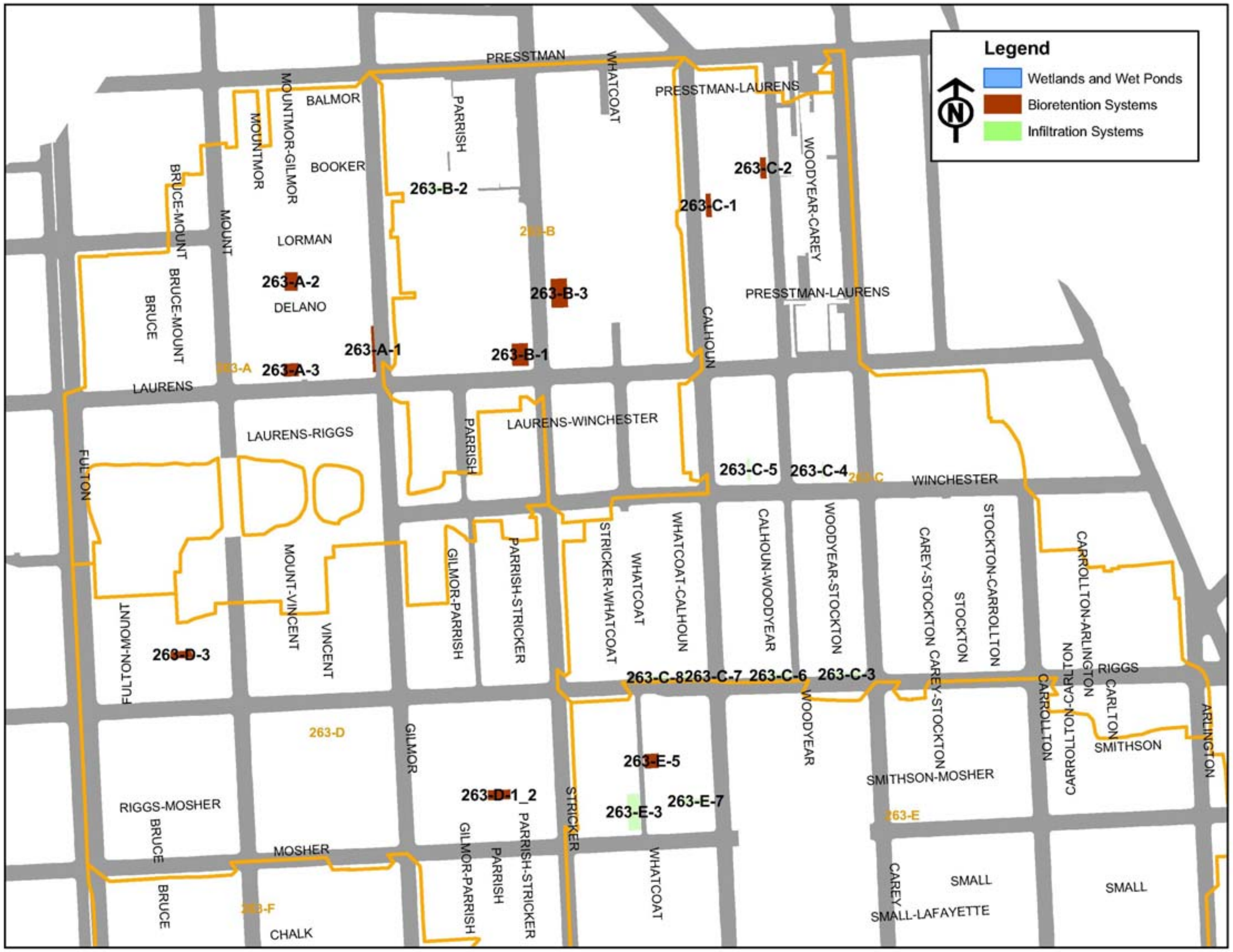


Figure 6: Proposed Improvements (1 of 7)

