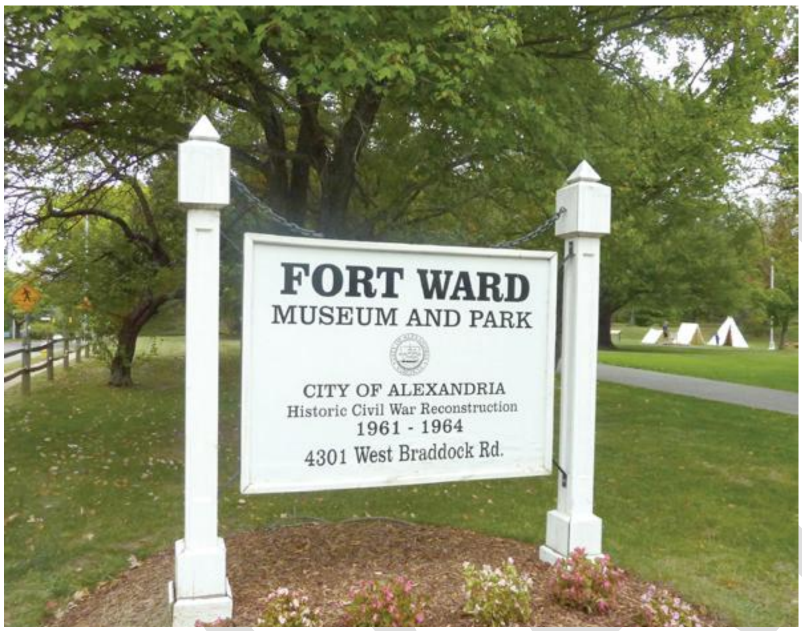
FORT WARD PARK
DRAINAGE MASTER PLAN



Prepared for

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Figures

Tables

Appendices

ADA	Americans with Disabilities Act
BMP	Best Management Practice
C	Rational Method Runoff Coefficient
cfs	cubic feet per second
City	City of Alexandria
CWA	Clean Water Act
DEQ	Virginia Department of Environmental Quality
EMO	Environmental Management Ordinance
ESC	Erosion and Sediment Control
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
IDF	Intensity-Duration-Frequency
in	inch
min	minute
MOT	Maintenance of Traffic
MS4	Small Municipal Separate Storm Sewer System
N/A	Not Applicable
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWP	Nationwide Permit
Park	Fort Ward Park
PVC	polyvinyl chloride
SSA	Storm and Sanitary Analysis
SWM	Stormwater Management
SWPPP	Stormwater Pollution Prevention Plan
T_c	time of concentration
T_t	calculated travel time
TMDL	Total Maximum Daily Load
URS	URS Corporation

USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VDHR	Virginia Department of Historic Resources
VPDES	Virginia Pollutant Discharge Elimination System
VSMP	Virginia Stormwater Management Program
WQS	Water Quality Standards

EXECUTIVE SUMMARY

This report summarizes URS Corporation's (URS') analyses of the potential opportunities to address the drainage and erosion issues in Fort Ward Park (Park) in the City of Alexandria (City), Virginia.

Fort Ward Park covers 43.46 acres of land on the west end of Old Town Alexandria, large areas of which is forested or grassy and has limited constructed stormwater systems and few existing stormwater controls. The Park is susceptible to nuisance flooding and erosion due to overland flow concentration and flooding on properties near the southeastern boundary of the Park.

URS conducted a field reconnaissance and examined 16 sites at the Park to evaluate the existing conditions and to identify potential measures to improve the drainage and sedimentation. In addition, URS performed hydrologic and hydraulic analyses to verify the capacity of the existing stormwater system (Sections Three and Four).

URS attended two public meetings held by the Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group. During the meetings, URS presented the engineering findings of this study and addressed stakeholders' comments.

Section Five of the report summarizes the drainage improvement recommendations based on the field observations, engineering calculations, and community input. The recommendations include both structural and nonstructural measures. Further analyses are performed and described in Section Six for three recommended storm drainage system improvements to address drainage issues on targeted sites. The recommendations include retrofitting the existing stormwater system to reduce sedimentation and to improve the water quality of runoff; constructing two diversion berms and an underground drainage pipe to improve the nuisance flooding and erosion at the Oakland Baptist Cemetery; and stream stabilization to reduce erosion and improve the overall health of the stream. Section Six includes preliminary description of the recommended improvements, design consideration, feasibility, and cost estimates on planning level.

Section Seven summarizes the regulatory and permitting considerations applicable to the recommended drainage improvements.

This report compliments the Fort Ward Park and Museum Area Management Plan and can be used as supporting documentation for future drainage improvements. The recommendations in the report are consistent with the recommended best practices in the Fort Ward Park and Museum Area Management Plan.

SECTION ONE: INTRODUCTION

1.1 AUTHORIZATION

The City of Alexandria (City) signed a contract with URS Corporation (URS) on April 30, 2013 to develop a *Storm Drainage Master Plan* for Fort Ward Park. The project was funded by the City.

1.2 BACKGROUND AND PURPOSE

Fort Ward Park (Park) is a historic park located in the City of Alexandria (City), Virginia. It is regarded as the best preserved fort and battery built to protect Washington, DC during the American Civil War (1861–1865). The Park is the home of the Fort Ward Museum, which features Civil War exhibits, interpretive programs, tours, lectures, and living history activities.

The Park covers 43.46 acres of land on the west end of Old Town Alexandria. Much of the Fort has been preserved or restored. An archaeological investigation conducted in 2011 identified and documented 22 previously unmarked grave sites.

The Park is susceptible to drainage problems including erosion due to overland flow concentration and flooding, especially on properties near the southeastern boundary of the Park. The challenge is to manage the stormwater runoff and to minimize flooding and erosion while preserving the historic and archaeological resources of the Park.

The City’s goals are to determine methods to improve the stormwater conveyance and minimize erosion while preserving the recreational, historic, and archaeological functions of the Park. The purpose of this study is to evaluate existing storm drainage problems and provide recommendations to the City for future storm drainage improvements in the Park while meeting the goals and expectations of the City.

URS performed the following tasks:

1. Identification of Drainage Problems: This task involves a desktop analysis using GIS, as well as field reconnaissance at the Park.
2. Hydrologic and Hydraulic Analysis: This task involves the hydraulic and hydrologic analyses within the Park drainage area.
3. General Recommendations: This task involves general recommendations for each of the drainage problems at the Park based on field investigation and hydrologic and hydraulic analysis.
4. Project Presentations to Stakeholders and the City: This task includes communicating and coordinating with the City and the stakeholder on project findings and recommendations.
5. Concept Design Plans: This task involves developing schematic concept plans for three recommended improvements.
6. Estimated Cost of Construction: This task involves developing preliminary cost estimates for construction of the recommended capital improvements.

1.3 STAKEHOLDER MEETINGS

URS attended two public meetings with the Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group. The intent of these meetings was to provide the stakeholders with information about the City's goals and the methods used in the course of this study. Stakeholders were also given an opportunity to express their thoughts and comments on existing drainage issues.

A number of public concerns were identified during these meetings, including the restoration effort necessary to correct the drainage and erosion issues in the cemetery and Marlboro Estate neighborhood.

The dates of the stakeholder meetings are presented in Table 1. The presentations for each stakeholder meeting can be found in Appendix A.

Table 1: Stakeholder Meetings

Meeting Date	Location	Attendees
June 12, 2013	Minnie Howard School	Representatives from the Advisory Group, the City, and URS
August 14, 2013	Minnie Howard School	Representatives from the Advisory Group, the City, URS, and Ladner/Klein Landscape Architects, PC

1.4 FORT WARD PARK AND MUSEUM AREA MANAGEMENT PLAN

The City has launched a long-term effort to develop the Fort Ward Park and Museum Area by documenting the historical, cultural, and recreational significance of the Park as well as risks and vulnerabilities. The ongoing effort was initiated in April 2012 by the City's Park and Recreation Commission. The Fort Ward Park and Museum Area Management Plan Management Plan synthesizes these efforts into a cohesive document that offers management recommendations to protect and enhance Park resources and benefit the public.

The Final Draft Fort Ward Park and Museum Area Management Plan (January 2014) outlines potential and anticipated improvements to the Park. These improvements include a series of Best Management Practices for the following topics:

- Park Stewardship
- Physical Changes
- Earthworks
- Land cover Establishment
- Plant Species Control

- Woodland Clearing
- Adapting Historic Road Traces as Trails.

Some of the Best Management Practices include specific recommendations relating to drainage issues on the site with respect to reducing erosion and improving stormwater conveyance such as: aerating soil and reseeding turf; redirecting stormwater away from sensitive areas; and maintaining clogged storm drain systems. The recommendations related to drainage systems contained in the Fort Ward Park and Museum Area Management Plan are consistent with and complement the information presented in this Drainage Master Plan.

SECTION TWO: STUDY AREA CHARACTERISTICS

2.1 STUDY AREA LOCATION

Fort Ward Park is at the west end of Old Town Alexandria and consists of 43.5 acres. The Park is bounded by Braddock Road to the south, Van Dorn Street to the north, and a residential community to the east. Figure 1 shows an aerial view of the Park and the existing condition on the site.

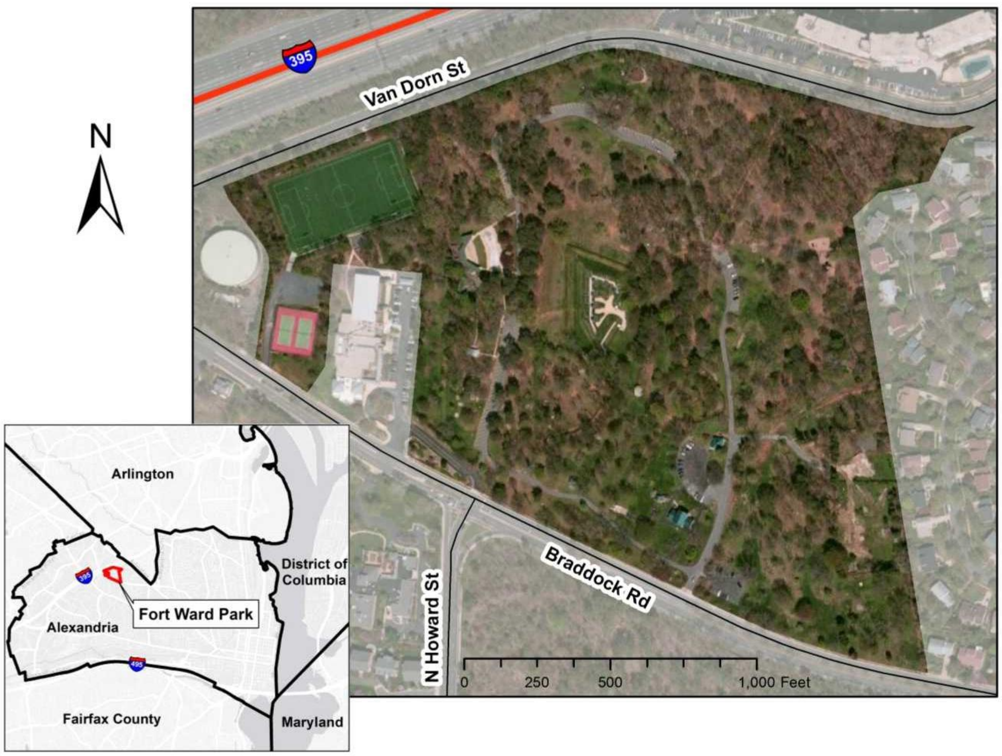


Figure 1: Fort Ward Park Vicinity Map

2.2 LAND USE

The Park land use is primarily public open space incorporating woodlands, meadows, the fort, and the cemetery. Approximately 3.5 acres of the site is developed and paved with impervious surface. The surrounding land use is made up of single-family residential zones, townhouse residential zones, and high-density apartment zones. The City of Alexandria provided 2009 zoning data that showed the current zoning of the Park is “Public Open Space.”

2.3 TOPOGRAPHY

The site has a rolling topography with moderate slopes. Topographic data were provided by the City and the vertical datum for the data is the North American Vertical Datum 1988 (NAVD 88).

The highest point is located near the center of the park and has an elevation of 290 feet. The lowest point is at the northeast corner of the Park with an elevation of 212 feet.

2.4 SOILS

Most of the Park consists of the Kingstowne-Sassafras-Neabsco complex, which has poorly drained soils with low infiltration rates and high clay content. Soils have also been compacted due to recreational use, vehicle traffic, and construction activities, further reducing infiltration capacity. Less than 10 percent of the Park is made up of moderately well drained loamy soils (Sassafras-Neabsco complex) with moderate infiltration capacity. Soil data were obtained from the 2009 Soil Survey Geographic database of the Natural Resources Conservation Service (NRCS).

2.5 CHALLENGES

2.5.1 Environmental Challenges

Drainage problems in the Park include erosion due to overland flow concentration and flooding on the cemetery and properties near the southeastern boundary of the Park.

In 2012, the City implemented interim drainage improvements on the east side of the Park to divert runoff from Oakland Baptist Church Cemetery and neighboring Marlboro Estates subdivision. The measures included installation of small catch basins, drainage pipes, and infiltration trench drains (Figure 2). The improvements provide a temporary solution to prevent runoff from flowing into the cemetery.

A recent report by the Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group (2013) explains that erosion remains the critical threat to the stability and preservation of the Fort and the integrity of the bastions. Erosion is caused by natural effects of weather; poor soil quality; lack of sunlight in some areas, which prevents the growth of healthy ground cover; uprooted trees, which disturb earthen remains; and foot traffic on the wall surfaces.

2.5.2 Archaeological Activities

Contemporary interest in the historical significance of Fort Ward Park as a whole and its African-American history, as well as a desire to preserve its cultural resources, led to an archaeological investigation starting in 2009. The City carried out a ground-penetrating radar survey to identify unmarked graves and then completed fieldwork in January 2011. The survey results confirmed the presence of many burial sites. Additional research and family accounts chronicled how the Fort neighborhood was lost in the process of the City’s efforts to purchase the land and create the historical park. The archaeological study documented 22 graves, 19 of which were unmarked, in the Jackson Cemetery on the west side of the Fort, the old graveyard adjoining the Oakland Baptist Cemetery, and in the eastern portion of the Park (Adams’ graves). Also discovered were foundations and artifacts associated with one of the earliest households at the Fort and an African-American school. It is believed that the Park harbors many more unmarked burial sites.

The ongoing archaeological investigation expands to suspected burial areas and home sites. A shovel test survey of the entire park will be performed at 30-foot intervals to identify sensitive resource areas. This will result in an updated cultural resource inventory in preparation for planning activities for the Park.

According to a memo by Office of the City Manager (2013), the archaeological investigation has identified 43 gravesites, including 3 burials marked by a gravestone and 40 unmarked burials.

2.5.3 Recreational Significance

The Park serves as a significant recreational resource to residents and visitors. A 2013 survey conducted by the Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group suggested the Park has more than 100 visitors on average per day. Park visitors enjoy outdoor recreational opportunities such as walking, jogging, picnicking, gatherings, and cultural events, and benefit from the playground facilities and dog park.

SECTION THREE: EXISTING STORM DRAINAGE CONDITION

The evaluation of the Fort Ward Park includes an analysis of existing land use, pervious and impervious areas, soils, development, and archaeological and natural resources of the site. Geographic Information System (GIS) data available from the City in 2012 were used to characterize the existing conditions. Field assessments were conducted to evaluate the ground condition, on-site stormwater collection system, and interim drainage solutions.

3.1 DATA REVIEW AND COLLECTION

The City of Alexandria provided URS with GIS data that included:

- 2-foot contours
- Aerial photographs
- City boundary
- City parcels
- Roads
- Zoning
- Building footprints
- Storm drain networks and nodes
- Streams
- 100-year floodplain boundary
- Parks
- Impervious coverage

URS conducted an extensive review of local development plans, archaeological investigations, and Park management plans to better understand the baseline conditions and the future vision for the Park. Additionally, potential restoration opportunities were evaluated based on the benefit they would provide to the City and the Advisory Group. The City provided information to URS as AutoCAD drawings, site plans, and reports. A summary of the data reviewed is provided in Table 2.

Table 2: Data Received from the City of Alexandria

Name	Author	Format
U.S. Geological Survey (USGS) quadrangle map, Alexandria (1945)	USGS	Quadrangle map in JPG format
Marlboro Estates Site Plan (1976)	City of Alexandria	Site Plan in PDF format
Fort Ward Archaeological Investigations (2010–2012)	City of Alexandria	GIS data
Survey files for Fort Ward archaeology investigations (2010–2012)	City of Alexandria	AutoCAD files
Fort Ward Park Interim Drainage Design Solution (2011)	City of Alexandria	PowerPoint Presentation in PDF format
Fort Ward Park Temporary Drainage Improvement (2011)	City of Alexandria	Site Plan in PDF format
Recommendations for the Management of Fort Ward Historical Park (2011)	Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group	Report in PDF format
Fort Ward Park/Bastion Walkway Project (2013)	City of Alexandria	Site Plans in PDF format

Name	Author	Format
City's Responses to Fort Ward Issues (2013)	City of Alexandria	Letter to Oakland Baptist Church and The Fort Ward and Seminary African-American Descendants Society in PDF format, dated May 6, 2013
2012–2013 Advisory Group Draft Recommendations	The Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group	Report in PDF format
Fort Ward Park and Museum Area Management Plan: Existing Conditions (Final Draft) (January 2014)	Fort Ward Advisory Group, City of Alexandria	Final Draft report in PDF format

3.2 FIELD RECONNAISSANCE

URS performed field reconnaissance to review the existing conditions of the Park. The purpose of the field assessment was to obtain information required to conduct hydrologic and hydraulic analyses, to observe the existing ground condition, to assess existing drainage issues, and to assess the possibility of drainage improvements. Factors that affect the potential for drainage improvements include site constraints, access issues, and utility conflicts.

During the field reconnaissance trip, URS staff conducted a detailed on-site investigation, and identified existing drainage problems. Field data collected at each location included:

- Location
- Observed problems at the site
- Sketch of site
- Sketch of identified potential improvement measures

Photographs were taken as part of the field reconnaissance to record the existing condition at each site.

The detailed field reconnaissance report is included in Appendix B.

3.3 EXISTING DRAINAGE PATTERN AND CONVEYANCE SYSTEM OVERVIEW

Figure 2 shows the general drainage patterns in the Park. There are three major outfalls in the Park. Approximately 35 percent of the site drains west to the storm drainage system underneath the football field to Outfall A.

Approximately 50 percent of the Park drains northeast to the Stormwater Management (SWM) Pond before entering the City's storm drainage system at Outfall C. The SWM Pond also captures the off-site runoff from the area west of Braddock Road and the Marlboro Estate subdivision.

The rest of the Park drains north via swales before entering the storm drainage system near Van Dorn Street at Outfall B.

Approximately 3.5 acres of the Park is developed with impervious surface (e.g., buildings, parking lots, and roads), with the remaining undeveloped land consisting of open field and grassy areas.

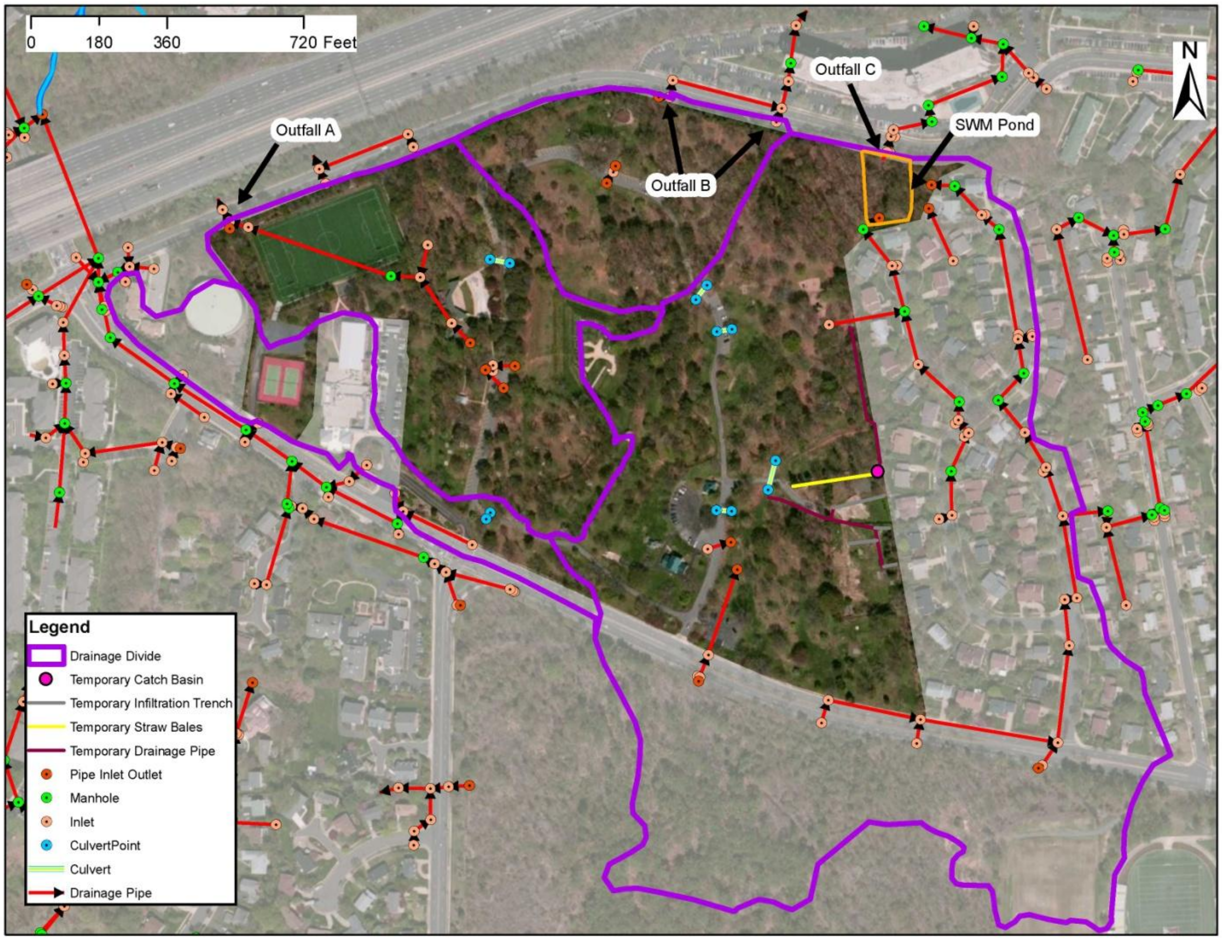


Figure 2: Drainage Patterns in Fort Ward Park

3.4 WATERSHED AND DRAINAGE BASINS

Fort Ward Park is part of the Four Mile Run watershed, which is approximately 20 square miles in area covering the Cities of Alexandria and Falls Church and portions of Arlington and Fairfax Counties. The Four Mile Run watershed is highly urbanized and approximately 85 percent of the watershed is considered to be a developed area. Fort Ward Park drains into the lower portion of the Four Mile Run through the storm sewer system via the various outfalls (shown in Figure 2).

3.5 EXISTING STORMWATER DEFICIENCIES

Combining the observations from the field reconnaissance and the results of hydrologic and hydraulic analysis, URS identified 16 sites that have or could develop drainage deficiencies.

Deficiencies include nuisance flooding, sedimentation and erosion, flooding during more extreme events, or a combination. Figure 3 shows the locations of the 16 sites.

The following information is provided for each site:

- Ownership: the party responsible for the site improvement.
- Existing conditions: a summary of existing site conditions, including the drainage capacity of swales and culverts if applicable.

Site Number	Ownership	Existing Conditions
1	City	Shallow drop inlet near the museum and the parking lot. No major problems noted during the field reconnaissance.
2	City	15-inch culvert crossing under the entrance road near bathrooms. A small ponding area was observed at the culvert inlet.
3	City/Private	Outlet of 18-inch pipe that collects runoff from upstream forested area and Braddock Road. Sediment and debris deposition was noted at the outfall.
4	City	Swale in the natural area with "No Mowing" sign nearby. No major problems noted during the field reconnaissance.
5	City	The 36-inch culvert under the road that leads to the utility yard appeared to be partially blocked; in addition, vegetation was overgrown around the culvert. Observed sediment and debris buildup at the 6-inch PVC underdrain pipe located just upstream of the 36-inch culvert.
6	City	Old Utility Yard. Several infiltration trenches have been installed to prevent runoff from reaching the cemetery. A temporary catch basin collects runoff from the small trench along the fence line, which divides the park property from the neighborhood. The runoff from the catch basin drains toward the 36-inch culvert and downhill of the cemetery. Temporary hay bales have been set up to prevent runoff from entering the cemetery.
7	City	The main stream channel that runs through the Park is eroded and there is concrete debris in the channel. A swale has formed from backyard drainage conveyance from residential property. In addition, there is a clogged inlet at the downstream end of the natural stream channel.
8	Private	The base areas are exposed on several gravestones in the cemetery. Depressions have formed in front of several graves from ponding during rain events. There are several areas of exposed, bare ground in the cemetery. A channel is forming through the cemetery where runoff flows during rain events.
9	City	A channel has formed on the hill adjacent to the playground. Two yard inlets collect drainage from the hill before it gets to the playground. One of them is completely covered by sediment and leaves. A channel has formed through the playground. There is a rock outfall and filter fabric at the outfall of the channel through the playground. There are areas of bare ground on the hill upstream of the playground.
10	City	A clogged yard inlet was noted near the footbridge over the swale surrounding the Fort. The cross-culvert inlet upstream from the rifle trench appeared to be clogged at the time of the field visit.
11	City/Private	There appear to be water quality issues in the Pond at the northeast corner of the Park boundary. The water is cloudy from sediment and appears discolored.
12	City	Park outfalls along Van Dorn Street. Inlets collecting drainage from the Park are clogged with debris. Channels have formed downstream of cross culverts discharging runoff.

