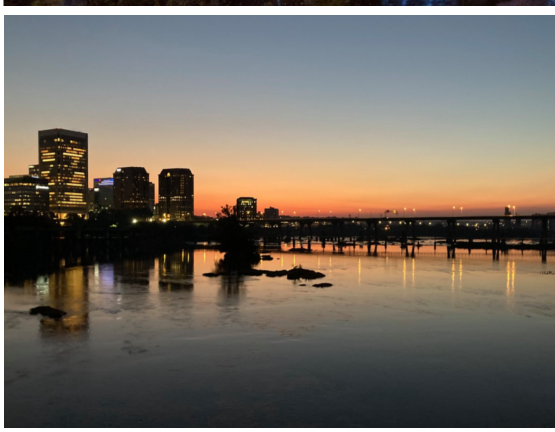
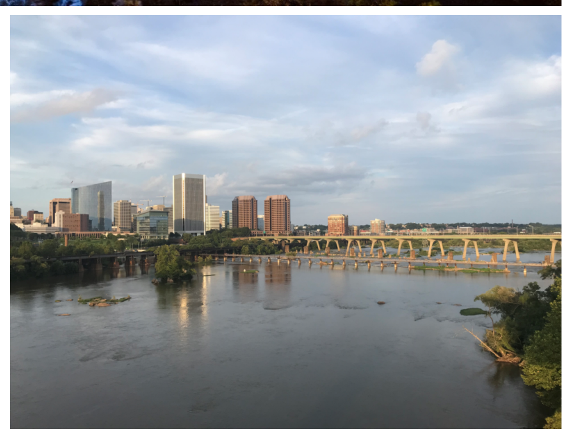
City of Richmond, Virginia
Department of Public Utilities
Final Plan Report

May 30, 2024





Prepared by Brown and Caldwell

Credit for Cover Photos:

1. Tommy Nikitiuk
2. Mark Lewis: Senior Construction Inspector for Richmond DPU Stormwater Utility
3. Susan Mitchell: Former Senior Account Director for West Cary Group

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AACE	Association for the Advancement of Cost Engineering
Cfs	Cubic feet per second
CFU	Colony forming units
CIWEM	Chartered Institution of Water and Environmental Management
CSO	Combined sewage overflow
CSS	Combined sewer system
DEQ	Department of Environmental Quality
DPU	Department of Public Utilities
DUC	Dynamic Underflow Control
DWF	Dry weather flow
DWO	Dry weather overflow
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
GI	Green Infrastructure
H&H	Hydrologic and Hydraulic
I/I	Inflow and infiltration
ILS	In-Line Storage
LQPI	Lowest Quintile Poverty Indicator
MG	Million gallons
MGD	Million gallons per day
MHI	Median Household Income
MS4	Municipal Separate Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NMC	Nine minimum controls
RIC	Richmond International Airport
RT-DSS	Real Time-Decision Support System
SO	Special Order
SRB	Shockoe Retention Basin
STV	Statistical Threshold Value
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
VELAP	Virginia Environmental Laboratory Accreditation Program
WQS	Water Quality Standards
WWF	Wet weather flow
WWTP	Richmond Wastewater Treatment Plant

SECTION 1

Executive Summary

1.1 Background

The City of Richmond, Virginia, (City) has a combined sewer system (CSS) that serves approximately 12,000 acres and is comprised of 25 active outfalls. For the past 50 years, the City has been proactively improving the CSS and the Wastewater Treatment Plant (WWTP), with approximately $780 million invested (adjusted to 2024 dollars) to reduce combined sewage volume and bacteria discharged to improve water quality in the James River.

In 2020, the Virginia General Assembly enacted Senate Bill 1064 (2020 Combined Sewer Overflow (CSO) Law). The 2020 CSO Law establishes specific timeframes for the development and implementation of a Final Plan to satisfy the requirements of any existing Special Order by Consent that has been issued for the CSS. It applies to the owner or operator of any CSS east of Charlottesville that discharges into the James River watershed. As the owner and operator of a CSS located east of Charlottesville that discharges into the James River, the City of Richmond (City) has developed this Final Plan.

The City has an existing "Special Order by Consent" for their combined sewer system (2005 Order) that was amended (Amendment) in 2020 with the Virginia Department of Environmental Quality (DEQ). The Amendment incorporates the deadlines specified in the 2020 CSO Law as reflected below.

	Due Date	Initiate Construction and Related Activities	Complete Construction and Related Activities
Interim Plan	✓ July 1, 2021	✓ July 1, 2022	July 1, 2027
Final Plan	July 1, 2024	July 1, 2025	July 1, 2035
TMDL Plan	July 1, 2030	NA	NA

The City is in the process of implementing the 10 projects identified in the 2021 Interim CSS Plan. Consistent with the requirements of the 2020 CSO Law, these projects will be completed by 2027. The Final Plan projects will further improve CSS performance beyond the post-Interim Plan conditions.

1.2 Final Plan Purpose

The Final Plan documents the identification and evaluation process used to select projects to meet the remaining requirements of the 2020 CSO Law, 2005 Order, and the 2010 James River Bacteria TMDL, in the most cost-effective manner.

Development of the Final Plan included the re-evaluation of the remaining 2005 Order Projects, to select improvements that provide the same or greater bacteria (Escherichia coliform [*E. coli*]) discharge reduction and water quality benefit, to comply with the 2020 CSO Law, 2005 Order, and 2010 Bacteria Total Maximum Daily Load (TMDL) James River requirements. There are three 2005 Order Projects that have not yet been completed:

1. **#13 – Lower Gillies Creek Conveyance Sewer**
2. **#15 – Additional 160-MGD High-Rate Disinfection at the WWTP**
3. **#19 – High-Rate Disinfection at the Shockoe Retention Basin**

Annual Bacteria Discharge Reduction 3,419,000 Billion CFUs

Selected Final Plan projects need to reduce the City's annual average CSS bacteria discharge by 3,419,000 billion CFUs to satisfy the requirements of the 2020 Law and 2005 Order.

Additional bacteria reductions in Gillies Creek and Almond Creek necessary to meet the 2010 Bacteria TMDL will be addressed in the future TMDL Plan. Any opportunity to provide bacteria reductions in these water bodies as part of the Final Plan will offset the actions needed to meet the 2010 Bacteria TMDL requirements, and thus will be an additional benefit for the City.

1.3 Planning Tool Improvements

To support development of the Final Plan, the City needed to improve the planning tools used to evaluate CSS performance under existing and future conditions. These tools include the CSS Hydrologic and Hydraulic (H&H) model and the James River water quality model. Updating these models required collection of monitoring data, calibrating the models to these data, and selection of an appropriate period of analysis for assessing CSO control performance.

1.4 Alternative Identification

Alternatives were identified throughout the City's CSS to reduce overflow events, volumes, and bacteria discharges.

A wide range of alternatives were identified throughout the City's CSS. The alternatives, and subsequently selected projects, utilize combinations of the following methods:

Storage	Tanks or tunnels that capture CSO volume in wet weather events and then drain the stored volume to a treatment facility after the event.
Treatment	Disinfect (remove bacteria) from the CSO before it is discharged to the receiving water body.
Conveyance	Pipelines to transport combined sewage flow to downstream treatment or storage facilities.
Separation	Replace the CSS with separate sanitary and stormwater sewer systems.
Green Infrastructure	Reduce stormwater that enters the combined sewer system by installing facilities that enhance stormwater detention or infiltration.

1.5 Initial Screening

The identified Alternatives were screened to determine feasibility, narrowing the available alternatives for further evaluation at specific CSO locations.

After the initial alternative identification, a screening process was followed to further investigate the feasibility and practicality of each project tailored for a given CSO location. The following screening criteria were defined with input from City staff and community stakeholders. An initial 35 projects were identified and then screened to 20 projects for the next step in the process.

Screening Criteria

- Technical Feasibility/Constructability
- Community Benefits/Impacts
- Regulatory and 3rd Party Impacts
- Operation and Maintenance Impacts

Alternative Identification
35 Projects

Initial Screening
20 Projects

1.6 Alternative Evaluation

Following the initial screening process, 20 alternatives were evaluated to identify the most impactful, cost-effective solutions for the City. Each of the alternatives was assessed using the following criteria: performance, cost, qualitative results, schedule, and cost effectiveness.

Performance

The City's CSS Hydrologic and Hydraulic Model, and the Receiving Water Quality Model were used to evaluate performance improvements

- Bacteria Load Reduction
- Overflow Volume Reduction
- Overflow Event Reduction
- Improvement Towards Compliance with WQS
- Remaining Local Overflow Events

Cost

Conceptual layouts for each project were developed and were used to develop AACE Class 5 cost estimates (Accuracy Range -50 to +100%)

- Construction Cost
- Annual Operation and Maintenance Cost
- Capital Cost
- 30-Year Life Cycle Cost

Qualitative

A custom qualitative evaluation and scoring system was developed to evaluate additional benefits/impacts that are not captured in the cost and performance criteria

- Community
- Environmental
- Operational
- Adaptability

Schedule

Schedules were developed to estimate the required duration for each major phase of the project

- Design
- Permitting
- Easement/Land Acquisition
- Procurement
- Construction

Cost-Effectiveness

Capital cost and performance metrics were utilized to identify the best "bang for the buck" projects

- $ / Bacteria Reduction
- $ / Overflow Volume Reduction
- $ / Overflow Event Reduction

1.7 Final Screening

A final screening process was conducted to identify projects that met the requirements of the 2020 CSO Law and 2005 Order in the most cost-effective manner.

Final Screening Criteria

CSS Bacteria Reduction
- Meet or exceed 2005 Order Requirements
- Provide bacteria reductions in Gillies Creek or Almond Creek

Cost Effectiveness
- High cost-effectiveness ($/Bacteria Reduction)

Public Benefit
- High Qualitative Score

Alternative Evaluation – 20 Projects → **Final Screening** – 4 Projects

1.8 Alternative Selection

Four projects, illustrated in Figure 1-1, were selected to be implemented and included in the Final Plan:

1. **Shockoe #1 – High-Rate Disinfection (HRD) in the Shockoe Retention Basin (SRB)**
2. **Southside #1 – Storage Facility in Canoe Run Park**
3. **Gillies Creek #1- Storage Facility at Outfall 031**
4. **Hilton Street #1 – Separation of the Outfall 012 drainage area**

Once these Final Plan projects are in operation, the annual average untreated CSO volume will be reduced by 75%

Water quality modeling has determined implementation of the selected projects will ensure that the City's remaining CSO discharges do not cause or contribute to an exceedance of water quality standards, at existing monitoring locations (illustrated in Figure 1-1). The benefits of the selected projects are summarized below:

Performance

CSS Bacteria Discharge Reduction (Annual Average)

James River: 4,416,000 Billion CFUs
- ✓ ~30% greater reduction than 2005 Order Projects

Almond Creek: 53,000 Billion CFUs
- ✓ ~100% greater reduction than 2010 Bacteria TMDL Requirement

Gillies Creek: 11,000 Billion CFUs
- ~20% greater reduction than the 2010 Bacteria TMDL Requirement

Cost

Total Estimated Capital Cost: $575 Million

(Escalated to the mid-point of construction and including Green Infrastructure)

Figure 1-1: Selected Final Plan Projects

Table 1-1. Summary of Selected Final Plan Projects

PROJECT		Annual Untreated Overflow Volume Reduction (MG)	Annual Bacteria Discharge Reduction (Billion CFUs)	Capital Cost ($M, mid-point of construction)	$/Bacteria Reduction (Billion CFU)	$/Gal Reduction
Shockoe #1	Convert a portion of the existing SRB to a 1,000 MGD HRD Facility	691	4,017,000	$340	$85	$0.5
Southside #1	New 6 MG Storage Tank to reduce bacteria at CSO 040	83	335,000	$160	$480	$1.9
Gillies Creek #1	New 1 MG Storage Tank to reduce bacteria at CSO 031	4	11,000	$30	$2,700	$7.5
Hilton Street #1	Separation of the CSO 012 drainage area	7	53,000	$35	$660	$5.0
Final Plan Projects (4)		785 MG	4,416,000	$565M[1]	$130	$0.7

Green Infrastructure[1] The City will continue to invest (up to $10 million by 2035) in the implementation of green infrastructure projects throughout the City to reduce runoff volume that enters the CSS.

1: The Final Plan Projects (4) plus Green Instructure implementation totals to $575M

The Gillies Creek #1 and Hilton Street #1 projects are currently under design and will be funded through the City's existing American Recovery Plan funding. However, additional funding is needed to implement the Shockoe #1 and Southside #1 projects, which comprise the majority of the costs ($500M).

1.9 Financial Capability Assessment

A financial capability assessment was conducted to evaluate how the City's ratepayers would be impacted by implementing the Final Plan:

Poverty Prevalence	✓ The City is an Environmental Justice Community. Approximately 25% of the population is living below the poverty level. The City's rates can be characterized as having a high/medium impact on the customer base in accordance with the EPA's lowest quintile poverty indicator (LQPI) metric.
Affordability Challenges	Approximately 70% of the City's previous CSS improvements ($780M in today's dollars) have been funded through rates. Rates are among the highest in the Commonwealth in both raw dollars and % of median household income.
Utility Rate Impacts	In addition to the CSO control projects in the Final Plan, the City must implement significant improvements to its aging water and wastewater treatment facilities and distribution and collection systems as part of routine maintenance and operation. Projected income growth through 2040 is estimated at approximately 4%. Increasing utility rates beyond 4% per year will exacerbate the financial impact to City residents, worsening the City's unaffordability issues. An average annual rate increase of 4.8% will be necessary to implement the Final Plan by 2035, even with the Final Plan being fully funded by grants.

The City will need additional financial grant funding support of approximately $500 million over the next five years to avoid having to request extensions to the July 1, 2035, Final Plan construction completion deadline.

.

SECTION 2

Introduction

This section covers the City's CSS history, path toward regulatory compliance for CSOs, the process that was used for developing this Final Plan, and the purpose of the Final Plan.

2.1 Combined Sewer System History

The original wastewater collection system, constructed in the late 1800's, was comprised of combined sewer pipes that carry both sanitary sewage and runoff from storms to the James River. In the 1940s, the City began construction of an interceptor system along the banks of the James River and its tributaries, to convey the combined sewage to the City of Richmond's Wastewater Treatment Plant (WWTP), which was constructed in the 1950s. Regulator structures were installed at CSO outfalls to allow combined sewage to overflow to the James River when the capacity of the interceptor system was exceeded during rainfall events. Since its original construction, the WWTP has undergone several significant expansions and upgrades over the years.

For the past 50 years, the City has been proactively improving the CSS and the WWTP (predominantly funded by ratepayers) to reduce CSOs, subsequently improving water quality in the James River. Starting with the construction of the Shockoe Retention Basin (SRB) in the 1980s, the City has invested approximately $780 million (adjusted to 2024 dollars) on the CSS improvements as shown in Figure 2-1 below:

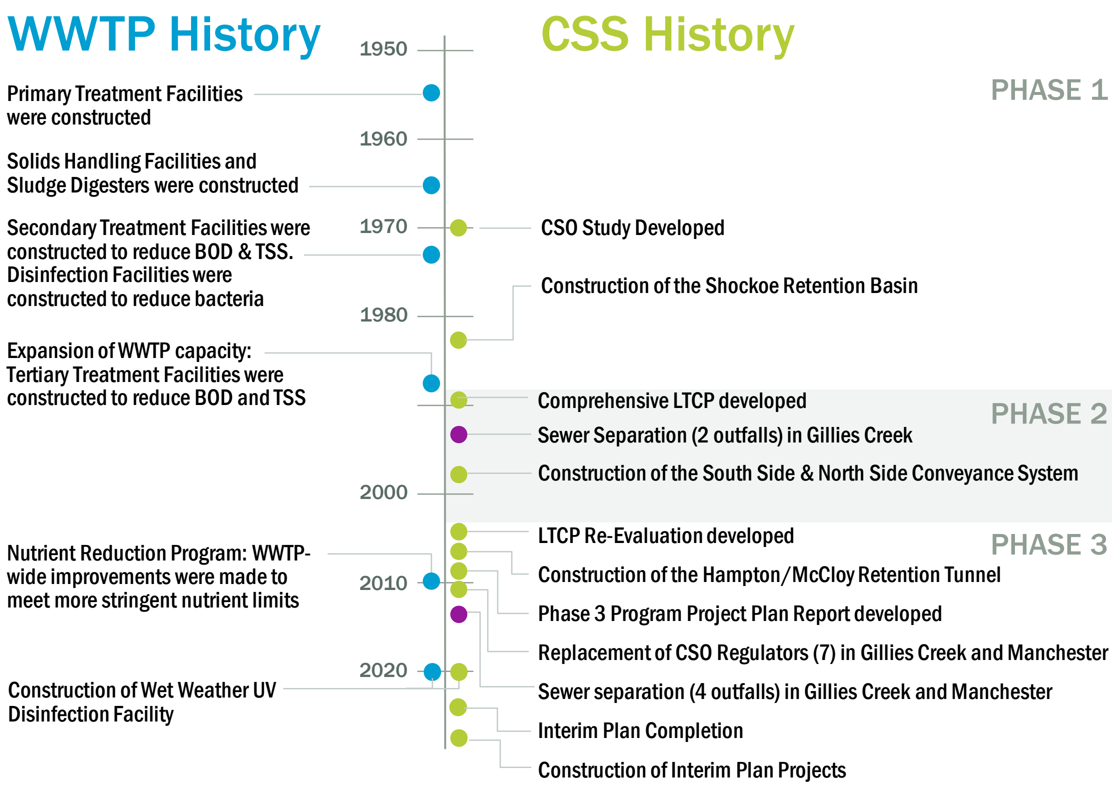


Figure 2-1: History of Richmond WWTP Upgrades and CSS Improvements

2.2 2005 Special Order by Consent

The City worked closely with the DEQ and the State Water Control Board to study and implement improvements to the CSS and WWTP.

In 2005, a Special Order by Consent (2005 Order) was entered between the State Water Control Board (Board) and the City to implement the improvements recommended in the 2002 Long Term Control Plan (LTCP). The 2005 Order identified 19 projects to be completed to reduce the quantity of CSO bacteria discharged to receiving waters.

There are three remaining 2005 Order Projects that have not yet been completed:

1. **#13 – Lower Gillies Creek Conveyance Sewer**
2. **#15 – Additional 160-MGD High-Rate Disinfection at the WWTP**
3. **#19 – High-Rate Disinfection at the Shockoe Retention Basin**

2.3 2010 Bacteria TMDL

The Bacteria TMDL demonstrated that the James River would meet water quality standards with the completion of the 2005 Order Projects and additional upstream improvements.