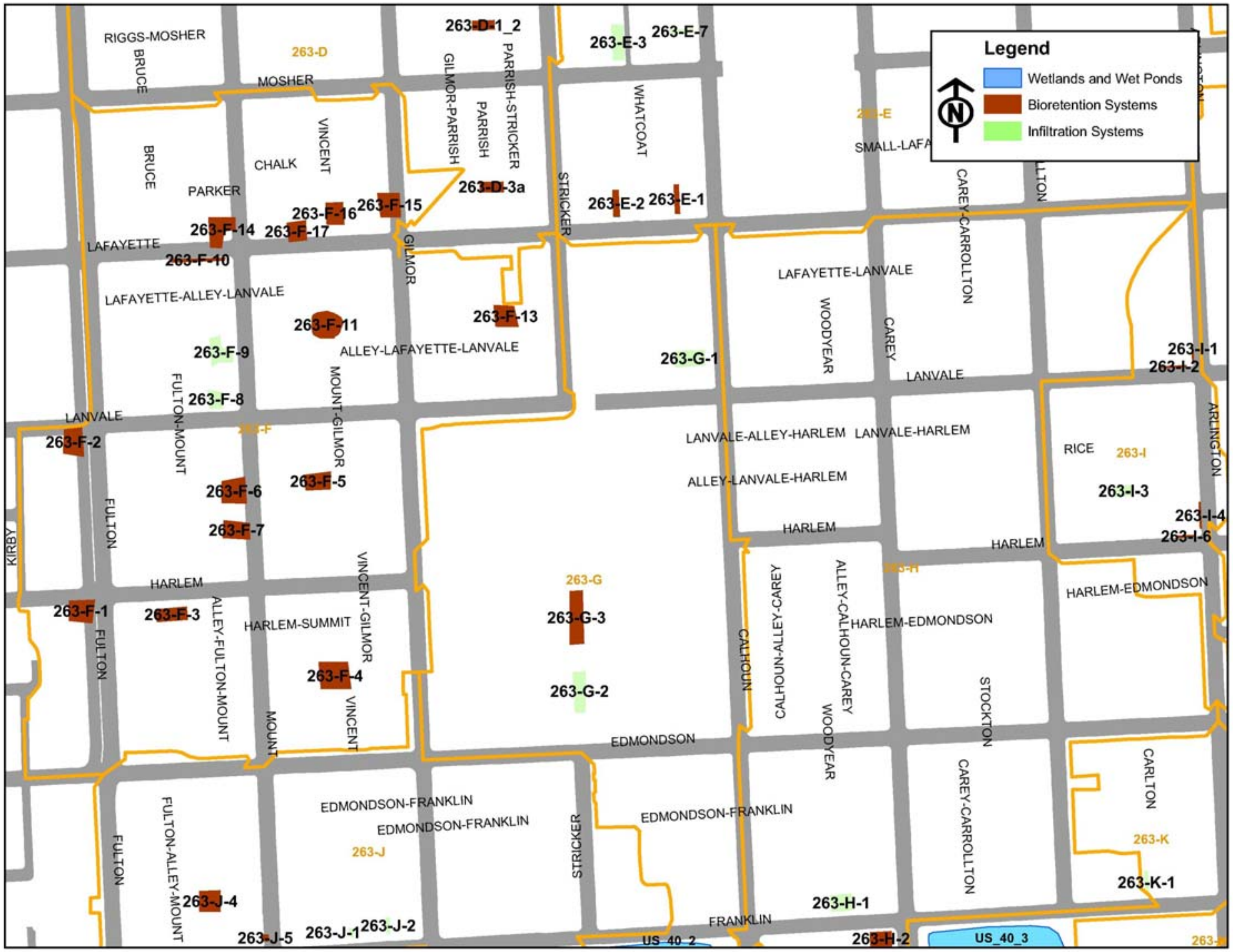


Figure 7: Proposed Improvements (2 of 7)

