NBC CSO Control Facilities Phase III Reevaluation

Executive Summary

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ES.1 Plan Overview, Financial Impact and Affordability Analysis

In 1992, Narragansett Bay Commission (NBC) first entered a Consent Agreement (CA) with the Rhode Island Department of Environmental Management (RIDEM) that established a schedule for Combined Sewer Overflow (CSO) control facility planning, design and construction. In 1998 RIDEM approved the Conceptual Design Report Amendment (CDRA) as NBC's long-term CSO control plan in accordance with the requirements of the CA. The CDRA established a three-phase program with the goal of reducing annual CSO volumes by 98 percent, and achieving an 80 percent reduction in shellfish bed closures.

The first two phases focused on the Field's Point Service Area and outfalls in Providence. The main component of Phase I was a deep rock storage tunnel in Providence that was designed to store CSO volumes during wet weather events for subsequent pump out and treatment at the Field's Point Wastewater Treatment Facility (FPWWTF). Phase I was completed in 2008 at a cost of $360M. Phase II consisted of interceptors to connect additional outfalls to the Providence Tunnel plus several sewer separation projects. The final portions of Phase II will be complete in 2015 at a cost of $197M. The third and final phase in the CDRA was also a deep rock tunnel for the Bucklin Point Service Area (BPSA) outfalls with a series of interceptors to connect outlying outfalls as well as sewer separation for a few residual areas in the Field's Point Service Area.

Because of the projected cost of Phase III and its impact on sewer rates NBC decided to reevaluate the currently approved Phase III plan to determine if the plan was affordable and if any modifications should be made to the Plan. Of particular interest was an evaluation of the feasibility of using Green Stormwater Infrastructure (GSI) as an alternative to conventional grey infrastructure solutions.

NBC engaged a team led by MWH and Pare Corporation (MWH/Pare) to update costs for the baseline plan, conduct an affordability analysis and reevaluate the technical solutions for Phase III in light of newer technologies and regulatory guidance. Particular emphasis was placed on using an Integrated Planning Framework (IPF) approach which allows NBC to consider all Clean Water Act costs and burdens to its ratepayers when evaluating affordability for the Phase III implementation.

The affordability analysis was completed in two steps. The first examined financial capacity based on NBC's current capital and operational spending and Phase III estimated costs. The second included the aforementioned NBC costs and an enhanced evaluation of necessary spending at local levels to include needs for asset renewal and replacement addressing 100-year old + infrastructure. Both included evaluations using the 1997 EPA Financial Capability Assessment (FCA) framework and a significantly more detailed Weighted Average Residential Index (WARi) approach which evaluates financial capability at a census tract level. The results of the Financial Capability Assessment for both steps are shown in Figure ES-1.

Based on Current Spending		Based on Necessary Spending	
EPA Guideline Residential Indicator	WARi™	EPA Guideline Residential Indicator	WARi™
1.67%	1.79%	1.89%	2.11%
Medium Burden	Medium Burden	Medium Burden	High Burden

Figure ES-1 - Summary Results of the Financial Capability Assessment

For both the EPA and WARi approaches using projected NBC costs and current community spending for local infrastructure, the residential indicator for the currently approved Phase III plan NBC service area is a "medium burden". However, the levels of spending in the ten municipalities that make up NBC are currently too low to be sustainable and provide no annual funding for collection system renewal and replacements. When adding a reasonable estimate of necessary local costs to the analysis, the residential indicator for the WARi approach is a "high burden".

Conclusions from this analysis are as follows:

- Indication of a "medium burden" using current spending levels is misleading because it does not include reasonable renewal and replacement costs for local infrastructure as provided in EPA's Integrated Planning Framework.
- The financial capability assessment based on the WARi approach and necessary infrastructure spending is the best approximation of financial burden currently available and leads to a Residential Indicator for the Baseline Plan of 2.11% and is a "high burden" with an average bill of $893.
- To provide the financial capacity to address those needs, the cost of the CSO program must be reduced or the current schedule for completion of Phase III must be extended.
- NBC's recommended plan must balance improvements in water quality with rates that are not an undue burden upon its ratepayers. The NBC considers a sewer rate that exceeds 2% of any member community's median household income and/or a rate that exceeds 2% of the household income for more than one-third of its ratepayers to be unaffordable with a target rate of $626 as a threshold for affordability.

ES.2 Bucklin Point Service Area Hydraulic Model

The hydraulic model for the Bucklin Point Service Area (BPSA) serves as an integral tool in the re-evaluation of Phase III of the NBC CSO control plan. The re-evaluation includes 28 overflows not previously addressed by Phases I and II of the NBC's CSO control plan. A map of the BPSA area is depicted in Figure ES-2.

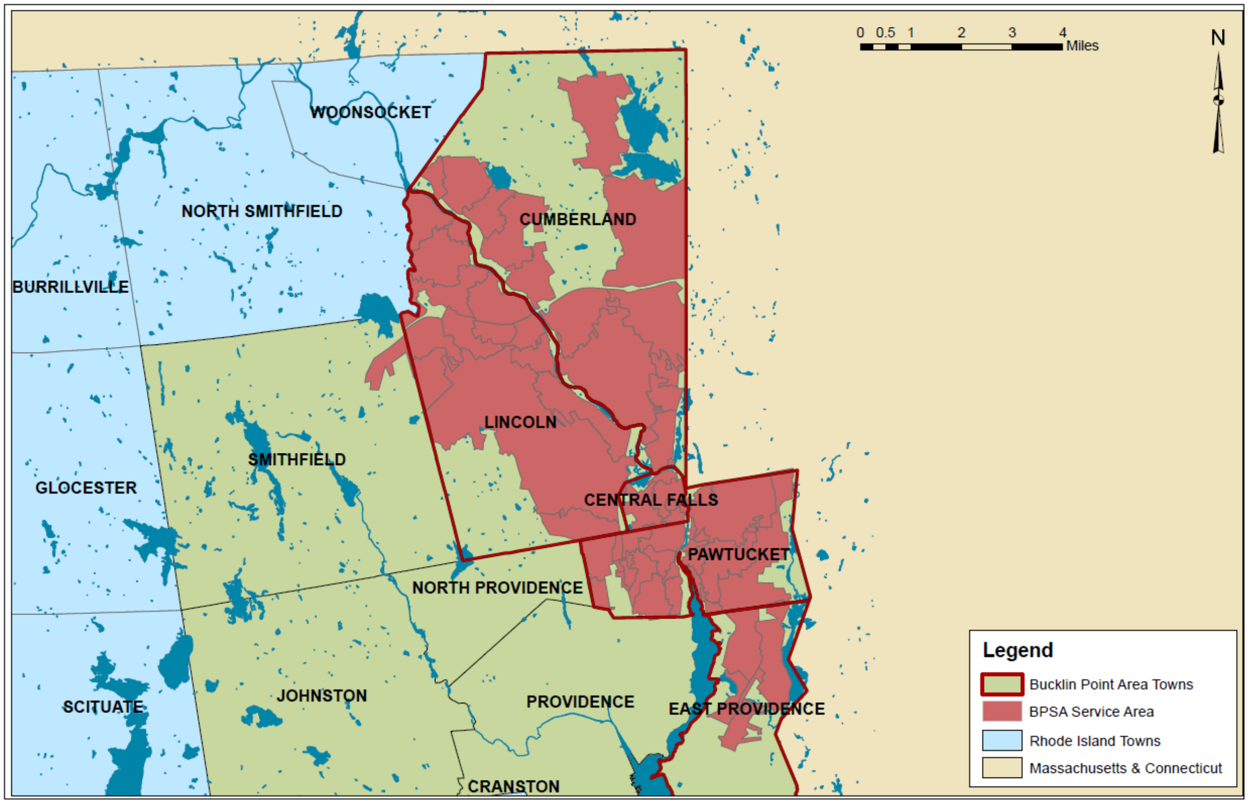

Figure ES-2 Bucklin Point Service Area

Following model updates and calibration, a new baseline model was developed. This model was used to determine the overflow volumes for the 3-month design storm. These results are presented in Table ES-1.

Table ES-1 3-Month Storm Overflow Volumes

Overflow No.	Interceptor	PHASE III BPSA Model 2011 (MG)
OF_101	BVI	0.4
OF_103	BVI	4.9
OF_104	BVI	0.5
OF_105	BVI	1.6
OF_201	BVI	1.3
OF_202	BVI	0.2
OF_203	BVI	0.4
OF_204	BVI	0.2

Overflow No.	Interceptor	PHASE III BPSA Model 2011 (MG)
OF_205	BVI	12.8
OF_207	BVI	0.0
OF_209	BVI	0.0
OF_212	BVI	0.6
OF_215	BVI	1.6
OF_216	BVI	0.0
OF_218	BVI	12.6
OF_002	BVI	0.0
OF_107	MVI	0.4
OF_206	MVI	0.1
OF_208	MVI	0.0
OF_210	MVI	3.2
OF_211	MVI	4.0
OF_213	MVI	2.0
OF_214	MVI	1.3
OF_217	MVI	2.7
OF_220	MVI	4.6
	Total (MG)	**56.49**

ES.3 Pollutant Loading and Water Quality

MWH/Pare performed updates to the receiving water quality model to support the reevaluation of the NBC's Phase III CSO Plan. The water quality model update incorporates the water quality improvements from Phase I and Phase II.

The fecal coliform (FC) loadings from CSOs, Tributary Rivers, storm sewers and wastewater treatment facilities were calculated. The percentage of the FC load form each of these sources for the 3 month design storm is shown in Table ES-2. The majority of the FC load (82.9%) is from the Combined Sewer Overflows.

Table ES-2 3-Month Storm Fecal Coliform Loadings

Phase	Design Storm (mo)	% CSO	% WWTF	% Rivers	% Storm Sewers
Post Phase I	3	86.5	0.0	7.1	6.4
Post Phase II	3	82.9	0.1	8.9	8.1

Five scenarios were evaluated to assess the impact on pollutant loadings and receiving water quality of proposed Phase III facilities in the BPSA. The results of this analysis were used to develop four alternatives for further evaluation.

ES.4 Alternatives Development and Technical Feasibility Screening

A detailed screening of the following technologies and control strategies was also conducted to aid in the development of the four alternatives:

- Green Stormwater Infrastructure (GSI)
- Sewer Separation
- Tunnels
- Interceptors
- Regulator Modifications
- Near Surface Storage Tanks
- Treatment (Screening and Disinfection) and Discharge
- Wetland Treatment

This analysis concluded that GSI alone would at best address only 36 % of the CSO volume and that it should be used as a supplement to grey infrastructure alternatives.

The technologies that were considered for each CSO for the evaluation of alternatives are indicated with a check mark in Table ES-3.

Table ES-3 – Summary of Alternatives following Technical Feasibility Screening

	Source			Pathway				Receptor					
Outfall	No GSI	Public Way GSI	Full GSI	Sewer Separation	Hydraulic Control & Stormwater Storage	Regulator Modification	Interceptor Storage	Satellite Treatment & Discharge	Near Surface Storage	Wetland Treatment	Pawtucket 220 Stub Tunnel	Pawtucket Tunnel	Main Spine Tunnel
35	✓	✓	✓	✓	✓								
36	✓	✓	✓			✓							✓
39	✓	✓	✓	✓			✓						
56	✓	✓	✓	✓			✓						
101	✓	✓	✓			✓			✓			✓	
103	✓	✓	✓						✓			✓	
104	✓	✓	✓						✓			✓	
105	✓	✓	✓						✓			✓	
107	✓	✓	✓			✓			✓			✓	
201	✓	✓	✓					✓	✓			✓	
202	✓	✓	✓			✓		✓	✓			✓	
203	✓	✓	✓					✓	✓			✓	
204	✓	✓	✓					✓	✓			✓	
205	✓	✓	✓					✓	✓			✓	
206	✓	✓	✓	✓	✓	✓			✓			✓	
207	✓	✓	✓			✓			✓			✓	
208	✓	✓	✓			✓			✓			✓	
209	✓	✓	✓			✓			✓			✓	
210	✓	✓	✓						✓			✓	
211	✓	✓	✓						✓			✓	
212	✓	✓	✓			✓		✓	✓			✓	
213	✓	✓	✓						✓			✓	
214	✓	✓	✓						✓			✓	
215	✓	✓	✓			✓		✓	✓			✓	
216	✓	✓	✓			✓		✓	✓			✓	
217	✓	✓	✓					✓	✓			✓	
218	✓	✓	✓					✓	✓			✓	
220	✓	✓	✓					✓	✓		✓	✓	

ES.5 Subsystem Alternatives Analysis

The technically feasible alternatives were evaluated against a range of criteria to determine the components of the redefined Phase III plan that best achieve NBC's goals. Subsystem alternatives were developed and compared against criteria that were developed by the Stakeholder Group to help select the four alternatives for final evaluation.

Based on the subsystem alternatives analysis, the subsystem components considered for the alternatives evaluation were:

- The Pawtucket Tunnel or NSS/Flow through treatment at the BPWWWTF
- The High & Cross Street Interceptor
- The Middle Street Interceptor
- Sewer Separation for 035
- West River Interceptor storage for 039 and 056 instead of sewer separation as proposed in the CDRA
- Hybrid/GSI sewer separation for 206 instead of sewer separation as proposed in the CDRA
- Stub Tunnel or NSS for 220 at an acceptable location instead of the Pawtucket Ave. Interceptor as proposed in the CDRA
- Green Stormwater Infrastructure (GSI) for system optimization.

ES.6 Alternative Plans and IPF Evaluation

Based on the subsystem alternatives analysis, the four alternative plans that were selected for evaluation for the Phase III CSO control program were:

- Alternative 1: Baseline CDRA – Currently Approved Plan
    - One phase
    - Complete 2025
- Alternative 2: Modified Baseline with Phased Implementation
    - Four phases
    - Complete 2038
- Alternative 3: Modified & Phased Baseline with Extended Schedule & Interim Water Quality Projects
    - Six phases
    - Complete 2047
- Alternative 4: Bucklin Point Wastewater Treatment Facility Storage & Treatment
    - Four phases
    - Complete 2038

The projected cost and resulting sewer rate at the completion of construction for the four alternatives are shown in Table ES-4.

Table ES-4 – Summary of Alternatives with Projected Capital Costs and Sewer Rates

Alternative	Projected Capital Cost at Completion	Projected Annual Sewer Rate per Household at Completion
Alternative 1 (Baseline CDRA – Currently Approved Plan)	$750M	$812
Alternative 2 (Modified Baseline with Phased Implementation)	$820M	$769
Alternative 3 (Modified & Phased Baseline with Extended Schedule & Interim Water Quality Projects)	$925M	$776
Alternative 4 (Bucklin Point Wastewater Treatment Facility Storage & Treatment)	$450M	$627

Alternatives 1, 2 and 3 did not meet NBC's affordability criterion of a sewer rate of $626 but Alternative 4 did. A water quality analysis using the water quality model was also conducted for the four alternatives for the 3 month storm. The results showed that Alternatives 1, 2 and 3 resulted in higher water quality improvements than Alternative 4.

ES.7 Revised Recommended Phase III CSO Plan

The NBC Board of Commissioners selected Alternative 2 because it met the water quality goals of the CSO Program, provided a schedule that allowed for adaptive management and had resulted in the most favorable sewer rate of the three tunnel alternatives. Although Alternative 4 was the least expensive alternative and had the lowest sewer rate impact, the Commission eliminated it because of the uncertainty as to whether it would meet the water quality goals of the CSO Program.

The selected conceptual design is summarized in the Table ES-5 and illustrated in Figure ES-3.

Table ES-5 – Summary of Conceptual Design

CSO Control Solution	*CSOs Controlled*
Phase A	
Pawtucket Tunnel, drop shafts & consolidation conduits	204, 205, 210, 211, 213, 214, 217
Regulator modifications	207, 208, 209, 212, 215, 216
GSI Project	212, 213, 214
Phase B	
Middle Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	201-203
High & Cross Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	103 - 105
206 Hybrid GSI / sewer separation	206
Regulator modifications	101, 202
GSI Project	101, 104, 105
Phase C	
220 Stub Tunnel or 220 Near Surface Storage Tank	220
Regulator modification	107
GSI Project	216, 217
Phase D	
035 Sewer separation	035
Regulator modification	036
West River Interceptor	039, 056
GSI Project	201-204

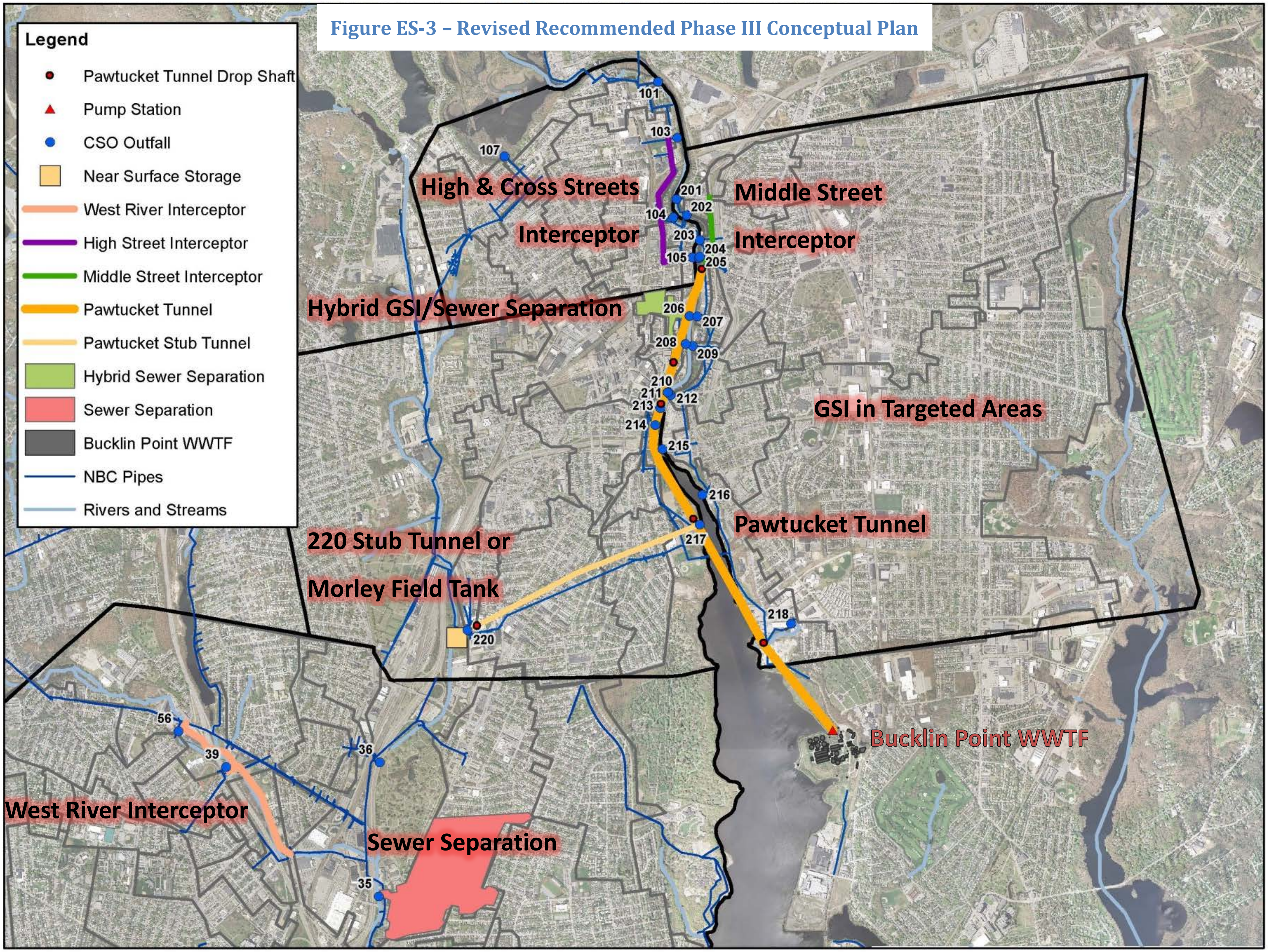
Figure ES-3 – Revised Recommended Phase III Conceptual Plan
Legend
Pawtucket Tunnel Drop Shaft
Pump Station
CSO Outfall
Near Surface Storage
West River Interceptor
High Street Interceptor
Middle Street Interceptor
Pawtucket Tunnel
Pawtucket Stub Tunnel
Hybrid Sewer Separation
Sewer Separation
Bucklin Point WWTF
NBC Pipes
Rivers and Streams
High & Cross Streets
Interceptor
Middle Street
Interceptor
Hybrid GSI/Sewer Separation
GSI in Targeted Areas
Pawtucket Tunnel
220 Stub Tunnel or
Morley Field Tank
Bucklin Point WWTF
West River Interceptor
Sewer Separation
101
103
107
201
202
104
203
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The Pawtucket Tunnel is the largest and most complex component of the overall Phase III plan. Consequently, Phase A is expected to require 3 years for the design phase and five years for the construction phase. All of the other sub-phases are expected to require two years for design and three years for construction. Accommodating the adaptive management planning with the IPF methodology discussed above, the resulting conceptual schedule for Phase III is as follows:

- 2015: Concept review and Consent Agreement modification
- 2016 - 2018: Phase A design, review and bidding
- 2019 – 2023: Phase A construction
- 2023: Initiate IPF evaluation of all regional CWA projects and affordability
- 2024 - 2025: Phase B design, review and bidding
- 2026 – 2028: Phase B construction
- 2028: Initiate IPF evaluation of all regional CWA projects and affordability
- 2029 - 2030: Phase C design, review and bidding
- 2031 – 2033: Phase C construction
- 2033: Initiate IPF evaluation of all regional CWA projects and affordability
- 2034 - 2035: Phase D design, review and bidding
- 2036 – 2038: Phase D construction

The recommended plan will satisfy the same design criteria and water quality goals of the program established by the CDRA. The extended schedule for Phase III will improve the affordability of the program and will provide the necessary flexibility to address changes and prioritize water quality improvements while maintaining affordability for the area's rate payers.

NBC established an affordability goal that its rates would not exceed 2% of any member community's median household income or would not exceed 2% of the household income for more than one-third of its ratepayers. That goal equates to a sewer bill of $626 per year. The projected rate at the end of Phase A, the Pawtucket Tunnel, is $670 which exceeds the affordability goal. NBC should proceed with design of Phase A, but should reevaluate its affordability before proceeding with construction of Phase A. A similar reevaluation should be conducted for each of the subsequent phases.

NBC CSO Control Facilities Phase III Reevaluation

Chapter 1 – Plan Overview, Financial Impact and Affordability Analysis

NBC CSO Control Facilities Phase III Reevaluation

Chapter 1 – Plan Overview, Financial Impact and Affordability Analysis

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1.1. Background and History

The Narragansett Bay Commission's (NBC) mission is to maintain a leadership role in the protection and enhancement of water quality in Narragansett Bay and its tributaries by providing safe and reliable wastewater collection and treatment services to its customers at a reasonable cost. NBC’s service area includes Providence, North Providence, Johnston, Pawtucket, Central Falls, Cumberland, Lincoln, the northern portion of East Providence and small sections of Cranston and Smithfield. The Narragansett Bay Commission owns and operates Rhode Island’s two largest wastewater treatment plants along with extensive infrastructure of interceptor sewers, pump stations, tide-gates, and combined sewer overflow (CSO) structures. The Field's Point Wastewater Treatment Facility (FPWWTF) located in Providence provides treatment of flow from the Providence River watershed in the southern portion of NBC’s service area. The Bucklin Point Wastewater Treatment Facility (BPWWTF) located in East Providence near Pawtucket provides treatment of flow from the Blackstone Valley watershed in the northern portion of NBC’s service area. The collection systems in the member communities are owned by the individual municipalities. The Cities of Providence, Pawtucket and Central Falls have combined systems; hence the NBC CSO structures lie within those communities. The other member communities have separate systems.

The Federal Clean Water Act (CWA), first enacted in 1972, establishes water quality standards and regulates discharges to the nation’s water bodies. Enforcement of the CWA is delegated to the State of Rhode Island and administered through the Rhode Island Department of Environmental Management (RIDEM) with input from the US Environmental Protection Agency (EPA). At present, NBC is responsible for discharges from the two WWTFs and from the CSOs, while the individual member communities are responsible for discharges from their separate stormwater drainage systems. Historically and throughout the country, CWA enforcement first focused on dry weather discharges from WWTFs, then on CSOs and more recently on separate stormwater discharges. That trend was mirrored in Rhode Island and in the NBC service area where upgrades to the FPWWTF and BPWWTF were first instituted, then attention was placed on CSOs and it is anticipated that stormwater restrictions will be forthcoming in the next decade.

In 1992, NBC first entered a Consent Agreement (CA) with RIDEM that established a schedule for CSO control facility planning, design and construction. In 1994, RIDEM approved the Conceptual Design Report (CDR) and NBC began preliminary design of those facilities. In that same year, EPA issued revised CSO policy and guidelines. With the input of a stakeholder group, NBC revisited the planning effort based on the revised guidelines, which culminated in the 1998 RIDEM approval of the Conceptual Design Report Amendment (CDRA) and the modification of the CA. The CDRA established a three-phase program with the goal of reducing annual CSO volumes by 98 percent, and achieving an 80 percent reduction in shellfish bed closures.

The first two phases focused on the Field’s Point Service Area and outfalls in Providence. The main component of Phase I was a deep rock storage tunnel in Providence that was designed to store CSO volumes during wet weather events for subsequent pump out and treatment at the FPWWTF. Phase I was completed in 2008 at a cost of $360M. Phase II consisted of interceptors to connect additional outfalls to the Providence Tunnel plus several sewer separation projects. The final portions of Phase II will be complete in 2015 at a cost of $197M. The third and final phase prescribed by the CDRA shifts the focus to the Bucklin Point Service Area and was conceived as a similar deep rock storage tunnel in Pawtucket with a series of interceptors to connect outlying outfalls as well as sewer separation for a few residual areas in the Field's Point Service Area. The procedure established by the CA requires the NBC to initiate preliminary design of the Phase III facilities upon the completion of Phase II.

1.2. CSO Phase III Baseline Plan Description

The 1998 CDRA estimated the total life-cycle costs of Phases I, II and III as $165.5M, $72.5M and $152.7M respectively. Actual Phase I and II construction costs were significantly higher than those estimates; therefore, as detailed in Chapter 4 of this report, the Phase III estimates were revised to reflect the experience gained to date and adjusted to present dollars. The CA requires NBC to construct approximately 13 capital projects with a total estimated cost, including administration and engineering, of over $740M by 2025 for CSO Phase III control as defined in the CDRA. Consistent with the presumptive approach established by the EPA policy and guidelines, the CDR and CDRA requires all facilities to be designed to capture the flow generated by a 3-month storm (defined as 1.6-inches of rain over a 6-hour period) resulting in four or fewer overflow events in a typical year. Table 1-1 is a listing of control solutions included in the CA, and Table 1-2 is an estimate of the projects' costs and relative timing[1].

The administrative approach for Phase III defined by the CA and the CDRA requires NBC to initiate design efforts immediately following completion of Phase II, submit both preliminary and final designs to RIDEM for review, and then immediately commence construction.

[1] Additional details related to the cost estimates are provided in Chapter 4, and further in Appendix 6.

Outfall	CSO Control Solution	Primary Control Measure	Secondary Control Measure
35	Sewer separation		
36	Regulator modification	Phase II 037 separation	
39	Sewer separation		
56	Sewer separation		
101	Regulator modification	Pawtucket tunnel	Capacity in BVI + High & Cross St interceptor
103	Upper High & Cross St interceptor	Pawtucket tunnel	Lower High & Cross St interceptor
104	Lower High & Cross St interceptor	Pawtucket tunnel	
105	Drop shaft 205 & conduit	Pawtucket tunnel	Conduit river crossing
107	Regulator modification	Pawtucket tunnel	Capacity in MVI + Pawtucket Ave interceptor
201	Middle St interceptor	Pawtucket tunnel	
202	Regulator modification	Pawtucket tunnel	Capacity in BVI + Middle St interceptor
203	Middle St interceptor	Pawtucket tunnel	
204	Regulator modification	Pawtucket tunnel	Drop shaft 205 & conduit
205	Drop shaft 205 & conduit	Pawtucket tunnel	
206	Sewer separation		
207	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
208	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
209	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
210	Drop shaft 210/211 & conduit	Pawtucket tunnel	
211	Drop shaft 210/211 & conduit	Pawtucket tunnel	
212	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
213	Drop shaft 213 & conduit	Pawtucket tunnel	
214	Regulator modification	Pawtucket tunnel	Capacity in TPI + Drop shaft 217
215	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
216	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
217	Drop shaft 217 & conduit	Pawtucket tunnel	
218	Drop shaft 218 & conduit	Pawtucket tunnel	
220	Pawtucket Ave interceptor	Pawtucket tunnel	Drop shaft 217 & conduit

Table 1-1 – CSO Phase III Baseline Plan Components

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
	Phase III Design			Phase III Construction							Total
Phase III											
Pawtucket Tunnel	$7,490,796.45	$7,490,796	$7,490,796	$121,517,365	$121,517,365	$121,517,365					$387,024,483
Drop shaft 218 & conduit	$921,791	$921,791	$921,791		$14,953,499	$14,953,499	$14,953,499				$47,625,870
Drop shaft 205 & conduit	$462,957	$462,957	$462,957			$7,510,188	$7,510,188	$7,510,188			$23,919,436
Drop shaft 210/211 & conduit	$528,408	$528,408	$528,408			$8,571,955	$8,571,955	$8,571,955			$27,301,091
Drop shaft 213 & conduit	$805,532	$805,532	$805,532			$13,067,521	$13,067,521	$13,067,521			$41,619,159
Drop shaft 217 & conduit	$911,751	$911,751	$911,751			$14,790,632	$14,790,632	$14,790,632			$47,107,149
High & Cross Street Interceptor		$458,282.58	$916,565.15					$7,434,362	$7,434,362	$7,434,362	$23,677,933
Middle Street Interceptor		$595,909.34	$893,864					$4,634,850	$4,634,850	$4,634,850	$15,394,325
Pawtucket Ave interceptor	$864,078	$1,728,155	$1,094,498			$16,001,440	$16,001,440	$16,001,440			$51,691,051
035 Sewer separation	$255,675	$511,350	$323,855						$7,886,485	$7,886,485	$16,863,850
039 Sewer separation	$327,116	$654,232	$414,347						$10,160,271	$10,160,271	$21,716,237
056 Sewer separation	$218,646	$437,293	$276,952						$6,784,919	$6,784,919	$14,502,730
206 Sewer separation	$71,836	$143,672	$90,992		$5,509,175						$5,815,675
Regulator Modifications	$10,443	$20,887	$13,228						$580,182.09		$624,740
Admin & Engineering					$841,409	$2,443,878	$2,443,878	$2,443,878	$3,881,118	$3,792,508	$15,846,669
Totals:	**$12,869,030**	**$15,671,016**	**$15,145,538**	**$121,517,365**	**$142,821,448**	**$198,856,478**	**$77,339,113**	**$74,454,826**	**$41,362,187**	**$40,693,395**	**$740,730,396**
Phase III Annual O&M Costs:	$0	$0	$0	$0	$0	$0	$0	$459,000	$474,000	$489,000	

Table 1-2 – CSO Phase III Baseline Plan Projects

1.3. The Regulatory Framework

1.3.1. CSO Control Policy

Among other things, USEPA regulates point-source discharges, including CSOs. In 1989 USEPA issued a *National CSO Control Strategy*, which was supplemented in 1994 when USEPA issued its *CSO Control Policy*.[2] One of the intentions of the *CSO Control Policy* was to provide guidance to Permittees as well as federal and state water quality regulatory agencies. A key expectation of the *CSO Control Policy* is that Permittees shall produce Long-Term Control Plans (LTCPs) to address CSO discharges. According to EPA's *CSO Guidance for Long-Term Control Plans*[3] the ability of the municipality to finance the final recommendations should be considered.

EPA's *CSO Control Policy* addresses the relative importance of financial issues when developing implementation schedules for CSO controls. The Policy states that an implementation schedule "may be phased based on the relative importance of adverse impacts upon Water Quality Standards and designated uses, Priority projects identified in a long-term plan and on a Permittee's financial capability."[4] Thus, an important purpose of this report is to provide a meaningful financial capability assessment (FCA)for NBC's Baseline Plan for review by RIDEM and USEPA.

The FCA must follow guidelines for determining financial impact as described in EPA's 1997 Financial Capability Assessment Guidelines (1997 Guidelines). The 1997 Guidelines also encourage Permittees to provide additional financial and economic information beyond the minimum required levels in order to encourage a broader perspective on local financial impacts. Since flexibility is an important aspect of the CSO Policy, Permittees are encouraged to submit any additional documentation that would create a more accurate and complete picture of their financial capability.

The analyses provided in this report reflect the 1997 Guidelines, but also an enhanced method for measuring the Residential Indicator in the service area. The so-called Weighted Average Residential Index (WARi ™) method[5] provides higher levels of detail by examining financial impacts at a census tract level. The details are discussed further in this Chapter.

1.3.2. Introduction to the 1997 Financial Capability Assessment (FCA) Methodology

In 1997, USEPA published the CSO Guidance for *Financial Capability Assessment and Schedule Development*[6]. Among other things, this document indicates that, for regulatory purposes, financial capability can be assessed using two phases: Phase 1 determines the Residential Indicator, and Phase 2 is an assessment of six additional parameters indicative of overall financial strength of the Permittee. The Phase 1 Residential Indicator (RI) is the quotient of the residential portion of the total costs of the CSO controls and any other existing operational

[2] USEPA, 59 Federal Regulations 18688, April 1994
[3] USEPA, Office of Water, EPA 832-B-95-002, September 1995, p.3-66
[4] Cited in USEPA *CSO Guidance for Long-Term Control Plan*, p.6
[5] WARi™ is a trademark of MWH Global and Hawksley Consulting
[6] USEPA, Office of Water, EPA 832-B-97-004, March 1997

and capital costs of the wastewater services, divided by median household income in the service area.

Phase 2 is only completed if the Residential Indicator is equal to or greater than one percent and examines six parameters intended to measure background or underlying financial capacity of the community, collectively called the Permittee Financial Capability Indicators. Two of these financial capability indicators address existing debt, two concern socio-economic conditions, and two concern property tax data. These six parameters are assumed to have the same weight of importance and compared with benchmark figures (nationwide data, for example) or against specific criteria provided by USEPA. Thus, the Residential Indicator is intended to represent a prospective financial burden, and the Permittee Financial Capability Indicators are intended to represent existing financial capacity to accommodate additional financial burden.

1.3.3. Limitations of the 1997 FCA Methodology

For several decades, Permittees have found many issues concerning the EPA 1997 Methodology in reviewing and assessing their individual financial burdens. In particular, the practice of applying a Median Household Income (MHI) metric to an entire service area has been questioned. In 2013, an issue brief regarding the assessment of affordability was published by the U.S. Conference of Mayors (USCM), American Water Works Association (AWWA), and Water Environment Federation (WEF).[7] One of the central issues brought to light in this publication was that MHI can be a highly misleading indicator of a community's ability to pay and it may not be best to use a community-wide MHI as the primary measure of affordability.

1.3.4. Integrated Planning Framework

Historically, the U.S. Environmental Protection Agency (EPA) and Rhode Island Department of Environmental Management (DEM) have focused on compliance with individual Clean Water Act (CWA) permits and requirements for wastewater, combined sewer, and stormwater discharges. As a result, municipalities and utility owners often struggled to balance competing CWA priorities with a limited financial capability. In 2011 and 2012, the EPA published guidance memorandums allowing for integrated planning approaches to comply with all objectives of the CWA. In its Press Release "Achieving Water Quality Through Municipal Stormwater and Wastewater Plans" dated October 28, 2011, the EPA encouraged states and communities to use an integrated planning approach in stormwater and wastewater management. In this memo, the EPA states "an (integrated) approach will help municipalities responsibly meet their CWA obligations by maximizing their infrastructure improvement dollars through the appropriate sequencing of work. … Integrated planning also can lead to the identification of sustainable and comprehensive solutions, such as green infrastructure, that improve water quality as well as support other quality of life attributes that enhance the vitality of communities." In addition, the EPA shows their support for green infrastructure by stating the "EPA strongly encourages the use of green infrastructure and related innovative technologies, approaches, and practices to manage stormwater as a resource, reduce sewer overflows, enhance environmental quality, and achieve other economic and community benefits."

[7] Assessing the Affordability of Federal Water Mandates – An Issue Brief, USCM AWWA & WEF, 2013

On June 5, 2012, the EPA issued a memorandum titled "Integrated Municipal Stormwater and Wastewater Planning Approach Framework" to provide additional guidance on creating effective integrated plans, including guiding principles and implementation.

The EPA's Integrated Planning Framework provides the flexibility to implement the most cost-effective CWA solutions in a sequence that prioritizes projects such that the most serious water quality and system issues can be addressed sooner. The integrated planning approach does not lower compliance standards. Instead, it allows agencies to consider a municipality/utility owner's financial capability for meeting all CWA requirements and prioritizing infrastructure improvements. Effectively it facilitates planning for CWA compliance in a responsible manner, with a focus on asset management, balancing an agency's most pressing problems in a manner that addresses health and environmental protection issues first, consideration of community impacts and disproportionate financial burdens, and showed support for innovative and sustainable technologies, especially green infrastructure.

1.3.5. New 2014 EPA FCA Framework

On November 24, 2014 the EPA issued the Financial Capability Assessment[8] for Municipal Clean Water Act Requirements. This new framework states that the EPA will continue to be guided by the 1997 Sewer Overflows -Guidance for Financial Capability as the basis to ensure general consistency, but the FCA Guidance also encourages Permittees "to submit any additional documentation that would create a more accurate and complete picture of their financial capability". This framework also builds on the progress already made in the May 2012 "Integrated Municipal Stormwater and Wastewater Planning Approach Framework, (Integrated Planning Framework)" and the experience gained from talking with communities about their financial capability in actual, on-the-ground circumstances. This additional critical information based on local financial impacts will be considered so that schedules can be revised from what the 1997 FCA Guidance might have suggested.

1.4. Costs of the Baseline Plan

The NBC's capital expenditures for the Baseline Plan is comprised of treatment facility improvements, infrastructure management projects, sewer and interceptor improvement projects, the remaining CSO Phase II costs, and the proposed CSO Phase III costs for projects defined in the CDRA. Total project costs are $915,817,693 in the 2015 to 2026 time frame distributed as shown in Table 1-3.

[8] EPA Financial Capability Assessment Framework November 24, 2014 accessed from http://water.epa.gov/polwaste/npdes/cso/upload/municipal_fca_framework.pdf

Year	WWTF Improvements	Infrastructure Management	Sewer Improvements & Interceptor Repair	CSO Phase II	CSO Phase III	Annual Total
2015	$22,476,211	$1,965,578	$3,018,930	$35,594,214	$0	**$63,054,933**
2016	25,743,500	1,686,900	5,226,363	8,924,731	12,869,030	**54,450,524**
2017	5,056,024	856,761	4,532,276	4,773,530	15,671,016	**30,889,607**
2018	2,125,922	621,300	5,325,966	0	15,145,538	**23,218,726**
2019	2,191,826	722,207	5,167,229	0	121,517,365	**129,598,626**
2020	2,259,772	564,943	2,259,772	0	142,821,448	**147,905,935**
2021	2,329,825	582,456	2,329,825	0	198,856,478	**204,098,584**
2022	2,402,050	600,512	2,402,050	0	77,339,113	**82,743,725**
2023	2,476,513	619,128	2,476,513	0	74,454,826	**80,026,981**
2024	2,553,285	638,321	2,553,285	0	41,362,187	**47,107,079**
2025	2,632,437	658,109	2,632,437	0	40,693,395	**46,616,378**
2026	2,714,043	678,511	2,714,043	0	0	**6,106,596**
Total	**$74,961,407**	**$10,194,726**	**$40,638,689**	**$49,292,475**	**$740,730,396**	**$915,817,693**

Table 1-3 –Capital Costs for the Baseline Plan-Including Phase III CSO

These capital projects are budgeted on a timeline to include design, construction and other implementation needs. The resulting capital plan will require financing and significant levels of debt with annual rate increases necessary to support the principal and interest payments, plus certain amounts of cash funding. Figure 1-1 shows the distribution of spending over the scheduled compliance period.

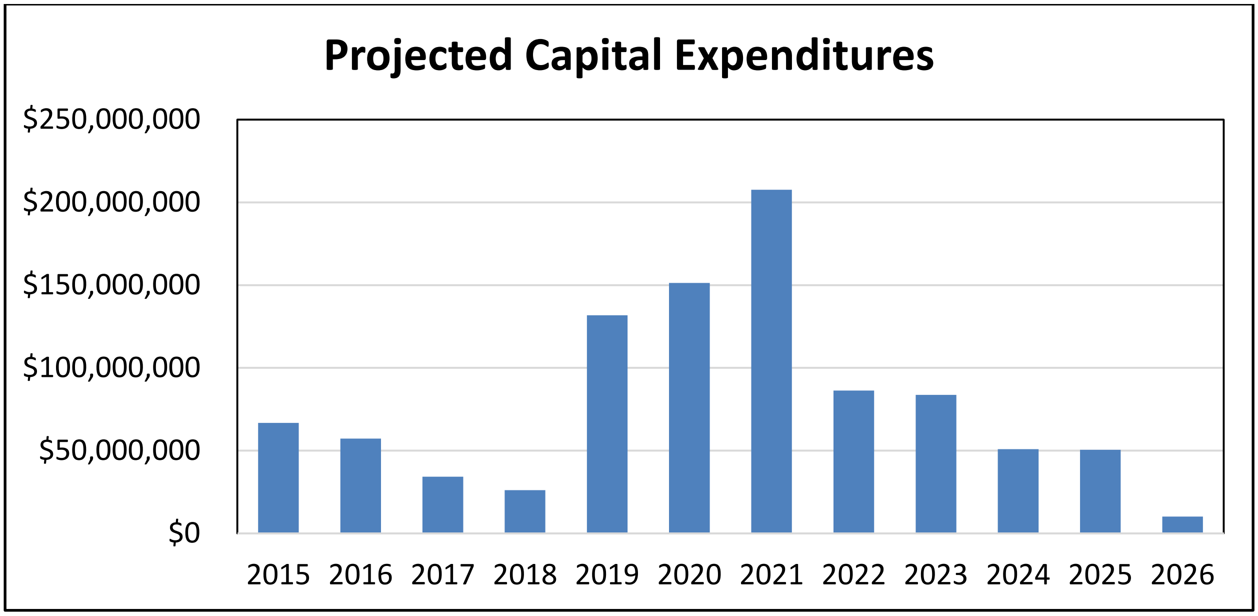

Figure 1-1 –Baseline Plan Capital Expenditures by Year

Rate increases shown in Figure 1-2 and Figure 1-3 will be required in order to support the capital costs projected in the Baseline Plan. The needed rate increases, each of which must be approved through a rate case process before the Rhode Island Public Utilities Commission. The total projected cumulative (compounded) rate increase is 84% through 2026 to fund the Baseline Plan inclusive of expected inflation.

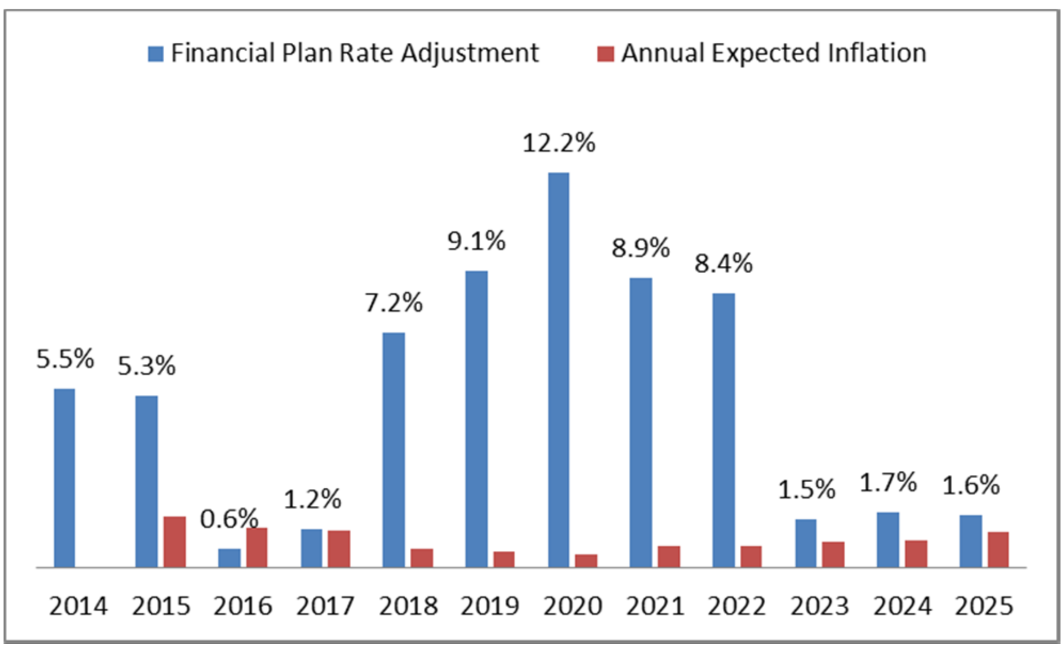

Figure 1-2 –Baseline Plan Projected Rate Increases

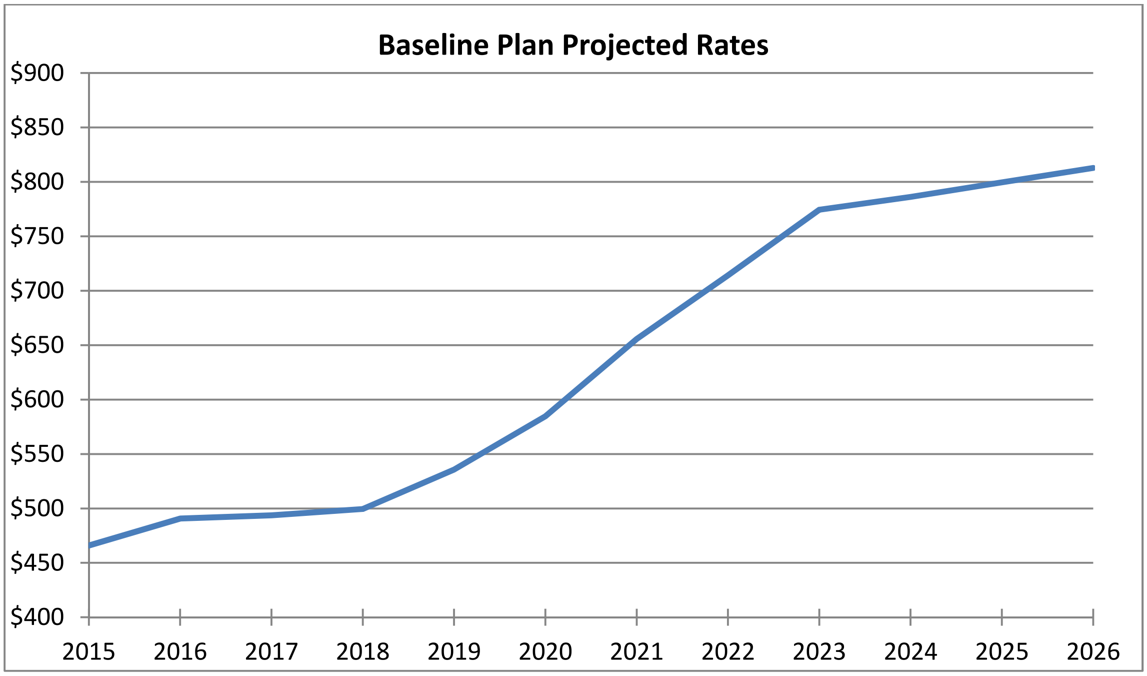

Figure 1-3 - Baseline Plan Projected Rate

1.5. Financial Capability Assessment Based on Current Spending

The first analysis of financial capability is performed using *existing* expenditures together with the proposed costs of the CSO Phase III Baseline control program. The analysis includes two tests for financial burden: one based on the EPA's 1997 Guidelines, and a second based on an enhanced and more detailed approach called WARi™. Section 1.5.1 discusses the results of the EPA Guideline approach, and Section 1.5.2 presents the WARi™ results.

1.5.1. 1997 EPA Guideline Approach

The 1997 EPA Guideline approach provides a financial capability "score" based on the results of two phases of analysis. In the first phase, a Residential Indicator is developed based on the expected cost per household (CPH) divided by median household income (MHI) in the NBC service area. If the Residential Indicator is less than 1% there is no need to proceed to Phase 2 and the CSO control program costs will automatically be considered a "medium burden" or less. Phase 2 includes a further analysis of additional factors in order to categorize the financial capability between a "medium" or "high" burden.

Phase 1 of the 1997 EPA Guideline Approach: The Residential Indicator

The Residential Indicator depends on two values: the CPH, and the MHI for the service area. The CPH is determined based on an evaluation of the CSO control program and other capital expenditures; the specific approach used for NBC is discussed in the subsequent sections of this report. MHI is arrived at by evaluating data from the US Census Bureau. If the quotient obtained by dividing CPH by MHI is higher than 2%, the Residential Indicator is said to indicate a "high burden." If the quotient is less than or equal to two percent, then the CSO control program is said to be of "medium burden" or less. Table 1-4 shows EPA's Residential Indicator criteria.

Financial Impact	Cost per Household
Low	Less than 1.0 percent of MHI
Mid-Range	1.0 - 2.0 percent of MHI
High	Greater than 2.0 percent of MHI

Table 1-4 – EPA Residential Indicator Criteria

The CPH evaluation considers the current and projected costs of actual wastewater collection and treatment expenditures, including CSO control facilities, and other costs directly associated with the wastewater collection and treatment system. In the NBC service area, collection systems are owned, operated, and maintained by local communities. These local O&M and capital costs specific to the member communities have not been included in the CPH as existing costs of service. They were considered, however, as *necessary* costs in the second analysis and will be discussed further in Section 1.6.

The CPH is a residential cost only and therefore excludes the share of system costs normally borne by the non-residential customer classes. Total costs of the system are known based on accounting and other financial records. The total costs are roughly allocated between residential and non-residential classes based on the ratio of respective sewer flows between the two classes. Table 1-5 is a summary of the CPH for NBC's Baseline Plan.

Row	Item	Unit	Value
Current Costs			
100	Annual O&M Costs	($s)	$ 40,955,964
101	Annual Capital and Debt Service	($s)	45,461,965
102	Subtotal	($s)	$ 86,417,929
Projected Costs			
103	Estimated Annual O&M Costs	($s)	$ 489,850
104	Estimated Annual Capital and Debt Service	($s)	66,675,714
105	Subtotal	($s)	$ 67,165,564
106	Total Current and Projected Costs	($s)	$ 153,583,493
107	Residential share of total costs	($s)	$ 93,753,926
108	Total number of Households in Service Area		118,683
109	Cost Per Household	($s)	$ 789.95

Table 1-5 – Cost Per Household – EPA Guidance Worksheet 1

It must be noted that all of the cost data included in the CPH determination are present annual numbers. This simply means that all costs are annualized and expressed in present-day dollars in order to estimate the financial impact of the total CSO program. It's more of a snapshot of what the program *will* cost when all of the construction is complete and the full operating and capital costs of the program are accounted for. Expressing the values in annualized amounts and in present dollars is a reasonable estimate of annual CPH that can be compared to today's median household income.

The following is a brief description of the individual line items from Table 1-5:

- Row 100 includes the existing operating and maintenance expenses of NBC based on financial records for the agency.

- Row 101 includes annual costs of $42,211,965 of existing wastewater system debt service, $250,000 of capital leases, and $3,000,000 of annual pay-as-you-go (not financed) capital outlay. The annual pay-as-you-go outlays are the recurring non-CSO Sewer related CIP. The number shown on Row 101 includes the actual sum of debt service NBC will pay on 23 outstanding issues in 2015. Table 1-6 provides a summary of the outstanding debt issues and the amount of debt service to be paid in 2015.

Item	Value
SRF POOL LOAN 1 - $14.781M	$ 1,039,232
SRF POOL LOAN 2 - $17.279M	1,191,363
SRF POOL LOAN 3 - $8.150M	572,825
SRF POOL LOAN 4 - $23.955M	1,552,880
SRF POOL LOAN 5 - $57M	3,877,014
SRF POOL LOAN 6 - $57M	3,371,046
SRF POOL LOAN 7 - $40M	2,428,646
SRF POOL LOAN 8 - $40M	2,588,962
SRF POOL LOAN 9 - $30M	1,815,044
SRF POOL LOAN 10 - $30M	1,787,489
SRF POOL LOAN 11 - $25M	1,653,876
SRF POOL LOAN 12 - $55M (8.3 M Forgiveness)	2,131,128
SRF POOL LOAN 12 - $2M ($301,895 M Forgiveness)	108,385
SRF POOL LOAN 13 - $20M	1,354,676
SRF POOL LOAN 14 - $30M (1,845,345.21 forgive)	1,960,568
SRF POOL LOAN 15 - $25,750,000 (354,202 forgive)	1,656,866
SRF POOL LOAN 16 - $25,000,000 (80,965.77 forgive)	1,613,453
SRF POOL LOAN 17 - $45,000,000	423,475
VRDO $70M 2008 Series A Refunding (Includes fees)	1,976,275
$45M 2005 Series A	2,250,000
$42.5M 2007 Series A	2,065,563
$71.48M 2013 Series A	3,136,650
$34.970M 2013 Series C	1,656,550
Total	$ 42,211,965

Table 1-6 – Existing Debt Service

- Row 103 includes $489,850 of projected costs for future O&M. Future O&M costs include a projection of *existing* costs to cover supplies, equipment, and staff associated with new assets built.

- Row 104 includes capital outlay and projected annual debt service related to the financing of the prospective CSO and wastewater collection and treatment CIP. NBC's planned financing terms were used to estimate the future debt service costs. NBC's capitalization plan is to fully fund the CSO Phase III plan capital requirements using a mix of revenue bonds, SFR loans and cash. For the calculation on row 104, it was assumed that the revenue bonds issued will have an interest rate of 5.0 percent, maturity of 20 years, and 1.0 percent cost of issuance and SFR loans at 3 percent for 20 years at 0.5 percent of issuance related costs. Table 1-3 is a summary of the CSO program's capital projects which, when financed with the above assumptions, results in an annual cash and debt service payments of $66,675,714 as shown in Row 104.

- Row 105 shows the sum of projected O&M, capital and debt service costs.

- Row 106 shows the sum of existing/current O&M, capital and debt service plus the projected O&M, capital and debt service costs.

- Row 107 shows the Residential Share of total current and future O&M, capital and debt service costs. EPA Guidance prescribes that this value is calculated by dividing the residential share of wastewater flow by the total flow. NBC's residential flow in fiscal year 2014 was 61.0 percent of total flow as shown in Table 1-7.

Billed Discharge (HCF/yr)		
Residential	8,357,380	61.0%
Commercial	4,923,040	36.0%
Industrial	410,267	3.0%
Total	13,690,687	100.0%

Table 1-7 – Residential Share of Wastewater Flow

- Row 108 presents the number of households in the service area. NBC serves 118,683 dwelling units, or households, according to fiscal year 2014 billing data.

- Row 109 shows the final computation of CPH, which is the residential share of costs divided by number of households, and is $789.95.

Dividing the CPH by the MHI in the NBC service area results in the Residential Indicator. Table 1-8 shows the calculation determined for NBC for this analysis.

Row	Item	Unit	Value
Median household income			
201	MHI in 2012	($)	$ 45,226
202	CPI adjustment factor - to 2014	(%)	1.043
203	Adjusted MHI	($)	$ 47,165
204	Annual cost per household	($)	$ 789.95
205	Residential indicator CPH as a percentage of adjusted MHI	(%)	1.67%

Table 1-8 – Residential Indicator

The following are brief descriptions of the values included in Table 1-8:

- Row 201 shows the weighted MHI to be $45,226 in 2012 for NBC's service area. The MHI is weighted to reflect each community's share of the total households. The details of weighted average MHI calculation for the NBC service area including all of the member communities are shown in Table 1-9.

Weighted Average MHI Calculation	*[A]*		*[B]*
Jurisdiction	MHI (1)	Number of Units (2)	Weight
Providence city, Rhode Island	38,243	51,605	43.50%
Pawtucket city, Rhode Island	40,383	25,179	21.22%
North Providence town, Rhode Island	50,939	11,514	9.70%
Cumberland town, Rhode Island	73,340	7,455	6.28%
Johnston town, Rhode Island	56,803	6,221	5.24%
Lincoln town, Rhode Island	75,445	6,909	5.82%
Central Falls city, Rhode Island	29,268	5,823	4.91%
East Providence city, Rhode Island	49,545	3,760	3.17%
Cranston city, Rhode Island	58,772	149	0.13%
Smithfield town, Providence County, Rhode Island	72,546	30	0.03%
Weighted Median Household Income of Member Communities			**45,226**

Table 1-9– Weighted Average MHI for NBC Service Area in 2012

- Row 203 is an indexing of the 2012 MHI value to the 2014 base year using the 5-year average of the Consumer Price Index (CPI)[9]. This adjustment is necessary in order to compare the CPH and MHI both in 2014 dollars.

- Row 204 is the CPH from Table 1-5.

- The Residential Indicator is calculated to be 1.67 percent of MHI as indicated on Row 205, placing it in the Mid-Range Financial Impact as defined earlier in Table 1-4.

[9] Published by the Bureau of Labor Statistics, http://www.bls.gov/cpi/

Phase 2 of the 1997 EPA Guideline Approach: Financial Capability Indicators

As stated previously, there are six Permittee Financial Capability Indicators in the Phase 2 analysis using the EPA Guideline Approach. These indicators are only examined if the Residential Indicator results in a value greater than 1%. Since the NBC Residential Indicator is 1.67%, analysis of the indicators in Table 1-10 is necessary:

Debt Indicators	Socio-Economic Indicators	Financial Management Indicators
Bond Rating	Unemployment Rate	Property Tax Collection Rate
Debt as % of Market Property Value	Median Household Income	Property Tax Revenue as % of Market Property Value

Table 1-10– Phase 2 Indicators for 1997 EPA Guideline Approach

Table 1-11 shows the EPA's Financial Capability criteria used to evaluate each of the indicators. Indicators are shown in the left-most column. Each of the Permittee's financial indicators is assessed as Strong, Mid-Range or Weak depending on the range of scores achieved.

Indicator	Strong	Mid-Range	Weak
Bond Rating	AAA-A (S&P) or Aaa-A (MIS)	BBB (S&P) or Baa (MIS)	BB-D (S&P) or Ba-C (MIS)
Net Debt / Property Value	Below 2%	2% - 5%	Above 5%
Unemployment Rate	>1% below National Average	±1% of National Average	>1% above National Average
Median Household Income	>25% above adj. National MHI	±25% of National Average	>25% below adj. National MHI
Property Tax / Property Value	Below 2%	2%-4%	Above 4%
Property Tax Collection Rate	Above 98%	94%-98%	Below 94%

Table 1-11– Financial Capability Indicator Criteria

The following is a summary of how NBC scored in each of the six indicators:

Bond Rating

There are several credit rating agencies used by local governments to assess credit worthiness ratings of bonds. Moody's Investors Service (Moody's or MIS) and Standard and Poor's Corporation (S&P) are two agencies that Cities and municipal organizations often use to rate their bonds. Fitch Ratings (Fitch) is another credit rating company that some issuers use.

In November 2013, NBC was issued a credit report by Standard & Poor's. NBC was given an AA-/stable review. The credit profile issued by S&P noted strong financial performance and competitive rates despite increases; however, NBC's strengths were offset by the lack of autonomous rate-setting authority and large costs associated with the CSO Phase II projects. NBC's recent bond rating of AA- results in a "Strong" rating for this indicator.

Net Debt to Property Value

Net debt is the amount of outstanding bonded debt of the community backed by tax revenue (not sewer revenues). It includes debt that is generally unrelated to wastewater and environmental systems. The direct net debt for NBC is a small portion of the total since most of the Commission's debt is financed through revenue bonds.

Because the Net Debt indicator is a ratio of debt to property value and because property value is the basis for ad valorem taxation that is used to pay general obligation debt, the EPA Guidance suggests the total debt figure to be net of revenue bond debt, as that form of debt is not paid by property taxes. The total debt of the communities within the service area, less revenue bond debt is $349,500,974.

Table 1-12 shows the computation of net debt as a percent of full market property value as suggested by EPA guidance. Total market value of property for the year 2014 was $25,013,985,449. The resulting ratio of net debt to property value of 1.4 percent indicates "Strong" financial capability.

Row	Item	Unit	Value
401	Direct net debt	($s)	349,500,974
402	Debt of overlapping entities	($s)	0
403	Overall net debt	($s)	349,500,974
404	Market value of property	($s)	25,013,985,449
405	Overall net debt as a percent of full market property value	(%)	1.4%

Table 1-12– Net Debt as a Percent of Full Market Property Value

Unemployment

The unemployment indicator is determined as shown in Table 1-.

Row	Item	Unit	Value
501	Unemployment rate of permittee	(%)	n/a
502	Weighted Average Unemployment rate of NBC Service Area	(%)	8.5%
503	Benchmark: Average national unemployment rate	(%)	6.1%
	Comparison of permittee with benchmark	(%)	+ 2.4%

Table 1-13 – Unemployment Rate

Unemployment is a critical leading factor to determine long-term economic health and financial stability of a community. It also provides insight into NBC's commercial and industrial customers' economic health. Whether or not the economy is doing well in terms of the unemployment rate depends on how far this rate is above the 6.1 percent national benchmark. Higher unemployment rates reflect economic conditions worse than the national average. The weighted average unemployment rate for the NBC service area in 2014 is 8.5 percent[10]. The City of Providence, as the community with the most households within the NBC service area, experienced unemployment rates between 10.9 percent and 7.4 percent during 2014 and averaged 9 percent for the year; Central Falls had a high of 11.8 percent but averaged 9.6 percent unemployment.

The weighted average unemployment rate of 8.5 percent is 2.4 percent higher than the national average for the same time indicating a "Weak" rating by EPA criteria.

Household Income

Unlike the Residential Indicator discussed earlier, the Household Income Indicator compares local MHI to national MHI as a measurement of relative wealth or poverty. As discussed previously, the weighted MHI for NBC's service area in 2012 was $45,226. The CPI based adjustment of MHI to the 2014 year is $47,165 is shown in Table 1-14.The U.S. Census Bureau reports that the Median Income of Households in the United States in 2012 was $51,771.[11] Applying the same CPI based adjustment to the national MHI to estimate 2014 MHI yields an adjusted figure of $53,990 as shown.

NBC's MHI is between 25 percent above and 25 percent below the national MHI indicating a "Mid-Range" rating by EPA criteria.

Row	Item	Unit	Value
601	MHI of permittee, adjusted to 2014	($)	47,165
602	National MHI in 2012	($)	51,771
603	CPI adjustment factor - to 2014	(%)	1.043
604	Benchmark: National MHI, adjusted to 2014	($)	53,990
	Comparison of permittee with benchmark	(%)	14.5%

Table 1-14 – Household Income Worksheet

[10] http://www.dlt.ri.gov/lmi/laus/town/laus14.htm

[11] U.S. Census Bureau, 2010-2012 ACS 3 Year Estimate, Table B19013

Property Tax Revenues as a Percent of Property Value

Property values and corresponding property taxes for NBC were compiled and presented in Table 1-15. The property tax revenue received for the NBC service area is 2.67% of the total market value. Based on EPA criteria, NBC falls into a "Mid-Range" capability.

Row	Item	Unit	Value
701	Full market value of real property	($s)	25,013,985,449
702	Property tax revenue	($s)	668,851,214
703	Property tax rev. as a percentage of full market property value	(%)	2.67%

Table 1-15– Property Tax Revenues as a Percent of Full Market Property Value

Tax Collection Efficiency

The last of the EPA Guidance financial capability indicators to review is property tax revenue collection rate. Computation of this indicator is shown in Table 1-16. Data used for this indicator are derived from Comprehensive Annual Financial Reports (CAFR) from each of the communities in NBC's service area. Because the combined community collections are between 94 percent and 98 percent of the amount levied, this ratio indicates "Mid-Range" rating by EPA's criteria.

Row	Item	Unit	Value
801	Property tax revenue collected	($s)	668,851,214
802	Property taxes levied	($s)	694,903,786
803	Property tax revenue collection rate	(%)	96.25%

Table 1-16– Property Tax Collection Rate

Total Financial Capability Indicator Scores

The Indicator values and scores of the six Financial Capability Indicators are compiled in Table 1-17. The EPA Guidance states that each Weak financial capability indicator shall be assigned a numeric value of 1. Similarly, Mid-Range indicators are assigned 2 and Strong indicators are assigned 3. The simple arithmetic average of the six indicators for the Commission is 2.17 indicating an overall "Mid-Range" capability.

Row	Item	Value	Score
901	Bond rating	AA-	3
902	Net debt percent of property value	1.4%	3
903	Unemployment rate compared with national average	+ 2.4%	1
904	Median household income compared with national average	14.5%	2
905	Property tax revenue percent of property value	2.67%	2
906	Property tax revenue collection rate	96.25%	2
907	Permittee indicator score		2.17

Table 1-17 – Summary of Financial Capability Indicators

Combining the Residential Indicator and the above Financial Capability Indicator score results in a financial capability assessment under the EPA Guideline Approach. Table 1-18 is the scoring matrix used to determine the final capability score. With an RI of 1.67% and a Financial Capability Indicator score of 2.17, the financial capability assessment for NBC's Baseline Plan is rated as a "medium burden". Based on EPA standards, the costs of Baseline Plan would be viewed as "affordable" for NBC's customers.

Permittee Financial Capability Indicators Score (Socioeconomic, Debt & Financial Indicators)	Residential Indicator (Cost per Household as a Percentage of MHI)		
	Low (Below 1.0%)	**Mid-Range (Between 1.0 and 2.0%)**	**High (Greater than 2.0%)**
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	**Medium Burden**	High Burden
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

Table 1-18 – NBC Financial Capability Matrix for the Baseline Plan

1.5.2. The WARi Approach

As mentioned previously in this report, EPA Guidance encourages utilities to provide additional documentation that helps create a more accurate and complete picture of their financial capability[12]. In response to EPA's request, the Weighted Average Residential Index (WARi™) was developed as a means of providing greater clarity and detail related to a Permittee's financial capability. WARi is intended to be an enhancement of the EPA Guideline Approach as it measures the Residential Indicator in significantly greater detail providing greater resolution for each community's unique income distribution, neighborhood characteristics, and actual financial

[12] USEPA, Assessing Financial Capability for Municipal Clean Water Act Requirements, January 18, 2013

burden for the wastewater system. Where the EPA Guideline Approach relies on two data points to determine Residential Indicator, WARi can include 53 data points for every neighborhood (measured as a census tract). For NBC, with 93 census tracts, WARi provides 4,929 data points for a single year resulting in a weighted average residential index that, as one might expect, is very different from the EPA's Guideline Approach. With 10 years in the CSO program schedule, WARi takes 49,290 data points into consideration in calculating the Residential Indicator for each year between now and the CSO program's completion.

Income Distribution

The EPA's Residential Indicator considers the cost per household as a percent of the MHI for the entire service area (i.e. population median), but falls short in considering the sometimes disproportionate distribution of incomes typical of most diverse populations. Figure 1-4 illustrates an example of the actual distribution of incomes for a census tract within the NBC service area (census tract #5). In this example, the distribution of income in the tract is skewed;[13] meaning a disproportionate amount of the population is not just below median household income, but far below the median as the below example illustrates.

The EPA's *Guidance for Preparing Economic Analyses*[14] recognizes the legitimacy of assessing impacts to all households across the income distribution, although the agency provides no direction or methodology for doing so. The data exist, however, to analyze and correct for skew in income distributions at a fairly detailed level. As illustrated in Figure 1-4, census data report the number of households at various income levels within 16 standardized income bins (like those shown below). Thus, there are at least 16 data points in each census tract to help inform the degree of skew in the population of household incomes, and in each census tract there is further a unique median income level and other easily derived measures of central tendency.

[13] In statistics, skew refers to the asymmetry of a data distribution
[14] USEPA 240-R-00-003, September 2000

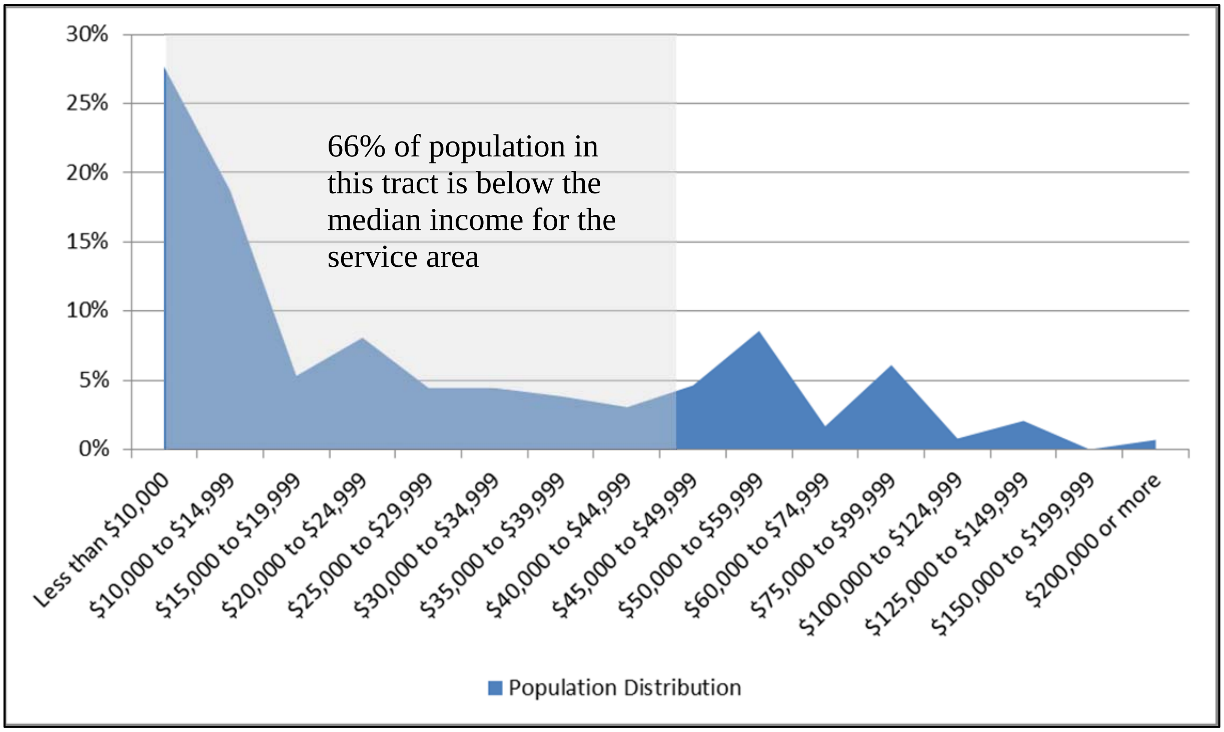

Figure 1-4 – City of Providence Census Tract #5 Population by Standardized Income Bins
(illustrative purposes)

The issue of income distribution is further exacerbated by the wide diversity of the NBC service area which includes ten separate municipalities. Providence, Pawtucket, and Central Falls make up approximately 2/3rds of the service accounts and each has an MHI below the weighted average for the service area as shown in Figure 1-5.

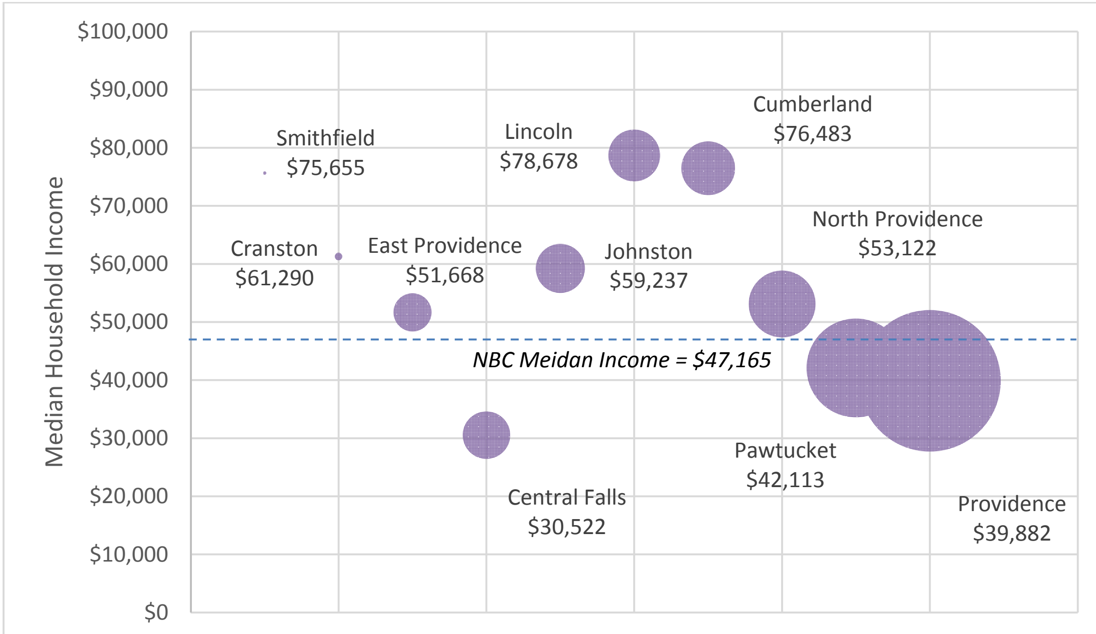

Figure 1-5 - 2014 CPI adjusted Weighted Average MHI by NBC Service Area Accounts

(bubbles indicate the relative number of service accounts in each municipality)

Neighborhoods

Throughout a community, clusters of neighborhoods tend to exhibit various incomes and socioeconomic characteristics. When using MHI as the indicator for an entire community, characteristics of individual neighborhoods are ignored. Specific impacts on disadvantaged communities, minorities, and urban centers can be lost when the data are not evaluated in greater detail. Impacts that may seem affordable when the Residential Indicator is viewed from the lens of the population median can easily result in clusters of severe unaffordability across wide sections of the geography for the service area. Neighborhood data are accessible from the census tract data published by the U.S. Census Bureau. For example, in the NBC service area, such data reveals that household income ranges from $11,612 to $130,482 across 93 census tracts. This is a difference of $118,870 between the highest and lowest MHI neighborhoods in the service area.

Actual Bills

The EPA's Residential Indicator calculation results in a uniform annual cost for all residents served by the utility. It assumes that each customer's financial burden is represented fairly by the average cost per household for the entire community. In reality, customers throughout the service area place different demands on the system, and have different bills as a result. It is a relatively simple matter to cross reference customer account addresses from NBC's billing database with individual census tracts using geocode data. Thus, obtaining actual bills for a census tract and determining an average bill for each tract is obtainable information and can be used to analyze a more accurate financial impact to households.

To calculate WARi, the following steps are completed:

1. Census tract data for the community is gathered to understand MHI and income distribution within each neighborhood.
2. A median income for each census tract is calculated based on the distribution of income unique to each tract.
3. Using NBC's actual billing records, an average bill by census tract is calculated.
4. A Residential Indicator is calculated for each census tract by dividing the average bill for the tract by its own median household income.
5. All calculations are repeated for each census tract.
6. The Residential Index for the service area is calculated by weighting the Residential Indicator from each tract by the number of households; summing the total weighted Residential Indicator results in a weighted average residential index (WARi) for the service area[15].

The resulting calculations are easily plotted into high to low burdens using the 1997 EPA Guideline values. Table 1-19 indicates the color key used in the tables and maps on the following pages showing examples of financial impacts in the NBC service area. Green areas on tables and maps indicate low financial burden and red areas indicate high financial burden.

Financial Impact		Index	Color
Low	Less than	1.00%	
Low-Mid	Up to	1.50%	
Mid	Up to	1.75%	
Mid-High	Up to	2.00%	
High	Higher than	2.00%	

Table 1-19 – Affordability Index Table and Map Key

An Example of How WARi Works – 2014

Looking at the NBC service area, an average annual bill of $430 in 2014 would have a different level of affordability depending on the income distribution within each census tract. At the income bucket level of $47,500, the $430 bill only represents a 0.90% income burden on the 2% affordability index and would be color-coded green. At the lower income levels, the $430 bill would be greater than 2% and would be color-coded red as unaffordable as shown in Table 1-20. The Table also shows the Residential Indicator for each census tract (far right column) where the average of actual bills for the census tract is compared to the median income in that tract. The weighted average Residential Indicator for NBC as a whole shows a value of 1.09% as of 2014

[15] Note that WARi can include additional consideration of individual income bins in each census tract resulting in a separate measure of average affordability. This approach was not used for NBC, however, in order to promote a more consistent comparison of WARi to the 1997 EPA Guidelines.

(lower-right corner of the chart). The number of households with financial burdens in excess of 2% can be counted in order to evaluate yet another measure of affordability impacts to the NBC service area. For 2014, the number of households with financial burdens in excess of 2% was approximately 31% of the households in the entire service area.

Tract	City/Town	Average Bill by Census Tract	$5,000	$12,500	$17,500	$22,500	$27,500	$32,500	$37,500	$42,500	$47,500	$55,000	$67,500	$87,500	$112,500	$137,500	$175,000	$200,000	EPA RI (Avg Bills & Tracts)
1.01	Providence city	$460.27	9.21%	3.68%	2.63%	2.05%	1.67%	1.42%	1.23%	1.08%	0.97%	0.84%	0.68%	0.53%	0.41%	0.33%	0.26%	0.23%	1.01%
1.02	Providence city	$460.15	9.20%	3.68%	2.63%	2.05%	1.67%	1.42%	1.23%	1.08%	0.97%	0.84%	0.68%	0.53%	0.41%	0.33%	0.26%	0.23%	1.23%
2	Providence city	$472.08	9.44%	3.78%	2.70%	2.10%	1.72%	1.45%	1.26%	1.11%	0.99%	0.86%	0.70%	0.54%	0.42%	0.34%	0.27%	0.24%	1.79%
3	Providence city	$460.10	9.20%	3.68%	2.63%	2.04%	1.67%	1.42%	1.23%	1.08%	0.97%	0.84%	0.68%	0.53%	0.41%	0.33%	0.26%	0.23%	1.45%
4	Providence city	$471.68	9.43%	3.77%	2.70%	2.10%	1.72%	1.45%	1.26%	1.11%	0.99%	0.86%	0.70%	0.54%	0.42%	0.34%	0.27%	0.24%	1.84%
5	Providence city	$450.53	9.01%	3.60%	2.57%	2.00%	1.64%	1.39%	1.20%	1.06%	0.95%	0.82%	0.67%	0.51%	0.40%	0.33%	0.26%	0.23%	2.70%
6	Providence city	$466.15	9.32%	3.73%	2.66%	2.07%	1.70%	1.43%	1.24%	1.10%	0.98%	0.85%	0.69%	0.53%	0.41%	0.34%	0.27%	0.23%	1.47%
7	Providence city	$459.10	9.18%	3.67%	2.62%	2.04%	1.67%	1.41%	1.22%	1.08%	0.97%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	3.02%
8	Providence city	$419.21	8.38%	3.35%	2.40%	1.86%	1.52%	1.29%	1.12%	0.99%	0.88%	0.76%	0.62%	0.48%	0.37%	0.30%	0.24%	0.21%	2.68%
9	Providence city	$394.07	7.88%	3.15%	2.25%	1.75%	1.43%	1.21%	1.05%	0.93%	0.83%	0.72%	0.58%	0.45%	0.35%	0.29%	0.23%	0.20%	1.50%
10	Providence city	$411.29	8.23%	3.29%	2.35%	1.83%	1.50%	1.27%	1.10%	0.97%	0.87%	0.75%	0.61%	0.47%	0.37%	0.30%	0.24%	0.21%	1.38%
11	Providence city	$401.19	8.02%	3.21%	2.29%	1.78%	1.46%	1.23%	1.07%	0.94%	0.84%	0.73%	0.59%	0.46%	0.36%	0.29%	0.23%	0.20%	1.02%
12	Providence city	$451.82	9.04%	3.61%	2.58%	2.01%	1.64%	1.39%	1.20%	1.06%	0.95%	0.82%	0.67%	0.52%	0.40%	0.33%	0.26%	0.23%	2.40%
13	Providence city	$429.15	8.58%	3.43%	2.45%	1.91%	1.56%	1.32%	1.14%	1.01%	0.90%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.21%	1.02%
14	Providence city	$487.90	9.76%	3.90%	2.79%	2.17%	1.77%	1.50%	1.30%	1.15%	1.03%	0.89%	0.72%	0.56%	0.43%	0.35%	0.28%	0.24%	1.62%
15	Providence city	$433.41	8.67%	3.47%	2.48%	1.93%	1.58%	1.33%	1.16%	1.02%	0.91%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	0.81%
16	Providence city	$481.43	9.63%	3.85%	2.75%	2.14%	1.75%	1.48%	1.28%	1.13%	1.01%	0.88%	0.71%	0.55%	0.43%	0.35%	0.28%	0.24%	1.50%
17	Providence city	$443.74	8.87%	3.55%	2.54%	1.97%	1.61%	1.37%	1.18%	1.04%	0.93%	0.81%	0.66%	0.51%	0.39%	0.32%	0.25%	0.22%	1.19%
18	Providence city	$467.32	9.35%	3.74%	2.67%	2.08%	1.70%	1.44%	1.25%	1.10%	0.98%	0.85%	0.69%	0.53%	0.42%	0.34%	0.27%	0.23%	1.56%
19	Providence city	$445.95	8.92%	3.57%	2.55%	1.98%	1.62%	1.37%	1.19%	1.05%	0.94%	0.81%	0.66%	0.51%	0.40%	0.32%	0.25%	0.22%	1.44%
20	Providence city	$445.64	8.91%	3.57%	2.55%	1.98%	1.62%	1.37%	1.19%	1.05%	0.94%	0.81%	0.66%	0.51%	0.40%	0.32%	0.25%	0.22%	1.54%
21.01	Providence city	$432.78	8.66%	3.46%	2.47%	1.92%	1.57%	1.33%	1.15%	1.02%	0.91%	0.79%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	0.87%
21.02	Providence city	$449.98	9.00%	3.60%	2.57%	2.00%	1.64%	1.38%	1.20%	1.06%	0.95%	0.82%	0.67%	0.51%	0.40%	0.33%	0.26%	0.22%	1.05%
22	Providence city	$453.53	9.07%	3.63%	2.59%	2.02%	1.65%	1.40%	1.21%	1.07%	0.95%	0.82%	0.67%	0.52%	0.40%	0.33%	0.26%	0.23%	1.37%
23	Providence city	$426.56	8.53%	3.41%	2.44%	1.90%	1.55%	1.31%	1.14%	1.00%	0.90%	0.78%	0.63%	0.49%	0.38%	0.31%	0.24%	0.21%	0.82%
24	Providence city	$428.40	8.57%	3.43%	2.45%	1.90%	1.56%	1.32%	1.14%	1.01%	0.90%	0.78%	0.63%	0.49%	0.38%	0.31%	0.24%	0.21%	0.59%
25	Providence city	$422.78	8.46%	3.38%	2.42%	1.88%	1.54%	1.30%	1.13%	0.99%	0.89%	0.77%	0.63%	0.48%	0.38%	0.31%	0.24%	0.21%	0.97%
26	Providence city	$425.68	8.51%	3.41%	2.43%	1.89%	1.55%	1.31%	1.14%	1.00%	0.90%	0.77%	0.63%	0.49%	0.38%	0.31%	0.24%	0.21%	1.72%
27	Providence city	$440.13	8.80%	3.52%	2.52%	1.96%	1.60%	1.35%	1.17%	1.04%	0.93%	0.80%	0.65%	0.50%	0.39%	0.32%	0.25%	0.22%	1.73%
28	Providence city	$429.46	8.59%	3.44%	2.45%	1.91%	1.56%	1.32%	1.15%	1.01%	0.90%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.21%	1.28%
29	Providence city	$441.35	8.83%	3.53%	2.52%	1.96%	1.60%	1.36%	1.18%	1.04%	0.93%	0.80%	0.65%	0.50%	0.39%	0.32%	0.25%	0.22%	1.13%
31	Providence city	$398.68	7.97%	3.19%	2.28%	1.77%	1.45%	1.23%	1.06%	0.94%	0.84%	0.72%	0.59%	0.46%	0.35%	0.29%	0.23%	0.20%	1.69%
32	Providence city	$386.34	7.73%	3.09%	2.21%	1.72%	1.40%	1.19%	1.03%	0.91%	0.81%	0.70%	0.57%	0.44%	0.34%	0.28%	0.22%	0.19%	0.53%
33	Providence city	$375.95	7.52%	3.01%	2.15%	1.67%	1.37%	1.16%	1.00%	0.88%	0.79%	0.68%	0.56%	0.43%	0.33%	0.27%	0.21%	0.19%	0.54%
34	Providence city	$527.27	10.55%	4.22%	3.01%	2.34%	1.92%	1.62%	1.41%	1.24%	1.11%	0.96%	0.78%	0.60%	0.47%	0.38%	0.30%	0.26%	0.40%
35	Providence city	$432.68	8.65%	3.46%	2.47%	1.92%	1.57%	1.33%	1.15%	1.02%	0.91%	0.79%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	0.69%
36.01	Providence city	$482.37	9.65%	3.86%	2.76%	2.14%	1.75%	1.48%	1.29%	1.13%	1.02%	0.88%	0.71%	0.55%	0.43%	0.35%	0.28%	0.24%	1.31%
36.02	Providence city	$467.42	9.35%	3.74%	2.67%	2.08%	1.70%	1.44%	1.25%	1.10%	0.98%	0.85%	0.69%	0.53%	0.42%	0.34%	0.27%	0.23%	0.69%
37	Providence city	$383.02	7.66%	3.06%	2.19%	1.70%	1.39%	1.18%	1.02%	0.90%	0.81%	0.70%	0.57%	0.44%	0.34%	0.28%	0.22%	0.19%	0.86%
101.01	East Providence city	$398.93	7.98%	3.19%	2.28%	1.77%	1.45%	1.23%	1.06%	0.94%	0.84%	0.73%	0.59%	0.46%	0.35%	0.29%	0.23%	0.20%	0.71%
101.02	East Providence city	$420.45	8.41%	3.36%	2.40%	1.87%	1.53%	1.29%	1.12%	0.99%	0.89%	0.76%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.61%
102	East Providence city	$394.70	7.89%	3.16%	2.26%	1.75%	1.44%	1.21%	1.05%	0.93%	0.83%	0.72%	0.58%	0.45%	0.35%	0.29%	0.23%	0.20%	0.94%
103	East Providence city	$384.49	7.69%	3.08%	2.20%	1.71%	1.40%	1.18%	1.03%	0.90%	0.81%	0.70%	0.57%	0.44%	0.34%	0.28%	0.22%	0.19%	0.93%
104	East Providence city	$365.07	7.30%	2.92%	2.09%	1.62%	1.33%	1.12%	0.97%	0.86%	0.77%	0.66%	0.54%	0.42%	0.32%	0.27%	0.21%	0.18%	0.81%
108	Central Falls city	$430.07	8.60%	3.44%	2.46%	1.91%	1.56%	1.32%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	1.76%
109	Central Falls city	$434.75	8.70%	3.48%	2.48%	1.93%	1.58%	1.34%	1.16%	1.02%	0.92%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	1.45%
110	Central Falls city	$447.36	8.95%	3.58%	2.56%	1.99%	1.63%	1.38%	1.19%	1.05%	0.94%	0.81%	0.66%	0.51%	0.40%	0.33%	0.26%	0.22%	1.31%
111	Central Falls city	$450.19	9.00%	3.60%	2.57%	2.00%	1.64%	1.39%	1.20%	1.06%	0.95%	0.82%	0.67%	0.51%	0.40%	0.33%	0.26%	0.23%	1.49%
112	Cumberland town	$433.79	8.68%	3.47%	2.48%	1.93%	1.58%	1.33%	1.16%	1.02%	0.91%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	0.93%
113.01	Cumberland town	$419.62	8.39%	3.36%	2.40%	1.86%	1.53%	1.29%	1.12%	0.99%	0.88%	0.76%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.68%
113.02	Cumberland town	$464.73	9.29%	3.72%	2.66%	2.07%	1.69%	1.43%	1.24%	1.09%	0.98%	0.84%	0.69%	0.53%	0.41%	0.34%	0.27%	0.23%	0.56%
114.01	Cumberland town	$429.92	8.60%	3.44%	2.46%	1.91%	1.56%	1.32%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.21%	0.46%
114.02	Cumberland town	$433.89	8.68%	3.47%	2.48%	1.93%	1.58%	1.34%	1.16%	1.02%	0.91%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	0.43%
114.03	Cumberland town	$419.46	8.39%	3.36%	2.40%	1.86%	1.53%	1.29%	1.12%	0.99%	0.88%	0.76%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.56%
115	Lincoln town	$431.28	8.63%	3.45%	2.46%	1.92%	1.57%	1.33%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	0.65%
116	Lincoln town	$537.76	10.76%	4.30%	3.07%	2.39%	1.96%	1.65%	1.43%	1.27%	1.13%	0.98%	0.80%	0.61%	0.48%	0.39%	0.31%	0.27%	0.58%
117.01	Lincoln town	$420.97	8.42%	3.37%	2.41%	1.87%	1.53%	1.30%	1.12%	0.99%	0.89%	0.77%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.69%
117.02	Lincoln town	$421.22	8.42%	3.37%	2.41%	1.87%	1.53%	1.30%	1.12%	0.99%	0.89%	0.77%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.47%
118	North Providence town	$457.98	9.16%	3.66%	2.62%	2.04%	1.67%	1.41%	1.22%	1.08%	0.96%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	0.87%
119.01	North Providence town	$459.74	9.19%	3.68%	2.63%	2.04%	1.67%	1.41%	1.23%	1.08%	0.97%	0.84%	0.68%	0.53%	0.41%	0.33%	0.26%	0.23%	1.11%
119.02	North Providence town	$496.07	9.92%	3.97%	2.83%	2.20%	1.80%	1.53%	1.32%	1.17%	1.04%	0.90%	0.73%	0.57%	0.44%	0.36%	0.28%	0.25%	0.94%
120	North Providence town	$448.74	8.97%	3.59%	2.56%	1.99%	1.63%	1.38%	1.20%	1.06%	0.94%	0.82%	0.66%	0.51%	0.40%	0.33%	0.26%	0.22%	0.65%
121.02	North Providence town	$456.22	9.12%	3.65%	2.61%	2.03%	1.66%	1.40%	1.22%	1.07%	0.96%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	1.10%
121.03	North Providence town	$454.30	9.09%	3.63%	2.60%	2.02%	1.65%	1.40%	1.21%	1.07%	0.96%	0.83%	0.67%	0.52%	0.40%	0.33%	0.26%	0.23%	1.13%
121.04	North Providence town	$464.11	9.28%	3.71%	2.65%	2.06%	1.69%	1.43%	1.24%	1.09%	0.98%	0.84%	0.69%	0.53%	0.41%	0.34%	0.27%	0.23%	1.06%
122	Johnston town	$493.54	9.87%	3.95%	2.82%	2.19%	1.79%	1.52%	1.32%	1.16%	1.04%	0.90%	0.73%	0.56%	0.44%	0.36%	0.28%	0.25%	0.69%
123	Johnston town	$469.91	9.40%	3.76%	2.69%	2.09%	1.71%	1.45%	1.25%	1.11%	0.99%	0.85%	0.70%	0.54%	0.42%	0.34%	0.27%	0.23%	0.72%
124.01	Johnston town	$458.80	9.18%	3.67%	2.62%	2.04%	1.67%	1.41%	1.22%	1.08%	0.97%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	0.73%
124.02	Johnston town	$446.89	8.94%	3.58%	2.55%	1.99%	1.63%	1.38%	1.19%	1.05%	0.94%	0.81%	0.66%	0.51%	0.40%	0.33%	0.26%	0.22%	0.80%
125	Johnston town	$458.14	9.16%	3.67%	2.62%	2.04%	1.67%	1.41%	1.22%	1.08%	0.96%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	1.19%
134	Cranston city	$457.09	9.14%	3.66%	2.61%	2.03%	1.66%	1.41%	1.22%	1.08%	0.96%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	0.74%
135	Cranston city	$453.20	9.06%	3.63%	2.59%	2.01%	1.65%	1.39%	1.21%	1.07%	0.95%	0.82%	0.67%	0.52%	0.40%	0.33%	0.26%	0.23%	0.85%
150	Pawtucket city	$421.23	8.42%	3.37%	2.41%	1.87%	1.53%	1.30%	1.12%	0.99%	0.89%	0.77%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	0.99%
151	Pawtucket city	$414.80	8.30%	3.32%	2.37%	1.84%	1.51%	1.28%	1.11%	0.98%	0.87%	0.75%	0.61%	0.47%	0.37%	0.30%	0.24%	0.21%	1.74%
152	Pawtucket city	$430.71	8.61%	3.45%	2.46%	1.91%	1.57%	1.33%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	3.71%
153	Pawtucket city	$415.68	8.31%	3.33%	2.38%	1.85%	1.51%	1.28%	1.11%	0.98%	0.88%	0.76%	0.62%	0.48%	0.37%	0.30%	0.24%	0.21%	1.25%
154	Pawtucket city	$420.22	8.40%	3.36%	2.40%	1.87%	1.53%	1.29%	1.12%	0.99%	0.88%	0.76%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	1.25%
155	Pawtucket city	$414.81	8.30%	3.32%	2.37%	1.84%	1.51%	1.28%	1.11%	0.98%	0.87%	0.75%	0.61%	0.47%	0.37%	0.30%	0.24%	0.21%	0.82%
156	Pawtucket city	$397.86	7.96%	3.18%	2.27%	1.77%	1.45%	1.22%	1.06%	0.94%	0.84%	0.72%	0.59%	0.45%	0.35%	0.29%	0.23%	0.20%	0.76%
157	Pawtucket city	$433.64	8.67%	3.47%	2.48%	1.93%	1.58%	1.33%	1.16%	1.02%	0.91%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	0.83%
158	Pawtucket city	$422.47	8.45%	3.38%	2.41%	1.88%	1.54%	1.30%	1.13%	0.99%	0.89%	0.77%	0.63%	0.48%	0.38%	0.31%	0.24%	0.21%	0.70%
159	Pawtucket city	$418.28	8.37%	3.35%	2.39%	1.86%	1.52%	1.29%	1.12%	0.98%	0.88%	0.76%	0.62%	0.48%	0.37%	0.30%	0.24%	0.21%	0.84%
160	Pawtucket city	$413.38	8.27%	3.31%	2.36%	1.84%	1.50%	1.27%	1.10%	0.97%	0.87%	0.75%	0.61%	0.47%	0.37%	0.30%	0.24%	0.21%	1.51%
161	Pawtucket city	$430.57	8.61%	3.44%	2.46%	1.91%	1.57%	1.32%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	1.51%
163	Pawtucket city	$430.98	8.62%	3.45%	2.46%	1.92%	1.57%	1.33%	1.15%	1.01%	0.91%	0.78%	0.64%	0.49%	0.38%	0.31%	0.25%	0.22%	0.76%
164	Pawtucket city	$412.48	8.25%	3.30%	2.36%	1.83%	1.50%	1.27%	1.10%	0.97%	0.87%	0.75%	0.61%	0.47%	0.37%	0.30%	0.24%	0.21%	1.34%
165	Pawtucket city	$440.66	8.81%	3.53%	2.52%	1.96%	1.60%	1.36%	1.18%	1.04%	0.93%	0.80%	0.65%	0.50%	0.39%	0.32%	0.25%	0.22%	0.82%
166	Pawtucket city	$422.79	8.46%	3.38%	2.42%	1.88%	1.54%	1.30%	1.13%	0.99%	0.89%	0.77%	0.63%	0.48%	0.38%	0.31%	0.24%	0.21%	1.20%
167	Pawtucket city	$407.83	8.16%	3.26%	2.33%	1.81%	1.48%	1.25%	1.09%	0.96%	0.86%	0.74%	0.60%	0.47%	0.36%	0.30%	0.23%	0.20%	1.30%
168	Pawtucket city	$424.67	8.49%	3.40%	2.43%	1.89%	1.54%	1.31%	1.13%	1.00%	0.89%	0.77%	0.63%	0.49%	0.38%	0.31%	0.24%	0.21%	0.66%
169	Pawtucket city	$455.75	9.12%	3.65%	2.60%	2.03%	1.66%	1.40%	1.22%	1.07%	0.96%	0.83%	0.68%	0.52%	0.41%	0.33%	0.26%	0.23%	0.70%
170	Pawtucket city	$434.13	8.68%	3.47%	2.48%	1.93%	1.58%	1.34%	1.16%	1.02%	0.91%	0.79%	0.64%	0.50%	0.39%	0.32%	0.25%	0.22%	0.84%
171	Pawtucket city	$420.13	8.40%	3.36%	2.40%	1.87%	1.53%	1.29%	1.12%	0.99%	0.88%	0.76%	0.62%	0.48%	0.37%	0.31%	0.24%	0.21%	1.08%
Total		**$439.02**	**8.78%**	**3.51%**	**2.51%**	**1.95%**	**1.60%**	**1.35%**	**1.17%**	**1.03%**	**0.92%**	**0.80%**	**0.65%**	**0.50%**	**0.39%**	**0.32%**	**0.25%**	**0.22%**	**1.09%**

Table 1-20 – WARi Analysis for NBC Service Area (2014 Avg. Bills)

Forecasting Financial Capability Using WARi

Using a long-term financial forecasting model based on the cost information discussed in Section 1.4, one can link projected rate increases to the existing bills in each census tract and produce a reasonable projection of future bills for each tract. By keeping the bills and the income data in 2014 dollars, the WARi analysis can provide a very detailed projection of future Residential Indicator for each tract and for the NBC service area as a whole.

The projected WARi residential indicator values for each census tract and for the entire service area in are provided on Table 1-21. The residential indicator for the entire service area is 1.79%. Detailed WARi model results are included in Appendix 2.

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2015	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
1.01	Providence city	1,277	$45,484	1.01%	1.07%	1.11%	1.10%	1.27%	1.54%	1.67%	1.69%
1.02	Providence city	1,399	37,438	1.23%	1.30%	1.34%	1.34%	1.55%	1.87%	2.03%	2.06%
2	Providence city	1,706	26,394	1.79%	1.89%	1.96%	1.94%	2.25%	2.72%	2.95%	2.99%
3	Providence city	1,943	31,833	1.45%	1.52%	1.58%	1.57%	1.82%	2.20%	2.38%	2.42%
4	Providence city	1,093	25,673	1.84%	1.94%	2.01%	2.00%	2.31%	2.79%	3.03%	3.07%
5	Providence city	787	16,713	2.70%	2.84%	2.95%	2.93%	3.39%	4.10%	4.45%	4.51%
6	Providence city	505	31,667	1.47%	1.55%	1.61%	1.60%	1.85%	2.24%	2.43%	2.46%
7	Providence city	536	15,203	3.02%	3.19%	3.30%	3.28%	3.80%	4.59%	4.98%	5.05%
8	Providence city	105	15,613	2.68%	2.83%	2.94%	2.92%	3.38%	4.08%	4.43%	4.49%
9	Providence city	774	26,276	1.50%	1.58%	1.64%	1.63%	1.89%	2.28%	2.47%	2.51%
10	Providence city	767	29,741	1.38%	1.46%	1.51%	1.50%	1.74%	2.10%	2.28%	2.31%
11	Providence city	937	39,341	1.02%	1.08%	1.12%	1.11%	1.28%	1.55%	1.68%	1.71%
12	Providence city	495	18,810	2.40%	2.53%	2.63%	2.61%	3.02%	3.65%	3.96%	4.02%
13	Providence city	1,418	41,888	1.02%	1.08%	1.12%	1.11%	1.29%	1.56%	1.69%	1.71%
14	Providence city	1,699	30,142	1.62%	1.71%	1.77%	1.76%	2.04%	2.46%	2.67%	2.71%
15	Providence city	971	53,469	0.81%	0.86%	0.89%	0.88%	1.02%	1.23%	1.34%	1.36%
16	Providence city	2,367	32,076	1.50%	1.58%	1.64%	1.63%	1.89%	2.28%	2.48%	2.51%
17	Providence city	1,236	37,295	1.19%	1.26%	1.30%	1.29%	1.50%	1.81%	1.96%	1.99%
18	Providence city	1,735	30,036	1.56%	1.64%	1.70%	1.69%	1.96%	2.37%	2.57%	2.60%
19	Providence city	1,503	30,901	1.44%	1.52%	1.58%	1.57%	1.82%	2.20%	2.38%	2.41%
20	Providence city	1,325	28,977	1.54%	1.62%	1.68%	1.67%	1.94%	2.34%	2.54%	2.57%
21.01	Providence city	1,013	49,818	0.87%	0.92%	0.95%	0.94%	1.09%	1.32%	1.43%	1.45%
21.02	Providence city	1,866	42,917	1.05%	1.11%	1.15%	1.14%	1.32%	1.59%	1.73%	1.75%
22	Providence city	1,618	33,169	1.37%	1.44%	1.50%	1.49%	1.72%	2.08%	2.26%	2.29%
23	Providence city	2,019	51,833	0.82%	0.87%	0.90%	0.89%	1.04%	1.25%	1.36%	1.38%
24	Providence city	2,149	72,704	0.59%	0.62%	0.64%	0.64%	0.74%	0.90%	0.97%	0.99%
25	Providence city	889	43,785	0.97%	1.02%	1.06%	1.05%	1.22%	1.47%	1.59%	1.62%
26	Providence city	1,179	24,819	1.72%	1.81%	1.88%	1.86%	2.16%	2.61%	2.83%	2.87%
27	Providence city	1,321	25,472	1.73%	1.82%	1.89%	1.88%	2.17%	2.63%	2.85%	2.89%
28	Providence city	1,871	33,430	1.28%	1.36%	1.40%	1.40%	1.62%	1.95%	2.12%	2.15%
29	Providence city	2,523	39,094	1.13%	1.19%	1.23%	1.23%	1.42%	1.72%	1.86%	1.89%
31	Providence city	1,223	23,575	1.69%	1.78%	1.85%	1.84%	2.13%	2.57%	2.79%	2.83%
32	Providence city	1,436	72,632	0.53%	0.56%	0.58%	0.58%	0.67%	0.81%	0.88%	0.89%
33	Providence city	1,898	69,830	0.54%	0.57%	0.59%	0.59%	0.68%	0.82%	0.89%	0.90%
34	Providence city	1,901	130,482	0.40%	0.43%	0.44%	0.44%	0.51%	0.61%	0.67%	0.68%
35	Providence city	1,561	62,750	0.69%	0.73%	0.75%	0.75%	0.87%	1.05%	1.14%	1.15%
36.01	Providence city	644	36,875	1.31%	1.38%	1.43%	1.42%	1.65%	1.99%	2.16%	2.19%
36.02	Providence city	588	68,088	0.69%	0.72%	0.75%	0.75%	0.86%	1.04%	1.13%	1.15%
37	Providence city	1,328	44,769	0.86%	0.90%	0.94%	0.93%	1.08%	1.30%	1.41%	1.43%
101.01	East Providence city	1,421	55,994	0.71%	0.75%	0.78%	0.77%	0.90%	1.08%	1.18%	1.19%
101.02	East Providence city	1,135	69,448	0.61%	0.64%	0.66%	0.66%	0.76%	0.92%	1.00%	1.01%
102	East Providence city	358	41,884	0.94%	0.99%	1.03%	1.02%	1.19%	1.43%	1.55%	1.58%
103	East Providence city	772	41,124	0.93%	0.99%	1.02%	1.02%	1.18%	1.42%	1.54%	1.56%
104	East Providence city	73	45,042	0.81%	0.86%	0.89%	0.88%	1.02%	1.23%	1.34%	1.36%
108	Central Falls city	1,371	24,386	1.76%	1.86%	1.93%	1.92%	2.22%	2.68%	2.91%	2.95%
109	Central Falls city	1,482	30,000	1.45%	1.53%	1.58%	1.58%	1.82%	2.20%	2.39%	2.42%
110	Central Falls city	1,783	34,120	1.31%	1.38%	1.43%	1.43%	1.65%	1.99%	2.16%	2.19%
111	Central Falls city	1,187	30,263	1.49%	1.57%	1.63%	1.62%	1.87%	2.26%	2.45%	2.49%
112	Cumberland town	1,834	46,466	0.93%	0.98%	1.02%	1.01%	1.18%	1.42%	1.54%	1.56%
113.01	Cumberland town	1,241	62,018	0.68%	0.71%	0.74%	0.74%	0.85%	1.03%	1.12%	1.13%
113.02	Cumberland town	925	82,298	0.56%	0.60%	0.62%	0.61%	0.71%	0.86%	0.93%	0.94%
114.01	Cumberland town	886	92,727	0.46%	0.49%	0.51%	0.50%	0.58%	0.71%	0.76%	0.78%
114.02	Cumberland town	456	100,238	0.43%	0.46%	0.47%	0.47%	0.54%	0.66%	0.71%	0.72%
114.03	Cumberland town	2,113	74,392	0.56%	0.59%	0.62%	0.61%	0.71%	0.86%	0.93%	0.94%
115	Lincoln town	2,090	65,909	0.65%	0.69%	0.72%	0.71%	0.82%	1.00%	1.08%	1.09%
116	Lincoln town	1,751	92,361	0.58%	0.61%	0.64%	0.63%	0.73%	0.89%	0.96%	0.97%
117.01	Lincoln town	1,690	60,962	0.69%	0.73%	0.76%	0.75%	0.87%	1.05%	1.14%	1.16%
117.02	Lincoln town	1,378	89,211	0.47%	0.50%	0.52%	0.51%	0.59%	0.72%	0.78%	0.79%
118	North Providence town	2,579	52,482	0.87%	0.92%	0.95%	0.95%	1.10%	1.33%	1.44%	1.46%
119.01	North Providence town	1,193	41,563	1.11%	1.17%	1.21%	1.20%	1.39%	1.68%	1.82%	1.85%
119.02	North Providence town	2,045	52,844	0.94%	0.99%	1.03%	1.02%	1.18%	1.43%	1.55%	1.57%
120	North Providence town	2,192	69,375	0.65%	0.68%	0.71%	0.70%	0.81%	0.98%	1.07%	1.08%
121.02	North Providence town	1,622	41,611	1.10%	1.16%	1.20%	1.19%	1.38%	1.67%	1.81%	1.83%
121.03	North Providence town	555	40,058	1.13%	1.20%	1.24%	1.23%	1.43%	1.73%	1.87%	1.90%
121.04	North Providence town	1,328	43,825	1.06%	1.12%	1.16%	1.15%	1.33%	1.61%	1.75%	1.77%
122	Johnston town	98	71,408	0.69%	0.73%	0.76%	0.75%	0.87%	1.05%	1.14%	1.16%
123	Johnston town	2,054	65,330	0.72%	0.76%	0.79%	0.78%	0.91%	1.09%	1.19%	1.20%
124.01	Johnston town	2,326	62,846	0.73%	0.77%	0.80%	0.79%	0.92%	1.11%	1.20%	1.22%
124.02	Johnston town	833	55,545	0.80%	0.85%	0.88%	0.87%	1.01%	1.22%	1.33%	1.35%
125	Johnston town	910	38,554	1.19%	1.25%	1.30%	1.29%	1.50%	1.81%	1.96%	1.99%
134	Cranston city	81	61,723	0.74%	0.78%	0.81%	0.81%	0.93%	1.13%	1.22%	1.24%
135	Cranston city	41	53,534	0.85%	0.89%	0.93%	0.92%	1.07%	1.29%	1.40%	1.42%
150	Pawtucket city	1,698	42,500	0.99%	1.05%	1.08%	1.08%	1.25%	1.51%	1.63%	1.66%
151	Pawtucket city	1,215	23,882	1.74%	1.83%	1.90%	1.89%	2.19%	2.64%	2.86%	2.91%
152	Pawtucket city	353	11,612	3.71%	3.91%	4.06%	4.03%	4.67%	5.64%	6.12%	6.20%
153	Pawtucket city	872	33,281	1.25%	1.32%	1.37%	1.36%	1.57%	1.90%	2.06%	2.09%
154	Pawtucket city	686	33,750	1.25%	1.31%	1.36%	1.35%	1.57%	1.89%	2.05%	2.08%
155	Pawtucket city	1,538	50,670	0.82%	0.86%	0.90%	0.89%	1.03%	1.25%	1.35%	1.37%
156	Pawtucket city	985	52,576	0.76%	0.80%	0.83%	0.82%	0.95%	1.15%	1.25%	1.27%
157	Pawtucket city	1,496	52,000	0.83%	0.88%	0.91%	0.91%	1.05%	1.27%	1.38%	1.39%
158	Pawtucket city	1,504	60,223	0.70%	0.74%	0.77%	0.76%	0.88%	1.07%	1.16%	1.17%
159	Pawtucket city	1,165	49,972	0.84%	0.88%	0.92%	0.91%	1.05%	1.27%	1.38%	1.40%
160	Pawtucket city	1,214	27,313	1.51%	1.60%	1.66%	1.65%	1.90%	2.30%	2.50%	2.53%
161	Pawtucket city	1,521	28,456	1.51%	1.60%	1.65%	1.65%	1.90%	2.30%	2.50%	2.53%
163	Pawtucket city	1,082	56,509	0.76%	0.80%	0.83%	0.83%	0.96%	1.16%	1.26%	1.28%
164	Pawtucket city	1,768	30,729	1.34%	1.42%	1.47%	1.46%	1.69%	2.04%	2.21%	2.25%
165	Pawtucket city	1,515	53,682	0.82%	0.87%	0.90%	0.89%	1.03%	1.25%	1.35%	1.37%
166	Pawtucket city	573	35,313	1.20%	1.26%	1.31%	1.30%	1.51%	1.82%	1.97%	2.00%
167	Pawtucket city	1,131	31,421	1.30%	1.37%	1.42%	1.41%	1.63%	1.97%	2.14%	2.17%
168	Pawtucket city	1,199	64,625	0.66%	0.69%	0.72%	0.71%	0.83%	1.00%	1.08%	1.10%
169	Pawtucket city	834	65,455	0.70%	0.73%	0.76%	0.76%	0.88%	1.06%	1.15%	1.16%
170	Pawtucket city	1,368	51,384	0.84%	0.89%	0.92%	0.92%	1.06%	1.29%	1.39%	1.41%
171	Pawtucket city	1,462	39,038	1.08%	1.14%	1.18%	1.17%	1.35%	1.64%	1.78%	1.80%
Total		**118,683**	**$48,716**	**1.07%**	**1.13%**	**1.17%**	**1.16%**	**1.35%**	**1.63%**	**1.77%**	**1.79%**

Table 1-21 – Projected WARi Results from Baseline Plan Forecast

1.5.3. FCA Conclusions Based on Current Spending

Evaluation of the Baseline Plan under both the EPA Guideline Approach and WARi indicate a total capability assessment of "medium burden." Based on these analyses, the costs of the Baseline Plan would be viewed as affordable by EPA. However, the analyses above have so far left out a critical piece of the future costs of sustaining the full wastewater services in the NBC service area. Neither of the above analyses include any provision for *necessary* capital spending to renew and replace the 100-year old+ network of pipelines that make up the collection systems of the local municipalities, nor do they take into account a focused look at the impact on the combined sewer communities of Providence, Pawtucket and Central Falls in the service area. These necessary costs were not included above because the EPA Guideline Approach restricts costs to those currently being incurred. None of the member communities have yet begun to spend considerable money on asset renewal and replacements, but with 100-year old pipelines abundant in many of the collection networks, particularly the combined sewer communities, it is clear that spending for renewal and replacement will need to increase significantly.

