City of Fairfax, Virginia

Watershed Management Plan

Final Report

July 2005

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Executive Summary

Introduction

The City of Fairfax, Virginia lies in the Accotink Creek watershed in Northern Virginia. The City is approximately six square miles, and is surrounded by Fairfax County. Accotink Creek and its tributaries within the City of Fairfax are important natural resources that provide recreational and aesthetic values that enhance the quality of life in the City. Many of the streams in the watershed are degrading as a result of the urban storm flows off of paved areas. The primary cause of stream degradation in the City of Fairfax is directly related to elevated volumes of uncontrolled stormwater runoff. Stormwater runoff impacts are common problems in highly urbanized areas. The City of Fairfax is characterized by commercial and high and low-density residential development that accounts for greater than 60% of total land use. Major transportation routes include Route 29 (Lee Highway), Route 236, and Route 123 (Chain Bridge Road). The City has approximately 70 miles of roadway, with approximately 50 miles (75 percent) served by the stormwater drainage system.

Increased stream flows impact the natural stream channel morphology, which affects the physical, chemical, and biological integrity of the stream. Stream bank erosion, which increases with increased stream flows, can lead to bank instability and increased sediment loading to the stream. This increased sediment load may cause water quality degradation and have negative impacts on fish, benthic invertebrates, and other aquatic life in the stream. If the stream flows into a waterbody used as a drinking source, expensive treatment procedures may be needed to remove the excessive sediment. In addition to problems associated with channel erosion, increased stream flows can scour stream beds, removing benthic organisms and aquatic habitat. Furthermore, surface runoff from impervious areas in the watershed may transport pollutants associated with developed areas, including, metals, organics, and other toxics which negatively impact the water quality of the receiving stream.

Field Assessments

As part of this study two field assessments were conducted, Stormwater System Survey and the Stream visual assessment. Stormwater system survey included a survey of existing stormwater structures to locate, inventory, and characterize the existing stormwater infrastructure in the City of Fairfax. Results of the stormwater infrastructure survey are detailed in a separate report entitled "Stormwater System Survey and GIS Mapping for City of Fairfax, Virginia - Phases I and II Final Report" dated August, 2003. However the following is a summary of findings:

- Over 3,600 stormwater structures located within the City of Fairfax were surveyed and characterized.
- A total of 145 stormwater outlet structures were identified and characterized.
- There are no municipally owned stormwater detention facilities in the City.
- There is only one regional facility in the City, located at the Farrcroft residential development.
- Approximately 5% of City downspouts are connected to the City's storm sewer system. The remaining 95% discharge to the ground surface or underground drains. Most unconnected downspouts discharge to the ground surface, pavement, or soil.
- There are currently 78 known privately owned on-site stormwater detention/retention facilities located in the City.
- The City has had a stormwater detention ordinance since 1974.
- No stormwater master plan or stormwater utility plan currently exists.
- There are currently approximately 78 known privately owned on-site stormwater detention/retention facilities in the City. The majority of these stormwater facilities are either underground pipes or dry ponds.

Stream Visual Assessment. A stream survey was conducted to assess the physical and biological health of streams located within the City of Fairfax. The field survey covered and analyzed every mile of stream within the City including Accotink Creek and its tributaries. Stream assessment results were compiled for a total of 72 stream reaches of variable length, representing all of the streams in the City. Physical and biological metrics specified in the protocols were used to quantify the physical and biological conditions of the streams within the City of Fairfax. It should be noted that biological conditions were evaluated qualitatively, no macroinvertebrate sampling was conducted to fully evaluate and quantify the biological conditions in the streams, and thus these data and information were limited in scope.

The City of Fairfax has completed full restoration projects on 2.2 miles of stream and stabilized 3.8 miles of stream. These stream improvement projects account for about 68% of stream miles within the City boundary; this clearly reflects the City's commitment to improving the stream conditions. Also, the results of the stream survey presented in the next sections show that the stream improvements positively contributed substantially to the physical conditions scores.

Simulation Results

Stream channel velocity data for streams within the City were obtained from the 1999 City of Fairfax Flood Study and analyzed for this watershed management plan. Channel velocity data for approximately 300 cross sections collected throughout the City were available for analysis. For the purposes of this study, two year recurrence storm interval data were evaluated. These data are summarized as follows:

- Approximately 23 (8%) of the measured cross sections had channel velocities greater than 8.0 feet/second.
- Approximately 80 (27%) of the measured cross sections had channel velocities greater than 6.0 feet/second.
- Approximately 150 (50%) of the measured cross sections had channel velocities greater than 5.0 feet/second.

Over 85 % of the 2 year flow velocities exceed 5.0 feet/second. For the purposes of this report, channel velocities that exceeded 6.0 feet/second were selected for evaluation, because channel velocities greater than 6.0 feet/second have the potential to increase channel erosion under normal stream conditions. The high channel velocities observed from these data are good indicators that there is a high potential for channel erosion within the City's watersheds.

Flow frequency analyses were performed on simulated stream flows in order to determine the number of times stream flows associated with existing land use conditions exceeded flows associated with the completely forested condition. Exceedance analyses were performed for three stream locations and for a one year forested peak flow as well as a ten year average forested peak flow. Comparison of the Accotink Creek and Daniels Run stream flows to the forested condition flows indicated that Accotink Creek flows tend to exceed the forested condition flows more often than Daniels Run. This lower exceedance rate in Daniels Run is attributed to a greater percentage of forested lands (lower impervious land cover) present under existing conditions.

The City should be commended for their persistent pursuit of stormwater improvements over the last decade. Through the recommendations of its stormwater system capital needs study, stream evaluation study, and flood study, the City of Fairfax has implemented stream restoration practices at numerous locations on Accotink Creek. Stream restoration was completed on 2.23 miles of stream and stream stabilization was completed on 3.8 miles of stream for a total of 6.83 miles of stream improvements. Considering that a total of 10.15 miles of stream exist within the City boundary, the City of Fairfax has made significant efforts to stabilize the stream banks to handle the urban stormwater runoff and flows. It is recommended that the City continues on the path of stream restorations and improvements. It is also important to note that results from the stream visual assessment clearly showed that stream with highest scores were located downstream of these restoration and improvement projects. The biological scores indicated that the streams are still stressed. It is anticipated that once the physical conditions are stabilized and the habitat are resorted, the biological integrity will be naturally restored.

Summary and Recommendations

Initially the City of Fairfax watershed management plan setout to answer basic questions related to stormwater and the ongoing degradation of the stream within the city boundary. Mainly, the objective was to estimate the volume of stormwater input to the streams, to assess the stream conditions under these flow conditions, and to make recommendations ranging from changes in regulation to use of structural and none structural BMPs.

As presented in Section 4, the stormwater flow under the existing conditions are at least 70% higher that the forested condition. This increase in stormwater flow is mainly due to the dominance of impervious cover in the City. The SWMM model was used to estimate the impacts of reducing the impervious cover on the stormwater flows. It was found that a 50 percent reduction in the impervious cover would be required to achieve a significant impact on the stormwater flows. This can be a noble goal to set and part of a long term control plan to reduce the volume of stormwater. However, in reality this type of reduction is significant and will require substantial changes in the regulations and enforcement.

In addition, the stormwater infrastructure survey indicated that the streams are used as an integral part of the stormwater drainage and conveyance system as evident by the presence of extensive system of stormwater drainage pipes and outfalls located in the stream banks. In general controlling the stormwater requires either elimination or reduction of the stormwater at the source or capturing and managing the storm water in the conveyance system though detention or retention to promote infiltration or delaying it to reduce the impacts on the receiving streams.

There are constraints when attempting to address the stormwater control in the City of Fairfax. These include:

- City is built-out; any attempts to control stormwater at the source will have to be accomplished through retrofits.
- Stormwater reduction at the source can be accomplished through LID methods. However these approaches need to be accepted and applied City wide. Currently, the city has no regulations or incentives to promote such methods.
- Space limitation to implement regional controls within the city to control the stormwater.

The City of Fairfax has completed improvement projects on the 70 percent of the stream reaches and these reaches received a reasonably good score for physical conditions when assessed. However, more time is needed for the biological community to get reestablished.

The following are a summary of recommendations for the City of Fairfax:

1. Continue the stream improvement projects. It is important to stabilize the physical conditions and restore the stream habitat prior to restoring the biological integrity of the streams.

2. While working with the watershed committee, concerned citizens, and stakeholders establish a long term goal for reducing the imperviousness in the City though use of LID methods. A reasonable target would be in the range from 10 to 20 percent.

3. Establish incentives for home owners and developers who implement LID or any on-site stormwater controls.

4. Maximize the benefits of the existing stormwater control facilities. This should include onsite or regional sites that exist throughout the City. The goal should be to target detention and controls of the 2-year storm flows since these flows are frequent and are responsible for stream degradation.

5. Review and revise the City of Fairfax existing stormwater ordinance to incorporate the goals and targets recommended in this plan.

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1.0 Introduction

The City of Fairfax, Virginia lies in the Accotink Creek watershed in Northern Virginia. The City is approximately six square miles, and is surrounded by Fairfax County. The headwaters of Accotink Creek originate within the City of Fairfax and flow southeast through Fairfax County to its confluence with the Potomac River at Gunston Cove.

Accotink Creek and its tributaries within the City of Fairfax are important natural resources that provide recreational and aesthetic values that enhance the quality of life in the City. Many of the streams in the watershed are degrading as a result of the urban storm flows off of paved areas. To protect the City's natural water resources it is important to evaluate the current stormwater management efforts and to recommend a scope and direction for future stormwater management programs.

Point sources do not appear to be an important factor in water quality impairment in the Accotink Creek watershed. The sources of stream degradation are broadly distributed throughout the watershed; in other words, non-point sources are the primary cause of stream degradation. Restoration of the watershed streams may be facilitated through the development of a comprehensive watershed management plan that addresses non-point source problems. This report presents the proposed Watershed Management Plan for the City of Fairfax, which evaluates the watershed conditions and recommends watershed initiatives that will restore the quality of water resources in the watershed.

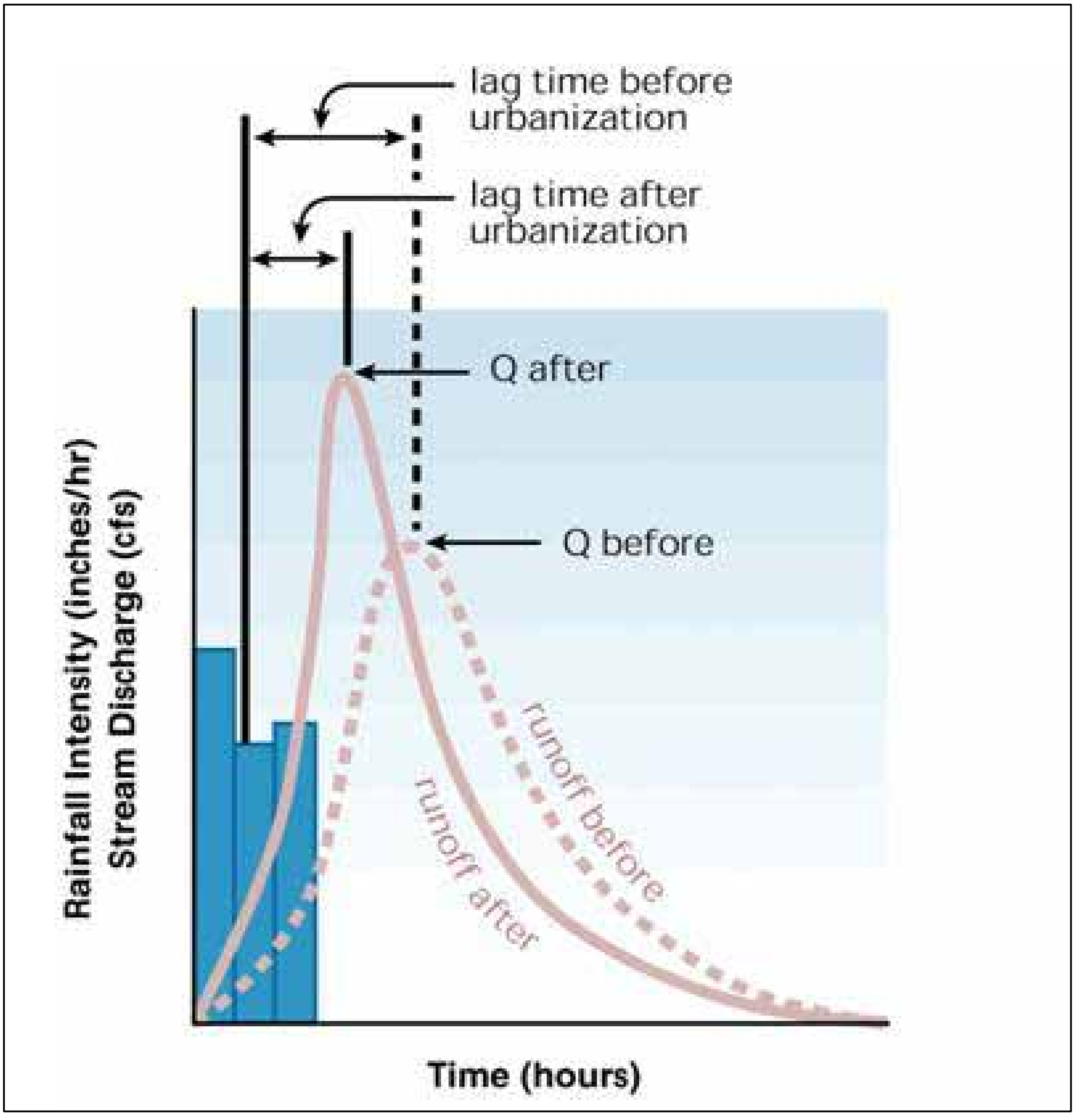
1.1 Problem Definition

The primary cause of stream degradation in the City of Fairfax is directly related to elevated volumes of uncontrolled stormwater runoff. Stormwater runoff impacts are common problems in highly urbanized areas. The City of Fairfax is characterized by commercial and high and low-density residential development that accounts for greater than 60% of total land use. Major transportation routes include Route 29 (Lee Highway), Route 236, and Route 123 (Chain Bridge Road). The City has approximately 70 miles of roadway, with approximately 50 miles (75 percent) served by the stormwater drainage system.

Land development and urbanization processes impact receiving streams by adversely altering watershed hydrology in several ways. The conversion of natural forested lands to impervious surfaces associated with land development results in an increased volume of surface runoff because less water is able to infiltrate into the ground. This leads to more water entering the stream by surface runoff than via groundwater pathways. Surface runoff is also delivered to the stream channel more quickly than water that infiltrates the soil and is transported to the stream via groundwater. This speedy movement to the receiving stream is expedited by curbs, gutters, and stormwater pipes which convey water rapidly from impervious surfaces to the stream. Consequently, stream flows in urbanized watersheds increase in magnitude as a function of impervious area. A schematic depicting the impacts of urbanization on stream hydrology is presented in Figure 1-1.

Increased stream flows impact the natural stream channel morphology, which affects the physical, chemical, and biological integrity of the stream. Stream bank erosion, which increases with increased stream flows, can lead to bank instability and increased sediment loading to the stream. This increased sediment load may cause water quality degradation and have negative impacts on fish, benthic invertebrates, and other aquatic life in the stream. If the stream flows into a waterbody used as a drinking source, expensive treatment procedures may be needed to remove the excessive sediment. In addition to problems associated with channel erosion, increased stream flows can scour stream beds, removing benthic organisms and aquatic habitat. Furthermore, surface runoff from impervious areas in the watershed may transport pollutants associated with developed areas, including, metals, organics, and other toxics which negatively impact the water quality of the receiving stream.

Figure 1-1: Impacts of Urbanization on Stream Hydrology



In Stream Corridor Restoration: Principles, Processes, and Practices. Interagency Stream Restoration Working Group (FISRWG) 1998.

As the City of Fairfax has developed and grown over the years, changes in land use have affected the stream conditions in many parts of the City. Uncontrolled stormwater runoff from impervious surfaces is the primary cause of stream degradation. All of the streams throughout the City have been impacted to some degree. As an example, the headwaters of the Accotink Creek near the historic district of the City have severely eroded stream banks caused by high stormwater flows (Figure 1-2). In this photo, erosive flows have resulted in undercut stream banks, to the extent that a tree is about to collapse into the stream.

Recent land development projects have included provisions for stormwater management practices that effectively slow and distribute high stormwater flows over a period of time, thereby reducing erosion in the streams. In effect, stormwater management practices try to restore hydrologic conditions present prior to land development. Since the establishment of stormwater regulations, the City of Fairfax has required stormwater improvements to accompany all City development projects. However, the City is still experiencing problems from development that occurred prior to the issuance of stormwater regulations, as well as the impacts of less than optimal stormwater facilities. Previous projects have restored the physical morphology of certain stream reaches within the City, but some reaches remain severely degraded.

Figure 1-2: Stream Bank Erosion in Accotink Creek near City Historic District

1.2 Current Stormwater Regulations

As an incorporated City in the Commonwealth of Virginia, the City of Fairfax is subject to numerous regulations as it relates to stormwater management. Some regulations are managed at a higher level of government and some are directly the responsibility of the City. The following sections discuss the federal, state, and local regulations with which the City must comply.

1.2.1 Federal Stormwater Regulations

The Clean Water Act (CWA) of 1972 is the principal federal statute protecting navigable waters and adjoining shorelines from pollution. Since its enactment, the CWA has formed the foundation for regulations detailing specific requirements for pollution prevention and response measures. Section 402 of the Clean Water Act established the National Pollutant Discharge Elimination System to limit pollutant discharges into streams, rivers, and bays. In the Commonwealth of Virginia, DEQ administers the program as the Virginia Pollutant Discharge Elimination System (VPDES).

Under the NPDES storm water program, operators of large, medium and regulated small municipal separate storm sewer systems (MS4s) require authorization to discharge pollutants under an NPDES permit. Medium and large MS4 operators are required to submit comprehensive permit applications and are issued individual permits. Regulated small MS4 operators (serving populations less than 100,000) have the option of choosing to be covered by an individual permit, a general permit, or a modification of an existing Phase I MS4s individual permit. The City of Fairfax is a small system and has opted for the General Permit, discussed below.

1.2.2 Commonwealth of Virginia Stormwater Regulations

The 2004 Virginia General Assembly passed House Bill 1177 transferring regulatory authority of National Pollutant Discharge Elimination System (NPDES) programs related to municipal separate storm sewer systems (MS4) and construction activities from the Department of Environmental Quality (DEQ) to the Department of Conservation and Recreation (DCR). This transfer became effective January 29, 2005. As a result, DCR is responsible for the issuance, denial, revocation, termination and enforcement of NPDES permits for the control of stormwater discharges from MS4s and land disturbing activities under the Virginia Stormwater Management Program. The Department of Environmental Quality continues to manage the remaining NPDES program.

The Department of Environmental Quality, the Department of Conservation and Recreation, and the Chesapeake Bay Local Assistance Department coordinate three separate State programs that regulate the management of pollution carried by stormwater runoff:

- The federal Clean Water Act requires large cities and urbanized counties and cities to develop stormwater management plans and obtain discharge permits for stormwater outfalls. DEQ manages this aspect of the Virginia Pollutant Discharge Elimination System program through permits issued to localities, as well as to companies that directly discharge industrial wastewater into streams.
- The Virginia Stormwater Management Act enables local governments to establish management plans and adopt ordinances that require control and treatment of stormwater runoff to prevent flooding and contamination of local waterways. Locally administered programs are voluntary but must meet or exceed the minimum standards contained in the Act regulations. DCR manages this element of the stormwater regulations.
- The Chesapeake Bay Preservation Act establishes requirements for stormwater management within designated Chesapeake Bay Preservation Areas that are within the Tidewater region of Virginia. Each local government enforces its own program, which has been based on a model developed by the Chesapeake Bay Local Assistance Board and Chesapeake Bay Local Assistance Department.

The City of Fairfax submitted a Registration Statement for a VPDES General Permit for Small MS4s in March 2003. In July 8, 2003, DEQ issued a determination that the BMPs and Measurable Goals proposed for the City's Stormwater Management Program are acceptable. This serves as confirmation that Fairfax is covered under the VPDES General Permit and establishes July 8, 2003 as the effective date. The General Permit No. VAR040064 indicates an effective date of December 9, 2002 and expiration date of December 9, 2007. Detailed performance requirements are included but monitoring stormwater discharges is not. However, if monitoring is performed, certain specific requirements must be met. The General Permit performance requirements are mostly specified in the “Minimum Control Measures” as follows:

1. Public education and outreach on stormwater impacts;
2. Public involvement/participation;
3. Illicit discharge detection and elimination;
4. Construction site stormwater runoff control;
5. Post-construction stormwater runoff in new development and redevelopment; and
6. Pollution prevention/good housekeeping for municipal operations.

Special conditions are included that address Total Maximum Daily Loads (TMDL) Allocations and Hazardous Substances or Oil Releases in Excess of Reportable Quantities. If TMDLs are approved for any water body into which the MS4 discharges, certain modifications to the stormwater Management Program may be necessary. Also certain reporting and response matters associated with hazardous substance releases may be required.

Stormwater Management Programs (SWM) programs are implemented by the Virginia Department of Conservation and Recreation (DCR) according to the Virginia Stormwater Management Law and Virginia Stormwater Management Regulations (VSWML&R). The law is codified at Title 10.1, Chapter 6, Article 1.1 of the Code of Virginia and the Regulations are found at Section 4VAC3-20 of the Virginia Administrative Code. These statutes specifically set forth regulations regarding land development activities to prevent water pollution, stream channel erosion, depletion of groundwater resources, and more frequent localized flooding to protect property value and natural resources. SWM programs operated according to the law are intended to address these adverse impacts and comprehensively manage the quality and quantity of stormwater runoff on a watershed-wide basis. Technical criteria, minimum ordinance requirements and administrative procedures are established for operating a local stormwater management program. In

1999, DCR published the “Virginia Stormwater Management Handbook” to serve as the primary guidance for SWM programs regarding basic hydrology and hydraulics, stormwater best management practice design and efficiency, and administrative guidelines to support compliance with state stormwater regulations.

DCR also implements the state Erosion and Sediment Control (ESC) Program according to the Virginia Erosion and Sediment Control Law, Regulations, and Certification Regulations (VESCL&R). The law is codified at Title 10.1, Chapter 5, Article 4 of the Code of Virginia, regulations are found at Section 4VAC30-50, and certification regulations are found at Section 4VAC50-50 of the Virginia Administrative Code. The ESC Program's goal is to control soil erosion, sedimentation, and nonagricultural runoff from regulated "land-disturbing activities" to prevent degradation of property and natural resources. The regulations specify "Minimum Standards," which include criteria, techniques and policies that must be followed on all regulated activities. These statutes delineate the rights and responsibilities of governments that administer an ESC program and those of property owners who must comply.

Recently, Virginia revised the State’s Chesapeake Bay Preservation Area (CBPA) Designation and Management Regulations (9 VAC 10-20-10 et seq). On December 10, 2001 the Chesapeake Bay Local Assistance Board (CBLAD) adopted the final amendments to the CBPA Designation and Management Regulations, which became effective on March 1, 2002. According to CBLAD, it is the responsibility of each locality to bring their local programs into compliance. CBPA requirements are address in the Ordinance Division 3 commentary presented in Section 1.3.2.

1.2.3 City of Fairfax Existing Regulations

Current stormwater regulations are found in the Fairfax City Code Chapter 110 Zoning Ordinance as follows:

- Division 2: Floodplains (Sections 110-56 through 110-60)
- Division 3:Chesapeake Bay Preservation (section 110-76 though 110-81)
- Division 11:
  - Storm Drainage Facilities
  - Subdivision I. In General (Sections 110-281 through 110-288)
  - Subdivision II. Specifications (Sections 110-306 through 110-316)
- Division 12:Erosion and Sediment Control (Section 110-336 through 110-347)

Division 2 regulations are established to protect against loss of life, health or property from flood, to permit alterations to developed sites and structures within the floodplain, to preserve and protect floodplains in a natural state for the preservation of wildlife habitat, to maintain natural integrity and function of streams, and to protect water quality. The floodplain is defined as any land area which is subject to inundation by waters of the 100-year flood as delineated or shown in the official flood insurance study (FIS) and accompanying flood insurance rate map (FIRM) dated February 19, 2003 (recent detailed Citywide engineering flood study). Permitted uses include agricultural (gardening and farming), outdoor recreation (parks, trails, athletic fields), parking, and residential accessory structures (decks and patios). Other uses are allowed with a special use permit. Special use permits are required if the area of impervious surface exceeds 2,500 sq. ft. or fill depth in excess of 12 in., and for any redevelopment. In any case the lowest floor must be 18 in. above the floodplain elevation, minimize impact, not increase the extent of flooding above or below the property, not adversely impact the channel capacity or erosion within the floodplain, minimize habitat impacts, and not negatively affect water quality.

Division 3 addresses the Chesapeake Bay Preservation Act and was recently modified by the City. The City of Fairfax amended and adopted their Code of Ordinance to assure compliance with the revised CBPA Designation and Management Regulations prior to the December 31, 2003 deadline and submitted it to the CBLAD for review. The Louis Berger/Gannett Fleming team provided a review of the City's original CBPA regulations and comments on the new draft regulation. This City Ordinance revision was independent of the work on this project.

Division 11 is presented in 2 parts in Subdivision I (In General) and II (Specifications). Subdivision I includes regulations that define the storm drainage facilities that must be provided by landowners to control rainfall runoff from and across their property and where possible preserve existing natural channels and minimize adverse effects of stormwater runoff on downstream drainage ways within the City. Performance standards and requirements are specified. Ponding facilities for detention or retention of stormwater must be capable of passing the most severe 24 hour storm considered reasonably characteristic or possible in that area. On-site drainage, streets, gutters, channels and detention/retention performance requirements are set. Design storms for each stormwater management element are specified. The design storm for culverts, storm sewers, channel, creek detention, and on-site detention is the 100 yr. storm. Streets, gutters, and inlets are required to be designed for the 10 yr. storm. On-site detention systems are required to limit the post-development peak runoff to a value no greater than the pre-developed condition. The pre-developed condition is established to be what existed on September 17, 1974.

No detention or retention is required for developments that increase runoff by less than 15% or occur on a site (lot) that is less than 1 acre in size. Interviews conducted by the City indicated that in nearly all of the existing detention/retention facilities reviewed, the 100 yr. storm requirement was satisfied. In many cases a variety of lesser storms are also addressed; for instance, outlets at some facilities may be sized to accommodate the 2 yr. storm. In all cases, the facility owner is responsible for the construction and maintenance of the detention/retention facilities, and the City may inspect the facilities and require the owner to make improvements or make the improvements with cost reimbursement if the owner does not comply.

Subdivision II specifies the design, construction, inspection and maintenance requirements for storm drainage facilities. All new land development must be approved by the Director of Public Works (DPW) before issuance of a building permit or approval of site plan and subdivision plats. A record of land use and water runoff rates as of September 17, 1974 is maintained by the DPW Director. Runoff coefficients are specified. Post development peak discharges from a facility operating at the spillway overflow level must be within 10% +/- of the pre-development peak. The provided minimum detention volume must be at least the additional runoff from the site for the 100 yr. storm for a six hour duration (which is 5.5 inches). Other factors for safety, erosion control and debris are specified.

Division 12 regulations establish adequate temporary construction and permanent control measures to prevent the erosion, flooding, siltation, sedimentation, overflow of stormwater, and uncontrolled drainage from land being subdivided or developed. A permit is required for land disturbing activities of 2,500 sq. ft. or more. Certain activities such as small disturbed area, gardening, utility maintenance and repair, mining, agriculture are exempt. All plans must be prepared in accordance with the current state erosion and sediment control regulations VR625-02-00 and the Virginia Erosion and Sediment Control Handbook A maintenance agreement and bond are required. Concentrated runoff from the site must be discharged to an adequate receiving facility or on-site detention must be developed that does not increase the predevelopment 2 yr. storm runoff (10 yr. storm if discharging to manmade channels or storm drain pipe).

1.2.4 City of Fairfax Public Facilities Manual (PFM)

Although not yet adopted, the City has hired a contractor to prepare a Public Facilities Manual (PFM) to address design criteria for the following City facilities:

- Stormwater Management/BMPs and Drainage;
- Erosion Control (will reference Virginia DCR details);
- Streets, Parking, Driveways, Sidewalks and Trails;
- Traffic Signals, Signage, and Roads;
- Water and Sanitary Sewer;
- Solid Waste and Recycling;
- Vegetative Preservation, Planting, and Screening;
- Fire Regulations;
- Street and Site Amenities; and
- Lighting.

It is recommended that City staff coordinate the results and recommendations contained in this watershed management plan into the PFM to promote the use of recommended stormwater management changes on City development projects.