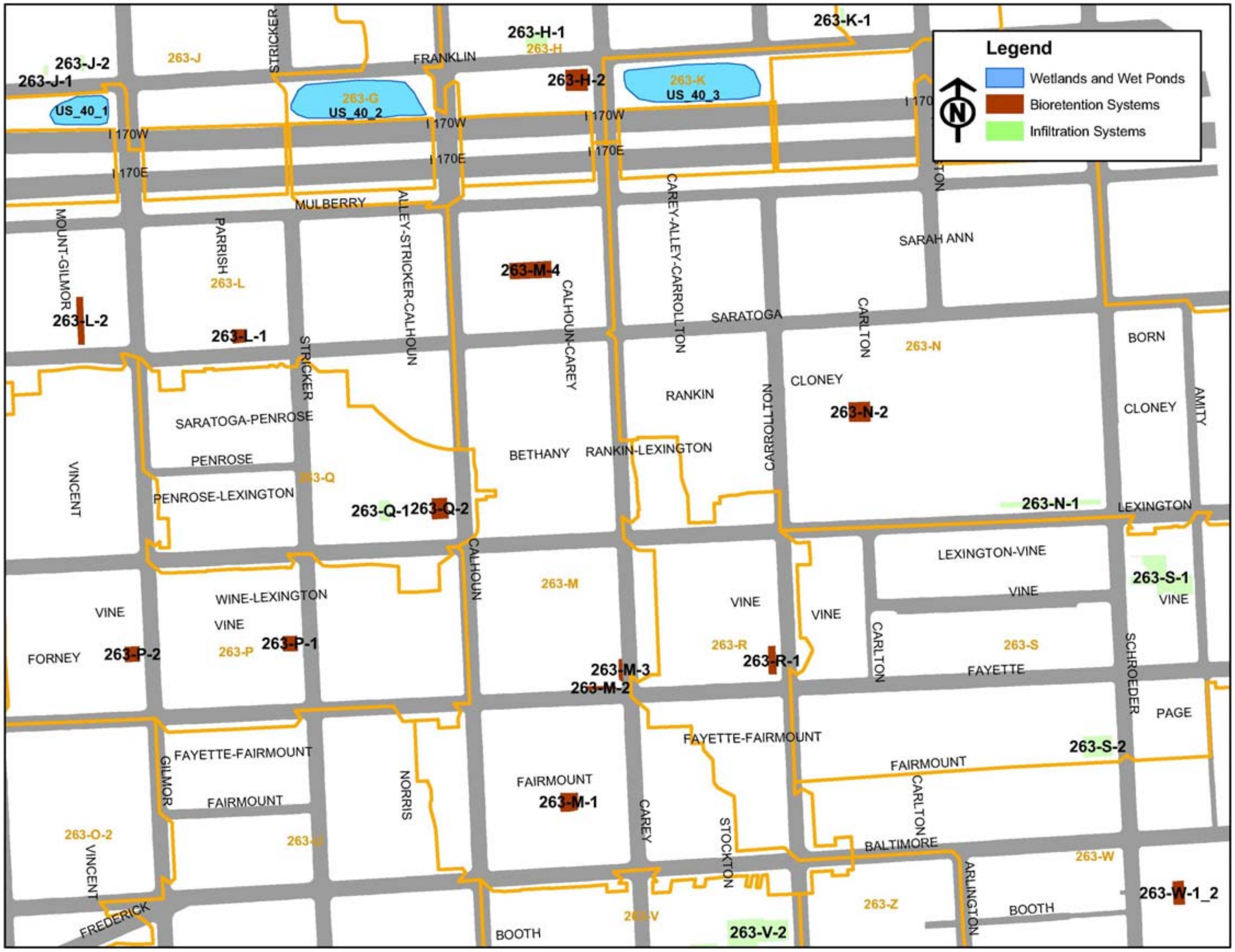


Figure 8: Proposed Improvements (3 of 7)

Figure 9: Proposed Improvements (4 of 7)

Figure 10: Proposed Improvements (5 of 7)

