NBC CSO Control Facilities Phase III Reevaluation

Appendix 1 – Member Community Sewer and Stormwater Needs

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1. Introduction

As discussed in Chapter 1, the Integrated Planning Framework seeks to evaluate all Clean Water Act-related projects together to develop an overall integrated capital improvement plan that prioritizes all wastewater, stormwater and CSO projects. The evaluation criteria developed above would be used to complete that prioritization on all CWA-related projects. Circumstances in the Greater Providence area, however, are such that separate entities are responsible for those potentially rated projects. NBC is responsible for wastewater treatment and CSOs. The member communities are responsible for the collection systems and stormwater discharges. Therefore, this section presents information on the member communities' collection systems, maintenance practices and potential needs to understand the potential projects that may be evaluated alongside Phase III CSO projects.

The purpose of this section is to develop capital improvement budget estimates for the Narragansett Bay Commission (NBC) member communities' stormwater and wastewater collection systems. This information has been compiled to support the affordability analysis of the proposed Phase III CSO Program. NBC's service area encompasses Providence, North Providence, Johnston, Pawtucket, Central Falls, Cumberland, Lincoln, the northern portion of East Providence, and small sections of Cranston and Smithfield. However, Cranston and Smithfield both maintain their own wastewater treatment facilities, which treat the majority of the Town's wastewater, with a relatively small amount of wastewater discharged to the NBC's interceptors. Therefore, these two municipalities have been excluded from this memorandum. The following sections of this memorandum include a description of the existing stormwater and wastewater collection systems in each community and an annual budgetary estimate for capital improvements in these member communities. The budgetary estimate is a rough order of magnitude estimate of capital costs that each member should be spending on capital upgrades given the age and amount of infrastructure in each community. These costs include construction costs, as well as planning and engineering. These costs are separate and above what the communities are currently spending on routine maintenance and operation of their systems.

2. Member Communities

2.1. Providence

The City of Providence is the capital of Rhode Island, is approximately 25.5 mi^2 in area and has a population of approximately 183,000. The median household income is approximately $38,250. The City is served by a combined sewer system (CSS) and municipal separate storm sewers (MS4). According to the Upper Narragansett Bay Regional Stormwater Utility Feasibility Study - Phase I, draft Final Report dated April 2014, approximately 35 percent of the City is served by the MS4, with the remaining 65 percent served by the CSS. The City was reported to include 16,000 catch basins and manholes, approximately 5,600 of which are MS4 catch basins and manholes, and 175 MS4 outfalls located along 370 miles of public roadway.

The City is currently undertaking a Stormwater Initiative, spearheaded by Director of Sustainability Ms. Sheila Dormody. The City was awarded a $75,000 grant, which covered Phase I of this program – a Does-It-Make-Sense (DIMS) study. The study was awarded to AMEC, and based on a meeting with the City of Providence in March 2014 and a Phase I report was completed in July, 2014. Phase II would consist of the development of plans for implementation and a rate structure to pay for the program. The City is currently conducting meetings to initiate Phase II. In addition, some stormwater-related projects are being initiated by the City's Parks & Recreation Department. Green stormwater infrastructure has been constructed in and around Roger Williams Park, and is maintained by the Parks Department.

City personnel indicated that stormwater and wastewater mapping exists in hard copy and scanned PDF formats, though CDM-Smith has been contracted to create a geographic information system (GIS) geodatabase of the sewer and drainage infrastructure. The City maintains one (1) sanitary pump station. Most of the City's CSS date to the 1880's and consists of predominantly clay pipe for smaller diameter pipe and brick pipe for larger diameter. There are a small number of pipes in the 60-inch to 72-inch diameter range, and a few around 36 inches in diameter, though the majority of the system is smaller diameter pipe. City personnel reported that the eastern portion of the City proximate to Brown University is primarily separated sewer and drainage.

It was reported that there are no current or proposed capital improvements planned for the CSS and MS4. In addition, there are no planned sewer repairs at this time. Repairs are generally made only when collapses affect surface roadways. No enterprise fund exists for stormwater or wastewater, with repairs and maintenance costs provided by the City's Department of Public Works (DPW) budget funded through the general tax base. Emergency sewer repairs in the City cost approximately $50,000-100,000 on an average year.

2.2. North Providence

The Town of North Providence, located in northeastern Rhode Island and north of Providence, is approximately 6 mi^2 in area and has a population of approximately 32,000. The median household income is approximately $50,950. The Town is served by a separate sewer system (SSS) and MS4. The Town is reported to have approximately 780 catch basins and manholes along 115 miles of public roadway and 49 MS4 outfalls. Any new pipe that is installed as part of a repair is polyvinyl chloride (PVC). The Town has one (1) sanitary pump station that was rebuilt approximately 4-5 years ago. The east side of the Town is much older than the west side of the Town. The west side of North Providence had sewers installed in the late 1970s, most of which are plastic. The east side of the Town bordering Pawtucket has a mix of clay and brick sewers. The majority of the SSS is 8-inch diameter pipe, with a few reaches of 12-inch diameter pipe. A small amount of septic systems exist in the Town near its border with Smithfield. According to the 2013 North Providence Comprehensive Community Plan, the sewer system is already at build-out. The report also indicates that significant infiltration/inflow (I/I) problems exist in the Town, with a large number of illegal connections into the SSS reported to exist via roof drains and sump pumps. However, the Town does not have the budget or staffing to execute a program to eliminate these illegal connections.

The majority of the MS4 drains to the Woonasquatucket River. Town personnel indicated that most of the Town drains via overland flow, with catch basins located in the western section of the Town. The Town no longer sands the roads during the winter months, and only applies salt to the roads. This has resulted in the Town eliminating catch basin cleaning due to the lack of sand application. The Town does not own or maintain any stormwater outfalls. These outfalls are owned and maintained by the Rhode Island Department of Transportation (RIDOT). Surface flooding areas within the Town are predominantly isolated to the eastern section of the Town and are related to stream elevations. The Town has one (1) stormwater pump station, which was built approximately 10-12 years ago and runs nearly constantly due to groundwater.

The Town does not have digital mapping of its SSS and MS4. The Town recently hired a full-time GIS technician to begin mapping for all Town departments, beginning with the Tax Assessor's Department. However, SSS and MS4 infrastructure were reported to be lower on the priority list. The Town currently maintains a part-time employee in charge of inspecting and mapping the MS4. The Town's stormwater manholes and outfalls have been located with global positioning system (GPS) technology, though an assessment of the conditions of these manholes and outfalls will not be completed for several years given the current staffing limitations.

Town personnel indicated that there is no capital improvement plan for the SSS and MS4. In lieu of an official capital improvement plan, the Town internally ranks issues on a 1-3 scale, where 3 is the worst and requires immediate attention. Each year, the Town's DPW requests a "wish list" from the Town Hall. However, funding is not typically available and most years only street collapses are repaired. According to Town personnel, the Sewer Department maintains a "hot spot" list, though emergency repairs have been infrequent in recent years. Funding for the Town's DPW and sewer repairs come from the general tax base. The operation and maintenance budget for SSS and MS4 was reported to be approximately $60,000-$70,000 per year, including the reactive spot repairs of the system.

2.3. Johnston

The Town of Johnston, located in northern Rhode Island and west of Providence, is approximately 24.5 mi^2 in area and has a population of approximately 28,750. The median household income is approximately $56,800. The Town is served by an SSS and MS4. According to the 2010 Johnston Facilities Plan Update, wastewater in Johnston is collected via the Town-owned SSS and conveyed to the NBC-owned interceptors. Collected wastewater ultimately discharges to NBC's Field's Point Wastewater Treatment Facility (WWTF) in Providence, RI. The Town-owned SSS includes approximately 58 miles of sewer lines and eight (8) sanitary pump stations. Almost all sewer pipes are 8 inches or 10 inches in diameter. The SSS is comprised of PVC, vitrified clay (VC), and asbestos cement pipe (AC), with the oldest sewers consisting primarily of clay.

Town personnel indicated that they are in the process of mapping all of the catch basins in Town and are also working with Applied Geographics to transfer all SSS and MS4 infrastructure into a GIS-based geodatabase. In addition, the Town recently purchased a jet/vacuum truck for adequate SSS maintenance. Johnston initiated a Sewer Enterprise Fund in 2011 to be used solely to fund sewer infrastructure. The yearly fee is $125 for a single-family residence, with additional fees applying to multi-family residences and commercial properties. Stormwater maintenance is funded through the Town's DPW general budget.

2.4. Pawtucket

The City of Pawtucket, located in northeastern Rhode Island and north of Providence, is approximately 9 mi^2 in area and has a population of approximately 71,150. The median household income is approximately $40,400. The City is served by a CSS and MS4; though only approximately 10 percent of the catch basins were reported to be connected to the MS4. The City was reported to include approximately 182 miles of road; 200 miles of CSS and MS4 pipes; 6,000 catch basins and manholes, approximately 600 of which are MS4 catch basins and manholes; 49 MS4 outfalls, and 19 CSS outfalls. City personnel indicated that there is no current or planned capital improvement plan for the CSS and MS4. Repairs are generally made only on a reactive basis, due to backup complaints and street collapses. Problem sewer areas exist throughout the City. The majority of the CSS is 100 years old and made of brick or clay tile. The City owns 5 sanitary pump stations that are maintained biweekly. Soil contamination was reported to be relatively common across the City, specifically in the vicinity of the old mills, which can complicate sewer repairs or replacement.

There is no enterprise account for the CSS and MS4 infrastructure. The City bonds for all capital improvement projects. The only source of funding for CSS and MS4 infrastructure is the general tax base. Each year the operating budgets are voted upon and two years ago the sewer and drainage operating budget was voted down and thus no budget was set aside for maintenance of the system. The maintenance budget for the two systems is approximately $80,000-$100,000 per year. All constituents are billed directly from NBC. No additional fee is assessed to maintain Pawtucket's CSS. If funding was available, the City would locate all CSS and MS4 infrastructure with GPS technology and compile this information into a GIS database. In addition, the City would perform a closed-circuit television (CCTV) inspection of the entire system to prioritize repairs and switch from a reactive approach to a proactive approach. A hydraulic analysis would also be performed for the entire system to identify system deficiencies and limitations.

2.5. Central Falls

The City of Central Falls, located in northeastern Rhode Island and north of Providence, is approximately 1.3 mi^2 in area and has a population of approximately 19,400. The median household income is approximately $29,300. The City has a CSS, and all drainage is believed to discharge to the CSS and NBC interceptors and is conveyed to the NBC's Bucklin Point WWTF in East Providence, RI. City personnel indicated that the majority of the gravity-fed CSS was constructed in the late 1800s and is made of brick or clay tile. However, the older brick and clay pipes were not reported to be a major problem, with most of the problems in the system due to catch basin laterals with chimney drops. The City was reported to include 1,158 catch basins and manholes and 7 CSS outfalls on its 27 miles of public roadway. A plan entitled "Map Showing Location of Sewers and Appurtenances in the City of Central Falls", dated November 1951, indicates that the City's CSS includes approximately 23 miles of pipeline. Up until the early 1990s, a residential neighborhood located within the City discharged directly to the Blackstone River. However, in the early 1990s, those residences were required to install grinder pumps and discharge to the CSS and NBC collection system. Individual properties are required to maintain these grinder pumps. The City has stormwater outfalls on the Blackstone River that are often impacted by the river level during storm events.

The City was recently released from receivership and because of funding constraints, no CSS capital improvement plan exists. Only emergency sewer incidents where the road surface is compromised are repaired. However, the City purchased a jet/vacuum truck in 2013 for the purpose of routinely cleaning of catch basins and sewers as needed. No enterprise fund exists for the CSS, with repairs and maintenance costs provided by the City's DPW budget funded through the general tax base. Residents and commercial properties receive sewer bills directly from NBC.

2.6. Cumberland

The Town of Cumberland, in the northeastern corner of Providence County, is approximately 28 mi^2 in area and has a population of approximately 33,500. The median household income is approximately $73,350. The Town is served by an SSS and MS4, with all new developments required to connect to the Town's SSS. The Town's 2012 Rhode Island Pollutant Discharge Elimination System (RIPDES) Small MS4 Annual Report indicates that approximately 160 roadway miles and 2,400 catch basins are located within the Town's regulated area. According to Town personnel, the SSS consists of predominantly 8-inch to 10-inch diameter pipe, though a few sections of 12-inch pipe exist in the old mill villages located within the Town adjacent to the Blackstone River. SSS infrastructure ranges in age from greater than 100 years old in the mill sections of Town to sewers installed during recent development projects. However, the majority of the Town's SSS infrastructure was installed in the 1970s and 1980s. The old pipes are brick and clay tile, while more recent installations are mostly PVC. The percentage of sewers that are original was reported to be no more than 10 percent. The Town owns and operates four (4) sanitary pump stations. All Town-owned pump stations have had pump upgrades in the last five (5) years. In addition, there are three (3) private sanitary pump stations located in Cumberland which are owned and operated by neighborhood associations. The Town internally manages stormwater within its municipal boundary to prevent discharge into the NBC system through the use of best management practices (BMPs) in all proposed commercial and industrial developments in accordance with the Town's Code of Ordinances.

The Town maintains an enterprise account for operation and maintenance of the SSS. The annual fee for a residential unit is $61 for a single family dwelling, while multi-family units are charged an equivalent dwelling unit fee. Commercial users are charged a rate based upon water consumption. The ordinance was created in 2003 and updated in 2009. MS4 infrastructure is maintained by the Town's Highway Department. According to Town personnel, the current year sewer budget is $40,000.

2.7. Lincoln

The Town of Lincoln, located in northeastern Rhode Island and north of Providence, is approximately 19 mi^2 in area and has a population of approximately 21,500. The median household income is approximately $75,450. The Town is served by an SSS and MS4. The SSS is available to approximately 99 percent of the geographic area of the Town, with areas outside the SSS service area served by individual sewage disposal systems (ISDS). Town personnel estimate that approximately 95 percent of the Town is connected to the SSS. The Town's SSS discharge to the NBC interceptors and is conveyed to NBC's Bucklin Point WWTF in East Providence, RI or Field's Point WWTF in Providence, RI. The Town has internally managed stormwater within its municipal boundary to prevent discharge into the NBC system through regulatory actions over the past two decades, with only one priority outfall to the TMDL-controlled Blackstone River located within the Town.

The SSS includes 97 miles of gravity sewers and 6 miles of force main ranging in age from prior to 1900 in some of the mill villages located within the Town to sewers installed during recent development projects. A major SSS construction program was conducted by the Town during the late 1980s to early 1990s, and all new development is required to connect to the SSS. The SSS consists of 32 pump stations, including 26 submersible pump stations, five (5) wet well pump stations, and one (1) screw pump station. The SSS is designed to accommodate a peak day design flow of 19.6 MGD, though the peak day wastewater flow projected by the Town's Final Wastewater Facilities Plan, dated November 2006, is 4.28 MGD. According to this Facilities Plan, the SSS is primarily of PVC construction, though VC, AC, ductile iron (DI), and reinforced concrete pipe (RCP) also exist within the system. The SSS is predominantly 8-inch diameter pipe, though the system also includes pipes up to 24 inches in diameter.

The Town is about to complete debt service payments on the approximate $40 million utilized to fund the SSS construction program conducted by the Town during the late 1980s to early 1990s. This project consisted of installation of sewers throughout the Town as well as construction of the connections to the NBC interceptors. Financial assistance provided through the Rhode Island Department of Environmental Management's (RIDEM's) State Revolving Fund (SRF) from 2010 to 2014 totals $2,902,500. These loans will fund a Sanitary Sewer Evaluation Study and I&I Study; engineering of improvements for 26 submersible stations, five (5) wet well pump stations, and one (1) screw pump station; and construction of improvements for 26 submersible stations, two (2) wet well pump stations, and one (1) screw pump station. The Town is also requesting an additional $800,000 of SRF funding for construction improvements to the remaining three (3) wet well pump stations. The Town bills residential properties a flat fee of $100/year that is deposited into a Sewer Enterprise Fund for operation and maintenance of the SSS. Commercial users pay a higher rate based on water usage. All users receive a separate bill from NBC solely for treatment. A betterment fee for connecting to the SSS is approximately $1,900. Yearly SSS operation and maintenance is about $800,000 to $850,000 per year, while the cost for operation and maintenance of the Town's MS4 is approximately $50,000 per year.

2.8. East Providence

The City of East Providence, located in eastern Rhode Island and east of Providence, is approximately 16.6 mi^2 in area and has a population of approximately 47,000. The median household income is approximately $49,550. The City is served by an SSS and MS4 and includes 150 miles of public roadway. East Providence was reported to include 66 miles of MS4 drainage, 2 miles of drainage swales, 2,109 catch basins, 966 curb inlets, 1,354 drainage manholes, 50 drywells, 133 outfalls, and 28 BMPs. The SSS consists of approximately 166.5 miles of gravity pipe and 6.5 miles of force main. The SSS includes PVC, DI, VC, AC, RCP, and steel pipe ranging in size from 1.5-inches to 48-inches in diameter. According to City personnel, the northern third of the City discharges to NBC's Bucklin Point WWTF, though the City is responsible for all maintenance of the SSS and MS4. City personnel indicated that no significant sewer or drainage improvements are proposed, as a $52 million upgrade to the City-owned WWTF and collection system, which handles the other two-thirds of the City, was recently completed. The City is working on I/I removal, but past work has not shown significant improvement in I/I. However, the recently-improved City-owned WWTF is now sized to accommodate the observed I/I in the City's SSS. United Water was contracted, beginning in 2010, to clean and televise the entire SSS on a 5-year plan. Based on the results of the CCTV inspection program, the City will develop a capital improvement plan. Catch basins are reportedly cleaned routinely in East Providence. The City is awaiting a Total Maximum Daily Load (TMDL) requirement for the Ten Mile River from the RIDEM, though the City currently performs fecal coliform testing at the City's outfalls and illicit discharge detection and elimination (IDDE) locations as necessary. City personnel reported a minimal number of illicit connections discovered through stormwater outfall monitoring. There are no green infrastructure initiatives ongoing in the City.

The City pays NBC directly and bills all users independent of where treatment occurs. NBC bills the City monthly, while the City bills residents quarterly. NBC bills customers based on water meter readings and uses a flow meter at the Bucklin Point WWTF. The City's yearly bill from NBC is approximately $3 million. Moreover, the City's residential sewer rate is now higher than the bills for the other member communities, due primarily to the upgrades the City recently completed at the City-owned WWTF. The City has recently begun repayment of the $52 million in bonds accrued for upgrades to the City-owned WWTF and collection system. The expenditures were divided in half between the treatment plant and collection system. A portion of the Town of Barrington's wastewater is discharged into the City's wastewater collection system; the City bills the Town of Barrington users directly for wastewater treatment. The City bills water and sewer together on one bill. While sewer rates have tripled since 2008, water rates have not risen. However, the water supply system was reported to be suffering as a result of inadequate funding. Since the original interview with the city about this project, the city has begun a $17,000,000 capital improvement project that includes a new water storage tank, 7,500 feet of transmission piping, and several miles of cleaning and lining. The City does not have a stormwater fee.

3. Capital Improvements

The NBC municipalities currently fund their stormwater and wastewater programs through general and enterprise funds, as well as low-interest loans and grants. Moreover, the age of the existing stormwater and wastewater infrastructure within each municipality ranges from very old (greater than 100 years) to relatively new (less than 40 years old) infrastructure, greatly affecting the degree of need for capital improvements. The analysis presented herein focuses on the development of an approximate capital improvement budget for NBC member communities' stormwater and wastewater collection systems. The budgets were prepared assuming the average life expectancy of buried sewer/stormwater pipe is approximately 100 years, which would require each community to replace or rehabilitate approximately 1 percent of their infrastructure on an annual basis (not including pump stations). In systems with very old infrastructure, the urgency to replace/rehabilitate is greater than in communities with newer infrastructure, which would mean some communities need to replace/rehabilitate more than 1 percent per year initially until the average age of their system is closer to 50 years. For each community, we divided the total pipe length by 100 to develop an annual pipe replacement/rehabilitation length. We then applied an age factor to that estimated length to reflect the urgency of replacement/rehabilitation. Because we do not know the exact mix of pipe length versus pipe age, the age factor is somewhat arbitrary and is based on our professional judgment as to what a realistic replacement plan might entail. Table 1 summarizes each community's sewer infrastructure replacement costs, and Table 2 summarizes each community's stormwater infrastructure replacement costs.

Table 1: Annual Budget for Municipal Wastewater Capital Improvements

Municipality	Total Pipe Length[1,2] (mi)	Average Pipe Age (yr)	Annual Pipe Replacement[3] (mi/yr)	System Age Factor (see below)	Annual Cost[4] (2014 USD)
Providence	370	110	3.7	1.5	$ 8,300,000
North Providence	115	60	1.2	1.1	$ 2,000,000
Johnston	58	50	0.6	1.0	$ 900,000
Pawtucket	180	100	1.8	1.5	$ 4,000,000
Central Falls	23	100	0.3	1.5	$ 680,000
Cumberland	100	35	1.0	0.8	$ 1,200,000
Lincoln	103	25	1.1	0.8	$ 1,500,000
East Providence	173	50	1.8	1.0	$ 2,700,000

1 For municipalities where total wastewater pipe length was not available, total roadway length was used.

2 Cumberland total wastewater pipe length based on PARE estimate.

3 Assumes a 100-year sanitary sewer pipe life expectancy.

4 Assumes a cost of $1.5 million (2014 USD) per mile of pipe replaced.

Age Factor	
100 years or greater	1.50
75-99 years	1.30
50-74 years	1.10
50 years	1.00
25-49 years	0.80
24 years or less	0.60

Table 2: Annual Budget for Municipal Stormwater Capital Improvements

Municipality	Total Pipe Length[1] (mi)	Average Pipe Age (yr)	System Age Factor (see below)	Annual Cost[2,3] (2014 USD)
Providence	130	75	1.3	$ 1,267,500
North Providence	115	75	1.3	$ 1,121,250
Johnston	58	50	1.0	$ 435,000
Pawtucket	20	75	1.3	$ 195,000
Central Falls	0	75	1.3	$ -
Cumberland	160	35	0.8	$ 960,000
Lincoln	103	25	0.8	$ 618,000
East Providence	66	50	1.0	$ 495,000

[1] For municipalities where total stormwater pipe length was not available, total wastewater pipe length was used.

[2] Includes pipe replacement and stormwater water quality improvement projects.

[3] Assumes a cost of $750,000 (2014 USD) per mile of pipe, and a replacement rate of 1% of pipe per year for a system age factor of 1.0.

Age Factor	
100 years or greater	1.50
75-99 years	1.30
50-74 years	1.10
50 years	1.00
25-49 years	0.80
24 years or less	0.60

The estimate of the annual cost for municipal wastewater capital improvements shown in Table 1 was developed based on a cost of $1.5 million (2014 USD) per mile of pipe replaced. For systems with a significant number of pump stations, PARE utilized a higher per-mile cost to include replacement costs for those stations. Similarly, PARE developed an estimate of the annual cost for municipal stormwater capital improvements as shown in Table 2 utilizing the total system pipe length, the average pipe age in each community, and a cost of $500,000 per mile of stormwater piping. The cost includes pipe replacement and stormwater water quality improvement projects (e.g., water quality BMPs).

It should be recognized that the levels of annual funding identified in the tables above, while appropriate for these communities might represent unattainable goals given the current fiscal constraints in each community. For example, it would be prudent for the City of Providence to invest $8M or more in their wastewater infrastructure on an annual basis; however, that level of funding may be outside the realm of possibility for the City. Therefore, for the purposes of identifying what the City may have to spend in the next 20 to 30 years on their wastewater infrastructure, it may be more appropriate to assume the City could invest half or even a quarter of that amount on an annual basis, which would still represent a significant increase in what they are spending currently. For planning purposes, it may be more appropriate to assume a fraction of what has been estimated in the tables above for the communities of Central Falls, North Providence, Pawtucket, East Providence, and Providence, given that they currently have no mechanism in place to fund their capital improvements. Lincoln, Johnston, and Cumberland all have enterprise funds that they can utilize to fund capital improvements, and while those funds may be underfunded compared to the costs identified above, they have a mechanism in-place to at least partially fund capital improvements in their systems.

NBC CSO Control Facilities Phase III Reevaluation

Appendix 2 – WARi Affordability Model Assumptions and Results

Table 1
Narragansett Bay Commission
WARi™ Affordability Model
Rate and Inflation Assumptions - Current Spending

Description	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
Financial Plan Rate Adjustment	0.0%	5.5%	5.3%	0.6%	1.2%	7.2%	9.1%	12.2%	8.9%	8.4%	1.5%	1.7%	1.6%
Annual Expected Inflation	0.0%	0.0%	1.6%	1.2%	1.1%	0.6%	0.5%	0.4%	0.7%	0.7%	0.8%	0.8%	1.1%
Cumulative Rate Adjustments	100.0%	105.5%	111.1%	111.8%	113.1%	121.3%	132.4%	148.5%	161.7%	175.3%	178.0%	181.0%	184.0%
Cumulative Inflation	100.0%	100.0%	101.6%	102.9%	104.0%	104.6%	105.2%	105.6%	106.3%	107.0%	107.9%	108.8%	110.0%
Index for Affordability	**100.0%**	**105.5%**	**109.4%**	**108.7%**	**108.7%**	**115.9%**	**125.9%**	**140.6%**	**152.1%**	**163.8%**	**164.9%**	**166.4%**	**167.3%**

Table 2
Narragansett Bay Commission
WARi™ Affordability Model
Rate and Inflation Assumptions - Necessary Spending

Description	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
Cost Rate Adjustment	0.0%	100.0%	50.0%	33.3%	25.0%	20.0%	16.7%	14.3%	12.5%	11.1%	10.0%	9.1%	8.3%
Annual Expected Inflation*	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cumulative Rate Adjustments	100.0%	200.0%	300.0%	400.0%	500.0%	600.0%	700.0%	800.0%	900.0%	1000.0%	1100.0%	1200.0%	1300.0%
Cumulative Inflation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Index for Affordability	**100.0%**	**200.0%**	**300.0%**	**400.0%**	**500.0%**	**600.0%**	**700.0%**	**800.0%**	**900.0%**	**1000.0%**	**1100.0%**	**1200.0%**	**1300.0%**

*No expected inflation, necessary cost estimates were calculated in current dollars and did not require any adjustment

Table 3
Narragansett Bay Commission
WARi™ Affordability Model
Projected Average Bill - Current Spending

Bills are in Current Dollars

Census Tract	City/Town	Number of Households	MHI	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
1.01	Providence city	1,277	$45,484	$460.27	$485.58	$503.31	$500.10	$500.40	$533.47	$579.32	$647.13	$700.10	$753.99	$759.16	$765.68	$769.89
1.02	Providence city	1,399	37,438	460.15	485.46	503.18	499.97	500.27	533.33	579.18	646.96	699.92	753.79	758.97	765.48	769.69
2	Providence city	1,706	26,394	472.08	498.05	516.23	512.94	513.25	547.16	594.20	663.74	718.07	773.34	778.65	785.33	789.65
3	Providence city	1,943	31,833	460.10	485.41	503.14	499.93	500.22	533.28	579.12	646.90	699.86	753.72	758.90	765.41	769.62
4	Providence city	1,093	25,673	471.68	497.63	515.80	512.51	512.81	546.70	593.70	663.18	717.47	772.69	778.00	784.67	788.99
5	Providence city	787	16,713	450.53	475.31	492.67	489.53	489.82	522.18	567.07	633.44	685.30	738.04	743.11	749.49	753.61
6	Providence city	505	31,667	466.15	491.79	509.75	506.50	506.80	540.29	586.73	655.40	709.05	763.63	768.87	775.47	779.74
7	Providence city	536	15,203	459.10	484.35	502.04	498.84	499.14	532.12	577.86	645.49	698.33	752.08	757.25	763.75	767.95
8	Providence city	105	15,613	419.21	442.26	458.41	455.49	455.76	485.88	527.65	589.40	637.65	686.73	691.44	697.38	701.21
9	Providence city	774	26,276	394.07	415.75	430.93	428.18	428.44	456.75	496.01	554.06	599.42	645.55	649.99	655.56	659.17
10	Providence city	767	29,741	411.29	433.92	449.76	446.89	447.16	476.71	517.69	578.27	625.61	673.76	678.39	684.21	687.98
11	Providence city	937	39,341	401.19	423.26	438.71	435.92	436.18	465.00	504.97	564.07	610.25	657.22	661.73	667.41	671.08
12	Providence city	495	18,810	451.82	476.67	494.07	490.92	491.22	523.67	568.69	635.25	687.25	740.15	745.23	751.63	755.76
13	Providence city	1,418	41,888	429.15	452.76	469.29	466.30	466.57	497.40	540.16	603.38	652.78	703.02	707.85	713.92	717.85
14	Providence city	1,699	30,142	487.90	514.73	533.53	530.13	530.44	565.49	614.11	685.98	742.13	799.26	804.74	811.65	816.11
15	Providence city	971	53,469	433.41	457.25	473.95	470.92	471.20	502.34	545.52	609.37	659.25	710.00	714.87	721.01	724.97
16	Providence city	2,367	32,076	481.43	507.90	526.45	523.09	523.40	557.99	605.96	676.88	732.29	788.65	794.07	800.88	805.29
17	Providence city	1,236	37,295	443.74	468.14	485.24	482.14	482.43	514.31	558.52	623.89	674.96	726.91	731.90	738.18	742.24
18	Providence city	1,735	30,036	467.32	493.02	511.02	507.76	508.06	541.64	588.20	657.04	710.83	765.54	770.79	777.41	781.68
19	Providence city	1,503	30,901	445.95	470.48	487.66	484.55	484.84	516.88	561.31	627.00	678.33	730.54	735.56	741.87	745.95
20	Providence city	1,325	28,977	445.64	470.15	487.31	484.21	484.49	516.51	560.91	626.56	677.85	730.02	735.03	741.34	745.42
21.01	Providence city	1,013	49,818	432.78	456.58	473.25	470.23	470.51	501.60	544.73	608.48	658.29	708.96	713.82	719.95	723.91
21.02	Providence city	1,866	42,917	449.98	474.73	492.07	488.93	489.22	521.55	566.38	632.67	684.46	737.14	742.20	748.57	752.69
22	Providence city	1,618	33,169	453.53	478.47	495.94	492.78	493.07	525.66	570.84	637.65	689.85	742.95	748.05	754.47	758.62
23	Providence city	2,019	51,833	426.56	450.02	466.46	463.48	463.76	494.40	536.90	599.74	648.83	698.77	703.57	709.61	713.51
24	Providence city	2,149	72,704	428.40	451.96	468.46	465.47	465.75	496.53	539.21	602.32	651.63	701.78	706.60	712.66	716.58
25	Providence city	889	43,785	422.78	446.04	462.33	459.38	459.65	490.02	532.15	594.43	643.09	692.59	697.34	703.33	707.20
26	Providence city	1,179	24,819	425.68	449.09	465.49	462.52	462.80	493.38	535.80	598.50	647.50	697.33	702.12	708.15	712.04
27	Providence city	1,321	25,472	440.13	464.33	481.29	478.22	478.51	510.12	553.98	618.81	669.47	721.00	725.95	732.18	736.21
28	Providence city	1,871	33,430	429.46	453.08	469.63	466.63	466.91	497.76	540.55	603.82	653.25	703.53	708.36	714.44	718.37
29	Providence city	2,523	39,094	441.35	465.62	482.63	479.55	479.83	511.54	555.51	620.53	671.33	723.00	727.96	734.21	738.25
31	Providence city	1,223	23,575	398.68	420.60	435.96	433.18	433.44	462.08	501.80	560.53	606.42	653.09	657.58	663.22	666.87
32	Providence city	1,436	72,632	386.34	407.59	422.48	419.78	420.03	447.79	486.28	543.19	587.66	632.89	637.24	642.71	646.24
33	Providence city	1,898	69,830	375.95	396.62	411.11	408.48	408.73	435.74	473.19	528.57	571.84	615.86	620.09	625.41	628.85
34	Providence city	1,901	130,482	527.27	556.27	576.59	572.91	573.25	611.13	663.67	741.34	802.03	863.76	869.69	877.15	881.98
35	Providence city	1,561	62,750	432.68	456.48	473.15	470.13	470.41	501.49	544.60	608.34	658.14	708.80	713.66	719.79	723.75
36.01	Providence city	644	36,875	482.37	508.90	527.49	524.12	524.43	559.09	607.15	678.21	733.73	790.20	795.63	802.46	806.87
36.02	Providence city	588	68,088	467.42	493.13	511.13	507.87	508.18	541.75	588.33	657.18	710.98	765.70	770.96	777.58	781.85
37	Providence city	1,328	44,769	383.02	404.09	418.84	416.17	416.42	443.93	482.10	538.52	582.60	627.45	631.75	637.18	640.68
101.01	East Providence city	1,421	55,994	398.93	420.88	436.24	433.46	433.72	462.38	502.13	560.90	606.81	653.52	658.00	663.65	667.30
101.02	East Providence city	1,135	69,448	420.45	443.57	459.77	456.84	457.11	487.31	529.21	591.14	639.54	688.76	693.49	699.44	703.29
102	East Providence city	358	41,884	394.70	416.40	431.61	428.86	429.11	457.47	496.79	554.94	600.37	646.57	651.01	656.60	660.21
103	East Providence city	772	41,124	384.49	405.63	420.44	417.76	418.01	445.63	483.94	540.58	584.83	629.85	634.17	639.62	643.13
104	East Providence city	73	45,042	365.07	385.15	399.21	396.67	396.90	423.13	459.51	513.28	555.30	598.04	602.15	607.32	610.66
108	Central Falls city	1,371	24,386	430.07	453.72	470.29	467.29	467.57	498.46	541.31	604.67	654.16	704.51	709.35	715.44	719.37
109	Central Falls city	1,482	30,000	434.75	458.66	475.41	472.38	472.66	503.89	547.21	611.26	661.29	712.19	717.08	723.24	727.21
110	Central Falls city	1,783	34,120	447.36	471.96	489.20	486.08	486.36	518.50	563.08	628.98	680.47	732.84	737.87	744.20	748.30
111	Central Falls city	1,187	30,263	450.19	474.95	492.29	489.15	489.44	521.79	566.64	632.96	684.77	737.48	742.54	748.92	753.04
112	Cumberland town	1,834	46,466	433.79	457.65	474.36	471.34	471.62	502.78	546.01	609.91	659.84	710.62	715.50	721.64	725.61
113.01	Cumberland town	1,241	62,018	419.62	442.69	458.86	455.93	456.21	486.35	528.16	589.97	638.27	687.40	692.12	698.06	701.90
113.02	Cumberland town	925	82,298	464.73	490.29	508.20	504.96	505.26	538.64	584.95	653.41	706.90	761.30	766.53	773.11	777.36
114.01	Cumberland town	886	92,727	429.92	453.56	470.13	467.13	467.41	498.29	541.13	604.46	653.94	704.28	709.11	715.20	719.13
114.02	Cumberland town	456	100,238	433.89	457.76	474.47	471.45	471.73	502.90	546.13	610.05	659.99	710.79	715.67	721.81	725.78
114.03	Cumberland town	2,113	74,392	419.46	442.53	458.69	455.76	456.03	486.17	527.96	589.75	638.03	687.14	691.85	697.79	701.63

Table 3
Narragansett Bay Commission
WARi™ Affordability Model
Projected Average Bill - Current Spending

Bills are in Current Dollars

Census Tract	City/Town	Number of Households	MHI	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
115	Lincoln town	2,090	65,909	431.28	455.00	471.62	468.61	468.89	499.87	542.85	606.38	656.02	706.51	711.36	717.47	721.41
116	Lincoln town	1,751	92,361	537.76	567.33	588.05	584.30	584.65	623.28	676.86	756.08	817.97	880.93	886.98	894.59	899.51
117.01	Lincoln town	1,690	60,962	420.97	444.13	460.34	457.41	457.68	487.92	529.87	591.88	640.33	689.62	694.36	700.31	704.17
117.02	Lincoln town	1,378	89,211	421.22	444.38	460.61	457.67	457.94	488.20	530.17	592.22	640.70	690.02	694.75	700.72	704.57
118	North Providence town	2,579	52,482	457.98	483.17	500.82	497.62	497.92	530.82	576.45	643.92	696.63	750.25	755.40	761.88	766.08
119.01	North Providence town	1,193	41,563	459.74	485.03	502.74	499.54	499.83	532.86	578.67	646.39	699.31	753.13	758.30	764.81	769.02
119.02	North Providence town	2,045	52,844	496.07	523.35	542.46	539.00	539.32	574.96	624.39	697.46	754.56	812.64	818.22	825.24	829.78
120	North Providence town	2,192	69,375	448.74	473.42	490.71	487.58	487.87	520.10	564.81	630.92	682.57	735.10	740.15	746.50	750.61
121.02	North Providence town	1,622	41,611	456.22	481.31	498.89	495.70	496.00	528.77	574.23	641.44	693.94	747.36	752.49	758.95	763.12
121.03	North Providence town	555	40,058	454.30	479.29	496.79	493.62	493.92	526.55	571.82	638.74	691.03	744.22	749.33	755.76	759.92
121.04	North Providence town	1,328	43,825	464.11	489.64	507.52	504.28	504.58	537.92	584.17	652.54	705.95	760.29	765.51	772.08	776.33
122	Johnston town	98	71,408	493.54	520.69	539.70	536.26	536.58	572.03	621.21	693.91	750.72	808.50	814.05	821.04	825.55
123	Johnston town	2,054	65,330	469.91	495.75	513.85	510.58	510.88	544.64	591.46	660.68	714.76	769.78	775.06	781.72	786.02
124.01	Johnston town	2,326	62,846	458.80	484.03	501.70	498.50	498.80	531.76	577.47	645.06	697.87	751.58	756.74	763.23	767.43
124.02	Johnston town	833	55,545	446.89	471.47	488.69	485.57	485.86	517.97	562.49	628.33	679.76	732.08	737.11	743.43	747.52
125	Johnston town	910	38,554	458.14	483.34	500.99	497.80	498.09	531.00	576.65	644.14	696.87	750.51	755.66	762.15	766.34
134	Cranston city	81	61,723	457.09	482.23	499.84	496.65	496.95	529.79	575.33	642.67	695.27	748.79	753.93	760.40	764.58
135	Cranston city	41	53,534	453.20	478.13	495.58	492.42	492.72	525.27	570.43	637.19	689.35	742.41	747.51	753.92	758.07
150	Pawtucket city	1,698	42,500	421.23	444.39	460.62	457.68	457.96	488.22	530.19	592.24	640.72	690.03	694.77	700.73	704.59
151	Pawtucket city	1,215	23,882	414.80	437.61	453.59	450.70	450.97	480.77	522.10	583.20	630.94	679.50	684.17	690.04	693.84
152	Pawtucket city	353	11,612	430.71	454.40	471.00	467.99	468.27	499.21	542.13	605.58	655.15	705.58	710.42	716.52	720.46
153	Pawtucket city	872	33,281	415.68	438.55	454.56	451.66	451.93	481.79	523.21	584.45	632.29	680.96	685.63	691.52	695.32
154	Pawtucket city	686	33,750	420.22	443.33	459.52	456.59	456.86	487.05	528.92	590.82	639.18	688.38	693.11	699.06	702.90
155	Pawtucket city	1,538	50,670	414.81	437.63	453.61	450.71	450.98	480.78	522.11	583.22	630.96	679.53	684.19	690.06	693.86
156	Pawtucket city	985	52,576	397.86	419.75	435.07	432.30	432.56	461.14	500.78	559.39	605.18	651.76	656.24	661.87	665.51
157	Pawtucket city	1,496	52,000	433.64	457.49	474.19	471.17	471.45	502.60	545.81	609.69	659.60	710.37	715.24	721.38	725.35
158	Pawtucket city	1,504	60,223	422.47	445.71	461.98	459.04	459.31	489.66	531.75	593.99	642.61	692.07	696.83	702.81	706.67
159	Pawtucket city	1,165	49,972	418.28	441.29	457.40	454.48	454.75	484.80	526.48	588.10	636.24	685.21	689.91	695.83	699.66
160	Pawtucket city	1,214	27,313	413.38	436.11	452.04	449.15	449.42	479.12	520.31	581.20	628.78	677.18	681.82	687.68	691.46
161	Pawtucket city	1,521	28,456	430.57	454.25	470.84	467.84	468.12	499.05	541.95	605.38	654.94	705.35	710.19	716.28	720.22
163	Pawtucket city	1,082	56,509	430.98	454.69	471.29	468.28	468.56	499.52	542.47	605.95	655.56	706.01	710.86	716.96	720.91
164	Pawtucket city	1,768	30,729	412.48	435.16	451.05	448.18	448.45	478.08	519.18	579.94	627.41	675.70	680.34	686.18	689.96
165	Pawtucket city	1,515	53,682	440.66	464.89	481.87	478.79	479.08	510.74	554.64	619.55	670.27	721.86	726.82	733.06	737.09
166	Pawtucket city	573	35,313	422.79	446.04	462.33	459.38	459.66	490.03	532.15	594.44	643.10	692.59	697.35	703.33	707.20
167	Pawtucket city	1,131	31,421	407.83	430.26	445.97	443.13	443.39	472.69	513.33	573.41	620.35	668.09	672.68	678.45	682.19
168	Pawtucket city	1,199	64,625	424.67	448.03	464.39	461.43	461.70	492.21	534.52	597.08	645.96	695.68	700.45	706.47	710.35
169	Pawtucket city	834	65,455	455.75	480.82	498.38	495.20	495.50	528.24	573.65	640.78	693.24	746.60	751.72	758.17	762.35
170	Pawtucket city	1,368	51,384	434.13	458.01	474.73	471.71	471.99	503.17	546.43	610.38	660.35	711.18	716.06	722.20	726.18
171	Pawtucket city	1,462	39,038	420.13	443.24	459.42	456.49	456.76	486.95	528.81	590.70	639.05	688.24	692.96	698.91	702.75
Total		**118,683**	**$48,716**	**$439.02**	**$463.17**	**$480.08**	**$477.02**	**$477.31**	**$508.85**	**$552.59**	**$617.26**	**$667.79**	**$719.19**	**$724.13**	**$730.34**	**$734.36**

Table 4
Narragansett Bay Commission
WARi™ Affordability Model
Projected Average Bill - Current + Necessary Spending - Total Bill

Bills are in Current Dollars

Census Tract	City/Town	Number of Households	MHI	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
1.01	Providence city	1,277	$45,484	$469.18	$503.42	$530.07	$535.78	$545.00	$586.98	$641.76	$718.48	$780.37	$843.18	$857.27	$872.71	$885.84
1.02	Providence city	1,399	37,438	469.07	503.29	529.94	535.65	544.87	586.84	641.61	718.31	780.19	842.99	857.08	872.51	885.64
2	Providence city	1,706	26,394	481.00	515.88	542.99	548.62	557.84	600.67	656.63	735.09	798.35	862.53	876.76	892.36	905.60
3	Providence city	1,943	31,833	469.02	503.25	529.89	535.60	544.82	586.79	641.56	718.25	780.13	842.91	857.01	872.44	885.57
4	Providence city	1,093	25,673	480.60	515.46	542.55	548.18	557.41	600.21	656.13	734.53	797.74	861.88	876.11	891.70	904.94
5	Providence city	787	16,713	459.45	493.15	519.43	525.20	534.41	575.70	629.51	704.80	765.57	827.23	841.22	856.52	869.56
6	Providence city	505	31,667	475.07	509.63	536.51	542.17	551.39	593.80	649.17	726.76	789.33	852.82	866.98	882.50	895.68
7	Providence city	536	15,203	468.02	502.19	528.80	534.52	543.73	585.63	640.30	716.85	778.61	841.28	855.36	870.78	883.90
8	Providence city	105	15,613	428.13	460.10	485.17	491.17	500.36	539.39	590.08	660.75	717.92	775.92	789.55	804.41	817.16
9	Providence city	774	26,276	402.99	433.59	457.69	463.86	473.03	510.26	558.44	625.41	679.69	734.75	748.10	762.59	775.12
10	Providence city	767	29,741	420.21	451.75	476.52	482.57	491.75	530.22	580.12	649.63	705.88	762.96	776.50	791.24	803.92
11	Providence city	937	39,341	410.11	441.10	465.47	471.59	480.77	518.51	567.41	635.42	690.52	746.41	759.84	774.44	787.03
12	Providence city	495	18,810	460.74	494.51	520.83	526.60	535.81	577.19	631.13	706.60	767.52	829.34	843.34	858.66	871.71
13	Providence city	1,418	41,888	438.07	470.60	496.05	501.97	511.17	550.92	602.60	674.74	733.05	792.21	805.96	820.95	833.80
14	Providence city	1,699	30,142	496.82	532.57	560.29	565.80	575.04	619.01	676.54	757.33	822.41	888.45	902.85	918.68	932.06
15	Providence city	971	53,469	442.33	475.09	500.70	506.60	515.80	555.86	607.96	680.72	739.53	799.19	812.98	828.04	840.92
16	Providence city	2,367	32,076	490.34	525.74	553.21	558.77	568.00	611.51	668.39	748.23	812.56	877.84	892.18	907.91	921.23
17	Providence city	1,236	37,295	452.66	485.98	512.00	517.82	527.03	567.82	620.96	695.24	755.23	816.10	830.01	845.21	858.19
18	Providence city	1,735	30,036	476.24	510.86	537.78	543.44	552.66	595.15	650.63	728.39	791.10	854.73	868.90	884.44	897.63
19	Providence city	1,503	30,901	454.87	488.32	514.42	520.23	529.44	570.39	623.74	698.36	758.60	819.73	833.67	848.90	861.90
20	Providence city	1,325	28,977	454.55	487.98	514.07	519.88	529.09	570.02	623.34	697.91	758.12	819.21	833.14	848.37	861.37
21.01	Providence city	1,013	49,818	441.70	474.42	500.01	505.91	515.11	555.12	607.16	679.83	738.56	798.15	811.93	826.98	839.86
21.02	Providence city	1,866	42,917	458.90	492.57	518.82	524.61	533.82	575.06	628.82	704.02	764.73	826.33	840.31	855.60	868.64
22	Providence city	1,618	33,169	462.45	496.31	522.70	528.46	537.67	579.17	633.28	709.01	770.12	832.14	846.16	861.50	874.57
23	Providence city	2,019	51,833	435.48	467.86	493.21	499.16	508.35	547.92	599.34	671.09	729.11	787.97	801.68	816.64	829.46
24	Providence city	2,149	72,704	437.32	469.80	495.22	501.15	510.35	550.04	601.65	673.67	731.90	790.97	804.71	819.69	832.53
25	Providence city	889	43,785	431.70	463.88	489.08	495.05	504.25	543.54	594.58	665.78	723.36	781.78	795.45	810.36	823.14
26	Providence city	1,179	24,819	434.60	466.93	492.25	498.20	507.40	546.90	598.23	669.86	727.77	786.53	800.23	815.18	827.99
27	Providence city	1,321	25,472	449.05	482.17	508.05	513.90	523.10	563.64	616.41	690.17	749.74	810.19	824.06	839.21	852.15
28	Providence city	1,871	33,430	438.38	470.92	496.39	502.31	511.51	551.28	602.99	675.17	733.52	792.72	806.47	821.47	834.32
29	Providence city	2,523	39,094	450.27	483.46	509.38	515.22	524.43	565.05	617.95	691.88	751.60	812.19	826.07	841.24	854.20
31	Providence city	1,223	23,575	407.59	438.44	462.72	468.86	478.03	515.59	564.24	631.88	686.69	742.28	755.69	770.25	782.82
32	Providence city	1,436	72,632	395.26	425.43	449.23	455.46	464.63	501.30	548.72	614.55	667.93	722.08	735.35	749.74	762.19
33	Providence city	1,898	69,830	384.86	414.46	437.86	444.16	453.32	489.25	535.63	599.93	652.12	705.05	718.20	732.44	744.80
34	Providence city	1,901	130,482	536.19	574.11	603.34	608.59	617.85	664.64	726.10	812.69	882.30	952.95	967.80	984.18	997.92
35	Providence city	1,561	62,750	441.60	474.32	499.90	505.80	515.00	555.01	607.04	679.69	738.41	797.99	811.77	826.82	839.70
36.01	Providence city	644	36,875	491.29	526.74	554.24	559.80	569.03	612.60	669.58	749.56	814.00	879.39	893.74	909.49	922.82
36.02	Providence city	588	68,088	476.34	510.96	537.89	543.55	552.77	595.27	650.76	728.54	791.25	854.89	869.07	884.61	897.80
37	Providence city	1,328	44,769	391.94	421.92	445.60	451.85	461.01	497.45	544.53	609.87	662.88	716.64	729.86	744.21	756.63
101.01	East Providence city	1,421	55,994	418.99	460.99	496.42	513.70	534.02	582.74	642.55	721.37	787.35	854.11	878.66	904.36	928.07
101.02	East Providence city	1,135	69,448	440.51	483.69	519.95	537.08	557.41	607.67	669.62	751.62	820.07	889.35	914.14	940.15	964.06
102	East Providence city	358	41,884	414.76	456.52	491.79	509.10	529.41	577.83	637.21	715.41	780.90	847.17	871.67	897.32	920.99
103	East Providence city	772	41,124	404.55	445.75	480.62	498.00	518.31	565.99	624.36	701.06	765.37	830.44	854.83	880.33	903.91
104	East Providence city	73	45,042	385.13	425.27	459.39	476.91	497.20	543.49	599.92	673.76	735.84	798.64	822.80	848.03	871.43
108	Central Falls city	1,371	24,386	435.31	464.20	486.01	488.25	493.77	529.91	578.00	646.60	701.34	756.93	767.01	778.34	787.51
109	Central Falls city	1,482	30,000	439.99	469.15	491.14	493.35	498.87	535.34	583.90	653.19	708.47	764.61	774.74	786.14	795.35
110	Central Falls city	1,783	34,120	452.60	482.44	504.92	507.04	512.57	549.95	599.77	670.91	727.64	785.26	795.53	807.10	816.44
111	Central Falls city	1,187	30,263	455.43	485.43	508.02	510.12	515.65	553.24	603.33	674.89	731.95	789.90	800.20	811.82	821.18
112	Cumberland town	1,834	46,466	450.07	490.21	523.20	536.45	553.01	600.45	659.95	740.13	806.34	873.40	894.56	916.98	937.22
113.01	Cumberland town	1,241	62,018	435.89	475.25	507.69	521.05	537.59	584.02	642.11	720.20	784.77	850.18	871.17	893.39	913.51
113.02	Cumberland town	925	82,298	481.01	522.85	557.03	570.07	586.64	636.31	698.89	783.63	853.40	924.08	945.59	968.44	988.97
114.01	Cumberland town	886	92,727	446.20	486.12	518.96	532.24	548.80	595.96	655.07	734.68	800.44	867.05	888.17	910.53	930.74
114.02	Cumberland town	456	100,238	450.17	490.31	523.31	536.56	553.12	600.57	660.08	740.27	806.49	873.56	894.72	917.14	937.39
114.03	Cumberland town	2,113	74,392	435.74	475.08	507.52	520.87	537.42	583.83	641.91	719.97	784.53	849.92	870.91	893.13	913.24

Table 4
Narragansett Bay Commission
WARi™ Affordability Model
Projected Average Bill - Current + Necessary Spending - Total Bill

Bills are in Current Dollars

Census Tract	City/Town	Number of Households	MHI	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
115	Lincoln town	2,090	65,909	445.02	482.48	512.84	523.57	537.59	582.32	639.03	716.30	779.68	843.91	862.50	882.35	900.04
116	Lincoln town	1,751	92,361	551.50	594.81	629.27	639.26	653.35	705.72	773.04	866.00	941.63	1,018.33	1,038.12	1,059.47	1,078.13
117.01	Lincoln town	1,690	60,962	434.71	471.61	501.57	512.37	526.38	570.37	626.05	701.80	764.00	827.02	845.50	865.20	882.79
117.02	Lincoln town	1,378	89,211	434.96	471.86	501.83	512.63	526.65	570.65	626.36	702.14	764.36	827.42	845.90	865.60	883.19
118	North Providence town	2,579	52,482	473.61	514.43	547.69	560.13	576.05	624.58	685.83	768.93	837.26	906.51	927.28	949.39	969.21
119.01	North Providence town	1,193	41,563	475.37	516.28	549.62	562.04	577.96	626.62	688.05	771.40	839.94	909.39	930.19	952.32	972.15
119.02	North Providence town	2,045	52,844	511.69	554.60	589.34	601.51	617.45	668.72	733.77	822.47	895.19	968.90	990.10	1,012.75	1,032.91
120	North Providence town	2,192	69,375	464.36	504.67	537.58	550.08	565.99	613.86	674.19	755.92	823.20	891.36	912.03	934.01	953.74
121.02	North Providence town	1,622	41,611	471.84	512.56	545.76	558.21	574.13	622.53	683.61	766.44	834.58	903.61	924.37	946.45	966.26
121.03	North Providence town	555	40,058	469.93	510.54	543.67	556.13	572.05	620.31	681.20	763.75	831.66	900.48	921.21	943.27	963.05
121.04	North Providence town	1,328	43,825	479.74	520.89	554.40	566.79	582.71	631.68	693.55	777.54	846.59	916.55	937.39	959.59	979.46
122	Johnston town	98	71,408	503.17	539.95	568.60	574.79	584.74	629.83	688.63	770.97	837.41	904.82	920.00	936.62	950.77
123	Johnston town	2,054	65,330	479.54	515.01	542.75	549.10	559.04	602.43	658.88	737.74	801.45	866.10	881.02	897.30	911.23
124.01	Johnston town	2,326	62,846	468.43	503.29	530.60	537.03	546.96	589.55	644.90	722.12	784.55	847.90	862.69	878.82	892.65
124.02	Johnston town	833	55,545	456.53	490.74	517.59	524.10	534.02	575.76	629.92	705.38	766.45	828.40	843.06	859.02	872.74
125	Johnston town	910	38,554	467.77	502.60	529.89	536.32	546.25	588.80	644.08	721.20	783.56	846.83	861.61	877.73	891.56
134	Cranston city	81	61,723	457.09	482.23	499.84	496.65	496.95	529.79	575.33	642.67	695.27	748.79	753.93	760.40	764.58
135	Cranston city	41	53,534	453.20	478.13	495.58	492.42	492.72	525.27	570.43	637.19	689.35	742.41	747.51	753.92	758.07
150	Pawtucket city	1,698	42,500	430.64	463.23	488.87	495.35	505.04	544.71	596.10	667.57	725.46	784.20	798.35	813.73	827.00
151	Pawtucket city	1,215	23,882	424.21	456.44	481.84	488.36	498.05	537.26	588.01	658.53	715.69	773.67	787.75	803.04	816.25
152	Pawtucket city	353	11,612	440.13	473.24	499.25	505.66	515.35	555.71	608.04	680.91	739.90	799.74	814.00	829.51	842.87
153	Pawtucket city	872	33,281	425.10	457.38	482.81	489.33	499.01	538.29	589.13	659.78	717.04	775.12	789.21	804.51	817.73
154	Pawtucket city	686	33,750	429.63	462.16	487.77	494.25	503.94	543.54	594.83	666.15	723.93	782.54	796.69	812.05	825.31
155	Pawtucket city	1,538	50,670	424.23	456.46	481.86	488.38	498.06	537.28	588.03	658.55	715.71	773.69	787.77	803.06	816.27
156	Pawtucket city	985	52,576	407.28	438.58	463.32	469.96	479.64	517.64	566.69	634.72	689.93	745.93	759.82	774.86	787.92
157	Pawtucket city	1,496	52,000	443.05	476.32	502.44	508.83	518.53	559.10	611.72	685.02	744.34	804.53	818.82	834.38	847.76
158	Pawtucket city	1,504	60,223	431.89	464.54	490.23	496.70	506.39	546.16	597.67	669.32	727.36	786.24	800.40	815.80	829.08
159	Pawtucket city	1,165	49,972	427.70	460.12	485.65	492.15	501.83	541.30	592.39	663.43	720.98	779.37	793.49	808.83	822.07
160	Pawtucket city	1,214	27,313	422.79	454.94	480.29	486.82	496.50	535.62	586.22	656.53	713.53	771.34	785.40	800.67	813.87
161	Pawtucket city	1,521	28,456	439.99	473.09	499.09	505.50	515.20	555.55	607.86	680.71	739.68	799.51	813.77	829.28	842.63
163	Pawtucket city	1,082	56,509	440.40	473.52	499.54	505.95	515.64	556.02	608.38	681.28	740.30	800.18	814.44	829.96	843.32
164	Pawtucket city	1,768	30,729	421.89	454.00	479.30	485.84	495.53	534.58	585.09	655.27	712.16	769.87	783.92	799.18	812.37
165	Pawtucket city	1,515	53,682	450.07	483.72	510.12	516.46	526.16	567.23	620.56	694.88	755.02	816.02	830.40	846.05	859.50
166	Pawtucket city	573	35,313	432.21	464.87	490.58	497.05	506.74	546.53	598.07	669.77	727.84	786.76	800.93	816.33	829.61
167	Pawtucket city	1,131	31,421	417.25	449.10	474.22	480.80	490.48	529.19	579.24	648.74	705.09	762.26	776.26	791.45	804.60
168	Pawtucket city	1,199	64,625	434.09	466.86	492.64	499.09	508.78	548.71	600.44	672.41	730.71	789.84	804.03	819.46	832.76
169	Pawtucket city	834	65,455	465.17	499.65	526.63	532.87	542.58	584.73	639.56	716.11	777.99	840.76	855.30	871.17	884.76
170	Pawtucket city	1,368	51,384	443.55	476.84	502.98	509.37	519.07	559.67	612.34	685.71	745.10	805.34	819.64	835.20	848.59
171	Pawtucket city	1,462	39,038	429.55	462.07	487.67	494.16	503.84	543.44	594.72	666.03	723.80	782.40	796.54	811.90	825.17
Total		**118,683**	**$48,716**	**$449.95**	**$474.69**	**$492.03**	**$488.89**	**$489.18**	**$521.50**	**$566.34**	**$632.62**	**$684.40**	**$737.08**	**$742.14**	**$748.51**	**$752.63**

Table 5
Narragansett Bay Commission
WARi™ Affordability Model
Projected Affordability - Current Spending

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2015	Projected 2016	Projected 2017	Projected 2018	Projected 2019	Projected 2020	Projected 2021	Projected 2022	Projected 2023	Projected 2024	Projected 2025	Projected 2026
1.01	Providence city	1,277	$45,484	1.01%	1.07%	1.11%	1.10%	1.10%	1.17%	1.27%	1.42%	1.54%	1.66%	1.67%	1.68%	1.69%
1.02	Providence city	1,399	37,438	1.23%	1.30%	1.34%	1.34%	1.34%	1.42%	1.55%	1.73%	1.87%	2.01%	2.03%	2.04%	2.06%
2	Providence city	1,706	26,394	1.79%	1.89%	1.96%	1.94%	1.94%	2.07%	2.25%	2.51%	2.72%	2.93%	2.95%	2.98%	2.99%
3	Providence city	1,943	31,833	1.45%	1.52%	1.58%	1.57%	1.57%	1.68%	1.82%	2.03%	2.20%	2.37%	2.38%	2.40%	2.42%
4	Providence city	1,093	25,673	1.84%	1.94%	2.01%	2.00%	2.00%	2.13%	2.31%	2.58%	2.79%	3.01%	3.03%	3.06%	3.07%
5	Providence city	787	16,713	2.70%	2.84%	2.95%	2.93%	2.93%	3.12%	3.39%	3.79%	4.10%	4.42%	4.45%	4.48%	4.51%
6	Providence city	505	31,667	1.47%	1.55%	1.61%	1.60%	1.60%	1.71%	1.85%	2.07%	2.24%	2.41%	2.43%	2.45%	2.46%
7	Providence city	536	15,203	3.02%	3.19%	3.30%	3.28%	3.28%	3.50%	3.80%	4.25%	4.59%	4.95%	4.98%	5.02%	5.05%
8	Providence city	105	15,613	2.68%	2.83%	2.94%	2.92%	2.92%	3.11%	3.38%	3.78%	4.08%	4.40%	4.43%	4.47%	4.49%
9	Providence city	774	26,276	1.50%	1.58%	1.64%	1.63%	1.63%	1.74%	1.89%	2.11%	2.28%	2.46%	2.47%	2.49%	2.51%
10	Providence city	767	29,741	1.38%	1.46%	1.51%	1.50%	1.50%	1.60%	1.74%	1.94%	2.10%	2.27%	2.28%	2.30%	2.31%
11	Providence city	937	39,341	1.02%	1.08%	1.12%	1.11%	1.11%	1.18%	1.28%	1.43%	1.55%	1.67%	1.68%	1.70%	1.71%
12	Providence city	495	18,810	2.40%	2.53%	2.63%	2.61%	2.61%	2.78%	3.02%	3.38%	3.65%	3.93%	3.96%	4.00%	4.02%
13	Providence city	1,418	41,888	1.02%	1.08%	1.12%	1.11%	1.11%	1.19%	1.29%	1.44%	1.56%	1.68%	1.69%	1.70%	1.71%
14	Providence city	1,699	30,142	1.62%	1.71%	1.77%	1.76%	1.76%	1.88%	2.04%	2.28%	2.46%	2.65%	2.67%	2.69%	2.71%
15	Providence city	971	53,469	0.81%	0.86%	0.89%	0.88%	0.88%	0.94%	1.02%	1.14%	1.23%	1.33%	1.34%	1.35%	1.36%
16	Providence city	2,367	32,076	1.50%	1.58%	1.64%	1.63%	1.63%	1.74%	1.89%	2.11%	2.28%	2.46%	2.48%	2.50%	2.51%
17	Providence city	1,236	37,295	1.19%	1.26%	1.30%	1.29%	1.29%	1.38%	1.50%	1.67%	1.81%	1.95%	1.96%	1.98%	1.99%
18	Providence city	1,735	30,036	1.56%	1.64%	1.70%	1.69%	1.69%	1.80%	1.96%	2.19%	2.37%	2.55%	2.57%	2.59%	2.60%
19	Providence city	1,503	30,901	1.44%	1.52%	1.58%	1.57%	1.57%	1.67%	1.82%	2.03%	2.20%	2.36%	2.38%	2.40%	2.41%
20	Providence city	1,325	28,977	1.54%	1.62%	1.68%	1.67%	1.67%	1.78%	1.94%	2.16%	2.34%	2.52%	2.54%	2.56%	2.57%
21.01	Providence city	1,013	49,818	0.87%	0.92%	0.95%	0.94%	0.94%	1.01%	1.09%	1.22%	1.32%	1.42%	1.43%	1.45%	1.45%
21.02	Providence city	1,866	42,917	1.05%	1.11%	1.15%	1.14%	1.14%	1.22%	1.32%	1.47%	1.59%	1.72%	1.73%	1.74%	1.75%
22	Providence city	1,618	33,169	1.37%	1.44%	1.50%	1.49%	1.49%	1.58%	1.72%	1.92%	2.08%	2.24%	2.26%	2.27%	2.29%
23	Providence city	2,019	51,833	0.82%	0.87%	0.90%	0.89%	0.89%	0.95%	1.04%	1.16%	1.25%	1.35%	1.36%	1.37%	1.38%
24	Providence city	2,149	72,704	0.59%	0.62%	0.64%	0.64%	0.64%	0.68%	0.74%	0.83%	0.90%	0.97%	0.97%	0.98%	0.99%
25	Providence city	889	43,785	0.97%	1.02%	1.06%	1.05%	1.05%	1.12%	1.22%	1.36%	1.47%	1.58%	1.59%	1.61%	1.62%
26	Providence city	1,179	24,819	1.72%	1.81%	1.88%	1.86%	1.86%	1.99%	2.16%	2.41%	2.61%	2.81%	2.83%	2.85%	2.87%
27	Providence city	1,321	25,472	1.73%	1.82%	1.89%	1.88%	1.88%	2.00%	2.17%	2.43%	2.63%	2.83%	2.85%	2.87%	2.89%
28	Providence city	1,871	33,430	1.28%	1.36%	1.40%	1.40%	1.40%	1.49%	1.62%	1.81%	1.95%	2.10%	2.12%	2.14%	2.15%
29	Providence city	2,523	39,094	1.13%	1.19%	1.23%	1.23%	1.23%	1.31%	1.42%	1.59%	1.72%	1.85%	1.86%	1.88%	1.89%
31	Providence city	1,223	23,575	1.69%	1.78%	1.85%	1.84%	1.84%	1.96%	2.13%	2.38%	2.57%	2.77%	2.79%	2.81%	2.83%
32	Providence city	1,436	72,632	0.53%	0.56%	0.58%	0.58%	0.58%	0.62%	0.67%	0.75%	0.81%	0.87%	0.88%	0.88%	0.89%
33	Providence city	1,898	69,830	0.54%	0.57%	0.59%	0.58%	0.59%	0.62%	0.68%	0.76%	0.82%	0.88%	0.89%	0.90%	0.90%
34	Providence city	1,901	130,482	0.40%	0.43%	0.44%	0.44%	0.44%	0.47%	0.51%	0.57%	0.61%	0.66%	0.67%	0.67%	0.68%
35	Providence city	1,561	62,750	0.69%	0.73%	0.75%	0.75%	0.75%	0.80%	0.87%	0.97%	1.05%	1.13%	1.14%	1.15%	1.15%
36.01	Providence city	644	36,875	1.31%	1.38%	1.43%	1.42%	1.42%	1.52%	1.65%	1.84%	1.99%	2.14%	2.16%	2.18%	2.19%
36.02	Providence city	588	68,088	0.69%	0.72%	0.75%	0.75%	0.75%	0.80%	0.86%	0.97%	1.04%	1.12%	1.13%	1.14%	1.15%
37	Providence city	1,328	44,769	0.86%	0.90%	0.94%	0.93%	0.93%	0.99%	1.08%	1.20%	1.30%	1.40%	1.41%	1.42%	1.43%
101.01	East Providence city	1,421	55,994	0.71%	0.75%	0.78%	0.77%	0.77%	0.83%	0.90%	1.00%	1.08%	1.17%	1.18%	1.19%	1.19%
101.02	East Providence city	1,135	69,448	0.61%	0.64%	0.66%	0.66%	0.66%	0.70%	0.76%	0.85%	0.92%	0.99%	1.00%	1.01%	1.01%
102	East Providence city	358	41,884	0.94%	0.99%	1.03%	1.02%	1.02%	1.09%	1.19%	1.32%	1.43%	1.54%	1.55%	1.57%	1.58%
103	East Providence city	772	41,124	0.93%	0.99%	1.02%	1.02%	1.02%	1.08%	1.18%	1.31%	1.42%	1.53%	1.54%	1.56%	1.56%
104	East Providence city	73	45,042	0.81%	0.86%	0.89%	0.88%	0.88%	0.94%	1.02%	1.14%	1.23%	1.33%	1.34%	1.35%	1.36%
108	Central Falls city	1,371	24,386	1.76%	1.86%	1.93%	1.92%	1.92%	2.04%	2.22%	2.48%	2.68%	2.89%	2.91%	2.93%	2.95%
109	Central Falls city	1,482	30,000	1.45%	1.53%	1.58%	1.57%	1.58%	1.68%	1.82%	2.04%	2.20%	2.37%	2.39%	2.41%	2.42%
110	Central Falls city	1,783	34,120	1.31%	1.38%	1.43%	1.42%	1.43%	1.52%	1.65%	1.84%	1.99%	2.15%	2.16%	2.18%	2.19%
111	Central Falls city	1,187	30,263	1.49%	1.57%	1.63%	1.62%	1.62%	1.72%	1.87%	2.09%	2.26%	2.44%	2.45%	2.47%	2.49%
112	Cumberland town	1,834	46,466	0.93%	0.98%	1.02%	1.01%	1.01%	1.08%	1.18%	1.31%	1.42%	1.53%	1.54%	1.55%	1.56%
113.01	Cumberland town	1,241	62,018	0.68%	0.71%	0.74%	0.74%	0.74%	0.78%	0.85%	0.95%	1.03%	1.11%	1.12%	1.13%	1.13%
113.02	Cumberland town	925	82,298	0.56%	0.60%	0.62%	0.61%	0.61%	0.65%	0.71%	0.79%	0.86%	0.93%	0.93%	0.94%	0.94%
114.01	Cumberland town	886	92,727	0.46%	0.49%	0.51%	0.50%	0.50%	0.54%	0.58%	0.65%	0.71%	0.76%	0.76%	0.77%	0.78%
114.02	Cumberland town	456	100,238	0.43%	0.46%	0.47%	0.47%	0.47%	0.50%	0.54%	0.61%	0.66%	0.71%	0.71%	0.72%	0.72%
114.03	Cumberland town	2,113	74,392	0.56%	0.59%	0.62%	0.61%	0.61%	0.65%	0.71%	0.79%	0.86%	0.92%	0.93%	0.94%	0.94%

Table 5
Narragansett Bay Commission
WARi™ Affordability Model
Projected Affordability - Current Spending

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2015	Projected 2016	Projected 2017	Projected 2018	Projected 2019	Projected 2020	Projected 2021	Projected 2022	Projected 2023	Projected 2024	Projected 2025	Projected 2026
115	Lincoln town	2,090	65,909	0.65%	0.69%	0.72%	0.71%	0.71%	0.76%	0.82%	0.92%	1.00%	1.07%	1.08%	1.09%	1.09%
116	Lincoln town	1,751	92,361	0.58%	0.61%	0.64%	0.63%	0.63%	0.67%	0.73%	0.82%	0.89%	0.95%	0.96%	0.97%	0.97%
117.01	Lincoln town	1,690	60,962	0.69%	0.73%	0.76%	0.75%	0.75%	0.80%	0.87%	0.97%	1.05%	1.13%	1.14%	1.15%	1.16%
117.02	Lincoln town	1,378	89,211	0.47%	0.50%	0.52%	0.51%	0.51%	0.55%	0.59%	0.66%	0.72%	0.77%	0.78%	0.79%	0.79%
118	North Providence town	2,579	52,482	0.87%	0.92%	0.95%	0.95%	0.95%	1.01%	1.10%	1.23%	1.33%	1.43%	1.44%	1.45%	1.46%
119.01	North Providence town	1,193	41,563	1.11%	1.17%	1.21%	1.20%	1.20%	1.28%	1.39%	1.56%	1.68%	1.81%	1.82%	1.84%	1.85%
119.02	North Providence town	2,045	52,844	0.94%	0.99%	1.03%	1.02%	1.02%	1.09%	1.18%	1.32%	1.43%	1.54%	1.55%	1.56%	1.57%
120	North Providence town	2,192	69,375	0.65%	0.68%	0.71%	0.70%	0.70%	0.75%	0.81%	0.91%	0.98%	1.06%	1.07%	1.08%	1.08%
121.02	North Providence town	1,622	41,611	1.10%	1.16%	1.20%	1.19%	1.19%	1.27%	1.38%	1.54%	1.67%	1.80%	1.81%	1.82%	1.83%
121.03	North Providence town	555	40,058	1.13%	1.20%	1.24%	1.23%	1.23%	1.31%	1.43%	1.59%	1.73%	1.86%	1.87%	1.89%	1.90%
121.04	North Providence town	1,328	43,825	1.06%	1.12%	1.16%	1.15%	1.15%	1.23%	1.33%	1.49%	1.61%	1.73%	1.75%	1.76%	1.77%
122	Johnston town	98	71,408	0.69%	0.73%	0.76%	0.75%	0.75%	0.80%	0.87%	0.97%	1.05%	1.13%	1.14%	1.15%	1.16%
123	Johnston town	2,054	65,330	0.72%	0.76%	0.79%	0.78%	0.78%	0.83%	0.91%	1.01%	1.09%	1.18%	1.19%	1.20%	1.20%
124.01	Johnston town	2,326	62,846	0.73%	0.77%	0.80%	0.79%	0.79%	0.85%	0.92%	1.03%	1.11%	1.20%	1.20%	1.21%	1.22%
124.02	Johnston town	833	55,545	0.80%	0.85%	0.88%	0.87%	0.87%	0.93%	1.01%	1.13%	1.22%	1.32%	1.33%	1.34%	1.35%
125	Johnston town	910	38,554	1.19%	1.25%	1.30%	1.29%	1.29%	1.38%	1.50%	1.67%	1.81%	1.95%	1.96%	1.98%	1.99%
134	Cranston city	81	61,723	0.74%	0.78%	0.81%	0.80%	0.81%	0.86%	0.93%	1.04%	1.13%	1.21%	1.22%	1.23%	1.24%
135	Cranston city	41	53,534	0.85%	0.89%	0.93%	0.92%	0.92%	0.98%	1.07%	1.19%	1.29%	1.39%	1.40%	1.41%	1.42%
150	Pawtucket city	1,698	42,500	0.99%	1.05%	1.08%	1.08%	1.08%	1.15%	1.25%	1.39%	1.51%	1.62%	1.63%	1.65%	1.66%
151	Pawtucket city	1,215	23,882	1.74%	1.83%	1.90%	1.89%	1.89%	2.01%	2.19%	2.44%	2.64%	2.85%	2.86%	2.89%	2.91%
152	Pawtucket city	353	11,612	3.71%	3.91%	4.06%	4.03%	4.03%	4.30%	4.67%	5.22%	5.64%	6.08%	6.12%	6.17%	6.20%
153	Pawtucket city	872	33,281	1.25%	1.32%	1.37%	1.36%	1.36%	1.45%	1.57%	1.76%	1.90%	2.05%	2.06%	2.08%	2.09%
154	Pawtucket city	686	33,750	1.25%	1.31%	1.36%	1.35%	1.35%	1.44%	1.57%	1.75%	1.89%	2.04%	2.05%	2.07%	2.08%
155	Pawtucket city	1,538	50,670	0.82%	0.86%	0.90%	0.89%	0.89%	0.95%	1.03%	1.15%	1.25%	1.34%	1.35%	1.36%	1.37%
156	Pawtucket city	985	52,576	0.76%	0.80%	0.83%	0.82%	0.82%	0.88%	0.95%	1.06%	1.15%	1.24%	1.25%	1.26%	1.27%
157	Pawtucket city	1,496	52,000	0.83%	0.88%	0.91%	0.91%	0.91%	0.97%	1.05%	1.17%	1.27%	1.37%	1.38%	1.39%	1.39%
158	Pawtucket city	1,504	60,223	0.70%	0.74%	0.77%	0.76%	0.76%	0.81%	0.88%	0.99%	1.07%	1.15%	1.16%	1.17%	1.17%
159	Pawtucket city	1,165	49,972	0.84%	0.88%	0.92%	0.91%	0.91%	0.97%	1.05%	1.18%	1.27%	1.37%	1.38%	1.39%	1.40%
160	Pawtucket city	1,214	27,313	1.51%	1.60%	1.66%	1.64%	1.65%	1.75%	1.90%	2.13%	2.30%	2.48%	2.50%	2.52%	2.53%
161	Pawtucket city	1,521	28,456	1.51%	1.60%	1.65%	1.64%	1.65%	1.75%	1.90%	2.13%	2.30%	2.48%	2.50%	2.52%	2.53%
163	Pawtucket city	1,082	56,509	0.76%	0.80%	0.83%	0.83%	0.83%	0.88%	0.96%	1.07%	1.16%	1.25%	1.26%	1.27%	1.28%
164	Pawtucket city	1,768	30,729	1.34%	1.42%	1.47%	1.46%	1.46%	1.56%	1.69%	1.89%	2.04%	2.20%	2.21%	2.23%	2.25%
165	Pawtucket city	1,515	53,682	0.82%	0.87%	0.90%	0.89%	0.89%	0.95%	1.03%	1.15%	1.25%	1.34%	1.35%	1.37%	1.37%
166	Pawtucket city	573	35,313	1.20%	1.26%	1.31%	1.30%	1.30%	1.39%	1.51%	1.68%	1.82%	1.96%	1.97%	1.99%	2.00%
167	Pawtucket city	1,131	31,421	1.30%	1.37%	1.42%	1.41%	1.41%	1.50%	1.63%	1.82%	1.97%	2.13%	2.14%	2.16%	2.17%
168	Pawtucket city	1,199	64,625	0.66%	0.69%	0.72%	0.71%	0.71%	0.76%	0.83%	0.92%	1.00%	1.08%	1.08%	1.09%	1.10%
169	Pawtucket city	834	65,455	0.70%	0.73%	0.76%	0.76%	0.76%	0.81%	0.88%	0.98%	1.06%	1.14%	1.15%	1.16%	1.16%
170	Pawtucket city	1,368	51,384	0.84%	0.89%	0.92%	0.92%	0.92%	0.98%	1.06%	1.19%	1.29%	1.38%	1.39%	1.41%	1.41%
171	Pawtucket city	1,462	39,038	1.08%	1.14%	1.18%	1.17%	1.17%	1.25%	1.35%	1.51%	1.64%	1.76%	1.78%	1.79%	1.80%
Total		**118,683**	**$48,716**	**1.07%**	**1.13%**	**1.17%**	**1.16%**	**1.16%**	**1.24%**	**1.35%**	**1.51%**	**1.63%**	**1.75%**	**1.77%**	**1.78%**	**1.79%**

Table 6
Narragansett Bay Commission
WARi™ Affordability Model
Projected Affordability - Current + Necessary Spending

Census Tract	City/Town	Number of Households	MHI	Current 2014	Projected 2015	Projected 2016	Projected 2017	Projected 2018	Projected 2019	Projected 2020	Projected 2021	Projected 2022	Projected 2023	Projected 2024	Projected 2025	Projected 2026
1.01	Providence city	1,277	$45,484	1.03%	1.11%	1.17%	1.18%	1.20%	1.29%	1.41%	1.58%	1.72%	1.85%	1.88%	1.92%	1.95%
1.02	Providence city	1,399	37,438	1.25%	1.34%	1.42%	1.43%	1.46%	1.57%	1.71%	1.92%	2.08%	2.25%	2.29%	2.33%	2.37%
2	Providence city	1,706	26,394	1.82%	1.95%	2.06%	2.08%	2.11%	2.28%	2.49%	2.79%	3.02%	3.27%	3.32%	3.38%	3.43%
3	Providence city	1,943	31,833	1.47%	1.58%	1.66%	1.68%	1.71%	1.84%	2.02%	2.26%	2.45%	2.65%	2.69%	2.74%	2.78%
4	Providence city	1,093	25,673	1.87%	2.01%	2.11%	2.14%	2.17%	2.34%	2.56%	2.86%	3.11%	3.36%	3.41%	3.47%	3.52%
5	Providence city	787	16,713	2.75%	2.95%	3.11%	3.14%	3.20%	3.44%	3.77%	4.22%	4.58%	4.95%	5.03%	5.12%	5.20%
6	Providence city	505	31,667	1.50%	1.61%	1.69%	1.71%	1.74%	1.88%	2.05%	2.29%	2.49%	2.69%	2.74%	2.79%	2.83%
7	Providence city	536	15,203	3.08%	3.30%	3.48%	3.52%	3.58%	3.85%	4.21%	4.72%	5.12%	5.53%	5.63%	5.73%	5.81%
8	Providence city	105	15,613	2.74%	2.95%	3.11%	3.15%	3.20%	3.45%	3.78%	4.23%	4.60%	4.97%	5.06%	5.15%	5.23%
9	Providence city	774	26,276	1.53%	1.65%	1.74%	1.77%	1.80%	1.94%	2.13%	2.38%	2.59%	2.80%	2.85%	2.90%	2.95%
10	Providence city	767	29,741	1.41%	1.52%	1.60%	1.62%	1.65%	1.78%	1.95%	2.18%	2.37%	2.57%	2.61%	2.66%	2.70%
11	Providence city	937	39,341	1.04%	1.12%	1.18%	1.20%	1.22%	1.32%	1.44%	1.62%	1.76%	1.90%	1.93%	1.97%	2.00%
12	Providence city	495	18,810	2.45%	2.63%	2.77%	2.80%	2.85%	3.07%	3.36%	3.76%	4.08%	4.41%	4.48%	4.56%	4.63%
13	Providence city	1,418	41,888	1.05%	1.12%	1.18%	1.20%	1.22%	1.32%	1.44%	1.61%	1.75%	1.89%	1.92%	1.96%	1.99%
14	Providence city	1,699	30,142	1.65%	1.77%	1.86%	1.88%	1.91%	2.05%	2.24%	2.51%	2.73%	2.95%	3.00%	3.05%	3.09%
15	Providence city	971	53,469	0.83%	0.89%	0.94%	0.95%	0.96%	1.04%	1.14%	1.27%	1.38%	1.49%	1.52%	1.55%	1.57%
16	Providence city	2,367	32,076	1.53%	1.64%	1.72%	1.74%	1.77%	1.91%	2.08%	2.33%	2.53%	2.74%	2.78%	2.83%	2.87%
17	Providence city	1,236	37,295	1.21%	1.30%	1.37%	1.39%	1.41%	1.52%	1.66%	1.86%	2.03%	2.19%	2.23%	2.27%	2.30%
18	Providence city	1,735	30,036	1.59%	1.70%	1.79%	1.81%	1.84%	1.98%	2.17%	2.43%	2.63%	2.85%	2.89%	2.94%	2.99%
19	Providence city	1,503	30,901	1.47%	1.58%	1.66%	1.68%	1.71%	1.85%	2.02%	2.26%	2.45%	2.65%	2.70%	2.75%	2.79%
20	Providence city	1,325	28,977	1.57%	1.68%	1.77%	1.79%	1.83%	1.97%	2.15%	2.41%	2.62%	2.83%	2.88%	2.93%	2.97%
21.01	Providence city	1,013	49,818	0.89%	0.95%	1.00%	1.02%	1.03%	1.11%	1.22%	1.36%	1.48%	1.60%	1.63%	1.66%	1.69%
21.02	Providence city	1,866	42,917	1.07%	1.15%	1.21%	1.22%	1.24%	1.34%	1.47%	1.64%	1.78%	1.93%	1.96%	1.99%	2.02%
22	Providence city	1,618	33,169	1.39%	1.50%	1.58%	1.59%	1.62%	1.75%	1.91%	2.14%	2.32%	2.51%	2.55%	2.60%	2.64%
23	Providence city	2,019	51,833	0.84%	0.90%	0.95%	0.96%	0.98%	1.06%	1.16%	1.29%	1.41%	1.52%	1.55%	1.58%	1.60%
24	Providence city	2,149	72,704	0.60%	0.65%	0.68%	0.69%	0.70%	0.76%	0.83%	0.93%	1.01%	1.09%	1.11%	1.13%	1.15%
25	Providence city	889	43,785	0.99%	1.06%	1.12%	1.13%	1.15%	1.24%	1.36%	1.52%	1.65%	1.79%	1.82%	1.85%	1.88%
26	Providence city	1,179	24,819	1.75%	1.88%	1.98%	2.01%	2.04%	2.20%	2.41%	2.70%	2.93%	3.17%	3.22%	3.28%	3.34%
27	Providence city	1,321	25,472	1.76%	1.89%	1.99%	2.02%	2.05%	2.21%	2.42%	2.71%	2.94%	3.18%	3.24%	3.29%	3.35%
28	Providence city	1,871	33,430	1.31%	1.41%	1.48%	1.50%	1.53%	1.65%	1.80%	2.02%	2.19%	2.37%	2.41%	2.46%	2.50%
29	Providence city	2,523	39,094	1.15%	1.24%	1.30%	1.32%	1.34%	1.45%	1.58%	1.77%	1.92%	2.08%	2.11%	2.15%	2.18%
31	Providence city	1,223	23,575	1.73%	1.86%	1.96%	1.99%	2.03%	2.19%	2.39%	2.68%	2.91%	3.15%	3.21%	3.27%	3.32%
32	Providence city	1,436	72,632	0.54%	0.59%	0.62%	0.63%	0.64%	0.69%	0.76%	0.85%	0.92%	0.99%	1.01%	1.03%	1.05%
33	Providence city	1,898	69,830	0.55%	0.59%	0.63%	0.64%	0.65%	0.70%	0.77%	0.86%	0.93%	1.01%	1.03%	1.05%	1.07%
34	Providence city	1,901	130,482	0.41%	0.44%	0.46%	0.47%	0.47%	0.51%	0.56%	0.62%	0.68%	0.73%	0.74%	0.75%	0.76%
35	Providence city	1,561	62,750	0.70%	0.76%	0.80%	0.81%	0.82%	0.88%	0.97%	1.08%	1.18%	1.27%	1.29%	1.32%	1.34%
36.01	Providence city	644	36,875	1.33%	1.43%	1.50%	1.52%	1.54%	1.66%	1.82%	2.03%	2.21%	2.38%	2.42%	2.47%	2.50%
36.02	Providence city	588	68,088	0.70%	0.75%	0.79%	0.80%	0.81%	0.87%	0.96%	1.07%	1.16%	1.26%	1.28%	1.30%	1.32%
37	Providence city	1,328	44,769	0.88%	0.94%	1.00%	1.01%	1.03%	1.11%	1.22%	1.36%	1.48%	1.60%	1.63%	1.66%	1.69%
101.01	East Providence city	1,421	55,994	0.75%	0.82%	0.89%	0.92%	0.95%	1.04%	1.15%	1.29%	1.41%	1.53%	1.57%	1.62%	1.66%
101.02	East Providence city	1,135	69,448	0.63%	0.70%	0.75%	0.77%	0.80%	0.88%	0.96%	1.08%	1.18%	1.28%	1.32%	1.35%	1.39%
102	East Providence city	358	41,884	0.99%	1.09%	1.17%	1.22%	1.26%	1.38%	1.52%	1.71%	1.86%	2.02%	2.08%	2.14%	2.20%
103	East Providence city	772	41,124	0.98%	1.08%	1.17%	1.21%	1.26%	1.38%	1.52%	1.70%	1.86%	2.02%	2.08%	2.14%	2.20%
104	East Providence city	73	45,042	0.86%	0.94%	1.02%	1.06%	1.10%	1.21%	1.33%	1.50%	1.63%	1.77%	1.83%	1.88%	1.93%
108	Central Falls city	1,371	24,386	1.79%	1.90%	1.99%	2.00%	2.02%	2.17%	2.37%	2.65%	2.88%	3.10%	3.15%	3.19%	3.23%
109	Central Falls city	1,482	30,000	1.47%	1.56%	1.64%	1.64%	1.66%	1.78%	1.95%	2.18%	2.36%	2.55%	2.58%	2.62%	2.65%
110	Central Falls city	1,783	34,120	1.33%	1.41%	1.48%	1.49%	1.50%	1.61%	1.76%	1.97%	2.13%	2.30%	2.33%	2.37%	2.39%
111	Central Falls city	1,187	30,263	1.50%	1.60%	1.68%	1.69%	1.70%	1.83%	1.99%	2.23%	2.42%	2.61%	2.64%	2.68%	2.71%
112	Cumberland town	1,834	46,466	0.97%	1.05%	1.13%	1.15%	1.19%	1.29%	1.42%	1.59%	1.74%	1.88%	1.93%	1.97%	2.02%
113.01	Cumberland town	1,241	62,018	0.70%	0.77%	0.82%	0.84%	0.87%	0.94%	1.04%	1.16%	1.27%	1.37%	1.40%	1.44%	1.47%
113.02	Cumberland town	925	82,298	0.58%	0.64%	0.68%	0.69%	0.71%	0.77%	0.85%	0.95%	1.04%	1.12%	1.15%	1.18%	1.20%
114.01	Cumberland town	886	92,727	0.48%	0.52%	0.56%	0.57%	0.59%	0.64%	0.71%	0.79%	0.86%	0.94%	0.96%	0.98%	1.00%
114.02	Cumberland town	456	100,238	0.45%	0.49%	0.52%	0.54%	0.55%	0.60%	0.66%	0.74%	0.80%	0.87%	0.89%	0.91%	0.94%
114.03	Cumberland town	2,113	74,392	0.59%	0.64%	0.68%	0.70%	0.72%	0.78%	0.86%	0.97%	1.05%	1.14%	1.17%	1.20%	1.23%

Table 6
Narragansett Bay Commission
WARi™ Affordability Model
Projected Affordability - Current + Necessary Spending

Census Tract	City/Town	Number of Households	MHI	*Current* 2014	*Projected* 2015	*Projected* 2016	*Projected* 2017	*Projected* 2018	*Projected* 2019	*Projected* 2020	*Projected* 2021	*Projected* 2022	*Projected* 2023	*Projected* 2024	*Projected* 2025	*Projected* 2026
115	Lincoln town	2,090	65,909	0.68%	0.73%	0.78%	0.79%	0.82%	0.88%	0.97%	1.09%	1.18%	1.28%	1.31%	1.34%	1.37%
116	Lincoln town	1,751	92,361	0.60%	0.64%	0.68%	0.69%	0.71%	0.76%	0.84%	0.94%	1.02%	1.10%	1.12%	1.15%	1.17%
117.01	Lincoln town	1,690	60,962	0.71%	0.77%	0.82%	0.84%	0.86%	0.94%	1.03%	1.15%	1.25%	1.36%	1.39%	1.42%	1.45%
117.02	Lincoln town	1,378	89,211	0.49%	0.53%	0.56%	0.57%	0.59%	0.64%	0.70%	0.79%	0.86%	0.93%	0.95%	0.97%	0.99%
118	North Providence town	2,579	52,482	0.90%	0.98%	1.04%	1.07%	1.10%	1.19%	1.31%	1.47%	1.60%	1.73%	1.77%	1.81%	1.85%
119.01	North Providence town	1,193	41,563	1.14%	1.24%	1.32%	1.35%	1.39%	1.51%	1.66%	1.86%	2.02%	2.19%	2.24%	2.29%	2.34%
119.02	North Providence town	2,045	52,844	0.97%	1.05%	1.12%	1.14%	1.17%	1.27%	1.39%	1.56%	1.69%	1.83%	1.87%	1.92%	1.95%
120	North Providence town	2,192	69,375	0.67%	0.73%	0.77%	0.79%	0.82%	0.88%	0.97%	1.09%	1.19%	1.28%	1.31%	1.35%	1.37%
121.02	North Providence town	1,622	41,611	1.13%	1.23%	1.31%	1.34%	1.38%	1.50%	1.64%	1.84%	2.01%	2.17%	2.22%	2.27%	2.32%
121.03	North Providence town	555	40,058	1.17%	1.27%	1.36%	1.39%	1.43%	1.55%	1.70%	1.91%	2.08%	2.25%	2.30%	2.35%	2.40%
121.04	North Providence town	1,328	43,825	1.09%	1.19%	1.27%	1.29%	1.33%	1.44%	1.58%	1.77%	1.93%	2.09%	2.14%	2.19%	2.23%
122	Johnston town	98	71,408	0.70%	0.76%	0.80%	0.80%	0.82%	0.88%	0.96%	1.08%	1.17%	1.27%	1.29%	1.31%	1.33%
123	Johnston town	2,054	65,330	0.73%	0.79%	0.83%	0.84%	0.86%	0.92%	1.01%	1.13%	1.23%	1.33%	1.35%	1.37%	1.39%
124.01	Johnston town	2,326	62,846	0.75%	0.80%	0.84%	0.85%	0.87%	0.94%	1.03%	1.15%	1.25%	1.35%	1.37%	1.40%	1.42%
124.02	Johnston town	833	55,545	0.82%	0.88%	0.93%	0.94%	0.96%	1.04%	1.13%	1.27%	1.38%	1.49%	1.52%	1.55%	1.57%
125	Johnston town	910	38,554	1.21%	1.30%	1.37%	1.39%	1.42%	1.53%	1.67%	1.87%	2.03%	2.20%	2.23%	2.28%	2.31%
134	Cranston city	81	61,723	0.74%	0.78%	0.81%	0.80%	0.81%	0.86%	0.93%	1.04%	1.13%	1.21%	1.22%	1.23%	1.24%
135	Cranston city	41	53,534	0.85%	0.89%	0.93%	0.92%	0.92%	0.98%	1.07%	1.19%	1.29%	1.39%	1.40%	1.41%	1.42%
150	Pawtucket city	1,698	42,500	1.01%	1.09%	1.15%	1.17%	1.19%	1.28%	1.40%	1.57%	1.71%	1.85%	1.88%	1.91%	1.95%
151	Pawtucket city	1,215	23,882	1.78%	1.91%	2.02%	2.04%	2.09%	2.25%	2.46%	2.76%	3.00%	3.24%	3.30%	3.36%	3.42%
152	Pawtucket city	353	11,612	3.79%	4.08%	4.30%	4.35%	4.44%	4.79%	5.24%	5.86%	6.37%	6.89%	7.01%	7.14%	7.26%
153	Pawtucket city	872	33,281	1.28%	1.37%	1.45%	1.47%	1.50%	1.62%	1.77%	1.98%	2.15%	2.33%	2.37%	2.42%	2.46%
154	Pawtucket city	686	33,750	1.27%	1.37%	1.45%	1.46%	1.49%	1.61%	1.76%	1.97%	2.14%	2.32%	2.36%	2.41%	2.45%
155	Pawtucket city	1,538	50,670	0.84%	0.90%	0.95%	0.96%	0.98%	1.06%	1.16%	1.30%	1.41%	1.53%	1.55%	1.58%	1.61%
156	Pawtucket city	985	52,576	0.77%	0.83%	0.88%	0.89%	0.91%	0.98%	1.08%	1.21%	1.31%	1.42%	1.45%	1.47%	1.50%
157	Pawtucket city	1,496	52,000	0.85%	0.92%	0.97%	0.98%	1.00%	1.08%	1.18%	1.32%	1.43%	1.55%	1.57%	1.60%	1.63%
158	Pawtucket city	1,504	60,223	0.72%	0.77%	0.81%	0.82%	0.84%	0.91%	0.99%	1.11%	1.21%	1.31%	1.33%	1.35%	1.38%
159	Pawtucket city	1,165	49,972	0.86%	0.92%	0.97%	0.98%	1.00%	1.08%	1.19%	1.33%	1.44%	1.56%	1.59%	1.62%	1.65%
160	Pawtucket city	1,214	27,313	1.55%	1.67%	1.76%	1.78%	1.82%	1.96%	2.15%	2.40%	2.61%	2.82%	2.88%	2.93%	2.98%
161	Pawtucket city	1,521	28,456	1.55%	1.66%	1.75%	1.78%	1.81%	1.95%	2.14%	2.39%	2.60%	2.81%	2.86%	2.91%	2.96%
163	Pawtucket city	1,082	56,509	0.78%	0.84%	0.88%	0.90%	0.91%	0.98%	1.08%	1.21%	1.31%	1.42%	1.44%	1.47%	1.49%
164	Pawtucket city	1,768	30,729	1.37%	1.48%	1.56%	1.58%	1.61%	1.74%	1.90%	2.13%	2.32%	2.51%	2.55%	2.60%	2.64%
165	Pawtucket city	1,515	53,682	0.84%	0.90%	0.95%	0.96%	0.98%	1.06%	1.16%	1.29%	1.41%	1.52%	1.55%	1.58%	1.60%
166	Pawtucket city	573	35,313	1.22%	1.32%	1.39%	1.41%	1.43%	1.55%	1.69%	1.90%	2.06%	2.23%	2.27%	2.31%	2.35%
167	Pawtucket city	1,131	31,421	1.33%	1.43%	1.51%	1.53%	1.56%	1.68%	1.84%	2.06%	2.24%	2.43%	2.47%	2.52%	2.56%
168	Pawtucket city	1,199	64,625	0.67%	0.72%	0.76%	0.77%	0.79%	0.85%	0.93%	1.04%	1.13%	1.22%	1.24%	1.27%	1.29%
169	Pawtucket city	834	65,455	0.71%	0.76%	0.80%	0.81%	0.83%	0.89%	0.98%	1.09%	1.19%	1.28%	1.31%	1.33%	1.35%
170	Pawtucket city	1,368	51,384	0.86%	0.93%	0.98%	0.99%	1.01%	1.09%	1.19%	1.33%	1.45%	1.57%	1.60%	1.63%	1.65%
171	Pawtucket city	1,462	39,038	1.10%	1.18%	1.25%	1.27%	1.29%	1.39%	1.52%	1.71%	1.85%	2.00%	2.04%	2.08%	2.11%
Total		**118,683**	**$48,716**	**1.09%**	**1.18%**	**1.24%**	**1.26%**	**1.29%**	**1.39%**	**1.52%**	**1.70%**	**1.85%**	**2.00%**	**2.03%**	**2.07%**	**2.11%**

NBC CSO Control Facilities Phase III Reevaluation

Appendix 3 – Bucklin Point Service Area

Model Build and Calibration Report

NBC CSO Control Facilities Phase III Reevaluation

Appendix 3 - Bucklin Point Service Area Model build and calibration report

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1. Introduction

This report outlines the development of the Bucklin Point Service Area (BPSA) sewer hydraulic model using Mike Urban 2014 (MU) software.

The model serves as an integral tool in the re-evaluation of the Narragansett Bay Commission (NBC) Phase III CSO control facilities. The re-evaluation includes 28 overflows not previously address by the Phases I and II; the outcome will be development of a Phase III CSO Program.

The BPSA overflows are located along the Blackstone, Seekonk and Moshassuck Rivers in the towns of Central Falls and Pawtucket. The BPSA area (tributary to the Bucklin Point Wastewter Treatment Facility) encompasses the entire towns of Central Falls and Pawtucket, as well as portions of Cumberland, East Providence and Lincoln, Rhode Island. A plan of the BPSA area is depicted in Figure 1 and also in Appendix A.

The hydraulic model used for the Phase III alternatives analysis was developed for the catchment areas immediately upstream of the 28 overflows, as outlined in the main body of this report. The model was then expanded to include the NBC interceptors in Cumberland, Lincoln and East Providence. The model extension is outlined in Appendix B.

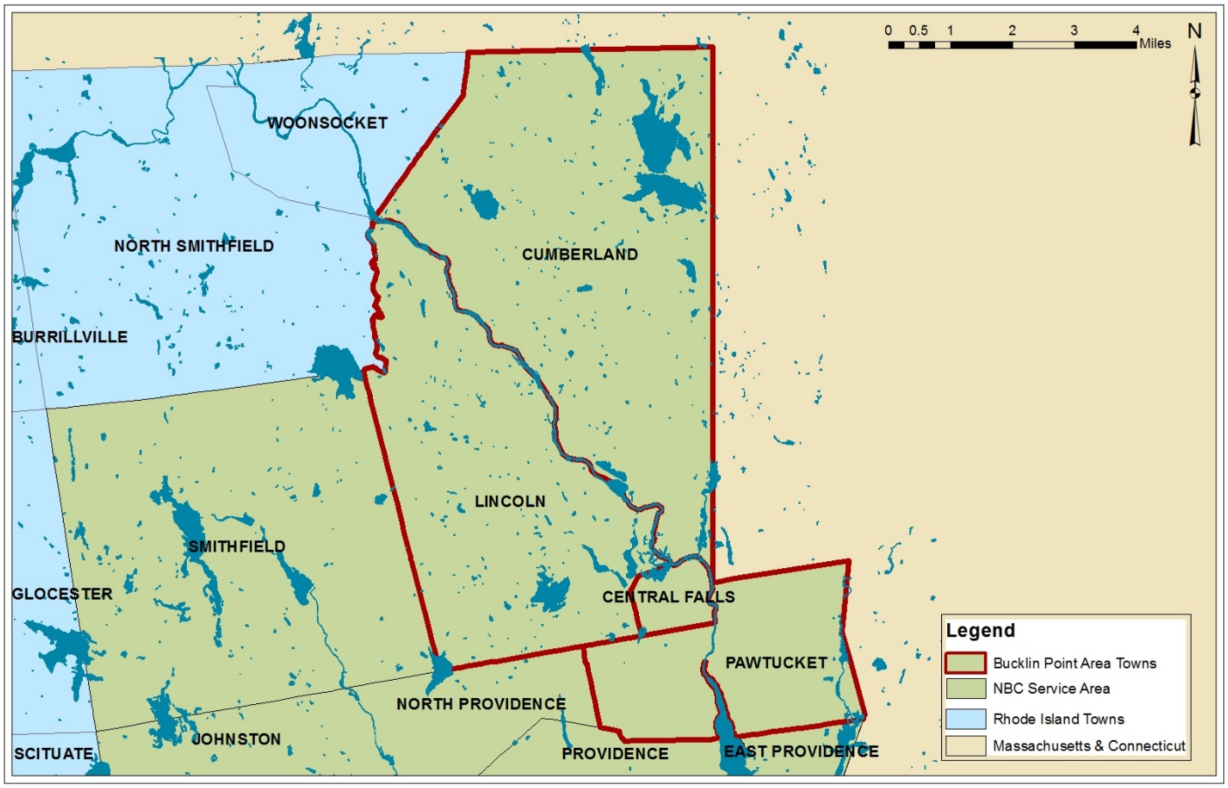

Figure 1: Bucklin Point Service Area

This document follows the model development process as detailed in MWH's Conceptual Framework and previously discussed in the Project Approach document; the process is summarized in Figure 2.

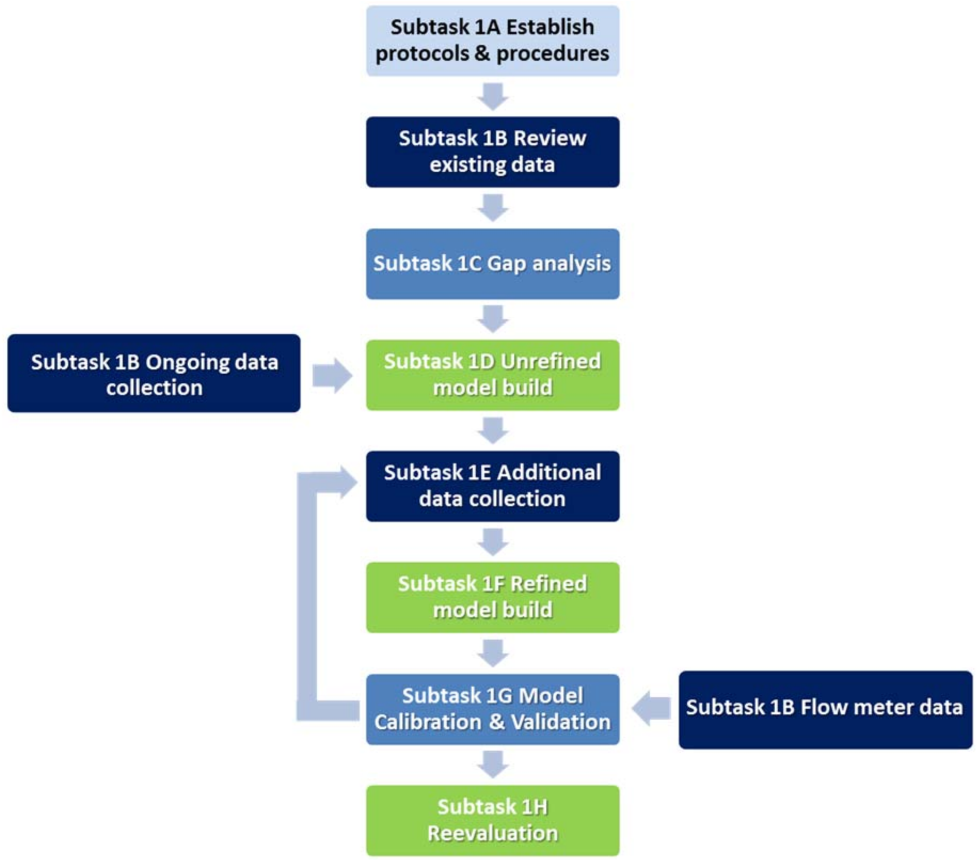

Figure 2: The MWH Conceptual Framework for building the BPSA model

2. Modeling Protocols and Procedures

The establishment of modeling protocols and procedures was carried out in close coordination with the NBC. This subtask began with a thorough review of all available documentation of the alternatives development and implementation as a part of Phases I and II. Particular focus was placed on the review of the documentation of model building and calibration during Phases I and II. In addition, a review of the Field's Point Service area (FPSA) model in Mike Urban was conducted in order to ensure consistency in model parameters and to determine those areas where MWH would propose a divergence from the previously established protocols.

2.1 Field's Point Service Area (FPSA) Model-Hydrologic Model Parameters

Central to the development of the BPSA model were the hydrologic inputs. A review of the previously constructed Field's Point Service Area (FPSA) model indicated that the model employed the RDI+ Kinematic Wave Hydrologic Models in Mike Urban. For consistency in model development, the same hydrologic models were applied in the development of the BPSA. The application of the kinematic wave and RDI hydrologic parameters were kept consistent with those used in the FPSA model.

The Hydrologic Parameters for the Kinematic Wave Model and the RDI models as applied to the BPSA model are presented in Figure 3 and Figure 4.

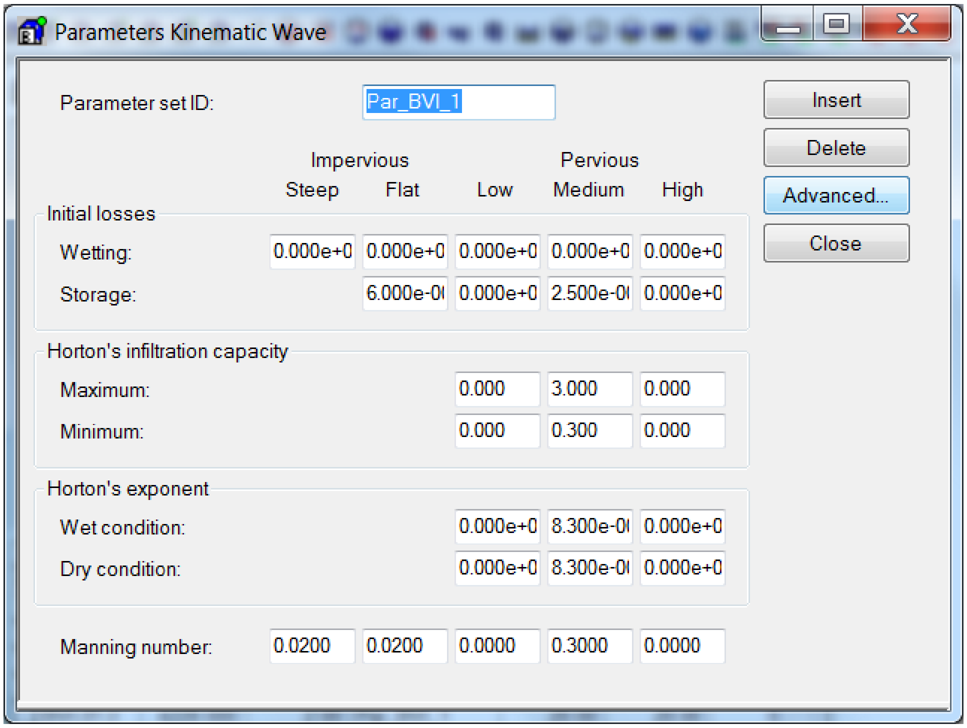

Figure 3: Kinematic Wave Hydrologic Parameters

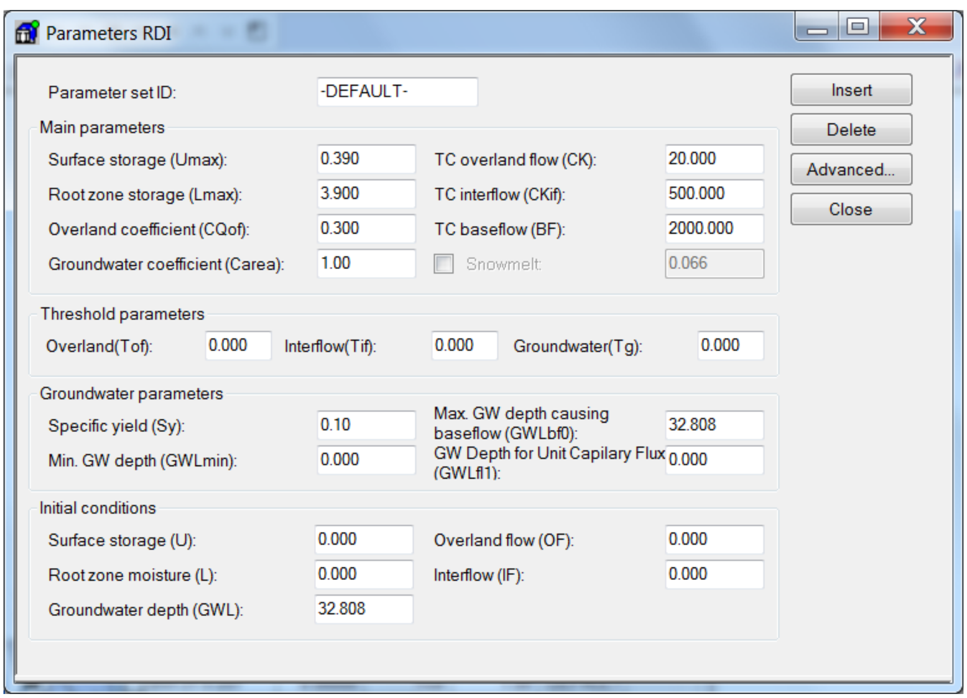

Figure 4: RDI Hydrologic Parameters

2.2 External Water Level Data

A review of the USGS Gauge data for the Blackstone/Seekonk and Moshassuck Rivers showed a lack of elevation data along the reaches of concern to the BPSA, therefore it was decided that external water level boundary conditions would not be included in this phase of model development. In future phases of model development, however, water level data for the region will be further sought out and added as available at all outfall locations.

2.3 Subcatchment Size and Meter Data Availability

The RJN Metering Data collected in 2005 was limited to 15 meter sites within BPSA (Reference #6). These meter locations dictated the load points for the application of the upstream model subcatchments. Since the BPSA model was to only contain only NBC's interceptor sewer network as no sewer information for the upstream communities was available, the meter coverage was sufficient to understand the overall flow distribution throughout the BPSA.

The model subcatchment sizes range from 1-ac to 1,000-ac with an average catchment size of approximately 100 Ac. The catchments established in the BPSA closely mirrored the FPSA model catchment size and distribution although the average subcatchment size is larger than recommended particularly when considering possible source control solutions. The ability to accurately model runoff routing in addition to volumes will be important in future design phases.

2.4 Existing Conditions after Model Calibration

The Chartered Institution of Water and Environmental Management (CIWEM) modeling guidelines were adopted as a standard for calibration. Only flow data was available from the 2005 and so only peak flow and volume comparisons were made.

NBC also confirmed at this juncture that any operational conditions found during the calibration (particularly related to the siphonic restrictions), would be included in the 'baseline model'; this model would form the basis for all subsequent analyses associated with this study. No simulations would be completed with a 'clean' system.

3. Review existing data/ongoing data collection/flow meter data

The reviewing and collecting the existing data began at project initiation and extended throughout the model build tasks, due to the limited project schedule, this task was broken into three parts;

- Reviewing existing data;
- Ongoing data collection; and
- Flow meter data.

The effective review and collection of data was dependent upon consistent communication with NBC representatives in the form of specific data requests and requests for clarification of existing information. These communications were ongoing and included two meetings between the project team and the NBC which served to consolidate and focus the data collection and review process.

3.1 Review of Existing Data

The review of existing data began with an assessment of data provided in the Requests for Proposals package, with a particular focus on the data requirements necessary for the development of the BPSA model. This data included;

- A GIS database of NBC-owned infrastructure and boundaries (included some information on the locally-owned infrastructure);
- A GIS database of State of Rhode Island-wide infrastructure including roadways, addresses, etc.;
- Historical plan and profile drawings of the interceptor networks belonging to the NBC (a comprehensive set of available historical drawings);
- Historical plan and profile drawings of the local sewer and drain networks in the NBC member communities including some of the outfall pipes (an incomplete set of the available historical drawings); and
- Flow metering and rainfall data collected as part of the RJN flow monitoring program carried out between April, 2005 and January, 2006.

3.2 NBC GIS-Database

The NBC GIS infrastructure database was reviewed for completeness of data. The GIS data were filtered using the criteria outlined in the 2007 Draft Technical Memorandum, *NBC Hydraulic Model Development-GIS Review* (Reference #1) in order to include only those features pertinent to the hydraulic modeling. These criteria are outlined in Table 1.

Table 1: GIS Data Filters

Attribute	Value
Ownership Code	50
Facility Type	blank, MH, ND, OF, RE, SI, SO or SU for manholes
Facility Type	blank, EOL, FM, G or SI for pipes
State	blank, ACT, BUR, DWC

The data review was focused on the fields necessary to populate the model network, as outlined in Table 2. The percent-complete values for the NBC data system-wide was calculated as part of the 2007 Draft Technical Memorandum, NBC Hydraulic Model Development-GIS Review. These results are presented in Table 2. The review carried out for the Bucklin Point Service Area model considered the data complete within the interceptor reaches tributary to the BPSA area which includes the Blackstone Valley Interceptor (BVI) and the Moshassuck Valley Interceptor (MVI). These percentages complete ranged between 53.4% and 100% with a median of 97.3%.

Table 2: Data Review Results

Layer Name	Field Name	# Records (BVI&MVI)	# Records incomplete ("Null" or Blank)	% Complete (System-Wide, 2007 Doc.)	% Complete (BVI&MVI)
GISVECTOR_bpsa_basins.shp	CODE/AREA	32	32	100.0	100.0
Utility.sewer.manholes	UNITID	654	20	98.4	96.9
Utility.sewer.manholes	RIM_ELEV	654	305	86.3	53.4 [1]
Utility.sewer.pipes	UNITID	562	16	56.0	97.2
Utility.sewer.pipes	UPSELEV	562	15	83.7	97.3
Utility.sewer.pipes	DWNELEV	562	29	82.7	94.8
Utility.sewer.pipes	UNITID2	562	15	56.0	97.3
Utility.sewer.pipes	MATERIAL	562	3	97.7	99.5
Utility.sewer.pipes	PIPE_SHAPE	562	4	96.8	99.3
Utility.sewer.pipes	PIPE_DMI & PIPE_DIM2	562	3	97.0	99.5
Utility.sewer.pipes	ELEV_TYPE	562	10	89.0	98.2

Note: 1: The rim elevation parameter in the sewer manholes layer stands out as being particularly sparsely populated with elevation data. This is a result of there being no elevations on the historical record drawings for the BPSA interceptor used to develop the GIS database. This lack of information did not significantly hinder the development of the BPSA model.

With the results of the initial GIS network data assessment complete, the model boundary conditions, key pump stations and the CSOs were then reviewed.

The data assessment provided an overview of the NBC interceptor networks tributary to the Bucklin Point Wastewater Treatment Facility (BPWWTF), as well as a sense of the CSO locations and key facilities in the service area. While the BVI and MVI extend north into the towns of Cumberland and Lincoln the CSOs are all located either on the MVI or on the downstream portion of the BVI, south of the border between Lincoln and Central Falls.

The upper portion of the BVI includes two large tributary interceptors, the Abbot Valley Interceptor (AVI) in the town of Cumberland and the Washington Highway Interceptor (WHI)/Upper Blackstone Valley Interceptor (UBVI) in the towns of Cumberland and Lincoln.

It was determined that the model development would be focused on the Lower BVI and the MVI and the CSOs and facilities along those interceptors, as the focus of model development was CSOs. Both the UBVI and the ARI were treated as boundary conditions in the model. The model build section of this memorandum will address the details of the incorporation of these boundary conditions using the metered data.

The existing data review also identified three key pump stations within the BPSA;

- Omega Pond Pump Station;
- Saylesville Pump Station; and
- Washington Highway Pump Station.

The Washington Highway Pump Station is located on the Washington Highway Interceptor (part of the Upper BVI, as previously stated). Data for this facility was therefore not required as part of the model build. The Omega Pond Pump Station is located in East Providence and is tributary to the Southern Influent Flume of the BPWWTP which was not included in this model.

The remaining pump station, Saylesville Pump Station, was the only station included in the BPSA MU model. The model building section of this memorandum will address the details of the inclusion of the pump stations in the model. Appendix C provides an overview of the BPSA infrastructure included in the MU model and is shown in Figure 5.

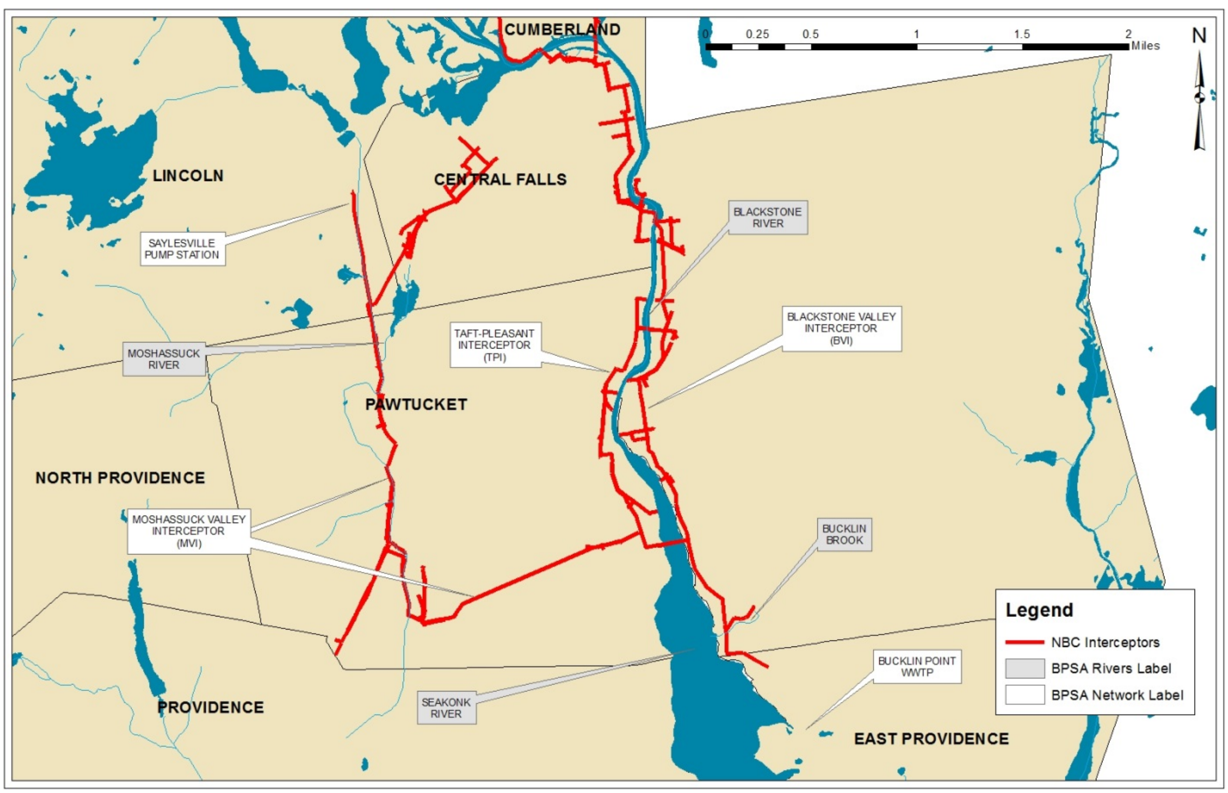

Figure 5: Bucklin Point Interceptor Network

3.3 Flow Meter Data

The flow metering data collected during the RJN metering study (Reference #6) was reviewed for meter locations within the BPSA. The NBC manhole identifier for each meter location was reviewed for accuracy in collaboration with the NBC. Table 3 outlines the 15 meter locations to be used in calibration of the BPSA model and Appendix D shows the location of the 15 meters within the BPSA interceptor network and is copied below in Figure 6.

Table 3: RJN Meter Locations

RJN Meter ID	NBC Manhole Identifier	Community	Interceptor
BVI-1T	Q180012	Pawtucket	BVI
BVI-2AT	Q180001Y	Pawtucket	BVI
BVI-2T	Q180001X	Pawtucket	BVI
BVI-3T	Q190010	Pawtucket	BVI
BVI-4T	Q220009	Pawtucket	BVI
BVI-5T	P230005	Central Falls	BVI
BVI-6T	P230025	Central Falls	BVI
BVI-7T	P230018	Pawtucket	BVI
MVI-1T	P190005	Pawtucket	TPI
MVI-2T	P190002	Pawtucket	MVI
MVI-3T	O190006	Pawtucket	MVI
MVI-4T	O190020	Pawtucket	MVI
MVI-5T	O210006	Lincoln	MVI
MVI-6T	O220007	Central Falls	MVI
MVI-7T	N230008	Lincoln	MVI

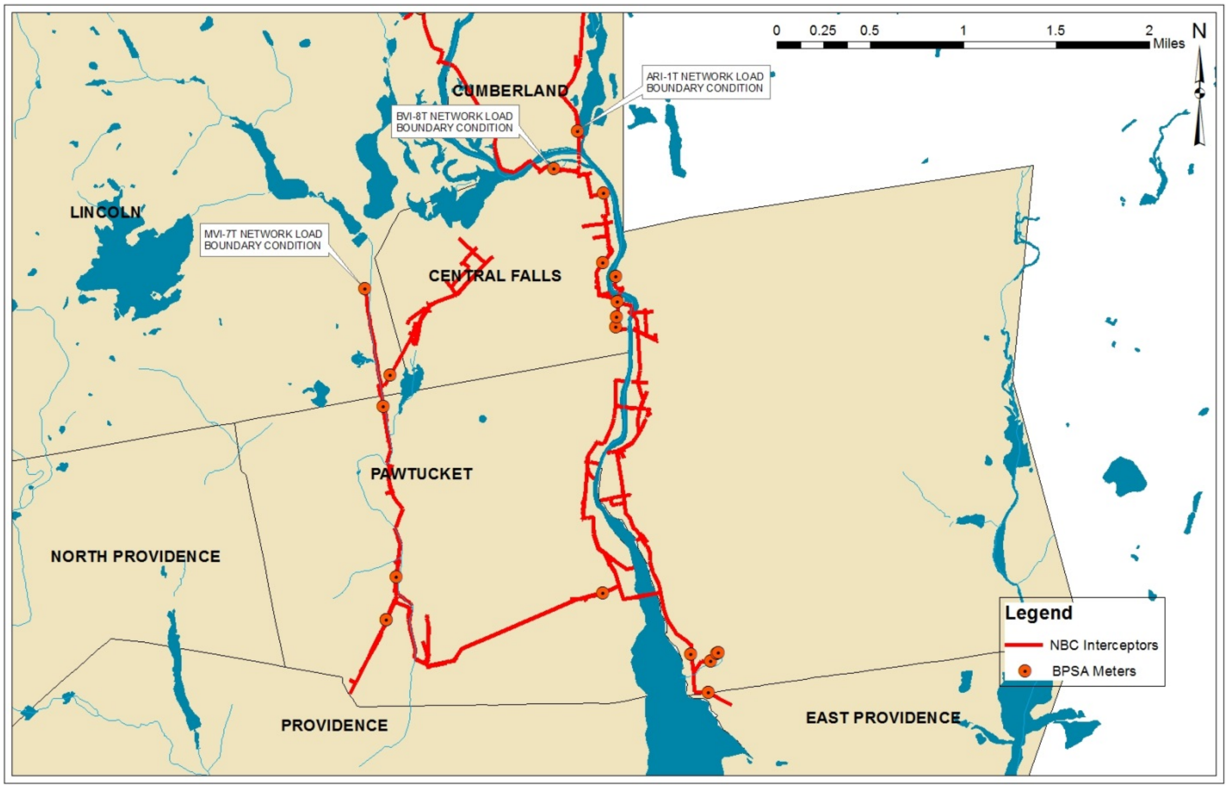

Figure 6: Bucklin Point Meters and Network Boundaries.

3.4 Rainfall-Derived Infiltration and Inflow Characterization

The EPA Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox was used to decompose the dry weather flow hydrograph data and to assess the breakdown of the population derived flows, rainfall-derived infiltration and inflows (RDII) and base flows associated with each meter. (Reference #7).

The RDII analysis linked the flow data and catchment data to determine the dry weather flow peaking factors and volumes. The results of the applying SSOAP was to assign indicative populations based on average consumption within each of the subcatchments and add nominal base flows as constant inflows to the system.

4. Gap Analysis

The initial GIS network data review indicated some missing data values in almost all of the fields (Table 2). In 10 of the 11 fields, however, only a small amount of manual effort was necessary in order to complete the records. The only significant gap in data was identified to be the manhole rim elevation data which was approximately 53.4% complete. It was determined that this data would be supplemented with rim elevations calculated using the available digital elevation model (DEM) data.

4.1 Manhole Rim Elevation Calculation

The Rhode Island Geographic Information System (RIGIS) website includes a database of geospatial data that can be downloaded free of charge. The site is hosted by the University of Rhode Island (URI) Environmental Data Center and is maintained by the URI Geospatial Extension Program. The Digital Elevation Model (DEM) available from RIGIS was based on the 2011 Northeast LiDAR project and was available for the entire state of Rhode Island. The DEM raster files covering the entire Bucklin Point service area were downloaded and were merged together to create one DEM mosaic in GIS for the BPSA area. The elevations provided in the DEM were in NAVD88 vertical datum (Reference #2).

Using the Spatial Analyst tool in ArcGIC 10.1, the rim elevations were extracted from the DEM mosaic for those manholes that were missing rim elevations. The rim elevations values (those existing in the database and those calculated using the DEM) were then converted into NGVD29 (the vertical datum being used in the MU model). The following formula was used to convert the NAVD88 elevations into NGVD29 elevations:

Equation 1: NAVD88 + 0.79' = NGVD29

4.2 Missing Interceptor Data

The NBC provided historical record drawings for most of the NBC-owned interceptor networks. The historical records included contract documents from the Blackstone Valley Sewer District Commission's interceptor work ranging from 1949-1954 including the following contracts:

Table 4: BPSA Interceptor Record Drawing Contracts

Contract No.	Contract Name	Year
Contract 7	Blackstone Valley Interceptor Section A, Bucklin Brook Branch Interceptor	1949
Contract 11	Blackstone Valley Interceptor Section B	1949
Contract 17	Taft-Pleasant Street Branch Interceptor Section A	1950
Contract 18	Taft-Pleasant Street Branch Interceptor Section B	1950
Contract 21	Blackstone Valley Interceptor Section C, Roosevelt Avenue, East Street and Mill Street Branches	1954
Contract 23	Moshassuck Valley Interceptor Section A	1953
Contract 24	Moshassuck Valley Interceptor Section B, Central Falls and Concord Street Branches	1954

These historical documents were used to manually update the pipe network and manhole database within GIS. Manually updated records included inserting missing pipe dimensions, pipe upstream and downstream elevations, pipe shape and pipe material. These manual updates were completed along the NBC-owned interceptor networks alone. The locally-owned sewer networks were not updated in the initial GIS database, as it was decided that the local sewers would be input directly into MU software during model development.

4.3 Missing Unit Identification Numbers

The NBC-assigned alpha-numerical manhole numbers were used as the unique identifiers for the network structures to be imported into the Mike Urban model. Where these manhole identifiers were missing, a new, unique identifier was assigned to each manhole by appending a suffix of "Z", "Y", "X", etc. to the closest downstream manhole on the network.

5. Unrefined Model Build

After the initial gap analysis and manual database updates were completed, the BPSA network within GIS was imported into the MU platform. The network which included pipes (MOUSE links) and manholes (MOUSE nodes) was then reviewed for connectivity and to ensure that all link and node data was complete.

5.1 Manhole Invert Elevation Calculation

The GIS database did not contain manhole invert information for all of the structures. In order to accurately profile the network manholes (and to accurately represent the in-system storage), the manhole inverts for each structure were calculated using the MU georeferencing field calculator. All manhole inverts were set at the outgoing pipe's upstream invert using the Mike URBAN "Interpolation and Assignment" tool. Where this information was missing, the inverts were manually updated using the historical record drawings.

5.2 Manhole Diameter Calculation

In many cases the manhole diameter information was incomplete for all of the structures in the GIS network. Where there was a missing manhole diameter, it was assigned using the field calculator tool in MU. The manhole diameter was assigned as a function of the pipes connected to a given manhole using the Rhode Island Department of Transportation standards represented in Table 5.

Table 5: Assumed Manhole Diameters

Assumed Manhole Diameter (feet)	4ft	5ft	6ft	8ft
Pipe Diameter (feet)	D<= 2'	2'>D<=3'	3'<D<= 4'	>4'

5.3 Model Catchment Representation

The catchment areas within the Bucklin Point Service Area were based upon the catchment delineations development during the RJN flow metering study (Reference #6), provided by NBC in the GISVECTOR_bpsa_basins.shp polygon file from GIS. The naming convention followed the BETA metering report catchment naming where:

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

The East Providence Interceptor Catchments do not include any overflow locations (with the exception of the Omega Pond Pump Stations diversion). Therefore they were not included in the first iteration of the model. The East Providence catchments include EPI-1T-1, EPI-2T-1, EPI-2T-2, EPI-2T-3, EPI-2T-4 & EPI-2T-5. Table 6 contains a full list of the catchments tributary to Bucklin Point that were included in the model. A map of the Bucklin Point catchments is provided in Appendix E and copied below in Figure 7.

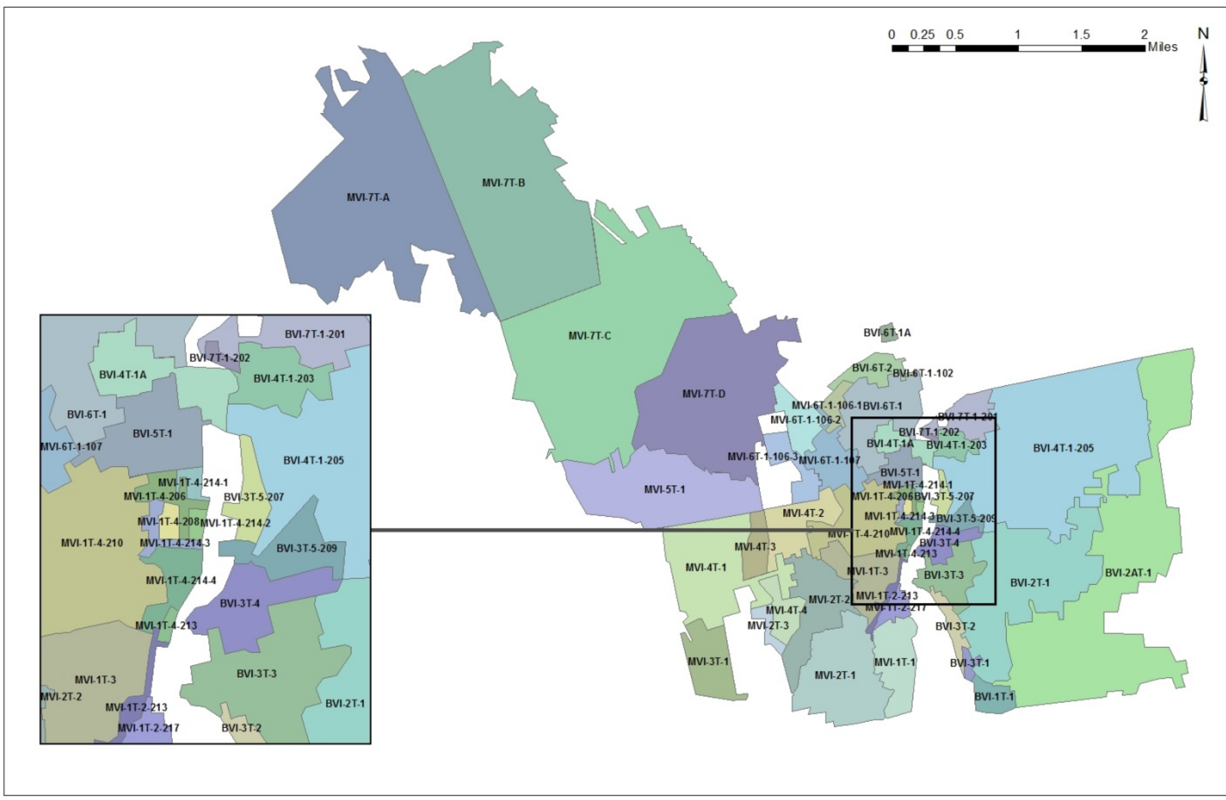

Figure 7: Bucklin Point Service Area Mike Urban Model Catchments.

Each catchment was assigned a total area (in hectares) as well as minimum and maximum elevations (in NGVD29). The minimum and maximum elevations for each catchment were calculated using the ArcGIS Spatial Analyst tool.

The population in each catchment was calculated using the RIGIS 2010 census data. The "Population in Households" attribute (HH9) was aggregated for each catchment area (Reference #3).

The length of each catchment was calculated empirically using the following formula:

Equation 2: Catchment Length = 2 x √(Catchment Area (SF)

The slope of the catchment was calculated using the following formula:

Equation 3: Slope (%) = (Max. Elevation – Min. Elevation) / Catchment Length

All of the catchment parameters calculated in GIS are presented in Table 6.

Table 6: BPSA Catchment Parameters

Catchment ID	Area (Ac)	Length (ft)	Min. Elevation (NGVD29)	Max. Elevation (NGVD29)	Slope (%)	Population (no.)
BVI-1T-1	46.41	2844	13.58	78.02	2.27%	329
BVI-2AT-1	1009.84	13265	51.02	98.85	0.36%	13206
BVI-2T-1	525.64	9570	47.75	107.16	0.62%	8069
BVI-3T-1	13.75	1548	28.97	75.02	2.98%	192
BVI-3T-2	38.39	2586	20.21	97.02	2.97%	768
BVI-3T-3	102.59	4228	24.15	110.91	2.05%	2684
BVI-3T-4	49.05	2923	21.39	106.46	2.91%	1130
BVI-3T-5-207	18.91	1815	30.51	109.13	2.58%	436
BVI-3T-5-209	34.44	2450	30.51	109.13	2.58%	281
BVI-4T-1-203	37.84	2568	26.69	115.36	0.67%	215
BVI-4T-1-205	969.80	12999	26.69	115.36	0.67%	5500
BVI-4T-1A	50.52	2967	25.68	167.32	4.77%	2432
BVI-5T-1	58.17	3184	45.37	122.78	2.43%	2042
BVI-6T-1	203.76	5958	35.56	137.94	1.72%	7776
BVI-6T-1-102	1.25	467	35.56	137.94	1.72%	48
BVI-6T-1A	9.49	1286	36.82	87.25	3.92%	148
BVI-6T-2	57.84	3175	44.94	114.90	2.20%	1765
BVI-7T-1-201	81.11	3759	38.01	119.98	2.13%	3392
BVI-7T-1-202	4.01	836	38.01	119.98	2.13%	176
MVI-1T-1	132.65	4808	32.78	160.62	2.66%	744

Catchment ID	Area (Ac)	Length (ft)	Min. Elevation (NGVD29)	Max. Elevation (NGVD29)	Slope (%)	Population (no.)
MVI-1T-2-213	16.67	1704	0.65	156.95	5.54%	715
MVI-1T-2-217	29.14	2253	0.65	156.95	5.54%	1250
MVI-1T-3	123.64	4641	33.63	133.88	2.16%	4352
MVI-1T-4-206	13.76	1549	0.68	108.50	1.62%	250
MVI-1T-4-208	5.07	940	0.68	108.50	1.62%	92
MVI-1T-4-210	193.43	5805	0.68	108.50	1.62%	3512
MVI-1T-4-213	3.01	725	0.68	108.50	1.62%	55
MVI-1T-4-214-1	5.10	942	0.68	108.50	1.62%	93
MVI-1T-4-214-2	3.61	793	0.68	108.50	1.62%	65
MVI-1T-4-214-3	8.64	1227	0.68	108.50	1.62%	157
MVI-1T-4-214-4	20.44	1887	0.68	108.50	1.62%	371
MVI-2T-1	294.42	7162	41.89	161.09	1.66%	6512
MVI-2T-2	188.35	5729	29.55	128.41	1.73%	6151
MVI-2T-3	23.46	2022	31.62	91.28	2.95%	47
MVI-3T-1	124.66	4661	54.38	185.46	2.81%	1634
MVI-4T-1	338.12	7676	32.79	151.98	1.55%	2486
MVI-4T-2	124.89	4665	43.18	104.44	1.31%	3674
MVI-4T-3	55.34	3105	35.10	103.32	2.20%	628
MVI-4T-4	60.07	3235	31.72	88.82	1.77%	239
MVI-5T-1	422.28	8578	45.47	318.33	3.18%	815
MVI-6T-1-106-1	30.24	2295	50.18	113.16	0.91%	1009
MVI-6T-1-106-2	74.70	3608	50.18	113.16	0.91%	2493
MVI-6T-1-106-3	67.69	3434	50.18	113.16	0.91%	2259
MVI-6T-1-107	103.98	4257	50.18	113.16	0.91%	3471
MVI-7T-A	1174.67	14306	172.82	439.14	1.86%	2014
MVI-7T-B	1171.71	14288	102.43	326.85	1.57%	1648
MVI-7T-C	1230.89	14645	72.68	324.55	1.72%	2110
MVI-7T-D	711.04	11131	46.35	316.15	2.42%	4698

5.4 BPSA Network Connectivity

The BPSA MU network was reviewed for appropriate connectivity and to ensure that the upstream-downstream relationships (using the invert elevations input in GIS) resulted in the correct interceptor network layout. Where pipes were noted to be going in the wrong direction they were manually corrected until an upstream-reach test included the entire interceptor network (all of the MVI and the Lower BVI). The BPSA Model in Mike Urban is shown in Figure 8, Figure 9 and Figure 10 these depict the long section profiles for the three main NBC interceptors in the BPSA, along with the locations of the overflow structures.

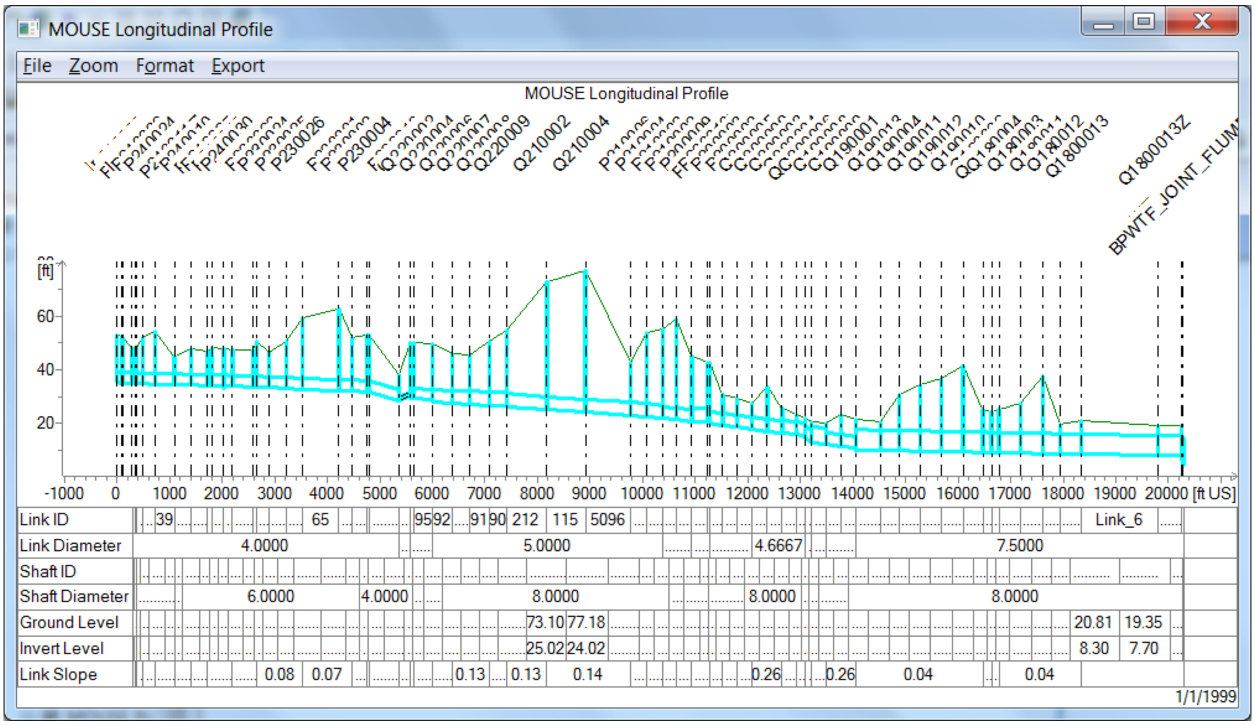

Figure 8: Blackstone Valley Interceptor-Long Section

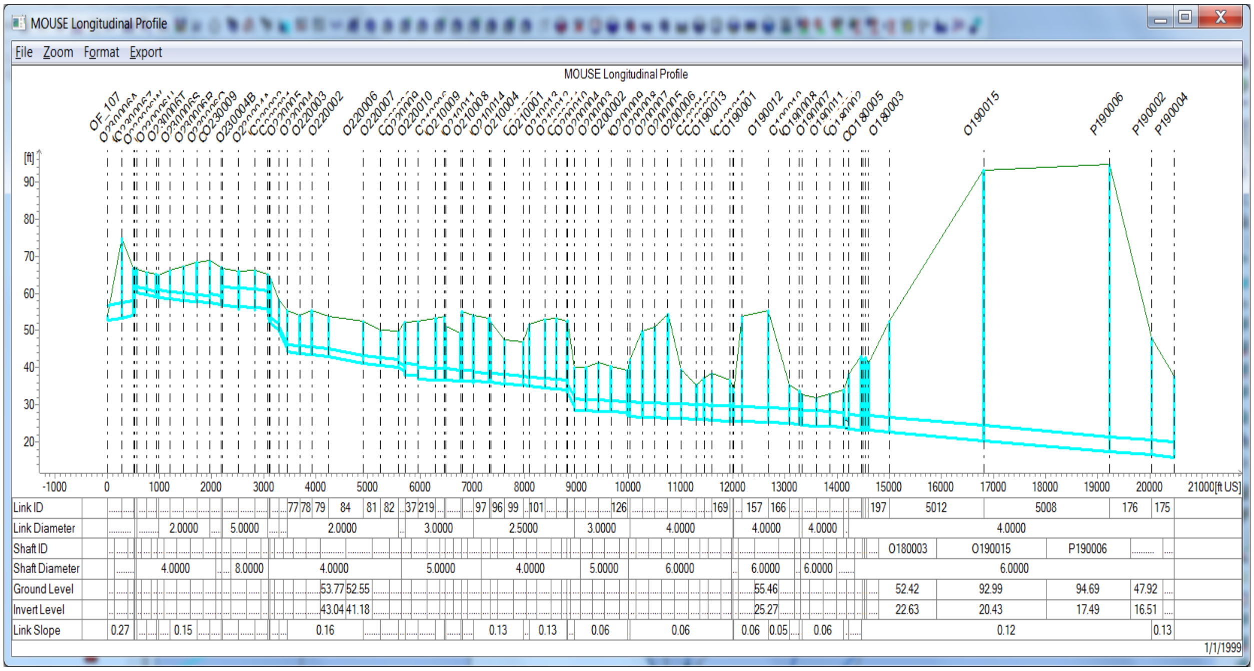

Figure 9: Moshassuck Valley Interceptor-Long Section

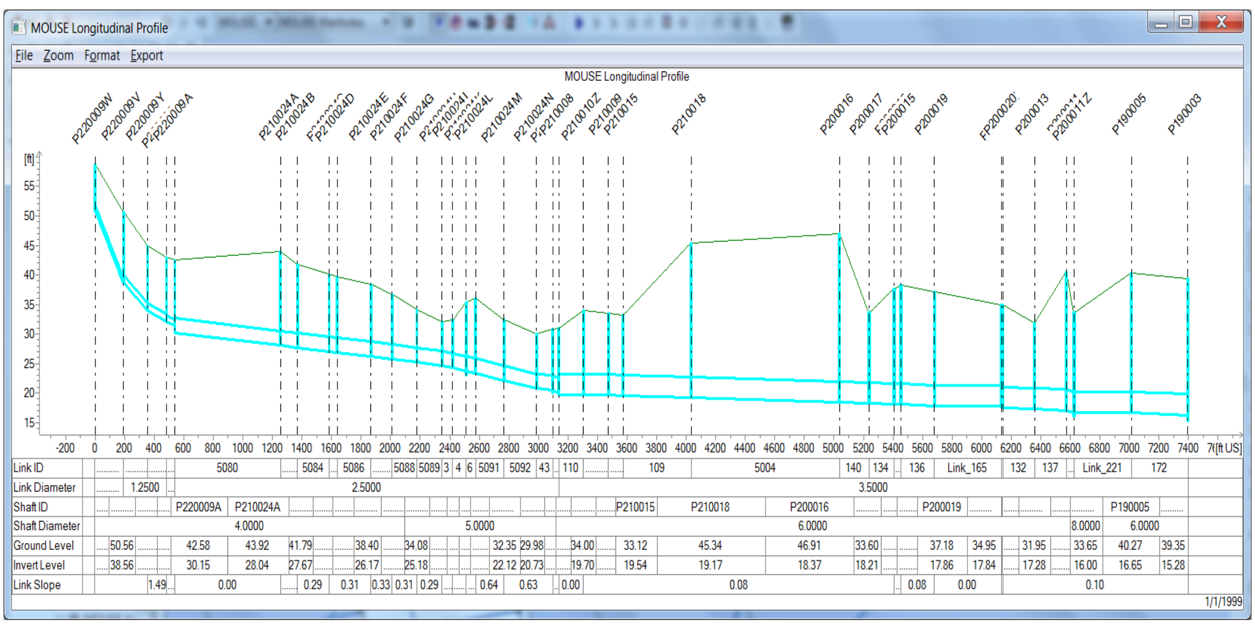

Figure 10: Taft-Pleasant Interceptor-Long Section

5.5 BPSA Regulator Structures

With the NBC-owned interceptor network created in Mike Urban, the next step in model development was to represent the overflow structures and overflow pipes along the interceptors in the Bucklin Point service area. This included representing the diversion structures and overflow pipes, as well as their connectivity to the NBC-interceptors. The overflow pipes and outfalls are owned by the local municipalities. Therefore, in addition to using the NBC-owned interceptor record drawings, the town-specific data for the member communities of Central Falls, Cumberland, Lincoln and Pawtucket was also used. The locally-owned record drawings were provided (where available) by the NBC. Figure 11 depicts each of the 28 overflow locations within the BPSA.

It should be noted that all of the historical record drawings were completed in the Providence Mean High Water Datum. The following formula was used to convert the Providence Mean High Water (MHW) elevations into NGVD29 elevations:

Equation 4: Providence Mean High Water (MHW) + 2.35' = NGVD29

Where the historical record drawings did not provide all of the necessary information, the data was supplemented using the regulator sketches provided in Section 5 of the Phase I-C Modelling User's Manual (Reference #9).

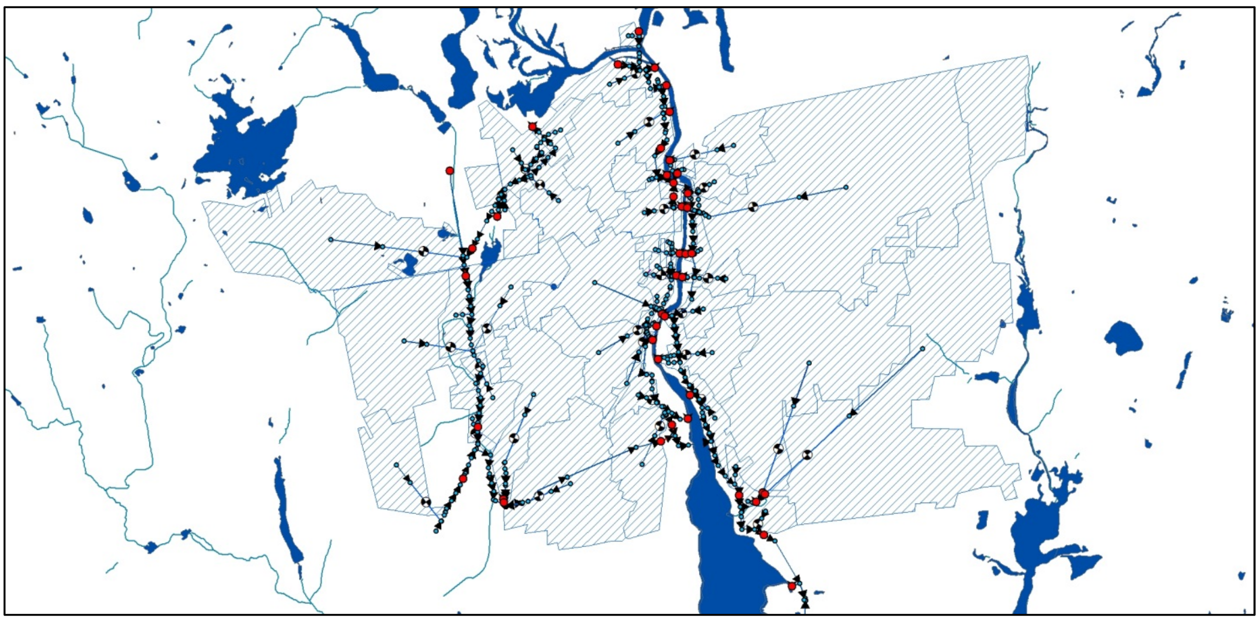

Figure 11: BPSA Mike Urban Model

6. Additional Data Collection

6.1 Pump Station and BPWWTP Records

As previously outlined in Section 3.2, both the Saylesville Pump Station and the Bucklin Point Wastewater Treatment Plant were identified as the facilities of note within the BPSA. The original data set did not provide sufficient detail for these two facilities, therefore data for both facilities was requested from NBC.

The Saylesville Pump Station is located in Lincoln, downstream of Catchment MVI-7T (see Appendix A). Record Drawings, pump details and operating data for Saylesville were requested from NBC in order to incorporate the pump station in the model. NBC provided the Record Drawings for Contract 95-701C, dated 1996, pump curve information, as well as pump on/off operating data.

The Bucklin Point Wastewater Treatment Plant receives flows from the Blackstone Valley Interceptor to the north, as well as from the East Providence Interceptor to the south (not included in this model). The BPWWTP is the receiving plant for the entire Interceptor network represented in the Bucklin Point Service Area Mike URBAN model. Details of the treatment plant upgrades (carried out in 2001), pump details and operating data were requested from the NBC. NBC provided the record drawings for Contract No. 01:807C, along with pump details and pump on/off operating data.

6.2 Outfalls 205, 219 & 220

The NBC carried out a regulator modification project in 2011 which included updates to outfalls 205, 219 and 220. These outfalls are located within the BPSA and are of particular interest, as all three contribute significant overflow volumes to the Blackstone and Moshassuck Rivers. The contract documents for this work (Contract 306.00C) were requested from the NBC in order to update the baseline model to 2011 conditions (see Section 9 herein).

6.3 Additional Regulator Data

The overflow regulator structures were inspected and detailed in the Phase 1-C Stormwater Management Model User's Manual (Reference #9), Section 5. The sketches provided most of the information necessary to incorporate the regulator structures and overflow pipes into the BPSA model. Where there was insufficient information, however, additional clarification was requested from the NBC. In particular, on the Taft-Pleasant interceptor (TPI), there were a number of regulators (OF_210, OF_211, OF_213, OF_214 and OF_217) for which the NBC provided additional clarification. Additional information was also requested for OF_106 and OF_107 located on the upper reaches of the Moshassuck Valley Interceptor (MVI).

7. Refined Model Build

The Bucklin Point service area network was further refined within the Mike URBAN modeling platform by further developing the catchment hydrology, as well as populating the data missing from various fields that did not exist within in the GIS database.

7.1 Catchment Hydrology

The local pipe networks upstream of the NBC interceptors in the member communities were not included in the model, due to the limited time and scope associated with the Phase III model development. Instead, a manhole storage node in MU was used to represent the in-pipe storage within each catchment. These nodes were given the same MUID as the catchments they represented.

The storage value calculated for each catchment was a function of the total pipe length (LF) (see Table 8). The storage volumes were calculated using the assumptions outlined in Table 7.

Table 7: Storage Volume Assumptions

Pipe Length (LF)<100,000 (A)	100,000<Pipe Length (LF)<200,000 (B)	Pipe Length (LF)>200,000 (C)
Assumed the average pipe size was 12" diameter	Assumed the average pipe size was 24" diameter	Assumed the average pipe size was 36" diameter
$Volume = \left(A * \pi * (1.5^2)\right) + \left(B * \pi * (1^2)\right) + (C * \pi * (1.5^2))$		

The storage basin's top elevation was assigned to be the average elevation within the catchment (the average between the minimum and maximum elevations calculated in GIS (Table 6). The bottom of the storage basin was assumed to be the invert of the manhole node on the network to which is was connected. Using the storage volume of the basin and the height of the storage basin (the difference between the top elevation and the invert elevation) a representative manhole diameter was input such that the manhole provided the estimated storage volume associated with the given catchment.

Each subcatchment was connected to the representative storage manhole of the same name. The storage manholes were then connected to the appropriate network manhole nodes (Table 8) with an orifice. The orifice invert level was set at the same elevation as the invert of the manhole node on the network and the orifice width and height were set equal to the inlet pipe diameter at that node. If that information was not available, the orifice diameter was estimated using the diameter of the interceptor at that point.

Within the BPSA, the northeastern most catchment, MVI-7T, covers approximately 4,288 Ac in Lincoln, Rhode Island. This area is significantly larger than the other catchments included in the model. It is 3 times the area of the next largest catchment (BVI-2AT) which is 1009 Ac. The loading from this large catchment area was resulting in model run errors at the downstream, receiving manhole node, as depth limit of the manhole was being far exceeded in the course of the simulation.

The catchment was disaggregated into 4 sections (MVI-7T-A-D) and a reach of 4 links was added to the model to represent the main sewer trunk for this catchment. Each of the 4 catchments was loaded to 4 separate manhole nodes along the main sewer trunk upstream of the Saylesville Pump Station.

After disaggregating the MVI-7T catchment into four catchments, the model remained unable to accurately represent the flow entering the Saylesville Pump Station (at MVI-7T). This was most likely due to the fact that the catchments are comprised of separated sanitary systems, they remain large catchments and the pump station is located immediately downstream of the meter location. The MVI-7T catchments were not included in any portion of the proposed Phase 3 work, therefore in order to facilitate model development the metered data was used as a node boundary condition just upstream of the MVI-7T meter location (node N230008). The treatment of catchment MVI-7T is further detailed in section 7.5 Boundary Conditions.

7.2 Model Hydrology – RDI + Kinematic Wave (B)

The BPSA MU model employed the Kinematic Wave + RDI Hydrological Model. The default parameters for the Kinematic Wave Model were kept unchanged, as previously discussed in Section 2.1.

Table 8: BPSA Catchment Storage and Loading

Catchment ID	Street Length (ft)	Storage Volume (CF)	Loading Node		Catchment ID	Street Length (ft)	Storage Volume (CF)	Loading Node
BVI-1T-1	6927	5438	Q180011		MVI-1T-4-208	1041	817	P210024X
BVI-2AT-1	215434	501541	Q180001Y		MVI-1T-4-210	39704	31168	P210026W
BVI-2T-1	107942	103438	Q180001X		MVI-1T-4-213	619	486	P210012B
BVI-3T-1	2893	2271	Q190012		MVI-1T-4-214-1	1046	821	P220009Y
BVI-3T-2	6566	5154	Q200011		MVI-1T-4-214-2	740	581	P210024A
BVI-3T-3	27642	21699	P200006X		MVI-1T-4-214-3	1774	1393	P210024X
BVI-3T-4	18117	14222	P210007W		MVI-1T-4-214-4	4195	3293	P210024K
BVI-3T-5-207	6232	4892	Q220011Y		MVI-2T-1	73826	57953	O180016U
BVI-3T-5-209	10434	8191	Q210003X		MVI-2T-2	53912	42321	O190016X
BVI-4T-1-203	67	53	Q2300002		MVI-2T-3	1306	1025	O190014
BVI-4T-1-205	1715	1347	Q220016Q		MVI-3T-1	30847	24215	N180008
BVI-4T-1A	8472	6651	P230019Z		MVI-4T-1	75842	59536	O200011
BVI-5T-1	14617	11474	P220005V		MVI-4T-2	15531	12192	O200012

Catchment ID	Street Length (ft)	Storage Volume (CF)	Loading Node		Catchment ID	Street Length (ft)	Storage Volume (CF)	Loading Node
BVI-6T-1	36169	28393	P240027Y		MVI-4T-3	2227	1748	O210014
BVI-6T-1-102	380	298	P240026Z		MVI-4T-4	6920	5432	O200011
BVI-6T-1A	1732	1360	P250013		MVI-5T-1	40341	31668	Q220009
BVI-6T-2	12415	9746	P240037		MVI-6T-1-106-1	15935	12509	O230006Y
BVI-7T-1-201	23267	18264	P2300006Z		MVI-6T-1-106-2	39371	30907	O230008Y
BVI-7T-1-202	1207	948	P2300012		MVI-6T-1-106-3	35675	28005	O230003
MVI-1T-1	34570	27137	P200012W		MVI-6T-1-107	54803	43020	O230008Z
MVI-1T-2-213	5577	4378	P210015X		MVI-7T-A	53542	181992	MVI-7T-A
MVI-1T-2-217	9749	7653	P200014		MVI-7T-B	43812	148919	MVI-7T-B
MVI-1T-3	40072	31457	P210012V		MVI-7T-C	56094	190667	MVI-7T-C
MVI-1T-4-206	2825	2218	P220009X		MVI-7T-D	124897	424529	MVI-7T-D

For each model subcatchment, the impervious versus pervious land area percentages were calculated in GIS using the RIGIS impervious raster image (Reference #4). These percentage values of impervious and pervious land area were calculated in GIS and were manually added to each catchment in MU (pervious and impervious percentages are presented in Table 9). The impervious and pervious percentages for each catchment were input in the Kinematic Wave Model in the "AIFlat" and "APHigh" parameters, respectively.

A majority of the catchments within the BPSA model area were identified to be combined-sewer catchments, however the following catchments are presumed to be sanitary catchments based upon the RJN Capacity Analysis Report (Reference #6); MVI-3T-1, MVI-4T-1 through MVI-4T-4 and MVI-5T. The Sanitary catchments were assigned a significantly smaller drainage area (as they are presumed to be separated systems). The drainage area for these sanitary catchments (6 in total) was set as 10-15% of the total catchment area. The drainage area for the remaining, combined catchments was maintained as the entire catchment area.

Table 9: BPSA Kinematic Wave Model Catchments

Catchment ID	Imp. AI Steep (%)	Imp. AI Flat (%)	Perv. AP Medium (%)	Catchment ID	Imp. AI Steep (%)	Imp. AI Flat (%)	Perv. AP 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
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				

7.3 Overflow Regulator Structures

The Phase 1-C Stormwater Management Model User's Manual (Reference #9) regulator sketches were used in conjunction with the historical record drawings in order to represent the diversion structures, overflow pipes and outfalls into 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, a reverse alphabetical suffix (beginning with Z) was added to 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 diversion structure locations is presented in Table 10.

Table 10: BPSA Overflows and Diversion Structures

Overflow Number	Interceptor Location*	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
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

Overflow Number	Interceptor Location*	Diversion Structure
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		

Appendix A contains documentation of the MU network developed at each overflow structure and outlet. Appendix A also includes the BVI, MVI and TPI long sections with the approximate locations of each regulator underflow connection indicated. Figure 12, Figure 13 and Figure 14 provide an overview of the regulator locations along the MVI, TPI and BVI, respectively.

