Capital Project No. WP-169
Long Term Control Plan II

Combined Sewer Overflow Long Term Control Plan for Jamaica Bay and Tributaries

Appendix G: Supplemental Documentation

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Department of Environmental Protection
Agency of the Chief Engineer

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APPENDIX G
CONTENTS

Responses to DEC Comment Letter Dated December 21, 2018

Major Comments:

1. **DEC Comment: Ribbed Mussels.** Under the selected alternative, the City has proposed construction of ribbed mussel beds in both Bergen and Thurston Basins to reduce bacterial load from CSOs and storm water discharges to these waterbodies. Ribbed mussels have not been considered under any other LTCP and represent a novel yet unproven technology. The ribbed mussel beds are the primary component of the selected alternative that will be used to reduce bacterial loads to both Basins (the other components have no or negligible impact on water quality) and the analysis presented in Appendix D assumes that the ribbed mussels will remove 10 percent of the bacterial load in the waterbodies. Based on that assumption, attainment levels in the Basins for the fecal coliform water quality standard will improve by up to 5 percent on an annual and recreational season basis.

   At present, the Department is reluctant to accept the City's analysis of the ribbed mussel performance. The information provided in Appendix D of the LTCP does not support the 10 percent removal efficiency assumption and a review of existing research on ribbed mussels by the Department did not reveal a solid basis for assuming a 10 percent removal efficiency either. Overall, the existing research indicates that ribbed mussels are capable of filtering particles from water columns, including plankton, organic matter, and bacteria. However, specific research on the use of ribbed mussels to remove fecal coliform in-situ is very limited. Moreover, the research conditions differed notably from what will be experienced in Bergen and Thurston Basins, which will be year-round, submerged deployment of very dense mussel beds in ambient waters with intermittent high volume flows of CSOs and stormwater.

   Overall, the very limited available bench-top arid small scale field-level research on the use of mussels for fecal coliform removal is insufficient to make a leap to full-scale engineering application with significant assumptions on bacterial removal and improvements in water quality. As such, implementation of the ribbed mussel project needs to include further assessment steps leading from planning and bench scale studies to a large-scale field study prior to proceeding to a full scale engineered application. The Department offers the following conceptual outline for an overall research and planning process to include ribbed mussels in the proposed alternative that provide a solid basis for full scale application and water quality benefits:

   Research and Planning Process

   - First, the City must develop a method or system for reliably culturing a large number of mussels for the mussel beds. The City has estimated it will need about 50 million mussels for the mussel beds but the LTCP does not provide any information on where the mussels will be obtained. According to the Department's Marine Resources experts, the mussels cannot be taken from adjacent marshes as they are integral to the marshes function and help to hold marsh peat in place. Although some research has been undertaken on culturing ribbed mussels, the state of that science is not sufficient to produce the quantity of mussels needed for the City's full-scale project. As the City is probably aware, one of the findings from the small-scale study by Galimany, et al. (2017)[1] that examined the use of mussels for bioextraction in the Bronx River

[1] Eve Galimany, Gary H. Wikfors, Mark S. Dixon, Carter R. Newell, Shannon L. Meseck, Dawn Henning, Yaqin Li, and Julie M. Rose (2017). Cultivation of the Ribbed Mussel (Geukensia demissa) for Nutrient Bioextraction in an Urban Estuary. *Environmental Science & Technology*, 51, 13311-13318.

estuary was that "[s]pat collection efforts from shore and within the water column were unsuccessful; this was identified as a key bottleneck to future large-scale implementation." Thus, a first key step is developing a reliable method for culturing the mussels.

- Once the City has established a method for culturing the mussels, it must undertake studies to confirm that the mussels are capable of removing fecal coliform via lab bench-top studies, including cytometry filtration and aquaculture studies. This phase should also include experiments to determine actual removal efficiencies for the mussels under conditions likely to be experienced in the field. Building on these bench-top tests, the City will then need to undertake mesocosm-level experiments to simulate field conditions.

- Following bench-top and mesocosm-level experiments, the City must undertake an in-situ pilot study (in accordance with all applicable laws and regulations). The in-situ study should be used to identify the key design factors that influence the performance of the mussel beds in filtering the targeted bacteria, including location within the waterbody, design of the placement of the mussels, mussel size and filtering capacity, waterbody retention times, existing water quality and particulate size, types of bacteria encountered, and mussel survivability and die off over time. The results from the various experiments and studies should be used to further develop appropriate models to represent the mussels and these models should be peer reviewed.

- Finally, based on in-situ study results, the City will need to consider measures to be taken to minimize bird attraction. The City eliminated from consideration tidal wetland/marsh restoration near the airport due to potential hazards from birds with aircraft. A subtidal deployment of ribbed mussels would presumably avoid bird attraction but would need to remain submerged even at low tide. Any infrastructure (rafts, racks, etc.) used to maintain the mussels sub-tidally must also be subtidal.

If the mussel bed will be intertidal, it would be exposed and needs to be outfitted with effective bird deterrents as birds are known to aggregate in large numbers to floating gear used for shellfish farming, or to any other structure that offers a perch in a marsh or estuary. Birds also result in additional fecal coliform loads, so their presence needs to be minimized for that reason as well.

In sum, for the ribbed mussel component of the selected alternative, the City needs to include a plan to undertake a series of experiments and studies that will gradually build upon each other and establish a solid basis for the design of a full-scale engineered application of ribbed mussels for improving water quality in Bergen and Thurston Basins. This plan should outline the major phases of research and study, including timeframes and milestones, and culminating in the submittal of an approvable engineering report. The approvable engineering report shall include any recommendations for full-scale application and updated projections on water quality impacts.

Until the City presents and commits to complete a more comprehensive process for con- firming the performance of the mussels as outlined above, including submission of an engineering report for the full-scale application, the Department cannot approve a full-scale engineered application of the ribbed mussels as a primary component of the LTCP. The Department is not opposed to the use of ribbed mussels for reducing bacterial load in the Basins, but feels it would be premature to approve construction of the mussel beds without first validating their performance, including their ability to filter high volumes of CSO, with peak flows as high as 555 MGD in Bergen Basin, within short periods of time. Based on the foregoing, the City must provide a more detailed description and schedule in the LTCP for conducting a planning and research process as outlined above to validate the performance of mussel beds, rather than proceeding to full-scale implementation. The process must include the submittal of an approvable engineering report documenting the basis for the design of the full-scale application along with projected water quality improvements. For assessment purposes under the LTCP analysis, a zero percent removal efficiency should be assumed for the ribbed mussels until the planning and research process is completed. Lastly, to better understand the assumptions made in the Appendix D analysis, the City must provide a copy of the engineering analysis completed to size the ribbed mussel beds presented in Figures 8-10 and 8-17.

DEP Response: *DEP acknowledges the complexities of installing and cultivating ribbed mussel colonies within Bergen Basin and Thurston Basin at such a large scale; challenges to restoring marsh islands within Jamaica Bay were also encountered but were ultimately resolved. Appendix D of the LTCP has been updated to address the comments provided by DEC and outlines the strategy and collaborative research efforts proposed by DEP to achieve the 10% reduction in bacterial concentrations in Bergen and Thurston basins through ribbed mussel deployment as targeted in the Jamaica Bay and Tributaries LTCP. The discussion focuses specifically on:*

- *Completed literature review to showcase impressive filtration capabilities*
- *Completed initial bench scale experiments to confirm literature review*
- *Proposed lab and in-situ experiments of increasing complexity, simulating the conditions of Bergen and Thurston Basins, to inform the design of full-scale engineering application*
- *Timeframes and milestones for completing proposed experiments, culminating in the submittal of an approvable engineering report*
- *Studied cultivation techniques and secured partnerships with multiple hatcheries for spawning large mussel populations*

In summation, DEP has committed to a significant effort to showcase the immense filtration capacity of ribbed mussel populations and is confident in the applicability of the proposed full-scale engineering application in conservatively reducing bacterial concentrations by 10% in Bergen Basin and Thurston Basin. DEP looks forward to frequent communication as outlined in the updated "Appendix D: Modeling Approach for Estimating the Pathogen Bioextraction in Jamaica Bay and Tributaries" to share additional information documenting the bacterial extraction capabilities of ribbed mussels and to provide periodic updates and receive feedback throughout the course of the planning, design and implementation of the Recommended Plan.

2. **DEC Comment**: **Southeast Queens (SEQ) Storm Sewer Buildout and High Level Sewer Separation (HLSS) in Springfield/Laurelton.** The SEQ storm sewer buildout and HLSS in Springfield and Laurelton have been long-standing projects planned by the City to alleviate flooding and sewer backups in this area of Queens as well as to reduce CSOs to Thurston Basin. The City has discussed the storm sewer buildout and HLSS in past planning documents but has never committed to complete the projects within the context of the CSO Order due to uncertainty of project funding and the long timeframe for implementation. However, the City has recently

allocated $1.9 billion to implement a portion of the storm sewer buildout over the next 10 years. While this funding may not result in the complete buildout of the storm sewers, it should allow for measurable progress on this project.

Given that the City has received substantial funding to complete a significant portion of the storm sewer buildout project within an intermediate timeframe of 10 years and that buildout will reduce CSOs, it seems reasonable that the City could include the pending construction as part of the selected alternative. The City has publicly stated on several occasions that the "bulk of the funding will go towards the construction of large trunk sewer spines along 150th" Street, Guy Brewer Boulevard, Farmers Boulevard, and Springfield Boulevard." These trunk lines are major components of the buildout that can readily be incorporated into the LTCP.