1.3 Recent Stormwater Investigations

The City of Fairfax has been diligently evaluating and improving stormwater management conditions for many years. Over the last ten years, the City has completed three (3) major investigations. These reports and associated actions are as follows:

- A *Stormwater System Capital Needs Study* was prepared in 1993. Nearly $9 million in projects were recommended. Most of these projects were focused on regional sediment traps, and stormwater detention facilities and stormwater management ponds. Stream restoration efforts were also proposed in this study, and based on opposition to the larger detention facilities and overall cost/benefit analyses, stream restoration practices were the recommendations selected for implementation.
- A *Fairfax City Stream Evaluation* was completed in 1996. Thirteen (13) extensively eroded stream reaches within the City were selected and prioritized, site-specific improvements identified and costs estimates developed. Over $1 million in improvements were recommended. Most of these improvements are now complete.
- A *City of Fairfax Flood Study* was prepared in 1999. Sophisticated hydraulic analyses were performed and mapping developed. New flood plain boundaries

were established for both the 100 yr. and 500 yr. floods. This report is the basis for current FEMA Flood Insurance Maps. Hydraulic analyses are provided for other recurrence interval storms down to the 2 yr. storm.

1.4 Goals of the Watershed Management Plan

The goals of the Watershed Management Plan are to:

- identify and evaluate stormwater runoff and stream degradation within the City of Fairfax watershed;
- determine and evaluate the effectiveness of management measures for reduction of stormwater runoff and reestablishment of stream stability;
- evaluate current stormwater management efforts and recommend scope and direction of future stormwater management program activities;
- determine necessary regulation changes to the City's existing stormwater ordinance;
- and to identify potential funding sources to support the final plan recommendations, development of outreach materials and help the City in conducting the stakeholder meetings, and development of materials to be incorporated within the City's web pages.

1.5 Watershed Management Plan Development Phases

The development of the City of Fairfax Watershed Management Plan involves several phases. The first phase consists of characterizing the existing conditions in the watershed through the development of a geographic information system (GIS). This includes assessment of the land use conditions and characterization of the stream reaches using existing data sources and data collected from field assessment surveys that were performed as part of this study.

The second phase consists of developing a hydrologic model of the watershed to identify and rank areas in the City of Fairfax with high runoff volumes that can potentially impact the stream reaches. The model was used to:

- examine existing environmental and land use management information to assess past and current condition of the entire City of Fairfax;
- identify problems associated with stormwater runoff;
- identify opportunities to preserve, restore or enhance natural resources and their functions;
- and to identify and assess potential management measures for the City of Fairfax to reduce or prevent environmental degradation.

2.0 Existing Watershed Conditions

The existing conditions of the City of Fairfax watershed were characterized as the first phase in development of the watershed management plan. This step involved the identification and evaluation of available data and information to establish the existing conditions. Data used to characterize existing watershed conditions included information on physiographic characteristics such as streams, soils, topography, and land use/land cover. Field surveys and assessments were also performed to collect data and evaluate existing conditions within the City. A stormwater infrastructure survey was conducted to locate public and private stormwater structures present in the city and to establish the connectivity of the stormwater collection system. Based on results of this survey, a stormwater system GIS with accompanying maps was developed. In addition, a stream assessment survey was performed to gauge existing conditions of the Accotink Creek and its tributaries within the City. The stream assessment involved visual assessment of overall stream health, including physical and limited biological factors.

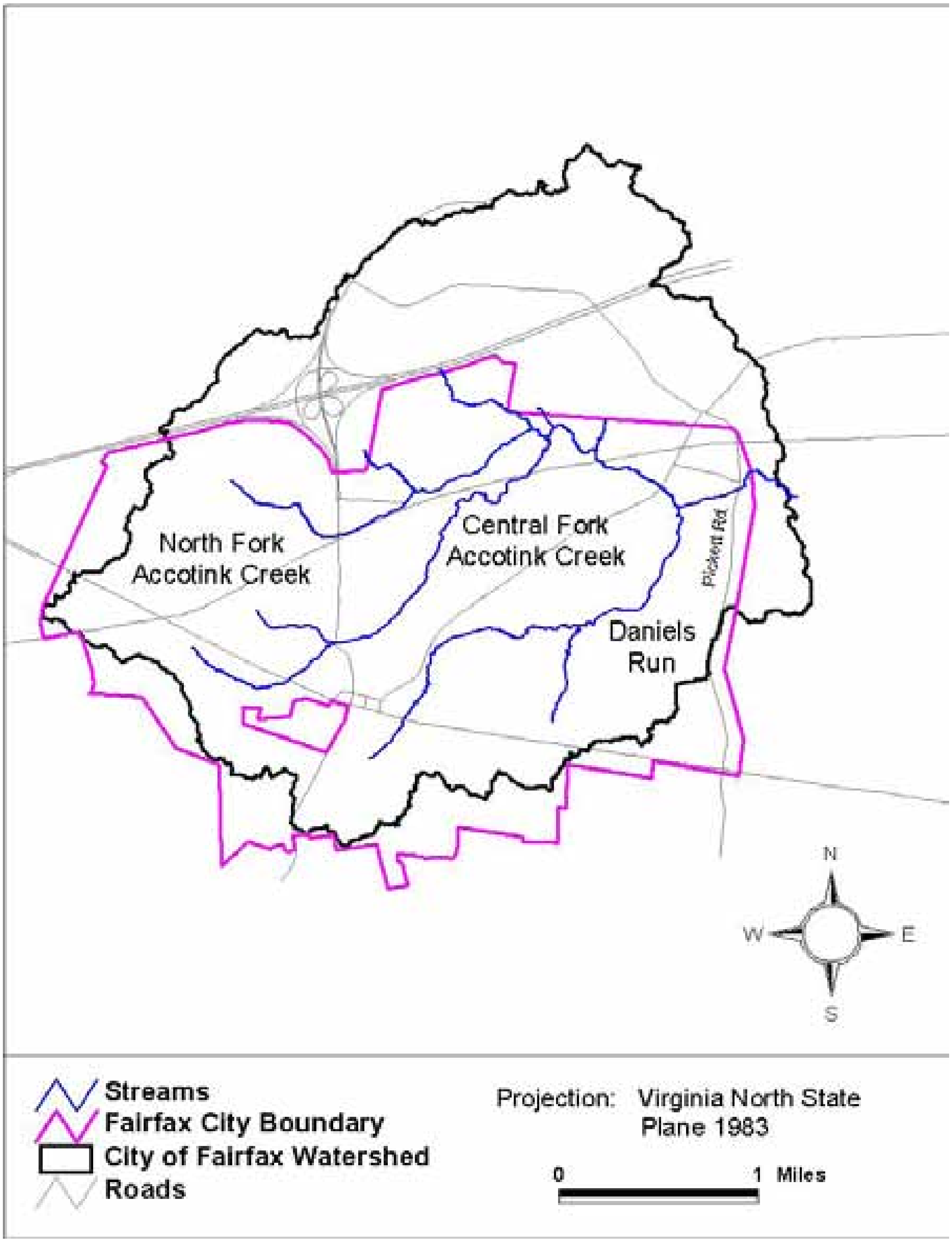
2.1 Watershed Characterization

2.1.1 Streams

Approximately 10 miles of stream channels exist in the City of Fairfax. Accotink Creek is the major receiving waterbody that drains the City. The Central Fork of Accotink Creek originates in the southwest section of the City, and flows in a northeast direction. There are two other major tributaries of Accotink Creek located within the City limits. The North Fork Accotink Creek originates in the northern section of the City, and flows in an easterly direction until its confluence with the Central Fork of Accotink Creek. The headwaters of the other main tributary, Daniels Run, begin in the southern section of the City, and flows in a northeast direction until its confluence with the Central Fork Accotink Creek. Accotink Creek leaves the City of Fairfax after flowing under Pickett Road in the northeast section of the City. The location of these streams within the City of Fairfax boundaries is presented in Figure 2-1.

The area drained by Accotink Creek extends beyond the boundaries of the City of Fairfax. Because watershed management is most effective when considered in a holistic context, it is important to consider the watershed draining into the City in order to develop an accurate watershed management plan for the City of Fairfax. The drainage area of the Accotink Creek watershed through the City of Fairfax was delineated using a 30-meter Digital Elevation Model (DEM) and USGS 7.5 minute quadrangle maps. The drainage area considered in the development of this watershed management plan was approximately 4,998 acres (7.8 square miles), of which approximately 3,408 acres (5.3 square miles), or 68% of the total drainage area, is located within the Fairfax City limits. The drainage area of Accotink Creek through the eastern boundary of the City of Fairfax is presented in Figure 2-1. Since Accotink Creek flows beyond the Fairfax City limits, for the purposes of this report the Accotink Creek drainage area from its headwaters to the eastern boundary of the City of Fairfax will be referred to as the City of Fairfax watershed.

Figure 2-1: Location of Major Streams within the City of Fairfax



2.1.2 Soils

The distribution of soils in the City of Fairfax watershed was analyzed in order to assess the infiltration capacity in the non-impervious areas of the City. Hydrologic soil groups are one method of classifying different levels of infiltration capacity among soils. Hydrologic soil group “B” designates soils that are well to moderately well drained, whereas hydrologic soil group “D” designates soils that are poorly drained. This means that soils in hydrologic group “B” allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group “B”, soils in hydrologic group “D” allow a smaller portion of the rainfall to infiltrate and become part of the ground water; consequently, more rainfall becomes part of the surface water runoff. Soils in hydrologic group “C” are intermediate between these two. The relative abundance of soils within the City of Fairfax watershed is presented in Table 2-1. Descriptions of the hydrologic soil groups are presented in Table 2-2. The soils in the watershed belong to primarily hydrologic soil group B (65.5%). Hydrologic soils groups C and D are also present.

The majority of soils in the City are well-drained and suitable for development. Most of the soils in the City fall into the Fairfax-Beltsville-Glenelg or Glenelg-Elioak-Manor soil associations (NRCS; state soil geographic (STATSGO) database). Both of these soil associations are characterized by rolling hills and are considered to be well-drained. Much of the soil within the City’s floodplains falls into the Chewacla-Wehadkee soil association. These soils are poorly drained, subject to flooding, and are not suitable for building. A fourth soil association, Orange-Bremo-Elbert, is found in the western portion of the City near Jermantown Road. Soils in this association are poorly drained with massive bedrock 2-5 feet below the surface. A floodplain map developed by the City of Fairfax shows the poorly drained soils within the City, and is presented in Appendix A.

Table 2-1: Hydrologic Soil Groups within the City of Fairfax Watershed

Hydrologic Soil Group	Acres	Percent of Watershed
B	3273.79	65.5
C	694.47	13.9
D	1029.82	20.6
Total	**4,998**	**100**

Table 2-2: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

Source: NRCS

2.1.3 Topography

A 30 meter digital elevation model (DEM) and USGS 7.5 minute quadrangle maps were used to characterize the topography of the City of Fairfax watershed. DEM data were obtained from USGS and compared to the Fairfax, Virginia USGS 7.5 minute quadrangle map. Elevation in the City of Fairfax watershed ranged from 425 feet above mean sea level at its highest point, to 285 feet above mean sea level at the point Accotink Creek flows out of the City.

2.1.4 Land Use

Land use within the City of Fairfax watershed was characterized using both the USGS National Land Cover Data (NLCD), and an existing condition land use dataset developed for the City of Fairfax from zoning regulations. The NLCD dataset was derived from satellite imagery collected circa 1992, whereas the City of Fairfax dataset was developed using the City's existing zoning classifications.

The distribution of land cover in the City of Fairfax watershed using the NLCD dataset is presented in Table 2-3. The dominant land cover classes in the watershed are low intensity residential lands (43.1%), deciduous forest (21.5%) and commercial/industrial/transportation lands (17.5%). Brief descriptions of the land cover types contained in the NLCD dataset are presented in Table 2-4. Figure 2-2 depicts the land cover distribution within the watershed. Forested lands and low intensity residential lands are relatively dispersed throughout the watershed, although there are a higher percentage of forested lands in the area of Daniels Run. Commercial lands are most prevalent along major roadways.

The land use distribution for the City of Fairfax existing conditions dataset is presented in Table 2-5. Dominant zoned land uses in the watershed are 1/3 acre zoned residential land (22.5%), 1/2 acre zoned residential land (13.3%), and townhouses (12.3%), which account for a combined 48.1% of land use in the City of Fairfax watershed. About 82% of the watershed is zoned for either residential, commercial, or transportation uses. Figure 2-3 depicts the land use zoning distribution within the watershed.

Table 2-3: NLCD Land Cover Distribution in City of Fairfax Watershed

Land Cover Category	Land Cover Type	Acres	Percent of Watershed's Land Area
Developed	Low Intensity Residential	2153.4	43.1
	High Intensity Residential	0.4	0.0
	Commercial/Industrial/Transportation	874.6	17.5
Forested	Deciduous Forest	1077.2	21.5
	Evergreen Forest	92.1	1.8
	Mixed Forest	393.8	7.9
Agricultural	Pasture/Hay	264.0	5.3
	Row Crop	1.1	0.0
Water/Wetlands	Open Water	9.1	0.2
	Woody Wetlands	8.6	0.2
	Emergent Herbaceous Wetlands	2.4	0.0
Other	Transitional	30.2	0.6
	Urban/Recreational Grasses	92.2	1.8
Total		**4,998**	**100**

Table 2-4: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/Industrial/Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: NLCD

Figure 2-2: NLCD Land Cover in the City of Fairfax Watershed

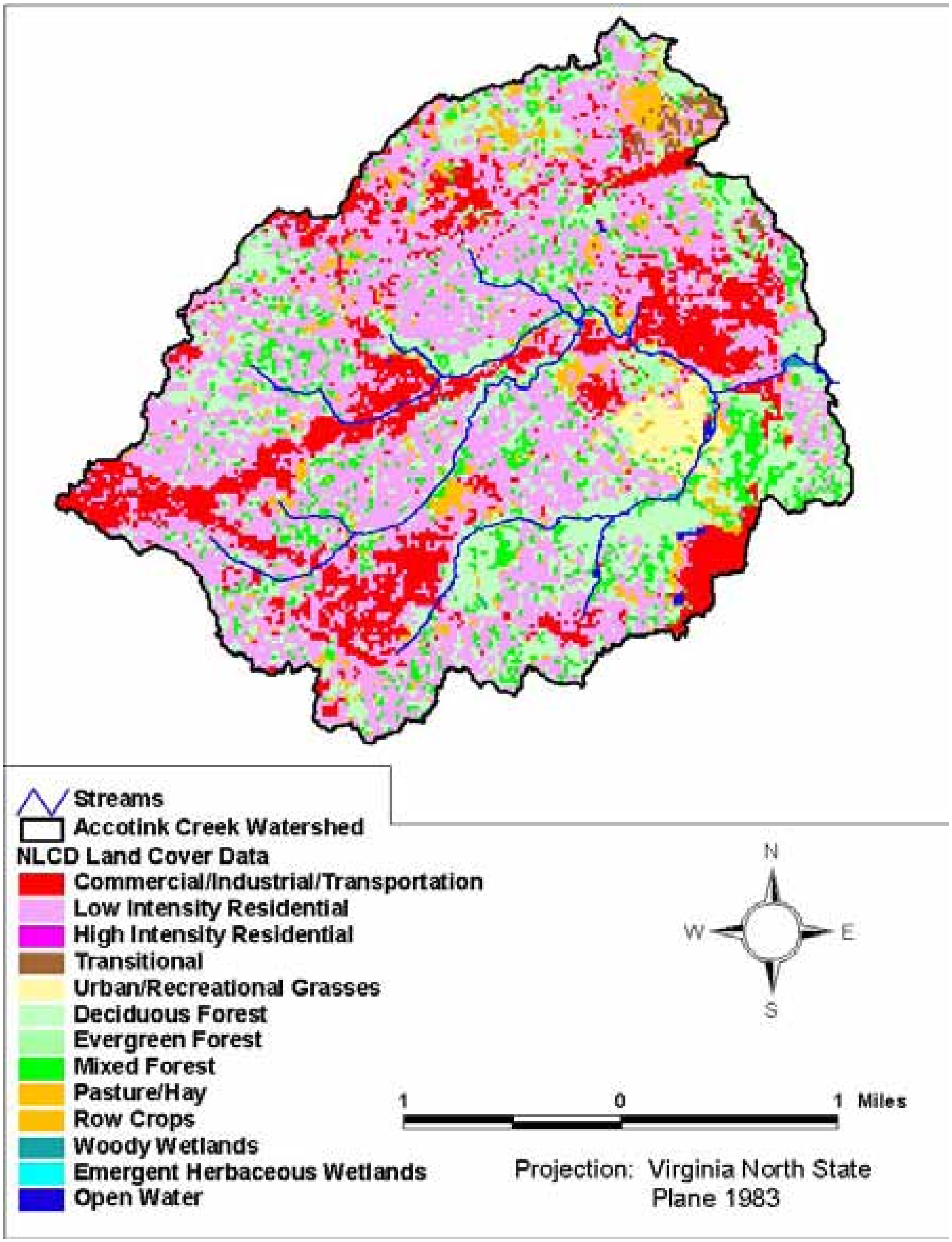
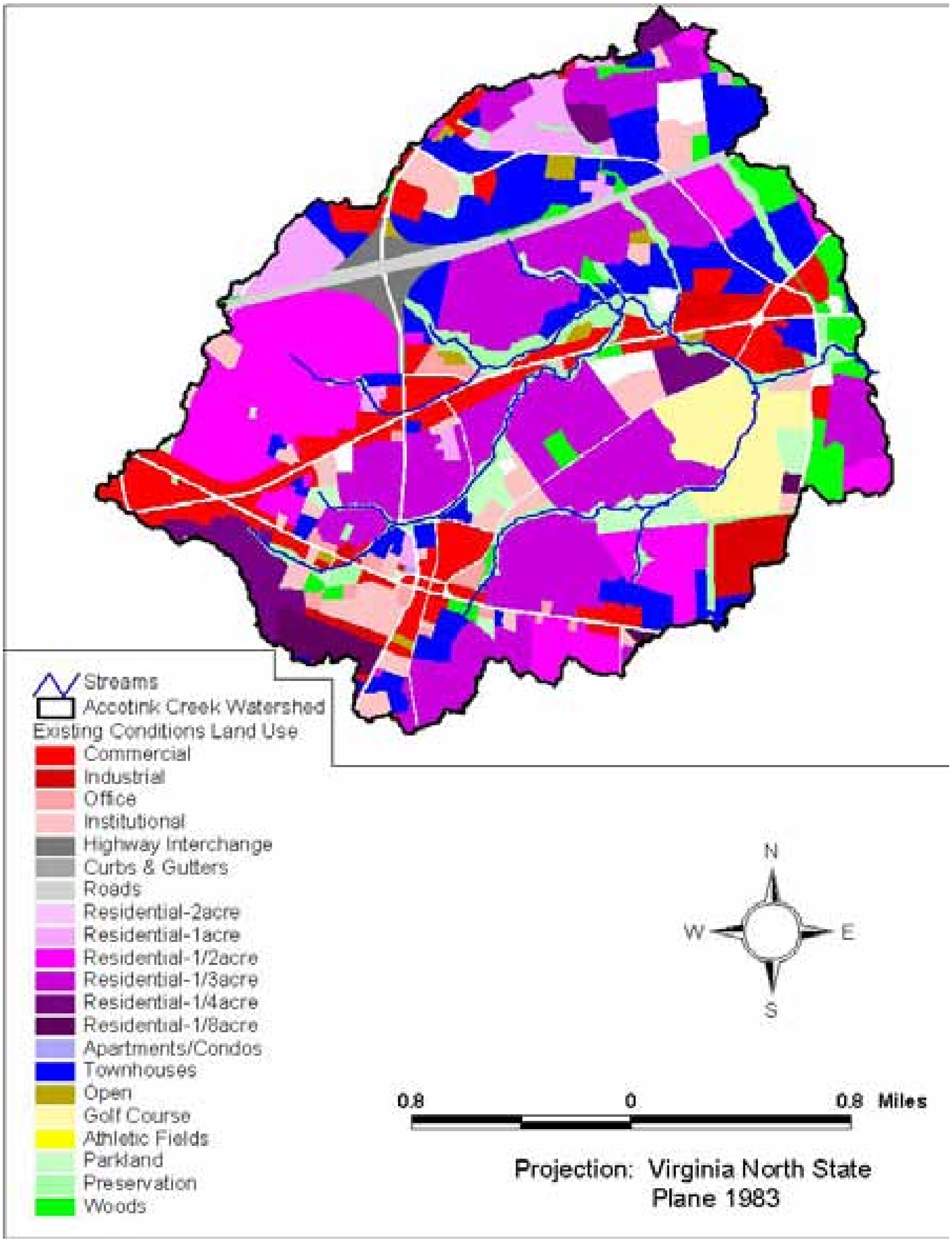


Table 2-5: Existing Zoned Conditions Land Use Distribution in the City of Fairfax Watershed

Land Use Category	Land Use Type	Acres	Percent of Watershed's Land Area
Residential	Apartments/Condominiums	1.1	0.0
	Residential -1/8 acre	60.9	1.2
	Residential -1/4 acre	161.1	3.2
	Residential -1/3 acre	1123.9	22.5
	Residential -1/2 acre	663.6	13.3
	Residential -1 acre	169.1	3.4
	Residential -2 acre	6.5	0.1
	Townhouses	615.2	12.3
Commercial/ Transportation/ Other	Commercial	545.2	10.9
	Highway Interchange	59.5	1.2
	Industrial	120.2	2.4
	Institutional	269.0	5.4
	Office	53.7	1.1
	Curbs & Gutters	172.0	3.4
	Roads	86.5	1.7
Natural/ Recreation	Athletic Fields	74.9	1.5
	Golf Course	207.3	4.1
	Open	37.6	0.8
	Parkland	145.6	2.9
	Preservation	252.3	5.1
	Woods	171.4	3.4
Total		**4,998**	**100**

Figure 2-3: Existing Conditions Land Use in the City of Fairfax Watershed



2.2 Field Assessments

2.2.1 Stormwater System Survey and GIS Mapping

A survey of existing stormwater structures was initiated in February, 2002, to locate, inventory, and characterize the existing stormwater infrastructure in the City of Fairfax. Results of the stormwater infrastructure survey are detailed in a separate report entitled "Stormwater System Survey and GIS Mapping for City of Fairfax, Virginia - Phases I and II Final Report" dated August, 2003. The key tasks addressed in the study included:

- locating the existing stormwater infrastructure;
- developing a database and inventory of the stormwater infrastructure;
- developing maps and a GIS layer of the stormwater structures inventory;
- developing maps and a GIS layer of the connectivity of the stormwater system.

Over 3,600 stormwater structures located within the City of Fairfax were surveyed and characterized. The location of each inlet and outlet in the stormwater system was identified, as was the location of stormwater retention structures in the City. The diameter, composition, and the direction of flow for each inlet and outlet in the stormwater system were also surveyed and recorded. A database was developed to house the information collected as part of the stormwater structures inventory and characterization. In addition, GIS layers were developed showing both the stormwater structures located in the City of Fairfax, as well as the connectivity of these structures. A map showing the location and connectivity of the stormwater pipes located in the City of Fairfax is presented in Figure 2-4.

Following completion of the Stormwater System Survey, an additional stormwater pipe field survey was performed to further characterize and assess the condition of outlet structures associated with the stormwater system. Results of the stormwater outlet survey are detailed in a separate report entitled "Stormwater Outlet Survey - City of Fairfax, Virginia" dated August, 2003. This survey was conducted in October of 2002 and focused on characterizing the conditions of stormwater outlet structures that discharge to Accotink Creek and its tributaries within the City of Fairfax. Stormwater discharge impacts on the receiving waters were assessed as part of the survey. The locations of stormwater outlets in the City of Fairfax are shown in Figure 2-5.

A total of 145 stormwater outlet structures were identified and characterized during the field survey. For each stormwater outlet, the physical condition of the structure, outfall channel conditions, and impacts to receiving streams were characterized and recorded on outlet data sheets. In addition, digital photos were taken for each outlet to document outlet conditions and facilitate locating outlets in the future. Outlet field data sheets included the following information:

- Stream Name
- Location Description and GPS Coordinates
- Photo Number and Description
- Outlet Description
- Outlet Diameter and Construction Material
- Outlet Condition and Description
- Evidence of Scour and/or Sediment Deposition
- Channel Conditions at Outfall
- Channel Conditions Downstream of Outfall

Figure 2-4: Location and Connectivity of Stormwater Pipes in the City of Fairfax

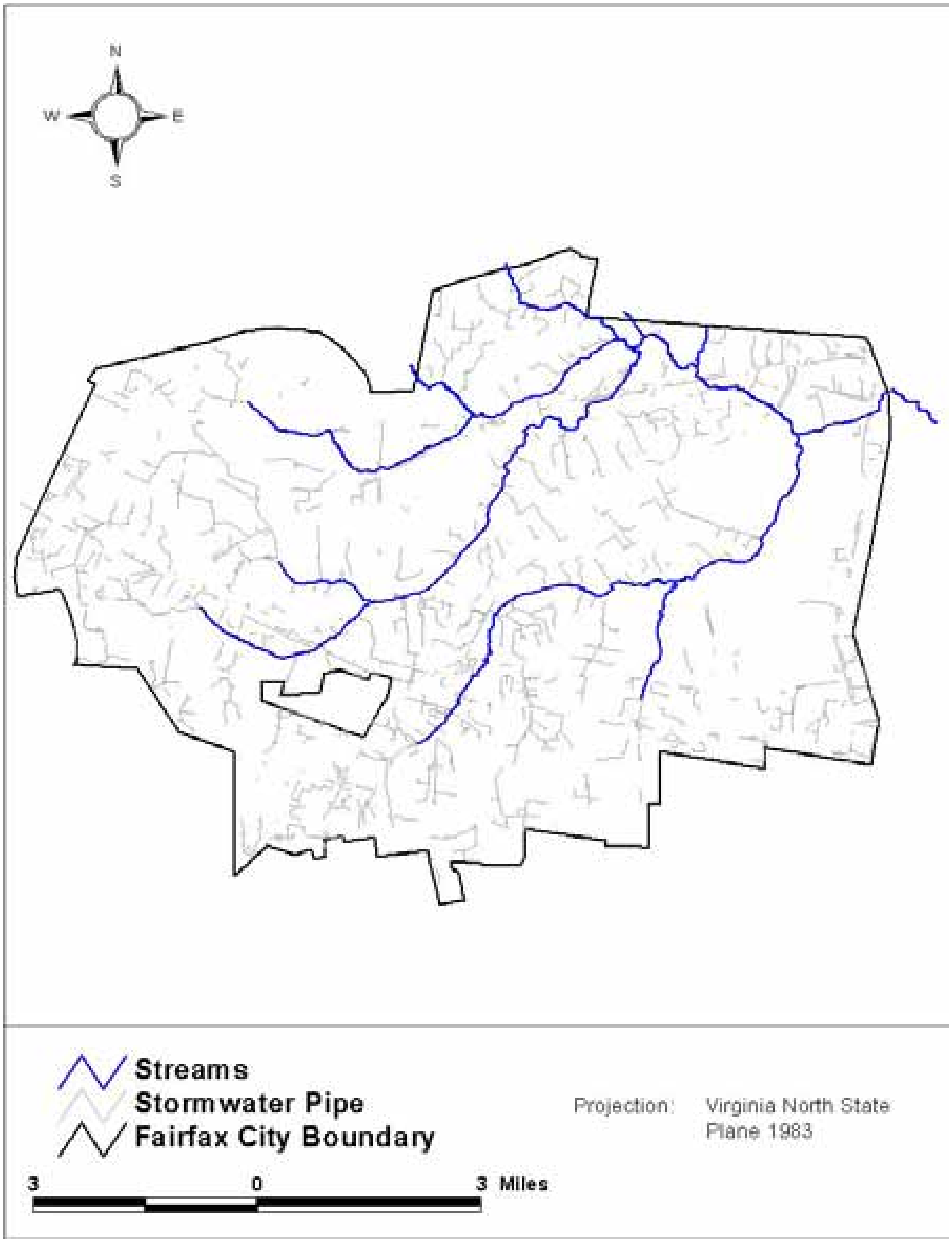
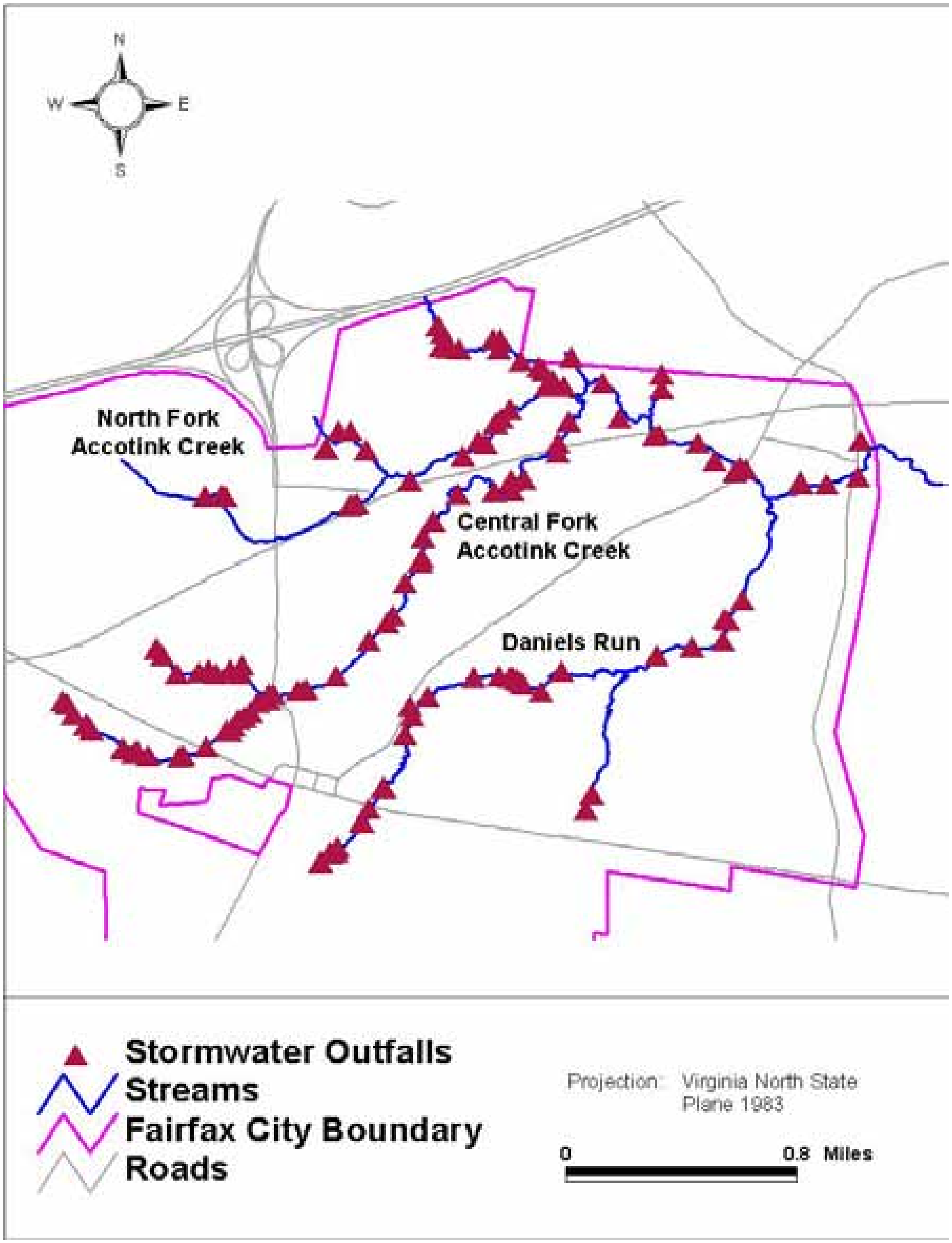


Figure 2-5: Location of Stormwater Outfalls in the City of Fairfax



2.2.2 Existing Stormwater Facilities

Existing stormwater controls were inventoried based on Fairfax City staff interviews and collected data. The following list summarizes existing stormwater facilities and conditions in the City of Fairfax:

- There are no municipally owned stormwater detention facilities in the City.
- There is only one regional facility in the City, located at the Farrcroft residential development.
- The sanitary sewer system is entirely separate from the stormwater system.
- There are currently no rooftop storage sites.
- Approximately 5% of City downspouts are connected to the City's storm sewer system. The remaining 95% discharge to the ground surface or underground drains. Most unconnected downspouts discharge to the ground surface, pavement, or soil.
- There are currently 78 known privately owned on-site stormwater detention/retention facilities located in the City.
- The City has had a stormwater detention ordinance since 1974.
- No watershed management plan, stormwater master plan, or stormwater utility plan currently exists.