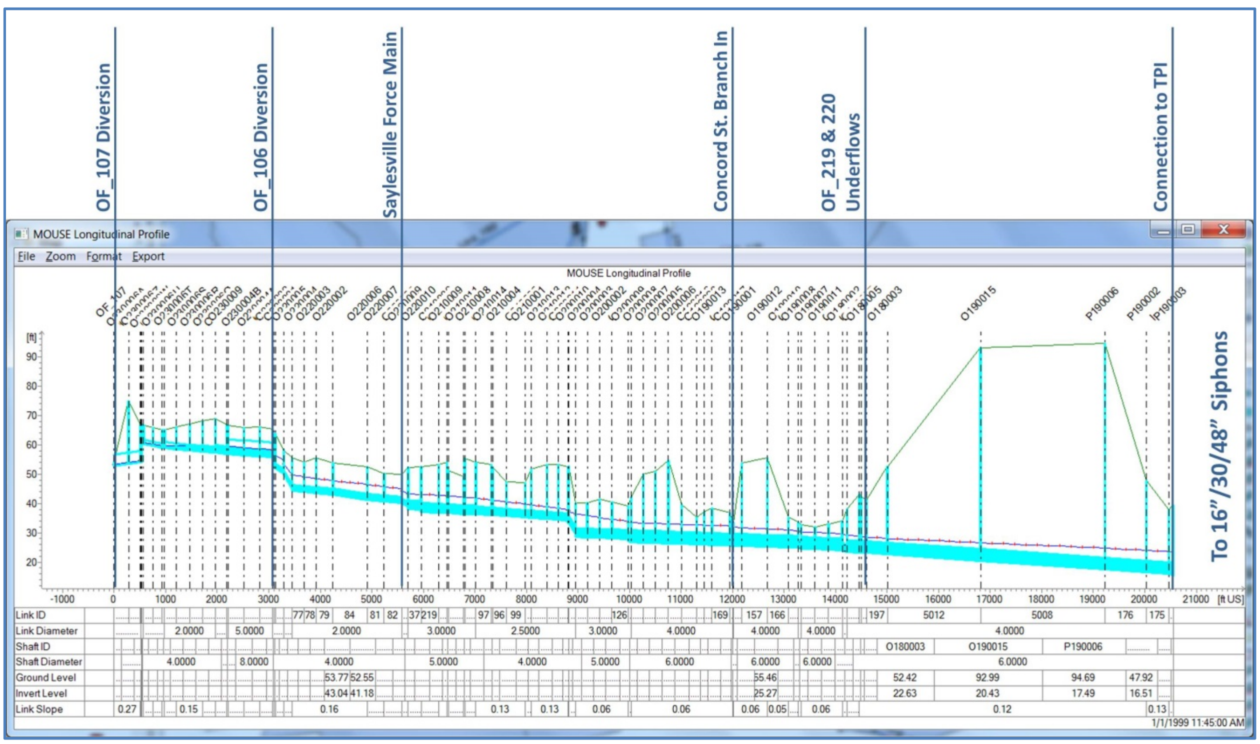

Figure 12: Moshassuck Valley Interceptor (MVI) and Overflow Locations

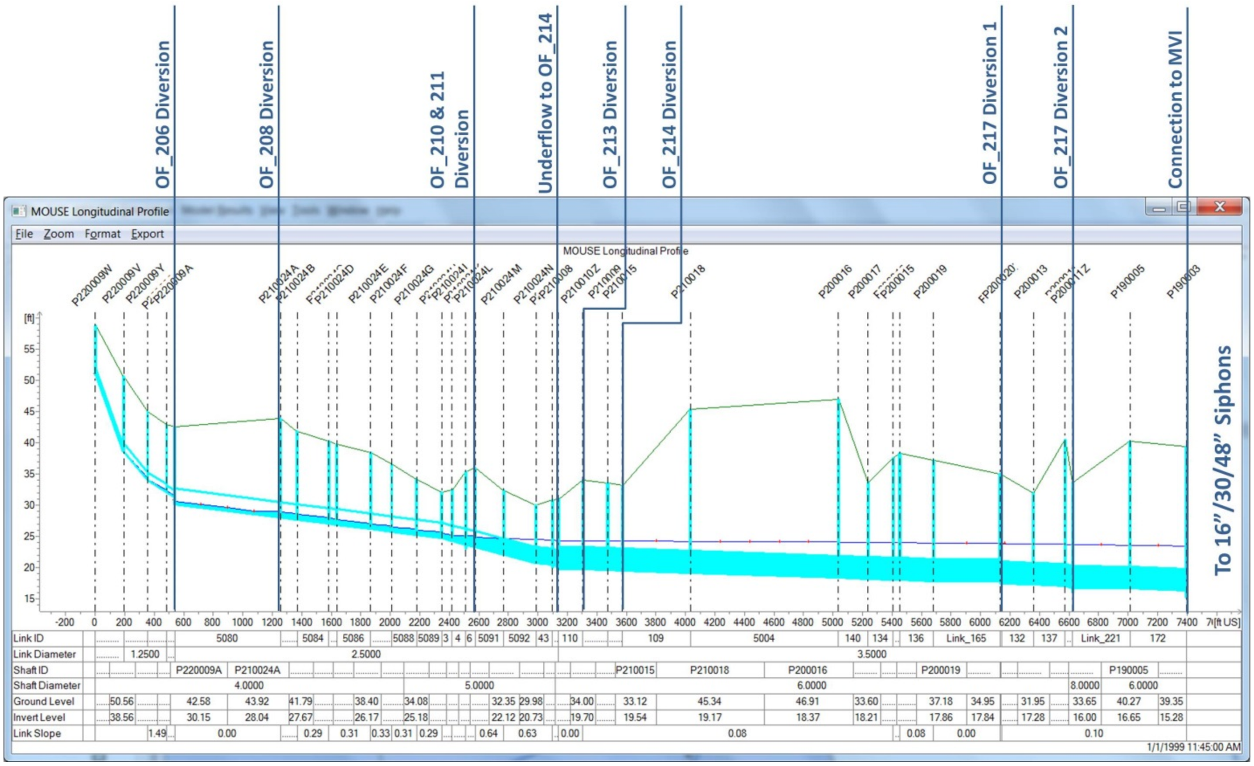

Figure 13: Taft-Pleasant Interceptor (TPI) and Overflow Locations

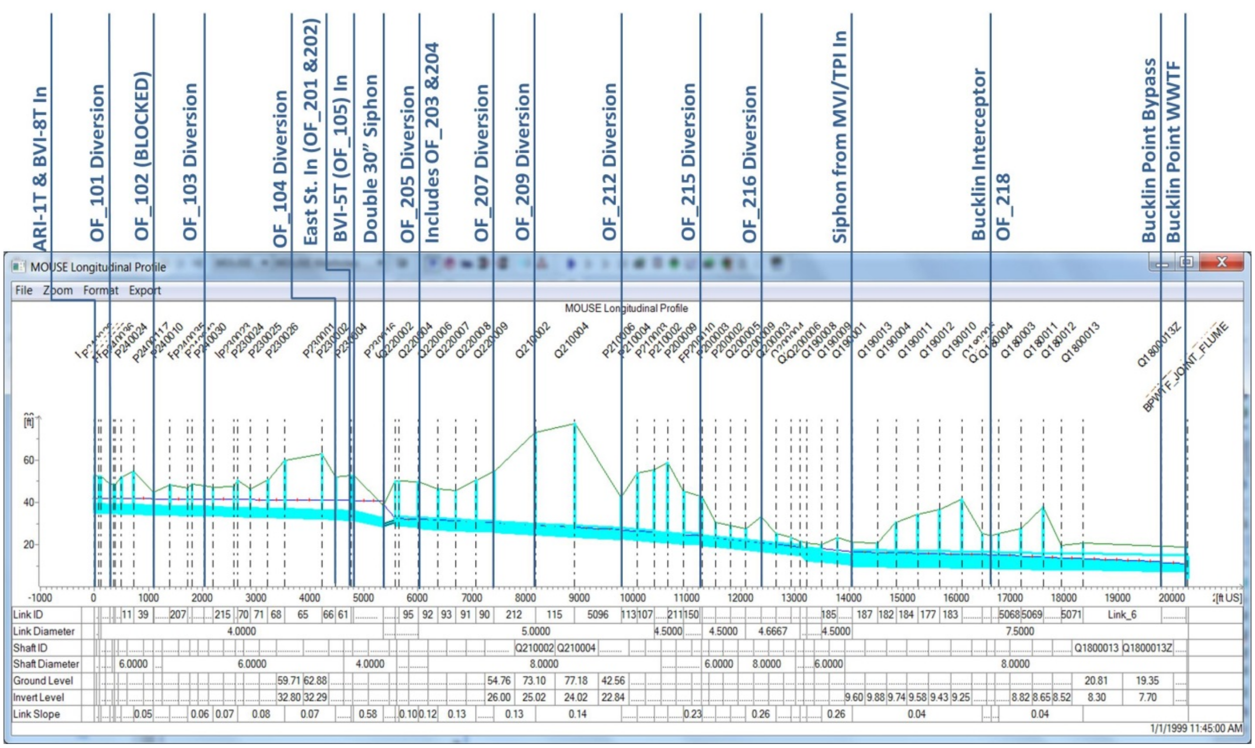

Figure 14: Blackstone Valley Interceptor (BVI) and Oerflow Locations

7.4 Pump Station and Treatment Plant Representation

Using the Historical Record Drawings provided by NBC (Contract 95-701C), the Saylesville Pump Station Sump Pit, Wetwells and two active pumps were added to the model just downstream of the MVI-7T flow meter. The pump stations configuration and pump operating details are provided below in Table 11**Error! Reference source not found.**. The pump curve for the existing pumps in the Saylesville Pump Station is provided in Appendix C attached.

Table 11: Saylesville Pump Station Data

Pump Station Element	Details*
Sump Pit	Size: 23' x 5' Invert Elevation: 37.73 Ground Elevation:53.0
Wetwells	Volume: (2)-1,450 CF (1)-1354 CF Invert Elevation: 29.36 Ground Elevation: 53.0
Pump Design	Design Flow: 2,200 GMP TDH: 35'
Pump Operation	Lead On: El. 38.73 Lag On: El. 39.23 All Off: El. 34.63
* All elevations in NGVD29 datum	

Using the BPWWTP historical record drawings (Contract No. 01:807C dated 2001) the influent flumes and the influent wet well were included in the model, along with the three influent screw pumps which convey flow from the wet well into the treatment facility (Figure 15). The record drawings were supplemented with the additional information provided by the NBC, presented in Table 12.

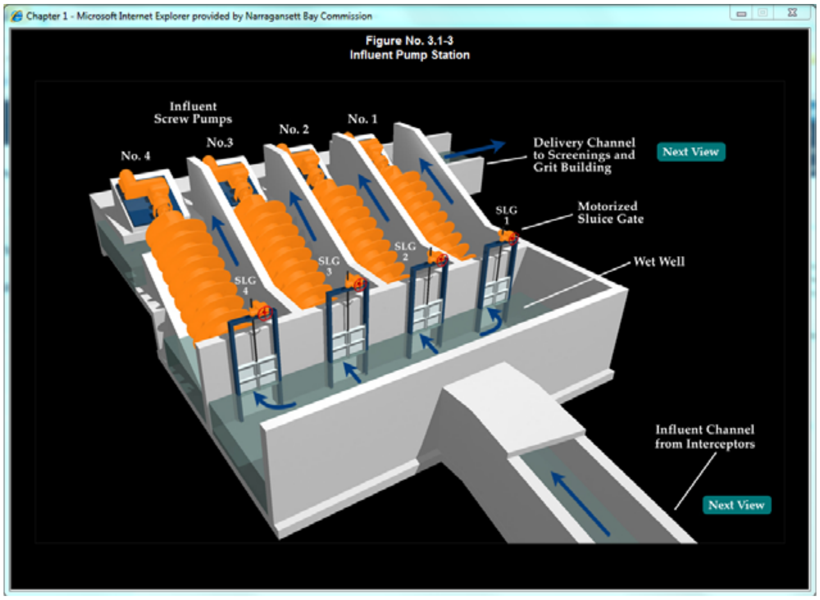

Figure 15: Bucklin Point WWTP Influent Screw Pump

Table 12: Bucklin Point Wastewater Treatment Plant

Plant Element	Details*
Pump Type	Three flight, Screw Type
Pump Flow Capacity	38.67 MGD
Wet Well	Invert Elevation: El. 4.41 Ground Elevation: El. 14.41
Pump On/Off Level	Pump No.1 On: El. 4.49 Pump No.1 Off: El. 4.41 Pump No.2 On: El. 8.71 Pump No.2 Off: El. 7.21 Pump No.3 On: El. 8.91 Pump No.3 Off: El. 7.51
* All elevations in NGVD29 datum	

7.5 Boundary Conditions

In addition to the existing interceptor network, diversion structures, outfalls and the catchment loading parameters, a number of boundary conditions were incorporated into the model to represent the metered data, dry weather flow and diurnal variability.

7.5.1 Upstream Metered Catchments

This model was developed to address the combined sewer overflows within the Bucklin Point Service Area. All of the 29 overflow locations fall along the Moshassuck River, as well as the southern reaches of the Blackstone River and the Seekonk River. There is a significant portion of the Blackstone Valley Interceptor (BVI) upstream of OF_101 (the River Street Diversion) that does not contain any CSOs. In addition, the entire Abbot Run Interceptor (ARI), also located upstream of OF_101, does not contain any CSO locations. As such, these interceptor reaches were incorporated into the model as boundary conditions.

The Abbot Run Interceptor network (Cumberland) is represented as an inflow from the ARI-1T flow meter. The maximum recorded flow value for this meter (during the period of record April 1, 2005 – January 31, 2006) was recorded as 6.55 MGD. The presumed maximum flow loaded into the model was 2 MGD, which was representative of the average of the flow data at that meter. The flow was loaded at P250005, the manhole at which it was recorded.

The Upper Blackstone Valley Interceptor network (Lincoln/Cumberland) is represented as an inflow from the BVI-8T flow meter. The maximum recorded flow value for this meter (during the period of record April 1, 2005 – January 31, 2006) was 17.03 MGD. The presumed maximum flow loaded into the model was 2 MGD, which was representative of the average of the flow data at that meter. The flow was loaded at P240017, the manhole at which it was recorded.

The MVI-7T catchment area (Lincoln) was too large to accurately calibrate using one meter location; therefore this region was represented as an inflow from the MVI-7T flow meter. The maximum recorded flow value for this meter (during the period of record April 1, 2005 – January 31, 2006) was 9.1 MGD. The presumed maximum flow loaded into the model was 1.10mgd, which was representative of the average of the flow data at that meter. The flow was loaded at P230008, the manhole at which it was recorded. Appendix C depicts these three northern metered boundary conditions and their relationship to the upper BVI interceptor network.

7.5.2 Dry Weather Flow

The Base flow for each catchment was calculated using the meter data provided in the RJN metering report (Reference #6). These flow values (cfs) were input as constant load Catchment-Type boundary conditions. They were given the same name as the relevant catchment with the prefix “DBF” for Design Base flow and the values are presented in Table 13.

Table 13: Dry Weather Base Flow Estimates

Dry Weather Flow Boundary Name	Dry Weather Flow (cf/day)		Dry Weather Flow Boundary Name	Dry Weather Flow (cf/day)
DWF_BVI-1T	491,410		DWF_MVI-1T-3	21,436
DWF_BVI-2AT	324,864		DWF_MVI-1T-4-206	2,386
DWF_BVI-2T	213,220		DWF_MVI-1T-4-208	879

Dry Weather Flow Boundary Name	Dry Weather Flow (cf/day)	Dry Weather Flow Boundary Name	Dry Weather Flow (cf/day)
DWF_BVI-3T-1	17,168	DWF_MVI-1T-4-210	33,536
DWF_BVI-3T-2	47,929	DWF_MVI-1T-4-213	522
DWF_BVI-3T-3	128,077	DWF_MVI-1T-4-214-1	884
DWF_BVI-3T-4	61,234	DWF_MVI-1T-4-214-2	625
DWF_BVI-3T-5-207	23,610	DWF_MVI-1T-4-214-3	1,499
DWF_BVI-3T-5-209	42,992	DWF_MVI-1T-4-214-4	3,544
DWF_BVI-4T-1-203	8,669	DWF_MVI-2T-1	132,248
DWF_BVI-4T-1-205	222,177	DWF_MVI-2T-2	84,604
DWF_BVI-4T-1A	11,574	DWF_MVI-2T-3	10,539
DWF_BVI-5T-1	18,181	DWF_MVI-3T-1	16,693
DWF_BVI-6T-1	46,185	DWF_MVI-4T-1	40,744
DWF_BVI-6T-1-102	284	DWF_MVI-4T-2	15,049
DWF_BVI-6T-1A	2,151	DWF_MVI-4T-3	6,669
DWF_BVI-6T-2	13,109	DWF_MVI-4T-4	7,238
DWF_BVI-7T-1-201	20,381	DWF_MVI-5T-1	86,023
DWF_BVI-7T-1-202	1,008	DWF_MVI-6T-1-106-1	4,226
DWF_MVI-1T-1	22,997	DWF_MVI-6T-1-106-2	10,441
DWF_MVI-1T-2-213	2,890	DWF_MVI-6T-1-106-3	9,461
DWF_MVI-1T-2-217	5,052	DWF_MVI-6T-1-107	14,533

7.5.3 Water Usage Boundary Condition

The water usage data for the cities of Central Falls and Pawtucket was provided by the NBC. This information was organized by NBC customer number and address. The addresses were not geospatially located, therefore they were not spatially distributed throughout the model catchments.

The Field's Point Hydraulic model employed spatially-distributed water use information for the FPSA communities and presented the average daily water usage values per capita (Reference

#5). The majority of water users in the FPSA fell between 26 and 100 gallons/per capita/day (gpcd). This information was used to determine an average water demand value for the BPSA model. A per capita water demand value was set at 40 gpcd (5.35 ft^3/ per capita/day) and was assigned to each catchment in order to calculate the water consumption based upon population. A standard multiplier of 2.0 was added as the Diurnal multiplier, "DESIGN" and this was applied over the Schedule_1 Calendar which included every day of the year. The effective water demand value, therefore, was approximately 80 gpcd. The population for each catchment was then calculated in GIS (see Section 1F.3 above). This per-capita water use value was incorporated in the model in addition to the already established dry weather flow values (Section 7.2.5).

8. Subtask 1G – Model Calibration and Validation

The rainfall data associated with the RJN flow meters were used to identify representative rainfall events for model calibration. The review identified several rainfall events, however many showed variable responses and therefore two events were chosen. These selected events were chosen based on the following criteria:

- varying durations;
- total rainfall volumes greater than 1.5-in;
- peak intensities greater than 0.4 in/hr; and
- completeness of coverage across all meters in the BPSA area (several meters were lacking data for the given storms but both gave the widest coverage).

Table 14 presents the information for each of the calibration storms.

Table 14: 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 (Reference #5)				

8.1 Calibration Approach

Calibration of the BPSA model using the RJN flow meter data was carried out working from the upstream reaches of the three interceptors (BVI, MVI and TPI) down to the Bucklin Point Wastewater Treatment Facility. Table 15 presents the RJN meters, their associated model catchments and their relative location along the interceptors, upstream to downstream.

Table 15: Meters and Associated Catchments

Blackstone Valley Interceptor			Moshassuck Valley Interceptor		
Meter	**Interceptor**	**Catchment**	**Meter**	**Interceptor**	**Catchment**
BVI-6T	BVI	BVI-6T-1	MVI-6T	MVI	MVI-6T-1-106-1
		BVI-6T-1-102			MVI-6T-1-106-2
		BVI-6T-1A			MVI-6T-1-106-3
		BVI-6T-2	MVI-5T	MVI	MVI-5T-1
BVI-7T	BVI	BVI-7T-1-201	MVI-4T	MVI	MVI-4T-1
		BVI-7T-1-202			MVI-4T-2
BVI-5T	BVI	BVI-5T-1			MVI-4T-3
		BVI-5T-ADD			MVI-4T-4
BVI-4T	BVI	BVI-4T-1-203	MVI-3T	MVI	MVI-3T-1
		BVI-4T-1-205	MVI-2T	MVI	MVI-2T-1
		BVI-4T-1A			MVI-2T-2
BVI-3T	BVI	BVI-3T-1			MVI-2T-3
		BVI-3T-2	MVI-1T	TPI	MVI-1T-1
		BVI-3T-3			MVI-1T-2-213
		BVI-3T-4			MVI-1T-2-217
		BVI-3T-5-207			MVI-1T-3
		BVI-3T-5-209			MVI-1T-4-206
BVI-2AT	BVI	BVI-2AT-1			MVI-1T-4-208
BVI-2T	BVI	BVI-2T-1			MVI-1T-4-210
BVI-1T	BVI	BVI-1T-1			MVI-1T-4-213
					MVI-1T-4-214-1
					MVI-1T-4-214-2
					MVI-1T-4-214-3
					MVI-1T-4-214-4

The goal of the BPSA model development was to produce a tool which best accurately represents the overflow discharge peaks and volumes, as well as the level of service in the NBC interceptor sewers throughout the system. With this in mind, the calibration procedure was focused on capturing the peak flows and the rainfall response time to peak at each meter.

As outlined in Section 7.2, GIS was used to determine the distribution between the impervious and pervious areas in each catchment (see Table 9). The calibration procedure was then 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.

The following sections outline the calibration process at each of the 15 meters, as well as a discussion of the limitations and the implications for the alternatives analysis and development of recommendations.

8.2 Blackstone Valley Interceptor

The modeled portion of the BVI is approximately 20,000 LF and includes 15 associated combined sewer overflows. The following sections outline calibration of the meters along the length of the BVI. Note the original comparisons are displayed on the left and the updated comparison on the right.

8.2.1 Meter BVI-6T

Meter BVI-6T is located at the upstream end of the BVI below Overflows OF_101 and OF_103. The meter includes flow from four catchments in the runoff model (see Table 15.) which cover an area of approximately 68 ac, as well as flow from the upper BVI (BVI-8T) and the Abbot Run Interceptor, as discussed in Section 7.5.1. The location of meter BVI-6T is shown in Figure 16.

The results of the calibration at BVI-6T for the 04/02/2005 and 09/15/2005 storms, respectively, are presented in Figures 17 and 18. As Figure 17 indicates, the meter shows significant fluctuations in flow, as well as some reversal in flow throughout the April rainfall event. The model is not capturing these fluctuations and reversals in flows, suggesting that there is some restricting effect in the downstream network that is not currently being represented. While the flow fluctuations could not be captured, the modelled results are producing a representative average flow value over the April rainfall time series in order to capture meter BVI-6T volumetrically.

As shown in Figure 18, the dry weather flow and the timing of the wet weather response was accurately captured in the 09/15/2005 event. However, once again the flow variation (peaks and valleys) during the September wet weather period were not captured and instead the model plateaus at the peak.

The results in both calibrations suggest that there is a flow restricting and releasing effect in the network that is not being accurately represented. Given the location of this meter, immediately upstream of two large inverted siphons, the transient nature of sediment in the network could be one factor that in not being accurately modelled.

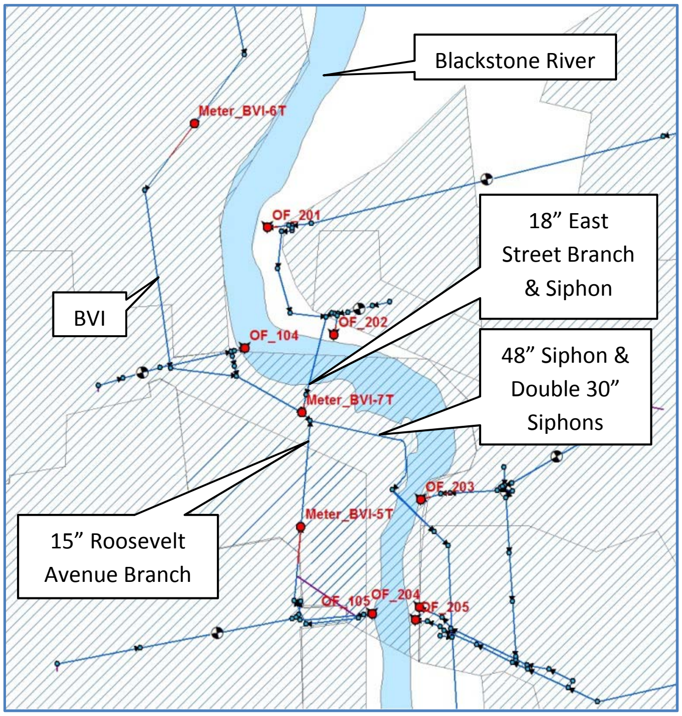

Figure 16: BVI-5T, BVI-6T and BVI-7T

The calibration results suggest that the model is providing a good representation of average flow at meter BVI-6T. The lack of representation of the backing up effect within the network should be considered during future iterations of modeling. These limitations in calibration of the model are discussed in more detail in Section 8.4.

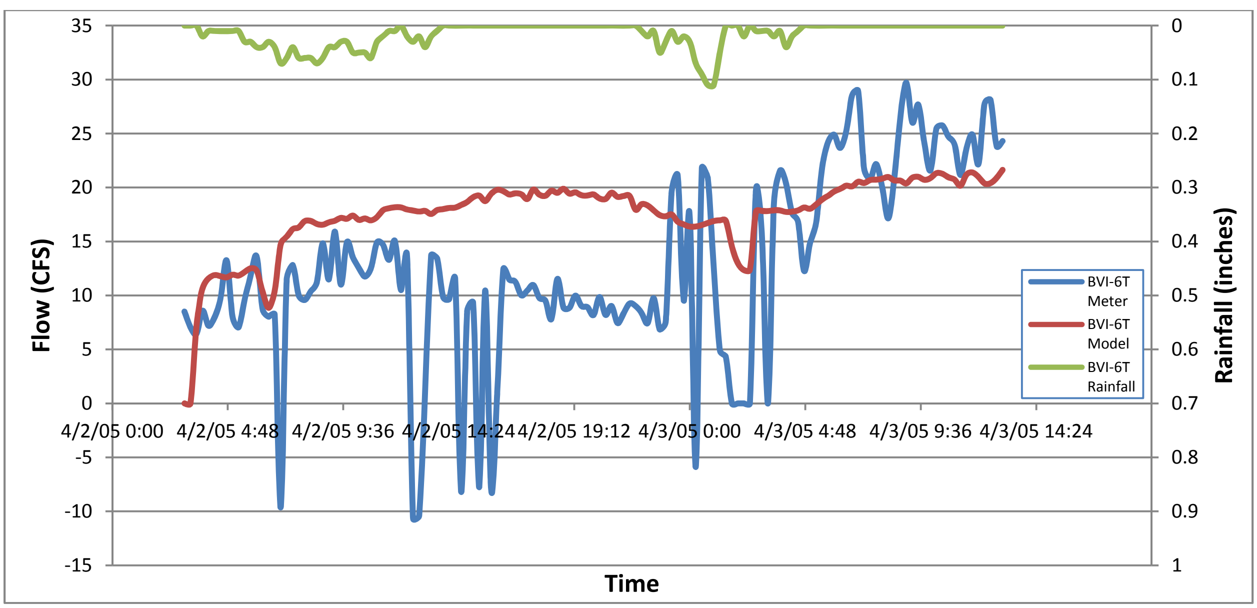

Figure 17: Calibration plot for BVI-6T on 04/02/2005.

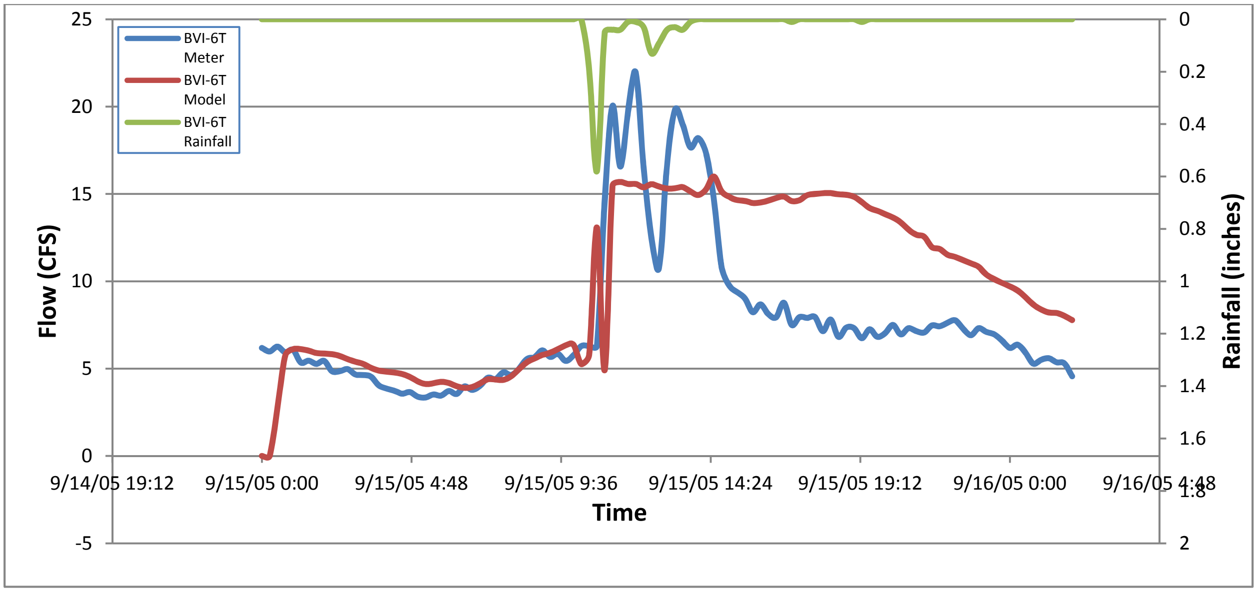

Figure 18: Calibration plot for BVI-6T on 09/15/2005.

8.2.2 Meter BVI-7T

Meter BVI-7T is located on the East Street Branch Interceptor, an 18" diameter branch that connects to the BVI just south of the Roosevelt Avenue Bridge (see Figure 14). The BVI-7T meter is located upstream of the branch connection to the BVI and immediately downstream of the 16" inverted siphon which crosses the Blackstone River at Roosevelt Avenue. Overflows OF_201 and OF_202 are located upstream of meter BVI-7T. The two catchments that contribute to Meter BVI-7T cover approximately 85 ac.

The results of calibration for the 04/02/2005 and 09/15/2005 storms are presented in Figures 19 and 20, respectively. The model closely captures the peak flows during the April rainfall event, as well as the flow draw down. At the end of the time series, however, much like the results from meter BVI-6T, when the metered flows exhibit large fluctuations and reversals, the model appears unable to represent those conditions. The results from the April storm are close to capturing the metered data volumetrically, with the exception of the final 2-3 hours.

The results of the 09/15/2005 calibration in Figure 20 show the model more accurately representing the peak flow conditions, however similar to the April rainfall event and to the results at meter BVI-6T, after capturing the initial peak intensity the model does not capture the wide variations in flow during the wet weather event. Of particular note is that the previous under prediction has become an over prediction in this instance; this is demonstration as to the sensitivity of the flow regime in this part of the BVI and the ever changing internal conditions.

The meter is located both downstream and upstream of siphons crossing the Blackstone River, therefore there are most likely restricting elements in the network, including the possibility of transient sediment deposits, that are not being captured in this model. These limitations in calibration of the model are discussed in more detail in Section 8.4.

The response to rainfall is reasonable although the downstream control during the September event hinders the model hydrograph shape.

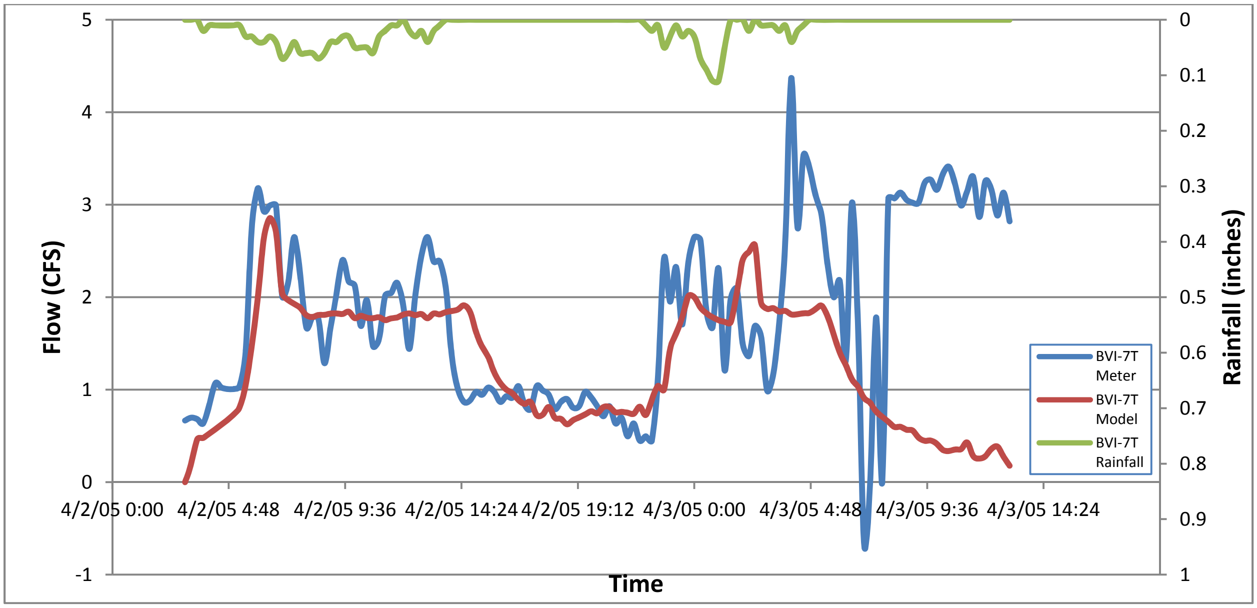

Figure 19: Calibration plot for BVI-7T on 04/02/2005.

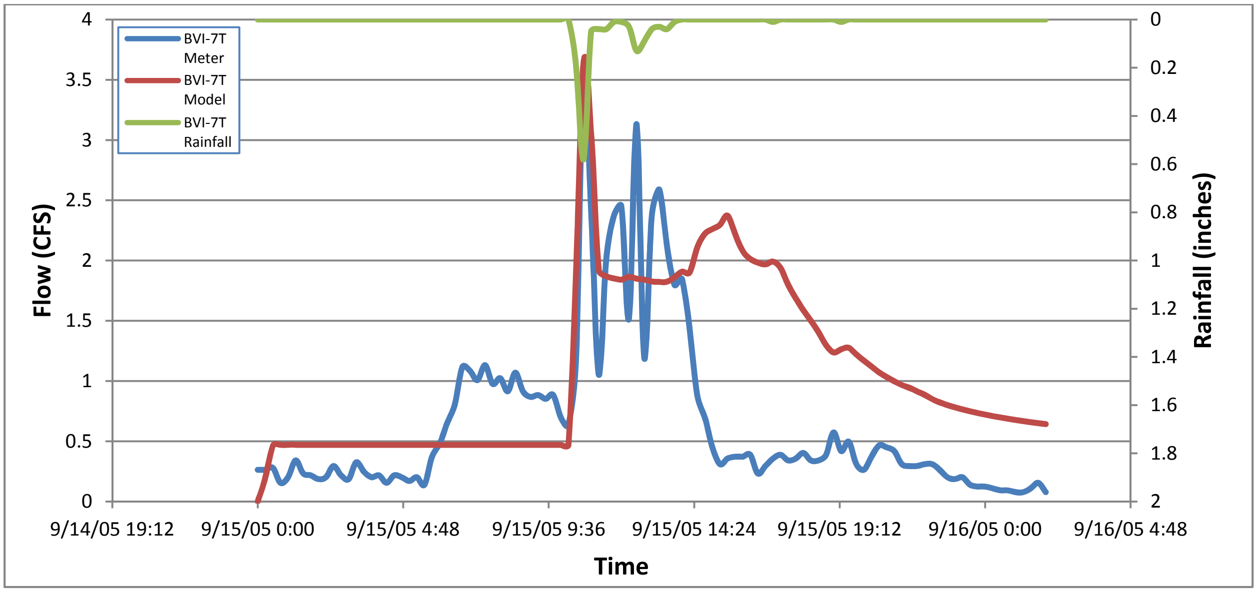

Figure 20: Calibration plot for BVI-7T on 09/15/2005.

8.2.3 Meter BVI-5T

Meter BVI-5T is located on the Roosevelt Avenue Branch Interceptor, a 15" diameter branch that connects to the BVI southeast of the Roosevelt Avenue Bridge (see Figure 14). The BVI-5T meter is located upstream of the Roosevelt Avenue connection to the BVI and downstream of OF_205. The two catchments that contribute flow to meter BVI-5T cover approximately 70 ac.

The results of calibration for the 04/02/2005 and 09/15/2005 storms are presented in Figures 21 and 22, respectively. As shown in Figure 21, the model is capturing the timing of the initial peak flow. It is, however, then underrepresenting the additional peak flows and peak variability throughout the April rainfall event. Similar to meters BVI-6T and BVI-7T, the results at BVI-5T suggest that there is some restriction in the downstream network that is not being accurately modelled. The Roosevelt Avenue branch is a drop connection into the BVI and is closely followed by the 48" and double-barreled 30" siphons previously mentioned. Both of these factors may explain the flow variability during set weather events that cannot be fully captured by the model.

The results from the September rainfall event also show the peak flow timing and intensity being correctly modelled, however the flow variability and drawdown during wet weather are not being represented. Again, this can most likely be explained by existing restrictions in the network as previously discussed. This limitation should be considered in future iterations of the model. These limitations in calibration of the model are discussed in more detail in Section 8.4.

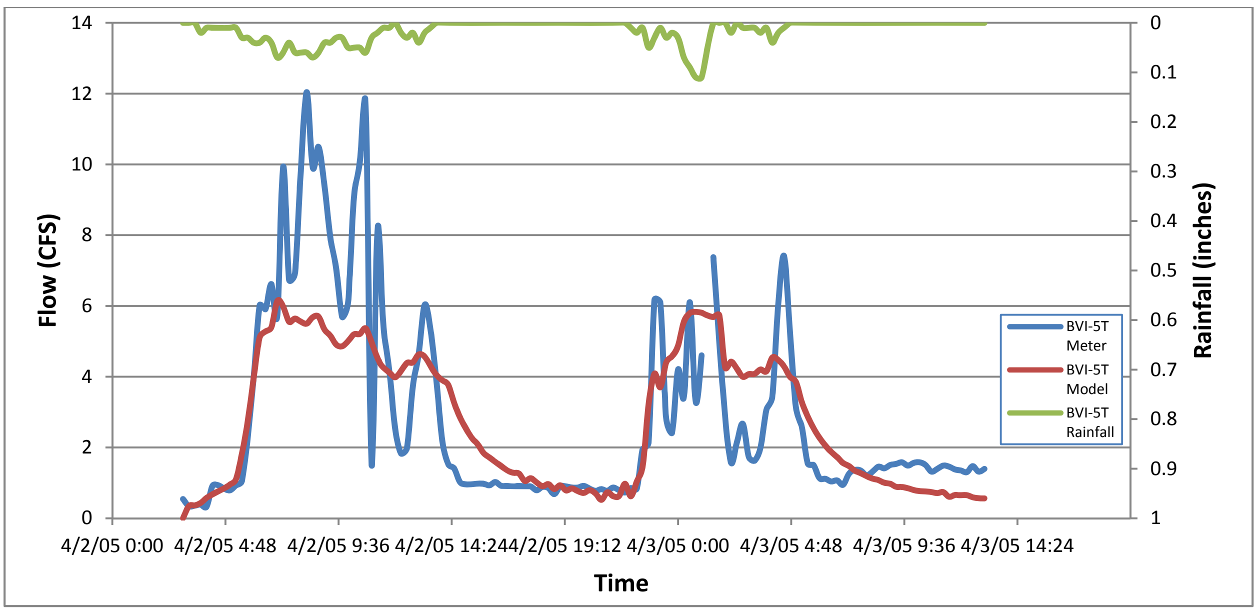

Figure 21: Calibration plot for BVI-5T on 04/02/2005.

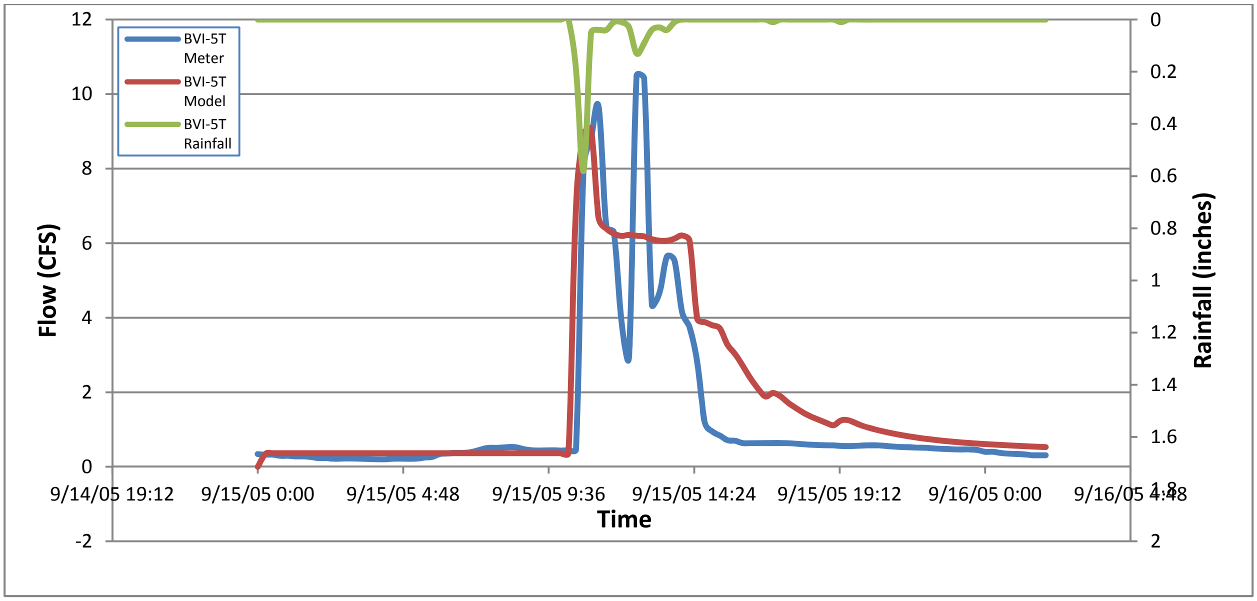

Figure 22: Calibration plot for BVI-5T on 09/15/2005.

In both calibrations, the model is producing a representative shape although the response to rainfall during the more severe storm in April misses some of the early runoff response.

8.2.4 Meter BVI-4T

Meter BVI-4T is located on the Blackstone Valley Interceptor downstream of overflows OF_203, OF_204 and OF_205. It is located approximately 1,900 LF downstream of the 30" double-barreled siphon crossing the Blackstone River. In addition to the flow from upstream catchments BVI-6T, BVI-5T and BVI-7T, the three catchments that contribute flow to BVI-4T cover approximately 1,060 ac.

The results of calibration at BVI-4T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 23 and 24, respectively. As shown in Figure 23, the peak flow values during the April rainfall event are being accurately modelled and the total average flow over the time series is representative, if slightly conservative.

While the model is representing the total volume at meter BVI-4T effectively, it is not representing the timing of the flow drawdown or the variation in peak flows. The same is true of the September rainfall event calibration results (Figure 24). These limitations in calibration of the model are discussed in more detail in Section 8.4.

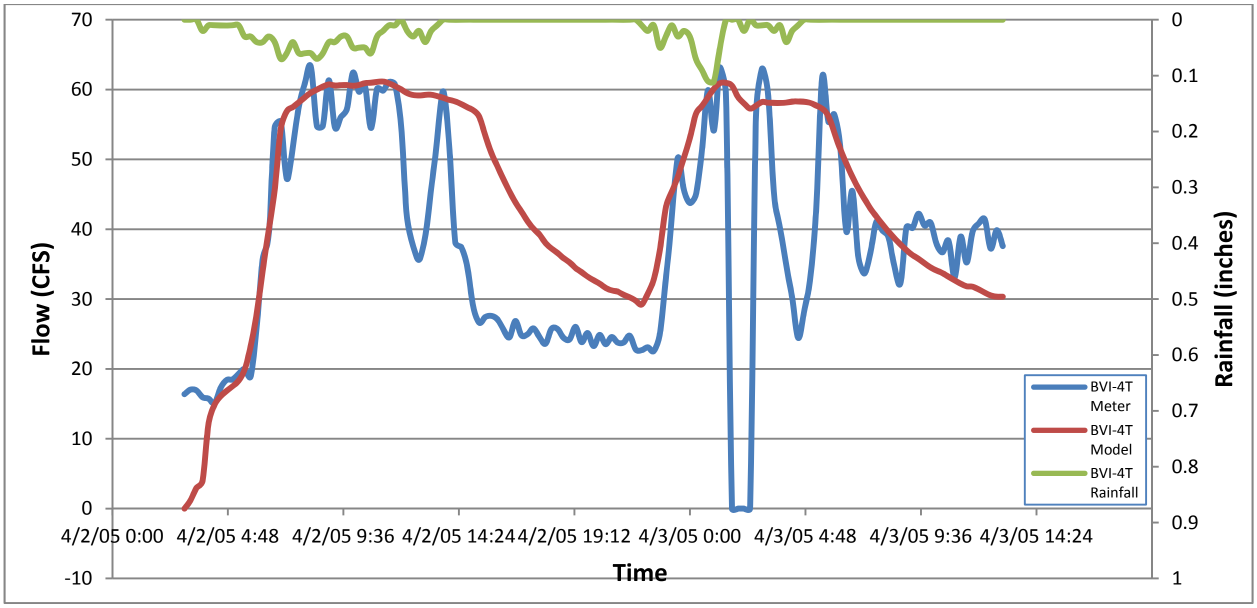

Figure 23: Calibration plot for BVI-4T on 04/02/2005.

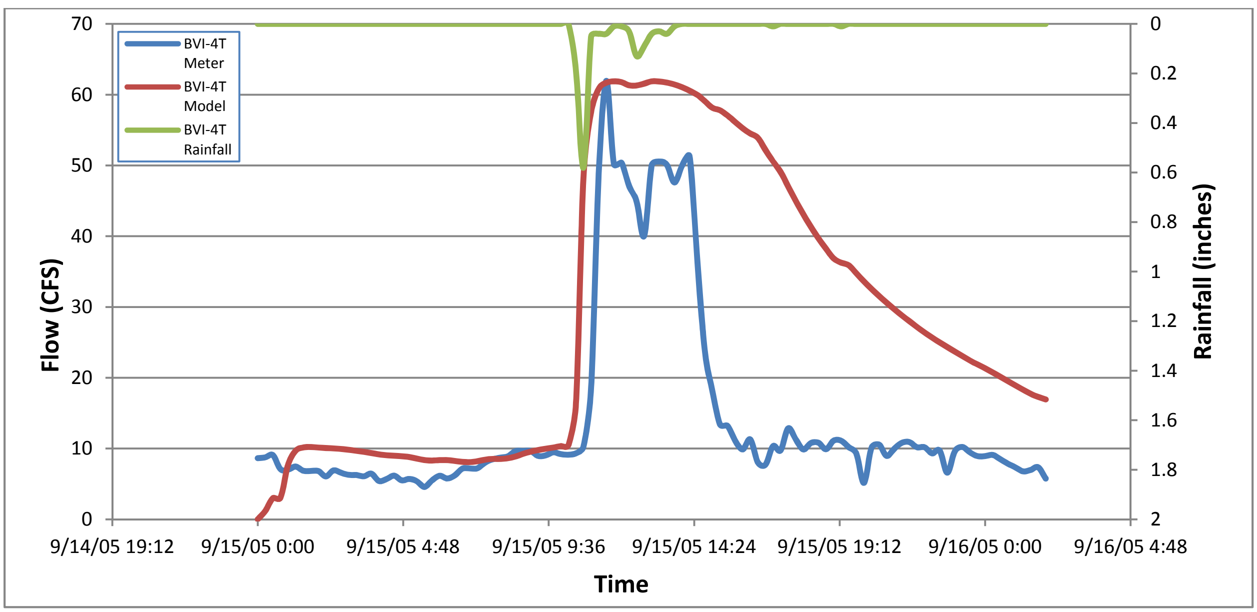

Figure 24: Calibration plot for BVI-4T on 09/15/2005.

The model is producing conservative results as it is over-predicting the total volume across the calibration time series in both cases. The implications of this on use of the model for alternatives assessment is further discussed in Section 8.5.

8.2.5 Meter BVI-3T

Meter BVI-3T is located on the Blackstone Valley Interceptor downstream of overflows OF_207, OF_209, OF_212, OF_215 and OF_216. The meter is located approximately 2,000 LF downstream of triple-barreled siphon crossing the Seekonk River, where the Moshassuck Valley interceptor connects to the Blackstone Valley Interceptor. In addition to the flow from upstream meter BVI-3T, the 6 catchments that contribute flow to meter BVI-4T cover approximately 258 ac.

The results of calibration at BVI-3T for the 09/15/2005 storm are presented in Figure 25. No results were available at BVI-3T for the 04/02/2005 rainfall event. As shown in Figure 25, the model is slightly over-predicting the peak flow intensity and the average flow throughout the event. The model appears to be capturing the timing of the wet weather response.

Similar to the results at meter BVI-4T, the model is not representing the peak flow variability during the wet weather event, or the draw down in flow. These limitations in calibration of the model are discussed in more detail in Section 8.4.

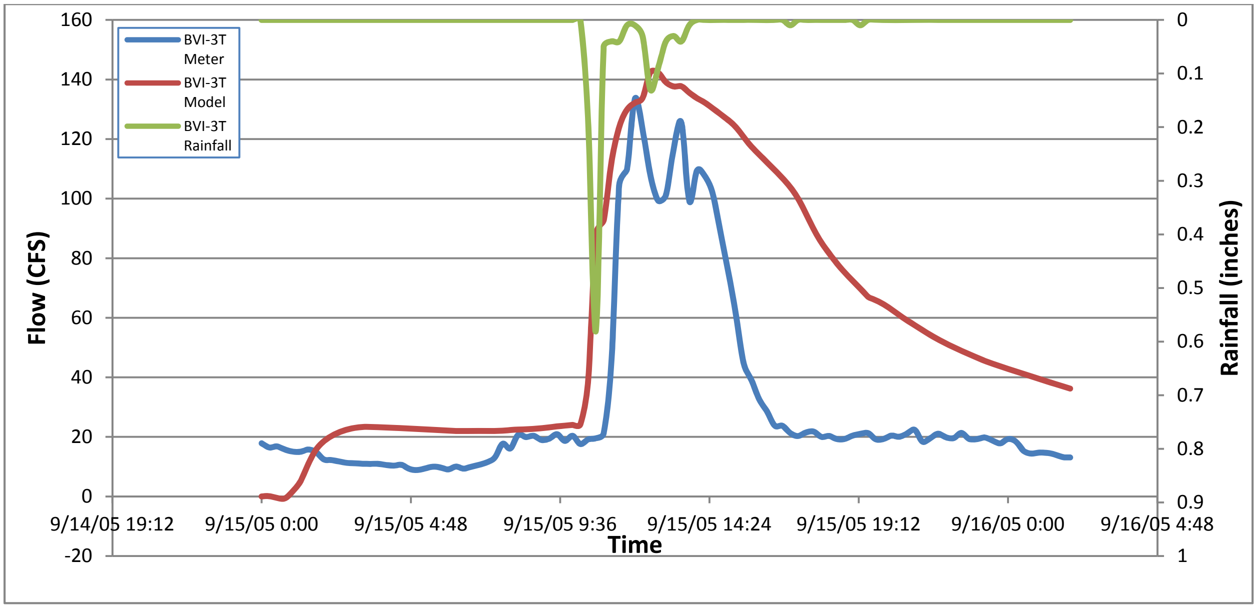

Figure 25: Calibration plot for BVI-3T on 09/15/2005.

During both storm events the model is over-calculating the total volume across the calibration time series. The implications of this on use of the model for alternatives assessment is further discussed in Section 8.5.

8.2.6 Meters BVI-2T and BVI-2AT

Meters BVI-2T and BVI-2AT are located at Beverage Hill Road upstream of overflow OF_218. Meter BVI-2T was installed on the 65" diameter local line that drains an approximate area of 526 Ac. The location and configuration of meters BVI-2T and BVI-2AT are presented in Figure 20.

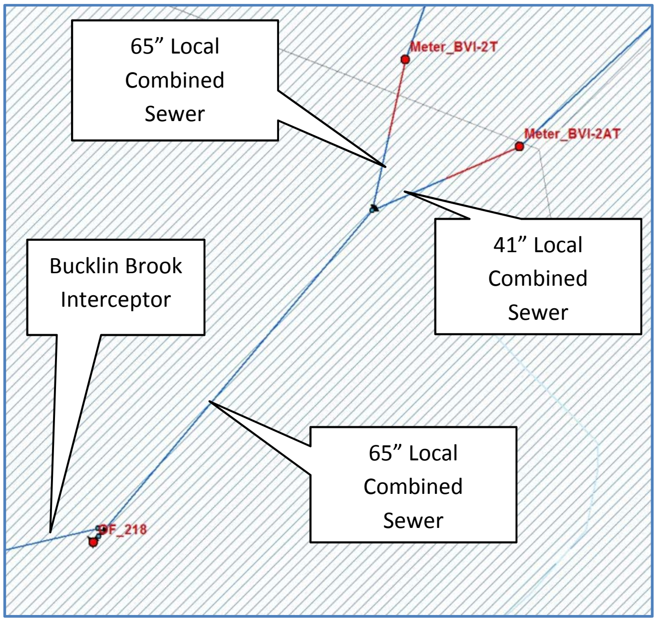

Figure 26: Meters BVI-2T and BVI-2AT

The results of calibration at BVI-2T for the 04/02/2005 storm are presented in Figures 21. Data was not available for Meter BVI-2T during the 09/15/2005 rainfall event. Given the large contributing area and the higher peak-intensity of the storm, it is possible that the meter failed during the September event.

The results presented in Figure 27 show that the model is under-predicting the peak flows. The results generally capture the timing of the peaks and the flow drawdown however they may be under predicting the total flow at this location. This should be considered in future model iterations and during alternatives assessment.

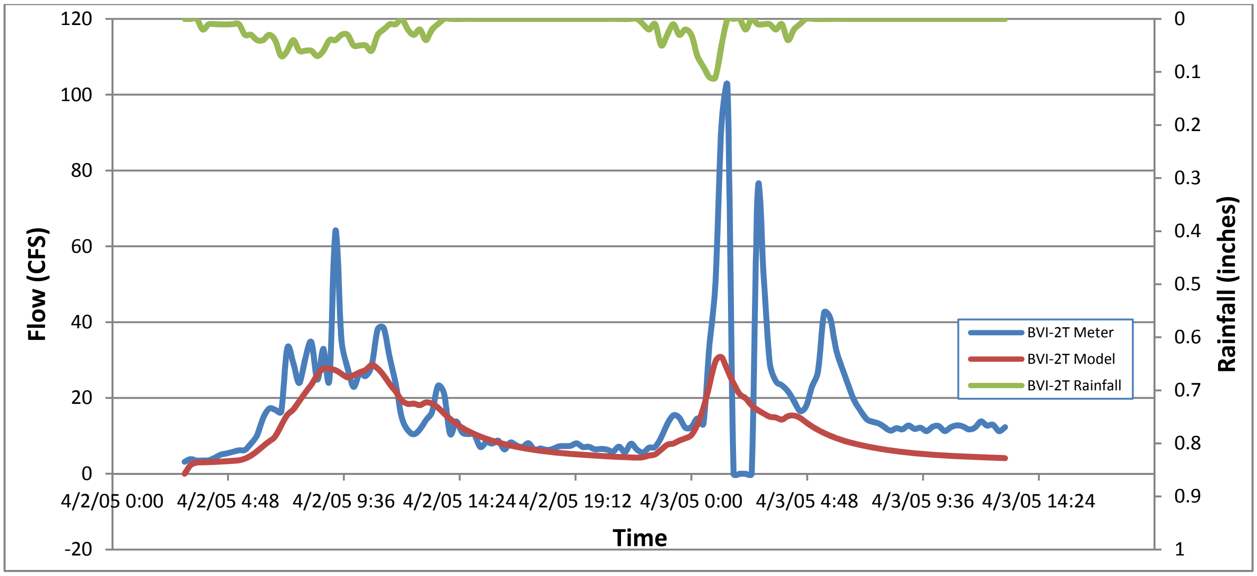

Figure 27: Calibration plot for BVI-2T on 04/02/2005.

Meter BVI-2AT is also located at Beverage Hill Road upstream of overflow OF_218. The meter was installed on the 41” diameter local line that drains an approximate area of 1,010 ac.

The results of calibration at BVI-2AT for the 04/02/2005 storm are presented in Figure 28. Data was not available for Meter BVI-2AT during the 09/15/2005 rainfall event. As was the case at BVI-2T, given the large contributing area and the higher peak-intensity of the storm, it is possible that the meter failed during the September event. The results presented in Figure 28 show that the model is almost representing the peak flows correctly. The timing of the drawdown appears to be delayed. These limitations in calibration of the model are discussed in more detail in Section 8.4.

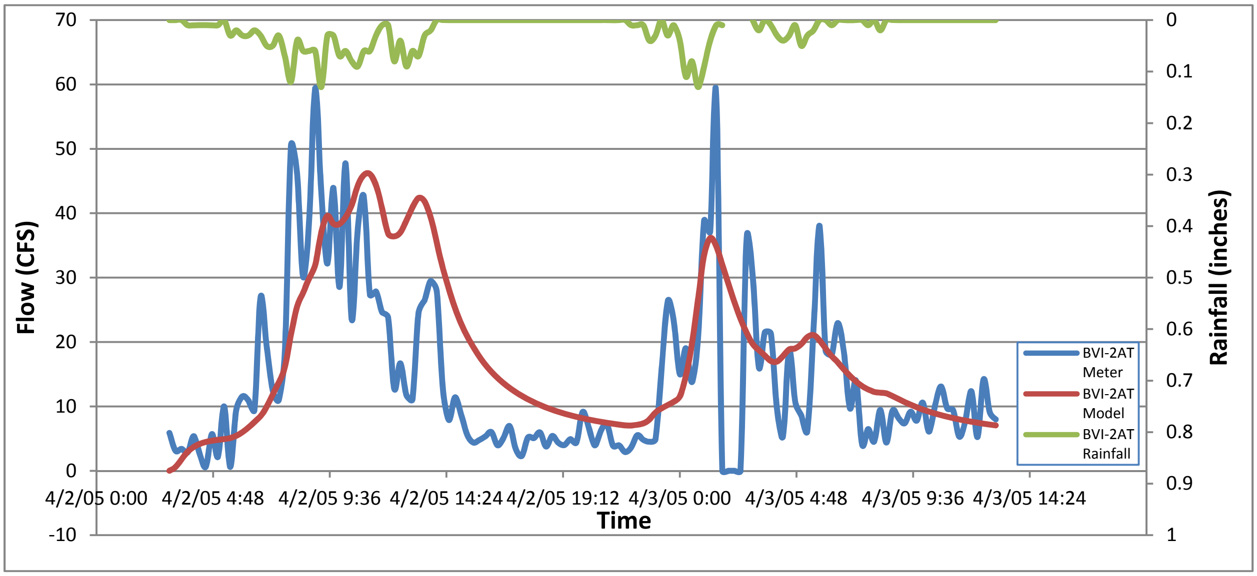

Figure 28: Calibration plot for BVI-2AT on 04/02/2005.

The results at BVI-2AT show a good comparative fit for both rainfall response (shape) and magnitude (peak flow).

8.2.7 Meter BVI-1T

Meter BVI-1T is located on the Blackstone Valley Interceptor downstream overflow OF_218 and the Bucklin Brook Interceptor connection. In addition to the flow from upstream meters BVI-3T, BVI-2T and BVI-2AT, there is one 46 ac catchment that contributes flow to meter BVI-1T. This meter is located just upstream of the Bucklin Point Wastewater Treatment Facility diversion structure and inflow. It represents the total flow-to-treatment volume, with the exception of any flow diverted to the Seekonk River at the BPWWTF.

The results of calibration at BVI-1T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 29 and 30, respectively. As shown in Figure 29 and similar to the results from the previous meters located on the BVI itself (BVI-4T & BVI-3T), the model is not capturing the flow variability during wet weather. Again, like BVI-3T and 4T, the timing of the peaks is being captured by the model however the drawdown timing is delayed. These limitations in calibration of the model are discussed in more detail in Section 8.4.

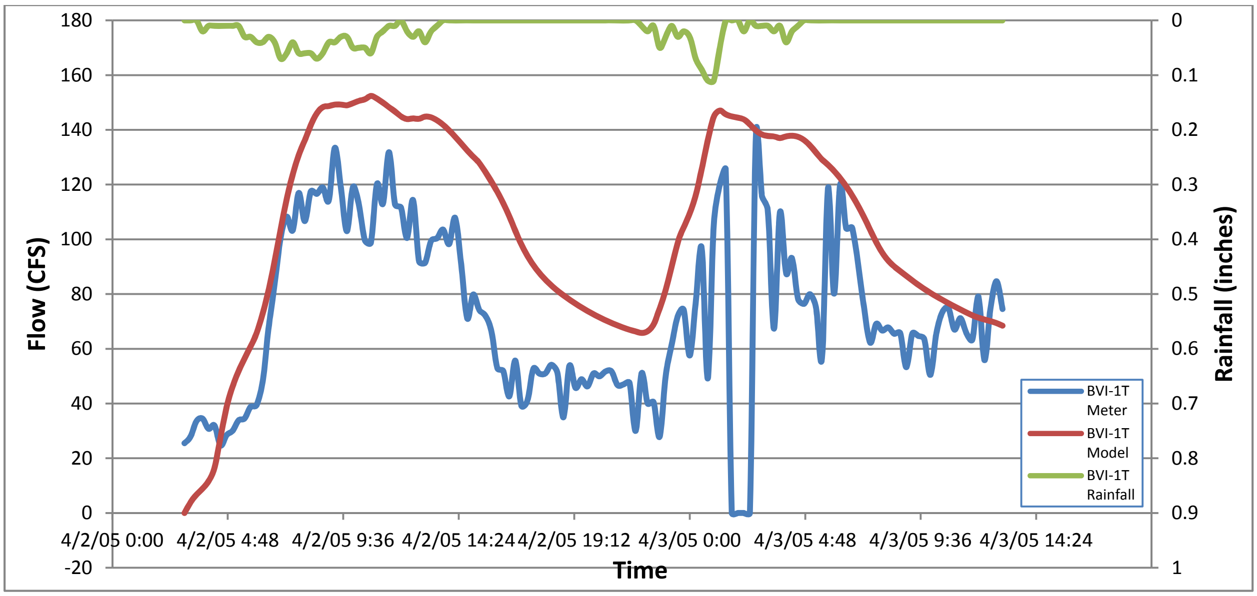

Figure 29: Calibration plot for BVI-1T on 04/02/2005.

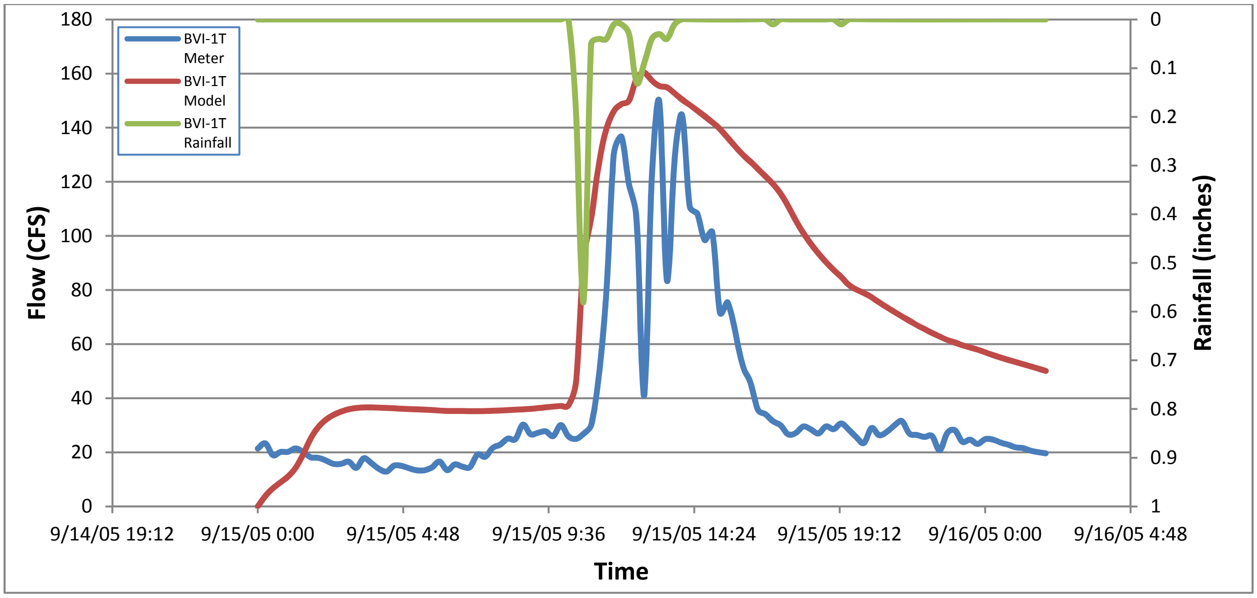

Figure 30: Calibration plot for BVI-1T on 09/15/2005.

The results at BVI-1T are conservative as they are over-predicting the total volume in the system across both time series. The implications of this on use of the model for alternatives assessment is further discussed in section 8.5.

8.3 Moshassuck Valley Interceptor

8.3.1 Meter MVI-6T

Meter MVI-6T is located on the Higgins Interceptor downstream overflows OF_106 and OF_107 and upstream of the Saylesville force main connection into the Moshassuck Valley Interceptor (MVI). There are four catchments which contribute flow to Meter MVI-6T which cover an area of approximately 277 ac.

The results of calibration at MVI-6T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 31 and 32, respectively. As shown in Figure 31, the model is closely capturing the peak intensity and timing of the peak flows. As in other previously discussed meters, however, the model is not capturing any variation in peak flow during the wet weather events. This limitation is further discussed in section 8.5.

The results at MVI-6T are conservative as they are slightly over-predicting the total volume in the system across both time series. The implications of this on use of the model for alternatives assessment is further discussed in Section 8.5

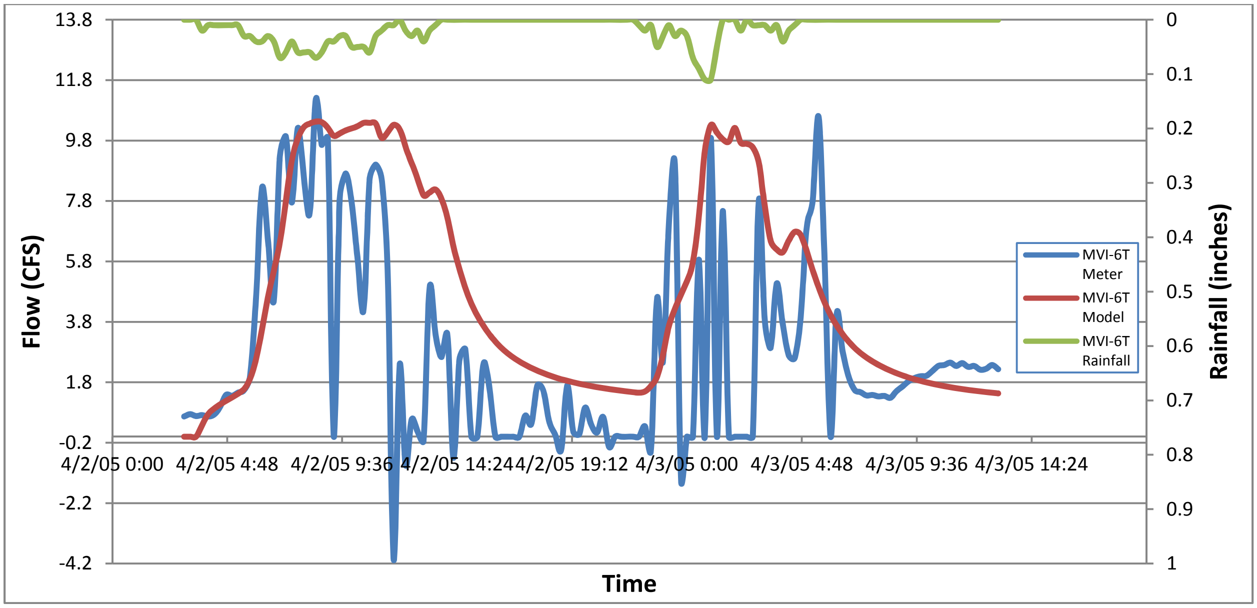

Figure 31: Calibration plot for MVI-6T on 04/02/2005.

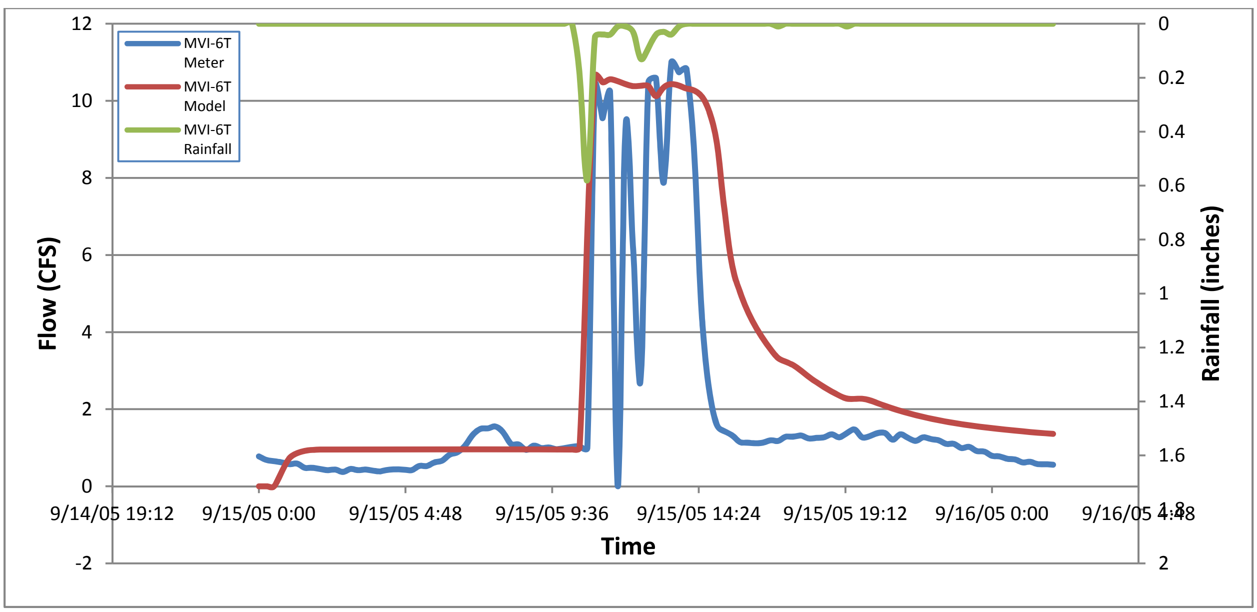

Figure 32: Calibration plot for MVI-6T on 09/15/2005.

8.3.2 Meter MVI-5T

Meter MVI-5T is located at the upstream-most end of the Moshassuck Valley Interceptor downstream overflows OF_106 and OF_107 and downstream of Saylesville force main connection into the MVI. In addition to flow from meter MVI-6T, there is one 422 Acre catchment which contributes flow to Meter MVI-5T. As previously discussed in Section 7.2, MVI-5T is presumed to be a separated catchment (per the RJN Capacity Analysis Report). As a sanitary catchment, the total area contributing to the Kinematic Wave model was assumed to be 64 ac, or 15% of the total catchment area.

The results of calibration at MVI-5T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 33 and 34, respectively. As shown in both calibration figures, the model produced a very close fit for both storms including peak flow intensity and timing, as well as an accurate representation of overall volume across the time series.

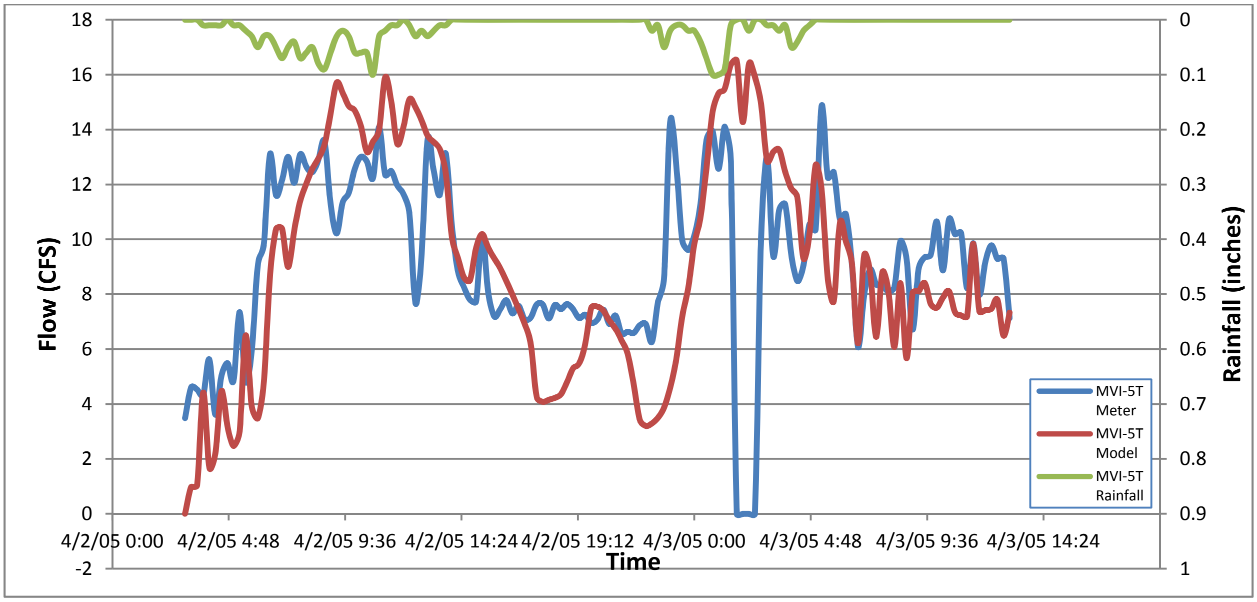

Figure 33: Calibration plot for MVI-5T on 04/02/2005.

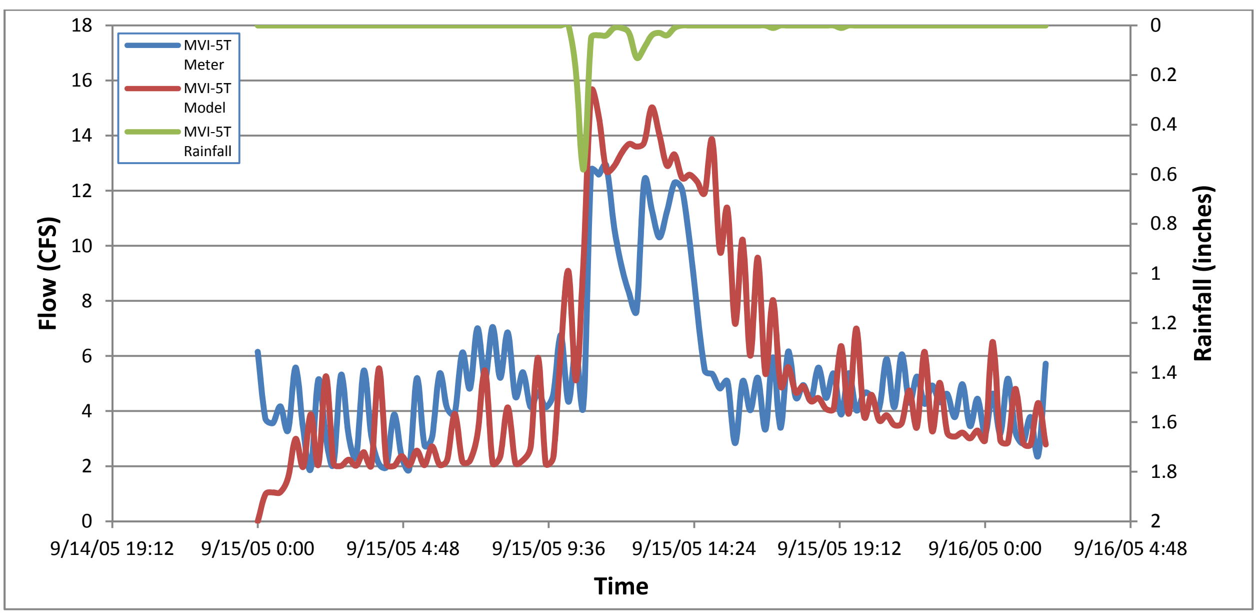

Figure 34: Calibration plot for MVI-5T on 09/15/2005.

8.3.3 Meter MVI-4T

Meter MVI-4T is located in the middle of Moshassuck Valley Interceptor. In addition to flow from meter MVI-5T, there are four catchments which contribute flow to Meter MVI-5T which cover an area of approximately 578 ac. As previously discussed in Section 7.2, MVI-4T is presumed to be a separated catchment (per the RJN Capacity Analysis Report). As a sanitary catchment, the total area contributing to the Kinematic Wave model was assumed to be 58 Ac, or 10% of the total catchment area.

The results of calibration at MVI-4T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 35 and 36, respectively. For both storm events the model is closely predicting the flows at meter MVI-4T including the peak flows, flow draw down and total volume. In the case of the September rainfall event (Figure 36), the peak flows in the model slightly under predict; however the total volume across the time period is being accurately represented.

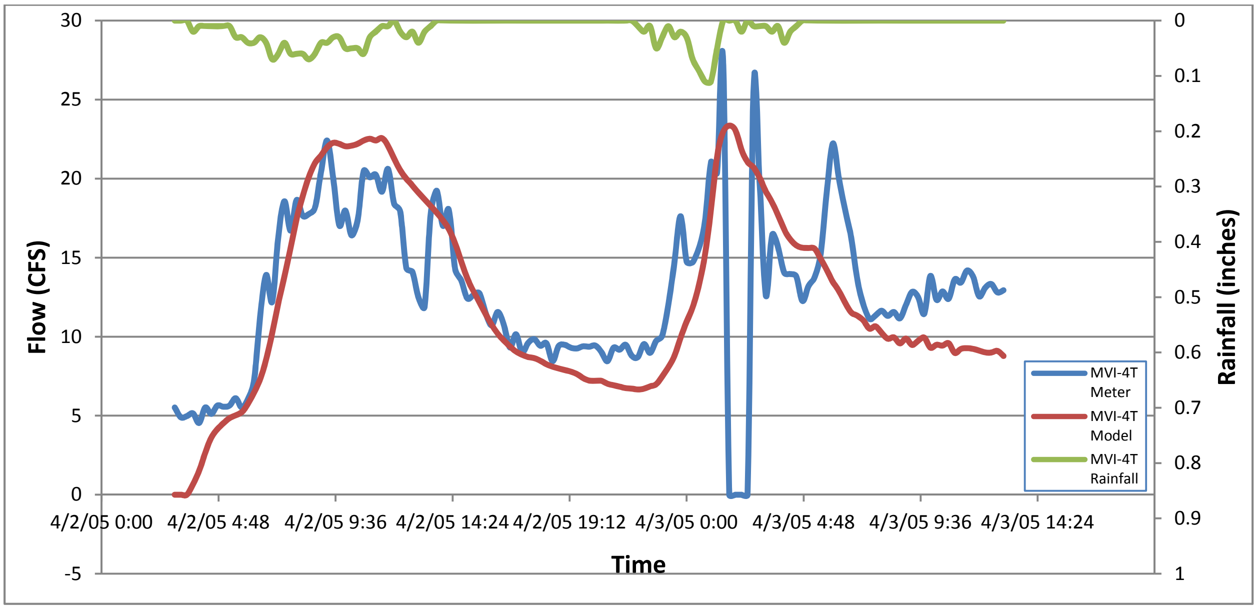

Figure 35: Calibration plot for MVI-4T on 04/02/2005.

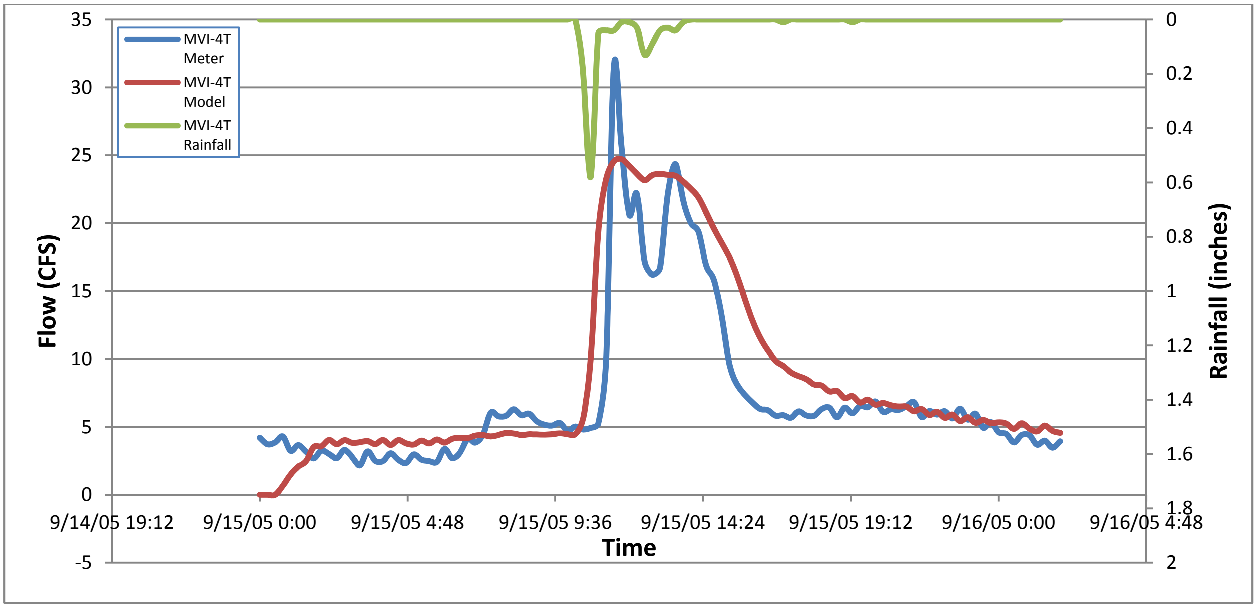

Figure 36: Calibration plot for MVI-4T on 09/15/2005.

8.3.4 Meter MVI-3T

Meter MVI-3T is located on the Concord Street Interceptor which flows into the Moshassuck Valley Interceptor upstream of the MVI crossing at the Moshassuck River. In addition to flow from meter MVI-4T, there is one catchment which contributes flow to Meter MVI-3T which covers an area of approximately 125 ac. As previously discussed in Section 7.2, MVI-3T is presumed to be a separated catchment (per the RJN Capacity Analysis Report). As a sanitary catchment, the total area contributing to the Kinematic Wave model was assumed to be 12.5 Ac, or 10% of the total catchment area.

The results of calibration at MVI-3T for the 04/02/2005 and 09/15/2005 storms are presented in Figures 37 and 38, respectively. The results of the 04/02/2005 show a close fit of the peak flow values, however the flow draw down is being over represented. Figure 38 shows the 09/15/2005 calibration results in a slight over-prediction of peak flow.

Meter MVI-3T, however, represents approximately 1.6% of the total flow-to-treatment at the Bucklin Point Wastewater Treatment Plant (BPWWTP) and there are no overflows located specifically on the Concord Street line. Therefore, the implications of the discrepancies between the measured and modelled data at MVI-3T will not have a significant effect on future model use or alternatives assessment.

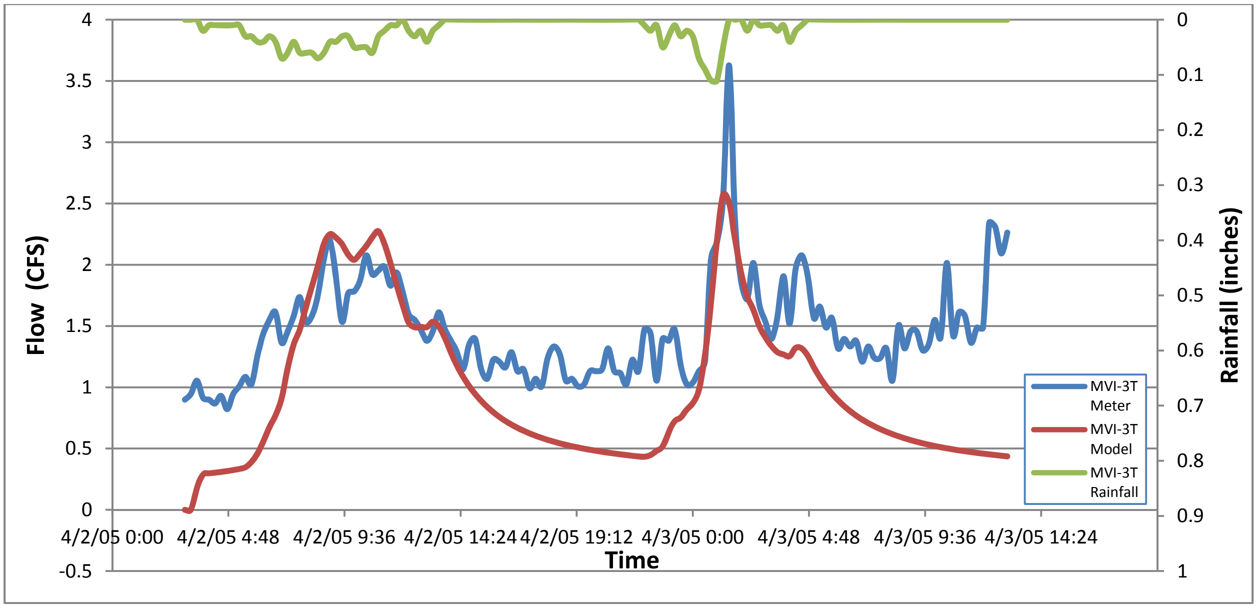

Figure 37: Calibration plot for MVI-3T on 04/02/2005.

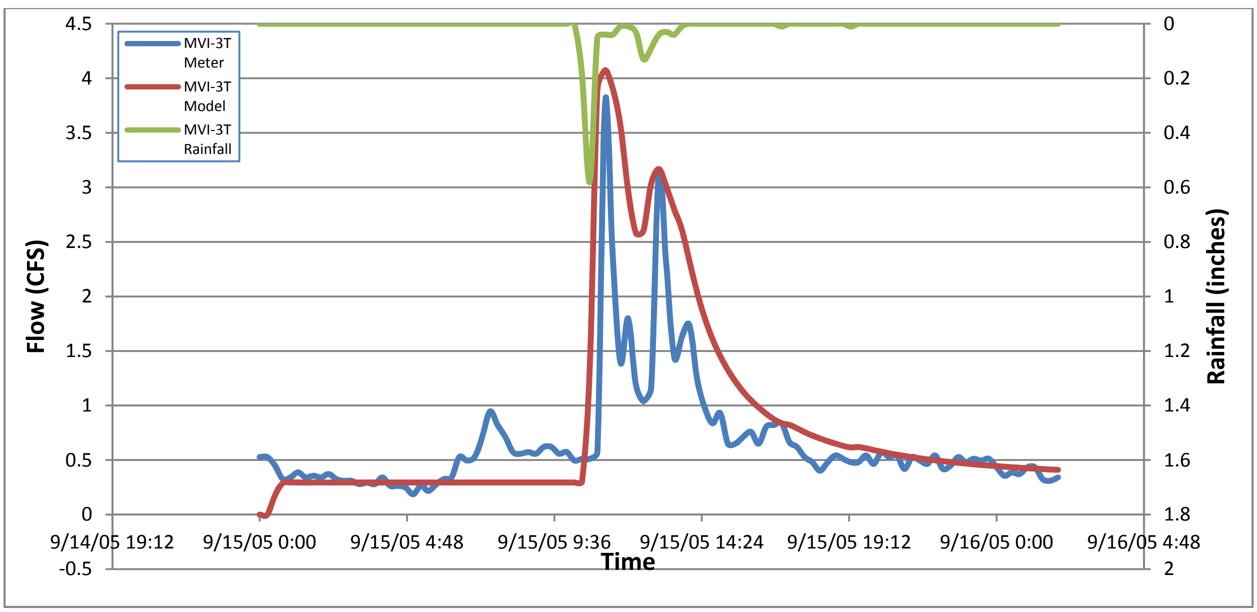

Figure 38: Calibration plot for MVI-3T on 09/15/2005.

8.3.5 Meter MVI-2T

Meter MVI-2T is located on the Moshassuck Valley Interceptor at the end of the 4' diameter deep rock tunnel and downstream of overflows OF_219 and OF_220. The meter is located just upstream of the MVI connection to the Taft-Pleasant Interceptor (TPI) and upstream of the triple-barreled siphon which crosses the Seekonk River.

In addition to flow from meters MVI-4T and MVI-3T, there are three catchments which contribute flow to Meter MVI-2T which cover an area of approximately 506 ac. The results of calibration at MVI-2T for the 09/15/2005 storm are presented in Figures 39. No flow data was available at MVI-2T for the 04/02/2005 rainfall event.

The results of the 09/15/2005 calibration show that the peak flow is being accurately captured by the model. The peak flow variability and flow draw down during the wet weather event are not being captured. This calibration limitation is further discussed in section 8.4.

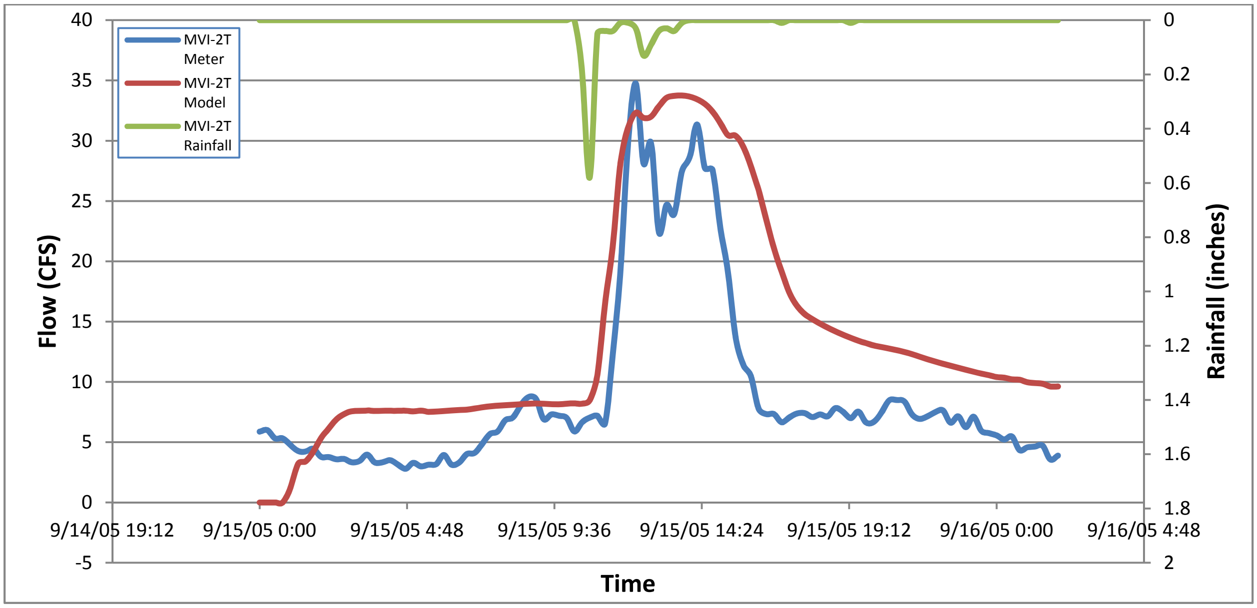

Figure 39: Calibration plot for MVI-2T on 09/15/2005.

8.3.6 Meter MVI-1T

Meter MVI-1T is located on the downstream-most end of the Taft-Pleasant Interceptor prior to its connection to the MVI. There are twelve catchments which contribute flow to Meter MVI-1T, covering an area of approximately 574 ac.

The results of calibration at MVI-1T for the 09/15/2005 storm are presented in Figure 40. No flow data was available at MVI-2T for the 04/02/2005 rainfall event. The results of the 09/15/2005 calibration show that the peak flow is being accurately captured by the model. Similar to the results at MVI-2T, however, the peak flow variability and flow draw down during the wet weather event are not being captured. This calibration limitation is further discussed in section 8.5.

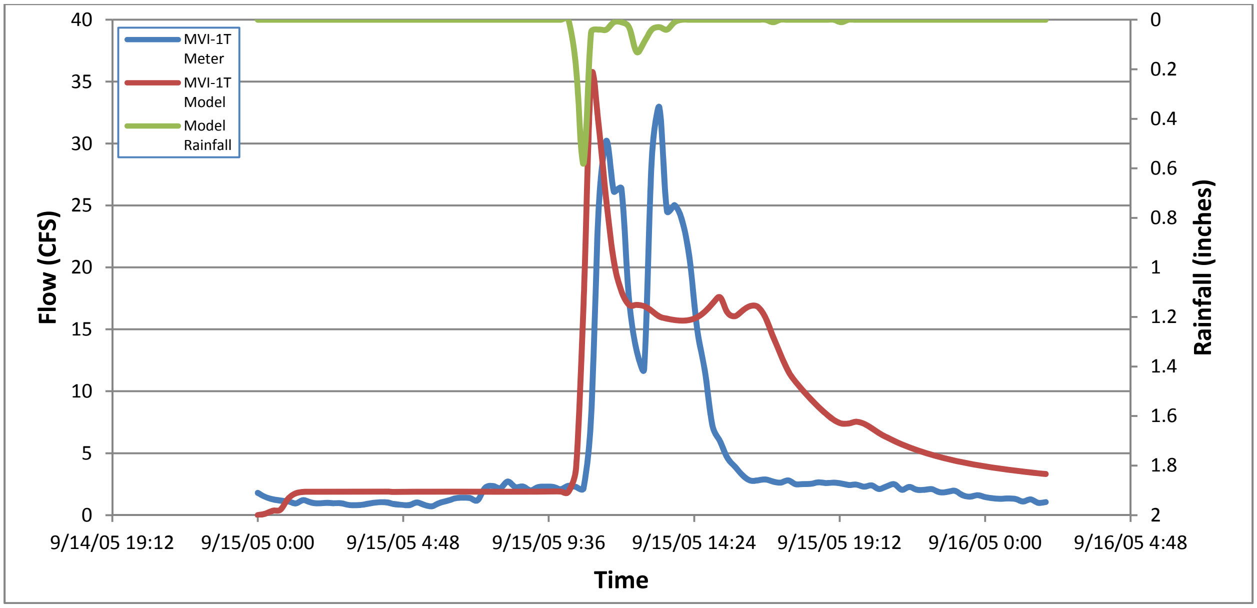

Figure 40: Calibration plot for MVI-1T on 09/15/2005.

8.4 Calibration Summary

Following the calibration exercise, the results were compared with the CIWEM guidelines. Table 16 and Table 17 summarize the results of the comparison. The guideline criteria applied was as follows:

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

Table 16: 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%

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
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 17: 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 model is closer to compliance for peak flows; this was a deliberate undertaking as these are more applicable to the performance of CSOs. The overall shapes of the hydrographs throughout section 8 generally confirm that the mass balance of the inflows is well represented and the response to rainfall is good. The system performance is somewhat hindered in terms of operational conditions and the interactions between the CSOs does have a clear effect on the model results.

8.5 Calibration Limitations-Peak Flow Intensity and Timing

Limitations in representation of timing and peak flow variability were observed in 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 model is comprised of large contributing catchments, particularly as compared to the level of regulation of flow into the interceptor network. The catchments range in size between 1 and 1,000 ac (averaging approximately 100 ac). In almost all cases, there are no local pipes included in the model. While the presumed storage inherent in the local pipe networks is being represented by a storage node (see discussion in Section 7.1), the flow generated by the hydrologic models is then loaded immediately upstream of the regulator structures. The combination of the large catchment areas and the direct loading to the regulator structures most likely contributes to the reduced level of sensitivity in the results.

The model is also missing much of the localized hydraulic and operational detail, due to a lack of information at that local level. These details include features such as structurally defective pipes, debris in pipes and regulator structures and other localized network conditions. The lack of detail at this level further limits the accurate representation of flow variability in the interceptors and lends the model to a reduced level of variability in the modeled flow values.

In order to further understand these variations in flow peaks and variability throughout the system, the model will require a significant amount of additional detail at the local sewer network level, as well as additional details about the conditions and operations associated with the NBC interceptors. In particular, any available condition assessment or restriction information in both the local networks and in NBC infrastructure might be gathered to further support development of a more refined model with a higher level of sensitivity.

8.6 CDRA Calibrated Model Comparison

After completion of the model calibration using the RJN meter data, the model was then run with the NBC 3-month design storm in order to calculate the overflow volumes throughout the BPSA (see Appendix F for a graph of the 3-month design storm). Table 18 presents the comparison between the CDRA results and the BPSA Model results (in million gallons). The total reported volume in the CDRA was approximately 54.4 MG, while the total reported volume in the BPSA model developed in MU was 58.5 MG, a 7% increase in modelled overflow volume. The modeled distribution of flow among the various overflows closely matched the CDRA-reported distribution. The only significant difference was identified at OF_210 and OF_211. The CDRA had no reported value for OF_211. In comparing the OF_210 volume in the CDRA (6.3 MG), however, the combination of OF_210 and OF_211 (7.2 MG) is comparable to the CDRA-reported volume.

Table 18: 3-Month Storm Overflow Volumes- Phase IC BPSA

Overflow No.	Interceptor	CDRA* (MG)	PHASE IC BPSA Model 2005 (MG)
OF_101	BVI	0.3	0.4
OF_103	BVI	4.8	4.9
OF_104	BVI	0.4	0.5
OF_105	BVI	1.6	1.6
OF_201	BVI	1.2	1.4
OF_202	BVI	0.0	0.2
OF_203	BVI	0.5	0.4
OF_204	BVI	0.0	0.2
OF_205	BVI	12.8	12.8
OF_207	BVI	0.3	0.0
OF_209	BVI	0.1	0.0
OF_212	BVI	0.5	0.6
OF_215	BVI	1.5	1.6
OF_216	BVI	0.0	0.0
OF_218	BVI	11.7	12.6
OF_002**	BVI	7.1	0.0
OF_107	MVI	-	0.4
OF_206	MVI	0.1	0.1
OF_208	MVI	0.0	0.0
OF_210	MVI	6.3	3.2
OF_211	MVI	-	4.0
OF_213	MVI	1.7	1.9
OF_214	MVI	0.0	0.6
OF_217	MVI	1.8	2.3
OF_219	MVI	3.0	3.1
OF_220	MVI	4.7	4.7
	Total (MG)* **	**54.52**	**58.47**

Overflow No.	Interceptor	CDRA* (MG)	PHASE IC BPSA Model 2005 (MG)
* CDRA, 1998 (Reference #8) ** OF_002 represents the BPWTF diversion outfall *** The total calculated volume does not include OF_002			

9. Reevaluation of CDRA Recommended CSO Plan

The calibrated model described in the preceding sections represented the Phase IC BPSA conditions (2005 BPSA). In order to reevaluate the recommended Phase III CSO alternative presented in the 1998 CDRA, an updated baseline model was developed to incorporate the Phase II implemented alternatives and bring the model baseline to 2011 conditions. Beginning with the Phase IC (2005) model, the system was adjusted for the Phase II modifications carried out in 2011. As previously stated, 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 developed with these regulator changes and the resulting overflow volumes for the 3-month design storm were calculated. These results are presented in Table 19.

As Tables 18 and 19 indicate, the 2011 updates which combined OF_219 and OF_220 resulted in a drop in the overflow volume at OF_220 from a combined total of 7.8 MG down to 4.6 MG (from OF_220 alone). While the combined overflow structures were designed to drop the total overflow volume reaching the Moshassuck River at this location it should be noted that the model predicts that this change in operation of OF_219 and OF_220 has resulted in changes at other BPSA overflows. As presented in Tables 18 and 19, the overflow volumes at OF_214 and OF_217 increased following the removal of OF_219. OF_214 and OF_217 are located on the TPI just upstream of its connection with the MVI. The model predicts that the additional flow being directed to the MVI as a result of the changes to OF_219 and OF_220 has increased the overflow volume at OF_214 by approximately 0.7MG and the volume at OF_217 by approximately 0.4 MG. This interconnectivity amongst overflows located along the various interceptors should be taken into consideration.

Table 19: 3-Month Storm Overflow Volumes 2011 Baseline vs. Phase III Recommended Alternative

Overflow No.	Interceptor	PHASE II BPSA Model 2011 (MG)	Phase III Recommended Alternative (MG)

Overflow No.	Interceptor	PHASE II BPSA Model 2011 (MG)	Phase III Recommended Alternative (MG)
OF_101	BVI	0.4	0.60
OF_103	BVI	4.9	-
OF_104	BVI	0.5	-
OF_105	BVI	1.6	-
OF_201	BVI	1.3	0.01
OF_202	BVI	0.2	0.15
OF_203	BVI	0.4	-
OF_204	BVI	0.2	-
OF_205	BVI	12.8	-
OF_207	BVI	0.0	0.04
OF_209	BVI	0.0	0.02
OF_212	BVI	0.6	0.60
OF_215	BVI	1.6	1.60
OF_216	BVI	0.0	0.01
OF_218	BVI	12.6	-
OF_002*	BVI	0.0	0.01
OF_107	MVI	0.4	0.37
OF_206	MVI	0.1	0.14
OF_208	MVI	0.0	0.01
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**	**3.56**
* OF_002 represents the BPWTF diversion outfall ** The total calculated volume does not include OF_002			

The 1998 Conceptual Design Report Amendment (Reference #8) outlined the Phase III recommended alternative for CSO Control in Section 10.1.4. The alternative summary, recreated from the CDRA, is presented in Table 20.

Table 20: Phase III CDRA Recommended CSO Alternative

Tunnel Length	CSOs Controlled	Tunnel Diameter	Associated Infrastructure
13,000 LF	210/211, 213, 217, 218, (OFs 201, 203, 204, 205, 103, 104, 105)	26-feet	5 Drop Shafts
9,100 LF	OFs 219 & 220	48-in Force Main 54-inch Gravity Main	Pump Station

The Phase III recommended 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 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. Appendix G contains the proposed plan and profile information for the three interceptors and the Pawtucket Tunnel proposed in the Phase III recommended alternative.

The infrastructure associated with the recommended alternative for Phase III was incorporated into the BPSA model and the model was then run with the 3-month design storm. The overflow volumes associated with the Phase III alternative are presented in Table 19. This alternative reduced the overflow volume 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 Pawtucket Tunnel (26-feet diameter) is presented in Figure 41. The tunnel is clearly surcharged during the 3-month storm, suggesting a larger diameter was necessary. The Phase III recommended alternative was then run with the Pawtucket Tunnel at a diameter of 28-feet (Figure 42).

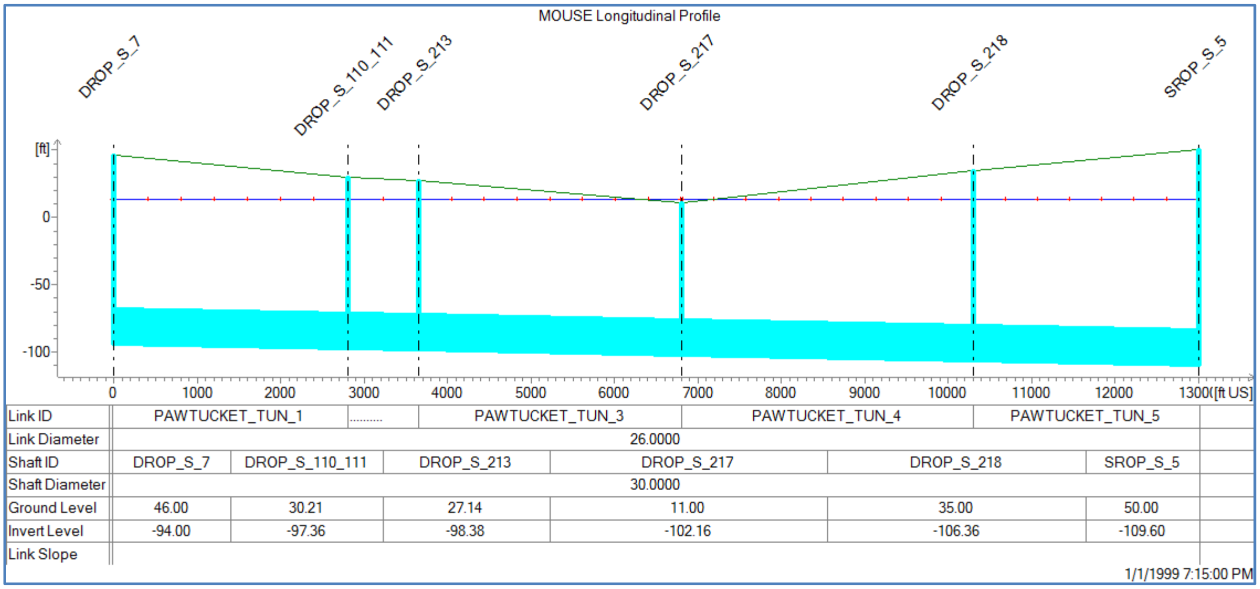

Figure 41: Phase III Level of service in the 26-foot Diameter Pawtucket Tunnel

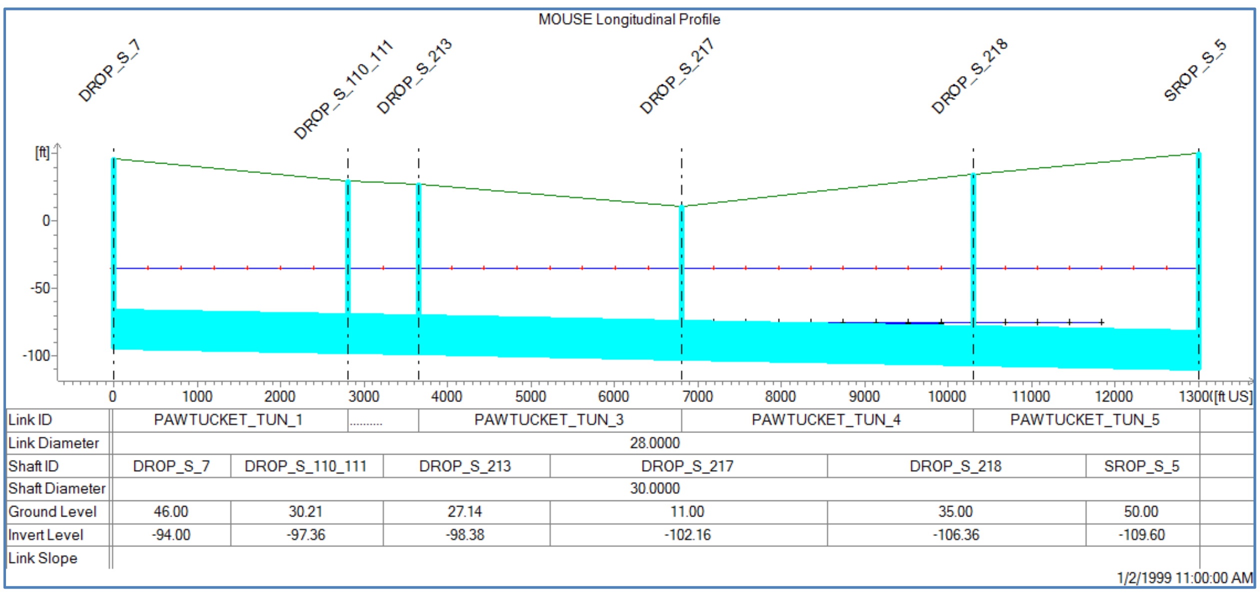

Figure 42: Phase III Level of Service in a 28-foot Diameter Pawtucket Tunnel

10. Conclusions

The BPSA model, as developed, has been reasonably calibrated for the planning decisions required in this stage of the Phase III CSO reevaluation. The levels of calibration are considered acceptable for the purposes of re-evaluating the Phase III CSO alternatives. The size of the system, the number of flow meters available and the approximations associated with modeling large subcatchment loaded directly onto the NBC Interceptor Sewer system are all short comings of the model in its current form but it does serve as the basis for a planning level effort and can (and will need to) be enhanced in the future should designs progress.

In majority of instances the meter volume calibrations were conservative and with the peak flows well matched. Where there are discrepancies they are largely down to one or more of the following:

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

The dynamic system interactions are the complex hydraulic inter-relationships between the CSO regulators and the interceptor sewers. Based on model observation of the underflow and overflow patterns at a number of overflow regulators, it was apparent that limitations in the downstream interceptor capacity were inhibiting underflow through the CSO structures. This was observed at the following overflows: OF_103, OF_104, OF_105, OF_201, OF_202, OF_213, OF_217 and OF_220. As an example of this underflow limitation, the overflow-underflow discharge (cfs) graph at the OF_202 regulator structure is presented in Figure 43: Example of underflow restriction. The underflow discharge peaks at approximately 0.35 cfs and then reverses flow direction. This reverse flow is the receiving interceptor gaining relief through via the CSO weir.

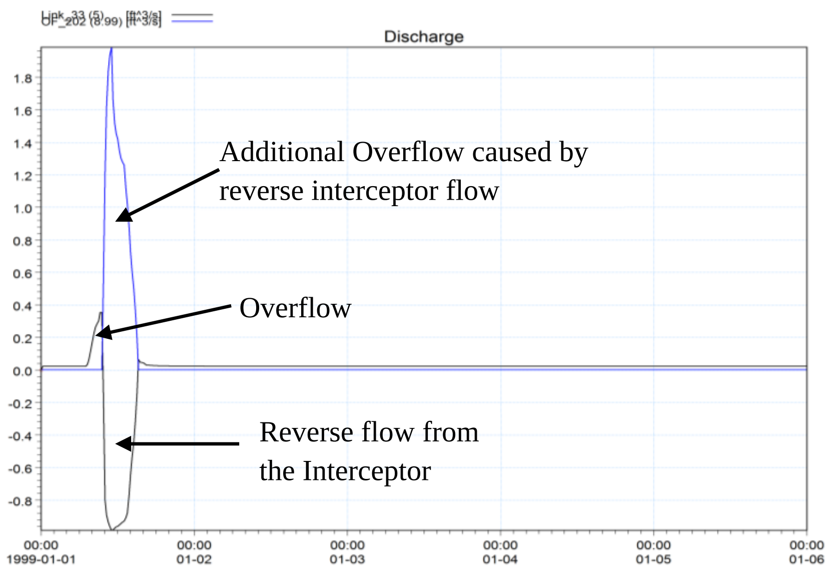

Figure 43: Example of underflow restriction at OF_202

In order to test the magnitude of these hydraulic restrictions, the model was run with free discharge at the underflows of the eight afore-mentioned regulator structures. Table 16 presents the total volume of underflow being restricted by the network limitations at each regulator structure. The results suggest that approximately 2.34 MG of overflow volume results from limitations in the interceptor network at a number of regulators.

Table 21: Restricted underflow volumes

Overflow No.	Restricted Underflow Volume (MG)	% Total 3-Month Overflow Volume (%)
OF_103	0.41	8%
OF_104	0.31	64%
OF_105	0.07	5%
OF_202	0.17	96%
OF_213	0.12	6%
OF_217	0.54	20%
OF_220	0.73	26%
Total	**2.35**	-

At most of the overflow locations, underflow restrictions are a small fraction of the total overflow volume. In such instances, any alternatives for overflow elimination would not depend solely on regulator modifications. In the case of overflows OF_104 and OF_202, however, the volume of flow restricted by the underflow capacity at the regulator appears to be significant (64% and 95%, respectively). This potential for overflow reduction should be considered in the alternatives assessment process. These underflow restrictions indicate the need for a model with more detailed information and confidence at the individual regulator structures.

The operational condition of NBC sewers was also an issue through the calibration task; specifically at the siphons locations throughout the system. Their influence over flows especially during periods of wet weather was particularly influential at the following overflows: OF_202, OF_204, OF_205 and OF_216. However the location of the siphons and their effect on CSO overflows in the upper reaches of the BVI in particular means that any adjustment to the operational conditions will also have an impact on the overflow predictions downstream. At present the overflows are based on what is deemed ‘best fit’ from the calibration efforts, but since these flow observations reflect the sewer conditions in 2005, they may differ from those currently being experienced.

The level of simplification of the BPSA model centers mainly on the lack of upstream (non NBC) sewer system incorporated into the model. Presently the subcatchment loadings are directly applied to the NBC sewers and although a nominal volume has been included to represent the omitted sewer system, the model in its present state must be used with caution in the future when developing solutions. Attempts have been made to differentiate fast and slow impervious rainfall response and generally the alignment of the peak flows during calibration was good. However, in the future when source control measures are investigated which by their nature are intended to distort the effects of rainfall to runoff response times, consideration will need to be given to including some local sewers to support the analyses.

As a final act under this task, the results of the re-evaluated the Phase III recommended alternative was undertaken; the components of the recommendations comprised:

- the Pawtucket Tunnel (26-feet diameter);
- five drop shafts;
- two CSO interceptors to feed into the Pawtucket Tunnel at its upstream end; and
- a pumps station and force main to convey flows from OF_220.

The model predictions found that recommended alternative for Phase III when simulated with the NBC 3-month design storm reduced the overflow volume by approximately 93%, bringing the total overflow volume to approximately 3.56 MG. The most significant finding was that the 26-ft tunnel diameter would need to be increased to 28-ft to capture the entire overflow volume from the 3-month design storm event.

11. Future Recommendations

Based on the findings from the BPSA model build the following recommendations are made to NBC as a possible indicator for future developments that will support the development of a Phase III CSO Program.

- Develop a more refined model for a more accurate representation of the relationship between the interceptor network and the CSO catchments;
- Geospatially locate the water usage data for the cities of Central Falls and Pawtucket in order to refine the base flow distribution between domestic and industrial water usage and, in turn, wastewater loads among the catchments;
- Undertake a new flow metering program to update the model operational performance and to strategically understand the dynamic interactions between the CSOs and the interceptor sewers;
- Increase the model coverage to include a select number of upstream sewer system components to support source control alternatives. This will likely involve targeted survey work to retrieve relevant and accurate data;
- Survey key assets on the NBC system to update recent changes. Update existing data to reflect the complex hydraulic structures that exist with the NBC service area;
- Collate data relating to operational conditions and procedures; identify specific operational hotspots and quantify issues;
- Add river level data to the model during the design phases to ensure boundary conditions are replicated satisfactory; and
- Investigate the ability of the current hydraulic modeling software to meet the future needs of the program.

12. References:

1 NBC Hydraulic Model Development – GIS Review. May, 2007.

2 RIGIS, 2013. Digital Elevation Model; DEM11. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.edc.uri.edu/rigis, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island

3 RIGIS, 2012. Census 2010; CensusSF1_2010. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.edc.uri.edu/rigis, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island.

4 RIGIS, 2011. Rhode Island Impervious Surfaces. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.edc.uri.edu/rigis, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island

5 Update Narragansett Bay Commission's Hydraulic Model Using Mike Urban Software, Prepared by CH2MHill for the NBC, August 2012, Revised November 2012.

6 Capacity Analysis Final Report and Report Appendices. RJN Group, Inc. October 6, 2006.

7 The Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox, EPA.

8 Conceptual Design Report, Narragansett Bay Commission. Prepared by Louis Berger & Associates. April 17, 1998.

9 Stormwater Management Model, Narragansett Bay Commission, Phase 1-C, User's Manual. Prepared by CH2M Hill. March, 1997.

10 Conceptual Design Report Amendment Reaffirmation, Narragansett Bay Commission. Prepared by Louis Berger & Associates. January 14, 2005

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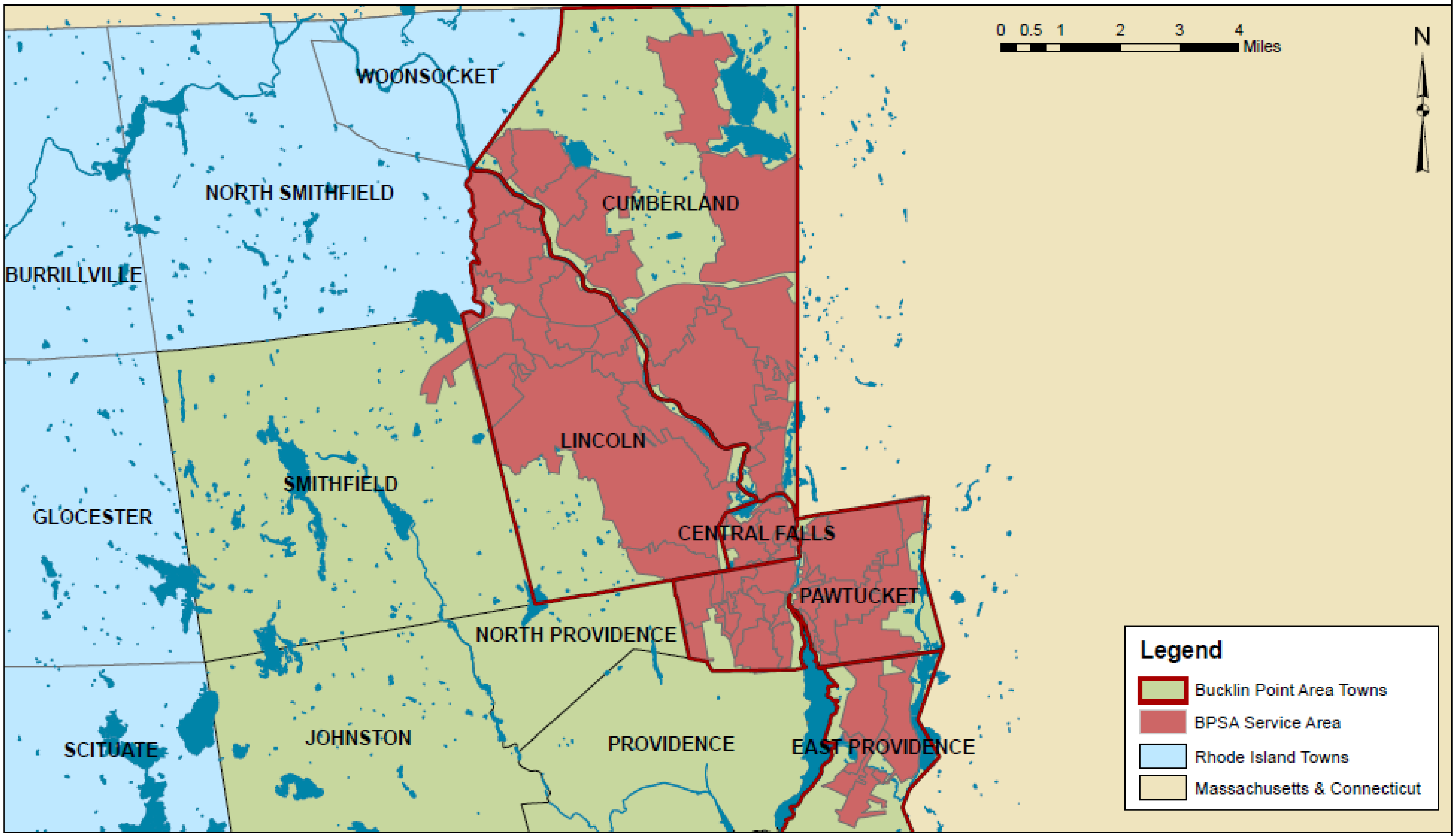
Appendix A: Bucklin Point Service Area



Appendix A: Bucklin Point Service Area

Appendix B: BPSA Model Extension

B1. Introduction

This appendix summarizes the Bucklin Point Service Area (BPSA) hydrologic and hydraulic model expansion. Expansion of the model included the addition of NBC interceptors in Cumberland, Lincoln, and East Providence. Model calibration was executed using available flow metering data from 2005.

The NBC Geographic Information System (GIS) data (the geodatabase) was used as the main source of network feature (e.g., pipes, manholes, pumps, and weirs) data in Cumberland, Lincoln, and East Providence. Tables 1 and 2 summarize model features associated with the interceptors of the extended model areas.

Table B1: BPSA Extended Model Network Features in Cumberland and Lincoln

Model Feature	Number	Comments
Manholes	353	All manholes missed invert elevation
Manholes with missing rim elevation	161	Missing rim elevations were assigned based on DEM elevation at manhole location.
Pipes	350	
Pump Stations	1	Washington Hwy PS (Capacity 5.75 MGD)
Catchments	29	

Table B2. BPSA Extended Model Network Features in East Providence

Model Feature	*Number*	*Comments*
Manholes	44	
Manholes with missing invert elevation	17	Missing invert elevations were interpolated from neighbor manholes with available data
Pipes	45	
Pump Stations	1	Omega Pond Pump Station (OPPS)
Pumps	3	Constant pumps set each @ at 7cfs[1]
Basins	1	
Weirs	1	Weir added between OPPS Basin and OPPS Outfall. Weir Crest and Elevation assumed as 8ft and 10ft, respectively.
Outfalls	2	Outfall BPWTF_EP_FLUME set as discharge point of EP service area to the Buckling Point WWTP (assuming free flow discharge).
Catchments	5	

[1] These values were assumed to better match metered data. It is recommended that current pumping settings are accurately represented in the model, particularly for evaluation of scenarios associated with flows within and/or from the EP area.

Several manhole invert elevations were missing in the NBC's utility geodatabase layer in Cumberland and Lincoln areas. However, most upstream and downstream pipe invert elevations were available in the pipe geodatabase layer. Therefore, manhole inverts were assumed to equal the lowest invert elevation of the connected pipes. Pipe invert elevations are provided in Providence Mean High Water (MHW) vertical datum in the NBC utility pipe layer. On the other hand, the model's vertical datum is in NGVD29, thus it was necessary to transform manhole and pipe invert elevations according to the following equation,

Equation B1: Manhole invert model elevation (NGVD29) = lowest invert elevation of any connected link (Providence Mean High Water (MHW)) + 2.35 ft.

Table 1 shows that 161(out of 353) manholes lacked rim elevations in the geodatabase. To fill the gaps, manhole rim elevations were directly assigned from the available DEM layer. Due to the fact that DEM elevations are provided in the NAVD88 vertical datum, the following equation was used to convert DEM-based rim elevations into the model NGVD29 vertical datum, according to the equation,

Equation B2: Elevation (ft, NGVD29) = Elevation (ft, NAVD88) + 0.79 ft.

NBC record drawings of the Washington Avenue Highway pump stations were used to gather the geometry of the wet well chamber per 2005 conditions. The current configuration of the PS was not implemented in the extended model. Figure 1 shows the extended Cumberland and Lincoln model catchment areas along manholes with missing rim elevation, pipes, and pump stations.

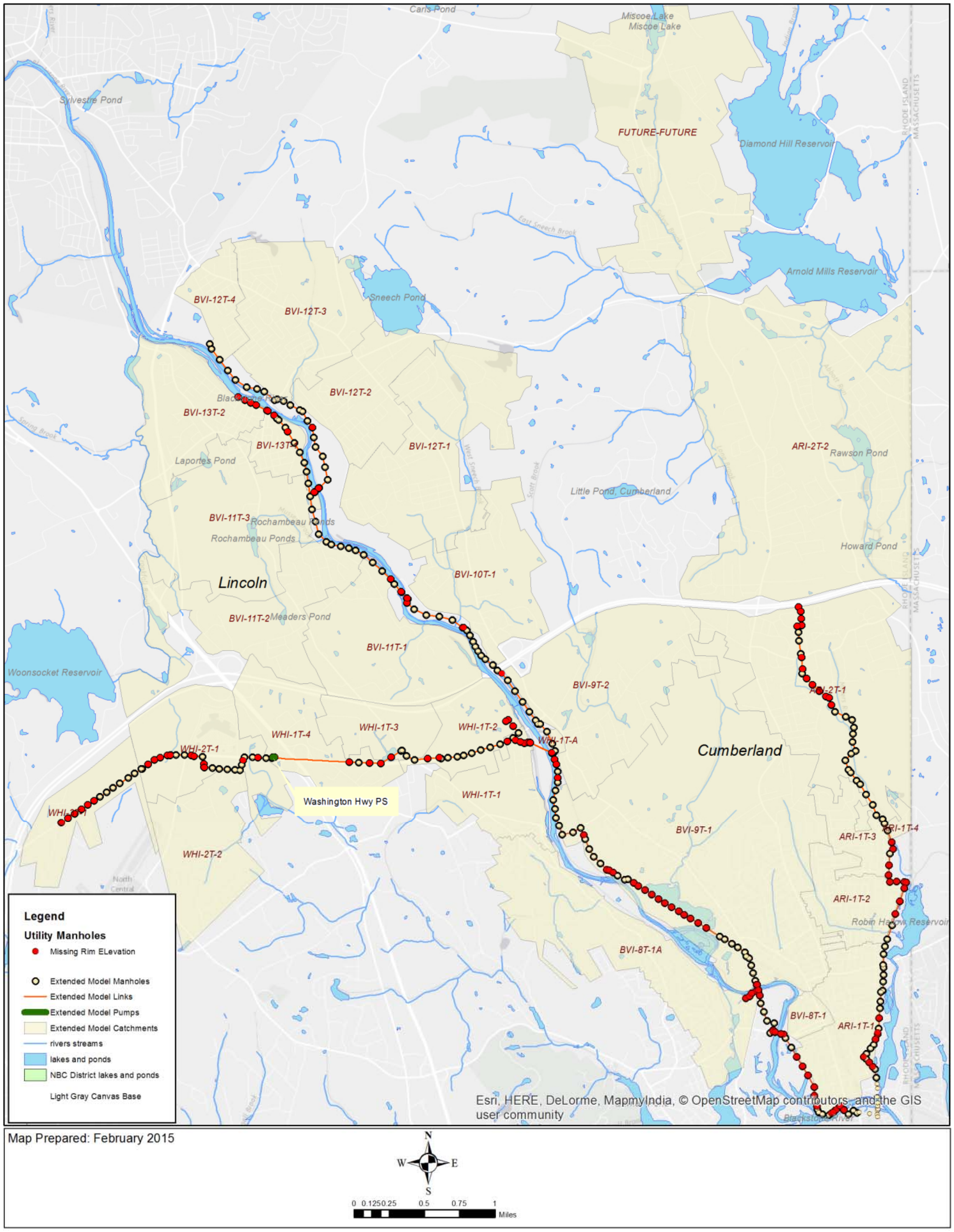


Figure B1. BPSA Model Extension and Manholes with missing Rim Elevation in Cumberland and Lincoln.

Within the East Providence area, a total of 17 manholes lacked invert elevations in the geodatabase layer. Manhole invert elevations were assigned based on available upstream/downstream invert elevations of connecting pipes. Elsewhere, extrapolated manhole invert elevations from neighboring manholes were used to fill the gaps. Figure 2 shows the extended East Providence model catchment areas along manholes with missing invert elevation, pipes, and pump stations.

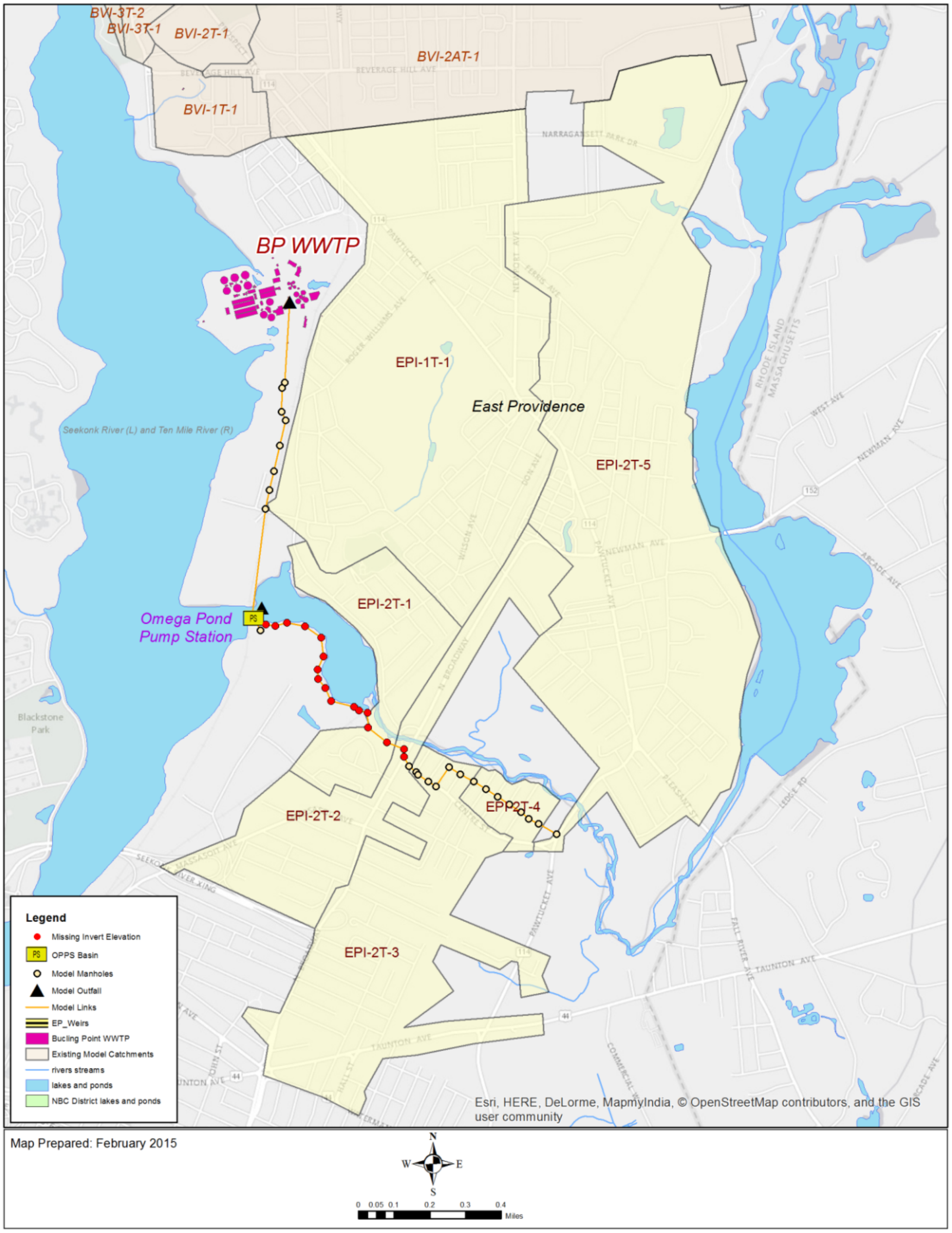


Figure B2. BPSA Model Extension and Manholes with missing Invert Elevation in East Providence.

B2. Calibration of the Extended Model Area

The extended model areas (Cumberland, Lincolns, and East Providence) was calibrated to match dry weather flow (DWF) and wet weather flow (WWF) responses measured the meter data collected by RJN during the period April 2005 – January 2006. Initially, calibration was performed to match observed DWF patterns. Next, WWF calibration was conducted to match flow responses measured at 13 flow meter locations for the selected calibration storms events. Figure 3 shows the location of the eleven flow meters used for calibration in Cumberland and Lincoln. Figure 4 shows the two flow meters used for calibration in East Providence.

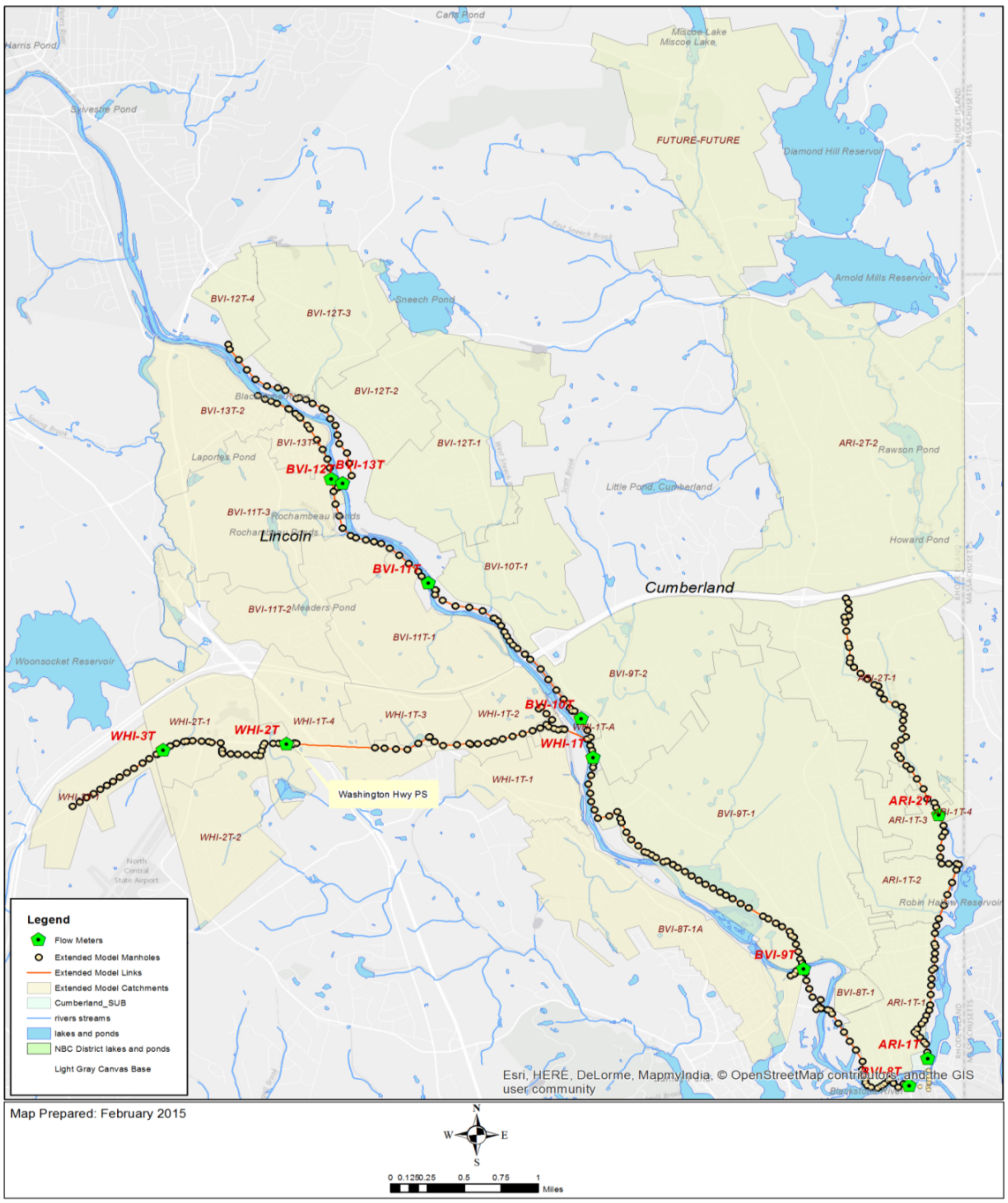


Figure B3. Flow Meters used for Calibration in Cumberland and Lincoln.

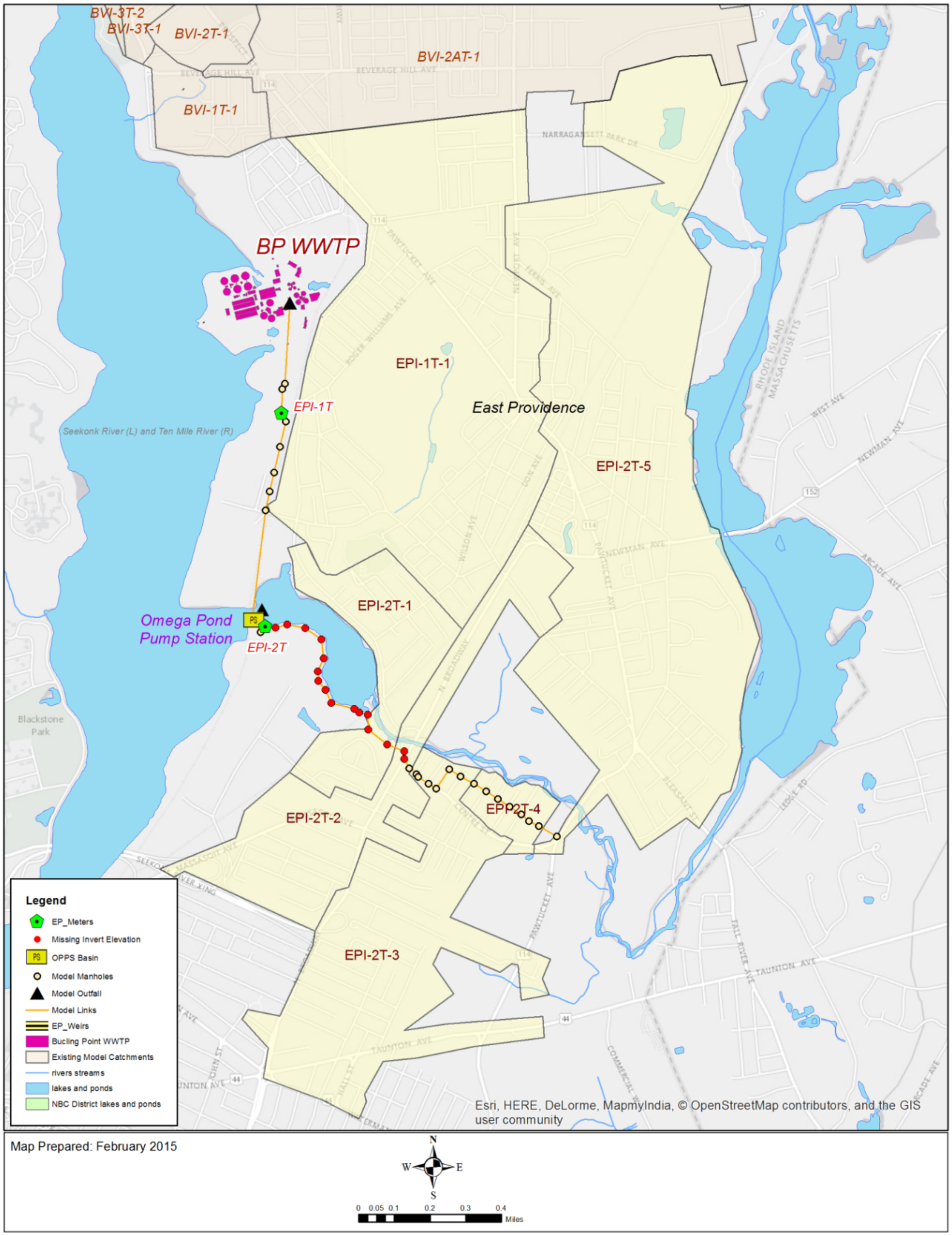


Figure B4. Flow Meters used for Calibration in East Providence.

B.2.1 Dry Weather Flow Calibration

Diurnal flow patterns were developed for 10 flow meters namely, ARI-1T, ARI-2T, BVI-13T, BVI-12T, BVI-10T, BVI-9T, WHI-3T, WHI-2T, EP-1T, and EP-2T. Each diurnal pattern was loaded at nodes upstream of the respective meter locations. Model runs covered periods of at least two dry days. This allowed to systematically adjusting the DWF loads at nodes upstream of a given flow meter during the calibration process. During this process, wastewater loads were adjusted until satisfactory matching between simulated and metered DWF hydrographs was achieved at each meter location. Additionally, two wastewater load levels were defined for the year's first and second semesters, respectively, to better reproduce the observed year-long variation in base sanitary flows.

B.2.2 Wet Weather Flow Calibration

The flow metered data in the extended model areas exhibits both fast response component (FRC) and slow response component (SRC) components. The FRC of flow is a direct consequence of rainfall and subsequent runoff into direct connections to the sewer system and was simulated using the kinematic wave storm-runoff transformation model. The slow response component (associated with the prolonged decaying limb of the flow hydrograph before residing back to antecedent DWF levels) was modeled using Mike Urban's RDI model.

Two rainfall events were selected for calibration, consistent with the existing BPSA model area, namely the April 2nd and the September 15th of 2005. Comparison between metered and modeled flow hydrographs are shown in Figures B6-B33. Visual inspection of the charts indicate a reasonable agreement between the two was attained regarding shape, time to peak, peak flow magnitude at most meter locations. A quantitative comparison is provided in Tables B3 to B6 which summarize percent difference between metered and simulated peak flows and cumulative volume for both calibrated storm events.

The accuracy of the model calibration is illustrated in Figures B32 and B33. These figures show the agreement between the metered and modeled values for peak flows (left panel) and for total volumes (right panel), respectively, for both calibration WWF events at all flow meter locations. Overall, the model reproduces metered flow within a reasonable level of accuracy, reflected by the proximity of most data points to the line of perfect fit, for both peak flow and total volume.

B.2.3 Updated BPSA Model

After calibration of the extended model in Cumberland, Lincoln, and East Providence areas was completed, the next step consisted in appending the extended model features to the existing BPSA model within Mike Urban. This was readily archived using Mike Urban's automatic export/Import toolset. After the extended and existing models were merged, the final step was to verify that the updated BPSA model reproduced the simulated results of the obtained at the 13 flow meter locations evaluated during calibration. Simulations using the updated entire BPSA model were conducted for the two calibrated storms of April 2nd and September 15th of 2005. Model calibration results were successfully reproduced at all 13 flow meter locations. This validated the merging of the extended and existing model extents. Figure 5 shows the entire updated BPSA model extents.

B.3.4 Summary and Conclusions

The updated Phase 3- BPSA hydrologic and hydraulic model includes an expanded network that covers NBC-owned interceptors in Pawtucket, Central Falls, Cumberland, Lincoln, and East Providence. Model calibration of the extended areas achieved a reasonable representation of pipe flows, volumes, and hydrograph patterns for two selected 2005 storm events.

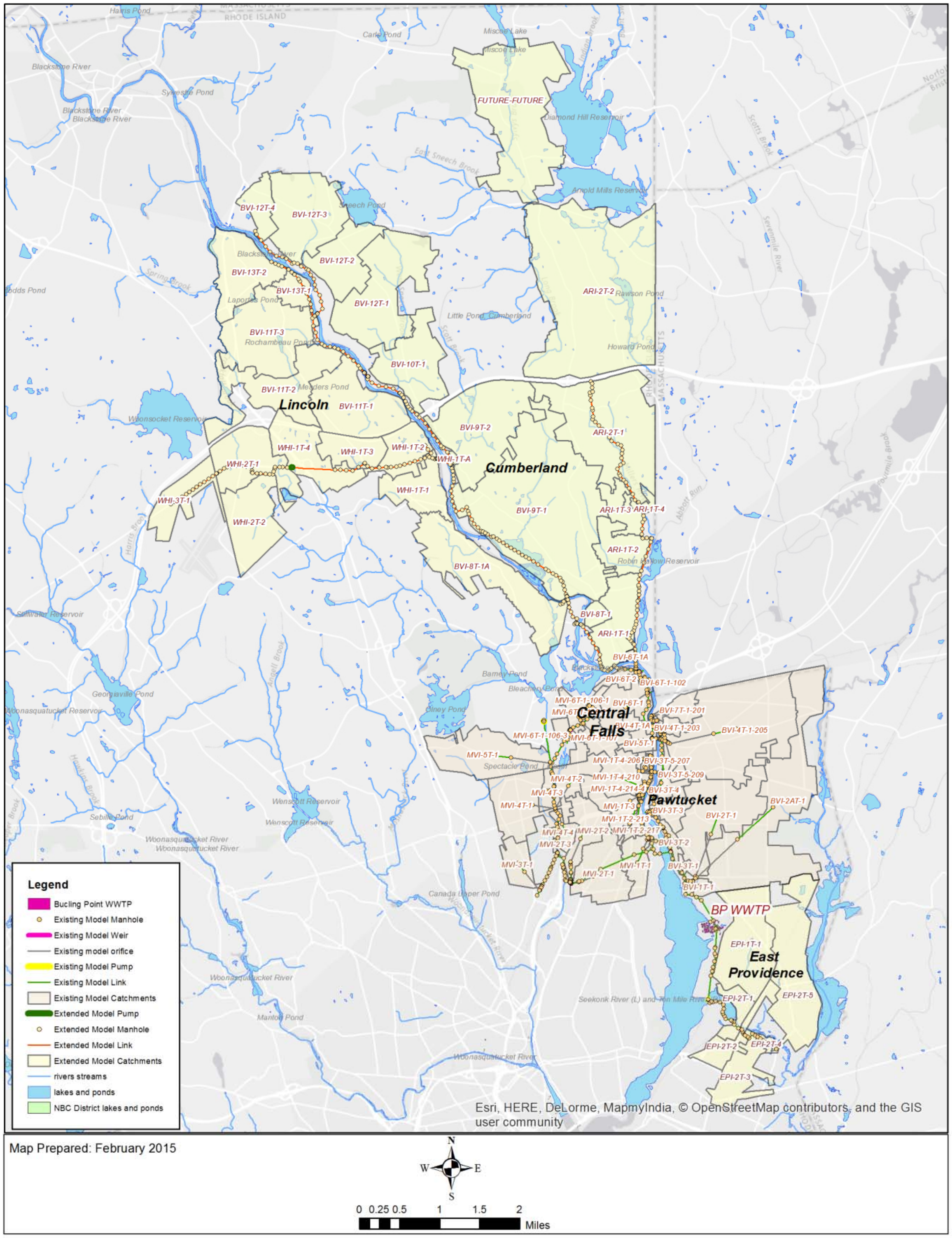


Figure B5. Updated BPSA Model Extents.

Figures B6-B18: Metered vs Simulated flow discharge hydrographs for calibration storm event on April 2, 2014

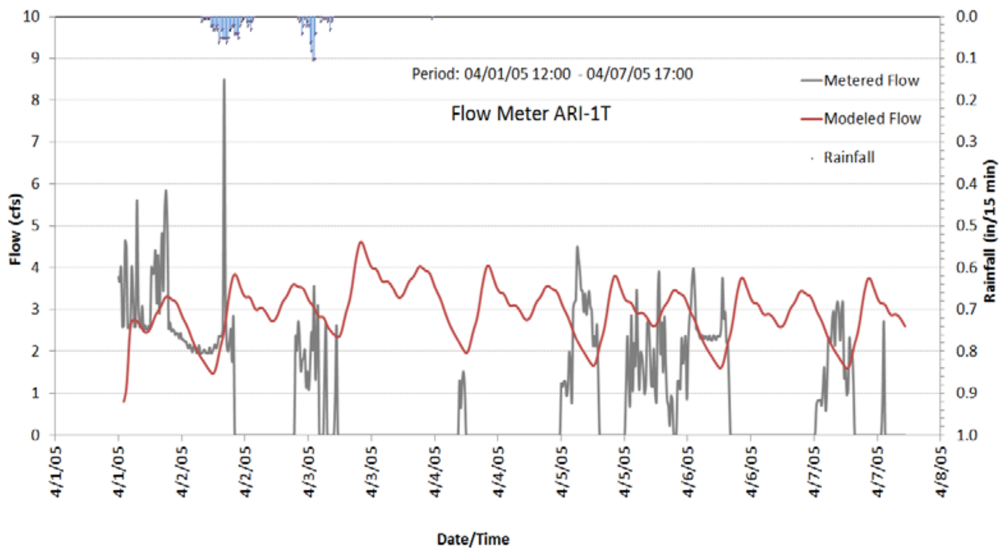


Figure B6 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter ARI-1T.

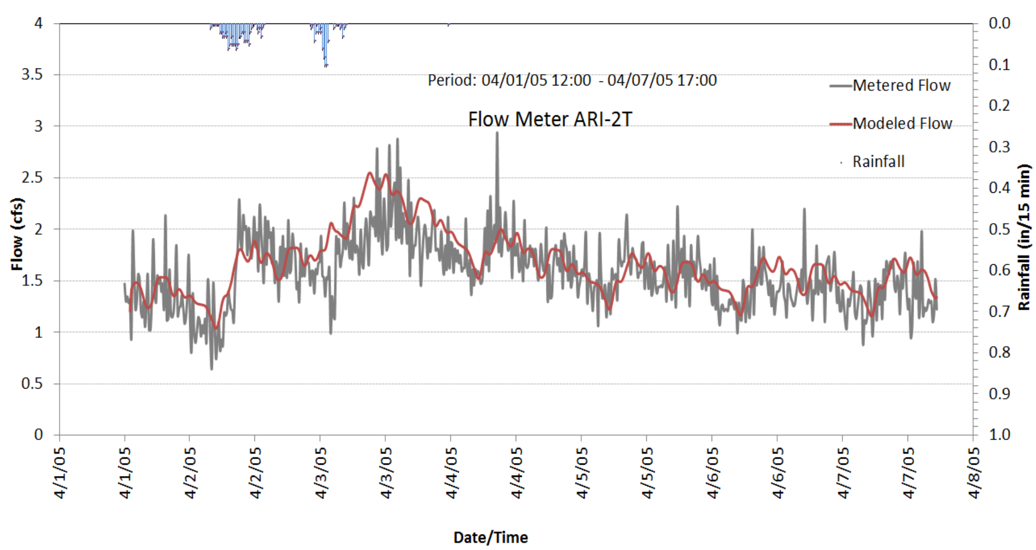


Figure B7 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter ARI-2T.

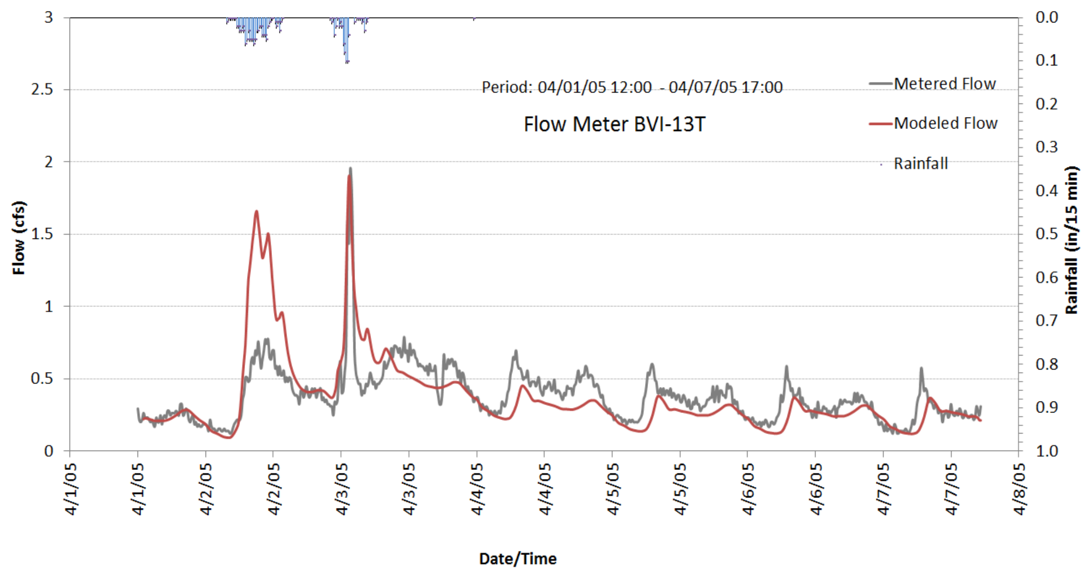


Figure B8– Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-13T.

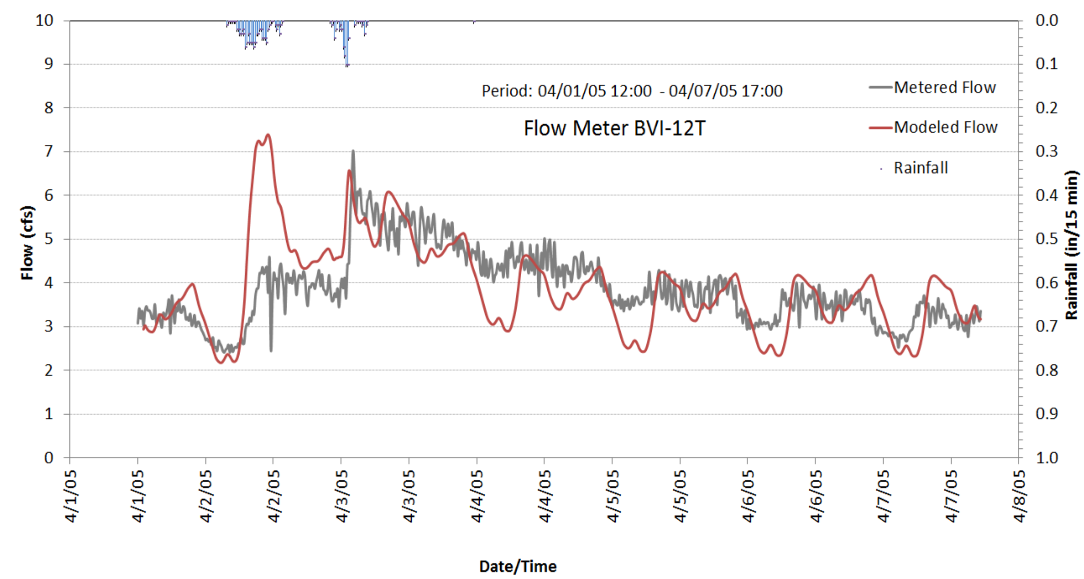


Figure B9 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-12T.

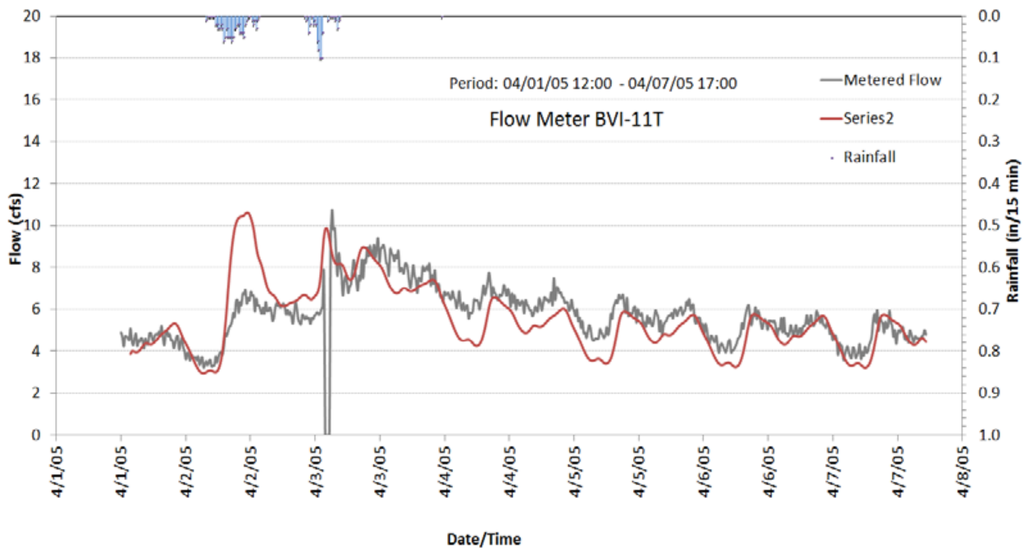


Figure B10– Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-11T.

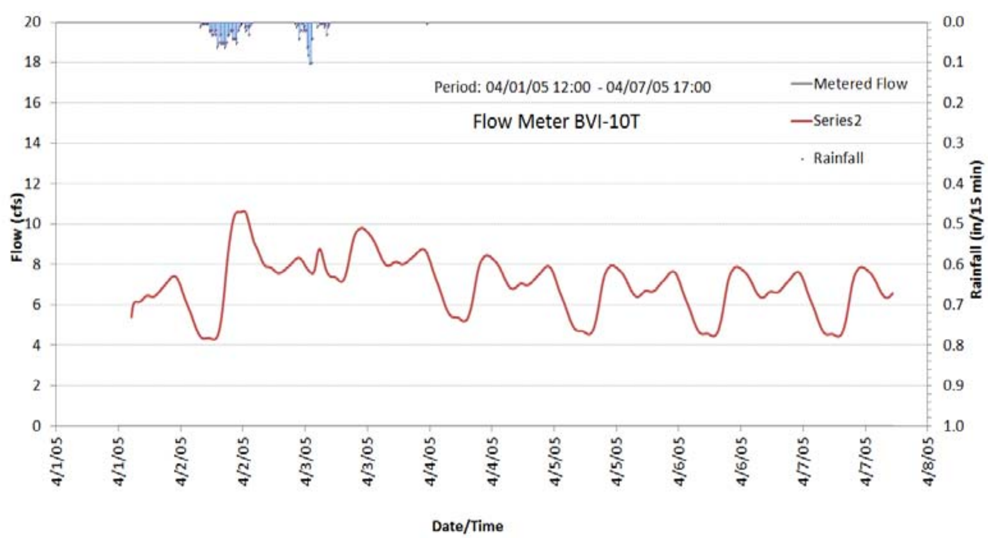


Figure B11 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-10T.

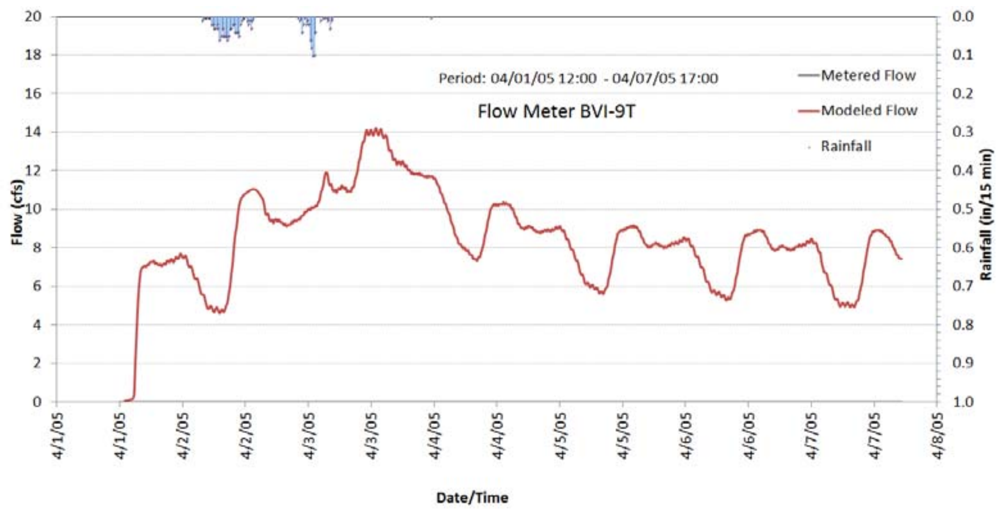


Figure B12 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-9T.

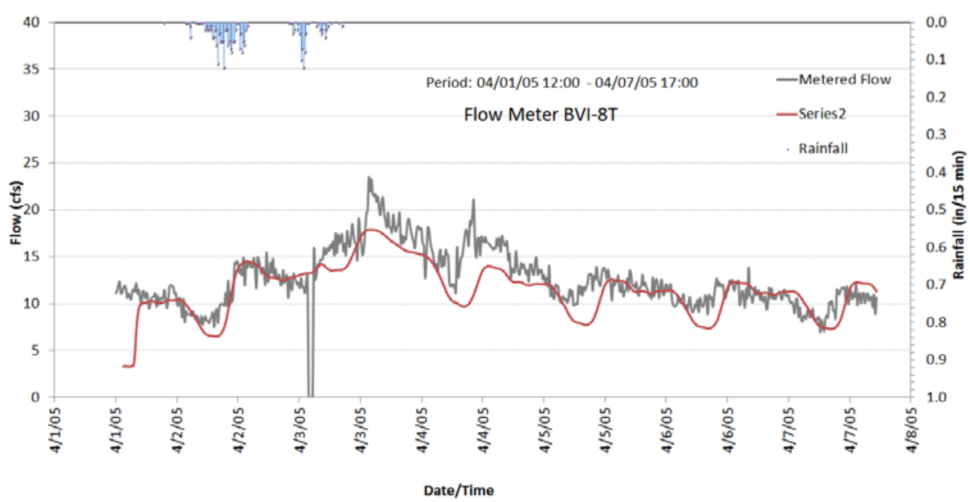


Figure B13 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter BVI-8T.