Moreover, future phases of the project, which may occur after 10 years, are well within the timeframe for this LTCP. Other LTCPs have included large tunnel projects that will take up to 25 years to complete, which is a comparable timeframe for the SEQ storm sewer buildout and HLSS in Springfield/Laurelton projects. As such, the City must consider including some or all of the SEQ storm sewer buildout and HLSS in Springfield/Laurelton projects within the selected alternative. The milestones can be structured to accommodate the uncertainty associated with future phases of the project, such as by incorporating more specific schedules for construction at future dates once they are known.

To facilitate further discussion on including the storm sewer building and HLSS projects as part of the selected alternative, the City must provide detailed information on the work to be undertaken with the $1.9 billion, including scopes of work for construction, maps where the work will be completed, and implementation schedules. Additionally, the City must provide water quality model projections for CSO overflows, storm water discharges, and water quality attainment assuming the full completion of the SEQ storm sewer buildout and HLSS in Springfield and Laurelton projects.

DEP Response: *The October 2011 Jamaica Bay and CSO Tributaries Waterbody Watershed Facilities Plan Report references both High Level Sewer Separation and High Level Storm Sewers. The term High Level Storm Sewers (HLSS) is used in relation to partial sewer separation methods that are limited to the diversion of stormwater sources located within public street and rights-of-way. This technology was retained for consideration on a site specific basis and was believed to be most cost-effective in areas near the shorelines where there is no need to build large diameter and long storm sewers to convey the separated stormwater to the receiving waterbody. The term sewer separation includes the diversion of stormwater sources from private residences or buildings such as rooftops and parking lots. Complete separation is almost impossible to attain in New York City since it requires re-plumbing of apartment, office and commercial buildings where roof drains are often interconnected with the building's interior plumbing. Due to the risks and legal issues associated with a public entity entering, inspecting and performing construction on private properties, DEP has limited the practices of diverting stormwater from the combined sewer system to the application of HLSS.*

The SEQ Storm Sewer Buildout is an extensive long-term drainage program covering approximately 7,000 acres, with a primary goal of relieving flooding issues throughout Southeast Queens through the construction of storm sewers. The Springfield/Laurelton HLSS component of *the program as currently envisioned is expected to result in CSO reductions at JAM 005/007. However, as discussed in the updates to Section 8 contained on pages 8-15 through 8-20, not only is this portion of the SEQ work not included in DEP's 10-year capital plan, its primary purpose is not CSO control.*

As requested by DEC, conceptual modeling has been performed for the purposes of simulating the changes in CSO and stormwater volume discharges to Thurston and Bergen Basins upon completion of the SEQ storm sewer buildout. The landside modeling results have been incorporated into the water quality model to assess the potential impacts to water quality attainment. Tables, figures and commentary summarizing the findings of this evaluation have been incorporated into the LTCP text on pages 8-15 through 8-20.

3. **DEC Comment: Additional Options to Improve Water Quality.** The analysis of alternatives included in the LTCP examined a broad range of alternatives and the alternative that was selected appeared to be the most cost-effective and feasible of those considered. The selected alternative, however, is not solely focused on CSO reduction and while it provides important non-water quality benefits, the associated improvements to water quality are minimal and uncertain. Thus, the City must reconsider or evaluate other alternatives that might enhance the water quality of the Bay or tributaries by either further reducing or mitigating CSOs, consistent with the CSO Control Policy, or by reducing other sources of impairment to the waterbodies on a voluntary basis similar to the tidal wetland restoration projects proposed in the LTCP. The following provides examples of some alternatives that should be further considered and the Department encourages the City to identify other options that may not have yet been considered.

   DEP Response: *Section 4 of the LTCP outlines over $1.03 billion in grey CSO infrastructure projects implemented under previous CSO control programs and facility plans, such as the Jamaica Bay Waterbody Watershed Facilities Plan (WWFP). These projects are included in the Baseline Conditions for the Jamaica Bay and Tributaries CSO LTCP and their implementation has resulted in high levels of water quality standards attainment for pathogens and dissolved oxygen in Paerdegat Basin, Spring Creek, Fresh Creek, Hendrix Creek and Shellbank Basin. These investments include over $600 million in BNR upgrades to the WRRFs tributary to Jamaica Bay, $300 million in existing and planned green infrastructure under the baseline conditions, $32 million in ecosystem restoration and research efforts for pathogen reduction and DO improvements and the multi-billion dollar Southeast Queens Sewer Buildout Program.*

   The CSO control alternatives analysis in Section 8 considered each of the CSO control technologies and strategies identified in the CSO Toolbox (Figure 8-4). Although approximately 70 alternatives were presented for control of CSOs throughout Jamaica Bay and its tributaries, the evaluation process considered over 100 alternatives, most of which were focused on Bergen and Thurston Basins. The initial evaluations were initially narrowed down after multiple iterations and consideration of reductions in CSO volume and frequency, impacts to hydraulic grade line, availability of property, constructability and other factors. Appendix A includes presentation slides outlining remaining alternatives just prior to the final cut performed in advance of selecting the alternatives to be presented in Section 8. These presentation slides summarize the recommendations for 40 basin specific controls evaluated specifically for Bergen and Thurston Basins, which were then reduced to the 27 basin specific alternatives for presentation in the LTCP. The analyses outlined in the LTCP further evaluated these alternatives based upon cost-

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performance, constructability, operability and other factors resulting in the seven specific alternatives retained for Bergen and Thurston Basin as outlined in Table 8-20.

The LTCP considered a wide range of grey infrastructure, however, there are many issues identified regarding constructability, maintenance and effectiveness of these alternatives as well as resulting projected water quality improvements. The analyses have shown that improvements in water quality attainment were minimal regardless of the level of CSO control. As indicated by the gap analysis presented in Section 6, water quality attainment for fecal coliform cannot be achieved with 100% CSO Control at the upstream ends of Bergen Basin (77% at BB5) and Thurston Basin (92% at TBH1 and 93% at TBH3). The very small gap (0-5%) in attainment between Baseline Conditions and 100% CSO Control results in a very low cost-benefit ratio for the grey alternatives considered for these waterbodies.

The Recommended Plan, consisting of Additional GI and Environmental Improvements, provides the highest cost-benefit ratio of the alternatives evaluated. In addition to the Triple-Bottom Line Benefits outlined in Table 8-33, the Recommended Plan will further the many ecosystem goals outlined in the City's OneNYC Plan providing additional quality of life and ecological improvements throughout Jamaica Bay and its tributaries.

a. **DEC Comment: HLSS at Fresh Creek.** Fresh Creek continues to receive around 300 million gallons per year of CSO and the head end of the waterbody does not attain the fecal coliform water quality standard on an annual (86 percent) or recreational season (93 percent) basis. The City is currently completing HLSS in the CSO drainage basin that overflows to Fresh Creek, but the 440 or so acres that are currently being separated represent only a portion of the area that is planned for separation. Another approximately 2400 acres is planned for separation. As such, the City must consider undertaking additional HLSS for Fresh Creek, to further improve water quality.

DEP Response: *Figure 7-7 of the October 2011 Jamaica Bay and CSO Tributaries WWFP identifies a total area of 2,395 acres tributary to Fresh Creek which includes the drainage areas proposed for HLSS. The WWFP evaluated variations of HLSS throughout the Fresh Creek drainage area. The preferred alternative was identified based upon a preliminary evaluation of constructability. The WWFP preferred alternative consisted of three phases of HLSS spanning a combined sewer drainage area of 443 acres.*

As DEP advanced design and construction of Phases 1, 2 and 3 of the HLSS, several constructability issues related to conflicts with existing utilities have been encountered and addressed. HLSS utilizes shallow constructed storm sewers to divert catch basins and other inflow sources from the combined sewer system. Due to the shallow construction, there is a high risk of conflict with gas, water, communications and other utilities that are all competing for space within the same road rights-of-way and are generally constructed within five feet of ground surface. To address these conflicts, the conceptual routes have been modified to route the proposed storm sewers around the conflicts identified during design and construction. These modifications reduced the drainage area served by the proposed HLSS to approximately 220 acres; in addition to HLSS full separation has been implemented over approximately 64 acres.

Previous evaluations of additional opportunities to expand HLSS upstream of Fresh Creek beyond Phases 1, 2, and 3 identified the following constructability and maintenance issues:

- *In order to convey additional HLSS flow to Fresh Creek, larger storm sewers would need to be constructed and cross Buckeye Fuel Lines running along Cozine Avenue. The depths of these fuel lines conflict with the elevation of the proposed HLSS, which could force the city to utilize siphons to cross Cozine Avenue. Siphons are not desirable for stormwater conveyance. Due to the intermittent flow patterns which are dependent upon precipitation, storm sewer siphons are susceptible to accumulation of debris, thereby requiring more frequent maintenance to maintain capacity and protect against flooding. Additionally, once the siphon is installed, if constructability issues are identified with later upstream phases of the HLSS work and sufficient head is not provided, the siphons may not function as designed.*

- *The design of the HLSS conveyance system is based on the assumption that streets are built to legal grade. In the area surrounding Fresh Creek, much of the area was not built to legal grade. Therefore, in order to install additional HLSS, streets will need to be raised, in some instances by multiple feet as opposed to inches above existing grade. This is very challenging as it may reduce accessibility of property owners to garages and basements.*

Upon reviewing the landside models in response to this comment, the LTCP modeling team found that the Baseline Conditions Models had some inconsistencies related to the simulation of HLSS and green infrastructure within the 26th Ward WRRF Sewershed. Specifically, these discrepancies were related to drainage area size inconsistencies in the landside modeling for Fresh Creek, Hendrix Creek and Spring Creek. Both HLSS and GI are represented in the model by reducing the runoff area tributary to the combined sewer system, and in the case of HLSS, runoff area is added to the separate storm drain system. It was determined that the runoff area adjustments did not appropriately account for flow reductions associated with both the HLSS and GI. Upon updating the respective subcatchment areas and confirming that the total drainage areas were correct, both prior to and after the addition of HLSS and GI, CSO discharges were found to be reduced for Spring Creek, Hendrix Creek and Fresh Creek. The approximate volume and frequency of CSO and stormwater discharges to Fresh Creek are shown below in Table 1, while Table 2 summarizes the related impacts to model-predicted water quality attainment at Fresh Creek Monitoring Station FC-1. All tables within the LTCP have been updated accordingly as part of the Supplemental Document. Some additional refinements were also made to the landside model to incorporate refinements made to the upland HLSS areas based on constructability issues. These updates to the HLSS have been accounted for in Table 1 below along with updated projected water quality attainment for Fresh Creek Monitoring Station FC-1.