Site Number	Ownership	Existing Conditions
13	City	Bare spots were noted on the hill near the soccer field. An inlet at the base of the hill is clogged and a channel has formed upstream of the inlet.
14	City	No problems were observed near the manhole and inlets near the soccer field and amphitheater.
15	City	Areas of exposed, bare ground were seen in the open areas near the parking lot, near the amphitheater and adjacent open area. The inlet adjacent to the west side of the Fort is clogged. There is a depression at the 15-inch culvert inlet under the parking lot. Sedimentation was seen in the parking lot due to blockage from a telephone pole being used as a landscape timber.
16	Private	Runoff from the properties in Marlboro Estates is draining onto Park property and contributing to drainage issues.

PVC = polyvinyl chloride

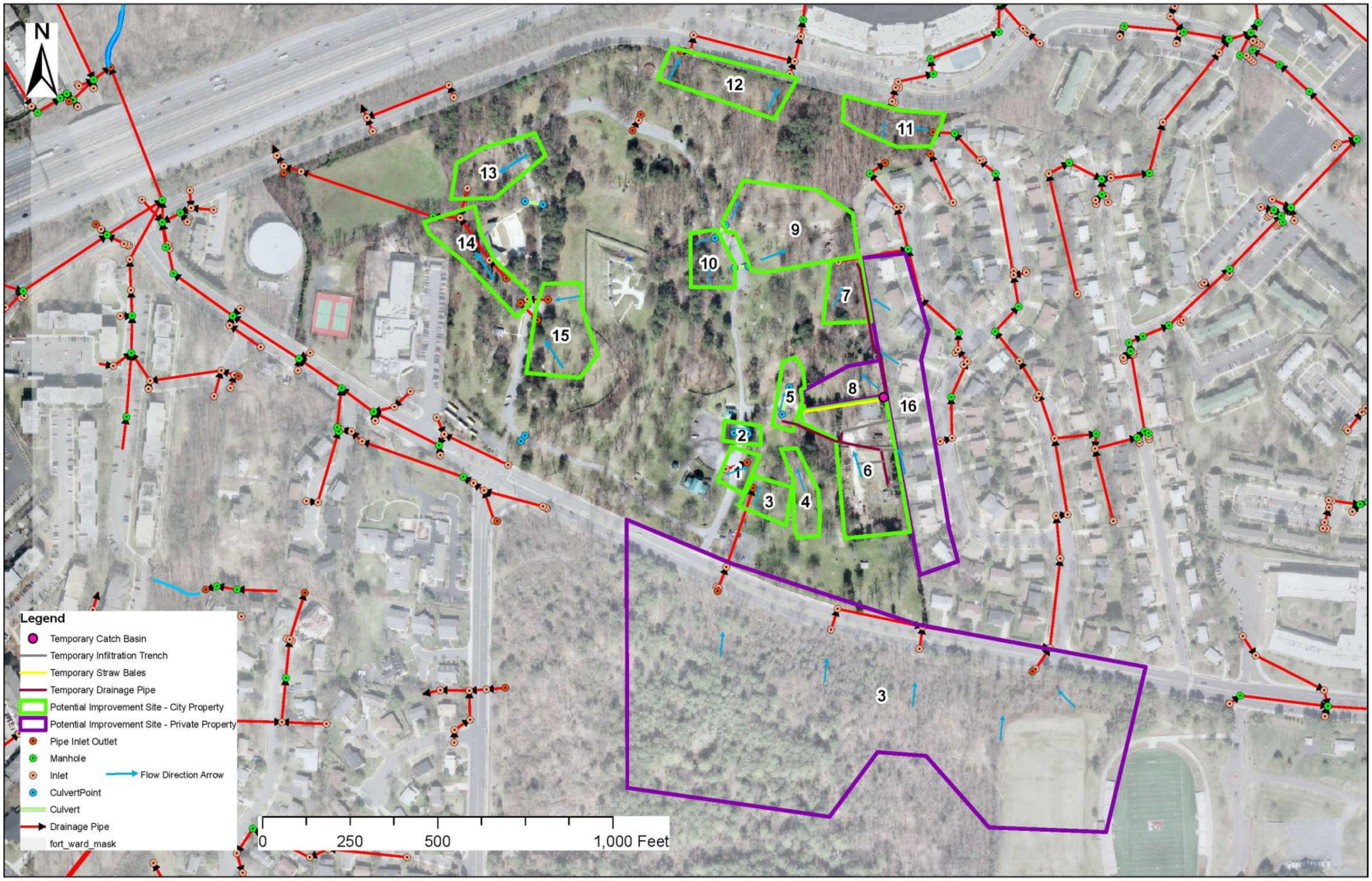


Figure 3: Fort Ward Park Sites for Potential Improvement

SECTION FOUR: ANALYSIS METHODOLOGY

4.1 HYDROLOGIC ANALYSIS

4.1.1 Modeling Development

URS performed a hydrologic analysis of the Park to develop a baseline model for the City. Results of the analysis shows the volume of water flowing through each location and can be used by the City for future Stormwater Management projects.

URS developed the hydrologic model using GIS mapping and Autodesk Storm and Sanitary Analysis (SSA) 2011 version 5.0 as requested by the City. The 2012 Zoning GIS data provided by the City were used along with data from the field reconnaissance in hydrologic modeling and calculations. URS developed the watershed delineation and attribute management using Esri ArcGIS 10. After conversations with the City on the preferred analytical method, the Rational Method was used to perform the hydrologic analysis for the Park. SSA was used to develop flows for the 1-, 2-, 10-, 25-, and 100-year storm events.

4.1.2 Modeling Input Parameters

After reviewing project specifications and recommendations, and understanding the project's objectives, specific data needs were defined and collected. The data sets used in the hydrologic modeling are described below.

The City provided 2-foot topographic data. The vertical datum used for this project is the North American Vertical Datum 1988 (NAVD 88), dated October 2012. The data were provided in a GIS shapefile format. The topographic data were used to delineate subwatersheds within the Park. The City also provided GIS zoning data. The 2009 City of Alexandria zoning data were used to represent existing land use. The GIS soil data coverage used for modeling the Park was obtained from the Soil Survey Geographic database (NRCS, 2009), which can be accessed at http://SoilDataMart.nrcs.usda.gov/.

Rainfall infiltration losses were estimated using the Rational Method Runoff Coefficient (C). The 2009 Alexandria zoning data contain five different land use types in the drainage area surrounding Fort Ward Park (Table 3). These zones were reclassified into four hydrologic soil groups based on their similarity in hydrologic responses. Each of these categories has a different C value depending on the hydrologic soil group classification of the land use. Due to the relative steepness of slopes within the park, C values were chosen based on 6 percent or greater land slope. Table 3 summarizes C values for the different zoning categories and four hydrologic soil groups. The rainfall intensity estimates were obtained from the rainfall Intensity-Duration-Frequency (IDF) curves for the City of Alexandria dated from 1941–1969.

Table 3: Land Use and C Values from Autodesk Storm and Sanitary Analysis 2011

No.	2009 Alexandria Zoning Categories	Equivalent C Category	C Value by Soil Type			
			A	B	C	D
1	Public Open Space	Open Space, less than 25 years	0.14	0.19	0.24	0.28
2	Public Open Space	Open Space, 25 years or greater	0.2	0.26	0.32	0.39
3	Residential Single Family Zone, 20,000 square-foot lot	Residential Lot Size 1/2 Acre, less than 25 years	0.24	0.28	0.32	0.37
4	Residential Single Family Zone, 20,000 square-foot lot	Residential Lot Size 1/2 Acre, 25 years or greater	0.32	0.36	0.42	0.48
5	Residential Single Family Zone, 8,000 square-foot lot	Residential Lot Size 1/4 Acre, less than 25 years	0.29	0.33	0.36	0.4
6	Residential Single Family Zone, 8,000 square-foot lot	Residential Lot Size 1/4 Acre, 25 years or greater	0.37	0.42	0.47	0.52
7	Residential Townhouse Zone	Residential Lot Size 1/8 Acre, less than 25 years	0.31	0.35	0.38	0.42
8	Residential Townhouse Zone	Residential Lot Size 1/8 Acre, 25 years or greater	0.4	0.44	0.49	0.54
9	Residential High Density Apartment Zone	Residential Lot Size 1/8 Acre, less than 25 years	0.31	0.35	0.38	0.42
10	Residential High Density Apartment	Residential Lot Size 1/8 Acre, 25 years or greater	0.4	0.44	0.49	0.54

4.1.3 Modeling Approach

URS developed the hydrologic model using Autodesk SSA 2011 (Autodesk, 2011) as requested by the City. Autodesk SSA can be used to model drainage systems using GIS shapefiles and user inputs. URS developed the terrain preprocessing, watershed delineation, and attribute management using ArcGIS 10 (Esri, 2010). The drainage map is shown in Figure 4.

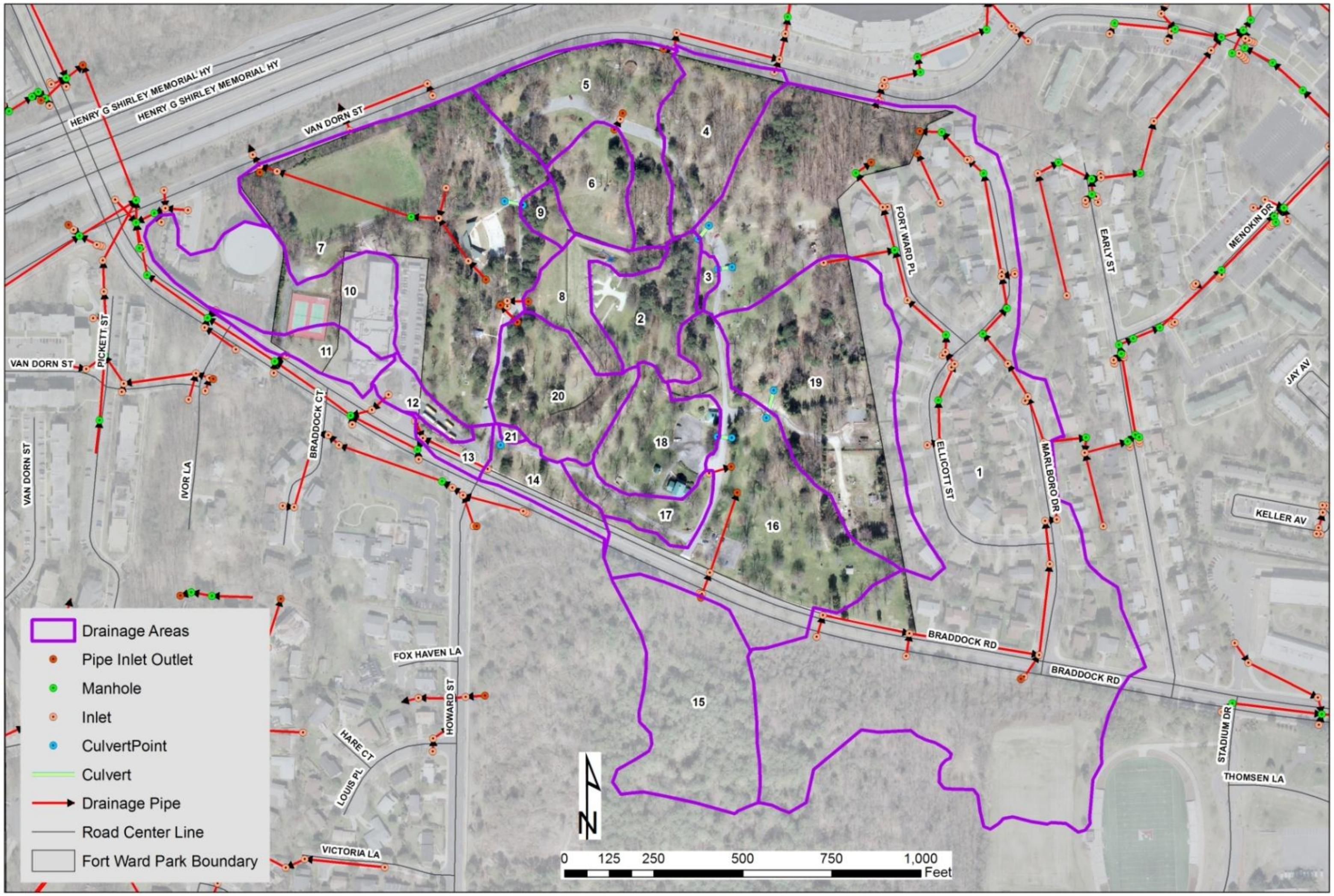


Figure 4: Fort Ward Park Drainage Divide Map

Key hydrologic parameters that are required for the SSA rainfall-runoff model include watershed-related parameters and precipitation data associated with design storms. Watershed-related input parameters needed for the SSA model include rainfall infiltration losses, drainage area, and time of concentration.

Rainfall infiltration losses were estimated using the Rational Method Runoff Coefficient, C, wherein C is the parameter used to represent drainage area properties including soil type, land use, and average slope. Composite runoff coefficients were calculated in the Subbasins tool in SSA. Table 4 shows the C values calculated for each sub-area.

Table 4: Hydrologic Parameters for Subbasins

Basin	Area (ac)	Runoff Coefficient (less than 25 years)	Runoff Coefficient (greater than 25 years)	Time of Concentration (min)
1	29.50	0.34	0.45	20.47
2	1.91	0.28	0.39	13.14
3	0.15	0.28	0.39	7.71
4	2.39	0.28	0.39	11.41
5	3.61	0.28	0.39	13.41
6	1.40	0.28	0.39	7.12
7	9.82	0.27	0.37	5.00
8	1.40	0.28	0.39	13.72
9	0.37	0.28	0.39	6.76
10	3.24	0.35	0.46	12.57
11	0.91	0.34	0.45	14.57
12	0.56	0.35	0.46	5.00
13	0.44	0.28	0.39	5.00
14	0.99	0.28	0.39	7.41
15	4.45	0.28	0.36	35.79
16	6.53	0.28	0.39	16.13
17	0.98	0.28	0.39	12.13
18	2.03	0.28	0.39	10.58
19	6.44	0.30	0.41	23.35
20	2.44	0.28	0.39	8.82
21	0.06	0.28	0.39	5.00

ac = acre
min = minute

The watershed subbasins shown in Figure 4 were delineated and the enclosed areas were calculated using 2-foot topography in ArcGIS 10. The subbasin sizes summarized in Table 4 were used as an input for the SSA model for the hydrologic simulation.

Time of concentration (T_c) is defined as the time it takes for stormwater runoff to travel from the most hydraulically distant point of the watershed to a point of interest within the watershed. T_c values for each subbasin were determined using the T_c estimation method described in NRCS TR55 (1986). Runoff from each sub-area was divided into a sheet flow segment (non-concentrated runoff from the most distant point), shallow concentrated flow segment, and channel flow and storm drain flow.

T_c values for sheet and shallow concentrated flows were estimated using generalized curves that relate surface and channel conditions, slope, and flow velocity. A maximum sheet flow segment length of 100 feet was used in accordance with NRCS recommendations. Shallow concentrated flow lengths were assumed to extend from the end of the sheet flow portion of runoff to the origin of a well-defined channel segment.

The velocities for channel flows were calculated using Manning's equation assuming the bankfull discharges. Hydraulic roughness characteristics were based on aerial imagery and field reconnaissance.

The calculated travel time (T_t) values for sheet flow, shallow concentrated flow, and channel flow were summed to give the total T_c value for each sub-area. The estimated T_c values for the sub-areas are summarized in Table 4.

Rainfall intensities for the City of Alexandria were input to the SSA model. The rainfall intensities for the 1-, 2-, 10-, 25-, and 100-year rainfall events were used to calculate the discharges at the 100-, 50-, 10-, 4-, and 1-percent-annual-chance events, respectively.

4.1.4 Summary of Results

Results of the hydrologic simulations are summarized in Table 5. Results of the SSA model are reported by subbasin name. The locations of the junctions and outfalls are shown in Figure 5.

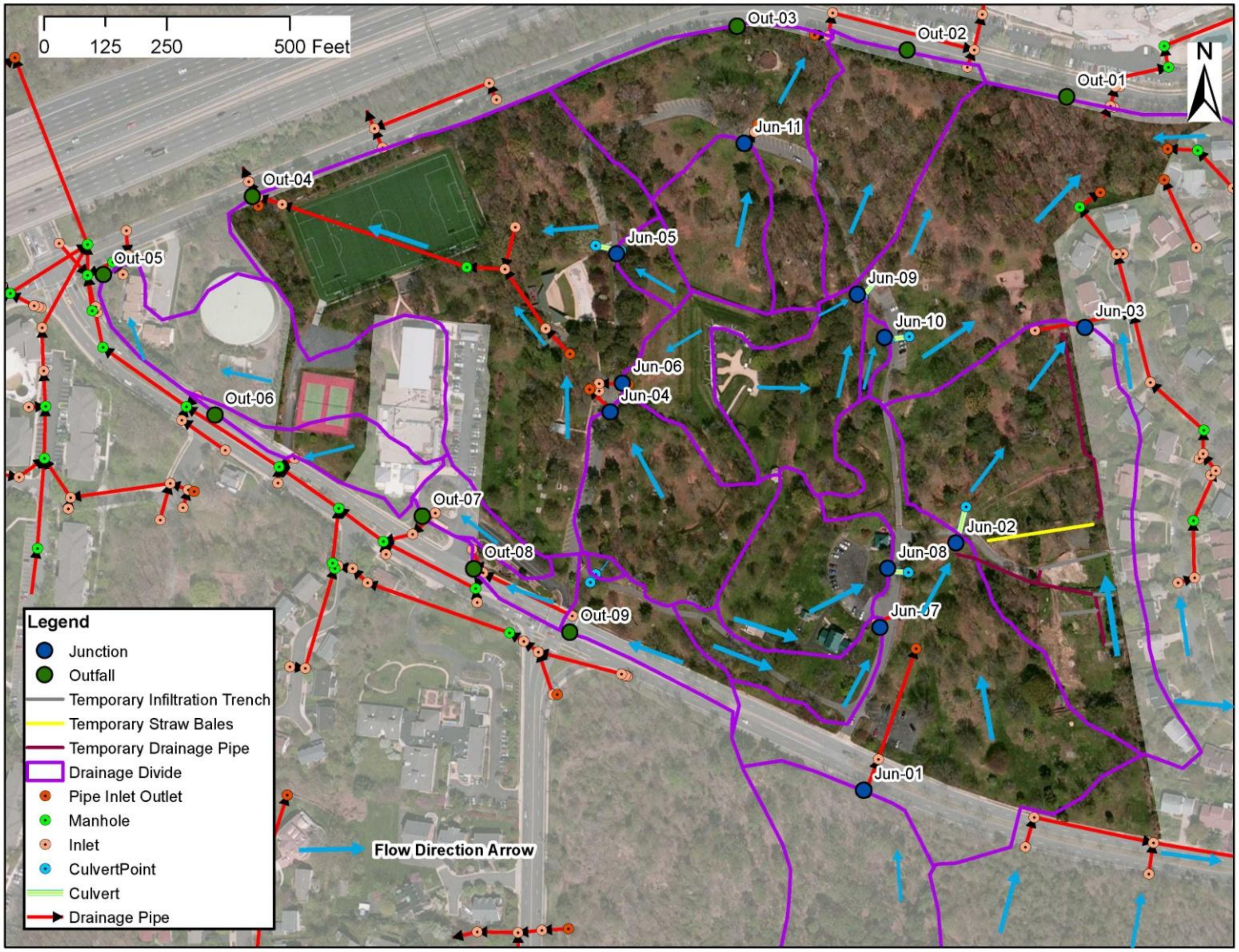


Figure 5: Fort Ward Park Drainage Divide Map with Junctions and Outfalls

Table 5: Summary of Hydrologic Analysis

Name	Drainage Area (ac)	Drainage Area within Park Limits (%)	Storm Event Flows (cfs)				
			1-yr	2-yr	10-yr	25-yr	100-yr
Subbasin 1	29.5	18.8	26.34	34.15	49.71	78.46	98.69
Subbasin 2	1.91	100	1.77	2.29	3.34	5.55	7.04
Subbasin 3	0.15	100	0.17	0.22	0.32	0.54	0.70
Subbasin 4	2.39	93.4	2.33	3.04	4.43	7.41	9.44
Subbasin 5	3.61	98	3.32	4.29	6.25	10.38	13.17
Subbasin 6	1.4	100	1.60	2.13	3.10	5.22	6.67
Subbasin 7	9.82	92.6	12.20	16.31	23.86	39.42	50.50
Subbasin 8	1.4	100	1.28	1.65	2.40	3.98	5.05
Subbasin 9	0.37	100	0.43	0.57	0.84	1.40	1.80
Subbasin 10	3.24	20.2	3.81	4.95	7.21	11.33	14.39
Subbasin 11	0.91	39.7	0.98	1.26	1.84	2.90	3.66
Subbasin 12	0.56	42.6	0.90	1.21	1.76	2.80	3.58
Subbasin 13	0.44	63	0.57	0.76	1.11	1.86	2.39
Subbasin 14	0.99	68.4	1.12	1.48	2.16	3.62	4.64
Subbasin 15	4.45	0	2.34	3.08	4.47	6.85	8.59
Subbasin 16	6.53	77.7	5.52	7.11	10.36	17.14	21.64
Subbasin 17	0.98	100	0.93	1.22	1.77	2.95	3.75
Subbasin 18	2.03	100	2.03	2.67	3.89	6.52	8.32
Subbasin 19	6.44	77.5	4.70	6.11	8.89	14.53	18.23
Subbasin 20	2.44	100	2.60	3.43	5.01	8.41	10.76
Subbasin 21	0.06	100	0.08	0.11	0.16	0.27	0.35
Junction 1	4.45	0	2.34	3.08	4.47	6.85	8.59
Junction 2	13.98	69.4	8.14	10.54	15.35	25.21	31.86
Junction 3	20.42	71	11.39	14.77	21.51	35.27	44.49
Junction 4	2.44	100	2.60	3.43	5.01	8.41	10.76
Junction 5	2.39	100	0.43	0.57	0.84	1.40	1.80
Junction 6	1.4	100	1.28	1.65	2.40	3.98	5.05
Junction 7	0.98	100	0.93	1.21	1.77	2.95	3.75
Junction 8	2.03	100	2.03	2.66	3.89	6.52	8.32
Junction 9	1.91	100	1.77	2.29	3.34	5.54	7.04
Junction 10	0.15	100	0.17	0.22	0.32	0.54	0.69
Junction 11	1.4	100	1.60	2.12	3.10	5.22	6.67
Outfall 1	65.97	71.7	37.02	48.00	69.88	111.38	140.15

Name	Drainage Area (ac)	Drainage Area within Park Limits (%)	Storm Event Flows (cfs)				
			1-yr	2-yr	10-yr	25-yr	100-yr
Outfall 2	2.39	93.4	2.33	3.04	4.43	7.41	9.44
Outfall 3	5.01	99	3.54	4.59	6.69	11.11	14.10
Outfall 4	14.02	98.2	14.45	19.27	28.19	46.67	59.76
Outfall 5	3.24	20.2	3.81	4.95	7.21	11.33	14.39
Outfall 6	0.91	39.7	0.98	1.26	1.84	2.90	3.66
Outfall 7	0.56	42.6	0.90	1.21	1.76	2.79	3.58
Outfall 8	0.99	63	0.57	0.76	1.11	1.86	2.39
Outfall 9	1.05	84.2	1.16	1.54	2.24	3.77	4.82

ac = acre
cfs = cubic feet per second
yr = year

Results from the SSA model are consistent with what was expected from field studies, which showed locations of eroded streams and the need for storm drain improvements. The results of this study can be used by the City for future stormwater management improvements or stream restoration projects. Additionally, the results of the hydrology are used to perform the hydraulic capacity analysis.

4.2 HYDRAULIC CAPACITY ANALYSIS

4.2.1 Modeling Development

URS performed a hydraulic capacity analysis for the cross culverts. The results of the hydraulic modeling will aid in future park improvement assessments and the City of Alexandria's management strategies for the park.

The hydraulic model for the Fort Ward Park Master Drainage Plan was developed using current Geographic Information System (GIS) datasets from the City and peak discharges calculated during the hydrologic analysis.

A culvert analysis program, HY-8, was used to analyze the performance of the culverts. There are 11 existing cross culverts in the Park and all of them were investigated for the conveyance capacity.