2.2.2.1 Onsite Stormwater Detention and Management

There are currently approximately 78 known privately owned on-site stormwater detention/retention facilities in the City. The majority of these stormwater facilities are either underground pipes or dry ponds.

Buried stormwater pipes can provide storage of stormwater during periods of heavy rainfall. Surface water is collected from sites using various drainage structures that are piped underground. The outlets for these storage facilities include controlled outlet structures to restrict flow from the site to "pre-developed" conditions. Although this type of facility reduces peak discharges, it does not reduce the overall volume of water leaving the site.

Dry ponds are surface depressions (ponds) that collect runoff during periods of heavy rainfall. The outlets for these storage facilities include controlled outlet structures to restrict the flow from the site to “pre-developed” conditions. The outlet structure is installed at the lowest elevation of the pond so that after the rainfall stops and pond drains, it returns to a dry condition. Although this type of facility reduces peak discharges, it does not reduce the overall volume of water leaving the site.

A summary of the 78 known stormwater detention facilities is presented in Table 2-6. Although geospatial information for the stormwater detention facilities was not readily available, GIS analyses were conducted in an attempt to quantify the exact locations of these facilities. The locations of the facilities that were able to be quantified using the available data and information are presented in Figure 2-6. Note that the facilities presented in Figure 2-6 do not represent an exhaustive list of the stormwater detention facilities located in the City.

Potential candidate areas for detention are shown in Figure 2-7. Potential candidate areas for outlet treatment are shown in Figure 2-8. Candidate areas are described by subwatersheds delineated by the City of Fairfax. Further discussion of subwatersheds is presented in Section 2.2.5 (P. 2-29).

Table 2-6: Summary of Stormwater Detention Facilities

Stormwater Facility Type	Number of Facilities
Underground Pipes	51
Dry Ponds	12
Sand Filters	3
Oil/grid Separators	2
Stormceptors	2
Wet Pond	1
Underground Vault	1
Percolation Trench	1
Dry Pond with Bioretention	1
Sand Filter with Underground Pipe	1
Stormceptor and Underground Pipe	1
Bioretention	1
Unidentified	1

Figure 2-6: Location of Stormwater Detention Facilities in the City of Fairfax

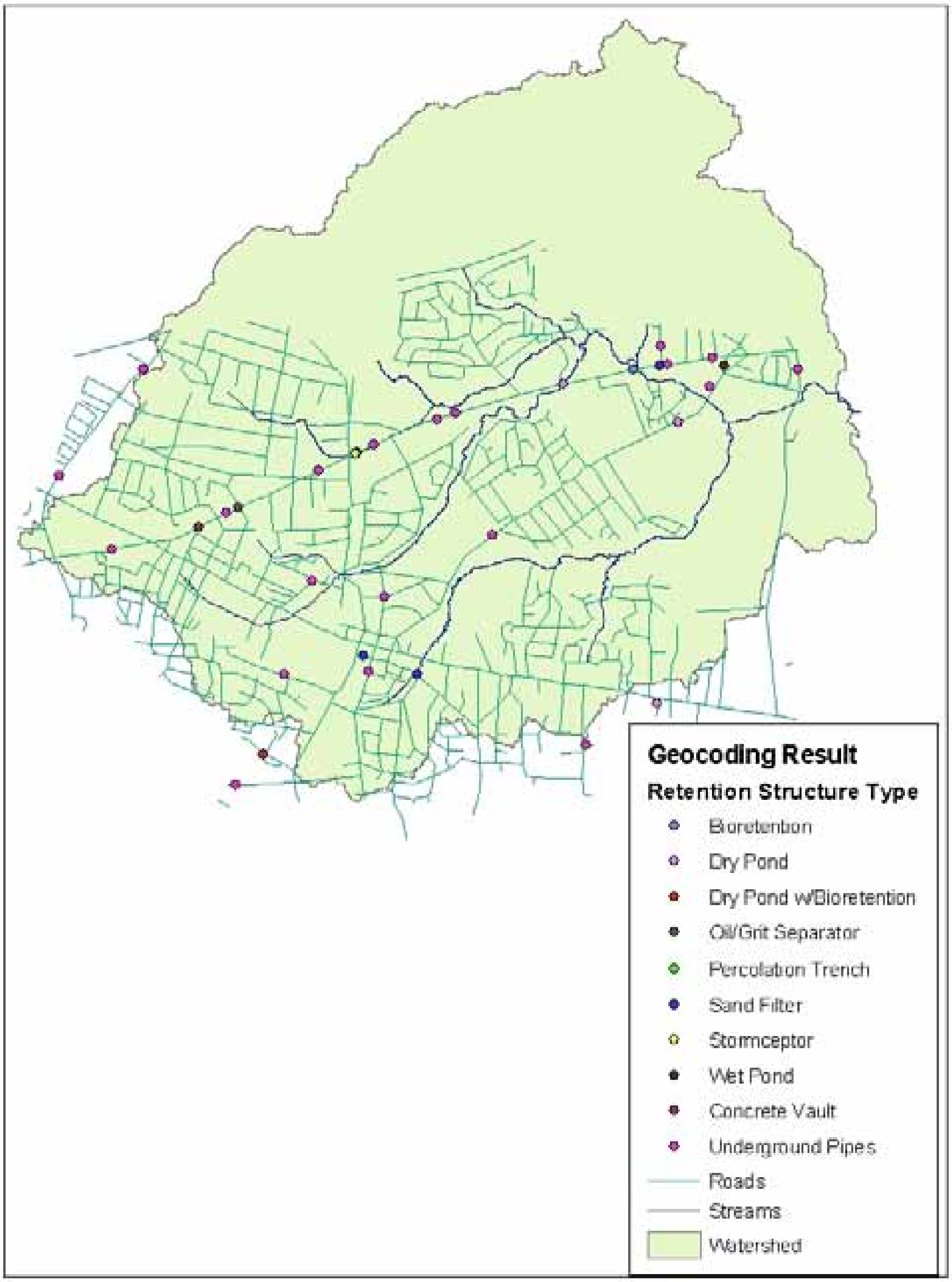


Figure 2-7: Candidate Areas for Detention in the City of Fairfax Watershed

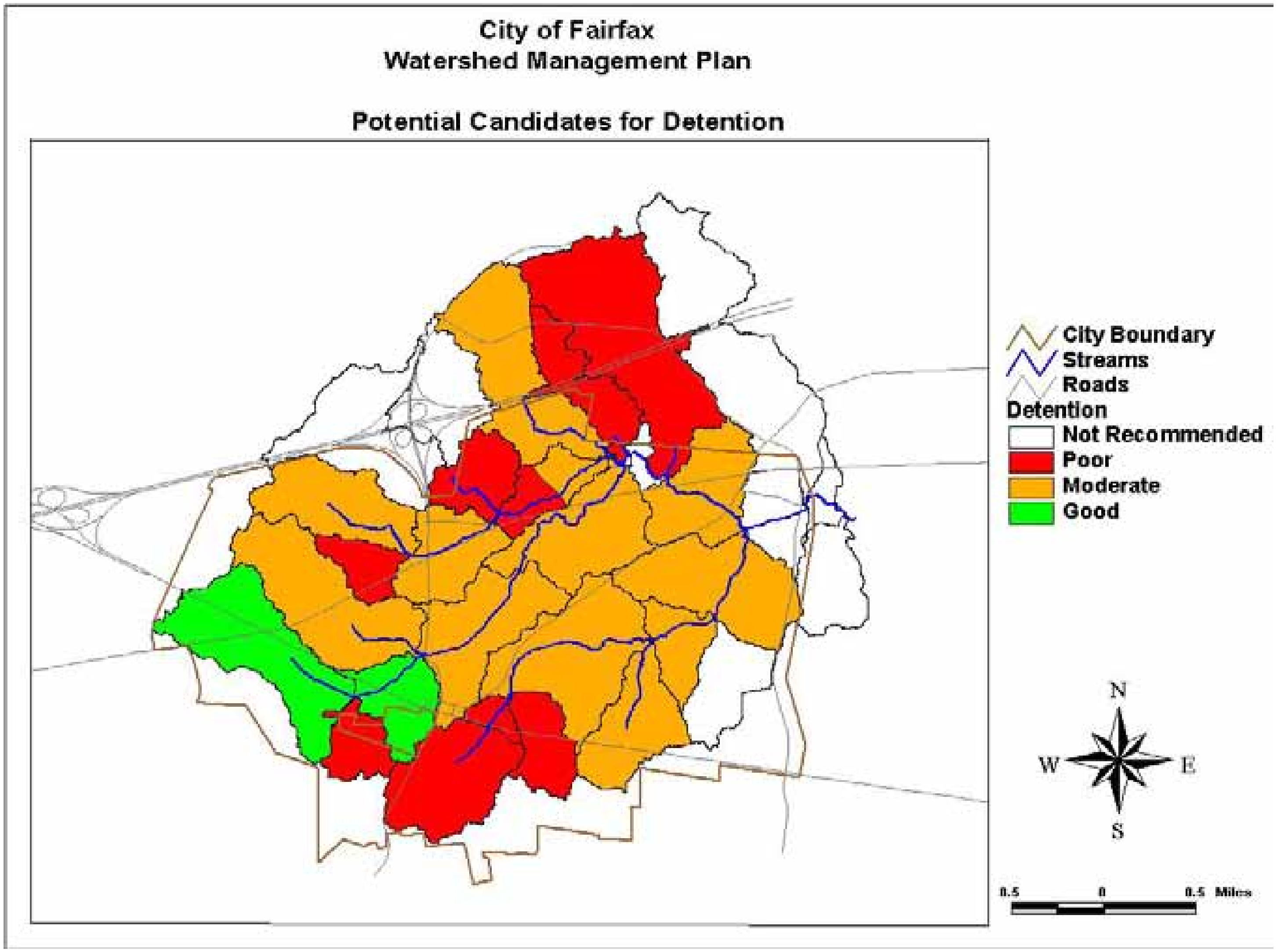
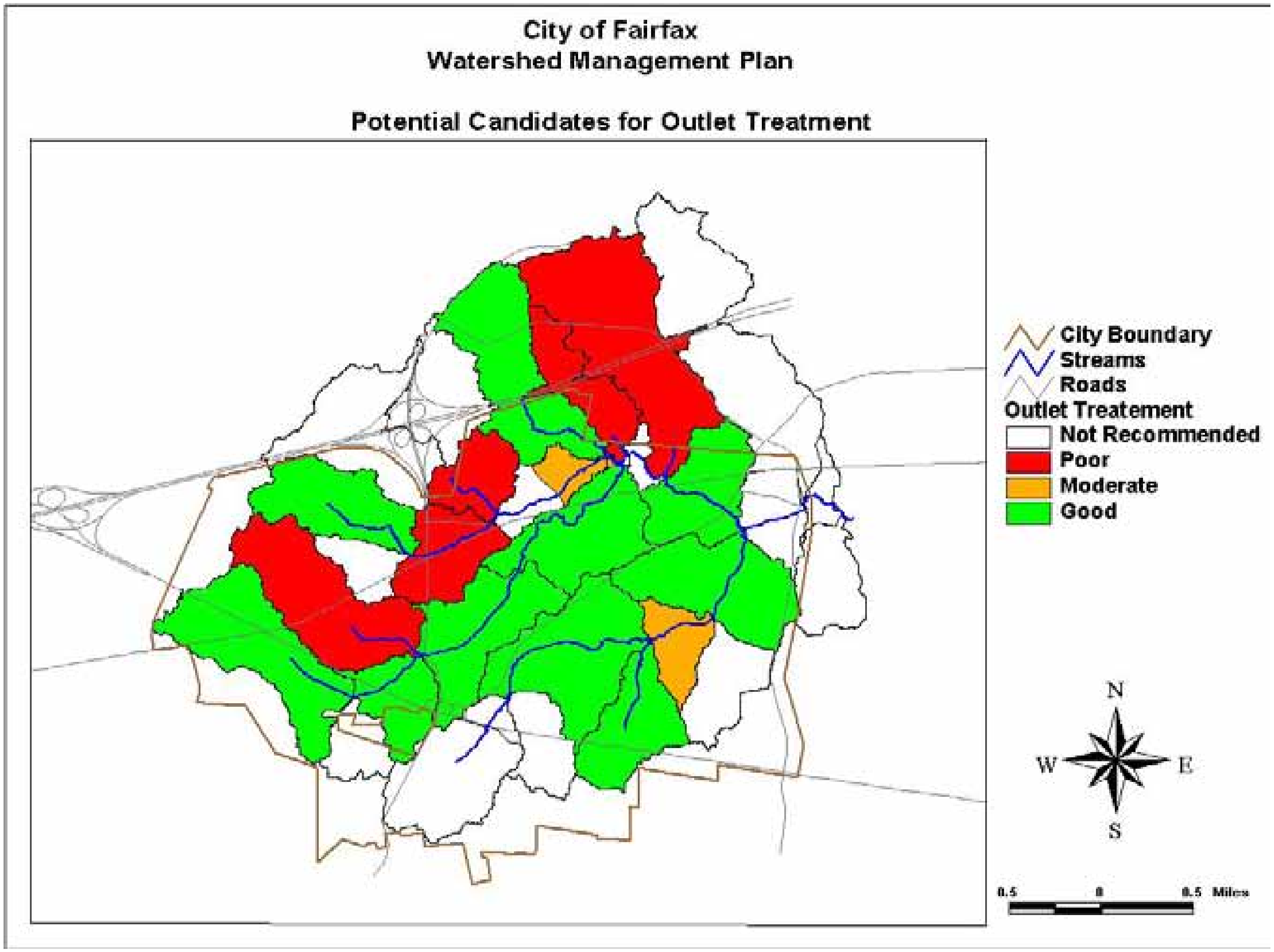


Figure 2-8: Candidate Areas for Outlet Treatment in the City of Fairfax Watershed



2.2.3 Stream Condition Assessment

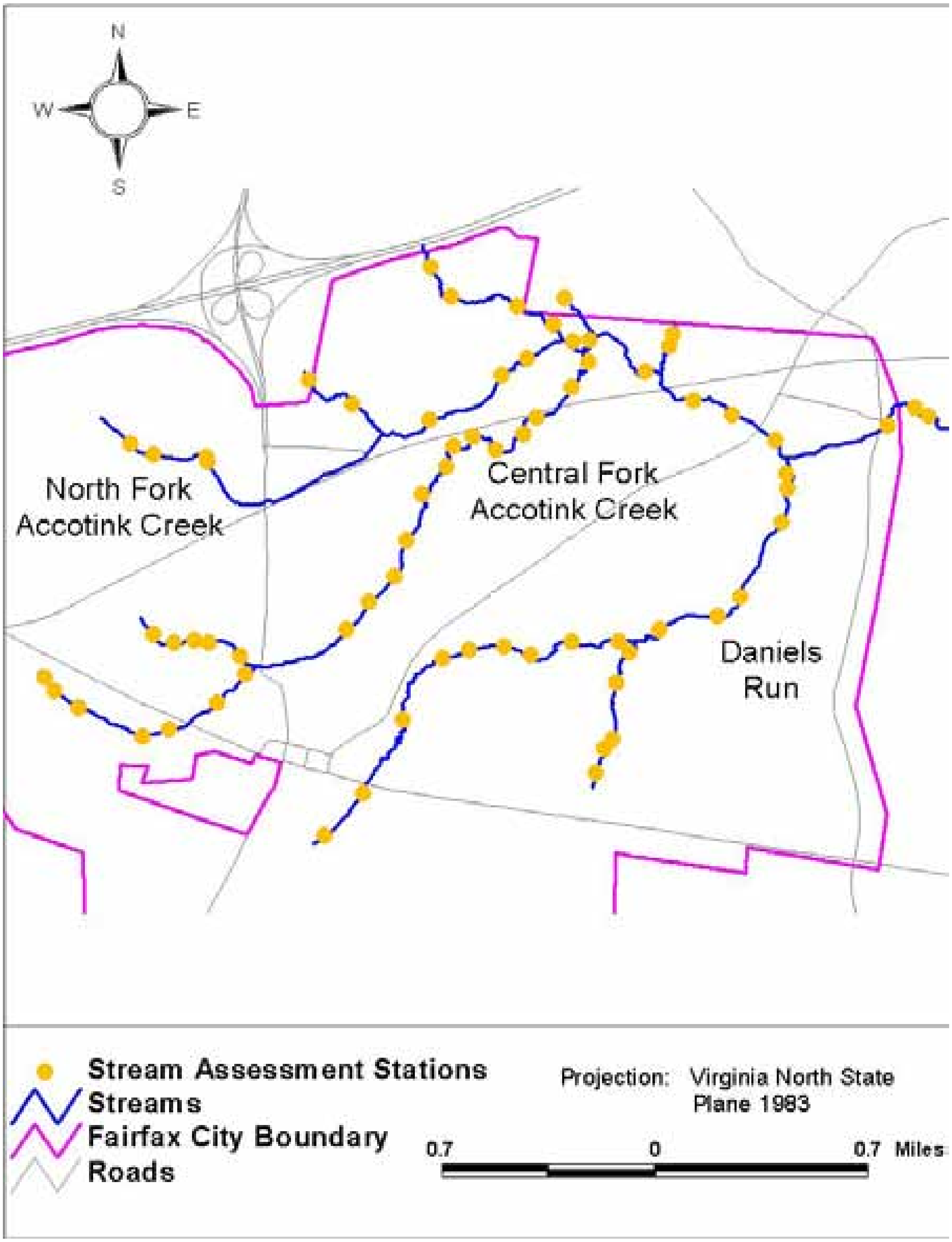
A stream survey was conducted in October, 2002 to assess the physical and biological health of streams located within the City of Fairfax. The field survey covered and analyzed every mile of stream within the City including Accotink Creek and its tributaries. Stream assessment results were compiled for a total of 72 stream reaches of variable length, representing all of the streams in the City. The location of the assessed stream reach stations are presented in Figure 2-9. Station locations represent the midpoint of the assessed stream reaches.

Assessment protocols were based on the Stream Visual Assessment Protocol developed by the U.S. Department of Agriculture (USDA, 1998). The Stream Visual Assessment Protocol provides a standard, repeatable protocol to evaluate conditions in streams and aquatic ecosystems. Physical and biological metrics specified in the protocols were used to quantify the physical and biological conditions of the streams within the City of Fairfax. It should be noted that biological conditions were evaluated qualitatively, no macroinvertebrate sampling was conducted to fully evaluate and quantify the biological conditions in the streams, and thus these data and information were limited in scope.

Metric scores were summed to provide an indication of both the relative physical and biological health of each stream reach. Physical and biological metrics scores were then averaged into a final assessment score providing an indication of overall stream health. Stream reaches were scored from 1 to 10, where scores of 0 to 6.0 indicated poor conditions, scores of 6.1 to 7.4 indicated fair conditions, scores of 7.5 to 8.9 indication good conditions, and scores of 9.0 to 10 indicated excellent conditions in the stream.

The City of Fairfax has completed full restoration projects on 2.2 miles of stream and stabilized 3.8 miles of stream. These stream improvement projects account for about 68% of stream miles within the City boundary; this clearly reflects the City's commitment to improving the stream conditions. Also, the results of the stream survey presented in the next sections show that the stream improvements positively contributed substantially to the physical conditions scores.

Figure 2-9: Location of Stream Assessment Stations in the City of Fairfax



2.2.3.1 Physical Conditions

Several metrics were examined in order to measure the physical characteristics of the streams. These included:

- Channel Condition
- Hydrologic Alteration
- Riparian Zone Vegetation
- Vegetative Protection
- Bank Stability

A summary of the physical conditions assessment scores, including the length of streams classified as excellent, good, fair and poor, is presented in Table 2-7. The results presented in the table are typical for streams flowing in highly urbanized areas where stormwater runoff is extremely high due to the dominant impervious cover. This causes high volumes of uncontrolled stormwater runoff to enter the stream and subject the stream channel to very high erosive forces. Despite the City of Fairfax's efforts to restore and protect the streams, only one percent of the stream reaches examined remain in excellent physical condition. However the City efforts paid off since twenty-six percent of stream reaches surveyed were given a physical conditions assessment score of good, 9 percent were given a physical conditions assessment scores of fair. The 65 percent of stream reached that were given a physical condition assessment score of poor show the impacts of uncontrolled stormwater flow and the potential erosive forces that these reaches experience after a moderate rainfall event.

The stream stations are presented by their physical conditions assessment score in Figure 2-10. Stations where stream restoration work has been previously conducted are also labeled in Figure 2-10. it is interesting to note that most stream reaches that received a good physical score were surrounding area where the City of Fairfax has recently completed improvement projects.

Figure 2-11 is a photograph taken during field surveys which displays poor stream bank conditions present just upstream of the mouth of Daniels Run. This station received a poor physical assessment score. Figure 2-12 displays a restored stream reach of Accotink Creek near its confluence with the North Fork. The restoration work on this reach has provided for stable stream banks. As a result, this station was assessed as being in good physical condition.

Table 2-7: Physical Condition Assessment Scores for City of Fairfax Streams

Assessment Score	Stream Length (Feet)	% of Streams
Excellent	300	1
Good	13,730	26
Fair	5,000	9
Poor	34,580	65
Total	**53,610**	**100**

Figure 2-10: Survey Assessment Results for Stream Physical Conditions

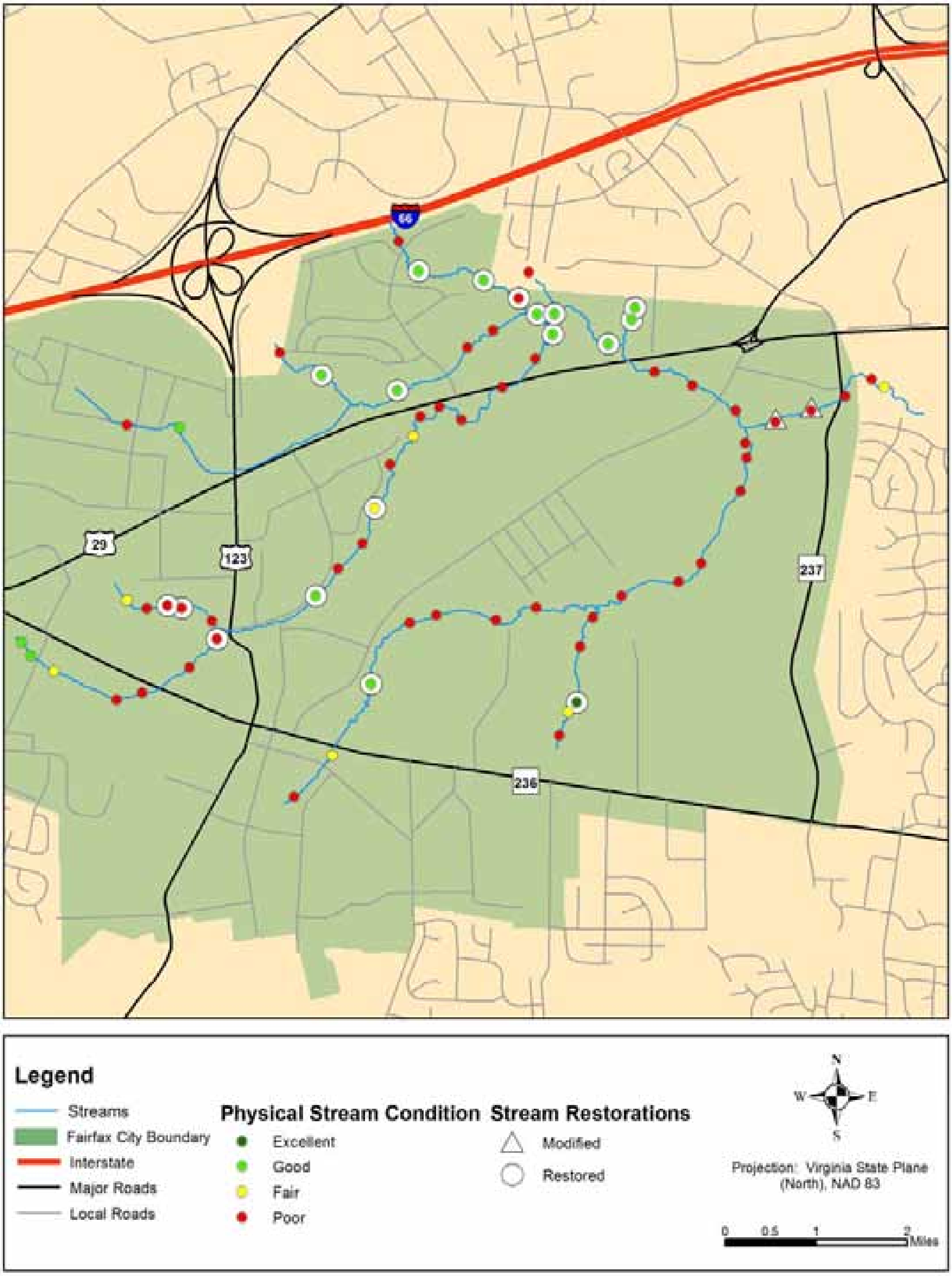


Figure 2-11: Poor Stream Bank Conditions near Mouth of Daniels Run

Figure 2-12: Restored Stream Reach of Accotink Creek near Confluence with North Fork

2.2.3.2 Habitat and Biological Conditions

Metrics examined in order to quantify habitat and biological conditions in the City of Fairfax streams included:

- Sediment Deposition
- Water Appearance
- Nutrient Enrichment
- Barriers to Fish Movement
- In-Stream Fish Cover
- Pools
- Insect/Invertebrate Habitat
- Canopy Cover
- Riffle Embeddedness
- Macroinvertebrates Observed

The hydrologic regime alteration that results from changes in the land use due to urbanization has a direct impact on the biological conditions in the stream. As previously mentioned, the City of Fairfax recently completed stream improvements on about 68% of the stream reaches. The physical conditions are showing signs of improvement but the biological integrity of these stream reaches has not been restored yet. It usually takes longer for the biological community to get reestablished in urban streams, other times the flow conditions are never suitable for biological community to get reestablished again. A summary of the habitat and biological assessment scores is presented in Table 2-8. No stream reaches that were examined were given habitat and biological assessment scores of excellent or good. Twenty percent of stream reaches surveyed were given a habitat and biological assessment score of fair, and 80 percent were given a habitat and biological assessment score of poor. The stream stations are presented by their habitat and biological condition assessment score in Figure 2-13. Stations where stream restoration work has been previously conducted are also labeled in Figure 2-13.

