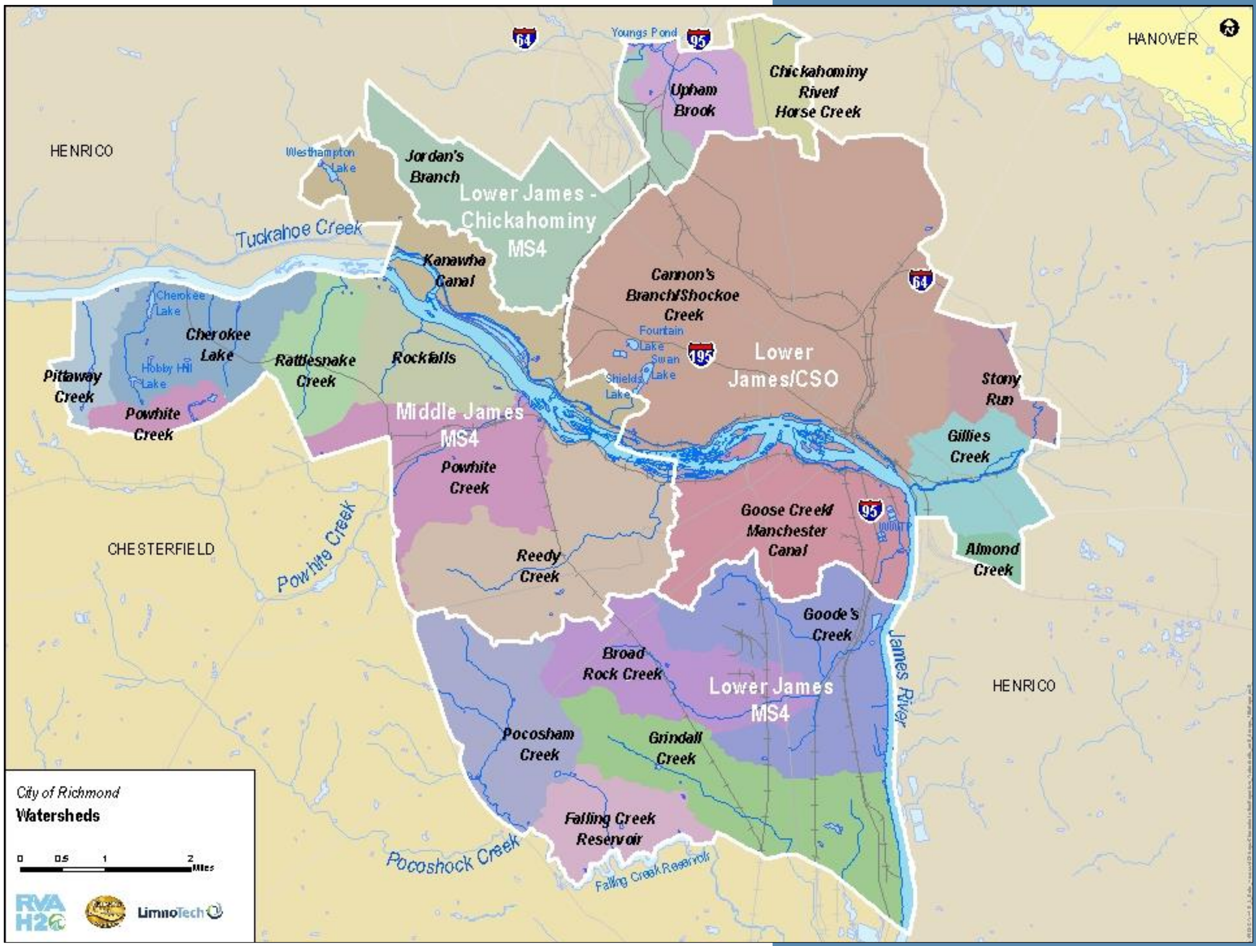

Watershed Characterization Report

Prepared for:
The City of Richmond

October 2015

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LimnoTech
Water | Scientists
Environment | Engineers

1015 18th Street, NW
Suite 900
Washington, DC 20036
202.833.9140
www.limno.com

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 Introduction

1.1 Background and Purpose

The City of Richmond has begun a multi-year process to develop an Integrated Water Resources Management Plan (IWRMP) using water quality and watershed data as the primary building blocks. As noted in Richmond's "Methodology for Integrated Watershed Management Including Integrated Planning and Watershed-based Permitting[1]," the intent of this management approach is to achieve cleaner water faster and more effectively and efficiently meet the City's regulatory obligations under the Clean Water Act (CWA). The Methodology document also includes extensive background information on the overall process. A condensed description of the process is included here. The overall IWRMP approach includes information and processes from a number of planning tools including watershed management planning, integrated planning and watershed-based permitting. The watershed-based permitting and integrated planning will be used to address point source discharges and source water protection issues within an overall Watershed Management Plan. A key component of the Watershed Management Plan is watershed characterization, which is the focus of this document.

The City operates and maintains multiple utilities that address water, including wastewater treatment, drinking water treatment and distribution, stormwater, and combined sewers. Each of these programs includes its own regulatory compliance and management requirements, and historically, have been addressed separately. Despite the historical approach, it is possible and beneficial to manage all of these programs and their associated requirements in a more coordinated and efficient manner through integrating the goals and requirements on a watershed basis.

A key issue making program integration both appealing and necessary is the regulatory focus on wet weather discharges and impacts. Discharges resulting from rainfall and snowmelt (wet weather events) include stormwater runoff, combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), and peak wet weather flows at the WWTP. These wet weather discharges are intermittent, somewhat unpredictable, and not easily characterized. They are extremely variable from one event to the next with respect to frequency, duration, and volume. This variability makes it challenging for municipalities, including Richmond, to manage wet weather discharges. It is also challenging for Virginia Pollutant Discharge Elimination System (VPDES) permit writers to draft permits that both effectively and efficiently address wet weather discharges.

The City's IWRMP approach includes the tools to make the integration and coordination of the different programs possible.

1.2 Integrated Water Resources Management Plan Elements

The IWRMP approach, being undertaken by the City, involves elements by which to coordinate its water management programs. Every element of this process will involve coordination with stakeholder groups, which will include providing input and assistance along each step of this process. Additional information regarding stakeholder involvement is included in Section 2 of this document.

[1] Found on City of Richmond's RVAH2O website - https://app.box.com/s/eiilnsnvckzqdovd922lrrvd0dxlkygt

The Watershed Management Plan will coordinate the identification of goals and stressors as well as the stakeholder outreach to increase effectiveness and efficiency.

The Watershed Management Plan provides the data and information that will be subsequently used to develop a watershed-based permit that will be designed to protect the City's watershed goals. The Watershed Management Plan involves a number of steps including:

1. Developing watershed characterization including information on elements such as:
    a. Physical and natural features, land use, waterbody conditions, pollutant sources, waterbody monitoring data, etc.
2. Setting goals and identifying solutions including:
    a. Developing indicators/targets, determining load reductions needed, developing management measures to achieve
3. Designing an implementation program including:
    a. Developing an implementation schedule, milestones, criteria to measure progress, monitoring approach, etc.
4. Implementing the Watershed Plan including:
    a. Identifying implementation strategies, conducting monitoring to track and evaluate effectiveness of implementation

Subsequently, **Integrated Planning** will be used to provide the framework for pulling together information gathered through the Watershed Management Planning process regarding sources and stressors and determining the best distribution of the City's resources to produce the greatest environmental gain.

Using comprehensive data from the Watershed Management Plan, as well as various models and visualization tools, Integrated Planning will proceed to prioritizing actions and investments based on cost effective progress.

A **watershed-based permitting** approach will provide the vehicle to implement the activities identified through the Watershed Management Planning and Integrated Planning activities, especially where municipal discharges are included. Watershed-based permitting is an approach to developing NPDES permits for multiple point sources within a defined geographic area (i.e., watershed boundaries). The primary difference between this approach and the approach that has historically been used for developing and issuing permits is the consideration of watershed goals and the impact of multiple pollutant sources and stressors, including nonpoint source contributions.

One key component in the overall watershed-based permitting process is the integration of programmatic requirements. The watershed-based permitting framework provides the structure for examining a specific area and all of the stressors within that area, data related to the stressors and water quality goals, and prioritizing actions based on those data. A watershed-based NPDES permitting approach may mean one permit to cover all discharges or a system for coordinating permits so they function as one consolidated plan of action. Regardless of which approach is used, the process requires clearly describing the watershed goals. Once goals are established, then it is necessary to conduct an assessment of any problems in the watershed that are adversely impacting the goals. After the assessment it is necessary to identify sources contributing to the problem and then focus on reducing the sources that will provide the greatest benefit in the water. The information gathered through the watershed management planning and integrated planning will be a key component of this goal setting and problem-solving process.

The watershed-based permitting process is the vehicle to run all of this: to require the data collection and the controls (limits) to work toward the goal of improved water quality.

The permit(s) will focus on watershed needs. Currently, the City has multiple permits. There is the potential to maintain the current approach of multiple permits and the permit requirements will be coordinated through the permit fact sheets. Or, another option is to issue one permit with all requirements for the multiple point sources.

1.3 Watershed Characterization

As noted earlier, a significant component of the Watershed Management Planning approach is the watershed characterization step.

Effective watershed management relies upon identification of the conditions and issues that characterize the watershed. Understanding existing water quality, along with the sources of pollutants or stressors that impact water quality standards (WQS), are key elements for developing priority actions to address any existing or potential problems. Collection of data and characterization of the watershed is the City's first step towards development of a Watershed Management Plan and associated efforts with development of integrated planning and watershed-based permits. Information and data collected in this phase serves as a foundation for subsequent steps of the watershed planning process.

The first step in watershed characterization was to determine the boundaries of the watershed or watersheds to be addressed. This watershed delineation process was completed recently and documented in the technical memorandum, "Draft Watershed Grouping Analysis[2]."

A number of studies have been previously conducted that provide watershed-based data for the City. For example, a series of Stormwater Master Plans have been developed for the City that have identified priority watersheds that are entirely or partially within the City limits. Combined with other appropriate data and information, these plans were reviewed and will provide information for determining areas of focus for the current watershed planning effort. Once the areas of interest are determined, a focused planning effort can begin on these watersheds.

Data needed for the characterization process came from a variety of sources, including but not limited to the following:

Existing Plans/Documentation:

- TMDL Reports
- Watershed Restoration Action Strategies
- Source Water Assessments
- Stormwater Master Plans
- Long Term Control Plan (LTCP)
- CSO Master Plans
- Permits

Local Government Sources:

- County and city planning offices
- Environmental departments
- Soil and water conservation districts
- Departments of economic development
- Water and Sanitation department

[2] Available at www.rvah2o.org.

- Public health department
- Transportation department

State and Federal Sources:

- Virginia Department of Environmental Quality
- Virginia Department of Agriculture and Consumer Services
- U.S. Department of Agriculture
- U.S. Environmental Protection Agency (USEPA)
- U.S. Geological Survey (USGS)
- National Climatic Data Center (NCDC)
- National Oceanic and Atmospheric Administration (NOAA)
- National Wetlands Inventory (NWI)
- U.S. Census Bureau

Caution was exercised to avoid collecting data that weren't applicable to the goals of developing a Watershed Management Plan.

Prior to carrying out the characterization process, an inventory was developed to organize and maintain the data[3]. During the data collection and the characterization process, a data gap analysis was conducted to evaluate whether the information currently available is sufficient for characterizing the watershed. In some cases, the data gap analysis indicated that additional data would need to be collected in order to more fully characterize certain aspects of the watershed. Where this occurred, it is described in more detail in the specific section of the Characterization Report below.

The following Characterization Report includes descriptions of the Physical and Natural Features of the watershed as well as, Land Use/Cover Characteristics, Infrastructure Features, Sensitive Areas and Public Interest/Watershed Group that are active in the watershed.

Another component of watershed characterization is the analysis of data to begin to identify sources and stressors that are or may cause an adverse impact on water quality. Once the causes have been identified, the next step is to determine the source of the cause and its effect on the aquatic ecosystem (source-stressor-response). In order to link the impairments to causes within a watershed framework, some key questions to be answered will include: What pollutant contributions are coming from upstream? What is the City contributing? What are downstream impacts? The answers to these questions will assist with the planning and prioritization for watershed management. Development of loading estimates is an important piece to reducing pollutant loads and meeting water quality goals. There are several approaches to calculating pollutant loads. In some cases, these estimates may have already been quantified and published in TMDLs. In other cases, pollutant loads may need to be estimated with water quality models. Loading analyses may determine how much of a pollutant load is acceptable to a receiving waterbody while others may focus on pollutant loads in terms of source categories in a watershed. The desired approach will be dependent upon the goals outlined in the Watershed Management Plan. This step will be described more fully in a subsequent report that will be developed after the data collection and analysis of the four watershed groups has been accomplished.

[3] Available at www.rvah2o.org.

1.4 Organization of the Report

Section 2 provides an overview of the stakeholder involvement process that was used during the development of the development of this Watersehed Characterization Report.

Sections 3 through 6 provide the detail associated with each of the watershed groupings including:

Section 3 –Lower James CSO watershed grouping

Section 4 – Lower James MS4 watershed grouping

Section 5 –Lower James-Chickahominy MS4 watershed grouping

Section 6 –Middle James MS4 watershed grouping

Section 7 summarizes the findings compiled in association within each of the watershed groupings as well as the City as a whole. These findings will be used to support the next steps of this process including the prioritization of goals and objectives for the City within the framework of this Integrated Water Resources Management approach and the identification, prioritization, and ultimate selection of the strategies that the City and its stakeholders will use to work toward achieving these goals.

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2 Stakeholder Involvement

Stakeholder involvement is a key element of Richmond's Integrated Water Resources Planning Process and the subsequent integrated NPDES permit. An initial step in this process was the identification of groups or individuals that would be interested in this process being initiated by the City or would potentially bring data, information, and insight to the table that could assist the City with reviewing the problems and looking at the relative contribution of all sources and the stressors on the watershed.

Richmond's Department of Public Utilities (DPU) reached out to a variety of stakeholders in and surrounding the City including environmental advocates, users of the James River, property owners, business, and state and local governmental agencies and representatives.

The initial stages of the stakeholder involvement process resulted in categorizing these participants into several groups based on expected technical knowledge and perceived level of interest and involvement. As a result, a Technical Workgroup was formed. This included representatives of groups such as:

- Chesapeake Bay Foundation
- James River Association & Riverkeepers
- Alliance for the Chesapeake Bay
- Virginia Department of Environmental Quality (VDEQ)
- Virginia Department of Health (VDH)
- City Department of Public Works (DPW)
- James River Park System
- Chesterfield & Henrico Counties
- Virginia Commonwealth University (VCU)

Additionally, a special interest and public stakeholder group was identified with those anticipated to have a high level of involvement. This group included representatives of organizations such as:

- Friends of James River Park
- Sierra Club – Falls of the James Group
- Home Builders Association of Virginia
- Hispanic Chamber of Commerce
- Richmond City Council Districts

Those in this special interest and public stakeholder group with an anticipated lower level of involvement included representatives from organizations such as:

- Richmond Audubon Society
- James River Advisory Committee
- Retail Merchants Associations
- Tenant, Civic and Neighborhood Associations

The tables in Appendix A depict the various stakeholders that have been invited to participate and/or are participating within this planning process. Table A1 includes local, state, and federal government organizations. Table A2 includes the various environmental, watershed, and recreational stakeholders in the City. Table A3 includes citizen and community group stakeholders and Table A4 includes private sector, businesses, and business association representatives. While many of these entities and organizations may be interested in issues across the City, a number of these stakeholders may have a more focused interest in a specific portion of the City. Those organizations having a specific geographic focus have been categorized in one of the four watershed groupings.

3 Lower James CSO Watershed Characterization

3.1 Watershed Summary

The City of Richmond Department of Public Utilities is working toward integrating its numerous CWA programs in order to increase management efficiency and achieve greater environmental benefits. To accomplish this, the City is using watershed management concepts to organize data and coordinate activities. This report provides a characterization of watersheds in the Lower James CSO area. These data will be used during the integration process to assist with prioritization and decision-making regarding application of resources.

The Lower James CSO area of Richmond is comprised of five watersheds: Cannon's Branch/Shockoe Creek, Stony Run, Gilles Creek, Almond Creek, and Goose Creek/Manchester Canal. The region is situated in the eastern side of the City and covers areas both north and south of the James River (Figure 3.1). The total area characterized in this watershed grouping is 21.6 square miles (Table 3-1).

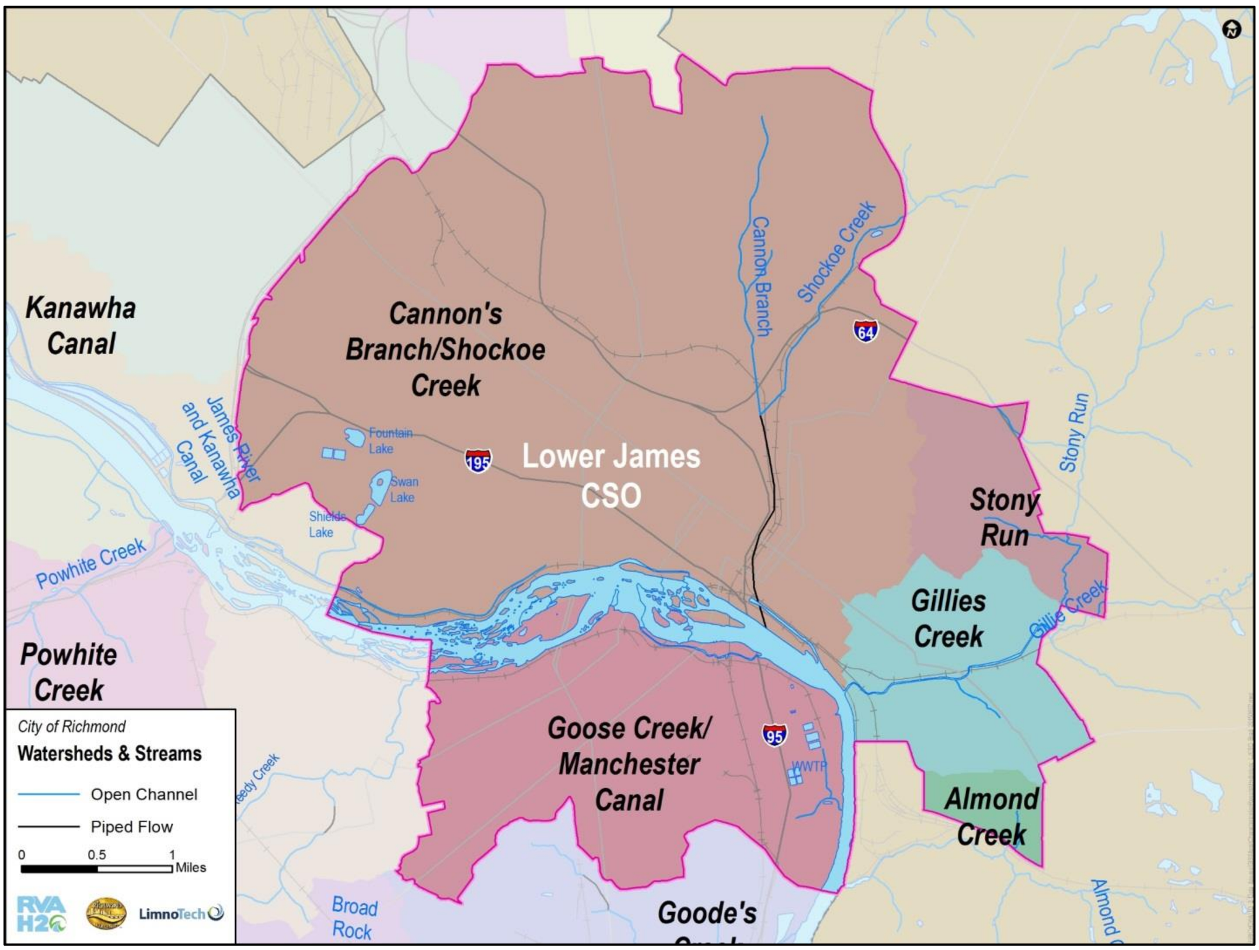

Figure 3.1 Watersheds and streams within the Lower James CSO watershed grouping

Table 3-1 Lower James CSO watershed area

Watershed	Watershed Area (sq. mi.)	% of Total Lower James/CSO
Almond Creek	0.3	1.5
Cannon's Branch/Shockoe Creek	14.0	65.0
Gillies Creek	1.8	8.3
Goose Creek/Manchester Canal	4.3	20.1
Stony Run	1.1	5.1
Total Lower James/CSO	**21.6**	**100.0**

3.2 Watershed Delineation

Delineation of watersheds in the City of Richmond was driven by the existing topography and collection systems. During the delineation process, each watershed boundary was carefully drawn to reflect how the slopes in the land surface and pipes transport water. A detailed discussion of the delineation is included in the Existing Watershed Data Assessment Report and the Watershed Delineation Technical Memorandum[4].

For characterization purposes in this report, five of the twenty watersheds in the City of Richmond have been grouped together:

- Almond Creek
- Cannon's Branch/Shockoe Creek
- Gilles Creek
- Goose Creek/Manchester Canal
- Stony Run

A discussion of both the individual characteristics of each watershed and overall characteristics of the watershed grouping is included below. The drivers behind the aggregation of these watersheds stem from two primary factors. First, the majority of runoff and streams in these watersheds flow directly to the Lower James River segment. This is an important distinction in terms of habitat and water quality issues since the Lower James is an estuarine area with tidal influence. Second, much of this area is served by the combined sewer system (CSS) (where stormwater is transported with the waste stream to the wastewater treatment plant (WWTP) located in the Goose Creek/Manchester Canal watershed). Under high flow conditions caused by storm events, the stormwater and wastewater exceed the capacity of the collection system and exit the collection system at CSO discharge points (Figure 3.2).

[4] Available at www.rvah2o.org.

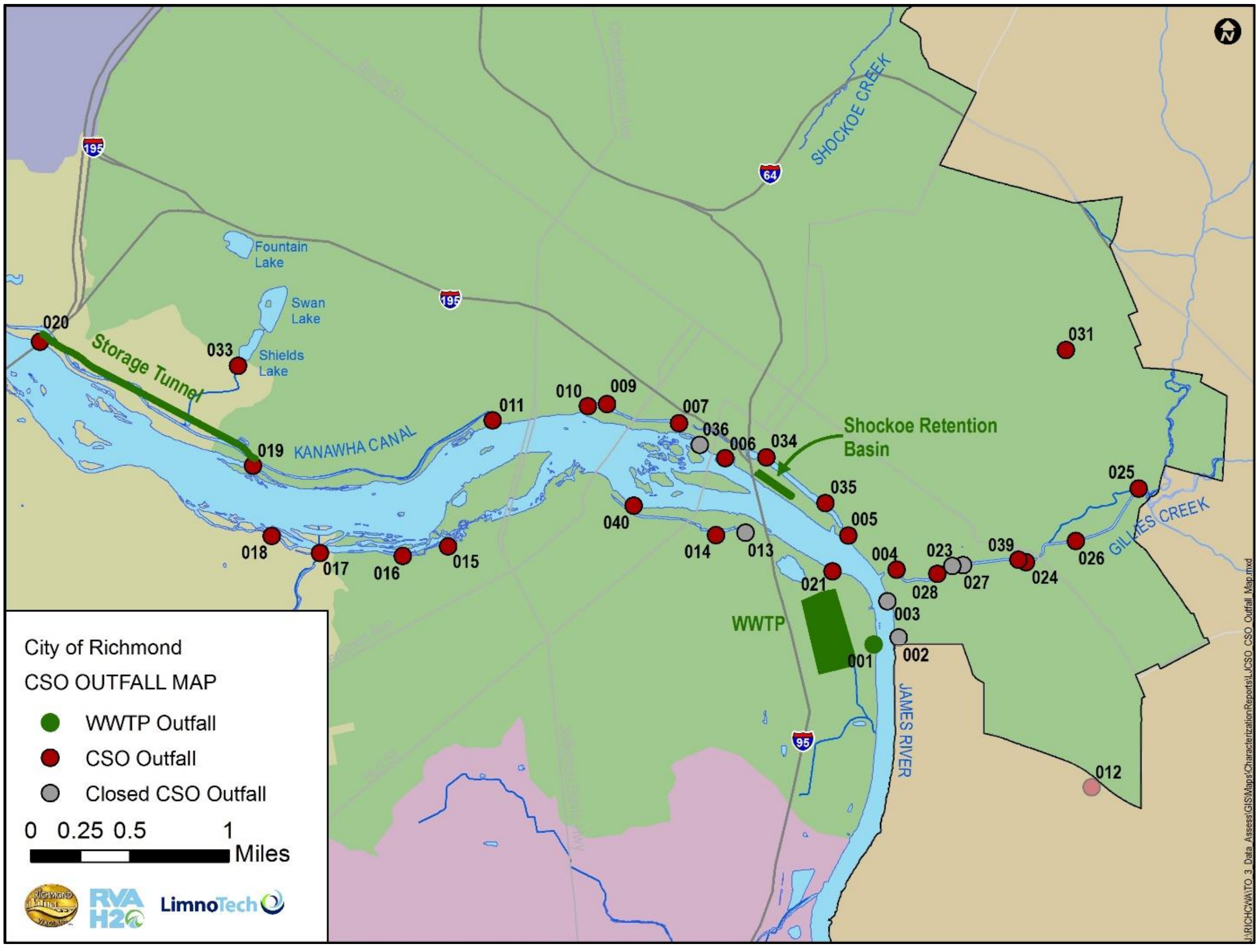

Figure 3.2 Lower James CSO outfalls

3.3 Watershed Features

Watershed characteristics are major factors that need to be considered when identifying pollution sources and determining appropriate methods to reduce them. This section will describe the watershed and stream characteristics. The Lower James CSO grouping of watersheds represents 21.6 square miles. As seen in **Error! Reference source not found.**, the largest watershed is Cannon's Branch/Shockoe reek and the smallest is Almond Creek.

A total of 18.4 miles of stream exist in the five watersheds. These watersheds include portions of seven of the nine City Council districts (1, 2, 3, 5, 6, 7, 8) in Richmond (Figure 3.3).

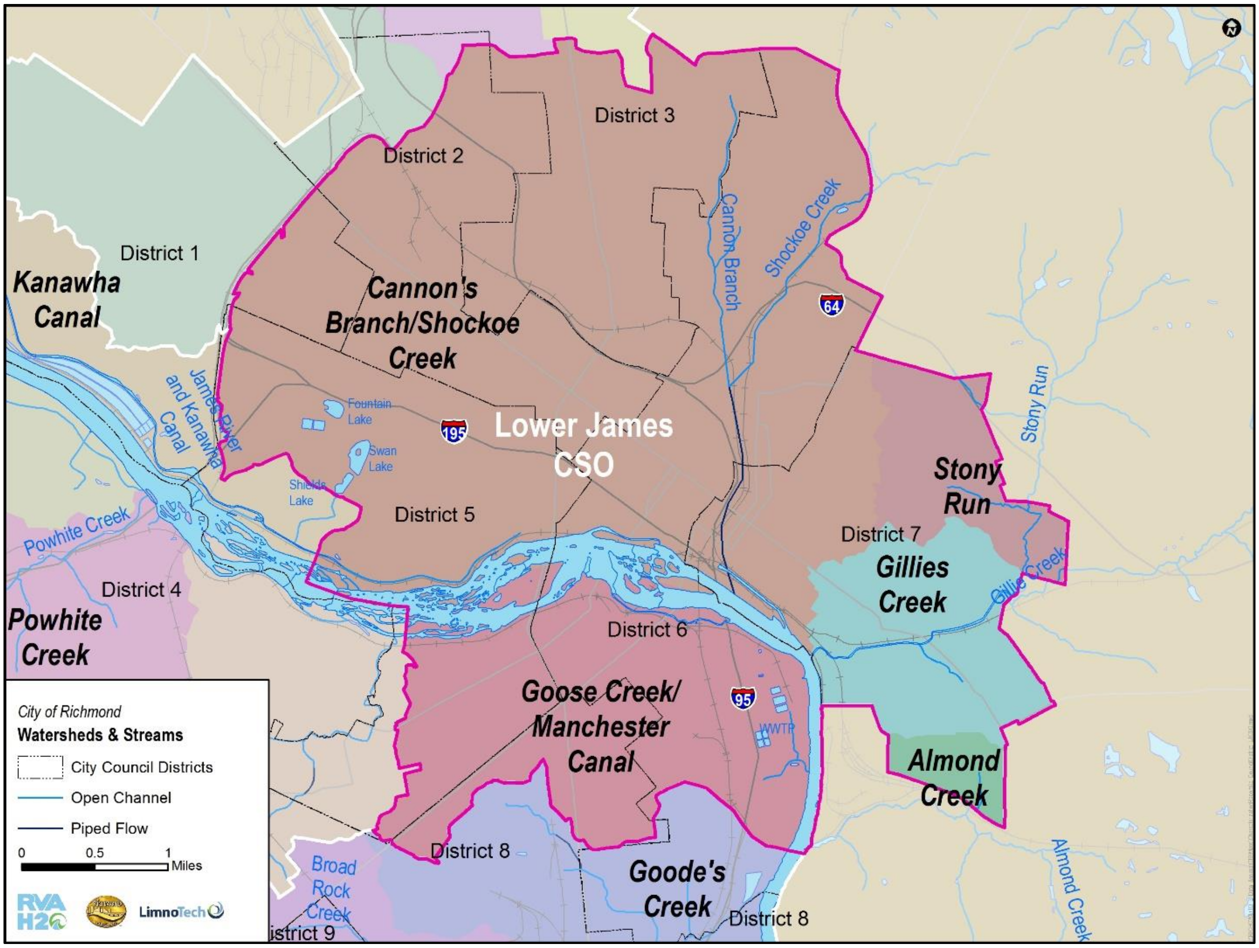

Figure 3.3 Lower James CSO City Council Districts

3.3.1 Physical and Natural Features

This section describes hydrology, geology, topography, soils, climate, and habitat. These are important features because they affect land uses and shape the chemical, biological, and hydrological characteristics of the Lower James CSO region.

3.3.1.a Hydrology

Within the five watersheds, the total length of stream ranges from 0.4 to 11.7 miles (Table 3-2). Hydrology in the Lower James CSO has been greatly altered over time. For example, portions of Shockoe Creek have been channelized to run parallel to roads and railroads. Additionally, almost two miles of the downstream portion of Shockoe Creek have been piped. Further hydromodification is seen in Gillies Creek, where 1.6 miles of stream, at the confluence with the James River, have been channelized with a concrete lining. The Manchester canal is manmade and short sections of Goose Creek have also been highly modified. This type of channelization and piping of streams is often seen in older urban centers. Stony Run, further away from the City center, has not been modified to the same degree as the other streams. The portion of Almond Creek watershed within the City of Richmond contains no streams.

Table 3-2 Lower James CSO watershed hydrology

Watershed	Open Channel Stream Distance (mi)	Wetland Area (ac)	Lake Area (ac)	Total Watershed Area (ac)
Almond Creek	--	--	--	206
Cannon's Branch/Shockoe Creek	11.7	424.1	37.9	8,985
Gillies Creek	0.4	16.3	--	1,147
Goose Creek/Manchester Canal	4.6	408.8	19.8	2,780
Stony Run	1.7	--	--	699
Total Lower James/CSO	**18.4**	**849.2**	**57.7**	**13,818**

The City has identified wetlands in the Cannon's Branch/Shockoe Creek, Gilles Creek, and Goose Creek/Manchester Canal[5]. However, a majority of these wetland areas are associated with James River or other riparian areas.

Fountain Lake and Swan Lake are the largest lakes within the Cannon's Branch/Shockoe Creek watershed. Other smaller lakes are also located within the Goose Creek/Manchester Canal watershed.

The Federal Emergency Management Agency (FEMA) has identified 100 year flood prone areas in all of the Lower James CSO watersheds except Almond Creek (Table 3-3). These areas are located along the James River and the major tributaries of each watershed. In addition to flood prone areas, FEMA-certified levees are located along the James River in the Cannon's Branch/Shockoe Creek and Goose Creek/Manchester Canal watersheds.

Table 3-3 Lower James CSO FEMA flood prone areas and levees

Watershed	100yr flood prone area (ac)	FEMA certified levee (miles)
Almond Creek	--	--
Cannon's Branch/Shockoe Creek	703.8	0.8
Gillies Creek	142.0	--
Goose Creek/Manchester Canal	812.6	2.4
Stony Run	21.6	--

[5] This dataset is derived from the US Fish and Wildlife Service's National Wetlands Inventory and is available online at ftp://ftp.ci.richmond.va.us/GIS/Shapefiles/Environmental/

All of the watersheds and their associated waterbodies in this grouping transport water to the James River. While flowing through the Lower James-CSO watersheds, the James River bed elevation drops approximately 70 feet[6]. This drop, over such a short distance (approximately 4.5 miles), contributes to the existence of rapids. In fact, Class IV rapids exist within this stretch of river[7].

The falls also serve as the head of tide on the James River (just upstream of Mayo Bridge). This is also where the split between the Middle and Lower James is delineated. The Middle James River is a non-tidal freshwater segment of river. The Lower James River is tidally influenced as seen in Figure 3.4 and is designated as a tidal freshwater segment by the State of Virginia[8].

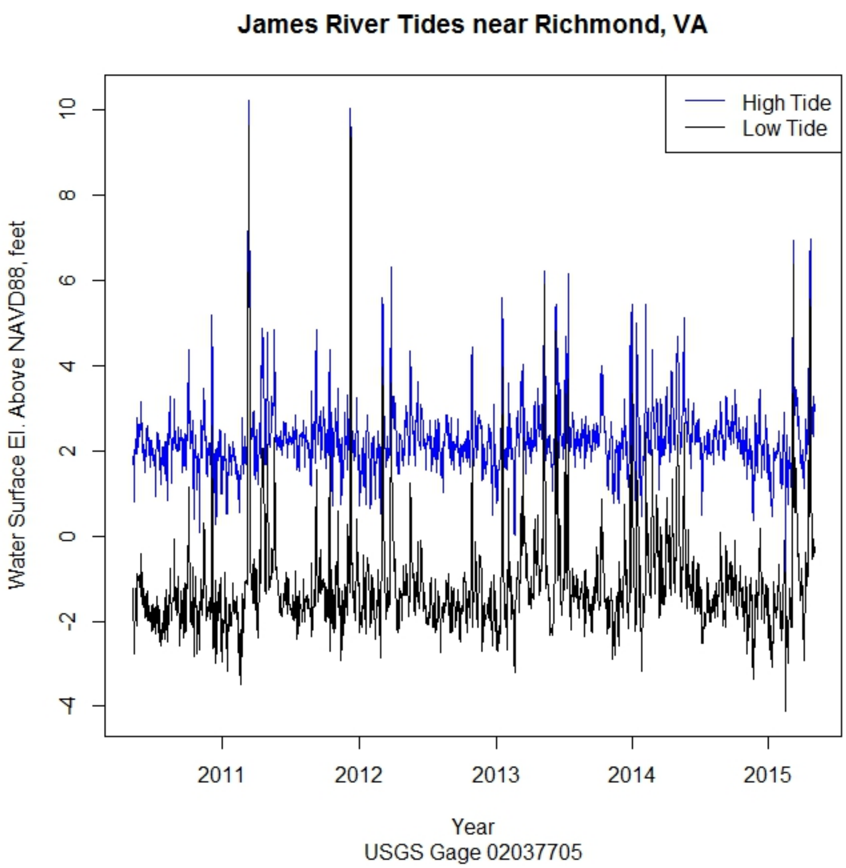

Figure 3.4 USGS gage 02037705[9]

3.3.1.b Geology

The City of Richmond straddles the division between the Coastal Plain and Piedmont physiographic provinces. As seen in Figure 3.5 the Lower James CSO watersheds are entirely in the Coastal Plain but are

[6] FEMA. Flood Insurance Study, City of Richmond, Virginia. Flood insurance number 510129V000B. July 16, 2014.
[7] American Whitewater. https://www.americanwhitewater.org/content/River/detail/id/1952/#tab-map
[8] 9VAC250260-140. Criteria for surface water. Available at: http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
[9] USGS. Gage 02037705. Available at: http://waterdata.usgs.gov/nwis/dv/?dd_cd=11_62620_00021,11_62620_00024&format=img_stats&site_no=02037705&set_arithscale_y=on&begin_date=20100505&end_date=20150505

along the dividing fall zone. The coastal plain upland areas are characterized by low slopes and gentle drainage divides[10]. The underlying geology tends to be fluvial with gravelly sand, silt, and clays.

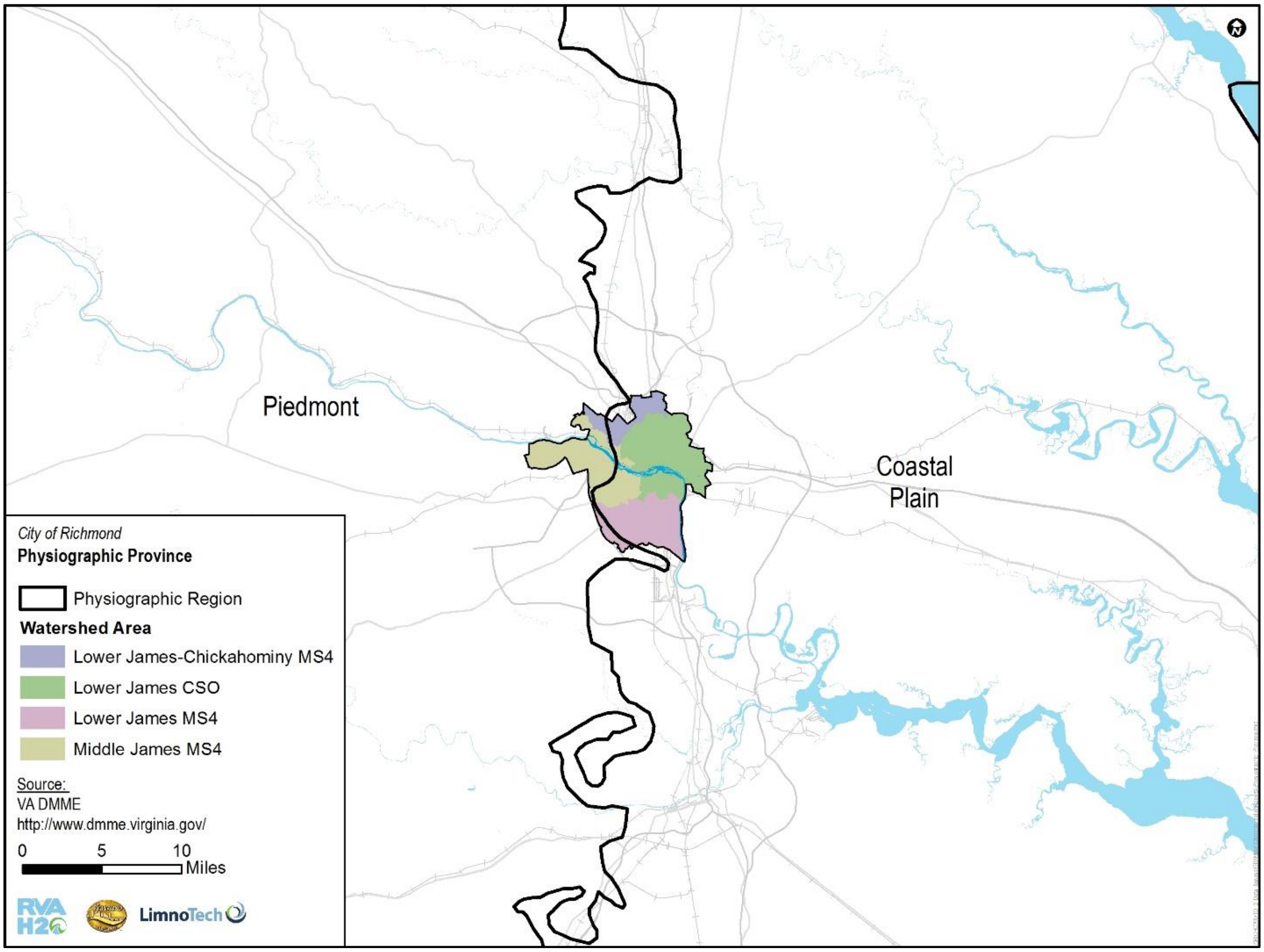

Figure 3.5 Physiographic provinces

[10] William and Mary Department of Geology. 2015. The Geology of Virginia: Coastal Plain province. Accessed April 2, 2015. http://web.wm.edu/geology/virginia/provinces/coastalplain/coastal_plain.html

3.3.1.c Topography

Watersheds in the Lower James CSO area are characterized by average slopes ranging from 3.5% to 7.5% (Table 3-4). Large portions of the watersheds are relatively flat. However, very steep slopes exist in the watersheds, particularly along the James and other major tributaries. For example, steep slopes are found along the James River towards the City center in the Cannon's Branch/Shockoe Creek watershed. Overall elevations in this area range from 0 feet to 232 feet. The highest elevations in the watersheds are seen near the edges of the City (Figure 3.6).

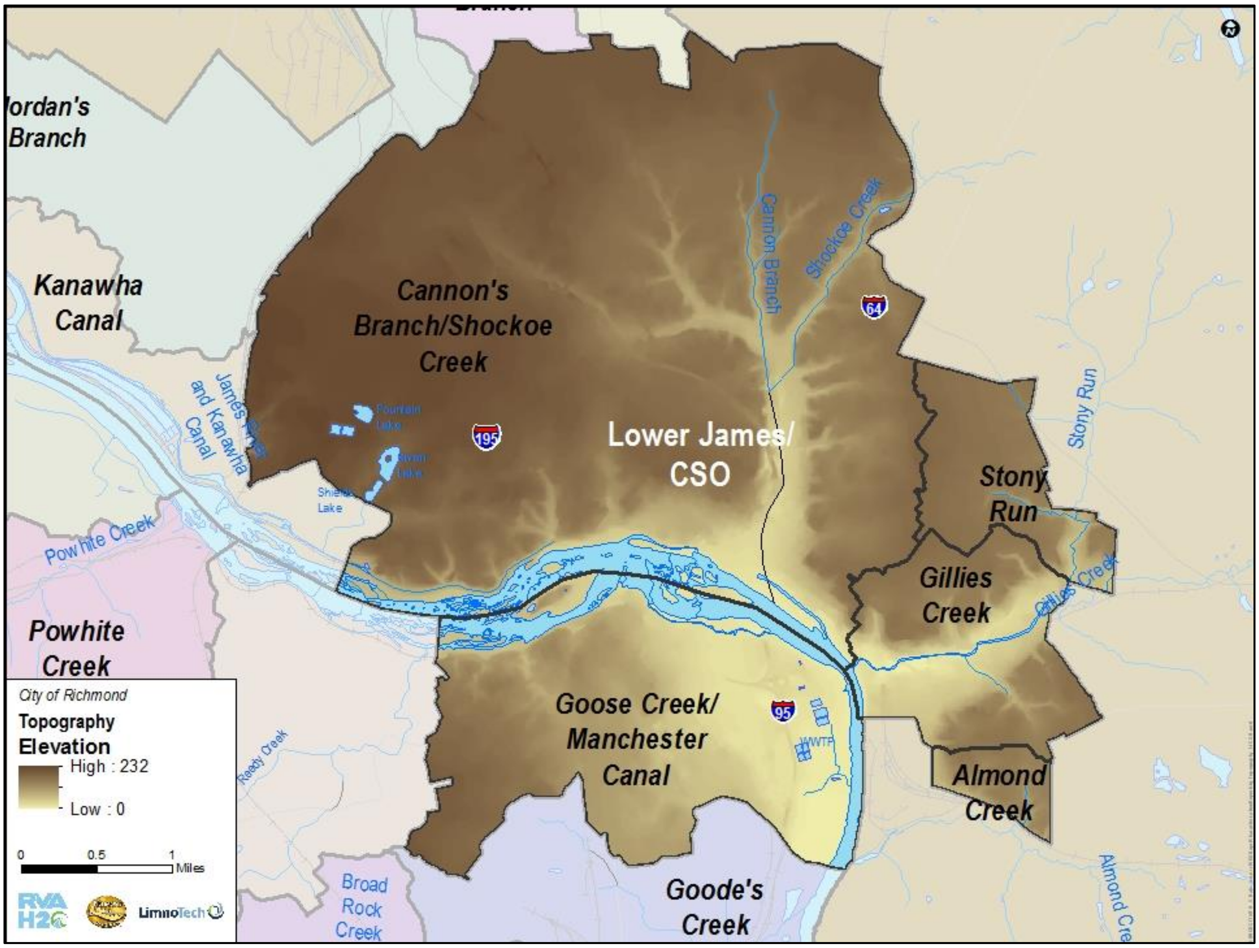

Figure 3.6 Topography of Lower James CSO

Table 3-4 Lower James CSO topography

Waterbody	Low Elevation (ft)	High Elevation (ft)	Average Slope (%)
Almond Creek	47	154	7.5%
Cannon's Branch/Shockoe Creek	0	232	3.9%
Gillies Creek	0	170	6.9%
Goose Creek/Manchester Canal	0	200	3.5%
Stony Run	44	180	3.6%
Lower James/CSO	0	232	4.1%

3.3.1.d Soils

Soils in the Lower James CSO watersheds are primarily composed of urban land complex soils and Udorthents[11]. Udorthents tend to mostly consist of overburden or waste rock and are often found near road or building construction. Both urban land and Udorthents soils have variable composition and have been heavily altered from their natural states.

Soils are assigned a hydrologic soil group (HSG) based on runoff and infiltration characteristics (Figure 3.7 and Figure 3.8). In some urban areas, the soils are so disturbed that the HSG cannot be assigned. This is true for 39% of the soils in the Lower James CSO watersheds (Table 3-5). In these cases, site-specific infiltration testing is required to better classify the ability of a soil to infiltrate water. HSG A soils are present in small amounts in all but the Almond Creek Watershed. These soils have a low runoff potential when thoroughly wet and infiltrate well. HSG B soils, which make up 87% of the Almond Creek watershed and represent the majority of soils in Cannon's Branch/Shockoe Creek and Goose Creek/Manchester watersheds, have a moderately low runoff potential when thoroughly wet. Both HSG A and HSG B soils are well suited for infiltration-type BMPs. Class C and D soils often require underdrains to insure water does not pond in these areas. 61% of the soils in the Stony Run watershed are classified as HSG C soils.

[11] USDA NRCS. 2009. Soil Survey of City of Richmond, VA. http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/virginia/VA760/0/Richmond_VA.pdf .

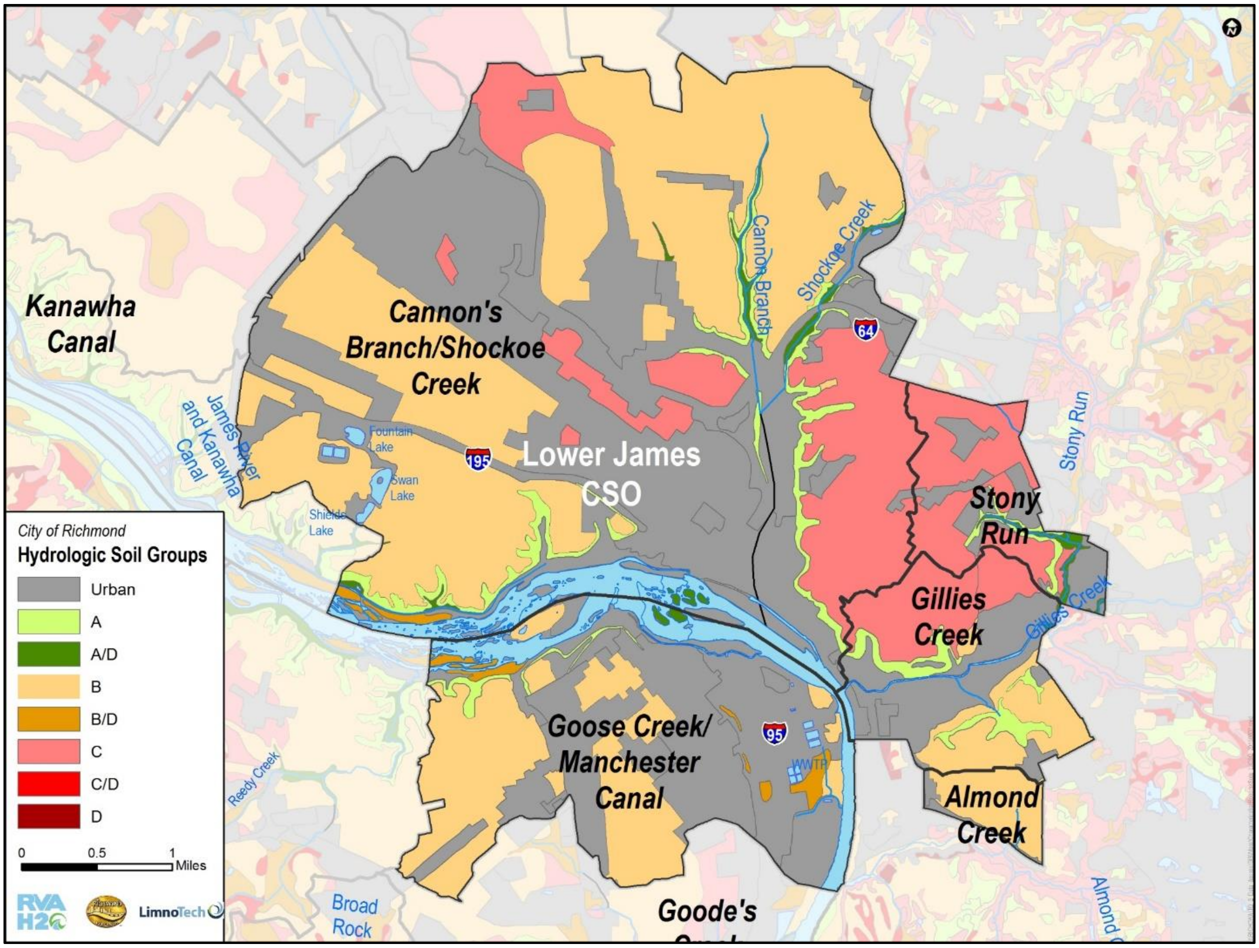

Figure 3.7 Lower James CSO hydrologic soil groups

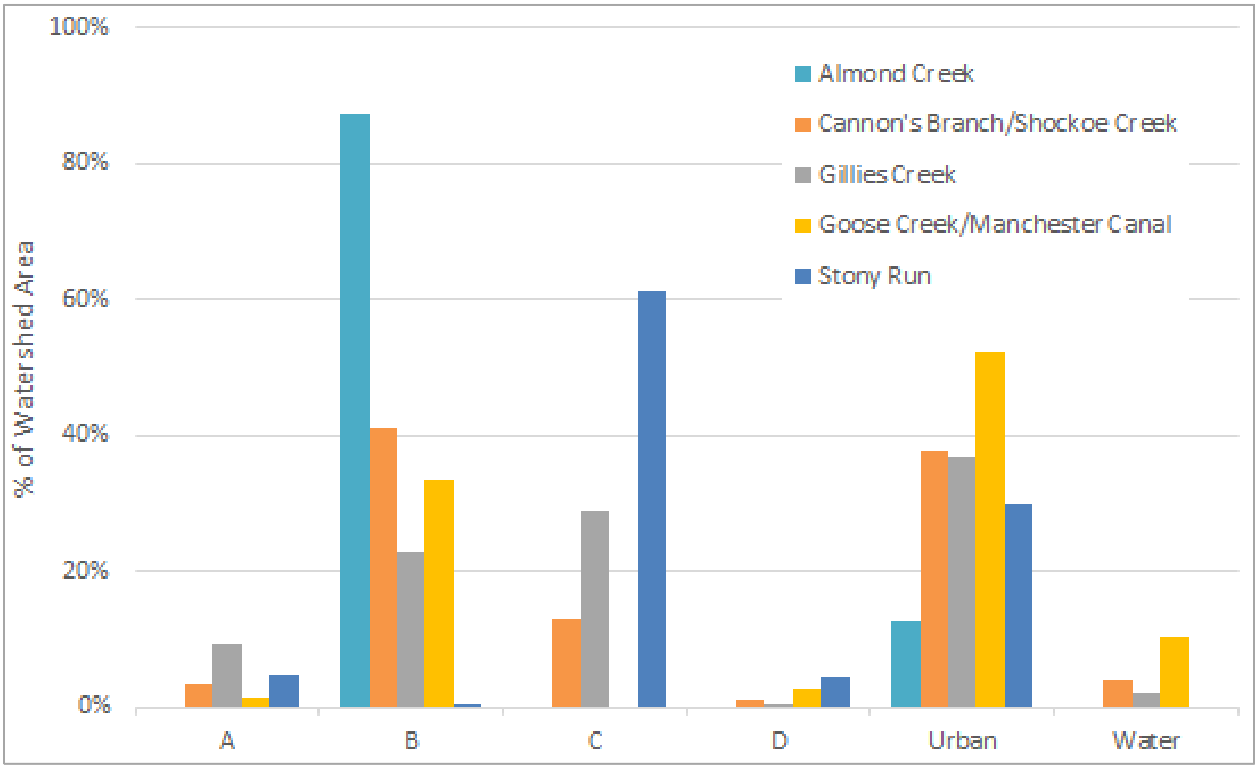

Figure 3.8 Lower James CSO hydrologic soil group

Table 3-5 Lower James CSO hydrologic soil groups

HSG	Almond Creek	Cannon's Branch/ Shockoe Creek	Gillies Creek	Goose Creek/ Manchester Canal	Stony Run	Lower James/ CSO Total
A	--	3.3%	9.3%	1.4%	4.7%	3.5%
B	87.3%	41.0%	22.9%	33.3%	0.0%	36.6%
C	--	12.9%	28.9%	--	61.1%	13.9%
D	--	1.1%	0.3%	2.8%	4.4%	1.6%
Urban	12.7%	37.6%	36.6%	52.3%	29.7%	39.7%
Water	--	4.1%	1.9%	10.1%	--	4.8%

3.3.1.e Climate

The City of Richmond has minimal climate variation across its watersheds. In general, the City of Richmond climate consists of hot and humid summers with mild and wet winters. Annual rainfall averages 43 inches throughout the year with relatively minimal seasonal variation[12]. Table 3-6 shows the range of average temperatures within the City of Richmond from 1948 to 2012 with a low of 27.8° F in January and an average high of 88.9° F in July[13].

Table 3-6 City of Richmond climate

Month	Average High Temperature (deg F)	Average Low Temperature (deg F)	Average Total Precipitation (in)	Average Total Snowfall (in)
January	47.3	27.8	3.09	4.2
February	50.6	29.6	2.91	4
March	59.2	36.6	3.76	2
April	70.3	45.6	3.02	0.1
May	77.7	54.7	3.7	0
June	85.4	63.4	3.7	0
July	88.9	68.2	4.86	0
August	87.2	66.9	4.85	0
September	80.9	59.7	3.87	0
October	70.6	47.7	3.34	0
November	60.9	38.3	3.27	0.3
December	50.4	30.5	3.28	2.3

3.3.2 Land Use/Cover Characteristics

Land use and land cover are important characteristics of watersheds. The way a land is being used has a direct link to the potential pollutants being produced.

3.3.2.a Current Land Cover

The most recent national land cover dataset available through the United States Geological Survey is the 2011 National Land Cover Database (NLCD)[14]. The NLCD provides a 16-class land cover classification scheme. As seen in Figure 3.9, developed land cover at varying intensities is seen throughout a majority of the Lower James CSO area. Some forested land cover is seen towards the edges of the City, particularly in the Stony Run watershed. Figure 3.10 further shows the prevalence of developed areas in the watersheds.

[12] FEMA. 2014. Flood Insurance Study, City of Richmond, Virginia. Flood insurance number 510129V000B. July 16, 2014.
[13] Southeast Regional Climate Center. 2015. Accessed April 2, 2015. https://www.sercc.com/
[14] Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment, 132: 159 – 175. http://www.mrlc.gov/nlcd2011.php

Across all five watersheds, developed land cover is prominent and makes up the greatest percentage of area.