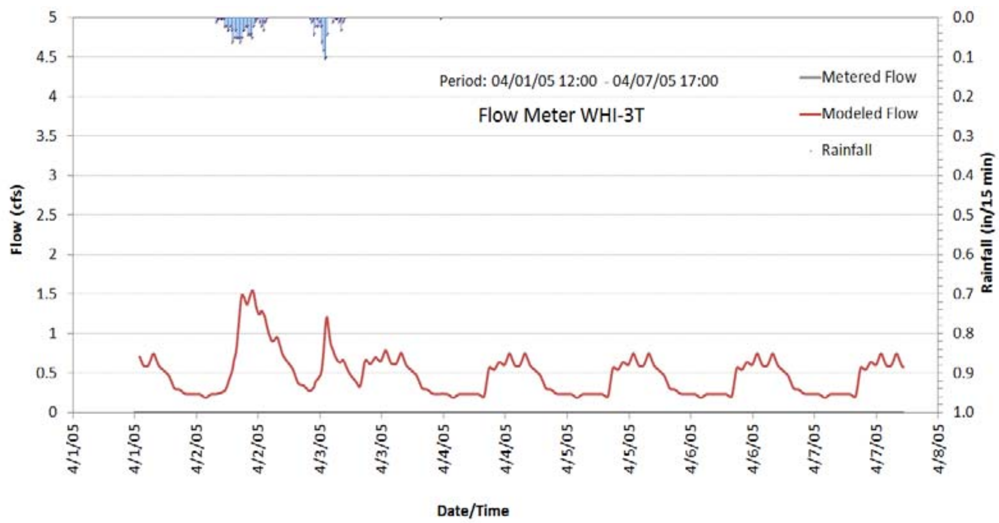


Figure B14– Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter WHI-3T.

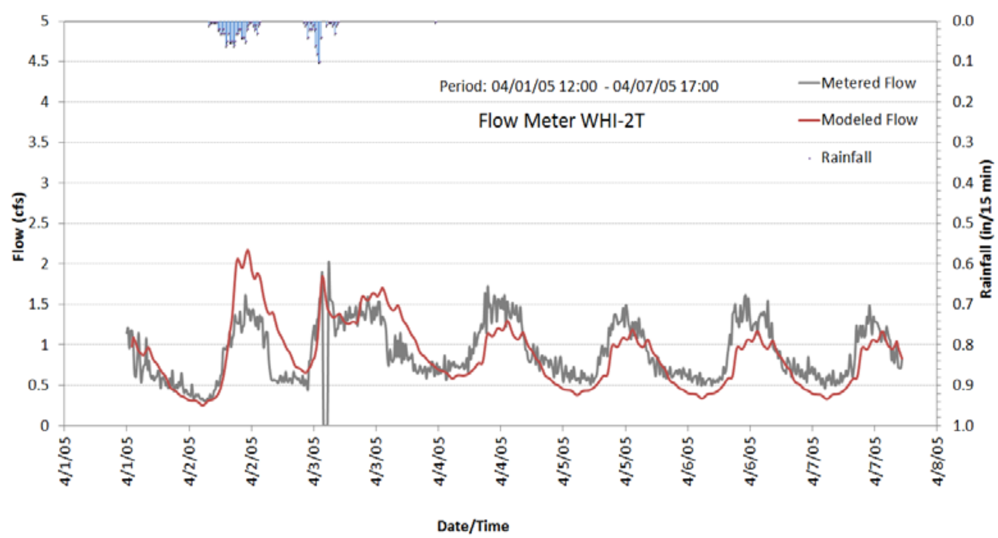


Figure B15 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter WHI-2T.

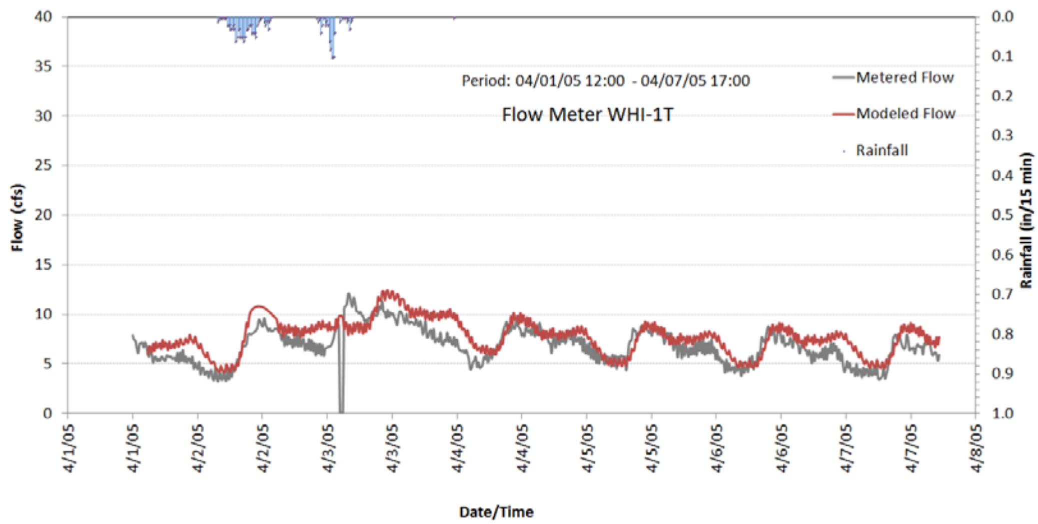


Figure B16 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter WHI-1T.

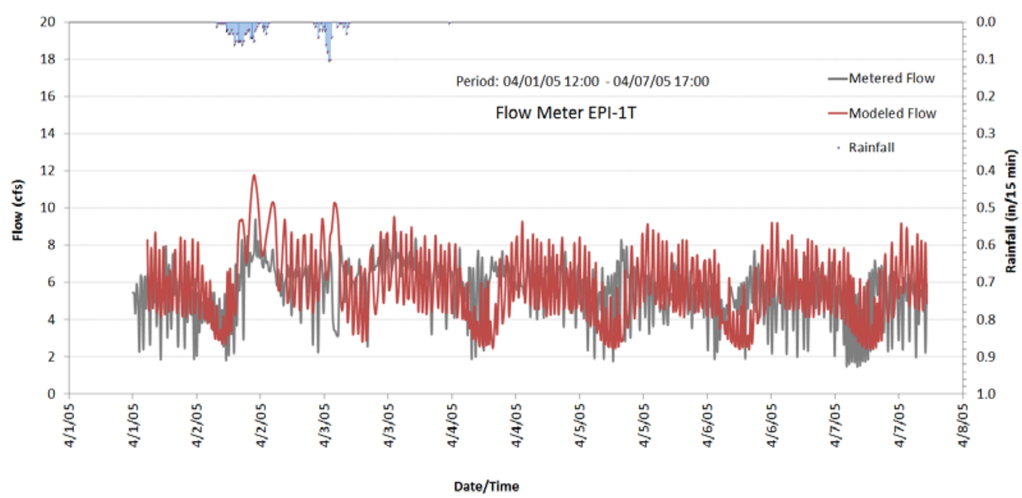


Figure B17 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter EPI-1T.

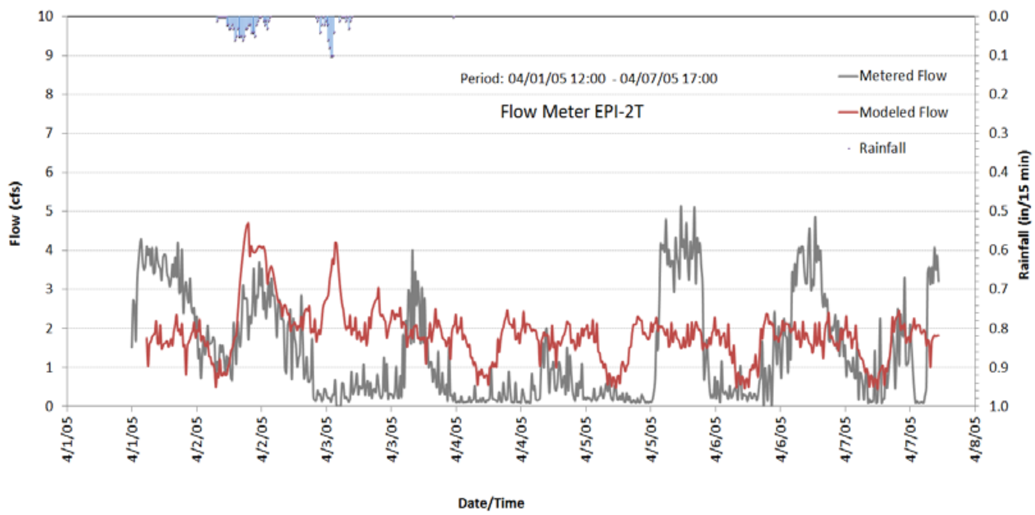


Figure B18 – Measured Vs Modeled flow discharge for the April 2, 2005 storm event at Flow Meter EPI-2T.

Figures B19-B31: Metered vs Simulated flow discharge hydrographs for calibration storm event on September 15, 2014.

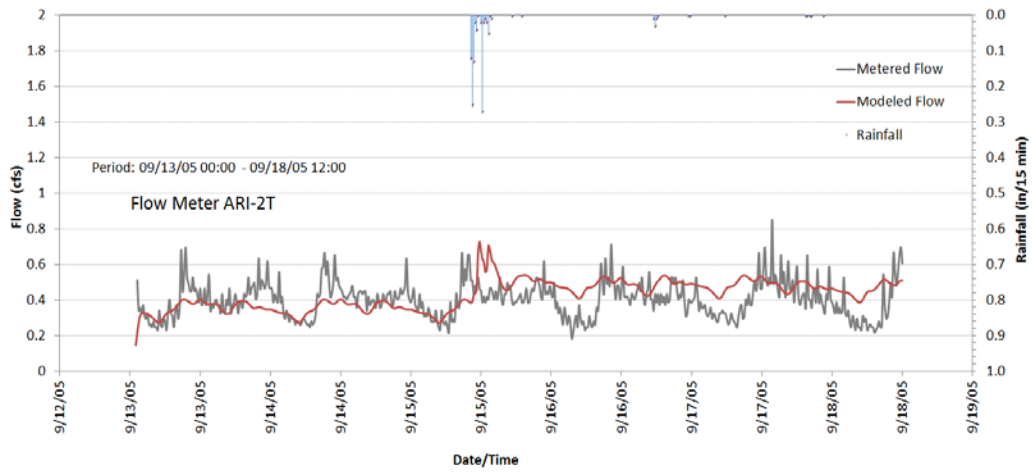


Figure B19– Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter ARI-2T.

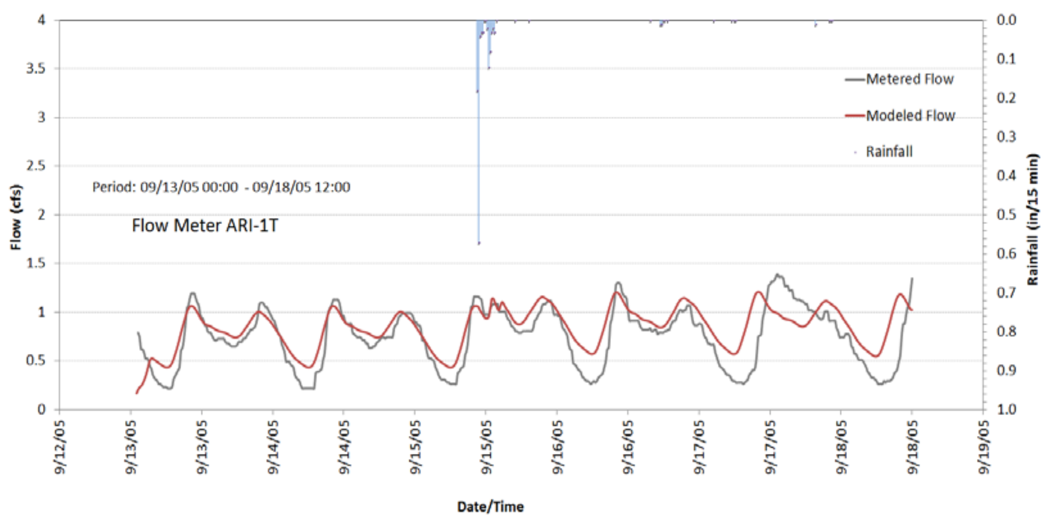


Figure B20 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter ARI-1T.

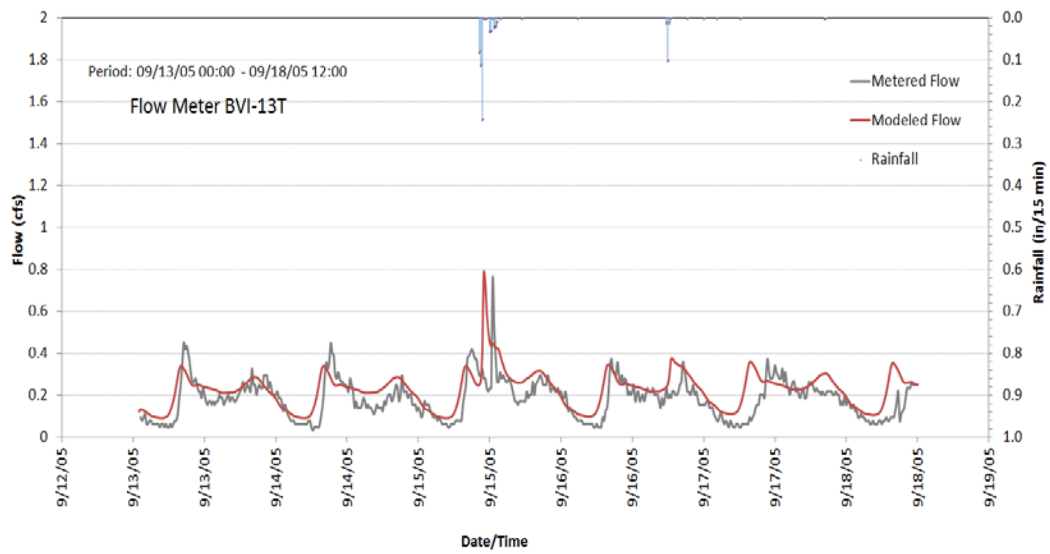


Figure B21 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-13T.

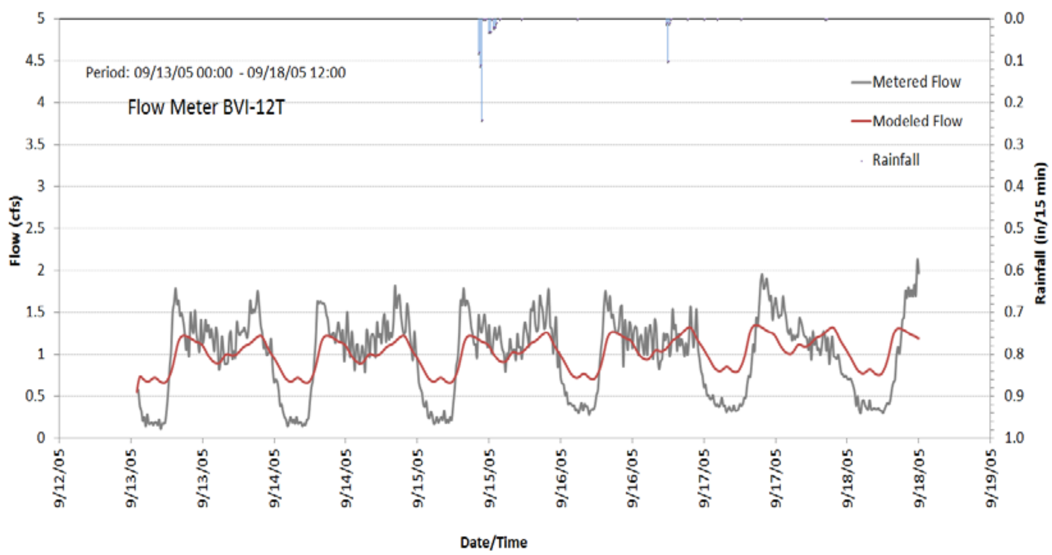


Figure B22 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-12T.

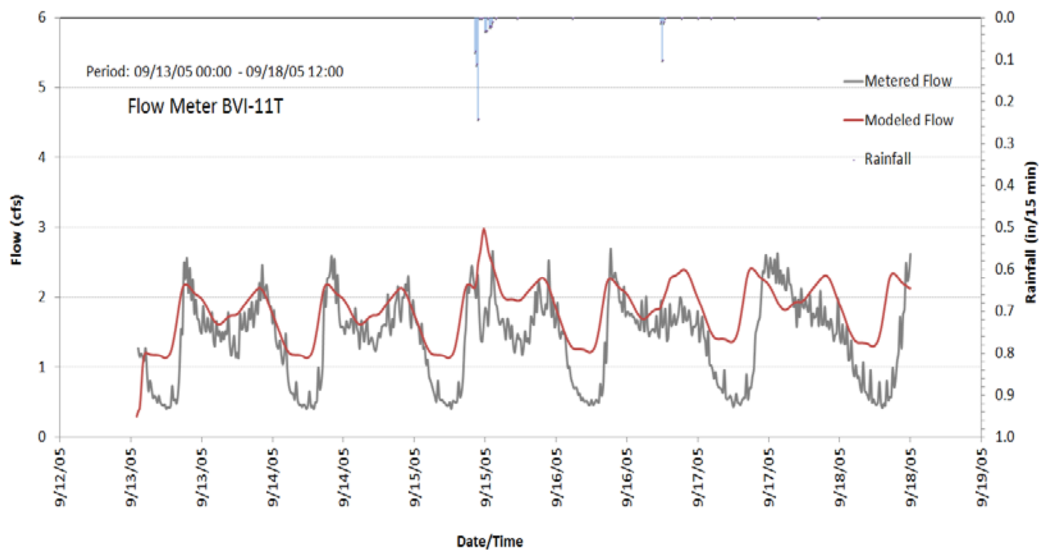


Figure B23 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-11T.

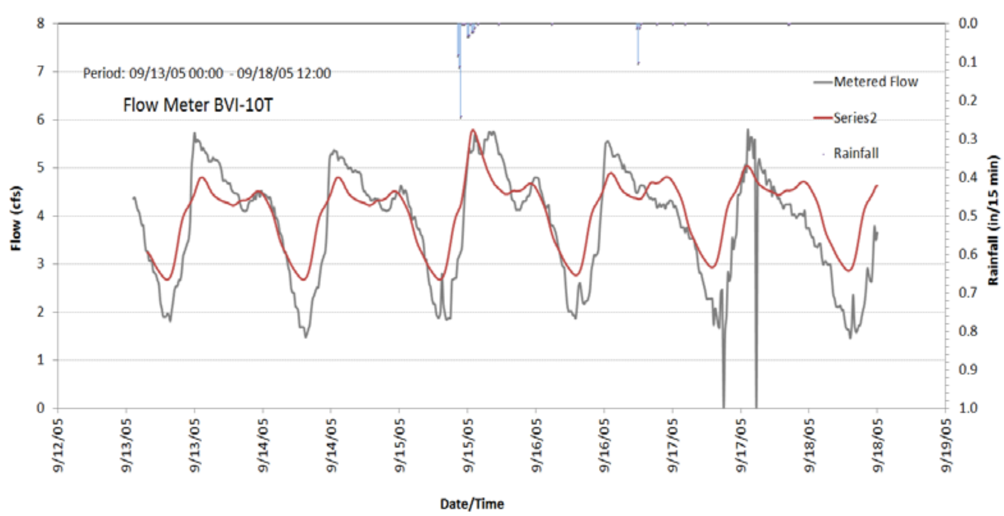


Figure B24 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-10T.

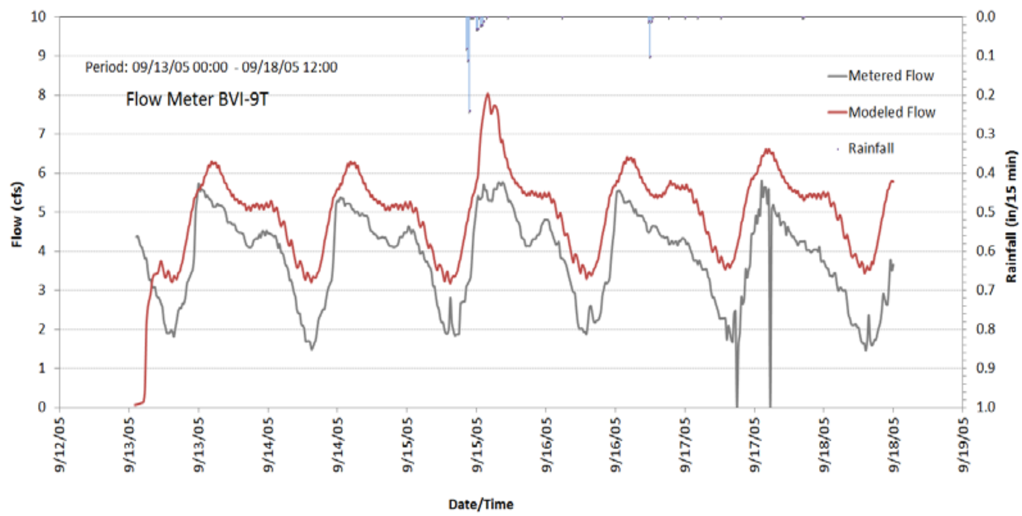


Figure B25– Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-9T.

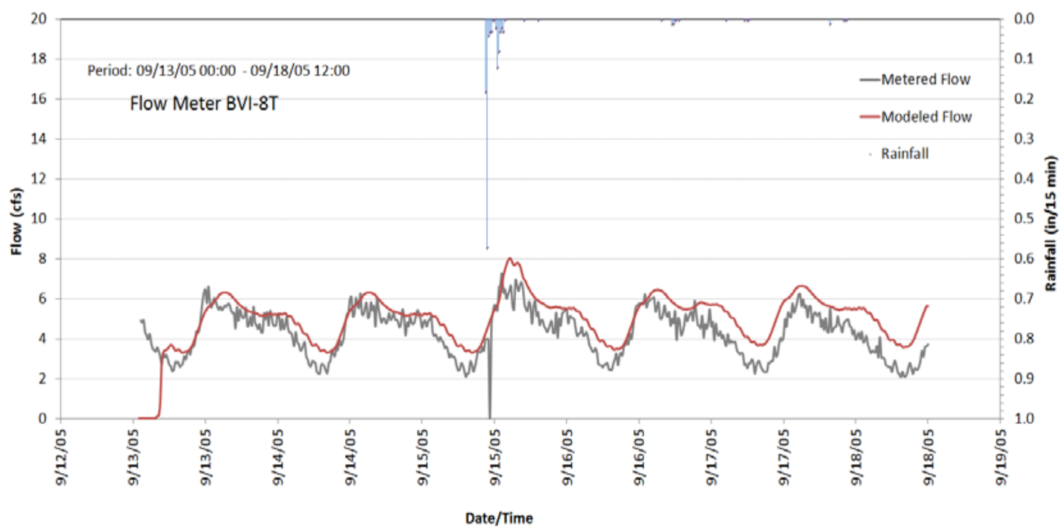


Figure B26 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter BVI-8T.

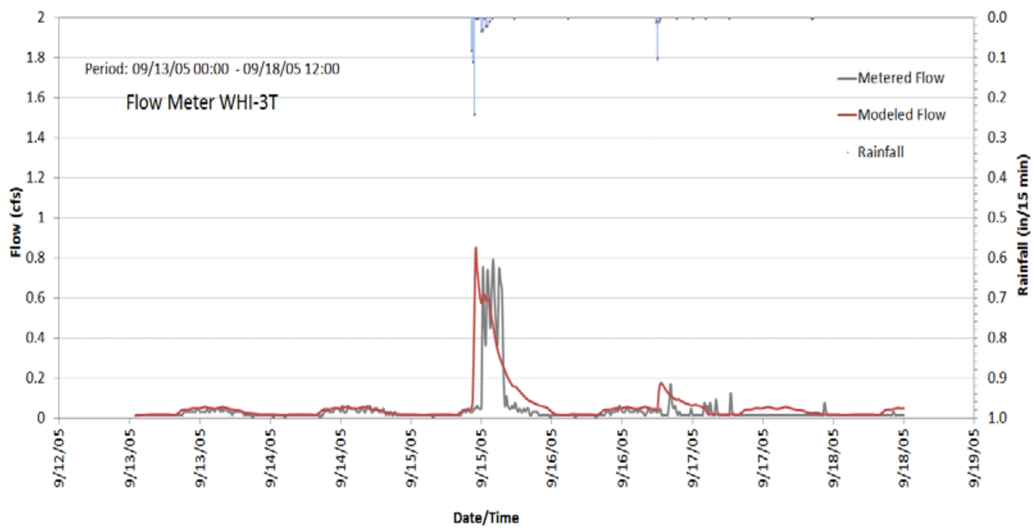


Figure B27 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter WHI-3T.

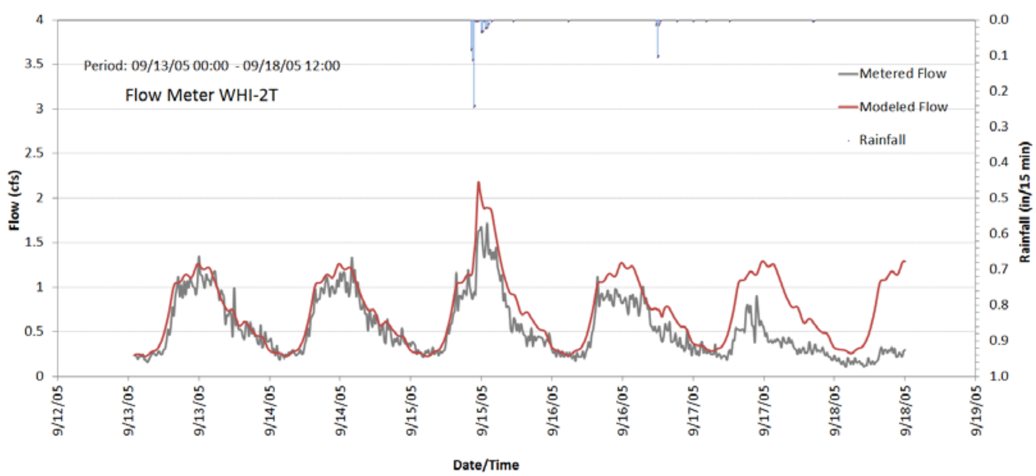


Figure B28 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter WHI-2T.

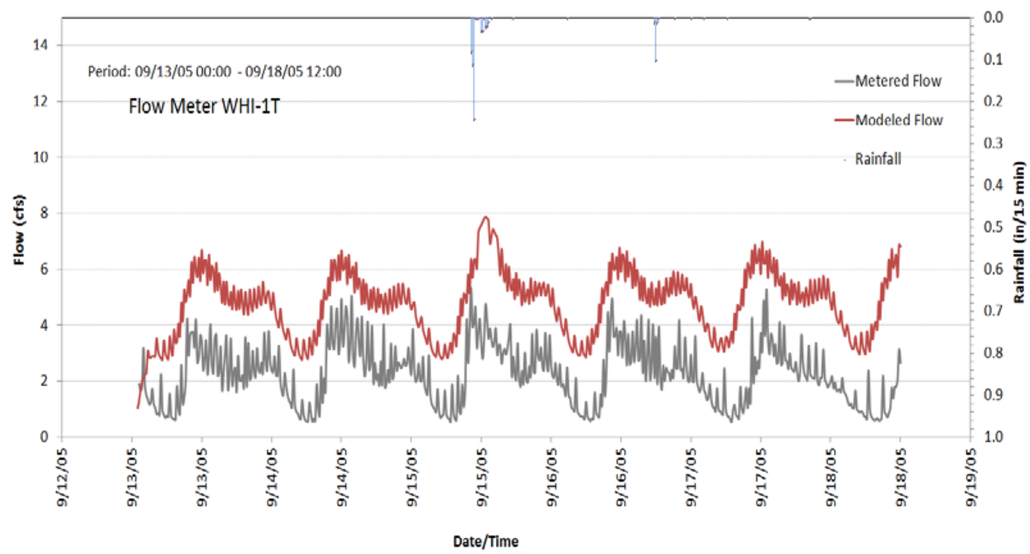


Figure B29– Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter WHI-1T.

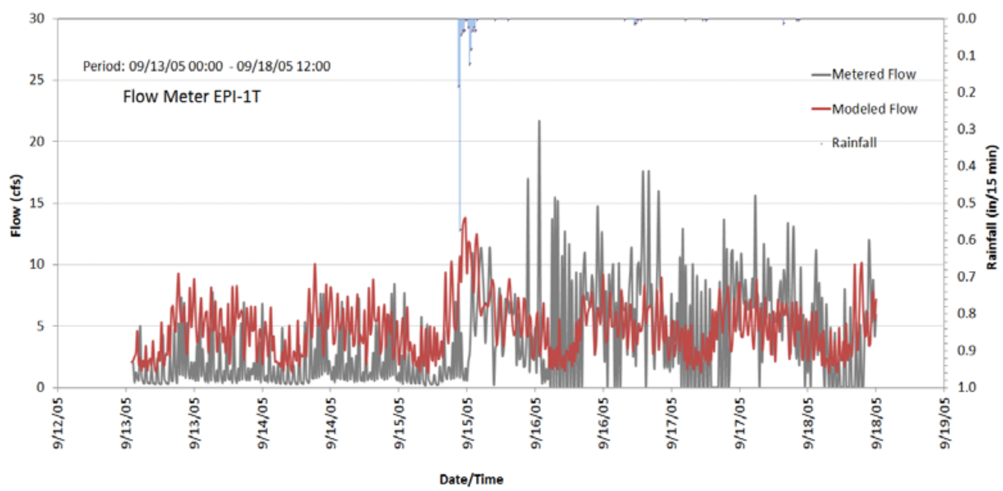


Figure B30 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter EPI-1T.

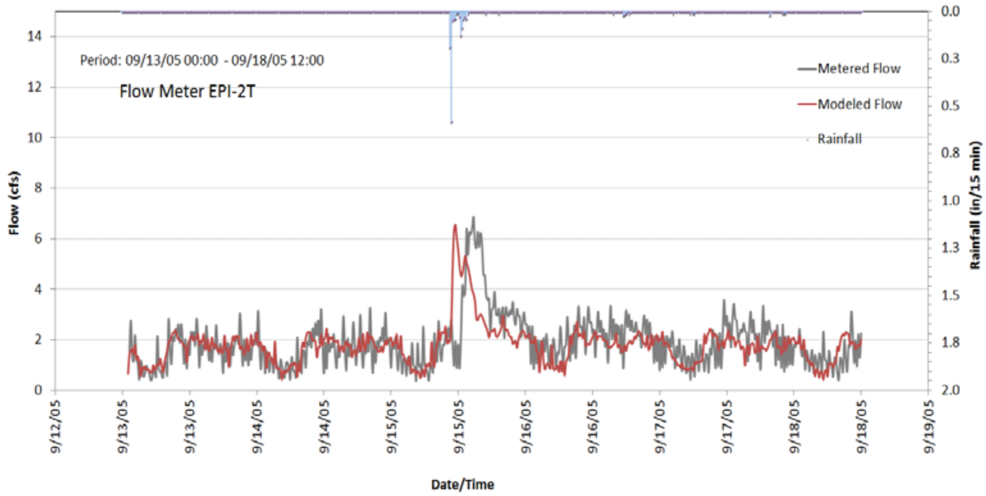


Figure B31 – Measured Vs Modeled flow discharge for the September 15, 2005 storm event at Flow Meter EPI-2T.

Table B3: % Difference between modeled and metered peak flows at meter locations for the April 1, 2014 storm event

	Peak Flow (cfs)			
Meter	**Meter**	**Model**	**% Difference**	**Notes**
ARI-2T	2.94	2.55	-13%	
ARI-1T	8.49	4.61	-46%	
BVI-13T	1.95	0.77	-60%	
BVI-12T	7.02	5.50	-22%	
BVI-11T	10.74	10.62	-1%	
BVI-10T	NA	10.65	NA	Meter data not available
BVI-9T	NA	14.23	NA	Meter data not available
BVI-8T	23.50	17.89	-24%	
WHI-3T	NA	1.54	NA	Meter data not available
WHI-2T	1.98	2.13	8%	
WHI-1T	12.08	12.44	3%	
EPI-1T	9.39	11.79	26%	
EPI-2T	5.12	4.69	-8%	

Table B4: % Difference between modeled and metered volumes at meter locations for the April 1, 2014 storm event

	Volume (cf)			
Meter	**Meter**	**Model**	**% Difference**	**Notes**
ARI-2T	837539	884959	6%	
	514553	1566848	205%	Large % Difference due lack of metered data over various time

ARI-1T				intervals
BVI-13T	203028	190706	-6%	
BVI-12T	2059046	1992150	-3%	
BVI-11T	3033784	2938077	-3%	
BVI-10T	NA	3700329	NA	Meter data not available
BVI-9T	NA	4520639	NA	Meter data not available
BVI-8T	6682709	6093415	-9%	
WHI-3T	NA	255733	NA	Meter data not available
WHI-2T	477175	460522	-3%	
WHI-1T	3619151	4114068	14%	
EPI-1T	2961606	3077332	4%	
EPI-2T	744680	989178	33%	

Table B5: % Difference between modeled and metered peak flows at meter locations for the September 15, 2014 storm event

	Peak Flow (cfs)			
Meter	**Meter**	**Model**	**% Difference**	**Notes**
ARI-2T	0.85	0.73	-14%	
ARI-1T	1.45	1.21	-17%	
BVI-13T	0.76	0.77	2%	
BVI-12T	2.12	1.31	-38%	
BVI-11T	2.69	2.97	10%	
BVI-10T	5.79	5.79	0%	
BVI-9T	5.79	7.98	38%	
BVI-8T	7.27	8.00	10%	
WHI-3T	0.79	0.84	6%	
WHI-2T	1.72	2.18	27%	
WHI-1T	5.32	7.86	48%	
EPI-1T	21.68	13.80	-36%	
EPI-2T	6.84	6.55	-4%	

Table B6: % Difference between modeled and metered volumes at meter locations for the September 15, 2014 storm event

	Volume (cf)			
Meter	**Meter**	**Model**	**% Difference**	**Notes**
ARI-2T	190341	201568	6%	
ARI-1T	353373	201568	-43%	
BVI-13T	86146	106968	24%	
BVI-12T	470532	479232	2%	
BVI-11T	664982	850329	28%	
BVI-10T	1793547	1904264	6%	

BVI-9T	1793547	2331138	30%
BVI-8T	2020053	2353053	16%
WHI-3T	18758	27441	46%
WHI-2T	255194	350382	37%
WHI-1T	1061664	2256472	113%
EPI-1T	1795454	2241647	25%
EPI-2T	890165	839309	-6%

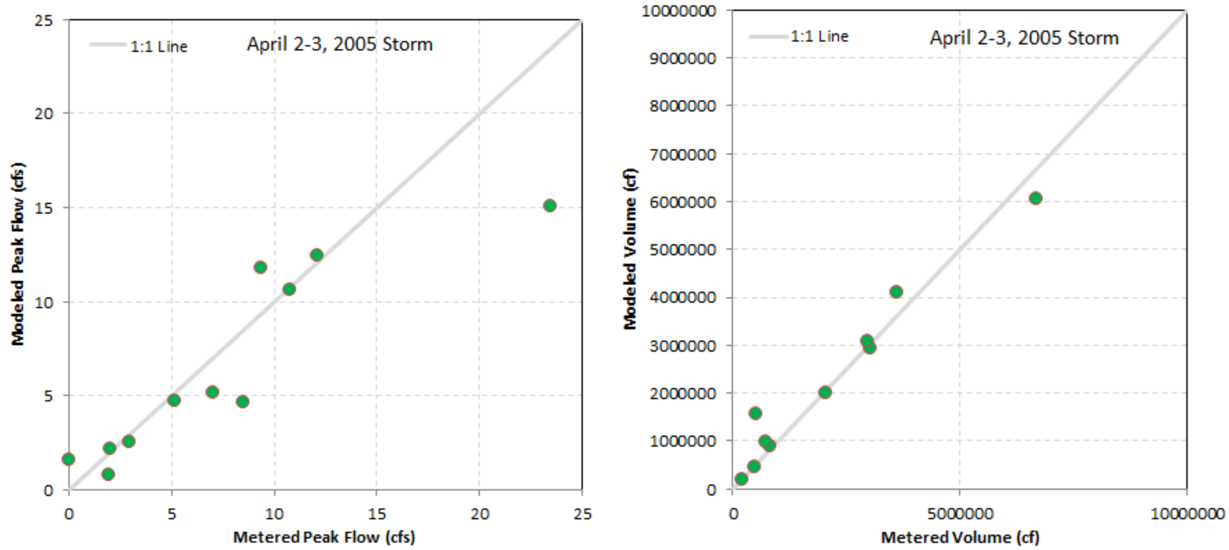


Figure B32. Modeled vs Metered peak flows (left) and volume (right) for the April 2, 2005 storm event.

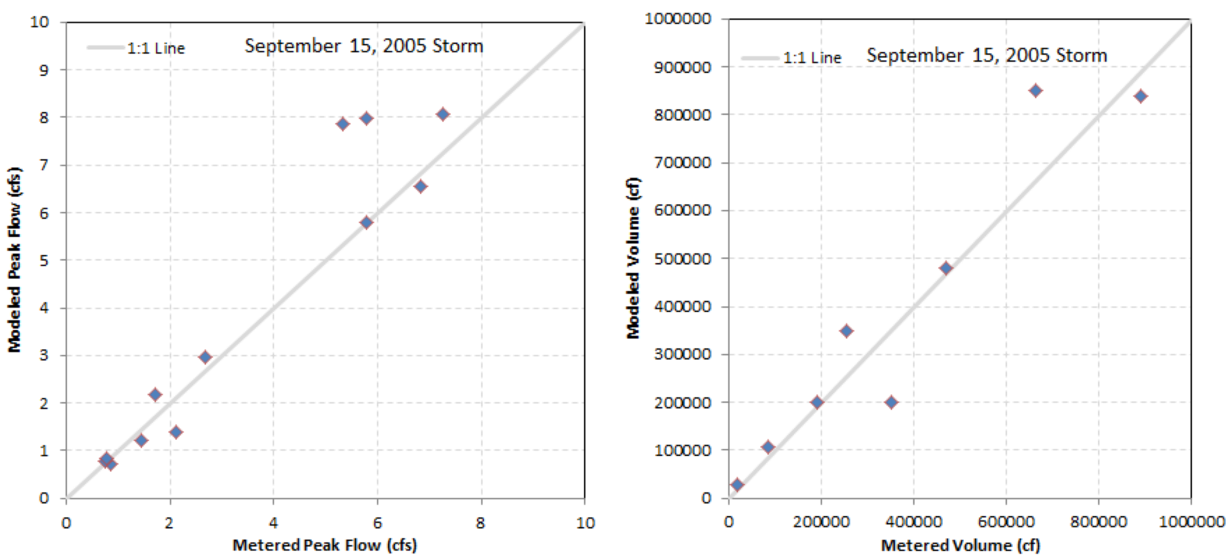
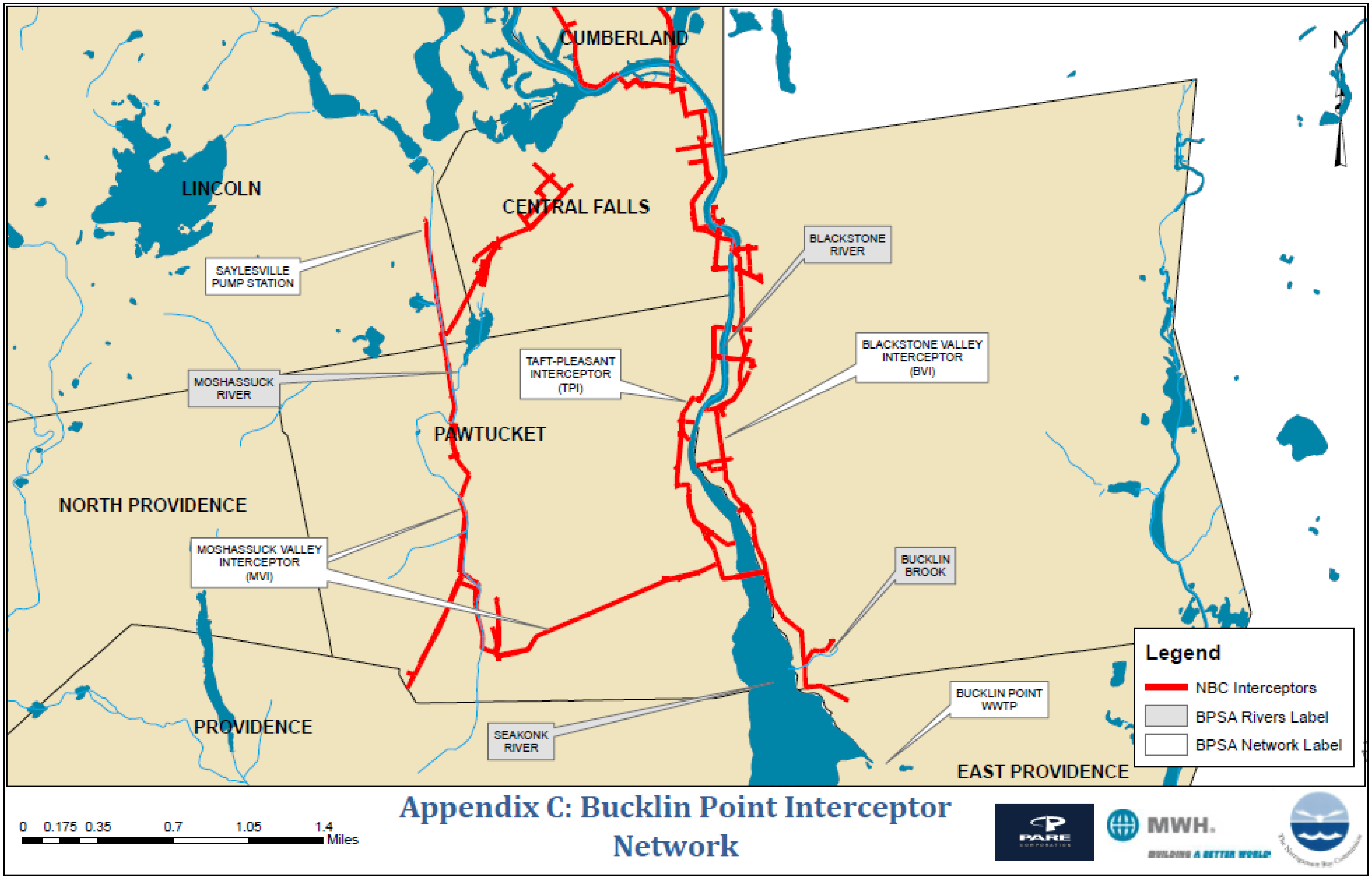
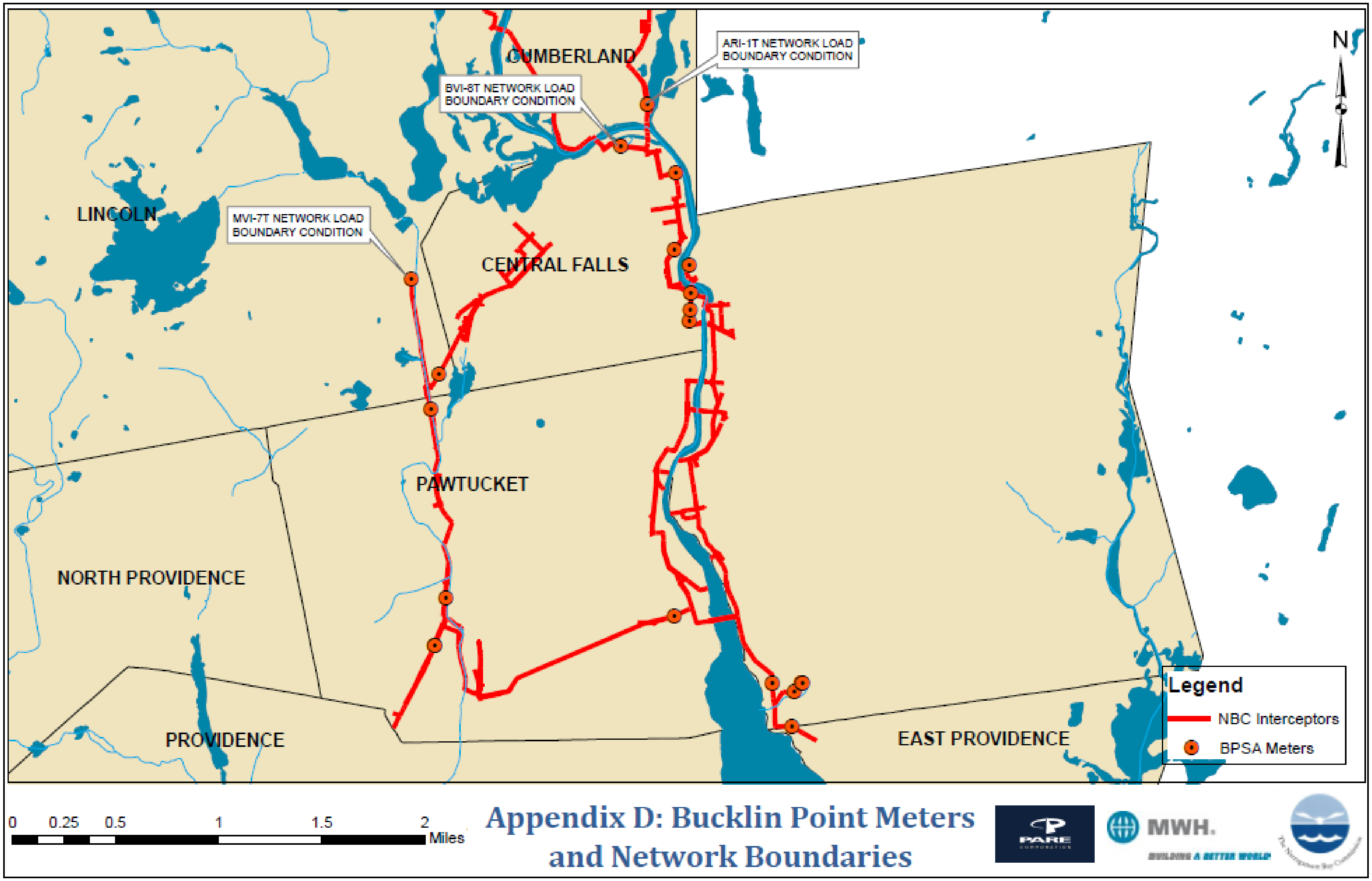


Figure B33. Modeled vs Metered peak flows (left) and volume (right) for the September 15, 2005 storm event.

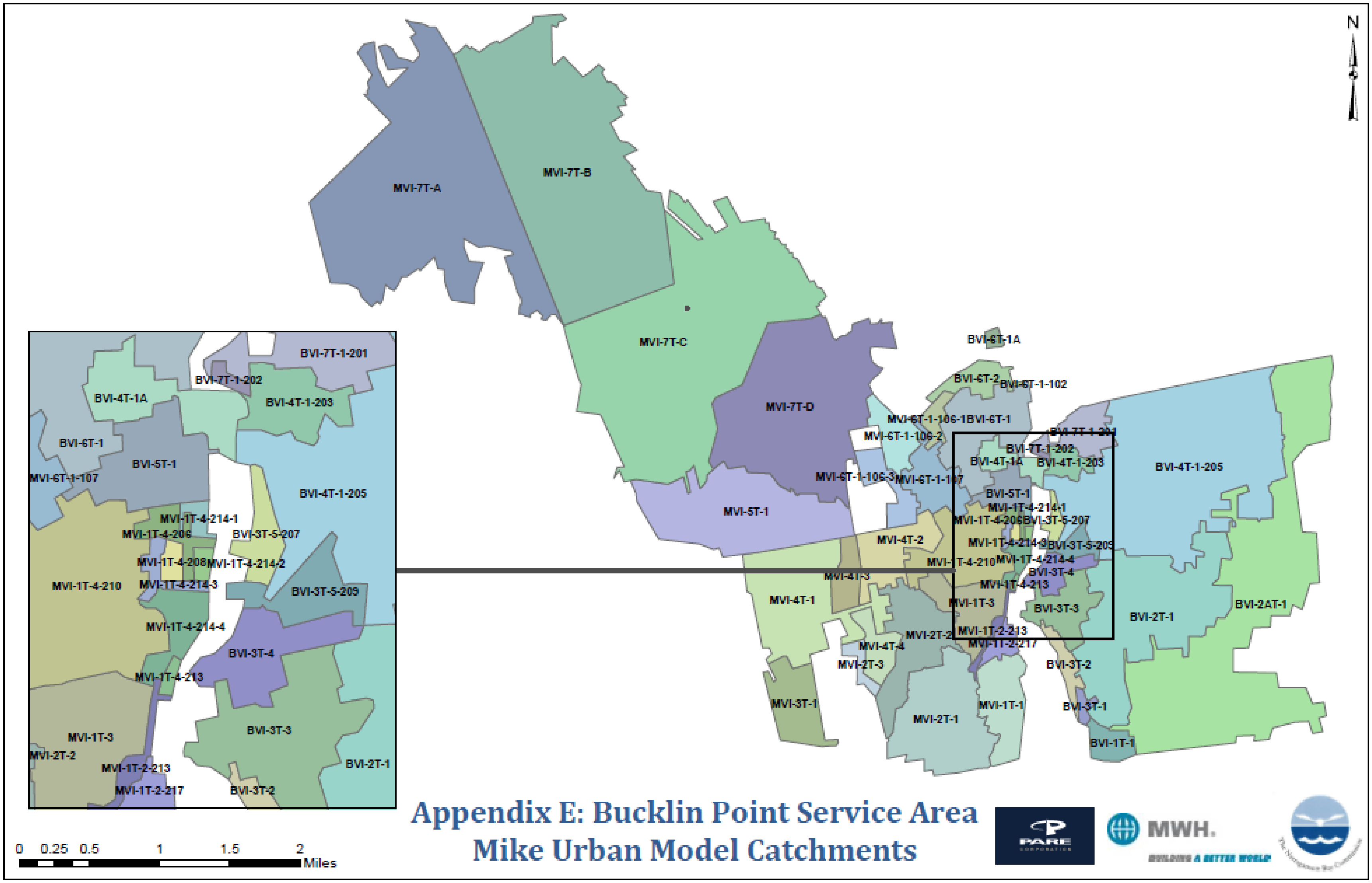
Appendix C: Bucklin Point Interceptor Network



Appendix D: Bucklin Point Meters and Network Boundaries

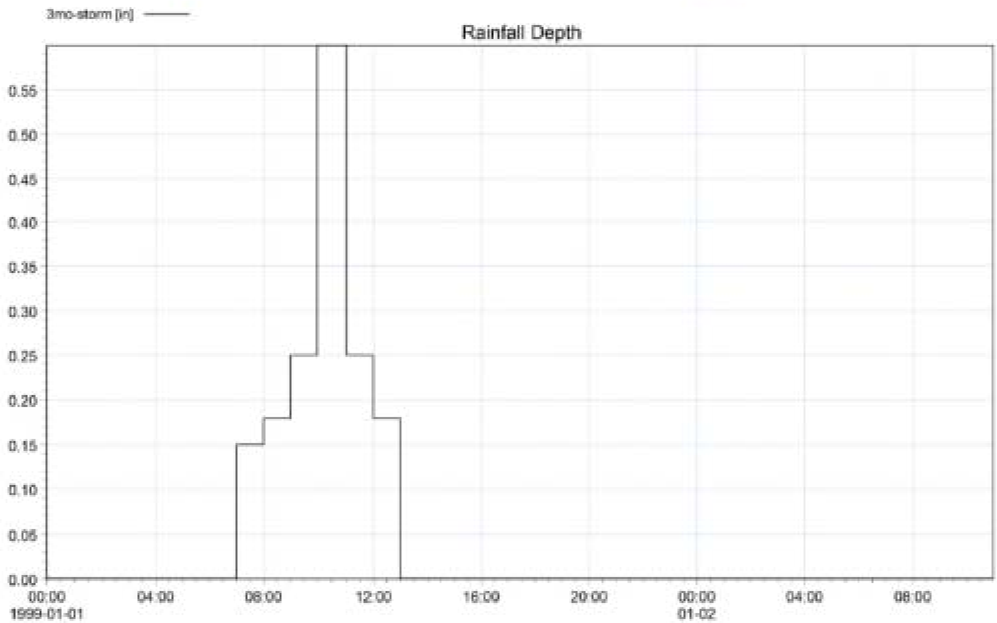


Appendix E: Bucklin Point Service Area Mike Urban Model Catchments

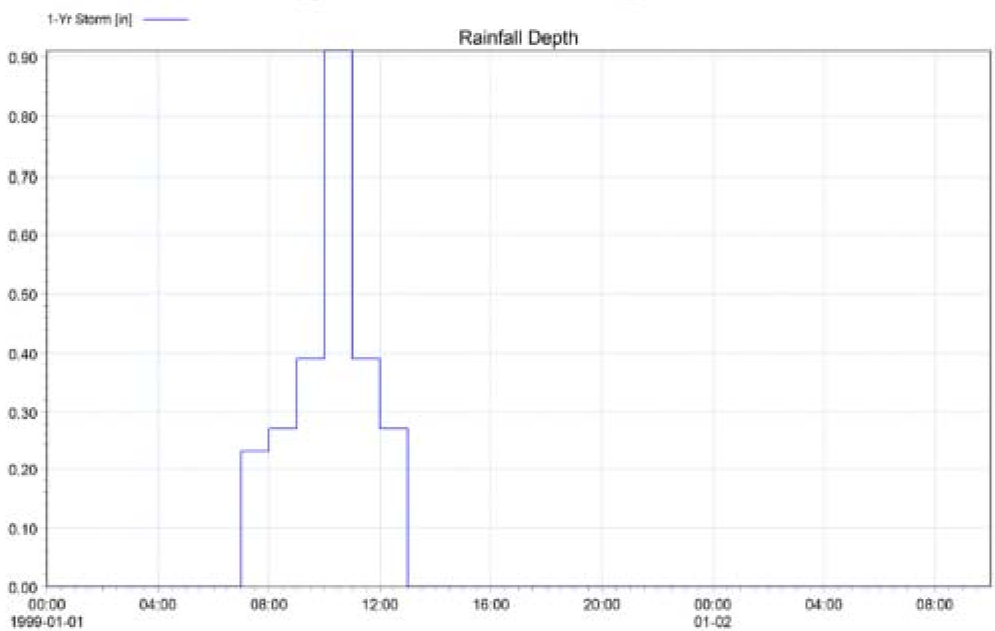


Appendix F: 3-Month and 12-Month Design Storms

Appendix F: 3-Month and 12-Month Design Storms

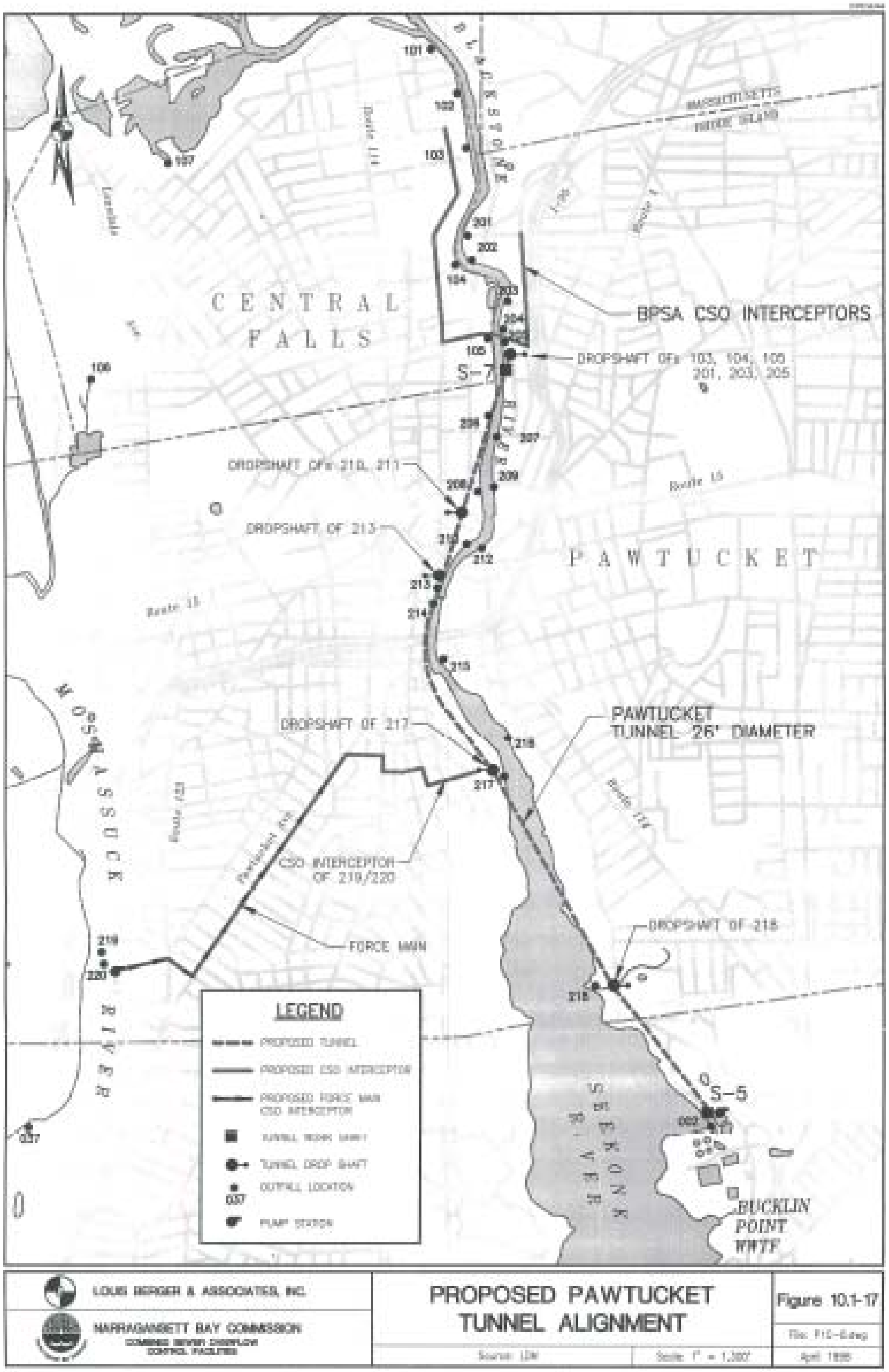


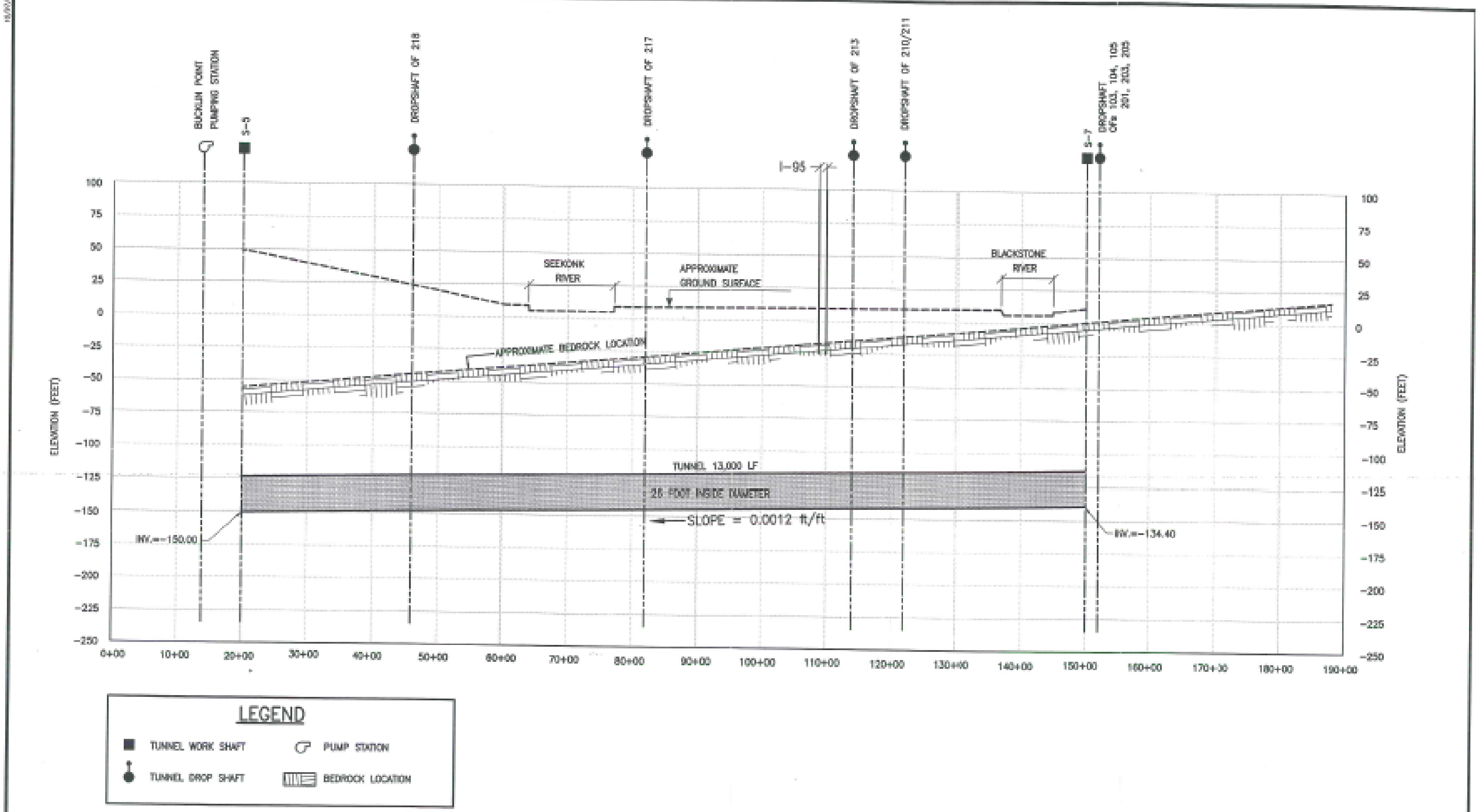
Appendix F.1: 3-Month Design Storm



Appendix F.2: 12-Month Design Storm

Appendix G: CDRA Phase III Plan and Profile Sheets





NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

PROFILE-PAWTUCKET TUNNEL

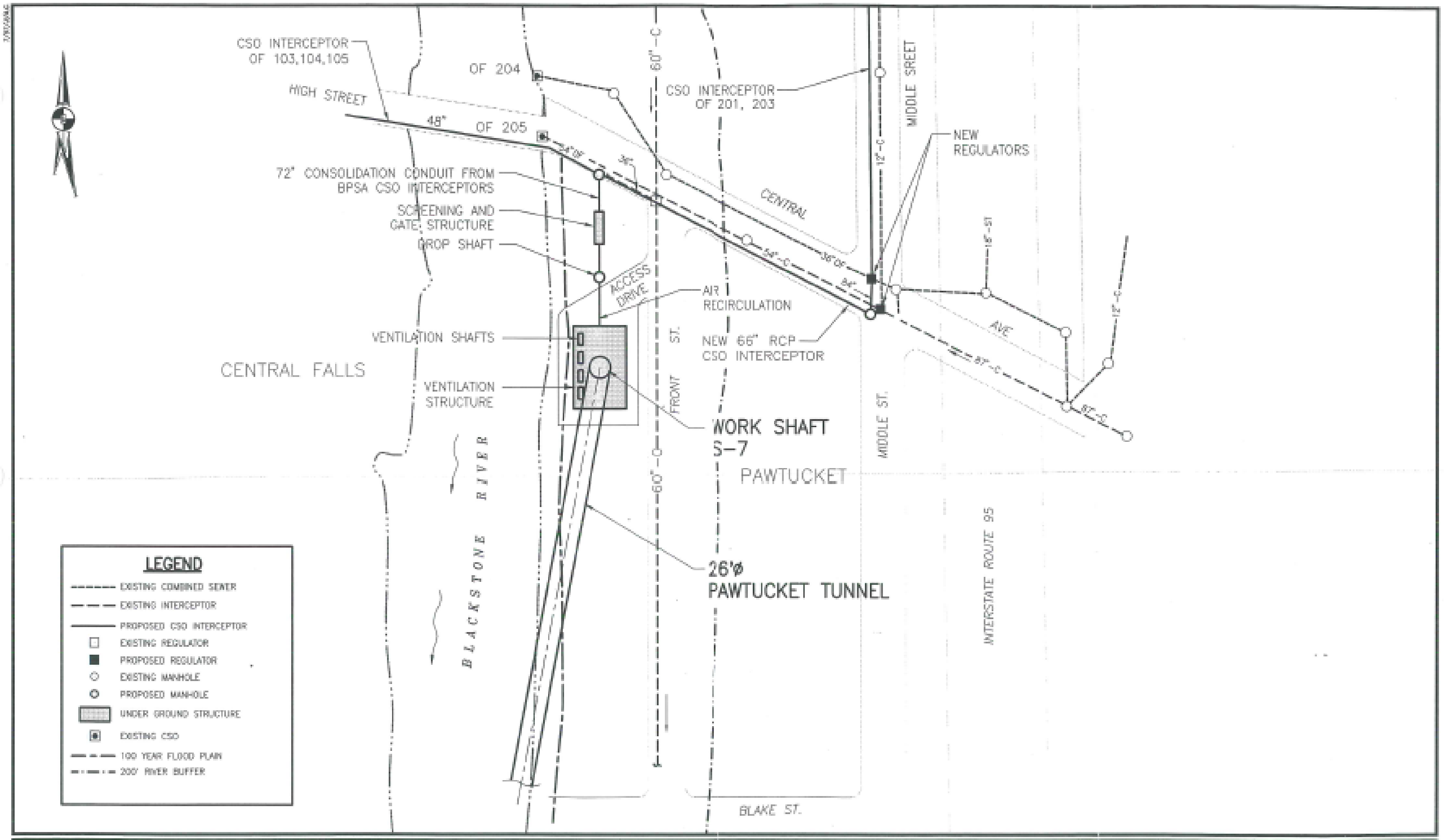
Figure: 10.1-18

File: P1C-4.dwg

Source: LDM

Scale: GRAPHICALLY REPRESENTED

March 1998



NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

WORK SHAFT S-7, FRONT STREET, PAWTUCKET TUNNEL SITE PLAN

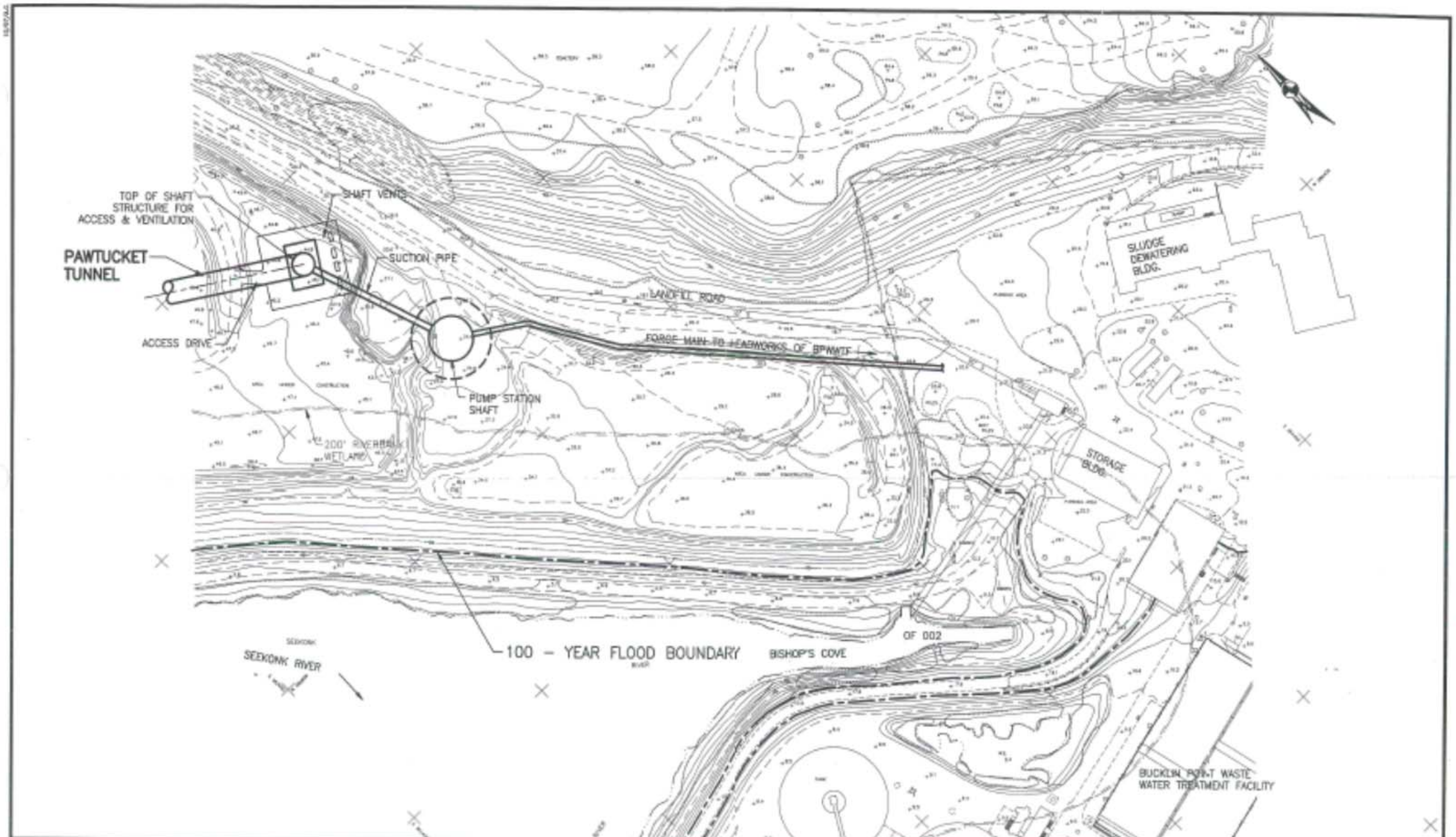
Figure: 10.1-19

File: P1C-57.dwg

Source: LDM

Scale: 1" = 100 Feet

March 1998



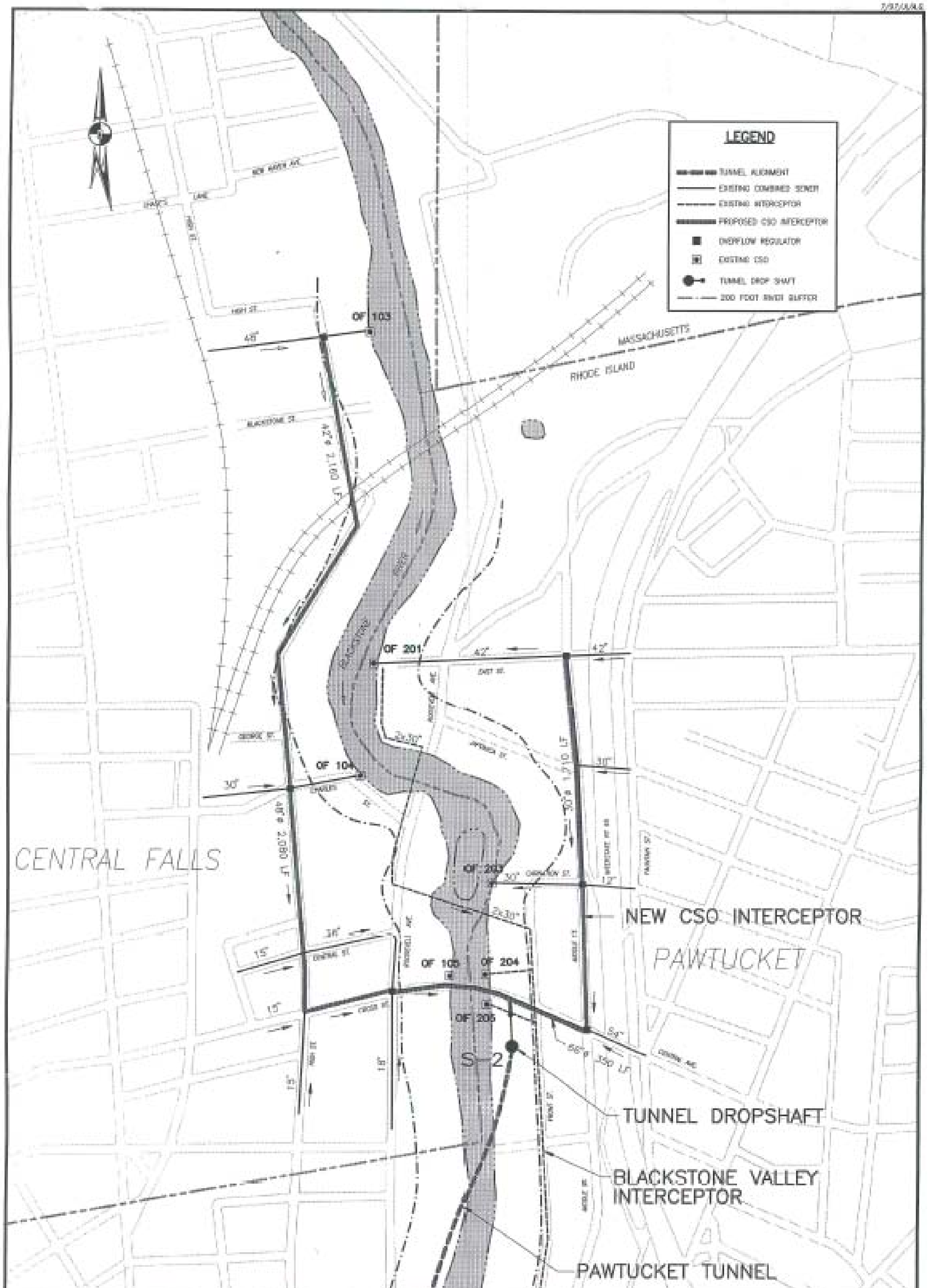
NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

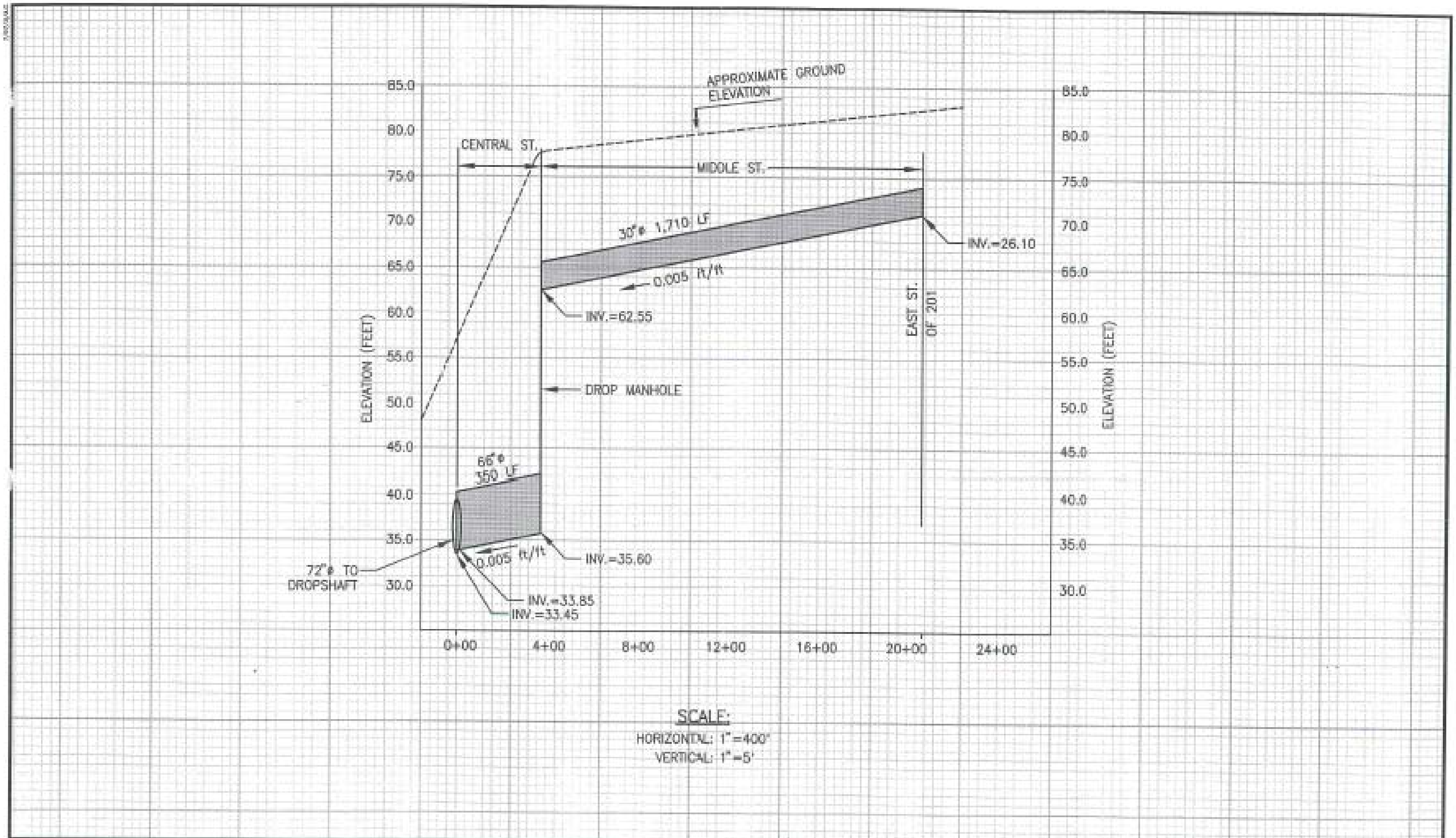
PROPOSED WORKSHAFT S-5
BUCKLIN POINT WWTF, EAST PROVIDENCE, SITE PLAN

Figure: 10.1-20

Source: LDM | Scale: 1" = 100 Feet | File: P1C-111.dwg | March 1998



LOUIS BERGER & ASSOCIATES, INC. NARRAGANSETT BAY COMMISSION COMBINED SEWER OVERFLOW CONTROL FACILITIES	**BPSA CSO INTERCEPTORS SITE PLAN**	Figure: 10.1-21 File: PIC-61.dwg
	Source: LDM — Scale: 1" =400 Feet	March 1998



NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

PROFILE-BPSA CSO INTERCEPTOR, OF 201 - OF 205

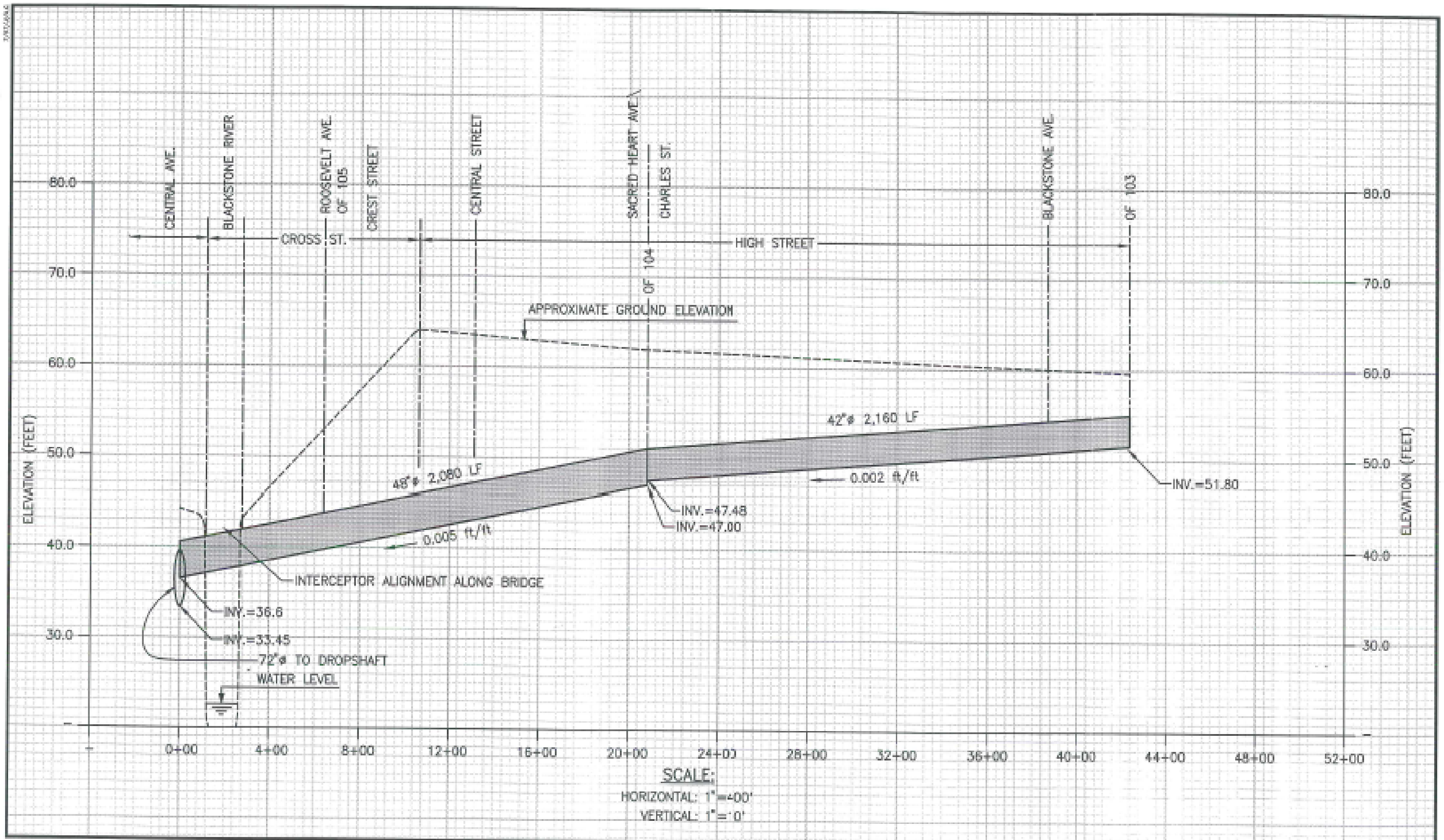
Figure: 10.1-22

File: P1C-5.dwg

Source: LDM

Scale: AS SHOWN

March 1998



NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

PROFILE - BPSA CSO INTERCEPTOR, OF 103, 104, 105

Figure: 10.1-23

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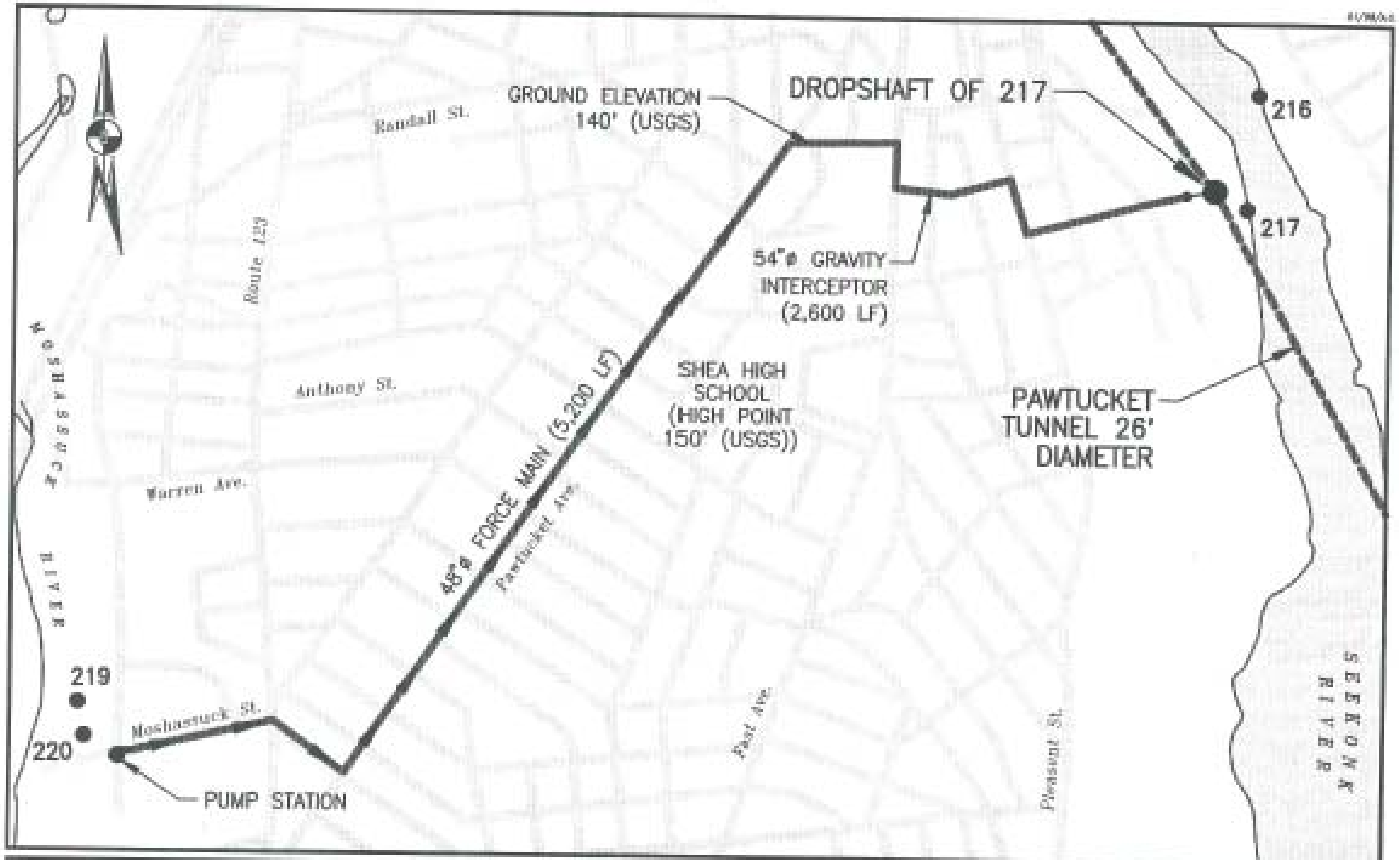
Source: LDM

Scale: AS SHOWN

March 1998



LOUIS BERGER & ASSOCIATES, INC.

NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW
CONTROL FACILITIES

OF 219/220 - FORCE MAIN, CSO INTERCEPTOR

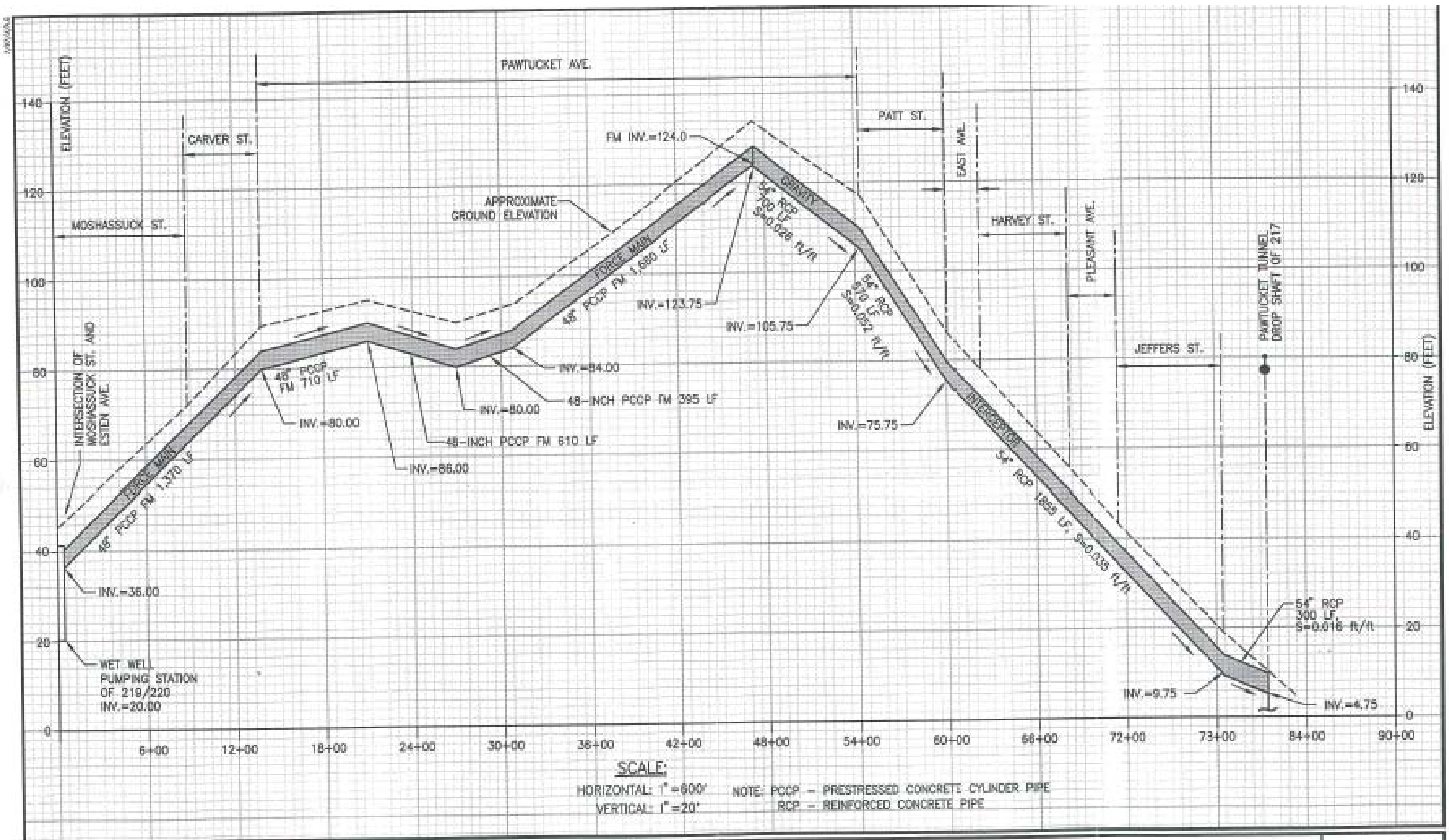
Figure: 10.1-24

File: P1C-102.dwg

Source: LDM

Scale: 1" = 700'

April 1998



NARRAGANSETT BAY COMMISSION
COMBINED SEWER OVERFLOW CONTROL FACILITIES

LOUIS BERGER & ASSOCIATES, INC.

PROFILE - OF 219/220 FORCE MAIN & GRAVITY INTERCEPTOR

Figure: 10.1-25

File: P1C-110.dwg

Source: LDM

Scale: AS SHOWN

April 1998

NBC CSO Control Facilities Phase III Reevaluation

Appendix 4 – Final Report: Evaluation of Water Quality Benefits of CSO Alternatives for Narragansett Bay

RPS

Final Report
Evaluation of Water Quality Benefits of CSO Alternatives for Narragansett Bay

Prepared for: MWH
Authors: Craig Swanson, Deborah Crowley, Tatsu Isaji, Daniel Mendelsohn and Cathleen Turner
Date: 15 June 2015
Project Number: 2013-303
RPS ASA | 55 Village Square Drive | South Kingstown, RI 02879

Executive Summary

MWH contracted RPS ASA on behalf of the Narragansett Bay Commission to perform a modeling study of fecal coliform (FC) concentrations within the receiving waters of Upper Narragansett Bay for a range of conditions and combined sewer overflow (CSO) configurations developed as part of a re-evaluation of alternatives originally developed under Phase III of the 1998 version of the Conceptual Design Report per a Consent Agreement with the Rhode Island Department of Environmental Management. The purpose of the modeling was to provide input from a receiving water quality improvement perspective to the larger benefit-to-cost analysis MWH was to perform. The present modeling study built on previous model applications of the WQMAP model system.

The previously calibrated model developed using RPS ASA's water quality modeling system WQMAP were used to simulate the circulation and FC concentrations within the study domain for a recent timeframe, March through August 2009 to ensure model validity. The model predictions of FC concentration were compared to available observations to evaluate the model's predictive ability for this application. Both the hydrodynamic and mass transport forcing were updated to reflect the recent timeframe which reflected Post Phase I CSO configuration. The data used for model load development indicated that the CSOs represented most (~ 77.3 %) of the loading to the system. Second to CSOs were the tributary loads (~22.7 %) and a relatively negligible amount (<0.1%) came from the waste water treatment facilities (WWTFs). The model and data were in good agreement. The model was able to successfully recreate the spatial and temporal variability and capture the range of the concentrations well. Furthermore the model successfully captured the trend of either above or below relevant thresholds most of the time at most locations. Limitations to the modeling included the assumptions necessary to define the loads and the sparse resolution of the tributary observations in space and time that contributed to uncertainty of the tributary loads. However, the most dominant loading factors were accounted for, including the major tributary loads and CSO loading.

The model was then used to evaluate the water quality based on loading for five CSO control alternatives developed by MWH as part of the Phase III reevaluation plus the controls developed and implemented for the earlier Phases I and II. Two hypothetical design storms, with 3-mo and 12-mo return periods, both with durations of six hours, were used in the evaluations of the seven scenarios. The Phase III alternatives ranged from single CSO removal to removal of all CSOs. In general, during design storms, the CSOs provided the largest fraction of FC loads to receiving waters followed by separated sewers (SS), rivers and WWTFs in descending order of load.

The model output was processed into three formats: time series of FC concentrations at four selected locations corresponding to NBC monitoring locations from the Seekonk River downstream to the start of the conditional closure at Conimicut Point; plan views of FC concentration contours for the Upper Bay,

and the Providence and Seekonk Rivers; and closure area tables expressed as area-time products for shellfishing and contact recreation FC concentration limits for six areas within the study area.

The time series at four selected stations for the 3-mo storm typically revealed an oscillating tidal component with a peak concentration indicative of the travel time down-river or –bay away from the FC source locations. For the northernmost Seekonk River and Providence Harbor stations the storm effects lasted approximately three days until dry weather FC concentration levels returned. The Providence River station showed storm levels greater than dry weather conditions for approximately eight days and the Upper Bay station for approximately 14 days.

Plan views of the study area for selected snapshots after the storm were generated for each of the seven scenarios and intercompared to show the extent of the FC concentration plumes moving down bay over time. The results at 0.5 days after the storm start were similar for all scenarios in extent of the concentration levels although the northern reaches of the Seekonk and Providence Rivers varied in peak concentrations depending on the load magnitude. At 1 and 2 days after storm start the concentrations were dropping for lower load magnitudes in the Seekonk although the downstream extent in the Providence River was similar for all scenarios. By 4 days the elevated concentrations reached into the conditional closure areas for all scenarios. By 8 days all scenarios showed reduced concentrations with the FC concentration levels and affected areas generally related to FC loads particularly in the lower Providence River and the conditional shellfish closure areas.

Finally closure area tables were prepared as area-time products for shellfishing and contact recreation FC concentration limits for six areas within the study area. For the southernmost conditional shellfish closure area B there was little effect even for the largest (Phase I) load. In conditional areas A and the Conimicut Triangle all scenarios showed an effect of closures expressed In acre/days generally ranking similarly to the source load ranking but modified by distance from the source loads to the specific closure area. The general trend continued for the contact recreation areas, Providence River SB, Providence River SB1 and Seekonk River SB1.

The 12-mo storm results followed the general trends seen in the 3-mo storm results but the magnitudes of the resulting FC concentrations and areas affected were significantly larger in response to the larger loads, particularly from CSOs.

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1 Introduction

MWH contracted RPS ASA on behalf of the Narragansett Bay Commission (NBC) to perform a modeling study of fecal coliform (FC) concentrations within the receiving waters of Upper Narragansett Bay for a range of conditions and combined sewer overflow (CSO) configurations developed as part of a re-evaluation of alternatives originally developed under Phase III of the 1998 version of the Conceptual Design Report (NBC, 1998) per a Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). The present modeling study built on previous model applications of the WQMAP model system (Swanson et al., 1993; Swanson et al., 1998) and to include a comparison of model predictions to more recent observational data as documented in NBC (2014). Two design storms of 3- and 12-month return periods were to be simulated for a range of CSO alternatives under this re-evaluation of final phase (III) of CSO control and the two earlier construction phases (I and II). The model results include plan views of the predicted FC concentrations in the Upper Bay at selected times during and after the storms, time series of FC concentrations at representative locations, and closure area metrics defined in terms of acre days above specific FC concentration thresholds for both shellfishing and contact recreation as defined in the Rhode Island water quality standards (RIDEM, 2010).

1.1 Study Area

The study area, shown in Figure 1.1 lies at the head of the Narragansett Bay. The area encompasses the Providence River, Seekonk River, and upper Narragansett Bay. The Providence River is formed by the confluence of the Moshassuck and Woonasquatucket Rivers in the center of Providence. From its head, the river runs south approximately 2 km (1.2 mi) to the hurricane barrier at Fox Point. The river is generally quite shallow and narrow in this reach but widens to 100-150 m (300-1500 ft) and deepens to 3-7 m (10-23 ft) at the barrier. Just below the hurricane barrier at India Point, the Seekonk River joins the Providence River. Below this point, the Providence River is relatively wide at 500 m (1660 ft). It expands to approximately 2 km (1.2 mi) below Fields Point and continues to widen to its mouth at Conimicut Point, 11.6 km (7.3 mi) south of Fox Point, where it becomes Upper Narragansett Bay. Upper Narragansett Bay extends to the northern end of Prudence Island.

The Seekonk River begins at the dam defining the head of the tide in Pawtucket. Above this dam the river is known as the Blackstone. The Seekonk is approximately 7.3 km (4.6 mi) long from its head to its mouth where it empties into the Providence River at India Point. At its northern and southern reaches it is relatively narrow, at 30 to 150 m (100 to 500 ft) wide with its central portion approximately 400 to 800 m (1300 to 2600 ft) wide with shallow areas along a central channel.

A navigation channel runs from Upper Narragansett Bay to Fox Point. The channel design depth is 12.2 m (40 ft) at MLW. It is typically 200 m (650 ft) wide below Fields Point and is flanked by wide shallow areas typically 1-2 m (3-7 ft) deep. Above Fields Point the deep dredged area widens to both banks of the river, 500 m (1600 ft), to accommodate shipping traffic. A shallow navigation channel, 5 m (16 ft) wide and 46 m (150 ft) deep runs up the Seekonk River.

The circulation in the Providence River, the Seekonk River and upper Narragansett Bay, is dominated by the tides. Based on an analysis of current data obtained at three locations in the river, Turner (1984) concluded that approximately 70-80% of current variance occurred at tidal frequencies. More than 50% of the variance in each record was present at the semidiurnal M2 constituent (12.42-hr) band. Similar results have been reported (ASA, 1985) from current observations made at Cold Spring Point in the Seekonk River.

The circulation in the area can also be influenced by the local wind field. Turner (1984) found a distinct response to wind events at 3 to 10 day periodicities in the Providence River. Currents at the 3 and 6 m (10 and 20 ft) depths showed an upwind flow to replace water moving downwind at the surface. The response of currents to wind events was also observed in the Seekonk River (ASA, 1985), however the response was significantly smaller.

Although much smaller in magnitude, the typical two-layered estuarine circulation contributes to net circulation in the area. Turner (1984) found mean current speeds in the Gaspee- Bullock Points transect to vary between 2.4-7.2 cm/s (0.079-0.24 ft/s). At the 3 and 6 m·(10 and 20 ft) depths, the mean current direction was upstream. This was attributed to the fact that at least 50% of the cross-sectional area of the transect was shallower than 3 m (10 ft). ASA (1985) observed a 2.3 cm/s (0.075 ft/s) down-estuary mean flow 1.5 m (5 ft) below the MLW surface and a 5.3 cm/s (0.18 ft/s) up-estuary mean flow 1.5 m (5 ft) above the bottom near Cold Spring Point in the Seekonk River. Modeling of the gravitational circulation (Mendelsohn and Swanson, 1991) also showed currents in the range from 1 cm/sec (0.3 in/sec) to 10 cm/sec (3.0 in/sec).

Figure 1-1.Study area.

1.2 Background

The NBC completed a comprehensive, multiphase plan in 1993 to address the need to control CSO discharges to the waters of the Providence River / Upper Narragansett Bay and its tributaries. The first phase was implemented in 2008 and the second phase is now nearing completion. NBC must now start work on a design to address the remaining CSOs identified in phase III and has contracted with MWH to evaluate the improvements in water quality from the first two phases, reevaluate the phase III recommendations, and develop updated design options with the goal to achieve control of CSO discharges up to a storm with a 3-mo return period. This reevaluation is warranted since the costs of the previous recommended alternatives have escalated while other options based on improved technology for grey and green infrastructure are now available. In addition USEPA has introduced new guidance on affordability and integrated planning for CSO projects which need to be incorporated into the Phase III planning.

The purpose of the modeling that MWH contracted with RPS ASA was to provide input from a receiving water quality improvement perspective to the larger benefit-to-cost analysis MWH was to perform.

2 Modeling Approach

The modeling approach for this study followed the earlier modeling efforts performed by ASA in support of the development and evaluation of a CSO control strategy from a water quality improvement perspective. The WQMAP modeling system used in these studies is described in the first section below, followed by a summary of previous WQMAP applications to the Upper Bay CSO problem.

2.1 WQMAP Model

In conducting aquatic environmental analyses, ASA has developed a modeling system, which integrates geographic information (land use, watersheds, etc.), environmental data (water quality parameters, surface elevations and velocities, stream flows, bathymetry, etc.) and models (analytical and numerical, hydrodynamic, pollutant transport, etc.). The power of such a system, called WQMAP (Water Quality Mapping and Analysis Program) (Mendelsohn, et al., 1995), is that it allows the user to model and analyze many different scenarios efficiently. A graphical user interface simplifies user inputs and allows a graphical display of model output. In addition, one of the modeling components within ASA's WQMAP has been specifically developed for application to the study of effluent fates in coastal waters.

The geographic information component of WQMAP holds user-specified layers of data appropriate for and available to be used to address a specific task. For example, in this instance such layers might include shorelines, discharge locations, sensitive habitats, monitoring data locations, etc. Each data layer can be easily input, either created directly in WQMAP or through import from existing geographic information system software. Data can be exported as well. Each layer can be displayed separately or in any combination.

The WQMAP computational engine is a family of general curvilinear coordinate system computer models including a boundary conforming gridding model (BFGRID), a hydrodynamic model (BFHYDRO), a single constituent mass transport model (BFMASS) and an eight state variable water quality, eutrophication model (BFWASP). These model components will be described briefly in the following sections.

2.1.1 BFGRID - Boundary Fitted Coordinate Grid Generation

The boundary fitted grid generation model is a tool used to build a grid of the study area on which the hydrodynamics and pollutant transport models run. The boundary-fitted coordinate system approach generates transformation functions such that all domain boundaries are coincident with coordinate lines. The grid generation is accomplished by using a set of coupled quasi-linear elliptic transformation equations to map an arbitrary horizontal multi-connected region from physical space to a rectangular mesh structure in the transformed horizontal plane (Mendelsohn, 1995; Spaulding, 1984; Thompson et al., 1977). While the transformed set of equations is considerably more complex than the original set, the transformed boundary conditions are specified on straight lines and the coordinate spacing is uniform in the transformed plane. It should further be noted that the orthogonal and conformal curvilinear grids, as well as the simple stretched rectangular grids, are special cases of the general curvilinear, boundary-fitted coordinate approach used here.

Key boundary points are specified by the user and the structure of computational grid (I,J coordinates) is defined on the map, interactively in a map based graphical user interface. After specifying key grid nodes (grid corners) along the domain boundary, the model interpolates the remaining boundary node locations and then solves the transformed equations to locate the interior nodes. The resulting non-orthogonal grid contains quadrilaterals of various sizes and orientation to both resolve fine details where needed and cover large areas where resolution is not required. The hydrodynamic and water quality models then use this grid in their numerical solution of the appropriate conservation equations.

2.1.2 BFHYDRO – Hydrodynamic Model

BFHYDRO is a three dimensional, general curvilinear coordinate, boundary-fitted computer model (Muin and Spaulding, 1997; Huang and Spaulding, 1995b; Muin, 1993) used to predict elevations, and current velocities in river, lake, coastal and ocean waters. The boundary-fitted model matches the model coordinates with the shoreline boundaries of the water body, accurately representing the study area. This system also allows the user to adjust the model grid resolution as desired. Development of the boundary fitted model approach has proceeded over more than two decades (Mendelsohn, 1998; Huang and Spaulding, 1995a; Muin, 1993; and Spaulding, 1984). The model may be applied in either two or three dimensions, depending on the nature of the inquiry and its complexity.

A detailed description of the model, with associated test cases, is included in Muin and Spaulding (1997). The publication was originally part of a Ph.D. dissertation (Muin, 1993), which extended the boundary fitted model capabilities developed by Swanson (1986), applying a contra-variant velocity formulation to the transformed momentum equations. A brief description of the model follows.

The boundary fitted method uses a set of coupled, quasi-linear, elliptic transformation equations to map an arbitrary horizontal multi-connected region from physical space to a rectangular mesh structure in the transformed horizontal plane (Spaulding, 1984). The three dimensional conservation of mass and momentum equations, with approximations suitable for lakes, rivers, and estuaries (Swanson, 1986; Muin, 1993) that form the basis of the model, are then solved in this transformed space. In addition a sigma stretching system is used in the vertical to map the free surface and bottom onto coordinate surfaces to resolve bathymetric variations. The resulting equations are solved using an efficient semi-implicit finite difference algorithm for the exterior mode (two dimensional vertically averaged), and by an explicit finite difference leveled algorithm for the vertical structure of the interior mode (three dimensional) (Swanson, 1986). The velocities are represented in their contra-variant form.

The basic equations are written in spherical coordinates to allow for accurate representation of large modeled areas. The conservation equations for water mass, momentum (in three dimensions) and constituent mass (temperature [heat] and salinity) form the basis of the model, and are well established. It is assumed that the flow is incompressible, that the fluid is in hydrostatic balance, the horizontal friction is not significant and the Boussinesq approximation applies all customary assumptions.

The boundary conditions are as follows:

- At land, the normal component of velocity is zero.
- At open boundaries, the free surface elevation must be specified, and temperature (and salinity for estuarine and coastal applications) specified on inflow. Surface elevation is based on the tides with an average range of 3.70 feet at the southern boundary of the model domain. Tidal data was obtained from NOAA Station 8454049 at Quonset Point.
- On outflow, temperature (heat) and salinity is advected out of the model domain.
- A bottom stress or a no slip condition is applied at the bottom. No temperature (heat) is assumed to transfer to or from the bottom, a conservative assumption as some transfer of heat to the bottom is expected to occur.
- A wind stress and appropriate heat transfer terms are applied at the surface.
- The surface heat balance includes all of the primary heat transfer mechanisms for environmental interaction

There are various options for specification of vertical eddy viscosity, A_v, (for momentum) and vertical eddy diffusivity, D_v, (for constituent mass [temperature and salinity]). The simplest formulation is that both are constant, A_{vo} and D_{vo}, throughout the water column. They can also be functions of the local Richardson number, which, in turn, is a function of the vertical density gradient and vertical gradient of horizontal velocity.

The set of governing equations with dependent and independent variables transformed from spherical to curvilinear coordinates, in concert with the boundary conditions, is solved by a semi-implicit, split mode finite difference procedure (Swanson, 1986). The equations of motion are vertically integrated and, through simple algebraic manipulation, are recast in terms of a single Helmholtz equation in surface elevation. This equation is solved using a sparse matrix solution technique to predict the spatial distribution of surface elevation for each grid.

The vertically averaged velocity is then determined explicitly using the momentum equation. This step constitutes the external or vertically averaged mode. Deviations of the velocity field from this vertically averaged value are then calculated, using a tridiagonal matrix technique. The deviations are added to the vertically averaged values to obtain the vertical profile of velocity at each grid cell thereby generating the complete current patterns. The methodology allows time steps based on the advective, rather than the gravity, wave speed as in conventional explicit finite difference methods, and therefore results in a computationally efficient solution procedure (Swanson, 1986; Muin, 1993).

The environmental heat transfer model, (Mendelsohn, 1998) at the water surface contains a balance of the important terms governing the flow of heat, including:

- short wave solar radiation
- long wave atmospheric radiation
- long wave radiation emitted from the water surface
- convection (sensible) heat transfer between water and air
- evaporation (latent) heat transfer between water and air

The temperature model follows the formulation of the coupled, three-dimensional, boundary-fitted, general curvilinear coordinate, hydrodynamic and salinity transport model system. The temperature model is integrated in the hydrodynamic model system and solves the temperature equation at each time step.

2.1.3 BFMASS – Pollutant Transport Model

The pollutant transport model system solves the conservation of mass equation on the boundary fitted grid to predict time varying fields of constituent concentration (Mendelsohn and Swanson, 1992). Single and multiple, constant and time varying loads can be applied in any configuration within the domain. Constituents can include pathogens, excess temperature, metals, suspended sediment, nutrients, dissolved or particulate, organics and conservative tracers.

The pollutant transport model is based on the three-dimensional conservation of pollutant mass equation modified to account for settling, sources and sinks of materials and interactions between water quality parameters. Mass conserving estimates of the time averaged turbulent velocity field are obtained from the hydrodynamic model and used to transport the pollutant. To be consistent with the hydrodynamic model equations, the pollutant mass conservation equation is also transformed both in the horizontal, to the boundary fitted coordinate system and in the vertical, to the sigma coordinate system.

The boundary conditions for the pollutant mass transport equation are as follows:

- for land boundaries, the bottom boundary and the water surface, the mass flux is zero
- at the open water tidal boundaries on outflow, mass is advected out of the domain by the appropriate normal velocity

- on tidal inflow either a concentration level can be specified or an assumed percentage of the outflow is returned.
- at open river/canal boundaries a concentration level is specified

A forward in time, centered in space implicit finite difference technique (Roache, 1976) is used to solve the mass conservation equation on the same grid used in the hydrodynamic model. Concentration values are defined at the center of each grid cell.

2.1.4 WQMAP System Applications

The BFHYDRO and BFMASS models in WQMAP have been successfully used in many hydrodynamic and pollutant transport studies both in the U.S. and worldwide with results accepted by a variety of federal and state government agencies, including the following:

- U. S. Environmental Protection Agency
- U. S. National Oceanic and Atmospheric Administration
- U. S. Army Corps of Engineers
- U.S. Naval Oceanographic Office
- Massachusetts Department of Environmental Protection
- Massachusetts Coastal Zone Management
- Rhode Island Department of Environmental Management
- Rhode Island Coastal Resources Management Council
- Vermont Agency of Natural Resources
- Connecticut Department of Environmental Protection
- New York State Department of Environmental Conservation
- South Carolina Department of Health and Environmental Control
- The World Bank
- Bahamas Environment, Science and Technology Commission
- Water Transportation Institute, China
- Royal Commission for Jubail and Yanbu

In addition, the WQMAP model systems have been applied to well over 100 hydrodynamic and pollutant transport engineering applications and many dozens of development and application studies have been published in peer review journals, technical briefs and conference proceedings.

2.2 Previous Application to CSOs for Upper Narragansett Bay

Modeling the FC transport in Narragansett Bay and the Providence River has been ongoing for 40 years. The starting point was the assessment of recovery time of the bay to a pulse load of sewage (Spaulding et al., 1974) by simulating CSO overflows due to a rainstorm event. In an effort to better understand the distribution of FC discharged by the rivers and sewage treatment plants, Hunter (1975) applied a three dimensional pollutant transport model to the upper bay (north of Conimicut Point), using the results from his two dimensional tidal hydrodynamic model as input. Model predictions were in reasonably good agreement with available data and indicated that the rivers were a major source of coliform pollution. Major problems with the modeling effort, in addition to a lack of adequate field data to verify the hydrodynamics model, were significant problems in specifying the flux of pollutants through the model boundary and lack of adequate coliform data for model verification.

Using a simpler approach, Swanson and Jayko (1988a) applied a box model methodology to Narragansett Bay. Swanson and Spaulding (1983) used a two dimensional vertically averaged water quality model to predict fecal coliform levels in upper Narragansett Bay for a variety of waste loading alternatives. A hydrodynamic model with a 300 m grid spacing provided circulation data. Swanson and Spaulding performed a sensitivity study to assess the impacts of dispersion coefficient, decay rate, and source strength on the predicted coliform concentrations.

While this model was sufficient to investigate alternate waste treatment strategies in the Providence River, the grid system was found to be too coarse to adequately represent the much narrower tributary rivers emptying into the Providence River, namely the Seekonk, Moshassuck, West, and Woonasquatucket Rivers. Limitations on computer power limited the refinement of the two dimensional model grid system.

Spaulding et al. (1985) and later Swanson et al. (1987) expanded the basic model to include laterally averaged multi-level channels capable of representing the Providence River and its tributaries. This model system consisted of a hydrodynamic component solving the conservation of water mass and momentum equations and a water quality component solving the conservation of pollutant mass equation. The model was first successfully applied to the Seekonk River and the Providence River south to Conimicut Point (Spaulding et al., 1985). Various treatment scenarios were investigated for CSO Area A which showed that major cleanup efforts in that CSO area would not result in significant improvement of water quality in the Seekonk or Providence Rivers. Other pollutant sources were found to contribute higher loads than the CSO loads from Area A.

Application was also made to CSO Area B, the Moshassuck and West Rivers (Swanson et al., 1987). The model area extended from the Providence city line on these two rivers south to the northern tip of Prudence Island in upper Narragansett Bay. Treatment of the CSO discharges was found to result in substantial reductions in fecal coliform levels, particularly in the freshwater portions of the rivers. Since a number of other CSO areas, for which no loading data were available, also empty into the Providence River, estimates of water quality improvement could only be made in a relative sense.

An additional application was made to CSO Area C, the Woonasquatucket River (Swanson and Jayko, 1988b). The model domain extended from the beginning of the tidal portion of the Woonasquatucket River south through the Providence River and upper Narragansett Bay to Prudence Island. Pollutants examined included fecal coliforms, copper, zinc, and biochemical oxygen demand. Two extreme scenarios were investigated: the present situation with no improvement and the complete elimination of CSO flows. The analysis for fecal coliforms was augmented by investigating the response of the upper bay to loads from other sources. Fecal coliform concentrations were approximately 100 times higher with CSO Area C loads in the Woonasquatucket River than without, dropping to approximately 10 times higher below the Hurricane Barrier. This difference was completely masked, however, when loads from other CSO areas were included in the simulations.

A companion modeling effort in the freshwater portion of the Woonasquatucket River was conducted by Camp, Dresser and McKee (1989). The model described is a one-dimensional time dependent model. Model results showed rapid transit time through the river with highest CSO impacts from fecal coliforms.

A study of water quality impacts from loads from CSO Area D, downtown Providence and the area extending down to the Field's Point WWTF, was conducted by Swanson et al (1991). A state-of-the-art boundary-fitted hydrodynamic and water quality system was employed to estimate FC and cadmium distributions under various storm sizes and treatment strategies.

The FC loads from CSO Area D were large enough to have a significant impact in the river. It was found that, even with the elimination of the three month storm loads through control by storage, fecal coliform water quality standards were still exceeded in the conditional closure area. This is due to other sources, besides those for CSO Area D, impacting the closure area.

More recently the model system was applied to the problem of FC in CSO loads from Central Falls and Pawtucket (Swanson and Isaji, 1992). A series of five design storms were run in conjunction with five design alternatives (including no control and full control). The three design alternatives provided substantially identical loads, on a system wide basis, to the receiving waters and thus had very similar impacts. Improvements based on acre-days exceeding either the 15 or 50 FC/100 ml standards showed that the greatest improvements (20%) occurred for the smallest rainstorm.

A major effort was started in 1991 to evaluate all the CSO areas together in order to allow system wide planning to commence. Swanson et al. (1993) reported on a multicomponent modeling effort with hydrodynamic and pollutant transport models applied to the Providence River / Upper Bay and separate tributary models that connected to the larger models. Four design storms were used with 3-, 6-, 12- and 24-month return frequencies and 13 mitigation alternatives were modeled. It was found that for the smaller storms a deep tunnel alternative and a mix of near surface storage and treatment along with a tunnel component performed best in reducing conditional area closures.

The most recent FC modeling that was focused on the NBC service areas was started in 1996 and reported by Swanson et al. (1998). This study consisted of a sensitivity study to CSO FC concentrations from 10^2 to 10^6 FC/100mL for 5 design storms, 1-, 2-, 3-, 6- and 12-mo return frequencies. The analysis showed that at smaller storms, the non-CSO loads from river and separated areas became significant and still impacted the conditional closure areas. Two year-long simulations, 1951 and 1978, were also performed to estimate the days of conditional area closure for average and wet years. It was found that, although significant water quality improvement would occur after reducing CSO loads, permanent reopening was not likely possible.

3 Comparison of Model Results to Recent Observations

The previously calibrated model grid and set up developed using RPS ASAs water quality modeling system WQMAP were used in this present study. Updated model forcing was applied and the hydrodynamic (BFHYDRO) and mass transport (BFMASS) models were used to simulate the circulation and FC concentrations within the study domain for a recent timeframe respectively. The model predictions of FC concentration were compared to available observations to evaluate the model applications predictive ability.

3.1.1 Modeling Timeframe

The modeling timeframe was associated with a period of time with suitable data for both the development of FC loads to force the model and in water observations for comparison of model predictions. The timeframe was delineated based on a data assessment performed by MWH (2015) and noted that it encompassed four specific wet weather events that occurred with subsequent in water sampling shortly thereafter that would be of use for model comparisons. The delineated time period was 16 March 2009 through 12 August 2009, though the hydrodynamic and mass transport model applications were simulated continuously from 17 March 2009 through 12 August 2009. The entire modeling timeframe was consistent with the completion of Phase I construction with the NBC service areas with respect to CSO configuration. More details of the selection of the timeframe can be found in the MWH (2015) report. The dates of notable wet weather events that came closest to a 3-month storm with subsequent in water observations available are summarized in Table 3-1.

Table 3-1 Summary of significant wet weather events during the modeling timeframe.

ID	Rainfall	System - Configuration
1	4/6/2009	Actual - Post Phase 1
2	6/14/2009	Actual - Post Phase 1
3	7/7/2009	Actual - Post Phase 1
4	7/21/2009	Actual - Post Phase 1

3.1.2 Available Observations

Throughout the modeling time period, in-water observations of FC concentrations were available at various stations from three distinct field monitoring plans: NBC tributary sampling, NBC in-bay sampling and RIDEM shell fishing area sampling. NBC tributary sampling (TRIB) of the Moshassuck, West, Woonasquatucket, Pawtuxet, and Blackstone Rivers is conducted on a weekly basis. NBC bay sampling (NBC) of the Providence River and Upper Narragansett Bay is conducted on a bi-weekly basis. RIDEM periodically monitors shellfish growing areas in Narragansett Bay (SHL). RIDEM's bay monitoring program is not synchronized with NBC's bay monitoring program. In all cases the observations were taken at the water surface and were measured in MPN/100mL. Figure 3-1 illustrates the stations available for comparison and their associated observational program source overlaid on the model gridded domain.

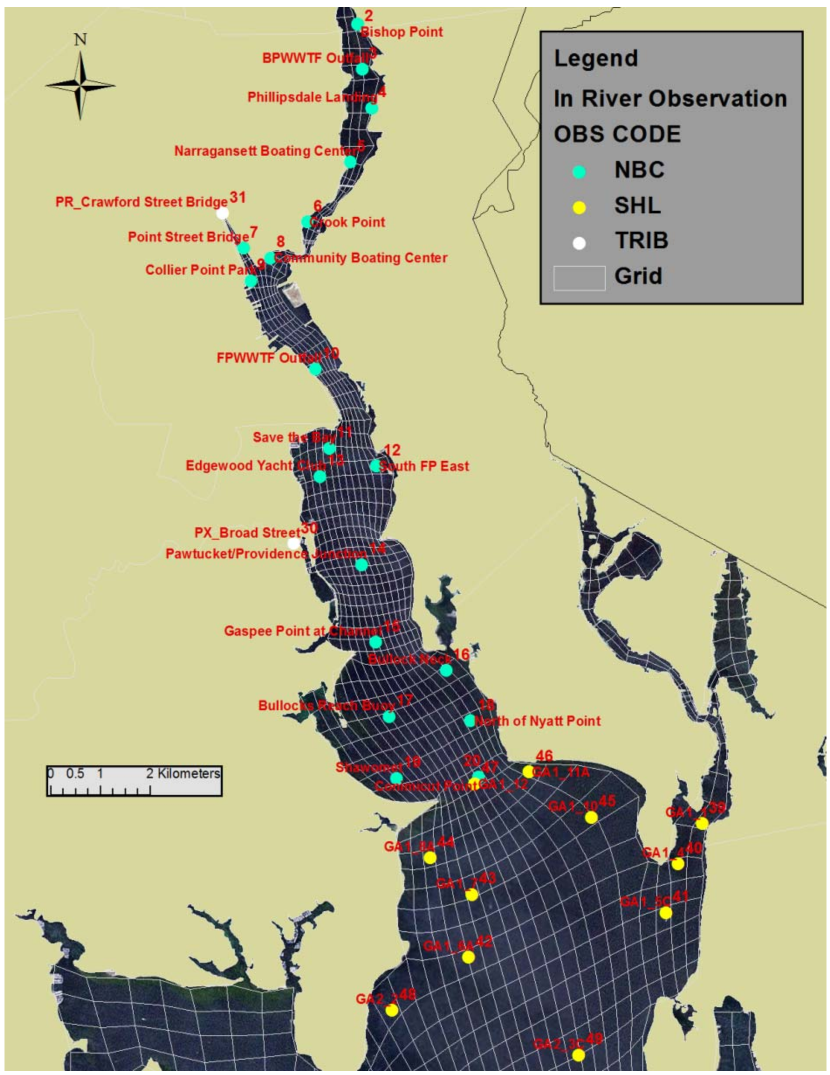


Figure 3-1. Illustration of location of available observations.

The in-water observations were used for both development of appropriate fecal coliform loads in tributaries and as in-water observation comparison points. The observations were not finely resolved in space or time and not synchronous amongst the set. These limitations affect both the ability to most accurately depict loads and the characterization of the receiving water concentrations. Though limited, the observations were the only available and therefore used for both load estimates (from tributaries) and used for a general comparison of the trend of the FC concentration in both space and time throughout the entire modeling timeframe as available.

3.2 Hydrodynamics

The mass transport model used to simulate FC concentrations within the model domain required definition of the model loads, model coefficients and a characterization of the spatial and temporal patterns of the currents during the modeling timeframe. With respect to the latter, the previously calibrated hydrodynamic model application was used with updated boundary conditions to develop current fields for the model domain for the period of interest. An overview of the present application specific inputs is provided below.

3.2.1 Boundary Conditions

The hydrodynamic model boundary conditions included tributary flow, plant flow and CSO flow as well as a definition of the tidal characteristics at the southern extent of the model grid. The schematic presented in Figure 3-2 illustrates the locations of the different boundary conditions. As described all of the CSO flow reaching the Bay via tributaries was added to the tributary heads for the purposes of hydrodynamic modeling to facilitate the location of model forcing while maintaining grid resolution. CSOs discharging directly into the Bay were added into the model domain at their exact geographic location.

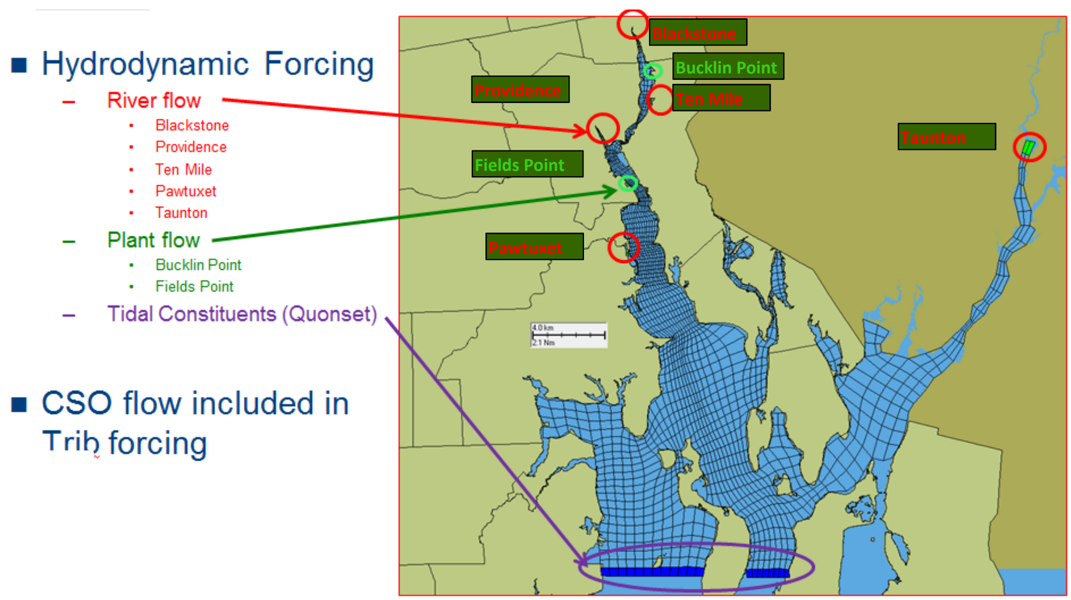


Figure 3-2-Schematic of hydrodynamic model forcing.

3.2.1.1 *Tributary River Flow*

Tributary river flow at a 15 minute interval was provided by MWH to RPS ASA for the Blackstone River, Providence River (Moshassuck, West and Woonasquatucket Rivers), Ten Mile River and Pawtuxet River at USGS gage locations as shown in Figure 3-3. For the purposes of hydrodynamic modeling the tributary inputs that defined the Providence River was calculated as the sum of the Moshassuck, West and Woonasquatucket River. RPS ASA obtained the daily USGS river flow from the Taunton River at the closest USGS gage to the head of the Taunton River. The Taunton flow does not significantly affect the hydrodynamics of the areas of interest but was included to be consistent with the previous modeling efforts (Swanson and Mendelsohn, 1993).

The location of available tributary flow was not coincident with the desired location of flow necessary for the modeling; therefore the tributary flow was subsequently scaled based on the watershed characteristics in order to adjust the flow for the appropriate location. The desired location and associated river flow input for the hydrodynamic model is at the point where along a given reach the CSOs enter the system and begin to dominate the flow additions from this point. The available flow at USGS locations, desired model flow and CSO flow outfall locations are also shown in Figure 3-3**.** Also, since each tributary of the Providence River (Moshassuck, West and Woonasquatucket) were sampled separately for in-river FC concentrations, their individual flows were desired for the purposes of developing appropriate flow weighted loads for the mass transport modeling (Section 3.3.1.2). In some cases the actual flow (USGS gage) was upstream of the desired modeling point and in other cases the USGS gage was downstream of such a point and therefore the flow was scaled accordingly up or down to reflect the appropriate addition or subtraction of flow. The appropriate flow scale was estimated based on the fraction of the watershed draining to the desired location versus the size of the watershed draining to the actual gaged location.

Table 3-2 summarizes the USGS source flow, scaling factor and time interval of the data set used to develop each individual data set. Figure 3-4 illustrates the flow time history at the Providence (sum of Woonasquatucket, West, and Moshassuck river flows), Blackstone, Ten Mile and Pawtuxet Rivers for the simulation time period at their confluence with the Bay.

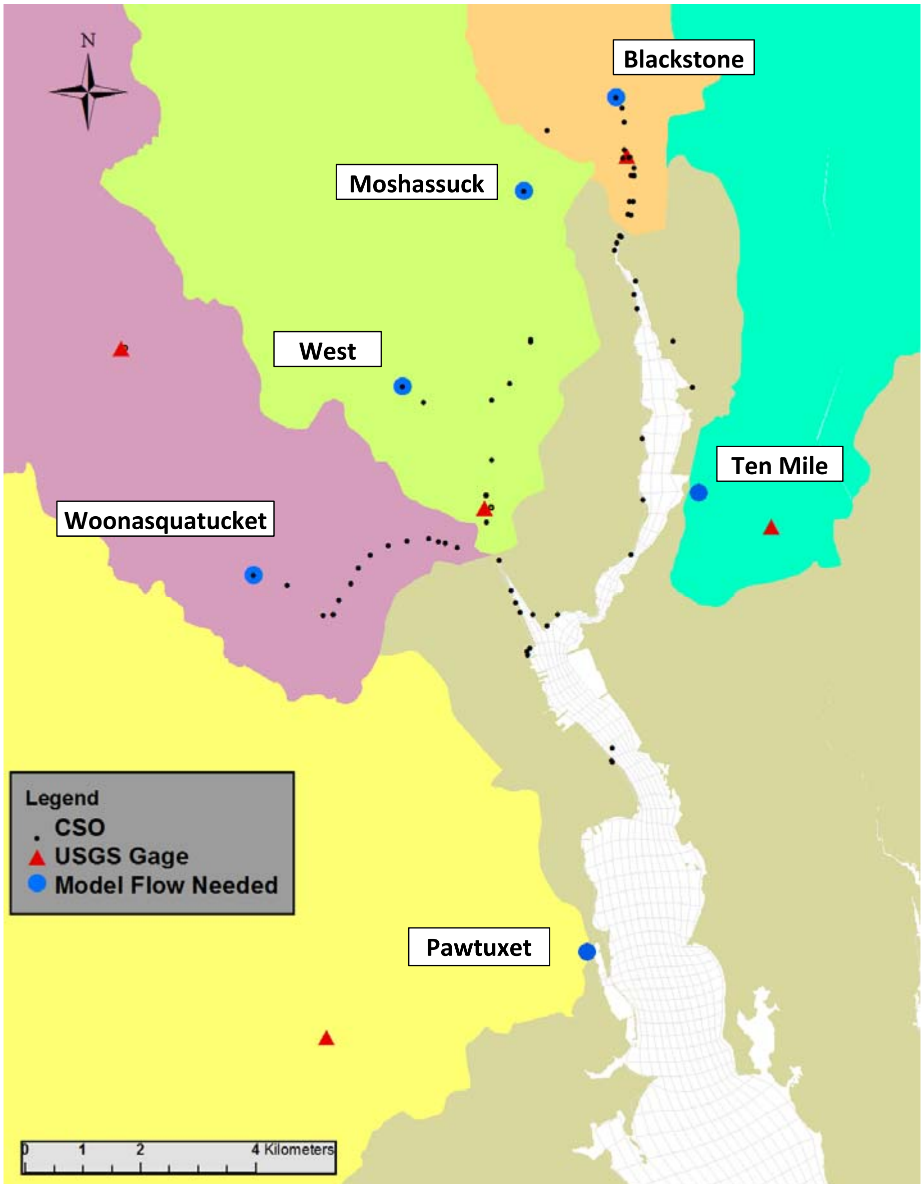


Figure 3-3. Illustration of CSOs, USGS gages and locations of desired flow for the hydrodynamic modeling simulation.

Table 3-2 Summary of USGS flow gages and applied scaling factors to reflect pre-CSO dominated domain.

Tributary	Time	USGS Flow Gauge Number	Flow Scaling
Moshassuck River	15 minute	USGS 01114000	0.377
West River	15 minute	USGS 01114000	0.208
Woonasquatucket	15 minute	USGS 01114500	1.168
Blackstone River	15 minute	USGS 01113895	0.985
Ten Mile River	15 minute	USGS 01109403	1.044
Pawtuxet River	15 minute	USGS 01116500	1.050
Taunton River	daily	USGS 01108000	1.000

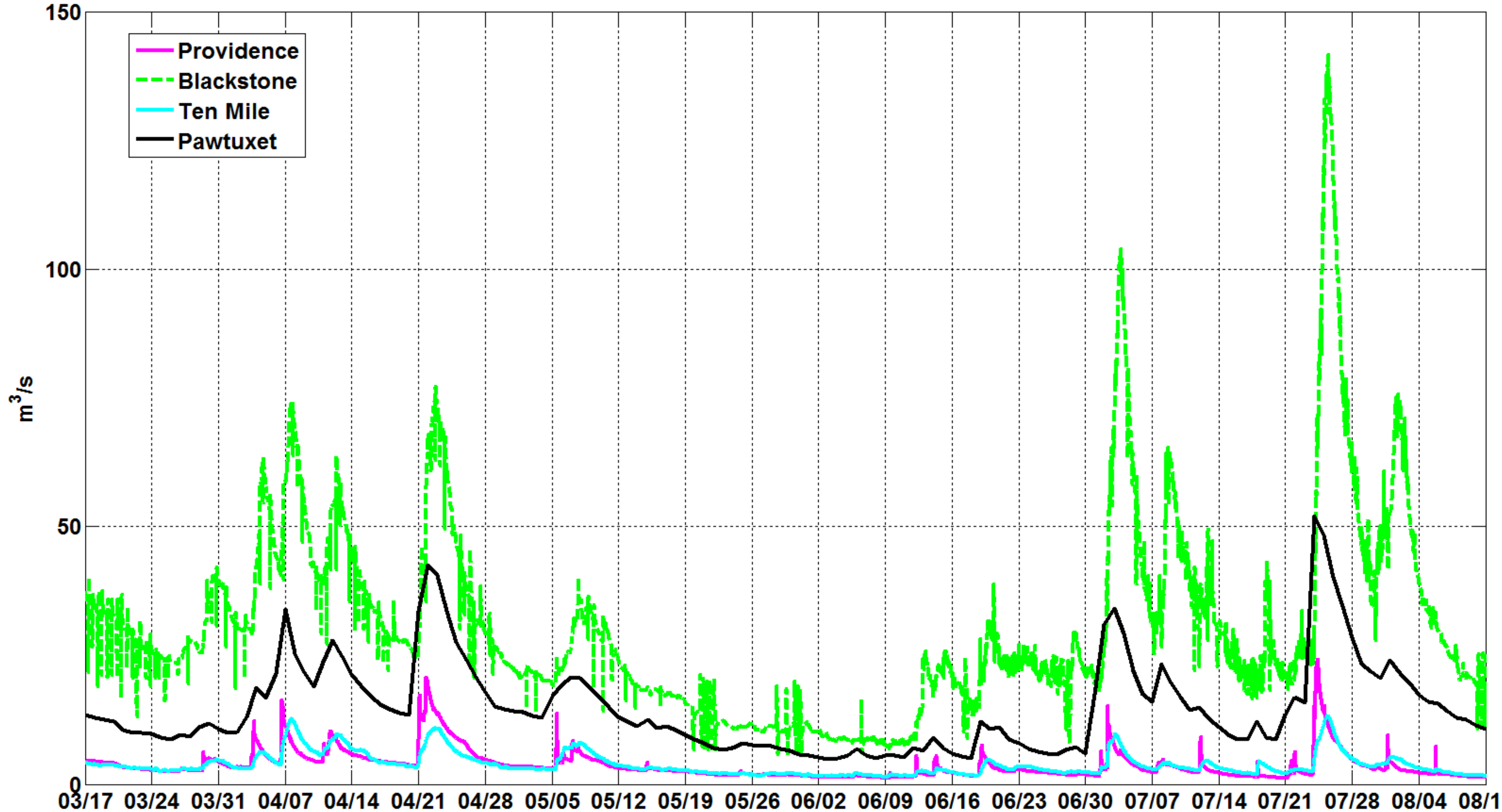


Figure 3-4.Time History of River flow for the Providence (Moshassuck, Woonasquatucket, and West– Pink), Blackstone (dashed Green), Ten Mile (cyan) and Pawtuxet Rivers (Black) for the simulation time period.

3.2.1.2 *Plant Flow*

Plant flow was provided by MWH to RPS ASA at 15 minute intervals for the Bucklin and Field's Point plants for the period of interest. No adjustment was necessary to the values provided for use in model inputs. See MWH (2015) for details on plant flow rates. The time history of flow for the plants is shown in Figure 3-5. Due to lack of reliable, long-term effluent data, the East Providence WWTF was not included as a source during this period. This assumption was deemed to not have any impact on the model long-term runs as the overall impact from WWTF is practically negligible.

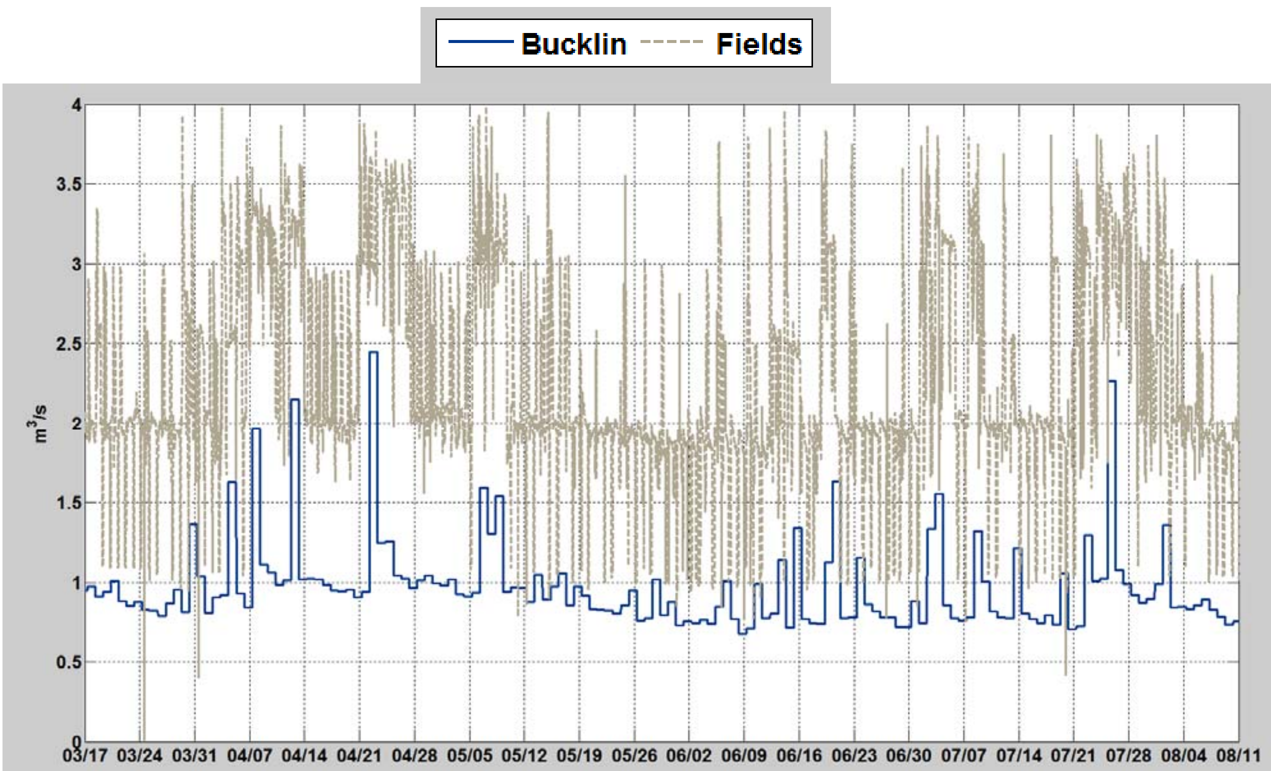


Figure 3-5.Time history of plant flow used in modeling.

3.2.1.3 *CSO Flow*

CSO flow was provided by MWH to RPS ASA for the all the CSOs at 15 minute intervals for the period of interest. No adjustment was necessary to the values provided for use in model inputs. See MWH (2015) for details on CSO flow rates. The flow for the CSOs that overflow to the Blackstone and Providence Rivers are shown in Figure 3-6. Investigating the flow patterns founds that for smaller events the overflow is greater in the Providence River however for larger storms the overflow is greater in the Blackstone River. Furthermore the overflows from CSOs in the Providence River take longer to recede than those from the Blackstone River for this configuration. Note that the Blackstone also includes those CSOs flowing into the Seekonk.

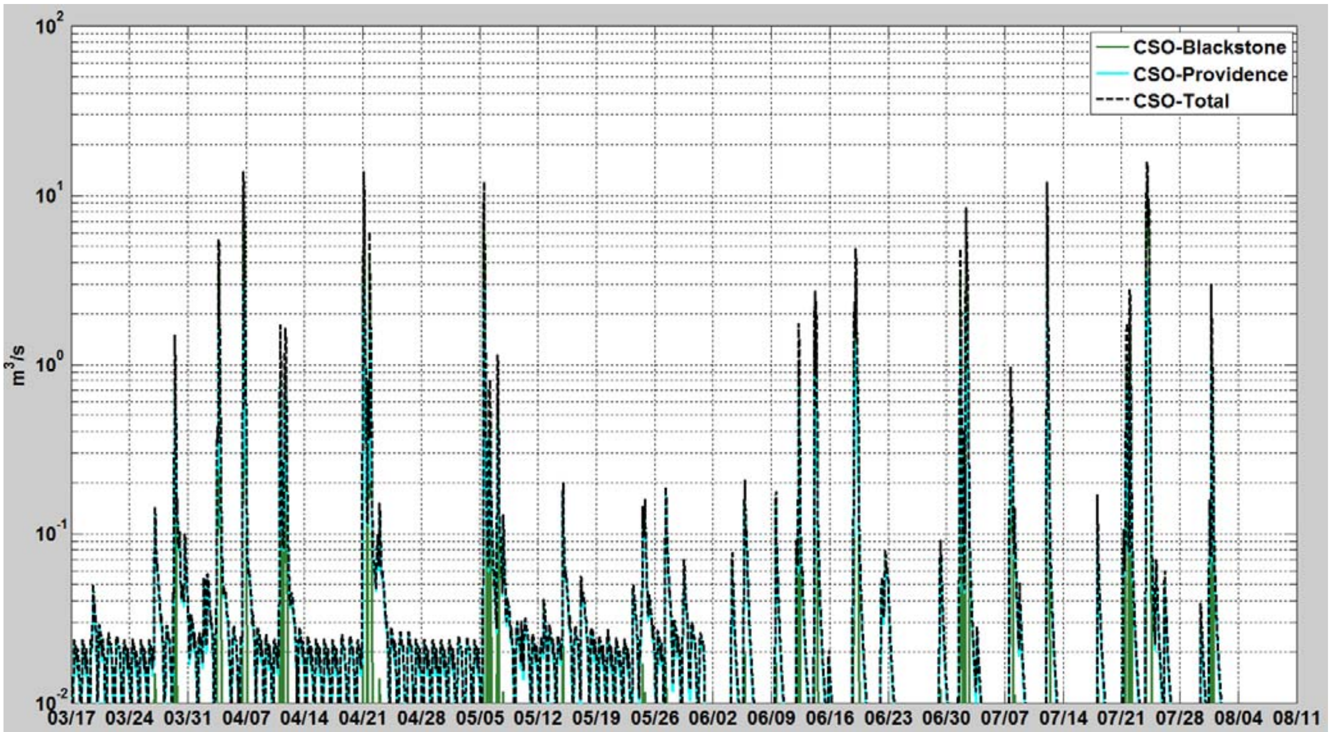


Figure 3-6.Time history of CSO flow used in modeling. Y-axis is log scale for ease of viewing variability.

3.2.1.4 *Tidal Constituents*

The southern boundary of the hydrodynamic model simulation was forced using the tidal constituents defined by the National Oceanographic and Atmospheric Administration (NOAA) at the NOAA Tide Gauge at Quonset Point (NOAA Station 8454049), consistent with the southern extent of the model grid. The five tidal constituents M2, N2, S2, O1 and K1 were used to define the tides as these represent the majority of the tidal characteristics. The number in the constituent roughly represents the number of times per day the constituent repeats, such that M2 represents a semi-diurnal (twice daily) constituent and O1 represents a diurnal (daily) constituent. The multiple constituents combine to provide daily variations of the high and low tidal elevations though centered on mean amplitude. The phase of each constituent represents the time offset of the constituent to that of the theoretical tide relative to Greenwich Mean Time (GMT). The amplitude and phase of each constituent are summarized in Table 3-3 which illustrates the dominant semidiurnal nature of the tides in the study area.

Table 3-3 Summary of tidal constituent characteristics at Quonset Point applied to define the southern domain tidal boundary condition.

Constituent	Amplitude (m)	Phase (degrees from Greenwich Mean Time)
M2	0.538	5.0
N2	0.133	349.4
S2	0.116	27.1
O1	0.048	198.2
K1	0.064	165.1

3.2.2 Simulation Results

The hydrodynamic model was used to recreate the ebb and flood of the tides as well as reflect the temporal variation of tributary and CSO flow input to the domain. Snapshots of flood and ebb currents from 6 April 2009 are shown for illustrative purposes. There were no observational data within the heart of the study area available for comparison. The speeds within the domain vary both spatially and temporally, though on average peak at less than 0.4 m/s.

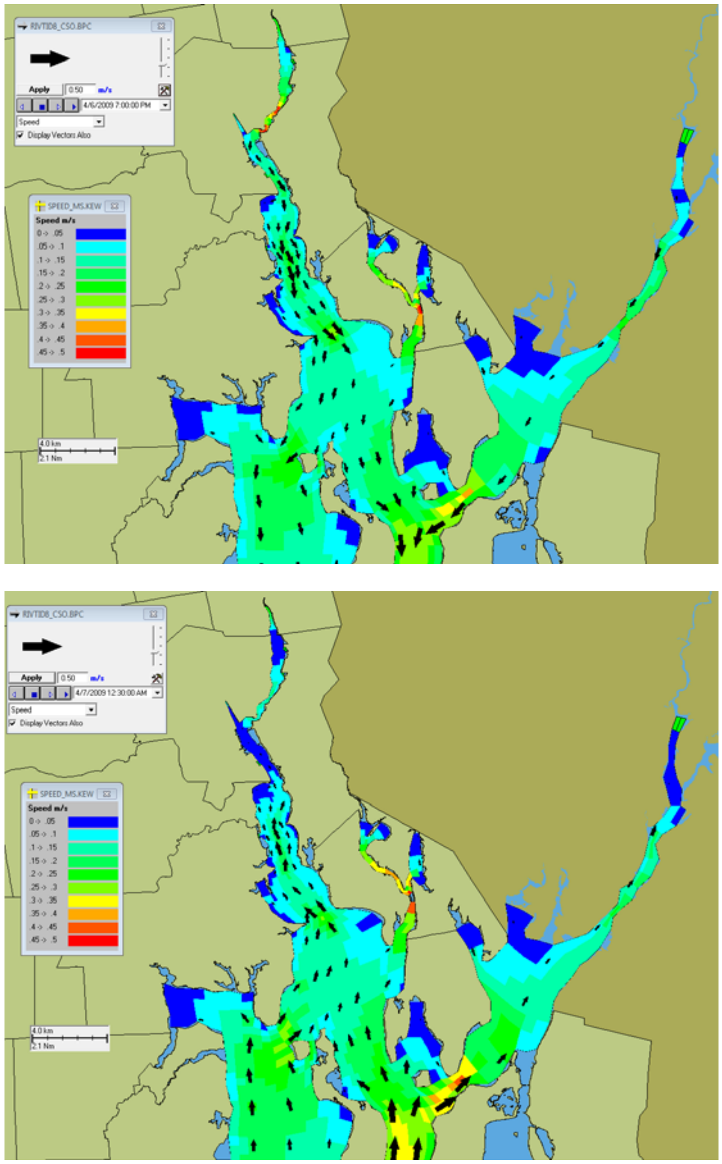


Figure 3-7.Snapshots of ebb (top) and flood (bottom) currents on 6 April 2009. Speed contours are shown in colors and vectors indicating direction are overlaid on top of contours.

3.3 Mass Transport

The mass transport model (BFMASS) was used to simulate the spatially and temporally varying FC concentrations within the model domain based on the hydrodynamics and FC loading during the period of interest (17 March 2009 through 12 August 2009). Consistent with the previous modeling the FC decay coefficient was maintained at 0.5/day, however a sensitivity study to this coefficient was also performed which evaluated both half (0.25/day) and double (1.0/day) this value. The previously calibrated mass transport model application was used with updated boundary conditions for simulations of the more recent period of interest.

3.3.1 Boundary Conditions

The mass transport model application boundary conditions included the spatially and temporally varying current fields (output from the hydrodynamic model simulation), pre CSO-dominated domain tributary loads of FC mass, CSO loads of FC mass, and plant loads of FC mass. Loads of FC mass were determined from the direct calculation of flow multiplied by concentration over each interval (15 minute resolution). The southern tidal boundary was assumed to contribute zero FC mass loading to the domain. A schematic of these forcing factors is presented in Figure 3-8.

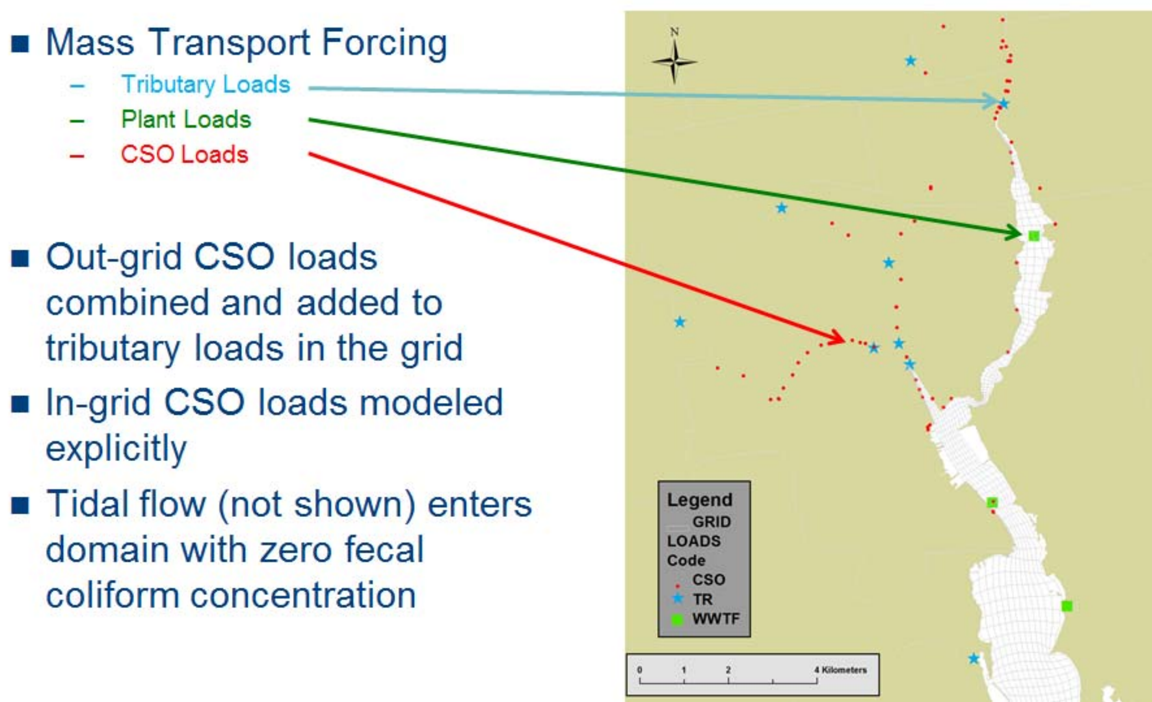


Figure 3-8. Illustration of mass transport boundary conditions.

3.3.1.1 *Hydrodynamic Current Fields*

The hydrodynamic current fields were developed for the specific time frame as documented in Section 3.2.

3.3.1.2 *Tributary River Load of FC Mass*

Tributary loads were developed from the tributary flow and in river FC observations at locations prior to the point where NBC CSOs begin to enter the tributary reaches, consistent with the hydrodynamic modeling. Tributary loads of FC mass were calculated based on tributary flow and corresponding concentration. The development of tributary flow was scaled from USGS gages based on the geometry of the watershed with respect to the point of interest as documented in Section 3.2.1.1. While tributary flow was available at a 15-minute temporal resolution, NBC's FC concentration observations that were provided by MWH were available on a much larger time step of approximately one week intervals. For the purposes of developing loads, the concentration was held constant over time between observations and the flow varied. There is some uncertainty with this approach however it is a best estimate based on lack of data or externally developed flow-concentration relationships. The location of tributary concentration was not consistent with the flow observation; however the closest observation prior to the point at which CSOs enter the domain was used for each reach. The location prior was used in order to remove the influence from the CSOs and rather capture the true tributary loading. The location of the FC concentration used for developing loads is shown for each available tributary in Figure 3-9. In lieu of available observations in the Ten Mile River a constant concentration of 20 MPN/ 100 mL was assumed. This value is the approximate dry weather geomean from lower sampling stations in the Ten Mile River obtained as part of a TMDL study for that river (RIDEM 2011). 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 and as such a lower bound of available dry weather samples at stations TM-8 (Omega Pond outlet) from that study were used to develop this concentration.

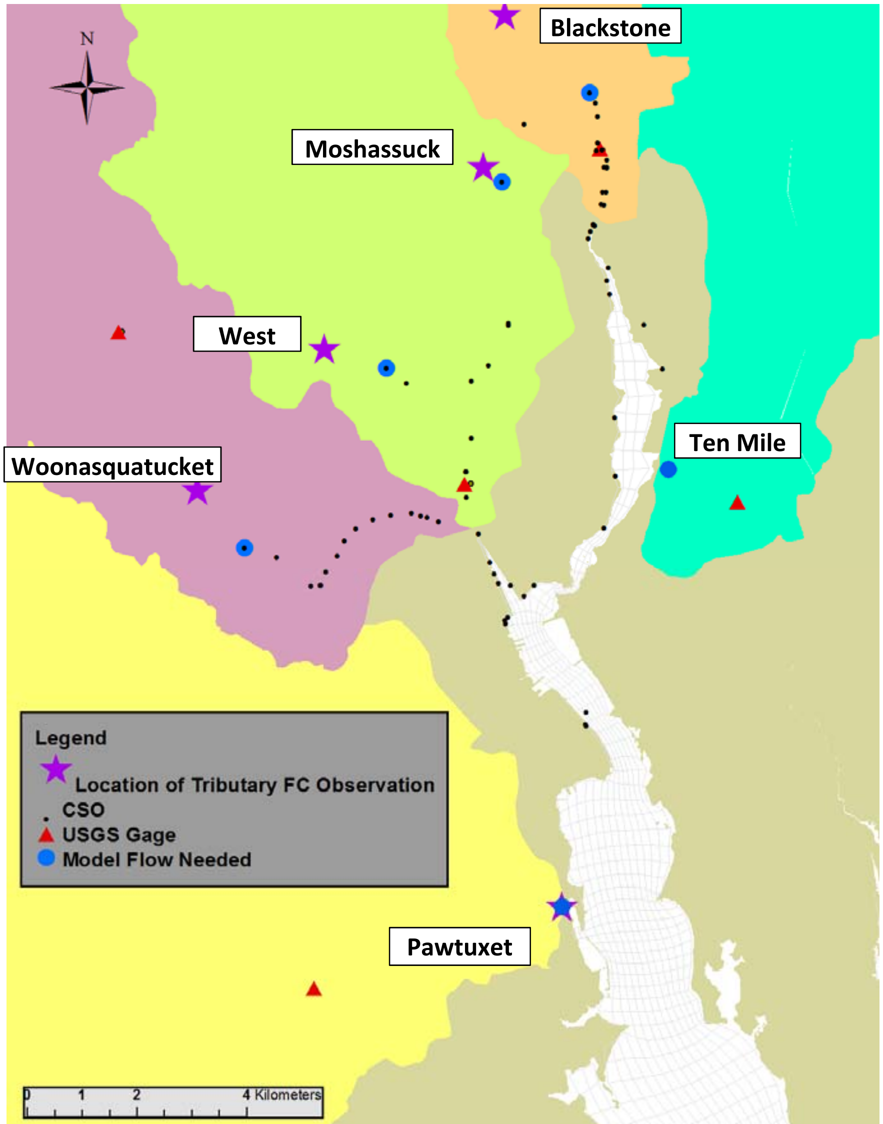


Figure 3-9. Illustration of CSOs, USGS gages, locations of desired flow and locations of tributary FC observation used for developing model loads.

The Providence River load was calculated as the flow weighted combination of the Moshassuck, West and Woonasquatucket Rivers which all had varying in river observations on each sampling day. Figure 3-10 illustrates the concentration (top panel) and flow (bottom panel) used for developing tributary background loads of FC to the domain. Furthermore the observations from within each river system are shown where available in the top panel, this illustrates the varying observations from the Providence River tributaries. Similarly the Pawtuxet River had multiple observations that were averaged for use in estimating concentrations and subsequently calculating the tributary load. The resulting tributary FC loads are shown in Figure 3-11.

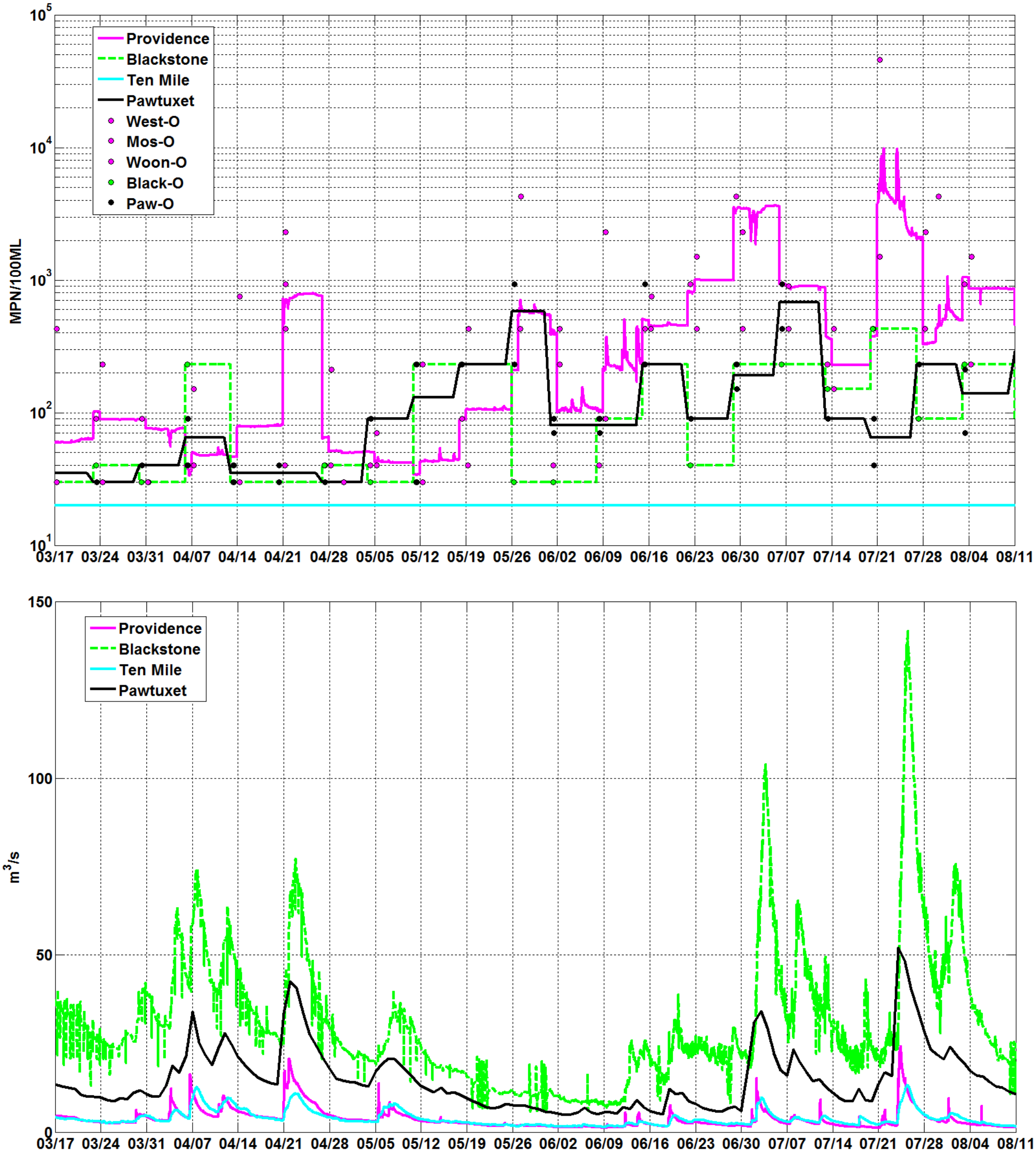


Figure 3-10.Time history of observed and modeled FC concentration (top) and flow (bottom) for use of developing FC loads for each tributary.