In 2010, the “Bacterial Total Maximum Daily Load Development for the James River and Tributaries – City of Richmond” (Bacteria TMDL) was developed by the DEQ. The Bacteria TMDL evaluated the 2005 Order Project bacteria reductions and their impact on the receiving water’s ability to comply with state water quality standards. The Bacteria TMDL ultimately quantified specific CSO bacteria reductions required to achieve water quality standard compliance in the following receiving waters (locations illustrated in Figure 2-2):

<table>
<tr><th>Water Body</th><th>Expected CSS Improvements in Bacteria TMDL</th><th>TMDL Required Bacteria Discharge Reductions[1]</th><th>Required for Final Plan?</th></tr>
<tr><td>James River</td><td>2005 Order Project Implementation</td><td>3,419,000 Billion CFUs</td><td>Yes</td></tr>
<tr><td>Gillies Creek</td><td>2005 Order Project Implementation + An Additional 95% bacteria reduction</td><td>46,000 Billion CFUs</td><td rowspan="2">No

(Future TMDL Plan)</td></tr>
<tr><td>Almond Creek</td><td>2005 Order Project Implementation + An Additional 52% bacteria reduction</td><td>27,000 Billion CFUs</td></tr>
</table>

1: Numeric bacteria reductions were quantified utilizing the CSS H&H Model (Section 3.4)

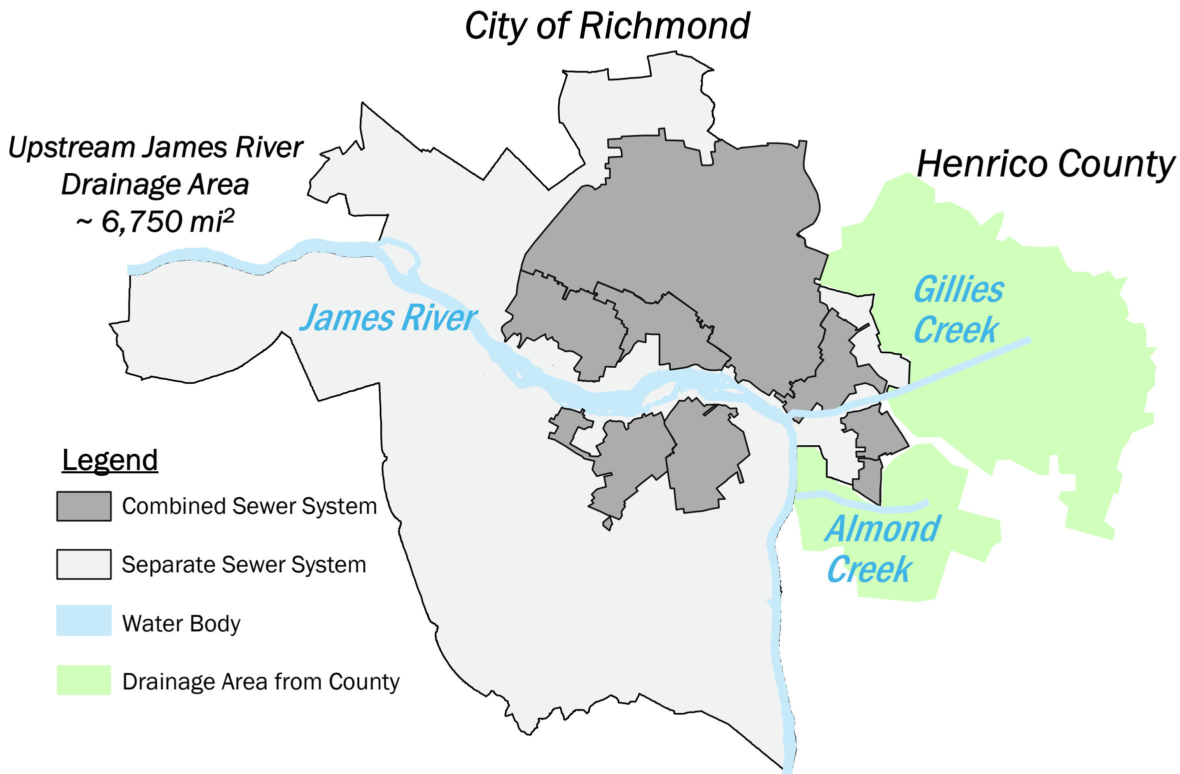


Figure 2-2: Water Bodies with CSS Reductions in 2010 Bacteria TMDL

2.4 Amendment to the 2005 Special Order by Consent

The 2020 CSO Law identifies deadlines to address the 2005 Order requirements.

In 2020, the Virginia General Assembly passed, and the Governor signed into law, the 2020 CSO Law, requiring the owner or operator of any CSS east of Charlottesville that discharges into the James River watershed to submit to the DEQ an Interim Plan and Final Plan to address the requirements of any consent special order issued by the Board. The City of Richmond is subject to this requirement.

The 2020 CSO Law identifies the following dates and tasks for the owner or operator:

	Purpose	Due Date	Initiate Construction and Related Activities	Complete Construction and Related Activities
Interim Plan	Identifies improvements that can be initiated in the short-term	✓ July 1, 2021 (Complete)	✓ July 1, 2022 (Complete)	July 1, 2027
Final Plan	Re-evaluates the remaining 2005 Order Projects and identifies system-wide improvements	July 1, 2024	July 1, 2025	July 1, 2035
TMDL Report	Identifies improvements to meet the requirements of the Bacteria TMDL	July 1, 2030	NA	NA

The 2005 Order was amended in 2020 to align with the 2020 CSO Law. The projects and improvements presented in the Interim and Final Plans establish a prioritized list of projects to complete the City's obligations under the 2005 Order. The identified projects are supported by the community and are the most cost-effective options.

The City is currently implementing the projects identified in the 2021 Interim CSS Plan. Consistent with the requirements of the 2020 CSO Law, these projects will be completed by 2027, and are expected to reduce approximately 180 MG of annual average CSO volume. Updates on the City's progress on the Interim Plan implementation can be found on the City's website (https://rvah2o.org/richmond-css/).

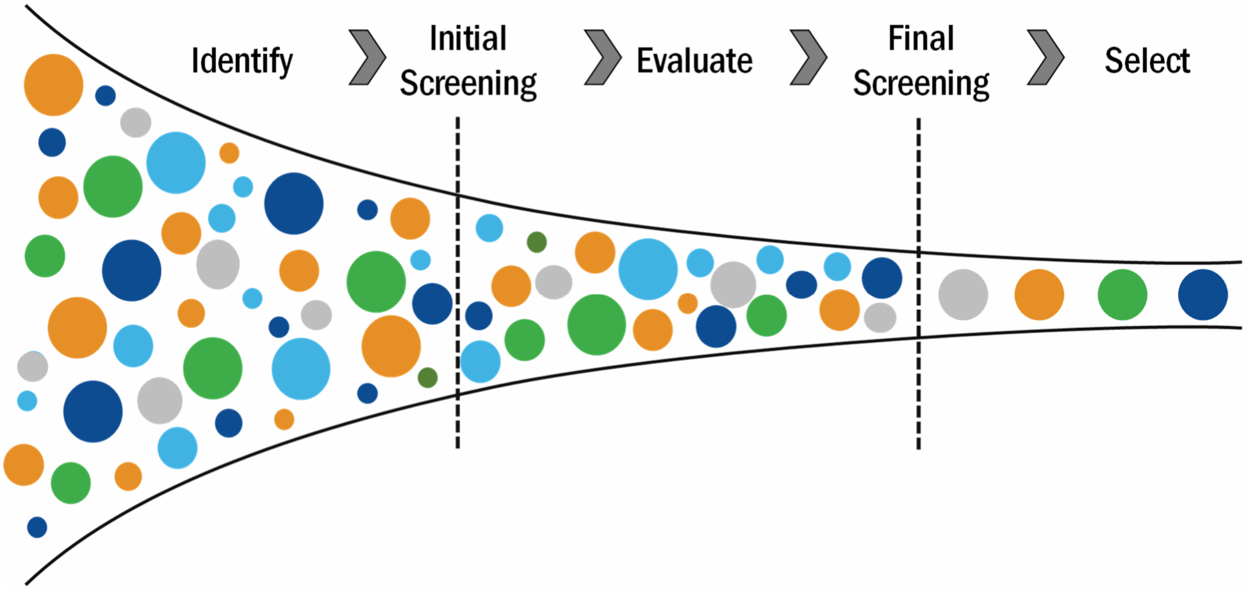
2.5 Final Plan Purpose

The Final Plan identifies the projects necessary to meet the remaining requirements of the 2020 CSO Law and 2005 Order.

Development of the Final Plan included the re-evaluation of the remaining 2005 Order Projects, with the objective of selecting improvements that provide the same or greater bacteria discharge reduction and water quality benefit, in the most cost-effective manner, to meet the requirements of the 2020 CSO Law, 2005 Order, and 2010 Bacteria TMDL (James River).

The James River Bacteria TMDL requires additional bacteria reductions in Gillies and Almond Creeks. Although actions to achieve those reductions will be identified in a future TMDL Plan, any opportunity to provide bacteria reductions in these water bodies in the Final Plan will be an additional benefit for the City.

The Final Plan Alternative Development process:



Each project selected for implementation in the Final Plan includes:

- ✓ **Estimated Schedule**
- ✓ **Projected CSO Volume, Event, and Bacteria Discharge Reductions**
- ✓ **Projected Water Quality Improvements**
- ✓ **Estimated Cost**
- ✓ **Proposed Funding Sources**

SECTION 3

System Characterization

This section describes the City's CSS, its current CSO control performance, the surface waters receiving CSO discharges, and the methodologies and tools that are used for evaluating potential CSO control projects.

3.1 Combined Sewer System Description

The City of Richmond has a central area that is served by the CSS, shown in Figure 3-1. The drainage area served by the CSS is approximately 12,000 acres and represents approximately one-third of the City's total area. There are currently 25 active CSO outfalls, which are grouped into eight (8) CSO districts.

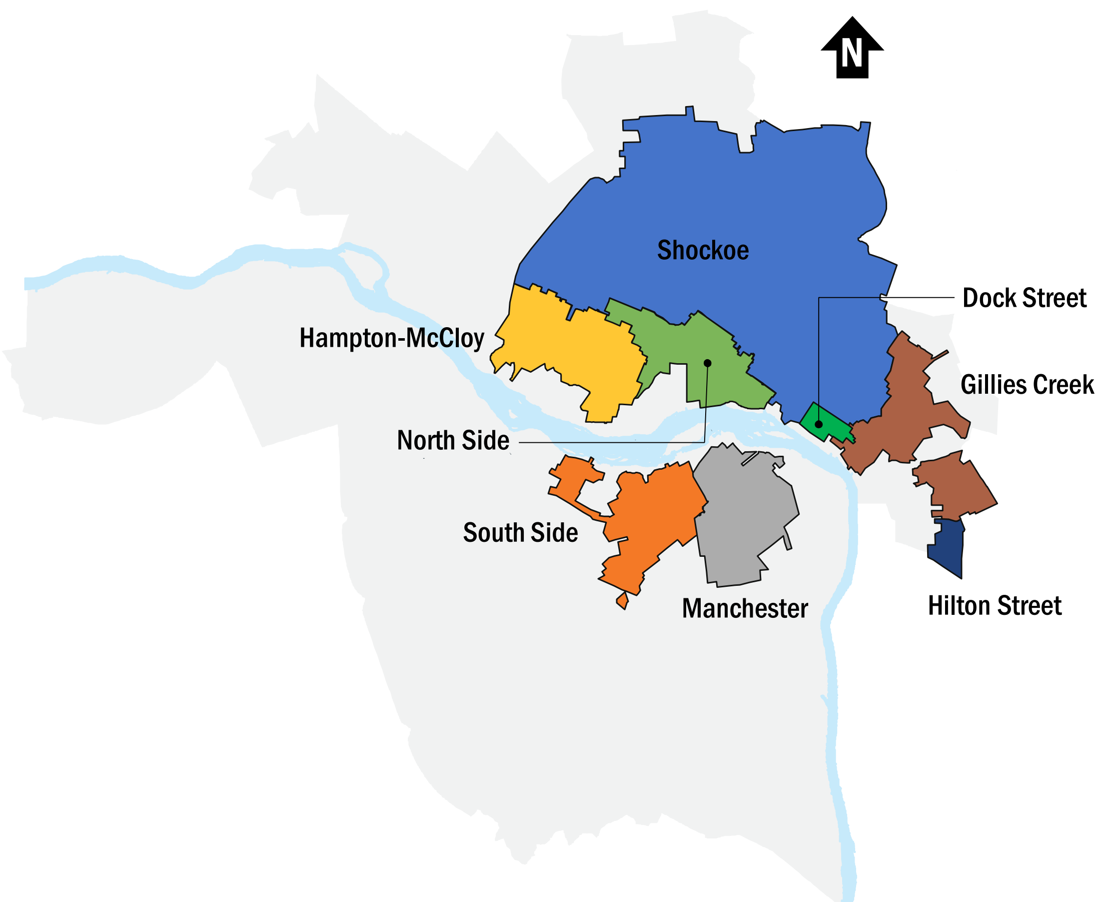


Figure 3-1: Richmond CSO Districts

Significant improvements have been made in each of the CSO districts to expand the conveyance and storage capacity of the system, reduce CSO volumes and events, and improve receiving water quality. Figure 3-2, Figure 3-3, and Table 3-1, on the page that follows, provide an overview of the CSS and identify key outfalls that contribute the largest CSO volume and bacteria loads to the receiving waters.

Below is a schematic of the remaining CSS outfalls and critical infrastructure in the City's CSS:

Figure 3-2: Richmond CSS Schematic

Shockoe and Southside Outfalls (CSO 006 and 040) account for approximately 90% of the bacteria load from the CSOs

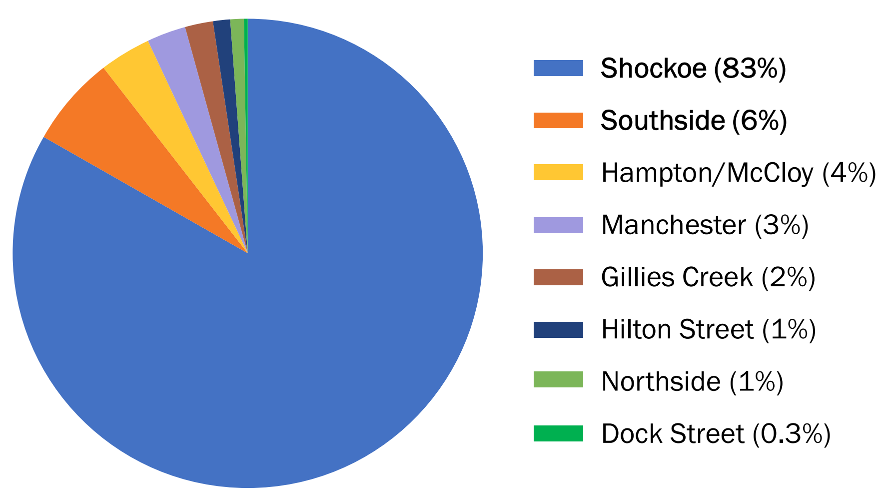


Figure 3-3: Modeled Average Annual CSO Bacteria Load Contributions (2005-2022)

Below is a summary of the modeled average annual overflow statistics for each CSS outfall.

Table 3-1. Modeled Average Annual CSO Statistics (2005-2022)

	PERFORMANCE		
CSO Outfall	Overflow Events	Overflow Volume (MG)	Overflow Bacteria (Billion CFUs)
Hampton/McCloy			
019	4	29.4	240,000
020	3	1.8	15,000
033	<1	0.2	2,000
Southside			
015	1	0.3	1,000
016	0	0	0
017	0	0	0
018	0	0	0
040	39	105.3	450,000
Northside			
007	5	2.2	12,000
009	1	0.6	3,000
010	1	2.4	13,000
011	6	6.5	37,000
Manchester			
014	13	41.0	41,000
021	41	149.7	152,000
Shockoe			
006	25	970.3	6,000,000
Dock Street			
005	5	4.0	12,000
034	1	0.6	4,000
035	4	1.0	3,000
Gillies Creek			
004	1	1.4	4,000
024	17	15.6	48,000
025	6	2.5	8,000
026	16	5.9	18,000
031	14	9.2	28,000
039	15	10.8	33,000
Hilton Street			
012	18	10.5	86,000
TOTALS	41 Systemwide Events	1,342	7,210,000

3.2 Receiving Water Bodies Description

There are three water bodies that receive combined sewage overflow: the James River, Gillies Creek, and Almond Creek.

James River

The James River starts 150 miles west of the City of Richmond and ultimately flows into the Chesapeake Bay.

The James River is a critical feature in the City's recreation, tourism and development economies. The River is used throughout the year for a wide variety of recreation including boating, fishing, and swimming.

Recent bacteria monitoring data has shown a significant reduction in bacteria concentrations, further discussed in Section 4.5.1.

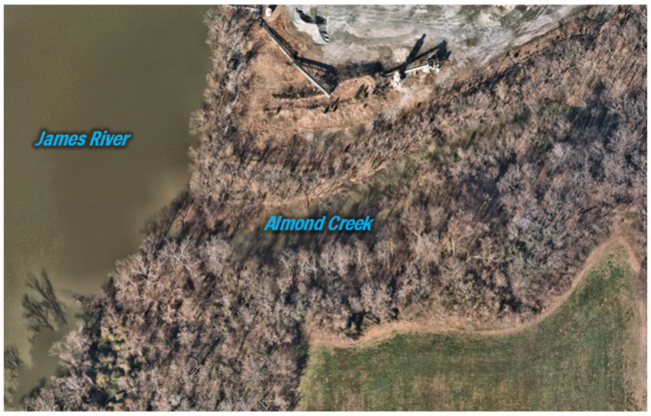
Gillies Creek

Gillies Creek is a concrete-lined stream channel that conveys flow to the James River. Approximately 80% of the Creek's drainage area is from Henrico County.

Public recreation is limited in the Gillies Creek channel because of the safety issues related to dangerous high flow conditions in wet weather.

The City has future plans to improve accessibility to the area surrounding Gillies Creek with parks, greenways, and trails.

Almond Creek



Almond Creek is located within Henrico County and conveys flow to the James River. Approximately 90% of the Creek's drainage area is from Henrico County.

Public recreation is limited in Almond Creek due to limited accessibility (mostly runs along private property) and low flow conditions that do not support boating, swimming, or fishing.

3.3 Hydrologic Evaluation Period

The hydrologic evaluation period is a set of rainfall and receiving water body conditions that are utilized to develop, evaluate, and select alternatives. This period serves as the basis for modeling activities, to demonstrate that the performance of the selected Final Plan projects complies with the City's regulatory obligations.

3.3.1 Background

The EPA's CSO Control Policy (1994), now codified into the Clean Water Act, requires the performance of CSO controls to be evaluated on a "system-wide annual average basis." The identification of average rainfall and river flow conditions is critical in selecting a representative, average hydrologic evaluation period. As illustrated in Table 3-2 below, the City has used a multi-year evaluation period in their previous planning documents, as it provides a more comprehensive assessment than a single "typical year." This approach also allows the assessment to consider a variety of upstream James River conditions that can have a profound influence on CSO discharge impacts on water quality.

Table 3-2. Historical Evaluation Periods

Document	Evaluation Period
Original Long-Term Control Plan	1974-1978
2002 Long-Term Control Plan Update	1974-1978
2017 RVA H2O Clean Water Plan	2011-2013
Interim Plan[1]	2019

1: The City's Interim Plan used 2019 as the evaluation period, in order to utilize the spatial rainfall data that was collected over that timeframe to inform modeling of the real time decision support system (RT-DSS).

For the Final Plan, the City selected to utilize a sequential 3-year period, to be consistent with the 2017 RVAH2O Clean Water Plan, that meets the following criteria:

Rainfall	Represent long-term average conditions, but also provide variability (dry and wet average years) to demonstrate how the proposed Final Projects will perform in various rainfall conditions.
James River	Represent long-term average river flow conditions, to minimize large peaks in upstream influent bacteria loading. Upstream James River flow is the main driver in bacteria concentrations that enter the City (upstream river flow accounts for 60-70% of the bacteria load in the James River).

The following data were collected and evaluated to inform the hydrologic evaluation period selection:

	Time Period	Meter	Data
Rainfall	1949-2021	NOAA Richmond International Airport gauge	Hourly
James River	1940-2021	USGS 02037500 (James River near Richmond)	Daily

An initial evaluation of the rainfall data demonstrated that the total annual rainfall values have increased from the 1940s to the 2020s. Based on this, it was considered appropriate to select the evaluation period from within the most recent 20-year period (2002-2021). The recent rainfall conditions will more closely reflect the expected operating rainfall conditions for the Final Plan projects.