4.2.2 Modeling Input Parameters

Key parameters that are required for HY-8 include discharge data, culvert data, tailwater data, and roadway data. The discharges for the 2-year, 10-year, 25-year, and 100-year storm events were obtained from the hydrologic analysis. The culvert data required by HY-8 include:

- Culvert shape
- Material (to define Manning's n values)
- Size
- Inlet type, edge condition, and depression
- Invert data
- Embankment data

The above culvert data were obtained from the GIS data provided by the City, the field reconnaissance, aerial images, and topographic information.

The downstream tailwater channel shape and condition were defined using topographic data provided by the City and the field reconnaissance observations. The following parameters are required when defining the roadway data for the culvert:

- Roadway profile
- Roadway station
- Crest length
- Crest elevation
- Roadway surface
- Top width

The above road data were obtained from the GIS data provided by the City, the field reconnaissance, aerial images, and topographic information. The roadway surface conditions were confirmed during the field reconnaissance trip. The values entered for the crest length and top width of the roadway have no effect on the hydraulic computations unless overtopping occurs.

4.2.3 Modeling Approach

URS determined the conveyance capacity of the existing drainage systems and for the limited existing cross culverts on the site. Defined conveyance systems are not prevalent on the site, and there are no closed drainage systems other than cross culverts. The flow capacities for the existing cross culverts were determined using the discharges from the hydrologic analysis.

Culvert capacities and associated velocities were computed using the Federal Highway Administration's HY-8. HY-8 was developed by Federal Highway Administration in the 1980s and has been continuously maintained and updated since. URS used the latest version, Version 7.2, to examine the hydraulic capacity of the cross culverts in the Fort Ward Park.

4.2.4 Summary of Results

The summary of the hydraulic capacity analysis (Table 6) shows that all the culverts, except Culverts 2, 18, and 20, are designed to convey 25-year storm events, provided routine maintenance is performed. For example, sedimentation in the culvert under West Braddock Road (Culvert 15) will cause the water to overtop the crossing road during the 25-year storm event. However, the conveyance can be restored by cleanup and routine maintenance. The detailed model output for each culvert is available in Appendix C.

Table 6: Summary of Culvert Capacity Analysis

Culvert ID	Subbasin ID	Site ID	Storm Event Flows (cfs)			Flows that would cause overtopping (cfs)	Will it be overtopped during a 25-year storm event?	Will it be overtopped during a 100-year storm event?
			10-yr	25-yr	100-yr			
Culvert 15	Subbasin 15	Site 3	4.47	6.85	8.59	8.25	No	Yes
Culvert 15*	Subbasin 15	Site 3	4.47	6.85	8.59	6.04	Yes	Yes
Culvert 17	Subbasin 17	Site 1	1.77	2.95	3.75	5.30	No	No
Culvert 18	Subbasin 18	Site 2	3.89	6.52	8.32	5.17	Yes	Yes
Culvert 16	Junction 2	Site 5	15.35	25.21	31.86	40.27	No	No
Culvert 3	Subbasin 3	Site 10	0.32	0.54	0.70	4.0	No	No
Culvert 2	Subbasin 2	Site 10	3.34	5.55	7.04	5.06	Yes	Yes
Culvert 6	Subbasin 6	N/A	3.10	5.22	6.67	7.55	No	No
Culvert 9	Subbasin 9	N/A	0.84	1.40	1.80	4.05	No	No
Culvert 8	Subbasin 8	Site 15	2.40	3.98	5.05	4.04	No	Yes
Culvert 20	Subbasin 20	Site 15	5.01	8.41	10.76	7.35	Yes	Yes
Culvert 21	Subbasin 21	Site 21	0.16	0.27	0.35	2.6	No	No

*with 1/3 of the culvert blocked by sedimentation

SECTION FIVE: RECOMMENDATIONS

5.1 GENERAL RECOMMENDATIONS

Over the course of the study, URS identified potential improvements to address nuisance flooding and erosion issues at the Park. These improvements are based on field observations, engineering analysis, and community input. The improvements include both structural and nonstructural measures. Nonstructural measures are defined as not requiring design and generally involving lower-cost activities that can be integrated into the maintenance already occurring at the Park. Structural measures, also referred to as capital projects, typically require additional analyses such as design development, geotechnical analysis, field surveying, archaeological investigation, and permitting. These measures typically involve greater effort and higher costs.

Nonstructural improvement options recommended for general implementation at the Park are listed below:

- Aeration and Turf Seeding: This alternative consists of aerating the soil to increase infiltration capacity and seeding turf. Aerated soil has a higher infiltration capacity (decreasing runoff) and is also more suitable for plant growth. Healthy turf reduces erosion while greatly improving park aesthetics. The Fort Ward Park and Museum Area Management Plan provides additional information on aeration of soils at the park
- Conveyance Improvements: This alternative includes cleanup and maintenance of the existing system, swales, closed systems, etc. This includes removing sediment and debris that decrease flow in existing conveyance systems, or avoiding cutting grass in infiltration trenches. These practices increase flow conveyance and decrease flooding frequency.
- Redirect Drainage from Homes: This alternative requires redirecting residential drainage away from erodible areas and sensitive resources by redirecting roof downspouts or sump pumps to storm drain systems. This option decreases runoff on to the Park by redirecting residential runoff.
- Mowing Maintenance Plan: This alternative requires a maintenance plan to clearly identify areas to be mowed and areas to avoid mowing. “No Mow” areas should also be established for drainage practices that use plant growth for retention, and where undesired pedestrian traffic is causing erosion.

General structural improvement options considered are as follows:

- Increase Culvert Capacity: This alternative involves increasing the size of culverts to accommodate the 25-year storm. This will lead to culverts surcharging less frequently, potentially avoiding nuisance flooding.
- Redirect Surface Flow: This alternative requires creating or upgrading an existing conveyance system. This can include swales, berms, culverts, etc. depending on the site requirements. Directly altering surface flow should be used where sheet flow is eroding sensitive areas.

- Level Spreader: This alternative involves implementation of gravel or riprap downstream of a culvert outlet to reduce erosion. Level spreaders reduce energy, converting high-velocity flow into sheet flow.
- Stream Restoration/Stabilization: This alternative consists of modifying an existing stream so it is more stable under existing and future flow conditions. This can decrease stream erosion, improve stream aesthetics, and decrease sediment loading downstream.
- Install Underground Best Management Practices (BMPs): This alternative involves adding water quality BMPs to an existing or proposed culvert. The BMPs are designed to trap sediment, debris, and other contaminants to improve water quality downstream.

5.2 GENERAL MAINTENANCE BEST PRACTICES FOR CEMETERY AREAS

The following summarizes best practices for grounds and headstone maintenance at cemeteries, but is focused on the Oakland Baptist Church Cemetery (Site 8), although the cemetery is not under City jurisdiction. The parties responsible for maintenance of the cemetery should view this document as general guidance and refer specifically to the Additional References and Resources at the end of this document to help determine the most appropriate methods and means of implementation.

5.2.1 Virginia Cemetery Regulations

The State of Virginia has a number of laws and regulations related to marked and unmarked cemeteries including ones that address impacts to graves and access to gravesites, among others (see Code of Virginia Titles 18 and 57). Questions regarding cemetery regulations in Virginia can be directed to the Virginia Department of Historic Resources (VDHR) at 804-367-2323 / http://www.dhr.virginia.gov/.

5.2.2 Maintenance Recommendations

Maintenance issues at cemeteries typically revolve around two often interconnected themes: vegetation and drainage. Vegetative issues include poor turf quality resulting from soil compaction and excessive shade and trees growing in and around graves, displacing headstones. Drainage issues at cemeteries are often related to sheet flow of water due to impervious surfaces upslope from the cemetery, compaction of soil around and within the cemetery proper, and poor soil drainage characteristics, such as impermeable clay layers; a high, or perched, water table can be another contributing factor. There are a number of mitigation measures that can be implemented by parties responsible for cemetery maintenance to address vegetative and drainage issues both outside a cemetery and within the boundary of a cemetery.

Turf Maintenance: Within the boundaries of a cemetery, poor drainage and erosion is most commonly related to soil compaction, which prevents water from infiltrating into the ground and instead contributing to surficial erosion or subsidence of head stones or pooling in depressions. Soil compaction issues can be addressed through a turf maintenance program, whereby the soil is aerated and appropriate grassy vegetation is planted as an erosion prevention technique. Such an activity may involve the removal or pruning of trees that are contributing to excessive shade or could be diverting water flow, but care must be taken to ensure that the trees removed do not contribute to the character and feeling of the cemetery and do not cause additional damage during the removal process. Mowing, edging, and related turf maintenance activities are major contributors to headstone damage. Any turf management program must include damage prevention measures.

Water Diversion: There are three main methods that can be used around a cemetery to redirect water flowing from upslope sources: berms (see Section 6.2 for example), ditches, and subsurface installations such as French drains or drainage tiles. Construction of any of these features can have adverse impacts to a cemetery due to either compaction of burials (e.g., berms) or physical disturbance of a burial (e.g., ditches and French drains). As such, it is important that an accurate map of the limits of burials, marked and unmarked, within the cemetery be prepared to ensure that such features will not be constructed through any burials.

Grave Depressions: While water can pool in grave depressions caused by casket and soil subsidence, it is recommended that these not be filled unless they pose a safety hazard, especially if an accurate map of the cemetery and all marked and unmarked burials has not been developed (Chicora Foundation, Inc. (CFI) N.D.a). Grave depressions are an important indicator of unmarked graves and filling of the depression can remove any sign of a burial if it is not properly mapped and/or marked. Issues with grave depressions collecting water can be mitigated by instituting a turf management program.

Conservation and Repair of Damaged Headstones: Trees and tree roots as well as drainage issues can cause subsidence of and damage to headstones. If resetting of headstones is feasible, care should be taken when identifying which headstones should be reset and the manner in which the resetting is undertaken. It is recommended that only headstones with a severe amount of tilting be reset. Headstones can contain internal cracking that is not visible to the naked eye and the process of resetting can result in failure of the stone, thus causing a more severe impact to the headstone and more costly repair. There are numerous methods for repairing cracked or broken headstones, but improper repair techniques can cause additional damage or minimally result in disfigurement. Additionally, it should be noted that mowing and other turf maintenance can be the most damaging activities to headstones, and proper guidance is critical to preventing damage from these activities.

5.2.3 Potential Funding Sources

A number of different options may exist for procuring funding to support cemetery maintenance activities. Within the City of Alexandria, it is recommended that the Alexandria Archaeology Museum be contacted at 703-746-4399 / http://alexandriava.gov/Archaeology. The VDHR is a resource that can be used to identify potential state and federal funding sources, and can be contacted at 804-367-2323 / http://www.dhr.virginia.gov/. The State, Tribal, and Local Plans & Grants Division of the National Park Service (http://www.nps.gov/history/hpg/) often works with State Historic Preservation Offices such as the VDHR. While cemeteries are not typically considered eligible for listing in the National Register of Historic Places (NRHP), there are a number of “Criteria Considerations” under which a cemetery may be considered eligible. VDHR may be able to provide guidance on the NRHP nomination process and possible funding sources.

A list of organizations that would provide additional funding sources is included in Additional References and Resources at the end of this document.

5.3 DESIGN STANDARDS FOR PROPOSED IMPROVEMENTS

Several design standards were used when considering proposed improvements to Fort Ward Park, including the following:

- The Four Mile Run Design Guidelines (2009)
- The Amendments to City of Alexandria Article XIII Environmental Management Ordinance (2006)
- The Virginia Stream Restoration & Stabilization Best Management Practices Guide (2004) – used when considering stream restoration improvements
- The Virginia Department of Transportation Drainage Manual (2002)
- The Virginia Erosion and Sediment Control Handbook (1992)

5.4 SITE-SPECIFIC RECOMMENDATIONS

Specific recommendations are summarized below for each of the sites shown in Figure 3. Section Six includes additional information for the recommended capital projects that were analyzed in detail.

5.4.1 Site 1

Two nonstructural measures are recommended for Site 1:

- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from culverts is recommended.

5.4.2 Site 2

Two nonstructural measures and one structural measure are recommended for Site 2:

- Increase culvert capacity: Increase the capacity of the 15-inch culvert under the entrance road near the bathrooms
- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from culverts is recommended. Re-grading to avoid ponding is also recommended.

5.4.3 Site 3

Two nonstructural measures and one structural measure are recommended for Site 3:

- BMP implementation: this alternative requires the installation of a BMP at the site or upstream of the outfall to remove sediment, trash, and debris. (See Section Six for concept design.)
- Level spreader: this alternative requires the implementation of a level spreader at the culvert outlet.
- Conveyance improvements: periodic removal of sediment and debris from culverts is recommended.

5.4.4 Site 4

One nonstructural measure is recommended for Site 4:

- Aeration and turf seeding

5.4.5 Site 5

Two nonstructural measures are recommended for Site 5:

- Aeration and turf seeding: seeding is recommended at the sloped area upstream of the 36-inch culvert.
- Conveyance improvements: periodic removal of sediment and debris from the 36-inch culvert and the 6-inch PVC pipes is recommended.

5.4.6 Site 6

One nonstructural measure and one structural measure are recommended for Site 6 (Old Utility Yard).

- Redirect surface flow: this alternative requires the construction of berms to direct runoff and to replace temporary hay bales. (See Section Six for concept design.)
- Mowing maintenance plan: reduce mowing due to the existing infiltration basins and graves.

5.4.7 Site 7

Two nonstructural measures and two structural measures are recommended for Site 7:

- Stream restoration/stabilization: this alternative involves implementing stream restoration measures for eroded stream banks. (See Section Six for concept design.)
- Redirect surface flow: this alternative requires developing a solution to effectively handle concentrated flow from the nearby residential property.
- Aeration and turf seeding

- Conveyance improvements: periodic removal of debris from the stream and yard inlets is recommended.

5.4.8 Site 8

Recommendations for the Oakland Baptist Cemetery property are discussed in Section 5.3.

5.4.9 Site 9

Two nonstructural measures and two structural measures are recommended for Site 9:

- Level spreader: this alternative requires the implementation of a level spreader at the culvert outlet to prevent concentrated flow.
- Redirect surface flow: this alternative requires the construction of a berm to direct runoff around playground area before the playground is relocated to a different location.
- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris at yard inlets is recommended.

5.4.10 Site 10

One nonstructural measure and one structural measure are recommended for Site 10:

- Increase culvert capacity: Increase the capacity of the 15 inch culvert.
- Aeration and turf seeding

5.4.11 Site 11

One nonstructural measure is recommended for Site 11:

- Community outreach: Conduct outreach activities with residents to prevent pollutants from entering the storm drain system.

5.4.12 Site 12

One nonstructural measure and two structural measures are recommended for Site 12:

- Level spreader: this alternative requires the implementation of a level spreader at the culvert outlet to prevent concentrated flow.
- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from inlets is recommended.

5.4.13 Site 13

Two nonstructural measures and one structural measure are recommended for Site 13:

- Level spreader: this alternative requires the implementation of a level spreader at the culvert outlet to prevent concentrated flow.
- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from inlets is recommended.

5.4.14 Site 14

Two nonstructural measures are recommended for Site 14:

- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from inlets is recommended.

5.4.15 Site 15

Two nonstructural measures and one structural measure are recommended for Site 15:

- Increase culvert capacity: Increase the capacity of the 15 inch culvert.
- Aeration and turf seeding
- Conveyance improvements: periodic removal of sediment and debris from inlets is recommended. A slight re-grading and the removal of the telephone pole at the upstream culvert are also recommended.

5.4.16 Site 16

One nonstructural measure is recommended for Site 16:

- Redirect surface flow: this alternative requires developing a solution to effectively handle concentrated flow from the nearby residential property.

SECTION SIX: RECOMMENDED CAPITAL IMPROVEMENT PROJECTS AND COST ESTIMATES

This section provides the concept design for the recommended capital improvement projects to address the flooding and erosion issues and improve the drainage on selected sites. The specific recommendations set forth in this section should be considered as conceptual only. Additional details and potential alternatives should be investigated and analyzed in the preliminary engineering phase of final project designs.

6.1 STORMWATER FILTER (SITE 3)

6.1.1 Existing Site Description

Sedimentation is occurring at the outfall 150 feet east of the Fort Ward Park Museum (Site 3). The flow at the outfall is made up of runoff from the 5-acre forested area south of Braddock Road and approximately 1 acre of Braddock Road. An 18-inch reinforced concrete pipe conveys water from Braddock Road to the outfall. The pipe was found to be adequate to convey the 25-year flood event as long as the pipe was not blocked by sediment. This site is the only area in the Park where offsite runoff enters and flows through the Park. The outfall is close to two parking lots and the museum, so it is considered a medium- to high-visibility area. The soils from the pipe inlet to the outfall are composed of hydrologic soil group D soils, which are poorly drained with low infiltration rates and high clay content.

6.1.2 Proposed Design

The primary goal for the proposed design is to improve the water quality of runoff at the Park. The secondary goal is to provide a solution that the community will accept while not detracting from the aesthetics of the Park. It is recommended that the existing sediment and debris within the outfall be removed prior to the implementation of any structural improvements at this location.

Existing Site 3 Outfall

The proposed retrofit to the Site 3 outfall is to install an underground stormwater filter beneath the parking lot southeast of the museum (Figure 6). Excavation of a portion of the parking lot is necessary and excess soil needs to be hauled offsite. The existing 18-inch reinforced concrete pipe would be cut in place and reconfigured and connected to the underground stormwater filter unit.

A filter such as the Contech StormFilter is recommended for adequate removal of sediment and other stormwater pollutants (including Phosphorous). Figure 7 shows a standard detail of this model. Within the StormFilter unit there is a bypass structure for overflow, pre-treatment to capture sediment, and filters to treat stormwater. Following installation, the excavated area of the parking lot would need to be resurfaced and regraded. More detailed calculations are needed for final design. Preliminary calculations used for conceptual design are provided in Appendix D.

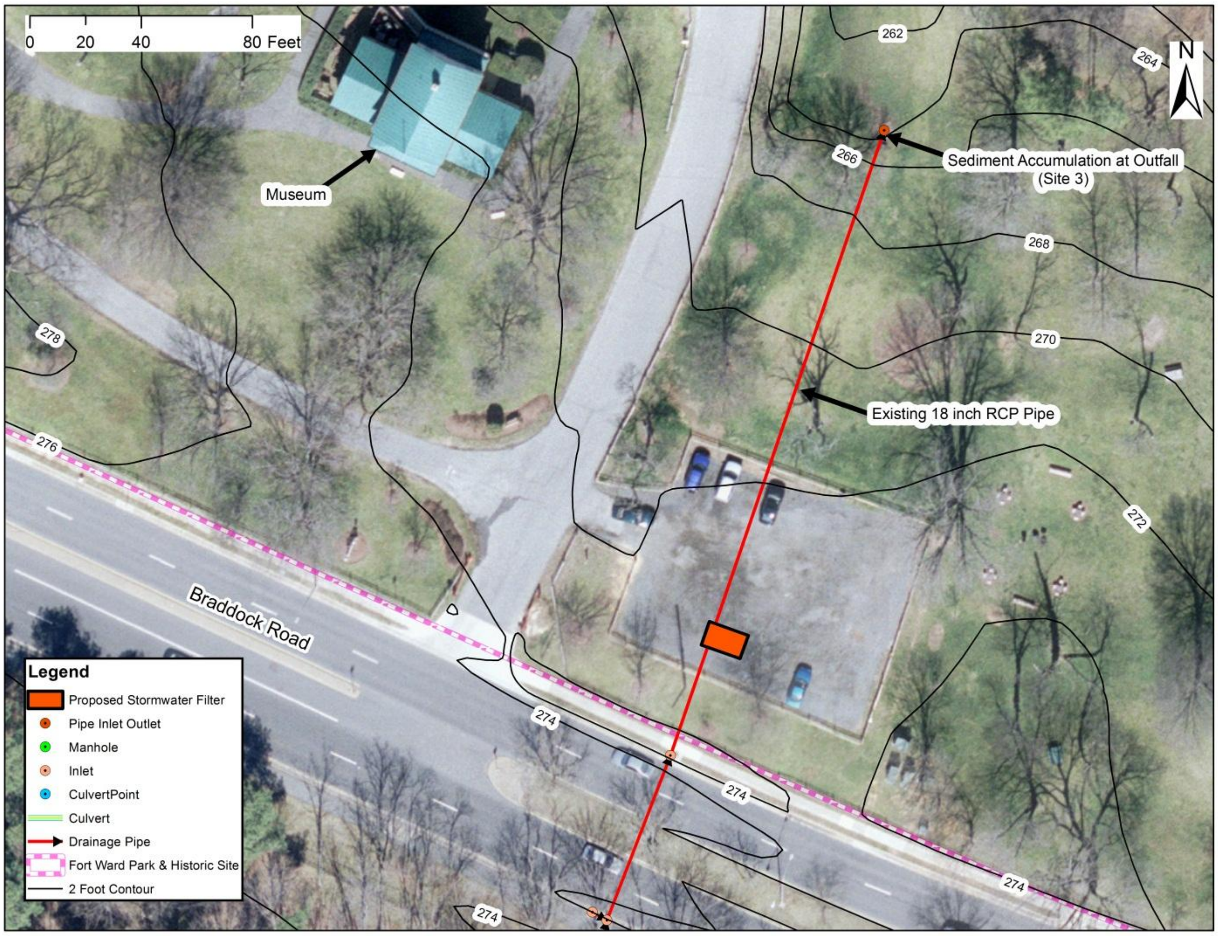
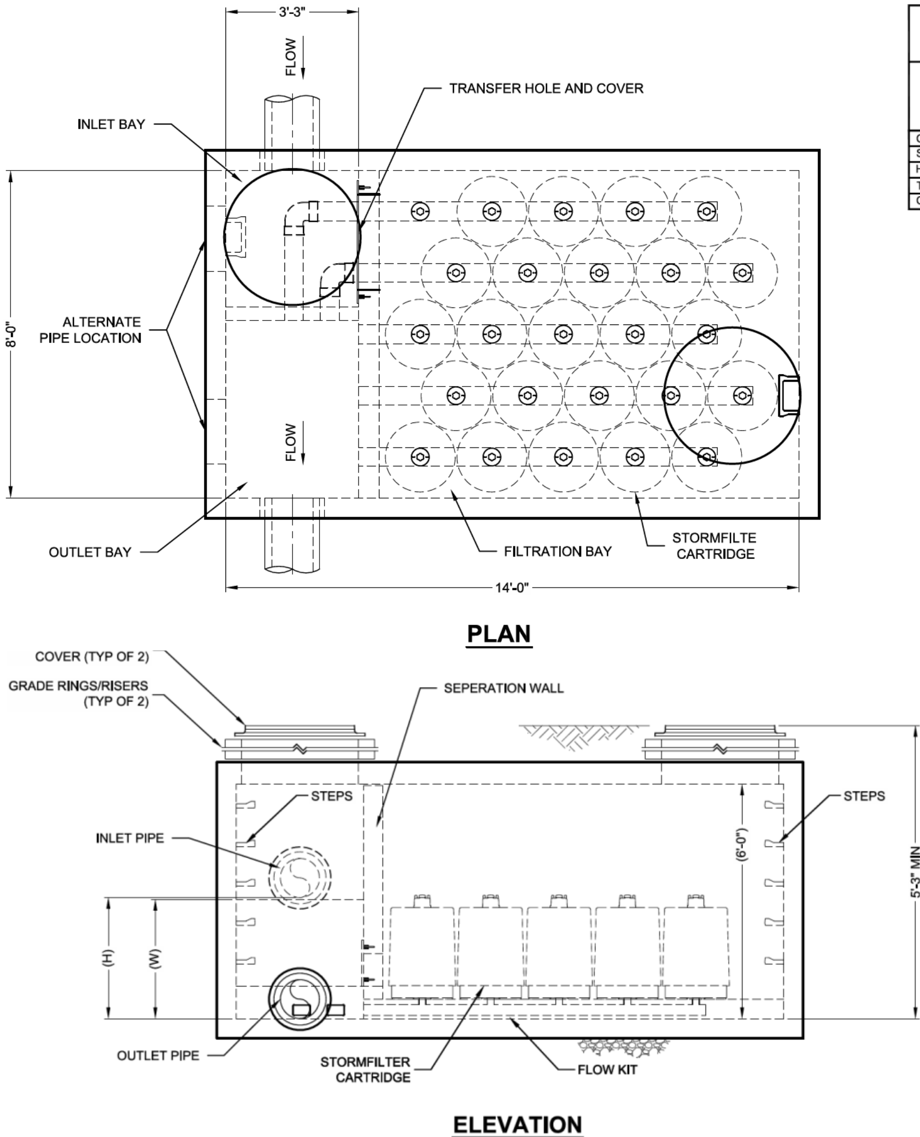


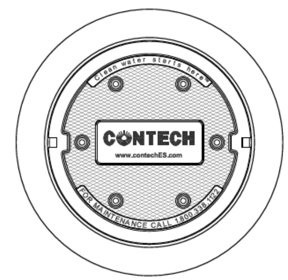
Figure 6: Proposed Stormwater Filter Concept Design



STORMFILTER DESIGN TABLE

- THE 8' x 14' PEAK DIVERSION STORMFILTER TREATMENT CAPACITY VARIES BY CARTRIDGE COUNT AND LOCALLY APPROVED SURFACE AREA SPECIFIC FLOW RATE. PEAK CONVEYANCE CAPACITY TO BE DETERMINED BY ENGINEER OF RECORD.
- THE PEAK DIVERSION STORMFILTER IS AVAILABLE IN A LEFT INLET (AS SHOWN) OR RIGHT INLET CONFIGURATION.
- ALL PARTS AND INTERNAL ASSEMBLY PROVIDED BY CONTECH UNLESS OTHERWISE NOTED.