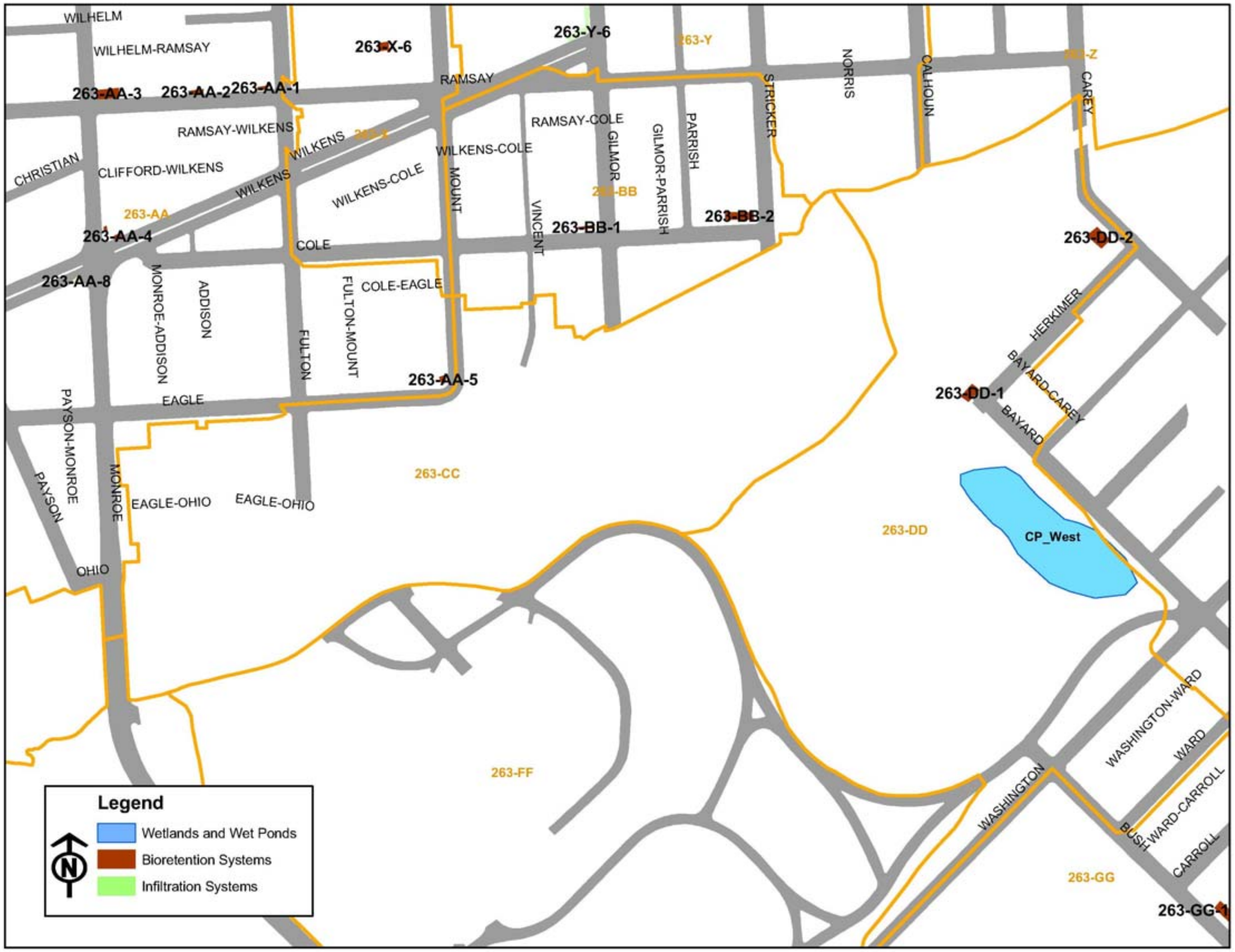


Figure 11: Proposed Improvements (6 of 7)