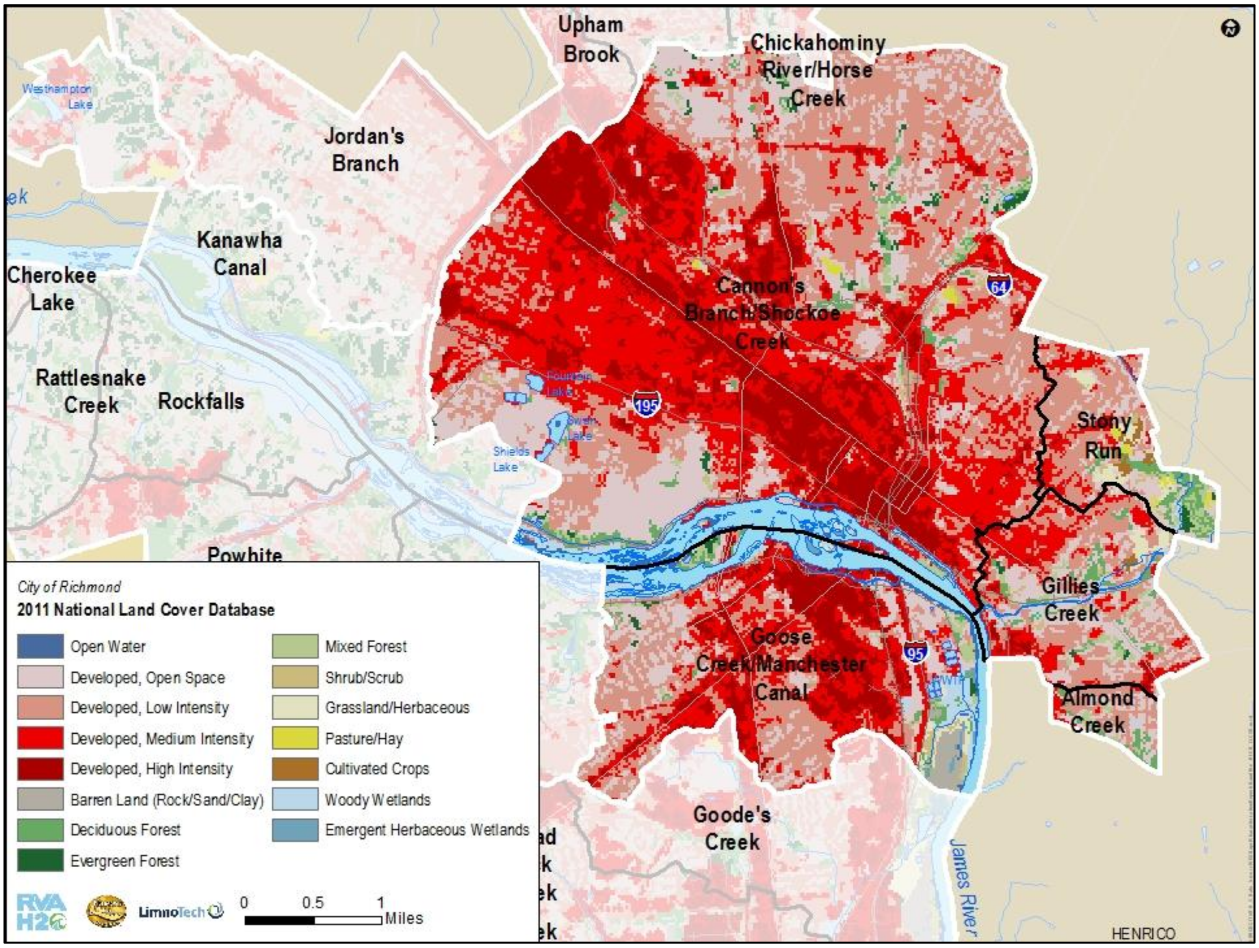

Figure 3.9 2011 NLCD for the Lower James CSO watershed grouping

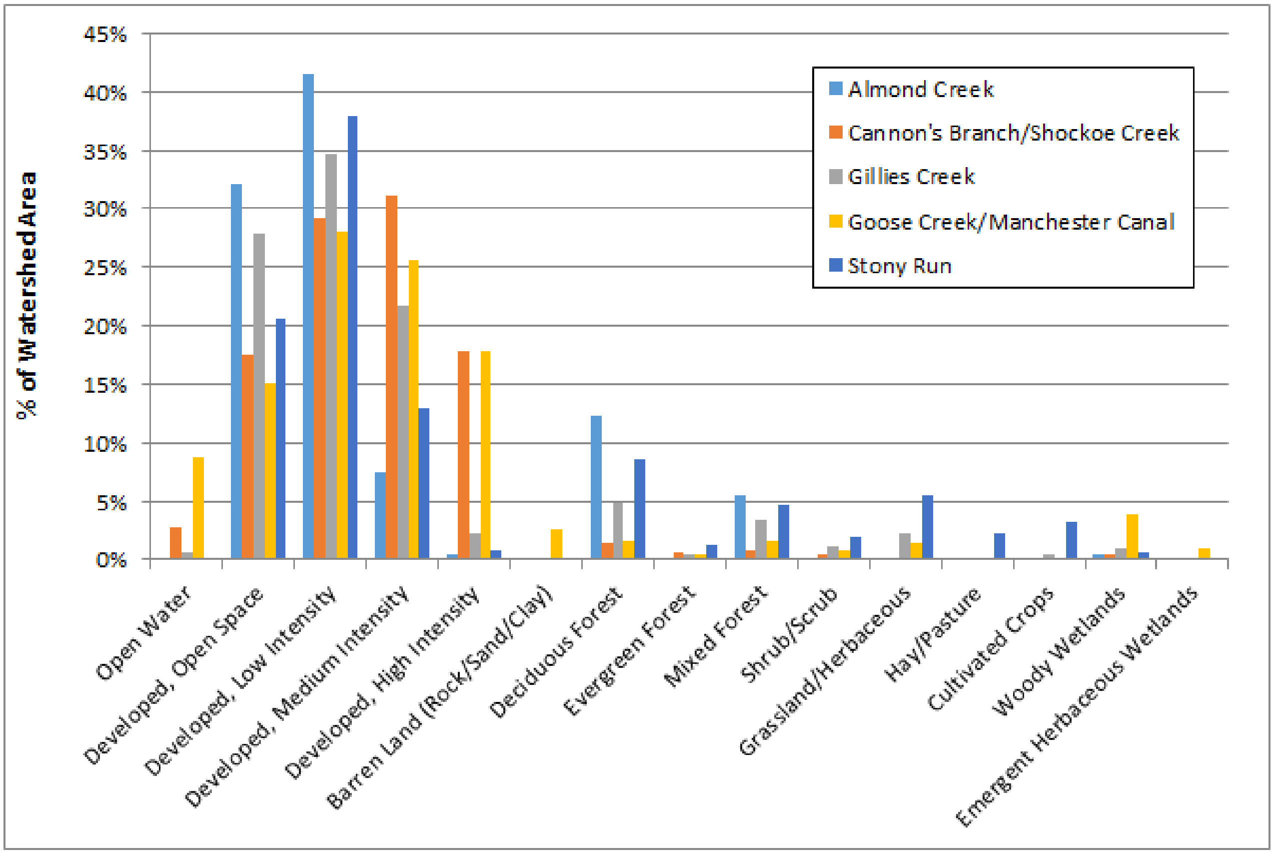

Figure 3.10 NLCD Percent Area within the Lower James CSO watershed grouping

Land cover within the City was also captured at a more local scale by the Virginia Geospatial Extension Program (VGEP). VGEP developed a five class land cover system focused on imperviousness and vegetation based on 2008 data[15]. Figure 3.11 shows how building and non-building imperviousness dominates the areas in the center of Cannon's Branch/Shockoe Creek and Goose Creek/Manchester Canal watersheds. Vegetation and tree canopy are found throughout the watersheds but are more prevalent towards the borders of the City.

From the breakdown of land cover by type (Table 3-7), it is possible to see that the Lower James CSO area is dominated by three land cover categories (non-building impervious, non-tree vegetation, and tree canopy). The five individual watersheds have similar composition. However, Stony Run and Almond Creek watersheds do have higher percentages of vegetation and tree canopy than the other three watersheds.

[15] VGEP Land Cover. Available at:
ftp://ftp.ci.richmond.va.us/GIS/Shapefiles/Environmental/VGEP_Landcover_README.doc

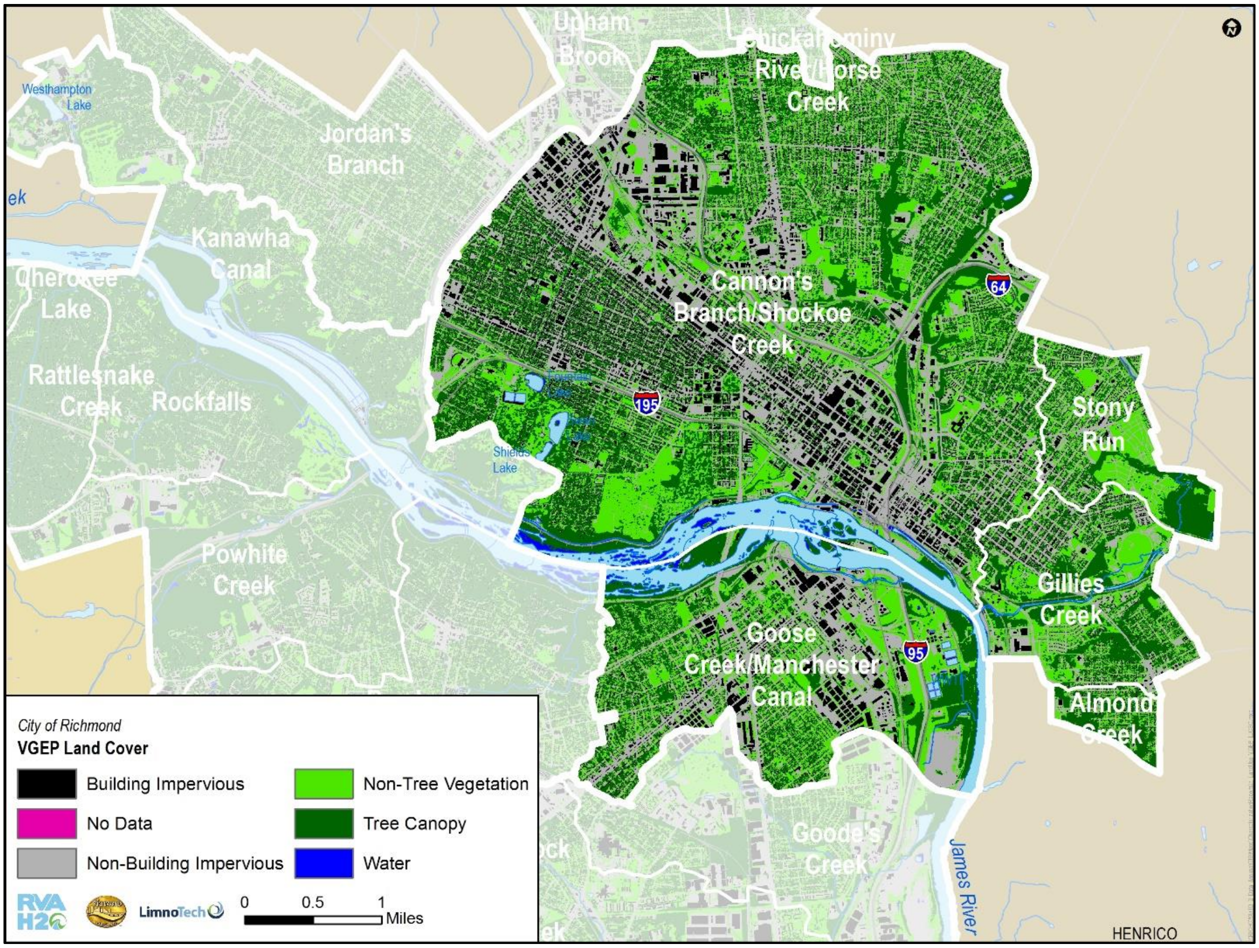

Figure 3.11 VGEP land cover for the Lower James CSO watershed grouping

Table 3-7 VGEP land cover percentage for the Lower James CSO watershed grouping

Watershed	Water (%)	Non-Building Impervious (%)	Non-Tree Vegetation (%)	Tree Canopy (%)	Building Impervious (%)
Cannon's Branch/Shockoe Creek	3.5	30.2	25.2	25.5	15.7
Gillies Creek	1	23.9	34	32	9
Almond Creek	0	16.6	25.3	48.8	9.3
Goose Creek/Manchester Canal	8.7	28.1	28.5	22.7	12
Stony Run	0	20.9	38.8	31.9	8.3
Lower James CSO	4.1	28.5	27.3	26.1	13.9

Imperviousness

Imperviousness in the five watersheds ranges from 29 to 51% with an overall imperviousness of 46% (Table 3-8). Almond Creek, Gilles Creek, and Stony Run have similar imperviousness around 30%. The watersheds in the urban area of the City have the greatest imperviousness. Although the percent imperviousness is slightly different between the five watersheds, the type and distribution of impervious surfaces are similar.

Figure 3.12 shows how impervious surfaces in the Lower James CSO area are dominated by buildings, roads, and parking. The more residential Stony Run watershed has a larger percentage of imperviousness attributed to driveways than the other watersheds.

Table 3-8 Lower James CSO watershed imperviousness

Watershed	Percent Impervious
Almond Creek	29.6
Cannon's Branch/Shockoe Creek	51.1
Gillies Creek	32.3
Goose Creek/Manchester Canal	41.0
Stony Run	29.2
Total Lower James/CSO	**46.0**

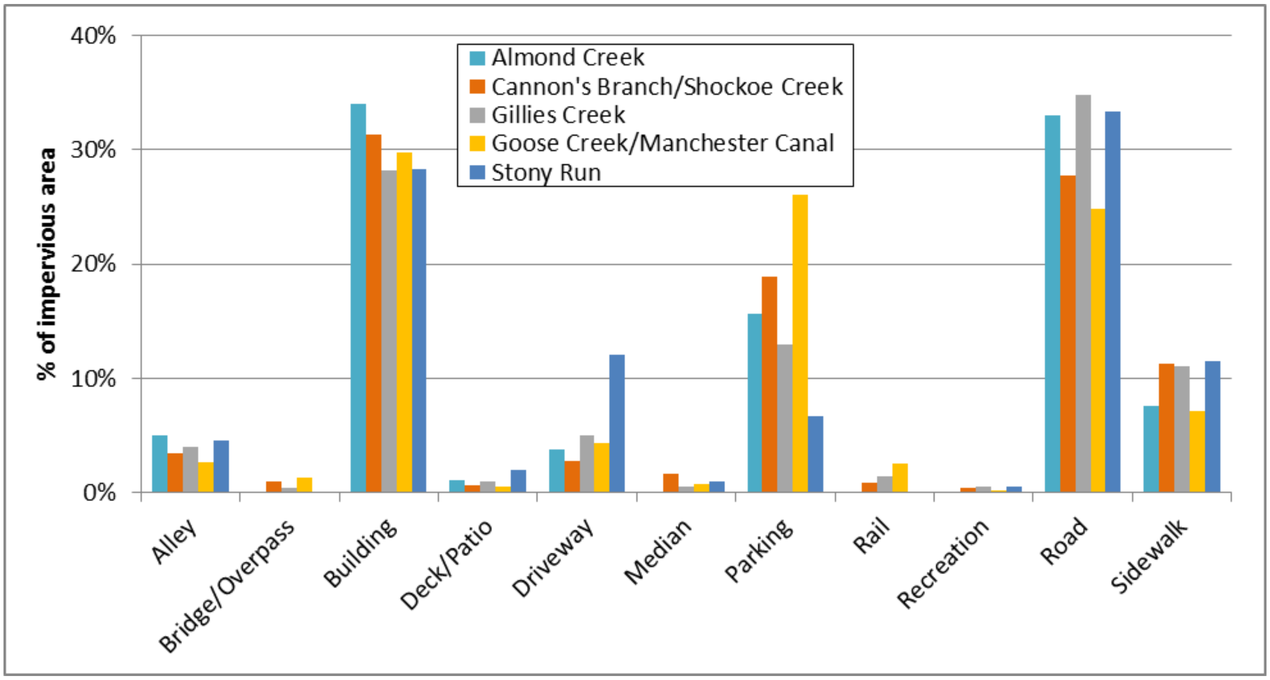

Figure 3.12 Lower James CSO impervious area by type

Septic Systems

According to City records, no septic systems are located in the Lower James CSO area. The absence of septic systems in this area is expected due to the urban and historic nature of the watersheds.

3.3.2.b Land Use

As part of the City's Master Plan, existing land use was mapped in 2008[16]. Residential and commercial land uses are found in all five watersheds (Figure 3.13). public, industrial, and residential land uses dominate the makeup of the Lower James CSO area (Figure 3.14). The built out nature of Cannon's Branch/Shockoe Creek and Goose Creek/Manchester Canal watersheds is reflected in the presence of urban land use categories. The urban areas match well with the developed and impervious land cover seen in the NLCD and VGEP land cover datasets.

[16] http://www.richmondgov.com/planninganddevelopmentreview/PlansAndDocuments.aspx

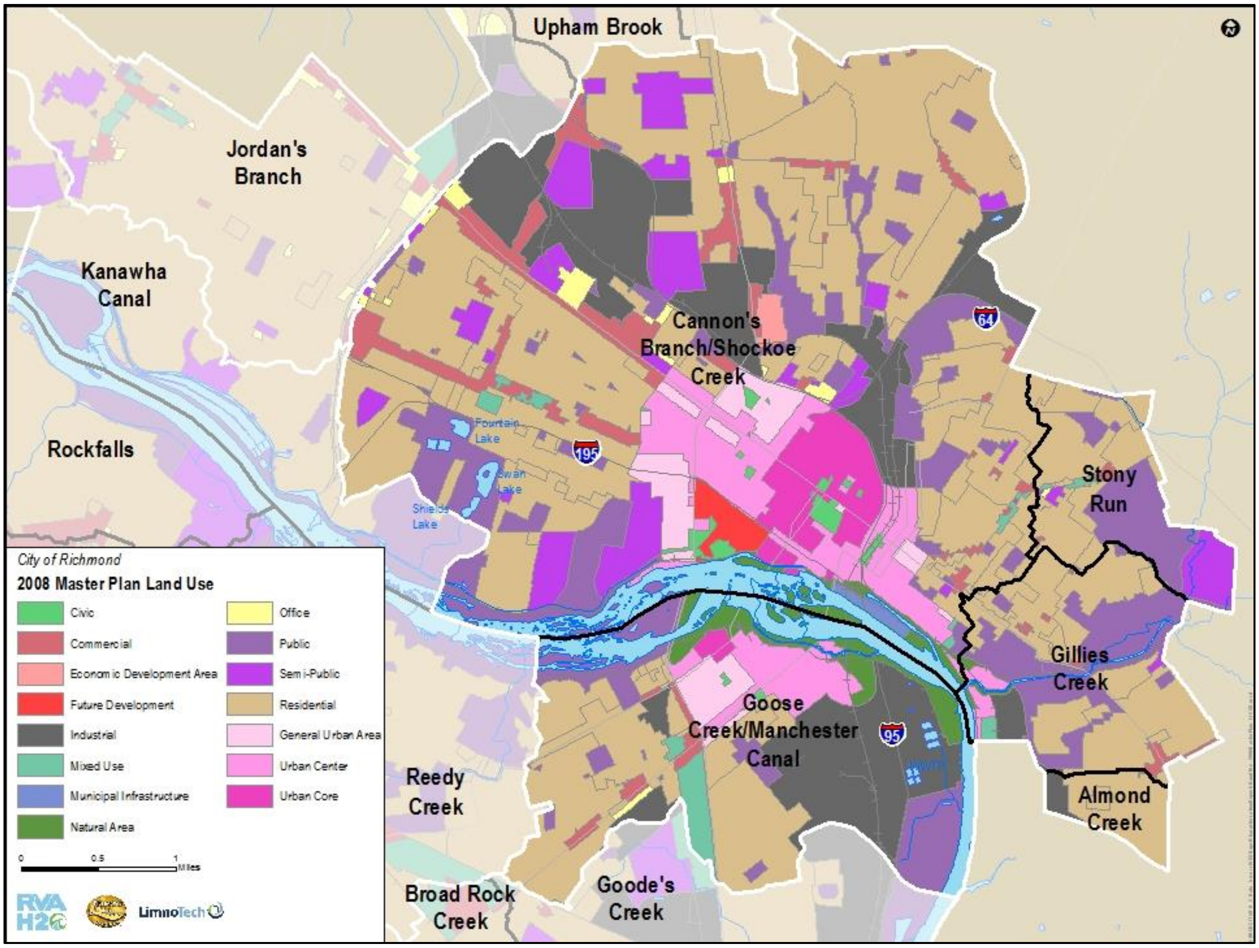

Figure 3.13 2008 Master Plan land use for the Lower James CSO watershed grouping

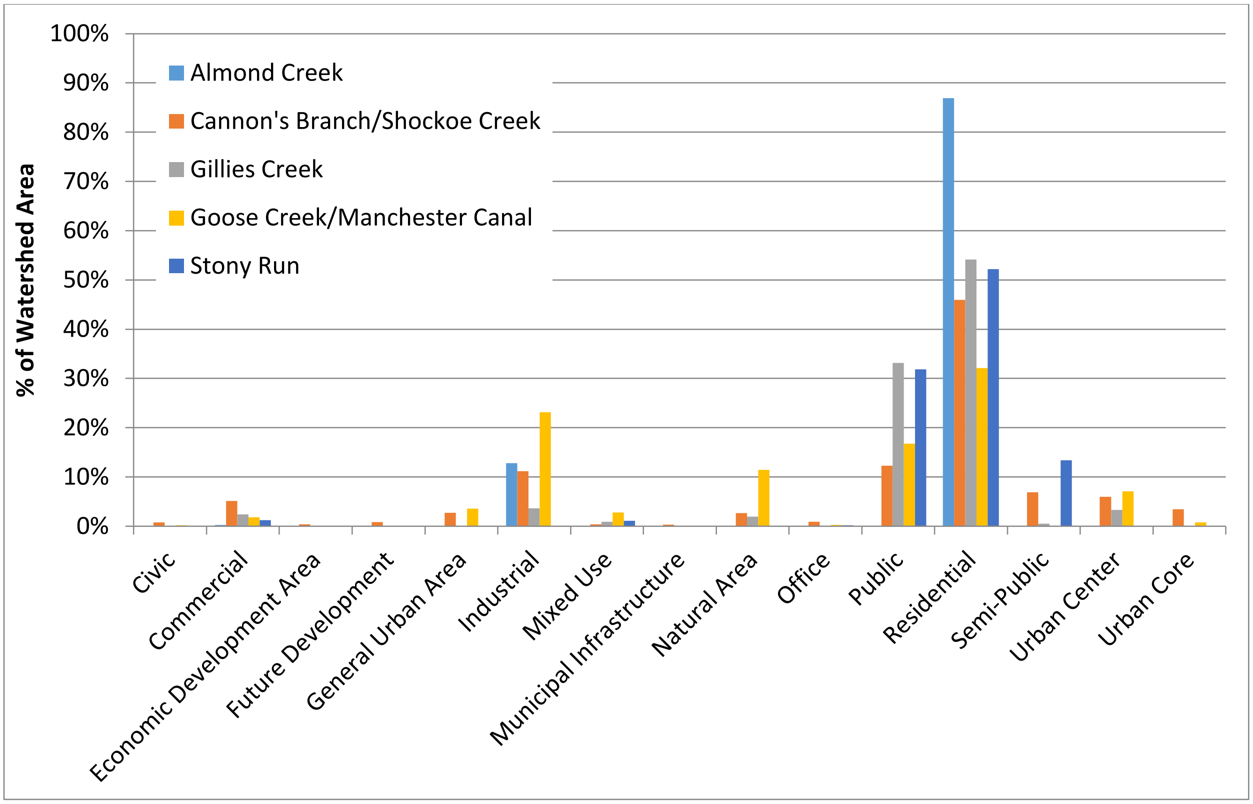

Figure 3.14 Land use within the Lower James CSO watershed grouping

The City of Richmond's Master Plan[17] addresses future planning efforts throughout the City, with a special focus on the James River. Within the Lower James CSO area, individual neighborhood plans have also been developed. In general, the City has land use goals focused on continuing to keep existing land uses and land use patterns moving forward. Richmond hopes to renovate vacant or underutilized lands all while preserving open space and protecting environmentally sensitive land[18].

Of particular interest to the characterization of the Lower James CSO area is the City of Richmond Riverfront plan[19]. In this plan, the City has identified the James River as an important natural and cultural resource that needs to be protected and enhanced in the future. Therefore, the City is developing approaches to provide greater visual and direct access to the James. A number of proposed parks along the riverfront have been identified to enhance interaction with the James (both in the riverine and tidal freshwater segments of river). For example, plans are being developed to provide public access to the James as part of the Mayo's Island redevelopment[20]. Along the James River, particularly from Mayo's Island to the wastewater treatment plan, the City has committed to improving water quality by reducing impervious surfaces and increasing habitat. They plan to promote the movement from hardscape to softscapes, maintain open space where available, and complete water course improvement projects[21].

[17] City of Richmond. 2001. Master Plan. Available at: http://www.richmondgov.com/planninganddevelopmentreview/PlansMaster.aspx
[18] City of Richmond. 2001. Master Plan: Land Use. Available at: http://www.richmondgov.com/planninganddevelopmentreview/documents/masterplan/10LandUse.pdf
[19] City of Richmond. 2013. Richmond Riverfront Plan. Available at: http://www.richmondgov.com/planninganddevelopmentreview/documents/2013-01-22FinalRichmondRiverfrontPlan_R2.pdf
[20] City of Richmond. 2005. James River Corridor. Available at: http://www.richmondgov.com/planninganddevelopmentreview/documents/brochureJamesRiverCorridor.pdf
[21] City of Richmond. 2013. Richmond Riverfront Plan. Page 17.

3.3.3 Infrastructure Features

Similar to other older Cities especially in the eastern United States, the City of Richmond is partially served by a CSS. The City covers a total of approximately 38,000 acres, with 12,000 acres within the combined sewer area. The remaining 26,000 acres are served by a separated sanitary and storm sewer system. Sanitary and the majority of any combined flows are treated by the Richmond WWTP. The CSS also includes the Shockoe Retention basin with a capacity of 44 million gallons[22] as well as the Hampton / McCloy CSO retention tunnel with a capacity of seven million gallons. Combined flows exceeding the system and plant capacity during wet weather events get discharged through CSO outfalls into the James River and its tributaries during wet weather periods. The municipal separate storm sewer system (MS4), which covers about 26,000 acres, discharges directly into the receiving waters through stormwater outfalls. The CSS area is represented by the hatched area in Figure 3.15.

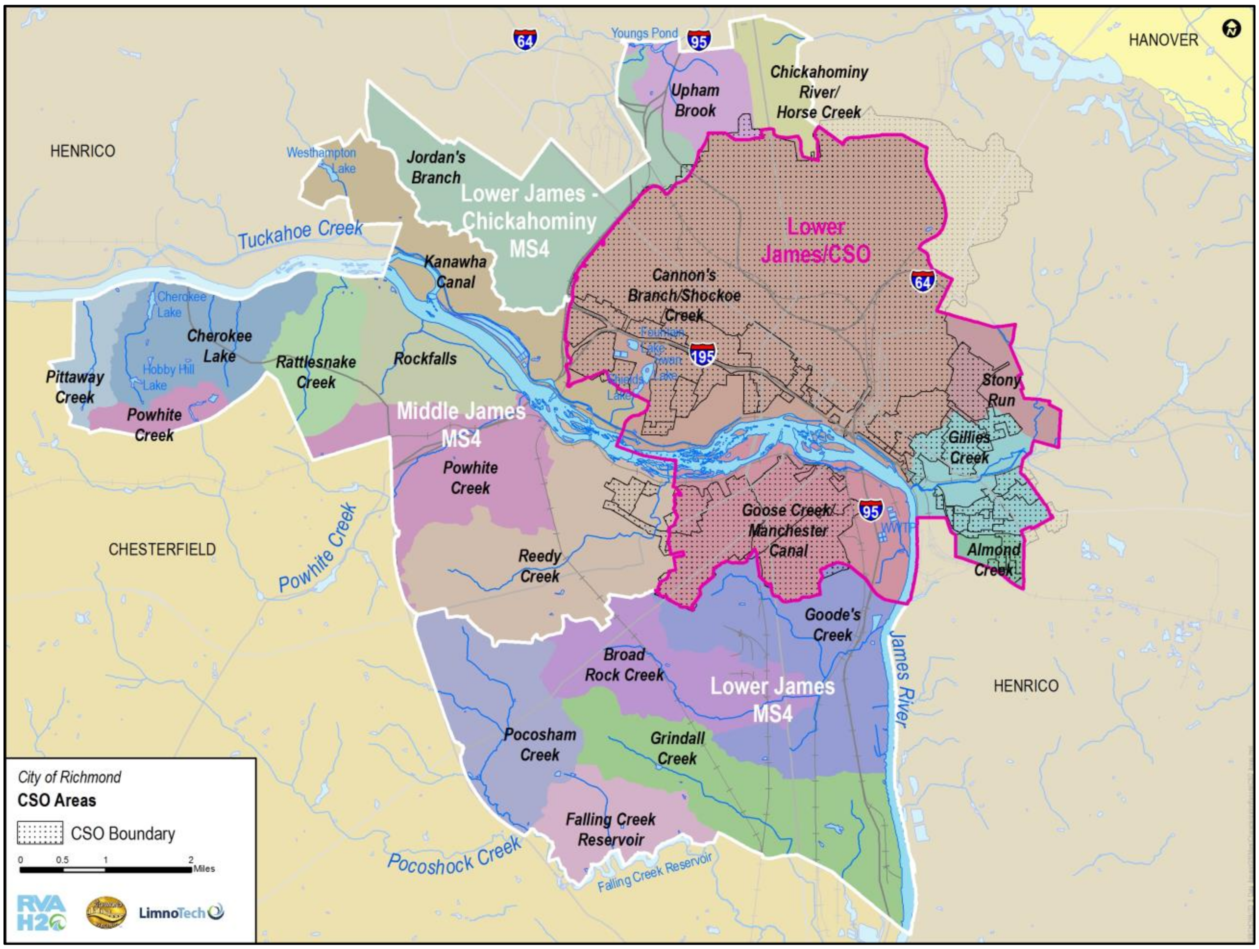

Figure 3.15 Combined sewer area

[22] The basin holds 35 MGD, while in-line storage holds an additional 9 MGD

3.3.4 Wastewater Collection System

3.3.4.a Description and History of CSO Control

The earliest efforts to control CSOs were made in 1946 in response to public demand for pollution control. The construction of interceptors and the WWTP started in the 1950s. Flow regulators were installed at all CSO locations to allow combined wastewater flows exceeding the interceptor (or plant) capacity to overflow into the river during wet weather periods. The Richmond WWTP on the south bank of the James River performed only primary treatment at this time. The plant was upgraded in 1973 to include secondary treatment after the completion of the City's first CSO study. The outcome of this and subsequent studies is listed in Table 3-9 below.

Table 3-9 History of CSO controls

Year	Study / Control detail
1970	Completion of the first study of CSO's.
1972	Completion of a CSO study recommending construction of a retention basin for the Shockoe CSO area.
1974	Initiation of a comprehensive CSO study, including extensive CSO sampling.
1978	Temporary suspension of the 1974 CSO study, awaiting the outcome of State of Virginia James River water quality studies.
1983	Completion of the construction of the Shockoe CSO area retention basin.
1985	Completion of State of Virginia Water Quality Model of the James River. Resumption of 1974 CSO study.
1987	Initiation of construction of WWTP improvements to increase plant capacity during wet weather events to allow emptying of Shockoe CSO area retention basin in two days and to accept additional wet weather flow.
1988	Completion of the comprehensive CSO study defining the LTCP for the CSO's.
1990	City completes the implementation of the initial elements (Phase I) of the approved plan.
1992	State Water Control Board issues a Special Order requiring implementation of additional elements included in Phase II of the plan. This Special Order includes a requirement 7(d) to Re-Evaluate the CSO Control Plan, at the end of Phase II to determine if changes should be made to the approved plans.
1996	The Department of Environmental Quality (DEQ) amended the Special Order to accelerate all the Northside CSO Control Projects and place on hold the swirl concentration project because this technology had not produced, nationwide, the expected results.
1998	City places in operation all CSO conveyance projects on the south and north sides of the James River.
1999	The DEQ Piedmont Regional office issues a Special Order by Consent requiring the city to advance the schedule of the re-evaluation of the CSO Control Plan consistent with the EPA National CSO Control Policy.
2002	City completes CSO Re-Evaluation Report.

Year	Study / Control detail
2003	City places in operation CSO Retention Tunnel on the north side of the James River.
2006	Completion of the Program Project Plan that shows the master plan for the Phase III CSO Controls.
2007	The DEQ is evaluating the WQS and developing a water quality model as part of the Richmond Area Total Maximum Daily Load.

3.3.4.b Long Term Control Plan System Upgrades

The study for the initial LTCP for the City of Richmond was released in 1988. Phase 1 controls of the approved plan were implemented in 1990. The implementation of the phase II controls began in 1992 under a special agreement with the Virginia Department of Environmental Quality (DEQ). The elements included in the Phase II are shown in Table 3-10 below:

Table 3-10 LTCP Phase II controls

CSO Project	Description	Completion
1	Southside conveyance system between Canoe Run and near Mayo's Island	In operation since 1998
2	Southside conveyance system between 42nd Street and Canoe Run	In operation since 1998
3	Northside conveyance system between Park Hydro and Shockoe	In operation since 1998
4 and 5	Hampton and McCloy CSO Retention Tunnel	In operation since 2003

3.3.4.c Combined Sewer System – Current Conditions

The separate and combined areas of the Richmond sewer system are linked with a system of interceptors and trunk sewers connecting the system to the WWTP. The combined area has 31 CSOs, 28 of which are within the "Lower James CSO" watershed grouping (see Section 3.2 – Watershed Delineation). All CSOs are controlled by a regulator structure. During dry conditions these regulators divert all dry-weather flows to the WWTP. During wet weather events, the regulator diverts combined flows exceeding the system capacity to the CSO. This allows maximized treatment of combined flow at the treatment plant. The CSO regulator capacity typically is in excess of three times the intercepted dry weather flow at the regulator location.

The combined sewer area also includes the Shockoe Retention basin, storage and retention facility in the Shockoe CSO area which holds the first 45 MG of combined flows that exceed the WWTP treatment capacity. Flow volumes stored at the Shockoe facility are usually released to the WWTP within 48 hours after the wet-weather event. Wet weather flow volumes exceeding the capacity of the Shockoe Retention basin are released through the Shockoe outfall (CSO 006).

Additional system storage in the combined sewer area is provided by the Hampton / McCloy CSO retention tunnel which was built in 2003. This structure is able to store a total volume of 7.2 MG combined wet weather flows in the Hampton and McCloy CSO area (CSOs 019 and 020). The retained flow volumes at the retention tunnel are also released to the WWTP within 48 hours after a wet weather event. Figure 3.16 shows the major infrastructure components of the City's combined sewer.

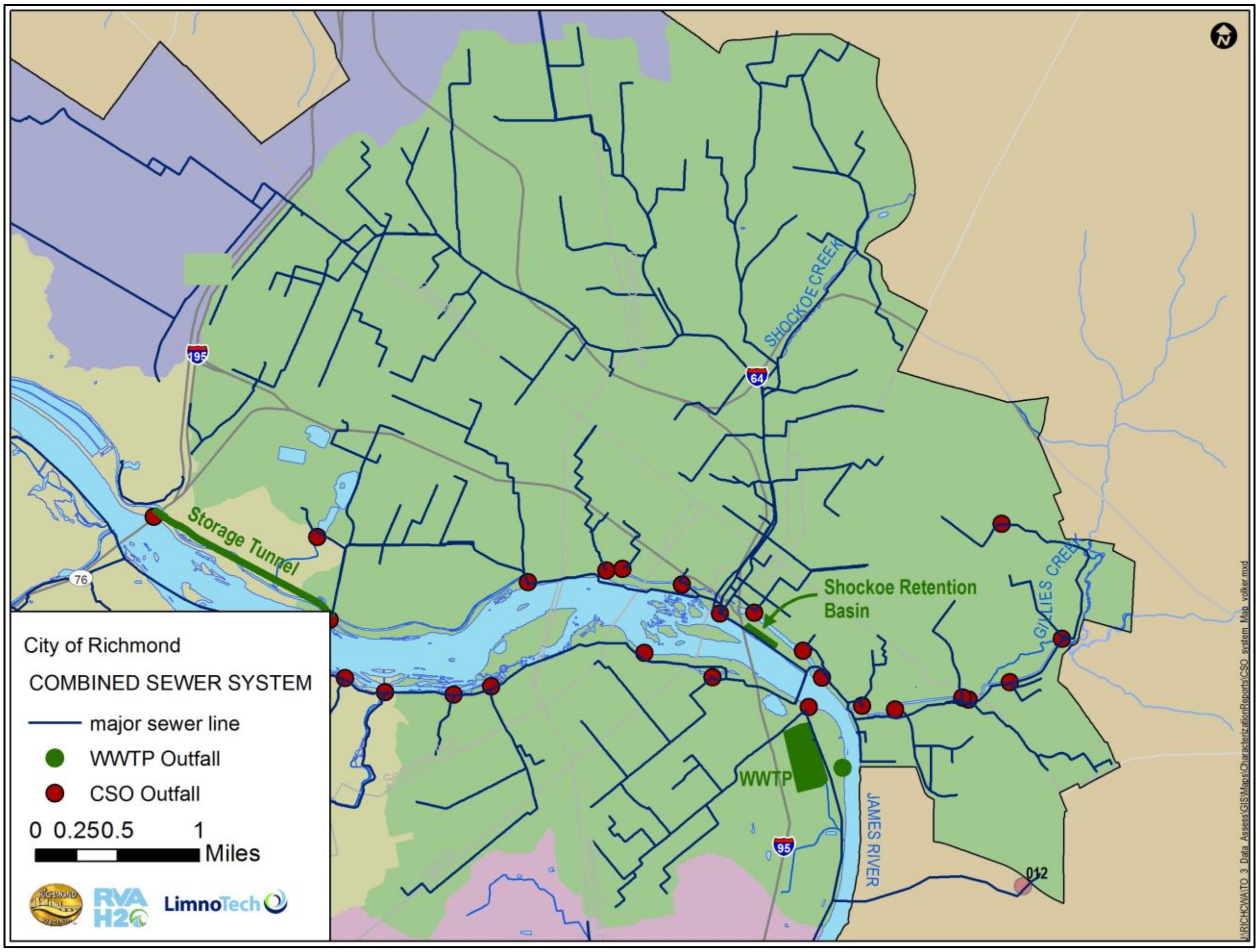

Figure 3.16 Major combined sewer system infrastructure features

3.3.4.d CSO Locations and Sewer Overflows

The City of Richmond has 31 active CSO overflow locations which are listed in the City's VPDES permit. All outfalls, their location as well as their typical annual overflow frequency and volume are listed in the Table 3-11 below. A map showing the location and status of all CSOs is shown in Figure 3.17.

Table 3-11 CSO locations in the Lower James CSO watershed grouping

Outfall	Designation	Outfall Location	Typical Year **	
			Frequency	Volume (MG)
~~002*~~	~~Orleans Street~~	*Outfall was removed in 2013*	*NA*	*NA*
~~003*~~	~~Nicholson Street~~	*Outfall was removed in 2013*	*NA*	*NA*
004	Bloody Run	North bank of Gillies Creek Paved Channel, 300 ft east of Rt 5	34	8.81
005	Peach Street	North bank of James River, 75' S of southern lock gate	2	0.10

Outfall	Designation	Outfall Location	Typical Year **	
			Frequency	Volume (MG)
006	Shockoe Creek	North bank of James River near Shockoe Diversion Structure	76	1,511.82
007	Byrd Street	End of 12 St. & downstream of Haxall Canal Spillway	0	0.00
009	Seventh Street	At Haxall Canal & 7th St. Footbridge	0	0.00
010	Gambles Hill	350 Tredegar St., 100' east of Haxall Canal Headgates	0	0.00
011	Park Hydro	At James River near 160 Tredegar St.	3	2.60
012	Hilton Street	Southside of Railroad tracks at Campbell Ave extended	14	2.20
~~**013***~~	~~Maury St~~	*Outfall was removed in 2011*	*NA*	*NA*
014	Stockton Street	South bank Machester Canal at Stockton St extended	13	20.05
015	Canoe Run	At River near W 22nd St. & Riverside Dr.	2	1.51
016	Woodland Heights	At River near W 26th St. & Riverside Dr.	0	0.00
017	Reedy Creek	At River near W 30th St. & 2001 Riverside Dr.	0	0.00
018	42nd Street	At River near W 42nd St. & Riverside Dr.	0	0.00
019	Hampton Street	North bank of James River at Hampton St extended	2	2.01
020	McCloy Street	North bank of James River under Powhite Bridge	0	0.00
021	Gordon Avenue	South bank of James River opposite entrance to WWTP	56	98.18
023	Old Ful St Bridge	South bank of Gillies Creek Paved Channel	0	0.00
024	White & Varina Streets	South bank of Gillies Creek Paved Channel, 300 ft west of Government Rd	25	7.31
025	Briel Street	North bank of Gillies Creek Paved Channel, 250 ft west of Jennie Scher Rd.	26	4.29
026	1250' East of Government Road	South bank of Gillies Creek Paved Channel, 1250 ft east of Government Rd	5	0.54
027	New W'Burg Road	South bank of Gillies Creek Paved Channel	0	0.00

Outfall	Designation	Outfall Location	Typical Year **	
			Frequency	**Volume (MG)**
028	Williamsburg Road & Gilles Creek	South bank of Gillies Creek Paved Channel, 80' west of Williamsburg Rd	10	1.43
031	Oakwood Cemetery	North corner of Oakwood Cemetery at Stony Run Creek	3	1.05
033	Shields Lake	SW of Shields Lake	0	0.00
034	19th & Dock Streets	North bank of City Dock at 19th St extended	48	39.25
035	25th & Dock Streets	North bank of Haxal Canal at 25th St extended	1	0.02
039	550' Downstream from Government Road	North bank of Gillies Creek Paved Channel, 550' west of Government Road	28	11.14
040	Diffuser	In River, on south side, between the Manchester (9th St) Bridge and the Mayo's (14th St) Bridge	44	91.73

(*)Outfall removed but listed in current VPDES permit, (**) 2014 data shown

3.3.4.e CSO Monitoring (Flow, Precipitation, Water Quality)

The City continuously monitors flow at 18 locations and precipitation at 6 locations for the Shockoe CSO Monitoring Program. Related monitoring information could not be obtained at this time.

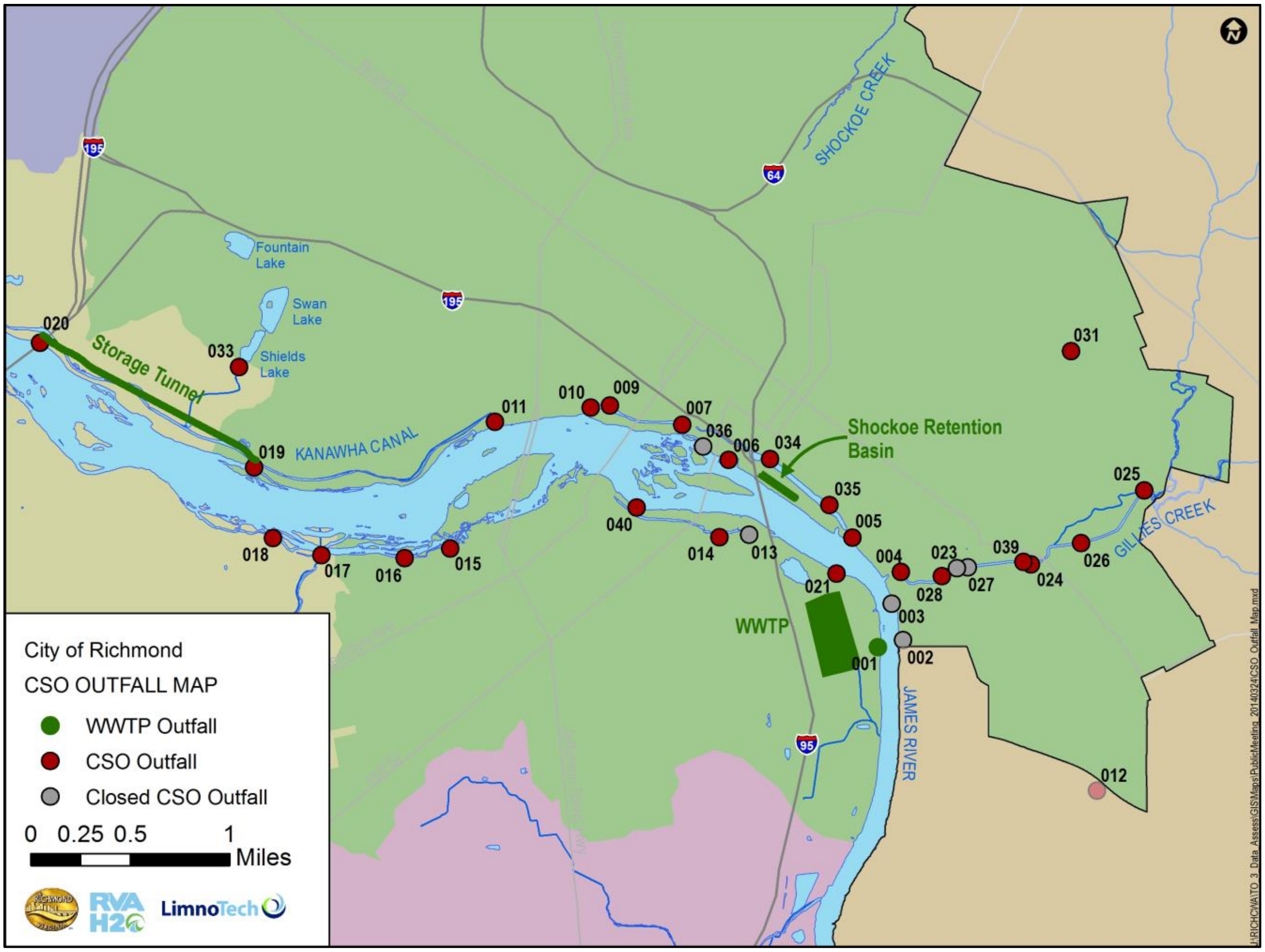

Figure 3.17 Location of CSO points in the Lower James CSO watershed grouping

3.3.4.f Modeling

The City of Richmond's first CSS model was built in 2001 based on EPA's Stormwater Management Model (SWMM, 4.4GU) as part of the LTCP. It was subsequently used for the City's annual and monthly CSO reporting requirements as part of their VPDES permit.

In 2004, an updated version of EPA's model (XP-SWMM) was used to develop a hydraulic model that evaluated dry weather capacities for interceptor boundary inflow from neighboring municipalities.

Two additional CSS models were developed in 2012 for pipe capacity evaluations in the Gillies Creek and Manchester Canal subsheds as part of the City's Stormwater Master Plan. Those models were based on InfoSWMM.

The City is currently combining and updating the existing hydrologic and hydraulic models of the sewer collection system as part of the update to their Wastewater Collection System Master Plan. The new model covers the whole sanitary area including the combined sewer area and areas outside of the City boundaries that discharge into the City's collection system. All major interceptors and active CSO overflow points are represented in the model. The model is currently being calibrated using metering data from multiple locations throughout the City using long-term monitoring data. After completion, the model will be used for generating monthly and annual CSO overflow reports as well as for pipe capacity analysis and scenario evaluation for the Collection System Master Plan.

3.3.4.g Current CSO Control Status

The City of Richmond is authorized to discharge treated flows from the City's sanitary and combined sewer areas through the WWTP as well as through their system of CSOs. This authorization is given in the City's VPDES permit issued by Virginia DEQ (permit No. VA0063177). The permit lists a number of conditions to be met by the City. One of the requirements is a continuous implementation of operation and maintenance activities relative to the CSOs and their effects on receiving water quality. These required activities are given in the nine minimum controls which are part of the VPDES permit. To date the City has successfully implemented the following controls[23]:

Proper Operation and Maintenance

- CSO control structures (e.g. regulators and tide gates) inspected and performed maintenance once per month
- Pumping Stations inspected, screenings removed and performed maintenance daily
- Regular program of sewer flushing

Maximize Use of Collection System for Storage

- CSO regulator controls set to optimize storage in intercepting system
- Shockoe Retention System (55mg) serves about 8,000 acres of CSS and captures an average of about 1,416 mg of combined sewer flow annually (about 43.1 percent) of the total that would otherwise overflow. Retained flow normally receives complete treatment within 48 hours.
- Approximately 25,000 feet of sewer are relined annually to reduce inflow and infiltration
- WWTP influent pumping normally adjusted during wet weather events to fill intercepting system to level of lowest overflow
- Tide gates adjusted and repairs made to control tidal intrusion
- Public and private facilities required to install stormwater storage in combined sewer area
- Floodwall pumping stations include excess flow holding ponds to maximize storage during flood periods

Review and Modify Pretreatment Requirements

- Pretreatment ordinance and program in effect
- CSO modeling and analysis does not show any impacts that might be attributed to nondomestic sources
- Several industries retain stormwater during wet weather events and control releases after the event to stay within pipe capacities
- Discharge of water treatment plant residuals to the CSS is stopped during wet weather events

Maximize Flow to the publically-owned treatment works (POTW) for Treatment

- Treatment rates at POTW are designed to be increased during wet weather events
- POTW has high flow treatment plan designed to convey in excess of twice the dry weather flow through complete treatment during wet weather events

[23] City of Richmond. 2015. Combined Sewer System Annual Report for 2014.

- Retention facilities are emptied within 48 hours following a wet weather event
- Retained flow receives complete treatment to permit limits

Eliminate Dry Weather Overflows (DWOs)

- Combined sewer diversion system design has capacity to convey in excess of three times the dry weather flow to WWTP
- Diversion facilities inspected regularly to insure they are in proper working order
- Pumping stations are monitored to detect any DWOs caused by clogging or equipment malfunction
- Shockoe retention facility continuously manned
- DPU maintains a 24-hour on-call team responsible to respond to reported DWOs
- No new combined sewers constructed inside or outside of the existing CSS area.

Control of Solid and Floatable Materials in CSOs

- Continuous screening provided at Shockoe retention facility for over two-thirds of the CSS
- New combined sewer conveyance system (under construction) equipped with continuous self-cleaning solids and floatables capture facilities
- Solids and floatables captured are removed at source or conveyed to WWTP for removal
- Increased screening during leaf season/leaf pickup twice per season
- Regular litter and annual free citywide litter cleanup programs
- Regular street cleaning and downtown sidewalks scrubbing programs
- Regular annual catch basin cleaning program

Pollution Prevention

- DPU has a regular public education program with facility tours including advice on proper disposal of substances (e.g., household wastes, leaves and use of fertilizer)
- Adopt a street and Clean City business awards programs
- Pretreatment program includes awareness programs that encourage industrial waste reduction through recycling and improved housekeeping
- DPU operates and maintains a septage receiving station
- Ordinances designed to prohibit entrance of any substances that may impair or damage the function and performance of collection and treatment systems

Public Notification

- CSO control facilities under construction are expected to reduce overflows at public use/access areas of James River to an average of from 0 to 1 per year with remaining overflows expected in winter months (e.g. high river flows, little public activity). If greater CSO exposure is subsequently identified, signs to be posted are evaluated for installation.
- Numerous public meetings and hearings have been held to provide the public information and obtain public input on the CSS, CSOs and control program

- Community meetings have been held to inform local groups on proposed control facilities
- Local press coverage of CSO program developments is continuing

Monitoring

- Conduct flow monitoring and wet weather overflow sampling for the Shockoe Creek outfall (006) combined sewer area once per permit cycle. Report is provided to VDEQ.
- A twice weekly and wet weather event instream monitoring/sampling program will be conducted on the James River for dissolved oxygen, temperature, pH and fecal coliform once per permit cycle.
- A complete SWMM based (sewer overflow model, SOM) hydraulic model has been created for the CSS. A CSO impact model has been developed for the tidal James River (PULSEQUAL). Both models will be updated and verified using the monitoring and sampling data once per permit cycle.

Improvements have been made to the majority of the CSO areas. An overview is given in Figure 3.18.

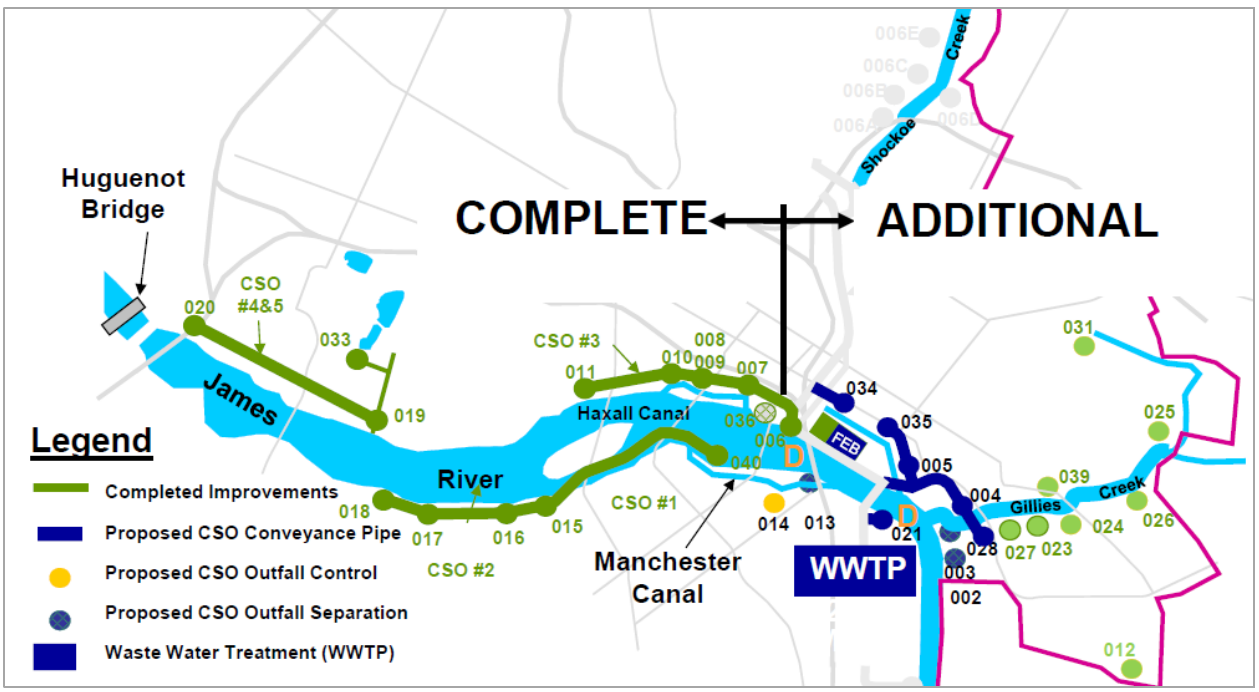

Figure 3.18 Completed CSO area improvements

3.3.4.h Sewer System Evaluation Surveys

The City of Richmond completed the Wastewater Collection System Master Plan in 2004, outlining multiple recommended improvements to be implemented over a ten-year period. Sewer rehabilitation is a major component of the program due to the average age of the sewer infrastructure. Sewer lining extends the service life and improves the capacity of the existing system, while isolated pipe replacement projects are targeted to address specific hydraulic capacity needs.

The Master Plan provided a general approach to system improvements, with the intent that detailed evaluations would be completed as the program is implemented within each basin. The entire service area includes 21 basins that have been further divided into 139 sewersheds. The Master Plan ranked the system condition within each sewershed based on service call history and pipe material. The top 10 priority sheds for the sewer system evaluation surveys (SSES) are shown in Table 3-12:

Table 3-12 SSES priority sewersheds

Rank	Shed-ID	SSES Status
1	SH-01	Completed
2	SH-27	Completed
3	SH-04	Completed
4	WE-07	Completed
5	PH-01	Completed
6	MN-02	In process
7	HM-02	In process
8	SH-10	Not started
9	SH-12	Not started
10	SJ-01	Not started

The sewershed individual SSES reports include a preliminary infrastructure condition assessment, field investigations and a rehabilitation plan summarized in an engineering report. All but one of the top 10 SSES priority subsheds are located within the “Lower James CSO” watershed area. Figure 3.19 shows the location of the SSES subsheds.

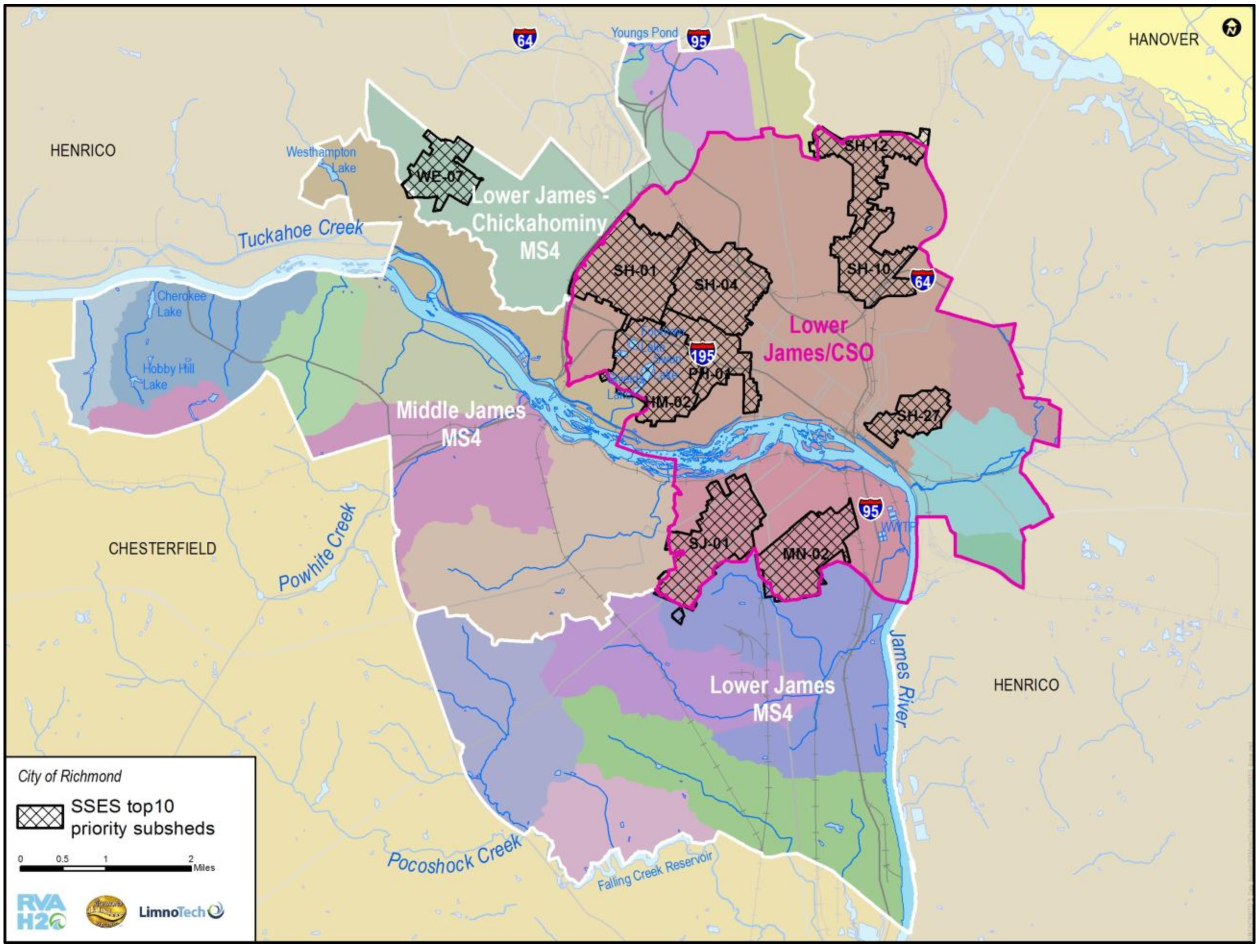

Figure 3.19 SSES study top 10 priority subsheds

3.3.5 Wastewater Treatment System

3.3.5.a Description and History

Richmond's WWTP is located on the south bank of the lower James River and was constructed in the 1950's. The initial WWTP performed only primary treatment including screening, grit removal and primary sedimentation. Upgrades to the WWTP included additional soil handling facilities, sludge digesters and a grit chamber in the 1960's. The WWTP was upgraded in 1973 to secondary treatment in order to reduce the biological oxygen demand (BOD) and total suspended solids (TSS). The plant capacity was increased in the late 1980's to enable additional treatment of wet weather flows in connection with the construction of the Shockoe Retention basin. Effluent filters were added to the WWTP in the early 1990's.

The plant currently serves a population of approximately 215,000 people and receives wastewater from roughly 58,000 connections within the City limits of Richmond as well from the neighboring counties of Henrico, Goochland, and Chesterfield. Fifty-three industrial contributors discharge to the WWTP, including 15 Categorical Industrial Users (CIU). The design capacity of the plant is 45 MGD for dry weather flow and up to 75 MGD for wet weather flow through the plant's main outfall 001 which is located at river mile 2-JMS108.83. An additional discharge capacity of up to 65 MGD wet weather flow is provided by outfall 041 which receives primary treatment. The operation of the Richmond WWTP is permitted by Virginia DEQ via VPDES permit VA0063177. An overview over the general wastewater treatment processes at the Richmond WWTP is listed in Table 3-13 below and additionally shown in Figure 3.20.

Table 3-13 City of Richmond WWTP treatment processes

Treatment process	Treatment Type
Primary Screening and grit removal	Primary
Secondary screening and grit removal	Primary
Primary settling with hydro degritting	Primary
UV disinfection and post aeration	Primary
Aeration basins (step aeration)	Secondary
Secondary settling	Secondary
Denitrification filters	Advanced
Filtration	Advanced
Anaerobic sludge digester	Solids Handling

The City of Richmond's current VPDES permit allows discharges through outfall 001 during dry weather conditions with up to 45 MGD and 75 MGD during wet weather conditions. The discharge conditions that have to be met by the VPDES permit are listed in Table 3-14.