The following section examines the FCA with the added perspective of necessary renewal and replacement costs.

1.6. Financial Capability Assessment Based on Necessary Spending

In order to understand the potential real impacts to the NBC customer base as it relates to both sewer and storm drain costs under the Clean Water Act requirements, it is also important to recognize that, besides the NBC treatment costs to customers, each member community also maintains and is legally responsible for the municipal sanitary collection systems in their respective cities. In order to better understand the full burden of infrastructure costs on communities, each municipality was surveyed for the underground pipe length, age and annual replacement costs to support an equivalent 50-year life. The residential portion of annual replacement costs for both sewer and storm drain assets for each community are provided in Table 1-22 and Table 1-23. Note that Smithfield and Cranston were not included in this analysis because of the very few households served by NBC and the negligible impact it would have on overall costs.

Municipality	Total Pipe Length (mi)	Average Pipe Age (yr)	Annual Pipe Replacement (mi/yr)	Annual Cost (2014 USD)	Residential Portion of Annual Costs (61%)
Providence	370	110	3.7	$8,300,000	$5,063,000
North Providence	115	60	1.2	$2,000,000	$1,220,000
Johnston	58	50	0.6	$900,000	$549,000
Pawtucket	180	100	1.8	$4,000,000	$2,440,000
Central Falls	23	100	0.3	$680,000	$414,800
Cumberland	100	35	1.0	$1,200,000	$732,000
Lincoln	103	25	1.1	$1,500,000	$915,000
East Providence	173	50	1.8	$2,700,000	$1,647,000

Table 1-22–Member Community Sewer System Estimated Cost Burdens

Municipality	Total Pipe Length (mi)	Average Pipe Age (yr)	Annual Cost (2014 USD)	Residential Portion of Annual Costs (61%)
Providence	130	75	$1,275,000	$777,750
North Providence	115	75	$1,125,000	$686,250
Johnston	58	50	$435,000	$265,350
Pawtucket	20	75	$195,000	$118,950
Central Falls	0	75	$0	$0
Cumberland	160	35	$960,000	$585,600
Lincoln	103	25	$615,000	$375,150
East Providence	66	50	$495,000	$301,950

Table 1-23–Member Community Storm System Estimated Cost Burdens

1.6.1. Including Necessary Spending in the EPA Guideline Approach

When the member community sewer and storm drain infrastructure cost burdens are added to the total NBC costs from the original EPA Guideline Approach, the original estimate of 1.67% from Table 1-8 is increased to 1.89% as shown in Table 1-24. Therefore, including the local renewal and replacement costs increases the Residential Indicator but not to the extent that it would reach the "high burden" category as outlined in 1.6 (note that the Phase 2 indicators would remain unchanged from earlier).

Total Current and Projected Costs	($s)	$173,709,155
Residential share of total costs	($s)	$106,039,489
Total number of Households in Service Area		118,683
Cost Per Household	($s)	$893
CPH as a percentage of adjusted MHI	(%)	1.89%

Table 1-24 –EPA Guideline Residential Indicator with Necessary Infrastructure Spending Included

1.6.2. Including Necessary Spending in the WARi Approach

Including the member community local infrastructure cost burdens into the WARi approach also results in an increase in the Residential Indicator. In order to calculate WARi correctly, the additional infrastructure costs are annualized and apportioned to the number of service households in each member community resulting in an updated annual expected bill for each census tract in constant 2014 dollars. A revised forecast of bills shows that NBC costs will increase above inflation at times, thus producing real cost increases. The local infrastructure costs were held constant at 2014 levels with no real cost increases. The WARi residential indicator projection for the entire service area in 2026 is 2.11%. Table 1-25 shows the WARi results for each census tract and for the NBC service area as a whole.

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
1.01	Providence city	1,277	$45,484	1.03%	1.17%	1.20%	1.41%	1.72%	1.88%	1.95%
1.02	Providence city	1,399	37,438	1.25%	1.42%	1.46%	1.71%	2.08%	2.29%	2.37%
2	Providence city	1,706	26,394	1.82%	2.06%	2.11%	2.49%	3.02%	3.32%	3.43%
3	Providence city	1,943	31,833	1.47%	1.66%	1.71%	2.02%	2.45%	2.69%	2.78%
4	Providence city	1,093	25,673	1.87%	2.11%	2.17%	2.56%	3.11%	3.41%	3.52%
5	Providence city	787	16,713	2.75%	3.11%	3.20%	3.77%	4.58%	5.03%	5.20%
6	Providence city	505	31,667	1.50%	1.69%	1.74%	2.05%	2.49%	2.74%	2.83%
7	Providence city	536	15,203	3.08%	3.48%	3.58%	4.21%	5.12%	5.63%	5.81%
8	Providence city	105	15,613	2.74%	3.11%	3.20%	3.78%	4.60%	5.06%	5.23%
9	Providence city	774	26,276	1.53%	1.74%	1.80%	2.13%	2.59%	2.85%	2.95%
10	Providence city	767	29,741	1.41%	1.60%	1.65%	1.95%	2.37%	2.61%	2.70%
11	Providence city	937	39,341	1.04%	1.18%	1.22%	1.44%	1.76%	1.93%	2.00%
12	Providence city	495	18,810	2.45%	2.77%	2.85%	3.36%	4.08%	4.48%	4.63%
13	Providence city	1,418	41,888	1.05%	1.18%	1.22%	1.44%	1.75%	1.92%	1.99%
14	Providence city	1,699	30,142	1.65%	1.86%	1.91%	2.24%	2.73%	3.00%	3.09%
15	Providence city	971	53,469	0.83%	0.94%	0.96%	1.14%	1.38%	1.52%	1.57%
16	Providence city	2,367	32,076	1.53%	1.72%	1.77%	2.08%	2.53%	2.78%	2.87%
17	Providence city	1,236	37,295	1.21%	1.37%	1.41%	1.66%	2.03%	2.23%	2.30%
18	Providence city	1,735	30,036	1.59%	1.79%	1.84%	2.17%	2.63%	2.89%	2.99%
19	Providence city	1,503	30,901	1.47%	1.66%	1.71%	2.02%	2.45%	2.70%	2.79%
20	Providence city	1,325	28,977	1.57%	1.77%	1.83%	2.15%	2.62%	2.88%	2.97%
21.01	Providence city	1,013	49,818	0.89%	1.00%	1.03%	1.22%	1.48%	1.63%	1.69%
21.02	Providence city	1,866	42,917	1.07%	1.21%	1.24%	1.47%	1.78%	1.96%	2.02%
22	Providence city	1,618	33,169	1.39%	1.58%	1.62%	1.91%	2.32%	2.55%	2.64%
23	Providence city	2,019	51,833	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.60%
24	Providence city	2,149	72,704	0.60%	0.68%	0.70%	0.83%	1.01%	1.11%	1.15%
25	Providence city	889	43,785	0.99%	1.12%	1.15%	1.36%	1.65%	1.82%	1.88%
26	Providence city	1,179	24,819	1.75%	1.98%	2.04%	2.41%	2.93%	3.22%	3.34%
27	Providence city	1,321	25,472	1.76%	1.99%	2.05%	2.42%	2.94%	3.24%	3.35%
28	Providence city	1,871	33,430	1.31%	1.48%	1.53%	1.80%	2.19%	2.41%	2.50%
29	Providence city	2,523	39,094	1.15%	1.30%	1.34%	1.58%	1.92%	2.11%	2.18%
31	Providence city	1,223	23,575	1.73%	1.96%	2.03%	2.39%	2.91%	3.21%	3.32%
32	Providence city	1,436	72,632	0.54%	0.62%	0.64%	0.76%	0.92%	1.01%	1.05%
33	Providence city	1,898	69,830	0.55%	0.63%	0.65%	0.77%	0.93%	1.03%	1.07%
34	Providence city	1,901	130,482	0.41%	0.46%	0.47%	0.56%	0.68%	0.74%	0.76%
35	Providence city	1,561	62,750	0.70%	0.80%	0.82%	0.97%	1.18%	1.29%	1.34%
36.01	Providence city	644	36,875	1.33%	1.50%	1.54%	1.82%	2.21%	2.42%	2.50%
36.02	Providence city	588	68,088	0.70%	0.79%	0.81%	0.96%	1.16%	1.28%	1.32%
37	Providence city	1,328	44,769	0.88%	1.00%	1.03%	1.22%	1.48%	1.63%	1.69%
101.01	East Providence city	1,421	55,994	0.75%	0.89%	0.95%	1.15%	1.41%	1.57%	1.66%
101.02	East Providence city	1,135	69,448	0.63%	0.75%	0.80%	0.96%	1.18%	1.32%	1.39%
102	East Providence city	358	41,884	0.99%	1.17%	1.26%	1.52%	1.86%	2.08%	2.20%
103	East Providence city	772	41,124	0.98%	1.17%	1.26%	1.52%	1.86%	2.08%	2.20%
104	East Providence city	73	45,042	0.86%	1.02%	1.10%	1.33%	1.63%	1.83%	1.93%
108	Central Falls city	1,371	24,386	1.79%	1.99%	2.02%	2.37%	2.88%	3.15%	3.23%
109	Central Falls city	1,482	30,000	1.47%	1.64%	1.66%	1.95%	2.36%	2.58%	2.65%
110	Central Falls city	1,783	34,120	1.33%	1.48%	1.50%	1.76%	2.13%	2.33%	2.39%
111	Central Falls city	1,187	30,263	1.50%	1.68%	1.70%	1.99%	2.42%	2.64%	2.71%
112	Cumberland town	1,834	46,466	0.97%	1.13%	1.19%	1.42%	1.74%	1.93%	2.02%
113.01	Cumberland town	1,241	62,018	0.70%	0.82%	0.87%	1.04%	1.27%	1.40%	1.47%
113.02	Cumberland town	925	82,298	0.58%	0.68%	0.71%	0.85%	1.04%	1.15%	1.20%
114.01	Cumberland town	886	92,727	0.48%	0.56%	0.59%	0.71%	0.86%	0.96%	1.00%
114.02	Cumberland town	456	100,238	0.45%	0.52%	0.55%	0.66%	0.80%	0.89%	0.94%
114.03	Cumberland town	2,113	74,392	0.59%	0.68%	0.72%	0.86%	1.05%	1.17%	1.23%
115	Lincoln town	2,090	65,909	0.68%	0.78%	0.82%	0.97%	1.18%	1.31%	1.37%
116	Lincoln town	1,751	92,361	0.60%	0.68%	0.71%	0.84%	1.02%	1.12%	1.17%
117.01	Lincoln town	1,690	60,962	0.71%	0.82%	0.86%	1.03%	1.25%	1.39%	1.45%
117.02	Lincoln town	1,378	89,211	0.49%	0.56%	0.59%	0.70%	0.86%	0.95%	0.99%
118	North Providence town	2,579	52,482	0.90%	1.04%	1.10%	1.31%	1.60%	1.77%	1.85%
119.01	North Providence town	1,193	41,563	1.14%	1.32%	1.39%	1.66%	2.02%	2.24%	2.34%
119.02	North Providence town	2,045	52,844	0.97%	1.12%	1.17%	1.39%	1.69%	1.87%	1.95%
120	North Providence town	2,192	69,375	0.67%	0.77%	0.82%	0.97%	1.19%	1.31%	1.37%
121.02	North Providence town	1,622	41,611	1.13%	1.31%	1.38%	1.64%	2.01%	2.22%	2.32%
121.03	North Providence town	555	40,058	1.17%	1.36%	1.43%	1.70%	2.08%	2.30%	2.40%
121.04	North Providence town	1,328	43,825	1.09%	1.27%	1.33%	1.58%	1.93%	2.14%	2.23%
122	Johnston town	98	71,408	0.70%	0.80%	0.82%	0.96%	1.17%	1.29%	1.33%
123	Johnston town	2,054	65,330	0.73%	0.83%	0.86%	1.01%	1.23%	1.35%	1.39%
124.01	Johnston town	2,326	62,846	0.75%	0.84%	0.87%	1.03%	1.25%	1.37%	1.42%
124.02	Johnston town	833	55,545	0.82%	0.93%	0.96%	1.13%	1.38%	1.52%	1.57%
125	Johnston town	910	38,554	1.21%	1.37%	1.42%	1.67%	2.03%	2.23%	2.31%
134	Cranston city	81	61,723	0.74%	0.81%	0.81%	0.93%	1.13%	1.22%	1.24%
135	Cranston city	41	53,534	0.85%	0.93%	0.92%	1.07%	1.29%	1.40%	1.42%
150	Pawtucket city	1,698	42,500	1.01%	1.15%	1.19%	1.40%	1.71%	1.88%	1.95%
151	Pawtucket city	1,215	23,882	1.78%	2.02%	2.09%	2.46%	3.00%	3.30%	3.42%
152	Pawtucket city	353	11,612	3.79%	4.30%	4.44%	5.24%	6.37%	7.01%	7.26%
153	Pawtucket city	872	33,281	1.28%	1.45%	1.50%	1.77%	2.15%	2.37%	2.46%
154	Pawtucket city	686	33,750	1.27%	1.45%	1.49%	1.76%	2.14%	2.36%	2.45%
155	Pawtucket city	1,538	50,670	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.61%
156	Pawtucket city	985	52,576	0.77%	0.88%	0.91%	1.08%	1.31%	1.45%	1.50%
157	Pawtucket city	1,496	52,000	0.85%	0.97%	1.00%	1.18%	1.43%	1.57%	1.63%
158	Pawtucket city	1,504	60,223	0.72%	0.81%	0.84%	0.99%	1.21%	1.33%	1.38%
159	Pawtucket city	1,165	49,972	0.86%	0.97%	1.00%	1.19%	1.44%	1.59%	1.65%
160	Pawtucket city	1,214	27,313	1.55%	1.76%	1.82%	2.15%	2.61%	2.88%	2.98%
161	Pawtucket city	1,521	28,456	1.55%	1.75%	1.81%	2.14%	2.60%	2.86%	2.96%
163	Pawtucket city	1,082	56,509	0.78%	0.88%	0.91%	1.08%	1.31%	1.44%	1.49%
164	Pawtucket city	1,768	30,729	1.37%	1.56%	1.61%	1.90%	2.32%	2.55%	2.64%
165	Pawtucket city	1,515	53,682	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.60%
166	Pawtucket city	573	35,313	1.22%	1.39%	1.43%	1.69%	2.06%	2.27%	2.35%
167	Pawtucket city	1,131	31,421	1.33%	1.51%	1.56%	1.84%	2.24%	2.47%	2.56%
168	Pawtucket city	1,199	64,625	0.67%	0.76%	0.79%	0.93%	1.13%	1.24%	1.29%
169	Pawtucket city	834	65,455	0.71%	0.80%	0.83%	0.98%	1.19%	1.31%	1.35%
170	Pawtucket city	1,368	51,384	0.86%	0.98%	1.01%	1.19%	1.45%	1.60%	1.65%
171	Pawtucket city	1,462	39,038	1.10%	1.25%	1.29%	1.52%	1.85%	2.04%	2.11%
Total		118,683	$48,716	1.09%	1.24%	1.29%	1.52%	1.85%	2.03%	2.11%

Table 1-25 - Updated WARi Approach with Necessary Infrastructure Spending Included

Increasing the Residential Indicator to 2.11 percent indicates that the financial burden from the Baseline Plan is of "high burden" to the NBC community as shown in Table 1-26.

Permittee Financial Capability Indicators Score (Socioeconomic, Debt & Financial Indicators)	Residential Indicator (Cost per Household as a Percentage of MHI)		
	Low (Below 1.0%)	Mid-Range (Between 1.0 and 2.0%)	High (Greater than 2.0%)
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	Medium Burden	**High Burden**
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

Table 1-26 - NBC Financial Capability Matrix for the Baseline Plan

Figure 1-6 illustrates the affordability over time for the census tracts within the service area for the Baseline plan plus the necessary improvements to local collection and stormwater systems.

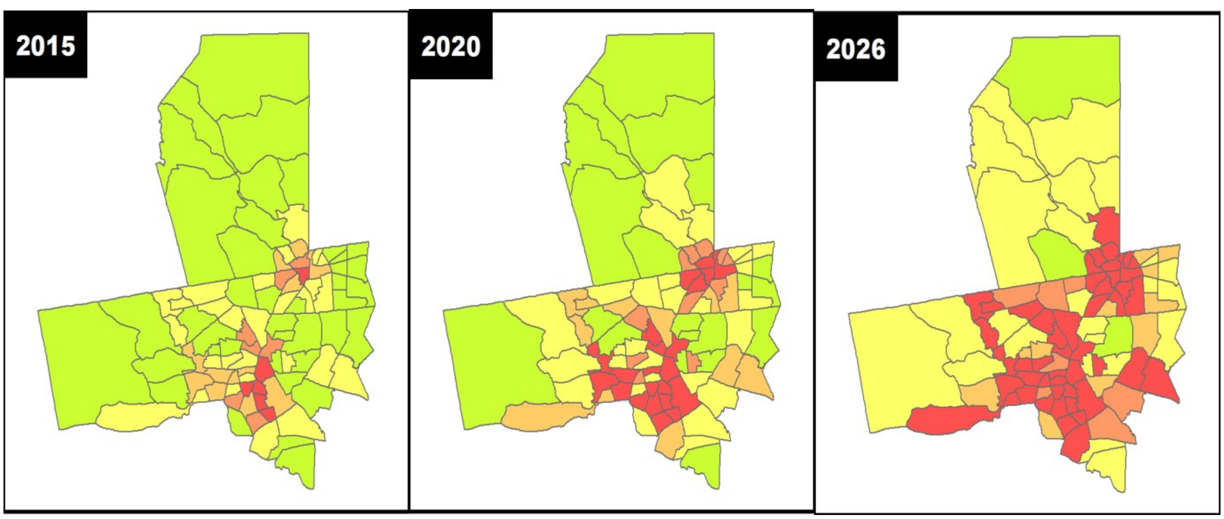

Figure 1-6 – Baseline NBC Afford Figure 1- ability Impact Map 2015, 2020 and 2026

1.7. Affordability Case Studies

In an effort to further evaluate the overall affordability of the Baseline Plan, NBC analyzed the specific cost impacts for three specific member communities. The cities of Providence and Pawtucket combined make up almost 65 percent of the service connections in the NBC service area. A third community, Central Falls, was also studied because of its particularly low household income relative to the rest of the communities. Thus, NBC was attempting to evaluate the topic of affordability for the two communities that make up the majority of the households in the service area, as well as a community with more pressing financial burdens already. The following is a summary of the case study findings.

1.7.1. The City of Providence

The City of Providence has an adjusted 2014 MHI of $39,882[16] with an average unemployment rate in 2014 of 9%[17]. The City spends on average $50,000 to $100,000 per year on emergency sewer repairs mainly from sewers pipe collapses underneath streets. While only emergency level funding is supporting infrastructure renewal and replacement, the near future requires a greater level of investment with the average age of sewer pipes estimated at 110 years. These costs will ramp up significantly during the Baseline Plan. The estimated residential portion of the annual replacement cost for the sanitary collection system is $5.06 million and for storm sewers is $0.778 million. If these O&M and capital costs were equated to a city utility bill, separate from the NBC bill and the capital component was financed at 4% for 20 years then the combined median bill for the City's and NBC's costs would increase from $451.21 in 2014 to $855.78 in 2026, with an estimated city portion of $115.95 in 2026 as shown in Table 1-.

Description	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
Average Annual Bill - NBC	$442.29	$483.66	$480.86	$556.71	$672.77	$729.52	$739.83
Estimated Average Bill - Providence	$8.92	$26.76	$44.60	$62.43	$80.27	$98.11	$115.95
Total Average Bill	**$451.21**	**$510.42**	**$525.46**	**$619.14**	**$753.04**	**$827.63**	**$855.78**
EPA - NBC	1.23%	1.34%	1.34%	1.55%	1.87%	2.03%	2.06%
EPA - NBC + Providence	1.25%	1.42%	1.46%	1.72%	2.09%	2.30%	2.38%

Table 1-27–Average Residential Annual Combined Bill for Providence

[16] Adjusted from 2012 to 2014 using the 5 year average CPI as outlined in EPA guidance

[17] http://www.dlt.ri.gov/lmi/laus/town/laus14.htm

Table 1-28 shows the increasing number of households in excess of the 2% financial burden by census tract by year for the City of Providence due to the combined projected rate increases.

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
1.01	Providence city	1,277	45,484	1.03%	1.17%	1.20%	1.41%	1.72%	1.88%	1.95%
1.02	Providence city	1,399	37,438	1.25%	1.42%	1.46%	1.71%	2.08%	2.29%	2.37%
2	Providence city	1,706	26,394	1.82%	2.06%	2.11%	2.49%	3.02%	3.32%	3.43%
3	Providence city	1,943	31,833	1.47%	1.66%	1.71%	2.02%	2.45%	2.69%	2.78%
4	Providence city	1,093	25,673	1.87%	2.11%	2.17%	2.56%	3.11%	3.41%	3.52%
5	Providence city	787	16,713	2.75%	3.11%	3.20%	3.77%	4.58%	5.03%	5.20%
6	Providence city	505	31,667	1.50%	1.69%	1.74%	2.05%	2.49%	2.74%	2.83%
7	Providence city	536	15,203	3.08%	3.48%	3.58%	4.21%	5.12%	5.63%	5.81%
8	Providence city	105	15,613	2.74%	3.11%	3.20%	3.78%	4.60%	5.06%	5.23%
9	Providence city	774	26,276	1.53%	1.74%	1.80%	2.13%	2.59%	2.85%	2.95%
10	Providence city	767	29,741	1.41%	1.60%	1.65%	1.95%	2.37%	2.61%	2.70%
11	Providence city	937	39,341	1.04%	1.18%	1.22%	1.44%	1.76%	1.93%	2.00%
12	Providence city	495	18,810	2.45%	2.77%	2.85%	3.36%	4.08%	4.48%	4.63%
13	Providence city	1,418	41,888	1.05%	1.18%	1.22%	1.44%	1.75%	1.92%	1.99%
14	Providence city	1,699	30,142	1.65%	1.86%	1.91%	2.24%	2.73%	3.00%	3.09%
15	Providence city	971	53,469	0.83%	0.94%	0.96%	1.14%	1.38%	1.52%	1.57%
16	Providence city	2,367	32,076	1.53%	1.72%	1.77%	2.08%	2.53%	2.78%	2.87%
17	Providence city	1,236	37,295	1.21%	1.37%	1.41%	1.66%	2.03%	2.23%	2.30%
18	Providence city	1,735	30,036	1.59%	1.79%	1.84%	2.17%	2.63%	2.89%	2.99%
19	Providence city	1,503	30,901	1.47%	1.66%	1.71%	2.02%	2.45%	2.70%	2.79%
20	Providence city	1,325	28,977	1.57%	1.77%	1.83%	2.15%	2.62%	2.88%	2.97%
21.01	Providence city	1,013	49,818	0.89%	1.00%	1.03%	1.22%	1.48%	1.63%	1.69%
21.02	Providence city	1,866	42,917	1.07%	1.21%	1.24%	1.47%	1.78%	1.96%	2.02%
22	Providence city	1,618	33,169	1.39%	1.58%	1.62%	1.91%	2.32%	2.55%	2.64%
23	Providence city	2,019	51,833	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.60%
24	Providence city	2,149	72,704	0.60%	0.68%	0.70%	0.83%	1.01%	1.11%	1.15%
25	Providence city	889	43,785	0.99%	1.12%	1.15%	1.36%	1.65%	1.82%	1.88%
26	Providence city	1,179	24,819	1.75%	1.98%	2.04%	2.41%	2.93%	3.22%	3.34%
27	Providence city	1,321	25,472	1.76%	1.99%	2.05%	2.42%	2.94%	3.24%	3.35%
28	Providence city	1,871	33,430	1.31%	1.48%	1.53%	1.80%	2.19%	2.41%	2.50%
29	Providence city	2,523	39,094	1.15%	1.30%	1.34%	1.58%	1.92%	2.11%	2.18%
31	Providence city	1,223	23,575	1.73%	1.96%	2.03%	2.39%	2.91%	3.21%	3.32%
32	Providence city	1,436	72,632	0.54%	0.62%	0.64%	0.76%	0.92%	1.01%	1.05%
33	Providence city	1,898	69,830	0.55%	0.63%	0.65%	0.77%	0.93%	1.03%	1.07%
34	Providence city	1,901	130,482	0.41%	0.46%	0.47%	0.56%	0.68%	0.74%	0.76%
35	Providence city	1,561	62,750	0.70%	0.80%	0.82%	0.97%	1.18%	1.29%	1.34%
36.01	Providence city	644	36,875	1.33%	1.50%	1.54%	1.82%	2.21%	2.42%	2.50%
36.02	Providence city	588	68,088	0.70%	0.79%	0.81%	0.96%	1.16%	1.28%	1.32%
37	Providence city	1,328	44,769	0.88%	1.00%	1.03%	1.22%	1.48%	1.63%	1.69%
Total		**51,605**	**$43,371**	**1.25%**	**1.42%**	**1.46%**	**1.72%**	**2.09%**	**2.30%**	**2.38%**

Table 1-28–Residential Index Applied By Census Tract by Year for Providence

In a time series of snapshots in Figure 1-7 capturing the affordability impacts of the City of Providence, 27,052 households or 52% reach and surpass the unaffordable threshold by 2026.

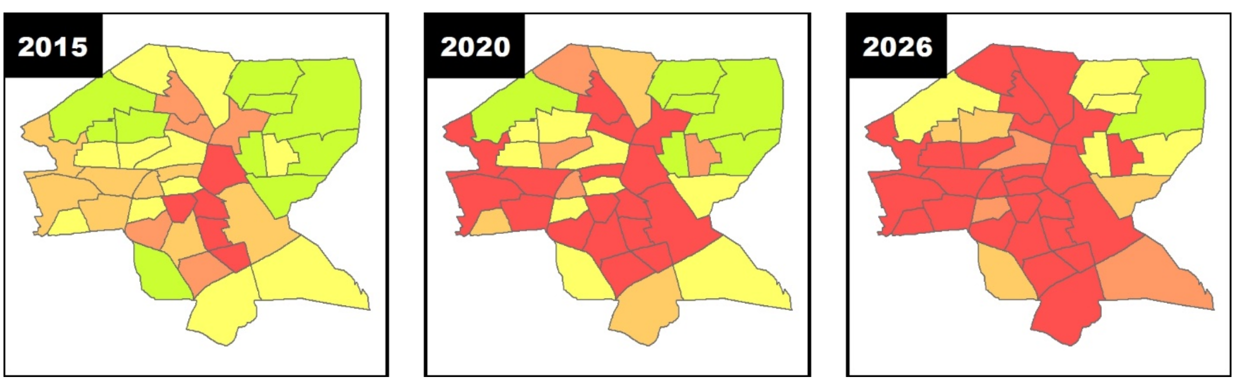

Figure 1-7 – Affordability Index Map Series for Providence 2015, 2020 and 2026

1.7.2. The City of Pawtucket

The City of Pawtucket has an adjusted 2014 MHI of $42,114[18] with an average unemployment rate of 9% in 2014[19]. The City of Pawtucket spends on average $80,000 to $100,000 per year on emergency sewer repairs mainly from sewers pipe collapses underneath streets. With an average sewer pipe age of 100 years, the critical need for a formal renewal and replacement plan is imminent. The estimated annual replacement cost for sanitary sewer is $4 million and for unfunded storm sewer costs is $195,000 per year. If these O&M and capital costs were equated to a city utility bill and the capital component was financed at 4% for 20 years then the combined median bill for the City's and NBC's costs would increase from $432.49 in 2014 to $830.10 in 2026, with a city portion of $122.41 as shown in Table 1-29.

Description	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
Average Annual Bill - NBC	$423.08	$462.64	$459.97	$532.52	$643.53	$697.82	$707.68
Estimated Average Bill - Pawtucket	$9.42	$28.25	$47.08	$65.91	$84.75	$103.58	$122.41
Total Average Bill	**$432.49**	**$490.89**	**$507.05**	**$598.43**	**$728.28**	**$801.40**	**$830.10**
EPA - NBC	1.08%	1.18%	1.17%	1.36%	1.64%	1.78%	1.80%
EPA - NBC + Pawtucket	1.10%	1.25%	1.29%	1.53%	1.86%	2.04%	2.12%

Table 1-29 – Average Residential Annual Combined Bill for Pawtucket

The combined projected rate increases when applied to each census tract by year produces the affordability chart in Table 1-30.

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
150	Pawtucket city	1,698	$42,500	1.01%	1.15%	1.19%	1.40%	1.71%	1.88%	1.95%
151	Pawtucket city	1,215	23,882	1.78%	2.02%	2.09%	2.46%	3.00%	3.30%	3.42%
152	Pawtucket city	353	11,612	3.79%	4.30%	4.44%	5.24%	6.37%	7.01%	7.26%
153	Pawtucket city	872	33,281	1.28%	1.45%	1.50%	1.77%	2.15%	2.37%	2.46%
154	Pawtucket city	686	33,750	1.27%	1.45%	1.49%	1.76%	2.14%	2.36%	2.45%
155	Pawtucket city	1,538	50,670	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.61%
156	Pawtucket city	985	52,576	0.77%	0.88%	0.91%	1.08%	1.31%	1.45%	1.50%
157	Pawtucket city	1,496	52,000	0.85%	0.97%	1.00%	1.18%	1.43%	1.57%	1.63%
158	Pawtucket city	1,504	60,223	0.72%	0.81%	0.84%	0.99%	1.21%	1.33%	1.38%
159	Pawtucket city	1,165	49,972	0.86%	0.97%	1.00%	1.19%	1.44%	1.59%	1.65%
160	Pawtucket city	1,214	27,313	1.55%	1.76%	1.82%	2.15%	2.61%	2.88%	2.98%
161	Pawtucket city	1,521	28,456	1.55%	1.75%	1.81%	2.14%	2.60%	2.86%	2.96%
163	Pawtucket city	1,082	56,509	0.78%	0.88%	0.91%	1.08%	1.31%	1.44%	1.49%
164	Pawtucket city	1,768	30,729	1.37%	1.56%	1.61%	1.90%	2.32%	2.55%	2.64%
165	Pawtucket city	1,515	53,682	0.84%	0.95%	0.98%	1.16%	1.41%	1.55%	1.60%
166	Pawtucket city	573	35,313	1.22%	1.39%	1.43%	1.69%	2.06%	2.27%	2.35%
167	Pawtucket city	1,131	31,421	1.33%	1.51%	1.56%	1.84%	2.24%	2.47%	2.56%
168	Pawtucket city	1,199	64,625	0.67%	0.76%	0.79%	0.93%	1.13%	1.24%	1.29%
169	Pawtucket city	834	65,455	0.71%	0.80%	0.83%	0.98%	1.19%	1.31%	1.35%
170	Pawtucket city	1,368	51,384	0.86%	0.98%	1.01%	1.19%	1.45%	1.60%	1.65%
171	Pawtucket city	1,462	39,038	1.10%	1.25%	1.29%	1.52%	1.85%	2.04%	2.11%
Total		**25,179**	**$43,775**	**1.10%**	**1.25%**	**1.29%**	**1.53%**	**1.86%**	**2.04%**	**2.12%**

Table 1–30 Residential Index Applied by Census Tract by Year for Pawtucket

[18] Adjusted from 2012 to 2014 using the 5 year average CPI as outlined in EPA guidance

[19] http://www.dlt.ri.gov/lmi/laus/town/laus14.htm

In a time series of snapshots in Figure 1-8 capturing the affordability impacts of the City of Pawtucket, 11,999 households or 48% reach and surpass the unaffordable threshold.

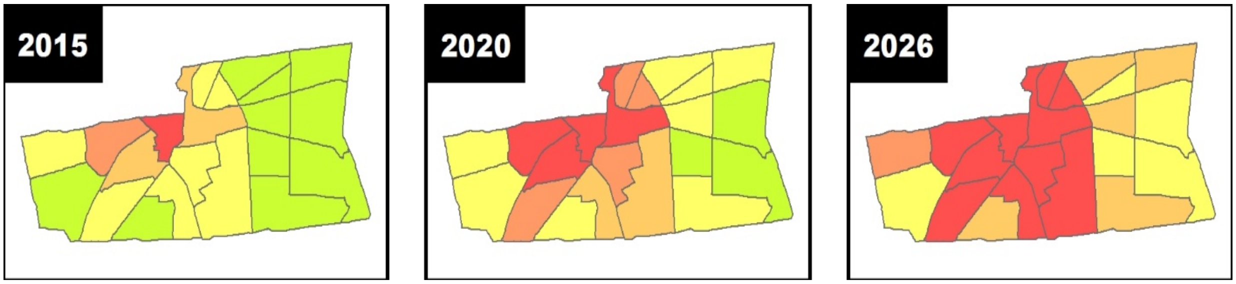

Figure 1-8–Residential Index Map Series for Pawtucket 2015, 2020 and 2026

1.7.3. The City of Central Falls

The City of Central Falls has an adjusted 2014 MHI of $30,522[20] and an average unemployment rate of 9.6%[21] in 2014The City of Central Falls does not have an estimated annual amount spent on emergency sewer repairs even though the average age of the sewer pipe is 100 years old. The estimated annual replacement costs for sanitary sewer is $680,000 and they do not have storm sewer infrastructure. If the capital costs were equated to a city bill and the capital component was financed at 4% for 20 years then the combined median bill for the City's and NBC's costs would increase from $445.62 in 2014 to $804.77 in 2026, with a city portion of $68.14. Due to the low income levels in the City of Central Falls, the combined bill quickly puts nearly all households over the 2% high burden threshold for affordability as shown in Table 1-31.

Description	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
Average Annual Bill - NBC	$440.38	$481.57	$478.78	$554.30	$669.85	$726.37	$736.63
Estimated Average Bill - Central Falls	$5.24	$15.72	$26.21	$36.69	$47.17	$57.66	$68.14
Total Average Bill	**$445.62**	**$497.29**	**$504.99**	**$590.99**	**$717.03**	**$784.02**	**$804.77**
EPA - NBC	1.49%	1.63%	1.62%	1.87%	2.26%	2.46%	2.49%
EPA - NBC + Central Falls	1.51%	1.68%	1.71%	2.00%	2.42%	2.65%	2.72%

Table 1-31–Average Residential Annual Combined Bill for Central Falls

The combined projected rate increases when applied to each census tract by year produces an affordability chart in Table 1-32 which highlights the increasing level of unaffordability by 2026.

[20] Adjusted from 2012 to 2014 using the 5 year average CPI as outlined in EPA guidance

[21] http://www.dlt.ri.gov/lmi/laus/town/laus14.htm

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2016	Projected 2018	Projected 2020	Projected 2022	Projected 2024	Projected 2026
108	Central Falls city	1,371	$24,386	1.79%	1.99%	2.02%	2.37%	2.88%	3.15%	3.23%
109	Central Falls city	1,482	30,000	1.47%	1.64%	1.66%	1.95%	2.36%	2.58%	2.65%
110	Central Falls city	1,783	34,120	1.33%	1.48%	1.50%	1.76%	2.13%	2.33%	2.39%
111	Central Falls city	1,187	30,263	1.50%	1.68%	1.70%	1.99%	2.42%	2.64%	2.71%
Total		**5,823**	**$29,993**	**1.51%**	**1.68%**	**1.71%**	**2.00%**	**2.42%**	**2.65%**	**2.72%**

Table 1-32 – Residential Index Applied By Census Tract by Year for Central Falls

In a time series of snapshots in Figure 1-9 capturing the affordability impacts of the City of Central Falls, 3,561 households or 61% reach and surpass the 2% threshold for high financial burden.

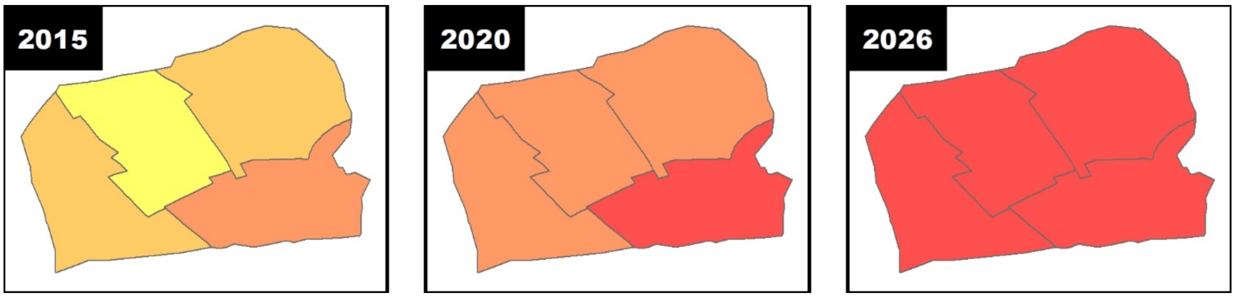

Figure 1-9 – Residential Index Map Series for Central Falls 2015, 2020 and 2026

1.8. Conclusion of Affordability Analysis for Baseline Plan

The analysis was completed in two steps. The first examined financial capacity based on NBC spending for wastewater service. The second included NBC costs and an enhanced evaluation of necessary spending at local levels to include needs for asset renewal and replacement addressing 100-year old + infrastructure. Both included evaluations using the 1997 EPA Financial Capability Assessment (FCA) framework and a significantly more detailed WARi approach which evaluates financial capability at a census tract level. The results of the Financial Capability Assessment for both steps are shown on Table 1-33.

Based on Current Spending		Based on Necessary Spending	
EPA Guideline Residential Indicator	WARi™	EPA Guideline Residential Indicator	WARi™
1.67%	**1.79%**	**1.89%**	**2.11%**
Medium Burden	Medium Burden	Medium Burden	High Burden

Table 1-33 - Summary Results of the Financial Capability Assessment

For both the EPA and WARi approaches using projected NBC costs and current community spending for local infrastructure, the Baseline Plan residential indicator for the NBC service area is a “medium burden”. However, the current levels of spending in the ten municipalities that make up NBC are too low to be sustainable and provide no annual funding for collection system renewal and replacements. When adding a reasonable estimate of necessary local costs to the analysis, the residential indicator for the WARi approach is a “high burden”.

After evaluating the Baseline Plan costs under the two different cost scenarios including current and necessary spending levels and under both the EPA Guideline Approach and the enhanced WARi approach, the conclusions are as follows:

- The initial indication of financial capability based on current spending levels under the EPA Guideline Approach and WARi results in a misleading indication of “medium burden” because it does not include reasonable renewal and replacement costs for local infrastructure by member communities as provided in EPA’s Integrated Planning Framework.

- The financial capability assessment based on the WARi approach and necessary infrastructure spending is the best approximation of financial burden currently available. Because WARi includes actual bills by individual census tracts and matches those bills to each census tract’s unique median income level, WARi results are more representative of what NBC’s ratepayers can afford. The resulting Residential Indicator for the Baseline Plan is 2.11% and a “high burden”. The average bill would be $893, which is unaffordable. Proceeding with the Baseline Plan would, therefore, preclude addressing reasonably anticipated collection system needs. To provide the financial capacity to address those needs, the cost of the CSO program must be reduced or the current schedule for completion of Phase III must be extended.

NBC is acutely aware of the diversity of its service area and is sensitive to maintaining rates that are affordable. The census and billing data collected for the WARi analysis can also be used to determine what is affordable for NBC ratepayers.

The census provides data on the number of households in each census tract divided into income buckets in $5,000 increments in 2012 dollars. Table 1-34 shows the rate that would be 2% of each income bucket, from $25,000 to $40,000. Table 1-34 also shows the percent of total households and number of NBC accounts in each income bucket for each member community for which the rate would be above 2% of that income bucket.

	2% Rate (2014$) =	$521		$626		$730		$834
	2% Rate (2012$) =	$500		$600		$700		$800
Municipality	Percent Census Households Below $25,000	Number Accounts Below $25,000	Percent Census Households Below $30,000	Number Accounts Below $30,000	Percent Census Households Below $35,000	Number Accounts Below $35,000	Percent Census Households Below $40,000	Number Accounts Below $40,000
Providence	37%	19,017	42%	21,610	47%	24,151	52%	26,871
Pawtucket	32%	8,094	38%	9,549	44%	11,202	50%	12,476
North Providence	25%	2,903	31%	3,547	35%	4,042	40%	4,639
Cumberland	15%	1,118	18%	1,321	22%	1,605	25%	1,848
Johnston	24%	1,502	29%	1,776	32%	1,989	36%	2,265
Lincoln	16%	1,079	20%	1,360	24%	1,651	28%	1,932
Central Falls	44%	2,574	51%	2,951	56%	3,277	61%	3,572
East Providence	27%	1,034	33%	1,242	37%	1,391	42%	1,569
Cranston	21%	31	25%	38	30%	45	34%	51
Smithfield	16%	5	19%	6	23%	7	27%	8
Member Communities Totals	31%	37,357	37%	43,399	42%	49,359	47%	55,232

Percent Census Household Below $x = (Census count in income bucket)/(Total Census Count) Note this is based on 2012$ from census data.

Number Households Below $x = (NBC Accounts)*(Percent Households Below $x) Assumes equal income distribution in census tract.

Table 1-34 – Income and Account Counts

Adjusting the income data for inflation to 2014 dollars, a bill of $626 would be unaffordable for 51% of the households in Central Falls and for a total of 37% of the households in the service area. A bill of $730 would result in unaffordable bills for 42%, or 49,359 accounts in the service area. A bill of $834 would be unaffordable for well over half of the residents of Providence, Pawtucket and Central Falls and would be unaffordable for a total of 55,232 accounts in the service area.

The NBC would like to maintain a sewer rate that is below 2% of household income for all of its ratepayers but this is not possible given current rates and the need to address its obligations for CSO control as required by federal regulations. NBC's recommended plan must balance improvements in water quality with rates that are not an undue burden upon its ratepayers. The NBC considers a sewer rate that exceeds 2% of any member community's median household income and/or a rate that exceeds 2% of the household income for more than one-third of its ratepayers to be unaffordable. From Table 1-34, this would be a target rate of $626.

NBC CSO Control Facilities Phase III Reevaluation

Chapter 2 – Development of a Hydraulic Model for the Bucklin Point Service Area

NBC CSO Control Facilities Phase III Reevaluation

Chapter 2 – Development of a Hydraulic Model for the Bucklin Point Service Area

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2.1 Introduction

This chapter summarizes the development of the Bucklin Point Service Area (BPSA) combined sewer hydraulic and hydrologic model using Mike Urban 2014 (MU) software.

The model serves as an integral tool in the re-evaluation of Phase III of the Narragansett Bay Commission (NBC) Combined Sewer Overflow (CSO) control plan. The re-evaluation includes 28 overflows not previously addressed by Phases I and II of the NBC's CSO control plan.

The BPSA overflows are located along the Blackstone, Seekonk and Moshassuck Rivers in the towns of Central Falls and Pawtucket. The BPSA area encompasses the entire cities of Central Falls and Pawtucket, as well as portions of Cumberland, East Providence Smithfield, and Lincoln, Rhode Island. A map of the BPSA area is depicted in Figure 2-1.

The hydraulic model network includes all NBC-owned interceptors in the Bucklin Point area. Smaller local community sewers have not been built into the hydraulic model network in detail. Instead, the community sewers are represented by their tributary flows at the appropriate interceptor connection locations.

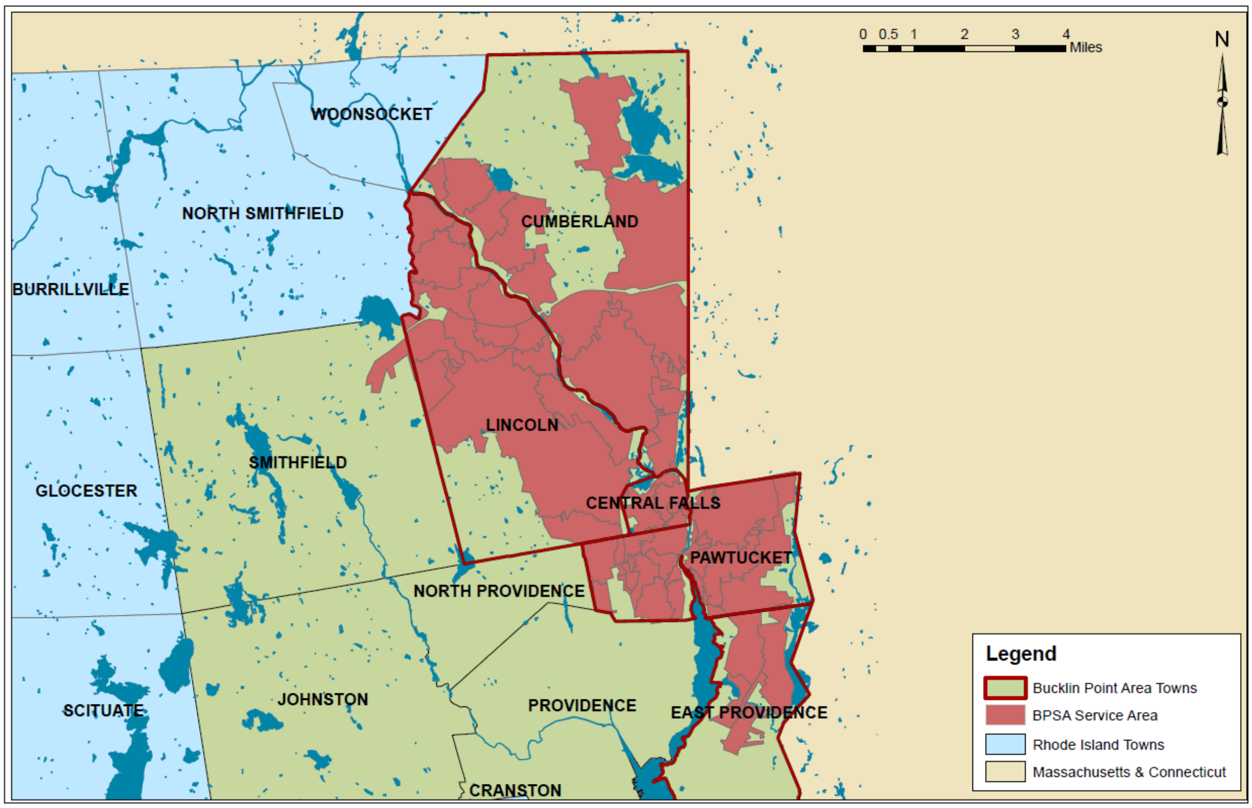


Figure 2-1 Bucklin Point Service Area

2.2 Model Development

2.2.1 Pipe Network

NBC's Geographic Information System (GIS) data files were reviewed for completeness and updated as needed. Missing rim elevations were estimated using the Digital Elevation Model (DEM) from the Rhode Island Geographic Information System (RIGIS). Record drawings were used to manually input missing data for the pipe network and manhole databases within GIS. Missing data included missing pipe dimensions, upstream and downstream invert elevations, pipe shape, and pipe material. The updated GIS files were then imported into Mike Urban software to create the hydraulic and hydrologic model of the service area.

The BPSA model was further refined with adjustment of manhole inverts to match the outgoing pipe's invert elevations, and manhole diameters assigned as a function of the pipes connected to the manholes to be consistent with the Rhode Island Department of Transportation standards. Subsequently, Saylesville, Omega Pond, Washington Highway, and the Bucklin Point Wastewater Treatment Facility (WWTF) influent pump station were incorporated into the model.

Overflow regulator structures were updated with current elevations and dimensions if they had been recently modified by construction of Phase I and II CSO improvements. The Phase 1-C Stormwater Management Model User's Manual (Section 2.6, Reference #9) regulator sketches and historical record drawings were used to represent new diversion structures, overflow pipes and outfalls in the BPSA model. This included the addition of weirs and orifices (which were named using the convention Weir_P190006, Weir_P190002, etc. and Orifice_P190006, Orifice_P190002, etc.). Where new manholes were added to the model and needed to be labeled with an ID, a reverse alphabetical suffix (beginning with Z) was used along with the most proximate manhole ID. The outfall pipes and outfall nodes were added into MU manually and were numbered using the prefix "OF_". A list of the Bucklin Point overflows and their respective interceptors and diversion structures is presented in Table 2-1.

Table 2-1 Bucklin Point Overflows and Regulator Locations

Overflow Number	Interceptor*	Diversion Structure
OF_002	BVI	Bucklin Point WTF Diversion
OF_101	BVI	River Street Diversion
OF_102	BVI	New Haven Street Diversion
OF_103	BVI	Aigan Street Diversion
OF_104	BVI	Charles Street Diversion
OF_105	BVI	Cross Street Diversion
OF_106	MVI	Emmett Street Diversion
OF_107	MVI	Richmond/Dexter Street Diversions
OF_201	BVI	East Street Diversion
OF_202	BVI	Roosevelt Ave Diversion
OF-203	BVI	Carnation Street Diversion
OF_204/OF_205	BVI	Central Street Diversion

Overflow Number	Interceptor*	Diversion Structure
OF_206	TPI	Blackstone Ave West Diversion
OF_207	BVI	Blackstone Ave East Diversion
OF_208	TPI	Exchange Street West Diversion
OF_209	BVI	Exchange Street East Diversion
OF_210/OF_211	TPI	Main Street West Diversion
OF_212	BVI	Main Street East Diversion
OF_213	TPI	East Ave Diversion
OF_214	TPI	Jenks Way Diversion
OF_217	TPI	Tidewater/Merry Street Diversion
OF_215	BVI	Division Street East Diversion
OF_216	BVI	Woodland/School Street Diversion
OF_218	BVI	Bucklin Brook Diversion
OF_219	MVI	Esten Street Diversion
OF_220	MVI	Moshassuck Street Diversion
*BVI=Blackstone Valley Interceptor, MVI=Moshassuck Valley Interceptor & TPI=Taft-Pleasant Interceptor		

Further detail of the BPSA model development is included in Appendix 3.

2.2.2 Catchment Areas

The catchment areas within the BPSA model were defined by the catchment delineations previously developed during the 2005-2006 RJN flow metering study (Section 2.6, Reference #6). Each catchment represents the part of the overall service area that drains to a particular regulator. The catchment naming convention in the BPSA model is consistent with the BETA metering report catchment naming convention where:

- BVI=Blackstone Valley Interceptor
- MVI=Moshassuck Valley Interceptor
- EPI=East Providence Interceptor

Figure 2-2 shows the locations of the BPSA model catchments.

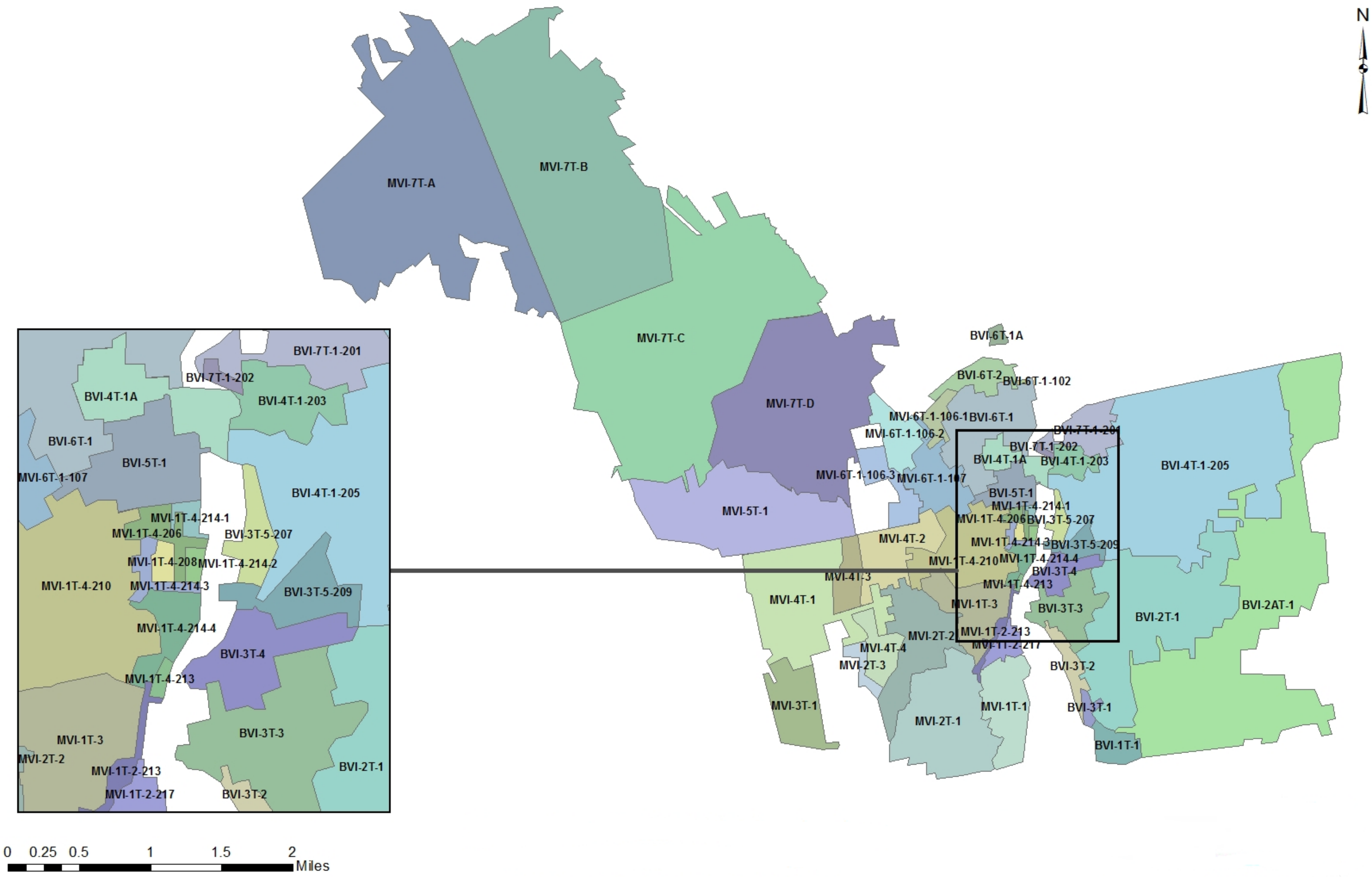


Figure 2-2 Bucklin Point Service Area Model Catchments

2.2.3 Model Hydrology

Since the BPSA model did not include a detailed local community sewer network within each regulator catchment area, each community sewer was represented by a compensatory storage volume. This was achieved by creating a manhole storage node to represent the in-pipe storage within each catchment and routing all flows through the node. This approach served to balance the catchment flow volumes during the wet weather events and prevented over prediction of overflows at the downstream regulators. In the model these nodes were given the same identifier as the catchments they represented.

For each model catchment, the impervious and pervious land area percentages were calculated in GIS using the RIGIS impervious raster image (Section 2.6, Reference #4). The impervious and pervious percentages for each catchment were input in the Mike Urban Kinematic Wave Model in the "AIFlat" and "APHigh" parameters, respectively. These allocations represent the variable runoff response times that are recognized when modeling mixed land uses over urban and suburban catchments.

A majority of the catchments within the BPSA model area are identified as combined-sewer catchments. The exceptions are MVI-3T-1, MVI-4T-1 through MVI-4T-4 and MVI-5T. Based on the 2006 RJN Capacity Analysis Report (Section 2.6, Reference #6), these catchments are identified as separated sanitary sewer areas.

In keeping with standard practice developed in the Fields Point Sewer Area model, the drainage area for the six sanitary sewer catchments was allocated as 10-15% of the total catchment area. The drainage area for the combined sewer catchments was allocated as the entire catchment area. Table 2-2 summarizes the impervious and pervious allocations for all BPSA catchments.

Table 2-2 BPSA Model Catchments Properties

Model Catchment ID	Imp. Steep (%)	Imp. Flat (%)	Perv. Medium (%)		Model Catchment ID	Imp. Steep (%)	Imp. Flat (%)	Perv. Medium (%)
BVI-1T-1	9	9	1		MVI-1T-3	20	40	5
BVI-2AT-1	8	8	1		MVI-1T-4-206	20	40	5
BVI-2T-1	13	13	1		MVI-1T-4-208	15	15	5
BVI-3T-1	9	9	1		MVI-1T-4-210	40	40	10
BVI-3T-2	10	12	1		MVI-1T-4-213	15	40	5
BVI-3T-3	20	20	1		MVI-1T-4-214-1	10	5	5
BVI-3T-4	21	21	1		MVI-1T-4-214-2	10	5	5
BVI-3T-5-207	15	15	1		MVI-1T-4-214-3	10	5	5
BVI-3T-5-209	8	10	1		MVI-1T-4-214-4	10	5	5
BVI-4T-1-203	30	35	1		MVI-2T-1	20	20	1
BVI-4T-1-205	28	28	1		MVI-2T-2	23	23	1

Model Catchment ID	Imp. Steep (%)	Imp. Flat (%)	Perv. Medium (%)		Model Catchment ID	Imp. Steep (%)	Imp. Flat (%)	Perv. Medium (%)
BVI-4T-1A	10	10	1		MVI-2T-3	10	15	1
BVI-5T-1	50	45	1		MVI-3T-1	40	40	20
BVI-5T-ADD	50	45	1		MVI-4T-1	60	5	1
BVI-6T-1	40	40	1		MVI-4T-2	60	5	1
BVI-6T-1-102	5	8	0		MVI-4T-3	60	5	1
BVI-6T-1A	5	8	0		MVI-4T-4	60	5	1
BVI-6T-2	28	28	1		MVI-5T-1	0.6	0.6	20
BVI-7T-1-201	30	30	1		MVI-6T-1-106-1	20	10	5
BVI-7T-1-202	20	20	1		MVI-6T-1-106-2	12.1	10	5
MVI-1T-1	15	40	5		MVI-6T-1-106-3	12.1	10	5
MVI-1T-2-213	20	40	5		MVI-6T-1-107	20	5	5
MVI-1T-2-217	12	15	5					

Key: Imp. – Impervious

Perv. - Pervious

2.2.4 Dry Weather Flow

Water usage data for the cities of Central Falls and Pawtucket were analyzed for the purpose of representing dry weather flow in the BPSA model. The water usage data (in HCF, hundred cubic feet) was provided for the model period April 1, 2005 through January 31, 2006. The data represented usage across all water users including residential, commercial and industrial, but included no information regarding the type of user at each location.

Using the data provided, the effective water demand was found to be approximately 80 gallons per capita day (gpcd). The existing population for each catchment area was estimated using the most recent available census occupancy rates in the GIS database (Section 2.6, Reference #3). The per-capita water usage value and population data were incorporated in the model.

The BPSA dry weather flow contributions were representative of current flows and did not include any projected population changes. The cities in this area are considered mature and built-out; therefore no significant population or land use changes would be expected. In addition, the dry weather flow volumes are small as compared to the wet weather flow volumes, therefore the effect of any DWF changes is presumed to be minimal.

2.3 Model Calibration

The BPSA model was calibrated to so that modeled results were comparable to observed results for 2005 rainfall events. The 2005 rainfall events had been analyzed previously to update the previous hydraulic model in 2012 (Section 2.6, Reference #5). The 2005 RJN data for 15 flow meters within the BPSA interceptor network were used in calibration of the BPSA model. Two of the 2005 rainfall events were chosen for model calibration based on the following criteria:

- varying durations;
- total rainfall volumes greater than 1.5-in;
- peak intensities greater than 0.4 in/hr; and
- adequate coverage across all meters in the BPSA area (several meters were lacking data for the given storms but two storms provided wider coverage than the rest).

Table 2-3 summarizes the characteristics of the two storms selected for calibration of the BPSA model.

Table 2-3 Calibration Rainfall Events-BPSA Model*

Date/Time	Duration (Hours)	Total Rainfall (inches)	Peak Intensity (inches/hr)	Return Period Based on TP40
4/2/2005 5:15	8	2.05	0.45	<1-year, 6 hour
9/15/2005 9:00	4	1.7	0.69	~1-year, 6 hour
*Recreated from the Phase 2 Model Report (Section 2.6, Reference #5)				

The Chartered Institution of Water and Environmental Management (CIWEM) modeling guidelines were adopted as a standard for calibration. Calibration of the BPSA model using the RJN flow meter data started at the upstream reaches of the three BPSA interceptors (BVI, MVI and TPI) and progressively continued downstream to the Bucklin Point WWTF. The calibration procedure was focused on capturing the peak flows and the rainfall response time to peak at each meter. The calibration procedure also focused on redistributing the impervious area percentages between the steep and flat categories in order to match the peak timing and intensity of flow at each meter.

2.3.1 Calibration Summary

Table 2-4 and Table 2-5 summarize the results of the calibration. In the tables, the modeled results are compared to the observed (metered) results for the two selected 2005 rainfall events. The CIWEM calibration guideline criteria applied were as follows:

- +25% to -15% acceptable variance for peak flow ; and
- +20% to -10% acceptable variance for volume of flow.

Table 2-4 Calibration Summary for 9/15/2005 Rainfall Event

Meter	9/15/2005 Rainfall Event					
	Total Volume (MG) Modeled	Total Volume (MG) Metered	CIWEM Compliance	Peak Discharge (CFS) Modeled	Peak Discharge (CFS) Metered	CIWEM Compliance
BVI-1T	51.4	26.6	48%	160.4	149.6	7%
BVI-2AT	8.9	-	-	55.4	-	-
BVI-2T	6.9	-	-	52	-	-
BVI-3T	41.6	21.9	47%	142.4	133.5	6%
BVI-4T	20	10	50%	61.9	62	0%
BVI-5T	1.3	0.9	31%	9.1	10.5	-15%
BVI-6T	6.9	5.4	22%	16	21.9	-37%
BVI-7T	0.8	0.5	38%	3.6	3.6	0%
MVI-1T	5.2	3.5	33%	35.3	32.9	7%
MVI-2T	9.8	6.4	35%	33.7	34.8	-3%
MVI-3T	0.6	0.5	17%	4.1	3.8	7%
MVI-4T	6	5	17%	24.7	31.4	-27%
MVI-5T	3.9	3.8	3%	15.6	12.9	17%
MVI-6T	2.2	1.4	36%	10.6	11	-4%

Note: cells shaded green confirm compliance with CIWEM Guidelines

Table 2-5 Calibration Summary for 4/2/2005 Rainfall Event

Meter	4/2/2005 Rainfall Event					
	Total Volume (MG) Modeled	Total Volume (MG) Metered	CIWEM Compliance	Peak Discharge (CFS) Modeled	Peak Discharge (CFS) Metered	CIWEM Compliance
BVI-1T	95.6	66.7	30%	152.4	138.6	9%
BVI-2AT	16.2	13.3	18%	46.1	59.4	-29%
BVI-2T	10.5	15.8	-50%	30.8	101.8	-231%
BVI-3T	82.5	-	-	135.6	-	-
BVI-4T	41.2	34.5	16%	61.2	63.3	-3%
BVI-5T	2.5	2.7	-8%	6.1	12	-97%
BVI-6T	16.2	11.8	27%	21.6	29.7	-38%
BVI-7T	1.2	1.7	-42%	2.9	4.4	-52%
MVI-1T	12.5	-	-	27.6	-	-
MVI-2T	17.2	-	-	31.9	-	-
MVI-3T	0.9	1.4	-56%	2.6	3.6	-38%
MVI-4T	11.5	11.9	-3%	23.4	27.3	-17%
MVI-5T	8.3	8.5	-2%	16.5	14.9	10%
MVI-6T	4.4	2.6	41%	10.4	11.2	-8%

Note: cells shaded green confirm compliance with CIWEM Guidelines

The comparisons show that the BPSA model is closer to CIWEM compliance for peak flows than for total volume. This calibration approach was intentional since peak flows are more applicable to the performance of CSOs. The overall shapes of the hydrographs also generally confirm that the mass balance of the inflows is adequately represented in the BPSA model and the system's modeled response to rainfall correlates well with the system's metered results. Further details of the calibration are included in Appendix 3.

2.3.2 Calibration Limitations-Peak Flow Intensity and Timing

The BPSA model demonstrates limitations in representing the timing and peak flow variability at all meters located along the BVI, as well as at meters MVI-1T, MVI-2T and MVI-6T.

These limitations may be the result of several factors inherent to the BPSA model development. The catchments range in size between 1 and 1,000 ac (averaging approximately 100 ac). In almost all cases, there are no local community pipe networks detailed in the model. While the presumed storage volumes in the local pipe networks is being represented by the storage nodes described in Section 2.2.3, the flow generated by the hydrologic models remains loaded immediately upstream of the regulator structures. The combination of the large catchment areas and the direct loading to the regulator structures in the model most likely contributes to the reduced level of sensitivity in the results. Existing system retention and controls within the upstream network are not included, therefore the runoff immediately arrives at the regulator structure, making the timing of the regulator operations difficult to represent. However, the calibration results do show the overall magnitude of the modeled wet weather response is sufficiently comparable with the observed (metered) data which enables the model to be used for overflow prediction at all BPSA regulators.

2.4 Reevaluation of CDRA Recommended CSO Plan

In order to reevaluate the recommended Phase III CSO alternative presented in the 1998 Conceptual Design Report Amendment (CDRA) (Section 2.6, Reference #8), the BPSA model network was updated to 2011 conditions to account for Phases I and II constructed improvements. NBC carried out a regulator modification project in 2011 (Contract 306.00C) which combined overflows OF_219 and OF_220 into one regulator and overflow pipe. A new baseline 2011 model was previously developed with these regulator changes and the resulting overflow volumes for the 3-month design storm were modeled. These results are presented in Table 2-6.

Table 2-6 3-Month Storm Overflow Volumes

Overflow No.	Interceptor	PHASE III BPSA Model 2011 (MG)
OF_035	-	0.8
OF_036	-	0
OF_039	-	0.5
OF_056	-	0.4
OF_101	BVI	0.4
OF_103	BVI	4.8
OF_104	BVI	0.5
OF_105	BVI	1.5
OF_201	BVI	1.3
OF_202	BVI	0.2
OF_203	BVI	0.4
OF_204	BVI	0.2
OF_205	BVI	12.7
OF_207	BVI	0

Overflow No.	Interceptor	PHASE III BPSA Model 2011 (MG)
OF_209	BVI	0
OF_212	BVI	0.6
OF_215	BVI	1.6
OF_216	BVI	0
OF_218	BVI	12.5
OF_002	BVI	0
OF_107	MVI	0.4
OF_206	MVI	0.1
OF_208	MVI	0
OF_210	MVI	3.1
OF_211	MVI	4
OF_213	MVI	2
OF_214	MVI	1.3
OF_217	MVI	2.7
OF_220	MVI	4.5
	Total (MG)	**56.49**

The 1998 CDRA (Section 2.6, Reference #8) outlined the Phase III recommended alternative for CSO Control in CDRA Section 10.1.4. The CDRA alternative included the Pawtucket Tunnel (26-feet diameter) to be constructed along the bank of the Blackstone and Seekonk Rivers. The tunnel would store flows from five overflows; OF210, OF_211, OF_213, OF_214 and OF_217. Five drop shafts would be required for construction and operation of the Pawtucket Tunnel.

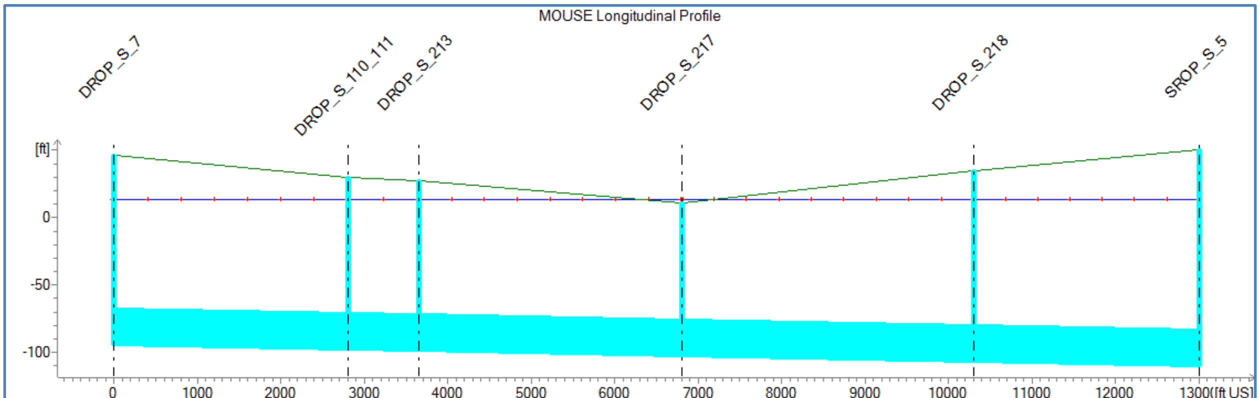
Phase III also included the construction of two CSO interceptors to feed into the Pawtucket Tunnel at its upstream end. The first, along Middle Street, would convey flows from overflows OF_201, OF_203 & OF_205 (on the East side of the Blackstone River). The second would be constructed along High and Cross Streets and would convey flows from OF_103, OF_104 and OF_105 (along the West side of the Blackstone River).

A third CSO interceptor was proposed under Phase III to convey flows from OF_219/OF_220 (which were combined in 2011 as part of Phase II). The CSO interceptor would be comprised of a pump station, approximately 4,800 LF of 48-inch force main and approximately 3,500 LF of

54-inch gravity main to convey overflow OF219/OF_220 to the Pawtucket Tunnel into the OF_217 drop shaft.

The infrastructure associated with the CDRA recommended alternative for Phase III was incorporated into the BPSA model and the model was then run with the 3-month design storm. This alternative reduced the overflow volume in the model by approximately 93%, bringing the total overflow volume to approximately 3.56 MG during the 3-month design storm.

A long section of the proposed Phase III Pawtucket Tunnel (26-feet diameter) from the BPSA model is presented in Figure 2-3. The tunnel is clearly surcharged in the model during the 3-month storm, suggesting a larger diameter would be necessary to prevent the surcharge. The CDRA Phase III recommended alternative was then modeled with the Pawtucket Tunnel with a diameter of 28-feet. The BPSA model results are presented in Figure 2-4.



Link ID	PAWTUCKET_TUN_1	....	PAWTUCKET_TUN_3	PAWTUCKET_TUN_4	PAWTUCKET_TUN_5	
Link Diameter	26.0000					
Shaft ID	DROP_S_7	DROP_S_110_111	DROP_S_213	DROP_S_217	DROP_S_218	SROP_S_5
Shaft Diameter	30.0000					
Ground Level	46.00	30.21	27.14	11.00	35.00	50.00
Invert Level	-94.00	-97.36	-98.38	-102.16	-106.36	-109.60
Link Slope						

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Figure 2-3 Phase III Level of Service in the 26-foot Diameter Pawtucket Tunnel

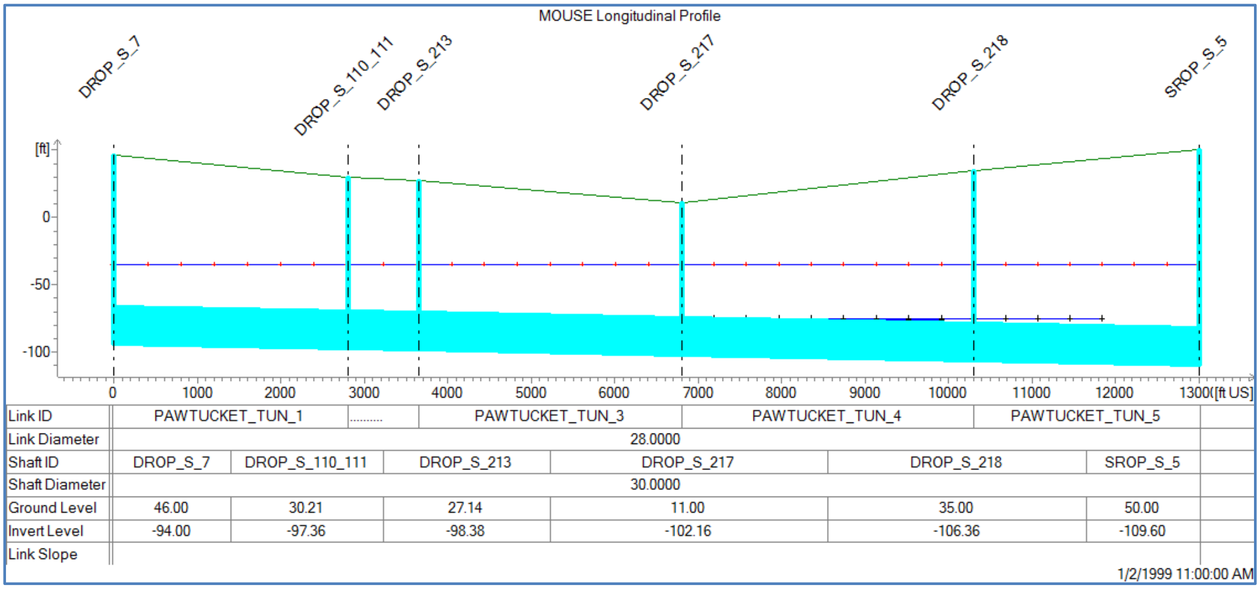

Figure 2-4 Phase III Level of Service in a 28-foot Diameter Pawtucket Tunnel

2.5 Conclusions

The BPSA model has been sufficiently developed and calibrated for planning decisions required in this stage of the Phase III CSO reevaluation. The level of calibration is considered acceptable for the purpose of re-evaluating Phase III CSO alternatives based on CIWEM guidelines and the intent for the use of the model results. Generally, meter volume calibrations are conservative and peak flows correlate well between modeled and metered results. However, there are recognized limitations of the model due to the size of the system, the number of flow meters available and the approximations associated with modeling large catchments loaded directly onto the NBC Interceptor Sewer system. Discrepancies are due to the following:

- dynamic system interactions;
- operational conditions of the NBC sewers; and
- the simplification of the model.

It would be appropriate to continue to develop and enhance the model in more detail to support design of specific Phase III elements. Therefore, this planning level BPSA model is suitable for the Phase III reevaluation planning, but not progressive detailed design.

For the planning level reevaluation, the Phase III recommended alternative was incorporated into the BPSA model and a simulation was performed using the three-month design storm. The model results indicate that the CDRA recommended alternative for Phase III, which includes the 26-ft diameter Pawtucket Tunnel, would reduce the overflow volume by approximately 93%, bringing the total overflow volume to approximately 3.56 MG. A second simulation was performed using the same Phase III recommended alternative except a 28-ft diameter Pawtucket Tunnel was modeled. This second simulation indicates that a 28-ft tunnel would be necessary to capture the entire overflow volume generated during the 3-month design storm.

2.6 References

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NBC CSO Control Facilities Phase III Reevaluation

Chapter 3 – Pollutant Loading & Water Quality

NBC CSO Control Facilities Phase III Reevaluation

Chapter 3 – Pollutant Loading & Water Quality

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3.1 Introduction

This chapter documents the update to the receiving water quality model to support the reevaluation of the NBC's Phase III CSO Plan. The water quality model update incorporates the benefits of the recent NBC Phase I and Phase II CSO improvements into the model. Fecal Coliform (FC) loadings reported herein were used for the calibration of the water quality model as well as for model simulations using the 3- and 12-month design events in post-Phase I, post-Phase II system conditions and in proposed Phase III alternative phasing analysis. For detailed water quality model results refer to Appendix 4. BOD and TSS total loads per CSO program phase and design storm are also included in this analysis; however, the fate and transport of these pollutants were not included in the reporting of the receiving water quality modeling results.

3.2 Fecal Coliform Loadings in the Calibration of the Water Quality Model

The model calibration period for FC ranged from March 16th to August 12th, 2009. This period was selected because the system was operating with fully completed Phase I facilities and because it had concurrent water quality, tributary flow and precipitation data as well as other information necessary to run and calibrate the water quality model. Additional information included sea level and flow velocities and flow direction within the Upper Narragansett Bay (Upper Bay) available from NOAA and USGS gauges. The start and end dates of the calibration period were selected based on the following criteria:

- The time period was approximately five months after the Phase I facilities came on-line, which allowed sufficient time for the Upper Bay to reach a new steady state regarding pollutant loadings and receiving water quality. This provides a post-Phase I baseline water quality condition in the Upper Bay for model calibration; and

- The selected dates also provided multiple dry weather days before and after the calibration period, which act as boundary conditions for the pollutant loadings included in the model.

Rainfall data for the calibration period was obtained from the Field's Point and Bucklin Point WWTF's rain gauges and provided by NBC. This data was supplemented with information from the rain gauge at the T.F. Green Airport, when necessary. The rainfall data was then used to run hydraulic simulations for the Field's Point system (in post Phase I conditions) and the Bucklin Point system (in existing conditions) in order to obtain CSO hydrographs during the calibration period.

Field's Point and Bucklin Point WWTF's effluent flow data during this period was provided by NBC. Maximum primary treatment capacity in Post-Phase I conditions at the Field's Point and Bucklin Point WWTFs is 200MGD and 116MGD, respectively.

A detailed description of the pollutant loadings used during the calibration period is provided in the following subsections.

3.2.1 Loads from CSO Overflows:

The Field's Point and Bucklin Point hydraulic models were run for the calibration period using the available rainfall data. CSO hydrographs and pollutographs were generated for each structure assuming a constant FC concentration of 250,000MPN/100mL. This concentration is consistent with the geometric mean for CSO discharges in the NBC's Draft Water Quality Report of 2013 that was reported at 249,372MPN/100mL. A constant FC concentration value was applied because significant differences between first flush, mid-storm, and end of storm samples were not present in most of the CSO samples collected by NBC between 2005 and 2013 as reported in the 2013 Draft Water Quality Report. Additionally, in this report, first flush is defined as the first thirty minutes from the beginning of the storm while the hydraulic model was run with one-hour time steps to reduce computational time for the five-month-long simulation for model calibration. While capturing the first flush phenomenon is ideal, it is highly unlikely that results would change at all at the different reporting stations with respect to just using an event mean concentration. The geographic and temporal scale of the model runs and, most significantly, the dilution power of the ocean waters (many orders of magnitude larger than the CSO flow contributions) make the first flush impact negligible at locations of concern located as far as Conimicut Point, which see the water quality impact several days after the spill occurred.

Figure 3-1 and Figure 3-2 depict the location of the CSO outfalls in the Field's Point and Bucklin Point service areas, respectively. Figure 3-3 and Figure 3-4 depict the composite CSO pollutographs from the Field's Point and the Bucklin Point system areas during the calibration period, respectively. Peaks in Figure 3-3 and Figure 3-4 represent increases in CSO FC loadings due to overflows. Bucklin Point CSO's have a higher FC loading than the FP CSO's because of the capture of the FP CSO's in the Phase I tunnel.

Figure 3-1. CSO outfalls in the Field's Point system area

Figure 3-2. CSO outfalls in the Bucklin Point system area

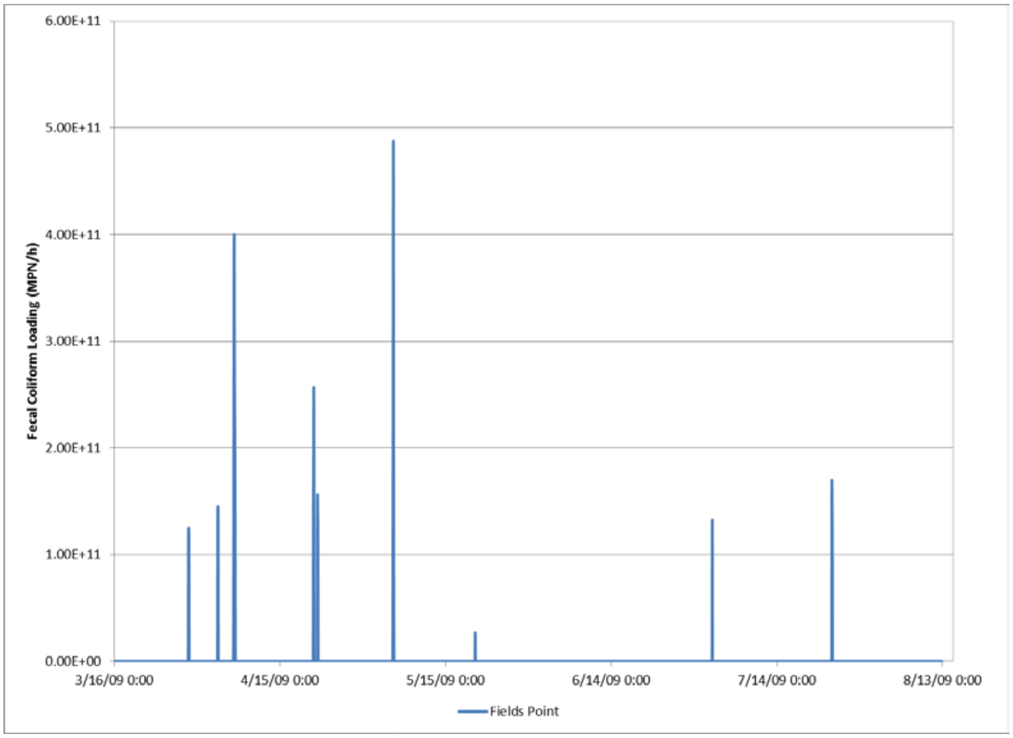

Figure 3-3. Field's Point system Fecal Coliform CSO loadings during the water quality model calibration period

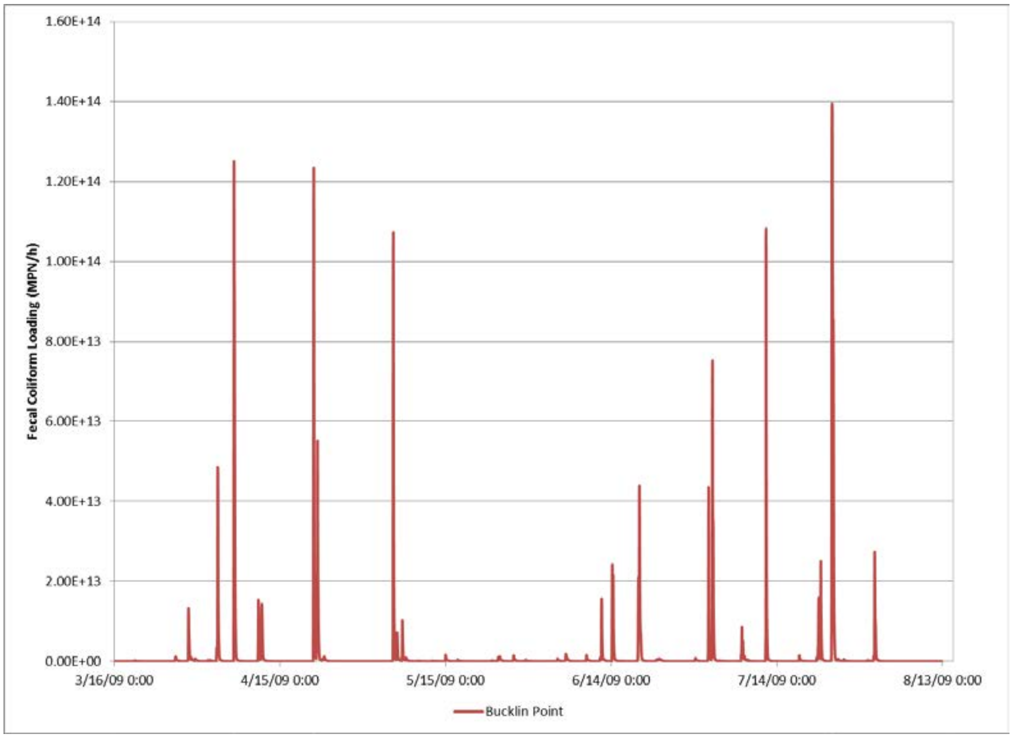

Figure 3-4. Bucklin Point system FC CSO loadings during the water quality model calibration period

3.2.2 Loads from Waste Water Treatment Facilities

The two NBC-owned waste water treatment facilities discharging to the Upper Bay, Field's Point and Bucklin Point, were included in the water quality model during the calibration run. Due to a lack of reliable, long-term effluent flow data, the East Providence WWTF was not included as a source during this period. It was deemed that the impact of this facility in model calibration was negligible (around 0.001% of the overall FC load in design storms) and would not affect any of the calibration parameters in the model. During design storms, loads from the East Providence WWTF were included for completeness as a fraction of the Bucklin Point WWTF FC loads and described in Section 3.3.1.2.

Pollutographs from the waste water facilities were generated assuming all effluent flows received primary or secondary treatment as peak inflow to the WWTF never exceeded maximum treatment capacity during the calibration period. A constant FC concentration of 4MPN/100mL was assumed for flows undergoing secondary treatment and 40MPN/100mL was assumed for flows only going through primary treatment. These FC concentrations were assumed for consistency with the effluent FC concentrations reported at the Field's Point WWTF in the NBC's Draft Water Quality Report of 2013. Primary treatment capacities at Field's Point and Bucklin Point WWTF are 200MGD and 116 MGD, respectively while secondary treatment capacities are 77MGD and 46MGD, respectively.

3.2.3 Pollutant Loads from Tributary Rivers

The main tributaries to the Upper Bay are the Blackstone River discharging to the north of the Seekonk River, the Moshassuck River, the West River, and the Woonasquatucket River which all merge prior to discharging to the Providence Harbor, the Ten Mile River in East Providence and the Pawtuxet River, which discharges between the Field's Point WWTF and Conimicut Point.

NBC periodically collects samples along the Blackstone River, Moshassuck River, West River, and the Woonasquatucket River upstream of the CSOs within the NBC's system shown in Figure 3-5.

These four upstream locations were used to establish tributary, background water quality conditions during model calibration as they are upstream of the NBC's CSO regulators and correspond to the following sampling stations:

- Whipple Bridge on the Blackstone River (site B-2 in Figure 3-5);
- Higginson Avenue Bridge on the Moshassuck River (site M-1 in Figure 3-5);
- Douglas Avenue Bridge on the West River (site WE-10 in Figure 3-5); and
- Manton Avenue Bridge on the Woonasquatucket River (site W-9 in Figure 3-5).

Additionally, NBC collects samples at one location (Broad Street) on the Pawtuxet River near the confluence with the Providence River identified as site PX-13 in Figure 3-5. Data from this sampling site was also used to estimate tributary FC loadings to the Upper Bay.

While the NBC did not collect flow data during the sampling program, concurrent flow data was obtained from USGS flow gauges located on each of the tributary rivers. The USGS gauging locations do not necessarily correspond with the exact same location as the water quality sampling stations and as a result of this geographic discrepancy, scaling factors based on watershed area were applied to the flow data so that it would more accurately reflect the NBC's FC sampling locations. The USGS flow gauge locations are depicted in Figure 3-5 and the flow scaling factors are provided in Table 3-1.

While tributary flows were available in 15-minute intervals, the FC concentration measurements were available at a much larger time step of approximately one week, which corresponds to the frequency NBC sampled tributaries upstream of CSOs during the model calibration period.

For the purposes of developing loads, the tributary concentrations were held constant over time between observations while the flow varied. There is some uncertainty with this approach, however it is a reasonable estimate based on available data and the externally developed flow-concentration relationships.

The Ten Mile River is not sampled by NBC because it does not have any CSO discharges to that water body. In lieu of available observations in the Ten Mile River a constant concentration of 20 MPN/ 100 mL was assumed for the calibration period. This value is the approximate dry weather geomean from station TM8, which is the Omega Pond outlet near the confluence with the Seekonk River obtained as part of the *Draft Surface Water Monitoring in the Ten Mile River Watershed Data Report* of April 2011 by the Rhode Island Department of Environmental Management (RIDEM). The TMDL study did not correspond to the present time period of interest and was not sampled sufficiently in space or time to develop a time varying estimate of concentration with varying flows and as such a lower bound of available dry weather samples was used. A constant concentration approach was adopted because concurrent sampling data was not available for the calibration period and helped simplify the long duration calibration runs. In the same study by RIDEM, geomean wet weather FC values for station TM-8 were reported at 78MPN/100mL, which is the same order of magnitude as the dry weather geomean. Based on these reported concentrations and small flows in the Ten Mile River, it becomes apparent that it is a marginal player in the overall water quality of the Upper Bay (around 0.05% of the overall FC loading during design events) and would not affect any of the model calibration parameters.

Figure 3-5. NBC sampling locations upstream of CSOs and USGS flow gauges used to calculate tributary FC background loadings

Table 3-1. Range of FC concentrations and flow scaling factors used to estimate background FC loadings from tributaries

Tributary	FC concentration ranges in tributary samples (MPN/100mL)	USGS Flow Gauge Number	Flow Scaling Factor
Moshassuck River	30-1,500	USGS 01114000	0.377
Woonasquatucket River	30-4,300	USGS 01114500	1.168
West River	30-46,000	USGS 01114000	0.208
Blackstone River	30-430	USGS 01113895	0.985
Ten Mile River	20	USGS 01109403	1.044
Pawtuxet River	30-930	USGS 01116500	1.050

3.2.4 Pollutant Loads from Separated Storm Sewers

Contributions from separated areas within the CSO service area were not included in the calibration runs as the hydraulic model only includes combined service areas within NBC's jurisdiction and the hydraulic model used to compute storm water loadings in 1993 and 1998 is no longer functional. It was anticipated that the relative weight of storm water FC contributions during the calibration period was very small because of major post-phase I CSO loadings during wet weather events and continuous dry and wet weather loadings from WWTF's and tributary rivers. Storm water loadings from areas outside of the CSO area are included in the loads for the tributary rivers.

However, contributions from separated areas were accounted for in the design event loading computations to maintain consistency with the design storms used in the 1993 and 1998 water quality modeling work by NBC. Loadings for the same storms are available in the *"Receiving Water Quality Modeling for Narragansett Bay Commission Combined Sewer Overflow Facilities"* and *"Receiving Water Quality Modeling of Combined Sewer Overflow Impact"* reports of 1993 and 1998 by Applied Science Associates (ASA). Figure 3-6 shows the stormwater discharge points in the water quality model.

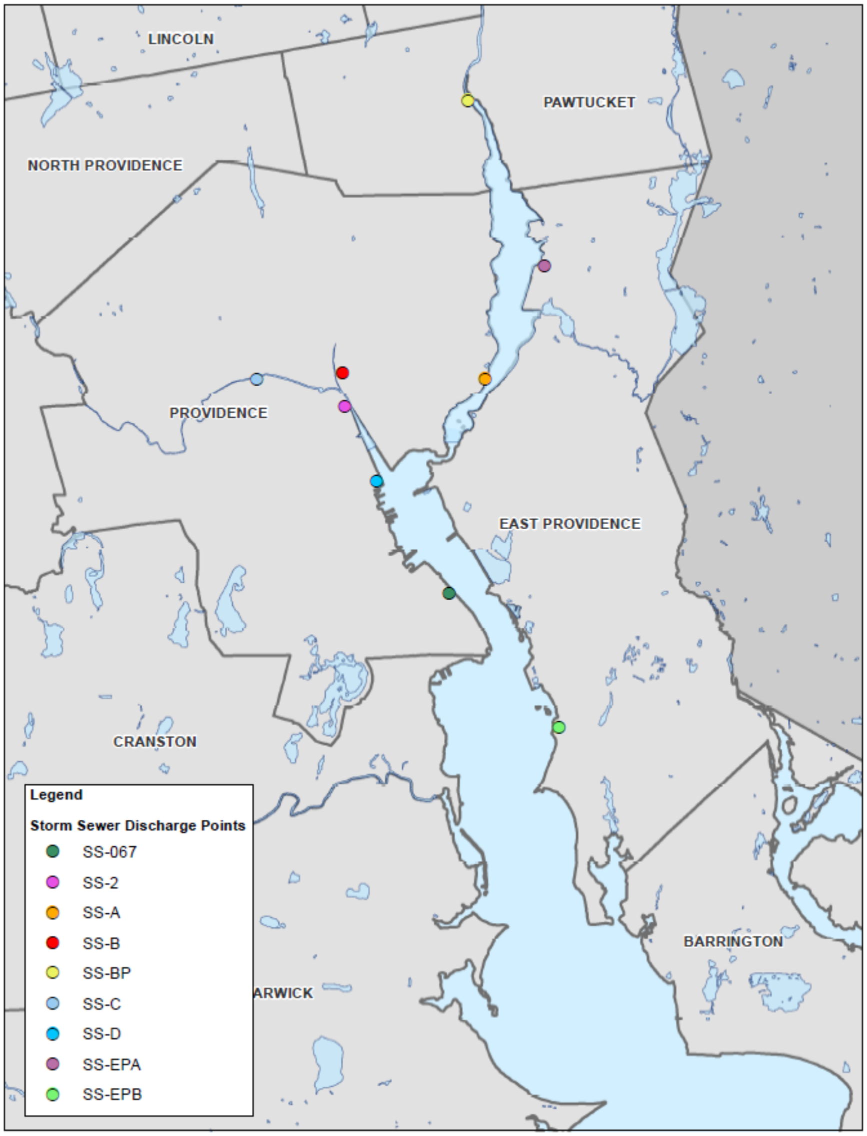

Figure 3-6. Location of storm water discharges in the water quality model

3.2.5 Pollutant Loads from Other Point Sources and Non-Point Sources

During the data gathering process, RIDEM was contacted with regard to facilities that have permitted discharges to the Upper Bay and its tributary rivers associated with construction and industrial activity. Currently, there are twelve (12) permitted stormwater discharges associated with construction activity and forty-three (43) permitted stormwater discharges associated with industrial activity that discharge stormwater directly into the Bay or its tributary rivers. None of these facilities sample their stormwater discharges, but both General Permits for stormwater discharges associated with construction activity and industrial activity enforce strict regulations for reducing concentrations of pollutants in stormwater discharges. As such, it is unlikely that any of the permitted facilities have significant pollutant loadings to the Bay or the Bay's tributary rivers and this has been reflected in the modeling of inflows. This assumption is consistent with previous water quality modeling efforts by NBC.

3.3 Fecal Coliform Loadings during Design Storms

For the computation of design storm FC loadings, four types of pollutant loadings were included in the water quality model:

- Background tributary flows;
- CSO overflows;
- Storm water flows; and
- WWTF flows

The design storms with their respective loadings were run for three different program phases:

- post-Phase I conditions;
- post-Phase II conditions; and
- Phase III alternative phasing analysis.

3.3.1 Post-Phase I System Conditions

3.3.1.1 Tributary Rivers Background Water Quality

Design Storm Synthetic Hydrograph Generation:

Development of synthetic river hydrographs was necessary to determine the loading time-series in each river and develop tributary pollutographs for the design storm. To create these, several storms similar to the 3- and 12-month design events with concurrent FC sampling data were identified using rainfall and FC sampling data provided by the NBC in the Field's Point and the Bucklin Point service areas. Time to peak, receding time, baseflow, and peak flow were identified per design storm and tributary. Subsequently, the 6-hour maximum rainfall accumulation for these candidate storms was computed to align with the design storm durations and in order to scale peak flows proportionally to the design storm rainfall depth. Since flows were obtained from the USGS gauges in Figure 3-5, the same flow scaling factors were used to adjust flows a second time, proportionally to their respective drainage areas at the sampling stations listed above. Synthetic hydrographs by tributary are presented in Figure 3-7 through Figure 3-12.

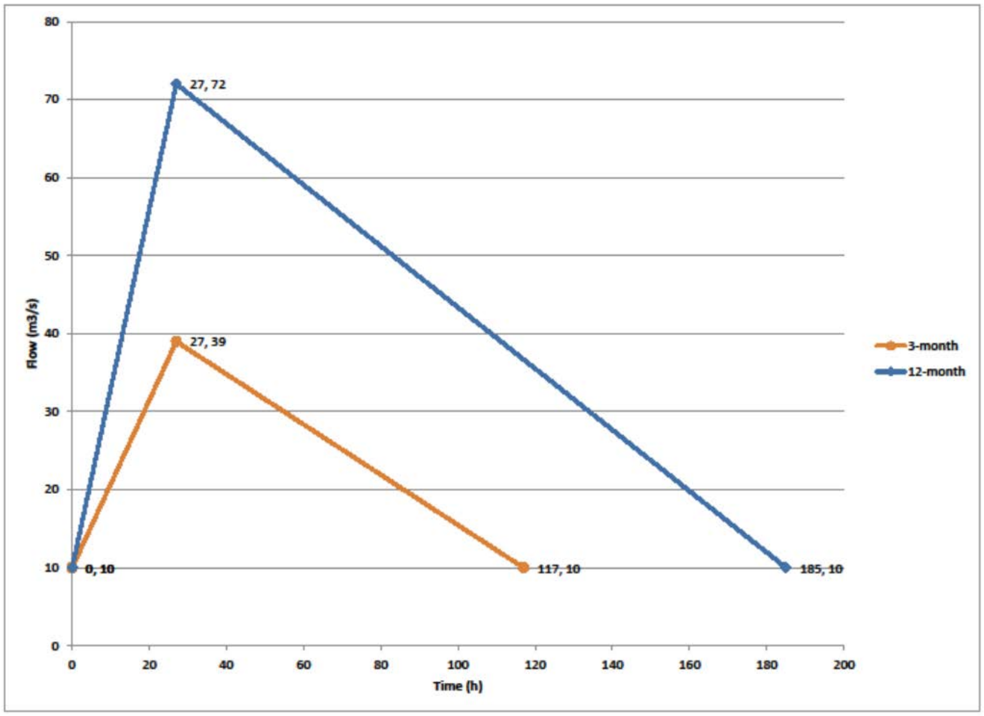

Figure 3-7. Blackstone River design storm synthetic hydrograph at sampling station B-2

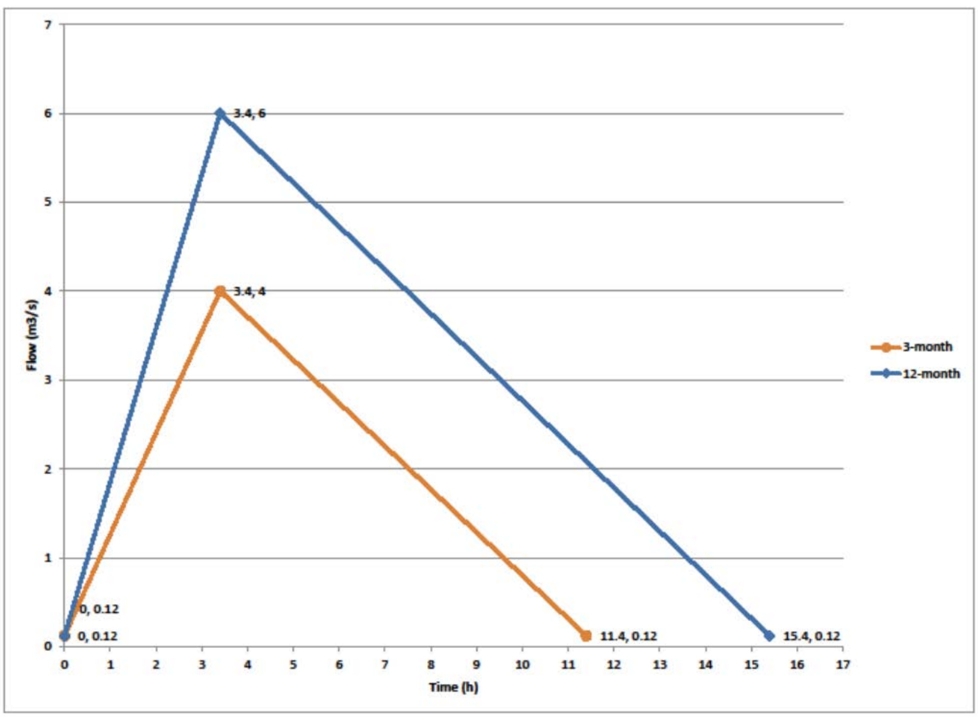

Figure 3-8. Moshassuck River design storm synthetic hydrograph at sampling station M-1

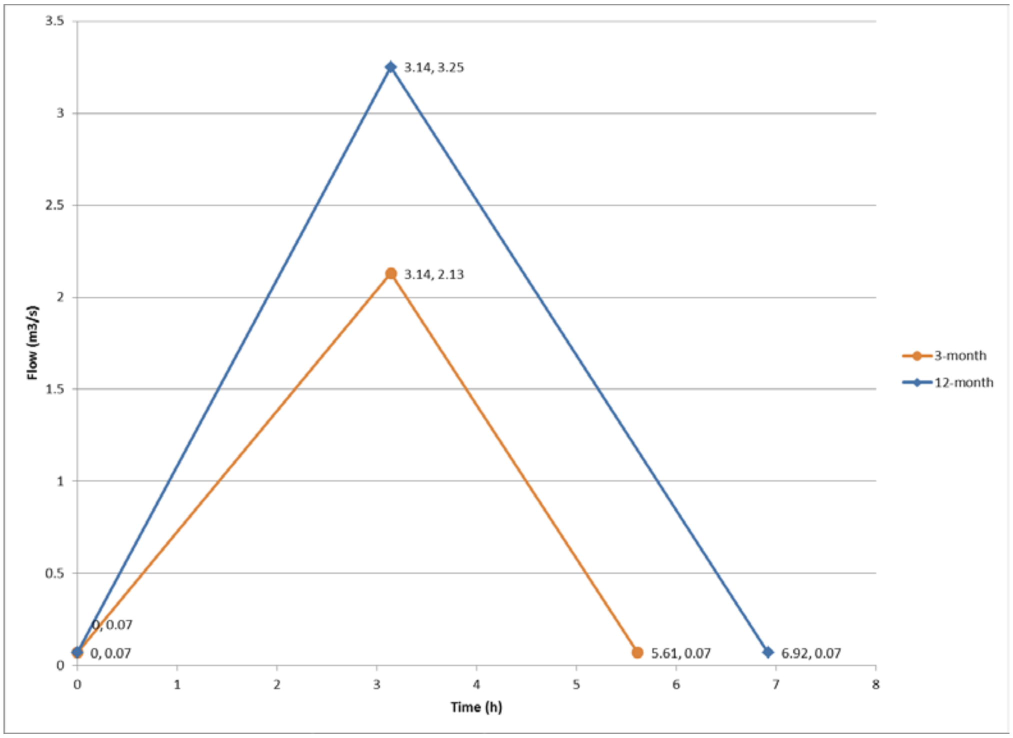

Figure 3-9. West River design storm synthetic hydrograph at sampling station WE-10

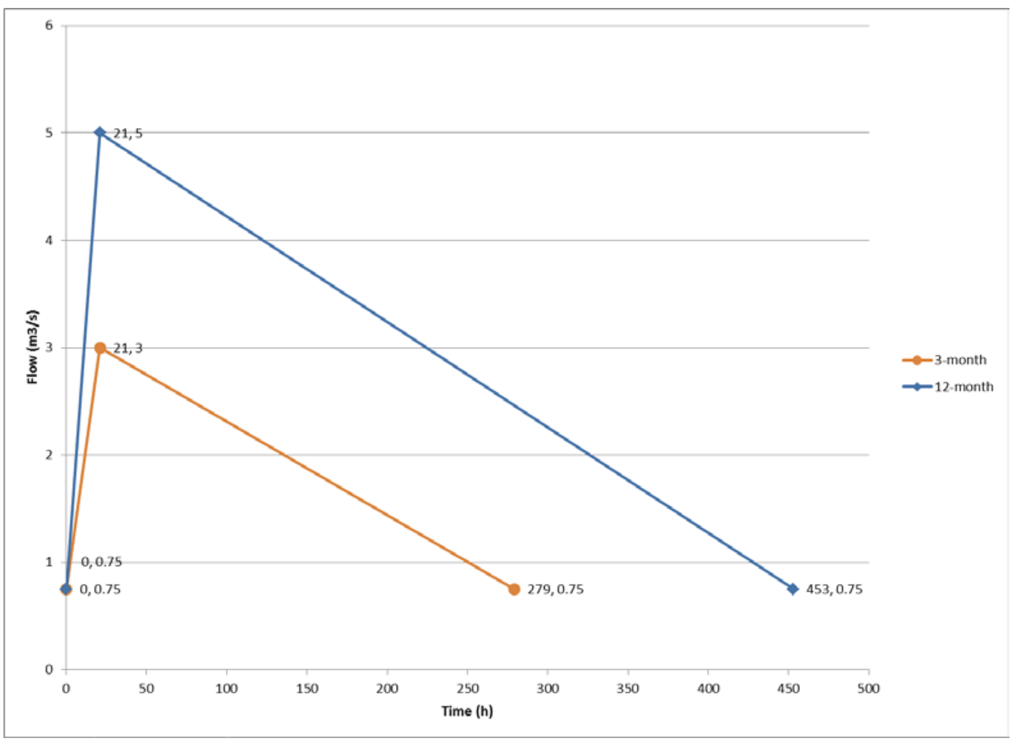

Figure 3-10. Woonasquatucket River design storm synthetic hydrograph at sampling station W-9

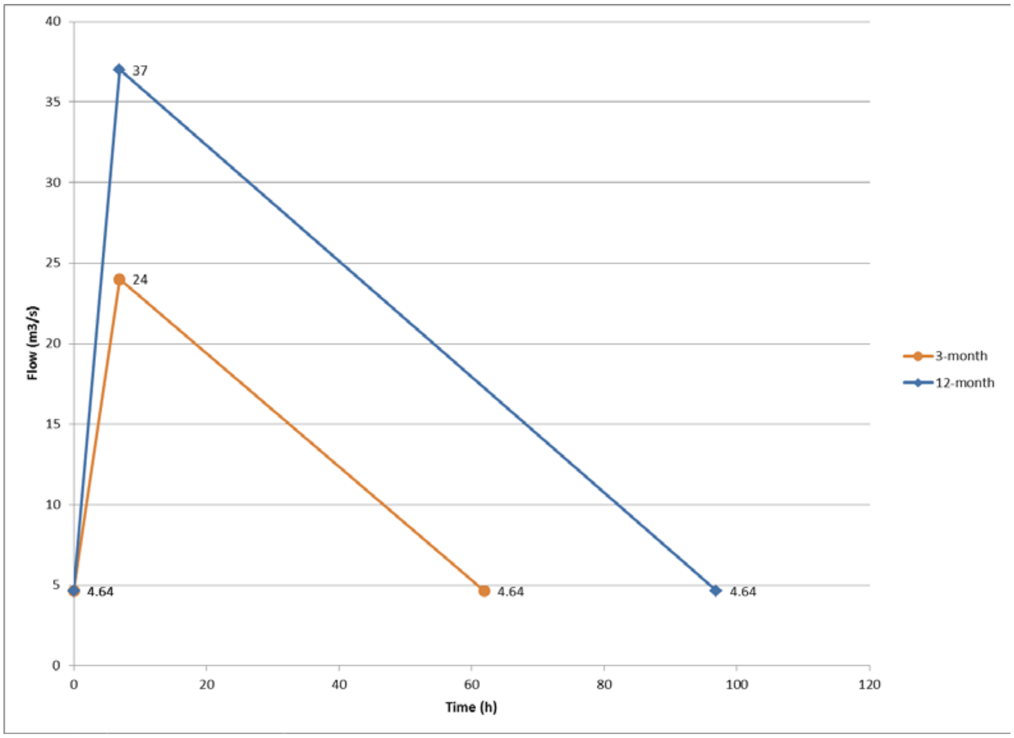

Figure 3-11. Pawtuxet River design storm synthetic hydrograph at sampling station PX-13

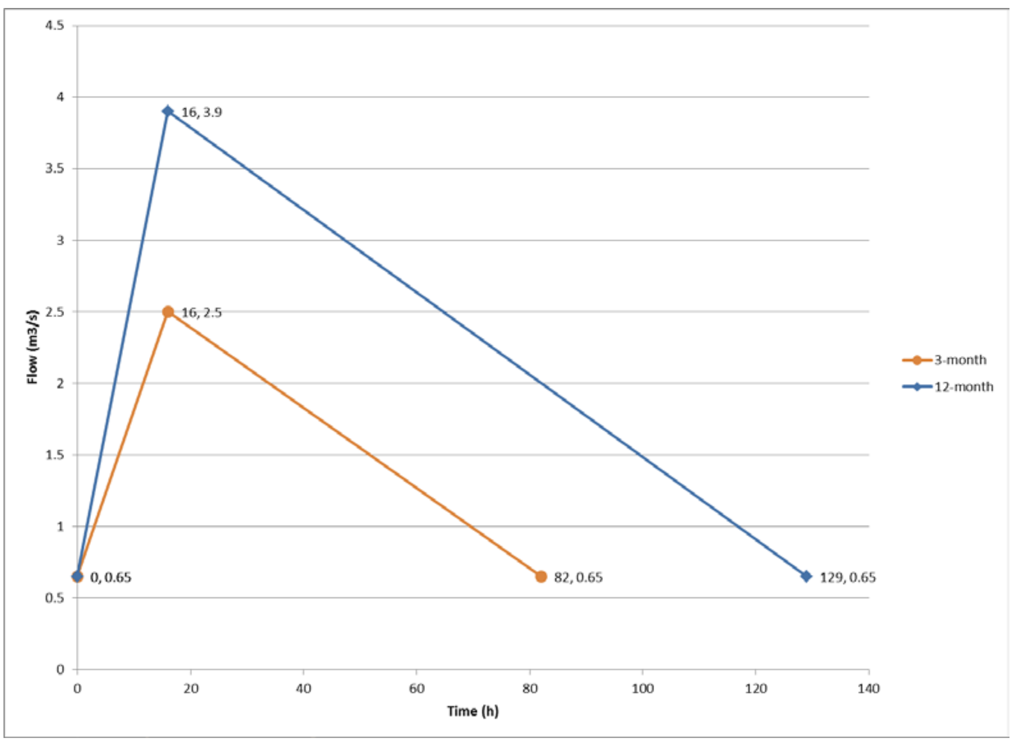

Figure 3-12. Ten Mile River design storm synthetic hydrograph downstream of Omega Pond

Background FC Concentrations:

For all tributaries with the exception of the Ten Mile River, which is not sampled by NBC, background FC concentrations were assigned using NBC's sampling data for storms with total rainfall accumulations comparable to the 3- and 12-month design events. Each tributary synthetic hydrograph was assumed to undergo three FC loading stages:

- Stage 1 (from the start of rainfall up to 12 hours after the beginning of the storm): FC concentrations for this stage were estimated by identifying NBC tributary samples between 2009 and 2013 (i.e. Phase II system conditions) that were collected shortly after storms that were similar in total rainfall accumulation and rainfall distribution to the 3- and 12-month design storms. When more than one storm was identified for a sampling station, the geomean of the FC concentrations was used. If storms similar to the 3- and 12-month design storm could not be identified, the FC geomean of all wet weather NBC samples between 2009 and 2013 for that station was used instead.