Figure 2-14 displays a barrier to fish movement present on Accotink Creek just downstream of the confluence with Daniels Run. This station received a poor habitat and biological assessment score.

Table 2-8: Habitat and Biological Condition Assessment Scores for City of Fairfax Streams

Assessment Score	Stream Length (Feet)	% of Streams
Excellent	0	0
Good	0	0
Fair	10,900	20
Poor	42,710	80
Total	53,610	100

Figure 2-13: Survey Assessment Results for Stream Habitat and Biological Conditions

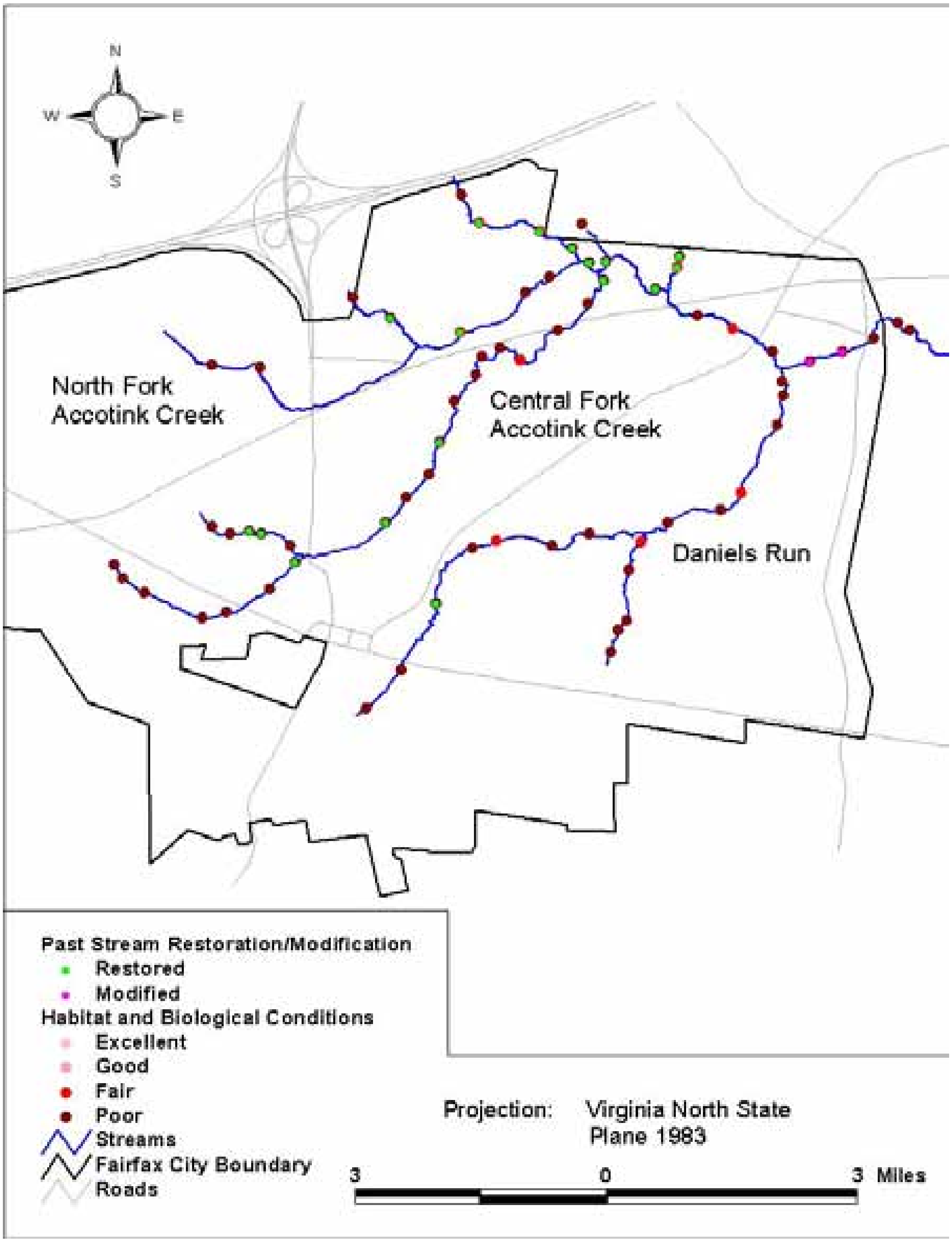


Figure 2-14: Barrier to Fish Movement on Accotink Creek Downstream of Daniels Run

2.2.3.3 Overall Stream Health

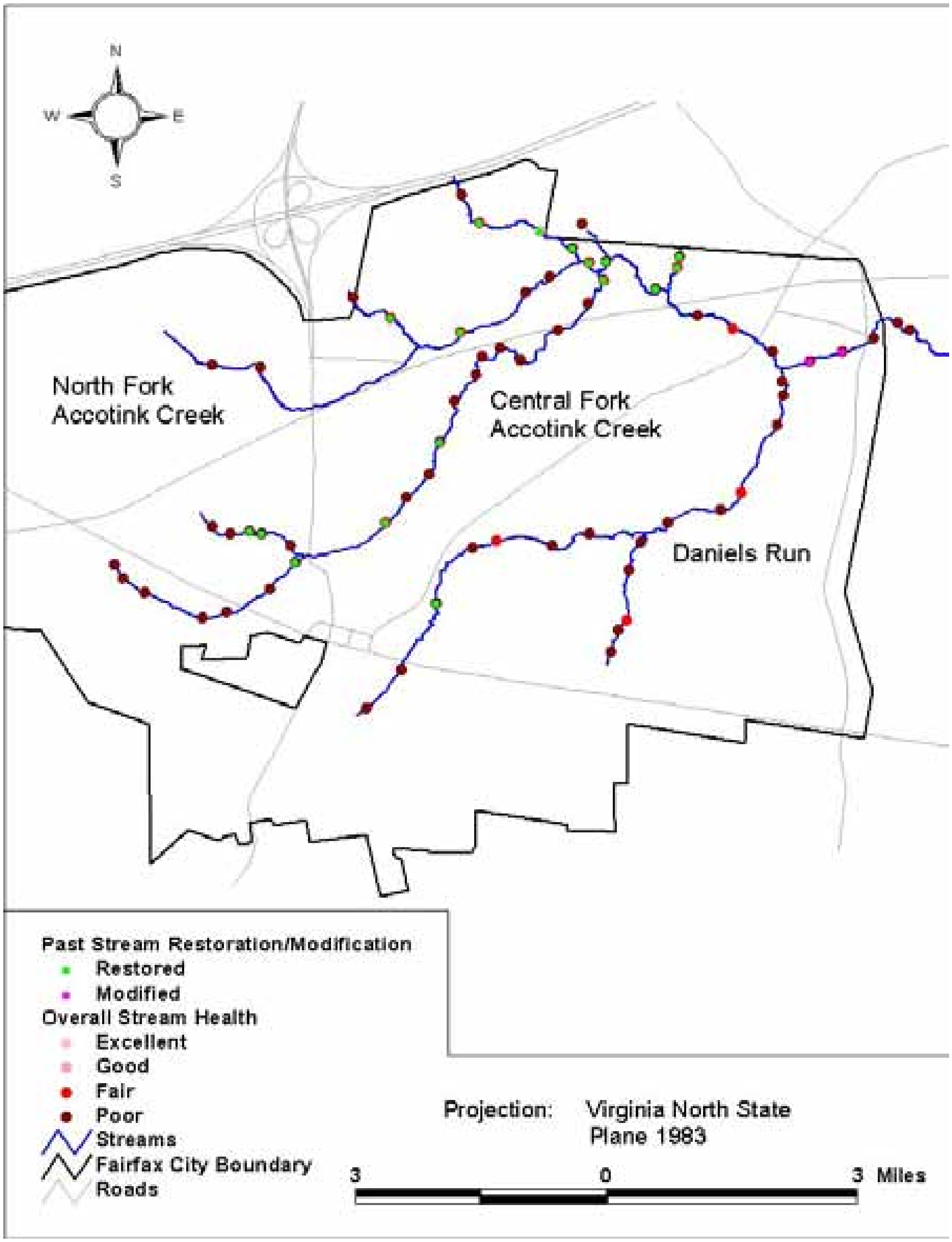
The Stream Visual Assessment Protocol provides a standard, repeatable protocol to evaluate conditions in streams and aquatic ecosystems. Physical and biological metrics specified in the protocols were used to quantify the physical and biological conditions of the streams within the City of Fairfax. It should be noted that biological conditions were evaluated qualitatively, no macroinvertebrate sampling was conducted to fully evaluate and quantify the biological conditions in the streams, and thus these data and information were limited in scope.

An assessment score indicative of overall stream health was calculated using the physical, habitat, and biological assessments. There were no stream reaches with an overall stream health assessment score of excellent. Three percent of stream reaches surveyed were given an overall stream health assessment score of good, 20 percent of the stream reaches were given an overall stream health assessment score of fair, and 77 percent were given an overall stream health assessment score of poor. A summary of the overall stream health assessment scores is presented in Table 2-9. The stream stations are presented by their overall stream health assessment score in Figure 2-15. Stations where stream restoration work has been previously conducted are also labeled in Figure 2-15.

Table 2-9: Overall Stream Health Assessment Scores for City of Fairfax Streams

Assessment Score	Stream Length (Feet)	% of Streams
Excellent	0	0
Good	1,350	3
Fair	10,900	20
Poor	41,360	77
Total	53,610	100

Figure 2-15: Survey Assessment Results for Overall Stream Health



2.2.4 Stream Channel Velocity

Stream channel velocity data for streams with the City were obtained from the 1999 City of Fairfax Flood Study, described in Section 1.3, and analyzed for this watershed management plan. Channel velocity data for approximately 300 cross sections collected throughout the City were available for analysis. For the purposes of this study, two year recurrence storm interval data were evaluated. These data are summarized as follows:

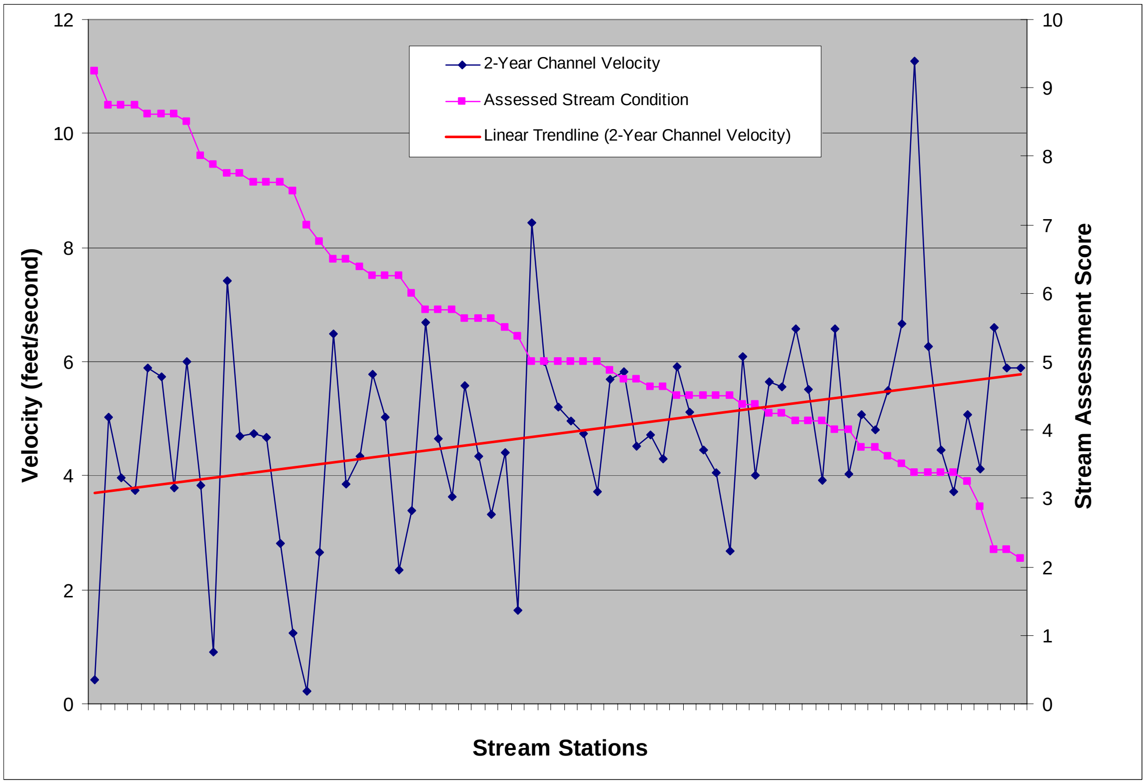
- Approximately 23 (8%) of the measured cross sections had channel velocities greater than 8.0 feet/second.
- Approximately 80 (27%) of the measured cross sections had channel velocities greater than 6.0 feet/second.
- Approximately 150 (50%) of the measured cross sections had channel velocities greater than 5.0 feet/second.

Over 85 % of the 2 year flow velocities exceed 5.0 feet/second. For the purposes of this report, channel velocities that exceeded 6.0 feet/second were selected for evaluation, because channel velocities greater than 6.0 feet/second have the potential to increase channel erosion under normal stream conditions. The high channel velocities observed from these data are good indicators that there is a high potential for channel erosion in within the City’s watersheds.

2.2.5 Relationship between Stream Condition Assessments and Channel Velocity

To examine the relationship between channel velocity and stream condition within the City, stream condition assessments were assigned channel velocities taken at the nearest cross section in the City of Fairfax Flood Study. This analysis indicated that there is an inverse relationship between channel velocity and stream condition in the City’s streams, with high channel velocities related to poor stream conditions, and low channel velocities related to good stream conditions (Figure 2-16). This relationship suggests that instream channel velocity data is generally considered an indicator of current stream conditions, as well as a likely indicator of future erosion potential.

Figure 2-16: Relationship between Channel Velocity and Stream Condition



A matrix describing overall stream conditions within the City was developed based on the channel velocity and stream assessment data. For this analysis, the City of Fairfax watershed was separated into 33 subwatersheds as defined by an existing watershed delineation GIS shapefile provided by the City. The model subwatersheds are shown in Figure 2-17. The Central Fork of Accotink Creek, the North Fork of Accotink Creek, and Daniels Run are represented by 15, 10, and 8 subwatersheds, respectively.

Streams were evaluated based on the number of occurrences of each observed data point within the stream assessment condition and channel velocity ranges described in Sections 2.2.3 and 2.2.4. The number of occurrences within the specified ranges for each of the 33 subwatersheds are presented in Appendix B. Areas of particular concern within the City of Fairfax watershed were identified by highlighting subwatersheds in which thresholds for assessment conditions and channel velocity were exceeded. The velocity threshold for the subwatersheds was any area in which observed velocities exceeded 8.0 feet/second, and the assessment condition threshold was any area in which the assessed stream condition was "poor." The results of the overall stream condition analysis are presented in Table 2-10. Highlighted subwatersheds indicate that the thresholds are exceeded. The number of times the assessment condition and channel velocity thresholds were exceeded are tabulated in Table 2-10. The ranking criteria and color rating for the overall stream condition analysis are presented in Table 2-11.

Predicted stream conditions for the subwatersheds based on the analysis described above are presented in Figure 2-18. Two subwatersheds in the Accotink watershed are identified as being in the worst condition. Twelve subwatersheds throughout the City are identified as being in the second most impaired category.

Figure 2-17: City of Fairfax Subwatershed Delineation

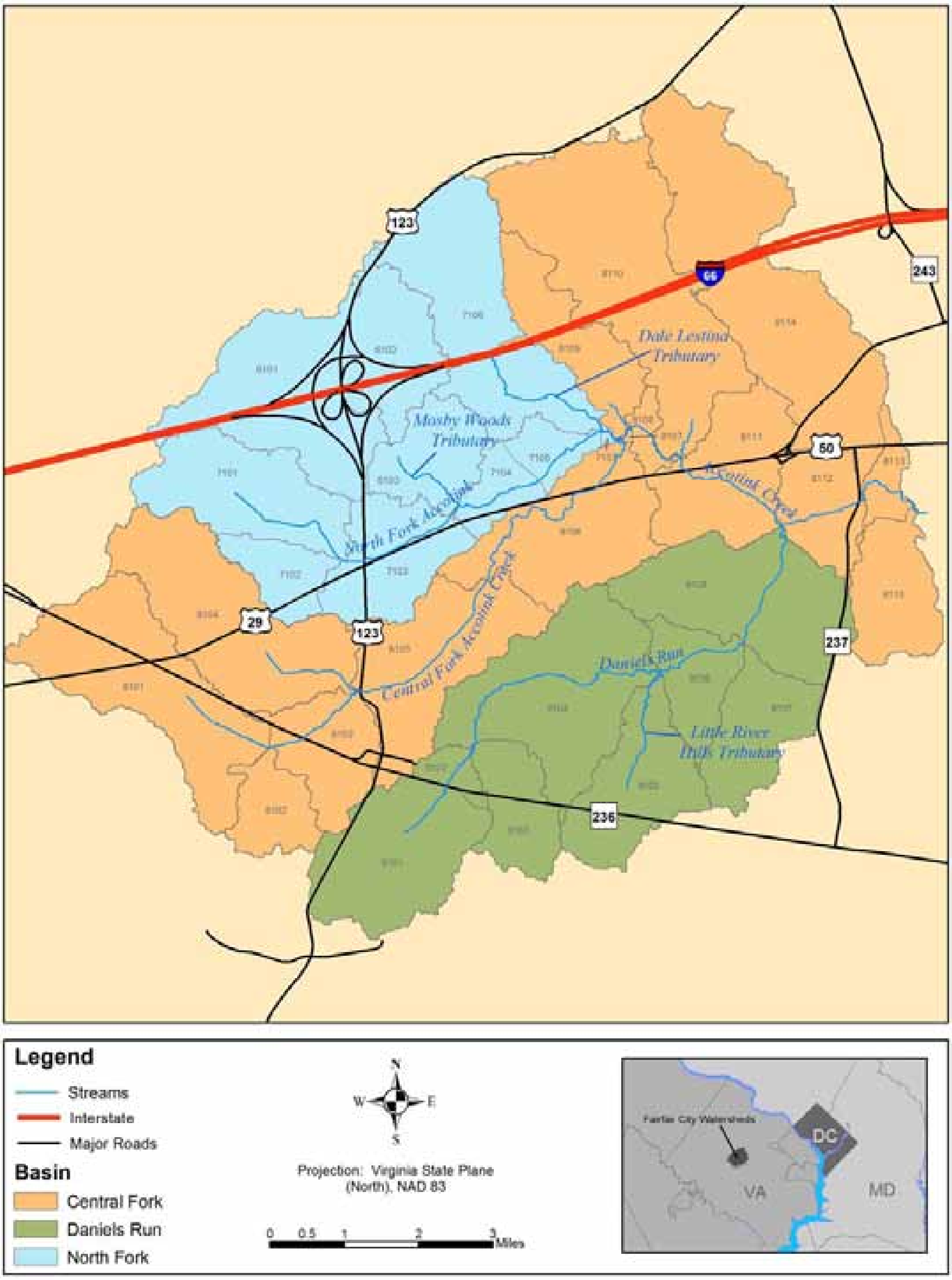


Table 2-10: Overall Stream Conditions in the City of Fairfax Subwatersheds

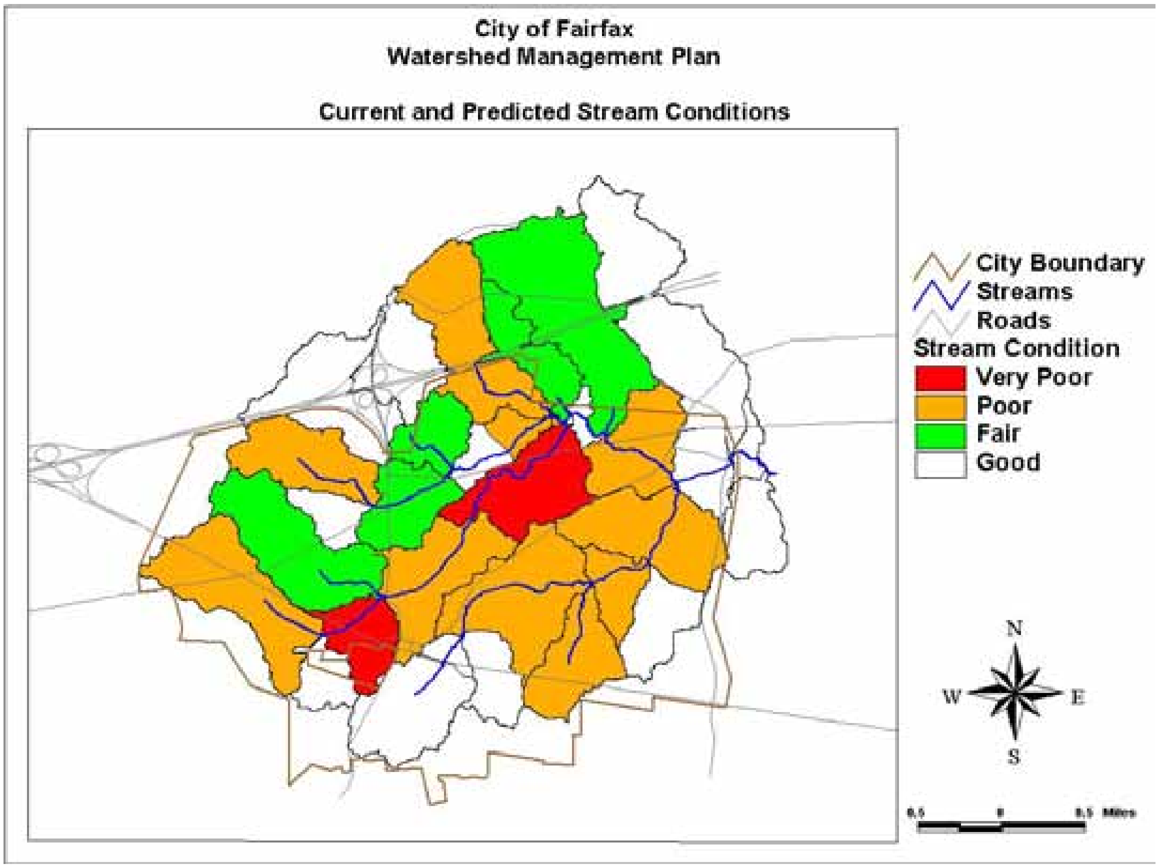
Drainage Subwatershed	Channel Velocity	Assessed Condition	Current and Predicted Stream Condition
Daniel's Run Subwatershed 1	2	1	7
Daniel's Run Subwatershed 2	0	0	0
Daniel's Run Subwatershed 3	0	2	7
Daniel's Run Subwatershed 4	1	1	6
Daniel's Run Subwatershed 5	0	0	0
Daniel's Run Subwatershed 6	0	0	0
Daniel's Run Subwatershed 7	0	0	0
Daniel's Run Subwatershed 8	2	1	7
Central Fork Accotink Subwatershed 1	0	0	0
Central Fork Accotink Subwatershed 2	0	0	0
Central Fork Accotink Subwatershed 3	0	0	0
Central Fork Accotink Subwatershed 4	0	1	5
Central Fork Accotink Subwatershed 5	1	1	6
Central Fork Accotink Subwatershed 6	1	0	4
Central Fork Accotink Subwatershed 7	0	0	0
Central Fork Accotink Subwatershed 8	1	0	4
Central Fork Accotink Subwatershed 9	0	0	0
Central Fork Accotink Subwatershed 10	1	2	8
Central Fork Accotink Subwatershed 11	1	1	6
Central Fork Accotink Subwatershed 12	2	2	9
Central Fork Accotink Subwatershed 13	0	1	5
Central Fork Accotink Subwatershed 14	0	0	0
Central Fork Accotink Subwatershed 15	1	0	4
North Fork Accotink Subwatershed 1	2	0	5
North Fork Accotink Subwatershed 2	0	1	5
North Fork Accotink Subwatershed 3	0	0	0
North Fork Accotink Subwatershed 4	1	0	4
North Fork Accotink Subwatershed 5	0	0	0
North Fork Accotink Subwatershed 6	0	0	0
North Fork Accotink Subwatershed 7	1	0	4
North Fork Accotink Subwatershed 8	0	0	0
North Fork Accotink Subwatershed 9	2	1	7
North Fork Accotink Subwatershed 10	0	1	5

The legend is explained in Table 2-11

Table 2-11: Ranking Criteria and Color Rankings for Overall Stream Condition Analysis

Channel Velocity			
Number of exceedances	Assigned Value		
0	Blank		
1	Green	(Low Erosion Potential)	
2	Orange	Moderate	
3	Red	(High Erosion Potential)	
Assessed Condition			
Number of exceedances	Assigned Value		
0	Blank	(Best Condition)	
1	Orange		
2	Red	(Worst Condition)	
Current and Predicted Stream Condition			
Channel Velocity	Assessed Condition	Assigned Score	
Red	Red	10	(Worst Condition)
Orange	Red	9	
Green	Red	8	
Blank	Red	7	
Red	Orange	8	
Orange	Orange	7	
Green	Orange	6	
Blank	Orange	5	
Red	Blank	6	
Orange	Blank	5	
Green	Blank	4	
Blank	Blank	0	(Best Condition)
Assigned Score	Designation		
8-10	Red	(Worst Condition)	
5-7	Orange		
2-4	Green		
0-2	Blank	(Best Condition)	

Figure 2-18: Current and Predicted Stream Conditions for City of Fairfax Subwatersheds



3.0 Watershed Modeling and Analysis

As discussed in the introduction, the primary cause of stream degradation in the City of Fairfax watershed is elevated volumes of uncontrolled, stormwater runoff attributed to impervious surfaces of developed land areas in the watershed. The conversion of natural forested lands to impervious surfaces associated with land development results in an increased volume of surface runoff which leads to higher stream flows (Figure 1-1). Increased stream flows impact the natural stream channel morphology which causes numerous problems relating to the physical, chemical, and biological integrity of the stream.

As the City of Fairfax has developed and grown over the years, changes in land use have resulted in severely degraded stream conditions in many parts of the City. The land use distributions provided in Tables 2-3 and 2-5 indicate the watershed is dominated by residential, commercial, and transportation land uses. Uncontrolled stormwater runoff from impervious surfaces is the primary cause of stream degradation.

3.1 Modeling Approach

Since stormwater runoff from non-point sources throughout the watershed is responsible for the stream degradation, a watershed hydrology model was selected to examine the problem. The EPA Storm Water Management Model (SWMM) was selected since it is designed for analysis of urban watersheds and it can be applied at the planning-level of analysis required for the Watershed Management Plan.

The goals of the SWMM model development were to estimate the frequency and magnitude of elevated stream flows that contribute to stream channel degradation and bank instability. Subwatershed delineation of the City of Fairfax watershed made it possible to estimate and analyze stream flows in specific regions of the City as well as for the entire watershed, thereby increasing the spatial resolution of the model. A total of 33 subwatersheds were evaluated in model simulations.

Using the available watershed data, a calibrated hydrologic model of the City of Fairfax watershed was developed. The goals of developing a calibrated watershed model were to identify areas of stormwater runoff and evaluate the linkage with resulting stream degradation. This will assist in determining the necessary management efforts required to control non-point source runoff and restabilize the stream banks in the watershed, and provide a framework for watershed restoration.

3.1.1 SWMM Blocks

SWMM consists of several simulation blocks. The simulation blocks used in City of Fairfax watershed model were the rain, runoff, and transport blocks. The rain block is used to process precipitation data, which is the primary source of water in the hydrology model. The output from the rain block is used subsequently by the runoff block. The runoff block generates hydrographs for each subwatershed based on the precipitation data and subwatershed characteristics including land uses, topography, and soils data. The output from the runoff block is subsequently used in the transport block which simulates the routing and transport of flow in the stream network.