3.3.2 Evaluation Criteria

The rainfall data from 2002-2021 were further evaluated under the following criteria:

1. Annual Rainfall
    - This metric represents the total annual rainfall, measured in inches.
    - Years with greater total annual rainfall typically have a greater number of CSO activations and higher volumes.
2. Annual Storm Events
    - This metric represents the total number of storm events (total rainfall exceeding 0.05-inches separated by at least 12-hours of continuous dry weather) for a given year.
    - Years with a greater number of storm events are more likely to have a greater number of CSO activations and higher volumes.
3. Annual Storm Events Greater than 0.25 inches
    - This metric represents a general rainfall threshold that can result in CSO events. This value is variable across the CSO outfalls, however 0.25-inches is historically representative for the majority of City outfalls.
4. Number of Back-to-Back Events
    - This metric represents the number of back-to-back storm events (24 hours or less between storm events).
    - Back-to-back storm events increase the probability of CSO events, as the first event can consume the available storage, conveyance, and treatment capacity in the CSS, leaving little capacity for the second storm event. The first event can also change hydrologic conditions (e.g., wetting the ground surface, raising the groundwater table) resulting in greater runoff in the second event.
5. Maximum Storm Rainfall (1st and 5th largest per year)
    - This metric represents the total rainfall from the 1st and 5th largest storm throughout the year. These storms can influence the design criteria for the Final Plan projects.
    - A bigger storm will require larger facilities and will increase the cost of a given project.

The James River data from 2002-2021 were further evaluated using the following criteria:

1. **25th Percentile Flow**
   - This metric represents the flow value that 25% of the annual River flowrates are at or below.
2. **Average Flow**
   - This metric represents the average annual River flow value.
3. **75th Percentile Flow**
   - This metric represents the flow value that 75% of the annual River flowrates are at or below.
   - Higher values suggest the River likely experienced sustained periods of high flow or flood conditions, which would increase the upstream bacteria loading to the River at the upstream City limit.

3.3.3 Selected Hydrologic Period

The 2011-2013 period was selected as the hydrologic evaluation period, consistent with the 2017 RVAH2O Clean Water Plan. As illustrated in Table 3-3 below, this period best represents long-term average rainfall and river conditions, while providing rainfall variability to evaluate the Final Plan projects over a variety of conditions.

Table 3-3. Hydrologic Evaluation Period Selection

Evaluation Criteria	2011	2012	2013	2011-2013 Average	2002-2021 Average
Rainfall Data Evaluation					
Annual Classification	Average	Dry	Wet		
Total Annual Rainfall (in.)	44.5	33.3	49.8	42.5	42.8
Total Annual Storm Events (#)	64	63	66	64	61
Storm Events >0.25 in. (#)	44	37	49	43	42
Back-to-Back Storm Events within 24-hours (#)	10	6	13	10	9
1st Largest Storm Rainfall Total (in.)	5.4	2.6	2.8	3.6	4.0
5th Largest Storm Rainfall Total (in.)	1.7	1.6	2.3	1.9	1.8
James River Flow Data Evaluation					
Annual Classification	Average	Low	High		
25th Percentile Flow (cfs)	2,530	1,763	3,080	2,458	2,698
Average Flow (cfs)	3,930	3,040	5,970	4,313	4,981
75th Percentile Flow (cfs)	7,910	7,023	10,500	8,478	9,518

The 2011-2013 period offers the following benefits as an evaluation period:

- This 3-year rainfall and James River flow period is the closest match of any sequential period to the 20-year average values.
- Each year can be classified as Dry, Average, and Wet based on rainfall totals, which provides total annual rainfall variability for the evaluation. Each year can also be classified as Average,

Low, and High based on the James River Flows, which also provides flow variability for the evaluation.

- The largest storm in 2011 had a rainfall total of 5.4-inches (2-year storm), which is much larger than the 20-year average. This will provide a “stress test” for the Final Plan evaluation to understand how the alternatives will perform in a significant storm event.
- The 2011 and 2012 river flows are below the 20-year average. Lower river flows typically carry lower bacteria loads, which means the relative contribution of bacteria from CSO discharges will be more pronounced when considering impacts on water quality during lower flow conditions. The 2013 river flows are above the 20-year average, and provide an alternate river condition that has higher bacteria concentration against which CSO impacts on water quality will be evaluated.

3.4 CSS Hydrologic and Hydraulic Modeling

The updated CSS H&H model, calibrated with system monitoring data, was used as an evaluation tool for the Final Plan.

The City’s CSS H&H Model was originally developed in 1998 and has been updated numerous times to add asset features and reflect system changes. The model can be used to simulate WWTP influent flows and CSO volumes discharged to the James River for representative long-term periods. The model also has the capability to simulate the effect of selected improvements on CSS overflow volume to local surface waters.

3.4.1 Level and Flow Monitoring Data

The City’s metering system enables a better understanding of how the CSS is operating and where potential improvements could be made.

The City expanded its CSS metering system in 2022 to collect additional system data to support the calibration of the CSS H&H model. Emphasis was placed on collecting data in the CSO 006 and 040 outfall drainage areas, as these were identified as priority areas for the Final Plan, because they account for 90% of the CSS bacteria discharged to the James River.

Rain Gauges	13 in total	Three (3) additional gauges were installed to collect rainfall data on the north side of the James River to better calibrate the Shockoe (CSO 006) drainage area
Flow Meters	44 in total	16 additional flow meters were installed in critical sewer interceptors
Level Sensors	55 in total	Four (4) additional level sensors were installed in the Shockoe Bottom area to better calibrate the Shockoe (CSO 006) drainage area

The data collected from May 2022 to May 2023 was utilized to calibrate the City’s CSS H&H model, so that it could better serve as a performance evaluation tool for the Final Plan. Data collected from 33 of the 99 metering locations were used to calibrate and validate the CSS H&H model and are shown in Figure 3-4.

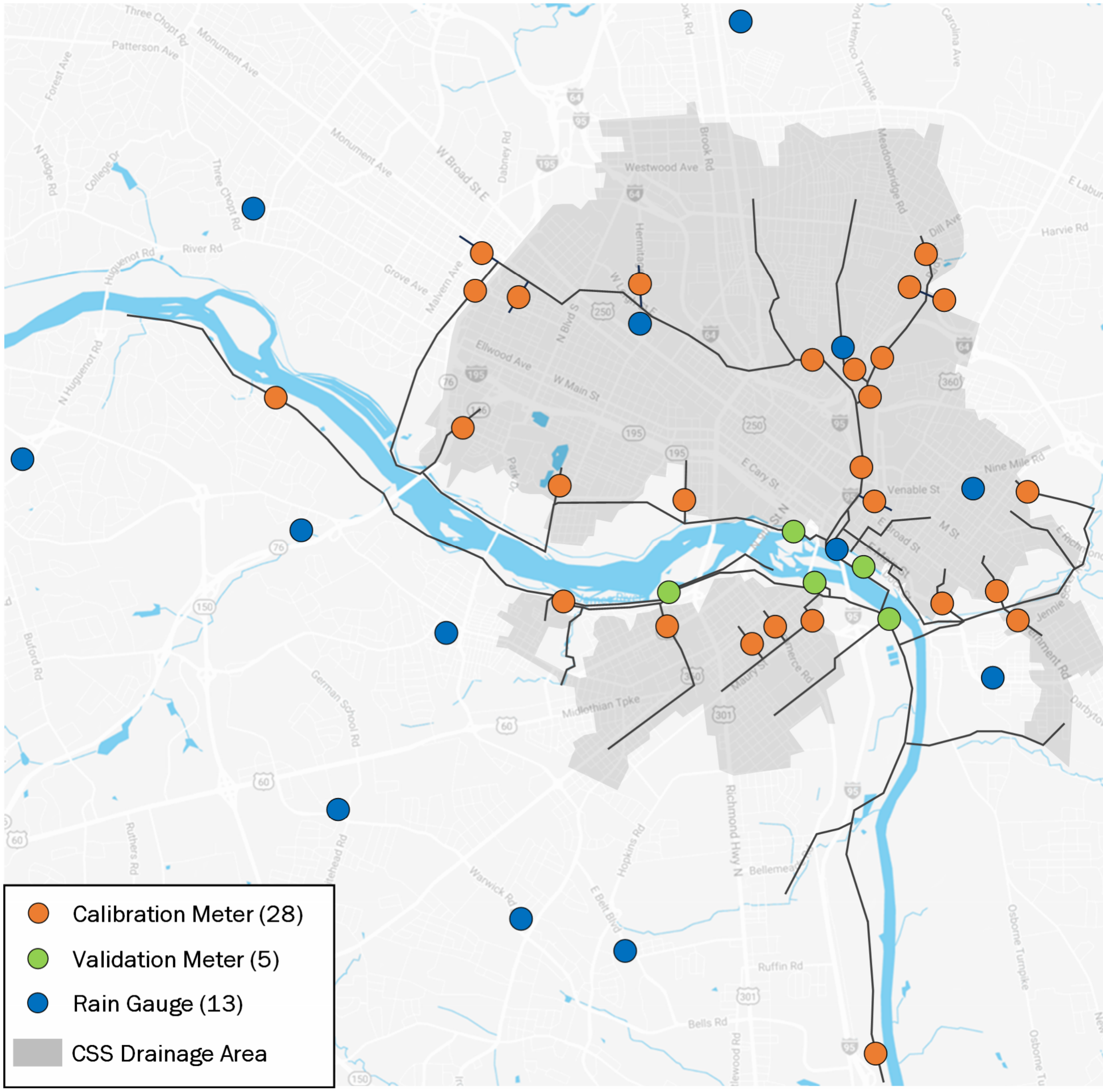


Figure 3-4: Key CSS Metering Locations

3.4.2 Rainfall Monitoring Data

The City experiences highly variable rainfall conditions, with widely varying rainfall totals at different locations. To better characterize geographic rainfall distribution, Ground Adjusted Radar Rainfall (GARR) data were developed for the monitoring period and utilized for the model calibration.

The spatial orientation of the rain gauges provides important information regarding the variability of rainfall during the calibration process. Single point precipitation measurements are typically not representative of the volume of precipitation falling over an entire tributary area during individual calibration events. To account for the spatial distribution of rainfall in the tributary area, GARR data were developed (on a 1 km by 1 km grid) using local rain gauge data and Next Generation Weather Radar (NEXRAD) Level II radar reflectivity data. The GARR data were developed for rainfall events in the May 2022 to May 2023 period to assist in the calibration process.

3.4.3 Model Updates

The model network for the existing CSS H&H model was reviewed to ensure it reflects the existing CSS system configuration. This review was conducted in two steps:

1. Document Review
    - City Atlas Sewer Plans and other Record Drawings were reviewed to corroborate the current model network features.
2. Field Investigation
    - Where warranted, field investigations were performed to confirm additional information that could not be identified from the document review.

The findings from the review, along with the identified updates to the CSS H&H model, are detailed in Appendix B.

3.4.4 Calibration

Calibration is the process of modifying model parameters and comparing model results to field measurements at key points in the collection system, with adjustments occurring iteratively until an acceptable match occurs.

Model calibration was completed for both dry and wet weather flows:

Dry Weather Calibration	Dry-weather diurnal flow patterns and average daily flows were updated for the calibration meter basins and the model was adjusted to match these data.
Wet Weather Calibration	Model parameters were adjusted to match the metered hydrograph shape and magnitude, including the peak flow rate, volume, and peak depth, to varying rain events over the monitoring period. A greater number of quality rain events results in a greater confidence in calibration and the ability of the model to be representative of the wet weather response of the collection system.

The "Chartered Institution of Water and Environmental Management" (CIWEM) wet weather criteria were utilized to qualitatively assess the calibration of each meter.

- Peak Flowrate
    - Modeled Peak Flowrate is +25 to -15% of the Metered Peak Flowrate
- Event Volume
    - Modeled Event Volume is +20 to -10% of the Metered Event Volume

In areas where these criteria were not achieved, the following steps were undertaken:

1. Calibrate to depth data
2. Update model parameters to:

- **Balance the difference between the modeled and metered flow/volume/depth**
- **Give precedence to larger rain events**
- **Be conservative (model overpredicts wet weather flow response in comparison to the observed meter data)**

At the conclusion of the calibration process, the CSS H&H model was confirmed to be acceptable for planning-level evaluations.

In areas where Final Plan projects are being considered, flow and level monitoring and model verification and/or adjustments will continue to be made to improve the calibration. The calibration process conducted and results to date are further detailed in Appendix B.

3.4.5 Baseline Scenario

The Baseline Scenario represents the Baseline Condition, accounting for known projects that are scheduled to be completed before the required completion of the Final Plan Projects (July 1, 2035).

The projects currently in progress, and included in the Baseline Scenario, are:

- **Cleaning of the following Facilities/Pipelines:**
  - **Shockoe Retention Basin**
  - **Hampton/McCloy Retention Tunnel**
  - **Shockoe 96-inch Interceptor / Twin 66-inch Siphons (1-ft of debris was assumed to remain in these sewers for the evaluation)**
- **Construction and operation of all ten Interim Plan Projects (Refer to City's website for the Interim Plan that details the ten projects.)**

The Baseline Scenario will be used as a reference point for comparison against all other modeling results.

The Baseline Scenario results confirmed that the CSO 006 and CSO 040 outfalls together discharge approximately 90% of the remaining CSO bacteria to the James River.

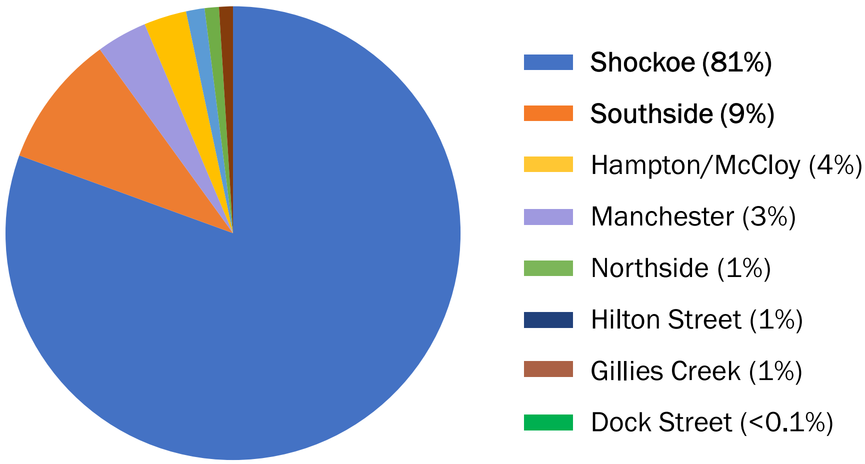


Figure 3-5: Average Annual CSO Bacteria Load Contributions (2011-2013)

3.5 Receiving Water Modeling

Water Quality improvement was the principal model result assessed to quantify the benefits associated with potential CSS Improvements.

The City utilizes a water quality model that was developed to support the 2017 Clean Water Plan and Interim Plan. The purpose of the water quality model is to both quantify bacteria loads and concentrations in the James River and predict future bacteria concentrations for the Final CSS Plan projects.

The modeled bacteria concentrations are compared against the Virginia water quality standards, to assess projected water quality improvements.

Virginia water quality standards (9VAC25-260-170) state that:

"In freshwater, *E.coli* bacteria shall not exceed a geometric mean of 126 counts/100mL and shall not have greater than 10% excursion frequency of a statistical threshold value (STV) of 410 counts/100mL, both in an assessment period of up to 90 days".

To evaluate compliance with WQS, the modeled bacteria concentrations are evaluated over a 90-day rolling average time period.

3.5.1 James River Monitoring Data

Receiving water monitoring data have been collected by the City, in a partnership with the Virginia Commonwealth University (VELAP accredited), and the James River Association (JRA), since 2010.

Samples at five monitoring stations, shown in Figure 3-6, were collected year-round on a weekly or bi-monthly basis. This data set was utilized to calibrate the James River water quality model.

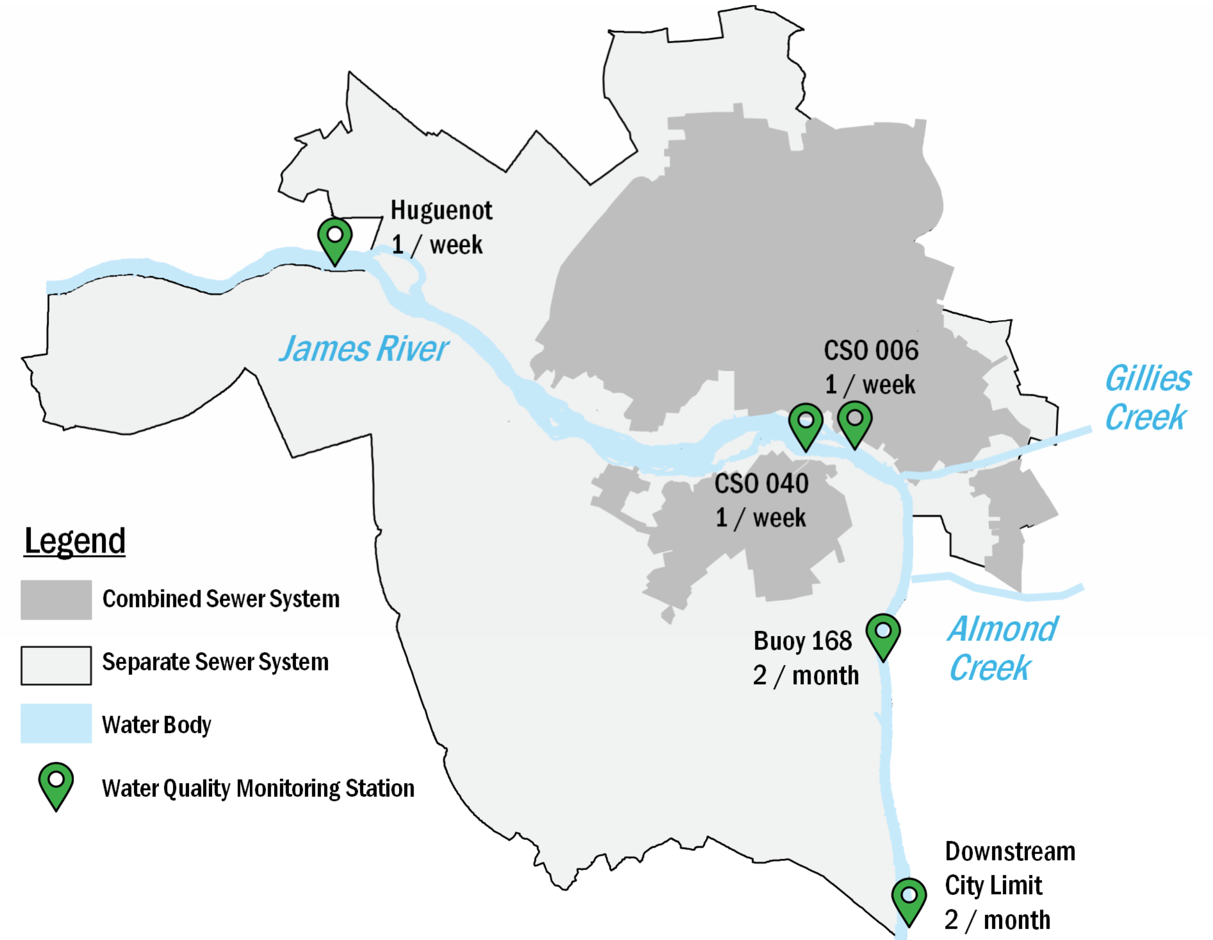


Figure 3-6: Monitoring Stations

Below are the main takeaways from the James River monitoring data review:

- Exceedances of *E. coli* water quality criteria can occur occasionally at each of the five monitoring locations.
- *E.coli* concentrations in the James River at the upstream City boundary (Huguenot Bridge) sometimes cause exceedances of water quality criteria. This indicates that there are bacteria sources that originate outside of the City and are, therefore, outside of the City's control. If these upstream sources of bacteria are not reduced, the James River within the City will experience exceedances of the water quality criteria regardless of what investments the City may make through the CSS Final Plan or TMDL Implementation Plan.
- *E.coli* concentrations in the James River are highest in the downtown area of Richmond where the major CSO discharges occur (CSO Outfalls 006 and 040). The investments that the City will make through the CSS Final Plan will have a significant and direct impact on the *E.coli* concentrations in these areas.
- *E.coli* concentrations are lower in the tidal section of the James River downstream of the CSO district; however, elevated levels persist for longer periods of time due to the tidal action of the River in this area that slows the net downstream movement of water.