- Stage 2 (from 12 to 24 hours from the beginning of the storm): The FC geomean concentrations of wet weather samples collected during storms smaller than the design storms in Stage 1 were used for this stage. When Stage 1 storms similar to the 3- and 12-month design events could not be identified, then loading Stages 1 and 2 were assigned the same FC concentration and computed as the FC geomean of all wet weather samples between 2009 and 2013 for that station.

- Stage 3 (24 hours after beginning of the storm): It was assumed that after 24 hours tributary rivers would have flushed any wet weather FC discharges and revert back to dry weather FC concentrations, which were computed as the FC geomean concentration of dry weather samples collected by NBC between 2009 and 2013 for that station.

For the Ten Mile River, Stage 1 and 2 FC concentrations were set at 78MPN/100mL, which corresponds to the wet weather geomean reported in the *Draft Surface Water Monitoring in the Ten Mile River Watershed Data Report* of April 2011 by RIDEM. The Stage 3 FC concentration was set at 24MPN/100mL which is the dry weather FC concentration geomean in the same study.

Tributary FC concentrations per loading phase for the 3-and 12-month design storms are included in Table 3-2 and Table 3-3, respectively.

Table 3-2. Tributary FC concentrations (in MPN/100mL) used in the 3-month design storm

	Blackstone	Moshassuck	Pawtuxet	West	Woonasquatucket	Ten Mile
Stage 1	930	667	1,463	4,300	5,679	78
Stage 2	274	397	219	1,496	381	78
Stage 3	70	177	90	774	297	24

Table 3-3. Tributary FC concentrations (MPN/100mL) used in the 12-month design storm

	Blackstone	Moshassuck	Pawtuxet	West	Woonasquatucket	Ten Mile
Stage 1	1,031	4,300	1,463	4,300	5,679	78
Stage 2	1,031	536	562	1,734	494	78
Stage 3	70	177	90	774	297	24

<u>Pollutographs:</u>

Resulting tributary, cumulative, loading pollutographs are presented in Figure 3-13 and Figure 3-14 for the 3- and 12-month design storms, respectively. As shown in these figures, the Pawtuxet and the Blackstone rivers are the major FC contributors while the Ten Mile River has the smallest contribution overall as expected.

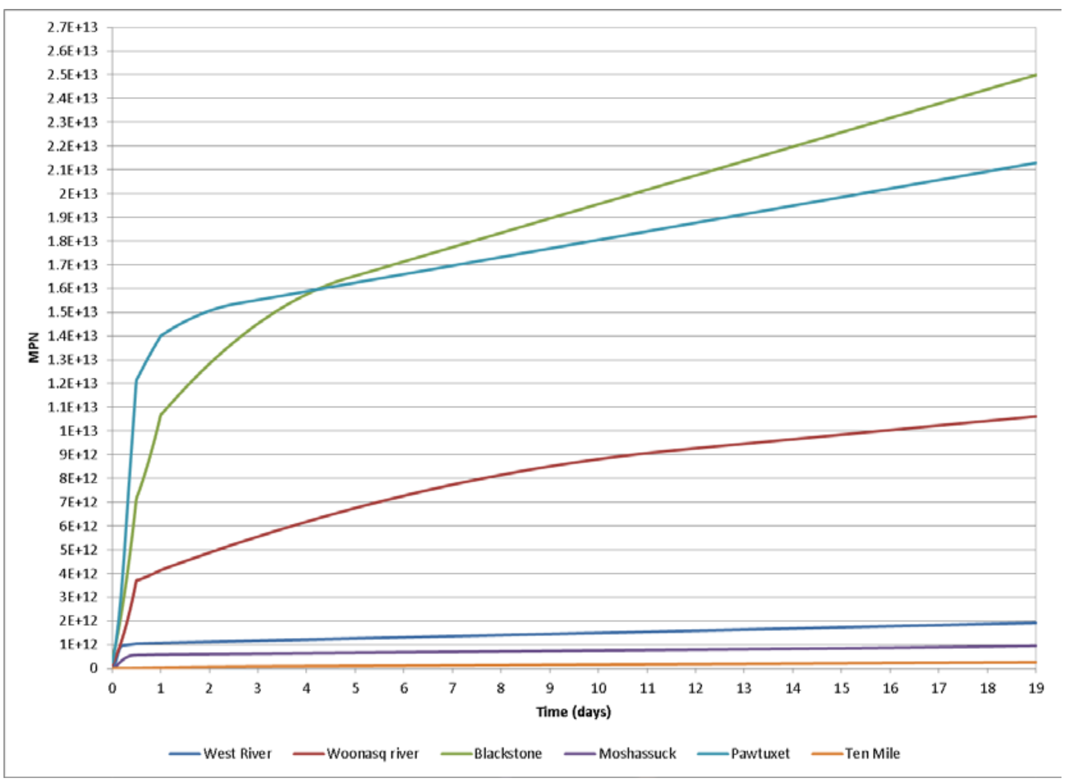

Figure 3-13. Background, tributary cumulative FC loading during the 3-month design storm

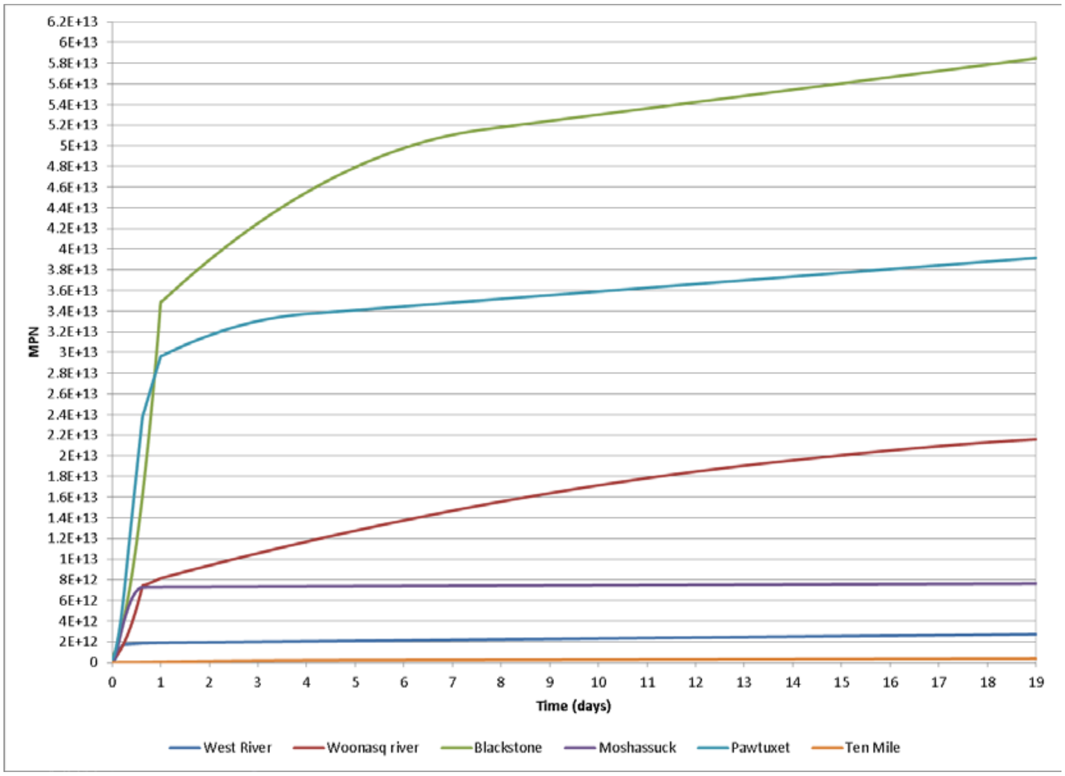

Figure 3-14. Background, tributary cumulative FC loading during the 12-month design storm

3.3.1.2 Loadings from Waste Water Treatment Facilities

FC pollutographs for the Field's Point and Bucklin Point WWTF's were computed using FC concentrations of 4 and 40MPN/100mL for secondary and primary treatment, respectively. Due to a lack of effluent flow data for the East Providence WWTF, design storm loadings from this facility were computed as a fraction (23%) of the Bucklin Point WWTF loading. This fraction was based on the ratio of design flows at both plants (10.4MGD at East Providence versus 46MGD at the Bucklin Point WWTF). Even though the East Providence WWTF was recently upgraded to a design flow of up to 14.2MGD, its contribution fraction was kept the same in order to evaluate the relative impacts of Phase III alternatives with respect to Phase I and Phase II system conditions. Figure 3-15 through Figure 3-17 depict the design storm cumulative pollutographs for the Bucklin Point, Field's Point, and East Providence WWTF's, respectively.

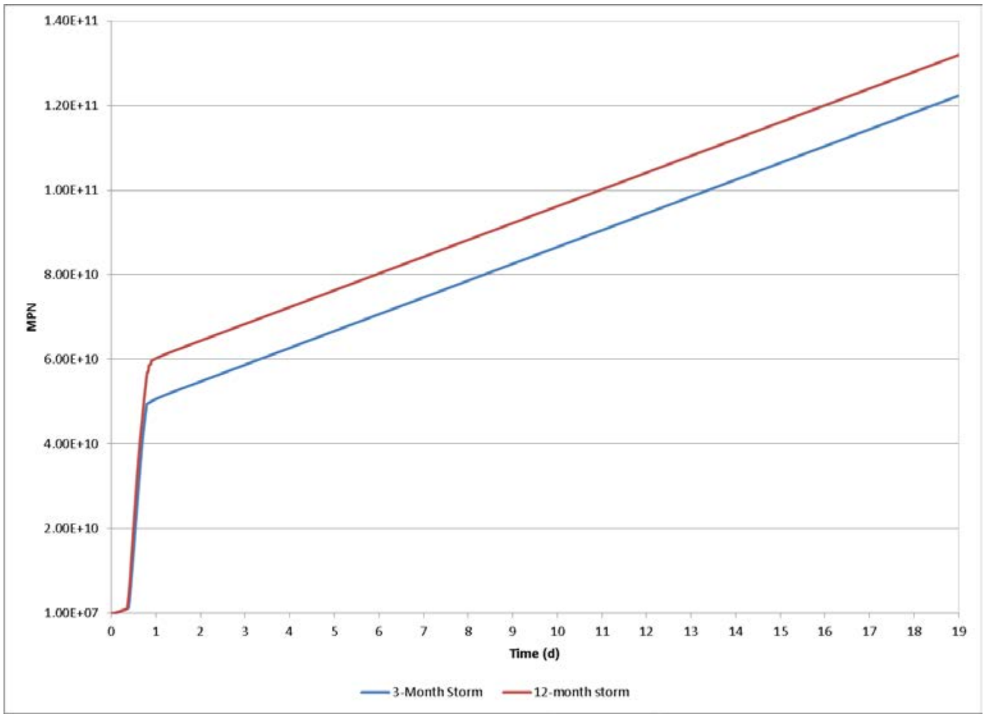

Figure 3-15. Bucklin Point WWTF cumulative FC loading during the 3- and 12-month design storms

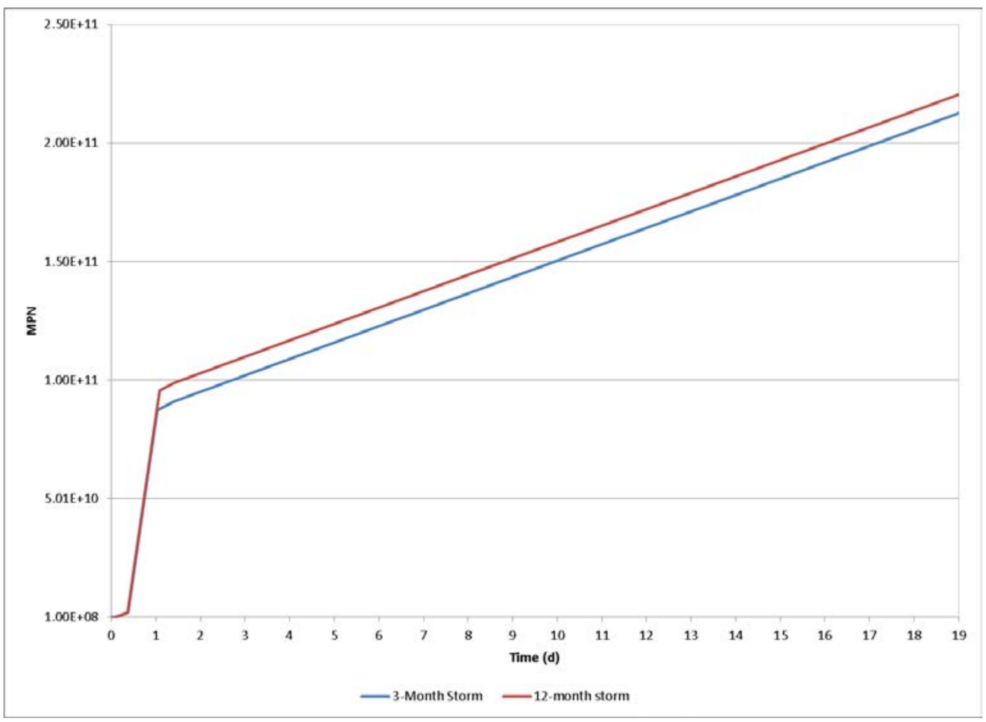

Figure 3-16. Field's Point WWTF cumulative FC loading during the 3- and 12-month design storms

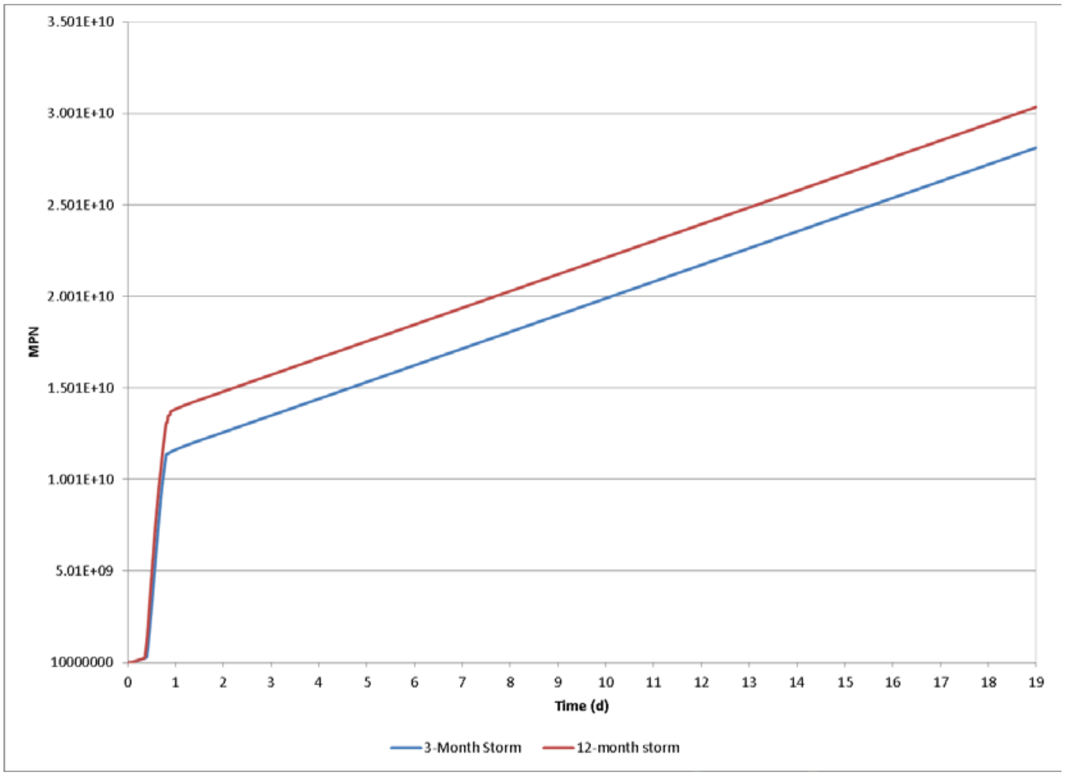

Figure 3-17. East Providence WWTF cumulative FC loading during the 3- and 12-month design storms

3.3.1.3 Loadings from Combined Sewer Overflows

Loadings from CSOs were generated using the same CSO concentrations used during model calibration described earlier in this chapter with the output hydrographs from the Field's Point and Bucklin Point systems generated by their respective hydraulic models. Cumulative CSO pollutographs for post-Phase I conditions for the Field's Point and Bucklin Point models during the 3- and 12-month design storms are shown in Figure 3-18 and Figure 3-19, respectively.

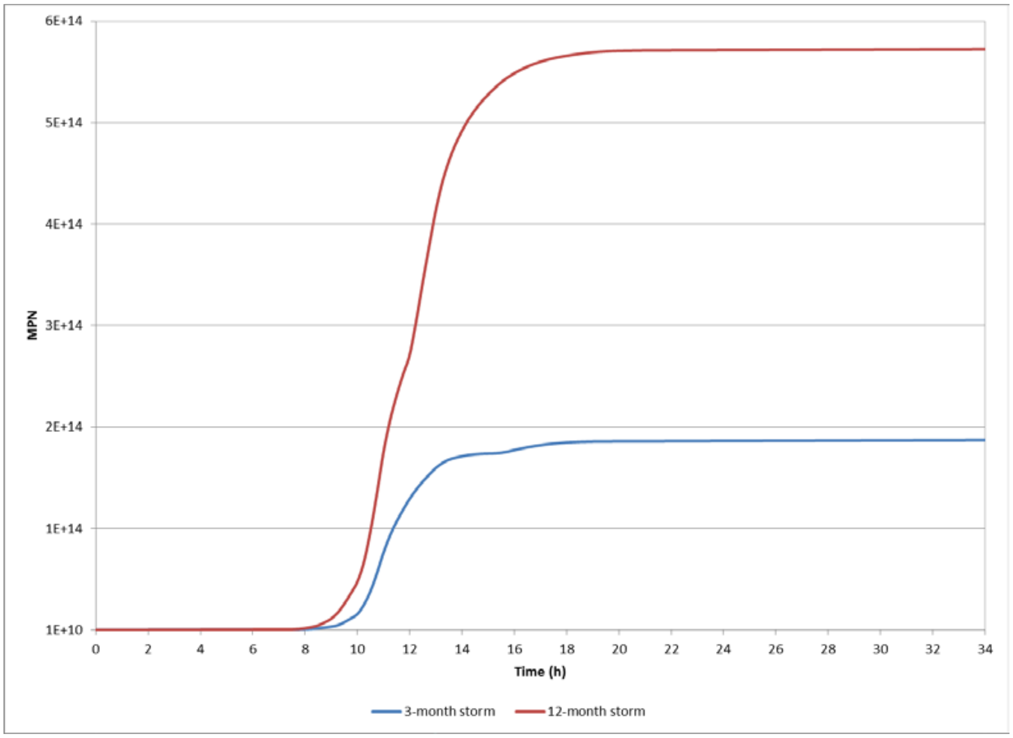

Figure 3-18. Post-Phase I, cumulative FC loading from Field's Point CSOs during the 3- and 12-month design storms

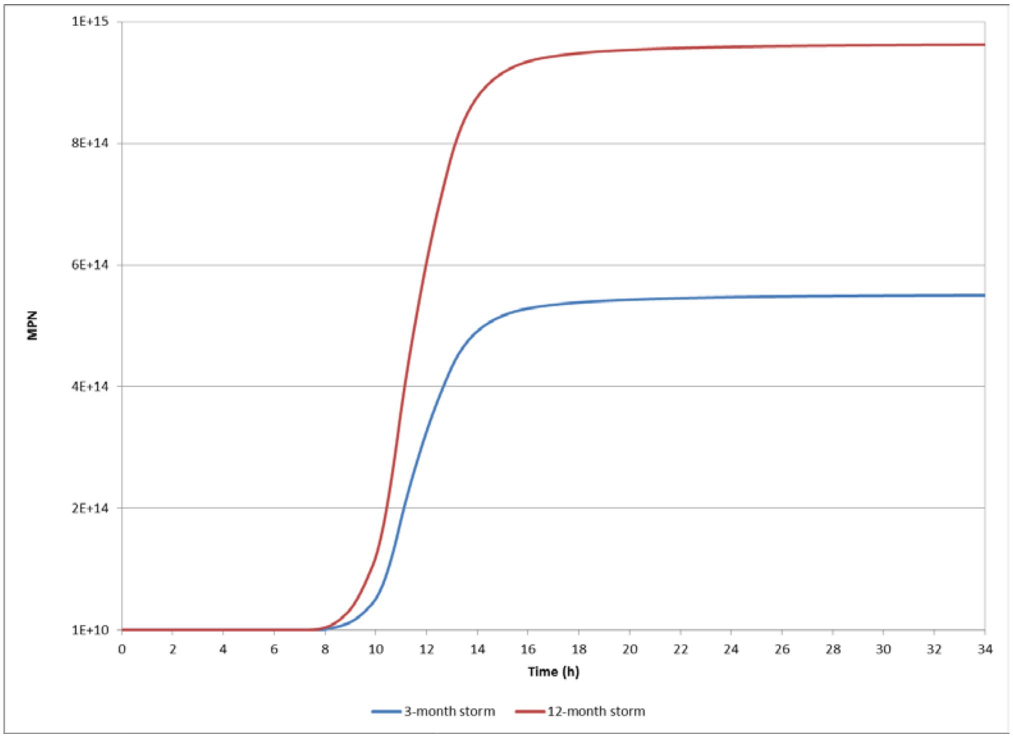

Figure 3-19. Post-Phase I, cumulative FC loading from Bucklin Point CSOs during the 3- and 12-month design storms

3.3.1.4 Loadings from Separated Areas

As indicated previously, FC loadings from separated areas during design storms were obtained from the *"Receiving Water Quality Modeling for Narragansett Bay Commission Combined Sewer Overflow Facilities"* and the *"Receiving Water Quality Modeling of Combined Sewer Overflow Impact"* reports of 1993 and 1998 by Applied Science Associates (ASA). In 1993 and 1998 storm water FC concentrations of 60,000MPN/100mL were used. This concentration was revised down to 10,000MPN/100mL, which better reflects typical FC concentration values in storm water samples from urban catchments in the NBC service area and elsewhere based on numerous national studies. This value is double the overall, median FC stormwater concentration (5,091MPN/100mL) for urban environments and very similar to the median FC stormwater concentration for mixed residential basins (11,210 MPNM/100mL) reported in the National Stormwater Quality Database (Maestre and Pitt, 2004). A summary of total FC loadings per source and design storm for post-Phase I system conditions is presented in Table 3-4.

Table 3-4. Post-Phase I FC Loadings per Source and Design Storm

	3-month		12-month	
Source	**Total Loading (MPN)**	**Percentage (%)**	**Total Loading (MPN)**	**Percentage (%)**
FP CSO	1.87E+14	21.95	5.72E+14	32.62
BP CSO	5.50E+14	64.55	9.62E+14	54.86
FP WWTF	2.13E+11	0.02	2.21E+11	0.01
BP WWTF	1.22E+11	0.01	1.32E+11	0.01
EP WWTF	2.81E+10	0.00	3.04E+10	0.00
Separated areas	5.47E+13	6.42	8.89E+13	5.07
Blackstone River	2.50E+13	2.93	5.85E+13	3.34
Moshassuck River	9.52E+11	0.11	7.63E+12	0.44
West River	1.91E+12	0.22	2.74E+12	0.16
Woonasquatucket River	1.06E+13	1.24	2.16E+13	1.23
Pawtuxet River	2.12E+13	2.49	3.92E+13	2.24
Ten Mile River	3.88E+11	0.05	5.70E+11	0.03

3.3.2 Post-Phase II System Conditions Loadings

In post-Phase II system conditions, FC loadings to the Upper Bay were estimated for the same sources described in Section 3.3.1. CSO FC loads were the only sources that varied with regards to post-Phase I condition. Very slight changes in the Bucklin Point CSO were reflected due to modifications in outfalls 219 and 220. The rest of the sources loads remained unchanged or had negligible change in overall FC loading.

3.3.2.1 Tributary River Background Loadings

In post-Phase II conditions tributary background loadings remained the same as in post-Phase I conditions that were described in Section 3.3.1.1.

3.3.2.2 Loadings from Waste Water Treatment Facilities

FC pollutographs for the Field's Point, Bucklin Point, and East Providence WWTF's in post-Phase II conditions were left unchanged with regards to those computed in Section 3.3.1.2 and depicted in Figure 3-15 through Figure 3-17.

3.3.2.3 Loadings from Combined Sewer Overflows

Loadings from CSOs were generated with the same CSO concentrations used during the model calibration process described previously but using output hydrographs from the Field's Point and Bucklin Point systems generated by the respective hydraulic models for Phase II conditions. Total CSO pollutographs in post-Phase II conditions for the Field's and Bucklin Point systems during the 3- and 12-month design storms are presented in Figure 3-20 and Figure 3-21, respectively.

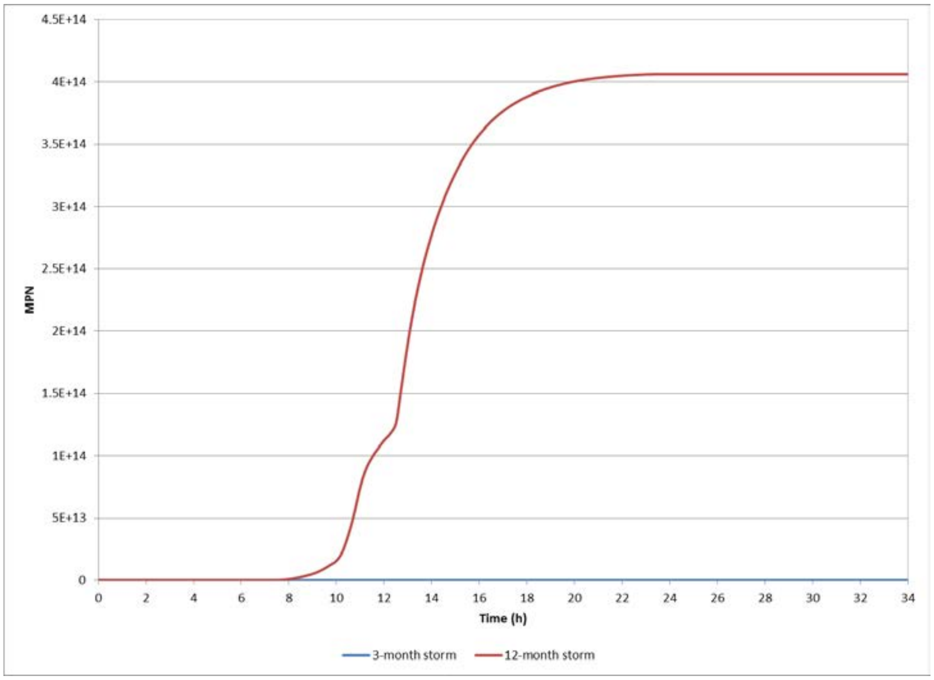

Figure 3-20. Post-Phase II cumulative FC loadings in the Field's Point CSO system during the 3- and 12-month design storms

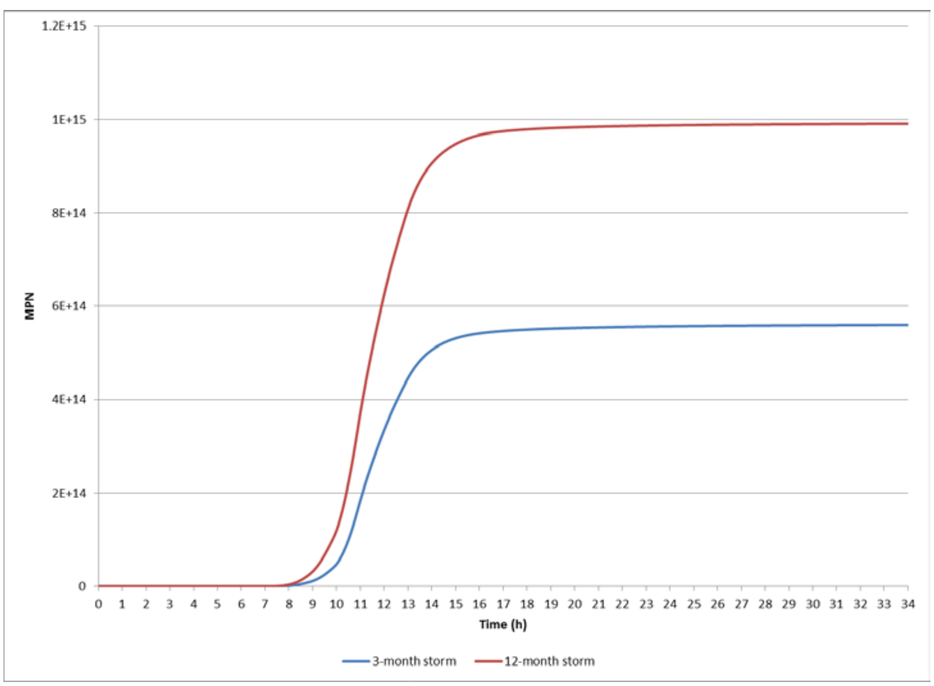

Figure 3-21. Post-Phase II cumulative FC loadings in the Bucklin Point CSO system during the 3-and 12-month design storms

3.3.2.4 Loadings from Separated Areas

For post- Phase II condition model runs, loadings from separated areas were assumed to remain unchanged or with negligible change with respect to post-Phase I conditions. FC loadings were quantified in Section 3.3.1.4

A summary of total FC loadings per source and design storm for post-Phase 2 system conditions is presented in Table 3-5.

Table 3-5. Post-Phase II FC Loadings per Source and Design Storm

	3-month		12-month	
Source	Total Loading (MPN)	Percentage (%)	Total Loading (MPN)	Percentage (%)
Fields Point CSO	0	0.00	4.06E+14	25.12
Bucklin Point CSO	5.60E+14	82.95	9.91E+14	61.30
Fields Point WWTF	2.13E+11	0.03	2.21E+11	0.01
Bucklin Point WWTF	1.22E+11	0.02	1.32E+11	0.01
East Providence WWTF	2.81E+10	0.00	3.04E+10	0.00
Separated sewer areas	5.47E+13	8.10	8.89E+13	5.50
Blackstone River	2.50E+13	3.70	5.85E+13	3.62
Moshassuck River	9.52E+11	0.14	7.63E+12	0.47
West River	1.91E+12	0.28	2.74E+12	0.17
Woonasquatucket River	1.06E+13	1.57	2.16E+13	1.34
Pawtuxet River	2.12E+13	3.14	3.92E+13	2.42
Ten Mile River	3.88E+11	0.06	5.70E+11	0.04

3.3.3 Fecal Coliform Loading in Phase III Alternative Scenarios

The following scenarios were evaluated to assess the impact on pollutant loadings and receiving water quality of proposed facilities in the Bucklin Point service area. This information is used to inform a potential phased approach for the program's third phase. Under Phase III scenarios, tributary and storm sewer background loadings remained unchanged with respect to Phase I and II conditions described previously. WWTF loadings also remained the same with the exception of scenario 4 described below. Table 3-6 is a compilation of all FC loadings for Phase I, Phase II, and different Phase III scenarios described below.

Scenario 1 – Removal of all Phase III CSOs for the 3-month design storm

- Pollutographs for the 3-month design storm were calculated with zero hydrographs for all CSOs in the Bucklin Point service area.
- Pollutographs for the 12-month design storm were computed with hydrographs obtained by subtracting the 3-month hydrograph from the 12-month hydrograph for all Phase III CSO structures.

Scenario 2 – Only CSO 220 removed for the 3-month design storm

- Pollutographs for the 3-month design storm were computed using a zero hydrograph for CSO 220 and with all other CSO hydrographs unchanged from Phase II.
- Pollutographs for the 12-month design storm were computed with a hydrograph for CSO 220 calculated as the difference between the 12-month and the 3-month CSO hydrographs and the rest of the structures unchanged from Phase II.

Scenario 3 – CSO 205 to 218 removed for the 3-month design storm (Tunnel application)

- Pollutographs for the 3-month design storm were computed using zero hydrographs for CSOs 205 to 218, all other CSO hydrographs remained unchanged from Phase II.
- Pollutographs for the 12-month design storm for CSOs 205 to 218 were recalculated as described in scenarios 1 and 2; all others remained unchanged from Phase II.

Scenario 4 – CSO 218 routed through Bucklin Point WWTF

- Pollutographs were generated by routing the 3- month and 12-month design storm flows generated at CSO 218 through the Bucklin Point WWTF with the rest of the structures left the same as in Phase II.
- The Bucklin Point WWTF has primary and secondary treatment capacities of 46MGD and 116MGD, respectively. It was assumed that once the primary treatment capacity is exceeded, all incoming flows in excess of the primary treatment capacity effectively became a CSO.

Scenario 5 – Storage/Treatment of CSO 205 to 218

- Pollutographs were generated by routing the 3-month design storm flows through an interceptor and storage tank system. Loadings predicted by the model resulted in a range from total removal, to volumes treated, to volumes discharged without treatment.
- Pollutographs for the 12-month design were generated the same way as for the 3-month event.

Table 3-6. Summary of FC loadings (in MPN) in Post-Phase I, Post-Phase II, and Phase III Scenarios during the 3- and 12-month design storms

Phase	Storm (mo)	Scenario	BPSA CSO	FPSA CSO	Total CSOs	WWTF				Rivers	Storm Sewers	Total Load	% CSO	% WWTF	% Rivers	% Storm Sewers
						BP	FP	EP	Total WWTF							
Post Phase I	3	n/a	5.50E+14	1.87E+14	7.37E+14	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**8.52E+14**	86.5	0.0	7.1	6.4
	12	n/a	9.62E+14	5.72E+14	1.53E+15	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.75E+15**	87.5	0.0	7.4	5.1
Post Phase II	3	n/a	5.60E+14	0	5.60E+14	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**6.75E+14**	82.9	0.1	8.9	8.1
	12	n/a	9.91E+14	4.06E+14	1.40E+15	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.62E+15**	86.4	0.0	8.0	5.5
Phase III	3	1	0	0	0	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**1.15E+14**	0.0	0.3	52.2	47.5
		2	5.17E+14	0	5.17E+14	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**6.32E+14**	81.8	0.1	9.5	8.7
		3	1.75E+14	0	1.75E+14	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**2.90E+14**	60.3	0.1	20.7	18.9
		4	4.77E+14	0	4.77E+14	1.37E+11	2.13E+11	2.81E+10	3.78E+11	6.01E+13	5.47E+13	**5.92E+14**	80.6	0.1	10.1	9.2
		5	2.31E+14	0	2.31E+14	1.22E+11	2.13E+11	2.81E+10	3.63E+11	6.01E+13	5.47E+13	**3.46E+14**	66.7	0.1	17.4	15.8
	12	1	4.31E+14	4.06E+14	8.37E+14	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.06E+15**	79.2	0.0	12.3	8.4
		2	9.48E+14	4.06E+14	1.35E+15	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.57E+15**	86.0	0.0	8.3	5.7
		3	6.06E+14	4.06E+14	1.01E+15	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.23E+15**	82.2	0.0	10.6	7.2
		4	9.17E+14	4.06E+14	1.32E+15	1.45E+11	2.21E+11	3.04E+10	3.96E+11	1.30E+14	8.89E+13	**1.54E+15**	85.8	0.0	8.4	5.8
		5	5.10E+14	4.06E+14	9.16E+14	1.32E+11	2.21E+11	3.04E+10	3.83E+11	1.30E+14	8.89E+13	**1.14E+15**	80.7	0.0	11.5	7.8

3.4 BOD and TSS Loadings from CSOs and WWTF's during Design Storms

BOD and TSS loadings were calculated with the same hydrographs used in the calculation of FC loadings. For CSO's, median concentrations reported in the NBC's Draft Water Quality Report of 2013 were used while for the WWTF's, median effluent concentrations provided by NBC were applied. Median concentrations for urban areas from the National Stormwater Quality Database (Maestre and Pitt., 2014) were adopted for separated storm sewers. BOD and TSS concentrations and final loadings per source and program phase are summarized in Table 3-7 and Table 3-8.

3.5 Water Quality Model and Modeling Results

Refer to Appendix 4 "Evaluation of Water Quality Benefits of CSO Alternatives for Narragansett Bay" for information regarding the water quality modeling program and modeling results for the scenarios described herein.

Table 3-7. Summary of estimated NBC's BOD loading (in lb.) in Post-Phase I, Post-Phase II, and Phase III Scenarios during the 3- and 12-month design storms (based on 34-hour hydrographs)

Phase	Storm (mo)	Scenario	BPSA CSO	FPSA CSO	Total CSOs	WWTF				Storm Sewers	NBC's BOD Load	Total BOD Load with Storm Sewers and EPWWTF	% CSO	% WWTF	% Storm Sewers
						BP	FP	EP	Total NBC's WWTF						
Post Phase I	3	n/a	17,935	6,277	**24,212**	5,752	5,075	1,323	**10,827**	**10,361**	**35,039**	**46,723**	51.8	26.0	22.2
	12	n/a	31,286	19,164	**50,450**	6,809	5,372	1,566	**12,181**	**16,840**	**62,631**	**81,037**	62.3	17.0	20.8
Post Phase II	3	n/a	18,749	0	**18,749**	5,752	5,075	1,323	**10,827**	**10,361**	**29,576**	**41,260**	45.4	29.4	25.1
	12	n/a	33,179	13,610	**46,789**	6,809	5,372	1,566	**12,181**	**16,840**	**58,970**	**77,376**	60.4	17.8	21.8
Phase III	3	1	0	0	**0**	5,752	5,075	1,323	**10,827**	**10,361**	**10,827**	**22,511**	0.0	54.0	46.0
		2	16,830	0	**16,830**	5,752	5,075	1,323	**10,827**	**10,361**	**27,657**	**39,341**	42.8	30.9	26.3
		3	6,843	0	**6,843**	5,752	5,075	1,323	**10,827**	**10,361**	**17,670**	**29,354**	23.3	41.4	35.3
		4	15,497	0	**15,497**	8,205	5,075	1,323	**13,280**	**10,361**	**28,777**	**40,461**	38.3	36.1	25.6
		5	7,665	0	**7,665**	5,752	5,075	1,323	**10,827**	**10,361**	**18,492**	**30,176**	25.4	40.3	34.3
	12	1	14,416	13,610	**28,026**	6,809	5,372	1,566	**12,181**	**16,840**	**40,207**	**58,613**	47.8	23.5	28.7
		2	30,818	13,610	**44,428**	6,809	5,372	1,566	**12,181**	**16,840**	**56,609**	**75,015**	59.2	18.3	22.4
		3	19,351	13,610	**32,961**	6,809	5,372	1,566	**12,181**	**16,840**	**45,142**	**63,548**	51.9	21.6	26.5
		4	29,710	13,610	**43,320**	9,059	5,372	1,566	**14,431**	**16,840**	**57,751**	**76,157**	56.9	21.0	22.1
		5	23,433	13,610	**37,043**	6,809	5,372	1,566	**12,181**	**16,840**	**49,224**	**67,630**	54.8	20.3	24.9

Assumed BOD concentrations:

- CSO and WWTF with primary treatment discharges: 38mg/L
- WWTF secondary treatment discharges : 4mg/L
- Separated sewer areas: 8.6mg/L

Table 3-8. Summary of estimated NBC's TSS loading (in lb.) in Post-Phase I, Post-Phase II, and Phase III Scenarios during the 3- and 12-month design storms (based on 34-hour hydrographs)

Phase	Storm (mo)	Scenario	BPSA CSO	FPSA CSO	Total NBC's CSOs	NBC's WWTF				SSs	NBC's TSS Load	Total TSS Load with Storm Sewers and EPWWTF	% CSO	% WWTF	% Storm Sewers
						BP	FP	EP	Total NBC'S WWTF						
Post Phase I	3	n/a	28,318	9,922	**38,240**	8,954	5,135	2,059	**14,089**	**69,881**	**52,329**	**124,269**	30.8	13.0	56.2
	12	n/a	49,400	30,259	**79,659**	10,621	7,360	2,443	**17,981**	**113,573**	**97,640**	**213,656**	37.3	9.6	53.2
Post Phase II	3	n/a	28,828	0	**28,828**	8,954	5,135	2,059	**14,089**	**69,881**	**42,917**	**114,857**	25.1	14.1	60.8
	12	n/a	50,915	21,490	**72,405**	10,621	7,360	2,443	**17,981**	**113,573**	**90,386**	**206,402**	35.1	9.9	55.0
Phase III	3	1	0	0	**0**	8,954	5,135	2,059	**14,089**	**69,881**	**14,089**	**86,029**	0.0	18.8	81.2
		2	26,574	0	**26,574**	8,954	5,135	2,059	**14,089**	**69,881**	**40,663**	**112,603**	23.6	14.3	62.1
		3	10,805	0	**10,805**	8,954	5,135	2,059	**14,089**	**69,881**	**24,894**	**96,834**	11.2	16.7	72.2
		4	24,468	0	**24,468**	12,825	5,135	2,059	**17,960**	**69,881**	**42,428**	**114,368**	21.4	17.5	61.1
		5	12,102	0	**12,102**	8,954	5,135	2,059	**14,089**	**69,881**	**26,191**	**98,131**	12.3	16.5	71.2
	12	1	22,784	21,490	**44,274**	10,621	7,360	2,443	**17,981**	**113,573**	**62,255**	**178,271**	24.8	11.5	63.7
		2	48,661	21,490	**70,151**	10,621	7,360	2,443	**17,981**	**113,573**	**88,132**	**204,148**	34.4	10.0	55.6
		3	30,554	21,490	**52,044**	10,621	7,360	2,443	**17,981**	**113,573**	**70,025**	**186,041**	28.0	11.0	61.0
		4	46,912	21,490	**68,402**	14,172	7,360	2,443	**21,532**	**113,573**	**89,934**	**205,950**	33.2	11.6	55.2
		5	37,000	21,490	**58,490**	10,621	7,360	2,443	**17,981**	**113,573**	**76,471**	**192,487**	30.4	10.6	59.0

Assumed TSS concentrations:

- CSO and WWTF primary treatment: 60mg/L
- WWTF secondary treatment: 6 mg/L
- Separated sewer areas: 58mg/L

References

Alex Maestre and Robert Pitt- 2004- "*National Stormwater Quality Database Version 1.1*" http://rpitt.eng.ua.edu/Research/ms4/Paper/Mainms4paper.html

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NBC CSO Control Facilities Phase III Reevaluation

Chapter 4 – Alternatives Development & Technical Feasibility Screening

NBC CSO Control Facilities Phase III Reevaluation

Chapter 4 – Alternatives Development & Technical Feasibility Screening

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4.1. Introduction

This chapter describes in detail the technical feasibility screening process and development of CSO control alternatives as part of the reevaluation of the Conceptual Design Report Amendment (CDRA) Phase III Recommended Plan.

4.2. Review of CDRA Phase III Recommended Plan

In 1998, RIDEM approved the Conceptual Design Report Amendment (CDRA) as NBC's Long Term CSO Control Plan. The CDRA amended NBC's Conceptual Design Report (CDR) which was approved by RIDEM in 1994 as the Long term Control Plan. Control strategies that were evaluated in the CDR and CDRA were:

- Sewer separation, which modifies the existing system and adds a second system of pipes to create independent sanitary sewer and storm drainage systems;
- Near-surface storage, which provides temporary, localized storage for CSO volumes;
- Localized treatment and discharge, which provides some level of pollutant removal and disinfection of CSO volumes prior to discharge at the outfalls;
- Regulator modifications, which reduce discharges from particular outfalls and relies upon existing interceptor capacity to store or convey CSO volumes to other locations for control
- Deep rock tunnel storage, which provides storage of large CSO volumes, typically from multiple outfalls requiring consolidation conduits or interceptor conveyance.

The 1997 *Conceptual Design Report Amendment* (CDRA) Phase III baseline recommended CSO control facilities consist of the construction of the Pawtucket Tunnel for storage, three interceptors to convey flow to the tunnel, sewer separation for four CSO catchments and regulator modifications at 12 CSOs. The Phase III baseline plan by CSO is shown on Figure 4-1 and summarized in Table 4-1.

Table 4-1 – CDRA Recommended Plan Breakdown

Outfall	CSO Control Solution	Downstream Elements	Secondary Requirement
035	Sewer separation	None	
036	Regulator modification	Phase II 037 separation	
039	Sewer separation	None	
056	Sewer separation	None	
101	Regulator modification	Pawtucket tunnel	Capacity in BVI + High & Cross St interceptor
103	Upper High & Cross St interceptor	Pawtucket tunnel	Lower High & Cross St interceptor
104	Lower High & Cross St interceptor	Pawtucket tunnel	
105	Drop shaft 205 & conduit	Pawtucket tunnel	Conduit river crossing
107	Regulator modification	Pawtucket tunnel	Capacity in MVI + Pawtucket Ave interceptor
201	Middle St interceptor	Pawtucket tunnel	
202	Regulator modification	Pawtucket tunnel	Capacity in BVI + Middle St interceptor
203	Middle St interceptor	Pawtucket tunnel	
204	Regulator modification	Pawtucket tunnel	Drop shaft 205 & conduit
205	Drop shaft 205 & conduit	Pawtucket tunnel	
206	Sewer separation		
207	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
208	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
209	Regulator modification	Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
210	Drop shaft 210/211 & conduit	Pawtucket tunnel	
211	Drop shaft 210/211 & conduit	Pawtucket tunnel	
212	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
213	Drop shaft 213 & conduit	Pawtucket tunnel	
214	Regulator modification	Pawtucket tunnel	Capacity in TPI + Drop shaft 217
215	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
216	Regulator modification	Pawtucket tunnel	Capacity in BVI + Drop shaft 218
217	Drop shaft 217 & conduit	Pawtucket tunnel	
218	Drop shaft 218 & conduit	Pawtucket tunnel	
220	Pawtucket Ave interceptor	Pawtucket tunnel	Drop shaft 217 & conduit

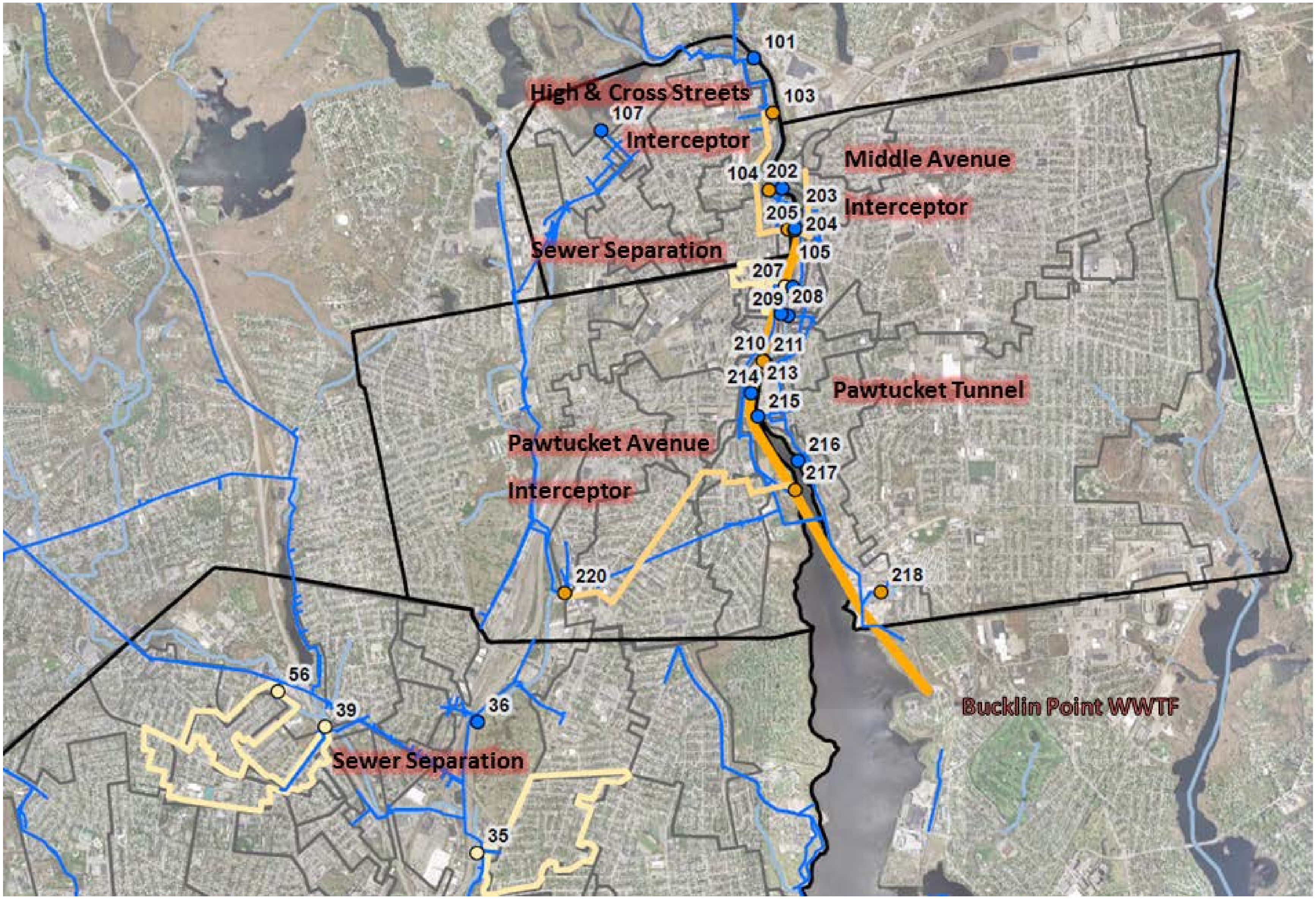


Figure 4-1 CDRA Phase III Recommended Plan

In the 17 years that have passed since the CDRA was approved, a number of changes have occurred. Water quality has improved as a result of the construction of the Phase I and II CSO control facilities. Better information is available on the costs of project construction for the tunnel, sewer separation and interceptor sewers, there is a better understanding of the impact of sewer separation on neighborhoods during construction and Green Stormwater Infrastructure (GSI) alternatives, which prevent storm water from entering the combined system, have emerged as a promising alternative to the traditional grey infrastructure alternatives evaluated in the CDRA.

FUNDAMENTAL CSO TECHNOLOGY DIFFERENCES

- Sewer separation
  - All wastewater to WWTF
  - All stormwater to rivers
  - Eliminates the CSO
  - Discharges urban runoff to rivers
- Tunnel & Near-surface storage
  - CSO volumes detained & subsequently treated at WWTF
  - CSO discharges to rivers for large storms
  - Urban runoff treated for small storms & first flush
- Localized treatment & discharge
  - CSO volumes minimally treated and discharged to rivers
  - Urban runoff treated for small storms & first flush
- Stormwater control
  - System optimization

Detailed descriptions of each of these control strategies, except for GSI, are provided in the CDR and CDRA documents. Additional description is provided in this report only when Phase I and II experience differed from previous assumptions or when technological advances since the CDRA was prepared alter how those approaches could be implemented.

As part of the overall strategy for assessing appropriate solutions for the project MWH/Pare has applied the Source-Pathway-Receptor approach. Source controls are generally considered localized smaller scale solutions in the upper reaches of sewersheds. Pathway solutions are generally applied to conveyance structures in both the major (streets) and minor (sewer) systems. Receptors are solutions applied in the lower reaches and are often termed ‘end-of-pipe’ solutions.

Source controls are comprised of various green storm water infrastructure (GSI) components. GSI seeks to approximate the natural hydrologic cycle, infiltrating, storing or using rainfall close to where it falls in the upper reaches of a catchment and preventing that rainfall from becoming runoff that will enter a closed drainage or combined sewer system.

Sewer separation is a Pathway solution. Flow slipping is a form of sewer separation, where the stormwater is temporarily detained either on the surface or below grade until it can be infiltrated or released after the peak of the storm event. Sewer separation can reduce or completely eliminate the discharge from CSOs but it can result in the discharge of pollutants, particularly bacteria, associated with the storm water.

Storage alternatives, including both deep rock tunnel and near-surface interceptors and tanks, are Receptor solutions. These solutions continue to allow sanitary and storm water to combine in the collection system but capture and store the flow so it does not discharge from the CSO. Large storms in excess of the storage capacity will still result in CSOs to the rivers. Localized treatment and discharge by means of screening and disinfection are also Receptor solutions.

The next section provides a discussion of the combined sewer overflow control strategies that are being considered.

4.3. Combined Sewer Overflow Control Strategies

This chapter describes the development of alternatives to the Phase III plan and provides a screening of those alternatives based on technical feasibility. Control Strategies to be addressed are:

- Green Stormwater Infrastructure
- Sewer Separation
- Tunnels
- Interceptors
- Regulator Modifications
- Near Surface Storage Tanks
- Treatment (Screening and Disinfection) and Discharge
- Wetland Treatment

Because GSI was not evaluated in the CDRA, the discussion of GSI will be more in depth than for the other control strategies.

4.4. Green Stormwater Infrastructure

4.4.1. Regulatory Framework

Given the multiple environmental, economic and social benefits associated with green infrastructure, EPA has supported and encouraged the implementation of green infrastructure for storm water runoff and sewer overflow management to the maximum extent possible.

In 2013, EPA published a series of Fact Sheets that provide guidance for incorporating GSI into various permitting and enforcement actions, including those related to CSO control. The fact sheet notes that "Green infrastructure can reduce the volume of water going into combined systems during precipitation events, which may reduce numbers and volumes of overflows. The guidance notes that "in most communities green infrastructure alone will not resolve CSO problems for large storms" and that GSI would need to be paired with grey infrastructure. The Fact Sheet also identifies critical components that must be included with any GSI component of a Long Term Control Plan (LTCP).

The EPA endorses a methodology that evaluates the community-wide potential for GSI, selects some representative areas for further assessment to determine how GSI would be specifically applied in areas of the community, and then scaling those conclusions back up to determine the community-wide GSI potential. The methodology specifically outlines the following steps:

- "Select a sample set of sewersheds that are generally representative of the service area as a whole, in terms of land uses, land ownership, soils, and topography.
- Characterize existing land use/land cover in the subwatersheds. This can often be done using aerial photographs and/or a community's geographic information system (GIS) coverage.
- Create templates for the various land uses in the sewersheds (e.g., typical single family residential lot, typical commercial/office site). Estimate the pervious and impervious areas for the templates.
- Identify green infrastructure opportunities for the different land use categories (templates) in the sewersheds, taking into account space needs, soil types, and slopes.

- Estimate the total green infrastructure that could be implemented in the sewershed by extrapolating from the templates to the sewershed as a whole. This estimate should take into account current and future zoning and institutional considerations, such as acceptance by property owners of green infrastructure features on private property. The level of buy-in to the green infrastructure program on the part of local property owners is an important variable, and needs to be explicitly considered in CSO planning. The estimate should also consider public properties and parks that may be good candidates for green infrastructure practices.
- Examine the cost-effectiveness of green infrastructure approaches. Will the green solutions reduce upfront or operational costs? Experiment with various combinations of green and grey infrastructure to determine what combination results in the lowest costs.
- Estimate the green infrastructure opportunities for the CSO service area as a whole by extrapolating from the sample set of sewersheds studied.
- Estimate the stormwater volumes that can be kept out of the system by the green infrastructure, taking into account the level of estimated implementation and the size of the practices. Also consider if there should be a margin of safety to reflect actual green implementation that may vary from projections, especially for sites not under the direct control of the sewer authority."

In 2014, EPA issued additional guidance providing specific proposed language to for use in modifying Consent Decrees to substitute GSI for "grey" infrastructure. And in March 2014, EPA published *Greening CSO Plans: Planning and Modeling Green Infrastructure for Combined Sewer Overflow (CSO) Control* as a technical resource for including GSI in CSO control plans.

The document highlights how the existing EPA CSO policies and guidance can be adapted to include GSI, specifically noting that "Green infrastructure approaches are adaptable in several components of the Nine Minimum Controls (NMCs)" and that the "1995 EPA Guidance for Long Term Control Plans identifies four categories of CSO control measures, and includes specific green infrastructure measures in the category labeled "Source Controls" (1995 EPA Guidance for LTCPs, Section 3.3.5.1)." The new guidance, however, does highlight the importance of monitoring. "As the previous section suggests the installation of green infrastructure controls may occur incrementally over time. By monitoring the effectiveness of green infrastructure controls as they are installed, municipalities can compare observed performance to modeled performance. If necessary, they can modify designs of remaining planned projects to meet a CSO control goal, or retrofit existing practices as necessary… For LTCPs incorporating green infrastructure approaches, an adaptive management approach can be employed during the implementation process. Adaptive management means monitoring and evaluating green infrastructure projects and practices as work proceeds, and adapting or revising plans and designs as appropriate based on lessons learned. Evaluating practices as work proceeds can often be a more effective approach than adopting a monitoring program confined to the post-construction phase."

Implementing GSI solutions in Phase III may require a phased approach in order to measure the success of GSI components in reducing CSO volumes and to then modify the recommended plan as necessary to achieve the goals of the CSO program.

Figure 4-2Error! Reference source not found. depicts the geographical extent of the GSI evaluation. Consideration is limited to areas within Central Falls, Pawtucket, and two specific locations in Providence.

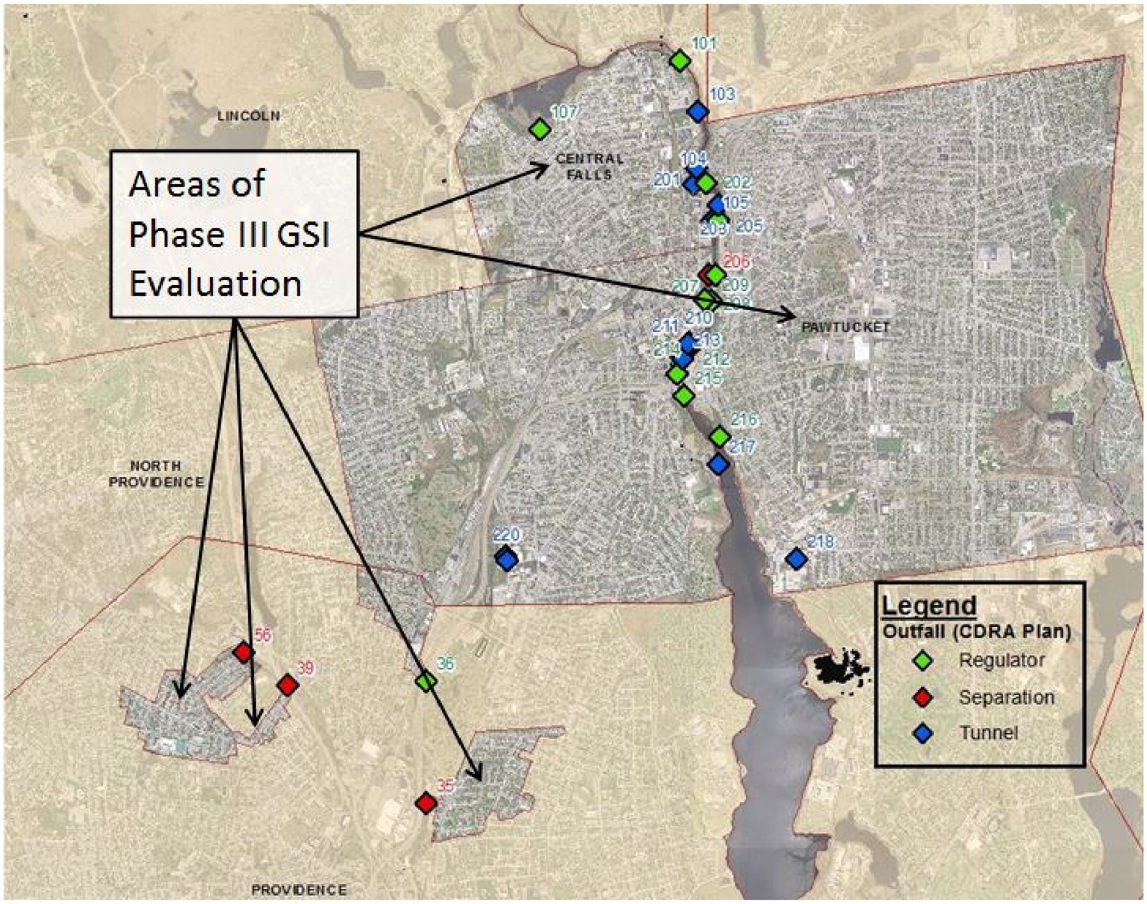


Figure 4-2 Sewersheds to Phase III CSOs

4.4.2. GSI Source Control Measures

One of the biggest changes since the CDRA has been the maturing of green and sustainable infrastructure technology. GSI is predominantly a control approach that seeks to approximate the natural water balance and intercept storm water before it enters the combined sewer system. Green technologies abate storm water by directing the storm flow to the land to be absorbed into the ground.

GSI is often integrated into new developments and called Low Impact Development or LID. However whether the GSI is part of new construction or retro-fitted into existing infrastructure, the goal is to control storm water at its source by reducing impervious areas or increasing infiltration into the ground.

The opportunities to implement GSI need to be established and then these can be assessed for their suitability and capability to provide storm water control to reduce the amount of storm water discharged to combined sewers.

Typical methods to control storm water are:

- Rain gardens
- Tree box filters
- Dry wells
- Ribbon driveways
- Porous paving
- Swales and under-drained swales
- Infiltration trenches and chambers
- Filter strips
- Detention basin / systems
- Wetlands
- Ponds
- Retention structures

GSI approaches are most successful when a number of the above methods are combined in the control program. Infiltration is a key component to the success of GSI as it provides overall storm water reduction. Detention and retention solutions will reduce the peak design discharge of a storm event, or are designed to reuse storm water for other purposes

GSI OVERVIEW	FUNDAMENTAL DIFFERENCES
➢ Advantages • Reduces flooding & CSO volumes • Improves community livability • Improves air quality • Reduces urban heat island effects • Improves water quality • Reduces energy use • Improves wildlife habitat (for large-scale) • Increases recreational opportunities (for large-scale) ➢ Disadvantages • Requires provisions to preserve and maintain functionality in perpetuity • Requires strong community and political support	➢ Infiltration • On site or nearby • Removes from system • Significant maintenance ➢ Detention • On site or in system • Delays discharge • Moderate maintenance ➢ Retention • Directly on site • Reuse • Zero discharge • Operations requirements

4.4.3. Evaluation of Feasibility of GSI for the Entire Phase III Area

One of the tasks in the Reevaluation was to determine if GSI could be an effective control strategy for eliminating, or at least reducing, overflows for all Phase III CSOs. Because of the number of potential GSI applications in the Phase III area, an eight step screening process was developed for evaluating a limited number of sites and then extrapolating these results to the entire area. This process is illustrated in Figure 4-3**Error! Reference source not found.**.

- **Step 1** • **Opportunity Assessment -** GIS based assessment of open spaces that could accommodate GSI solutions
- **Step 2** • **Land Use -** Review of land use to ensure current and planned uses fit in with GSI proposals
- **Step 3** • **Legislation -** Consideration of legislative barriers and drivers; are there and planning restrictions that would prevent the use of GSI or drivers to support their use
- **Step 4** • **Landform -** Topography and soil conditions are there any likely prohibitions on the implementation of GSI techniques
- **Step 5** • **Calculations** - what area could be drained by the GSI proposals and what type of land take and controls will be required to manage flows
- **Step 6** • **Effectiveness -** do the opportunities and calculations assessments indicate that the GSI would be an effective solution
- **Step 7** • **Scalability -** can the GSI be replicated at a scale that would be useful and meaningful
- **Step 8** • **Suitability** - do the proposals fit into the local area, community and utility needs and wishes, avoiding long term negative legacies and vulnerabilities

Figure 4-3 GSI sample areas for Phase III CSOs

This screening process was deemed feasible because the homogeneity of the Phase III area land use characteristics, which are predominantly urban, means sample areas can be investigated in detail and the results applied at a wider scale with some degree of certainty to reflect overall trends and suitability. The application of the eight steps, their description and the results of the application are described below.

4.4.4. Step 1: Opportunity Assessment

Selection of Sample Areas

The first activity in the Opportunity Assessment was to select a limited number of sample areas for analysis with the intent that the results of this analysis would be extrapolated to the entire Phase III CSO area. Eight sample areas were selected, three in the FP CSO service area, and five in the BP CSO area. Information on the sample areas is provided in Table 4-2.

Table 4-2 - GSI Sample Areas

	Location	Service Area	CSO Catchment	Metered subcatchment	Area (ac)
1	Pawtucket	BPSA	220	MVI-2T-1	294
2	Pawtucket	BPSA	220	MVI-2T-2	188
3	Pawtucket	BPSA	220	MVI-4T-1	338
4	Pawtucket	BPSA	206	MVI-1T-4	14
5	Providence	FPSA	035	n/a	137
6	Providence	FPSA	039	n/a	102
7	Providence	FPSA	056	n/a	69
8	Central Falls	BPSA	103	BVI-6T-1	204

The three CSO catchments in the FPSA are the only CSO catchments in the FPSA that were not addressed in Phases I and II. Therefore, they were included in the evaluation in order to determine if GSI is a suitable alternative to the currently recommended sewer separation for these three areas. The suitability for the results of the five sample subcatchments in the BP CSO service area will be applied to the entire CSO service area as they were deemed to represent the area servicing the Phase III CSOs. The RI Geographic Information Systems (RIGIS) aerial imagery was used to identify sites suitable for GSI source control measures. Within these eight sample areas 602 individual sites were identified as potential sites where GSI could be implemented.

The 602 individual sites were comprised of the following:

- parking lots
- open spaces
- medians;
- parking lanes
- residential streets
- flat roofs

Where flat roofs were identified, these generally pertained to commercial properties or multi-family units with a roof area greater than two typical residential homes. Public and private parking lots larger than a single family home were identified as opportunities. Parking lane opportunities were identified in roadways with one or two parking lanes or which were wide enough for implementation of GSI methods such as curb bump outs, rain gardens or pervious pavement. Roadways without parking lanes were identified as potential for sidewalk tree pits or drywell installations in the right-of-way.

Each of the 602 sites was given a unique identifier and detailed information was gathered such as:

- Street name
- Subcatchment
- GSI type
- size (in acres);

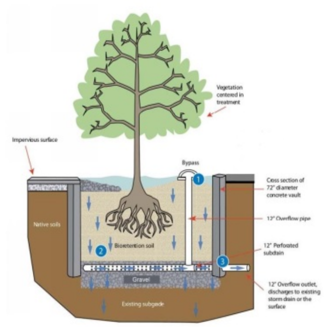
- current land use
- ownership (public / private).

Review of Current GSI Methods

The Opportunity Assessment included a review of current GSI methods for controlling storm water at the source. Examples of these methods are shown in Table 4-3, Table 4-4 and Table 4-5.

Table 4-3 Infiltration Technologies

GSI	Description	Example	Costs and Maintenance *
Stormwater Raingarden Bump Out	A stormwater raingarden bump out is curb extention that intercepts stormwater runoff flowing along a gutter line before being captured by a receiving inlet. The raingarden bump out is vegetated, and usually depressed to capture and store stormwater so it can be infiltrated through a designed porous media cross section or taken up by the plant material prior to overflowing to the receiving inlet. Besides promoting infiltration and removal of stormwater from the system, raingarden bump outs provide stormwater quality treatment during the rainfall events.		Installation Costs: $18/sq. ft to $25/sq. ft Maintenance: sediment removal, pruning, weeding filter media replacement– $2.5/sq. ft per year

GSI	Description	Example	Costs and Maintenance *
Tree Box Filter	A tree box filter is another method of collecting stormwater runoff and promoting infiltration and treatment. The tree box filter can be designed to be a series of trees or as a single unit. These filters are set inside of the curbline along the roadway shoulder normaly adjacent to a pedestrian sidewalk. The tree box filter inlet allows the runoff to flow into a planter filled with a permeable filter media and/or stone that will store, treat, and infiltrate the stormwater runoff and also allow for the stormwater to be taken up by the planted vegetation. Overflow from the stormwater events is directed to overflow pipes that connect back to the drainage infrastructure within the roadway.	  Source: RI Stormwater Design and Installation Manual 2010	Installation Costs: $5,000/Tree to $7,500/proprietary unit Maintenance: sediment removal, media replacement – $100 per year/unit
Dry Wells	Dry wells are concrete leaching structures that promote direct infiltration of stormwater runoff but do not provide for water quality treatment. These structures can be used directly as a leaching catchbasin in areas that do not have heavy debris or sediment collection, or in tandem with a deep sump catchbasin within roadways or paved areas.		Installation Costs: $5,000/unit Maintenance: sediment removal – $100 per year/unit

GSI	Description	Example	Costs and Maintenance *
Permeable Pavement	Permeable pavement or interlocking pavers are an engineered pavement system that comes in many variantions. Standard types include permeable asphalt pavement or concrete pavement, concrete or brick pavers, open celled concrete pavers or grid grass pavers. Permeable pavement or interlocking pavers provides direct infiltration and temporary stormwater storage through a pourous surface structure and underground stone base section draining to the underlying soils.	 	Installation Costs: $8/sq. ft Maintenance: sediment removal, vacuuming – $3/sq. ft per year
Infiltration Chambers	Infiltration chambers are a structural approach to promoting infiltration of stormwater. These systems can be constructed of high density polyethylene or concrete, and can be installed in small or large configurations depending upon the stormwater infiltration necessary or site limitations. These systems can be installed under lawn or pavement areas saving space for other use activities or parking. Pretreatment proprietary devices or water quality structures are normally installed upstream of these systems.		Installation Costs: $ 225/Chamber or $6.50/cu. ft of storage Maintenance: sediment removal at pretreatment device – $100 per year/unit

** Infiltration GSI technologies installation costs vary with the type selected. Maintenance for these systems is required to be done on an annual basis for the system to continue to provide the pretreatment and infiltration as designed. Maintenance would include sediment removal, vegetation or media replacement or vacuuming. The following is a list of general installation and maintenance costs for GSI technologies outlined in the report. The costs are taken from recent projects completed in New England.*

Table 4-4 Detention Technologies

GSI	Description	Example	Costs and Maintenance **
Underground Detention Systems	Underground detention systems are a structural approach to reducing the peak stormwater runoff in a storm event by intercepting stormwater runoff and metering it out back into the existing storm drain system. These systems can be constructed of high density polyethylene pipe, metal pipe, or concrete box type structures, and can be installed in small or large configurations depending upon the detention required for a given project. These systems can be installed under lawns, roadways, or pavement areas. Pretreatment proprietary devices or water quality structures are normally installed upstream of these systems.	 	Installation Costs: $6.50/cu. ft of storage. Maintenance: sediment removal at pretreatment device – $100 per year/unit.

GSI	Description	Example	Costs and Maintenance **
Surface Detention Systems	As with the underground detention systems surface detention systems are designed to reduce the peak stormwater runoff in a storm event by intercepting stormwater runoff and metering it out back into the existing storm drain system. These systems are integrated into the surface landscape and can take up considerable site area depending upon the detention required for a given project. Surface detention systems normally have a pretreatment area built into the design that would treat the stormwater for water quality prior to discharge to the larger detention cell.	  	Installation Costs: $ varies based upon size $20/sq. ft +/-. Maintenance: sediment removal, mowing, replanting - $1/sq. ft per year for sediment removal or mowing, replanting costs varies.

*** Detention GSI technologies installation costs vary with the size designed and required to provide the stormwater detention and peak flow management desired for each individual project. Maintenance for these systems is required to be done on an annual basis for the system to continue to provide the volume and treatment as designed. Maintenance would include sediment removal, mowing or vegetation replacement. The following is a list of general installation and maintenance costs for GSI technologies outlined in the report.*

Table 4-5 Retention Technologies

GSI	Description	Example	Costs and Maintenance ***
Underground Retention Systems	Underground retention systems are another structural approach that instead of reducing the peak stormwater runoff in a storm event by intercepting stormwater runoff and metering it out back the system retains the stormwater for reuse. The reuse of stormwater could be for irrigation purposes or building reuse for fire protection or grey water flushing. These systems can be constructed as a building cistern or from high density polyethylene pipe, metal pipe, or concrete box type structures installed underground.		Installation Costs: $1.00-$1.50/Gal + / - of water stored Maintenance: sediment removal at pretreatment device – $100 per year/unit
Stormwater Wetland Retention Systems	Stormwater wetland retention systems are systems of stormwater retention that employs the use of natural wetlands to store, treat and control stormwater discharges, and also provide a natural habitat for animal species. These systems are designed with multiple water storage pools and different wetland regimes that as stormwater runoff flows through the system pollutant removal is achieved by settling and vegetation uptake. Large storage pools can be designed into the wetland system to provide large volumes of stormwater storage.		Installation Costs: $2.3/cu. ft of water stored Maintenance: sediment removal, replacement plantings – 2%-5% of capital costs or $0.1/cu. ft of water stored

**** As with the Detention GSI technologies, Retention GSI installation costs vary with the size designed and required to provide the stormwater retention desired for treatment or reuse for each individual project. Maintenance for these systems is required to be done on an annual basis for the system to continue to provide the volume and treatment as designed. Maintenance would include sediment removal, mowing or vegetation replacement. The following is a list of general installation and maintenance costs for GSI technologies outlined in the report.*

Site Visits

Following identification of the 602 sites, a series of site visits were undertaken. The site visits were restricted to those areas where additional confirmation as to the suitability of GSI was needed and / or the GSI could be a substantial element of any CSO reduction alternative.

Criteria were developed to be used during the site visits to determine the suitability and feasibility of GSI. The criteria were as follows:

- Porous paving criteria:
  - 0%-5% slope – if steeper areas do any special design considerations apply;
  - Infiltration opportunities
  - No infiltration design – is overflow to storm system viable;
  - Infiltration design – infiltrate to subgrade or deeper; and
  - Proximity of raised sidewalks, parking lots, median strips.
- Rain gardens criteria:
  - Residential and small commercial lot applications
  - Parking lot islands.
- Bio-infiltration
  - Linear features opportunities in street application of boulevard strips and row roadside ditches
  - Park space and beautification projects
  - Parking lot islands
- Down spout disconnects and residential rain gardens

Table 4-6 summarizes the findings of the site surveys for the sample areas and more specifically the CSO catchments identified in Table 4-2. The site IDs are included as a unique reference for each visit and link to the location plans in Appendix 5.

Table 4-6 Site Survey Summary

CSO Catchment	Site ID	Service Area	Description
220	1	BPSA	The 54,000 sq. ft parking area was further reviewed, and though GSI opportunities are available, such as porous paving or bio infiltration this parking area's stormwater flows directly to the Moshassuck River and not into the combined sewer system. Implementation of GSI would not reduce stormwater currently going to the system, but could provide improvements to water quality or flooding within the river.
220	2	BPSA	Park and 200,000 sq. ft parking area was visitied and GSI opportunities are available, such as rain gardens, field soil improvements, porous paving and bio infiltration. The field and parking area's stormwater flow though is shed directly to the Moshassuck River and not into the combined sewer system. Implementation of GSI would not reduce stormwater currently going to the system but could provide improvements to the existing park and for the water quality or flooding within the river.
220	3	BPSA	132,000 sq. ft parking area was visited and there are GSI opportunities that could be implemented such as porous paving or bio infiltration. It appears that this parking area's stormwater flows directly to the Moshassuck River and not into the combined sewer system. Implementation of GSI would again not reduce stormwater currently going to the system, but could provide improvements to water quality or flooding within the river.
206	4a	BPSA	The CSO 206 watershed field investigation was focused on the two parking areas near the intersection of St. Mary's Way and Blackstone Avenue. One parking lot, between High Street and St. Mary's Parish Center, extends the length of St. Mary's Way and is 60ft wide. The lot was empty during the field review, and it has 9ft x 18ft parking spaces and a 24ft wide drive aisle. Three catch basins were observed on the east edge of the parking lot. The southernmost had an outlet pipe to the east. The northernmost catch basin, which was also the low point of the site, discharged to the middle catch basin. The middle catch basin didn't have a visible outlet pipe, although we anticipate discharge to the east.

CSO Catchment	Site ID	Service Area	Description
206	4b	BPSA	The second parking lot, between St. Mary's Way and Roosevelt Ave, is larger and had more vehicles during the time of our visit. There are six rows of parking with three drive aisles and some interior landscaping along Roosevelt Ave. Field measurements indicate the overall width of the parking lot was 185ft. Stormwater runoff from this parking lot flows towards Roosevelt Avenue and the existing combined sewer system. After visiting the site, a suitability analysis was conducted on the existing soil conditions and their ability to handle water. Soil Survey data provided through the Natural Resources Conservation Service show that the soil in the investigation area is urban land, which means that these two parking lots are in an urban area with predominantly impervious areas. It is difficult to assess the drainage properties of these soils without onsite investigations to determine the permeability rate of the urban fill. Implementation of GSI within this area could be accomplished by the introduction of a rain garden system along the Roosevelt Avenue parking lot frontage and tree box filters within the interior of the parking lot.
039 & 056	5	FPSA	Veazie Park was further reviewed, and it was determined due to Veazie Park being at a higher elevation than the area's collection system that implementation of GSI would prove to be costly due to the need for stormwater pipe rerouting and the difficulty of getting stormwater from the upper watershed areas to the park.
039 & 056	6	FPSA	Parking areas surrounding Branch Avenue were further reviewed, and though GSI opportunities are available, such as porous paving or bio infiltration these parking area's stormwater flows directly to the West River and not into the combined sewer system. Implementation of GSI would not reduce stormwater currently going to the system, but could provide improvements to water quality or flooding within the river.
039 & 056	7	FPSA	The RI School for the Deaf was visited and discussions with the engineer of record showed that a large infiltration system was installed on the west side of the school providing infitration for the roof runoff. Stormwater from the parking surfaces were also managed with detention sytems in the front of the school. Further opportunities at this site were limited.

CSO Catchment	Site ID	Service Area	Description
056	8	FPSA	Focused on the northern half of Douglas Avenue due to the apparent better suitability for green stormwater infrastructure practices based upon existing roadway and curbing conditions, the site visit considered the existing topography and also soil conditions. Stansbury, Lancashire, Sherwood, Vandewater, Grand Broadway and Cornwall Streets were the primary locations. Stansbury and Vandewater Streets were relatively flat with a few high points and low points observed. The two streets had sidewalks and curbing (with minimal reveal) along both sides with curb inlets to collect stormwater. These curb inlets convey water to the combined sewer system. Vandewater Street was the only one-way street in the area and was on average 19ft wide. Stansbury Street has two-way traffic and there were cars parked on both sides of the street although there were parking restrictions due to the elementary school at the end of the street. Sherwood and Lancashire Streets are both two-way streets without sidewalks or curbing. They varied in width between 25ft and 34ft. There were a few high points and low points observed on Sherwood and Lancashire Streets, but the overall stormwater runoff from the areas reviewed seemed to be collecting at low points in the middle of both streets. There were both dry wells and curb inlets along Sherwood Street that infiltrate water or convey runoff to the combined sewer system, respectively. Lancashire Street did not have any curb inlets that would be connected to the combined sewer, and only had dry wells that promoted infiltration of stormwater. Grand Broadway and Cornwall Street run perpendicular to the previously mentioned streets, and both have two-way traffic without sidewalks or curbing. Grand Broadway transitions into Glasgow Street at the intersection with Sherwood Street and was on average 40ft wide. It is relatively flat, but there is a low point just beyond its transition to Glasgow Street. No drainage structures were observed on Grand Broadway and runoff flows to the adjacent side streets. Cornwall Street is approximately 22ft wide and receives stormwater runoff from a high point on Sherwood Street which then drains down Cornwall Street towards Vandewater Street. There weren't any drainage structures observed on Cornwall Street. After visiting the watershed, a suitability analysis was conducted on the existing soil conditions and their ability to handle water. Soil Survey data provided through the Natural Resources Conservation Service show that the soil in the investigation area is either Merrimac-Urban land complex or Hinckley soils. The drainage rating for Merrimac-Urban soils is unknown, however the Hinckley soils are shown as excessively drained. Both soils are listed in Hydrologic Soil Group A, which means they have a high rate of water transmission, are suitable for infiltration, and are typically either well drained or excessively drained sands. Implementation of GSI within this area could be accomplished by the introduction of a tree box filter system along Grand Broadway, and the addition of dry wells placed upstream of inlets on streets such as Vandewater.

CSO Catchment	Site ID	Service Area	Description
035	9	FPSA	Branch Avenue in the catchment of 035 area was reviewed and the roadway stormwater flows directly to the Moshassuck River and not into the combined sewer system. Implementation of GSI would not reduce stormwater currently going to the system, but could provide improvements to water quality or flooding within the river.

Following the review of suitable GSI methods and the site visits, applications of infiltration, detention and retention facilities were developed for sample sites in the eight sample areas. These are illustrated in Table 4-7.

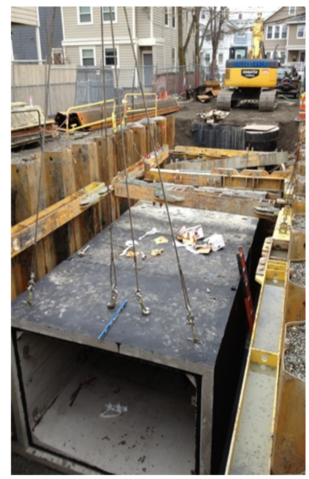
Table 4-7 Application of GSI Techniques

Location	Description
Grand Broadway at Stansbury Street CSOs 039 & 056	Several opportunities were evaluated in the CSO 039 / 056 watershed located in Providence. Grand Broadway was identified as an opportunity to provide an infiltration GSI approach based existing site conditions and underlying soil infiltration characteristics. Grand Broadway at Stansbury Street is approximately 40' wide and is generally flat (see existing picture below). These conditions gives us the opportunity to install stormwater rain garden bumpouts and pervious pavement shoulders as an infiltration GSI technique promoting infiltration and removal of stormwater before entering the combined system.

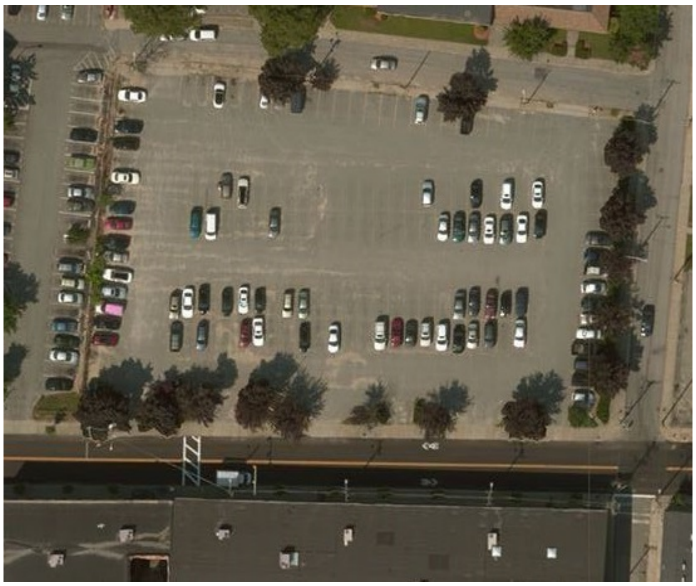
Existing	Proposed GSI
	
The opportunity is for infiltration devices that will initially detain runoff from the highway; the design would be to infiltrate the majority of the captured flow although there would be the potential for overflowing to the combined sewer system at a controlled rate.	Image showing pervious paving (left) in combination with rain garden bumpouts on the right.

Location	Description
Vanderwater Street CSOs 039 & 056	Vanderwater Street was also identified as an opportunity to provide an infiltration GSI approach in this watershed. Vanderwater Street is a one way street with a smaller width (only 19’ wide) and has flat slope on its upper end between Douglas Avenue and Cronwall Street, (see existing picture below). In this section of Vanderwater Street there are no stormwater inlets, and stormwater runs its full length to the intersection of Cornwall Street. These conditions do not lead to a raingarden bumpout solution but does give us the opportunity to install a drywell and tree box filter as an infiltration GSI technique promoting infiltration and removal of stormwater before entering the combined system at Cornwall Street.

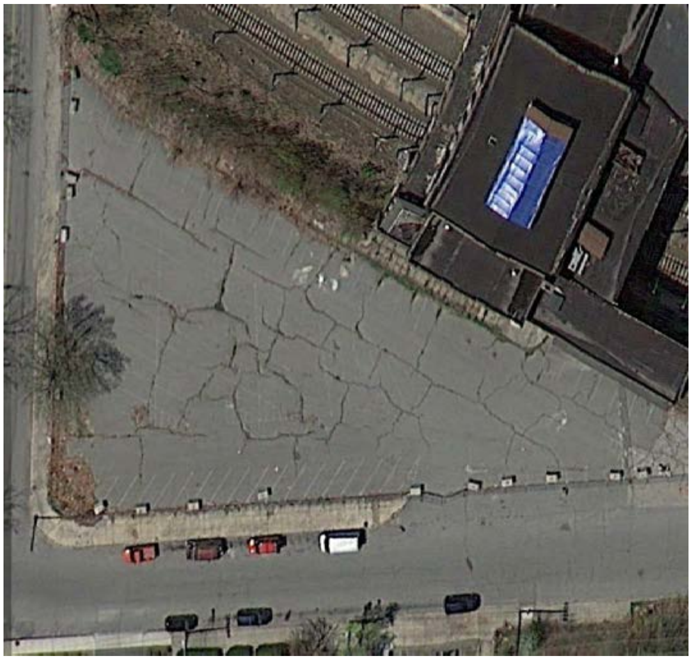
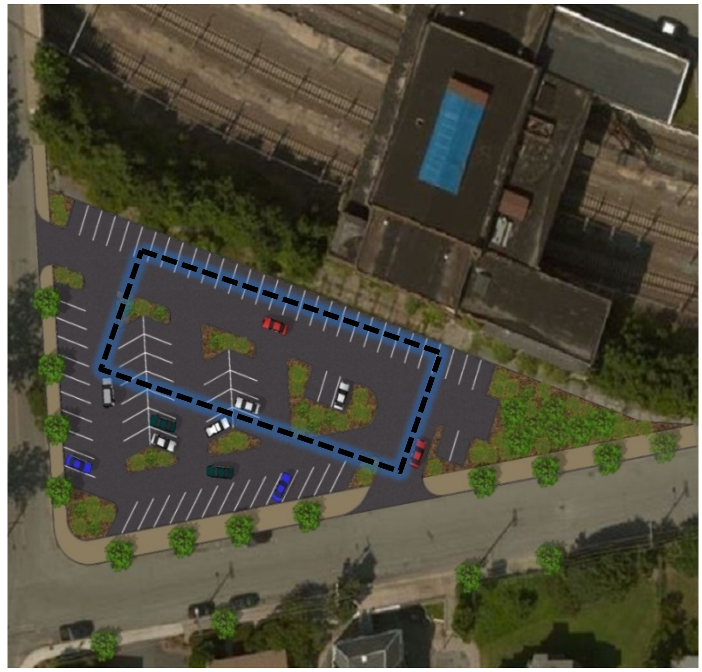
Existing	Proposed GSI
	
This location offers an opportunity for infiltration although the relatively narrow street cofines the appropreate GSI to a smaller footprint.	Image showing pervious Tree Box Filter / Drywell. The key in this instance was to create GSI which fits into the current surrounding, but is both effective for CSO flow control and unobtrusive.

<table>
<tr><th>Location</th><th colspan="2">Description</th></tr>
<tr><td>North Main Street
CSO 035</td><td colspan="2">North Main Street was identified as an opportunity to provide a detention GSI approach based existing up-gradient CSO 035 watershed site conditions and underlying soil infiltration characteristics that were outlined above. Though the up gradient watershed has limited opportunities for GSI, there is an opportunity to install underground detention structures under North Main Street that could capture the redirected upstream watershed runoff and meter the detained stormwater to the combined system after the peak storm event has passed. Though there is limited infiltration potential upstream, there also may be an opportunity to combine the underground detention GSI solution with a surface stormwater raingarden bumpouts. The raingarden bumpouts would promote some infiltration and provide water quality treatment of the North Main Street stormwater before entering the combined system, (see existing and proposed pictures below).</td></tr>
<tr><th>Existing</th><th colspan="2">Proposed GSI</th></tr>
<tr><td>
This location offers more infiltration potential but also based on the topography the GSI could offer a means of capturing runoff from areas beyond the highway in which it is located.</td><td>
Stormwater Raingarden Bumpout installed above would offer the necessary GSI appeal and could support some levels of infiltration.</td><td>
Stormwater detention installed below attenuate addition flow to ‘slow’ runoff entering the combined sewers.</td></tr>
</table>

Location	Description
Roosevelt and Blackstone Avenue CSO 206	For stormwater retention opportunities sites in the CSO 206 catchment were evaluated. One area that was identified as potential areas that stormwater could be collected and potentially reused for existing or future redevelopment was the parking areas at the intersections of Roosevelt and Blackstone Avenue The parking area could be redeveloped to include several of the infiltration GSI techniques but are a prime area for the installation of a large underground retention system that could store the stormwater for reuse for irrigation, fire protection, or adjacent building reuse.

Existing	Proposed GSI
 This location could offer the potential for a retetion facilty in an urban space without the changing of land use. This is an important consideration when retro-fitting GSI as fucntional land use removal can create a negative legacy associted with the location.	 The site could encompass a Stormwater Underground Retention system with the retained runoff potentially being used as a non-potable water source for the existing mill facility.

Location	Description
Montgomery and Barton Street CSO 206	Montgomery and Barton Street were also selected. The parking area could be redeveloped to include several of the infiltration GSI techniques but are a prime area for the installation of a large underground retention system that could store the stormwater for reuse for irrigation, fire protection for future adjacent redevelopment.

Existing	Proposed GSI
 Another example of a retetion facilty in an urban space.	 The site could encompass a Stormwater Underground Retention system with the retained runoff potentially being used as a non-potable water source for adjacent future building redevelopment.

The findings from the site visits confirmed that the GSI proposals could be taken forward to subsequent steps.

Step 1 identified a 602 individual GSI opportunities across the eight sample areas.

4.4.5. Step 2: Land Use

The 602 sites identified in Step 1 were further evaluated against environmental hazard sites, major transportation thoroughfares and existing GSI installations under the NBC Stormwater Program.

The NBC Stormwater Mitigation Program was begun in 2003 and requires property owners who are applying for a new sewer connection or to increase their wastewater discharge by more than 20% to mitigate and reduce stormwater runoff by the installation of green stormwater infrastructure and LID techniques. Between 2003 and 2013, the NBC Stormwater Mitigation

Program has permitted over 113 projects that have removed over 6.8 Million Gallons of storm water from the NBC sewer system.

GIS data on environmental hazards in the CSO service area was obtained from RIGIS and reviewed. Any GSI site in close proximity to known environmental hazard sites was removed from further consideration. Sites that had an existing stormwater management facility through the NBC Stormwater Program were also removed from further consideration.

Opportunities directly adjacent to, or on major transportation thoroughfares, such as interstates, railroad tracks and heavily traveled local roadways were also removed from further consideration at this stage. These locations have been logged and could be reconsidered for GSI applications in the future. Other sites with incompatible current land uses were also removed from further consideration.

Following Step 2 the 602 individual GSI opportunities reduced to 544.

4.4.6. Step 3: Legislation

The third step of the process was to evaluate any legislative barriers that would affect GSI implementation. As this is a preliminary GSI feasibility task, for this study FEMA flood zone data was obtained and compared with opportunities continued on from the Step 2 screening. Sites located in a flood zone were removed from further consideration.

The major consideration for this step was land ownership. The difference between implementing GSI on Public and Private land is different from both a legislative perspective and a technical approach. The ownership of the land impacts assumptions regarding long-term success, since maintenance of the systems is necessary for a successful outcome.

At this stage of the project no GSI locations were removed on the basis of them being either on public or private land. However, this ownership information was retained for use later in the process. The application of GSI to both public and private lands will be investigated but with the understanding that application of GSI to public land will be easier to implement.

- ➢ Land use and ownership
  - Current imperviousness and open space.
  - Selection of GSI types dependent on:
    - public,
    - commercial or
    - residential land use.
  - Easements & maintenance plans for private land.
- ➢ Implementation on private property with private funds
  - Ordinance provisions / financial incentives.
  - Redevelopment rate.
- ➢ Implementation partnerships
  - Public – Public
  - Public – Private
  - Public – Non-profit

No further legislative barriers were identified. The results of the Step 3 screening are in Appendix 5.

Following Step 3 the 522 individual GSI opportunities remained unchanged.

4.4.7. Step 4: Landform

Before the benefits of GSI can be determined for a CSO program, the general potential for GSI implementation at a location must be determined based on soil types and topography.

- ➢ Soil types
  - Many GSI practices rely upon infiltration.
  - Tight soils restrict GSI types.
- ➢ Topography
  - Best on slopes under 5%.
  - Effectively impossible on slopes greater than 25%.

Where soils are permeable, infiltration-based GSI such as porous pavement and bioswales can be considered. Where soils are tight, GSI is restricted to retention-based systems such as green roofs or wetlands. Topography with slopes under 5% is preferable and slopes over 12% are prohibitive. The fourth step of the process evaluated the topography and soil conditions at each site that remained after Step 3 screening. Sites identified as opportunities for flat roof GSI were not evaluated for Step 4 and passed through to the next step, as soils and slope do not impact roof-based GSI.

The 2011 digital elevation model available from RIGIS was compared to the sites and the slope was calculated for every three foot interval of ground surface. For each site, the range of slopes was determined and a slope factor (SLF) was assigned to each site. Figure 4-4 depicts the general topography and Table 4-8 summarizes the criteria for assessing GSI suitability based on slope.

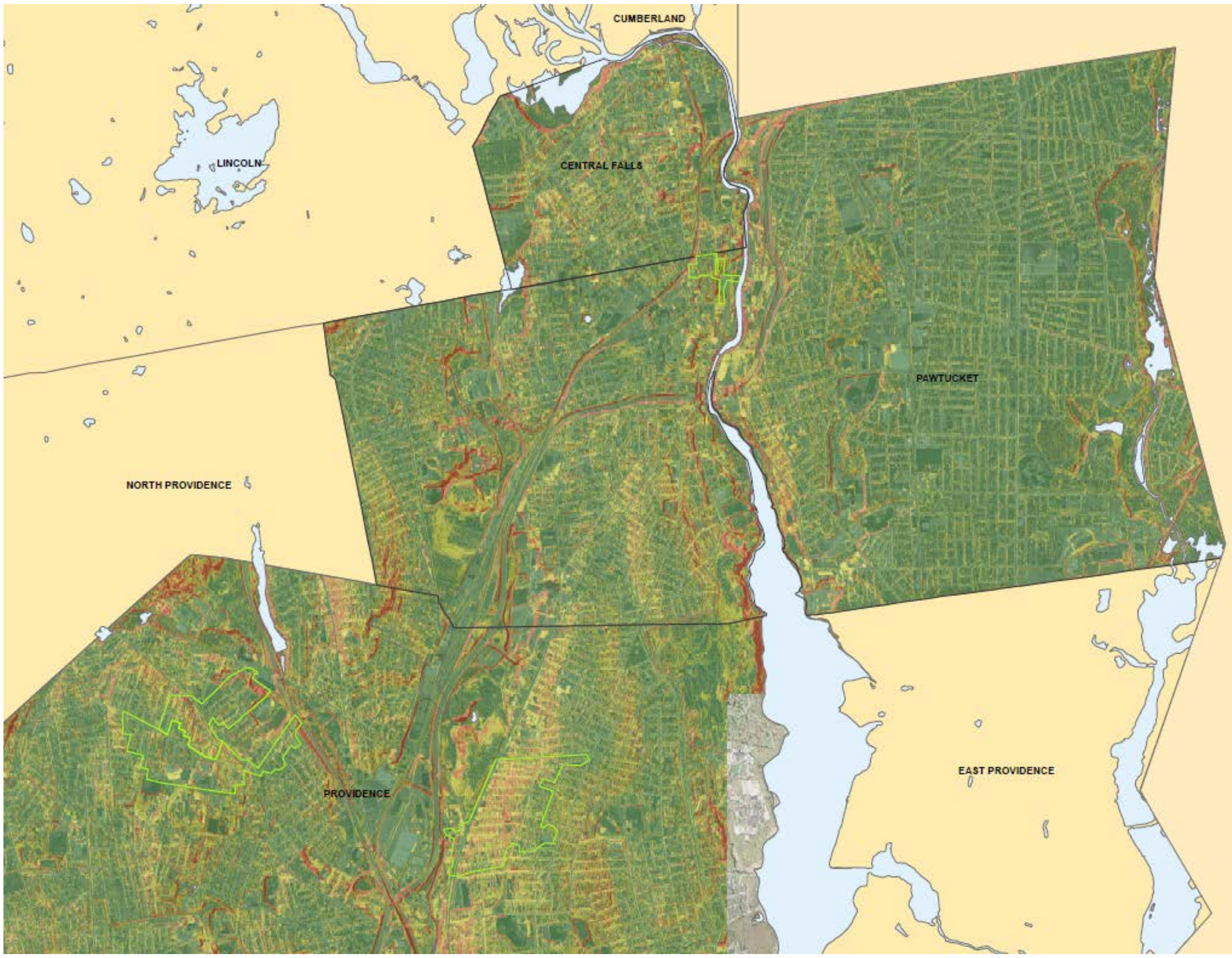


Figure 4-4 Topography across the Phase III CSO Service Area

Areas with steep slopes are generally along the ridge running between the Moshassuck and Blackstone / Seekonk Rivers and on the banks of the rivers, particularly the Seekonk. Otherwise, much of the Phase III CSO area has topography that would be conducive for GSI.

Table 4-8 GSI suitability based on slope

Slope	SLF	GSI Suitability
S <=5%,	1.00	Good
5% < S <=10%,	0.50	Possible
10% < S <=12%,	0.15	Difficult
S >12%	0.00	Poor

The SLF was applied to adjust the GSI site according to the suitability of the land. If the slope was less than or equal to 5%, the site was deemed suitable for GSI and a SLF of 1.00 was applied to the area. If the slope was between 5% and 10%, GSI was deemed possible but difficult and a

SLF of 0.50 was applied to the area. If the slope was between 10% and 12%, GSI was deemed possible on only a small part of the identified area and a SLF of 0.15 was applied to the area. If the slope is greater than 12%, the site was unsuitable for GSI and eliminated from further GSI consideration.

After the slope factor screening, those sites deemed ‘good’ or ‘possible’ for GSI were evaluated for soil conditions. Soil data available from RIGIS was used to determine the underlying soil type and hydrologic group. Figure 4-5 is a map of the soil type and their corresponding hydrologic soil group in the Phase III service area. A soil factor (SOF) was applied to account for the different levels of infiltration potential typical of each soil hydrologic group. Table 4-9 summarizes the SOFs.

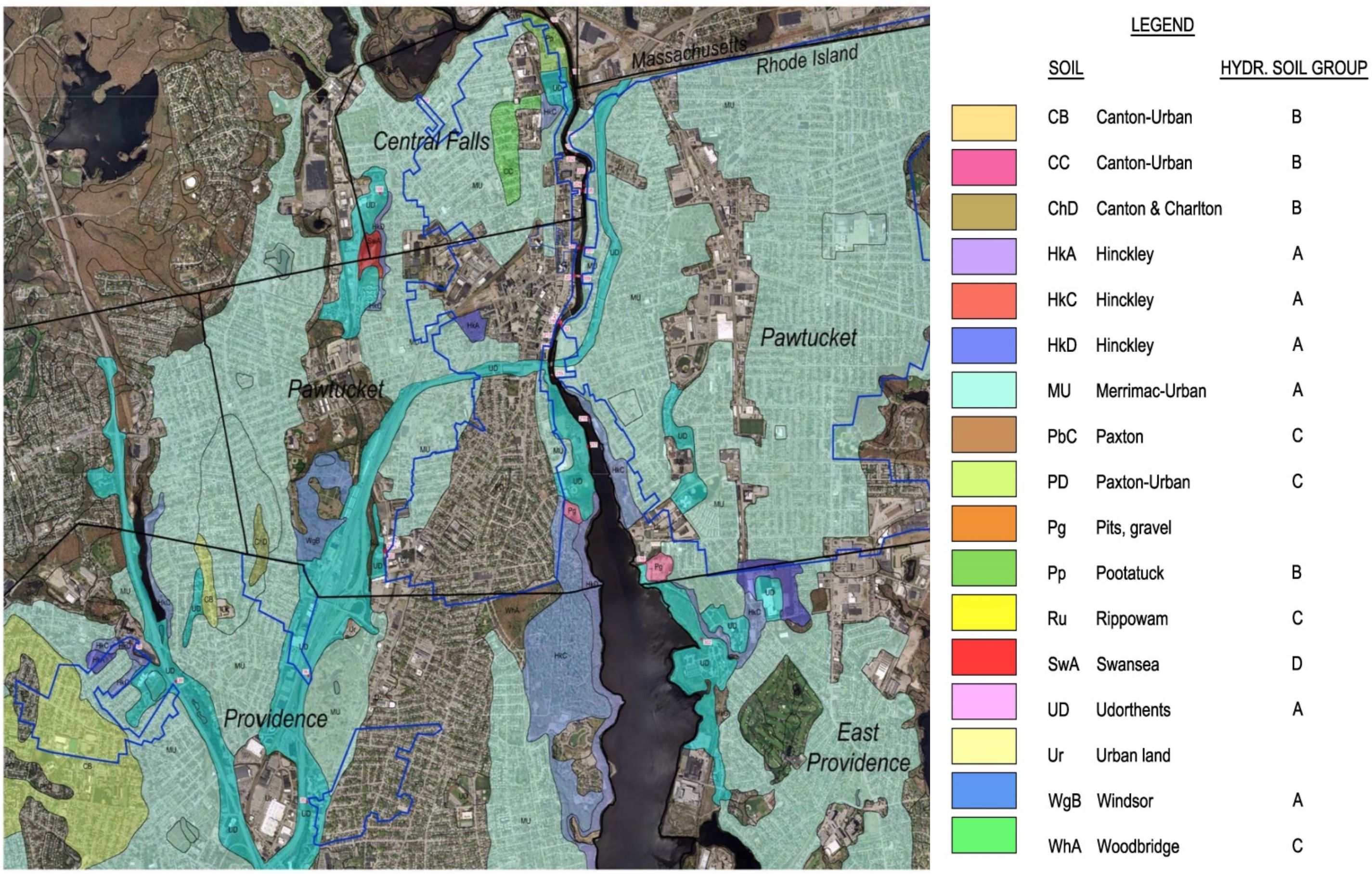


Figure 4-5 Infiltration potential across the Phase III CSO Service Area

In general, the soils are good for infiltration. The ridge that defines the basin divide between the Moshassuck and Blackstone / Seekonk Rivers has soils that do not promote infiltration. Therefore, the neighborhoods on either side of East Avenue in Pawtucket and Hope Street in Providence are not likely to support infiltration-based GSI techniques. Some of the historic industrial sections of Pawtucket have surface soils that were significantly disturbed during development and may contain contamination. While the soils in these areas may support infiltration, GSI would need to be evaluated on a case-by-case basis for contamination. For the purposes of the evaluation, these areas were considered not suitable for infiltration.

Table 4-9 GSI suitability based on soil

Hydr. Soil Group	SOF	GSI Suitability
A	1.00	Good
B	0.50	Possible
C	0.15	Difficult
D	0.00	Not suitable
U	n/a	Urban fill

Soils classified as Urban Fill, or U, were evaluated on a case-by-case basis, taking into account the historical land use (highway, downtown district, mill buildings, etc.) as well as surrounding soil classifications. In general, sites located within urban fill soils were removed from further consideration due to the variable nature and unknown quality of the soils. To determine whether a site was suitable for GSI a simple calculation was derived based on multiplying the slope factor with the soil factor. If the product of the two values was greater than zero, then the site was deemed suitable. The results of the landform assessment are in Appendix 5.

Following Step 4 the 522 individual GSI opportunities reduced to 449.

4.4.8. Step 5: Calculations

Following the screening of the sites in steps 1 through 4, Step 5 calculated the CSO volume that would be controlled by GSI for the eight sample areas. These calculated volume reductions will be used in Step 6 to determine the effectiveness of GSI for CSO overflow reduction over the entire Phase III CSO area.

To assess the feasibility of GSI across the eight sample areas, ‘typical’ GSI solutions were created for the most prevalent land uses, one for public land and one for private land. Each scenario consisted of an assortment of GSI techniques that would be applicable across the entire Phase III CSO area. Using this information in conjunction with the findings from screening steps 1 to 4, each sample area was developed into a conceptual design. Figure 4-6 shows the example conceptual design in sample area BVI-3T-3. All conceptual designs are included in Appendix 5.

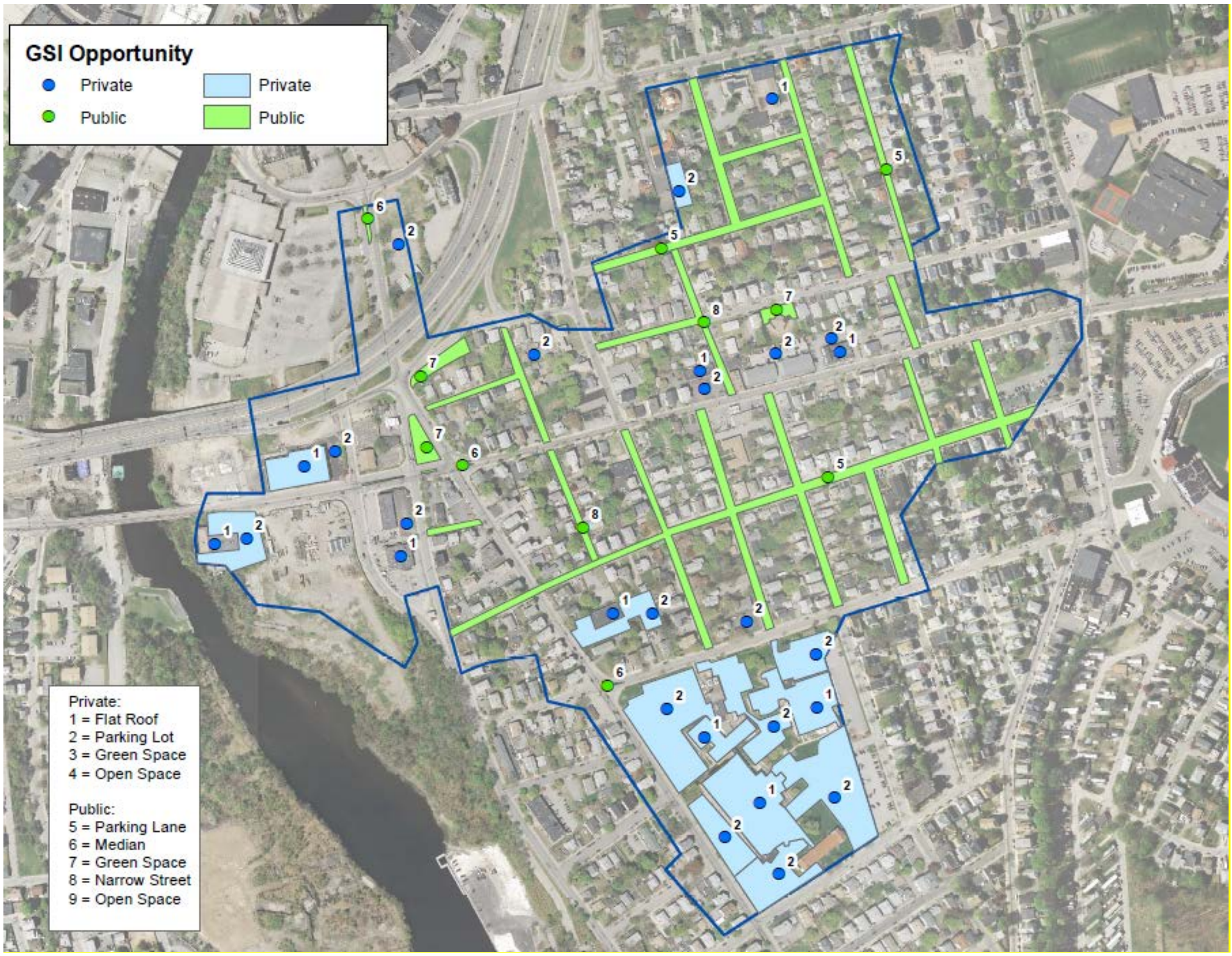


Figure 4-6 CSO 215 (BVI-3T-3) GSI Opportunities

Table 4-10 and Table 4-11 summarize the land uses, GSI solutions included, the design criteria assumptions and the approximate density of the solutions in the conceptual designs.

Table 4-10 Private Land GSI elements

Private Land			
Land Use	**GSI Solution**	**Design Criteria**	**Approximate density**
Residential	Porous Pavement & Bioretention Parking Lots	18-in Reservoir Course at 40% void space equates to 7.2-in depth of storage	3 at 20,000 sq. ft (50 Spaces) Average
Residential Property	Flat Roof (including green roof)	15-in snow load at 10:1 SLE (snow to liquid equivalent) equates to 1.5-in storage	2 at 5,000 sq. ft
Residential Property	Rain Garden	4-in depth between surface and subsurface storage equates to 4-in depth of storage	15 at 1,500 sq.ft of Roof Area

Table 4-11 Public Land GSI elements

Public Land			
Land Use	**GSI Solution**	**Design Criteria**	**Approximate density**
Parking Lanes	Porous Pavement	12-in Reservoir Course at 30% void space equates to 3.6-in depth of storage	6ft wide by 36in deep with 30% void space
Parking Lanes	Tree Box Filter	4-foot dia MH at 6-ft of storage depth, for each 0.02 acres (50LF*15-ft wide road) equates to 36 cu.ft storage	1 Tree Box Filter per 40-LF
Parking Lanes	Raingarden / Bumpout	4-in depth between surface and subsurface storage equates to 4-in depth of storage	1 Raingarden Bumpout per 300-LF
Narrow Streets	Dry well / infiltration catch basin	4-foot dia MH at 6-ft of storage depth, for each 0.02 acres (50LF*15-ft wide road) equates to 76 cu.ft storage	1 Drywell/ICB per 0.02 acres (approx. 50-LF on 16-ft wide roadways); 10-ft Deep Drywell/Infiltration Catch Basin: 6-ft storage
Medians	Bioswale	4-in depth between surface and subsurface storage 4-in depth of storage	Plan area

The potential storage volumes for each conceptual design were calculated for two conditions:

- GSI located on public land; and
- GSI located on public and private, termed 'all' land use.

For both conditions, the calculated volume was applied pro-rata across each sample area to give a total GSI control volume that would be retained during wet weather events. Table 4-12 summarizes the calculated volumes for each sample area.