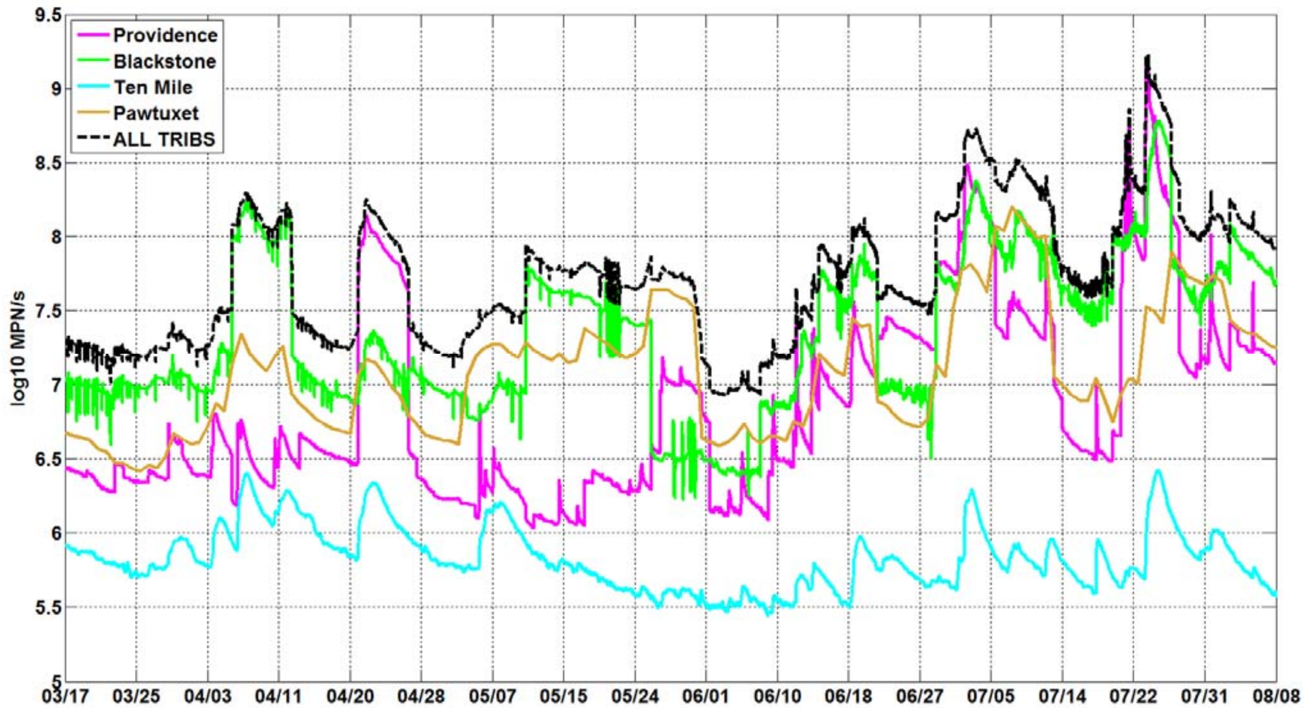


Figure 3-11.Time history of tributary FC loads used in modeling.

3.3.1.3 *Plant Load of FC Mass*

Plant flow and concentration was provided by MWH to RPS ASA for the Bucklin and Field's Point plants for the period of interest. No adjustment was necessary to the values provided for use in model inputs. Please refer to MWH (2015) for details on plant flow rates and concentrations. These values were used to develop the plant FC mass loading. As stated in Section 3.2.1.2, due to lack of reliable, long-term effluent data, the East Providence WWTF was not included as a source during this period. This assumption was deemed not to have any impact on the model long-term runs as the overall impact from WWTF is negligible.

3.3.1.4 *CSO Load of FC Mass*

The model gridded domain extent was maintained as in previous modeling efforts (Swanson and Mendelsohn, 1993). As such, a portion of the CSOs are located north of the model domain extent. These loads were combined and applied at the northern extent of the most appropriate tributary to which they overflow (Providence or Blackstone). Note that the 'Blackstone' reflects the Seekonk River as well, however the geographic locations were named reflecting the headwaters. The CSOs that were located within the model gridded domain had loads applied directly at the appropriate location. **Error! Reference source not found.** provides an illustration of this concept as well as the geographic extent of loads referred to as Blackstone vs Providence.

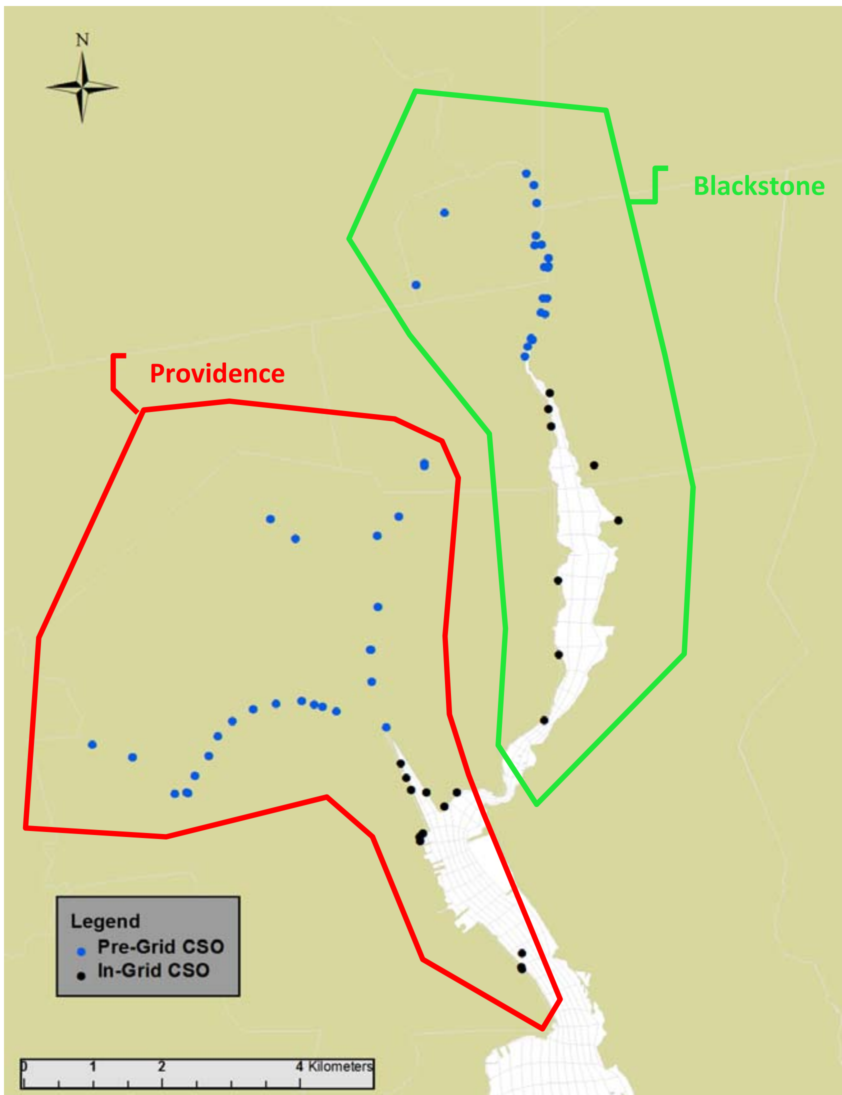


Figure 3-12. Schematic of pre-grid and in-grid CSOs.

For each CSO the flow and concentration was provided by MWH to RPS ASA for all of the CSOs in Field's Point and Bucklin Point service area for the period of interest. The flow varied, however concentration during overflowing periods was always 250,000 MPN/ 100 ML. No adjustment was necessary to the values provided for use in model inputs. Please refer to MWH (2015) for details on CSO flow rates and concentration. These values were used to develop the CSO FC mass loading as shown in Figure 3-13.

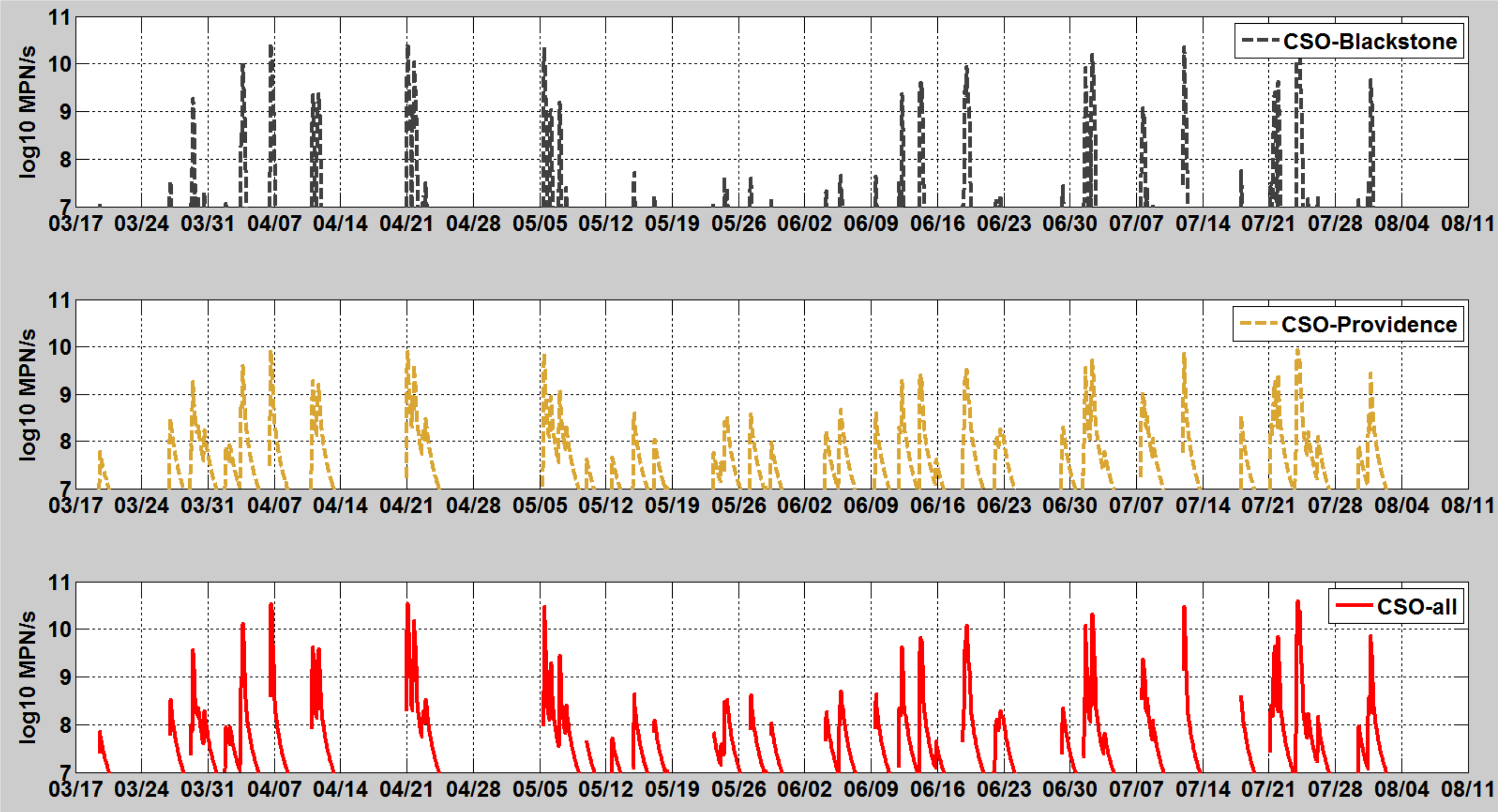


Figure 3-13.Time history of CSO FC loading rate used in modeling.

The Blackstone River CSOs are shown in the upper plot, Providence River CSOs in the middle plot and the combination of all CSOs are shown in the bottom plot. Note that the geographic region Blackstone includes the Seekonk River; Figure 3-12 illustrates the geographic extent of the Blackstone and Providence geographic regions.

3.3.1.5 *Load Summary*

For the time period of interest the loading rate and cumulative loads from all contributing sources (tributary, plants and CSOs) are shown in Figure 3-14 and

Figure 3-15 respectively and summarized in Table 3-4. These show that the CSO loads account for most (~77.3 %) of the loading to the system. Second to CSOs are the tributary loads (~22.7 %) and a relatively negligible amount (<0.1%) comes from the plants. The CSOs that overflow to the Providence River account for 27.9% of the total load and those that overflow to the Blackstone account for 49.4% of the total load from this time period.

Table 3-4 Summary cumulative FC load during the time period of interest (17 March 2009 through 12 August 2009).

	Log_{10} MPN*	**Percent of Total**
Blackstone Tributary	14.8	10.7
Providence Tributary	14.6	6.9
Ten Mile Tributary	13.0	0.2
Pawtuxet Tributary	14.4	4.9
All Tributaries	15.0	22.7
Bucklin Point Plant	11.9	0.01
Fields Point Plant	12.3	0.04
All Plants	12.4	0.05
Blackstone River CSOs	15.4	49.4
Providence River CSOs	15.2	27.9
All CSOs	15.6	77.3
All Loads	**15.7**	100.0

*Note that the Log10 representation of the loads are rounded/truncated and as such direct use of these values would appear to result in a different percentage calculation however the percentages were calculated using the actual (and not rounded) numbers.

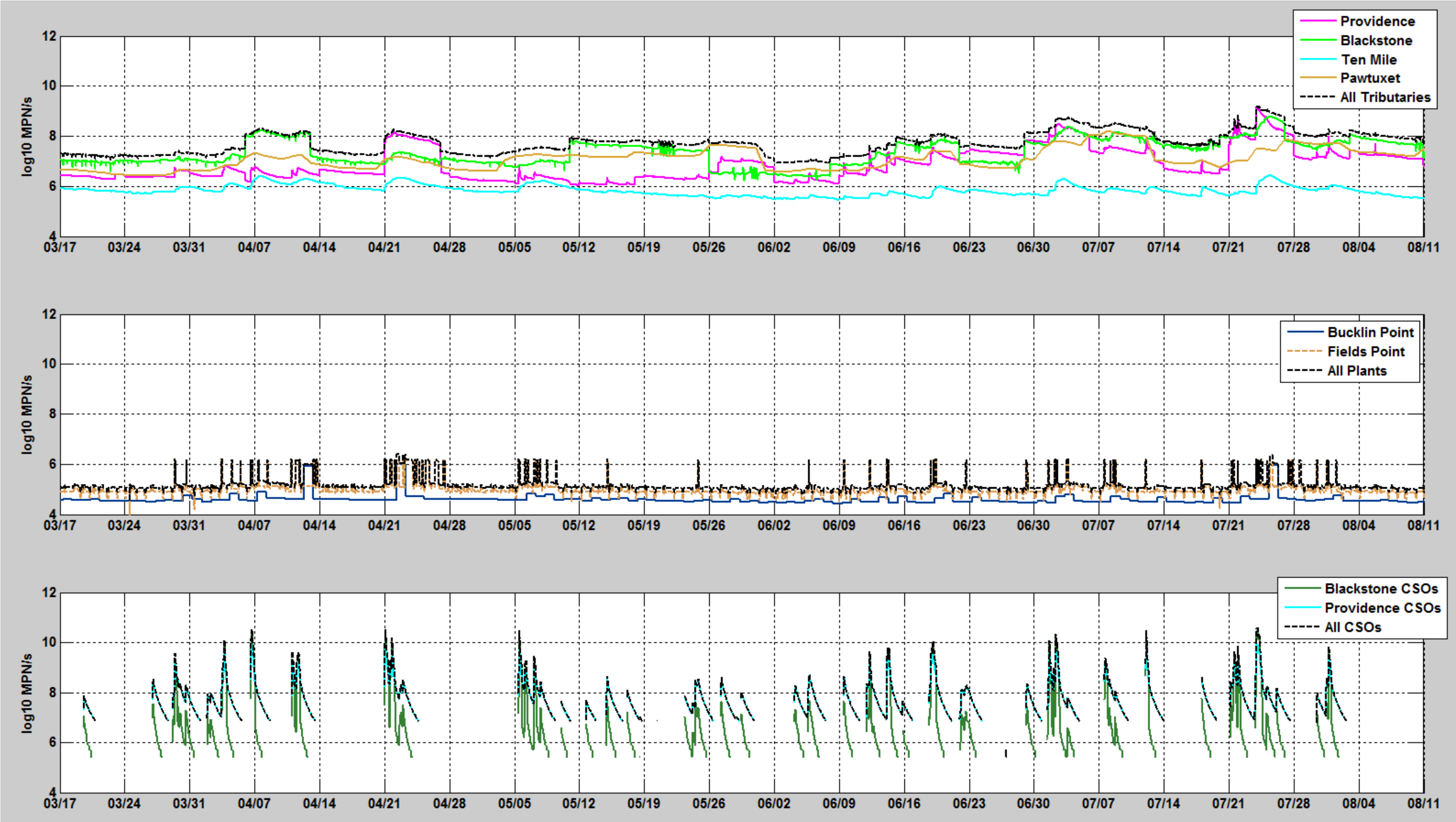


Figure 3-14. Loading rate of FC to the study area from tributaries (top panel), plants (middle panel) and CSOs (bottom panel).

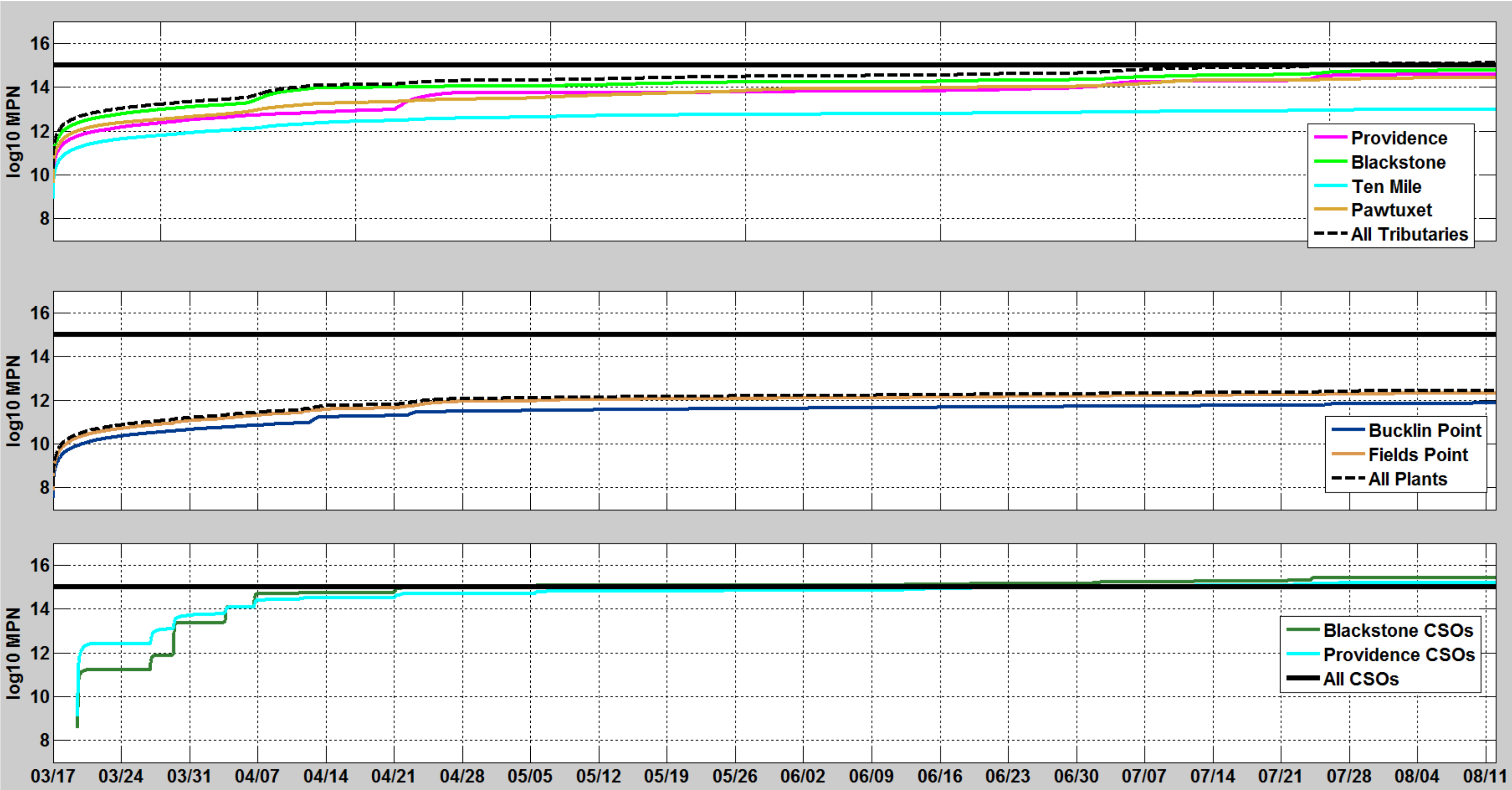


Figure 3-15. Cumulative load of FC to the study area from tributaries (top panel), plants (middle panel) and CSOs (bottom panel). A solid black line is shown at a reference level of 15 (1E+15)

3.3.2 Simulation Results

The mass transport model was run for a base case and two sensitivity cases. The model was used to simulate FC concentrations within the receiving water. The model predicted time history of concentration was compared with observations of FC concentrations at discrete locations (as shown in Figure 3-1) as available.

3.3.2.1 *Base Case*

Comparisons of model predictions to all available observations of FC concentrations from the entire period of interest for the base case (decay of 0.5/day) are presented in Figure 3-16 through Figure 3-21. The figures are presented from north to south in the domain. Each figure contains multiple individual panels representing specific stations. For each station the model prediction is presented as a solid colored line and the observations presented as a solid circular marker of the same color. Additionally two solid black lines in the horizontal illustrate either the 50 MPN/100 mL and 400 MPN/100mL or14 MPN/ 100mL and the 49 MPN/ 100mL thresholds of interest for reference, these references are graphically called out in the upper left panel of Figure 3-16.

The model and data are in good agreement. The model was able to recreate the spatial and temporal variability well and capture the range of magnitude of the concentrations well. Furthermore the model captured the trend of either above or below relevant thresholds well most of the time at most locations. Investigating the stations in the lower bay it can be noted that a possible additional source of FC coming from the Warren River may be present though not included in the model due to lack of data for proper characterization. This theory is based on the fact that observations on the east side of the lower bay (close to the Warren River mouth) are often higher than those on the west. For example observations at stations 39 40 and 41 (close to the Warren River mouth) are relatively higher than observations at stations 42, 43, 44, 45, 46 which are north or west of the Warren River mouth. Furthermore observations at stations 48 and 49, located southwest and southeast of the Warren River mouth respectively are also lower than observations at stations 39, 40 and 41, suggesting that the impacts from the Warren river are relatively localized.

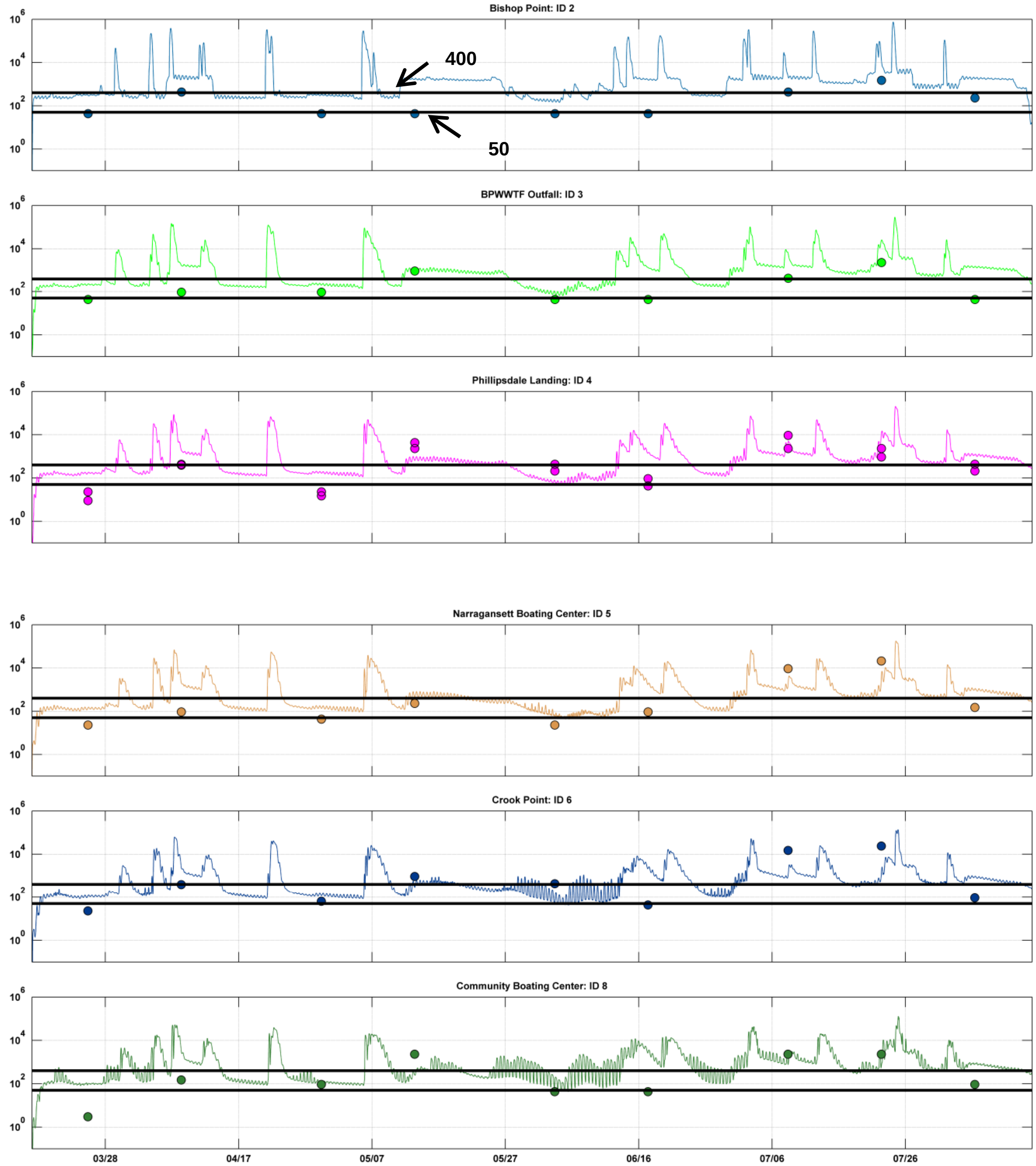


Figure 3-16. Model predictions (solid line) and observations of FC in the Seekonk River. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 50 MPN/100mL and 400 MPN/100mL.

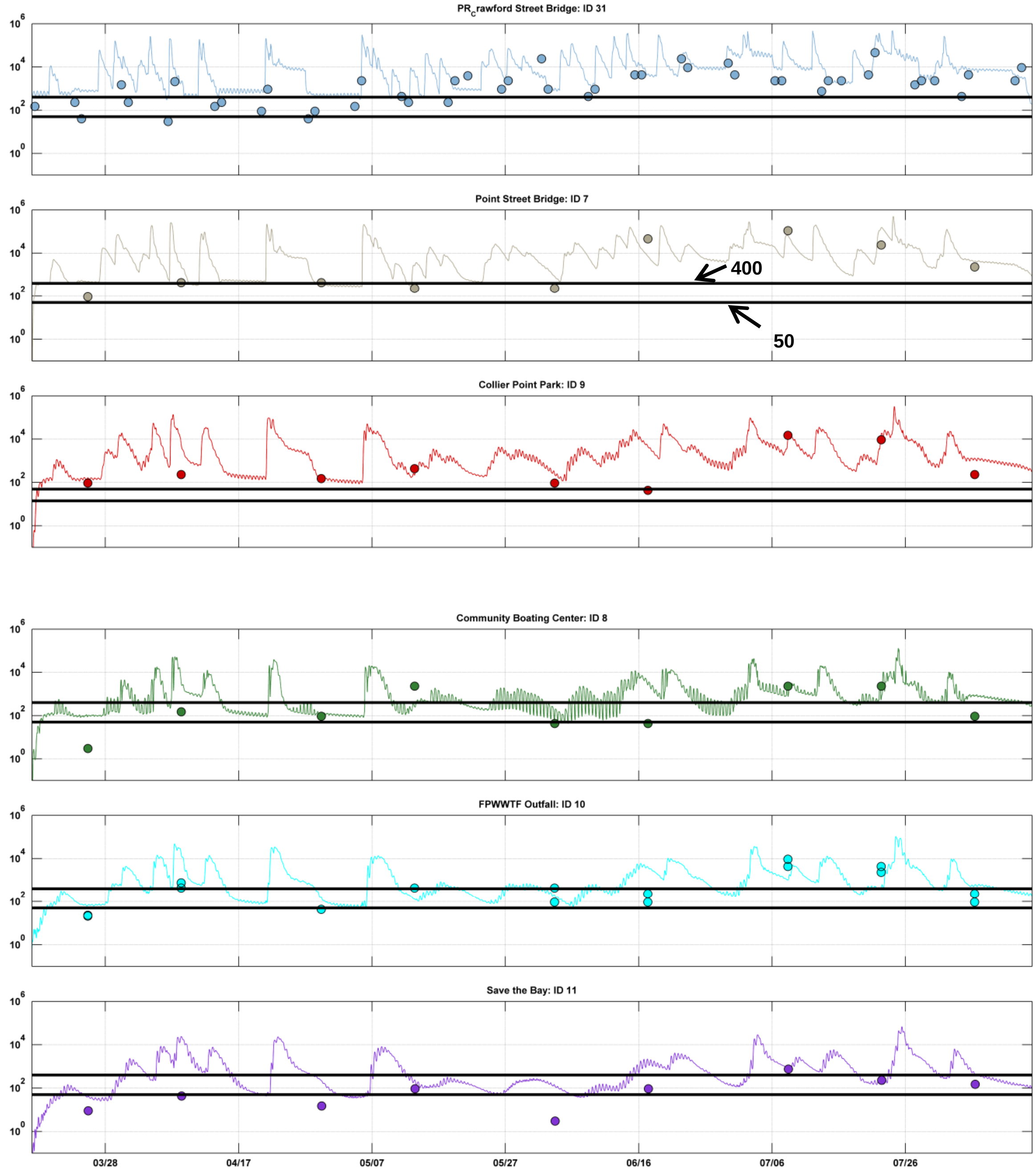


Figure 3-17. Model predictions (solid line) and observations of FC in Providence Harbor. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 50 MPN/100mL and 400MPN/100mL.

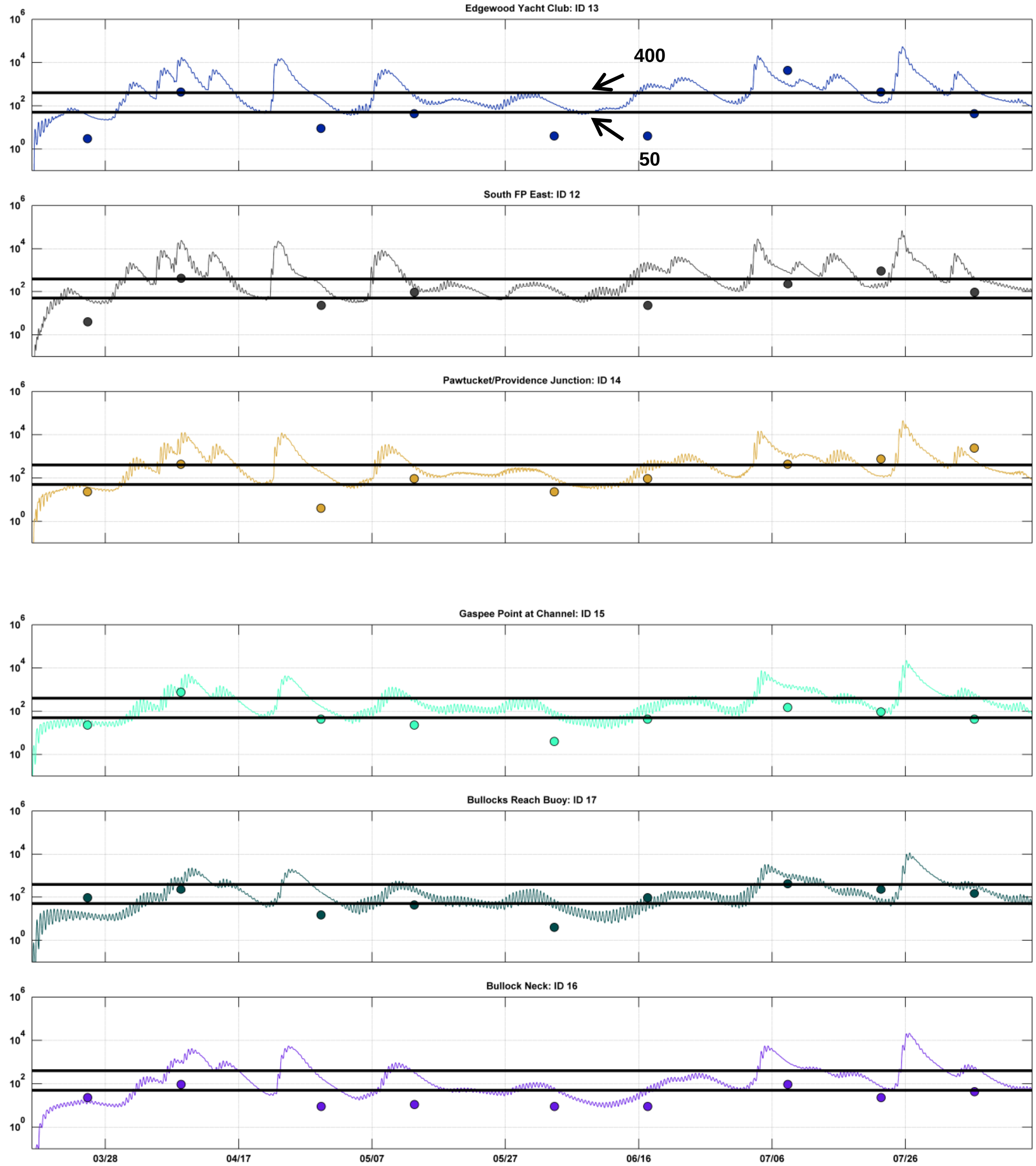


Figure 3-18. Model predictions (solid line) and observations of FC in the Upper Bay. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 50 MPN/100mL and 400MPN/100mL.

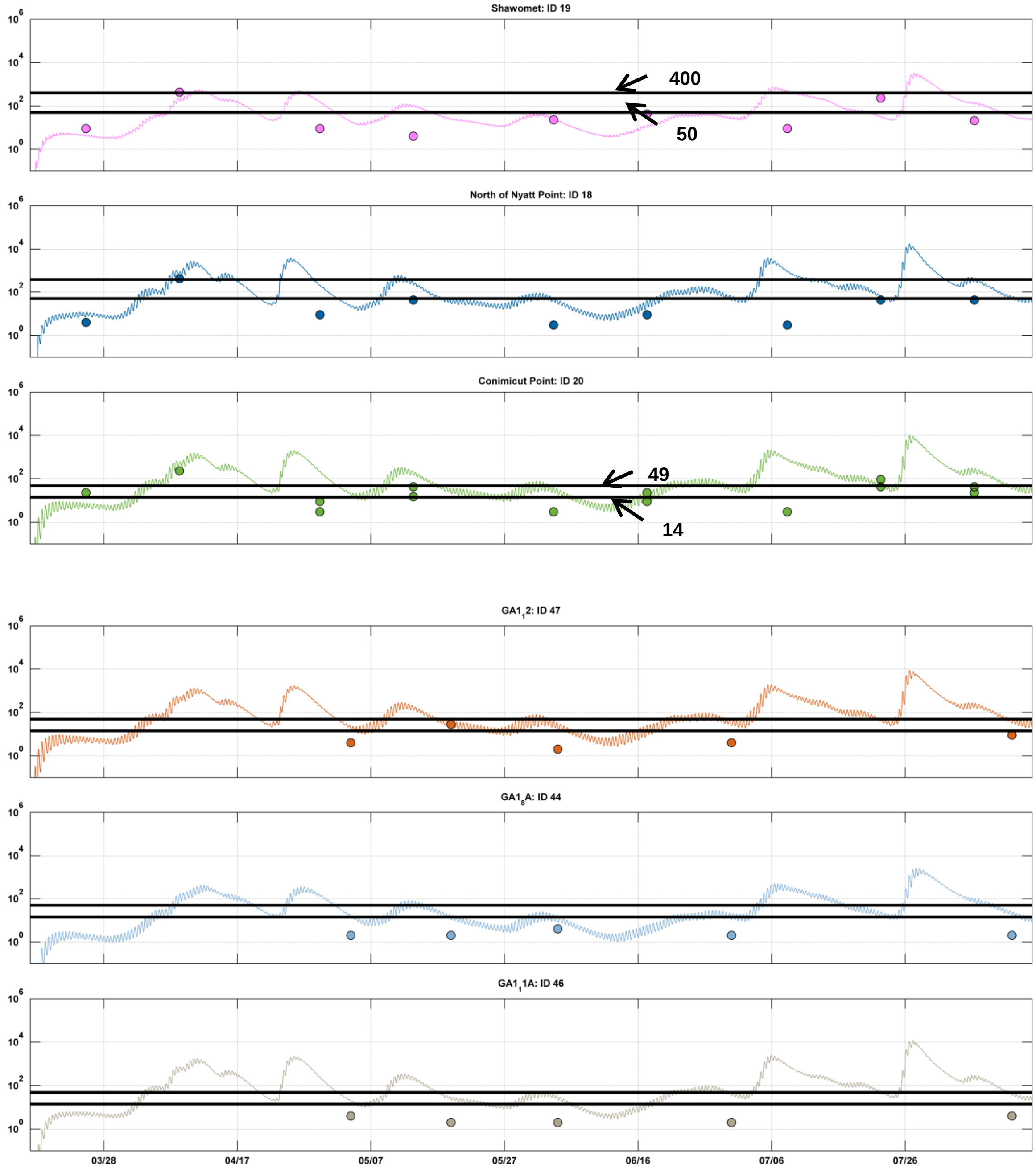


Figure 3-19. Model predictions (solid line) and observations of FC in the Upper Bay and Conditional Areas A and B. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 50MPN/100 ML and 400 MPN/100 ML in the upper two panels and 14 MPN/100mL and 49 MPN/100mL in the lower four panels.

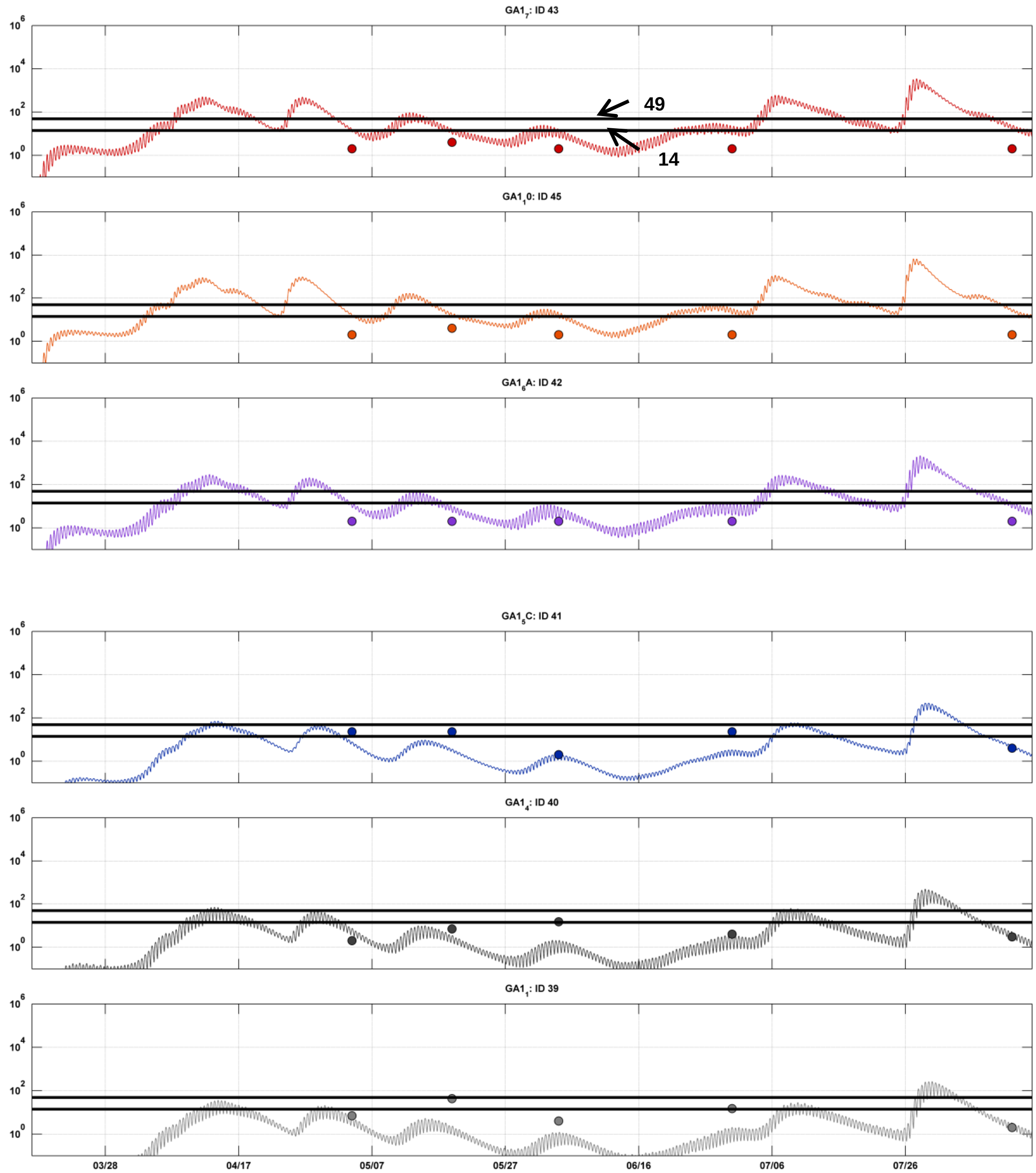


Figure 3-20. Model predictions (solid line) and observations of FC in Conditional Areas A and B. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 14 MPN/100mL and 49 MPN/100mL.

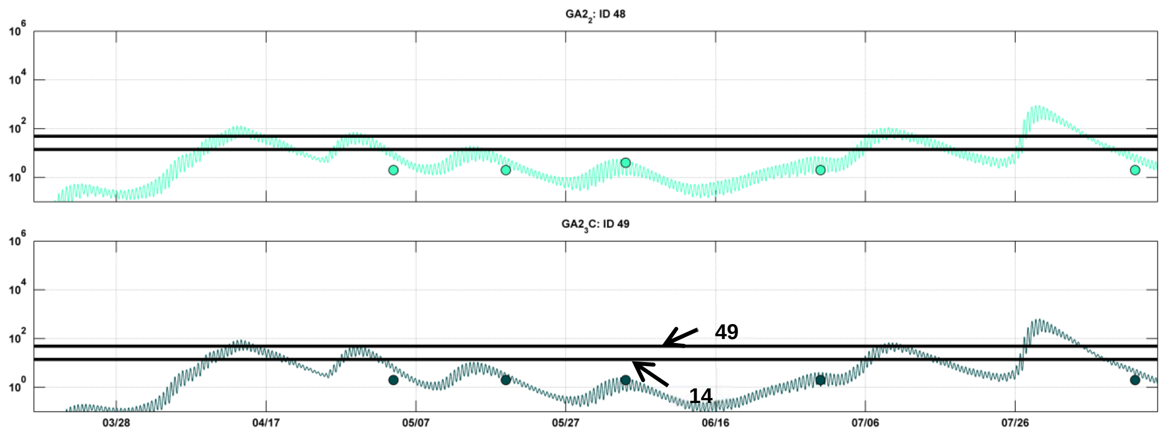


Figure 3-21. Model predictions (solid line) and observations of FC in Conditional Area B. Y axis is in units of MPN/100mL. The two solid horizontal black lines represent 14 MPN/100mL and 49 MPN/100mL.

3.3.2.2 *Sensitivity Cases*

In addition to the base case run with a decay coefficient of 0.5/day, two additional runs were simulated that investigated the sensitivity of the predictions to the decay coefficient. The sensitivity runs used either half (0.25/day) or double (1.0/day) the decay coefficient which represent allowing slower and faster decay respectively. A subset of the entire set of stations, the locations of which are shown in Figure 3-22, are presented with both sensitivity runs shown in addition to the base case. The base case is presented as a solid colored line and the sensitivity runs are presented as dashed black lines, with the greater values associated with the 0.25/day decay coefficient (slower decay) and the lower line associated with the 1.0/day decay coefficient (faster decay). Figure 3-23 and Figure 3-24 illustrates the model predictions for the subset of stations for each of the simulations. This figure illustrates that the best capture of the variability of FC concentrations is associated with the 0.5/day rate. The decay rate has less influence in the northern portion of the domain however has a greater influence further from the northern sources where the concentrations are attenuated based on both the time decay and dilution/mixing.

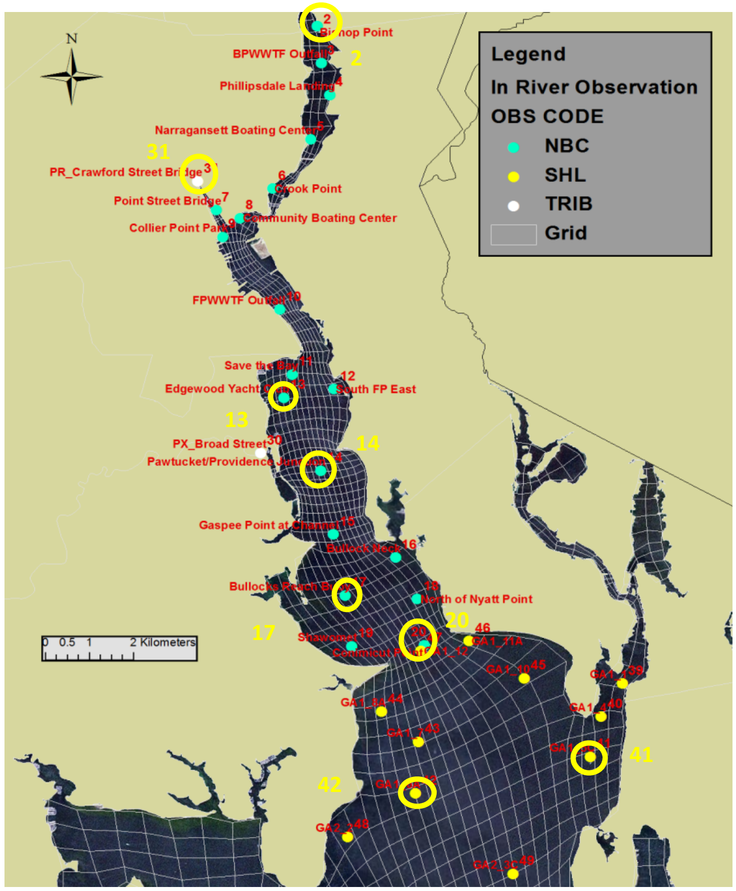


Figure 3-22. Location of subset of stations for presentation of sensitivity runs.

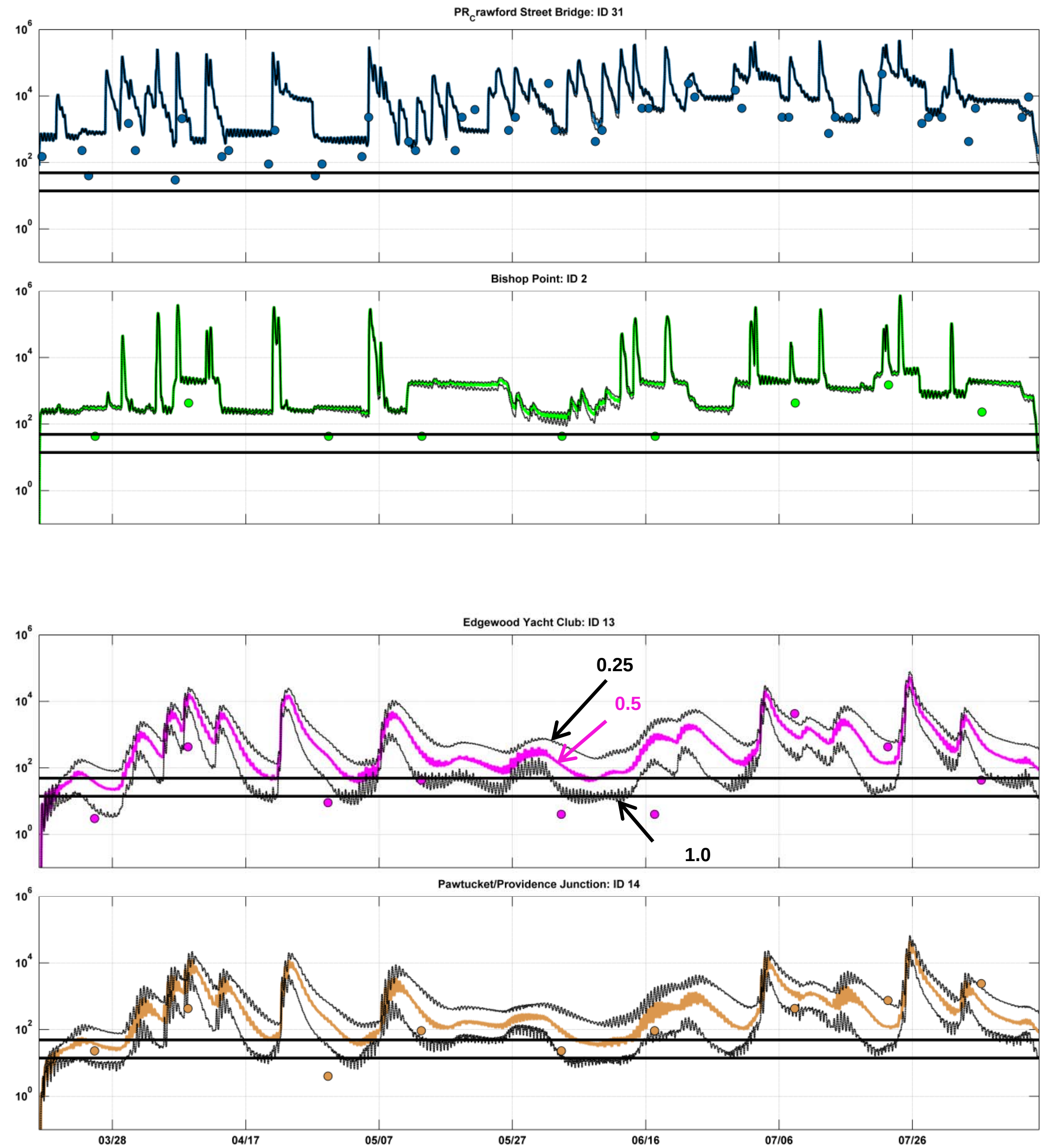


Figure 3-23. Model predictions of base case (solid color line) and two sensitivity runs (dashed black lines) and observations of FC at select stations within the study domain for the entire period of interest. Y axis is in units of MPN/100mL.

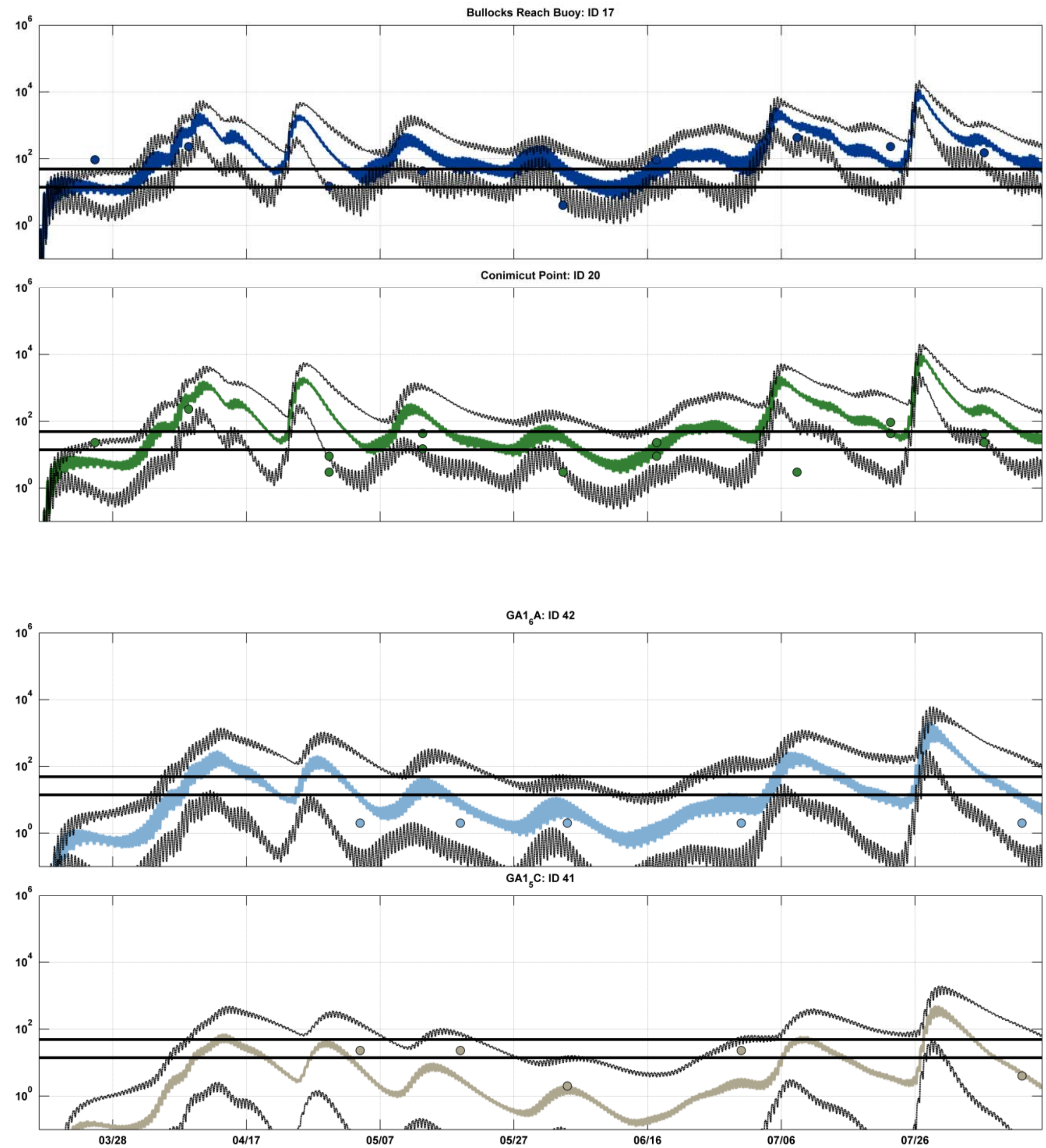


Figure 3-24. Continued model predictions of base case (solid color line) and two sensitivity runs (dashed black lines) and observations of FC at select stations within the study domain for the entire period of interest. Y axis is in units of MPN/100mL.

4 Model Applications for Design Storms

The calibrated model was used to simulate the receiving water quality for the three CSO construction phases. Phase I has been completed and is operational while Phase II is still under construction. Phase III is the primary focus of this modeling study and multiple Phase III treatment alternatives were developed by MWH.

For each phase and alternatives both a 3-month and 12-month design storm was simulated. These storms varied with respect to flow volume and were developed by MWH and provided to RPS ASA in a similar manner as the 7-month calibration run described in Section 3. Source types that were included in the modeling included CSOs, WWTFs, separated sewers (SS), and tributaries (rivers). Details of the FC loadings for each source are documented in MWH (2015).

4.1 Hydrodynamic Simulations

The hydrodynamic model that is described in Section 3 was used for the design storm simulations with adjustments to the tributary inputs to the system. Table 4-1 characterizes the time history of tributary flow relative to the storm beginning at Hour 0. A constant dry weather pre-storm flow was developed by MWH based on analysis of historical data, followed by a linear rise starting at Hour 0 and peaking at different times for each river. The post storm flow reduction was also assumed linear and dropped from the peak to the post storm dry weather level at different times for each river and design storm. For modeling purposes the Woonasquatucket, Moshassuck, and West River loads were combined into a single load denoted as the Providence River.

Table 4-1 Chronology of design storm river hydrographs.

River	Chronology	Time (hr) for 3-mo Storm	3-mo Storm flow (m^3/s)	Time (hr) for 12-mo Storm	12-mo Storm flow (m^3/hr)
Blackstone					
	Storm Start (Dry Weather)	0	10	0	10
	Peak Flow	27	39	27	72
	Post Storm (Dry Weather)	117	10	185	10
Moshassuck					
	Storm Start (Dry Weather)	0	0.12	0	0.12
	Peak Flow	3.4	4	3.4	6
	Post Storm (Dry Weather)	11.4	0.12	15.4	0.12
Pawtuxet					
	Storm Start (Dry Weather)	0	4.64	0	4.64
	Peak Flow	12	24	12	37
	Post Storm (Dry Weather)	62	4.64	96	4.64
Ten Mile					
	Storm Start (Dry Weather)	0	0.65	0	0.65
	Peak Flow	16	2.5	16	3.9
	Post Storm (Dry Weather)	82	0.65	129	0.65
Woonasquatucket					
	Storm Start (Dry Weather)	0	0.75	0	0.75
	Peak Flow	21	3	21	5
	Post Storm (Dry Weather)	279	0.75	453	0.75
West					
	Storm Start (Dry Weather)	0	0.07	0	0.07
	Peak Flow	3.14	2.13	3.14	3.25
	Post Storm (Dry Weather)	5.61	0.07	6.92	0.07

4.2 Water Quality Simulations

The water quality simulations are presented in the context of the 3- and 12-month design storms superimposed on dry weather background conditions for river and WWTF sources. A summary of the discharge concentrations are given in Table 4-2 for each river developed by MWH (2015) from NBC dry weather tributary monitoring data as well as the standard secondary treatment level for WWTFs that were used in calculating the dry weather loads to the modeled area. In order to show the impact of the source loads and background loads on the rivers and Upper Bay, the simulation results are displayed showing shellfishing standards being met at the beginning and at the end of simulations. However, NBC sampling efforts have shown that water quality standards are not being met during dry weather. Figure 4-1 shows the dry weather geomean concentration levels in the Providence and Seekonk Rivers. Dry weather is defined as no rainfall on the sampling date and three days prior to the sampling date.

Table 4-2 Dry weather (background) concentrations for river and WWTF discharges.

Source	FC/100mL
Blackstone River	70
Moshassuck River	177
Pawtuxet River	90
Ten Mile River	24
West River	774
Woonasquatucket River	297
Field’s Point WWTF	4
Bucklin Point WWTF	4
East Providence WWTF	4

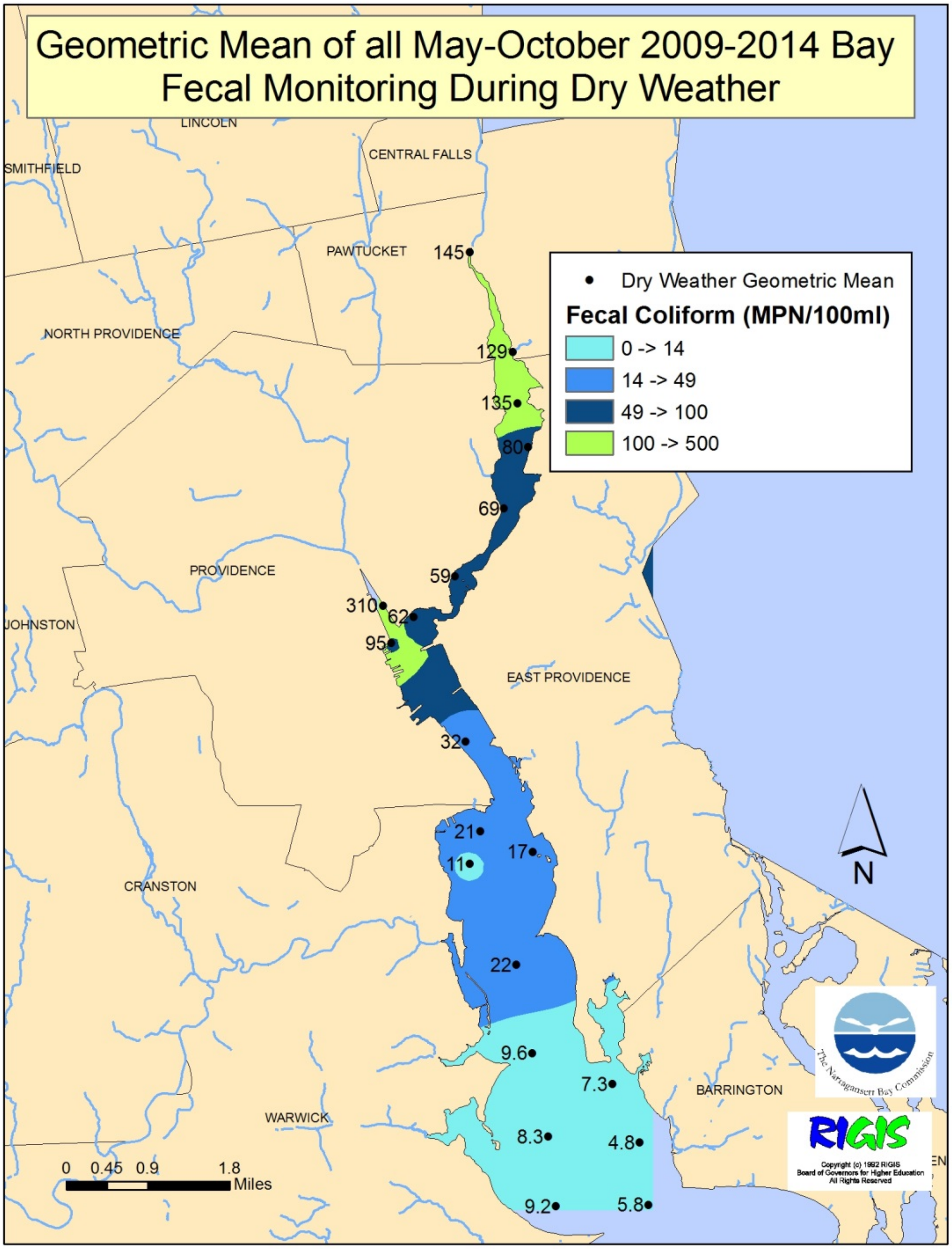


Figure 4-1. Geomean concentrations of NBC monitoring data during dry weather.

Descriptions of the CSO phases and alternatives that were developed by MWH (2015) are summarized in Table 4-3 below. It should be noted that the water quality scenarios described below were run for the purposes of understanding water quality impacts of various options. The water quality alternative naming does not correspond to the alternative plans in the main report.

Table 4-3 Summary of CSO phases and alternatives.

Phase / Alternative	3-mo Design Storm	12-mo Design Storm
I	CSO control in the Field's Point Service Area with the primary control being construction of a storage tunnel to capture the CSO flows during a storm and then pumped to the FP WWTF for treatment. Construction was completed in 2008. MWH simulated system flows for that phase.	MWH simulated system flows for that phase.
II	The second phase focused on two interceptors along the Woonasquatucket and Moshassuck Rivers and is scheduled for completion in 2015. MWH simulated system flows for that phase.	MWH simulated system flows for that phase.
III-1	**Removal of all Phase III CSOs.** Eliminated the flows from all Phase III CSOs.	Modified the flows from all CSOs by subtracting the 3-mo flows from the Phase II 12-mo flows.
III-2	**Only CSO 220 removed.** Eliminated the flow from CSO 220 with all other CSO flows unchanged from Phase II.	Modified the flow from CSO 220 by subtracting the 3-mo flow from the Phase II 12-mo flows with all other CSO flows unchanged from Phase II.
III-3	**CSO 205 to 218 removed (tunnel application)** Eliminated the flows from CSO 205 through 218 with all other CSO flows unchanged from Phase II.	Modified the flows from CSO 205 through 218 by subtracting the 3-mo flow from the Phase II 12-mo flows with all other CSO flows unchanged from Phase II.
III-4	**CSO 218 routed through the WWTP** Rerouted the flow from CSO 218 through the BP WWTF for treatment with all other CSO flows unchanged from Phase II.	Rerouted the flow from CSO 218 through the BP WWTF for treatment with all other CSO flows unchanged from Phase II.
III-5	**Storage/Treatment** CSOs 205 to 218 rerouted via an interceptor to tank storage and discharged with various levels of treatment.	CSOs rerouted via an interceptor to tank storage and discharged with various levels of treatment.

4.2.1 3-Month Design Storm

4.2.1.1 *3-Month Loading Summary*

The 3-month design storm was originally chosen as the storm to which the CSO controls would be designed. This meant that it was previously intended that all the CSO loads for this severity of storm would be captured. This study evaluates a scenario that represents that original intent as well as other alternatives. Table 4-4 presents a summary by source type of total load expressed as percentage of the total discharged during the simulation period starting six hours before the storm starts and ending 19 days later. Figure 4-2 shows this summary in histogram form. Table 4-5 shows the relative percentage distribution by source. For this storm the CSOs are the largest load source, with the Phase III alternatives varying from 60.3 to 81.8% of the total load with the exception of alternative 1 which has no CSO load. The river loads are constant across the alternatives and vary between 9.5 and 52.2% of the total for Phase III alternatives. Storm sewers are also constant across the alternatives and smaller than the rivers, varying between 8.7 and 47.5% of total load for Phase III alternatives. The WWTFs are insignificant. More details describing the development of the loads are found in MWH (2015).

Table 4-4 Summary by source of FC loads for the 3-mo storm for all scenarios.

Phase - Alternative	CSOs (FC)	WWTFs (FC)	Storm Sewers (FC)	Rivers (FC)	Total (FC)	Rank by Highest Total
I	7.37E+14	3.63E+11	5.47E+13	6.01E+13	8.52E+14	1
II	5.60E+14	3.63E+11	5.47E+13	6.01E+13	6.75E+14	2
III-1	0.00	3.63E+11	5.47E+13	6.01E+13	1.15E+14	7
III-2	5.17E+14	3.63E+11	5.47E+13	6.01E+13	6.32E+14	3
III-3	1.75E+14	3.63E+11	5.47E+13	6.01E+13	2.90E+14	6
III-4	4.77E+14	3.78E+11	5.47E+13	6.01E+13	5.92E+14	4
III-5	2.31E+14	3.63E+11	5.47E+13	6.01E+13	3.46E+14	5

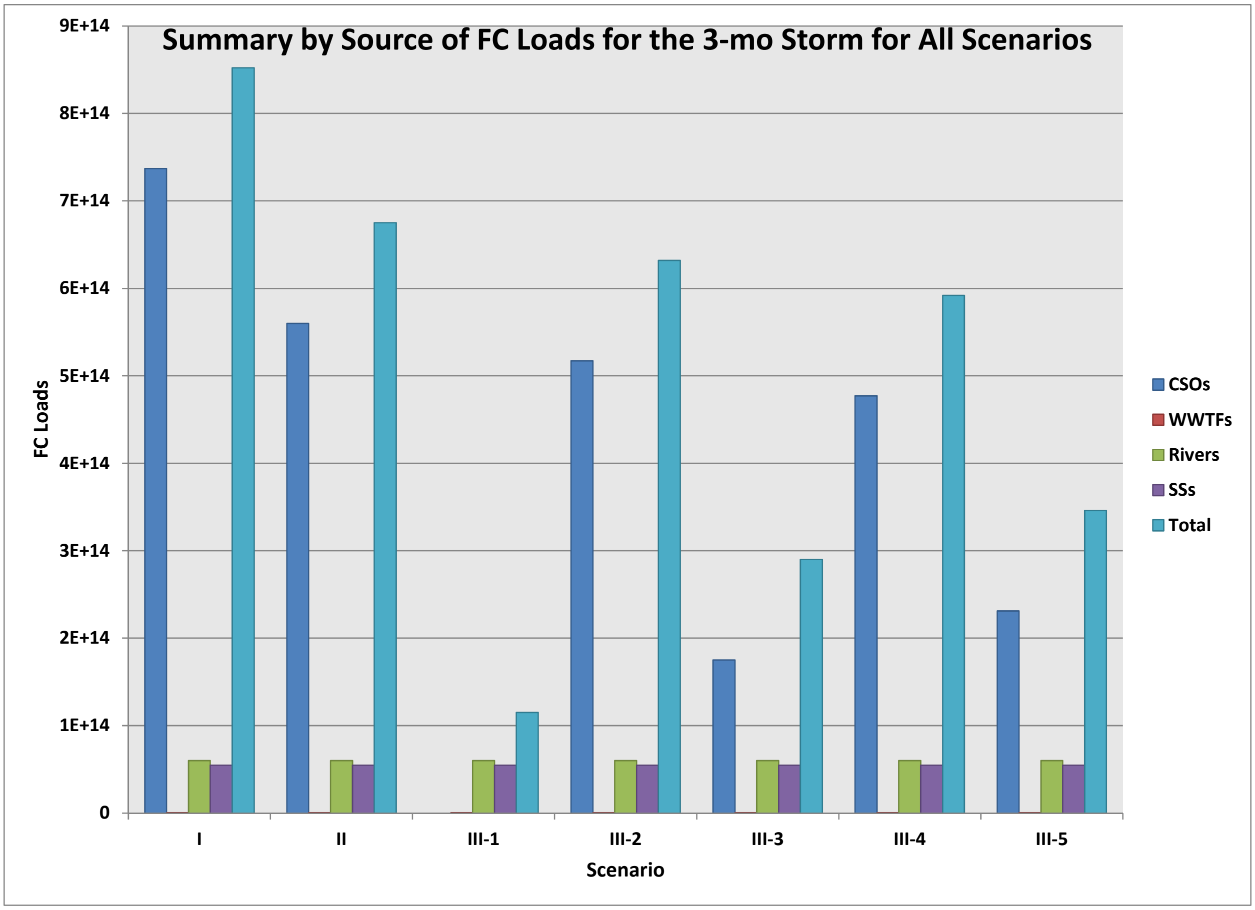


Figure 4-2: Summary by source of FC loads for the 3-month storm for all scenarios.

Table 4-5 Percentage by source of FC loads for the 3-mo storm for all scenarios.

Phase - Alternative	CSOs (%)	WWTFs (%)	Storm Sewers (%)	Rivers (%)	Total (%)
I	86.5	0.0	6.4	7.1	100.0
II	82.9	0.1	8.1	8.9	100.0
III-1	0.0	0.3	47.5	52.2	100.0
III-2	81.8	0.1	8.7	9.5	100.0
III-3	60.3	0.1	18.9	20.7	100.0
III-4	80.6	0.1	9.2	10.1	100.0
III-5	66.7	0.1	15.8	17.4	100.0

The 0% shown for CSO loading under III-1 is actually zero as all CSO overflows are captured. This is in contrast to the WWTF loading for Phase I which is nonzero but more than three orders of magnitude less than the total load.

4.2.1.2 *3-Month Simulation Results*

The model results are shown in a variety of formats: time series of FC concentrations at selected locations corresponding to NBC monitoring locations; plan views of FC concentration contours for the Upper Bay, and the Providence and Seekonk Rivers; and closure area tables expressed as area-time products for shellfishing and contact recreation FC concentration limits.

4.2.1.2.1 Time Series of FC Concentrations

The time series shown below are model outputs selected for four NBC monitoring stations located from north to south:

- Station 5 in the Seekonk River near the Narragansett Boating Center
- Station 9 in the Providence Harbor near Collier Point Park
- Station 13 in the Providence River near the Edgewood Yacht Club
- Station 20 at the Providence River / Upper Bay boundary near Conimicut Point

Each of

Figure 4-3 through Figure 4-6 below shows the seven model scenarios (phases I and II, phase III with 5 alternatives) for each station for the 3-mo storm. The time axis is referenced to the start of the storm and varies according to the duration of the elevated concentrations.

Station 5 - Narragansett Boating Center shown in

Figure 4-3 exhibits a range of concentrations during the first three days characterized by a large variation with sharp peaks due to the tides transporting higher concentrations south on ebb and lower concentrations north on flood. Phase I starts out with the highest concentrations during the first ebb tide (peak at 0.33 days) but is generally matched by phases II and III-2 during the second ebb tide (peak at 0.67 days) and continues through the third ebb tide peak at 1.13 days with the highest concentration of 7,600 FC/100mL. The largest peaks for all alternatives (except phase III-1) occurs at the third ebb tide peak with phase III-4 at 6,400 III-5 at 2,600 and III-3 at 1,700 FC/100mL. Phase III-1 peaks at 1,000 FC/100mL at the first ebb tide peak. All the scenarios drop to low dry weather levels in less than 4 days from the start of the storm.

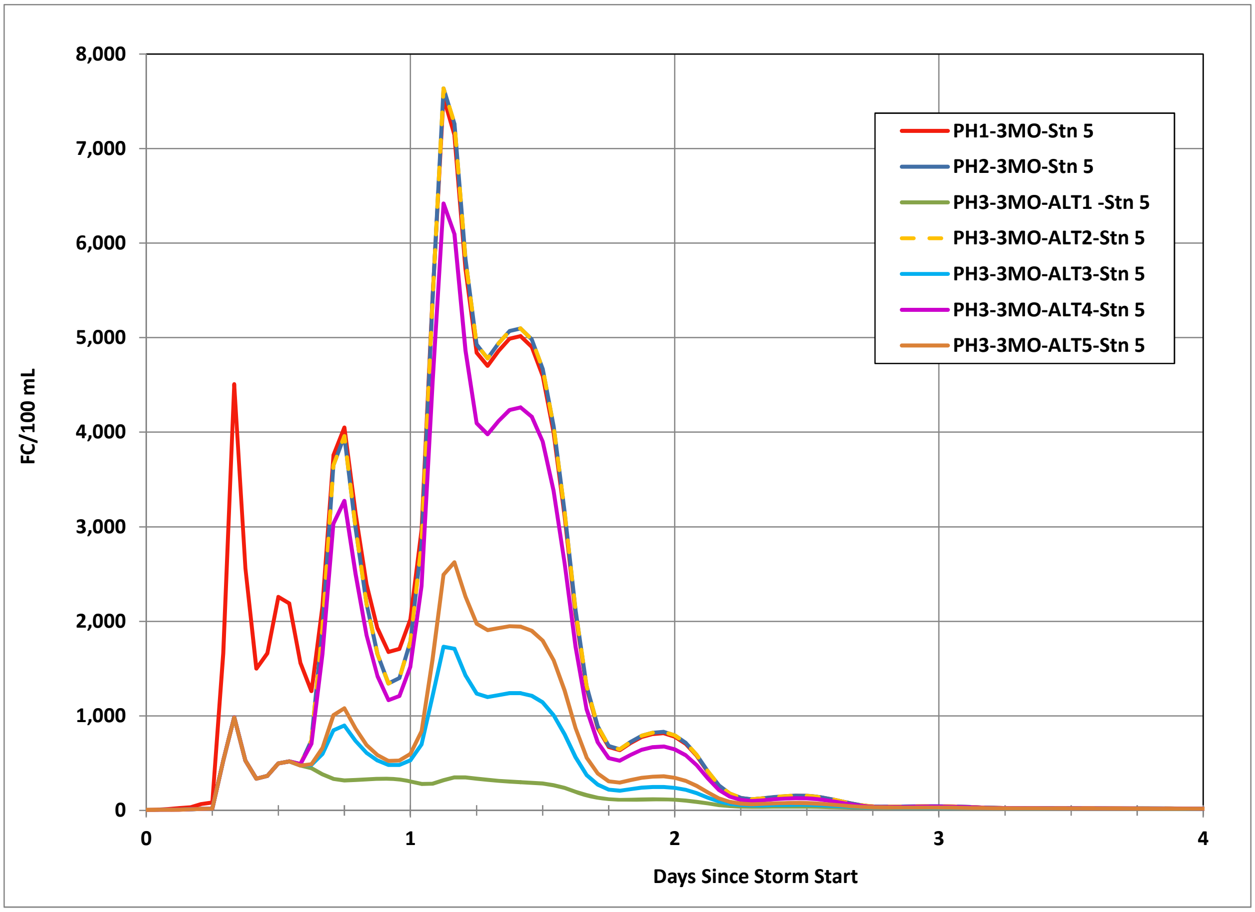


Figure 4-3. Time series of FC concentrations during simulation period for all 3-mo scenarios at Stn 5 – Narragansett Boating Center.

Station 9 - Collier Point Park shown in Figure 4-4 exhibits tidal peaks but the first one at 0.33 days is much smaller than the later ones. All the phases and alternative reach their maximum concentrations at the third ebb tide peak (just after the beginning of the 2nd day) with I at 19,900 FC/100mL; II, III-3 and III-4 at 7,900 FC/100mL; for III-2 at 4,600, and III-1 at 1,500 FC/100mL. All the scenarios drop to low dry weather levels within 3 days from the start of the storm.

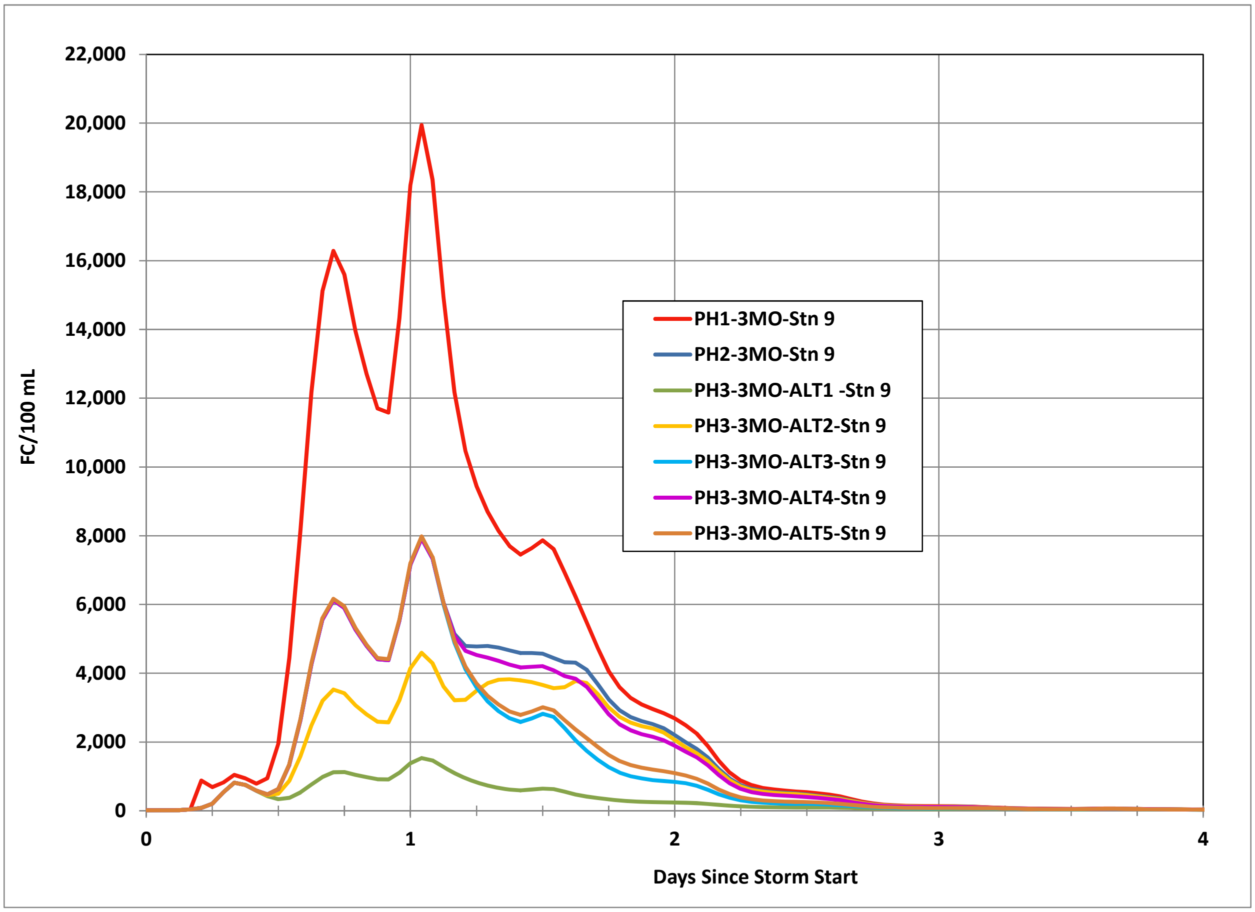


Figure 4-4. Time series of FC concentrations during simulation period for all 3-mo scenarios at Stn 9 – Collier Point Park.

Station 13 - Edgewood Yacht Club shown in Figure 4-5 exhibits the typical tidal-induced variation until approximately 8 days after the storm start. The largest peak (at 2.25 days) was from phase 1 at 2,460 FC/100mL followed by maxima peaks at 2.75 days of 1,610 for II, 1,500 for III-2, and 1,390 for III-4. The maxima for the remaining scenarios occurred at 2.25 days: 890 for III-5, 800 for III-3, and 220 for III-1.

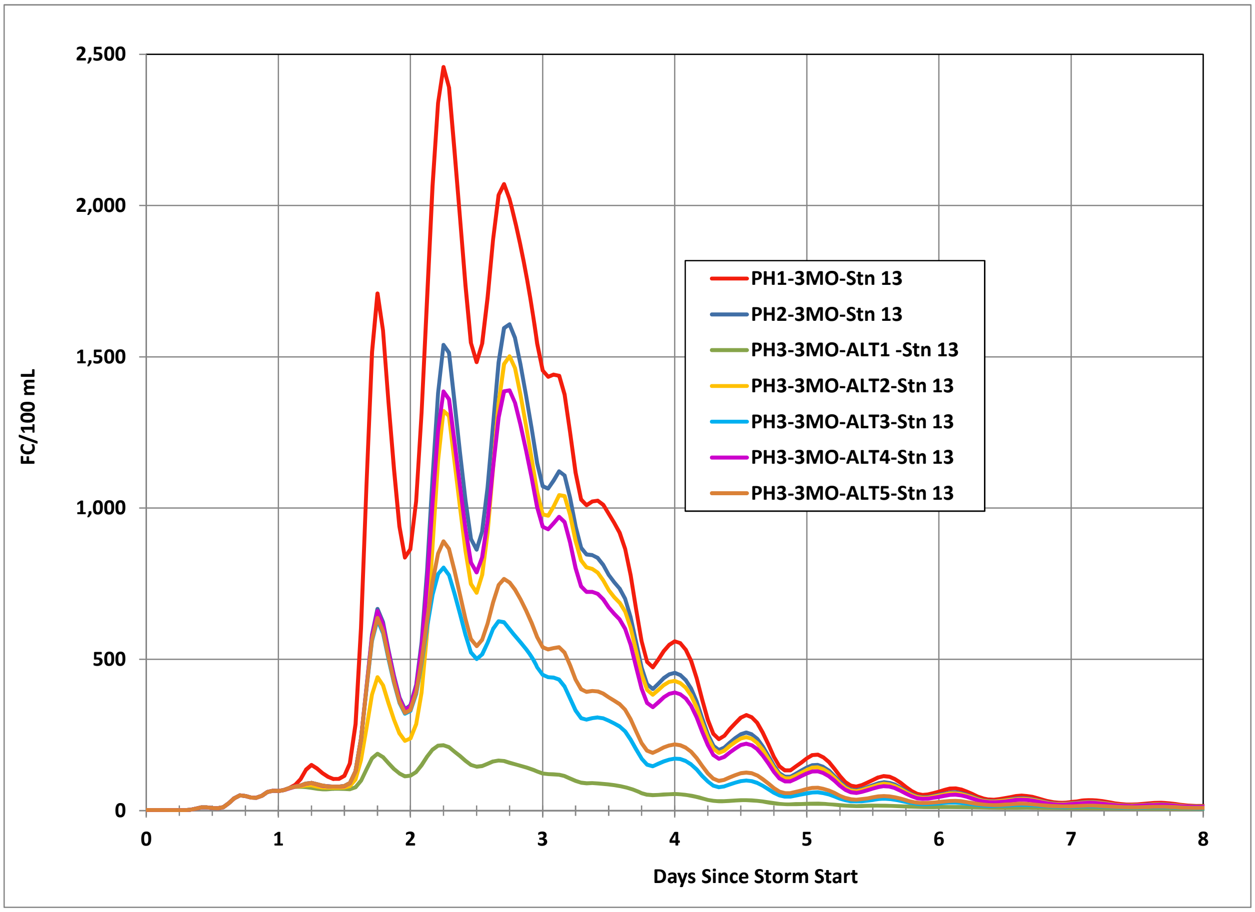


Figure 4-5. Time series of FC concentrations during simulation period for all 3-mo scenarios at Stn 13 – Edgewood Yacht Club.

Station 20 – Conimicut Point shown in Figure 4-6 also exhibits the tidal induced variation throughout the time series with a significant time lag due to the distance traveled from the source loads to Station 20. The storm induced concentrations begin to rise after 1 day subsequent to the start of the storm and return to pre-storm, dry weather concentration approximately 14 days after the storm start. The largest maxima occur at 4.88 days for phase I at 151, II at 101, III-4 at 91, and III-2 at 89 FC/100mL and occur at 4.33 days for III-5 at 62, III-3 at 56.The peak for III-1 at 34 FC/100mL occurs at 2.33 days.

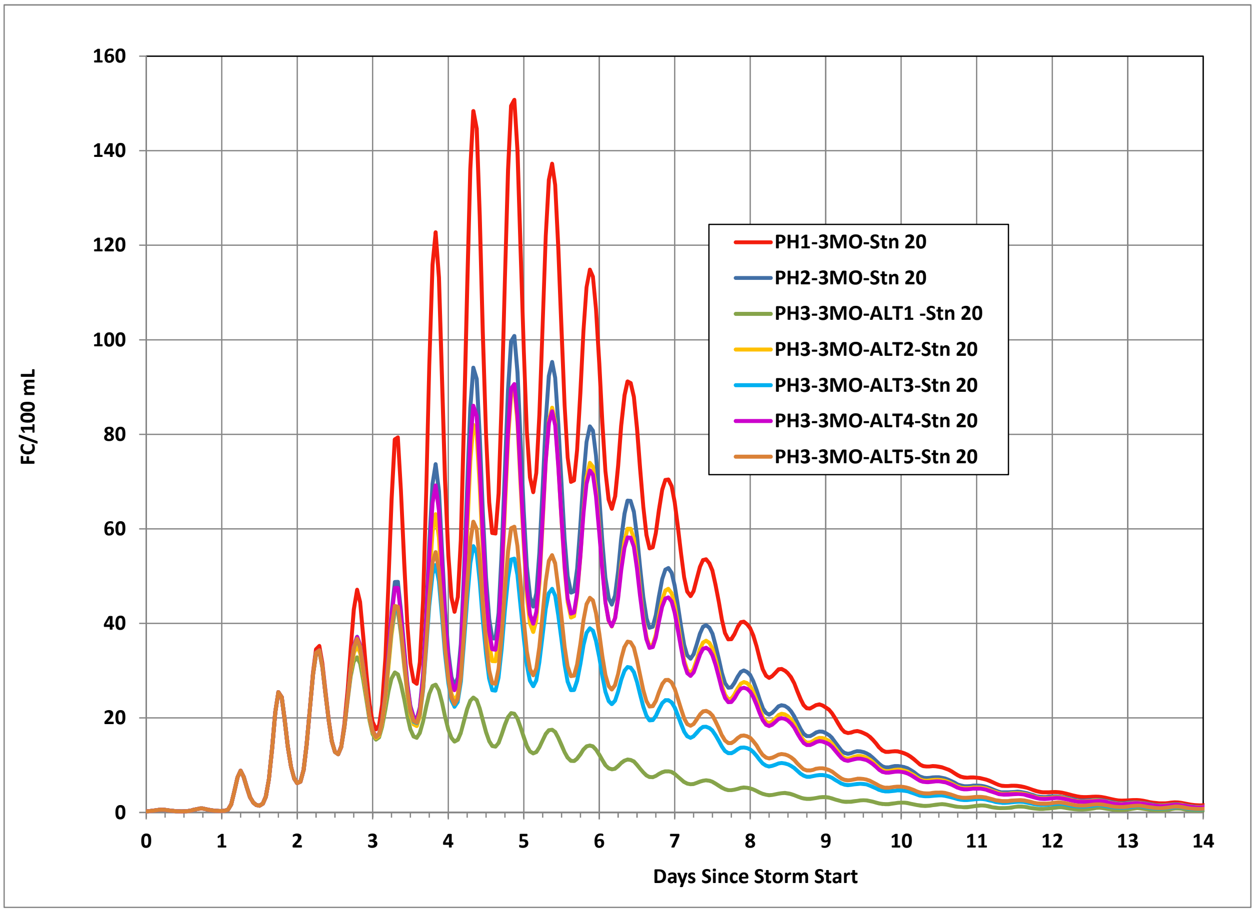


Figure 4-6. Time series of FC concentrations during simulation period for all 3-mo scenarios at Stn 20 – Conimicut Point.

The ranking of the maximum concentrations for each scenario by station is shown in Table 4-6. The stations closest to and within the areas where discharges occur are most affected by the proximate loads. For those scenarios with almost identical maximum concentrations multiple rankings are given. Thus Stn 5 and Stn 9 show different scenario rankings compared to the total load ranking due to their locations upstream of some of the CSO load sources while Stn 13 and Stn 20 are generally consistent with the total load ranking because of their distance downstream from the CSO load sources.

Table 4-6 Comparative ranking of peak concentrations for the 3-mo storm scenarios by station.

Phase - Alternative	Stn 5	Stn 9	Stn 13	Stn 20	Total Load Ranking
I	1/2/3	1	1	1	1
II	1/2/3	2/3/4/5	2	2	2
III-1	7	7	7	7	7
III-2	1/2/3	6	3	3/4	3
III-3	6	2/3/4/5	6	6	6
III-4	4	2/3/4/5	4	3/4	4
III-5	5	2/3/4/5	5	5	5

4.2.1.2.2 Plan View of FC Concentration Contours

Plan views of the FC concentration contours were generated for all seven 3-mo scenarios for various times after the start of the storm at 0.5, 1, 2, 4, 6, 8, and 10 days. All seven scenarios (Phases I and II, and Phase III alternatives 1 through 5) are shown juxtaposed in each of the seven figures. The concentrations are color coded as shown in the legend.

Plan views for 0.5 days after the start of the storm are shown in Figure 4-7. The Providence River below Gaspee Point and all of the Upper Bay is unaffected by the storm loads but the upper reaches of the Providence and Seekonk River see dramatically different concentrations among the scenarios due to the proximity of the storm loads. Phases I, II, III-2 and III-4 show some areas ranging from 20,000 to 100,000 FC/100mL at the head of the Blackstone River while all but Phase III-1 scenario show that range at the head of the Providence River. Scenarios III-3 and III-5 show between 10,000 and 20,000 FC/100mL while the maximum for phase III-1 is limited to between 1,000 and 5,000 FC/100mL since all CSOs are controlled. The effect of the Pawtuxet River is clearly seen spreading into the Providence River from its mouth located between Fields and Gaspee Points.

Plan views for 1 day after the start of the storm are shown in Figure 4-8. Since the 3-mo design storm lasts only 6 hrs all the concentrations in the Providence and Seekonk Rivers have diminished to concentrations below the 0.5-day levels although phase I stills shows an exceedance above 20,000 FC/100mL in the uppermost Providence River above the hurricane barrier. Phase III-1 generally shows levels below 500 FC/100mL in the Seekonk River since all CSOs are controlled. The plumes from the sources are merging in the Providence River and the southernmost extent has moved south of Gaspee

Point for all scenarios indicative of the proximity of river and separated sewer loads located south of Fields Point.

Plan views for 2 days after the start of the storm are shown in Figure 4-9. Flushing and decay continue to cause reduction in concentrations in the Seekonk and upper Providence Rivers compared to one day earlier. The highest concentrations are seen in the Providence River from Fields Point north to the Providence Harbor area to between 1,000 and 5,000 FC/100mL for all scenarios except phase III-1 (no CSO loads) where the range is between 100 and 500 FC/100mL. The FC plume (> 14 FC/100mL) now extends south of Gaspee Point almost to the conditional closure areas below Conimicut Point for all scenarios.

Plan views for 4 days after the start of the storm are shown in Figure 4-10. The FC concentrations in the Seekonk River and the Providence Harbor area have diminished to below 49 FC/100mL with the upper Providence River (above the hurricane barrier) still in the range of 100 to 500 FC/100mL. Between Fields Point and below Gaspee Point the levels have dropped to between 100 and 1000 FC/100mL for phases I, II and III-2, while III-3, III-4 and III-5 have fallen to between 100 and 500 FC/100mL, and III-1 ranges between 14 and 100 FC/100mL. The FC plume extends into the conditional closure area with a concentration between 14 and 49 FC/100mL for all scenarios.

Plan views for 6 days after the start of the storm are shown in Figure Figure 4-11. The Providence River above the hurricane barrier ranges between 100 and 500 FC/100mL while the Seekonk River except at its head are now below 14 FC/100mL. The Providence River is now below 49 FC/100mL above Fields Point where a local concentration minimum occurs with an increase moving downstream. Concentrations range between 100 and 500 FC/100mL in the vicinity of Gaspee Point for phases I, II, III-2, and III-4, with phase I showing the southernmost extent just into the conditional closure area. Phase III-1 shows a range between 14 and 49 FC/100mL in the Gaspee Point area while phases III-3 and III-5 show concentrations between 14 and 100 FC/100mL.

Plan views for 8 days after the start of the storm are shown in Figure Figure 4-12. All concentrations are now below 49 FC/100mL except somewhat downstream from the heads of the Seekonk and Providence Rivers. The extent of the FC plume into the conditional closure area is no longer moving downstream but is similar to the 6-day extent. Concentrations for phase III-1 (no CSOs) are now below 14 FC/100mL everywhere except near the mouth of the Pawtuxet River and heads of the Seekonk and Providence Rivers indicating dry weather loads are the cause.

Plan views for 10 days after the start of the storm are shown in Figure 4-13. Except for near the Pawtuxet River mouth and the heads of the Seekonk and Providence Rivers all concentrations are below 14 FC/100mL.

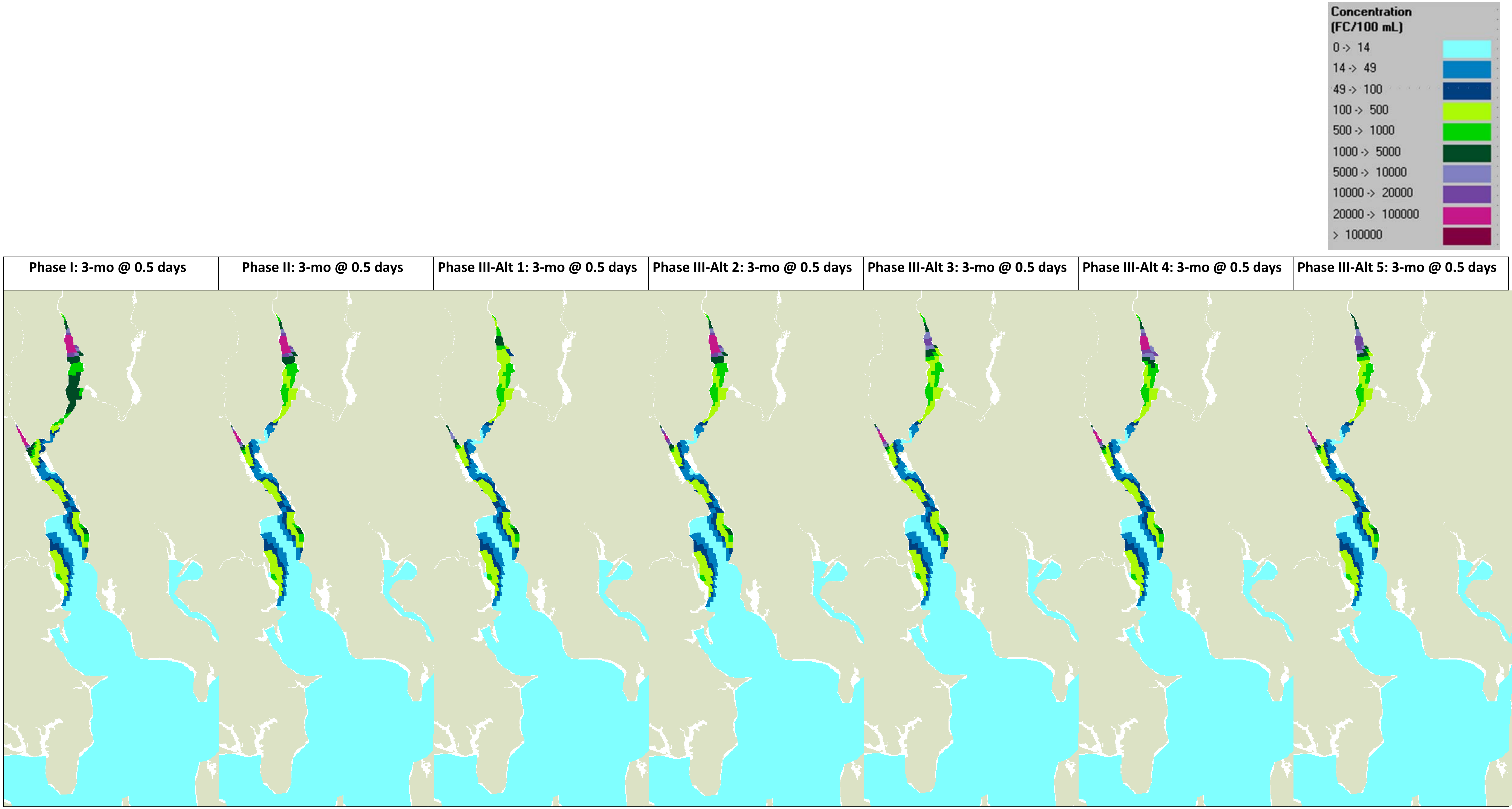
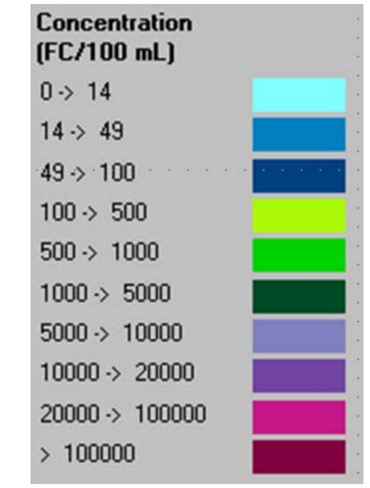


Figure 4-7. Scenario plan views of FC concentrations 0.5 days after start of 3-mo storm.



Phase I: 3-mo @ 1 day	Phase II: 3-mo @ 1 day	Phase III-Alt 1: 3-mo @ 1 day	Phase III-Alt 2: 3-mo @ 1 day	Phase III-Alt 3: 3-mo @ 1 day	Phase III-Alt 4: 3-mo @ 1 day	Phase III-Alt 5: 3-mo @ 1 day

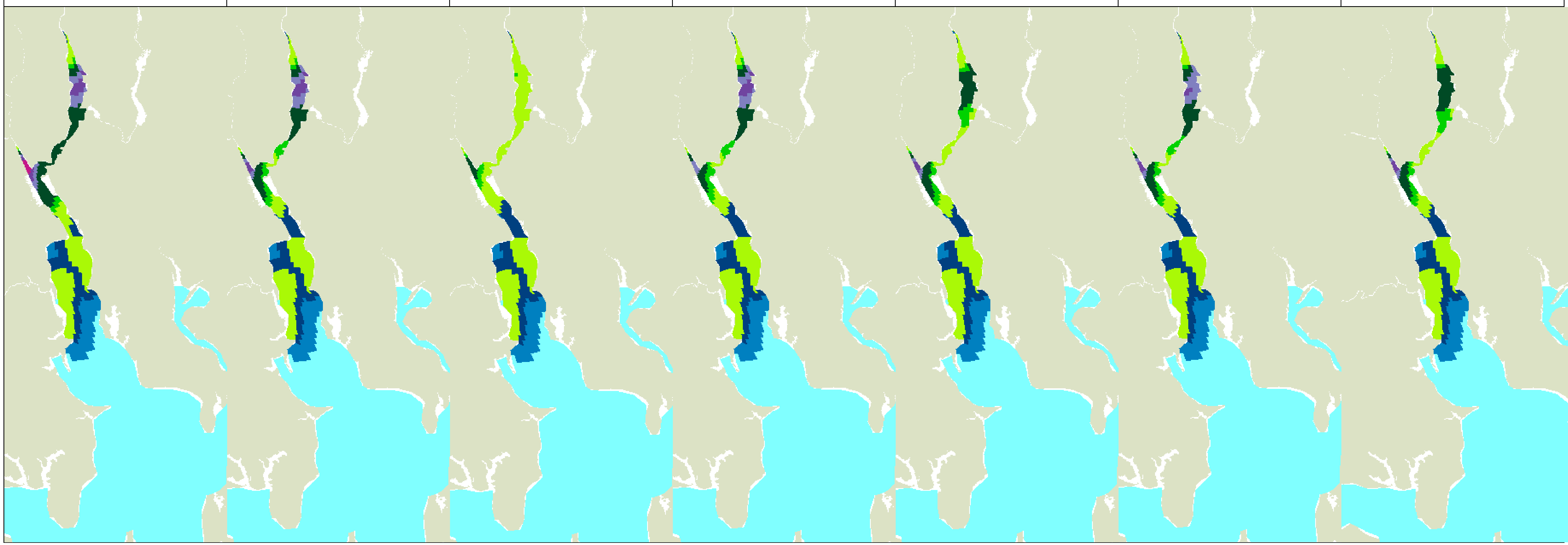
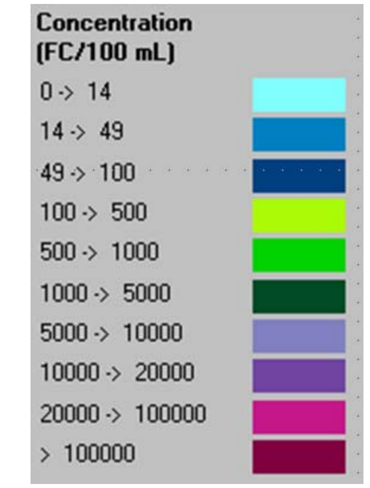


Figure 4-8. Scenario plan views of FC concentrations 1 day after start of 3-mo storm.



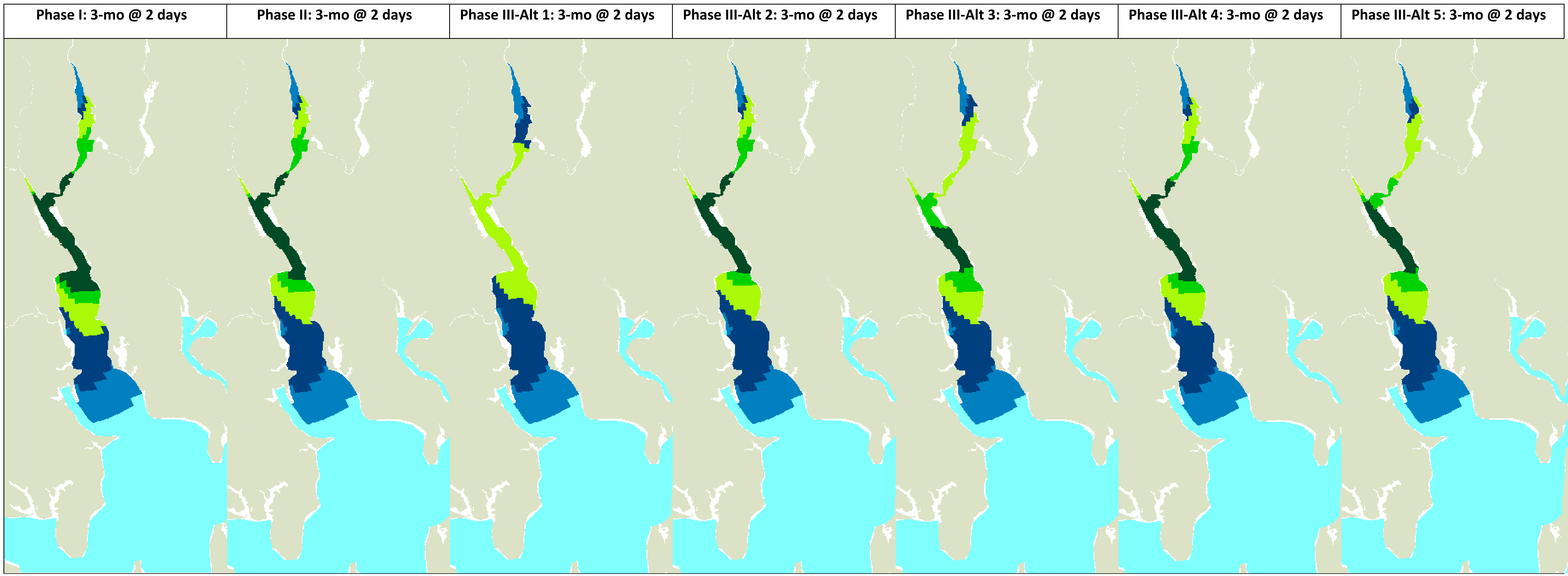


Figure 4-9. Scenario plan views of FC concentrations 2 days after start of 3-mo storm.

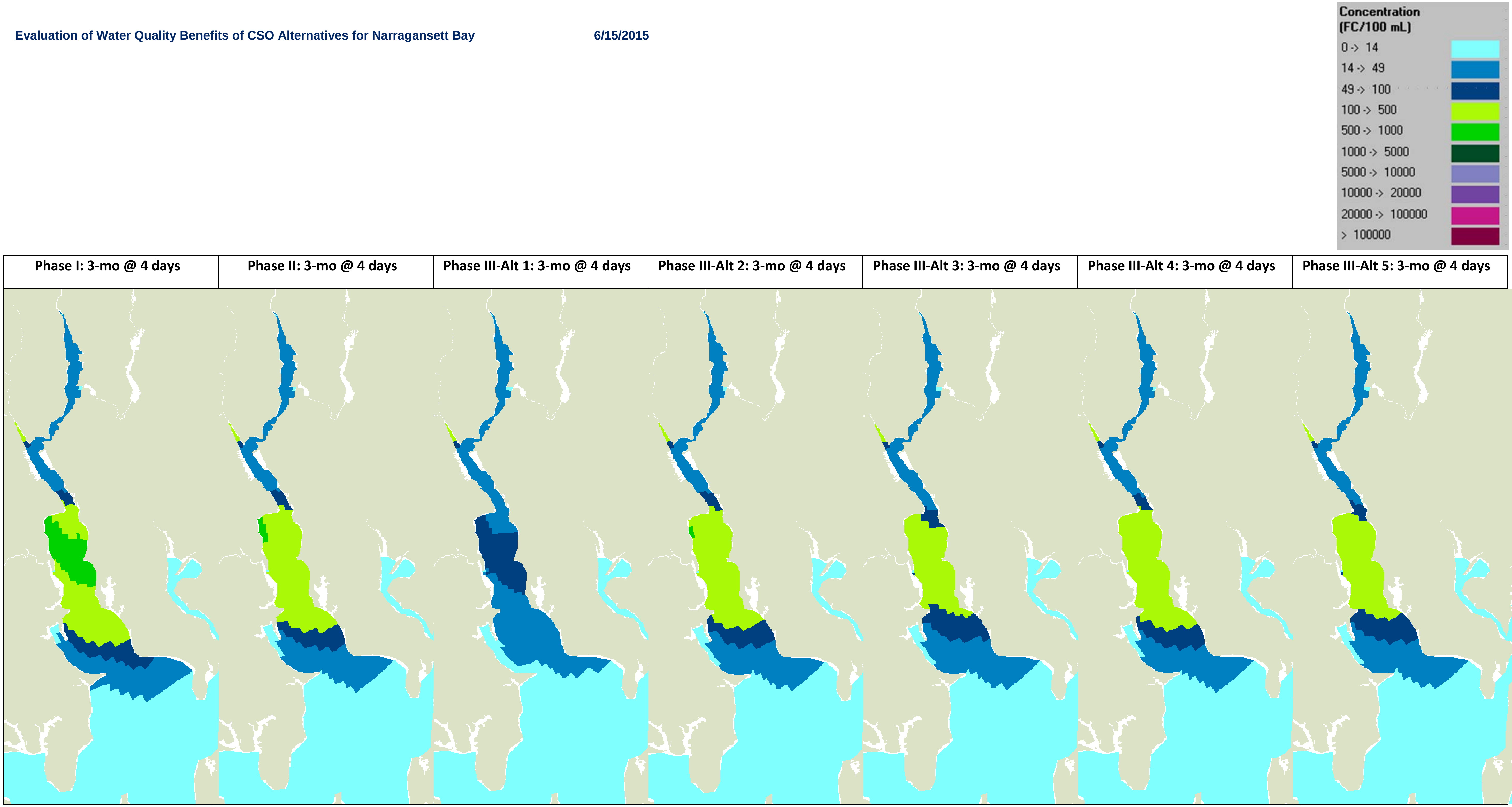
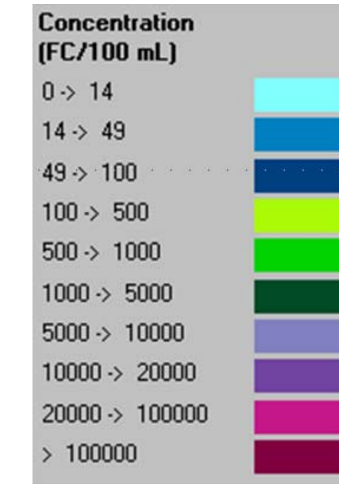


Figure 4-10. Scenario plan views of FC concentrations 4 days after start of 3-mo storm.



Phase I: 3-mo @ 6 days	Phase II: 3-mo @ 6 days	Phase III-Alt 1: 3-mo @ 6 days	Phase III-Alt 2: 3-mo @ 6 days	Phase III-Alt 3: 3-mo @ 6 days	Phase III-Alt 4: 3-mo @ 6 days	Phase III-Alt 5: 3-mo @ 6 days

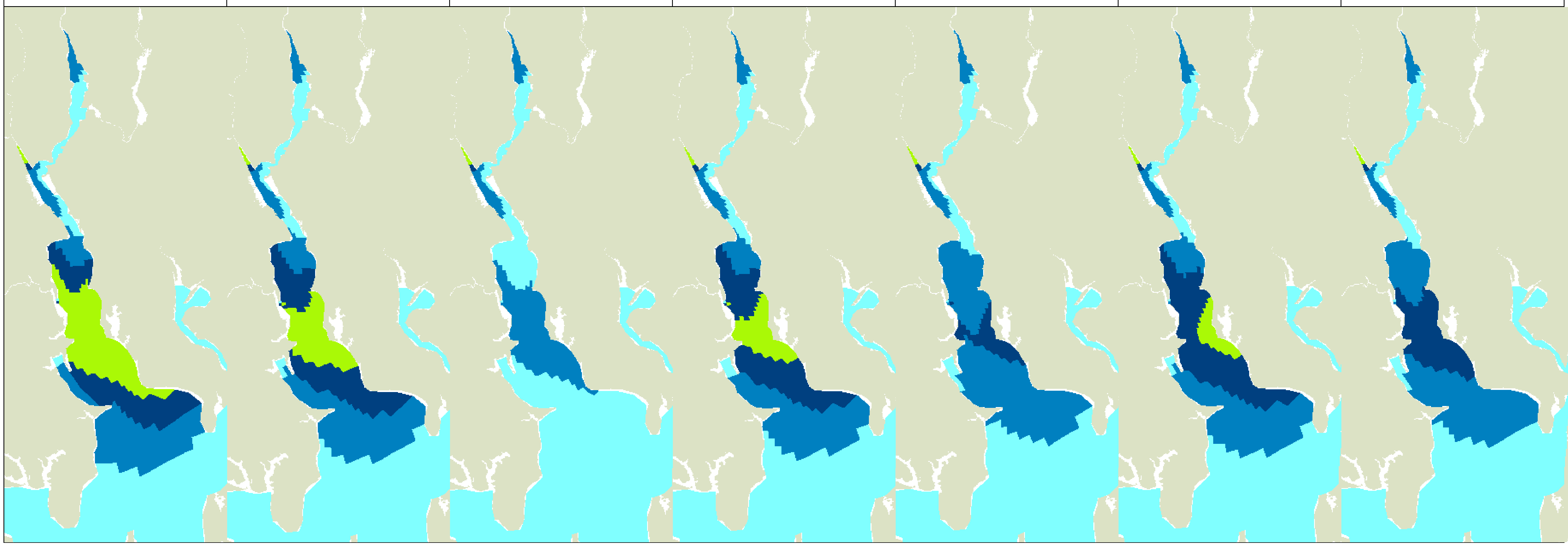
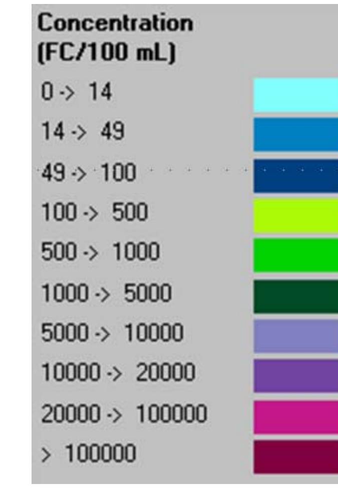


Figure 4-11. Scenario plan views of FC concentrations 6 days after start of 3-mo storm.



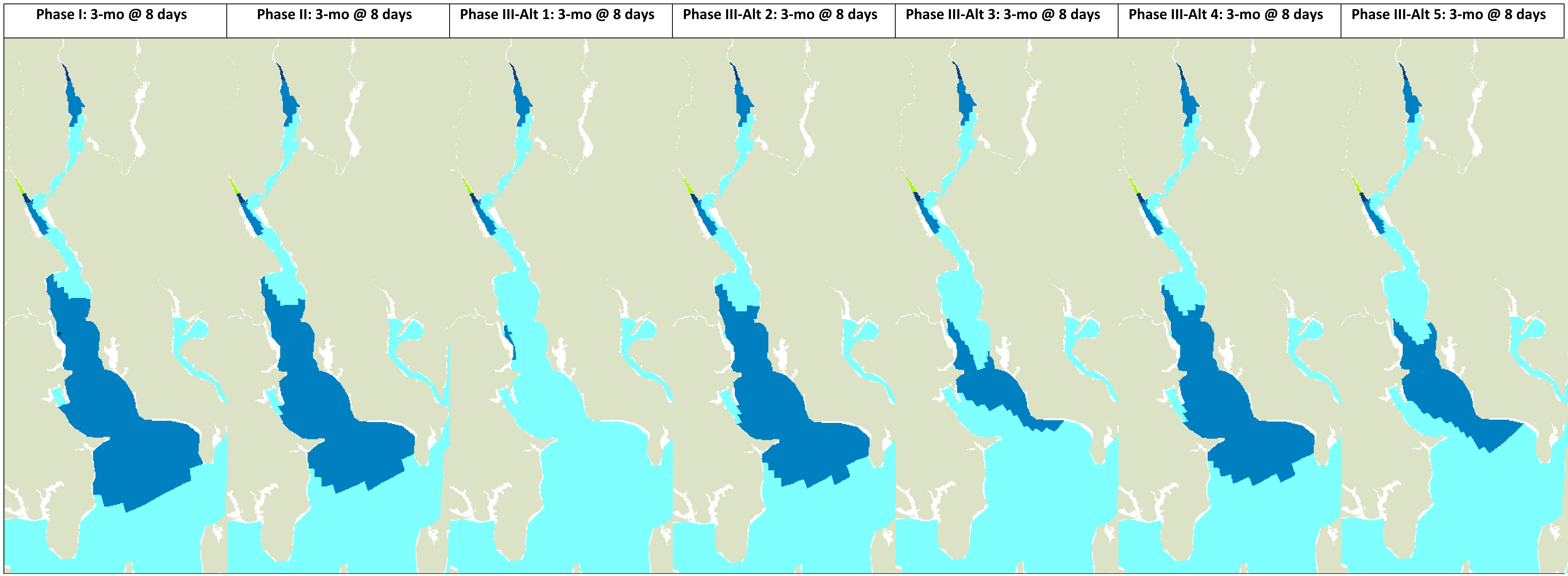


Figure 4-12. Scenario plan views of FC concentrations 8 days after start of 3-mo storm.

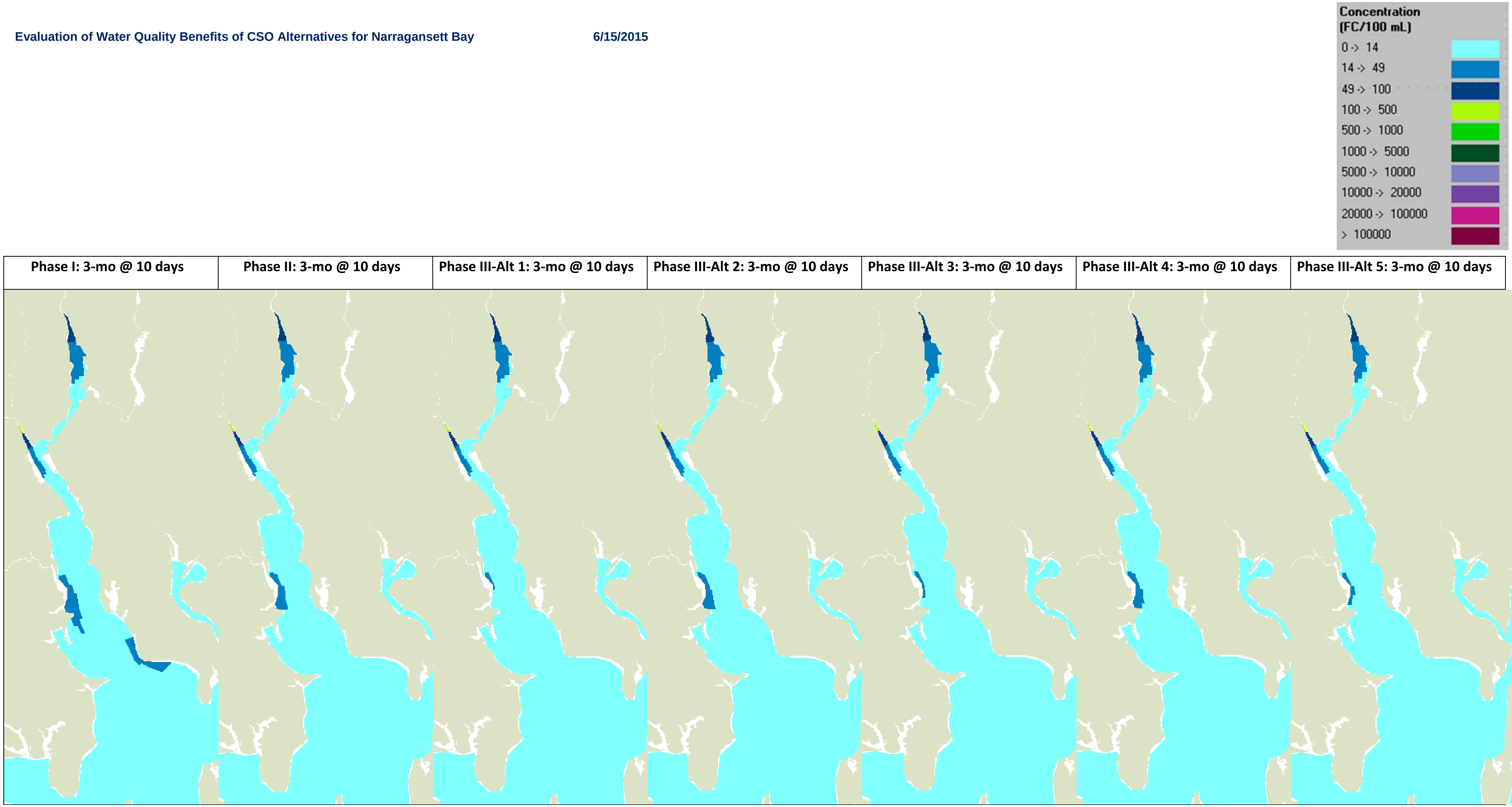


Figure 4-13. Scenario plan views of FC concentrations 10 days after start of 3-mo storm.

4.2.1.2.3 Closure Area Tables

State designated conditional closure and water classification areas are presented in Figure 4-14 and a summary of the RIDEM definitions of FC bacteria criterion for the different classifications is presented in Table 4-7.

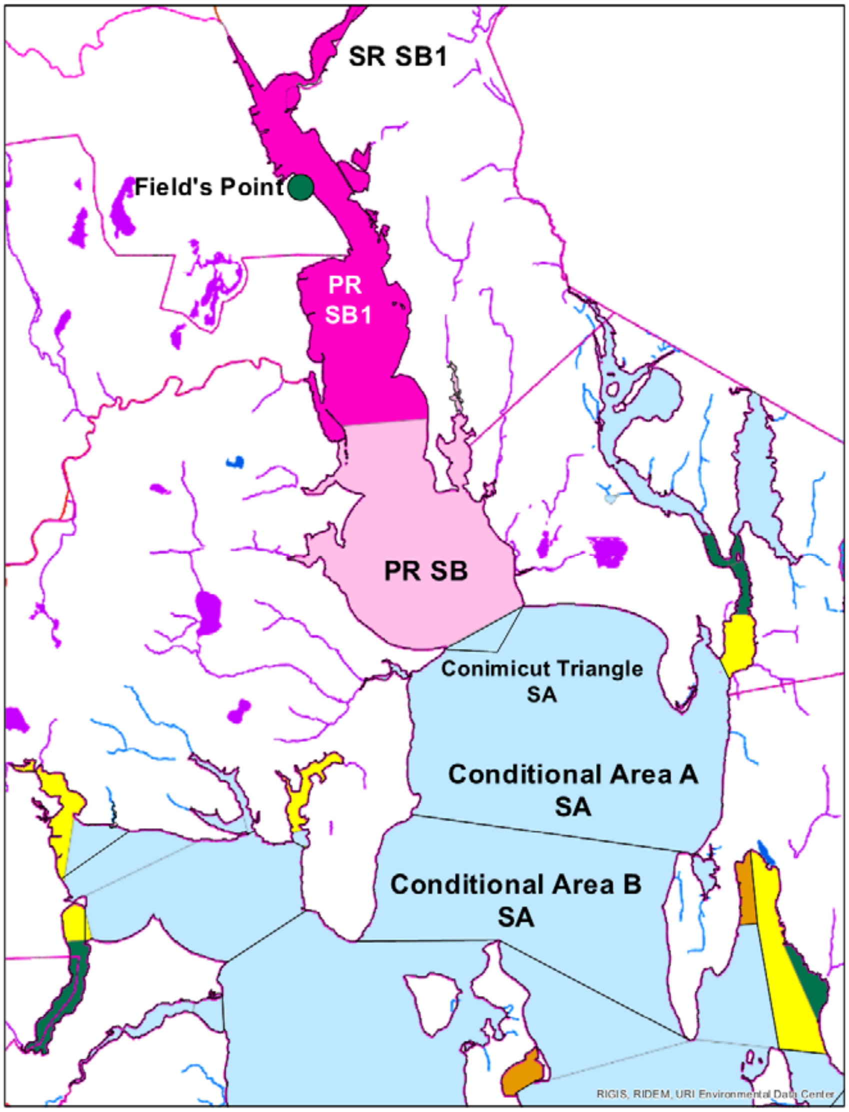


Figure 4-14. Designated conditional closure areas and water quality classification areas.

Table 4-7 Definition of FC bacteria criterion for water quality classification areas (RIDEM 2010).

<table>
<tr><th>Criterion</th><th>CLASS SA, SA {b}</th><th>CLASS SB, SB1, SB{a}, SB {a}</th></tr>
<tr><td rowspan="2">Fecal Coliform Bacteria (MPN/100mL)</td><td>Shellfishing Criteria: Not to exceed a geometric mean MPN value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution.</td><td></td></tr>
<tr><td colspan="2">Primary Contact Recreational/Swimming Criteria-Not to exceed a geometric mean value of 50 MPN/100mL and not more than 10% of the total samples taken shall exceed 400 MPN/100mL, applied only, when adequate enterococci data are not available.</td></tr>
</table>

Closure areas were determined from model results by determining how much a given closure area exceeded a given concentration threshold and the duration of that exceedance. Table 4-8 presents the six closure areas (from south to north) encompassing Upper Narragansett Bay plus the Providence and Seekonk Rivers. These areas include the three conditional shellfishing closure areas and the three SB contact recreational areas. The two shellfishing thresholds, a geomean of 14 FC/100mL and a 90th percentile of 49 FC/100mL, were used as metrics for the three conditional areas. The two contact recreational standards, a geomean of 50 FC/100mL and a 90th percentile of 400 FC/100mL, were used as metrics for the three SB areas. The relevant criteria for each area are based on RIDEM water quality standards (RIDEM, 2010).The sizes of these areas were obtained from shapefiles downloaded from the Rhode Island Geographic Information System (http:www.edc.uri.edu/rigis).

Table 4-8 Areas and limits used in the closure area and duration determination from model results.

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

Tables were generated for each closure area for the 3-mo storm showing results from the seven model runs (1 each for Phase 1 and Phase 2; 5 alternatives for Phase 3). Specifically, a closure, expressed in acre-days, is defined by checking each model grid cell in an area to determine if its concentration exceeds a threshold for that timestep. If so then the product of the area of the grid cell times the model timestep (30 min) is added to the running total for that scenario and closure area.

Table 4-9 shows the 3-mo design storm results for Conditional Area B located south of Conditional Area A. As this area is the furthest removed from the loads entering the Providence and Seekonk River there is no effect at either threshold except for phase I and II.

Table 4-9 Three-month design storm results for conditional area B using the shellfish closure metrics.

Conditional Area B	14 FC/100mL	49 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	266	0
II	1	0
III-1	0	0
III-2	0	0
III-3	0	0
III-4	0	0
III-5	0	0

Table 4-10 shows the 3-mo design storm results for Conditional Area A located south of Conimicut Point. The phase 1 results are the highest for both thresholds followed, in descending order by phase II, III-4, III-2, III-5, III-3, and III-1. This ranking generally follows the FC load ranking given in Table 4-4.

Table 4-10 Three-month design storm results for conditional area A using the shellfish closure metrics.

Conditional Area A	14 FC/100mL	49 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	15,300	2,800
II	10,900	1,110
III-1	1,960	0
III-2	9,710	784
III-3	5,860	69
III-4	9,890	833
III-5	6,620	148

Table 4-11 shows the 3-mo design storm results for the Triangular Conditional Area located at Conimicut Point. The phase 1 results are the highest for both thresholds followed, in descending order by phase II, III-2, III-4, III-5, III-3, and III-1. This ranking generally follows the FC load ranking given in Table 4-4 and for conditional area A.

Table 4-11 Three-month design storm results for Conimicut triangle conditional area using the shellfish closure metrics.

Conimicut Triangle	14 FC/100mL	49 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	2,040	840
II	1,860	423
III-1	744	0
III-2	1,810	323
III-3	1,440	61
III-4	1,790	335
III-5	1,530	100

Table 4-12 shows the 3-mo design storm results for the Providence River SB area located between Conimicut and Gaspee Points. The phase 1 results are again the highest for both thresholds followed, in descending order by phase II, III-4, III-2, III-5, III-3, and III-1. This ranking generally follows the FC load ranking given in Table 4-4 and for conditional areas A and Conimicut Triangle.

Table 4-12 Three-month design storm results for the Providence River - SB area using the contact recreation closure metrics.

Providence River-SB	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	11,300	530
II	9,040	113
III-1	1,880	1
III-2	8,350	65
III-3	5,590	1
III-4	8,420	65
III-5	6,220	1

Table 4-13 shows the 3-mo design storm results for the Providence River SB1 area located north of Gaspee Point and the Providence SB area. The phase 1 results are again the highest for both thresholds followed, in descending order by phase II, III-2, III-4, III-5, III-3, and III-1. This ranking generally follows the FC load ranking given in Table 4-4 conditional areas A and Conimicut Triangle, and for Providence SB.

Table 4-13 Three-month design storm results for the Providence River – SB1 area using the contact recreation closure metrics.

Providence River-SB1	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	10,200	4,200
II	9,820	3,320
III-1	6,300	221
III-2	9,690	3,000
III-3	8,170	1,750
III-4	9,530	3,010
III-5	8,590	2,050

Table 4-14 shows the 3-mo design storm results for the Seekonk River SB1 area. The phase 1 results for the 50 FC/100mL threshold are similar to the other scenarios in acre-days since many major loads are located in this River. The higher 400 FC/100mL threshold results are somewhat more differentiated with phases I, II, III-2 and III-4 similar followed by phases III-3 and III-5 and phase III-1 the lowest.

Table 4-14 Three-month design storm results for the Seekonk River – SB1 area using the contact recreation closure metrics.

Seekonk River-SB1	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	1,420	646
II	1,400	619
III-1	1,180	162
III-2	1,400	619
III-3	1,260	450
III-4	1,360	594
III-5	1,300	497

4.2.2 12-Month Design Storm

4.2.2.1 *12-Month Loading Summary*

The 12-month design storm was chosen to provide an indication of the resulting water quality effects of a larger storm that that would not be captured by the proposed 3-mo storm CSO control alternatives.

Table 4-15 presents a summary by source type of total load expressed as number of FCs discharged during the simulation period starting six hours before the storm starts and ending 19 days later. Figure Figure 4-15 shows this summary in histogram form. Table 4-16 shows the relative percentage distribution by source. For this storm the CSOs are again the largest load source, with the Phase III alternatives varying from 79.2 to 86.0% of the total load just slightly less than the Phase I and II percentages of 87.5 and 86.4%, respectively. The river loads are constant and vary between 8.3 and 12.3% of the total for Phase III alternatives with the storm sewers (also constant) smaller than the rivers, varying between 5.7and 8.4% for Phase III. The WWTFs remain insignificant. More details describing the development of the loads are found in MWH (2015).

Table 4-15 Summary by source of FC loads for the 12-mo storm for all scenarios.

Phase - Alternative	CSOs (FC)	WWTFs (FC)	Storm Sewers (FC)	Rivers (FC)	Total (FC)	Rank by Highest Total
I	1.53E+15	3.83E+11	8.89E+13	1.30E+14	1.75E+15	1
II	1.40E+15	3.83E+11	8.89E+13	1.30E+14	1.62E+15	2
III-1	8.37E+14	3.83E+11	8.89E+13	1.30E+14	1.06E+15	7
III-2	1.35E+15	3.83E+11	8.89E+13	1.30E+14	1.57E+15	3
III-3	1.01E+15	3.83E+11	8.89E+13	1.30E+14	1.23E+15	5
III-4	1.32E+15	3.96E+11	8.89E+13	1.30E+14	1.54E+15	4
III-5	9.16E+14	3.83E+11	8.89E+13	1.30E+14	1.14E+15	6

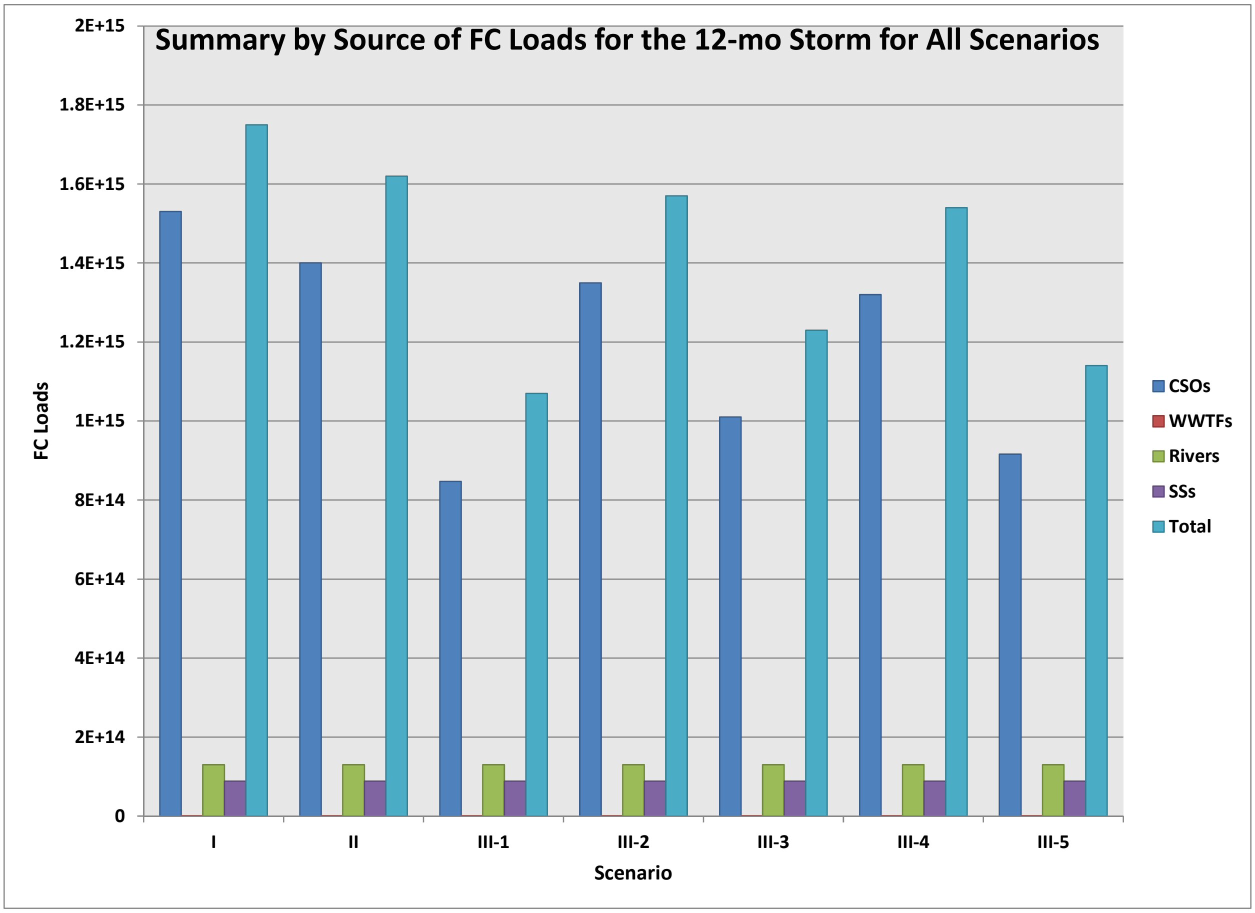


Figure 4-15. Summary by source of FC loads for the 12-month storm for all scenarios.

Table 4-16. Percentage by source of FC loads for the 12-mo storm for all scenarios.

Phase - Alternative	CSOs (%)	WWTFs (%)	Storm Sewers (%)	Rivers (%)	Total (%)
I	87.5	0.0	5.1	7.4	100.0
II	86.4	0.0	5.5	8.0	100.0
III-1	79.2	0.0	8.4	12.3	100.0
III-2	86.0	0.0	5.7	8.3	100.0
III-3	82.2	0.0	7.2	10.6	100.0
III-4	85.8	0.0	5.8	8.4	100.0
III-5	80.7	0.0	7.8	11.5	100.0

As with the 3-mo storm the WWTF loadings for all phases and alternatives for the 12-mo storm are nonzero but are typically three orders of magnitude less than the total loads.

4.2.2.2 *12-Month Simulation Results*

The model results are shown in a variety of formats: time series of FC concentrations at selected locations corresponding to NBC monitoring locations; plan views of FC concentration contours for the Upper Bay, and the Providence and Seekonk Rivers; and closure area tables expressed as area-time products for shellfishing and contact recreation FC concentration limits.

4.2.2.2.1 Time Series of FC Concentrations

The time series shown below are the same as for the 3-mo design storm which were selected for the four NBC monitoring stations located from north to south:

- Station 5 in the Seekonk River near the Narragansett Boating Center
- Station 9 in the Providence Harbor near Collier Point Park
- Station 13 in the Providence River near the Edgewood Yacht Club
- Station 20 at the Providence River / Upper Bay boundary near Conimicut Point

Each of Figure 4-16 through Figure 4-19 below shows the seven model scenarios (phases I and II, phase III with 5 alternatives) for each station for the 12-mo storm. The time axis is referenced to the start of the storm and varies according to the duration of the elevated concentrations.

Station 5 - Narragansett Boating Center shown in Figure 4-16 exhibits a range of concentrations during the first three days characterized by a large variation with sharp peaks due to the tides transporting higher concentrations south on ebb and lower concentrations north on flood in a manner similar to the results for the 3-mo storm. Phase I starts out with the highest concentrations during the first ebb tide (peak at 0.33 days) but is generally matched by phases II and III-2 during the second ebb tide (peak at 0.67 days) and continues through the third ebb tide peak at 1.13 days with the highest concentration of about 13,500 FC/100mL. The largest peak for all alternatives occurs at the third ebb tide peak with phase III-4 at 12,400 FC/100mL, III-3 at 7,600, III-5 at 5,800, III-1 at 6,100 FC/100mL. All the scenarios drop to low dry weather levels in less than 4 days from the start of the storm.

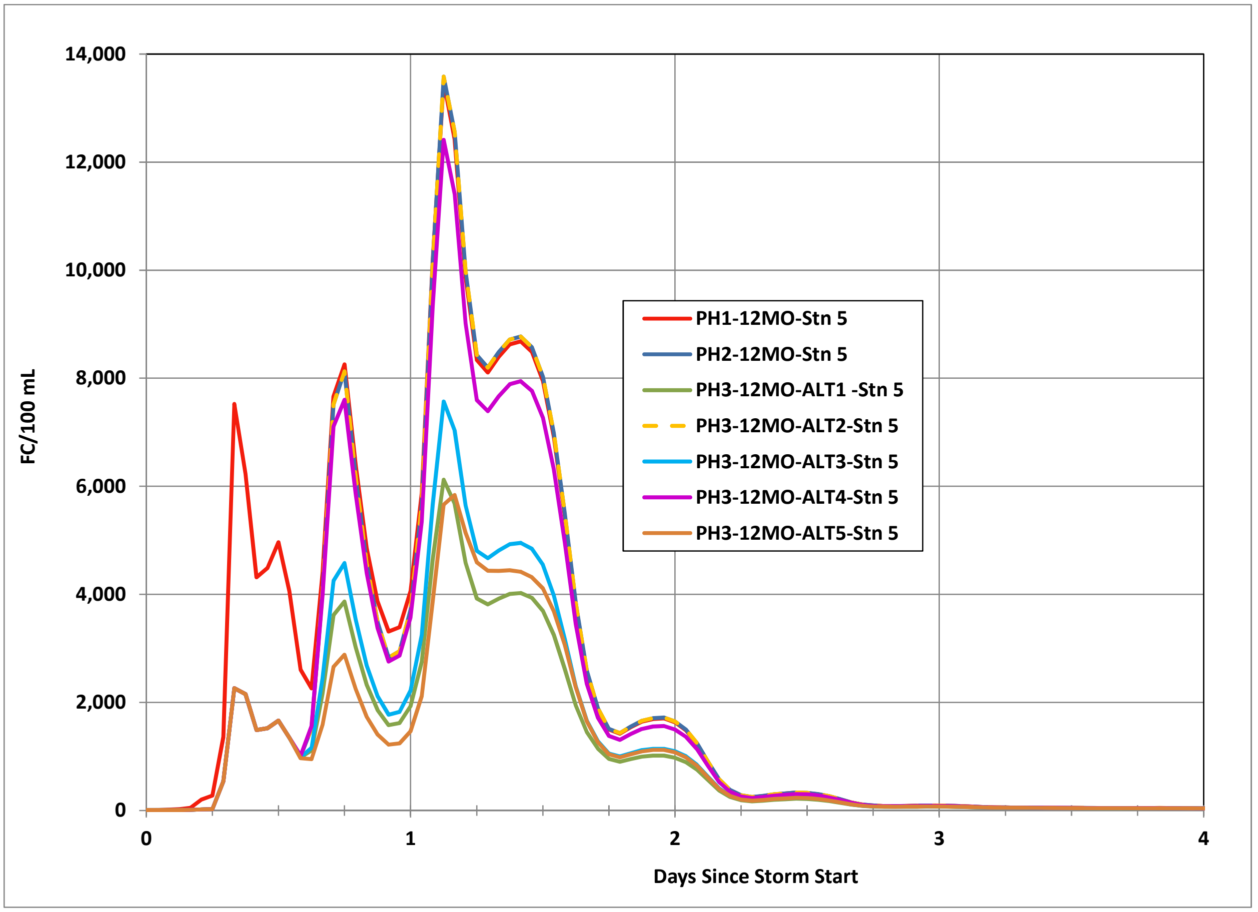


Figure 4-16. Time series of FC concentrations during simulation period for all 12-mo scenarios at Stn 5 – Narragansett Boating Center.

Station 9 - Collier Point Park shown in Table 4-14 exhibits tidal peaks but the first one at 0.33 days is much smaller than the later ones. All the scenarios reach their maximum concentrations at the second ebb tide peak at 0.67 days with I at 60,000 FC/100mL; II, III-3, III-4, and III-5 at 48,500 FC/100mL; ; III-2 at 44,700 and III-1 at 41,100. All the scenarios drop to low dry weather levels within 3 days from the start of the storm.

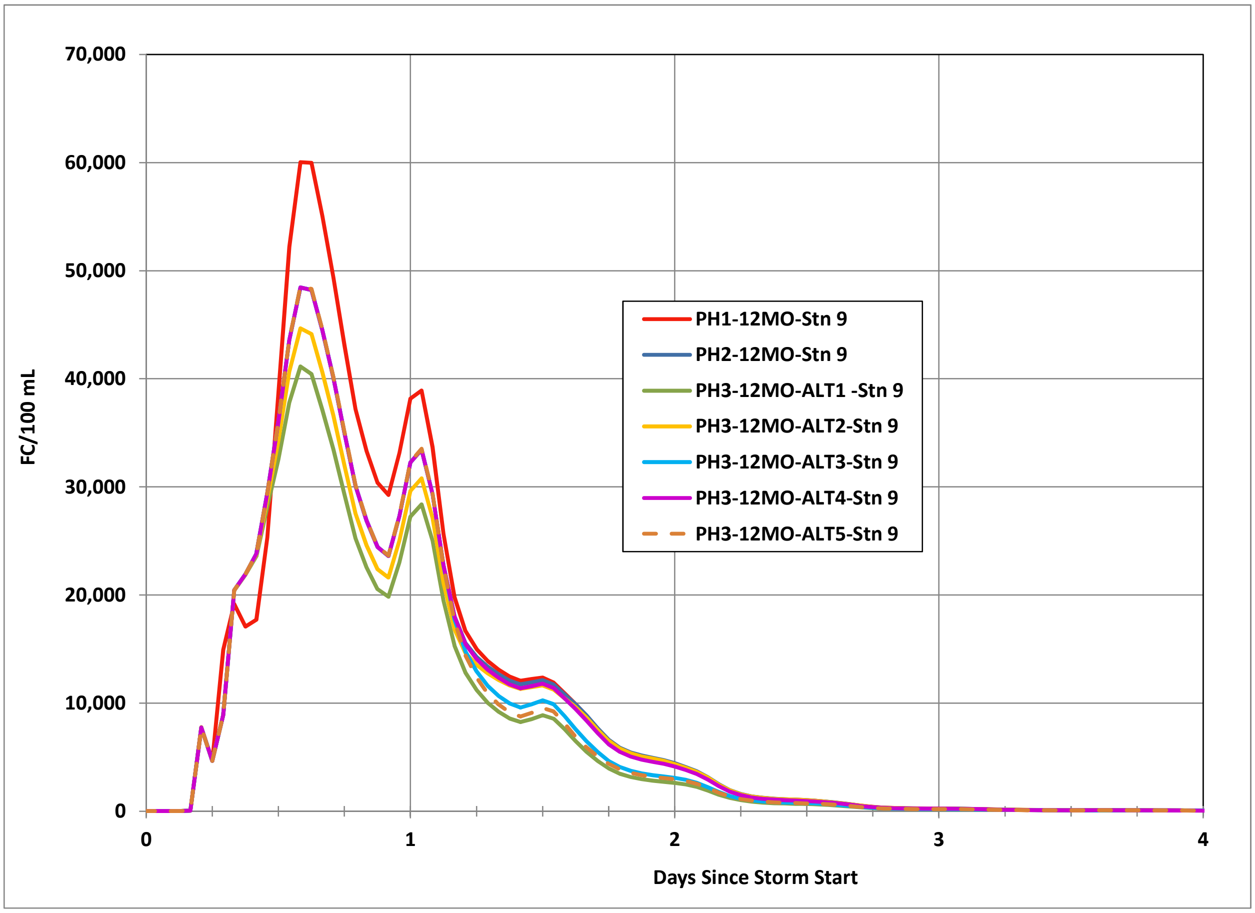


Figure 4-17. Time series of FC concentrations during simulation period for all 12-mo scenarios at Stn 9 – Collier Point Park.

Station 13 - Edgewood Yacht Club shown in Figure 4-18 exhibits the typical tidal induced variation until approximately 8 days after the storm start. The largest peak (at 1.75 days) was from phase I at 5,290 FC/100mL followed by maxima peaks at 2.25 days of 4,560 for II, 4,420 for III-4, and 4,370 for III-2. Peaks of 4,230 for III-3, 4,220 for III-5 and 3,670 FC/100mL for III-1 also occur at 1.75 days similar to Phase I.

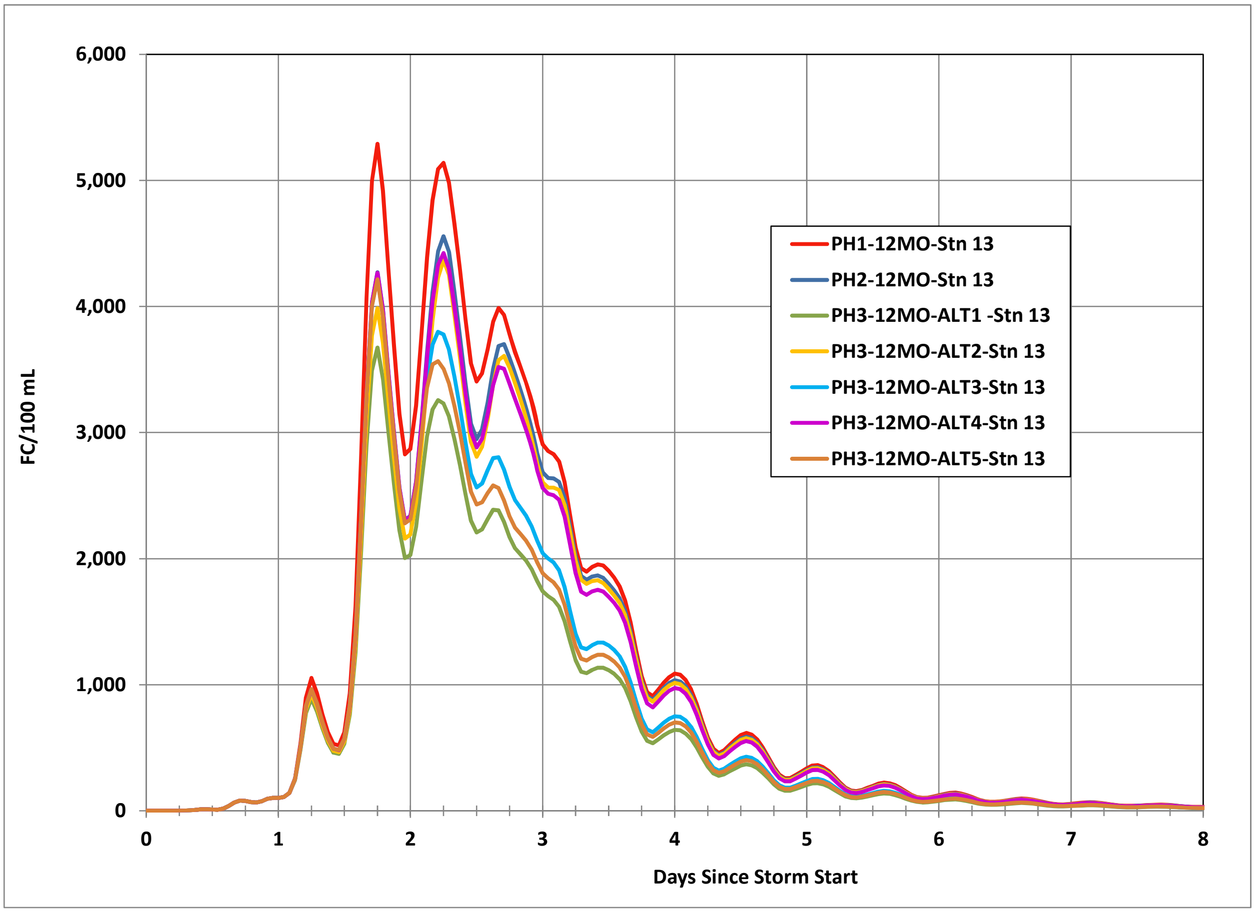


Figure 4-18. Time series of FC concentrations during simulation period for all 12-mo scenarios at Stn 13 – Edgewood Yacht Club.

Station 20 – Conimicut Point shown in Figure 4-19 also exhibits the tidal induced variation throughout the time series with a significant time lag due to the distance traveled from the source loads to Station 20. The storm induced concentrations begin to rise after 1 day subsequent to the start of the storm and return to pre-storm, dry weather concentration approximately 14 days after the storm start. The largest maxima occur at 4.33 days for I at 360, II at 320, III-4 at 310, III-2 at 305, III-3 at 280, III-5 at 270 and III-1 at 240 FC/100mL.These peaks generally follow the load ranking shown in Table 4-4.

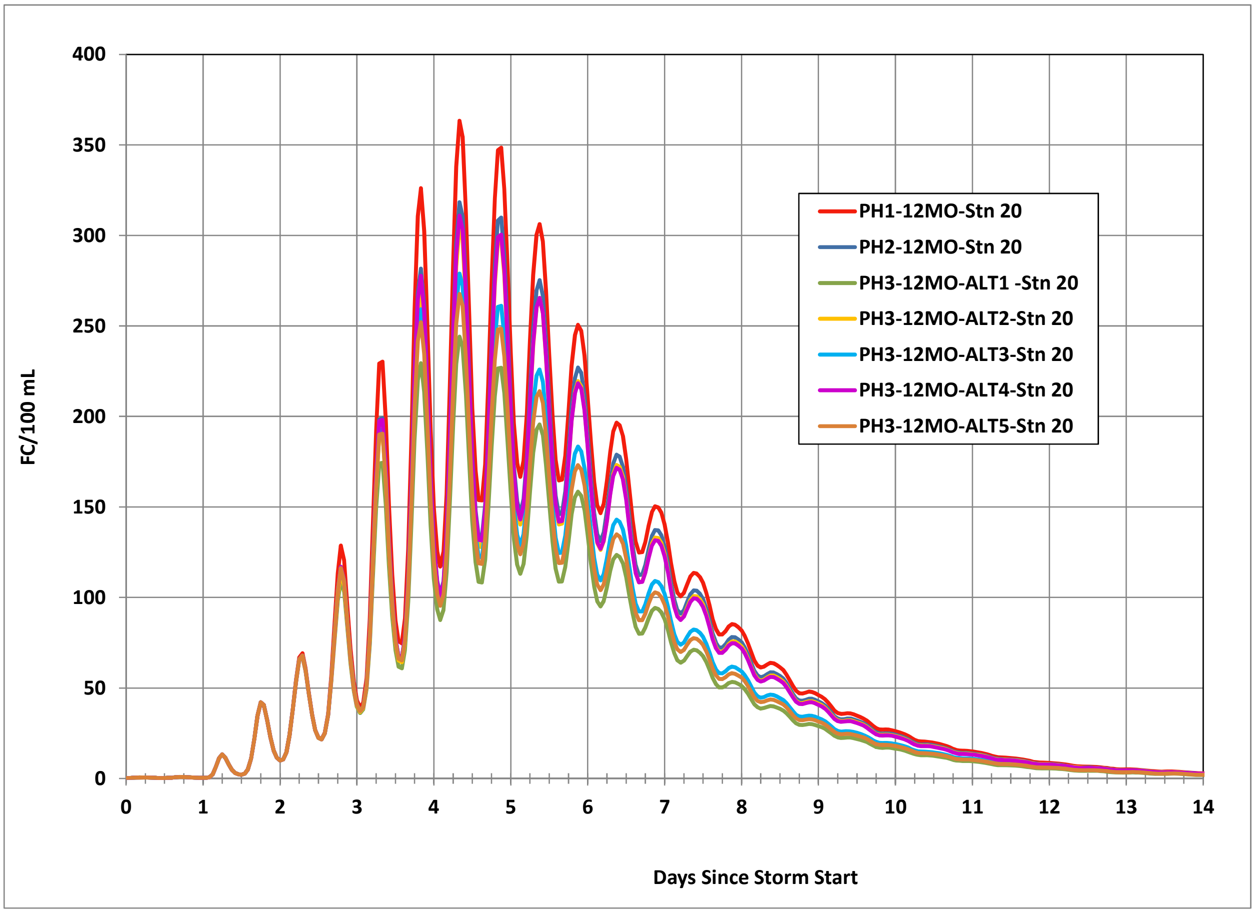


Figure 4-19. Time series of FC concentrations during simulation period for all 12-mo scenarios at Stn 20 – Conimicut Point.

The ranking of the maximum concentrations for each scenario by station is shown in Table 4-17. The stations closest to and within the areas where discharges occur are most affected by the proximate loads. For those scenarios with almost identical maximum concentrations multiple rankings are given. Thus Stn 5 and Stn 9 show different scenario rankings compared to the total load ranking due to their locations upstream of some of the CSO load sources while Stn 13 and Stn 20 are generally consistent with the total load ranking (except for the slight difference of resulting concentrations for Phase 1 and Phase III-4 compared to load) because of their distance downstream from the CSO load sources.

Table 4-17 Comparative ranking of peak concentrations for the 12-mo storm scenarios by station.

Phase - Alternative	Stn 5	Stn 9	Stn 13	Stn 20	Total Load Ranking
I	1/2/3	1	1	1	1
II	1/2/3	2/3/4/5	2	2	2
III-1	6	7	7	7	7
III-2	1/2/3	6	4	3/4	3
III-3	5	2/3/4/5	5	5	5
III-4	4	2/3/4/5	3	3/4	4
III-5	7	2/3/4/5	6	6	6

4.2.2.2.2 Plan View of FC Concentration Contours

As was done with the 3-mo design storm results plan views of the FC concentration contours were generated for all seven 12-mo scenarios for various times after the start of the storm at 0.5, 1, 2, 4, 6, 8, and 10 days. All seven scenarios (Phases I and II, and Phase III alternatives 1 through 5) are shown juxtaposed in each of the seven figures. The concentrations are color coded as shown in the legend.

Plan views for 0.5 days after the start of the storm are shown in Figure 4-20. The Providence River below Gaspee Point and all of the Upper Bay is unaffected by the storm loads but the upper reaches of the Providence and Seekonk River see somewhat different concentrations among the scenarios due to the proximity of the storm loads. All phases show concentrations above 100,000 FC/100mL in the Providence River above the hurricane barrier and levels between 20,000 and 100,000 FC/100mL at the head of the Seekonk River. The effect of the Pawtuxet River is clearly seen spreading into the Providence River from its mouth located between Fields and Gaspee Points.

Plan views for 1 day after the start of the storm are shown in Figure 4-21 Since the 12-mo design storm lasts only 6 hrs all the concentrations in the Providence and Seekonk Rivers have somewhat diminished to concentrations below from the 0.5-day levels although all phases still shows an exceedance above 20,000 FC/100mL in the uppermost Providence River above the hurricane barrier. Phases I, II and, III-2 also show levels above 20,000 FC/100mL in the Seekonk River. The plumes from the sources have merged in the Providence River and the southernmost extent has moved south of Gaspee Point for all scenarios indicative of the proximity of river and separated sewer loads located south of Fields Point.

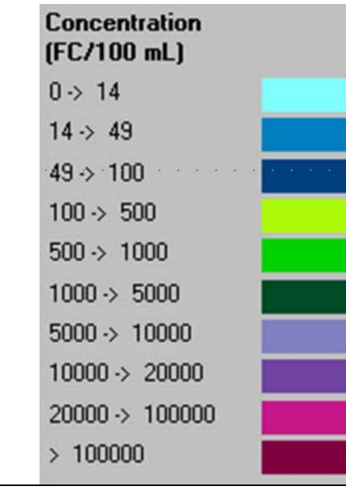
Plan views for 2 days after the start of the storm are shown in Figure 4-22. Flushing and decay continue to cause reduction in concentrations in the Seekonk and upper Providence Rivers compared to one day earlier. The highest concentrations are seen in the Providence River from Fields Point north to the Providence Harbor area to between 5,000 and 10,000 FC/100mL for phases I, II, III-2, and III-4 while the remaining phases show levels between 1,000 and 5,000 FC/100mL. The FC plume (> 14 FC/100mL) now extends almost to the conditional closure areas below Conimicut Point for all scenarios.

Plan views for 4 days after the start of the storm are shown in Figure 4-23. The FC concentrations in the Seekonk River and the Providence Harbor have diminished to below 100 FC/100mL with the upper Providence River above the hurricane barrier still in the range of 100 to 500 FC/100mL. Between Fields Point and below Gaspee Point the levels have dropped to between 500 and 5,000 FC/100mL for phases I, II, III-2, and III-4, while III-1, III-3 and III-5 have fallen to between 500 and 1000 FC/100mL. The FC plume extends well into the conditional closure area with a concentration between 100 and 500 FC/100mL for all scenarios.

Plan views for 6 days after the start of the storm are shown in Figure 4-24. The Providence River above the hurricane barrier range between 100 and 500 FC/100mL while the Seekonk River except at its head are now below 49 FC/100mL. The Providence River is now below 49 FC/100mL above Fields Point and an increase moving downstream. Concentrations are between 100 and 500 FC/100mL from below Fields Point down into the conditional areas past Conimicut Point. Portions of Conditional Area B show a range between 14 and 49 FC/100mL for all phases.

Plan views for 8 days after the start of the storm are shown in Figure 4-25. All concentrations are now below 49 FC/100mL in the Seekonk River except somewhat downstream from the head of the Seekonk and Providence Rivers. The extent of the FC plume into the conditional closure area is no longer moving downstream but is similar to the 6-day extent. All phases show an area with elevated levels between 49 and 100 FC/100mL in the lower Providence River and a portion of the conditional closure area.

Plan views for 10 days after the start of the storm are shown in Figure 4-26. The upper Seekonk River, lower Providence River and portions of the conditional closure areas range between 14 and 49 FC/100mL except for the head of the Seekonk River and the Providence River above the hurricane barrier. The lower Seekonk River and Providence River below Fields Point are below 14 FC/100mL with higher concentrations toward and including the conditional closure area.