3.5.2 CSS Outfall Monitoring Data

CSS Outfall event mean concentrations (EMCs) are the E. coli concentration values that are assigned to each outfall. The resulting EMCs are utilized with model-simulated flow data to calculate the bacterial load that overflows to the James River.

Sampling was conducted at several of the City's key outfalls over six storms: 006, 040, 021 and 039. The data collected from this sampling effort was utilized to update outfall EMCs that were originally developed in the 1990s, and is provided in Appendix C. Table 3-5 provides both the previous EMC values and the updated 2023 EMC values by CSO district.

Table 3-5: Percent of Time James River Samples Exceed WQS

CSO District	Original *E. coli* EMC Value (100 mL)	2023 *E. coli* EMC Value (CFU / 100mL)	Potential Factors in EMC changes[1]	Key Takeaways
Shockoe	111,000	164,000	The City's population has increased by ~40,000 residents since the 1990s. There is a much larger sanitary component in the Shockoe drainage area then there was in the 1990s.	Increase in the EMC value places an even higher focus on the CSO 006 Outfall
Southside	318,000	112,500	New controls were installed in Phase 2 that reduced overflow activations. This requires a larger storm to create an overflow event, which has a more dilute bacteria strength due to a higher contribution from stormwater runoff.	Significant reduction in the EMC value
Manchester	34,000	26,750	Negligible change	Confirmed to be a much lower bacteria concentration (as compared to other CSS Districts) primarily due to land use in the contributing drainage area
Gillies Creek	205,000	81,600	New regulator structures were installed in Phase 3 that reduced overflow activations. This requires a larger storm to create an overflow event, which has a more dilute bacteria strength due to a higher contribution from stormwater runoff.	Significant reduction in the EMC value
Hampton/McCloy	215,000	215,000	No sampling was conducted for these outfalls since they were not a focus in the Final Plan	
Hilton Street	215,000	215,000		
Northside	150,000	150,000		

1: Original EMCs were developed based on fecal coliform concentrations and were later converted to E. coli values using an industry-standard equation.

3.5.3 Model Updates

The water quality model was reviewed and updated to reflect current conditions in the CSS infrastructure and physical characteristics of the Richmond area and James River. The major updates to the model included:

- Utilizing the United States Geological Survey (USGS) software package (LOADEST) to estimate the upstream boundary *E. coli* concentrations.
- Changing James River upstream flow inputs and downstream tidal water levels to represent the 2011-2013 (performance evaluation period) and 2019-2021 (calibration period) flow conditions.
- Updating the Richmond MS4 and CSO flows and *E. coli* source inputs to represent the 2011 to 2013 and 2019 to 2021 flow conditions.

3.5.4 Existing Conditions

In order to confirm that the water quality model reasonably simulates observed *E. coli* bacteria concentrations in the James River, the model was run over the 2019 to 2021 time period and compared to the James River monitoring data. This comparison showed that the water quality model continues to:

- Capture the central tendencies of the monitoring data.
- Capture the variability of bacteria going from upstream to downstream within the City of Richmond limits.
- Capture the variability of bacteria due to seasonal or local weather patterns.
- Provide a slightly more conservative estimate of *E.coli* concentrations in the James River as compared to the monitoring data (i.e.: in this context, more conservative means higher *E.coli* concentrations).

A detailed description of the Existing Conditions Model Scenario and the water quality modeling results are included in Appendix D.

3.5.5 Baseline Scenario

The Baseline Scenario performance assessment was simulated over the Final Plan hydrologic evaluation period (2011 to 2013) and represents the Existing Condition and includes projects that are identified in Section 3.4.4.

The Baseline Scenario will be used as a reference point to compare all other modeling results against.

Upstream sources provide the largest bacteria source to the James River and the CSS provides the 2nd largest bacteria source.

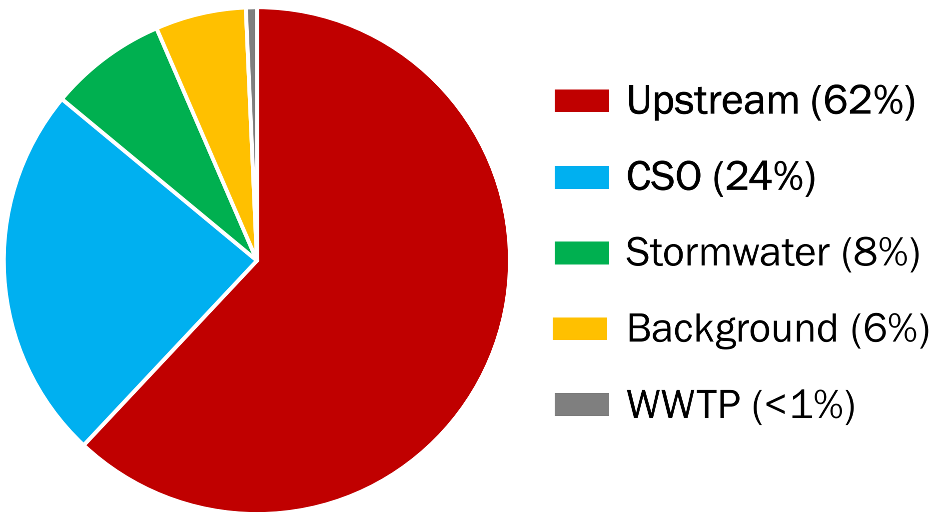


Figure 3-7: Average Annual James River Bacteria Load Contributions (Baseline 2011 to 2013)

The 90-day geomean standard of 126 CFU/100mL is not exceeded at any of the five key locations over the 2011 to 2013 evaluation period.

- The highest geomean concentrations are observed at the CSO Outfall 006 and 040 locations in the James River. These are the two primary areas that the CSS Final Plan targets for improvement.

The 90-day STV exceedance criterion of 10% is exceeded three times (December 2011, September 2012, and July 2013) at two locations: CSO Outfall 040 and Downstream City Limit.

- Implementation of the CSS Final Plan projects, and particularly the reduction of CSO discharges at CSO Outfalls 006 and 040, are intended to reduce these exceedances.

SECTION 4

Alternative Identification

Numerous alternatives were identified throughout the City's CSS that could reduce CSO volume and bacteria discharge. These Alternatives were then screened to identify the most optimum and suitable alternatives for further evaluation and selection.

4.1 CSO Control Methods

A wide range of methods were identified and screened for potential application in each of the City's CSS Districts. The methods are grouped into the following categories:

Storage	Tanks or tunnels that capture CSO volume in wet weather events and then drain the stored volume to a treatment facility after the event.
Treatment	Disinfect (remove bacteria) from the CSO before it is discharged to the receiving water body.
Conveyance	Pipelines to transport combined sewage flow to downstream treatment or storage facilities
Separation	Replace the CSS with separate sanitary and stormwater sewer systems.
Green Infrastructure	Reduce stormwater that enters the combined sewer system

4.1.1 Storage

This control method diverts CSO flow to a storage facility during a wet weather event, instead of overflowing to a receiving water body. After the event, the stored volume is drained back to the CSS for eventual treatment. Storage facilities are commonly tanks or tunnels. Storage tanks can be constructed above ground or underground and can be filled and drained by gravity or by pumping.

Tunnels provide underground storage with the additional benefit of conveying flow along the tunnel alignment. This dual purpose of storage/conveyance can be very cost-effective in some applications as it can address system capacity bottlenecks or eliminate the need for very large tunnel dewatering pumping.

The City operates the Shockoe Retention Basin, which is a 35 MG underground storage tank that fills and drains by gravity.

The City operates the Hampton/McCloy Storage Tunnel that is 5,400-ft long and has a 14-foot diameter (7.2 MG of storage)

	Pros	Cons
Storage	• Storage tanks are effective for individual or remote outfalls • Storage tunnels are effective for multiple outfalls where combined conveyance and storage is beneficial • City has experience in operating and maintaining a large storage tank • Construction can be limited to a single location	• For tanks, adequate space is needed for the footprint, which could require land acquisition • Debris and solids management is critical to maintain storage capacity and minimize odor concerns

4.1.2 Treatment

Wet weather treatment of CSOs involves screening, primary sedimentation, and disinfection to reduce bacteria before it is discharged to a receiving water body. There are multiple disinfection technologies that can be used to treat CSO such as: sodium hypochlorite, UV light, etc. The most common method to disinfect CSOs is by dosing the disinfectant sodium hypochlorite, allowing adequate contact time for the disinfectant to kill the bacteria, and then dosing sodium bisulfite to neutralize any remaining disinfectant before the treated effluent is discharged to the receiving water body.

The City operates a 65-MGD High-Rate Disinfection Facility at the wastewater treatment plant that uses ultraviolet technology to reduce bacteria before it is discharged into the James River.

	Pros	Cons
Treatment	• Requires a relatively small footprint as compared to storage • Very effective in reducing bacteria	• Requires a significant O&M commitment • Treatment located at a remote facility can be challenging to operate

4.1.3 Conveyance

Conveyance sewers are designed with the capacity to transport peak flow rates during a storm event to a downstream facility for treatment or storage. Capacity upgrades to the downstream existing facilities or new facilities are usually required to handle the additional flow transported by the conveyance sewer.

Conveyance sewers can be near surface sewers that are installed through open cut or trenchless methods, or they can be deep underground tunnels that are typically paired with a dewatering pump station.

The City's CSO 003 Pipeline (7.5-foot diameter) on the north side of the River conveys additional flow to the Shockoe Retention Basin.

	Pros	Cons
Conveyance	• Effective for collecting CSOs from outfalls that are in close proximity for consolidation to storage or treatment facilities • Flexibility in construction methods (trenchless, tunneling) can be utilized to be less disruptive to the community	• Typically paired with new or upgraded downstream facilities • Construction can be cost prohibitive and infeasible in some areas of the City

4.1.4 Separation

Sewer separation is the conversion of a combined sewer system to separate sanitary and stormwater sewer systems. The separation removes stormwater runoff from the sanitary sewer system, which reduces the flow volume and limits or prevents overflow events.

Sewer separation is commonly used in smaller drainage areas or remote systems for CSO control. Although disruptive, smaller or remote separation projects can provide an opportunity to re-invest in the utilities, sidewalks and roadways in the area. This method, however, would be infeasible, too disruptive and too costly to be applied on a City-wide scale.

The City has separated eight smaller/remote drainage areas in the past 30 years.

	Pros	Cons
Separation	• Effective for small or remote drainage systems • Can provide upgraded utilities, sidewalks, and roads	• Cost prohibitive on large scales • Construction is very disruptive to the surrounding community • Requires a stormwater discharge location near the separation work to be cost-effective

4.1.5 Green Infrastructure

Green infrastructure (GI) is a method that aims to reduce stormwater volume and peak flow rates that may enter the CSS, through detention and infiltration. GI is typically used to complement other CSO control methods.

GI can provide additional community benefits such as: improved aesthetics, reduced flooding, air quality improvements, reduced heat island effects, and increased recreational opportunities. The implementation of GI is highly dependent on land use, the availability of or opportunities for impervious drainage area, topography, and proximity to a storm sewer, stream or pervious soils, and is not suitable in all areas.

The City has implemented over 50 Green Infrastructure projects over the past ten years to reduce runoff volume and to provide community benefits.

	Pros	Cons
Green Infrastructure	• Effective for smaller drainage areas with low flows • Provides additional community benefits	• Not suited to provide significant overflow volume reduction • Typically more expensive than other control methods on a $ per gallon basis • Requires significant maintenance • Requires a long implementation period for large scale programs

4.2 Initial Alternative Sizing

Each alternative was initially sized utilizing the 2011 to 2013 CSS H&H Baseline model data (overflow volumes and peak flow rates), while verifying that the physical footprint was available for construction. This was an iterative process that was updated during the performance evaluation (Section 6.1) and will need to be further refined in the future preliminary and detailed design phases for each of the selected projects.

Detailed information on the sizing of each alternative is provided in Appendix E.

4.3 Initial Alternative Screening

The City's CSS was evaluated to assess the applicability of various CSO control methods to reduce CSO volume and bacteria discharge. After the initial alternative identification, a screening process was conducted that identified 20 alternatives suitable for further evaluation.

Once the initial alternatives were identified, a screening process was used to further investigate the feasibility and practicality of each alternative. The initial screening process included an evaluation of the following:

1. **Technical Feasibility**
2. **Community Benefits and Impacts**
3. **Regulatory and 3rd Party Impacts**
4. **Operation and Maintenance Impacts**

Through the screening process, several alternatives were modified, combined, or removed from further consideration.

At the conclusion of the screening process, 20 alternatives remained for further evaluation. These alternatives are illustrated in Figure 4-1. Table 4-1 summarizes the key points of the remaining 2005 Order Projects and each of the 20 alternatives. A detailed description of each of the identified projects is available in Appendix E.

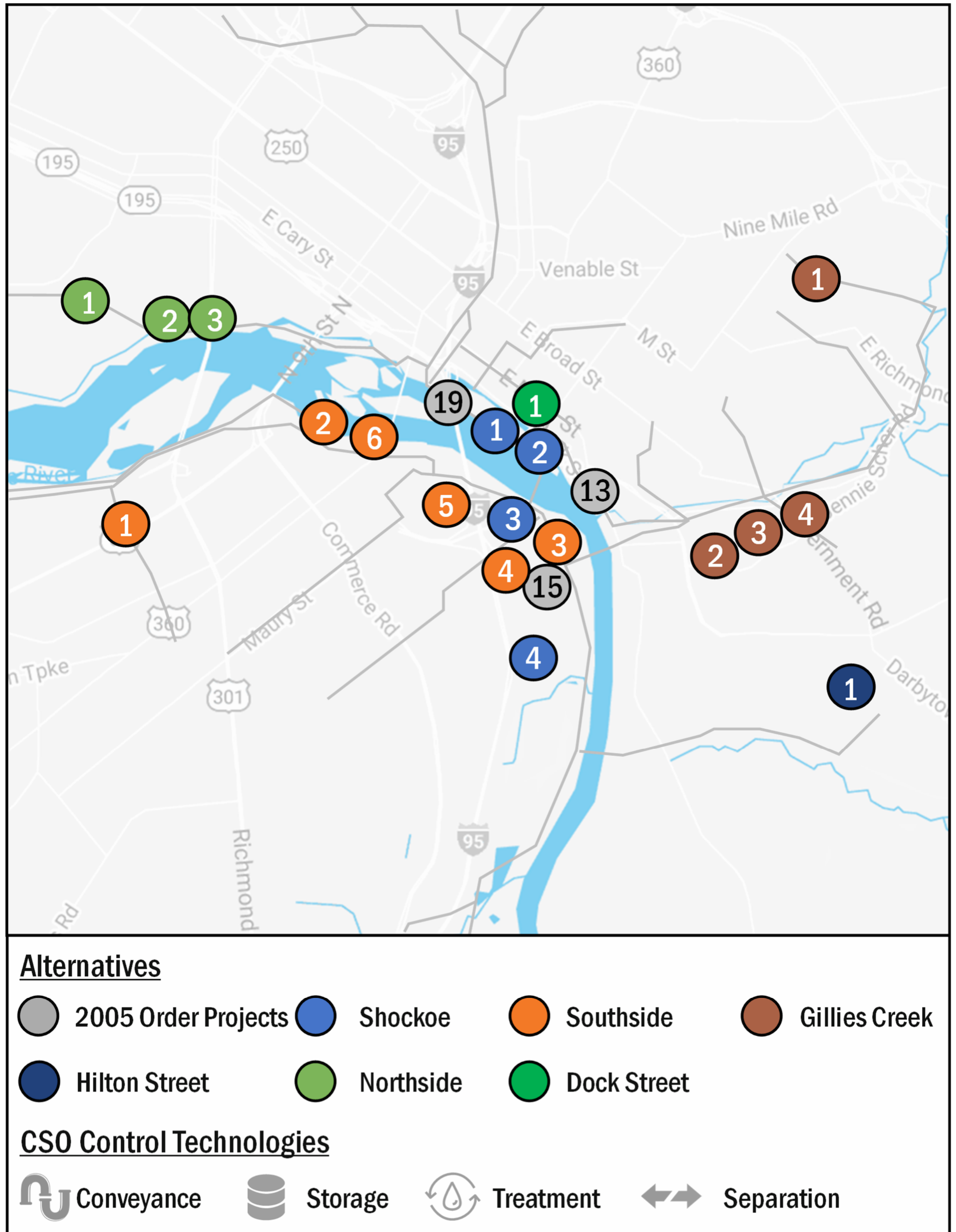


Figure 4-1 Identified Alternatives

Table 4-1. Summary of Identified Alternatives		
ALTERNATIVE		ALTERNATIVE DESCRIPTION
Remaining 2005 Order Projects		
13		Conveyance sewer from Outfalls 004, 005, 034 and 035 to the WWTP (7-ft to 8-ft diameter)
15		High-Rate Disinfection Facility at the WWTP (160-MGD) to increase ability to handle additional wet weather flows
19		High-Rate Disinfection Facility on Chapel Island to control Outfall 006 (3,300-MGD)
Shockoe		
1		Convert a portion of the SRB to a High-Rate Disinfection Facility (1,000 MGD)
2		High-Rate Disinfection Facility on Chapel Island (1,000 MGD)
3		Tunnel from Outfall 006 to the WWTP (16-ft diameter) and a Storage Tank (50-MG) and High-Rate Disinfection Facility (100-MGD) at the WWTP
4		Tunnel from Outfall 006 to the southern end of the WWTP (16-ft diameter) and a High-Rate Disinfection Facility at the WWTP (150-MGD)
5		Tunnel from Outfall 006 to the Vulcan Quarry (approximately a 3-billion-gallon storage facility), with a dewatering pump station to the WWTP
Southside/Manchester		
1		Storage Tank in Canoe Run Park (6 MG)
2		Structure to Utilize In-Line Storage in the CSO 040 Outfall pipe (1.5 MG)
3		Storage Tank at the WWTP to serve Outfall 021 (10 MG)
4		High-Rate Disinfection Facility at the WWTP (100 MGD)
5		Sewer to convey flow from CSO 040 and 014 to the WWTP (8-ft diameter) and a Storage Tank in the flood detention pond (12 MG)
6		Sewer to convey flow from CSO 040 and 014 to the WWTP (8-ft diameter) and a High-Rate Disinfection Facility at the WWTP (150-MGD)
Gillies Creek		
1		Storage Tank at Outfall 031 (1 MG)
2		Conveyance sewer from Outfalls 024, 026 and 039 (6-ft diameter) to a Storage Tank in Gillies Creek Park (2.5 MG)
3		Conveyance sewer from Outfalls 024, 026 and 039 (6-ft diameter) to a tunnel (8-ft diameter) that is paired with either of the Shockoe 3, 4 or 5 Alternatives.
4		Conveyance sewer from Outfalls 004, 024, 025, 026 and 039 (6-ft diameter) to a Storage Tank in Gillies Creek Park (3.5 MG)
Hilton Street		
1		Separation of the combined sewer drainage area
Northside		
1		Conveyance sewer from Outfall 011 to the existing Hampton/McCloy Storage Tunnel (5-ft diameter)
2		Storage Pipe for Outfall 011 (0.5 MG)
3		Storage Tank for Outfall 011 (0.5 MG)
Dock Street		
1		Conveyance sewer from Outfalls 005, 034 and 035 to the SRB (5-ft diameter)

SECTION 5

Alternative Evaluation

Following the initial screening, the 20 identified Alternatives and the three remaining 2005 Order Projects were evaluated using the following criteria to identify the most impactful, viable, and cost-effective solutions.