Table 1. Model Predicted CSO Discharge Statistics for Fresh Creek

Landside and Water Quality Modeling Conditions	CSO Statistics (2008 Typical Year)		Stormwater Statistics (2008 Typical Year)	
	Total (MG/yr)	Discharges per year	Total (MG/yr)	Discharges per year
LTCP Baseline Conditions	300	25	522	80
Updated LTCP Baseline Conditions	232	12	528	81

As set forth in the LTCP, DEP evaluated attainment with current New York State water quality standards for fecal coliform in the tributaries to Jamaica Bay, including Fresh Creek. Table 6-7 of the LTCP has been updated to summarize the updated model-calculated fecal coliform attainment for 10-year baseline and 100% CSO control conditions. As indicated in Table 6-7, all monitoring stations in Fresh Creek except for FC1 are projected to be in attainment of the Primary Contact WQ Criteria for fecal coliform greater than 95% of the time under Baseline Conditions, on both an annual and recreational season basis. At station FC-1, located at the upstream end of the tributary, the updated modeling projects fecal coliform attainment to be 85% on an annual basis, and 93% for the recreational season. The gap analysis indicates that 100% CSO control within the Fresh Creek sewershed would result in 90% attainment on an annual basis, and 98% attainment for the recreational season.

Table 2 provides a comparison of the model predicted water quality attainment at Monitoring Station FC-1 for fecal coliform for the updated model and the model results presented in the June 2018 LTCP. The model corrections and subsequent changes in CSO and stormwater discharge result in a net reduction of 1% in the annual attainment for fecal coliform for Baseline Condition and 100% CSO Control.

Table 2. Model Predicted WQ Attainment for Fresh Creek Monitoring Station FC-1

Model Conditions	Baseline Conditions		100% CSO Control	
	Annual WQ Attainment	Rec. Season WQ Attainment	Annual WQ Attainment	Rec. Season WQ Attainment
	% Attainment (GM<200 cfu/100mL)(1)		% Attainment (GM<200 cfu/100mL)(1)	
June 2018 LTCP WQ Modeling	86	93	91	98
Updated LTCP WQ Modeling	85	93	90	98

Note:
(1) Based upon 10-year model runs.

A more detailed look at the impacts to baseline conditions WQ attainment over the 10 year modeling period indicates that there are two months (November 2002 and April 2011) where the *changes cause monthly geometric means to exceed the fecal coliform WQ standard of 200 cfu/100mL and one month (April 2004) where the monthly geomean is reduced and is now in achievement of the WQ standard. Table 3 provides a summary of the changes in the monthly geomeans, and the CSO and stormwater statistics from the June 2018 LTCP Baseline Conditions Model to the Updated Baseline Conditions Model. The monthly geometric means that exceed the WQ Standard of 200 cfu/100mL are shown in red text below.*

Table 3 – Model Predicted Statistics for Months Impacted by Model Updates for Fresh Creek Monitoring Station FC-1

Source	November 2002					
	June 2018 Baseline Conditions			Update Baseline Conditions		
	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)
CSO	0	0	187	0	0	207
Storm	14	240		24	389	

Source	April 2004					
	June 2018 Baseline Conditions			Update Baseline Conditions		
	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)
CSO	36	22	204	26	21	199
Storm	18	179		32	245	

Source	April 2011					
	June 2018 Baseline Conditions			Update Baseline Conditions		
	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)	Volume (MG)	Duration Discharge (hrs)	Monthly GM (cfu / 100mL)
CSO	21	7	196	15	5	204
Storm	15	147		25	256	

The model updates result in the net reduction in model projected fecal coliform WQ attainment of 1% (or 1 month over the 10 year modeling period). The cause of the changes in attainment appear to be as follows:

1) *November 2002: Sizable increases in stormwater volume (71%) and duration (62%) cause the monthly GM to increase from 187 to 207 cfu/100mL.*

2) *April 2004: CSO volume decreases by nearly 40% and appears to be the primary cause of the decrease in the monthly GM from 204 to 199 cfu/100mL.*

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3) April 2011: While CSO volume and duration decrease, the increases in stormwater volume (67%) and duration (74%) appear to be the cause of the increase in the GM from 196 to 204 cfu/ 100mL.

In consideration of the impacts to fecal coliform concentrations from the increased volume and duration of stormwater discharges, the constructability issues encountered to date, and impacts to private property owners, application of additional HLSS within the Fresh Creek watershed will not improve water quality standards attainment, and will not be considered further.

The Executive Summary, Section 6, Section 8 and the UAA have been revised to reflect the updated model-predicted attainment and the constructability issues that have resulted in changes to the areas where HLSS is being implemented within the Fresh Creek watershed.

b. **DEC Comment: Floatables Control at Fresh Creek.** The City's annual floatables monitoring report indicates that floatables may be a problem for this tributary (station J9A). As such, the City must consider undertaking floatables control for Fresh Creek, to further improve water quality and aesthetics.

DEP Response*: Monitoring Station J9A is located at the confluence of Fresh Creek with Jamaica Bay. DEP operates and maintains a netting facility at CSO Outfall 26W-003 (located at the upstream end of Fresh Creek near Monitoring Station FC-1). The 2017 and 2018 CSO BMP Annual Reports indicate that 21 cubic yards (cy) and 3 cy of floatables were captured, respectively, by the existing floatables containment nets in Fresh Creek.*

Floatables downstream of the nets are in part associated with tidal changes in the creek and non-CSO discharges. Floatables have also been observed in the creek in relation to shoreline erosion downstream of the nets. As the existing floatables control facilities are performing effectively, alternative floatables technologies will not be considered. Text has been added to Page 8-77 of Section 8 to address floatables controls for Fresh Creek.

c. **DEC Comment: Disinfection at Thurston Basin.** The City evaluated the construction of a disinfection facility (comprised of chlorination and dechlorination) for CSO Outfalls JAM-005 and JAM-007 that discharge into Thurston Basin, however, this alternative was determined to be infeasible due to siting issues and other technical challenges associated with construction and operation. For this alternative, both the chlorination and dechlorination facilities were sited close to the discharge end of the CSO outfalls. However, the CSO being discharged at these two outfalls overflows at regulators located much further upstream, and there is a large quantity of stormwater discharged downstream of the CSO regulators as well as some tidal influence in the outfalls, which is also subject to chlorination and dechlorination. In order to alleviate some of the challenges associated with siting the disinfection facility at the downstream reach of the CSO outfall and reduce the amount of flow that would be subject to disinfection to only CSO, the City must consider siting the disinfection facility further upstream and utilize the length of the outfall for contact time and consumption of the chlorine through mixing with the stormwater and tidal water. To facilitate further discussion on this alternative, the City must provide a to-scale schematic illustrating the location of the stormwater discharges into the Thurston Basin CSO outfalls vis a vis location of the CSO regulators and outfall discharges and a preliminary analysis of the feasibility of this disinfection configuration.

DEP Response: *Disinfection of CSO Outfalls JAM-005 and JAM-007 was evaluated in Section 8 of the LTCP with further details provided in a technical memo in Appendix E. To address the above concerns, additional text was incorporated into Section 8 (Pages 8-56 through 8-60). The text further emphasizes the concerns with successful operation of this CSO control alternative and addresses the request to evaluate application of disinfectant at points closer to Regulators JA-06 and JA-07, as well as a new regulator to be constructed at 147 Avenue and 229th Street under the SEQ Storm Sewer Buildout Program. While moving the disinfection application point upstream increases available contact time, it further complicates system operation as a result of the additional storm sewers and stream flows that connect to the multiple barrel sewers between the points for application of chlorination and dechlorination chemicals.*

In consideration of the highly variable operating conditions, complexity in flow and dosing controls in multiple barrels, access concerns with portion of the outfall pipe and flow control structures needing to be located on Port Authority property; it was determined that successful implementation of an outfall disinfection system for Thurston Basin would be extremely complicated and pose a high risk of failing to consistently achieve permit limits. As a result, outfall disinfection is not considered to be feasible for Thurston Basin.

d. **DEC Comment: In-Line Storage.** The City evaluated in-line storage to reduce CSOs to Bergen and Thurston Basins, but eliminated this alternative for various technical reasons. However, for Thurston Basin, the City must consider installation of tide gates to reduce the tidal influence for these outfalls for the in-line storage option.