Phase I: 12-mo @ 0.5 days	Phase II: 12-mo @ 0.5 days	Phase III-Alt 1: 12-mo @ 0.5 days	Phase III-Alt 2: 12-mo @ 0.5 days	Phase III-Alt 3: 12-mo @ 0.5 days	Phase III-Alt 4: 12-mo @ 0.5 days	Phase III-Alt 5: 12-mo @ 0.5 days

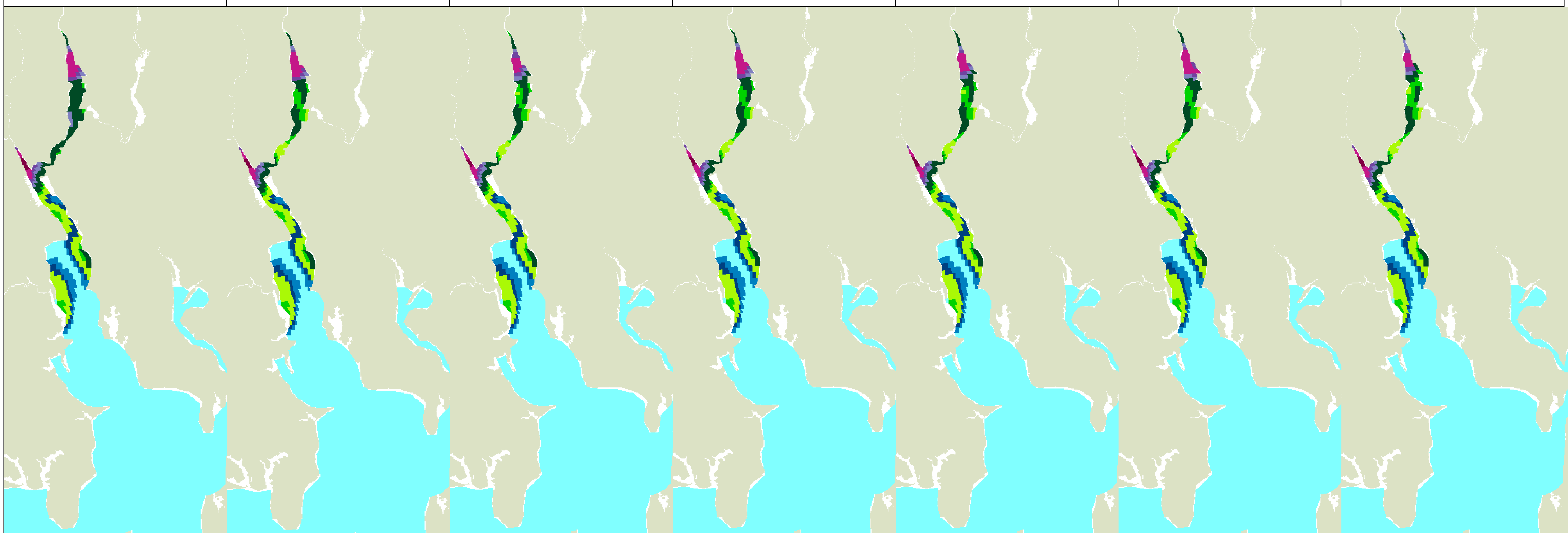


Figure 4-20. Scenario plan views of FC concentrations 0.5 days after start of 12-mo storm.

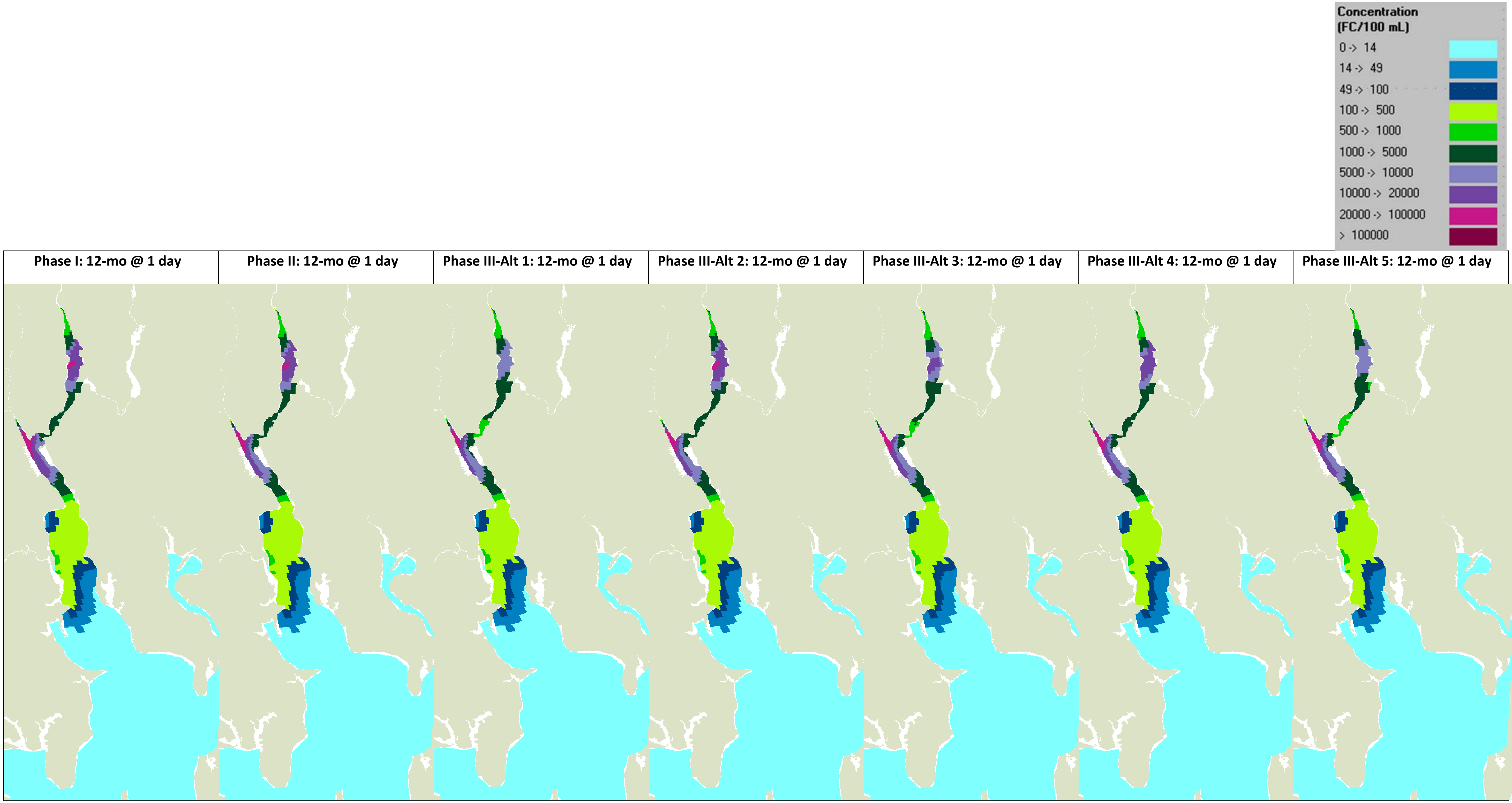


Figure 4-21. Scenario plan views of FC concentrations 1 day after start of 12-mo storm.

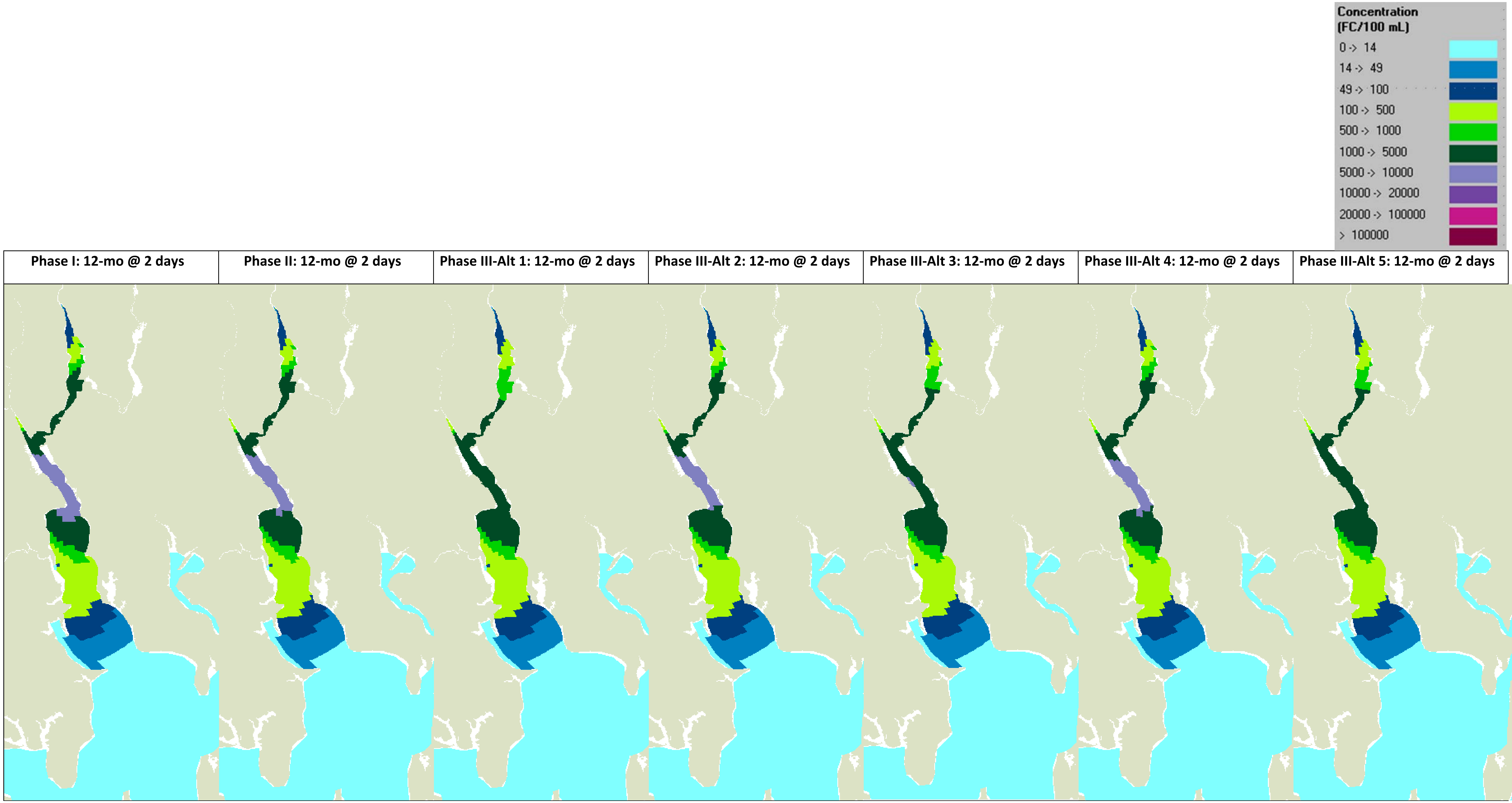


Figure 4-22. Scenario plan views of FC concentrations 2 days after start of 12-mo storm.

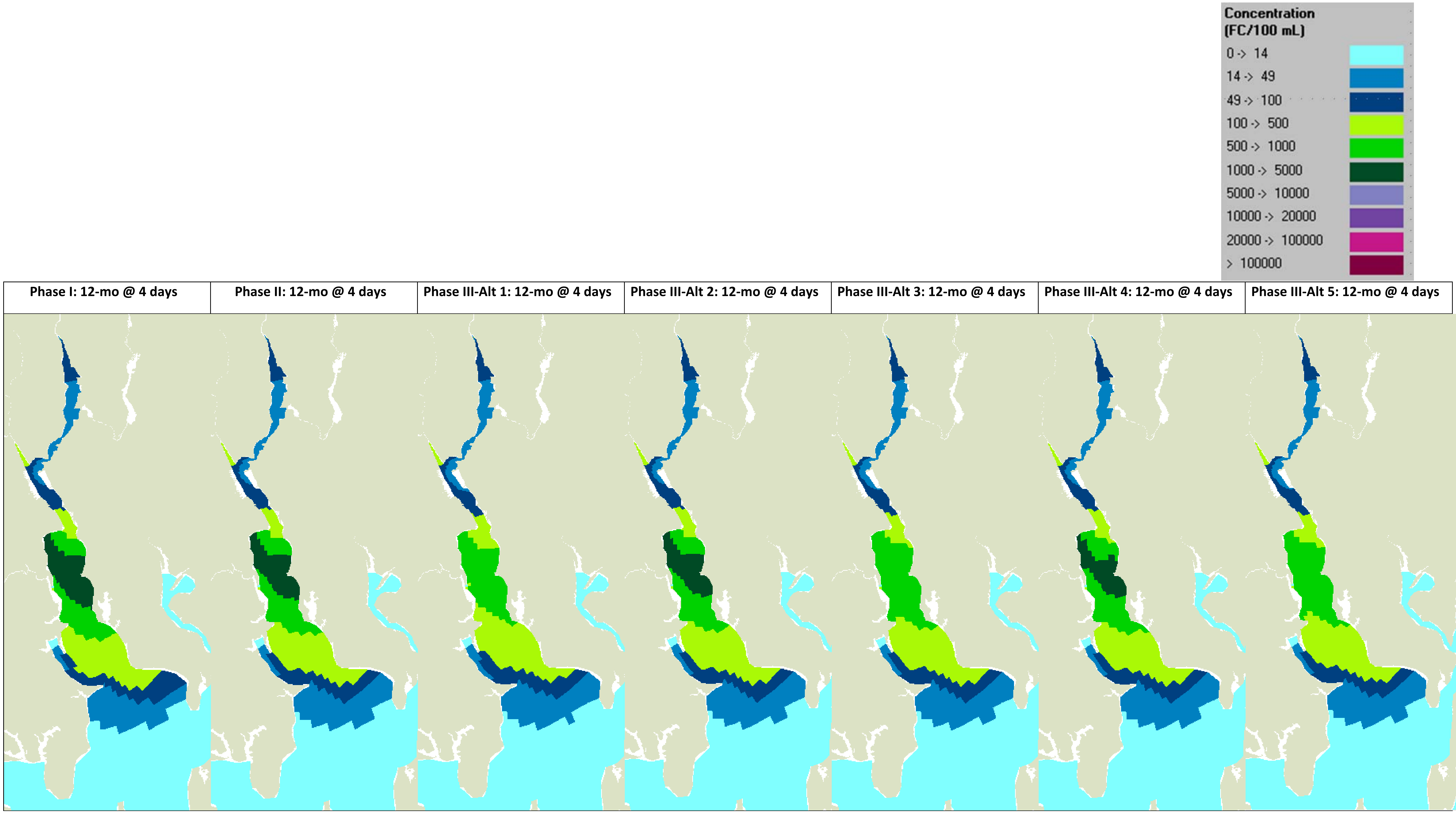


Figure 4-23. Scenario plan views of FC concentrations 4 days after start of 12-mo storm.

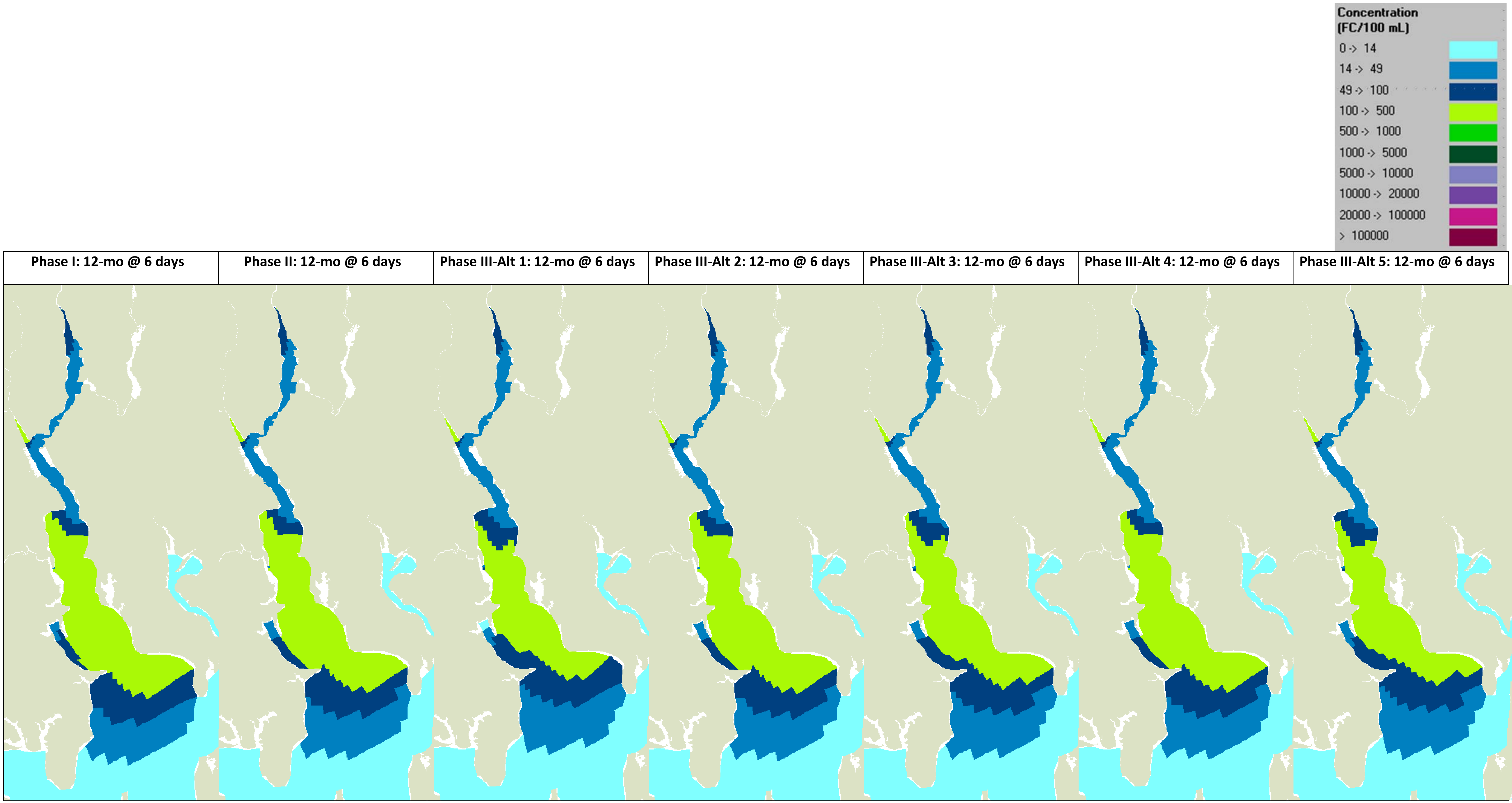


Figure 4-24. Scenario plan views of FC concentrations 6 days after start of 12-mo storm.

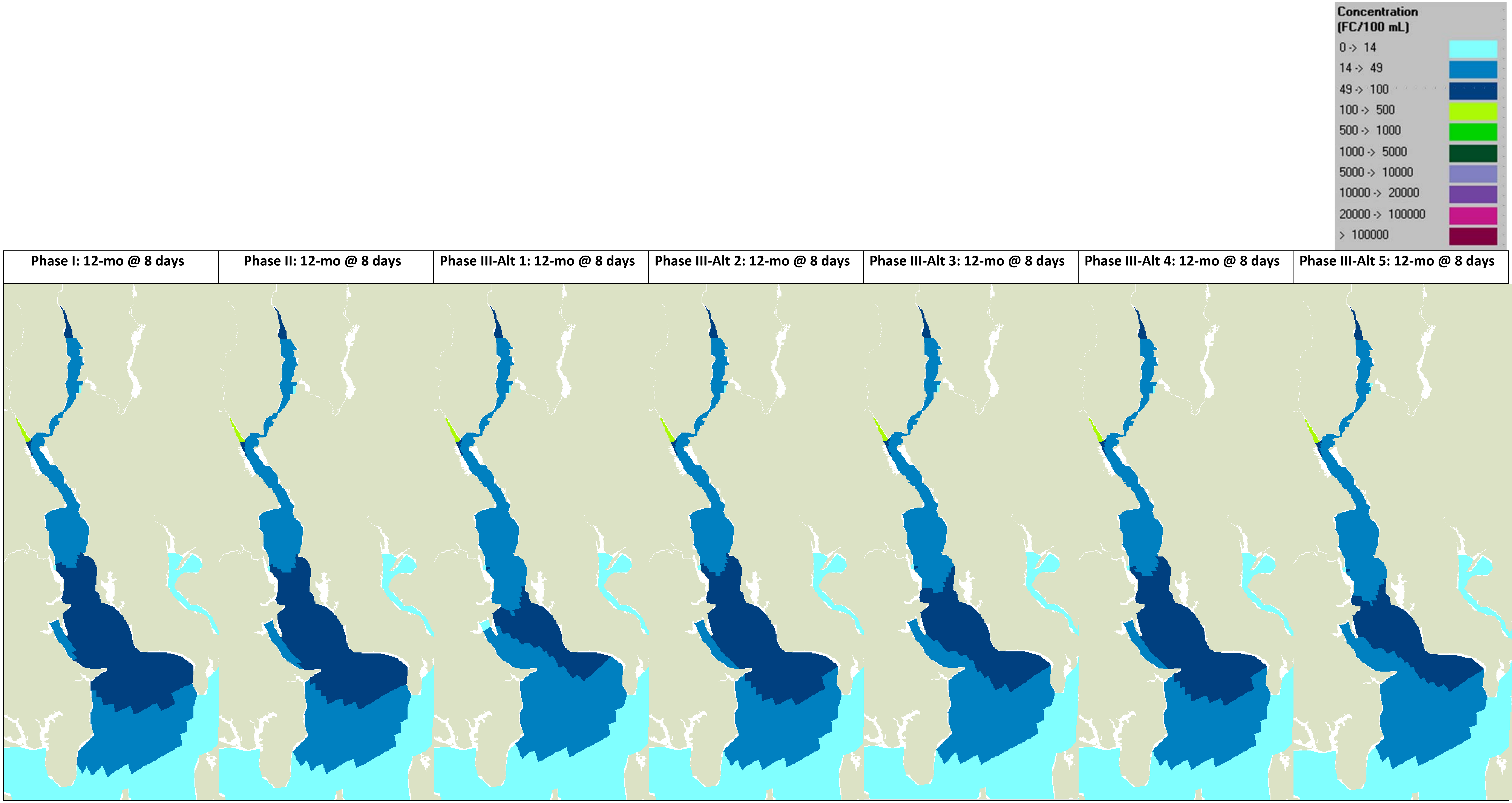


Figure 4-25. Scenario plan views of FC concentrations 8 days after start of 12-mo storm.

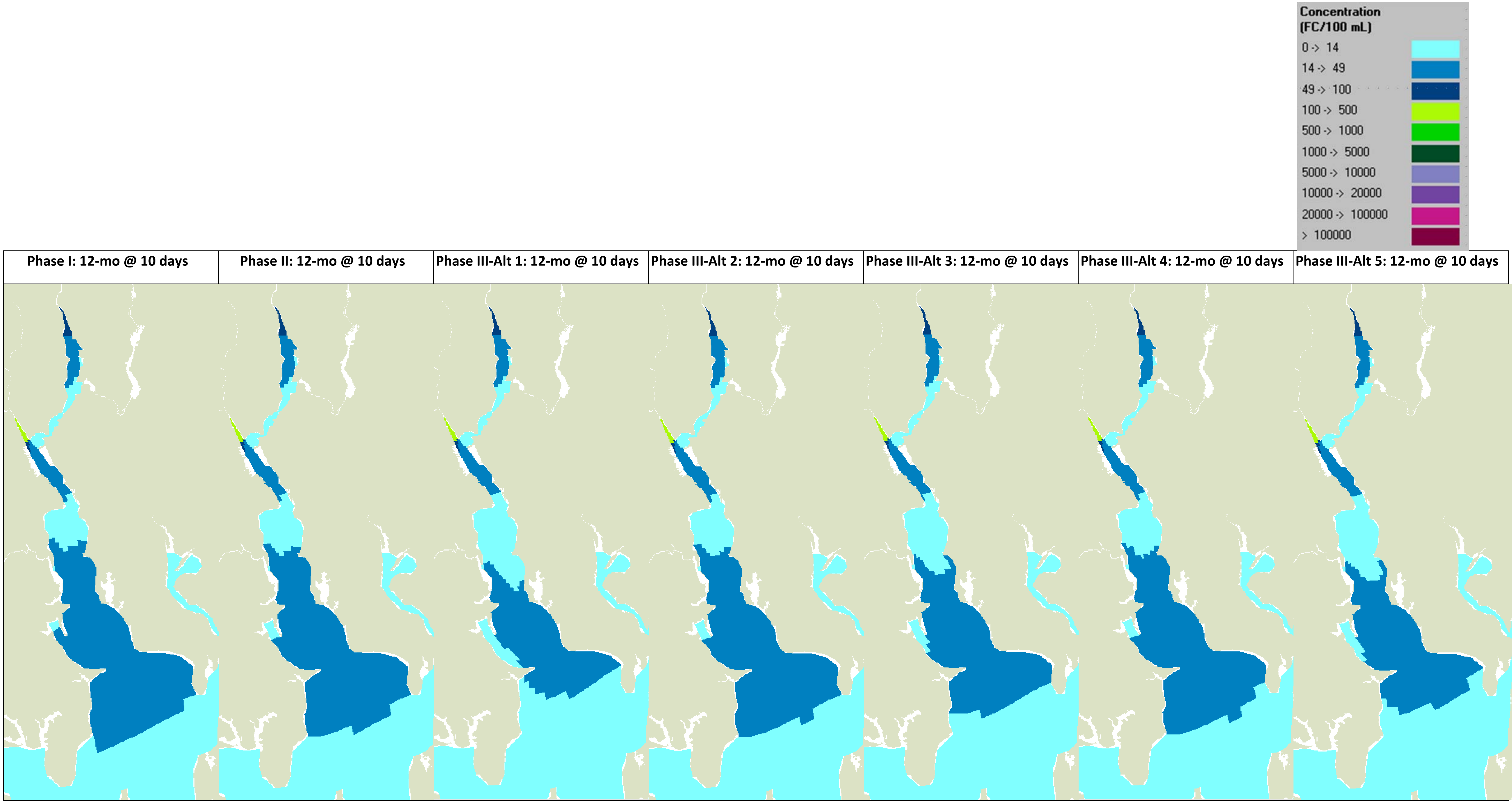


Figure 4-26. Scenario plan views of FC concentrations 10 days after start of 12-mo storm.

4.2.2.2.3 Closure Area Tables

Closure areas for the 12-mo design storm were determined from model results in a similar manner as was done for the 3-mo storm. The closure areas and threshold limits are found in

Table 4-8 in the 3-mo storm section above. Tables were generated for each closure area for the 12-mo storm showing results from the seven model runs (1 each for Phase 1 and Phase 2; 5 alternatives for Phase 3). Table 4-18 shows the 12-mo design storm results for Conditional Area B located south of Conditional Area A. The phase I results are the highest for the 14 FC/100mL threshold followed, in descending order by phase II, III-4, III-2, III-5, III-3, and III-1. This ranking generally agrees with the FC load ranking given in Table 4-15.

As this area is the furthest removed from the loads entering the Providence and Seekonk River there is no effect at the 49 FC/100mL threshold except for phase I.

Table 4-18 Twelve-month design storm results for conditional area B using the shellfish closure metrics.

Conditional Area B	14 FC/100mL	49 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	3,920	6
II	3,090	0
III-1	1,700	0
III-2	2,840	0
III-3	2,290	0
III-4	2,910	0
III-5	2,110	0

Table 4-19 shows the 12-mo design storm results for Conditional Area A located south of Conimicut Point. The Phase I results are the highest for both thresholds followed closely, in descending order, by phase II, III-2, III-4, III-3, III-5, and III-1. This ranking generally follows the FC load ranking given in

Table 4-15 and for conditional area A.

Table 4-19 Twelve-month design storm results for conditional area A using the shellfish closure metrics.

Conditional Area A	14 FC/100mL	49 FC/100mL
Phase	AcreDay	AcreDay
I	26,900	10,100
II	25,700	8,850
III-1	22,000	6,270
III-2	25,300	8,490
III-3	23,600	7,390
III-4	25,300	8,590
III-5	23,100	7,000

Table 4-20 shows the 12-mo design storm results for the Triangular Conditional Area located at Conimicut Point. The phase 1 results are the highest for both thresholds followed closely in descending order by phase II, III-2, III-4, III-3, III-5, and III-1. This ranking generally follows the FC load ranking given in

Table 4-15 and for conditional areas A and B.

Table 4-20 Twelve-month design storm results for Conimicut triangle conditional area using the shellfish closure metrics.

Conimicut Triangle	14 FC/100mL	49 FC/100mL
Phase	AcreDay	AcreDay
I	2,500	1,600
II	2,450	1,530
III-1	2,270	1,320
III-2	2,440	1,510
III-3	2,330	1,410
III-4	2,430	1,500
III-5	2,300	1,380

Table 4-21 shows the 12-mo design storm results for the Providence River SB area located between Conimicut and Gaspee Points. The phase 1 results are again the highest for both thresholds followed closely, in descending order by phase II, III-2, III-4, III-5, III-3, and III-1. This ranking generally follows the FC load ranking given in Table 4-15 and for conditional areas A, B, and Conimicut Triangle.

Table 4-21 Twelve-month design storm results for the Providence River - SB area using the contact recreation closure metrics.

Providence River-SB	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	16,800	3,180
II	16,300	2,700
III-1	14,500	1,630
III-2	16,200	2,560
III-3	15,200	2,090
III-4	16,100	2,580
III-5	14,900	1,930

Table 4-22 shows the 12-mo design storm results for the Providence River SB1 area located north of Gaspee Point and the Providence SB area. The phase 1 results are again the highest for both thresholds followed closely, in descending order by phase II, III-2, III-4, III-3, III-5, and III-1. This ranking generally follows the FC load ranking given in Table 4-15 conditional areas A, B and Conimicut Triangle, and for Providence SB.

Table 4-22 Twelve-month design storm results for the Providence River – SB1 area using the contact recreation closure metrics.

Providence River-SB1	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	12,300	6,060
II	12,200	5,960
III-1	11,300	5,250
III-2	12,200	5,920
III-3	11,600	5,490
III-4	12,100	5,870
III-5	11,500	5,390

Table 4-23 shows the 12-mo design storm results for the Seekonk River SB1 area. The phase 1 results for both thresholds are similar to the other scenarios in acre-days since many major loads are located in this River. The effects of the source location and source load magnitude are clearly shown here as they combine to generate acredays for III-5 that are slightly smaller than for III-1, which would be expected to be the smallest, consistent with all the other areas and concentration thresholds.

Table 4-23 Twelve-month design storm results for the Seekonk River – SB1 area using the contact recreation closure metrics.

Seekonk River-SB1	50 FC/100mL	400 FC/100mL
Phase	**AcreDay**	**AcreDay**
I	2,480	801
II	2,460	780
III-1	2,420	732
III-2	2,460	780
III-3	2,430	739
III-4	2,450	769
III-5	2,410	725

5 Conclusions

A computer modeling study was performed to evaluate the receiving water quality benefits of various alternatives developed for the reevaluation of the Phase III recommendations for CSO control from the NBC service areas to Upper Narragansett Bay and the Providence and Seekonk Rivers. The modeling built on previous modeling conducted by RPS ASA. Fecal coliform (FC) was used as the indicator proxy for water quality. FC sources included CSO, WWTFs, storm sewers, and rivers.

5.1 Comparison to Observations

The previously calibrated model developed using RPS ASA's water quality modeling system WQMAP were used to simulate the circulation and FC concentrations within the study domain for a recent timeframe, March through August 2009. The model predictions of FC concentration were compared to available observations to evaluate the model's predictive ability for this application. Both the hydrodynamic and mass transport forcing were updated to reflect the recent timeframe which reflected Post Phase I CSO configuration. The data used for model load development indicated that the CSOs represented most (~ 77.3%) of the loading to the system. Second to CSOs were the tributary loads (~22.7 %) and a relatively negligible amount (<0.1%) came from the WWTFs. The CSOs that overflow to the Providence River accounted for 27.9% of the total load and those that overflow to the Blackstone accounted for 49.4% of the total load for this time period. The model and data were in good agreement. The model was able to successfully recreate the spatial and temporal variability and capture the range of the concentrations well. Furthermore the model successfully captured the trend of either above or below relevant thresholds most of the time at most locations. Limitations to the modeling included the assumptions necessary to define the loads and the sparse resolution of the tributary observations in space and time that contributed to uncertainty of the tributary loads. However, the most dominant loading factors were accounted for, including the major tributary loads and CSO loading.

5.2 Design Storms

The model was then used to evaluate the water quality based on loading for five CSO control alternatives developed by MWH as part of the Phase III reevaluation plus the controls developed and implemented for the earlier Phases I and II. Two hypothetical design storms, with 3-mo and 12-mo return periods, both with durations of six hours, were used in the evaluations of the seven scenarios. The Phase III alternatives ranged from single CSO removal to removal of all CSOs. In general the CSOs provided the largest fraction of FC loads to receiving waters followed by rivers, SSs, and WWTFs in descending order of load.

The model output was processed into three formats: time series of FC concentrations at four selected locations corresponding to NBC monitoring locations from the Seekonk River downstream to the start of the conditional closure at Conimicut Point; plan views of FC concentration contours for the Upper Bay, and the Providence and Seekonk Rivers; and closure area tables expressed as area-time products for shellfishing and contact recreation FC concentration limits for six areas (three conditional areas and three SB areas) within the study area.

5.2.1 3-mo Storm

The time series at the four stations for the 3-mo storm typically revealed an oscillating tidal component with a peak concentration indicative of the travel time down-river or –bay away from the FC source locations. For the northernmost Seekonk River and Providence Harbor stations the storm effects lasted approximately three days until dry weather FC concentration levels returned. The Providence River station showed storm levels for approximately eight days and the Upper Bay station for approximately 14 days. Recovery of levels to the 14 FC/100mL shellfish standard took approximately eight days for full CSO control (Alternative 1) and 10 days for no CSO control (Phase II) at the Upper Bay Station on the northern edge of the conditional shellfish closure areas. Both the Providence River and Upper Bay stations showed FC concentration levels consistent with the total FC source loads while the two northern stations responded differently due to their proximity to the load locations.

Plan views of the study area for seven snapshots after the storm were generated for each of the seven scenarios and intercompared to show the extent of the FC concentration plumes moving down bay over time. The results at 0.5 days after the storm start were similar for all scenarios in extent of the concentration levels although the northern reaches of the Seekonk and Providence Rivers varied in peak concentrations depending on the load magnitude. By 1 day after storm start the concentrations were dropping for lower load magnitudes (Phase III alternatives 1, 3 and 5) in the Seekonk although the downstream extent in the Providence River was similar for all scenarios. This differentiation among scenarios continued at 2 days both in the Seekonk River and Providence Harbor areas with higher concentrations and larger affected areas for Phases I, II, III-2, III-4 and III-5 and lowest concentrations for III-1 with all scenarios reaching the lower Providence River. By 4 days the elevated concentrations, > 14 FC/100mL, reached into the conditional closure areas for all scenarios. This continued at 6 days with III-1 showing almost complete return to dry weather concentrations with higher concentrations and large extents for I, II, III-2 and III-4. By 8 days all scenarios (away from the Blackstone River mouth and the Providence River above the hurricane barrier) showed concentrations less than the 49 FC/100mL upper 10% limit and III-1 below the 14 FC/100mL almost everywhere. By 10 days only small areas adjacent to the rivers exhibited exceedances above 14 but less than 49 FC/100mL.

Finally closure area tables were prepared as area-time products for shellfishing and contact recreation FC concentration limits for six areas within the study area. For the southernmost conditional shellfish closure area B there was little effect even for Phase I. In conditional areas A and the Conimicut Triangle all scenarios showed an effect of closures expressed In acre/days generally ranking the same as the source load ranking but modified by distance from the source loads to the specific closure areas. The general trend continued for the contact recreation areas, Providence River SB, Providence River SB1 and Seekonk River SB1.

5.2.2 12-mo Storm

As with the 3-mo storm results the time series at the four stations for the 12-mo storm typically revealed an oscillating tidal component with a peak concentration indicative of the travel time down-river or –bay away from the FC source locations. For the northernmost Seekonk River and Providence Harbor stations the storm effects lasted approximately three days until dry weather FC concentration levels returned, similar to the 3-mo storm results. The Providence River station showed storm levels for approximately eight days and the Upper Bay station for approximately 14 days again similar to the 3-mo storm results. It took approximately 11 days for levels to return to the 14 FC/100mL shellfish standard limit at the Upper Bay Station on the northern edge of the conditional shellfish closure areas. Both the Providence River and Upper Bay stations showed FC concentration levels generally consistent with the total FC source loads while the two northern stations were more affected by their proximity to the load locations.

Plan views of the study area for seven snapshots after the 12-mo storm were generated for each of the seven scenarios and intercompared to show the extent of the FC concentration plumes moving down bay over time. The results at 0.5 days after the storm start were similar for all scenarios in extent of the concentration levels although the northern reaches of the Seekonk and Providence Rivers varied somewhat in peak concentrations depending on the load magnitude. By 1 day after storm start the concentrations were beginning to drop for lower load magnitudes (Phase III alternatives 1, 3, 4 and 5) in the Seekonk although the downstream extent in the Providence River were similar for all scenarios. This differentiation among scenarios continued at 2 days primarily in the Providence River area at and north of Fields Point with higher concentrations and larger affected areas for Phases I, II, III-2, and III-4 with all scenarios reaching the lower Providence River just north of Conimicut Point. By 4 days the elevated concentrations, between 100 and 500 FC/100mL, reached into the conditional closure areas for all scenarios and continued at 6 days. By 8 days all scenarios showed concentrations less than 100 FC/100mL and the conditional closure area still up to 100 FC/100mL. By 10 days only the northern Seekonk River, Providence Harbor, the lower Providence River and the conditional area exhibited exceedances above 14 but less than 49 FC/100mL.

Finally closure area tables were prepared as area-time products for shellfishing and contact recreation FC concentration limits for six areas within the study area. For the three conditional shellfish closure areas all scenarios showed an effect of closures expressed In acre/days generally ranking the same as the source load ranking but modified by distance from the source loads to the specific closure areas. The general trend continued for the contact recreation areas, Providence River SB, Providence River SB1 and Seekonk River SB1.

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NBC CSO Control Facilities Phase III Reevaluation

Appendix 5 – Technical Memorandum: Grey Infrastructure Variant Alternatives and Technical Memorandum: Green Stormwater Infrastructure Feasible Alternatives Analysis

NBC CSO Control Facilities Phase III Reevaluation

Technical Memorandum – Grey Infrastructure Variant Alternatives

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1. Introduction

Early in 2015, following nearly 15 years of construction to abate 35 CSOs, the Narragansett Bay Commission (NBC) must initiate the design to address its remaining 28 overflows. This regulatory timeframe affords NBC just one critical year to reevaluate the Phase III recommendations of the 1998 Conceptual Design Report Amendment (CDRA) and the evaluations of the preceding Conceptual Design Report (CDR). In the decades that have passed since the last planning effort, several conditions have changed. Phase I and II solutions have improved water quality in Narragansett Bay. The real costs and compilations of project construction, particularly sewer separation and interceptor sewers, have escalated. Technological advancements have improved the effectiveness of grey and green infrastructure.

This technical memorandum is one of two that describe the development and definition of alternative components to the Phase III plan. This memo focuses upon “grey alternatives” and summarizes work associated with *Subtask 3A – Establish Baseline and Grey Infrastructure Variant Alternatives*, *Subtask 3D – Near Surface Storage Alternatives*, and *Subtask 3E – Deep Rock Tunnels Alternatives*. A subsequent memo will focus upon “green alternatives and will summarize work associated with *Subtask 3B – Evaluation of Feasibility of GSI for the Entire Phase III Area* and *Subtask 3C – Feasibility of GSI alternatives for Specific Overflows*.

Combined Sewer Overflow control strategies include:

- Stormwater control, which prevents stormwater from entering the combined system;
- 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; and
- Deep rock tunnel storage, which provides storage of large CSO volumes, typically from multiple outfalls requiring consolidation conduits or interceptor conveyance.

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 are provided in the CDR and CDRA documents. Those descriptions and the analysis of specific applications at the various NBC CSO locations are incorporated by reference into this Phase III Reevaluation. Additional description is provided in this report only when Phase I & II experience differed from previous assumptions or when technological advances since the time of the CDRA alter how those approaches could be implemented.

Table 1 at the end of this section summarizes the alternative strategies considered for each outfall within this Phase III Reevaluation. It should be noted that consolidation conduits or regulator modifications may be required for a specific CSO to be addressed by a specific strategy; however, the volume of that CSO would be considered in the capacity of any shared solution.

As part of the overall strategy for assessing appropriate solutions for the project MWH/Pare has applied an approach called Source-Pathway-Receptor. This approach is a hierarchical decision making system that considers solutions based on size, location and applicability in dealing with runoff flows and volumes. Source controls are generally considered localized smaller scale solutions in the upper reaches of sewersheds, pathway are solutions that can be applied on conveyance route in both the major (streetscape) and minor (sewers) systems. Receptors are solutions applied in the lower reaches and are often termed ‘end-of-pipe’ solutions.

In terms of CSO control techniques, the primary Source controls are comprised of various green stormwater 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.

On the Source-Pathway-Receptor scale, sewer separation is regarded as a Pathway solution. Sewer separation of a combined sewer completely segregates sanitary flow from stormwater. After separation the sanitary flows remain within the sewer passing for wastewater treatment at an appropriate facility (i.e. the Fields Point or Bucklin Point WWTFs), the stormwater in in contrast is discharged to decentralized locations (i.e. the rivers), ideally closer to their sources. While sewer separation can reduce or completely eliminate the discharge from associated CSOs and therefore bacterial pollution, it can result in the discharge of hydrocarbon, heavy metal and sediment related polluted urban runoff under wet weather conditions.

Storage alternatives, including both deep rock tunnel and near-surface interceptors and tanks, are regarded as Receptor solutions. These solutions continue to allow sanitary and stormwater to combine in the collection system but capture it prior to designated CSO activation levels. They detain combined sewer volumes up to their design capacity and subsequently pump those volumes to the centralized WWTFs for a high degree of treatment and discharge. Large storms in excess of the storage capacity will still result in CSOs to the rivers; however, polluted urban runoff for smaller storms and for the first flush of larger storms will be retained in the sewer system prior to being treated at the WWTFs.

Localized treatment and discharge alternatives, which in this case consider simple screening and disinfection of combined sewer flows, are also Receptor solutions. They detain and locally treat CSO volumes up to their design capacity which after treatment are discharged to an adjacent water body. During more severe wet weather each facility will continue to treat up to the design parameters with excess volumes discharged untreated to the receiving water body.

Finally, stormwater control, or flow slipping, is a form of system optimization that manipulates the Source and Pathway interface. It acts a partial *de facto* sewer separation and seeks to prevent stormwater from combining with sanitary volumes under certain conditions, namely the CSO design targets, 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. The goal is to arrive at the same results as the storage options but in a more cost-effective manner. Large storms would still produce CSO discharges to the rivers, but urban runoff discharges would be controlled.

Table 1 Summary of Technical Evaluation

	Source			Pathway			Receptor				
Outfall	**No GSI**	**Public Way GSI**	**All GSI**	**Sewer Separation**	**Hydraulic Control & Stormwater Storage**	**Interceptor Relief**	**Satellite Treatment & Discharge**	**Near Surface Storage**	**Pawtucket Stub Tunnel**	**Pawtucket Tunnel**	**Increased underflow**
35	Baseline	Alternative Development	Alternative Development	Baseline	Alternative Development	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Not applicable	Presumed unviable based on CDRA
36	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Not applicable	Baseline via regulator modification
39	Baseline	Alternative Development	Alternative Development	Baseline	Alternative Development	Alternative Development	Alternative Development	Alternative Development	Alternative Development	Not applicable	Presumed unviable based on CDRA
56	Baseline	Alternative Development	Alternative Development	Baseline	Alternative Development	Alternative Development	Alternative Development	Alternative Development	Alternative Development	Not applicable	Presumed unviable based on CDRA
101	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 103-105)	Not applicable
103	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via High & Cross St interceptor	Not applicable
104	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via High & Cross St interceptor	Not applicable
105	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via drop shaft 205 & river crossing	Not applicable
107	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (?dependent on 220?)	Not applicable
201	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via Middle St interceptor	Not applicable
202	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 201-205)	Not applicable
203	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via Middle St interceptor	Not applicable
204	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 201-205)	Not applicable
205	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via drop shaft 205	Not applicable
206	Baseline	Alternative Development	Alternative Development	Baseline	Alternative Development	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Alternative Development	Not applicable
207	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205)	Not applicable
208	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205)	Not applicable
209	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205)	Not applicable
210	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via dropshaft 210	Not applicable
211	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via dropshaft 210	Not applicable

	Source			Pathway			Receptor				
Outfall	No GSI	Public Way GSI	All GSI	Sewer Separation	Hydraulic Control & Stormwater Storage	Interceptor Relief	Satellite Treatment & Discharge	Near Surface Storage	Pawtucket Stub Tunnel	Pawtucket Tunnel	Increased underflow
212	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205)	Not applicable
213	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via dropshaft 210	Not applicable
214	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 210)	Not applicable
215	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205/218)	Not applicable
216	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via regulator modification (dependent on 205/218)	Not applicable
217	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via dropshaft 217	Not applicable
218	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Presumed unviable based on CDRA	Alternative Development	Alternative Development	Not applicable	Baseline via dropshaft 218	Not applicable
220	Baseline	Alternative Development	Alternative Development	Presumed unviable based on CDRA	Not evaluated - lack of collection system data	Alternative Development	Alternative Development	Alternative Development	Alternative Development	Baseline via Pawtucket Ave Interceptor & dropshaft 217	Unviable based on tunnel capacity

Baseline	previously included in CDRA will be reevaluated
Alternative Development	new alternatives will be developed
Presumed unviable based on CDRA	previously considered in the CDRA and deemed to be unviable
Not applicable	Not applicable as an approach at that location
Not evaluated - lack of collection system data	Alternatives that are contained within the member communities systems, remote from the NBC sewer network

2. Previously recommended facilities

As defined by the 1997 *Conceptual Design Report Amendment* (CDRA), the Phase III CSO control facilities consist of the construction of the deep Pawtucket Tunnel for storage and interceptors to pick up 12 CSO structures, sewer separation in 4 CSO catchments, and regulator modifications at an additional 12 CSOs. The recommended facilities were conceptually designed in Section 10 of the CDRA. A summary of the recommended alternatives for each CSO considered under Phase III and taken from the CDRA is shown in Figure 1.

Table 1
Summary of Abatement Alternatives for Phase III Overflows

Alternatives	Overflows
Tunnel and Interceptors	103,104, 105, 201, 203, 205, 210, 211, 213, 217, 218, 220
Sewer Separation	035, 039, 056, 206
Regulator Modifications	036, 101,107, 202, 204, 207, 208, 209, 212, 214, 215, 216

Figure 1 - CDRA Recommended Phase III CSO Alternatives

The Phase III baseline plan by CSO is shown in Figure 2 and summarized in Table 2.

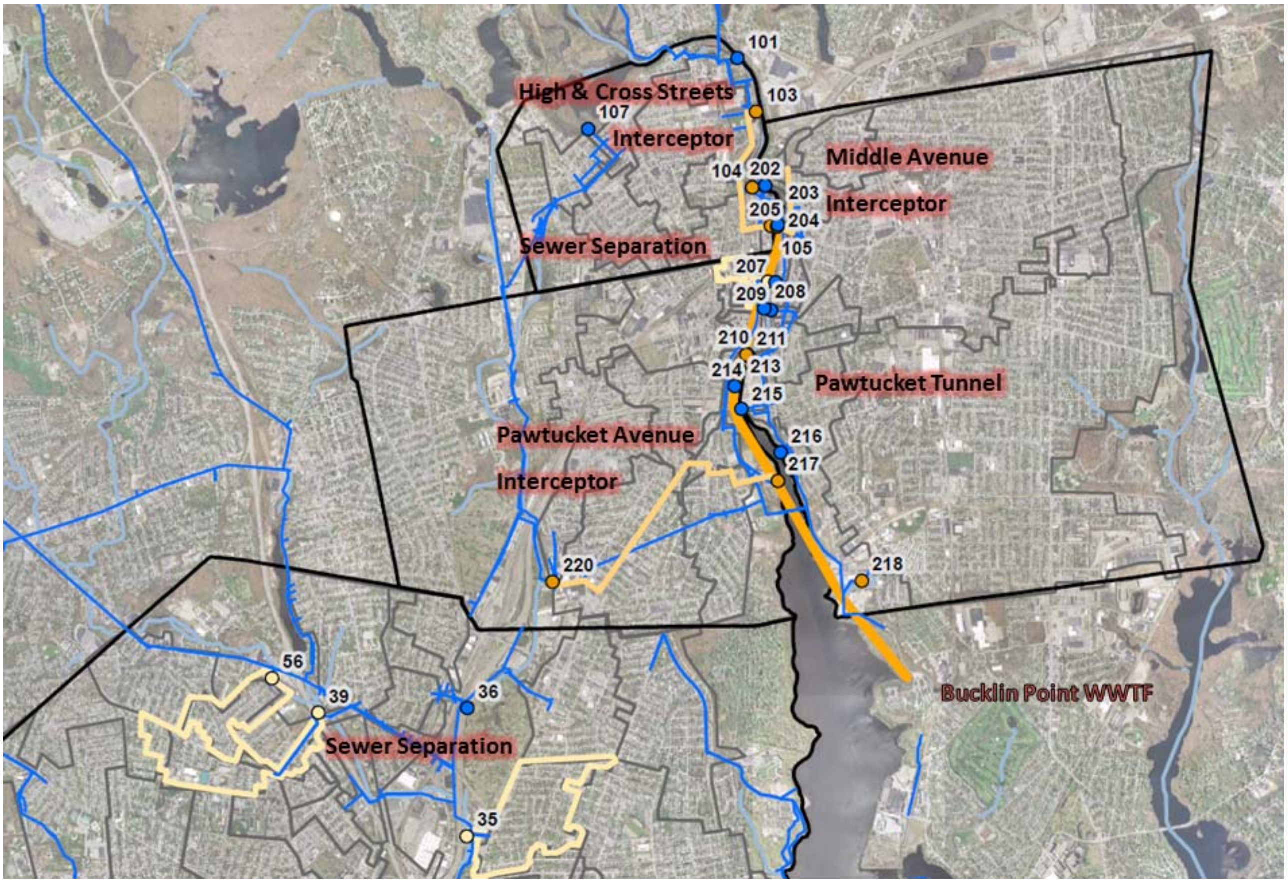

Figure 2 CDRA Phase III Recommended Plan

Table 2 – Baseline Plan by CSO

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

The CDRA used XP-SWMM software to develop a hydraulic model to compute CSO discharge volumes and peak flows for five design storms: 1-month, 2-month, 3-month, 5-month, and 1-year, 6-hour storm events. Those five design storms were used to size CSO control facilities for the system alternatives. The Pawtucket Tunnel was sized to provide storage of the overflow volume generated during the 3-month, 6-hour storm, however, the consolidation conduits to convey CSOs to the tunnel facilities were sized to convey the 1-year, 6-hour storm flows. CSO interceptors were sized to convey the overflow volume generated during the 3-month, 6-hour storm to the tunnel facilities or consolidation conduits.

The Bucklin Point Service Area MIKE Urban hydraulic model developed for this Phase III Reevaluation effort has been used to refine those design parameters and inform the alternatives analysis.

The individual components of the overall baseline Phase III plan defined by the CDRA work together as a system to achieve the CSO abatement goals of that plan. For example, a regulator modification for CSO 215 is not a viable solution on its own unless a dropshaft is provided near CSO 217 to the Pawtucket Tunnel to provide the requisite capacity in the Blackstone Valley Interceptor and a long-term control solution. Many of the shared solutions were developed based on the geographic proximity of CSOs or logistical arrangements based on topographic conditions. Table 2 below provides an overview of the baseline plan components and their associated CSOs.

Table 3 – Baseline Plan Components

Design Capacity (MG)	CSO Control Solution	CSOs Controled
0.09	035 Sewer separation	035
0.07	039 Sewer separation	039
0.20	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
1.97	Drop shaft 213 & conduit	213
4.97	Pawtucket Ave interceptor	107, 220
8.95	Drop shaft 217 & conduit	107, 214, 217, 220
14.76	Drop shaft 218 & conduit	212, 215, 216, 218
55.16	Baseline Pawtucket tunnel	101 - 107, 201 - 205, 207 - 220

Consequently, the development of alternatives and evaluation of them against the baseline CDRA recommendations must follow a similar systematic approach.

3. Stormwater Flow Control and Management

Stormwater flow control and management focuses on the source and pathway of stormwater to minimize impact on a combined sewer. Anything that can be done to keep stormwater out of the combined system amounts to sewer separation. This can include hydraulic controls that keep stormwater on the surface to promote storage and infiltration at targeted location. This can also include taking advantage of locally separate flows for stormwater detention and release to the combined system after storm events pass.

Stormwater management was described in detail in the CDRA in the technology evaluations, section 6 in that report. The original recommended plan did not include any stormwater management for CSO abatement, however, technological advancements and improvements in operational efficiencies since development of the CDRA warrant the additional detailed descriptions included in this memorandum. Also, supplemental information based on NBC's project experience in Phases I & II of the CSO Program, recent field investigations, as well as stakeholder input is included herein.

The stakeholders group was concerned about how surface improvements would be maintained and by whom, either by NBC or by the member community.

3.1. Hydraulic controls

Inlet control has been used successfully for a number of years across the country. The intent of inlet control is to reduce the rate of stormwater inflow into an existing combined sewer to the hydraulic capacity of that sewer, regardless of rainfall intensity. It was originally developed to relieve basement flooding but is also used as part of stormwater management in the form of downspout disconnection, temporary street ponding, catch basin flow restrictors as well as surface features such as raised crosswalks. There exist over 30,000 installations for stormwater management.

HYDRAULIC CONTROLS

- Advantages
  - Keeps stormwater out of combined sewer
  - Can be integrated with GSI
  - Low Capital Costs
  - Low Operation and Maintenance Costs
- Disadvantages
  - Strategic surface ponding
  - Often requires specific surface conditions or improvements
  - Limited by specific health and safety consideration including FEMA regulations

Downspout disconnection is widely used to reduce direct uncontrolled flow to the sewer by rerouting roof downspouts to splash pads with drainage to green space, dry wells, created pervious areas or street catch basins.

Temporary street ponding is strategically created using flow controllers in catch basins to prevent or slow the overload to the combined sewer system, thus allowing the system to handle the flow and prevent overflows and basement backups.

Flow restrictors as shown here in Figure 3 are placed within catch basins are also widely used to induce overland flow from sensitive areas to either outlet discharge points or more attractive capture/storage locations. This is also known as "flow-slipping".

Figure 3 - Stormwater Flow Control - Vortex Throttle

Surface features such as raised crosswalks can be strategically placed to direct overland flow to storage or to maximize street storage potential. Systems of catch basin flow controllers paired with surface features can generate controlled street storage at low cost.

Figure 4 - Stormwater Flow Control - Detention Storage

Stormwater inlet control has strong positive benefits to combined sewer system by reducing peak flows, providing relief for basement backups, and minimizing the need and degree for sewer separation and local relief sewers. However, there are several disadvantages that must be carefully assessed when evaluating inlet control. Temporary street ponding may be viewed by residents as a negative impact. Ponding is perceived by many communities to increase the liability of ice ponding and slippery conditions. In reality, this has not been a problem in cold-weather urban communities and is a common practice. Inlet controls require street maintenance to clean up silt and debris from induced curbline overland flow, or to insure impervious and smooth street surfaces to minimize sub base damage and micro "pockets" of street ponding.

3.2. Stormwater Storage Tanks

Once runoff is controlled and kept separate from the combined system, a range of green and grey solutions can be employed. Tank storage of stormwater has a similar systematic impact as combined flow storage. It relieves pressure on the interceptor system during storm events and therefore eliminates CSO up to the design threshold. For smaller storms up to the design capture volume urban runoff is treated at the WWTFs; for larger storms above the design capture volume CSOs are discharged to the rivers. Compared to combined storage tanks, stormwater storages tanks are significantly easier and cheaper to build and operate due to cleaning and odor control requirements. The key to minimizing cleaning is BMP catchbasins and strategically located sump manhole structures upstream of the tank. As an example, to date 10 stormwater tanks have been installed in Cambridge, MA and sediment cleaning is required every 2-years on average.

STORMWATER STORAGE TANKS

- Advantages
  - Provides capacity relief for existing interceptors and WWTF infrastructure
  - Odorless storage
    - Expands siting possibilities
  - Lower operation and maintenance costs
  - Provides for treatment of stormwater at WWTF
  - Can be integrated with GSI
- Disadvantages
  - Requires dedicated stormwater collection system
  - Requires land acquisition or easements
  - Susceptible to grit buildup (can be mitigated)

Stormwater storage tanks can be either retention or detention facilities. Vortex throttles are frequently used for detention facilities.

3.3. Stormwater Flow Control

Stormwater flow control, or flow slipping, involves managing the stormwater at the source before it gets into the pathway of the combined sewer system. Stormwater flow control is closely related to GSI, however, there are some "grey" systems that deal with stormwater, and determining how stormwater control through inlet control and localized storage could reduce the extent of sewer separation is discussed herein.

3.3.1. 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 stormwater to flow down the hill which in turn could minimize the amount of new infrastructure necessary to separate the system. Stormwater would be captured near the bottom of the hill before it reaches North Main St, shown here in Figure 6, and could be stored in a new stormwater interceptor or linear stormwater tanks before discharging back to the combined system, or back to the river.

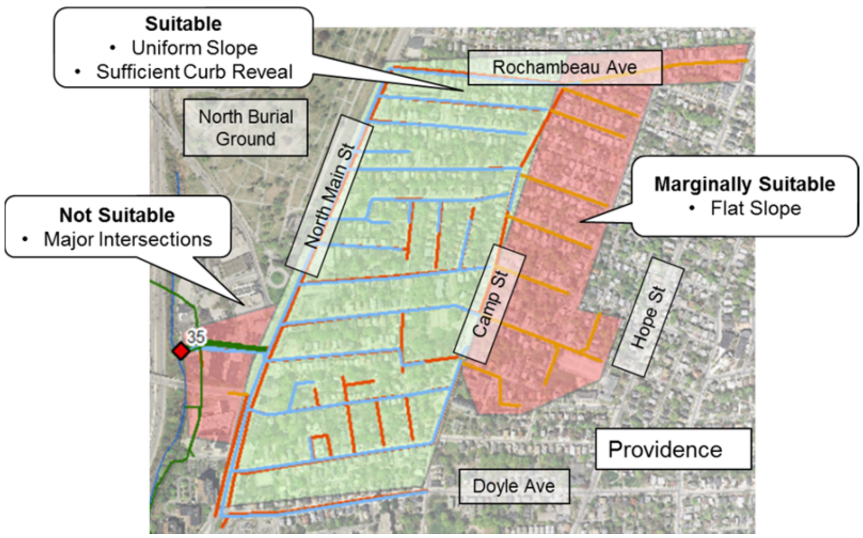

Figure 5 - Stormwater Management CSO 035

As shown in Figure 5, 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 shown below in Figure 7. The lower section at the outfall is not being considered further for overland flow due to close proximity to the high traffic intersections.

Figure 6 - North Main St

Figure 7 - Cypress St

The approach for stormwater flow control at Outfall 035 is assumed to include:

- Inlet Control
  - Downspout Disconnection (Add quantity here and for estimate??, ADD TO HYBRID)
  - 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)
- Installation of new consolidation drain pipe on North Main Street (500 LF, 24-48" dia.)
- Adjacent utility work
- Surface Restoration

Stormwater flow control at Outfall 035 on its own does not reduce the stormwater flow enough remove the overflow during the design storm. A hybrid approach to sewer separation incorporating the above stormwater flow control and GSI is evaluated in Section 4.4.1.

3.3.2. Outfalls 039/056

The catchments for Outfalls 039 and 056 in Providence are slated for sewer separation as part of the previously recommended Phase III. To look at stormwater flow control, the catchments have been combined and broken into three sections as shown in Figure 8. The east section closest to

056, such as Grand Broadway and Vandewater Street shown below in Figure 11 and Figure 12 respectively, is not suitable for stormwater flow control as the streets are dead flat and have little to no curb reveal. The middle section between Admiral St and Douglas Ave is marginally suitable for stormwater control. It has sufficient slope but a very small curb reveal, shown here on Veazie Street in Figure 10, and would need to be captured before reaching heavily traveled Douglas Ave, shown in Figure 9. The west section between Admiral St and Providence College is not suitable for stormwater control as it has minimal curb reveal, minimal slope and would need to be captured before reaching heavily traveled Admiral St.

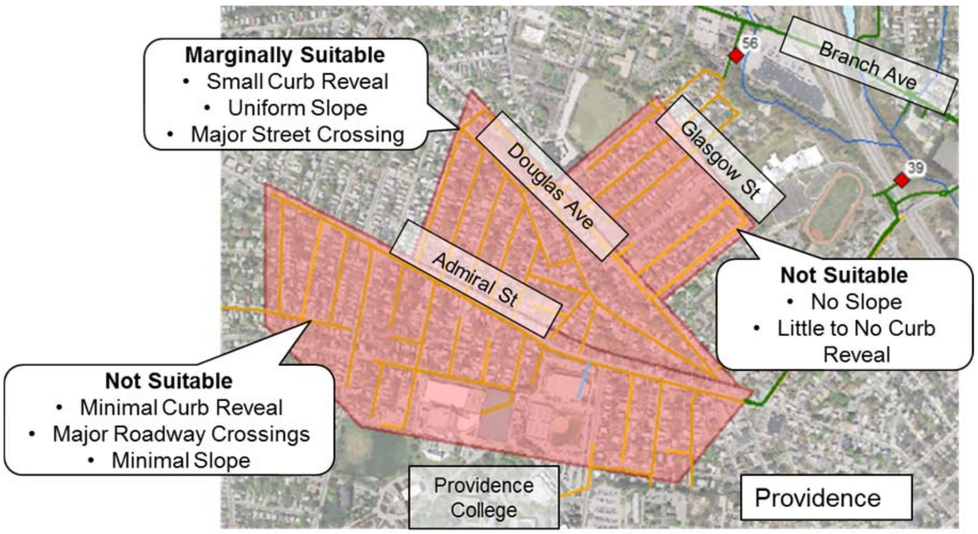

Figure 8 - Stormwater Management CSOs 039/056

Figure 9 – Douglas Ave at Admiral St

Figure 10 - Veazie St at Sunbury St

Figure 11 - Grand Broadway at Stansbury St

Figure 12 - Vandewater St at Grand Broadway

Stormwater flow control for catchments 039 and 056 will not be evaluated further for stormwater management as an alternative to sewer separation for the reasons stated above. However, stormwater management, such as inlet control, may be combined with sewer separation or GSI to increase its effectiveness and refine the scope of new construction.

3.3.3. Outfall 206

The catchment for Outfall 206 in Pawtucket on the border of Central Falls is slated for sewer separation as part of the Phase 3 baseline condition. This is only 14 acres and slopes west-to-east down to the Blackstone River. There are commercial properties are located along Roosevelt Ave that would be impacted by construction disruptions such as increased noise and traffic. Other abutters who are potential sensitive to sewer separation construction include two churches in the area, the Chinese Christian Church on Roosevelt and St. Mary's Orthodox Church on High St and St. Mary's Way, and the YMCA located off of Roosevelt just to the north of the outfall.

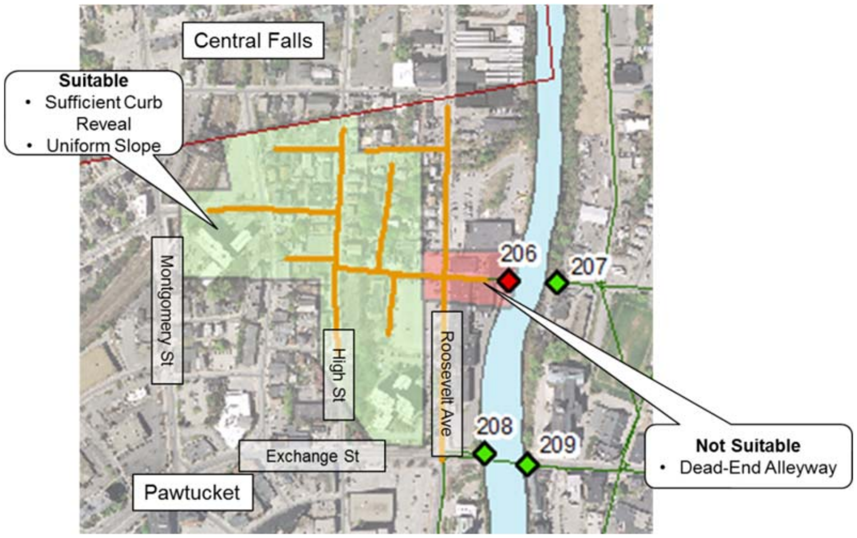

Figure 13 - Stormwater Management CSO 206

West of Roosevelt Ave, shown here in Figure 14 and Figure 15, the catchment has reasonable curb reveal and enough slope where promoting overland flow could move stormwater down the hill and minimize the amount of new infrastructure necessary to separate the system. Stormwater would be captured near the bottom of the hill before it reaches Roosevelt Ave and could be stored in a stormwater tank before discharging back to the combined system, or to the river.

East of Roosevelt Ave, shown here in Figure 14, the catchment is not suitable for overland flow as Blackstone Ave is a dead-end alleyway surrounded by commercial properties.

Figure 14 - Blackstone Ave West of Roosevelt Ave

Figure 15 - Roosevelt Ave at Blackstone Ave

Figure 16 **- Blackstone Ave East of Roosevelt Ave**

4. Sewer Separation

Sewer separation involves taking a combined system and creating separate sanitary sewer and storm drain pipe networks. In many cases, the old combined pipes and manholes can be rehabilitated and reused as either sanitary or storm pipes and serve alongside new pipes serving the alternate purpose. In some cases, the old network must be abandoned entirely due to poor condition and two entirely new systems must be constructed. Similarly, in many instances the interceptor capacity allows a CSO location to be closed entirely, and the CSO can be converted to a storm drain outfall. In other cases a new storm drain outfall must be constructed and permitted.

The primary goal of sewer separation is to remove storm water from the sewer collection system. This reduction in storm water flows helps relieve the local system as well as the downstream interceptors. Separation removes flows that would otherwise be transported to the treatment plant and can be discharged near the runoff sources. In some cases, increased stormwater discharge to flood-prone rivers can require additional mitigation, in the form of in-line or surface storage, to protect low-lying properties and flood vulnerable facilities. Sewer separation can also result in polluted urban runoff being discharged to receiving water bodies, which if unmitigated can impact water quality, particularly compared to rainfall conditions below the CSO activation level where flow was previously sent to the treatment plant. It is important that sewer separation also includes removal of any sanitary connections that connect to existing storm systems to prevent illicit discharges.

SEWER SEPARATION

- 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, section 6 of both reports. The basic components of sewer separation have not changed. Additional information provided in this memorandum is intended to supplement the information provided in the previous reports based on NBC's project experience in Phases I & II of the CSO Program, recent field investigations, as well as stakeholder input.

4.1. NBC CSO Program Phase II Sewer Seperation Lessons Learned

Phase II of NBC's CSO program included sewer separation in several Providence sewersheds. The lessons learned during those separation efforts inform how future separation will likely proceed and help to better define the benefits, costs and impacts of Phase III separation efforts.

4.1.1. Neighborhood Impacts

SEWER SEPARATION - Neighborhood Impacts

- Impacts to Businesses from Reduced Visibility, Access
- Impacts to Pedestrians and Traffic from Road Conditions
- Impacts on Residents from Noise, Dust, other Nuisances

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, as experienced in areas impacted by NBC's Phase II separation projects and shown in Figure 17. Most of the local sewers in Phase III study areas date back to the original installations of the late 1800s and early 1900s. In most cases, utilities such as water, gas, and underground electric are located above sewer and drain pipes. The coordination involved with relocated and upgrading old utility services can significantly impact the schedule and cost of separation.

Figure 17 – NBC Phase II Sewer Separation Neighborhood Impacts

4.1.2. Utility Issues

In most cases, utilities such as water, gas, and underground electric are located above sewer and drain pipes. The coordination involved with relocated and upgrading old utility services, such as water main installation shown in Figure 18 during Phase II separation, 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 as shown in Figure 19. Encroachment within close proximity to old gas mains often necessitates complete replacement with new, plastic gas mains.

SEWER SEPARATION - Utility Issues

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

Figure 18 - NBC Phase II Sewer Separation Utility Installation

Figure 19 - NBC Phase II Sewer Separation Utility Conflicts

4.1.3. Surface Restoration

SEWER SEPARATION - Restoration Issues

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

If a utility were to replace their pipe or duct banks on a stretch of road, a trench patch (typically a couple feet wide) is often acceptable resurfacing post-construction. However, the depth of excavation required for sewer and drain and associated utility conflicts often lead to complete restoration of the surface is often required. Additionally, installation of catch basins along the edge of roadways intrudes into sidewalks, driveways, and landscaped areas and can impact above ground utility infrastructure (utility poles, hydrants) as shown in Figure 20. Surface restoration adds significant cost, but does provide the opportunity for local communities to improve streetscapes as shown in Figure 21 where Hope Street was improved as part of Phase II sewer separation.

Figure 20 - NBC Phase 2 Sewer Separation Surface Restoration

Figure 21 - NBC Phase 2 Sewer Separation Surface Improvements

4.2. 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; and
- actual costs from NBC's Phase II Sewer Separation projects bid results Table 4.

Table 4 – NBC Phase II and Other Planning

<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 027 (303.05C)</td><td>Residential[1]</td><td>99%</td><td>16,275</td><td>634</td></tr>
<tr><td>NBC Phase II CSO 037 West (303.06C)</td><td>Residential[1]</td><td>91%</td><td>11,657</td><td>767</td></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 5 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 5 – 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

Outfall Catchment	Catchment Area (acre)	Unit Cost ($/acre)	Existing Pipe Length (LF)	Unit Cost ($/LF existing pipe
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.

4.3. 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 22, which includes the entire cities of Central Falls and Pawtucket as well as Phase III baseline sewer separation areas in Providence discussed in section 4.4.

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 6 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 4.4. 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 4.2. 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 6 represent construction costs only and are exclusive of costs for geotechnical investigations, design, engineering during construction, construction management, and right-of-way acquisitions.

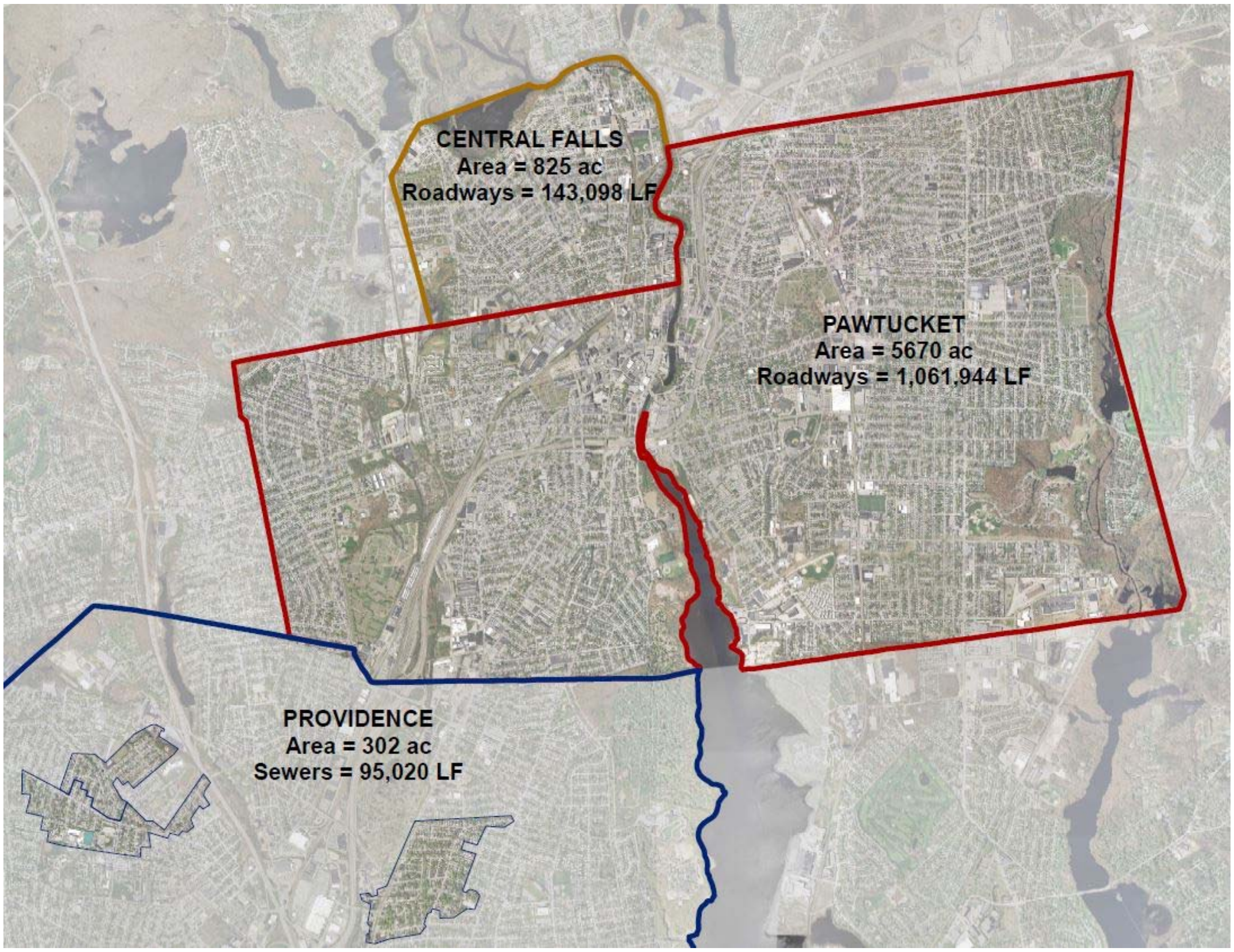

Figure 22 - Total Sewer Separation of Phase III Study Area

Table 6 - Total Sewer Separation

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 3 Baseline)	See Section 4.4					$54,161,000
Total						$1,503,367,000

While the total sewer separation of the Phase III study area would eliminate CSOs it would introduce new points of discharge for stormwater runoff. 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.

4.4. Phase III Baseline Sewer Separation Areas

The Phase III CSO Baseline Alternative, as shown in Figure 23, designates sewer separation for CSOs 035, 039 and 056 in northern Providence to mitigate discharges to the West and Moshassuck Rivers, and CSO 206 in Pawtucket to mitigate discharge to the Blackstone River.

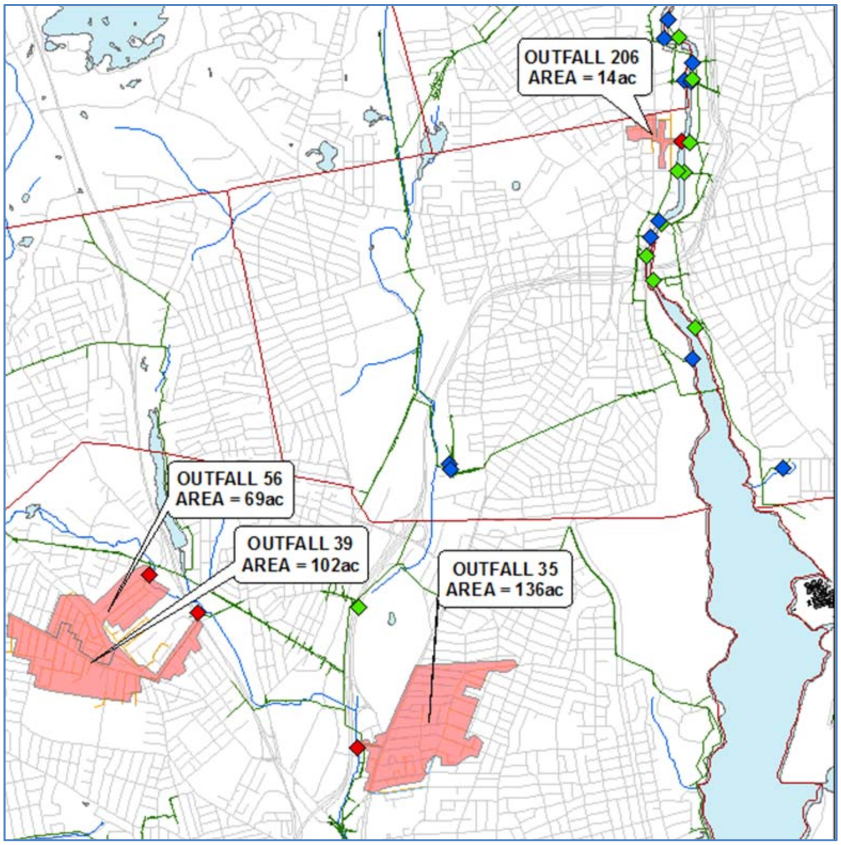

Figure 23 - NBC CDRA Phase III Sewer Separation

4.4.1. CSO Outfall 035

The catchment tributary to Outfall 035 is approximately 136 acres of mixed residential and commercial use located in northeastern Providence located between North Main St, Rochambeau Ave, Hope St and Doyle Ave. There are commercial properties are located along North Main Street that would be impacted by construction disruptions such as increased noise and traffic. Other abutters who are potential sensitive to sewer separation construction include the North Burial Ground to the west, Brown University to the south and east, and Hope High School to the south. The topography of this neighborhood slopes significantly and from east to west down to North Main Street.

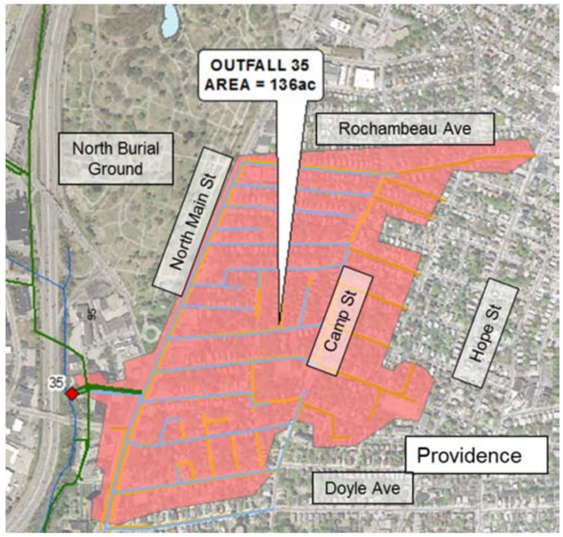

Figure 24 - Sewer Separation CSO 035

The 035 CSO catchment is adjacent to CSO catchments 027 and 037 which located just to the north and northeast. At the time of this writing, the catchments for 027/037 are under construction as sewer separation projects part of Phase II of NBC's CSO Program. The ongoing separation projects cover approximately 413 acres and have caused numerous disruptions to residents, commuter traffic and local businesses in the area. There are sections of both Rochambeau Avenue and North Main St (north of Rochambeau) that have been or are scheduled to be resurfaced during current separation of catchment 037 that may require excavation and reconstruction for separation of catchment 035.

A major difference between the adjacent catchments 027 and 037, is that the collection system in the 035 catchment area consists of a two-pipe system comprising sanitary and combined sewers as shown in Figure 24. The streets shown in blue have two existing pipes, while the pipes shown in yellow have one existing pipe. Since the majority of the catchment already exists as a two-pipe system, the separation of 035 is unique in that not all streets are likely to see new construction. However, a detailed inspection program would need to be completed to evaluate the condition of the existing pipes for maximum potential reuse, as well as to determine if cross-connections exist between the two pipe networks. Cross-connections would need to be removed to prevent illicit sanitary discharges into the separated stormwater network.

Table 7 - 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

During the April 2014 Stakeholders Group meeting, stakeholders raised several specific concerns regarding sewer separation in this area, including:

- Burdening the same group of nearby residents and businesses with construction-phase impacts who have been impacted by Phase II sewer separation projects in CSO catchments 027 and 037

- Producing negative localized flooding impacts as a result of downspout disconnection.
- Requiring complicated and costly roadway reconstruction requirements for work in North Main Street.

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

As discussed previously in section 3.3.1 stormwater flow control is recommended at Outfall 035. The opportunities for public GSI in this catchment are minimal due to significant slopes and marginal soils. Therefore, the combination of stormwater flow control and GSI alongside sewer separation was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 25.

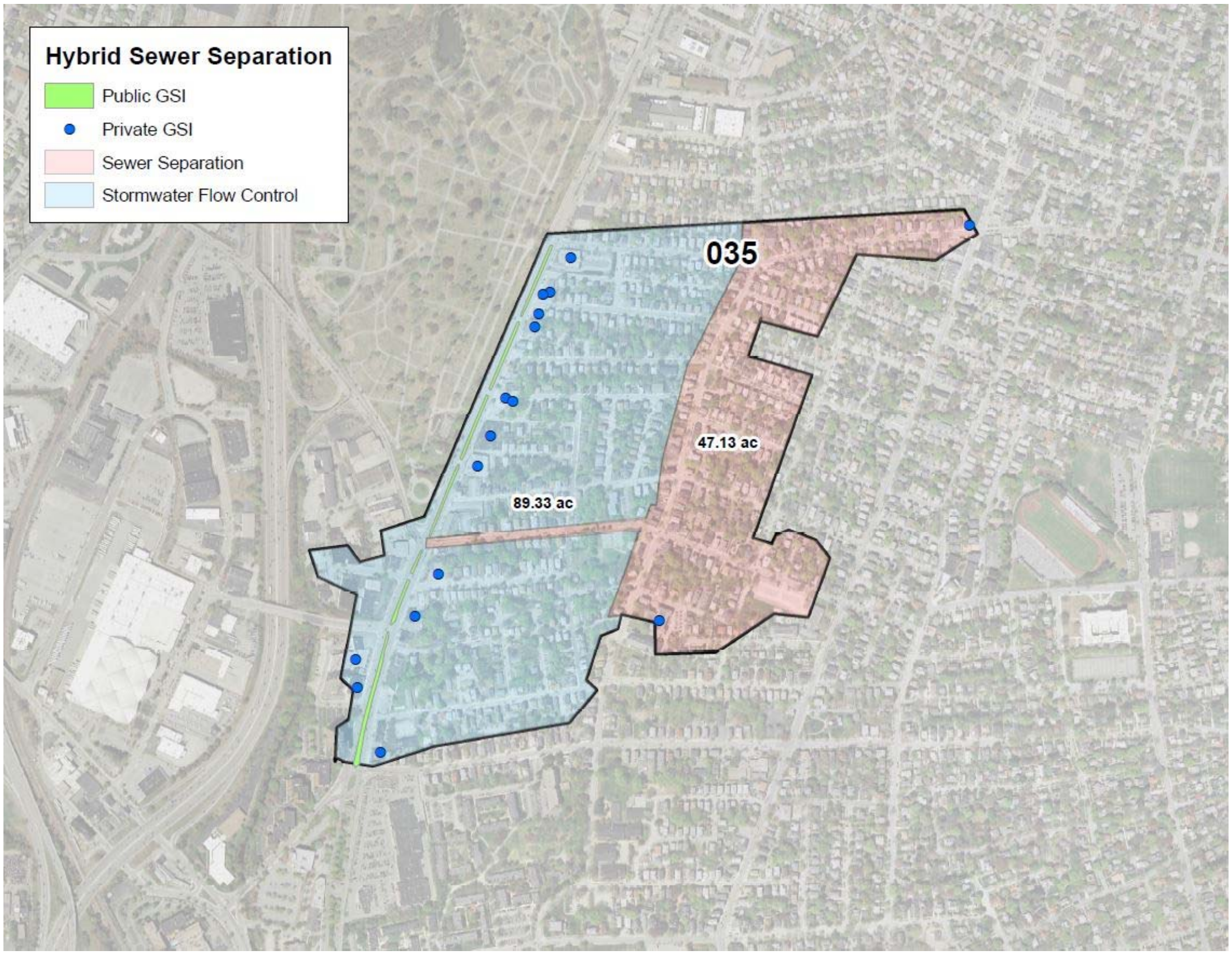

Figure 25 - Hybrid Sewer Separation Outfall 035

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
    - 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)

4.4.2. 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 St, and Providence College. There are commercial properties located along Douglas Ave and Admiral Ave that would be impacted by construction disruptions such as increased noise and traffic. Other abutters who are potential sensitive to sewer separation construction include Providence College with facilities located to the southwest and the Rhode Island School for the Deaf located between outfalls 056 and 039.

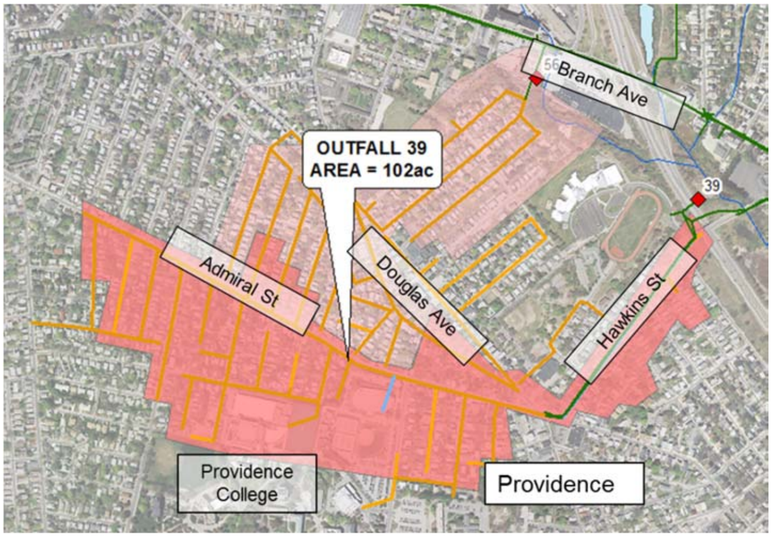

Figure 26 – Sewer Separation CSO 039

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 8 - 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

During the April 2014 Stakeholders Group meeting, stakeholders raised concerns that 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

As discussed previously in section 3.3.2 stormwater flow control is not recommended at Outfall 039. Public GSI alone will not eliminate overflow at Outfall 039. Therefore, the combination of GSI alongside sewer separation was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 27.

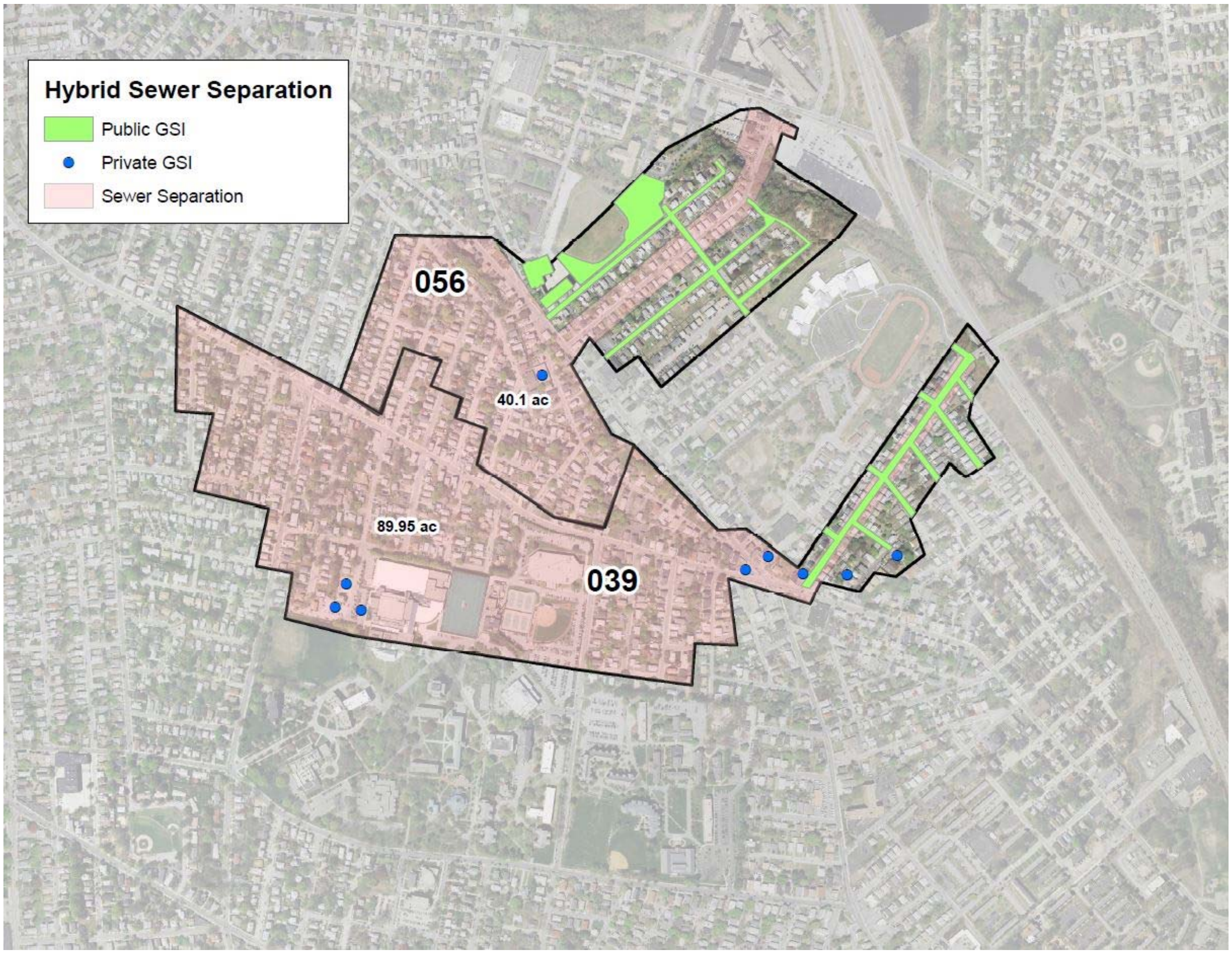

Figure 27 - Hybrid Sewer Separation Outfalls 039/056

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)

4.4.3. 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 are located along Douglas Ave and Branch Ave that would be impacted by construction disruptions such as increased noise and traffic. Other abutters who are potential 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.

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.

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.

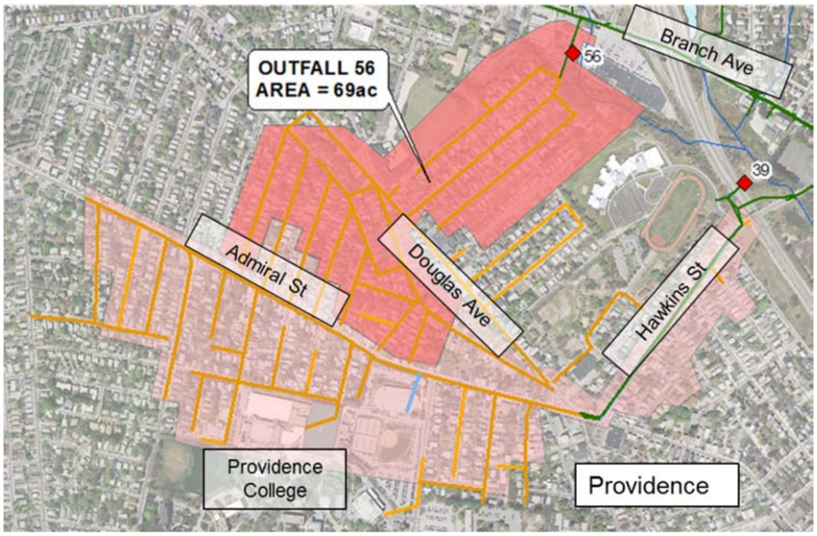

Figure 28 – Sewer Separation CSO 056

Table 9 – 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

The stakeholders raised concern that 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 (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

As discussed previously in section 3.3.2 stormwater flow control is not recommended at Outfall 056. Public GSI alone will not eliminate overflow at Outfall 056. Therefore, the combination of GSI alongside sewer separation was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 27.

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)

4.4.4. 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 disruptions such as increased noise and traffic. Other abutters who are potential 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 collection system in this catchment consists of single-pipe combined sewer. The neighborhood slopes from west to east down the Blackstone River.

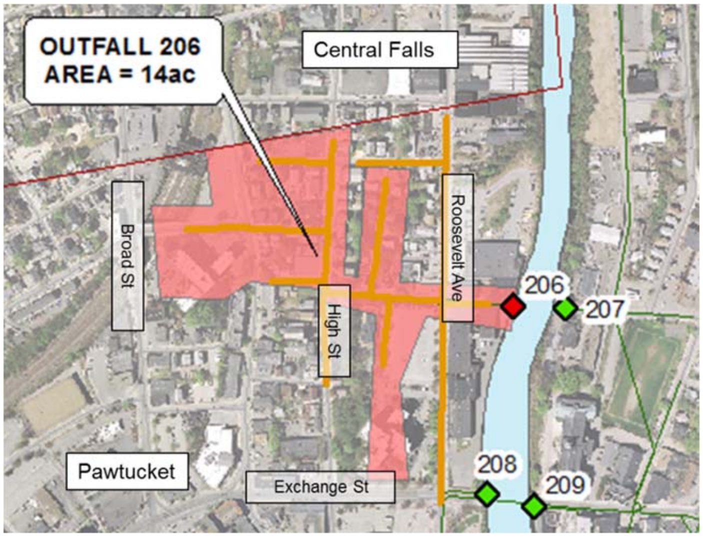

Figure 29 – Sewer Separation CSO 206

Table 10 - 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, 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 (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

As discussed previously in section 3.3.3 stormwater flow control is recommended at Outfall 206. The opportunities for public GSI in this catchment are moderate due to significant slopes and unknown urban soils and will not eliminate the overflow alone. Therefore, the combination of stormwater flow control and GSI alongside sewer separation was evaluated to reduce the extent of sewer separation. The hybrid separation approach is shown in Figure 30.

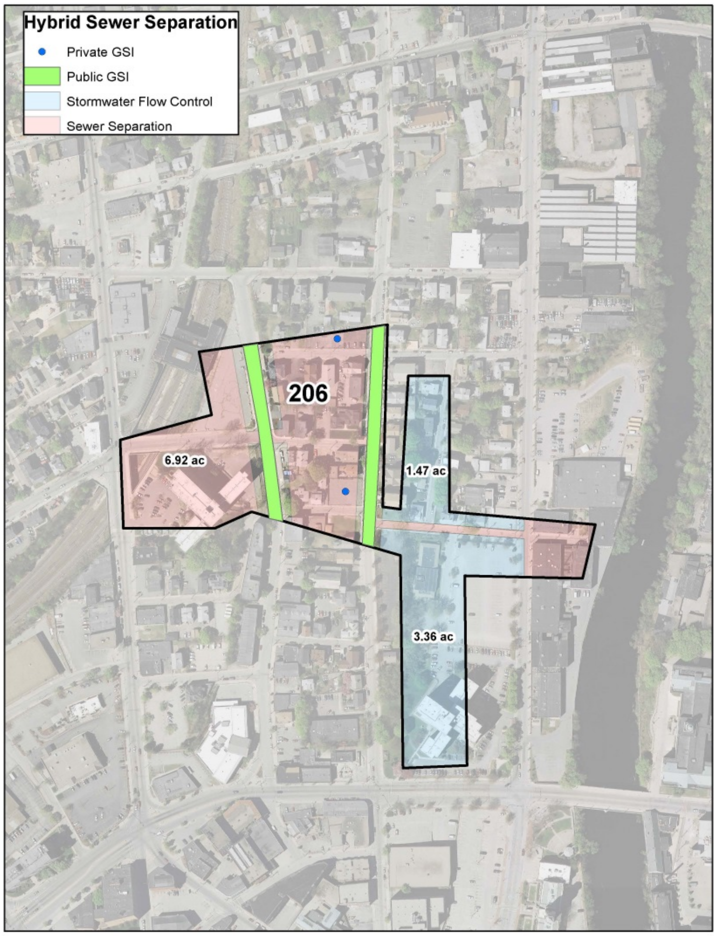

Figure 30 - Hybrid Sewer Separation Outfall 206

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)

5. Deep-Rock Tunnel

On the Source-Pathway-Receptor spectrum, tunnel storage systems are the ultimate Receptor solution for large systems. 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, consequently, 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 virtually any other option; therefore, tunnels become a cost-effective solution for large flows. Tunnels provide temporary storage for combined flow volumes that are pumped out and treated during dry conditions at the wastewater treatment facilities, therefore, the tunnel solution 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, section 6 of both reports. The basic components of tunnel storage have not changed. Additional information provided in this memorandum is intended to supplement the information provided in the previous reports based on NBC's project experience in Phases I & II of the CSO Program, recent field investigations, as well as stakeholder input.

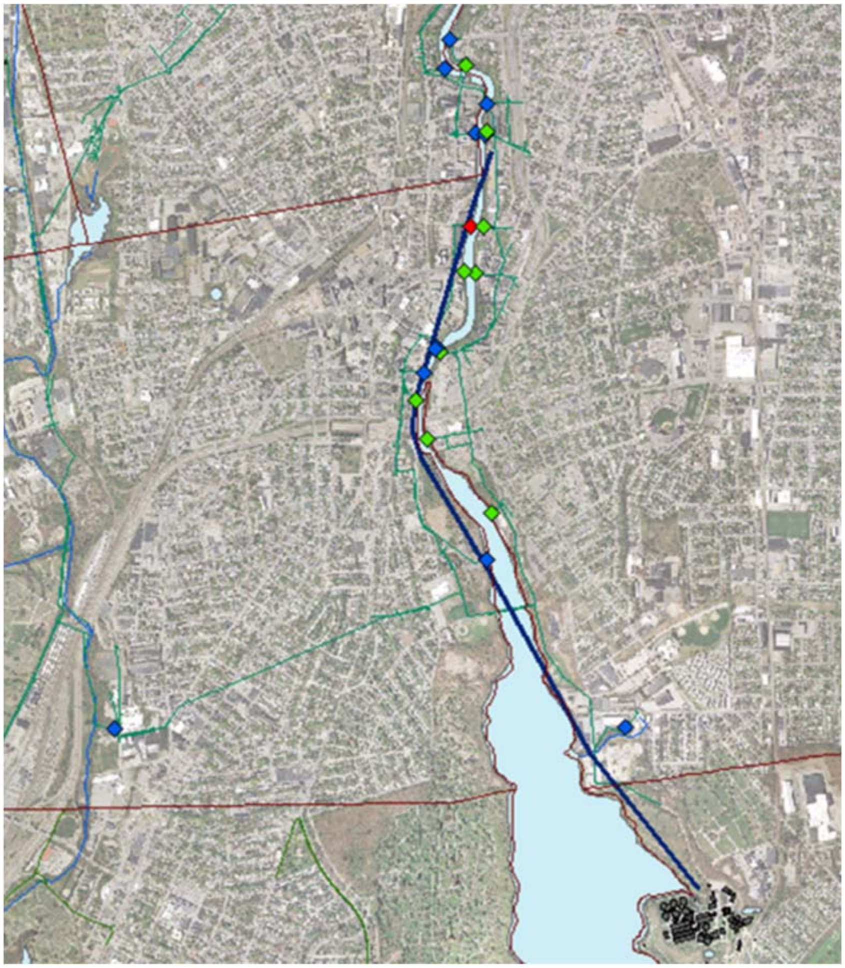

Figure 31 – Pawtucket Tunnel (CDRA Route)

5.1. Pawtucket Tunnel

The Pawtucket Tunnel as defined in the CDRA as having a storage volume of 51 MG, 26 feet in diameter with 5 dropshafts and 2 working shafts, and extending 13,000 lf 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 31. Bedrock in the region is typically 15 to 100 feet below grade, and the tunnel is planned to be 150 to 200 feet below grade.

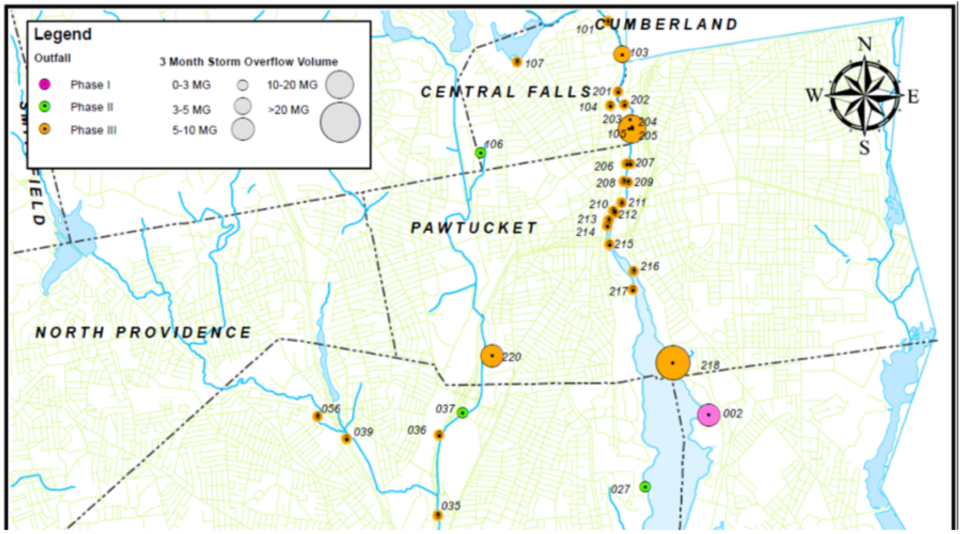

Figure 32 – BPSA CSO Overflow Volumes

The Pawtucket Tunnel aligns to capture two of the largest volume CSOs in the NBC system, 218 and 205, as well as four other intermediary CSOs via drop shafts, highlighted in Figure 32. Six additional CSOs are to be connected to the tunnel via interceptors. Nine further CSOs would receive regulator modifications that would utilize existing interceptor system capacity augmented by the tunnel system.

Based on lessons learned, field observations, input from the stakeholders and hydraulic modelling, the baseline design for the Pawtucket Tunnel would likely 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

5.2. 220 Stub Tunnel

The CDRA identified an alternative to the Pawtucket Avenue interceptor for Outfall 220, intended to be evaluated further in Phase 3 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 33. The Pawtucket Stub Tunnel was proposed as 10-ft diameter, between 70-190 ft below grade, and nearly 9,100 LF. The CDRA proposed this could also reduce the size of the Pawtucket Tunnel from 26-ft diameter down 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

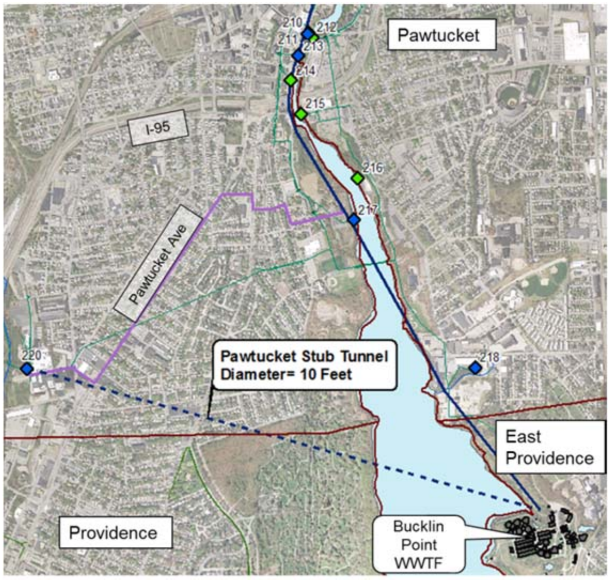

Figure 33 - Pawtucket Ave Stub Tunnel

The stub tunnel would involve at least one additional working shaft and an additional drop shaft, both located in the vicinity of Outfall 220 shown here in Figure 34.

Figure 34 - Outfall 220

The stub tunnel alternative for would significantly reduce the disruption to roadway traffic, commercial properties, and residential neighborhoods along the proposed interceptor route. This alternative was discussed at the April 2014 Stakeholders Group meeting; however, no specific concerns or special considerations were identified.

Based on lessons learned, field observations and input from the stakeholders, this alternative consists of the following:

- Temporary launching/receiving pit located adjacent to outfall 220.
- Drop shaft to pick up overflows from outfall 220.
- Deep-rock tunnel between outfall 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.

**Tunnel sizes and connection with Pawtucket Tunnel listed above may be revised after alternatives analysis*

5.3. Branch Avenue Tunnel Adit

The BAI located in Providence was also evaluated for connection to the Pawtucket Tunnel by extending the 220 Stub Tunnel. The 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 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 deep geotechnical information indicates that an ancient, buried thalweg, or low elevation associated with an historical river bed, bisects this adit route. Consequently, constructing a tunnel between 220 and the BAI is not technically feasible.

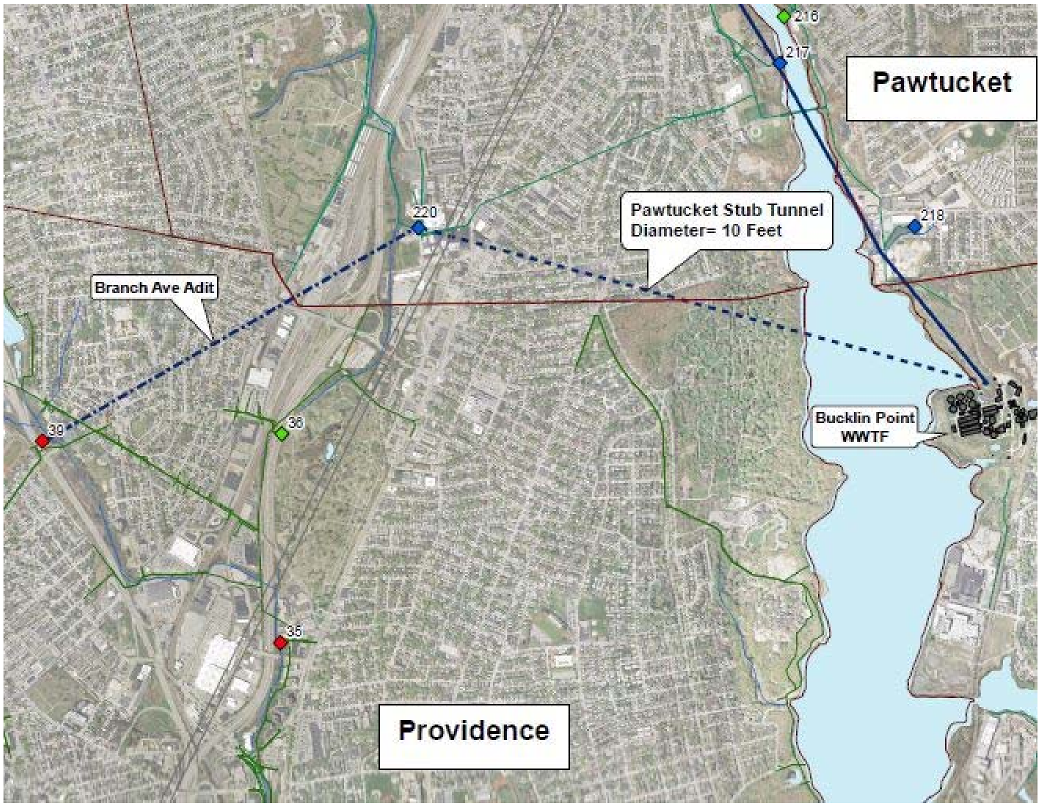

Figure 35 - Branch Ave Adit

5.4. 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 11. 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 11 - Cost Equations for Tunnels

Source Document	Date of Publication	Cost Equation[1]	Figure ID

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.

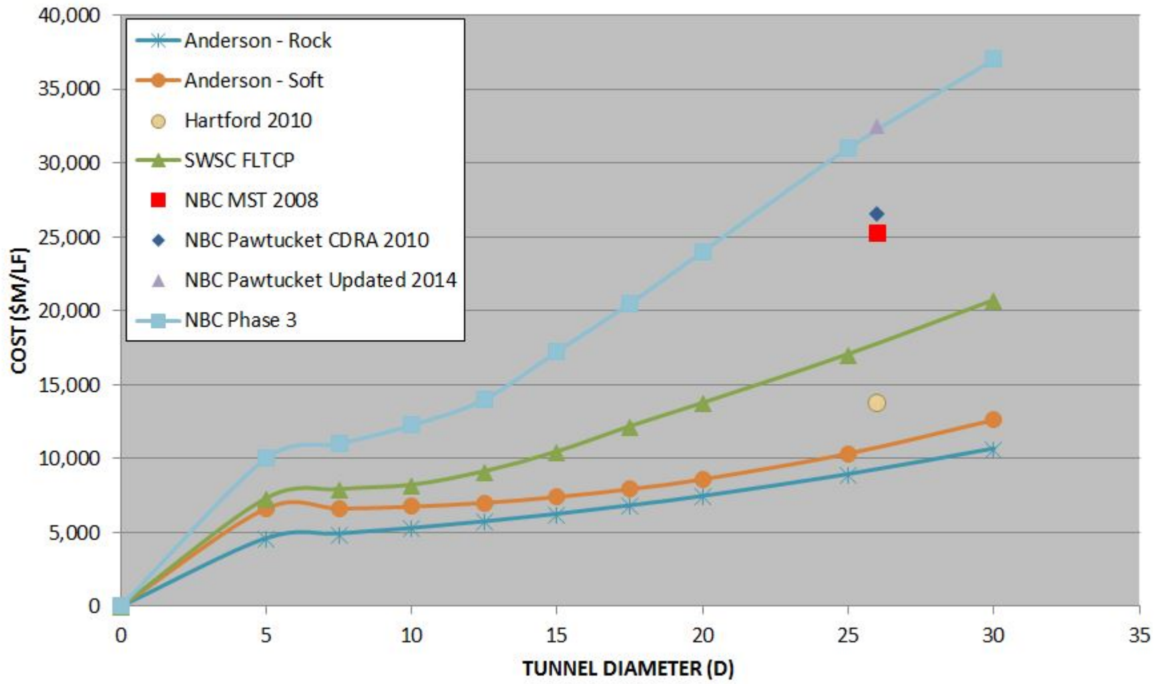

Figure 36 - Construction Cost Curves for Tunnels

Figure 36 shows cost curves developed from the cost equations for deep tunnel facilities in Table 11 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.

6. 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 where public health could be at risk. 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 section6.4.

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 memorandum 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.

6.1. 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 37 below depicts one of the drive pits used to construct a tunnel conveyance interceptor under Phase II of NBC’s CSO Program.

Figure 37 – NBC Phase 2 Interceptor Construction

6.2. Interceptor Costs

For purposes of this report, interceptor sewers refer to conduits that consolidate overflow volumes to storage alternatives such as deep-rock tunnels or near-surface storage tanks, or as in-line storage. Interceptor sewers drain by gravity and are considered to be constructed near the surface, generally less than 30-ft below grade, as opposed to consolidation conduits for deep-rock tunnels. Interceptor sewers 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. Interference can be due to pavement, traffic, and utilities. Surface restoration can range from riverbank protection and roadway reconstruction.

NBC Phase III estimates for these costs were developed using engineer's estimates and bid results from the NBC's Phase II Interceptor Projects (Woonasquatucket and Seekonk river interceptors) as well as nearby Springfield, MA projects completed in 2009. Table 12 below 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 12 - 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”-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.

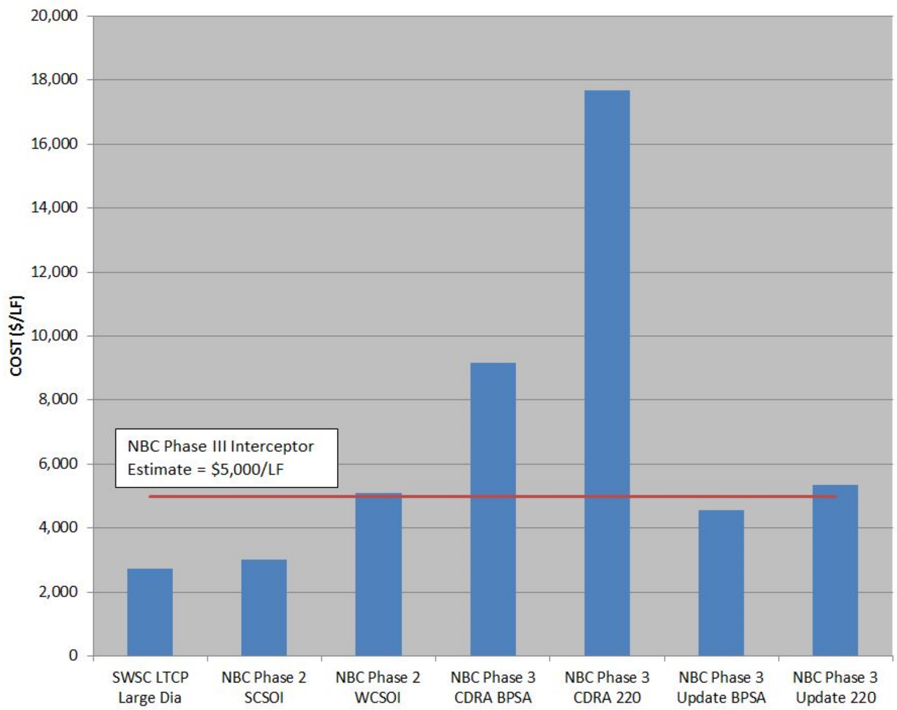

Figure 38 - Construction Costs for Interceptors

The costs per linear foot of interceptor construction are shown in Figure 38. The NBC Phase II SCSOI and WCSOI estimates provide estimated cost indicators for NBC Phase III interceptors(s). The NBC Phase III cost estimate used 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.

6.3. 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. See Figure 39 for the approximate location of the three new interceptors.

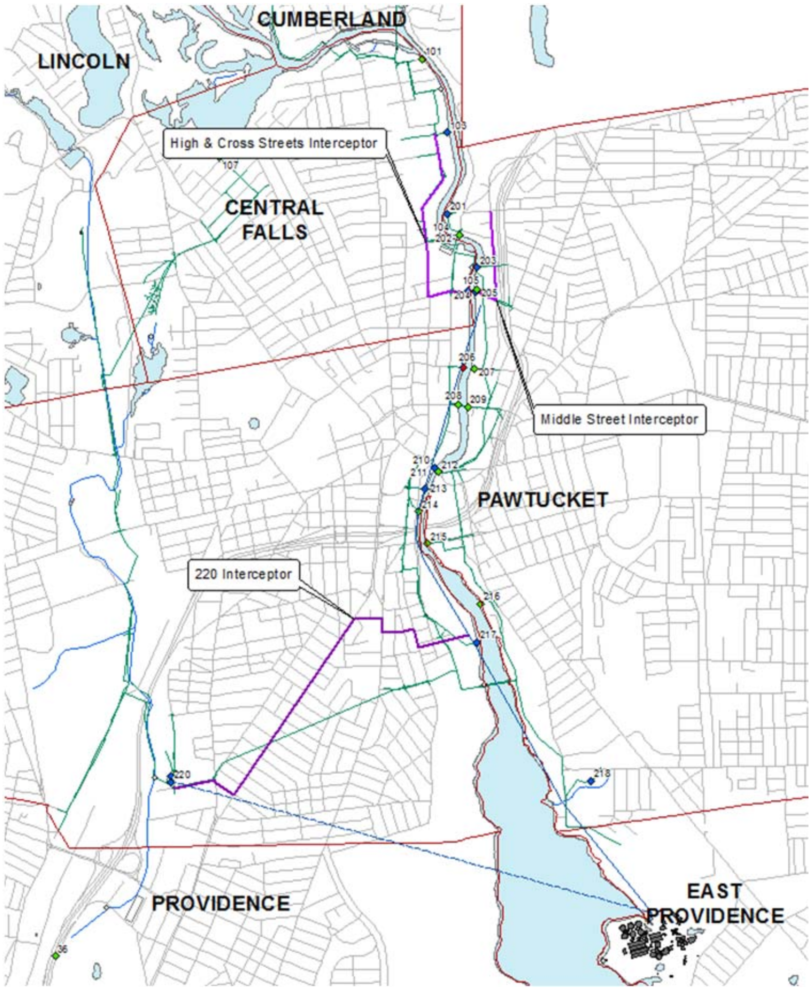

Figure 39 – Interceptors to Pawtucket Tunnel (CDRA)

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 combined OF219/220 in western Pawtucket, an interceptor, consisting of a pump station, force main and gravity main, would convey flows from the remote CSO 220 to the middle section of the tunnel.

The CDRA identified as an alternative to the interceptor a 10-foot diameter, 9,100 LF stub tunnel cutting across Pawtucket and allowing for a change in the configuration of the Pawtucket Tunnel as depicted in Figure 39.

6.3.1. 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 40.

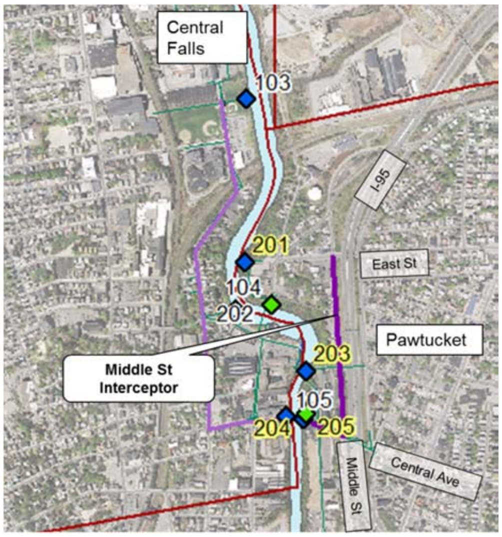

Figure 40 - Middle St Interceptor

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 41). 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 41 - 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 42) 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 42 - Middle St at Central St (Pawtucket)

Based on lessons learned, field observations and input from the stakeholders, the baseline 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

  **Pipe sizes listed above may be revised after analysis of MWH hydraulic model*

6.3.2. 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 43.

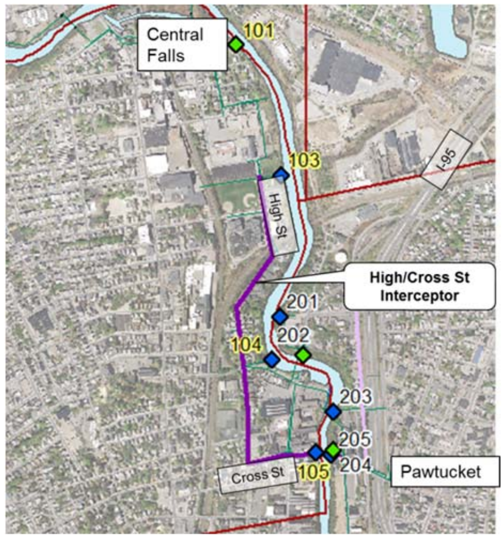

Figure 43 - High St/Cross St Interceptor (Central Falls)

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 44 the road pinches down to only let one car through at a time through with a blind entrance. The section of High St north of the railroad overpass is home to several public ball fields, a park and the Donald W. Wyatt Detention Facility. 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 44 - 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 (seen here in Figure 45), 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 St, 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 45 - Cross St Bridge

During the April 2014 Stakeholders Group meeting, the stakeholders raised concern that the railroad crossing on High Street is critical and must stay in active service during all construction activities, noting that coordination with the owners of the rail road right-of-way will likely extend the schedule for the project and add cost.

Based on lessons learned, field observations and input from the stakeholders, the 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
  **Pipe sizes listed above may be revised after analysis of MWH hydraulic model*

6.3.3. Pawtucket Avenue Interceptor

The CDRA recommended plan included the new Pawtucket Ave interceptor, located in southern Pawtucket and as a pathway for overflows from the MVI to the Pawtucket Tunnel near outfall 217. The outfall for CSO 220 lies about 30-feet above outfall for CSO217 but due to an elevation gain of nearly 90-feet along the proposed route, a pump station and 48-inch, 4,745 LF force main would be required along with a 54-inch 3,425 LF gravity interceptor, as shown in Figure 46.

The existing Moshassuck Valley Interceptor (MVI) crosses southern Pawtucket to the Blackstone Valley Interceptor (BVI) via a 4-ft diameter, 4,400 LF tunnel. The Outfall at 220 is located just upstream of the existing tunnel and results in the third largest overflow within the

BPSA at nearly 7.6 MG during the 3-month storm. Outfall 220 was recently combined with outfall 219 into one overflow structure, referred herein as simply Outfall 220.

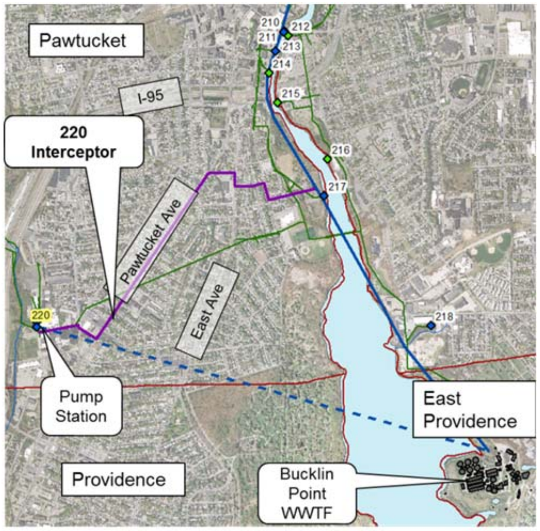

Figure 46 - Pawtucket Ave Interceptor (Pawtucket)

Outfall 220 discharges to the Moshassuck River at the intersection of Moshassuck Street and Esten Avenue. The area is dominated by larger commercial properties as well as 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 seen below in Figure 47. The interceptor route turns off of Pawtucket Avenue onto Patt Street before winding down through a steep, tightly developed residential neighborhood (see Figure 48) before crossing Pleasant Street at Jeffers Street and connecting to a drop shaft into the Pawtucket Tunnel alongside Outfall 217. In the vicinity of the proposed drop shaft location is 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.

Figure 47 - Pawtucket Ave

Figure 48 - Harvey St

Figure 49 - Esten Ave

This alignment was discussed at the April 2014 Stakeholders Group meeting, and it was generally agreed that construction in these areas an along this route would be difficult; however, no specific concerns or special considerations were identified.

Based on lessons learned, field observations and input from the stakeholders, the baseline 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.
  **Pipe sizes and pump station volume listed above may be revised after analysis of MWH hydraulic model*

6.3.4. 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 6.4.1.

6.3.4.1. 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 included in below:

- Option 1 – Shown in Figure 50, 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. The force main meanders through city streets 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 syphon. 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 – Shown in Figure 51, 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 – Shown in Figure 52, 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.

Figure 50 - Branch Avenue to Moshassuck River Interceptor Connection Option 1

Figure 51 - Branch Avenue to Moshassuck River Interceptor Connection Option 2

Figure 52 - Branch Avenue to Moshassuck River Interceptor Connection Option 3

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 Branch Avenue interceptor will encounter significant hydraulic issues. During wet weather the entire length of the sewer beneath Branch Avenue becomes surcharged, not just locally but along a length covering more than 25,000 Lf. The surcharging is the result of a general hydraulic incapacity but is further compounded by localized choke points.

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 that look 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 53 shows a longsection of the BAI in the hydraulic model showing the HGL predictions for the 3-month storm simulation.

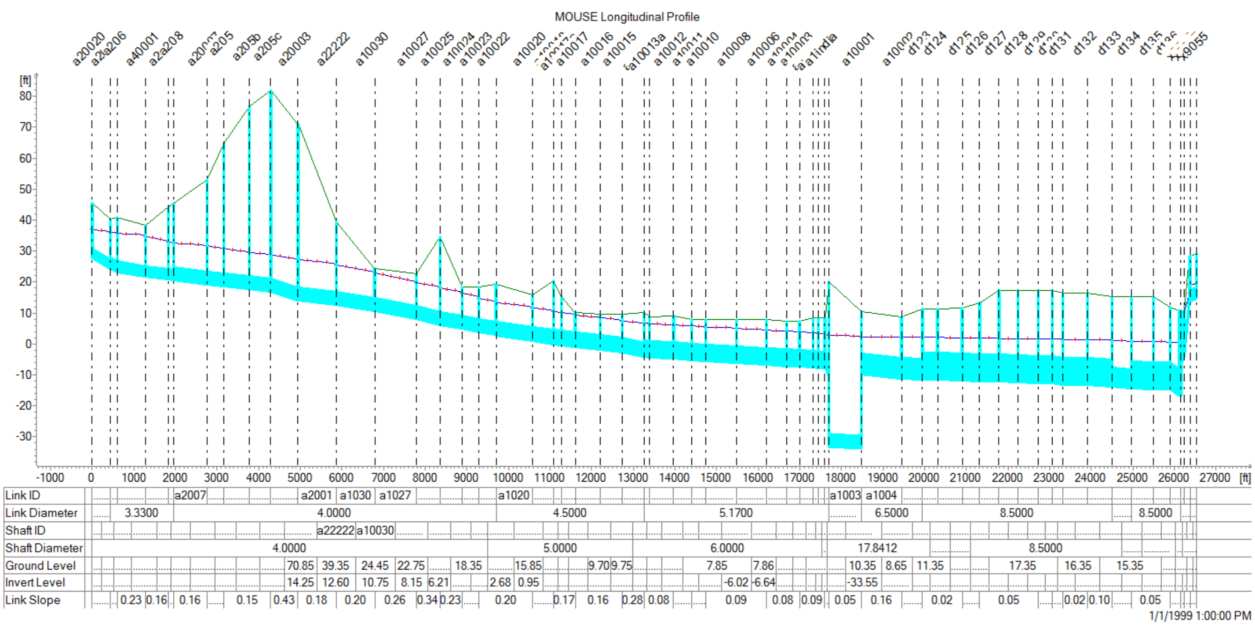

Figure 53 - Hydraulic model results for the Branch Avenue sewer during the 3-month storm simulation

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.

6.4. 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.

6.4.1. 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 54, was depicted in plan and profile in figures 6.1-10 and 6.1-11 respectively is 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

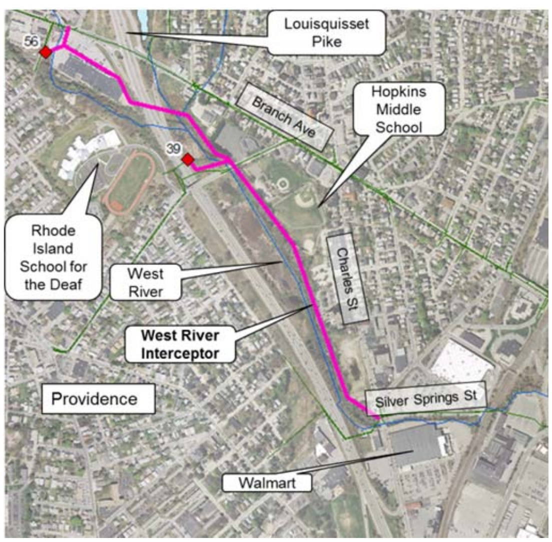

Figure 54 – Interceptor Relief Storage for CSOs 039/056 (CDR West River Interceptor)

As originally proposed, 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 54, 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 a concentrated impact on select 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 6.3.4.1, 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.

This alternative to sewer separation was discussed at the April 2014 Stakeholders Group meeting. The group acknowledged that both the West River Interceptor and sewer separation would produce significant construction-phase impacts to the area; however, the hydraulic benefits of the interceptor may exceed those of sewer separation. The group also explored the option of extending the interceptor to the Main Spine Tunnel; however, it was noted that the tunnel was not designed or constructed with the capacity to accommodate the additional flows.

7. Regulator Modifications

Regulators and control structures are used to optimize the diversion of dry weather and excess wet weather flows to downstream facilities such as interceptors, storage facilities and treatment facilities. 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 appropriate

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 13 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 13 – 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

8. Localized Combined Flow Handling

8.1. 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 in hydraulically beneficial locations. 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.

It is important to note that the overall 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 following sections describe the major considerations for storage facilities including tank configurations, influent/effluent hydraulics, pumping scenarios, heating, ventilation, and air conditioning (HVAC), and Odor Control, and cleaning systems.

- 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

Near Surface Storage (NSS) was described in detail in both the CDR and CDRA in the technology evaluations, section 6 in both reports. The original recommended plan did not include any NSS facilities, however, technological advancements and improvements in operational efficiencies since development of the CDR and CDRA warrant the additional detailed descriptions included in this memorandum. Also, supplemental information based on NBC's project experience in Phases I & II of the CSO Program, recent field investigations, as well as stakeholder input is included herein.

8.1.1. Tank Configurations

The following sections are intended to describe several possible alternatives to the configuration and operation of a CSO storage tank itself, independent of the washdown, and pumping aspects, to the extent possible.

8.1.1.1. Retention and Detention

Wet weather storage tanks can be used for retention or detention modes of operation. Retention tanks accept a limited volume of liquid and do not overflow the excess (they do not have effluent weirs or orifices), so the flow is bypassed at the head of the tank. For detention tanks, flow enters at the influent end and generally exits at the opposite end once a set overflow elevation is achieved.

8.1.1.2. Tank Geometry and Layout

The volume and configuration of a CSO storage tank must be large enough to provide storage for the design storm. The tank's geometry and supplemental systems will be evaluated using the following criteria:

- CSO tank volume and configuration will be large enough to provide storage for chosen design storm;
- Self-cleaning and solids conveyance will be optimized with appropriate channel lengths, training walls, bottom slopes, and effluent channels;
- Supplemental mechanical components and systems will be selected to control operations and maintenance costs;
- Clean-up operations will be designed to minimize potable water use;
- Structures associated with the tank and ancillary systems will be minimized.

The hydraulic geometries established for the treatment and cleaning of the tank system is critical to the operational success of the CSO tank. Although a variety of tank sizes and configurations exist, the criteria defined above largely drive the tank layout design towards an optimum configuration.

8.1.1.2.1. Above Ground Tank Concept

Above-ground storage tanks are typically circular, wire-wound prestressed concrete tanks. Costs for this type of tank have come down over the years to the point where it doesn't make economic sense to consider an above-grade, rectangular tank for storage purposes. Influent pumping scenarios are discussed below in Section 8.1.3.1.

8.1.1.2.2. Below Ground Tank Concept

Although a prestressed concrete tank can be buried, the amount of extra excavation and space required for construction make it less economical. In addition, there are structural, geotechnical, and cleaning considerations that a cast-in-place, rectangular tank can more readily address. For these reasons, only rectangular storage tanks will be considered for below-grade concepts. Effluent pumping scenarios needed for a below ground tank are discussed below in Section 8.1.3.2.

8.1.1.2.3. Combination or Two Tank Concept

Depending on modeling results, the use of two tanks or a combination of above-grade tank and below-grade tank (or expanded wetwell) to handle the wide range of storm events can be evaluated.

Although having two tanks would increase the capital cost, there may be operational cost savings for HVAC, odor control, cleaning and maintenance that may make it a more feasible option. An expanded wetwell could provide additional storage that would reduce the number of activations for a large storage tank and reduce tank cleaning efforts and expenditures.

8.1.1.3. Tank Classification and Functionality

Two classifications of tank related to personnel access are presented for consideration in this section, 1) open access and 2) closed. Open access and closed tank concepts have no effect on the functionality of the tank from a washdown or operating standpoint. Ultimately, the impacts associated with the ventilation and tank access should drive the decisions on what configuration will be incorporated. Open air tank concepts are not being considered due to the urban residential and commercial locations of storage within the Phase III study area.

8.1.1.3.1. "Open Access"" Tank Concept

For the purposes of this report, the "open access" tank concept refers to a covered tank (below or above-grade) that allows complete personnel access throughout the storage tank without the need for auxiliary ventilation, lighting, or confined space equipment (although this type of tank may still be considered a confined space by the Occupational, Safety and Health Administration, OSHA). The open access tank alignment is conducive to secondary cleaning operations and inspection of the tanks or maintenance of equipment located within the tank. Open access tanks offer the advantage of easy inspection and maintenance of the entire tank from within or from catwalks above the tank compartments. The disadvantage is that the tank has an exposed water surface that requires 12 air changes per hour (ACH) be provided for the safety of the personnel and equipment located within. Furthermore, additional tank height is needed above the required storage volume dimensions to allow for personnel access space. This requirement imposes both additional construction and HVAC cost. See Figure 55 for a photo of an "open access" tank located below ground.

Figure 55 - Union Park, MWRA, Boston, MA

8.1.1.3.2. Closed Tank Concept

For the purposes of this report, a "closed" tank concept refers to a covered tank (below or above-grade) that is normally inaccessible, except through dedicated, sealed, access hatches. Access requires auxiliary ventilation, lighting, and confined space entry equipment and training to allow entry into the tank. Galleries and hatches can be strategically located to facilitate maintenance and inspection at critical locations like tank influent or equipment areas. The advantage of this arrangement is that the storage tank is isolated from all personnel areas, minimizing ventilation and odor control requirements and minimizes construction costs. The disadvantage is that inspection or maintenance within the tanks will require auxiliary ventilation, lighting, or confined space equipment.

8.1.2. Hydraulics Controls

8.1.2.1. Diversion Structure Overflow Control

When a sewer exceeds its maximum flow capacity, flow must be diverted from the sewer system into a storage tank, relief sewer, or to a water body or ground surface to relieve pressure and eliminate flooding upstream in the system. In the past, this has typically been accomplished using a fixed sidespill weir to allow excess flows to spill out of a diversion chamber and into an overflow pipe or structure. Fixed weirs, however, do have several disadvantages in that they typically need to be very long and do not provide any true flow control, simply releasing more flow as the head rises above the weir. In recent years new technologies have been developed to reduce the effective size of these fixed weirs and provide greater flow control and backflow prevention.

8.1.2.1.1. Bending Weirs

An overflow bending weir operates on the principle that the water surface elevation in an overflow diversion structure can be maintained at a constant level by raising or lowering a flexible weir level. In essence, as overflow rates increase, the bending weir will gradually open to release these higher flow rates while maintaining a constant hydraulic grade line in the upstream pipe network while the weir capacity is not exceeded. In addition, the bending weir can be designed such that it does not begin to release flow until a set design flow level is reached in the diversion chamber, thus maximizing upstream storage and minimizing spill events. When flows exceed design capacity, the device lowers to flat position, acting as a fixed weir. The compact design of these units make them easily installed within limited space constraints and the weirs can be designed flush with the wall of the chamber to eliminate backflow issues or transmission of sewer gases to the outfall. Finally, bending weirs operate using either an integrated counterweight design that functions based on flow and gravity, with a flexible metal sheet, or with springs designed to bend when a specific hydraulic head is attained on the upstream side eliminating the need for electrically actuated parts and additional power supplies.

8.1.2.2. Tank Dewatering Options

Below-grade tank tanks would be dewatered with the effluent pump station. The above-grade alternative has a few options for dewatering.

8.1.2.2.1. Passive Control - Vortex Throttle

A vortex throttle is a passive flow control device that controls the flow rate delivered from an upstream reservoir to a downstream location based on a head-discharge curve. The vortex flow throttle has no moving parts and flow is regulated over the entire head using only the hydraulic properties of the unit and the fluid flowing through it.

Fluid enters the regulator housing through the horizontal inlet connected tangentially to the housing. During low flow conditions water smoothly passes through the unit under gravity conditions. As the flow and upstream head increases, the water forms a conical vortex creating a hydraulic brake. Entrapped air is exhausted through a vent. The vortex flow throttle is mounted to the structure floor using brackets and the outlet pipe can be either flange mounted or inserted into the structure’s discharge pipe.

8.1.2.2.2. Passive Control – Hydroslide

Passive control devices could be installed in a downstream structure that would eliminate the need for level sensors or electric valves. An example includes installing a Hydroslide valve in a small structure before connection of the tank draindown pipe to the trunk line. A Hydroslide is a valve equipped with a float that progressively opens or closes an orifice based on the water level in the structure where the Hydroslide unit is installed. The water levels for opening or closing can be determined by adjusting the length of the arm that connects the float with the metal blade that blocks the orifice.

8.1.2.2.3. Mechanical – Flow Control Valve

The discharge pipe at the bottom of the tank would have a modulating flow control valve tied to a level sensor in a downstream junction chamber and/or to a magnetic flowmeter. This would limit the discharge rate of the tank to prevent surcharging in the interceptor.

8.1.3. Influent and Effluent Pumping Systems

The two basic strategies for pumping systems in CSO tanks include influent and effluent pumping. Influent pumping facilities are located upstream of the proposed storage tank. In this arrangement the proposed storage tank can be located above-grade and discharge can flow by gravity back to the interceptor sewer. Effluent pumping facilities are located downstream of the proposed storage tank. Under this arrangement the proposed facility can be underground and out of sight to neighbors. The pumping systems at the end of the process are required to elevate the discharge above the hydraulic grade line of the interceptor sewer.

The cost for construction will be greatly impacted by the choice of influent or effluent pumping systems. With influent pumping, construction of a storage tank will require less excavation. While this cost savings may favor influent pumping systems, effluent pumping will allow the storage tank to be located below grade, which can reduce the visual impact of the facility.

8.1.3.1. Influent Pumping Scenario

The influent pumping scenario will accept combined sewer overflows from a diversion structure. The flow will enter the pumping station wet well where it will then be pumped to the storage tank. Dynamic hydraulic modeling will determine the peak flow capacity that will be required for the influent pumping scenario. Effluent from the storage tank will then flow by gravity to a downstream junction structure at an elevation greater than the design hydraulic grade line.

Because the pumping lift is provided upstream of the storage tank, the influent pumping scenario allows the facility to be constructed above grade. The advantages and disadvantages of an above grade structure were discussed in Section 8.1.1.2.1.

A drawback to influent pumping is the complexity of operation and maintenance of the pumping operations that are required to match influent flows.

8.1.3.2. Effluent Pumping Scenario

Effluent pumping systems are located downstream of the storage tank such that flow from the interceptors would converge at the end of a rectangular storage tank. Depending on the final tank design, the storage tank effluent would then enter a pumping station wet well and be discharged directly into a downstream junction chamber. Based on the conceptual hydraulic profile, the effluent pumps would need to have a capacity to drain the full tank in less than 24 hours. Effluent pumps are typically substantially smaller than influent pumps for similar sized storage tanks as they do not have to be sized to match influent flow rates.

Because there is no pumping upstream of the storage tank, it would have to be constructed as a below grade structure. The pumping station itself would be significantly deeper under this scenario than the influent pumping scenario.

The primary advantage of the effluent pumping scenario is the simplicity of the pumping operation as compared to influent pumping. In an influent pumping scenario, the pumps need to keep up with a wider range of influent flows corresponding to the CSO overflow rates. In the effluent pumping scenario, the pumps have a lower required capacity as they only need to ensure the tank can be dewatered in a timely fashion. In the effluent pumping scenario, excess flow above the design storage volume would be discharged to the receiving water body.

Another advantage is maintaining of the aesthetic quality of the existing project area can be preserved as with effluent pumping the storage tank would be located below grade. The only above grade structures may include access ports to the facility and electrical and control facilities, which are often no more than a kiosk.

The primary drawback to the effluent pumping scenario is construction cost as the storage would be constructed deeper under this scenario. This can drive up the cost for excavation, dewatering and stabilization.

8.1.4. HVAC and Odor Control

HVAC equipment provides comfort and safety for operating and maintenance personnel, protect equipment, and help control odor emissions. They are designed to provide adequate fresh air for personnel, remove excess heat generated from equipment in warm weather, and maintain an adequate temperature for personnel during cold weather. Odor control systems are provided as part of the ventilation systems where odors or emissions are a concern.

8.1.4.1. Odor Control

Storage tank odor control systems typically serve the storage tank, pump station wetwell and possibly a diversion structure. It is important to note that the size of the odor control system is greatly impacted by the ventilation requirements associated with the storage tank. Because that is the greatest air volume for the facility, the tank configuration as discussed in Section 8.1.1 is critical in determining the ventilation requirements for the facility. Wet scrubbers and activated carbon are two of the most common odor control methods in wastewater facilities.

8.1.4.1.1. Wet Scrubbers

Wet scrubbers are extremely versatile and can remove a variety of both corrosive gases and liquid particulates from an air stream. Wet scrubbers are highly efficient and routinely achieve 99 percent or better collection efficiency for gas absorption and liquid entrainment separation. A typical wet scrubber system includes: a scrubbing tower complete with scrubbing solution spray system, packing material, mist eliminator, exhaust fan with associated ductwork, scrubbing solution recycle system, and chemical storage and handling system including storage tanks, metering pumps, piping and valves, and instrumentation and controls.

Some of the more common parameters that must be taken into account when designing a wet scrubbing odor control system include the inlet air stream conditions and volumes, removal efficiency and discharge limits, materials of construction, scrubbing liquid and chemicals, pressure drop through the packing media, air velocity through the scrubber, retention time in the scrubber, and maintenance requirements.

8.1.4.1.2. Activated Carbon

Activated carbon adsorption is a separation process based on the ability of activated carbon to remove gaseous or liquid components from a flow stream. It has been used as a primary odor control system and as a polishing step following other odor control methods. It has been found that activated carbon is effective in removing hydrogen sulfide as well as reducing organic odors. A typical activated carbon odor control system consists of air pretreatment units (optional), activated carbon vessels, exhaust fans, ductwork, and controls. The activated carbon bed is used until adverse breakthrough occurs, at which time it must be replaced or reactivated.

One of the most critical steps in designing an activated carbon system is to accurately estimate the characteristics of the contaminated air. Failure to properly estimate these parameters can result in poor performance or higher than anticipated carbon replacement (or regeneration). Other factors that affect the design include velocity through the bed, dwell time, pretreatment of the gas stream, moisture content in the air stream, and carbon replacement or regeneration.

8.1.5. Tank Cleaning

There are many approaches to cleaning away debris and sediment from detention tanks, the simplest methods including hand labor with shovels, brooms, and high-pressure hoses for small tanks, and small bulldozers or clamshells for larger open tanks. The more modern methods include sophisticated technologies such as tipping buckets or flushing gates which are often self-actuating.

Originally tanks were cleaned utilizing primary and dedicated secondary cleaning operations because the primary method was ineffective and required that the secondary cleaning be an integral part of the overall cleaning procedure to adequately clean the tank. Primary cleaning operations such as traveling bridges, fixed spray headers and nozzles and submerged mixers require dedicated secondary cleaning technologies (water cannons or high pressure hoses). However, as technology and maintenance personnel competence has evolved, many tanks now only incorporate efficient means of primary cleaning such as tipping flushers and flush gates. From a functional perspective a "Primary" method of cleaning is considered highly effective if little "mop-up" cleaning is required. Often the "mop-up" incorporates visual tank inspection and periodic washdown of debris in tank corners and other locations that were bypassed by the primary flushing operation. Some flushing methods are nearly self-sufficient and require little or no personnel interactions other than starting the system (tipping flushers and flush gates), while others need operators to guide the cleaning operations (water cannons and traveling bridges).

It is important to note that the method of flushing also impacts the configuration of the tank's bottom. Bottom sloping enhances the removal of settled solids during tank draining and cleaning operations. If header nozzle systems are used for washdown, the tank is typically configured with a center trough, traversing the length of the tank, and sloping towards the effluent end and the tank bottom slopes from the sidewalls to the trough at 3-10%. Where tipping flushers or flush gates are used, the channel bottom slopes at 2-3% from the flusher end towards a large, wide collecting trough at the opposite end of the tank.

The floor design should consider the maximum admissible slopes to ensure high scouring velocities during drainage and cleaning operations, while optimizing the depth, area and overall storage tank volume. Tank bottom design should incorporate input from the flushing equipment supplier to assure proper operation and sizing. The design of the end trough for tipping flusher and flush gate installation is as critical as the tank design and must be sufficiently wide in its cross section to prevent "splash back" from occurring. Peculiarities in terms of special side sloping are discussed with each method.

There are four practical methods that are feasible from an operational standpoint for cleaning the accumulated sludge and debris from the storage tank. Two of the methods are similar and include wash down nozzles attached to a moveable bridge; and fixed headers and jetting nozzles. The two remaining cleaning methods are tipping flushers and flushing gates. Variations of these methods have been adapted for circular tanks.

8.1.5.1. Primary Flushing Systems

8.1.5.1.1. Traveling Bridges

There are three general types of traveling bridges that have been used to clean SSO and CSO storage tanks. Two of these methods (traveling bridges with scrapers or suction pickups) have been shown to have limited success in fully cleaning tanks, and typically require extensive secondary washdown to effectively clean the tanks. Consequently these two methods will not be considered as viable alternatives.

The third traveling bridge type is the traveling bridge with washdown nozzles. In this configuration, each cell is equipped with a moveable bridge which is equipped with a traveling pump and a piping system with an array of spray nozzles spaced along the bottom and sides of the pipes a close distance to the bottom and side walls of the tank. This traveling bridge typically makes several passes along the cell, washing down the interior floor and walls with washdown water pumped through the nozzles. Typically a secondary means of cleaning is included in the form of a water cannon attached to the traveling bridge.

An advantage of this system is that both the primary and secondary modes of cleaning are located in a central location, the bridge. The disadvantages of the system include (1) large quantities of water consumed during washdown operation, (2) the traveling bridge mechanism requires frequent maintenance, (3) initial installation is complicated and includes many mechanical components, (4) a secondary mode of cleaning is required to supplement the spray headers, and (5) there are high structural costs associated with the water supply reservoir for each basin. Due to the high capital costs extensive O&M aspects, this method is not recommended.

8.1.5.1.2. Fixed Spray Nozzles & Headers

Fixed spray nozzle and header systems are generally comprised of an extensive piping network with multiple valves, booster pumps and controls and a washdown wet well. The spray headers and nozzles are generally suspended inside the tanks they clean. This alternative requires secondary cleaning operations, typically with water cannons, because of the inefficiency of the spray nozzles to clean the entire tank. A dedicated secondary cleaning system must be used in conjunction with this technology.

The tank bottom required for this system slopes steeply (approximately 10%) from the sidewalls to a center trough, and the center trough slopes at 2 – 3% toward an effluent trough. Disadvantages associated with this alternative include: (1) large quantities of water are consumed during the cleaning operation, (2) the system requires a secondary, concurrent mode of cleaning to supplement the spray headers (i.e. water cannons), (3) floatables get caught on the header system and (4) excessive sediment and debris can accumulate anywhere the nozzles don’t reach. Due to the high capital costs and extensive O&M associated with this methodology, this approach is not recommended.

8.1.5.1.3. *Tipping Flushers*

Tipping flushers (TF) systems have been used in North America for the past 30 years. During this time they've proven to be an extremely effective method of cleaning sedimented debris from the floors of all types of tanks. The system generally includes filling pipes and valves, a pumping system, a wet well, and the tipping flusher vessels. The TF is a cylindrical stainless steel vessel that is ideally suspended above the maximum water level on the back wall of the storage tank. The units can be filled with rain water, ground water, or potable water, but require a filling system consisting of 2" – 3" headers with appropriate controls. Just prior to overtopping the vessel with water, the center of gravity shifts and causes the unit to rotate and discharge its contents down the back wall of the tank. A curved fillet at the intersection of the wall and tank floor redirects the flushwater (with minimum energy loss) horizontally across the floor of the tank. The flushing force removes the sedimented debris from the tank floor and transports it to a collection sump located at the opposite end of the tank.

The size of a tipping flusher required to clean a given tank depends on the flushing distance, the height the unit is suspended above the tank invert, and the slope of the tank floor in the flushing direction. The TF's vary in size from 24 to 193 gal/ft of flusher length, with a maximum length/span of approximately 30-ft. The maximum effective flushing length is between 160-175 feet because the wave cannot be sustained and tends to break up into rivulets beyond this distance. Experience with flushing in the 180-200 foot range is mixed, and it has been observed that often 2 flushes are necessary to achieve adequate cleaning at these extended lengths.

These systems have tank floors that slope from the flusher location to the collection trough at 1 – 3% (2% is desirable because quality control is difficult for flatter slopes). Tipping flushers require flushing lanes that are about equal to the width of the flusher to control the flow direction of the flush wave. This is accomplished by training walls that are about 15" to 18" high, and run the full length of the tank terminating at the collection trough. All walls parallel to the path of the flushing flow should be perpendicular to the tank bottom, with no fillets, to ensure the lower wall edges are cleaned. There is an upper effective height limit for placement of the tipping flusher where additional height does not enhance the flusher performance further, (approximately 20 feet). The wall beneath the flushers must be continuous (i.e. contain no openings, penetrations, or obstructions) to assure wave continuity.

Experience to date with these systems indicates that the dedicated secondary cleaning operations, using concurrently operated water cannons or high pressure hoses, are not needed. If the first flush of the basin does not remove all of the sediment, the basin can be re-flushed or "mopped-up" by fire hoses. In most cases, tank sidewalls are generally hand troweled to a very smooth finish to prevent buildup from occurring, and consequently don't require frequent washdown.

The advantage of this system is the lack of a required secondary tank cleaning apparatus, minimal mechanical equipment, low O&M costs, and the ability to automate the flushing cycle, thereby requiring no manned operation during tank dewatering and flushing. The disadvantages are the need for a pumped water supply to the tipping flushers.

8.1.5.1.4. *Flushing Gates*

The flushing gate was originally developed in Germany (1985) as a method for flushing sediments in pipe segments (in-line storage or troublesome flat trunk and interceptor sewers).

The unique aspect of this technology is that the flushing water volume is generated using only the contents of the tank (i.e. no external water source is required).

The system is comprised of two basic elements, a gate and a closed circuit hydraulic actuation system utilizing a float control mechanism. A low level wall is constructed across the short axis of the influent end of the tank (approximately 5 to 6.5 feet high). The wall is located on the influent end of the tank to guarantee filling the space behind the wall prior to filling the rest of the tank as shown in Figure 56. The system is activated by the instantaneous opening of a stainless steel gate mounted on the face of the wall. The release of the gate creates a "dam break" scenario which generates a high velocity flush wave (generally trying to maintain a velocity in excess of 6 fps). Normally the width of the flushing gate is approximately 0.7 of the effective flushing lane width. The volume retained behind the wall required for proper cleaning is a function of flushing length and floor slope. The "nominal" design volume can be adjusted by changing the height of a level standpipe on the backside of the wall. The hydraulic system can also be connected to a central control system (on or offsite) with auto or manual override.

These systems have tank floors that slope from the flush gate location to the collection trough at 1 – 3%. The flush gates require training walls on the tank bottom that are about 15" to 18" high, and run the full length of the tank to control the flow direction of the wave. All walls parallel to the path of flushing flow should be perpendicular to the tank bottom, with no fillets to ensure the lower wall edges are cleaned.

This technology is similar in concept to the tipping flushers. One main difference between the two technologies is that the tipping flushers are suspended above the tank floor and flush down sidewall, thereby taking advantage of the potential to kinetic energy conversion. In practice, this means that the flush gates need about 20% more flushing volume than tipping flushers for comparable tank floor slope and tank lengths. However, since the flush volume consists of stored wastewater, there is no additional cost associated with this volume. The experience with flush gate systems to date indicates that dedicated concurrent secondary cleaning operations, using water cannons or high pressure hoses, are not required. If the flush of the basin using tank contents does not remove all of the sediment, the basin can either be re-flushed (requiring an external water source for filling), or "mopped-up" using fire hoses. The largest length flushed with flushing gates is approximately 300 feet, while flushing lengths of 230-ft are fairly common.

The advantage of this system are similar to those associated with the tipping flushers, primarily the lack of a required secondary tank cleaning apparatus, minimal mechanical equipment, low O&M costs, and the ability to automate the flushing cycle, thereby not requiring manned operation during tank dewatering and flushing. An additional advantage in this scenario is that no water pumping is required, minimizing the capital costs for mechanical equipment. However, the disadvantage is that this method utilizes combined sewage separated from the tank. This water may be contaminated with solids and debris. Also, should a second flush cycle be required to fully clean the tank, water will need to be pumped into the flushing chamber, eliminating the benefit of using captured combined sewage. The flush gate technology minimizes the amount of weight and cost of stainless steel as the storage wall is concrete.

Figure 56 – Circular CSO Storage Tank with Flush Gates

A similar flushing system has been developed for circular tanks. Flush water is held in a storage reservoir. The filling occurs by means of a backwater gate near the ground or above the overspill crest of the container itself. At the end of a storm event and after the system has emptied, the retained flushing water is released by the instant opening of the flushing vessel as shown in Figure 57. This creates a high energy flushing wave which mixes and carries the sediment from the center of the tank radially to the receiving sump. An external water source is commonly used permitting repetitive flushing if desired. MWH has found that this technology is typically cost prohibitive beyond 175-foot diameter tanks.

Figure 57 – Example of Round Tank Flushing System

8.1.5.2. Secondary Flushing Systems

8.1.5.2.1. Water Cannons

Water cannons are typically used to washdown corners, areas around piping, and other hard to reach places. They are typically used in conjunction with spray header systems, both fixed and traveling bridge configurations. These systems require extensive piping and valve networks, booster pumps, a supply wet well and are manually operated. Water cannons typically have a maximum discharge rate of 400 gpm each at a working pressure of 40 to 70 psi and have a useful working spray radius of 70 to 100 feet. Cannons can rotate 360 degrees horizontally and have about 100 to 120 degrees range of motion in the vertical direction. Water cannons should be provided with shut-off/isolation valves and 1-inch nozzles. Spray down and cleanup times required per cannon vary depending on the facility, types of solids loading, and time of solids exposure. However, cleanup times of 5 to 15 minutes per water cannon are common.

8.1.5.2.2. High Pressure Hoses

Most CSO facilities have washdown high pressure hose systems on-site for miscellaneous cleanup operations. This system can often be utilized for secondary cleaning operations by providing hose gates where required. This system requires a piping and valve network, booster pumps, and a supply wet well. Hose gate connections are provided throughout the facility to accommodate cleaning operations and if this technology is used as a true secondary flushing system than it will require an open tank layout. Hose connections are typically 1–¼ inch and utilize similar water usage and pressure requirements to a water cannon system. Hoses, however, allow the flexibility to move the discharge point around because the hose is not fixed like a water cannon.

8.1.5.3. Recommended Flushing System

Flushing system recommendations are specific to the tank configuration (circular versus rectangular). For circular tank configurations, round tank flushing system are preferred. For rectangular tank configurations, flushing gates or tipping buckets are preferred.

8.1.6. CSO Storage Tanks Costs

Storage basins are capable of retaining overflows until system capacity is available to transport stored volume to treatment facilities. For this report, storage basins refer to off-line storage tanks. It is assumed that all storage tanks will require pumping facilities with the capacity to dewater the tank within 24 hours of pump activation.

Construction cost equations for typical covered concrete storage basins are shown in Table 14. 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 14 - 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
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 58 shows curves developed from the cost equations for storage basins in Table 14 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.

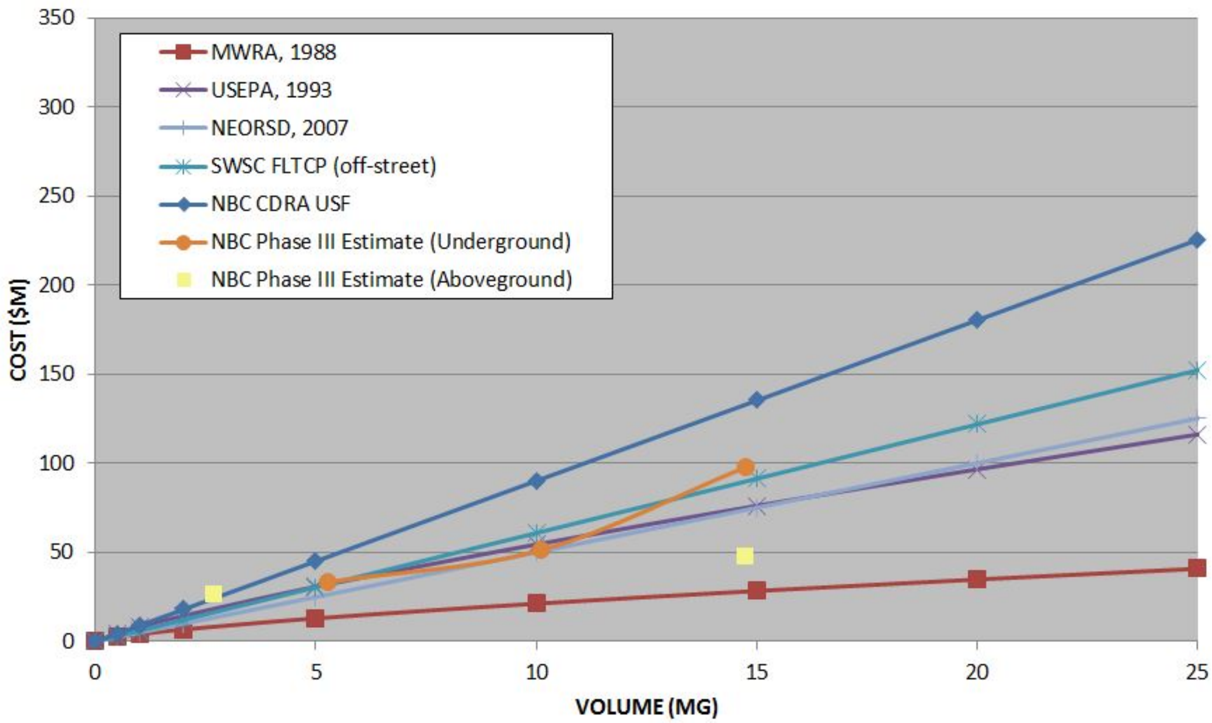

Figure 58 – Construction Cost Curves for Near-Surface Storage

The SWSC 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.

8.2. 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 included high-rate disinfection and some form of solids removal. For efficient performance it is necessary that these facilities are located adjacent to outfalls. They are similar to storage facilities in the underground tankage required, but also add a larger above ground footprint with a utilities building for 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 primary treatment of CSOs prior to discharge to the receiving water, a majority of pollutants in the CSO discharges are untreated which can be detrimental to the receiving water bodies. Satellite treatment facilities also require high initial capital investment and can be expensive to operate and maintain depending on the frequency of wet weather events that trigger facility operation.

Satellite treatment was described in detail in both the CDR and CDRA in the technology evaluations, 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 memorandum. Also, supplemental information based on NBC’s project experience in Phases I & II of the CSO Program, recent field investigations, as well as stakeholder input is included herein.

In addition to technical considerations discussed in the following sections, implementation of any CSO treatment and discharge facility would encounter regulatory requirements. These matters were discussed at the 4 September 2014 Stakeholder meeting, and representatives from both Rhode Island DEM and US EPA Region 1 offered comments. Treatment and discharge is fundamentally different from the other solutions as it removes only a certain percentage of the pollution and therefore results in discharge of residual contamination. Consequently, prior to endorsing a plan containing such a facility, DEM would likely require additional detailed data and evaluation, possibly including a full Use Attainability Analysis that would involve rigorous hydraulic and water quality modeling. Moreover, the representative from EPA viewed any system that did not include at least secondary treatment in addition to screening and disinfection would not comply with the Clean Water Act. Therefore, while screening and disinfection could be part of an interim CSO plan developed within the limits of affordability to improve water quality, ultimately additional abatement would be required to achieve water quality goals of the Clean Water Act.

8.2.1. Disinfection

Solids removal by way of screening, sedimentation, and filtration achieves a preliminary reduction in microorganisms and bacteria, but a further reduction of bacterial concentrations is required prior to discharge into receiving water bodies. This further reduction is considered to be disinfection and refers to the process of selective inactivation and/or destruction of pathogenic microorganisms that are typically found in CSO discharges. The intensity and variability of CSO events increase the operational difficulties of disinfection methods.

There are several alternatives for chemical 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.

8.2.1.1. Chlorination / Dechlorination

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 has 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.

The use of chlorine disinfection facilities was previously studied by NBC in the CDRA and rejected by the stakeholders group as an acceptable alternative due to the potential for residual chlorine and chlorine byproducts to harm the aquatic life in the receiving water bodies.

The concerns of the CDRA stakeholder group hold true for this Reevaluation, as stated in the CDRA, "during the evaluation process, the Stakeholders raised concerns regarding the potential toxicity impacts to aquatic life due to chlorine usage at SC/D facilities. The chlorine dosage necessary to achieve sufficient fecal coliform removal for SC/D facilities would be significantly higher than S/D facilities, to overcome the chlorine demand associated with a lower quality effluent. Although dechlorination facilities would be included, any deficiency in the reliability of these systems could potentially result in elevated TRC levels. Stakeholders also commented on the limited level of treatment that the SC/D technology provides. These concerns resulted in the elimination of system alternatives that included SC/D facilities."