Table 4-12 Sample areas GSI potential volumes

Catchment		Screened GSI Potential[5]				GSI Potential Implementation Rate		
ID[1]	**Area (ac)**	All Area[2] (ac)	All Volume[2] (MG)	Public Area (ac)	Public Volume[4] (MG)	All GSI[2] (gal /ac)	Public GSI (gal /ac)	Public GSI[4] (%)
MVI-2T-1	294	29.59	1.67	3.70	0.36	5685	1235	22
MVI-2T-2	188	32.18	2.32	11.36	0.54	12316	2863	23
MVI-4T-1	338	21.28	1.87	2.85	0.24	5535	700	13

Catchment		Screened GSI Potential[5]				GSI Potential Implementation Rate		
ID[1]	**Area (ac)**	All Area[2] (ac)	All Volume[2] (MG)	Public Area (ac)	Public Volume[4] (MG)	All GSI[2] (gal /ac)	Public GSI (gal /ac)	Public GSI[4] (%)
BVI-3T-3	103	15.51	0.85	2.55	0.21	8242	2019	24
035	137	3.99	0.20	0.48	0.05	1455	378	26
039	102	1.95	0.17	0.91	0.09	1641	875	53
056	69	3.87	0.21	3.68	0.17	3001	2448	82
BVI-6T-1	204	27.28	1.61	9.58	0.51	7879	2486	32

Notes: [1] IDs are the sample areas.

[2] 'All' refers to both Public and Private GSI areas.

[3] The percentage for public is the proportion of all possible GSI.

[4] Public includes only public rights of way, institutional and municipal facilities are included in 'All'.

[5] Volumes presented in this table are storage provided by GSI.

The values from this analysis were then used in the hydraulic model to predict the effect of GSI on reducing CSO overflow volumes. Appendix 5 includes the results of applying Step 5.

Following Step 5 the 449 individual GSI opportunities remained unchanged.

4.4.9. Step 6: Effectiveness

In this step, the remaining 449 GSI opportunities from Step 5 were evaluated for effectiveness in capturing runoff. Reviewing the GSI locations it was apparent that due to the land use some identified GSI locations offered a very limited opportunity to capture runoff from the local area. In these instances the GSI was deemed ineffective and removed. Ratios between total runoff from a location and the amount that GSI could capture were estimated and the ratio was used to determine effectiveness based on the following criteria

- sites on public property required a capture a ratio of 0.5; and
- sites on private properties required a capture ratio of 0.75.

These ratios offered a best estimate as to the efficacy of GSI in sites that based on practicality were not suitable for GSI. This step facilitated the removal of 110 unsuitable commercial and industrial locations, leaving 349 possible GSI opportunities.

Following Step 6 the 449 individual GSI opportunities reduced to 349.

4.4.10. Step 7: Scalability

The scalability step is designed to eliminate any locations that would cause unacceptable cost or effort in terms of implementation and / or future maintenance. The only sites affected by this step would be where a single GSI approach would be feasible and where large numbers would be necessary to meet the effectiveness criteria. At this stage of the process it was considered that all 349 remaining opportunities had at least two possible GSI approaches and therefore no opportunities were screened out during this step.

Following Step 7 the 349 individual GSI opportunities remained unchanged.

4.4.11. Step 8: Suitability

The GSI solutions in Step 1 and as presented in the conceptual design in Step 5 are as follows:

- porous pavement
- bioretention parking lots
- green roofs
- rain gardens
- tree box filters
- dry well/infiltration catch basin
- bioswales

These solutions are the most suitable for the NBC's Phase III CSO service area. These solutions keep storm water out of the combined sewer and provide "co-benefits" by improvement in aesthetics and quality of life.

4.4.12. Results of the Feasibility Study

Table 4-13 summarizes the GSI opportunities across the screening process and the total GSI volume determined to be feasible in each sample area.

Table 4-13 Results from GSI Screening Process

	Meter Catchment		MVI-2T-1	MVI-2T-2	MVI-4T-1	BVI-3T-3	BVI-6T-1	035	039	056
	CSO Catchment		220	220	220	215	103	035	039	056
	Service Area		BPSA	BPSA	BPSA	BPSA	BPSA	FPSA	FPSA	FPSA
	Area (acres)		294.42	188	338.12	102.59	203.76	137	102	69
Step 1 - All Opportunities	Sites Identified	Total	134	141	117	55	77	45	25	8
		Public	20	41	19	21	26	9	12	5
		Private	114	100	98	34	51	36	13	3
	Area (acres)	Total	104.8	85.1	117.0	33.5	66.4	30.1	29.9	14.5
		Public	55.0	47.2	78.3	13.2	33.1	19.3	17.6	13.5
		Private	49.8	37.9	38.8	20.4	33.4	10.8	12.3	1.0
Step 2 - Land Use Screening	Sites Remaining	Total	118	126	112	46	70	44	20	8
		Public	18	31	18	18	24	9	10	5
		Private	100	95	94	28	46	36	10	3
	Area (acres)	Total	48.2	52.2	68.2	18.5	46.3	17.4	9.6	9.2
		Public	8.2	19.0	32.1	3.4	18.2	6.8	4.2	8.2
		Private	40.0	33.1	36.1	15.1	28.1	10.6	5.4	1.0
Step 3 - Legislative Screening	Sites Remaining	Total	118	123	105	46	61	44	20	5
		Public	18	29	16	18	21	9	10	4
		Private	100	94	89	28	40	36	10	1
	Area (acres)	Total	48.2	49.0	52.8	18.5	37.9	17.4	4.5	5.0
		Public	8.2	17.0	25.0	3.4	14.5	6.8	1.8	4.8
		Private	40.0	32.0	27.8	15.1	23.4	10.6	2.7	0.2

	Meter Catchment		MVI-2T-1	MVI-2T-2	MVI-4T-1	BVI-3T-3	BVI-6T-1	035	039	056
	CSO Catchment		220	220	220	215	103	035	039	056
	Service Area		BPSA	BPSA	BPSA	BPSA	BPSA	FPSA	FPSA	FPSA
	Area (acres)		294.42	188	338.12	102.59	203.76	137	102	69
Step 4 - Landform Screening	Sites Remaining	Total	101	99	92	45	50	37	20	5
		Public	14	25	12	18	16	8	10	4
		Private	87	74	80	27	34	29	10	1
	Area (acres)	Total	30.7	33.2	29.0	15.8	28.4	5.1	4.5	4.4
		Public	4.0	12.4	9.0	2.8	9.4	1.1	1.8	4.2
		Private	26.8	20.9	20.0	13.0	19.1	4.0	2.7	0.2
Steps 5 -8 - Calculations Effectiveness Scalability Suitability Screening	Sites Remaining	Total	59	91	82	38	47	18	10	4
		Public	6	20	6	11	16	2	2	3
		Private	53	71	76	27	31	16	8	1
	Area (acres)	Total	29.6	32.2	21.3	15.5	27.3	4.0	2.0	3.9
		Public	3.7	11.4	2.9	2.6	9.6	0.5	0.9	3.7
		Private	25.9	20.8	18.4	13.0	17.7	3.5	1.0	0.2
Effective Storage Volume	Volume (MG)	Total	1,673,817	2,315,482	1,871,486	845,511	1,605,464	199,351	167,371	207,100
		Public	363,530	942,644	269,185	207,116	756,069	51,768	89,270	199,270
		Private	1,310,287	1,372,837	1,602,301	638,395	849,395	147,583	78,101	7,830

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The application of these results across the entire Phase III CSO area based on the conceptual GSI designs was a planning level effort to identify GSI capability and capacity. This approach offers sufficient information across the area for modeling GSI as an alternative for CSO control both in isolation and in combination with grey solutions

4.4.13. Potential of GSI to Reduce Overflow Volumes

Following completion of the eight step screening process the hydraulic models for both BPSA and FPSA were updated with the GSI results and a simulation was run for the NBC 3-month design storm. The results are shown in Table 4-14.

Table 4-14 Overflow results from the 3-month design storm simulation

Overflow no.	Overflow Volumes		
	Current Conditions (MG)	All GSI (MG)	Public GSI (MG)
BPSA			
OF_101	0.38	0.19	0.32
OF_102	0.00	0.00	0.00
OF_103	4.88	3.78	4.49
OF_104	0.49	0.27	0.41
OF_105	1.64	1.37	1.55
OF_107	0.37	0.27	0.33
OF_201	1.34	1.13	1.29
OF_202	0.18	0.13	0.16
OF_203	0.40	0.25	0.35
OF_204	0.16	0.00	0.08
OF_205	12.8	8.88	11.82
OF_206	0.14	0.13	0.14
OF_207	0.04	0.00	0.03
OF_208	0.01	0.00	0.01
OF_209	0.02	0.00	0.01
OF_210	3.17	3.06	3.11
OF_211	3.96	3.90	3.93
OF_212	0.60	0.39	0.54
OF_213	1.98	1.64	1.86
OF_214	1.26	0.60	1.04
OF_215	1.58	0.91	1.39

Overflow no.	Overflow Volumes		
	Current Conditions (MG)	All GSI (MG)	Public GSI (MG)
OF_216	0.01	0.00	0.00
OF_217	2.71	1.99	2.49
OF_218	12.58	4.98	10.69
OF_220	4.60	1.97	3.85
FPSA			
OF_035	0.77	0.68	0.75
OF_039	0.46	0.43	0.44
OF_056	0.42	0.38	0.39
Total (MG)	**56.95**	**36.50**	**51.47**
	Difference	**20.45**	**5.48**
	% Reduction	**36**	**10**

Note: the Current Conditions are taken from the latest BPSA and FPSA models and may differ from those previously reported in the CDRA.

The results show that by applying GSI across all types of land ownership a 36% reduction in CSO overflows is predicted compared with 10% for those in the public areas. These results show that GSI alone will not be able to provide the overflow reductions necessary to meet the EPA requirements for CSO control and that GSI would only be part of the overall solution to managing flows within each CSO catchment.

When considering the impact of GSI on each individual CSO catchment the results indicate that the 'All' GSI scenario would be sufficient to remove the CSO overflows up to a 3-month storm event at OFs 204, 207, 208, 209 and 216.

During the development of the BPSA model and in particular when assessing CSO overflows, the BPSA system was found to be a fine balance between the underflow and overflow at each regulator. Many of the overflows at least in part are caused by the reversing of flows from the downstream interceptor sewers. During wet weather conditions, flows backup through the regulators and contribute to the overflow volumes. During these conditions no amount of GSI in a single catchment will reduce the overflow to zero during a 3-month storm event.

Table 4-15 details the relationship between the GSI implementation volume and the overflow reduction volume attainable if GSI were implemented on both public and private land. The ratio is the overflow volume reduction divided by the implemented volume.

Table 4-15 Ratio between GSI Implementation and CSO Overflow Reduction

Overflow No.	Overflow Volume Reduction (MG)	Implemented All GSI Storage Volume (MG)	Ratio
OF_101	0.21	0.38	0.6
OF_102	0	0.00	0.0
OF_103	1.24	1.61	0.8
OF_104	0.27	0.33	0.8
OF_105	0.32	0.38	0.8
OF_107	0.1	1.01	0.1
OF_201	0.21	0.26	0.8
OF_202	0.05	0.03	1.9
OF_203	0.17	0.25	0.7
OF_204	0.16	0.00	0.0
OF_205	4.07	6.30	0.6
OF_206	0.01	0.01	0.7
OF_207	0.04	0.12	0.3
OF_208	0.01	0.01	0.0
OF_209	0.02	0.22	0.1
OF_210	0.12	0.19	0.6
OF_211	0.06	0.00	0.0
OF_212	0.25	0.32	0.8
OF_213	0.39	0.42	0.9
OF_214	0.7	0.04	16.7
OF_215	0.75	0.85	0.9
OF_216	0.01	0.25	0.0
OF_217	0.75	0.79	1.0
OF_218	7.65	8.41	0.9
OF_220	2.73	5.91	0.5
OF_035	0.09	0.20	0.5
OF_039	0.03	0.17	0.2
OF_056	0.04	0.21	0.2
Total	**20.45**	**28.67**	**0.7**

Three noteworthy points associated with the comparison in Table 15 are:

- The ratio between the GSI volume and the overflow reduction varies significantly
- In the case of OF_14 the CSO reduction was completely out of proportion with the GSI storage volume, demonstrating that effect of reversal of flows in the interceptor and that GSI alone in a single CSO catchment may not be sufficient to reduce CSO to zero during a 3-month design storm; and
- When considered system wide, for every gallon of GSI implemented the reduction in overflow volume will be 0.7 gallons.

4.4.14. GSI Capital Costs

The cost estimates for GSI were developed from the conceptual design for sample area BVI-3T-3. Using the GSI components and applying New England construction costs from 2013 and 2014 GSI projects, a cost estimate was established for the entire sample area. These estimates are shown in Table 4-16. The basis for the cost estimates is provided in Appendix 5.

Table 4-16 GSI Sample Area Project Cost (BVI-3T-3)

GSI Type	Cost Estimate of Sample Sites[1] (2018 $)	Ratio of Sample Sites vs Screened Sites (%)[3]	Cost Estimate for Sample Catchment[1] (2018 $)	Volume Implemented[4] (gal)	Cost per Volume Implemented[1,4] (2018 $/gal)
Public	8,416,889	100%	8,416,889	207,241	40.61
Private	2,100,000	30%	7,000,000	638,137	10.97
All[2]	-	-	15,416,889	845,377	18.24

Notes: [1] Costs are escalated to mid-2018 at 3% per year and include allowances for geotechnical investigations, design, engineering during construction, construction management and contingency.

[2] ‘All’ refers to both Public and Private GSI areas.

[3] Ratio of Sample Sites vs Screened Sites (%) is the proportion of the sample area that was used to generate the cost estimates. These were deemed sufficient for cost estimating purposes.

[4] Volumes presented in this table refer to storage volumes.

Table 4-17 details the cost per gallon of implementing GSI. However, a better indicator is the cost per gallon of CSO reduction. Figure 4-7 shows a comparison between the two costs. The cost of implementation for the public and private GSI is shown as ‘flat line’ cost estimates whereas the cost per gallon reduced are represented by the histogram. In CSO catchments where the CSO reduction cost exceeds the implementation cost, implementation of GSI is not cost effective.

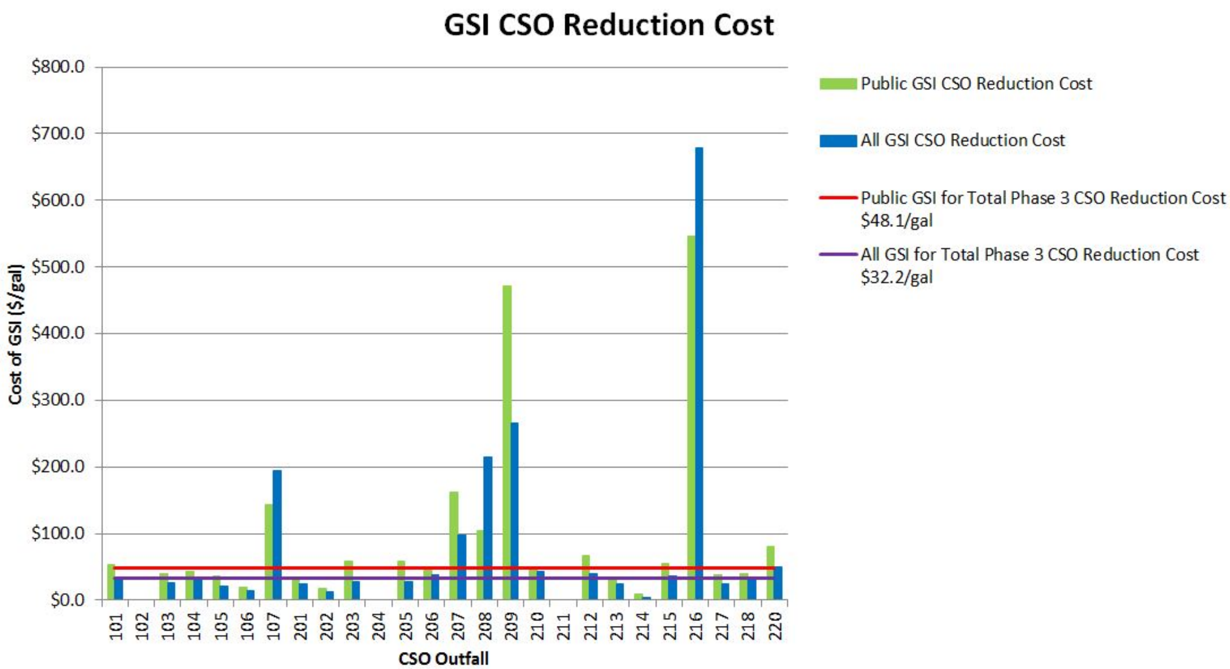

Figure 4-7 Cost per gallon GSI implementation compared to cost per gallon CSO reduction

Table 4-17 shows the estimated costs for GSI implementation at each CSO in the Phase III area.

Table 4-17 Phase III CSO Service Area GSI Capital Costs

CSO Outfall	Public GSI Basin Cost ($)	Private GSI Basin Cost ($)	Full GSI Basin Cost ($)	Public GSI CSO Reduction Cost ($/gal)	Full GSI CSO Reduction Cost ($/gal)
OF_101	3,825,210	3,101,522	6,926,732	54.2	33.7
OF_102	0	0	0	0	0
OF_103	20,732,777	12,103,459	32,836,236	39.8	26.4
OF_104	3,341,401	2,709,244	6,050,646	42.9	30.7
OF_105	3,847,256	3,119,397	6,966,653	36.6	21.6
OF_106	5,269,420	4,272,502	9,541,922	19.1	13.5
OF_107	10,315,705	8,364,085	18,679,789	143.8	193.7
OF_201	2,682,238	2,174,787	4,857,025	32.2	25.0
OF_202	265,223	215,045	480,268	17.0	13.3
OF_203	2,502,500	2,029,054	4,531,553	58.0	27.8
OF_204	0	0	0	0	0
OF_205	64,139,831	52,005,268	116,145,099	58.9	27.5

CSO Outfall	Public GSI Basin Cost ($)	Private GSI Basin Cost ($)	Full GSI Basin Cost ($)	Public GSI CSO Reduction Cost ($/gal)	Full GSI CSO Reduction Cost ($/gal)
OF_206	280,113	75,706	355,819	45.4	37.9
OF_207	1,250,835	1,014,191	2,265,026	162.2	97.7
OF_208	335,393	0	335,393	103.8	214.9
OF_209	2,277,656	1,846,748	4,124,405	471.2	266.6
OF_210	3,936,340	1,063,876	5,000,215	49.8	43.7
OF_211	0	0	0	0	0
OF_212	3,244,093	2,630,346	5,874,439	67.0	40.0
OF_213	4,344,176	3,489,155	7,833,331	30.8	24.4
OF_214	1,704,786	95,408	1,800,193	8.4	4.2
OF_215	8,434,692	7,019,506	15,454,198	55.1	36.3
OF_216	2,539,203	2,058,813	4,598,017	546.1	678.6
OF_217	8,000,617	6,486,987	14,487,604	38.4	23.7
OF_218	85,541,098	69,357,647	154,898,744	39.3	31.7
OF_220	60,110,890	48,802,524	108,913,415	80.0	50.0
Linked to BPWWTF	3,979,109	3,226,305	7,205,413	n/a	n/a
Total	**302,900,561**	**237,261,575**	**540,162,136**	**48.1**	**32.2**

Note: the catchment referred to as 'Linked to BPWWTF' is an area north of the treatment facility that is not within a CSO catchment but where GSI could be applied as part of an overall BPSA strategy.

4.4.15. GSI Potential to Control Phase III CSOs-Conclusion

GSI is a concept which seeks to manage storm water by integrating physical structures with good practice techniques. A screening process was developed, using available information, to determine if any GSI proposals would be feasible. Using an auditable and clear process allowed this reevaluation to assess GSI potential across the entire Phase III CSO Service Area. Potential sites were subsequently converted to feasible opportunities based on land use, landform, effectiveness, scalability and suitability.

Infiltration

- Advantages
  - Provides infiltration and volume reduction
  - Provides water quality improvement
  - Can be installed at a smaller scale
- Disadvantages
  - Underlying soils need to permeable to be effective
  - Cost for larger pervious pavement & infiltration chamber installations
  - Maintenance

Detention

- Advantages
  - Reduction of peak flows
  - Water quality improvement
  - Provides opportunity for infiltration volume reduction
- Disadvantages
  - Land area needed for installation
  - Costs for larger installations

Retention

- Advantages
  - Large volume of stormwater storage
  - Stormwater wetland water quality improvement
- Disadvantages
  - Construction cost
  - Land disturbance
  - Operations cost

During the Reevaluation, technologies were screened to determine which were feasible for different sites. It was determined that there are some limitations to the application of GSI based on the hydraulic performance of the existing interceptor sewers. This results in GSI in some instances not being the most appropriate solution to reduce CSO overflows during the 3-month storm.

The analysis showed that GSI can be regarded as an alternative to grey solutions and although the land use across the entire area is largely homogenous, there are land use and topographic challenges that restrict the wide scale implementation of GSI.

The BPSA and FPSA hydraulic models were run using the results of the screening analysis. The model predicted that a GSI only approach could potentially reduce total CSO volumes by 10% and 34% for 'Public' or 'All' GSI scenarios respectively. These results are on the proviso that GSI is implemented in every CSO catchment identified.

Based on cost estimates for construction of GSI, it was found that there was a wide fluctuation in the cost benefits associated with the implementation of GSI based on the cost estimates compared with the reduction in CSO volume.

The cost results found that GSI implementation at OF_107, OF_207, OF_208, OF_209 and OF_216 could have higher than average cost making these CSO catchments less favorable. However, these costs need to be balanced against the potential for GSI being able to eliminate CSO; model results show that area wide GSI implementation has the potential to eliminate CSOs overflows at OF_204, OF_207, OF_208, OF_209 and OF_216 for the 3-month storm.

While there are many opportunities for implementation of GSI for reduction of CSO volumes GSI solutions alone will not provide the reductions needed to meet EPA CSO control requirements. Therefore, a "grey" component will be needed to achieve the required reductions in CSO overflows. Cost estimates developed for CSO control show that for many of the CSOs, GSI is not cost effective and that the cost/gal can be relatively high. Summarizing the findings of the GSI suitability investigations for the Phase III CSO Program, there are three reasons to keep GSI as an alternative for further consideration:

- As an alternative to where site constraints for grey infrastructure are limiting;
- Optimize the design of the selected grey infrastructure alternatives based on a cost-benefit analysis
- Provide additional control and flexibility in the future. GSI could contribute to adaptive management for future designs and plan modification.

4.5. Sewer Separation

The primary goal of sewer separation is to remove storm water from the sewer collection system. This is done by constructing new storm drains and diverting the storm water flow from the existing combined sewer system to the new storm drains. This reduction in storm water flows eliminates CSO discharges during wet weather. However, the storm water discharged from the separate storm sewers does contain pollutants which can impact water quality.

<u>SEWER SEPARATION</u>

- Advantages
  - Reduced stormwater discharge to NBC interceptors
    - May help upstream and downstream discharges
  - Reduced treatment volume
  - Potential for improved streetscape
  - Potential for other utility improvements
  - Potential for increased level of service
    - Reduced sanitary backups
    - Reduced localized flooding
  - Potential for resiliency planning
- Disadvantages
  - Increased stormwater discharge to flood-prone rivers may require mitigation
  - Increased pollutant loads, particularly nutrients, to receiving water bodies
  - Major disruptions to residential and commercial areas
    - Street closures and traffic delays
    - Economic impact to businesses
  - Illicit discharge potential
  - Utility coordination (water, gas, electric)

Sewer separation was described in detail in both the CDR and CDRA in the technology evaluations, in Chapter 6 of both reports. The basic components of sewer separation have not changed. This section supplements the information provided in the previous reports based on NBC's project experience in Phase II of the CSO Program and recent field investigations.

4.5.1 Phase II Sewer Separation

Phase II of NBC's CSO program included sewer separation in two Providence CSO sewersheds in Providence. Problems were encountered during construction related to neighborhood impacts, utilities and restoration.

SEWER SEPARATION - Utility Issues

- Utility Crossings/Conflicts Complicate Drain Installation
- Inaccurate/Incomplete Mapping Represents Significant Risk

Sewer separation in urban areas often requires extensive open cut excavation to install new sewers or replace failing old infrastructure. This causes disruption to vehicle and pedestrian traffic as well as noise and dust hazards in residential and commercial areas and is very disruptive to residents and businesses in the area. These problems were most pronounced in the Hope St. business district. Utilities such as water, gas, and underground electric are located above sewer and drain pipes. The coordination involved with relocating and upgrading old utility services, such as water and gas mains, and electric lines can significantly impact the schedule and cost of merely separating the pipes. Old utility services are often inaccurately or incompletely mapped, increasing the risk of conflicts arising during construction. In some cases, narrow streets with robust utility infrastructure make installation of new drainage manholes alongside other utilities, including sewer manholes, problematic. Work in close proximity to old gas mains often necessitates complete replacement with new, plastic gas mains, at a very high cost.

SEWER SEPARATION - Restoration Issues

- Costly Pavement & Concrete Base Replacement
- Sidewalk and Curb Replaced Beyond Original Limits
- Several New Wheelchair Ramps Added During Construction

The depth of excavation required for sewer and drain and associated utility conflicts often requires restoration of the road surface from curb to curb. Additionally, installation of catch basins along the edge of roadways intrudes into sidewalks, driveways, and landscaped areas and can impact above ground utility infrastructure such as utility poles and fire hydrants. Figure 4-8 shows an example of the Phase II sewer separation work in progress and Figure 4-9 shows a post construction separated area.

Figure 4-8 - NBC Phase 2 Sewer Separation Surface Restoration

Figure 4-9 - NBC Phase 2 Sewer Separation Surface Improvements

4.5.1.1. Sewer Separation Costs

The separation of combined sewer systems typically involves the construction of a new system that conveys all stormwater runoff or sanitary flow depending on the existing system configuration. This report assumes the construction of a new system used to convey only stormwater runoff and the existing system used for conveyance of only sanitary flows, as well as the rehabilitation of a portion of the existing combined system.

Estimated costs are based upon approximate quantities of separated sewers as defined in the CDRA. The sewer separation costs assume open-cut construction, including trench excavation, sheeting, dewatering, backfilling, pipe bedding, installation of surface restoration, as well as utility replacement. Costs for the required construction effort will vary between service areas since they are dependent upon traffic flow and the density of building and houses in the area. The cost estimates for Phase III were developed using two datasets:

- recent planning efforts in Springfield, MA, summarized in **Table 4-18**; and
- actual costs from NBC's Phase II Sewer Separation projects bid results **Table 4-19**.

Table 4-18 – NBC Phase II and Other Planning

Source	Area Designation	Construction Percent Complete	Pipe Length (LF)	Unit Cost ($/LF existing pipe)[2]
NBC Phase II CSO 027 (303.05C)	Residential[1]	99%	16,275	634
NBC Phase II CSO 037 West (303.06C)	Residential[1]	91%	11,657	767

<table>
<tr><th>Source</th><th>Area Designation</th><th>Construction Percent Complete</th><th>Pipe Length (LF)</th><th>Unit Cost ($/LF existing pipe)[2]</th></tr>
<tr><td>NBC Phase II CSO 037 South (303.07C)</td><td>Residential[1]</td><td>50%</td><td>12,700</td><td>689</td></tr>
<tr><td>NBC Phase II CSO 037 North (303.08C)</td><td>Residential[1]</td><td>76%</td><td>10,450</td><td>794</td></tr>
<tr><td rowspan="3">Springfield, MA Long-Term Control Plan</td><td>Residential</td><td rowspan="3">Planning Level Estimate</td><td rowspan="3">n/a</td><td>833</td></tr>
<tr><td>Commercial</td><td>1,281</td></tr>
<tr><td>Urban Commercial</td><td>1,525</td></tr>
</table>

1 Area Designation of NBC Phase II areas were determined by project team site visits.
2 All unit Costs were escalated to mid-point 2018 for comparison with other estimates.

Estimates from the bid results from NBC's Phase II Sewer Separation projects were evaluated against the recent bid results from similar projects in Springfield, MA and Cambridge, MA and found to be comparable. However, not all of the NBC Phase II Sewer Separation projects were complete at the time of review (Fall 2014).

Table 4-19 presents the unit costs used to estimate sewer separation costs. Note the large discrepancy in unit cost between 035 and other catchments is due to a portion of the existing catchment in CSO 035 consisting of a two-pipe system which reduces the extents of separation which is detailed later in this section. The costs presented herein represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management and land acquisitions.

Table 4-19 – NBC Phase III Sewer Separation Construction Costs

Outfall Catchment	Catchment Area (acre)	Unit Cost ($/acre)	Existing Pipe Length (LF)	Unit Cost ($/LF existing pipe
035	136	$115,978	54,420	$290
039	102	$199,221	24,420	$832
056	69	$196,664	16,180	$839
206	14	$317,349	5,140	$864

The O&M cost for new pipe as part of sewer separation is estimated at $0.23 per linear foot per year. The O&M cost is based on routine cleaning, inspection, and televising of the new sewers once every five years.

4.5.2. Phase III Total Sewer Separation (Elimination)

The elimination of CSO overflow in the NBC Phase III study area would involve complete sewer separation of the existing combined system, shown in Figure 4-10 includes the entire cities of Central Falls and Pawtucket as well as Phase III baseline sewer separation areas in Providence.

In pursuing the total sewer separation of the Phase III study area it would eliminate all CSOs, however, it would also result new points of discharge for storm water runoff. Based on current industry trends, it is likely that under these circumstances the new storm water outfalls would require additional mitigation in the future to address the discharge of pollutants and water quality, particularly bacteria, associated with the storm water.

The content of Table 4-20 summarizes total sewer separation costs for the Phase III study area based. The cost estimates for sewer separation in the Providence Phase III CDRA areas were evaluated using detailed collection system information (pipe sizes, lengths, locations, etc), as detailed in Section 4.5.3. However, the lack of digital mapping or comprehensive network database type records for Central Falls and Pawtucket let to a level of uncertainty with the existing collection system. To develop an estimate of the extent of existing collection systems in both cities, the total length of roadway was calculated using RIGIS data.

To develop a unit cost estimate for Central Falls and Pawtucket a comparison was made using the estimates for the Providence Phase III CDRA areas (CSO 035 excluded as it is partially separated) and estimates detailed in Section 4.5.1.1. The comparison yielded that a unit cost of $835/LF would best represent sewer separation in the two cities. To account for the level of uncertainty of the existing collection system, a contingency of 20% was applied to the unit cost estimate for Central Falls and Pawtucket, resulting in a unit cost estimate of $1,000/LF. The costs presented in Table 4-20 represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

Table 4-20 - Total Sewer Separation Costs

City	Source of Estimate	Roadway Length (LF)	Ratio of Existing Sewer Length to Roadway Length	Estimated Existing Sewer Length (LF)	Unit Cost ($/LF Existing Pipe)	Cost ($)
Central Falls	Roadway Calc	171,721	0.98	168,287	$1,000	168,287,000
Pawtucket	Roadway Calc	1,307,060	0.98	1,280,919	$1,000	1,280,919,000
Providence (Phase III CDRA Areas)	See Section 4.5.3					54,161,000
Total						1,503,367,000

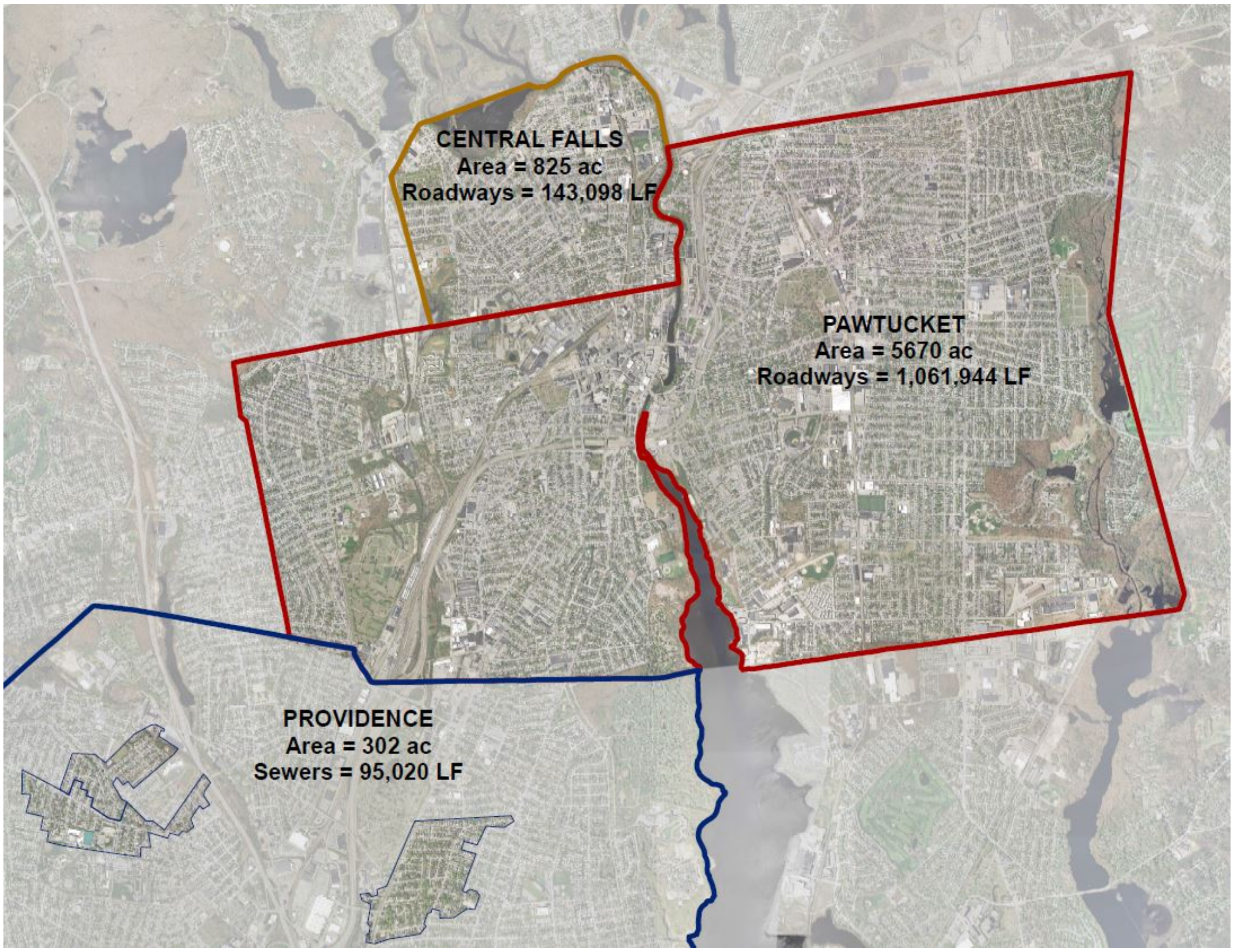

Figure 4-10 - Total Sewer Separation of Phase III Study Area

4.5.3. Evaluation of Outfalls for Sewer Separation

The Phase III Baseline Alternative, as shown in Figure 4-11, designates sewer separation for CSOs 035, 039 and 056 in Providence which discharge to the West and Moshassuck Rivers and CSO 206 in Pawtucket which discharges to the Blackstone River. Sewer separation will be considered for these four overflows because this is what is approved for these alternatives in the CDRA. However, due to the costs for sewer separation, the problems encountered during the Phase II sewer separation construction and the water quality impacts of the storm water discharges from the storm drains, sewer separation was not considered for any other overflows.

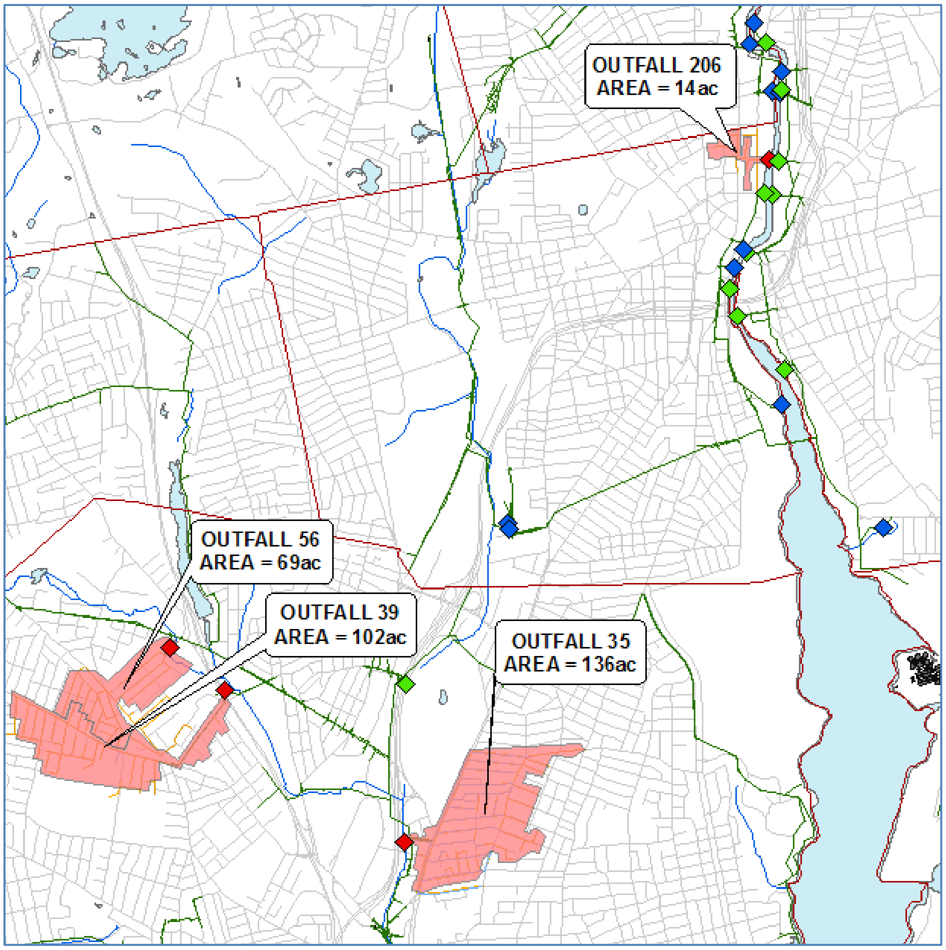

Figure 4-11 - NBC CDRA Phase III Sewer Separation

4.5.3.1. CSO Outfall 035

The catchment tributary area for Outfall 035 is shown on Figure 4-12. It consists of approximately 136 acres of mixed residential and commercial use and slopes significantly from east to west down to North Main Street.

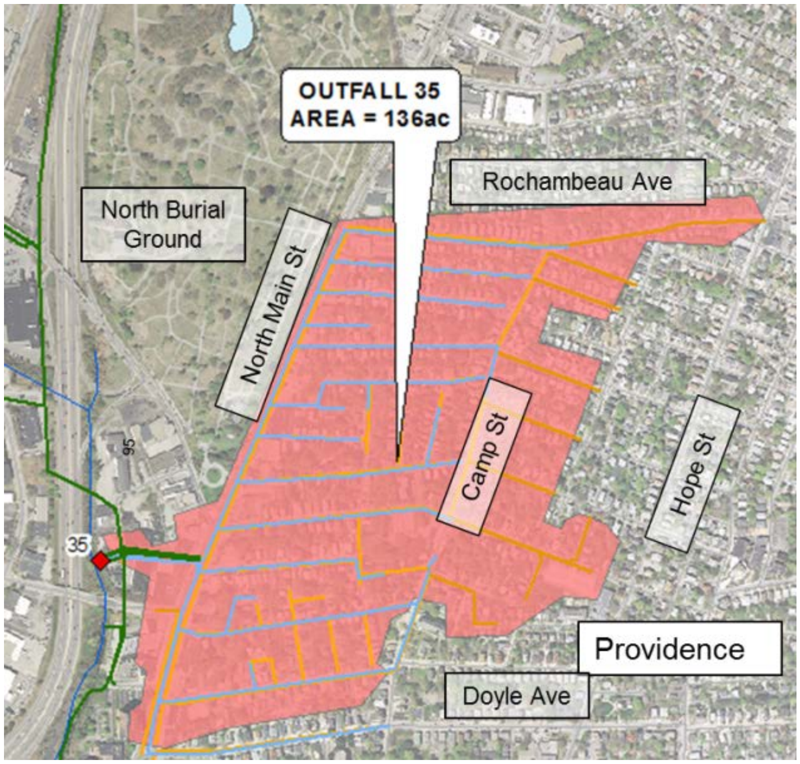

Figure 4-12 - Sewer Separation CSO 035

The CSO 035 catchment area is adjacent to CSO catchments 027 and 037 which were separated in Phase II. A major difference between the adjacent catchments 027 and 037 and 035 is that most of the collection system in the 035 catchment area currently consists of a two-pipe system comprising sanitary and combined sewers as shown in Figure 4-12. It is possible that some of the pipes assumed to be combined are in fact separate storm drains, but until that can be verified through illicit detection and field inspections they are assumed for the purpose of this evaluation to be combined. The streets shown in blue have separated sewers along with combined sewers while the streets shown in yellow have combined sewers. Since the majority of the catchment already has a two-pipe system, full separation for 035 would be required in about 20% of the streets. However, a detailed inspection program would need to be completed to evaluate the condition of the existing pipe as well as to determine if cross-connections exist in the separated area. Table 4-21 summarizes the sewers in the CSO 035 catchment.

Table 4-21 - Existing Sewer System in CSO 035

Existing Pipe Size (in)	8	10	12	15	18-24	27-48	>48
Existing Pipe Length (ft)	1,260	0	31,420	8,640	4,430	6,390	2,280

Based on lessons learned, field observations and input from the stakeholders, the baseline sewer separation approach for this area is assumed to include:

- Installation of new drain pipe network, 20% addition to existing pipes (10,884 LF, 8-24" dia.)
- Replacement of 10% of existing pipes (5,442 LF)

- Rehabilitation of 10% of existing pipes (5,442 LF)
- Reuse of 80% of existing pipes (43,536 LF)
- Illicit connection detection
    - Closed-circuit television (CCTV) inspection of all drain pipes
    - Private property building inspections
    - Dye-Testing of suspicious lateral connections
- Adjacent utility work
    - Limited to roadways impacted by separation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (13,061 LF) and service connections up to right-of-way only for roadways where existing pipe is replaced
    - Replacement of 90% of existing gas main (7,347 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company* only for roadways where existing pipe is replaced
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (3,000 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (13,061 LF)

Hybrid Separation

The opportunities for public GSI in this catchment, discussed in section 2, are minimal due to significant slopes and marginal soils but there is some opportunity along North Main St. Therefore, the combination of storm water flow control and GSI alongside sewer separation was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 4-13.

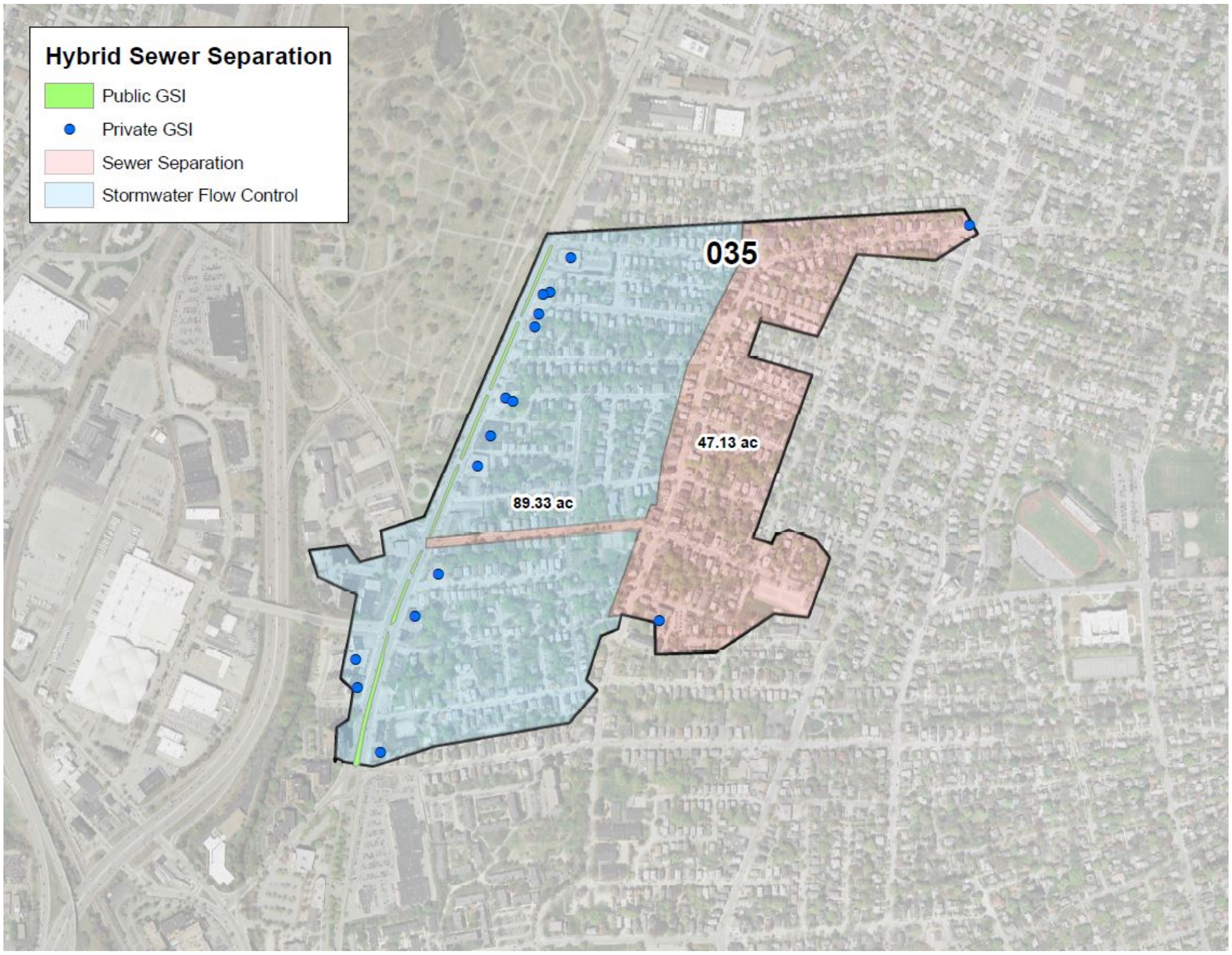

Figure 4-13 - Hybrid Sewer Separation Outfall 035

The hybrid separation reduces the extent of sewer separation by 5,442 LF of 8-54" pipe. The approach for this area is assumed to include:

- Green Stormwater Infrastructure in Public Right-of-Way
    - Median Area GSI (North Main Street, 2,000 LF)
- Stormwater Flow Control
    - Downspout Disconnection
    - Flow Throttle existing catch basins on side streets between Camp St and North Main St (48 EA)
    - Additional catch basin inlet capacity at side street intersections with North Main St (24 EA)
    - Stormwater Storage on North Main Street (150,000 gallons, 1,500 LF of 10'x10' box culvert)
- Sewer Separation (Isn't this the same as straight sewer separation alternative?)
    - Installation of new drain pipe network, 20% addition to existing pipes (10,884 LF, 8-24" dia.) Replacement of 10% of existing pipes in separation area (2,621 LF)
    - Rehabilitation of 10% of existing pipes in separation area (2,621 LF)
    - Reuse of 80% of existing pipes in separation area and 100% of existing pipes in stormwater flow control area (49,178 LF)

- Adjacent utility work
    - Limited to roadways impacted by separation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (10,804 LF) and service connections up to right-of-way where existing pipe is replaced
    - Replacement of 90% of existing gas main (12,155 LF) and service connections up to right-of-way where existing pipe is replaced *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (2,701 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (10,804 LF)
- Outfall 035
- The catchment tributary to Outfall 035 is slated for sewer separation to remove stormwater before it reaches the NBC's system as part of the Phase III baseline condition. The neighborhood generally slopes from east to west down to North Main Street with the side streets having both pronounced curb reveal and sufficient slope to promote overland flow allowing storm water to flow down the hill which in turn could minimize the amount of new infrastructure necessary to separate the system. Storm water would be captured near the bottom of the hill before it reaches North Main St, shown in Figure 4-14. Flows could be stored in a new storm water interceptor or linear stormwater tanks before discharging back to the combined system, or back to the river.

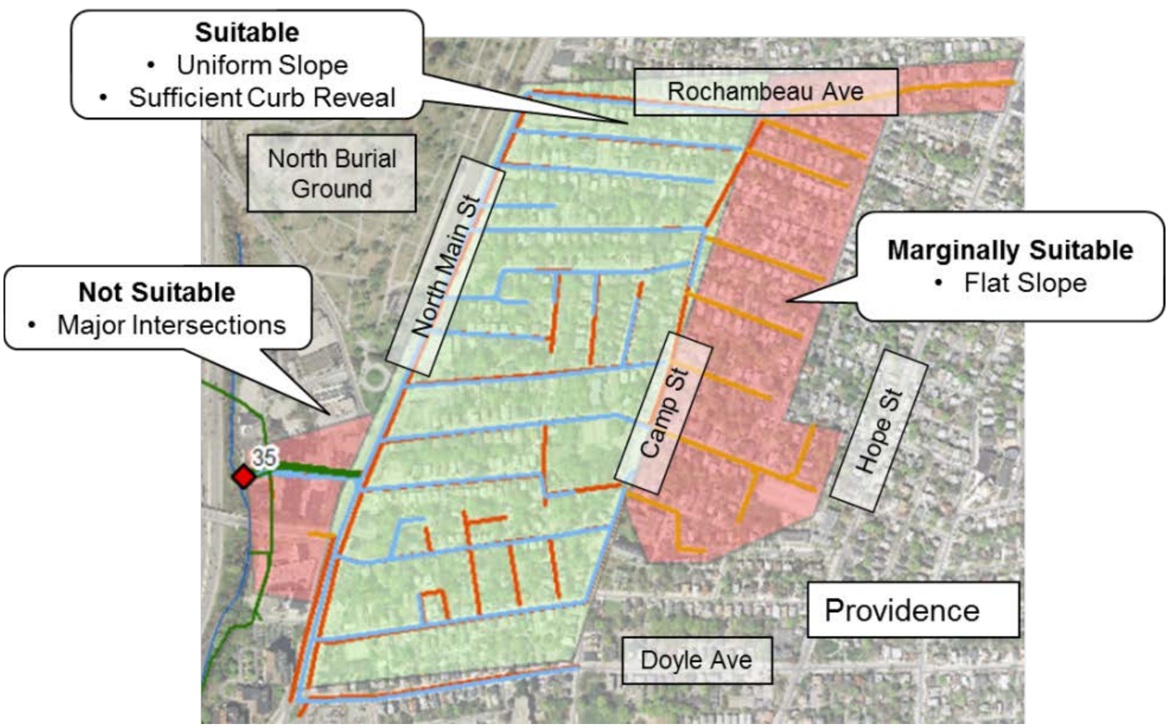

Figure 4-14 - Stormwater Management CSO 035

As shown in Figure 4-14 the eastern section of the neighborhood between Camp Street and Hope Street is only marginally suitable for stormwater control in place of sewer separation, as it has a very low, east-to-west slope and would need to cross Camp Street. The middle section between Camp Street and North Main Street is ideal for promoting overland flow along the east-west sloping streets such as Cypress Street. The lower section at the outfall is not being considered further for overland flow due to close proximity to the high traffic intersections

4.5.3.2. CSO Outfall 039

The catchment tributary to Outfall 039 is a neighborhood of mixed residential and commercial use located in northern Providence in the vicinity of Hawkins St, Douglas Ave, Admiral Ave, and Providence College. There are commercial properties located along Douglas Ave and Admiral Ave that would be impacted by construction. The Rhode Island School for the Deaf, located between outfalls 056 and 039, is also a potentially sensitive abutter. The area is shown on Figure 4-15.

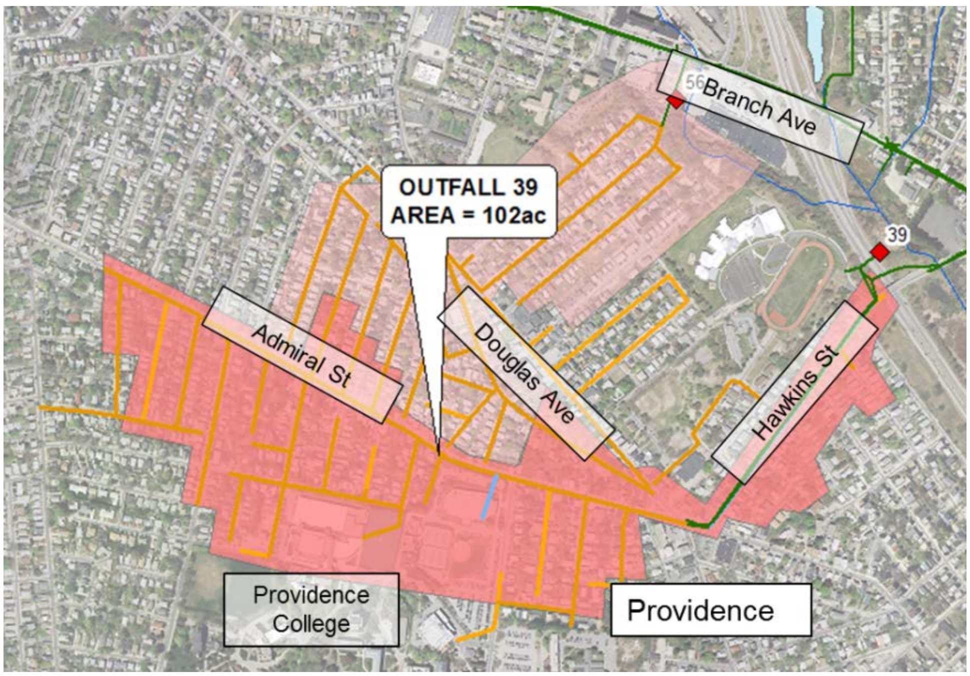

Figure 4-15 - Sewer Separation CSO 039

The collection system in catchment 039 consists of a single-pipe combined sewer. There is one street that may have a separated storm drain. The topography of this neighborhood slopes from southwest to northeast, from Providence College to Douglas Ave. There is a steep drop in elevation just before Branch Ave. Table 4-22 summarizes the sewers in the CSO 039 catchment.

Table 4-22 - Existing Sewer System in CSO 039

Existing Pipe Size (in)	8	10	12	15	18-24	27-48	>48
Existing Pipe Length (ft)	1,320	0	16,870	970	2,010	3,250	0

The West River in this area is prone to flooding and any additional stormwater discharge as a result of sewer separation could exasperate the problem.

Based on lessons learned, field observations and input from the stakeholders, the baseline sewer separation approach for this area is assumed to include:

- Installation of new drain pipe network in 90% of existing sewer pipe network (21,978 LF, 8-24" dia.)
- Replacement of 0% of existing pipes (0 LF)
- Rehabilitation of 10% of existing sewer pipe network (4,574 LF)
- Reuse of 90% of existing sewer pipe network (21,978 LF)
- Adjacent utility work
    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (19,536 LF) and service connections up to right-of-way
    - Replacement of 90% of existing gas main (21,978 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (4,884 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (19,536 LF)

Hybrid Separation

GSI was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 4-16.

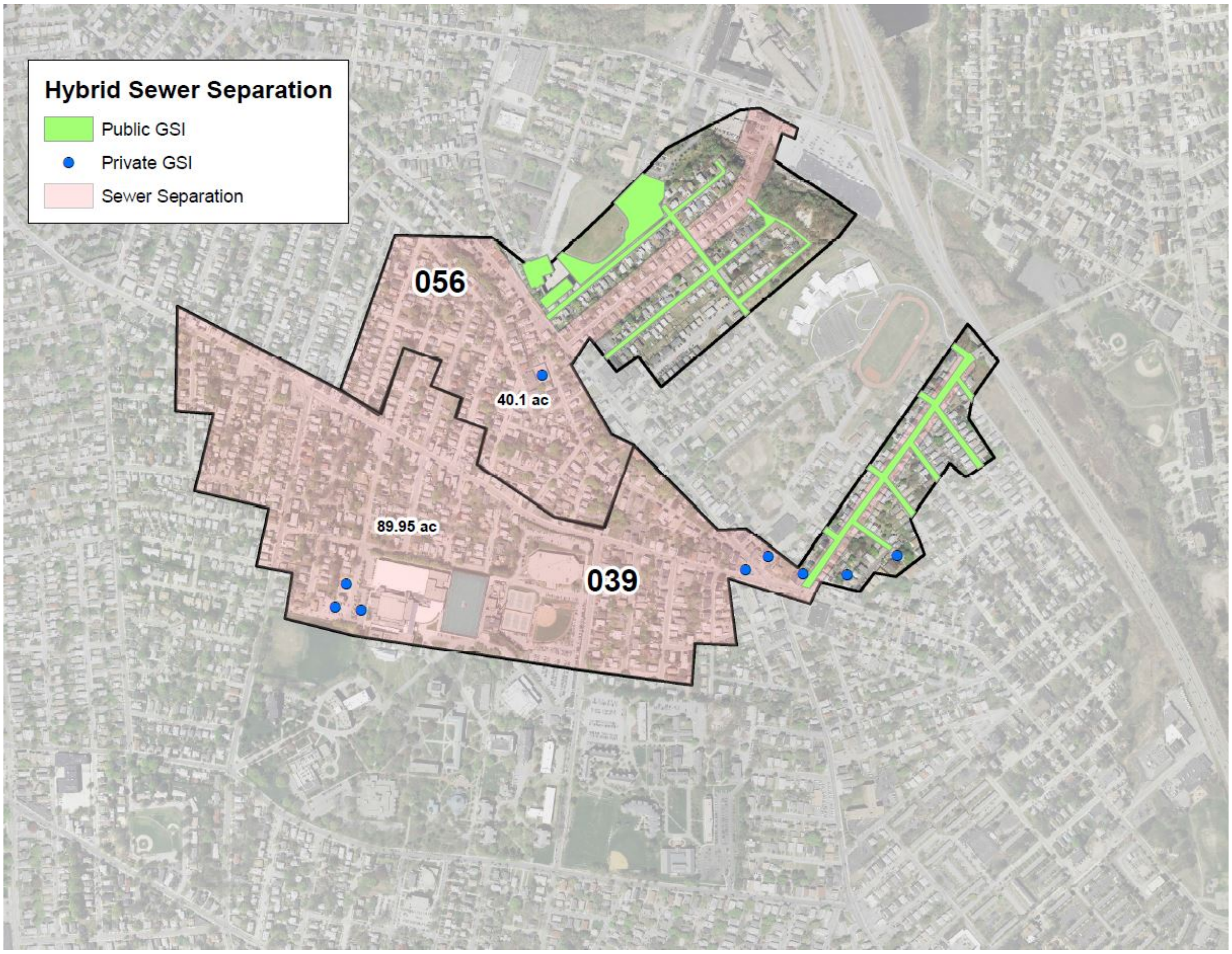

Figure 4-16 - Hybrid Sewer Separation Outfalls 039/056

The hybrid separation reduces the extent of sewer separation by 1,800 LF of 12" pipe. The approach for this area is assumed to include:

- Green Stormwater Infrastructure in Public Right-of-Way
    - Parking Lane GSI (side streets off Hawkins St, 1,800 LF)
    - Parking Lane GSI (Hawkins St, 1,600 LF)
- Stormwater Flow Control
    - Downspout Disconnection
- Installation of new drain pipe network in 90% of existing sewer pipe network (20,178 LF, 8-24" dia.)
- Replacement of 0% of existing pipes (0 LF)
- Rehabilitation of 10% of existing sewer pipe network (4,574 LF)
- Reuse of 90% of existing sewer pipe network (21,978 LF)
- Adjacent utility work
    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (16,143 LF) and service connections up to right-of-way

- Replacement of 90% of existing gas main (18,160 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (4,035 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (16,143 LF)

4.5.3.3. CSO Outfall 056

The catchment tributary to Outfall 056 is a neighborhood of mixed residential and commercial use located in northern Providence in the vicinity of Vanderwater St between Branch Ave, Douglas Ave and Admiral St. There are commercial properties located along Douglas Ave and Branch Ave that would be impacted by construction. Other abutters who are potentially sensitive to sewer separation construction include the Veazie Street Elementary School located at the corner of Douglas Ave and Stansbury St, Providence College with facilities located to the southwest and the Rhode Island School for the Deaf located between outfalls 056 and 039. Also, the intersection of Douglas Ave and Admiral Ave is a high-traffic intersection; see Figure 4-17.

A small area on Veazie St to the north of this catchment has had repeated stormwater flooding issues and the City of Providence is undertaking design to remedy the localized issue.

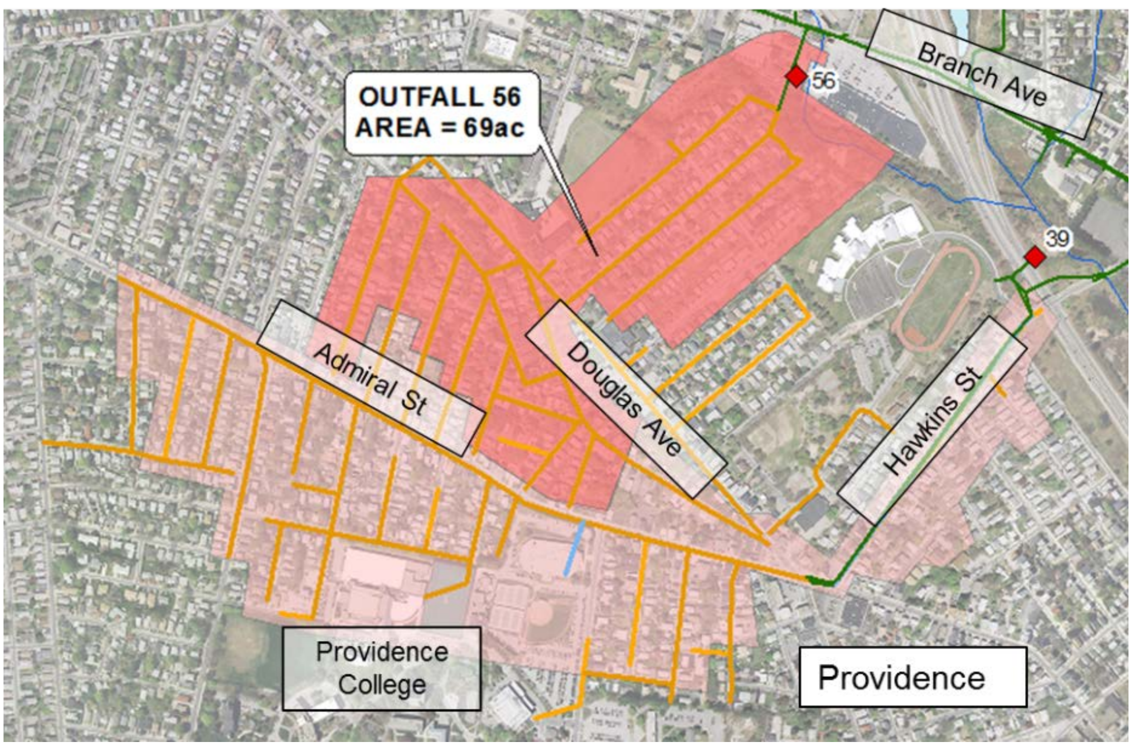

Figure 4-17 – Sewer Separation CSO 056

The collection system in this catchment consists of single-pipe combined sewer. The topography of this neighborhood slopes from southwest to northeast, from Admiral St to Branch Ave with a large flat area from Douglas Ave to just before Branch Ave. There is a steep drop in elevation just before Branch Ave. Table 4-23 summarizes the sewers in the CSO 056 catchment.

Table 4-23 – Existing Sewer System in CSO 056

Existing Pipe Size (in)	8	10	12	15	18-24	27-48	>48
Existing Pipe Length (ft)	890	0	11,350	0	1,440	2,500	0

Based on lessons learned, field observations and input from the stakeholders, the baseline sewer separation approach for this area is assumed to include:

- Installation of new drain pipe network in 90% of existing sewer pipe network (14,562 LF, 8-24” dia.)
- Replacement of 0% of existing pipes (0 LF)
- Rehabilitation of 10% of existing sewer pipe network (1,618 LF)
- Reuse of 90% of existing sewer pipe network (14,562 LF)
- Adjacent utility work
    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (12,944LF) and service connections up to right-of-way
    - Replacement of 90% of existing gas main (14,562 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (3,236 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (12,944 LF)

Hybrid Separation

GSI was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 4-16.

The hybrid separation reduces the extent of sewer separation by 4,360 LF of 12” pipe. The approach for this area is assumed to include:

- Green Stormwater Infrastructure in Public Right-of-Way
    - Parking Lane GSI (Stansbury St, Grand Broadway, Sherwood St, Lancashire St, Cornwall St, 4,360 LF)
- Stormwater Flow Control
    - Downspout Disconnection
- Installation of new drain pipe network in 90% of existing sewer pipe network (10,262 LF, 8-24” dia.)
- Replacement of 0% of existing pipes (0 LF)
- Rehabilitation of 10% of existing sewer pipe network (1,618 LF)

- Reuse of 90% of existing sewer pipe network (14,562 LF)
- Adjacent utility work
    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (8,210 LF) and service connections up to right-of-way
    - Replacement of 100% of existing gas main (9,236 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (2,053 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (8,210 LF)

4.5.3.4. CSO Outfall 206

The catchment tributary to Outfall 206 is approximately 14 acres of mixed residential and commercial use located in Pawtucket on the border of Central Falls. The area is a central business district of Pawtucket centered around Blackstone Ave on the west bank of the Blackstone River, extending up to include portions of Roosevelt Ave, High St, and Montgomery St. There are commercial properties are located along Roosevelt Ave that would be impacted by construction. Other abutters who are potentially sensitive to sewer separation construction include two nearby churches, the Chinese Christian Church on Roosevelt and St. Mary's Orthodox Church on High St and St. Mary's Way and a YMCA located off of Roosevelt just to the north of Outfall 206. The area is shown on Figure 4-18.

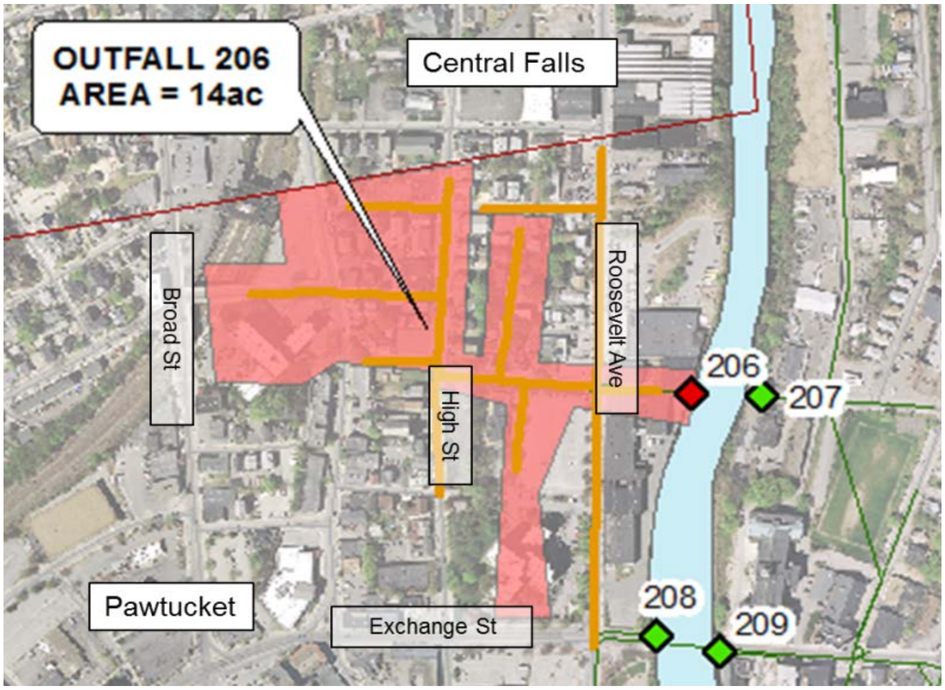

Figure 4-18 – Sewer Separation CSO 206

The collection system in this catchment consists of single-pipe combined sewer. The neighborhood slopes from west to east down the Blackstone River. Table 4-24 summarizes the sewers in the CSO 056 catchment.

Table 4-24 - Existing Sewer System in CSO 206

Existing Pipe Size (in)	8	10	12	15	18-24	27-48	>48
Existing Pipe Length (ft)	1,980	530	940	610	320	760	0

Based on lessons learned and field observations, the baseline sewer separation approach for this area is assumed to include:

- Installation of new drain pipe network in 90% of existing sewer pipe network (4,626 LF, 8-24” dia.)
- Replacement of 0% of existing pipes (0 LF)
- Rehabilitation of 10% of existing sewer pipe network (514 LF)
- Reuse of 90% of existing sewer pipe network (4,626 LF)
- Adjacent utility work
    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (4,112 LF) and service connections up to right-of-way
    - Replacement of 90% of existing gas main (4,626 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (1,028 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (4,112 LF)

Hybrid Separation

Public GSI opportunities are moderate due to significant slopes and unknown urban soils and will not eliminate the overflow alone. Storm water flow control is also possible in this catchment. Therefore, the combination of storm water flow control and GSI were evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 4-19.

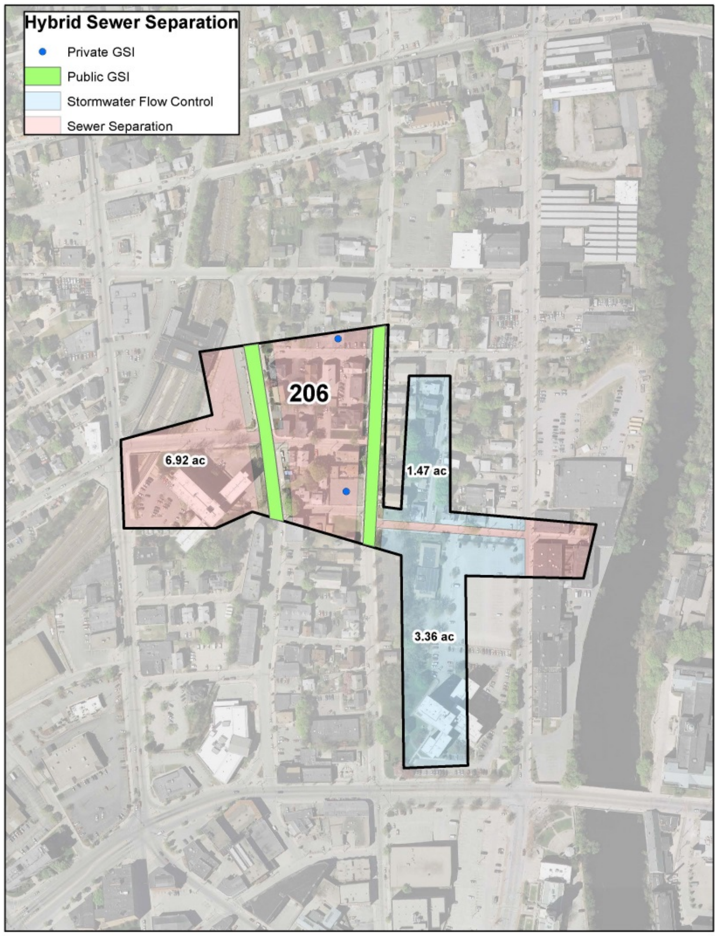

Figure 4-19 - Hybrid Sewer Separation Outfall 206

The hybrid separation reduces the extent of sewer separation by 3,000 LF of 8-54" pipe. The approach for this area is assumed to include:

- Green Stormwater Infrastructure in Public Right-of-Way
  - Parking Lane GSI (Jackson St and High Street, 1,000 LF)
- Stormwater Flow Control
  - Downspout Disconnection
  - Flow Throttle existing catch basins (High St, Blackstone Ave, Darrow St and St Mary's Way, 7 EA)
  - Additional catch basin inlet capacity at on Blackstone Ave (4 EA)
  - Stormwater Storage in parking lot off Blackstone Ave (140,000 gallons, 42'x45'x10')
- Sewer Separation
  - Installation of new drain pipe network in 90% of existing sewer pipe network (1,626 LF, 8-24" dia.)
  - Replacement of 0% of existing pipes (0 LF)
  - Rehabilitation of 10% of existing sewer pipe network (514 LF)
  - Reuse of 90% of existing sewer pipe network (4,626 LF)
- Adjacent utility work

    - Limited to roadways impacted by excavation only, no utility work on roadways without separation related excavation
    - Replacement of 80% of existing water main (1,300 LF) and service connections up to right-of-way
    - Replacement of 90% of existing gas main (1,464 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company*
    - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
    - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
    - Full-depth reconstruction of 20% of excavated roadways (326 LF)
    - Grind-overlay reconstruction of 80% of excavated roadways (1,300 LF)

4.6. Deep-Rock Tunnel

Deep tunnels are generally constructed where surface land availability is limited and are effective at minimizing surface disruption during construction. Tunnels must be constructed deep below any building foundations or utilities to avoid disturbance or damage. Tunnels must be protected from infiltration and exfiltration, and require structural stability both during construction and permanently. Construction in hard rock is preferable.

DEEP-ROCK TUNNEL

- Advantages
    - Facilitates full secondary treatment of combined flows
    - Construction impacts limited to shaft locations
    - Low operation and maintenance costs
    - Provides operational flexibility
    - Cost effective for large flows
- Disadvantages
    - Large-scale effort & cost

While tunnel construction is expensive, it benefits more from the economy of scale than any other option. Therefore, tunnels become a cost-effective solution for large volumes. Tunnels provide temporary storage for combined flow during the storm. After the storm, the stored flow is pumped out and treated during dry conditions at the wastewater treatment facilities. The high level of treatment results in excellent pollutant removal from both the wastewater and stormwater and consequently improved receiving water quality.

Tunnel storage was described in detail in both the CDR and CDRA in the technology evaluations in Chapter 6 of both reports. The basic components of tunnel storage have not changed. Additional information provided in this chapter is intended to supplement the information provided in the previous reports based on NBC's project experience in Phases I and II of the CSO Program. The CDRA route for the Pawtucket Tunnel is shown in Figure 4-20.

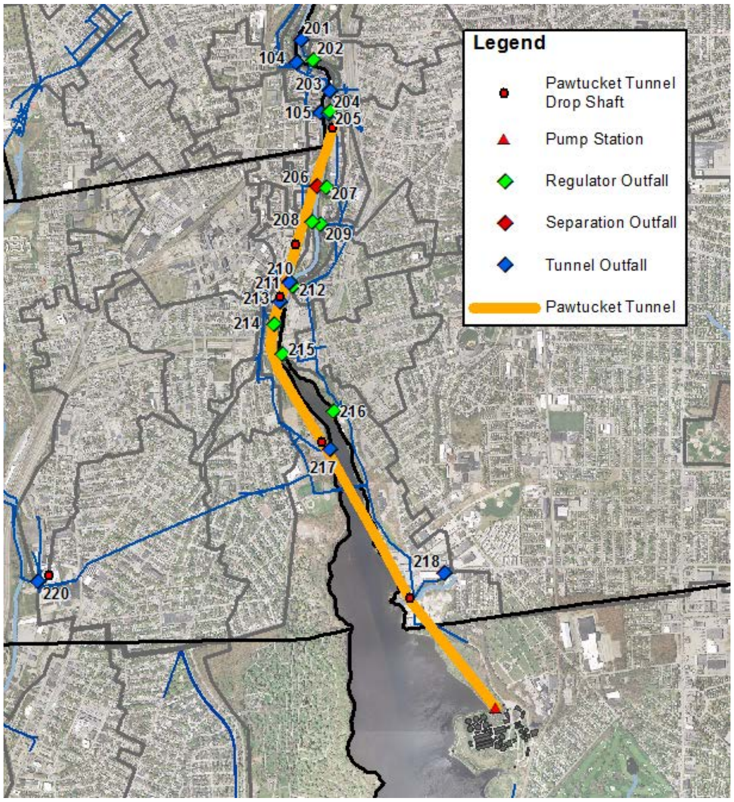

Figure 4-20 – Pawtucket Tunnel (CDRA Route)

4.6.1. Pawtucket Tunnel

The Pawtucket Tunnel in the CDRA has a storage volume of 51 MG, is 26 feet in diameter with 5 dropshafts and 2 working shafts, and extends 13,000 feet from just north of the Bucklin Point Wastewater Treatment Facility in East Providence to the Central Falls / Pawtucket border near the Blackstone River, as shown in Figure 4-21. Bedrock in the region is typically 15 to 100 feet below grade. The tunnel would be 150 to 200 feet below grade.

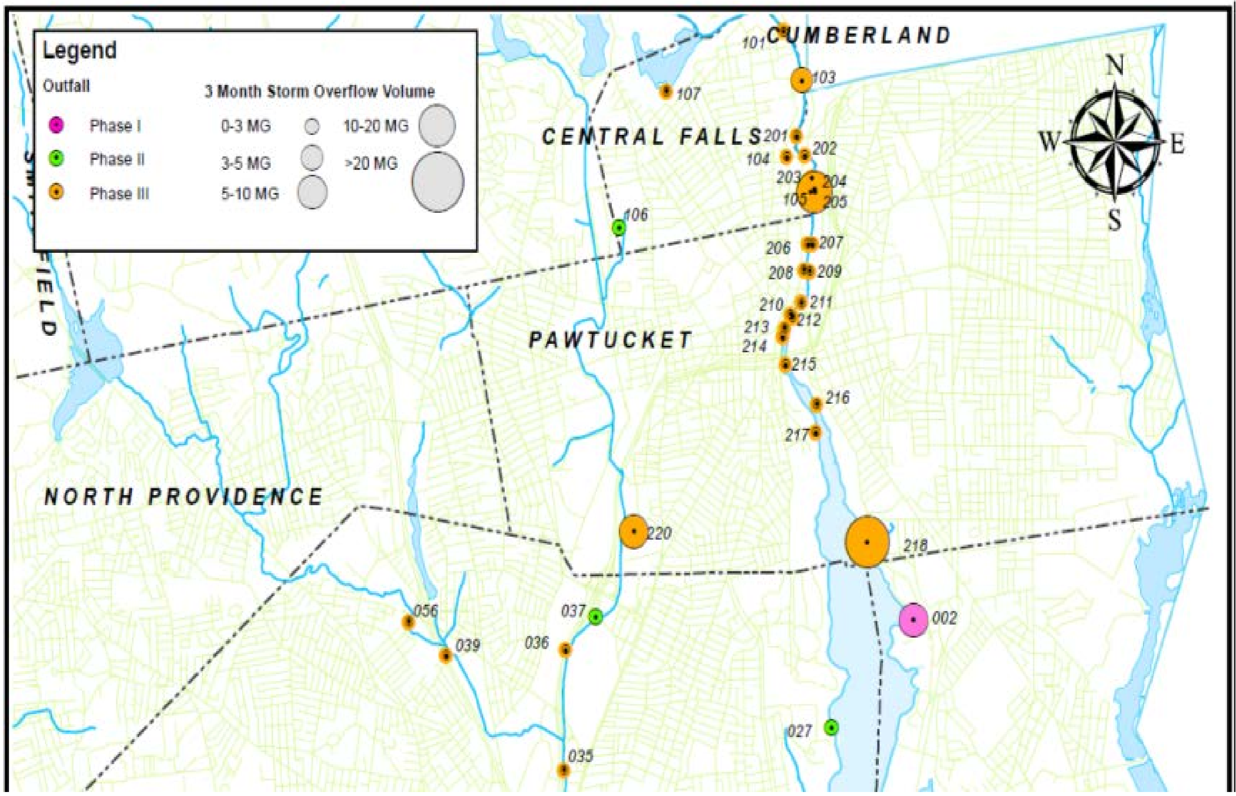

Figure 4-21 – BPSA CSO Overflow Volumes

The tunnel will capture the two largest volume CSOs in the NBC system, 218 and 205, as well as four other intermediary CSOs via drop shafts. Six additional CSOs are to be connected to the tunnel via interceptors. Regulators at nine other CSOs would be modified so that the overflows could be directed to the existing interceptor system.

Based on the tunnel work in Phases I and II and hydraulic modelling results, the baseline design for the Pawtucket Tunnel would be modified to consist of the following:

- Tunnel dimensions – 28 ft ID, 13,000 LF and constructed using precast concrete segments
- Five dropshafts – 6-8 ft ID, 145-175 ft deep, 2 ft thick concrete walls constructed using ground freezing through soil/overburden and rock dowels through bedrock
- Two launching/receiving workshafts – 30 ft ID, 145-200 ft deep, 2.5 ft thick concrete walls constructed using ground freezing through soil/overburden and rock dowels through bedrock
- One pumping station located within 1,000 ft of the Bucklin Point WWTF 260 ft deep with 2.5 thick concrete walls constructed using ground freezing through soil/overburden and rock dowels through bedrock
    - Utility Shaft – 32 ft ID, 260 ft deep
    - Access Shaft – 12 ft ID, 260 ft deep
    - Pump Cavern – 62 ft wide by 70 ft deep by 120 ft long
- Two-stage pumping operation with eight 19 MGD pumps split evenly between divided lower and intermediate levels, with three pumps in operation and one on standby at each level

- Five consolidation conduits (48-72" ID, total of 5,200 LF) to convey flow from outfalls to the dropshafts

4.6.2. 220 Stub Tunnel

The CDRA identified an alternative to the Pawtucket Avenue interceptor for Outfall 220, intended to be evaluated further in Phase III preliminary design. The alternative included a deep-rock stub tunnel that would extend from a dropshaft at Outfall 220 and connect with the Pawtucket Tunnel just north of the BPWWTF, as shown in Figure 4-22. The Pawtucket Stub Tunnel was proposed as 10-ft diameter, between 70-190 ft. below grade, and nearly 9,100 feet long. The CDRA suggested that the stub tunnel could reduce the size of the Pawtucket Tunnel from 26-ft diameter to 24.5-ft diameter.

- Advantages
  - Significantly reduce disruption to roadway and neighborhoods along interceptor route
  - Little to no utility coordination required
  - Isolated construction areas
  - Removes need for pump station, reducing operation and maintenance costs
  - Increase operational flexibility of system
- Disadvantages
  - Requires additional deep rock boring evaluation
  - Requires additional deep rock drop shaft

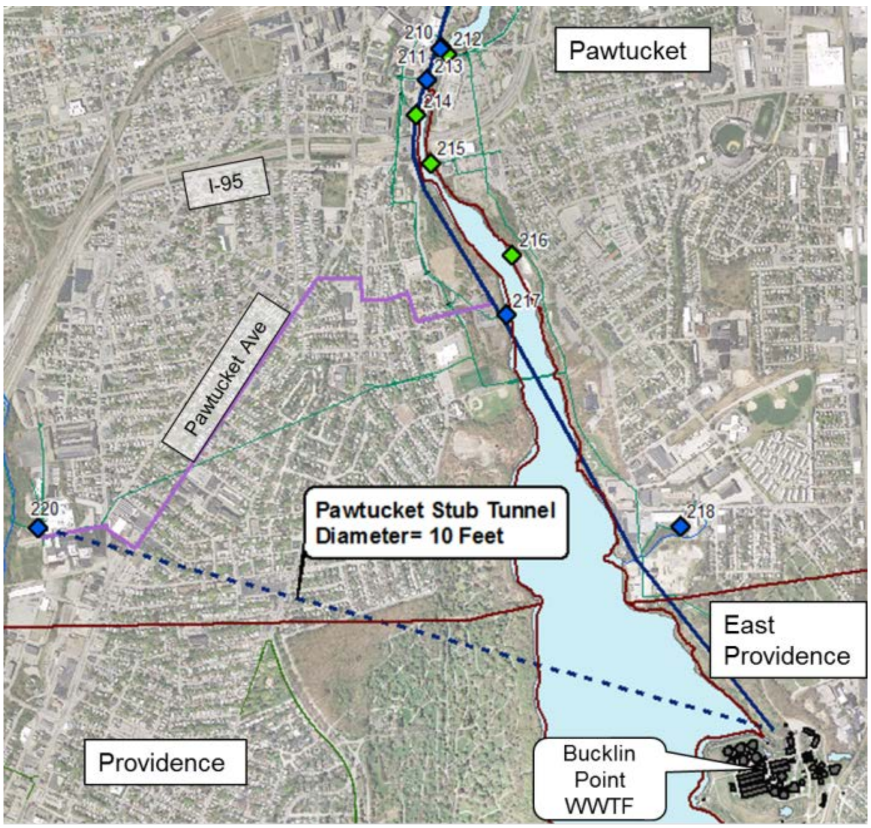

Figure 4-22 - Pawtucket Ave Stub Tunnel

The stub tunnel would involve one additional drop shaft at Outfall 220; the location is shown in Figure 4-23.

Figure 4-23 - Outfall 220

The stub tunnel alternative would significantly reduce the disruption to roadway traffic, commercial properties, and residential neighborhoods along the proposed interceptor route. This alternative consists of the following:

- Drop shaft to pick up overflow from OF 220.
- Deep-rock tunnel between OF 220 and the proposed Bucklin Point Tunnel Pump Station that is 10 ft ID, 9,100 LF in length, and 70-190 ft below grade constructed by blasting

4.6.2.1. Branch Avenue Tunnel Adit

The BAI located in Providence was also evaluated for connection to the Pawtucket Tunnel by extending the 220 Stub tunnel discussed in section 4.6.2. The tunnel adit would extend approximately 6,300 LF from Outfall 220 to the vicinity of Outfall 039 or Outfall 056. The adit would require at least one an additional drop shaft to collect overflows from Branch Ave and potential one additional work shaft. A potential site for the additional drop shaft could be the playing fields behind the Hopkins Junior High School. The tunnel adit would require a consolidation conduit or regulator modification for outfalls 039/056.

A Branch Ave. Tunnel adit would be significantly less disruptive than sewer separation for the neighborhoods tributary to outfalls 039/056, as well as potentially less disruptive than the West River Interceptor alternative.

However, a review of the available geotechnical information indicates that an ancient, buried thalweg, or low bedrock elevation associated with an historical river bed, bisects this adit route. Consequently, constructing a tunnel between 220 and the BAI is not technically feasible.

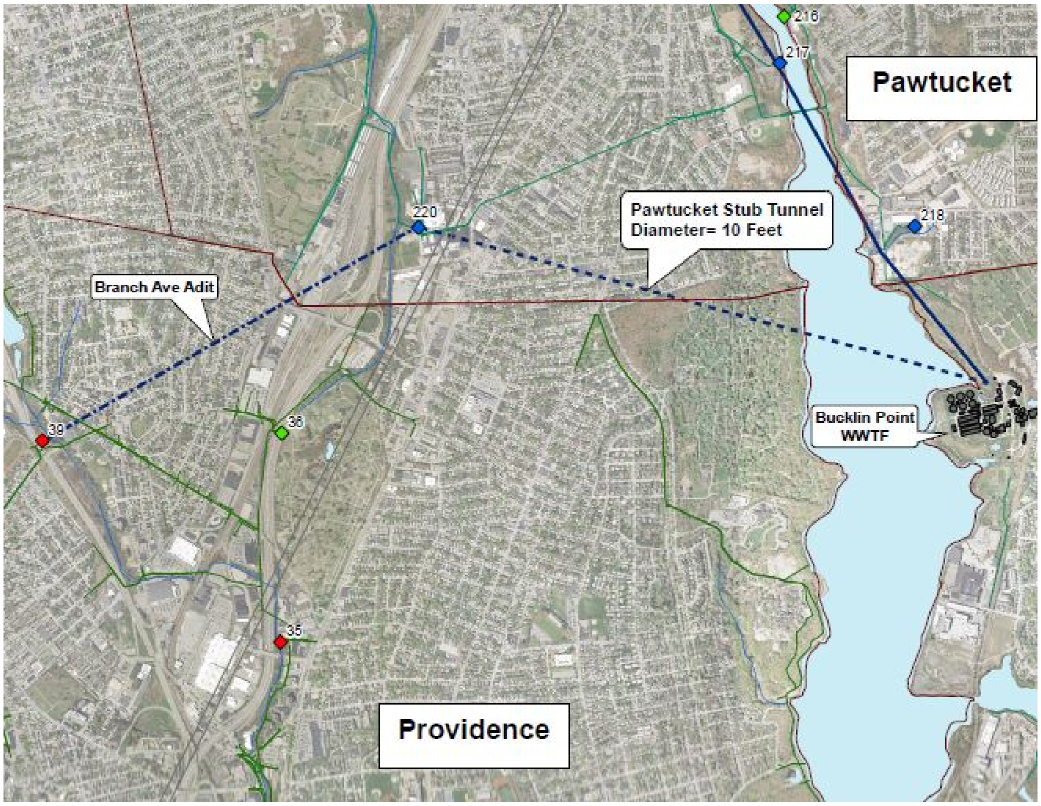

Figure 4-24 - Branch Avenue Tunnel Adit

4.6.3. Tunnel Costs

Typical deep tunnel facilities include:

- Access shafts
- Air vent shafts
- Drop shafts
- Consolidation conduits
- Coarse screens
- Inlet structures
- Outlet structures
- Dewatering system (typically a pump station)
- Odor control systems
- Tunnel

Construction cost equations for typical deep tunnel facilities are shown in Table 4-25. The cost equations represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

Table 4-25 - Cost Equations for Tunnels

Source Document	Date of Publication	Cost Equation[1]	Figure ID
Anderson, IN – CSO Long Term Control Plan (Greeley and Hansen)	June, 2007	$C=5.21*D^2 + 60.8*D + 4183.7$	Anderson – Rock, 2007
		$C=10.78*D^2 - 137.65*D + 7042.06$	Anderson – Soft, 2007
South Hartford Conveyance and Storage Tunnel (SHCT) PDR (CDM)	February, 2010	Proprietary Tunnel Estimation Database (TED)	Hartford, 2010
Springfield, MA – FLTCP Construction Estimate	2011	Estimate based on SHCT and Anderson, IN	SWSC FLTCP
NBC Main Spine Tunnel	2008	Final Construction Cost	NBC MST 2008
NBC Pawtucket Tunnel (CDRA Estimate)	2010	Construction Cost Estimate	NBC Pawtucket (CDRA 2010)
NBC Pawtucket Tunnel (Updated 2014)	2014	Construction Cost Estimate Updated for Reevaluation	NBC Pawtucket (Updated 2014)

[1] Construction costs (C) have units of millions of dollars adjusted to ENR CCI=9,845 and escalated to mid-point 2018 using 3%/yr. Tunnel diameters (D) have units of feet.

The Anderson, IN cost equations were developed for tunnels in both rock and soft ground with diameters between 7 and 30 feet in diameter. Shaft costs were not included in these cost equations.

The South Hartford Conveyance Tunnel (SHCT) preliminary design estimated cost was developed by a proprietary Tunnel Estimating Database for its 2010 preliminary design report (PDR). Shaft costs were included. This cost was not able to be adjusted for current and future cost as the original ENR CCI is unknown.

The Springfield, MA Final Long-Term Control Plan (FLTCP) was derived using the Anderson, IN cost equations and the SHCT cost data point to create a new cost equation.

The NBC Main Spine Tunnel (MST) was a summation of the NBC CSO Program Phase I construction contracts and Phase II construction contracts associated with the MST. The Phase I construction contracts began in 2001 and were completed in 2008. Costs for shafts, pump station and tunnel adits are included.

The NBC Pawtucket Tunnel CDRA is the cost estimate that was issued in the 2010 CDRA 2nd Reaffirmation. Costs for shafts and pump station were assumed to be included. Consolidation conduits were assumed to be excluded.

The NBC Pawtucket Tunnel Update is the cost estimate that was developed for this study, the 2014 Phase III Reevaluation. Costs for shafts, pump station, tunnel adits, and consolidation conduits are included.

The NBC MST project and Pawtucket Tunnel estimates provide an estimated cost indicator for NBC Phase III tunnel(s). Since the SHCT cost was the only other cost data point available local to the NBC and was unable to be adjusted due to unknown original ENR CCI, a cost equation could not be derived. Instead, the Springfield FLTCP cost equation was adjusted to create a new cost equation using the NBC MST and Pawtucket Tunnel estimated construction costs.

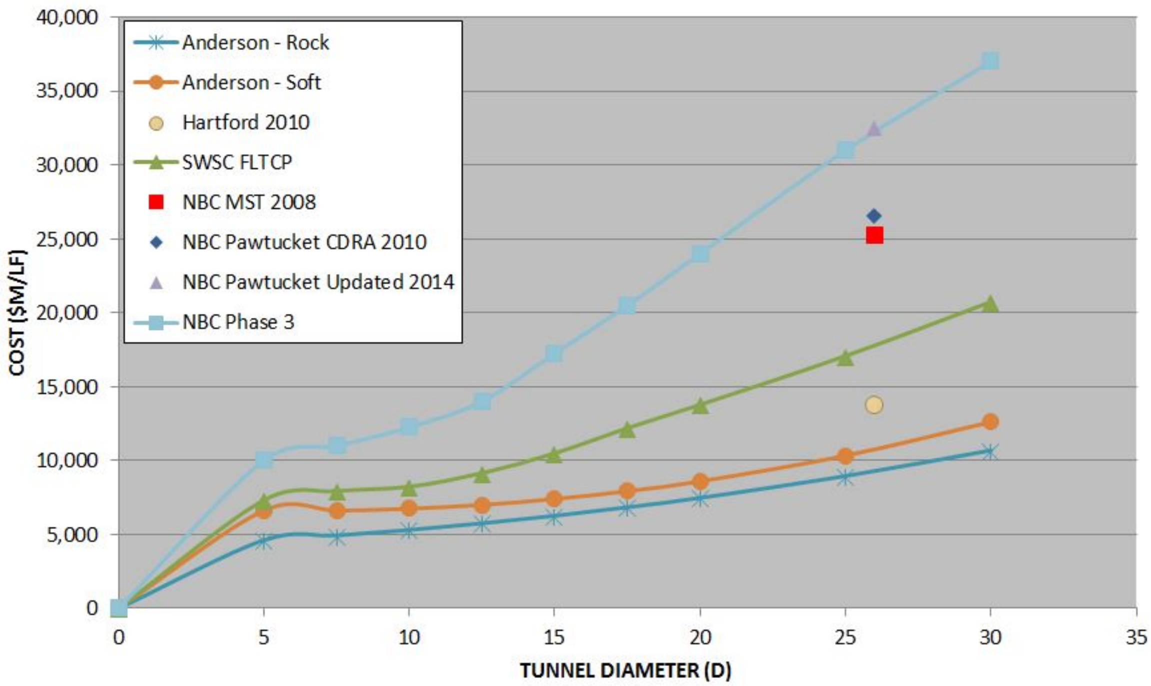

Figure 4-25 - Construction Cost Curves for Tunnels

Figure 4-25 shows cost curves developed from the cost equations for deep tunnel facilities in Table 4-25 above, including the new cost equation labeled as NBC Phase III. The NBC Phase III cost equation was used to develop representative costs for deep tunnel facilities since it is the "high average" curve. The cost curves represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

The O&M cost for new deep-rock tunnels is estimated at $8,500 per million gallon of storage per year. The O&M cost is based on NBC's expenditures in fiscal 2013 on the Phase I tunnel escalated to 2018. The cost includes electricity, operations staff and equipment maintenance for the tunnel pump station as well as routine maintenance and cleaning at each tributary outfall gate and screening structure.

4.7. Interceptors for Tunnel Connections and Relief Storage

Because of the depth of the tunnel, the complexity of connecting surface overflows to it, and system logistics, interceptor sewers (i.e. main trunk lines as opposed to smaller collection lines) will be required to make those connections. In most cases, the existing interceptor network does not have capacity or follow particular routes to facilitate those connections, and new interceptors need to be built.

- Advantages
  - Eases siting requirements of tunnel dropshafts or storage / treatment facilities
  - Provides additional system storage
  - Low operation and maintenance costs
  - Helps relieve strained collection systems
- Disadvantages
  - Major disruption of surface roads
  - Deep excavation / Micro-tunneling
  - May require land or easement acquisition
  - Potential for utility conflicts
- Considerations
  - Extreme weather resiliency
  - Inter-basin transfers of flows

The NBC-owned collection system consists entirely of interceptor sewers to collect local flows throughout the member communities and provide a pathway to the treatment plant, with CSO outfalls along the way acting as relief points during wet weather to prevent system backups into buildings or at street level. The interceptors being evaluated in this section are not being proposed to "upsize" or replace the existing interceptors, but to provide a pathway to the Pawtucket Tunnel for existing CSO outfall flows that are remote in relation to the proposed tunnel alignment. There is one interceptor that is being evaluated as relief storage discussed in section 4.8.

Interceptor conveyance to storage was described in detail in both the CDR and CDRA in the technology evaluations in section 6 in both reports. The basic components of interceptor conveyance to storage have not changed. Additional information provided in this chapter is intended to supplement the information provided in the previous reports based on NBC's project experience in Phases I and II of the CSO Program, recent field investigations, as well as stakeholder input.

4.7.1. NBC Phase II Interceptor Construction

Phase II included construction of the Woonasquatucket and Seekonk interceptors. While portions of these large-diameter sewers included open cut construction, much of it was accomplished with trenchless installation which included micro-tunneling or pipe jacking between drive pits and receiving pits. In general, the construction is less disruptive to the neighborhoods, and given the depth of construction requires less utility coordination than sewer separation. Figure 4-26 below depicts one of the drive pits used to construct a tunnel conveyance interceptor under Phase II of NBC's CSO Program.

Figure 4-26 – NBC Phase II Interceptor Construction

4.7.2. Interceptor Costs

Interceptor sewers refer to conduits that consolidate overflow volumes to the tunnel or near-surface storage tanks. Interceptor sewers drain by gravity and are constructed near the surface, generally less than 30-ft below grade. They are assumed to be constructed using pipe-jacking and/or micro-tunneling methods, similar to Phase II of NBC's CSO Abatement Program. Construction costs for interceptor and relief sewers are dependent upon sewer diameter, the depth of construction, and the amount of interference encountered during construction activities due to pavement, traffic, and utilities. Surface restoration may be required for from riverbanks and roadways. Cost estimates for Interceptors were developed using engineer's estimates and bid results from the NBC's Phase II Interceptor Projects (Woonasquatucket and Seekonk river interceptors) and nearby Springfield, MA projects completed in 2009. Table 4-26 presents the unit costs used to estimate interceptor and relief sewer costs. The costs included herein represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

Table 4-26 - Cost Estimate Sources for Interceptors

Source Document	Date of Publication	Cost ($/LF)[1]	Figure ID
Springfield, MA – FLTCP Construction Estimate	2011	2,745	SWSC FLTCP
NBC Phase II Seekonk River CSO Interceptor Construction Cost	2014	3,013	NBC Phase 2 SCSOI
NBC Phase II Woonasquatucket River CSO Interceptor Construction Cost	2014	5,106	NBC Phase 2 WCSOI
NBC Phase III CDRA BPSA Interceptors Construction Estimate	2010	9,177	NBC Phase 3 CDRA BPSA
NBC Phase III CDRA 220 Interceptor Construction Estimate	2010	17,691	NBC Phase 3 CDRA 220
NBC Phase III Update BPSA Interceptors Construction Estimate	2014	4,547	NBC Phase 3 Update BPSA
NBC Phase III Update 220 Interceptor Construction Estimate	2014	5,342	NBC Phase 3 Update 220

[1] Construction costs (C) have units of millions of dollars adjusted to ENR CCI=9,845 and escalated to mid-point 2018 using 3%/yr.

The Springfield, MA Final Long-Term Control Plan (FLTCP) was estimated for interceptor pipes larger than 18-in diameter and located within City roadway rights-of-way.

The NBC Phase II Seekonk River CSO Interceptor (SCSOI) was a summation of the NBC CSO Program Phase II construction contracts associated with the SCSOI. The Phase II construction contracts began in 2011 and completed in 2014. Costs for tunnel related construction included in those construction contracts has been removed from the unit cost presented in this report.

The NBC Phase II Woonasquatucket River CSO Interceptor (WCSOI) was a summation of the NBC CSO Program Phase II construction contracts associated with the WCSOI as of mid-2014. The Phase II construction contracts began in 2011 and are expected to be completed in 2014. Costs for tunnel related construction included in those construction contracts has been removed from the unit cost presented in this report.

The NBC Phase III CDRA BPSA Interceptors is the cost estimate that was issued in the 2010 CDRA 2nd Reaffirmation. Costs for consolidation conduits and tunnel adits, among other tunnel-related construction items, were assumed to be included. A breakdown of tunnel related construction included was not available to separate costs.

The NBC Phase III CDRA 220 Interceptor is the cost estimate that was issued in the 2010 CDRA 2nd Reaffirmation. Costs for a pump station and force main are assumed to be included. Costs for consolidation conduits and tunnel adits, among other tunnel-related construction items, were assumed to be included. A breakdown of tunnel related construction included was not available to separate costs.

The NBC Phase III Update BPSA Interceptors is the cost estimate that was developed for this study, the 2014 Phase III Reevaluation. Costs for tunnel related construction are excluded.

The NBC Phase III Update 220 Interceptor is the cost estimate that was developed for this study, the 2014 Phase III Reevaluation. Costs for a pump station and force main are included. Costs for tunnel related construction are excluded.

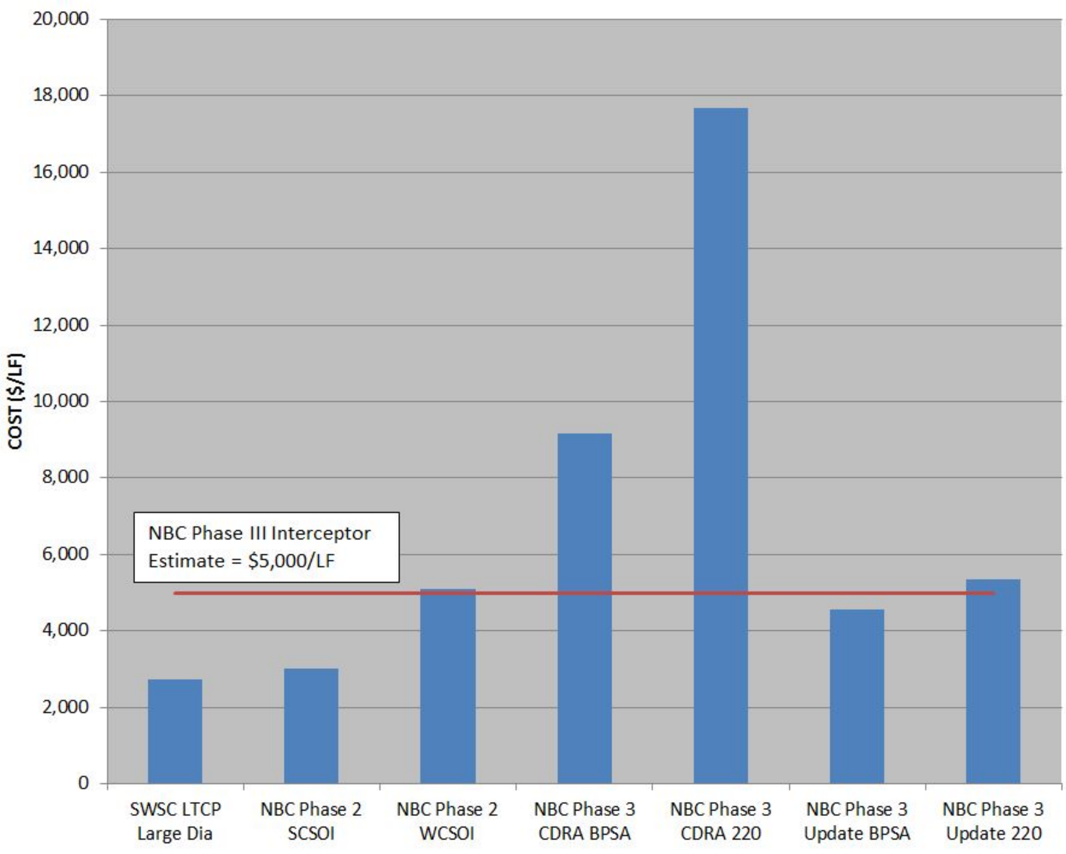

Figure 4-27 - Construction Costs for Interceptors

The costs per linear foot of interceptor construction are shown in Figure 4-27. The NBC Phase III cost estimate was based on the Phase II WCSOI construction cost. The costs included herein represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

The O&M cost for new interceptors is estimated at $2.30 per linear foot per year. The O&M cost is based on routine cleaning, inspection, and televising of the new sewers once every five years.

4.7.3. Interceptors to Pawtucket Tunnel

The CDRA recommended plan included three new interceptor sewers to bring flow from the more remote CSOs to the tunnel alignment along the Blackstone River. Figure 4-28 details the approximate location of the three new interceptors.

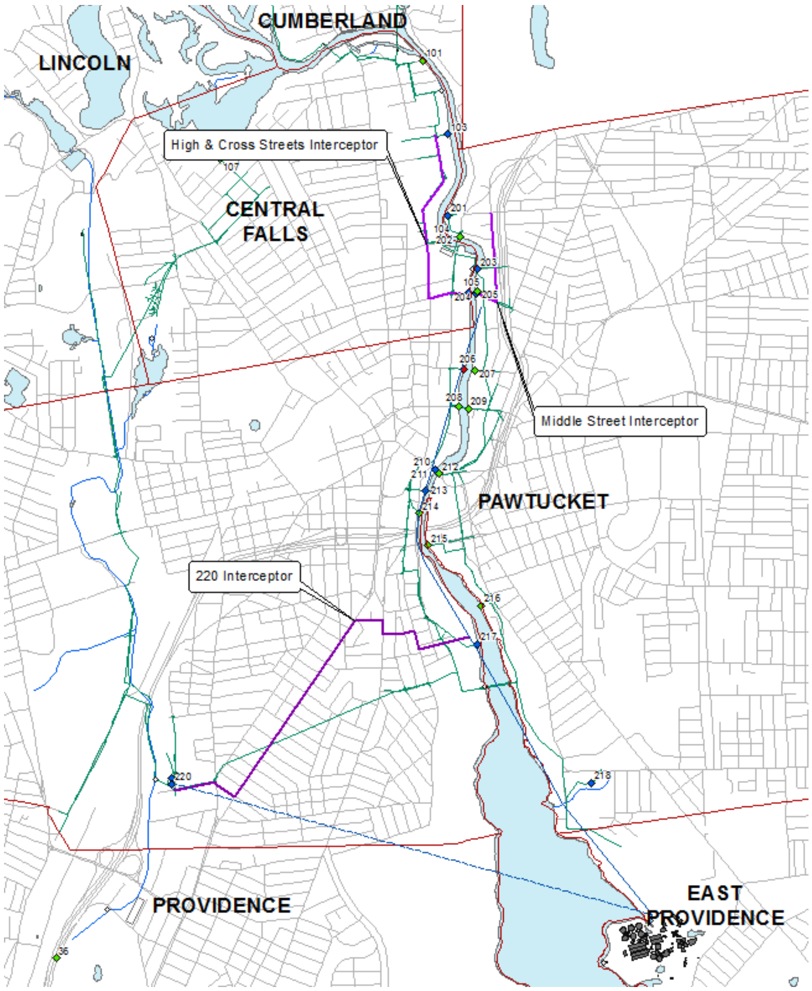

Figure 4-28 – Interceptors to Pawtucket Tunnel (CDRA)

From the northern end of the tunnel, two interceptors would extend north to convey flows from the CSOs 103-105 and 201-205: one along Middle Street in Pawtucket and another along High and Cross Streets into Central Falls. For the recently OF 220 in western Pawtucket, an interceptor, consisting of a pump station, force main and gravity main, would convey flows from CSO 220 to the middle section of the tunnel.

As previously discussed, the CDRA identified the stub tunnel as an alternative to the Pawtucket Avenue Interceptor.

4.7.3.1. Middle Street Interceptor

The CDRA recommended plan included the Middle Street Interceptor as a pathway for CSO outfalls 201, 203, and 205 to the northern terminus of the Pawtucket Tunnel, just south of Central Ave, as shown in Figure 4-29.

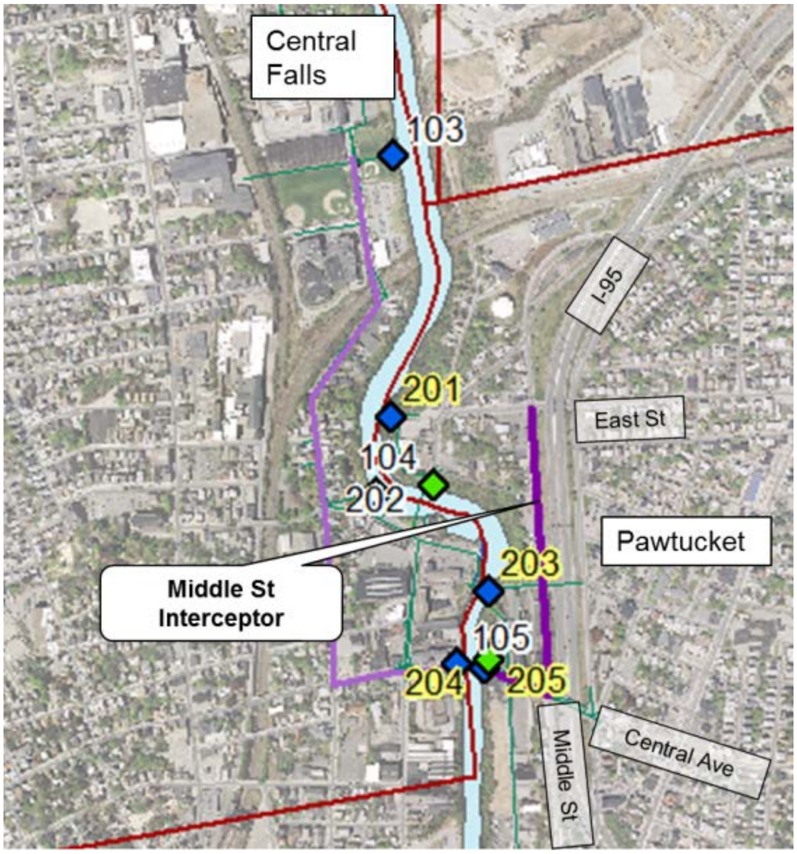

Figure 4-29 - Middle St Interceptor

Middle Street is located in Pawtucket between I-95 and the Blackstone River. The northern half is a two-lane, one way road between the off-ramp and on-ramp to I-95 exit 30, with commercial properties lining the west side of the road (see Figure 4-30). South of the onramp to I-95, Middle St is a one lane residential road with parking on both sides of the road. Along Middle Street, a 30-inch diameter interceptor is proposed to pick up overflow volumes from CSO 201 and 203. The 30-inch interceptor would run 1,710 LF at a depth of 12-15-ft below grade.

Figure 4-30 - Middle St (Pawtucket)

Where Middle St intersects Central Ave, the Middle St Interceptor is proposed to take a 90-degree turn west onto Central Ave (see Figure 4-31) where it increases in size to 66-inch diameter to pick up overflow volume from 204/205. At the intersection, the interceptor also drops to 25-45 feet below grade. The interceptor would run 350 feet before again turning south to connect to the northern-most tunnel drop shaft S-2. Cross Street is one of only two connecting streets between Pawtucket and Central Falls across the Blackstone River. It is home to several commercial properties and the Blackstone Landing condo complex, an 82-unit condo building at the site of the Green and Daniels textile mill originally built in the 1860s.