- **Performance**
- **Cost**
- **Cost Effectiveness**
- **Climate Change Resiliency**
- **Qualitative Benefits/Impacts**

5.1 Performance Evaluation

The 20 identified alternatives and the three remaining 2005 Order Projects were built into the CSS H&H model, and model simulations were run for each individual project over the 2011 to 2013 hydrologic evaluation period. The model results were then compared back to the Baseline Modeling scenario (Section 3.4.5 and Appendix B) to quantify improvements to the following performance metrics:

Annual Average Overflow Volume Reduction (MG)	Some of the projects have system-wide impacts, so the system-wide overflow volume reduction was evaluated
Annual Average Local Overflow Event Reduction (#)	The benefits of some of the projects can be attributed to a specific outfall. For these projects, the number of events reduced and the remaining overflow events after project completion were quantified to determine which projects would result in fewer remaining overflows
Annual Average Remaining Local Overflow Events (#)	
Annual Average Bacteria Load Reduction (Billion cfu/year)	Bacteria loads associated with remaining overflow events were calculated using the *E. Coli* CSO EMCs that were updated after recent data collection (Section 3.5.3)

Table 5-1 summarizes improvements to these performance metrics, as compared to the Baseline Modeling Scenario.

Table 5-1. Alternative Performance Evaluation Summary

ALTERNATIVE[1]	ANNUAL AVERAGE PERFORMANCE			
	Untreated Overflow Volume Reduction (MG)	Overflow Event Reductions (#)	Remaining Local Overflow Events (#)	Bacteria Load Reduction (Billion CFU/year)
Remaining 2005 Order Projects				
13 – Conveyance Sewer	2	10	0	12,000
15 – WWTP HRD	61	15	1	62,000
19 – Shockoe HRD	723	9	2	3,345,000
Shockoe				
1 – HRD in SRB	691	8	3	4,017,000
2 – Shockoe HRD	703	9	2	4,094,000
3 – EQ Storage/HRT	642	8	4	3,703,000
4 – Tunnel/HRT	653	8	4	3,771,000
5 – Quarry Storage	728	9	2	4,293,000
Southside/Manchester				
1 – 040 Storage	83	27	10	335,000
2 – In-line Storage	50	20	16	211,000
3 – WWTP Storage	67	11	6	68,000
4 – WWTP HRD	83	10	7	84,000
5 – Conveyance Sewer and Storage	159	33	6	490,000
6 – Conveyance Sewer and HRD	238	33	6	668,000
Gillies Creek				
1 - 031 Storage	4	13	1	11,000
2 – Central Storage	10	20	1	29,000
3 - Tunnel	10	21	1	30,000
4 – Conveyance Sewer and Storage	15	20	1	48,000
Hilton Street				
1 - Separation	7	29	0	53,000
Northside				
1 – Diversion Sewer	6	2	9	26,000
2 – Storage Pipe	5	9	2	28,000
3 – Storage Tank	5	9	2	28,000
Dock Street				
1 – Conveyance Sewer	1	10	0	9,000

1: Refer to Section 4.3 and Appendix E for a description of each alternative.

A review of the performance evaluation, with comparisons made among projects within each CSO District, is summarized below:

Remaining 2005 Order Projects	The 2005 Order Projects provide the basis for the regulatorily required bacteria load reduction value of 3,419,000 billion CFU. Projects #13 and #15 both provide limited bacteria load reduction, due to the focus of Project #13 being implemented on lower volume outfalls, and the focus of Project #15 being executed on Outfall 021, that has a very low bacteria EMC value. Project #19 provides the highest bacteria load reduction of the 2005 Order Projects; however, it provides less bacteria reduction than other Shockoe alternatives due to a less effective bacteria disinfection rate.
Shockoe	Each alternative meets and exceeds the regulatorily required bacteria load reduction value of 3,419,000 billion CFU. Alternatives #1 and #2 both provide high-rate disinfection on Chapel Island. Alternative #1 converts a portion of the SRB to a HRD Facility, which removes approximately 4.5-MG of storage from this facility. Despite the reduction in storage volume, this alternative performs very similarly to Alternative #2 (which leaves the SRB intact and includes construction of a new HRD facility). Alternative #5 (Quarry Storage) provides the best performance of all the alternatives, due to the large storage volume of approximately 3 billion gallons that allows the stored volume to receive full treatment at the WWTP.
Southside/ Manchester	Alternatives #1 and #2 provide storage to reduce overflow volume/bacteria at CSO 040. Alternative #1 is the better performing of the two, and significantly reduces overflow volume and events at the CSO 040 outfall. Alternatives #3 and #4 are focused on reducing overflow volume/bacteria loading at CSO 021. The CSO 021 outfall has a low bacteria concentration, so while these alternatives reduce considerable CSO volume, they do not remove significant bacteria loading. Alternatives #5 and #6 involve extending the CSO 040 Outfall pipeline to the WWTP and provide the best performance of all the Southside/Manchester alternatives.
Gillies Creek	Alternative #1 performs well to reduce both overflow volume and bacteria loading from CSO 031. Alternative #2 and #3 are both focused on CSO Outfalls 024, 026 and 039. Both of these alternatives significantly reduce overflow volumes and bacteria loading. Alternative #4 addresses all of the CSO Outfalls in Gillies Creek except for CSO Outfall 031. This is the only alternative, in addition to Alternative #1, that will meet the TMDL performance requirements for Gillies Creek.
Hilton Street	This Alternative will eliminate the CSS drainage area for the CSO 012 Outfall and will meet the TMDL performance requirements for Almond Creek.
Northside	Alternative #1 provides the best performance but results in additional overflow volume at CSO Outfall 019, which is located in a sensitive area of the James River.
Dock Street	This Alternative provides limited benefit in reducing bacteria loading to the James River.

5.2 Climate Change Resiliency Evaluation

Climate change projection models indicate that future rainfall events could become larger/more intense and that sea levels could rise. These conditions could be impactful to the performance of the City's CSS in a potential future state:

- **Larger/more intense rainfall events would result in more CSS bacteria discharged to the receiving water bodies.**
- **The James River is tidal to the 14th Street Bridge, which encompasses CSO Outfalls 005, 006 (the City's largest), and 021. An increased River level could impact the ability of the CSS to overflow safely to the River and could lead to upstream flooding.**

In order to understand the impacts of climate change on the City's CSS, a climate change future state was developed utilizing data projections from MARISA and the NASA Interagency Sea Level Rise tools.

The 20 identified alternatives and the three remaining 2005 Order Projects were run in the CSS H&H model under the climate change state. The model results were then compared back to the typical hydrologic evaluation period scenarios (Section 5.1) to quantify the following metrics:

- **Increase in Overflow Volume (MG)**
- **Increase in Overflow Events (#)**
- **Remaining Local Overflow Events (#)**

Table 5-2 summarizes the impacts of the future climate change state on each of the alternatives.

Table 5-2. Future Climate Change Performance Impact Evaluation Summary			
ALTERNATIVE[1]	ANNUAL AVERAGE CLIMATE CHANGE IMPACTS		
	Increase in Untreated Overflow Volume (MG)	Additional Overflow Events (#)	Remaining Local Overflow Events (#)
Remaining 2005 Order Projects			
13 – Conveyance Sewer	0.1	1	1
15 – WWTP HRD	1	0	1
19 – Shockoe HRD	7	0	2
Shockoe			
1 – HRD in SRB	84	0	2
2 – Shockoe HRD	80	0	2
3 – EQ Storage/HRT	126	0	3
4 – Tunnel/HRT	96	0	2
5 – Quarry Storage	29	0	2
Southside/Manchester			
1 – 040 Storage	25	3	13
2 – In-line Storage	23	2	18
3 – WWTP Storage	12	0	6
4 – WWTP HRD	0	0	5
5 – Conveyance Sewer and Storage	52	2	8
6 – Conveyance Sewer and HRD	41	3	9
Gillies Creek			
1 - 031 Storage	2	1	2
2 – Central Storage	3	1	2
3 - Tunnel	0.1	0	1
4 – Conveyance Sewer and Storage	4	1	2
Hilton Street			
1 - Separation	0	0	0
Northside			
1 – Diversion Sewer	4	2	11
2 – Storage Pipe	3	1	3
3 – Storage Tank	3	1	3
Dock Street			
1 – Conveyance Sewer	0.4	1	1

1: Refer to Section 4.3 and Appendix E for a description of each alternative.

A review of the climate change performance impact, with comparisons made among projects within each CSO District, is summarized below:

Remaining 2005 Order Projects	All three of the remaining 2005 Order Projects provide significant resiliency to potential climate change effects, as all are relatively oversized, even for the future climate change state. Project #19 only utilizes a maximum of 70% of its design treatment capacity during the largest rainfall events.
Shockoe	Alternative #5 (Quarry Storage) provides the most resiliency to handle potential climate change effects, since it has an oversized storage volume of approximately 3 billion gallons. All of the Shockoe Alternatives experience few or no additional overflow events. This is due to the increased tidal river elevation that makes it more difficult to overflow out of the system at Outfall 006.
Southside/ Manchester	Alternatives #3 and #4 only focus on the CSO 021 outfall and experience the smallest change in a climate change state. This is due to the increased tidal river elevation that makes it more difficult to overflow out of the system, and this allows the new improvements in these Alternatives to be further utilized. The overflow volume for Alternative #2 increases by approximately 50% in a climate change state. This Alternative is not resilient to climate change effects due to its limited storage volume of 1.5 million gallons.
Gillies Creek	Alternatives #1, #2 and #4 experience more overflow volume in a climate change state. This increase in overflow volume is primarily attributed to two large storms, which are further intensified in the climate change state.
Hilton Street	This Alternative eliminates the CSS drainage area for the CSO 012 Outfall and is not affected by the climate change state.
Northside	All the Alternatives experience more overflow volume in a climate change state. This increase in overflow volume is primarily attributed to two large storms, which are further intensified in the climate change state.
Dock Street	This Alternative experienced very nominal change in the climate change state and is resilient to the potential effects.

5.3 Qualitative Evaluation

Each identified project has additional qualitative, community, environmental, and operational benefits and impacts that are not considered in the performance and cost evaluations.

A scoring system was developed to quantify this evaluation and assign a Qualitative Benefit Score for each project, to better summarize potential project benefits outside of the developed performance and cost metrics.

A survey was conducted among the members of the CSS Public Stakeholder Group and various City departments to assist in the development of the scoring system. The survey included an inquiry requesting that the participants score each of the qualitative evaluation criteria from most important to least important. The survey responses (32 in total) were then used to develop the weights for each of the criteria in the scoring system, which are shown in Table 5-3.

Table 5-3. Qualitative Evaluation Criteria Weighting

Category	Weight	Topic
Constructability	2.3	Estimated Project Schedule Duration (Design, Permitting, Procurement, Construction)
	2.3	Required land acquisition and/or construction easements
	2.0	Improvements to existing assets identified in CIP
	1.8	Conflicts with aboveground and/or subsurface features/utilities
	1.3	Risk of construction means and methods
Operation and Maintenance	2.9	Opportunity to improve sewer system performance
	2.5	Risk of sewer system flooding due to equipment failures
	1.8	New Facility/Equipment maintenance requirements
	1.6	Additional staff required for operations and maintenance
	1.1	Familiarity with new Facilities/Equipment
Adaptability	4.4	Resiliency to potential climate change impacts
	3.4	Ability to support and work in coordination with future CSS Improvements
	3.4	Resiliency to potential river floods
Land Use and Permitting	3.3	Project located in Environmentally sensitive areas
	2.3	Opportunities to coordinate with future development
	2.0	Required Federal/State Permits/Coordination
	0.8	Required VPDES permitting modifications
Community	3.5	Opportunities for Water Quality Improvements in Social Vulnerability Areas
	2.9	Opportunity to provide surrounding community give backs (public space improvements)
	2.3	Tree Removal/Mitigation
	2.1	Impacts to surrounding community during construction

Adaptability was valued most highly compared to other categories, with *Resiliency to potential climate change impacts* receiving the greatest value of all topics. *Opportunities for water quality improvements in socially vulnerable areas* and *Project located in environmentally sensitive areas* were also valued highly compared to other topics. Topics pertaining to *Constructability* and *Operation and Maintenance* were of less value to the group.

The qualitative benefit scores and estimated project implementation durations are summarized in Table 5-4, A detailed breakdown is provided in Appendix E.

A higher score indicates a greater Qualitative Benefit. The highest score that an alternative can achieve in the scoring system is 100. Since the scope and size of these alternatives significantly varies, these scores are best suited to compare alternatives within each CSO District.

Table 5-4. Qualitative Evaluation Summary		
ALTERNATIVE[1]	Qualitative Assessment	
	Benefit Score	Estimated Implementation Duration (Years)
Remaining 2005 Order Projects		
13 – Conveyance Sewer	64	5
15 – WWTP HRD	56	6.5
19 – Shockoe HRD	62	6.5
Shockoe		
1 – HRD in SRB	68	6.5
2 – Shockoe HRD	64	6.5
3 – EQ Storage/HRT	49	8.5
4 – Tunnel/HRT	53	8.5
5 – Quarry Storage	51	9.5
Southside/Manchester		
1 – 040 Storage	74	5.5
2 – In-line Storage	59	4.5
3 – WWTP Storage	63	5.5
4 – WWTP HRD	56	6.5
5 – Conveyance Sewer and Storage	53	7
6 – Conveyance Sewer and HRD	45	7.5
Gillies Creek		
1 – 031 Storage	83	3.5
2 – Central Storage	73	5
3 – Tunnel	65	6.5
4 – Conveyance Sewer and Storage	65	5.5
Hilton Street		
1 – Separation	87	3.5
Northside		
1 – Diversion Sewer	68	2.5
2 – Storage Pipe	72	3.5
3 – Storage Tank	67	4
Dock Street		
1 – Conveyance Sewer	66	3

1: Refer to Section 4.3 and Appendix E for a description of each alternative.

A review of the qualitative scores and project durations, with comparisons made among projects within each CSO District, are summarized below:

Remaining 2005 Order Projects	These projects have relatively low qualitative benefit scores. Project #19 has a lower score than several of the Shockoe Alternatives since it would require significant work and expansion on Chapel Island.
Shockoe	Alternative #1 provides the greatest qualitative benefit of any of the Shockoe Alternatives, since it requires a smaller construction footprint, and it offers the ability to be paired with public space improvements on Chapel Island. Alternatives #3, #4 and #5 are estimated to require more time to complete than Alternatives #1 and #2 due to the necessary complex construction activities (tunneling, deep pump stations and improvements at the Quarry).
Southside/ Manchester	Alternative #1 provides the greatest qualitative benefit of any of the Southside Alternatives, since the project will be within City owned property and it offers the ability to be paired with public space improvements in Canoe Run Park. Alternatives #5 and #6 are estimated to require more time to complete than the other Southside/Manchester alternatives due to the large scale of construction required (new pipeline under the James River and improvements at the WWTP).
Gillies Creek	Alternative #1 provides the greatest qualitative benefit of any of the Gillies Creek Alternatives and also requires the least amount of estimated time to reach completion.
Hilton Street	Alternative #1 provides the greatest qualitative benefit of any of the evaluated Alternatives across all CSO Districts, and also requires the least amount of estimated time to reach completion.
Northside	All of the alternatives provide similar qualitative benefit, but Alternatives #1 and #2 require the least amount of estimated time to reach completion.
Dock Street	Alternative #1 provides a relatively low qualitative benefit in comparison with other evaluated alternatives across all CSO Districts, since the construction will likely be very impactful to the surrounding community.

5.4 Cost Evaluation

Conceptual construction costs, annual operations and maintenance (O&M) costs, and 30-year life cycle costs were developed for each project.

These cost estimates, prepared for each of the alternatives, are considered Class 5 estimates as defined by the Association for the Advancement of Cost Engineering (AACE), and are presented in 2024 dollars. The accuracy range for Class 5 estimates is -50 percent to +100 percent.

In order to develop the estimates, a conceptual layout with initial design criteria was developed for each project. The conceptual layouts and design criteria are further detailed in Appendix E.

The following items were considered while developing the cost estimates for each project:

Construction Cost	Demolition Structural Improvements Civil Improvements Mechanical Improvements Erosion and Sediment Control and other Site Improvements Contingencies • Construction Contingency (it is likely that additional improvements will be identified as the conceptual designs are progressed)
Annual O&M Cost	Labor: Inspections, Cleaning, etc. Maintenance of new Assets Operating Costs Contingency (it is likely that additional O&M requirements will be identified as the projects are progressed)
30-Year Lifecycle Cost	Expected future project costs that may be incurred within the 30-Year Life Cycle period • It was assumed that Electrical and Instrumentation and Control equipment will need to be replaced after 15 years

Table 5-5 summarizes the cost estimates. A detailed breakdown is provided in Appendix E.

Table 5-5. Alternative Cost Estimate Summary					
ALTERNATIVE[1]	AACE CLASS 5 COST ESTIMATES (in 2024 Dolars)				
	Construction ($M)	Capital ($M)[2]	O&M ($M)	15-Year Improvements ($M)	30-Year Life Cycle Cost ($M)
Remaining 2005 Order Projects					
13 – Conveyance Sewer	$60	$90	$0.2	$0.1	$95
15 – WWTP HRD	$145	$215	$2	$10	$300
19 – Shockoe HRD	$335	$500	$2	$6	$570
Shockoe					
1 – HRD in SRB	$150	$225	$2	$4	$285
2 – Shockoe HRD	$230	$345	$2	$4	$410
3 – EQ Storage/HRT	$625	$935	$4	$11	$1,070
4 – Tunnel/HRT	$415	$620	$4.5	$16	$790
5 – Quarry Storage	$770	$1,080	$4	$5.5	$1,210
Southside/Manchester					
1 – 040 Storage	$75	$110	$0.2	$1	$120
2 – In-line Storage	$20	$30	$0.1	$0.1	$30
3 – WWTP Storage	$50	$75	$0.1	$0.5	$80
4 – WWTP HRD	$95	$140	$1.5	$7	$200
5 – Conveyance Sewer and Storage	$205	$310	$0.5	$1	$325
6 – Conveyance Sewer and HRD	$270	$410	$20	$10	$495
Gillies Creek					
1 - 031 Storage	$15	$25	$0.1	$0.2	$30
2 – Central Storage	$60	$90	$0.2	$0.4	$100
3 - Tunnel	$125	$190	$0.5	$0.1	$205
4 – Conveyance Sewer and Storage	$100	$150	$0.5	$0.5	$160
Hilton Street					
1 - Separation	$20	$30	$0.1	$0.02	$35
Northside					
1 – Diversion Sewer	$10	$15	$0.1	$0.1	$20
2 – Storage Pipe	$25	$40	$0.1	$0.1	$45
3 – Storage Tank	$35	$55	$0.1	$0.2	$60
Dock Street					
1 – Conveyance Sewer	$30	$45	$0.1	$0.1	$50

1: Refer to Section 4.3 and Appendix E for a more detailed description of each alternative.

2: The City of Richmond standard multiplier of 1.5 was applied to the construction cost estimates to develop the Capital Cost estimate. This multiplier accounts for the cost of design and construction/administration services.

A review of the cost estimates, with comparisons made among projects within each CSO District, is presented below:

Remaining 2005 Order Projects	Project #13 has a relatively high cost due to the length and depth of the proposed conveyance sewer. Projects #15 and #19 have high costs due to the large size of the proposed treatment facilities.
Shockoe	Alternative #1 has the lowest estimated cost since it does not require any additional conveyance or pumping and utilizes existing tankage for the HRD Facility. Alternative #5 has the highest estimated cost due to the acquisition of the Quarry property and the subsequent improvements required to utilize it as a storage facility.
Southside/ Manchester	Alternative #2 has the lowest estimated cost since it makes use of existing inline storage in the CSO 040 outfall pipe. Alternatives #5 and #6 have higher estimated costs since they include long pipelines in the James River and further improvements at the WWTP.
Gillies Creek	Alternative #1 has the lowest estimated cost; however, it only addresses the remote CSO Outfall 031. Alternative #3 has the highest estimated cost due to the construction of a tunnel to the WWTP. It appears to be more cost effective to control CSO volume in the Gillies Creek District through local storage.
Hilton Street	Alternative #1 is one of the least expensive alternatives evaluated among all CSO Districts.
Northside	Alternative #2 utilizes a storage pipe and is estimated to be less costly than Alternative #3 which utilizes a new storage tank to provide the same volume.
Dock Street	Alternative #1 is relatively expensive in relation to its CSO modest volume reduction, due to the congested project work area.