8.2.1.2. Ultraviolet Disinfection

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: 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.

A UV disinfection system consists of: UV lamps; transparent quartz sleeves that surround the UV lamps; structure that supports the lamps and sleeves and holds them into place; and the power supply for the system. UV systems can be classified by whether they operate as open-channel flow systems or closed-vessel pressurized systems. Closed-vessel systems are more common for drinking water applications, while open-channel flow systems are commonly used for wastewater applications. Closed vessels can be used on wastewater systems that are pumped.

UV disinfection is fundamentally different than 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 15.

Table 15 – 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 has increasingly become 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.

8.2.1.2.1. UV Lamps

Mercury vapor lamps are the most common source of UV light for all systems as the mercury vapor emits UV light with optimum germicidal effects. The germicidal UV light wavelengths range from 200 to 300 nm, with the optimum germicidal effect occurring at 253.7 nm. Other types of lamps such as pulsed UV system and microwave are still in the evaluation and testing phase and thus not considered further for this report. Three categories of UV mercury lamp technology are used in disinfection:

- Low-pressure, low intensity (LPLI) lamps with mercury vapor at $2x10^{-5}$ to $2x10^{-3}$ psi
- Low-pressure, high-output (LPHO) lamps with mercury vapor at $2x10^{-5}$ to $2x10^{-3}$ psi
- Medium-pressure (MP) lamps with mercury vapor at 2 to 200 psi

The two mercury vapor pressure ranges give the highest conversion of electrical energy to UV light. LPLI systems are not used for most wastewater disinfection applications as they are not as robust as the LPLH and also require considerably more lamps. LPHO lamps are more efficient in converting electricity to germicidal UV light, but the total UV output is much weaker than from a medium-pressure lamp. The LPHO lamps have special design features to maintain mercury pressure at an optimum level under high discharge currents. A new generation of MP lamps offers more concentrated outputs around specific wavelengths (e.g. "multiwave" lamps). MP lamp systems and most LPHO lamp systems are equipped with automatic cleaning systmes that eliminate the need to disrupt the process and remove lamps for cleaning of the reactor; representing a significant reduction in labor costs.

Table 16 - UV Lamp Comparison

	LPHO	MP
Mercury Vapor Pressure, psi	$2x10^{-5}$ to $2x10^{-3}$	2 to 200
Operating Temperature, °C	60 to 250	600 to 900
UV Light Spectrum, nm	Monochromatic (near 254)	Polychromatic (200-450)
Electrical to Germicidal UV Conversion Efficiency, %	30 to 40	10 to 20
Power Consumption, W	170 to 1,600	2,000 to 20,000
Relative Number of Lamps Required for a Given Dose	High	Low
Rated Lifetime, hr	8,000 to 12,000	3,000 to 8,000

8.2.1.2.2. Water Quality Impacts on UV

CSO water characteristics are highly variable, and often will have poor water quality with low UVT and high solids content. The stormwater portion of combined flows can vary from 200 mg/L of TSS and UVT below 20% during the first flush to 90 mg/L of TSS and UVT approaching 65% by the end of the storm. The sanitary component of the combined flow increases the variability of the CSO volume characteristics. The worse the quality of the water is, the larger 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.

In order to determine if UV disinfection is feasible for a particular CSO application, it is required that water quality testing that includes UVT monitoring and collimated beam testing be conducted at each outfall. This testing will determine if CSO flows have characteristics that enable UV disinfection, and if the discharge from a UV system would achieve disinfection requirements, typically log reduction (LRV) targets or target concentrations of bacteria.

8.2.1.2.3. Primary Treatment

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. These types of facilities use microsand and chemical coagulant, such as aluminum or ferric chloride, to enhance flocculation and act as a ballast to aid rapid settlement. The use of a ferric based coagulant should be avoided when combined with UV disinfection due to the adverse impact iron concentration can have on UV transmittance. Any method of primary settlement will result in solids handling and odor control facilities.

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, and 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.

8.2.1.3. Peracetic Acid

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.

8.2.2. Treatment and Discharge Costs

Construction cost equations for typical disinfection facilities are shown in Table 17 below. 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 17 – 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

Source Document	Date of Publication	Cost Equation	Figure ID
[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 NBC 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 1998 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
  - hypochlorite, dechlorination equipment.

Figure 59 shows curves developed from the cost equations for disinfection facilities in Table 17 above.

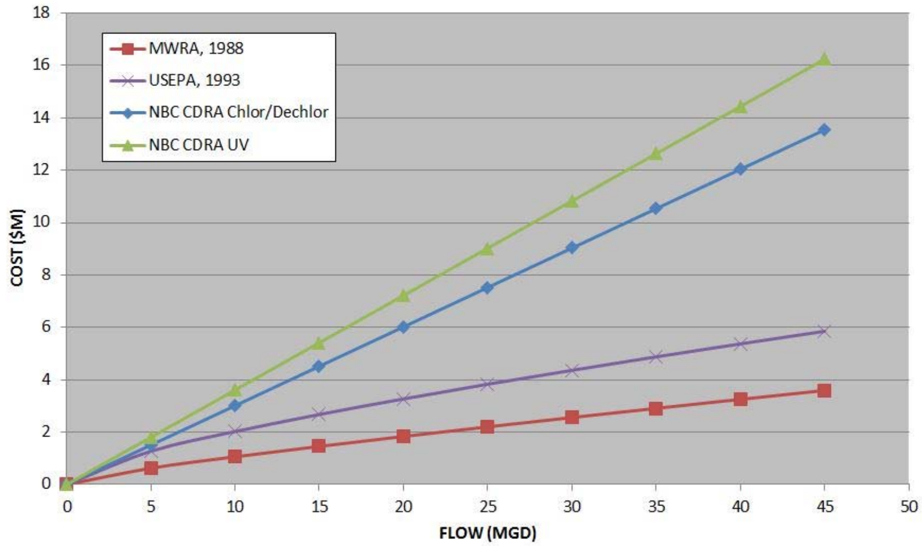

Figure 59 – Construction Cost Curves for Screening and Disinfection Facilities

The NBC 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 previous 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 costs stated in the NBC CDRA stated operation and maintenance 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.

8.2.3. Siting

During the previous Stakeholder process for the CDR and CDRA, disinfection and discharge was eliminated from consideration primarily owing to concerns regarding the introduction of toxic residuals from the process into the area's waters and the transportation and storage of the treatment chemicals in the neighborhoods adjacent to the outfalls. Those same concerns were echoed in the current Stakeholder process. Moreover, the Stakeholders noted that the sites identified for localized alternatives were immediately adjacent to public open spaces, including parks and playing fields that would be incompatible with the presence of treatment facilities.

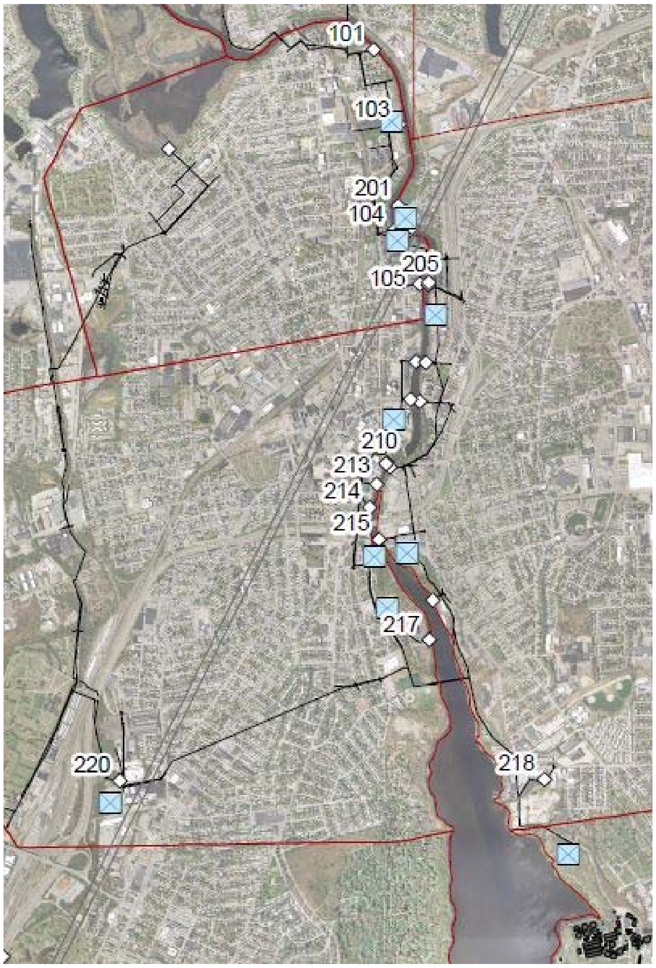

Figure 60 - Localized Combined Flow Handling

8.3. 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.

8.4. Localized Alternatives

Localized alternatives, either tanks or treatment, must be located at or near their associated CSO. In the urbanized Phase III areas, the lack of suitable sites is a challenge. However, in locations where the baseline recommendations present known challenges, such as sewer separation or the need for interceptors for connection to the Pawtucket Tunnel, localize alternatives may provide a more optimized solution, namely:

- A location near 039 and 056 as an alternative to sewer separation;
- A location near 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.

Sustainable solutions are often defined as the combination of "grey" and "green" infrastructure. The EPA and others have highlighted the fact that "green" infrastructure rarely constitutes a total CSO solution and that green stormwater measures must be combined with grey infrastructure to develop an effective long term control strategy. Consequently, for an alternative to the Pawtucket Tunnel to be considered, a scenario in which green stormwater management combines with localized grey infrastructure must be developed. Therefore, localized solutions for the following locations must be evaluated:

- A location near 205 to handle the large CSO volume from outfalls 201 through 205;
- A location near 210 to accommodate outfalls 210, 211 and 212;
- A location near 213 and 214 to accommodate those outfalls;
- A location near 217, and
- A location near 218 to handle the large CSO volume from that outfall.

The primary localized alternative for each of those locations is considered to be a CSO storage tank. Treatment and discharge options at those locations suffer the concerns noted above and would require water quality testing and system piloting to confirm technical feasibility. However, that additional preliminary design effort, while out the scope and time constraints for this Phase III Reevaluation effort, could realize cost savings. Therefore, the treatment and discharge option will not be entirely eliminated from consideration. Rather, those options will be carried as system optimization possibilities for future evaluation.

8.4.1. Outfalls 039/056

In addition to the West River Interceptor discussed in section 6.4.1, 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. However, the recently reconstructed school incorporated underground stormwater management systems of its own, and thus 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.

8.4.2. Outfall 220

A local facility at the remote location of Outfall 220 could be an alternative to the proposed Pawtucket Avenue Interceptor or the Stub Tunnel. The area in Pawtucket surrounding Outfall 220 is predominately large commercial properties with a few large parking lots as well as Morley Field, shown in Figure 61. Outfall 220 is located in southwestern Pawtucket east of Interstate 95 and the Moshassuck River, west of the intersection of Rt 122/Main St and Rt 1/Pawtucket Ave and north of Rt 126/Smithfield Ave.

Figure 61 - Morley Field

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 62. The facility was evaluated to be located at the Morley Field ballpark owned by the City of Pawtucket, located 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.

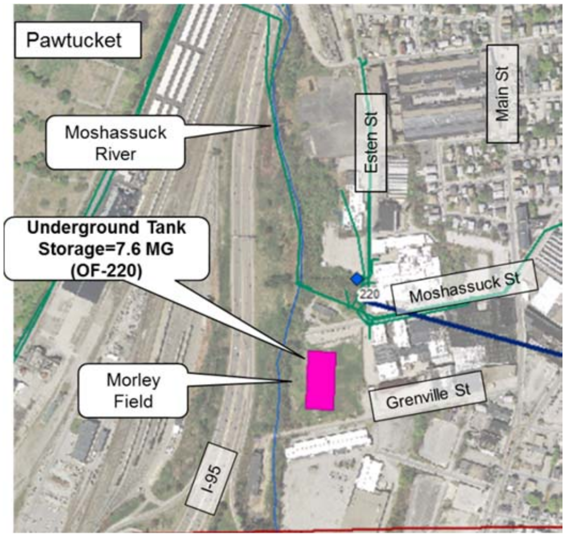

Figure 62 – CDR NSS for CSO 220

This alternative was discussed during the April 2014 Stakeholders Group meeting, and it was concluded that with the proper protections, a subsurface tank at Morley Field would likely be acceptable to the community. The group concluded that above-ground tanks in this area would not be well received. The group engaged in some discussion regarding the use of any one of the parking lots along Esten Street for a NSS tank; however, all of those lots support some sort of use ranging from parking to farmers markets, and it was concluded that construction-phase mitigation would not appease the land owners.

The previously evaluated facility along with early stakeholder feedback was taken into consideration prior to developing the following NSS alternatives.

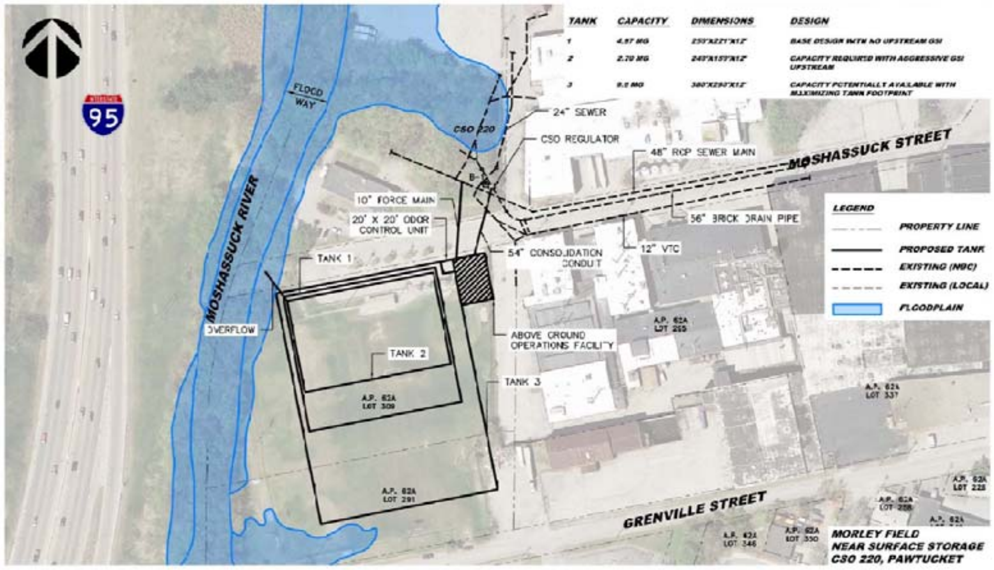

Figure 63 – NSS for CSO 220

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 63. "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.

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. Lastly, 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. Lastly, 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 disinfection facility was considered at the Morley Field site to accommodate the 3-month storm overflow volume for CSO 220. The facility would a consolidation conduit from CSO 220 as well as equipment and tankage for screening and UV disinfection. Due to site constraints and operational limitations, primary treatment would not be feasible at the Morley Field site. Water quality testing and pilot testing would be required for evaluation and design of a disinfection facility. While screening and disinfection alone would improve the water quality of the design overflow volume it is unlikely the facility would meet long-term goals for water quality improvements, as discussed previously in section 8.2.

8.4.3. Outfalls 101/103

A local facility in this area of Central Falls would be intended to control discharges from both outfalls 101 and 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 64. The facility was evaluated 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 65. A consolidation conduit would be needed to bring flow from CSO 101 to the facility, and would run parallel to the existing NBC interceptor.

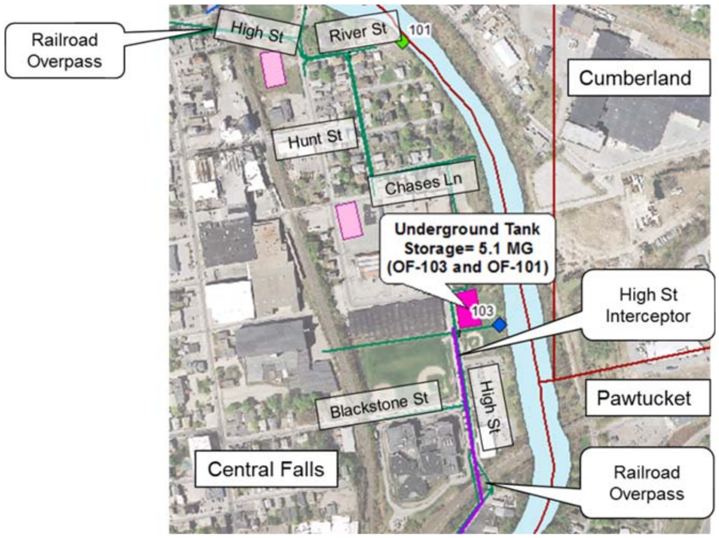

Figure 64 – CDR NSS for CSOs 101/103 (BPSA-6)

Figure 65 - Pierce Park (Central Falls)

This alternative was discussed at the April 2014 Stakeholders Group meeting. The stakeholders group commented that any construction plans along the Blackstone River in Central Falls should coordinate with the City's waterfront development plans. The group agreed that the Pierce Park site would be compatible with a subsurface storage tank; however, given the residential and recreational access to the site, a treatment and discharge facility would not be considered appropriate.

The previously evaluated facility along with early stakeholder feedback was taken into consideration prior to developing the following NSS alternatives.

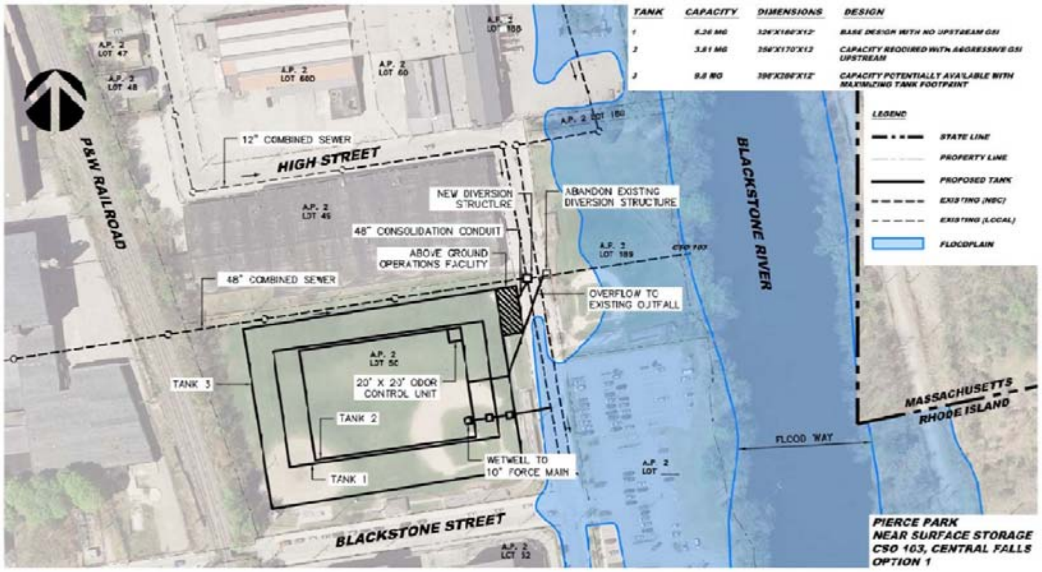

Figure 66 – NSS for CSO 101/103 Option 1

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 66, Option 1, located on A.P. 2 Lot 50 in Central Falls consists of three potential underground tank configurations. “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. Lastly, 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 67, 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.

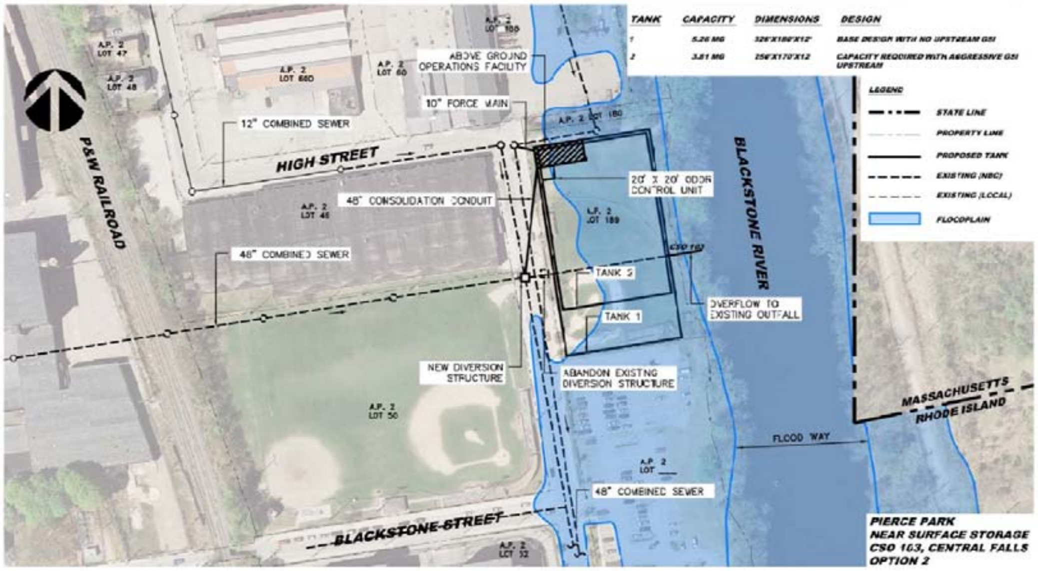

Figure 67 - NSS for CSO 101/103 Option 2

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. As with Option 1, this would create a significant social burden on the community, which would need to be strongly considered and mitigated prior to moving this option beyond the conceptual design phase.

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.

8.4.4. 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.

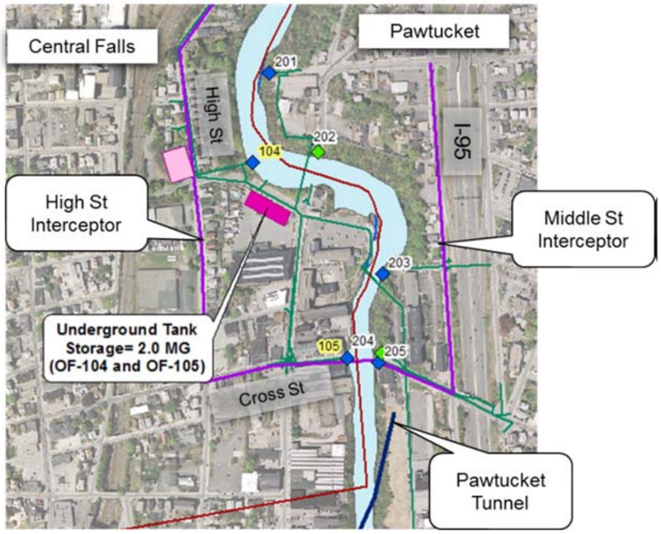

Figure 68 – CDR NSS for CSOs 104/105 (BPSA-8)

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 68. 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 looked at for this location due to the residential properties nearby and concern for odor issues, chemical storage, and access requirements, the small overflow volume, and the depth of construction required.

This alternative was discussed at the April 2014 Stakeholders Group meeting; however, no specific comments were offered by stakeholders either promoting or discouraging the evaluation of a NSS tank at this location if one for outfalls 101 and 103 is feasible.

The previously evaluated facility along with early stakeholder feedback was taken into consideration prior to developing the following NSS alternatives.

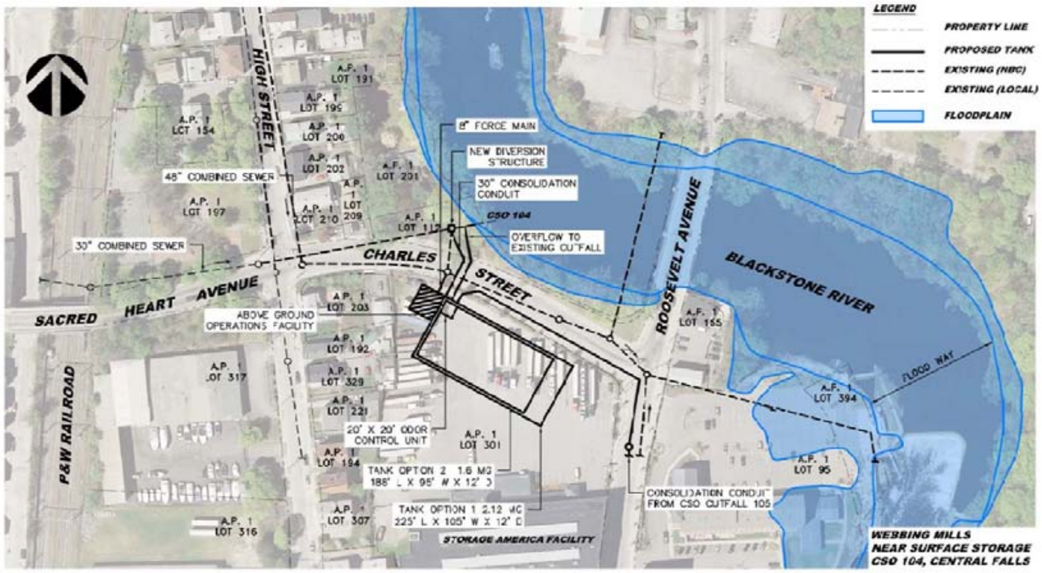

Figure 69 - NSS for CSOs 104/105

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 69. “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.

8.4.5. Outfalls 201/202/203/204/205

Local flow control in this area of Pawtucket would be intended to control discharges from one of the two largest overflows 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 201/202/203/204/205 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 70. 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 71, the Central Street location has recently been renovated and a ribbon cutting ceremony was held in 2013 for a large commercial user.

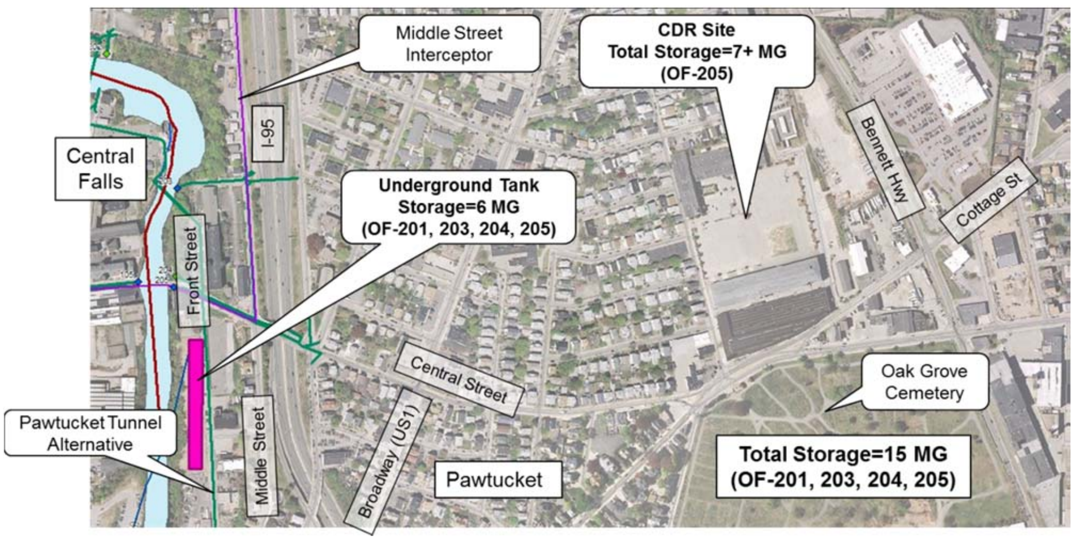

Figure 70 – CDR NSS for CSOs 201/203/204/205 (BPSA-2 & 3)

Figure 71 - 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.

The CDR alternative of two NSS facilities in this catchment was discussed at the April 2014 Stakeholders Group meeting. The stakeholders group commented that any construction plans along the Blackstone River in Pawtucket should coordinate with the City's waterfront development plans. Also, concern was raised regarding suitable upstream sites for potential storage within the catchment for outfall 205 and the collective response from the stakeholder group was there is a lack of available land along Central and Cottage streets. The group also noted that the Front Street site is the only open space in the area, therefore siting a treatment facility at this location that would require buildings and other surface-based facilities would be unfavorable. To further that conclusion, a subsurface storage tank would only be considered if the surface could be restored to a vegetated public open space.

The previously evaluated facility along with early stakeholder feedback was taken into consideration prior to developing the following NSS alternatives.

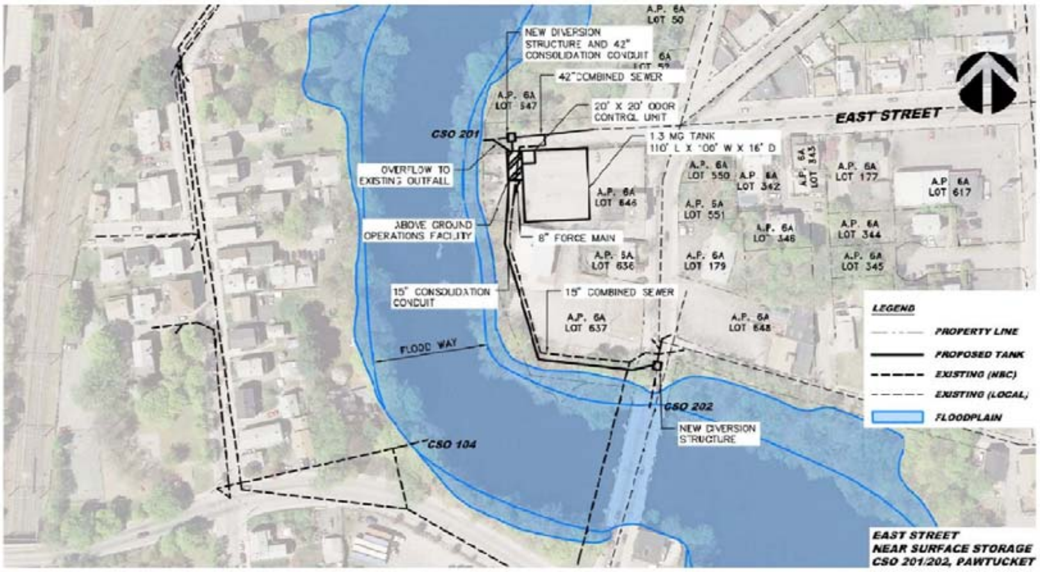

Figure 72 - NSS for CSOs 201/202

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 72. 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 tank 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 located, increasing the depth of gravity sewer installation and resulting in a deeper tank excavation.

Figure 73 - NSS for 203/204/205

The NSS alternative for CSO 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 73. 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 6.3.1, to convey flow from CSOs 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 6.3.1, regulator modifications at CSOs 202 and 204, and as well as equipment and tankage for screening and UV disinfection. Due to site constraints and operational limitations, primary treatment would not be feasible at the Front Street site.

Water quality testing and pilot testing would be required for evaluation and design of a disinfection facility. While screening and disinfection alone would improve the water quality of the design overflow volume it is unlikely the facility would meet long-term goals for water quality improvements, as discussed previously in section 8.2.

8.4.6. Outfalls 210/211

Local flow control 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.

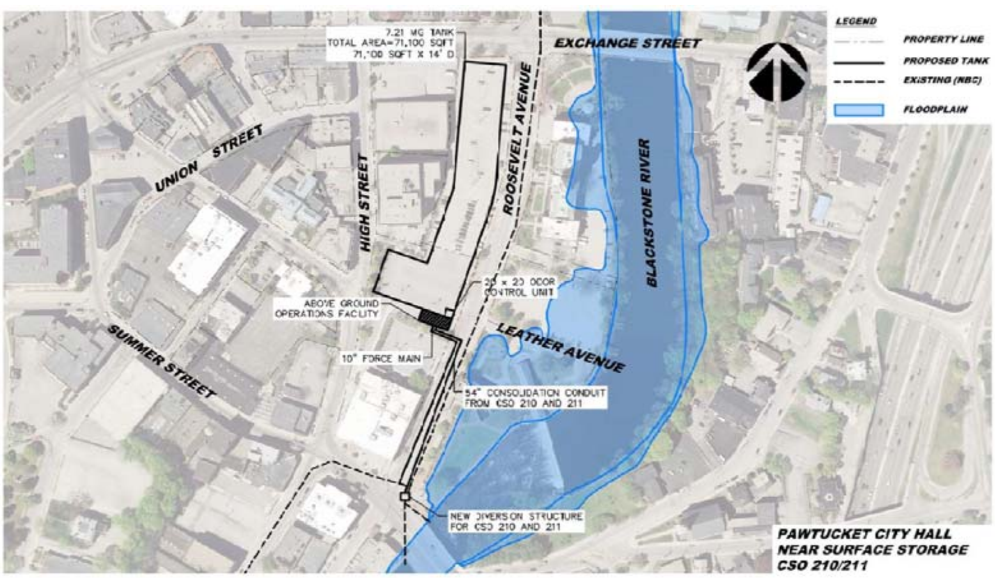

Figure 74 - NSS for CSOs 210/211

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 74. 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 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.

8.4.7. 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 75 - 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 75. 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.

8.4.8. 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.

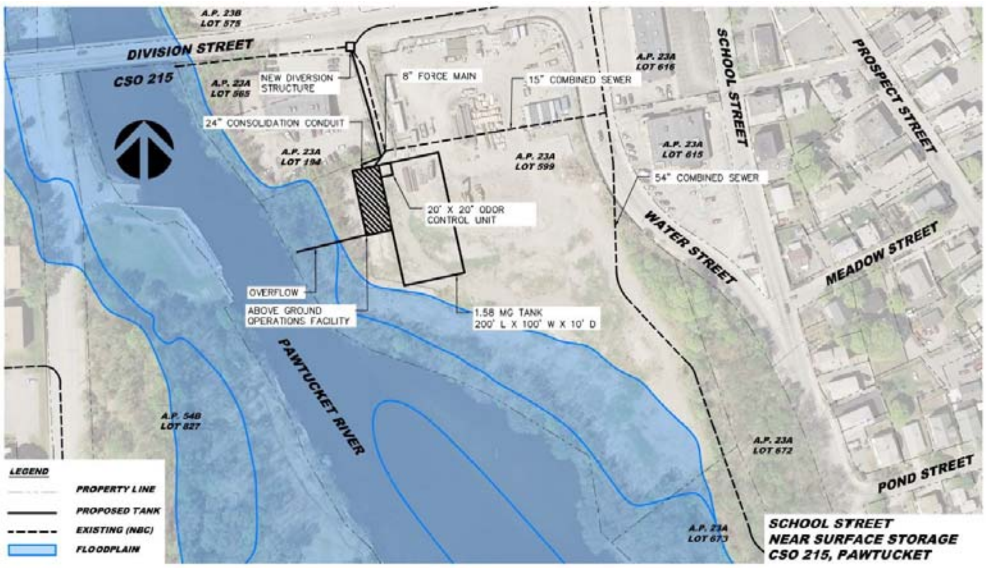

Figure 76 - NSS for CSO 215

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 76. 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.

8.4.9. 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.

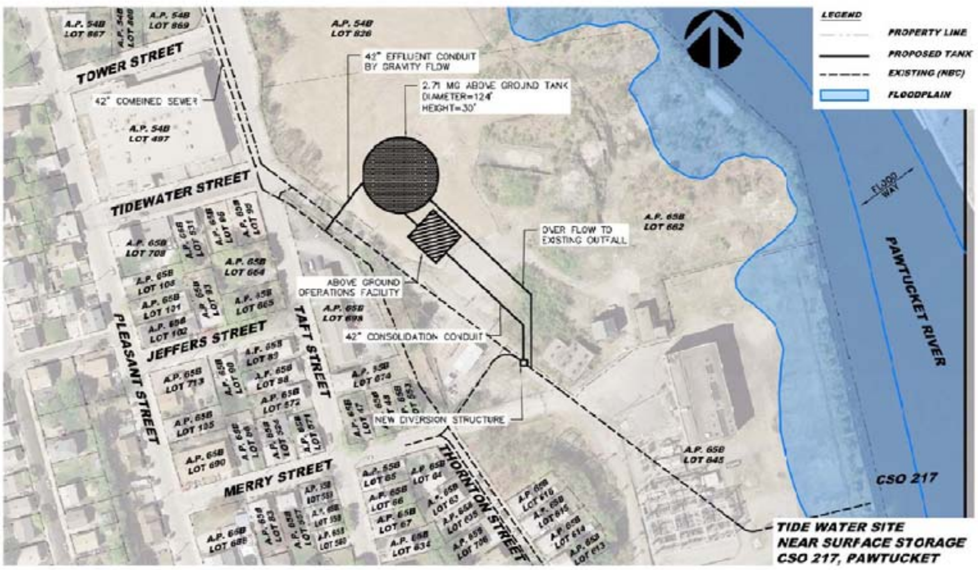

Figure 77 - NSS for CSO 217

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 77. 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.

8.4.10. Outfall 218

CSO Outfall 218 is located on the border of Pawtucket and East Providence at the Seekonk River. 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 pockets of residential neighborhoods. The Boys and Girls Club of Pawtucket has recreational facilities on the Blackstone River at their Elson Campus. Dunnell Park is home to several recreational ballfields. Mount St Mary's Cemetery is to the southeast, and the Bucklin Point WWTF is to the south.

Local flow control in this area of Pawtucket would be intended to control discharges from the other of the two largest overflows in the Bucklin Point Service Area, Outfall 218. Furthermore, 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.

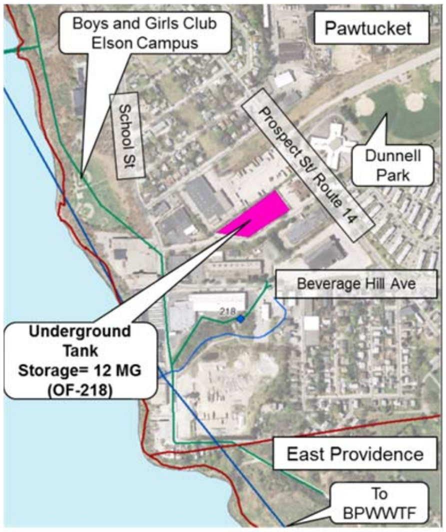

Figure 78 – CDR NSS for CSO 218

Figure 79 – NSS Below-Ground for CSO 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 79, or possibly multiple aboveground tanks shown in

Figure 80. 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.

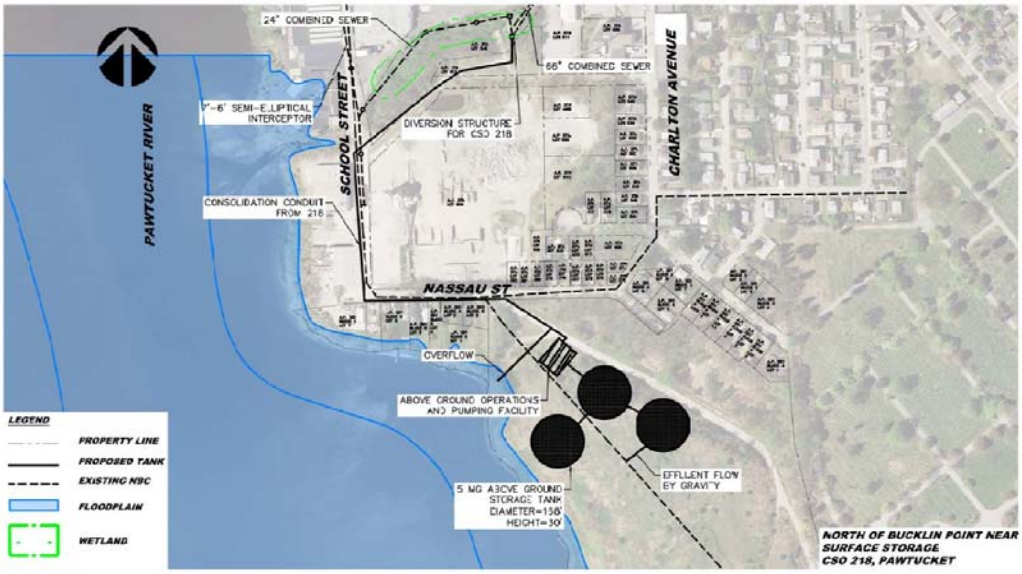

Figure 80 – NSS Above-Ground for CSO 218

Site constraints for this outfall include the significant length of pipe necessary to connect the existing system to the tank and the site's status as a closed landfill. As a former sludge landfill, excavation at the site will disturb potentially contaminated soil and will generate spoils that require offsite disposal at a potentially high cost. The slope of the former landfill will also result in a large amount of earthwork necessary to construct the proposed tank(s).

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.

9. Alternatives Development and Technical Feasibility Screening Conclusion

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 18.

Table 18 – 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	✓	✓	✓			✓			✓			✓	
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214	✓	✓	✓						✓			✓	
215	✓	✓	✓			✓		✓	✓			✓	
216	✓	✓	✓			✓		✓	✓			✓	
217	✓	✓	✓					✓	✓			✓	
218	✓	✓	✓					✓	✓			✓	
220	✓	✓	✓					✓	✓		✓	✓	

NBC CSO Control Facilities Phase III Reevaluation

Technical Memorandum – Green Stormwater Infrastructure Feasible Alternatives Analysis

Contents

Figures

Tables

1. Introduction

This technical memorandum (TM) is one of two that describe the development and definition of alternative components to the Phase III plan. This memo focuses upon "green alternatives" and summarizes work associated with *Subtask 3B – Evaluation of Feasibility of GSI for the Entire Phase III Area* and *Subtask 3C – Feasibility of GSI alternatives for Specific Overflows*. A subsequent memo will focus upon "green alternatives and will summarize work associated with *Subtask 3A – Establish Baseline and Grey Infrastructure Variant Alternatives*, *Subtask 3D – Near Surface Storage Alternatives*, and *Subtask 3E – Deep Rock Tunnels Alternatives*.

This TM summarizes the technical components of the Green Stormwater Infrastructure (GSI) control alternatives which were considered for incorporation into the reevaluation of NBC's CSO Control Facilities Phase III recommended plan.

Figure 1 depicts the geographical extent of the GSI evaluation; consideration is limited to areas within Central Falls, Pawtucket, and two specific locations in Providence. The legend shows the locations of the Phase III CSOs and the Conceptual Design Report Amendment (1998) (CDRA) recommended solutions.

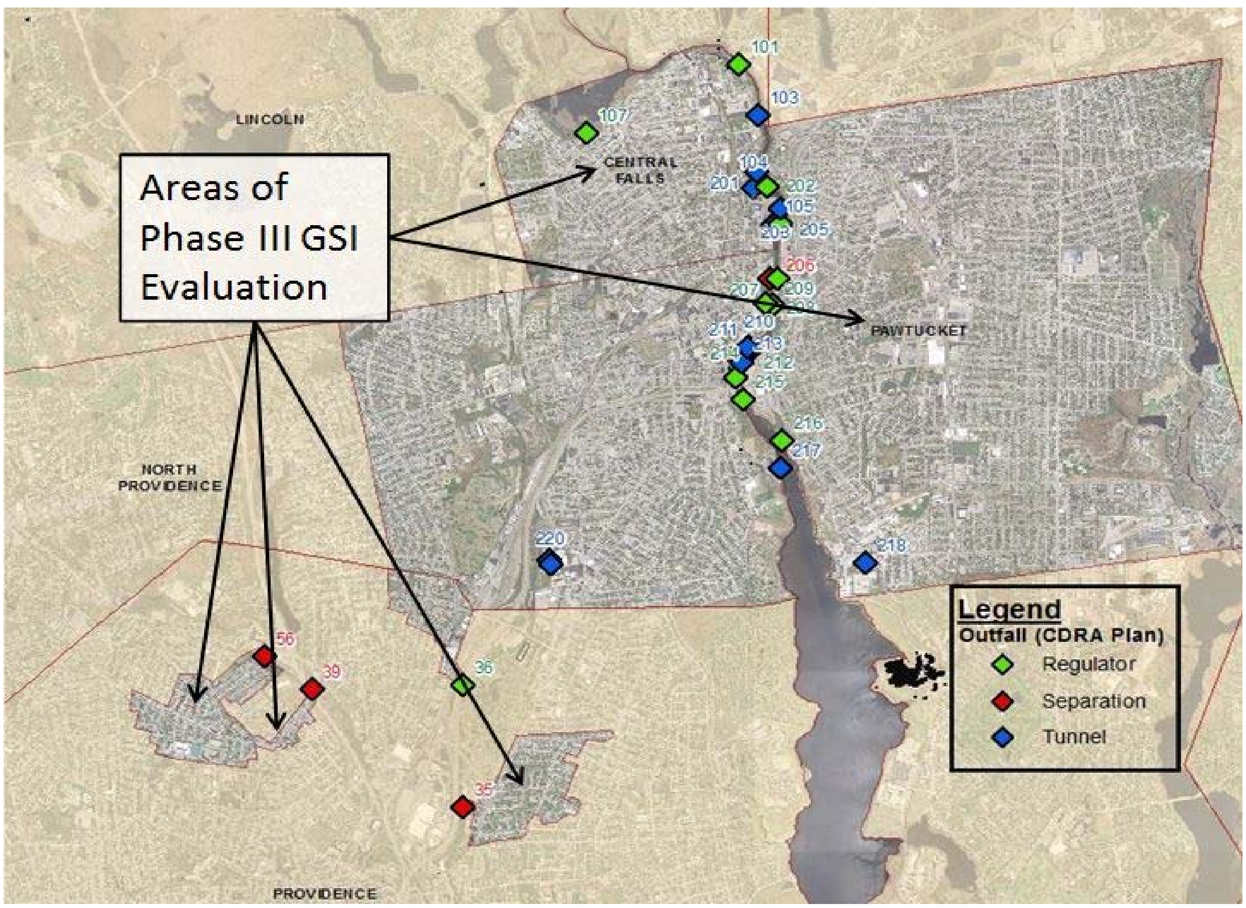


Figure 1 Sewersheds to Phase III CSOs

One of the biggest changes since the last planning effort 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 stormwater before it enters the combined sewer system.

In highly urbanized environments like the NBC's service areas, the construction of separate storm and sanitary systems to replace combined sewers is extremely expensive. However, it is often overlooked that any measure that keeps stormwater out of the combined system amounts to de facto sewer separation.

GSI, while often difficult to implement in urban environments, can prove to be a cost-effective alternative to traditional hard-pipe sewer separation. Recent studies in Washington DC, Philadelphia and Seattle amongst others, have found the capital cost of implementing GSI to be similar to that of grey infrastructure meaning that GSI is steadily becoming a viable and approach to wet weather flow management for CSO abatement projects. In the case of NBC the tight urban land use of the member communities coupled with the magnitude of the CSO overflows suggest that there are very few watersheds where GSI will be able to provide the entire solution, however, it could be effective when augmented to more traditional approaches. The Phase III re-evaluation must consider the potential for GSI to ensure that the most appropriate and applicable solutions are identified; this will be with a view to realizing alternative environmental and social benefits as well as economic viability.

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 reduce or eliminate water pollution by:

- reducing impervious cover,
- increasing on-site infiltration,
- eliminating sources of contaminants, and
- removing pollutants from stormwater runoff.

Previously, the approach to developing alternatives for a LTCP was to start at the end of the pipe. By doing so there was an immediate sense for the scale of the CSO control required. The relationship between CSO volume and the size of the required control facility whether it be a tunnel or a tank or a disinfection system was directly related.

With GSI, the approach is the reverse. The opportunities to implement GSI need to be established and then these can be assessed for their suitability and capability to provide stormwater control and reduce CSO overflows.

In developing an approach to GSI suitability for the Phase III CSOs, MWH adopted a Source-Pathway-Receptor (S-P-R) scale. Matching GSI techniques to land availability and to stormwater inflow reduction required a coherent and measured approach. S-P-R offers the ability to implement a wide range of location specific techniques but coordinate their overall impact to maximize the potential for CSO reduction. The considerations of an S-P-R approach are summarized in Figure 2 and the components of the approach are summarized thereafter.

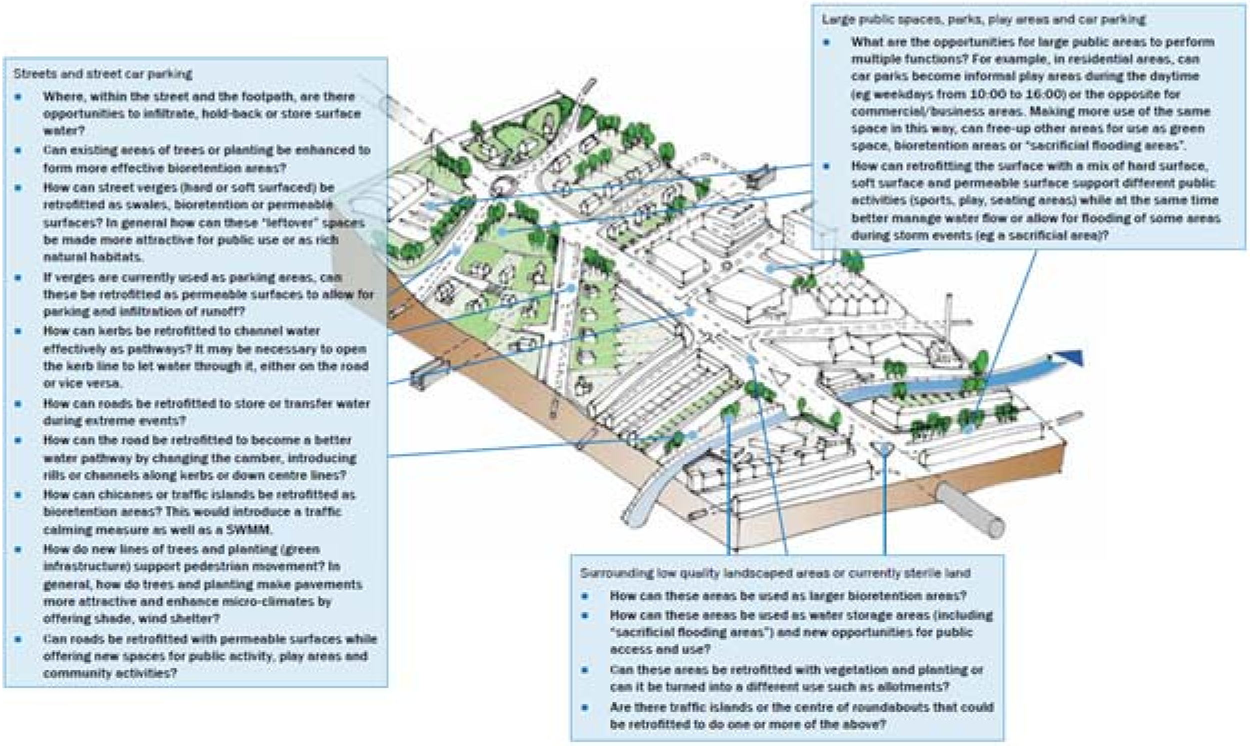


Figure 2 Public Way Source and Surface Pathway Design Considerations

1.1. Source Control Measures

Source Control measures are identified to reduce peak storm water flows in the system. Generally at the land parcel level these techniques are usually small in size and large in number. Managing localized flows source control techniques are usually detention and / or infiltration GSI approaches. Source control elements are normally chosen on the ability to fit into the existing landscape and attenuate flows and are closely associated with GSI on private properties, although not exclusively; these typically included but are not limited to:

- Rain gardens
- Tree box filter
- Dry wells
- Ribbon driveways
- Porous paving

1.2. Pathway Measures

Pathway opportunities are inherently the management of storm water during conveyance. Traditional approaches to pipe systems center on collection of runoff and transportation elsewhere as rapidly as possible. The GSI approaches follow similar ideals although not the rapid transportation. The ability to manage flow rates to detain and release and / or infiltrate into the ground makes pathway GSI a fundamental part of any sustainable system.

Overall pathway strategic measures will be the primary controlling factor to reduce the CSO activation. Synonymous with highway drainage typical examples of pathway measures include:

- Swales and under-drained swales
- Infiltration trenches and chambers
- Filter strips
- Detention basin / systems

1.3. Receptor Measures

Reducing peak flows during wet weather events are invariably managed throughout the upper reaches of the system but the final management level of the hierarchy are receptors.

Following the hierarchy, receptors are large in size and few in number, fulfilling the role of retention or longer term detention, infiltration is often possible but is not the primary function of receptor measures. Often capable of realizing wider environmental benefits through amenity and biodiversity usage, receptor measures require large land take and present potential health and safety consideration in the urban environment. The most recognizable measures, typical examples of receptor measures include:

- Wetlands
- Ponds
- Retention structures

GSI approaches can employ individual practices focusing on one of the categories above, but are successful when implemented in a combined approach as well. Infiltration is a key component to the success of GSI as it provides an overall stormwater reduction by infiltration as well as removal of pollutants. Detention and retention solutions will reduce the peak design discharge of a storm event, or are designed to reuse stormwater for other purposes. A well designed GSI will provide both a reduction in peak flows and improved water quality stormwater management solution. Below is a summary of GSI techniques and values.

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

2. Regulatory Framework

The Environmental Protection Agency (EPA) highlights that "Given the multiple environmental, economic and social benefits associated with green infrastructure, EPA has supported and encouraged the implementation of green infrastructure for stormwater runoff and sewer overflow management to the maximum extent possible. EPA enforcement in particular has taken a leadership role in the incorporation of green infrastructure remedies in municipal Clean Water Act (CWA) settlements."

- Illinois Consent Decree 2014
  - Reduce flooding, focus on vacant parcels, improve socio-economic conditions
- Chattanooga, Tennessee Consent Decree 2013
  - Produce land use policy, public participation process, implementation schedule
- Kansas City, Kansas Consent Decree 2013
  - Pilot GSI projects that may replace or supplement grey infrastructure
- Seattle, Washington Consent Decree 2013
  - Provides opportunity for GSI to replace grey infrastructure
- Washington DC Consent Decree 2005, Partnership Agreement 2012
  - "Green Design Challenge" to private sector
- Boston, Massachusetts Consent Decree 2012
  - GSI demonstration projects, includes CSO and other pollutant controls

Information on examples is provided at:

http://water.epa.gov/infrastructure/greeninfrastructure/enforcement.cfm

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."

Therefore, while this section defines GSI alternatives, implementing those GSI solutions in the context of the Phase III program may require a phased approach that measures the success of those GSI components in reducing CSO volumes and adapts the recommended plan as necessary to achieve the goals of the NBC Phase III CSO program.

3. Overview of GSI Alternatives Development

3.1. 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 3**Error! Reference source not found.**.

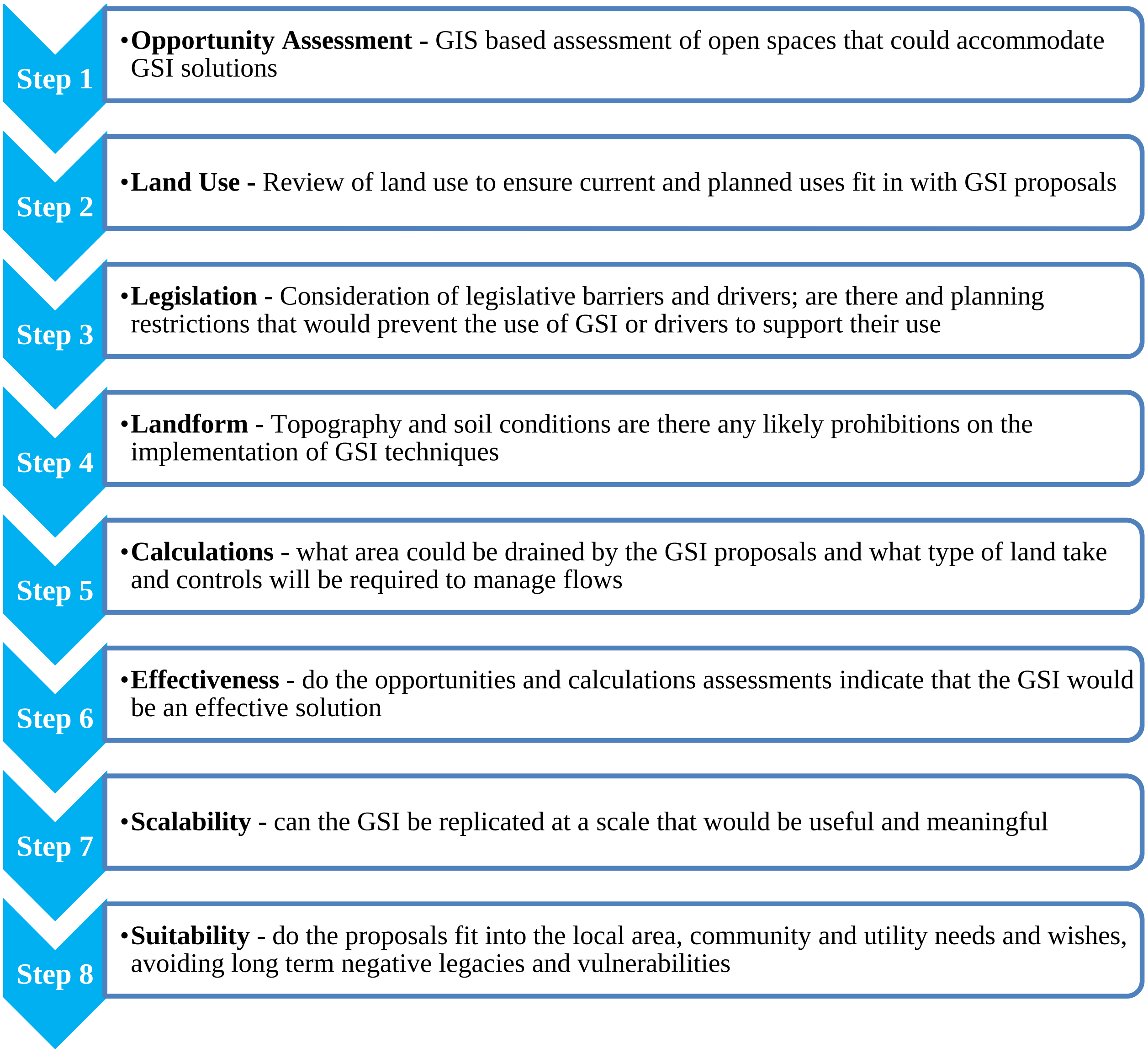


Figure 3 GSI sample areas for Phase III CSOs

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.

3.1.1. 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 1.

Table 1 - 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:

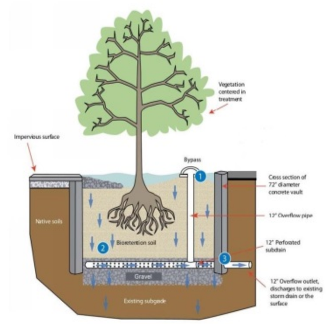
- Street name
- Subcatchment
- GSI type
- size (in acres);
- current land use
- ownership (public / private).

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 2, Table 3 and Table 4.

Table 2 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 3 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 Retention Technologies

GSI	Description	Example	Costs and Maintenanc e ***
Undergroun d 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 5 summarizes the findings of the site surveys for the sample areas and more specifically the CSO catchments identified in Table 1. The site IDs are included as a unique reference for each visit and link to the location plans in Appendix B.

Table 5 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 6.

Table 6 Application of GSI Techniques

<table>
<tr><th>Location</th><th colspan="2">Description</th></tr>
<tr><td>Grand Broadway at Stansbury Street
CSOs 039 & 056</td><td colspan="2">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.</td></tr>
<tr><th colspan="2">Existing</th><th>Proposed GSI</th></tr>
<tr><td colspan="2">
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.</td><td>
Image showing pervious paving (left) in combination with rain garden bumpouts on the right.</td></tr>
</table>

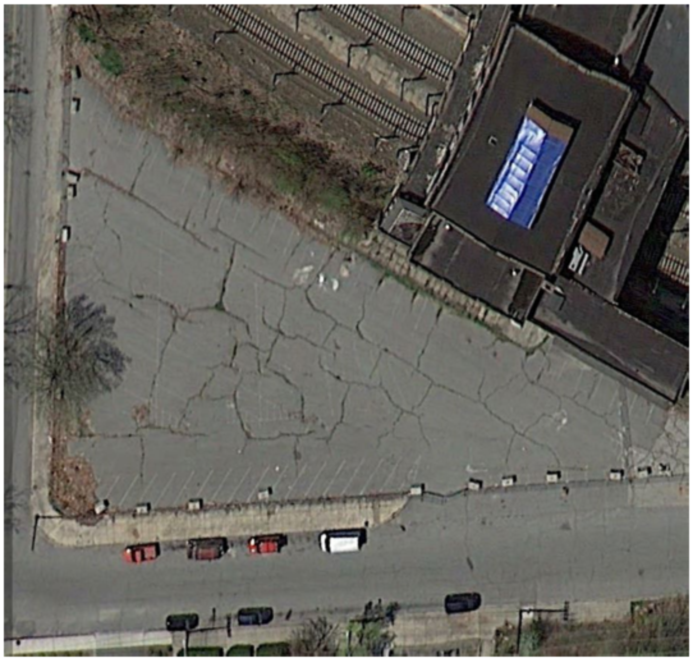
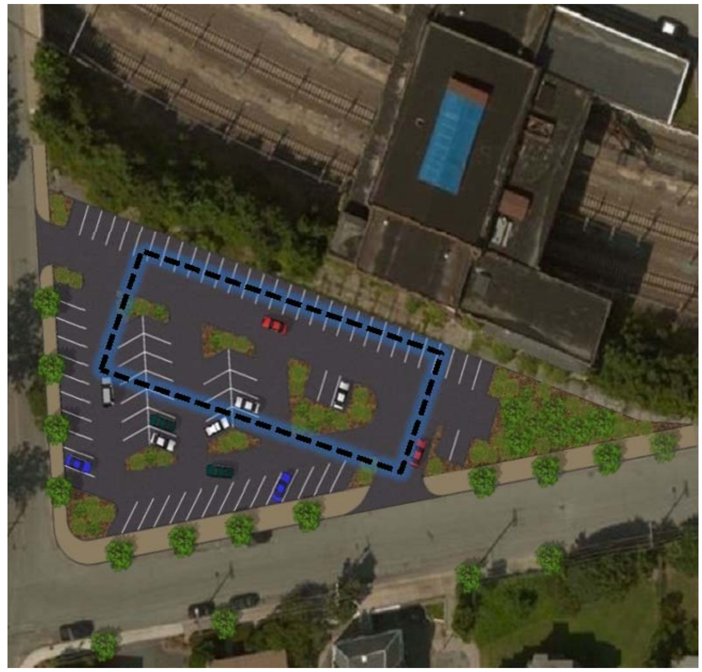
<table>
<tr><th>Location</th><th colspan="2">Description</th></tr>
<tr><td>Vanderwater Street
CSOs 039 & 056</td><td colspan="2">Vanderwater Street was also identified as an opportunity to provide an infiltration GSI approach in this watershed. Vanderwater Street is a one way street with a smaller width (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.</td></tr>
<tr><th colspan="2">Existing</th><th>Proposed GSI</th></tr>
<tr><td colspan="2">
This location offers an opportunity for infiltration although the relatively narrow street cofines the appropreate GSI to a smaller footprint.</td><td>
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.</td></tr>
</table>

Location	Description
North Main Street CSO 035	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).

Existing	Proposed GSI	
 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.	 Stormwater Raingarden Bumpout installed above would offer the necessary GSI appeal and could support some levels of infiltration.	 Stormwater detention installed below attenuate addition flow to ‘slow’ runoff entering the combined sewers.

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.

3.1.2. 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 primary focus of this step was to match strategies to the variety of land use types that are synonymous with the urban environment. Figure 4 shows some typical GSI solutions for an urban catchment.

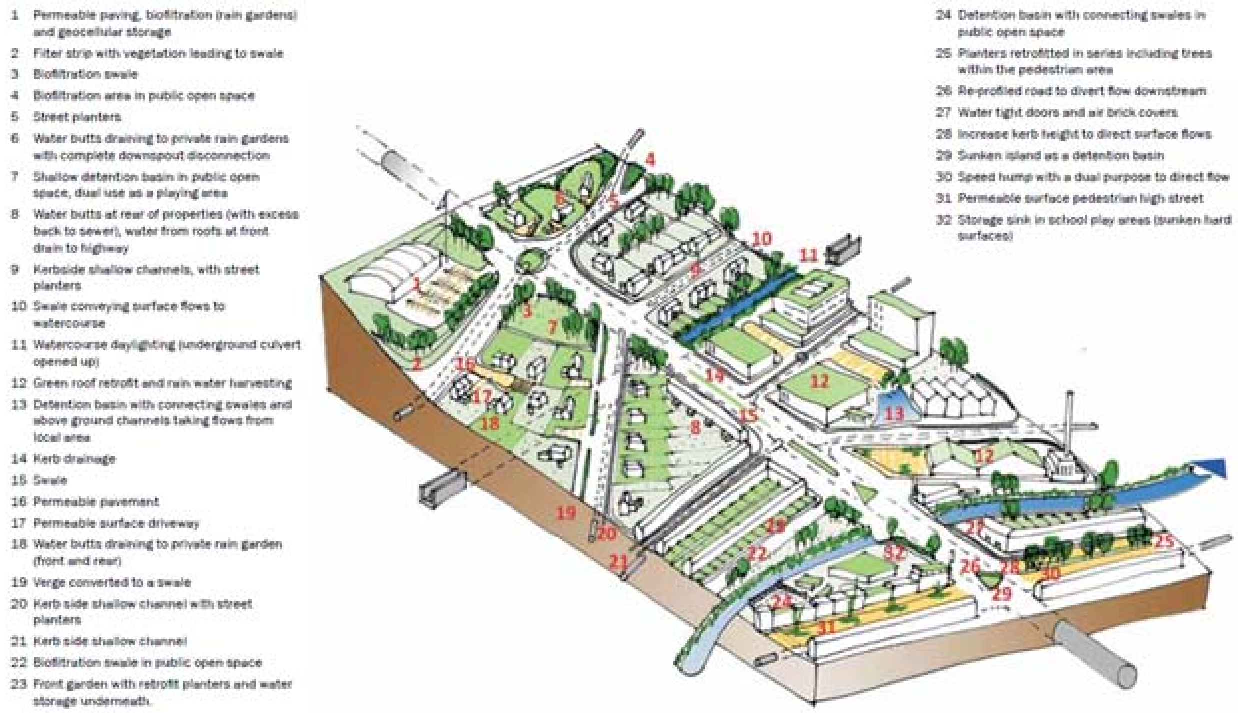


Figure 4 Matching Strategies to Land Use Types

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.

3.1.2.1. NBC Stormwater Mitigation Program

During Step 1 the existing information pertaining to NBC's Stormwater Mitigation Program was also reviewed and incorporated into the GSI Opportunities selection. NBC has since 2003 implemented a Stormwater Mitigation Program to deal with the large amounts of stormwater runoff that enters the NBC's sanitary sewer system during large rain events. The Stormwater Mitigation Program requires all builders of new project to develop a stormwater management plan 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 incorporated stormwater GSI and LID technologies. Figure 5 shows the progress across this period and demonstrates how these projects have mitigated over 6.8 Million Gallons of stormwater from the NBC sewer system. (Based upon a 3-month - 1.65 inch storm event).

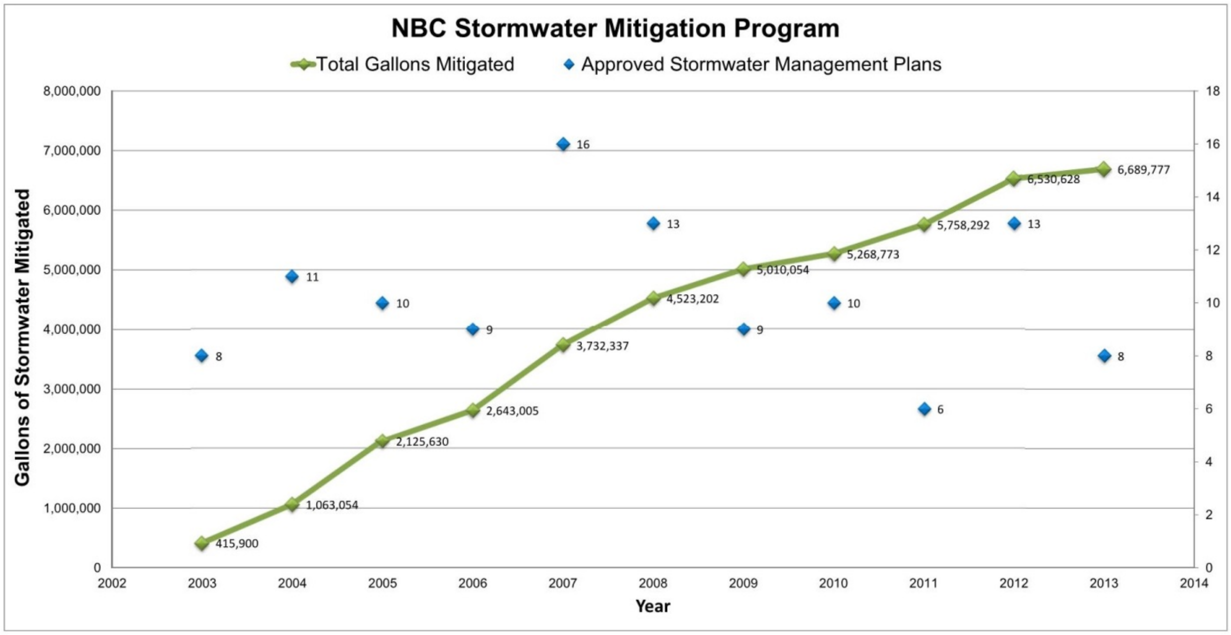


Figure 5 NBC Stormwater Mitigation Program Progress

The existing NBC stormwater mitigation program has proven that it is technically feasible to remove stormwater from the combined system using on-site controls. However, as the program is only triggered by new sewer connections or increases in wastewater discharge by more than 20%, there are a number of redevelopment projects every year that the program does not capture. To make the use of on-site GSI more widespread, the program could be expanded. This could either take the form of an increase in the NBC program, or adoption of the same mitigation requirements for any building, zoning or planning permits issued by the member communities. 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.

3.1.3. 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 A.

Following Step 3 the 522 individual GSI opportunities remained unchanged.

3.1.4. 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 6 depicts the general topography and Table 7 summarizes the criteria for assessing GSI suitability based on slope.

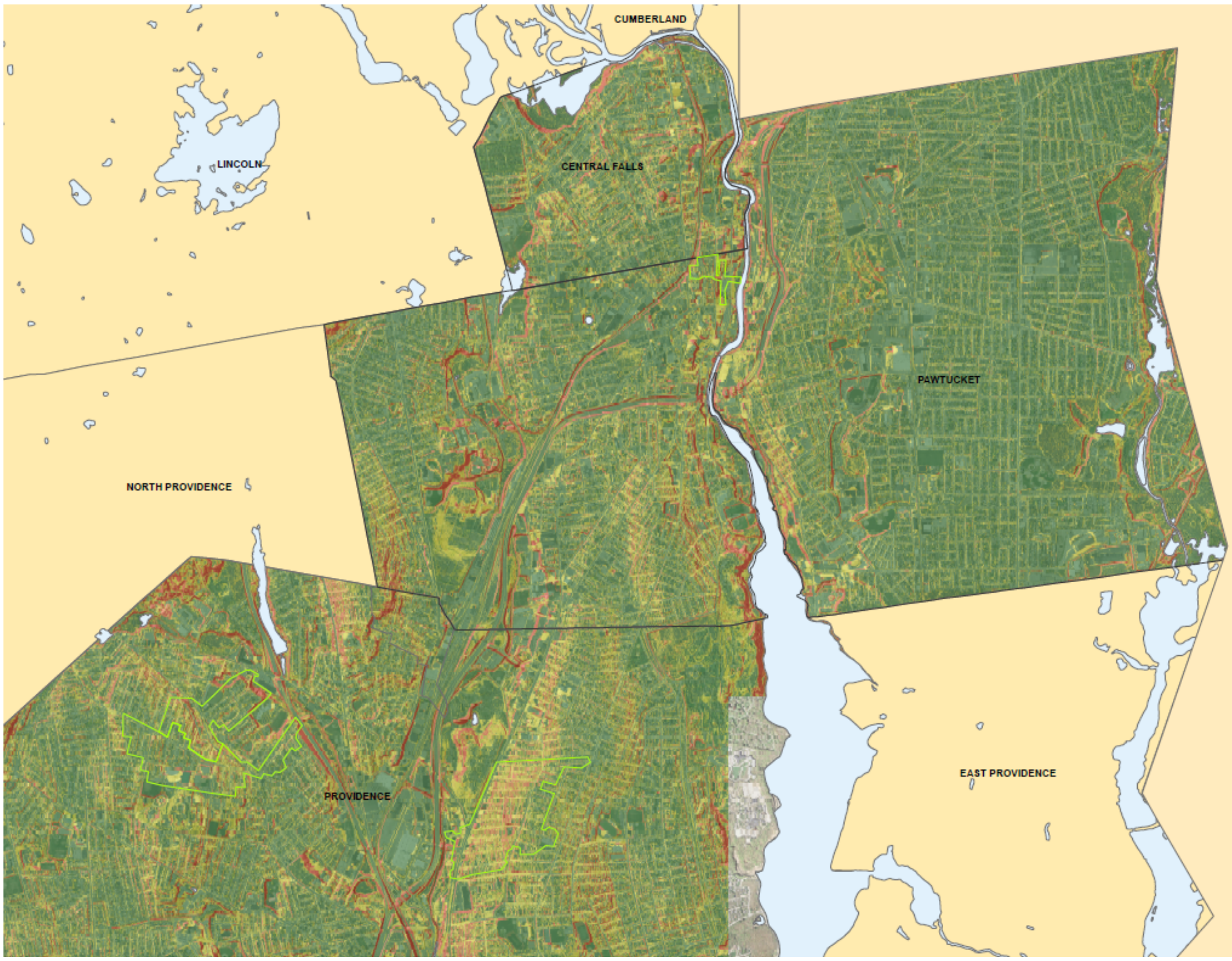


Figure 6 Topography across the Phase III CSO Service Area

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 7 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

Slope	SLF	GSI Suitability
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 7 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 8 summarizes the SOFs.

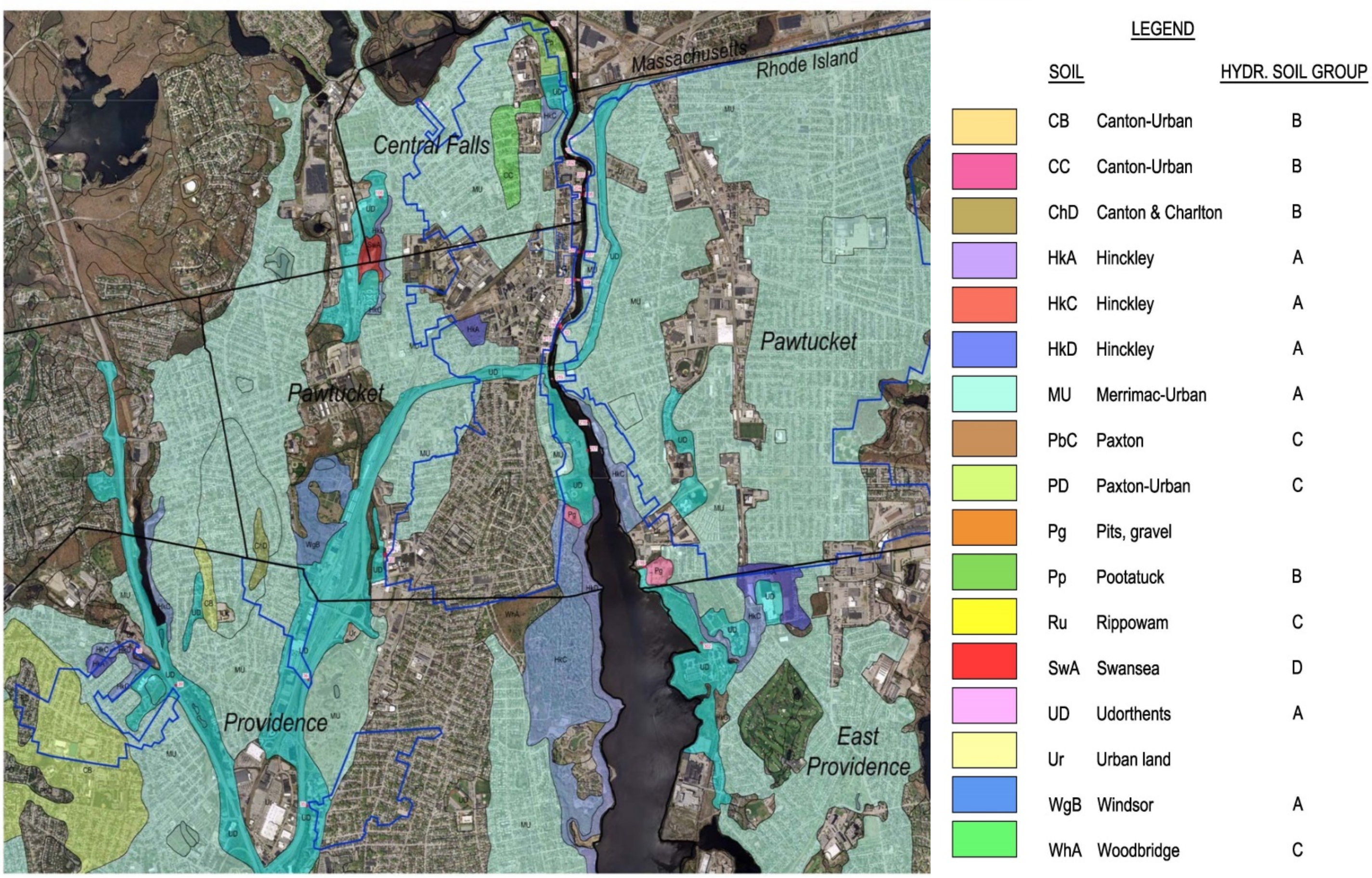


Figure 7 Infiltration potential across the Phase III CSO Service Area

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 8 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 A.

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

3.1.5. 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 8 shows the example conceptual design in sample area BVI-3T-3. All conceptual designs are included in Appendix C.

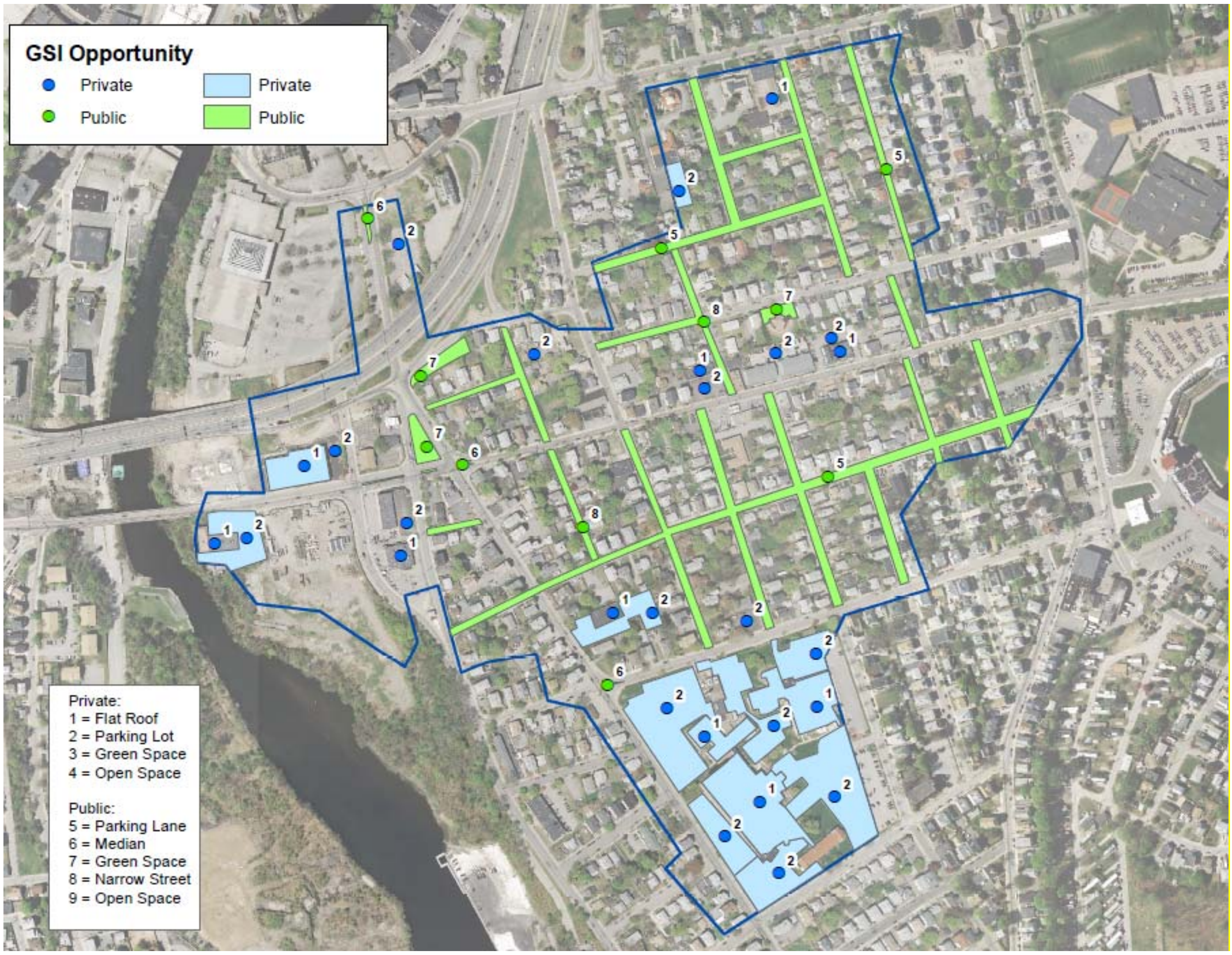


Figure 8 CSO 215 (BVI-3T-3) GSI Opportunities

Table 9 and Table 10 summarize the land uses, GSI solutions included, the design criteria assumptions and the approximate density of the solutions in the conceptual designs.

Table 9 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 10 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 11 summarizes the calculated volumes for each sample area.

Table 11 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 A includes the results of applying Step 5.

Following Step 5 the 449 individual GSI opportunities remained unchanged.

3.1.6. 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.

3.1.7. 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.

3.1.8. 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.

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

4. GSI Application Results

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. The detailed breakdown of the screening process is included in Appendix A.

4.1.1. 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 12.

Table 12 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
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 13 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 13 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

Overflow No.	Overflow Volume Reduction (MG)	Implemented All GSI Storage Volume (MG)	Ratio
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.

4.1.2. 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 14. The basis for the cost estimates is provided in Appendix D.

Table 14 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 15 details the cost per gallon of implementing GSI. However, a better indicator is the cost per gallon of CSO reduction. Figure 9 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.

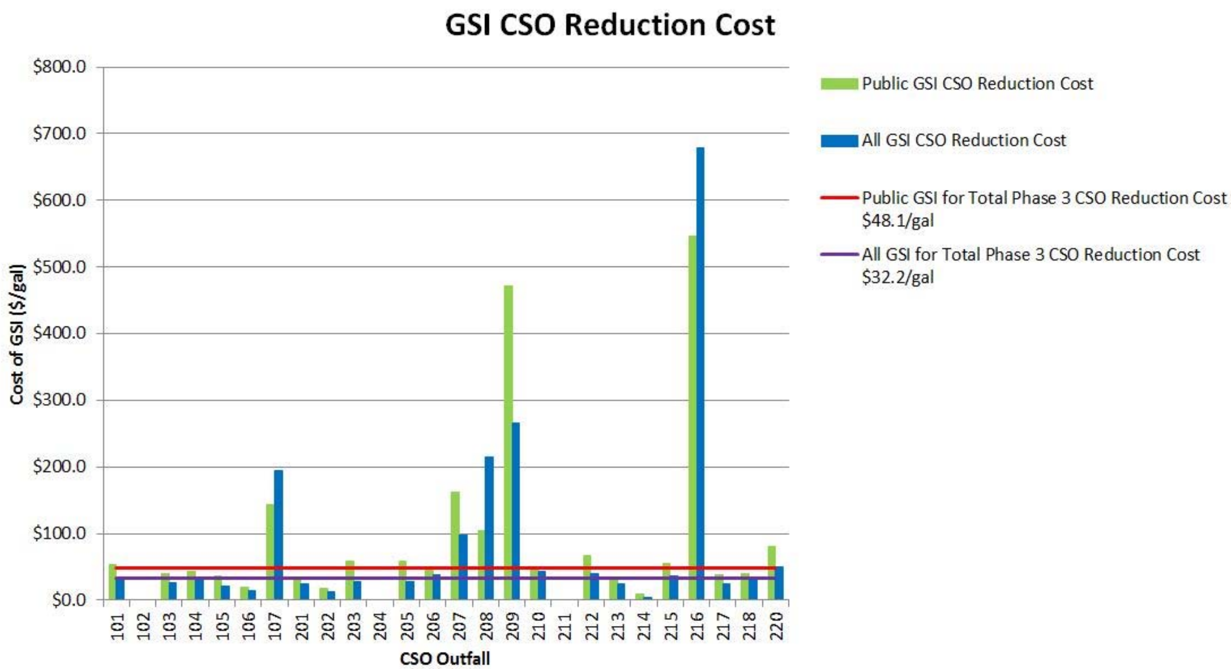


Figure 9 Cost per gallon GSI implementation compared to cost per gallon CSO reduction

Table 15 shows the estimated costs for GSI implementation at each CSO in the Phase III area.

Table 15 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.

5. GSI Potential for Phase III CSOs Conclusion

5.1.1. 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 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.is that it is not the entire answer to the CSO reduction needs. 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.

Appendix A – Results from GSI Screening Process

Table A1 GSI Screening Results

	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

Appendix B – Site Visit Location Plans

CSO OF_206

CSO OF_220

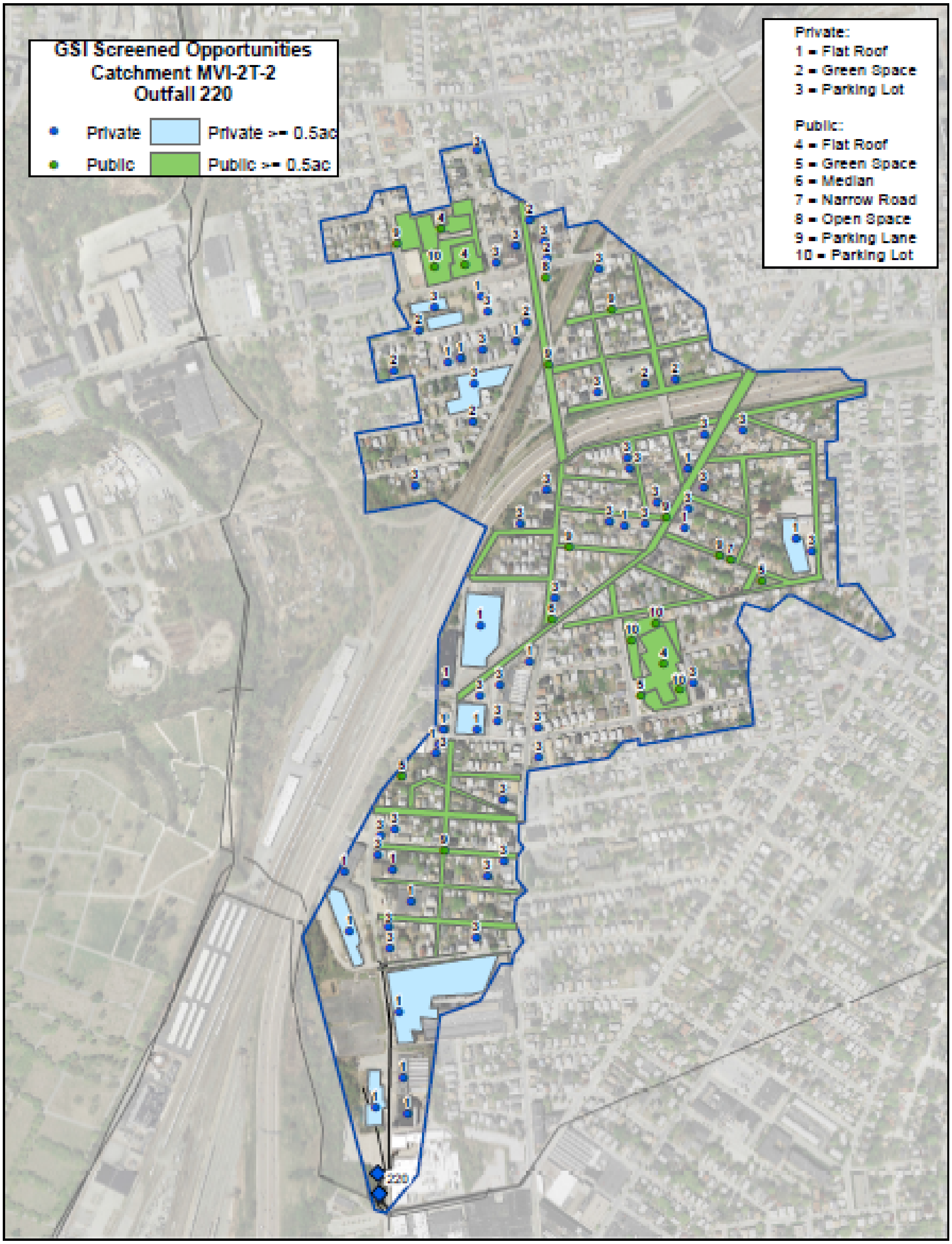

GSI Site Survey
Outfall 220
1
2
3
220
MARION TER
CAMPBELL TER
MAIN ST
MOSHASSUCK ST
GRENVILLE ST
ANN MARY ST
NASHUA ST
N MAIN ST
COLLYER ST
EXIT

CSO OF_035

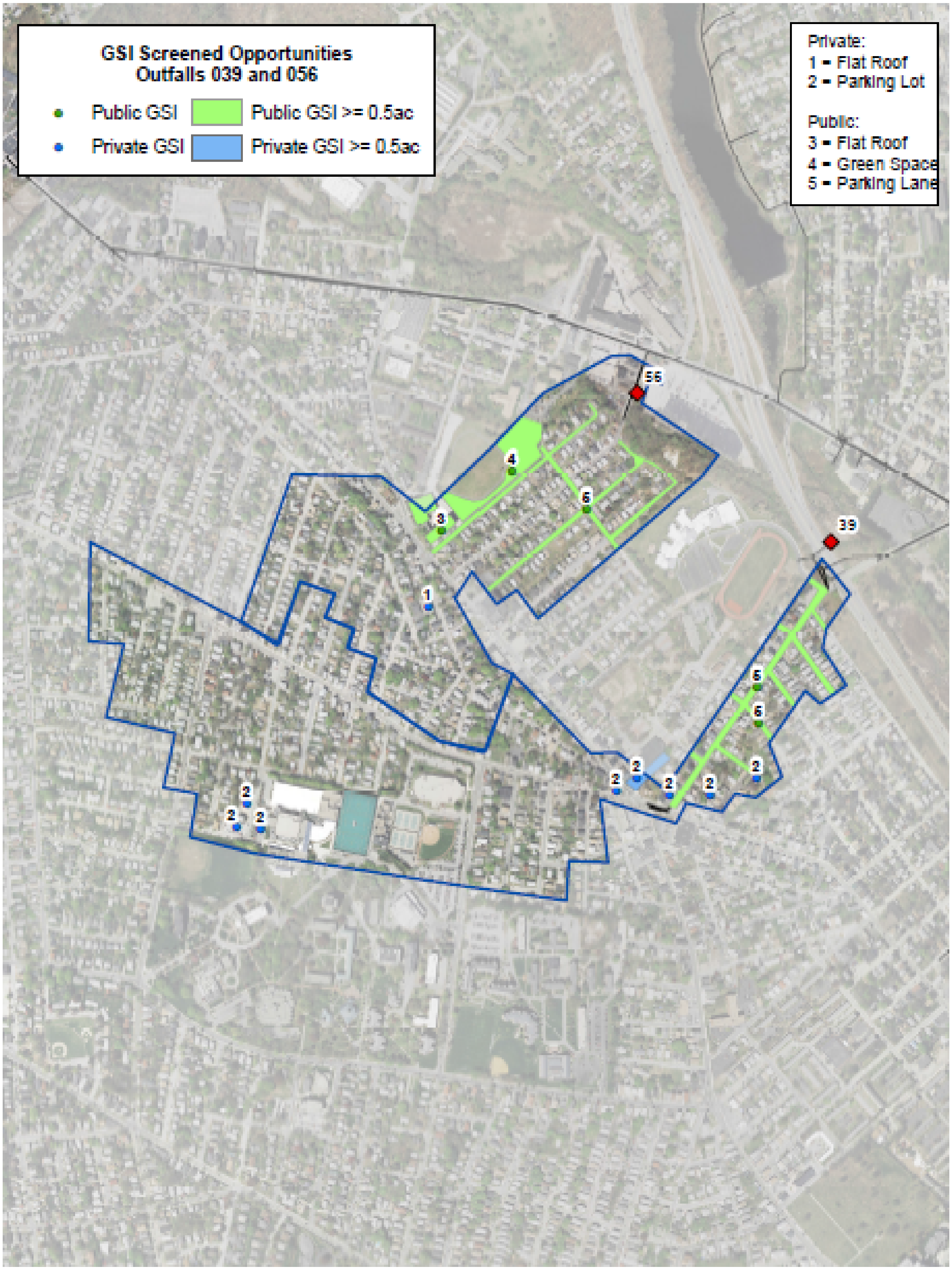
CSOs OF_039 and OF_056

Appendix C – Conceptual Designs

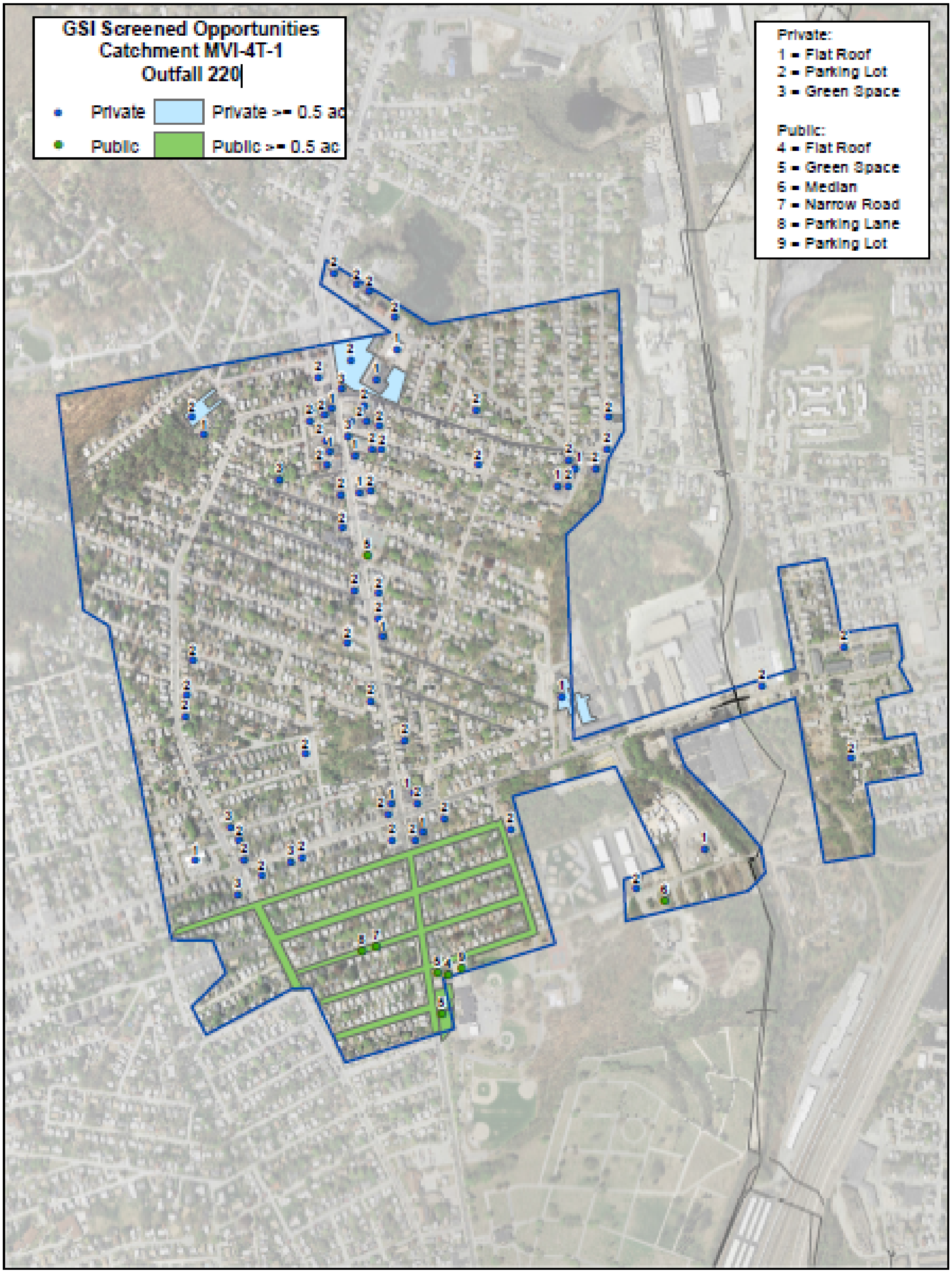
Catchment MVI-2T-2 OF_ 220



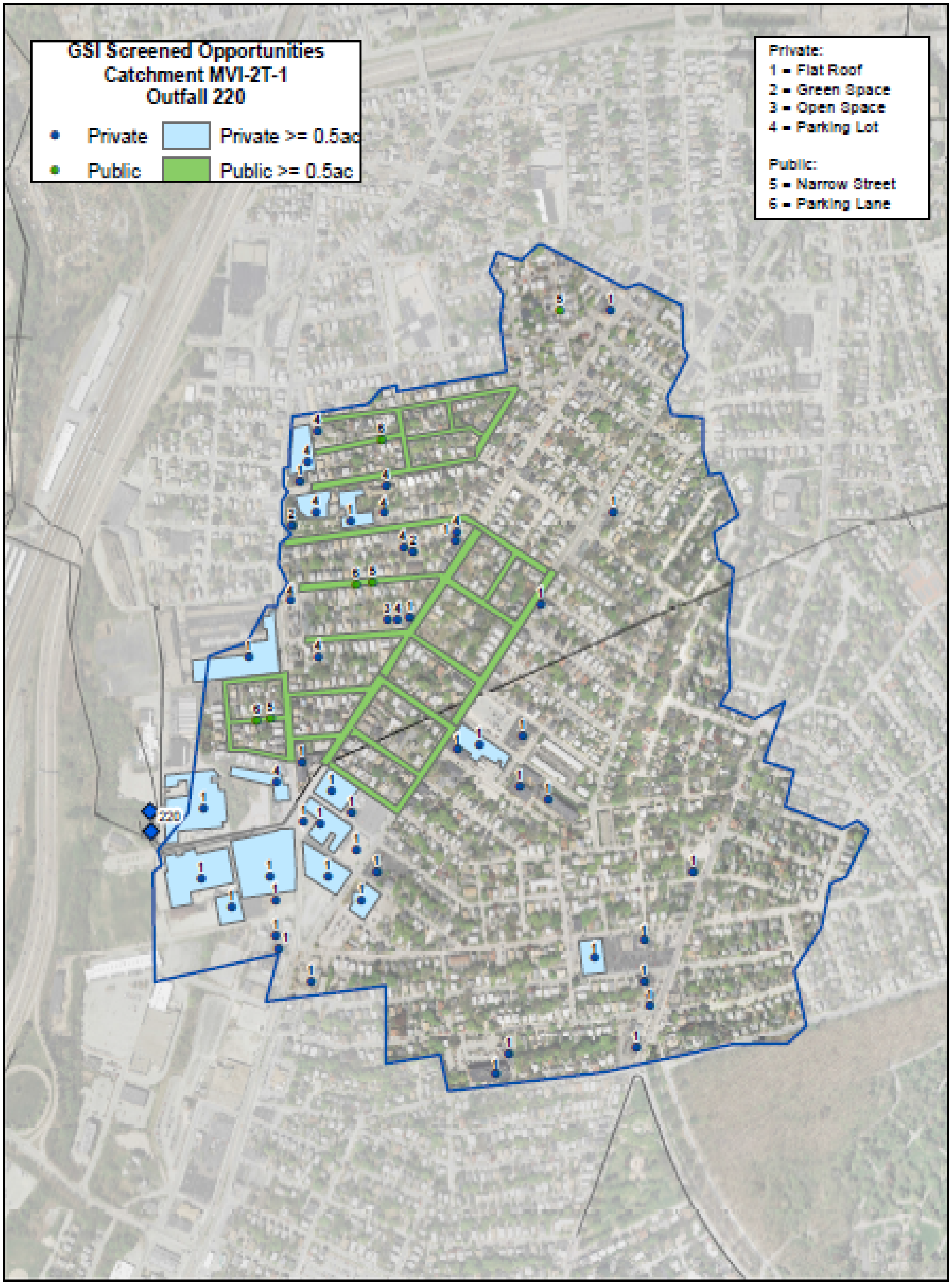
Catchment for OF_ 039 and OF_056



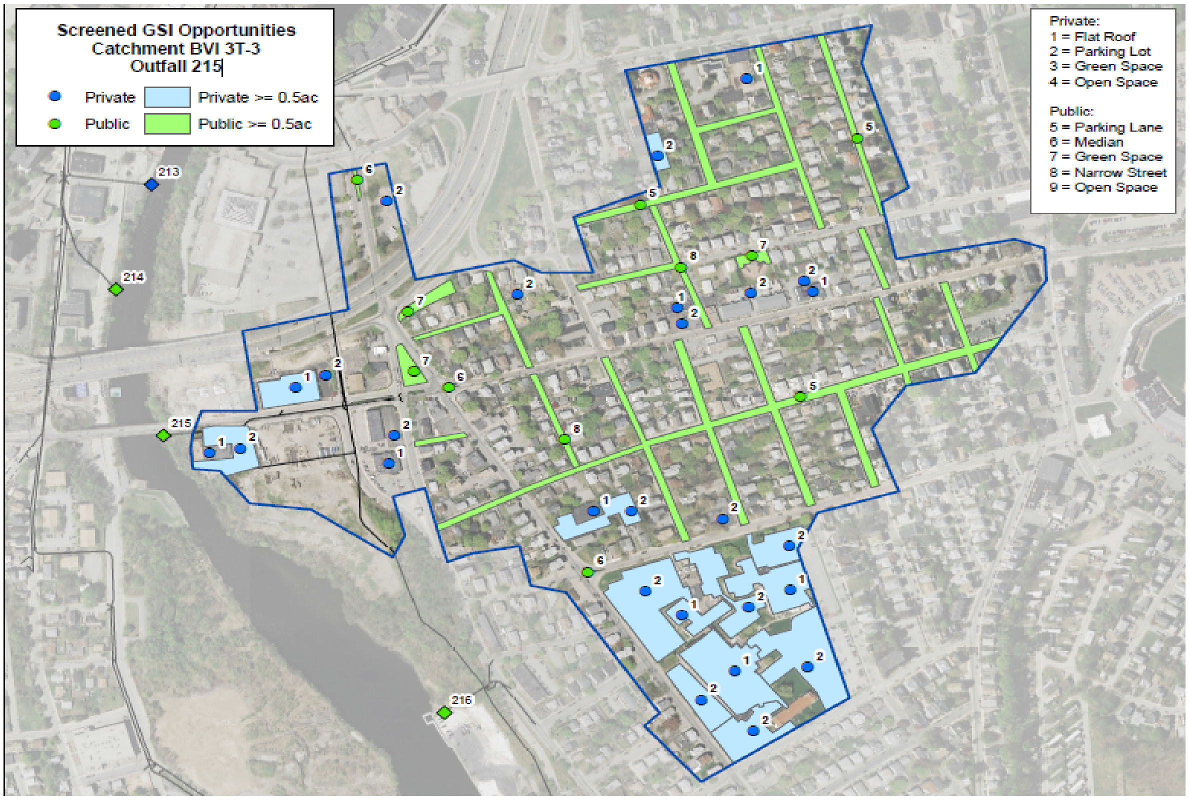
Catchment MVI-4T-1 OF_220



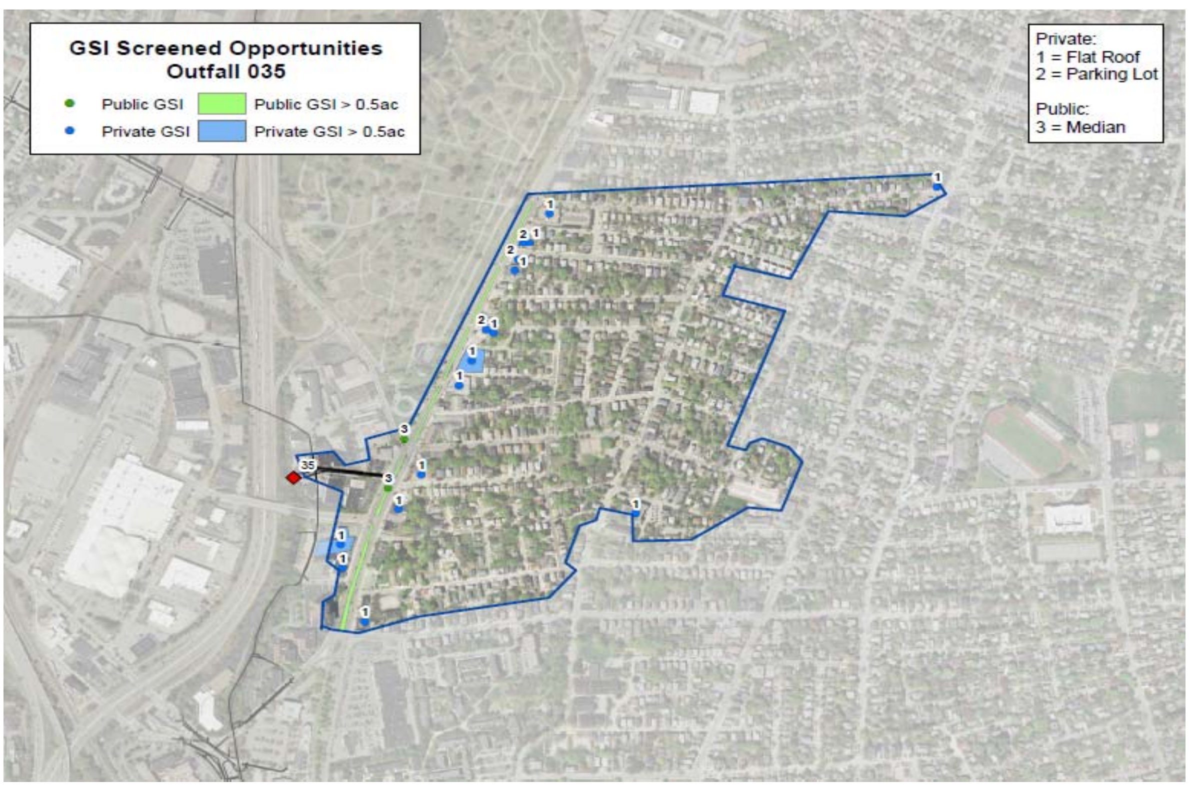
Catchment MVI-2T-1 OF_ 220



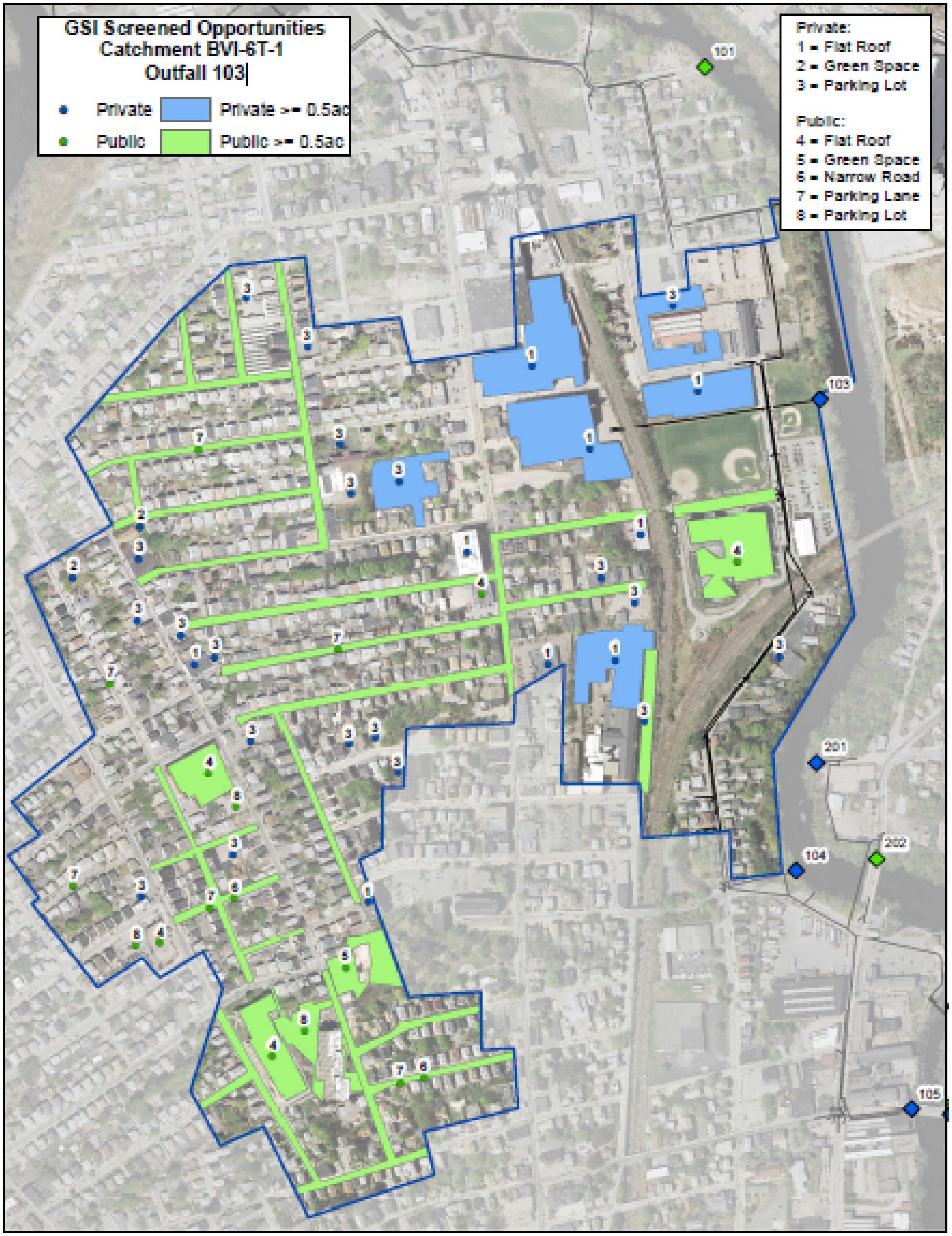
Catchment BVI 3T-3 OF_215



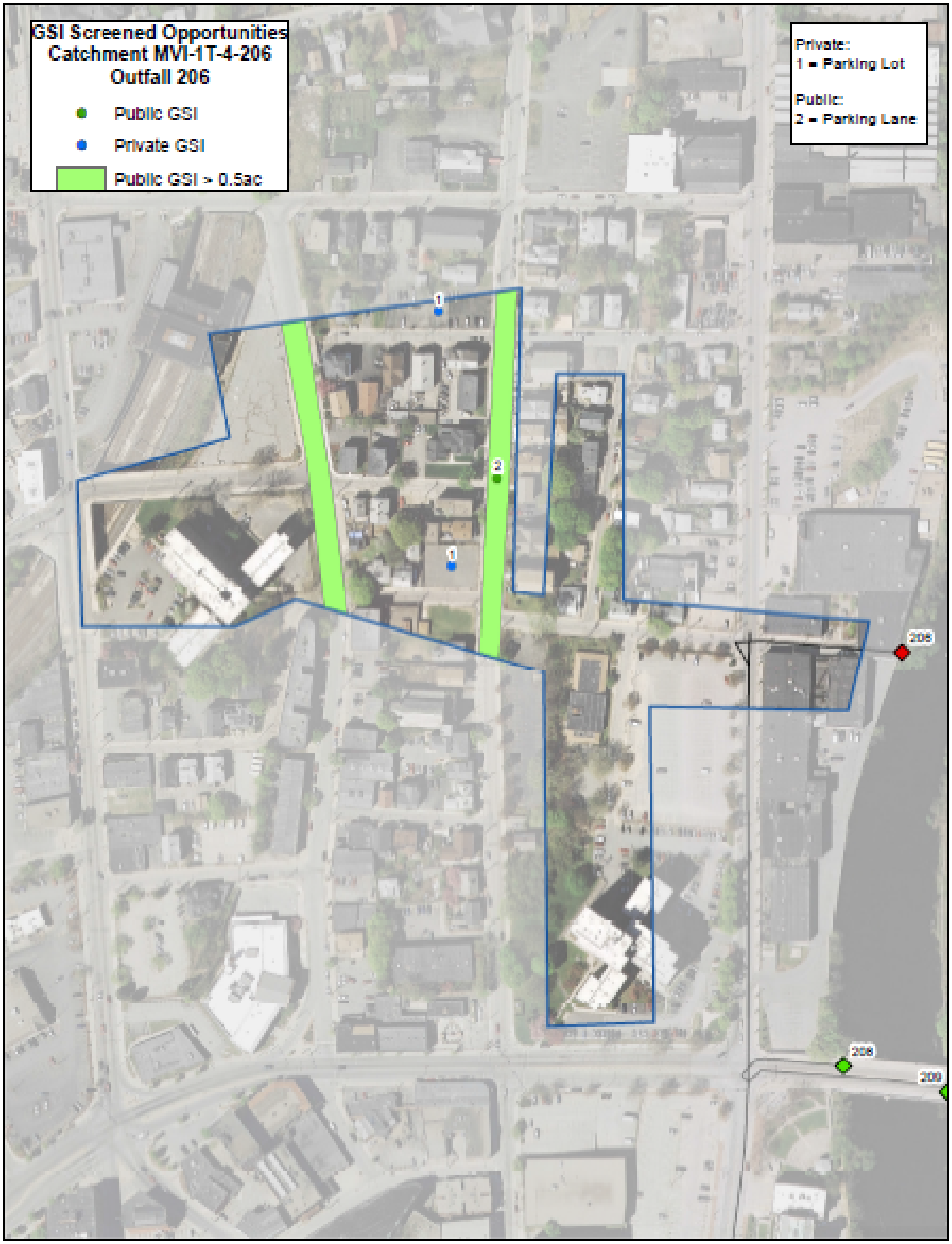
Catchment for OF_ 035



Catchment BVI-6T-1 OF_103



Catchment MVI-1T-4-206 OF_206



Appendix D – Cost Estimation Background Data

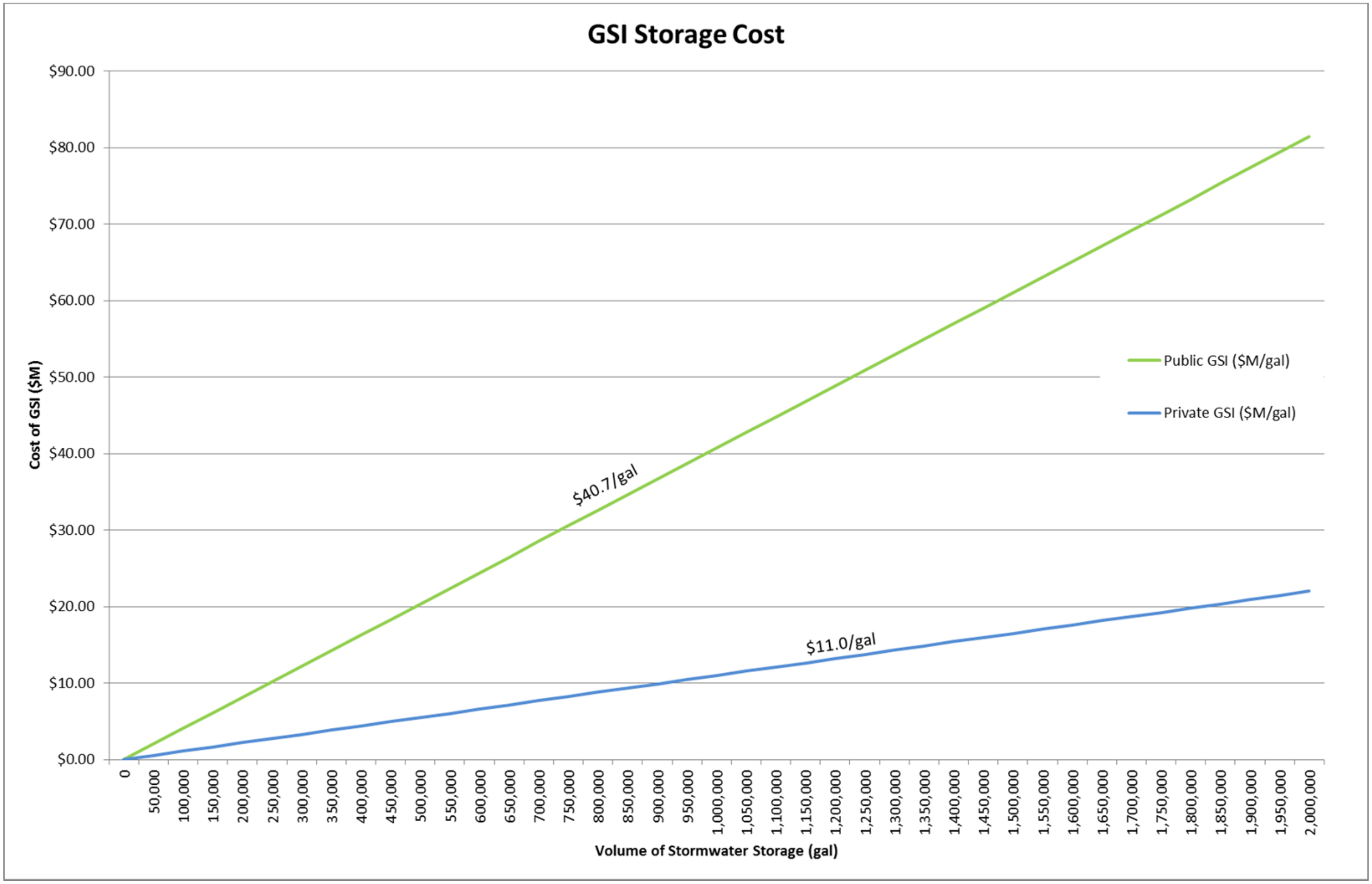
Table D-1 Public GSI Cost Estimation

GSI Technology	Item	Description	Quantity	Unit
Parking Lanes				
	Excavation & Disposal of Bituminous Asphalt	10' wide by 4" deep asphalt disposal	26,334	CF
	Excavation & Disposal of Gravel Roadway Base and Soil	4' wide by 8" deep gravel subbase beneath asphalt disposal, 6' wide by 32" deep gravel subbase beneath porous asphalt disposal	147,467	CF
	Porous Ashpalt (30% void space)	6' wide by 36" deep with 30% void space	142,200	CF
	Roadway Asphalt	4' wide by 4" deep asphalt reconstruction adjacent to porous asphalt	10,534	CF
	Roadway Gravel Base	4' wide by 8" deep gravel roadway base course adjacent to porous asphalt	21,067	CF
	Concrete Sidewalk	4' wide by 4" deep concrete sidewalk adjacent to porous asphalt	10,534	CF
	Granite Curbing	Remove and replace existing granite curb along entire length of porous asphalt and/or bumpouts; assume 20% reduction for driveway curb cuts	6,320	LF
	Tree Box Filter	1 Tree Box Filter per 40-LF	198	EA
	Raingarden Bumpout	1 Raingarden Bumpout per 300-LF	27	EA
	Remove and Reset Catch Basin Frame and Cover	1 CB Frame and Cover to remove and reset per 300 LF	27	EA
	Remove and Reset Street Signage	1 Sign to remove and reset per 100 LF	27	EA
	Traffic Management Plan	Traffic Management for Construction	3	EA
Narrow Streets				
	4'-dia perforated Drywell / Infiltration Catch Basin with Grate	1 Drywell/ICB per 0.02 acres (approx. 50-LF on 16-ft wide roadways); 10' Deep Drywell/Infiltration Catch Basin: 6' storage, 0.5' thick base, 3.5' min freeboard above invert in; Includes Grate	37	EA
	Excavation & Disposal of Bituminous Asphalt	6' wide by 4" deep excavation and disposal	349	CF
	Excavation & Disposal of Gravel Base and Soil	6' wide by 9'-8" deep excavation and disposal of material	10,113	CF
	3/4" Crushed Stone Backfill	1' wide by 9' deep 3/4" crushed stone backfill surrounding Drywell/ICB	262	CF
	Roadway Asphalt	1' wide by 4" deep asphalt reconstruction surrounding drywell	2,069	CF
	Roadway Gravel Base	4' wide by 8" deep gravel roadway base course surrounding drywell	4,137	CF
	Filter Fabric	Filter Fabric surrounding drywell structure	6,974	SF
	Traffic Management	Traffic Management for Construction	2	EA
Medians				
	Excavation and Disposal of Concrete/Bituminous Median	3' depth of median removal	13014	CF
	Filter Fabric	2 layers of filter fabric (above and below stone)	8676	SF
	Vegetated Swale Material	Plantings across entire surface	4338	SF
	Soil for Plantings	6" of soil media	2169	CF
	2" Crushed Stone	2.5' depth of 2" crushed stone for storage / infiltration	10845	CF
	Granite Curbing	Remove and replace existing granite curb along entire permiter of median, with exclusions for inlets; assume 10% reduction for inlets	238	LF
	Traffic Management	Traffic Management for Construction	3	EA
Exclusions				
	Utility Relocation / Replacement	No gas, water, sewer, drain construction		
	Remainder of Roadway Reconstruction	Roadway reconstruction beyond direct impact and immediate adjacent impact is not included in this project		
	Opposite Sidewalk Reconstruction	Sidewalk reconstruction on opposite site of street from parking lane GSI is not included in this project		
	Underdrain Piping	No underdrain piping to nearby catchbasins, infiltration only		
	Catch Basin Replacement	CB will only have frames and covers replaced		

Table D-2 Private GSI Cost Estimation

GSI Technology	Item	Description	Quantity	Unit
Porous Pavement & Bioretention Parking Lots - (3 at 20,000 SF) (50 Spaces) Average				
	Excavation & Disposal of Bituminous Asphalt	20,000 SF by 4" deep asphalt disposal	6,667	SY
	Excavation & Disposal of Gravel Roadway Base and Soil	20,000 SF by 12" deep gravel subbase beneath porous asphalt disposal	2,222	CY
	Porous Ashpalt (30% void space)	20,000 SF by 4" deep with 30% void space	6,667	SY
	Gravel Base	20,000 SF by 16" deep base course (4" of 3/4" dia washed crush stone, 8" AASHTO M-6 Sand Filter Course, 4" of 3/8" dia washed crushed stone) under porous asphalt	2,956	CY
	Concrete Curbing	100 LF of 6" precast curbing per Bioretention System	1,200	LF
	Raingarden/Bioretention Area	1 Bioretention Area per 5,000 S.F of parking surface (260 SF of surface area) includes excavation	336	CY
	Soil/Plantings	36" Bioretention Soil Media - 75% plant coverage	12	EA
	Install Catch Basin Frame and Cover	1 CB Frame and Cover per Bioretention System	12	EA
	Install Drainage Pipe to existing storm drainage system	100 LF of 12" HDPE drain line per Bioretention System	1,200	LF
	Parking Lot ReStriping	4" White Epoxy Resin Markings - 36 LF per parking space	5,400	LF
Ribbon Residential Driveways (15 at 12' W x 50' L) Average				
	Excavation & Disposal of Bituminous Asphalt	4' wide by 3" deep excavation and disposal	335	SY
	Excavation & Disposal of Compacted Gravel Base and Soil	4' wide by 12" excavation and disposal of material	115	CY
	3/4" Crushed Stone Backfill	4' wide by 8" deep 3/4" crushed stone for drainage	75	CY
	Loam & Seed	4" Loam and Seed	335	SY
Green Roof (2 at 5,000 SF)				
	Intallation of extensive low profile green roof components (Includes Removal of existing roof membrane)		10,000	SF
	1. Structural Support			
	2. Vapor Barrier			
	3. Thermal Insulation			
	4. Cover Board			
	5. Waterproof membrane			
	6. Root barrier			
	7. Drainge Layer			
	8. Filter Membrane			
	9. Growing Medium	Low growth media 2-6"		
	10. Vegetation	Low growing plants 13-50 lbs/sf		
Residential Rain Garden (15 at 1,500 SF of Roof Area)				
	Removal of Lawn and Top Soil	Removal of 6" of lawn and top soil	25	CY
	Excavation for Raingarden	Excavation per 1,500 of roof area treated for water quality (80 sf of surface area)	70	CY
	Soil/Plantings	36" Bioretention Soil Media - 75% plant coverage	15	Ea
	Lawn loam & reseeding around edges	Loam and reseed damaged areas	85	SY
Total Cost				
Exclusions				
	Utility Relocation / Replacement	No gas, water, sewer construction		
	Underdrain Piping	No underdrain piping to existing storm drain system, infiltration only		
	Structural Repairs or Replacement	No Structural Repairs or Replacement of roof for handling additional soil and water loads from a green roof installation		

Figure D-3 Public and Private GSI Cost Estimation Curves



NBC CSO Control Facilities Phase III Reevaluation

Appendix 6 – Subsystem Alternatives Analysis Estimates of Probable Cost Detail

NBC CSO Control Facilities Phase III Reevaluation

Appendix 6 – Subsystem Alternatives Analysis Estimates of Probable Cost Detail

Introduction

This Appendix provides the detailed calculations and backup for the estimates of probable construction costs to support the Subsystem Alternatives Analysis presented in Chapter 5. Tabulated data include:

- Class 5 conceptual planning level buildup of estimates of probable construction cost for all systems identified in the Baseline plan,
- Class 5 conceptual planning level buildup of estimates of probable construction cost for technically feasible alternatives identified in Chapter 4,
- Class 5 conceptual planning level buildup of estimates of probable construction cost for the Green Stormwater Infrastructure (GSI) selected technologies identified in Chapter 4,
- Buildup of GSI costs for each CSO catchment based on the analysis presented in Chapter 4,
- The scenario builder worksheet used to determine how subsystems interact and calculate proportional CSO volume to common elements,
- The cost apportionment worksheet used to allocate proportional costs of common elements to each subsystem based on CSO volume ratios.