Figure 4-31 - Middle St at Central St (Pawtucket)

The CDRA baseline alternative consists of the following:

- Interceptor along Middle Street that is 30 inch ID, 1,710 LF in length, and 12-15 ft below grade. Due to proximity of interstate and historic mill building installation methods of micro-tunneling or pipe-jacking may be required.
- Drop manhole at the intersection of Middle Street and Central Street
- Interceptor along Central Street that is 66 inch ID, 350 LF in length, and 25-45 ft below grade. Due to depth of construction, installation methods of micro-tunneling or pipe-jacking will be required.
- Removal of contaminated soil from 15% of surface area up to 15-ft deep. Assumed contamination based on historic use of area and recent projects within

4.7.3.2. High Street and Cross Street Interceptor

The CDRA recommended plan included the High and Cross Streets Interceptor as a pathway for CSO outfalls 103, 104, and 105 to the Pawtucket Tunnel. The interceptor is located within Central Falls just west of the Blackstone River as shown in Figure 4-32.

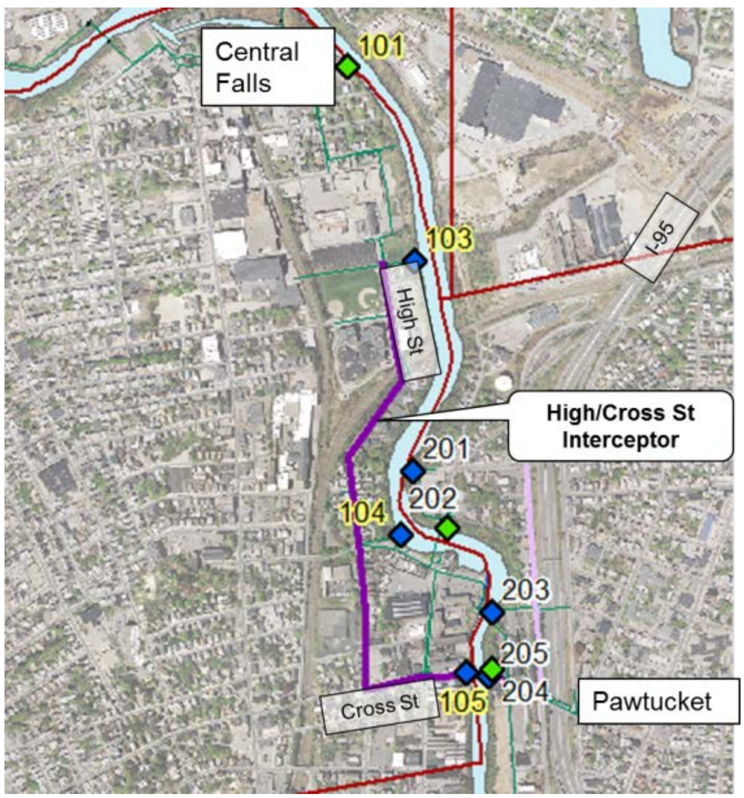

Figure 4-32 - High St/Cross St Interceptor (Central Falls)

High St is a two-lane road providing access to a mix of commercial and residential properties along the Blackstone River. There is a major traffic impediment where High St crosses beneath the railroad tracks, as shown here in Figure 4-33 the road pinches down to one lane. Several public ball fields, a park and the Donald W. Wyatt Detention Facility are located on the section of High St north of the railroad overpass. The section of High St south of the railroad overpass to Charles St is a mix of residential and commercial properties. The interceptor in this section would be 42-inch in diameter, 2,160 LF and approx. 8-15 feet deep.

Figure 4-33 - High St Railroad Overpass

At the intersection of High St and Charles St, the interceptor would transition to 48-inch in diameter and run another 2,080 LF down High St to Cross St, turn east and run along the bridge over the Blackstone River before turning south again and connecting with the Middle St interceptor on the way to northern-most drop shaft, S2. This section of the interceptor would be approx. 15-22-ft deep except for at the bridge crossing. While the CDRA recommended the new interceptor cross the river hanging off of the side of the Cross St Bridge (shown in Figure 4-34), the structural requirements and aesthetics associated with hanging pipe of this size on the side of the bridge would likely be prohibitive enough to require the river to be crossed by pipe-jacking or micro-tunnel beneath the river bottom. On the Central Falls side of Cross Street, it is a tight 2-lane roadway with residential and commercial properties on either side before crossing through the Central Falls Historic Mill District between Roosevelt Ave and the Blackstone River.

Figure 4-34 - Cross St Bridge

The modified baseline consists of the following:

- Interceptor along High Street (north of Charles St) that is 42 inch ID, 2,160 LF in length, and 8-15 ft below grade. In areas of active railway, installation methods of micro-tunneling or pipe-jacking will be required.
- Interceptor along south High Street (south of Charles St), Cross Street, and Central St (in Pawtucket) that is 48 inch ID, 2,080 LF in length, and 15-22+ ft below grade. Due to depth of construction and proximity of businesses, installation methods of micro-tunneling or pipe-jacking will be required. The interceptor will cross beneath the Blackstone River.
- Removal of contaminated soil from 15% of surface area up to 15-ft deep. Assumed contamination based on historic use of area and recent projects within.

4.7.3.3. Pawtucket Avenue Interceptor

The CDRA recommended plan included the new Pawtucket Ave interceptor, located in southern Pawtucket, to convey for OF 220 to the Pawtucket Tunnel near OF 217. The elevation difference between OF 220 and OF 217 requires that a pump station and 48-inch, 4,745 LF force main and a 54-inch 3,425 LF gravity interceptor would be required as shown in Figure 4-35.

OF 220 is the third largest overflow by predicted volume within the BPSA.

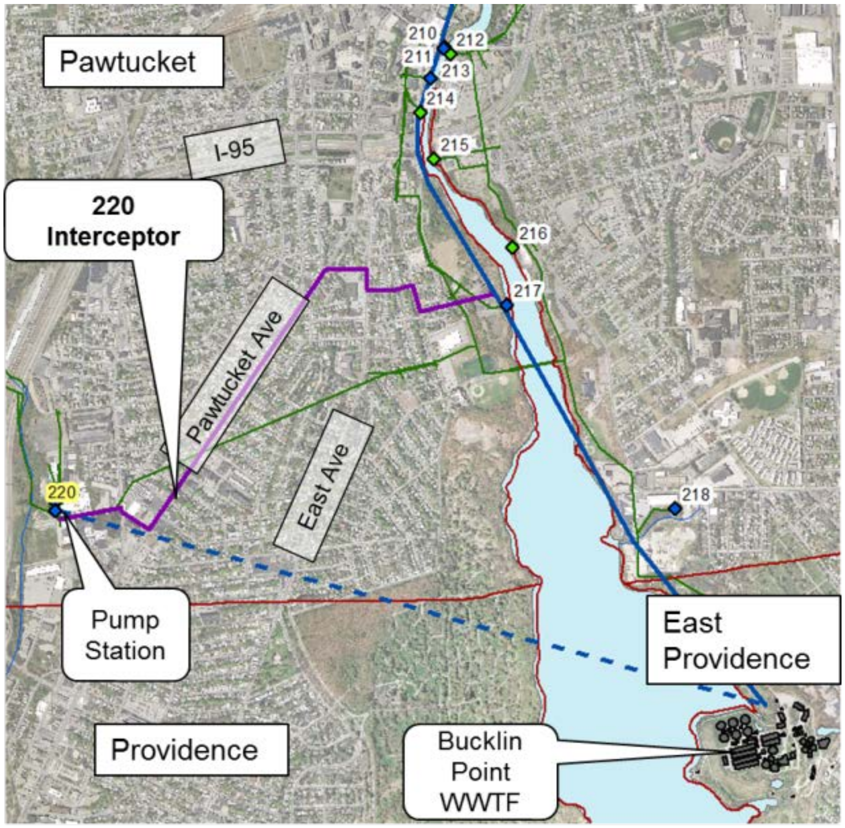

Figure 4-35 - Pawtucket Ave Interceptor (Pawtucket)

OF 220 discharges to the Moshassuck River at the intersection of Moshassuck Street and Esten Avenue, shown on Figure 4-36. The area has large commercial and industrial properties and a public ball field (Morley field). The pump station and wet well would be located at or near outfall 220. The proposed interceptor route travels up Moshassuck Street to heavily traveled Pawtucket Ave (also US 1) through commercial and residential properties, as shown on Figure 4-37. The interceptor route turns off of Pawtucket Avenue onto Patt Street before winding down through a steep, densely developed residential neighborhood (see Figure 4-38) before crossing Pleasant Street at Jeffers Street and connecting to a drop shaft into the Pawtucket Tunnel alongside OF 217 The International Charter School on Pleasant Street, Francis J Varieur Elementary School on Pleasant Street, and a large National Grid electric facility on the Blackstone River are in the vicinity of the proposed drop shaft location.

Figure 4-36 - Esten Avenue

Figure 4-37 - Pawtucket Avenue

Figure 4-38 - Harvey Street

The alternative for the Pawtucket Avenue Interceptor consists of the following:

- Pump station and wet well adjacent to outfall 220.
- Interceptor force main along Pawtucket Ave that is 48 inch ID, 4,745 LF in length and 10-15 ft below grade. Due to disruption to surface, installation methods of micro-tunneling or pipe-jacking may be required.
- Interceptor gravity main along Patt St, East St, Harvey St, along Middle Street that is 54 inch ID, 3,425 LF in length, and 10-15 ft below grade. Due to proximity of residential properties installation method of micro-tunneling may be required.

4.7.4. Branch Avenue Interceptor Improvements

The Branch Avenue Interceptor (BAI) located in Providence was evaluated in the vicinity of Outfalls 039 and 056 to potentially relieve the two outfalls while also providing relief to sanitary sewer overflows in the vicinity. The evaluation examined the construction of a new relief sewer adjacent to the existing BAI, as well as increasing the diameter of the BAI. A review of the existing infrastructure in Branch Ave as well as a windshield survey of potential routes determined that either option would not be feasible due to crowded utilities and the narrow, heavily trafficked roadway. The West River Interceptor, proposed in the CDR, is evaluated for potential relief in Section 4.8.1.

4.7.4.1. Branch Avenue to Moshassuck River Interceptor Connection

As a tunnel option between the two locations was not feasible, a conventional interceptor consisting of a pump station, force main and gravity sewer was considered. The routing of such an interceptor is complicated by the surface road network including major traffic routes, rail road, interstate, and cemeteries between the two locations. To capture CSO flow and possibly provide interceptor relief to reduce SSOs, three options were conceived and routing for each is illustrated below in Figure 4-39, Figure 4-40 and Figure 4-41:

Figure 4-39 - Branch Ave to Moshassuck River Interceptor Option 1

Figure 4-40 - Branch Ave to Moshassuck River Interceptor Option 2

Figure 4-41 - Branch Ave to Moshassuck River Interceptor Option 3

- Option 1 – CSO flow is conveyed from 056 and 039 via gravity flow to a pump station near Hawkins Street. The gravity pipe runs through a wooded area along the West River, in order to avoid work in Branch Avenue, which is a very busy road. From the pump station, flow is conveyed through a force main to 219/220 then to Concord Street, where at the end of Concord Street it crosses beneath the rail lines, I-95, and the Moshassuck River. This particular crossing point is the narrowest crossing in the area where the rail lines, I-95, and the Moshassuck all converge at this one location. Moreover, this is the same location as the existing MVI siphon. It may be feasible to directional drill the pipe under all three with one pit excavation on either side. However, this particular crossing point adds length to the overall force main due to the circuitous route it takes to get back to 219/220.
- Option 2 – CSO flow is conveyed to a pump station behind the apartment complex at the end of Lombardi Street. From the pump station, flow is conveyed through a force main to the same crossing point as Option 1. One benefit of this option is that it includes more gravity pipe, which may reduce the overall pump size in the pump station. However, the overall length of pipe is longer than Option 1 and this option would likely require more rigorous permitting through the DEM due to its proximity to the West River.
- Option 3 – CSO flow is conveyed via gravity to a pump station near Hawkins Street. A portion of the gravity line runs down Branch Avenue before going off-road to the pump station. From the pump station, the alignment is the same as Option 1.

When developing options for the sewer system in the vicinity of the BAI, it should be noted that any option that involves a connection with the BAI will encounter significant hydraulic issues. The hydraulic model simulation for the 3-month storm shown in Figure 4-42 demonstrates how during wet weather, not only does the 8,900 lf of BAI becomes surcharged, but that the surcharging extends a further 16,000 lf downstream through the interceptor sewers towards the Fields Point WWTF.

A sewer that has these hydraulic characteristics means that the pressure head sitting above the crown of the pipe will always be looking to find relief. Currently the CSOs located along the length which connect to the BAI are offering this relief which means that the CSO spills are not just coming from the upstream catchments, but are being also driven from the downstream interceptor sewer, via reverse flows into the CSO underflows pipes.

The hydraulic model confirmed this theory and demonstrated a further difficulty in that, if capacity is created through options to reduce the CSO overflows in lower reaches of the interceptor, those flows being held back through hydraulic incapacity currently will be partially released and will fill the void created, lowering the HGL in the upper reaches but having little or no impact at the CSOs.

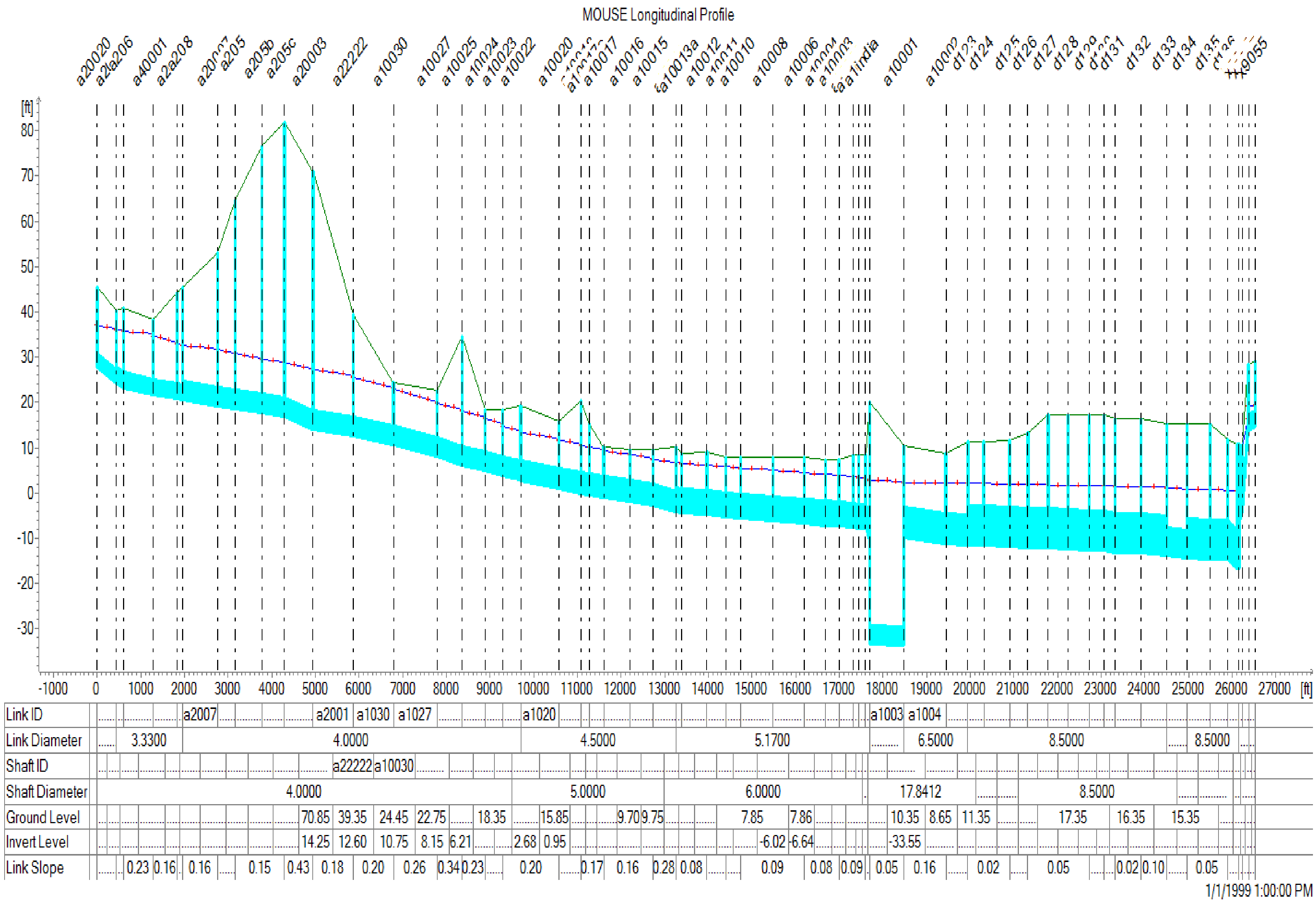

Figure 4-42 - Hydraulic model results for the Branch Avenue sewer during the 3-month storm simulation

The features to note from the model are that the HGL is permanently above the crown of the BAI and is precariously close to the ground elevation in four locations.

CSO reduction options for this project will therefore need to be developed in conjunction with the assumption that the surcharging in the Branch Avenue sewer has been controlled. The likelihood is that any solution developed to reduce surcharge levels would have a positive effect on CSO overflows. Therefore the development of a composite solution should be considered. However, current levels of wider system understanding and what possible composite solutions would be most appropriate are beyond the scope of this study and will need to be addressed by further investigation.

4.8. Interceptors for Relief Storage

Relief storage involves construction of a new interceptor pipe in parallel to the existing interceptor system. The new interceptor would be designed to hold and convey flow that would otherwise overflow at existing outfalls or other relief points such as manhole covers or basement backups resulting in sanitary sewer overflows.

4.8.1. West River Interceptor – Outfalls 039/056

The West River Interceptor was previously included as part of the CDR recommendations. In addition to being evaluated as an alternative to sewer separation for Outfalls 039 and 056, it would provide relief for the existing Branch Avenue Interceptor and add storage capacity to the NBC system. The proposed route, shown here in Figure 4-43, was depicted in plan and profile in figures 6.1-10 and 6.1-11 respectively in the CDR.

- Advantages
  - Replaces sewer separation in 039 and 056 neighborhoods
  - Provides relief for Branch Ave Interceptor
- Disadvantages
  - Difficult construction
    - Requires jacking or boring beneath highway
    - Proximity to West River
    - Accessibility concerns
  - Easement acquisition requirement

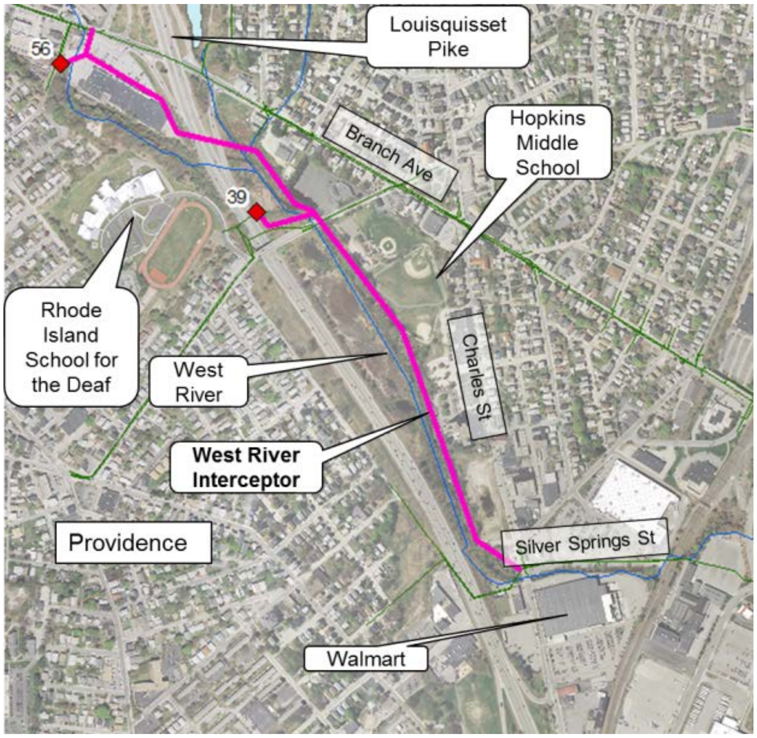

Figure 4-43 – Interceptor Relief Storage for CSOs 039/056 (CDR West River Interceptor)

It was to be 6 feet in diameter, 4,600 feet in length and approximately 10-25 feet below grade. The route, shown in Figure 4-43, travels along the east bank of the West River between Branch Ave and Silver Spring Street. It was to begin at the Branch Ave Interceptor near Outfall 056, close to the intersection of Branch Ave and Vandewater Street. It would travel along Branch Avenue in front of the shopping plaza before crossing the Louisquisset Pike (Highway 146) and river. From there it would parallel the West River behind several commercial properties, the Esek Hopkins Middle School fields, and the Charles Place senior housing property before connecting into the Moshassuck River Interceptor at Silver Springs Street near the Walmart.

The West River Interceptor could provide much needed relief for the Branch Ave Interceptor. It also provides an alternative to 170 acres of sewer separation in the 039/056 neighborhoods. However, the construction of a 6-ft diameter interceptor beneath a highway and river, along a river bank, in front of several businesses, behind a school and elderly housing has an impact on several properties. Construction methods such as pipe-jacking and micro-tunneling, similar to those used for Phase II interceptors, can minimize the surface impact but that still requires several construction sites and a relatively straight alignment. It would also require the acquisition of a new easement across multiple properties.

As discussed in section 4.7.4.1, the BAI suffers from significant hydraulic issues. The existing interceptor and outfalls are impacted by flows from both upstream catchments and downstream capacity limitations. CSO reduction options for this project will therefore need to be developed in conjunction with the assumption that the surcharging in the Branch Avenue sewer has been controlled.

4.9. Regulator Modifications

Regulators and control structures are used to optimize the diversion of dry weather and excess wet weather flows to existing interceptors. Regulator modifications are necessary to redirect flow from certain CSOs as part the alternatives discussed in this report and can range from simple adjustment of a weir to a new structure.

In the CDRA Phase III recommendations there are 11 CSOs identified for regulator modification as a solution. The CSOs identified in the CDRA include 036, 101, 107, 202, 204, 207, 208, 209, 212, 214, 215 and 216. CSO 102 was originally included but has since been blocked with a masonry seal. However during the re-evaluation process as alternative options are being considered, it is uncertain whether the regulator modifications as prescribed in the CDRA are still applicable.

The hydraulic modeling has found that the dynamic interaction between the CSOs, the capacities of the connecting interceptor sewer and the specific type of option being considered will all have a bearing as to the viability of regulator modification at any specific CSO. Therefore the suitability of regulator modifications cannot be determined until the alternative analysis is completed and specific recommendations are made.

Estimated costs for this Reevaluation are based on the type and complexity of regulator modifications. Costs were based on the recent bid results from NBC Phase II construction costs as well as from similar scale projects in Springfield, MA and Cambridge, MA. Table 4-27 below presents the unit costs used to estimate regulator and control structure costs. The costs included herein represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions. The O&M costs for regulator modifications are included in interceptor and tunnel cost estimates.

Table 4-27 – Regulator Modifications Construction Costs

Type of Regulator Modification	Unit Cost ($)	Unit
Internal Weir Adjustment	40,000	EA
New Structure – Simple	356,000	EA
New Structure – Complex	610,000	EA

4.10. Localized Combined Flow Handling

4.10.1. Near Surface Combined Flow Storage

Storage technologies reduce CSOs by attenuating peak flow from storm events through temporary storage of peak flow volumes. Stored flows are released to the collection system and wastewater treatment facilities after the storm subsides.

Storage facilities are usually limited by land availability. They are most effective in downstream locations at or near overflow regulators or near treatment facilities. They are preferably sited in parallel to the existing collection system and operate in detention mode, where stored flows are returned to the collection system once a storm event subsides and capacity in the existing system becomes available.

- Advantages
  - Provides storage of peak flows
    - Stored flow treated at WWTF after storm event
  - Localized construction impact
- Disadvantages
  - Screening and/or Floatable Control required
  - Odor Control required
  - Operation and Maintenance of remote facilities
  - Limited siting possibilities in dense urban areas
  - Land acquisition requirement

The design of a tank must take into consideration all aspects viewed as a system to ensure a properly designed tank that will meet its operational objectives. The major considerations for storage facilities include tank configurations, influent/effluent hydraulics, pumping scenarios, heating, ventilation, and air conditioning (HVAC), and Odor Control, and cleaning systems.

4.10.2. CSO Storage Tanks Costs

Near Surface Storage (NSS) was described in detail in both the CDR and CDRA in the technology evaluations, section 6 in both reports. The recommended plan did not include any NSS tanks, however, this technology was included in the reevaluation to verify determine if it might now be preferable to other options.

Construction cost equations for typical covered concrete storage basins are shown in Table 4-28. It is assumed that all storage tanks will require pumping facilities with the capacity to dewater the tank within 24 hours of pump activation. The costs equations represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

Table 4-28 - Cost Equations for Concrete Storage Tanks

Source Document	Date of Publication	Cost Equation[1]	Figure ID
Draft MWRA Combined Sewer Overflow Facilities Plan - Technical Memorandum 2-8: Criteria for the Development and Evaluation of Preliminary Alternatives	Sep-88	$C = 4.16*V^{0.71}$	MWRA, 1988
EPA Manual - Combined Sewer Overflow Control (EPA/625/R-93-007)	Sep-93	$C = 8.39*V^{0.826}$	USEPA, 1993

Source Document	Date of Publication	Cost Equation[1]	Figure ID
Evaluation of Planning Level Estimates of Probable Construction Cost (AECOM 2007)	May-07	C = 5.01*V	NEORSD, 2007
Springfield, MA FLTCP Off-Street Construction Estimate	Feb-11	C=6.1*V	SWSC FLTCP (off-street)
NBC CDRA Underground Storage Facility Cost Estimate	April-98[2]	C=9.27*V	NBC CDRA USF
[1] Construction costs (C) have units of millions of dollars adjusted to ENR CCI=9,845 and escalated to mid-point 2018 using 3%/yr. Volumes (V) have units of million gallons.			

The MWRA 1988 cost equation was developed for a closed concrete basin with aeration and washdown. The cover is assumed to be constructed of pre-cast reinforced concrete. The source document did not state that pumping facilities were included nor did it allow for the differentiation between a buried basin and one with a foundation at grade.

The USEPA 1993 equation represents near-surface storage and includes coarse screening, floatables control, and disinfection components; it does not account for pumping costs.

Recent work completed in 2007 by the Northeast Ohio Regional Sewer District (NEORSD) on their CSO Facilities Planning efforts provides a good source of data for a variety of technologies. The NEORSD equation represents a compilation of seven storage tank projects ranging in size from 1.15 MG to 15 MG.

The SWSC FLTCP cost equations were based on recent projects in Springfield, MA as well as bid results for recent similar scale projects in Cambridge, MA. This cost includes coarse screening and floatables control.

The NBC CDRA Underground Storage Facilities (USF) is the high-end of the cost estimate that was used for technology evaluation in the 1998 CDRA (Table 6.1-1). This cost is assumed to include floatables control, mechanical flushers and pumping.

Figure 4-44 shows curves developed from the cost equations for storage basins in Table 4-28 above. The costs curves represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

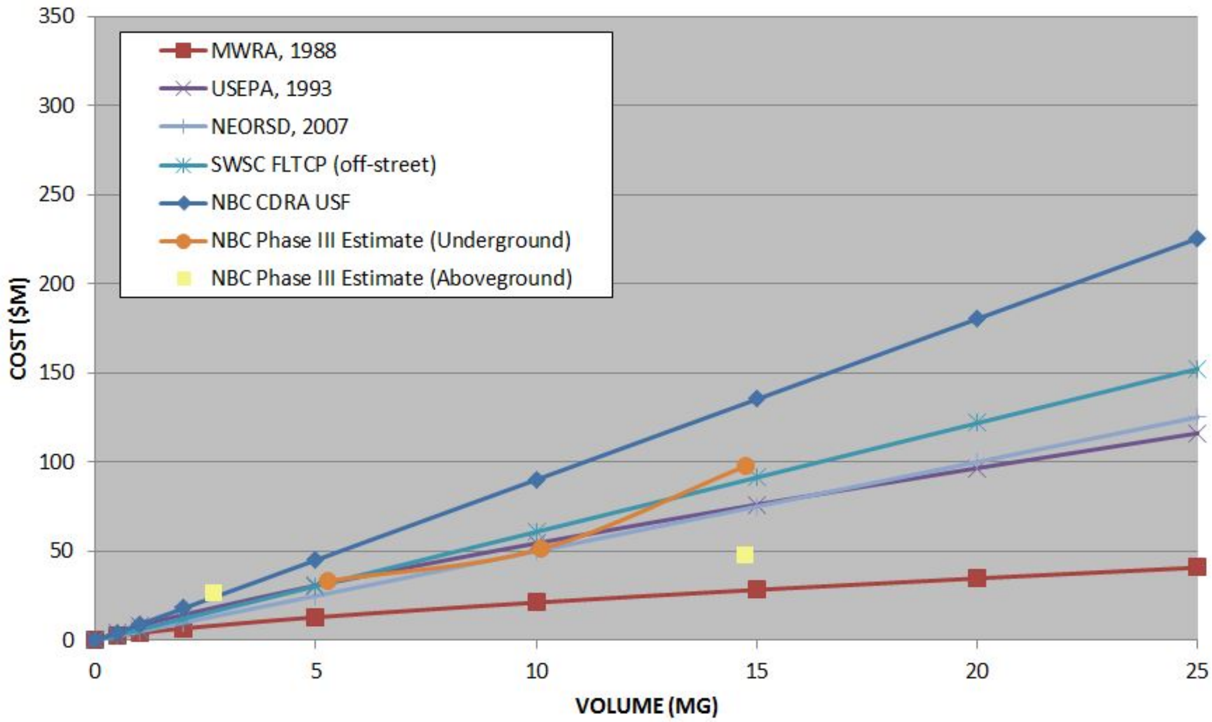

Figure 4-44 – Construction Cost Curves for Near-Surface Storage

The Springfield FLTCP cost equations were used to develop NSS tank costs for this Reevaluation because it is a "high average" curve that closely matches estimates developed for this reevaluation as well as other recent studies. The costs curves represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

4.11. Combined Flow Treatment and Discharge

Satellite treatment facilities are usually installed in situations where expanding the existing treatment plant or the conveyance system is not a feasible option. These facilities typically include high-rate disinfection and screening to provide some solids removal and are located adjacent to outfalls. The tank volume required is usually less than for storage only tanks because treatment is provided. Therefore, the site footprint can be smaller. However, an aboveground building is required for the screening equipment and chemical storage. Easy and secure site access is required for chemical storage and delivery as well as routine maintenance.

- Advantages
  - Provides capacity relief for existing interceptors and WWTF infrastructure
  - Localized construction impact
- Disadvantages
  - High capital costs
  - High operation and maintenance costs
  - Residual pollutant loading to receiving waters
  - Limited siting adjacent to outfalls
  - Chemical storage and delivery
  - Land acquisition requirement
  - Residuals discharge

While satellite treatment facilities provide some solids removal and reduction of bacteria through on-site disinfection, this level of treatment is less than for storage only facilities where all the stored flow is pumped to a treatment for secondary treatment. However, treatment and discharge facilities are not as limited as storage only tanks in the volume of flow that can be treated.

Storage only tanks can store only the volume they were designed for. When that volume is reached, any additional flow will be discharged to the receiving water without treatment. A flow through treatment facility can provide some level of treatment throughout a storm event.

Satellite treatment was described in detail in both the CDR and CDRA in the technology evaluations in section 6 in both reports. The original recommended plan did not include any satellite treatment facilities, however, technological advancements and improvements in operational efficiencies since development of the CDR and CDRA warrant the additional detailed descriptions included in this chapter. In addition to technical considerations , implementation of any CSO treatment and discharge facility would need to comply with regulatory requirements which were discussed at the 4 September 2014 Stakeholder meeting by representatives from both Rhode Island DEM and US EPA Region 1. Because treatment and discharge facilities do not provide the same level of treatment as storage only facilities Consequently, DEM would likely require additional detailed data and evaluation prior to approving a plan containing such a facility. Moreover, the representative from EPA viewed any screening and disinfection option as an interim solution that would ultimately require additional treatment to achieve the water quality goals of the Clean Water Act.

4.11.1. Disinfection

Bacterial reduction in flow through treatment facilities is provided through disinfection.

There are several alternatives for disinfection that can be implemented at CSO screening and disinfection facilities (SC/D), such as chlorine disinfection, ultraviolet radiation (UV), peracetic acid (PAA), ozonation and chlorine dioxide. These alternatives were evaluated in the CDRA in section 6.1.10 and sodium hypochlorite was selected as the preferred disinfectant. Since the completion of the CDRA, the use of both PAA and UV for disinfection has expanded and improved. This report will reevaluate the use of chlorination/dechlorination, PAA and UV facilities for Phase III CSO applications.

The most widely used disinfectant for water, wastewater, and combined sewage has been chlorine. Chlorine disinfection has the advantage of a common, reliable disinfectant. The primary disadvantages of chlorine disinfection are the potential toxicity of chlorine residuals and byproducts and hazardous transportation and storage of the chemical. At certain concentrations chlorine residuals and byproducts are toxic to aquatic life. Both gaseous and liquid chlorine have health risks associated with transportation, storage and handling of the chemical. However, sodium hypochlorite can be used as the chemical disinfectant to mitigate the storage and handling risks.

Chlorine disinfection is capable of providing a 2 to 4 log reduction in bacterial densities for most CSOs. The feasibility and effectiveness is highly variable and dependent on influent water quality.

UV disinfection is a physical process that uses photochemical energy to damage cellular proteins and nucleic acids in order to prevent further replication. The primary advantage of UV disinfection is that it is a physical process and thus no chemicals are added. However, the effectiveness is dependent on specific characteristics of the water and the treatment system such as UV Transmittance (UVT), the dose of UV radiation, detention time, and the reactor configuration. Effectiveness is directly related to suspended material which may shade the pathogens from the radiation.

UV disinfection is different from chemical disinfection with respect to the inactivation mechanism, the response of microorganisms, and the factors that impact disinfection. The differences between UV light and chemical disinfection are summarized in Table 4-29.

Table 4-29 – Comparison of Chemical and UV Disinfection

Factor	Chemical Disinfection	UV Disinfection
Disinfection mechanism	Pathogen is killed by exposure to chemical (e.g., destruction of cell wall). Associated chemical reactions well understood.	DNA is damaged by UV light, and pathogen replication is prevented. Cell structure is left intact. Associated optical interactions relatively more complex.
Flow through reactor	Water, disinfectant, and pathogens flow together.	Water and pathogens flow past a fixed UV light field.
Detention Time	Relatively long and measurable. A key variable in determination of regulatory compliance.	Very short. Path taken by pathogen more important.
Chlorine Removal	Dechlorination chemical required.	Not required.
Primary factors impacting disinfection effectiveness	• Residual concentration • Contact time • Temperature • pH • Type of chemical	• Water quality (e.g., UVT) • Characteristics of UV equipment • UV intensity distribution • Contact time • Power quality
Hazard	High (chemical e.g. chlorine gas may be hazard	Low (UV light is primary hazard)

UV disinfection is becoming an alternative to chlorination at wastewater treatment facilities where the process is placed at the end of the treatment train. UVT for secondary effluent is typically 60% to 70%, and UVT for advanced wastewater treatment processes can exceed 70%. More recently, manufactures have developed UV systems that are rated for flows with UVT down to the 15% or 20% range. Consequently, UV can be considered for CSO applications as part of a wet weather treatment and discharge system.

CSO water characteristics are highly variable and often will have poor water quality with low UVT and high solids content. Specifically, the lower the UV transmittance, the higher the required dose of UV light and contact time to achieve the required level of disinfection. This leads to a larger facility footprint and higher operation costs, or may render UV disinfection ineffective at certain levels. Where TSS is found in concentrations greater than 30 mg/L, UV disinfection is not recommended without primary treatment. Without primary treatment other than screening, UV disinfection is capable of providing a 1 to 3 log reduction in bacterial densities for most CSOs. The feasibility and effectiveness is highly variable and dependent on influent water quality.

Primary treatment or greater is preferred upstream of UV disinfection to reduce the solids content, increase UVT, and improve the quality of the overflow volume. However, the space required for conventional primary treatment is not available near outfall sites. Where space is limited, high rate clarification systems such as ACTIFLO® can significantly reduce the facility footprint. The sensitivity of these systems to changing conditions typically requires active operation of the facilities to achieve the treatment objectives of the technologies and mitigation of ancillary impacts. Consequently, the majority of installations are wet weather side-train treatment systems within the confines of a wastewater treatment facility. These systems are not routinely implemented in remote or unattended locations.

When paired with primary treatment such as high rate clarification, the influent water quality to UV treatment is greatly improved. This improvement in water quality can increase the capability of UV disinfection to a 4 log reduction in bacterial densities for most CSOs.

High-rate clarification systems paired with UV disinfection may constitute a feasible alternative for certain CSOs in the Phase III area. However, sufficient data does not currently exist to reach a definitive determination regarding the cost of such a system or its water quality benefits. Any installation would require the above described water quality testing followed by pilot testing of the candidate clarification and disinfection system.

Peracetic Acid is another disinfection option. While information is not yet available for large scale CSO applications, EPA has recently approved different formulations of PAA for application to municipal wastewater. PAA has been used for years in Europe as a substitute for sodium hypochlorite. It has the advantages of a 6-10 times lower chemical dosage, no need for deactivation as well as no disinfection by-products. There are several full-scale wastewater treatment facilities in design and construction that will use PAA as sole effluent disinfectant.

PAA is capable of providing a 2 to 4 log reduction in bacterial densities for most CSOs.

Due to the lack of data on performance in CSO application, PAA is not being considered as a viable near-term alternative. However, depending on the sequencing and schedule for the ultimate Phase III plan, PAA could be considered for pilot testing at remote CSOs to determine its feasibility for implementation in the later stages of Phase III.

4.11.2. Treatment and Discharge Costs

Construction cost equations for typical disinfection facilities are shown in Table 4-30. The costs equations represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions. Due to the variability of UV disinfection, only the cost equation used in the CDRA is included below. Also, PAA is not included in this section as sufficient data was not available.

Table 4-30 – Cost Equations for Screening and Disinfection

Source Document	Date of Publication	Cost Equation	Figure ID
Draft MWRA Combined Sewer Overflow Facilities Plan - Technical Memorandum 2-8: Criteria for the Development and Evaluation of Preliminary Alternatives[2]	September, 1988	C = [0.0643*Q0.963] + [0.0559*Q0.655 + 0.083*Q0.417]	MWRA, 1988
EPA Manual - Combined Sewer Overflow Control (EPA/625/R-93-007)[2]	September, 1993	C = [0.2028*Q0.843] + [0.298*Q0.464]	USEPA, 1993
NBC CDRA Chlorine Disinfection Construction Estimate	April 1998*	C=.301*Q	NBC CDRA Chlor/Dechlor
NBC CDRA UV Disinfection Construction Estimate	April 1998*	C=.361*Q	NBC CDRA UV
[1] Construction costs (C) have units of millions of dollars adjusted to ENR CCI=9,845 and escalated to mid-point 2018 using 3%/yr. Flows (Q) have units of million gallons per day (MGD).			
[2] Cost equations include both screening and disinfection.			
[3] CDRA costs were derived from a 1996 Basis.			

The MWRA 1988 cost equation is a combination of the equations derived for disinfection and mechanical screening. The disinfection equation was derived by combining costs for a gaseous chlorine feed system (allowable flow range from 1 to 150 mgd) with costs for a sulfur dioxide dechlorination facility (allowable flow range from 0.1 to 100 mgd). The mechanical screening equation assumes bar spacing between 5/8 to 1½ inches. The following equipment was included in the calculated cost estimate:

- Mechanical Screening Equipment
  - Screens and screen housing
  - Collection flumes
  - Flow splitters and weirs
  - Electrical equipment
  - Instrumentation equipment
- Disinfection Equipment
  - Chemical feeders
  - Chemical storage tanks
  - Chemical metering pumps

- Reaction tank with one minute of detention time
    - Mixer
    - Instrumentation equipment
    - Evaporators, as required
    - Standby chlorinator

The USEPA 1993 cost equation is a combination of the equations derived for disinfection and mechanical screening. The disinfection cost equation was based on a liquid sodium hypochlorite system with a liquid sodium bisulfate dechlorination system. The mechanical screening equation assumes bar spacing between 5/8 to 1½ inches. The following equipment was included:

- Mechanical Screening Equipment
    - Screens and screen housing
    - Collection flumes
    - Flow splitters and weirs
    - Electrical equipment
    - Instrumentation equipment
- Disinfection Equipment
    - Chemical storage tanks
    - Chemical metering pumps
    - Piping and valves
    - Diffuser
    - Chlorine residual analyzer

The CDRA construction estimates for both chlorine disinfection and UV disinfection are the high-end of the cost estimates that were used for technology evaluation in the CDRA (Table 6.1-1). The costs for UV disinfection were not stated but are assumed to include influent bar screening and a UV system that utilizes low-pressure, high-output lamps. The costs for chlorine disinfection as stated in CDRA section 6.3.2 included:

- Mechanical Screening Equipment
    - Bar Screens (2-inch)
    - Microscreening (<1/4-inch)
    - Concrete Channels/Tanks
    - Pressure Washing Equipment
    - Solids Handling/Removal
    - Electrical & Instrumentation Equipment
- Chlorination Equipment
    - Chemical Storage Tanks (Sodium Hypochlorite)
    - Metering Pumps
    - Injection Diffusers
    - Electrical & Instrumentation Equipment
    - Channelized Tankage
- Dechlorination Equipment
    - Chemical Storage Tanks (Sodium Bisulfite)
    - Metering Pumps
    - Injection Diffusers
    - Electrical & Instrumentation Equipment

- o hypochlorite, dechlorination equipment.

Figure 4-45 shows curves developed from the cost equations for disinfection facilities in Table 4-30.

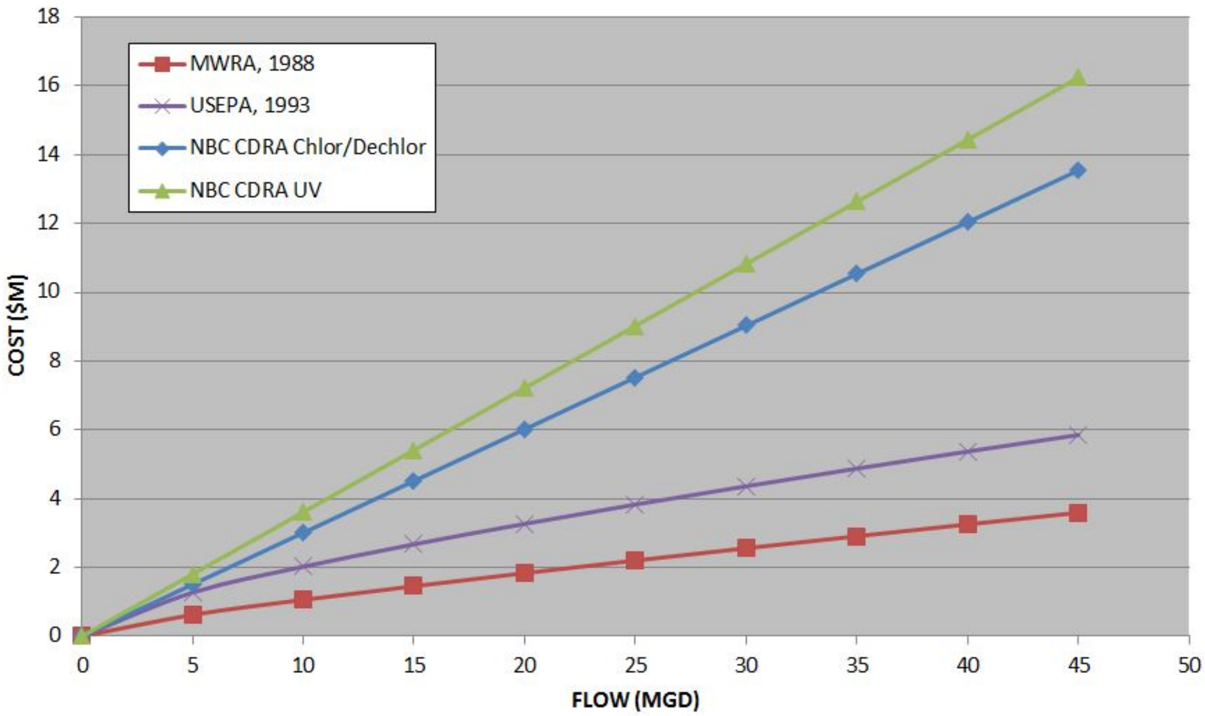

Figure 4-45 – Construction Cost Curves for Screening and Disinfection Facilities

The CDRA cost equations for screening and disinfection facilities were used to develop satellite treatment costs for this Reevaluation because it is a "high average" curve and recent construction cost data was not available for similar projects in the region. The costs curves represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions. As noted previously the necessity of primary treatment, the site footprint, as well as operational effectiveness of screening and disinfection technologies are highly dependent on influent water quality characteristics and cost can range significantly.

Operation and maintenance (O&M) costs for screening and disinfection facilities are highly dependent on the frequency and size of storm events and as such can vary widely. For the purposes of this reevaluation, the operation and maintenance costs in the NBC CDRA will be used for evaluation. The O&M costs presented in the CDRA range between $4,000-10,000/MGD, as presented in Table 6.2.1 in the CDRA, when updated to 2018.

4.12. Locations for NSS

NSS tanks and flow through treatment facilities are usually located at or near their associated CSO. In the urbanized Phase III areas, the lack of suitable sites is a challenge. However, NSS or flow through facilities may be a feasible alternative at the following CSO locations:

- OF 039 and 056 as an alternative to sewer separation
- OF 220 as an alternative to the Pawtucket interceptor
- Locations in Central Falls near the Blackstone River as an alternative to the High & Cross Street interceptor.

As an alternative to the Pawtucket Tunnel, NSS and flow through facilities were considered for the following locations:

- near 205 for outfalls 201 through 205
- near 210 for outfalls 210, 211 and 212
- near 213 for outfalls 213 and 214
- near 217
- near 218

NSS facilities are evaluated for each of these locations.. The results of the evaluation for the NSS facilities are also applicable to the flow through treatment facilities. However, during the development of the CDR and CDRA, concerns were raised regarding disinfection and discharge because of the transportation and storage of chlorine in the neighborhoods near these outfalls. These same concerns apply to the sites identified for this reevaluation many of which are adjacent to public open spaces, including parks and playing fields.

4.12.1. Outfalls 039/056

In addition to the West River Interceptor discussed in section 4.8.1, a local NSS tank was evaluated as an alternative to sewer separation proposed for Outfalls 039 and 056 located within Providence.

A storage tank in the vicinity of 039 and 056 would be approximately 0.41MG. The only site in the area identified as a candidate for NSS is the playing fields at the Rhode Island School for the Deaf. The alternative was removed from further consideration due to siting constraints. Other open space in the area is not located near central sewer lines where flow could be diverted.

4.12.2. Outfall 220

An NSS facility at OF 220 could be an alternative to the proposed Pawtucket Avenue Interceptor or the Stub Tunnel.

The CDR evaluated a 9.21 MG underground storage tank (B-2/BPSA-4) to control discharges from CSO outfalls 037, 219, 220 in Pawtucket, as shown in Figure 4-46. The facility was located at the Morley Field ballpark, owned by the City of Pawtucket, at the intersection of Esten Ave and Moshassuck St. The previous evaluation included a consolidation conduit to bring flow from CSO 037 to the facility. However, the catchment tributary to CSO 037 is undergoing complete sewer separation under Phase II of the CSO program. Also, CSOs 219 and 220 have been combined into a single outfall, CSO 220.

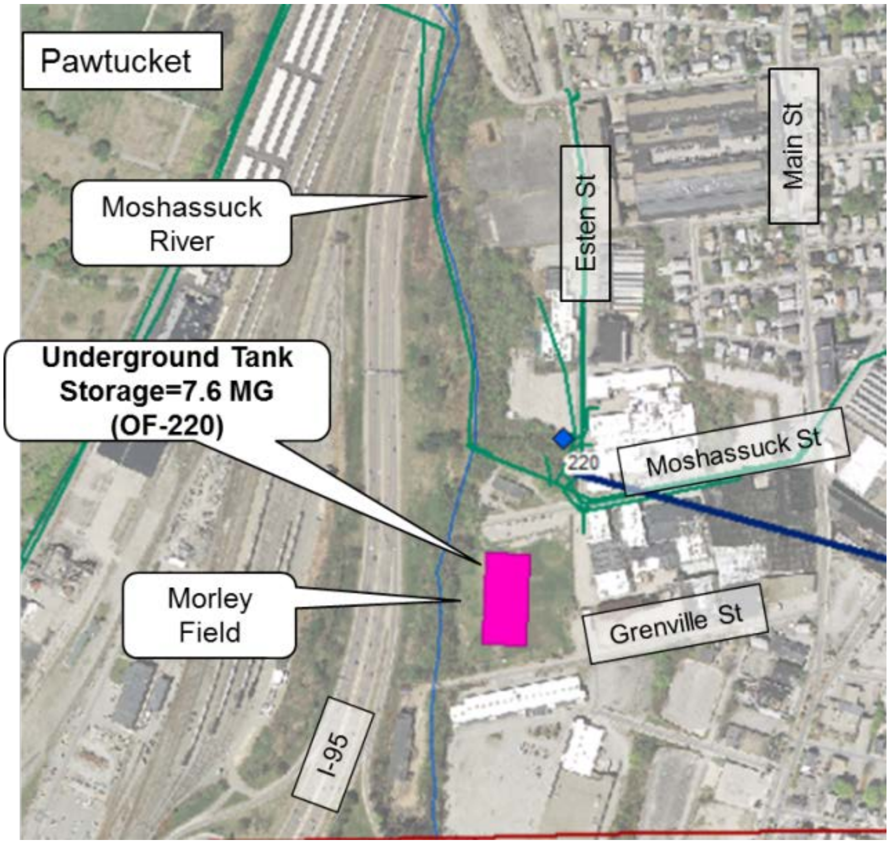

Figure 4-46 – CDR NSS for CSO 220

A view of Morley Field is shown in Figure 4-47.

Figure 4-47 - Morley Field

The NSS alternative for CSO 220, located on A.P. 62A Lots 291 and 309 in Pawtucket, consists of three potential tank configurations as shown in Figure 4-48. "Tank 1" is a 4.97 MG tank with dimensions 250 ft.(L) x 221 ft.(W) x 12 ft.(D) to accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. "Tank 2" is a 2.70 MG tank with dimensions 240 ft.(L) x 150 ft.(W) x 12 ft.(D) designed to accommodate the 3-month storm overflow volume with aggressive implementation of GSI upstream of the outfall. "Tank 3" is a 9.9 MG tank with dimensions 380 ft.(L) x 290 ft.(W) x 12 ft.(D). This design exceeds system capacity requirements and is the maximum capacity we believe is available on this parcel. A new diversion structure and approximately 110 feet of 54-inch consolidation conduit would be required for all three tank options. Approximately 125 feet of 8-inch force main piping is also required.

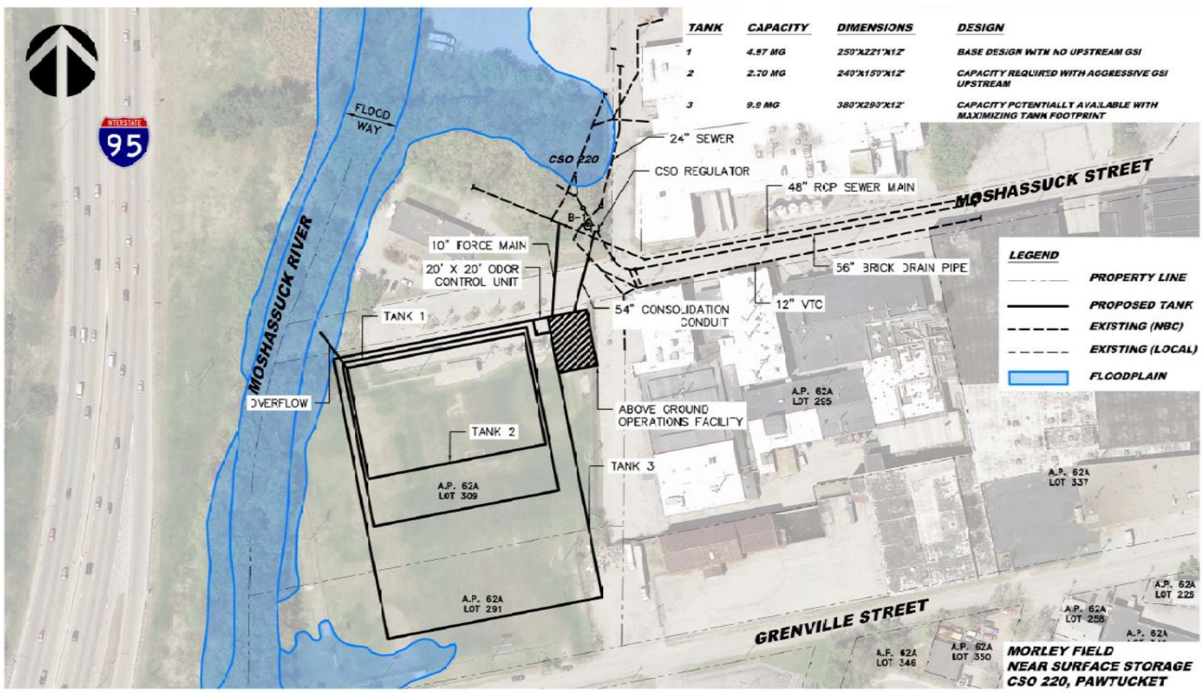

Figure 4-48 – NSS for CSO 220

Constraints for this option include the site's current use as an athletic field and the expectation that groundwater is high in the area around the site. Any operations facilities sited inside the athletic field would have significant detrimental impact on the field's use because the City of Pawtucket would be without the use of a large athletic facility for an extended period of time during construction, possibly two to three construction seasons. The result could be a significant social burden to the community, which would need to be strongly considered and mitigated prior to moving this option beyond the conceptual design phase. Due to its proximity to the Moshassuck River, excavation may be difficult and dewatering may be a substantial component of the tank construction.

A screening and chlorine disinfection facility could also be located at the Morley Field site. However, because of the need to store chlorine at the site in close proximity to the ball field makes screening and disinfection less desirable at this site. Due to site constraints and operational limitations, primary treatment would not be feasible at the Morley Field site so UV disinfection would not be feasible.

4.12.3. Outfalls 101/103

The proposed Phase III controls for outfalls 101 and 103 are regulator modification and the High St Interceptor respectively. The area surrounding Outfall 103 is primarily commercial with some residential streets near Outfall 101. The Wyatt Detention Facility (max security prison) is located on High St at Blackstone St. The Central Falls DPW is located on High St at Hunt St. A recently closed industrial light bulb factory (Osram) was located just on the other side of the railroad tracks.

The CDR evaluated a 4.3 MG underground storage tank (BPSA-6) to control discharges from CSOs OF 101 and OF 103 in Central Falls, as shown in Figure 4-49.

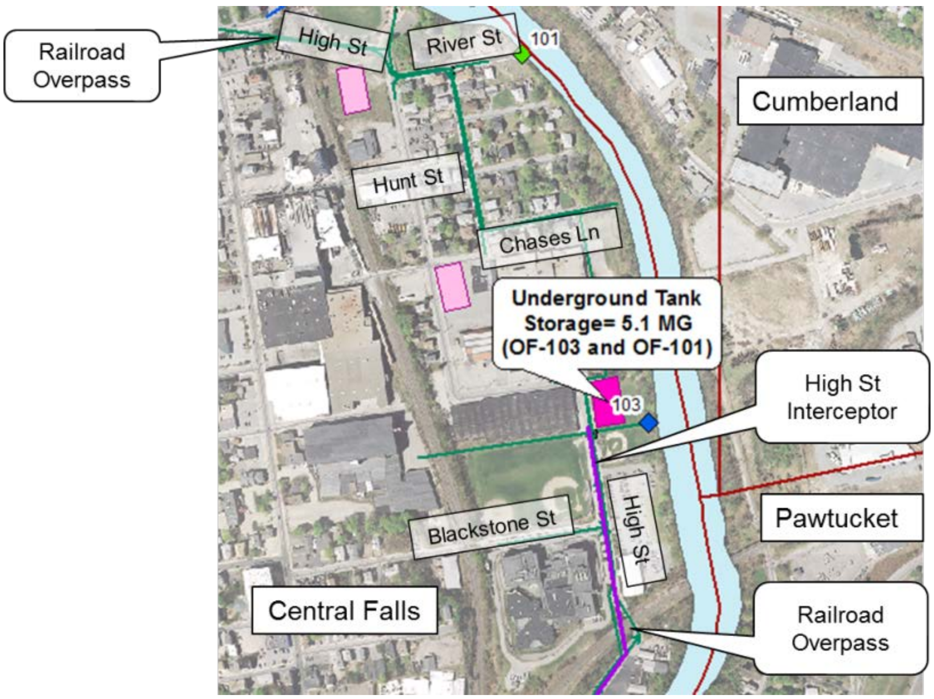

Figure 4-49 – CDR NSS for CSOs 101/103 (BPSA-6)

The facility was to be located underground at the waterfront ballpark owned by the City of Central Falls east of High St on the Blackstone River, shown in Figure 4-50. A consolidation conduit would be needed to bring flow from CSO 101 to the facility, and would run parallel to the existing NBC interceptor.

Figure 4-50 - Pierce Park (Central Falls)

The Pierce Park site would be compatible with a subsurface storage tank, however, a treatment and discharge facility is not desirable due to the need for chlorine storage at the site, which offers a potential hazard in a public place.

Two options were identified for the NSS alternative for CSO 103. Each option would include a regulator modification at CSO 101 to convey flow to the NSS alternative at CSO 103. As shown in Figure 4-51, Option 1, located on A.P. 2 Lot 50 in Central Falls consists of three potential underground tank configurations.

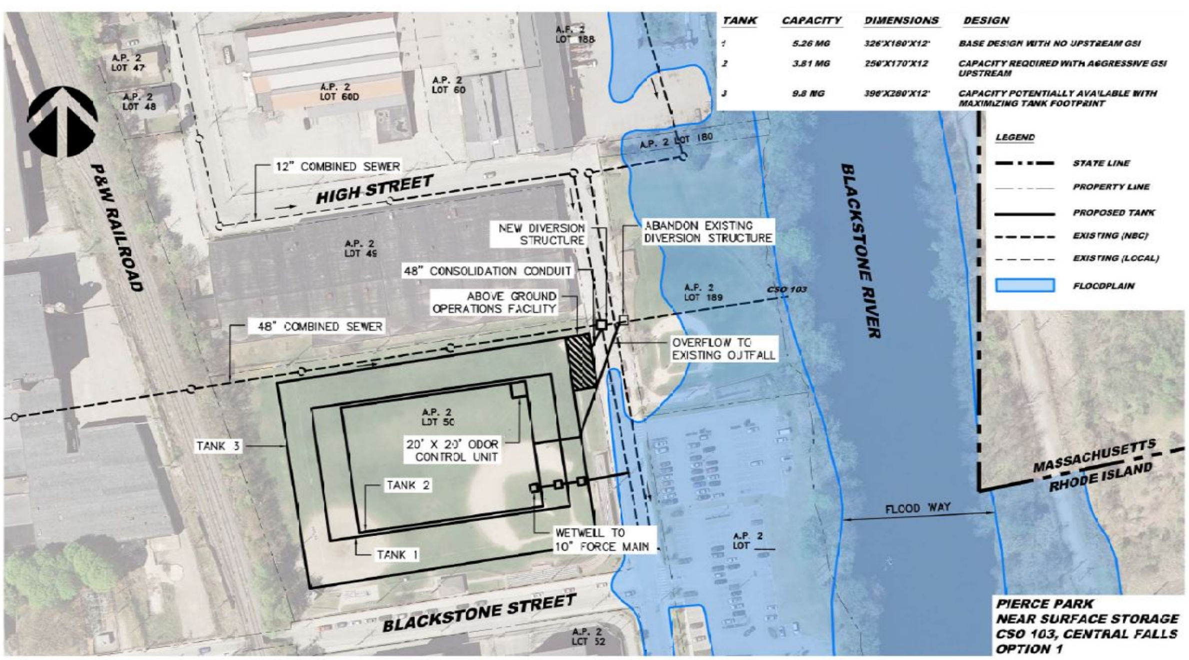

Figure 4-51 – NSS for CSO 101/103 Option 1

"Tank 1" is a 5.26 million gallon (MG) tank with dimensions 326 ft.(L) x 180 ft.(W) x 12 ft.(D) that could accommodate the 3-month storm overflow volume under existing system conditions with no upstream green stormwater infrastructure (GSI). "Tank 2" is a 3.81 MG tank with dimensions 250 ft.(L) x 170 ft.(W) x 12 ft.(D). This design could accommodate the 3-month storm overflow volume with the aggressive use of GSI implemented upstream of the outfall. "Tank 3" is a 9.8 MG tank with dimensions 390 ft.(L) x 280 ft.(W) x 12 ft.(D). This design volume exceeds the 3-month storm overflow and is the maximum volume we believe is available on this particular parcel. All three tanks were assumed to have a sidewall depth of approximately 12 feet, which represents a reasonable wall height for a buried tank. Concrete walls much greater than 12 feet would require additional construction considerations, which would disproportionately impact the cost of the tank. All three proposed tank alternatives would include approximately 30 feet of 48-inch gravity consolidation conduit and 60 feet of 8-inch force main piping.

Constraints associated with Option 1 include this site's current use as an athletic field, one of only a few in Central Falls, as well as an expected high groundwater table. Furthermore, any aboveground operations facilities would need to be sited outside the limits of the athletic field, which may be difficult based on space constraints. Any operations facilities sited inside the athletic field would have significant detrimental impact on the field's use because the City of Central Falls would be without the use of a large athletic facility for an extended period of time during construction, possibly two to three construction seasons. The result would be a significant social burden to the community, which would need to be strongly considered and mitigated prior to moving this option beyond the conceptual design phase.

As shown in Figure 4-52, Option 2 consists of two potential underground tank configurations, previously identified as "Tank 1" and "Tank 2" in Option 1 above, but is located northeast of Option 1 on A.P. 2 Lot 189. Similar to Option 1, during a large storm event, the combined sewer will be conveyed from a new diversion structure through approximately 170 feet of 48-inch consolidation conduit to the aboveground operations facility for screening prior to discharge into the tank. This option also includes approximately 30 feet of 8-inch force main piping.

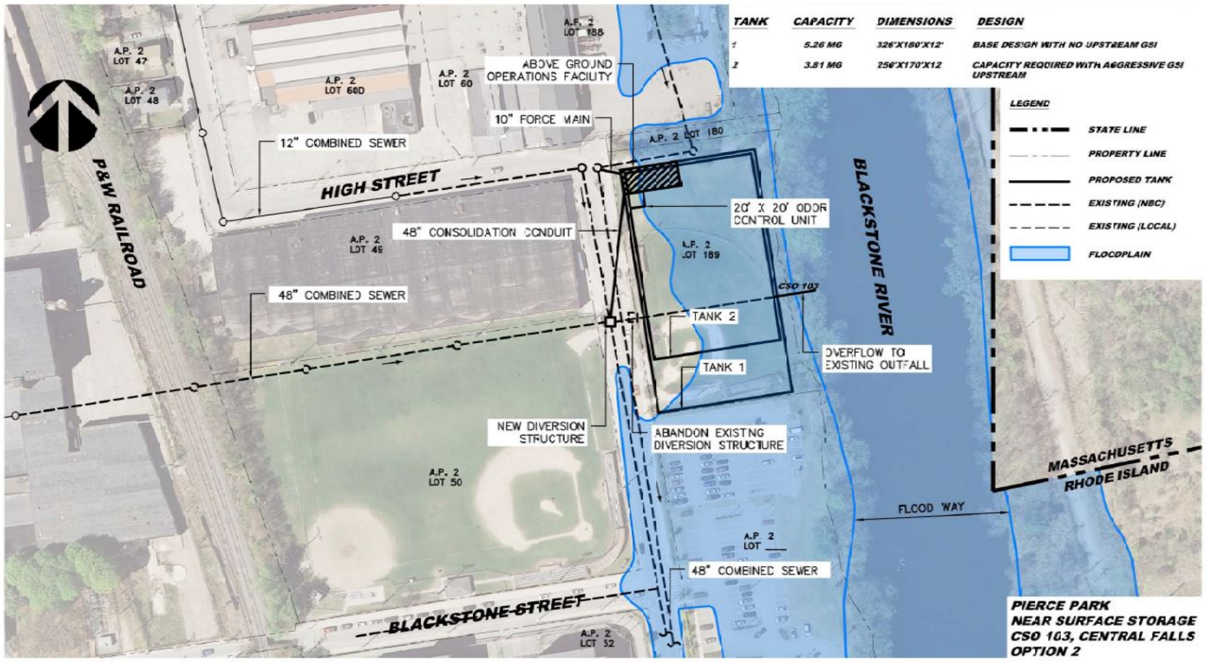

Figure 4-52 - NSS for CSO 101/103 Option 2

Option 2 is constrained by the site's current use as an athletic field and an expected high groundwater table. Moreover, this option is located within the 100-year floodplain of the Blackstone River. Due to its proximity to the river, excavation may be difficult and dewatering may be more significant during construction than for Option 1. Similar to Option 1, the City of Central Falls will be without the use of this athletic field for an extended period of time during construction, possibly two to three construction seasons.

If the Pawtucket Tunnel is not part of the recommended alternative, a NSS facility in this area will be a required part of the suite of solutions. If the Pawtucket Tunnel is determined to be the most appropriate solution, a further benefit of a local detention facility in this area would be that it could reduce the length of the High St Interceptor to just pick up outfalls 104 and 105.

4.12.4. Outfalls 104/105

A local facility for outfalls 104 and 105 should only be considered if a local facility is also suitable for outfalls 101 and 103. If the Pawtucket Tunnel stays in as a solution, an interceptor from outfalls 101 and 103 would likely pass directly adjacent to outfalls 104 and 105, rendering a local facility unnecessary. If a local facility works for outfalls 101 and 103, handling local facility for 104 and 105 would remove the need for the High/Cross St interceptor. However, consolidation interceptors would likely still be necessary to transport the overflows to the facility.

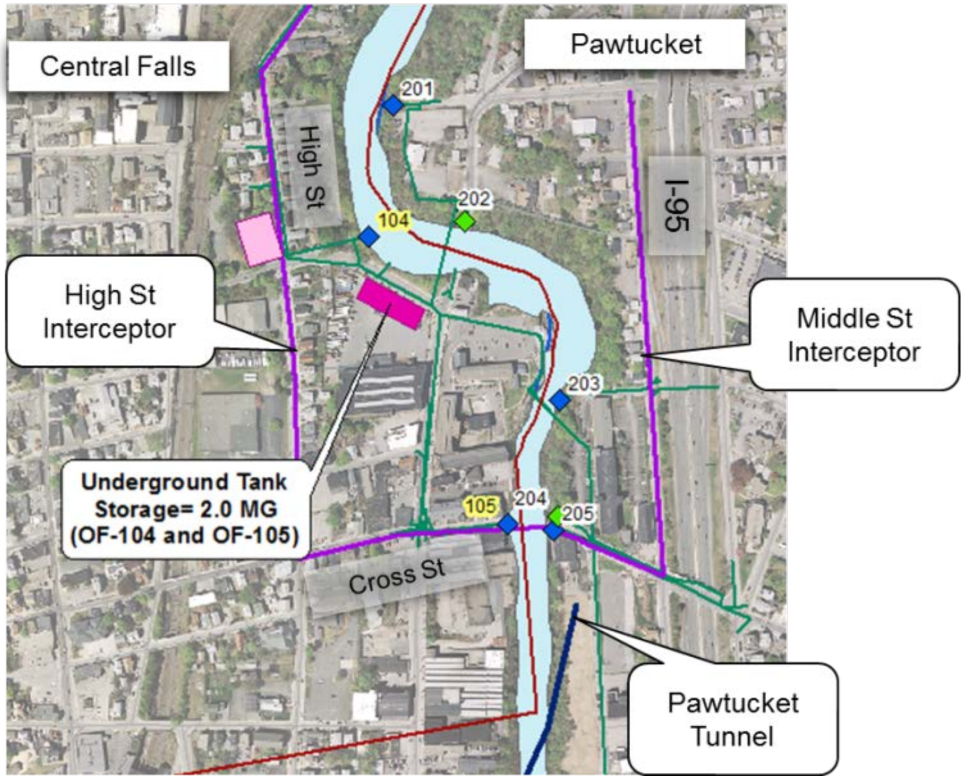

Figure 4-53 – CDR NSS for CSOs 104/105 (BPSA-8)

The area surrounding outfalls 104 and 105 is a mix of commercial and residential properties, as well as several industrial users. The Central Falls Historic Mill District is located on the Blackstone River.

The CDR evaluated a 1.7 MG underground storage tank (BPSA-8) to control discharges from CSO outfalls 104 and 105 in Central Falls. The facility was to be located at the parking lot west of the Roosevelt Ave and Sacred Heart Ave intersections owned by Elizabeth Webbing Mills as shown in Figure 4-53. Separate consolidation conduits for CSOs 104 and 105 were proposed to divert flow to the tank location, paralleling the existing interceptor.

The CDR noted “that because of the hydraulics imposed by the existing CSO regulator weir heights, the depth of cut for this facility at this site will have to be close to 20-ft because of higher ground surface. Available information suggests that this depth may involve significant rock excavation”. This would likely lead to very expensive excavation and construction in this area.

Treatment and discharge is not being considered for this location due to its proximity to occupied buildings.

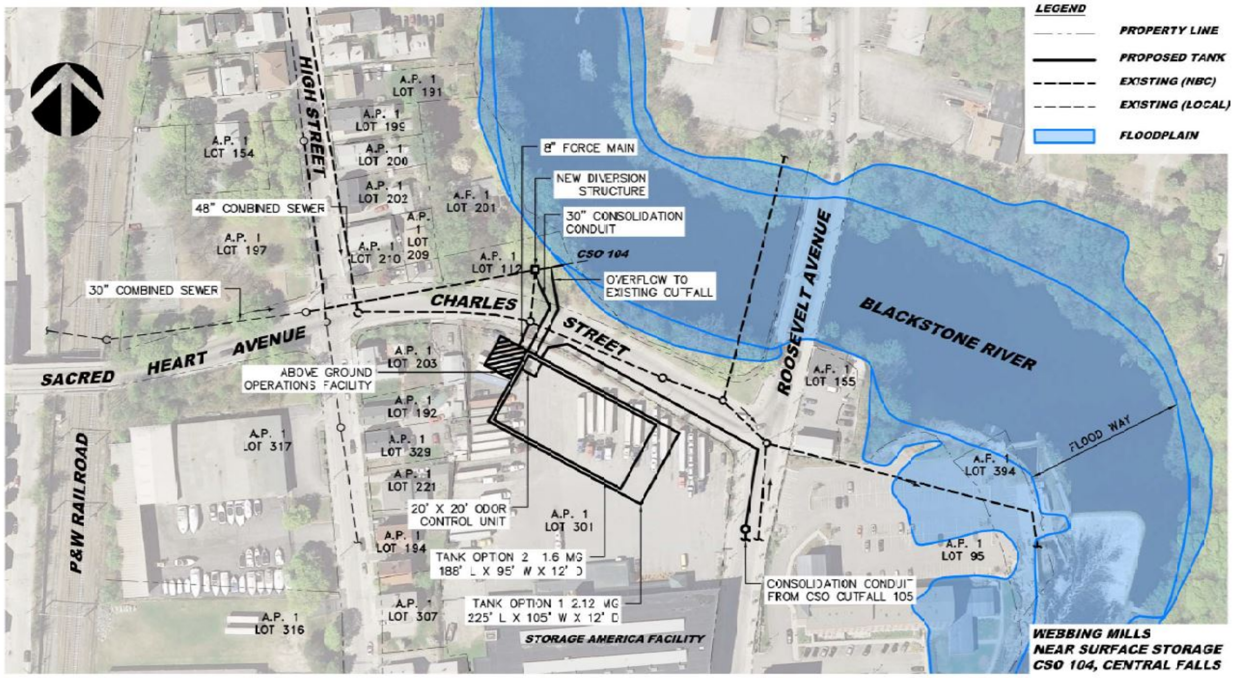

Figure 4-54 - NSS for CSOs 104/105

The NSS alternative for CSO 104, located on A.P. 1 Lot 301 in Central Falls consists of two potential underground tank configurations as shown in Figure 4-54. “Tank 1” is a 2.12 MG tank with dimensions 225 ft.(L) x 105 ft.(W) x 12 ft.(D) that could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. “Tank 2” is a 1.6 MG tank with dimensions 188 ft.(L) x 95 ft.(W) x 12 ft.(D) that could accommodate the 3-month storm overflow volume with aggressive use of GSI implemented upstream of the outfall. A new diversion structure and approximately 110 feet of 30-inch consolidation conduit would be required for this option. Approximately 30 feet of 8-inch force main piping is also proposed. A consolidation conduit from CSO 105 would be required to convey flow to the NSS tank.

Constraints associated with this location include the site’s current use as a storage and vehicle rental facility, as well as shallow bedrock reported in the vicinity of the proposed tank location. During construction, this business would be without use of this area of the site for two to three years, which would be expected to have a significant adverse impact on their operations. This option would have significant localized economic impact as the result of the disruption caused to the site during construction, which would need to be considered and mitigated prior to moving beyond the conceptual design phase with this option. In addition, the proposed tank would need to be designed to accommodate loading from tractor trailers, which utilize this area for parking. Furthermore, it does not appear that this site has adequate additional space for construction staging, resulting in the required daily transportation of construction material and equipment to the site from an off-site location or cooperation with an abutting property owner to obtain temporary use of their lot as a construction staging area. Ledge is reported to be shallow at a site abutting the proposed tank site to the north along Charles Street. Shallow bedrock encountered during construction could result in a significant increase in construction cost and duration.

4.12.5. Outfalls 201, 202, 203, 204, 205

A NSS facility in this area of Pawtucket would control discharges from one the second largest overflow in the Bucklin Point Service Area, Outfall 205, as well as the nearby overflows of 201, 202, 203, and 204. The modeling conducted for the Reevaluation indicates that the CSO volume requiring mitigation from this section of the system totals nearly 15 MG.

The 201-205 outfalls are located on the eastern bank of the Blackstone River at the northern edge of Pawtucket between the Massachusetts border and Central Ave. The area is comprised of a mix of residential and commercial properties, Interstate 95 just to the east, the Pawtucket Water Supply Board offices and an above ground water storage tank.

Due to the very large volume, the local storage option in the previous studies was subdivided into two facilities, shown in Figure 4-55. The CDR evaluated two underground storage facilities in this area of Pawtucket: a 5.9 MG tank (BPSA-2) to control discharges from CSO outfalls 201, 203 and a portion of 205; and a 7.0 MG tank (BPSA-3) to control a portion of CSO outfall 205. CSO 202 was to be closed off with a masonry seal and CSO 204 was to be controlled with a regulator modification. The 5.9 MG storage facility would be located on Front St south of Central St, with the Middle St Interceptor transporting flows to the facility. The 7.0 MG tank was to be located in a large, private parking lot on Cottage St at Central St. While the Front Street location is still undeveloped, as shown in Figure 4-55, the Central Street location was renovated in 2013 for a large commercial user.

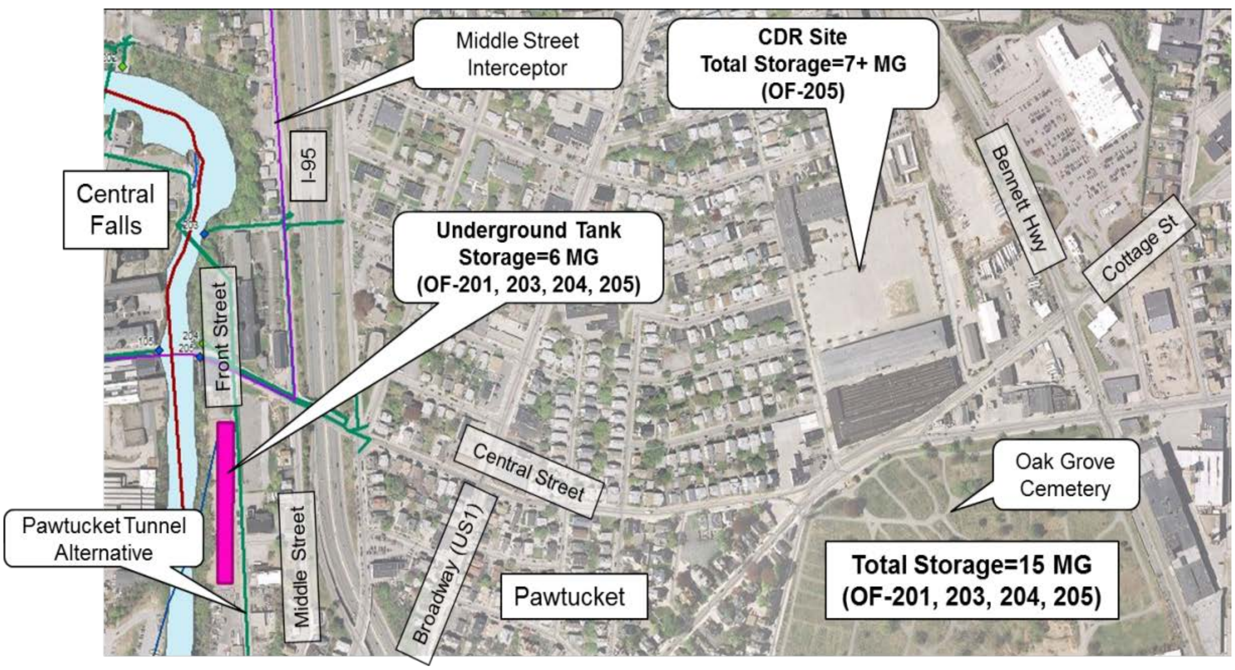

Figure 4-55 – CDR NSS for CSOs 201/203/204/205 (BPSA-2 & 3)

A view of the undeveloped location on Front Street is shown in Figure 4-56.

Figure 4-56 - Front Street (CDR Proposed Site)

The immediate area along the Blackstone River as well as surrounding area was historically comprised of mill-type industrial facilities. There are several known sites of Brownfield contamination, some of which have been at least partially mitigated in recent years. However any excavation in this area should expect to encounter an undetermined degree of contaminated material.

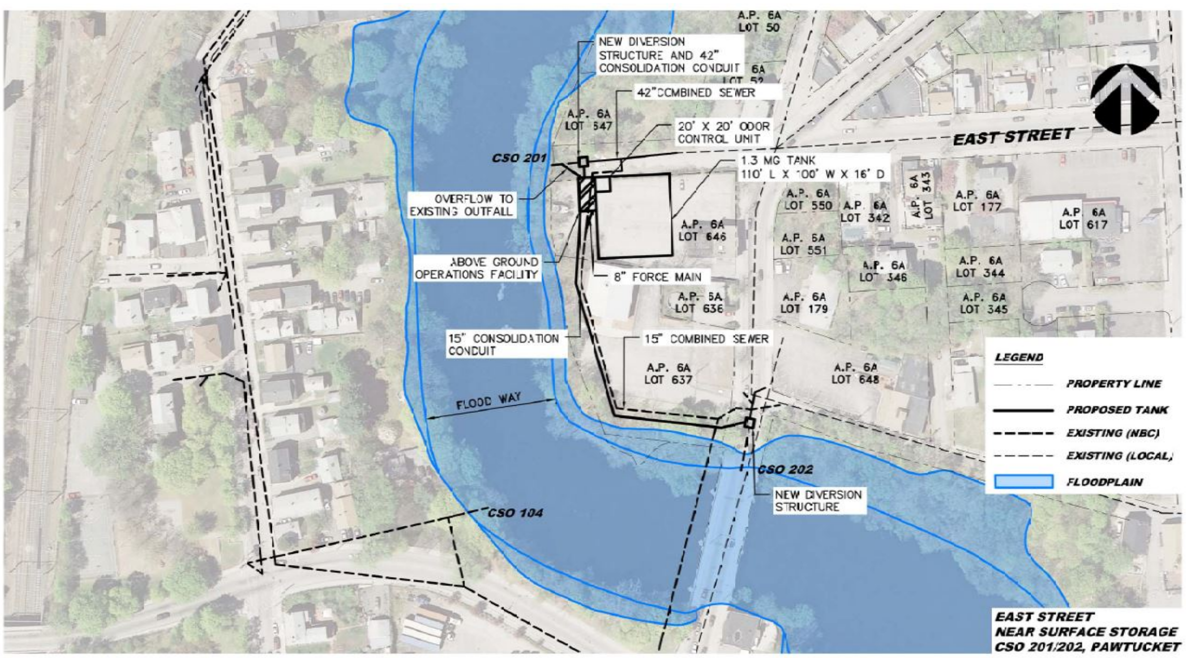

Figure 4-57 - NSS for CSOs 201/202

The NSS alternative for CSOs 201 and 202, located on A.P. 6A Lot 646 in Pawtucket, consists of one potential underground tank configuration as shown in Figure 4-57. This alternative is a

1.3 MG tank with dimensions of 110 ft.(L) x 100 ft.(W) x 16 ft.(D) that could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. This option would include two new diversion structures, one for each outfall. Approximately 470 feet of 15-inch consolidation conduit would be required from the CSO 202 diversion structure to the tank and approximately 15 feet of 42-inch consolidation conduit would be required from the CSO 201 diversion structure to the tank. Approximately 25 feet of 8-inch force main piping would also be required to pump combined stormwater back into the collection system following the storm event.

Constraints associated with the NSS alternative for these outfalls include the existing utilities on the proposed parcel, which limited space for tank construction. This alternative would also require a significant length of pipe to convey flow from the existing system to the tank from CSO 202. In addition, the consolidation conduit that will divert flow from the existing CSO 202 to the proposed tank will traverse the Pawtucket YMCA property located south of the site, potentially disrupting the activities of the facility during pipe installation. Moreover, the elevation at CSO 202 is below the proposed tank location, increasing the depth of gravity sewer installation and resulting in a deeper tank excavation.

Figure 4-58 - NSS for 203/204/205

The NSS alternative for OF 203, 204 and 205, located on A.P. 20A Lots 5, 9, and 629 in Pawtucket, consists of one potential underground tank configuration as shown in Figure 4-58. This alternative is a 10.10 MG tank with dimensions of 620 ft.(L) x 100 ft.(W) x 24 ft.(D) that could accommodate the 3-month storm overflow volume, but would require aggressive upstream GSI due to site space constraints. A new diversion structure and approximately 200 feet of 78-inch consolidation conduit would be required for this option in addition the Middle Street Interceptor, discussed in section 4.7.3, to convey flow from OFs 201, 202, and 203. Approximately 20 feet of 8-inch force main piping would also be required to pump combined stormwater back into the collection system following the storm event.

The most significant constraint to this site is its overall size. While the parcel is over 14 acres in size, the tank volume is significant. The entire parcel would be utilized for the tank; however, even maximizing the space available it seems unlikely that the entire overflow volume (over 12 MG) could be accommodated on this site. Other constraints for this outfall include its proximity to the Blackstone River and the proposed depth of tank construction. This option is partially located within the 100-year floodplain of the Blackstone River and requires at least a 24-foot deep tank, as the tank footprint has been maximized within the available area at this location. This depth could cause difficulties during tank excavation and require substantial dewatering during tank construction.

The combination of both the tanks, at East Street and at Front Street, could potentially provide enough storage capacity for the design overflow volumes at outfalls 201-205.

A screening and disinfection facility was considered at the Front Street site to accommodate the 3-month storm overflow volume for CSOs 201-205. The facility would include the Middle Street Interceptor, as discussed in section 4.7.3, regulator modifications at CSOs 202 and 204, and as well as equipment and tankage for screening and disinfection. Due to site constraints and operational limitations, primary treatment would not be feasible at the Front Street site. Chlorine disinfection would not be desirable due to the need for storage of chemicals in proximity to occupied buildings in the area.

4.12.6. Outfalls 210, 211

An NSS facility in this area of Pawtucket would be intended to control discharges from both outfalls 210 and 211. The proposed Phase III control for these outfalls is a drop shaft connecting to the Pawtucket Tunnel. The modeling conducted for the Reevaluation indicates that the CSO volume requiring mitigation from this section of the system totals nearly 7.1 MG.

The 210/211 outfalls are located on the west bank of the Blackstone River in downtown Pawtucket at Roosevelt Avenue and Main Street. The area is comprised of primary commercial businesses and municipal buildings. Pawtucket City Hall and the historic Slater Mill dam are located just to the north along Roosevelt Ave.

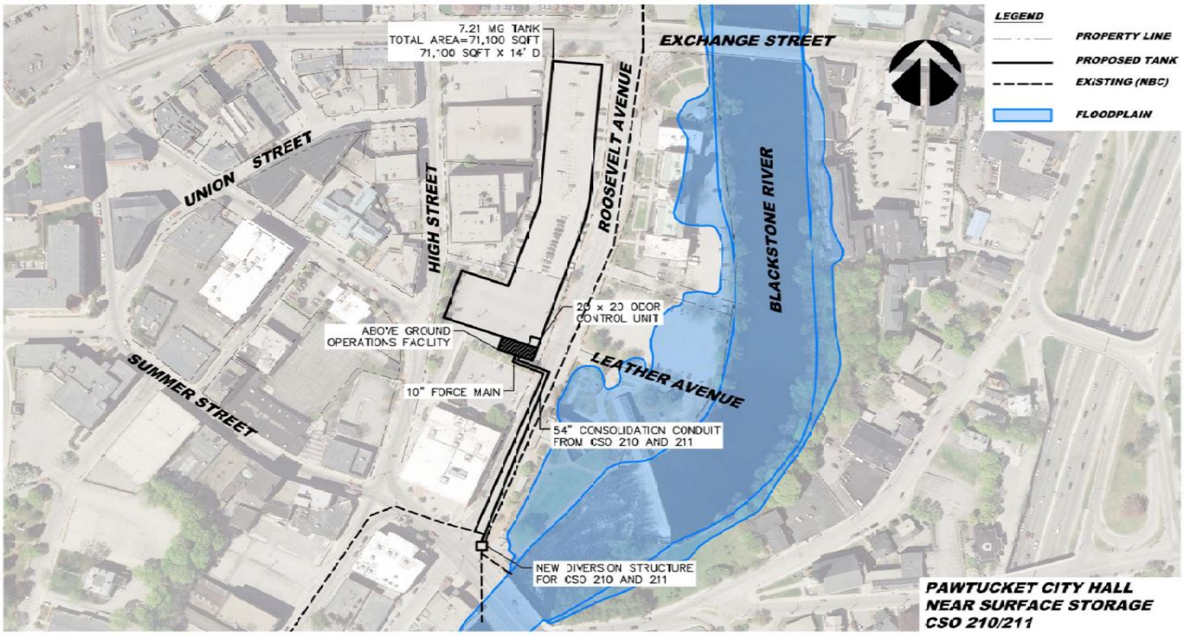

Figure 4-59 - NSS for CSOs 210/211

The NSS alternative for CSOs 210 and 211, located on A.P. 43A Lot 621 in Pawtucket, consists of one potential underground tank configuration as shown in Figure 4-59. This alternative is a 7.21 MG irregularly-shaped tank with an area of 71,100 square feet and depth of 14 feet. This is the depth required in order to accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. A new diversion structure and approximately 500 feet of 54-inch consolidation conduit would be required for this option. Approximately 450 feet of 8-inch force main piping would also be required to pump combined stormwater back into the collection system following the storm event.

Constraints associated with the NSS alternative for these outfalls include the site's use as the Pawtucket City Hall parking lot as well as the overall disruption of a major, long-term construction project in a high-traffic area of Pawtucket. With this option, the City of Pawtucket would be without the use of the parking lot for an extended period of time and would have to modify its parking arrangements for visitors and staff accordingly. This is located in a high-traffic area of Pawtucket, and traffic patterns may require intermittent interruptions to accommodate construction vehicles entering and exiting the site.

4.12.7. Outfalls 213, 214

Local flow control in this area of Pawtucket would be intended to control discharges from both outfalls 213 and 214. The proposed Phase III control for these outfalls is a drop shaft connecting to the Pawtucket Tunnel. The modeling conducted for the Reevaluation indicates that the CSO volume requiring mitigation from this section of the system totals nearly 3.3 MG.

The 213/214 outfalls are located on the west bank of the Blackstone River in downtown Pawtucket along Roosevelt Ave/Taft St between Main Street and the I-95 overpass. The area is comprised of primary commercial businesses.

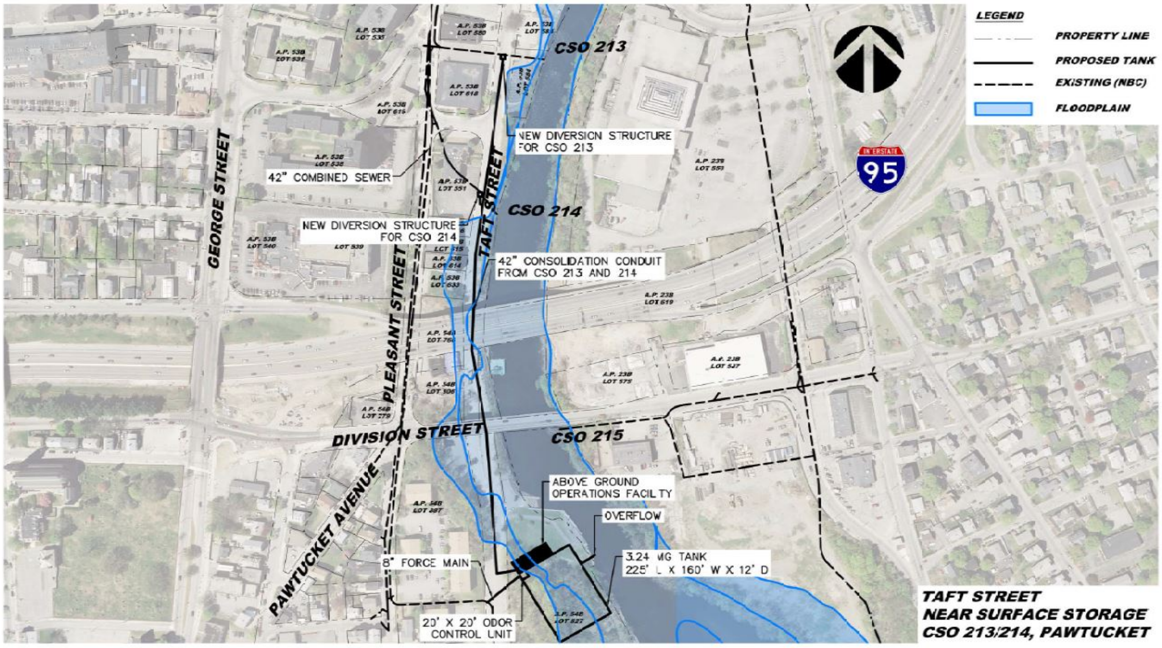

Figure 4-60 - NSS for CSOs 213/214

The NSS alternative for CSOs 213 and 214, located on A.P. 54B Lot 827 in Pawtucket, consists of one potential underground tank configuration as shown in Figure 4-60. This alternative is a 3.24 MG tank with dimensions 225 ft.(L) x 160 ft.(W) x 12 ft.(D) that could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. A new diversion structure for each outfall and approximately 1,400 feet of 42-inch consolidation conduit would be required for this option. Approximately 120 feet of 8-inch force main piping would also be required to pump combined stormwater back into the collection system following the storm event.

Site constraints for these outfalls include the significant length of pipe necessary to connect the existing system to the tank, its proximity to the Blackstone River. In addition, the site is currently a public park, which would be disrupted during construction, potentially for two to three construction seasons. The tank's proximity to the Blackstone River may result in significant challenges during excavation, and dewatering may be significant during tank construction. In addition, a significant amount of site clearing would be necessary to install this tank, potentially having a permanent adverse effect on the character of the park.

4.12.8. Outfall 215

Local flow control in this area of Pawtucket would be intended to control discharges from outfall 215. The proposed Phase III control for this outfall is a regulator modification that would convey flow to the Pawtucket Tunnel using the existing interceptors. The modeling conducted for the Reevaluation indicates that the CSO volume requiring mitigation from this section of the system totals nearly 1.6 MG.

The 215 outfall is located on the east bank of the Blackstone River in downtown Pawtucket at Division Street. The area is comprised of primary commercial businesses with residential neighborhoods nearby at School St.

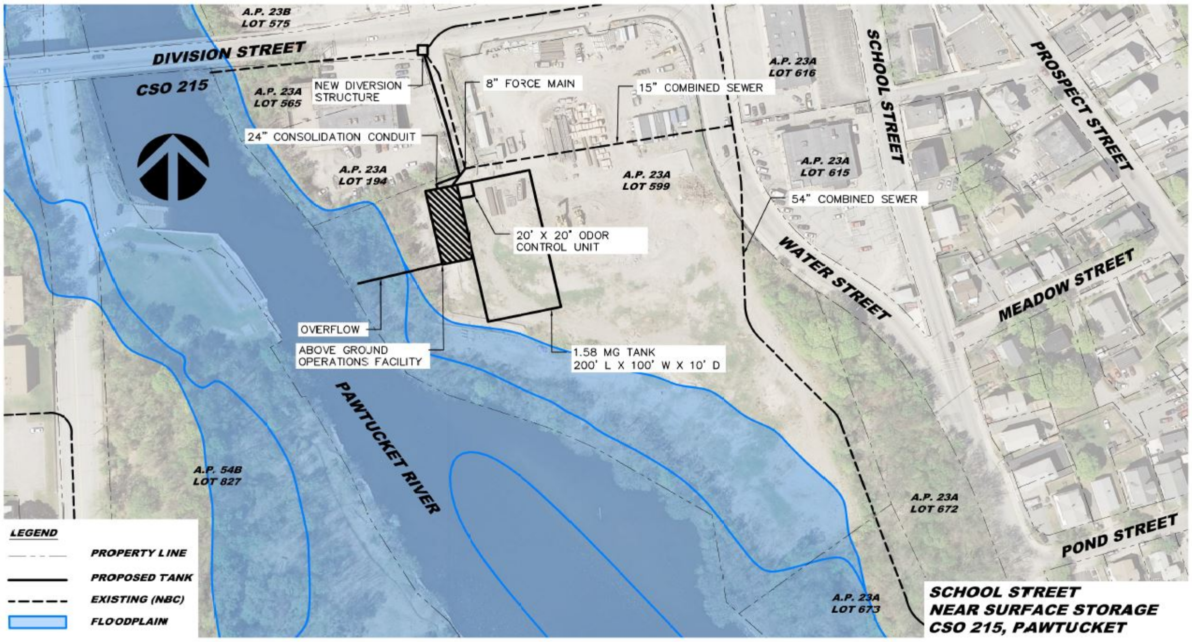

Figure 4-61 - NSS for CSO 215

The NSS alternative for CSO 215, located on A.P. 23A Lot 599 in Pawtucket, consists of one potential underground tank configuration as shown in Figure 4-61. This alternative is a 1.58 MG tank with dimensions 200 ft.(L) x 100 ft.(W) x 10 ft.(D) that could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. A new diversion structure and approximately 230 feet of 24-inch consolidation conduit would be required for this option. Approximately 30 feet of 8-inch force main piping would also be required to pump combined stormwater back into the collection system following the storm event.

Constraints associated with this outfall include the site's proximity to the Blackstone River and its current use as a private materials storage area. This option's proximity to the Blackstone River may result in challenges during excavation, and dewatering may be more significant during tank construction. The business' operations may be impacted during tank construction, and the proposed tank would need to be designed to accommodate future use of the site by the property owner following completion of the project.

4.12.9. Outfall 217

Local flow control in this area of Pawtucket would be intended to control discharges from outfall 217. The proposed Phase III control for these outfalls is a drop shaft connecting to the Pawtucket Tunnel. The modeling conducted for the Reevaluation indicates that the CSO volume requiring mitigation from this section of the system totals nearly 2.7 MG.

The 217 outfall is located on the west bank of the Seekonk River in southern Pawtucket at the Tidewater Site off of Taft Street. The area is comprised of a residential neighborhood with two schools and a large NSTAR facility. The International Charter School is located on Pleasant St between Tower St and Tidewater St. The Francis J. Varieur School is located on Pleasant St and Bowles Ct.

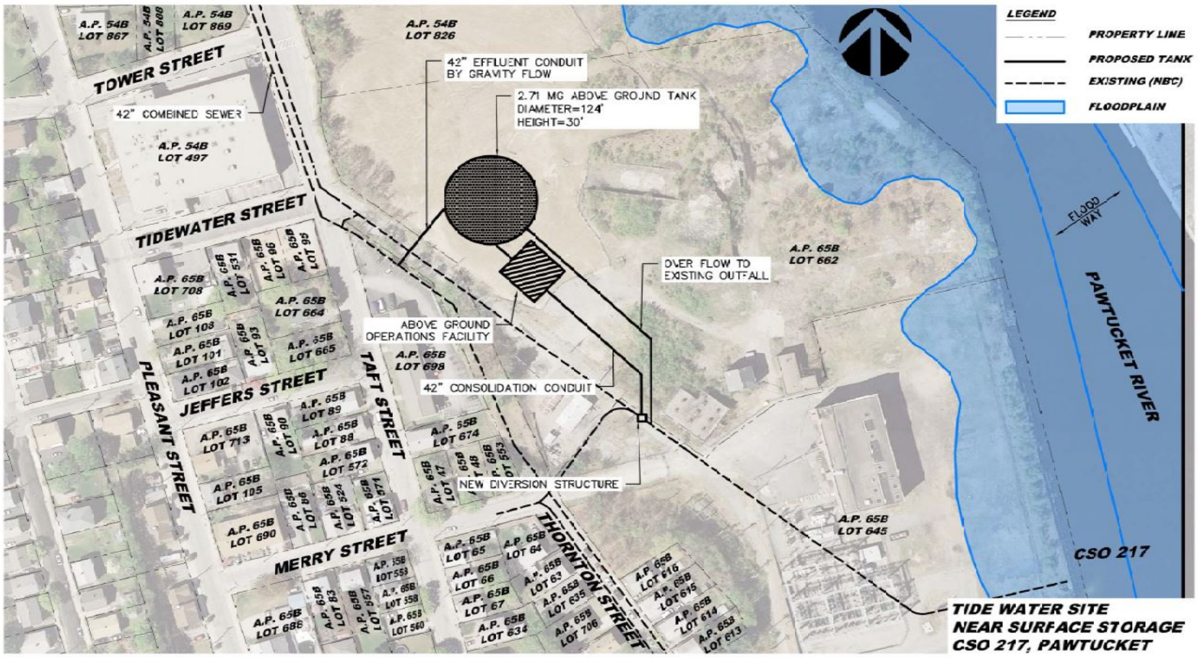

Figure 4-62 - NSS for CSO 217

The NSS alternative for CSO 217, located on A.P. 65B Lot 662 in Pawtucket, consists of one potential tank configuration as shown in Figure 4-62. This alternative is a 2.71 MG circular, aboveground tank with a diameter of 124 feet and height of 30 feet. This design could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI.

An aboveground tank alternative was selected for this site because of its former use as a manufactured gas plant and electric generation facility, which is under the jurisdiction of the Rhode Island Department of Environmental Management (RIDEM) as a contaminated site. The tank has been designed as an aboveground tank to minimize disturbance to potentially contaminated soil. Unlike the underground tanks considered for other outfalls, flow into this tank would need to be pumped, and flow out of this tank would flow via gravity back into the collection system. This configuration would require larger pumps to accommodate the inflow rate during the storm, which is a far greater flow rate than what would be required to empty an underground tank of comparable size. The proposed tank will include approximately 600 feet of 42-inch gravity outlet pipe and 30 feet of 8-inch force main piping. It would also include an overflow to the existing outfall for flows exceeding the 3-month design storm.

4.12.10. Outfall 218

CSO Outfall 218 is located on the border of Pawtucket and East Providence at the Seekonk River, see Figure 4-63. It is located on Beverage Hill Ave between School Street and Prospect Street. The area surrounding the outfall is primarily industrial facilities with a few commercial properties as well as several residential neighborhoods. The Boys and Girls Club of Pawtucket has recreational facilities on the Blackstone River at their Elson Campus and Dunnell Park has several recreational ball fields. Mount St Mary's Cemetery is to the southeast, and the Bucklin Point WWTF is to the south.

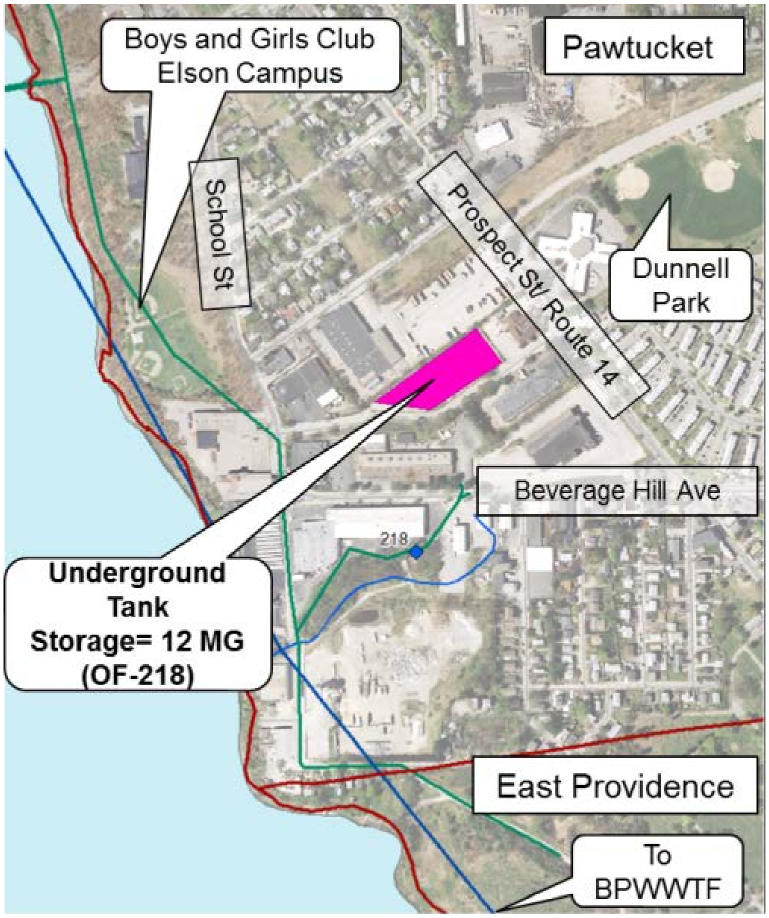

Figure 4-63 – CDR NSS for CSO 218

An NSS facility in this area of Pawtucket would control discharges from the largest overflow in the Bucklin Point Service Area, OF 218. The CDRA recommends regulator modification for 212, 215 and 216 which add their overflow volumes to the Blackstone Valley Interceptor. That additional surcharging would require additional mitigation at a localized 218 facility. The modeling indicates a design capacity requirement of approximately 14.8 MG. A facility in this location could be part of a suite of solutions that is an alternative to the Pawtucket Tunnel. It would need to be combined with localized options for the large outfalls of 205 and 220, as the 218 outfall is located just north of the Bucklin Point WWTF, and thus any deep-rock tunnel option for either 205 or 220 would pass almost directly adjacent to 218.

The NSS for CSO 218 would be located on property owned by the Narragansett Bay Commission in Pawtucket and would consist of an underground tank configuration shown in Figure 4-64, or possibly multiple aboveground tanks shown in Figure 4-65. This alternative would need to accommodate approximately 14.76 MG. A below ground tank would have dimensions of 500 ft.(L) x 330 ft.(W) x 12 ft.(D), which could accommodate the 3-month storm overflow volume under existing system conditions with no upstream GSI. Three 5-million gallon above ground tanks, 168 feet in diameter and 30 feet tall, could accommodate the overflow volume. A new diversion structure and approximately 1,900 feet of 66-inch consolidation conduit would be required for this option. Approximately 35 feet of 8-inch force main piping is also proposed.

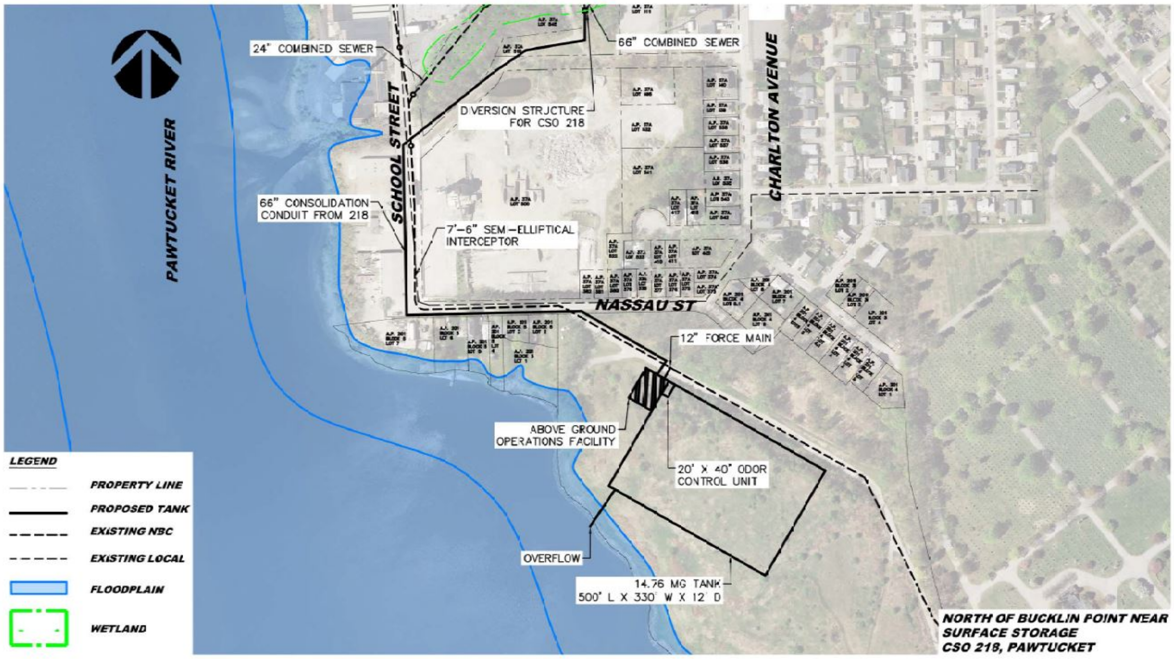

Figure 4-64 – NSS Below-Ground for CSO 218

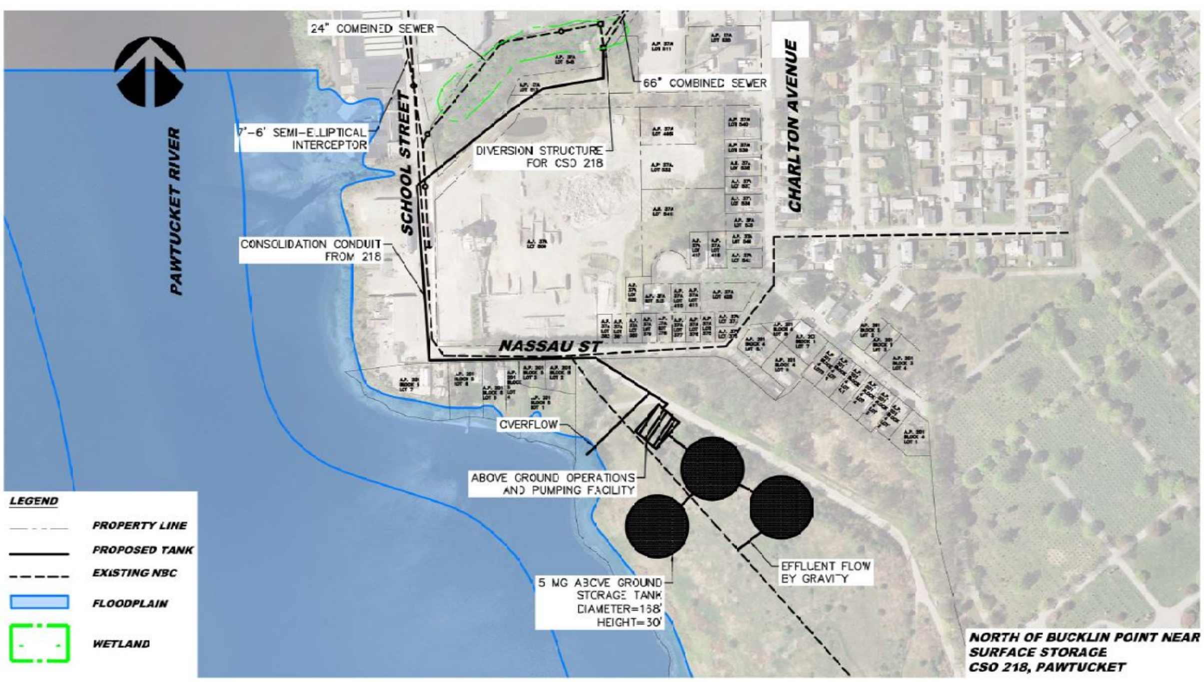

Figure 4-65 – NSS Above-Ground for CSO 218

A screening and disinfection facility was considered at the Bucklin Point site to accommodate the 3-month storm overflow volume for CSO 218. The facility would require a consolidation conduit from CSO 218, regulator modifications at 212, 215, and 216, as well as equipment and tankage for screening and chlorine disinfection which would be feasible at this location because there are no occupied buildings nearby and chlorine is already stored on the site to provide disinfection for the wastewater treatment plant. Primary treatment may be feasible at this location.

4.13. Wetlands Treatment

All of the Phase III outfalls are located in densely developed areas, and none are within a reasonable distance to open land of sufficient size to accommodate a wetland treatment system. Consequently, no such wetland treatment alternatives could be generated for the Phase III Reevaluation.

4.14. Summary of Alternatives Technical Feasibility Screening

The previous sections provide the detailed analysis that generated and evaluated the Phase III baseline components and various alternative solutions. The conclusions of those efforts are summarized in the table below. The technologies that are being considered for each CSO for the evaluation of alternatives are indicated with a check mark in Table 4-31.