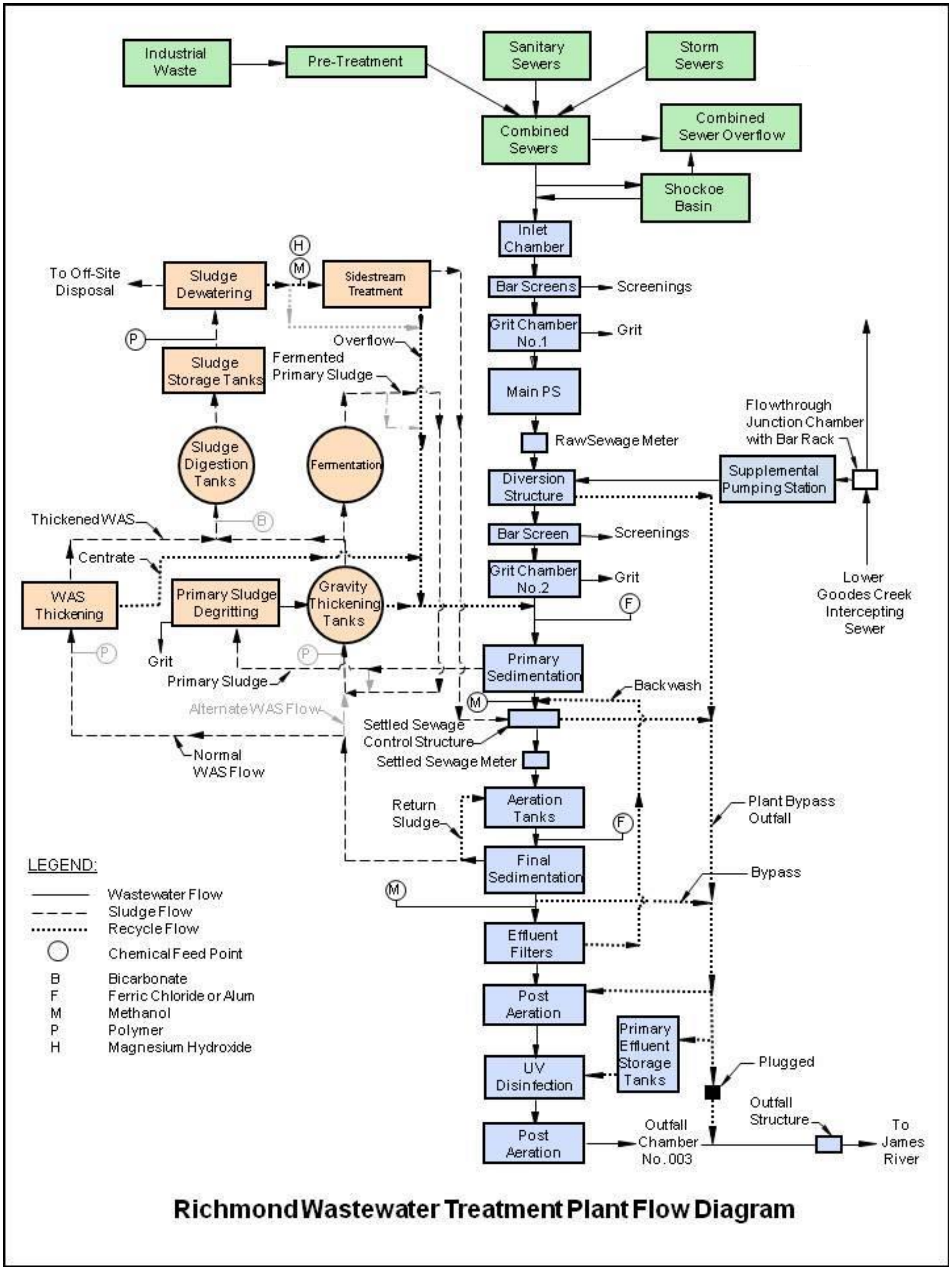

Figure 3.20 Richmond WWTP flow process

Table 3-14 VPDES permit (VA0063177) discharge limits

Effluent Characteristics		Discharge Limitations					
		Monthly Average		7-Day rolling average		Minimum	Maximum
Flow (MGD)		NL		NA		NA	NL
CBOD5	June – Oct.	NL mg/l	NL kg/day	8.0 mg/l	1361 kg/day	NA	NA
CBOD5	Nov. - May	14.3 mg/l	2434 kg/day	21.4 mg/l	3651 kg/day	NA	NA
Suspended solids	June – Oct.	NL mg/l	NL kg/day	10 mg/l	1703 kg/day	NA	NA
Suspended solids	Nov. - May	18 mg/l	3066 kg/day	27 mg/l	4599 kg/day	NA	NA
Ammonia-N	June – Oct.	6.4 mg/l	1090 kg/day	9.36 mg/l weekly average		NA	NA
Ammonia-N	Nov. - May	15.2 mg/l	2588 kg/day	22.8 mg/l weekly average		NA	NA
Total Phosphorus Calendar year average		0.5 mg/l		NA		NA	NA
Total Nitrogen Calendar year average		8.0 mg/l		NA		NA	NA
E.coli		126 N/100 ml (geometric mean)		NA		NA	NL
pH		NA		NA		6.0 S.U.	9.0 S.U.
Dissolved oxygen		NA		NA		5.6 mg/l	NA

3.3.5.b WWTP monitoring

The plant influent and effluent flow are continuously monitored. All water quality parameters listed in the table above are frequently monitored and sampled per VPDES permit requirements. The City's 2013 VPDES fact sheet compiles the monitoring data from recent DMRs (previous 5 years). The reported monitoring data by the WWTP for important parameters are given in Table 3-15 below.

Table 3-15 DMR result compilation

Parameter	Maximum daily value	Average daily value	
		Value	Number of samples
pH (minimum)	4.2 S.U.	NA	NA
pH (maximum)	8.6 S.U.	NA	NA
Flow rate	85.0 MGD	54.9 MGD	1827
Temperature (winter)	15.7 deg. C.	14.5 deg. C.	848
Temperature (summer)	31.3 deg. C.	24.5 deg. C.	612
cBOD5	64.7 mg/l	3.2 mg/l	1827
Fecal Coliform	2420 N/100 ml	10 N/100 ml	1006
TSS	129.0 mg/l	4 mg/l	1826

3.3.5.c WWTP Upgrades – Current and Planned

Virginia DEQ issued a special order of consent to the City of Richmond in 2005 regarding the implementation of a plan to control CSOs. A requirement of the Consent Order is making updates to the WWTP[24]:

- Wet weather flow improvements at WWTP: Solids Removal Improvements Project

  Upgrades to the primary treatment facilities to provide reliable treatment of up to 140 MGD wet weather flow; upgrades solids handling facilities to handle an increased solids loading associated with the increased CSO wet weather flow treatment

- Wet weather flow improvements at WWTP: Wet weather disinfection Facilities Project

  Maximizes the wet weather treatment capacity to 300 MGD at WWTP; controls Gordon Avenue (CSO 021) outfall to 4 overflows per year. Upgrades the coarse screens, primary grit removal facilities, Main Pumping Station, and fine screens to provide reliable treatment of up to 300 MGD wet weather flow; Constructs a new wet weather disinfection facility at WWTP to treat flows up to 215 MGD (55 MGD primary effluent plus 160 MGD wet weather flow)

- Wet weather flow improvements at WWTP: Expand Secondary Wet Weather Flow Treatment Project

  Install sedimentation enhancing technologies such as inclined plate settlers in the final sedimentation tanks to increase the solids capture efficiency for up to 85 MGD wet weather flow; upgrades the return sludge and sludge withdrawals to increase the capacity of this facility.

[24] Virginia DEQ State Water Control Board. 2005. Enforcement Action – Special Order by Consent issued to the City of Richmond, February, 2005 for Permit No. VA0063177.

3.3.6 Stormwater System

3.3.6.a General System Description

The City of Richmond operates and maintains an MS4 system which serves approximately 24,500 acres of the City, 1,070 acres are within the Lower James / CSO area.. The City's MS4 system is operated under the Virginia Stormwater Regulation 4VAC50-60 (Small MS4 permit).

3.3.6.b Stormwater Collection System Components

Inflow into the MS4 system within the Lower James CSO Watershed area is handled by 650 inlets which are listed in Table 3-16 below and shown in Figure 3.21.

Table 3-16: Stormwater inlets within Lower James / CSO Watershed (MS4) area

Inlet type	Almond Creek	Cannon's Branch/Shockoe Creek	Gillies Creek	Goose Creek/ Manchester Canal	Stony Run	Sum
Curb Inlet	0	32	18	11	5	66
Grate Inlet	0	7	3	7	1	18
Roof Drain	0	1	1	0	0	2
Unknown	37	144	113	98	172	564
Grand Total	**37**	**184**	**135**	**116**	**178**	**650**

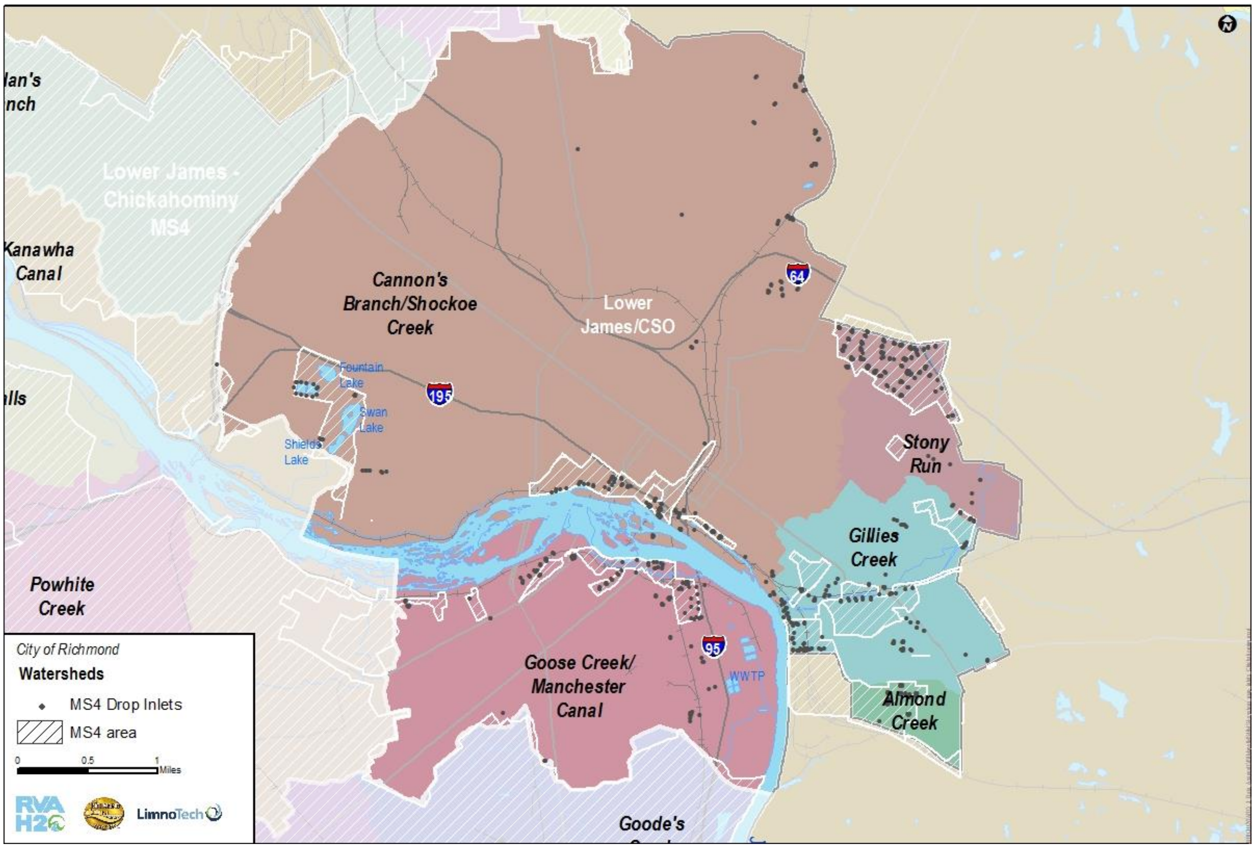

Figure 3.21: Stormwater inlets within Lower James / CSO Watershed (MS4) area

Stormwater conveyance is provided by a network of open channels, culverts and pipes. The combined length of the stormwater system in the Lower James Watershed area is about 176 miles.

Flow in undeveloped areas is often conveyed by open drainage channels which are composed of a mix of different materials (summarized in Table 3-17) which make up about 31% of the stormwater conveyance system in the Lower James / CSO Watershed area.

Table 3-17: Open drainage channels in Lower James / CSO Watershed Area

Channel material	Channel length (ft.)					
	Almond Creek	Cannon's Branch/Shockoe Creek	Gillies Creek	Goose Creek/ Manchester Canal	Stony Run	Sum
Asphalt	0	0	0	0	0	0
Brickwork	0	0	0	0	0	0
Concrete	0	6,807	283	383	0	7,473
Rip Rap	0	0	84	48	0	131

Channel material	Channel length (ft.)					
	Almond Creek	Cannon's Branch/Shockoe Creek	Gillies Creek	Goose Creek/ Manchester Canal	Stony Run	Sum
Unknown	4,625	2,298	2,475	2,649	2,317	14,364
Vegetation	1,157	3,261	7,470	7,712	1,807	21,406
Grand Total	**5,782**	**12,365**	**10,312**	**10,792**	**4,124**	**43,374**

Stormwater flow in open drainage channels is conveyed underneath roads and other channel crossings via closed culverts (summarized in Table 3-18).

Table 3-18: Stormwater culverts in Lower James / CSO Watershed Area

Culvert size	Number of culverts	total length of culverts (ft)
Unknown	32	2,604
< 12 inches	1	43
12 - 24 inches	7	467
27 - 48 inches	5	587
54 - 96 inches	5	446
> 108 inches	6	1,421
Grand Total	**56**	**5,567**

Developed areas are mainly drained by underground pipes with various pipe sizes (summarized in Table 3-19). Pipes make up about 69% of the stormwater conveyance system within the Lower James Watershed area.

Table 3-19: Stormwater pipes in Lower James / CSO Watershed Area

Pipe size	Pipe length (ft.)					
	Almond Creek	Cannon's Branch/Shockoe Creek	Gillies Creek	Goose Creek/ Manchester Canal	Stony Run	Total
unknown	0	1,352	5,570	3,015	202	10,138
< 12 inches	518	1,145	1,174	4,334	450	7,621
12 - 24 inches	3,171	15,996	11,450	8,741	15,316	54,675
27 - 48 inches	2,529	4,362	2,952	5,377	5,034	20,255
54 - 72 inches	0	954	467	258	2,375	4,054
78 - 96 inches	0	0	0	0	0	0
> 96 inches	0	0	0	0	0	0
Grand Total	**6,218**	**23,810**	**21,612**	**21,725**	**23,377**	**96,742**

A mix of different best management practices (BMPs) within the stormwater area provide pollution control (summarized in Table 3-20).

Table 3-20: BMPs within Lower James CSO Watershed area

BMP type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Unknown	0	2	0	4	0	6
Bioretention Filter	0	9	0	3	1	13
Detention Basin	0	6	1	6	0	13
Extended Detention Pond	0	3	1	2	0	6
Filters	0	1	0	0	0	1

BMP type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Grass Channels	0	1	0	0	0	1
Infiltration	0	5	0	2	0	7
Other	0	4	1	4	0	9
Permeable Pavement	0	2	0	2	0	4
Rainwater Harvesting	0	2	0	1	0	3
Rooftop Disconnection	0	0	0	1	0	1
Vegetated Roof	0	1	0	0	0	1
Grand Total	**0**	**36**	**3**	**25**	**1**	**65**

Storm water outfalls are defined as points where a storm sewer system discharges to a receiving water or to another MS4. This includes discharges from pipes, ditches, swales, and other points of concentrated storm water flow. Identified outfall locations are summarized in Table 3-21 and shown in Figure 3.22 below. This includes locations of storm water discharge from and to Henrico County.

Table 3-21: Stormwater outfalls in Lower James CSO Watershed area

Outfall type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Open Channel - Regulated	0	0	2	1	0	3
Open Channel - from Henrico County	0	1	1	0	1	3
Open Channel - to Henrico County	2	0	0	0	1	3
Open Channel – Other *	0	9	13	7	12	41

Outfall type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Pipe - Regulated	0	2	2	2	0	6
Pipe – Other *	0	27	28	14	9	78
Unknown	0	1	1	0	0	2
Grand Total	**2**	**40**	**47**	**24**	**23**	**136**

(*) This includes types like road drainage, parcel drainage and other miscellaneous or unclear outfall classifications

Figure 3.22: Stormwater outfalls in Lower James CSO Watershed area

3.3.6.c Stormwater Master Plan

The City developed a first draft of a Stormwater System Master Plan in 2005 with the primary goal to address historic and reoccurring drainage problems. This plan has been expanded in area and scope in 2012 to include the development of watershed based plans resulting in a subsequent list of capital improvement projects (CIPs) that not only address historic problems but also integrate legal regulations, the hydraulic function of the existing drainage network as well as root-cause areas. Part of the plans for each of the investigated watersheds is a review of existing asset inventory data, mapping and CIPs, as well as a characterization of the existing system infrastructure and conditions. Engineering evaluations, including hydraulic modeling and pollutant load calculations, were performed on existing systems and proposed systems to develop a comprehensive CIP list which was then prioritized and ranked using a priority ranking system developed as part of the master planning process. The following watersheds have been analyzed so far:

- Broad Rock Creek
- Brock Rock Creek
- Cherokee Lake
- Falling Creek
- Gillies Creek
- Goodes Creek
- Grindall Creek
- Jordan's Branch
- Manchester Canal
- Pocosham Creek
- Reedy Creek
- Riverfront
- Willow Oaks Creek

An overview map of the stormwater master plan priority watershed areas is shown in Figure 3.23. The Stormwater Master Plan areas within the "Lower James CSO" watershed are Stony Run, Gillies Creek and Manchester Canal.

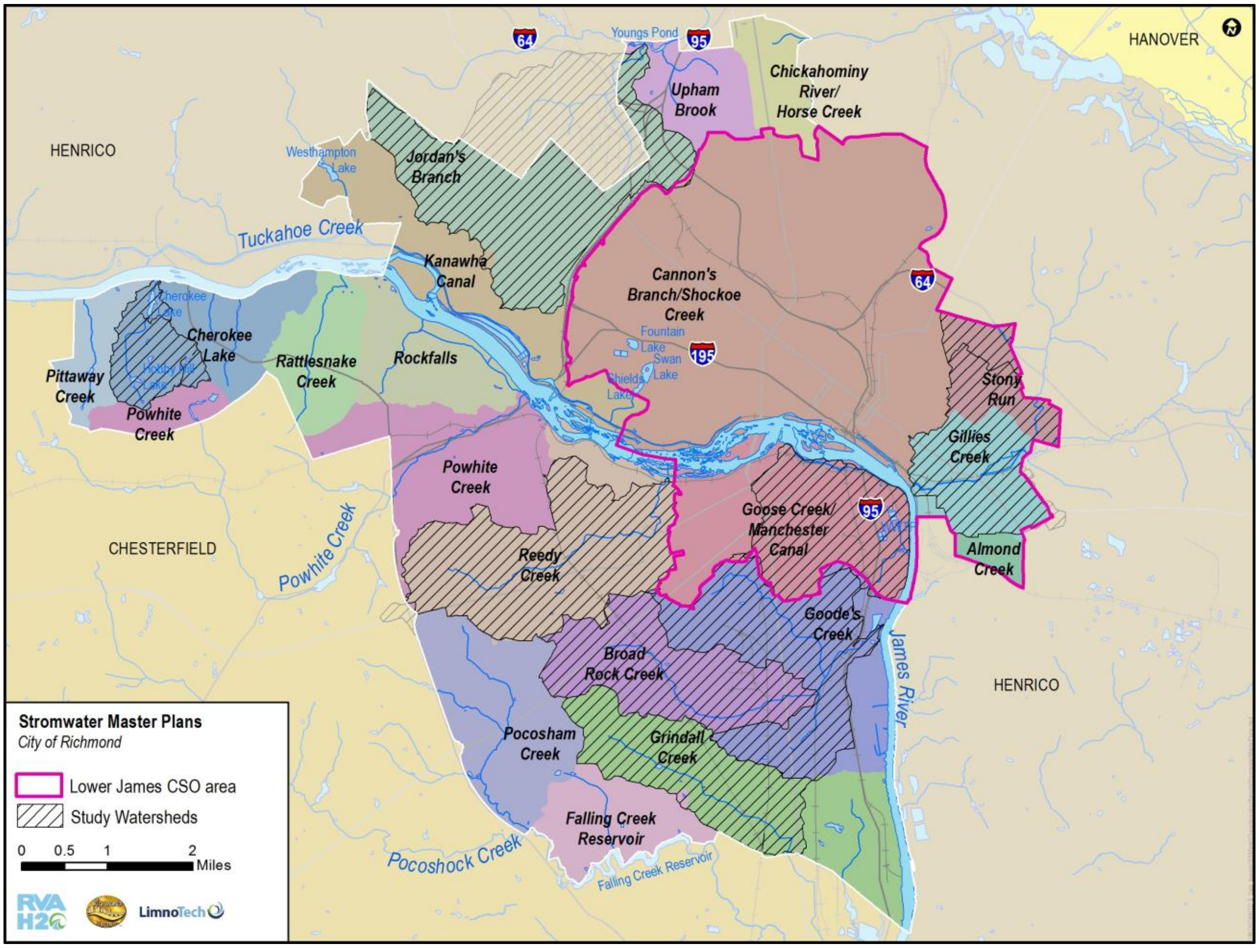

Figure 3.23 Location of Stormwater Master Plan priority watersheds

3.3.6.d Stormwater Modeling

Hydrologic and hydraulic InfoSWMM models were developed for all Stormwater System Master Plan watersheds. Important stormwater network features including pipes, culverts and channels were included. These uncalibrated models were used for an analysis of instream flow velocities, capacity analysis as well as for an evaluation of the water quality (modeled pollutants were total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) based on estimated values using DCR's Runoff Reduction Method). Model results were subsequently used for the development and evaluation of improvement alternatives.

3.3.7 Sensitive Areas

EPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) provides a framework for the control of CSO discharges through the NPDES permitting process. This policy establishes the expectation that CSO communities will give the highest priority to the control of CSO discharges within "sensitive areas". The Policy and EPA Combined Sewer Overflows Guidance for Long-Term Control Plans (EPA 832-B-95-002) define sensitive areas as:

- Outstanding National Resource Waters ("Exceptional State Waters" or "Tier III" waters in Virginia)
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contract recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas
- Shellfish beds

While this sensitive area analysis is applicable only to Richmond's CSO area, the data and information provided does help to characterize the Lower James CSO watershed grouping.

The City's LTCP discusses the six criteria for sensitive areas identified in the CSO policy were evaluated for the James River and its tributaries in the vicinity of Richmond's CSO outfalls. No Outstanding National Resource Waters have been designated in the vicinity of Richmond (State of Virginia, 9 VAC 25-260). No National Marine Sanctuaries have been designated within the state of Virginia. Additionally, no commercial shellfish harvesters operate within the study area.

The Virginia Department of Conservation & Recreation (DCR) Natural Heritage Program's Database was used to assess the presence of threatened or endangered species in the CSO area of Richmond. The database did not include or indicate the presence of any species on the Federal- or State-listed threatened or that endangered species or critical habitat of any species was found in the CSO area.

Richmond's drinking water intake is on the James River near the downstream end of Williams Island. This is over three miles upstream of the CSO area along the James River.

The original LTCP study identified the sensitive areas associated with the City's CSS as the south and north James River Park areas. These two areas are primarily in the vicinity of public contact recreation waters, especially the south side James River Park, which receives a large number of visitors each year, particularly during the summer months. CSOs in these areas discharge into canals and pools which can be slow moving and therefore have limited capability for flushing and diluting pollutants as they progress toward the main channel of the river. For this reason, CSO discharges to these areas exerted significant public health, aesthetic and water quality impacts, although the pollutant loads of these areas are relatively small compared to the total pollutant load for all CSOs in the City.

3.4 Water Quality

Water quality in Richmond can be evaluated by analyzing water quality and biological data within the context of area waterbodies' water quality standards and impairment listings. Evaluation of current water quality is essential to the process of identifying pollutant sources and stressors.

Existing data sources for water quality, biological (fish, benthic macroinvertebrates, and habitat indices), flow, and point sources have been identified across various groups and agencies, including City of Richmond's own data collection efforts, Virginia DEQ programs, USGS monitoring efforts, non-agency (NGOs, universities) programs, and citizen and stakeholder groups' monitoring efforts. Virginia DEQ incorporates external data sources, including quality-controlled citizen data, when determining whether a waterbody is impaired.

3.4.1 Designated Uses

All Virginia state waters are designated for aquatic life, wildlife, recreational uses, and fish consumption (*Virginia Administrative Code 9VAC25-260-10, section A*). Other designated uses that may be assigned to select waterbodies include shellfishing and public water supply uses.

There are additional designated use categories for tidal tributaries to the Chesapeake Bay: migratory fish spawning and nursery, shallow-water submerged aquatic vegetation, open water aquatic life, deep water aquatic life, and deep channel seasonal refuge.

Table 3-22 summarizes the designated uses that have been assigned to one or more waterbody segments in the Lower James CSO watersheds, by waterbody type. Note that waterbody segments may extend well outside of the Lower James CSO watersheds group; this is particularly true for estuarine segments.

Table 3-22 Lower James CSO watershed grouping designated uses

<table>
<tr><th>Designated Use</th><th>Tidal Freshwater waterbodies</th><th>Riverine waterbodies</th><th>Reservoir waterbodies</th></tr>
<tr><td>Aquatic Life</td><td>X</td><td>X</td><td rowspan="11">No waterbodies are classified as reservoirs in Lower James CSO watersheds</td></tr>
<tr><td>Fish Consumption</td><td>X</td><td>X</td></tr>
<tr><td>Public Water Supply</td><td></td><td></td></tr>
<tr><td>Recreation</td><td>X</td><td>X</td></tr>
<tr><td>Wildlife</td><td>X</td><td>X</td></tr>
<tr><td>Shellfishing</td><td></td><td></td></tr>
<tr><td>Migratory Fish Spawning & Nursery</td><td>X</td><td>n/a</td></tr>
<tr><td>Deep Channel Seasonal Refuge</td><td></td><td>n/a</td></tr>
<tr><td>Deep Water Aquatic Life</td><td></td><td>n/a</td></tr>
<tr><td>Open Water Aquatic Life</td><td>X</td><td>n/a</td></tr>
<tr><td>Shallow Water Submerged Aquatic Vegetation</td><td>X</td><td>n/a</td></tr>
</table>

3.4.2 303(d) Status

Under Section 303(d) of the Clean Water Act, states are required to submit to EPA a TMDL Priority List every other year. In Virginia, this list is contained in its biannual Water Quality Assessment 305(b)/303(d) Integrated Report, a joint publication of DEQ, DCR, and the state Department of Health. Waters are placed into federal categories based on each waterbody segment's (or 'assessment unit') support for its designated uses. Virginia supplements the federal categories with its own subcategories to better describe and track attainment/impairment.

The waterbody segments in the Lower James CSO watersheds (Figure 3.24) have all been placed in one of four of the following EPA categories / Virginia subcategories in most recent (2014) Integrated Report:

- **EPA Category 2:** Available data and/or other information indicate that some, but not all of the designated uses are supported.
    - **Virginia Category 2B:** Waters are of concern to the state but no water quality standard exists for a specific pollutant, or the water exceeds a state screening value or toxicity test.
- **EPA Category 3:** Insufficient data and/or information to determine whether any designated uses are met.
    - **Virginia Category 3A:** No data are available within the data window of the current assessment to determine if any designated use is attained and the water was not previously listed as impaired.
- **EPA Category 4A:** Water is impaired or threatened for one or more designated uses but does not require a TMDL. A new TMDL is not necessary to address the newly identified impaired tributaries if TMDL modeling, source identification and reductions cover the entire watershed and the TMDL has been approved by EPA. These waters are primarily related to shellfish and/or recreational bacteria impairments but could include benthic impairments**.**
- **EPA Category 5:** Waters are impaired or threatened and require a TMDL.
    - **Virginia Category 5D:** The water quality standard is not attained where TMDLs for a pollutant(s) have been developed but one or more pollutants are still causing impairment requiring additional TMDL development.

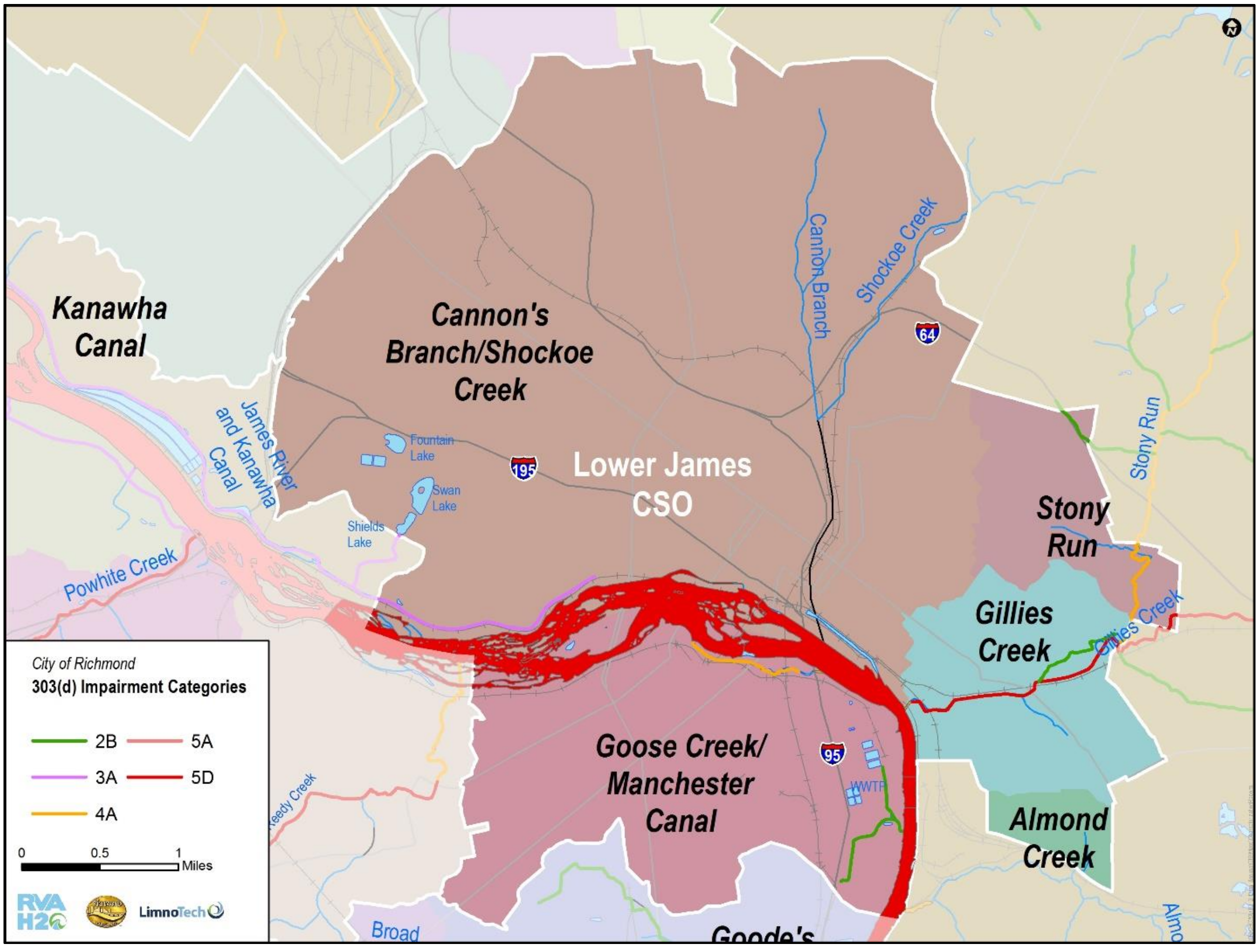

Figure 3.24 Lower James CSO watershed grouping 303(d) impairment categories

For the impaired waterbody segments, the impairment causes identified in the 2014 Integrated Report for the Lower James CSO watersheds include:

- Chlorophyll-a
- *E. coli*
- Estuarine Bioassessments
- Dissolved Oxygen
- PCB in Fish Tissue
- PCB in Water Column
- Aquatic Plants (macrophytes)
- pH
- Chlordane
- DDE
- DDT
- Mercury in Fish Tissue

3.4.3 Monitoring Programs

Within the Lower James CSO watersheds, most of the water quality data collection efforts have been led by Virginia Department of Environmental Quality (VADEQ) and the City of Richmond. Other organizations collecting data within the City of Richmond include federal, local, and volunteer/non-profit organizations, and industrial permittees. Data currently compiled by the City of Richmond from known monitoring programs are presented in Table 3.19.

Table 3-23 Summary of water quality monitoring programs

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Virginia Shallow Water Monitoring Program- DATAFLOW Cruises	Virginia Institute of Marine Science--College of William & Mary (VIMS)	Academic	2005-2008	CM	n/a	1	20	3	31,317	DATAFLOW Cruises record results every 2-4 seconds
NCDC Global Historical Climatology Network	National Climatic Data Center	Federal	2013-2015	MET	1	n/a	daily	1	716	Does not include Richmond International Airport (which falls outside City of Richmond boundary)
VAR051382 Water Quality Sampling	Asphalt Emulsion Inc.	Industrial	2011-2013	SRC	1	1	3	3	9	
VAR051133 Water Quality Sampling	Estes Express Lines	Industrial	2014	SRC	1	1	1	4	15	
VAR051888 Water Quality Sampling	Kenan Transport LLC	Industrial	2009-2014	SRC	1	1	5	4	21	
VAR051818 Water Quality Sampling	Richmond Recycling Company	Industrial	2010-2013	SRC	1	1	4	8	32	
City of Richmond CSO Monitoring	City of Richmond	Local	2012-2013	SRC	22	3	299	3	892	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Richmond Wastewater Treatment Plant (VA0063177) Water Quality Sampling	City of Richmond	Local	2000-2015	SRC	1	1	1,480	30	15,711	
VCU James River Water Quality Monitoring	Virginia Commonwealth University (VCU)	Academic	2010-2014	WQ	2	2	285	14	4,253	
Virginia Institute of Marine Science Fish Tissue Sampling Program	Virginia Institute of Marine Science--College of William & Mary	Academic	2001-2009	WQ	3	1	151	21	1,390	
Virginia Shallow Water Monitoring Program-Continuous Monitoring	Virginia Institute of Marine Science--College of William & Mary	Academic	2005-2008	WQ	1	1	243	29	1,917	
City of Richmond Routine Water Quality Monitoring	City of Richmond	Local	2013	WQ	28	3	28	9	64	
VADEQ 512 20 3.0 TMDL Activities	Virginia Department of Environmental Quality (VADEQ)	State	2009-2013	WQ	4	1	179	27	3,194	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
VADEQ Chesapeake Bay Tributary Monitoring	Virginia Department of Environmental Quality	State	2000-2013	WQ	1	1	168	36	4,898	
VADEQ Pollutant Complaint Investigation / Spill Containment	Virginia Department of Environmental Quality	State	2014	WQ	1	1	1	43	43	
VADEQ Post-TMDL Implementation Monitoring	Virginia Department of Environmental Quality	State	2013-2014	WQ	4	1	51	21	646	
VADEQ QA/QC Program	Virginia Department of Environmental Quality	State	2010-2013	WQ	3	1	8	38	166	
VADEQ Routine sampling	Virginia Department of Environmental Quality	State	2007-2014	WQ	73	2	703	44	5,217	
VADEQ Special Studies	Virginia Department of Environmental Quality	State	2009-2011	WQ	3	1	4	10	40	
Chesapeake Bay Program Water Quality and Habitat Monitoring	Chesapeake Bay Program	Federal	2009-2014	WQ	1	1	123	32	2,401	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
James River Association (JRA) Routine Water Quality Sampling	James River Association	Volunteer /NGO	2013	WQ	3	1	39	4	195	
VADEQ Non-Tidal Stream Monitoring Program	Virginia Department of Environmental Quality	State	2005-2010	WQ, BIO/HAB	5	2	29	122	3,526	Includes WQ, BIO/HAB metric parameters; macroinvertebrate taxa were excluded

[1] Data types: BIO/HAB=Biological/habitat; CM=Continuous monitoring; MET=Meteorological; SRC=Point source; WQ=Water quality.
[2] NGO=Non-governmental organization

3.4.4 Water Quality Data

Water quality sampling data were collected at 111 stations (fixed locations) within the Lower James CSO watersheds. Of those 111 stations, 87 had 10 or fewer sampling events, with the remaining 24 stations providing 1,864 sampling events. From a total of 2,012 sampling events, 24,540 individual samples (single-parameter observations) were collected. While data were collected from 2000 to 2014, over 90% of the samples were collected since 2006. There are 151 different parameters for which there are samples; of those parameters, 70 had fewer than 10 samples each. Figure 3.25 depicts the number of water quality sampling events by station.

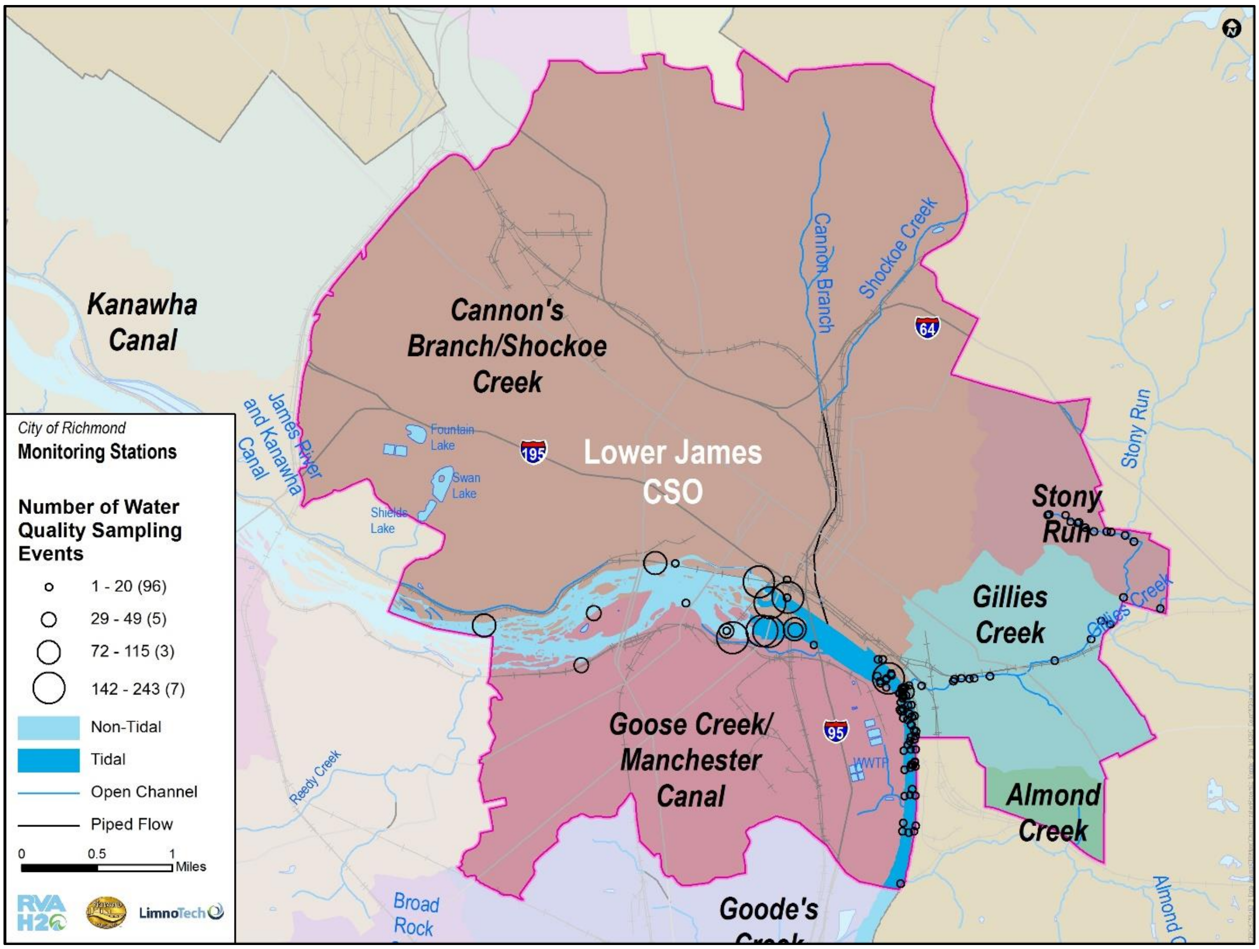

Figure 3.25 Lower James CSO watershed grouping water quality sampling stations by number of sampling events

Appendix B includes plots for Chesapeake Bay TMDL parameters for which there were a significant number of data points available. They include total nitrogen, total phosphorous, and total suspended solids concentrations, by station, for water bodies within the Lower James CSO watershed area. Additional also in Appendix B include those parameters for which there are little-to-no data available. In many cases, these parameters are also not considered to be major pollutants or impairment sources.

Available point source data for discharge points within the Lower James CSO watersheds consist of flow and water quality sampling from the Richmond Wastewater Treatment Plant effluent and other permitted facilities within the watersheds, and flow, duration, and frequency monitoring for the combined sewer outfalls within the watersheds. Data largely consist of discharge monitoring report (DMR) content, but more recent 2012-2015 WWTP and CSO data include more frequent sampling in addition to DMR-based data. Permitted facilities are listed below in Table 3-24; locations and number of samples are shown on Figure 3.26.

Table 3-24 Permitted Facilities in Lower James CSO Watersheds

VPDES Permit Number	Description/Owner	Permit Type	Number of Sampling events	Number of Samples
VA0063177	Richmond WWTP	Individual	1,480	15,711
VA0063177	Combined Sewer Outfalls (qty. 23)*	Individual	299	892
VAR051133	Estes Express Lines	General: Industrial Activity	1	15
VAR051382	Asphalt Emulsion Incorporated	General: Industrial Activity	3	9
VAR051818	Richmond Recycling Company	General: Industrial Activity	4	32
VAR051888	Kenan Transport LLC	General: Industrial Activity	5	21

* One of the 23 combined sewer outfalls has no associated data.

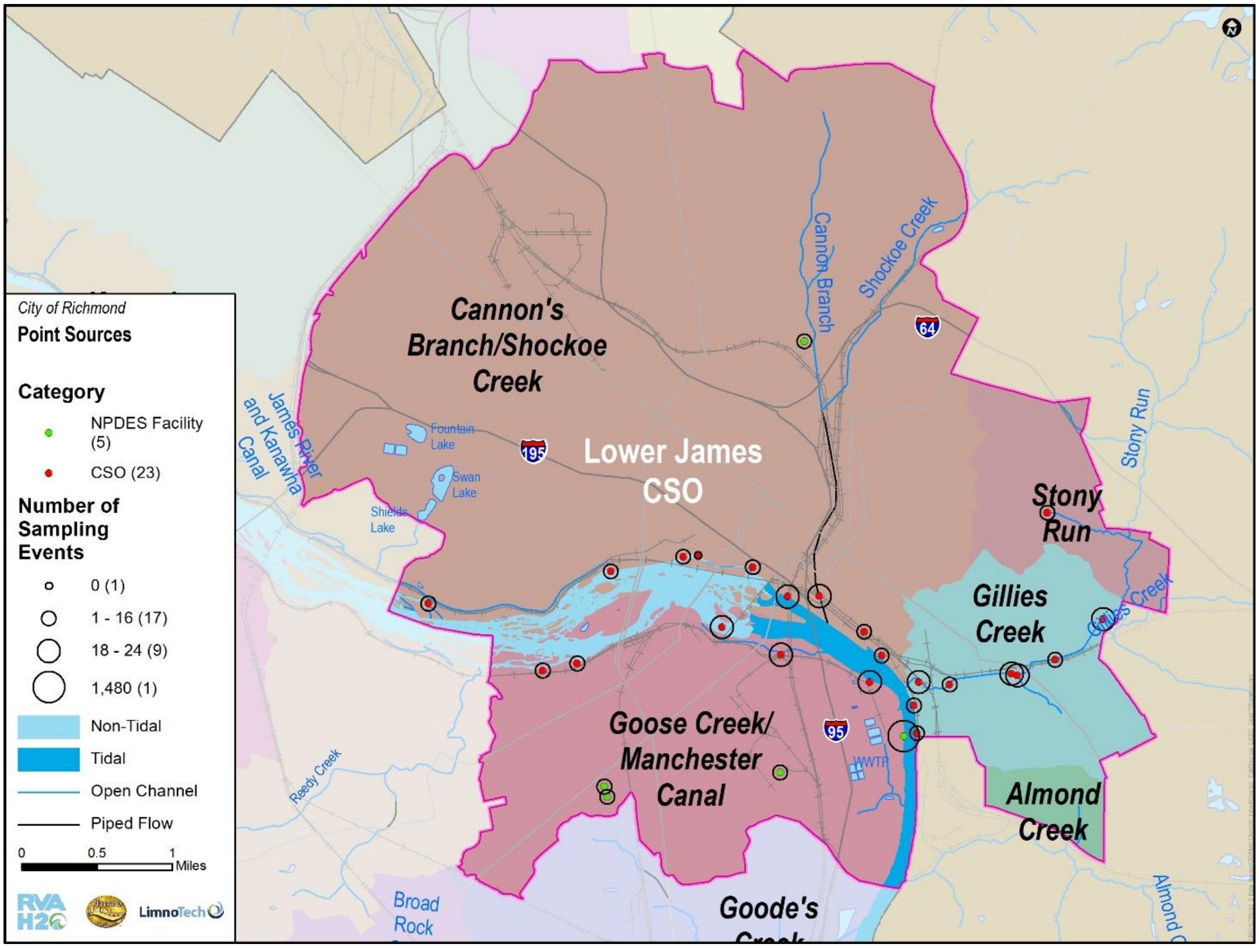

Figure 3.26 Lower James CSO watershed grouping point sources by number of sampling events

The VIMS DATAFLOW continuous-monitoring data set from cruises of the tidal James River yielded over 22,000 sampling events within the City of Richmond, with each sampling event including temperature, turbidity, and chlorophyll data. Of those sampling events, over 10,000 ocurred within the portion of the tidal James River that is within the Lower James CSO watersheds. Cruises were conducted from 2005 to 2008 from April to September. Viewed collectively, the data sets from these cruises indicate seasonal/temperature-based variances in chlorophyll concentrations. A visual inspection suggests that the river mile, or spatial location has minimal affect on the chlorophyll concentrations in the James.

3.4.5 Biological Conditions

Biological and habitat-related data consist of fish count and fish tissue data, benthic macroinvertebrate data that include taxa counts, metric scores and index scores, and habitat metric scores. All data were obtained through queries of the Chesapeake Bay Program Living Resources Database. Figure 3.27 depicts the number of biological sampling events and habitat assessments conducted by station.

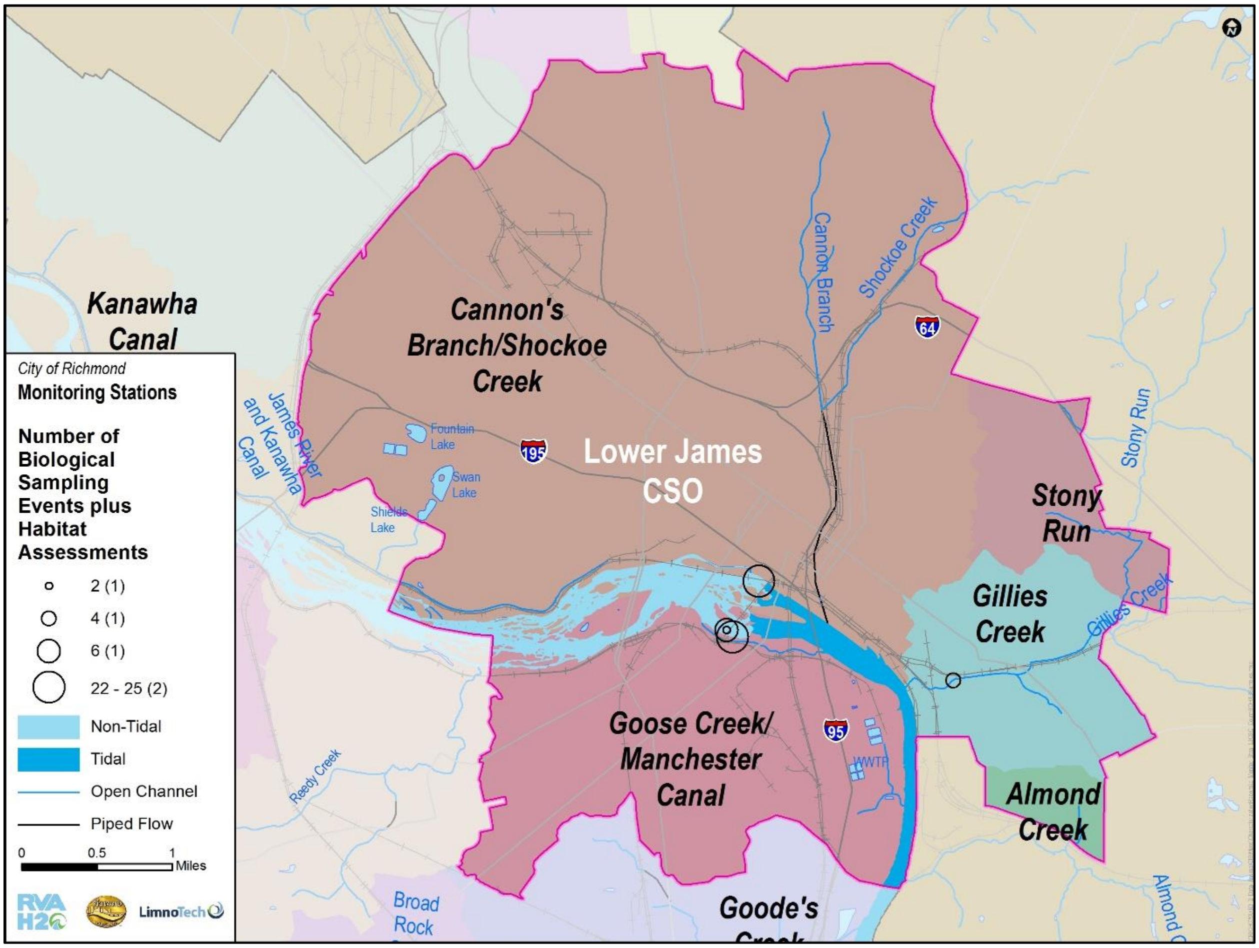

Figure 3.27 Biological and habitat data sampling and assessment stations by number of sampling events and habitat assessments

Benthic macroinvertebrate metrics were calculated by the Chesapeake Bay Program Living Resources Database (CBP 2012). A limited number of the benthic macroinvertebrate metrics are then used to develop scores using one of two multi-metric indices: the Bay Program's own Benthic Index of Biotic Integrity (CB B-IBI) or the Coastal Plain Macroinvertebrate Index (CPMI)[25]. These multi-metric indices can then be used to assess the quality of the biological community as a whole. For the Lower James CSO watersheds, only CPMI scores were generated from the available data. All data were collected in the non-Tidal James River and in Gillies Creek.

CPMI scores are expressed as percentages of the maximum value of 30, and are categorized as excellent (67-100%), good (50-67%), fair (30-50%), poor (17-30%) and very poor (0-17%). Gillies Creek had twelve CPMI scores calculated based on two sampling events, those scores ranged from 0 to 47, with an average score of 9 and a median score of 7. The James River had 168 CPMI scores calculated from 28 sampling events, those scores ranged from 0 to 93, with an average score of 25 and a median score of 20.

Benthic macroinvertebrate taxa data were also collected in the Lower James CSO watersheds. These data consisted of 23 taxa counts for Gillies Creek based on two sampling events, and 468 counts for the James

[25] Chesapeake Bay Program. 2012. The 2012 User's Guide to Chesapeake Bay Program Biological Monitoring Data.

River based on 28 sampling events. Counts may represent one of a number of taxonomic ranks (species, genus, family, etc.).

Additional habitat data were collected using EPA Rapid Bioassessment Protocols (RBP) for evaluating stream habitats. For the Lower James/CSO sheds, these data included 290 results for fourteen different habitat metrics. Table 3-25 summarizes habitat metric counts, ranges, averages and medians. All habitat data were collected on the non-tidal James River and on Gillies Creek. Scoring for all metrics is on a scale of 0 (severely degraded) to 20 (pristine condition).

Table 3-25 Summary of habitat data

Habitat Metric	Metric Count	Minimum Value	Maximum Value	Average Value	Median Value
Bank Stability	29	17	20	19	19
Bank Vegetation	29	2	14	6	5
Channel Alteration	29	0	16	11	11
Embeddedness	26	8	16	12	13
Epifaunal Substrate	29	5	16	13	14
Flow	29	13	20	18	18
Pool Substrate	3	5	13	10	12
Pool/Glide Quality	3	2	17	11	13
Riffle/Run/Pool Ratio	26	17	20	19	19
Riparian Vegetation Score	18	2	14	5	5
Riparian Vegetation Zone Width	11	4	15	6	5
Sedimentation	29	6	17	13	14
Sinuosity	3	2	11	7	9
Velocity/Depth Ratio	26	15	20	18	19

3.4.6 Pollutant Sources

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. For segments within the Lower James CSO watershed group, the following suspected sources were identified:

- MS4 Discharges
- Combined Sewer Overflows
- Non-Point Sources
- Municipal Point Source Discharges

- Industrial Point Source Discharges
- Atmospheric Deposition (nitrogen, toxics)
- Clean Sediments
- Internal Nutrient Cycling
- Loss of Riparian Habitat

3.4.7 Stressors

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Table 3-26 includes stressors that Virginia DEQ has identified as being most prevalent. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value.

Table 3-26 Most frequent stressors to Virginia waterbodies

With WQS/Screening Value	*Without* WQS/Screening Value
Biomonitoring Indices (VSCI/CPMI)	Streambed Sedimentation
pH below 6	Habitat Disturbance
Nickel in Sediment	Total Phosphorus
Dissolved Nickel	Total Nitrogen
Dissolved Cadmium	CCU Metals Index
Mercury in Sediment	Ionic Strength
Dissolved Oxygen	

It should be noted that the analysis of sources and stressors will be completed within the next phase of the project. Analysis of collected data will be spatially linked with listings of impaired water body segments to identify or confirm potential sources and stressors within a watershed. Data upon which an impairment listing is based will also be compared with other data sources that have been compiled, to help determine whether additional data may support/strengthen or weaken an impairment listing, and whether additional review may be warranted.

4 Lower James MS4

4.1 Watershed Summary

The Lower James MS4 area of Richmond is comprised of five watersheds: Broad Rock Creek, Falling Creek Reservoir, Goode's Creek, Grindall Creek, and Pocosham Creek. The region is situated in the southern side of the City and covers areas west of the James River (Figure 4.1). The total area characterized in this watershed grouping is 15.8 square miles (Table 4-1).

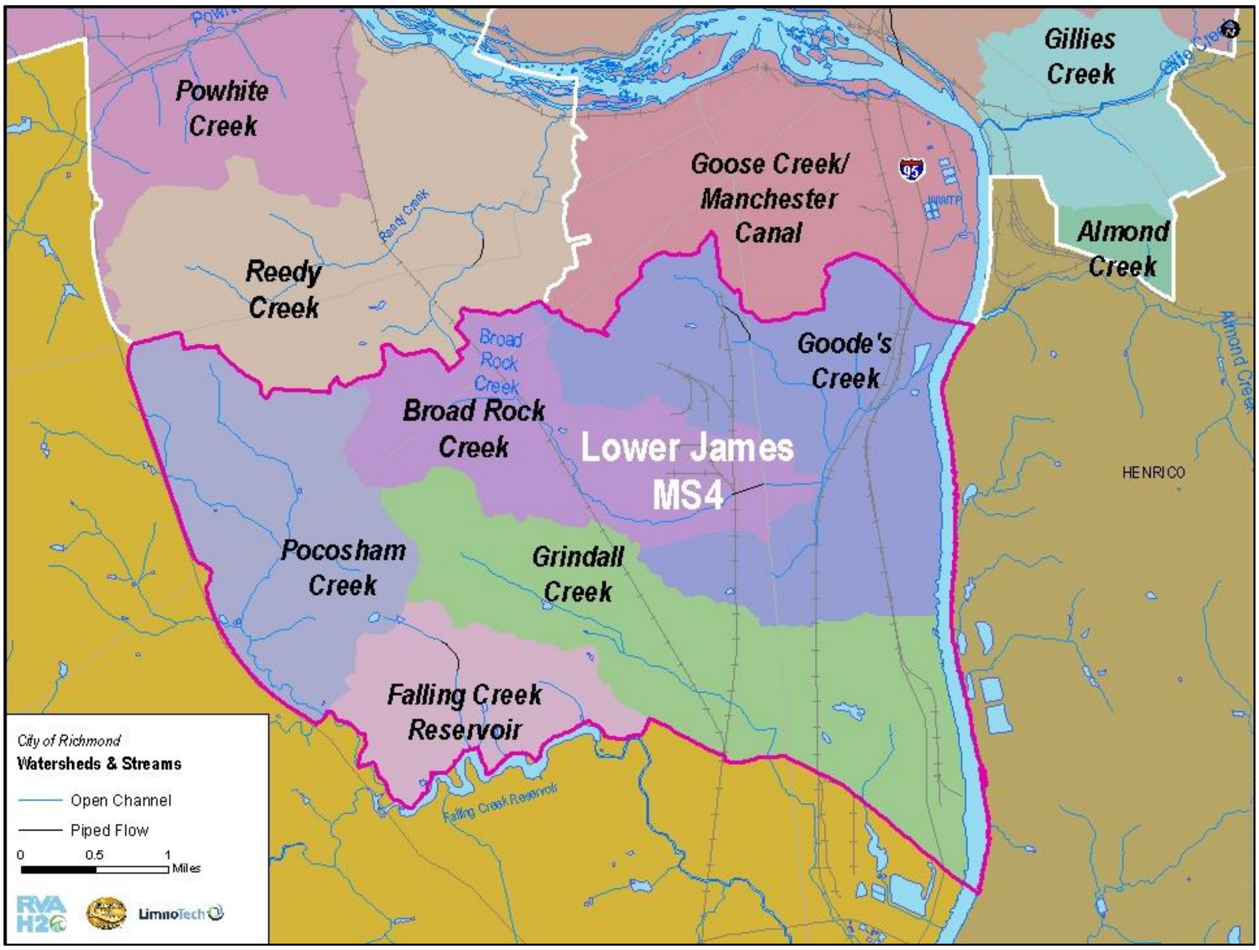

Figure 4.1 Watersheds and streams within the Lower James MS4 watershed grouping

Table 4-1 Lower James MS4 watershed Area

Watershed	Watershed Area (sq. mi.)	% of Total Lower James/MS4
Broad Rock Creek	2.7	17.4

Falling Creek Reservoir	1.6	10.1
Goode's Creek	4.3	27.3
Grindall Creek	4.2	26.6
Pocosham Creek	2.9	18.6
Total Lower James/MS4	**15.8**	**100.0**

4.2 Watershed Delineation

Delineation of watersheds in the City of Richmond was driven by the existing topography and collection systems. During the delineation process, each watershed boundary was carefully drawn to reflect how the slopes in the land surface and pipes transport water. A detailed discussion of the delineation is included in the Existing Watershed Data Assessment Report and the Watershed Delineation Technical Memorandum[26].

For characterization purposes in this section, five of the twenty watersheds in the City of Richmond have been grouped together:

- Broad Rock Creek
- Falling Creek Reservoir
- Goode's Creek
- Grindall Creek
- Pocosham Creek

4.3 Watershed Features

The Lower James MS4 grouping of watersheds represents 15.8 square miles. As seen in Table 4-1, the largest watershed is Goode's Creek and the smallest is Falling Creek Reservoir.