DEP Response: *To create and maximize in-line storage within the outfall over the range of tides, mechanically operated gates and controls would be necessary, rather than the traditional hinged tide gates used at most of the City's CSO outfalls. Considering the past history of malfunctions to similar equipment at the Spring Creek AWWTP and the high risk of flooding throughout SEQ, DEP will not consider CSO control alternatives that would require automated electro-mechanical systems to store or control flow within a sewer or tank. Maintaining existing drainage to this community is a high priority for DEP as evidenced by the SEQ Storm Sewer Buildout Program.*

Additional text has been provided on pages 8-53 through 8-55 of Section 8 to further address this comment and associated concerns. A summary and illustration of Alternative T-10 In-line Storage of CSO and Stormwater Within Outfall JAM-005/007 are also provided.

e. **DEC Comment - Floatables Control.** The City evaluated floatables control at the largest outfalls that only have floatables booms, in particular JAM-003A, JAM-005, JAM-007, and 26W-003, and indicated that the alternatives were abandoned due to adverse impacts to hydraulic grade line in upstream sewers. However, the only floatables control technology considered was underflow baffles. Netting facilities downstream of the regulator should not have any impact on the HGL, so the City may want to consider that technology as well. Additionally, for floatables control at Fresh Creek and Hendrix Creek, the LTCP states the alternative was abandoned due to no CSO benefits. While floatables control does not reduce CSO volumes, it does mitigate floatables from CSO and improve attainment with the water quality standard for floatables, so it should not be eliminated because it does not reduce CSO volume. As such, the City must reconsider underflow baffles for floatables control at the largest outfalls where it does not impact the HGL.

***DEP Response**: Floatables control facilities are operated in each of the Jamaica Bay tributaries that receive CSO discharges, as follows:*

- *Floatables containment booms are located downstream of the CSO outfalls in Thurston Basin for JAM-005/007, Bergen Basin for JAM-003/003A and JAM-006, and Hendrix Creek for 26W-004. Skimmer boats are utilized to retrieve the floatables captured by the booms. In addition to floatables from CSOs, the booms in Thurston and Bergen Basins are sited such that floatables are also captured from storm sewers, and the vast majority of wet weather flow being discharged into Bergen and Thurston Basin is stormwater. The Thurston Basin boom also provides floatables capture for two unnamed streams conveying runoff from areas surrounding Springfield Park and Idlewild Park. In addition, the Port Authority maintains a containment upstream of DEP's boom which is believed to have resulted in a reduction in the capture recorded at the DEP boom. Replacing the booms with netting facilities or underflow baffles would eliminate these ancillary water quality benefits.*

- *A netting facility is operated at CSO 26W-003 for capture of floatables at this CSO outfall, which discharges to Fresh Creek.*

- *Floatables are currently captured in the CSO Retention Facilities at the head ends of Spring Creek and Paerdegat Basin.*

- *DEP has also replaced or modified catch basins to include hoods and sumps for capture of floatables. These collection system upgrades, in addition to the increased frequency of catch basin cleaning and street sweeping has significantly reduced the volume of floatables that are captured at the containment booms. DEP is conducting a study to quantify floatables under its MS4 program.*

Each of the above floatables control technologies is identified as an accepted practice in the USEPA Guidance for NMCs and Floatables Control Technology Fact Sheet. The fact sheet specifically references boom and skimming operations in Jamaica Bay, as well as catch basin modifications throughout New York City. To be responsive to DEC's comment, DEP has further investigated alternatives for providing end-of-pipe nets in Thurston Basin at JAM005/007, Bergen Basin at JAM003/003A, and Hendrix Creek at 26W-004. LTCP Section 8 text has been updated on the following pages for each tributary:

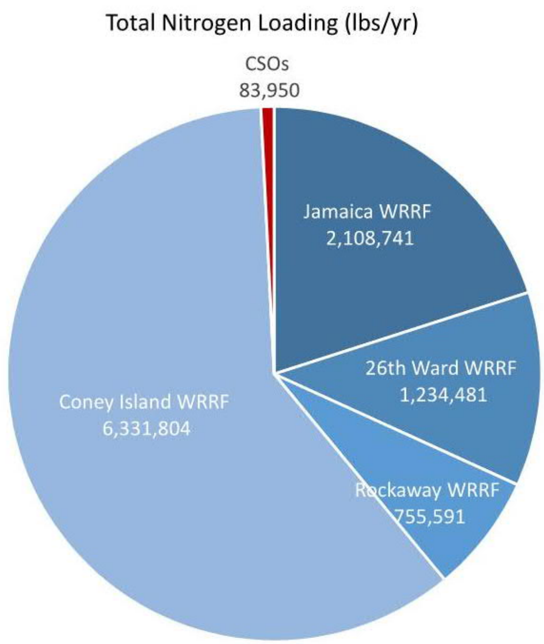
Bergen Basin: 8-34 to 8-36;
Thurston Basin: 8-50 to 8-52;
Spring Creek: 8-66;
Hendrix Creek: 8-69 to 8-70;
Fresh Creek: 8-77; and
Paerdegat Basin: 8-81.

Considering the well documented effectiveness of the current BMP programs for floatables capture, DEP believes that the existing approach to floatables control in the tributaries to Jamaica Bay meets the intent of the BMP requirements for floatables control, and that additional investment in alternative floatables control technologies would not provide substantial improvements in floatables capture.

f. **DEC Comment - Nitrogen Reduction.** In the 2006 Jamaica Bay Comprehensive Plan, the City evaluated the nitrogen contributions from CSO to the Bay and their impacts on water quality, in particular dissolved oxygen. At that time, the CSOs did not have a significant impact in comparison to the wastewater treatment plants. However, the nitrogen loads from the treatment plants has been reduced under the Biological Nutrient Removal program, and it seems reasonable for the City to reevaluate the CSO nitrogen contributions under the LTCP to determine if they have a more measurable impact on dissolved oxygen in the Bay. In conjunction with this evaluation, the City might also consider other projects that further reduce nutrient load to the Bay, not directly related to CSOs. The City has completed numerous upgrades to the wastewater treatment plants to reduce nitrogen loading to Jamaica Bay, however, the level of chlorophyll-a has remained relatively unchanged over time in the water- body (based on post-construction monitoring data). Thus, the City must examine alternatives that might further reduce nutrient loading to the Bay, either from CSOs or from the treatment plants, such as reducing the transshipment of sludge to 26^{th} Ward wastewater treatment plant.

DEP Response: *Table 4 provides a summary of model-predicted fecal coliform, Enterococcus, and Biochemical Oxygen Demand (BOD) discharged to Jamaica Bay and its tributaries from WRRFs and CSO Outfalls under Baseline Conditions for the 2008 typical year. Total Nitrogen (TN) loads for the WRRFs and CSO Outfalls are provided for 2017 DMR and CSO TN Reporting. The table illustrates that fecal coliform and Enterococcus loads are predominantly from CSOs making pathogens the primary focus of the CSO LTCP, while BOD and TN are primarily associated with WRRF effluent discharges.*

In addition, TN loading is consistent with the findings of other LTCPs which indicate that CSOs typically contribute negligible nutrient loads to receiving waters. The annual system-wide nutrient load for CSOs is typically comparable to the daily load from the WRRFs. The adjacent figure below illustrates that the model-predicted load from all Jamaica Bay and Tributaries CSOs is significantly less than the annual TN contribution from each of the four WRRFs.



Considering the extremely small TN loads contributed by CSOs to Jamaica Bay and its tributaries, it is not cost-effective to address TN related water quality issues through CSO control. Reduction of TN loads related to non-CSO sources is outside the scope of this LTCP and continues to be addressed through the nitrogen management program and the SPDES Permit for each WRRF.

Table 4. Loads for Baseline Conditions

Parameter	Jamaica(1)	26th Ward(1)	Rockaway(2)	Coney Island(2)	CSOs
Fecal Coliform ($x10^{12}$ cfu/100mL) (3)	43	31	13	26	68,250
Enterococcus ($x10^{12}$ cfu/100mL) (3)	22	15	6	4	37,430
BOD (lbs/yr) (3)	1,816,374	951,515	332,734	2,800,572	425,593
TN (lbs/day) (4)	5,777	3,382	2,070	17,347	230
TN (lbs/yr) (4)	2,108,741	1,234,481	755,591	6,331,804	83,950

Notes:
(1) BNR upgrades with carbon addition are fully operational.
(2) BNR upgrades are under construction.
(3) Based on LTCP model predicted loads for typical 2008 rainfall year.
(4) Based on 2017 DMR data and 2017 CSO TN report.

4. **DEC Comment: Green Infrastructure.** According to the LTCP, the City's baseline commitment for green infrastructure for Jamaica Bay and its tributaries was to manage 1-inch of storm water runoff from 877 acres, which will reduce CSOs to these waterbodies by about 202 MGY for an average rainfall year (note: see additional comment below on the baseline green infrastructure commitment). The selected alternative includes additional green infrastructure beyond the baseline commitment in both CSO and separately sewer areas that drain to Bergen and Thurston Basins. Specifically, the City will manage 1-inch of storm water runoff from 147 acres in the Thurston Basin drainage area, which will reduce CSO by 6 MGY and storm water by 22 MGY to this waterbody, as well as manage 1-inch of storm water runoff from 232 acres in the Bergen Basin drainage area, which will reduce CSO by 9 MGY and storm water by 211 MGY to this waterbody.