Table 4-31 – Summary of Alternatives following Technical Feasibility Screening

	Source			Pathway				Receptor					
Outfall	No GSI	Public Way GSI	Full GSI	Sewer Separation	Hydraulic Control & Stormwater Storage	Regulator Modification	Interceptor Storage	Satellite Treatment & Discharge	Near Surface Storage	Wetland Treatment	Pawtucket 220 Stub Tunnel	Pawtucket Tunnel	Main Spine Tunnel
35	✓	✓	✓	✓	✓								
36	✓	✓	✓			✓							✓
39	✓	✓	✓	✓			✓						
56	✓	✓	✓	✓			✓						
101	✓	✓	✓			✓			✓			✓	
103	✓	✓	✓						✓			✓	
104	✓	✓	✓						✓			✓	
105	✓	✓	✓						✓			✓	
107	✓	✓	✓			✓			✓			✓	
201	✓	✓	✓					✓	✓			✓	
202	✓	✓	✓			✓		✓	✓			✓	
203	✓	✓	✓					✓	✓			✓	
204	✓	✓	✓					✓	✓			✓	
205	✓	✓	✓					✓	✓			✓	
206	✓	✓	✓	✓	✓	✓			✓			✓	
207	✓	✓	✓			✓			✓			✓	
208	✓	✓	✓			✓			✓			✓	
209	✓	✓	✓			✓			✓			✓	
210	✓	✓	✓						✓			✓	
211	✓	✓	✓						✓			✓	
212	✓	✓	✓			✓		✓	✓			✓	
213	✓	✓	✓						✓			✓	
214	✓	✓	✓						✓			✓	
215	✓	✓	✓			✓		✓	✓			✓	
216	✓	✓	✓			✓		✓	✓			✓	
217	✓	✓	✓					✓	✓			✓	
218	✓	✓	✓					✓	✓			✓	
220	✓	✓	✓					✓	✓		✓	✓	

NBC CSO Control Facilities Phase III Reevaluation

Chapter 5 – Subsystem Alternatives Analysis

NBC CSO Control Facilities Phase III Reevaluation

Chapter 5 – Subsystem Alternatives Analysis

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5.1. Introduction

The previous chapter defined alternative CSO control strategies throughout the Phase III area. That chapter documented the design parameters established for conceptual designs for CSO control strategies for the Phase III CSO locations. That effort resulted in a screening of potential strategies and technologies based on technical feasibility for specific locations. This chapter follows the next step in the reevaluation process whereby those technically feasible alternatives are evaluated against a range of criteria to determine the components of the redefined Phase III plan that best achieves NBC's goals.

This chapter first presents the development of criteria by which to evaluate the alternatives. The second section discusses how the overall Phase III area was divided into subsystems for the purposes of comparing alternatives. Subsequent sections present the refined description and evaluation of those subsystem alternatives using the criteria selected by the Stakeholder Group. This chapter concludes with the selection of the preferred subsystem components for Phase III.

5.2. Evaluation & Prioritization Criteria

The purpose of the Phase III reevaluation is to define the components of the CSO abatement program, determine the schedule that accommodates affordability, and sequence the individual projects to realize the maximum benefits as soon as possible. One of the goals of the Phase III reevaluation effort is to place the CSO control projects within the context of the EPA's Integrated Planning Framework (IPF) so that an optimized overall plan that maximizes the benefits of rate- and tax-payers funding for stormwater, wastewater and combined sewer overflow mitigation projects can be developed for the entire NBC service area regardless of regulatory driver or executing entity. Consequently, the adopted criteria for the Phase III alternatives evaluation must enable several different analyses. First, the criteria must facilitate the analysis of alternatives to aid in the selection of preferred technologies or mitigation strategies for individual locations. Second, the criteria must facilitate the prioritization of those selected alternatives for each location against other candidate projects to aid in the sequencing of those projects. Finally, the criteria must take a broader view and achieve applicability for not only CSO projects but also stormwater and sanitary system improvement projects to achieve the goals of the IPF process.

Beyond their various applications, the evaluation and prioritization criteria must reflect the goals of the area stakeholders including NBC, regulators, member communities, citizens, and interest groups. Therefore, the Stakeholder Group was central to the selection and weighting of the criteria. The follow sections detail the evolution of that process.

5.2.1. Candidate Criteria

The June 2014 Stakeholder Group meeting focused on selecting and weighting criteria. That effort involved first identifying a wide range of candidate criteria from several sources including the previous NBC CSO planning efforts, the 2014 Stakeholder discussions at other meetings, and criteria adopted by other communities executing similar IPF efforts.

The development of the original CSO mitigation plan utilized evaluation criteria to select alternatives. When the NBC CSO program was first taking shape in the early 1990's, the alternatives were evaluated on a scale of 1 to 3 for their relative advantages and disadvantages relative to five criteria:

- System Performance which captured how well the system would operate,
- Water Quality Benefits which reflected CSO reductions;
- Environmental Issues which captured both construction-phase and potential operations-phase impacts;
- Constructability Analysis which included how well projects could be phased; and
- Cost Effective evaluation which measured cost/benefits and efficiency.

When the plan was refined in the mid 1990's, the alternatives were further ranked against six criteria:

- Portion of CSO Addressed which captured how well an alternative would capture large outfalls or consolidations of outfalls to abate large volumes;
- Performance which captured the effectiveness and reliability of pollutant removal;
- Operational Concerns which evaluated how robust a solution was and what safety issues might impact NBC staff and the public;
- Construction Impacts which included land acquisition requirements and short-term disruptions including traffic;
- Long-Term Impacts to the community such as noise and odor and to the environment such as habitat disruption; and
- Cost including capital and O&M.

Section 9 in the CDR and Section 9 in the CDRA describe the formulation and application of those criteria. A significant amount of analysis went into evaluating each of the alternatives and the actual issues considered go beyond a simple reading of the criteria titles. Consolidating the previous criteria and better delineating their intent to separate candidate criteria yields the following list:

- Water quality (bacteria) benefits – resulting from CSO reduction;
- Water quality (toxics) risks – related to residuals discharge from chlorine disinfection;
- System effectiveness – including how efficient a solution is at reducing large-volume CSOs;
- System reliability – in terms of demonstrated success and operational needs;
- Implementation / phasing flexibility – how flexible the system is both in terms of operations and in terms of how parts of it can be phased
- Construction-phase disruptions – measuring short-term impacts to residents and businesses;
- Constructability / Construction-phase risks – accounting for uncertainty during construction that could result in higher than planned costs;
- Operational robustness – measuring the need for intervention or active operations;
- Operational impacts & risks – accounting for impacts to residents and businesses during regular operations and maintenance, and the risks to people and the environment from those activities;
- Capital costs

- O&M costs

During the course of discussions at the Stakeholder meetings several potential evaluation criteria emerged that had not been considered during the previous planning efforts. Those new candidate criteria included:

- Other water quality indicators beyond bacteria and residuals, including nutrients and possibly other more exotic pollutants;
- Flooding risks;
- Scalability considering potential changes in future water quality requirements or design storms;
- Resiliency for climate change;
- The potential to increase levels of service for sanitary and storm drainage in the service areas; and
- The co-benefits of any solutions that could produce surface, roadway or quality of life improvements.

Unlike the previous planning efforts that focused on solutions that would clearly be within the control of NBC, the reevaluation considers solutions, like GSI, that are distributed throughout the communities. The administration of those solutions, including operations and maintenance considerations, could not be firmly established within the timeframe for completing the reevaluation. For the purposes of the reevaluation, that was not considered grounds for eliminating those control technologies; however, it was acknowledged that those administrative details would make their adoption more complicated than alternatives that did not face those challenges. Therefore, it was acknowledged that Implementation & Administration should be added as an evaluation criterion.

Recent IPF efforts in Springfield, Massachusetts, Baltimore, Maryland, Atlanta, Georgia, and Akron, Ohio have also incorporated other rating criteria that were presented to the Stakeholder Group for consideration:

- Springfield has an old system, much of which will require rehabilitation or replacement. Therefore, they placed a priority on CSO facilities that would replace older existing infrastructure.
- Similarly, Springfield favored alternatives that the hydraulic model indicated would afford them redundancy for both operational flexibility and to facilitate other repairs or upgrades.
- Springfield acknowledged that regulatory requirements may change in the future, so alternatives that offered flexibility to meet changing CSO limits, treatment plant limits, stormwater discharge requirements and design storm changes were considered advantageous.
- Similarly, Springfield favored solutions that could optimize CSO controls due to changed conditions in the future and be adaptable or expandable at a relatively low cost.
- Baltimore adopted separate water quality criteria for different contaminants including bacteria, nitrogen, phosphorus, sediment and trash.
- Baltimore favored habitat preservation and restoration, as well as creation of recreational facilities and urban tree canopy.

- Baltimore placed an emphasis on projects that would improve low income or blighted areas.
- Similarly, Baltimore favored options that would create jobs.
- In Atlanta, infrastructure spending is focused on projects that support growth and economic development.
- Atlanta also favors projects that include regional partnerships.
- Like others, reliability and redundancy is preferred in Atlanta.
- Atlanta also seeks to enhance the public's perception and expectations of their wet utility provider.
- Akron is also considering lifecycle costs including reduced energy and chemical consumption.
- Finally, Akron is including quality of life issues that include considerations for increasing education, aesthetics and property values while reducing crime, noise and odors.

5.2.2. Criteria Categories

When evaluating alternatives, historically that assessment has been done in terms of costs and benefits. For CSO projects in simplest terms, benefits are quantified as water quality improvements, and costs are the sum of capital and O&M present worth equating to a "bottom line". The previous NBC criteria mostly fall into those categories.

Proponents of sustainability have championed expanding the range of those criteria and adding a third criterion to evaluate social impacts. This approach includes using specific measures like pathogen removal, job creation and improvement to services to arrive at a "triple bottom line" that scores alternatives against regulatory, economic and social impacts. The concept is that using only economic and environmental factors, you may arrive at viable solutions, but by adding social measures, you find solutions that are bearable, equitable or ideally sustainable. The intersection of the categories to yield improved community solutions is illustrated in Figure 1.

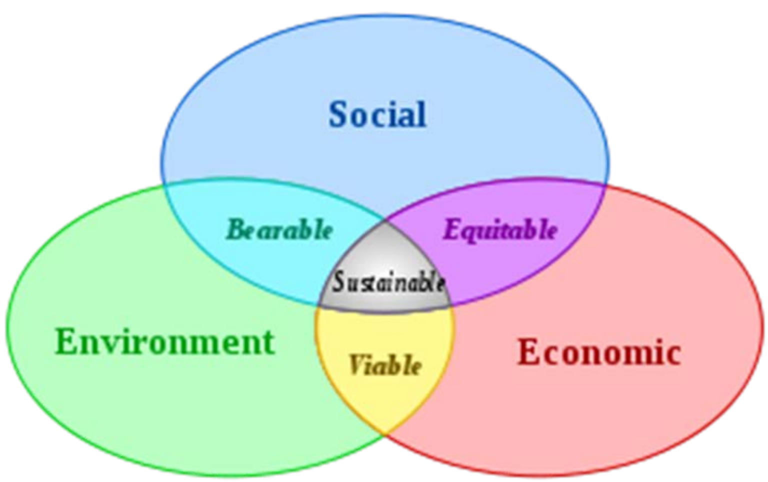


Figure 1 – Triple Bottom Line

The triple bottom line approach also provides a framework to classify evaluation criteria and manage the alternatives evaluation and project prioritization processes. The June 2014 Stakeholder Group meeting included a discussion of the candidate criteria outlined in the previous section in terms of triple bottom line categories:

- Environmental Criteria
  - Water quality (bacteria) benefits
  - Water quality (nutrients) benefits
  - Water quality (toxics & exotic) benefits & risks
  - Flooding risks
  - Scalability (for future water quality requirements or design storms)
  - Resiliency (for climate change)
  - Administrative / Institutional considerations
  - System reliability / Operational robustness
  - Implementation / phasing flexibility
  - Habitat preservation & restoration
- Economic Criteria
  - Capital costs
  - O&M costs
  - Cost effectiveness / efficiency
  - Constructability / Construction-phase risks
  - Operational flexibility for optimization
  - Renewal of existing infrastructure
  - Support growth & economic development
  - Regional partnering potential
- Social Criteria
  - Co-benefits (surface improvements, quality of life)
  - Level of service benefits
  - Construction-phase disruptions
  - Impacts & risks to residents, businesses and environment from operations & maintenance
  - Quality of life (property values, crime reduction, aesthetics, education)
  - Recreational access
  - Customer satisfaction
  - Targeting of improvements to low income / blighted areas
  - Public image
  - Job stimulus

The discussions with the Stakeholder Group led to the conclusion that certain criteria that related to how to implement solutions or how solutions related to benefits that were not singularly environmental, economic or social in nature did not neatly fit into one of the three categories. Therefore, the group agreed to create a fourth category: Implementation.

5.2.3. Final Evaluation & Prioritization Criteria

The discussions at the July Stakeholder meeting helped refine and define the candidate criteria. The Stakeholders received worksheets for the purposes of selecting and weighting both the criteria and the categories. Fourteen of the Stakeholders representing a broad spectrum of interests submitted their completed worksheets. Those responses were analyzed and composite weighting scores for each category and criteria were developed as tabulated in the following sections.

Table 5-1 Environmental Criteria

Weight	Evaluation Criteria	Description
40%	Water quality (bacteria) impacts	Changes in bacteria loading to receiving waters including the Bay and contributing rivers, largely associated with sanitary and combined overflows
20%	Flooding risks from stormwater systems	Changes in localized and regional flooding produced by modifications to stormwater management and conveyance infrastructure
20%	Water quality (nutrients) impacts	Changes in nutrient (nitrogen & phosphorus) loading to receiving waters including the Bay and contributing rivers, largely associated with stormwater discharges
20%	Scalability & adaptability	Ability to increase or modify flow handling or treatment capacity to accommodate future water quality requirements or design storm intensities

Weight	Evaluation Criteria	Description
40%	Water quality (bacteria) impacts	Changes in bacteria loading to receiving waters including the Bay and contributing rivers, largely associated with sanitary and combined overflows
20%	Flooding risks from stormwater systems	Changes in localized and regional flooding produced by modifications to stormwater management and conveyance infrastructure
20%	Water quality (nutrients) impacts	Changes in nutrient (nitrogen & phosphorus) loading to receiving waters including the Bay and contributing rivers, largely associated with stormwater discharges
20%	Scalability & adaptability	Ability to increase or modify flow handling or treatment capacity to accommodate future water quality requirements or design storm intensities

Two other candidate criteria were included for consideration:

- Water quality (toxics & exotic) impacts – Changes in other pollutant loadings (e.g. metals in stormwater, emerging contaminants in sanitary, and toxic residuals from CSO disinfection) to receiving waters; and
- Non-Aquatic environmental impacts – Energy, heat island, carbon sequestration and other non-water-based environmental attributes

However, those criteria received relatively low composite weighting, and were therefore not carried forward for use in the alternatives analysis.

Table 5-2 Economic Criteria

Weight	Evaluation Criteria	Description
45%	Capital costs	Initial costs and expenses including construction, engineering, administration and financing
25%	Operations & Maintenance costs	Continuing costs including administration, labor and materials for regular operations, maintenance and planned rehabilitation
10%	Constructability / Construction-phase risks	Complexity, dependency on unknown conditions (e.g. geotechnical) or external requirements (e.g. land acquisition) that could significantly impact capital costs
10%	Cost per gallon captured	Attribute of capturing large volumes or providing substantial benefits from a single, efficient or cost effective solution
10%	Operational flexibility for optimization	Ability to modify system performance to meet water quality goals without requiring capital projects for system alterations or additions

Three other candidate criteria were included for consideration:

- Support economic development – Ability to provide short-term stimulus from construction jobs, long-term creation of O&M jobs, or support of real estate development through infrastructure
- Regional partnering potential – Potential for cost-sharing with municipalities, agencies, land owners or interest groups through public or private partnerships

- Renewal of existing infrastructure – Coincidental replacement of aging infrastructure that will otherwise require rehabilitation within the planning period

However, those criteria received relatively low composite weighting, and were therefore not carried forward for use in the alternatives analysis.

Table 5-3 Social Criteria

Weight	Evaluation Criteria	Description
35%	Fishable, shellfishable & swimmable waters	Support of additional water-based improvements that increase the fishing, shellfishing and swimming potential of the area waters
25%	Co-benefits & quality of life	Ability to facilitate coincidental improvements to other infrastructure (e.g. streetscape, greenspace, recreational) that impact quality of life or public health
20%	Operations & maintenance impacts and risks	Odor, noise, traffic, contamination and other impacts to residents, businesses and the environment from normal operations and emergency conditions
20%	Construction-phase disruptions	Acute, short-term impacts such as traffic, noise, dust, vibration and service interruptions to residents and businesses in project areas

Three other candidate criteria were included for consideration:

- Level of sanitary service – Impacts to sanitary service (e.g. frequency or severity of backups, odor control, etc.)
- Urban renewal and environmental justice – Alignment with other initiatives to improve low income and blighted areas
- Public image for NBC and the region – Potential for influencing the reputation of the region for intelligent infrastructure and environmental stewardship both internally and externally

However, those criteria received relatively low composite weighting, and were therefore not carried forward for use in the alternatives analysis.

Table 5-4 Implementation Criteria

Weight	Evaluation Criteria	Description
40%	Administrative / Institutional considerations	Degree to which the responsible party for implementation is known and empowered to construct and operate the project/alternative at the time of evaluation
30%	System reliability / Operational robustness	Sensitivity of a system to changes in conditions and the degree to which it must be inspected and actively managed to operate correctly
30%	Climate change resiliency & recovery	Capacity for providing resiliency against climate change and reducing recovery costs associated with post-event recovery

One other candidate criterion was included for consideration:

- Implementation / phasing flexibility – Degree to which the project/alternative could be subdivided or combined with other projects/alternatives to achieve incremental progress toward overall goals

However, that criterion received relatively low composite weighting, and was therefore not carried forward for use in the alternatives analysis.

5.2.4. Summary of Criteria and Weighting Factors

In addition to providing weightings for the individual criteria, the Stakeholders provided weightings for the four categories shown in Table 5-5.

Table 5-5 Weighting Factors by TBL Categories

Weight	Category
35%	Environmental
30%	Economic
18%	Social
17%	Implementation

Multiplying the weights for each category to the weights for each criterion in that category yields the composite weighting factor for each criterion shown in Table 5-6

Table 5-6 Composite Weighting Factors

Evaluation Criteria	Weighting	Factor
Environmental Criteria	**35%**	
Water quality (bacteria) impacts	40%	14.00%
Water quality (nutrients) impacts	20%	7.00%
Flooding risks from stormwater systems	20%	7.00%
Scalability & adaptability	20%	7.00%
Economic Criteria	**30%**	
Capital costs	45%	13.50%
Operations & Maintenance costs	25%	7.50%
Constructability / Construction-phase risks	10%	3.00%
Cost per gallon captured	10%	3.00%
Operational flexibility for optimization	10%	3.00%
Social Criteria	**18%**	
Fishable, shellfishable & swimmable waters	35%	6.30%
Co-benefits & quality of life	25%	4.50%
Operations & maintenance impacts and risks	20%	3.60%
Construction-phase disruptions	20%	3.60%
Implementation Criteria	**17%**	
Administrative / Institutional considerations	40%	6.80%
System reliability / Operational robustness	30%	5.10%
Climate change resiliency & recovery	30%	5.10%

Those factors sum to 100% and indicate the relative weights assigned by the Stakeholder Group to each criterion. Those criteria and factors form the basis for selecting alternatives and prioritizing projects.

5.3. Subsystem Delineation & Design Objectives

The previous CSO planning efforts that culminated in the development of the CDRA were based on the EPA CSO Control Policy and the “Presumption Approach.” The Presumption Approach acknowledges the difficulty in collecting the data and providing the analysis to prove water quality standards attainment of the “Demonstration Approach” and instead defines minimum criteria for CSO control. Consistent with the Presumption Approach criteria, the previous CSO planning effort defined the volume to be captured by the NBC CSO control facilities as equivalent to a 3-month storm which would, in theory, result in systems that generated 4 or fewer CSO events in a typical year. For the purposes of analyzing alternatives to the Baseline Phase III plan defined by the CDRA, that same design basis was adopted. The BPSA hydraulic model was run using the 3-month storm to determine the volume discharged at each of the Phase III outfalls. The GSI alternatives developed and described in the Alternatives Development chapter were modeled GSI in public ways and on private property and results developed for all three source control cases (i.e. no source control, GSI in public way, and full GSI implementation to include private property). The remaining CSO volumes after GSI implementation in each of the catchments define the volume that must be accommodated by corresponding grey infrastructure. Those volumes define the basis of design for the Phase III alternatives. Figure 2 below shows the locations of the outfalls and illustrates the relative magnitude of the CSO volumes for each regulator structure for the 3-month storm.

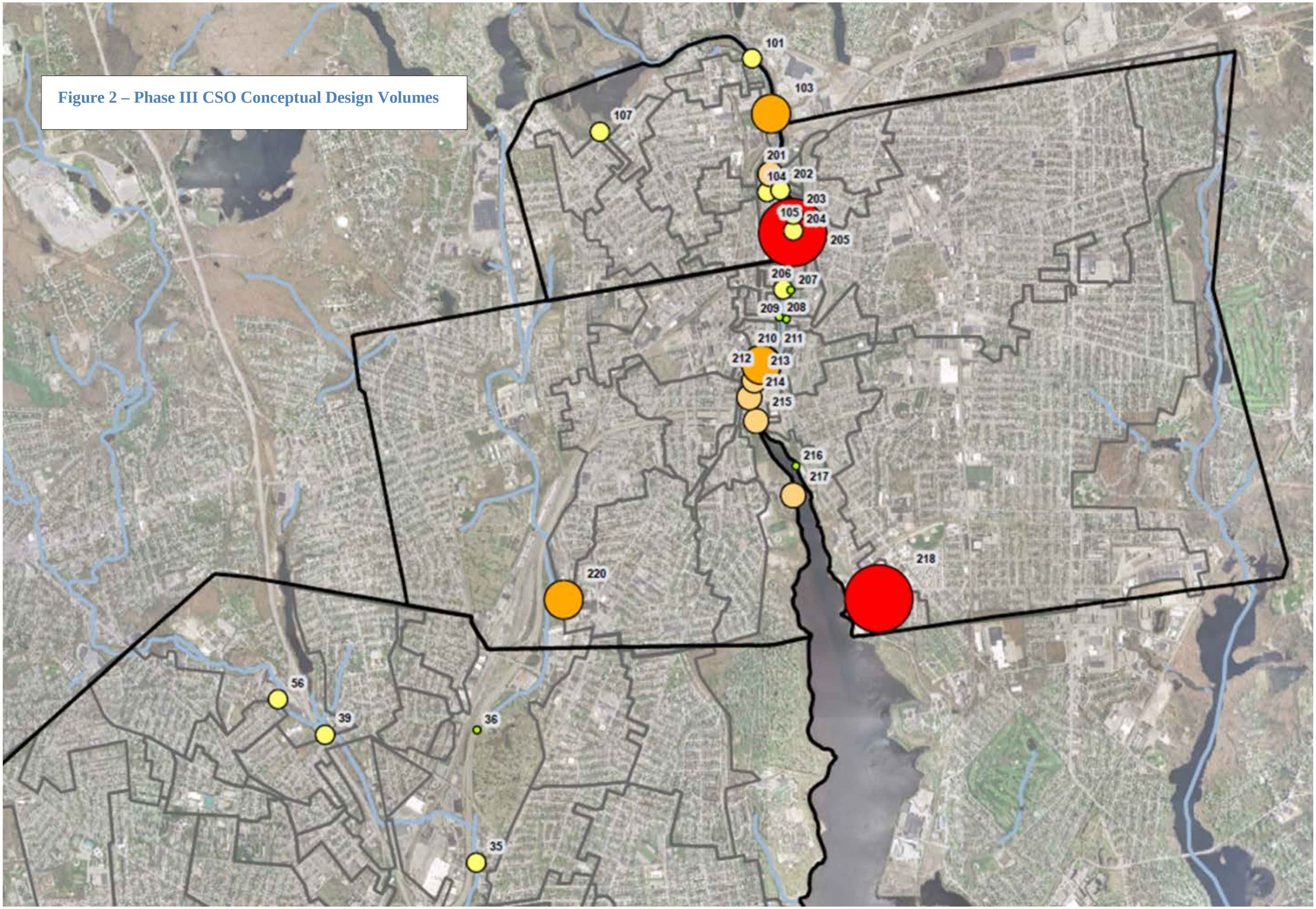


Figure 2 – Phase III CSO Conceptual Design Volumes

The specific volumes associated with each of those outfalls for the 3-month storm are summarized in Table 5-7:

Table 5-7 CSO Volumes for the 3-Month Storm

	CSO Volume (MG)		
Outfall	**No Source Control**	**Public Way GSI**	**Full GSI**
35	0.77	0.75	0.68
36	0.10	0.10	0.10
39	0.46	0.44	0.43
56	0.42	0.39	0.38
101	0.38	0.32	0.17
103	**4.88**	4.49	3.64
104	0.49	0.41	0.22
105	1.64	1.55	1.32
107	0.37	0.33	0.27
201	1.34	1.29	1.13
202	0.17	0.16	0.13
203	0.40	0.35	0.23
204	0.16	0.08	0.01
205	**12.81**	11.82	8.73
206	0.14	0.14	0.13
207	0.04	0.03	0.01
208	0.01	0.01	0.01
209	0.02	0.01	0.00
210	**3.17**	3.11	3.05
211	**3.96**	3.93	3.90
212	0.60	0.54	0.35
213	1.97	1.86	1.59
214	1.26	1.04	0.56
215	1.58	1.39	0.83
216	0.01	0.00	0.00
217	2.71	2.49	1.96
218	**12.58**	10.68	4.93
220	**4.60**	3.85	1.87
Volume Controlled:		**10%**	**34%**

The Phase III plan seeks to reduce the number of CSO events to 4 or fewer at each of the outfalls. However, it is not always cost effective to control each individual outfall with its own constructed solution. Based on how flow is routed and the existing interceptor system works, outfalls can be grouped together to form subsystems. More efficient control solutions can then be developed for each of those subsystems.

The grouping of outfalls into subsystems for the Baseline Phase III solutions presented in the CDRA provides a basis for evaluating alternatives. The geographic limits of the catchments associated with each of these subsystems is illustrated in Figure 3 below

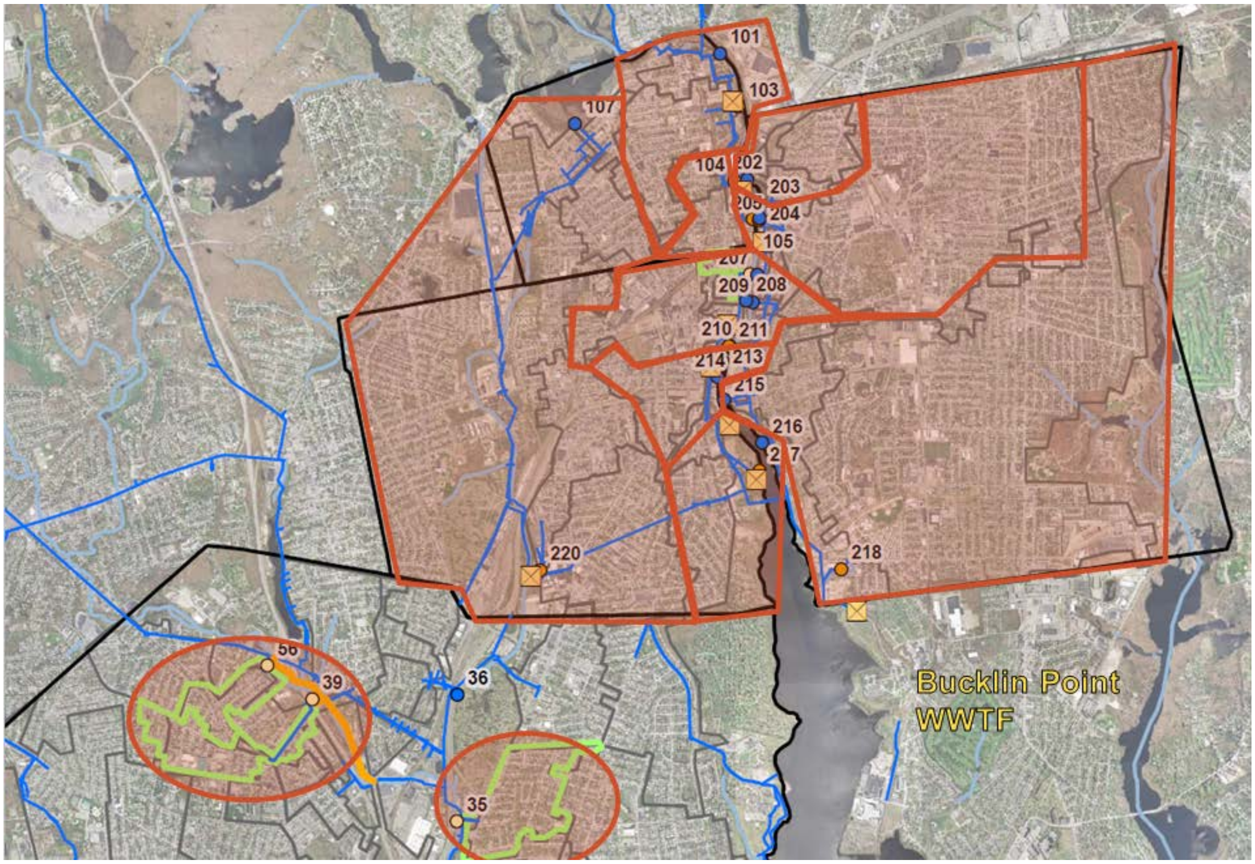


Figure 3 - Phase III Subsystem Catchments

Table 5-8 below presents the subsystems in the CDRA Baseline Phase III plan with the associated CSO control solutions and the overflow volumes for those subsystems.

Table 5-8 CDRA Baseline Phase III Subsystems

Design Capacity (MG)	CSO Control Solution	CSOs Controled
0.77	035 Sewer separation	035
0.46	039 Sewer separation	039
0.42	056 Sewer separation	056
0.14	206 Sewer separation	206
5.26	Upper High & Cross St interceptor	101, 103
5.74	Lower High & Cross St interceptor	101, 103, 104
1.91	Middle St interceptor	201, 202, 203
22.27	Drop shaft 205 & conduit	101, 103, 104, 105, 201, 202, 203, 204, 205
7.21	Drop shaft 210/211 & conduit	207, 208, 209, 210, 211
3.24	Drop shaft 213 & conduit	213, 214
4.97	Pawtucket Ave interceptor	107, 220
7.68	Drop shaft 217 & conduit	107, 217, 220
14.76	Drop shaft 218 & conduit	212, 215, 216, 218
0.00	No Source control	
55.16	Baseline Pawtucket tunnel	101 - 107, 201 - 205, 207 - 220
	Regulator modification	101, 107, 202, 204, 207, 208, 209, 212, 214, 215

Table 5-9 illustrates subsystem groupings using alternative technologies to the CDRA Baseline Plan that were evaluated in Chapter 4.

Table 5-9 Phase III Alternative Technology Subsystems

Design Capacity (MG)	CSO Control Solution	CSOs Controled
0.77	Hybrid GSI / Sewer separation	035
0.46	Hybrid GSI / Sewer separation	039
0.42	Hybrid GSI / Sewer separation	056
0.14	Parking lot stormwater tanks	206
5.26	High Street Tank	101, 103
2.12	Webbing Mills Tank	104, 105
1.26	East Street Tank (Viper VoIP Corporation)	201, 202
8.97	Front St Tank / T&D with GSI	203, 204, 205
7.21	City Hall Tank	207, 208, 209, 210, 211
3.24	Apex (or other location) Tank	213, 214
4.97	Morley Field tank, or Stub tunnel	107, 220
2.71	Tidewater Tank / T&D	217
14.02	Bucklin Point landfil tank / T&D	212, 215, 216, 218
5.41	GSI in select sewersheds	039, 056, 201, 202, 203, 204, 205, 206, 215
0.00	Tunnel	
	Regulator modifications	036, 101, 107, 204, 207, 208, 209, 212, 215, 216

5.4. Subsystem Alternatives Evaluation

The Baseline and Alternative subsystem groupings discussed above are compared and evaluated according to the evaluation criteria discussed previously. A discussion of each subsystem comparison is provided below.

5.4.1. 035 Subsystem

The Baseline CDRA plan for outfall 035 is traditional sewer separation and the alternative is a hybrid of stormwater controls, GSI and sewer separation. Table 5-10 presents the subsystem costs and the evaluation criteria scores.

Table 5-10 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 035

		035	
		035 Sewer separation	035 Hybrid GSI / Sewer separation
Volume Captured (Mgal)		0.77	0.77
Capital Cost $		$19,200,000	$24,700,000
Annual O&M Cost $		$12,517	$16,428
Cap Cost per Gallon Captured (calc) ($/gal)		24.99	32.19
Environmental Criteria			
Water quality (bacteria) impacts	14%	0.5	0.5
Water quality (nutrients) impacts	7%	1	4
Flooding risks from stormwater systems	7%	0	3.0
Scalability & adaptability	7%	5	6.5
Economic Criteria			
Capital costs	14%	9	8
Operations & Maintenance costs	8%	8	8
Constructability / Construction-phase risks	3%	1	1
Cost per gallon captured	3%	3	2
Operational flexibility for optimization	3%	5	5.5
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	0.5	0.5
Co-benefits & quality of life	5%	8	8.5
Operations & maintenance impacts and risks	4%	4	3.5
Construction-phase disruptions	4%	0	0.0
Implementation Criteria			
Administrative / Institutional considerations	7%	3	2.5
System reliability / Operational robustness	5%	7	5
Climate change resiliency & recovery	5%	5	5.5
Composite Rating & Ranking:		**3.9**	**4.2**

In terms of composite rating, the two alternatives score very closely, and the benefits and impacts of the two alternatives are similar. Traditional sewer separation is more favorable because of lower cost due to the majority of the 035 catchment currently having a dual-pipe system. Because separate storm water pipes are present, the benefits of GSI are reduced. Furthermore the area's topography and soils are not conducive for GSI.

In conclusion, the hybrid GSI/sewer separation alternative is eliminated from further consideration, and the traditional sewer separation approach is the recommended subsystem alternative.

5.4.2. 039- 056 Subsystem

The Baseline CDRA plan for outfalls 039 and 056 is traditional sewer separation and a hybrid of GSI and sewer separation is an alternative. The West River Interceptor to provide storage of the overflows is a third alternative. Table 5-11 presents the subsystem costs and evaluation criteria scores.

Table 5-11 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 039 and 056

		056, 039		
		039-056 Sewer separation	039-056 Hybrid GSI / Sewer separation	West River Interceptor
Volume Captured (Mgal)		0.88	0.88	0.88
Capital Cost $		$41,200,000	$37,900,000	$34,900,000
Annual O&M Cost $		$9,338	$7,921	$9,660
Cap Cost per Gallon Captured (calc) ($/gal)		46.70	42.95	39.57
Environmental Criteria				
Water quality (bacteria) impacts	14%	0.5	0.5	0.5
Water quality (nutrients) impacts	7%	1	2	6
Flooding risks from stormwater systems	7%	0	3.5	6
Scalability & adaptability	7%	5	6.5	6
Economic Criteria				
Capital costs	14%	6	6	7
Operations & Maintenance costs	8%	9	9	9
Constructability / Construction-phase risks	3%	1	1	2
Cost per gallon captured	3%	1	1	1
Operational flexibility for optimization	3%	5	5.5	7
Social Criteria				
Fishable, shellfishable & swimmable waters	6%	0.5	0.5	0.5
Co-benefits & quality of life	5%	8	8.5	5
Operations & maintenance impacts and risks	4%	4	3.5	4
Construction-phase disruptions	4%	0	1.5	2
Implementation Criteria				
Administrative / Institutional considerations	7%	3	2.5	5
System reliability / Operational robustness	5%	7	5	7
Climate change resiliency & recovery	5%	5	5.5	6
Composite Rating & Ranking:		**3.5**	**3.9**	**4.7**

The composite rating indicates that the West River Interceptor is more favorable than either the traditional sewer separation or the hybrid GSI/sewer separation alternatives, which rate similarly. The latter two alternatives scored unfavorably for several criteria including construction-phase disruptions, flooding risks and discharge of nutrients. The West River Interceptor scored favorably for capital costs, operational flexibility and reliability.

In conclusion, both the traditional sewer separation and the hybrid GSI/sewer separation alternatives are eliminated from further consideration, and the West River Interceptor approach is the recommended subsystem alternative.

5.4.3. 206 Subsystem

The Baseline CDRA plan for outfall 206 is traditional sewer separation and a hybrid of storm water controls, GSI and sewer separation is the alternative. Table 5-12 presents the subsystem costs and the evaluation criteria scores.

Table 5-12 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 206

		206	
		206 Sewer separation	206 Hybrid GSI / Parking lot stormwater tanks / Sewer separation
Volume Captured (Mgal)		0.14	0.14
Capital Cost $		$6,500,000	$4,900,000
Annual O&M Cost $		$1,182	$7,709
Cap Cost per Gallon Captured (calc) ($/gal)		45.92	34.94
Environmental Criteria			
Water quality (bacteria) impacts	14%	0.5	0.5
Water quality (nutrients) impacts	7%	3	7
Flooding risks from stormwater systems	7%	0	8
Scalability & adaptability	7%	5	7
Economic Criteria			
Capital costs	14%	10	10
Operations & Maintenance costs	8%	10	9
Constructability / Construction-phase risks	3%	1	1
Cost per gallon captured	3%	1	2
Operational flexibility for optimization	3%	5	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	0.5	0.5
Co-benefits & quality of life	5%	8	10
Operations & maintenance impacts and risks	4%	4	2
Construction-phase disruptions	4%	0	1
Implementation Criteria			
Administrative / Institutional considerations	7%	3	0
System reliability / Operational robustness	5%	7	2
Climate change resiliency & recovery	5%	5	6
Composite Rating & Ranking:		**4.3**	**4.9**

The composite ranking indicates that the hybrid GIS/sewer separation alternative is more favorable than the traditional sewer separation alternative. While the traditional sewer separation scored favorably for the Implementation category criteria, it would result in higher flooding risks and discharge of nutrients. The hybrid approach scored more favorably for capital costs, co-benefits and operational flexibility.

In conclusion, the traditional sewer separation alternative is eliminated from further consideration and the hybrid GSI/sewer separation approach is the recommended subsystem alternative.

5.4.4. 101-103 Subsystem

The Baseline CDRA solution includes a regulator modification for outfall 101 and construction of the High and Cross Streets Interceptor to convey flow from Outfall 103 to Drop shaft 205 and the Pawtucket Tunnel. The cost associated with this solution includes the costs for the interceptor plus the flow-weighted portion of the Pawtucket Tunnel costs. The High Street near surface storage tank is a feasible alternative. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-13 presents the subsystem costs and the evaluation criteria scores.

Table 5-13 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 101 and 103

		101, 103	
		Upper High & Cross St interceptor	High Street Tank
Volume Captured (Mgal)		5.26	5.26
Capital Cost $		$65,400,000	$63,500,000
Annual O&M Cost $		$51,142	$170,100
Cap Cost per Gallon Captured (calc) ($/gal)		12.45	12.08
Environmental Criteria			
Water quality (bacteria) impacts	14%	3	3
Water quality (nutrients) impacts	7%	6	6
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	4	4
Operations & Maintenance costs	8%	6	2
Constructability / Construction-phase risks	3%	1	2
Cost per gallon captured	3%	7	8
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	3	3
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	3	0
Implementation Criteria			
Administrative / Institutional considerations	7%	6	3
System reliability / Operational robustness	5%	7	3
Climate change resiliency & recovery	5%	6	6
Composite Rating & Ranking:		**4.8**	**4.0**

The composite ranking indicates that the High & Cross Street Interceptor to the Pawtucket Tunnel alternative is more favorable than the High Street near surface storage tank. The capital cost of the two alternatives are essentially equivalent. The Baseline approach scored favorably for O&M cost and the Implementation category criteria. The storage tank scored unfavorably with both construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility on a site used for recreation. More importantly, the storage tank scored very unfavorably for construction-phase disruption as the construction would take a public ball field out of service for two to three years.

The High Street NSS tank alternative is eliminated from further consideration and the interceptor connection to the Pawtucket Tunnel is the recommended subsystem alternative.

5.4.5. 104- 105 Subsystem

The Baseline CDRA solution is construction of the lower reaches of the High and Cross Streets Interceptor to transport flows to Drop shaft 205 and the Pawtucket Tunnel. The cost associated with this solution includes the costs for the interceptor plus the flow-weighted portion of the Pawtucket Tunnel costs. The Webbing Mills near surface storage tank is the alternative. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-14 presents the subsystem costs and the evaluation criteria scores.

Table 5-14 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 104 and 105

		104, 105	
		Lower High & Cross St interceptor	Webbing Mills Tank
Volume Captured (Mgal)		2.12	2.12
Capital Cost $		$18,300,000	$50,200,000
Annual O&M Cost $		$17,107	$87,900
Cap Cost per Gallon Captured (calc) ($/gal)		8.64	23.60
Environmental Criteria			
Water quality (bacteria) impacts	14%	2	2
Water quality (nutrients) impacts	7%	6	6
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	9	5
Operations & Maintenance costs	8%	8	5
Constructability / Construction-phase risks	3%	2	2
Cost per gallon captured	3%	9	3
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	2	2
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	3	0
Implementation Criteria			
Administrative / Institutional considerations	7%	6	3
System reliability / Operational robustness	5%	7	3
Climate change resiliency & recovery	5%	6	6
Composite Rating & Ranking:		**5.5**	**4.0**

The composite ranking indicates that the High and Cross Street Interceptor to the Pawtucket Tunnel alternative is more favorable than the Webbing Mills Tank alternative. The Baseline approach scored favorably for capital and O&M costs and the Implementation category criteria.

The storage tank scored unfavorably for both construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility on a private site. More importantly, the storage tank scored very unfavorably for construction-phase disruption as the construction would require taking over a private parking lot for two to three years.

In conclusion, the Webbing Mills Tank alternative is eliminated from further consideration, and the interceptor connection to the Pawtucket Tunnel solution is the recommended subsystem alternative.

5.4.6. 201- 202 Subsystem

The Baseline CDRA solution is to construct the Middle Street Interceptor to transports flow to drop shaft 205 and the Pawtucket Tunnel. The cost associated with this solution includes the costs for the interceptor plus the flow-weighted portion of the Pawtucket Tunnel costs. The alternative is the East Street near surface storage tank. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-15 presents the subsystem costs and scores against the evaluation criteria.

Table 5-15 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 201 and 202

		201, 202	
		Middle St interceptor	East Street Tank (Viper VoIP Corporation)
Volume Captured (Mgal)		1.51	1.51
Capital Cost $		$25,200,000	$45,400,000
Annual O&M Cost $		$65,734	$132,789
Cap Cost per Gallon Captured (calc) ($/gal)		16.62	29.98
Environmental Criteria			
Water quality (bacteria) impacts	14%	1	1
Water quality (nutrients) impacts	7%	6	6
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	8	5
Operations & Maintenance costs	8%	6	4
Constructability / Construction-phase risks	3%	3	2
Cost per gallon captured	3%	5	2
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	1	1
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	3	0
Implementation Criteria			
Administrative / Institutional considerations	7%	6	3
System reliability / Operational robustness	5%	7	3
Climate change resiliency & recovery	5%	6	6
Composite Rating & Ranking:		**5.0**	**3.6**

The composite ranking indicates that the Middle Street Interceptor to the Pawtucket Tunnel alternative is more favorable than the East Street Tank alternative. The Baseline approach scored favorably for capital and O&M costs and the Implementation category criteria. The storage tank scored unfavorably for both construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility on a private site. More importantly, the storage tank scored very unfavorably for construction-phase disruption as the construction would require taking over a private parking lot for two to three years.

In conclusion, the East Street Tank alternative is eliminated from further consideration, and the interceptor connection to the Pawtucket Tunnel solution is the recommended subsystem alternative.

5.4.7. 203-205 Subsystem

The Baseline CDRA solution involves connection of the three overflows to the Pawtucket Tunnel via drop shaft 205. The cost associated with this solution includes the costs for the drop shaft 205 plus the flow-weighted portion of the Pawtucket Tunnel costs. The Front Street near surface storage tank is the alternative. Due to the limited size of the Front Street site, GSI would be required in the catchments to reduce the volume to make this alternative feasible. Table 5-16 presents the subsystem costs and the evaluation criteria scores.

Table 5-16 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 203, 204, and 205

		203, 204, 205	
		Drop shaft 205 & conduit	Front St Tank with GSI
Volume Captured (Mgal)		13.37	13.37
Capital Cost $		$112,100,000	$237,700,000
Annual O&M Cost $		$156,073	$1,143,980
Cap Cost per Gallon Captured (calc) ($/gal)		8.38	17.78
Environmental Criteria			
Water quality (bacteria) impacts	14%	10	10
Water quality (nutrients) impacts	7%	10	10
Flooding risks from stormwater systems	7%	5	6.5
Scalability & adaptability	7%	6	6.5
Economic Criteria			
Capital costs	14%	2	0
Operations & Maintenance costs	8%	3	0
Constructability / Construction-phase risks	3%	5	2
Cost per gallon captured	3%	10	5
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	10	10
Co-benefits & quality of life	5%	5	7
Operations & maintenance impacts and risks	4%	5	2.5
Construction-phase disruptions	4%	4	0.5
Implementation Criteria			
Administrative / Institutional considerations	7%	7	1.5
System reliability / Operational robustness	5%	8	2.5
Climate change resiliency & recovery	5%	7	6
Composite Rating & Ranking:		**6.4**	**5.0**

The composite ranking indicates that the Pawtucket Tunnel alternative is more favorable than the Front Street near surface storage tank alternative. The Baseline approach scored favorably for capital and O&M costs and the Implementation category criteria. The storage tank scored unfavorably both for construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility at the Front Street site. The storage tank scored very unfavorably for construction-phase disruption as the construction would prevent the use of the park, one of the few open space resources in Pawtucket for two to three years. Moreover, the tank would limit the future use of the site, which the City of Pawtucket has identified as a priority redevelopment location.

In conclusion, the Front Street Tank alternative is eliminated from further consideration, and the Pawtucket Tunnel solution is the recommended subsystem alternative.

5.4.8. 207-211 Subsystem

The Baseline CDRA solution involves regulator modifications for outfalls 207, 208 and 209 and conveyance of from 210 and 211 to the Pawtucket Tunnel via drop shaft 210/211. The cost associated with this solution includes the costs for drop shaft 210/211 plus the flow-weighted portion of the Pawtucket Tunnel costs. The City Hall near surface storage tank is the alternative. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-17 presents the subsystem costs and the evaluation criteria scores.

Table 5-17 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 207, 208, 209, 210 and 211

		207, 208, 209, 210, 211	
		Drop shaft 210/211 & conduit	City Hall Tank
Volume Captured (Mgal)		7.21	7.21
Capital Cost $		$80,100,000	$45,100,000
Annual O&M Cost $		$206,674	$290,000
Cap Cost per Gallon Captured (calc) ($/gal)		11.10	6.25
Environmental Criteria			
Water quality (bacteria) impacts	14%	5	5
Water quality (nutrients) impacts	7%	7	7
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	3	6
Operations & Maintenance costs	8%	2	1
Constructability / Construction-phase risks	3%	4	1
Cost per gallon captured	3%	8	10
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	5	5
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	4	0
Implementation Criteria			
Administrative / Institutional considerations	7%	7	3
System reliability / Operational robustness	5%	8	3
Climate change resiliency & recovery	5%	7	6
Composite Rating & Ranking:		**5.2**	**4.7**

The composite ranking indicates that the Pawtucket Tunnel alternative is more favorable than the City Hall near surface storage tank alternative. The Baseline approach scored favorably for O&M cost and the Implementation category criteria. The storage tank scored unfavorably for both construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility on a site with public parking access. More importantly, the storage tank scored very unfavorably for construction-phase disruption as the construction would require taking over the parking lot for City Hall and the Pawtucket police department for two to three years. The configuration of the tank required by the site limitation will cause significant construction-phase and ongoing operations-phase difficulties.

In conclusion, the City Hall Tank alternative is eliminated from further consideration, and the connection to the Pawtucket Tunnel solution is the recommended subsystem alternative.

5.4.9. 213-214 Subsystem

The Baseline CDRA solution is to convey the flow from 213 and 214 to the Pawtucket Tunnel via drop shaft 213. The cost associated with this solution includes the costs for drop shaft 213 plus the flow-weighted portion of the Pawtucket Tunnel costs. The near surface storage tank at 213 is the alternative. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-18 presents the subsystem costs and scores against the evaluation criteria.

Table 5-18 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 213 and 214

		213, 214	
		Drop shaft 213 & conduit	213 Tank
Volume Captured (Mgal)		3.24	3.24
Capital Cost $		$65,100,000	$72,400,000
Annual O&M Cost $		$75,439	$149,400
Cap Cost per Gallon Captured (calc) ($/gal)		20.10	22.36
Environmental Criteria			
Water quality (bacteria) impacts	14%	3	3
Water quality (nutrients) impacts	7%	6	6
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	4	3
Operations & Maintenance costs	8%	5	3
Constructability / Construction-phase risks	3%	4	3
Cost per gallon captured	3%	4	4
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	3	3
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	4	0
Implementation Criteria			
Administrative / Institutional considerations	7%	7	3
System reliability / Operational robustness	5%	8	3
Climate change resiliency & recovery	5%	7	6
Composite Rating & Ranking:		**5.0**	**3.8**

The composite ranking indicates that the Pawtucket Tunnel alternative is more favorable than the 213 near surface storage tank alternative. The Baseline approach scored favorably for capital and O&M costs and the Implementation category criteria. The storage tank scored unfavorably for both construction-phase risks associated with potential contaminated soil and operations-phase impacts associated with operating a facility at a remote site.

In conclusion, the 213 near surface storage tank alternative is eliminated from further consideration and connection to the Pawtucket Tunnel is the recommended subsystem alternative.

5.4.10. 217 Subsystem

The Baseline CDRA solution is to convey flow from OF 217 to the Pawtucket Tunnel via drop shaft 217. The cost associated with this solution includes the costs for drop shaft 217 plus the flow-weighted portion of the Pawtucket Tunnel costs. The alternative is the Tidewater Site above-ground storage tank. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-19 presents the subsystem costs and the evaluation criteria scores.

Table 5-19 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 217

		217	
		Drop shaft 217 & conduit	Tidewater Above-ground Tank
Volume Captured (Mgal)		2.71	2.71
Capital Cost $		$35,600,000	$36,000,000
Annual O&M Cost $		$21,305	$94,000
Cap Cost per Gallon Captured (calc) ($/gal)		13.15	13.28
Environmental Criteria			
Water quality (bacteria) impacts	14%	2	2
Water quality (nutrients) impacts	7%	6	6
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	7	7
Operations & Maintenance costs	8%	7	5
Constructability / Construction-phase risks	3%	3	2
Cost per gallon captured	3%	7	6
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	2	2
Co-benefits & quality of life	5%	5	4
Operations & maintenance impacts and risks	4%	5	3
Construction-phase disruptions	4%	4	1
Implementation Criteria			
Administrative / Institutional considerations	7%	7	3
System reliability / Operational robustness	5%	8	3
Climate change resiliency & recovery	5%	7	6
Composite Rating & Ranking:		**5.4**	**4.4**

The composite ranking indicates that the Pawtucket Tunnel alternative is more favorable than the Tidewater tank alternative. The Baseline approach scored favorably for O&M costs and the Implementation category criteria. The storage tank scored unfavorably for both construction-phase and operations-phase impacts associated with operating a facility on a private site with known contamination. More importantly, the storage tank scored very unfavorably for construction-phase risks associated with working on the known contaminated Tidewater site.

In conclusion, the Tidewater Tank alternative is eliminated from further consideration, and the connection to the Pawtucket Tunnel solution is the recommended subsystem alternative.

5.4.11. 212, 215, 216, 218 Subsystem

The Baseline CDRA solution involves regulator modifications for outfalls 212, 215 and 216 and conveyance of flow from 218 to the Pawtucket Tunnel via drop shaft 218. The cost associated with this solution includes the costs for drop shaft 218 plus the flow-weighted portion of the Pawtucket Tunnel costs. The Bucklin Pont Landfill near surface storage tank is a feasible alternative as is a flow through treatment facility. GSI in the contributing area could be used to optimize the design of either grey system alternative. Table 5-20 presents the subsystem costs and the evaluation criteria scores.

Table 5-20 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 212, 215, 216 and 218

		212, 215, 216, 218	
		Drop shaft 218 & conduit	Bucklin Point Landfill Tank
Volume Captured (Mgal)		14.76	14.76
Capital Cost $		$152,600,000	$183,300,000
Annual O&M Cost $		$216,010	$532,147
Cap Cost per Gallon Captured (calc) ($/gal)		10.34	12.42
Environmental Criteria			
Water quality (bacteria) impacts	14%	10	10
Water quality (nutrients) impacts	7%	10	10
Flooding risks from stormwater systems	7%	5	5
Scalability & adaptability	7%	6	6
Economic Criteria			
Capital costs	14%	1	1
Operations & Maintenance costs	8%	1	1
Constructability / Construction-phase risks	3%	4	3
Cost per gallon captured	3%	9	7
Operational flexibility for optimization	3%	7	7
Social Criteria			
Fishable, shellfishable & swimmable waters	6%	10	10
Co-benefits & quality of life	5%	5	5
Operations & maintenance impacts and risks	4%	5	5
Construction-phase disruptions	4%	4	2
Implementation Criteria			
Administrative / Institutional considerations	7%	7	3
System reliability / Operational robustness	5%	8	3
Climate change resiliency & recovery	5%	7	6
Composite Rating & Ranking:		**6.1**	**5.4**

The composite ranking indicates that the Pawtucket Tunnel alternative is more favorable than the Bucklin Point Landfill Tank alternative. The Baseline approach scored favorably for capital and

O&M costs and the Implementation category criteria. Compared to other tank alternatives, this site has the least constraints for either a near surface storage tank or a screening and disinfection treatment facility and is a possible alternative to the tunnel for this overflow. In order for the storage/screening and disinfection facility alternative to be feasible for 218, it would also have to include an alternative to the tunnel for all the other CSO's that are addressed in the Pawtucket tunnel alternative.

In conclusion, the Bucklin Pont Tank alternative could be part of an alternative solution. However, the connection to the Pawtucket Tunnel is the recommended subsystem alternative.

5.4.12. 107- 220 Subsystem

The Baseline CDRA solution involves a regulator modification for outfall 107 and conveyance of the flow from 220 to the Pawtucket Tunnel via the Pawtucket Avenue Interceptor and drop shaft 217. The cost associated with this solution includes the costs for the interceptor plus the flow-weighted portion of the Pawtucket Tunnel costs. The Morley Field near surface storage tank and the 220 Stub Tunnel are also feasible alternatives. Those solutions provide storage volume; therefore Pawtucket Tunnel costs need not be apportioned. GSI in the contributing area could be used to optimize the design of any grey system alternative. Table 5-21 presents the subsystem costs and the evaluation criteria scores.

Table 5-21 Comparison of CDRA Baseline and Alternative Technology Controls Outfall 107 and 220

		107, 220		
		Pawtucket Ave interceptor	Morley Field tank	220 Stub Tunnel
Volume Captured (Mgal)		4.97	4.97	4.97
Capital Cost $		$125,600,000	$66,900,000	$93,700,000
Annual O&M Cost $		$107,944	$167,100	$107,944
Cap Cost per Gallon Captured (calc) ($/gal)		25.26	13.45	18.84
Environmental Criteria				
Water quality (bacteria) impacts	14%	3	3	3
Water quality (nutrients) impacts	7%	6	6	6
Flooding risks from stormwater systems	7%	5	5	5
Scalability & adaptability	7%	6	6	6
Economic Criteria				
Capital costs	14%	2	3	2
Operations & Maintenance costs	8%	4	3	4
Constructability / Construction-phase risks	3%	1	2	4
Cost per gallon captured	3%	3	6	4
Operational flexibility for optimization	3%	7	7	7
Social Criteria				
Fishable, shellfishable & swimmable waters	6%	3	3	3
Co-benefits & quality of life	5%	5	4	5
Operations & maintenance impacts and risks	4%	3	3	5
Construction-phase disruptions	4%	1	0	4
Implementation Criteria				
Administrative / Institutional considerations	7%	4	3	7
System reliability / Operational robustness	5%	7	3	8
Climate change resiliency & recovery	5%	6	6	7
Composite Rating & Ranking:		**4.0**	**3.8**	**4.6**

The composite ratings indicate that the 220 Stub Tunnel is the most favorable alternative. The 220 Stub Tunnel scores favorably for both O&M costs and for the Implementation category criteria. Moreover, the 220 Stub Tunnel could be part of a systematic improvement that would provide relief for the Branch Avenue Interceptor SSO problems as described in the Alternatives Development chapter. The Morley Field Tank scores favorably for capital cost; however, it scores very unfavorably for construction-phase disruption as the construction would take one of Pawtucket's only public recreational assets out of service for two to three years. The overall costs for the Pawtucket Avenue Interceptor alternative are high since the cost associated with the interceptor are added to the costs associated with building capacity for 107 and 220 into the Pawtucket Tunnel. The hydraulic model indicates that to accommodate the flow from the 220 subsystem, the Pawtucket Tunnel diameter would need to be 28 feet. Either the Stub Tunnel or the Morley Field Tank would provide the storage capacity for the 220 subsystem, and the Pawtucket Tunnel diameter could remain 26 feet as described in the CDRA resulting in an overall cost savings. The Interceptor alternative scores for constructability and operations risks are low as the only feasible route for the interceptor is on a very heavily trafficked, yet narrow roadway that does not have good detour options.

In conclusion, the Pawtucket Avenue Interceptor is eliminated from further consideration, and the storage capacity of the Pawtucket Tunnel can be planned accordingly. The 220 Stub Tunnel is the recommended alternative. However, during the preliminary design phase, an alternate design for a near surface storage tank that has fewer construction phase disruptions and less cost could be developed. Therefore, that option is not eliminated from further consideration.

5.5. Subsystem Alternatives Analysis Conclusion

The CSO abatement strategies in the CDRA include sewer separation, regulator modifications and deep rock tunnel storage with interceptors. The technical feasibility screening completed during the Alternatives Development concluded that GSI alone cannot meet the requirements of a CSO Control Plan, but that GSI can be used in conjunction with other alternatives to improve their performance. Alternate CSO abatement strategies are hybrid GSI/sewer separation and near surface storage/flow through treatment (screening and disinfection).

The subsystem alternatives evaluation using the criteria set forth by the Stakeholders determined that site-specific characteristics determine the favorability of traditional sewer separation versus hybrid GSI/sewer separation and that near surface tank storage was generally unfavorable when compared to tunnel storage due to the difficulty of siting the near surface tanks. Near surface storage and flow through treatment are, however, considered feasible at the Bucklin Point Wastewater Treatment Facility (BPWWTF) because of availability of land and distance from abutters. For this alternative to be feasible it would have to include an alternative to address all the other CSO's to be addressed by the tunnel alternative. Conceptually, this could be accomplished by providing an interceptor to convey flow from the upstream CSO's that would be addressed by the tunnel to a storage tank or flow through facility to be constructed at the BPWWTF. This would be an alternative to the Tunnel alternative.

The next step in the evaluation process will be the Evaluation of Plan Alternatives. Based on the subsystem alternatives analysis, the following subsystem components to be included in the alternatives evaluation are:

- The Pawtucket Tunnel or NSS/Flow through treatment at the BPWWWTF
- The High & Cross Street Interceptor
- The Middle Street Interceptor
- Sewer Separation for 035
- West River Interceptor storage for 039 and 056 instead of sewer separation as proposed in the CDRA
- Hybrid/GSI sewer separation for 206 instead of sewer separation as proposed in the CDRA
- Stub Tunnel or NSS for 220 at an acceptable location instead of the Pawtucket Ave. Interceptor as proposed in the CDRA

- Green Stormwater Infrastructure for system optimization.

Specific solutions for each outfall location are shown in Table 22:

Table 5-22 Specific Control Solutions for Further Evaluation

CSO Control Solution	CSOs Controlled
Revised Phase III Components	
035 Sewer separation (limited scope, existing dual pipe system)	035
West River Interceptor	039, 056
206 Hybrid GSI / sewer separation	206
Pawtucket Tunnel via drop shafts & consolidation conduits or NSS/Flow through treatment at BPWWTF via new intercepter	204, 205, 210, 211, 213, 214, 217
Middle Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	201-203
High & Cross Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	101 - 105
Regulator modifications facilitated by interceptor relief via Pawtucket Tunnel or new interceptor	101, 107, 202-204, 207-209, 212, 215, 216, (036)
GSI for system optimization (capital & operational)	101-105, 201-204, 213-217 (1)
220 Stub Tunnel or Near Surface CSO Storage Tank	107, 220 (BAI system)

(1) Recommended target areas for GSI based on conceptual modeling. Preliminary design including detailed modeling of local collection systems is required to refine or modify those initial recommendations.

These components are depicted graphically in Figure 4 and Figure 5.

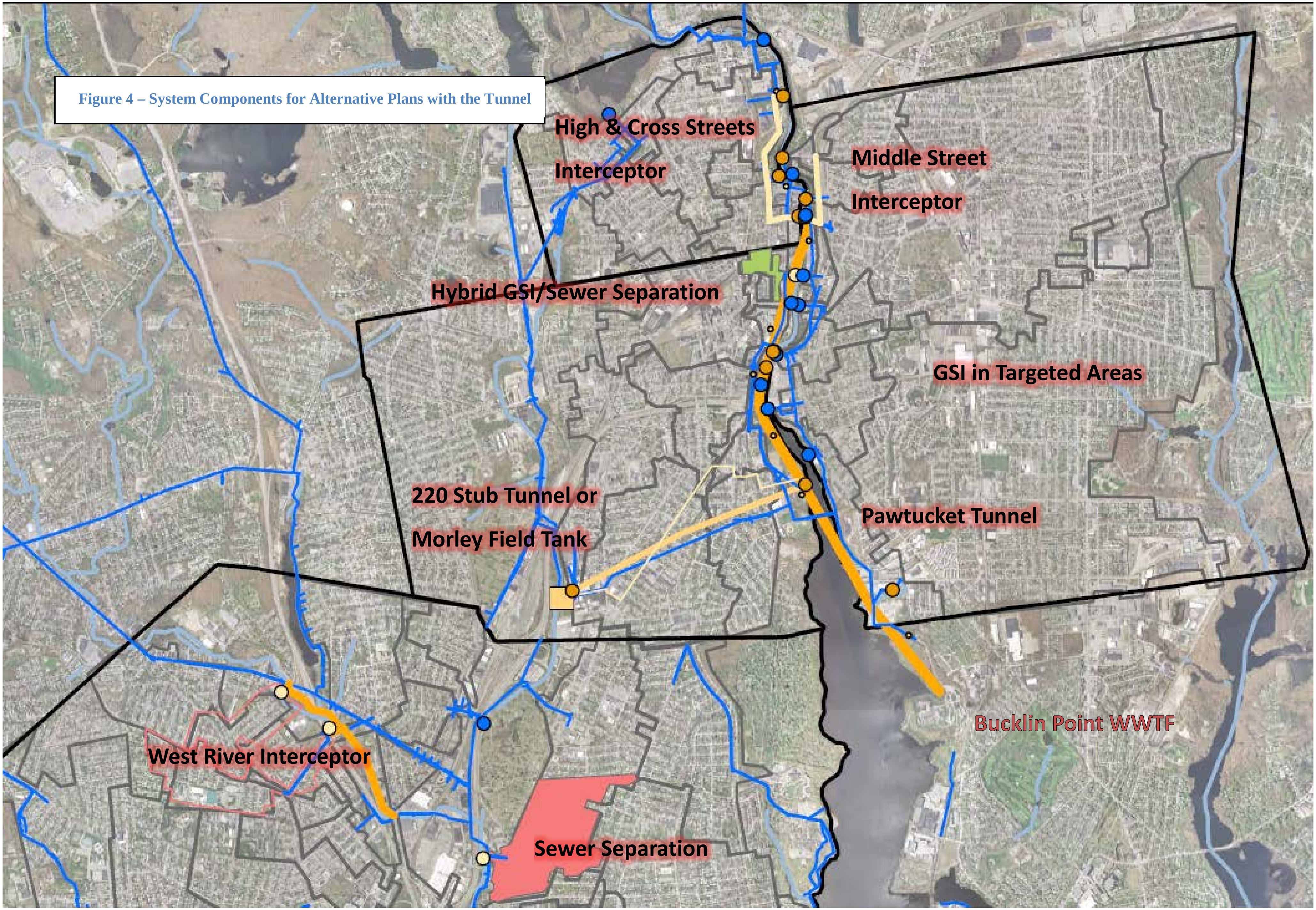
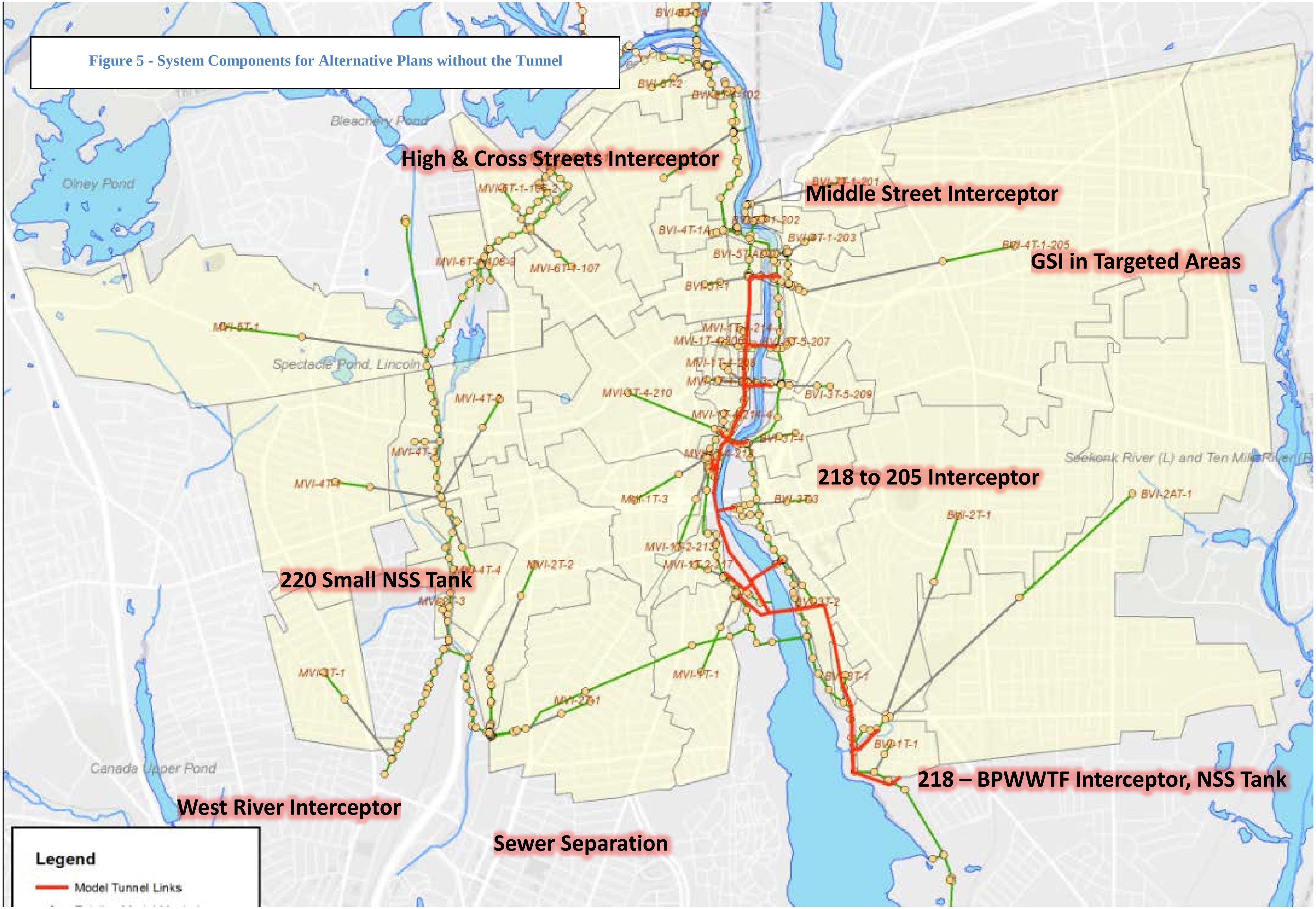


Figure 4 – System Components for Alternative Plans with the Tunnel
High & Cross Streets
Interceptor
Middle Street
Interceptor
Hybrid GSI/Sewer Separation
GSI in Targeted Areas
220 Stub Tunnel or
Morley Field Tank
Pawtucket Tunnel
Bucklin Point WWTF
West River Interceptor
Sewer Separation

Figure 5 - System Components for Alternative Plans without the Tunnel



NBC CSO Control Facilities Phase III Reevaluation

Chapter 6 – Alternative Plans & Integrated Planning Framework Evaluation

NBC CSO Control Facilities Phase III Reevaluation

Chapter 6 – Alternative Plans & IPF Evaluation

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6.1. Introduction

Previous chapters of this Revised CDRA Supplement have discussed the development of hydraulic, water quality and financial models to support the reevaluation effort, and the assessment of specific components of the overall plan and alternatives to those projects. This chapter presents the analysis and evaluation of four complete plan alternatives. This introduction section summarizes the key conclusions of other chapters that inform the evaluation of those alternative plans.

6.1.1. Financial Capacity and Affordability Assessment

Chapter 1 – Overview and Affordability Analysis examined the affordability of the Baseline Phase III plan as defined by the CDRA with costs updated to reflect lessons learned from Phase I and II as well as recent costing data for urban areas. The analysis was performed using both the 1997 EPA methodology as well as an enhanced methodology consistent with the November 2014 affordability guidance issued by EPA that supports the EPA's Integrated Planning Framework initiative started in 2012. The two-step 1997 methodology calculated that NBC's financial capacity is strong, and that the post-Phase III NBC bills would equate to 1.67% of median household income (MHI) for the NBC Service Area, which indicates a "Medium Burden" and would conclude that the Baseline plan is affordable. However, the enhanced methodology strongly indicates otherwise when factors included in the November 2014 guidance are examined, specifically:

- Inclusion of other Clean Water Act costs that are or may be experienced by the member communities over the planning period.
- Geographic income distribution over the NBC Service Area and within the member communities.

The enhanced WARi methodology concluded that when adding a reasonable estimate of necessary local costs to the analysis, the residential indicator for the Baseline plan equals 2.11% of MHI, or a "high burden". The current levels of spending by the municipalities that make up NBC are too low to be sustainable and financial capacity must be reserved for necessary future investments to address deferred collection system maintenance and expanded stormwater management requirements. The projected bills accounting for all of those costs would total $893, which is unaffordable for over 65% of Central Falls, 54% of Providence and 52% of Pawtucket households.

The following criteria have been established to evaluate the acceptability of the revised Phase III plan alternatives:

- The alternative must be able to accommodate an adaptive management approach that facilitates a reassessment of financial conditions and environmental goals at regular intervals to properly target rate payer investments in collection system, wastewater treatment, stormwater management and CSO abatement projects.
- The alternative must meet the NBC affordability goal for its sewer services that does not exceed 2% of any member community's median household income and/or that does not exceed 2% of the household income for more than one-third of its ratepayers. Based on the analysis presented in Chapter 1, that goal equates to a target rate of $626.

6.1.2. Engineering and Environmental Analyses

In addition to meeting the affordability goal for rates, the overall CWA-defined water quality goals for the CSO program must also be achieved. To evaluate how those goals were to be achieved, several analyses were completed.

Chapter 2 – Development of a Hydraulic Model for the Bucklin Point Service Area (BPSA) produced a hydraulic model that can estimate system flows and CSO overflow volumes from both the current and proposed combined sewer network for a range of precipitation events. Table 6-1a below summarizes the CSO volumes associated with the three-month storm predicted by the BPSA model and Table 6-1b summarizes the results from the Field's Point Service Area (FPSA) model.

Table 6-1a – 3-Month BPSA CSO Volumes

Outfall	CSO Volume (MGal)	Outfall	CSO Volume (MGal)	Outfall	CSO Volume (MGal)
101	0.38	204	0.16	212	0.6
103	4.82	205	12.69	213	1.98
104	0.49	206	0.14	214	1.29
105	1.49	207	0.04	215	1.58
107	0.37	208	0.01	216	0.01
201	1.34	209	0.02	217	2.71
202	0.17	210	3.14	218	12.49
203	0.4	211	3.96	220	4.51
				Total	**54.79**

Table 6-1b – 3-Month FPSA CSO Volumes

Outfall	CSO Volume (MGal)
35	0.75
36	0.1
39	0.45
56	0.4
Total	**1.70**

Chapter 3 – Water Quality and Pollutant Loading analyzed how those CSOs as well as other contamination sources including wastewater treatment facility discharges and stormwater outfalls contribute bacterial loading to Narragansett Bay. Various different control scenarios were developed to test the sensitivity of water quality using a model of the bay. The details of that model are provided in Appendix 4, and summarized in Section 6.2 below. Those results informed the alternatives analysis presented in this chapter.

Chapter 4 – Alternatives Definition & Technical Feasibility Screening investigated and evaluated a wide range of CSO control strategies throughout the Phase III areas and determined which technical approaches would be most appropriate for specific locations.

Chapter 5 – Subsystem Alternatives Analysis compared those technically feasible approaches for each Phase III region to select the group of subsystems that best meet the evaluation criteria selected by the Stakeholder Group. Table 6-2 below summarizes the selected components of the overall Phase III program, and identifies the individual CSOs and CSO volume associated with each component.

Table 6-2 – Phase III Subsystems and CSO Volumes

Abatement Solution	CSOs Abated	Design Capacity (MGal)
Pawtucket Tunnel & Drop Shafts + Regulator Modifications	204-205, 207-218	40.90
High Street Interceptor	101-105	7.38
Middle Street Interceptor	201-203	1.91
206 Hybrid Sewer Separation	206	0.14
220 Stub Tunnel or NSS Tank	107, 220	4.97
West River Interceptor	039, 056	0.88
035 Sewer Separation	035, 036	0.87
Green Stormwater Infrastructure projects ranked by efficiency		
$10M GSI Project #1	212, 213, 214 partial	0.40
$10M GSI Project #2	101, 104, 105 partial	0.22
$10M GSI Project #3	216, 217 partial	0.22
$10M GSI Project #4	201 - 204 partial	0.19
$10M GSI Project #5	215 partial	0.18
$10M GSI Project #6	103 partial	0.19
$10M GSI Project #7	103 partial	0.19
$10M GSI Project #8	205 partial	0.12
$10M GSI Project #9	205 partial	0.12
$10M GSI Project #10	205 partial	0.12
$10M GSI Project #11	205 partial	0.12
$10M GSI Project #12	205 partial	0.12
$10M GSI Project #13	205 partial	0.12

For the purposes of evaluating alternative plans, GSI projects were bundled into packages targeting a $10M total. The actual amount of GSI incorporated into any plan may change once preliminary design and more advanced modeling is complete. However, this base assumption is presented for this analysis to compare different plans. The selection of CSO areas listed in the table above was based on two criteria. First, areas that could potentially reduce the extent and cost of corresponding grey infrastructure were targeted. Second, the cost per gallon of CSO reduction calculated for the GSI evaluations presented in Chapters 4 and 5 was used to rank the targeted areas based on efficiency.

6.2. Water Quality Assessment

The water quality model was used to perform a sensitivity analysis to determine the effect on water quality of the Phase I and Phase II improvements and of controlling selected Phase III CSO's.

The first analysis evaluated the success of Phases I and II of the CSO program to understand the current conditions and determine if the Phase III design goals could be modified. The water quality model predicts instantaneous Fecal Coliform concentrations, expressed as FC / 100mL, at different time steps after the 3-month design storm. Figure 6-19 below provides the color coding key. In general, any shade of blue always complies with recreational contact standards. The lightest green shade is in the range of the 90th percentile for contact standards; therefore, samples would need to be offset by lower concentrations to meet statistical standards. Darker shades of green as well as purple and red shades would indicate potential problems meeting contact standards. The lightest shade of blue always complies with shellfishing standards. The medium and darker blue shades are in the range of the geomean and 90th percentile for shellfishing standards. Any other colors would indicate potential problems meeting shellfishing standards.

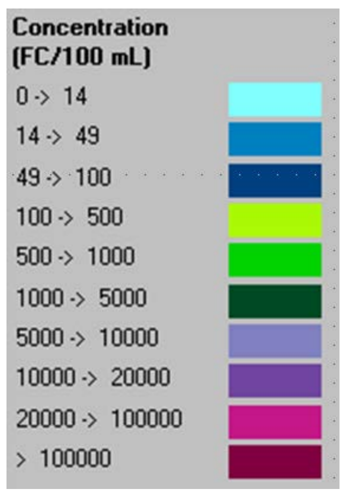
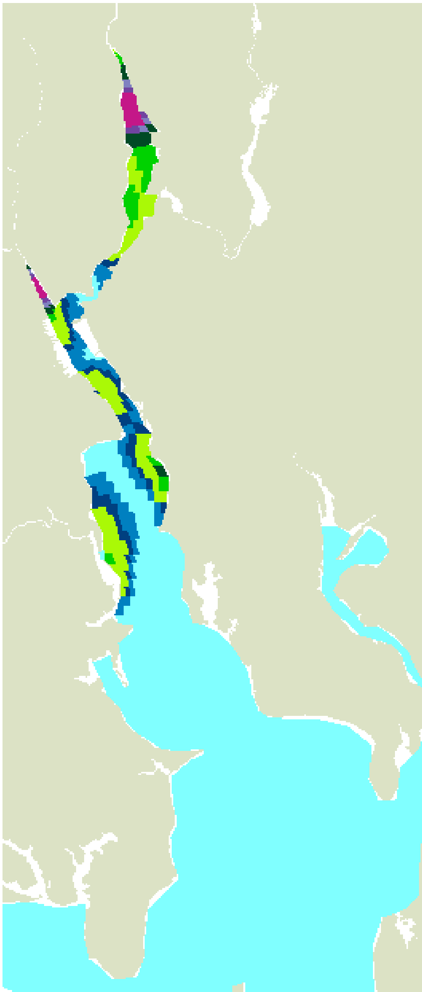
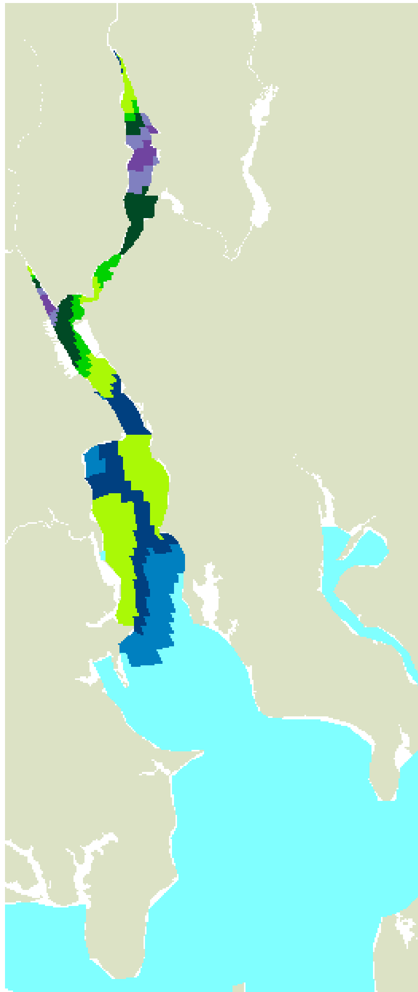
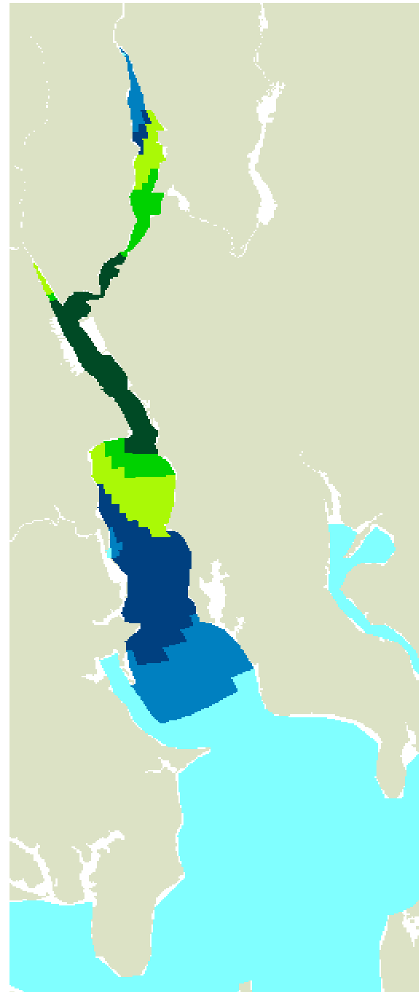
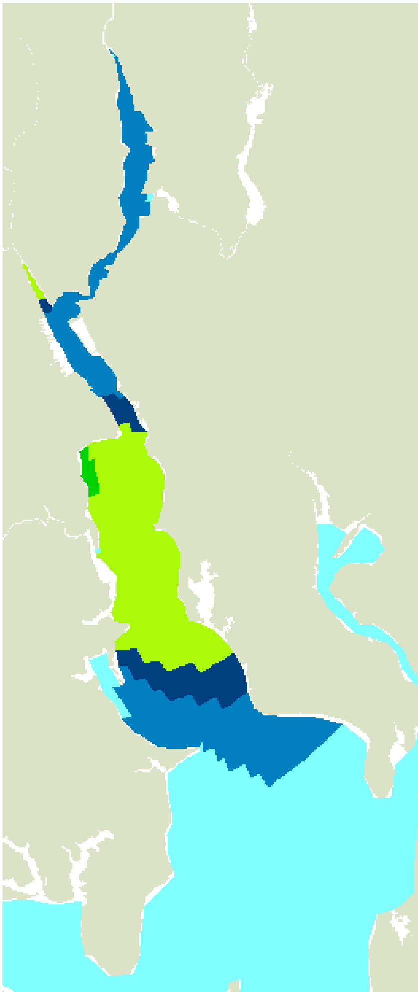
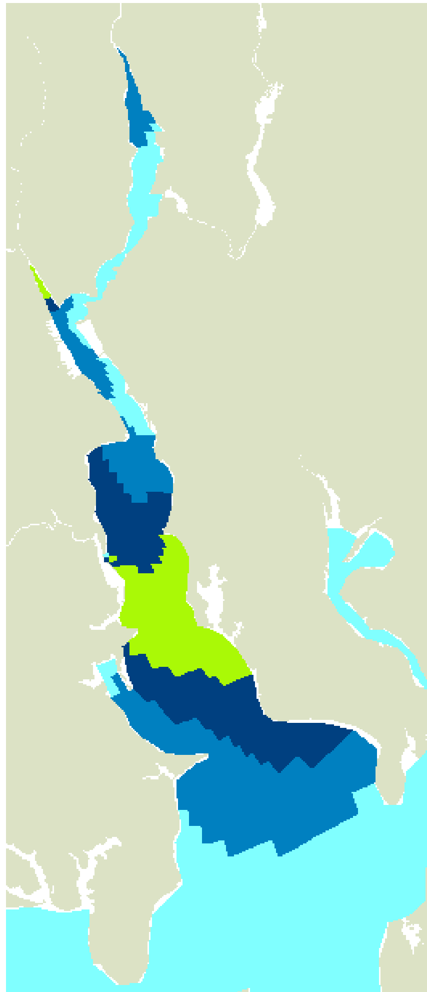
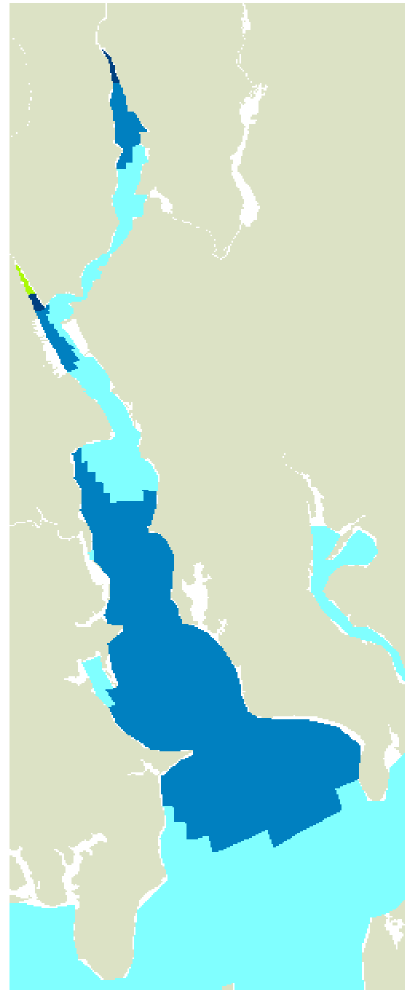


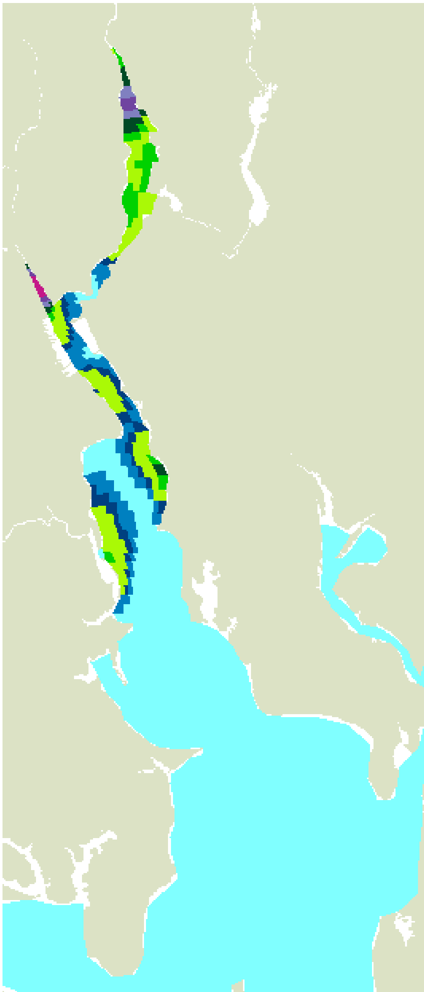
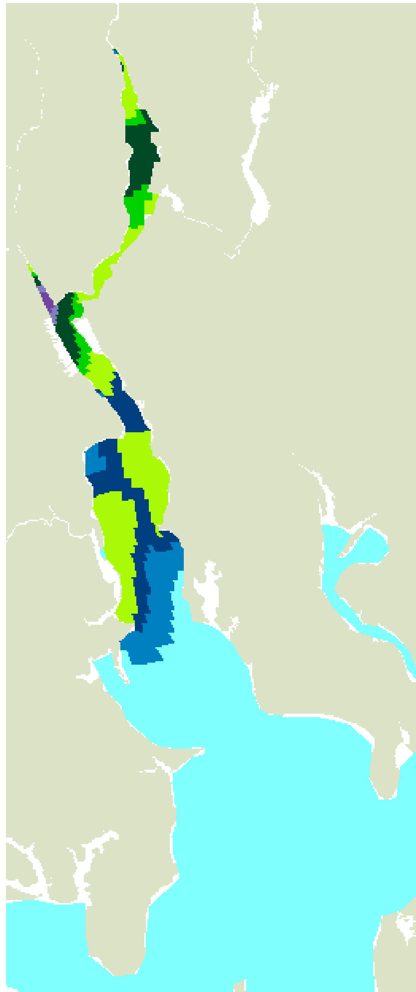
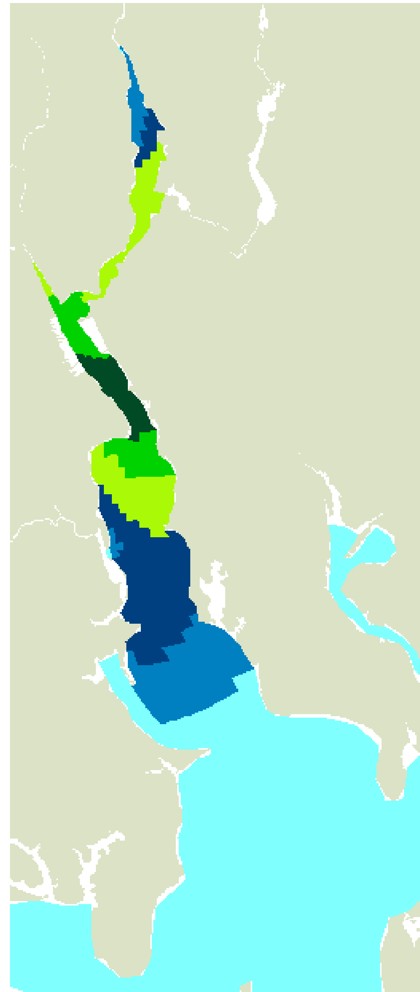
Figure 6-1 – Fecal Coliform Concentration Color Codes

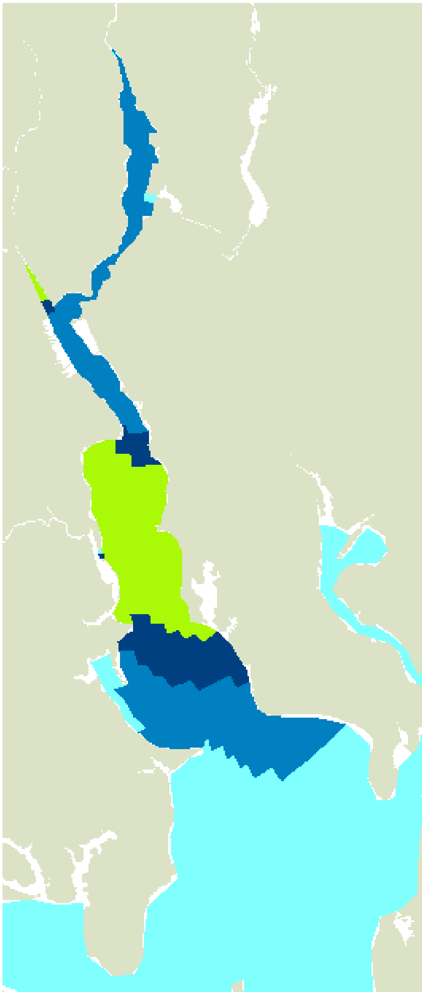
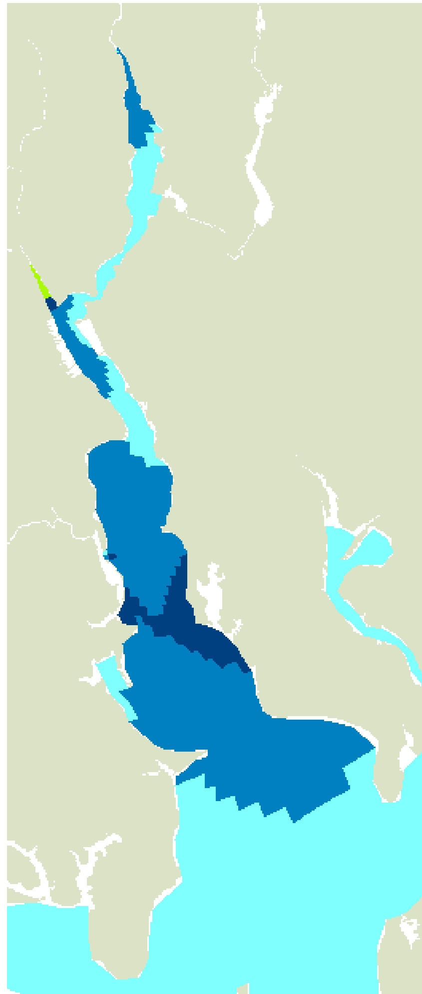
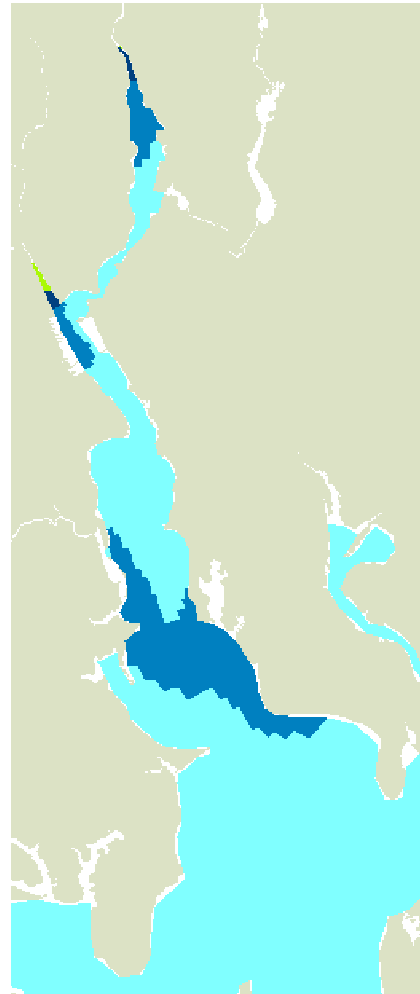
The series of maps below demonstrate that current Post-Phase II conditions fail to attain water quality standards at various locations and at different times. For the day following the storm, concentrations in the Seekonk and Providence Rivers are thousands of times higher than the geomean standard and hundreds of times higher than the 90th percentile standard. The plume travels south over time and continues to impact shellfishing standards at Conimicut Point past the 8 day mark. The conclusion of this first analysis is that significant water quality impacts remain after the completion of Phases I and II and that Phase III CSO's will need to be addressed in order to meet water quality standards.

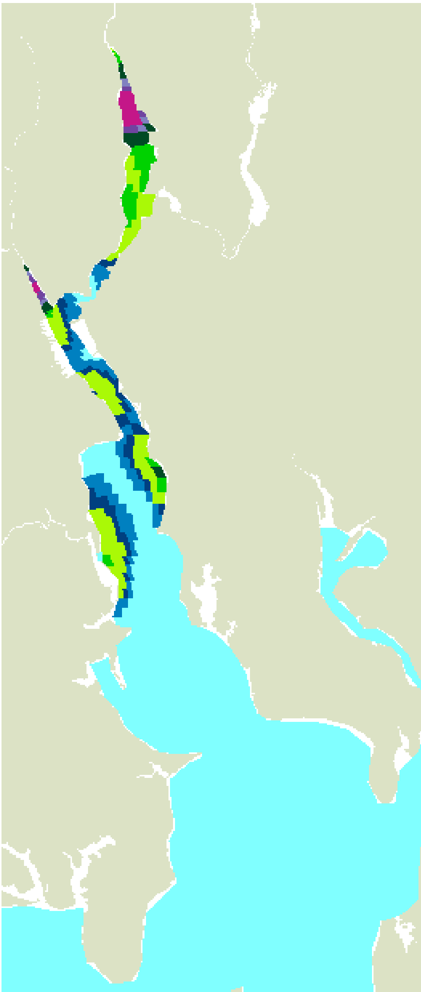
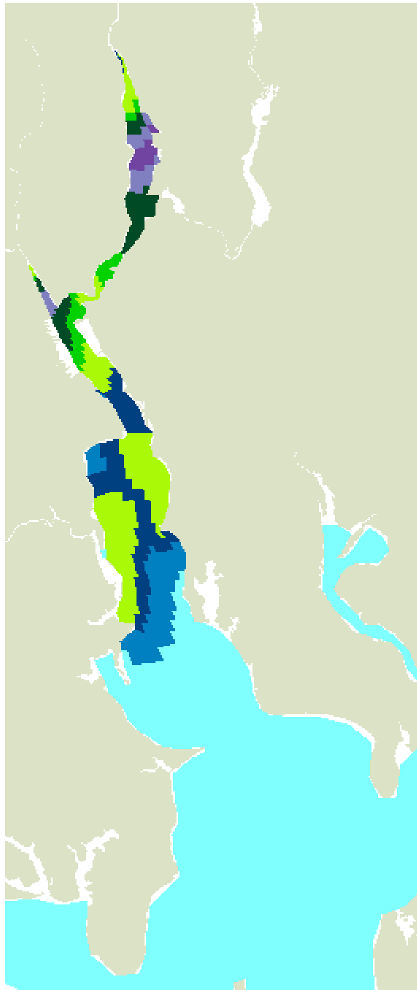
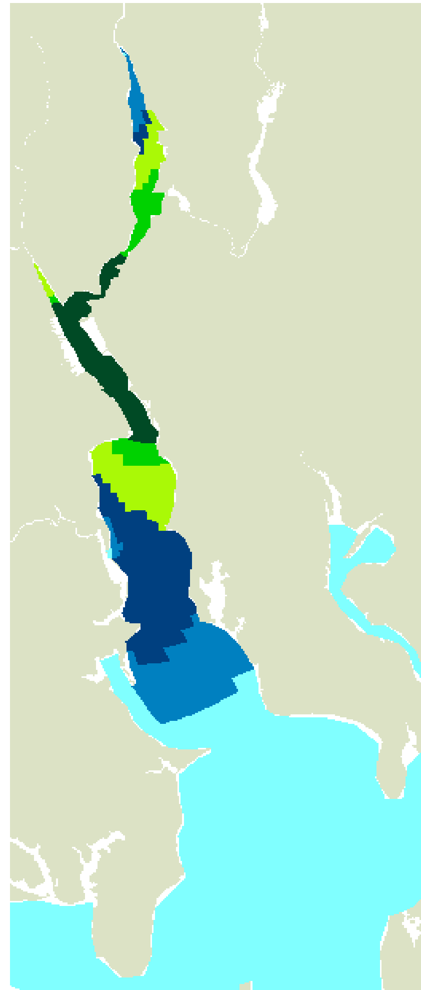
Post-Phase II, 0.5 days	Post-Phase II, 1 day	Post Phase II, 2 days
		

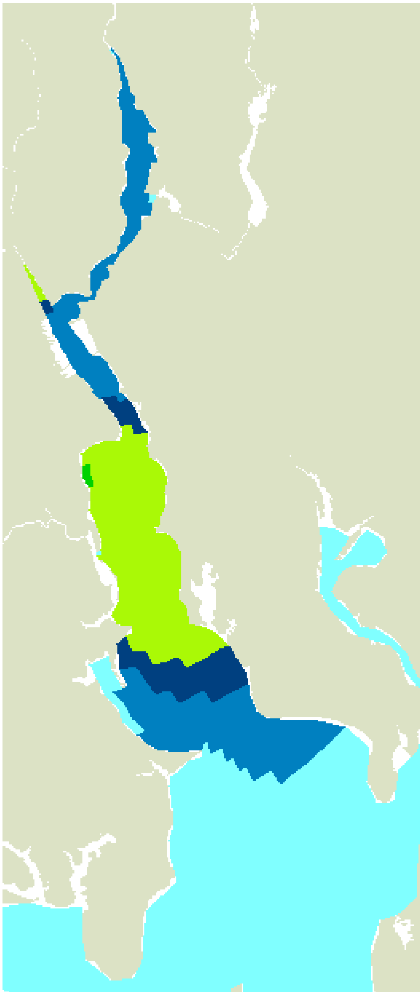
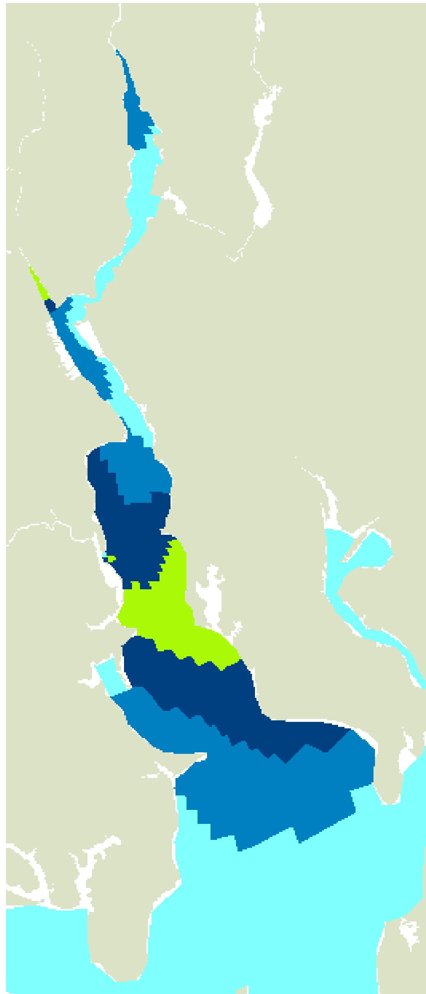
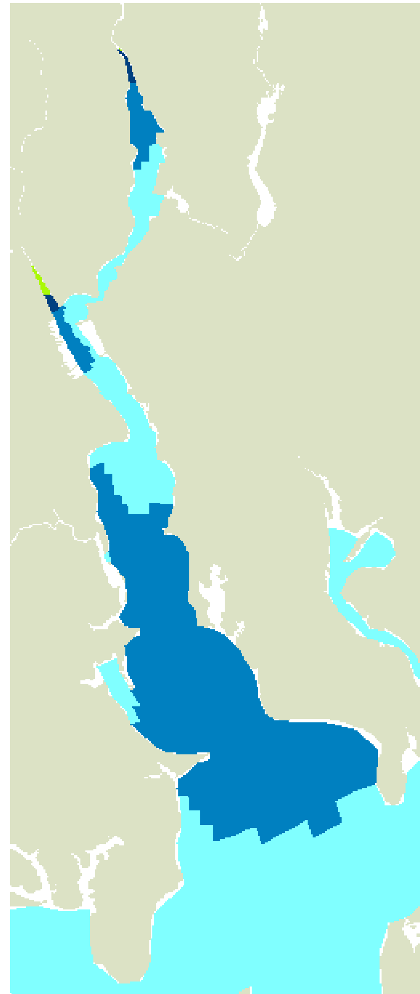
Post-Phase II, 4 days	Post-Phase II, 6 days	Post Phase II, 8 days
		

A second analysis was performed to understand the effect of eliminating only OFs 205-218 and the effect of eliminating only OF 220. OFs 205-218 account for approximately 80 percent of the total CSO load to the Seekonk River, which has substantial flow. OF 220 accounts for less than 10 percent of the total CSO volume but discharges to the Moshassuck River, that has relatively small flow. The following series of plots from the Scenario 3 loading as described in Chapter 3 illustrate that while concentrations immediately following the storm still exceed standards, the Pawtucket Tunnel would significantly improve conditions in the Seekonk compared to current conditions. Concentrations at days 6 and 8 are significantly improved with concentrations below shellfishing standards being achieved by day 8. The series of plots for the OF 220 only analysis (Scenario 2 in Chapter 3) do not show significant improvements with the exception of the confluence of the Providence and Seekonk Rivers one day following the storm. The conclusion of the test is that OF 220 only has an impact on a very small area and for a very short duration of time and that addressing OFs 205-218 will have a much greater impact on water quality.

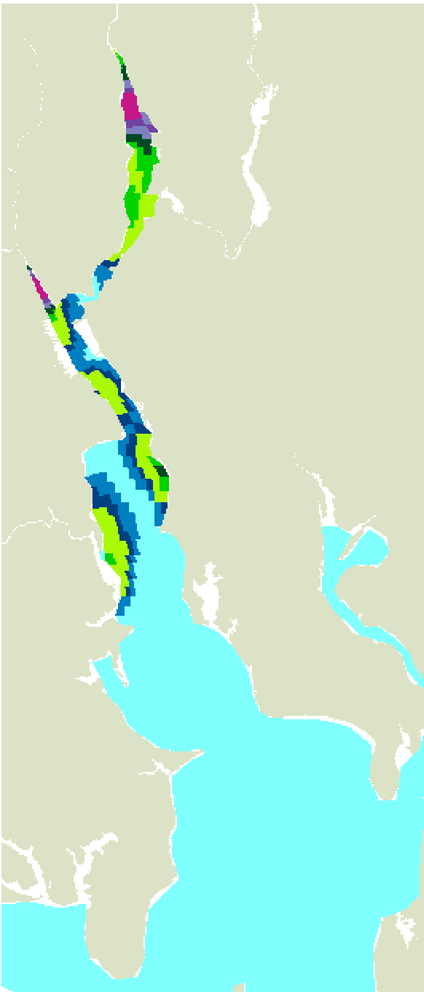
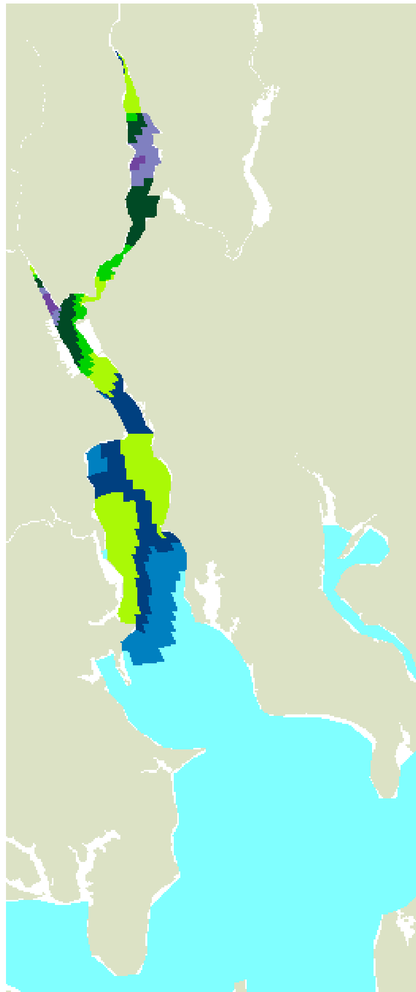
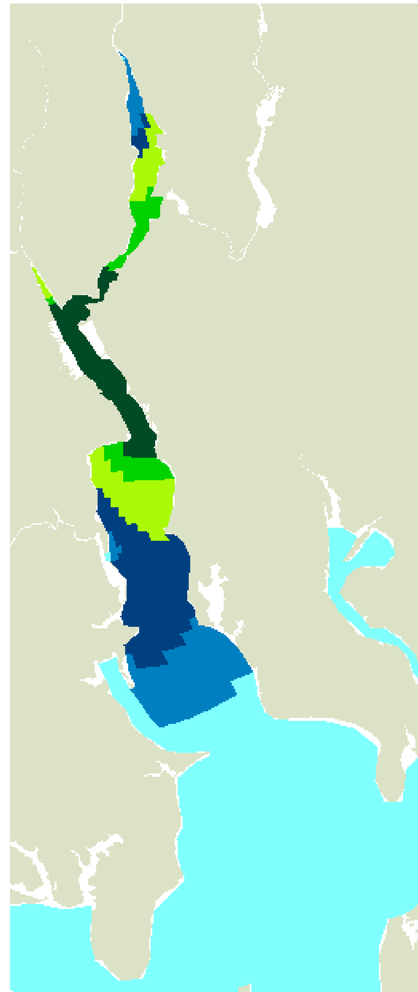
Outfalls 205-218, 0.5 days	Outfalls 205-218, 1 day	Outfalls 205-218, 2 days
		

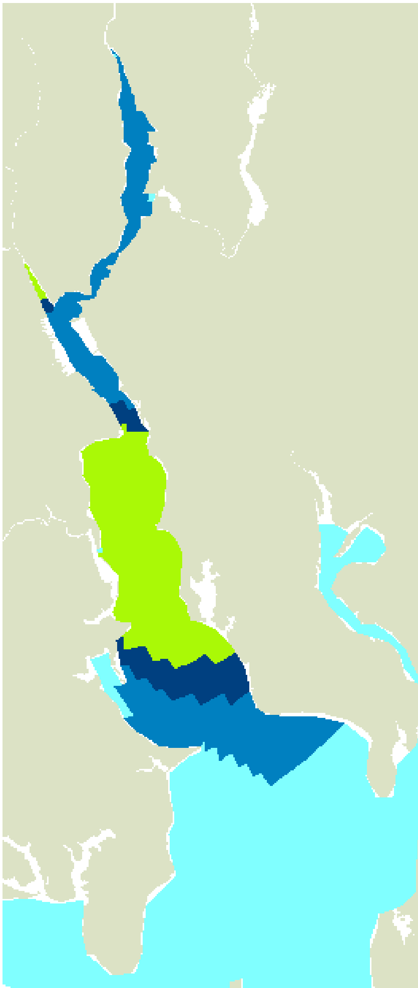
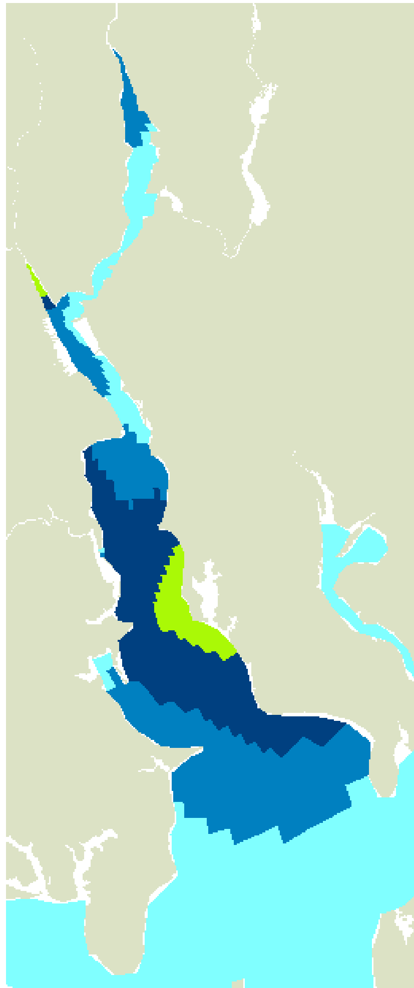
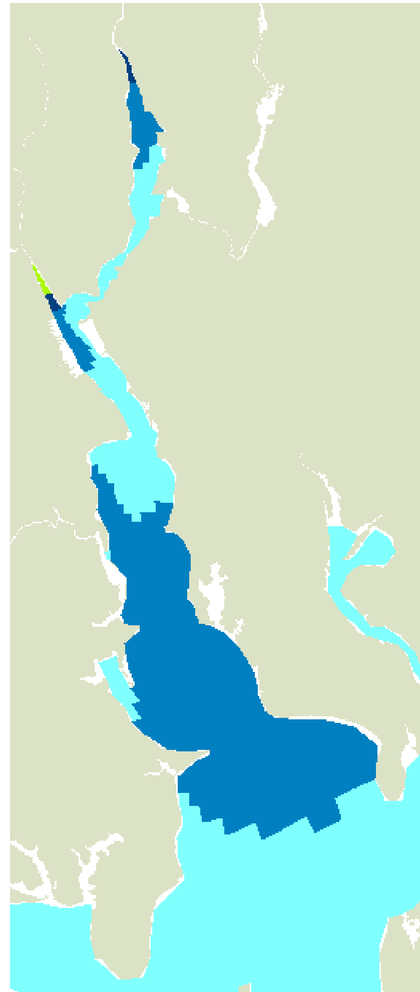
Outfalls 205-218, 4 days	Outfalls 205-218, 6 days	Outfalls 205-218, 8 days
		

Outfall 220, 0.5 days	Outfall 220, 1 day	Outfall 220, 2 days
		

Outfall 220, 4 days	Outfall 220, 6 days	Outfall 220, 8 days
		

The last analysis was to determine the benefits of routing flow from 218, the largest outfall in the Phase III area, through the Bucklin Point wet weather treatment facility to use its full treatment capacity during wet weather. This is scenario 4 in Chapter 3. Compared to current conditions, only very slight improvements in the days following the storm were predicted. Therefore, it was concluded that this concept was not worth further consideration as part of any alternative plan.