CARTRIDGE HEIGHT	27"		18"		LOW DROP	
SYSTEM HYDRAULIC DROP (H - REQ'D. MIN.)	3.05'		2.3'		1.8'	
HEIGHT OF WEIR (W)	3.00'		2.25'		1.75'	
TREATMENT BY MEDIA SURFACE AREA	2 gpm/ft²	1 gpm/ft²	2 gpm/ft²	1 gpm/ft²	2 gpm/ft²	1 gpm/ft²
CARTRIDGE FLOW RATE (gpm)	22.5	11.25	15	7.5	10	5



FRAME AND COVER
(DIAMETER VARIES)
N.T.S.

SITE SPECIFIC
DATA REQUIREMENTS

STRUCTURE ID			*
WATER QUALITY FLOW RATE (cfs)			*
PEAK FLOW RATE (cfs)			*
RETURN PERIOD OF PEAK FLOW (yrs)			*
# OF CARTRIDGES REQUIRED			*
CARTRIDGE FLOW RATE			*
MEDIA TYPE (CSF, PERLITE, ZPG)			*
PIPE DATA:	I.E.	MATERIAL	DIAMETER
INLET PIPE	*	*	*
OUTLET PIPE	*	*	*
INLET BAY RIM ELEVATION			*
FILTER BAY RIM ELEVATION			*
ANTI-FLOTATION BALLAST		WIDTH	HEIGHT
		*	*
NOTES/SPECIAL REQUIREMENTS:			

PERFORMANCE SPECIFICATION
FILTER CARTRIDGES SHALL BE MEDIA-FILLED, PASSIVE, SIPHON ACTUATED, RADIAL FLOW, AND SELF CLEANING. **RADIAL MEDIA DEPTH SHALL BE 7-INCHES**. FILTER MEDIA CONTACT TIME SHALL BE AT LEAST **37 SECONDS**.
SPECIFIC FLOW RATE SHALL BE **2 GPM/SF (MAXIMUM)**. SPECIFIC FLOW RATE IS THE MEASURE OF THE FLOW (GPM) DIVIDED BY THE MEDIA SURFACE CONTACT AREA (SF). MEDIA VOLUMETRIC FLOW RATE SHALL BE **6 GPM/CF OF MEDIA (MAXIMUM)**.

GENERAL NOTES
1. CONTECH TO PROVIDE ALL MATERIALS UNLESS NOTED OTHERWISE.
2. DIMENSIONS MARKED WITH ( ) ARE REFERENCE DIMENSIONS. ACTUAL DIMENSIONS MAY VARY.
3. FOR FABRICATION DRAWINGS WITH DETAILED STRUCTURE DIMENSIONS AND WEIGHTS, PLEASE CONTACT YOUR CONTECH REPRESENTATIVE. www.ContechES.com
4. STORMFILTER WATER QUALITY STRUCTURE SHALL BE IN ACCORDANCE WITH ALL DESIGN DATA AND INFORMATION CONTAINED IN THIS DRAWING. CONTRACTOR TO CONFIRM STRUCTURE MEETS REQUIREMENTS OF PROJECT.
5. STRUCTURE SHALL MEET AASHTO HS20 LOAD RATING, ASSUMING EARTH COVER OF 0' - 5' AND GROUNDWATER ELEVATION AT, OR BELOW, THE OUTLET PIPE INVERT ELEVATION. ENGINEER OF RECORD TO CONFIRM ACTUAL GROUNDWATER ELEVATION. CASTINGS SHALL MEET AASHTO M306 AND BE CAST WITH THE CONTECH LOGO.

INSTALLATION NOTES
A. ANY SUB-BASE, BACKFILL DEPTH, AND/OR ANTI-FLOTATION PROVISIONS ARE SITE-SPECIFIC DESIGN CONSIDERATIONS AND SHALL BE SPECIFIED BY ENGINEER OF RECORD.
B. CONTRACTOR TO PROVIDE EQUIPMENT WITH SUFFICIENT LIFTING AND REACH CAPACITY TO LIFT AND SET THE STORMFILTER STRUCTURE (LIFTING CLUTCHES PROVIDED).
C. CONTRACTOR TO INSTALL JOINT SEALANT BETWEEN ALL SECTIONS AND ASSEMBLE STRUCTURE.
D. CONTRACTOR TO PROVIDE, INSTALL, AND GROUT PIPES. MATCH OUTLET PIPE INVERT WITH OUTLET BAY FLOOR.
E. CONTRACTOR TO TAKE APPROPRIATE MEASURES TO PROTECT CARTRIDGES FROM CONSTRUCTION-RELATED EROSION RUNOFF.
F. CONTRACTOR TO REMOVE THE TRANSFER HOLE COVER WHEN THE SYSTEM IS BROUGHT ONLINE.

The Stormwater Management StormFilter®
THIS PRODUCT MAY BE PROTECTED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS: 5,322,629; 5,524,576; 5,707,527; 5,985,157; 6,027,639; 6,649,048; RELATED FOREIGN PATENTS, OR OTHER PATENTS PENDING.

CONTECH® ENGINEERED SOLUTIONS LLC
www.ContechES.com
9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069
800-338-1122 513-645-7000 513-645-7993 FAX

Figure 7: Stormwater Filter Example Standard Detail: Peak Diversion StormFilter

6.1.3 Improvements and Benefits

The current drainage system is adequate for water conveyance, but not water quality. A stormwater filter would intercept fine sediment, oil, floating debris, sinking debris, and nutrients. A StormFilter with twenty filter cartridges is rated to treat up to 1 cfs, which is sufficient to meet Virginia requirements for stormwater filters. Stormwater filters have emergency spillways allowing safe conveyance of up to the 100-year storm, although excess water would not be treated. The proposed retrofit would improve aesthetics by reducing sediment, debris, and pollutant loading into the Park.

6.1.4 Project Design Considerations

The proposed design is consistent with the Four Mile Watershed design guidelines, as well as the Amendment to the City of Alexandria Article XIII Environmental Management Ordinance. The design would involve the installation of a stormwater filter. In order for maintenance access the stormwater filter needs to be installed in or adjacent to the parking lot. Several trees would have to be removed if the filter were installed to the north or south of the parking lot. Construction in the proposed location would require excavation within the existing parking lot and would not impact existing trees. The amount of parking at the Park would be temporarily impacted during construction.

The proposed stormwater filter would detract from the Park aesthetically during construction, but would neither be visible nor take up valuable park space following completion. This is one of the benefits compared to a retention pond or bio-swale, for which more space would be needed.

6.1.5 Feasibility

Construction access to the parking lot will be available through the main entrance on Braddock Road. The parking lot is located near the entrance, so the Park Loop Road would not be impacted. No utilities are expected to be impacted, although further coordination with the City will be needed during detailed design for confirmation.

The environmental impacts of the proposed design would not be substantial as long as construction occurred in the parking lot. The trees on either side of the parking lot would be impacted if the stormwater filter were installed in the grass areas north or south of the proposed location. There would be a temporary loss of public parking during construction at the proposed location. Temporary fences and barriers would be required for safety.

The site is located within a High Cultural Resource Protection area as specified by the Alexandria Archeology Office of Historic Alexandria. Therefore, an archeological investigation at the site is required prior to or in conjunction with construction. The proposed concept design could occur concurrently or prior to installation of pervious pavement for the parking lot if desired by the City.

Routine inspection and maintenance would be required for the proposed stormwater filter. Cleaning would be required during dry periods to remove the sediment and debris that were retained. To clean the cartridges workers must enter the vault and remove cartridges for cleaning above ground. A maintenance plan is recommended to ensure that the unit would continue to function as it was designed. Permitting and regulations are discussed in Section Seven.

6.2 DIVERSION BERM AROUND CEMETERY (SITE 6)

6.2.1 Existing Site Description

Existing Site 6 Hay Bales

Runoff from the utility yard (Site 6) to the Oakland Baptist Cemetery (Site 8) is eroding the cemetery site. Temporary practices including hay bales, trenches, culverts, and a catch basin are in place to control runoff (Figure 3). The drainage area includes 0.2 acre of developed area (driveways and buildings) and 1.5 acres of grass or bare earth. The utility yard and the cemetery are composed of hydrologic soil group D soils, which are poorly drained with low infiltration rates and high clay content.

6.2.2 Proposed Design

The primary goal for the proposed design is to limit erosion and nuisance flooding at the Oakland Baptist Cemetery. The secondary goal is to provide a permanent solution that will have community acceptance and look more aesthetically appealing than the current hay bale practice.

The proposed site improvements are two permanent earthen diversion berms to direct runoff from the utility yard to a catch basin. Figure 8 displays the proposed location of the two diversion berms. The northern berm keeps runoff from entering the cemetery while the southern berm keeps runoff from the road off the site. The berm would follow the natural slope (4 percent) south of the Oakland Baptist Cemetery. The proposed berm would be approximately 1.5 feet tall, with a minimum 2:1 side slopes (depending on obstructions), and would be 1 foot wide at the top (Figure 9). Erosion protection matting would extend from the base of the berm to the existing grade, and the upstream face would be protected using erosion protection matting or other erosion prevention measures (see Figure 9). The remainder of the berm would be made up of fill. The entire berm can be seeded with grass unless an impervious material is required to protect the berm slope instead of erosion protection matting. There are several potential options for the protected slope including erosion control matting, porous pavers, or riprap.

For the proposed design, both diversion berms lead to a catch basin (yard inlet) that is connected to a 12-inch reinforced concrete pipe (Figure 8). The pipe would extend from the catch basin to the stream with outlet protection to reduce flow velocity. Outlet protection options include stone (e.g., riprap), a level spreader, and a concrete structure. Preliminary calculations are available in Appendix D.

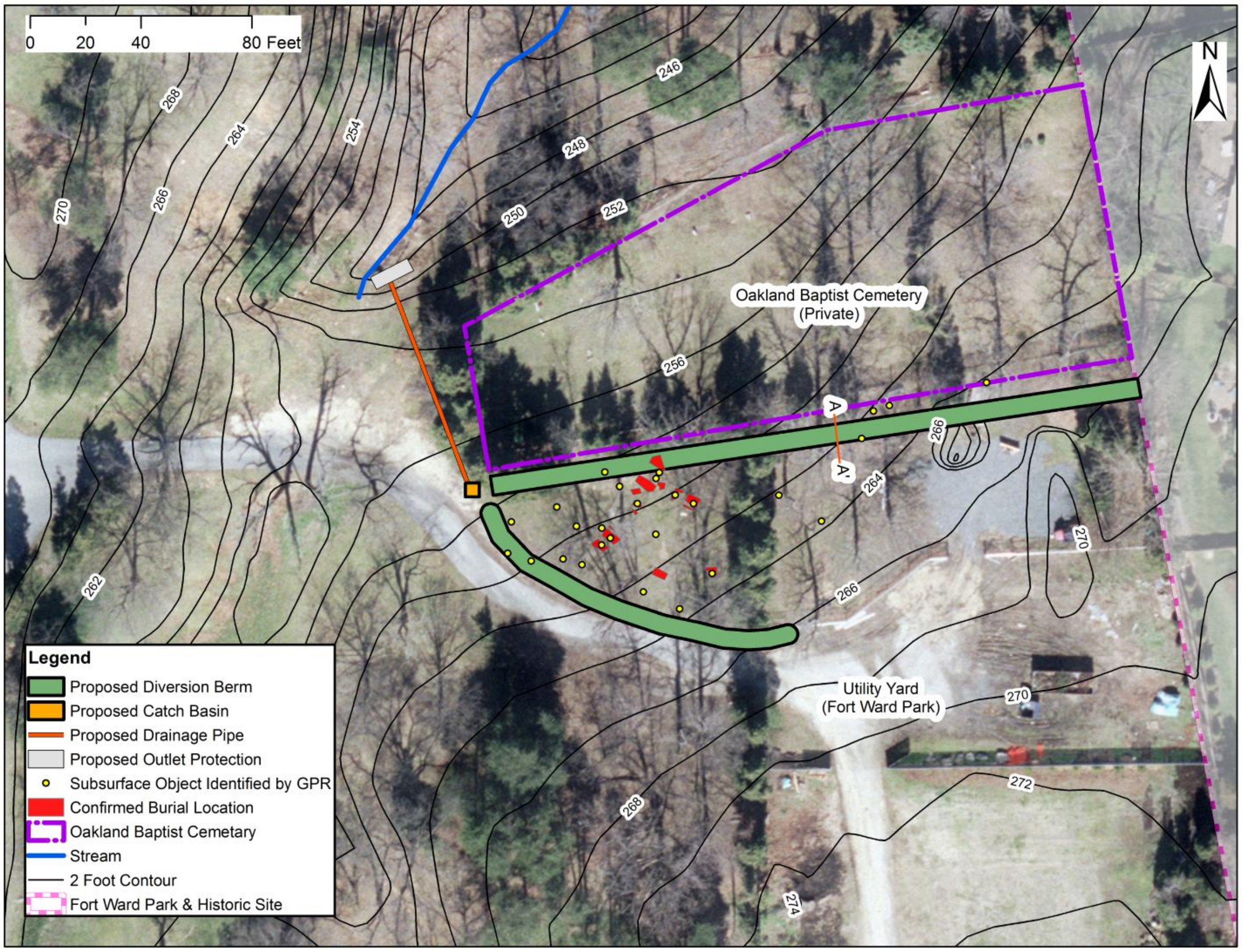


Figure 8: Proposed Diversion Berm Concept Design

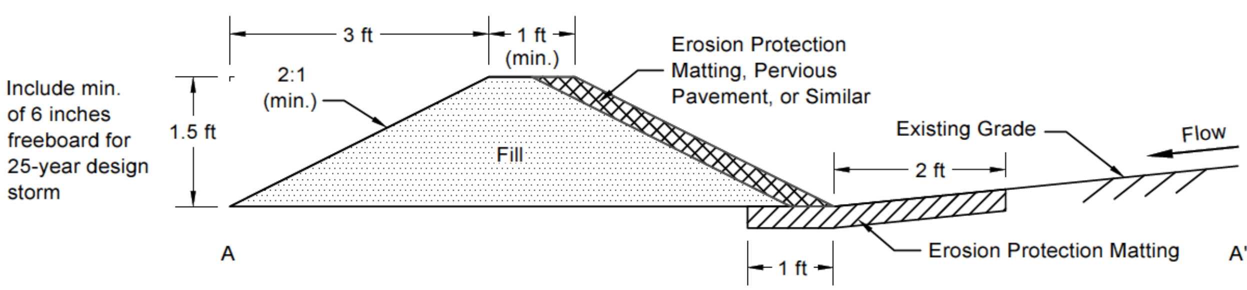


Figure 9: Proposed Diversion Berm Concept Design Cross-Section A – A'

6.2.3 Improvements and Benefits

The temporary drainage solutions at the utility yard require a more permanent upgrade to direct runoff away from sensitive areas. The berms would direct sheet flow into concentrated flow with erosion preventative measures (e.g., the erosion protection matting). Runoff from the Park would no longer have access to Oakland Baptist Cemetery. The catch basin and drainage pipe would direct runoff from the site directly into the stream, alleviating some of the sedimentation concerns at the road (Site 5).

6.2.4 Project Design Consideration

The proposed design involves bringing fill and erosion protection matting onsite and creating two diversion berm segments. The proposed design also requires the installation of a catch basin, drainage pipe, and outlet protection. The site would need to be cleared of debris and some vegetation would need to be trimmed or removed. The design is flexible so most trees should be avoidable, although it is possible that some trees may need to be removed and replaced. Construction of the berm would require compaction, as well as seeding with grass or other vegetation. Installation of the underground drainage solution would require excavation, placement of the drainage structures, backfill, and seeding grass. Construction of the proposed concept design would affect the public when construction was occurring near the unpaved road, and when trucks were hauling soil into the area.

The site is located within a Maximum Cultural Resource Protection area as specified by the Alexandria Archeology Office of Historic Alexandria. There are several confirmed burial sites and potential burial sites that have been identified in the area surrounding the proposed berms (Figure 8). Due to the confirmed and potential burial sites, digging south of Oakland Baptist Cemetery is not considered to be an option. Due to this constraint, below-ground techniques that otherwise may have been suitable for the site (e.g., wet swales, infiltration trenches, and stormwater pipes) were not considered to replace the hay bales. These below-ground techniques also would have been complicated by the large numbers of trees in the area. There are no confirmed burial sites west of the Oakland Baptist Cemetery where the drainage pipe has been proposed. Careful archeological study will need to occur prior to construction to verify that no historical artifacts or burials would be impacted by the design. Above ground techniques were not suitable for this area because they would interfere with public access to the Oakland Baptist Cemetery.

6.2.5 Feasibility

Construction access to the proposed site will be available through Fort Ward Park Loop Road via Braddock Road. The proposed construction site would be located near the southeastern Fort Ward Park entrance so the Park Loop Road would not be significantly impacted by construction traffic. No utilities are expected to be impacted, although further coordination with the City would be needed during detailed design for confirmation.

The environmental impacts of the proposed design primarily involve potential impacts to trees north of the berm. These impacts will need to be considered during final design, and most of the trees should be avoidable. The public would temporarily lose access to a small portion of the Park, and temporary fences or barriers could be necessary to keep the public out of construction areas. An archeological investigation will be required prior to or in conjunction with construction.

Routine maintenance would be required for the proposed berms. This maintenance would include seeding grass, clearing of debris, and occasional visual inspections. The catch basin would also need to be cleaned periodically. Permitting and regulations are discussed in Section Seven.

6.3 STREAM STABILIZATION (SITE 7)

6.3.1 Existing Site Description

Bank erosion is occurring along the intermittent stream (Site 7) northeast of the Oakland Baptist Cemetery. The banks are incised, and a significant amount of sediment is accumulating at the northern segment of the stream prior to entering the closed storm drain system. The drainage area consists of 2 acres of developed area (roads and buildings) and 18 acres of undeveloped area (grass and brush). The area surrounding the stream is composed of hydrologic soil group D soils, which are poorly drained with low infiltration rates and high clay content, as noted previously. The material within the stream is coarser, but the grain size distribution has not been determined. The existing stream slope is approximately 6 percent on average and is greater than 7 percent at some locations.

6.3.2 Proposed Design

The primary goal for the proposed design is to limit erosion and sedimentation along the intermittent stream northeast of Oakland Baptist Cemetery. The secondary goal is to provide a solution that will have community acceptance and look more aesthetically appealing than the current incised channel.

The proposed site improvement is a stream stabilization, including the replacement of the two yard inlets at the downstream boundary of the stream reach. The proposed stream stabilization strategy is to connect the channel to its floodplain and add a step-pool configuration for improved channel stability and function. The Virginia Stream Restoration & Stabilization Best Management Practices Guide (2004) was used to estimate the geometry and spacing of the step-pool configuration. Based on the estimated channel conditions (without survey), seven steps are expected at approximately 50-foot intervals. The steps would have heights varying from 0.5 to 1.5 feet and would be preceded by pools that are approximately 10 feet long. The proposed stream slope would be approximately 4 percent as a result of the elevation drops from step-pool geometry. The step-pools would require Class II rip-rap or equivalent, and fill would be required for most of the stabilization reach. For this application, it is recommended that more aesthetic rocks, such as river rocks, be utilized. Figure 10 show the layout of the improvements and Figure 11 shows a conceptual cross-section of the nonstructural locations for the concept design. Figure 12 shows a conceptual cross-section for the steps and pools for the concept design. The final stabilization design is not expected to be trapezoidal; however, it was assumed for concept-level design purposes. The two damaged yard inlets north of the restoration reach will be replaced with standard yard inlets.

Both stream restoration and stream stabilization are complex because of the dynamic nature of streams. Detailed survey and analysis will be necessary prior to detailed design. Preliminary calculations that were used to estimate the appropriate stabilization design are available in Appendix D.

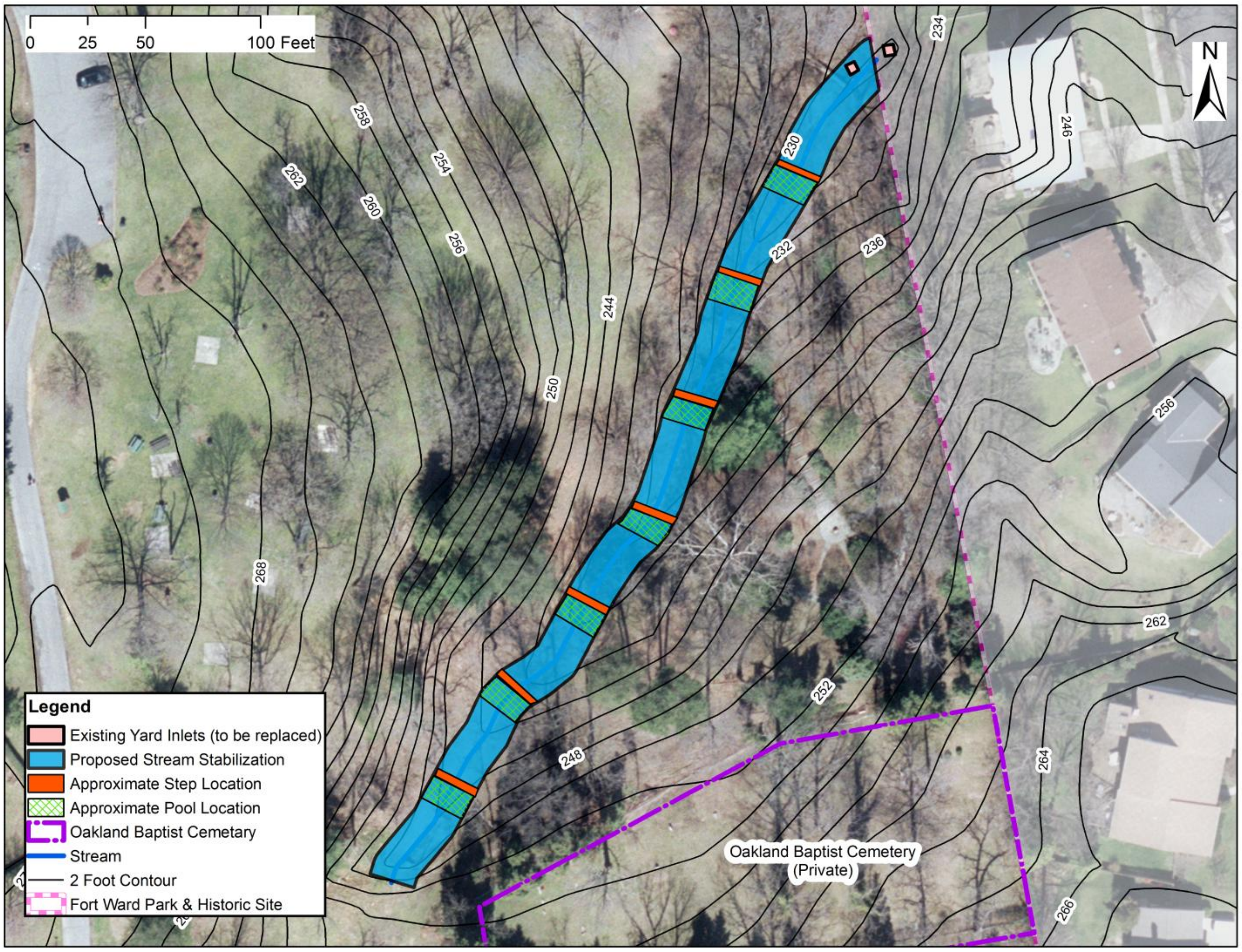


Figure 10: Proposed Stream Stabilization Concept Design

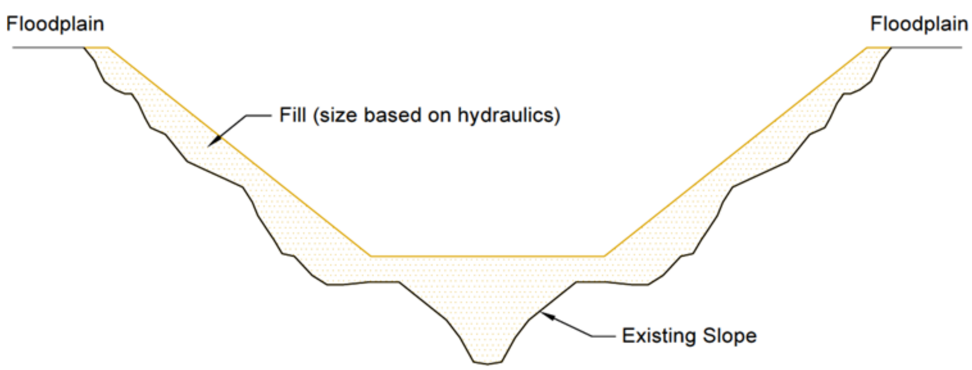


Figure 11: Typical Cross-Section Concept Design (Not to Scale)

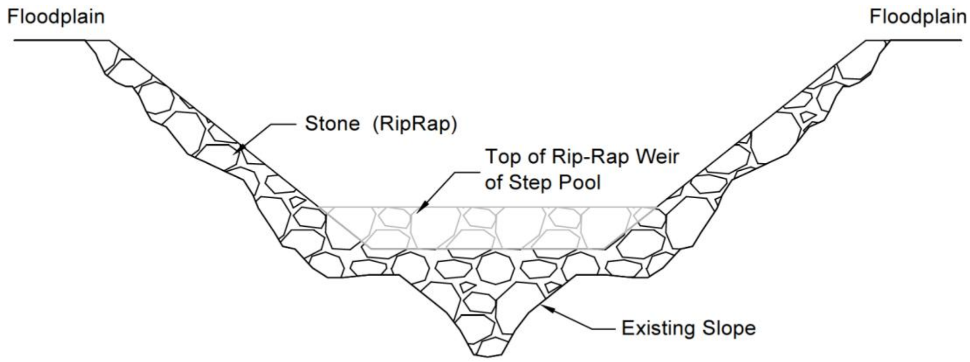


Figure 12: Step-Pool Cross-Section Concept Design (Not to Scale)

6.3.3 Improvements and Benefits

Incised stream banks indicate that a stream is not in a stable state. Without intervention, the stream condition is expected to continue to degrade with time. If the proposed stream stabilization occurs, the banks would be stabilized due to the addition of stone structures, lower channel slope, and an increase in channel roughness (due to the steps and pools). Pools would also allow for settling of fine particles, as well as providing potential habitat. Replacing the yard inlets would improve conveyance from the stream to the existing stormwater network.