5.5 Cost Effectiveness Evaluation

The conceptual capital cost estimates (Table 5-5) and estimated project performance improvements (Table 5-1) were utilized to evaluate the cost effectiveness of each project with respect to: Volume Reduction, Overflow Event Reduction, and Bacteria Load Reduction.

The cost effectiveness metrics for each project are summarized below in Table 5-6.

Table 5-6. Alternative Cost-Effectiveness Summary

ALTERNATIVE[1]	COST EFFECTIVENESS		
	$/Bacteria Reduction (Billion CFUs)	$/Volume Reduction (gal)	$M/Event Reduction
Remaining 2005 Order Projects			
13 – Conveyance Sewer	$7,500	$47	$9
15 – WWTP HRD	$3,500	$3.5	$14
19 – Shockoe HRD	$150	$0.7	$54
Shockoe			
1 – HRD in SRB	$55	$0.3	$27
2 – Shockoe HRD	$85	$0.5	$38
3 – EQ Storage/HRT	$250	$1.5	$120
4 – Tunnel/HRT	$165	$1.0	$65
5 – Quarry Storage	$250	$1.5	$115
Southside/Manchester			
1 – 040 Storage	$330	$1.3	$4
2 – In-line Storage	$140	$0.6	$1.5
3 – WWTP Storage	$1,100	$1.1	$7
4 – WWTP HRD	$1,670	$1.7	$15
5 – Conveyance Sewer and Storage	$635	$2.0	$9
6 – Conveyance Sewer and HRD	$615	$1.7	$13
Gillies Creek			
1 - 031 Storage	$2,275	$7	$2
2 – Central Storage	$3,100	$10	$5
3 - Tunnel	$6,300	$19	$9
4 – Conveyance Sewer and Storage	$3,100	$10	$8
Hilton Street			
1 - Separation	$570	$5	$1

Table 5-6. Alternative Cost-Effectiveness Summary

ALTERNATIVE[1]	COST EFFECTIVENESS		
	$/Bacteria Reduction (Billion CFUs)	$/Volume Reduction (gal)	$M/Event Reduction
Northside			
1 – Diversion Sewer	$580	$2.5	$7.5
2 – Storage Pipe	$1,400	$8	$4
3 – Storage Tank	$2,000	$11	$6
Dock Street			
1 – Conveyance Sewer	$5,000	$30	$4

1: Refer to Section 4.3 and Appendix E for a more detailed description of each alternative.

A review of the cost effectiveness metrics, with comparisons made among projects within each CSO District, is presented below:

Remaining 2005 Order Projects	2005 Order Projects #13 and #15 are the least cost-effective alternatives to remove bacteria from the James River among all alternatives in their respective areas of the CSS. While Project #19 is the most cost-effective of the remaining 2005 Order Projects, it is less cost-effective than the other evaluated Chapel Island disinfection facilities (Shockoe Alternatives #1 and #2).
Shockoe	Alternative #1 is the most cost-effective alternative to remove bacteria from the James River among all CSO Districts.
Southside/ Manchester	Alternatives #1 and #2 are the most cost-effective alternatives to remove bacteria from the James River within this CSO District. Alternative #3 is one of the more cost-effective alternatives to remove CSO volume from the River, but is much less cost-effective from a bacteria load reduction standpoint. The bacteria concentrations at the CSO 021 outfall are much lower than at other outfalls in the City due to the land use in the drainage area (predominately open area/industrial and very limited residential contribution).
Gillies Creek	Alternative #1 is the most cost-effective alternative to remove bacteria from Gillies Creek. However, in comparison to alternatives in other CSO Districts it is not very cost-effective. The CSO bacteria load discharged to Gillies Creek is relatively small, making it more expensive to remove in comparison to bacteria load reduction at CSO Outfalls 006 and 040.
Hilton Street	Alternative #1 is a relatively cost-effective alternative to remove bacteria from Almond Creek, when compared to the other Final Plan alternatives. Additionally, this alternative (sewer separation) will eliminate CSO events in this District.
Northside	Alternative #1 is the most cost-effective alternative to remove bacteria in the Northside area.
Dock Street	Alternative #1 is a very cost-infective alternative to remove bacteria from the James River.

5.6 Project Evaluation Summary

The data developed from the performance, cost, qualitative, and cost effectiveness evaluations is summarized for each project below in Table 5-7:

Table 5-7. Alternative Performance Evaluation Summary

ALTERNATIVE	PERFORMANCE (ANNUAL AVERAGE)				CLIMATE CHANGE IMPACTS (ANNUAL AVERAGE)			QUALITATIVE		COST					COST EFFECTIVENESS		
	Untreated Overflow Volume Reduction (MG)	Overflow Event Reductions (#)	Remaining Local Overflow Events (#)	Bacteria Load Reduction (Billion CFU/year)	Increase in Untreated Overflow Volume (MG)	Additional Overflow Events (#)	Remaining Local Overflow Events (#)	Benefit Score	Estimated Alternative Implementation Duration (Years)	Construction ($M)	Capital ($M)	O&M ($M)	15-Year Improvements ($M)	30-Year Life Cycle Cost ($M)	$/Bacteria Reduction (Billion CFUs)	$/Volume Reduction (gal)	$M/Event Reduction
Remaining 2005 Order Projects																	
13 – Conveyance Sewer	2	10	0	12,000	0.1	1	1	64	5	$60	$90	$0.2	$0.1	$95	$7,500	$47	$9
15 – WWTP HRD	61	15	1	62,000	1	0	1	56	6.5	$145	$215	$2	$10	$300	$3,500	$3.5	$14
19 – Shockoe HRD	723	9	2	3,345,000	7	0	2	62	6.5	$335	$500	$2	$6	$570	$150	$0.7	$54
Shockoe																	
1 – HRD in SRB	691	8	3	4,017,000	84	0	2	68	6.5	$150	$225	$2	$4	$285	$55	$0.3	$27
2 – Shockoe HRD	703	9	2	4,094,000	80	0	2	64	6.5	$230	$345	$2	$4	$410	$85	$0.5	$38
3 – EQ Storage/HRT	642	8	4	3,703,000	126	1	3	49	8.5	$625	$935	$4	$11	$1,070	$250	$1.5	$120
4 – Tunnel/HRT	653	8	4	3,771,000	96	0	2	53	8.5	$415	$620	$4.5	$16	$790	$165	$1.0	$65
5 – Quarry Storage	728	9	2	4,293,000	29	0	2	51	9.5	$770	$1,080	$4	$5.5	$1,210	$250	$1.5	$115
Southside/Manchester																	
1 – 040 Storage	83	27	10	335,000	25	3	13	74	5.5	$75	$110	$0.2	$1	$120	$330	$1.3	$4
2 – In-line Storage	50	20	16	211,000	23	2	18	59	4.5	$20	$30	$0.1	$0.1	$30	$140	$0.6	$1.5
3 – WWTP Storage	67	11	6	68,000	12	0	6	63	5.5	$50	$75	$0.1	$0.5	$80	$1,100	$1.1	$7
4 – WWTP HRD	83	10	7	84,000	0	0	5	56	6.5	$95	$140	$1.5	$7	$200	$1,670	$1.7	$15
5 – Conveyance Sewer and Storage	159	33	6	490,000	52	2	8	53	7	$205	$310	$0.5	$1	$325	$635	$2.0	$9
6 – Conveyance Sewer and HRD	238	33	6	668,000	41	3	9	45	7.5	$270	$410	$20	$10	$495	$615	$1.7	$13
Gillies Creek																	
1 - 031 Storage	4	13	1	11,000	2	1	2	83	3.5	$15	$25	$0.1	$0.2	$30	$2,275	$7	$2
2 – Central Storage	10	20	1	29,000	3	1	2	73	5	$60	$90	$0.2	$0.4	$100	$3,100	$10	$5
3 - Tunnel	10	21	1	30,000	0.1	0	1	65	6.5	$125	$190	$0.5	$0.1	$205	$6,300	$19	$9
4 – Conveyance Sewer and Storage	15	20	1	48,000	4	1	2	65	5.5	$100	$150	$0.5	$0.5	$160	$3,100	$10	$8
Hilton Street																	
1 - Separation	7	29	0	53,000	0	0	0	87	3.5	$20	$30	$0.1	$0.02	$35	$570	$5	$1
Northside																	
1 – Diversion Sewer	6	2	9	26,000	4	2	11	68	2.5	$10	$15	$0.1	$0.1	$20	$580	$2.5	$7.5
2 – Storage Pipe	6	9	2	28,000	3	1	3	72	3.5	$25	$40	$0.1	$0.1	$45	$1,400	$8	$4
3 – Storage Tank	6	9	2	28,000	3	1	3	67	4	$35	$55	$0.1	$0.2	$60	$2,000	$11	$6
Dock Street																	
1 – Conveyance Sewer	1	10	0	9,000	0.4	1	1	66	3	$30	$45	$0.1	$0.1	$50	$5,000	$30	$4

1: Refer to Section 4.3 and Appendix E for a more detailed description of each alternative.

SECTION 6

Project Selection

Utilizing the data presented in Section 5, the 20 alternatives were further evaluated through a final screening process.

6.1 Selected Final Plan Projects

Projects that provide regulatory compliance for the 2020 CSO Law and the 2005 Order, in the most cost-effective manner, with community benefits, were selected to be implemented within the Final Plan:

Overflow Bacteria Reduction	✓ Meet or exceed required James River bacteria reductions ✓ Provide bacteria reductions in Gillies Creek or Almond Creek
Cost-Effectiveness	✓ High cost-effectiveness to remove bacteria
Qualitative Benefit	✓ Provide benefits to the community in addition to water quality improvements

A review of the bacteria reduction, cost effectiveness, and qualitative benefits, with comparisons made among projects within each CSO District, is presented below:

Remaining 2005 Order Projects	2005 Order Projects #13 and #15 are some of the least cost-effective alternatives that were evaluated. Both of these projects provide nominal bacteria reduction. Project #19 is not as cost-effective when compared to the Shockoe #1 and #2 alternatives, since the Project #19 HRD Facility is oversized.
Shockoe	Alternative #1 is the most cost-effective alternative to meet the 2005 Order and 2010 Bacteria TMDL regulatory requirements for the James River. It also offers the opportunity to provide the greatest benefit and least impact to the community.
Southside/ Manchester	Alternative #1 is one of the most cost-effective alternatives to reduce bacteria discharged at CSO 040. It is not as cost-effective as Alternative #2, but it does reduce 60% more bacteria since it provides a greater storage volume. Alternative #1 also offers the greatest potential public benefit of all the Southside/Manchester Alternatives. Alternatives #3 to #6 are the least cost-effective in removing bacteria discharged since they address Outfall 021 which has a very low bacteria EMC.

Gillies Creek

Alternative #1 is the most cost-effective alternative to remove bacteria from Gillies Creek.

Alternative #4 is the only alternative that meets the 2010 Bacteria TMDL requirements but would require a very large financial investment. The Gillies Creek area will be further evaluated in the future TMDL Plan.

Hilton Street

Alternative #1 is the only viable alternative that meets the 2010 Bacteria TMDL requirements. This alternative is moderately cost-effective when compared to alternatives in other CSO Districts.

Northside

These alternatives provide minimal performance benefit and are not necessary to meet regulatory requirements.

Dock Street

This alternative is one of the least cost-effective projects among all CSO Districts.

At the conclusion of the final screening process, four projects were selected for implementation. These four projects, along with their expected cost and performance improvements, are presented in Table 6-1.

Table 6-1. Selected Final Plan Projects

PROJECT	Untreated Overflow Volume Reduction (MG)	Bacteria Reduction (Billion CFUs)	Qualitative Benefit Score	Capital Cost Estimate ($M, escalated to mid-point of construction)	$/Bacteria Reduction (Billion CFU)
Shockoe #1 HRD in SRB	691	4,017,000	68	$340	$55
Southside #1 040 Storage	83	335,000	74	$160	$330
Gillies Creek #1 031 Storage	4	11,000	83	$30	$2,275
Hilton Street 1 Separation	7	53,000	87	$35	$570
TOTALS	785 MG	4,416,000		$565M[1]	$125

Green Infrastructure[1]

The City will continue to invest (up to $10 million by 2035) in the implementation of green infrastructure projects throughout the City to reduce runoff volume that enters the CSS.

1: The Final Plan Projects (4) plus Green Instructure implementation totals to $575M

The four selected projects meet and exceed the regulatory requirements for the Final Plan.

Water Body	Required for Final Plan?	Bacteria TMDL Required Bacteria Reductions	Final Plan Bacteria Reductions
James River	Yes	3,419,000 Billion CFUs	4,416,000 Billion CFUs
Gillies Creek	No (TMDL Plan)	46,000 Billion CFUs	11,000 Billion CFUs
Almond Creek		27,000 Billion CFUs	53,000 Billion CFUs

The selected Final Plan projects significantly reduce untreated overflow volume and bacteria from two of largest outfalls in the City's CSS (006 and 040). Once these improvements are complete, the untreated overflow volume and bacteria discharged to the James River will be substantially reduced.

- **Reduce annual average untreated overflow volume by approximately 75% (785 MG)**
- **Reduce annual average CSS overflow bacteria to the James River by approximately 85%**
- **Reduce annual average CSS overflow bacteria to Almond Creek by 100%**

6.1.1 Water Quality Improvements

The water quality model results from these four selected projects show 100% compliance with the bacteria water quality standards at all five of the existing monitoring locations in the James River over the 2011 to 2013 evaluation period. This demonstrates that the implementation of the selected projects will ensure that the City's remaining CSO discharges do not cause or contribute to an exceedance of water quality standards in the James River, at existing monitoring locations.

Details on the improvements demonstrated by water quality modeling are shown in Appendix D.

The Final Plan will reduce the CSOs from the 2nd largest bacteria load to the James River to the 2nd smallest

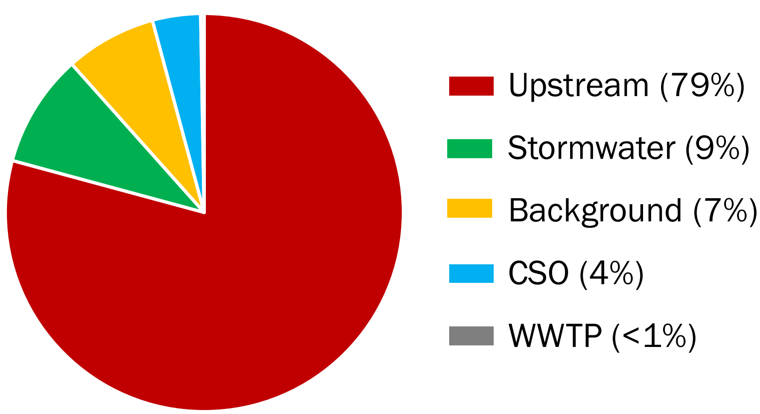


Figure 6-1: Average Annual James River Bacteria Load Contributions (Final Plan Improvements over 2011-2013 period)

6.2 Remaining 2005 Order Project Comparison

The 2020 Amendment to the Special Order by Consent includes a provision that allows proposed projects in the Final Plan to be substituted for projects previously identified in the 2005 Order. The substitution process is subject to DEQ approval and is contingent upon the Final Plan projects achieving the same or better CSO improvement than a project included in the 2005 Order, in a more cost-effective manner.

There are three (3) remaining projects identified in the 2005 Order that have yet to be completed.

A comparison of the performance, cost, and cost-effectiveness metrics for the remaining 2005 Order Projects and the selected Final Plan projects is provided in Table 6-2.

Table 6-2. Remaining 2005 Order Project Evaluation Summary

Projects			PERFORMANCE		COST ESTIMATES	COST EFFECTIVENESS	
			Untreated Overflow Volume Reduction (MG)	Bacteria Load Reduction (Billion CFU/year)	Capital Cost ($M)	$/Bacteria Reduction (Billion CFU)	$/Volume Reduction (gal)
2005 Order Projects	#13	Gillies Creek Conveyance Sewer	2	12,000	$90	$7,500	$47
	#15	160 HRT at WWTP	61	62,000	$215	$3,500	$3.5
	#19	3,300 HRD at SRB	723	3,345,000	$500	$150	$0.7
	Total		786	3,419,000	$805	$235	$1.0
Selected Final Plan Projects	Shockoe #1 HRD in SRB		691	4,017,000	$225	$55	$0.3
	Southside #1 040 Storage		83	335,000	$110	$330	1.3
	Total		774	4,352,000	$335	$77	$0.4

As compared to the remaining 2005 Order Projects #13, #15 and #19, the two selected Final Plan Projects (Shockoe #1 and Southside #1):

- **Provide nearly identical overflow volume reduction at a lower cost**
- **Provide greater bacteria loading reduction at a lower cost**
- **Provide improved compliance with water quality standards in key locations in the James River**
  - **The water quality model demonstrates that implementation of the remaining 2005 Order Projects would result in an exceedance of the STV water quality criteria in two locations over the 2011 to 2013 period.**
  - **In comparison, the selected Final Plan projects are shown to meet WQS throughout the 2011 to 2013 period at all the monitored locations.**
- **Provide more cost effective solutions, based on overflow volume and bacteria loading reduction**

The substitution of the Shockoe #1 and Southside #1 projects for the three 2005 Special Order Projects #13, #15 and #19 was approved by the DEQ in a April 19, 2024 letter to the City. This letter is available in Appendix F.

SECTION 7

Implementation Plan

The Final Plan construction and related activities initiation and completion deadlines are:

Final Plan Construction Initiation	Final Plan Construction Completion
July 1, 2026	July 1, 2035

7.1 Implementation Schedule

An implementation schedule, illustrated in Figure 7-1, has been developed for the Final Plan. The schedule forecasts both project milestones and completion. The schedule considers each project's anticipated timelines, performance improvements, opportunities for project consolidation, and other qualitative benefits.

While the City is committed to completing the projects by July 1, 2035, there may be circumstances that prevent that from occurring. If changes in the schedule occur, the City will notify VADEQ of such changes, as provided in the 2020 CSO Law and amended consent order.

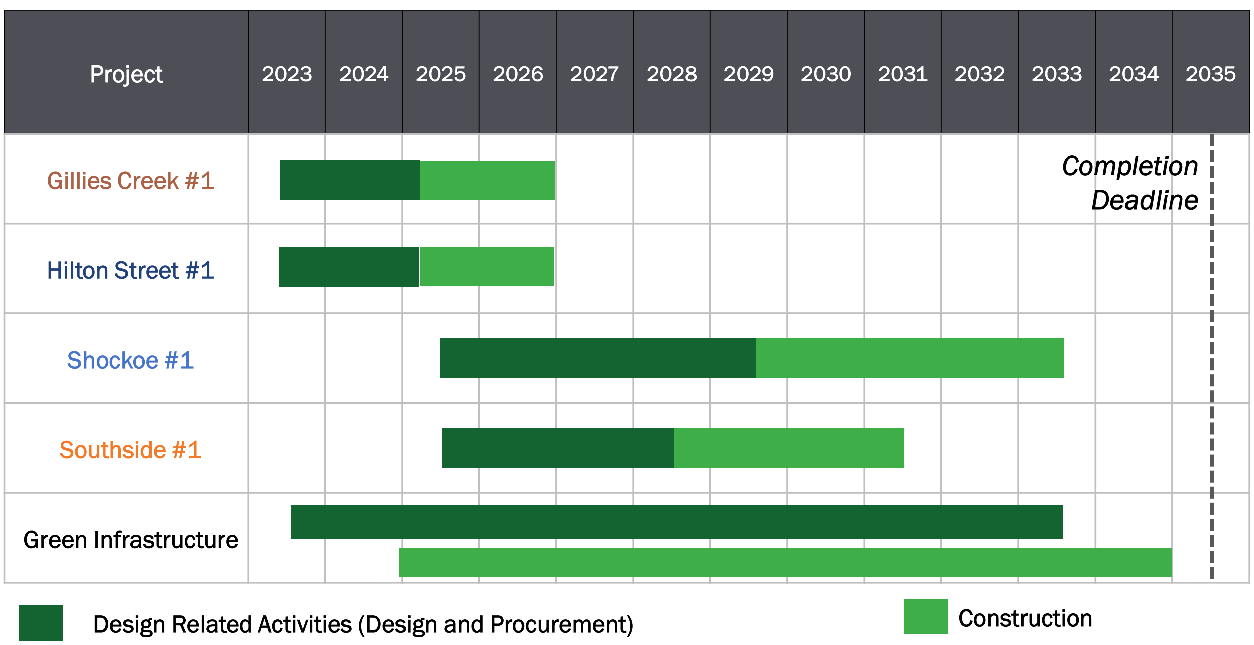


Figure 7-1 Final Plan Implementation Schedule

The design of the Gillies Creek #1 and Hilton Street #1 projects began in 2023 to utilize the City's American Rescue Plan (ARP) funding for these projects.