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
CSO Interceptor (Ofs 219,220)																					
BPSA CSO Interceptor																					
Sewer Separation																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
CSO Interceptor (Ofs 219,220)																	**43,640,290**				
BPSA CSO Interceptor																	**28,645,350**				
Sewer Separation	Note: Includes Items A through H highlighted in yellow below																**54,106,233**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**130,094,342**				
Total																	679,698,098				
Apportionment of Conjunction costs																					
035 Sewer separation									**28%**	**9,412,823**	0	658,898	188,256	753,026	282,385	0	**11,295,388**				
039 Sewer separation									**38%**	**12,884,550**	0	901,919	257,691	1,030,764	386,537	0	**15,461,460**				
056 Sewer separation									**25%**	**8,536,938**	0	597,586	170,739	682,955	256,108	0	**10,244,326**				
206 Sewer separation									**8%**	**2,711,982**	0	189,839	54,240	216,959	81,359	0	**3,254,378**				
CSO Control Solution																					
035 Sewer separation	Replacement of 10% of dual pipe system; rehabilitation of 10% of dual pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths									**15,772,970**	63,601	1,104,108	315,459	1,261,838	473,189	190,804	**19,181,969**				
039 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**20,320,541**	74,360	1,422,438	406,411	1,625,643	609,616	223,080	**24,682,089**				
056 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**13,569,839**	50,329	949,889	271,397	1,085,587	407,095	150,987	**16,485,123**				
206 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**4,442,883**	17,309	311,002	88,858	355,431	133,286	51,927	**5,400,696**				
Upper High & Cross St interceptor	42" micro-tunneled or jacked interceptor north of Charles St, including roadway & utility improvements at jacking pits									**7,323,323**	73,233	512,633	146,466	585,866	219,700	219,700	**9,080,920**				
Lower High & Cross St interceptor	48" micro-tunneled or jacked interceptor south of Charles St, including river crossing plus roadway & utility improvements at jacking pits									**10,035,866**	100,359	702,511	200,717	802,869	301,076	301,076	**12,444,473**				
Middle St interceptor	30" and 66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**11,286,162**	112,862	790,031	225,723	902,893	338,585	338,585	**13,994,840**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Pawtucket Ave interceptor	Pump station, 48" and 54" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**43,640,290**	436,403	3,054,820	872,806	3,491,223	1,309,209	1,309,209	**54,113,959**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Baseline Update																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	High	Accuracy Range $ AACE Low	High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%					
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
CSO Interceptor (Ofs 219,220)																					
BPSA CSO Interceptor																					
Sewer Separation																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
CSO Interceptor (Ofs 219,220)																	**43,640,290**				
BPSA CSO Interceptor																	**28,645,350**				
Sewer Separation	Note: Includes Items A through H highlighted in yellow below																**54,106,233**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**130,094,342**				
Total																	**679,698,098**				
Apportionment of Conjunction costs																					
035 Sewer separation									**28%**	**9,412,823**	0	658,898	188,256	753,026	282,385	0	**11,295,388**				
039 Sewer separation									**38%**	**12,884,550**	0	901,919	257,691	1,030,764	386,537	0	**15,461,460**				
056 Sewer separation									**25%**	**8,536,938**	0	597,586	170,739	682,955	256,108	0	**10,244,326**				
206 Sewer separation									**8%**	**2,711,982**	0	189,839	54,240	216,959	81,359	0	**3,254,378**				
CSO Control Solution																					
035 Sewer separation	Replacement of 10% of dual pipe system; rehabilitation of 10% of dual pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths									**15,772,970**	63,601	1,104,108	315,459	1,261,838	473,189	190,804	**19,181,969**				
039 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**20,320,541**	74,360	1,422,438	406,411	1,625,643	609,616	223,080	**24,682,089**				
056 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**13,569,839**	50,329	949,889	271,397	1,085,587	407,095	150,987	**16,485,123**				
206 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**4,442,883**	17,309	311,002	88,858	355,431	133,286	51,927	**5,400,696**				
Upper High & Cross St interceptor	42" micro-tunneled or jacked interceptor north of Charles St, including roadway & utility improvements at jacking pits									**7,323,323**	73,233	512,633	146,466	585,866	219,700	219,700	**9,080,920**				
Lower High & Cross St interceptor	48" micro-tunneled or jacked interceptor south of Charles St, including river crossing plus roadway & utility improvements at jacking pits									**10,035,866**	100,359	702,511	200,717	802,869	301,076	301,076	**12,444,473**				
Middle St interceptor	30" and 66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**11,286,162**	112,862	790,031	225,723	902,893	338,585	338,585	**13,994,840**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Pawtucket Ave interceptor	Pump station, 48" and 54" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**43,640,290**	436,403	3,054,820	872,806	3,491,223	1,309,209	1,309,209	**54,113,959**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Baseline Update																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**
Consolidation Conduits		**Unit Cost ($/LF) used in comparison to Phase 1**																			
Consolidation Conduit between 210 and 211 and drop shaft	**54"-diameter consolidation conduit between outfall and drop shaft location across from City Hall**		**600**	**LF**	Assumption	Class 5	**6,640,537**	1,992,161	833,446	9,466,144	94,661	662,630	189,323	757,292	283,984	283,984	11,738,019	-30.00%	50.00%	8,216,613	17,607,028
Consolodation Conduit between 213 and 214 and drop shaft	**48"-diameter consolidation conduit between outfall and drop shaft location across from City Hall or at Tidewater Site**		**1,300**	**LF**	Assumption	Class 5	**13,949,566**	4,184,870	1,750,793	19,885,229	198,852	1,391,966	397,705	1,590,818	596,557	596,557	24,657,684	-30.00%	50.00%	17,260,379	36,986,526
Consolidation Conduit between 217 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at Tidewater Site *Sized to include 220 Volume***		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit between 218 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at old landfill site north of BPWWTF**		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit btwn High/Middle St Interceptors and Shaft S-7	**72"-diameter consolidation conduit between outfall 205 and Shaft S-7**		**300**	**LF**	Assumption	Class 5	**3,426,231**	1,027,869	430,022	4,884,122	48,841	341,889	97,682	390,730	146,524	146,524	6,056,312	-30.00%	50.00%	4,239,418	9,084,468
Consolidation Conduits							**57,370,598**	**17,211,179**	**7,200,515**	**81,782,293**	**817,823**	**5,724,761**	**1,635,646**	**6,542,583**	**2,453,469**	**2,453,469**	**101,410,043**			**70,987,030**	**152,115,065**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Construction Cost Estimate														
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations- Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
CSO Interceptor (Ofs 219,220)																					
BPSA CSO Interceptor																					
Sewer Separation																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
CSO Interceptor (Ofs 219,220)																	**43,640,290**				
BPSA CSO Interceptor																	**28,645,350**				
Sewer Separation	Note: Includes Items A through H highlighted in yellow below																**54,106,233**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**130,094,342**				
Total																	**679,698,098**				
Apportionment of Conjunction costs																					
035 Sewer separation									**28%**	**9,412,823**	0	658,898	188,256	753,026	282,385	0	**11,295,388**				
039 Sewer separation									**38%**	**12,884,550**	0	901,919	257,691	1,030,764	386,537	0	**15,461,460**				
056 Sewer separation									**25%**	**8,536,938**	0	597,586	170,739	682,955	256,108	0	**10,244,326**				
206 Sewer separation									**8%**	**2,711,982**	0	189,839	54,240	216,959	81,359	0	**3,254,378**				
CSO Control Solution																					
035 Sewer separation	Replacement of 10% of dual pipe system; rehabilitation of 10% of dual pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths									**15,772,970**	63,601	1,104,108	315,459	1,261,838	473,189	190,804	**19,181,969**				
039 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**20,320,541**	74,360	1,422,438	406,411	1,625,643	609,616	223,080	**24,682,089**				
056 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**13,569,839**	50,329	949,889	271,397	1,085,587	407,095	150,987	**16,485,123**				
206 Sewer separation	Construction of separate pipe system; replacement of 0% of single pipe system; rehabilitation of 10% of existing pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenche									**4,442,883**	17,309	311,002	88,858	355,431	133,286	51,927	**5,400,696**				
Upper High & Cross St interceptor	42" micro-tunneled or jacked interceptor north of Charles St, including roadway & utility improvements at jacking pits									**7,323,323**	73,233	512,633	146,466	585,866	219,700	219,700	**9,080,920**				
Lower High & Cross St interceptor	48" micro-tunneled or jacked interceptor south of Charles St, including river crossing plus roadway & utility improvements at jacking pits									**10,035,866**	100,359	702,511	200,717	802,869	301,076	301,076	**12,444,473**				
Middle St interceptor	30" and 66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**11,286,162**	112,862	790,031	225,723	902,893	338,585	338,585	**13,994,840**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Pawtucket Ave interceptor	Pump station, 48" and 54" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**43,640,290**	436,403	3,054,820	872,806	3,491,223	1,309,209	1,309,209	**54,113,959**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Baseline Update																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate														
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**
Consolidation Conduits		**Unit Cost ($/LF) used in comparison to Phase 1**																			
Consolidation Conduit between 210 and 211 and drop shaft	**54"-diameter consolidation conduit between outfall and drop shaft location across from City Hall**		**600**	**LF**	Assumption	Class 5	**6,640,537**	1,992,161	833,446	9,466,144	94,661	662,630	189,323	757,292	283,984	283,984	11,738,019	-30.00%	50.00%	8,216,613	17,607,028
Consolodation Conduit between 213 and 214 and drop shaft	**48"-diameter consolidation conduit between outfall and drop shaft location across from City Hall or at Tidewater Site**		**1,300**	**LF**	Assumption	Class 5	**13,949,566**	4,184,870	1,750,793	19,885,229	198,852	1,391,966	397,705	1,590,818	596,557	596,557	24,657,684	-30.00%	50.00%	17,260,379	36,986,526
Consolidation Conduit between 217 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at Tidewater Site *Sized to include 220 Volume***		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit between 218 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at old landfill site north of BPWWTF**		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit btwn High/Middle St Interceptors and Shaft S-7	**72"-diameter consolidation conduit between outfall 205 and Shaft S-7**		**300**	**LF**	Assumption	Class 5	**3,426,231**	1,027,869	430,022	4,884,122	48,841	341,889	97,682	390,730	146,524	146,524	6,056,312	-30.00%	50.00%	4,239,418	9,084,468
Consolidation Conduits							**57,370,598**	**17,211,179**	**7,200,515**	**81,782,293**	**817,823**	**5,724,761**	**1,635,646**	**6,542,583**	**2,453,469**	**2,453,469**	**101,410,043**			**70,987,030**	**152,115,065**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Shaft S-7	**36 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the receiving shaft for the tunnel which will also be used for OF's 103,104,105,201,203,205**																				
Mob			1	LS	Assumption	Class 5	**77,818**	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	**424,000**	127,200	38,160	589,360	5,894	41,255	11,787	47,149	17,681	17,681	730,806	-30.00%	50.00%	511,564	1,096,210
Excavation Soil			10	VFT	Assumption	Class 5	**378,597**	113,579	34,074	526,250	5,262	36,837	10,525	42,100	15,787	15,787	652,550	-30.00%	50.00%	456,785	978,825
Excavation Rock			135	VFT	Assumption	Class 5	**1,400,690**	420,207	126,062	1,946,959	19,470	136,287	38,939	155,757	58,409	58,409	2,414,229	-30.00%	50.00%	1,689,960	3,621,344
Liner			145	VFT	Assumption	Class 5	**2,119,501**	635,850	190,755	2,946,106	29,461	206,227	58,922	235,689	88,383	88,383	3,653,172	-30.00%	50.00%	2,557,220	5,479,758
Teardown U/G			1	LS	Assumption	Class 5	**164,429**	49,329	14,799	228,556	2,286	15,999	4,571	18,285	6,857	6,857	283,410	-30.00%	50.00%	198,387	425,115
Teardown Surface			1	LS	Assumption	Class 5	**252,662**	75,799	22,740	351,200	3,512	24,584	7,024	28,096	10,536	10,536	435,488	-30.00%	50.00%	304,842	653,232
Demob			1	LS	Assumption	Class 5	**148,562**	44,569	13,371	206,501	2,065	14,455	4,130	16,520	6,195	6,195	256,061	-30.00%	50.00%	179,243	384,092
Shaft S-7							**4,966,259**	**1,489,878**	**449,727**	**6,905,863**	**69,059**	**483,410**	**138,117**	**552,469**	**207,176**	**207,176**	**8,563,270**			**5,994,289**	**12,844,906**
Adit/Deaeration 218	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 218							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 217	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 217							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 213	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 213							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 210/211	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 210/211							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate														
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Adit/Deaeration 205	**deaeration chamber - part of Shaft S-7 shaft**																				
Adit/Deaertion Chamber				FT	Assumption	Class 5	0	0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Adit/Deaeration 205							**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**			**0**	**0**
Screening Structure/Approach Channel 218	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 218			100	FT	Assumption	Class 5	1,752,137	525,641	219,909	2,497,687	24,977	174,838	49,954	199,815	74,931	74,931	3,097,132	-30.00%	50.00%	2,167,992	4,645,697
Screening Structure/Approach Channel 218							**1,752,137**	**525,641**	**219,909**	**2,497,687**	**24,977**	**174,838**	**49,954**	**199,815**	**74,931**	**74,931**	**3,097,132**			**2,167,992**	**4,645,697**
Screening Structure/Approach Channel 217	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 217			100	FT	Assumption	Class 5	1,752,137	525,641	219,909	2,497,687	24,977	174,838	49,954	199,815	74,931	74,931	3,097,132	-30.00%	50.00%	2,167,992	4,645,697
Screening Structure/Approach Channel 217							**1,752,137**	**525,641**	**219,909**	**2,497,687**	**24,977**	**174,838**	**49,954**	**199,815**	**74,931**	**74,931**	**3,097,132**			**2,167,992**	**4,645,697**
Screening Structure/Approach Channel 213	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 213			100	FT	Assumption	Class 5	1,784,137	535,241	223,925	2,543,303	25,433	178,031	50,866	203,464	76,299	76,299	3,153,696	-30.00%	50.00%	2,207,587	4,730,544
Screening Structure/Approach Channel 213							**1,784,137**	**535,241**	**223,925**	**2,543,303**	**25,433**	**178,031**	**50,866**	**203,464**	**76,299**	**76,299**	**3,153,696**			**2,207,587**	**4,730,544**
Screening Structure/Approach Channel 210/211	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 210/211			100	FT	Assumption	Class 5	1,784,137	535,241	223,925	2,543,303	25,433	178,031	50,866	203,464	76,299	76,299	3,153,696	-30.00%	50.00%	2,207,587	4,730,544
Screening Structure/Approach Channel 210/211							**1,784,137**	**535,241**	**223,925**	**2,543,303**	**25,433**	**178,031**	**50,866**	**203,464**	**76,299**	**76,299**	**3,153,696**			**2,207,587**	**4,730,544**
Screening Structure/Approach Channel for S-7 Shaft	**20 ft by 25 ft by 300 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel S-7 Shaft			300	FT	Assumption	Class 5	4,031,022	1,209,307	505,929	5,746,257	57,463	402,238	114,925	459,701	172,388	172,388	7,125,359	-30.00%	50.00%	4,987,751	10,688,039
Screening Structure/Approach Channel for S-7 Shaft							**4,031,022**	**1,209,307**	**505,929**	**5,746,257**	**57,463**	**402,238**	**114,925**	**459,701**	**172,388**	**172,388**	**7,125,359**			**4,987,751**	**10,688,039**
Floatable Controls / Regulator Modifications																					
Floatable Controls																					
CSO Conduit 207			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 209			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 212			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 215			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
Regulator To Be Blocked																					
OF 101			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 107			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 202			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 204			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 208			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 214			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 216			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
Modified Regulators			12	ea		Class 5	25,000	7,500	3,138	427,653	4,277	29,936	8,553	34,212	12,830	12,830	530,289	-30.00%	50.00%	371,202	795,434
Floatable Controls / Regulator Modifications							**1,095,000**	**328,500**	**137,432**	**1,952,947**	**19,529**	**136,706**	**39,059**	**156,236**	**58,588**	**58,588**	**2,421,654**			**1,695,158**	**3,632,482**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
BPSA CSO INTERCEPTORS																					
Middle St Interceptor: 1710 lft of 30 inch on Middle St	30" diameter 1710 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	1,710	lft	CDRA	Class 5	3,065	920	385	7,471,598	74,716	523,012	149,432	597,728	224,148	224,148	9,264,782	-30.00%	50.00%	6,485,347	13,897,172
Middle St Interceptor: 1710 lft of 30 inch on Middle St	Restoration Allowance -10% of Construction Cost		10%							747,160	7,472	52,301	14,943	59,773	22,415	22,415	926,478	-30.00%	50.00%	648,535	1,389,717
Middle St Interceptor: 350 lft of 66" Cross St	66" diameter 350 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	350	lft	CDRA	Class 5	5,589	1,677	701	2,788,549	27,885	195,198	55,771	223,084	83,656	83,656	3,457,801	-30.00%	50.00%	2,420,461	5,186,701
Middle St Interceptor: 350 lft of 66" Cross St	Restoration Allowance -10% of Construction Cost		10%							278,855	2,789	19,520	5,577	22,308	8,366	8,366	345,780	-30.00%	50.00%	242,046	518,670
High St Interceptor: 2080 lft of 48 inch on High and Cross	48" diameter 2080 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	2,080	lft	CDRA	Class 5	3,077	923	386	9,123,514	91,235	638,646	182,470	729,881	273,705	273,705	11,313,158	-30.00%	50.00%	7,919,210	16,969,736
High St Interceptor: 2080 lft of 48 inch on High and Cross	Restoration Allowance -10% of Construction Cost		10%							912,351	9,124	63,865	18,247	72,988	27,371	27,371	1,131,316	-30.00%	50.00%	791,921	1,696,974
High St Interceptor: 2160 lft of 42 inch on High St	42" diameter 2160 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	2,160	lft	CDRA	Class 5	2,162	649	271	6,657,566	66,576	466,030	133,151	532,605	199,727	199,727	8,255,382	-30.00%	50.00%	5,778,768	12,383,073
High St Interceptor: 2160 lft of 42 inch on High St	Restoration Allowance -10% of Construction Cost		10%							665,757	6,658	46,603	13,315	53,261	19,973	19,973	825,538	-30.00%	50.00%	577,877	1,238,307
BPSA CSO INTERCEPTORS SUBTOTAL										**28,645,350**	**286,454**	**2,005,175**	**572,907**	**2,291,628**	**859,361**	**859,361**	**35,520,234**			**24,864,164**	**53,280,351**
OUTFALLS 219/220 CSO INTERCEPTOR																					
Pump Station	Unknow-say 2 pumps 250 hp each, discharge head 104-ft, wet well depth 26-ft below grade (allowance)		1	ls	CDRA	Class 5	3,000,000	900,000	376,526	4,276,526	42,765	299,357	85,531	342,122	128,296	128,296	5,302,893	-30.00%	50.00%	3,712,025	7,954,339
Pump Station	Restoration Allowance -10% of Construction Cost		10%							427,653	4,277	29,936	8,553	34,212	12,830	12,830	530,289	-30.00%	50.00%	371,202	795,434
Force Main	48" PCCP 1370 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	4,745	lft	CDRA	Class 5	2,986	896	375	20,196,677	201,967	1,413,767	403,934	1,615,734	605,900	605,900	25,043,880	-30.00%	50.00%	17,530,716	37,565,820
Force Main	Restoration Allowance -10% of Construction Cost		10%							2,019,668	20,197	141,377	40,393	161,573	60,590	60,590	2,504,388	-30.00%	50.00%	1,753,072	3,756,582
Gravity Main	54" RCP 2600 liner ft, 15-25 ft below grade	micro-tunnel / pipe-jack	3,425	lft	CDRA	Class 5	3,113	934	391	15,199,787	151,998	1,063,985	303,996	1,215,983	455,994	455,994	18,847,736	-30.00%	50.00%	13,193,415	28,271,604
Gravity Main	Restoration Allowance -10% of Construction Cost		10%							1,519,979	15,200	106,399	30,400	121,598	45,599	45,599	1,884,774	-30.00%	50.00%	1,319,342	2,827,160
OUTFALLS 219/220 CSO INTERCEPTOR SUBTOTAL										**43,640,290**	**436,403**	**3,054,820**	**872,806**	**3,491,223**	**1,309,209**	**1,309,209**	**54,113,959**			**37,879,772**	**81,170,939**
SEWER SEPARATION																					
OF 035	total of 54420 LF		54,420																		
1260 lft of 8 inch, total existing	existing 8" diameter		1,260		City Record Plans	Class 5															
126 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	10%	126	lft	Estimate	Class 5	207	62	26	37,180	372	2,603	744	2,974	1,115	1,115	46,103	-30.00%	50.00%	32,272	69,155
126 lft of 8 inch, rehab existing	rehab existing 8" diameter, 60% of total	10%	126	lft	Estimate	Class 5	28	8	3	4,991	50	349	100	399	150	150	6,189	-30.00%	50.00%	4,332	9,284
252 lft of 8 inch, new pipe	new 8" diameter, 0% of existing	20%	252	lft	Estimate	Class 5	189	57	24	67,758	678	4,743	1,355	5,421	2,033	2,033	84,019	-30.00%	50.00%	58,814	126,029
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans	Class 5															
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	10%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 60% of total	10%	0	lft	Estimate	Class 5	31	9	4	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, 0% of existing	20%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
31420 lft of 12 inch, total existing	existing 12" diameter		31,420		City Record Plans	Class 5															
3142 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	10%	3,142	lft	Estimate	Class 5	217	65	27	971,932	9,719	68,035	19,439	77,755	29,158	29,158	1,205,196	-30.00%	50.00%	843,637	1,807,793
3142 lft of 12 inch, rehab existing	rehab existing 12" diameter, 60% of total	10%	3,142	lft	Estimate	Class 5	36	11	5	161,519	1,615	11,306	3,230	12,922	4,846	4,846	200,284	-30.00%	50.00%	140,199	300,426
6284 lft of 12 inch, new pipe	new 12" diameter, 0% of existing	20%	6,284	lft	Estimate	Class 5	197	59	25	1,764,706	17,647	123,529	35,294	141,176	52,941	52,941	2,188,235	-30.00%	50.00%	1,531,765	3,282,353
8640 lft of 15 inch, total existing	existing 15" diameter		8,640		City Record Plans	Class 5															
864 lft of 15 inch, replace existing	replace 15" diameter, 20% of total	10%	864	lft	Estimate	Class 5	226	68	28	278,351	2,784	19,485	5,567	22,268	8,351	8,351	345,155	-30.00%	50.00%	241,608	517,732
864 lft of 15 inch, rehab existing	rehab existing 15" diameter, 60% of total	10%	864	lft	Estimate	Class 5	44	13	6	54,484	545	3,814	1,090	4,359	1,635	1,635	67,560	-30.00%	50.00%	47,292	101,339
1728 lft of 15 inch, new pipe	new 15" diameter, 0% of existing	20%	1,728	lft	Estimate	Class 5	205	62	26	504,972	5,050	35,348	10,099	40,398	15,149	15,149	626,166	-30.00%	50.00%	438,316	939,248
4430 lft of 18-24 inch, total existing	existing 18-24" diameter		4,430	lft	City Record Plans	Class 5															
443 lft of 18-24 inch, replace existing	replace 18-24" diameter, 20% of total	10%	443	lft	Estimate	Class 5	268	80	34	169,242	1,692	11,847	3,385	13,539	5,077	5,077	209,860	-30.00%	50.00%	146,902	314,790
443 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 60% of	10%	443	lft	Estimate	Class 5	65	20	8	41,177	412	2,882	824	3,294	1,235	1,235	51,059	-30.00%	50.00%	35,742	76,589
886 lft of 18-24 inch, new pipe	new 18-24" diameter, 0% of existing	20%	886	lft	Estimate	Class 5	244	73	31	308,172	3,082	21,572	6,163	24,654	9,245	9,245	382,134	-30.00%	50.00%	267,493	573,200
6390 lft of 25-48 inch, total existing	existing 25-48" diameter		6,390	lft	City Record Plans	Class 5															
639 lft of 25-48 inch, replace existing	replace 25-48" diameter, 20% of total	10%	639	lft	Estimate	Class 5	465	140	58	423,569	4,236	29,650	8,471	33,885	12,707	12,707	525,225	-30.00%	50.00%	367,658	787,838
639 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 60% of	10%	639	lft	Estimate	Class 5	146	44	18	132,702	1,327	9,289	2,654	10,616	3,981	3,981	164,551	-30.00%	50.00%	115,185	246,826
1278 lft of 25-48 inch, new pipe	new 25-48" diameter, 0% of existing	20%	1,278	lft	Estimate	Class 5	423	127	53	770,622	7,706	53,944	15,412	61,650	23,119	23,119	955,571	-30.00%	50.00%	668,899	1,433,356
2280 lft of 49-54 inch, total existing	existing 49-54" diameter		2,280	lft	City Record Plans	Class 5															
228 lft of 49-54 inch, replace existing	replace 49-54" diameter, 20% of total	10%	228	lft	Estimate	Class 5	646	194	81	209,960	2,100	14,697	4,199	16,797	6,299	6,299	260,351	-30.00%	50.00%	182,246	390,526
228 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 60% of	10%	228	lft	Estimate	Class 5	236	71	30	76,592	766	5,361	1,532	6,127	2,298	2,298	94,974	-30.00%	50.00%	66,482	142,461
456 lft of 49-54 inch, new pipe	new 49-54" diameter, 0% of existing	20%	456	lft	Estimate	Class 5	588	176	74	382,219	3,822	26,755	7,644	30,578	11,467	11,467	473,951	-30.00%	50.00%	331,766	710,927
OF 039	total of 24420 LF		24,420									0	0	0	0	0					
1320 lft of 8 inch, total existing	existing 8" diameter,		1,320	lft	City Record Plans	Class 5															
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
132 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	132	lft	Estimate	Class 5	31	9	4	5,810	58	407	116	465	174	174	7,204	-30.00%	50.00%	5,043	10,806
1188 lft of 8 inch, new pipe	new 8" diameter, 100% of existing	90%	1,188	lft	Estimate	Class 5	189	57	24	319,429	3,194	22,360	6,389	25,554	9,583	9,583	396,092	-30.00%	50.00%	277,264	594,138
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans	Class 5															
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	0	lft	Estimate	Class 5	34	10	4	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, 100% of existing	90%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
16870 lft of 12 inch, total existing	existing 12" diameter		16,870	lft	City Record Plans	Class 5															
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
1687 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	1,687	lft	Estimate	Class 5	40	12	5	96,359	964	6,745	1,927	7,709	2,891	2,891	119,485	-30.00%	50.00%	83,639	179,227
15183 lft of 12 inch, new pipe	new 12" diameter, 100% of existing	90%	15,183	lft	Estimate	Class 5	197	59	25	4,263,770	42,638	298,464	85,275	341,102	127,913	127,913	5,287,074	-30.00%	50.00%	3,700,952	7,930,611
970 lft of 15 inch, total existing	existing 15" diameter		970	lft	City Record Plans	Class 5															
0 lft of 15 inch, replace existing	new 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
97 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	97	lft	Estimate	Class 5	49	15	6	6,796	68	476	136	544	204	204	8,428	-30.00%	50.00%	5,899	12,641
873 lft of 15 inch, new pipe	new 15" diameter, 100% of existing	90%	873	lft	Estimate	Class 5	205	62	26	255,116	2,551	17,858	5,102	20,409	7,653	7,653	316,344	-30.00%	50.00%	221,441	474,516
2010 lft of 18-24 inch, total existing	existing 18-24" diameter		2,010	lft	City Record Plans	Class 5															
0 lft of 18-24 inch, replace existing	new 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
201 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	201	lft	Estimate	Class 5	72	22	9	20,759	208	1,453	415	1,661	623	623	25,741	-30.00%	50.00%	18,019	38,611
1809 lft of 18-24 inch, new pipe	new 18-24" diameter, 100% of existing	90%	1,809	lft	Estimate	Class 5	244	73	31	629,214	6,292	44,045	12,584	50,337	18,876	18,876	780,225	-30.00%	50.00%	546,158	1,170,338
3250 lft of 25-48 inch, total existing	existing 25-48" diameter		3,250	lft	City Record Plans	Class 5															
0 lft of 25-48 inch, replace existing	new 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
325 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	325	lft	Estimate	Class 5	162	49	20	74,992	750	5,249	1,500	5,999	2,250	2,250	92,991	-30.00%	50.00%	65,093	139,486
2925 lft of 25-48 inch, new pipe	new 25-48" diameter, 100% of existing	90%	2,925	lft	Estimate	Class 5	423	127	53	1,763,746	17,637	123,462	35,275	141,100	52,912	52,912	2,187,046	-30.00%	50.00%	1,530,932	3,280,568
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans	Class 5															
0 lft of 49-54 inch, replace existing	new 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, 100% of existing	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
OF 056	total of 16180 LF		16,180									0	0	0	0	0					
890 lft of 8 inch, total existing	existing 8" diameter,		890	lft	City Record Plans																
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
89 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	89	lft	Estimate	Class 5	31	9	4	3,917	39	274	78	313	118	118	4,857	-30.00%	50.00%	3,400	7,286
801 lft of 8 inch, new pipe	new 8" diameter, 100% of existing	90%	801	lft	Estimate	Class 5	189	57	24	215,372	2,154	15,076	4,307	17,230	6,461	6,461	267,062	-30.00%	50.00%	186,943	400,593
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans																
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	0	lft	Estimate	Class 5	34	10	4	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, 100% of existing	90%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
11350 lft of 12 inch, total existing	existing 12" diameter		11,350	lft	City Record Plans																
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
1135 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	1,135	lft	Estimate	Class 5	40	12	5	64,829	648	4,538	1,297	5,186	1,945	1,945	80,388	-30.00%	50.00%	56,272	120,582
10215 lft of 12 inch, new pipe	new 12" diameter, 100% of existing	90%	10,215	lft	Estimate	Class 5	197	59	25	2,869,940	28,699	200,896	57,399	229,595	86,098	86,098	3,558,726	-30.00%	50.00%	2,491,108	5,338,089
0 lft of 15 inch, total existing	existing 15" diameter		0	lft	City Record Plans																
0 lft of 15 inch, replace existing	new 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	0	lft	Estimate	Class 5	49	15	6	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 15 inch, new pipe	new 15" diameter, 100% of existing	90%	0	lft	Estimate	Class 5	205	62	26	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
1440 lft of 18-24 inch, total existing	existing 18-24" diameter		1,440	lft	City Record Plans																
0 lft of 18-24 inch, replace existing	new 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
144 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	144	lft	Estimate	Class 5	72	22	9	14,872	149	1,041	297	1,190	446	446	18,441	-30.00%	50.00%	12,909	27,662
1296 lft of 18-24 inch, new pipe	new 18-24" diameter, 100% of existing	90%	1,296	lft	Estimate	Class 5	244	73	31	450,004	4,500	31,500	9,000	36,000	13,500	13,500	558,005	-30.00%	50.00%	390,604	837,008
2500 lft of 25-48 inch, total existing	existing 25-48" diameter		2,500	lft	City Record Plans																
0 lft of 25-48 inch, replace existing	new 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
250 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	250	lft	Estimate	Class 5	162	49	20	57,687	577	4,038	1,154	4,615	1,731	1,731	71,531	-30.00%	50.00%	50,072	107,297
2250 lft of 25-48 inch, new pipe	new 25-48" diameter, 100% of existing	90%	2,250	lft	Estimate	Class 5	423	127	53	1,356,279	13,563	94,940	27,126	108,502	40,688	40,688	1,681,786	-30.00%	50.00%	1,177,250	2,522,679
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans																
0 lft of 49-54 inch, replace existing	new 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, 100% of existing	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
OF 206	total of 5140 LF		5,140																		
1980 lft of 8 inch, total existing	existing 8" diameter,		1,980	lft	City Record Plans																
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
198 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	198	lft	Estimate	Class 5	31	9	4	8,715	87	610	174	697	261	261	10,806	-30.00%	50.00%	7,564	16,210
1980 lft of 8 inch, new pipe	new 8" diameter, 100% of existing	100%	1,980	lft	Estimate	Class 5	189	57	24	532,381	5,324	37,267	10,648	42,591	15,971	15,971	660,153	-30.00%	50.00%	462,107	990,229
530 lft of 10 inch, total existing	existing 10" diameter		530	lft	City Record Plans																
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
53 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	53	lft	Estimate	Class 5	34	10	4	2,570	26	180	51	206	77	77	3,187	-30.00%	50.00%	2,231	4,781
530 lft of 10 inch, new pipe	new 10" diameter, 100% of existing	100%	530	lft	Estimate	Class 5	192	58	24	145,022	1,450	10,152	2,900	11,602	4,351	4,351	179,827	-30.00%	50.00%	125,879	269,741
940 lft of 12 inch, total existing	existing 12" diameter		940	lft	City Record Plans																
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
94 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	94	lft	Estimate	Class 5	40	12	5	5,369	54	376	107	430	161	161	6,658	-30.00%	50.00%	4,660	9,987
940 lft of 12 inch, new pipe	new 12" diameter, 100% of existing	100%	940	lft	Estimate	Class 5	197	59	25	264,096	2,641	18,487	5,282	21,128	7,923	7,923	327,479	-30.00%	50.00%	229,236	491,219
610 lft of 15 inch, total existing	existing 15" diameter		610	lft	City Record Plans																
0 lft of 15 inch, replace existing	new 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
61 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	61	lft	Estimate	Class 5	49	15	6	4,274	43	299	85	342	128	128	5,300	-30.00%	50.00%	3,710	7,950
610 lft of 15 inch, new pipe	new 15" diameter, 100% of existing	100%	610	lft	Estimate	Class 5	205	62	26	178,399	1,784	12,488	3,568	14,272	5,352	5,352	221,215	-30.00%	50.00%	154,850	331,822
320 lft of 18-24 inch, total existing	existing 18-24" diameter		320	lft	City Record Plans																
0 lft of 18-24 inch, replace existing	new 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
32 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	32	lft	Estimate	Class 5	72	22	9	3,305	33	231	66	264	99	99	4,098	-30.00%	50.00%	2,869	6,147
320 lft of 18-24 inch, new pipe	new 18-24" diameter, 100% of existing	100%	320	lft	Estimate	Class 5	244	73	31	111,112	1,111	7,778	2,222	8,889	3,333	3,333	137,779	-30.00%	50.00%	96,445	206,669
760 lft of 25-48 inch, total existing	existing 25-48" diameter		760	lft	City Record Plans																
0 lft of 25-48 inch, replace existing	new 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
76 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	76	lft	Estimate	Class 5	162	49	20	17,537	175	1,228	351	1,403	526	526	21,746	-30.00%	50.00%	15,222	32,618
760 lft of 25-48 inch, new pipe	new 25-48" diameter, 100% of existing	100%	760	lft	Estimate	Class 5	423	127	53	458,121	4,581	32,068	9,162	36,650	13,744	13,744	568,070	-30.00%	50.00%	397,649	852,105
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans																
0 lft of 49-54 inch, replace existing	new 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, 100% of existing	100%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
OF 102	Removed																				
SEWER SEPARATION SUBTOTAL			**100,160**							**20,559,940**	**205,599**	**1,439,196**	**411,199**	**1,644,795**	**616,798**	**616,798**	**25,494,326**			**17,846,028**	**38,241,488**
Subtotal										**$516,057,462**	**$5,160,575**	**$36,124,022**	**$10,321,149**	**$41,284,597**	**$15,481,724**	**$15,481,724**	**$639,911,253**			**$447,937,877**	**$959,866,880**
Items Below Are Assumed To Be Done In Conjuction With Items of Work Above Therefore No Cost for Design, Engineering During Construction, Construction Management, Owner and Right Of Way Costs Have Been Allocated to These Items																					
A) Rebuild Full Roadway (full-depth)	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	12,413	lf	Phase 2 Lessons Learned	Class 5	180	54	23	3,185,123		222,959	63,702	254,810	95,554		3,822,147	-30.00%	50.00%	2,675,503	5,733,221
B) Grind and overlay full roadway	Interceptor Jacking/Receiving Pits plus See Separation Roadway-Utility Quantities tab for assumptions	sewer separation and interceptor launch/receive/jack pits	49,653	lf	Phase 2 Lessons Learned	Class 5	44	13	6	3,114,342		218,004	62,287	249,147	93,430		3,737,211	-30.00%	50.00%	2,616,047	5,605,816
C) Remove/Replace Full Length Curb & Gutter	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	49,653	lf	Phase 2 Lessons Learned	Class 5	40	12	5	2,831,220		198,185	56,624	226,498	84,937		3,397,464	-30.00%	50.00%	2,378,225	5,096,196
D) Remove/Replace Full Length Sidewalk	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	26,459	lf	Phase 2 Lessons Learned	Class 5	84	25	11	3,168,273		221,779	63,365	253,462	95,048		3,801,928	-30.00%	50.00%	2,661,349	5,702,892
E) Rebuild Water Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	45,994	lf	Phase 2 Lessons Learned	Class 5	200	60	25	13,112,856		917,900	262,257	1,049,029	393,386		15,735,428	-30.00%	50.00%	11,014,799	23,603,142
F) Rebuild Gas Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	25,871	lf	Phase 2 Lessons Learned	Class 5	120	36	15	4,425,589		309,791	88,512	354,047	132,768		5,310,707	-30.00%	50.00%	3,717,495	7,966,060
G) Add for Hazardous Material Allowance	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	28,746	lf	Stakeholder input	Class 5	13	4	2	516,319		36,142	10,326	41,305	15,490		619,582	-30.00%	50.00%	433,708	929,374
H)Add for All Import Backfill	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	28,746	lf		Class 5	78	23	10	3,192,571		223,480	63,851	255,406	95,777		3,831,085	-30.00%	50.00%	2,681,759	5,746,627
Subtotal										**$33,546,293**		**$2,348,241**	**$670,926**	**$2,683,703**	**$1,006,389**		**$40,255,552**			**$28,178,886**	**$60,383,328**
Total										**$549,603,755**	**$5,160,575**	**$38,472,263**	**$10,992,075**	**$43,968,300**	**$16,488,113**	**$15,481,724**	**$680,166,805**			**$476,116,763**	**$1,020,250,207**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total												
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Hybrid CSO 035																		**14,467,766**				
Hybrid CSO 039																		**10,028,905**				
Hybrid CSO 056																		**7,890,858**				
Hybrid CSO 206																		**1,718,936**				
Misc. Sewer Separation Costs (road reconstruction, utilities, etc)																		**31,920,230**				
Design/ Design Support/ Construction Management/ Owner/ ROW																		**8,185,552**				
Total																		**74,212,246**				
Split of associated work																						
Hybrid CSO 035									**28%**	**7,380,614**	$0	$516,643	$147,612	$590,449	$221,418	$0	**1,476,123**					
Hybrid CSO 039									**39%**	**10,261,086**	$0	$718,276	$205,222	$820,887	$307,833	$0	**2,052,217**					
Hybrid CSO 056									**26%**	**6,798,705**	$0	$475,909	$135,974	$543,896	$203,961	$0	**1,359,741**					
Hybrid CSO 206									**8%**	**2,159,786**	$0	$151,185	$43,196	$172,783	$64,794	$0	**431,957**					
CSO Control Solution																						
Hybrid GSI / SW Tank / Sewer separation	Replacement & rehabilitation of portions of dual pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths									**21,848,380**	$144,678	$1,529,387	$436,968	$1,747,870	$655,451	$434,033	**4,948,387**					
Hybrid GSI / Sewer separation	Construction of smaller separate pipe system; replacement & rehabilitation of portions of existing pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched le									**20,289,991**	$100,289	$1,420,299	$405,800	$1,623,199	$608,700	$300,867	**4,459,154**					
Hybrid GSI / Sewer separation	Construction of smaller separate pipe system; replacement & rehabilitation of portions of existing pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched le									**14,689,563**	$78,909	$1,028,269	$293,791	$1,175,165	$440,687	$236,726	**3,253,547**					
Hybrid GSI / Parking lot stormwater tanks	Construction of smaller separate pipe system; replacement & rehabilitation of portions of existing pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched le									**3,878,722**	$17,189	$271,511	$77,574	$310,298	$116,362	$51,568	**844,502**					
Hybrid Public GSI & Sewer Separation - CSO 035																						
Sewer Separation Only - OF 035	total of 54420 LF		54,420																			
1260 lft of 8 inch, total existing	existing 8" diameter,		1,260		City Record Plans	Class 5																
126 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	10%	126	lft	Estimate	Class 5	207	62	26	37,180	372	2,603	744	2,974	1,115	1,115		46,103	-30.00%	50.00%	32,272	69,155
126 lft of 8 inch, rehab existing	rehab existing 8" diameter, 60% of total	10%	126	lft	Estimate	Class 5	28	8	3	4,991	50	349	100	399	150	150		6,189	-30.00%	50.00%	4,332	9,284
252 lft of 8 inch, new pipe	new 8" diameter, separation area only	20%	252	lft	Estimate	Class 5	189	57	24	67,758	678	4,743	1,355	5,421	2,033	2,033		84,019	-30.00%	50.00%	58,814	126,029
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans	Class 5																
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	10%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 60% of total	10%	0	lft	Estimate	Class 5	31	9	4	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, separation area only	20%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
31420 lft of 12 inch, total existing	existing 12" diameter		31,420		City Record Plans	Class 5																
3142 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	10%	3,142	lft	Estimate	Class 5	217	65	27	971,932	9,719	68,035	19,439	77,755	29,158	29,158		1,205,196	-30.00%	50.00%	843,637	1,807,793
3142 lft of 12 inch, rehab existing	rehab existing 12" diameter, 60% of total	10%	3,142	lft	Estimate	Class 5	36	11	5	161,519	1,615	11,306	3,230	12,922	4,846	4,846		200,284	-30.00%	50.00%	140,199	300,426
6284 lft of 12 inch, new pipe	new 12" diameter, separation area only	20%	6,284	lft	Estimate	Class 5	197	59	25	1,764,706	17,647	123,529	35,294	141,176	52,941	52,941		2,188,235	-30.00%	50.00%	1,531,765	3,282,353
8640 lft of 15 inch, total existing	existing 15" diameter		8,640		City Record Plans	Class 5																
864 lft of 15 inch, replace existing	replace 15" diameter, 20% of total	10%	864	lft	Estimate	Class 5	226	68	28	278,351	2,784	19,485	5,567	22,268	8,351	8,351		345,155	-30.00%	50.00%	241,608	517,732
864 lft of 15 inch, rehab existing	rehab existing 15" diameter, 60% of total	10%	864	lft	Estimate	Class 5	44	13	6	54,484	545	3,814	1,090	4,359	1,635	1,635		67,560	-30.00%	50.00%	47,292	101,339
1728 lft of 15 inch, new pipe	new 15" diameter, separation area only	20%	1,728	lft	Estimate	Class 5	205	62	26	504,972	5,050	35,348	10,099	40,398	15,149	15,149		626,166	-30.00%	50.00%	438,316	939,248
4430 lft of 18-24 inch, total existing	existing 18-24" diameter		4,430	lft	City Record Plans	Class 5																
443 lft of 18-24 inch, replace existing	replace 18-24" diameter, 20% of total	10%	443	lft	Estimate	Class 5	268	80	34	169,242	1,692	11,847	3,385	13,539	5,077	5,077		209,860	-30.00%	50.00%	146,902	314,790
443 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 60% of	10%	443	lft	Estimate	Class 5	65	20	8	41,177	412	2,882	824	3,294	1,235	1,235		51,059	-30.00%	50.00%	35,742	76,589
886 lft of 18-24 inch, new pipe	new 18-24" diameter, separation area only	20%	886	lft	Estimate	Class 5	244	73	31	308,172	3,082	21,572	6,163	24,654	9,245	9,245		382,134	-30.00%	50.00%	267,493	573,200
6390 lft of 25-48 inch, total existing	existing 25-48" diameter		6,390	lft	City Record Plans	Class 5																
639 lft of 25-48 inch, replace existing	replace 25-48" diameter, 20% of total	10%	639	lft	Estimate	Class 5	465	140	58	423,569	4,236	29,650	8,471	33,885	12,707	12,707		525,225	-30.00%	50.00%	367,658	787,838
639 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 60% of	10%	639	lft	Estimate	Class 5	146	44	18	132,702	1,327	9,289	2,654	10,616	3,981	3,981		164,551	-30.00%	50.00%	115,185	246,826
1278 lft of 25-48 inch, new pipe	new 25-48" diameter, separation area only	20%	1,278	lft	Estimate	Class 5	423	127	53	770,622	7,706	53,944	15,412	61,650	23,119	23,119		955,571	-30.00%	50.00%	668,899	1,433,356
2280 lft of 49-54 inch, total existing	existing 49-54" diameter		2,280	lft	City Record Plans	Class 5																
228 lft of 49-54 inch, replace existing	replace 49-54" diameter, 20% of total	10%	228	lft	Estimate	Class 5	646	194	81	209,960	2,100	14,697	4,199	16,797	6,299	6,299		260,351	-30.00%	50.00%	182,246	390,526
228 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 60% of	10%	228	lft	Estimate	Class 5	236	71	30	76,592	766	5,361	1,532	6,127	2,298	2,298		94,974	-30.00%	50.00%	66,482	142,461
456 lft of 49-54 inch, new pipe	new 49-54" diameter, separation area only	20%	456	lft	Estimate	Class 5	588	176	74	382,219	3,822	26,755	7,644	30,578	11,467	11,467		473,951	-30.00%	50.00%	331,766	710,927
Stormwater Flow Control - CSO 035	GSI in public ROWs																					
Flow Throttles	vortex flow throttles on east-west streets		48	ea	Estimate	Class 5	2,000	600	251	136,849	1,368	9,579	2,737	10,948	4,105	4,105		169,693	-30.00%	50.00%	118,785	254,539
Additional 5 ft double grate catch basins	new 5' diameter double grate CBs, assume		24	ea	Estimate	Class 5	10,000	3,000	1,255	342,122	3,421	23,949	6,842	27,370	10,264	10,264		424,231	-30.00%	50.00%	296,962	636,347
1500 LF of 10 ft x 10 ft stormwater storage tank	0.15 MG Storage Tank; new 10'x10' box		1,500	lft	Estimate	Class 5	4,000	1,200	502	8,553,053	85,531	598,714	171,061	684,244	256,592	256,592		10,605,786	-30.00%	50.00%	7,424,050	15,908,678
Reduction of Replaced Sewer due to Stormwater Flow Control - CSO 035																						
0 lft of 8 inch	8" diameter		-126	lft	Estimate	Class 5	207	62	26	-37,180	-372	-2,603	-744	-2,974	-1,115	-1,115		-46,103	-30.00%	50.00%	-32,272	-69,155
0 lft of 10 inch	10" diameter		0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
5404 lft of 12 inch	(flow control on side streets btwn North		-3,142	lft	Estimate	Class 5	217	65	27	-971,932	-9,719	-68,035	-19,439	-77,755	-29,158	-29,158		-1,205,196	-30.00%	50.00%	-843,637	-1,807,793
3456 lft of 15 inch	(flow control on side streets btwn North		-864	lft	Estimate	Class 5	226	68	28	-278,351	-2,784	-19,485	-5,567	-22,268	-8,351	-8,351		-345,155	-30.00%	50.00%	-241,608	-517,732
1772 lft of 18-24 inch	(flow control on side streets btwn North		-443	lft	Estimate	Class 5	268	80	34	-169,242	-1,692	-11,847	-3,385	-13,539	-5,077	-5,077		-209,860	-30.00%	50.00%	-146,902	-314,790
2556 lft of 25-48 inch	(flow control on side streets btwn North		-639	lft	Estimate	Class 5	465	140	58	-423,569	-4,236	-29,650	-8,471	-33,885	-12,707	-12,707		-525,225	-30.00%	50.00%	-367,658	-787,838
912 lft of 49-54 inch	(flow control on North main remove all		-228	lft	Estimate	Class 5	646	194	81	-209,960	-2,100	-14,697	-4,199	-16,797	-6,299	-6,299		-260,351	-30.00%	50.00%	-182,246	-390,526
Reduction of Rehab Sewer due to Stormwater Flow Control - CSO 035																						
0 lft of 8 inch	8" diameter		-126	lft	Estimate	Class 5	28	8	3	-4,991	-50	-349	-100	-399	-150	-150		-6,189	-30.00%	50.00%	-4,332	-9,284
0 lft of 10 inch	10" diameter		0	lft	Estimate	Class 5	31	9	4	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
5404 lft of 12 inch	(flow control on side streets btwn North		-3,142	lft	Estimate	Class 5	36	11	5	-161,519	-1,615	-11,306	-3,230	-12,922	-4,846	-4,846		-200,284	-30.00%	50.00%	-140,199	-300,426
3456 lft of 15 inch	(flow control on side streets btwn North		-864	lft	Estimate	Class 5	44	13	6	-54,484	-545	-3,814	-1,090	-4,359	-1,635	-1,635		-67,560	-30.00%	50.00%	-47,292	-101,339
1772 lft of 18-24 inch	(flow control on side streets btwn North		-443	lft	Estimate	Class 5	65	20	8	-41,177	-412	-2,882	-824	-3,294	-1,235	-1,235		-51,059	-30.00%	50.00%	-35,742	-76,589
2556 lft of 25-48 inch	(flow control on side streets btwn North		-639	lft	Estimate	Class 5	146	44	18	-132,702	-1,327	-9,289	-2,654	-10,616	-3,981	-3,981		-164,551	-30.00%	50.00%	-115,185	-246,826
912 lft of 49-54 inch	(flow control on North main remove all		-228	lft	Estimate	Class 5	236	71	30	-76,592	-766	-5,361	-1,532	-6,127	-2,298	-2,298		-94,974	-30.00%	50.00%	-66,482	-142,461
Public GSI - CSO 035	GSI in public ROWs		1	ls	GSI Estimates					1,699,161	16,992	118,941	33,983	135,933	50,975	50,975		2,106,960	-30.00%	50.00%	1,474,872	3,160,440
Reduction of New Sewer due to GSI - CSO 035																						
0 lft of 8 inch	8" diameter		0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch	10" diameter		0	lft	Estimate	Class 5	211	63	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
200 lft of 12 inch	(GSI in median on north main removes 5		-200	lft	Estimate	Class 5	217	65	27	-61,867	-619	-4,331	-1,237	-4,949	-1,856	-1,856		-76,715	-30.00%	50.00%	-53,701	-115,073
0 lft of 15 inch	15" diameter		0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 18-24 inch	18-24" diameter		0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 25-48 inch	25-48" diameter		0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch	49-54" diameter		0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
HYBRID GSI & SEWER SEPARATION - CSO 035 SUBTOTAL										**14,467,766**	**144,678**	**1,012,744**	**289,355**	**1,157,421**	**434,033**	**434,033**		**17,940,030**			**12,558,021**	**26,910,045**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate				Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpoint 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total												
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Hybrid Public GSI & Sewer Separation - CSO 039																						
Sewer Separation Only - OF 039	total of 24420 LF		24,420									0	0	0	0	0						
1320 lft of 8 inch, total existing	existing 8" diameter,		1,320	lft	City Record Plans	Class 5																
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
132 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	132	lft	Estimate	Class 5	31	9	4	5,810	58	407	116	465	174	174		7,204	-30.00%	50.00%	5,043	10,806
1188 lft of 8 inch, new pipe	new 8" diameter, separation area only	90%	1,188	lft	Estimate	Class 5	189	57	24	319,429	3,194	22,360	6,389	25,554	9,583	9,583		396,092	-30.00%	50.00%	277,264	594,138
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans	Class 5																
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	0	lft	Estimate	Class 5	34	10	4	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, separation area only	90%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
16870 lft of 12 inch, total existing	existing 12" diameter		16,870	lft	City Record Plans	Class 5																
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
1687 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	1,687	lft	Estimate	Class 5	40	12	5	96,359	964	6,745	1,927	7,709	2,891	2,891		119,485	-30.00%	50.00%	83,639	179,227
15183 lft of 12 inch, new pipe	new 12" diameter, separation area only	90%	15,183	lft	Estimate	Class 5	197	59	25	4,263,770	42,638	298,464	85,275	341,102	127,913	127,913		5,287,074	-30.00%	50.00%	3,700,952	7,930,611
970 lft of 15 inch, total existing	existing 15" diameter		970	lft	City Record Plans	Class 5																
0 lft of 15 inch, replace existing	new 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
97 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	97	lft	Estimate	Class 5	49	15	6	6,796	68	476	136	544	204	204		8,428	-30.00%	50.00%	5,899	12,641
873 lft of 15 inch, new pipe	new 15" diameter, separation area only	90%	873	lft	Estimate	Class 5	205	62	26	255,116	2,551	17,858	5,102	20,409	7,653	7,653		316,344	-30.00%	50.00%	221,441	474,516
2010 lft of 18-24 inch, total existing	existing 18-24" diameter		2,010	lft	City Record Plans	Class 5																
0 lft of 18-24 inch, replace existing	new 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
201 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	201	lft	Estimate	Class 5	72	22	9	20,759	208	1,453	415	1,661	623	623		25,741	-30.00%	50.00%	18,019	38,611
1809 lft of 18-24 inch, new pipe	new 18-24" diameter, separation area only	90%	1,809	lft	Estimate	Class 5	244	73	31	629,214	6,292	44,045	12,584	50,337	18,876	18,876		780,225	-30.00%	50.00%	546,158	1,170,338
3250 lft of 25-48 inch, total existing	existing 25-48" diameter		3,250	lft	City Record Plans	Class 5																
0 lft of 25-48 inch, replace existing	new 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
325 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	325	lft	Estimate	Class 5	162	49	20	74,992	750	5,249	1,500	5,999	2,250	2,250		92,991	-30.00%	50.00%	65,093	139,486
2925 lft of 25-48 inch, new pipe	new 25-48" diameter, separation area only	90%	2,925	lft	Estimate	Class 5	423	127	53	1,763,746	17,637	123,462	35,275	141,100	52,912	52,912		2,187,046	-30.00%	50.00%	1,530,932	3,280,568
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans	Class 5																
0 lft of 49-54 inch, replace existing	new 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, separation area only	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Reduction of New Sewer due to GSI - CSO 039																						
0 lft of 8 inch	none			lft	New	Class 5	189	57	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch	none			lft	New	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
1800 lft of 12 inch	GSI on side streets off Hawkins removes 9		-1,200	lft	New	Class 5	197	59	25	-337,144	-3,371	-23,600	-6,743	-26,972	-10,114	-10,114		-418,059	-30.00%	50.00%	-292,641	-627,088
0 lft of 15 inch	none			lft	New	Class 5	205	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 18-24 inch	none			lft	New	Class 5	244	73	31	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 25-48 inch	no reduction on Hawkings due to GSI, new			lft	New	Class 5	423	127	53	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch	none			lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Public GSI - CSO 039	GSI in public ROWs		1	ls	GSI Estimate					2,930,058	29,301	205,104	58,601	234,405	87,902	87,902		3,633,272	-30.00%	50.00%	2,543,290	5,449,908
HYBRID GSI & SEWER SEPARATION - CSO 039 SUBTOTAL										**10,028,905**	**100,289**	**702,023**	**200,578**	**802,312**	**300,867**	**300,867**		**12,435,842**			**8,705,089**	**18,653,763**
Hybrid Public GSI & Sewer Separation - CSO 056																						
Sewer Separation Only - OF 056	total of 16180 LF		16,180									0	0	0	0	0						
890 lft of 8 inch, total existing	existing 8" diameter,		890	lft	City Record Plans																	
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
89 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	89	lft	Estimate	Class 5	31	9	4	3,917	39	274	78	313	118	118		4,857	-30.00%	50.00%	3,400	7,286
801 lft of 8 inch, new pipe	new 8" diameter, separation area only	90%	801	lft	Estimate	Class 5	189	57	24	215,372	2,154	15,076	4,307	17,230	6,461	6,461		267,062	-30.00%	50.00%	186,943	400,593
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans																	
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	0	lft	Estimate	Class 5	34	10	4	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, separation area only	90%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
11350 lft of 12 inch, total existing	existing 12" diameter		11,350	lft	City Record Plans																	
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
1135 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	1,135	lft	Estimate	Class 5	40	12	5	64,829	648	4,538	1,297	5,186	1,945	1,945		80,388	-30.00%	50.00%	56,272	120,582
10215 lft of 12 inch, new pipe	new 12" diameter, separation area only	90%	10,215	lft	Estimate	Class 5	197	59	25	2,869,940	28,699	200,896	57,399	229,595	86,098	86,098		3,558,726	-30.00%	50.00%	2,491,108	5,338,089
0 lft of 15 inch, total existing	existing 15" diameter		0	lft	City Record Plans																	
0 lft of 15 inch, replace existing	new 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	0	lft	Estimate	Class 5	49	15	6	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 15 inch, new pipe	new 15" diameter, separation area only	90%	0	lft	Estimate	Class 5	205	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
1440 lft of 18-24 inch, total existing	existing 18-24" diameter		1,440	lft	City Record Plans																	
0 lft of 18-24 inch, replace existing	new 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
144 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	144	lft	Estimate	Class 5	72	22	9	14,872	149	1,041	297	1,190	446	446		18,441	-30.00%	50.00%	12,909	27,662
1296 lft of 18-24 inch, new pipe	new 18-24" diameter, separation area only	90%	1,296	lft	Estimate	Class 5	244	73	31	450,004	4,500	31,500	9,000	36,000	13,500	13,500		558,005	-30.00%	50.00%	390,604	837,008
2500 lft of 25-48 inch, total existing	existing 25-48" diameter		2,500	lft	City Record Plans																	
0 lft of 25-48 inch, replace existing	new 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
250 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	250	lft	Estimate	Class 5	162	49	20	57,687	577	4,038	1,154	4,615	1,731	1,731		71,531	-30.00%	50.00%	50,072	107,297
2250 lft of 25-48 inch, new pipe	new 25-48" diameter, separation area only	90%	2,250	lft	Estimate	Class 5	423	127	53	1,356,279	13,563	94,940	27,126	108,502	40,688	40,688		1,681,786	-30.00%	50.00%	1,177,250	2,522,679
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans																	
0 lft of 49-54 inch, replace existing	new 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, separation area only	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Reduction of New Sewer due to GSI - CSO 056																						
0 lft of 8 inch	none		0	lft	New	Class 5	189	57	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch	none		0	lft	New	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
4360 lft of 12 inch	(No SD on Stansbury St, Grand Broadway,		-4,360	lft	New	Class 5	197	59	25	-1,224,957	-12,250	-85,747	-24,499	-97,997	-36,749	-36,749		-1,518,947	-30.00%	50.00%	-1,063,263	-2,278,421
0 lft of 15 inch	none		0	lft	New	Class 5	205	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 18-24 inch	none		0	lft	New	Class 5	244	73	31	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 25-48 inch	none		0	lft	New	Class 5	423	127	53	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch	none		0	lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Public GSI in CSO 056	GSI in public ROWs		1	ls	GSI Estimates					4,082,915	40,829	285,804	81,658	326,633	122,487	122,487		5,062,814	-30.00%	50.00%	3,543,970	7,594,221
HYBRID GSI & SEWER SEPARATION - CSO 056 SUBTOTAL										**7,890,858**	**78,909**	**552,360**	**157,817**	**631,269**	**236,726**	**236,726**		**9,784,664**			**6,849,265**	**14,676,996**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Construction Cost Estimate: Contingency	Construction Cost Estimate: Escalation Mid Point 2018 using 3%/yr	Construction Cost Estimate: Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpoint 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Hybrid Public GSI & Sewer Separation - CSO 206																						
OF 206	total of 5140 LF		5,140																			
1980 lft of 8 inch, total existing	existing 8" diameter,		1,980	lft	City Record Plans																	
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
198 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	198	lft	Estimate	Class 5	31	9	4	8,715	87	610	174	697	261	261		10,806	-30.00%	50.00%	7,564	16,210
1782 lft of 8 inch, new pipe	new 8" diameter, separation area only	90%	1,782	lft	Estimate	Class 5	189	57	24	479,143	4,791	33,540	9,583	38,331	14,374	14,374		594,138	-30.00%	50.00%	415,896	891,206
530 lft of 10 inch, total existing	existing 10" diameter		530	lft	City Record Plans																	
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
53 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	53	lft	Estimate	Class 5	34	10	4	2,570	26	180	51	206	77	77		3,187	-30.00%	50.00%	2,231	4,781
477 lft of 10 inch, new pipe	new 10" diameter, separation area only	90%	477	lft	Estimate	Class 5	192	58	24	130,520	1,305	9,136	2,610	10,442	3,916	3,916		161,845	-30.00%	50.00%	113,291	242,767
940 lft of 12 inch, total existing	existing 12" diameter		940	lft	City Record Plans																	
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
94 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	94	lft	Estimate	Class 5	40	12	5	5,369	54	376	107	430	161	161		6,658	-30.00%	50.00%	4,660	9,987
846 lft of 12 inch, new pipe	new 12" diameter, separation area only	90%	846	lft	Estimate	Class 5	197	59	25	237,687	2,377	16,638	4,754	19,015	7,131	7,131		294,731	-30.00%	50.00%	206,312	442,097
610 lft of 15 inch, total existing	existing 15" diameter		610	lft	City Record Plans																	
0 lft of 15 inch, replace existing	replace 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
61 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	61	lft	Estimate	Class 5	49	15	6	4,274	43	299	85	342	128	128		5,300	-30.00%	50.00%	3,710	7,950
549 lft of 15 inch, new pipe	new 15" diameter, separation area only	90%	549	lft	Estimate	Class 5	205	62	26	160,559	1,606	11,239	3,211	12,845	4,817	4,817		199,093	-30.00%	50.00%	139,365	298,640
320 lft of 18-24 inch, total existing	existing 18-24" diameter		320	lft	City Record Plans																	
0 lft of 18-24 inch, replace existing	replace 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
32 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	32	lft	Estimate	Class 5	72	22	9	3,305	33	231	66	264	99	99		4,098	-30.00%	50.00%	2,869	6,147
288 lft of 18-24 inch, new pipe	new 18-24" diameter, separation area only	90%	288	lft	Estimate	Class 5	244	73	31	100,001	1,000	7,000	2,000	8,000	3,000	3,000		124,001	-30.00%	50.00%	86,801	186,002
760 lft of 25-48 inch, total existing	existing 25-48" diameter		760	lft	City Record Plans																	
0 lft of 25-48 inch, replace existing	replace 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
76 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	76	lft	Estimate	Class 5	162	49	20	17,537	175	1,228	351	1,403	526	526		21,746	-30.00%	50.00%	15,222	32,618
684 lft of 25-48 inch, new pipe	new 25-48" diameter, separation area only	90%	684	lft	Estimate	Class 5	423	127	53	412,309	4,123	28,862	8,246	32,985	12,369	12,369		511,263	-30.00%	50.00%	357,884	766,894
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans																	
0 lft of 49-54 inch, replace existing	replace 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, separation area only	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Stormwater Flow Control - CSO 206	GSI in public ROWs																					
Flow Throttles	vortex flow throttles on east-west streets		7	ea	Estimate	Class 5	2,000	600	251	19,957	200	1,397	399	1,597	599	599		24,747	-30.00%	50.00%	17,323	37,120
Additional 5 ft double grate catch basins	new 5' diameter double grate CBs, assume		4	ea	Estimate	Class 5	10,000	3,000	1,255	57,020	570	3,991	1,140	4,562	1,711	1,711		70,705	-30.00%	50.00%	49,494	106,058
140,000 gal stormwater storage tank	0.14 MG Storage Tank; new		140,000	gal	Estimate	Class 5	4	1	1	798,285	7,983	55,880	15,966	63,863	23,949	23,949		989,873	-30.00%	50.00%	692,911	1,484,810
Reduction of New Sewer due to Stormwater Flow Control - CSO 206																						
-891 lft of 8 inch	SFW removes new drain by 1/2		-891	lft	New	Class 5	189	57	24	-239,572	-2,396	-16,770	-4,791	-19,166	-7,187	-7,187		-297,069	-30.00%	50.00%	-207,948	-445,603
-477 lft of 10 inch	SFW removes new drain		-477	lft	New	Class 5	192	58	24	-130,520	-1,305	-9,136	-2,610	-10,442	-3,916	-3,916		-161,845	-30.00%	50.00%	-113,291	-242,767
-446 lft of 12 inch	SFW removes remainder of new drain		-446	lft	New	Class 5	197	59	25	-125,305	-1,253	-8,771	-2,506	-10,024	-3,759	-3,759		-155,379	-30.00%	50.00%	-108,765	-233,068
-274.5 lft of 15 inch	SFW removes 1/2 new drain		-275	lft	New	Class 5	205	62	26	-80,280	-803	-5,620	-1,606	-6,422	-2,408	-2,408		-99,547	-30.00%	50.00%	-69,683	-149,320
-144 lft of 18-24 inch	SFW removes 1/2 new drain		-144	lft	New	Class 5	244	73	31	-50,000	-500	-3,500	-1,000	-4,000	-1,500	-1,500		-62,001	-30.00%	50.00%	-43,400	-93,001
-342 lft of 25-48 inch	SFW removes 1/2 new drain		-342	lft	New	Class 5	423	127	53	-206,154	-2,062	-14,431	-4,123	-16,492	-6,185	-6,185		-255,631	-30.00%	50.00%	-178,942	-383,447
0 lft of 49-54 inch	none		0	lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Public GSI in CSO 056	GSI in public ROWs		1	ls	GSI Estimates					225,898	2,259	15,813	4,518	18,072	6,777	6,777		280,113	-30.00%	50.00%	196,079	420,170
Reduction of New Sewer due to GSI - CSO 206																						
0 lft of 8 inch	none		0	lft	New	Class 5	189	57	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch	none		0	lft	New	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
-400 lft of 12 inch	GSI removes new drain on Jackson St and		-400	lft	New	Class 5	197	59	25	-112,381	-1,124	-7,867	-2,248	-8,991	-3,371	-3,371		-139,353	-30.00%	50.00%	-97,547	-209,029
0 lft of 15 inch	none		0	lft	New	Class 5	205	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 18-24 inch	none		0	lft	New	Class 5	244	73	31	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 25-48 inch	none		0	lft	New	Class 5	423	127	53	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch	none		0	lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
HYBRID GSI & SEWER SEPARATION - CSO 206 SUBTOTAL										**1,718,936**	**17,189**	**120,326**	**34,379**	**137,515**	**51,568**	**51,568**		**2,131,481**			**1,492,036**	**3,197,221**
Items Below Are Assumed To Be Done In Conjuction With Items of Work Above Therefore No Cost for Design, Engineering During Construction, Construction Management, Owner and Right Of Way Costs Have Been Allocated to These Items; No costs where GSI reduces need for new drains, misc. costs have been included in GSI cost																						
A) Rebuild Full Roadway (full-depth)	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	9,227	lf	Phase 2 Lessons Learned	Class 5	180	54	23	2,367,648		165,735	47,353	189,412	71,029			2,841,177	-30.00%	50.00%	1,988,824	4,261,766
B) Grind and overlay full roadway	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	44	13	6	2,315,033		162,052	46,301	185,203	69,451			2,778,040	-30.00%	50.00%	1,944,628	4,167,060
C) Remove/Replace Full Length Curb & Gutter	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	40	12	5	2,104,576		147,320	42,092	168,366	63,137			2,525,491	-30.00%	50.00%	1,767,843	3,788,236
D) Remove/Replace Full Length Sidewalk	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf	Phase 2 Lessons Learned	Class 5	84	25	11	2,762,255		193,358	55,245	220,980	82,868			3,314,707	-30.00%	50.00%	2,320,295	4,972,060
E) Rebuild Water Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	200	60	25	10,522,878		736,601	210,458	841,830	315,686			12,627,454	-30.00%	50.00%	8,839,217	18,941,180
F) Rebuild Gas Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	20,761	lf	Phase 2 Lessons Learned	Class 5	120	36	15	3,551,471		248,603	71,029	284,118	106,544			4,261,766	-30.00%	50.00%	2,983,236	6,392,648
G) Add for Hazardous Material Allowance	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf	Stakeholder input	Class 5	13	4	2	414,338		29,004	8,287	33,147	12,430			497,206	-30.00%	50.00%	348,044	745,809
H)Add for All Import Backfill	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf		Class 5	78	23	10	2,561,992		179,339	51,240	204,959	76,860			3,074,390	-30.00%	50.00%	2,152,073	4,611,585
Subtotal										**$26,600,191**		**$1,862,013**	**$532,004**	**$2,128,015**	**$798,006**			**$31,920,230**			**$22,344,161**	**$47,880,344**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
CSO Control Solution									**Accuracy Range % AACE: +**	**50%**												
High Street Tank	CSO tank with odor control; discharge PS; equipment building; 160 lf consolodation conduit; discharge FM; ballfield & additional surface restoration; contaminated soil mitigation (known @ Wyatt Facility)									**46,137,345**	461,373	3,229,614	922,747	3,690,988	1,384,120	1,384,120	**11,072,963**					
Webbing Mills Tank	CSO tank with odor control; discharge PS; equipment building; 100 lf consolodation conduit; discharge FM; parking lot & additional surface restoration; rock excavation									**36,770,038**	367,700	2,573,903	735,401	2,941,603	1,103,101	1,103,101	**8,824,809**					
East Street Tank (Viper VoIP Corporation)	CSO tank with odor control; discharge PS; equipment building; 100 lf consolodation conduit; discharge FM; parking lot & additional surface restoration									**28,284,644**	282,846	1,979,925	565,693	2,262,772	848,539	848,539	**6,788,315**					
Front St Tank / T&D with GSI	CSO tank with odor control; discharge PS; equipment building; consolodation conduit; discharge FM; park & additional surface restoration; contaminated soil mitigation (brownfield site); plus Middle Ave Intercepto									**87,752,234**	877,522	6,142,656	1,755,045	7,020,179	2,632,567	2,632,567	**21,060,536**					
City Hall Tank	CSO tank with odor control; discharge PS; equipment building; 470 lf consolodation conduit; discharge FM; parking lot & additional surface restoration; (NOTE: required Full GSI accounted separately)									**31,768,241**	317,682	2,223,777	635,365	2,541,459	953,047	953,047	**7,624,378**					
213 Tank	CSO tank with odor control; discharge PS; equipment building; 1,400 lf consolodation conduit; discharge FM; park & additional surface restoration									**52,642,499**	526,425	3,684,975	1,052,850	4,211,400	1,579,275	1,579,275	**12,634,200**					
Morley Field tank	CSO tank with odor control; discharge PS; equipment building; 110 lf consolodation conduit; discharge FM; ballfield & additional surface restoration									**48,616,998**	486,170	3,403,190	972,340	3,889,360	1,458,510	1,458,510	**11,668,079**					
Tidewater Tank / T&D	Above ground CSO tank with odor control; diversion structure; influent PS; equipment building; 580 lf consolodation conduit with surface restoration; discharge FM; contaminated soil mitigation (Tidewater site)									**26,399,758**	263,998	1,847,983	527,995	2,111,981	791,993	791,993	**6,335,942**					
Bucklin Point landfil tank / T&D	CSO tank with odor control; discharge PS; equipment building; 1,900 lf consolodation conduit; discharge FM; park & additional surface restoration; contaminated soil mitigation (sludge/ash landfill)									**118,536,984**	1,185,370	8,297,589	2,370,740	9,482,959	3,556,110	3,556,110	**28,448,876**					
CSO Control Solution									**Accuracy Range % AACE: +**	**0%**												
West River Interceptor	72" dia micro-tunnel/pipe jack; 039 056 consolodation conduits; Charles St regulator structure; reconstruction of under- and over-flows to MRI; riverbank, park & roadway restoration									**28,130,421**	281,304	1,969,129	562,608	2,250,434	843,913	843,913	**6,751,301**					
West River Interceptor (CSO 039/056)																						
12" Connecting Conduit from CSO 056	12" diameter 200 linear ft, 10 ft below grade	pipe-jack river crossing	200	lft	CDR	Class 5	2,300	690	289	655,734	6,557	45,901	13,115	52,459	19,672	19,672		813,110	-30.00%	50.00%	569,177	1,219,665
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							131,147	1,311	9,180	2,623	10,492	3,934	3,934		162,622	-30.00%	50.00%	113,835	243,933
West River Interceptor (Branch Ave to Louisquisset Pike)	72" diameter 150 linear ft, 20 ft below grade	micro-tunnel / pipe-jack	150	lft	CDR	Class 5	5,200	1,560	653	1,111,897	11,119	77,833	22,238	88,952	33,357	33,357		1,378,752	-30.00%	50.00%	965,126	2,068,128
Urban Restoration	Restoration Allowance -10% of Construction Cost		10%							111,190	1,112	7,783	2,224	8,895	3,336	3,336		137,875	-30.00%	50.00%	96,513	206,813
West River Interceptor (Louisquisset Pike to CSO 039)	72" diameter 1900 linear ft, 20-28 ft below grade	micro-tunnel / pipe-jack	1,900	lft	CDR	Class 5	2,800	840	351	7,583,707	75,837	530,859	151,674	606,697	227,511	227,511		9,403,797	-30.00%	50.00%	6,582,658	14,105,695
Highway Crossing - Louisquisset Pike	Risk Allowance - 5% of Construction Cost		5%							379,185	3,792	26,543	7,584	30,335	11,376	11,376		470,190	-30.00%	50.00%	329,133	705,285
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							1,516,741	15,167	106,172	30,335	121,339	45,502	45,502		1,880,759	-30.00%	50.00%	1,316,532	2,821,139
66" Connecting Conduit from CSO 039	66" diameter 150 linear FT, 10 ft below grade	pipe-jack river crossing	150	lft	CDR	Class 5	3,900	1,170	489	833,923	8,339	58,375	16,678	66,714	25,018	25,018		1,034,064	-30.00%	50.00%	723,845	1,551,096
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							166,785	1,668	11,675	3,336	13,343	5,004	5,004		206,813	-30.00%	50.00%	144,769	310,219
West River Interceptor (CSO 039 to Charles St)	72" diameter 2520 linear ft, 20-28 ft below grade	micro-tunnel / pipe-jack	2,520	lft	CDR	Class 5	2,900	870	364	10,417,618	104,176	729,233	208,352	833,409	312,529	312,529		12,917,847	-30.00%	50.00%	9,042,493	19,376,770
Riverbank & Ballfield Restoration	Restoration Allowance -20% of Construction Cost		20%							2,083,524	20,835	145,847	41,670	166,682	62,506	62,506		2,583,569	-30.00%	50.00%	1,808,499	3,875,354
Regulator Structure (Charles Street)	New Regulator Structure, 28 ft below grade	open cut	1	EA	CDR	Class 5	700,000	210,000	87,856	997,856	9,979	69,850	19,957	79,828	29,936	29,936		1,237,342	-30.00%	50.00%	866,139	1,856,012
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							199,571	1,996	13,970	3,991	15,966	5,987	5,987		247,468	-30.00%	50.00%	173,228	371,202
12" Underflow to Mooshassuck River Interceptor	12" diameter 150 linear FT, 28 ft below grade	pipe-jack	150	lft	CDR	Class 5	3,900	1,170	489	833,923	8,339	58,375	16,678	66,714	25,018	25,018		1,034,064	-30.00%	50.00%	723,845	1,551,096
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							166,785	1,668	11,675	3,336	13,343	5,004	5,004		206,813	-30.00%	50.00%	144,769	310,219
12" Overflow to Mooshassuck River Interceptor	36" diameter 250 linear FT, 20 ft below grade	pipe-jack	250	lft	CDR	Class 5	2,200	660	276	784,030	7,840	54,882	15,681	62,722	23,521	23,521		972,197	-30.00%	50.00%	680,538	1,458,296
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							156,806	1,568	10,976	3,136	12,544	4,704	4,704		194,439	-30.00%	50.00%	136,108	291,659
West River Interceptor (CSO 039/056) SUBTOTAL										**28,130,421**	**281,304**	**1,969,129**	**562,608**	**2,250,434**	**843,913**	**843,913**		**32,474,208**			**22,731,946**	**48,711,312**
Near Surface Storage - CSO 103 Option 2 Tank 1 (5.26 MG)																						
Groundwater Level	14 Ft BGS		1	LS			200,000	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553		353,526	-30.00%	50.00%	247,468	530,289
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume	Included Disposal of Excess	54,382	CY	Estimate	Class 5	21	6	3	1,627,962	16,280	113,957	32,559	130,237	48,839	48,839		2,018,673	-30.00%	50.00%	1,413,071	3,028,010
Rock Removal	5% minimum assumption, not encountered in nearest borings	Included Disposal	2,719	CY	Estimate	Class 5	32	10	4	124,035	1,240	8,682	2,481	9,923	3,721	3,721		153,804	-30.00%	50.00%	107,663	230,706
Crushed Stone Bedding	12" Crushed Stone Bedding	Revised Qty from 2249 to 2900	2,900	CY	Estimate	Class 5	30	9	4	124,019	1,240	8,681	2,480	9,922	3,721	3,721		153,784	-30.00%	50.00%	107,649	230,676
Structural Concrete (326'L x 180'W x 12'D)	Structural Concrete	Revised Qty from 11308 to 7480	7,480	CY	Estimate	Class 5	1,257	377	158	13,403,147	134,031	938,220	268,063	1,072,252	402,094	402,094		16,619,902	-30.00%	50.00%	11,633,932	24,929,853
Backfill	Backfill		4,907	CY	Estimate	Class 5	5	2	1	34,975	350	2,448	699	2,798	1,049	1,049		43,369	-30.00%	50.00%	30,358	65,053
48" Diameter Consolidation Conduit	48" Diameter Gravity Inlet Pipe		164	lft	Estimate	Class 5	3,692	1,108	463	863,225	8,632	60,426	17,264	69,058	25,897	25,897		1,070,399	-30.00%	50.00%	749,279	1,605,598
10" Diameter DI Force Main	12" Diameter DI Discharge Force Main		27	lft	Estimate	Class 5	273	82	34	10,507	105	736	210	841	315	315		13,029	-30.00%	50.00%	9,120	19,544
12" Diameter Overflow Pipe	12" diameter overflow pipe		50	lft	Estimate	Class 5	300	90	38	21,383	214	1,497	428	1,711	641	641		26,514	-30.00%	50.00%	18,560	39,772
Ballfield restoration - surface	6" Loam & Seed Restoration to park		1,182	CY	Estimate	Class 5	49	15	6	82,563	826	5,779	1,651	6,605	2,477	2,477		102,378	-30.00%	50.00%	71,664	153,566
Ballfield restoration - equipment	reconstruction little league ballfield		1	LS	Estimate	Class 5	100,000	30,000	12,551	142,551	1,426	9,979	2,851	11,404	4,277	4,277		176,763	-30.00%	50.00%	123,734	265,145
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				316,571	3,166	22,160	6,331	25,326	9,497	9,497		392,548	-30.00%	50.00%	274,784	588,822
Odor Control Equipment	1 GAC unit (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Discharge Pump Station	1 discharge pump station, 3-pump system 2 duty 1 standby, 5.26 MGD capacity		1	LS	Estimate	Class 5	5,300,000	1,590,000	665,197	7,555,197	75,552	528,864	151,104	604,416	226,656	226,656		9,368,444	-30.00%	50.00%	6,557,911	14,052,666
Eqiupment Building	20'x40'?		1	LS	Estimate	Class 5	280,000	84,000	35,142	399,142	3,991	27,940	7,983	31,931	11,974	11,974		494,937	-30.00%	50.00%	346,456	742,405
Contaminated Soil Mitigation	Contaminated Soil Risk - 20% of subtotal (Contamination found during adjacentWyatt Facility construction)		20%							5,126,372	51,264	358,846	102,527	410,110	153,791	153,791		6,356,701	-30.00%	50.00%	4,449,691	9,535,051
Near Surface Storage - CSO 103 Option 2 Tank 1 (5.26 MG) SUBTOTAL										**30,758,230**	**307,582**	**2,153,076**	**615,165**	**2,460,658**	**922,747**	**922,747**		**38,140,205**			**26,698,144**	**57,210,308**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	High	Accuracy Range $ AACE Low	High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Near Surface Storage - CSO 205 (10.1 MG)																						
Groundwater Level	n/a						0	0	0	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume	Included Disposal of Excess	96,250	CY	Estimate	Class 5	21	6	3	2,881,310	28,813	201,692	57,626	230,505	86,439	86,439		3,572,824	-30.00%	50.00%	2,500,977	5,359,236
Rock Removal	5% minimum assumption, not encountered in nearest borings	Included Disposal	4,813	CY	Estimate	Class 5	32	10	4	219,528	2,195	15,367	4,391	17,562	6,586	6,586		272,215	-30.00%	50.00%	190,551	408,323
Crushed Stone Bedding	12" Crushed Stone Bedding	Revised Qty from 2404 to 3600	3,600	CY	Estimate	Class 5	30	9	4	153,955	1,540	10,777	3,079	12,316	4,619	4,619		190,904	-30.00%	50.00%	133,633	286,356
Structural Concrete (620'L x 100'W x 24'D)	Structural Concrete	Revised Qty from 14292 to 11210	11,210	CY	Estimate	Class 5	1,257	377	158	20,086,802	200,868	1,406,076	401,736	1,606,944	602,604	602,604		24,907,634	-30.00%	50.00%	17,435,344	37,361,451
Backfill	Backfill		8,520	CY	Estimate	Class 5	5	2	1	60,727	607	4,251	1,215	4,858	1,822	1,822		75,301	-30.00%	50.00%	52,711	112,952
78" Diameter Gravity Consolidation Conduit	78" Diameter Gravity Inlet Pipe		200	lft	Estimate	Class 5	5,200	1,560	653	1,482,529	14,825	103,777	29,651	118,602	44,476	44,476		1,838,336	-30.00%	50.00%	1,286,835	2,757,504
12" Diameter DI Force Main	12" Diameter DI Discharge Force Main		20	lft	Estimate	Class 5	273	82	34	7,783	78	545	156	623	233	233		9,651	-30.00%	50.00%	6,756	14,477
12" Diameter Overflow Pipe	12" diameter overflow pipe		50	lft	Estimate	Class 5	300	90	38	21,383	214	1,497	428	1,711	641	641		26,514	-30.00%	50.00%	18,560	39,772
Park Restoration - surface	6" Loam & Seed Restoration to park		1,283	CY	Estimate	Class 5	49	15	6	89,617	896	6,273	1,792	7,169	2,689	2,689		111,126	-30.00%	50.00%	77,788	166,688
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				417,938	4,179	29,256	8,359	33,435	12,538	12,538		518,244	-30.00%	50.00%	362,771	777,365
Odor Control Equipment	2 GAC units (20'x20' pad)		1	LS	Estimate	Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691		441,908	-30.00%	50.00%	309,335	662,862
Discharge Pump Station	1 discharge pump station, 3-pump system, 2 duty 1 standby, 10.1 MGD capacity		1	LS	Estimate	Class 5	8,600,000	2,580,000	1,079,376	12,259,376	122,594	858,156	245,188	980,750	367,781	367,781		15,201,626	-30.00%	50.00%	10,641,138	22,802,439
Eqiupment Building	30'x50'?		1	LS	Estimate	Class 5	525,000	157,500	65,892	748,392	7,484	52,387	14,968	59,871	22,452	22,452		928,006	-30.00%	50.00%	649,604	1,392,009
Contaminated Soil Mitigation	Contaminated Soil Risk - 30% of subtotal (Former Brownfield Site)		30%							11,764,011	117,640	823,481	235,280	941,121	352,920	352,920		14,587,374	-30.00%	50.00%	10,211,162	21,881,061
ADD SUBTOTAL FROM MIDDLE STREET INTERCEPTOR																						
Near Surface Storage - CSO 205 (10.1 MG) SUBTOTAL										**50,977,381**	**509,774**	**3,568,417**	**1,019,548**	**4,078,190**	**1,529,321**	**1,529,321**		**63,211,953**			**44,248,367**	**94,817,929**
Near Surface Storage - CSO 218 Below Ground (14.76 MG)																						
Groundwater Level	n/a						0	0	0	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume	Included Disposal of Excess	276,156	CY	Estimate	Class 5	21	6	3	8,266,919	82,669	578,684	165,338	661,354	248,008	248,008		10,250,980	-30.00%	50.00%	7,175,686	15,376,469
Rock Removal	5% minimum assumption, not encountered in nearest borings	Included Disposal	13,808	CY	Estimate	Class 5	32	10	4	629,870	6,299	44,091	12,597	50,390	18,896	18,896		781,038	-30.00%	50.00%	546,727	1,171,557
Crushed Stone Bedding	12" Crushed Stone Bedding	Revised Qty from 6235 to 7200	7,200	CY	Estimate	Class 5	30	9	4	307,910	3,079	21,554	6,158	24,633	9,237	9,237		381,808	-30.00%	50.00%	267,266	572,712
Structural Concrete (500'L x 330'W x 12'D)	Buried Tank Structural Concrete	Revised Qty from 2947 to 7620	7,620	CY	Estimate	Class 5	1,400	420	176	15,207,328	152,073	1,064,513	304,147	1,216,586	456,220	456,220		18,857,087	-30.00%	50.00%	13,199,961	28,285,630
Backfill	Backfill		129,641	CY	Estimate	Class 5	5	2	1	924,022	9,240	64,682	18,480	73,922	27,721	27,721		1,145,787	-30.00%	50.00%	802,051	1,718,681
66" Diameter Gravity Consolidation Conduit	66" Diameter Gravity Inlet Pipe		1,896	lft	Estimate	Class 5	3,113	934	391	8,414,247	84,142	588,997	168,285	673,140	252,427	252,427		10,433,666	-30.00%	50.00%	7,303,566	15,650,500
12" Diameter DI Force Main	12" Diameter DI Discharge Force Main		35	lft	Estimate	Class 5	273	82	34	13,621	136	953	272	1,090	409	409		16,890	-30.00%	50.00%	11,823	25,335
12" Diameter Overflow Pipe	12" diameter overflow pipe		100	lft	Estimate	Class 5	300	90	38	42,765	428	2,994	855	3,421	1,283	1,283		53,029	-30.00%	50.00%	37,120	79,543
Park Restoration - surface	6" Loam & Seed Restoration to park		3,211	CY	Estimate	Class 5	49	15	6	224,288	2,243	15,700	4,486	17,943	6,729	6,729		278,117	-30.00%	50.00%	194,682	417,176
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				2,009,319	20,093	140,652	40,186	160,746	60,280	60,280		2,491,556	-30.00%	50.00%	1,744,089	3,737,334
Odor Control Equipment	2 GAC units (20'x40' pad)		1	LS	Estimate	Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691		441,908	-30.00%	50.00%	309,335	662,862
Discharge Pump Station	1 discharge pump station , 3-pump system, 2 duty 1 standby,14.76 MGD capacity		1	LS	Estimate	Class 5	10,600,000	3,180,000	1,330,393	15,110,393	151,104	1,057,728	302,208	1,208,831	453,312	453,312		18,736,888	-30.00%	50.00%	13,115,821	28,105,332
Eqiupment Building	30'x50'?		1	LS	Estimate	Class 5	525,000	157,500	65,892	748,392	7,484	52,387	14,968	59,871	22,452	22,452		928,006	-30.00%	50.00%	649,604	1,392,009
Contaminated Soil Mitigation	Contaminated Soil Risk - 50% of subtotal (Former Sludge/Ash Landfill)		50%							26,341,552	263,416	1,843,909	526,831	2,107,324	790,247	790,247		32,663,525	-30.00%	50.00%	22,864,467	48,995,287
Near Surface Storage - CSO 218 Below Ground (14.76 MG) SUBTOTAL										**79,024,656**	**790,247**	**5,531,726**	**1,580,493**	**6,321,973**	**2,370,740**	**2,370,740**		**97,990,574**			**68,593,402**	**146,985,861**
Near Surface Storage - CSO 217 Above Ground (2.71 MG)																						
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
124'-diameter by 30-ft tall Circular Above Ground Tank	Wire-wound Circular Prestressed Concrete Tank		1	LS	Estimate	Class 5	2,100,000	630,000	263,569	2,993,569	29,936	209,550	59,871	239,485	89,807	89,807		3,712,025	-30.00%	50.00%	2,598,417	5,568,037
48" Diameter Gravity Consolidation Conduit	48" Diameter Gravity Influent Pipe		580	lft	Estimate	Class 5	3,077	923	386	2,544,057	25,441	178,084	50,881	203,525	76,322	76,322		3,154,630	-30.00%	50.00%	2,208,241	4,731,946
8" Diameter DI Force Main	8" Diameter DI Influent Force Main		31	lft	Estimate	Class 5	258	77	32	11,401	114	798	228	912	342	342		14,138	-30.00%	50.00%	9,896	21,206
Influent Pump Station	1 influent pump station with wet well, 3-pump system, 2 duty 1 standby, 2.71 MGD capacity		1	LS	Estimate	Class 5	3,800,000	1,140,000	476,933	5,416,933	54,169	379,185	108,339	433,355	162,508	162,508		6,716,998	-30.00%	50.00%	4,701,898	10,075,496
12" Diameter Overflow Pipe	12" diameter overflow pipe		100	lft	Estimate	Class 5	300	90	38	42,765	428	2,994	855	3,421	1,283	1,283		53,029	-30.00%	50.00%	37,120	79,543
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				1,688,562	16,886	118,199	33,771	135,085	50,657	50,657		2,093,817	-30.00%	50.00%	1,465,672	3,140,725
Odor Control Equipment	1 GAC units (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Equipment Building	20'x40'?		1	LS	Estimate	Class 5	140,000	42,000	17,571	199,571	1,996	13,970	3,991	15,966	5,987	5,987		247,468	-30.00%	50.00%	173,228	371,202
Contaminated Soil Mitigation	Contaminated Soil Risk - 30% of subtotal (Tidewater Site)		30%							4,061,501	40,615	284,305	81,230	324,920	121,845	121,845		5,036,262	-30.00%	50.00%	3,525,383	7,554,392
Near Surface Storage - CSO 217 Above Ground (2.71 MG) SUBTOTAL										**17,599,839**	**175,998**	**1,231,989**	**351,997**	**1,407,987**	**527,995**	**527,995**		**21,823,800**			**15,276,660**	**32,735,700**
Near Surface Storage - CSO 104 Tank Dimensions: 225 ft x 105 ft x 12 ft (2.12 MG)																						
Groundwater Level	14 Ft BGS		1	LS			200,000	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553		353,526	-30.00%	50.00%	247,468	530,289
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume		28,026	CY	Estimate	Class 5	21	6	3	838,975	8,390	58,728	16,780	67,118	25,169	25,169		1,040,329	-30.00%	50.00%	728,231	1,560,494
Rock Removal	5% minimum assumption, not encountered in nearest borings		1,401	CY	Estimate	Class 5	32	10	4	63,922	639	4,475	1,278	5,114	1,918	1,918		79,263	-30.00%	50.00%	55,484	118,895
Crushed Stone Bedding	12" Crushed Stone Bedding		924	CY	Estimate	Class 5	30	9	4	39,536	395	2,767	791	3,163	1,186	1,186		49,024	-30.00%	50.00%	34,317	73,536
Structural Concrete (326'L x 180'W x 12'D)	Structural Concrete		6,332	CY	Estimate	Class 5	1,257	377	158	11,346,465	113,465	794,253	226,929	907,717	340,394	340,394		14,069,616	-30.00%	50.00%	9,848,731	21,104,424
Backfill	Backfill		9,074	CY	Estimate	Class 5	5	2	1	64,676	647	4,527	1,294	5,174	1,940	1,940		80,198	-30.00%	50.00%	56,139	120,297
30" Diameter Gravity Pipe	48" Diameter Gravity Inlet Pipe		111	lft	Estimate	Class 5	3,065	920	385	484,998	4,850	33,950	9,700	38,800	14,550	14,550		601,398	-30.00%	50.00%	420,979	902,097
8" Diameter Force Main	12" Diameter DI Discharge Force Main		30	lft	Estimate	Class 5	273	82	34	11,675	117	817	233	934	350	350		14,477	-30.00%	50.00%	10,134	21,715
6" Pavement Restoration (Paved)	12" diameter overflow pipe		500	lft	Estimate	Class 5	300	90	38	214,024	2,140	14,982	4,280	17,122	6,421	6,421		265,390	-30.00%	50.00%	185,773	398,085
Parking lot restoration - surface	6" Loam & Seed Restoration to park		1,182	CY	Estimate	Class 5	49	15	6	82,563	826	5,779	1,651	6,605	2,477	2,477		102,378	-30.00%	50.00%	71,664	153,566
Ballfield restoration - equipment	reconstruction little league ballfield		0	LS	Estimate	Class 5	100,000	30,000	12,551	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				257,118	2,571	17,998	5,142	20,569	7,714	7,714		318,826	-30.00%	50.00%	223,178	478,239
Odor Control Equipment	1 GAC unit (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Discharge Pump Station	1 discharge pump station, 3-pump system 2 duty 1 standby, 5.26 MGD capacity		1	LS	Estimate	Class 5	5,300,000	1,590,000	665,197	7,555,197	75,552	528,864	151,104	604,416	226,656	226,656		9,368,444	-30.00%	50.00%	6,557,911	14,052,666
Eqiupment Building	20'x40'?		1	LS	Estimate	Class 5	280,000	84,000	35,142	399,142	3,991	27,940	7,983	31,931	11,974	11,974		494,937	-30.00%	50.00%	346,456	742,405
Contaminated Soil Mitigation	Contaminated Soil Risk -10% of subtotal (Contamination found during adjacentWyatt Facility construction)		10%							2,228,487	22,285	155,994	44,570	178,279	66,855	66,855		2,763,324	-30.00%	50.00%	1,934,327	4,144,986

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate												Accuracy Range % AACE		Accuracy Range $ AACE	
							Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 with Escalation Included to Midpoint 2018 using 3%/yr				
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Near Surface Storage - CSO 104 Tank Dimensions: 225 ft x 105 ft x 12 ft (2.12 MG) SUBTOTAL										**24,513,358**	**245,134**	**1,715,935**	**490,267**	**1,961,069**	**735,401**	**735,401**		**30,396,565**			**21,277,595**	**45,594,847**
Near Surface Storage - CSO 210 Tank Dimensions (irregular): 72,700 ft2 x 14 ft (7.21MG)																						
Groundwater Level	14 Ft BGS		1	LS			200,000	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553		353,526	-30.00%	50.00%	247,468	530,289
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume		76,500	CY	Estimate	Class 5	21	6	3	2,290,080	22,901	160,306	45,802	183,206	68,702	68,702		2,839,699	-30.00%	50.00%	1,987,789	4,259,549
Rock Removal	5% minimum assumption, not encountered in nearest borings		3,825	CY	Estimate	Class 5	32	10	4	174,482	1,745	12,214	3,490	13,959	5,234	5,234		216,358	-30.00%	50.00%	151,451	324,537
Crushed Stone Bedding	12" Crushed Stone Bedding		2,814	CY	Estimate	Class 5	30	9	4	120,360	1,204	8,425	2,407	9,629	3,611	3,611		149,247	-30.00%	50.00%	104,473	223,870
Structural Concrete (326'L x 180'W x 12'D)	Structural Concrete		2,684	CY	Estimate	Class 5	1,257	377	158	4,809,365	48,094	336,656	96,187	384,749	144,281	144,281		5,963,612	-30.00%	50.00%	4,174,528	8,945,418
Backfill	Backfill		7,546	CY	Estimate	Class 5	5	2	1	53,785	538	3,765	1,076	4,303	1,614	1,614		66,694	-30.00%	50.00%	46,686	100,041
54" Diameter Gravity Pipe	48" Diameter Gravity Inlet Pipe		468	lft	Estimate	Class 5	3,113	934	391	2,076,934	20,769	145,385	41,539	166,155	62,308	62,308		2,575,399	-30.00%	50.00%	1,802,779	3,863,098
10" Diameter Force Main	12" Diameter DI Discharge Force Main		450	lft	Estimate	Class 5	273	82	34	175,124	1,751	12,259	3,502	14,010	5,254	5,254		217,153	-30.00%	50.00%	152,007	325,730
6" Pavement Restoration (Paved)	12" diameter overflow pipe		0	lft	Estimate	Class 5	300	90	38	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
6" Pavement Restoration (Paved)	6" Loam & Seed Restoration to park		1,500	CY	Estimate	Class 5	49	15	6	104,775	1,048	7,334	2,095	8,382	3,143	3,143		129,921	-30.00%	50.00%	90,945	194,881
Ballfield restoration - equipment	reconstruction little league ballfield		0	LS	Estimate	Class 5	100,000	30,000	12,551	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				567,654	5,677	39,736	11,353	45,412	17,030	17,030		703,891	-30.00%	50.00%	492,724	1,055,837
Odor Control Equipment	1 GAC unit (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Discharge Pump Station	1 discharge pump station, 3-pump system 2 duty 1 standby, 5.26 MGD capacity		1	LS	Estimate	Class 5	5,300,000	1,590,000	665,197	7,555,197	75,552	528,864	151,104	604,416	226,656	226,656		9,368,444	-30.00%	50.00%	6,557,911	14,052,666
Eqiupment Building	20'x40'?		1	LS	Estimate	Class 5	280,000	84,000	35,142	399,142	3,991	27,940	7,983	31,931	11,974	11,974		494,937	-30.00%	50.00%	346,456	742,405
Contaminated Soil Mitigation	Contaminated Soil Risk - 10% of subtotal (Contamination found during adjacentWyatt Facility construction)		10%							1,925,348	19,253	134,774	38,507	154,028	57,760	57,760		2,387,431	-30.00%	50.00%	1,671,202	3,581,147
Near Surface Storage - CSO 210 Tank Dimensions (irregular): 72,700 ft2 x 14 ft (7.21MG) SUBTOTAL										**21,178,827**	**211,788**	**1,482,518**	**423,577**	**1,694,306**	**635,365**	**635,365**		**26,261,746**			**18,383,222**	**39,392,619**
Near Surface Storage - CSO 213/214 Tank 225 ft x 160 ft x 12 ft (3.24 MG)																						
Groundwater Level	14 Ft BGS		1	LS			200,000	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553		353,526	-30.00%	50.00%	247,468	530,289
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume		33,292	CY	Estimate	Class 5	21	6	3	996,609	9,966	69,763	19,932	79,729	29,898	29,898		1,235,795	-30.00%	50.00%	865,056	1,853,692
Rock Removal	5% minimum assumption, not encountered in nearest borings		1,665	CY	Estimate	Class 5	32	10	4	75,932	759	5,315	1,519	6,075	2,278	2,278		94,156	-30.00%	50.00%	65,909	141,234
Crushed Stone Bedding	12" Crushed Stone Bedding		1,391	CY	Estimate	Class 5	30	9	4	59,485	595	4,164	1,190	4,759	1,785	1,785		73,761	-30.00%	50.00%	51,633	110,642
Structural Concrete (326'L x 180'W x 12'D)	Structural Concrete		7,166	CY	Estimate	Class 5	1,257	377	158	12,840,886	128,409	898,862	256,818	1,027,271	385,227	385,227		15,922,699	-30.00%	50.00%	11,145,889	23,884,049
Backfill	Backfill		3,386	CY	Estimate	Class 5	5	2	1	24,134	241	1,689	483	1,931	724	724		29,926	-30.00%	50.00%	20,948	44,888
42" Diameter Gravity Pipe	48" Diameter Gravity Inlet Pipe		1,408	lft	Estimate	Class 5	3,662	1,099	460	7,350,422	73,504	514,530	147,008	588,034	220,513	220,513		9,114,523	-30.00%	50.00%	6,380,166	13,671,784
8" Diameter Force Main	12" Diameter DI Discharge Force Main		115	lft	Estimate	Class 5	273	82	34	44,754	448	3,133	895	3,580	1,343	1,343		55,495	-30.00%	50.00%	38,846	83,242
	12" diameter overflow pipe		0	lft	Estimate	Class 5	300	90	38	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
6" Loam & Seed Restoration (Park)	6" Loam & Seed Restoration to park		740	CY	Estimate	Class 5	49	15	6	51,676	517	3,617	1,034	4,134	1,550	1,550		64,078	-30.00%	50.00%	44,855	96,117
Ballfield restoration - equipment	reconstruction little league ballfield		0	LS	Estimate	Class 5	100,000	30,000	12,551	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				1,579,728	15,797	110,581	31,595	126,378	47,392	47,392		1,958,862	-30.00%	50.00%	1,371,203	2,938,293
Odor Control Equipment	1 GAC unit (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Discharge Pump Station	1 discharge pump station, 3-pump system 2 duty 1 standby, 5.26 MGD capacity		1	LS	Estimate	Class 5	5,300,000	1,590,000	665,197	7,555,197	75,552	528,864	151,104	604,416	226,656	226,656		9,368,444	-30.00%	50.00%	6,557,911	14,052,666
Eqiupment Building	20'x40'?		1	LS	Estimate	Class 5	280,000	84,000	35,142	399,142	3,991	27,940	7,983	31,931	11,974	11,974		494,937	-30.00%	50.00%	346,456	742,405
Contaminated Soil Mitigation	Contaminated Soil Risk - 10% of subtotal (Contamination found during adjacentWyatt Facility construction)		10%							3,190,454	31,905	223,332	63,809	255,236	95,714	95,714		3,956,164	-30.00%	50.00%	2,769,314	5,934,245
Near Surface Storage - CSO 213/214 Tank 225 ft x 160 ft x 12 ft (3.24 MG) SUBTOTAL										**35,094,999**	**350,950**	**2,456,650**	**701,900**	**2,807,600**	**1,052,850**	**1,052,850**		**43,517,799**			**30,462,459**	**65,276,699**
Near Surface Storage - CSO 220 Tank 250 ft x 221 ft x 12 ft (4.97 MG)																						
Groundwater Level	14 Ft BGS		1	LS			200,000	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553		353,526	-30.00%	50.00%	247,468	530,289
Diversion Struction	New Diversion Structure		1	EA			300,000	90,000	37,653	427,653	4,277	29,936	8,553	34,212	12,830	12,830		530,289	-30.00%	50.00%	371,202	795,434
Tank Excavation	Total Excavation Volume		78,968	CY	Estimate	Class 5	21	6	3	2,363,955	23,640	165,477	47,279	189,116	70,919	70,919		2,931,304	-30.00%	50.00%	2,051,913	4,396,955
Rock Removal	5% minimum assumption, not encountered in nearest borings		3,948	CY	Estimate	Class 5	32	10	4	180,111	1,801	12,608	3,602	14,409	5,403	5,403		223,337	-30.00%	50.00%	156,336	335,006
Crushed Stone Bedding	12" Crushed Stone Bedding		2,117	CY	Estimate	Class 5	30	9	4	90,520	905	6,336	1,810	7,242	2,716	2,716		112,245	-30.00%	50.00%	78,571	168,367
Structural Concrete (326'L x 180'W x 12'D)	Structural Concrete		9,313	CY	Estimate	Class 5	1,257	377	158	16,688,232	166,882	1,168,176	333,765	1,335,059	500,647	500,647		20,693,408	-30.00%	50.00%	14,485,385	31,040,112
Backfill	Backfill		31,343	CY	Estimate	Class 5	5	2	1	223,397	2,234	15,638	4,468	17,872	6,702	6,702		277,012	-30.00%	50.00%	193,909	415,518
54" Diameter Gravity Pipe	48" Diameter Gravity Inlet Pipe		110	lft	Estimate	Class 5	3,077	923	386	482,494	4,825	33,775	9,650	38,599	14,475	14,475		598,292	-30.00%	50.00%	418,804	897,438
8" Diameter Force Main	12" Diameter DI Discharge Force Main		125	lft	Estimate	Class 5	273	82	34	48,645	486	3,405	973	3,892	1,459	1,459		60,320	-30.00%	50.00%	42,224	90,481
	12" diameter overflow pipe		0	lft	Estimate	Class 5	300	90	38	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Ballfield restoration - surface	6" Loam & Seed Restoration to park		1,182	CY	Estimate	Class 5	49	15	6	82,563	826	5,779	1,651	6,605	2,477	2,477		102,378	-30.00%	50.00%	71,664	153,566
Ballfield restoration - equipment	reconstruction little league ballfield		1	LS	Estimate	Class 5	100,000	30,000	12,551	142,551	1,426	9,979	2,851	11,404	4,277	4,277		176,763	-30.00%	50.00%	123,734	265,145
Additional Surface Restoration Requirements	20% of surface and roadway work		20%	LS	Estimate	Class 5				281,460	2,815	19,702	5,629	22,517	8,444	8,444		349,011	-30.00%	50.00%	244,308	523,516
Odor Control Equipment	1 GAC unit (20'x20' pad)		1	LS	Estimate	Class 5	150,000	45,000	18,826	213,826	2,138	14,968	4,277	17,106	6,415	6,415		265,145	-30.00%	50.00%	185,601	397,717
Discharge Pump Station	1 discharge pump station, 3-pump system 2 duty 1 standby, 5.26 MGD capacity		1	LS	Estimate	Class 5	5,300,000	1,590,000	665,197	7,555,197	75,552	528,864	151,104	604,416	226,656	226,656		9,368,444	-30.00%	50.00%	6,557,911	14,052,666
Eqiupment Building	20'x40'?		1	LS	Estimate	Class 5	280,000	84,000	35,142	399,142	3,991	27,940	7,983	31,931	11,974	11,974		494,937	-30.00%	50.00%	346,456	742,405
Contaminated Soil Mitigation	Contaminated Soil Risk - 10% of subtotal (Contamination found during adjacentWyatt Facility construction)		10%							2,946,485	29,465	206,254	58,930	235,719	88,395	88,395		3,653,641	-30.00%	50.00%	2,557,549	5,480,462
Near Surface Storage - CSO 220 Tank 250 ft x 221 ft x 12 ft (4.97 MG) SUBTOTAL										**32,411,332**	**324,113**	**2,268,793**	**648,227**	**2,592,907**	**972,340**	**972,340**		**40,190,051**			**28,133,036**	**60,285,077**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE: Low	Accuracy Range % AACE: High	Accuracy Range $ AACE: Low	Accuracy Range $ AACE: High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Public/Private GSI Estimate for Sample Area within BVI-3T-3																					
GSI Technology		**Assumptions**																			
Parking Lanes	Excavation & Disposal of Bituminous Asphalt		26,334	CF	5	Class 5	130,578	39,173	16,389	186,140	1,861	13,030	3,723	14,891	5,584	5,584	230,814	-30.00%	50.00%	161,570	346,221
	Excavation & Disposal of Gravel Roadway Base and Soil		147,467	CF	2	Class 5	329,840	98,952	41,398	470,190	4,702	32,913	9,404	37,615	14,106	14,106	583,035	-30.00%	50.00%	408,125	874,553
	Porous Ashpalt (30% void space)		142,200	CF	1	Class 5	196,507	58,952	24,663	280,122	2,801	19,609	5,602	22,410	8,404	8,404	347,352	-30.00%	50.00%	243,146	521,028
	Roadway Asphalt		10,534	CF	7	Class 5	76,827	23,048	9,642	109,518	1,095	7,666	2,190	8,761	3,286	3,286	135,802	-30.00%	50.00%	95,061	203,703
	Roadway Gravel Base		21,067	CF	1	Class 5	18,606	5,582	2,335	26,523	265	1,857	530	2,122	796	796	32,889	-30.00%	50.00%	23,022	49,333
	Concrete Sidewalk	Exp Jt at 20' oc, Tooled Joints at 4' oc	10,534	CF	46	Class 5	489,541	146,862	61,442	697,845	6,978	48,849	13,957	55,828	20,935	20,935	865,328	-30.00%	50.00%	605,729	1,297,992
	Granite Curbing	Assume 20% of Mtl Damaged in Removal will need to be replaced	6,320	LF	64	Class 5	407,271	122,181	51,116	580,568	5,806	40,640	11,611	46,445	17,417	17,417	719,905	-30.00%	50.00%	503,933	1,079,857
	Tree Box Filter	Assumed 48" x 48" tree Filter Box	198	EA	11,609	Class 5	2,298,671	689,601	288,503	3,276,776	32,768	229,374	65,536	262,142	98,303	98,303	4,063,202	-30.00%	50.00%	2,844,241	6,094,803
	Raingarden Bumpout	Assumed a 4' x 8' bump out with, brick edging, 5-3gallon, 10-1gallon and 20 ground cover plants per Raingarden.	27	EA	2,179	Class 5	58,834	17,650	7,384	83,868	839	5,871	1,677	6,709	2,516	2,516	103,997	-30.00%	50.00%	72,798	155,995
	Remove and Reset Catch Basin Frame and Cover	All Frames and Flat Covers replaced per below assumption. Assume 10% of Mtl Damaged in Removal will need to be replaced.	27	EA	2,043	Class 5	55,165	16,550	6,924	78,638	786	5,505	1,573	6,291	2,359	2,359	97,511	-30.00%	50.00%	68,258	146,267
	Remove and Reset Street Signage		27	EA	771	Class 5	20,814	6,244	2,612	29,671	297	2,077	593	2,374	890	890	36,791	-30.00%	50.00%	25,754	55,187
	Traffic Management Plan	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Also Included 1 Traffic Management Plan for site. Labor to sit up only.	3	EA	6,515	Class 5	19,544	5,863	2,453	27,860	279	1,950	557	2,229	836	836	34,547	-30.00%	50.00%	24,183	51,820
Narow Streets	4'-dia perforated Drywell / Infiltration Catch Basin with Grate		37	EA		Class 5	184,657	55,397	23,176	263,230	2,632	18,426	5,265	21,058	7,897	7,897	326,405	-30.00%	50.00%	228,484	489,608
	Excavation & Disposal of Bituminous Asphalt		349	CF		Class 5	275,984	82,795	34,638	393,418	3,934	27,539	7,868	31,473	11,803	11,803	487,838	-30.00%	50.00%	341,486	731,757
	Excavation & Disposal of Gravel Base and Soil		10,113	CF		Class 5	22,646	6,794	2,842	32,282	323	2,260	646	2,583	968	968	40,030	-30.00%	50.00%	28,021	60,045
	3/4" Crushed Stone Backfill		262	CF		Class 5	1,560	468	196	2,224	22	156	44	178	67	67	2,758	-30.00%	50.00%	1,930	4,136
	Roadway Asphalt		2,069	CF		Class 5	17,429	5,229	2,187	24,845	248	1,739	497	1,988	745	745	30,808	-30.00%	50.00%	21,566	46,212
	Roadway Gravel Base		4,137	CF		Class 5	2,940	882	369	4,191	42	293	84	335	126	126	5,197	-30.00%	50.00%	3,638	7,795
	Filter Fabric		6,974	SF		Class 5	1,726	518	217	2,460	25	172	49	197	74	74	3,051	-30.00%	50.00%	2,136	4,576
	Traffic Management	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Labor to setup only.	2	EA		Class 5	10,185	3,056	1,278	14,519	145	1,016	290	1,162	436	436	18,003	-30.00%	50.00%	12,602	27,005
Medians	Excavation and Disposal of Concrete/Bituminous Median		13,014	CF		Class 5	34,220	10,266	4,295	48,781	488	3,415	976	3,902	1,463	1,463	60,488	-30.00%	50.00%	42,342	90,732
	Filter Fabric		8,676	SF		Class 5	2,147	644	269	3,061	31	214	61	245	92	92	3,795	-30.00%	50.00%	2,657	5,693
	Vegetated Swale Material	Assumed 1 ground cover plant per .75 SF	4,338	SF		Class 5	34,367	10,310	4,313	48,990	490	3,429	980	3,919	1,470	1,470	60,748	-30.00%	50.00%	42,524	91,122
	Soil for Plantings		2,169	CF		Class 5	10,168	3,050	1,276	14,495	145	1,015	290	1,160	435	435	17,973	-30.00%	50.00%	12,581	26,960
	2" Crushed Stone		10,845	CF		Class 5	26,465	7,940	3,322	37,726	377	2,641	755	3,018	1,132	1,132	46,780	-30.00%	50.00%	32,746	70,171
	Granite Curbing	Assume 10% of Mtl Damaged in Removal will need to be replaced	238	LF		Class 5	19,708	5,912	2,474	28,094	281	1,967	562	2,248	843	843	34,836	-30.00%	50.00%	24,386	52,255
	Traffic Management	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Labor to setup only.	3	EA		Class 5	15,278	4,583	1,918	21,779	218	1,525	436	1,742	653	653	27,006	-30.00%	50.00%	18,904	40,509
Subtotal							**$4,761,678**			**$6,787,814**	**$67,878**	**$475,147**	**$135,756**	**$543,025**	**$203,634**		**$8,416,889**			**$5,891,822**	**$12,625,334**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Parking Lanes	Excavation & Disposal of Bituminous Asphalt		26,334	CF	5	Class 5	130,578	39,173	16,389	186,140	1,861	13,030	3,723	14,891	5,584	5,584	230,814	-30.00%	50.00%	161,570	346,221
	Excavation & Disposal of Gravel Roadway Base and Soil		147,467	CF	2	Class 5	329,840	98,952	41,398	470,190	4,702	32,913	9,404	37,615	14,106	14,106	583,035	-30.00%	50.00%	408,125	874,553
	Porous Ashpalt (30% void space)		142,200	CF	1	Class 5	196,507	58,952	24,663	280,122	2,801	19,609	5,602	22,410	8,404	8,404	347,352	-30.00%	50.00%	243,146	521,028
	Roadway Asphalt		10,534	CF	7	Class 5	76,827	23,048	9,642	109,518	1,095	7,666	2,190	8,761	3,286	3,286	135,802	-30.00%	50.00%	95,061	203,703
	Roadway Gravel Base		21,067	CF	1	Class 5	18,606	5,582	2,335	26,523	265	1,857	530	2,122	796	796	32,889	-30.00%	50.00%	23,022	49,333
	Concrete Sidewalk	Exp Jt at 20' oc, Tooled Joints at 4' oc	10,534	CF	46	Class 5	489,541	146,862	61,442	697,845	6,978	48,849	13,957	55,828	20,935	20,935	865,328	-30.00%	50.00%	605,729	1,297,992
	Granite Curbing	Assume 20% of Mtl Damaged in Removal will need to be replaced	6,320	LF	64	Class 5	407,271	122,181	51,116	580,568	5,806	40,640	11,611	46,445	17,417	17,417	719,905	-30.00%	50.00%	503,933	1,079,857
	Tree Box Filter	Assumed 48" x 48" tree Filter Box	198	EA	11,609	Class 5	2,298,671	689,601	288,503	3,276,776	32,768	229,374	65,536	262,142	98,303	98,303	4,063,202	-30.00%	50.00%	2,844,241	6,094,803
	Raingarden Bumpout	Assumed a 4' x 8' bump out with, brick edging, 5-3gallon, 10-1gallon and 20 ground cover plants per Raingarden.	27	EA	2,179	Class 5	58,834	17,650	7,384	83,868	839	5,871	1,677	6,709	2,516	2,516	103,997	-30.00%	50.00%	72,798	155,995
	Remove and Reset Catch Basin Frame and Cover	All Frames and Flat Covers replaced per below assumption. Assume 10% of Mtl Damaged in Removal will need to be replaced.	27	EA	2,043	Class 5	55,165	16,550	6,924	78,638	786	5,505	1,573	6,291	2,359	2,359	97,511	-30.00%	50.00%	68,258	146,267
	Remove and Reset Street Signage		27	EA	771	Class 5	20,814	6,244	2,612	29,671	297	2,077	593	2,374	890	890	36,791	-30.00%	50.00%	25,754	55,187
	Traffic Management Plan	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Also Included 1 Traffic Management Plan for site. Labor to sit up only.	3	EA	6,515	Class 5	19,544	5,863	2,453	27,860	279	1,950	557	2,229	836	836	34,547	-30.00%	50.00%	24,183	51,820
Narow Streets	4'-dia perforated Drywell / Infiltration Catch Basin with Grate		37	EA		Class 5	184,657	55,397	23,176	263,230	2,632	18,426	5,265	21,058	7,897	7,897	326,405	-30.00%	50.00%	228,484	489,608
	Excavation & Disposal of Bituminous Asphalt		349	CF		Class 5	275,984	82,795	34,638	393,418	3,934	27,539	7,868	31,473	11,803	11,803	487,838	-30.00%	50.00%	341,486	731,757
	Excavation & Disposal of Gravel Base and Soil		10,113	CF		Class 5	22,646	6,794	2,842	32,282	323	2,260	646	2,583	968	968	40,030	-30.00%	50.00%	28,021	60,045
	3/4" Crushed Stone Backfill		262	CF		Class 5	1,560	468	196	2,224	22	156	44	178	67	67	2,758	-30.00%	50.00%	1,930	4,136
	Roadway Asphalt		2,069	CF		Class 5	17,429	5,229	2,187	24,845	248	1,739	497	1,988	745	745	30,808	-30.00%	50.00%	21,566	46,212
	Roadway Gravel Base		4,137	CF		Class 5	2,940	882	369	4,191	42	293	84	335	126	126	5,197	-30.00%	50.00%	3,638	7,795
	Filter Fabric		6,974	SF		Class 5	1,726	518	217	2,460	25	172	49	197	74	74	3,051	-30.00%	50.00%	2,136	4,576
	Traffic Management	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Labor to setup only.	2	EA		Class 5	10,185	3,056	1,278	14,519	145	1,016	290	1,162	436	436	18,003	-30.00%	50.00%	12,602	27,005
Medians	Excavation and Disposal of Concrete/Bituminous Median		13,014	CF		Class 5	34,220	10,266	4,295	48,781	488	3,415	976	3,902	1,463	1,463	60,488	-30.00%	50.00%	42,342	90,732
	Filter Fabric		8,676	SF		Class 5	2,147	644	269	3,061	31	214	61	245	92	92	3,795	-30.00%	50.00%	2,657	5,693
	Vegetated Swale Material	Assumed 1 ground cover plant per .75 SF	4,338	SF		Class 5	34,367	10,310	4,313	48,990	490	3,429	980	3,919	1,470	1,470	60,748	-30.00%	50.00%	42,524	91,122
	Soil for Plantings		2,169	CF		Class 5	10,168	3,050	1,276	14,495	145	1,015	290	1,160	435	435	17,973	-30.00%	50.00%	12,581	26,960
	2" Crushed Stone		10,845	CF		Class 5	26,465	7,940	3,322	37,726	377	2,641	755	3,018	1,132	1,132	46,780	-30.00%	50.00%	32,746	70,171
	Granite Curbing	Assume 10% of Mtl Damaged in Removal will need to be replaced	238	LF		Class 5	19,708	5,912	2,474	28,094	281	1,967	562	2,248	843	843	34,836	-30.00%	50.00%	24,386	52,255
	Traffic Management	Assumed 50 of Plastic Jersy Barrier, 2 large signs and 2 med signs per Traffi Management location. Labor to setup only.	3	EA		Class 5	15,278	4,583	1,918	21,779	218	1,525	436	1,742	653	653	27,006	-30.00%	50.00%	18,904	40,509
Subtotal							**$4,761,678**			**$6,787,814**	**$67,878**	**$475,147**	**$135,756**	**$543,025**	**$203,634**		**$8,416,889**			**$5,891,822**	**$12,625,334**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Construction Cost Estimate			Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total											
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Private Property GSI					PARE												19.35%				
																	124.00%	6,787,814			
Porous Pavement & Bioretention Parking Lots - (3 at 20,000 SF) (50 Spaces) Average	Excavation & Disposal of Bituminous Asphalt	20,000 SF by 4" deep asphalt disposal	6,667	SY	$ 6.00		$ 40,000.00	12,000	5,020	57,020	570	3,991	1,140	4,562	1,711	1,711	70,705	-30.00%	50.00%	49,494	106,058
	Excavation & Disposal of Gravel Roadway Base and Soil	20,000 SF by 12" deep gravel subbase beneath porous asphalt disposal	2,222	CY	$ 9.50		$ 21,200.00	6,360	2,661	30,221	302	2,115	604	2,418	907	907	37,474	-30.00%	50.00%	26,232	56,211
	Porous Ashpalt (30% void space)	20,000 SF by 4" deep with 30% void space	6,667	SY	$ 34.50		$ 230,000.00	69,000	28,867	327,867	3,279	22,951	6,557	26,229	9,836	9,836	406,555	-30.00%	50.00%	284,589	609,833
	Gravel Base	20,000 SF by 16" deep base course (4" of 3/4" dia washed crush stone, 8" AASHTO M-6 Sand Filter Course, 4" of 3/8" dia washed crushed stone) under porous asphalt	2,956	CY	$ 40.00		$ 118,300.00	35,490	14,848	168,638	1,686	11,805	3,373	13,491	5,059	5,059	209,111	-30.00%	50.00%	146,378	313,666
	Concrete Curbing	100 LF of 6" precast curbing per Bioretention System	1,200	LF	$ 25.00		$ 30,000.00	9,000	3,765	42,765	428	2,994	855	3,421	1,283	1,283	53,029	-30.00%	50.00%	37,120	79,543
	Raingarden/Bioretention Area	1 Bioretention Area per 5,000 S.F of parking surface (260 SF of surface area) includes excavation	336	CY	$ 9.50		$ 3,200.00	960	402	4,562	46	319	91	365	137	137	5,656	-30.00%	50.00%	3,959	8,485
	Soil/Plantings	36" Bioretention Soil Media - 75% plant coverage	12	EA	$ 2,500.00		$ 30,000.00	9,000	3,765	42,765	428	2,994	855	3,421	1,283	1,283	53,029	-30.00%	50.00%	37,120	79,543
	Install Catch Basin Frame and Cover	1 CB Frame and Cover per Bioretention System	12	EA	$ 2,500.00		$ 30,000.00	9,000	3,765	42,765	428	2,994	855	3,421	1,283	1,283	53,029	-30.00%	50.00%	37,120	79,543
	Install Drainage Pipe to existing storm drainage system	100 LF of 12" HDPE drain line per Bioretention System	1,200	LF	$ 55.00		$ 66,000.00	19,800	8,284	94,084	941	6,586	1,882	7,527	2,823	2,823	116,664	-30.00%	50.00%	81,665	174,995
	Parking Lot ReStriping	4" White Epoxy Resin Markings - 36 LF per parking space	5,400	LF	$ 0.40		$ 2,200.00	660	276	3,136	31	220	63	251	94	94	3,889	-30.00%	50.00%	2,722	5,833
								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Ribbon Residential Driveways (15 at 12' W x 50' L) Average								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	Excavation & Disposal of Bituminous Asphalt	4' wide by 3" deep excavation and disposal	335	SY	$ 6.00		$ 2,100.00	630	264	2,994	30	210	60	239	90	90	3,712	-30.00%	50.00%	2,598	5,568
	Excavation & Disposal of Compacted Gravel Base and Soil	4' wide by 12" excavation and disposal of material	115	CY	$ 9.50		$ 1,100.00	330	138	1,568	16	110	31	125	47	47	1,944	-30.00%	50.00%	1,361	2,917
	3/4" Crushed Stone Backfill	4' wide by 8" deep 3/4" crushed stone for drainage	75	CY	$ 40.50		$ 3,100.00	930	389	4,419	44	309	88	354	133	133	5,480	-30.00%	50.00%	3,836	8,219
	Loam & Seed	4" Loam and Seed	335	SY	$ 4.60		$ 1,600.00	480	201	2,281	23	160	46	182	68	68	2,828	-30.00%	50.00%	1,980	4,242
								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Green Roof (2 at 5,000 SF)								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	Intallation of extensive low profile green roof components (Includes Removal of existing roof membrane)		10,000	SF	$ 20.00		$ 200,000.00	60,000	25,102	285,102	2,851	19,957	5,702	22,808	8,553	8,553	353,526	-30.00%	50.00%	247,468	530,289
	1. Structural Support							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	2. Vapor Barrier							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	3. Thermal Insulation							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	4. Cover Board							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	5. Waterproof membrane							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	6. Root barrier							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	7. Drainge Layer							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	8. Filter Membrane							0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	9. Growing Medium	Low growth media 2-6"						0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	10. Vegetation	Low growing plants 13-50 lbs/sf						0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Residential Rain Garden (15 at 1,500 SF of Roof Area)								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
	Removal of Lawn and Top Soil	Removal of 6" of lawn and top soil	25	CY	$ 18.50		$ 500.00	150	63	713	7	50	14	57	21	21	884	-30.00%	50.00%	619	1,326
	Excavation for Raingarden	Excavation per 1,500 of roof area treated for water quality (80 sf of surface area)	70	CY	$ 9.50		$ 700.00	210	88	998	10	70	20	80	30	30	1,237	-30.00%	50.00%	866	1,856
	Soil/Plantings	36" Bioretention Soil Media - 75% plant coverage	15	Ea	$ 771.00		$ 11,600.00	3,480	1,456	16,536	165	1,158	331	1,323	496	496	20,505	-30.00%	50.00%	14,353	30,757
	Lawn loam & reseeding around edges	Loam and reseed damaged areas	85	SY	$ 4.60		$ 400.00	120	50	570	6	40	11	46	17	17	707	-30.00%	50.00%	495	1,061
								0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Subtotal							**$792,000**			**$1,129,003**	**$11,290**	**$79,030**	**$22,580**	**$90,320**	**$13,655**	**$33,870**	**$1,399,964**			**$979,975**	**$2,099,946**

GSI Implementation Extrapolation

Basin	CSO	Area	All GSI	Public GSI	Private GSI	Public GSI Unit Cost*	Private GSI Unit Cost*	Public GSI Basin Cost	Private GSI Basin Cost	Full GSI Basin Cost
			29,727,382	*7,894,296*				*321,297,828*	*240,163,955*	*561,461,783*
(ID)		(acres)	(gal)	(gal)	(gal)	($/gal)	($/gal)	($)	($)	($)
BVI-1T-1	N/A	46.41	301,678	75,420	226,259	$40.7	$11.0	$3,069,579	$2,488,848	$5,558,426
BVI-6T-2	101	57.84	375,942	93,986	281,957	$40.7	$11.0	$3,825,210	$3,101,522	$6,926,732
BVI-6T-1	103	203.76	1,609,719	509,405	1,100,314	$40.7	$11.0	$20,732,777	$12,103,459	$32,836,236
BVI-4T-1A	104	50.52	328,393	82,098	246,295	$40.7	$11.0	$3,341,401	$2,709,244	$6,050,646
BVI-5T-1	105	58.17	378,109	94,527	283,582	$40.7	$11.0	$3,847,256	$3,119,397	$6,966,653
MVI-6T-1-106-1	106	30.24	90,706	22,676	68,029	$40.7	$11.0	$922,933	$748,324	$1,671,257
MVI-6T-1-106-2	106	74.70	224,108	56,027	168,081	$40.7	$11.0	$2,280,299	$1,848,891	$4,129,191
MVI-6T-1-106-3	106	67.69	203,065	50,766	152,299	$40.7	$11.0	$2,066,187	$1,675,287	$3,741,474
MVI-6T-1-107	107	103.98	1,013,828	253,457	760,371	$40.7	$11.0	$10,315,705	$8,364,085	$18,679,789
BVI-7T-1-201	201	81.11	263,611	65,903	197,708	$40.7	$11.0	$2,682,238	$2,174,787	$4,857,025
BVI-7T-1-202	202	4.01	26,066	6,517	19,550	$40.7	$11.0	$265,223	$215,045	$480,268
BVI-4T-1-203	203	37.84	245,946	61,486	184,459	$40.7	$11.0	$2,502,500	$2,029,054	$4,531,553
BVI-4T-1-205	205	969.80	6,303,669	1,575,917	4,727,752	$40.7	$11.0	$64,139,831	$52,005,268	$116,145,099
MVI-1T-4-206	206	13.76	13,765	6,882	6,882	$40.7	$11.0	$280,113	$75,706	$355,819
BVI-3T-5-207	207	18.91	122,932	30,733	92,199	$40.7	$11.0	$1,250,835	$1,014,191	$2,265,026
MVI-1T-4-208	208	5.07	8,241	8,241	0	$40.7	$11.0	$335,393	$0	$335,393
BVI-3T-5-209	209	34.44	223,848	55,962	167,886	$40.7	$11.0	$2,277,656	$1,846,748	$4,124,405
MVI-1T-4-210	210	193.43	193,432	96,716	96,716	$40.7	$11.0	$3,936,340	$1,063,876	$5,000,215
BVI-3T-4	212	49.05	318,830	79,707	239,122	$40.7	$11.0	$3,244,093	$2,630,346	$5,874,439
MVI-1T-2-213	213	16.67	50,003	12,501	37,502	$40.7	$11.0	$508,779	$412,523	$921,302
MVI-1T-3	213	123.64	370,916	92,729	278,187	$40.7	$11.0	$3,774,070	$3,060,057	$6,834,127
MVI-1T-4-213	213	3.01	3,014	1,507	1,507	$40.7	$11.0	$61,327	$16,575	$77,902
MVI-1T-4-214-1	214	5.10	5,097	2,548	2,548	$40.7	$11.0	$103,718	$28,032	$131,750
MVI-1T-4-214-2	214	3.61	3,607	1,803	1,803	$40.7	$11.0	$73,395	$19,836	$93,232
MVI-1T-4-214-3	214	8.64	8,644	4,322	4,322	$40.7	$11.0	$175,895	$47,539	$223,435
MVI-1T-4-214-4	214	20.44	33,213	33,213	0	$40.7	$11.0	$1,351,777	$0	$1,351,777
BVI-3T-3	215	102.59	845,377	207,241	638,137	$40.7	$11.0	$8,434,692	$7,019,506	$15,454,198
BVI-3T-2	216	38.39	249,553	62,388	187,165	$40.7	$11.0	$2,539,203	$2,058,813	$4,598,017
MVI-1T-1	217	132.65	596,907	149,227	447,680	$40.7	$11.0	$6,073,529	$4,924,483	$10,998,012
MVI-1T-2-217	217	29.14	189,394	47,349	142,046	$40.7	$11.0	$1,927,088	$1,562,504	$3,489,592
BVI-2AT-1	218	1009.84	3,281,993	820,498	2,461,494	$40.7	$11.0	$33,394,275	$27,076,439	$60,470,715
BVI-2T-1	218	525.64	5,124,995	1,281,249	3,843,746	$40.7	$11.0	$52,146,822	$42,281,207	$94,428,030
MVI-2T-1	220	294.42	1,472,107	363,611	1,108,497	$40.7	$11.0	$14,798,949	$12,193,466	$26,992,415
MVI-2T-2	220	188.35	1,940,034	538,689	1,401,345	$40.7	$11.0	$21,924,648	$15,414,797	$37,339,445
MVI-2T-3	220	23.46	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-3T-1	220	124.66	373,979	93,495	280,485	$40.7	$11.0	$3,805,240	$3,085,330	$6,890,569
MVI-4T-1	220	338.12	1,149,607	236,684	912,924	$40.7	$11.0	$9,633,034	$10,042,159	$19,675,193
MVI-4T-2	220	124.89	811,757	202,939	608,818	$40.7	$11.0	$8,259,626	$6,696,994	$14,956,621
MVI-4T-3	220	55.34	166,034	41,508	124,525	$40.7	$11.0	$1,689,393	$1,369,778	$3,059,172
MVI-4T-4	220	60.07	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-7T-1	220	4288.27	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-7T-A	220	1174.67	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-7T-B	220	1171.70	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-7T-C	220	1230.89	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-7T-D	220	711.04	0	0	0	$40.7	$11.0	$0	$0	$0
BVI-3T-1	N/A	13.75	89,389	22,347	67,042	$40.7	$11.0	$909,530	$737,457	$1,646,987
BVI-6T-1A	N/A	9.49	0	0	0	$40.7	$11.0	$0	$0	$0
MVI-5T-1		422.28	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-1T-1		499.10	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-2T-1		95.82	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-2T-2		149.62	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-2T-3		233.33	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-2T-4		23.29	0	0	0	$40.7	$11.0	$0	$0	$0
EPI-2T-5		615.37	0	0	0	$40.7	$11.0	$0	$0	$0
ARI-1T			0	0	0	$40.7	$11.0	$0	$0	$0
BVI-8T			0	0	0	$40.7	$11.0	$0	$0	$0
BDI-1T			0	0	0	$40.7	$11.0	$0	$0	$0
BDI-2T			0	0	0	$40.7	$11.0	$0	$0	$0

Providence	035	137.00	199,351	51,768	147,583	$40.7	$11.0	$2,106,960	$1,623,411	$3,730,371
Providence	039	102.00	167,371	89,270	78,101	$40.7	$11.0	$3,633,272	$859,111	$4,492,383
Providence	056	69.00	349,153	310,984	38,169	$40.7	$11.0	$12,657,035	$419,858	$13,076,893

* *all unit costs are in 2018 dollars*

Narragansett Bay Commission - Phase III Reevaluation
Alternatives Evaluation
Subsystem & Scenario Planner

	Source Control											
	Model Run:	Existing system, w & w/o source controls. 23 July 2014 runs										
	Cost Estimate:											
	No GSI	Public Way GSI				Full GSI				Private GSI		
Outfall	CSO Volume (MG)	CSO Volume (MG)	Controled Volume (MG)	Cap. Cost ($M)	O&M Cost ()	CSO Volume (MG)	Controled Volume (MG)	Cap. Cost ($M)	O&M Cost ()	Controled Volume (MG)	Cap. Cost ($M)	O&M Cost ()
35	0.77	0.75	0.02			0.68	0.09	$0	$0	0.07		
36	0.10	0.10	0.00			0.10	0.00	$0	$0	0.00		
39	0.46	0.44	0.02			0.43	0.03	$0	$0	0.01		
56	0.42	0.39	0.03			0.38	0.04	$0	$0	0.01		
101	0.38	0.32	0.06	$3,825,210		0.17	0.21	$6,926,732	$0	0.15	$3,101,522	
103	4.88	4.49	0.38	$20,732,777		3.64	1.24	$32,836,236	$0	0.86	$12,103,459	
104	0.49	0.41	0.07	$3,341,401		0.22	0.27	$6,050,646	$0	0.20	$2,709,244	
105	1.64	1.55	0.09	$3,847,256		1.32	0.32	$6,966,653	$0	0.23	$3,119,397	
107	0.37	0.33	0.04	$10,315,705		0.27	0.11	$18,679,789	$0	0.06	$8,364,085	
201	1.34	1.29	0.05	$2,682,238		1.13	0.21	$4,857,025	$0	0.16	$2,174,787	
202	0.17	0.16	0.01	$265,223		0.13	0.04	$480,268	$0	0.03	$215,045	
203	0.40	0.35	0.05	$2,502,500		0.23	0.16	$4,531,553	$0	0.11	$2,029,054	
204	0.16	0.08	0.08	$0		0.01	0.15	$0	$0	0.07	$0	
205	12.81	11.82	1.00	$64,139,831		8.73	4.09	$116,145,099	$0	3.09	$52,005,268	
206	0.14	0.14	0.00	$280,113		0.13	0.01	$355,819	$0	0.00	$75,706	
207	0.04	0.03	0.01	$1,250,835		0.01	0.04	$2,265,026	$0	0.02	$1,014,191	
208	0.01	0.01	0.00	$335,393		0.01	0.00	$335,393	$0	0.00	$0	
209	0.02	0.01	0.01	$2,277,656		0.00	0.02	$4,124,405	$0	0.01	$1,846,748	
210	3.17	3.11	0.06	$3,936,340		3.05	0.12	$5,000,215	$0	0.06	$1,063,876	
211	3.96	3.93	0.03	$0		3.90	0.06	$0	$0	0.03	$0	
212	0.60	0.54	0.06	$3,244,093		0.35	0.25	$5,874,439	$0	0.18	$2,630,346	
213	1.97	1.86	0.11	$4,344,176		1.59	0.39	$7,833,331	$0	0.27	$3,489,155	
214	1.26	1.04	0.22	$1,704,786		0.56	0.70	$1,800,193	$0	0.48	$95,408	
215	1.58	1.39	0.18	$8,434,692		0.83	0.75	$15,454,198	$0	0.56	$7,019,506	
216	0.01	0.00	0.01	$2,539,203		0.00	0.01	$4,598,017	$0	0.00	$2,058,813	
217	2.71	2.49	0.22	$8,000,617		1.96	0.75	$14,487,604	$0	0.54	$6,486,987	
218	12.58	10.68	1.90	$85,541,098		4.93	7.65	$154,898,744	$0	5.75	$69,357,647	
220	4.60	3.85	0.75	$60,110,890		1.87	2.73	$108,913,415	$0	1.97	$48,802,524	

	CSO Volume (MG)					
Outfall	No Source Control	Public Way GSI	Full GSI			All GSI Unhindered (MG)
35	0.77	0.75	0.68	0.002775228	0.003	0.00
36	0.10	0.10	0.10	0.115777906	0.120	0.01
39	0.46	0.44	0.43	0.003269365	0.004	0.00
56	0.42	0.39	0.38	0.015813056	0.017	0.01
101	0.38	0.32	0.17			
103	**4.88**	4.49	3.64	0.027088169	0.036	0.13
104	0.49	0.41	0.22	0.015466575	0.035	0.01
105	1.64	1.55	1.32	0.000427472	0.001	0.00
107	0.37	0.33	0.27	0.012635577	0.018	0.00
201	1.34	1.29	1.13	0.003632209	0.004	0.00
202	0.17	0.16	0.13	2.361796967	3.159	0.41
203	0.40	0.35	0.23			
204	0.16	0.08	0.01			
205	**12.81**	11.82	8.73	0.000236358	0.000	0.00
206	0.14	0.14	0.13	2.501147163	2.666	0.35
207	0.04	0.03	0.01			
208	0.01	0.01	0.01	0.375210081	0.444	0.01
209	0.02	0.01	0.00	44.65609353	698.296	1.05
210	**3.17**	3.11	3.05	0.261834435	0.272	0.83
211	**3.96**	3.93	3.90	0.308502424	0.313	1.22
212	0.60	0.54	0.35	2.226450999	3.781	1.33
213	1.97	1.86	1.59	0.821389006	1.021	1.62
214	1.26	1.04	0.56	2.417578776	5.424	3.05
215	1.58	1.39	0.83	2.47524277	4.697	3.90
216	0.01	0.00	0.00	207.5158595	866.631	1.85
217	2.71	2.49	1.96	0.867873166	1.203	2.35
218	**12.58**	10.68	4.93	0.060879077	0.155	0.77
220	**4.60**	3.85	1.87	1.786272004	4.386	8.22
Volume Controlled:		10%	34%			

	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%

Na
Alt
Sut

Baseline Tunnel Scenario - BT1

Capital Cost	Annual O&M Cost	Design Capacity (MG)	CSO Control Solution	CSOs Controled
$19,181,969	$12,517	0.77	035 Sewer separation	035
$24,682,089	$5,617	0.46	039-056 Sewer separation	039
$16,485,123	$3,721	0.42	039-056 Sewer separation	056
$6,466,988	$1,182	0.14	206 Sewer separation	206
$9,989,013	$4,830	5.26	Upper High & Cross St interceptor	101, 103
$13,688,921	$4,830	5.74	Lower High & Cross St interceptor	101, 103, 104
$15,394,325	$4,830	1.91	Middle St interceptor	201, 202, 203
$23,919,436	$0	22.27	Drop shaft 205 & conduit	101, 103, 104, 105, 201, 202, 203, 204, 205
$27,301,091	$0	7.21	Drop shaft 210/211 & conduit	207, 208, 209, 210, 211
$41,619,159	$0	3.24	Drop shaft 213 & conduit	213, 214
$59,525,355	$18,860	4.97	Pawtucket Ave interceptor	107, 220
$47,107,149	$0	7.68	Drop shaft 217 & conduit	107, 217, 220
$47,625,870	$0	14.76	Drop shaft 218 & conduit	212, 215, 216, 218
$0	$0	0.00	No Source control	
$387,024,483	$433,500	55.16	Baseline Pawtucket tunnel	101 - 107, 201 - 205, 207 - 220
$719,426	$50,000	6.58	Regulator modification	101, 107, 202, 204, 207, 208, 209, 212, 214, 215
$740,730,396				

Baseline Tunnel Scenario - BT1

Model Run: BPSA-1 & FPSA-1 - No source control (23 July 2014 run)

Cost Estimate: Complete 12 Aug 2014 - Midpoint of construction 2018

Outfall	Source Controls	CSO Volume (MG)	CSO Control Solution	Systematic / Receptor Control Requirement	Secondary Requirement
35	No GSI	0.77	Sewer separation		
36	No GSI	0.10	Regulator modification	Phase II 037 separation	
39	No GSI	0.46	Sewer separation		
56	No GSI	0.42	Sewer separation		
101	No GSI	0.38	Regulator modification	Baseline Pawtucket tunnel	Capcity in BVI + High & Cross St interceptor
103	No GSI	4.88	Upper High & Cross St interceptor	Baseline Pawtucket tunnel	Lower High & Cross St interceptor
104	No GSI	0.49	Lower High & Cross St interceptor	Baseline Pawtucket tunnel	
105	No GSI	1.64	Drop shaft 205 & conduit	Baseline Pawtucket tunnel	Conduit river crossing
107	No GSI	0.37	Regulator modification	Baseline Pawtucket tunnel	Capacity in MVI + Pawtucket Ave interceptor
201	No GSI	1.34	Middle St interceptor	Baseline Pawtucket tunnel	
202	No GSI	0.17	Regulator modification	Baseline Pawtucket tunnel	Capcity in BVI + Middle St interceptor
203	No GSI	0.40	Middle St interceptor	Baseline Pawtucket tunnel	
204	No GSI	0.16	Regulator modification	Baseline Pawtucket tunnel	Drop shaft 205 & conduit
205	No GSI	12.81	Drop shaft 205 & conduit	Baseline Pawtucket tunnel	
206	No GSI	0.14	Sewer separation		
207	No GSI	0.04	Regulator modification	Baseline Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
208	No GSI	0.01	Regulator modification	Baseline Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
209	No GSI	0.02	Regulator modification	Baseline Pawtucket tunnel	Capacity in TPI/BVI + Drop shaft 210/211
210	No GSI	3.17	Drop shaft 210/211 & conduit	Baseline Pawtucket tunnel	
211	No GSI	3.96	Drop shaft 210/211 & conduit	Baseline Pawtucket tunnel	
212	No GSI	0.60	Regulator modification	Baseline Pawtucket tunnel	Capacity in BVI + Drop shaft 218
213	No GSI	1.97	Drop shaft 213 & conduit	Baseline Pawtucket tunnel	
214	No GSI	1.26	Regulator modification	Baseline Pawtucket tunnel	Capacity in TPI + Drop shaft 213
215	No GSI	1.58	Regulator modification	Baseline Pawtucket tunnel	Capacity in BVI + Drop shaft 218
216	No GSI	0.01	Regulator modification	Baseline Pawtucket tunnel	Capacity in BVI + Drop shaft 218
217	No GSI	2.71	Drop shaft 217 & conduit	Baseline Pawtucket tunnel	
218	No GSI	12.58	Drop shaft 218 & conduit	Baseline Pawtucket tunnel	
220	No GSI	4.60	Pawtucket Ave interceptor	Baseline Pawtucket tunnel	Drop shaft 217 & conduit

1) Matches "Baseline" cost estimate

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

Na
Alt
Sub

No Tunnel Scenario - NT1

Cap. Cost ($M)	Annual O&M Cost	Controled Volume (MG)	Design Capacity (MG)	CSO Control Solution	CSOs Controled
$24,707,386	$16,428		0.77	035 Hybrid GSI / Sewer separation	035
$21,844,330	$5,203		0.46	039-056 Hybrid GSI / Sewer separation	039
$16,018,462	$2,719		0.42	039-056 Hybrid GSI / Sewer separation	056
$4,920,420	$7,709		0.14	206 Hybrid GSI / Parking lot stormwater tanks /	206
$62,931,338	$120,100		5.26	High Street Tank	101, 103
$50,154,331	$87,900		2.12	Webbing Mills Tank	104, 105
$38,580,255	$79,600		1.26	East Street Tank (Viper VoIP Corporation)	201, 202
$119,694,047	$179,600		8.97	Front St Tank with GSI	203, 204, 205
$43,331,881	$140,000		7.21	City Hall Tank	207, 208, 209, 210, 211
$71,804,368	$99,400		3.24	213 Tank	213, 214
$66,313,585	$117,100		4.97	Morley Field Tank	107, 220
$36,009,270	$94,000		2.71	Tidewater Above-ground Tank	217
$161,684,447	$227,300		14.02	Bucklin Point Landfil Tank	212, 215, 216, 218
$144,115,578	$1,122,416	5.40		GSI in select sewersheds	039, 056, 201, 202, 203, 204, 205, 206, 215
$0	$0		0.00	Tunnel	
$583,318	$50,000			Regulator modifications	036, 101, 107, 204, 207, 208, 209, 212, 215, 216

No Tunnel Scenario - NT1

Model Run:

Cost Estimate: Provide design data for large grey alts. to Tony P.

Outfall	Source Controls	Controled Volume (MG)	CSO Volume (MG)	CSO Control Solution	Systematic / Receptor Control Requirement	Secondary Requirement
35	No GSI	0.00	0.77	035 Hybrid GSI / Sewer separation		Hydraulic controls
36	No GSI	0.00	0.10	Regulator modifications	Phase II 037 separation	
39	No GSI	0.00	0.46	039-056 Hybrid GSI / Sewer separation		
56	No GSI	0.00	0.42	039-056 Hybrid GSI / Sewer separation		
101	No GSI	0.00	0.38	Regulator modifications		High Street Tank
103	No GSI	0.00	4.88	High Street Tank		
104	No GSI	0.00	0.49	Webbing Mills Tank		High Street Tank
105	No GSI	0.00	1.64	Webbing Mills Tank		High Street Tank
107	No GSI	0.00	0.37	Regulator modifications		Middle St interceptor + Front St Tank / S&D
201	Full GSI	0.21	1.13	East Street Tank (Viper VoIP Corporation)		
202	Full GSI	0.04	0.13	East Street Tank (Viper VoIP Corporation)		
203	Full GSI	0.16	0.23	Lower Middle St interceptor		Front St Tank with GSI
204	Full GSI	0.15	0.01	Regulator modifications		Front St Tank with GSI
205	Full GSI	4.09	8.73	Front St Tank with GSI		
206	No GSI	0.00	0.14	206 Hybrid GSI / Parking lot stormwater tanks / Sewer		Hydraulic controls
207	No GSI	0.00	0.04	Regulator modifications	City Hall Tank	Capacity in TPI/MVI
208	No GSI	0.00	0.01	Regulator modifications	City Hall Tank	Capacity in TPI/MVI
209	No GSI	0.00	0.02	Regulator modifications	City Hall Tank	Capacity in TPI/MVI
210	No GSI	0.00	3.17	City Hall Tank		
211	No GSI	0.00	3.96	City Hall Tank		
212	No GSI	0.00	0.60	Regulator modifications	Bucklin Point Landfil Tank	Capacity in BVI + Bucklin Point Landfill Tank / T&D
213	No GSI	0.00	1.97	213 Tank		
214	No GSI	0.00	1.26	213 Tank		
215	Full GSI	0.75	0.83	Regulator modifications	Bucklin Point Landfil Tank	Capacity in BVI + Bucklin Point Landfill Tank / T&D
216	No GSI	0.00	0.01	Regulator modifications	Bucklin Point Landfil Tank	Capacity in BVI + Bucklin Point Landfill Tank / T&D
217	No GSI	0.00	2.71	Tidewater Above-ground Tank		
218	No GSI	0.00	12.58	Bucklin Point Landfil Tank		
220	No GSI	0.00	4.60	Morley Field Tank		

1A) Defines upper limit design capacity for grey alts. (for 3-month storm design basis)

Controled Vo	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

Na
Alt
Sub

Tunnel Alternative Scenario One -TA1

Cap. Cost ($M)	Annual O&M Cost	Controled Volume (MG)	Design Capacity (MG)	CSO Control Solution	CSOs Controled
$19,181,969	$12,517		0.77	035 Sewer separation	035
$17,440,861	$4,830		0.46	West River Interceptor	039
$17,440,861	$4,830		0.42	West River Interceptor	056
$6,466,988	$1,182		0.14	206 Hybrid GSI / Parking lot stormwat	206
$9,989,013	$4,830		5.26	Upper High & Cross St interceptor	101, 103
$13,688,921	$4,830		2.12	Lower High & Cross St interceptor	104, 105
$15,394,325	$4,830		1.51	Middle St interceptor	201, 202
$23,919,436	$0		13.37	Drop shaft 205 & conduit	203, 204, 205
$27,301,091	$0		7.21	Drop shaft 210/211 & conduit	207, 208, 209, 210, 211
$41,619,159	$0			Drop shaft 213 & conduit	
$93,000,000	$18,860		4.97	**220 Stub Tunnel**	107, 220 (+039, 056)
$47,107,149	$0		5.95	Drop shaft 217 & conduit	213, 214, 217
$47,625,870	$0		14.76	Drop shaft 218 & conduit	212, 215, 216, 218
$0	$0	0.00		GSI in select sewersheds	
$387,024,483	$433,500		55.30	Baseline Pawtucket tunnel	101 - 107, 201 - 218
$719,426	$50,000			Regulator modifications	036, 101, 107, 202, 204, 207, 208, 209, 212, 215, 216

Stub tunnel cost provided by Tom Brueckner

Tunnel Alternative Scenario One -TA1

Model Run:

Cost Estimate: Provide design data for large grey alts. to Tony P.

Outfall	Source Controls	Controled Volume (MG)	CSO Volume (MG)	CSO Control Solution	Systematic / Receptor Control Requirement	Secondary Requirement
35	No GSI	0.00	0.77	035 Sewer separation		Hydraulic controls
36	No GSI	0.00	0.10	Regulator modifications	Phase II 037 separation	
39	No GSI	0.00	0.46	West River Interceptor		
56	No GSI	0.00	0.42	West River Interceptor		
101	No GSI	0.00	0.38	Regulator modifications		Upper High & Cross St interceptor
103	No GSI	0.00	4.88	Upper High & Cross St interceptor		
104	No GSI	0.00	0.49	Lower High & Cross St interceptor	Alternate Pawtucket Tunnel	
105	No GSI	0.00	1.64	Lower High & Cross St interceptor	Alternate Pawtucket Tunnel	Conduit river crossing
107	No GSI	0.00	0.37	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in MVI + 220 Stub Tunnel
201	No GSI	0.00	1.34	Middle St interceptor	Alternate Pawtucket Tunnel	
202	No GSI	0.00	0.17	Regulator modifications	Alternate Pawtucket Tunnel	Capcity in BVI + Middle St interceptor
203	No GSI	0.00	0.40	Middle St interceptor	Alternate Pawtucket Tunnel	
204	No GSI	0.00	0.16	Regulator modifications	Alternate Pawtucket Tunnel	Drop shaft 205 & conduit
205	No GSI	0.00	12.81	Drop shaft 205 & conduit	Alternate Pawtucket Tunnel	
206	No GSI	0.00	0.14	206 Hybrid GSI / Parking lot stormwater tanks / Sewer	Alternate Pawtucket Tunnel	Capacity in TPI/BVI + Drop shaft 210/211
207	No GSI	0.00	0.04	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in TPI/BVI + Drop shaft 210/211
208	No GSI	0.00	0.01	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in TPI/BVI + Drop shaft 210/211
209	No GSI	0.00	0.02	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in TPI/BVI + Drop shaft 210/211
210	No GSI	0.00	3.17	Drop shaft 210/211 & conduit	Alternate Pawtucket Tunnel	
211	No GSI	0.00	3.96	Drop shaft 210/211 & conduit	Alternate Pawtucket Tunnel	
212	No GSI	0.00	0.60	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in BVI + Drop shaft 218
213	No GSI	0.00	1.97	Drop shaft 217 & conduit	Alternate Pawtucket Tunnel	Capacity in TPI + Drop shaft 213/214/217
214	No GSI	0.00	1.26	Drop shaft 217 & conduit	Alternate Pawtucket Tunnel	Capacity in TPI + Drop shaft 213/214/217
215	No GSI	0.00	1.58	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in BVI + Drop shaft 218
216	No GSI	0.00	0.01	Regulator modifications	Alternate Pawtucket Tunnel	Capacity in BVI + Drop shaft 218
217	No GSI	0.00	2.71	Drop shaft 217 & conduit	Alternate Pawtucket Tunnel	Capacity in TPI + Drop shaft 213/214/217
218	No GSI	0.00	12.58	Drop shaft 218 & conduit	Alternate Pawtucket Tunnel	
220	No GSI	0.00	4.60	220 Stub Tunnel	Alternate Pawtucket Tunnel	

1A) Defines upper limit design capacity for grey alts. (for 3-month storm design basis)

Na
Alt
Sub

Grey Alternate Scenario

Use CSO spills from BPSA Run 1 output to design tanks. Run 1A FPSA for West River Interceptor design

Provide design data for large grey alts. to Tony P.

Source Controls	CSO Volume (MG)	CSO Control Solution	Systematic / Receptor Control Requirement	Secondary Requirement
No GSI	0.09	Route 1 stormwater tank		Hydraulic controls
No GSI	0.10	Regulator modification	Phase II 037 separation	
No GSI	0.07	West River Interceptor, or 220 Tunnel Adit		
No GSI	0.20	West River Interceptor, or 220 Tunnel Adit		
No GSI	0.38	Regulator modifications		Pierce Park Tank
No GSI	4.88	Pierce Park Tank		
No GSI	0.49	Webbing Mills Tank		Pierce Park Tank
No GSI	1.64	Webbing Mills Tank		Pierce Park Tank
No GSI	0.37	Regulator modifications		Middle St interceptor + Front St Tank / S&D
No GSI	1.34	East Street Tank (Viper VoIP Corporation)		
No GSI	0.17	East Street Tank (Viper VoIP Corporation)		
No GSI	0.40	Lower Middle St interceptor		Front St Tank / T&D
No GSI	0.16	Regulator modifications		Front St Tank / T&D
No GSI	12.81	Front St Tank / T&D		
No GSI	0.14	Parking lot stormwater tanks		Hydraulic controls
No GSI	0.04	Regulator modification	City Hall Tank	Capacity in TPI/MVI
No GSI	0.01	Regulator modification	City Hall Tank	Capacity in TPI/MVI
No GSI	0.02	Regulator modification	City Hall Tank	Capacity in TPI/MVI
No GSI	3.17	City Hall Tank		
No GSI	3.96	City Hall Tank		
No GSI	0.60	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
No GSI	1.97	Apex (or other location) Tank		
No GSI	1.26	Apex (or other location) Tank		
No GSI	1.58	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
No GSI	0.01	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
No GSI	2.71	Tidewater Tank / T&D		
No GSI	12.58	Bucklin Point landfil tank / T&D		
No GSI	4.60	Morley Field tank, or Stub tunnel	Baseline Pawtucket tunnel	

1A) Defines upper limit design capacity for grey alts. (for 3-month storm design basis)

Full Green + Grey Alternate (i.e. tunnel minimization) Scenario

BPSA-2 & FPSA-2 - Full GSI implementation, use CSO spills provide design basis (23 July 2014 run)

Provide design data for public way & private GSI, small grey alts. & miminum tunnel to Tony P.

Source Controls	CSO Volume (MG)	CSO Control Solution	Systematic / Receptor Control Requirement	Secondary Requirement
Full GSI		Route 1 stormwater tank (small)		Hydraulic controls
Full GSI		Regulator modification	Phase II 037 separation	
Full GSI		West River Interceptor (small), or 220 Tunnel Adit		
Full GSI		West River Interceptor (small), or 220 Tunnel Adit		
Full GSI	0.17	Regulator modifications		Pierce Park Tank / S&D (small)
Full GSI	3.63	Pierce Park Tank / S&D (small)		
Full GSI	0.29	Webbing Mills Tank (small)		Pierce Park Tank / S&D (small)
Full GSI	1.32	Webbing Mills Tank (small)		Pierce Park Tank / S&D (small)
Full GSI	0.28	Regulator modifications		Middle St interceptor + Front St Tank / S&D
Full GSI	1.15	East Street Tank (Viper VoIP Corporation)		Front St Tank / S&D (small)
Full GSI	0.14	East Street Tank (Viper VoIP Corporation)		Middle St interceptor + Front St Tank / S&D
Full GSI	0.23	Lower Middle St interceptor		Front St Tank / S&D (small)
Full GSI	0.01	Regulator modifications		Middle St interceptor + Front St Tank / S&D
Full GSI	8.58	Front St Tank / S&D (small)		
Full GSI	0.13	Parking lot stormwater tanks (small)		Hydraulic controls
Full GSI	0.02	Regulator modification	City Hall Tank / T&D	Capacity in TPI/MVI
Full GSI	0.01	Regulator modification	City Hall Tank / T&D	Capacity in TPI/MVI
Full GSI	0.01	Regulator modification	City Hall Tank / T&D	Capacity in TPI/MVI
Full GSI	3.06	City Hall Tank / T&D		
Full GSI	3.90	City Hall Tank / T&D		
Full GSI	0.45	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
Full GSI	1.65	Apex (or other location) Tank / T&D		
Full GSI	0.83	Apex (or other location) Tank / T&D		
Full GSI	1.15	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
Full GSI	0.00	Regulator modification	Bucklin Point landfil tank / T&D	Capacity in BVI + Bucklin Point Landfill Tank / T&D
Full GSI	2.10	Tidewater Tank / T&D		
Full GSI	7.69	Bucklin Point landfil tank / T&D		
Full GSI	2.42	Morley Field tank / T&D, or Stub tunnel		

2) Defines lower limit design capacity for grey alts. & tunnel (for 3-month storm design basis)

Public Way Green + Grey Alternate Scenario

BPSA-3 & FPSA-3 - Public way source control, use CSO spills provide design basis

Provide design data for medium grey alts. & tunnel to Tony P. if the large shakes out as cost-effective against baseline and/or the small doesn't give us enough to scale

Source Controls	Primary Solution	Secondary Requirement
Public way GSI	Route 1 stormwater tank (medium)	Hydraulic ctrls
Public way GSI		
Public way GSI	West River Interceptor (medium)	
Public way GSI	West River Interceptor (medium)	
Public way GSI	Pierce Park Tank (medium)	
Public way GSI	Pierce Park Tank (medium)	
Public way GSI	Pierce Park + Webbing Mills Tanks (med)	
Public way GSI	Pierce Park + Webbing Mills Tanks (med)	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Parking lot stormwater tanks (med)	Hydraulic ctrls
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	Mid-size Pawtucket tunnel	
Public way GSI	*3 sub alts: Morley Field tank / T&D / Stub tunnel	

3) Defines mid-point design capacity for grey alts. & tunnel (for 3-month storm design basis)

Design Capacity (MG)	CSO Control Solution	CSOs Controled
0.09	Route 1 stormwater tank	035
0.07	West River Interceptor, or 220 Tunnel Adit	039
0.20	West River Interceptor, or 220 Tunnel Adit	056
0.14	Parking lot stormwater tanks	206
5.26	Pierce Park Tank	101, 103
2.12	Webbing Mills Tank	104, 105
1.51	East Street Tank (Viper VoIP Corporation)	201, 202
13.37	Front St Tank / T&D	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 (+039, 056)
2.71	Tidewater Tank / T&D	217
14.76	Bucklin Point landfil tank / T&D	212, 215, 216, 218
	East Street Tank (Viper VoIP Corporation)	201, 202

Design Capacity (MG)	CSO Control Solution	CSOs Controled
0.00	Route 1 stormwater tank (small)	035
0.00	West River Interceptor (small), or 220 Tunnel Adit	039
0.00	West River Interceptor (small), or 220 Tunnel Adit	056
0.13	Parking lot stormwater tanks (small)	206
3.81	Pierce Park Tank / S&D (small)	101, 103
1.60	Webbing Mills Tank (small)	104, 105
1.52	East Street Tank (Viper VoIP Corporation)	201, 202, 203
10.10	Front St Tank / S&D (small)	201, 202, 203, 204, 205
7.00	City Hall Tank / T&D	207, 208, 209, 210, 211
2.49	Apex (or other location) Tank / T&D	213, 214
2.70	Morley Field tank / T&D, or Stub tunnel	107, 220 (+039, 056)
2.10	Tidewater Tank / T&D	217
9.29	Bucklin Point landfil tank / T&D	212, 215, 216, 218
28.22		
39.09		
4.73		

Narragansett Bay Commission - Phase III Reevaluation
Alternatives Evaluation
Subsystem Flow/Cost Apportionment

Baseline Tunnel Scenario - BT1	Outfall:	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	
CSO Control Solution	Design Capacity (MG)	0.77	0.10	0.46	0.42	0.38	4.88	0.49	1.64	0.37	1.34	0.17	0.40	0.16	12.81	0.14	0.04	0.01	0.02	3.17	3.96	0.60	1.97	1.26	1.58	0.01	2.71	12.58	4.60	
035 Sewer separation	0.77	100%																												100%
039-056 Sewer separation	0.46			100%																										100%
039-056 Sewer separation	0.42				100%																									100%
206 Sewer separation	0.14															100%														100%
Upper High & Cross St interceptor	5.26					7%	93%																							100%
Lower High & Cross St interceptor	5.74					7%	85%	8%																						100%
Middle St interceptor	1.91										70%	9%	21%																	100%
Drop shaft 205 & conduit	22.27					2%	22%	2%	7%		6%	1%	2%	1%	58%															100%
Drop shaft 210/211 & conduit	7.21																1%	0%	0%	44%	55%									100%
Drop shaft 213 & conduit	3.24																						61%	39%						100%
Pawtucket Ave interceptor	4.97									8%																			92%	100%
Drop shaft 217 & conduit	7.68									5%																	35%		60%	100%
Drop shaft 218 & conduit	14.76																					4%			11%	0%		85%		100%
No Source control	0.00																													
Baseline Pawtucket tunnel	55.16					1%	9%	1%	3%	1%	2%	0%	1%	0%	23%		0%	0%	0%	6%	7%	1%	4%	2%	3%	0%	5%	23%	8%	100%
Regulator modification	6.58		100%							100%		100%		100%			100%	100%	100%			100%		100%	100%					

Baseline Tunnel Scenario - BT1	Outfall:	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	
CSO Control Solution	Capital Cost ($M)																													
035 Sewer separation	$19,181,969	$19,181,969	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$19,181,969
039-056 Sewer separation	$24,682,089	$0	$0	$24,682,089	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$24,682,089
039-056 Sewer separation	$16,485,123	$0	$0	$0	$16,485,123	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$16,485,123
206 Sewer separation	$6,466,988	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,466,988	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,466,988
Upper High & Cross St interceptor	$9,989,013	$0	$0	$0	$0	$721,179	$9,267,834	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,989,013
Lower High & Cross St interceptor	$13,688,921	$0	$0	$0	$0	$904,677	$11,625,959	$1,158,285	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,688,921
Middle St interceptor	$15,394,325	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,797,009	$1,407,339	$3,189,977	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,394,325
Drop shaft 205 & conduit	$23,919,436	$0	$0	$0	$0	$407,713	$5,239,503	$522,007	$1,760,500	$0	$1,439,605	$187,646	$425,331	$171,174	$13,765,956	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$23,919,436
Drop shaft 210/211 & conduit	$27,301,091	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$164,477	$53,956	$88,767	$12,008,716	$14,985,175	$0	$0	$0	$0	$0	$0	$0	$0	$27,301,091
Drop shaft 213 & conduit	$41,619,159	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$25,386,736	$16,232,423	$0	$0	$0	$0	$0	$41,619,159
Pawtucket Ave interceptor	$59,525,355	$0	$0	$0	$0	$0	$0	$0	$0	$4,468,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$55,057,355	$59,525,355
Drop shaft 217 & conduit	$47,107,149	$0	$0	$0	$0	$0	$0	$0	$0	$2,288,423	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$16,619,410	$0	$28,199,315	$47,107,149
Drop shaft 218 & conduit	$47,625,870	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,929,927	$0	$0	$5,082,577	$28,701	$0	$40,584,666	$0	$47,625,870
No Source control	$0																													
Baseline Pawtucket tunnel	$387,024,483	$0	$0	$0	$0	$2,662,941	$34,221,330	$3,409,443	$11,498,545	$2,619,136	$9,402,650	$1,225,591	$2,778,013	$1,118,004	$89,911,071	$0	$304,832	$99,998	$164,515	$22,256,201	$27,772,583	$4,197,021	$13,853,615	$8,858,080	$11,053,104	$62,417	$19,021,172	$88,259,668	$32,274,552	$387,024,483
Regulator modification	$719,426	$0	$719,426	$0	$0	$0	$0	$0	$0	$719,426	$0	$719,426	$0	$719,426	$0	$0	$719,426	$719,426	$719,426	$0	$0	$719,426	$0	$719,426	$719,426	$0	$0	$0	$0	$7,194,258
		$19,181,969	$719,426	$24,682,089	$16,485,123	$4,696,509	$60,354,626	$5,089,735	$13,259,045	$10,094,985	$21,639,264	$3,540,001	$6,393,322	$2,008,604	$103,677,027	$6,466,988	$1,188,735	$873,380	$972,708	$34,264,917	$42,757,758	$6,846,373	$39,240,350	$25,809,929	$16,855,107	$91,118	$35,640,583	$128,844,333	$115,531,223	**$747,205,228**
																														Checks

Baseline Tunnel Scenario - BT1	Outfall:	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	
CSO Control Solution	Annual O&M Cost																													
039-056 Sewer separation	$12,517	$12,517	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,517
039-056 Sewer separation	$5,617	$0	$0	$5,617	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$5,617
206 Sewer separation	$3,721	$0	$0	$0	$3,721	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,721
Upper High & Cross St interceptor	$1,182	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,182	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,182
Lower High & Cross St interceptor	$4,830	$0	$0	$0	$0	$349	$4,481	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Middle St interceptor	$4,830	$0	$0	$0	$0	$319	$4,102	$409	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Drop shaft 205 & conduit	$4,830	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,388	$442	$1,001	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Drop shaft 210/211 & conduit	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drop shaft 213 & conduit	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pawtucket Ave interceptor	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drop shaft 217 & conduit	$18,860	$0	$0	$0	$0	$0	$0	$0	$0	$1,416	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,444	$18,860
Drop shaft 218 & conduit	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
No Source control	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Baseline Pawtucket tunnel	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Regulator modification	$433,500	$0	$0	$0	$0	$2,983	$38,331	$3,819	$12,879	$2,934	$10,532	$1,373	$3,112	$1,252	$100,708	$0	$341	$112	$184	$24,929	$31,108	$4,701	$15,517	$9,922	$12,380	$70	$21,305	$98,858	$36,150	$433,500
0	$50,000	$0	$50,000	$0	$0	$0	$0	$0	$0	$50,000	$0	$50,000	$0	$50,000	$0	$0	$50,000	$50,000	$50,000	$0	$0	$50,000	$0	$50,000	$50,000	$0	$0	$0	$0	$500,000
		$12,517	$50,000	$5,617	$3,721	$3,651	$46,914	$4,228	$12,879	$54,349	$13,919	$51,814	$4,112	$51,252	$100,708	$1,182	$50,341	$50,112	$50,184	$24,929	$31,108	$54,701	$15,517	$59,922	$62,380	$70	$21,305	$98,858	$53,595	**$989,887**

No Tunnel Scenario - NT1		Outfall:	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	
CSO Control Solution		Design Capacity (MG)	0.77	0.10	0.46	0.42	0.38	4.88	0.49	1.64	0.37	1.13	0.13	0.23	0.01	8.73	0.14	0.04	0.01	0.02	3.17	3.96	0.60	1.97	1.26	0.83	0.01	2.71	12.58	4.60	
	Controled Volume (MG)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.04	0.16	0.15	4.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	
035 Hybrid GSI / Sewer separation	0.00	0.77	100%																												100%
039-056 Hybrid GSI / Sewer separation	0.00	0.46			100%																										100%
039-056 Hybrid GSI / Sewer separation	0.00	0.42				100%																									100%
206 Hybrid GSI / Parking lot stormwater tanks /	0.00	0.14															100%														100%
High Street Tank	0.00	5.26					7%	93%																							100%
Webbing Mills Tank	0.00	2.12							23%	77%																					100%
East Street Tank (Viper VoIP Corporation)	0.00	1.26										90%	10%																		100%
Front St Tank with GSI	0.00	8.97												3%	0%	97%															100%
City Hall Tank	0.00	7.21																1%	0%	0%	44%	55%									100%
213 Tank	0.00	3.24																						61%	39%						100%
Morley Field Tank	0.00	4.97									8%																			92%	100%
Tidewater Above-ground Tank	0.00	2.71																										100%			100%
Bucklin Point Landfil Tank	0.00	14.02																					4%			6%	0%		90%		100%
GSI in select sewersheds	5.40	0.00	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	1%	3%	3%	76%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	0%	0%	0%	100%
Tunnel	0.00	0.00																													0%
Regulator modifications	0.00	0.00		100%			100%				100%				100%			100%	100%	100%			100%	100%		100%	100%				

No Tunnel Scenario - NT1	Outfall:	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	
CSO Control Solution	Capital Cost ($M)																													
035 Hybrid GSI / Sewer separation	$24,707,386	$24,707,386	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$24,707,386
039-056 Hybrid GSI / Sewer separation	$21,844,330	$0	$0	$21,844,330	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$21,844,330
039-056 Hybrid GSI / Sewer separation	$16,018,462	$0	$0	$0	$16,018,462	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$16,018,462
206 Hybrid GSI / Parking lot stormwater tanks / Sewer separation	$4,920,420	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,920,420	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,920,420
High Street Tank	$62,931,338	$0	$0	$0	$0	$4,543,466	$58,387,873	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$62,931,338
Webbing Mills Tank	$50,154,331	$0	$0	$0	$0	$0	$0	$11,470,250	$38,684,082	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$50,154,331
East Street Tank (Viper VoIP Corporation)	$38,580,255	$0	$0	$0	$0	$0	$0	$0	$0	$0	$34,577,232	$4,003,023	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$38,580,255
Front St Tank with GSI	$119,694,047	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,116,990	$100,289	$116,476,767	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$119,694,047
City Hall Tank	$43,331,881	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$261,056	$85,638	$140,890	$19,060,053	$23,784,244	$0	$0	$0	$0	$0	$0	$0	$0	$43,331,881
213 Tank	$71,804,368	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$43,799,023	$28,005,345	$0	$0	$0	$0	$0	$71,804,368
Morley Field Tank	$66,313,585	$0	$0	$0	$0	$0	$0	$0	$0	$4,977,528	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$61,336,057	$66,313,585
Tidewater Above-ground Tank	$36,009,270	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$36,009,270	$0	$0	$36,009,270
Bucklin Point Landfil Tank	$161,684,447	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,900,183	$0	$0	$9,576,850	$102,618	$0	$145,104,796	$0	$161,684,447
GSI in select sewersheds	$144,115,578	$0	$0	$0	$0	$0	$0	$0	$0	$0	$5,653,600	$1,175,687	$4,331,945	$4,051,215	$109,021,087	$0	$0	$0	$0	$0	$0	$0	$0	$0	$19,882,043	$0	$0	$0	$0	$144,115,578
Tunnel	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Regulator modifications	$583,318	$0	$583,318	$0	$0	$583,318	$0	$0	$0	$583,318	$0	$0	$0	$583,318	$0	$0	$583,318	$583,318	$583,318	$0	$0	$583,318	$583,318	$0	$583,318	$583,318	$0	$0	$0	$6,416,500
		$24,707,386.13	$583,318.21	$21,844,330.12	$16,018,461.93	$5,126,783.97	$58,387,872.50	$11,470,249.51	$38,684,081.94	$5,560,845.76	$40,230,832.29	$5,178,710.45	$7,448,935.31	$4,734,822.94	$225,497,853.78	$4,920,419.74	$844,374.11	$668,955.88	$724,208.12	$19,060,053.31	$23,784,244.24	$7,483,501.25	$44,382,341.49	$28,005,345.11	$30,042,211.21	$685,935.84	$36,009,269.73	$145,104,795.63	$61,336,057.32	**$868,526,198**
																														Checks

No Tunnel Scenario - NT1	Outfall:	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	
CSO Control Solution	Annual O&M Cost																													
039-056 Hybrid GSI / Sewer separation	$16,428	$16,428	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$16,428
039-056 Hybrid GSI / Sewer separation	$5,203	$0	$0	$5,203	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$5,203
206 Hybrid GSI / Parking lot stormwater tanks / Sewer separation	$2,719	$0	$0	$0	$2,719	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2,719
High Street Tank	$7,709	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,709	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,709
Webbing Mills Tank	$120,100	$0	$0	$0	$0	$8,671	$111,429	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$120,100
East Street Tank (Viper VoIP Corporation)	$87,900	$0	$0	$0	$0	$0	$0	$20,103	$67,797	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$87,900
Front St Tank with GSI	$79,600	$0	$0	$0	$0	$0	$0	$0	$0	$0	$71,341	$8,259	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$79,600
City Hall Tank	$179,600	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,677	$150	$174,772	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$179,600
213 Tank	$140,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$843	$277	$455	$61,581	$76,844	$0	$0	$0	$0	$0	$0	$0	$0	$140,000
Morley Field Tank	$99,400	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$60,632	$38,768	$0	$0	$0	$0	$0	$99,400
Tidewater Above-ground Tank	$117,100	$0	$0	$0	$0	$0	$0	$0	$0	$8,790	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$108,310	$117,100
Bucklin Point Landfil Tank	$94,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$94,000	$0	$0	$94,000
GSI in select sewersheds	$227,300	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,700	$0	$0	$13,463	$144	$0	$203,992	$0	$227,300
Tunnel	$1,122,416	$0	$0	$0	$0	$0	$0	$0	$0	$0	$44,032	$9,157	$33,739	$31,552	$849,089	$0	$0	$0	$0	$0	$0	$0	$0	$0	$154,847	$0	$0	$0	$0	$1,122,416
Regulator modifications	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
0	$50,000	$0	$50,000	$0	$0	$50,000	$0	$0	$0	$50,000	$0	$0	$0	$50,000	$0	$0	$50,000	$50,000	$50,000	$0	$0	$50,000	$50,000	$0	$50,000	$50,000	$0	$0	$0	$550,000
		$16,427.60	$50,000.00	$5,202.60	$2,718.60	$58,670.88	$111,429.12	$20,102.65	$67,797.35	$58,789.58	$115,372.80	$17,415.78	$38,415.53	$81,702.58	$1,023,861.91	$7,709.45	$50,843.44	$50,276.68	$50,455.20	$61,580.70	$76,843.98	$59,700.45	$110,631.73	$38,768.27	$218,310.77	$50,144.26	$94,000.00	$203,991.92	$108,310.42	**$2,849,474**

Tunnel Alternative Scenario One -TA1		Outfall:	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	
CSO Control Solution		Design Capacity (MG)	0.77	0.10	0.46	0.42	0.38	4.88	0.49	1.64	0.37	1.34	0.17	0.40	0.16	12.81	0.14	0.04	0.01	0.02	3.17	3.96	0.60	1.97	1.26	1.58	0.01	2.71	12.58	4.60	
	Controled Volume (MG)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
035 Sewer separation	0.00	0.77	100%																												100%
West River Interceptor	0.00	0.46			100%																										100%
West River Interceptor	0.00	0.42				100%																									100%
206 Hybrid GSI / Parking lot stormwater tanks /	0.00	0.14															100%														100%
Upper High & Cross St interceptor	0.00	5.26					7%	93%																							100%
Lower High & Cross St interceptor	0.00	2.12							23%	77%																					100%
Middle St interceptor	0.00	1.51										88%	12%																		100%
Drop shaft 205 & conduit	0.00	13.37												3%	1%	96%															100%
Drop shaft 210/211 & conduit	0.00	7.21																1%	0%	0%	44%	55%									100%
Drop shaft 213 & conduit	0.00	0.00																													0%
220 Stub Tunnel	0.00	4.97									8%																			92%	100%
Drop shaft 217 & conduit	0.00	5.95																						33%	21%			46%			100%
Drop shaft 218 & conduit	0.00	14.76																					4%			11%	0%		90%		105%
GSI in select sewersheds	0.00	0.00	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Baseline Pawtucket tunnel	0.00	50.33					1%	10%	1%	3%		3%	0%	1%	0%	25%	0%	0%	0%	0%	6%	8%	1%	4%	3%	3%	0%	5%	25%		100%
Regulator modifications	0.00	0.00		100%			100%				100%		100%		100%			100%	100%	100%			100%			100%	100%				

Tunnel Alternative Scenario One -TA1		Outfall:	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	
CSO Control Solution		Cap. Cost ($M)																													
035 Sewer separation		$19,181,969	$19,181,969	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$19,181,969
West River Interceptor		$17,440,861	$0	$0	$17,440,861	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,440,861
West River Interceptor		$17,440,861	$0	$0	$0	$17,440,861	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,440,861
206 Hybrid GSI / Parking lot stormwater tanks / Sewer separation		$6,466,988	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,466,988	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,466,988
Upper High & Cross St interceptor		$9,989,013	$0	$0	$0	$0	$721,179	$9,267,834	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,989,013
Lower High & Cross St interceptor		$13,688,921	$0	$0	$0	$0	$0	$0	$3,130,644	$10,558,277	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,688,921
Middle St interceptor		$15,394,325	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,619,135	$1,775,190	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,394,325
Drop shaft 205 & conduit		$23,919,436	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$708,353	$285,075	$22,926,008	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$23,919,436
Drop shaft 210/211 & conduit		$27,301,091	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$164,477	$53,956	$88,767	$12,008,716	$14,985,175	$0	$0	$0	$0	$0	$0	$0	$0	$27,301,091
Drop shaft 213 & conduit		$41,619,159	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
220 Stub Tunnel		$93,000,000	$0	$0	$0	$0	$0	$0	$0	$0	$6,980,622	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$86,019,378	$93,000,000
Drop shaft 217 & conduit		$47,107,149	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,637,658	$9,998,807	$0	$0	$21,470,684	$0	$0	$47,107,149
Drop shaft 218 & conduit		$47,625,870	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2,032,522	$0	$0	$5,352,768	$30,227	$0	$42,742,158	$0	$50,157,675
GSI in select sewersheds		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Baseline Pawtucket tunnel		$387,024,483	$0	$0	$0	$0	$2,918,630	$37,507,179	$3,736,810	$12,602,608	$0	$10,305,469	$1,343,269	$3,044,751	$1,225,352	$98,544,114	$1,082,944	$334,101	$109,600	$180,312	$24,393,187	$30,439,239	$4,600,009	$15,183,805	$9,708,612	$12,114,396	$68,410	$20,847,539	$96,734,147	$0	$387,024,483
Regulator modifications		$719,426	$0	$719,426	$0	$0	$719,426	$0	$0	$0	$719,426	$0	$719,426	$0	$719,426	$0	$0	$719,426	$719,426	$719,426	$0	$0	$719,426	$0	$0	$719,426	$719,426	$0	$0	$0	$7,913,684
			$19,181,969.34	$719,425.79	$17,440,860.80	$17,440,860.80	$4,359,234.20	$46,775,012.88	$6,867,453.27	$23,160,884.55	$7,700,047.68	$23,924,604.02	$3,837,884.75	$3,753,104.14	$2,229,852.82	$121,470,121.86	$7,549,931.88	$1,218,004.23	$882,981.16	$988,504.83	$36,401,902.97	$45,424,413.94	$7,351,956.65	$30,821,462.80	$19,707,418.98	$18,186,590.27	$818,062.98	$42,318,223.15	$139,476,304.97	$86,019,378.10	**$736,026,454**
																															Checks

Tunnel Alternative Scenario One -TA1		Outfall:	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	
CSO Control Solution		Annual O&M Cost																													
West River Interceptor		$12,517	$12,517	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,517
West River Interceptor		$4,830	$0	$0	$4,830	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
206 Hybrid GSI / Parking lot stormwater tanks / Sewer separation		$4,830	$0	$0	$0	$4,830	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Upper High & Cross St interceptor		$1,182	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,182	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,182
Lower High & Cross St interceptor		$4,830	$0	$0	$0	$0	$349	$4,481	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Middle St interceptor		$4,830	$0	$0	$0	$0	$0	$0	$1,105	$3,725	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Drop shaft 205 & conduit		$4,830	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,273	$557	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,830
Drop shaft 210/211 & conduit		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drop shaft 213 & conduit		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
220 Stub Tunnel		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drop shaft 217 & conduit		$18,860	$0	$0	$0	$0	$0	$0	$0	$0	$1,416	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,444	$18,860
Drop shaft 218 & conduit		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
GSI in select sewersheds		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Baseline Pawtucket tunnel		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Regulator modifications		$433,500	$0	$0	$0	$0	$3,269	$42,011	$4,186	$14,116	$0	$11,543	$1,505	$3,410	$1,372	$110,378	$1,213	$374	$123	$202	$27,322	$34,095	$5,152	$17,007	$10,874	$13,569	$77	$23,351	$108,350	$0	$433,500
0		$50,000	$0	$50,000	$0	$0	$50,000	$0	$0	$0	$50,000	$0	$50,000	$0	$50,000	$0	$0	$50,000	$50,000	$50,000	$0	$0	$50,000	$0	$0	$50,000	$50,000	$0	$0	$0	$550,000
			$12,516.60	$50,000.00	$4,830.00	$4,830.00	$53,617.82	$46,492.49	$5,290.16	$17,841.36	$51,415.64	$15,816.02	$52,061.54	$3,410.38	$51,372.50	$110,377.70	$2,395.19	$50,374.22	$50,122.76	$50,201.96	$27,322.42	$34,094.51	$55,152.40	$17,007.14	$10,874.46	$63,569.14	$50,076.63	$23,351.00	$108,350.39	$17,444.36	**$1,040,209**

NBC CSO Control Facilities Phase III Reevaluation

Appendix 7 – Alternative Plan Analysis Estimates of Probable Cost and Worksheet Details

NBC CSO Control Facilities Phase III Reevaluation

Appendix 7 –Alternative Plan Analysis Estimates of Probable Cost and Worksheet Details

Introduction

This Appendix provides the detailed calculations and backup for the estimates of probable construction costs, timelines and backup sheets to support the Alternative Plan Analysis presented in Chapter 6. Tabulated data includes:

- Class 5 conceptual planning level buildup of estimates of probable construction cost for all subsystems,
- Worksheet for additional contingencies,
- Phase and project sequencing resulting in cash flows for each Alternative, and
- Cumulative cost and CSO volume reduction worksheet.