   The LTCP does not provide detailed information on how these CSO and storm water reductions were calculated or their estimated cost. At first glance, based on capture ratios alone, it does not appear that the additional green infrastructure is cost-effective, because there is very little CSO reduction achieved despite the sizable amount of green infrastructure proposed for both basins. For the baseline green infrastructure commitment, the ratio of CSO reduction per impervious acre managed (MG/Ac) is about 0.23 MG/Ac, and this ratio is consistent with citywide ratio of 0.22 MG/Ac presented in the June 2016 GI Metrics Report. However, the additional green infrastructure has a ratio of only 0.04 MG/Ac, about a fifth of the citywide ratio and a tenth of the ratio for green infrastructure with high percentage of retention assets, which is 0.4 MG/Ac.

   While the additional green infrastructure will also reduce storm water discharges to Bergen and Thurston Basins, the overall level of reduction is minimal compared to the volume of storm water being discharged. As such, it appears that there is very little benefit from constructing additional green infrastructure in the drainage areas for these two basins. To better understand the technical basis for the GI, the City must provide a more detailed explanation of how the projected reductions for CSO and storm water for the additional green infrastructure in Thurston and Bergen Basins were calculated, their estimated costs, and their projected water quality benefits.

DEP Response: *GI practices, as currently represented by NYC InfoWorks models, simulate capturing stormwater runoff from managed impervious areas upstream of their connection to the sewer network model (see Figure 1-5 of Performance Metrics Report [2016], also shown here). While the stormwater runoff reduction benefits from GI practices at the local tributary drainage area-scale are independent of the sewer system type, the end-of-pipe benefits vary based on the type of the sewer system and its characteristics.*

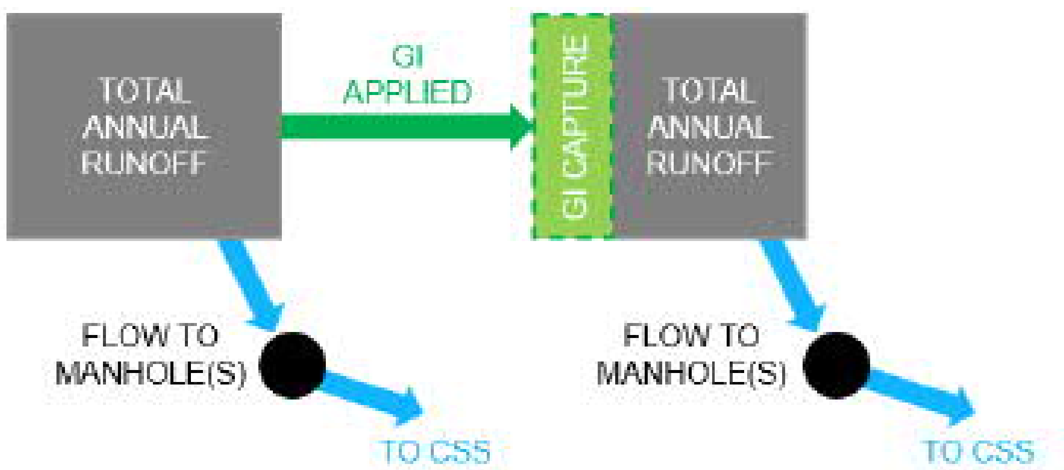


Figure 1-5. Schematic of the Stormwater Runoff Reduction from GI Capture

As illustrated in Figure ES-8 (below), the majority of the Baseline GI is implemented within the portions of the collections system where the combined sewer drainage systems have been built-out, resulting in a ratio of CSO reduction per impervious area managed that is consistent with the City-Wide projections. However, the additional GI proposed under the LTCP Recommended Plan is located in the areas planned for the SEQ Sewer Buildout and therefore the calibrated landside model for this drainage area presented in the LTCP had unusually low runoff coefficients attributed to the lack of storm sewers in the area. As a result, the initial projected benefits of GI in reducing end-of-pipe wet weather volumes were much lower than typically anticipated. Regardless, GI provides ancillary benefits in capturing storm flow such as upland flood relief, reduction in carbon footprint, ecosystem habitat creation, heat island reduction and property value benefits.

At DEC's request, DEP revised the GI modeling by assuming the full SEQ Buildout Conditions and assessed the benefit of GI in Bergen and Thurston basins in reducing CSO and stormwater discharges. To evaluate the GI-specific benefits, reductions were calculated based on two scenarios that assume full SEQ Buildout, one with GI and another without GI. With the full system buildout, the GI provides end-of-pipe stormwater discharge reduction of 239 MG in Bergen and 209 MG in Thurston Basin (refer to Table 5 for tabulated results).

The SEQ Buildout will implement HLSS in the combined Laurelton area tributary to Thurston Basin. Since HLSS is planned, GI implementation has been removed from the Baseline and Recommended Plan, both with and without the SEQ Buildout. This GI implementation effort includes 74 greened acres; in the prior Baseline condition it results in a reduction of 32 MGY of CSO to Thurston Basin. Under the Recommended Plan, both with and without the SEQ Buildout, this 74 greened acres of GI is now implemented in the storm area tributary to Thurston Basin. Figure ES-8 below provides the details of how the shift of the 74 green acres of GI to the storm area will impact the stormwater discharge to Thurston Basin under the Recommended Plan with SEQ Buildout scenario. Please see Section 5 for the details related to the impact under the Recommended Plan without SEQ Buildout scenario.

Although the Recommended Plan with SEQ Buildout scenario will not result in a Thurston Basin CSO reduction attributed to GI, the SEQ Buildout does result in a CSO reduction of 160 MGY when compared to the Baseline. This 160 MGY reduction is predominantly (152 MGY) a result of the planned HLSS within the Laurelton area; the remaining 8 MGY reduction is attributed to the residual effect of GI implementation in the storm only area of Thurston Basin since capacity in the East Interceptor is freed up allowing more CSO to get in as opposed to overflowing.

Table 5. Model Predicted GI Performance for SEQ Buildout Conditions (2008 Typical Year)

Waterbody	Total Stormwater Volume SEQ Buildout without GI (MG)	Total Stormwater Volume SEQ Buildout with GI (MG)	Total Reduction in Stormwater Volume (MG)
Bergen Basin	5,139	4,787	239
Thurston Basin	4,203	3,994	206

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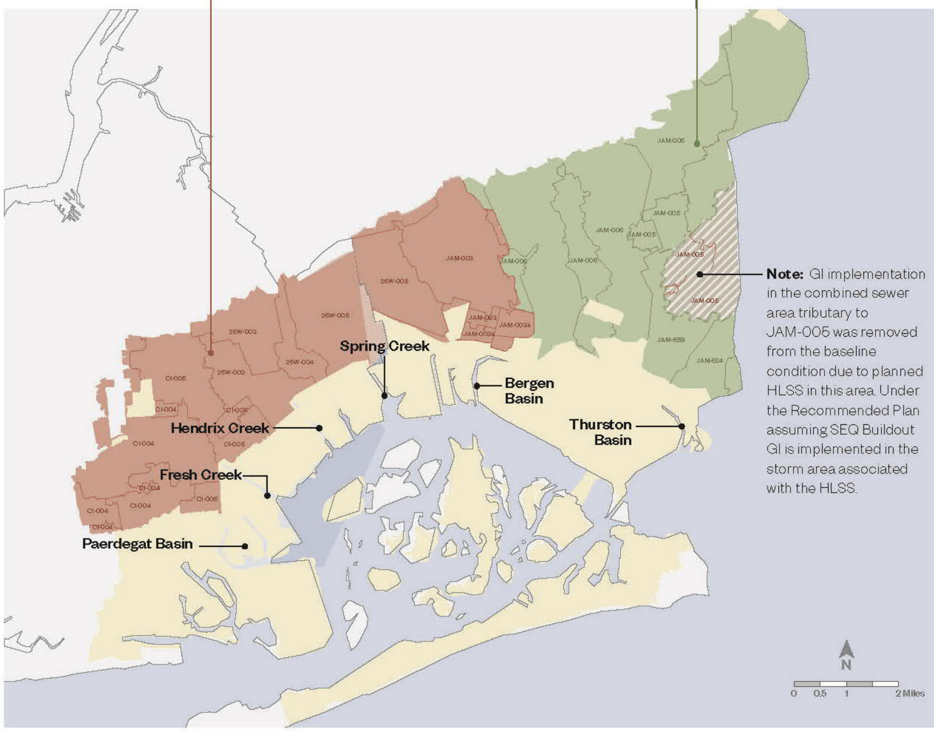
Figure ES-8. Revised GI CSO Baseline and GI Expansion in Recommended Plan

CSO GREEN INFRASTRUCTURE (GI) BASELINE ASSUMING SEQ BUILDOUT	
Greened Acres	803 ac.
CSO Reduction	169 MGY
Stormwater Reduction	Not applicable

RECOMMENDED PLAN ASSUMING SEQ BUILDOUT		
Additional Benefits	Thurston Basin	Bergen Basin
Greened Acres	221 ac.	232 ac.
CSO Reduction	0 MGY	0 MGY
Stormwater Reduction	209 MGY	239 MGY



Miscellaneous Comments:

5. **DEC Comment: Chapter 8.** Provide figures (similar to Figure ES-8) that show attainment levels for the entire Jamaica Bay as well as tributaries for fecal coliform, enterococcus, and dissolved oxygen standards for the selected alternative. The figures provided, such as Figure ES-2, only show the tributaries and the northern half of the Bay. Additionally, provide a similar figure in the Executive Summary for the baseline, 100 percent CSO reduction, and selected alternative showing the attainment levels for the proposed enterococci 130 cfu/100mL STV standard.