7.2 Spending Projections

A projected spending plan for the Final Plan, based on the implementation schedule, is presented in Figure 7-2.

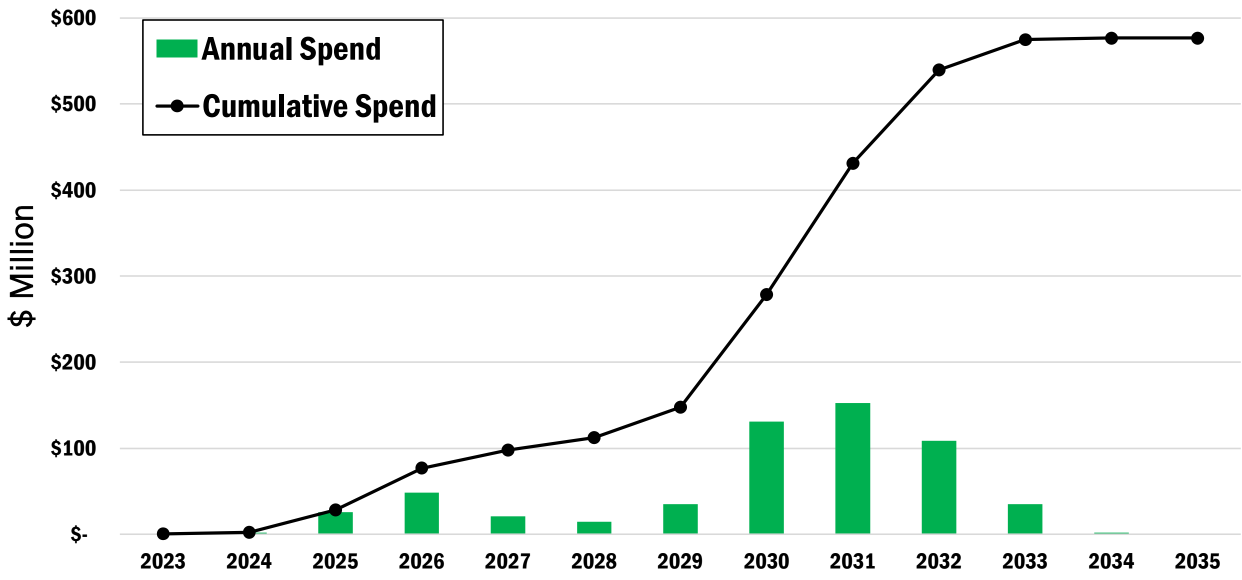


Figure 7-2 Final Plan Projected Spend Plan

As revealed in Figure 7-2, the majority of the spending will likely occur between 2029 and 2032, during the construction of the larger Shockoe #1 and Southside #1 projects.

SECTION 8

Financial Capability

The City of Richmond is an environmental justice community with approximately 25% of the population living below the poverty level. An expensive CSO Program will further burden rate payers unless significant grant funds are made available to the City. This section summarizes both the current rate burden of City residents and the City's financial capability to invest in further improvements to the CSS. Additional details can be found in Appendix G.

8.1 Current Financial State

The City is the fifth most populated metropolitan city in the Commonwealth of Virginia and has experienced 11% growth in population since 2012. The City has approximately 48,000 wastewater customers, that have a lower level of income as compared to State and National averages. Additionally, the City's wastewater utility rates are among the highest in the State, in both raw dollars, as well as when viewed as a percentage of median household income (MHI).

Metric	City of Richmond	Virginia	United States
Population below Poverty Level	22%	11%	13%
Lowest Quintile Income (<20%)	$22,420	$27,500	$30,600
Median Household Income	$59,600	$86,000	$74,500
Monthly Wastewater Rate	$81	$66	NA

An unexpectedly large bill for households near the 20th percentile of income can be financially devastating, as some of these households are on a fixed income such as social security or disability. They are often referred to as the "working poor" as they are typically not eligible for social services assistance and, as such, they are a key population when monitoring affordability concerns.

As an Enterprise Fund, the Department of Public Utilities (DPU) operates on a self-sustaining basis and must increase revenue to cover increased costs. The costs of operating the wastewater system and making capital improvements to maintain the level of service, reduce CSO volume, and reinvest in aging infrastructure have increased significantly over the past decade.

The increases in capital and operating costs, despite accompanying population growth, have required rate increases of 5.2% per year on average since 2012, to support reinvestment into the City's aging systems and to enable the City to remain in a sound financial position.

8.2 Financial Capability Assessment

The 2023 "Clean Water Act Financial Capability Assessment Guidance" (2023 Guidance) provides a method to evaluate financial capability utilizing the following:

1. **Lowest Quintile Poverty Indicator (LQPI) Metric**
2. **Comprehensive financial planning model**

This method provides a granular examination of affordability and is more reflective of actual impacts on customers in comparison to other evaluation methods.

8.2.1 Lowest Quintile Poverty Indicator

The lowest quintile poverty indicator (LQPI) is a metric that combines the results of six indicators and is used to benchmark the severity and prevalence of poverty within the community's service area. This metric is utilized to identify how customers are impacted by their utility rates (low, medium or high).

The 2023 Guidance states: "EPA strongly encourages additional subsidy or grant considerations from governmental funding sources for entities that show a "medium" or "high" impact LQPI score".

- **The City's LQPI is 1.5, which borders between High and Medium Impact.**
- **25% of customers are located within High impact census tracts.**

The LQPI shows that the City has an affordability issue with a significant portion of the ratepayers being highly burdened by the current wastewater rates. Future rate increases must be kept at or below the growth of household incomes to prevent further exacerbating the affordability capacity of the City's ratepayers.

8.2.2 Financial Planning Model

The City maintains a financial planning and rate model that forecasts operating expenses, identifies capital financing mechanisms and annual cashflow requirements, monitors key financial metrics, and identifies the wastewater rates required to support future improvements.

This financial model was utilized to evaluate necessary rate increases to support the implementation of the Final Plan along with the other significant improvements, which include:

- Aging water and wastewater treatment plants
- Aging Collection/Distribution system infrastructure
- Potentially more stringent nutrient removal requirements to meet Chesapeake Bay restoration goals
- Potential PFAS treatment requirements
- Increasing restrictions on wastewater biosolids disposal

The projected Final Plan costs were evaluated over several scenarios that varied based on the amount of provided grant funding along with the remaining balance financed through other sources:

Scenario	Funding ($M)			
	Grants	Virginia Clean Water Revolving Loan Funding	Water Infrastructure Finance and Innovation Act Loans	Utility Revenue Bonds
Low Grant	$100	$200	$200	$125
Medium Grant	$250	$150	$175	$50
High Grant	$400	$100	$75	$50
All Grant	$625	$0	$0	$0

The required rate increases through 2040 to support the City's improvements are shown in Figure 8-1, along with the projected increases to household income for the City's ratepayers.

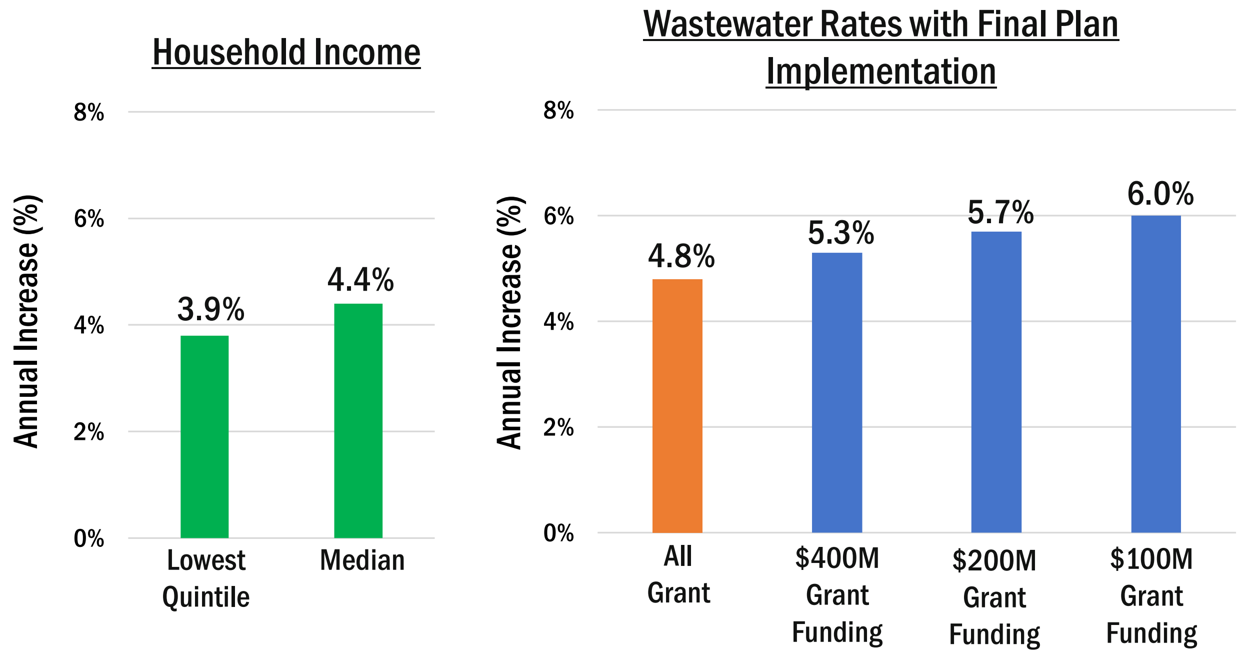


Figure 8-1 Projected % Annual Increase (through 2040)

A 4.8% annual rate increase would more than double the existing monthly wastewater rates by 2040, to approximately $150/month.

The City has significant investments to make in the upcoming years at their treatment facilities and collection/distribution systems, that require rates to increase independent of the Final Plan implementation. Even in the "All Grant Funding" scenario for the Final Plan, the required rate increases will outpace the projected City's income growth of approximately 4%, which will further worsen the City's affordability challenges.

8.3 Proposed Funding Strategies

Final Plan projects Gillies Creek #1 and Hilton Street #1 will be funded through the City's existing available American Recovery Plan funding. However, the remaining two projects (Shockoe #1 and Southside #1) are significant investments, which coupled with the accelerated construction completion deadline, July 1, 2035, will require rate increases that will outpace the projected income growth of the ratepayers.

The City will need financial grant funding support of approximately $500 million over the next five years to avoid having to request extensions to the July 1, 2035, Final Plan construction completion deadline.

The City will be ready to procure construction services for the Final Plan projects in the 2028 to 2029 timeframe. If the City has not secured grant funding guarantees for a substantial portion of the cost of these projects, the City will not be in a financial position to incur the additional debt needed to advance these large projects into construction, and will be forced to seek an extension of the 2035 deadline as provided for under Section D Paragraph 2.a of the December 2, 2020 Amendment to the City's 2005 CSO Special Order by Consent.

SECTION 9

Operational Plan

The Operational Plan describes how each of the selected Final Plan alternatives will be operated over the following conditions:

- Design Condition Operation
- Excess Flow Operation

9.1 Shockoe #1 (HRD in SRB) - Operational Plan

An operational schematic of the Shockoe #1 alternative is shown in Figure 9-1.

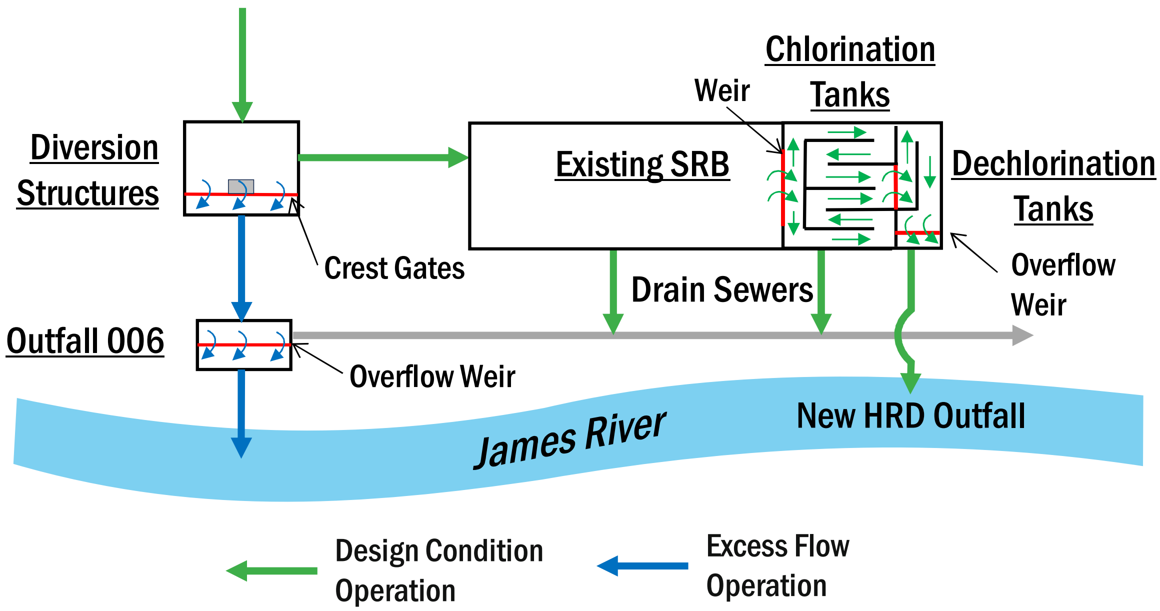


Figure 9-1 Shockoe #1 Operational Schematic

Capacity	Frequency of Operation	Duration of Operation
1,000 MGD	20 times per Year	120 hours per year

Design Condition Operation	• Dry weather flow will pass through the Diversion Structures to the Shockoe 96-Inch Interceptor, where it will be conveyed to the WWTP for treatment.
	• In wet weather events, flow will be diverted from the Diversion Structures to the existing SRB for storage.
	• In larger wet weather events, the capacity in the storage portion of the facility will be utilized and then flow will be diverted over a weir to the new HRD portion of the facility.
	• Once the flow enters the HRD Facility, it will be dosed and mixed with sodium hypochlorite to begin the disinfection process. The flow will pass through chlorination contact tanks for at least 10 minutes, before it overtops a second weir.
	• The flow will then be dosed and mixed with sodium bisulfite to remove residual chlorine. The flow will pass through dichlorination contact tanks for at least 1 minute before it overtops a weir and is discharged into the James River.
	• At the end of the event:
	    • The remaining stored volume in the SRB and HRD Facility will be drained to the WWTP for treatment.
	    • A cleaning cycle will be conducted on the SRB and HRD Facility to remove residual debris and settled solids that could interfere with future operation. This material will either be removed through the existing truck ramp or flushed to the interceptor system.

Excess Flow Operation	• In extreme wet weather events, the influent flow rates can exceed the design flow rate of the HRD Facility. In such conditions, the excess flow will continue through the existing infrastructure to overflow untreated at the existing 006 Outfall. • In extreme wet weather events, the crest gates in the Diversion Structures may be lowered to prevent upstream flooding that could damage private property. In such conditions, flow to the SRB and new HRD Facility will be limited. • A prolonged extreme wet weather event could occur in which the HRD Facility utilizes all of the available disinfectant chemical and is unable to continue to provide disinfection until additional chemical is delivered. The chemical storage facility will be sized in the detailed design phase of the project to mitigate this potential occurrence.

9.2 Southside #1 (040 Storage) - Operational Plan

An operational schematic of the Southside #1 alternative is shown in Figure 9-2.

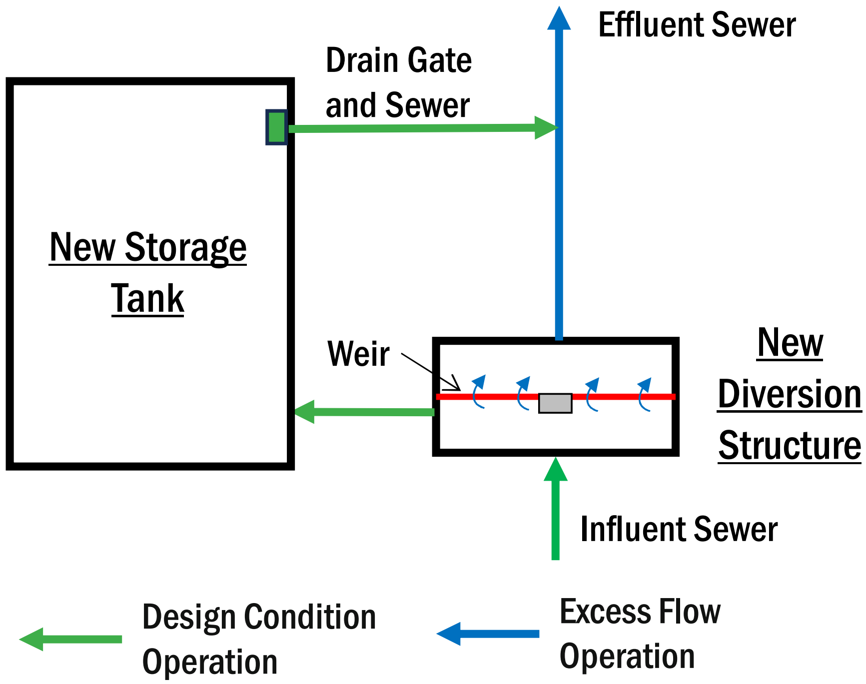


Figure 9-2 Southside #1 Operational Schematic

Capacity	Frequency of Operation	Duration of Operation
6 MG	40 times per Year	720 hours per year

Design Condition Operation

- Dry weather flow will pass through the Diversion Structures to the Southside Interceptor where it will be conveyed to the WWTP for treatment.
- In wet weather events, flow will be diverted from the New Diversion Structure into the New Storage Tank.
- At the end of the event:
  - The stored volume in the Storage Tank will be drained to the sewer system where it will be conveyed to the WWTP for treatment.
  - A cleaning cycle will be conducted in the Storage Tank to remove residual debris and settled solids that could interfere with future operation.

Excess Flow Operation

- In extreme wet weather events, the influent volume can exceed the design volume of the Storage Tank, or the influent flowrate can exceed the design diversion rate. In these events, the excess flow will overtop the weir in the New Diversion Structure and continue through the existing infrastructure to overflow at the existing 015 and/or 040 outfalls.

9.3 Gillies Creek #1 (031 Storage) - Operational Plan

An operational schematic of the Gillies Creek #1 alternative is shown in Figure 9-3.