Outfall 218/BPWWTF, 0.5 days	Outfall 218/BPWWTF, 1 day	Outfall 218/BPWWTF, 2 days
		

Outfall 218/BPWWTF, 4 days	Outfall 218/BPWWTF, 6 days	Outfall 218/BPWWTF, 8 days
		

As discussed at the conclusion of Chapter 5, the construction of a near surface storage tank at the BPWWTF for storage and treatment is technically feasible. The hydraulic model was used to predict the maximum volume that could be conveyed to that location from the outfalls on the Seekonk and Blackstone Rivers by a new interceptor. The stored, treated and untreated overflow volumes from the hydraulic model were used as inputs to the water quality model. This was Scenario 5 in Chapter 3. Because the water quality improvements were significantly better than routing Outfall 218 only through the existing BPWWTF wet weather treatment facilities, this alternative was kept for further evaluation.

6.3. Integrated Planning Framework Analysis

As discussed in Chapter 1, the EPA's Integrated Planning Framework (IPF) provides the flexibility to implement the most cost-effective CWA solutions in a sequence which will prioritize projects among CSO control, stormwater management, wastewater collection and treatment systems. The integrated planning approach does not lower compliance standards.

Instead, it allows agencies to consider a municipal/utility owner's financial capability for meeting all CWA requirements and prioritizing infrastructure improvements.

Applying the IPF to this reevaluation effort requires consideration of the CSO projects, other NBC capital improvement needs for its interceptor and treatment facilities and collection system and stormwater management projects that are currently the responsibility of the member communities. Evaluation of the non-CSO NBC capital improvement plan indicates that the projects contained within are generally upgrades and replacement of aging equipment that is critical to the continuing operation of NBC's assets. Moreover, the costs associated with those projects were minimal compared to the potential CSO projects. Consequently, those projects were presumed critical to continued operations and excluded from the IPF evaluation. The IPF evaluation only considered NBC CSO projects and the needs of member communities to improve their collection systems and to manage stormwater.

Appendix 1 provides a detailed accounting of the current operations and maintenance practices, capital improvement plans, and condition assessments of each of the member communities for their sewer collection systems and stormwater management. The administration and scale of each of the member community's plans for operations and improvements to their systems varies, with some communities funding work through the general tax base and others having dedicated enterprise funds.

With the exception of East Providence, which just completed upgrades to its treatment facility, most communities are focused nearly exclusively on operations and maintenance and none have a significant capital improvement plan for their sewer collection systems. Therefore at present, none of the member communities have identified collection system improvement projects that could be specifically evaluated against the CSO program in the context of the IPF, however, the reevaluation did include estimates of necessary improvements. Significant investments will need to be made to the collection systems in Providence, Pawtucket and Central Falls where the majority of the combined systems are over a hundred years old and have not been maintained. As presented in Chapter 1, the estimated annual cost for the needed improvements to the local systems is $21.2M. Legislation has been introduced in the R.I. General Assembly in the last two years that could result in NBC taking over the local sewer systems. Should this legislation pass, NBC may incur the costs associated with making those improvements to the local sewer systems which could have a significant effect on NBC user rates.

Similarly, while some initial planning efforts are underway in advance of the anticipated stormwater control rules, there are no discrete stormwater improvement projects that could be specifically evaluated against the CSO program at this time. Therefore, to facilitate an initial IPF evaluation, the reevaluation effort included an estimate of what those investments could total given the extent of each community's separate stormwater system. As presented in Appendix 1 and summarized in Chapter 1, for the Service Area those costs could result in $5.1M in projects per year. Most of those projects would be to replace pipes and to alleviate flooding.

Bacteria is the primary contaminant of concern for CSO's and, as discussed in Chapter 3 and summarized in Table 6-3, CSOs are the primary source of the bacterial loading to the Bay.

Table 6-3 – Summary of Bacterial Loading

Source	Bacterial Load Concentration	% of Total Bacterial Load
CSO	240,000	89
WWTF's	4-40	0
Tributaries	200-2,000	3.9
Storm Sewers	10,000	6.6

Stormwater from separate storm sewers in Providence, Pawtucket and Central Falls and flow from tributaries contribute only a small percentage of the bacterial loading. The Phase III CSO plan would result in a significant reduction in bacterial loadings. A comparison of the ratings of the stormwater and CSO programs using the evaluation criteria discussed in Chapter 5 is shown in Table 6-4.

Table 6-4 – Comparison of Stormwater and CSO Program

Evaluation Criteria	Stormwater Program	CSO Program	Weighting	Factor
Environmental Criteria			**35%**	
Water quality (bacteria) impacts	1	10	40%	14.00%
Water quality (nutrients) impacts	6	6	20%	7.00%
Flooding risks from stormwater systems	7	7	20%	7.00%
Scalability & adaptability	6	6	20%	7.00%
Economic Criteria			**30%**	
Capital costs	8	5	45%	13.50%
Operations & Maintenance costs	3	6	25%	7.50%
Constructability / Construction-phase risks	2	2	10%	3.00%
Cost per gallon captured	2	7	10%	3.00%
Operational flexibility for optimization	4	7	10%	3.00%
Social Criteria			**18%**	
Fishable, shellfishable & swimmable waters	1	8	35%	6.30%
Co-benefits & quality of life	7	6	25%	4.50%
Operations & maintenance impacts and risks	5	4	20%	3.60%
Construction-phase disruptions	3	2	20%	3.60%
Implementation Criteria			**17%**	
Administrative / Institutional considerations	5	5	40%	6.80%
System reliability / Operational robustness	7	7	30%	5.10%
Climate change resiliency & recovery	6	6	30%	5.10%
Weighted Score	**4.68**	**6.33**		

The ratings and the bacterial loading percentages indicate that the CSO program is a higher priority than stormwater. However, because the benefits of stormwater mitigation projects are often very localized, it is possible that over time, individual stormwater projects could be identified that are of high priority. And although not rated by the evaluation criteria or a source of bacterial loadings, maintenance of local sewer infrastructure is a high priority because of its impact on public health. In order to provide resources to any one of these three programs as needed, an adaptive management approach will need to be implemented.

6.4. Phase III CSO Program Alternatives

6.4.1. Evaluation of Alternative Plans

Based on the subsystems analysis in Chapter 5, the affordability goals in Chapter 1 and the water quality sensitivity analysis in this chapter, four alternatives were developed for further evaluation. These alternatives are:

- Alternative 1: Baseline CDRA – Currently Approved Plan
  - One phase
  - Complete 2025
- Alternative 2: Modified Baseline with Phased Implementation
  - Four phases
  - Complete 2038
- Alternative 3: Modified Baseline with Extended Schedule & Interim Water Quality Projects
  - Six phases
  - Complete 2047
- Alternative 4: Bucklin Point Wastewater Treatment Facility Storage & Treatment
  - Four phases
  - Complete 2038

The first three alternatives all satisfy the design objective in the CDRA to capture the CSO volume produced by a 3-month design storm. This is consistent with the EPA's presumptive approach that restricts overflows to no more than four events in a typical year. Alternative 4 does not achieve that goal but was evaluated to determine the impacts of a lower cost, no tunnel alternative. A full sewer separation was considered but eliminated due to high cost and disruption during construction.

The following sections introduce and provide a general overview of the four alternative plans.

6.4.2. Alternative 1: Baseline CDRA

The currently approved Phase III plan was defined by the 1998 Comprehensive Design Report Amendment (CDRA). That report and the Consent Agreement (CA) between NBC and DEM establish Phase III as a single phase, which would be administered by submitting preliminary designs to DEM for review within one year of the completion of Phase II. Following DEM approval of the preliminary design plans, NBC would complete and submit final design plans to DEM for review. Once approved, all of the projects within Phase III would be bid, and the intent of the CDRA and CA was to construct the facilities as quickly as possible. The December 2010 Reaffirmation of the CDRA proposed an 8 year schedule for design and construction that would be completed in 2022. As part of this Reevaluation, an analysis of required design activities as well as a constructability and logistics analysis of the Phase III facilities was performed. That analysis concluded that an 11-year schedule would be more realistic and that Alternative 1 would adhere to the following schedule:

- 2015 – 2018: Regulatory Review, Design, Bidding
- 2019 – 2023: Construction of the Pawtucket Tunnel, OF 206 Sewer Separation, and the Pawtucket Avenue Interceptor

- 2024 – 2025: Construction of the High & Middle Street Interceptors, and the OF 035, 039, and 056 Sewer Separation.

Timeline of Costs, Benefits and Rate Increases

In 2015, an increase in customer rates is anticipated to accommodate the final costs associated with Phase II and other commitments not associated with Phase III. Additional rate increases will accommodate the Phase III design-phase costs in 2016 through 2018. In year five of the program, 2019, construction of the Pawtucket Tunnel could commence and continue through the end of 2023 when the elimination of the CSO volumes of OFs 204 through 218 would be achieved. The sewer separation for OF 206 would take place in 2020 realizing a CSO reduction at the end of that year. Construction of the Pawtucket Avenue Interceptor would begin in 2021 and finish at the end of 2023 when the CSO volumes from 220 and 107 would be eliminated. In 2024 and 2025, construction would shift to the interceptors that bring the northernmost OFs to the Tunnel as well as the remaining OFs in the FPSA in Providence, which will eliminate the remaining Phase III CSO volumes. The cost of that construction would require rate increases in every year of the program with the highest increases in 2021 through 2023 when construction is at its peak. Figure 6-2 illustrates the cumulative costs (in orange bars) and CSO volume reductions (in purple area graphs). Figure 6-3 shows the expected rate increases (in orange bars).

The projected sewer rate at the end of construction of Alternative 1 is $812.

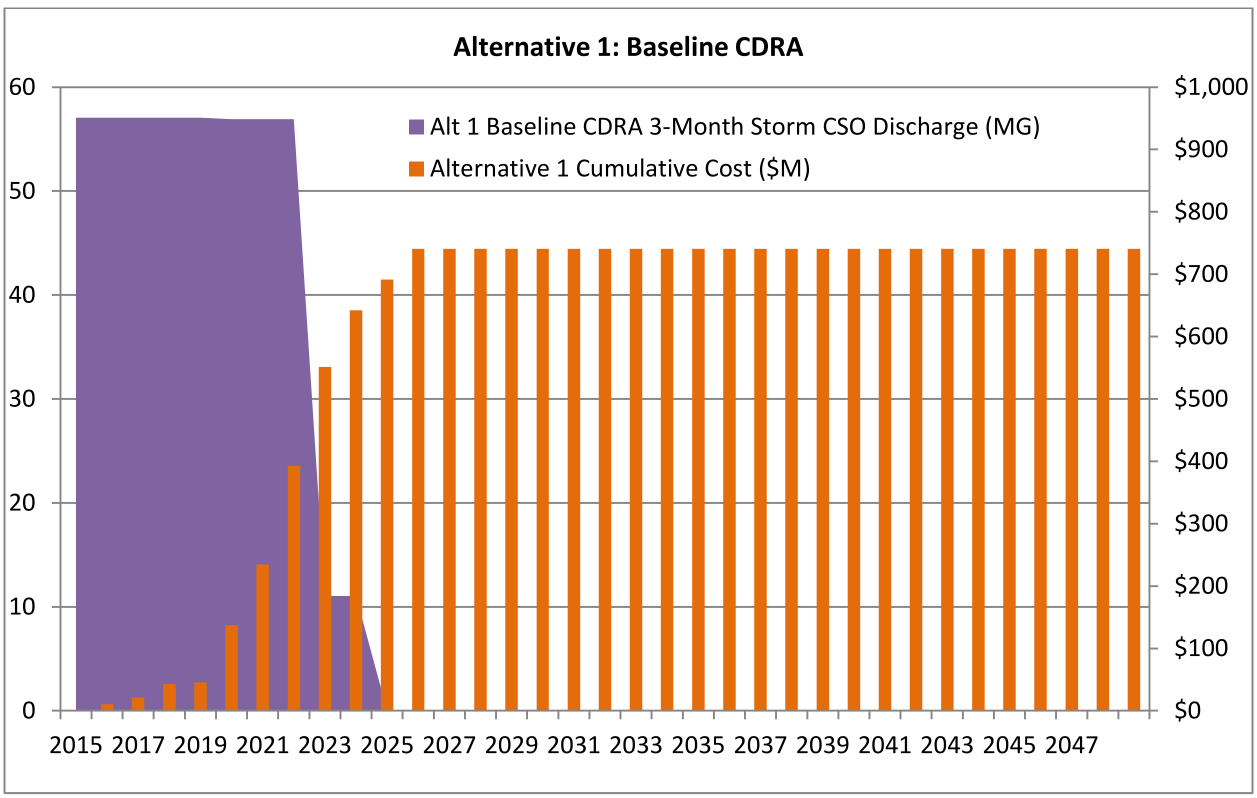


Figure 6-2 – Alternative 1 Cumulative Costs and CSO Volume Reductions

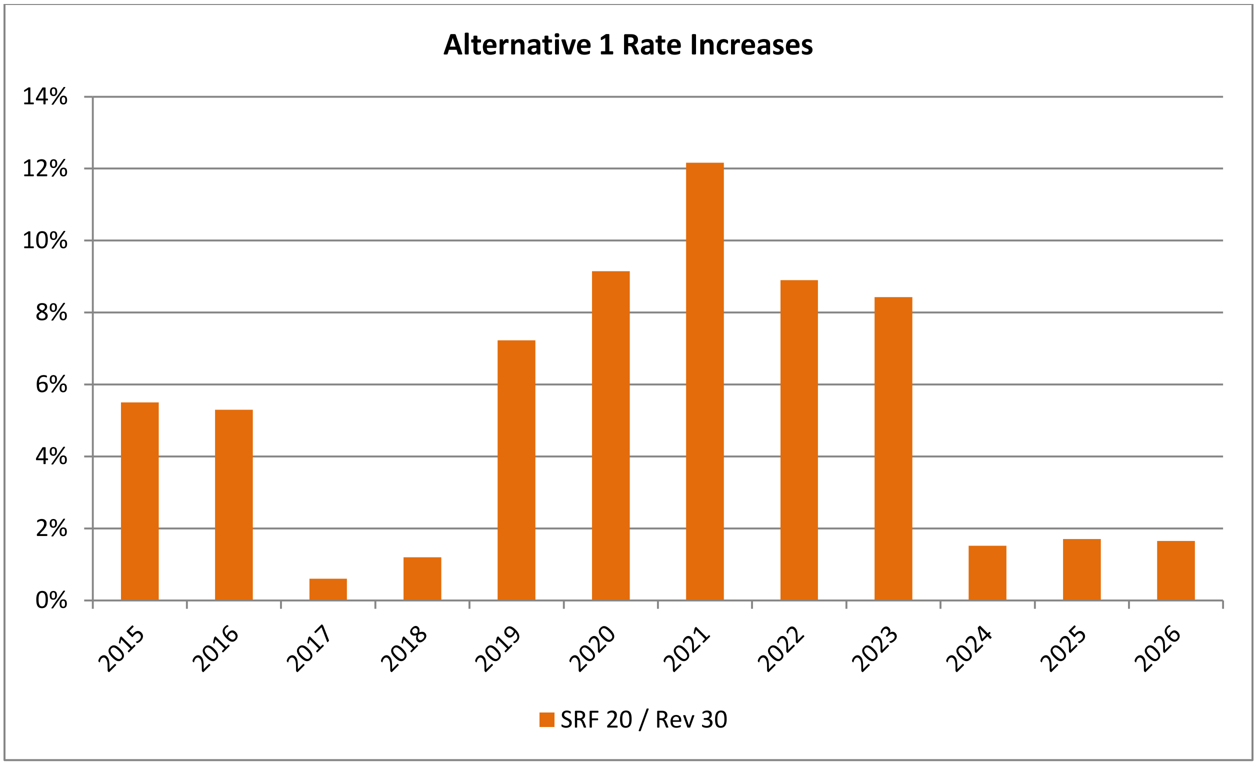


Figure 6-3 – Alternative 1 Annual Percentage Rate Adjustments

6.4.3. Alternative 2: Modified Baseline with Phased Implementation

The Subsystem Alternatives Analysis detailed in Chapter 4 concluded that many components of the Baseline CDRA Phase III plan remain the most preferred approach to CSO abatement, and it also concluded that for a few subsystems, alternate approaches would produce increased benefits for comparable costs. Therefore, the first characteristic of Alternative 2 is the modification of the components of Phase III to incorporate those revised and new elements, most notably, GSI. The second characteristic of Alternative 2 is the proposal of dividing the program into sub-phases. This subdivision has several bases:

- First, the quantity of construction in Phase III is approximately equivalent to Phases I and II combined; consequently, administering that volume of construction as one phase would present difficulties.
- Second, the logistics of how the interceptors relate and connect to the tunnel establish a basis for initiating design of the interceptors after the tunnel drop shafts are substantially complete to avoid redesign based on field changes.
- Third, the completion of an Integrated Plan that incorporates and prioritizes local sewer and stormwater projects was hampered by the lack of municipal capital improvement plans. The addition of sub-phases would establish a framework in which non-CSO projects developed over the next several years could be incorporated into an Integrated Plan.
- Fourth, the affordability analysis using the models discussed in this chapter indicate that Phase III and other Clean Water Act commitments may pose an affordability burden for

the NBC rate payers, particularly in the economically stressed areas of Central Falls, Providence and Pawtucket. Therefore, extending the schedule for Phase III may be necessary, and would be best accommodated by incorporation of sub-phases that will include reevaluation of the affordability of the program.

Component Prioritization and Sequencing

The evaluation and prioritization criteria, which were selected and weighted by the Stakeholder Group, were designed not only to facilitate the subsystem alternatives analysis, but also to prioritize any projects within the context of an Integrated Plan. Table 6-5 presents the scoring of the revised Phase III components against those criteria. Table 6-6 summarizes the key CSO volumes, costs and scores associated with each component.

Table 6-5 –Component Scores

Evaluation Criteria	Weighting Factor	Public Way GSI Projects 1 - 4	Public Way GSI Projects 5 - 8	035 Sewer Separation	West River Interceptor	206 Hybrid Sewer Separation	220 Stub Tunnel or NSS Tank	Pawtucket Tunnel (incl. DS & RM)	High Street Interceptor	Middle Street Interceptor
Environmental Criteria										
Water quality (bacteria) impacts	14.0%	4	3	5	6	2	8	10	9	7
Water quality (nutrients) impacts	7.0%	4	3	1	6	2	8	10	9	7
Flooding risks from stormwater systems	7.0%	7	7	0	6	8	5	5	5	5
Scalability & adaptability	7.0%	8	8	5	6	7	6	6	6	6
Economic Criteria										
Capital costs	13.5%	8	8	6	3	10	2	1	4	7
Operations & Maintenance costs	7.5%	3	3	6	7	8	4	1	8	10
Constructability / Construction-phase risks	3.0%	1	1	1	2	1	4	4	2	2
Cost per gallon captured	3.0%	3	1	6	2	4	7	8	10	9
Operational flexibility for optimization	3.0%	6	6	5	7	7	7	7	7	7
Social Criteria										
Fishable, shellfishable & swimmable waters	6.3%	4	3	5	6	2	8	10	9	7
Co-benefits & quality of life	4.5%	9	9	8	5	10	5	5	5	5
Operations & maintenance impacts and risks	3.6%	3	3	4	4	2	5	5	5	5
Construction-phase disruptions	3.6%	3	3	0	2	1	4	4	3	3
Implementation Criteria										
Administrative / Institutional considerations	6.8%	2	2	3	5	0	7	7	6	6
System reliability / Operational robustness	5.1%	3	3	7	7	2	8	8	7	7
Climate change resiliency & recovery	5.1%	6	6	5	6	6	7	7	6	6
Weighted Score		**4.96**	**4.63**	**4.38**	**5.18**	**4.87**	**5.85**	**6.07**	**6.52**	**6.50**
Score Ranking		**6**	**8**	**9**	**5**	**7**	**4**	**3**	**1**	**2**

Table 6-6 – Component Volumes, Costs and Ranking

	Volume Captured (Mgal)	Capital Cost $	Annual O&M Cost $	Cap Cost per Gallon Captured ($/gal)	Weighted Score	Score Ranking
Public Way GSI Projects 1 - 4	0.26	$10,000,000	$200,000	$38	4.96	**6**
Public Way GSI Projects 5 - 8	0.17	$10,000,000	$200,000	$58	4.63	**8**
035 Sewer Separation	0.87	$19,200,000	$12,500	$22	4.38	**9**
West River Interceptor	0.88	$38,400,000	$10,000	$44	5.18	**5**
206 Hybrid Sewer Separation	0.14	$4,700,000	$8,000	$34	4.87	**7**
220 Stub Tunnel	4.97	$93,000,000	$40,000	$19	5.85	**4**
Pawtucket Tunnel & Drop Shafts + Regulator Modifications	40.90	$577,300,000	$434,000	$14	6.07	**3**
High Street Interceptor	7.38	$23,700,000	$8,000	$3	6.52	**1**
Middle Street Interceptor	1.91	$15,400,000	$7,000	$8	6.50	**2**

Based on the evaluation, the High Street and Middle Street Interceptors are the highest priority projects based on the costs and benefits, followed closely by the Pawtucket Tunnel. However, logistically, those interceptors transfer flow to the tunnel for abatement; consequently, the tunnel must be constructed first. Therefore, based on the triple bottom line, the Pawtucket Tunnel would be designed and constructed as Phase A, after which the High Street and Middle Street Interceptors would be constructed at Phase B. Addressing OF 220 is the next highest priority; therefore either the 220 Stub Tunnel or a near surface storage tank for 220 would comprise Phase C. Finally, the lowest priority projects, the West River Interceptor and Sewer Separation for OF 035 both in the FPSA and both of which address relatively small volumes for higher costs, would be deferred to the final Phase D. The reevaluation concluded that GSI should be incorporated into the Phase III plan to increase benefits and reduce the design requirements of the corresponding grey infrastructure components. Therefore, $10M is allocated for GSI projects for each phase. GSI locations would be prioritized based on the analysis presented in Chapter 4. It is assumed that the Consent Agreement would be modified to allow the subdivision of Phase III and that the cycle requiring preliminary designs of subsequent phases to be submitted for review within one year following the completion of the previous phase would remain. The schedule for Alternative 2 would be as follows:

- 2015: Concept review and consent agreement modification
- 2016 - 2018: Phase A design, review and bidding
- 2019 – 2023: Phase A – Pawtucket Tunnel, Drop Shafts & Regulator Modifications; GSI in 212, 213, 214
- 2024 - 2025: Phase B design, review and bidding
- 2026 – 2028: Phase B – High & Cross Street Interceptor; Middle Street Interceptor; 206 Hybrid Separation; GSI in 101, 104, 105
- 2029 - 2030: Phase C design, review and bidding
- 2031 – 2033: Phase C – 220 Stub Tunnel; GSI in 216, 217
- 2034 - 2035: Phase D design, review and bidding
- 2036 – 2038: Phase D – West River Interceptor; 035 Separation; GSI in 201 thru 204

Timeline of Costs, Benefits and Rate Increases

As with Alternative 1, rate increases are anticipated in 2015 and 2016 to fund the Phase II closeout as well as non-CSO commitments. Those increases as well as modest increases in the subsequent two years will allow for design to commence. Rate increases would continue throughout the tunnel construction duration until 2023 when the tunnel is completed and the volumes associated with OFs 204 through 218 are abated. The only rate increase required for Phase B would coincide with the initiation of construction of the interceptors in 2026, the volume reduction of which would be realized at the end of 2028. The 220 Stub Tunnel would require rate increases in the early 2030's, which should be sufficient through the completion of the Alternative including Phase D. Figures 6-4 illustrates the cumulative costs (in blue bars) and CSO volume reductions over time (as a brown area graph). Figure 6-5 shows the expected rate increases (in blue bars).

The projected sewer rate at the end of construction of Alternative 2 is $769.

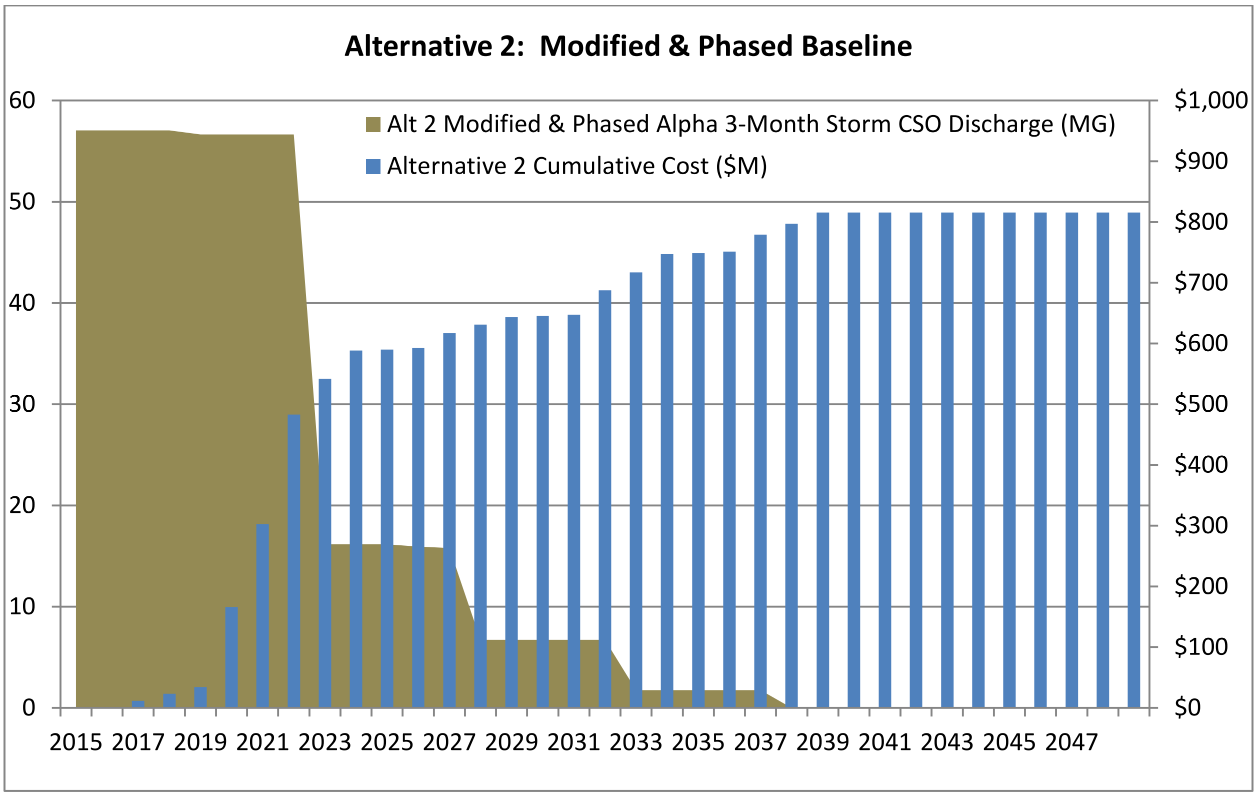


Figure 6-4 – Alternative 2 Cumulative Costs and CSO Volume Reductions

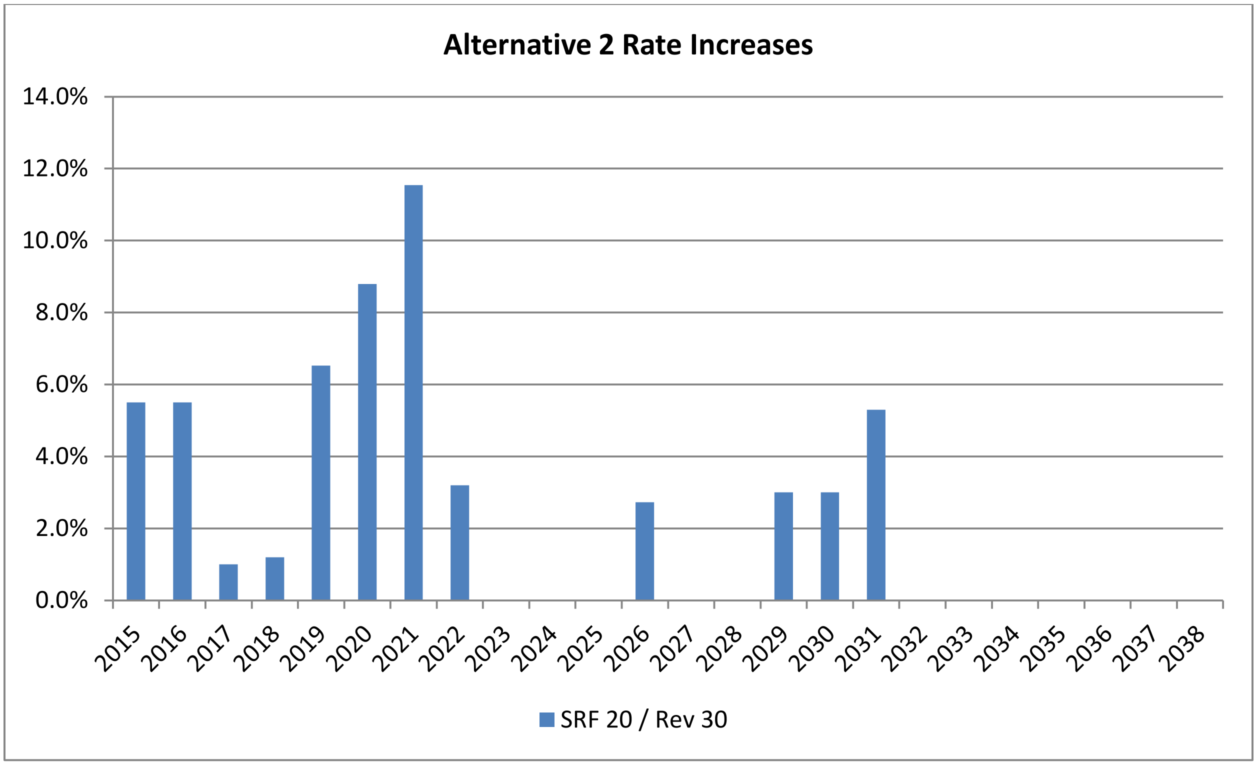


Figure 6-5 – Alternative 2 Annual Percentage Rate Adjustments

6.4.4. Alternative 3: Modified & Phased Baseline with Extended Schedule & Interim Water Quality Projects

Alternative 2 satisfied the objectives of subdividing Phase III into a more manageable program that could better incorporate technical, regulatory and financial changes into subsequent projects. However, the project prioritization based on the triple bottom line evaluation criteria resulted in sequencing the tunnel first. While the tunnel was recognized as having the largest water quality benefit and providing it at an efficient cost per gallon captured, throughout the Stakeholder process, it was recognized that the tunnel bore the highest cost and therefore caused concerns regarding the associated rate increases. While difficulties regarding siting and regulatory compliance had been highlighted, many Stakeholders had identified the potential for disinfection to improve water quality until the tunnel could be more affordable. Alternative 3, therefore, was developed to evaluate an option that would extend the overall schedule, defer tunnel construction to a later date, sequence other projects earlier, and include additional projects that would improve water quality in the interim.

Component Sequencing

From the list of modified Phase III projects, Phase A would involve the design and construction of the Hybrid GSI / Sewer Separation for OF 206, which would abate that outfall, and GSI for portions of the catchments to OFs 212, 213 and 214, which would reduce but not fully abate those CSOs. Phase A would also include an interim water quality improvement project by the construction of an interceptor from OF 218, the single largest volume outfall, to the Bucklin Point Wastewater Treatment Facility (BPWWTF). That interceptor would route flow to the existing BPWWTF wet weather facility for primary settling and disinfection. Further study would be required to determine the capacity of the existing wet weather facility to accommodate the flows or upgrades that would be required to treat additional flows. The routing of additional flows to the BPWWTF would also require regulatory review. However, the concept would be to provide water quality improvements until the tunnel could be constructed and provide the long-term solution for OF 218 volumes.

In terms of permanent CSO abatement projects, Phase B would consist entirely of GSI projects, and would target the construction of $10M of GSI per year. Phase B would also include an interim water quality improvement project consisting of the construction of a screening and disinfection facility for OF 220. That facility would require a treatability study as part of preliminary design and would also require regulatory review and permitting. The duration of Phase B could be extended until the tunnel was deemed affordable. The Phase B GSI projects would not likely abate any outfall in full, but would reduce CSO discharges to the Bay. For the purposes of evaluation, Phase B's duration was assumed to be two years for design and three years for construction.

Phase C would design and construct the Pawtucket Tunnel to abate OFs 204 through 218. This phase is analogous to Phase A of Alternative 2. Once the tunnel construction was complete, the routing of flows from the OF 218 through the BPWWTF would be discontinued.

Phase D would include additional GSI and construct the High Street and Middle Street Interceptors to connect OFs 101 through 105 plus 201 through 203 to the Pawtucket Tunnel. This is identical to Phase B of Alternative 2.

Phase E would include additional GSI and construct the West River Interceptor and the Sewer Separation for OF 035 in the FPSA. This is identical to Phase D of Alternative 2.

As the 220 Stub Tunnel is also an expensive solution, its construction would be deferred to Phase F. The construction is identical to Phase C of Alternative 2. Once the Stub Tunnel construction is complete, the interim screening and disinfection facility for 220 could be decommissioned or repurposed to provide treatment for storms larger than the 3-month storm.

The schedule for Alternative 3 would be as follows:

- 2015: Concept review
- 2016 - 2017: Phase A design, review and bidding
- 2018 – 2019: Phase A – 218-BPWWTF Wet Weather Interceptor; 206 Hybrid Separation; GSI in 212, 213, 214
- 2020 - 2021: Phase B design, review and bidding
- 2022 – 2024: Phase B – 220 Screening & Disinfection; GSI in 101, 104, 105, 216, 217, 201 thru 204 (Note: this phase could be extended)
- 2025 - 2027: Phase C design, review and bidding
- 2028 – 2032: Phase C – Pawtucket Tunnel, Drop Shafts & Regulator Modifications; GSI in 215 (218-BPWWTF off-line)
- 2033 - 2034: Phase D design, review and bidding
- 2035 – 2037: Phase D – High & Cross Street Interceptor; Middle Street Interceptor; GSI in 205
- 2038 - 2039: Phase E design, review and bidding
- 2040 – 2042: Phase E – West River Interceptor; 035 Separation; GSI in 205

- 2043 - 2044: Phase F design, review and bidding
- 2045 – 2047: Phase F – 220 Stub Tunnel; GSI in 205 (220 Disinfection off-line)

Timeline of Costs, Benefits and Rate Increases

As with the other Alternatives, rate increases are anticipated in the short-term for non-Phase III expenses. A series of small rate increases through 2023 are projected to be required to accommodate Phases A and B. Over those years, small decreases in untreated CSO volumes associated with the OF 206 Hybrid Sewer Separation and the GSI projects are anticipated; however those volumes are relatively small. In 2019, the temporary routing of OF 218 flows through the BPWWTF will result in treatment of CSO volumes. In 2024, the completion of the OF 220 screening and disinfection facility would provide treatment for additional CSO volumes. In 2028 through 2031, a series of larger rate increases will be required to fund tunnel construction, which when complete would capture the volumes from OFs 204 through 218 and allow the routing of 218 through the BPWWTF to cease. The rate increases associated with the tunnel are projected to generate sufficient funds to cover the construction of the northern interceptors and the FPSA CSO facilities that would reduce untreated discharges in 2037 and 2042 respectively. The construction of the 220 Stub tunnel would require rate increases in 2046 through 2048 and would capture the volume from OF 220, eliminating the need for the screening and disinfection facility there in 2048. Figures 6-6 illustrates the cumulative costs (green bars) and CSO volume reductions over time (as red area graphs) The volumes that would be treated by the OF 218 routing to the BPWWTF and the OF 220 screening and disinfection facility are represented by the lighter shade of red. The darker shade of red represents untreated CSO discharges. Figure 6-7 shows the expected rate increases (green bars).

The projected sewer rate at the end of construction of Alternative 3 is $776.

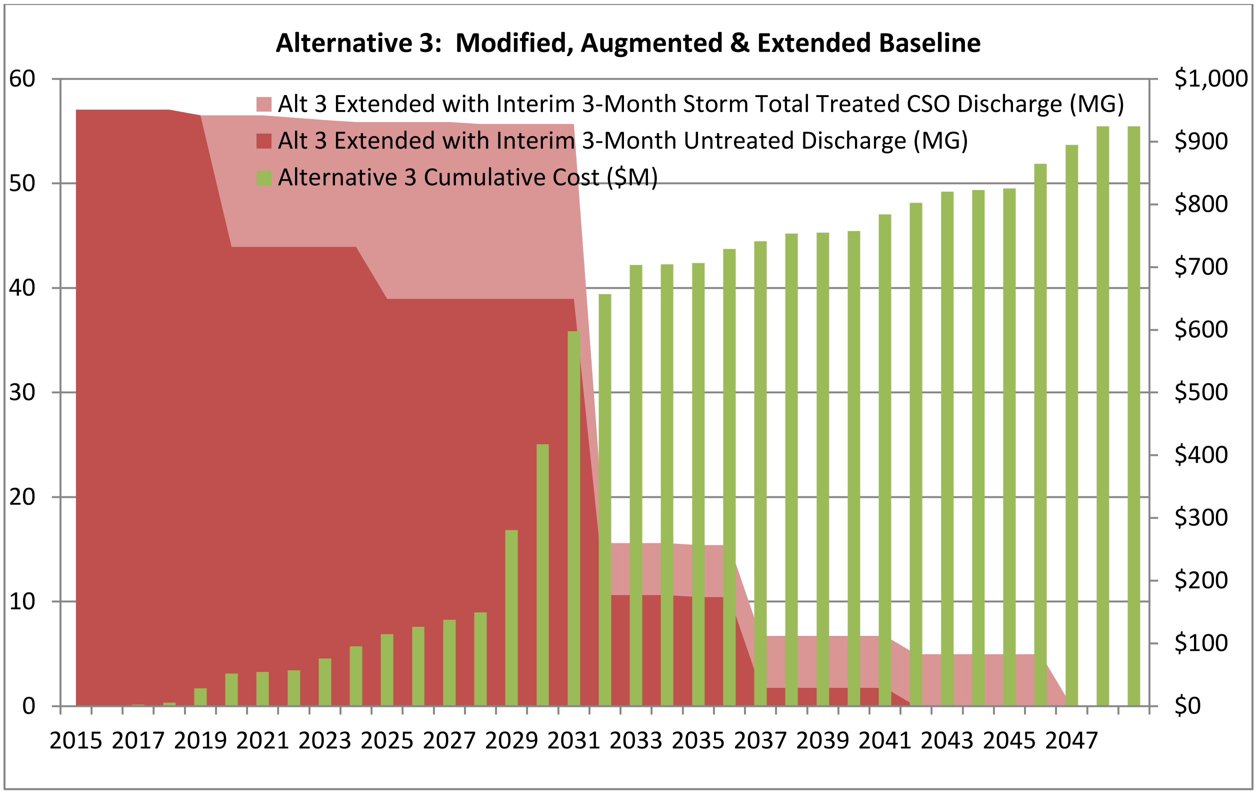


Figure 6-6 – Alternative 3 Cumulative Costs and CSO Volume Reductions

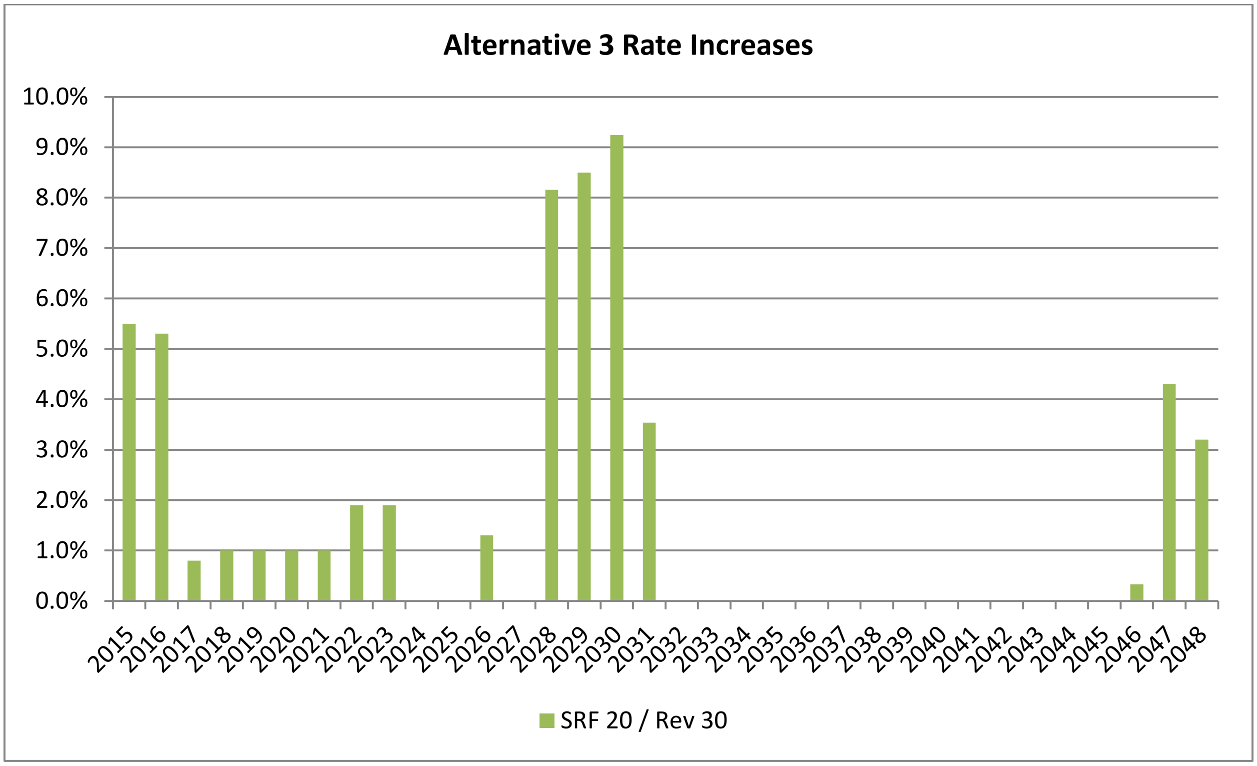


Figure 6-7 – Alternative 3 Annual Percentage Rate Adjustments

6.4.5. Alternative 4: Bucklin Point Wastewater Treatment Facility Storage & Treatment

The Alternatives Development and Subsystem Alternatives Analyses concluded that there is no technically feasible, cost-competitive alternative to the tunnel that would satisfy the same control requirements. Full sewer separation costs including construction, design and contingency would exceed $2B. Implementing GSI to the fullest extent technically feasible would not eliminate CSO volumes from the 3-month storm. Decentralizing storage by utilizing tanks in lieu of the tunnel was cost-prohibitive and infeasible due to the lack of candidate sites for the tanks required. Remote treatment options faced similar siting issues, would require an extensive regulatory review, and may not be ultimately permitted by RIDEM or EPA.

Alternative 3 was developed to address Stakeholder concerns related to the affordability of the tunnel by deferring that construction to a later date. However, a number of Stakeholders expressed interest in an alternative that did not include the tunnel at all, preferring to explore the water quality benefits that could be gained by less expensive treatment options. While there was an acknowledgement that a treatment-based alternative would not satisfy the same control criteria as the tunnel-based alternatives and would face a difficult regulatory approval process, it was decided to develop and include a non-tunnel alternative in this alternative plan analysis.

Components and Sequencing

The subsystem alternatives development and analysis presented in Chapters 3 and 4 were all predicated on the same assumption that abatement goals established during the previous conceptual planning efforts in the 1990s would remain the same. Namely, any selected alternative would provide the capacity to store or otherwise eliminate the CSO volume produced by a 3-month storm. The selection of that storm and definition of that volume are detailed in the CDR and CDRA, but are generally aligned with the presumptive approach outlined in the EPA CSO policy that establishes the goal of allowing no more than four overflow events during a typical year. Alternatives 1 through 3 all satisfy those parameters, but rely upon the tunnel to capture 95% of the design volume. While some of the subsystems of Alternative 4 bear resemblance to the revised baseline plan, the central component of the plan was conceived differently. The concept was to define the infrastructure that could reasonably be constructed given the constraints highlighted during the subsystem alternatives analysis and then determine the resulting level of CSO abatement. The following subsections detail those components.

Phase A – OF 218 Interceptor and BPWWTF Storage / Treatment Tank

The subsystem alternatives analysis concluded that a near-surface storage tank located near the BPWWTF with an interceptor to convey flows from OF 218 to that location was a technically feasible and cost-effective solution. Ultimately, the Pawtucket Tunnel proved to be a preferable solution for OF 218 and the only feasible solution for the other outfalls north of OF 218. However, an interceptor and near-surface storage/treatment represents a reasonable alternative. Additional investigations would be necessary to optimize the system, but for the purposes of evaluation, Phase A would consist of the construction of a 10-foot diameter interceptor from OF 218 to the BPWWTF, constructed by soft-ground micro-tunneling, plus a 14 million gallon near-surface storage/treatment tank. To increase the water quality benefits of the system, disinfection would be added to the new tank. Conceptually, for any storm producing less than 14 MG, the entire volume would be stored in the tank for subsequent pump-out and advanced treatment at the BPWWTF. When storms produced additional volumes, the storage tank would operate like a primary settling tank, and overflows would be disinfected prior to discharge so that the system would operate as a second wet weather facility at the BPWWTF.

Hydraulic modeling of the conceptual interceptor indicated that the 12.6 MG 3-month overflow from OF 218 could be conveyed to the tank. That volume would be stored in the tank and subsequently pumped to the BPWWTF for advanced treatment. Therefore Phase A would result in the elimination of that volume. Consistent with Alternatives 2 and 3, Phase A for Alternative 4 would also include a $10M GSI project.

Phase B – OF 218 to 205 Interceptor & 220 Storage / Treatment

The subsystem alternatives analysis concluded that either storage or disinfection facilities for OF 220 at Morley Field would present technical challenges and, more significantly, social impacts. Other sites in the area would require negotiations with property owners, but for the purposes of developing a non-tunnel alternative, it was assumed that a site could be procured and a storage / treatment facility similar to the one described above could be constructed. That facility was conceived to be a 3 MG tank that would pump to the existing Moshassuck Valley Interceptor after the storm for advanced treatment at the BPWWTF, and that would include a disinfection system to provide some level of treatment for larger volumes from larger storms.

Phase B would also include the extension of the interceptor from OF 218 to OF 205. Like the Phase A interceptor, it would conceptually be a 10-foot diameter interceptor, constructed by soft-ground micro-tunneling. That diameter is the limit for that type of construction. Larger diameter interceptors would require different construction methods and approach the level of complexity of the Pawtucket Tunnel and were therefore not considered. Hydraulic modeling of the conceptual interceptor indicated that during the 3-month storm, approximately 20 MG would be conveyed to the BPWWTF storage / treatment tank. When added to the Phase A volumes, this would result in a total of 14 MG being stored and approximately 18 MG receiving disinfection. Due to high peak flow rates, particularly from OF 205, the capacity of the interceptor would be exceeded and result in the discharge of approximately 8 MG of untreated CSO volume. As above, Phase B would include a GSI project that would reduce total CSO volumes.

Phase C – High and Middle Streets Interceptors

Continuing the extension of the storage / treatment system to the northernmost OFs, Phase C would incorporate the same interceptors defined in Alternative 2, Phase B. However, as those interceptors in Alternative 2 would discharge to the tunnel without limitation, for Alternative 4, those interceptors would connect to the 10-foot diameter interceptor described above. Hydraulic modeling indicated that the extension of these interceptors would result in only the conveyance of an additional 1 MG to the storage / treatment facility for the same capacity limitations discussed above. This would result in a discharge of approximately 9 MG of untreated CSO volume. As above, Phase C would include a GSI project that would reduce total CSO volumes.

Phase D – West River Interceptor and OF 035 Sewer Separation

Alternative 4's Phase D would be identical to Alternative 2's Phase D and Alternative 3's Phase E and would include the final abatement facilities in the FPSA as well as a GSI project in the Phase III area.

Conceptual Schedule

For the purposes of evaluation the following schedule was assumed for Alternative 4:

- 2015: Concept review and consent agreement modification
- 2016 - 2018: Phase A design, review and bidding
- 2019 – 2023: Phase A – 218 Interceptor, 14MG BP storage and treatment tank, GSI in 212, 213, 214
- 2024 - 2025: Phase B design, review and bidding
- 2026 – 2028: Phase B – 220 2.7 MG storage and treatment tank; 218 to 205 Interceptor; GSI in 101, 104, 105
- 2029 - 2030: Phase C design, review and bidding
- 2031 – 2033: Phase C – High & Cross Street Interceptor; Middle Street Interceptor; GSI in 216, 217
- 2034 - 2035: Phase D design, review and bidding
- 2036 – 2038: Phase D – West River Interceptor; 035 Separation; GSI in 201 thru 204

Timeline of Costs, Benefits and Rate Increases

As with the other Alternatives, rate increases are anticipated in the short-term for non-Phase III expenses, which would be followed by minimal rate increases to initiate Phase III. In 2020 and 2021 modest rate increases would be required to fund the interceptor and storage tank construction which would go on line in 2023 and produce a reduction in CSO volumes. Moderate rate increases would again be necessary in 2026 through 2028 to fund the interceptor extension that would result in a modest reduction in untreated CSO volumes and also facilitate the treatment of a sizable CSO volume. In preparation for Phase C and D, incremental rate increases would precede smaller reductions in CSO volumes. Figure 6-8 illustrates the cumulative costs and CSO volume reductions. The volumes that would be treated by the BPWWTF and OF 220 storage / treatment facilities are represented by the lighter shade of orange. The darker shade of orange represents untreated CSO discharges. Figure 6-9 shows the expected rate increases.

The projected sewer rate at the end of Alternative 4 is $627.

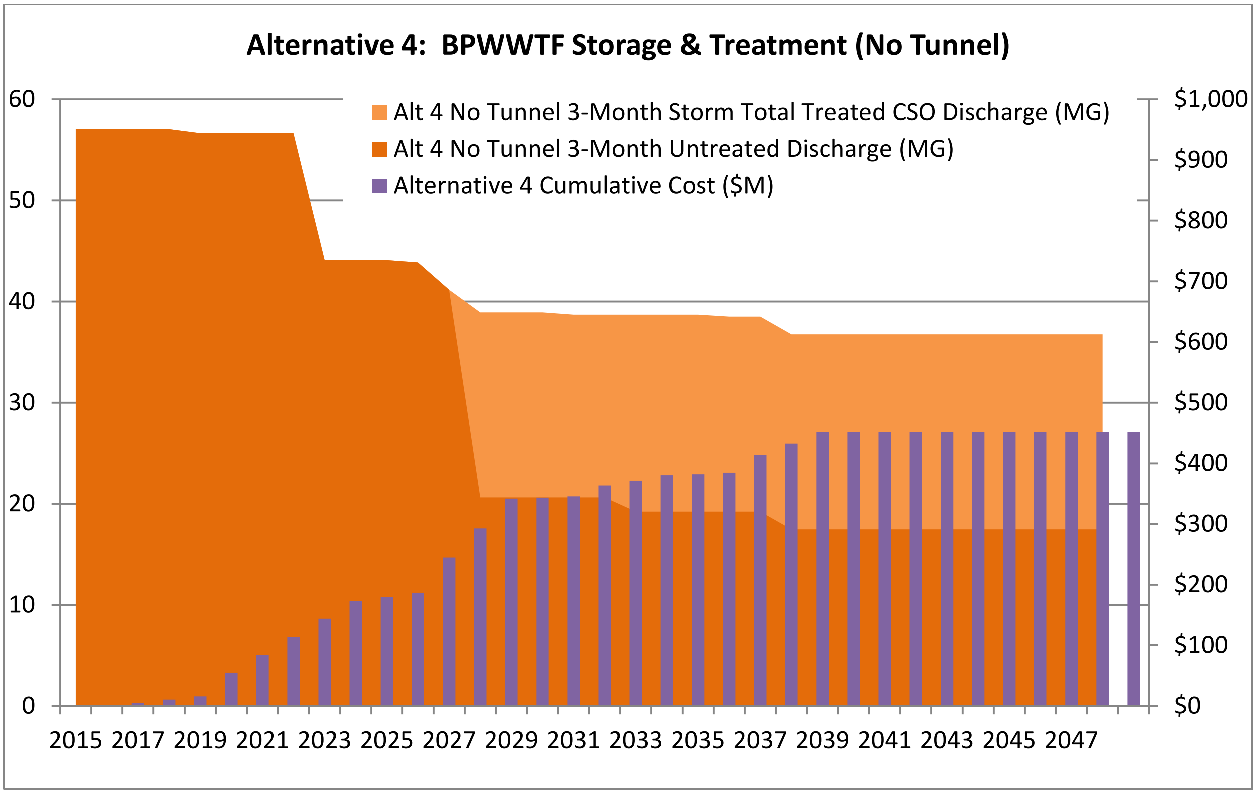


Figure 6-8 – Alternative 4 Cumulative Costs and CSO Volume Reductions

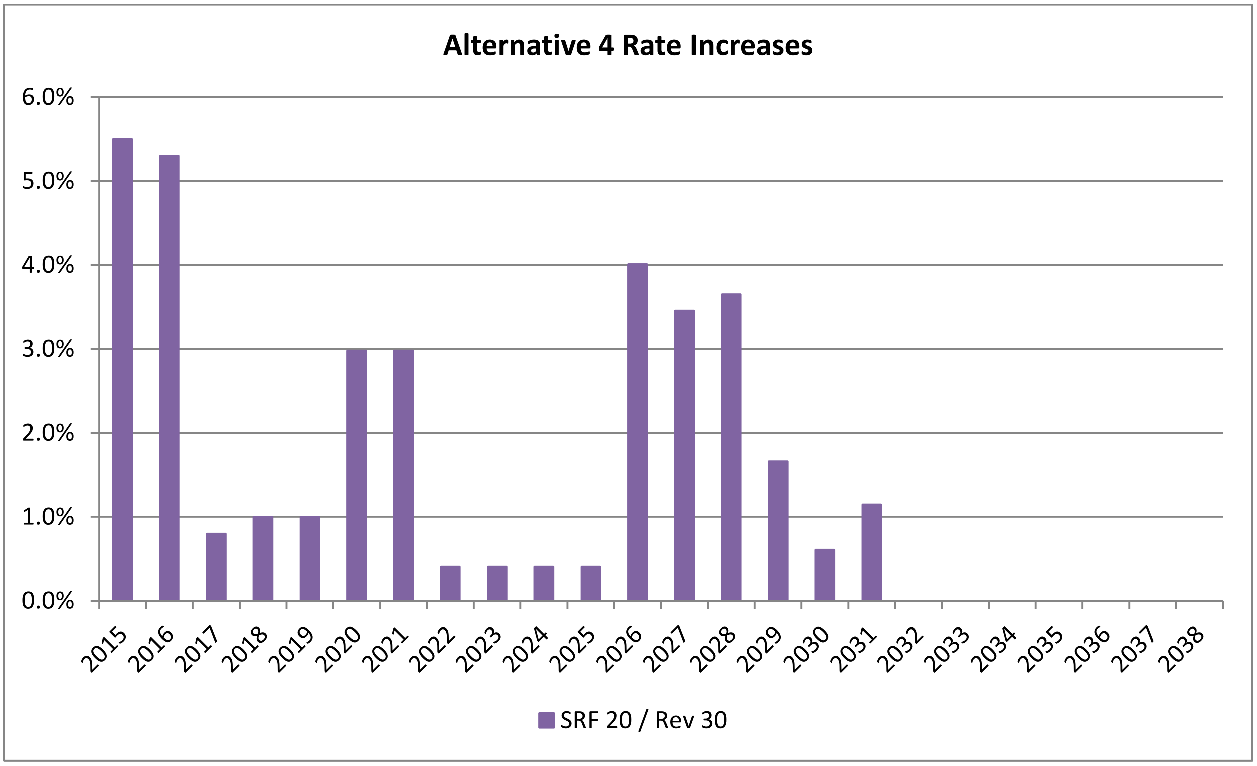


Figure 6-9 – Alternative 4 Annual Percentage Rate Adjustments

6.5. Cost, Rate and Affordability Comparisons

The following subsections discuss the costs, average residential bills and affordability of the four alternatives.

6.5.1. Total Program Cost

As illustrated in Figure 6-10, Alternative 4 is the least expensive option. The estimated costs associated with Alternative 4 would accumulate gradually to a total $450M by the end of 2038. The Alternative 1 cost would accumulate rapidly to a total of $750M by the end of 2025. Alternative 1 does not include GSI or the OF 220 Stub Tunnel as do Alternatives 2 and 3. If they were to be included, those costs would increase to $820M. The schedule for Alternative 2 is 13 years longer than for Alternative 1 with completion in 2038. For alternative 2, costs would rise rapidly to $630M in 2028 when the tunnel is complete and then increase gradually for the remainder of the program. Due to the inclusion of additional interim water quality improvement projects, Alternative 3 bears the highest total cost but has the longest schedule. Costs would accumulate gradually until 2027 when the tunnel construction would begin and accumulate rapidly during tunnel construction to $703 by 2032. Costs would then accumulate gradually to $925M by 2047.

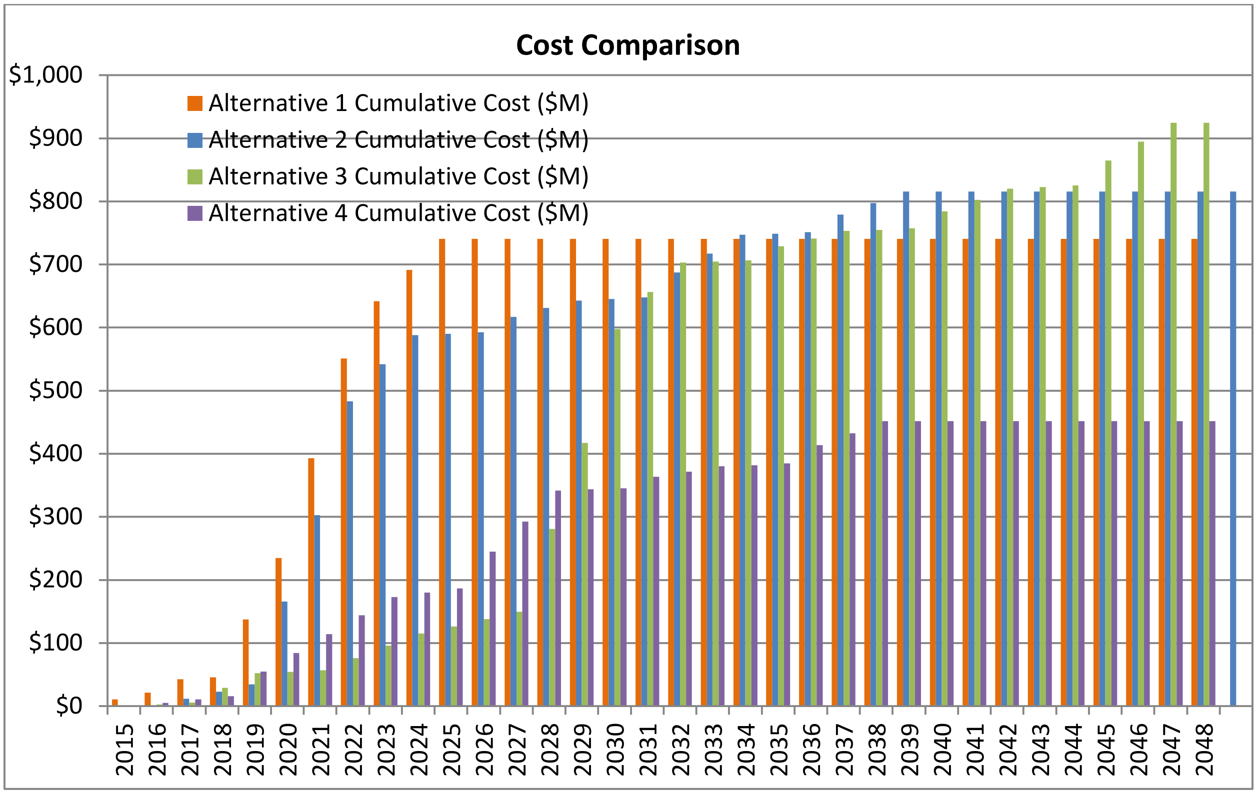


Figure 6-10 – Cumulative Cost Comparison

All of the costs discussed above are for Phase III capital expenditures only and are not inclusive of other NBC capital improvements or O&M costs. The costs are also held in constant dollars and do not include inflation or adjustments for financing costs in the future. Therefore, the further out on the timeline, the higher the uncertainty regarding the actual cost, as inflation and cost of capital will have greater variability. Because of its long schedule, the Alternative 3 cost estimate has the most uncertainty.

6.5.2. Average Residential Bills

Figure 6-11 illustrates the impact that the various alternatives are projected to have on average bills. Due to projected capital improvement expenses for Phase II, upgrades at the two treatment facilities, improvements to the interceptor system and other costs, rates are projected to increase even if no Phase III work proceeds. Those non-Phase III expenses are expected to increase the annual bill for the average household to $516 by 2031. Alternative 4 has the lowest rate impacts of the four alternatives with rates increasing gradually to $627 by 2031. Alternative 2 would require rapid increases in early years, followed by stepped increased to a high of $769 in 2031. By the end of construction in 2048, Alternative 3 would ultimately result in even higher bills of $776 by the end of its construction in 2048; however, it would succeed in keeping rates in line with Alternative 4 through 2028. Due to the high volume of simultaneous construction and the resulting need to issue bonds, Alternative 1 is the worst case for average annual household bills, increasing rapidly to $812 in 2026.

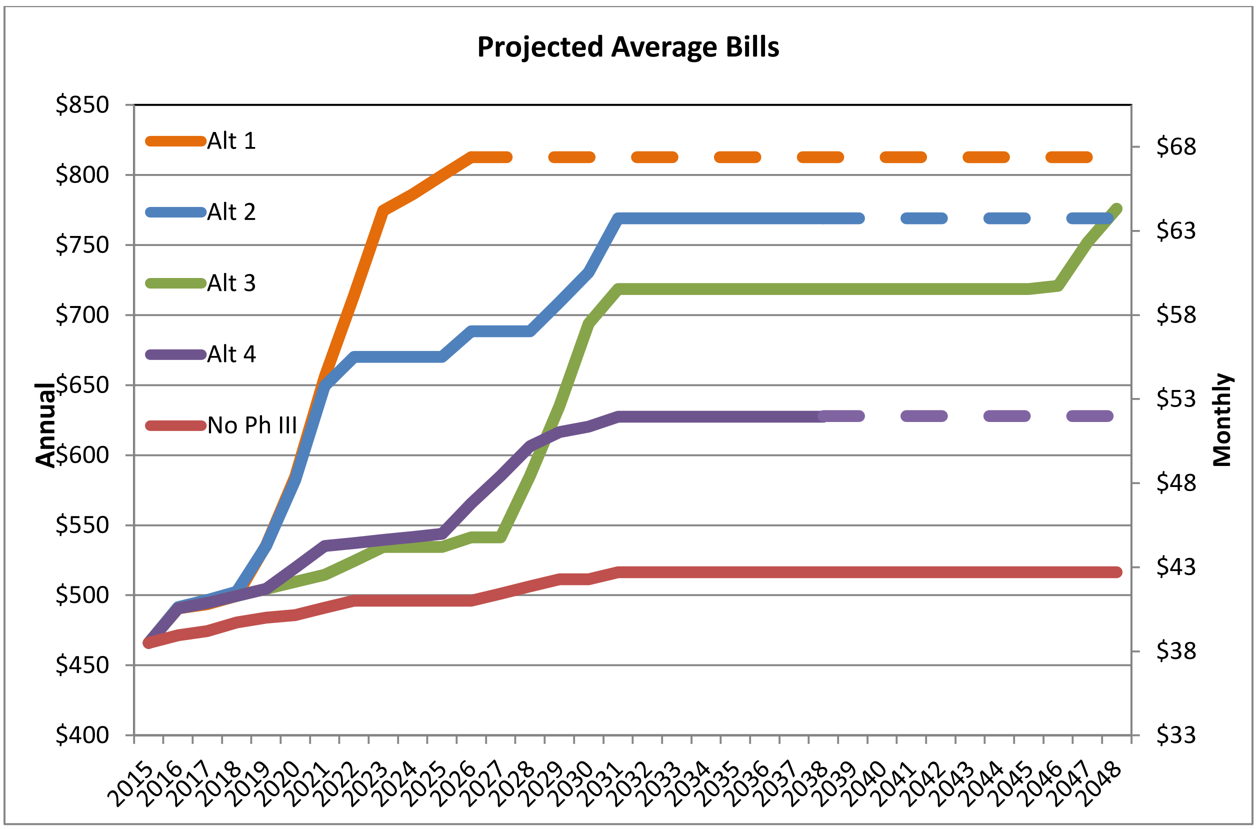


Figure 6-11 – Projected Average Bills

6.5.3. MHI Index Affordability – NBC Costs

As discussed in Chapter 1, the traditional 1997 EPA Phase I method of determining affordability would be to place these average household bills in the context of Median Household Income (MHI) for the entire NBC service area. For this analysis, only NBC costs are considered, including non-CSO capital improvements and continuing O&M costs. Figure 6-12 illustrates that all Alternatives are below the 2% MHI threshold that EPA considers High Burden. Increases in the index coincide with the rate increases discussed above. Rate increases are discounted for inflation over time to align future bills with the current MHI. Discounting for inflation provides a view of the projected affordability over time, while keeping MHI and projected average bills in today's dollars. For years in which rates do not increase or rates increase less than inflation, the affordability index improves (i.e. the percentage becomes a lower number) because the methodology assumes that as MHI increases, rates as a percent of MHI decrease. The affordability index improves following completion of construction or remains unchanged in years in which new debt is not required for construction.

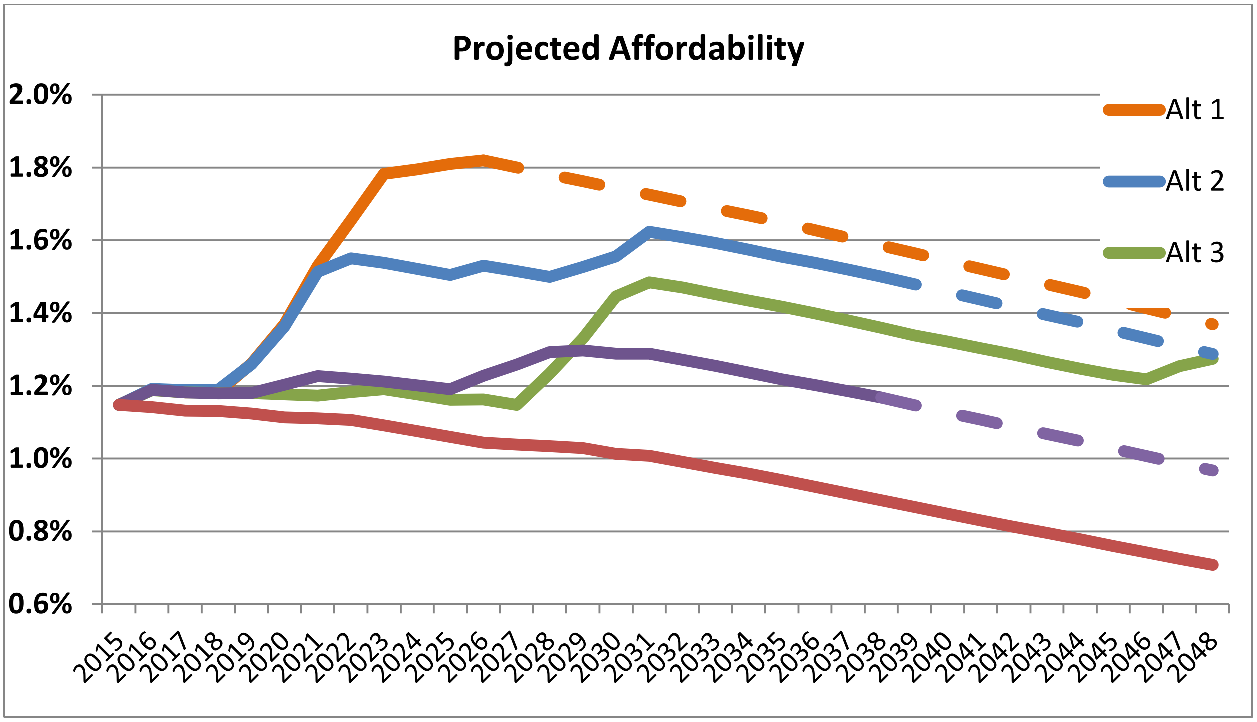


Figure 6-12 – Projected Affordability vs. 2% MHI, NBC Service Area, NBC Costs

However, as discussed in Chapter 1, recent guidance from EPA allows for the consideration of income distribution over a service area. The communities in the NBC district have a wide range of median incomes as illustrated in Table 6-7.

Table 6-7 – Median Household Income by Community

Municipality	NBC Accounts	MHI (2012$)	MHI (2014$)	2% MHI (2014$)
Providence	51,605	$38,243	$39,882	$798
Pawtucket	25,179	$40,383	$42,113	$842
North Providence	11,514	$50,939	$53,122	$1,062
Cumberland	7,455	$73,340	$76,483	$1,530
Johnston	6,221	$56,803	$59,237	$1,185
Lincoln	6,909	$75,445	$78,678	$1,574
Central Falls	5,823	$29,268	$30,522	$610
East Providence	3,760	$49,545	$51,668	$1,033
Cranston	149	$58,772	$61,290	$1,226
Smithfield	30	$72,546	$75,655	$1,513
Member Communities Totals & Weighted Average	118,645	$45,226	$47,164	$943

* Based on 2014 billing data

Central Falls is the most economically distressed of the member communities with a MHI 2% index of $610, and nearly all Phase III alternatives pose affordability issues for it. However, at nearly ten times the population of Central Falls and with an MHI 2% index of $798, Providence offers an interesting case study for how the different alternatives may impact a single community. Figure 6-13 illustrates that considering only NBC costs and the MHI of NBC's largest community, Alternative 1 exceeds the 2% affordability threshold. The extension of the Alternative 2 schedule prevents that alternative from crossing the 2% threshold, with the index reaching 1.9% at the end of the program.

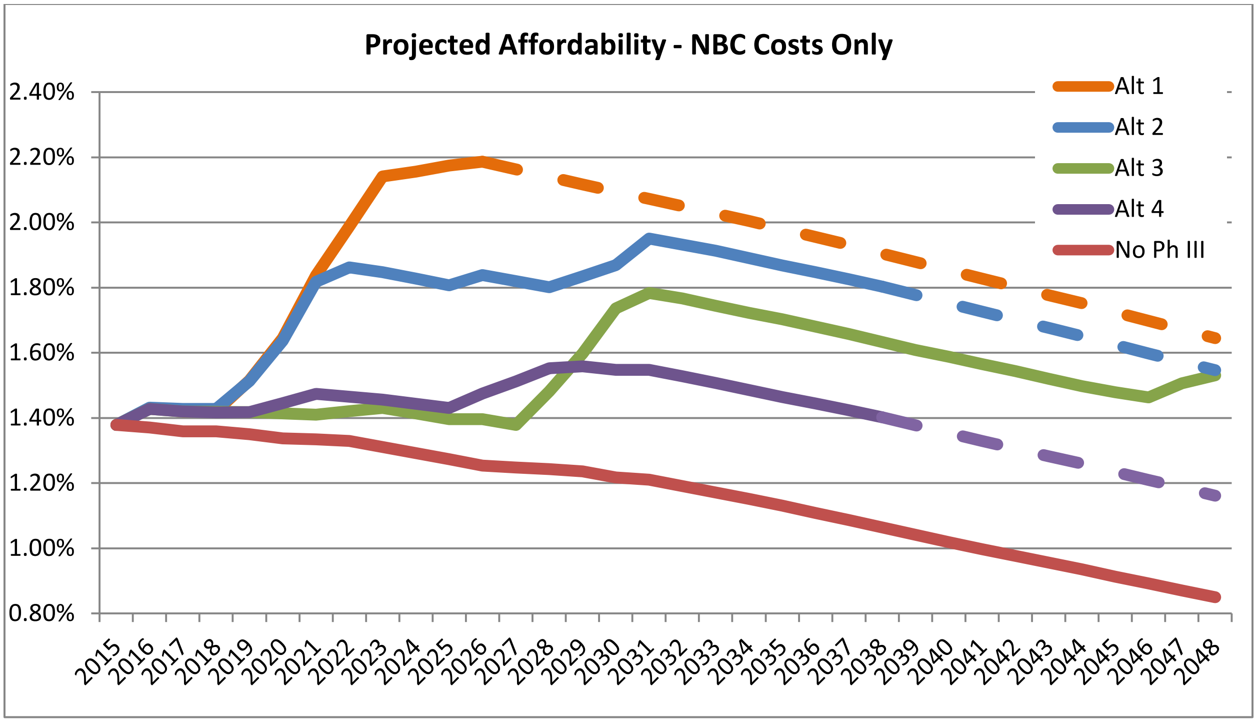


Figure 6-13 – Projected Affordability vs. 2% MHI, City of Providence, NBC Costs

This Providence-focused case study illustrates how each Alternative compares against the base affordability determinations described in Chapter 1. The large variability in income distribution throughout the service area skews the calculation of MHI. Considering only the City of Providence, where nearly half of the service area's population resides, Alternative 1 would present a heavy burden but the other alternatives would be medium burden.

6.5.4. MHI Index Affordability – Including Potential Providence Costs

The new guidance also allows for the consideration of Clean Water Act related expenses incurred by local communities within the NBC district. In this case, those costs would include any improvements the member communities need to make to their collection systems or to comply with the RIPDES/NPDES MS4 stormwater requirements. However, as detailed in Appendix 1, the member communities, particularly the Cities of Central Falls, Providence and Pawtucket, do not currently have capital improvement plans or expend substantial funds on such programs. Because of the relative size of the Providence sewer system compared to Central Falls or Pawtucket, Providence again serves as a good case study for the impact of increased spending on sewer infrastructure on Providence ratepayers. The projected annual expenditure of $8M on repairs and improvements to the collection system and $2M on stormwater mitigation projects would increase rates beyond the 2% MHI affordability limit for all the alternatives as shown in Figure 6-14.

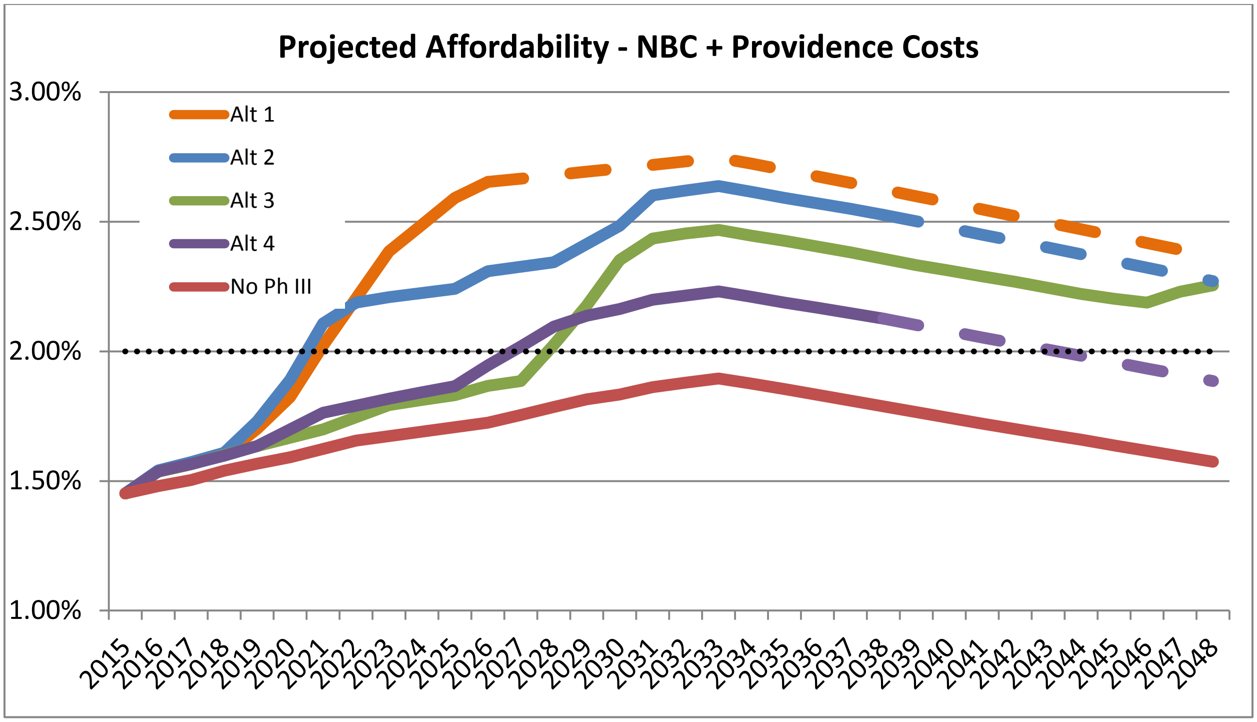


Figure 6-14 - Affordability vs. 2% MHI, City of Providence, NBC Costs + Collection System CIP

6.5.5. Financial Considerations Conclusion

The affordability analysis provided above shows that the projected rates for Alternatives 1, 2 and 3, assuming only NBC CSO costs, all exceed the affordability criterion to maintain NBC rates below $626. Alternative 4 meets this criterion. When the costs for necessary collection and stormwater system spending are added to the NBC costs, the impact on ratepayers is even greater.

The other criterion established at the beginning of this Chapter, that an adaptive management approach could be used, is met by all the alternatives but Alternative 1.

6.6. CSO Volume and Water Quality Comparisons

The following subsections discuss CSO volume reductions and expected water quality improvements for the four alternatives.

6.6.1. CSO Volume

Figure 6-15 compares the CSO volume reductions of the four alternatives. Alternative 1 achieves CSO abatement the fastest by capturing 80% of the total volume in 2023 and all of the design volume by the end of 2025. Alternative 2 moderately delays full achievement of the abatement, but achieves substantial completion within a rapid timeframe by capturing 72% of the flow in 2023, 88% of the volume by 2028, and the full design volume by the end of 2038. Alternative 3 significantly delays full abatement, only capturing 2% of the volume in 2025, 73% in 2035 and the full design volume by 2047. However, Alternative 3 would provide treatment for 22% of the

CSO volume from 2020 to 2025, 30% of the CSO volume from 2025 to 2035, and 9% of the volume for the remainder of the program. Alternative 4 never archives full abatement as defined by the CDRA and CA; however, it does capture 22% of the design volume in 2022 and ultimately 36% of the design volume by 2038. Alternative 4 also provides treatment for 33% of the CSO volume.

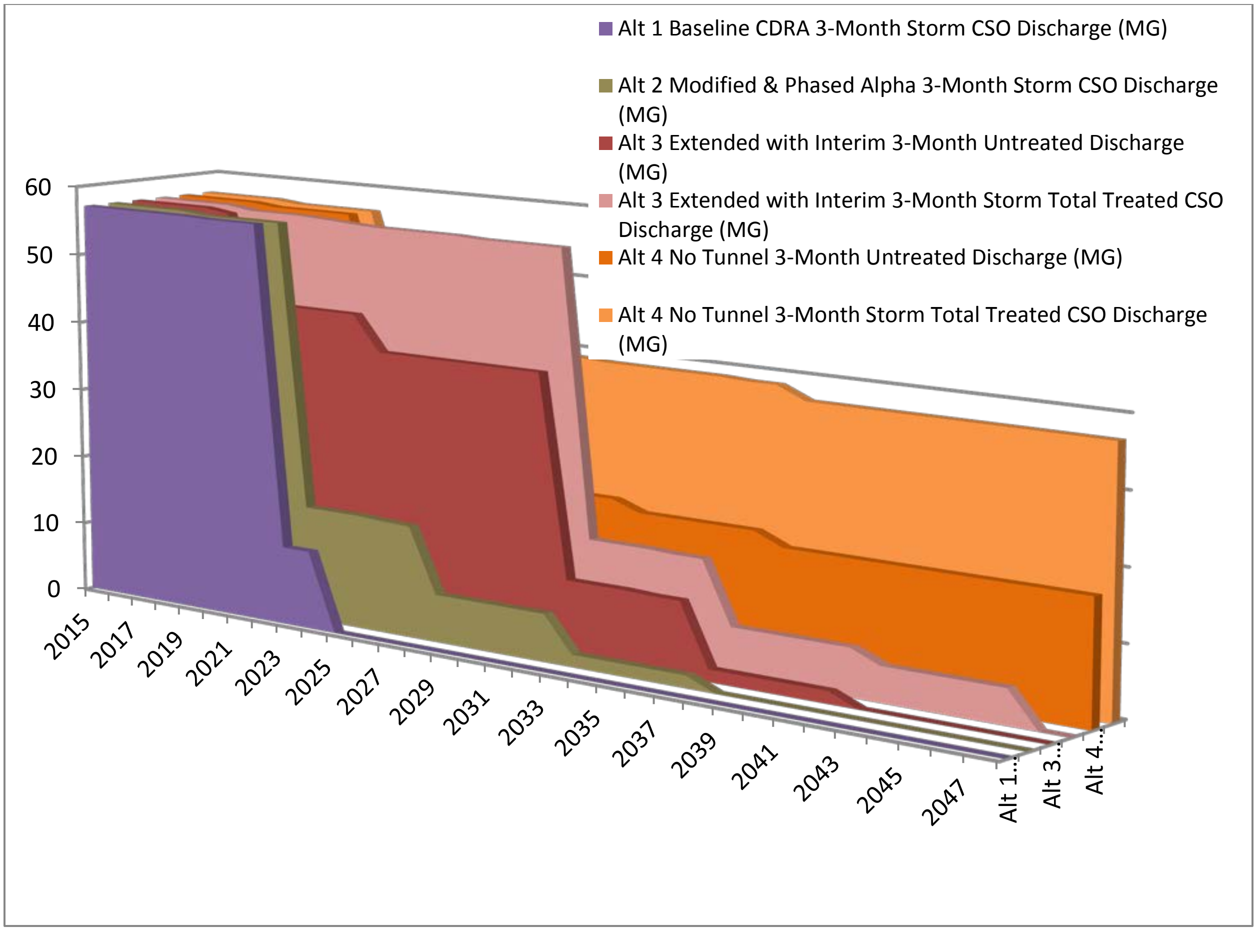


Figure 6-15 – CSO Volume Comparison

The analysis illustrates that Alternatives 1, 2 and 3 achieve the greatest CSO volume reductions.

6.6.2. Water Quality Model Results

As detailed in Appendix 4, the water quality model was used to predict fecal coliform concentrations throughout the Bay for a period extending 19 days following the design storm for a number of CSO control scenarios. Analysis of those model results at several locations throughout the Bay provide insights into how the CSO discharges for each of the Alternative Plans discussed above relate to water quality improvements and attainment of water quality standards.

Station 5 – The Narragansett Boating Center is located just downstream of the BPSA WWTF and is influenced by CSOs on the Blackstone and Seekonk Rivers. For this area, the recreational contact standards apply, therefore, the geomean of all samples taken at that location need to be below 50 Fecal Coliform (FC) per 100 mL and 90 percent of all samples need to be below 400 FC/100mL to meet standards. Figure 6-16 illustrates model results at the location. Under current, post-Phase II conditions, the model predicts peak concentrations of 7,640 FC/100mL and indicates that standards are exceeded continuously for 2 days. The model predicts that Alternative 4 would reduce the peak to 2,620 FC/100mL; however the exceedance period would only be modestly reduced from Phase II conditions. Full Phase III implementation of Alternatives 1, 2 or 3 would dramatically reduce the peak concentration to 980 FC/100mL, and reduce the exceedance period to 1 day. The lower peak and shorter duration would result in conditions that result in data significantly more compliant with the geomean and 90th percentile standards. It should be noted that for this scenario during the 3-month storm, all CSOs are controlled and any water quality violations are attributable to stormwater discharges and other discharges outside of the Phase III combined sewer area. Finally, the model was run for the tunnel-only scenario under which the CSOs that would connect to the High and Middle Street interceptors would remain active. That condition would be achieved in 2023 by Alternatives 1 and 2 and in 2032 by Alternative 3. The model predicts a peak concentration of 1,730 FC/100mL and an exceedance period of just under 2 days. Therefore, the construction of the tunnel reduces concentrations by 77 percent compared to Phase II and would statistically improve the geomean and 90th percentile standards.

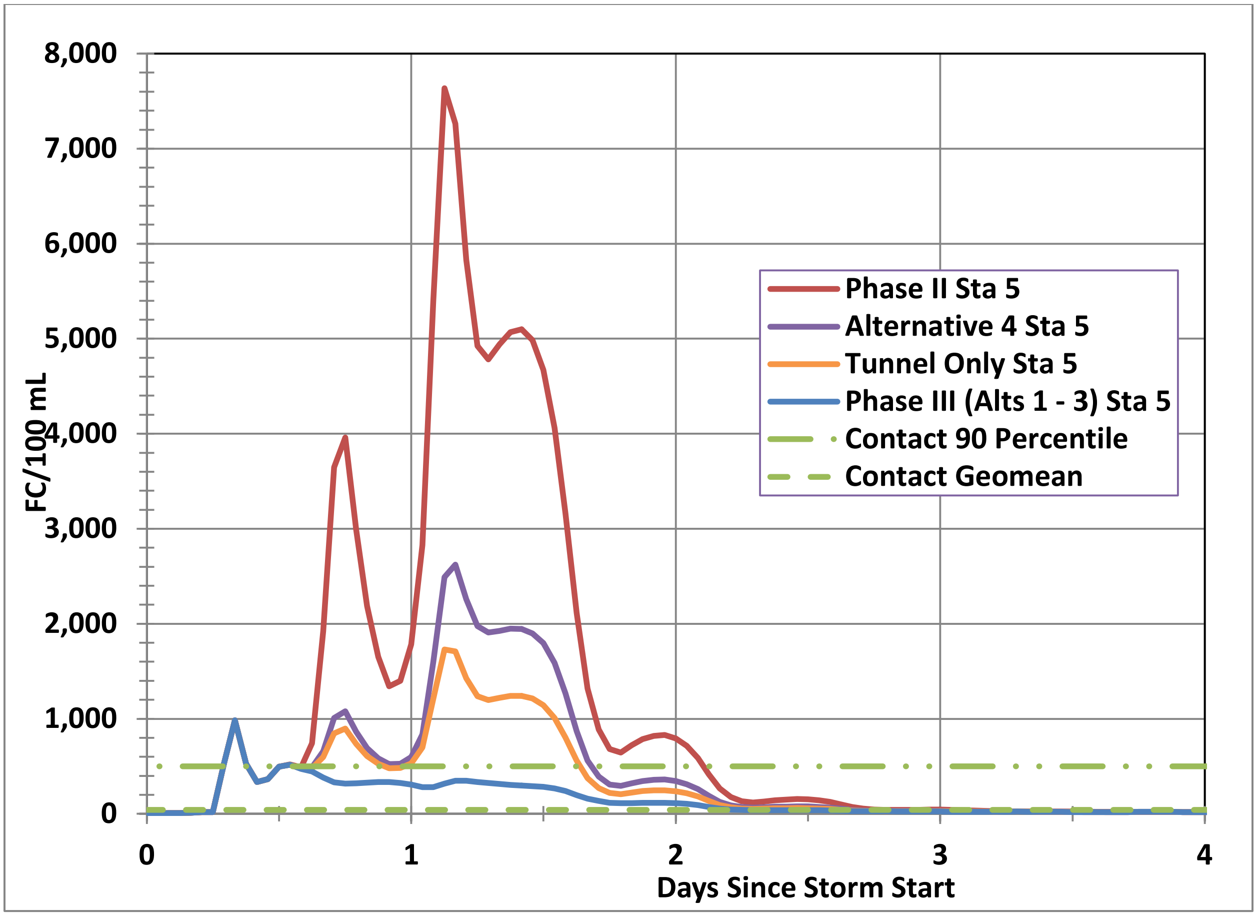


Figure 6-16 – Bacterial Concentrations at Narragansett Boating Center

The model results and existing data all indicate that water quality at the Narragansett Boating Center is typically impaired even during dry conditions. However, the current post-Phase II bacteria spikes are considerable, and all Phase III alternatives would significantly reduce those concentrations. Of the phased alternatives, Alternative 2 provides the best performance by realizing substantial improvements early in the program and ultimately realizing the best improvements that could be achieved before addressing other sources.

Station 13 – The Edgewood Yacht Club is located just downstream of the FPSA WWTF and is downstream of all Phase III CSOs. For this area, the recreational contact standards apply, therefore, the geomean of all samples taken at that location need to be below 50 Fecal Coliform (FC) per 100 mL and 90 percent of all samples need to be below 400 FC/100mL to meet standards. Figure 6-17 illustrates model results at the location. Under current, post-Phase II conditions, the model predicts peak concentrations of 1,590 FC/100mL and indicates that standards are exceeded continuously for 4 days. The model predicts that Alternative 4 would reduce the peak to 860 FC/100mL, and the exceedance period would be reduced to 3 days. Full Phase III implementation of Alternatives 1, 2 or 3 would dramatically reduce the peak concentration to 190 FC/100mL, meaning that water quality would continuously obtain contract standards. Finally, the model was run for the tunnel-only scenario under which all CSO other than OFs 204 through 218 would remain active. That condition would be achieved in 2023 by Alternatives 1 and 2 and in 2032 by Alternative 3. The model predicts a peak concentration of

780 FC/100mL and an exceedance period of just under 3 days. Therefore, the construction of the tunnel reduces concentrations by 50 percent compared to Phase II and would statistically improve the geomean and 90th percentile standards.

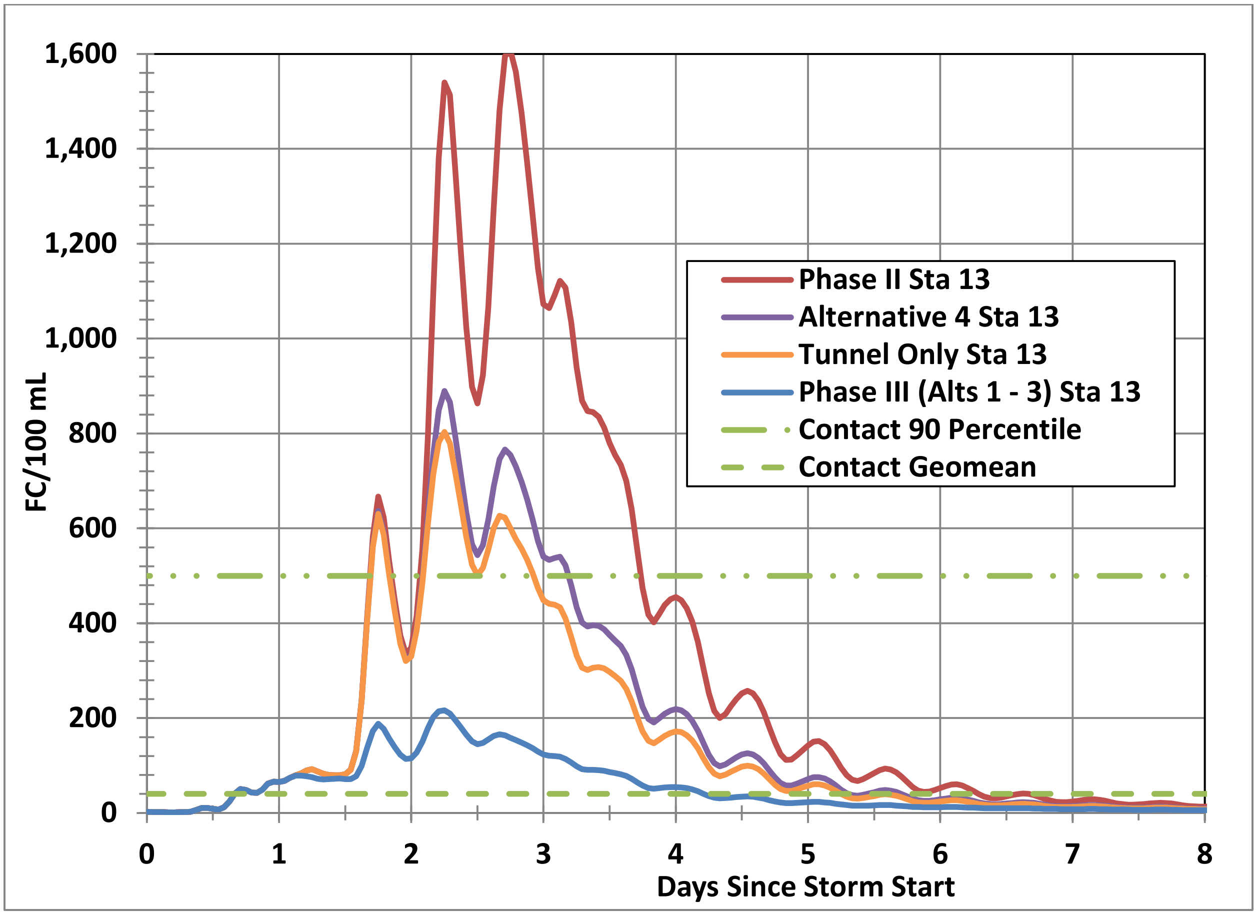


Figure 6-17 – Bacterial Concentrations at Edgewood Yacht Club

As with other locations, non-CSO loadings contribute to impairments at the Edgewood Yacht Club; however, the concentrations due to CSO discharges are nearly an order of magnitude greater. The model predicts that while Alternative 4 would produce improvements, the other alternatives perform much better.

For Station 20 – Conimicut Point, the shellfishing standards apply, therefore, the geomean of all samples taken at that location need to be below 14 Fecal Coliform (FC) per 100 mL and 90 percent of all samples need to be below 49 FC/100mL to meet standards. Figure 6-18 illustrates model results at the location. Under current, post-Phase II conditions, the model predicts peak concentrations of 100 FC/100mL and indicates that standards are exceeded continuously for 8 days due to the influence of the tides. The model predicts that Alternative 4 would reduce the peak to 60 FC/100mL; however the exceedance period would only be modestly reduced from Phase II conditions. Full Phase III implementation of Alternatives 1, 2 or 3 would dramatically reduce the peak concentration to 30 FC/100mL, which is below the 90th percentile standard, and reduce the exceedance period of the geomean standard to 4 days. The lower peak and shorter duration would result in conditions that result in data significantly more compliant with the geomean standards. It should be noted that for this scenario during the 3-month storm, all CSOs are controlled and any water quality violations are attributable to stormwater discharges and other discharges outside of the Phase III combined sewer area. Finally, the model was run for the tunnel-only scenario that would be achieved in 2023 by Alternatives 1 and 2 and in 2032 by Alternative 3. The model predicts a peak concentration of 50 FC/100mL and an exceedance period of 4 days. Therefore, the construction of the tunnel would statistically improve the geomean and 90th percentile standards.

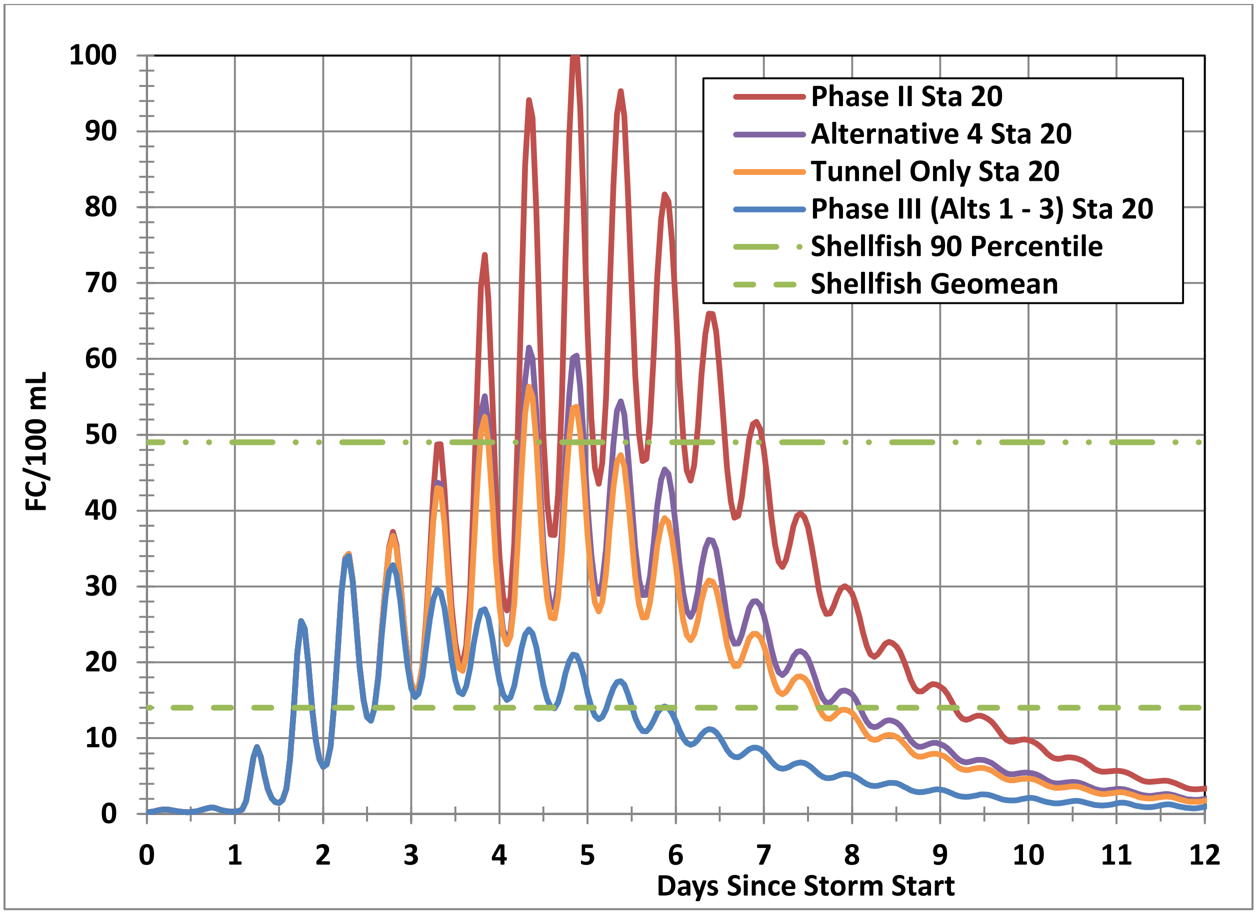


Figure 6-18 – Bacterial Concentrations at Conimicut Point

While the results of the water quality model do indicate that non-CSO sources contribute to impairments, the results also demonstrate that the Phase III program would have an important positive impact on water quality. Alternatives 1 through 3 all reduce peak concentrations below the 90 percentile standard which is a noteworthy achievement. The definition of that standard necessitates the collection 9 samples for every one sample above the threshold. Therefore, reducing peak concentrations below that level significantly increases use attainment. The fact that the tunnel-only model results very nearly meet that standard strongly supports the selection of Alternative 2.

The results of the water quality modeling were also exported as plan views with FC concentrations depicted in colors for various times after the design storm. These plan views illustrate how the plumes travel throughout the Bay over time and provide an impression of how concentrations at various locations in the Bay compare to water quality standards. Figure 6-19 below provides the color coding key. In general, any shade of blue always complies with recreational contact standards. The lightest green shade is in the range of the 90th percentile for contact standards; therefore, samples would need to be offset by lower concentrations to meet statistical standards. Darker shades of green as well as purple and red shades would indicate potential problems obtaining contract standards. Similarly, the lightest shade of blue always complies with shellfishing standards. The medium and darker blue shades are in the range of the geomean and 90th percentile for shellfishing standards; therefore, samples would need to be offset by lower concentrations to meet statistical standards. Any other colors would indicate potential problems obtaining shellfishing standards.

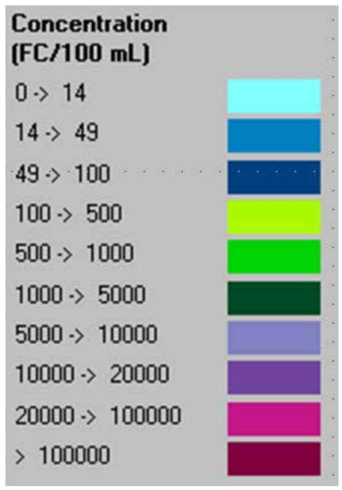
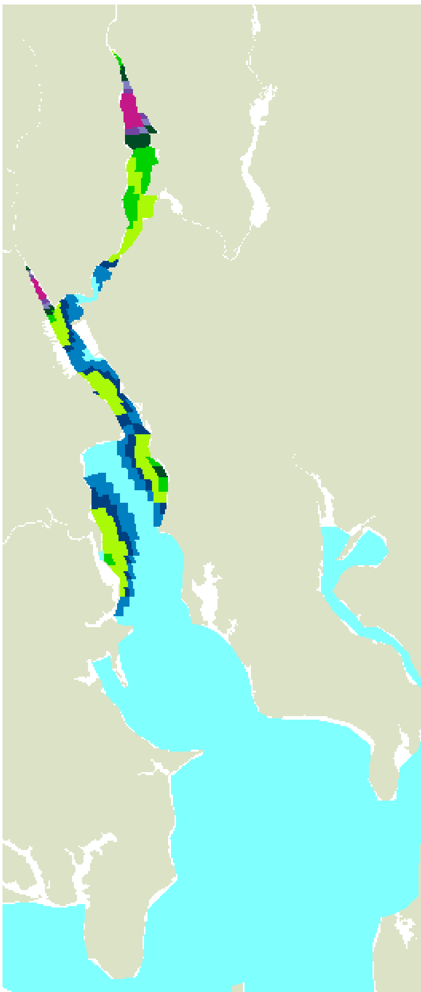
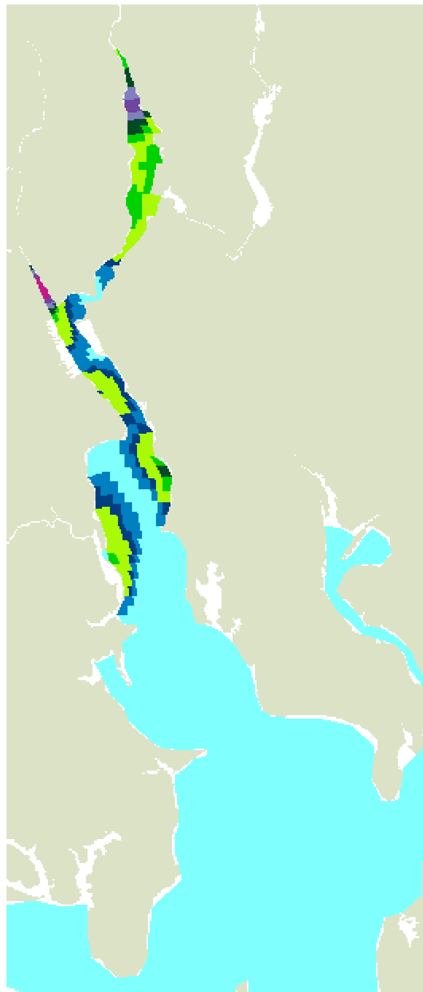
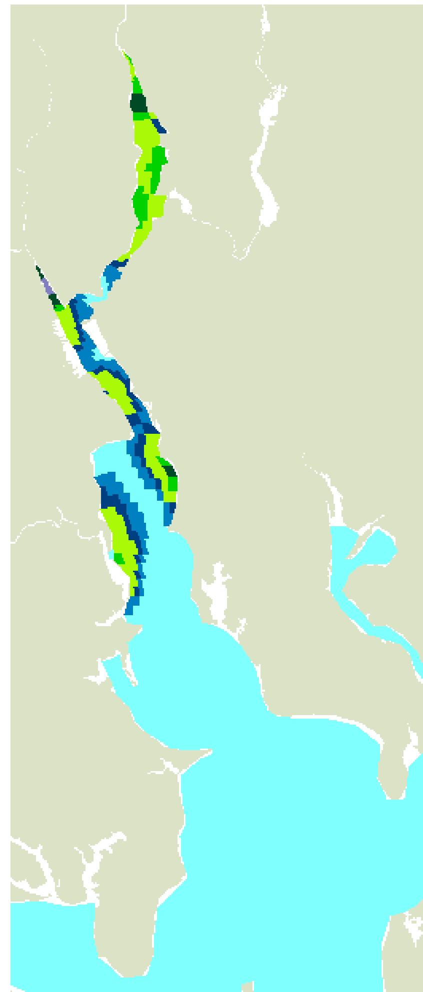
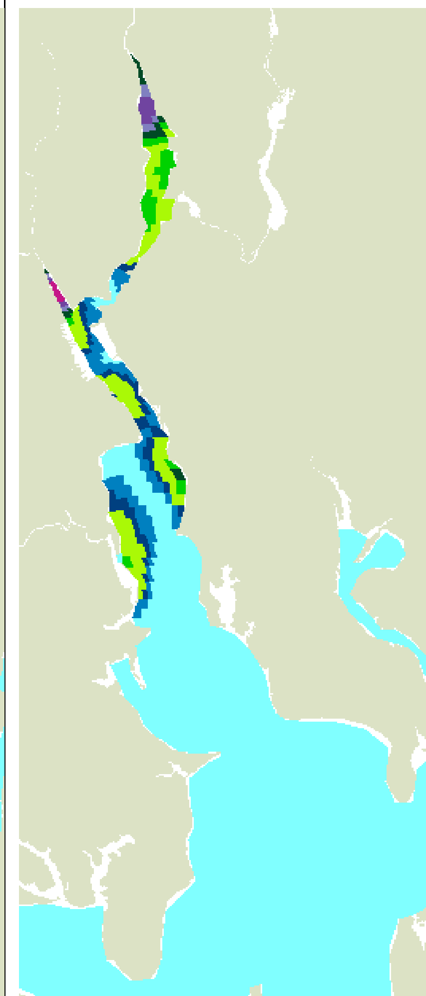


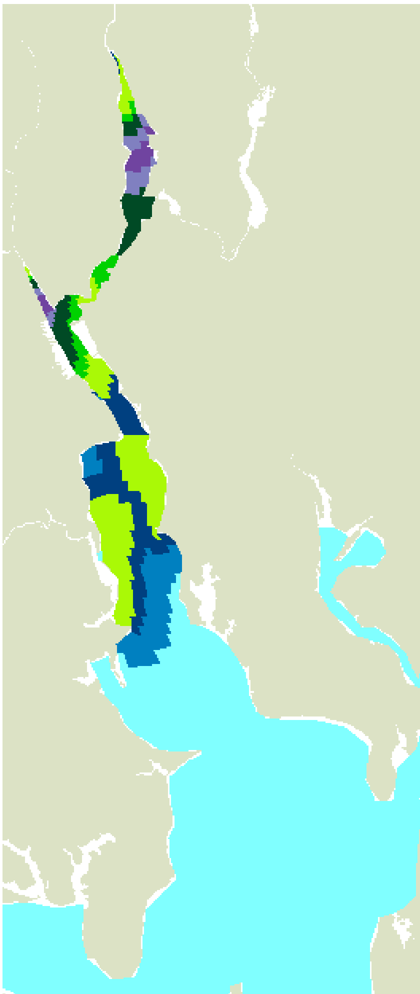
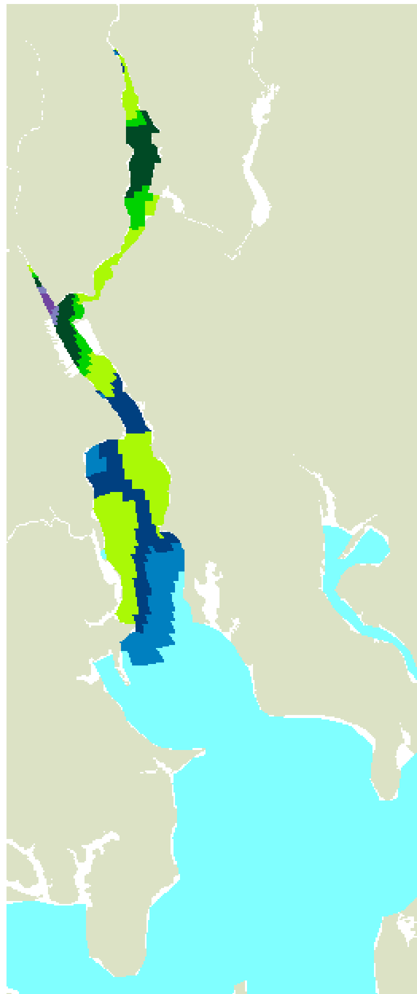
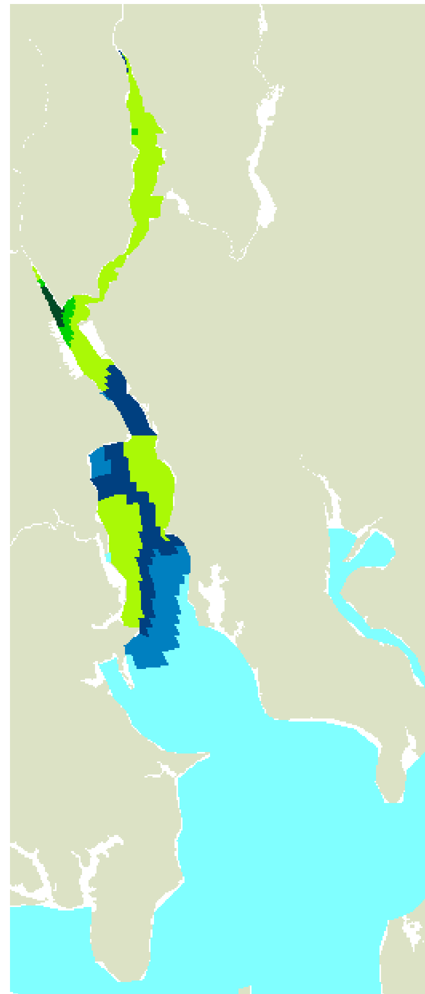
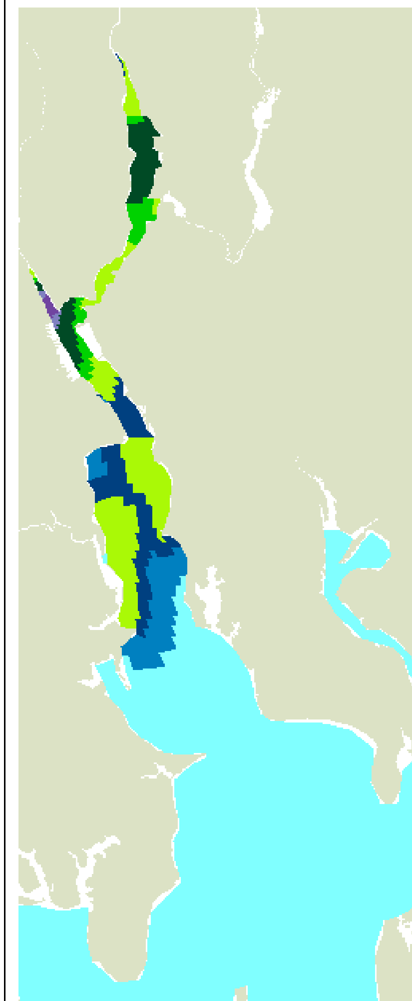
Figure 6-19 – Fecal Coliform Concentration Color Codes

The following pages provide the plan view plots for the Alternatives over the time steps following the 3-month storm.