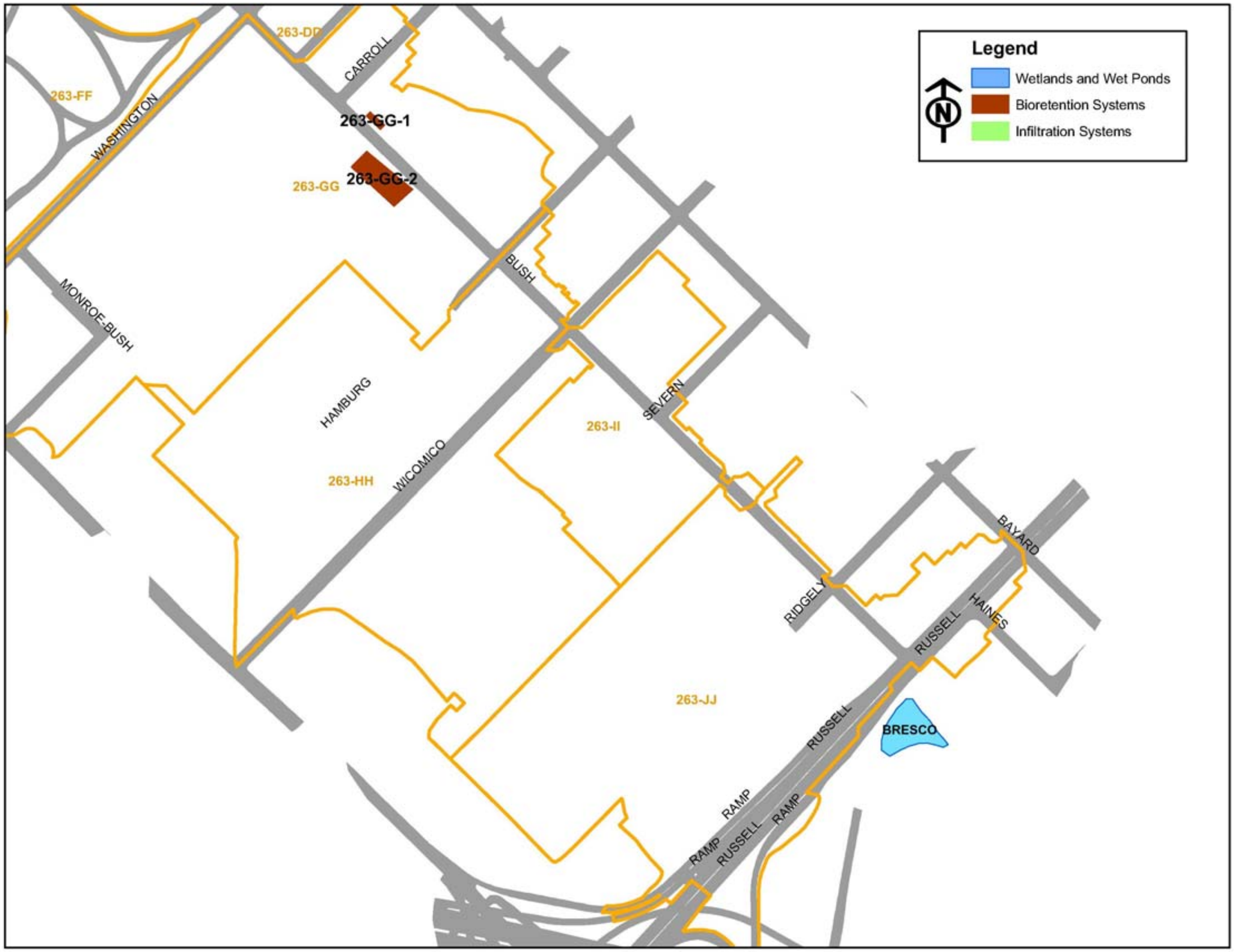


Figure 122: Proposed Improvements (7 of 7)

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Appendix A Visual Glossary

Appendix B BMP Design and Cost Spreadsheets

Appendix C Photos

Appendix D SWMM Modeling of Proposed Improvements

The existing conditions model was unchanged from the submittal with Task A of the project. For this task, however, BMPs were modeled in order to estimate the pollutant reduction achievable from the proposed improvements.

Three types of BMPs were modeled:

- Small-scale structural BMPs
- Regional structural BMPs
- Street sweeping

Structural BMPs

All structural BMPs were modeled in the TRANSPORT block of SWMM, using a node feature called a Water Quality Splitter. The node treats flows below a user-set limit and bypasses flows above that limit with no treatment. The reasoning behind this split is that BMPs are typically designed for a certain flow (WQv, for example) and once that flow is reached there is no capacity to treat additional flow.

Treatment is represented by a percent reduction for each pollutant, in the same manner as other models, such as the Simple Method. Percent reduction was derived from the informataion shown in Tables 14 and 15 in the report. For the small-scale BMPs, a removal efficiency representative of the mix of projects was derived. The majority of the area was treated by some type of bioretention BMP (75%). An equal amount of area was treated by porous pavement or infiltration systems (12.5% each). As a result, the final removal efficiency was weighted toward bioretention, as follows:

Pollutant	ED Wet Pond	Wetlands	Bioretenti on	Infiltration	Porous Pavement	Small-Scale Efficiency Used
TSS	80	75	80	90	90	80
TP	50	50	60	60	65	60
TN	35	30	40	50	85	45
TKN						
NOx	60	65	15	80	80	30
BOD5	45	45	65	80	80	70
FC	70	75	35	90	90	50
Cd						
Cu	55	40	95	70	70	90
Zn	70	40	95	95	95	95
Pb						
TPH	80	85	84			80
Phenols						
O&G	80	85	84			80

Flows to the BMPs were calculated using the RUNOFF block of SWMM. Drainage areas for each BMP were delineated earlier in the project, and these were used to summarize area and imperviousness for each BMP. Other catchment parameters (subcatchment width, depression storage, infiltration) remained the same as the overall subwatershed.

Street Sweeping

Street sweeping was modeled in the RUNOFF block using the routines provided for this purpose. Removal efficiencies were derived from James, William, et. al (2000), Claytor (2000), and Caraco (2001), and compared to those used in the Stony Run Watershed Restoration Plan (EA, 2001). The set of removal efficiencies used in the study are shown in the last column of the table below.

Source:	James	James	Claytor	Caraco	Caraco	Caraco		2001	
Pollutant	SWMM Vacuum 1K to10K 2 pass	SWMM Mech 2 pass	CWP (Average, Weekly, High-Eff)	CWP WTM Weekly SFR Mech	CWP WTM Weekly SFR Regen	CWP WTM Weekly SFR Vac Assist	AVG Vacuum	EA Stony Run Plan	USE
TSS	60	75	55.0	30	64	78	64	50	60
TP			42.5	24	51	62	52	40	40
TN				24	51	62		40	40
TKN	54	58					54		50
NOx									
BOD	50	58					50		50
FC									
Cd	57	45					57	50	50
Cu	63	58	42.5				53	50	50
Zn	69	64	37.5				53	40	40
Pb	79	65	47.5				63	50	50
TPH									
Phenol									
O&G									

Appendix E Stormwater Management Strategy for Catchment O -- Center for Watershed Protection