3.1.2 Precipitation and Evaporation

Precipitation data from Washington National Airport was considered to be representative of the rainfall condition in the City of Fairfax watershed. A ten-year model simulation period from 1990 to 2000 was selected in order to capture a variety of wet and dry hydrologic years for evaluation and analysis of resulting stream flows. Table 3-1 provides a summary of measured annual precipitation at Washington National Airport for 1990-2000. The mean annual precipitation is 38.1 inches per year, with a minimum of 29.6 inches in 1991 and a maximum of 50.2 in 1996. For this planning level study, snowmelt was not considered to be a significant factor and was not included in model simulations. Separation of storm events was based on a four hour period of dry weather.

Mean monthly evaporation rates were determined based on literature review for watersheds in the region. The mean monthly evaporation rates used in the model are provided in Table 3-2.

Table 3-1: Annual Precipitation at Washington National Airport

Year	Total Precipitation (inches)
1990	40.8
1991	29.6
1992	36.4
1993	41.4
1994	37.6
1995	39.9
1996	50.2
1997	32.2
1998	33.3
1999	40.0
Average	38.1
Maximum	50.2
Minimum	29.6

Table 3-2: Mean Monthly Evaporation Rates

Month	Evaporation (inch/day)
Jan	0.0526
Feb	0.0693
Mar	0.1065
Apr	0.1627
May	0.2023
Jun	0.2326
Jul	0.2442
Aug	0.2233
Sept	0.164
Oct	0.1148
Nov	0.0803
Dec	0.0542

3.1.3 Subwatershed Delineation and Characterization

The City of Fairfax watershed was represented in the SWMM model using 33 subwatersheds defined from an existing watershed delineation provided by the City as part of the City of Fairfax Flood Study conducted in 1999. The model subwatersheds are shown in Figure 3-1. The Central Fork of Accotink Creek, the North Fork of Accotink Creek, and Daniels Run are represented by 15, 10, and 8 subwatersheds, respectively. SWMM model input data for the runoff block were generated for each subwatershed to account for spatial variability in the watershed as discussed in the following sections. SWMM model results were computed for four main watershed drainage locations (called model nodes) shown in Figure 3-2. Model node 89 represents the entire watershed drainage area of Accotink Creek at the City limit. Node 95 represents the drainage area for the Daniels Run tributary to the Central Fork of Accotink Creek. Node 75 represents the drainage area for the North Fork tributary to the Accotink Creek. Node 84 represents the Central Fork of Accotink Creek at the confluence with the North Fork.

Figure 3-1: City of Fairfax Subwatershed Delineation

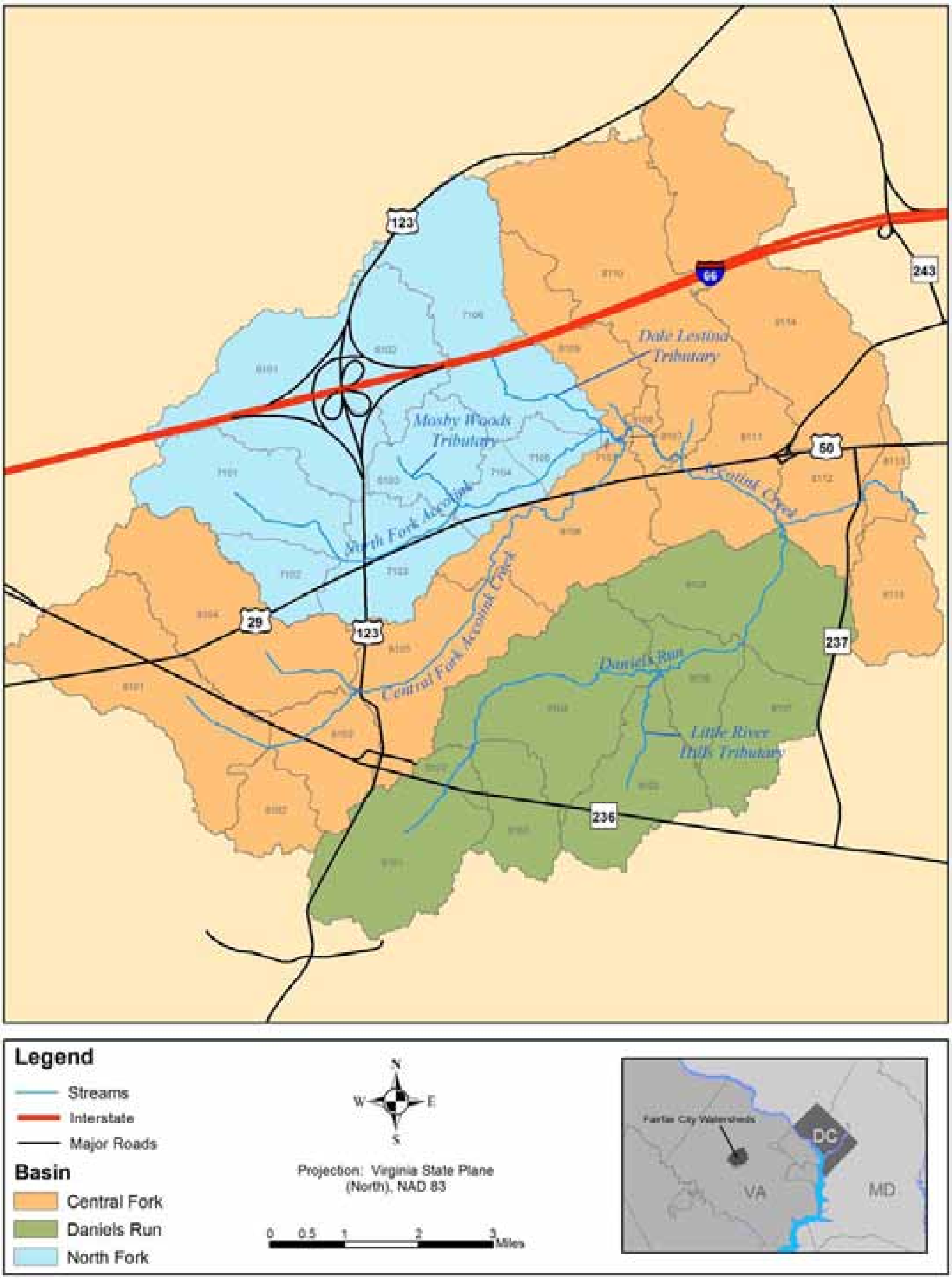
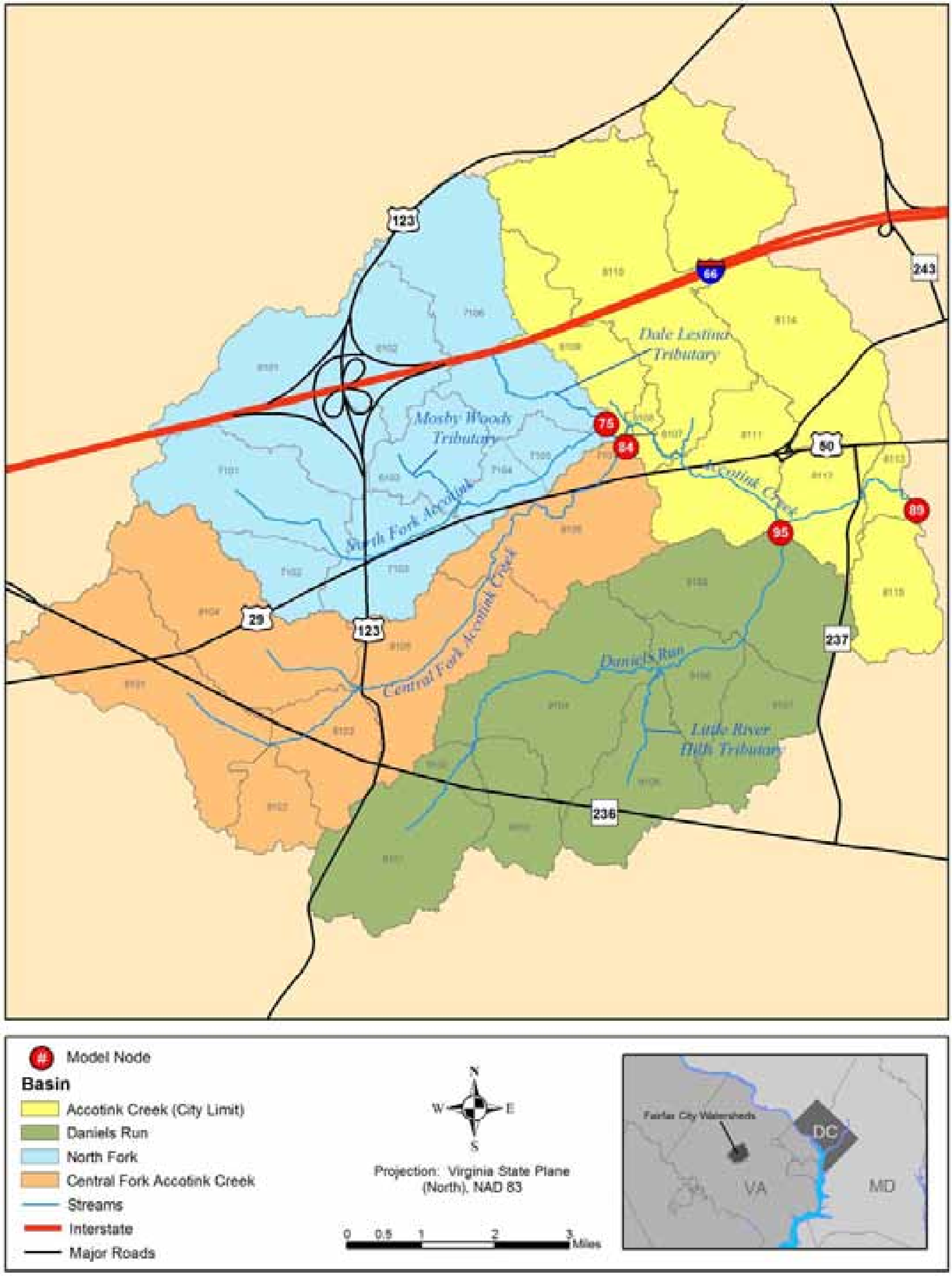


Figure 3-2: Location of Model Nodes Used for Reporting Model Simulated Stream Flows



3.1.3.1 Land Use and Subwatershed Imperviousness

The National Land Cover Data (NLCD) and existing zoning conditions land use datasets were used as the basis for determining the percent imperviousness for each subwatershed in the model. The land use distributions were presented previously in Tables 2-3 and 2-5.

The percent of impervious area in each subwatershed directly affects the volume of surface runoff generated. In particular, directly connected impervious area (DCIA) is used in the SWMM model to establish the link between surface runoff from impervious areas and stream flow. The impervious percentage of each watershed was determined by assigning a DCIA value to each land use type and then computing an area-weighted average for each subwatershed. This analysis was performed for both the NLCD and existing land use datasets. DCIA percentage values for each land use type were derived from published values determined by the Northern Virginia Planning District Commission (Center for Watershed Protection, 1998). DCIA percentage values for each land use type for the NLCD and City of Fairfax existing land use datasets are presented in Tables 3-3 and 3-4. In general, the DCIA percentage values were similar between the two datasets. In model simulations, subwatershed DCIA percentage values were represented as the average obtained from both the NLCD and existing land use datasets. The computed DCIA percentages for each model subwatershed are shown in Figure 3-3. Subwatershed DCIA percentages ranged from a minimum of about 3% to a maximum of about 56%.

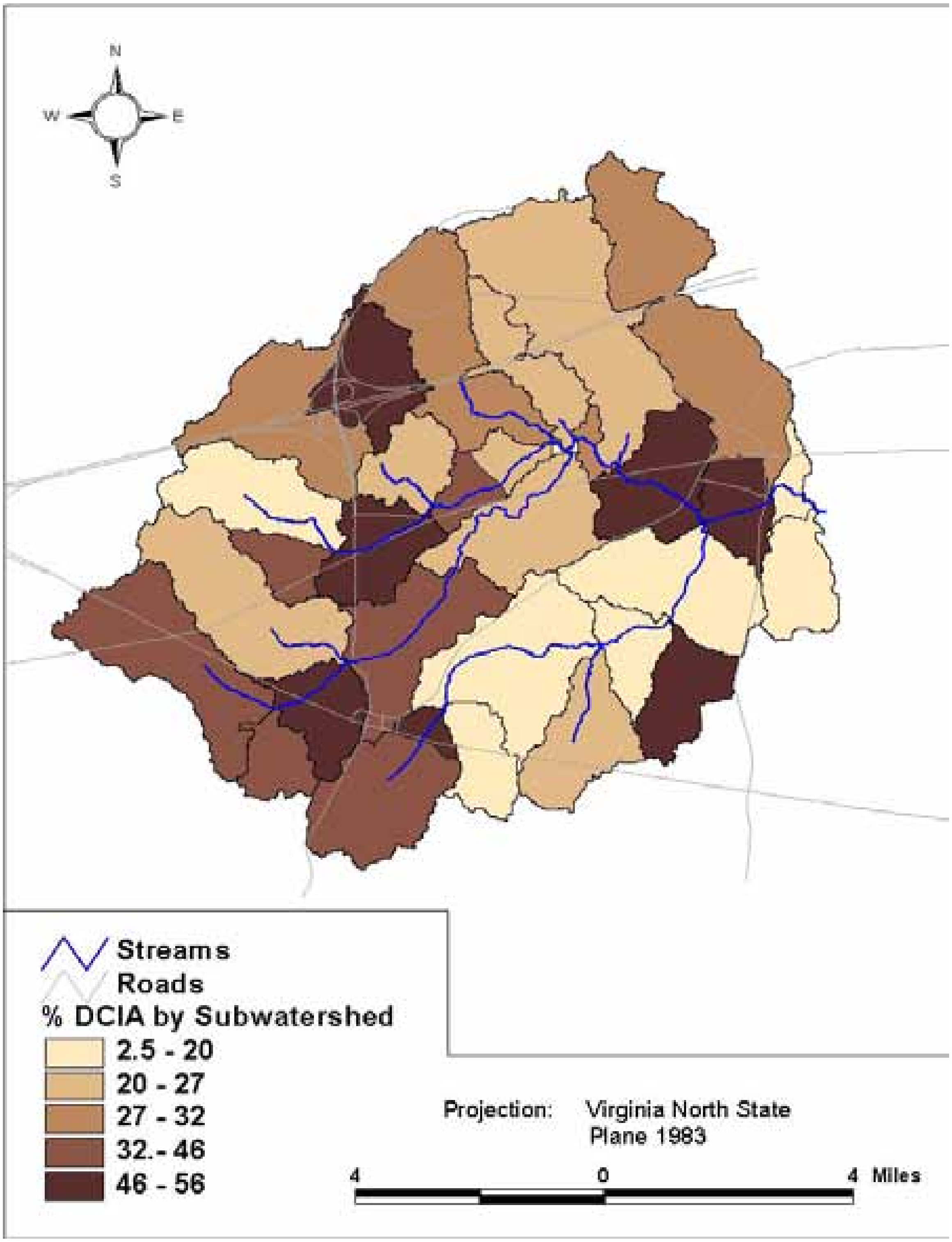
Table 3-3: NLCD Land Use Types and DCIA Percentages

NLCD Land Use Type	% DCIA
Low Intensity Residential	25
High Intensity Residential	60
Commercial/Industrial/Transportation	90
Urban/Recreational Grasses	4
Row Crops	3
Pasture/Hay	5
Water/wetlands	100
Forested	1.5
Transitional	1.5

Table 3-4: City of Fairfax Existing Land Use Types and DCIA Percentages

Existing Land Use Type	% DCIA
Residential 2 Acre	6
Residential 1 Acre	12
Residential 1/2 Acre	18
Residential 1/3 Acre	20
Residential 1/4 Acre	25
Residential 1/8 Acre	35
Townhouses	50
Apartments	70
Commercial	90
Institutions	70
Athletic Fields	4
Parkland	1

Figure 3-3: Model DCIA Percentages Used for Each Subwatershed



3.1.3.2 Subwatershed Width and Slope

Subwatershed width and slope were calculated based on methodologies presented in the SWMM manual. Subwatershed slopes were estimated from USGS topographic quad sheets and a 30-meter Digital Elevation Model (DEM). Estimated slopes represent the average pathway of overland flow to stream or stormwater inlet locations. Since subwatershed width is defined as the length of overland flow, the delineated subwatersheds and stream coverage were used to create a main drainage channel through each subwatershed in order to define the subwatershed width. Since subwatersheds are irregular in shape and drainage channels are not necessarily centered, the width was calculated based on the following equations (USEPA, 1992):

$$S_k = (A_2 - A_1)/A$$

$$W = (2 - S_k)L$$

Where
S_k = skew factor (0-1)
A_1 = area to one side of channel
A_2 = area to other side of channel
A = total area
W = catchment width
L = length of main drainage channel

3.1.3.3 Depression Storage

Pervious and impervious depression storage values of 0.15 in. and 0.08 in., respectively were assigned in the SWMM model. These estimates were based on processed subwatershed slopes and the SWMM manual.

3.1.3.4 Manning's Roughness Coefficient

Average Manning's roughness coefficients for overland flow were computed for each subwatershed. Table 3-5 presents the Manning's coefficients applied to NLCD land use types to derive area-weighted average values for each subwatershed.

Table 3-5: Manning's Coefficients for Land Use Types

NLCD Land Use Type	Manning's Coefficient
Low Intensity Residential	0.013
High Intensity Residential	0.013
Commercial/Industrial/Transportation	0.013
Urban/Recreational Grasses	0.25
Row Crops	0.15
Pasture/Hay	0.2
Water/wetlands	0.4
Forested	0.4
Transitional	0.01

3.1.3.5 Infiltration

The Horton infiltration model was used to simulate soil infiltration in the watershed. The maximum infiltration, ultimate infiltration, and decay rate of infiltration were assigned based on soil hydrologic groups present in the watershed using the values presented in Table 3-6.

Table 3-6: Horton Infiltration Model Parameter Values For Soil Hydrologic Groups

Infiltration Parameter	Soil Hydrologic Group				
	A	B	B/C	C	D
Maximum (in.)	2	1.5	1.25	1	0.5
Ultimate (in.)	0.065	0.05	0.0425	0.035	0.02
Decay (per sec.)	0.00115	0.00115	0.00115	0.00115	0.00115

3.1.4 Stream Flow Routing

The transport block simulates the routing and transport of flow in the stream network. For this planning level study, all streams were modeled as trapezoidal channels based on data contained in available GIS coverages and measurements collected during field survey assessments. In particular, stream channel length and slope were estimated from USGS quad maps, DEM, and RF3 stream networks, as well as field measurements. Stream morphology was primarily estimated based on cross-sectional data collected as part of the stream assessment survey.

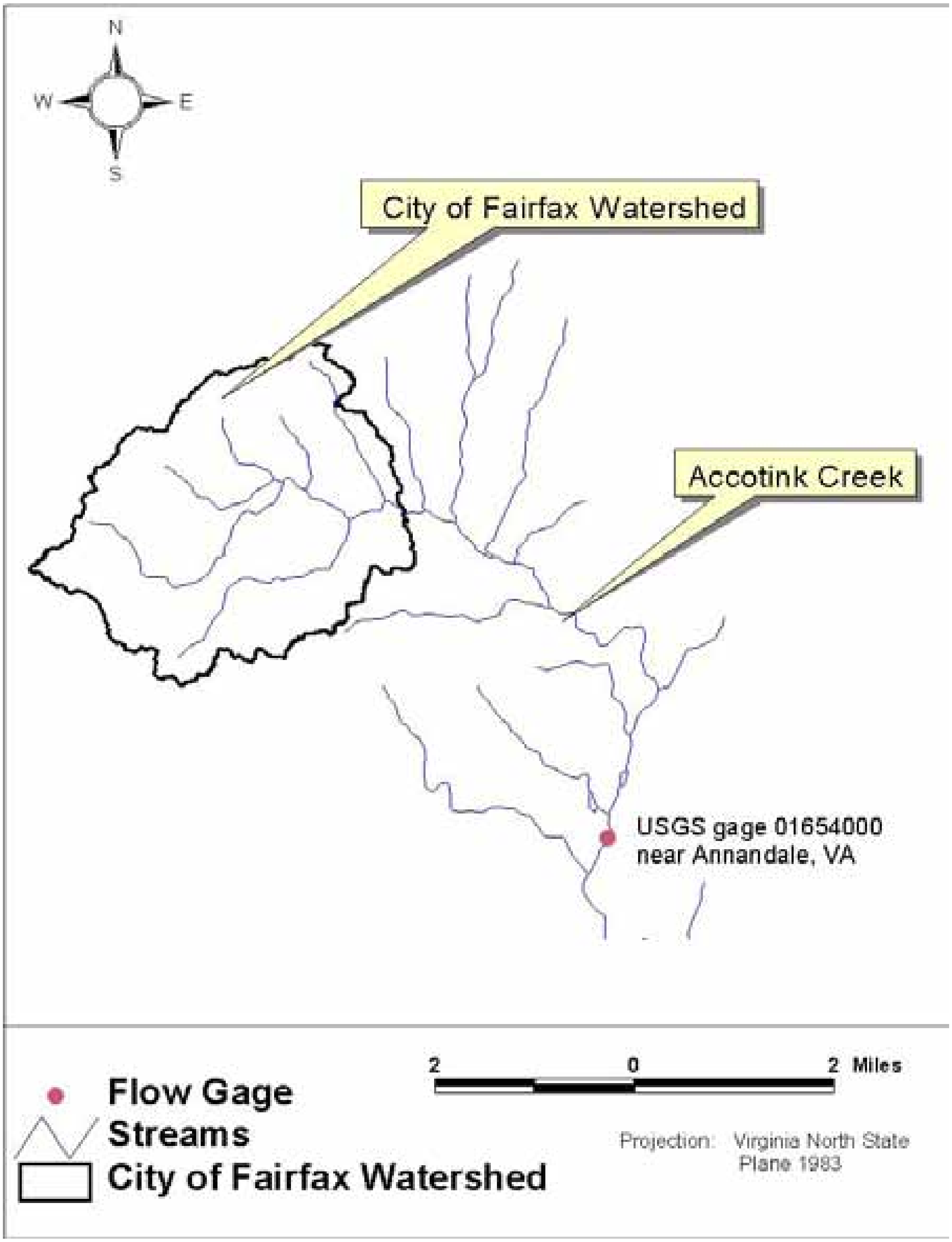
3.2 Stream Hydrology and Model Calibration

3.2.1 Stream Flow Estimation

Observed stream flow data can be used for calibration of the SWMM model. Ideally, model calibration would be based on flow data for Accotink Creek at the boundary of the watershed model area. Flow data, however, do not exist at this location. Therefore, it was necessary develop an estimate of stream flow for this point on Accotink Creek based on available flow data for a hydrologically similar watershed.

GIS mapping was used to locate USGS gages within hydrologic unit 02070010 to identify similar watersheds with sufficient flow data. The USGS gage located on Accotink Creek near Annandale, VA (Station 01654000) was selected as the best source of flow data because it is located downstream of the City of Fairfax (Figure 3-4). The watershed drained at this gage includes the modeled watershed area as a subwatershed. Therefore, the two watersheds share a similar hydrology. The drainage area at the gage is 23.5 square miles, compared with 7.8 square miles for the modeled watershed.

Figure 3-4: Location of USGS gage 01654000 on Accotink Creek



In order to perform watershed comparisons, it was necessary to delineate the watershed area drained at the gage. High resolution 30-meter USGS Digital Elevation Models, based on 7.5 minute quadrangle topographic maps, were obtained and used in BASINS to develop a delineated watershed. The delineated watershed encompasses an area of 23.4 square miles, which compares well with the USGS reported area of 23.5 square miles for the gage.

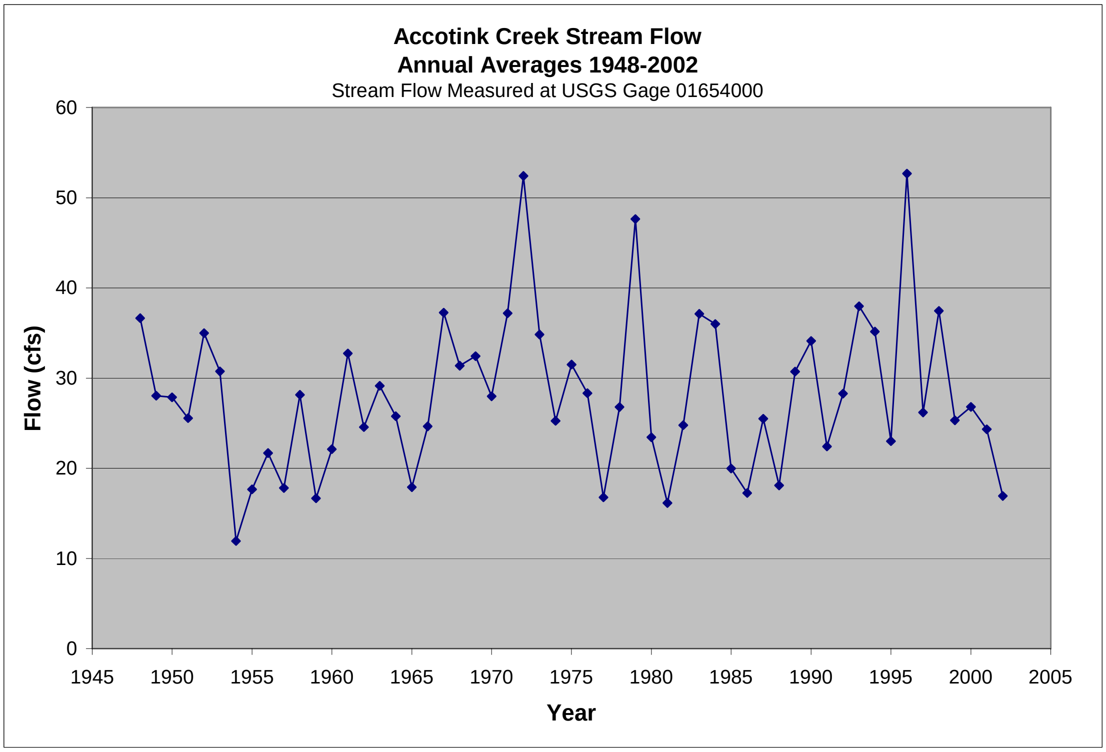
The hydrologic similarity between the two watersheds was verified based on land use/land cover and soil type comparisons. National Land Cover Data (NLCD) was obtained for both watersheds and used to characterize land uses. A comparison of land use distributions is presented in Table 3-7. The City of Fairfax watershed is slightly more urban than the Accotink watershed due to a higher percentage of low intensity residential and commercial land use. The Accotink watershed has a slightly higher percentage of forested lands. Overall, the land use is very similar between these two watersheds.

Table 3-7: Comparison of Land Cover in the City of Fairfax Watershed and the Accotink Creek Watershed at USGS Station 10654000

Land Cover Category	Land Cover Type	% of Watershed	
		City of Fairfax Watershed	Accotink Creek Watershed
Developed	Low Intensity Residential	43.1	38.2
	High Intensity Residential	0.0	0.0
	Commercial/Industrial/Transportation	17.5	15.6
Forest	Deciduous Forest	21.5	26.1
	Evergreen Forest	1.8	2.4
	Mixed Forest	7.9	9.7
Agricultural	Pasture/Hay	5.3	4.5
	Row Crops	0.0	0.0
Water/Wetlands	Open Water	0.2	0.2
	Woody Wetlands	0.2	1.3
	Emergent Herbaceous Wetlands	0.0	0.1
Other	Transitional	0.6	1.3
	Urban/Recreational Grasses	1.8	0.6
Total		**100**	**100**

The stream flow for the City of Fairfax watershed was estimated based on flow at USGS gage 01654000. Daily flow records from 1947 to the present exist for the gage. In addition, hourly flow data exist for 1990 to the present. Average annual stream flow data for USGS gage 01654000 is presented in Figure 3-5. The ratio of the City of Fairfax watershed to the Accotink Creek watershed at the gage was applied to the flow record to compute the flow series used in City of Fairfax watershed model calibration.