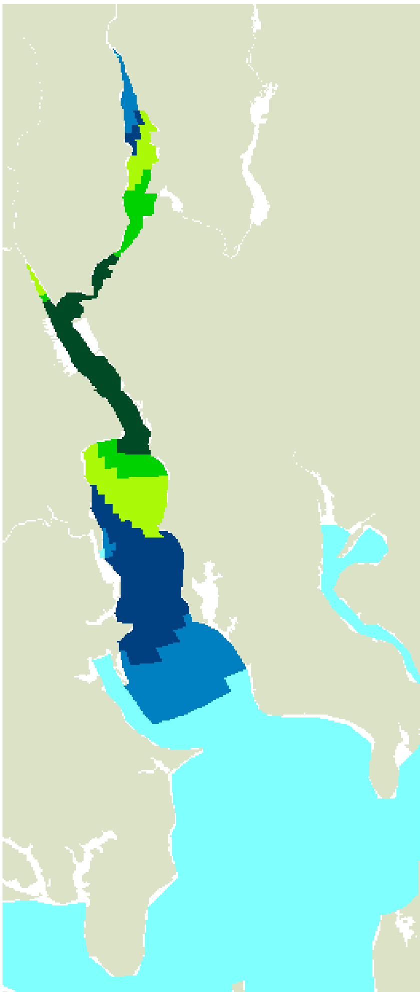
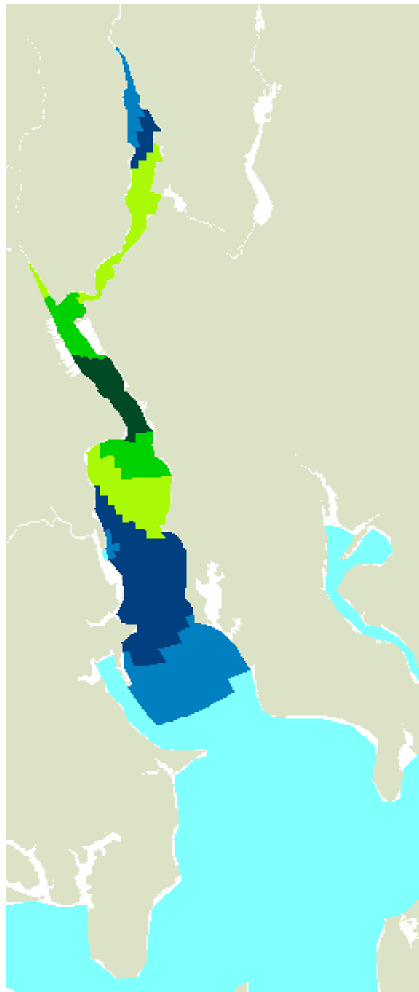
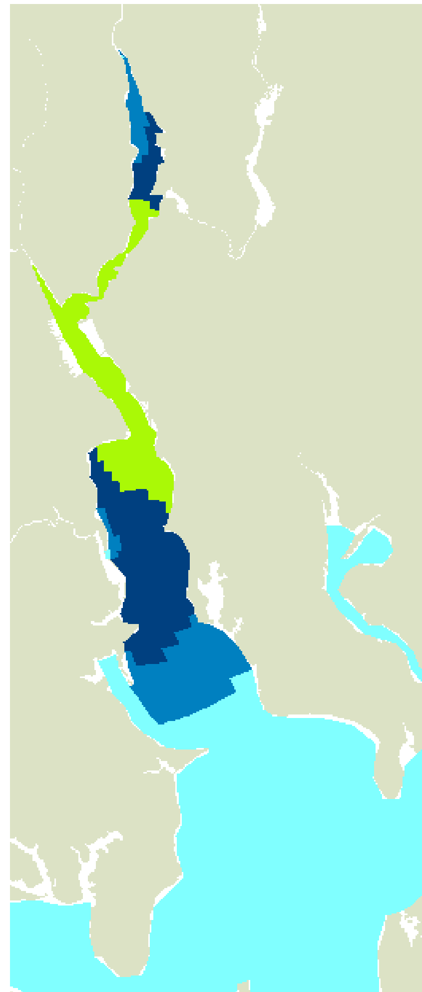
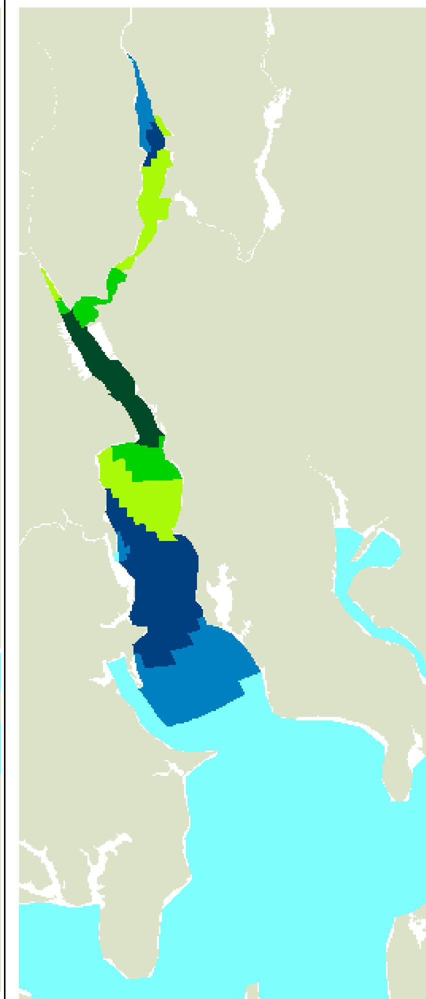
Plan view of Fecal Coliform concentrations 0.5 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)
			

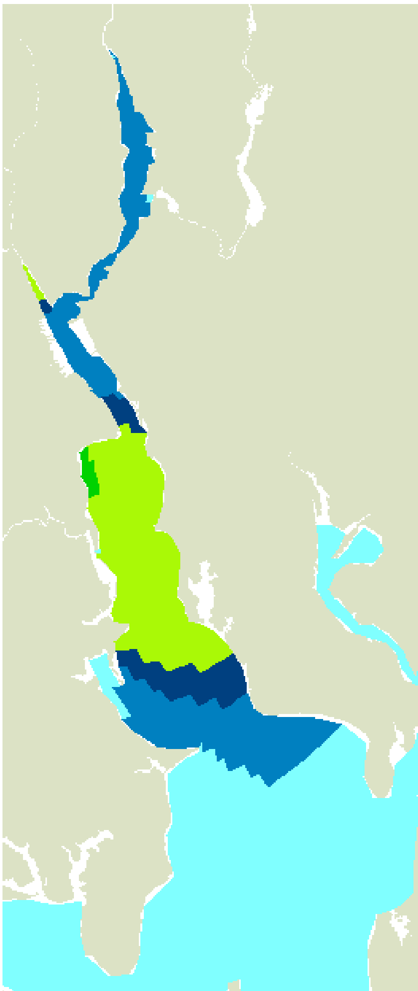
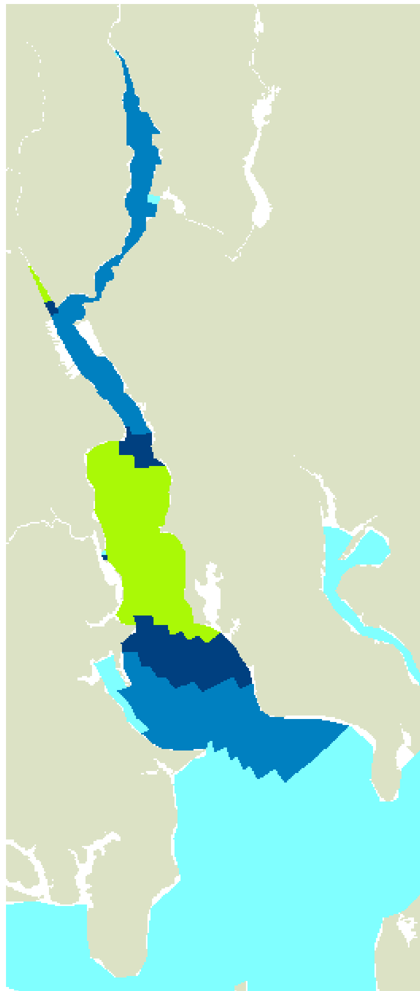
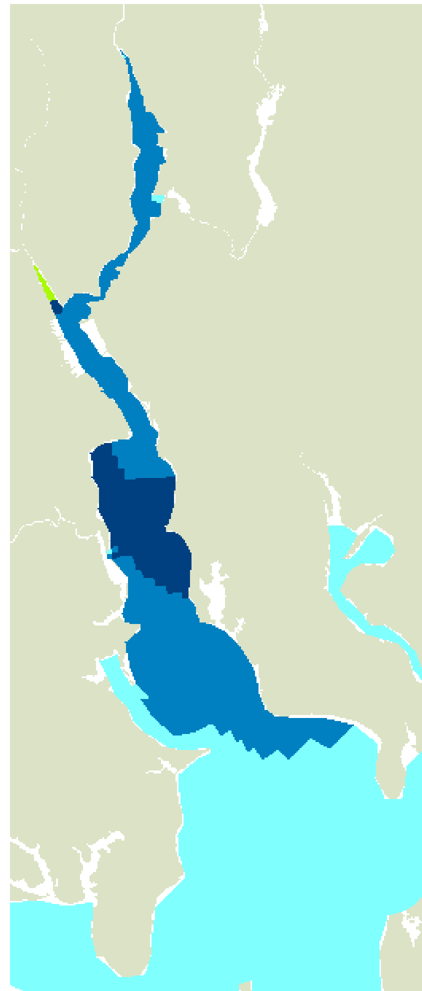
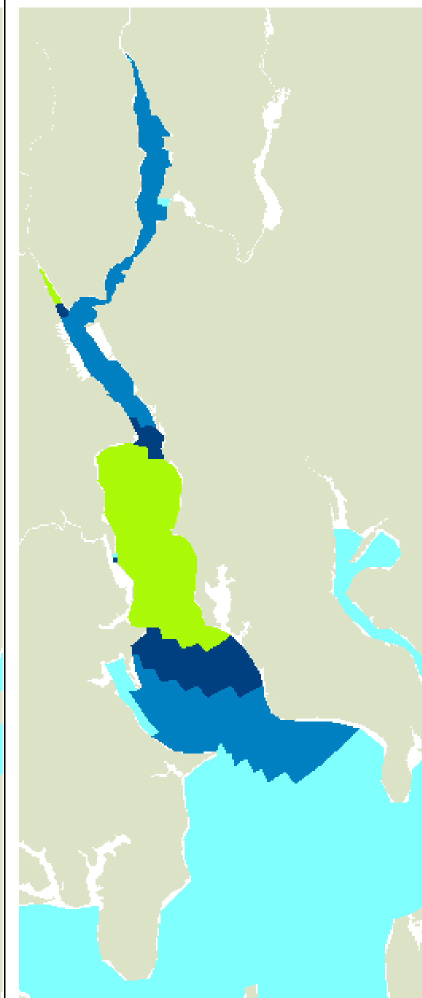
Plan view of Fecal Coliform concentrations 1 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)
			

Plan view of Fecal Coliform concentrations 2 days after start of 3-month storm

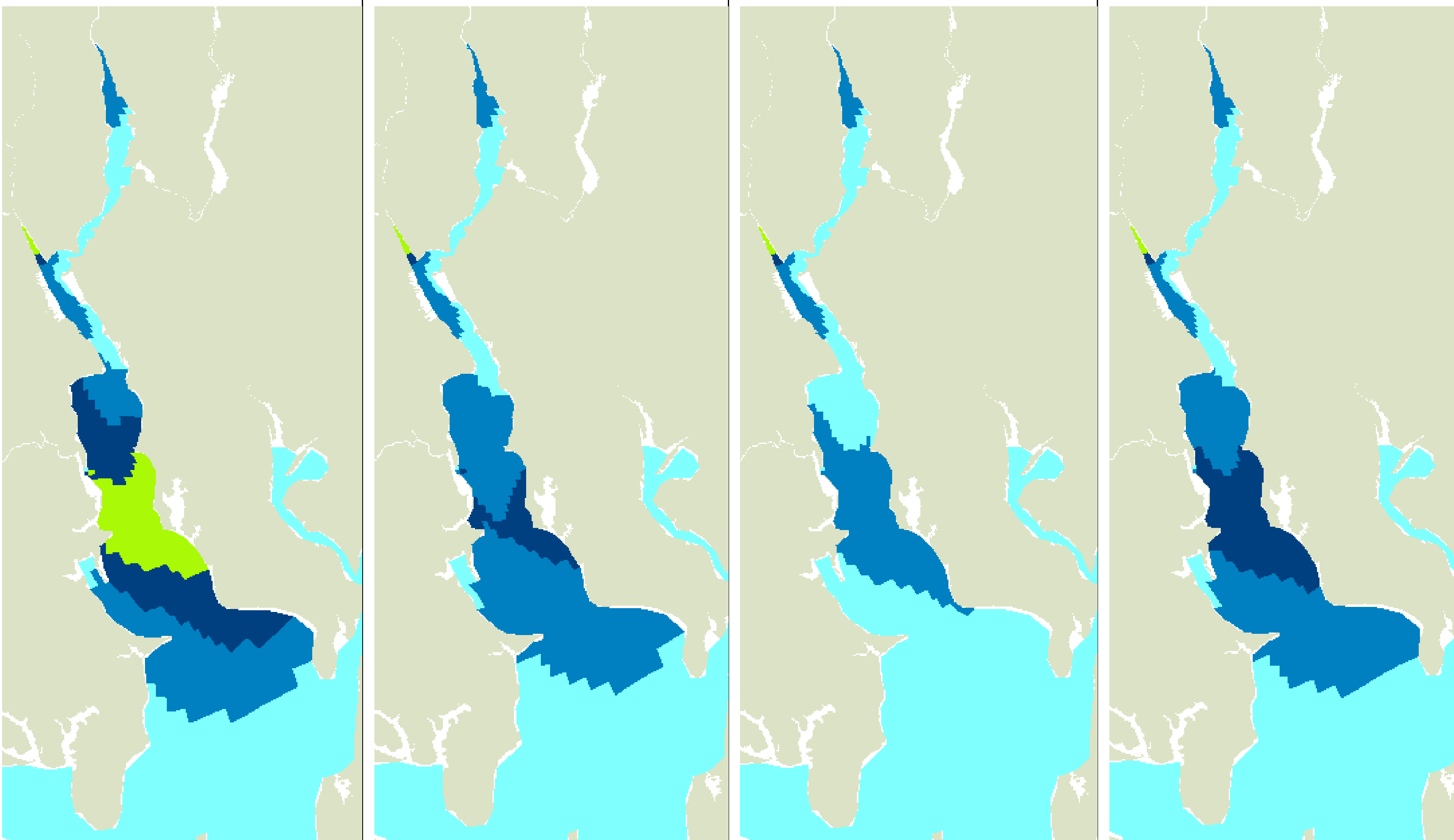
Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)
			

Plan view of Fecal Coliform concentrations 4 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)
			

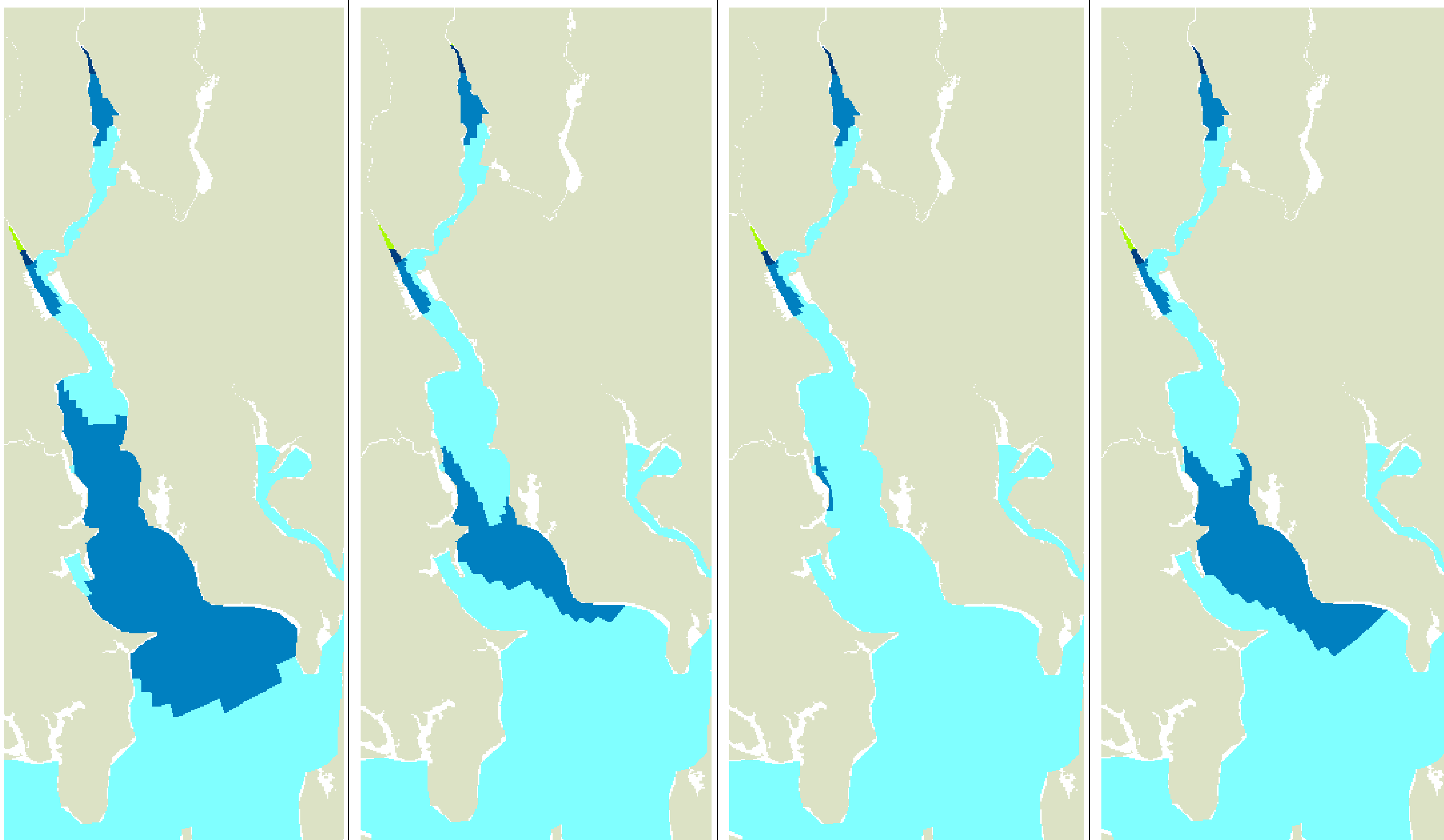
Plan view of Fecal Coliform concentrations 6 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)

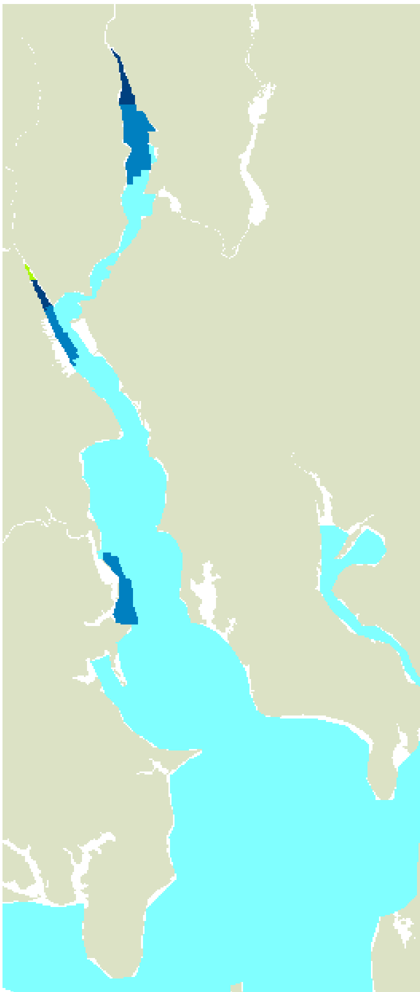
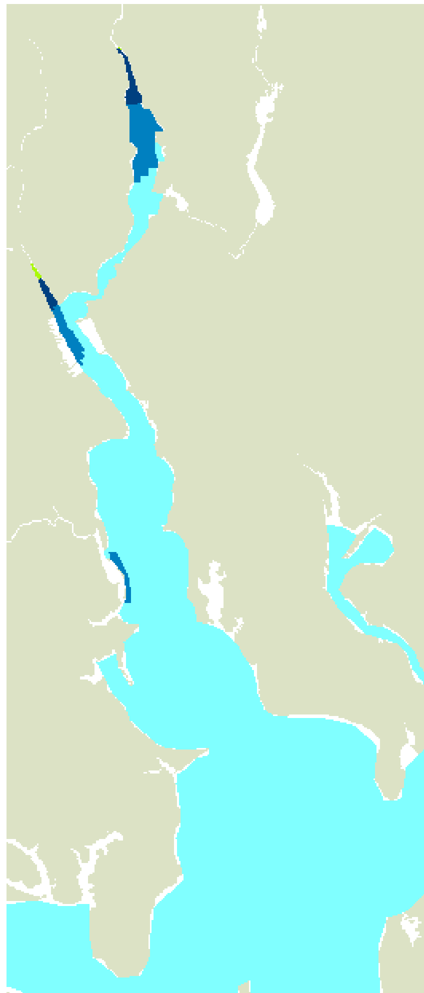
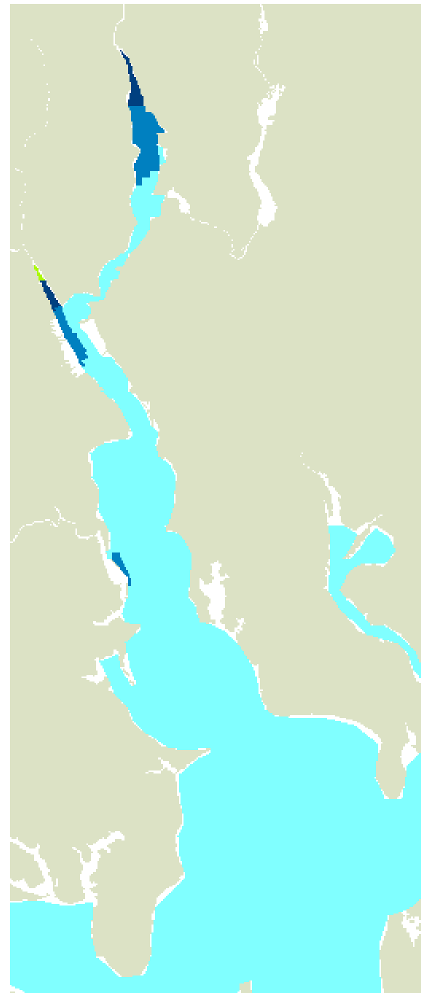
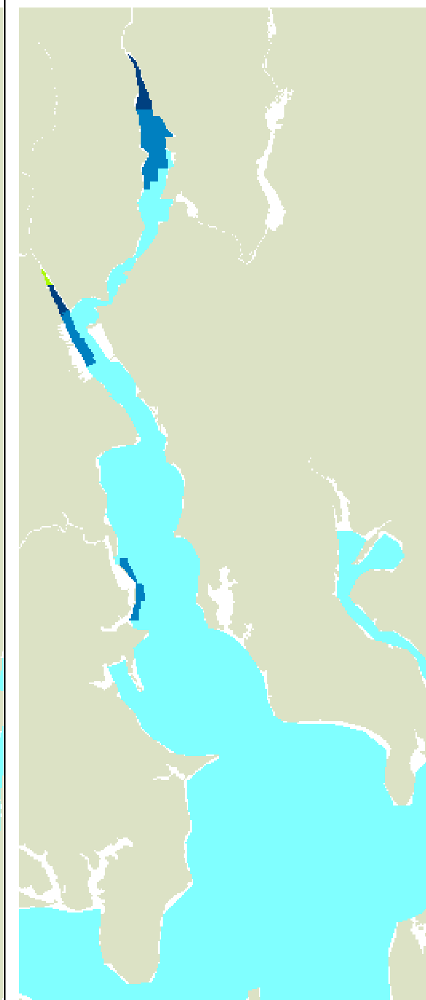


Plan view of Fecal Coliform concentrations 8 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)



Plan view of Fecal Coliform concentrations 10 days after start of 3-month storm

Phase II (2015)	**Tunnel Only** (Alt 1&2: 2023, Alt 3: 2032)	**Full Phase III** (Alt 1: 2025, Alt 2: 2038 Alt 4: 2047)	**Alternative 4** (2038)
			

The side-by-side plan views for each time step on the preceding pages illustrate the water quality improvements predicted by the model for each of the alternative plans and provide a timeline for when those improvements would be expected from each plan. It is also interesting to note the concentration and movement of the FC plumes for each case.

Under current, post-Phase II conditions, plumes of high concentration exceeding 20,000 FC/100mL originate at the Providence and Blackstone/Seekonk Rivers immediately following the storm event. One day following the storm, high concentrations exceeding 10,000 FC/100mL remain at the Providence and Blackstone/Seekonk Rivers, and concentrations ranging from 500 to 5,000 FC/100mL are noted between Bucklin and Fields Points. By day 2, concentrations in the Seekonk start to fall below 500 FC/100mL, but concentrations between the Providence River and Fields Point remain above 1,000 FC/100mL. By day 4, concentrations north of Fields Point drop below contact standards; however, the plume reaches Conimicut Point with concentrations of concern compared to shellfishing standards. Those concentrations remain concerning through day 8 and drop below the threshold by day 10.

For Alternative 4, immediately following the storm event, concentrations in excess of 20,000 FC/100mL originate at the Providence River, and concentrations exceeding 10,000 FC/100mL originate at the Blackstone/Seekonk River. One day following the event, concentrations near the Providence River exceed 10,000 FC/100mL, and concentrations near Bucklin Point fall below 5,000 FC/100mL. On day 2, concentrations between the Providence River and Fields Point range from 1,000 to 5,000 FC/100mL, but concentrations in the Seekonk start to fall below 1,000 FC/100mL and the plume advances south of Fields Point. By day 4, similar to Phase II conditions, concentrations north of Fields Point drop below contact standards but at Conimicut Point the concentrations are above shellfishing standards. By day 6, concentrations meet contact standards, which is an improvement over post-Phase II conditions, but concentrations remain high at Conimicut Point. On day 8, those concentrations start to fall below thresholds, but do not completely dissipate until day 10.

The model indicates that for tunnel-only case, which is included in Alternatives 1 through 3 but occur in different years, the plume movement is nearly identical to Alternative 4; however, concentrations are marginally lower. Compared to Alternative 4, contact standards are fully achieved a day sooner throughout the study area, and shellfishing standards at Conimicut Point are also achieved a day sooner.

For the full implementation of Alternatives 1 through 3, all CSOs are eliminated for the 3-month storm, therefore remaining FC concentrations are attributable to stormwater system discharges and sources outside of the NBC combined sewer area. Immediately following the storm event, concentrations in excess of 5,000 FC/100mL originate at the Providence River, and concentrations exceeding 1,000 FC/100mL originate at the Blackstone/Seekonk River. One day following the event, concentrations near the Providence River exceed 1,000 FC/100mL; however, concentrations elsewhere approach contact standards. By day 4, concentrations north of Fields Point are well within contact standards, concentrations south of Fields Point are close to standards, and the plume with concentration near shellfishing standards reaches Conimicut Point. By day 6, concentrations throughout the modeled area are within all standards.

State designated conditional closure and water classification areas are presented in Figure 6-20 and a summary of the RIDEM definitions of FC bacteria criterion for the different classifications is presented in Table 6-8.

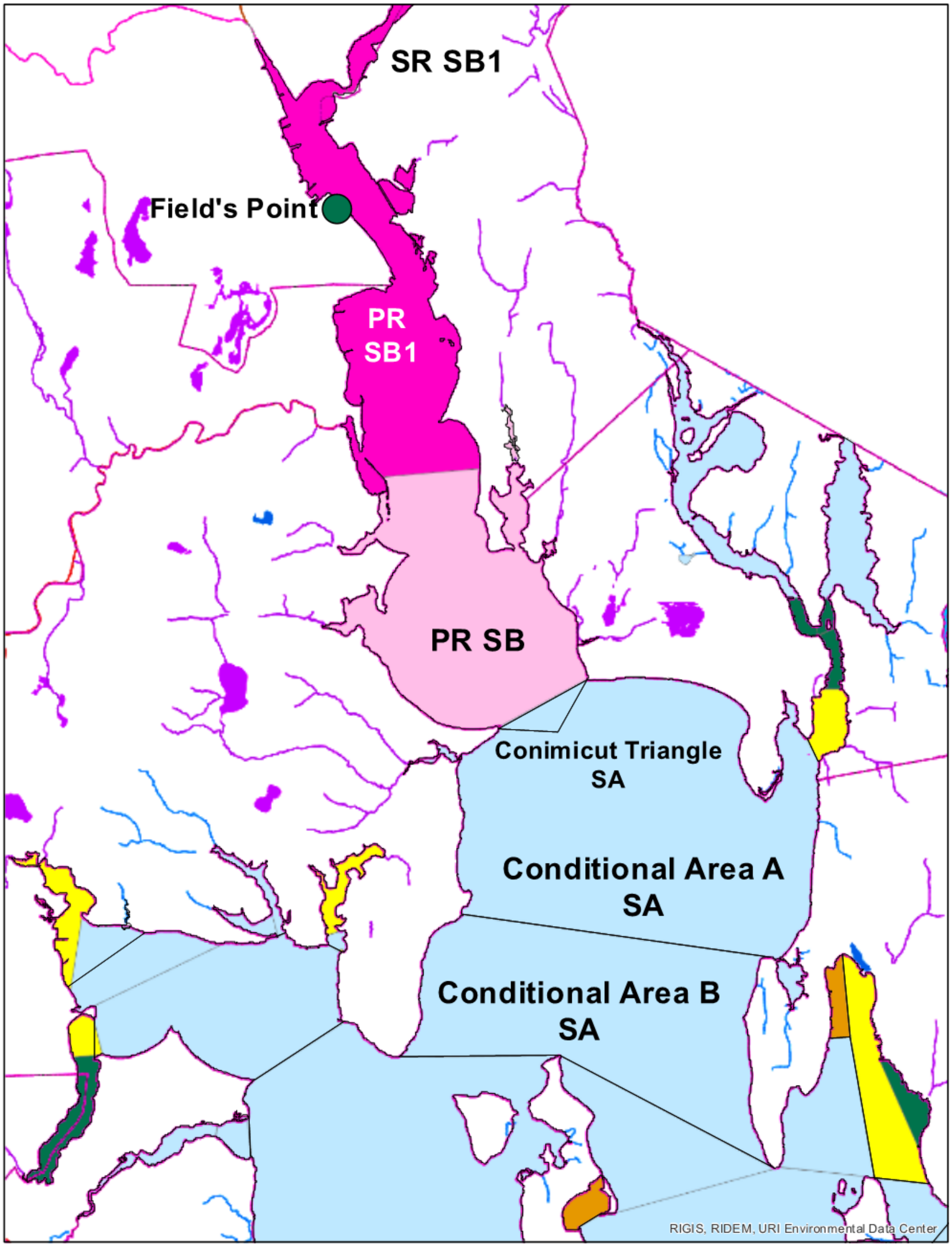


Figure 6-20 Designated Conditional Closure Areas and Water Quality Classification Areas

Area	Geomean Limit	Upper 10% Limit	Area Size (ac)
Conditional Area B	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	3,711
Conditional Area A	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	5,836
Conimicut Triangle Conditional Area	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	119
Providence River SB	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	3,000
Providence River SB1	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	2,355
Seekonk River SB1	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	708

Table 6-8: Summary of Fecal Coliform Bacteria Criterion for Water Classification Areas

The model was run for the 3 month storm to determine the impact on shellfishing and contact recreational uses in each of the six areas shown on Figure 6-20. The areas and limits used in the closure area determination and model results are shown in Table 6-9. The results of the model runs for Post Phase II, Full Phase III, Tunnel only and Alternative 4 are shown in Table 6-9 in terms of acre-days (the number of days and the area for each of those days) that the standard was exceeded.

Alternatives	Conditional Area B		Conditional Area A		Conimicut Triangle		Providence River - SB		Providence River - SB1		Seekonk River - SB1	
	FC/100mL		FC/100mL		FC/100mL		FC/100mL		FC/100mL		FC/100mL	
	14	49	14	49	14	49	50	400	50	400	50	400
	Acre Days		Acre Days		Acre Days		Acre Days		Acre Days		Acre Days	
Post Phase II	1	0	10,900	1,110	1,860	423	9,040	113	9,820	3,320	1,400	619
Full Phase III	0	0	1,960	0	744	0	1,880	1	6,300	221	1,180	162
Tunnel Only	0	0	5,860	69	1,440	61	5,590	1	8,170	1,750	1,260	450
Alt. 4	0	0	6,620	148	1,530	100	6,220	1	8,590	2,050	1,300	497

Table 6-9: Three-month design storm results showing exceedance of standards for shellfishing and contact recreation in acre-days.

These results show that Full Phase III provides the most water quality improvement. The results for the Tunnel Only and Alternative 4 are comparable with the Tunnel only performing slightly better. All the Alternatives resulted in better water quality than for Post Phase II except for the Seekonk River where the improvement in water quality was not substantially different than Post Phase II.

The model results are consistent with available water quality data and indicate that while non-CSO loads contribute to impairments, the high concentrations associated with the CSO overflows are vastly greater. The water quality goals of the region are best served by first addressing CSOs and then abating other sources. The model results also indicate that for the 3-month design storm, alternatives that fall shy of that design objective would have impacts to water quality. Further analysis of those results indicates that construction of the tunnel alone would outperform Alternative 4, which would support the conclusion that Alternative 2 is the most favorable of the adaptive management plans.

6.7. Alternative Plan Evaluation Conclusion

The Integrated Planning Framework allows for establishing priorities among CSO projects, storm water programs and sewer system infrastructure improvements. Based on fecal coliform loadings, CSO projects have a higher priority than stormwater, except for possibly some localized stormwater projects. Local sewer infrastructure needs should be addressed concurrently with the CSO project. The schedule for performing work on all three of these components should be established by means of an adaptive management approach which would allow priorities to be revised if warranted.

Alternatives 1, 2 and 3 do not meet NBC's affordability criterion of a sewer rate of $626 but they do meet the water quality design objectives defined by the CA and CDRA. Although Alternative 2 and Alternative 3 ultimately provide the same water quality improvements, Alternative 2 provides the benefits sooner than Alternative 3 because the tunnel is the first component to be constructed in Alternative 2. Because of their longer schedules, Alternatives 2 and 3 also meet the adaptive management criterion. Alternative 4 provides the lowest cost option and provides for adaptive management affordability success but does not satisfy the water quality design objectives defined by the CA and CDRA.

NBC CSO Control Facilities Phase III Reevaluation

Chapter 7 – Revised Recommended Plan

NBC CSO Control Facilities Phase III Reevaluation
Chapter 7 – Revised Recommended Plan

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7.1. Introduction

The conceptual plan for the Narragansett Bay Commission (NBC) Phase III CSO control facilities underwent a financial, environmental and engineering reevaluation. The details of that reevaluation are summarized in the previous six chapters. This chapter presents the details of the revised recommended Phase III plan.

7.2. Selection of the Recommended Plan

As documented in Appendix 8, seven stakeholder workshops were held from March to December 2014. The Stakeholders Group was informed on all aspects of the reevaluation process and provided input on their concerns which included impact on rates, effects of climate change and the benefits of implementing GSI. These concerns were addressed in developing and evaluating the four alternatives that were submitted to the NBC Board of Commissioners for selection of the recommended plan.

The Board of Commissioners was regularly updated throughout the reevaluation process. A progress report on the Reevaluation was presented at the October 21, 2014 Board of Commissioners meeting by MWH/Pare. A second update was provided by MWH/Pare at the December 9, 2014 meeting. MWH/Pare presented the evaluation of the four alternatives at the January 6 workshop and further explained the alternatives impacts at the March 17, 2015 Board meetings. A final workshop was held for the Board on April 27, 2015. At the April 28, 2015 Board meeting, the Long Range Planning Committee recommended and the Board, after extensive discussion, approved Alternative 2 as the Recommended Plan.

It is important to point out that several Commissioners expressed concern regarding the impact of Phase III on sewer rates but approved going forward with the recommended plan with the understanding that NBC monitor the impact on rates and affordability as the plan was implemented. One Commissioner voted against approving the plan because the cost did not justify the water quality benefits to be attained. One Commissioner voiced concern that only a portion of the recommended plan be implemented in order to reduce the rate impact. A copy of the transcript of the 28 April 2015 Board of Commissioners meeting minutes approving the plan is provided in Appendix 10.

The Board selected Alternative 2 because it met the water quality goals of the CSO Program, provided a schedule that allowed for adaptive management and had resulted in the most favorable sewer rate of the three tunnel alternatives. Although Alternative 4 was the least expensive alternative and had the lowest sewer rate impact, the Commission eliminated it because of the uncertainty as to whether it would meet the water quality goals of the CSO Program.

7.3. Program Components and Design Objectives

Alternative 2 is to be constructed in four phases. The following subsections describe the facilities to be constructed in each phase.

7.3.1. Phase A – Pawtucket Tunnel

The first phase of the program will include the design and construction of a deep rock storage tunnel and a demonstration green storm water infrastructure (GSI) project. The Pawtucket

Tunnel will be designed to provide storage volume at least equal to the overflow volume resulting from the 3-month design storm from the overflows on the Seekonk and Blackstone Rivers (i.e. CSO 101 through 105, and 201 through 218) after other system controls are put in place, including those in subsequent phases. For example, the northern interceptors to be built in Phase B will be required to connect outfalls 101 through 105 and 201 through 203 to the tunnel; however, capacity will be provided for those outfalls in Phase A construction. The Pawtucket Tunnel alignment, drop shaft locations, consolidation conduits, regulator modifications and other system controls completed during Phase A will capture the 3-month design volumes from outfalls 204 through 218.

The Pawtucket Tunnel conceptual design includes the following:

- Deep rock tunnel, 150 to 200 feet below grade extending from just north of the Bucklin Point Wastewater Treatment Facility in East Providence to the Central Falls / Pawtucket border near the Blackstone River.
- Tunnel dimensions – 13,000 linear feet, and 26 feet internal diameter for volume from outfalls 101 through 105 and 201 through 218.
- Two launching/receiving work shafts – 30 ft. ID, 145-200 ft. deep
- Five drop shafts – 6-8 ft. ID, 145-175 ft. deep. Drop shaft locations are conceived to be near the following outfalls: 205, 210, 213, 217 and 218. Note the receiving work shaft is conceived to be converted to the drop shaft for 205.
- One pumping station located within 1,000 ft. of the Bucklin Point WWTF 260 ft. deep
    - Utility Shaft – 32 ft. ID, 260 ft. deep
    - Access Shaft – 12 ft. ID, 260 ft. deep
    - Pump Cavern – 62 ft. wide by 70 ft. deep by 120 ft. long
- Two-stage pumping operation with eight 19 MGD pumps split evenly between divided lower and intermediate levels, with three pumps in operation and one on standby at each level.
- Five consolidation conduits (48-72" ID, total of 5,200 LF) to convey flow from nearby outfalls to the drop shafts.
- Regulator modifications for the following outfalls: 204, 207, 208, 209, 212, 214, 215, and 216.

The tunnel diameter for Alternative 2 is 26 ft, as opposed to the 28 ft needed for the baseline plan because of the storage volume provided by the stub tunnel or storage tank. The alternatives for outfall 220 are further detailed in section 7.3.3. The actual tunnel diameter and associated system storage capabilities will be determined during future preliminary design efforts.

Phase A will also include a GSI demonstration project. Based on investigations and modeling performed for the reevaluation, the project should target areas that contribute flow to outfalls 212, 213 and 214; however, the preliminary design effort may alter that conclusion. The conceptual design elements include installation of permeable pavement in the parking lanes of roadways, rain garden / bioswale bumpouts in the parking lanes, treewells in sidewalks, infiltrating catch basins, and other similar elements to increase retention and infiltration of stormwater. The conceptual design also involves partnering with property owners to install bioswales, raingardens, infiltration chambers, green roofs and other such low impact development features.

7.3.2. Phase B – Northern Interceptors

The second phase of the program will include the design and construction of new interceptors, regulator modifications and other system improvements that will convey flow from the outfalls on the northern portion of the Blackstone River to the Pawtucket Tunnel. The second phase will also include sewer separation and GSI in the catchment for outfall 206 as well as a GSI project designed to optimize overall system performance. All facilities will be designed to accommodate overflow volumes resulting from the 3-month design storm. The controls completed during Phase A capture the volumes from outfalls 101 through 105, and 201 through 203 plus 206.

The conceptual design for the High and Cross Street Interceptor includes:

- Interceptor along High Street (north of Charles St) that is 42 inch ID, 2,160 LF in length, and 8-15 ft. below grade.
- Interceptor along south High Street (south of Charles St), Cross Street, and Central St. (in Pawtucket) that is 48 inch ID, 2,080 LF in length, and 15-22 ft. below grade. The interceptor will cross beneath the Blackstone River.
- Connections to the Blackstone Valley Interceptor and/or structures to direct flow from CSOs103, 104 and 105 to the High and Cross Street Interceptors.
- Regulator modification for outfall 101.

The conceptual design for the Middle Street Interceptor includes:

- Interceptor along Middle Street that is 30 inch ID, 1,710 LF in length, and 12-15 ft below grade. Drop manhole at the intersection of Middle Street and Central Street
- Interceptor along Central Street that is 66 inch ID, 350 LF in length, and 25-45 ft below grade. Micro-tunneling or pipe-jacking will be required.
- Structures to divert flow from the Pawtucket system and/or outfalls 201 through 203 to the Middle Street Interceptor.
- Regulator modification for outfall 202.
- Potential regulator modifications for regulators 201 and 203.

Phase B will also include a GSI project with elements described in Phase A above. Based on investigations and modeling performed for the reevaluation, the project should target areas that contribute flow to outfalls 101, 104 and 105.

The recommended conceptual design for the northern interceptors is essentially the same as described in the CDRA with a few technical modifications based on Phase II experience. The recommendation of the GSI project was not included in the CDRA, and represents a program enhancement.

7.3.3. Phase C – Outfall 220 Subsystem

The third phase of the program will capture and provide storage volume for outfalls 107 and 220 on the Moshassuck River. The storage volume will be provided either by a near surface storage tank near outfall 220 or a deep rock stub tunnel from the Pawtucket Tunnel to a location near outfall 220. The specific solution including other system requirements will be determined following additional investigation and preliminary design. The third phase will also include a GSI project designed to optimize overall system performance.

The conceptual design for the 220 stub tunnel includes:

- Deep-rock tunnel, 70 to 200 feet below grade extending between outfall 220 and the drop shaft for 217.
- Tunnel dimensions conceptually 7,000 linear feet and 11 feet internal diameter. Actual dimensions should be optimized with the Pawtucket Tunnel design.
- Drop shaft at outfall 220, 6-8 ft. ID, 70 ft. deep.
- Regulator modification for outfall 107.

Alternately, the conceptual design for the 220 near surface storage tank includes:

- An underground, concrete storage tank with dimensions 250 ft.(L) x 221 ft.(W) x 12 ft.(D) and cleaning equipment
- Odor control equipment and building
- Discharge pump station and force main
- Assumed 110 lf consolidation conduit
- Regulator modification for outfall 107.

Phase C will also include a GSI project with elements described in Phase A above. Based on investigations and modeling performed for the reevaluation, the project should target areas that contribute flow to outfalls 216 and 217.

The CDRA conceptual plan for this subsystem was the Pawtucket Avenue Interceptor. The reevaluation analysis concluded that the Pawtucket Avenue Interceptor would result in substantial impacts during construction and present long-term operational difficulties. Therefore the recommended conceptual plan represents a redefinition of this subsystem's solution. The recommendation of the GSI project was not included in the CDRA, and represents a program enhancement.

7.3.4. Phase D – West River Interceptor and 035 Sewer Separation

The final phase of the program will include a GSI project designed to optimize overall system performance, sewer separation for the catchment contributing to outfall 035, regulator modification to outfall 036, the West River Interceptor and other system modifications required to address outfalls 039 and 056. The West River Interceptor will be designed to provide storage and conveyance to relieve the Branch Avenue Interceptor and address overflows 039 and 056. All facilities will be designed to accommodate overflow volumes resulting from the 3-month design storm. The controls completed during Phase D address the volumes from outfalls 035, 036, 039 and 056.

The West River Interceptor conceptual design is 6 feet in diameter, 4,600 feet in length and approximately 10-25 feet below grade. The route follows the east bank of the West River beginning at the Branch Ave Interceptor (BAI) near Outfall 056, close to the intersection of Branch Ave and Vandewater Street and connects to the Moshassuck River Interceptor at Silver Springs Street near the Walmart. The West River Interceptor provides relief for the BAI and storage capacity to accommodate the overflows from 039 and 056.

The conceptual design for sewer separation in the 035 catchment includes:

- Installation of new drain pipe network, 20% addition to existing pipes (10,884 LF, 8-24" dia.)
- Replacement of 10% of existing pipes (5,442 LF)
- Rehabilitation of 10% of existing pipes (5,442 LF)
- Reuse of 80% of existing pipes (43,536 LF)
- Illicit connection detection
  - Closed-circuit television (CCTV) inspection of all drain pipes
  - Private property building inspections
  - Dye-Testing of suspicious lateral connections
- Adjacent utility work
  - Limited to roadways impacted by separation only, no utility work on roadways without separation related excavation
  - Replacement of 80% of existing water main (13,061 LF) and service connections up to right-of-way only for roadways where existing pipe is replaced
  - Replacement of 90% of existing gas main (7,347 LF) and service connections up to right-of-way *at a 50-50 cost split with gas company* only for roadways where existing pipe is replaced
  - Coordination with electric and telecom utilities for upgrades to privately owned infrastructure prior to subsurface construction
- Surface Restoration
  - Limited to roadways impacted by excavation only, no surface work on roadways without separation related excavation
  - Full-depth reconstruction of 20% of excavated roadways (3,000 LF)
  - Grind-overlay reconstruction of 80% of excavated roadways (13,061 LF)

The sewer separation project will eliminate outfall 035 and create capacity in the Moshassuck River Interceptor to facilitate a regulator modification at outfall 036.

Phase D will also include a GSI project with elements described in Phase A above. Based on investigations and modeling performed for the reevaluation, the project should target areas that contribute flow to outfalls 201 through 204.

The recommended conceptual design for the 035 sewer separation is essentially the same as described in the CDRA with a few technical modifications based on Phase II experience. The CDRA conceptual plan for the 039-056 subsystem was sewer separation. The reevaluation analysis concluded that West River Interceptor better met the evaluation criteria established by the Stakeholder Group. Therefore the recommended conceptual plan represents a redefinition of that subsystem's solution. The recommendation of the GSI project was not included in the CDRA, and represents a program enhancement.

7.4. Conceptual Design Summary

The conceptual design is summarized in Figure 7-1 and illustrated in Figure 7-2.

CSO Control Solution	*CSOs Controlled*
Phase A	
Pawtucket Tunnel, drop shafts & consolidation conduits	204, 205, 210, 211, 213, 214, 217
Regulator modifications	207, 208, 209, 212, 215, 216
GSI Project	212, 213, 214
Phase B	
Middle Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	201-203
High & Cross Street Interceptor to Pawtucket Tunnel via Drop Shaft 205	103 - 105
206 Hybrid GSI / sewer separation	206
Regulator modifications	101, 202
GSI Project	101, 104, 105
Phase C	
220 Stub Tunnel or 220 Near Surface Storage Tank	220
Regulator modification	107
GSI Project	216, 217
Phase D	
035 Sewer separation	035
Regulator modification	036
West River Interceptor	039, 056
GSI Project	201-204

Figure 7-1 – Summary of Conceptual Design

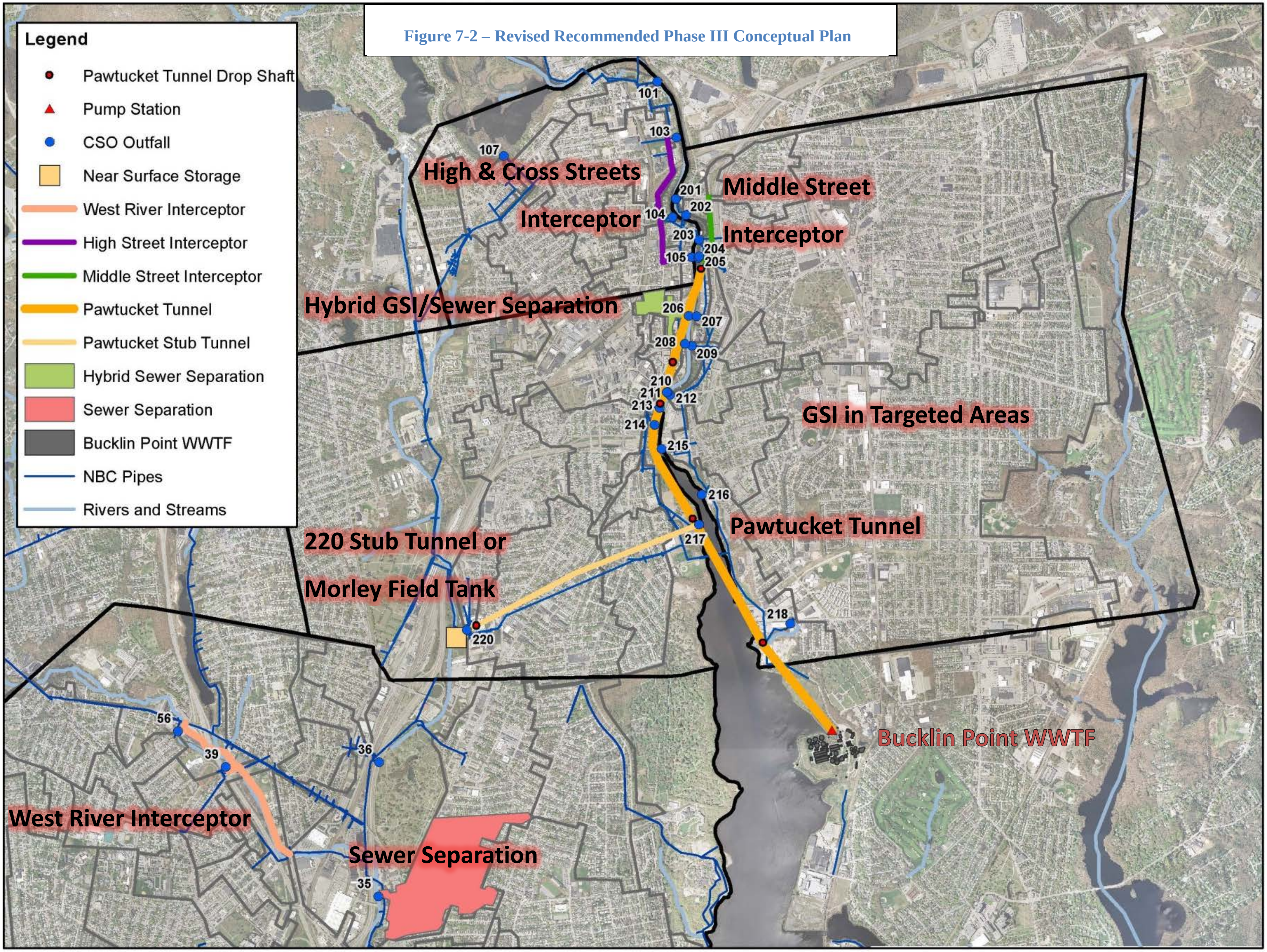
Figure 7-2 – Revised Recommended Phase III Conceptual Plan
Legend
Pawtucket Tunnel Drop Shaft
Pump Station
CSO Outfall
Near Surface Storage
West River Interceptor
High Street Interceptor
Middle Street Interceptor
Pawtucket Tunnel
Pawtucket Stub Tunnel
Hybrid Sewer Separation
Sewer Separation
Bucklin Point WWTF
NBC Pipes
Rivers and Streams
High & Cross Streets
Interceptor
Middle Street
Interceptor
Hybrid GSI/Sewer Separation
GSI in Targeted Areas
Pawtucket Tunnel
220 Stub Tunnel or
Morley Field Tank
Bucklin Point WWTF
West River Interceptor
Sewer Separation
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7.5. Design Optimization Recommendations

The investigations and analyses performed during the reevaluation process were sufficient to determine the components of the plan that satisfy the water quality and affordability parameters for the program. The data collected and the hydraulic model developed were suitable to evaluate the conceptual design presented above and conclude that those facilities will achieve the design intent. Several opportunities may exist to optimize the conceptual design and reduce overall cost while maintaining the same level of CSO control. For example, the existing interceptor siphons under the Blackstone and Seekonk Rivers constitute hydraulic bottlenecks. The Moshassuck Valley, Taft-Pleasant and Blackstone Valley interceptors have complex interactions that influence several different outfalls. Additional evaluation using the hydraulic model may help to better understand those issues and to potentially define system improvements.

7.6. Hydraulic Performance of Recommended Plan

7.6.1. Objectives and background

The NBC hydraulic model of the Bucklin Point Service Area (BPSA) was developed specifically for the purpose of reevaluating the Phase III CSOs. The model was used to the determine the response to rainfall in the BPSA and the systemic restrictions and controls that cause the CSO overflows. The recommended Phase III plan will retain the 3-month storm CSO overflow volume of 56.49 MG.

7.6.2. Typical Year Rainfall Analysis

The recommended plan must reduce the number of overflows to no more than four per year for the typical year. A hydraulic model simulation was run for a continuous year of rainfall to demonstrate conformance with the four overflows per year criteria. This evaluation demonstrates a wider range of CSO compliance since observed rainfall data varies in terms of frequency, total depth and antecedent conditions and offers a more robust test of the system.

The rainfall used for the year-long simulation was the 1951 precipitation observation. Selected from more than 65 years of observed historical precipitation, this rainfall series covers all wet and dry periods in 1951 and is defined as a the ‘typical year’. The rainfall data is from the Providence T.F. Green State Airport rain gauge. The 1951 rainfall had a total depth of 45.6-in.

The results of the year-long simulation using the 1951 rainfall for the revised recommended Phase III plan are provided in Table 7-1.

Table 7-1 – Phase III plan typical year performance summary

CSO	Existing Conditions		Phase III plan		Volume reduction (%)
	Spill #	Volume (MG)	Spill #	Volume (MG)	
101	30	216.58	3	1.19	-99.5
103	48	365.91	4	3.66	-99
104	42	80.25	3	0.95	-98.8
105	41	28.9	5	0.81	-97.2
106	21	12.55	4	1.53	-87.8
107	44	5.49	3	0.99	-81.9
201	37	20.97	0	0	-100
202	52	56.61	4	0.07	-99.9
203	24	4.04	2	0.23	-94.3
204	4	3.02	0	0	-100
205	36	189.76	6	0.14	-91.9
206	20	1.34	3	0.09	-93.3
207	5	0.19	1	0.02	-91.7
208	2	0.04	3	0.09	137.1
209	3	0.09	4	0.12	33.4
210	44	45.62	3	0.24	-99.5
211	69	116.12	6	0.99	-99.1
212	40	9.37	3	0.44	-95.3
213	29	25.31	4	12.64	-50.1
214	23	17.12	3	21.1	23.2
215	63	33.55	3	0.49	-98.5
216	2	0.08	2	0.13	73.1
217	44	48.14	4	6.84	-85.8
218	68	295.07	3	4.06	-98.6
220	29	54.7	5	4.41	-82.8
Total	**820**	**1630.82**	**81**	**61.23**	**-96.2**
Av. Per CSO	**32.8**		**3.24**		

The results show that the revised recommended Phase III plan does meet the 4 overflows per year criteria on average across the BPSA. Localized hydraulics and system performance at this reevaluation stage do cause some variance to 4 overflows at some of the CSOs.

7.7. Water Quality Performance of the Recommended Plan

As presented in Chapter 3 and Appendix 4, Phases I and II of the NBC CSO program have improved water quality in the Bay. Recent data and the water quality model indicate that overflows from the Phase III area and other background loadings continue to result in water quality impairments.

The results of the water quality model were exported as plan views with bacterial concentrations depicted in colors for various times after the design storm. These plan views illustrate how the plumes travel throughout the Bay over time and provide an impression of how concentrations at various locations in the Bay compare to water quality standards. Figure 7-3 below provides the color coding key. In general, any shade of blue always complies with recreational contact standards. The lightest green shade is in the range of the 90th percentile for contact standards. Darker shades of green and purple and red shades indicate potential problems obtaining contact standards. Similarly, the lightest shade of blue always complies with shellfishing standards. The medium and darker blue shades are in the range of the geomean and 90th percentile for shellfishing standards. Any other colors would indicate potential problems meeting shellfishing standards.

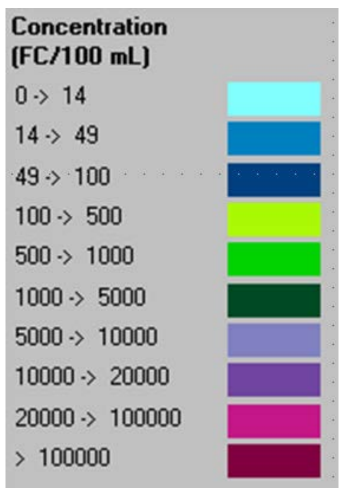
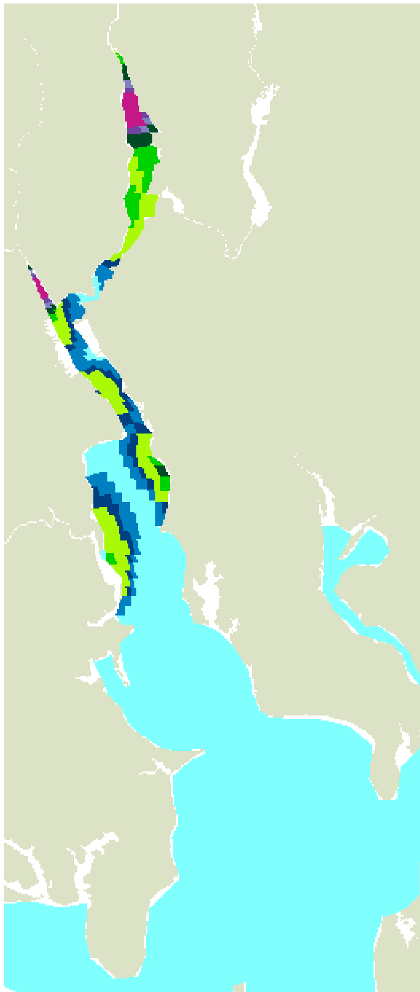
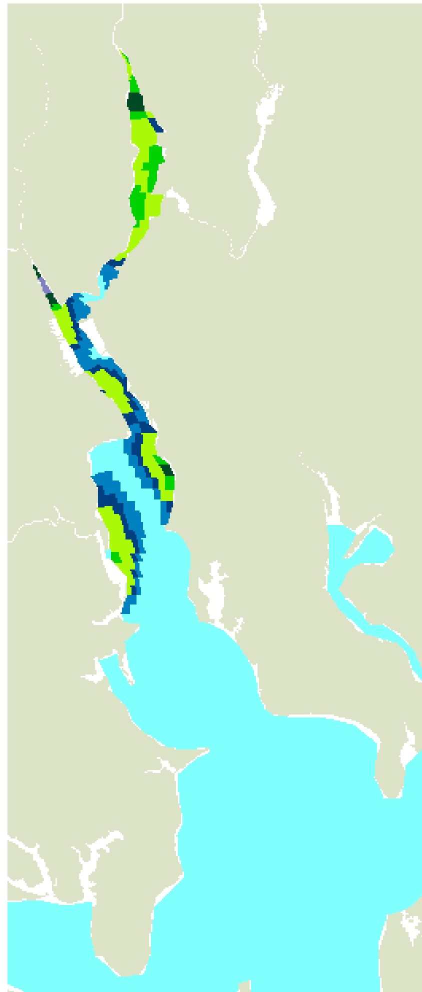


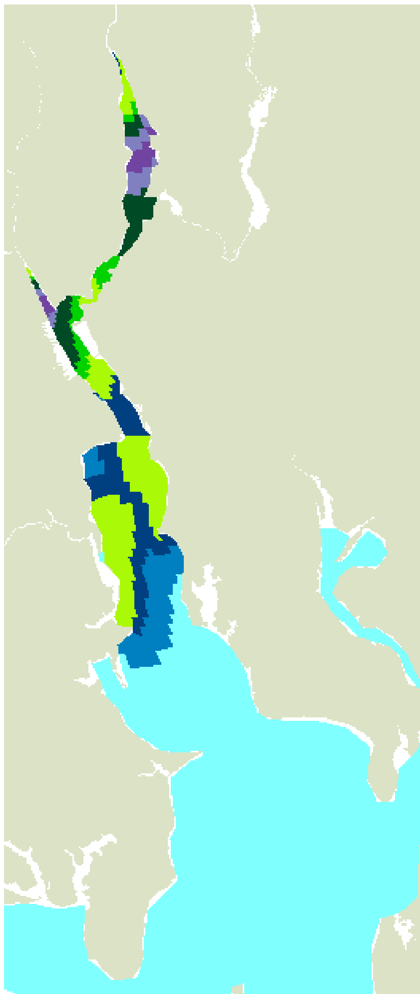
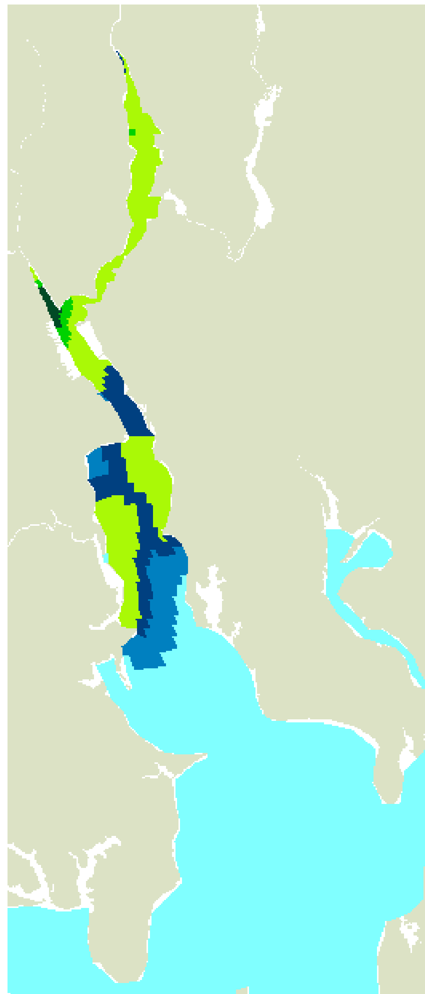
Figure 7-3 – Fecal Coliform Concentration Color Codes

The following pages provide the plan view plots for the current post-Phase II conditions and the projected post-Phase III conditions at the time steps following the 3-month storm.

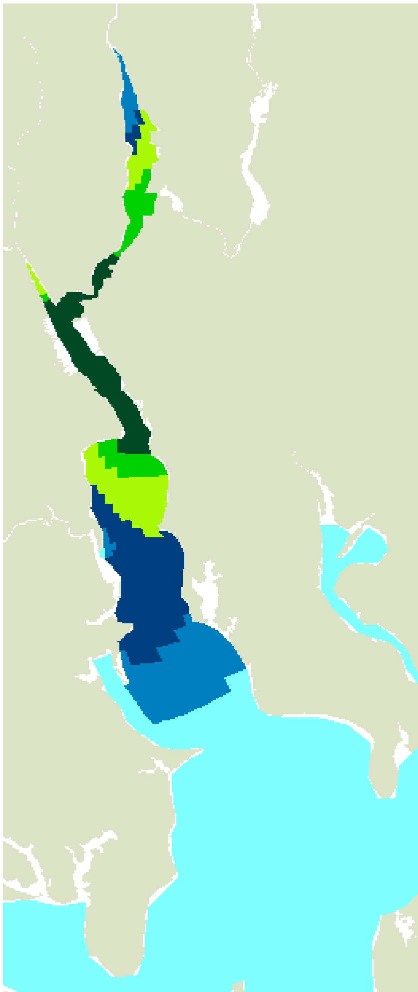
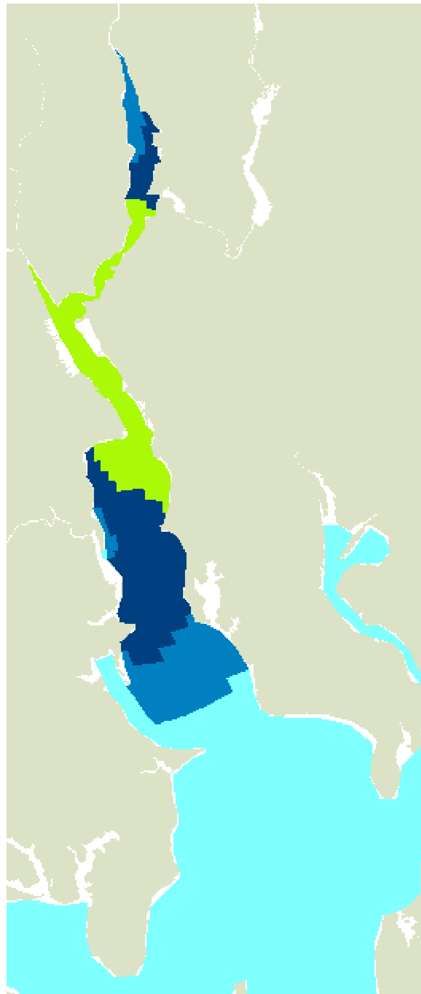
Plan view of Fecal Coliform concentrations 0.5 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

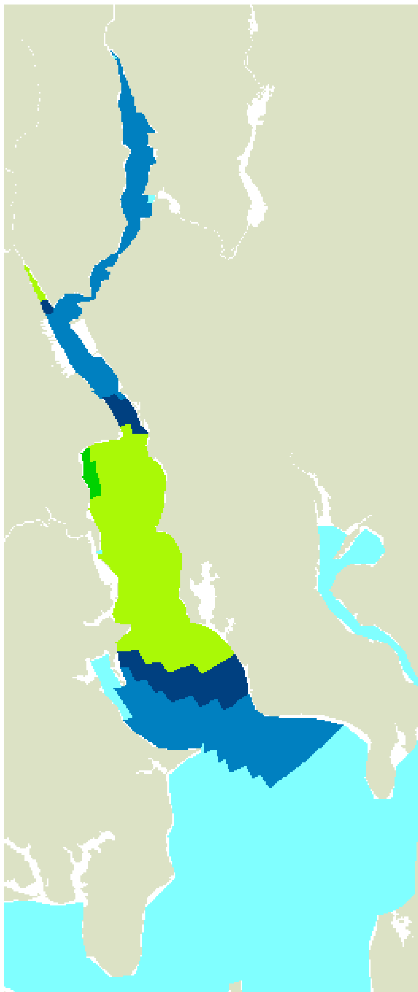
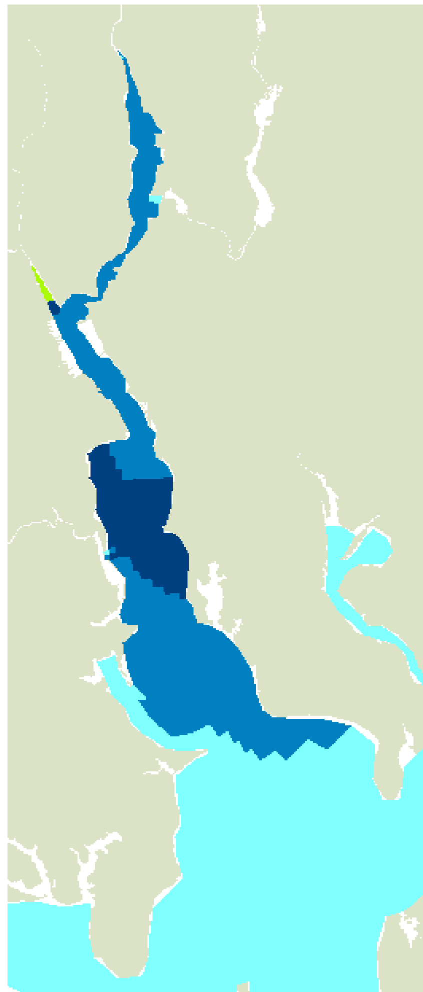
Plan view of Fecal Coliform concentrations 1 day after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

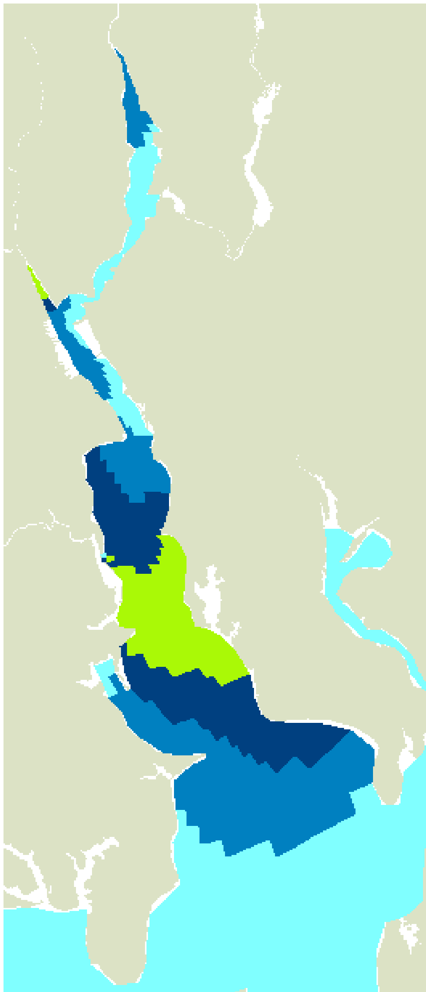
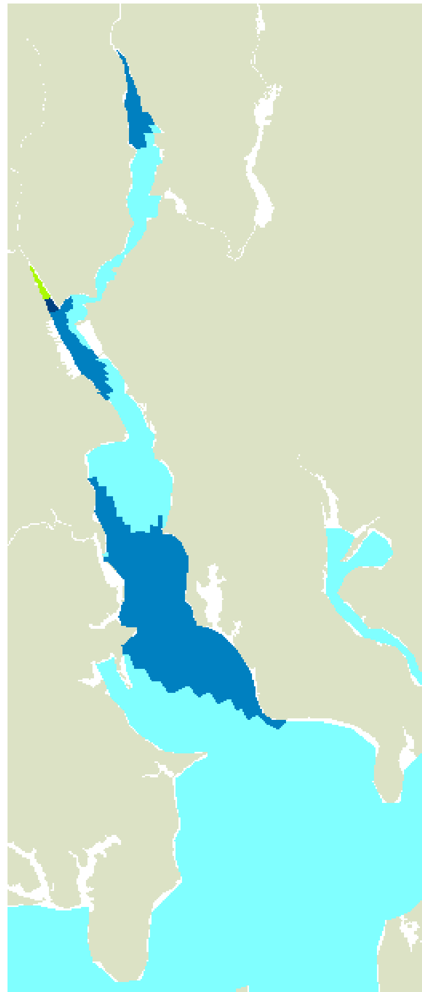
Plan view of Fecal Coliform concentrations 2 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

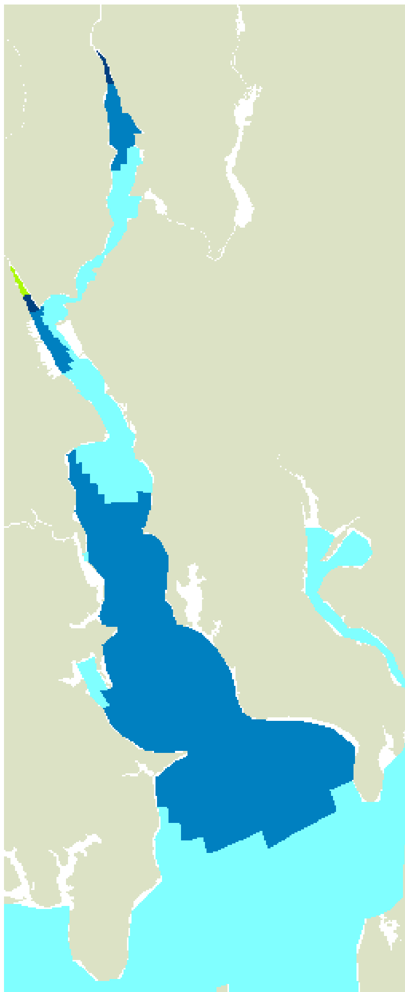
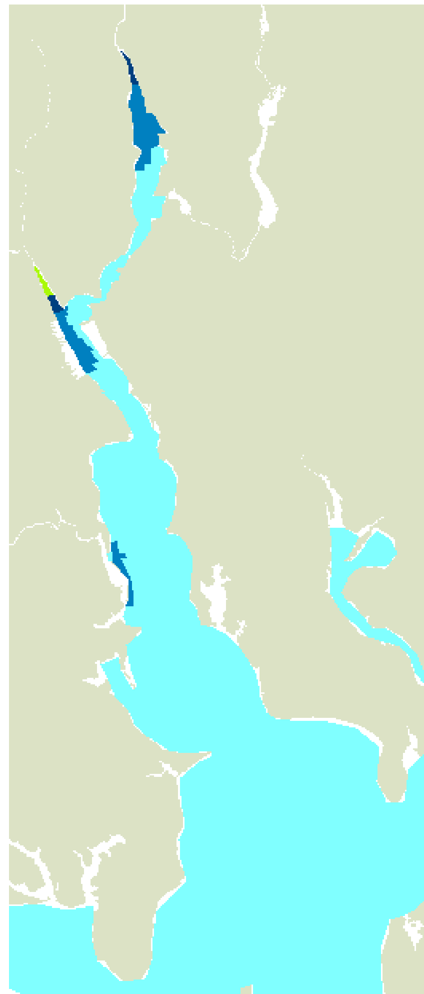
Plan view of Fecal Coliform concentrations 4 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

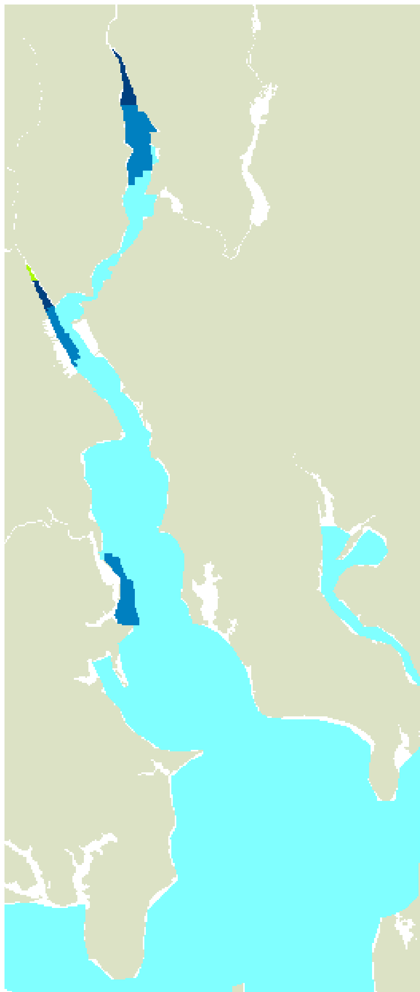
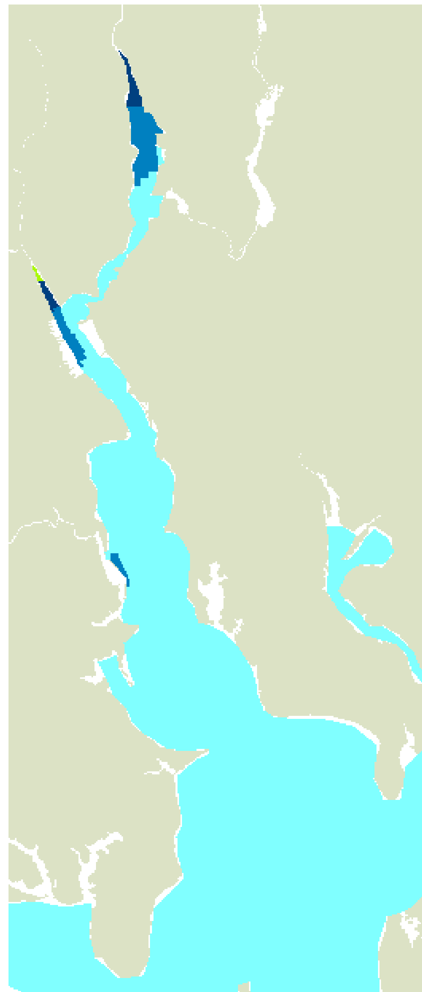
Plan view of Fecal Coliform concentrations 6 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

Plan view of Fecal Coliform concentrations 8 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

Plan view of Fecal Coliform concentrations 10 days after start of 3-month storm

Post-Phase II (2015)	**Post-Phase III** (2038)
	

Under current, post-Phase II conditions, there are plumes of high concentration exceeding 20,000 Fecal Coliform (FC) per 100mL at the Providence and Blackstone/Seekonk Rivers immediately following the storm event. One day following the storm, high concentrations exceeding 10,000 FC/100mL remain at the Providence and Blackstone/Seekonk Rivers and range from 500 to 5,000 FC/100mL between Bucklin and Field's Points. By day 2, concentrations in the Seekonk start to fall below 500 FC/100mL, but concentrations between the Providence River and Field's Point remain above 1,000 FC/100mL. By day 4, concentrations north of Field's Point drop below contact standards; however, the plume reaches Conimicut Point with concentrations exceeding shellfishing standards until day 8 and drop below the threshold by day 10.

For the post-Phase III condition, all CSOs are eliminated for the 3-month storm. Therefore, remaining FC concentrations are attributable to stormwater system discharges and sources outside of the NBC combined sewer area. Immediately following the storm event, concentrations are in excess of 5,000 FC/100 mL at the Providence River and concentrations exceed 1,000 FC/100mL at the Blackstone/Seekonk River. One day following the event, concentrations near the Providence River exceed 1,000 FC/100mL; however, concentrations elsewhere approach contact standards. By day 4, concentrations north of Field's Point are well within contact standards, concentrations south of Field's Point are close to standards, and the plume with concentration near shellfishing standards reaches Conimicut Point. By day 6, concentrations throughout the modeled area are within all standards.

The water quality model was calibrated to and can provide predicted results for specific locations throughout the area. Figure 7-4 illustrates station locations in the model.

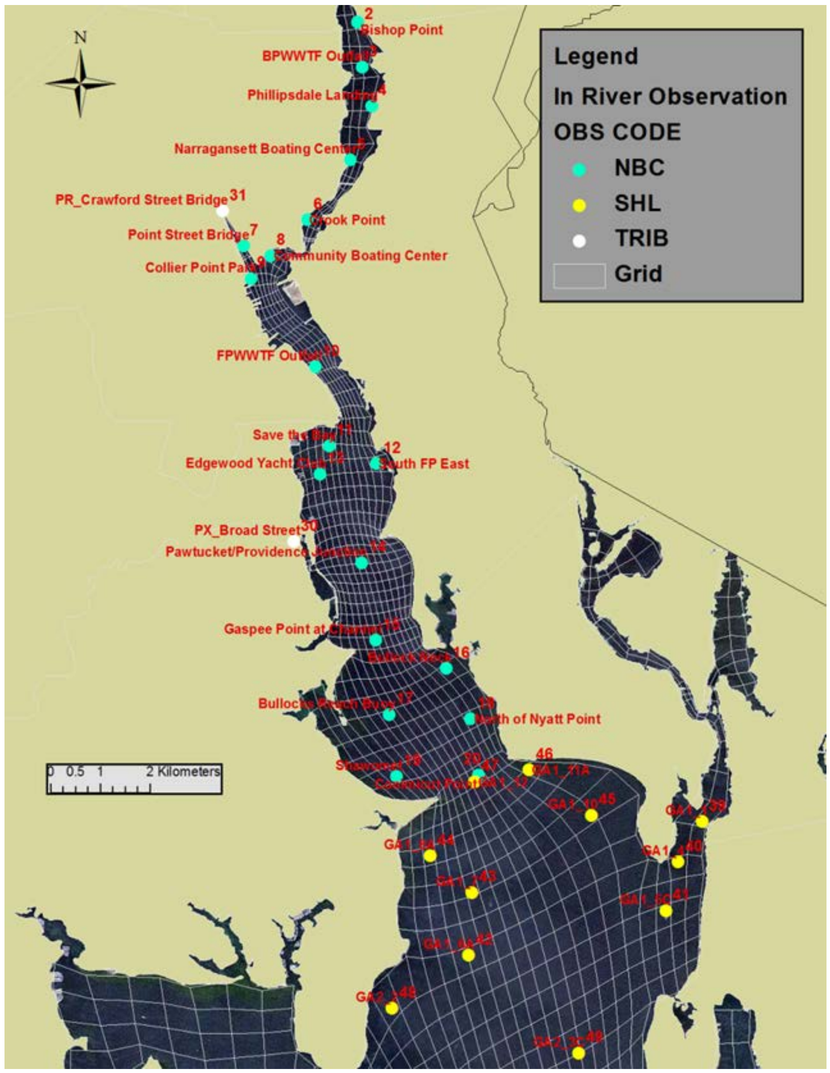


Figure 7-4 – Station Locations

Figure 7-5 illustrates the instantaneous bacterial concentrations predicted by the model following the 3-month storm for post-Phase II and post-Phase III conditions at Station 5 – The Narragansett Boating Center which is located just downstream of the BPSA WWTF and which is influenced by CSOs on the Blackstone and Seekonk Rivers. For this area, the recreational contact standards apply, therefore, the geomean of all samples taken at that location need to be below 50 Fecal Coliform (FC) per 100 mL and 90 percent of all samples need to be below 400 FC/100mL to meet standards. Available water quality sampling data indicate that those statistical standards are exceeded even during dry weather likely due to non-CSO sources and residual loads from CSOs following storms. The model results illustrate the significant impact that Phase III will have on bacterial concentrations, reducing all but a transient spike below the 90 percentile standard.

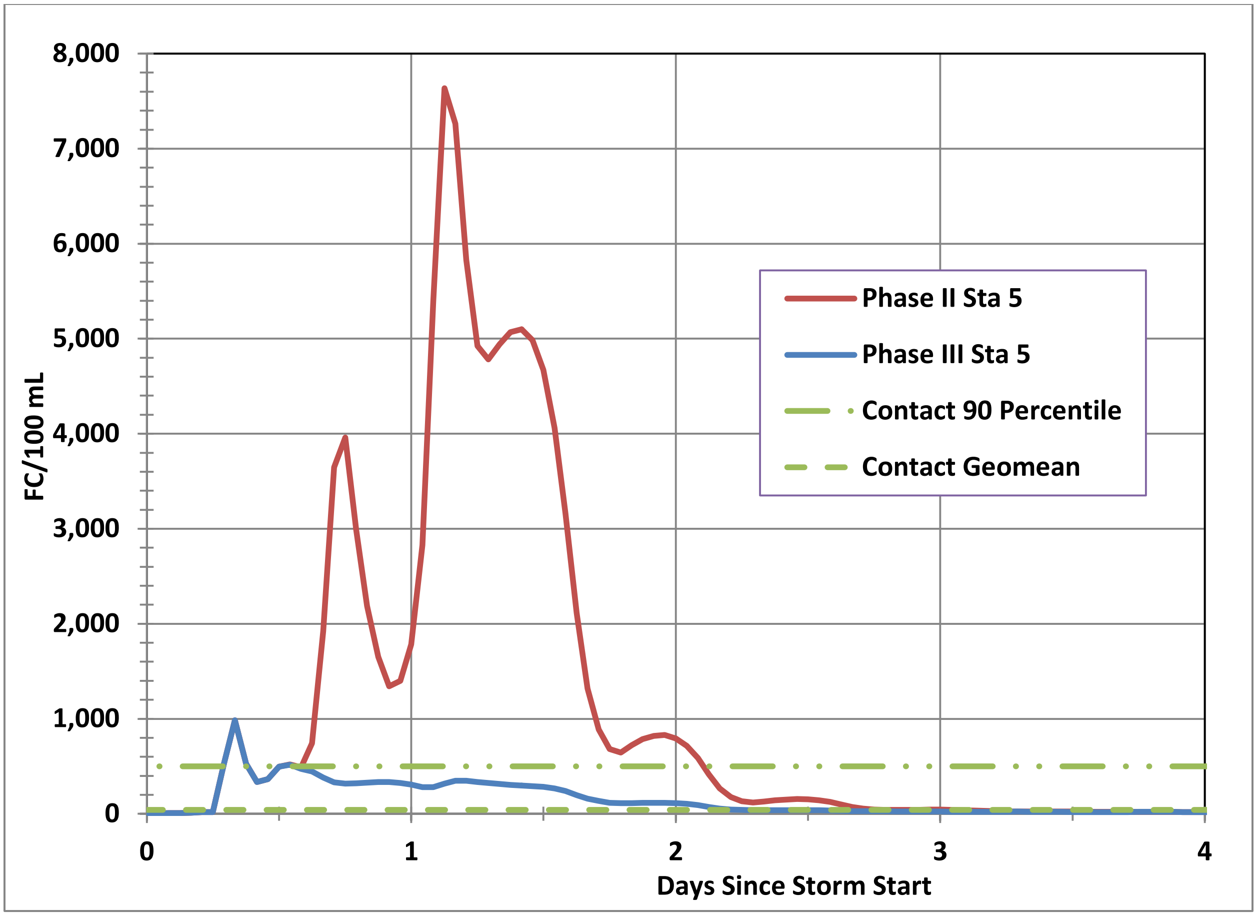


Figure 7-5 – Bacterial Concentrations at Narragansett Boating Center

Figure 7-6 illustrates the instantaneous bacterial concentrations predicted by the model following the 3-month storm for post-Phase II and post-Phase III conditions at Station 13. This station is at the Edgewood Yacht Club, which is located downstream of all Phase III CSOs. For this area, the contact recreation standards apply. Available water quality sampling data indicate that standards are exceeded even during dry weather likely due to non-CSO sources and residual loads from CSOs following storms. The modeling results imply that 10 days of dry weather must follow the 3 month storm for standards to be met. Following Phase III, the model results imply that duration would be reduced to 5 days.

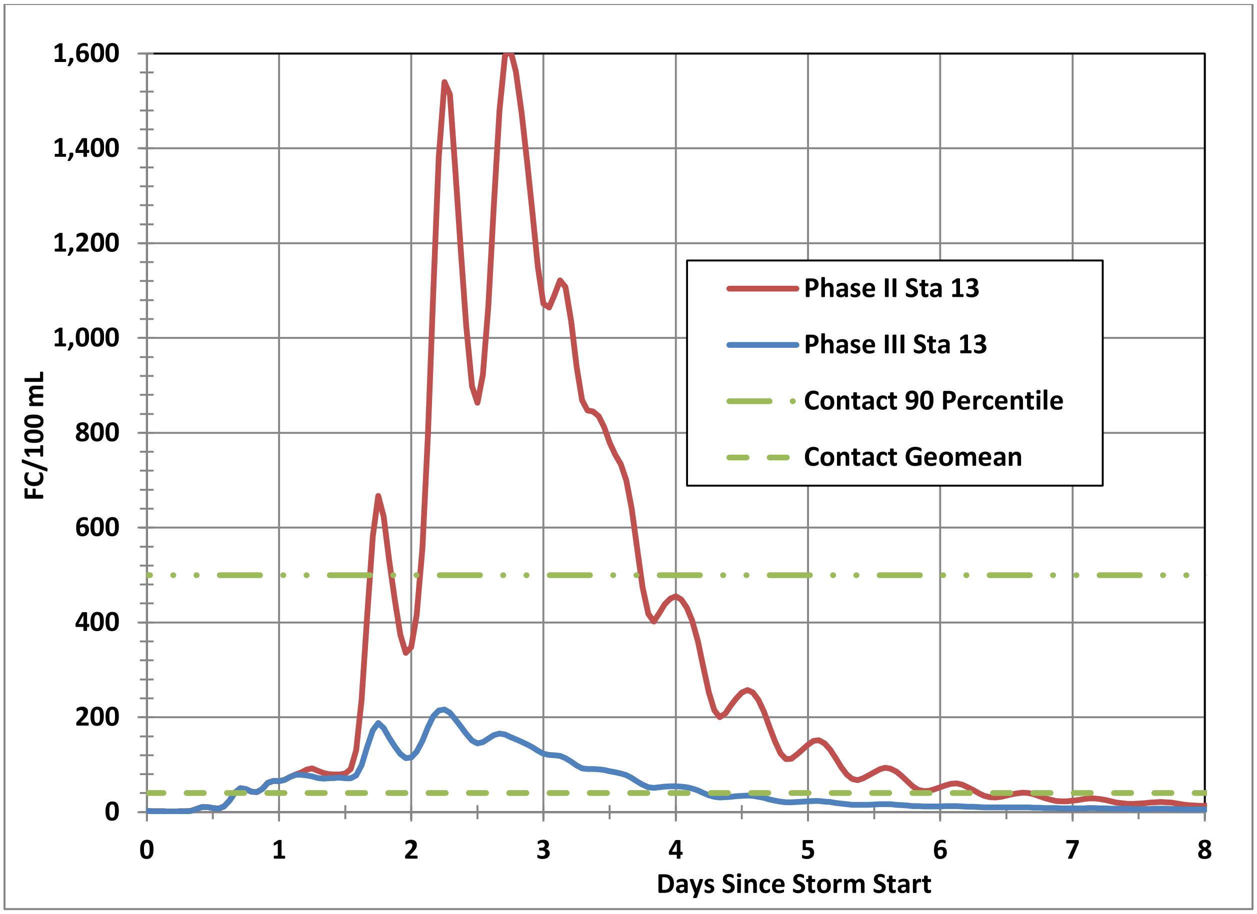


Figure 7-6 – Bacterial Concentrations at Edgewood Yacht Club

Figure 7-7 illustrates the instantaneous bacterial concentrations predicted by the model following the 3-month storm for post-Phase II and post-Phase III conditions at Station 20. This station is at Conimicut Point, where shellfishing standards apply. Therefore, the geomean of all samples taken at that location need to be below 14 FC per 100 mL and 90 percent of all samples need to be below 49 FC/100mL to meet standards. The model results indicate that the plume takes several days to reach Conimicut Point. For the 3-month storm, current post-Phase II conditions result in concentrations in excess of the 90 percentile standard from day 3 through day 7. Phase III would reduce peak concentrations below that threshold, which represents a significant improvement in water quality and standards attainment. While non-CSO loads following Phase III construction would result in concentrations higher than 14 FC/100mL following the 3-month storm, the duration over that threshold would be reduced by 4.5 days compared to post-Phase II conditions.

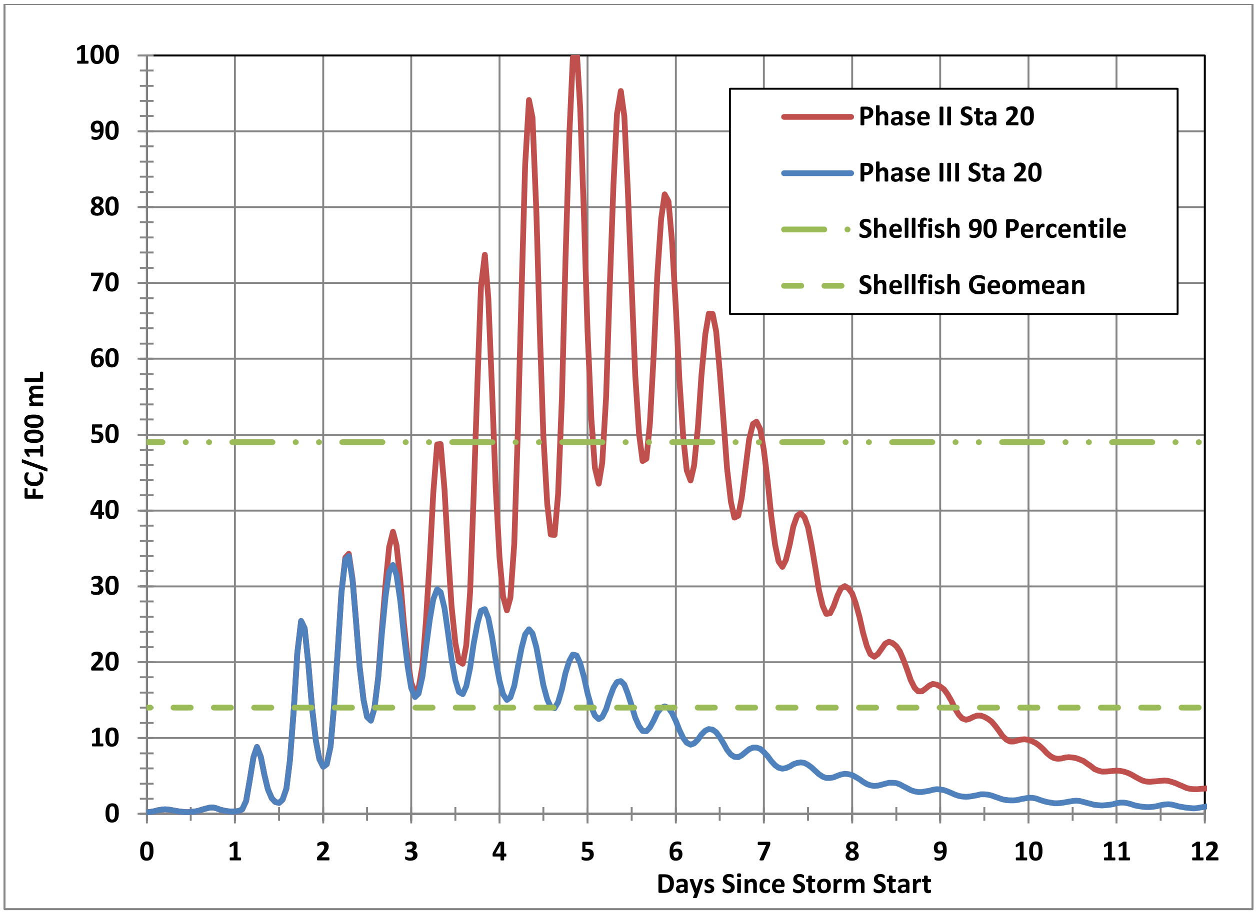


Figure 7-7 – Bacterial Concentrations at Conimicut Point

The model results were also used to calculate the area that exceeds standards and the duration for which those standards are predicted to be exceeded. That analysis defines a metric of Acre-Days that provides an understanding of water quality for different alternatives. Figure 7-8 depicts the location of different areas that the model can examine. Tables 7-2 and 7-3 provide those results for the 3-month storm for the Providence and Seekonk Rivers and for Conimicut Triangle and Conditional Area A.

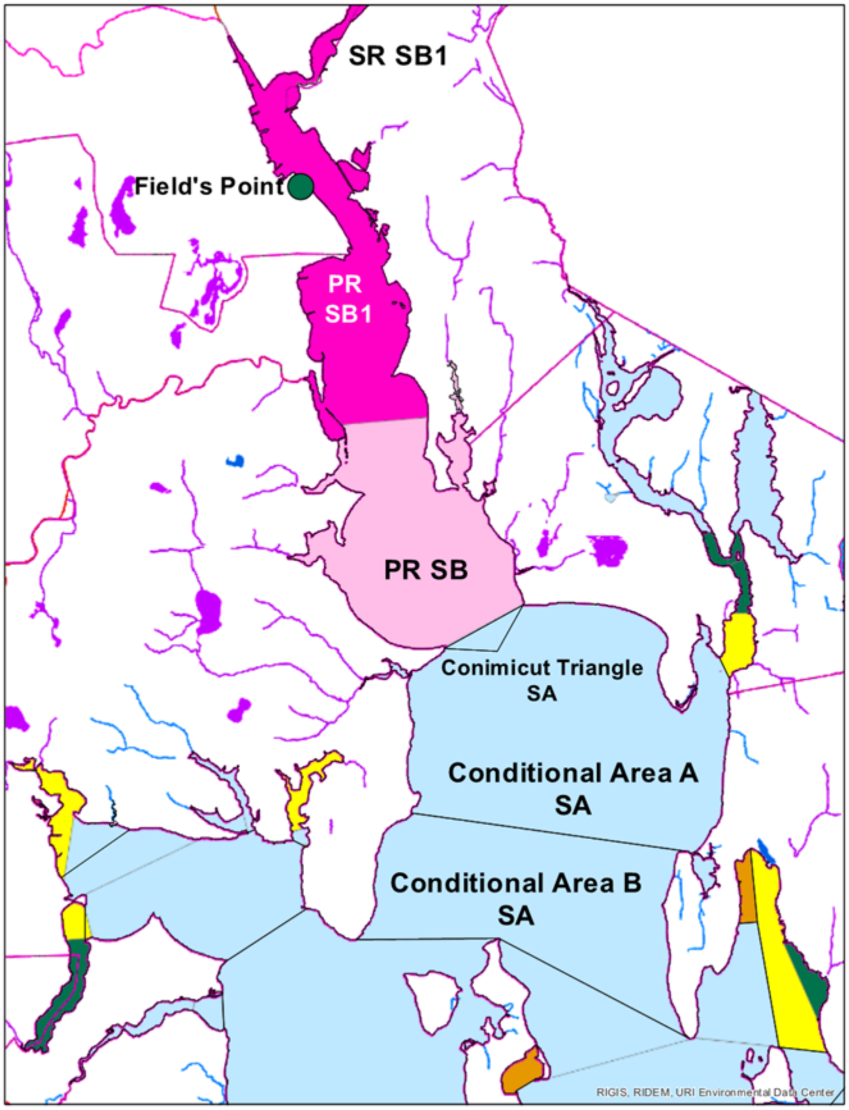


Figure 7-8 – Area Definitions

Table 7-2 – Non-Attainment at Providence and Seekonk River, 3-Month Storm

	Providence River		Seekonk River	
Standard:	50 FC/100mL	400 FC/100mL	50 FC/100mL	400 FC/100mL
Post-Phase II	9,040 AcreDays	113 AcreDays	1,400 AcreDays	619 AcreDays
Post-Phase III	1,880 AcreDays	1 AcreDays	1,180 AcreDays	162 AcreDays
Percent Improvement	**79%**	**99%**	**16%**	**74%**

Table 7-3 – Non-Attainment at Conimicut Point and Conditional Area A, 3-Month Storm

	Conimicut Triangle		Conditional Area A	
Standard:	14 FC/100mL	40 FC/100mL	14 FC/100mL	40 FC/100mL
Post-Phase II	1,860 AcreDays	423 AcreDays	10,900 AcreDays	1,110 AcreDays
Post-Phase III	744 AcreDays	0 AcreDays	1,960 AcreDays	0 AcreDays
Percent Improvement	**60%**	**100%**	**82%**	**100%**

The analysis concludes that non-CSO loadings will continue to contribute to water quality impairments in the region. However, the water quality improvements achieved by the Recommended Phase III program will significantly reduce bacterial concentrations in Narragansett Bay following any storm up to the design capacity of the Phase III facilities.

7.8. Conceptual Schedule

The Pawtucket Tunnel is the largest and most complex component of the overall Phase III plan. Consequently, Phase A is expected to require 3 years for the design phase and five years for the construction phase. All of the other sub-phases are expected to require two years for design and three years for construction. Accommodating the adaptive management planning with the IPF methodology discussed above, the resulting conceptual schedule for Phase III is as follows:

- 2015: Concept review and Consent Agreement modification
- 2016 - 2018: Phase A design, review and bidding
- 2019 – 2023: Phase A construction
- 2023: Initiate IPF evaluation of all regional CWA projects and affordability
- 2024 - 2025: Phase B design, review and bidding
- 2026 – 2028: Phase B construction
- 2028: Initiate IPF evaluation of all regional CWA projects and affordability
- 2029 - 2030: Phase C design, review and bidding
- 2031 – 2033: Phase C construction
- 2033: Initiate IPF evaluation of all regional CWA projects and affordability
- 2034 - 2035: Phase D design, review and bidding
- 2036 – 2038: Phase D construction

7.9. Projected Rate Impacts

The projected expenditures for Alternative 2 are presented for each of the four phases in the following tables.

Phase A ($M)

	2016	2017	2018	2019	2020	2021	2022	2023
	Phase III-A Design			Phase III-A Construction				
Phase III-A								
Pawtucket Tunnel	$7.49	$7.49	$7.49	$121.52	$121.52	$121.52		
Drop shaft 218 & conduit	$0.92	$0.92	$0.92		$14.95	$14.95	$14.95	
Drop shaft 205 & conduit	$0.46	$0.46	$0.46			$7.51	$7.51	$7.51
Drop shaft 210/211 & conduit	$0.53	$0.53	$0.53			$8.57	$8.57	$8.57
Drop shaft 213 & conduit	$0.81	$0.81	$0.81			$13.07	$13.07	$13.07
Drop shaft 217 & conduit	$0.91	$0.91	$0.91			$14.79	$14.79	$14.79
Regulator Modifications & Floatables Controls	$0.05	$0.05	$0.05					$2.51
GSI Project Allowance	$0.33	$0.33	$0.33	$10.00				
Totals:	**$11.51**	**$11.51**	**$11.51**	**$131.52**	**$136.47**	**$180.41**	**$58.89**	**$46.45**

Phase B ($M)

	2024	2025	2026	2027	2028
	Phase III-B Design		Phase III-B Construction		
Phase III-B					
GSI Project Allowance	$0.50	$0.50	$10.00		
High & Cross Street Interceptor	$0.46	$0.92	$7.43	$7.43	$7.43
Middle Street Interceptor	$0.60	$0.89	$4.63	$4.63	$4.63
206 Hybrid GSI / Sewer Separation	$0.17	$0.25	$2.15	$2.15	
Totals:	**$1.72**	**$2.56**	**$24.22**	**$14.22**	**$12.07**

Phase C ($M)

	2029	2030	2031	2032	2033
	Phase III-C Design		Phase III-C Construction		
Phase III-C					
GSI Project Allowance	$0.50	$0.50	$10.00		
220 Stub Tunnel Alternative	$1.86	$1.86	$29.76	$29.76	$29.76
Totals:	**$2.36**	**$2.36**	**$39.76**	**$29.76**	**$29.76**

Phase D ($M)

	2034	2035	2036	2037	2038
	Phase III-D Design		Phase III-D Construction		
Phase III-D					
GSI Project Allowance	$0.50	$0.50	$10.00		
West River Interceptor	$0.74	$1.49	$12.05	$12.05	$12.05
035 Sewer Separation	$0.34	$0.68	$6.05	$6.05	$6.05
Totals:	**$1.58**	**$2.67**	**$28.10**	**$18.10**	**$18.10**

Based on those projected capital improvements, plus the other project commitments and ongoing operations of its interceptor and treatment facilities and the financing assumptions discussed in Chapter 1, NBC's projected average residential bills over the planning period are illustrated in Figure 7-9.

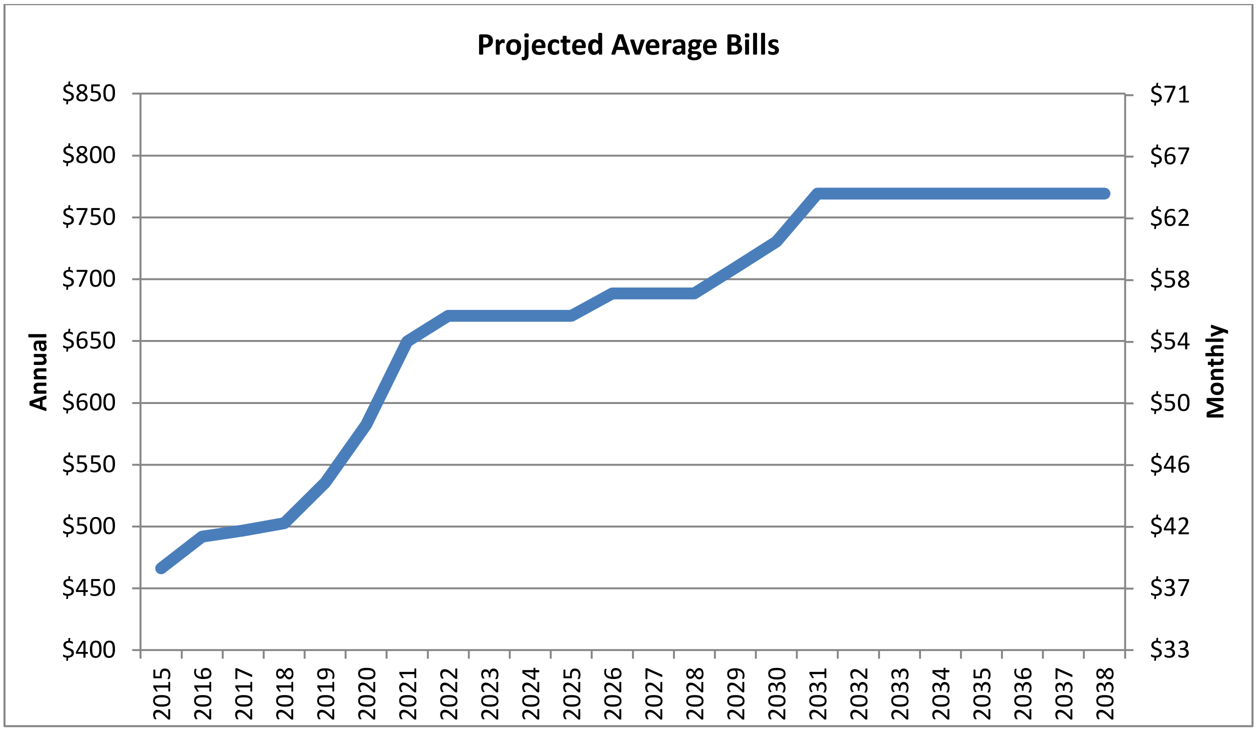


Figure 7-9 – Projected Average Bills

Public Financial Management, Inc. (PFM) was engaged to perform an independent analysis of the rate impact of the Phase III program and provide a second opinion on the associated rate projections. PFM modeled individual cash flows into the future through a collaborative process with NBC to determine appropriate year-over-year growth rates, reasonable trend assumptions on line items, and other considerations for non-user fee revenues, non-operating revenues, and certain uses of funds. PFM structured its projections with two key features: debt would be issued in any year needed to cover additional capital costs, and user rates would be uniformly raised to maintain at least1.25x coverage where required. For any debt issuance, the first $25 million would be issued using State Revolving Fund financing, and any further requirements would utilize open market bonds. NBC and PFM worked extensively to ensure all projections were a consistent reflection of NBC's cash flows and operations. The resulting debt structure assumptions were slightly different from those in the MWH/Pare analysis above, therefore, the rate increases predicted by PMF were somewhat accelerated but ultimately lower as illustrated in Figure 7-10 below.

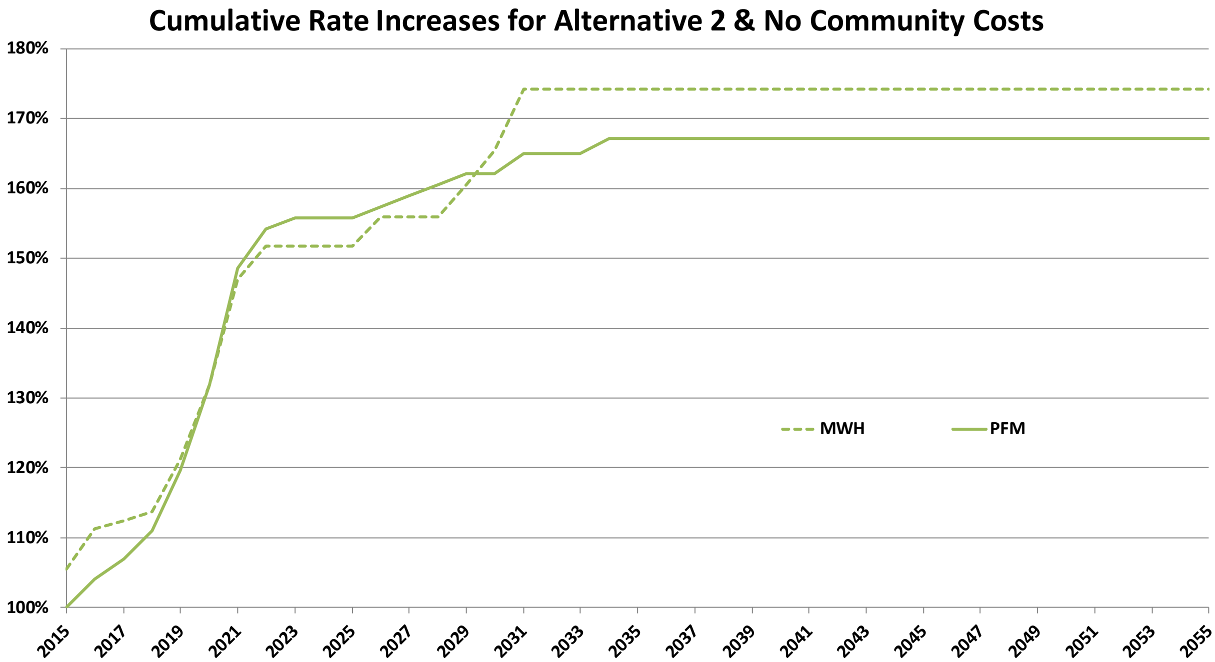


Figure 7-10 – Projected Rate Increase Comparison with PMF Assumptions

The PFM analysis ultimately projected rates to reach $767 by the end of the program compared to the $769 projected by the MWH/Pare analysis. Therefore, the independent estimate confirmed the validity of the rate projections presented.

7.10. Conclusion

The recommended plan will satisfy the same design criteria and water quality goals of the program established by the CDRA. The revised Phase III plan incorporates lessons learned during the first two phases of the CSO program and the input from the Stakeholder Group. The extended schedule for Phase III will improve the affordability of the program and will provide the necessary flexibility to address change and prioritize water quality improvements while maintaining affordability for the area's rate payers.

Based on the affordability analysis presented in Chapter 1, NBC established an affordability goal that its rates would not exceed 2% of any member community's median household income or would not exceed 2% of the household income for more than one-third of its ratepayers. That goal equates to a sewer bill of $626. The projected rate for Alternative 2 at the end of construction in 2038 is $769, which exceeds the goal. The projected rate at the end of Phase A, the Pawtucket Tunnel, is $670 which also exceeds the affordability goal. Since there is some uncertainty as to what the actual costs will be for Phase A, what actual rate will be affordable according to NBC's affordability goal and what the cost of other projects such as local sewer infrastructure improvements will be in the future, NBC should proceed with design of Phase A but should reevaluate its affordability before proceeding with construction of Phase A. A similar reevaluation should be conducted for each of the three subsequent phases.