A total of 33.9 miles of stream exist in the five watersheds. These watersheds include portions of three of the nine City Council districts (6, 8, 9) in Richmond (Figure 4.2).

[26] Available at www.rvah2o.org.

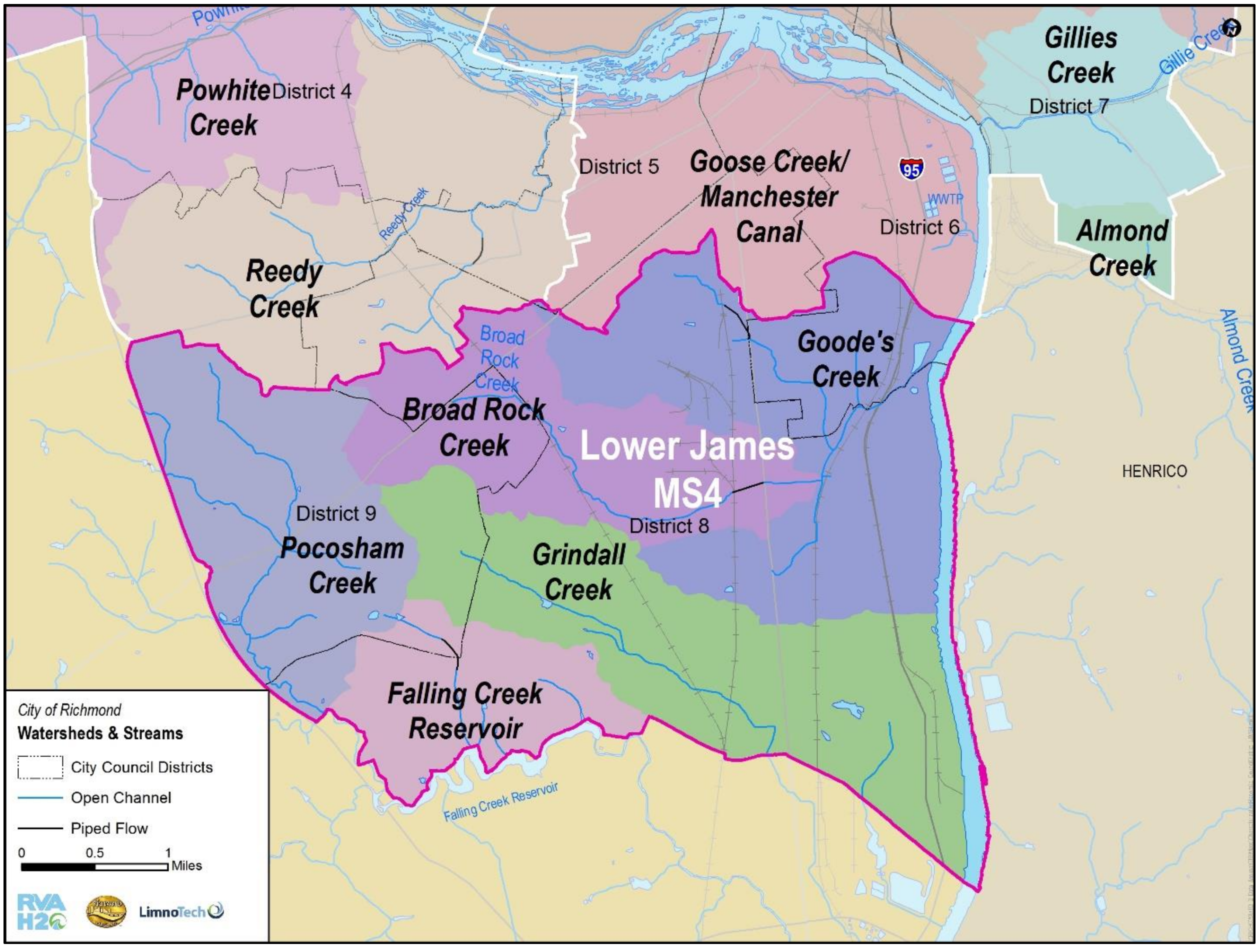

Figure 4.2 Lower James MS4 City Council Districts

4.3.1 Physical and Natural Features

This section describes hydrology, geology, topography, soils, climate, and habitat. These are important features because they affect land uses and shape the chemical, biological, and hydrological characteristics of the Lower James MS4 region.

4.3.1.a Hydrology

Within the five watersheds, the total length of stream ranges from 4.8 to 8.6 miles (Table 4-2). Hydrology in the Lower James MS4 has been modified over time to accommodate development. For example, portions of Grindall Creek have been channelized to run parallel to roads and railroads. Additionally, the downstream extent of Goode's Creek is confined by roads and development with little floodplain access. Broad Rock Creek, a tributary of Goode's Creek, is not as confined and has a well-defined riparian buffer. Pocosham Creek and Falling Creek Reservoir, which both feed Falling Creek Reservoir, have not been modified to the same degree as the other streams.

Table 4-2 Lower James MS4 watershed hydrology

Watershed	Open Channel Stream Distance (mi)	Wetland Area (ac)	Lake Area (ac)	Total Watershed Area (ac)
Broad Rock Creek	6.3	13.5	0.8	1,753
Falling Creek Reservoir	4.8	13.6	3.0	1,020
Goode's Creek	7.1	88.0	22.3	2,754
Grindall Creek	8.6	86.6	17.7	2,680
Pocosham Creek	7.0	25.3	2.3	1,873
Total Lower James/MS4	**33.9**	**227.0**	**46.1**	**10,080**

The City has identified wetlands in all of the five watersheds of the Lower James MS4 grouping. The wetland areas are interspersed throughout the watersheds.

There are multiple lakes in the Lower James MS4 watershed, the size of the lakes range from less than 0.1 acres to 10.6 acres. Many of these lakes are actually BMPs and used for stormwater management. The two largest waterbodies are located within the Grindall Creek and Goode's Creek watersheds.

The FEMA has identified 100 year flood prone areas in all of the Lower James MS4 watersheds except Falling Creek Reservoir (Table 4-3). These areas are located along the James River and the major tributaries of each watershed except for Falling Creek Reservoir.

Table 4-3 Lower James MS4 FEMA flood prone areas

Watershed	100yr flood prone area (ac)
Broad Rock Creek	47.5
Falling Creek Reservoir	--
Goode's Creek	490.7
Grindall Creek	312.8
Pocosham Creek	80.1

All of the watersheds and their associated waterbodies in this grouping transport water to the James River. This section of the James is tidally influenced and is designated as a tidal freshwater segment by the State of Virginia[27]. While flowing through the Lower James-MS4 watersheds, the James River bed elevation drops approximately 27 feet[28]. This is a much more gradual bed elevation change than seen in the more upstream Lower James-CSO area.

4.3.1.b Geology

The City of Richmond straddles the division between the Coastal Plain and Piedmont physiographic provinces. As seen in Figure 3.5, above, the Lower James MS4 watersheds are primarily in the Coastal Plain with a small area in the Piedmont. The coastal plain upland areas are characterized by low slopes and gentle drainage divides[29]. The underlying geology tends to be fluvial with gravelly sand, silt, and clays.

4.3.1.c Topography

Watersheds in the Lower James MS4 area are characterized by average slopes ranging from 2.3% to 6.8% (Table 4-4). Very steep slopes exist in the watersheds, particularly along the James River and Falling Creek Reservoir however the majority of the watershed is flat. Steep slopes are found along the James River in the Goode's Creek and Grindall Creek watershed. Overall elevations in this area range from -1 feet to 262 feet. The highest elevations in the watersheds are seen near the western edge of the watershed.

[27] 9VAC250260-140. Criteria for surface water. Available at: http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
[28] FEMA. Flood Insurance Study, City of Richmond, Virginia. Flood insurance number 510129V000B. July 16, 2014.
[29] William and Mary Department of Geology. 2015. The Geology of Virginia: Coastal Plain province. Accessed April 2, 2015. http://web.wm.edu/geology/virginia/provinces/coastalplain/coastal_plain.html

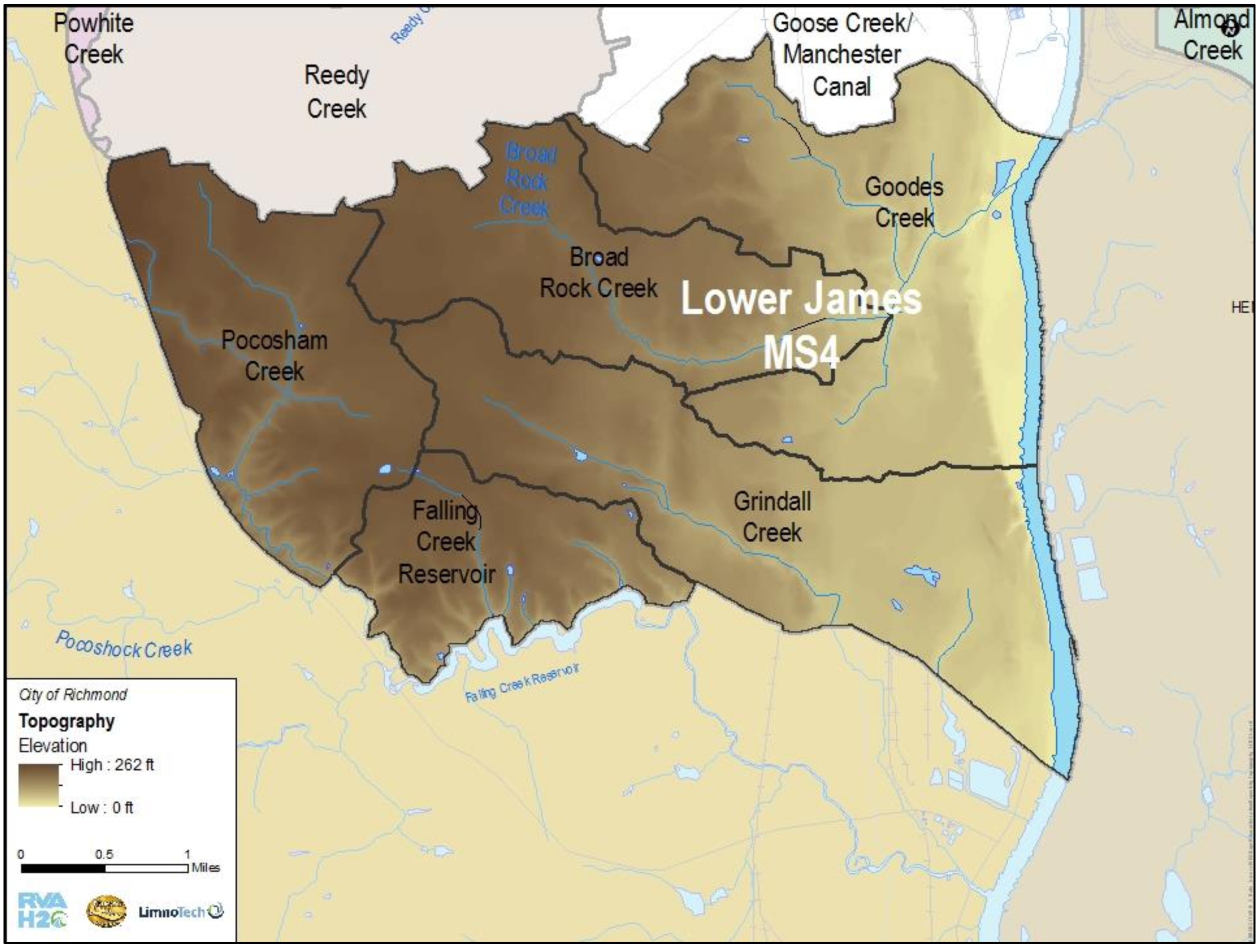

Figure 4.3 Topography of Lower James MS4

Table 4-4 Lower James MS4 topography

Waterbody	Low Elevation (ft)	High Elevation (ft)	Average Slope (%)
Broad Rock Creek	38	221	2.3
Falling Creek Reservoir	58	221	6.8
Goode's Creek	0	205	3.2
Grindall Creek	-1	221	2.7
Pocosham Creek	117	262	3.9
Lower James/MS4	-1	262	3.4

4.3.1.d Soils

Soils in the Lower James MS4 watersheds vary greatly. In some watersheds the soils are primarily composed of urban land complex and Faceville-Gritney-Urban Land complex soils[30].

Soils are assigned a hydrologic soil group (HSG) based on runoff and infiltration characteristics. In some urban areas, the soils are so disturbed that the infiltration cannot be determined and are assigned to the Urban classification. This is true for a large percentage of the soils in Goode's Creek and Grindall Creek (Figure 4.4). In these cases, site-specific infiltration testing is required to better classify the ability of a soil to infiltrate water. HSG A soils are most present in Pocosham Creek and Falling Creek Reservoir. These soils have a low runoff potential when thoroughly wet and infiltrate well. HSG B soils, which comprise the majority of the Falling Creek Reservoir watershed and are present in all of the other watersheds (Figure 4.5), have a moderately low runoff potential when thoroughly wet. Both HSG A and HSG B soils are well suited for infiltration-type BMPs. Class C and D soils often require underdrains to insure water does not pond in these areas.

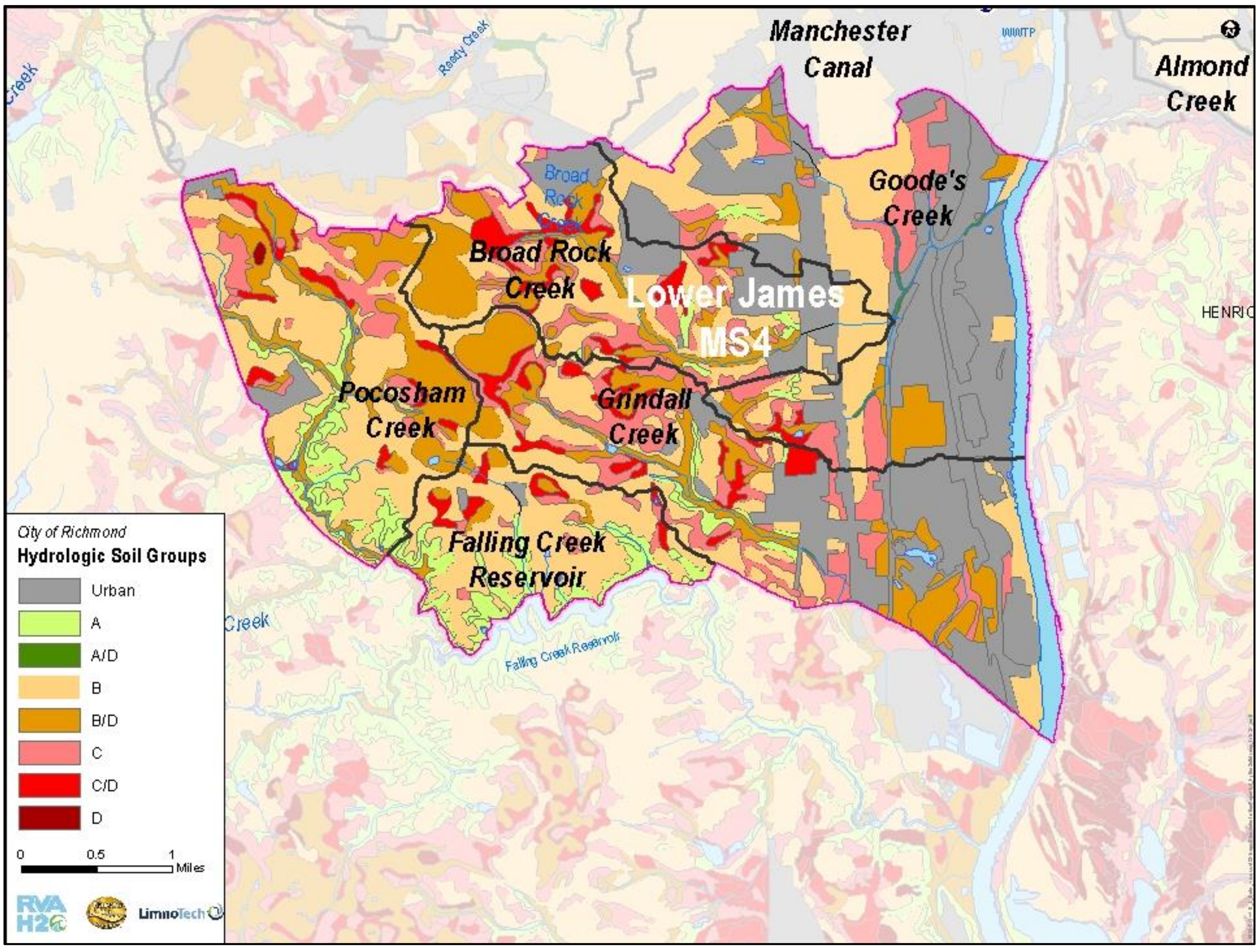

Figure 4.4 Lower James MS4 hydrologic soil group

30 USDA NRCS. 2009. Soil Survey of City of Richmond, VA. http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/virginia/VA760/0/Richmond_VA.pdf .

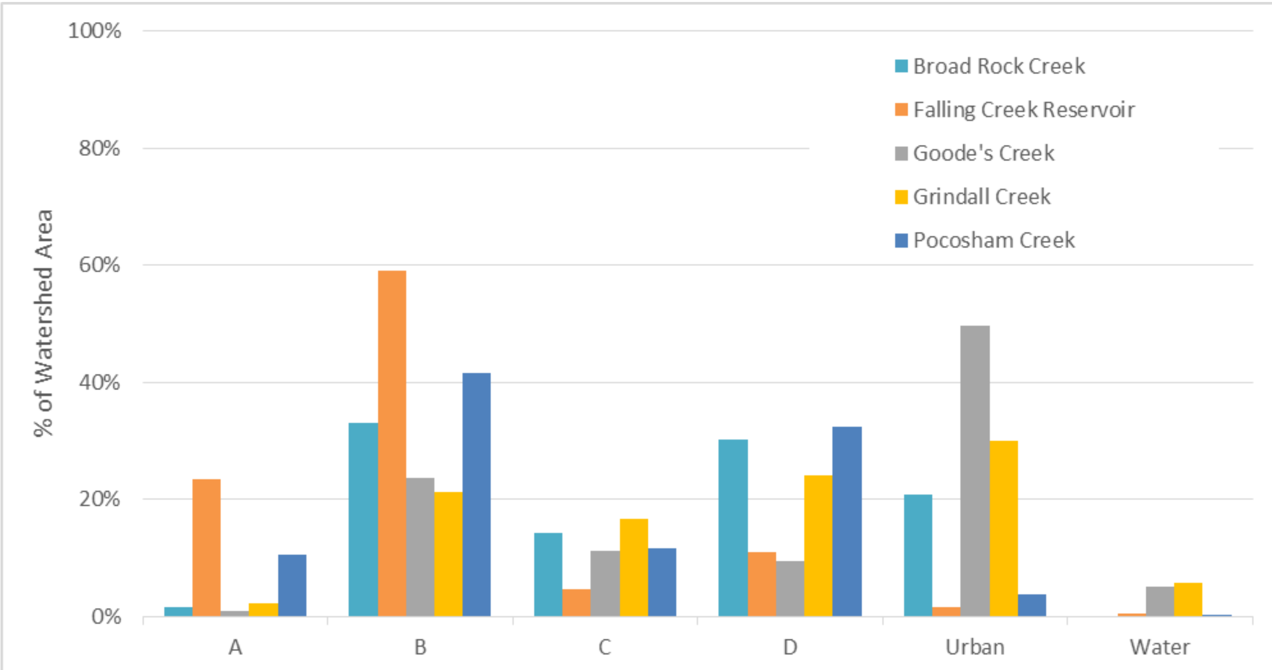

Figure 4.5 Lower James MS4 hydrologic soil group

4.3.2 Land Use/Cover Characteristics

Land use and land cover are important characteristics of watersheds. Land use describes how humans are interacting with and managing the landscape. Land cover is a description of what physically exists on the ground. Current Land Cover

The NLCD land cover for the Lower Middle James MS4 shows developed land cover at varying intensities throughout a majority of the watershed Figure 4.6. The eastern portion of the watershed including Goode's Creek, Grindall Creek, and Broad Rock Creek is the most developed. Forested land cover is seen throughout the watersheds but there is very little in Goode's Creek. Figure 4.7 further shows the prevalence of developed areas in the watersheds. Across all five watersheds, developed land cover is prominent and makes up the greatest percentage of area. The Pocosham Creek and Falling Creek Reservoir watersheds have the largest percentage of forest cover.

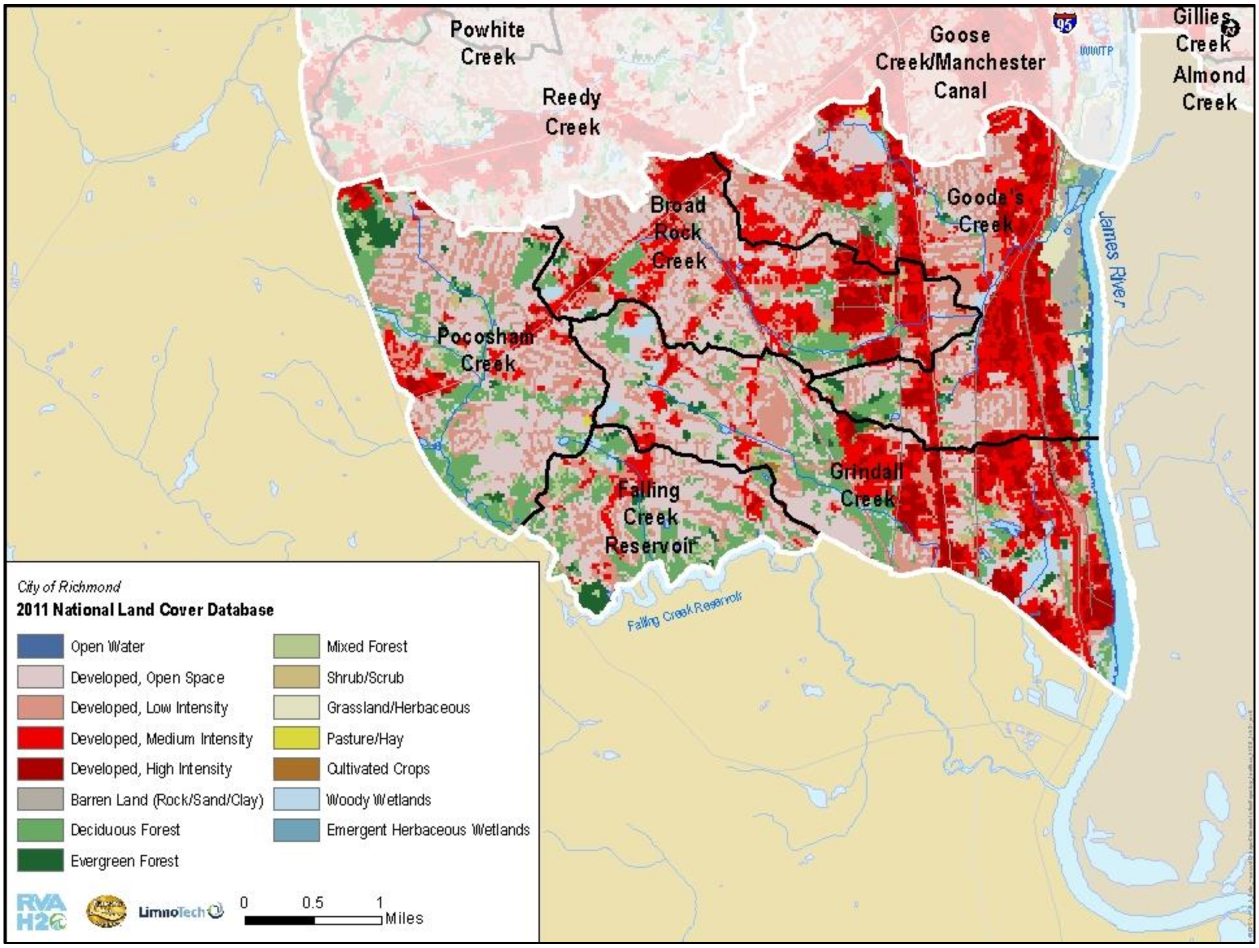

Figure 4.6 2011 NLCD for the Lower James MS4 watershed grouping

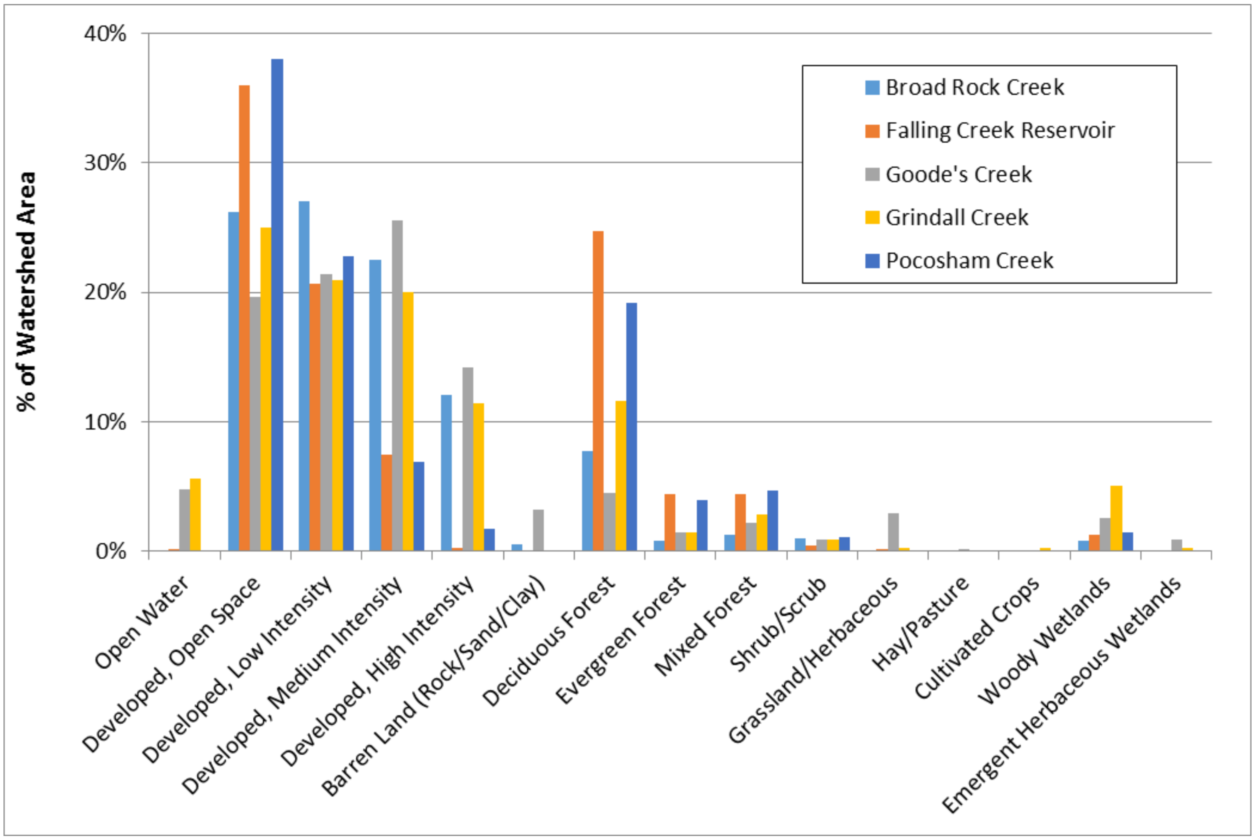

Figure 4.7 NLCD Percent Area within the Lower James MS4 watershed grouping

The VGEP land cover data (Figure 4.8) shows how building and non-building imperviousness dominates the eastern areas Goode's Creek, Brood Rock Creek, and Grindall Creek. Vegetation and tree canopy are more prevalent in the western watersheds, especially in Falling Creek Reservoir.

From the breakdown of land cover by type (Table 4-5), it is possible to see that the Lower James MS4 area is dominated by three land cover categories (non-building impervious, non-tree vegetation, and tree canopy). Broad Rock Creek and Goode's Creek have the largest percentages of impervious areas. Falling Creek Reservoir and Pocosham Creek have the largest percentage of forested areas and the lowest percentage of impervious area.

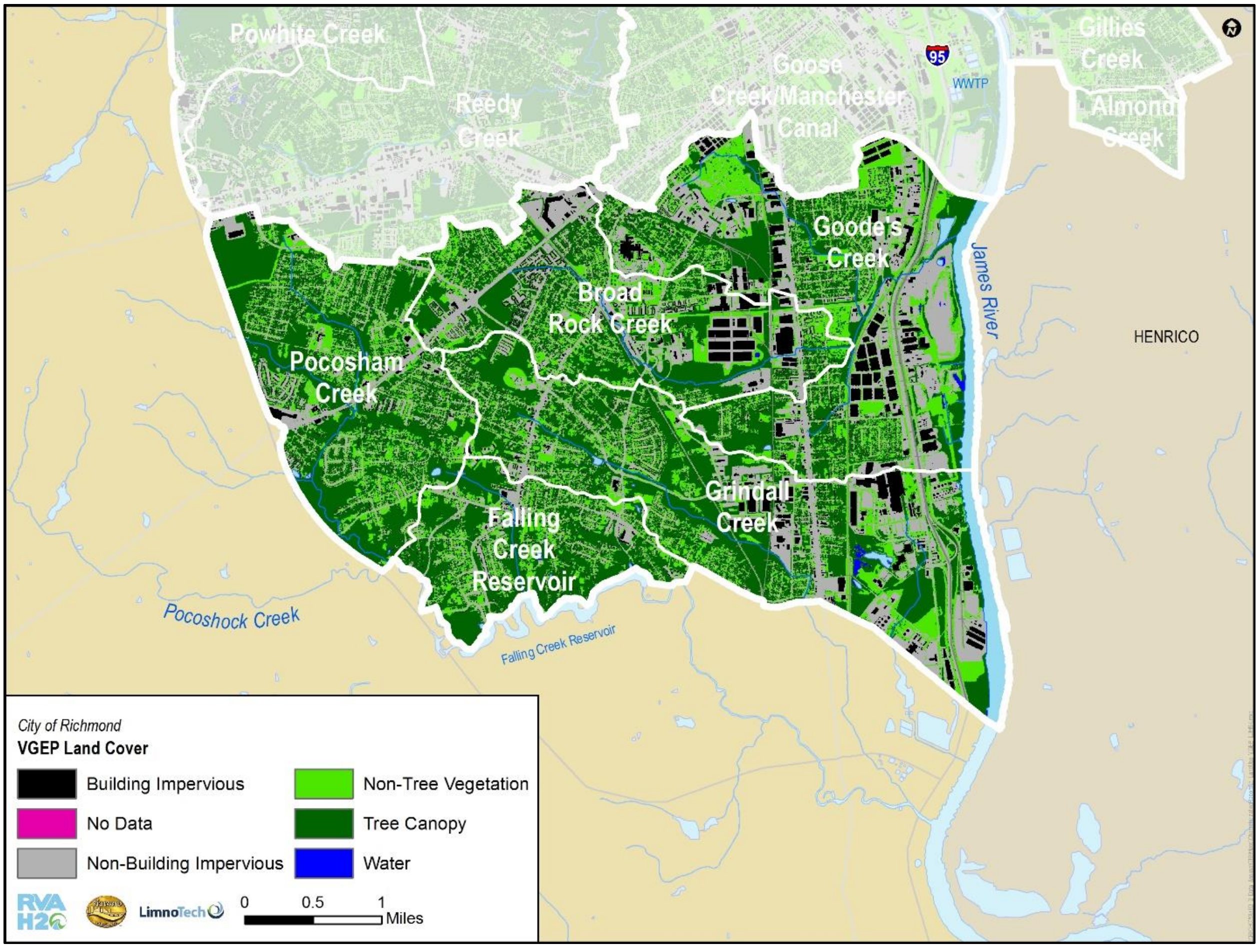

Figure 4.8 VGEP land cover for Lower James MS4

Table 4-5 Lower James MS4 VGEP land cover percentage

Watershed	Water (%)	Non-Building Impervious (%)	Non-Tree Vegetation (%)	Tree Canopy (%)	Building Impervious (%)
Broad Rock Creek	0.1	28.3	23.7	35.2	12.7
Falling Creek Reservoir	0.2	17.6	22.6	54	5.5
Goode's Creek	4.7	29.2	26.7	27.7	11.7
Grindall Creek	5.5	25.3	22.5	38	8.7
Pocosham Creek	0.1	17.2	23.1	52.8	6.8
Lower James/MS4	2.8	24.6	24	39.1	9.5

Imperviousness

Imperviousness in the five watersheds ranges from 22 to 39% with an overall imperviousness of 32% (Table 4-6). Broad Rock Creek and Goode's Creek have similar imperviousness around 39%. The watersheds in the urban eastern part of the Lower James MS4 have the greatest imperviousness, these areas are along the I-95 and Route 1 corridors. Pocosham Creek and Falling Creek Reservoir have similar imperviousness around 22%.

The impervious surfaces in the Lower James MS4 area are dominated by buildings parking, roads, and driveways (Figure 4.9). The more residential watersheds, Pocosham Creek and Falling Creek Reservoir, have a larger percentage of imperviousness attributed to driveways and less attributed to parking than the other watersheds.

Table 4-6 Lower James MS4 watershed imperviousness

Watershed	Percent Impervious
Broad Rock Creek	39.1
Falling Creek Reservoir	22.2
Goode's Creek	38.4
Grindall Creek	32.6
Pocosham Creek	22.5
Total Lower James/MS4	**32.4**

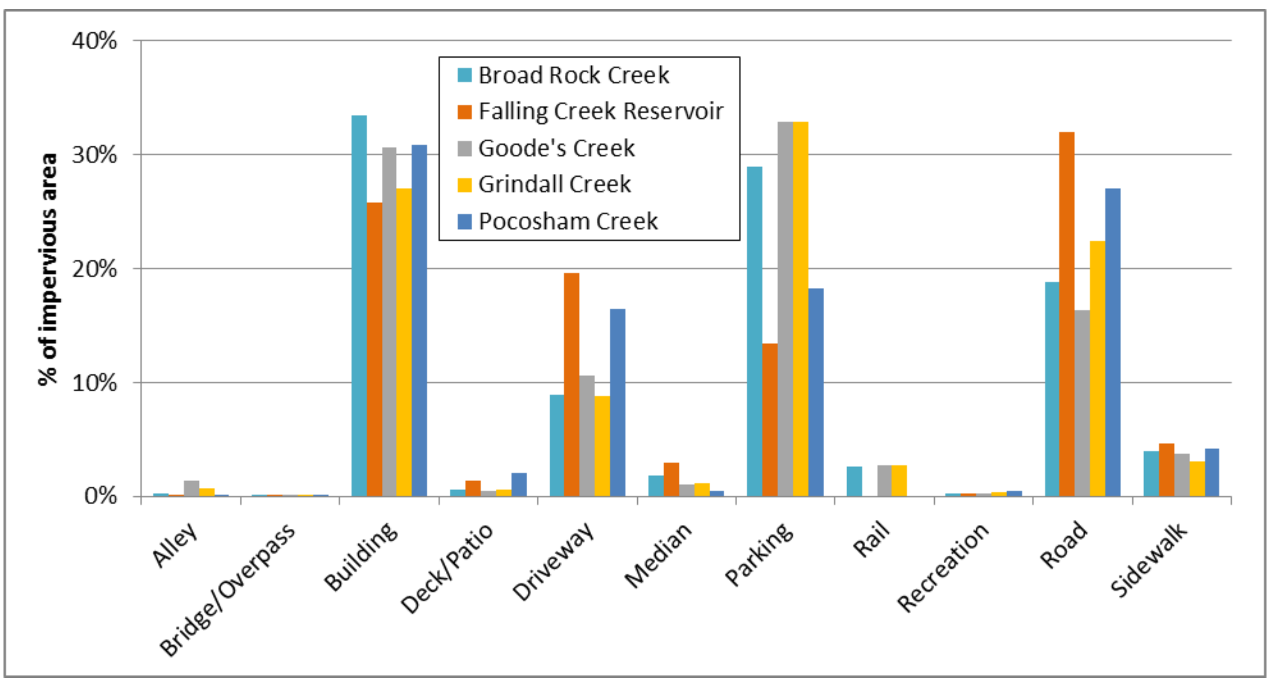

Figure 4.9 Lower James MS4 impervious area by type

Septic Systems

According to City records, 14 septic systems are located in the Lower James MS4 area. Ten septic systems are found within the Falling Creek Reservoir watershed, and two septic tanks are located both the Pocosham Creek and Broad Rock Creek watersheds.

4.3.2.a Land Use

As part of the City's Master Plan, existing land use was mapped in 2008[31]. Residential land uses are found in all five watersheds (Figure 4.10). Public, industrial, and residential land uses dominate the makeup of the Lower James MS4 area (Figure 4.11). The more impervious watersheds, Goode's Creek and Grindal Creek, are reflected in the presence of an expansive industrial land use. Pocosham Creek and Falling Creek Reservoir watersheds have the most residential and commercial areas.

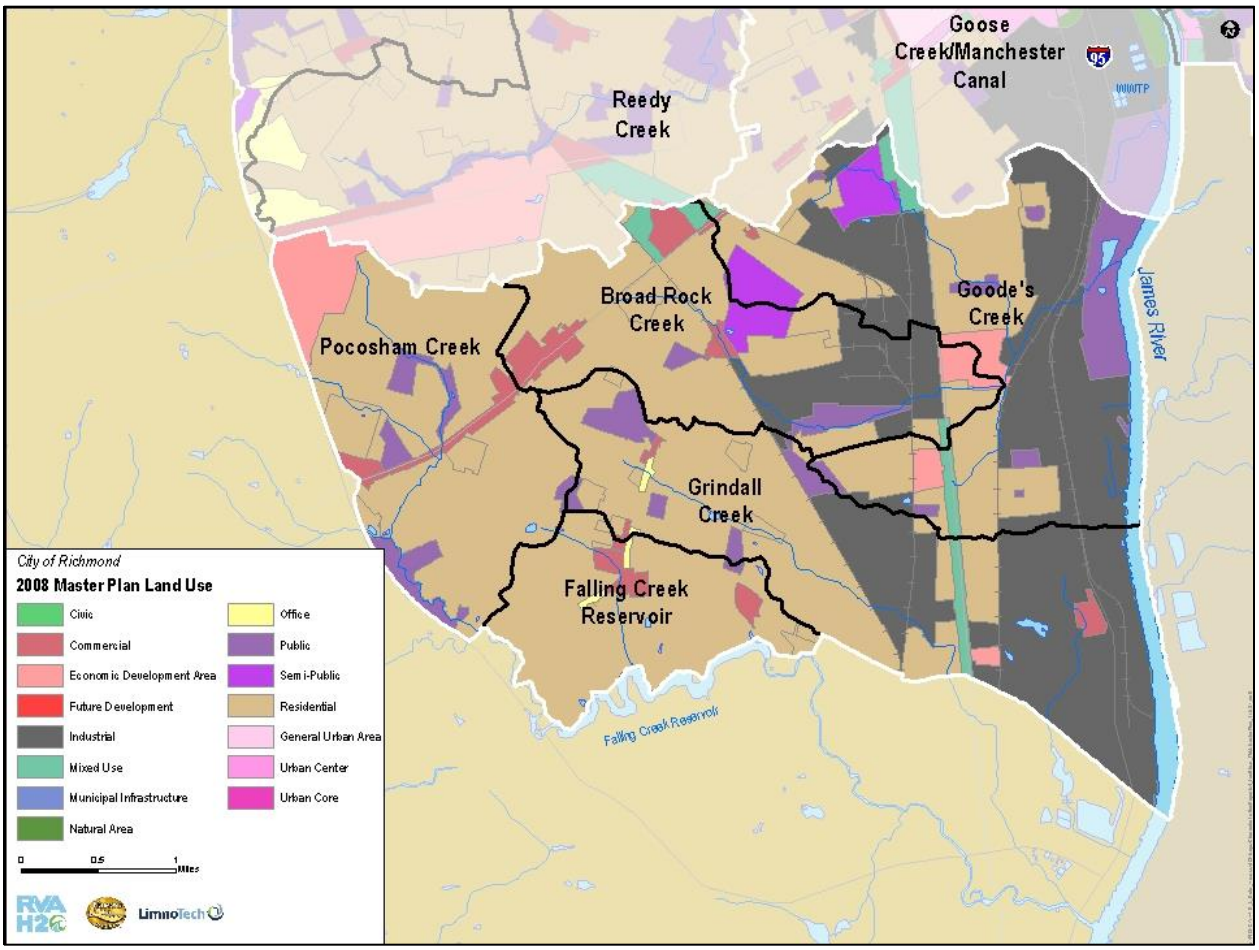

Figure 4.10 2008 Master Plan land use for Lower James MS4 watershed grouping

[31] http://www.richmondgov.com/planninganddevelopmentreview/PlansAndDocuments.aspx

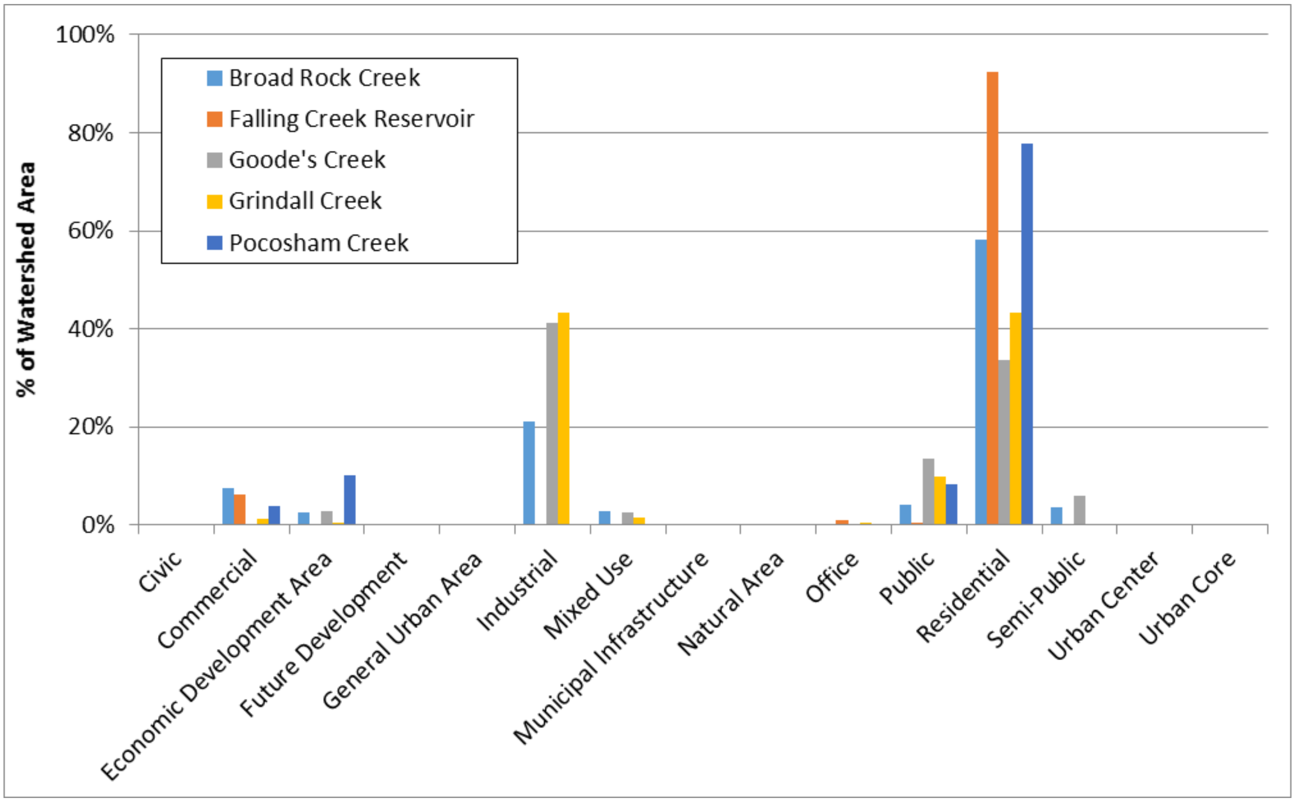

Figure 4.11 Lower James MS4 Master Plan land use

4.3.3 Infrastructure Features

As discussed in Section 3.3.3, above, the City covers a total of approximately 38,000 acres, with 12,000 acres within the combined sewer area with the remaining area are served by a separated sanitary and storm sewer system, and direct runoff. The MS4 area within the Lower James watershed grouping is represented by the hatched area in Figure 4.12.

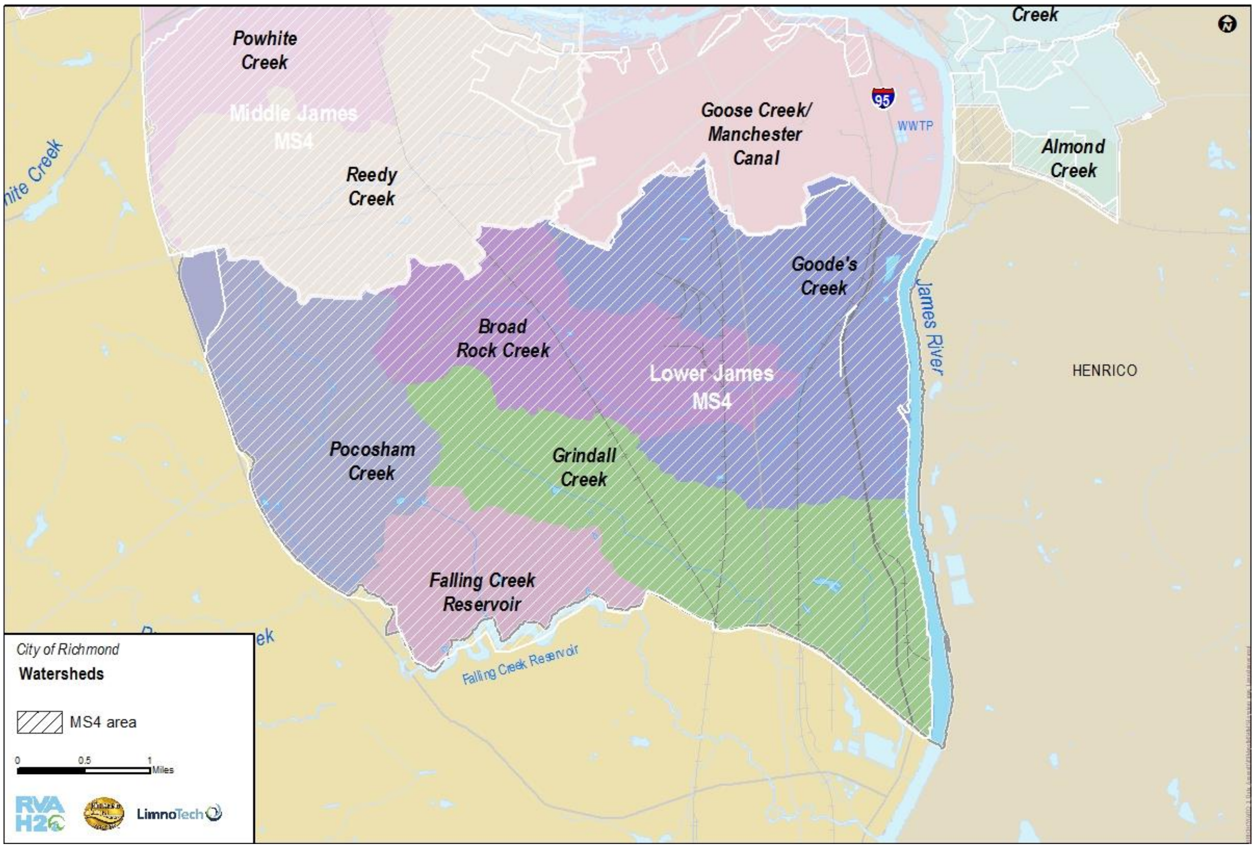

Figure 4.12 MS4 area in Lower James Watershed area

4.3.4 Stormwater System

4.3.4.a General System Description

The City of Richmond operates and maintains an MS4 system which serves approximately 24,500 acres of the City. The Lower James watershed area covers 10,080 acres, 9,653 of which are served by the MS4 system, 396 acres are draining directly into the receiving waters (shown in Table 4-7).

Table 4-7 drainage types in Lower James Watershed area

Receiving Water	MS4 area (acres)	Direct drainage (acres)	Total (acres)
Broad Rock Creek	1,753	0	1,753
Falling Creek Reservoir	1,009	11	1,020
Goode's Creek	2,588	166	2,754
Grindall Creek	2,537	143	2,680
Pocosham Creek	1,766	107	1,873

4.3.4.b Stormwater Collection System Components

Inflow into the MS4 system within the Lower James watershed area is handled by 2,130 inlets which are listed in Table 4-8 below and shown in Figure 4.13.

Table 4-8 Stormwater inlets within Lower James Watershed area

Inlet type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Curb Inlet	285	87	414	437	173	1,396
Grate Inlet	46	21	18	44	52	181
Roof Drain	0	0	0	29	0	29
Unknown	145	19	243	58	59	524
Grand Total	**476**	**127**	**675**	**568**	**284**	**2,130**

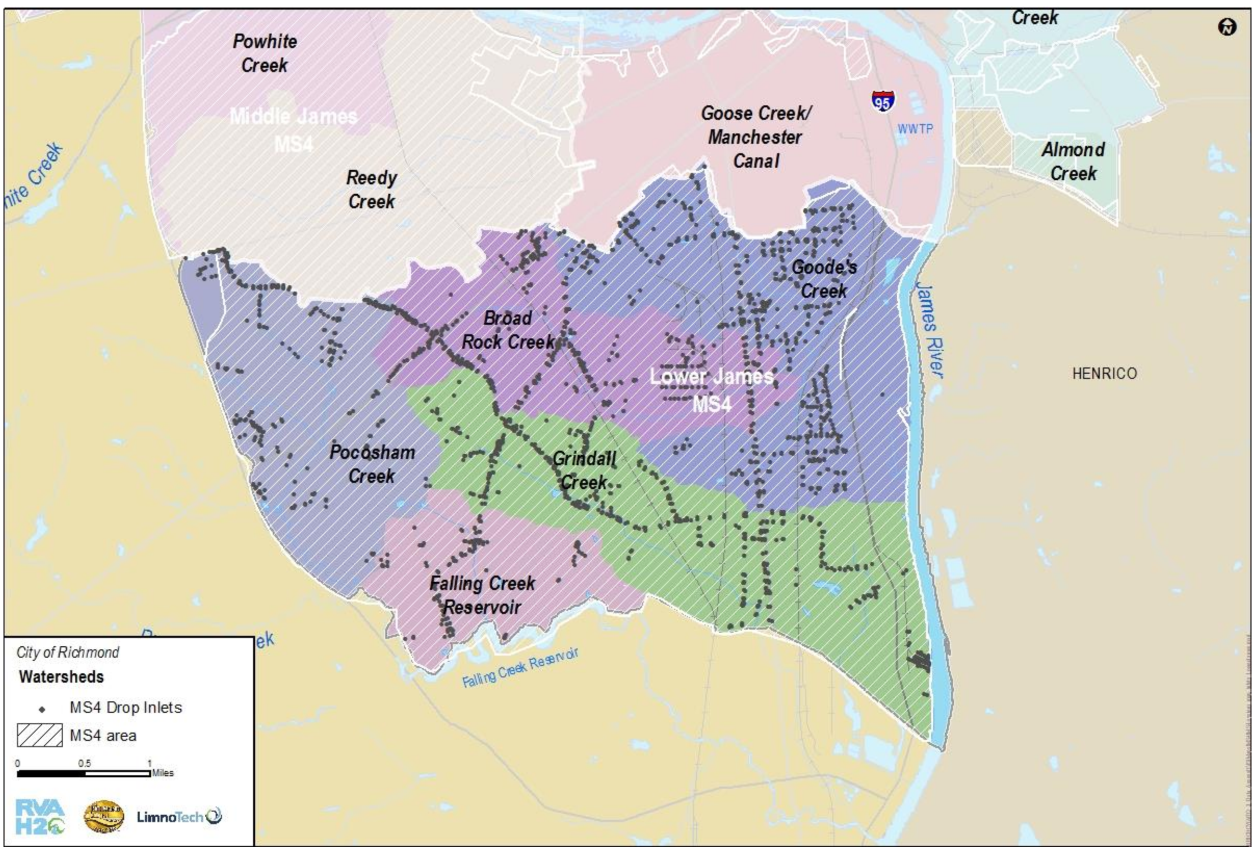

Figure 4.13 Stormwater inlets within Lower James Watershed area

Stormwater conveyance is provided by a network of open channels, culverts and pipes. The combined length of the stormwater system in the Lower James Watershed area is about 176 miles.

Flow in undeveloped areas is often conveyed by open drainage channels which are composed of a mix of different materials (summarized in Table 4-9) which make up about 31% of the stormwater conveyance system in the Lower James Watershed area.

Table 4-9 Open drainage channels in Lower James Watershed Area

Channel material	Channel length (ft.)					
	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Asphalt	711	1,910	68	0	1,153	3,841
Brickwork	0	0	0	0	0	0
Concrete	8,785	12,202	5,989	15,140	10,533	52,649
Rip Rap	44	384	927	4,708	1,525	7,588
Unknown	74,504	45,657	32,890	62,342	122,960	338,353
Vegetation	19,082	16,826	23,697	32,473	26,247	118,326
Grand Total	**103,126**	**76,979**	**63,571**	**114,663**	**162,418**	**520,758**

Stormwater flow in open drainage channels is conveyed underneath roads and other channel crossings via closed culverts (summarized in Table 4-10).

Table 4-10 Stormwater culverts in Lower James Watershed Area

Culvert size	Number of culverts	total length of culverts (ft)
Unknown	2,460	61,458
< 12 inches	263	8,797
12 - 24 inches	459	19,565
27 - 48 inches	74	4,074
54 - 96 inches	21	2,388
> 108 inches	7	658
Grand Total	3,284	96,940

Developed areas are mainly drained by underground pipes with various pipe sizes (summarized in Table 4-11). Pipes make up about 69% of the stormwater conveyance system within the Lower James Watershed area.

Table 4-11 Stormwater pipes in Lower James Watershed Area

Pipe size	Channel length (ft.)					
	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
unknown	4,447	5,465	24,230	11,007	4,452	49,601
< 12 inches	396	0	680	364	683	2,123
12 - 24 inches	32,054	7,773	48,329	41,498	21,022	150,677
27 - 48 inches	15,321	1,752	24,701	18,130	8,400	68,304
54 - 72 inches	3,208	431	9,112	9,174	4,627	26,553
78 - 96 inches	0	0	2,648	4,962	3,338	10,948
> 96 inches	0	0	2,856	1,135	401	4,393
Grand Total	**55,426**	**15,421**	**112,556**	**86,271**	**42,924**	**312,599**

A mix of different best management practices (BMPs) within the stormwater area provide pollution control (summarized in Table 4-12 and shown in Figure 4.14).

Table 4-12 BMPs within Lower James Watershed area

BMP type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Unknown	3	0	8	3	0	14
Bioretention Filter	0	0	0	4	0	4
Detention Basin	1	0	3	5	2	11
Dry Swale	1	0	1	1	0	3
Extended Detention Pond	0	0	2	0	0	2
Grass Channels	0	1	0	0	0	1
Infiltration	0	0	3	1	2	6
Other	0	0	0	2	0	2
Wet Pond	2	0	0	2	2	6
Grand Total	**7**	**1**	**17**	**18**	**6**	**49**

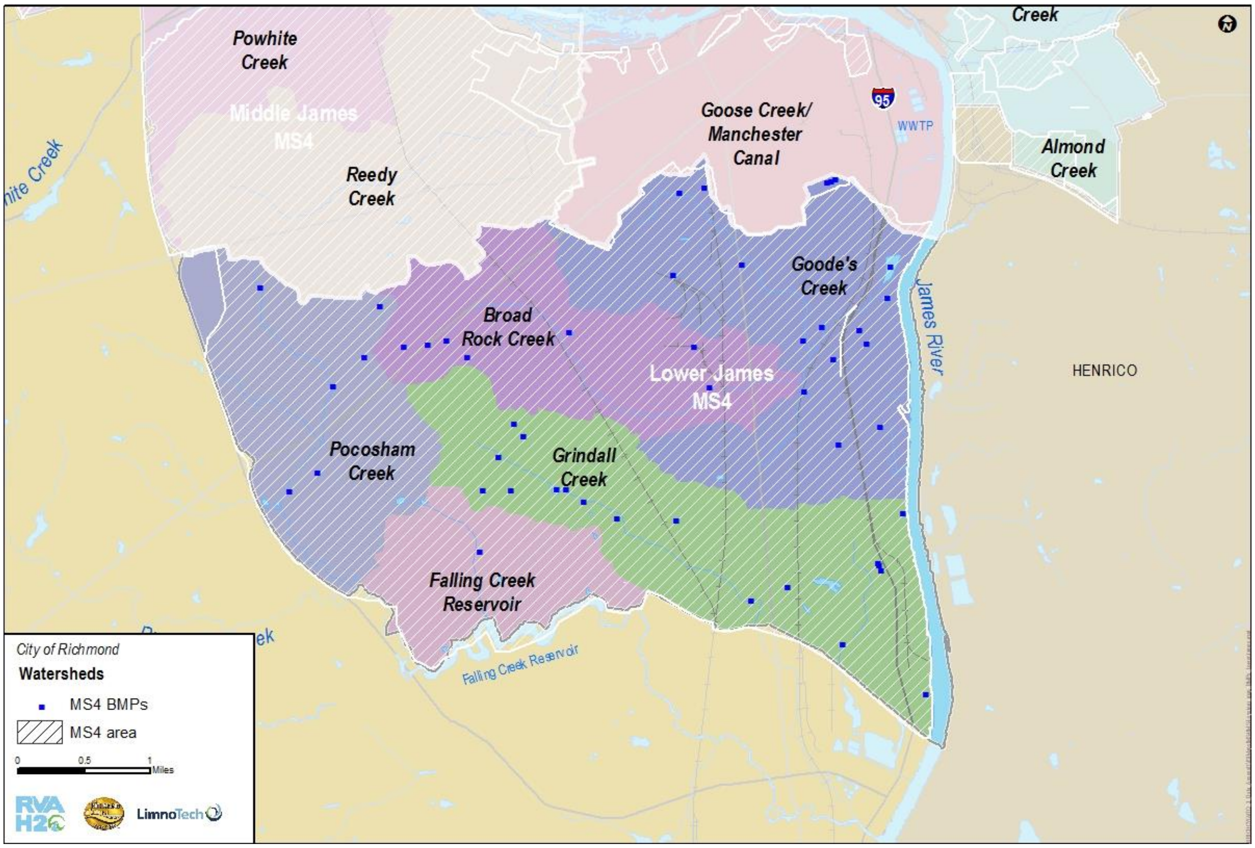

Figure 4.14 BMPs within Lower James Watershed area

Storm water outfalls are defined as points where a storm sewer system discharges to a receiving water or to another MS4. This includes discharges from pipes, ditches, swales, and other points of concentrated storm water flow. Identified outfall locations are summarized in Table 4-13 and shown in Figure 4.15 below. This includes locations of storm water discharge from and to Henrico County.