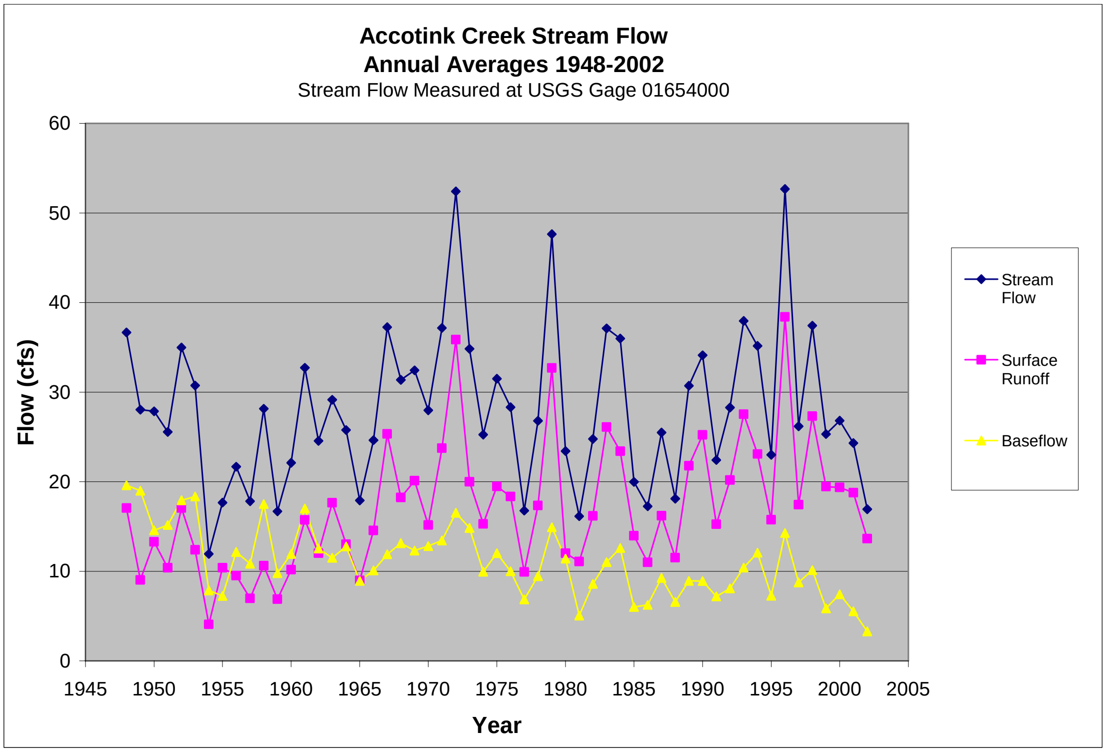
Figure 3-5: Average Annual Stream Flow at USGS Gage 01654000



3.2.2 Stream Flow Components

The impacts of urbanization in the Accotink Creek watershed over time were analyzed using the Hydrograph Separation Program (HYSEP). HYSEP allows users to estimate the groundwater, or base flow component to stream flow. By subtracting the groundwater component from the total stream flow, the percentage of total stream flow contributed from surface runoff can also be estimated. HYSEP was run for the entire period of record (1948-2002) for which flow data was available at USGS gage 01654000. The local minimum hydrograph separation approach (Pettyjohn and Henning, 1979) was used to separate the base flow and surface runoff components of the total stream flow. The base flow and surface runoff components of the total stream flow at USGS gage 01654000 over time are presented in Figure 3-6.

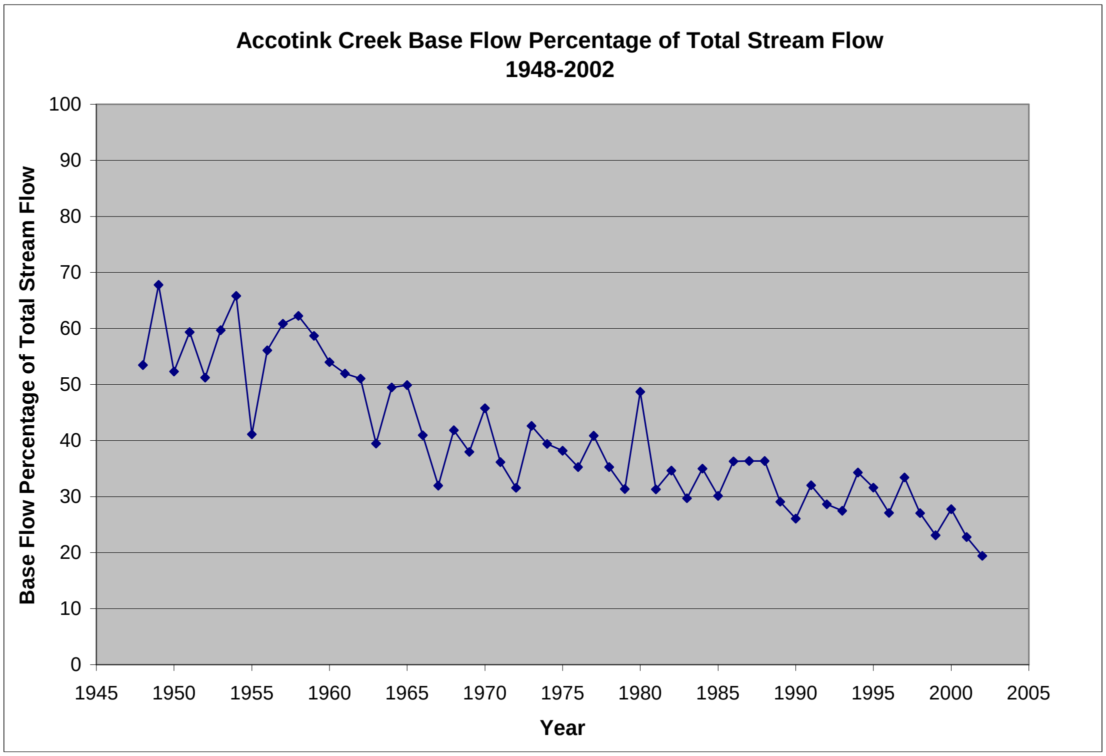
Figure 3-6: Base Flow and Surface Runoff Components of Stream Flow at USGS Gage 01654000



To assess the impacts of urbanization on stream hydrology, the percentage of base flow contributing to the total stream flow was analyzed over time. Figure 3-7 presents the base flow percentage of total stream flow for the years of 1948 to 2002. The percentage of base flow contributing to Accotink Creek stream flow at USGS gage 01654000 has decreased over time, from comprising approximately 60 percent of the total stream flow in 1949 to comprising about 20 percent of the total stream flow in 2002. However total stream flow, defined as the sum of the contributing base flow and surface runoff, has remained fairly constant over this time period. This indicates that a greater percentage of the total stream flow in Accotink Creek has come from surface runoff as a result of increases in impervious land areas, a result that is typical of recently developed watersheds. Since the City of Fairfax watershed has similar land uses and shares a similar hydrology with the Accotink Creek watershed at the USGS gage, it is reasonable to project that the hydrology of the City of Fairfax watershed has been altered in the same way or perhaps to an even greater extent since the City's watershed is slightly more developed.

This altered watershed hydrology has resulted in very high surface runoff flows that have severely degraded the streams within the City of Fairfax. High surface runoff flows result in elevated stream flows that natural stream channels cannot physically accommodate, resulting in stream bank and channel erosion. Therefore, it is important for the City to have appropriate infrastructure and management practices in place in order to manage stormwater runoff originating from developed areas.

Figure 3-7: Percentage of Base Flow Contributing to Stream Flow at USGS Gage 01654000



3.2.3 Hydrology Calibration

Hydrologic model parameters were refined so that runoff volumes and peaks were in agreement with observed flow values based on the USGS flow gage 01654000. Calibration was performed based on precipitation and flow gage data for 1998, which was representative of an average hydrologic year in the City of Fairfax watershed. Results of the hydrology calibration are presented in Figure 3-8. Calibration statistics are presented in Table 3-8. The modeled flow volume represented about 76% of the observed flow volume for the USGS gage, adjusted for area. The difference in modeled flow volume is related to the different precipitation and flow records used for calibration.

The USGS gage represents an estimate of flow at Braddock Road, near the boundary of the City of Fairfax watershed. The precipitation data for Reagan National Airport represents an approximation of rainfall conditions in the watershed. In general, model predictions reflect flow variations observed at the USGS gage station, as evidenced by an R^2 value of 0.71. Error in the total flow calibration resulted from the use of precipitation data from Reagan National Airport, which is several miles away from the study area and thus represents an approximation of conditions in the City of Fairfax watershed. Additionally, USGS flow data were taken downstream of the City of Fairfax watershed on Accotink Creek. However, these data were the best and closest available for use in this study, and did provide reasonable estimates of conditions in the City of Fairfax watershed. The error in the total flow was due to variation in the summer flows when storms tend to be localized and intense in the from of thunderstorms.

Table 3-8: SWMM Model Calibration Statistics

SWMM Simulation	Simulation Period	R2 Correlation Value	Total Flow % Error
City of Fairfax watershed	1/1/98 – 12/31/98	0.71	24%

The simulated model flow is displayed for model node 89 which represents the mouth of the City of Fairfax watershed. Following calibration, model simulations were performed for the period of 1990 to 2000 and results were verified with observed stream flow data as shown in Figure 3-9. Results for 1990 were discarded to allow for the model to stabilize.

Figure 3-8: SWMM Model Hydrologic Calibration for 1998

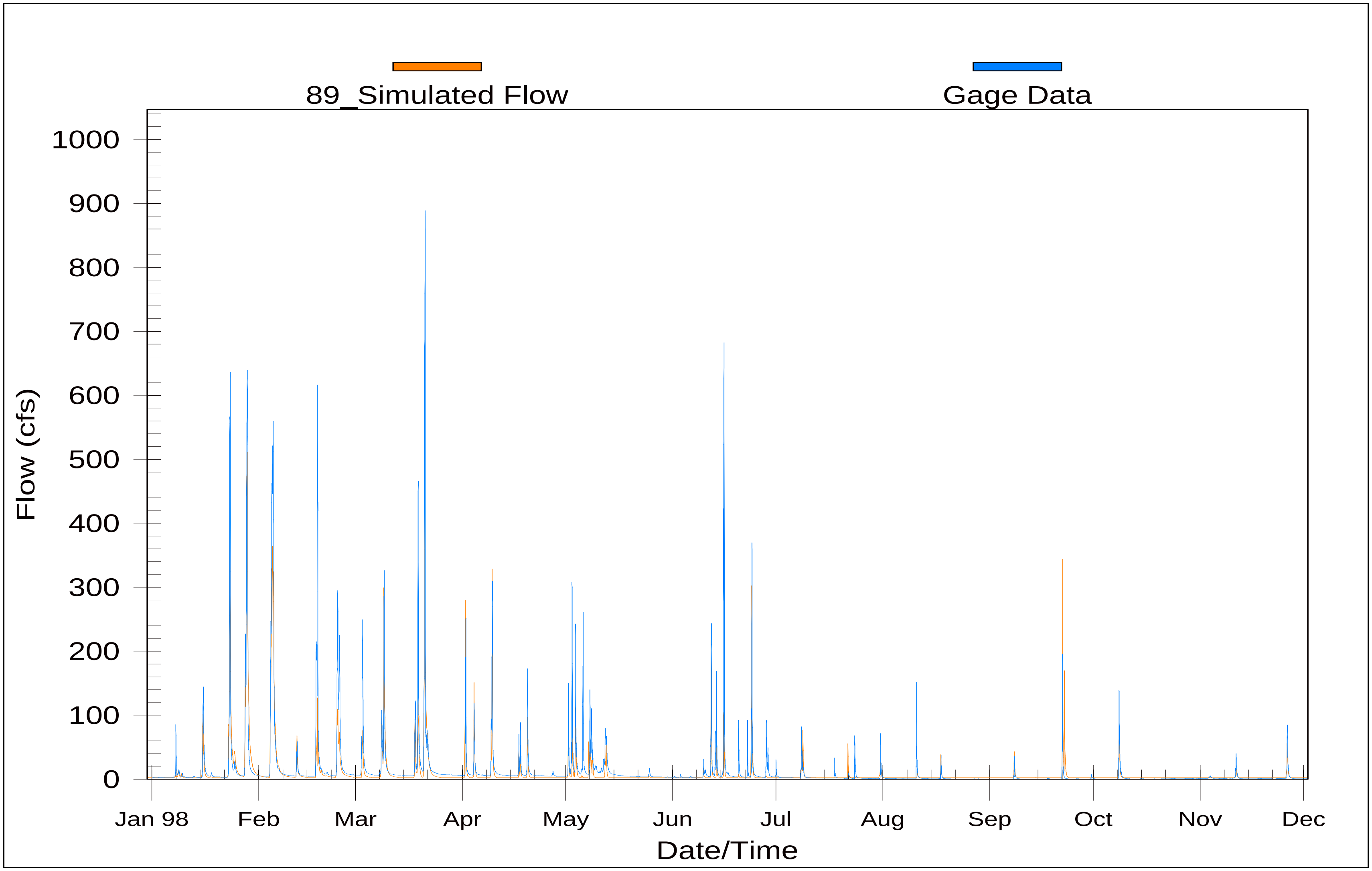
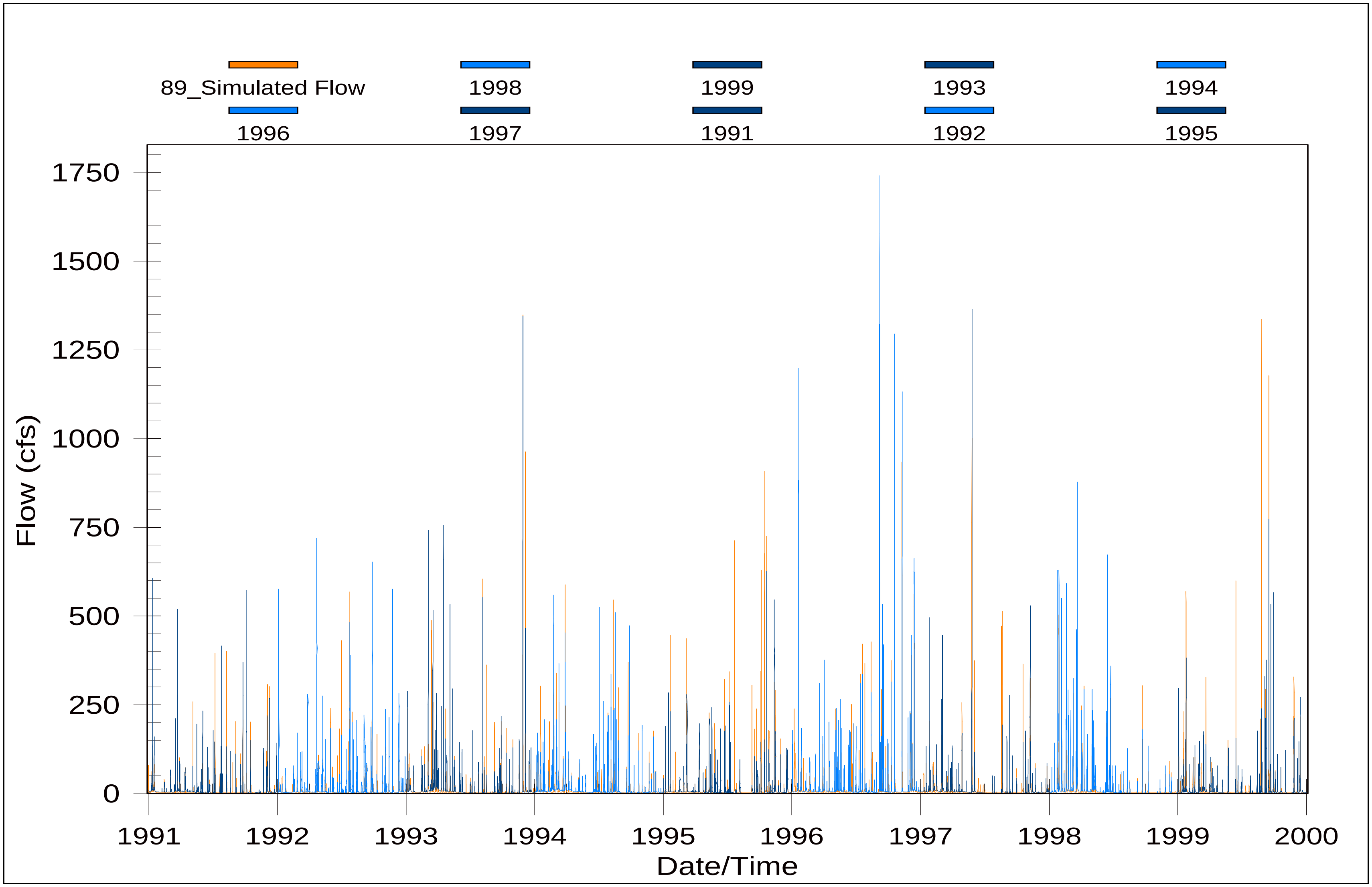


Figure 3-9: Simulated Stream Flow vs. USGS Gage for 1991-2000



3.3 Model Simulation Scenarios

The calibrated SWMM model was used to simulate stream flow for several different scenarios representing various degrees of reduction of DCIA. The implementation of stormwater best management practices (BMPs) can effectively reduce the percentage of directly connected impervious areas to the stream, thereby reducing and slowing surface runoff flows that are delivered to the stream. For example, detention basins are designed to store stormwater during storm periods and release the flow over a longer period of time that is more reflective of the natural hydrology. By running the SWMM model for various DCIA reduction scenarios, it was possible to evaluate the relationship between management practices and resulting stream flow.

The following model simulation scenarios were performed for the period of 1990 - 2000:

- Existing land use condition based on average of NLCD and City land use datasets
- Forested condition representing pre-development state
- Reduction of DCIA
    - 10 percent
    - 25 percent
    - 50 percent
    - 75 percent

The results of the model simulations of existing land use conditions versus a completely forested condition are presented in Figure 3-10. As expected, stream flows for existing conditions are significantly greater than simulated flows considering a completely forested condition.

Predicted stream flows for all model scenario simulations are summarized in Table 3-9. Stream flow results are tabulated for the four watershed drainage locations shown previously in Figure 3-2. For each location and each model simulation scenario, the maximum flow rate is provided as well as the total flow, baseflow, and storm flow volumes for the simulation period. In addition, for each scenario, ratio comparisons to the forested condition flow are provided in order to evaluate the relationship between changes in the land use impervious percentage and corresponding stream flow.

The effects of the percentage of DCIA in the watershed on resulting stream flow are displayed in Figures 3-11 and 3-12. Figure 3-11 displays model simulated stream flows for Accotink Creek for a one week period in March 1995, while Figure 3-12 displays simulated stream flows for Daniels Run. In both cases, stream flows for existing and forested land use conditions are displayed along with the model scenario involving 50% reduction of DCIA in the watershed. In the case of Accotink Creek, the peak stream flow associated with existing conditions is about twice that for forested conditions. The 50% reduction in DCIA results in peak stream flows that are in the middle of existing and forested condition stream flows.

Figure 3-10: Comparison of Simulated Stream Flow for Existing and Forested Conditions

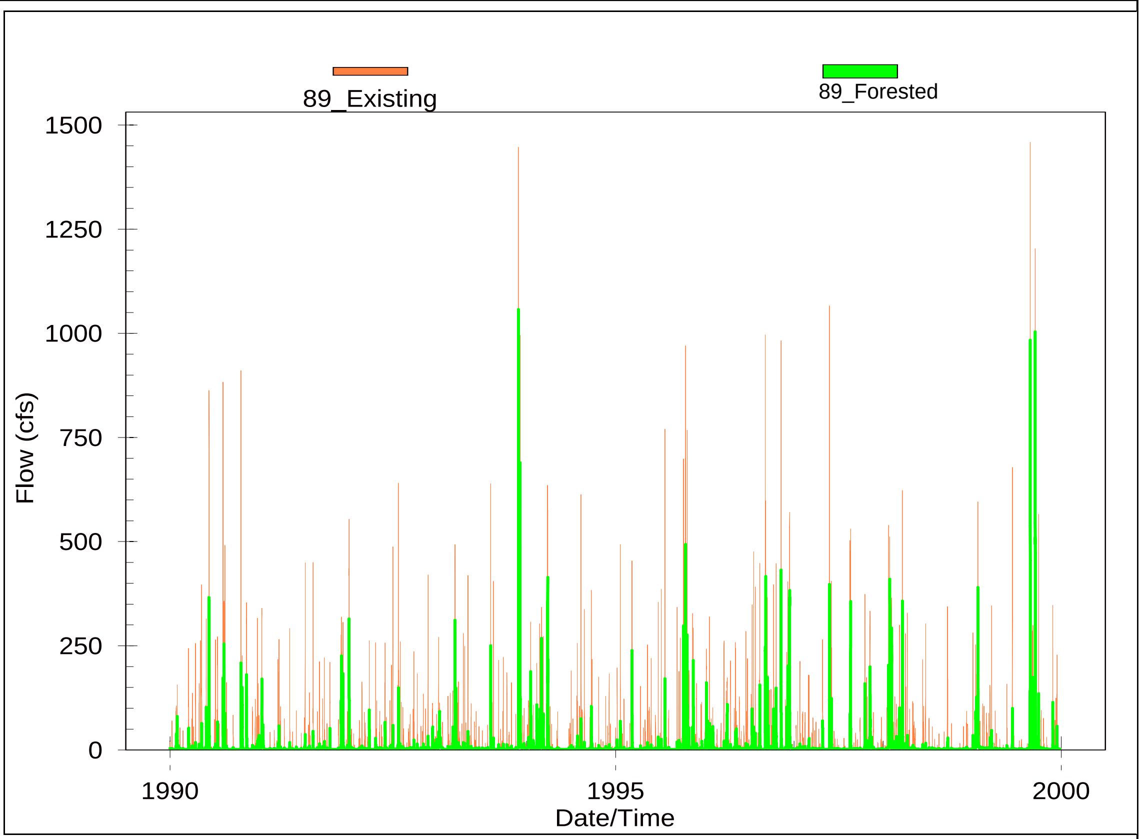


Table 3-9 shows the percent increase in storm flow under the existing conditions relative to the forested (i.e., background) conditions. Additionally, scenarios that reduce directly connected impervious areas (DCIA) by 10 percent, 25 percent, 50 percent, and 75 percent relative to the existing conditions are also presented in Table 3-9. Reducing DCIA by 50 percent yields an improved condition in which stormwater volume is reduced by 40 percent as compared to the existing conditions (measured at Node 89). Similarly, at Node 95 a 50 percent reduction in DCIA yields a 35 percent reduction in stormwater volume as compared to the existing conditions.

Table 3-9 can also be used to estimate the percent reduction in DCIA required to meet a targeted stormwater volume reduction. For example, a 50 percent reduction in DCIA would be required to meet a 50 percent stormwater volume reduction goal.

Table 3-9: Stream Flow Comparisons for SWMM Model Scenario Simulations

Model Node	Stream Name	DCIA Condition	Maximum Flow (cfs)	Total Flow (ft^3)	Base Flow (ft^3)	Storm Flow (ft^3)	Ratio Relative to Forested Maximum Flow	Ratio Relative to Forested Total Flow	% Increase Storm Flow Relative to Forested
89	Accotink Creek (@ City Limit)	Existing	1459	3146000000	840749760	2305250240	1.4	1.8	79.8
		10% Reduction	1430	3053000000	840749760	2212250240	1.4	1.7	72.5
		25% Reduction	1382	2907000000	840749760	2066250240	1.3	1.6	61.1
		50% Reduction	1289	2655000000	840749760	1814250240	1.2	1.4	41.5
		75% Reduction	1177	2385000000	840749760	1544250240	1.1	1.2	20.4
		Forested	1058	2123000000	840749760	1282250240	1.0	1.0	0.0
95	Daniels Run	Existing	494	709900000	202776480	507123520	1.5	1.7	69.9
		10% Reduction	479	690100000	202776480	487323520	1.5	1.6	63.3
		25% Reduction	454	659200000	202776480	456423520	1.4	1.5	52.9
		50% Reduction	408	606700000	202776480	403923520	1.3	1.4	35.4
		75% Reduction	355	551800000	202776480	349023520	1.1	1.2	17.0
		Forested	320	501200000	202776480	298423520	1.0	1.0	0.0
84	Accotink Creek (@ North Fork)	Existing	516	759900000	195207840	564692160	1.8	2.0	98.1
		10% Reduction	498	734600000	195207840	539392160	1.7	1.9	89.3
		25% Reduction	469	694200000	195207840	498992160	1.6	1.8	75.1
		50% Reduction	413	625600000	195207840	430392160	1.4	1.5	51.0
		75% Reduction	341	551900000	195207840	356692160	1.2	1.3	25.2
		Forested	294	480200000	195207840	284992160	1.0	1.0	0.0
75	North Fork Accotink	Existing	474	836100000	208452960	627647040	1.7	1.8	76.6
		10% Reduction	461	812000000	208452960	603547040	1.6	1.7	69.8
		25% Reduction	453	773400000	208452960	564947040	1.6	1.6	59.0
		50% Reduction	414	705900000	208452960	497447040	1.4	1.4	40.0
		75% Reduction	348	634300000	208452960	425847040	1.2	1.2	19.8
		Forested	287	563800000	208452960	355347040	1.0	1.0	0.0

Figure 3-11: Comparison of Storm Flows in Accotink Creek (City Boundary) under Existing Conditions, 50% Impervious Reduction, and 100 % Forested Scenarios

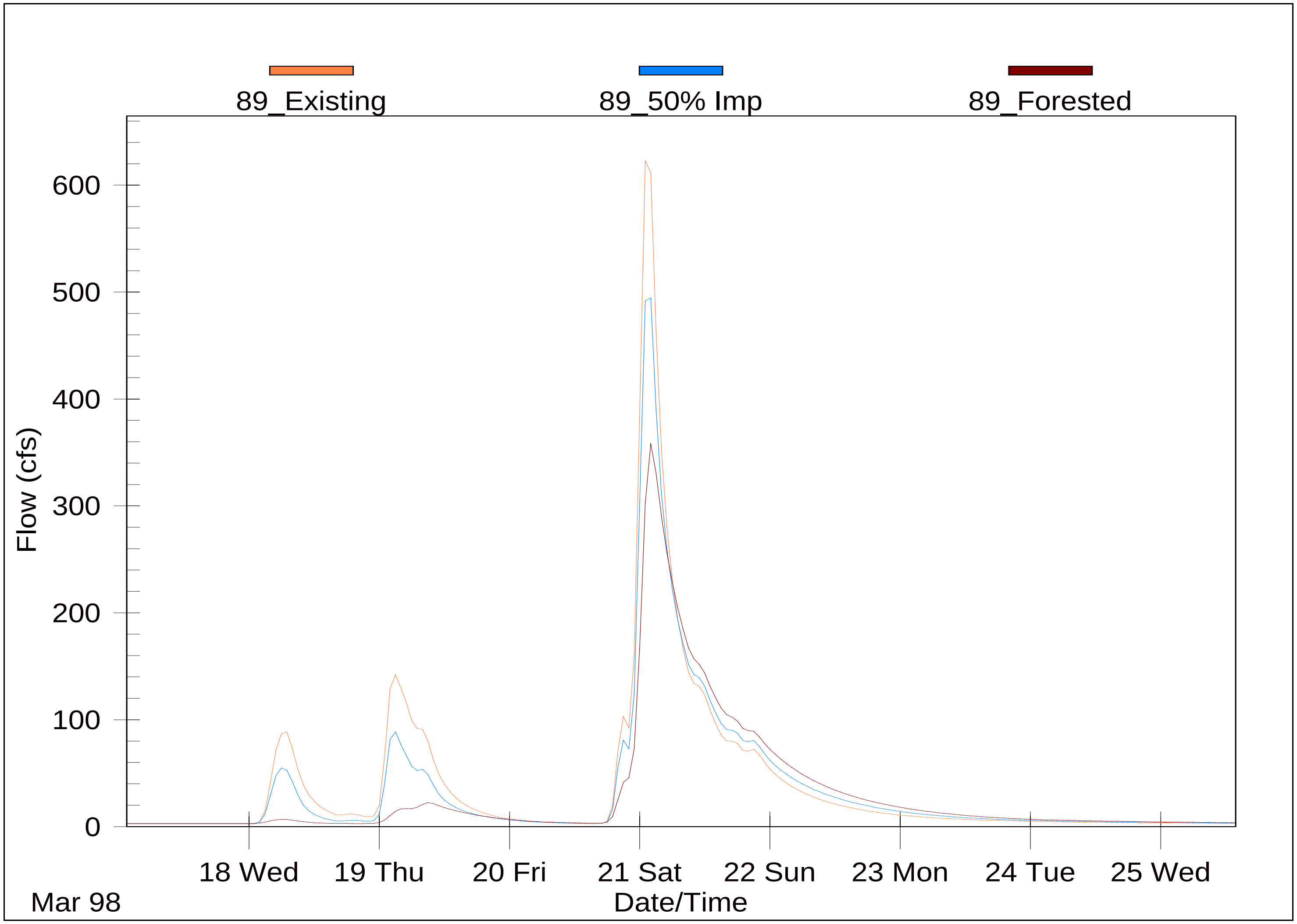
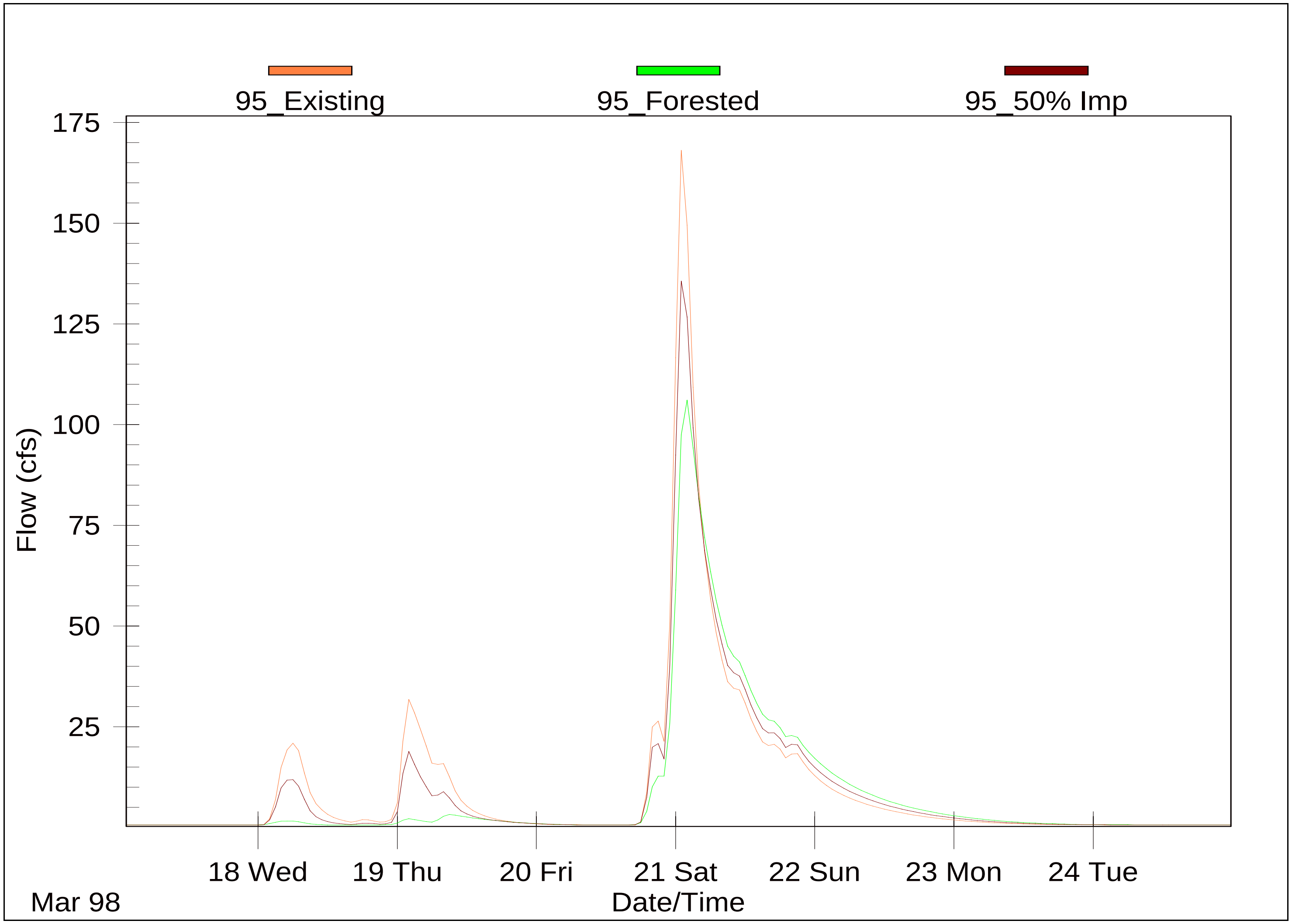


Figure 3-12: Comparison of Storm Flows in Daniels Run (at confluence with Accotink Creek) under Existing Conditions, 50% Impervious Reduction, and 100% Forested Scenarios



3.3.1 Flow Frequency Analysis

Frequency analyses were performed on simulated stream flows in order to determine the number of times stream flows associated with existing land use conditions exceeded flows associated with the completely forested condition (Table 3-10). Exceedance analyses were performed for three stream locations and for a one year forested peak flow as well as a ten year average forested peak flow. It is evident from Table 3-10, that peak stream flows for existing conditions often exceed flows expected under forested conditions throughout the watershed. However, the Accotink Creek stream flows tend to exceed the forested condition more often Daniels Run. This lower exceedance in Daniels Run is attributed to a greater percentage of forested lands present under existing conditions.