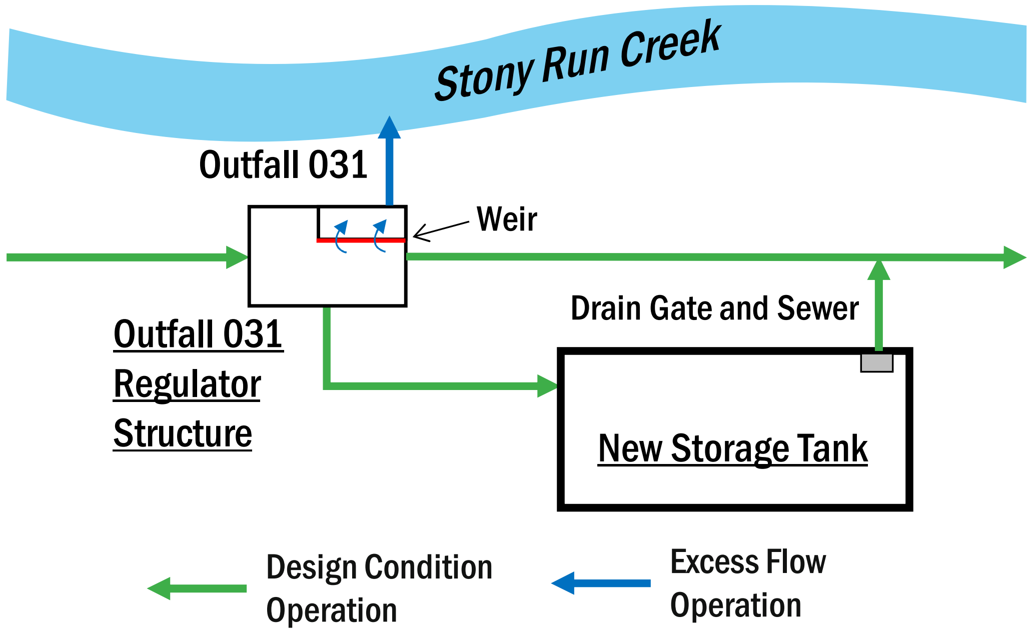


Figure 9-3 Gillies Creek #1 Operational Schematic

Capacity	Frequency of Operation	Duration of Operation
1 MG	32 times per Year	120 hours per year

Design Condition Operation	• Dry weather flows will pass through the Outfall 031 Regulator Structure to the Gillies Creek Interceptor where it will be conveyed to the WWTP for treatment.
	• In wet weather events, flow will be diverted from the Outfall 031 Regulator Structure into the New Storage Tank.
	• At the end of the event:
	  • The stored volume in the Storage Tank will be drained to the sewer system where it will be conveyed to the WWTP for treatment.
	  • A cleaning cycle will be conducted in the Storage Tank to remove residual debris and settled solids that could interfere with future operation.

Excess Flow Operation	• In extreme wet weather events, the influent volume can exceed the design volume of the Storage Tank or the influent flowrate can exceed the design diversion rate. In these events, the excess flow will overtop the weir in the Outfall 031 Regulator Structure and overflow at the 031 outfall.

9.4 Hilton Street #1 Operational Plan

The Hilton Street #1 alternative will separate the combined sewer system into a separate sewer and storm sewer system. No regular operation will be required for this alternative.

SECTION 10

Post Construction Monitoring Plan

The goal of the post construction monitoring plan is to demonstrate (through data and modeling) that the Final Plan projects meet the regulatory requirements of the 2005 Order.

Data will be collected over a 3-year period following full operation of the new facilities. This monitoring data will be utilized to demonstrate that the Final Plan projects are performing as designed and will be supplemented and supported with collection system modeling data as required.

The new monitoring data, along with the data from existing City CSS sensors, will be utilized to recalibrate the City's CSS H&H model. This model will then be used to demonstrate the performance of the Final Plan projects over the selected hydrologic evaluation period (2011 to 2013) for compliance with the 2005 Order performance requirements. An evaluation report will be developed within 5 years of achieving full operation of the new facilities that will document:

1. **Monitoring data/results**
2. **Variances in data from design assumptions**
3. **Compliance with design performance criteria**
4. **If necessary, re-evaluation and/or corrective actions**

The following sections identify the additional monitoring data that will be collected at each of the Final Plan projects to help support this evaluation. The City will continue to collect data from the existing CSS system and will continue to conduct water quality sampling in the James River and tributaries as necessary. During the design of each project, additional sensors may be identified to support facility operation. If such sensors would be beneficial for post-construction monitoring, they will be used as appropriate.

10.1 Shockoe #1 (HRD in SRB) - Post Construction Monitoring

A schematic of the monitoring locations for the Shockoe #1 alternative is shown in Figure 10-1.

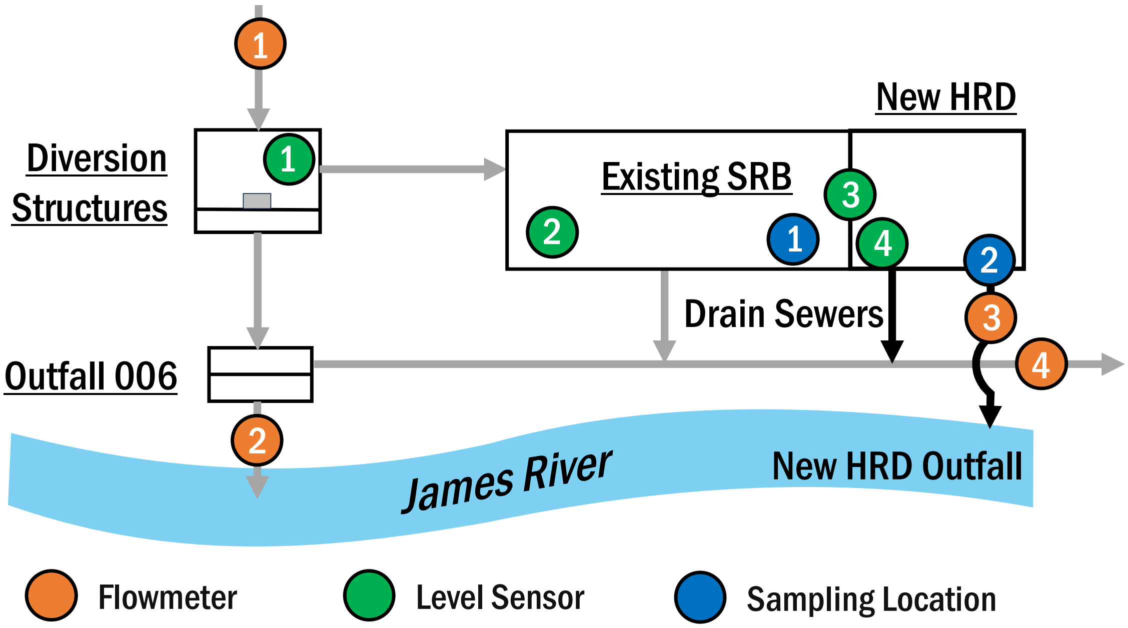


Figure 10-1 Shockoe #1 Monitoring Schematic

Flowmeters	1. Monitor influent flow to be used for model calibration 2. Monitor overflow events and volume 3. Monitor the New HRD treatment flows and volume 4. Monitor level and flow rate in the existing interceptor system
Level Sensors	1. Monitor that flow is being diverted to the New HRD as designed 2. Monitor the level in the SRB 3. Monitor the level in the SRB Facility and inform HRD operations 4. Monitor the level in the HRD Facility to inform drainage operations
Sampling Locations	1. Collect HRD influent grab samples and auto-composite samples to monitor: o Bacteria o Total Suspended Solids 2. Collect HRD effluent and grab samples and auto-composite samples to monitor: o Bacteria o Residual Chlorine o Total Suspended Solids

10.2 Southside #1 (040 Storage) - Post Construction Monitoring

A schematic of the monitoring locations for the Southside #1 alternative is shown in Figure 10-2.

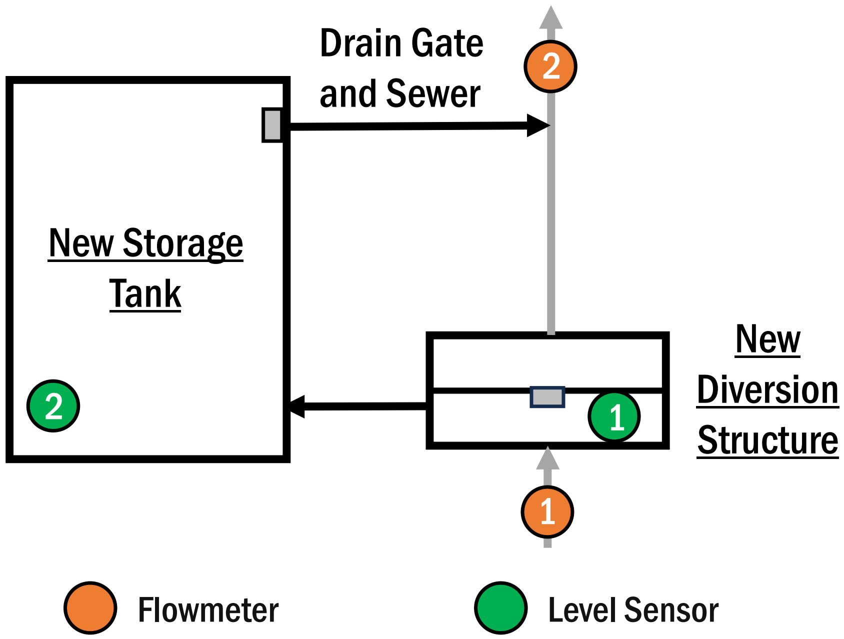


Figure 10-2 Southside #1 Monitoring Schematic

Flowmeters	1. Monitor influent flow to be used for model calibration 2. Monitor flow sent downstream to the Outfall 015 Regulator
Level Sensors	1. Monitor that flow is being diverted to the storage tank as designed 2. Monitor the storage volume of the new storage tank

10.3 Gillies Creek #1 (031 Storage) - Post Construction Monitoring

A schematic of the monitoring locations for the Gillies Creek #1 alternative is shown in Figure 10-3.

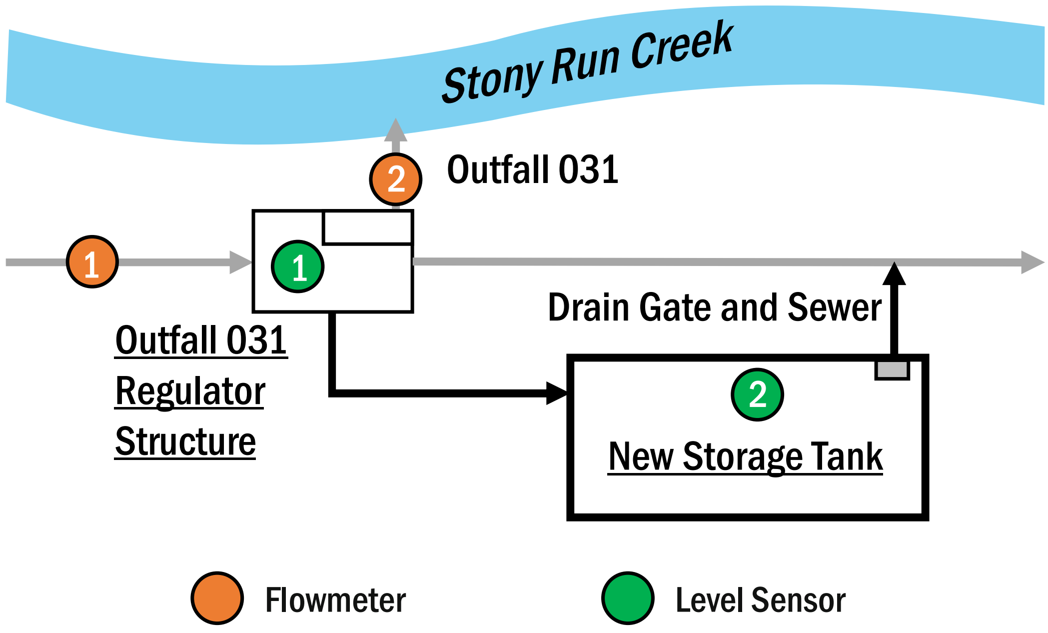


Figure 10-3 Gillies Creek #1 Monitoring Schematic

Flowmeters	1. Monitor influent flow to be used for model calibration 2. Monitor overflow events and volume
Level Sensors	1. Monitor that flow is being diverted to the storage tank as designed 2. Monitor the storage volume of the new storage tank

10.4 Hilton Street #1 (Separation) - Post Construction Monitoring

A schematic of the monitoring locations for the Hilton Street #1 alternative is shown in Figure 10-4.

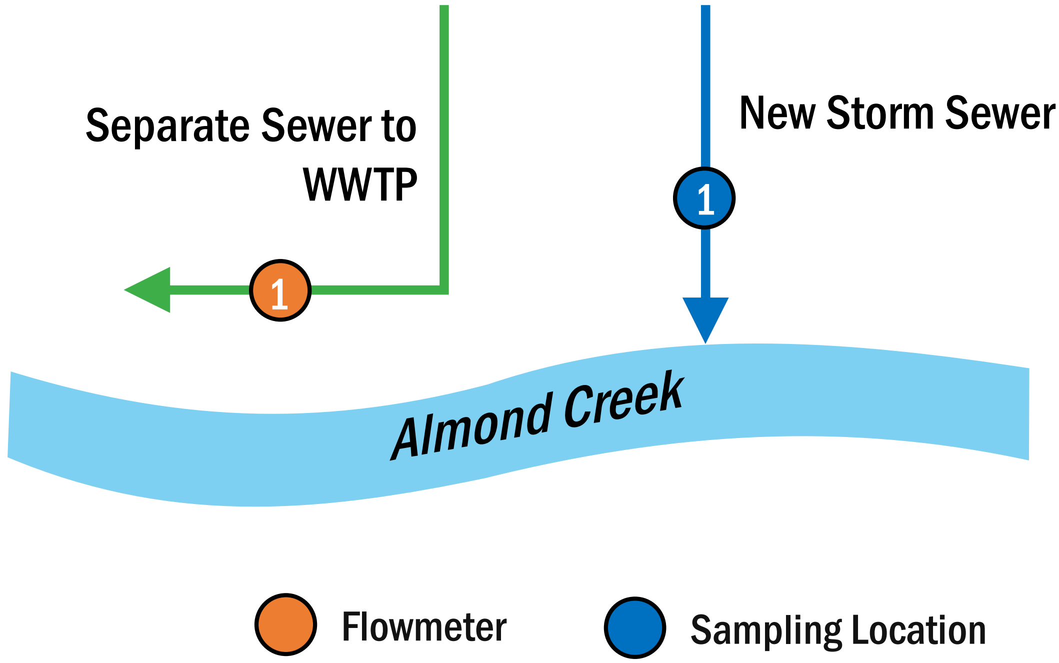


Figure 10-4 Hilton Street #1 Monitoring Schematic

Flowmeters	1. Quantify peak flow in wet weather events
Sampling Locations	1. Collect samples to quantify bacteria concentrations in the storm sewer system, as necessary to verify separation

SECTION 11

Stakeholder Engagement

The City developed a Stakeholder Engagement Plan to educate, inform, and receive input and feedback from stakeholders and the public throughout the development of the Final Plan. This engagement was implemented with several methods:

- CSS Public Stakeholder Group
- City Council
- RVAH2O Technical Stakeholder Group
- VADEQ Update Meetings
- Digital Outreach
- Special Interest Group Meetings

11.1 CSS Public Stakeholder Group

In 2022, the City formed a new Public Stakeholder Group (PSG) to assist in the development of the Final Plan.

This 18-person group includes two members from each of the City's nine Council districts. As ratepayers who deserve the highest-quality service, the residents of the City are critical stakeholders in the development of the Final Plan. The members were selected based on recommendations from City Council members, their liaisons, and neighborhood associations.

DPU Director April N. Bingham welcomes members to the first Final Plan Public Stakeholder Group meeting in May 2022.

The City met with the PSG virtually on a bi-monthly basis to discuss the development of the Final Plan. Throughout these meetings the PSG was utilized to:

1. **Review and monitor the development of the Final Plan**
2. **Provide input on the alternative qualitative scoring system**
3. **Provide input and insight from their communities**
4. **Share progress with their communities**

Twelve PSG meetings were conducted, which culminated in the PSG presenting feedback, summarized below, from their communities regarding the selected Final Plan alternatives:

Support	1. **Supportive of the City's efforts to improve water quality and appreciative of the efforts to do so in a cost-effective manner.** 2. **Supportive of the selected alternatives projects but will want to be involved throughout the development of the Southside #1 project to better understand the potential traffic and park access impacts, as more details are available.** 3. **Supportive of the City's efforts to continue to implement green infrastructure throughout the City.**
Concerns	1. **Concern of how the funding of these projects will impact their rates as there are already widespread affordability issues with the current rates.** • **City Response:** **The City will make every effort to obtain grant funding to support the implementation of Final Plan to reduce the burden on the ratepayers.** 2. **Concern with how the new facilities will perform in the future (additional City residents and climate change effects).** • **City Response:** **Future conditions will be considered during facility sizing. Facilities will be sized accordingly or designed to be adaptable for future expansions.** 3. **Concerned about the potential traffic, odor, and park access impacts from the Southside #1 project.** • **City Response:** **The community will be engaged throughout the development of the project as more details are available.**

The feedback received from the PSG was valuable in the development of the Final Plan and will be applied throughout the design of the projects. All PSG meeting materials and recordings are available on the City's RVAH2O website.

11.2 City Council

Throughout the development of the Final Plan, City staff has presented status updates at the bi-monthly City Government Operations Committee. This meeting includes City Council members and their staff, and is open for public attendance and comment. The City Council has been supportive of DPU's efforts in the development of the Final Plan.

In April 2022, City Resolution No. 2022-R025 was adopted:

"to express the City Council's support for highly prioritizing appropriations for the construction of the combined sewer system plan projects by July 1, 2035, to improve water quality in the James River in a financially stable manner."

11.3 RVAH2O Technical Stakeholder Group

Formed in 2014, the RVAH2O Technical Stakeholder Group consists of dozens of representatives from the community, including environmental groups and other stakeholders.

Five meetings were conducted with the RVAH2O Technical Stakeholder Group throughout the development of the Final Plan.

Meeting #1 (November 2021): Discuss the purpose of the Final Plan, development schedule, and the system characterization efforts.

Meeting #2 (March 2022): Discuss the evaluation criteria of the Final Plan and the formation of the PSG.

Meeting #3 (October 2022): Discuss the alternative identification and screening process and provide an update on the PSG engagement.

Meeting #4 (April 2023): Discuss the screened alternatives for the City's largest outfall (006) and provide an update on the PSG engagement.

Meeting #5 (December 2023): Discuss the regulatory performance requirements, climate change evaluation, and selected alternatives.

Feedback from the Technical Stakeholder Group has been positive. The Technical Stakeholder Group supports the City's selected alternatives included in this Final Plan. The Group views the selected alternatives as cost-effective solutions to reduce overflow volume and bacteria to the James River.

11.4 DEQ Coordination

17 Meetings have been conducted with DEQ to discuss the development of the Final Plan.

Throughout the development of the Final Plan, the City met with DEQ, typically bi-monthly, to include the agency in decision-making and allow for full involvement and inclusion in the process. These ongoing bimonthly meetings allowed DEQ to track the progress and the process of the Final Plan's development and provide the City with the opportunity to obtain important feedback from the agency, such as the Final Plan's purpose, modeling criteria, and solutions.

11.5 Additional Outreach

The City continues engaging the public and stakeholders through their website, social media, and meetings with special interest groups.

Digital	The City has worked diligently to continually enhance its digital presence. Background information on the CSS, resources, reports, and presentations are all maintained on the RVAH2O.org website.
Social Media	The award-winning RVAH2O social media accounts – Twitter (X), Instagram, and Facebook – serve as additional avenues for two-way communication between City residents and DPU. These active accounts provide updates on ongoing efforts, operations and maintenance activities, and the Interim and Final Plans alongside basic, general CSS education. DPU has found that sharing online through these platforms keeps followers engaged and the audience growing, speaking to the efficacy of consistent, transparent, and clear information.
Special Interest Group Meetings	The City prioritizes communication with special interest groups. Meetings have been held with the followings organizations to discuss the Final Plan: 1. James River Association 2. Chesapeake Bay Foundation 3. Chesapeake Bay Commission

Appendix A: Amendment to the 2005 Special Order by Consent

Appendix B: CSS H&H Model Documentation

Appendix C: CSS Outfall Monitoring Data

Appendix D: Water Quality Model Documentation

Appendix E: Final Plan Project Details

Appendix F: DEQ Substitution Approval Letter

Appendix G: Financial Capability Assessment