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								Construction Cost Estimate													
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**#REF!**				
Total																	**#REF!**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber NOTE: IF BROUGHT TO PLANT, WOULD THIS CHANGE?									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	26' Diameter Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Post-Reevaluation, Pre-Value Engineering																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	Accuracy Range % AACE High	Accuracy Range $ AACE Low	Accuracy Range $ AACE High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Consolidation Conduits		**Unit Cost ($/LF) used in comparison to Phase 1**																			
Consolidation Conduit between 210 and 211 and drop shaft	**54"-diameter consolidation conduit between outfall and drop shaft location across from City Hall**		**600**	**LF**	Assumption	Class 5	**6,640,537**	1,992,161	833,446	9,466,144	94,661	662,630	189,323	757,292	283,984	283,984	11,738,019	-30.00%	50.00%	8,216,613	17,607,028
Consolodation Conduit between 213 and 214 and drop shaft	**48"-diameter consolidation conduit between outfall and drop shaft location across from City Hall or at Tidewater Site**		**1,300**	**LF**	Assumption	Class 5	**13,949,566**	4,184,870	1,750,793	19,885,229	198,852	1,391,966	397,705	1,590,818	596,557	596,557	24,657,684	-30.00%	50.00%	17,260,379	36,986,526
Consolidation Conduit between 217 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at Tidewater Site *Sized to include 220 Volume***		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit between 218 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at old landfill site north of BPWWTF**		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit btwn High/Middle St Interceptors and Shaft S-7	**72"-diameter consolidation conduit between outfall 205 and Shaft S-7**		**300**	**LF**	Assumption	Class 5	**3,426,231**	1,027,869	430,022	4,884,122	48,841	341,889	97,682	390,730	146,524	146,524	6,056,312	-30.00%	50.00%	4,239,418	9,084,468
Consolidation Conduits							**57,370,598**	**17,211,179**	**7,200,515**	**81,782,293**	**817,823**	**5,724,761**	**1,635,646**	**6,542,583**	**2,453,469**	**2,453,469**	**101,410,043**			**70,987,030**	**152,115,065**
Shaft S-7	**36 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the receiving shaft for the tunnel which will also be used for OF's 103,104,105,201,203,205**																				
Mob			1	LS	Assumption	Class 5	**77,818**	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	**424,000**	127,200	38,160	589,360	5,894	41,255	11,787	47,149	17,681	17,681	730,806	-30.00%	50.00%	511,564	1,096,210
Excavation Soil			10	VFT	Assumption	Class 5	**378,597**	113,579	34,074	526,250	5,262	36,837	10,525	42,100	15,787	15,787	652,550	-30.00%	50.00%	456,785	978,825
Excavation Rock			135	VFT	Assumption	Class 5	**1,400,690**	420,207	126,062	1,946,959	19,470	136,287	38,939	155,757	58,409	58,409	2,414,229	-30.00%	50.00%	1,689,960	3,621,344
Liner			145	VFT	Assumption	Class 5	**2,119,501**	635,850	190,755	2,946,106	29,461	206,227	58,922	235,689	88,383	88,383	3,653,172	-30.00%	50.00%	2,557,220	5,479,758
Teardown U/G			1	LS	Assumption	Class 5	**164,429**	49,329	14,799	228,556	2,286	15,999	4,571	18,285	6,857	6,857	283,410	-30.00%	50.00%	198,387	425,115
Teardown Surface			1	LS	Assumption	Class 5	**252,662**	75,799	22,740	351,200	3,512	24,584	7,024	28,096	10,536	10,536	435,488	-30.00%	50.00%	304,842	653,232
Demob			1	LS	Assumption	Class 5	**148,562**	44,569	13,371	206,501	2,065	14,455	4,130	16,520	6,195	6,195	256,061	-30.00%	50.00%	179,243	384,092
Shaft S-7							**4,966,259**	**1,489,878**	**449,727**	**6,905,863**	**69,059**	**483,410**	**138,117**	**552,469**	**207,176**	**207,176**	**8,563,270**			**5,994,289**	**12,844,906**
Adit/Deaeration 218	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 218							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 217	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 217							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 213	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 213							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Construction Cost Estimate Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	High	Accuracy Range $ AACE Low	High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%					
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**#REF!**				
Total																	**#REF!**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber NOTE: IF BROUGHT TO PLANT, WOULD THIS CHANGE?									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	26' Diameter Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Post-Reevaluation, Pre-Value Engineering																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
							Construction Cost Estimate														
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate														
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**#REF!**				
Total																	**#REF!**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber NOTE: IF BROUGHT TO PLANT, WOULD THIS CHANGE?									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	26' Diameter Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Post-Reevaluation, Pre-Value Engineering																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	Accuracy Range % AACE High	Accuracy Range $ AACE Low	Accuracy Range $ AACE High
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE Low	Accuracy Range % AACE High	Accuracy Range $ AACE Low	Accuracy Range $ AACE High
							Construction Cost Estimate														
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Consolidation Conduits		**Unit Cost ($/LF) used in comparison to Phase 1**																			
Consolidation Conduit between 210 and 211 and drop shaft	**54"-diameter consolidation conduit between outfall and drop shaft location across from City Hall**		**600**	**LF**	Assumption	Class 5	**6,640,537**	1,992,161	833,446	9,466,144	94,661	662,630	189,323	757,292	283,984	283,984	11,738,019	-30.00%	50.00%	8,216,613	17,607,028
Consolodation Conduit between 213 and 214 and drop shaft	**48"-diameter consolidation conduit between outfall and drop shaft location across from City Hall or at Tidewater Site**		**1,300**	**LF**	Assumption	Class 5	**13,949,566**	4,184,870	1,750,793	19,885,229	198,852	1,391,966	397,705	1,590,818	596,557	596,557	24,657,684	-30.00%	50.00%	17,260,379	36,986,526
Consolidation Conduit between 217 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at Tidewater Site *Sized to include 220 Volume***		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit between 218 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at old landfill site north of BPWWTF**		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit btwn High/Middle St Interceptors and Shaft S-7	**72"-diameter consolidation conduit between outfall 205 and Shaft S-7**		**300**	**LF**	Assumption	Class 5	**3,426,231**	1,027,869	430,022	4,884,122	48,841	341,889	97,682	390,730	146,524	146,524	6,056,312	-30.00%	50.00%	4,239,418	9,084,468
Consolidation Conduits							**57,370,598**	**17,211,179**	**7,200,515**	**81,782,293**	**817,823**	**5,724,761**	**1,635,646**	**6,542,583**	**2,453,469**	**2,453,469**	**101,410,043**			**70,987,030**	**152,115,065**
Shaft S-7	**36 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the receiving shaft for the tunnel which will also be used for OF's 103,104,105,201,203,205**																				
Mob			1	LS	Assumption	Class 5	**77,818**	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	**424,000**	127,200	38,160	589,360	5,894	41,255	11,787	47,149	17,681	17,681	730,806	-30.00%	50.00%	511,564	1,096,210
Excavation Soil			10	VFT	Assumption	Class 5	**378,597**	113,579	34,074	526,250	5,262	36,837	10,525	42,100	15,787	15,787	652,550	-30.00%	50.00%	456,785	978,825
Excavation Rock			135	VFT	Assumption	Class 5	**1,400,690**	420,207	126,062	1,946,959	19,470	136,287	38,939	155,757	58,409	58,409	2,414,229	-30.00%	50.00%	1,689,960	3,621,344
Liner			145	VFT	Assumption	Class 5	**2,119,501**	635,850	190,755	2,946,106	29,461	206,227	58,922	235,689	88,383	88,383	3,653,172	-30.00%	50.00%	2,557,220	5,479,758
Teardown U/G			1	LS	Assumption	Class 5	**164,429**	49,329	14,799	228,556	2,286	15,999	4,571	18,285	6,857	6,857	283,410	-30.00%	50.00%	198,387	425,115
Teardown Surface			1	LS	Assumption	Class 5	**252,662**	75,799	22,740	351,200	3,512	24,584	7,024	28,096	10,536	10,536	435,488	-30.00%	50.00%	304,842	653,232
Demob			1	LS	Assumption	Class 5	**148,562**	44,569	13,371	206,501	2,065	14,455	4,130	16,520	6,195	6,195	256,061	-30.00%	50.00%	179,243	384,092
Shaft S-7							**4,966,259**	**1,489,878**	**449,727**	**6,905,863**	**69,059**	**483,410**	**138,117**	**552,469**	**207,176**	**207,176**	**8,563,270**			**5,994,289**	**12,844,906**
Adit/Deaeration 218	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 218							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 217	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 217							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 213	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 213							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate														
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																					
Pawtucket Tunnel																					
Design, Administration, Construction Management, Land and Insurance																					
Total																					
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																					
Pawtucket Tunnel																	**339,476,642**				
Consolidation Conduits/ Floatables Control/ Regulator Modifications																	**83,735,240**				
Design/ Design Support/ Construction Management/ Owner/ ROW																	**#REF!**				
Total																	**#REF!**				
Drop shaft 205 & conduit	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)									**17,536,243**	175,362	1,227,537	350,725	1,402,899	526,087	526,087	**21,744,941**				
Drop shaft 210/211 & conduit	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber									**20,015,462**	200,155	1,401,082	400,309	1,601,237	600,464	600,464	**24,819,173**				
Drop shaft 213 & conduit	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber									**30,512,580**	305,126	2,135,881	610,252	2,441,006	915,377	915,377	**37,835,599**				
Drop shaft 217 & conduit	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber									**34,536,033**	345,360	2,417,522	690,721	2,762,883	1,036,081	1,036,081	**42,824,681**				
Drop shaft 218 & conduit	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber NOTE: IF BROUGHT TO PLANT, WOULD THIS CHANGE?									**34,916,327**	349,163	2,444,143	698,327	2,793,306	1,047,490	1,047,490	**43,296,246**				
No Source control																					
Baseline Pawtucket tunnel	26' Diameter Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out									**283,742,290**	2,837,423	19,861,960	5,674,846	22,699,383	8,512,269	8,512,269	**351,840,439**				
Regulator modification										**527,438**	5,274	36,921	10,549	42,195	15,823	15,823	**654,023**				
Floatables Controls 207, 209, 212, 215										**1,425,509**	14,255	99,786	28,510	114,041	42,765	42,765	**1,767,631**				
Post-Reevaluation, Pre-Value Engineering																					
Pawtucket Tunnel	**26 ft inside diameter 13,000 linear ft. precast liner for entire length of tunnel**																				
Pawtucket Tunnel	Tunnel excavation and lining		13,000	lft	Section 7 1998	Class 5	118,694,042	35,608,213	14,897,148	169,199,403	1,691,994	11,843,958	3,383,988	13,535,952	5,075,982	5,075,982	209,807,259	-30.00%	50.00%	146,865,081	314,710,889
PAWTUCKET TUNNEL SUBTOTAL							**118,694,042**	**35,608,213**	**14,897,148**	**169,199,403**	**1,691,994**	**11,843,958**	**3,383,988**	**13,535,952**	**5,075,982**	**5,075,982**	**209,807,259**			**146,865,081**	**314,710,889**
Bucklin Point Utility Shaft	**36 ft diameter excavated, 32 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	ls	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			1	LS	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			110	VFT	Assumption	Class 5	1,565,913	469,774	196,536	2,232,223	22,322	156,256	44,644	178,578	66,967	66,967	2,767,956	-30.00%	50.00%	1,937,569	4,151,934
Liner			150	VFT	Assumption	Class 5	2,654,539	796,362	333,168	3,784,069	37,841	264,885	75,681	302,725	113,522	113,522	4,692,245	-30.00%	50.00%	3,284,572	7,038,368
Teardown U/G			260	VFT	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
1100 Bucklin Point Utility Shaft							**10,384,586**	**3,115,376**	**1,303,357**	**14,803,319**	**148,033**	**1,036,232**	**296,066**	**1,184,266**	**444,100**	**444,100**	**18,356,115**			**12,849,281**	**27,534,173**
Bucklin Point Access Shaft	**14 ft diameter excavated, 11 ft diameter finished, 260 ft deep (does not include mech/elect/building-see mech/elect/building item)**																				
Surface Work/Setup			1	LS	Assumption	Class 5	1,162,809	348,843	145,943	1,657,594	16,576	116,032	33,152	132,608	49,728	49,728	2,055,417	-30.00%	50.00%	1,438,792	3,083,126
Excavation Soil			110	VFT	Assumption	Class 5	2,079,861	623,958	261,041	2,964,860	29,649	207,540	59,297	237,189	88,946	88,946	3,676,427	-30.00%	50.00%	2,573,499	5,514,640
Excavation Rock			150	VFT	Assumption	Class 5	1,352,603	405,781	169,764	1,928,147	19,281	134,970	38,563	154,252	57,844	57,844	2,390,903	-30.00%	50.00%	1,673,632	3,586,354
Liner			260	VFT	Assumption	Class 5	1,867,316	560,195	234,365	2,661,875	26,619	186,331	53,238	212,950	79,856	79,856	3,300,726	-30.00%	50.00%	2,310,508	4,951,088
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Bucklin Point Access Shaft							**6,879,680**	**2,063,904**	**863,460**	**9,807,044**	**98,070**	**686,493**	**196,141**	**784,564**	**294,211**	**294,211**	**12,160,735**			**8,512,515**	**18,241,103**
Bucklin Point Pump Cavern	**Cavern 62 ft wide by 70 ft deep by 117 long excavated**																				
Excavation Rock			1	LS	Assumption	Class 5	9,505,934	2,851,780	1,193,078	13,550,793	135,508	948,555	271,016	1,084,063	406,524	406,524	16,802,983	-30.00%	50.00%	11,762,088	25,204,474
Liner			1	LS	Assumption	Class 5	3,993,074	1,197,922	501,166	5,692,162	56,922	398,451	113,843	455,373	170,765	170,765	7,058,281	-30.00%	50.00%	4,940,797	10,587,422
Bucklin Point Pump Cavern							**13,499,008**	**4,049,702**	**1,694,244**	**19,242,955**	**192,430**	**1,347,007**	**384,859**	**1,539,436**	**577,289**	**577,289**	**23,861,264**			**16,702,885**	**35,791,896**
Connection Between Pump Cavern and S-5	**8 ft by 8 ft adit driven from S-5 to pump cavern followed by installation of a 6 ft diameter pipe enclased in concrete**																				
Excavation Rock			250	LF	Assumption	Class 5	918,209	275,463	115,243	1,308,915	13,089	91,624	26,178	104,713	39,267	39,267	1,623,055	-30.00%	50.00%	1,136,138	2,434,582
Liner			250	LF	Assumption	Class 5	783,004	234,901	98,274	1,116,179	11,162	78,133	22,324	89,294	33,485	33,485	1,384,062	-30.00%	50.00%	968,843	2,076,093
Connection Between Pump Cavern and S-5							**1,701,213**	**510,364**	**213,517**	**2,425,094**	**24,251**	**169,757**	**48,502**	**194,008**	**72,753**	**72,753**	**3,007,117**			**2,104,982**	**4,510,675**
Mechancial/Electrical/Misc-Allowance for Bucklin Point Pumping Station	**Mech/Electrical/Misc-allowance for pumps, screens, surface enclosures (buildings),**																				
Mechancial/Electrical/Misc-Allowance			1	LS	Assumption	Class 5	37,650,000	11,295,000	4,725,407	53,670,407	536,704	3,756,928	1,073,408	4,293,633	1,610,112	1,610,112	66,551,304	-30.00%	50.00%	46,585,913	99,826,956
Mechancial/Electrical/Misc-Allowance							**37,650,000**	**11,295,000**	**4,725,407**	**53,670,407**	**536,704**	**3,756,928**	**1,073,408**	**4,293,633**	**1,610,112**	**1,610,112**	**66,551,304**			**46,585,913**	**99,826,956**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Shaft S-5	**34 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the launch shaft for the tunnel**																				
Mob			1	LS	Assumption	Class 5	438,610	131,583	55,049	625,242	6,252	43,767	12,505	50,019	18,757	18,757	775,301	-30.00%	50.00%	542,710	1,162,951
Surface Work/Setup			1	LS	Assumption	Class 5	1,841,258	552,377	231,094	2,624,730	26,247	183,731	52,495	209,978	78,742	78,742	3,254,665	-30.00%	50.00%	2,278,265	4,881,997
Excavation Soil			110	VFT	Assumption	Class 5	3,905,785	1,171,736	490,210	5,567,731	55,677	389,741	111,355	445,418	167,032	167,032	6,903,986	-30.00%	50.00%	4,832,790	10,355,980
Excavation Rock			90	VFT	Assumption	Class 5	921,983	276,595	115,717	1,314,295	13,143	92,001	26,286	105,144	39,429	39,429	1,629,726	-30.00%	50.00%	1,140,808	2,444,588
Liner			200	VFT	Assumption	Class 5	2,557,433	767,230	320,980	3,645,643	36,456	255,195	72,913	291,651	109,369	109,369	4,520,598	-30.00%	50.00%	3,164,418	6,780,896
Teardown U/G			1	LS	Assumption	Class 5	164,429	49,329	20,637	234,395	2,344	16,408	4,688	18,752	7,032	7,032	290,650	-30.00%	50.00%	203,455	435,975
Teardown Surface			1	LS	Assumption	Class 5	252,662	75,799	31,711	360,172	3,602	25,212	7,203	28,814	10,805	10,805	446,613	-30.00%	50.00%	312,629	669,920
Demob			1	LS	Assumption	Class 5	155,636	46,691	19,534	221,860	2,219	15,530	4,437	17,749	6,656	6,656	275,107	-30.00%	50.00%	192,575	412,661
Shaft S-5							**10,237,796**	**3,071,339**	**1,284,934**	**14,594,068**	**145,941**	**1,021,585**	**291,881**	**1,167,525**	**437,822**	**437,822**	**18,096,645**			**12,667,651**	**27,144,967**
Drop Shaft/Vent Shaft 218	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			175	VFT	Assumption	Class 5	2,057,946	617,384	258,290	2,933,620	29,336	205,353	58,672	234,690	88,009	88,009	3,637,689	-30.00%	50.00%	2,546,382	5,456,533
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 218							**2,993,920**	**898,176**	**375,763**	**4,267,859**	**42,679**	**298,750**	**85,357**	**341,429**	**128,036**	**128,036**	**5,292,146**			**3,704,502**	**7,938,218**
Drop Shaft/Vent Shaft 217	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			160	VFT	Assumption	Class 5	1,791,168	537,350	224,807	2,553,326	25,533	178,733	51,067	204,266	76,600	76,600	3,166,124	-30.00%	50.00%	2,216,287	4,749,186
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 217							**2,727,142**	**818,143**	**342,280**	**3,887,565**	**38,876**	**272,130**	**77,751**	**311,005**	**116,627**	**116,627**	**4,820,581**			**3,374,406**	**7,230,871**
Drop Shaft/Vent Shaft 213	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			150	VFT	Assumption	Class 5	1,664,266	499,280	208,880	2,372,426	23,724	166,070	47,449	189,794	71,173	71,173	2,941,808	-30.00%	50.00%	2,059,266	4,412,712
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 213							**2,600,240**	**780,072**	**326,353**	**3,706,665**	**37,067**	**259,467**	**74,133**	**296,533**	**111,200**	**111,200**	**4,596,265**			**3,217,385**	**6,894,397**
Drop Shaft/Vent Shaft 210/211	**drop shaft- 9 ft dimeter excavated and 6 ft diameter finished / vent shaft - 4 ft diameter excavated and 2 ft diameter finished (method is to blind hole drill and insert pipe whch was backfilled with concrete**																				
Mob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	341,892	102,568	42,910	487,370	4,874	34,116	9,747	38,990	14,621	14,621	604,339	-30.00%	50.00%	423,037	906,508
Setup Surface			1	LS	Assumption	Class 5	172,814	51,844	21,690	246,348	2,463	17,244	4,927	19,708	7,390	7,390	305,471	-30.00%	50.00%	213,830	458,207
Excavation/Line			145	VFT	Assumption	Class 5	1,609,526	482,858	202,010	2,294,393	22,944	160,608	45,888	183,551	68,832	68,832	2,845,048	-30.00%	50.00%	1,991,534	4,267,572
Teardown U/G			1	LS	Assumption	Class 5	71,178	21,353	8,933	101,465	1,015	7,103	2,029	8,117	3,044	3,044	125,816	-30.00%	50.00%	88,072	188,725
Teardown Surface			1	LS	Assumption	Class 5	194,454	58,336	24,406	277,196	2,772	19,404	5,544	22,176	8,316	8,316	343,723	-30.00%	50.00%	240,606	515,584
Demob			1	LS	Assumption	Class 5	77,818	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Drop Shaft/Vent Shaft 210/211							**2,545,500**	**763,650**	**319,483**	**3,628,633**	**36,286**	**254,004**	**72,573**	**290,291**	**108,859**	**108,859**	**4,499,505**			**3,149,653**	**6,749,257**

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Consolidation Conduits		**Unit Cost ($/LF) used in comparison to Phase 1**																			
Consolidation Conduit between 210 and 211 and drop shaft	**54"-diameter consolidation conduit between outfall and drop shaft location across from City Hall**		**600**	**LF**	Assumption	Class 5	**6,640,537**	1,992,161	833,446	9,466,144	94,661	662,630	189,323	757,292	283,984	283,984	11,738,019	-30.00%	50.00%	8,216,613	17,607,028
Consolodation Conduit between 213 and 214 and drop shaft	**48"-diameter consolidation conduit between outfall and drop shaft location across from City Hall or at Tidewater Site**		**1,300**	**LF**	Assumption	Class 5	**13,949,566**	4,184,870	1,750,793	19,885,229	198,852	1,391,966	397,705	1,590,818	596,557	596,557	24,657,684	-30.00%	50.00%	17,260,379	36,986,526
Consolidation Conduit between 217 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at Tidewater Site *Sized to include 220 Volume***		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit between 218 and drop shaft	**60"-diameter consolidation conduit between outfall and drop shaft location at old landfill site north of BPWWTF**		**1,500**	**LF**	Assumption	Class 5	**16,677,132**	5,003,140	2,093,127	23,773,399	237,734	1,664,138	475,468	1,901,872	713,202	713,202	29,479,014	-30.00%	50.00%	20,635,310	44,218,521
Consolidation Conduit btwn High/Middle St Interceptors and Shaft S-7	**72"-diameter consolidation conduit between outfall 205 and Shaft S-7**		**300**	**LF**	Assumption	Class 5	**3,426,231**	1,027,869	430,022	4,884,122	48,841	341,889	97,682	390,730	146,524	146,524	6,056,312	-30.00%	50.00%	4,239,418	9,084,468
Consolidation Conduits							**57,370,598**	**17,211,179**	**7,200,515**	**81,782,293**	**817,823**	**5,724,761**	**1,635,646**	**6,542,583**	**2,453,469**	**2,453,469**	**101,410,043**			**70,987,030**	**152,115,065**
Shaft S-7	**36 ft diameter excavated, 26 ft diameter finished, 200 ft deep (does not include mech/elect/building-see mech/elect/building item), this shaft is assumed to be the receiving shaft for the tunnel which will also be used for OF's 103,104,105,201,203,205**																				
Mob			1	LS	Assumption	Class 5	**77,818**	23,345	9,767	110,930	1,109	7,765	2,219	8,874	3,328	3,328	137,554	-30.00%	50.00%	96,287	206,330
Surface Work/Setup			1	LS	Assumption	Class 5	**424,000**	127,200	38,160	589,360	5,894	41,255	11,787	47,149	17,681	17,681	730,806	-30.00%	50.00%	511,564	1,096,210
Excavation Soil			10	VFT	Assumption	Class 5	**378,597**	113,579	34,074	526,250	5,262	36,837	10,525	42,100	15,787	15,787	652,550	-30.00%	50.00%	456,785	978,825
Excavation Rock			135	VFT	Assumption	Class 5	**1,400,690**	420,207	126,062	1,946,959	19,470	136,287	38,939	155,757	58,409	58,409	2,414,229	-30.00%	50.00%	1,689,960	3,621,344
Liner			145	VFT	Assumption	Class 5	**2,119,501**	635,850	190,755	2,946,106	29,461	206,227	58,922	235,689	88,383	88,383	3,653,172	-30.00%	50.00%	2,557,220	5,479,758
Teardown U/G			1	LS	Assumption	Class 5	**164,429**	49,329	14,799	228,556	2,286	15,999	4,571	18,285	6,857	6,857	283,410	-30.00%	50.00%	198,387	425,115
Teardown Surface			1	LS	Assumption	Class 5	**252,662**	75,799	22,740	351,200	3,512	24,584	7,024	28,096	10,536	10,536	435,488	-30.00%	50.00%	304,842	653,232
Demob			1	LS	Assumption	Class 5	**148,562**	44,569	13,371	206,501	2,065	14,455	4,130	16,520	6,195	6,195	256,061	-30.00%	50.00%	179,243	384,092
Shaft S-7							**4,966,259**	**1,489,878**	**449,727**	**6,905,863**	**69,059**	**483,410**	**138,117**	**552,469**	**207,176**	**207,176**	**8,563,270**			**5,994,289**	**12,844,906**
Adit/Deaeration 218	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 218							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 217	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 217							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 213	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 213							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Adit/Deaeration 210/211	**deaeration chamber - 18 ft by 18 ft excavated, 16 ft by 16 ft finised for 65 ft length/ adit connecting deaeration chamber to tunnel -10 ft by 10 ft excavated, 8 ft by 8 ft finished for 250 ft length**																				
Adit/Deaertion Chamber			315	FT	Assumption	Class 5	3,070,751	921,225	385,406	4,377,383	43,774	306,417	87,548	350,191	131,321	131,321	5,427,954	-30.00%	50.00%	3,799,568	8,141,932
Adit/Deaeration 210/211							**3,070,751**	**921,225**	**385,406**	**4,377,383**	**43,774**	**306,417**	**87,548**	**350,191**	**131,321**	**131,321**	**5,427,954**			**3,799,568**	**8,141,932**
Adit/Deaeration 205	**deaeration chamber - part of Shaft S-7 shaft**																				
Adit/Deaertion Chamber				FT	Assumption	Class 5	0	0	0	0	0	0	0	0	0	0	0	-30.00%	50.00%	0	0
Adit/Deaeration 205							**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**			**0**	**0**
Screening Structure/Approach Channel 218	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 218			100	FT	Assumption	Class 5	1,752,137	525,641	219,909	2,497,687	24,977	174,838	49,954	199,815	74,931	74,931	3,097,132	-30.00%	50.00%	2,167,992	4,645,697
Screening Structure/Approach Channel 218							**1,752,137**	**525,641**	**219,909**	**2,497,687**	**24,977**	**174,838**	**49,954**	**199,815**	**74,931**	**74,931**	**3,097,132**			**2,167,992**	**4,645,697**
Screening Structure/Approach Channel 217	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 217			100	FT	Assumption	Class 5	1,752,137	525,641	219,909	2,497,687	24,977	174,838	49,954	199,815	74,931	74,931	3,097,132	-30.00%	50.00%	2,167,992	4,645,697
Screening Structure/Approach Channel 217							**1,752,137**	**525,641**	**219,909**	**2,497,687**	**24,977**	**174,838**	**49,954**	**199,815**	**74,931**	**74,931**	**3,097,132**			**2,167,992**	**4,645,697**
Screening Structure/Approach Channel 213	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 213			100	FT	Assumption	Class 5	1,784,137	535,241	223,925	2,543,303	25,433	178,031	50,866	203,464	76,299	76,299	3,153,696	-30.00%	50.00%	2,207,587	4,730,544
Screening Structure/Approach Channel 213							**1,784,137**	**535,241**	**223,925**	**2,543,303**	**25,433**	**178,031**	**50,866**	**203,464**	**76,299**	**76,299**	**3,153,696**			**2,207,587**	**4,730,544**
Screening Structure/Approach Channel 210/211	**20 ft by 25 ft by 100 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel 210/211			100	FT	Assumption	Class 5	1,784,137	535,241	223,925	2,543,303	25,433	178,031	50,866	203,464	76,299	76,299	3,153,696	-30.00%	50.00%	2,207,587	4,730,544
Screening Structure/Approach Channel 210/211							**1,784,137**	**535,241**	**223,925**	**2,543,303**	**25,433**	**178,031**	**50,866**	**203,464**	**76,299**	**76,299**	**3,153,696**			**2,207,587**	**4,730,544**
Screening Structure/Approach Channel for S-7 Shaft	**20 ft by 25 ft by 300 ft length with assumed static screen/gates**																				
Screening Structure/Approach Channel S-7 Shaft			300	FT	Assumption	Class 5	4,031,022	1,209,307	505,929	5,746,257	57,463	402,238	114,925	459,701	172,388	172,388	7,125,359	-30.00%	50.00%	4,987,751	10,688,039
Screening Structure/Approach Channel for S-7 Shaft							**4,031,022**	**1,209,307**	**505,929**	**5,746,257**	**57,463**	**402,238**	**114,925**	**459,701**	**172,388**	**172,388**	**7,125,359**			**4,987,751**	**10,688,039**
Floatable Controls / Regulator Modifications																					
Floatable Controls																					
CSO Conduit 207			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 209			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 212			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
CSO Conduit 215			1	ls		Class 5	250,000	75,000	31,377	356,377	3,564	24,946	7,128	28,510	10,691	10,691	441,908	-30.00%	50.00%	309,335	662,862
Regulator To Be Blocked																					
OF 101			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 107			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 202			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 204			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 208			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 214			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
OF 216			1	ls		Class 5	10,000	3,000	1,255	14,255	143	998	285	1,140	428	428	17,676	-30.00%	50.00%	12,373	26,514
Modified Regulators			12	ea		Class 5	25,000	7,500	3,138	427,653	4,277	29,936	8,553	34,212	12,830	12,830	530,289	-30.00%	50.00%	371,202	795,434
Floatable Controls / Regulator Modifications							**1,095,000**	**328,500**	**137,432**	**1,952,947**	**19,529**	**136,706**	**39,059**	**156,236**	**58,588**	**58,588**	**2,421,654**			**1,695,158**	**3,632,482**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate																	
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total 2010	2010 Total Projected to Mid Point 2018 Using 3%/yr Escalation	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%					Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																								
BPSA CSO Interceptor																	6,650,000							
Design, Administration, Construction Management, Land and Insurance																								
Total																	6,650,000							
Amounts from Conceptual Design Report Amendment Second Reafrirmation December 22, 2010 Page 9																								
BPSA CSO Interceptor																		45,640,000	57,815,387	**28,645,350**				
Design/ Design Support/ Construction Management/ Owner/ ROW																		98,952,000	125,349,433	**#REF!**				
Total																		144,592,000	183,164,820	**#REF!**				
Upper High & Cross St interceptor	42" micro-tunneled or jacked interceptor north of Charles St, including roadway & utility improvements at jacking pits									**7,323,323**	73,233	512,633	146,466	585,866	219,700	219,700	**1,757,598**			**9,080,920**				
Lower High & Cross St interceptor	48" micro-tunneled or jacked interceptor south of Charles St, including river crossing plus roadway & utility improvements at jacking pits									**10,035,866**	100,359	702,511	200,717	802,869	301,076	301,076	**2,408,608**			**12,444,473**				
Middle St interceptor	30" and 66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits									**11,286,162**	112,862	790,031	225,723	902,893	338,585	338,585	**2,708,679**			**13,994,840**				
Post-Reevaluation, Pre-Value Engineering																								
BPSA CSO INTERCEPTORS																								
Middle St Interceptor: 1710 lft of 30 inch on Middle St	30" diameter 1710 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	1,710	lft	CDRA	Class 5	3,065	920	385	7,471,598	74,716	523,012	149,432	597,728	224,148	224,148				9,264,782	-30.00%	50.00%	6,485,347	13,897,172
Middle St Interceptor: 1710 lft of 30 inch on Middle St	Restoration Allowance -10% of Construction Cost		10%							747,160	7,472	52,301	14,943	59,773	22,415	22,415				926,478	-30.00%	50.00%	648,535	1,389,717
Middle St Interceptor: 350 lft of 66" Cross St	66" diameter 350 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	350	lft	CDRA	Class 5	5,589	1,677	701	2,788,549	27,885	195,198	55,771	223,084	83,656	83,656				3,457,801	-30.00%	50.00%	2,420,461	5,186,701
Middle St Interceptor: 350 lft of 66" Cross St	Restoration Allowance -10% of Construction Cost		10%							278,855	2,789	19,520	5,577	22,308	8,366	8,366				345,780	-30.00%	50.00%	242,046	518,670
High St Interceptor: 2080 lft of 48 inch on High and Cross	48" diameter 2080 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	2,080	lft	CDRA	Class 5	3,077	923	386	9,123,514	91,235	638,646	182,470	729,881	273,705	273,705				11,313,158	-30.00%	50.00%	7,919,210	16,969,736
High St Interceptor: 2080 lft of 48 inch on High and Cross	Restoration Allowance -10% of Construction Cost		10%							912,351	9,124	63,865	18,247	72,988	27,371	27,371				1,131,316	-30.00%	50.00%	791,921	1,696,974
High St Interceptor: 2160 lft of 42 inch on High St	42" diameter 2160 linear ft, 15-25 ft below grade	micro-tunnel / pipe-jack	2,160	lft	CDRA	Class 5	2,162	649	271	6,657,566	66,576	466,030	133,151	532,605	199,727	199,727				8,255,382	-30.00%	50.00%	5,778,768	12,383,073
High St Interceptor: 2160 lft of 42 inch on High St	Restoration Allowance -10% of Construction Cost		10%							665,757	6,658	46,603	13,315	53,261	19,973	19,973				825,538	-30.00%	50.00%	577,877	1,238,307
BPSA CSO INTERCEPTORS SUBTOTAL										**28,645,350**	**286,454**	**2,005,175**	**572,907**	**2,291,628**	**859,361**	**859,361**				**35,520,234**			**24,864,164**	**53,280,351**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 with Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
Hybrid CSO 206																		1,718,936				
Misc. Sewer Separation Costs (road reconstruction, utilities, etc)																		31,920,230				
Design/ Design Support/ Construction Management/ Owner/ ROW																		#REF!				
Total																		#REF!				
Split of associated work																						
Hybrid CSO 206									**8%**	**2,159,786**	$0	$151,185	$43,196	$172,783	$64,794	$0	**431,957**					
CSO Control Solution																						
Hybrid GSI / Parking lot stormwater tanks	Construction of smaller separate pipe system; replacement & rehabilitation of portions of existing pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched lengtl									**3,878,722**	$17,189	$271,511	$77,574	$310,298	$116,362	$51,568	**844,502**					
Hybrid Public GSI & Sewer Separation - CSO 206																						
OF 206	total of 5140 LF		5,140																			
1980 lft of 8 inch, total existing	existing 8" diameter,		1,980	lft	City Record Plans																	
0 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	0%	0	lft	Estimate	Class 5	207	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
198 lft of 8 inch, rehab existing	rehab existing 8" diameter, 50% of total	10%	198	lft	Estimate	Class 5	31	9	4	8,715	87	610	174	697	261	261		10,806	-30.00%	50.00%	7,564	16,210
1782 lft of 8 inch, new pipe	new 8" diameter, separation area only	90%	1,782	lft	Estimate	Class 5	189	57	24	479,143	4,791	33,540	9,583	38,331	14,374	14,374		594,138	-30.00%	50.00%	415,896	891,206
530 lft of 10 inch, total existing	existing 10" diameter		530	lft	City Record Plans																	
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	0%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
53 lft of 10 inch, rehab existing	rehab existing 10" diameter, 50% of total	10%	53	lft	Estimate	Class 5	34	10	4	2,570	26	180	51	206	77	77		3,187	-30.00%	50.00%	2,231	4,781
477 lft of 10 inch, new pipe	new 10" diameter, separation area only	90%	477	lft	Estimate	Class 5	192	58	24	130,520	1,305	9,136	2,610	10,442	3,916	3,916		161,845	-30.00%	50.00%	113,291	242,767
940 lft of 12 inch, total existing	existing 12" diameter		940	lft	City Record Plans																	
0 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	0%	0	lft	Estimate	Class 5	217	65	27	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
94 lft of 12 inch, rehab existing	rehab existing 12" diameter, 50% of total	10%	94	lft	Estimate	Class 5	40	12	5	5,369	54	376	107	430	161	161		6,658	-30.00%	50.00%	4,660	9,987
846 lft of 12 inch, new pipe	new 12" diameter, separation area only	90%	846	lft	Estimate	Class 5	197	59	25	237,687	2,377	16,638	4,754	19,015	7,131	7,131		294,731	-30.00%	50.00%	206,312	442,097
610 lft of 15 inch, total existing	existing 15" diameter		610	lft	City Record Plans																	
0 lft of 15 inch, replace existing	replace 15" diameter, 20% of total	0%	0	lft	Estimate	Class 5	226	68	28	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
61 lft of 15 inch, rehab existing	rehab existing 15" diameter, 50% of total	10%	61	lft	Estimate	Class 5	49	15	6	4,274	43	299	85	342	128	128		5,300	-30.00%	50.00%	3,710	7,950
549 lft of 15 inch, new pipe	new 15" diameter, separation area only	90%	549	lft	Estimate	Class 5	205	62	26	160,559	1,606	11,239	3,211	12,845	4,817	4,817		199,093	-30.00%	50.00%	139,365	298,640
320 lft of 18-24 inch, total existing	existing 18-24" diameter		320	lft	City Record Plans																	
0 lft of 18-24 inch, replace existing	replace 18-24" diameter, 20% of total	0%	0	lft	Estimate	Class 5	268	80	34	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
32 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 50% of	10%	32	lft	Estimate	Class 5	72	22	9	3,305	33	231	66	264	99	99		4,098	-30.00%	50.00%	2,869	6,147
288 lft of 18-24 inch, new pipe	new 18-24" diameter, separation area only	90%	288	lft	Estimate	Class 5	244	73	31	100,001	1,000	7,000	2,000	8,000	3,000	3,000		124,001	-30.00%	50.00%	86,801	186,002
760 lft of 25-48 inch, total existing	existing 25-48" diameter		760	lft	City Record Plans																	
0 lft of 25-48 inch, replace existing	replace 25-48" diameter, 20% of total	0%	0	lft	Estimate	Class 5	465	140	58	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
76 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 50% of	10%	76	lft	Estimate	Class 5	162	49	20	17,537	175	1,228	351	1,403	526	526		21,746	-30.00%	50.00%	15,222	32,618
684 lft of 25-48 inch, new pipe	new 25-48" diameter, separation area only	90%	684	lft	Estimate	Class 5	423	127	53	412,309	4,123	28,862	8,246	32,985	12,369	12,369		511,263	-30.00%	50.00%	357,884	766,894
0 lft of 49-54 inch, total existing	existing 49-54" diameter		0	lft	City Record Plans																	
0 lft of 49-54 inch, replace existing	replace 49-54" diameter, 20% of total	0%	0	lft	Estimate	Class 5	646	194	81	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 50% of	10%	0	lft	Estimate	Class 5	262	79	33	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch, new pipe	new 49-54" diameter, separation area only	90%	0	lft	Estimate	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Stormwater Flow Control - CSO 206	GSI in public ROWs																					
Flow Throttles	vortex flow throttles on east-west streets		7	ea	Estimate	Class 5	2,000	600	251	19,957	200	1,397	399	1,597	599	599		24,747	-30.00%	50.00%	17,323	37,120
Additional 5 ft double grate catch basins	new 5' diameter double grate CBs, assume		4	ea	Estimate	Class 5	10,000	3,000	1,255	57,020	570	3,991	1,140	4,562	1,711	1,711		70,705	-30.00%	50.00%	49,494	106,058
140,000 gal stormwater storage tank	0.14 MG Storage Tank; new		140,000	gal	Estimate	Class 5	4	1	1	798,285	7,983	55,880	15,966	63,863	23,949	23,949		989,873	-30.00%	50.00%	692,911	1,484,810
Reduction of New Sewer due to Stormwater Flow Control - CSO 206																						
-891 lft of 8 inch	SFW removes new drain by 1/2		-891	lft	New	Class 5	189	57	24	-239,572	-2,396	-16,770	-4,791	-19,166	-7,187	-7,187		-297,069	-30.00%	50.00%	-207,948	-445,603
-477 lft of 10 inch	SFW removes new drain		-477	lft	New	Class 5	192	58	24	-130,520	-1,305	-9,136	-2,610	-10,442	-3,916	-3,916		-161,845	-30.00%	50.00%	-113,291	-242,767
-446 lft of 12 inch	SFW removes remainder of new drain after		-446	lft	New	Class 5	197	59	25	-125,305	-1,253	-8,771	-2,506	-10,024	-3,759	-3,759		-155,379	-30.00%	50.00%	-108,765	-233,068
-274.5 lft of 15 inch	SFW removes 1/2 new drain		-275	lft	New	Class 5	205	62	26	-80,280	-803	-5,620	-1,606	-6,422	-2,408	-2,408		-99,547	-30.00%	50.00%	-69,683	-149,320
-144 lft of 18-24 inch	SFW removes 1/2 new drain		-144	lft	New	Class 5	244	73	31	-50,000	-500	-3,500	-1,000	-4,000	-1,500	-1,500		-62,001	-30.00%	50.00%	-43,400	-93,001
-342 lft of 25-48 inch	SFW removes 1/2 new drain		-342	lft	New	Class 5	423	127	53	-206,154	-2,062	-14,431	-4,123	-16,492	-6,185	-6,185		-255,631	-30.00%	50.00%	-178,942	-383,447
0 lft of 49-54 inch	none		0	lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
Public GSI in CSO 056	GSI in public ROWs		1	ls	GSI Estimates					225,898	2,259	15,813	4,518	18,072	6,777	6,777		280,113	-30.00%	50.00%	196,079	420,170
Reduction of New Sewer due to GSI - CSO 206																						
0 lft of 8 inch	none		0	lft	New	Class 5	189	57	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 10 inch	none		0	lft	New	Class 5	192	58	24	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
-400 lft of 12 inch	GSI removes new drain on Jackson St and		-400	lft	New	Class 5	197	59	25	-112,381	-1,124	-7,867	-2,248	-8,991	-3,371	-3,371		-139,353	-30.00%	50.00%	-97,547	-209,029
0 lft of 15 inch	none		0	lft	New	Class 5	205	62	26	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 18-24 inch	none		0	lft	New	Class 5	244	73	31	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 25-48 inch	none		0	lft	New	Class 5	423	127	53	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
0 lft of 49-54 inch	none		0	lft	New	Class 5	588	176	74	0	0	0	0	0	0	0		0	-30.00%	50.00%	0	0
HYBRID GSI & SEWER SEPARATION - CSO 206 SUBTOTAL										**1,718,936**	**17,189**	**120,326**	**34,379**	**137,515**	**51,568**	**51,568**		**2,131,481**			**1,492,036**	**3,197,221**
Items Below Are Assumed To Be Done In Conjuction With Items of Work Above Therefore No Cost for Design, Engineering During Construction, Construction Management, Owner and Right Of Way Costs Have Been Allocated to These Items; No costs where GSI reduces need for new drains, misc. costs have been included in GSI cost																						
A) Rebuild Full Roadway (full-depth)	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	9,227	lf	Phase 2 Lessons Learned	Class 5	180	54	23	2,367,648		165,735	47,353	189,412	71,029			2,841,177	-30.00%	50.00%	1,988,824	4,261,766
B) Grind and overlay full roadway	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	44	13	6	2,315,033		162,052	46,301	185,203	69,451			2,778,040	-30.00%	50.00%	1,944,628	4,167,060
C) Remove/Replace Full Length Curb & Gutter	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	40	12	5	2,104,576		147,320	42,092	168,366	63,137			2,525,491	-30.00%	50.00%	1,767,843	3,788,236
D) Remove/Replace Full Length Sidewalk	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf	Phase 2 Lessons Learned	Class 5	84	25	11	2,762,255		193,358	55,245	220,980	82,868			3,314,707	-30.00%	50.00%	2,320,295	4,972,060
E) Rebuild Water Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	36,909	lf	Phase 2 Lessons Learned	Class 5	200	60	25	10,522,878		736,601	210,458	841,830	315,686			12,627,454	-30.00%	50.00%	8,839,217	18,941,180
F) Rebuild Gas Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	20,761	lf	Phase 2 Lessons Learned	Class 5	120	36	15	3,551,471		248,603	71,029	284,118	106,544			4,261,766	-30.00%	50.00%	2,983,236	6,392,648
G) Add for Hazardous Material Allowance	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf	Stakeholder input	Class 5	13	4	2	414,338		29,004	8,287	33,147	12,430			497,206	-30.00%	50.00%	348,044	745,809
H)Add for All Import Backfill	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	23,068	lf		Class 5	78	23	10	2,561,992		179,339	51,240	204,959	76,860			3,074,390	-30.00%	50.00%	2,152,073	4,611,585
Subtotal										**$26,600,191**		**$1,862,013**	**$532,004**	**$2,128,015**	**$798,006**			**$31,920,230**			**$22,344,161**	**$47,880,344**

Narragansett Bay Commission CSO Control Facilities Program

							Construction Cost Estimate																	
Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total 2010	2010 Total Projected to Mid Point 2018 Using 3%/yr Escalation	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%					Low	High	Low	High
Amounts from Conceptual Design Report 1998 Page 10-42																								
Sewer Separation																	26,730,000							
Design, Administration, Construction Management, Land and Insurance																								
Total																	26,730,000							
Amounts from Conceptual Design Report Amendment Second Reafirmation December 22, 2010 Page 9																								
Sewer Separation	Note: Includes Items A through H highlighted in yellow below																	71,446,000	90,505,655	**39,906,439**				
Design/ Design Support/ Construction Management/ Owner/ ROW																		98,952,000	125,349,433	**#REF!**				
Total																		170,398,000	215,855,088	**#REF!**				
Apportionment of Conjunction costs																	**Totals**							
035 Sewer separation									**28%**	**9,412,823**	0	658,898	188,256	753,026	282,385	0	**1,882,565**			**11,295,388**				
CSO Control Solution																								
035 Sewer separation	Replacement of 10% of dual pipe system; rehabilitation of 10% of dual pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths									**15,772,970**	63,601	1,104,108	315,459	1,261,838	473,189	190,804	**3,409,000**			**19,181,969**				
Post-Reevaluation, Pre-Value Engineering																								
SEWER SEPARATION																								
OF 035	total of 54420 LF		54,420																					
1260 lft of 8 inch, total existing	existing 8" diameter		1,260		City Record Plans	Class 5																		
126 lft of 8 inch, replace existing	replace 8" diameter, 20% of total	10%	126	lft	Estimate	Class 5	207	62	26	37,180	372	2,603	744	2,974	1,115	1,115				46,103	-30.00%	50.00%	32,272	69,155
126 lft of 8 inch, rehab existing	rehab existing 8" diameter, 60% of total	10%	126	lft	Estimate	Class 5	28	8	3	4,991	50	349	100	399	150	150				6,189	-30.00%	50.00%	4,332	9,284
252 lft of 8 inch, new pipe	new 8" diameter, 0% of existing	20%	252	lft	Estimate	Class 5	189	57	24	67,758	678	4,743	1,355	5,421	2,033	2,033				84,019	-30.00%	50.00%	58,814	126,029
0 lft of 10 inch, total existing	existing 10" diameter		0	lft	City Record Plans	Class 5																		
0 lft of 10 inch, replace existing	replace 10" diameter, 20% of total	10%	0	lft	Estimate	Class 5	211	63	27	0	0	0	0	0	0	0				0	-30.00%	50.00%	0	0
0 lft of 10 inch, rehab existing	rehab existing 10" diameter, 60% of total	10%	0	lft	Estimate	Class 5	31	9	4	0	0	0	0	0	0	0				0	-30.00%	50.00%	0	0
0 lft of 10 inch, new pipe	new 10" diameter, 0% of existing	20%	0	lft	Estimate	Class 5	192	58	24	0	0	0	0	0	0	0				0	-30.00%	50.00%	0	0
31420 lft of 12 inch, total existing	existing 12" diameter		31,420		City Record Plans	Class 5																		
3142 lft of 12 inch, replace existing	replace 12" diameter, 20% of total	10%	3,142	lft	Estimate	Class 5	217	65	27	971,932	9,719	68,035	19,439	77,755	29,158	29,158				1,205,196	-30.00%	50.00%	843,637	1,807,793
3142 lft of 12 inch, rehab existing	rehab existing 12" diameter, 60% of total	10%	3,142	lft	Estimate	Class 5	36	11	5	161,519	1,615	11,306	3,230	12,922	4,846	4,846				200,284	-30.00%	50.00%	140,199	300,426
6284 lft of 12 inch, new pipe	new 12" diameter, 0% of existing	20%	6,284	lft	Estimate	Class 5	197	59	25	1,764,706	17,647	123,529	35,294	141,176	52,941	52,941				2,188,235	-30.00%	50.00%	1,531,765	3,282,353
8640 lft of 15 inch, total existing	existing 15" diameter		8,640		City Record Plans	Class 5																		
864 lft of 15 inch, replace existing	replace 15" diameter, 20% of total	10%	864	lft	Estimate	Class 5	226	68	28	278,351	2,784	19,485	5,567	22,268	8,351	8,351				345,155	-30.00%	50.00%	241,608	517,732
864 lft of 15 inch, rehab existing	rehab existing 15" diameter, 60% of total	10%	864	lft	Estimate	Class 5	44	13	6	54,484	545	3,814	1,090	4,359	1,635	1,635				67,560	-30.00%	50.00%	47,292	101,339
1728 lft of 15 inch, new pipe	new 15" diameter, 0% of existing	20%	1,728	lft	Estimate	Class 5	205	62	26	504,972	5,050	35,348	10,099	40,398	15,149	15,149				626,166	-30.00%	50.00%	438,316	939,248
4430 lft of 18-24 inch, total existing	existing 18-24" diameter		4,430	lft	City Record Plans	Class 5																		
443 lft of 18-24 inch, replace existing	replace 18-24" diameter, 20% of total	10%	443	lft	Estimate	Class 5	268	80	34	169,242	1,692	11,847	3,385	13,539	5,077	5,077				209,860	-30.00%	50.00%	146,902	314,790
443 lft of 18-24 inch, rehab existing	rehab existing 18-24" diameter, 60% of	10%	443	lft	Estimate	Class 5	65	20	8	41,177	412	2,882	824	3,294	1,235	1,235				51,059	-30.00%	50.00%	35,742	76,589
886 lft of 18-24 inch, new pipe	new 18-24" diameter, 0% of existing	20%	886	lft	Estimate	Class 5	244	73	31	308,172	3,082	21,572	6,163	24,654	9,245	9,245				382,134	-30.00%	50.00%	267,493	573,200
6390 lft of 25-48 inch, total existing	existing 25-48" diameter		6,390	lft	City Record Plans	Class 5																		
639 lft of 25-48 inch, replace existing	replace 25-48" diameter, 20% of total	10%	639	lft	Estimate	Class 5	465	140	58	423,569	4,236	29,650	8,471	33,885	12,707	12,707				525,225	-30.00%	50.00%	367,658	787,838
639 lft of 25-48 inch, rehab existing	rehab existing 25-48" diameter, 60% of	10%	639	lft	Estimate	Class 5	146	44	18	132,702	1,327	9,289	2,654	10,616	3,981	3,981				164,551	-30.00%	50.00%	115,185	246,826
1278 lft of 25-48 inch, new pipe	new 25-48" diameter, 0% of existing	20%	1,278	lft	Estimate	Class 5	423	127	53	770,622	7,706	53,944	15,412	61,650	23,119	23,119				955,571	-30.00%	50.00%	668,899	1,433,356
2280 lft of 49-54 inch, total existing	existing 49-54" diameter		2,280	lft	City Record Plans	Class 5																		
228 lft of 49-54 inch, replace existing	replace 49-54" diameter, 20% of total	10%	228	lft	Estimate	Class 5	646	194	81	209,960	2,100	14,697	4,199	16,797	6,299	6,299				260,351	-30.00%	50.00%	182,246	390,526
228 lft of 49-54 inch, rehab existing	rehab existing 49-54" diameter, 60% of	10%	228	lft	Estimate	Class 5	236	71	30	76,592	766	5,361	1,532	6,127	2,298	2,298				94,974	-30.00%	50.00%	66,482	142,461
456 lft of 49-54 inch, new pipe	new 49-54" diameter, 0% of existing	20%	456	lft	Estimate	Class 5	588	176	74	382,219	3,822	26,755	7,644	30,578	11,467	11,467				473,951	-30.00%	50.00%	331,766	710,927
SEWER SEPARATION SUBTOTAL			**#REF!**							**6,360,146**	**63,601**	**445,210**	**127,203**	**508,812**	**190,804**	**190,804**				**7,886,581**			**5,520,607**	**11,829,872**
Items Below Are Assumed To Be Done In Conjuction With Items of Work Above Therefore No Cost for Design, Engineering During Construction, Construction Management, Owner and Right Of Way Costs Have Been Allocated to These Items																								
A) Rebuild Full Roadway (full-depth)	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	12,413	lf	Phase 2 Lessons Learned	Class 5	180	54	23	3,185,123		222,959	63,702	254,810	95,554					3,822,147	-30.00%	50.00%	2,675,503	5,733,221
B) Grind and overlay full roadway	Interceptor Jacking/Receiving Pits plus See Separation Roadway-Utility Quantities tab for assumptions	sewer separation and interceptor launch/receive/jack pits	49,653	lf	Phase 2 Lessons Learned	Class 5	44	13	6	3,114,342		218,004	62,287	249,147	93,430					3,737,211	-30.00%	50.00%	2,616,047	5,605,816
C) Remove/Replace Full Length Curb & Gutter	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	49,653	lf	Phase 2 Lessons Learned	Class 5	40	12	5	2,831,220		198,185	56,624	226,498	84,937					3,397,464	-30.00%	50.00%	2,378,225	5,096,196
D) Remove/Replace Full Length Sidewalk	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	26,459	lf	Phase 2 Lessons Learned	Class 5	84	25	11	3,168,273		221,779	63,365	253,462	95,048					3,801,928	-30.00%	50.00%	2,661,349	5,702,892
E) Rebuild Water Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	45,994	lf	Phase 2 Lessons Learned	Class 5	200	60	25	13,112,856		917,900	262,257	1,049,029	393,386					15,735,428	-30.00%	50.00%	11,014,799	23,603,142
F) Rebuild Gas Infrastructure	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	25,871	lf	Phase 2 Lessons Learned	Class 5	120	36	15	4,425,589		309,791	88,512	354,047	132,768					5,310,707	-30.00%	50.00%	3,717,495	7,966,060
G) Add for Hazardous Material Allowance	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	28,746	lf	Stakeholder input	Class 5	13	4	2	516,319		36,142	10,326	41,305	15,490					619,582	-30.00%	50.00%	433,708	929,374
H)Add for All Import Backfill	See Separation Roadway-Utility Quantities tab for assumptions	ONLY sewer separation	28,746	lf		Class 5	78	23	10	3,192,571		223,480	63,851	255,406	95,777					3,831,085	-30.00%	50.00%	2,681,759	5,746,627
Subtotal										**$33,546,293**		**$2,348,241**	**$670,926**	**$2,683,703**	**$1,006,389**					**$40,255,552**			**$28,178,886**	**$60,383,328**

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate: Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations- Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total 1998	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%			Low	High	Low	High
CSO Control Solution									**Accuracy Range % AACE: +**	**0%**												
West River Interceptor	72" dia micro-tunnel/pipe jack; 039 056 consolodation conduits; Charles St regulator structure; reconstruction of under- and over-flows to MRI; riverbank, park & roadway restoration									**28,130,421**	281,304	1,969,129	562,608	2,250,434	843,913	843,913	**6,751,301**					
West River Interceptor (CSO 039/056)																						
12" Connecting Conduit from CSO 056	12" diameter 200 linear ft, 10 ft below grade	pipe-jack river crossing	200	lft	CDR	Class 5	2,300	690	289	655,734	6,557	45,901	13,115	52,459	19,672	19,672		813,110	-30.00%	50.00%	569,177	1,219,665
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							131,147	1,311	9,180	2,623	10,492	3,934	3,934		162,622	-30.00%	50.00%	113,835	243,933
West River Interceptor (Branch Ave to Louisquisset Pike)	72" diameter 150 linear ft, 20 ft below grade	micro-tunnel / pipe-jack	150	lft	CDR	Class 5	5,200	1,560	653	1,111,897	11,119	77,833	22,238	88,952	33,357	33,357		1,378,752	-30.00%	50.00%	965,126	2,068,128
Urban Restoration	Restoration Allowance -10% of Construction Cost		10%							111,190	1,112	7,783	2,224	8,895	3,336	3,336		137,875	-30.00%	50.00%	96,513	206,813
West River Interceptor (Louisquisset Pike to CSO 039)	72" diameter 1900 linear ft, 20-28 ft below grade	micro-tunnel / pipe-jack	1,900	lft	CDR	Class 5	2,800	840	351	7,583,707	75,837	530,859	151,674	606,697	227,511	227,511		9,403,797	-30.00%	50.00%	6,582,658	14,105,695
Highway Crossing - Louisquisset Pike	Risk Allowance - 5% of Construction Cost		5%							379,185	3,792	26,543	7,584	30,335	11,376	11,376		470,190	-30.00%	50.00%	329,133	705,285
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							1,516,741	15,167	106,172	30,335	121,339	45,502	45,502		1,880,759	-30.00%	50.00%	1,316,532	2,821,139
66" Connecting Conduit from CSO 039	66" diameter 150 linear FT, 10 ft below grade	pipe-jack river crossing	150	lft	CDR	Class 5	3,900	1,170	489	833,923	8,339	58,375	16,678	66,714	25,018	25,018		1,034,064	-30.00%	50.00%	723,845	1,551,096
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							166,785	1,668	11,675	3,336	13,343	5,004	5,004		206,813	-30.00%	50.00%	144,769	310,219
West River Interceptor (CSO 039 to Charles St)	72" diameter 2520 linear ft, 20-28 ft below grade	micro-tunnel / pipe-jack	2,520	lft	CDR	Class 5	2,900	870	364	10,417,618	104,176	729,233	208,352	833,409	312,529	312,529		12,917,847	-30.00%	50.00%	9,042,493	19,376,770
Riverbank & Ballfield Restoration	Restoration Allowance -20% of Construction Cost		20%							2,083,524	20,835	145,847	41,670	166,682	62,506	62,506		2,583,569	-30.00%	50.00%	1,808,499	3,875,354
Regulator Structure (Charles Street)	New Regulator Structure, 28 ft below grade	open cut	1	EA	CDR	Class 5	700,000	210,000	87,856	997,856	9,979	69,850	19,957	79,828	29,936	29,936		1,237,342	-30.00%	50.00%	866,139	1,856,012
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							199,571	1,996	13,970	3,991	15,966	5,987	5,987		247,468	-30.00%	50.00%	173,228	371,202
12" Underflow to Mooshassuck River Interceptor	12" diameter 150 linear FT, 28 ft below grade	pipe-jack	150	lft	CDR	Class 5	3,900	1,170	489	833,923	8,339	58,375	16,678	66,714	25,018	25,018		1,034,064	-30.00%	50.00%	723,845	1,551,096
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							166,785	1,668	11,675	3,336	13,343	5,004	5,004		206,813	-30.00%	50.00%	144,769	310,219
12" Overflow to Mooshassuck River Interceptor	36" diameter 250 linear FT, 20 ft below grade	pipe-jack	250	lft	CDR	Class 5	2,200	660	276	784,030	7,840	54,882	15,681	62,722	23,521	23,521		972,197	-30.00%	50.00%	680,538	1,458,296
Riverbank Restoration	Restoration Allowance -20% of Construction Cost		20%							156,806	1,568	10,976	3,136	12,544	4,704	4,704		194,439	-30.00%	50.00%	136,108	291,659
West River Interceptor (CSO 039/056) SUBTOTAL										**28,130,421**	**281,304**	**1,969,129**	**562,608**	**2,250,434**	**843,913**	**843,913**		**32,474,208**			**22,731,946**	**48,711,312**

Narragansett Bay Commission CSO Control Facilities Program

CSO Outfall	Public GSI Basin Cost: Construction Total Escalated Mid Point 2018	Public GSI Basin Cost: Administration Total Escalated Mid Point 2018	Private GSI Basin Cost: Construction Total Escalated Mid Point 2018	Private GSI Basin Cost: Administration Total Escalated Mid Point 2018	Full GSI Basin Cost: Construction Total Escalated Mid Point 2018	Full GSI Basin Cost: Administration Total Escalated Mid Point 2018
101	$3,084,847	$740,363	$2,501,227	$600,295	$5,586,074	$1,340,658
103	$16,719,982	$4,012,796	$9,760,854	$2,342,605	$26,480,836	$6,355,401
104	$2,694,678	$646,723	$2,184,874	$524,370	$4,879,553	$1,171,093
105	$3,102,626	$744,630	$2,515,643	$603,754	$5,618,268	$1,348,384
106	$4,249,532	$1,019,888	$3,445,566	$826,936	$7,695,098	$1,846,824
107	$8,319,117	$1,996,588	$6,745,230	$1,618,855	$15,064,346	$3,615,443
201	$2,163,095	$519,143	$1,753,861	$420,927	$3,916,956	$940,069
202	$213,889	$51,333	$173,424	$41,622	$387,313	$92,955
203	$2,018,145	$484,355	$1,636,334	$392,720	$3,654,479	$877,075
204	$0	$0	$0	$0	$0	$0
205	$51,725,670	$12,414,161	$41,939,733	$10,065,536	$93,665,403	$22,479,697
206	$225,897	$54,215	$61,053	$14,653	$286,951	$68,868
207	$1,008,738	$242,097	$817,896	$196,295	$1,826,634	$438,392
208	$270,478	$64,915	$0	$0	$270,478	$64,915
209	$1,836,820	$440,837	$1,489,313	$357,435	$3,326,133	$798,272
210	$3,174,468	$761,872	$857,964	$205,911	$4,032,432	$967,784
211	$0	$0	$0	$0	$0	$0
212	$2,616,204	$627,889	$2,121,246	$509,099	$4,737,450	$1,136,988
213	$3,503,368	$840,808	$2,813,835	$675,320	$6,317,202	$1,516,129
214	$1,374,827	$329,958	$76,942	$18,466	$1,451,769	$348,424
215	$6,802,171	$1,632,521	$5,660,892	$1,358,614	$12,463,063	$2,991,135
216	$2,047,745	$491,459	$1,660,333	$398,480	$3,708,078	$889,939
217	$6,452,111	$1,548,507	$5,231,441	$1,255,546	$11,683,552	$2,804,052
218	$68,984,756	$16,556,341	$55,933,586	$13,424,061	$124,918,342	$29,980,402
220	$48,476,525	$11,634,366	$39,356,874	$9,445,650	$87,833,399	$21,080,016
Misc to BPWWTF	$3,208,959	$770,150	$2,601,859	$624,446	$5,810,817	$1,394,596
Total Phase 3 Area						

CSO Outfall	Public GSI (gal)	Private GSI (gal)	All GSI (gal)	Public GSI Basin Cost ($)	Private GSI Basin Cost ($)	Full GSI Basin Cost ($)	Existing Overflow Volume (FINAL-2011) (gal)	Public GSI Overflow Volume (gal)	Public GSI CSO Reduction Vol (gal)	GSI Storage Vol vs CSO Reduction Vol * (%)	Public GSI CSO Reduction Cost ($/gal)	Full GSI Overflow Volume (gal)	Full GSI CSO Reduction Volume (gal)	CSO Reduction Vol vs GSI Capture Vol * (%)	Public GSI CSO Reduction Cost ($/gal)
101	93,986	281,957	375,942	$3,825,210	$3,101,522	$6,926,732	379,542	308,905	70,637	133%	$54.2	173,908	205,634	183%	$33.7
103	509,405	1,100,314	1,609,719	$20,732,777	$12,103,459	$32,836,236	4,877,469	4,355,747	521,722	98%	$39.8	3,631,172	1,246,297	129%	$26.4
104	82,098	246,295	328,393	$3,341,401	$2,709,244	$6,050,646	485,939	407,890	78,049	105%	$42.9	288,757	197,182	167%	$30.7
105	94,527	283,582	378,109	$3,847,256	$3,119,397	$6,966,653	1,638,855	1,533,728	105,127	90%	$36.6	1,316,225	322,630	117%	$21.6
106	129,470	388,409	517,879	$5,269,420	$4,272,502	$9,541,922	1,185,889	908,806	277,083	47%	$19.1	475,552	710,337	73%	$13.5
107	253,457	760,371	1,013,828	$10,315,705	$8,364,085	$18,679,789	373,298	301,543	71,755	353%	$143.8	276,846	96,452	1051%	$193.7
201	65,903	197,708	263,611	$2,682,238	$2,174,787	$4,857,025	1,340,133	1,256,722	83,411	79%	$32.2	1,145,350	194,783	135%	$25.0
202	6,517	19,550	26,066	$265,223	$215,045	$480,268	174,680	159,060	15,620	42%	$17.0	138,516	36,164	72%	$13.3
203	61,486	184,459	245,946	$2,502,500	$2,029,054	$4,531,553	395,943	352,753	43,190	142%	$58.0	232,712	163,231	151%	$27.8
204	0	0	0	$0	$0	$0	159,346	63,995	95,351	0%	$0.0	7,463	151,883	0%	$0.0
205	1,575,917	4,727,752	6,303,669	$64,139,831	$52,005,268	$116,145,099	12,814,769	11,725,036	1,089,733	145%	$58.9	8,579,484	4,235,285	149%	$27.5
206	6,882	6,882	13,765	$280,113	$75,706	$355,819	140,828	134,655	6,173	111%	$45.4	131,437	9,391	147%	$37.9
207	30,733	92,199	122,932	$1,250,835	$1,014,191	$2,265,026	43,447	35,731	7,716	398%	$162.2	20,262	23,185	530%	$97.7
208	8,241	0	8,241	$335,393	$0	$335,393	14,253	11,019	3,234	255%	$103.8	12,692	1,561	528%	$214.9
209	55,962	167,886	223,848	$2,277,656	$1,846,748	$4,124,405	23,448	18,614	4,834	1158%	$471.2	7,974	15,474	1447%	$266.6
210	96,716	96,716	193,432	$3,936,340	$1,063,876	$5,000,215	3,172,113	3,092,912	79,201	122%	$49.8	3,057,445	114,668	169%	$43.7
211	0	0	0	$0	$0	$0	3,958,348	3,900,128	58,220	0%	$0.0	3,901,209	57,139	0%	$0.0
212	79,707	239,122	318,830	$3,244,093	$2,630,346	$5,874,439	598,190	549,760	48,430	165%	$67.0	451,101	147,089	217%	$40.0
213	106,737	317,196	423,932	$4,344,176	$3,489,155	$7,833,331	1,974,517	1,833,052	141,465	75%	$30.8	1,653,257	321,260	132%	$24.4
214	41,887	8,673	50,560	$1,704,786	$95,408	$1,800,193	1,262,517	1,057,995	204,522	20%	$8.4	833,859	428,658	12%	$4.2
215	207,241	638,137	845,377	$8,434,692	$7,019,506	$15,454,198	1,575,368	1,422,253	153,115	135%	$55.1	1,149,587	425,781	199%	$36.3
216	62,388	187,165	249,553	$2,539,203	$2,058,813	$4,598,017	8,897	4,247	4,650	1342%	$546.1	2,121	6,776	3683%	$678.6
217	196,575	589,726	786,301	$8,000,617	$6,486,987	$14,487,604	2,711,034	2,502,286	208,748	94%	$38.4	2,099,107	611,927	128%	$23.7
218	2,101,747	6,305,241	8,406,987	$85,541,098	$69,357,647	$154,898,744	12,579,399	10,397,834	2,181,565	96%	$39.3	7,689,169	4,890,230	172%	$31.7
220	1,476,926	4,436,593	5,913,519	$60,110,890	$48,802,524	$108,913,415	4,600,000	3,847,738	752,262	196%	$80.0	2,421,686	2,178,314	271%	$50.0
Misc to BPWWTF	97,767	293,300	391,067	3,979,109	3,226,305	7,205,413									
Total Phase 3 Area	7,442,274	21,569,234	29,011,508	302,900,561	237,261,575	540,162,136	56,488,976	50,183,202	6,305,774	118%	$48.1	39,697,642	16,791,334	173%	$32.2

Narragansett Bay Commission CSO Control Facilities Program

Name	Description	Owner Preferred Construction Method	Estimating Quantity	Estimating Quntity Unit	Source	Estimate Class	Construction Cost Estimate Base Cost	Contingency	Escalation Mid Point 2018 using 3%/yr	Construction Total	Geotechnical Investigations-Determinations Allowance	Design	Engineering During Construction	Construction Management	Onwner	Right of Way	Total MCP 2014 wth Escalation Included to Midpiont 2018 using 3%/yr	Accuracy Range % AACE		Accuracy Range $ AACE	
								30.00%	12.55%		1.00%	7.00%	2.00%	8.00%	3.00%	3.00%		Low	High	Low	High
Total																	**#REF!**				
218-BPWWTF CSO Interceptor	66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits NOTE: PLACEHOLDER, NEEDS ESTIMATE									**27,390,083**	273,901	1,917,306	547,802	2,191,207	821,702	821,702	**33,963,702**				
218-BPWWTF CSO INTERCEPTOR																					
66 inch Interceptor on XXX St	66" diameter, 15-25 ft below grade	micro-tunnel / pipe-jack	5,000	lft	CDRA	Class 5	3,425	1,028	430	24,411,838	244,118	1,708,829	488,237	1,952,947	732,355	732,355	30,270,680	-30.00%	50.00%	21,189,476	45,406,019
Surface restoration on XXX St	Restoration Allowance -10% of Construction Cost		10%							2,441,184	24,412	170,883	48,824	195,295	73,236	73,236	3,027,068	-30.00%	50.00%	2,118,948	4,540,602
66 inch Interceptor on YYY St	66" diameter, 15-25 ft below grade	micro-tunnel / pipe-jack	100	lft	CDRA	Class 5	3,425	1,028	430	488,237	4,882	34,177	9,765	39,059	14,647	14,647	605,414	-30.00%	50.00%	423,790	908,120
Surface restoration on YYY St	Restoration Allowance -10% of Construction Cost		10%							48,824	488	3,418	976	3,906	1,465	1,465	60,541	-30.00%	50.00%	42,379	90,812
218-BPWWTF CSO INTERCEPTOR SUBTOTAL										**27,390,083**	**273,901**	**1,917,306**	**547,802**	**2,191,207**	**821,702**	**821,702**	**33,963,702**			**23,774,592**	**50,945,554**

Narragansett Bay Commission - Phase III Reevaluation

Alternative Plan Evaluation

Component Costs

		Estimate of Probable Construction Cost	Constructors Engr. & Admin. Total (2018$)	Additional Contingency	Capital Improvements Total (2018$)	Included system components
Sub-Phase	**Redefined Phase III Program**					
III-A	Pawtucket Tunnel	$283,742,290	$68,098,150	10%	$387,024,483	26' Diameter Tunnel excavation & lining; launch shaft S-5; BP utility & access shafts; pump cavern; connection adit between S-5 & cavern; PS fit-out
III-A	Drop shaft 218 & conduit	$34,916,327	$8,379,919	10%	$47,625,870	Drop shaft 218, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber
III-A	Drop shaft 205 & conduit	$17,536,243	$4,208,698	10%	$23,919,436	Exit Shaft S-7, 300' consolodation conduit, screening & approach structure, (no adit or deaeration chamber included)
III-A	Drop shaft 210/211 & conduit	$20,015,462	$4,803,711	10%	$27,301,091	Drop shaft 210, 600' consolodation conduit, screening & approach structure, adit & deaeration chamber
III-A	Drop shaft 213 & conduit	$30,512,580	$7,323,019	10%	$41,619,159	Drop shaft 213, 1,300' consolodation conduit, screening & approach structure, adit & deaeration chamber
III-A	Drop shaft 217 & conduit	$34,536,033	$8,288,648	10%	$47,107,149	Drop shaft 217, 1,500' consolodation conduit, screening & approach structure, adit & deaeration chamber
III-A	Regulator Modifications & Floatables Controls	$1,952,947	$468,707	10%	$2,663,820	
III-A	GSI Project Allowance	$10,000,000	$1,000,000	0%	$11,000,000	
Sub-Phase	**Redefined Phase III Program**					
III-A	GSI Project Allowance	$10,000,000	$1,000,000	0%	$11,000,000	
III-B	High & Cross Street Interceptor	$17,359,189	$4,166,205	10%	$23,677,933	42" and 48" micro-tunneled or jacked interceptor, including river crossing plus roadway & utility improvements at jacking pits
Sub-Phase	**Redefined Phase III Program**					
III-C	Middle Street Interceptor	$11,286,162	$2,708,679	10%	$15,394,325	30" and 66" micro-tunneled or jacked interceptors, including roadway & utility improvements at jacking pits
III-C	206 Hybrid GSI / Sewer Separation	$3,878,722	$844,502	0%	$4,723,224	Construction of smaller separate pipe system; replacement & rehabilitation of portions of existing pipe system; RoW GSI; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths
Sub-Phase	**Redefined Phase III Program**					
III-A	GSI Project Allowance	$10,000,000	$1,000,000	0%	$11,000,000	
III-D	220 Stub Tunnel Alternative	$68,181,818	$16,363,636	10%	$93,000,000	10' Diameter Tunnel from Pawtucket Tunnel drop shaft 217 to 220
Sub-Phase	**Redefined Phase III Program**					
III-A	GSI Project Allowance	$10,000,000	$1,000,000	0%	$11,000,000	
III-E	West River Interceptor	$28,130,421	$6,751,301	10%	$38,369,894	72" dia micro-tunnel/pipe jack; 039 056 consolodation conduits; Charles St regulator structure; reconstruction of under- and over-flows to MRI; riverbank, park & roadway restoration
III-E	035 Sewer Separation	$15,772,970	$3,409,000	0%	$19,181,969	Replacement of 10% of dual pipe system; rehabilitation of 10% of dual pipe system; surface improvements for entire area; water, gas & haz soil replacement for trenched lengths
					$815,608,352	

Narragansett Bay Commission - Phase III Reevaluation

Scenario Evaluation

Alternative 2 - "Fast Tunnel" Program Timeline

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
	Concept Review	Phase III-A Design			Phase III-A Construction					Phase III-B Design		Phase III-B Construction		
Phase III-A														
Pawtucket Tunnel		$7,490,796.45	$7,490,796	$7,490,796	$121,517,365	$121,517,365	$121,517,365							
Drop shaft 218 & conduit		$921,791	$921,791	$921,791		$14,953,499	$14,953,499	$14,953,499						
Drop shaft 205 & conduit		$462,957	$462,957	$462,957			$7,510,188	$7,510,188	$7,510,188					
Drop shaft 210/211 & conduit		$528,408	$528,408	$528,408			$8,571,955	$8,571,955	$8,571,955					
Drop shaft 213 & conduit		$805,532	$805,532	$805,532			$13,067,521	$13,067,521	$13,067,521					
Drop shaft 217 & conduit		$911,751	$911,751	$911,751			$14,790,632	$14,790,632	$14,790,632					
Regulator Modifications & Floatables Controls		$51,558	$51,558	$51,558					$2,509,146					
GSI Project Allowance		$333,333	$333,333	$333,333	$10,000,000									
Phase III-B														
GSI Project Allowance										$500,000	$500,000	$10,000,000		
High & Cross Street Interceptor										$458,282.58	$916,565.15	$7,434,362	$7,434,362	$7,434,362
Middle Street Interceptor										$595,909.34	$893,864	$4,634,850	$4,634,850	$4,634,850
206 Hybrid GSI / Sewer Separation										$168,900.38	$253,350.57	$2,150,486.59	$2,150,487	
Phase III-C														
GSI Project Allowance														
220 Stub Tunnel Alternative														
Phase III-D														
GSI Project Allowance														
West River Interceptor														
035 Sewer Separation														
Totals:	**$0**	**$11,506,127**	**$11,506,127**	**$11,506,127**	**$131,517,365**	**$136,470,864**	**$180,411,160**	**$58,893,795**	**$46,449,443**	**$1,723,092**	**$2,563,780**	**$24,219,699**	**$14,219,699**	**$12,069,212**

Narragansett Bay Commission -

Scenario Evaluation

Alternative 2 - "Fast Tunnel" Program

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	
	Phase III-C Design		Phase III-C Construction			Phase III-D Design		Phase III-D Construction													Total
Phase III-A																					
Pawtucket Tunnel																					$387,024,483
Drop shaft 218 & conduit																					$47,625,870
Drop shaft 205 & conduit																					$23,919,436
Drop shaft 210/211 & conduit																					$27,301,091
Drop shaft 213 & conduit																					$41,619,159
Drop shaft 217 & conduit																					$47,107,149
Regulator Modifications & Floatables Controls																					$2,663,820
GSI Project Allowance																					$10,999,999
Phase III-B																					
GSI Project Allowance																					$11,000,000
High & Cross Street Interceptor																					$23,677,933
Middle Street Interceptor																					$15,394,325
206 Hybrid GSI / Sewer Separation																					$4,723,224
Phase III-C																					
GSI Project Allowance	$500,000	$500,000	$10,000,000																		$11,000,000
220 Stub Tunnel Alternative	$1,860,000.00	$1,860,000.00	$29,760,000	$29,760,000	$29,760,000																$93,000,000
Phase III-D																					
GSI Project Allowance						$500,000	$500,000	$10,000,000													$11,000,000
West River Interceptor						$742,643.11	$1,485,286	$12,047,321	$12,047,321	$12,047,321											$38,369,894
035 Sewer Separation						$340,900	$681,800	$6,053,090	$6,053,090	$6,053,090											$19,181,969
Totals:	**$2,360,000**	**$2,360,000**	**$39,760,000**	**$29,760,000**	**$29,760,000**	**$1,583,543**	**$2,667,086**	**$28,100,411**	**$18,100,411**	**$18,100,411**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$815,608,351**

Narragansett Bay Commission - Phase III Reevaluation

Scenario Evaluation

Alternative 3 - "Slow Tunnel" Program Timeline with Interim Water Quality Projects Added

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
	Concept Review	Phase III-A Design		Phase III-A Construction		Phase III-B Design		Phase III-B Construction		
Phase III-A										
218-BPWWTF Wet Weather Interceptor (Interim water quality project)		$1,972,086	$1,972,086	$16,379,269	$16,379,269					
206 Hybrid GSI / Sewer Separation		$253,350.57	$253,350.57	$2,108,261.50	$2,108,261					
Public Way GSI Demonstration Project		$316,449.29	$316,449.29	$2,628,287.17	$2,628,287					
Private Property GSI Demonstration Project		$256,580.51	$256,580.51	$2,131,043.65	$2,131,044					
Phase III-B										
220 Screening & Disinfection (Interim water quality project)						$1,189,180.33	$1,189,180.33	$9,447,377	$9,447,377	$9,447,377
Public Way GSI Early Gain Projects						$1,244,055	$1,244,055	$9,883,325	$9,883,325	$9,883,325
Phase III-C										
Pawtucket Tunnel										
Drop shaft 218 & conduit										
Drop shaft 205 & conduit										
Drop shaft 210/211 & conduit										
Drop shaft 213 & conduit										
Drop shaft 217 & conduit										
Regulator Modifications & Floatables Controls										
GSI Project Allowance										
Phase III-D										
GSI Project Allowance										
High & Cross Street Interceptor										
Middle Street Interceptor										
Phase III-E										
West River Interceptor										
035 Sewer Separation										
Public Way GSI System Optimization Projects										
Phase III-F										
GSI Project Allowance										
Morley Field NSS Tank Alternative										
220 Stub Tunnel Alternative										
Totals:	**$0**	**$2,798,466**	**$2,798,466**	**$23,246,862**	**$23,246,862**	**$2,433,235**	**$2,433,235**	**$19,330,702**	**$19,330,702**	**$19,330,702**
Revised Baseline CSO	$0	$253,351	$253,351	$2,108,261	$2,108,261	$0	$0	$0	$0	$0
Optional interim projects	$0	$2,545,116	$2,545,116	$21,138,600	$21,138,600	$2,433,235	$2,433,235	$19,330,702	$19,330,702	$19,330,702

Narragansett Bay Commission - Phase III Reevalu

Scenario Evaluation

Alternative 3 - "Slow Tunnel" Program Timeline with Inter

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
	Phase III-C Design			Phase III-C Construction					Phase III-D Design		Phase III-D Construction		
Phase III-A													
218-BPWWTF Wet Weather Interceptor (Interim water quality project)													
206 Hybrid GSI / Sewer Separation													
Public Way GSI Demonstration Project													
Private Property GSI Demonstration Project													
Phase III-B													
220 Screening & Disinfection (Interim water quality project)													
Public Way GSI Early Gain Projects													
Phase III-C													
Pawtucket Tunnel	$7,490,796.45	$7,490,796	$7,490,796	$121,517,365	$121,517,365	$121,517,365							
Drop shaft 218 & conduit	$921,791	$921,791	$921,791		$14,953,499	$14,953,499	$14,953,499						
Drop shaft 205 & conduit	$462,957	$462,957	$462,957			$7,510,188	$7,510,188	$7,510,188					
Drop shaft 210/211 & conduit	$528,408	$528,408	$528,408			$8,571,955	$8,571,955	$8,571,955					
Drop shaft 213 & conduit	$805,532	$805,532	$805,532			$13,067,521	$13,067,521	$13,067,521					
Drop shaft 217 & conduit	$911,751	$911,751	$911,751			$14,790,632	$14,790,632	$14,790,632					
Regulator Modifications & Floatables Controls	$51,558	$51,558	$51,558					$2,509,146					
GSI Project Allowance	$333,333	$333,333	$333,333	$10,000,000									
Phase III-D													
GSI Project Allowance									$500,000	$500,000	$10,000,000		
High & Cross Street Interceptor									$458,283	$916,565	$7,434,362	$7,434,362	$7,434,362
Middle Street Interceptor									$297,955	$595,909	$4,833,487	$4,833,487	$4,833,487
Phase III-E													
West River Interceptor													
035 Sewer Separation													
Public Way GSI System Optimization Projects													
Phase III-F													
GSI Project Allowance													
Morley Field NSS Tank Alternative													
220 Stub Tunnel Alternative													
Totals:	**$11,506,127**	**$11,506,127**	**$11,506,127**	**$131,517,365**	**$136,470,864**	**$180,411,160**	**$58,893,795**	**$46,449,443**	**$1,256,237**	**$2,012,474**	**$22,267,849**	**$12,267,849**	**$12,267,849**
Revised Baseline CSO	$11,506,127	$11,506,127	$11,506,127	$131,517,365	$136,470,864	$180,411,160	$58,893,795	$46,449,443	$1,256,237	$2,012,474	$22,267,849	$12,267,849	$12,267,849
Optional interim projects	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Narragansett Bay Commission - Phase III Reevalu

Scenario Evaluation

Alternative 3 - "Slow Tunnel" Program Timeline with Inter

	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	
	Phase III-E Design		Phase III-E Construction			Phase III-F Design		Phase III-F Construction				Total
Phase III-A												
218-BPWWTF Wet Weather Interceptor (Interim water quality project)												$36,702,711
206 Hybrid GSI / Sewer Separation												$4,723,224
Public Way GSI Demonstration Project												$5,889,473
Private Property GSI Demonstration Project												$4,775,248
Phase III-B												
220 Screening & Disinfection (Interim water quality project)												$30,720,492
Public Way GSI Early Gain Projects												$32,138,086
Phase III-C												
Pawtucket Tunnel												$387,024,483
Drop shaft 218 & conduit												$47,625,870
Drop shaft 205 & conduit												$23,919,436
Drop shaft 210/211 & conduit												$27,301,091
Drop shaft 213 & conduit												$41,619,159
Drop shaft 217 & conduit												$47,107,149
Regulator Modifications & Floatables Controls												$2,663,820
GSI Project Allowance												$10,999,999
Phase III-D												
GSI Project Allowance												$11,000,000
High & Cross Street Interceptor												$23,677,933
Middle Street Interceptor												$15,394,325
Phase III-E												
West River Interceptor	$742,643.11	$1,485,286	$12,047,321	$12,047,321	$12,047,321							$38,369,894
035 Sewer Separation	$340,900	$681,800	$6,053,090	$6,053,090	$6,053,090							$19,181,969
Public Way GSI System Optimization Projects	$346,636	$693,272	$8,589,796									$9,629,705
Phase III-F												
GSI Project Allowance						$500,000	$500,000	$10,000,000				$11,000,000
Morley Field NSS Tank Alternative												$0
220 Stub Tunnel Alternative						$1,860,000.00	$1,860,000.00	$29,760,000	$29,760,000	$29,760,000		$93,000,000
Totals:	**$1,430,179**	**$2,860,358**	**$26,690,208**	**$18,100,411**	**$18,100,411**	**$2,360,000**	**$2,360,000**	**$39,760,000**	**$29,760,000**	**$29,760,000**	**$0**	**$924,464,066**
Revised Baseline CSO	$1,430,179	$2,860,358	$26,690,208	$18,100,411	$18,100,411	$2,360,000	$2,360,000	$39,760,000	$29,760,000	$29,760,000	$0	**$814,238,056**
Optional interim projects	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$110,226,010**

Narragansett Bay Commission - Phase III Reevaluation

Scenario Evaluation

Alternative 4 - "Screening & Disinfection" Program Timeline

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
	Concept Review	Phase III-A Design			Phase III-A Construction					Phase III-B Design		Phase III-B Construction		
Phase III-A														
218 Interceptor / Storage / Disinfection		$5,000,000.00	$5,000,000	$5,000,000	$29,000,000	$29,000,000	$30,000,000	$30,000,000	$29,000,000					
GSI Project Allowance		$333,333	$333,333	$333,333	$10,000,000									
Phase III-B														
220 Screening & Disinfection										$1,400,000	$1,400,000	$8,000,000	$8,000,000	$9,000,000
218 to 205 Interceptor										$5,000,000.00	$5,000,000.00	$40,000,000	$40,000,000	$40,000,000
GSI Project Allowance										$500,000	$500,000	$10,000,000		
Phase III-C														
GSI Project Allowance														
205 to 103 and 201 Interceptors														
Phase III-D														
GSI Project Allowance														
West River Interceptor														
035 Sewer Separation														
Totals:	**$0**	**$5,333,333**	**$5,333,333**	**$5,333,333**	**$39,000,000**	**$29,000,000**	**$30,000,000**	**$30,000,000**	**$29,000,000**	**$6,900,000**	**$6,900,000**	**$58,000,000**	**$48,000,000**	**$49,000,000**

Notes:

1) Alternative Kappa does not achieve the water quality design goals of the other Alternatives.

2) Additional investigations are required to determine the technical feasiblity of these concepts. Therefore, final costs may vary considerably from those presented here

3) Costs are in 2018$

Narragansett Bay Commission - Phase III Re

Scenario Evaluation

Alternative 4 - "Screening & Disinfection" Program

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	
	Phase III-C Design		Phase III-C Construction			Phase III-D Design		Phase III-D Construction			Total
Phase III-A											
218 Interceptor / Storage / Disinfection											$162,000,000
GSI Project Allowance											$10,999,999
Phase III-B											$0
220 Screening & Disinfection											$27,800,000
218 to 205 Interceptor											$130,000,000
GSI Project Allowance											$11,000,000
Phase III-C											$0
GSI Project Allowance	$500,000	$500,000	$10,000,000								$11,000,000
205 to 103 and 201 Interceptors	$1,300,000	$1,300,000	$8,000,000	$8,000,000	$9,000,000						$27,600,000
Phase III-D											$0
GSI Project Allowance						$500,000	$500,000	$10,000,000			$11,000,000
West River Interceptor						$750,000.00	$1,500,000	$13,000,000	$13,000,000	$13,000,000	$41,250,000
035 Sewer Separation						$350,000	$600,000	$6,000,000	$6,000,000	$6,000,000	$18,950,000
Totals:	**$1,800,000**	**$1,800,000**	**$18,000,000**	**$8,000,000**	**$9,000,000**	**$1,600,000**	**$2,600,000**	**$29,000,000**	**$19,000,000**	**$19,000,000**	**$451,599,999**
											$451,599,999

Notes:
1) Alternative Kappa does not achieve the water qu
2) Additional investigations are required to determ
3) Costs are in 2018$

Narragansett Bay Commission - Phase III Reevaluation

Scenario Evaluation

Alternative 1 - "Baseline" Program Timeline

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2048	
	Concept Review	Phase III Design			Phase III Construction									Total
Phase III (Same as Alt 2)														
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
Floatables Controls														$0
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
Phase III (Different from Alt 2)														$0
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:	**$0**	**$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**	**$0**	**$0**	**$740,730,396**
														$740,730,396

Year	Alternative 2: Modified & Phased Baseline Alternative 2 Cumulative Cost ($M)	Component Completion	CSOs Abated	3-Month Storm CSO Volume Eliminated (MG)	Alt 2 Modified & Phased Alpha 3-Month Storm CSO Discharge (MG)	
2015	$0.00				57.06	
2016	$11.51				57.06	
2017	$23.01				57.06	
2018	$34.52				57.06	
2019	$166.04	$10M GSI Project #1	212, 213, 214 partial	0.40	56.66	
2020	$302.51				56.66	
2021	$482.92				56.66	
2022	$541.81				56.66	
2023	$588.26	Pawtucket Tunnel & Drop Shafts + Regulator Modifications	204-205, 207-218	40.50	16.16	0.283
2024	$589.98				16.16	
2025	$592.55				16.16	0.72
2026	$616.77	$10M GSI Project #2	101, 104, 105 partial	0.22	15.94	
2027	$630.99	206 Hybrid Sewer Separation	206	0.14	15.79	
2028	$643.06	High Street Interceptor & Middle Street Interceptor	101 - 105 & 201 - 203	9.07	6.73	0.118
2029	$645.42				6.73	
2030	$647.78				6.73	
2031	$687.54	$10M GSI Project #3	216, 217 partial	0	6.73	
2032	$717.30				6.73	
2033	$747.06	220 Stub Tunnel or NSS Tank	107, 220	4.97	1.75	
2034	$748.64				1.75	
2035	$751.31				1.75	0.97
2036	$779.41	$10M GSI Project #4	201 - 204 partial	0	1.75	
2037	$797.51				1.75	
2038	$815.61	West River Interceptor & 035 Sewer Separation	035, 036, 039, 056	1.75	0.00	
2039	$815.61				0.00	
2040	$815.61				0.00	
2041	$815.61				0.00	
2042	$815.61				0.00	
2043	$815.61				0.00	
2044	$815.61				0.00	
2045	$815.61				0.00	
2046	$815.61				0.00	
2047	$815.61				0.00	
2048	$815.61				0.00	

Year	Alternative 3: Modified, Augmented & Extended Baseline Alternative 3 Cumulative Cost ($M)	Component Completion	CSOs Abated	3-Month Storm CSO Volume Eliminated (MG)	Alt 3 Extended with Interim 3-Month Storm Total Treated CSO Discharge (MG)	3-Month Storm CSO Volume Treated (MG)	Alt 3 Extended with Interim 3-Month Untreated Discharge (MG)	
2015	$0.00				57.06		57.06	
2016	$2.80				57.06		57.06	
2017	$5.60				57.06		57.06	
2018	$28.84				57.06		57.06	
2019	$52.09	206 Hybrid Sewer Separation, GSI Project #1	206 + 212-214 partial	0.54	56.52		56.52	
2020	$54.52	*218 -BPWWTF Wet Weather*			56.52	12.58	43.94	
2021	$56.96				56.52		43.94	
2022	$76.29	$10M GSI Project #2	101, 104, 105 partial	0.22	56.29		43.94	
2023	$95.62	$10M GSI Project #3	216, 217 partial	0.22	56.07		43.94	
2024	$114.95	$10M GSI Project #4	201 - 204 partial	0.19	55.87		43.94	0.98
2025	$126.46	*220 Screening & Disinfection*			55.87	4.97	38.96	0.32
2026	$137.96				55.87		38.96	0.68
2027	$149.47				55.87		38.96	
2028	$280.98	$10M GSI Project #5	215 partial	0.18	55.69		38.96	
2029	$417.46				55.69		38.96	
2030	$597.87				55.69		38.96	
2031	$656.76				55.69		38.96	
2032	$703.21	Pawtucket Tunnel & Drop Shafts + Regulator Modifications	204-205, 207-218	40.09	15.60		10.63	
2033	$704.47				15.60		10.63	
2034	$706.48				15.60		10.63	0.27
2035	$728.75	$10M GSI Project #6	103 partial	0.19	15.41		10.44	0.82
2036	$741.01				15.41		10.44	
2037	$753.28	High Street Interceptor & Middle Street Interceptor	101 - 105 & 201 - 203	8.68	6.73		1.75	
2038	$754.71				6.73		1.75	
2039	$757.57				6.73		1.75	
2040	$784.26	$10M GSI Project #7	103 partial	0.00	6.73		1.75	
2041	$802.36				6.73		1.75	
2042	$820.46	West River Interceptor & 035 Sewer Separation	035, 036, 039, 056	1.75	4.97		0.00	
2043	$822.82				4.97		0.00	
2044	$825.18				4.97		0.00	
2045	$864.94	$10M GSI Project #8	205 partial		4.97		0.00	
2046	$894.70				4.97		0.00	
2047	$924.46	220 Stub Tunnel or NSS Tank	107, 220	4.97	0.00		0.00	
2048	$924.46				0.00		0.00	

Year	Alternative 4: BPWWTF Storage & Treatment (No Tunnel)							
	Alternative 4 Cumulative Cost ($M)	Component Completion	CSOs Abated	3-Month Storm CSO Volume Eliminated (MG)	Alt 4 No Tunnel 3-Month Storm Total Treated CSO Discharge (MG)	3-Month Storm CSO Volume Treated (MG)	Alt 4 No Tunnel 3-Month Untreated Discharge (MG)	
2015	$0.00				57.06		57.06	
2016	$5.33				57.06		57.06	
2017	$10.67				57.06		57.06	
2018	$16.00				57.06		57.06	
2019	$55.00	$10M GSI Project #1	212, 213, 214 partial	0.40	56.66		56.66	
2020	$84.00				56.66		56.66	
2021	$114.00				56.66		56.66	
2022	$144.00				56.66		56.66	
2023	$173.00	*218 Interceptor / Storage / Disinfection*		12.56	44.10	0.00	44.10	
2024	$179.90				44.10		44.10	
2025	$186.80				44.10		44.10	0.23
2026	$244.80	$10M GSI Project #2	101, 104, 105 partial	0.22	43.87		43.87	
2027	$292.80	*220 small tank*		2.70	41.17		41.17	
2028	$341.80	*218 to 205 Interceptor*		2.24	38.93	18.30	20.63	
2029	$343.60				38.93		20.63	
2030	$345.40				38.93		20.63	
2031	$363.40	$10M GSI Project #3	216, 217 partial	0.22	38.71	-0.22	20.63	
2032	$371.40				38.71		20.63	
2033	$380.40	205 to 103 and 201 Interceptors			38.71	1.40	19.23	
2034	$382.00				38.71		19.23	
2035	$384.60				38.71		19.23	0.66
2036	$413.60	$10M GSI Project #4	201 - 204 partial	0.19	38.51	-0.19	19.23	
2037	$432.60				38.51		19.23	
2038	$451.60	West River Interceptor & 035 Sewer Separation	035, 036, 039, 056	1.75	36.76		17.47	0.69
2039	$451.60				36.76		17.47	
2040	$451.60				36.76		17.47	
2041	$451.60				36.76		17.47	
2042	$451.60				36.76		17.47	
2043	$451.60				36.76		17.47	
2044	$451.60				36.76		17.47	
2045	$451.60				36.76		17.47	
2046	$451.60				36.76		17.47	
2047	$451.60				36.76		17.47	
2048	$451.60				36.76		17.47	0.64

Year	Alternative 1: Baseline CDRA					
	Alternative 1 Cumulative Cost ($M)	Component Completion	CSOs Abated	3-Month Storm CSO Volume Eliminated (MG)	Alt 1 Baseline CDRA 3-Month Storm CSO Discharge (MG)	
2015	$10.66				57.06	
2016	$21.31				57.06	
2017	$42.62				57.06	
2018	$45.47				57.06	
2019	$137.30				57.06	
2020	$234.64	206 Sewer Separation	206	0.14	56.91	
2021	$392.89				56.91	
2022	$551.15				56.91	
2023	$641.88	Pawtucket Tunnel & Drop Shafts + Regulator Modifications; 220 Interce	204-205, 207-218	45.87	11.05	0.193595
2024	$691.59				11.05	
2025	$740.73	High & Middle Interceptors; 035, 039, 056 Sewer Separation	All others	11.05	0.00	
2026	$740.73				0.00	
2027	$740.73				0.00	
2028	$740.73				0.00	
2029	$740.73				0.00	
2030	$740.73				0.00	
2031	$740.73				0.00	
2032	$740.73				0.00	
2033	$740.73				0.00	
2034	$740.73				0.00	
2035	$740.73				0.00	
2036	$740.73				0.00	
2037	$740.73				0.00	
2038	$740.73				0.00	
2039	$740.73				0.00	
2040	$740.73				0.00	
2041	$740.73				0.00	
2042	$740.73				0.00	
2043	$740.73				0.00	
2044	$740.73				0.00	
2045	$740.73				0.00	
2046	$740.73				0.00	
2047	$740.73				0.00	
2048	$740.73				0.00	

NBC CSO Control Facilities Phase III Reevaluation

Appendix 8 – Stakeholders Report

NBC CSO Control Facilities Phase III Reevaluation
Appendix 8 – Stakeholders Report

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Attachments

1. Introduction and Background

In 1997, the Narragansett Bay Commission (NBC) convened a stakeholders group to advise on the construction alternatives for NBC's three-phase Combined Sewer Overflow (CSO) Abatement Project. This effort was recognized by the National Association of Clean Water Agencies with a National Environmental Achievement Award and, more importantly, was an important factor in the development of NBC's ultimate CSO plan. In 2001, Phase I of the project began, and since its completion in 2008, water quality has dramatically improved in upper Narragansett Bay and the Providence River. Phase II of the project is scheduled for completion in early 2015, and as part of Phase III, NBC elected to undertake a re-evaluation of technologies and methods for CSO control.

The stakeholder process for the CSO Phase III re-evaluation consisted of a total of seven workshops: one three-hour workshop per month from March through December 2014, excluding July, August, and November 2014. These workshops addressed the regulatory, environmental, and economic issues involved with Phase III design and construction. All workshops took place at the NBC Corporate Office Building, 1 Service Road, Providence, RI 02905.

2. Stakeholder Group

The stakeholder group for this project is comprised of individuals from a broad cross-section of the NBC service area, and includes residents, government agency representatives, trade association representatives, non-profit organizations, and business owners. The following individuals were invited to attend.

Name	Organization
Grover Fugate	RI CRMC
Laura McNamara	East Prov. Chamber of Commerce
Greg Geritt	Environment Council of RI
Janet Coit	RI DEM
John Gregory	NRI Chamber of Commerce
Kevin Flynn	RI Division of Planning
Caroline Karp	Center for Environmental Studies
Paul Lemont	City of East Providence
John Simmons	RI Public Expenditure Council
Phil Holmes	RISA/CAC
Mike McGiveney	RISA
Curt Spalding	EPA Region 1
Stephen Medeiros	RI Saltwater Angles Assn.
Chris Bardt	Narragansett Boat Club
Donald Grebien	Pawtucket City Hall

Meg Curran	RI Public Utilities Commission
Peter Kilmartin	RI Attorney General
Marcel Valois	Commerce Corp. RI
Harold Gadon	CAC
Tom Ahern	RI Public Utilities Commission
William Sequino	RI Clean Water Finance Agency
Joseph Polisena	Johnston Town Hall
John Martin	AARP Rhode Island
Chief of Staff	Office of the Governor
Jonathan Stone	Save the Bay
Richard Licht	Dept. of Administration
T. Joseph Almond	Lincoln Town Hall
Michael Fine, MD.	RI Department of Health
Scott Fay	Congressman David Cicilline's Office
Kristin Nicholson	Congressman James Langevin's Office
Bob Billington	Blackstone Valley Tourism Council
Ames B. Colt, Ph.D.	Office of the Governor/ DEM
Tom Borden, Esq.	Narragansett Bay Estuary Program
Angel Tavares	Providence City Hall
Charles A. Lombardi	North Providence Town Hall
Daniel J. McKee	Cumberland Town Hall
James A. Diossa	Central Falls City Hall
George Carvalho	Senator Whitehouse's Office
Raymond D. Simone	Senator Jack Reed's Office
Brian Bishop	RI WISE USE

While not all of the invitees were able to attend the stakeholder workshops, many individuals delegated their stakeholder responsibility to other members of their organization. In addition, a number or invitees opted not to participate in the stakeholder process. The meetings were open to the public and were attended by a number of people outside the official stakeholder group.

3. Stakeholder Workshops

The following is a summary of each of the CSO stakeholder workshops. The agenda, minutes, and presentation material for each workshop can be accessed through the NBC's web site at this URL:

http://www.narrabay.com/en/ProgramsAndProjects/Combined%20Sewer%20Overflow%20Project/CSO%20Phase%20III.aspx

3.1. Workshop #1 (March 12, 2014, 1:00pm - 4:00pm)

The first workshop commenced with an introduction by moderator Mr. Mike Domenica of Water Resource Associates (WRA), including a short history of the project and the purpose of the stakeholders group in assisting and advising NBC in defining Phase III. This was followed by group introductions and welcoming remarks by Mr. Raymond J. Marshall, Executive Director of NBC. Mr. Marshall emphasized that the affordability of the program is the biggest concern to NBC and that the next phase will review innovative ways to address the project (e.g., green infrastructure) and welcomed other options from stakeholders which may mitigate the impact of necessary work to be completed as part of Phase III. The welcoming remarks were concluded by a review of the ground rules for the stakeholders process and followed by presentations by NBC and MWH Global (MWH), the principal consultant for the NBC Phase III re-evaluation.

Mr. Thomas Brueckner of NBC was the first presenter and provided an overview of the CSO program to the stakeholders and indicated that the CSOs must be addressed to meet Federal water quality standards. A review of the history of the CSO program began with a Consent Agreement signed between NBC and the RIDEM in 1992 establishing the schedule for planning, design, and construction of CSO facilities. This was followed by a 1994 Conceptual Design Report (CDR), which was approved by the RIDEM in 1994 and included construction over a 9-year time period at a cost of $478M and a rate increase from $125 to $425/year. However, due to cost, technical concerns, and a revision to the Federal CSO policy by the U.S. Environmental Protection Agency (EPA), NBC decided to re-evaluate this CDR. The re-evaluation was conducted with input from the stakeholders group and resulted in the RIDEM-approved CDR Amendment (CDRA), which included construction over a 17-year time period at a cost of $390M and a rate increase from $165 to $300/year. Mr. Brueckner indicated that the goal of the three-phase program is a 98-percent reduction in annual CSO volume and an 80-percent reduction in shellfish bed closures. He then informed the stakeholders of the adverse impact that the program's cost overrun has on the ratepayers and the need to assess this escalating cost in the Phase III re-evaluation. The presentation concluded with the primary tasks of the Phase III re-evaluation as follows:

1. Bucklin Point Service Area hydraulic model development;
2. CSO program water quality evaluation;
3. Phase III CSO abatement method re-evaluation;
4. Phase III cost estimation;
5. Project area mapping;
6. Soil/rock boring program implementation, as necessary; and
7. Stakeholder meeting on results of re-evaluation.

A few questions and concerns were addressed by the stakeholders with regard to pending legislation, which could include NBC acquiring select municipal sewer lines and pump stations.

NBC indicated that acquisition would be up to the municipality and would include a one-year study period. A discussion on NBC's user rate system and a temporary shutdown scheduled for the existing tunnel due to Phase II work was also addressed at this stage of the workshop.

A second presentation was made by Mr. Richard Raiche of MWH with regard to the project team's approach to the Phase III re-evaluation. The presentation began with an introduction to the consultant team followed by a summary of the currently-defined Phase III CSO program and a discussion of the proposed approach to evaluating alternatives. This was followed by an introduction to the Integrated Planning Framework, or IPF, which is a process used by MWH that is based on EPA guidance that allows MWH to evaluate and sequence Phase III recommendations along with other regional wastewater and stormwater improvements. An affordability analysis was also discussed prior to closing the presentation with an outline of the remaining stakeholder meetings. The workshop concluded with a financial capacity analysis discussion led by Mr. Greg Bard of MWH.

3.2. Workshop #2 (April 10, 2014, 1:00pm - 4:00pm)

The second workshop included a presentation on the role of gray infrastructure in the third phase of the CSO project. Prior to initiation of the presentation, NBC led a discussion on affordability analysis for the project and revisited some of the topics discussed during Workshop #1. Revisited topics from the first workshop included questions and comments related to water quality, including technical and financial alternatives available to meet the federal water quality standards. NBC stated that the EPA would have a representative at Workshop #3 to address questions related to project affordability and verify that the re-evaluation is being conducted in accordance with the EPA's CSO Control Policy and most recent supplementary guidance documentation. NBC added that in order to be consistent with EPA methodology, the median income to be used in the affordability analysis will be based on the median household income (MHI) of the residents of the community, not the median income of the property owners as suggested during the first workshop. NBC also stated that the affordability analysis will be completed using the residential indicator as prescribed by EPA, though an estimate of the comparable commercial and industrial rates will be performed based on the affordable residential rate.

The gray infrastructure presentation was performed by MWH and Pare Corporation (PARE). The presentation defined the gray infrastructure alternatives and explored the fundamental differences between each alternative. The alternatives discussed included sewer separation, tunnel and near-surface storage, localized treatment and discharge, and stormwater control. Mr. Timothy Thies of PARE presented the group with a review of the sewer separation performed as part of NBC's Phase II CSO project and discussed the sewer separation alternatives proposed as part of Phase III. Mr. Thomas Brueckner of NBC voiced his concern with sewer separation due to the neighborhood impacts, the resulting stormwater discharge that must be properly controlled, and long-term maintenance requirements of the new stormwater infrastructure. Other members of the stakeholders group expressed similar reservations toward the separate storm sewer approach to CSO abatement. Mr. Richard Raiche of MWH presented the group with the next major component of the project, the Phase III Pawtucket Tunnel. The tunnel is proposed to extend from the Bucklin Point Treatment Plant in East Providence to the border of Pawtucket and Central Falls. Mr. Timothy Thies followed with a discussion on the interceptors to the Pawtucket Tunnel and the proposed alternative to the interceptors, the Phase III Stub Tunnel.

The Stub Tunnel would connect Outfall 220, a major CSO, to the Pawtucket Tunnel at the Bucklin Point Treatment Plant.

Following a brief intermission, Mr. Thies continued the gray infrastructure presentation with a segment on localized combined flow handling. Mr. Keith Gardner of MWH described the proposed combined flow handling alternatives to the group, including the West River Interceptor, near-surface combined flow storage facilities, and localized treatment and discharge facilities. The presentation concluded with an overview of stormwater control and management alternatives, including the use of flow controls, stormwater storage, and green stormwater infrastructure (GSI).

3.3. Workshop #3 (May 22, 2014, 9:00am - 12:00pm)

The third workshop included a discussion on affordability issues and a presentation on the role of GSI in the third phase of the CSO project. The workshop began with introductory comments by Mr. Mike Domenica of WRA and Mr. Thomas Brueckner of NBC. Mr. Brueckner reviewed the key elements of Workshop #2, including a summary of the advantages and disadvantages of each gray infrastructure alternative. This was followed by a presentation by Mr. Michael Wagner of the EPA on affordability as it relates to the Phase III CSO project. Mr. Wagner indicated that the EPA screening tool for responding to a state recommendation to change water quality standards is 2% of the MHI for wastewater rates. However, the EPA is flexible on requiring a higher level of CSO control even if the 2% MHI is not met if the community has other substantial expenses which must be addressed (e.g., drinking water infrastructure upgrades, transportation infrastructure upgrades, landfill closures). He further emphasized that the EPA also considers widespread social and economic impacts in the community when making a determination on changes in water quality standards. A lengthy discussion then ensued at the workshop on the question of affordability and the legal obligation of the commission to continue the CSO abatement program in accordance with the federal Clean Water Act. Other points of interest voiced by the stakeholders included the role of pollutants other than bacteria on water quality and the beneficial uses of the Narragansett Bay and its tributaries (e.g., swimming and shellfishing) which are affected by the CSO discharges.

Following a short recess, a presentation on GSI was made to the stakeholder group by Mr. Richard Raiche and Mr. Nick Anderson of MWH and Mr. Scott Lindgren of PARE. Mr. Raiche emphasized that GSI may reduce the size of the gray infrastructure to control CSO discharges, but cannot entirely eliminate the gray alternatives. The presentation separated GSI into three primary categories: infiltration, detention, and retention. A review of the advantages and disadvantages of each GSI category was examined, followed by a discussion on considerations for evaluating potential GSI locations, specifically soil types and topography within the NBC Phase III CSO sewershed. Other considerations reviewed included land use and ownership, implementing GSI on private property with private funds, and implementation partnerships. Mr. Lindgren presented specific GSI examples to the stakeholders for each of the three primary GSI categories that may be utilized at appropriate locations in the Phase III CSO sewershed. The presentation concluded with a discussion by Mr. Anderson on the benefits of GSI as part of the Phase III CSO project. Specifically, by implementing GSI, the peak of the stormwater hydrograph (plot of discharge vs. time), which is elevated due to urbanization and results in CSOs, may be reduced and result in the design of smaller grey infrastructure alternatives.

Prior to adjourning, Mr. Michael Gagnon, Public Works Director for the Town of Lincoln, stated that the ratepayers and communities that aren't conveying stormwater to the system that leads to the CSOs should not be paying for the CSO project. Moreover, in the future when these member communities are required to treat their separate stormwater, these communities will have to fund these projects unaided by other member communities in the NBC sewer system area. Mr. Gagnon emphasized that there is an inherent unfairness to the rate structure used to pay for the CSO program where all member communities are asked to pay the same rate while the cause of the CSOs is concentrated in only certain member communities. Mr. Raymond J. Marshall of NBC indicated that this issue has already been addressed in the Rhode Island Supreme Court, and the court has said it's one district, one rate.

3.4. Workshop #4 (June 19, 2014, 9:00am - 12:00pm)

The fourth workshop included a continuation on the discussion of GSI in the third phase of the CSO project, a presentation on the Regional Stormwater Utility Project, and commencement of the evaluation criteria selection process. The workshop began with introductory comments by Mr. Mike Domenica of WRA and Mr. Thomas Brueckner of NBC. With regard to the issue presented by the stakeholders on the inclusion of projected precipitation magnitudes in the re-evaluation process, Mr. Brueckner reported that the National Oceanic Atmospheric Administration (NOAA) is currently updating these precipitation projections and the data should be available by September 2015. Therefore, although these projections will not be available for the re-evaluation, the precipitation projections will be used in the design phase of any facilities that are determined through the Phase III re-evaluation project.

This was followed by a presentation by Mr. Richard Raiche of MWH on GSI as it relates to the Phase III CSO project. Mr. Raiche began with a cursory review of the GSI alternatives discussed at Workshop #3. The existing soils and topography in the region were reported to be predominantly favorable for GSI, with the exception of a few regions of less favorable soil. Moreover, some areas include urban fill with a high likelihood of contamination which would discourage the use of GSI. In response to a stakeholder's inquiry on these contaminants, Mr. Raiche indicated that a contamination vetting will be incorporated into the design phase should GSI be chosen as a significant component of the Phase III CSO project. Categories of GSI reviewed included infiltration, detention, and retention solutions. This was followed by a presentation by Mr. Nick Anderson of MWH on the implementation of GSI at representative sewersheds within NBC's service area. Mr. Anderson emphasized to the group that the solution to the CSO will be a combination of green and gray infrastructure, and that part of the scope of the Phase III re-evaluation project is optimizing this combination.

The GSI presentation was followed by a discussion from Ms. Sheila Dormody, Director of Sustainability for the City of Providence, with respect to the Upper Narragansett Bay Regional Stormwater Utility Study. Ms. Dormody informed the stakeholders that a fee based on how much one is contributing to the stormwater management problem is allowed in accordance with the Rhode Island Stormwater Management and Utility District Act of 2002. Moreover, the results of the first phase of the study revealed that the most effective and co-efficient way to manage stormwater and meet the minimum control measures prescribed by the EPA's Municipal Separate Storm Sewer System (MS4) Program is through a regional stormwater utility. Phase I of the study is complete and Phase II is expected to begin in the late summer of 2014. A discussion among the stakeholders regarding the cost of this regional stormwater utility ensued.

The workshop concluded with a presentation by MWH and a group discussion on the criteria to be used in evaluating the Phase III CSO project alternatives, specifically employing the IPF methodology. A document was distributed to the stakeholders that included a listing of the proposed evaluation criteria. MWH requested that the stakeholders rate the criteria in order of importance to them. An email of the document was to be delivered to the stakeholders by Ms. Jamie Samons of NBC. Criteria not included on the document could be added to the list by the stakeholders. The document was to be completed and returned to Ms. Samons. Results of the criteria selection activity were scheduled for assessment as part of Workshop #5.

3.5. Workshop #5 (September 4, 2014, 9:00am - 12:00pm)

The fifth workshop began with introductory comments by Mr. Thomas Brueckner of NBC. Mr. Brueckner addressed the sole outstanding issue from the previous workshop, stating that NOAA will be updating their precipitation projections in September 2015 and NBC will utilize these projections for the design of the Phase III facilities. The participants were also informed that an additional stakeholder meeting will be scheduled for November to adequately cover all pertinent issues necessary to finalize the recommended plan for Phase III. The introduction was followed by a presentation by Mr. Richard Raiche of MWH on Alternatives Development, Hydraulic Model Results, and Evaluation Criteria.

Mr. Raiche began with a review of the CSO mitigation strategies assessed as part of the Phase III re-evaluation project. These included source (i.e., stormwater controls, GSI), pathway (i.e., stormwater storage, sewer separation, regulator modifications, interceptor relief), and receptor (i.e., treatment and discharge, near surface storage, deep tunnel storage) mitigation strategies. A discussion on the permitting of the proposed alternatives, specifically screening and disinfection, was performed among stakeholders. Mr. Angelo Liberti of the RIDEM indicated that, should affordability deem all other alternatives unavailable, it may be considered as an interim solution. Mr. David Turin of the EPA further stated that screening and disinfection would not meet the requirements of the Clean Water Act of secondary treatment, even if it is permitted in the short term. This was followed by a discussion by Mr. Raiche on rating criteria for the alternatives evaluation. Mr. Anderson of MWH then addressed the stakeholders with the methodology and findings of an assessment performed by MWH with respect to implementation of GSI as part of the Phase III CSO project. The results of the assessment indicated that a 10% reduction in CSOs would be achieved if GSI was implemented on public land only, while a 34% reduction would be achieved if GSI were implemented on both public and private land.

After a brief intermission, a presentation and discussion on the Phase III alternatives evaluation and conceptual design was performed by MWH and PARE. Alternatives considered as part of the evaluation included the Phase III baseline alternative (i.e., Pawtucket Tunnel), a stub tunnel, interceptors, sewer separation, green infrastructure, and near-surface storage. Mr. Keith Gardner of MWH provided a presentation on sewer separation, including hybrid sewer separation-GSI alternatives. This was followed by a review of the near-surface storage tank options presented by Mr. Timothy Thies of PARE. The impact to businesses and local communities as well as the limitations on the size of the proposed tanks was discussed. Mr. Lance Hill, DPW Director for the City of Pawtucket, stated that the tank options would be difficult for the communities to manage. The workshop was concluded with a brief presentation by Mr. Phil Holmes of the Rhode Island Shellfishermen's Association. Mr. Holmes stated that the shellfishermen are concerned about the shellfish beds in the lower Narragansett Bay and requested volumes from the major overflows be reduced. Moreover, Mr. Holmes also requested that Phase III be separated into two phases so that the worst offenders could be addressed most quickly.

3.6. Workshop #6 (October 23, 2014, 9:00am - 12:00pm)

The sixth workshop commenced with introductory remarks by moderator Mr. Mike Domenica and a review of an outstanding issue from the previous workshop by Mr. Thomas Brueckner of NBC. The issue was related to secondary treatment requirements for satellite treatment facilities. A deliberation on this matter between NBC and EPA staff revealed that screening and disinfection at satellite treatment facilities can be considered as an interim solution and will not require immediate implementation of secondary treatment. The introduction was followed by a presentation by MWH on the affordability analysis performed for the third phase of the CSO project.

MWH presented a thorough analysis on the finances of NBC as well as municipalities located within the NBC service area that was used to create a model for estimating affordability of the Phase III CSO program. In total, NBC's long-term capital improvement program from 2015 to 2026 is estimated to cost approximately $916 million, $741 million of which would result from the Phase III CSO program as presented in the CDRA. According to the EPA guidance documentation, if the sewer rates exceed 2% of the MHI then the project is considered unaffordable, though other economic factors may result in unaffordability at rates below 2% of the MHI. The EPA residential indicator for the NBC service area was 1.67% of the MHI; however, many census tracts within the service area were above the 2% MHI affordability threshold. The presentation also included an analysis of member community wastewater and stormwater capital improvement project costs and its effect on affordability. Case studies for the cities of Providence, Central Falls, and Pawtucket were also exhibited to the stakeholders.

Mr. Jan Reitsma, Special Advisor for Policy and Legislative Affairs for the Office of the Governor, indicated that the stakeholders meetings should not lose focus of its primary objective: to develop the most cost-effective solution to protecting one of the State's key assets, the Narragansett Bay. Mr. Michael Gagnon, Public Works Director for the Town of Lincoln, added that "the Bay is here for the whole state and perhaps we should not think about lengthening the time of this construction but shortening the time, being a little more aggressive, and expanding the tax base. So the state in its entirety should be bearing the cost of this; not just the seven communities."

After a brief intermission, a presentation and discussion on subsystem alternatives and alternative costs was performed by MWH. The presentation consisted of a review of the baseline (i.e., tunnel, interceptors, sewer separation) and alternative (i.e., GSI, near-surface storage, screening and disinfection) subsystem costs. Although some components are still in the evaluation stage, the revised Phase III components were presented to the stakeholders and included sewer separation, interceptors, GSI, and a tunnel. Stakeholders expressed concerns with the implementation of GSI, water quality goals, storm intensity predictions, nonresidential affordability analysis as part of the Phase III re-evaluation.

3.7. Workshop #7 (December 4, 2014, 9:00am - 12:00pm)

The seventh and final workshop began with remarks by NBC Chairman Mr. Vincent Mesolella. This was followed by a presentation of the alternative scenarios by Mr. Richard Raiche of MWH. The four alternative plans reviewed included the baseline CDRA (Alternative 1), the modified and phased baseline CDRA (Alternative 2), the modified and phased baseline CDRA with extended schedule and interim water quality projects (Alternative 3), and storage and treatment at the Bucklin Point Treatment Plant (Alternative 4). Each alternative was discussed and compared in terms of project components, costs, water quality, scheduling and duration, and optimization potential.

Alternative 1 includes sewer separation, interceptors, and the Pawtucket Tunnel. The plan would cost approximately $750 million and be completed by the end of 2025. Alternative 2 includes sewer separation, interceptors, GSI, the Pawtucket Tunnel, and the Stub Tunnel. The alternative would include four phases and be completed at a cost of approximately $710-$810 million by the end of 2038. A number of optimization concepts (e.g., sewer separation and interceptor reduction, increased GSI, tunnel extension, real-time controls) were presented that could potentially reduce the cost of the alternative by $50-$100 million. Overall completion of the alternative including optimization concepts would be 2031-2035. Alternative 3 includes sewer separation, interceptors, GSI, the Pawtucket Tunnel, the Stub Tunnel, and a screening and disinfection facility. The alternative would include six phases and be completed at a cost of approximately $825-$925 million by the end of 2047. Alternative 4 includes sewer separation, interceptors, GSI, and near-surface storage facilities. The alternative would include four phases and be completed at a cost of approximately $450 million by the end of 2038. However, this option would require additional investigations. Mr. Raiche indicated that the four alternatives will be presented to the NBC Board of Commissioners for analysis and determination of the preferred alternative for the Phase III CSO Project.

The workshop concluded with a discussion by Ms. Sheila Dormody of the City of Providence on the proposed stormwater utility district.

NBC CSO Control Facilities Phase III Reevaluation

Appendix 9 – Subsurface Exploration Program

NBC CSO Control Facilities Phase III Reevaluation

Appendix 9 - Subsurface Exploration Program

Table of Contents

1. Background/Purpose

Pare Corporation (PARE) understands that the Narragansett Bay Commission (NBC) requires a geotechnical subsurface investigation program for the third phase of the Combined Sewer Overflow (CSO) Abatement Project to be located in the northern portion of Providence extending into the communities of Pawtucket, Central Falls, and North Providence. It is further understood that the proposed CSO project consists of a system of new deep rock tunnel, drop shafts, and interceptors together with associated pump stations and GSI/Sewer separators, to be constructed as shown in the attached Figure 1 titled "Proposed Phase III CSO Upgrades"[1]. An integral part of the design phase is the development and implementation of a subsurface exploration program to develop a geotechnical report inclusive of recommendations for the design and construction of the proposed structures. Based upon this understanding that the final alignment scheme and the depth of the components have not been finalized, PARE has developed a proposed preliminary scope of work based upon recommended exploration for each structure type.

The purpose of the subsurface exploration program is to identify the existing subsurface conditions; evaluate potential implications the observed conditions may have upon the proposed structures; further design and evaluation; and provide geotechnical parameters and recommendations for use during the design and construction of the shafts, tunnels, buildings, and other site improvements associated with the proposed project.

2. Scope

An intrusive geotechnical subsurface investigation program will be performed to supplement the information obtained during the desk-study performed as part of the Phase III Re-evaluation.

Based upon the preliminary layout presented in the attached Figure 1, it is anticipated that a truck-mounted drilling rig may be used to undertake the majority of the borings; however, where the proposed tunnel crosses Narragansett Bay a barge-mounted drilling rig will be utilized to complete the borings.

The inspection program should be coordinated by a geotechnical engineer with field personnel observing drilling conditions, visually identifying the SPT soil samples utilizing standard classification systems, classifying rock cores, and recording groundwater levels during the advancement of the exploration.

Please note that this exploration program should consider environmental evaluation and testing for the presence of potential contaminants as the proposed alignments pass through urbanized areas with diverse industrial and manufacturing histories. Prior to the commencement of any sub-surface investigation, it is recommended that an environmental due diligence task be undertaken, similar to a Phase I Environmental Site Assessment (ASTM E1527, latest addition), or comparable evaluation to identify the potential for sub-surface contamination that may impact the means and methods of the exploration program, as well as the construction project.

[1] Based upon figure titled "Alternative 2: Modified & Phased Baseline" provided by MWH Global.

3. Locations

3.1 Deep Rock Tunnel (Pawtucket Tunnel)

Borings should be performed at approximately 500-foot[2] intervals (no intervals greater than 500 feet) along the proposed deep rock tunnel. The borings should be advanced to the depth of the tunnel plus up to 20 feet. Rock cores should be retrieved to the design depth if bedrock is encountered prior to the bottom of the boring. Soil samples should be obtained at 10-foot intervals within the natural soil deposits.

The rock cores obtained from the drilling operations should be collected and classified in order to identify and characterize the fractures, hardness, strength, and composition. The cores should be logged for total core recovery, solid core recovery, Rock Quality Designation (RQD), and fracture logging. Once the rock cores have been identified and analyzed, a rock profile should be created along the alignment with anticipated rock properties and estimated volume of rock which may be encountered. Laboratory testing to confirme unconfined compressive strength should be completed upon a subset of the samples recovered.

Based upon the attached Figure 1, the Pawtucket Tunnel is anticipated to be 2.5-3.0 miles long. With this understanding, it is estimated that between 40 and 55 borings will be required, with approximately 10 of those located within Upper Narragansett Bay or its contributing water bodies.

3.2 Proposed Interceptors

Borings should be performed at 300-foot intervals along each proposed interceptor and should be advanced to at least 10 feet below the proposed bottom elevation of the alignment. Rock cores should be completed as required to reach the design depth if bedrock is encountered prior to the bottom of the boring. Split spoon sampling should be completed continuously through fill layers and at 5 foot intervals within natural soil deposits. A soil and rock profile should be generated to estimate the volume of rock which may be encountered.

It is anticipated that a truck-mounted drilling rig can be used for undertaking the borings along each proposed interceptor(s). The following table provides approximate lengths of interceptor tunnels and the estimated number of borings required, utilizing the naming convention and layout shown on the attached figure.

Table 3.2.1 – Interceptor Exploration Program

Interceptor Name	Approximately Length	Estimated Number of Borings
High & Cross Streets	0.5 – 1.0 miles	8 - 20
Middle Street	0.25 – 0.75 miles	4 – 15
220 Stub Tunnel	1.0 – 1.5 miles	20 – 30
West River	0.75 – 1.25 miles	15 - 25
TOTALS:	**2.5 – 4.5 miles**	**47 - 90**

[2] Referencing AASHTO 1988 Guidelines for Vertical/Inclined Borehole Spacing.

3.3 Drop Shafts

Borings at the locations of proposed sewer separators, pump stations, and drop shafts should be arrayed pending final layout of each proposed structure.

No less than two borings should be completed at each drop shaft location. Additional borings may be required at each location depending on the diameter of the shaft. The boring(s) should be advanced to at least 10 feet below the proposed bottom elevation of the shaft. Soil and rock sampling should be undertaken as described within Section 3.2.

It is anticipated that a truck-mounted drilling rig can be used for undertaking the borings at the drop shaft locations.

3.4 Pump Stations

Borings should be performed at the proposed pump stations to at least four times the greatest base dimension below the bottom of the chamber. At least two borings should be performed at each structure and at 100 feet spacing for larger structures with any one sidewall longer than 100 feet. Soil and rock sampling should be undertaken as described within Section 3.2.

It is anticipated that a truck-mounted drilling rig can be used for undertaking the borings along each proposed interceptor.

3.5 GSI/Sewer Seperation

Borings should be performed along the alignment of the GSI/sewer separation at approximately 300 foot intervals with a minimum of 2 per segment. In areas where underground structures or at-grade water quality features are proposed as part of a GSI program, such as infiltration systems, retention/detention basins, storage chambers, etc., at least 2 boring should be completed within the footprint of any such feature, and borings should be completed at a frequency of at least one boring per 1,000 square feet of feature footprint. Borings should be advanced to at least 5 feet below the proposed bottom elevation of the sewer. Soil and rock sampling should be undertaken as described within Section 3.2.

It is anticipated that a truck-mounted drilling rig can be used for undertaking the borings along each pipe segment or GIS feature.

3.6 Temporary Earth Support

Given the nature of the proposed project, temporary earth support will likely be required for both shallow and deep structures. The exploration program should be designed to provide sufficient detail to design the excavation support and dewatering. Consideration must be given to impacts to adjacent structures due to changes in effective stress as well as settlement and lateral movement.

4. Instrumentation

4.1 Observation Wells

It is recommended that the final exploration program incorporate the installation of groundwater monitoring wells for pump stations and sewer separation. Once installed the wells should be monitored to determine seasonal fluctuation as well as high groundwater conditions. It is recommended that the wells be monitored throughout the design process.

4.2 Piezometers

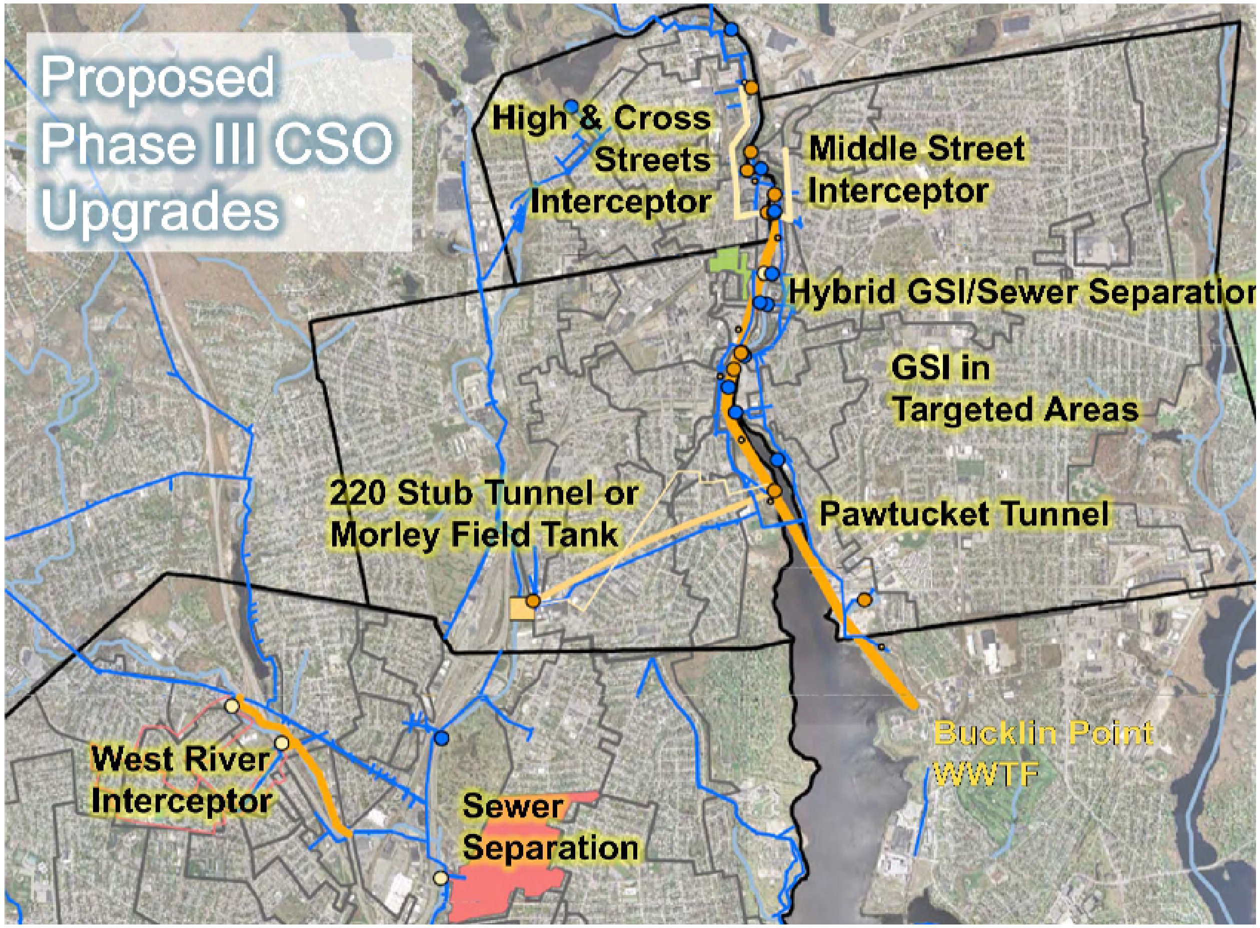
It is recommended that vibrating wire piezometers be installed within selected explorations along the tunnel alignment and at each drop shaft.

5. Summary

The following table summarizes the recommended geotechnical exploration program. Prior to the commencement of design of any project element, it is recommended that a comprehensive geotechnical investigation be planned and undertaken that meets the minimum recommendations outlined below.

Table 5.1 – Summary of Geotechnical Exploration Recommendations

Structure	Recommended Spacing	Recommended Depth	Sampling Interval	Laboratory Testing	Instrumentation
Deep Rock Tunnel	500 feet	20 feet below tunnel invert	10-foot intervals through natural soil deposits; continuously through the bedrock to the bottom of the exploration	Unconfined compression testing of the rock	Vibrating wire piezometers at select locations
Interceptors	300 feet	10 feet below invert	Continuous through all fill layers; at 5-foot intervals through natural soil deposits; continuously through the bedrock to the bottom of the exploration		None Required
Drop Shafts	2 per structure (minimum)	10 feet below bottom of the shaft			Vibrating wire piezometers at select locations
Pump Stations	2 per structure (minimum)	four times the greatest base dimension below the bottom of the chamber		Gradation analysis, CIU tri-axial testing and Direct Shear testing for deeper excavations	Observation wells at select locations
GSI/Sewer Separation	300 feet, minimum 2 per segment 2 per GSI feature and one every 1,000 sq.ft.	5 feet below the sewer invert			
Temporary Earth Support	Minimum 2 per location. Can be combined with structure borings	up to but not limited to 30 feet below the bottom of the excavation			None Required



PROJECT NO. 14106.00

DATE: JUNE 2015

PARE CORPORATION
ENGINEERS - SCIENTISTS - PLANNERS
8 BLACKSTONE VALLEY PLACE
LINCOLN, RI 02865
401-334-4100

FIGURE 1
PROPOSED PHASE III CSO UPGRADES
NBC CSO CONTROL FACILITIES PHASE III REEVALUATION

PROVIDENCE, RHODE ISLAND

SCALE: NOT TO SCALE

L:\14106.00 NBC Phase III CSO Re-evaluation\REPORTS\Figure 1 - Proposed Phase III CSO Upgrades.dwg

NBC CSO Control Facilities Phase III Reevaluation

Appendix 10 – Minutes for the Board of Commissioners Meeting April 28, 2015 (Approval of Resolution 2015:09-2)

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

NARRAGANSETT BAY COMMISSION

IN RE: BOARD OF COMMISSIONERS MEETING

DATE: April 28, 2015
TIME: 11:00 A.M.
PLACE: Narragansett Bay Commission
Corporate Office Building
One Service Road
Providence, RI 02905

COMMISSIONERS:

Vincent Mesolella, Chairman
Raymond Marshall, Executive Director & Secretary
Robert Andrade
Dr. Richard Burroughs
Bruce Campbell
Mario Carlino
Michelle Deroche
Michael Dichiro
Jonathan Farnum
Seth Handy
Joseph Kimball
Paul Lemont
Ronald Leone
John MacQueen
Joan Milas
Al Montanari
Alan Nathan

Angelo Rotella
Richard Worrell

STAFF & GUESTS

Paul Nordstrom, NBC
Rich Bernier, NBC
Jamie Samons, NBC
Jennifer Harrington, NBC
George Palmisciano, Pare Corp.
Laurie Horridge, NBC
Tom Brueckner, MWH
Karen Musumeci, NBC
Rich Raiche, MWH
Thomas Uva, NBC
Robert Otoski, CDM Smith
Karen Giebink, NBC
Dan Berger, PFM
Alex Kuffner, Providence Journal
David Bowen, Wright-Pierce
Ambar Espinoza, RI Public Radio
Mike Stuard, NBC
Gail Degnan, NBC
Sherri Arnold, NBC
Sean Searles, MWH
Leah Foster, NBC
Robert Otoski, CDM Smith
Melissa Carter, MWH
Al Mancini, DPUC
Jean Lynch, CAC
John Zuba, NBC
Christine Cooper, NBC
Steve Maceroni, PFM
Jamie Samons, NBC
John Motta, NBC
Harold Gadon, CAC
Topher Hamblett, Save the Bay
Mark Thomas, NBC
Sandor Bodo, Providence Journal
Pamela Bhatia, NBC

(MEETING COMMENCED AT 11:09 A.M.)

CHAIRMAN MESOLELLA: Good morning, everyone. We'll call the meeting to order of the Narragansett Board of Commissioners at 11:00, April 28th, 2015.

The first order of business is the approval of the previous. Have all of our members had an opportunity to review the previous minutes?

COMMISSIONER MONTANARI: Yes.

CHAIRMAN MESOLELLA: We have a motion to approve the previous minutes by Commissioner Montanari. Discussion? Commissioner Farnum. Previous discussion on the previous as presented. Hearing none. All of those that are in favor will say aye. Are there any opposed? There are none opposed, and that motion carries.

(UNANIMOUS VOTE)

CHAIRMAN MESOLELLA: Moving along to Item Number 3, which is the Election of Officers. At this time the Chairman will turn the gavel over to the Executive Director for nominations.

MR. MARSHALL: Mr. Chairman, I

would like to open the floor up to nominations for the positions of Chairman, Vice Chairman and Treasurer. Commissioner MacQueen?

COMMISSIONER MACQUEEN: I make a motion that the secretary cast one vote for the position of officers Mr. Mesolella for Chairman, Mr. Chairman, Rotella for Vice Chairman and Mr. Andrade for treasurer.

MR. MARSHALL: Is there a second?

COMMISSIONER BURROUGHS: Second.

MR. MARSHALL: Okay, a motion's been made and seconded. Are there any other nominations? Is there any discussion? Hearing none. We'll close the floor to nominations and the secretary will cast as directed by the motion. One vote for the existing slate, and congratulations.

(APPLAUSE)

CHAIRMAN MESOLELLA: The first thing, of course, I'd like to say is thank you for your vote of confidence. I truly appreciate it. And as I've always done in the last 36 years I've been a member of this Commission, I offer my one thousand percent support for this commission and commissioners and so thank you

all very much. We have a very exciting year coming up. And, of course, I appreciate your participation and your contributions. Thank you, very much. And thank you Mr. Vice Chair for your support and treasurer, Commissioner Andrade. Thank you.

Okay. Moving right along. You probably noticed that there's a little bit of a different order on the agenda today. The first order of business would be the Chairman's Report. The Chairman does not have much of a report except to say that earlier in the course of the day there was a construction engineering, an operations committee meeting. The Chairman offered to the committee that we will be putting out to the public a request for proposal/qualifications for Renewable Energy proposals.

The Commission will be soliciting these proposals pursuant to a statute that was passed by the general assembly allowing us to net meter and to buy or purchase energy from outside sources off site. So this is available for viewing. Any of the commissioners can take a look at it. If not, Tom Uva and our staff is

going to making some tweaks to it, nothing substantial right now. Minor changes. And then prior to our next meeting, this will be out to the public. That's the first thing. The second thing is something that's been in the paper almost everyday for the last month which is the Pawtucket Red Sox issue. Perhaps some of our members heard I was a guest on the Buddy Cianci show with regard Pawtucket proposed, the original Pawtucket proposed stadium, or Prov Sox. I'm not sure what it will be, but it will be something.

So it appears, it doesn't appear, as a matter of fact we have several large structures on that site which take up most of left field and perhaps some part of center field. We were approached by the owners of Paw Sox with regard to our cooperation of regard to relocating some of those structures. We originally thought that they were going to ask us to absorb the cost associated with that. As it turned out, they did not ask us to absorb the cost. They said that they would absorb the cost, and they were really soliciting our corporation with regard to testing the hydraulic

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and make sure it worked as a system, and that is exactly what I said on the radio with Buddy Cianci. We consider ourselves to be part of the solution, not a part of the problem. We hadn't heard from the general assembly or the Governor's Office regarding the issue, but in terms of our cooperation, they could expect a hundred percent cooperation from us as long as our ratepayers were not asked to bear the cost. As we know today, in fact, there's an article in the paper. I don't know what the status of it is. It may very well be that they have found another site.

So we're all just sitting waiting for the next shoe to drop. And as things develop, we'll make absolutely certain that we keep the Board apprised except to say that I told the owners as far as I and the Board was concerned that our ratepayers had no interest in picking up any of the costs associated with those improvements. Okay. So having said that, Mr. Chairman --

CHAIRMAN MESOLELLA: Anybody have any questions with regard to that? I mean, I don't think anyone really knows what's going to

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happen in the next several weeks, but it will be interesting. So other than that, the Chairman has no further report. The next order of business is the Executive Director's Report which is Item Number 5. Mr. Secretary, do you have a report for us today?

MR. MARSHALL: Yes, sir, I do.

CHAIRMAN MESOLELLA: Please proceed.

MR. MARSHALL: Field's Point and Bucklin Point Wastewater Treatment Plants are gearing up for the nitrogen removal season which starts May 1st. Actually, Bucklin Point has done a really good job maintaining the system. It's just the nature of what we designed and installed over there. So they're already up to speed. And Field's Point is coming into compliance as we speak. We've been coordinating on a regular basis with Rhode Island Resource Recovery. Their discharge is now coming to

Field's Point. It has been since November. Their pretreatment system has been starting up in the last six weeks. We work closely with them and DEM to try to make this transition as smooth as possible. We had a problem during the

month with the tunnel odor control system, and we're working to resolve those problems. Some of the filters or strainers needed to be replaced, so we're in the process of doing that.

As far as the turbines go, we generated 62 percent of the Field's Point Wastewater Treatment Facility power needs in March. And lastly, at Field's Point, we continue to work on the problem that we have with the blowers. Going through the manufacturer who has replaced a number of the different components of those systems. And the good news is we now have 8 of 9 blowers available. With the 9th one about ready to come on-line in the next week or two. So we'll be fully operational for the start of the season. Then we'll see what happens from there. We also have other contingency plans in case we start having additional difficulties.

In interceptor maintenance we had

no dry weather overflows in the month of March. That was good news. And engineering spent a lot of their time this month preparing for last night's presentation on CSO Phase III. In the construction area, the new lab building is

really making progress. I don't know if you were able to take a look at what's going on across the street, but all the structural steelwork is done or essentially done. And other then that, we've been working on Phase II of the CSO Program we're doing cleanup and paving and landscaping to try to tidy the areas up so that we can pretty much disappear from people's lives, and I'm sure they'll be very pleased with that.

In Administration and Finance, the FY-'15 Budget is in good shape. We're running about 8.9 percent below the year-to-date target, and that's attributable to a lower personnel cost, a lower O&M cost, primarily to through bio-solids and chemical use. And debt service is about 5 percent below projections. The FY-'16 Budget has reached the point where we can schedule a Finance Committee meeting on the preliminary budget. And we agree to do that at the May board meeting on the May board meeting day. So they'll probably be about an hour allocated for the Finance Committee at the May -- I'll give you the exact date. I think it's the 27th, but let me be certain of that. May

27th and then the full board will vote on the final budget in June. We went through with the 2007 Series A Revenue Bonds refinancing. They were priced on March 31st and they achieved a net present value savings of 2.5 million dollars. And we continue to work with the Clean Water Finance Agency on the next borrowing.

We need a debt service schedule from them so we can go to the PUC and file for a rate increase not to exceed 4 percent for debt service. And they also approved working with DEM that we can go for a 30-year issue rather than a 20-year issue than much of what we're financing is really long-term facilities. And in the month of March customer service billed 6.9 million dollars and collected 9 million dollars.

So that was a good month for us. PP&R Policy, Planning and Regulation, as the

Chairman pointed out, put together this RFP, so we can go out for net metering opportunities as well as they put together an excellent application to EPA that allowed us receive the EPA's Region 1 annual excellence award. And that was actually given to us on April 22nd.

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Tom Uva and Laurie Horridge went up to receive the award. And it's really based upon the entire spectrum of our accomplishments here at NBC, which you have all supported strongly over the years, so we'll have a little award photograph session probably at the next meeting.

And in Executive we viewed about 150 pieces of proposed legislation. Joanne will have a legislative report for you a little later. We attended a House Finance Committee Meeting and testified on the Governor's budget item involving 2.8 million dollars being taken from NBC in order to pay debt service on state debt associated with the Old Bay Bonds. So we have a meeting scheduled with the administration, May 9th, I believe it is, to go over that in more detail with them and to let them know based upon our reading of the trust indenture, as well as a PUC ruling that that's not a viable option for them to do that.

As the Chairman indicated, we met with Pawtucket Red Sox owners, and we staff have met with their consultants regarding the proposed location of the ballpark, and the consultants are very in tune with what we have

on that site and what needs to be moved. And finally, we had a lien sale. It was successfully completed about a week ago and we collected $526,000 thousand dollars as a result of that effort. And that is my report, Mr. Chairman.

CHAIRMAN MESOLELLA: Okay. Commissioner Carlino?

MR. CARLINO: Do we know -- what was the final estimate, or we don't have a final estimate to relocate our facility where the ball park is going. Is it 5 million, 7 million, or we don't know that?

MR. MARSHALL: Our estimate was $7 million. But we tend to be very conservative in our estimates. I think their estimate is a more aggressive one, but I'm not saying that. It couldn't be accomplished for five and a half million or whatever number they threw out. It's not really any different than any time we come to you with a bid that we want to award if you look at the range of the bids. There's always a certain spread there and this is a similar type thing.

CHAIRMAN MESOLELLA: So at the

meeting, actually, it was Commissioner Rotella who pressed him on that very same issue. And he indicated that they would be taking it as a private function. So he indicated that their cost would probably be less than ours because they didn't have the bureaucracy that we have to deal with, and well, he --

COMMISSIONER ROTELLA: The bidding process, and the --

CHAIRMAN MESOLELLA: You know, the bidding process and all of the kinds of associated costs that we have. So what was his number, $5 million?

COMMISSIONER ROTELLA: Five million.

CHAIRMAN MESOLELLA: He said he had heard me on the radio saying 7 or 7 and a half million, which is what our engineers, our group had determined. And they said way too much. I don't know what it is, but he said it's five.

COMMISSIONER ROTELLA: If I may, Mr. Chairman, he also concluded in that five million the cost of the moving of the Narragansett Grid gas line. It was included in that $5 million dollar price. So what he

thought would be 5 million for all of the movement necessary.

Again, their plan, I asked them what he thought the total cost of the investment would be of the stadium. He said about 70 million and then another 10 million for the garage, right?

CHAIRMAN MESOLELLA: Yes.

COMMISSIONER ROTELLA: So I was trying to establish what percent. It's not a giant percentage, but obviously, some percentage of the total cost.

CHAIRMAN MESOLELLA: Not including National Grid, which, of course, you'd know more about that than we would. And he said he could get that approval in two weeks. Two weeks, done.

COMMISSIONER WORRELL: Is that two years?

CHAIRMAN MESOLELLA: Two weeks, he said. Did you tell him about the turbines.

I told him that. I said, you know, I have to tell, I can't -- we'll cooperate with you, but in terms of, you know, that gas line, I have no idea how long it's going to take you to

do that. He wants to throw the first pitch out for the 2017 season. I don't know if time is going to allow that to happen. By the way, we were very, very diligent in explaining to him that there is a shaft that cannot be moved. And that we had encountered odor control issues the last shaft we did on Calvary Street, you may recall.

We had to put a structure, build a structure on top of the Calvary Street shaft. And I told him, and I made certain that he knew that we did not grow roses here. And that he could expect that at certain times during the course of the year that you might be experiencing, you know, odor issues, and that he best consider an expense associated with a stack of some kind.

MR. MARSHALL: By the way, I think he was listening to the Chairman because if you look at the rendering now. If you look directly out in center field, what you see is like a lighthouse-type structure. That would shield an odor controlled system like we have at the Foundry complex.

CHAIRMAN MESOLELLA: I certainly

didn't want, you know, in the effort to cooperate at the end of the day it gets built and there's an odor issue, of course, the finger will be pointed to the NBC. So we wanted to make certain that everyone knew that right out in front. Karen, did you take minutes at that meeting?

MS. MUSUMECI: Yes.

CHAIRMAN MESOLELLA: So we're on the record for that. So, all right. Any other questions regarding the Executive Director's Report. Hearing none. Moving right along. Harold, you're up. Citizens Advisory Committee.

MR. GADON: Thank you, Mr. Chairman, a very short report. At a well-attended meeting held on last Wednesday, Tom Brueckner gave an understandable presentation on the topic of the day, Phase III Alternatives.

I'll now be able to report at our next meeting on May 20 that Alternative 2 is being chosen so that NBC will now proceed to discuss a review with DEM. Thank you.

CHAIRMAN MESOLELLA: So, for the record, Alternative 2 had been proposed and

offered. The committee hasn't chosen it yet. But we will take a vote on it soon.

MR. GADON: Getting ahead.

CHAIRMAN MESOLELLA: Okay, moving forward. And speaking of Alternative 2, the next committee reporting is the Long-Range Planning Committee. Commissioner Carlino, do you have a report for us today?

COMMISSIONER CARLINO: Yes.

CHAIRMAN MESOLELLA: Please proceed.

COMMISSIONER CARLINO: We met this morning the board and we accepted and approved Resolution 2015-09-2, which is Alternative Number 2 for CSO Phase III. Five were in favor, one was against. And if I could just say before we go to a vote. We've spent the last eight months on this since September, numerous presentations, a lot of work by the staff, and Tom Brueckner, Ray Marshall, and other staff members, consultants MWH, PFM spent a lot of time answering our questions, our concerns. I think the Chairman and the Executive Director have made it very clear that we have an obligation. We signed an agreement. We have to

move forward. I know there's been a lot of due diligence by all the commissioners. All of us spent numerous extra time; two workshops within those eight months, numerous hours probably offsite talking about it. We all have concerns. We all have concerns about the cost, about the benefit, about the water quality, the median household income. But we felt as a committee that we have to move forward. What's critical is the next steps as the director had pointed out.

We're going to do an evaluation report. We then have to submit to Rhode Island DEM our plan what we've chosen, and I think at that point we have to really sit down and hold their feet to the fire and say, you know, this is how much money we're going to spend, $800 million dollars approximately.

And what type of water quality are we really getting and what effects is it going to have on low income, and so forth. So I know that's a lot of the concerns of the Commissioners. And we voted in favor to approve Alternative Number 2 in a 5 to 1 vote.

CHAIRMAN MESOLELLA: So

Commissioner, are you now making a motion to approve Resolution 2015-09-2?

COMMISSIONER CARLINO: Correct.

CHAIRMAN MESOLELLA: I have a motion from Commissioner Carlino to approve Resolution 2015-09-2, option 2, Phase III of the CSO program. Do we have a second? Seconded by Commissioner Montanari, Commissioner Leone, Commissioner MacQueen, Commissioner Lemont. Okay. Further discussion on the motion? Commissioner Burroughs.

COMMISSIONER BURROUGHS: Yes, thank you, Mr. Chairman. I was the one negative vote on the committee. And I wanted to briefly indicate my reservations about the proposal. For those of you who don't have it, there's a short sheet on trying to pull all of this together.

I first want to thank the staff and consultants for really moving very, very quickly to bring this to this point, given the complexity of the decision. How big and how complex is this decision? We're asked in a few minutes now to vote on bonding that will be two or three times the size of the statewide bonding

of last fall. But this bonding is targeted on 118,000 households, so it's a large burden on a smaller population.

Secondly, because the Narragansett Bay Commission has been out in front on many of these issues, we're also, through the actions that we take today, beginning to set some national precedent about how consent decrees are likely to be handled. And the area of contention for me in that regard is that our aspirations for water quality under the Water Quality Act are beyond what engineering or prudent finance can deliver.

So the question is, how do we

redirect the discussion to water quality? And in the table that I handed out, I looked specifically now at Alternative 2, the cost of that alternative and the benefits.

And one way of thinking about the benefits is to say how many days does it take us to get back into compliance with the EPA regulations after a rainfall event? And if we look at the Narragansett boating center, we find that it takes about two and a half days, whether or not we spend the billion dollars for the

investment. So in that part of the estuary, we're not seeing an immediate benefit, although we are in compliance with the regulations spending a lot of money. When we move down to Conimicut, that period that takes us to get back into compliance is 5.3 days. If we spend the money, the billion dollars.

If we just stop at the end of Phase II, it takes us 9.3 days. So as some have observed, we are spending in this part of the system a billion dollars, more or less, to get an improvement in water quality for a four-day period.

Now, obviously, there are lots of other things going on, but I mention this just to indicate that, because the way the system is set up, we're asked to make improvements even when the cost of the improvement is very high, we need to recognize that going forward.

And finally, I think it's important to recognize that the cost of this, which is another way of managing it or designing for it, is very high. And that in what we learned last night in the workshop by year 2026, 54 percent of the households in our service area will be

over the 2 percent median household income. So we've got two sets of rules here. One set of rules is make the estuary as clean as possible. The other set of rules is don't overspend. And I guess I'm going to come down on the side of the don't overspend, and we'll have to vote nay as this matter comes to fruition. Thank you.

CHAIRMAN MESOLELLA: Thank you, Dr. Burroughs. Comments, further comments? Commissioner Worrell.

COMMISSIONER WORRELL: I will vote in favor of Alternative 2 today, but I do so with some great reservations in that the cost of option 2 that we were planning on voting for, as Commissioner Burroughs has said, drives the household cost per family to over the 2 percent guideline from EPA for over 50 percent of the families in our service area within a period of 10 or 12 years after we get going on this thing. I would love to see when we go into our negotiations with DEM and EPA that we say to them, look, here's our option 2 which we have recommended and which we are prepared to go along with, but we insist that you back down on forcing us to do the entire option, give us the

opportunity to prove to you that we can do an excellent job and stay within the less than 2 percent for a large portion of our service area without going the full route.

In other words, we're being asked today to approve 7 or 8 hundred-million dollars of expenses on this option 2. It may well be as Commissioner Burroughs points out that that really isn't going to amount to an awful lot, but if EPA and DEM are going to force us into that, okay, we will go ahead and do it because we're a responsible organization.

But I do not want to go before EPA and DEM without a reservation that we are going to fight to keep those rates for these ratepayers down below that 2 percent. That 50 something percentage of the households above the 2 percent, that includes the fact that we've got to pay some attention to the lateral sewer connections throughout the City of Providence, which are in deplorable conditions which have not been maintained, and those need upgrading. That cost has got to be passed down to those ratepayers. It hasn't even addressed the issue that throughout the rate paying area, you've got

septic systems which are in deplorable condition. They haven't been fixed up. The owners of the properties will not fix them up. The enforcement people within the cities and towns shy away from this issue because they don't want to be the ones to inform a homeowner, look, you've got a septic system which doesn't work and it's only going to cost you 12,000 bucks and you must get it done within 90 days. You can imagine how popular that would make all the local politicians.

And they duck that issue like they

were ducking the plaque, and they will continue to do that unless somebody brings pressure on them to do it.

If they're forced to start addressing the issue of all of these broken septic systems, not to mention the sewer lines that go directly from a lot of the homes into the sewer system, the stormwater system, not to mention that fact which is another huge cost, because it's a lot cheaper to connect your toilet to the storm system when the plumber -- when you wink at the plumber on the price of it, than it is to do the job right. So there are a

lot of costs that nobody wants to talk about, which are going to raise that number of percentage of households over the 2 percent guidelines of DEM. I want to get -- and we will be negotiating with DEM and EPA. And I want us to push those issues as hard as we can. So that at the end of the day, we're going to be beyond criticism when the homeowners point out, look, I'm paying a lot more than 2 percent.

And they're going to be a lot of those people doing that. So that's a point that

I wanted to make. The other point that I wanted to make is, we talk about green infrastructure as being part of option 2, and that's great. But I think we talk about green infrastructure being looked at well down the stream of this construction project.

I think we ought to be starting to talk more and push more on green infrastructure right from the beginning. But that's a relatively unimportant details. But with those reservations, I will vote in favor of this because I think it's an excellent move on our part. Thank you.

CHAIRMAN MESOLELLA: Commissioner

Nathan, you have a comment?

COMMISSIONER NATHAN: The problem with pushing back expenses is the project doesn't get started until build a tunnel to begin with and that is the major piece of expenditure, so no matter how you do this, that comes first, you can't prolong the cost of that. The other thing is, I agree with Dr. Burroughs, I am going to vote for this, as well, but I think your argument should be in an addendum to what we send to DEM and EPA. Because I don't think you're wrong. These couple of days cost a fortune.

CHAIRMAN MESOLELLA: So Commissioner Milas.

COMMISSIONER MILAS: Yes, I agree with everything everyone has said. I will vote for it, but with great reluctance for all of the reasons stated. And I hope that that reluctance will be communicated strongly to both DEM and EPA that we know we have to comply, but we're not happy with the compliance.

CHAIRMAN MESOLELLA: Okay. Anyone else? Commissioner Burroughs.

COMMISSIONER BURROUGHS: Following

up on Commissioner Nathan's thought, what is the procedure, should this plan go forward, in terms of when it would be reviewed again?

CHAIRMAN MESOLELLA: Commissioner Burroughs, I know that Commissioner Carlino addressed that at the subcommittee meeting, but you want to address that?

COMMISSIONER CARLINO: So according to the presentation last night during the workshop, hopefully we will approve the alternative today, then there's going to be a reevaluation report that's going to be due in June according to the schedule. We submit to Rhode Island DEM/EPA in July of 2015. They will review. It looks like we said from July to November. And then we'll negotiate revisions to the Consent Agreement and schedule. That's going to occur in November/December time frame 2015. And then in January of 2016, we will sign the revised Consent Agreement. That's the schedule.

COMMISSIONER BURROUGHS: So what we end up signing in January of 2016, then locks us in for what time period before we review the consent agreement?

MR. MARSHALL: Five years.

COMMISSIONER BURROUGHS: So we would either have to resolve the issues that he raised before January, or the next time we could do that would be five years after January of 2016.

MR. MARSHALL: We can certainly have the conversation with them as soon as we submit the report to them, that expresses the concern, you know, that the board members have voiced, and to let them know that we want to try to sit down and work something out that is reasonable and affordable that is some type of a, who knows, it could end up being a variation of phases.

And then five years from now, when we do the reaffirmation, they call it, then we'll have another opportunity to reevaluate again, because that's what you need to do, is look at what your game plan is five years out, then you continue to look at the rest of the plate that you have in place if you want to make modifications. That's when you can formally do it, but hopefully we can get some understanding in these initial negotiations over the next six

or seven months.

COMMISSIONER BURROUGHS: So I guess my bottom-line question which I'm afraid of the answer too is under Alternative 2, does the tunnel machine go into the ground before or after that five-year review period?

MR. MARSHALL: I think according to the schedule that we laid out for you, the plans and specs would be completed and approved. And it's, I would say, cuts it close as to whether or not we actually begin construction or award a bid prior to that reaffirmation. It runs that close.

Now, remember, we only allocated six-months review. I think it's six months DEM reviewed at a couple of different points. So sometimes it takes a little longer, and once in a while it is shorter. So it's going to be right on the edge.

CHAIRMAN MESOLELLA: Commissioner Handy.

COMMISSIONER HANDY: Yeah, I will vote for Option 2. I did in the Committee meeting and I will again as well, reservations as well. And the only thing I would add is, I

think it's important to note to EPA and the DEM that we have other priorities. I assume that the agency has other priorities. This is a huge investment. It probably will impact our capacity to deliver on other priorities in terms of spending.

And I think we just need to be clear. The impact of those, that decision on the ratepayers and also on our capacity to address things like operating cost in the capacity to operate well. So I think they need to look at this decision not in a vacuum, but in association with all of our spending priorities.

CHAIRMAN MESOLELLA: Okay. Commissioner Nathan.

COMMISSIONER NATHAN: I know this baseball field gets a lot of press. We are talking about a project that is at least ten times more expensive. If we don't watch the PR for ourselves related to this, we're going to end up in trouble.

So it is -- we have to make sure that we control what we say and what we do to the public, because some people know about it, but not everybody knows about it. It's never in

the papers, and it's ten times bigger than the ballpark. So I think we have to watch and control this. So that we don't end up looking like a bunch of anti the people, something.

CHAIRMAN MESOLELLA: Yes. And you know, that is a good point, Commissioner. And I would just simply say that the decisions that we make, and I'm not talking solely about this decision, but I think everyone will agree that when we are confronted with major decisions we go through a very protracted process.

This process alone, this process to which we conclude, hopefully we'll conclude today. I shouldn't say conclude, in other words, it's not going to be concluded, but at least we're moving forward with -- begin today. We're going to begin to conclude. This is the beginning of the conclusion.

We went through a process, and the Stakeholder process which was very public, a very public process. All the individuals, all the agencies, all of the environmental groups and anyone else who felt that they had a stake and the decisions that this Board's going to make today, had an opportunity to come forward

and speak.

It was a very public, very public process. And then what was concluded that perhaps we're confronted with these options, which, of course any time you are spending public money is difficult decisions to make. But sometimes we have to make difficult decisions, and we have to make the decisions that are in the best interest of the environment, the economy, and in the best interest of the society at-large. And I think we're being very prudent here today.

The option that we're selecting gives us the opportunity to revisit it, as we submit to the various agencies, and the Board will have an opportunity to deliberate at some point on it again. Commissioner Lemont.

COMMISSIONER LEMONT: Mr. Chairman, we've had discussion on this for months. I move the question.

CHAIRMAN MESOLELLA: Thank you. Is there a motion to move the question? And according to Robert's Rules, once a question has been moved and seconded and passed. Counselor, is it five minutes, seven minute-discussion?

MR. DEANGELIS: Probably 10 minutes.

CHAIRMAN MESOLELLA: The General Assembly, it is 10 minutes. I don't know if there's any other comments, but we do have a formal motion to move the question and seconded the motion by Commissioner MacQueen, Commissioner Farnum. All in favor of seconding the motion will say aye. Anybody opposed? There are none opposed. That question is moved.

(UNANIMOUS)

We are going to debate and discuss this matter, according to Counsel, 10 minutes. That's what the General Assembly does. I don't know if there's any other comments to be made anyway. Does anyone have any comments to make with regard or questions with regard to the motion that's before us? Commissioner Milas.

COMMISSIONER MILAS: Does this work like a regular reg process? Is there a public comment period for this? Does the public have an opportunity to present in front of DEM or ask questions?

MR. MARSHALL: No, there's no public hearing-type process for this. I don't

know if there is any type of review that it undergoes, Tom, do you know?

MR. BRUECKNER: I'm not sure. I don't know if we have to have a hearing or not. I will find that out from DEM.

CHAIRMAN MESOLELLA: Commission Rotella, you had some issues you wanted to --

COMMISSIONER ROTELLA: Yeah. I'm just trying quickly draw some attention to those who were here last night. We have this report that was given to us. And if you look on page 5, then on page 9. Page 5 talks about economic impact analysis of the alternatives. And 9 talks about the economic impact analysis of Alternative 2, specifically.

In no way I'm trying to sugar coat of what we're doing or possibly going to do, but this is a very labor intensive project. And it will create a bunch of jobs, a lot of jobs. Alternative 2 talks about over 4,000 jobs, and also -- and quite a bit of tax -- additional state and tax dollars. And my question is, is there any way that we can -- I know the state is in fiscal trouble today, but who knows, this project is going to go for a long time,

recapture or going back, as they like to say, some of the additional tax money that would be generated back to the commission to help pay for part of this project, and again, reduce the cost to the ratepayers.

CHAIRMAN MESOLELLA: Yeah. And so

pursuant to that question, I thought I reported to the Board that I've already had a meeting with the governor's office, and I met with the speaker of the house, and I think on Friday I'm meeting with the senate president. And I have already indicated to them that this project is an enormous economic generator for the State of Rhode Island.

It's going to be generating significant income tax dollars, and that I thought that we should have a very meaningful discussion about getting some appropriation in the state budget, specifically, to support the ratepayers who are going to shoulder the burden for this particular project.

I pointed out that some of the poorer communities in our service area are footing the bill for the improvements which are more recognized downstream we're they're not

participating in the cost at all. Unfortunately, it was not an argument that was lost on the governor or the speaker. And I'm certain it will not be lost on the senate president.

So while I didn't get any

commitments and I know this is a very difficult fiscal year for the state, it seems to me that once this project is actually in motion and actually generating income tax dollars, that that discussion can get much more serious. So I hope that answers your question. Further discussion on the matter? Further discussion? Comments? Okay.

As such, you've heard the motion. It has been seconded. There is no further comment or discussion. All those that are in favor of passage of Resolution 2015:09-2 will say aye. Are there any opposed? Let the record reflect that Commissioner Burroughs has cast a vote in opposition to approval. Okay. Moving right along.

Next committee reporting. Thank you, very much. Next committee reporting is the CEO Committee. Commisioner Macqueen, do you

have a report for us today?

COMMISSIONER MACQUEEN: I have one, Mr. Chairman. Review and Approval of Resolution 2015:10; Award of Contract 304.59C Improvements to the Interceptor Fiscal Year 2015

Recommendation for Award.

MR. MARSHALL: Yes. This is a contract that we do on an annual basis. We make improvements to our interceptor system based upon the cleaning and inspection contracts that are entered into. And this year we had three bidders for the contract. The lowest responsive and responsible builder is Insituform Technologies at $811,289.

The contract involves cleaning, televising and lining of approximately 4,600 feet of interceptors ranging from 8 inch to 56 inch rehabilitating 213 vertical feet of manhole. Replacement of 30 feet of interceptor and modifications to two existing regulators. This is a company that's known to us. They've done work for us before.

They do a very good job. There will be some ancillary cost including police details, soil and material testing, as well as

staff time associated with the inspection and administration.

So we request your approval of Resolution 2015:10 to Award a Contract to Insituform Technologies for an amount not to exceed $811,289 that is subject to the approval of the Contractor's MBE/WBE plan and EEO requirements by the Rhode Island Department of Administration.

CHAIRMAN MESOLELLA: Okay, Commissioner MacQueen moves passage of Resolution 2015:10, seconded by Commissioner Montanari. Further discussion on Resolution 2015:10? Hearing none. All of those that are in favor will say aye? Are there any opposed? There are none opposed, and that motion carries. Further report?

COMMISSIONER MACQUEEN: That's all I have, Mr. Chairman.

CHAIRMAN MESOLELLA: No further report. Moving forward. Finance Committee. Commissioner Andrade, do you have a report for us today?

COMMISSIONER ANDRADE: Yes, I do, Mr. Chairman. The Committee approved Resolution

2015:11, Authorization to Enter into a Contract for Pension Auditing Services for fiscal years 2014, 2015 and 2016. I move approval of that resolution.

CHAIRMAN MESOLELLA: Thank you. I have a motion to approve Resolution 2015:11 which is Authorization to Enter into a Contract for Pension Auditing Services. Hagan Sahady?

MR. MARSHALL: Hagan Sahady.

CHAIRMAN MESOLELLA: Hagan Sahady. All right. Do we have a second? Second from Commissioner Kimball and Commissioner Lemont. Discussion on the matter? Hearing none. All of those that are in favor will say aye. Are there any opposed? There are none opposed and that motion carries.

(UNANIMOUS)

CHAIRMAN MESOLELLA: Commissioner Campbell?

COMMISSIONER CAMPBELL: No meeting.

CHAIRMAN MESOLELLA: No meeting on Personnel. Rules & Regs. We heard from Rules & Regs today. Ad Hoc Committee, no report. Executive Committee did not meet. There is no report. Compensation Committee. Commissioner

Kimball.

COMMISSIONER KIMBALL: Mr. Chairman, I'd like to recommend that the Board enter into Executive Session pursuant to Section

42-46-5A1 to discuss the job performance of employee who has been notified in advance of this meeting in accordance with the statute.

Okay. We have a motion to go into Executive Session from Commissioner Kimball, seconded by Commissioner Rotella. All in favor of moving into Executive Session will say aye. Any opposed? There are none opposed, and the motion carries.

And I apologize ladies and gentlemen, but you're going to have to vacate the premises for about 10 minutes or 15 minutes. So I would just ask our guests, including our stenographer, to take vacate the premises.

(OFF THE RECORD)

(EXECUTIVE SESSION AT 12:20 P.M.)

(EXECUTIVE SESSION CONCLUDED AT 12:55 P.M.)

CHAIRMAN MESOLELLA: All right. Thank you, ladies and gentlemen for your patience. We're back into open session. We are now at the Compensation Committee Report.

Commissioner Kimball, do you care to proceed further with your report?

COMMISSIONER KIMBALL: Mr.

Chairman, now that we're back into open session, I'd like to recommend that the minutes for the closed session will be sealed, and we'll have a motion to seal them.

COMMISSIONER ROTELLA: I'll move.

COMMISSIONER KIMBALL: Do I have a second?

COMMISSIONER DICHIRO: Second.

COMMISSIONER KIMBALL: All those in favor? Any opposed? The motion carries.

(UNANIMOUS)

Mr. Chairman, I'd like to move to approve Resolution 2015:06 Approval of the Final Report, Results & Recommendations by Employers Association of the Northeast Regarding their Market Analysis for Positioning of Executive Director & Senior Management.

CHAIRMAN MESOLELLA: I have a motion to approve Resolution 2015:06 Approval of the Final Report, Results & Recommendations by Employers Association. We have a second, Commissioner Milas, Commissioner Montanari,

Commissioner Leone, Commissioner Carlino, Commissioner Andrade and Commissioner Farnum. Further discussion? Hearing none. All of those in favor will say aye. Are there any opposed? There are none opposed and the motion carries. Further report. Commissioner Kimball.

COMMISSIONER KIMBALL: Mr. Chairman, I'd like to move approval of Resolution 2015:07, the Approval of Salary Ranges for the Executive Director and Senior Management as recommended by the Employers Association of the Northeast.

CHAIRMAN MESOLELLA: Okay. We have a motion to approve Resolution 2015:07 for Executive Director and Senior Management. Second. Second by Commissioner Montanari, Leone and MacQueen. Discussion on the resolution? Hearing none. All of those that are in favor will say aye. Are there any opposed? There are none opposed, and that motion carries. Commissioner Kimball.

COMMISSIONER KIMBALL: Mr. Chairman, I'd like to move approval of Resolution 2015:08, the Approval of the Executive Director's Employment Contract.

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CHAIRMAN MESOLELLA: We have a motion approved. Resolution 2015:08, seconded by Commissioner Lemont, Commissioner Leone, Commissioner MacQueen. Actually, it's everybody. The entire Board of directors seconds that motion. Discussion on the matter? Hearing none. All of those that are in favor will say aye. Are there any opposed? There are none opposed, and that motion carries.

(UNANIMOUS)

CHAIRMAN MESOLELLA: Further report. Commission Kimball.

COMMISSIONER KIMBALL: Mr. Chairman, we have no other business to come before the Compensation Committee.

CHAIRMAN MESOLELLA: Excellent. Okay, moving right along. Where's Joanne. Joanne, do you have a report today?

MS. MACERONI: Mr. Chairman, you all have a copy of my report. As you'll see, I added ten bills since the March report. They range in topics from condemnation to open meetings. And you will also see there were three bills where we are proposing some technical amendments. We're not proposing to

change the intent of the legislation. We're trying to make it clearer. I'd be happy to go through each one. I know it's a late hour, so if you'd like me to do that, if not --

CHAIRMAN MESOLELLA: I don't think that's necessary, Joanne. We've got the eggplant parm waiting. All right. Okay. Anyone have any questions for Joanne? I don't think so. All right. Thank you, very much. Moving right along. New business. Any new business to come before the commission today? New business. None to speak of. Other business of any kind, old business, new business, other business? None?

COMMISSIONER ROTELLA: Move adjournment.

CHAIRMAN MESOLELLA: We have a motion to adjourn, seconded by, I think the entire Board today. I think so. Thank you, very much. All in favor of adjournment will say aye. Any opposed? None opposed. We are adjourned. And once again, I'd like to thank all of you for your vote of confidence selecting me Chairman again. Thank you.

MR. MARSHALL: And I'd like to

thank all of you for your vote of confidence.

(APPLAUSE)

(HEARING CONCLUDED AT 1:00 P.M.)

C-E-R-T-I-F-I-C-A-T-E

I, PAULA J. CAMPAGNA, CSR, a Notary Public, do hereby certify that the foregoing is a true, accurate, and complete transcript of my notes taken at the above-entitled hearing.

IN WITNESS WHEREOF, I hereunto set my hand this 18th day of May, 2015.

____

PAULA J. CAMPAGNA, CSR, NOTARY PUBLIC/CERTIFIED COURT REPORTER

MY COMMISSION EXPIRES: April 25, 2018

IN RE: NBC Monthly Board Meeting

DATE: April 28, 2015