Table 4-13 Stormwater outfalls in Lower James Watershed area

Outfall type	Broad Rock Creek	Falling Creek Reservoir	Goode's Creek	Grindall Creek	Pocosham Creek	Total
Open Channel - Regulated	1	1	3	0	30	35
Open Channel - from Henrico County	0	0	0	0	2	2
Open Channel - to Henrico County	0	9	0	3	0	12
Open Channel – Other *	39	18	49	39	61	206
Pipe - Regulated	2	1	8	5	14	30
Pipe – Other *	80	9	49	39	22	199
Unknown	0	1	0	0	0	1
Grand Total	**122**	**39**	**109**	**86**	**129**	**485**

(*) This includes types like road drainage, parcel drainage and other miscellaneous or unclear outfall classifications

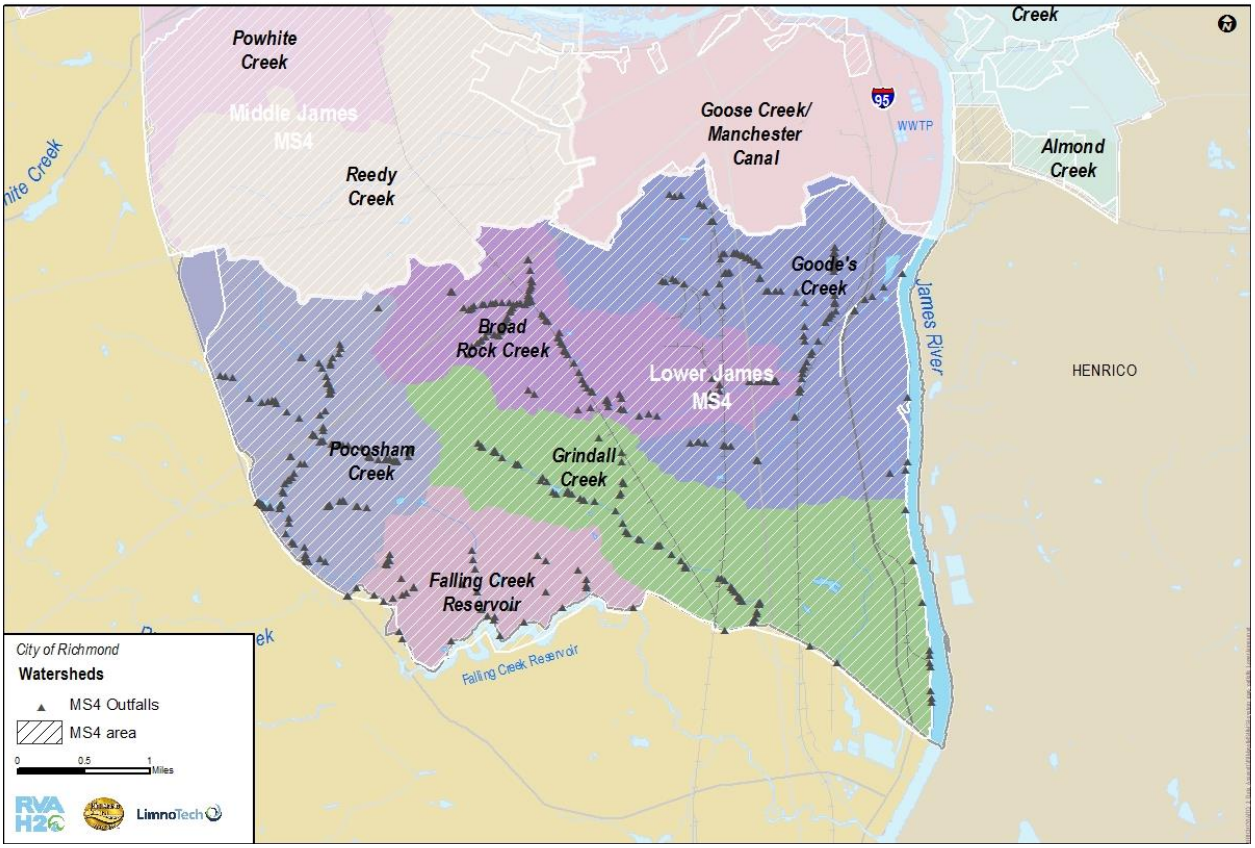

Figure 4.15 Stormwater outfalls within Lower James Watershed area

4.3.4.c Stormwater Master Plan

The City developed a first draft of a Stormwater System Master Plan in 2005 and expanded its area and scope in 2012. An overview and a general description of the current and planned Stormwater Master Plans is provided in Section 3, above.

The Stormwater Master Plan areas within the Lower James Watershed area are Broad Rock Creek, Goodes Creek, Grindall Creek and Pocosham Creek (shown in Figure 4.16).

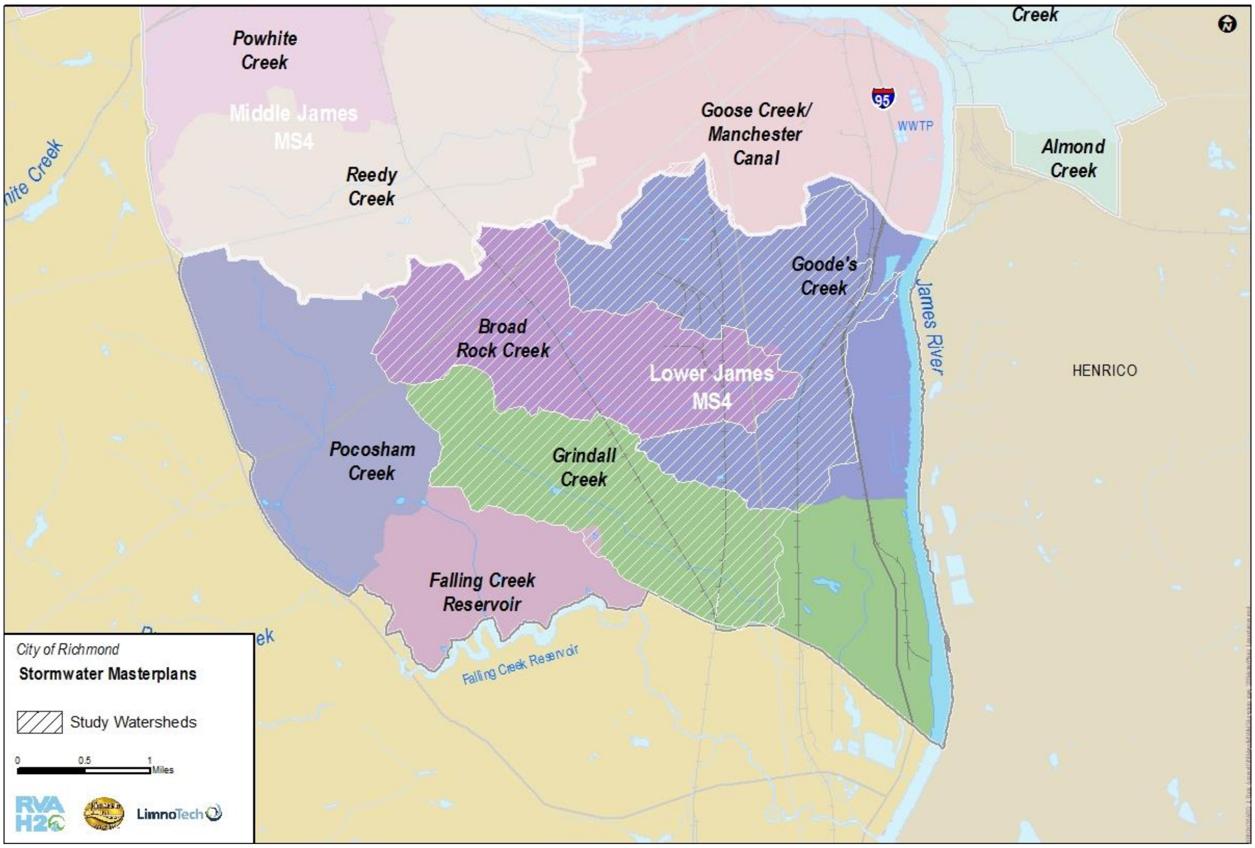

Figure 4.16 Stormwater Master Plans within Lower James Watershed area

4.3.4.d Stormwater Modeling

Hydrologic and hydraulic InfoSWMM models were developed for the Stormwater System Master Plan watersheds within the Lower James Watershed area. Important stormwater network features including pipes, culverts and channels were included. These uncalibrated models were used for an analysis of instream flow velocities, capacity analysis as well as for an evaluation of the water quality (modeled pollutants were TN, TP, TSS based on estimated values using DCR's Runoff Reduction Method). Model results were subsequently used for the development and evaluation of improvement alternatives.

4.4 Water Quality

Water quality in Richmond can be evaluated by analyzing water quality and biological data within the context of area waterbodies' water quality standards and impairment listings. Evaluation of current water quality is essential to the process of identifying pollutant sources and stressors.

Existing data sources for water quality, biological (fish, benthic macroinvertebrates, and habitat indices), flow, and point sources have been identified across various groups and agencies, including City of Richmond's own data collection efforts, Virginia DEQ programs, USGS monitoring efforts, non-agency (NGOs, universities) programs, and citizen and stakeholder groups' monitoring efforts. Virginia DEQ incorporates external data sources, including quality-controlled citizen data, when determining whether a waterbody is impaired.

4.4.1 Designated Uses

All Virginia state waters are designated for aquatic life, wildlife, recreational uses, and fish consumption (*Virginia Administrative Code 9VAC25-260-10, section A*). Other designated uses that may be assigned to select waterbodies include shell-fishing and public water supply uses.

There are additional designated use categories for tidal tributaries to the Chesapeake Bay: migratory fish spawning and nursery, shallow-water submerged aquatic vegetation, open water aquatic life, deep water aquatic life, and deep channel seasonal refuge.

Table 4-14summarizes the designated uses that have been assigned to one or more waterbody segments in the Lower James MS4 watersheds, by waterbody type. Note that waterbody segments may extend well outside of the Lower James MS4 watersheds group; this is particularly true for estuarine segments.

Table 4-14 Lower James MS4 watershed grouping designated uses

Designated Use	Tidal Freshwater waterbodies	Riverine waterbodies	Reservoir waterbodies
Aquatic Life	X	X	X
Fish Consumption	X	X	X
Public Water Supply			
Recreation	X	X	X
Wildlife	X	X	X
Shellfishing			
Migratory Fish Spawning & Nursery	X	n/a	n/a
Deep Channel Seasonal Refuge		n/a	n/a
Deep Water Aquatic Life		n/a	n/a

Designated Use	Tidal Freshwater waterbodies	Riverine waterbodies	Reservoir waterbodies
Open Water Aquatic Life	X	n/a	n/a
Shallow Water Submerged Aquatic Vegetation	X	n/a	n/a

4.4.2 303(d) Status

Under Section 303(d) of the Clean Water Act, states are required to submit to EPA a TMDL Priority List every other year. In Virginia, this list is contained in its biannual Water Quality Assessment 305(b)/303(d) Integrated Report, a joint publication of DEQ, DCR, and the state Department of Health. Waters are placed into federal categories based on each waterbody segment's (or 'assessment unit') support for its designated uses. Virginia supplements the federal categories with its own subcategories to better describe and track attainment/impairment.

The waterbody segments in the Lower James MS4 watersheds (Figure 4.17) have all been placed in one of three of the following EPA categories / Virginia subcategories in most recent (2014) Integrated Report:

- **EPA Category 2:** Available data and/or other information indicate that some, but not all of the designated uses are supported.
    - **Virginia Category 2B:** Waters are of concern to the state but no water quality standard exists for a specific pollutant, or the water exceeds a state screening value or toxicity test.
- **EPA Category 4A:** Water is impaired or threatened for one or more designated uses but does not require a TMDL. A new TMDL is not necessary to address the newly identified impaired tributaries if TMDL modeling, source identification and reductions cover the entire watershed and the TMDL has been approved by EPA. These waters are primarily related to shellfish and/or recreational bacteria impairments but could include benthic impairments**.**
- **EPA Category 5:** Waters are impaired or threatened and require a TMDL.
    - **Virginia Category 5D:** The water quality standard is not attained where TMDLs for a pollutant(s) have been developed but one or more pollutants are still causing impairment requiring additional TMDL development.

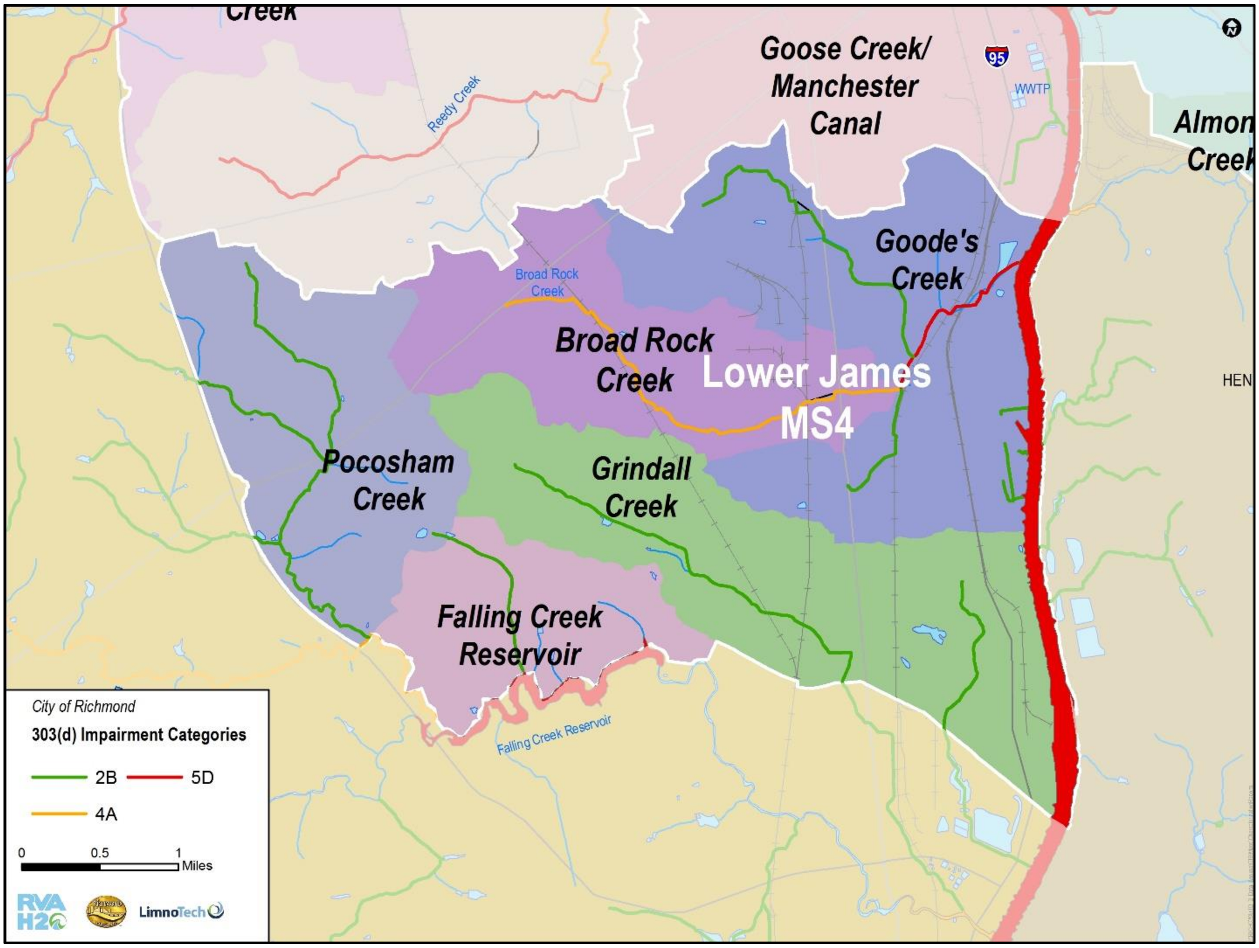

Figure 4.17 Lower James MS4 watershed grouping 303(d) impairment categories

For the impaired waterbody segments, the impairment causes identified in the 2014 Integrated Report for the Lower James MS4 watersheds include:

- Chlorophyll-a
- *E. coli*
- Estuarine Bioassessments
- Dissolved Oxygen
- PCB in Fish Tissue
- PCB in Water Column
- Aquatic Plants (macrophytes)

4.4.3 Monitoring Programs

Within the Lower James MS4 watersheds, most of the water quality data collection efforts have been led by Virginia Department of Environmental Quality (VADEQ) and the City of Richmond. Other organizations collecting data within the City of Richmond include federal, local, and volunteer/non-profit organizations, and industrial permittees. Data currently compiled by the City of Richmond from known monitoring programs are presented in Table 4-15.

Table 4-15 Summary of water quality monitoring programs

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Old Dominion University Benthic Biological Monitoring Program	Old Dominion University (ODU)	Academic	2006	BIO/HAB	1	1	1	5	5	No habitat data
Virginia Shallow Water Monitoring Program-DATAFLOW Cruises	Virginia Institute of Marine Science--College of William & Mary (VIMS)	Academic	2005-2008	CM	n/a	1	20	3	35,646	DATAFLOW Cruises record results every 2-4 seconds
VAR052128 Water Quality Sampling	Alloy Polymers	Industrial	2014-2015	SRC	1	1	2	3	6	
VAR051484 Water Quality Sampling	Branscome Richmond	Industrial	2013-2015	SRC	1	1	3	3	9	
VAR050613 Water Quality Sampling	Carpenter Company	Industrial	2014	SRC	1	1	1	3	9	
VAR050727 Water Quality Sampling	Closed Edelsons Recycling Company Landfill	Industrial	2013	SRC	1	1	1	2	2	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
VAR050603 Water Quality Sampling	Eubank Trucks Inc.	Industrial	2011-2015	SRC	1	1	3	4	13	
VAG110308 Water Quality Sampling	Hanson Concrete Products	Industrial	2012	SRC	1	1	12	11	132	
VAR051176, VAR051549 Water Quality Sampling	International Paper Co.	Industrial	2014-2015	SRC	2	1	4	10	34	
VA0058378, VA0086151 Water Quality Sampling	Kinder Morgan	Industrial	2000-2015	SRC	2	1	323	15	2,274	
VAG840078 Water Quality Sampling	Luck Stone	Industrial	2004-2015	SRC	1	1	50	13	386	
VAR051151Water Quality Sampling	Packaging Corporation of America	Industrial	2014-2015	SRC	1	1	3	3	9	
VAR051019 Water Quality Sampling	Phillip Morris USA, Inc.	Industrial	2014-2015	SRC	1	1	2	3	48	
VAR050563 Water Quality Sampling	Smith Iron and Metal Company, Inc	Industrial	2010-2015	SRC	1	1	5	10	43	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
VAR050588 Water Quality Sampling	SMM Southeast LLC	Industrial	2012	SRC	1	1	1	8	8	
VAR051103 Water Quality Sampling	Sonoco Products Company	Industrial	2012-2015	SRC	1	1	4	4	36	
VA0085499, VAR050554 Water Quality Sampling	Spruance Genco LLC	Industrial	2000-2015	SRC	2	2	209	21	6,374	
VAR050910 Water Quality Sampling	Upaco Adhesives	Industrial	2014-2015	SRC	1	1	2	3	36	
VA0087734 Water Quality Sampling	VEPCO Maintenance and Supply	Industrial	2000-2015	SRC	1	1	147	17	869	
VAG840120 Water Quality Sampling	Vulcan Construction Materials	Industrial	2004-2015	SRC	1	1	53	12	451	
VAR051122 Water Quality Sampling	Whitehurst Transport Inc.	Industrial	2010-2013	SRC	1	1	3	2	6	
VAR051020 Water Quality Sampling	PCI of Virginia LLC	Local	2010-2015	SRC	1	1	6	7	93	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Old Dominion University Benthic Biological Monitoring Program	Old Dominion University (ODU)	Academic	2006	WQ	1	1	2	6	6	
VCU James River Water Quality Monitoring	Virginia Commonwealth University (VCU)	Academic	2010-2014	WQ	2	1	282	15	2,828	
Virginia Shallow Water Monitoring Program-Continuous Monitoring	Virginia Institute of Marine Science--College of William & Mary (VIMS)	Academic	2006-2008	WQ	1	1	349	28	2,348	
City of Richmond Routine Water Quality Monitoring	City of Richmond	Local	2012-2013	WQ	22	3	22	7	54	
VADEQ Chesapeake Bay Tributary Monitoring	Virginia Department of Environmental Quality (VADEQ)	State	2000-2013	WQ	1	1	1,105	38	12,051	
VADEQ QA/QC Program	Virginia Department of Environmental Quality (VADEQ)	State	2010	WQ	1	1	1	24	54	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
VADEQ Routine sampling	Virginia Department of Environmental Quality (VADEQ)	State	2007-2012	WQ	7	3	548	12	2,871	
Chesapeake Bay Program Water Quality and Habitat Monitoring	Chesapeake Bay Program	Federal	2013-2014	WQ	1	1	32	31	851	

[1] Data types: BIO/HAB=Biological/habitat; CM=Continuous monitoring; MET=Meteorological; SRC=Point source; WQ=Water quality.
[2] NGO=Non-governmental organization

4.4.4 Water Quality Data

Water quality sampling data were collected at 34 stations within the Lower James MS4 watersheds. Nine stations accounted for 2,316 sampling events, with the remaining 25 stations represent a single sampling event each. From that total of 2,341 sampling events, 21,063 individual samples (single-parameter observations) were collected. While data were collected from 2000 to 2014, 83% of the samples were collected since 2006. There are 60 different parameters for which there are samples. **Error! Reference ource not found.** depicts the number of water quality sampling events conducted by station.

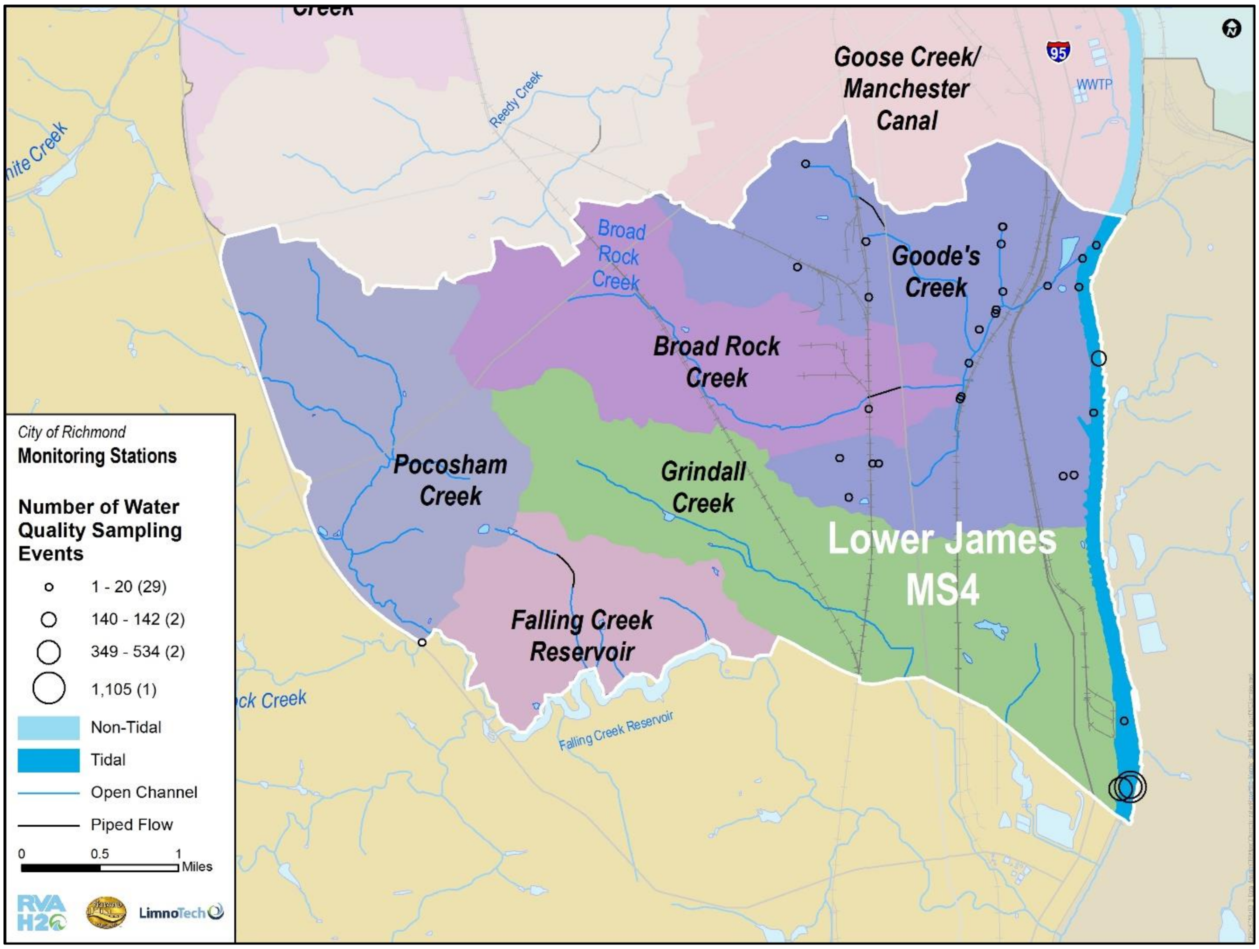

Figure 4.18 Lower James MS4 watershed grouping water quality sampling stations by number of sampling events

Available point source data for discharge points within the Lower James MS4 watersheds consist of flow and water quality sampling from 23 permitted facilities. Data consist of discharge monitoring report (DMR) content. Permitted facilities are listed below in Table 4-16; locations and number of sampling events are shown on Figure 4.19.

Table 4-16 Permitted Facilities in Lower James MS4 Watersheds

VPDES Permit Number	Description/Owner	Permit Type	Number of Sampling Events	Number of Samples
VA0058378	Kinder Morgan Southeast Terminal	Individual	187	1,514
VA0085499	Spruance Genco LLC	Individual	202	6,361
VA0086151	Kinder Morgan Transmix Company	Individual	136	760
VA0087734	VEPCO Maintenance and Supply	Individual	147	869
VAG110308	Hanson Concrete Products	General: Concrete	12	132
VAG840078	Luck Stone – South Richmond Plant	General: Non-Metallic Mineral Mining	50	386
VAG840120	Vulcan Construction Materials LP - Richmond Quarry	General: Non-Metallic Mineral Mining	53	451
VAR050554	Spruance Genco LLC	General: Industrial Activity	7	13
VAR050563	Smith Iron and Metal Company Inc.	General: Industrial Activity	5	43
VAR050588	SMM Southeast LLC – Richmond	General: Industrial Activity	1	8
VAR050603	Eubank Trucks Incorporated	General: Industrial Activity	3	13
VAR050613	Carpenter Company Richmond Division	General: Industrial Activity	1	9
VAR050727	Closed Edelsons Recycling Company Landfill	General: Industrial Activity	1	2
VAR050910	Upaco Adhesives - Division of Worthen Industries	General: Industrial Activity	2	36
VAR051019	Philip Morris USA Incorporated	General: Industrial Activity	2	48
VAR051020	Port of Richmond	General: Industrial Activity	6	93
VAR051103	Sonoco Products Company	General: Industrial Activity	4	36

VPDES Permit Number	Description/Owner	Permit Type	Number of Sampling Events	Number of Samples
VAR051122	Whitehurst Transport Incorporated	General: Industrial Activity	3	6
VAR051151	Packaging Corporation of America	General: Industrial Activity	3	9
VAR051176	International Paper Company - Richmond Plant	General: Industrial Activity	2	12
VAR051484	Branscome Richmond - Deepwater Terminal Rd	General: Industrial Activity	3	9
VAR051549	International Paper - Richmond Recycling Center	General: Industrial Activity	2	22
VAR052128	Alloy Polymers	General: Industrial Activity	2	6

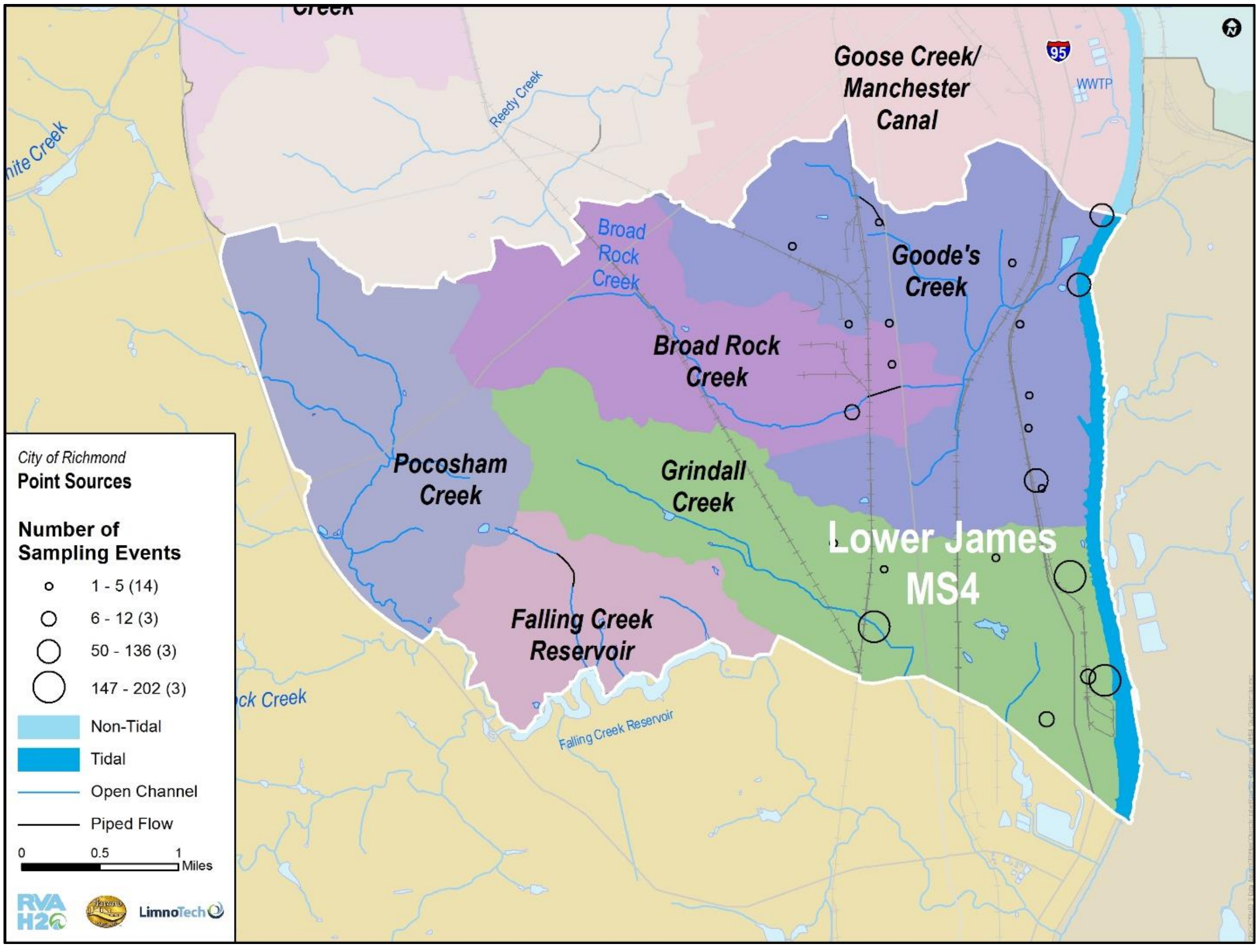

Figure 4.19 Lower James MS4 watershed grouping point sources by number of sampling events

The VIMS DATAFLOW continuous-monitoring data set from cruises of the tidal James River yielded over 22,000 sampling events within the City of Richmond, with each sampling event including temperature, turbidity, and chlorophyll data. Of those sampling events, about 12,000 were conducted within the portion of the tidal James River that is within the Lower James MS4 watersheds. Cruises were conducted from 2005 to 2008 from April to September. Viewed collectively, the data sets from these cruises indicate seasonal/temperature-based variances in chlorophyll concentrations, but no correlation with river mile is evident.

4.4.5 Biological Conditions

Biological and habitat-related data consist of fish count and fish tissue data, benthic macroinvertebrate data that include taxa counts, metric scores and index scores, and habitat metric scores. All data were obtained through queries of the Chesapeake Bay Program Living Resources Database.

Benthic macroinvertebrate metrics were calculated by the Chesapeake Bay Program Living Resources Database (CBP 2012). A limited number of the benthic macroinvertebrate metrics are then used to develop scores using one of two multi-metric indices: the Bay Program's own Benthic Index of Biotic Integrity (CB B-IBI) or the Coastal Plain Macroinvertebrate Index (CPMI)[32]. These multi-metric indices can then be used to assess the quality of the biological community as a whole. For the Lower James MS4

[32] Chesapeake Bay Program. 2012. The 2012 User's Guide to Chesapeake Bay Program Biological Monitoring Data.

watersheds, only CB B-IBI scores were generated from the available data. All data were collected in the James River. Figure 4.20 shows the combined number of biological samples collected and habitat assessments conducted, by station.

The CB B-IBI scores on a scale of 1 to 5. The James River within the Lower James MS4 watersheds had five CPMI scores calculated from one sample; all five scores were 5.

Benthic macroinvertebrate taxa data were also collected in the Lower James MS4 watersheds. These data consisted of 16 taxa for the James River based on one sampling event. Counts may represent one of a number of taxonomic ranks (species, genus, family, etc).

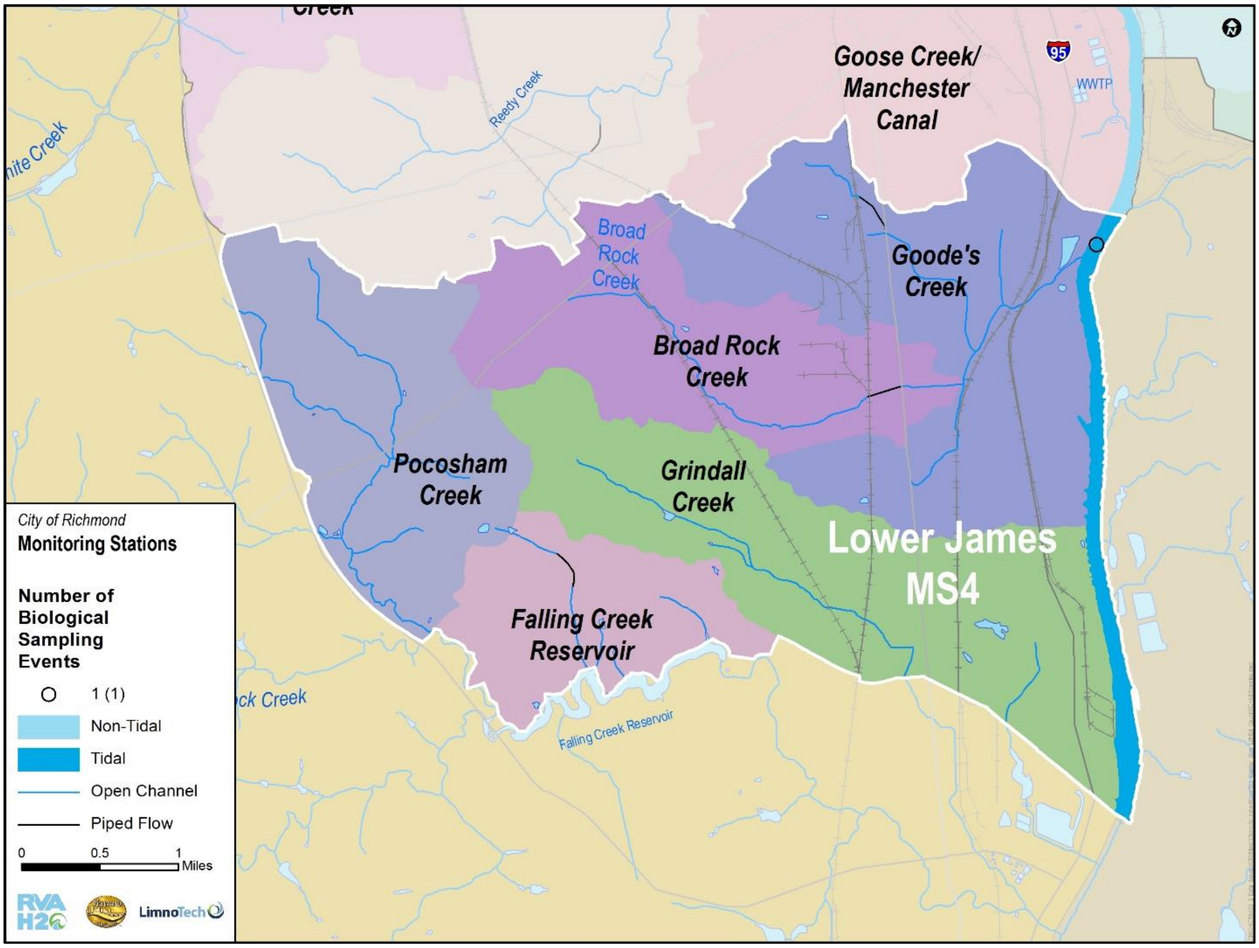

Figure 4.20 Biological sampling stations by number of sampling events

4.4.6 Pollutant Sources

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. For segments within the Lower James MS4 watershed group, the following suspected sources were identified:

- MS4 Discharges
- Combined Sewer Overflows
- Non-Point Sources
- Municipal Point Source Discharges
- Industrial Point Source Discharges
- Atmospheric Deposition (nitrogen)
- Clean Sediments
- Internal Nutrient Cycling

- Loss of Riparian Habitat

4.4.7 Stressors

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Table 4-17 includes stressors that Virginia DEQ has identified as being most prevalent. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value.

Table 4-17 Most frequent stressors to Virginia waterbodies

With WQS/Screening Value	*Without* WQS/Screening Value
Biomonitoring Indices (VSCI/CPMI)	Streambed Sedimentation
pH below 6	Habitat Disturbance
Nickel in Sediment	Total Phosphorus
Dissolved Nickel	Total Nitrogen
Dissolved Cadmium	CCU Metals Index
Mercury in Sediment	Ionic Strength
Dissolved Oxygen	

It should be noted that the analysis of sources and stressors will be completed within the next phase of the project. Analysis of collected data will be spatially linked with listings of impaired water body segments to identify or confirm potential sources and stressors within a watershed. Data upon which an impairment listing is based will also be compared with other data sources that have been compiled, to help determine whether additional data may support/strengthen or weaken an impairment listing, and whether additional review may be warranted.

5 Lower James-Chickahominy MS4

5.1 Watershed Summary

The Lower James-Chickahominy MS4 area of Richmond is comprised of three watersheds: Jordan's Branch, Upham Brook, and Chickahominy River/Horse Creek. The region is situated in the northern side of the City and covers areas north James River (Figure 5.1). The total area characterized in this watershed grouping is 6.5 square miles (Figure 5.1).

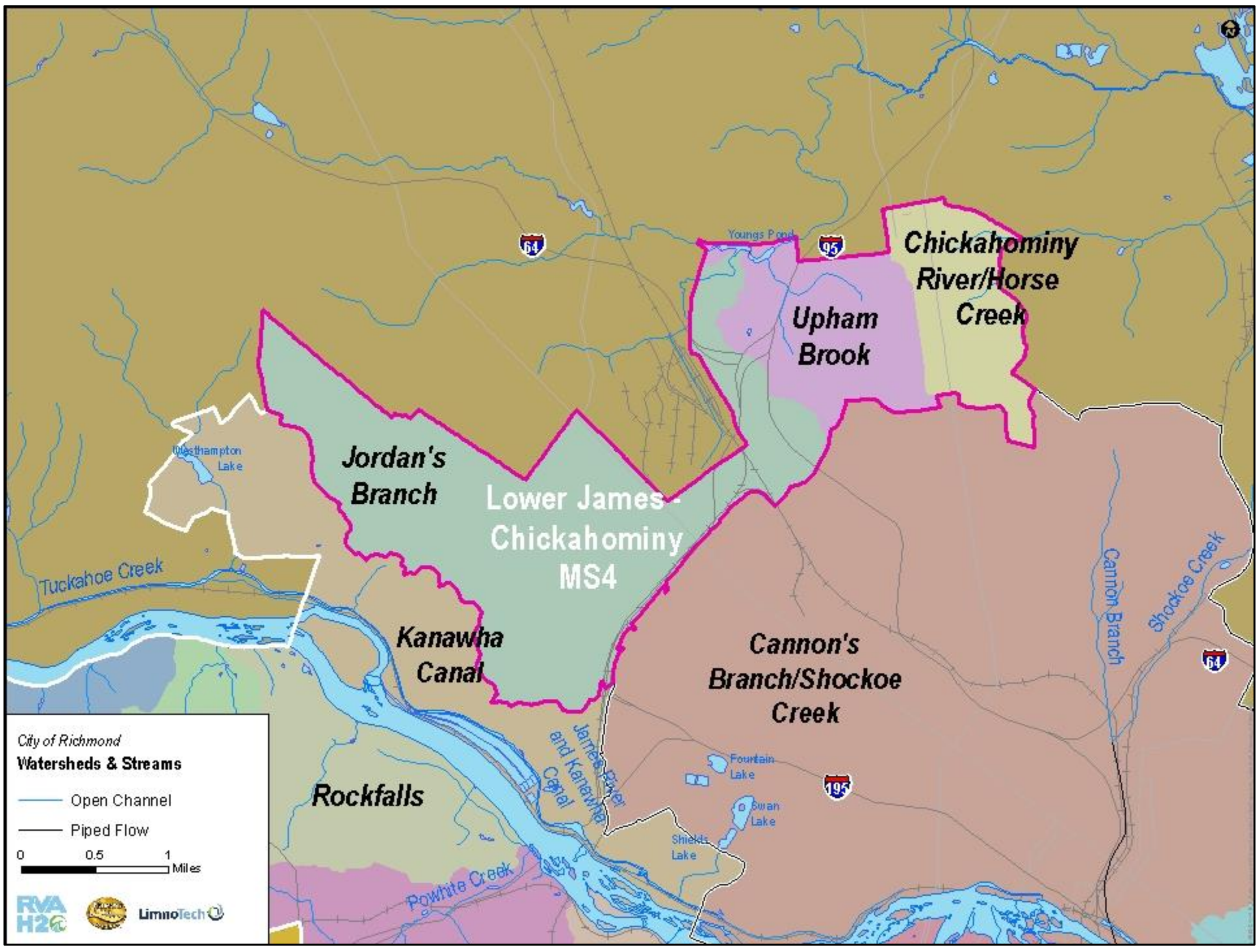

Figure 5.1 Watersheds and streams within the Lower James-Chickahominy MS4 watershed grouping

Table 5-1 Lower James-Chickahominy MS4 watershed Area

Watershed	Watershed Area (sq. mi.)	% of Total Lower James-Chickahominy/MS4
Chickahominy River/Horse Creek	1.0	15.5
Jordan's Branch	4.2	64.4
Upham Brook	1.3	20.1
Total Lower James Chickahominy/MS4	**6.5**	**100.0**

5.2 Watershed Delineation

Delineation of watersheds in the City of Richmond was driven by the existing topography and collection systems. During the delineation process, each watershed boundary was carefully drawn to reflect how the slopes in the land surface and pipes transport water. A detailed discussion of the delineation is included in the Existing Watershed Data Assessment Report and the Watershed Delineation Technical Memorandum[33].

For characterization purposes in this section, three of the twenty watersheds in the City of Richmond have been grouped together:

- Chickahominy River/Horse Creek
- Jordan's Branch
- Upham Brook

5.3 Watershed Features

Watershed characteristics are major factors that need to be considered when identifying pollution sources and determining appropriate methods to reduce them. This section will describe the watershed and stream characteristics. The Lower James-Chickahominy MS4 grouping of watersheds represents 6.5 square miles. As seen in

[33] Available at www.rvah2o.org.

Table 5-1, the largest watershed is Jordan's Branch and the smallest is Chickahominy River/Horse Creek.

A total of 4.4 miles of streams exist in the five watersheds. These watersheds include portions of three of the nine City Council districts (1, 2, 3) in Richmond Table 5-2.

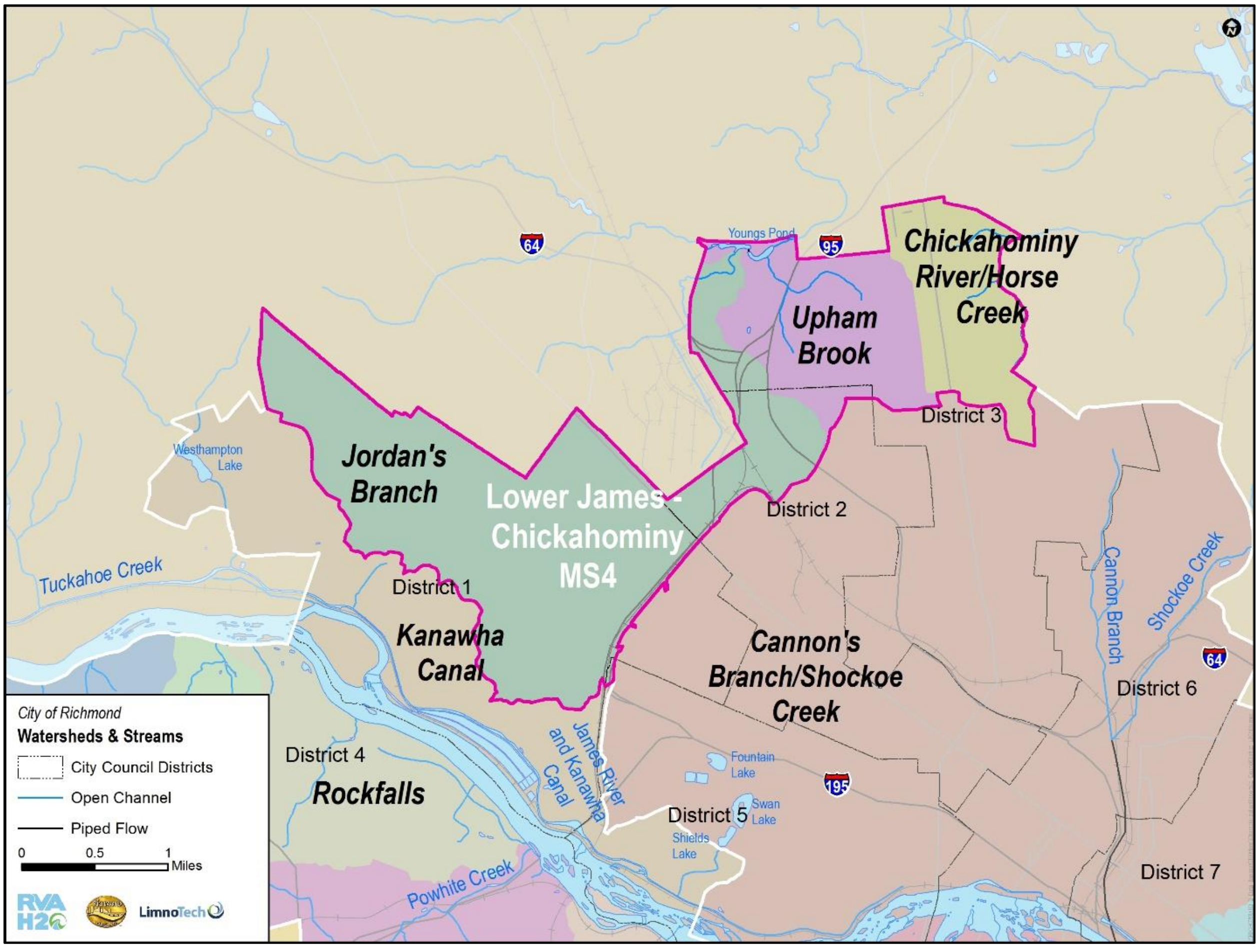

Figure 5.2 Lower James-Chickahominy MS4 City Council District

5.3.1 Physical and Natural Features

This section describes hydrology, geology, topography, soils, climate, and habitat. These are important features because they affect land uses and shape the chemical, biological, and hydrological characteristics of the Lower James-Chickahominy MS4 region.

5.3.1.a Hydrology

Within the three watersheds, the total length of stream ranges from 0.7 to 2.0 miles (Table 5-2). Hydrology in the Lower James-Chickahominy MS4 has been modified over time to varying degrees. For example, Jordan's Branch in the watershed is in a natural state with a wide riparian corridor. However, Upham Branch and its tributaries are confined by residential and commercial development with varying amounts of riparian corridor. Horse Creek and its tributaries appear to be in their natural condition with a riparian corridor and some residential development on the margins. The southwestern portion of Jordan's Branch watershed contains no streams.

Table 5-2 Lower James-Chickahominy MS4 watershed hydrology

Watershed	Open Channel Stream Distance (mi)	Wetland Area (ac)	Lake Area (ac)	Total Watershed Area (ac)
Chickahominy River/Horse Creek	1.7			643
Jordan's Branch	0.7	8.7	0.9	2,662
Upham Brook	2.0	10.8	8.2	831
Total Lower James-Chickahominy/MS4 Total	**4.4**	**19.5**	**9.2**	**4,136**

The City has identified wetlands in Jordan's Branch and Upham Brook[34]. These wetland areas are associated with the confluence of Jordan's Branch and Upham Brook.

Young's Pond is the only lake within the Lower James-Chickahominy watershed, which is located at the confluence of Jordan's Branch and Upham Brook. The lake water level and flow is controlled by Young's Pond Dam.

The FEMA has identified 100 year flood prone areas in Upham Brook and Jordan's Branch watersheds (Table 5-3). These areas are located at the confluence of Upham Brook and Jordan's Branch.

Table 5-3 Lower James-Chickahominy MS4 FEMA flood prone areas

Watershed	100yr flood prone area (ac)
Chickahominy River/Horse Creek	--
Jordan's Branch	7.9
Upham Brook	38.1

5.3.1.b Geology

The City of Richmond straddles the division between the Coastal Plain and Piedmont physiographic provinces. As seen in Figure 5.3the Lower James-Chickahominy MS4 watersheds are primarily in the Coastal Plain but are along the dividing fall zone. The coastal plain upland areas are characterized by low slopes and gentle drainage divides[35]. The underlying geology tends to be fluvial with gravelly sand, silt, and clays. A small portion of the area is within the Piedmont region.

[34] This dataset is derived from the US Fish and Wildlife Service's National Wetlands Inventory and is available online at ftp://ftp.ci.richmond.va.us/GIS/Shapefiles/Environmental/

[35] William and Mary Department of Geology. 2015. The Geology of Virginia: Coastal Plain province. Accessed April 2, 2015. http://web.wm.edu/geology/virginia/provinces/coastalplain/coastal_plain.html

5.3.1.c Topography

Watersheds in the Lower James-Chickahominy MS4 area are characterized by gradual slopes ranging from 1.8% to 2.5% (Figure 5.4). The majority of the watersheds are relatively flat. Some steep slopes exist on the divide between the Upham Branch and Jordan's Branch watersheds. Overall elevations in this area range from 140 feet to 312 feet. The highest elevations in the watersheds are in Jordan's Branch.

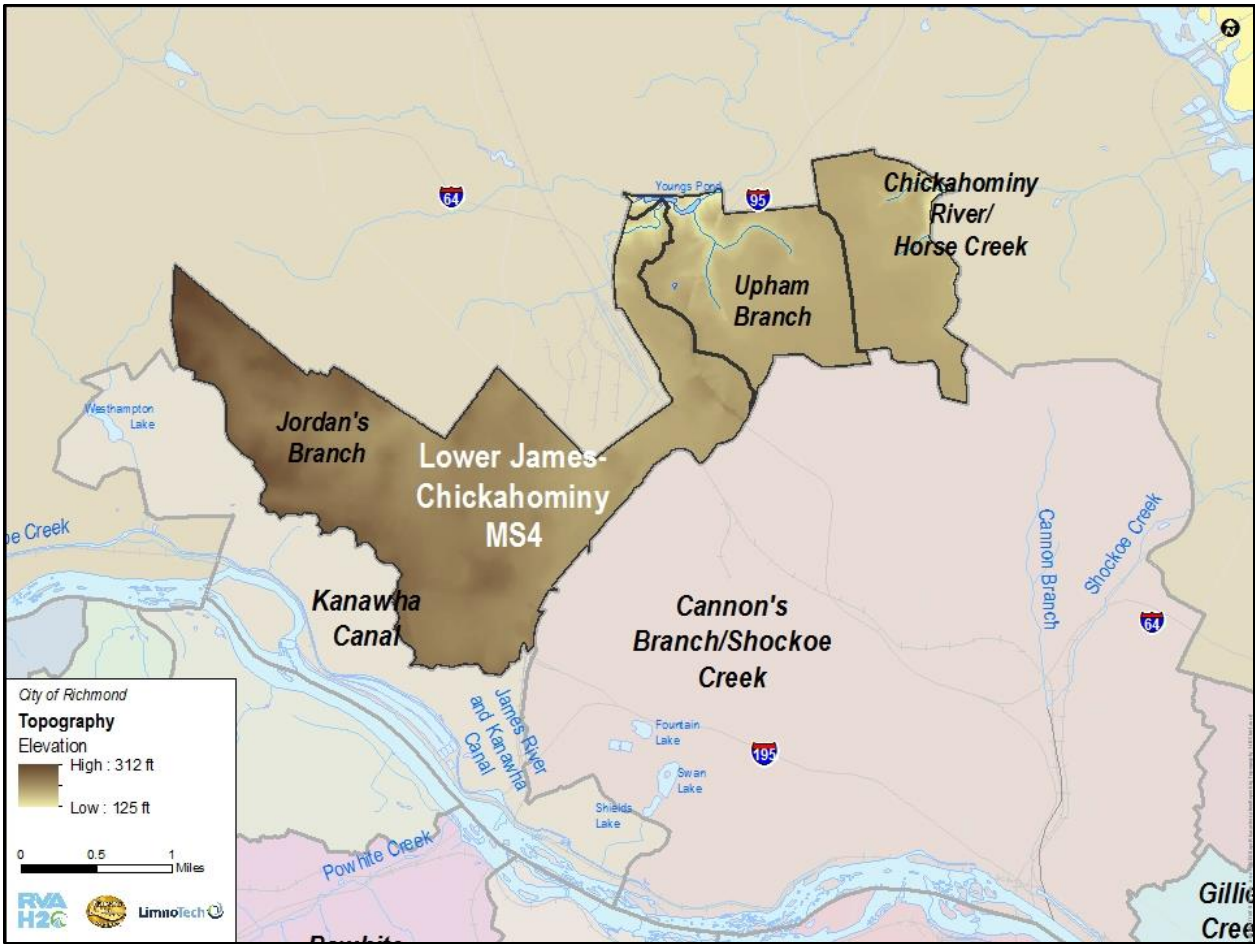

Figure 5.3 Topography of Lower James-Chickahominy MS4

Table 5-4 Lower James-Chickahominy MS4 topography

Waterbody	Low Elevation (ft)	High Elevation (ft)	Average Slope (%)
Chickahominy River/Horse Creek	137	200	1.8
Jordan's Branch	140	312	2.2
Upham Brook	125	213	2.5
Lower James-Chickahominy/MS4	125	312	2.2

5.3.1.d Soils

Soils in the Lower James-Chickahominy MS4 watersheds are dominated by Turbeville-Urban land complex soils[36]. Soils are assigned a hydrologic soil group (HSG) based on runoff and infiltration characteristics (Figure 5.4). In some urban areas, the soils are so disturbed that the HSG cannot be assigned. This is true for 20% of the soils in the Lower James-Chickahominy MS4 watersheds (Table 5-5). In these cases, site-specific infiltration testing is required to better classify the ability of a soil to infiltrate water. HSG A soils are only present in the Chickahominy River/Horse Creek watershed. These soils have a low runoff potential when thoroughly wet and infiltrate well. HSG B soils, which make up the majority of Chickahominy River/Horse Creek and Jordan's Branch watersheds and represent 40% of Upham Brook watershed. HSG B soils have a moderately low runoff potential when thoroughly wet. Both HSG A and HSG B soils are well suited for infiltration-type BMPs. Class C and D soils often require underdrains to insure water does not pond in these areas. 44% of the soils in the Upham Brook watershed are classified as HSG C soils.

[36] USDA NRCS. 2009. Soil Survey of City of Richmond, VA. http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/virginia/VA760/0/Richmond_VA.pdf .

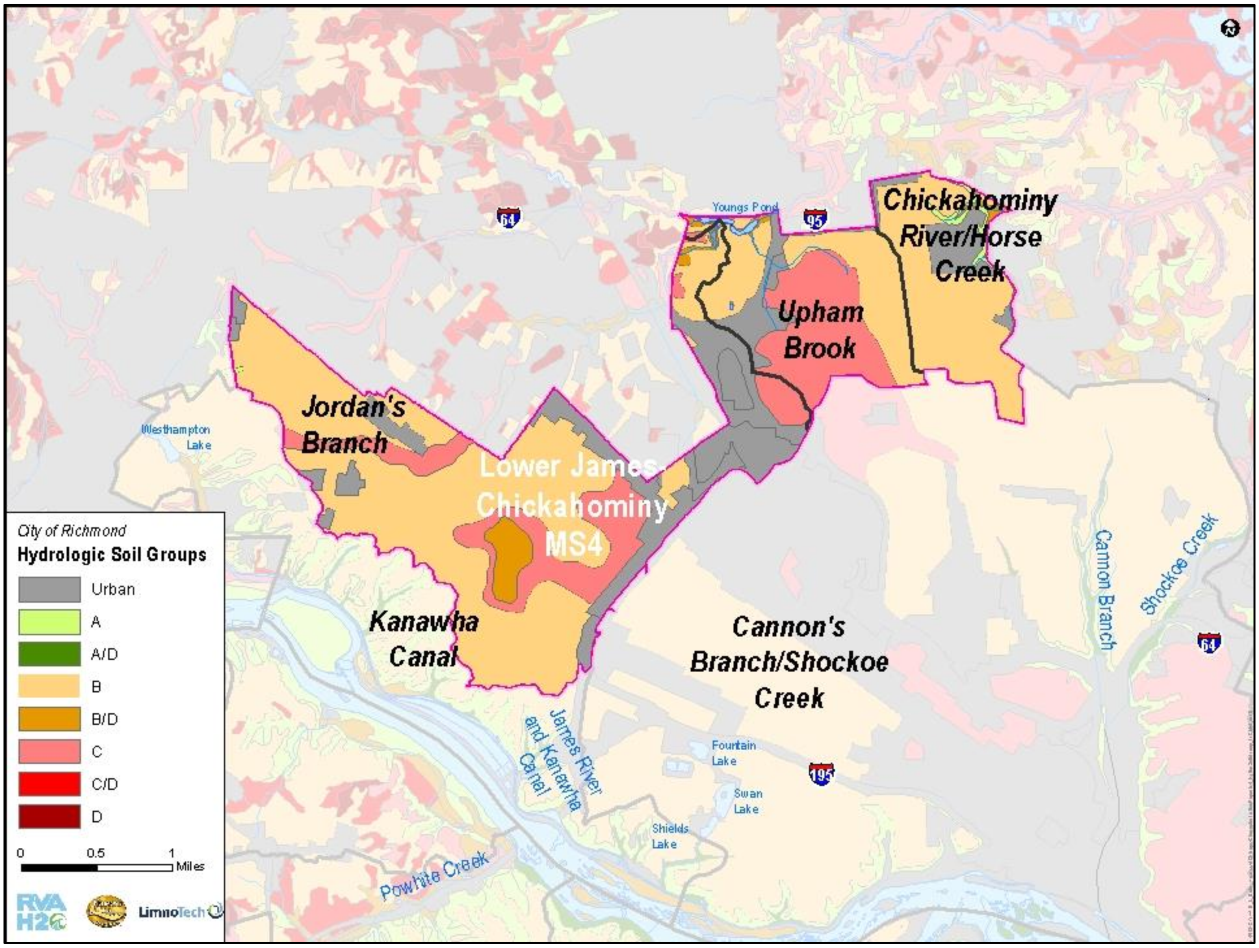

Figure 5.4 Lower James-Chickahominy MS4 hydrologic soil groups

Table 5-5 Lower James-Chickahominy MS4 hydrologic soil groups

HSG	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Lower James-Chickahominy/MS4 total
A	3.9%	0.1%	0.1%	0.7%
B	74.7%	58.5%	40.2%	57.3%
C	0.2%	15.9%	44.0%	19.1%
D	3.3%	3.2%	1.8%	2.9%
Urban	17.9%	22.3%	12.9%	19.7%
Water		0.1%	1.0%	0.3%

5.3.2 Land Use/Cover Characteristics

Land use and land cover are important characteristics of watersheds. The way a land is being used has a direct link to the potential pollutants being produced.