   DEP Response: *LTCP Table ES-2 and Figures ES-2 and ES-3 summarized model calculated attainment of existing and potential future WQ Criteria for the Recommended Plan. Figures ES-14 through ES-16 summarized model calculated attainment of Baseline Conditions and 100% CSO Control. As model calculated WQS compliance was attained throughout Jamaica Bay for Existing Fecal Coliform, Potential Future Enterococcus and Existing Dissolved Oxygen Criteria, all figures were truncated to focus on the tributaries. As requested, updated copies of the figures have been provided in the revised Executive Summary section contained in Attachment E herein. These figures have been expanded to show all of Jamaica Bay. The figure numbers and associated text references have been renumbered accordingly. As requested, figures for the Recommended Plan*

(ES-4), Baseline Conditions (ES-20), and 100 percent CSO reduction (ES-21) have also been provided for the amended STV standard.

6. **DEC Comment: Page 1-4.** The Interstate Environmental Commission is not part of NEIWPCC as of September 2018, it is an independent organization.

   DEP Response: *The second and third paragraph of Section 1.2c New York State Policies and Regulations (page 1-4 of Section 1) are deleted and hereby replaced with the following:*

   "On June 4, 2019, DEC adopted Amended Enterococci WQ Criteria for coastal Class SB waters, which apply to Jamaica Bay (a coastal Class SB waterbody), but not the tributaries (all Class I waterbodies). As requested by DEC, DEP assessed compliance with those proposed criteria for all waters considered in this LTCP including the tributaries.*

   The States of New York, New Jersey and Connecticut are signatories to the Tri-State Compact, which designated the Interstate Environmental District and created the Interstate Environmental Commission (IEC). The Interstate Environmental District includes all saline waters of greater NYC, including Jamaica Bay and Tributaries. The IEC was recently incorporated into, and is now part of, the New England Interstate Water Pollution Control Commission (NEIWPCC), a similar multi-state compact of which NYS is a member."

   The footnote at the bottom of page 1-4 is deleted and replaced with the following:

   "The amended Enterococci WQ Criteria only apply to coastal SB and SA waters."

7. **DEC Comment**: Figures 2-3 and 6-2. Explain the difference between areas designated as "storm drainage" and "MS4 drainage". In previous LTCPs, the City has not similarly differentiated the separately sewered areas in the drainage basins.

   DEP Response: *"MS4 drainage" consists of areas that are tributary to the outfalls identified in the City's MS4 SPDES Permit. "Storm drainage" consists of all areas tributary to stormwater conveyance that go to an outfall, but excludes those outfalls that are designated as DEP MS4 as well as permitted transportation and airport stormwater sources. "Direct drainage" consists of all drainage areas that enter a waterbody directly via overload flow and are not tributary to a storm sewer.*

8. **DEC Comment: Section 2.2.a.5.** Provide a figure showing the specific sensitive areas in Jamaica Bay and its tributaries, such as locations associated with endangered species and any public bathing beaches.

   DEP Response: *Figure 2-29 provides the location of public access points including parks and boat launches. There are no public bathing beaches within Jamaica Bay. While threatened and endangered species have been observed and documented within the Jamaica Bay project area, State and Federal resource agencies do not provide discrete locations of threatened and endangered species as a security measure. Therefore, it is assumed that each of the threatened and endangered species could occur throughout the Jamaica Bay and Tributaries LTCP study area.*

   A memo summarizing the Sensitive Area Analysis for Jamaica Bay LTCP is attached in

Attachment K of this Supplemental Document and has been incorporated into the Jamaica Bay LTCP as Appendix G. The following sentence is hereby added to Section 2.2.a.5 Identification of Sensitive Areas at the bottom of Page 2-64: "Additional details in support of Table 2-12 are provided in the memo entitled Sensitive Area Analysis for Jamaica Bay LTCP as provided in Appendix G."

9. **DEC Comment:** Provide a copy of CSO-LTCP: Basis for Modeling - Jamaica Bay and Tributaries and Jamaica Bay LTCP Sewer System and Water Quality Modeling Report.

   DEP Response: *The Basis for Modeling Memo has been updated and is provided in Attachment B. The Sewer System and Water Quality Modeling Report has also been updated and is provided in Attachment C of this Supplemental Document.*

10. **DEC Comment: Section 6.3.** The gap analysis does not need to examine attainment with DO for the next higher use classification. For Class I waterbodies, examine attainment with only the existing DO water quality standard, which is never less than 4.0 mg/l.

    DEP Response: *Table 6-9 provides DO attainment of Existing WQ Criteria for Baseline and 100% CSO Control for the Class I tributaries and Jamaica Bay which is Class SB. The gap analyses provided in Table 6-10 was performed consistent with prior LTCPs. The assessment of attainment with DO for the next higher use classification was deleted.*

11. **DEC Comment: Section 8.1.C.** The use of a NPV factor 24.505, based on a 100-year useful life, does not seem reasonable given the nature of the projects included in the selected alternative. A useful life of 20 years, as has been used for other LTCPs, seems more reasonable.

    DEP Response: *All CSO controls must be evaluated on the same basis. As tunnels have a useful life of 100 years, the cost of operations and maintenance, as well as rehabilitation of equipment and facilities with shorter useful lives must be accounted for in properly comparing the net present value of the other CSO control alternatives with the various tunnel alternatives.*

12. **DEC Comment: Section 8.1.i.** The justification for elimination of the mechanical aeration does not make any sense. Aeration can be used even though elimination of the CSOs does not notably improve attainment levels, in fact, that very rationale would support use of instream mechanical aeration. Additionally, Figure 8-4 does not show that the technology has been eliminated from consideration. Please confirm that the narrative and figure are correct.

    DEP Response: *The narrative and figure are correct. Text has been added to Page 8-12 to further clarify the initial screening of mechanical aeration. The legend for Figure 8-4 indicates that mechanical aeration was completed in accordance with the Waterbody/Watershed Facilities Plan (WWFP). The Shellbank Basin Destratification System was recommended in the Jamaica WWFP and implemented to address DO attainment issues. Section 4.2 provides the following project summary and status for this project:*

    - *<u>Project Summary</u>: Due to the variable depth throughout Shellbank Basin, temperature stratification presented a major water quality issue resulting in depleted dissolved oxygen levels, aquatic species deaths, and odor complaints. The destratification project included* *the installation of air compressors, diffuser piping, and associated equipment at the head of Shellbank Basin to provide mixing of the entire water column to address temperature stratification issues.*

- *<u>Status</u>: Project was completed in November 2010.*

Model calculated DO WQ attainment for the 2008 typical year rainfall is summarized in LTCP Table 6-8 for Baseline Conditions. While attainment results were projected to fall just short of the 95% attainment goal at monitoring stations in Thurston Basin (90% at TBH1 & TBH3), Bergen Basin (89% at BB5) and Hendrix Creek (94% at HC1), modeling of 100% CSO capture had negligible improvements (ranging from 1-3%) for DO attainment. While LTCP Table 8-39 summarizes model calculated attainment for the Recommended Plan, the water quality model is not equipped to estimate the dissolved oxygen improvements associated with the GI, environmental dredging, wetlands restoration or ribbed mussel colony creation proposed for each of these respective watersheds. Considering the attainment levels for DO in these waterbodies under Baseline Conditions, DEP does not believe that there is sufficient justification to install in-stream mechanical aeration. No further projects should be considered until the Recommended Plan is implemented and post construction compliance monitoring has been performed to evaluate the improvements in the water quality attainment for dissolved oxygen criteria.

13. **DEC Comment: Section 8-4.k.** Provide a detailed breakdown of the cost estimate for each component of the selected alternative (e.g. wetlands, dredging, mussels, and green infrastructure).

    DEP Response: *Table 8-42 below has been inserted on page 8-126 of Section 8 and provides a detailed cost breakdown of the Recommended Plan segregated by waterbody in support of the Probable Bid Costs identified in Table 8-34.*

Table 8-42.- Recommended Plan Breakdown of Probable Bid Cost

Waterbody	GI Cost ($ Millions)	Environmental Dredging Cost ($ Millions)	Ribbed Mussel Cost ($ Millions)	Tidal Wetlands Restoration Cost ($ Millions)	Total Cost ($ Millions)
Thurston Basin	$104.0	$0.0	$5.8	$0.0	**$109.8**
Bergen Basin	$106.4	$27.0	$4.6	$0.0	**$138.0**
Spring Creek	$0.0	$0.0	$0.0	$16.3	**$16.3**
Hendrix Creek	$0.0	$0.0	$0.0	$3.1	**$3.1**
Fresh Creek	$0.0	$0.0	$0.0	$17.0	**$17.0**
Paerdegat Basin	$0.0	$0.0	$0.0	$5.6	**$5.6**
Jamaica Bay	$0.0	$0.0	$0.0	$20.5	**$20.5**
PBC Total (2018 $)	**$210.4**	**$27.0**	**$10.4**	**$62.5**	**$310.3**

14. **DEC Comment: Section 8.2.a.2.** Describe in more detail the alternatives B-1f and 26W-1, “Real time control of existing private building retention facilities" considered for Bergen Basin, Spring Creek, Hendrix Creek, and Fresh Creek and why they were eliminated from consideration.