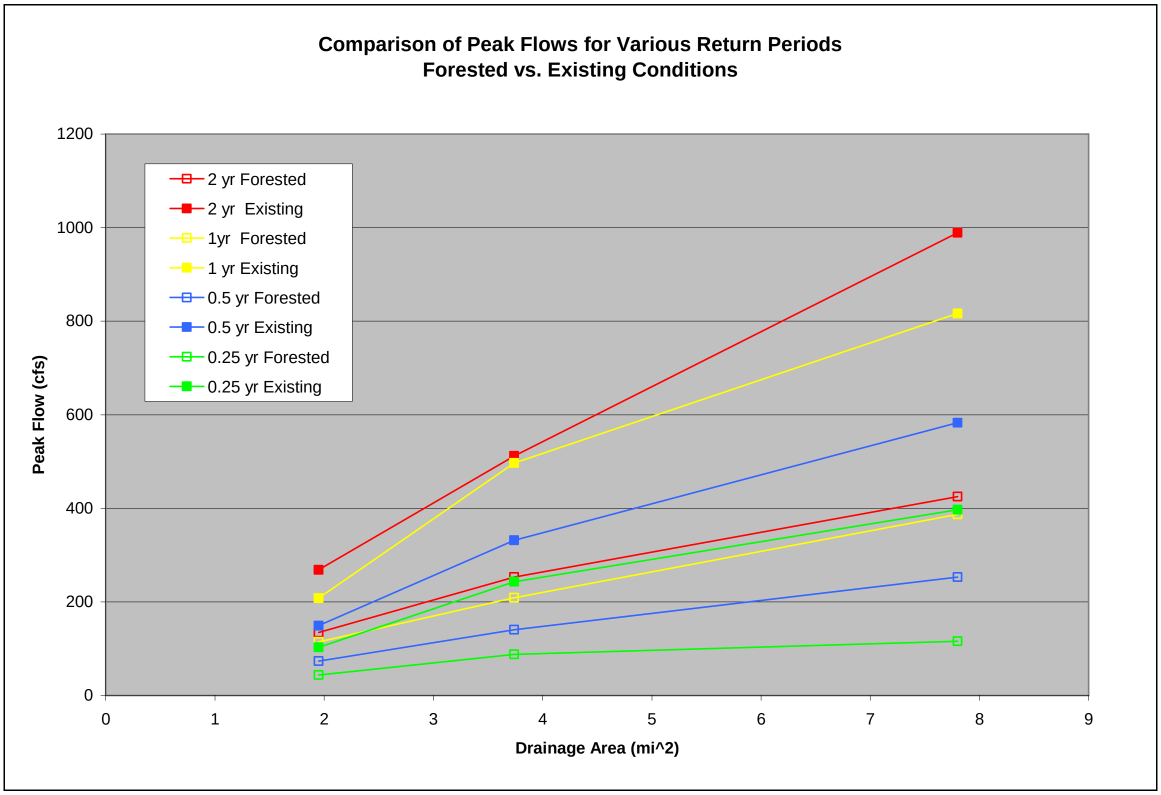
Table 3-10: Frequency of Exceedance of Forested Peak Flow at Model Nodes

Node	Stream	Exceedance of Forested 1-Year Peak Flow		Exceedance of Forested 10-Year Average Peak Flow	
		No.	%	No.	%
95	**Daniels Run**	2	0.4	179	35
841	**Accotink Creek at North Fork Confluence**	16	3.1	349	67
89	**Accotink Creek at City Limit**	54	10.4	422	81

Total number of storm events is 518
Forested condition 1-year peak flow is 380 cfs
Forested condition 10-year average peak flow is 37 cfs

In addition, peak flows for various return periods were determined for both existing and forested land use conditions. Results of these analyses are displayed in Figure 3-13 which provides peak flows for given return periods for three watershed drainage areas. The watershed drainage area at the City Limit is 7.8 square miles. In each case the peak flows associated with forested conditions are significantly less than corresponding flows for existing conditions. These results indicate that the streams in the City of Fairfax are frequently subjected to much higher stream flows during storm events than would be expected under a natural forested condition. As an example, the magnitudes of peak stream flows that are expected to occur every two years under forested conditions are approximately equivalent to the peak stream flows that occur every 3 months (0.25 year) under existing conditions. It is the increased frequency of high stream flow events that has caused excessive erosion and degradation of the streams within the City of Fairfax.

Figure 3-13: Comparison of Peak Flows for Various Return Periods



4.0 Watershed Management Recommendations

The City should be commended for their persistent pursuit of stormwater improvements over the last decade. Through the recommendations of its stormwater system capital needs study, stream evaluation study, and flood study, the City of Fairfax has implemented stream restoration practices at numerous locations on Accotink Creek. Stream restoration was completed on 2.23 miles of stream and stream stabilization was completed on 3.8 miles of stream for a total of 6.83 miles of stream improvements. Considering that a total of 10.15 miles of stream exist within the City boundary, the City of Fairfax has made significant efforts to stabilize the stream banks to handle the urban stormwater runoff and flows. It is recommended that the City continues on the path of stream restorations and improvements. It is also important to note that results from the stream visual assessment clearly showed that stream with highest scores were located downstream of these restoration and improvement projects. The biological scores indicated that the streams are still stressed. It is anticipated that once the physical conditions are stabilized and the habitat are resorted, the biological integrity will be naturally restored.

However, problems still exist, and there is still work to be done to improve stormwater detention, such as retrofitting existing facilities and encouraging low impact development. Overall stream health (calculated using the physical, biological, and habitat assessment scores presented in Section 2.0) is fair to poor in the majority of the City, erosion potential remains at a very high level, sedimentation is a problem, and down-cutting streams threaten City utilities and surrounding property. Hydrology simulation scenarios, presented in Section 3.0, indicate that the amount of stormwater runoff generated under the existing conditions is almost double the runoff that would be generated under 100 percent forested conditions. The simulation results also indicate that the magnitude of stormwater runoff that is expected to occur every two years under 100 percent forested conditions occurs approximately four times a year under the existing conditions.

There are many interests and philosophies in the City regarding potential solutions to current and anticipated stormwater challenges. Potential solutions, presented in the next sections of this report, may be implemented in a variety of ways and at different rates. Such improvements require a committed effort for successful runoff control implementation. Public involvement and cost are obvious challenges. Conversely, a slower pace solution may include retrofitting existing onsite detention facilities and moving toward Low Impact Development (LID) with encouraged but not legislated implementation. The City should consider the issues identified in this report and determine the philosophy for implementation. This philosophy becomes the framework on which individual initiatives are developed. Important question to consider include:

1. How quickly are improvements desired?
2. What types of approaches are desired?
3. Are there initiatives that are unacceptable?
4. What are the short and long term objectives of the watershed management plan?
5. What is the willingness of the citizens and developers to fund improvements?

The City should develop facilitation groups to coordinate among the many parties, interests and objectives for these initiatives. Such groups should meet as soon as practical and identify common and distinct elements. Redundancy should be minimized wherever possible and distinct elements should be assigned to the appropriate group.

A committee comprised of members of the public and watershed stakeholders was formed to evaluate the watershed management recommendations. The committee met on three occasions to review the work, and assist in the formation of the recommendations and setting the goals for the City's watershed management plan. A summary of the committee recommendations is presented in Appendix E.

Specific management practices, improvements, and recommendations for the City of Fairfax watershed are detailed in the following sections. For each potential improvement or management practice, a brief discussion is presented, followed by a series of recommendations that would improve the physical and biological conditions in the City's streams.

4.1 Stormwater Detention

Stormwater detention includes any type of dry or wet pond that detains peak flows and releases the detained volume at a later time; or holds stormwater in a permanent holding facility (pond) which provides water quality and groundwater recharge benefits. Each has its own merits and should be selected on a case-by-case basis. These facilities would be most effective in particular areas. Those subwatersheds within the City that have the highest impervious surface generally produce more surface runoff than those areas with less impervious area and are good targets for new detention facilities. Subwatersheds that are geographically highest in the watershed are also good candidates since detention there slows the time of concentration and flattens the hydrograph curve. Detention facilities in the lower portions of the watershed are not recommended since the detained peak discharge is released at a later time in the storm and can have a multiplying effect when released at a time when higher peak flows from the upper portions of the watershed are flowing. The City should focus improvements in highly impervious headwater areas to gain the most benefit from additional stormwater detention.

Outlet treatment refers to a variety of potential improvements located at or near the outlet of existing stormwater facilities and their associated natural receiving facilities. Improvements could include control structures that reduce peak discharges during low recurrence interval events, diversion to off-line retention, and instream measures designed to reduce channel velocity. Each of these measures requires engineering evaluation and design on a case-by-case basis. Constructed swales are one example of in-channel measure to slow velocity and encourage infiltration. Where outlets are located beyond the floodplain, wet retention systems may be effective. Within the floodplain, installations should be limited to those that slow channel velocity or control peak flows for detention purposes. In-stream measures to reduce channel velocity are intended to affect only low flow storms and typically not designed to have a large impact on larger storms.

Subwatersheds that contain a long length of main stem stream per drainage area are not good candidates for outlet treatment, since each outlet is collecting a relatively small amount of runoff. Conversely, subwatersheds with a relatively small length of mainstem stream are collecting a larger amount of runoff and are good candidates for outlet treatment. Candidate subwatersheds for stormwater detention and outlet treatment are presented in Figures 4-1 and 4-2, respectively. The City should focus improvements in these areas to gain the most benefit from outlet treatment.

4.1.1 Stormwater Detention Recommendations

The City's stormwater ordinance should be rewritten to reflect current approaches to stormwater management. Specific recommendations related to stormwater detention that should serve to improve conditions in the City's streams include the following:

1. Maintain the 1974 existing condition provision.
2. Encourage and/or incorporate low impact development elements into stormwater management requirements. Emphasize stormwater retention (bioretention and infiltration) in addition to detention. Incorporate early planning conferences between the City and developer into current plan review process. Also develop incentives for developers to incorporate low impact development and other stormwater control measures.
3. Consider regional facilities to gain rapid benefit and improve existing stream conditions. Identify locations that would provide significant stormwater detention benefit while minimizing impact on surrounding properties. Consider currently publicly owned sites, but attempt to avoid pristine, heavily forested areas.
4. Focus improvements in subwatersheds identified in Figures 4-1 and 4-2.
5. Consider providing incentives for developer who can incorporate stormwater reductions in their plans.

Figure 4-1: Candidate Areas for Detention in the City of Fairfax Watershed

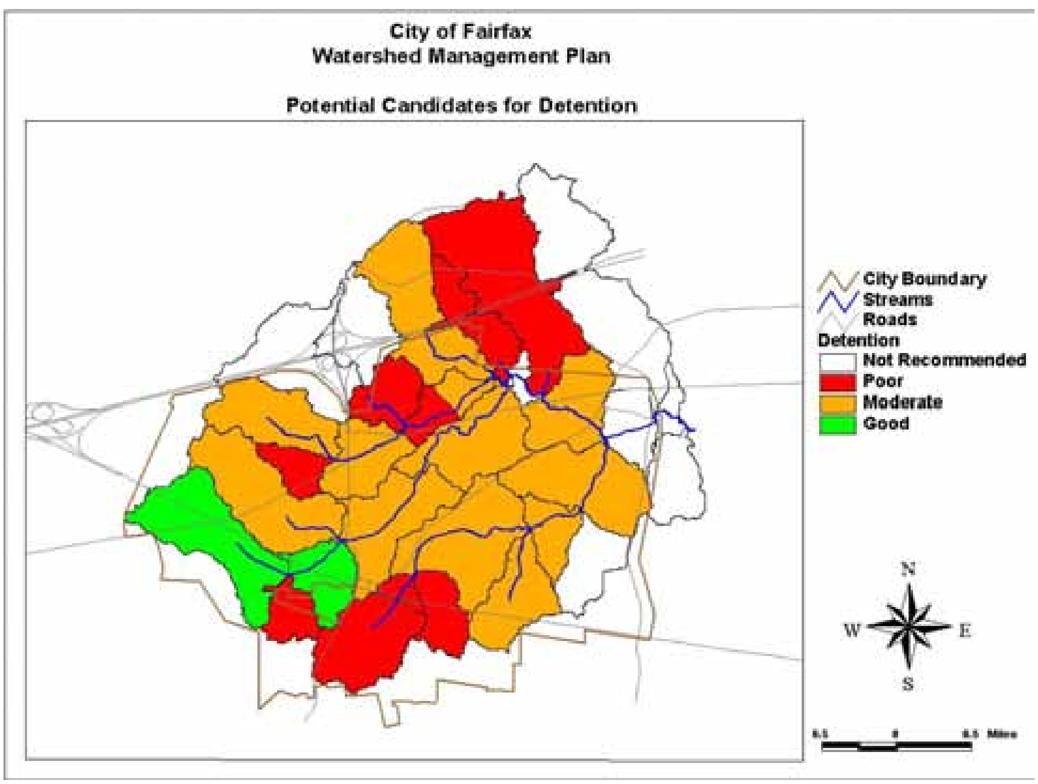
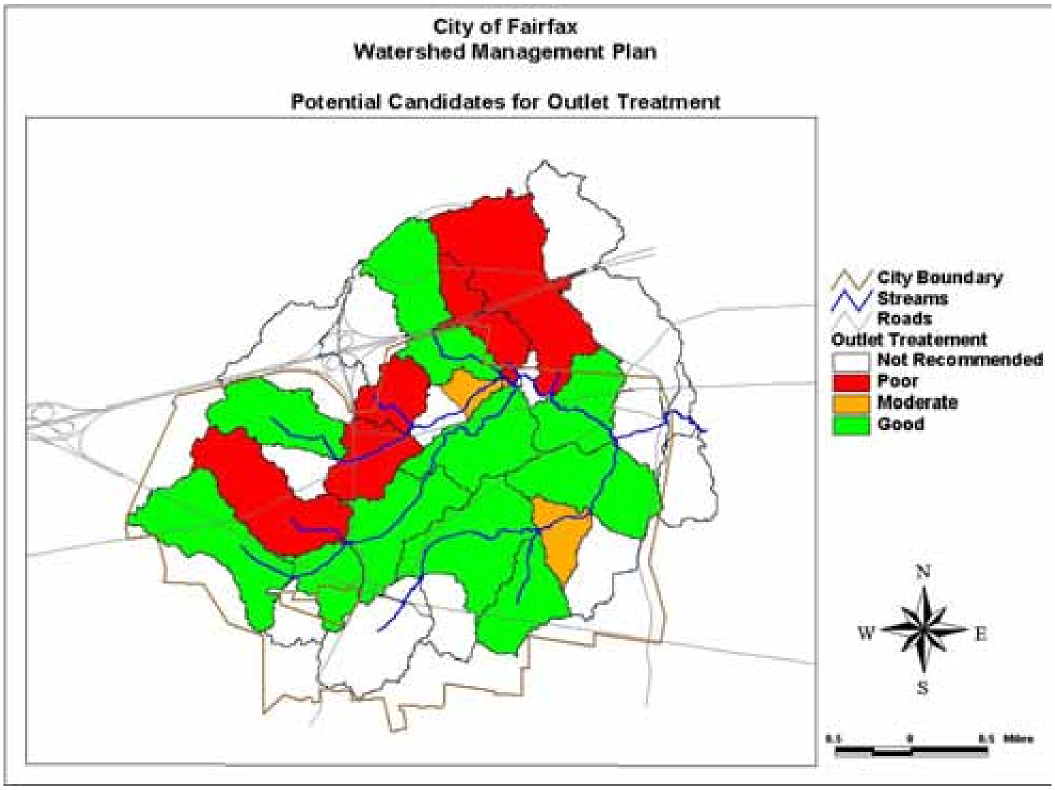


Figure 4-2: Candidate Areas for Outlet Treatment in the City of Fairfax Watershed



4.2 Retrofitting/Expanding Existing Facilities

There are 78 known privately owned on-site detention facilities and 1 regional facility in the City. Retrofit opportunities are generally as follows:

1. expand the facility to provide additional storage capacity by raising the crest or broadening the pond;
2. modify the control structure to provide additional low flow protection if not included in the original design.

Visits to representative stormwater management sites with City staff and examination of City files to assess the nature of existing facilities indicate that a variety of approaches are used. Some stormwater computations appeared to address only the 100 year storm. Others included the 100 year storm, and other storms such as 10 year and 25 year storms. Most surrounding municipalities require stormwater detention for 2 year and 10 year storms and provide an overflow for storms in excess of 10 year. The City should consider adopting a similar approach. All existing systems should be examined for retrofit opportunities and a 2 year control structure should be added where feasible.

Since the current regulations require a 100 year design, additional runoff could be channeled to some facilities; if a lower design storm requirement was adopted. Facilities designed to accommodate the 100 year storm should have more volume than required to accommodate the 10 year storm. Special care for property right issues and easements is necessary. The City must also determine a method for funding and implementing these improvements.

4.2.1 Retrofitting/Expanding Existing Facilities Recommendations

Recommendations related to retrofitting or expansion of existing facilities that should serve to improve conditions in the City's streams include the following:

1. Assess feasibility of retrofitting all onsite detention systems for 2 year control structures.
2. Assess feasibility of channeling additional stormwater runoff to those facilities that are currently designed to handle the 100 year storm and retrofit for a 10 year maximum detention capability and appropriate larger flow storm passage.
3. Determine appropriate funding mechanism to accomplish these improvements.
4. Develop uniform approach to design, operating and maintaining detention facilities and incorporate into the public facilities manual.
5. Coordinate approaches with the public facilities manual and other stormwater management initiatives.

4.3 Low Impact Development

In general, it is undeveloped municipalities that are aggressively pursuing Low Impact Development (LID). Fairfax County has adopted a position that allows and encourages LID but does not legislate its implementation nor establish specific design guidelines. Guidelines are currently being developed by the state of Virginia that will provide more detailed information to make it easier for localities to adopt LID practices.

It is possible for many of the elements of LID to be implemented in the City. During development of the public facilities manual, the City should at least consider allowing and encouraging LID to be used where feasible. The City should also perform a study to determine the specific LID measures that may be effective and identify potential barriers and related solutions. The City may also want to select upcoming public projects as demonstration projects to familiarize citizens and developers with the concept. For example, the new City of Fairfax police station and city hall projects include LID measures.

A public outreach program to explain LID and provide references should be developed. A list of basic LID references is included in Appendix C. An excellent reference is the Prince George's County Low Impact Design Strategies, which includes a section on public outreach development. It may be relatively easy to initiate some simple LID programs, such as rain barrels, coincident with the public outreach program. The City should encourage LID in all redevelopment.

Common installations include rain barrels, cisterns, infiltration trenches, bioretention facilities, and dry wells. Example sketches for these LID measures are shown from Prince George's County publications included in Appendix D. A Municipal Guide to Low Impact Development is also presented in Appendix D. Basic design guidelines should also be established to guard against a property owner installing a facility that negatively impacts surrounding property.

4.3.1 Low Impact Development Recommendations

Recommendations related to low impact development that should serve to improve conditions in the City's streams include the following:

1. Develop a public outreach program to advise the public of the benefits associated with LID. Preliminary materials are included in Appendix D.
2. Develop self-help program to guide property owners that want to retrofit their property for LID measures. Start with relatively easy programs such as rain barrels and rain gardens.
3. Modify stormwater regulations to encourage LID to be considered for new developments and redevelopments. Establish minimum performance criteria for voluntarily constructed LID measures.
4. Determine appropriate transition pace from current conditions to desired ultimate conditions for LID. Consider voluntary and/or required retrofits for existing homes. Consider requiring LID applications for residential and commercial developments and redevelopments.

5. Consider incentives to promote the removal of stormwater connections to the City storm sewer system and the installation of onsite LID systems (rain barrels, rain gardens, etc.).
6. Assess current public works and zoning requirements and develop City philosophy on development approach. Adopt coordinated guidelines for required improvements that allow LID applications.

4.4 Additional Recommendations

4.4.1 Streambank Restoration

1. Maintain the stream reaches restoration and improvement efforts at locations throughout the City. The City has completed numerous stream improvement projects that resulted in reasonably good physical conditions and stability.
2. Prioritize the worst stream reaches, and coordinate improvements with overall watershed strategy. Utilize regional and holistic approaches where possible.
3. Develop a plan for at a minimum, annual monitoring of channel conditions, and modify approach as necessary.
4. Coordinate with the City of Fairfax Department of Public Utilities to jointly establish improvements that protect/relocate utilities and preserve or improve the streambank to provide future utility protection and streambank stability.

4.4.2 MS4 Permit Coordination

1. Coordinate all watershed activities with the MS4 General Permit. Many elements required are common to other watershed initiatives, particularly public outreach.

4.4.3 Public Outreach

1. Develop public education and outreach programs that satisfy the MS4 requirements. Investigate sources of grants and other mechanisms that may be used to develop and fund these programs.
2. Include appropriate public involvement and participation to meet MS4 requirements and satisfy other watershed objectives.
3. Develop staged program to reflect current philosophies of the City toward overall stormwater improvements and LID.
4. Adopt staged approach to LID. Begin with public education and awareness on LID elements. Provide resources web links, self-help guide for those residents interest in implementing their own projects.

5. Use public forum to receive feedback and make decisions on level of LID adoption that is appropriate. Also use public outreach to roll out new programs as adopted.

4.5 Implementation

As stated above, implementation should focus on areas which stand to gain the most benefit from the implementation of management practices or other improvements. The following suggestions are provided to guide the City in determining which of the aforementioned recommendations will be pursued:

1. Determine City policy on watershed issues and develop framework plan for desired improvements and timeframes. Coordinate with ongoing programs for PFM development, MS4 implementation, and other active programs.
2. Identify specific initiatives and develop programs.
3. Funding should be considered as various improvement programs are considered. Nearly any program can be successful if City officials and citizens are committed to spending the money to implement it. Many of the recommendations in this report are innovative approaches and may require innovative funding mechanisms. The following list of potential sources are included as a starting point:
   - Current City budget;
   - Pro-rata contributions toward drainage improvements;
   - Tax incentives for implementing desirable projects;
   - City participation for implementing desirable private projects;
   - Stormwater Utility;
   - Grants and bond financing for major projects.
4. Determine necessary regulation changes and implement as appropriate.
5. Monitor performance and modify regulations periodically to enhance the program as conditions change.

4.6 Summary

Initially the City of Fairfax watershed management plan setout to answer basic questions related to stormwater and the ongoing degradation of the stream within the city boundary. Mainly, the objective was to estimate the volume of stormwater input to the streams, to assess the stream conditions under these flow conditions, and to make recommendations ranging from changes in regulation to use of structural and none structural BMPs.

As presented in Section 4, the stormwater flow under the existing conditions are at least 70% higher that the forested condition. This increase in stormwater flow is mainly due to the dominance of impervious cover in the City. The SWMM model was used to estimate the impacts of reducing the impervious cover on the stormwater flows. It was found that a 50 percent reduction in the impervious cover would be required to achieve a significant impact on the stormwater flows. This can be a noble goal to set and part of a long term control plan to reduce the volume of stormwater. However, in reality this type of reduction is significant and will require substantial changes in the regulations and enforcement.

In addition, the stormwater infrastructure survey indicated that the streams are used as an integral part of the stormwater drainage and conveyance system as evident by the presence of extensive system of stormwater drainage pipes and outfalls located in the stream banks. In general controlling the stormwater requires either elimination or reduction of the stormwater at the source or capturing and managing the storm water in the conveyance system though detention or retention to promote infiltration or delaying it to reduce the impacts on the receiving streams.

There are constraints when attempting to address the stormwater control in the City of Fairfax. These include:

- City is built-out; any attempts to control stormwater at the source will have to be accomplished through retrofits.

- Stormwater reduction at the source can be accomplished through LID methods. However these approaches need to be accepted and applied City wide. Currently, the city has no regulations or incentives to promote such methods.

- Space is limited to implement regional controls within the city to control the stormwater.

The City of Fairfax has completed improvement projects on about 70 percent of the stream reaches and these reaches received a reasonably good score for physical conditions when assessed. However, more time is needed for the biological community to get reestablished.

The following are a summary of recommendations for the City of Fairfax:

1. Continue the stream improvement projects. It is important to stabilize the physical conditions and restore the stream habitat to enable the natural restoration of the biological integrity of the streams.