Stream stabilization substantially improves the aesthetics of urban streams, and is often well received by the public. An educational sign is recommended to explain why stabilization occurred, as well as the benefits to a healthy stream.

6.3.4 Project Design Considerations

The proposed stream stabilization requires stone and sediment to be brought onsite. The installation of the elevated step-pool configuration would occur in the stream followed by the addition of fill to connect the channel to its floodplain. Pump-around diversion will be required to temporarily pump base flow around segments of the stream channel that are under construction.

Several other options were considered for stabilization design. These include connecting the bank to the channel by creating inset floodplains (cutting into the bank instead of raising the channel). The site is located within a Maximum Cultural Resource Protection area as specified by the Alexandria Archeology Office of Historic Alexandria due to potential burial sites in the area. Because of its location in the Maximum Cultural Resource Protection area, stream or bank excavation is not an option. Other stream structures including cross-vanes and log drops were also considered, but they generally require more excavation than step-pools.

Replacing the existing yard inlets would require excavation of the current inlets and hauling of the excess material offsite. The new yard inlets would also need to be installed and connected to the existing stormwater network.

6.3.5 Feasibility

Construction access to the proposed stream stabilization site would be available through Fort Ward Park Loop Road via Braddock Road. It will be necessary to drive on grass from the Park Loop Road. No utilities are expected to be impacted, although further coordination with the City would be needed during detailed design for confirmation.

Ideally, no trees would be removed during the stabilization process, but it is possible that some may need to be removed or relocated. It is also possible that trees could be damaged as a result of equipment. Trees may be planted following the stream restoration to help meet the City of Alexandria's Urban Forestry Plan goal of 40 percent tree cover over the City. Sediment control practices will have to be implemented during construction to avoid negatively impacting downstream waters.

The area surrounding the stream stabilization site will need to be temporarily closed off to the public. Fencing and signs may be necessary to keep park visitors from accessing the construction areas. Once the stabilization is complete, periodic inspection would be required to verify that there was not substantial movement of channel aggregate. In the two years following stream stabilization, some steps and pools typically require slight adjustments to function efficiently in the long term. Permitting and regulations are discussed in Section Seven.

6.4 COST ESTIMATE

Costs have been estimated for each of the proposed improvements described in sections 6.1-6.3.

The cost estimate described below should be considered as planning level only, and should be updated and refined with preliminary engineering and final project design.

The estimated costs for the proposed stormwater filter are shown in Table 7. The unit cost for the stormwater filter unit and installation was based on correspondence with Contech for the StormFilter. The remaining unit costs are from the Fairfax County Land Development Services 2013 Comprehensive Unit Price document as requested by the City of Alexandria.

Table 7: Stormwater Filter Concept Design Estimated Costs (Site 3)

Item	Quantity	Units	Unit Cost	Total
Excavation	70	CY	$23.36	$1,635.20
StormFilter Filtration System	1	EA	$60,000.00	$60,000.00
StormFilter Installation	1	EA	$15,000.00	$15,000.00
Restore Parking Area	30	SY	$35.04	$1,051.20
Mobilization	1	EA	$10,000.00	$10,000.00
CY = Cubic Yard		Initial Project Costs		$87,686.40
EA = Each		Maintenance	25%	$21,921.60
SY = Square Yard		Erosion and Sediment Control	20%	$17,537.28
		Subtotal 1		$127,145.28
		Contingency	25%	$31,786.32
		Subtotal 2		$158,931.60
		Engineering		$40,000.00
		Total		**$198,931.60**

The estimated costs for the proposed diversion berm concept design are shown in Table 8. The unit costs are from the Fairfax County Land Development Services 2013 Comprehensive Unit Price document as requested by the City of Alexandria.

Table 8: Diversion Berm Concept Design Estimated Project Costs (Site 6)

Item	Quantity	Units	Unit Cost	Total
Fill	100	CY	$23.36	$2,336.00
Excavation	30	CY	$29.20	$876.00
Erosion Control Matting	400	SY	$1.87	$748.00
Grading	700	SY	$0.90	$630.00
Clearing / Grubbing	1	AC	$7,006.50	$7,006.50
Tree Planting	5	EA	$525.49	$2,627.45
Catch Basin (Yard Inlet)	1	EA	$5,464.37	$5,464.37
12" Reinforced Concrete Pipe	80	LF	$47.88	$3,830.40
Outlet Protection (RipRap)	5	SY	$56.05	$280.25
Grass Seeding and Fertilizer	1000	SY	$2.34	$2,340.00
Mobilization	1	EA	$10,000.00	$10,000.00
AC = Acres		Initial Project Costs		$36,138.97
CY = Cubic Yard		Berm Maintenance	25%	$9,034.74
EA = Each		Erosion and Sediment Control	20%	$7,227.79
LF = Linear Feet		Subtotal 1		$52,401.51
SY = Square Yard		Contingency	25%	$13,100.38
		Subtotal 2		$65,501.88
		Engineering		$50,000.00
		Total		**$115,501.88**

The estimated costs for the proposed stream stabilization are shown in Table 9. The unit cost for step-pools is from the Virginia Stream Restoration & Stabilization Best Management Practices Guide (2004). The remaining unit costs are from the Fairfax County Land Development Services 2013 Comprehensive Unit Price document as requested by the City of Alexandria.

Table 9: Stream Stabilization Concept Design Estimated Project Costs (Site 7)

Item	Quantity	Units	Unit Cost	Total
Step Pools (Stone and Labor)	410	Ton	$50.00	$20,500.00
Fill	350	CY	$23.36	$8,176.00
Grading	1000	SY	$0.90	$900.00
Clearing / Grubbing	1	AC	$7,006.50	$7,006.50
Tree Planting	5	EA	$525.49	$2,627.45
Yard Inlet	2	EA	$5,736.69	$11,473.38
Dispose of Existing Yard Inlet	10	CY	$40.88	$408.80
Temporary Pump Around	2	Month	$11,677.00	$23,354.00
Mobilization	1	EA	$10,000	$10,000.00
AC = Acres	Initial Project Costs			$84,446.13
CY = Cubic Yard	Step-Pool Maintenance		25%	$21,111.53
EA = Each	Erosion and Sediment Control		20%	$16,889.23
SY = Square Yard	Subtotal 1			$122,446.89
	Contingency		25%	$30,611.72
	Subtotal 2			$153,058.61
	Engineering			$50,000.00
	Total			**$203,058.61**

SECTION SEVEN: PERMITTING REQUIREMENTS AND FUTURE REGULATIONS

7.1 FEDERAL REGULATIONS

7.1.1 General

The Clean Water Act (CWA) of 1972 and its amendments are the primary federal law that protects "navigable waters" of the U.S. from water pollution. Titles III and IV of CWA discuss EPA's Water Quality Standards (WQS) program and the National Pollutant Discharge Elimination System (NPDES) program.

CWA gives individual states the authority to implement CWA on all lands including federal property. In Virginia, the Virginia Department of Environmental Quality (DEQ) is responsible for issuing NPDES construction activity permits and NPDES Small Municipal Separate Storm Sewer System (MS4) permits. The terminology in Virginia is slightly different: the NPDES program is called the Virginia Pollutant Discharge Elimination System (VPDES) program and the NPDES permits are called Virginia Stormwater Management Program (VSMP) permits.

When activities require discharge of dredged or fill material into Waters of the U.S., a permit authorized by the U.S. Army Corps of Engineers (USACE) pursuant to section 404 of the Clean Water Act (CWA) (33 U.S.C. 1344) and a Virginia Water Protection permit Section 401 Certification must be obtained prior to conducting work.

7.1.2 Total Maximum Daily Loads (TMDLs) and Waste Load Allocations

Title III of the CWA discusses the federal WQS program. States are responsible for setting WQS by designating uses for each water body (e.g., drinking water use, primary contact/swimming use, fishing use, shell-fishing use, and aquatic life use) and applying water quality criteria to protect the designated uses.

TMDLs, which are the maximum amounts of pollutants that a water body can receive and still meet WQS, are developed for impaired waters listed in the 2012 Virginia 305(b)/303(d) Waster Quality Assessment Integrated Report. The TMDL applicable to Fort Ward Park is shown in Table 10.

Table 10: Impairments of Nearby Waterbodies from the 2012 Virginia 305(b)/303(d) List

Associated Waterbody	Pollution Status	Cause for Impairment	Source
Four Mile Run	Impaired	E. Coli	Illicit connections/hook-ups to storm sewers Wastes from pets Waterfowl

Source: Virginia Environmental GIS dataset "2012 Draft Water Quality Assessment GIS Applications" available at: http://www.deq.virginia.gov/ConnectWithDEQ/VEGIS/2012DraftWQMAssessmentGISApplications.aspx

A bacteria TMDL for the Four Mile Run watershed was completed and approved in 2002.

The TMDL implementation plan was approved in 2004, which called for "proper pet waste disposal." The Park is in compliance with the implementation plan since it has a pet waste station at the dog exercise area. This is the only dog exercise area within the non-tidal Four Mile Run watershed.

7.1.3 Approvals for Bank Stabilization Projects

USACE issued Nationwide Permit 13 (NWP 13) for bank stabilization projects on February 21 2012. NWP (13) authorizes bank stabilization up to 500 feet in length and up to 1 cubic yard of material per running foot placed along the bank below the plane of the ordinary high water mark. The recommended bank stabilization project in Section Six is less than 500 feet long. Therefore, no additional permitting is required from USACE.

A Virginia Water Protection Permit is required for bank stabilization projects, and the City needs to submit the Virginia Joint Permit Application to the Virginia Marine Resources Commission, which serves as the clearinghouse for Federal and State wetland and waterway permits.

7.2 STATE REGULATIONS

Legislation passed by the 2012 General Assembly integrated and consolidated components of the Erosion and Sediment Control (ESC) Act, the Stormwater Management Act, and the Chesapeake Bay Preservation Act so that these regulatory programs could be implemented in a consolidated and more consistent and efficient manner. The new regulations were approved by the Board of Conservation and Recreation on September 28, 2012, and became effective on November 21, 2012.

During construction, a land disturbance permit may be required for ESC. These permits are issued by localities as part of their ESC program. A stormwater permit may be required to discharge stormwater from a construction activity. Such a permit may also be required to discharge stormwater through a stormwater conveyance system owned or operated by a government entity. DEQ administers these stormwater permits under the VSMP Permit Regulations, authorized by the Virginia Stormwater Management Act. As mandated by CWA and the Code of Federal Regulations, federal permitting requirements have been incorporated into the VSMP permit regulations.

7.2.1 General Permit for Discharge of Stormwater from Small Municipal Separate Storm Sewer System (MS4)

Under the VSMP permit regulations, the City is required to control stormwater pollution to the maximum extent practicable and to develop a pollution prevention plan – known as a Municipal Separate Storm Sewer System (MS4) Program Plan. The current MS4 permit for the City is valid from July 1, 2013 to June 30 2017.

7.2.2 General Permit for Discharge of Stormwater from Construction Activities (VAR10)

The Virginia DEQ administers VSMP's General Permit for Discharges of Stormwater from Construction Activities. The General VSMP Permit authorizes stormwater discharges from the following types of land-disturbing activities at Fort Ward Park:

- Operators of construction activities resulting in land disturbance equal to or greater than one acre;
- Construction activities with land disturbance less than one acre that are part of a larger common plan of development or sale that disturb one or more acres. A larger common plan of development or sale is a contiguous area where separate and distinct construction may be taking place at different times on different schedules.

To be in compliance with the general permit, it is necessary to follow the steps listed below. In most cases, construction projects at the Park will be contracted out; however, the City of Alexandria is ultimately responsible for ensuring that a Stormwater Pollution Prevention Plan (SWPPP) is written and implemented for all regulated construction activities, and that construction activities are properly registered.

- Prepare a Registration Statement
- Prepare a site-specific SWPPP
- Apply for permit coverage
- Conduct construction in accordance with the permit and SWPPP
- Submit a notice of termination after construction is complete

A registration statement (Form DEQ199-146) and fee form (DEQ199-213) must be completed and submitted to the State along with the appropriate fee payment.

The SWPPP must be prepared prior to submitting a registration statement for permit coverage. The SWPPP is to be retained at the construction site along with a copy of the permit and permit coverage letter.

7.3 CITY OF ALEXANDRIA PERMIT REQUIREMENTS

Currently, the City plans to amend the Environmental Management Ordinance (EMO) and the Erosion and Sediment Control Ordinance to comply with several new regulatory requirements. The proposed EMO is available on the City website (http://www.alexandriava.gov/tes/oeq/info/default.aspx?id=3844) and the first hearing is scheduled for March 11, 2014.

No land-disturbing activities may commence until the final site plan is approved by the City and a state construction general permit has been issued.

7.3.1 Floodplain

The Park does not have lands designated as Federal Emergency Management Agency (FEMA) floodplains.

7.3.2 Chesapeake Bay Preservation

The Park does not have lands designated as a Chesapeake Bay Preservation Area.

7.3.3 Maintenance of Traffic (MOT) Permit

The City requires a permit on any work in the public right-of-way (street, grass strip [area between the sidewalk and the street], sidewalk, public alleys). Types of work that require a permit includes: placing a ladder and/or scaffolding on the sidewalk; closing the sidewalk; crossing the curb, gutter, and sidewalk with heavy equipment, a dumpster, or a crane; lane closure; stockpiling materials in the public right-of-way; trailer in the public right-of-way; temporary fence in the public right-of-way; hauling construction debris, materials, or equipment; excavation in the public right-of-way; and special events such as a block party, foot race/walk-a-thon, or parade/procession.

City code definition of "street" [see code section 1-1-5(13)] - The word "street" shall include avenues, boulevards, highways, roads, alleys, lanes, viaducts, bridges and the approaches thereto and all other public thoroughfares in the city and shall mean the entire width thereof between abutting property lines; it shall be construed to include a sidewalk or footpath, unless the contrary is expressed or unless such construction would be inconsistent with the manifest intent of the council.

A permit for work in/use of the public right-of-way should be applied for 5 business days prior to the start of the work. A drawing will be required showing the location of the work/use and equipment, together with a maintenance of traffic plan.

SECTION EIGHT: CONCLUSIONS

Fort Ward Park is susceptible to nuisance flooding and erosion due to overland flow and flooding. URS conducted a field reconnaissance and examined 16 sites at the Park to evaluate the existing conditions and identify potential measures to improve drainage and reduce sedimentation. URS also performed hydrologic and hydraulic analyses to verify the capacity of the existing stormwater systems. Most culverts are designed to convey 25-year storm events, provided routine maintenance is performed.

This report summarizes the drainage improvement recommendations based on the field observations, engineering calculations, and community input. The most frequent recommendations for the 16 sites evaluated by URS were for nonstructural improvements. These include turf seeding, soil aeration, and routine maintenance. Structural improvements were also recommended at some of the sites, including at the locations of the three proposed concept designs. The concept designs include a stormwater filter, stream stabilization, and a diversion berm.

SECTION NINE: REFERENCES

Ad Hoc Fort Ward Park and Museum Area Stakeholder Advisory Group, 2013 "2012-2013 Advisory Group Draft Recommendations" http://alexandriava.gov/uploadedFiles/recreation/parks/FWAdHOc2012and2013DraftRec.pdf, accessed July 18, 2013.

Arlington County and City of Alexandria, 2009 "Four Mile Run Design Guidelines" http://alexandriava.gov/uploadedFiles/planning/info/FourMileRunDesignGuidelinesFINALAugust.pdf, accessed July 22, 2013.

Autodesk, 2010, Autodesk Storm and Sanitary Analysis Stand-Alone 2011, User's Guide, April 2010.

City of Alexandria, 2006 "Amendments to the City of Alexandria Article XIII Environmental Management Ordinance" http://www.alexandriava.gov/uploadedFiles/tes/info/Article_XIII_2006.pdf, accessed February 3, 2014.

Esri, 2010. ArcGIS Version 10.0. www.esri.com/.

Fairfax County Department of Public Works, 2013 "Land Development Services 2013 Comprehensive Unit Price Schedule Effective March 15, 2013" http://www.fairfaxcounty.gov/dpwes/publications/2013ups.pdf, accessed February 3, 2014.

Federal Lands Highway Division Engineers, HY-8 Version 7.2., https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/.

Maryland Hydrology Panel, 2010 *Application of Hydrologic Methods in Maryland*, Third Edition, September 2010.

NRCS, 1986 "Urban Hydrology for Small Watersheds TR55," June 1986.

NRCS, 2009 "US General Soil Map," http://SoilDataMart.nrcs.usda.gov/, accessed July 2013.

Office of the City Manager, 2013 "City Manager Response to Fort Ward Park Issues," May 6, 2013.

Virginia Department of Conservation and Recreation, 2004 "The Virginia Stream Restoration & Stabilization Best Management Practices Guide" http://www.deq.virginia.gov/Portals/0/DEQ/Water/Publications/BMPGuide.pdf, accessed February 3, 2014.

Virginia Department of Environmental Quality, 1992 "The Virginia Erosion and Sediment Control Handbook" http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications/ESCHandbook.aspx, accessed February 3, 2014.

Virginia Department of Transportation, 2002 "Drainage Manual" http://www.virginiadot.org/business/resources/LocDes/DrainageManual/START_VDOT_Drainage_Manual.pdf, accessed February 3, 2014.

Additional References and Resources

Bucksten, Denys

2013 *Cemetery Drainage cited as model*. Mooney Cemetery in Hghland Park installs permeable pavers. http://www.chicagotribune.com/news/local/suburbs/highland_park_deerfield/ct-tl-lk-0919-highland-park-cemetery-drainage-20130916,0,6791885.story Chicago Tribune, Chicago Illinois. Accessed 4 February 2014.

Chicora Foundation, Inc. (CFI)

N.Da. *Best Practices for Cemetery Lawn Maintenance*. http://www.chicora.org/pdfs/Lawn%20Maintenance.pdf Accessed 5 February 2014.

N.D.b *Resetting Tilted Markers*. http://www.chicora.org/resetting.html Accessed 5 February 2014.

Illinois Historic Preservation Agency

N.D. *Illinois Historic Cemetery Preservation Handbook: A Guide to Basic Preservation*. Illinois Historic Preservation Agency and Illinois Department of Natural Resources, Springfield. http://www.dnr.illinois.gov/naturalresources/cultural/documents/ilhistoriccemeterypreservationhandbook.pdf Accessed 4 February 2014.

King, Gregg G., with Susan Kosky, Kathleen Glynn, and Glady Saborio

2004 *Michigan Historic Cemeteries Preservation Guide*. Michigan State Historic Preservation Office, The Charter Township of Canton Historic District Commission, and Department of Leisure Service, Michigan. http://www.michigan.gov/documents/hal_mhc_shpo_Cemetery_Guide_105082_7.pdf Accessed 4 February 2014.

Mitchell, Peter

2009 *Stoke Road Cemetery: Concerns regarding ground conditions*. Peter Mitchell Associates, Harrietsham, Kent, United Kingdom.

Potter, Elisabeth Walton, and Beth M. Boland

1992 *Guidelines for Evaluating and Registering Cemeteries and Burial Places*. National Register Bulletin 41, National Park Service, Department of the Interior, Washington, D.C. http://www.nps.gov/nr/publications/bulletins/nrb41/ Accessed 4 February 2014.

Strangstad, Lynette

1995 *A Graveyard Preservation Primer*. Altamira Press, published in cooperation with Association for Gravestone Studies, Walnut Creek, California.

Texas Historical Commission
N.D. *Preserving Historic Cemeteries: Texas Preservation Guidelines*. Texas Historical Commission, Austin. http://www.thc.state.tx.us/public/upload/publications/preserving-historic-cemeteries-2011.pdf Accessed 4 February 2014.

Trinkley, Michael
2011 Conservation Talk: Trees and Stones. American Grave Society Quarterly 35(3):24-26. http://www.chicora.org/pdfs/AGS%20Conservation%20Talk%20-%20Trees%20&%20Stones.pdf Accessed 4 February 2014.

Trippe-Dillon, Tammie
1999 *Grave Concerns: A Preservation Manual for Historic Cemeteries in Arkansas*. Arkansas Preservation Program. http://www.arkansaspreservation.com/pdf/publications/grave_concerns.pdf Accessed 4 February 2014.