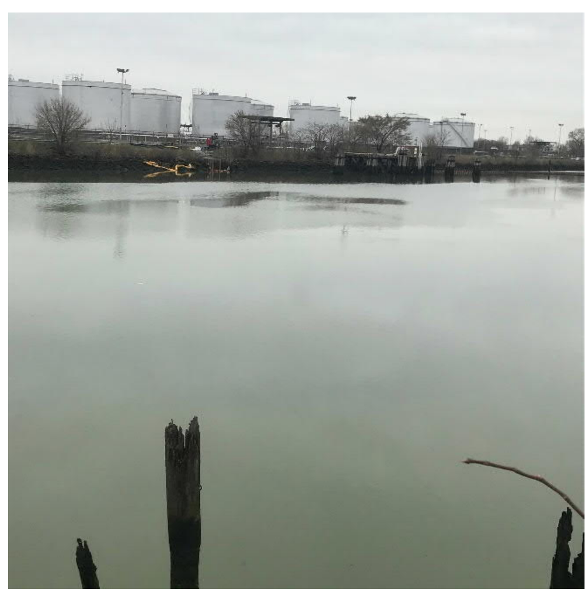
    DEP Response: *The text on page 8-25 of Section 8 relating to the sewersheds tributary to the Jamaica WWTP was expanded to provide further details on the evaluation of real time control of private stormwater management systems. Text was also added to Page 8-26 to address similar concerns for implementation of real time controls on private stormwater management facilities within the 26th Ward WWTP sewershed.*

15. **DEC Comment**: **Page 8-54.** The discussion under Spring Creek alternatives indicates that the CSO chlorination study is still ongoing, although the City has stated before that it is complete. Confirm that the statements regarding the pilot study are correct or revise as needed.

    DEP Response: *The Spring Creek study was completed in June 2018 and the report was posted to DEP’s website around the same time that the LTCP was drafted. This statement has been amended on Page 8-67 of Section 8 of the LTCP. Conclusions from this study have also been added to page 8-67.*

16. **DEC Comment**: Confirm if the City has bathymetry for the head-end of Bergen Basin or provide photos of the exposed sediments during low tide if readily available.

    DEP Response: *Bathymetry is not readily available. Photos of the conditions in Bergen Basin during low tide are provided below. The photo to the left shows exposed sediments along the bank of Bergen Basin near CSO-003/003A. The dark shadowing in the photo to the right is an area (between CSO-003/003A and CSO-006 where the depth is shallow and is exposed during extreme low tide. As indicated in the LTCP, environmental dredging in Bergen Basin will be performed to removed odor causing exposed sediments and provide sufficient depth for ribbed mussel installation.*



17. **DEC Comment: Inflow and Infiltration.** The LTCP indicates that inflow and infiltration are a problem within some of the sewersheds covered under this LTCP (e.g. Coney Island Creek WWTP, 26th Ward WWTP, and Jamaica WWTP). Specifically, the LTCP states that the Paerdegat CSO retention facility and Spring Creek AWWTP both receive I&I, and the southeast Queens area contributes inflow to the Jamaica WWTP due to a lack of storm sewers. The Department requests more specific information on the magnitude of the I&I in these sewersheds and the extent to which the City has monitored its collection system to identify the specific areas where the great contributions of I&I are occurring. Section 7.2.2 of the 2011 Jamaica Bay/Tribs Waterbody/Watershed Facility Plan states that I&I control would be reevaluated during the development of Jamaica Bay/Tribs LTCP, but the LTCP does not indicate if any further I&I assessments were completed. Lastly, confirm that the original baseline conditions for the InfoWorks model included I&I for Paerdegat and Spring Creek CSO storage tanks.

    DEP Response: *Section 8 (page 8-14) has been revised to further expand on source controls for addressing infiltration/inflow. The added text also confirms that I/I is accounted for in the modeling of the Paerdegat Basin CSO Facility and the Spring Creek AWWTP. The modeling also reflects the capture of inflow sources associated with HLSS and GI that has been implemented, is planned or under construction in the combined sewer service areas within the Jamaica and 26th Ward WRRF Sewer Service Areas.*

18. **DEC Comment: Table 9-16.** It would be more appropriate if the cost estimates for the CSO program were all presented in the same year dollars or include a footnote that indicates otherwise.

    DEP Response: *Table 9-16 on page 9-40 of Section 9 is hereby replaced with the following table. Footnotes 2 and 3 have been provided for additional clarification.*

Table 9-16. Financial Commitment to CSO Reduction

New York City's CSO Program	Financial Commitment ($B)
Waterbody/Watershed Facility Plan and other CSO Projects	$2.7(1)
Green Infrastructure Program	$1.6(2)
LTCP/Submitted and Approved	$5.0(3)
Total	**$9.2**

Notes:
(1) Reflects costs incurred or committed to date for implementation of projects identified in the WWFP or the cost to complete other CSO projects to date.
(2) Reflects costs incurred or committed to date for the GI Program.
(3) Reflects costs escalated to midpoint construction for submitted and approved LTCP plans as shown in Table 9-14. Total LTCP costs are not currently known. A conceptual $5.7B in LTCP spending through 2045 is assumed for the affordability assessment. The total LTCP cost estimates will evolve over the next year and will be updated when the Citywide LTCP is completed.

19. **DEC Comment**: Confirm if the City examined the collection system for Jamaica WWTP, 26th Ward WWTP, and Coney Island Creek WWTP using the Optimizer software.

    DEP Response: *DEP has not evaluated the collection systems tributary to the Jamaica WRRF, 26th Ward WRRF or the Coney Island WRRF using Optimizer software. InfoWorks modeling of the collection systems tributary to these WRRFs performed as part of the Jamaica Bay and Tributaries CSO LTCP alternatives evaluations found the hydraulic grade lines within these systems to be very sensitive to regulator modifications and other low cost measures for optimizing system performance. The modeling is reflective of the projects recommended and implemented in accordance with the recommendations contained in Jamaica Bay Waterbody Watershed Facilities Plan which identified low cost collection system improvements to reduce CSOs by maximizing wet weather flow to the WRRFs.*

20. **DEC Comment**: During past discussions related to the Rockaway sewershed, the City has stated that the collection system in this sewershed is completely separated. However, in the LTCP the City states that sewershed has CSOs, implying that a portion of sewershed had a combined sewer system. The City and Department are currently confirming the configuration of the sewer system as part of negotiations to resolve the Rockaway 2xDDWF notice of violation. Any references to CSOs from the Rockaway sewershed should be revised to be consistent with these discussions between the Department and City.

    DEP Response: *Discussions with DEC are ongoing regarding the Rockaway 2xDDWF NOV referenced in DEC's comment. References in the LTCP to the Rockaway WRRF and any associated outfalls are consistent with the current SPDES permit. As has been discussed with DEC, storm sewer construction remains ongoing in the Rockaway WRRF sewershed and DEP intends to confirm the configuration of the Rockaway WRRF sewer system and associated outfalls. Analysis included within the LTCP indicates that no CSO discharges are occurring under modeled conditions.*

21. **DEC Comment**: According to a "June 14, 2016 Green Infrastructure Performance Metrics Report Briefing for DEC", presented by the City, the baseline GI commitment for Jamaica Bay and its tributaries was to manage 1-inch of storm water runoff from 1153 acres, or about 14.6 percent of the impervious surface, which would result in a reduction in CSO of about 248 MG. The LTCP presents different values for both the acres of impervious surface managed and CSO reduction and the City needs to explain in more detail the reasons for the differences in baseline values.

    DEP Response: *As DEP continues to implement the Green Infrastructure (GI) Program throughout the City, projects are tracked from planning stages through implementation and activation. From the time the 2016 GI Performance Metrics Report was issued to the submission of this LTCP, some of the projects originally planned were eliminated or relocated and new projects have been identified to work towards achieving the program's overall goals. Additional information is collected as planned projects advance to design, which may influence the feasibility of implementation. Siting and type of facilities may change due to groundwater conditions, permeability of soils, conflicts with utilities, public feedback, and other impacts. The LTCP reflects the latest information available based upon the project tracking performed under the GI Program.*