5.3.2.a Current Land Cover

Developed land cover at varying intensities is seen through the Lower James-Chickahominy MS4 area (Figure 5.5). Some forested land cover is seen towards the northern edges of the City. Figure 5.6 further shows the prevalence of developed areas in the watersheds. Across all five watersheds, developed land cover is prominent and makes up the greatest percentage of area. Jordan's Branch has the highest percentage of developed, high intensity land cover.

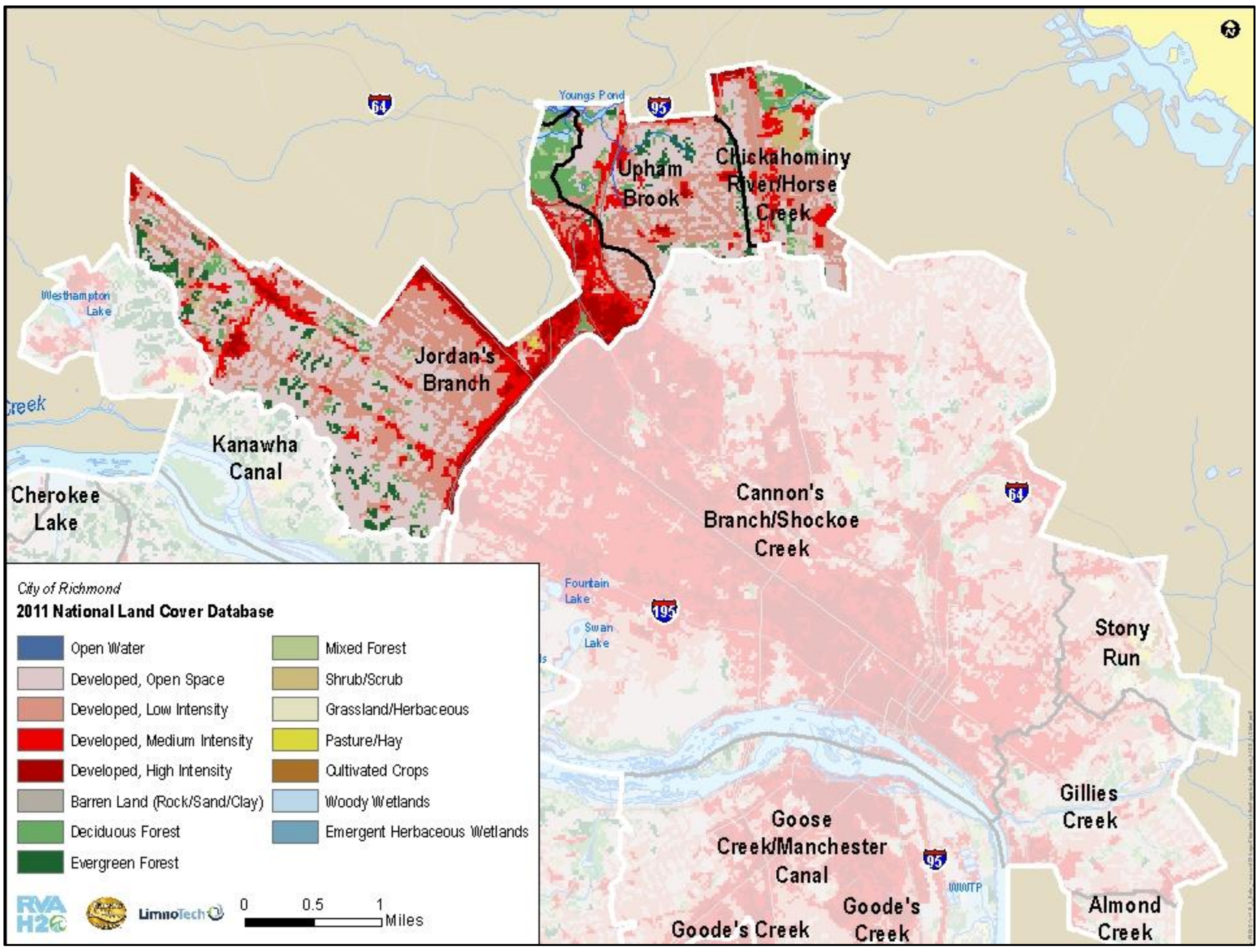

Figure 5.5 2011 NLCD for the Lower James-Chickahominy MS4 watershed grouping

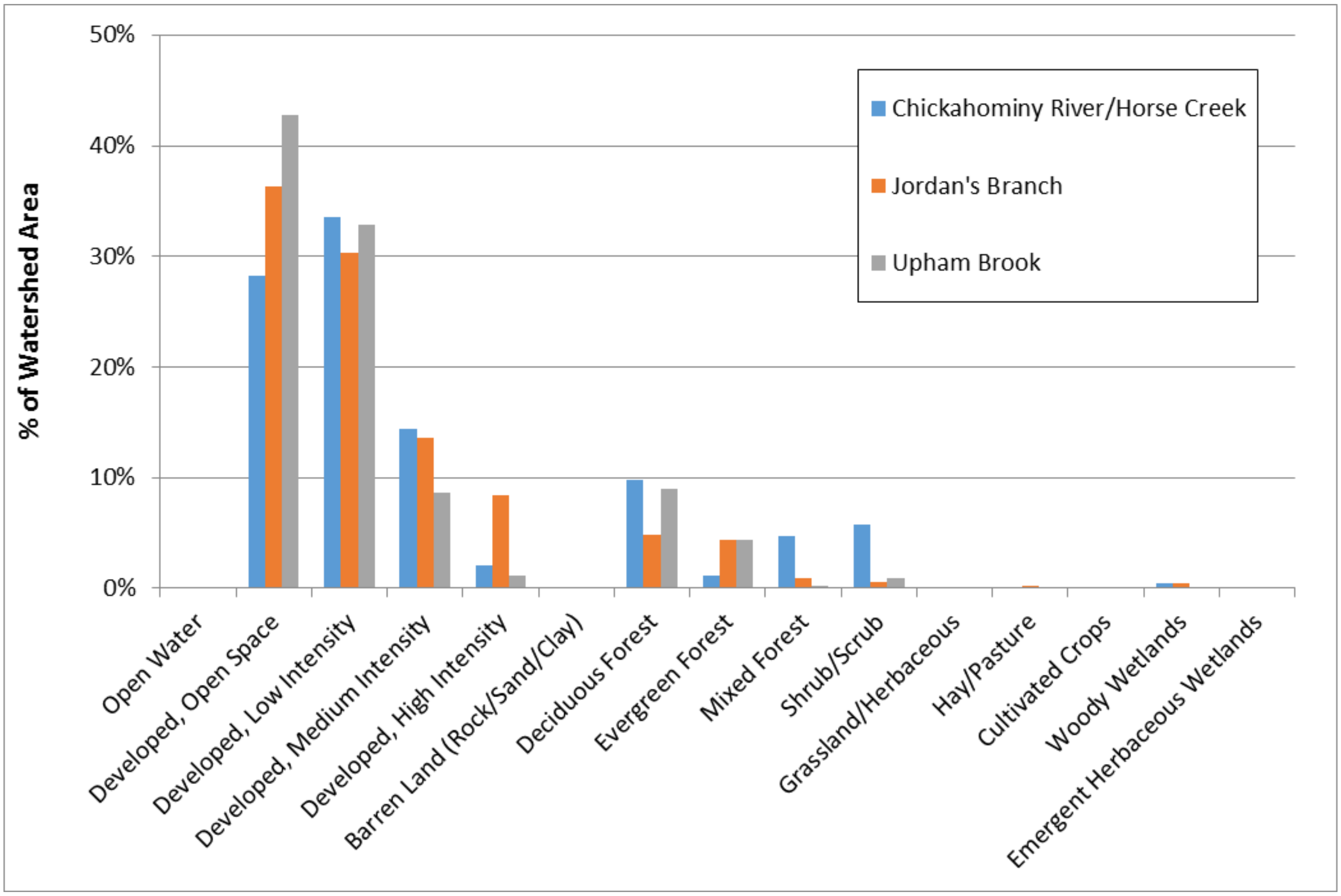

Figure 5.6 NLCD Percent Area within the Lower James-Chickahominy watershed grouping

The VGEP land cover dataset which is focused on imperviousness and vegetation based on 2008 data[37] is shown in Figure 5.7. Non-Building imperviousness, non-tree vegetation, and tree canopy are almost equally represented by the three watersheds.

From the breakdown of land cover by type by percentage (Table 5-6), it's clear that the Lower James-Chickahominy MS4 area is dominated by three land cover categories (non-building impervious, non-tree vegetation, and tree canopy). The three individual watersheds have similar composition. However, Jordan's Branch and Upham Brook have a larger percentage of tree canopy than the Chickahominy River/Horse Creek watershed. Jordan's Branch does have a slightly larger percentage of impervious building area than the other two watersheds.

[37] VGEP Land Cover. Available at:
ftp://ftp.ci.richmond.va.us/GIS/Shapefiles/Environmental/VGEP_Landcover_README.doc

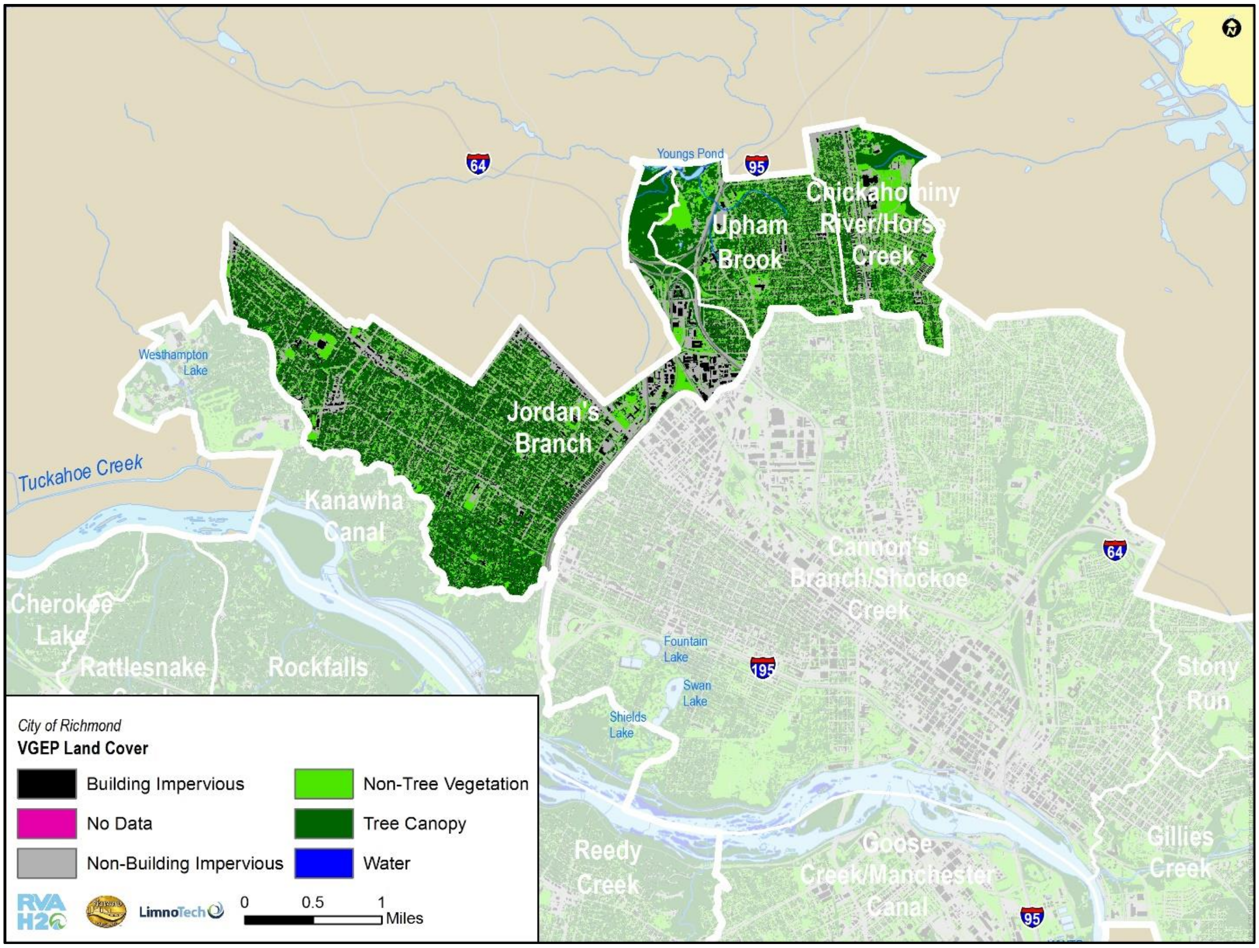

Figure 5.7 VGEP land cover for the Lower James-Chickahominy MS4 watershed grouping

Table 5-6 Lower James-Chickahominy MS4 VGEP land cover percentage

Watershed	Water (%)	Non-Building Impervious (%)	Non-Tree Vegetation (%)	Tree Canopy (%)	Building Impervious (%)
Chickahominy River/Horse Creek	0	28.2	30.4	30.8	10.6
Jordan's Branch	0.1	25.2	19.2	43.3	12.3
Upham Brook	0.7	20.9	27.7	41.7	9
Lower James-Chickahominy/MS4	0.2	24.8	22.6	41	11.4

Imperviousness

Imperviousness in the three watersheds ranges from 33 to 44% with an overall imperviousness of 41% (Table 5-7). Chickahominy River/Horse Creek and Upham Brook have similar imperviousness around 35%. Jordan's Branch has the highest percentage of imperviousness as a portion of area are large buildings.

Figure 5.8 shows how impervious surfaces in the Lower James-Chickahominy MS4 area are dominated by buildings, roads, and parking. The more residential Stony Run watershed has a larger percentage of imperviousness attributed to driveways than the other watersheds.

Table 5-7 Lower James-Chickahominy MS4 watershed imperviousness

Watershed	Percent Impervious
Chickahominy River/Horse Creek	36.4
Jordan's Branch	43.9
Upham Brook	33.5
Total Lower James-Chickahominy/MS4	**40.6**

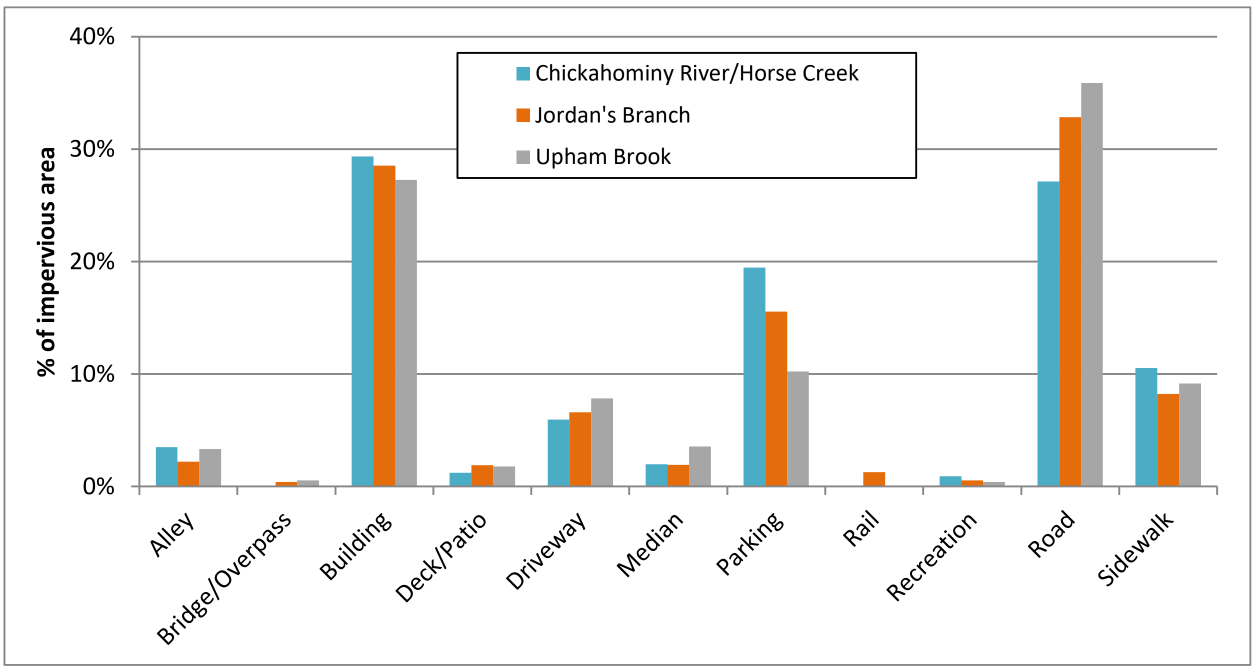

Figure 5.8 Lower James-Chickahominy MS4 impervious area by type

Septic Systems

According to City records, no septic systems are located in the Lower James-Chickahominy MS4 area.

5.3.2.b Land Use

As part of the City's Master Plan, existing land use was mapped in 2008[38]. Residential and public land uses are found in all three watersheds (Figure 5.9). The residential land use is the majority for all three watersheds in the Lower James-Chickahominy MS4 area (Figure 5.10). Jordan's Branch has a sizeable industrial area which matches with the impervious land cover seen in the NLCD and VGEP land cover datasets. Both the Upham Brook and Chickahominy River/Horse Creek watersheds have a sizeable area of public space.

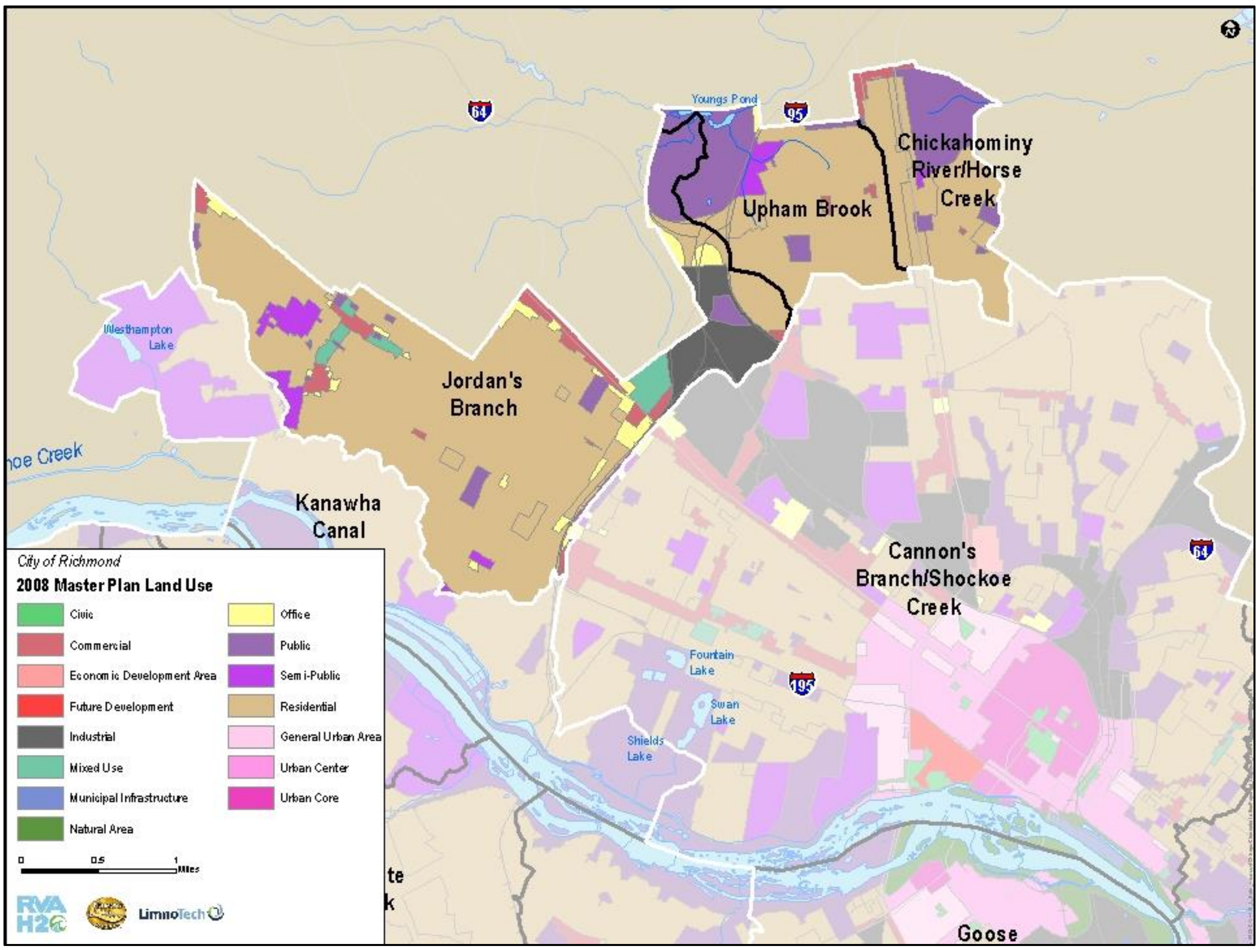

Figure 5.9 2008 Master Plan land use for the Lower James-Chickahominy MS4 watershed grouping

38 http://www.richmondgov.com/planninganddevelopmentreview/PlansAndDocuments.aspx

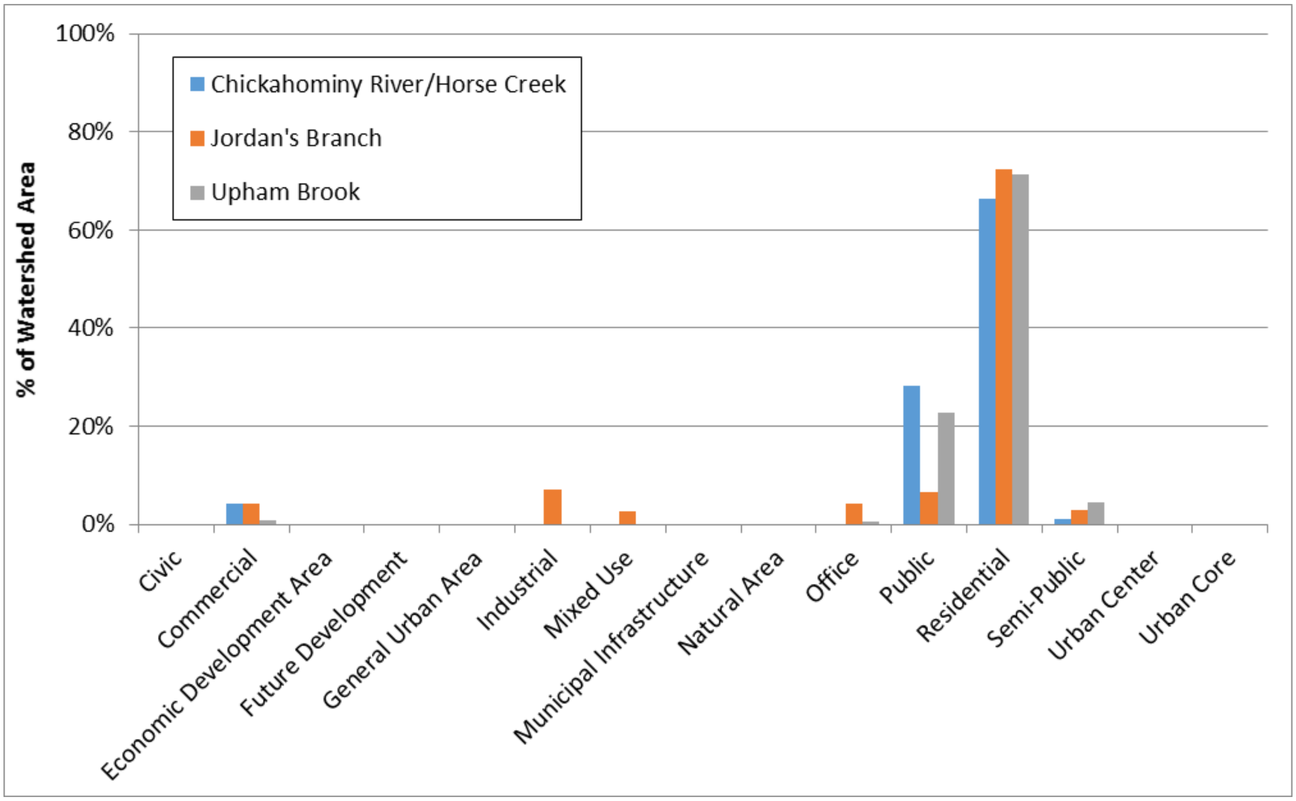

Figure 5.10 Lower James-Chickahominy MS4 Master Plan land use

5.3.3 Infrastructure Features

As discussed in Section 3.3.3, above, the City covers a total of approximately 38,000 acres, with 12,000 acres within the combined sewer area with the remaining area are served by a separated sanitary and storm sewer system, and direct runoff. The MS4 area within the Lower James-Chickahominy watershed grouping is represented by the hatched area in Figure 5.11.

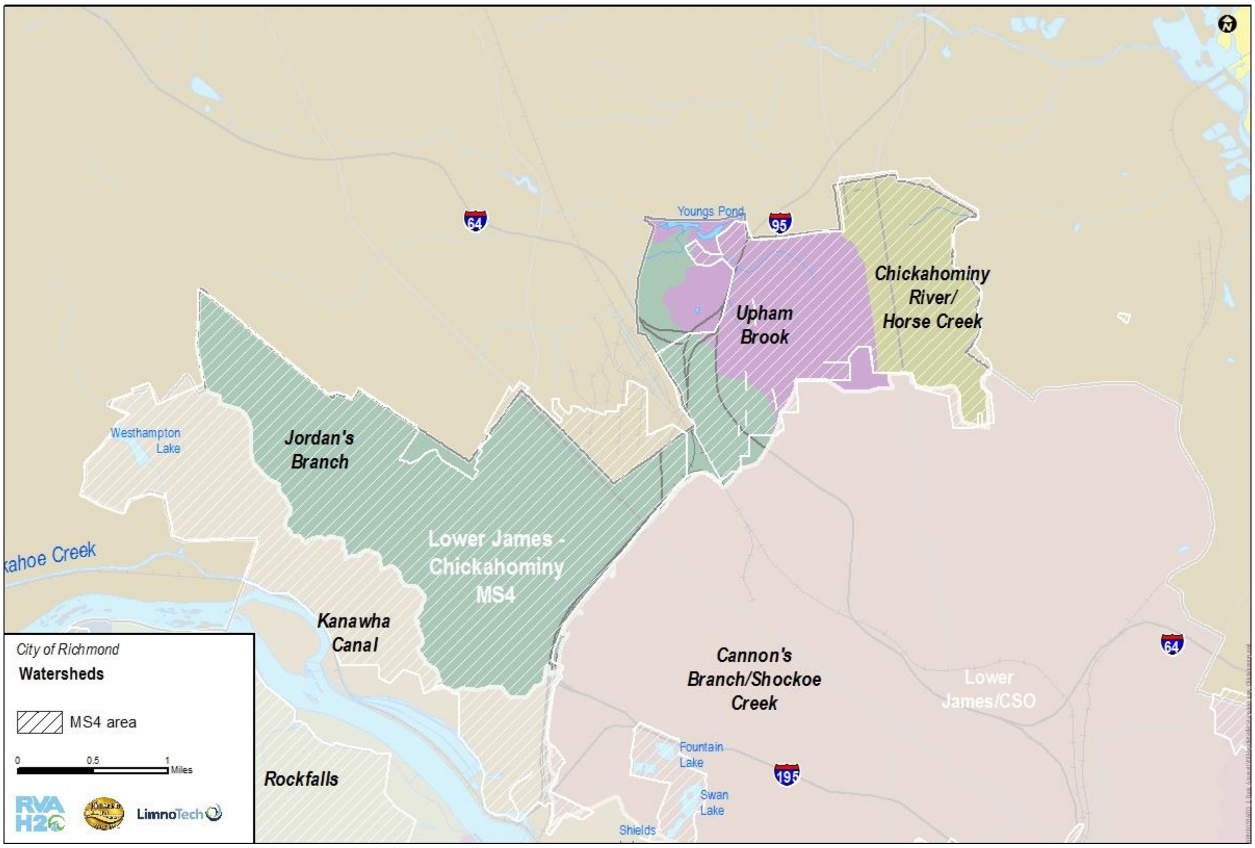

Figure 5.11 MS4 area in Lower James-Chickahominy Watershed area

5.3.4 Stormwater System

5.3.4.a General System Description

The City of Richmond operates and maintains an MS4 system which serves approximately 24,500 acres of the City. The Lower James-Chickahominy watershed area covers 4,136 acres, 3,705 of which are served by the MS4 system, 455 acres are draining directly into the receiving waters (shown in Table 5-8).

Table 5-8 drainage types in Lower James-Chickahominy Watershed area

Receiving Water	MS4 area (acres)	Direct drainage (acres)	Total (acres)
Chickahominy River/Horse Creek	632	11	643
Jordan's Branch	2,435	227	2,662
Upham Brook	638	193	831

5.3.4.b Stormwater Collection System Components

Inflow into the MS4 system within the Lower James-Chickahominy watershed area is handled by 2,592 inlets which are listed in Table 5-9 below and shown in Figure 5.12.

Table 5-9 Stormwater inlets within Lower James-Chickahominy Watershed area

Inlet type	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
Curb Inlet	305	1,675	376	2,356
Grate Inlet	5	24	4	33
Roof Drain	0	0	0	0
Unknown	92	91	20	203
Grand Total	**402**	**1,790**	**400**	**2,592**

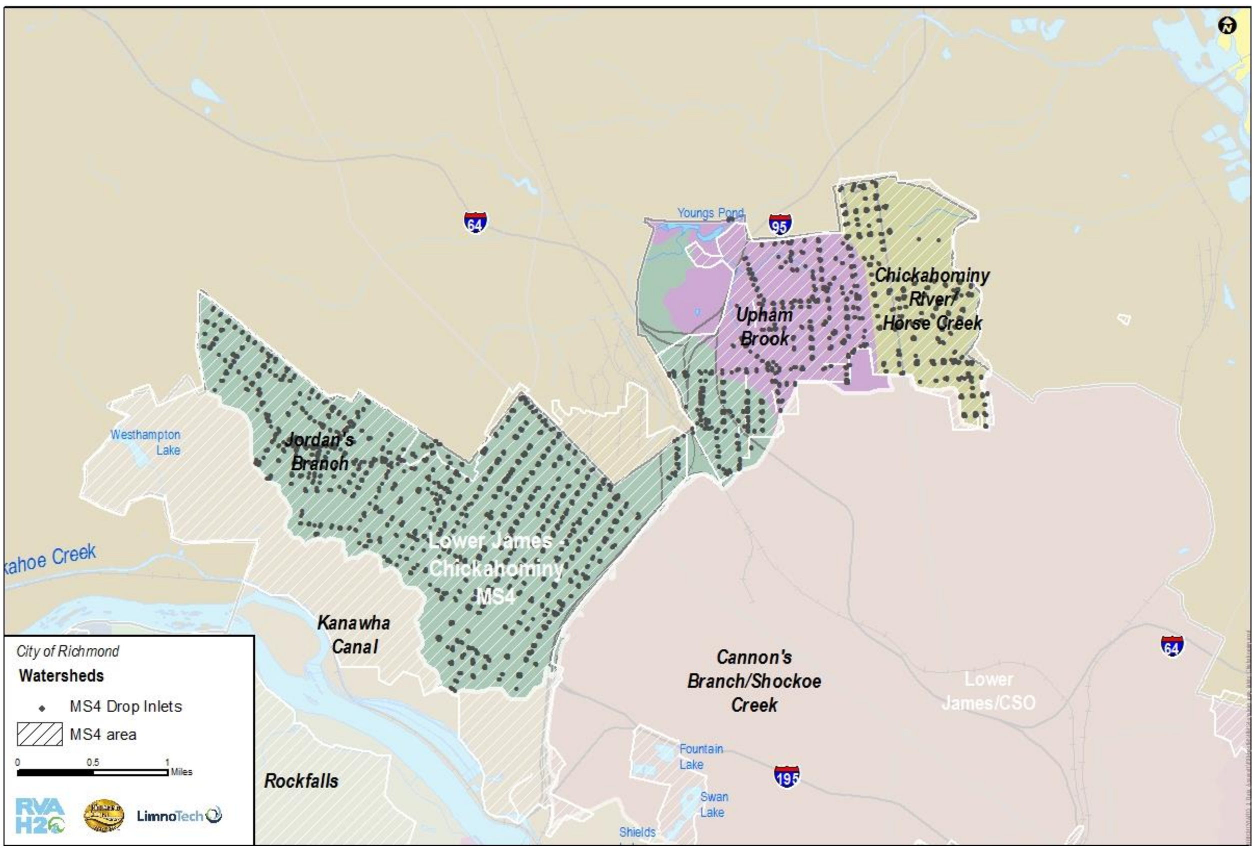

Figure 5.12 Stormwater inlets within Lower James-Chickahominy Watershed area

Stormwater conveyance is provided by a network of open channels, culverts and pipes. The combined length of the stormwater system in the Lower James-Chickahominy area is about 71 miles.

Flow in undeveloped areas is mostly conveyed by open drainage channels which are composed of a mix of different materials (summarized in

Table 5-10). These make up only 1% of the stormwater conveyance system within the Lower James-Chickahominy Watershed area.

Table 5-10 Open drainage channels in Lower James-Chickahominy Watershed Area

Channel material	Channel length (ft.)			
	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
Asphalt	0	0	0	0
Brickwork	0	0	0	0
Concrete	0	340	0	0
Rip Rap	0	0	0	0
Unknown	80	1,628	0	80
Vegetation	762	50	2,028	762
Grand Total	**842**	**2,018**	**2,028**	**842**

Stormwater flow in open drainage channels is conveyed underneath roads and other channel crossings via closed culverts (summarized in Table 5-11).

Table 5-11 Stormwater culverts in Lower James-Chickahominy Watershed Area

Culvert size	Number of culverts	total length of culverts (ft)
Unknown	3	765
< 12 inches	1	13
12 - 24 inches	1	58
27 - 48 inches	0	0
54 - 96 inches	4	1,666
> 108 inches	1	113
Grand Total	**10**	**2,615**

Developed areas are mainly drained by underground pipes with various pipe sizes (summarized in

Table 5-12). Pipes make up about 99% of the stormwater conveyance system within the Lower James-Chickahominy Watershed area.

Table 5-12 Stormwater pipes in Lower James-Chickahominy Watershed Area

Pipe size	Channel length (ft.)			
	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
unknown	9,778	49,235	11,140	70,153
< 12 inches	764	1,818	893	3,474
12 - 24 inches	32,745	107,846	27,091	167,683
27 - 48 inches	13,590	53,278	15,466	82,334
54 - 72 inches	5,408	22,925	4,121	32,453
78 - 96 inches	0	5,516	692	6,208
> 96 inches	0	5,174	0	5,174
Grand Total	**62,285**	**245,791**	**59,403**	**367,479**

A mix of different BMPs within the stormwater area provide pollution control (summarized in Table 5-13 and shown in Figure 5.13).

Table 5-13 BMPs within Lower James-Chickahominy Watershed area

BMP type	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
Unknown	0	7	0	7
Bioretention Filter	0	9	0	9
Detention Basin	0	4	0	4
Grass Channels	0	2	0	2
Infiltration	0	2	0	2
Other	0	1	0	1
Grand Total	**0**	**25**	**0**	**25**

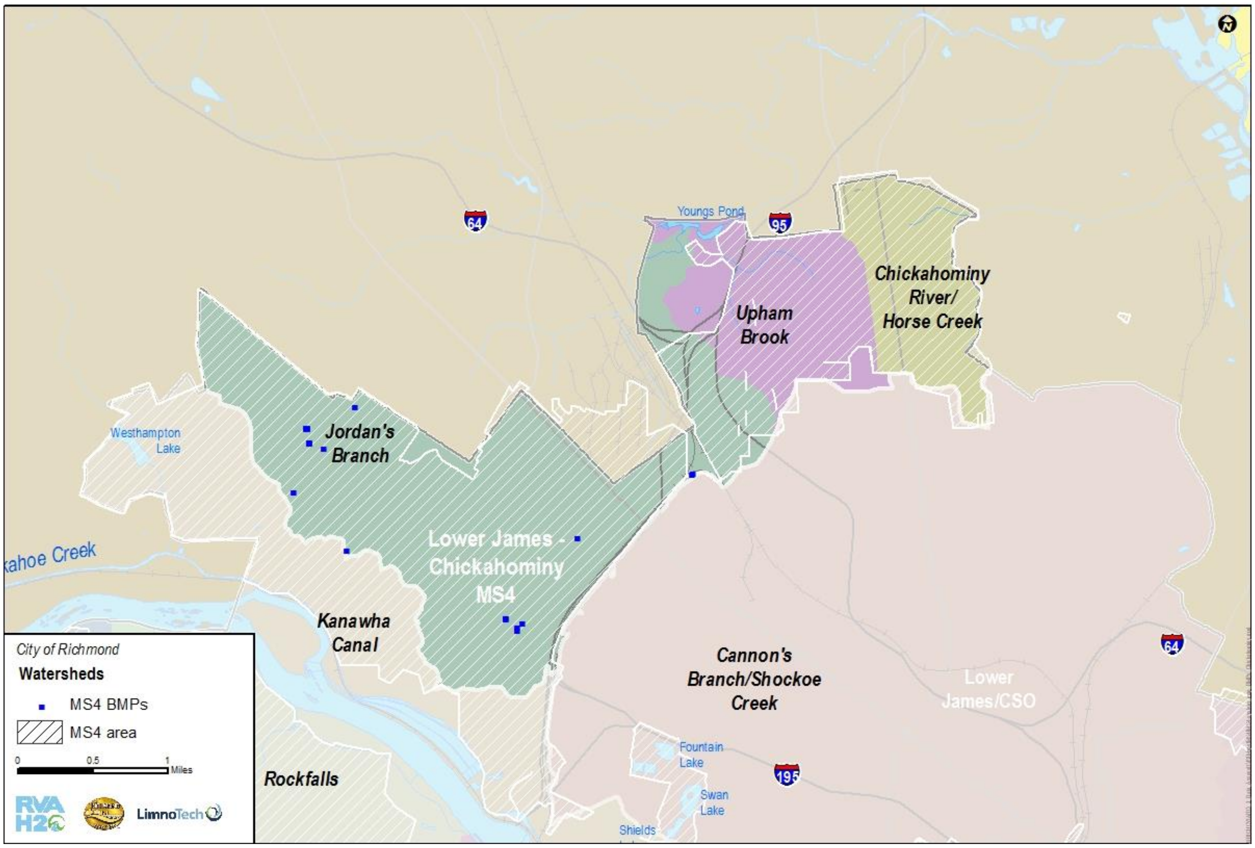

Figure 5.13 BMPs within Lower James-Chickahominy Watershed area

Storm water outfalls are defined as points where a storm sewer system discharges to a receiving water or to another MS4. This includes discharges from pipes, ditches, swales, and other points of concentrated storm water flow. Identified outfall locations are summarized in

Table 5-14 and shown in Figure 5.14 below. This includes locations of storm water discharge from and to Henrico County.

Table 5-14 Stormwater outfalls in Lower James-Chickahominy Watershed area

Outfall type	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
Open Channel - from Henrico County	0	1	0	1
Open Channel - to Henrico County	0	2	0	2

Outfall type	Chickahominy River/Horse Creek	Jordan's Branch	Upham Brook	Total
Open Channel – Other *	2	7	2	11
Pipe - to Henrico County	0	2	0	2
Pipe – Other *	7	13	12	32
Grand Total	**9**	**25**	**14**	**48**

(*) This includes types like road drainage, parcel drainage and other miscellaneous or unclear outfall classifications

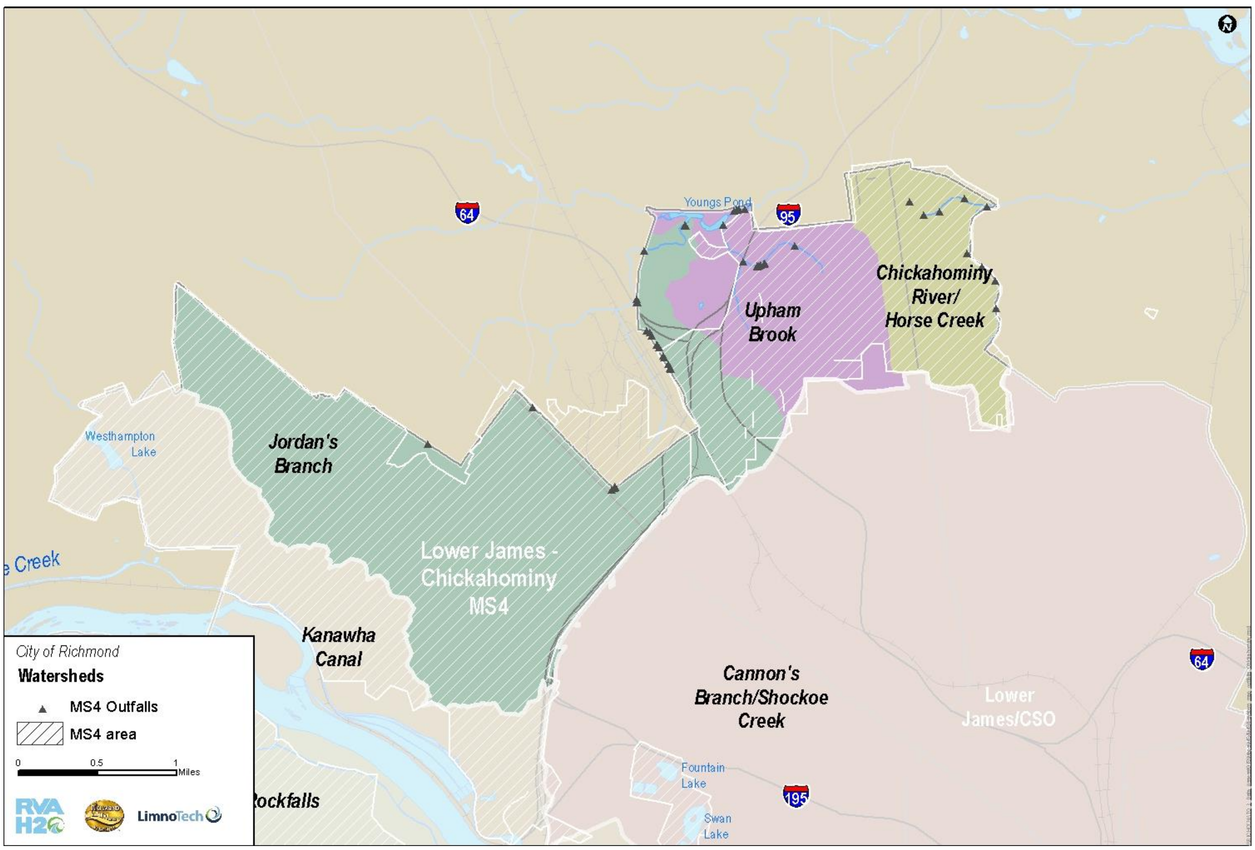

Figure 5.14 Stormwater outfalls within Lower James-Chickahominy Watershed area

5.3.4.c Stormwater Master Plan

The City developed a first draft of a Stormwater System Master Plan in 2005 and expanded its area and scope in 2012. An overview and a general description of the current and planned Stormwater Master Plans is provided in Section 3, above.

The only Stormwater Master Plan area within the Lower James Watershed area Jordan's Branch (shown in Figure 5.15).

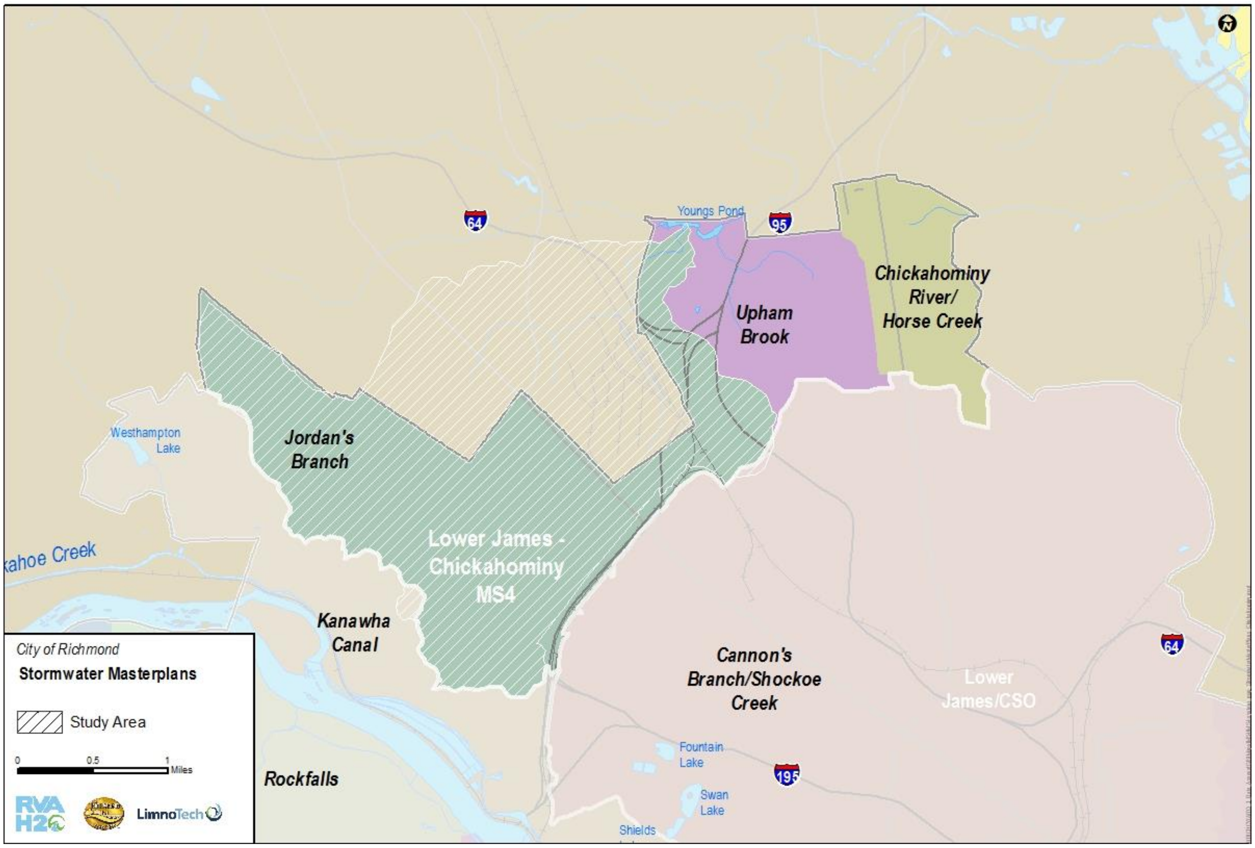

Figure 5.15 Stormwater Master Plans within Lower James-Chickahominy Watershed area

5.3.4.d Stormwater Modeling

Hydrologic and hydraulic InfoSWMM models were developed for the Jordan's Branch Stormwater System Master Plan watershed within the Lower James-Chickahominy Watershed area. Important stormwater network features including pipes, culverts and channels were included. These uncalibrated models were used for an analysis of instream flow velocities, capacity analysis as well as for an evaluation of the water quality (modeled pollutants were TN, TP, TSS based on estimated values using DCR's Runoff Reduction Method). Model results were subsequently used for the development and evaluation of improvement alternatives.

5.4 Water Quality

Water quality in Richmond can be evaluated by analyzing water quality and biological data within the context of area waterbodies' water quality standards and impairment listings. Evaluation of current water quality is essential to the process of identifying pollutant sources and stressors.

Existing data sources for water quality, biological (fish, benthic macroinvertebrates, and habitat indices), flow, and point sources have been identified across various groups and agencies, including City of Richmond's own data collection efforts, Virginia DEQ programs, USGS monitoring efforts, non-agency (NGOs, universities) programs, and citizen and stakeholder groups' monitoring efforts. Virginia DEQ incorporates external data sources, including quality-controlled citizen data, when determining whether a waterbody is impaired.

5.4.1 Designated Uses

All Virginia state waters are designated for aquatic life, wildlife, recreational uses, and fish consumption (*Virginia Administrative Code 9VAC25-260-10, section A*). Other designated uses that may be assigned to select waterbodies include shell-fishing and public water supply uses.

There are additional designated use categories for tidal tributaries to the Chesapeake Bay: migratory fish spawning and nursery, shallow-water submerged aquatic vegetation, open water aquatic life, deep water aquatic life, and deep channel seasonal refuge.

Table 5-15 summarizes the designated uses that have been assigned to one or more waterbody segments in the Lower James-Chickahominy MS4 watersheds, by waterbody type. Note that waterbody segments may extend well outside of the Lower James-Chickahominy MS4 watersheds group.

Table 5-15 Lower James-Chickahominy MS4 watershed grouping designated uses

<table>
<tr><th>Designated Use</th><th>Riverine waterbodies</th><th>Tidal Freshwater waterbodies</th><th>Reservoir waterbodies</th></tr>
<tr><td>Aquatic Life</td><td>X</td><td rowspan="11">No waterbodies are classified as tidal freshwater segments in Lower James-Chickahominy MS4 watersheds</td><td rowspan="11">No waterbodies are classified as reservoirs in Lower James-Chickahominy MS4 watersheds</td></tr>
<tr><td>Fish Consumption</td><td>X</td></tr>
<tr><td>Public Water Supply</td><td></td></tr>
<tr><td>Recreation</td><td>X</td></tr>
<tr><td>Wildlife</td><td>X</td></tr>
<tr><td>Shellfishing</td><td></td></tr>
<tr><td>Migratory Fish Spawning & Nursery</td><td>n/a</td></tr>
<tr><td>Deep Channel Seasonal Refuge</td><td>n/a</td></tr>
<tr><td>Deep Water Aquatic Life</td><td>n/a</td></tr>
<tr><td>Open Water Aquatic Life</td><td>n/a</td></tr>
<tr><td>Shallow Water Submerged Aquatic Vegetation</td><td>n/a</td></tr>
</table>

5.4.2 303(d) Status

Under Section 303(d) of the Clean Water Act, states are required to submit to EPA a TMDL Priority List every other year. In Virginia, this list is contained in its biannual Water Quality Assessment 305(b)/303(d) Integrated Report, a joint publication of DEQ, DCR, and the state Department of Health. Waters are placed into federal categories based on each waterbody segment's (or 'assessment unit') support for its designated uses. Virginia supplements the federal categories with its own subcategories to better describe and track attainment/impairment.

The waterbody segments in the Lower James-Chickahominy MS4 watersheds (Figure 5.16) have all been placed in one of two of the following EPA categories / Virginia subcategories in most recent (2014) Integrated Report:

- **EPA Category 2:** Available data and/or other information indicate that some, but not all of the designated uses are supported.
  - **Virginia Category 2B:** Waters are of concern to the state but no water quality standard exists for a specific pollutant, or the water exceeds a state screening value or toxicity test.
- **EPA Category 4A:** Water is impaired or threatened for one or more designated uses but does not require a TMDL. A new TMDL is not necessary to address the newly identified impaired tributaries if TMDL modeling, source identification and reductions cover the entire watershed and the TMDL has been approved by EPA. These waters are primarily related to shellfish and/or recreational bacteria impairments but could include benthic impairments.

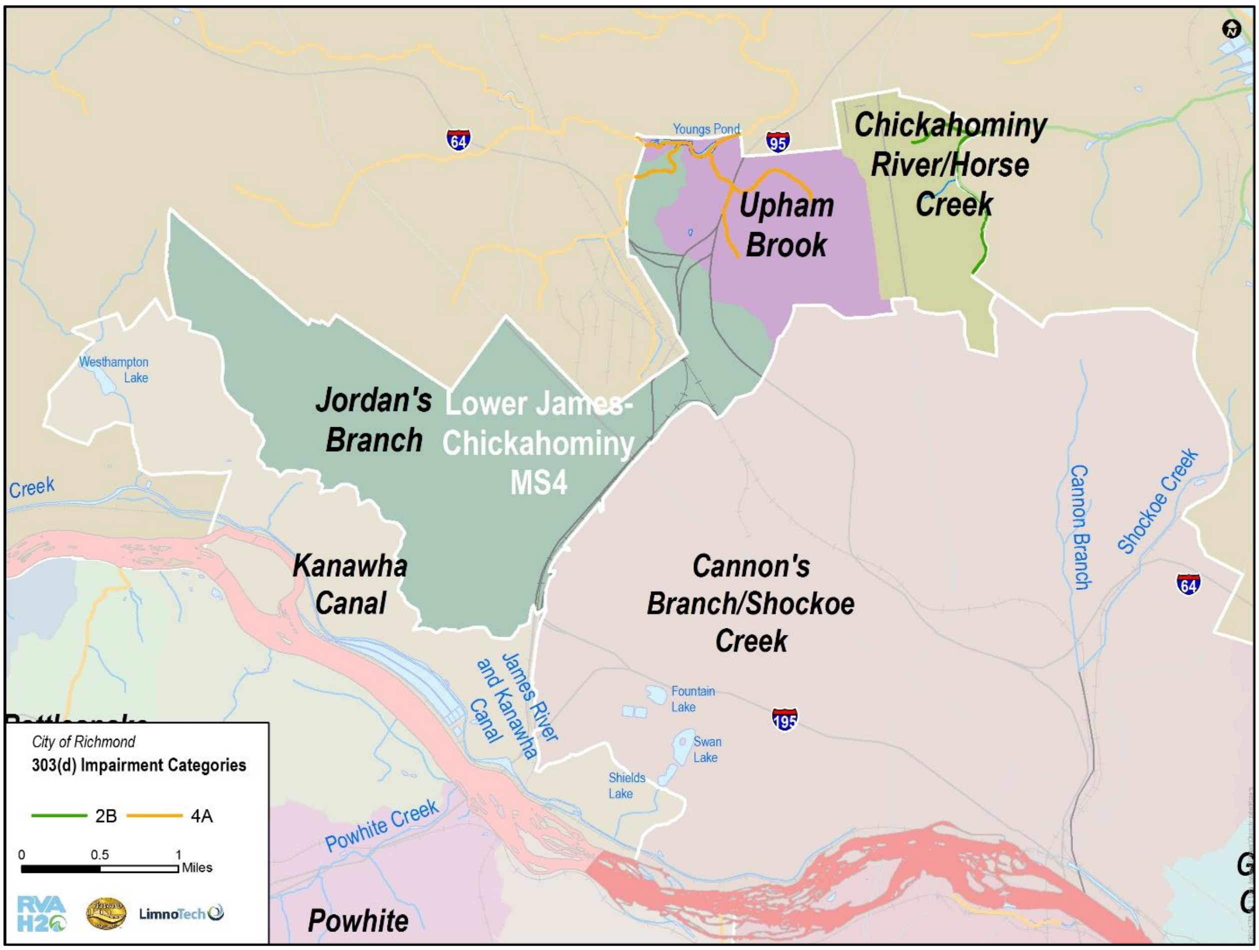

Figure 5.16 Lower James-Chickahominy MS4 watershed grouping 303(d) impairment categories

For the impaired waterbody segments, the lone impairment cause identified in the 2014 Integrated Report for the Lower James-Chickahominy MS4 watersheds was *E. coli*.

5.4.3 Monitoring Programs

Within the Lower James-Chickahominy MS4 watersheds, much of the water quality data collection efforts have been led by Virginia Department of Environmental Quality (VADEQ) and Virginia Commonwealth

University (VCU) . Other organizations collecting data within the City of Richmond include federal, local, and volunteer/non-profit organizations. Data currently compiled by the City of Richmond from known monitoring programs are presented in Table 5-16.

Table 5-16 Summary of water quality monitoring programs

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
INteractive STream Assessment Resource (INSTAR)	Virginia Commonwealth University (VCU)	Academic	2000-2001	BIO/HAB	1	1	3	104	312	
NCDC Global Historical Climatology Network	National Climatic Data Center	Federal	2010-2014	MET	1	n/a	daily	1	1,636	
City of Richmond Routine Water Quality Monitoring	City of Richmond	Local	2011-2012	WQ	5	1	5	6	27	
VADEQ Routine sampling	Virginia Department of Environmental Quality (VADEQ)	State	2012	WQ	1	1	4	62	108	
VMN Routine Water Quality Sampling	Virginia Master Naturalists--Riverine Chapter	Volunteer/NGO	2009-2013	WQ	4	1	76	6	353	

[1] Data types: BIO/HAB=Biological/habitat; CM=Continuous monitoring; MET=Meteorological; SRC=Point source; WQ=Water quality.
[2] NGO=Non-governmental organization

5.4.4 Water Quality Data

Water quality sampling data were collected at 10 stations within the Lower James-Chickahominy MS4 watersheds. Of those 10 stations, 5 had a single sampling event, with the remaining five stations providing 80 sampling events. From a total of 85 sampling events, 488 individual samples (single-parameter observations) were collected. Data from these watersheds cover 2009 to 2013. There are 64 different parameters for which there are samples; of those parameters, 59 had fewer than 10 samples each. Figure 5.17 depicts the number of water quality sampling events conducted by station.