Virginia Department of Historic Preservation (VFHR)
N.D. Cemetery Preservation: Frequently Asked Questions. http://www.dhr.virginia.gov/homepage_general/faq_cem_presv.htm

American Institute for Conservation of Historic and Artistic Works
http://www.conservation-us.org/grants-scholarships

Association for Preservation Technology and Training
https://ncptt.nps.gov/grants/

Getty Conservation Institute
http://www.getty.edu/grants/

National Endowment for the Humanities
http://www.neh.gov/grants

National Institute for Conservation Heritage Preservation
https://www.heritagepreservation.org/

National Trust for Historic Preservation
http://www.preservationnation.org/resources/find-funding/

Research Grant Guides
www.researchgrant.com

Preservation Virginia
http://preservationvirginia.org/

Saving Graves
http://www.savinggraves.net/

Appendix A

Public Meeting Presentations

Fort Ward Park Master Drainage Plan

Prepared for City of Alexandria

Presented by URS Corporation

June 12, 2013

URS | Fort Ward Park Master Drainage Plan

Introductions – URS

Zhongyan Xu, PhD, PE

Project Manager

Mary Roman, PE

Contract Manager/Technical Liaison

URS | Fort Ward Park Master Drainage Plan

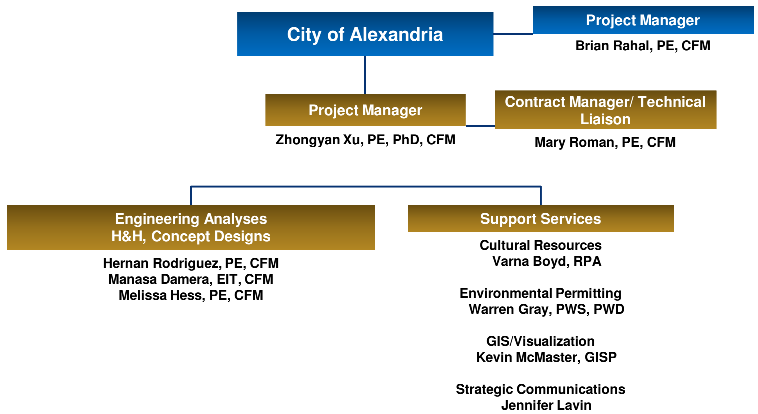
2

Agenda

- Team Organization
- Project Goals and Objectives
- Project Work Plan
- Project Schedule

URS | Team Organization

Project Organization



URS | Fort Ward Park Master Drainage Plan

5

URS Approach

- National leader in water resources with local expertise
- Dedicated project team members with required planning, regulatory, and engineering expertise
- Results oriented approach:
  - Objective prioritization of problems and solutions
  - Effective assessment of drainage issues
  - Experience with a wide range of cost effective drainage solutions
  - Efficient concept development and feasibility evaluation

URS | Fort Ward Park Master Drainage Plan

6

URS | **Project Goals and Objectives**

Issue: Flooding and Erosion

- Nuisance flooding and erosion in the park and at adjacent properties

Pictures obtained from ttps://www.facebook.com/pages/The-Ft-Ward-and-Seminary-African-American-Descendants-Society/

Project Goals and Objectives

- Identify potential drainage improvements
- Develop effective solutions
- Minimize impacts to the historic nature of the park
- Minimize impacts to adjacent properties

Work with Local Government and Citizens to Create Viable Solutions

- Focus on approaches that balance the historical, natural and recreational significance of the park
- Address important municipal issues:
  - Flooding
  - Sewer system function
  - Erosion
- Coordinate with on-going projects
  - Fort Ward Park and Museum Management Plan
  - Park Walkway Project
  - Interim Drainage Solutions
  - Archaeological Investigation

Community Outreach

- Provide Information
- Solicit support
- Address needs
- Obtain consensus

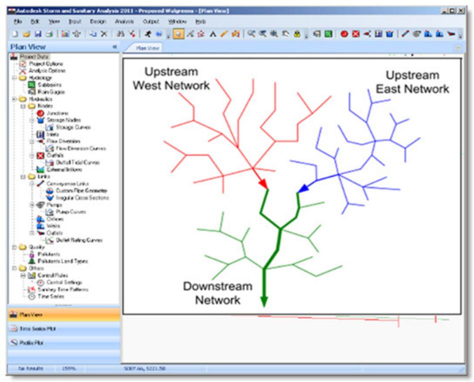
URS | Fort Ward Park Master Drainage Plan

11

URS | **Project Work Plan**

Project Work Plan

- Hydrologic/Hydraulic Analyses
  - Hydrologic Modeling
  - Hydraulic Capacity Analyses
  - Identify drainage system deficiencies and proposed improvements



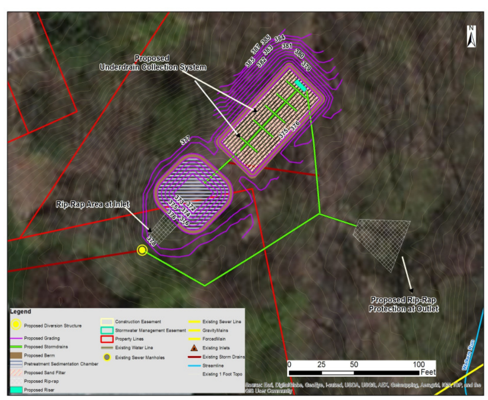
Overall Drainage Patterns

Project Work Plan

- Identify Potential Solutions
  - Conveyance Improvements (e.g., swales, closed systems, other)
  - Redirect drainage away from erodable areas and sensitive resources
  - Encourage infiltration to reduce runoff
- Conduct Feasibility Assessment
  - Technical
  - Permitting
  - Cultural Resources Impacts

Project Work Plan

- Concept Plans and Computations
  - A 10% concept plan with site grading
  - Planning level capacity analysis
- Cost Estimate Development
  - Cost estimate including design, permitting and construction



Graphics obtained from Hyde Park Dry Pond Project and Maryland Storm Water Manual

URS | Project Schedule

Project Schedule

- Draft H&H Report: Late Summer 2013
- Concept Improvement Plans: Fall 2013
- Public Meeting: Winter 2013
- Final Report Submission: Winter 2013

Questions

Fort Ward Park Master Drainage Plan

Prepared for the City of Alexandria

Presented by URS Corporation

August 14, 2013

Agenda

- Project Status
- Overview of Technical Analyses
- Next Steps

URS | **Project Status**

Project Schedule

- Field Reconnaissance: Complete July 2013
- Draft Hydrologic/Hydraulic Analyses Report: Late Summer 2013

  On Schedule
- Concept Improvement Plans: Fall 2013
- Public Meeting: Winter 2013
- Final Report Submission: Winter 2013

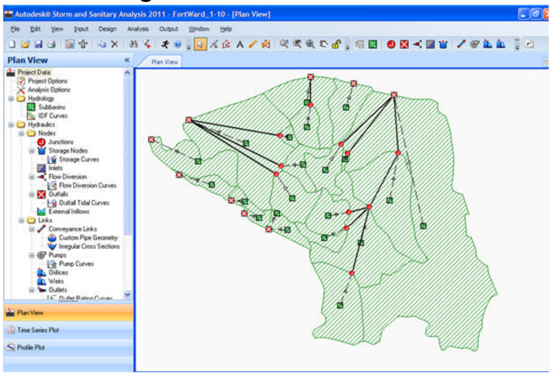
Project Status

- Since last public meeting on June 12, 2013
  - Field Reconnaissance: June 28, 2013
  - Hydrologic & Hydraulic Analysis:
    - Hydrologic Analyses: Completed
    - Hydraulic Capacity Analyses: Completed
    - Identification of drainage system deficiencies and proposed improvements: in progress
    - Report: in progress

URS | Technical Analyses

Hydrologic and Hydraulic Analyses

- Developed drainage area map with 21 subbasins
- Hydrologic analyses conducted utilizing available land use, soils information, and drainage areas
- Hydrologic Analyses conducted using Rational Method.
- Estimated capacity of existing culverts using HY-8



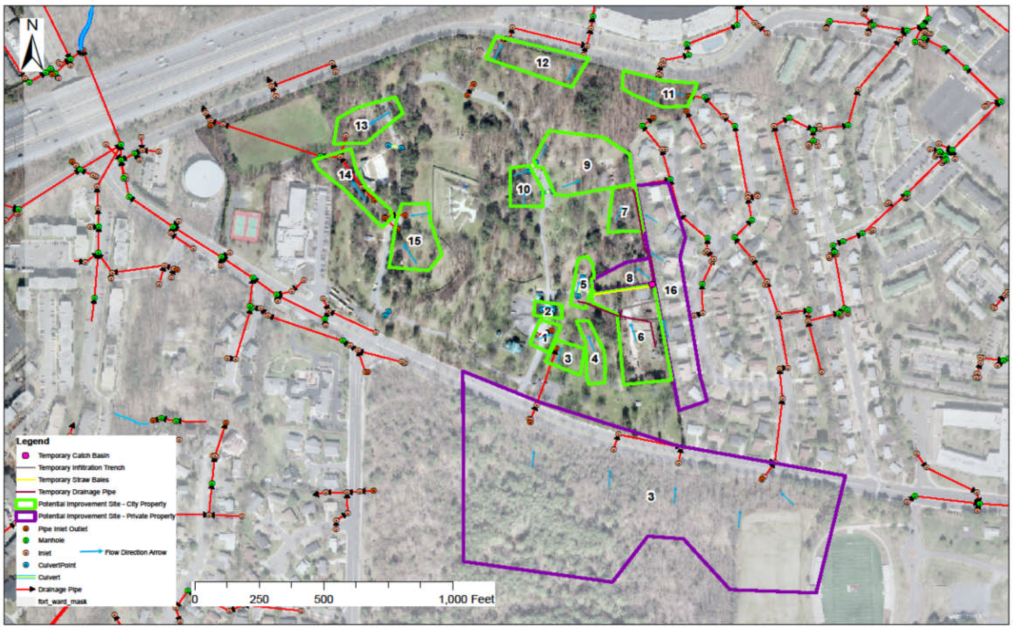
URS | Fort Ward Park Master Drainage Plan

Analyses of Potential Drainage Issues

- Conducted field visit to assess drainage conditions
- Identified potential drainage improvements
- 16 sites were identified with existing drainage condition problems

URS | Fort Ward Park Master Drainage Plan

Site Map



Site 1

- Shallow drop inlet near the museum and the parking lot. No major problems noted during the field trip.

Upstream Inlet

Downstream Outlet

Site 2

- 15" culvert crossing under the entrance road near bathrooms. A small ponding area was observed at the culvert inlet.

Upstream Inlet

Downstream Outlet

URS | Fort Ward Park Master Drainage Plan

Site 3

- Outlet of 18" pipe that collects runoff from upstream forested area and Braddock Road. Sediment and debris deposition was noted at the outfall.

Downstream Outlet

Downstream of the Outlet

URS | Fort Ward Park Master Drainage Plan

Site 4

- Swale in the natural area with "No Mowing" sign nearby. No major problems noted during the field trip.

Site 5

- The 36" culvert under the road that leads to the utility yard is partially blocked and vegetation was overgrown around the culvert. Observed sediment and debris build up at the 6” PVC underdrain pipe that located just upstream of the 36” culvert.

Upstream Face of the Culvert

Sedimentation on the Road

Site 6

- Old Utility Yard. Several infiltration trenches have been installed to prevent runoff from reaching the cemetery. A temporary catch basin collects runoff from the small trench along the fence line which divides the park property from the neighborhood. The runoff from the catch basin drains to an area uphill of the road over the 36” culvert and downhill of the cemetery. Temporary hay bales have been setup up to prevent runoff from entering the cemetery.

Infiltration Trenches

Hay Barrel

Downstream of the Outlet

Catch Basin

URS | Fort Ward Park Master Drainage Plan

Site 7

- Main stream channel that runs through the park is eroded and there is concrete debris in the channel. A swale has formed from backyard drainage conveyance from residential property. In addition, there is a clogged inlet at downstream end of the natural stream channel.

Stream Bed

Swale from the backyard

URS | Fort Ward Park Master Drainage Plan

Site 8

- The base areas are exposed on several gravestones in the cemetery. Depressions have formed in front of several graves from ponding during rain events. There are several areas of exposed, bare ground in the cemetery. A channel is forming through the cemetery where runoff flows during rain

Exposed Gravestone

Exposed Bare Ground and Gravestone

Exposed Bare Ground

Site 9

- A channel has formed on the hill adjacent to the playground. There are two yard inlets that collect drainage from the hill before it gets to the playground. One of these inlets is completely covered by sediment and leaves. A channel has formed through the playground. There is a rock outfall and filter fabric at the outfall of the channel through the playground. There are areas of bare ground on the hill upstream of the playground.

Channel in the playground

Channel upstream of the playground

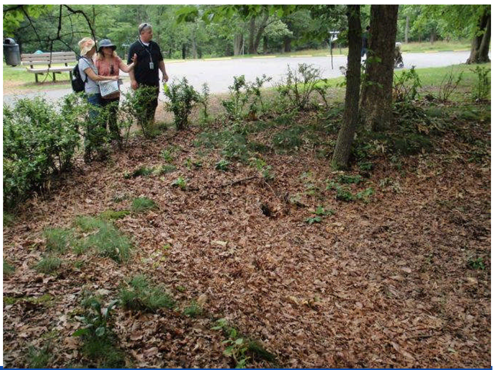
Exposed Bare Ground

Site 10

- There is a clogged yard inlet near the footbridge over the swale surrounding the Fort. The cross culvert inlet upstream from the rifle trench appeared to be clogged at the time of the field visit.

Clogged Inlet near Footbridge

Clogged Inlet



URS | Fort Ward Park Master Drainage Plan

Site 11

- Pond at the NE corner of Park boundary. Potential water quality issues.

Inlet feeding into SWM pond from Marlboro Properties

SWM Riser

URS | Fort Ward Park Master Drainage Plan

Site 12

- Park outfalls along Van Dorn Street. Inlets collecting drainage from parks are clogged with debris. Channels have formed downstream of cross culverts discharging runoff

Clogged Inlet Outfall at the Park Property Line

Upstream Channel of the Outfall

URS | Fort Ward Park Master Drainage Plan

Site 13

- There are bare spots on hill near the soccer field. An inlet at the base of the hill is clogged and a channel has formed upstream of the inlet.

Bare Ground

Channel Upstream

Clogged Inlet

URS | Fort Ward Park Master Drainage Plan

Site 14

- No problems were observed near the manhole and inlets near soccer field and amphitheater.

Upstream

Inlet next to Amphitheater

URS | Fort Ward Park Master Drainage Plan

Site 15

- There are areas of exposed, bare ground in the open areas near the parking lot near amphitheater and adjacent open area. The inlet adjacent to the west side of the Fort is clogged. There is a depression at 15” inlet to the cross culvert under the parking lot. Sedimentation in the parking lot due to blockage from telephone poll being used as a landscape timber.

Bare Ground

Sedimentation at the parking lot

Depression at the inlet

URS | Fort Ward Park Master Drainage Plan

Site 16

- Runoff from the properties in Marlboro Estates is draining onto Park property and contributing to drainage issues

Potential Solutions - General

- Encourage infiltration to reduce runoff (re-seeding, reduced mowing, soil amendments, etc.)
- Conveyance Improvements (e.g., clean-up and maintenance of the existing system, swales, closed systems, etc.)
- Redirect drainage away from erodable areas and sensitive resources (long-term solutions include: roof downspouts and sump pumps to storm drain system, etc.)

URS | Next Steps

Next Steps

- Solicit ideas for potential solutions from work group
- Complete the H&H Report
- Select sites for concept design development
- Develop concept designs for selected improvements

Questions

URS | Fort Ward Park Master Drainage Plan

Appendix B
Field Reconnaissance Report

URS Corporation (URS) performed a detailed field reconnaissance with Brian Rahal, PE, the City Engineer, on June 28, 2013, to inspect the condition of the on-site stormwater collection system and interim drainage solutions. Ground condition was also inspected for signs of erosion and sedimentation. Photographs were taken as part of the field reconnaissance to record the existing condition.

To prepare the field reconnaissance trip, URS obtained and reviewed the 2-foot contour interval topographic information in the digital format provided by City of Alexandria (City). In addition, URS examined the drainage network showing the locations and orientation of pipe systems at the Fort Ward Park (Park), provided by the City. During the field reconnaissance trip, URS conducted a throughout on-site investigation on the existing drainage system and verified the onsite and offsite drainage area boundaries.

The results of the field reconnaissance confirmed that the most on-site drainage systems that collect and divert runoff from off-paved areas are functional. However, erosion and sedimentation were observed at various locations. Engineering calculations were performed to verify the capacity of the cross culverts and drainage systems (summarized in Appendix B).

URS inspected the surrounding areas of the Park, including a number of outfall points along Van Dorn Street. The field reconnaissance showed outfall pipes with built-up debris, which are typical for locations that lack regular maintenance and inspection.

URS also inspected the stormwater management pond near the Marlboro Subdivision. Due to limited access in wooded areas, only representative locations were inspected. The results showed unstable areas immediately above the riser and the degradation of the channels in the wooded areas.

Figure B-1 identifies the locations of all photographs. Figure B- 2 to Figure B- 106 shows the existing conditions.

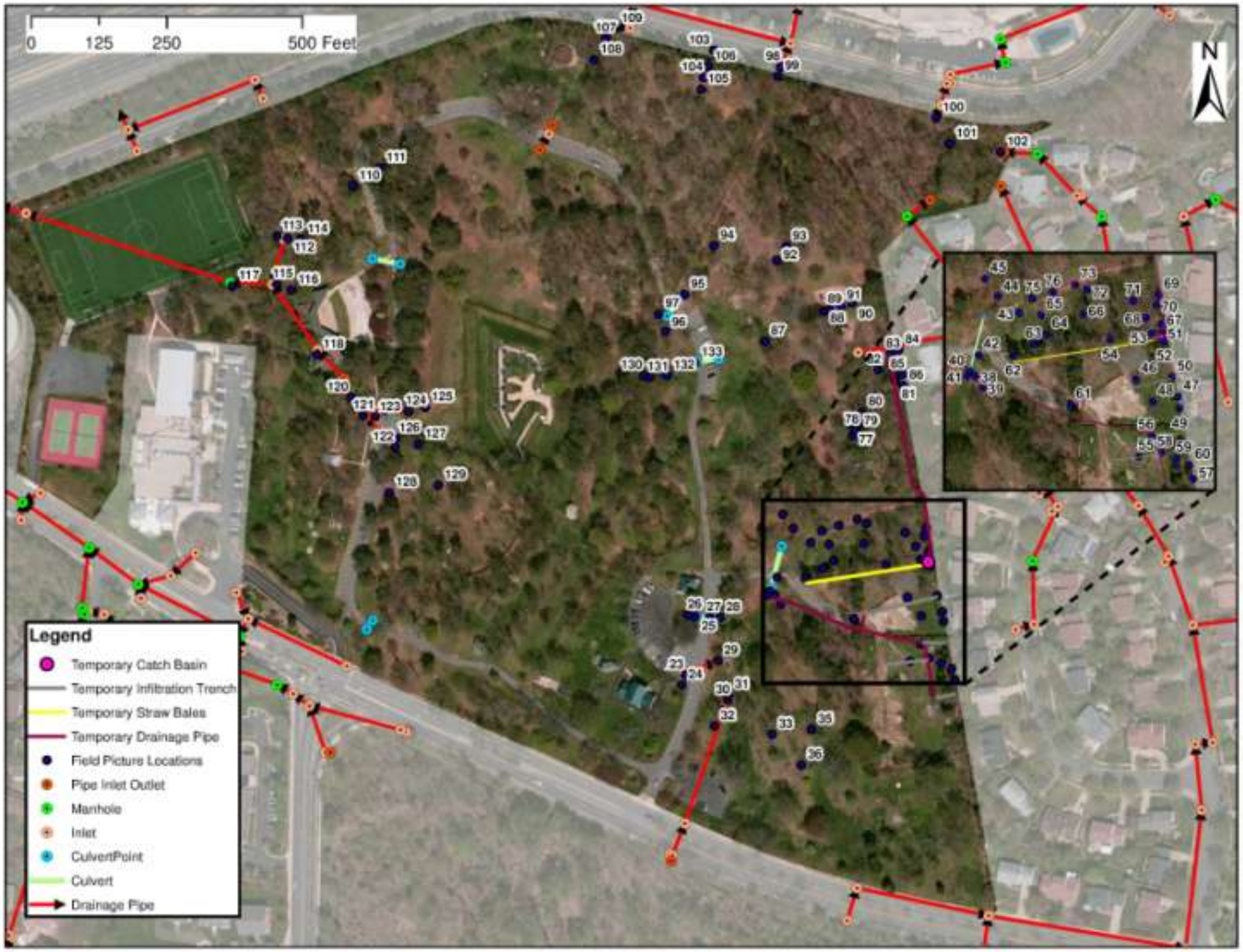


Figure B-1: Fort Ward Park Field Reconnaissance Location Map

Figure B-2: Shallow drop inlet next to the parking lot (Location ID #23)

Figure B-3: Upstream of the shallow drop inlet (Location ID #24)

Figure B-4: Outlet of the 15-inch concrete pipe. No erosion was observed(Location ID#29)

Figure B- 5: Inlet of the 15-inch concrete pipe next to the parking lot (Location ID #25). Observed a small ponding area at the inlet

Figure B- 6: Upstream of the 15-inch concrete pipe (Location ID #26)

Figure B- 7: Downstream of the 15-inch concrete pipe (Location ID #27)

Figure B- 8: Outlet of the 15-inch concrete pipe (Location ID #28)

Figure B- 9: Outlet of 18-inch concrete pipe. Observed built-up debris and sedimentation, which may come from roadway (Location ID #30)

Figure B- 10: Downstream of the 18-inch concrete pipe. Observed built-up debris (Location ID #31)

Figure B- 11: Open space upstream between the parking lot and the swale (Location ID #32)

Figure B- 12: Open space upstream between the parking lot and the swale (Location ID #33)

Figure B- 13: The swale. No erosion observed (Location ID #35)

Figure B- 14: The sign at the swale (Location ID #36)

Figure B- 15: Blocked Outlet for 6-inch PVC underdrain pipe. Observed built-up debris and tree branches (Location ID #38)

Figure B- 16: Upstream of the 6-inch PVC underdrain pipe (Location ID #39)

Figure B- 17: Inlet of the 36-inch culvert. Observed built-up tree branches at the inlet (Location ID #40)

Figure B- 18: Inlet of the 36-invch culvert. Observed built-up tree branches at the inlet (Location ID #41)

Figure B- 19: Road Crossing of the 36-inch culvert. Observed sedimentation at the road (Location ID #42)

Figure B- 20: Silt fence downstream of the culvert (Location ID #43)

Figure B- 21: Downstream channel of the culvert (Location ID #44)

Figure B- 22: Downstream overbanks of the culvert (Location ID #45)

Figure B- 23: Trench drain along the chain-linked fence on the City property (Location ID #46)

Figure B- 24: Area adjacent to the backyard of a private property. The area was seeded to improve drainage and prevent erosion. No erosion was observed (Location ID #47)

Figure B- 25: Open space (Location ID #48)

Figure B- 26: Swale by the chain-linked fence along the property boundary (Location ID #49)

Figure B- 27: Swale at the chain-linked fence (Location ID #50)


Figure B- 28: Catch basin as interim drainage solution (Location ID #51)


Figure B- 29: Upstream of the catch basin (Location ID #52)

Figure B- 30: Hay barrel along the fence to the outfall pipe (Location ID #53)

Figure B- 31: Hay barrel along the fence to the outfall pipe (Location ID #54)

Figure B- 32: Open space (Location ID #55)

Figure B- 33: Trench drain along the fence (Location ID #56)

Figure B- 34: Area near a private property upstream of the trench drain. Observed dryness after the storm (Location ID #57)

Figure B- 35: Covered catch basin/trench drain (Location ID #58)

Figure B- 36: Trench drain. Homeowners covered the bare soil with mulch which helped to improve the drainage. Observed dry ground after the storm (Location ID #59)

Figure B- 37: Fence along the private properties. Observed dry ground after the storm (Location ID #60)

Figure B- 38: Gate at the City property (Location ID #61)

Figure B- 39: End of the hay barrel along the cemetery fence. (Location ID #62)

Figure B- 40: Exposed head stone in the cemetery (Location ID #63)

Figure B- 41: Exposed head stone in the cemetery (Location ID #64)

Figure B- 42: Depression in front of the grave (Location ID #65)

Figure B- 43: Exposed bare ground in the cemetery (Location ID #66)

Figure B- 44: Exposed bare ground at southeast corner of the cemetery (Location ID #67)

Figure B- 45: Exposed bare ground at southeast corner facing west (Location ID #68)

Figure B- 46: Exposed bare ground along the property fence (Location ID #69)

Figure B- 47: Three grave stones (at the southeast corner) (Location ID #70). Used to be ponded after storms. Observed dry ground after the storm due to the interim drainage solution


Figure B- 48: Exposed bare ground at southeast corner facing northwest (Location ID #71)


Figure B- 49: Upstream of the swale outfall in the cemetery (Location ID #72)

Figure B- 50: Downstream of the swale outfall in the cemetery (Location ID #73)

Figure B- 51: Outfall outside the cemetery (Location ID #75)

Figure B- 52: Outfall from the cemetery (Location ID #76)

Figure B- 53: Stream. Observed debris in the channel. (Location ID #77)

Figure B- 54: Streambed and overbanks (Location ID #78)

Figure B- 55: Upstream of the foot bridge (Location ID #79)


Figure B- 56: Downstream of the foot bridge (Location ID #80)


Figure B- 57: Swale from the properties (Location ID 81)


Figure B- 58: Streambed (Location ID 82). Observed channel erosion


Figure B- 59: Inlet next to the stream (Location ID #83)

Figure B- 60: Inlet next to the property (Location ID #84)

Figure B- 61: Rock channel in the Property upstream of the swale (Location ID #86)

Figure B- 62: Channel upstream of the playground (Location ID #87). Observed erosion

Figure B- 63: Inlet at the playground (Location ID #88)

Figure B- 64: Blocked Inlet at the playground (Location ID #89)

Figure B- 65: Downstream of the playground (Location ID #64)


Figure B- 66: Swale in the playground (Location ID #91)


Figure B- 67: Bare ground next to the playground (Location ID #92)


Figure B- 68: Bare ground next to the playground (Location ID #92)


Figure B- 69: Upstream of the drainage inlet (Location ID #96). The inlet appeared to be clogged

Figure B- 70: Upstream of the Drainage Inlet (Location ID #97)

Figure B- 71: Inlet next to the street (Location ID #98)

Figure B- 72: Upstream of the inlet (Location ID #99)

Figure B- 73: Stormwater management (SWM) pond riser (Location ID #100)

Figure B- 74: Upstream of the SWM facility (Location ID # 101)

Figure B- 75: Inlet feeding into the SWM pond from the Marlboro properties (Location ID #102)

Figure B- 76: Outfall from the Park along N. Van Dorn Street (Location ID #103). Observed outlet clogged by debris

Figure B- 77: Upstream channel of the outfall (Location ID 104)


Figure B- 78: Upstream area of the outfall from the Park (Location ID #105)


Figure B- 79: Concrete channel in the Park (Location ID #106)

Figure B- 80: Upstream area of the outfall (Location ID #107)

Figure B- 81: Upstream area of the outfall (Location ID #108)

Figure B- 82: Inlet outfall at the Park property line (Location ID #109). Observed clogged inlet

Figure B- 83: Open space (Location ID #110). Observed bare ground

Figure B- 84: Open space (Location ID #111). Observed bare ground

Figure B- 85: Inlet (Location ID #112). Observed built-up debris clogging the inlet

Figure B- 86: Downstream area of the manhole (Location ID #113)

Figure B- 87: Upstream area of the inlet (Location ID #114). Observed debris and sedimentation

Figure B- 88: Inlet (Location ID #115). Observed vegetation clogging the inlet

Figure B- 89: Upstream Area of the Inlet (Location ID #116)

Figure B- 90: Manhole near the soccer field (Location ID #117)

Figure B- 91: Inlet next to amphitheatre (Location ID #118)

Figure B- 92: Inlet culvert next to amphitheatre (Location ID #119)

Figure B- 93: Upstream of the inlet (Location ID #120)

Figure B- 94: Outlet of the 15-inch culvert crossing (Location ID #121).