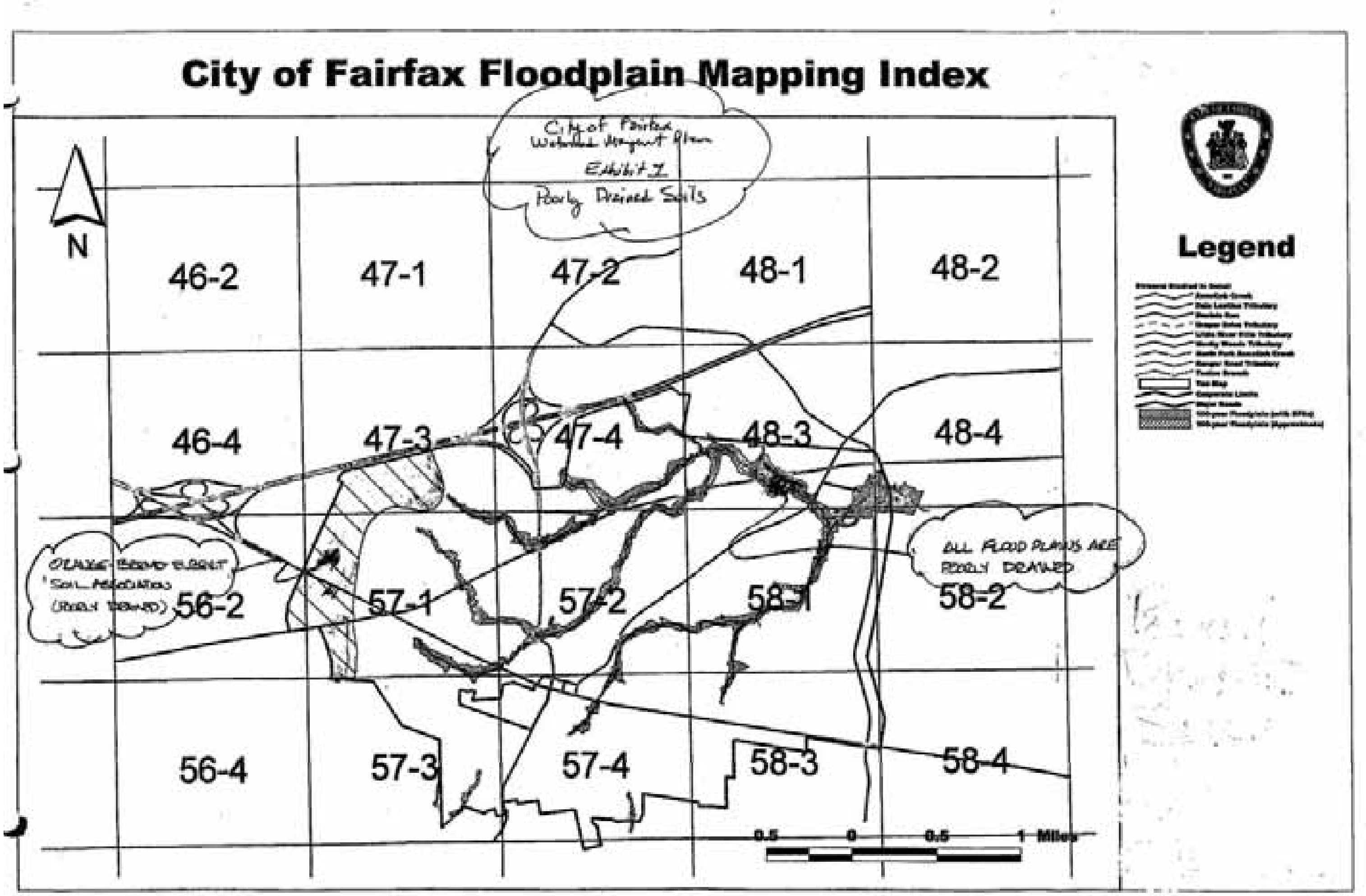
2. While working with the watershed committee, concerned citizens, and stakeholders to establish a long term goal for reducing the imperviousness in the City through the use of LID methods. A reasonable target within the next 10 years would be in the range from 10 to 20 percent.

3. Establish incentives for home owners and developers who implement LID or any on-site stormwater controls.

4. Maximize the benefits of the existing stormwater control facilities. This should include onsite or regional sites that exist throughout the City. The goal should be to target detention/retention to control of the 2-year storm flows since these flows are frequent and are responsible for stream degradation.

5. Review and revise the City of Fairfax existing stormwater ordinance to incorporate the goals and targets recommended in this plan.

Appendix A: City of Fairfax Floodplain Mapping Index



Source: Dewberry and Davis Floodplain Mapping Study

Appendix B: Stream Assessment Condition and Channel Velocity Evaluation

Drainage Area/Subarea	Approx. Stream Length	Velocity = 8.0-12.00 fps		Velocity = 7.0-7.99 fps		Velocity = 6.0-6.99 fps		Assessed Condition 2.0-3.99		Assessed Condition 4.0-5.99	
		Occurrences	Occurrences/mile	Occurrences	Occurrences/mile	Occurrences	Occurrences/mile	Occurrences	Occurrences/mile	Occurrences	Occurrences/mile
Daniel's Run Subarea 1	2900	1	1.8	1	1.8	4	7.3	3	5.5	1	1.8
Daniel's Run Subarea 2	0										
Daniel's Run Subarea 3	2100	0	0.0	0	0.0	1	2.5	1	2.5	2	5.0
Daniel's Run Subarea 4	5200	1	1.0	3	3.0	2	2.0	0	0.0	5	5.1
Daniel's Run Subarea 5	0										
Daniel's Run Subarea 6	1400	0	0.0	1	3.8	0	0.0	0	0.0	1	3.8
Daniel's Run Subarea 7	1200	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Little River Hills Tributary	2800	0	0.0	3	5.7	5	9.4	1	1.9	2	3.8
Accotink Creek Subarea 1											
Accotink Creek Subarea 2											
Accotink Creek Subarea 3											
Accotink Creek Subarea 4	1900	0	0.0	0	0.0	2	5.6	0	0.0	2	5.6
Accotink Creek Subarea 5	2800	1	1.9	2	3.8	0	0.0	1	1.9	2	3.8
Accotink Creek Subarea 6	900	0	0.0	0	0.0	2	11.7	0	0.0	0	0.0
Accotink Creek Subarea 7	1600	0	0.0	1	3.3	0	0.0	0	0.0	0	0.0
Accotink Creek Subarea 8	700	0	0.0	0	0.0	2	15.1	0	0.0	0	0.0
Accotink Creek Subarea 9	300	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Accotink Creek Subarea 10	5300	1	1.0	1	1.0	2	2.0	2	2.0	4	4.0
Accotink Creek Subarea 11	3900	2	2.7	0	0.0	5	6.8	0	0.0	3	4.1
Accotink Creek Subarea 12	2400	1	2.2	2	4.4	1	2.2	2	4.4	2	4.4
Accotink Creek Subarea 13	2200	0	0.0	1	2.4	0	0.0	1	2.4	0	0.0
Accotink Creek Subarea 14	0										
Accotink Creek Subarea 15	2300	1	2.3	1	2.3	1	2.3	0	0	4	9.2
North Fork Accotink Creek Subarea 1	500	1	10.6	1	10.6	0	0.0	0	0.0	0	0.0
North Fork Accotink Creek Subarea 2	3400	0	0.0	1	1.6	2	3.1	1	1.6	1	1.6
North Fork Accotink Creek Subarea 3	1900	0	0.0	1	2.8	0	0.0	0	0.0	1	2.8
North Fork Accotink Creek Subarea 4	2000	1	2.6	0	0.0	1	2.6	0	0.0	1	2.6
North Fork Accotink Creek Subarea 5											
North Fork Accotink Creek Subarea 6											
North Fork Accotink Creek Subarea 7	2900	4	7.3	1	1.8	0	0.0	0	0.0	0	0.0
North Fork Accotink Creek Subarea 8	0										
North Fork Accotink Creek Subarea 9	3000	4	7.0	2	3.5	6	10.6	1	1.8	2	3.5
North Fork Accotink Creek Subarea 10	1800	0	0.0	1	2.9	2	5.9	0	0.0	2	5.9
Threshold			**1**		**4**		**7**		**1**		**4**

NOTES:

1. **Channel Velocity is 2 year R.I. storm data taken from March 1999 Dewberry & Davis Flood Study.**
2. **Assessed Condition based on field assessments performed by Louis Berger (2002).**
3. **Above thresholds are selected to identify significant observations.**
   Any observation of velocity over 8 f.p.s. or Poor stream condition is considered significant.
   Other thresholds selected based on engineering judgment.
4. **Occurences that exceed identified threshold are idenfiied in yellow and reffered to as "hits".**

Appendix C: Low Impact Development References

www.lowimpactdevelopment.org/index.htm

- **Good General Information and links**

www.lid-stormwater.net/

- **Urban Design Tools for waterhed managers**

ftp://lowimpactdevelopment.org/pub

- **FTP Site to download EPA LID Literature Review on effectiveness**
- **Prince George's County Maryland LID Analysis and Design Strategies**
- **Miscellaneous Documents and Brochures**

www.epa.gov/owow/nps/lid/

- **EPA Website and additional links**

www.huduser.org/publications/destech/lowImpactDevl.html

- **HUD Site**

www.chesapeake.org/stac/pubs/wrkshops/ILIDMergedFinalReport.pdf

- **Impediments to LID Workshop**

www.goprincegeorgescounty.com/Government/AgencyIndex/DER/PPD/lid.asp?h=20&s=40&n=50&n1=160

- **Prince George's County LID Website**

http://www.lid-stormwater.net/clearinghouse/home.htm

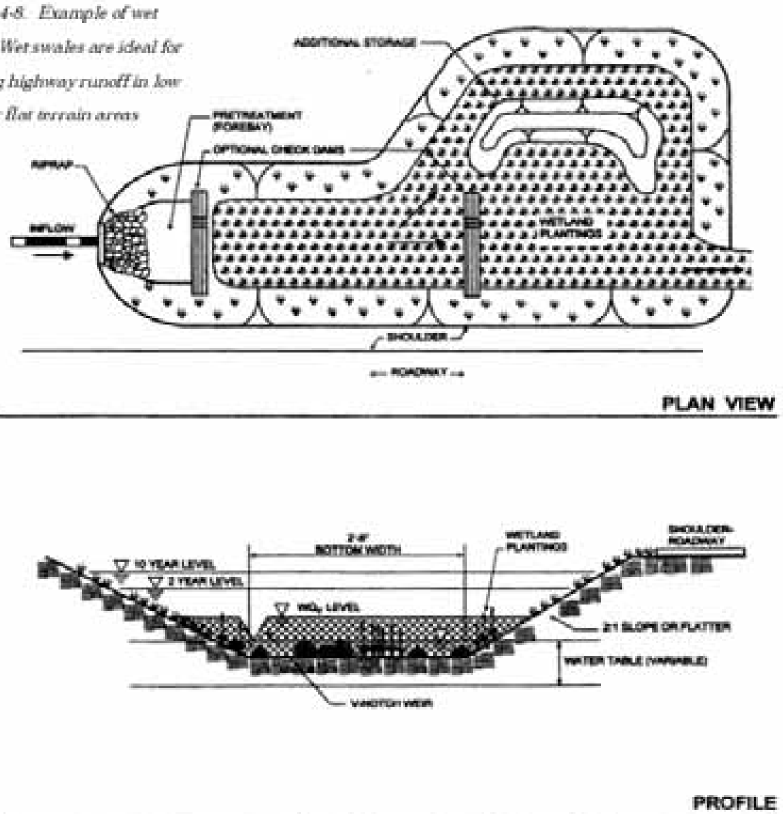
- **National LID Clearinghouse**

Appendix D: Stormwater Improvement Examples

Example of Wet Swale

(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

Figure 4-8. Example of wet swale. Wet swales are ideal for treating highway runoff in low lying or flat terrain areas



peak discharge and provide water quality treatment before discharge to a downstream location (Figure 4-8). The wet swale typically has water tolerant vegetation permanently growing in the retained body of water. These systems are often used on highway designs.

Design Considerations. The key design considerations for grassed swales are summarized in Table 4-7. Detailed design guidance is provided in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984), *Design of Stormwater Filtering Systems* (CRC, 1996), and *Maryland Stormwater Design Manual* (MDE, 1998).

Low-Impact Development Integrated Management Practices 4-17

Rain Barrel Applications in LID

(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

a typical rain barrel. Rain barrels also can be used to store runoff for later reuse in lawn and garden watering

Design Considerations. Rainwater from any type of roofing material can be directed to rain barrels. To be aesthetically acceptable, rain barrels can be incorporated into the lot's land-scaping plan or patio or decking design. Rain barrels placed at each corner of the front side of the house should be landscaped for visual screening. Gutters and downspouts are used to convey water from rooftops to rain barrels. Filtration screens should be used on gutters to prevent clogging of debris. Rain barrels should also be equipped with a drain spigot that has garden hose threading, suitable for connection to a drip irrigation system. An overflow outlet must be provided to bypass runoff from large storm events. Rain barrels must be designed with removable, child-resistant covers and mosquito screening on water entry holes. The size of the rain barrel is a function of the rooftop surface area that drains to the barrel, as well as the inches of rainfall to be stored. For example, one 42-gallon barrel provides 0.5 inch of runoff storage for a rooftop area of approximately 133 square feet.

Figure 4-10. Rain barrel application to LID

Cisterns in LID Applications

(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

Cisterns

Stormwater runoff cisterns are roof water management devices that provide retention storage volume in underground storage tanks. On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs.

Figure 4-11. Cistern. Image courtesy of Pow Plastics, Ltd., Devon, England

Design Considerations. Cisterns are applicable to residential, commercial, and industrial LID sites. Due to the size of rooftops and the amount of imperviousness of the drainage area, increased runoff volume and peak discharge rates for commercial or industrial sites may require larger-capacity cisterns. Individual cisterns can be located beneath each downspout, or storage volume can be provided in one large, common cistern. Premanufactured residential use cisterns come in sizes ranging from 100 to 1,400 gallons (Figure 4-11). Cisterns should be located for easy maintenance or replacement.

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Infiltration Trenches in LID Applications

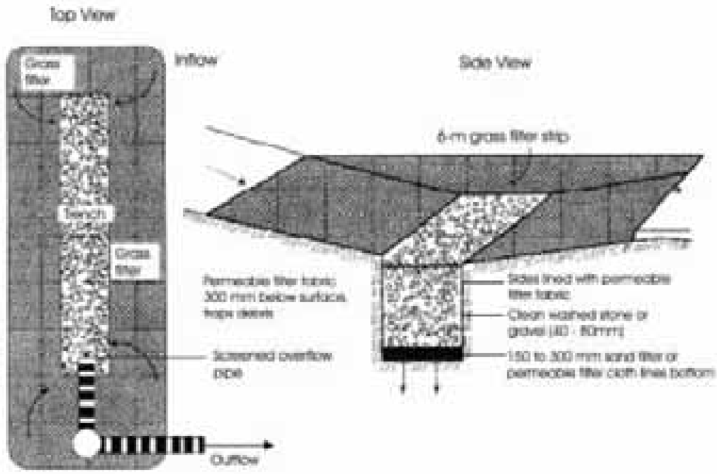
(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

Infiltration Trenches

An infiltration trench is an excavated trench that has been back-filled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, usually over a period of several days. Infiltration trenches are very adaptable IMPs, and the availability of many practical configurations make them ideal for small urban drainage areas (Figure 4-12). They are most effective and have a longer life cycle when some form of pretreatment is included in their design. Pretreatment may include techniques like vegetated filter strips or grassed swales (Figure 4-7). Care must be taken to avoid clogging of infiltration trenches, especially during site construction activities.

Design Considerations. The key design considerations for the infiltration trench are summarized in Table 4-8. Detailed design guidance is provided in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984), *Maintenance of Stormwater Management Structures: A Departmental Summary* (MDE, 1986); and *Maryland Stormwater Design Manual* (MDE, 1998).

Figure 4-12. Median strip infiltration trench design (adapted from MWCOG, 1987).



Typical Bioretention Facility

(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

Low-Impact Development: An Integrated Environmental Design Approach

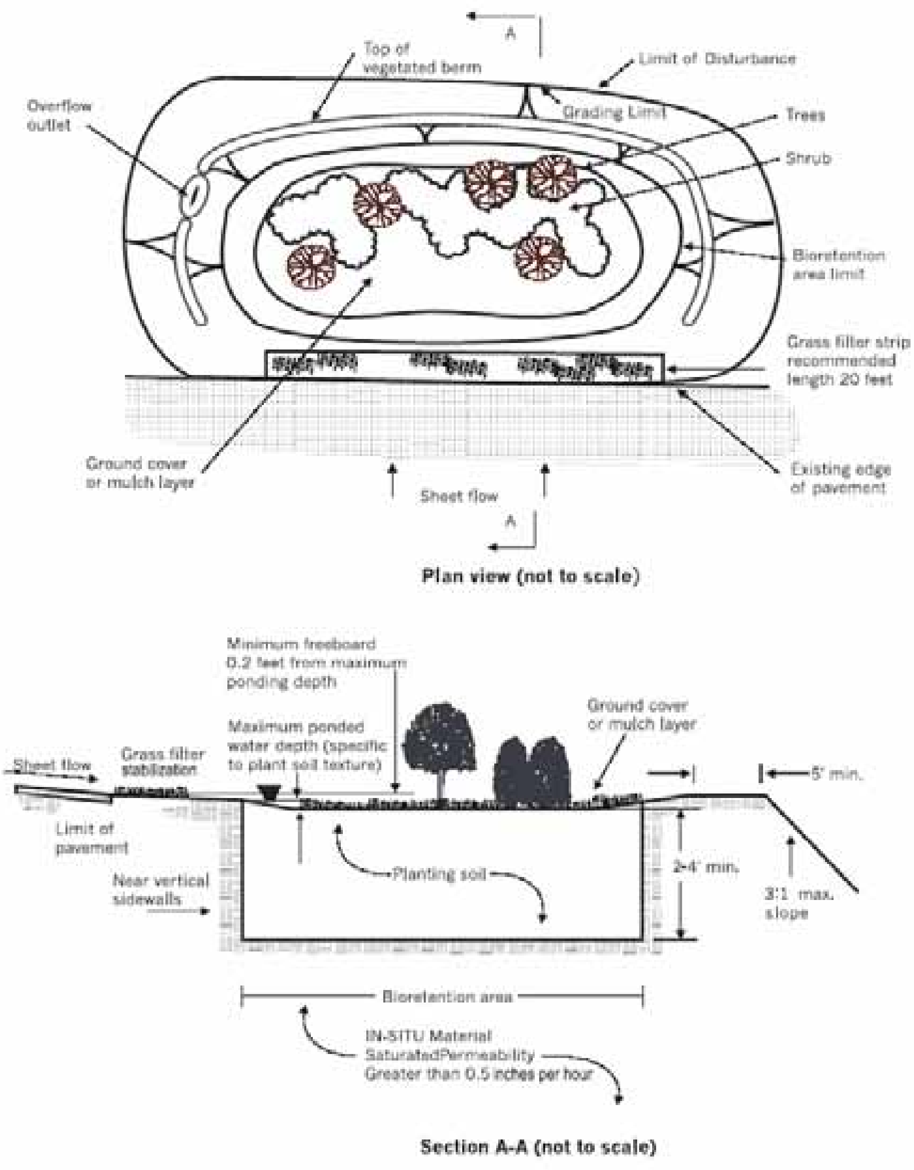


Figure 4-3. Typical bioretention facility

4-10 *Low-Impact Development Integrated Management Practices*

Dry Wells

(Low Impact Development Design Strategies, Prince George's County, MD Department of Environmental Resources)

Dry Wells

A dry well consists of a small excavated pit backfilled with aggregate, usually pea gravel or stone. Dry wells function as infiltration systems used to control runoff from building rooftops. Another special application of dry wells is modified catch basins, where inflow is a form of direct surface runoff. Figure 4-4 shows a typical detail of a dry well.

Dry wells provide the majority of treatment by processes related to soil infiltration, including adsorption, trapping, filtering, and bacterial degradation.

Design considerations. The key design considerations for dry wells are summarized in Table 4-5. Detailed design guidance can be obtained in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984); *Maintenance of Stormwater Management Structures, a Departmental Summary* (MDE, 1986); and *Maryland Stormwater Design Manual* (MDE, 1998).

Dry Wells

Small excavated trenches backfilled with stone, designed to hold and slowly release rooftop runoff

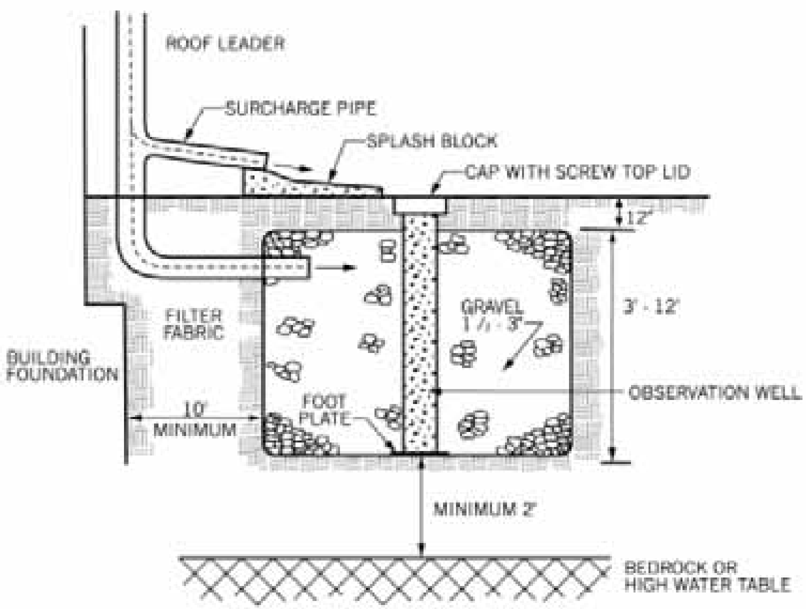
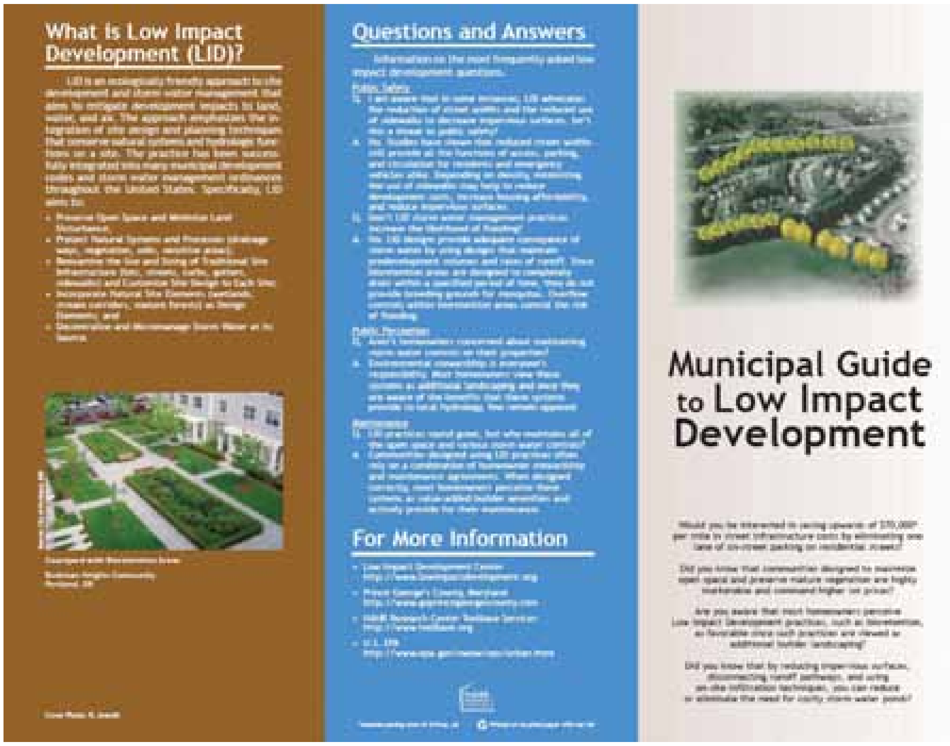


Figure 4-4. Typical dry well

Low-Impact Development Integrated Management Practices 4-11

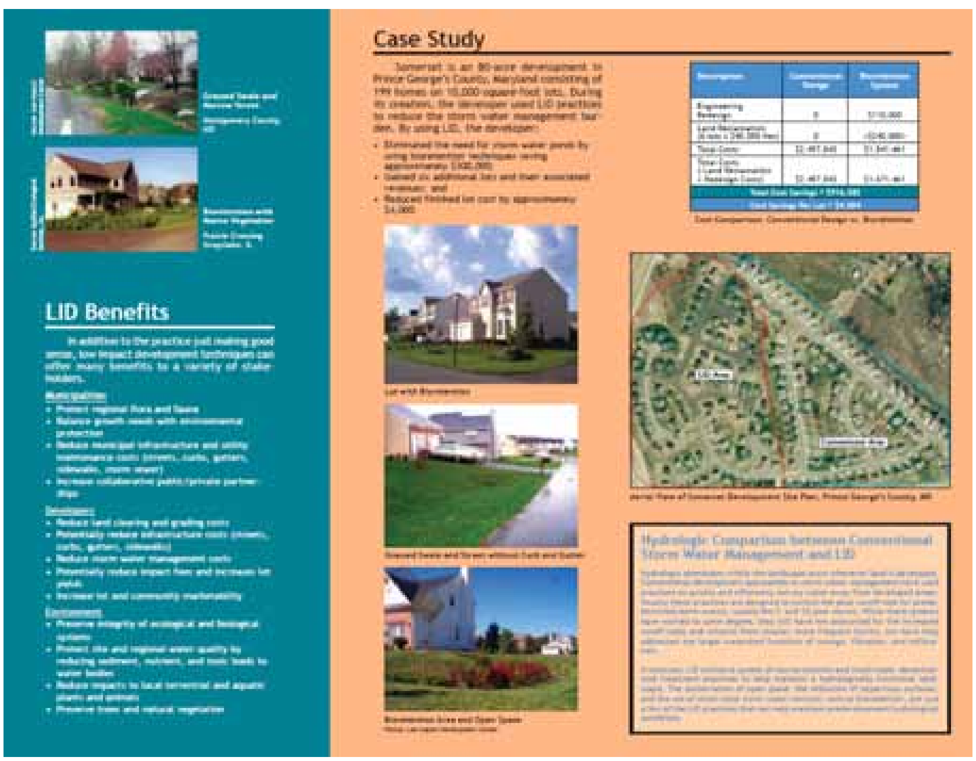


What is Low Impact Development (LID)?

Questions and Answers

For More Information

Municipal Guide to Low Impact Development



LID Benefits

Case Study

Appendix E: City of Fairfax Citizen Watershed Committee Recommendations

Prioritization of Goals

- Peak flow reduction was ranked as the first priority.
- Focus should be to reduce impervious areas.
- Ultimate goal over 50 years is to reduce peak flows by 50 percent.
- Short-term goal is to reduce peak flows by 10 percent.
- Other priorities-
  - Habitat benefits
  - Water Quality Improvements- reduction of fecal coliform, nitrogen, phosphorus and sediment entering the city's streams.
  - Stream conditions
  - Community involvement

General Committee Input:

- Recommend changes to city stormwater ordinance-
  - focus on 2 and 10 year design storms with input from consultant on what other local jurisdictions have adopted in their ordinance.
  - remove 1974 condition and request input from city staff on best approach to setting a baseline condition. In 1974 much of the city was already developed so this is not a good baseline.
  - Recommend that redevelopment sites reduce stormwater flows by 20 percent over the existing conditions. Consultant input requested on how this scenario will impact overall storm flows.
- Revise site plan review checklist to include review of LID options.
- Require developers to install bike racks to reduce on-site parking demands.
- Provide incentives to business owners in the form of tax relief if they reduce on-site imperviousness of their site and/or incorporate LID measures.
- Promote use of LID measures on city owned properties.
- Require homeowners that use the interest free loan program under the city's Renaissance Housing Program to provide some on-site retention if they increase the imperviousness of their property. Cost of required improvements are estimated to be less than $500.
- Request the City Council to continue efforts to purchase green space and/or take dilapidated properties and turn them into green space.
- The city should adopt a policy to implement green building and LID concepts for city owned properties as a model for other city developments.
- Require developers in new or redeveloped areas to restore vegetation and plant native trees and shrubs in the stream buffer areas.

- Recommend that the city conduct a detailed study to determine what existing stormwater structures could be retrofitted and the associated reductions in stormwater flows that would result.
- Promote retrofitting sites to increase on-site infiltration by installing curb cuts to allow water to flow onto unpaved areas.
- Promote environmental education to increase awareness of city streams and community involvement in watershed stewardship activities.
- On-site detention and LID measures are preferred over regional ponds. Past studies showed that space is limited and ponds would achieve limited reductions. Past proposed projects were not favored by area residents.
- Stream gauging station proposed to monitor existing stream conditions and over time document results of implementing flow reduction measures. Options discussed included a joint City of Fairfax and GMU project.
- Stream restoration-
    - The Committee is divided on this issue with some in favor of full stream restoration and others only wanting to provide selective improvements.

For more information regarding the citizen watershed committee, contact the Department of Public Works.