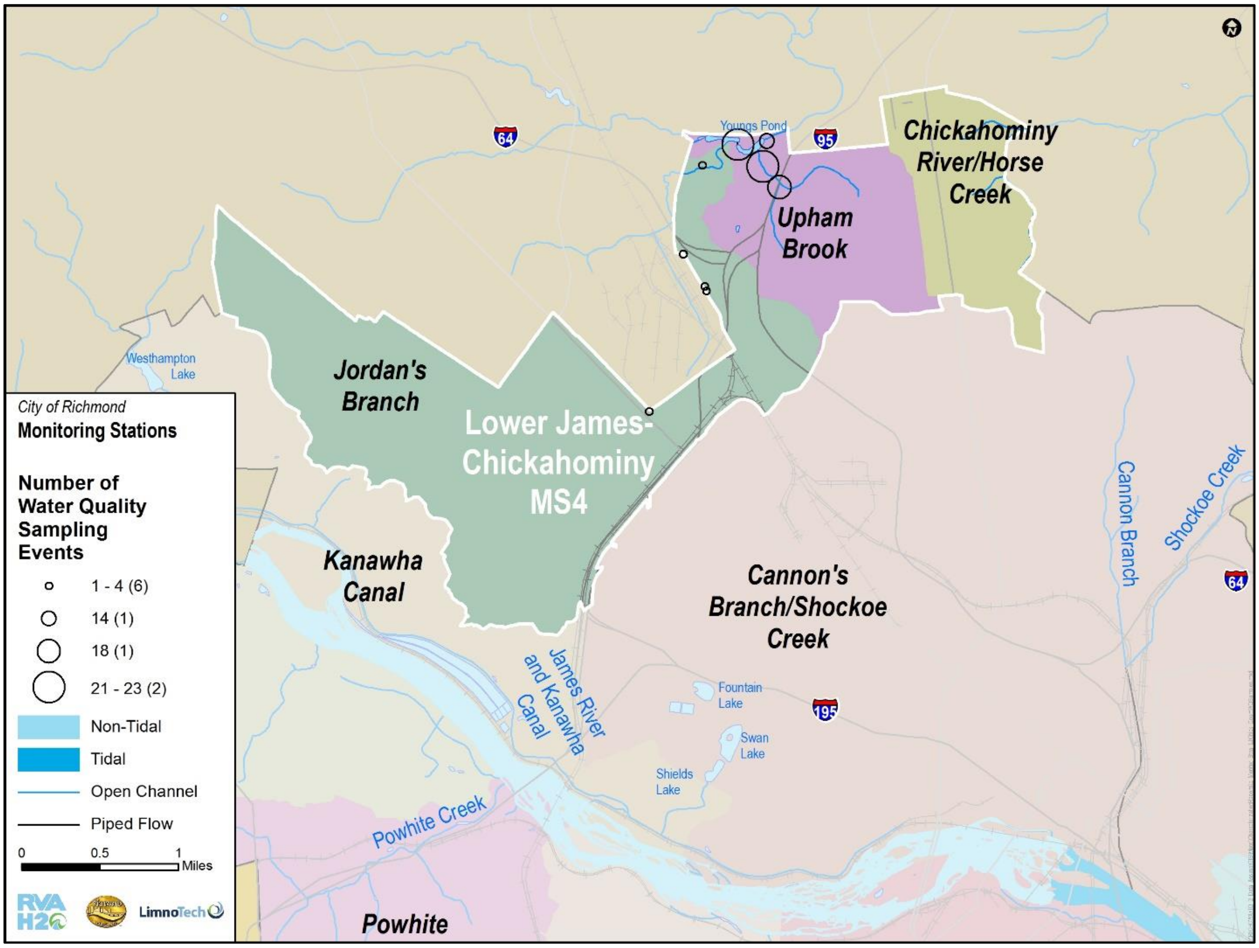

Figure 5.17 Lower James-Chickahominy MS4 watershed grouping water quality sampling stations by number of sampling events

5.4.5 Biological Conditions

Biological and habitat-related data consist of fish count and fish tissue data, benthic macroinvertebrate data that include taxa counts, metric scores and index scores, and habitat metric scores. All data were obtained through queries of the Chesapeake Bay Program Living Resources Database.

Benthic macroinvertebrate metrics were calculated by the Chesapeake Bay Program Living Resources Database (CBP 2012). A limited number of the benthic macroinvertebrate metrics are then used to develop scores using one of two multi-metric indices: the Bay Program's own Benthic Index of Biotic

Integrity (CB B-IBI) or the Coastal Plain Macroinvertebrate Index (CPMI)[39]. These multi-metric indices can then be used to assess the quality of the biological community as a whole. For the Lower James-Chickahominy MS4 watersheds, only CPMI scores were generated from the available data. All data were collected in tributary to Upham Brook. Figure 5.18 shows the combined number of biological sampling events by station.

CPMI scores are expressed as percentages of the maximum value of 30, and are categorized as excellent (67-100%), good (50-67%), fair (30-50%), poor (17-30%) and very poor (0-17%). The Upham Brook tributary had 18 CPMI scores calculated based on three sampling events, those scores ranged from 0 to 13, with an average score of 2 and a median score of 0.

Benthic macroinvertebrate taxa data were also collected in the Lower James-Chickahominy MS4 watersheds. These data consisted of 28 taxa counts for the Upham Brook tributary based on three sampling events. Counts may represent one of a number of taxonomic ranks (species, genus, family, etc).

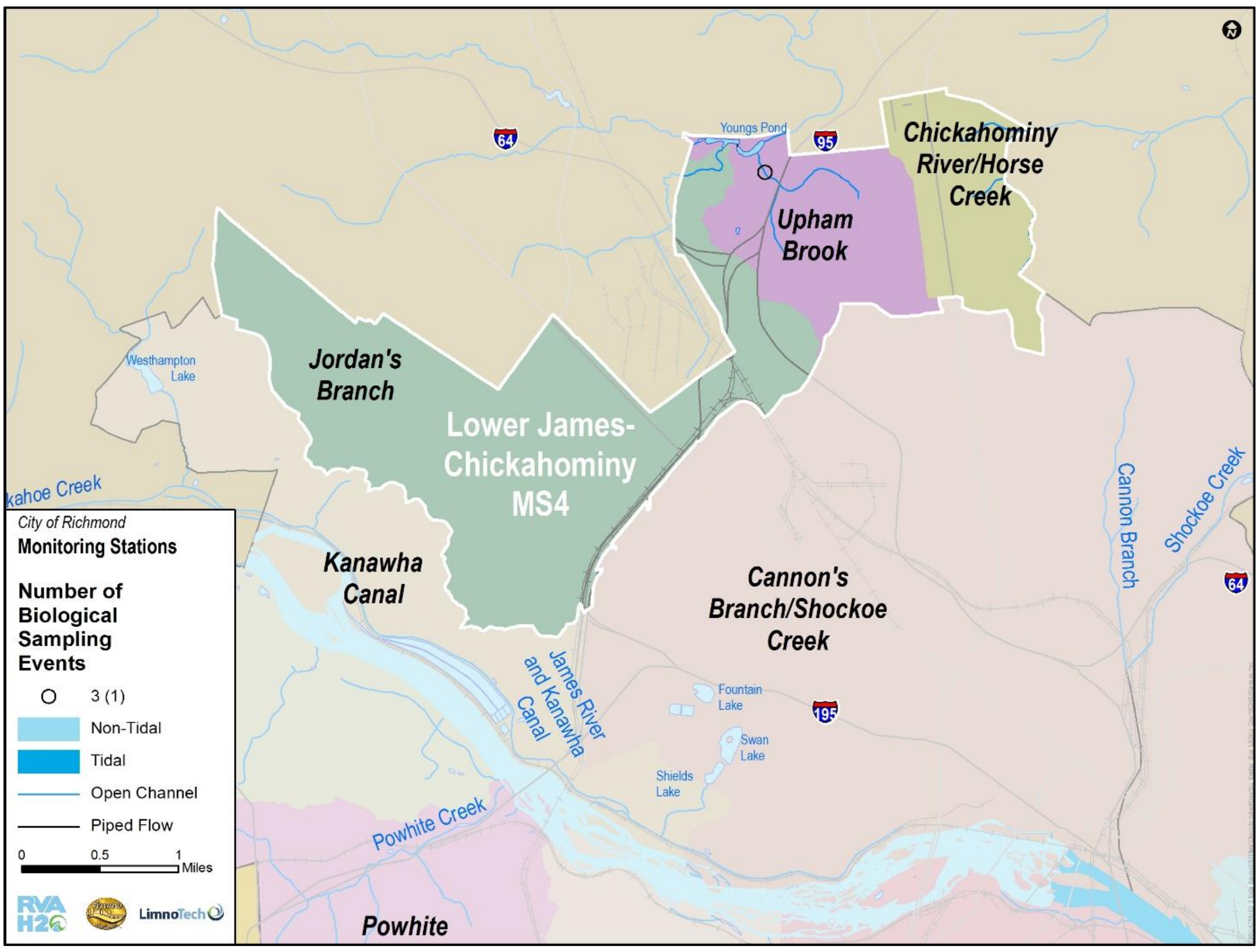

Figure 5.18 Biological sampling stations by number of sampling events

39 Chesapeake Bay Program. 2012. The 2012 User's Guide to Chesapeake Bay Program Biological Monitoring Data.

5.4.6 Pollutant Sources

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. For segments within the Lower James-Chickahominy MS4 watershed group, the following suspected sources were identified:

- Sanitary Sewer Overflows (collection system failures)
- Non-Point Sources

5.4.7 Stressors

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Table 5-17 includes stressors that Virginia DEQ has identified as being most prevalent. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value.

Table 5-17 Most frequent stressors to Virginia waterbodies

With WQS/Screening Value	*Without* WQS/Screening Value
Biomonitoring Indices (VSCI/CPMI)	Streambed Sedimentation
pH below 6	Habitat Disturbance
Nickel in Sediment	Total Phosphorus
Dissolved Nickel	Total Nitrogen
Dissolved Cadmium	CCU Metals Index
Mercury in Sediment	Ionic Strength
Dissolved Oxygen	

It should be noted that the analysis of sources and stressors will be completed within the next phase of the project. Analysis of collected data will be spatially linked with listings of impaired water body segments to identify or confirm potential sources and stressors within a watershed. Data upon which an impairment listing is based will also be compared with other data sources that have been compiled, to help determine whether additional data may support/strengthen or weaken an impairment listing, and whether additional review may be warranted.

6 Middle James MS4

6.1 Watershed Summary

The Middle James MS4 area of Richmond is comprised of seven watersheds: Cherokee Lake, Kanawha Canal, Pittaway Creek, Powhite Creek, Rattlesnake Creek, Reedy Creek, and Rockfalls. The region is situated in the western side of the City and covers areas both north and south of the James River (Figure 6.1). The total area characterized in this watershed grouping is 18.7 square miles.

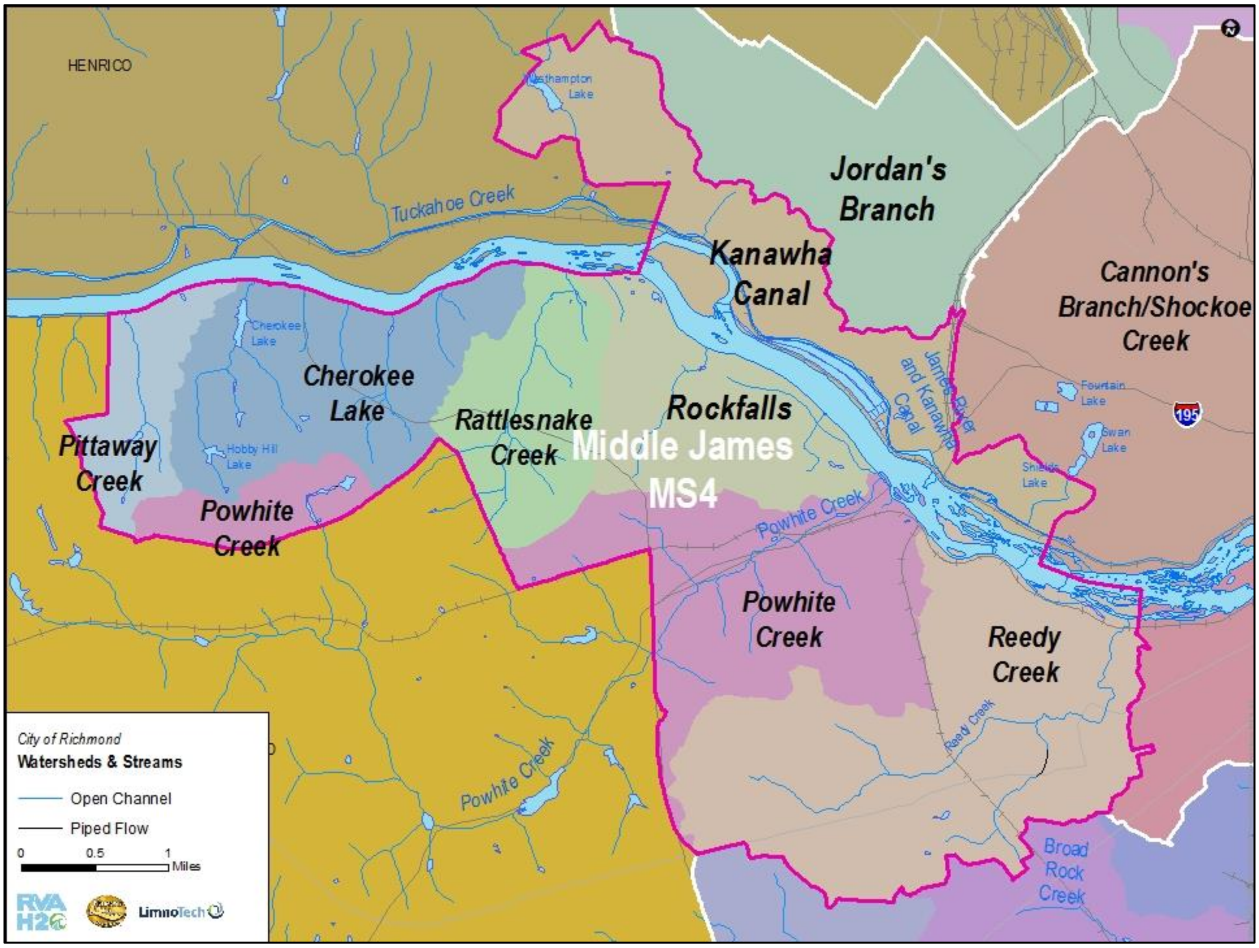

Figure 6.1 Watersheds and streams within the Middle James MS4 watershed grouping

As shown in Table 6-1the largest watershed is Reedy Creek and the smallest is Pittaway Creek.

Table 6-1 Middle James MS4 watershed area

Watershed	Watershed Area (sq. mi.)	% of Total Lower James/MS4
Cherokee Lake	2.4	12.9
Kanawha Canal	3.4	18.2
Pittaway Creek	0.9	4.6
Powhite Creek	3.7	19.8
Rattlesnake Creek	1.5	8.0
Reedy Creek	4.8	25.7
Rockfalls	2.0	10.9
Total Middle James/MS4	**18.7**	**100.0**

6.2 Watershed Delineation

For characterization purposes in this section, seven of the twenty watersheds in the City of Richmond have been grouped together:

- Cherokee Lake
- Kanawha Canal
- Pittaway Creek
- Powhite Creek
- Rattlesnake Creek
- Reedy Creek
- Rockfalls

6.3 Watershed Features

Watershed characteristics are major factors that need to be considered when identifying pollution sources and determining appropriate methods to reduce them. This section will describe the watershed and stream characteristics. The Middle James MS4 grouping of watersheds represents 18.7 square miles (Figure 6.2).

A total of 48.5 miles of stream exist in the five watersheds. These watersheds include portions of five of the nine City Council districts (1, 4, 5, 8, 9) in Richmond (Figure 6.2).

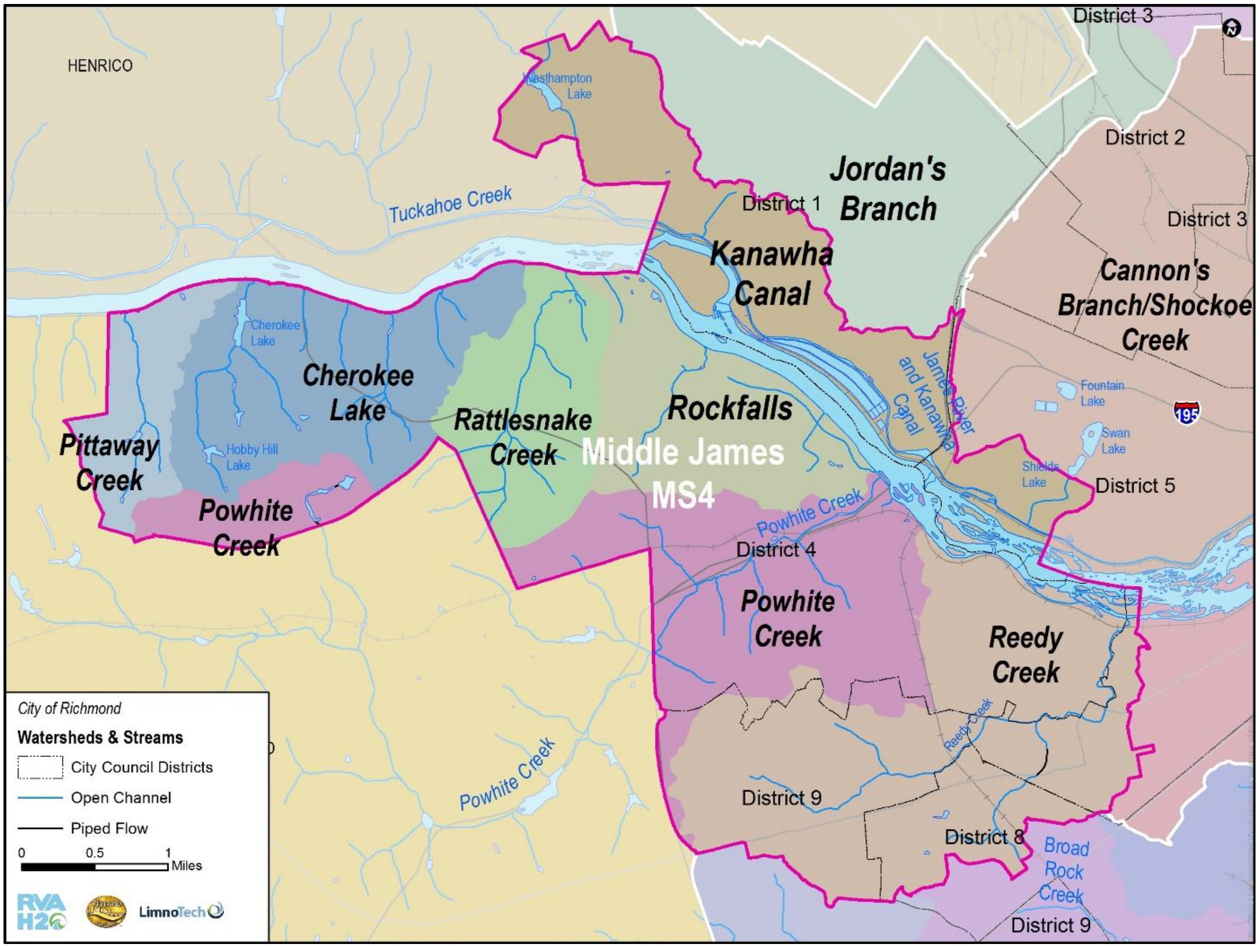

Figure 6.2 Middle James MS4 City Council Districts

6.3.1 Physical and Natural Features

This section describes hydrology, geology, topography, soils, climate, and habitat. These are important features because they affect land uses and shape the chemical, biological, and hydrological characteristics of the Middle James MS4 region.

6.3.1.a Hydrology

Within the seven watersheds, the total length of stream ranges from 3.0 to 16.5 miles (Table 6-2). The streams in the Middle James MS4 vary from being in their natural state to heavily modified. For example, portions of Reedy Creek have been channelized in order to run parallel to roads and railroads. Also, portions of Reedy Creek are channelized with a concrete lining. Other streams and tributaries, such as Rattlesnake Creek, appear to be in their natural state with a riparian corridor. Nearly all streams have commercial or residential development on the fringe of their river corridor.

Table 6-2 Middle James MS4 watershed hydrology

Watershed	Open Channel Stream Distance (mi)	Wetland Area (ac)	Lake Area (ac)	Total Watershed Area (ac)
Cherokee Lake	6.6	44.6	22.7	1,549
Kanawha Canal	16.5	470.0	17.4	2,176
Pittaway Creek	3.0	5.1	3.7	555
Powhite Creek	6.9	103.2	17.5	2,366
Rattlesnake Creek	3.0	10.5	0.5	956
Reedy Creek	5.8	243.2	3.9	3,075
Rockfalls	6.7	207.0	10.6	1,301
Total Middle James/MS4	**48.5**	**1083.6**	**76.4**	**11,977**

The City has identified wetlands in the all of the watersheds within the Middle James MS4[40]. A majority of these wetland areas are associated with James River. Other wetland areas include natural wetland areas and constructed ponds.

Westhampton Lake and Cherokee Lake are the largest lakes within the Middle James MS4. There are many other ponds, reservoirs, BMPs, and lakes throughout the Middle James MS4.

The FEMA has identified 100 year flood prone areas in all of the Middle James MS4 watersheds (Table 6-3). These areas are located along the James River and the major tributaries of each watershed.

Table 6-3 Middle James MS4 FEMA flood prone areas

Watershed	100yr flood prone area (ac)
Cherokee Lake	128.5
Kanawha Canal	523.2
Pittaway Creek	37.2
Powhite Creek	135.8
Rattlesnake Creek	75.1
Reedy Creek	320.9

[40] This dataset is derived from the US Fish and Wildlife Service's National Wetlands Inventory and is available online at ftp://ftp.ci.richmond.va.us/GIS/Shapefiles/Environmental/

Watershed	100yr flood prone area (ac)
Rockfalls	344.2

All of the watersheds and their associated waterbodies in this grouping are tributaries to the James River. While flowing through the Middle James –MS4 area, the James River bed elevation drops approximately 15 feet[41].

The falls also serve as the head of tide on the James River (just upstream of Mayo Bridge). This is also where the split between the Middle and Lower James is delineated. The Middle James River is a non-tidal freshwater segment of river.

6.3.1.b Geology

The City of Richmond straddles the division between the Coastal Plain and Piedmont physiographic provinces. As seen in Figure 3.5 the Middle3 James MS4 watersheds are divided between the Coastal Plain and the Piedmont. The coastal plain upland areas are characterized by low slopes and gentle drainage divides. The underlying geology tends to be fluvial with gravelly sand, silt, and clays.

6.3.1.c Topography

Watersheds in the Middle James MS4 area have a wide range of slopes ranging from 3.0% to 9.9% (Table 6-4). The Reedy Creek watershed is relatively flat. However, the other watersheds have very steep slopes, particularly along the James and other major tributaries. In particular, Cherokee Lake and Kanawha Canal have some very steep slopes. Overall elevations in this area range from 49 feet to 374 feet (Figure 6.3). The highest elevations in the watersheds are seen near the southern edge of Powhite Creek and Pittaway Creek.

[41] FEMA. Flood Insurance Study, City of Richmond, Virginia. Flood insurance number 510129V000B. July 16, 2014.

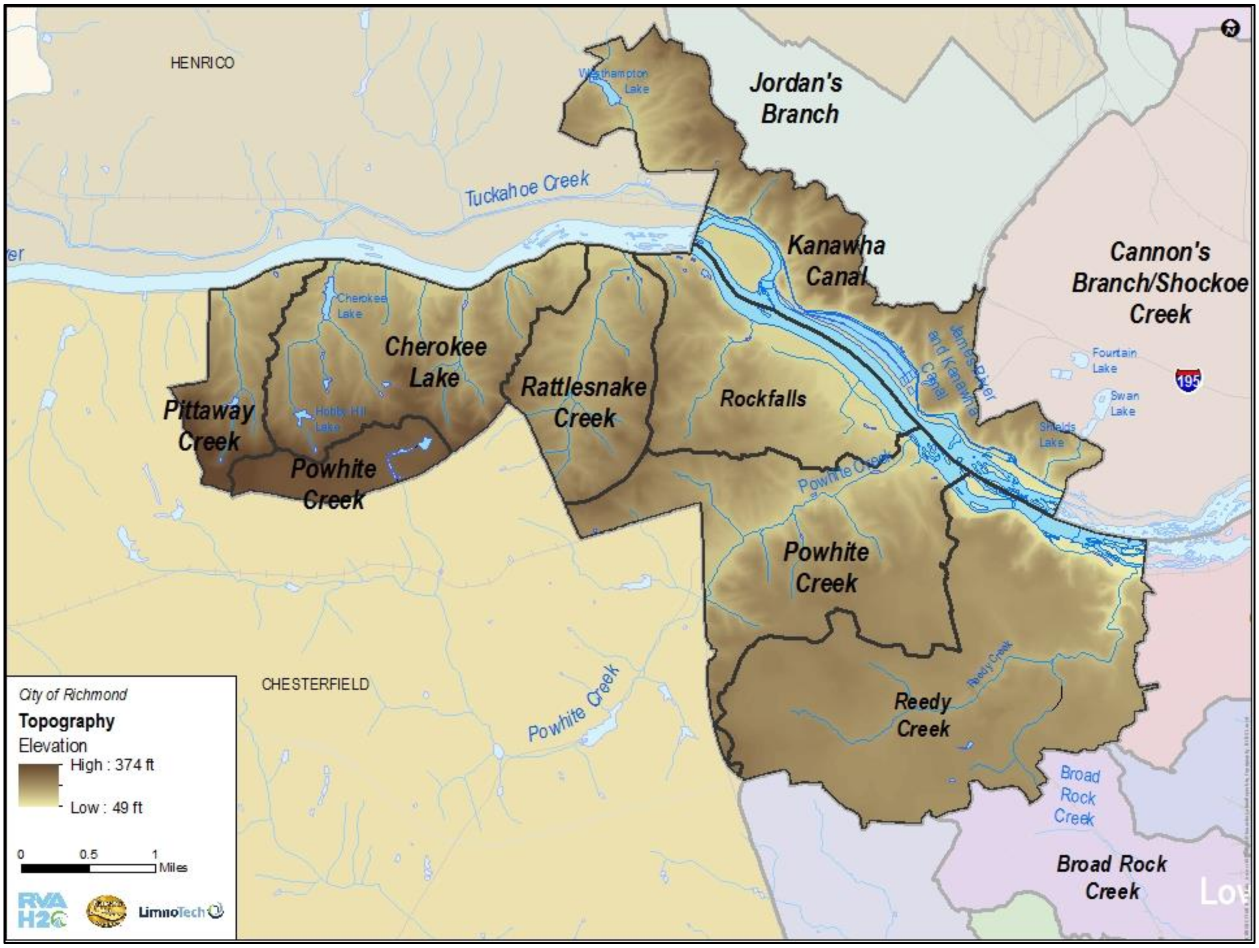

Figure 6.3 Topography of Middle James MS4

Table 6-4 Middle James MS4 topography

Waterbody	Low Elevation (ft)	High Elevation (ft)	Average Slope (%)
Cherokee Lake	102	353	9.9
Kanawha Canal	59	303	9.9
Pittaway Creek	115	374	9.5
Powhite Creek	69	372	5.7
Rattlesnake Creek	102	305	7.8
Reedy Creek	49	271	3.7
Rockfalls	80	277	6.0
Middle James/MS4	49	374	6.9

6.3.1.d Soils

The HSG of soils in the Middle James MS4 vary depending on the watershed (Figure 6.4 and Figure 6.5). In some urban areas, the soils are so disturbed that the HSG cannot be assigned. This is true for 19% of the soils in the Reedy Creek watershed (Table 6-5). In these cases, site-specific infiltration testing is required to better classify the ability of a soil to infiltrate water. HSG A soils are present in all watersheds with large percentages in the Rattlesnake Creek and Pittaway Creek watersheds. These soils have a low runoff potential when thoroughly wet and infiltrate well. HSG B soils, which represent the majority of soils in Cherokee Lake, Kanawha Canal, and Pittaway Creek watersheds, have a moderately low runoff potential when thoroughly wet. Both HSG A and HSG B soils are well suited for infiltration-type BMPs. Class C and D soils often require underdrains to insure water does not pond in these areas. These soils are more prevalent in the Powhite Creek, Rattlesnake Creek, Reedy Creek, and Rockfalls watersheds.

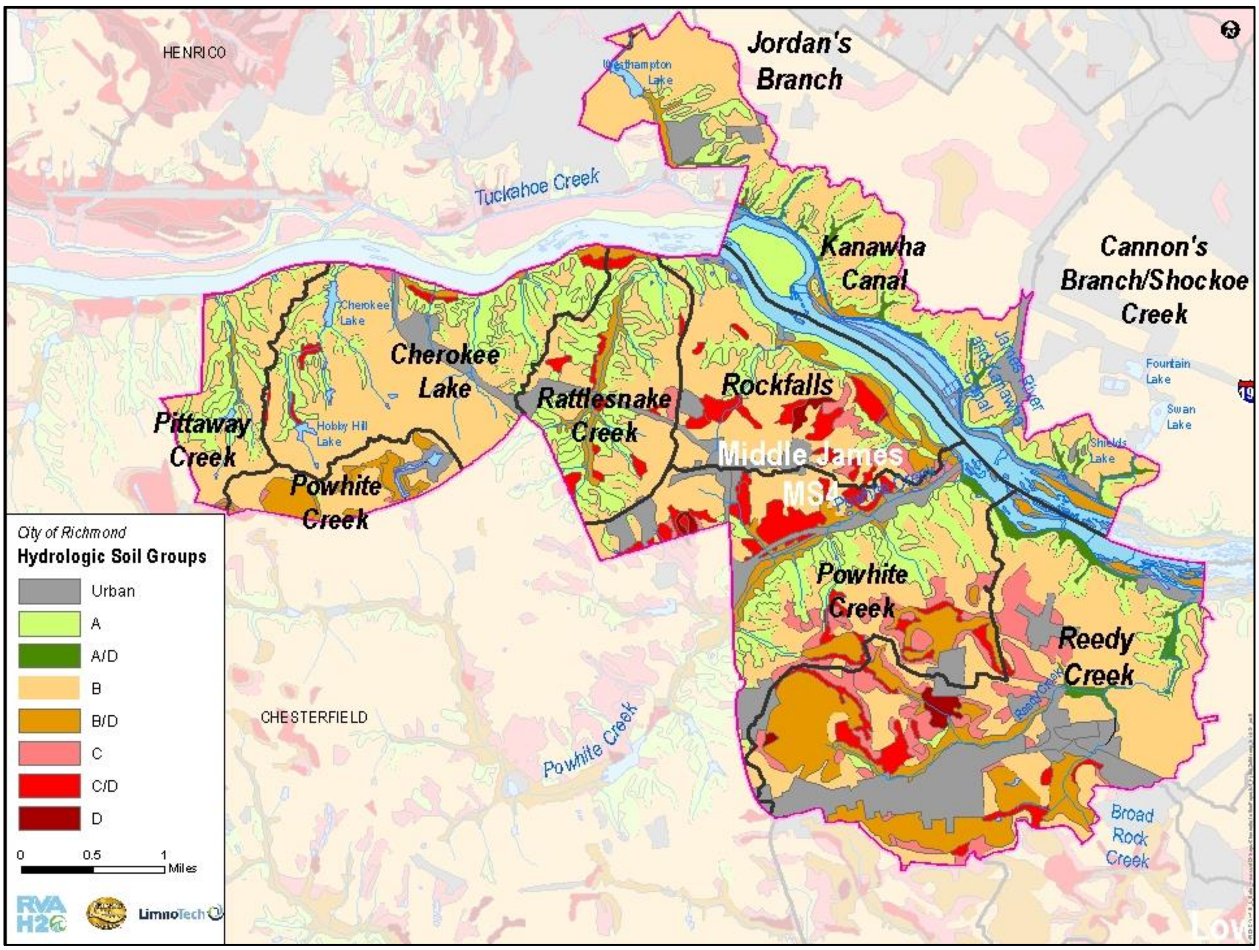

Figure 6.4 Middle James MS4 hydrologic soil group

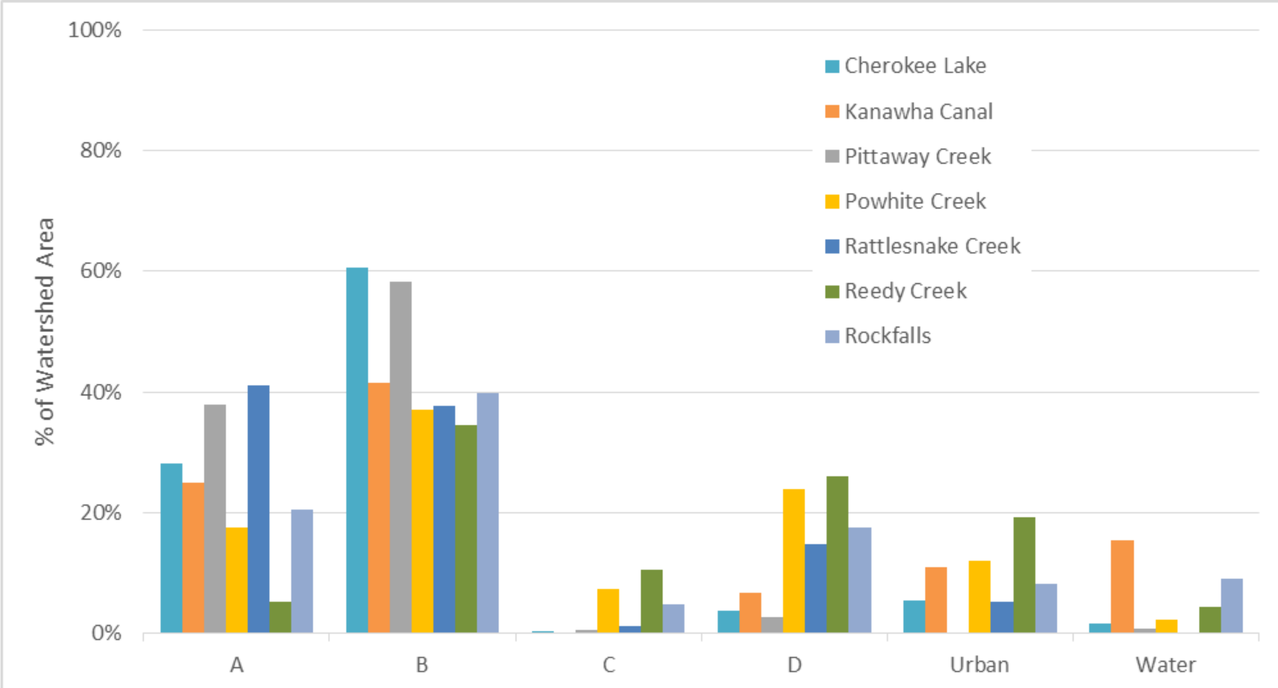

Figure 6.5 Middle James MS4 hydrologic soil group

Table 6-5 Middle James MS4 hydrologic soil groups

HSG	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattlesnake Creek	Reedy Creek	Rockfalls	Middle James/MS4 Total
A	28.2%	25.1%	37.9%	17.5%	41.1%	5.2%	20.6%	20.3%
B	60.6%	41.6%	58.2%	37.0%	37.8%	34.6%	39.9%	41.6%
C	0.3%	0.2%	0.5%	7.4%	1.2%	10.4%	4.7%	4.9%
D	3.8%	6.8%	2.7%	23.8%	14.7%	26.1%	17.5%	16.3%
Urban	5.5%	11.0%		12.1%	5.2%	19.3%	8.3%	11.3%
Water	1.6%	15.4%	0.7%	2.2%	0.1%	4.4%	9.0%	5.6%

6.3.2 Land Use/Cover Characteristics

Land use and land cover are important characteristics of watersheds. The way a land is being used has a direct link to the potential pollutants being produced.

6.3.2.a Current Land Cover

The NLCD land cover classification shows developed and forest land cover at varying intensities throughout the Middle James MS4 area (Figure 6.6). The Reedy Creek and Powhite Creek watersheds both have large expanses of high and medium intensity developed areas. Figure 6.7 further shows the prevalence of developed and forested areas in the watersheds.

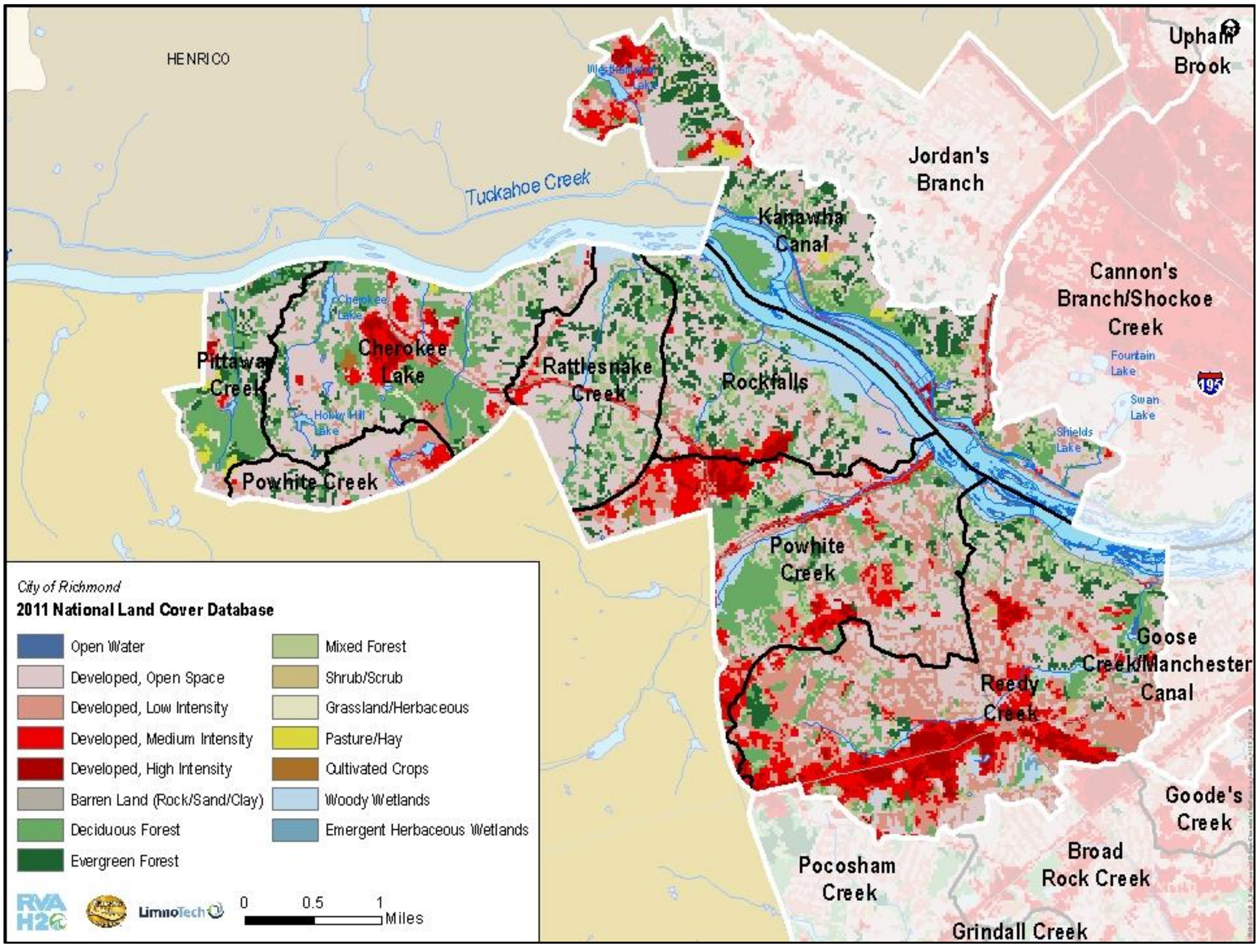

Figure 6.6 2011 NLCD for the Middle James MS4 watershed grouping

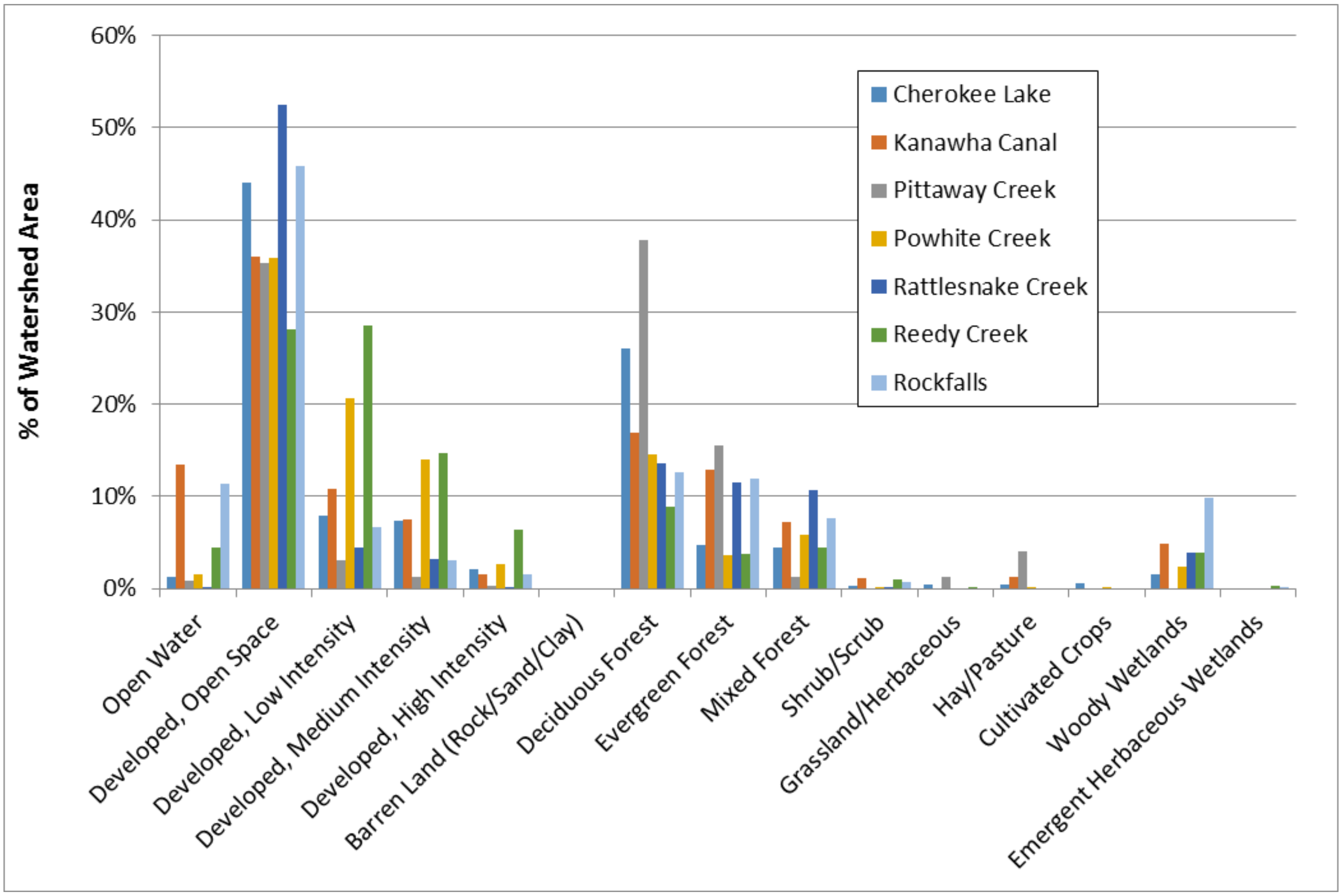

Figure 6.7 NLCD Percent Area within the Middle James MS4 watershed grouping

The VGEP land cover dataset shows how tree canopy and non-tree vegetation dominate the Middle James MS4 watershed (Figure 6.8). Impervious areas are seen scattered throughout the watersheds.

From the breakdown of land cover by type (Table 6-6), it is possible to see that the Middle James MS4 area is dominated by two land cover categories (non-tree vegetation, and tree canopy). The five individual watersheds have similar composition. However, the Reedy Creek, Powhite Creek, and and Cherokee Creek watersheds do have higher percentages of imperviousness compared to the rest of the watersheds.

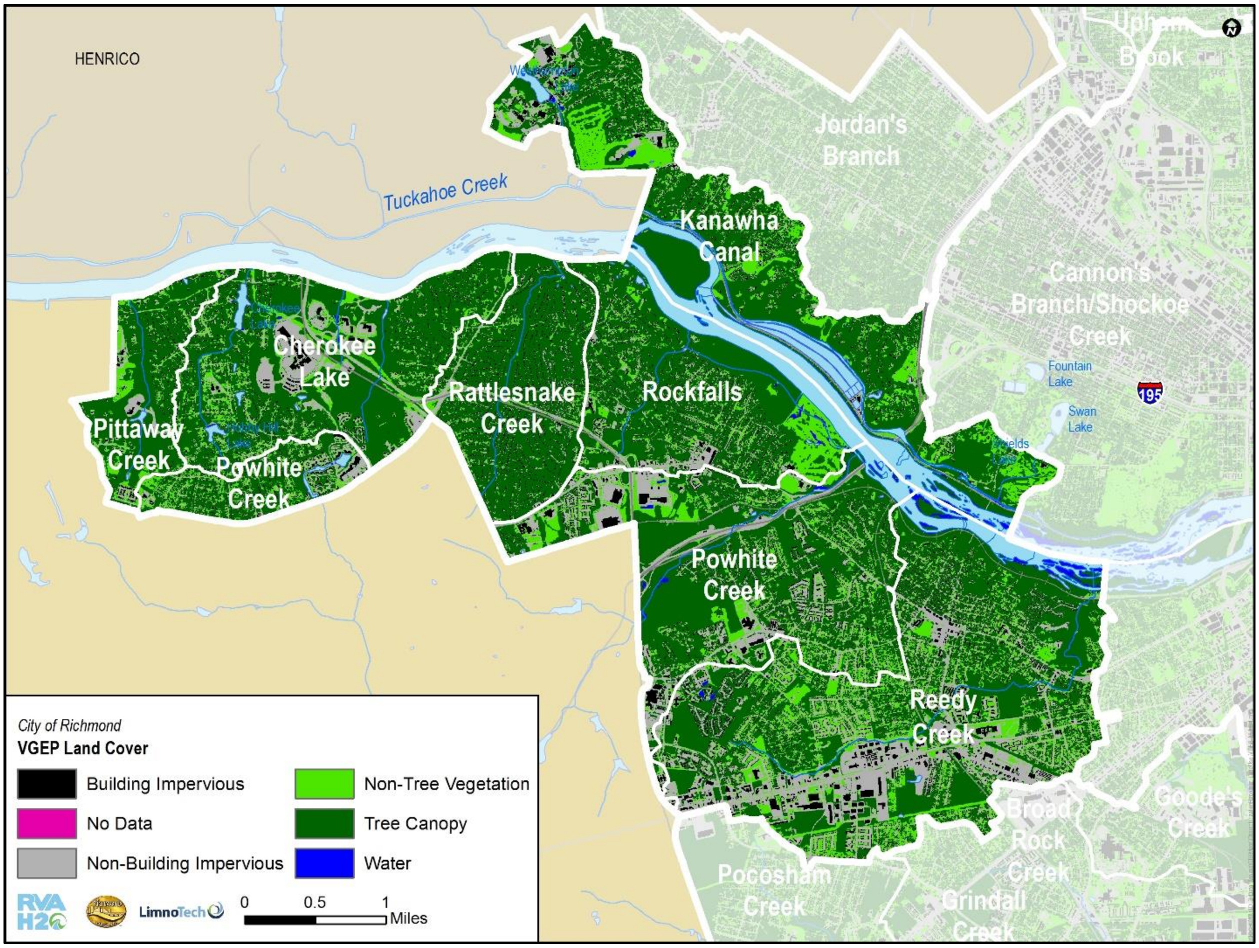

Figure 6.8 VGEP land cover for Middle James MS4 watershed grouping

Table 6-6 Middle James MS4 VGEP land cover percentage

Watershed	Water (%)	Non-Building Impervious (%)	Non-Tree Vegetation (%)	Tree Canopy (%)	Building Impervious (%)
Cherokee Lake	1.2	14.7	12.7	66.2	5.1
Kanawha Canal	14.6	10.1	16.5	54.8	4.1
Pittaway Creek	0.1	8.3	13.9	73.8	4
Powhite Creek	2	19.4	15.9	55.1	7.6
Rattlesnake Creek	0	8	5	80.7	6.2
Reedy Creek	4.3	23.7	18.4	44.4	9.3
Rockfalls	9.8	9.4	13.3	62.2	5.3
Middle James/MS4	5.4	15.7	15	57.4	6.5

Imperviousness

Imperviousness in the seven watersheds ranges from 13 to 34% with an overall imperviousness of 25% (Table 6-7). Kanawha Canal, Rockfalls, Rattlesnake Creek, and Cherokee Lake have similar imperviousness around 20%. The watersheds in the southern area (Powhite Creek and Reedy Creek) have the greatest imperviousness.

Figure 6.9 shows how impervious surfaces in the Middle James MS4 area are dominated by buildings, driveways, roads, and parking. The more residential Pittaway Creek watershed has a larger percentage of imperviousness attributed to driveways than the other watersheds. Reedy Creek, one of the more developed watersheds, has the largest percentage of parking and the lowest percentage of driveways.

Table 6-7 Middle James MS4watershed imperviousness

Watershed	Percent Impervious
Cherokee Lake	22.0
Kanawha Canal	18.4
Pittaway Creek	13.8
Powhite Creek	27.6
Rattlesnake Creek	21.6
Reedy Creek	33.6
Rockfalls	18.4
Total Middle James/MS4	**24.6**

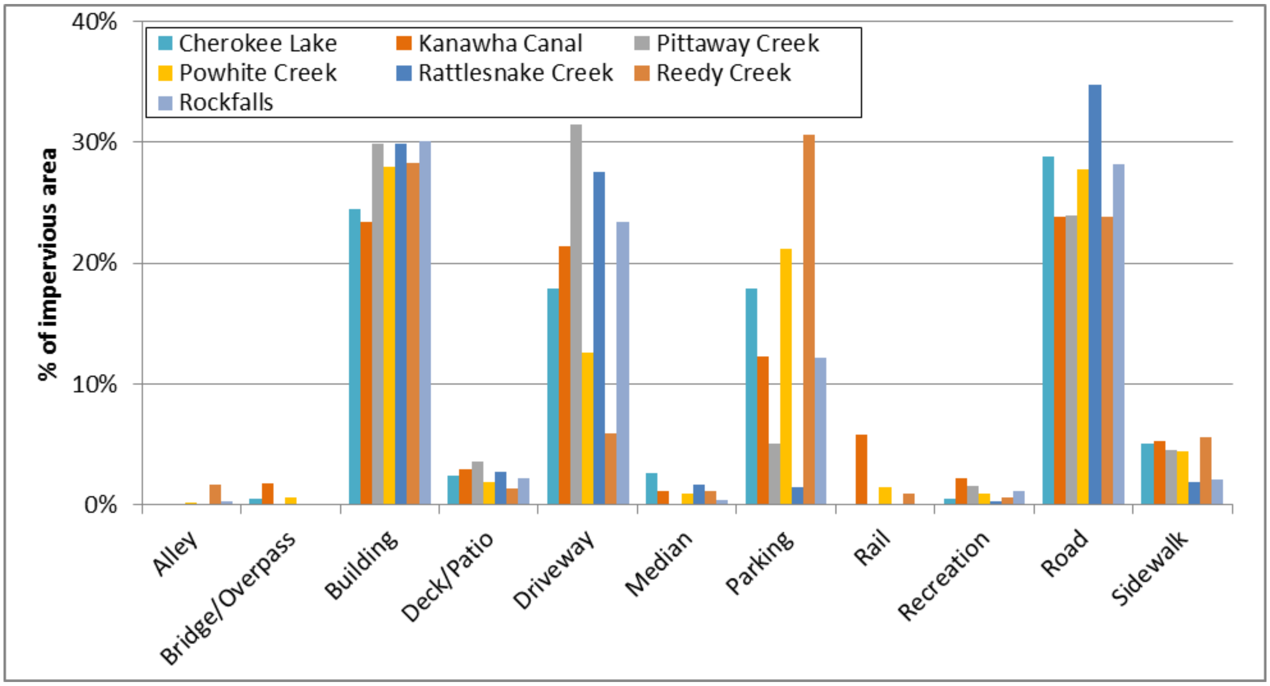

Figure 6.9 Middle James MS4 impervious area by type

Septic Systems

According to City records, 19 septic systems are located in the Middle James MS4 area. The Cherokee Lake watershed contains the most septic systems (11). Pittaway Creek (3), Powhite Creek (3), and Rattlesnake Creek (2) make up the remaining eight septic systems in the Middle James MS4 area.

6.3.2.b Land Use

As part of the City's Master Plan, existing land use was mapped in 2008[42]. Residential land use is found in all five watersheds (Figure 6.10). Residential, public, semi-public land uses dominate the makeup of the Middle James MS4 area with residential as the majority for all watersheds (Figure 6.11). Reedy Creek has the largest economic development area land use which corresponds to the other impervious and land cover datasets. The Rattlesnake Creek and Pittaway Creek watersheds are only comprised of residential, semi-public, and public land uses.

[42] http://www.richmondgov.com/planninganddevelopmentreview/PlansAndDocuments.aspx

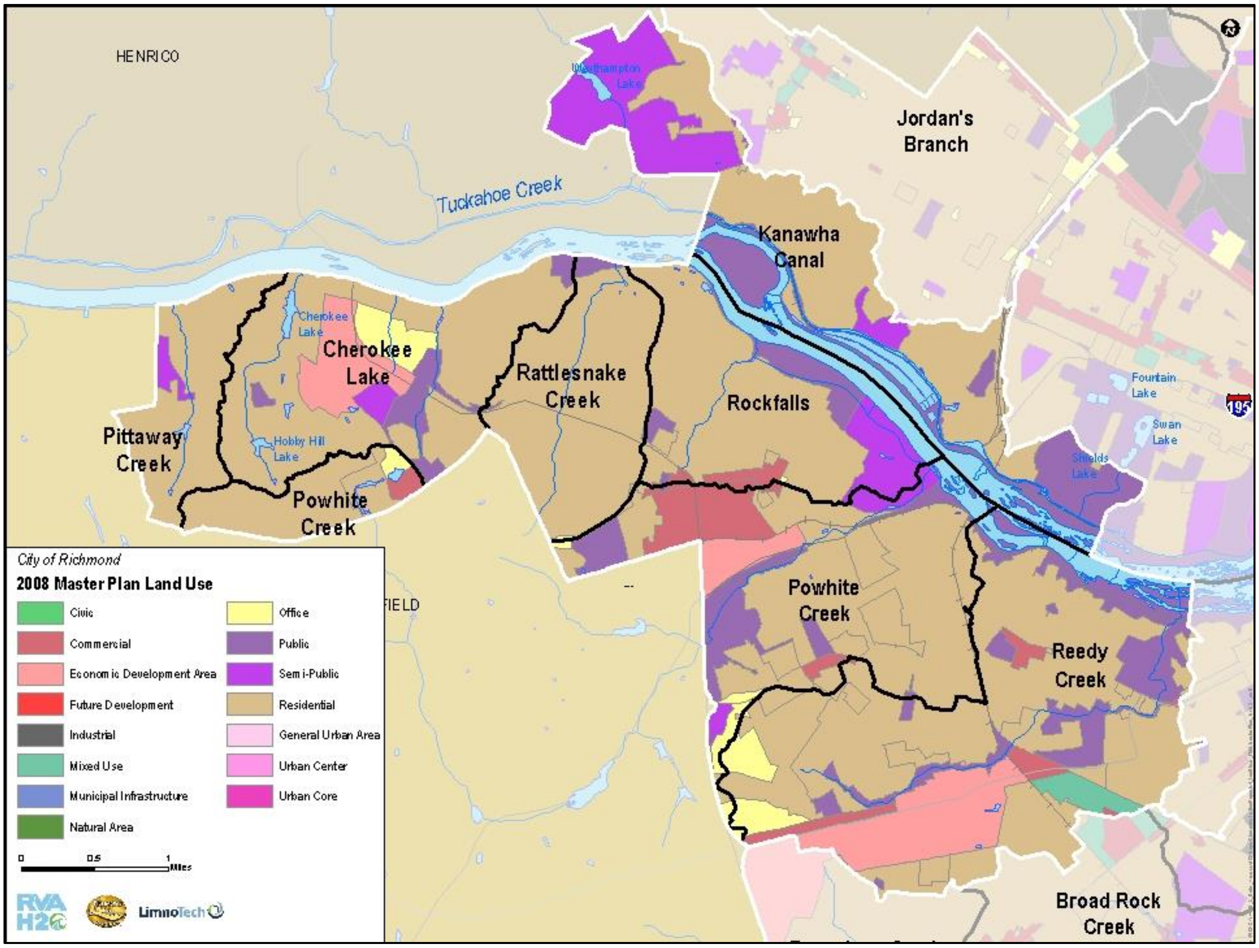

Figure 6.10 2008 Master Plan land use for the Middle James MS4 watershed grouping

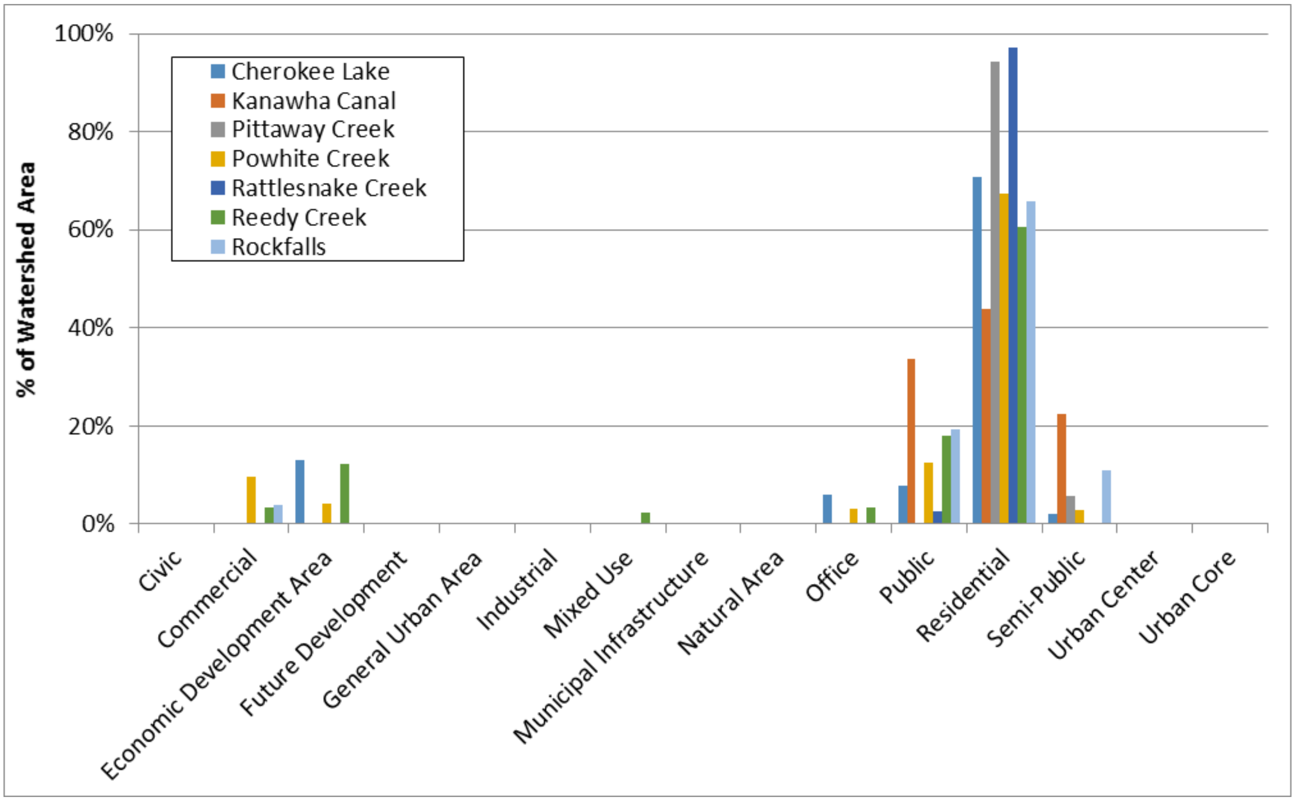

Figure 6.11 Middle James MS4 Master Plan land use

6.3.3 Infrastructure Features

As discussed in Section 3.3.3, above, the City covers a total of approximately 38,000 acres, with 12,000 acres within the combined sewer area with the remaining area served by a separated sanitary and storm sewer system, and direct runoff. The MS4 area within the Middle James watershed grouping is represented by the hatched area in Figure 6.12.