Figure B- 95: Inlet of the 15-inch culvert crossing (Location ID #122). Observed depression at the inlet

Figure B- 96: Parking lot next to the Inlet (Location ID #126). Observed sedimentation at the parking lot

Figure B- 97: Inlets at the parking lot near the amphitheater (Location ID #123)


Figure B- 98: Inlet adjacent to the west Side of the fort (Location ID #124). Observed debris at the inlet


Figure B- 99: Upstream area of the inlet (Location ID #125)

Figure B- 100: Open space (Location ID #127). Observed bare ground

Figure B- 101: Open space (Location ID #128). Observed bare ground

Figure B- 102: Open space (Location ID #129). Observed bare ground near the silt fence

Figure B- 103: Inlet near the footbridge (Location ID #130)

Figure B- 104: Clogged inlet near the footbridge (Location ID #131)

Figure B- 105: PVC Outlet by the footbridge. Observed clogging during previous storm events (Location ID #132)

Figure B- 106: Inlet of the culvert to the Playground (Location ID #133)

Appendix C
Hydrologic Analysis

INTRODUCTION

URS Corporation (URS) performed a hydrologic analysis as part of the Fort Ward Park (Park) Master Drainage Plan. The results of the hydrologic modeling will aid in future park improvement assessments and the City of Alexandria's (City's) management strategies for the park.

The hydrologic model for the Fort Ward Park Master Drainage Plan was developed using current Geographic Information System (GIS) datasets and the precipitation data from the City. Soil data for the City was obtained from the Natural Resources Conservation Service (NRCS) Web site. The following report summarizes the process used in developing the hydrologic model.

WATERSHED DATA

After reviewing project specifications and recommendations, and understanding the project's goal and objectives, specific data needs were defined and collected. The data sets used in the hydrologic modeling are described below:

Topography: 2-foot topographic data was provided by the City for the Fort Ward Park area. The vertical datum for the topographic data is the North American Vertical Datum 1988 (NAVD 88), dated October 2012. The data was provided as a GIS shapefile. The topographic data was used to delineate subwatershed within Fort Ward Park.

Soil Data: The Soil Survey Geographic database (NRCS, 2009), which can be accessed at http://SoilDataMart.nrcs.usda.gov/, was used to obtain GIS soil data coverage for modeling the Fort Ward Park area.

Land Use Data: GIS zoning data was provided by the City. The 2009 City of Alexandria zoning data was used to represent existing conditions land use.

Rational Method Runoff Coefficient: Rainfall infiltration losses were estimated using the Rational Method Runoff Coefficient (C). The 2009 Alexandria zoning data contains five different land use types in the drainage area surrounding Fort Ward Park. These zones were reclassified into four categories based on their similarity in hydrologic responses. Each of these categories has a different C value depending on the hydrologic soil group classification of the land. Due to the relative steepness of slopes within the park, C values were chosen based on 6 percent or greater land slope. Table C-1 summarizes C values for the different zoning categories and four hydrologic soil groups.

Table C-1: Land Use and C Values from Autodesk Storm and Sanitary Analysis 2011

			C Value by Soil Type			
No.	**2009 Alexandria Zoning Categories**	**Equivalent C Category**	**A**	**B**	**C**	**D**
1	Public Open Space	Open Space, less than 25 years	0.14	0.19	0.24	0.28
2	Public Open Space	Open Space, 25 years or greater	0.2	0.26	0.32	0.39
3	Residential Single Family Zone, 20,000 square-foot lot	Residential Lot Size ½ Acre, less than 25 years	0.24	0.28	0.32	0.37
4	Residential Single Family Zone, 20,000 square-foot lot	Residential Lot Size ½ Acre, 25 years or greater	0.32	0.36	0.42	0.48
5	Residential Single Family Zone, 8,000 square-foot lot	Residential Lot Size ¼ Acre, less than 25 years	0.29	0.33	0.36	0.4
6	Residential Single Family Zone, 8,000 square-foot lot	Residential Lot Size ¼ Acre, 25 years or greater	0.37	0.42	0.47	0.52
7	Residential Townhouse Zone	Residential Lot Size 1/8 Acre, less than 25 years	0.31	0.35	0.38	0.42
8	Residential Townhouse Zone	Residential Lot Size 1/8 Acre, 25 years or greater	0.4	0.44	0.49	0.54
9	Residential High Density Apartment Zone	Residential Lot Size 1/8 Acre, less than 25 years	0.31	0.35	0.38	0.42
10	Residential High Density Apartment	Residential Lot Size 1/8 Acre, 25 years or greater	0.4	0.44	0.49	0.54

HYDROLOGIC MODEL

URS developed the hydrologic model using Autodesk Storm and Sanitary Analysis (SSA) 2011 (Autodesk, 2010) as requested by the City. Autodesk SSA is a modeling program that can be used to model drainage systems using GIS shapefiles and user inputs. URS developed the terrain preprocessing, watershed delineation, attribute management using ArcGIS 10 (ESRI, 2010). The drainage map with the 2-foot contour is shown in below (Figure C-1).

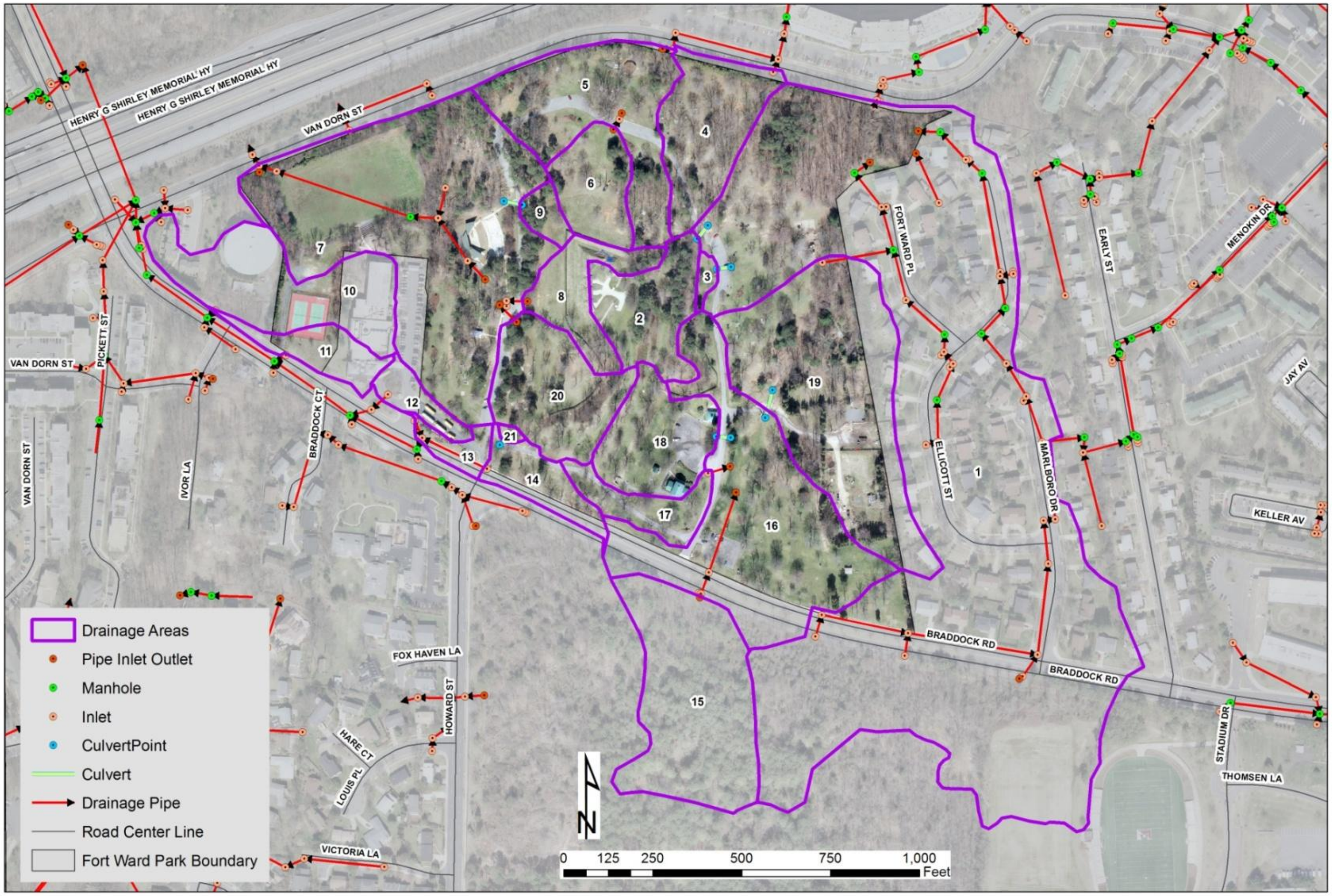


Figure C-1: Fort Ward Park Drainage Divide Map

Watershed Parameters

Key hydrologic parameters that are required for the SSA rainfall-runoff model include watershed-related parameters and precipitation data associated with design storms. Watershed-related input parameters needed for the SSA model include rainfall infiltration losses, drainage area size, and rain-runoff time of concentration.

Rational Method Runoff Coefficient: Rainfall infiltration losses were estimated using the Rational Method Runoff Coefficient, C, wherein C is the parameter used to represent drainage area properties including soil type, land use, and average slope. C values for each sub-area were derived based on soil types in the study area, land uses in the study area and the relationships among soil type, land use, and C value given in Table C-2. Composite runoff coefficients were calculated in the Subbasins tool in SSA.

Table C-2: Hydrologic Parameters for Subbasins

Basin	Area (ac)	Runoff Coefficient (less than 25 years)	Runoff Coefficient (greater than 25 years)	Time of Concentration (min)
1	29.50	0.34	0.45	20.47
2	1.91	0.28	0.39	13.14
3	0.15	0.28	0.39	7.71
4	2.39	0.28	0.39	11.41
5	3.61	0.28	0.39	13.41
6	1.40	0.28	0.39	7.12
7	9.82	0.27	0.37	5.00
8	1.40	0.28	0.39	13.72
9	0.37	0.28	0.39	6.76
10	3.24	0.35	0.46	12.57
11	0.91	0.34	0.45	14.57
12	0.56	0.35	0.46	5.00
13	0.44	0.28	0.39	5.00
14	0.99	0.28	0.39	7.41
15	4.45	0.28	0.36	35.79
16	6.53	0.28	0.39	16.13
17	0.98	0.28	0.39	12.13
18	2.03	0.28	0.39	10.58
19	6.44	0.30	0.41	23.35
20	2.44	0.28	0.39	8.82
21	0.06	0.28	0.39	5.00

ac = acre
min = minute

Drainage Area Size: The watershed subbasins shown in Figure C-1 were delineated and the enclosed areas were calculated using 2-foot topography in ArcGIS 10. The subbasin sizes summarized in Table C-2 were then input into the SSA model for the hydrologic simulation.

Subbasin Time of Concentration: Time of concentration (T_c) is defined as the time it takes for stormwater runoff to travel from the most hydraulically distant point of the watershed to a point of interest within the watershed. T_c values for each subbasin were determined using the T_c estimation method described in NRCS TR55 (1986). Runoff from each sub-area was divided into a sheet flow segment (non-concentrated runoff from the most distant point), shallow concentrated flow segment, and channel flow and storm drain flow.

T_c values for sheet and shallow concentrated flows were estimated using generalized curves that relate surface and channel conditions, slope, and flow velocity. A maximum sheet flow segment length of 100 feet was used, as this is conservative and in accordance with NRCS recommendations. Shallow concentrated flow lengths were assumed to extend from the end of the sheet flow portion of runoff to the origin of a well-defined channel segment.

Velocities for channel flows were calculated using Manning's equation and the bankfull discharges. Hydraulic roughness characteristics were based on aerial imagery and field reconnaissance.

The calculated travel time (T_t) values for sheet flow, shallow concentrated flow, and channel flow were summed to give the total T_c value for each sub-area. The estimated T_c values for the sub-areas are summarized in Table C-2

Precipitation Data: Precipitation data used as input in the SSA model include rainfall intensities for the City of Alexandria. The rainfall intensities for the 1-, 2-, 10-, 25- and 100-year rainfall events were used to calculate the discharges at the 100-, 50-, 10-, 4- and 1-percent-annual-chance events, respectively. The rainfall intensity estimates were obtained from the rainfall Intensity-Duration-Frequency (IDF) curves for the City of Alexandria dated from 1941-1969. The IDF curve used for this study is shown in Figure C-2.

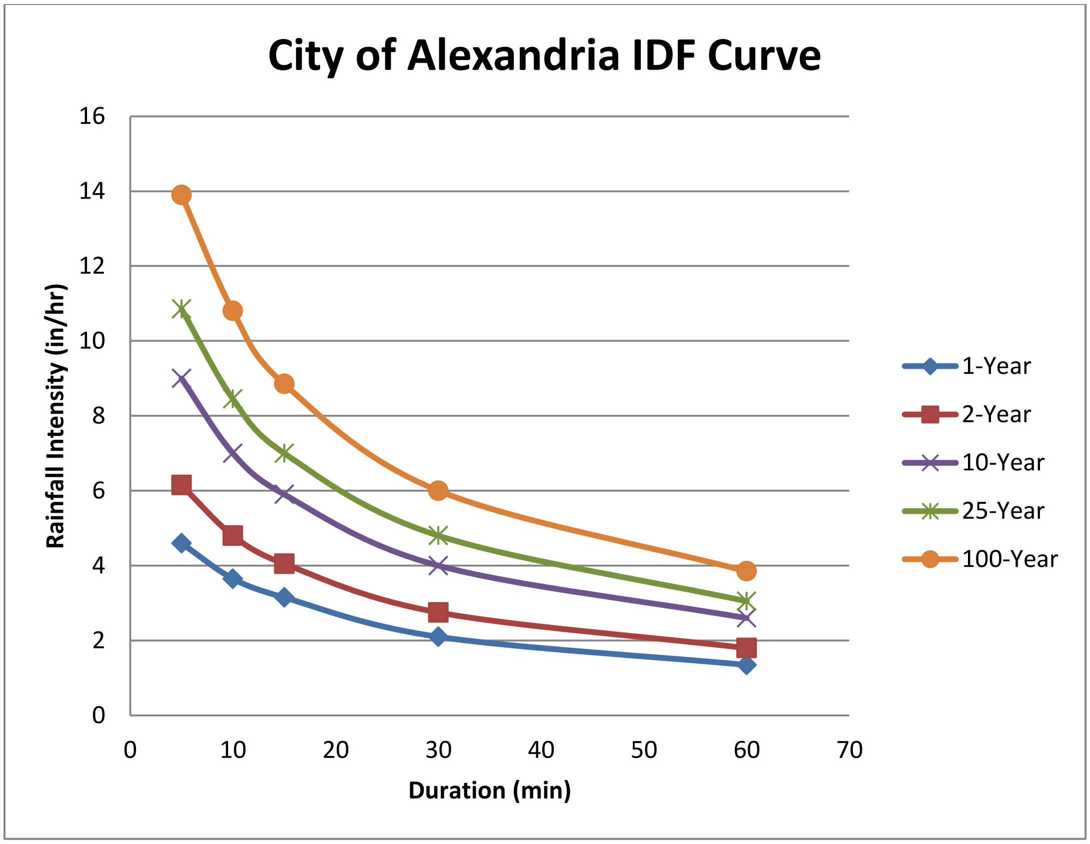


Figure C-2: Fort Wart Park IDF curve

SUMMARY RESULTS

Results of the hydrologic simulations are summarized in Table C-3. Results of the SSA model are reported by subbasin name. The locations of the junctions and outfalls are shown in Figure C-3.

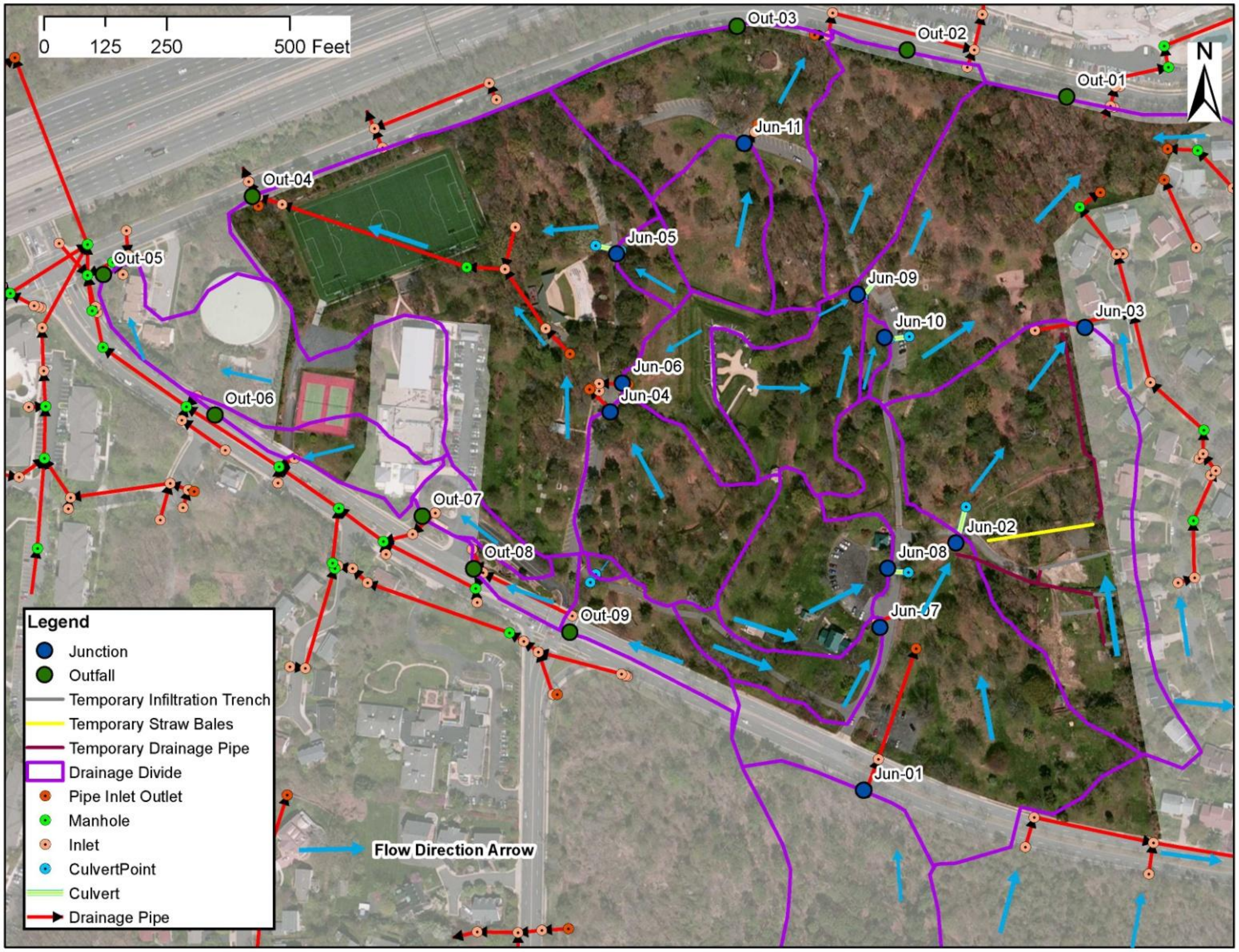


Figure C-3: Fort Ward Park drainage divide map with junctions and outfalls

Table C-3: Summary of Hydrologic Analysis

Name	Drainage Area (ac)	Drainage Area within Park Limits (%)	Storm Event Flows (cfs)				
			1-yr	2-yr	10-yr	25-yr	100-yr
Subbasin 1	29.5	18.8	26.34	34.15	49.71	78.46	98.69
Subbasin 2	1.91	100	1.77	2.29	3.34	5.55	7.04
Subbasin 3	0.15	100	0.17	0.22	0.32	0.54	0.70
Subbasin 4	2.39	93.4	2.33	3.04	4.43	7.41	9.44
Subbasin 5	3.61	98	3.32	4.29	6.25	10.38	13.17
Subbasin 6	1.4	100	1.60	2.13	3.10	5.22	6.67
Subbasin 7	9.82	92.6	12.20	16.31	23.86	39.42	50.50
Subbasin 8	1.4	100	1.28	1.65	2.40	3.98	5.05
Subbasin 9	0.37	100	0.43	0.57	0.84	1.40	1.80
Subbasin 10	3.24	20.2	3.81	4.95	7.21	11.33	14.39
Subbasin 11	0.91	39.7	0.98	1.26	1.84	2.90	3.66
Subbasin 12	0.56	42.6	0.90	1.21	1.76	2.80	3.58
Subbasin 13	0.44	63	0.57	0.76	1.11	1.86	2.39
Subbasin 14	0.99	68.4	1.12	1.48	2.16	3.62	4.64
Subbasin 15	4.45	0	2.34	3.08	4.47	6.85	8.59
Subbasin 16	6.53	77.7	5.52	7.11	10.36	17.14	21.64
Subbasin 17	0.98	100	0.93	1.22	1.77	2.95	3.75
Subbasin 18	2.03	100	2.03	2.67	3.89	6.52	8.32
Subbasin 19	6.44	77.5	4.70	6.11	8.89	14.53	18.23
Subbasin 20	2.44	100	2.60	3.43	5.01	8.41	10.76
Subbasin 21	0.06	100	0.08	0.11	0.16	0.27	0.35
Junction 1	4.45	0	2.34	3.08	4.47	6.85	8.59
Junction 2	13.98	69.4	8.14	10.54	15.35	25.21	31.86
Junction 3	20.42	71	11.39	14.77	21.51	35.27	44.49
Junction 4	2.44	100	2.60	3.43	5.01	8.41	10.76
Junction 5	2.39	100	0.43	0.57	0.84	1.40	1.80
Junction 6	1.4	100	1.28	1.65	2.40	3.98	5.05
Junction 7	0.98	100	0.93	1.21	1.77	2.95	3.75
Junction 8	2.03	100	2.03	2.66	3.89	6.52	8.32
Junction 9	1.91	100	1.77	2.29	3.34	5.54	7.04

Name	Drainage Area (ac)	Drainage Area within Park Limits (%)	Storm Event Flows (cfs)				
			1-yr	2-yr	10-yr	25-yr	100-yr
Junction 10	0.15	100	0.17	0.22	0.32	0.54	0.69
Junction 11	1.4	100	1.60	2.12	3.10	5.22	6.67
Outfall 1	65.97	71.7	37.02	48.00	69.88	111.38	140.15
Outfall 2	2.39	93.4	2.33	3.04	4.43	7.41	9.44
Outfall 3	5.01	99	3.54	4.59	6.69	11.11	14.10
Outfall 4	14.02	98.2	14.45	19.27	28.19	46.67	59.76
Outfall 5	3.24	20.2	3.81	4.95	7.21	11.33	14.39
Outfall 6	0.91	39.7	0.98	1.26	1.84	2.90	3.66
Outfall 7	0.56	42.6	0.90	1.21	1.76	2.79	3.58
Outfall 8	0.99	63	0.57	0.76	1.11	1.86	2.39
Outfall 9	1.05	84.2	1.16	1.54	2.24	3.77	4.82

ac = acre
cfs = cubic feet per second
yr = year

CONCLUSION

Results from the SSA model are consistent with what was expected from field studies, which showed locations of eroded streams and the need for storm drain improvements. The results of this study can be used by the City for future stormwater management improvements or stream restoration projects. Additionally, the results of the hydrology will be used to perform the hydraulic capacity analysis portion of the Fort Ward Park Drainage Study.

REFERENCES

Autodesk, 2010, *Autodesk Storm and Sanitary Analysis Stand-Alone 2011, User's Guide*, April 2010

ESRI, 2010. ArcGIS Version 10.0. www.esri.com/.

Maryland Hydrology Panel, 2010. *Application of Hydrologic Methods in Maryland*, Third Edition, September 2010.

NRCS, 1986. *Urban Hydrology for Small Watersheds TR55*, June 1986

NRCS, 2009, US General Soil Map, http://SoilDataMart.nrcs.usda.gov/, accessed on July 2013

Appendix D
Concept Design Calculations

INTRODUCTION

URS Corporation (URS) created three concept designs as part of the Fort Ward Park (Park) Drainage Master Plan. These designs are described in Section Six of the report. The calculations used to estimate the geometry and hydraulics for the concept designs are provided in this Appendix. All calculations are rough estimates considered sufficient for a 10 percent design. Additional effort will be required for final design.

Concept designs have been created for sites 3, 6, and 7 (Figure D-1). Proposed modifications to the utility yard (Site 6) reduce flow from the Park into the Oakland Baptist Cemetery (Site 8). Hydrologic modeling data for these sites is also summarized in this appendix.