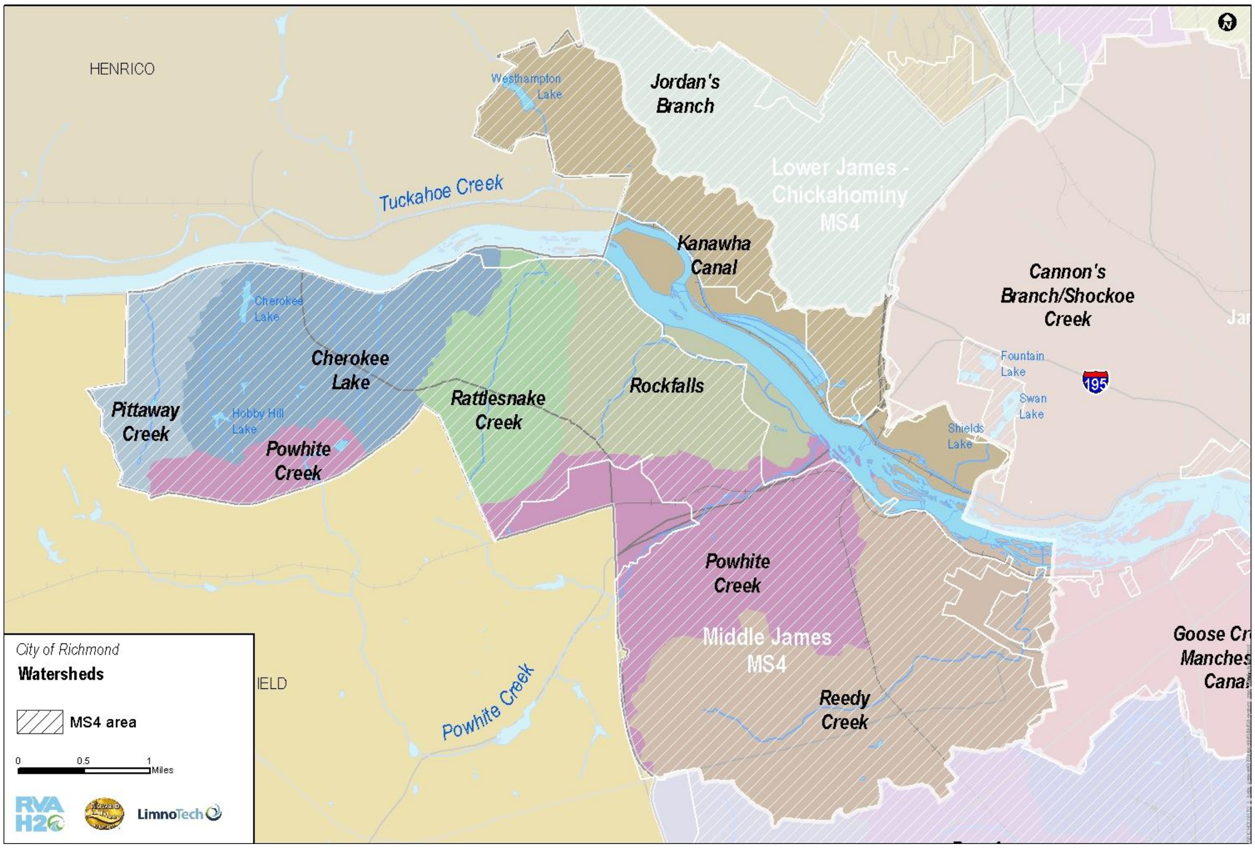

Figure 6.12 MS4 area in Middle James Watershed area

6.3.4 Stormwater System

6.3.4.a General System Description

The City of Richmond operates and maintains an MS4 system which serves approximately 24,500 acres of the City. The Middle James watershed area covers 11,978 acres, 9,978 of which are served by the MS4 system, 396 acres are draining directly into the receiving waters (shown in Table 6-8).

Table 6-8 Drainage types in Middle James Watershed area

Receiving Water	MS4 area (acres)	Direct drainage (acres)	Total (acres)
Cherokee Lake	1,527	22	1,549
Kanawha Canal	1,323	853	2,176
Pittaway Creek	554	1	555
Powhite Creek	1,955	411	2,366
Rattlesnake Creek	934	22	956
Reedy Creek	2,720	355	3,075
Rockfalls	965	336	1,301

6.3.4.b Stormwater Collection System Components

Inflow into the MS4 system within the Middle James watershed area is handled by 2,130 inlets which are listed in Table 6-9 below and shown in Figure 6.13.

Table 6-9 Stormwater inlets within Middle James Watershed area

Inlet type	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattle-snake Creek	Reedy Creek	Rock-falls	Total
Curb Inlet	191	68	18	448	14	692	49	1,480
Grate Inlet	83	28	10	309	69	213	82	794
Roof Drain	0	0	0	0	0	0	0	0
Un-known	41	76	0	52	2	574	0	745
Grand Total	315	172	28	809	85	1,479	131	3,019

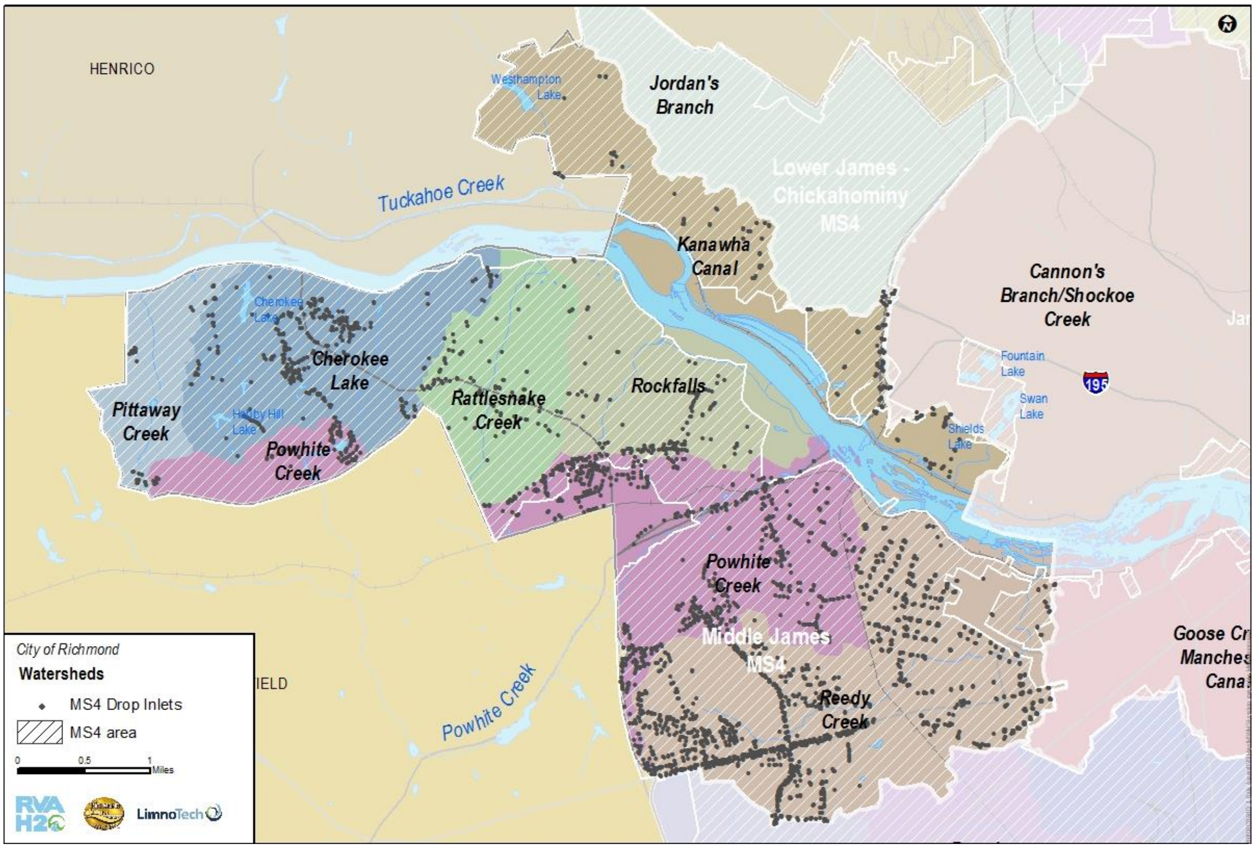

Figure 6.13 Stormwater inlets within Middle James Watershed area

Stormwater conveyance is provided by a network of open channels, culverts and pipes. The combined length of the stormwater system in the Middle James Watershed area is about 280 miles.

Flow in undeveloped areas is often conveyed by open drainage channels which are composed of a mix of different materials (summarized in

Table 6-10) which make up about 70% of the stormwater conveyance system in the Lower James Watershed area.

Table 6-10 Open drainage channels Middle James Watershed Area

Channel material	Channel length (ft.)							
	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattle-snake Creek	Reedy Creek	Rock-falls	Total
Asphalt	17,981	0	2,122	22,771	33,917	1,127	32,508	110,425
Brickwork	0	0	82	373	466	0	205	1,126
Concrete	27,637	4,966	2,767	10,056	10,987	7,320	5,995	69,728
Rip Rap	3,943	0	1,139	1,687	4,703	131	1,122	12,725
Unknown	39,801	1,737	6,810	23,055	17,025	22,414	18,872	129,714
Vegetation	74,282	22,040	22,036	193,229	92,493	102,504	95,165	601,748
Grand Total	**163,644**	**28,744**	**34,957**	**251,171**	**159,589**	**133,496**	**153,866**	**925,467**

Stormwater flow in open drainage channels is conveyed underneath roads and other channel crossings via closed culverts (summarized in Table 6-11).

Table 6-11 Stormwater culverts in Middle James Watershed Area

Culvert size	Number of culverts	total length of culverts (ft)
Unknown	3,082	82,333
< 12 inches	414	11,203
14 - 24 inches	1,982	61,126
27 - 48 inches	196	10,371
54 - 96 inches	41	3,677
> 108 inches	2	281
Grand Total	**5,717**	**168,991**

Developed areas are mainly drained by underground pipes with various pipe sizes (summarized in Table 6-12). Pipes make up about 30% of the stormwater conveyance system within the Lower James Watershed area.

Table 6-12 Stormwater pipes in Middle James Watershed Area

Pipe size	Channel length (ft.)							
	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattle-snake Creek	Reedy Creek	Rock-falls	Total
unknown	10,318	2,866	0	14,707	14	7,819	742	36,465
< 12 inches	661	481	64	1,489	619	5,054	755	9,123
12 - 24 inches	23,087	12,848	3,343	63,763	8,746	109,898	11,294	232,979
27 - 48 inches	8,999	4,542	406	20,035	4,811	44,335	3,897	87,025
54 - 72 inches	0	648	0	5,303	782	8,180	1,326	16,239
78 - 96 inches	0	0	0	0	0	2,566	0	2,566
> 96 inches	0	0	0	0	0	0	0	0
Grand Total	**43,064**	**21,385**	**3,813**	**105,296**	**14,971**	**177,852**	**18,014**	**384,397**

A mix of different BMPs within the stormwater area provide pollution control (summarized in

Table 6-13 and shown in Figure 6.14).

Table 6-13 BMPs within Middle James Watershed area

BMP type	Cherokee Lake	Kanawha Canal	Pittawa y Creek	Powhite Creek	Rattle -snake Creek	Reedy Creek	Rock-falls	Total
Unknown	5	0	0	7	0	9	2	23
Bio-retention Filter	2	4	0	1	0	0	1	8
Construc-ted Wetlands	0	0	0	0	0	1	0	1
Detention Basin	1	3	0	6	1	4	0	15
Dry Swale	0	1	1	0	1	0	1	4
Extended Detention Pond	2	1	1	1	0	1	0	6
Filters	1	0	0	0	0	1	0	2
Grass Channels	1	0	0	0	0	1	0	2
Infiltra-tion	4	8	0	0	4	2	0	18
Other	0	2	0	0	0	0	0	2
Rooftop Discon-nection	0	1	0	0	0	0	0	1
Vegetated Roof	0	0	0	0	0	0	1	1
Wet Pond	2	0	0	0	0	0	1	3
Wet Swale	0	0	0	0	0	1	0	1
Grand Total	**18**	**20**	**2**	**15**	**6**	**20**	**6**	**87**

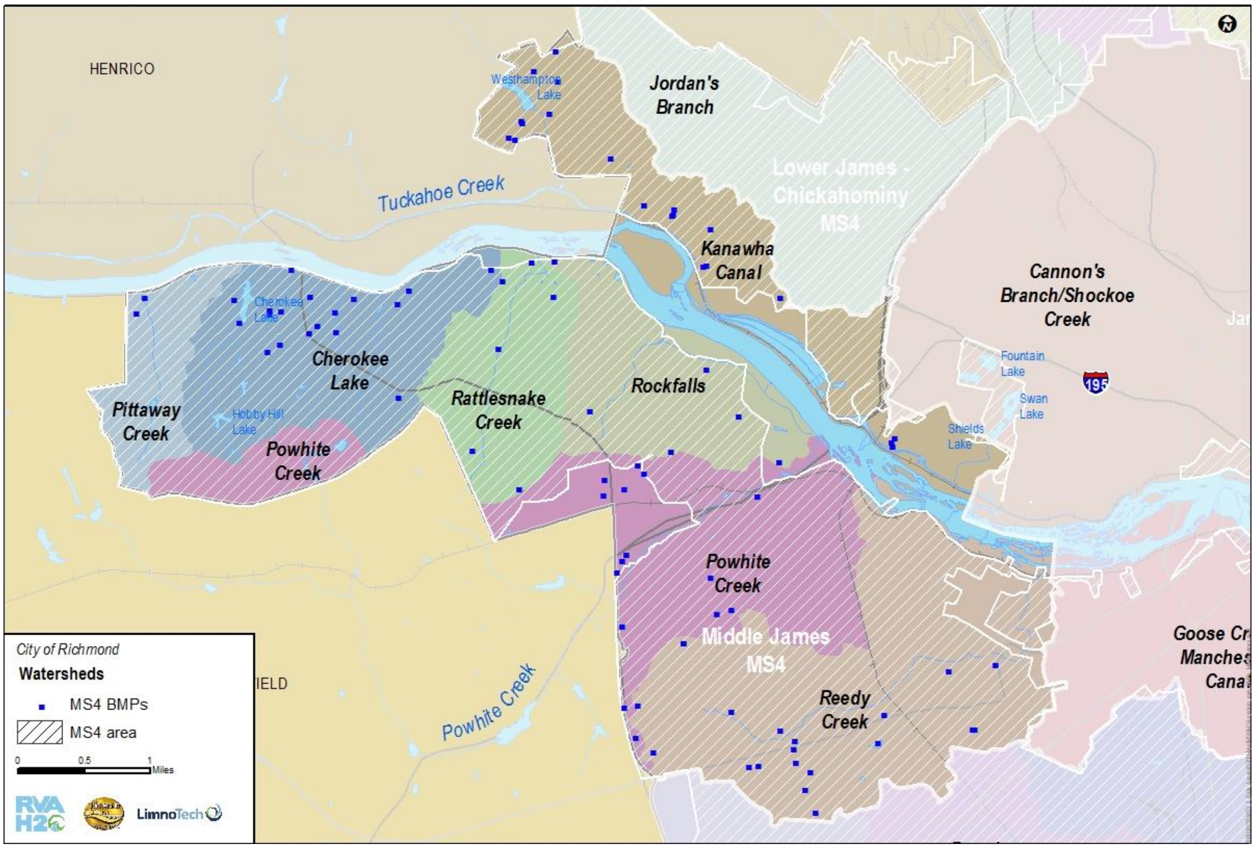

Figure 6.14 BMPs within Middle James Watershed area

Storm water outfalls are defined as points where a storm sewer system discharges to a receiving water or to another MS4. This includes discharges from pipes, ditches, swales, and other points of concentrated storm water flow. Identified outfall locations are summarized in Table 6-14 and shown in Figure 6.15 below. This includes locations of storm water discharge from and to Henrico County and Chesterfield County.

Table 6-14 Stormwater outfalls in Middle James Watershed area

Outfall type	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattle -snake Creek	Reedy Creek	Rock -falls	Total
Open Channel - Regulated	0	0	0	6	5	4	4	19
Open Channel - from Henrico County	0	4	0	0	0	0	0	4

Outfall type	Cherokee Lake	Kanawha Canal	Pittaway Creek	Powhite Creek	Rattle -snake Creek	Reedy Creek	Rock -falls	Total
Open Channel - from Chesterfield County	0	0	0	1	0	0	0	1
Open Channel - to Henrico County	0	1	0	0	0	0	0	1
Open Channel - to Chesterfield County	0	0	0	1	0	0	0	1
Open Channel - Other	72	27	26	44	35	61	47	312
Pipe - Regulated	1	0	0	14	3	23	0	41
Pipe - Other	16	9	3	53	25	41	14	161
Unknown	0	0	0	2	0	2	0	4
Grand Total	**89**	**41**	**29**	**121**	**68**	**131**	**65**	**544**

(*) This includes types like road drainage, parcel drainage and other miscellaneous or unclear outfall classifications

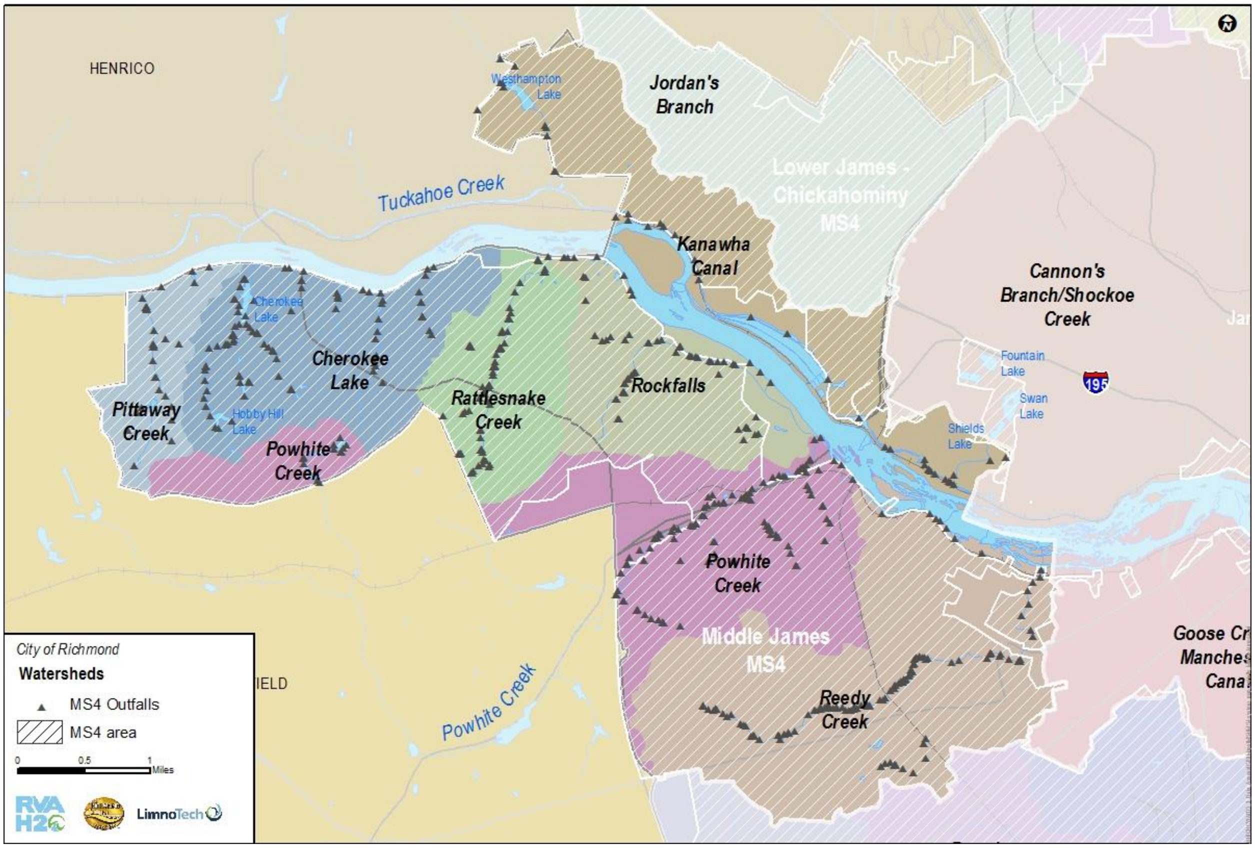

Figure 6.15 Stormwater outfalls within Middle James Watershed area

6.3.4.c Stormwater Master Plan

The City developed a first draft of a Stormwater System Master Plan in 2005 and expanded its area and scope in 2012. An overview and a general description of the current and planned Stormwater Master Plans is provided in Section 3, above.

The Stormwater Master Plan areas within the Middle James Watershed area are Reedy Creek and Cherokee Lake (shown in Figure 6.16).

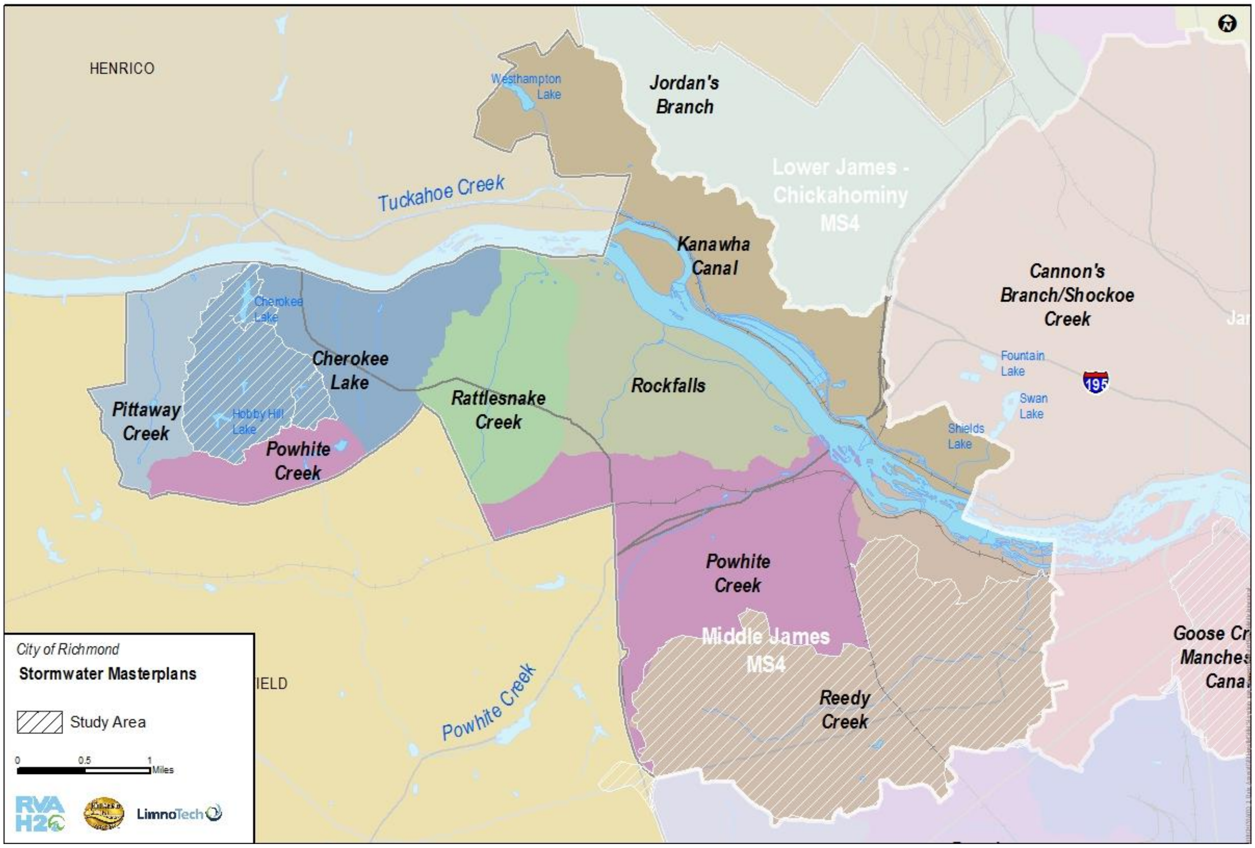

Figure 6.16 Stormwater Master Plans within Middle James Watershed area

6.3.4.d Stormwater Modeling

Hydrologic and hydraulic InfoSWMM models were developed for the Stormwater System Master Plan watersheds within the Middle James Watershed area. Important stormwater network features including pipes, culverts and channels were included. These uncalibrated models were used for an analysis of instream flow velocities, capacity analysis as well as for an evaluation of the water quality (modeled pollutants were TN, TP, TSS based on estimated values using DCR's Runoff Reduction Method). Model results were subsequently used for the development and evaluation of improvement alternatives.

6.4 Water Quality

Water quality in Richmond can be evaluated by analyzing water quality and biological data within the context of area waterbodies' water quality standards and impairment listings. Evaluation of current water quality is essential to the process of identifying pollutant sources and stressors.

Existing data sources for water quality, biological (fish, benthic macroinvertebrates, and habitat indices), flow, and point sources have been identified across various groups and agencies, including City of Richmond's own data collection efforts, Virginia DEQ programs, USGS monitoring efforts, non-agency (NGOs, universities) programs, and citizen and stakeholder groups' monitoring efforts. Virginia DEQ incorporates external data sources, including quality-controlled citizen data, when determining whether a waterbody is impaired.

6.4.1 Designated Uses

All Virginia state waters are designated for aquatic life, wildlife, recreational uses, and fish consumption (*Virginia Administrative Code 9VAC25-260-10, section A*). Other designated uses that may be assigned to select waterbodies include shell-fishing and public water supply uses.

There are additional designated use categories for tidal tributaries to the Chesapeake Bay: migratory fish spawning and nursery, shallow-water submerged aquatic vegetation, open water aquatic life, deep water aquatic life, and deep channel seasonal refuge.

Table 6-15 summarizes the designated uses that have been assigned to one or more waterbody segments in the Middle James MS4 watersheds, by waterbody type. Note that waterbody segments may extend well outside of the Middle James MS4 watersheds group.

Table 6-15 Middle James MS4 watershed grouping designated uses

<table>
<tr><th>Designated Use</th><th>Riverine waterbodies</th><th>Reservoir waterbodies</th><th>Tidal Freshwater waterbodies</th></tr>
<tr><td>Aquatic Life</td><td>X</td><td>X</td><td rowspan="10">No waterbodies are classified as tidal freshwater segments in Middle James MS4 watersheds</td></tr>
<tr><td>Fish Consumption</td><td>X</td><td>X</td></tr>
<tr><td>Public Water Supply</td><td>X</td><td>X</td></tr>
<tr><td>Recreation</td><td>X</td><td>X</td></tr>
<tr><td>Wildlife</td><td>X</td><td>X</td></tr>
<tr><td>Shellfishing</td><td></td><td></td></tr>
<tr><td>Migratory Fish Spawning & Nursery</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Deep Channel Seasonal Refuge</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Deep Water Aquatic Life</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Open Water Aquatic Life</td><td>n/a</td><td>n/a</td></tr>
</table>

Designated Use	Riverine waterbodies	Reservoir waterbodies	Tidal Freshwater waterbodies
Shallow Water Submerged Aquatic Vegetation	n/a	n/a	

6.4.2 303(d) Status

Under Section 303(d) of the Clean Water Act, states are required to submit to EPA a TMDL Priority List every other year. In Virginia, this list is contained in its biannual Water Quality Assessment 305(b)/303(d) Integrated Report, a joint publication of DEQ, DCR, and the state Department of Health. Waters are placed into federal categories based on each waterbody segment's (or 'assessment unit') support for its designated uses. Virginia supplements the federal categories with its own subcategories to better describe and track attainment/impairment.

The waterbody segments in the Middle James MS4 watersheds (Figure 6.17) have all been placed in one of six of the following EPA categories / Virginia subcategories in most recent (2014) Integrated Report:

- **EPA Category 2:** Available data and/or other information indicate that some, but not all of the designated uses are supported.
  - **Virginia Category 2A:** Waters are supporting all of the uses for which they are monitored.
- **EPA Category 3:** Insufficient data and/or information to determine whether any designated uses are met.
  - **Virginia Category 3A:** No data are available within the data window of the current assessment to determine if any designated use is attained and the water was not previously listed as impaired.
  - **Virginia Category 3D:** Data collected by a citizen monitoring or other organization indicate that designated use(s) are being attained but the methodology and/or data quality has not been approved for such a determination.
- **EPA Category 4A:** Water is impaired or threatened for one or more designated uses but does not require a TMDL. A new TMDL is not necessary to address the newly identified impaired tributaries if TMDL modeling, source identification and reductions cover the entire watershed and the TMDL has been approved by EPA. These waters are primarily related to shellfish and/or recreational bacteria impairments but could include benthic impairments.
- **EPA Category 5:** Waters are impaired or threatened and require a TMDL.
  - **Virginia Category 5A:** A water quality standard is not attained. The water is impaired or threatened for one or more designated uses (excluding shellfish use) by a pollutant(s) and requires a TMDL.
  - **Virginia Category 5D:** The water quality standard is not attained where TMDLs for a pollutant(s) have been developed but one or more pollutants are still causing impairment requiring additional TMDL development.

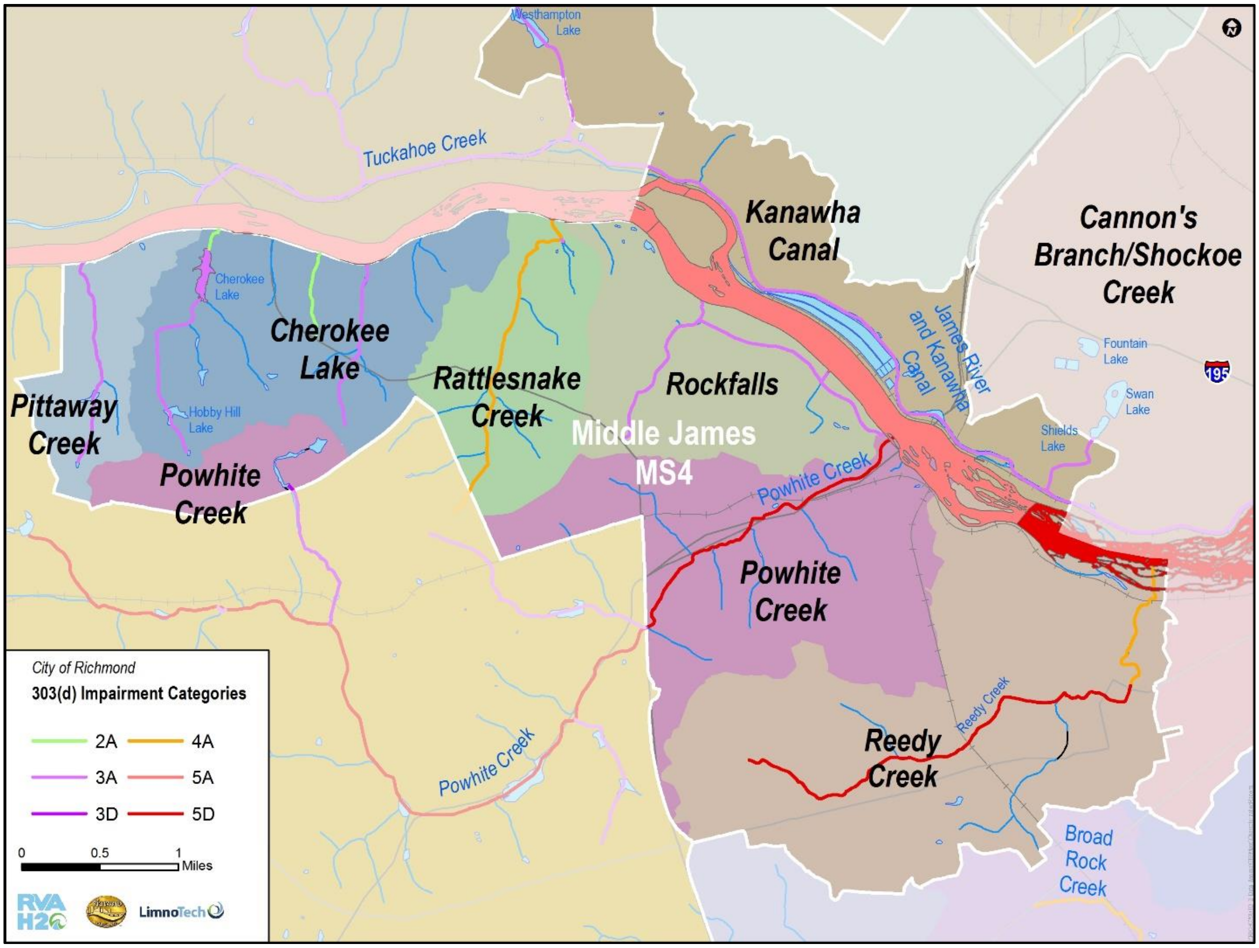

Figure 6.17 Middle James MS4 watershed grouping 303(d) impairment categories

For the impaired waterbody segments, the impairment causes identified in the 2014 Integrated Report for the Middle James MS4 watersheds include:

- Chlorophyll-a
- *E. coli*
- Benthic-Macroinvertebrate Bioassessments
- Dissolved Oxygen
- PCB in Fish Tissue
- Aquatic Plants (macrophytes)
- Chlordane
- DDE
- DDT
- Mercury in Fish Tissue

6.4.3 Monitoring Programs

Within the Middle James MS4 watersheds, most of the water quality data collection efforts have been led by Virginia Department of Environmental Quality (VADEQ), USGS, and various volunteer/non-profit organizations. Other organizations collecting data within the City of Richmond include federal and local organizations and industrial permittees. Data currently compiled by the City of Richmond from known monitoring programs are presented in Table 6-16.

Table 6-16 Summary of water quality monitoring programs

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Virginia DEQ Non-Tidal Stream Monitoring Program	Virginia Department of Environmental Quality (VADEQ)	State	2005-2010	BIO/HAB	2	1	15	104	1,700	
VAR051102 Water Quality Sampling	Chesterfield Auto Parts	Industrial	2010-2014	SRC	1	1	3	6	15	
VAR052028 Water Quality Sampling	Greater Richmond Transit Co	Industrial	2012-2015	SRC	1	1	4	4	14	
VAR050657 Water Quality Sampling	UPS Freight	Industrial	2010-2015	SRC	1	1	3	4	9	
City of Richmond CSO Monitoring	City of Richmond	Local	2012-2013	SRC	3	2	8	3	22	
USGS Routine Water Quality Monitoring	USGS	Federal	2007-2012	WQ	1	1	111	12	995	
512 20 3.0 TMDL Activities	Virginia Department of Environmental Quality (VADEQ)	State	2009-2013	WQ	2	1	92	26	1,584	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Pollutant Complaint Investigation / Spill Containment	Virginia Department of Environmental Quality (VADEQ)	State	2014	WQ	1	1	3	48	134	
Post-TMDL Implementation Monitoring	Virginia Department of Environmental Quality (VADEQ)	State	2013-2014	WQ	2	1	23	11	209	
VADEQ Ambient Watershed Monitoring	Virginia Department of Environmental Quality (VADEQ)	State	2011-2012	WQ	1	1	12	8	90	
VADEQ QA/QC Program	Virginia Department of Environmental Quality (VADEQ)	State	2009-2013	WQ	2	1	8	42	147	
VADEQ Routine sampling	Virginia Department of Environmental Quality (VADEQ)	State	2007-2012	WQ	13	4	273	37	2,191	
Virginia DEQ Non-Tidal Stream Monitoring Program	Virginia Department of Environmental Quality (VADEQ)	State	2005-2010	WQ	2	1	14	4	56	
Alliance for Chesapeake Bay (ACB) Routine Water Quality Sampling	Alliance for Chesapeake Bay (ACB)	Volunteer / NGO	2005-2012	WQ	6	3	95	8	803	

Sampling Program Description	Survey Agency	Agency Type[2]	Year(s)	Data Type(s)[1]	Station Count	Waterbodies Sampled	Sampling Events	Parameter Count	Sample Count	Comments
Chesapeake Bay Non-Tidal Network Monitoring	Chesapeake Bay Non-Tidal Network	Volunteer / NGO	2010-2014	WQ	1	1	53	39	1,844	
Chesapeake Bay Program Water Quality and Habitat Monitoring	Chesapeake Bay Program	Federal	2009-2010	WQ	1	1	5	34		

[1] Data types: BIO/HAB=Biological/habitat; CM=Continuous monitoring; MET=Meteorological; SRC=Point source; WQ=Water quality.
[2] NGO=Non-governmental organization

6.4.4 Water Quality Data

Water quality sampling data were collected at 19 stations within the Middle James MS4 watersheds. Of those 19 stations, 10 had fewer than 10 sampling events, with the remaining nine stationsproviding 669 sampling events. From a total of 689 sampling events, 8,205 individual samples (single-parameter observations) were collected. Data from these watersheds cover 2005 to 2014. There are 117 different parameters for which there are samples; of those parameters, 64 had fewer than 10 samples each. Figure 6.18 depicts the number of water quality sampling events by station.

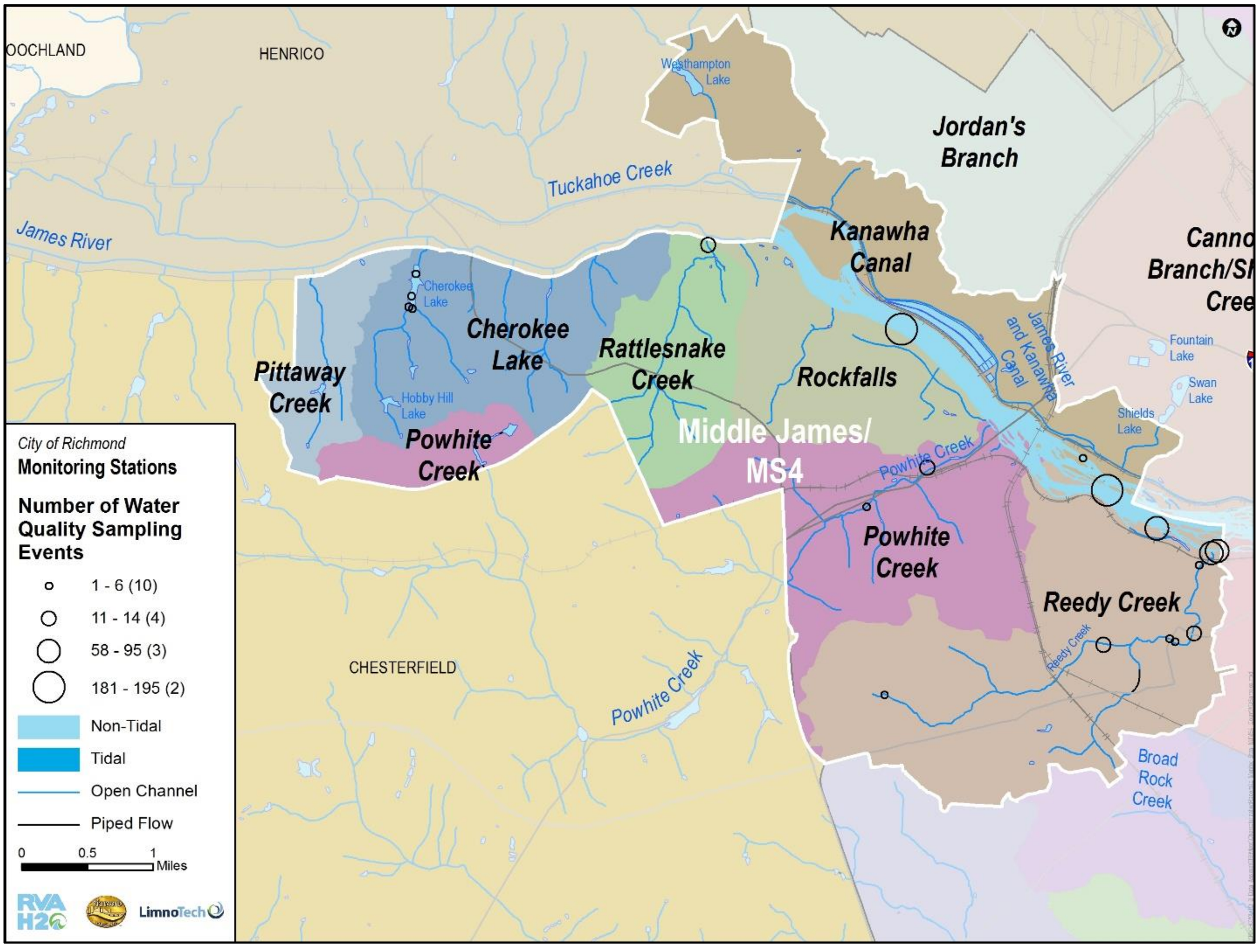

Figure 6.18 Middle James MS4 watershed grouping water quality sampling stations by number of sampling events

Available point source data for discharge points within the Middle James MS4 watersheds consist of flow and water quality sampling from three permitted facilities within the watersheds and flow, duration, and frequency monitoring for the four combined sewer outfalls within the watersheds. Data consist of discharge monitoring report (DMR) content. Permitted facilities are listed below in Table 6-17; locations and number of samples are shown on Figure 6.19.

Table 6-17 Permitted Facilities in Lower James CSO Watersheds

VPDES Permit Number	Description/Owner	Permit Type	Number of Sampling Events	Number of Samples
VA0063177	Combined Sewer Outfalls (qty. 4)*	Individual	8	22
VAR050657	UPS Freight - Richmond	General: Industrial Activity	3	9
VAR051102	Chesterfield Auto Parts	General: Industrial Activity	3	15
VAR052028	Greater Richmond Transit Co - Oper and Maintenance	General: Industrial Activity	4	14

* One of the four combined sewer outfalls has no associated data.

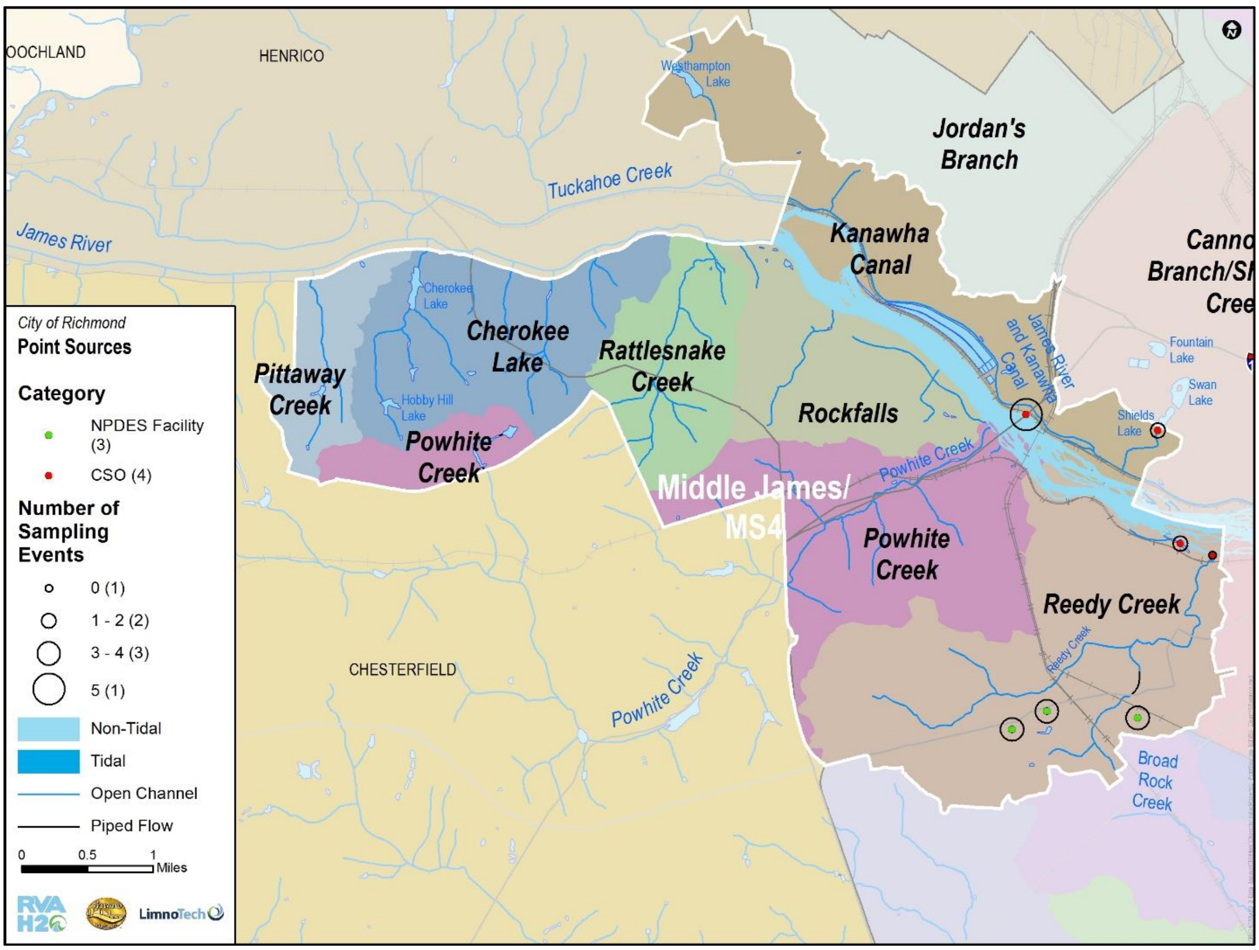

Figure 6.19 Middle James MS4 watershed grouping point sources by number of sampling events

6.4.5 Biological Conditions

Biological and habitat-related data consist of fish count and fish tissue data, benthic macroinvertebrate data that include taxa counts, metric scores and index scores, and habitat metric scores. All data were obtained through queries of the Chesapeake Bay Program Living Resources Database.

Benthic macroinvertebrate metrics were calculated by the Chesapeake Bay Program Living Resources Database (CBP 2012). A limited number of the benthic macroinvertebrate metrics are then used to develop scores using one of two multi-metric indices: the Bay Program's own Benthic Index of Biotic Integrity (CB B-IBI) or the Coastal Plain Macroinvertebrate Index (CPMI)[43]. These multi-metric indices can then be used to assess the quality of the biological community as a whole. For the Middle James MS4 watersheds, only CPMI scores were generated from the available data. All data were collected in the James River. Figure 6.20 shows the combined number of biological samples collected and habitat assessments conducted, by station.

CPMI scores are expressed as percentages of the maximum value of 30, and are categorized as excellent (67-100%), good (50-67%), fair (30-50%), poor (17-30%) and very poor (0-17%). The James River in the Middle James MS4 watersheds had 90 CPMI scores calculated from 15 sampling events, those scores ranged from 7 to 93, with an average score of 29 and a median score of 20.

Benthic macroinvertebrate taxa data were also collected in the Middle James MS4 watersheds. These data consisted of 343 taxa counts for the James River based on 15 sampling events. Counts may represent one of a number of taxonomic ranks (species, genus, family, etc.).

Additional habitat data were collected using EPA Rapid Bioassessment Protocols (RBP) for evaluating stream habitats. For the Middle James MS4 sheds, these data included 140 results for eleven different habitat metrics. Table 6-18 summarizes habitat metric counts, ranges, averages and medians. All habitat data were collected on the James River. Scoring for all metrics is on a scale of 0 (severely degraded) to 20 (pristine condition).

Table 6-18 Summary of habitat data

Habitat Metric	Metric Count	Minimum Value	Maximum Value	Average Value	Median Value
Bank Stability	14	18	20	19	19
Bank Vegetation	14	16	18	17	17
Channel Alteration	14	13	18	16	17
Embeddedness	14	11	15	13	14
Epifaunal Substrate	14	12	17	15	15
Flow	14	16	20	18	19
Riffle/Run/Pool Ratio	14	17	20	19	19
Riparian Vegetation Score	8	10	16	14	14

43 Chesapeake Bay Program. 2012. The 2012 User's Guide to Chesapeake Bay Program Biological Monitoring Data.

Habitat Metric	Metric Count	Minimum Value	Maximum Value	Average Value	Median Value
Riparian Vegetation Zone Width	6	11	15	13	13
Sedimentation	14	12	17	14	14
Velocity/Depth Ratio	14	17	20	18	19

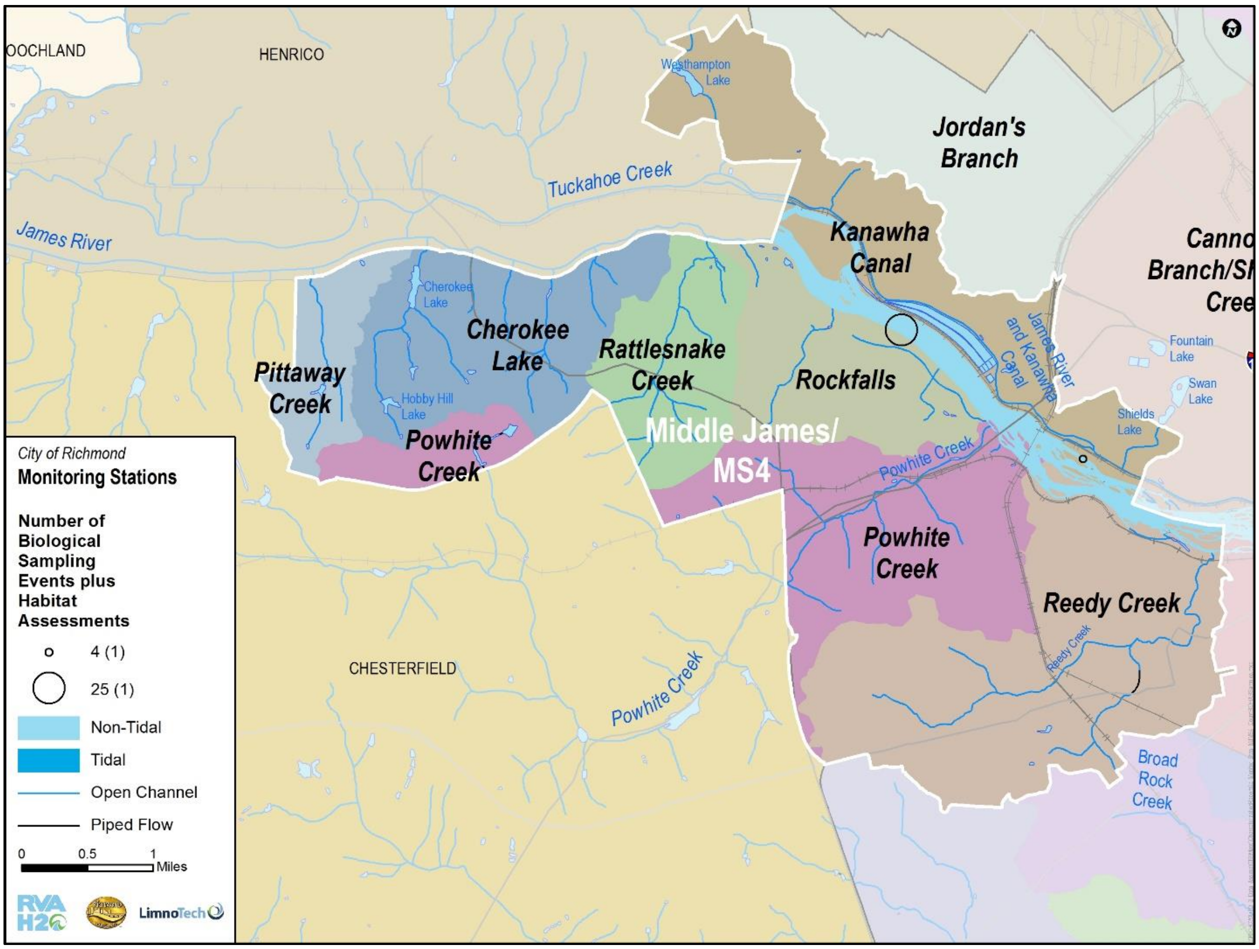

Figure 6.20 Biological and habitat data sampling and assessment stations by number of sampling events and habitat assessments

6.4.6 Pollutant Sources

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. For segments within the Middle James MS4 watershed group, the following suspected sources were identified:

- MS4 Discharges
- Combined Sewer Overflows
- Non-Point Sources
- Municipal Point Source Discharges

- Atmospheric Deposition (toxics)
- Clean Sediments

6.4.7 Stressors

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Table 6-19 includes stressors that Virginia DEQ has identified as being most prevalent. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value.

Table 6-19 Most frequent stressors to Virginia waterbodies

With WQS/Screening Value	*Without* WQS/Screening Value
Biomonitoring Indices (VSCI/CPMI)	Streambed Sedimentation
pH below 6	Habitat Disturbance
Nickel in Sediment	Total Phosphorus
Dissolved Nickel	Total Nitrogen
Dissolved Cadmium	CCU Metals Index
Mercury in Sediment	Ionic Strength
Dissolved Oxygen	

It should be noted that the analysis of sources and stressors will be completed within the next phase of the project. Analysis of collected data will be spatially linked with listings of impaired water body segments to identify or confirm potential sources and stressors within a watershed. Data upon which an impairment listing is based will also be compared with other data sources that have been compiled, to help determine whether additional data may support/strengthen or weaken an impairment listing, and whether additional review may be warranted.

7 Summary of Findings

7.1 Watershed Features

The characteristics of the four watershed groupings are diverse when compared to each other. Physical and natural features including the hydrology, geology, topography, and soils along with the land cover and land use help to define the characteristics of each watershed grouping.

Waterways in the Lower James CSO are heavily modified and altered. Shockoe Creek and Cannon Branch both are channelized and then become piped near their confluence until the stream daylights into the James River. Gillies Creek, although not piped, is channelized with a concrete. The City of Richmond is bisected by the Coastal Plain and Piedmont physiographic borders, but the Lower James CSO is the only watershed grouping located entirely in the Coastal Plain province. Topography of the watershed is characterized by steep slopes bordering the James River and tributaries with more gradual slopes in the urban area. Because the Lower James CSO is predominantly urban, the soils are primarily classified as urban soils with high runoff potential and very low infiltration rates. However, some areas exist with moderate infiltration in the upper Cannon Branch watershed. Nearly all of the land cover of the watershed is developed with an overall imperviousness of 46%, the greatest of all the watershed groupings. There are multiple land uses in the watershed with residential, industrial, and urban being the most prevalent.

The hydrology of the Lower James MS4 watershed grouping is heavily modified in the eastern portion of the grouping while mostly natural in the western portion. Several streams in the Goode's Creek, Broad Rock Creek, Grindall Creek, and Falling Creek Reservoir are channelized and even piped in some areas. Generally, the watershed slopes from west to east with flat and steeper sloped areas scattered throughout. Along the eastern portion of the grouping an industrial and highly developed area exists along the I-95 and railroad corridor, which results in disturbed soils with low infiltration rates. Residential areas with interspersed forest lands make up the western portion of the watershed where soil infiltration rates are higher.

Streams and waterways in the Middle James MS4 are also modified though to varying degrees. Reedy Creek and Powhite Creek are both channelized. Further modification is seen in Reedy Creek where some reaches are piped. In the western portion of the grouping, the streams are mostly in their natural condition. Similar to other groupings, steep slopes are found along the James River and tributaries though some flatter areas exist in the Reedy Creek watershed. In terms of land cover, forested and developed areas are seen throughout the grouping. The outlier of the watershed group is the Reedy Creek with its developed land uses and cover. Soils with low infiltration rates are most abundant in the Powhite Creek and Reedy Creek watersheds, especially near the developed areas. Less developed areas have soils with moderate to high infiltration rates. Residential areas are abundant throughout the grouping with other land uses such as public lands scattered throughout.

There are few streams in the Lower James-Chickahominy MS4, however the streams are in their natural conditions or slightly modified. Unlike the other watershed groupings, the topography of the Lower James-Chickahominy MS4 is mostly flat with little relief. A majority of the watershed is developed with a range of intensities, although there are smaller forested areas. In the highly developed portion of the Lower James-Chickahominy MS4, the soils have low infiltration rates. The less developed areas contain soils with moderate infiltration rates. Land use in the watershed is mostly residential with minor public and industrial areas.

7.2 Infrastructure Features

Similar to other older Cities especially in the eastern United States, the City of Richmond is partially served by a CSS. The City covers a total of approximately 38,000 acres, with 12,000 acres within the combined sewer area. The remaining 26,000 acres are served by a separated sanitary sewer system. 24,500 of these acres are served by a storm sewer system (MS4), the remaining approximate 1,950 acres are direct stormwater runoff. Stormwater flows are discharged directly into the receiving waters through stormwater outfalls. Sanitary and the majority of any combined flows are treated by the Richmond WWTP, combined flows exceeding the system capacity during wet weather events are discharged into the receiving waters through combined sewer outfalls (CSOs).

The City of Richmond's MS4 system is operated under the Virginia Stormwater Regulation 4VAC50-60 (Small MS4 permit) and includes over 220 miles of pipe, 280 miles of open channel and 50 miles of culverts which discharges stormwater flows at over 1,200 outfall locations. A list with key parameters of the City of Richmond's MS4 infrastructure in each of the identified watershed groupings of this report is provided in Table 7-1.

Table 7-1: Key MS4 sewer infrastructure elements

Infrastructure type	
Pipes	220 miles
Culverts	52 miles
Open channels	284 miles
Inlets	8,460
Manholes	3,075
Outfalls	1,262
BMPs	226

The sanitary and combined sewer system includes over 980 miles of pipe. The capacity of the City's wastewater treatment plant (WWTP) which is serving approximately 215,000 people is 45 MGD during dry weather and up to 75 MGD during wet weather. Combined sewer flows during wet weather events which would exceed the plant's capacity can stored at the 44 MG Shockoe Retention facility and the 7 MG Hampton / McCloy CSO Retention Tunnel. Any remaining wet weather flow volumes are discharged through the City's 31 active CSOs. Discharges from the WWTP and all CSOs are permitted by Virginia DEQ via VPDES Permit VA0063177. A list with key parameters of the City of Richmond's sanitary and combined sewer infrastructure in each of the identified watershed groupings of this report is provided in

Table 7-2.

Table 7-2: Key sanitary / CSO infrastructure elements

Infrastructure type	
Gravity main sewers	982 miles
Force main sewers	1.1 miles
Inlets	9,818
Manholes	20,518
Outfalls	32
Pump Stations	12

7.3 Water Quality

The number of available samples across data types – water quality sampling, biological sampling, and habitat assessments – are biased heavily towards the James River, with little-to-no data available in tributary streams. Additionally, there is a lack of hydraulic data within the City, with the only local USGS gauges located outside the City limits. Table 7-3 summarizes samples by data type and receiving water category. This table also highlights the dearth of biological samples and habitat assessments. Dividing the data on a regional basis reveals that the majority of available water quality samples were collected in the Lower James CSO and Lower James MS4 watershed groupings, while the majority of biological and habitat samples were collected in the Lower James CSO and the Middle James MS4. Table 7-4 summarizes samples by data type and watershed group.

Other types of data, such as hydraulic and meteorological samples, are more limited. There is no hydraulic data available within the city limits. While there are two USGS stations within the city limits (James River at Boulevard Bridge [USGS #02037618] and James River at City Locks [USGS #02037705]), neither station has flow data. The two closest USGS gaging stations with daily flow data are James River and Kanawha Canal Near Richmond (USGS #02037000) and James River Near Richmond (USGS #02037500), both of which are located upstream of the city. There is meteorological data available, but there are only two stations within the city (one in the Lower James CSO and another in the Lower James-Chickahominy MS4), both of which provide daily rainfall totals.

Table 7-3: Overall Sample/Assessment Counts by Data Type and Receiving Water Category

Data Type	James River	Tributaries
Water Quality	4,759	368
Biological	44	5
Habitat	44	5

Table 7-4: Overall Sample/Assessment Counts by Data Type and Watershed Group

Data Type	Lower James CSO	Lower James MS4	Lower James-Chickahominy MS4	Middle James MS4
Water Quality	2,012	2,341	85	689
Biological	30	1	3	15
Habitat	30	1	3	15