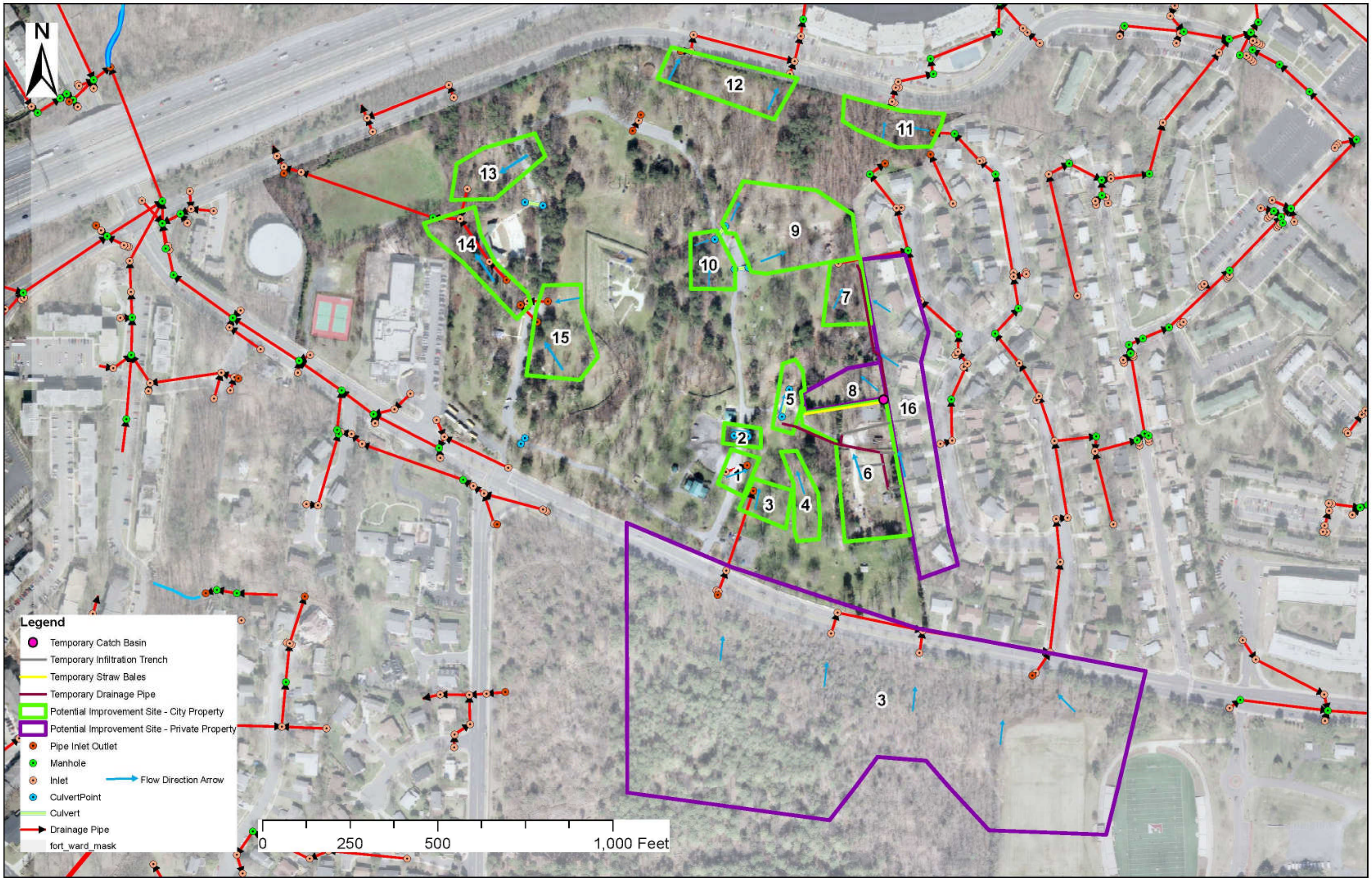


Figure D-1: Fort Ward Park Sites for Potential Improvements

FLOW CALCULATIONS

The hydrologic analysis of Fort Ward Park developed flows for the 1-, 2-, 10-, 25-, and 100-year storm events. These flows were calculated for the drainage areas shown in Figure D-2. The drainage area for the proposed stream stabilization concept design at Site 7 was identical to the outfall of drainage area 19. These flows did not have to be recalculated for the concept design. The drainage areas for the proposed concept designs at Site 3 and Site 6 varied from those originally calculated for this study. The drainage areas for the two proposed concept designs are shown in Figure D-3.

The C value was estimated for each of the two drainage areas following the methodology outlined in Section 4.1 of the Master Plan. The times of concentration for the drainage areas were also calculated following the methodology outlined in Section 4.1 of the Master Plan. The calculated C value and times of concentration are shown in Table D-1. The flows calculated for each site are shown in Table D-2.

Table D-1: Hydrologic Parameters for Concept Design Drainage Areas

Concept Site ID	Area (Acres)	Runoff Coefficient (less than 25 years)	Runoff Coefficient (more than 25 years)	Time of Concentration (min)
Site 3	5.9	0.3	0.4	36
Site 6	1.7	0.3	0.4	20

Table D-2: Summary of Hydrologic Analysis for Concept Design

Concept Site ID	Storm Event Flows (cfs)				
	1-yr	2-yr	10-yr	25-yr	100-yr
Site 3	3.4	3.9	6.1	9.2	11.4
Site 6	1.3	1.6	2.4	3.9	4.9
Site 7*	11.4	14.8	21.5	35.3	44.5

cfs = cubic feet per second

*Flow estimate from Junction 3 of Master Plan Hydrologic Analysis

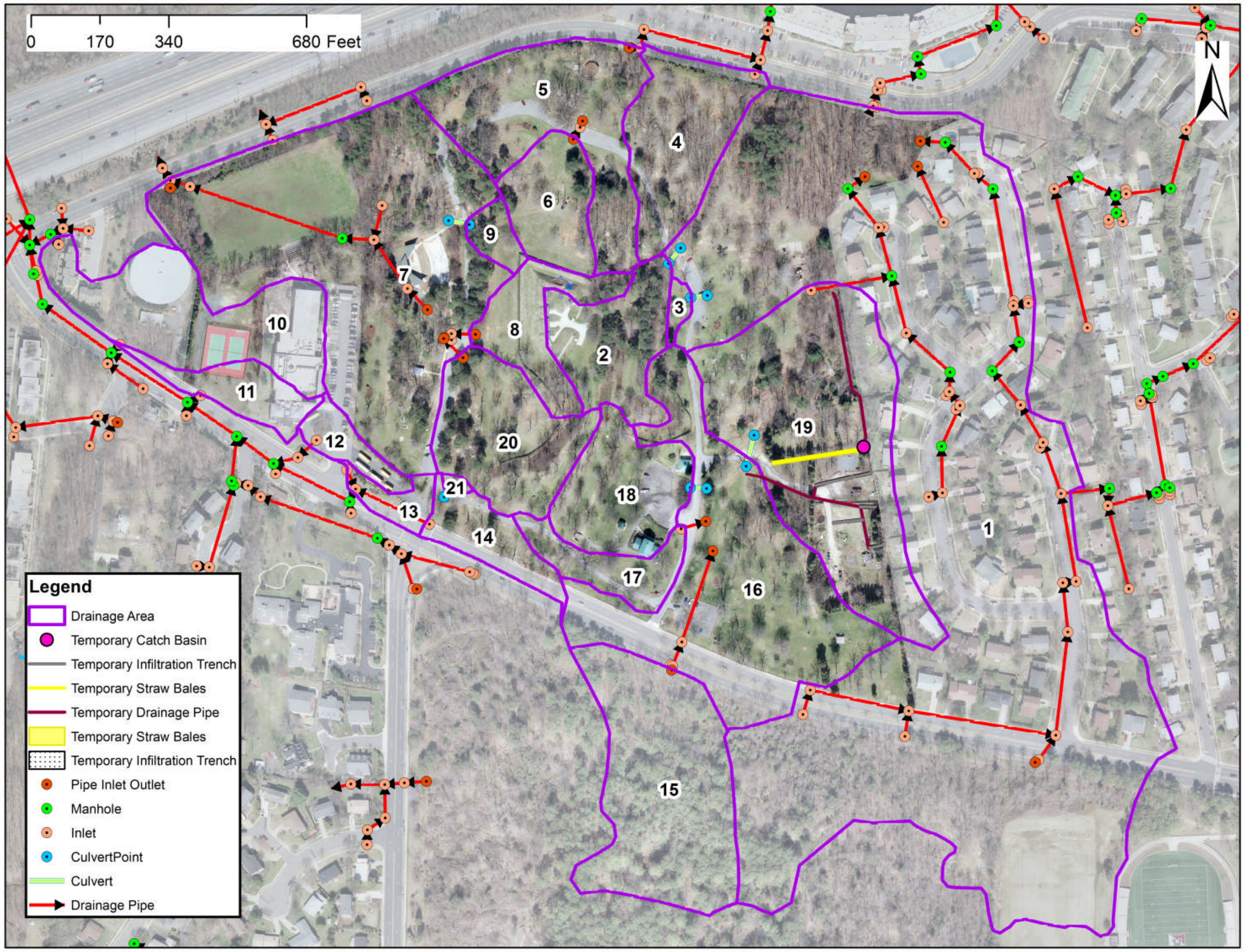


Figure D-2: Fort Ward Drainage Areas from Hydrologic Analysis

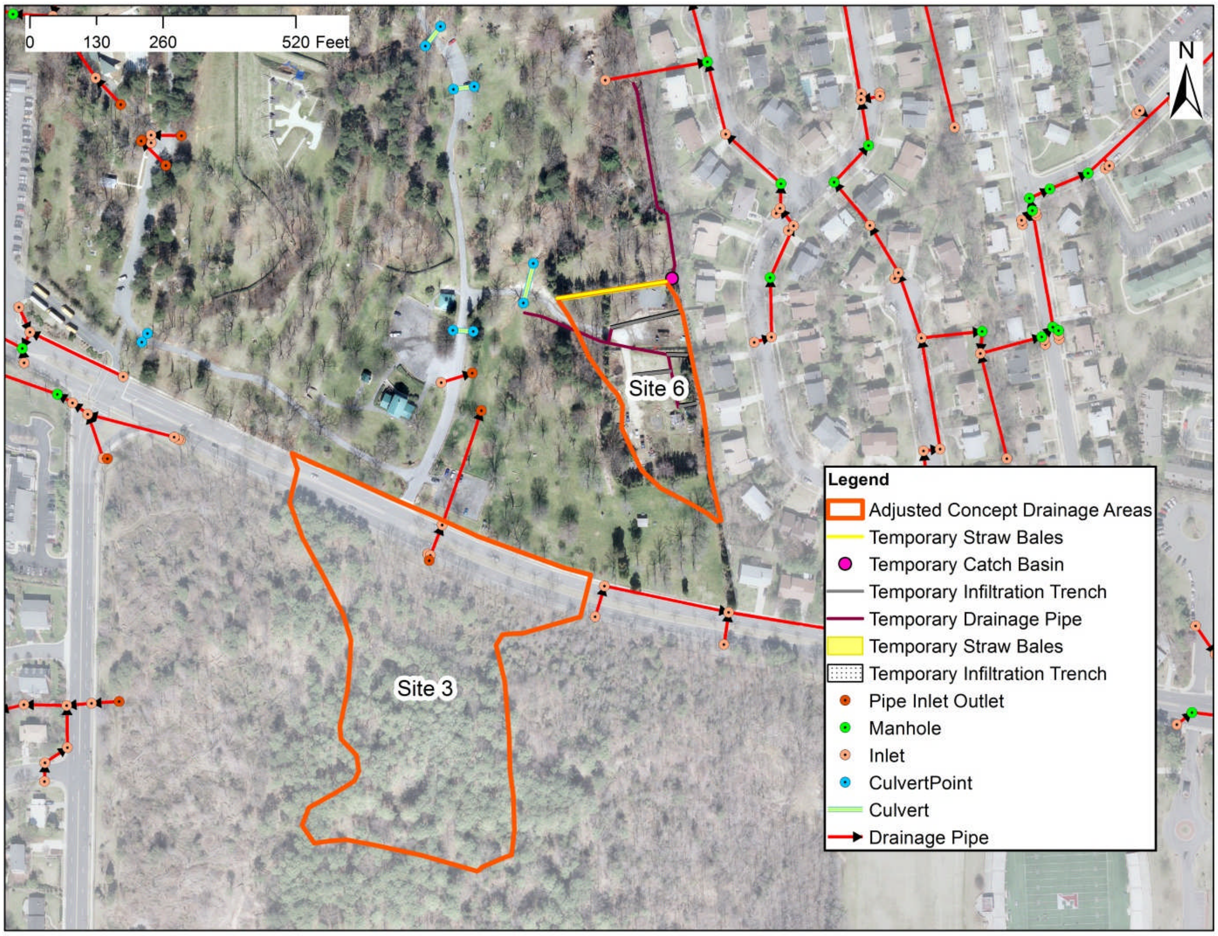


Figure D-3: Fort Ward Concept Design Drainage Area

SITE-SPECIFIC CONCEPT DESIGN CALCULATIONS

Stormwater Filter (Site 3)

The City of Alexandria requested a stormwater filter for concept design at Site 3 (Figure D-4). The Contech StormFilter was chosen as an example of a stormwater filter. As specified in Amendments to the City of Alexandria Article XIII Environmental Management Ordinance (2006), the proposed system can be designed to meet the 10-year storm event. The StormFilter is an approved Best Management Practice (BMP) in the Commonwealth of Virginia. Guidance for StormFilter design from Stormwater Management Inc. (2004) requires design using a rainfall intensity of 0.35 inches/hour. Using modified rational method with the parameters from Table D-2 the design flow is 1 cubic foot per second (cfs). This requires approximately twenty 27-inch filter cartridges in a concrete casing. The external dimensions for this casing are 15 feet long, 9 feet wide, and 6 feet deep. This unit is not necessarily recommended for final design, but is used to give a concept-level estimate of geometry and costs.

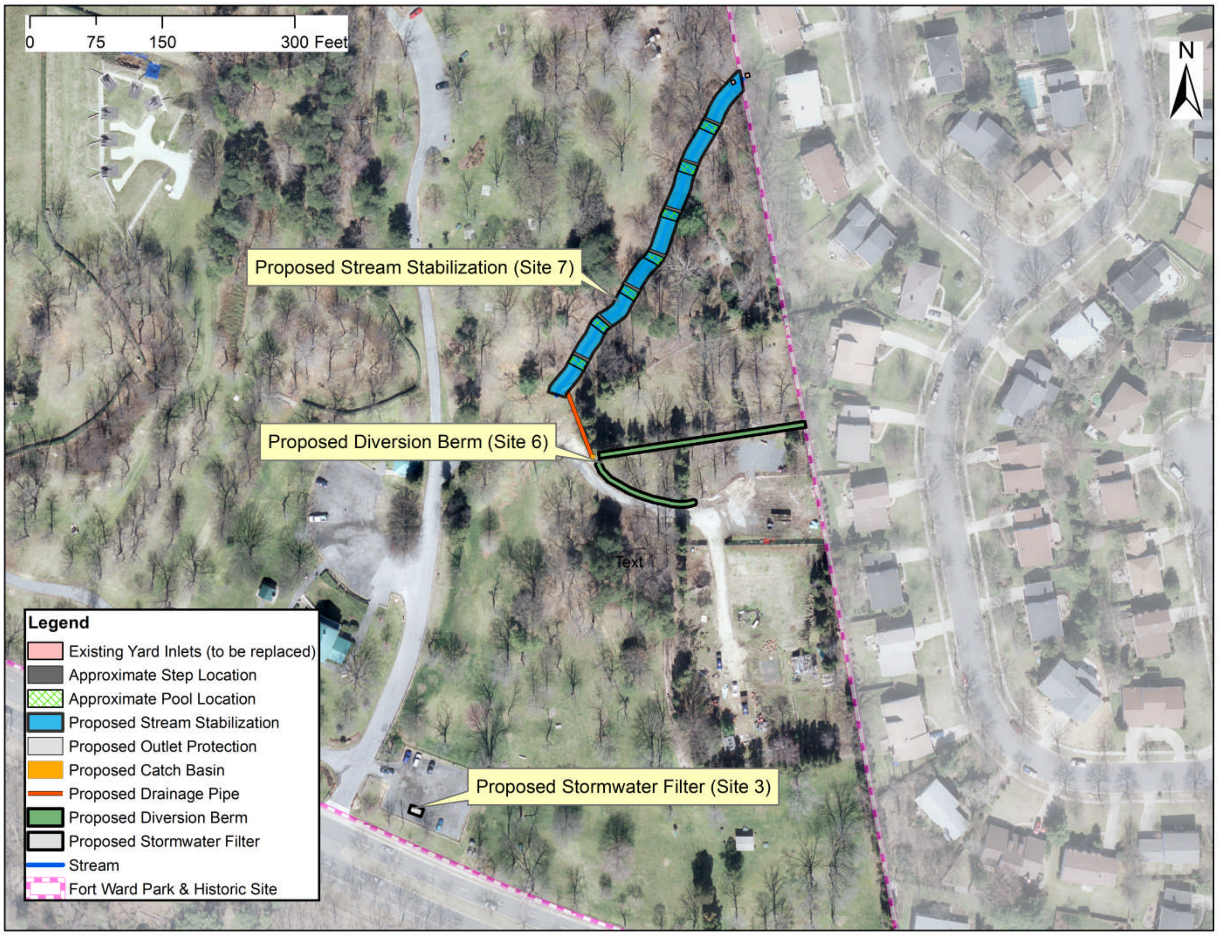


Figure D-4: Proposed Concept Design Location

Diversion Berm (Site 6)

The proposed concept design for Site 6 is a permanent earth berm to replace the existing hay bales located between Site 6 and Site 7 (Figure D-1, Figure D-4), another diversion berm to keep runoff from the road out of the utility yard, and an underground drainage pipe to direct runoff to the stream. A proposed concept cross section is shown in Figure D-5. The height of the proposed berm was estimated using Manning's equation. The channel is "V" shaped (see Figure D-5) with the existing grade slope of 10:1 (H:V) on one side, and the berm slope of 2:1 (H:V) on the other side. The berm side slope was estimated as a minimum of 2:1 (H:V) as a compromise between stability and obstruction constraints. Most of the wetted perimeter lies on the existing grade, so a roughness coefficient for short grass of 0.15 is assumed (Virginia Department of Transportation Drainage Manual). The existing slope in the direction of flow was 4 percent as determined by GIS topography. The flow from Table D-2 was used to estimate the depth associated with the 10-year flow (0.7 feet) and 25-year flow (0.8 feet). Due to uncertainty about the topography, a minimum 6-inch freeboard is recommended, resulting in a berm height of approximately 1.5 feet.

The berm geometry is calculated based on the peak flow considering the entire site 6 drainage area (Figure D-3). This is reasonable for the berm closest to the cemetery but may be overdesigned for the berm east of the entrance road. This level of calculation is considered sufficient for 10% design but the geometry of the two berms will need to be computed separately for final design.

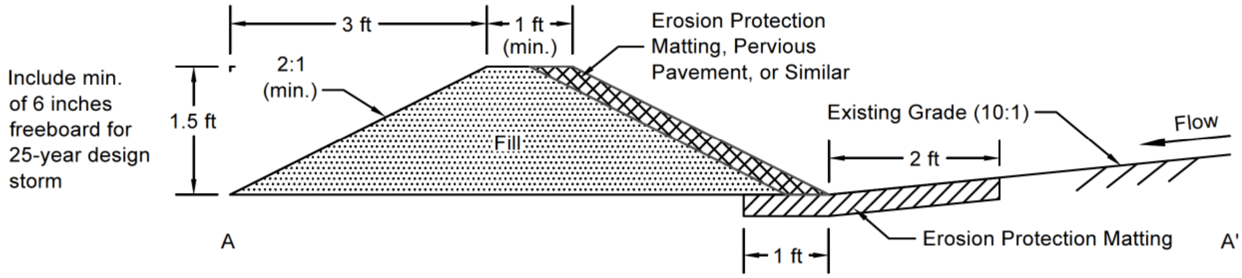


Figure D-5: Proposed Diversion Berm Concept Design Cross Section

The design meets the permissible velocity for grass-lined channel guidelines in Table 5-14 of the Virginia Sediment and Control Handbook (1992). The handbook indicates a permissible velocity range of 2.5 to 6 feet per second (ft/sec) for slopes less than 5 percent. The permissible velocity varies depending on the grass type, but the estimated velocity for the proposed concept design of 1 ft/s would meet this requirement regardless of the grass type.

The proposed design also involves a catch basin and drainage pipe to convey water from the berm to the stream. A 12-inch reinforced concrete drainage pipe is the minimum size that is recommended for catch basin. A 12-inch pipe is sufficient to convey the 10- and 25- year storm events. Excavation will be required during construction. The proposed design recommends outlet protection to avoid erosion at the stream. Potential outlet protection measures include stone (e.g., riprap), a level spreader, or a concrete slab. For cost estimates the outlet protection is assumed to be riprap.

Stream Stabilization (Site 7)

The proposed concept design for Site 7 is a step-pool stream stabilization with fill in the stream reach between steps and pools to connect the channel to its floodplain (Figure D-4). The two existing yard inlets at the downstream boundary of the stream would also be replaced as part of the proposed design. The Virginia Stream Restoration & Stabilization Best Management Practices Guide was used to estimate the geometry of the proposed stream stabilization concept design. Stream stabilization is complex due to the dynamic nature of streams. Detailed survey and analysis will be necessary prior to the final design. The calculations described in this section are based on limited data, and should be used for 10 percent concept design only.

The bankfull flow is the flow where the water level in a channel reaches its floodplain. This flow generally corresponds with the 1- and 2-year rainfall event. The bankfull width of the stream was estimated to be approximately 20 feet based on field investigation. According to the Virginia

Stream Restoration & Stabilization Best Management Practices Guide, step spacing should be 1 to 4 bankfull widths for channel slopes between 3 and 6.5 percent. Using a spacing of 2.5 bankfull widths, the step spacing was estimated to be 50 feet. For a stream reach of approximately 420 feet, this would correspond with 7 steps. (The stabilization should neither start nor end with a step.)

According to the Virginia Stream Restoration & Stabilization Best Management Practices Guide, natural steps generally fall between 1 and 2 feet above pool elevation. An average height of 1.5 feet was assumed for the proposed concept design. It was also assumed that each pool was approximately 10 feet long and was constructed upstream of the steps. With 10-foot-long pools preceding each 1.5-foot-tall step drop, the slope for the remainder of the channel was calculated to be approximately 0.035 ft/ft. With this slope, the ratio of the mean steepness (step height divided by the distance between steps) to the mean channel slope is 1.7. This falls within the 1 to 2 range recommended in the Virginia Stream Restoration & Stabilization Best Management Practices Guide for channel stability.

The channel will need to be constructed with stone around steps and pools and fill for the remainder of the channel. Excavation is not advised at the stabilization location due to the potential for historic burial sites. The proposed concept design therefore uses fill without any excavation. The average depth of fill over the reach invert would be approximately 1.5 feet. According to the Virginia Stream Restoration & Stabilization Best Management Practices Guide, the stones used for steps and pools should be approximately 1.5 feet long, requiring Class II riprap or similar. The median length for Class II riprap is 1.6 feet according to the Virginia Erosion and Sediment Control Handbook.

Manning's equation was used to estimate the velocity if the proposed stream stabilization was performed. The roughness coefficient was calculated using the Virginia Erosion and Sediment Control Handbook. An earth channel with minor irregularities and appreciable obstructions is expected to have a roughness coefficient of 0.05. Assuming a trapezoidal channel with a width of 3 feet, side slopes with 3:1 slope, and a bankfull flow of 14.8 cfs (Table D-2), the depth of flow is approximately 0.8 feet with a velocity of 3.6 feet. This height should correspond with the channel bank, but survey and detailed design would be needed to verify this. The computed velocity meets the Virginia Erosion and Sediment Control Handbook permissible velocity for unlined earth channels with fine gravel or a mixture of cobbles and fine sediments. The detailed channel design would be somewhat irregular, so lower velocities would be expected.

REFERENCES

Stormwater Management Inc., 2004 "Information regarding modification of design storm method for Stormwater Management, Inc. stormwater treatment systems in the Commonwealth of Virginia"

City of Alexandria, 2006 "Amendments to the City of Alexandria Article XIII Environmental Management Ordinance" http://www.alexandriava.gov/uploadedFiles/tes/info/Article_XIII_2006.pdf, accessed February 3, 2014.

Virginia Department of Conservation and Recreation, 2004 "The Virginia Stream Restoration & Stabilization Best Management Practices Guide" http://www.deq.virginia.gov/Portals/0/DEQ/Water/Publications/BMPGuide.pdf, accessed February 3, 2014.

Virginia Department of Environmental Quality, 1992 "The Virginia Erosion and Sediment Control Handbook" http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications/ESCHandbook.aspx, accessed February 3, 2014.

Virginia Department of Transportation, 2002, "Drainage Manual" http://www.virginiadot.org/business/resources/LocDes/DrainageManual/START_VDOT_Drainage_Manual.pdf, accessed February 3, 2014.