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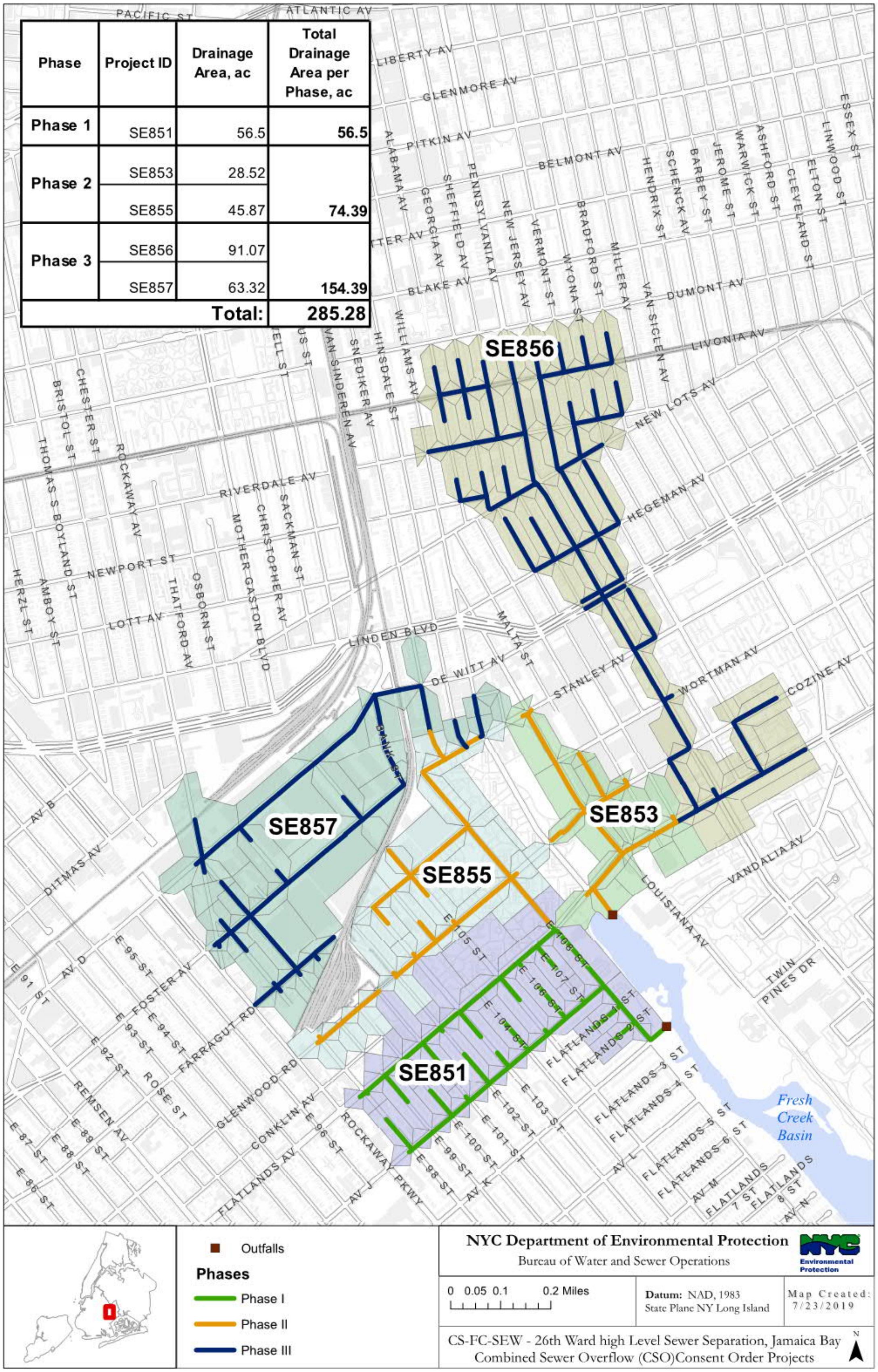
Responses to DEC Comment Letter Dated June 5, 2019

The Department (DEC) reviewed the information provided in the City's letter and requests the following additional information to better understand how the proposed changes will affect the area where sewer separation will occur and the associated CSO reduction. Please provide the following information:

1. **DEC Comment:** A schematic showing the layout of the sewer lines for all three phases of HLSS, the boundaries of the area encompassing each separate phase, and the associated acreage for each phase.

   DEP Response: *See schematic on next page.*

Phase	Project ID	Drainage Area, ac	Total Drainage Area per Phase, ac
Phase 1	SE851	56.5	**56.5**
Phase 2	SE853	28.52	
	SE855	45.87	**74.39**
Phase 3	SE856	91.07	
	SE857	63.32	**154.39**
		Total:	**285.28**



2. **DEC Comment:** Estimated construction costs for Phase 2 and Phase 3 HLSS (taking into consideration work associated with this modification request, and if readily available, the extra work to resolve the NYCHA steam pipe conflict).

   DEP Response: *Costs are provided below*

Fresh Creek HLSS – Phase 2 and 3 Costs

Phase	Project ID	Description	Total Estimate/ Construction Cost per Project	Total Cost
Phase 2	SE853	Contract Amount	$51,747,690.80	**$88,530,522.50**
	SE855	Contract Amount	$36,782,831.70	
		Steam Pipe Offset Design Services	$650,000.00	
		Overrun Cost (Sewer Upsizing in E 108th St and Stanley Av)	$1,463,220.00	
Phase 3	SE856	Preliminary Estimate	$143,400,000.00	**$243,900,000.00**
	SE857	Preliminary Estimate	$100,500,000.00	
Total:				**$332,430,522.50**

3. **DEC Comment:** The total projected reduction in CSOs for all three phases of HLSS and comparison to projected reductions under Jamaica Bay WWFP.

   DEP Response: The following table summarizes the projected reduction in CSO and water quality attainment for the updated Baseline Conditions Modeling in comparison to the Jamaica Bay Waterbody Watershed Facilities Plan (WWFP) and the Baseline Conditions presented in the June 2018 Jamaica Bay and Tributaries CSO LTCP.

Model Predicted Statistics for Fresh Creek Monitoring Station FC1

Landside and Water Quality Modeling Conditions	Total Annual CSO Volume (MG/yr)(1)	Frequency of CSO Overflow(1)	Total Annual Stormwater Volume (MG/yr)	Frequency of Stormwater Overflow
WWFP Preferred Alternative	189	26	600	N/A
LTCP Baseline Conditions	300	15	522	80
Updated LTCP Baseline Conditions	232	12	528	81

Note:

(1) CSO volume and frequency of overflow are based upon the results of the 2008 Typical Year model run for LTCP and 1988 for WWFP

4. **DEC Comment:** Projected water quality attainment for Fresh Creek associated with CSO reductions in item 3 (taking into consideration corrections to modeling for green infrastructure as identified for the Jamaica Bay LTCP).

   DEP Response: *The changes in model predicted fecal coliform water quality attainment as a result of the updates to the GI and HLSS modeling are provided in the table below. The projected recreational season fecal coliform water quality attainment, for the Baseline Conditions (considering the GI and HLSS updates) is illustrated in the figure below.*

Model Predicted Fecal Coliform WQ Attainment for Fresh Creek Monitoring Station FC1

Landside and Water Quality Modeling Conditions	% Attainment Annual (GM<200 cfu/100mL)(1)	% Attainment Rec. Season (GM<200 cfu/100mL)(1)
WWFP Preferred Alternative	92(2)	N/A
LTCP Baseline Conditions	86	93
Corrected LTCP Baseline Conditions	85	93

Notes:
(1) Water quality attainment is based upon 10-year model runs.
(2) WWFP fecal coliform attainment was based upon an annual GM of <2,000 cfu/100mL.

Model Predicted Fecal Coliform Recreational Season WQ Attainment for Fresh Creek Monitoring Station FC1

AECOM with Hazen

Additional Report Updates for Consistency with the Responses to DEC Comments Above

General Revision

All references to "WWTP" shall be replaced with "WRRF" throughout the entire LTCP document.

Section 2

The first paragraph on page 2-51 is hereby deleted and replaced as follows:

"On June 4, 2019, DEC publicly noticed the adoption of water quality standards that include application of Amended Enterococci WQ Criteria to coastal SB waters during the primary contact recreation season, and a reclassification for the Upper and portion of the Lower New York Bay from Class I to Class SB. Although the adopted revisions to the WQS are not effective until November 1, 2019, this LTCP includes assessment of attainment with both the Existing WQ Criteria and the Amended Enterococci WQ Criteria*. Based on the June 4, 2019 public notice provided by DEC, the Amended Enterococci WQ Criteria* modeled for this LTCP will include a 30-day rolling GM for Enterococci of 35 cfu/100mL with a not-to-exceed 90th percentile STV of 130 cfu/100mL. In accordance with the proposed rulemaking, these criteria would not apply to the tributaries of Jamaica Bay that are non-coastal Class I waters. However, as requested by DEC, DEP assessed compliance with those proposed criteria for all waters considered in this LTCP including the tributaries."*

The footnotes at the bottom of pages 2-51 and 2-56 are hereby deleted and replaced as follows:

*"*Amended Enterococci WQ Criteria only apply to coastal Class SB and SA waters."*

The first paragraph on page 2-56 is hereby deleted and replaced as follows:

"As described above, on June 4, 2019, DEC publicly noticed a revision to the WQS that included application of the Amended Enterococci WQ Criteria to coastal SB waters during the primary contact recreation season and the reclassifications of certain waterbodies. This LTCP includes assessment of attainment with both the Existing WQ Criteria and the Amended Enterococci WQ Criteria*. Based on DEC's June 4 notice, the Amended Enterococci WQ Criteria* modeled for this LTCP will include a 30-day rolling GM for Enterococci of 35 cfu/100mL with a 90th percentile STV of 130 cfu/100mL. In accordance with the proposed rulemaking, these criteria would not apply to the tributaries of Jamaica Bay that are non-coastal Class I waters. However, as requested by DEC, DEP assessed compliance with those proposed criteria for all waters considered in this LTCP including the tributaries."*

Section 5

The third paragraph on page 5-4 is hereby deleted and replaced as follows:

"Jamaica Bay and its tributaries are priority watersheds for DEP's GI Program, and DEP seeks to saturate priority watersheds with GI based on the specific opportunities each watershed presents. DEP has over 1,081 GI assets in construction or constructed, including ROW practices, public property retrofits, and GI implementation on private properties as of 2017. In addition, thousands of additional assets are currently planned or in design. All built and planned GI assets are projected to result in a CSO volume reduction of approximately 169 MGY, based on the 2008 baseline rainfall condition."

Figure 5-2 on page 5-6 is hereby deleted and replaced as follows:

CSO GREEN INFRASTRUCTURE (GI) BASELINE	
Greened Acres	803 ac.
CSO Reduction	169 MGY
Stormwater Reduction	Not applicable

RECOMMENDED PLAN (GI)		
Additional Benefits	**Thurston Basin**	**Bergen Basin**
Greened Acres	221 ac.	232 ac.
CSO Reduction	8 MGY	0 MGY
Stormwater Reduction	30 MGY	211 MGY

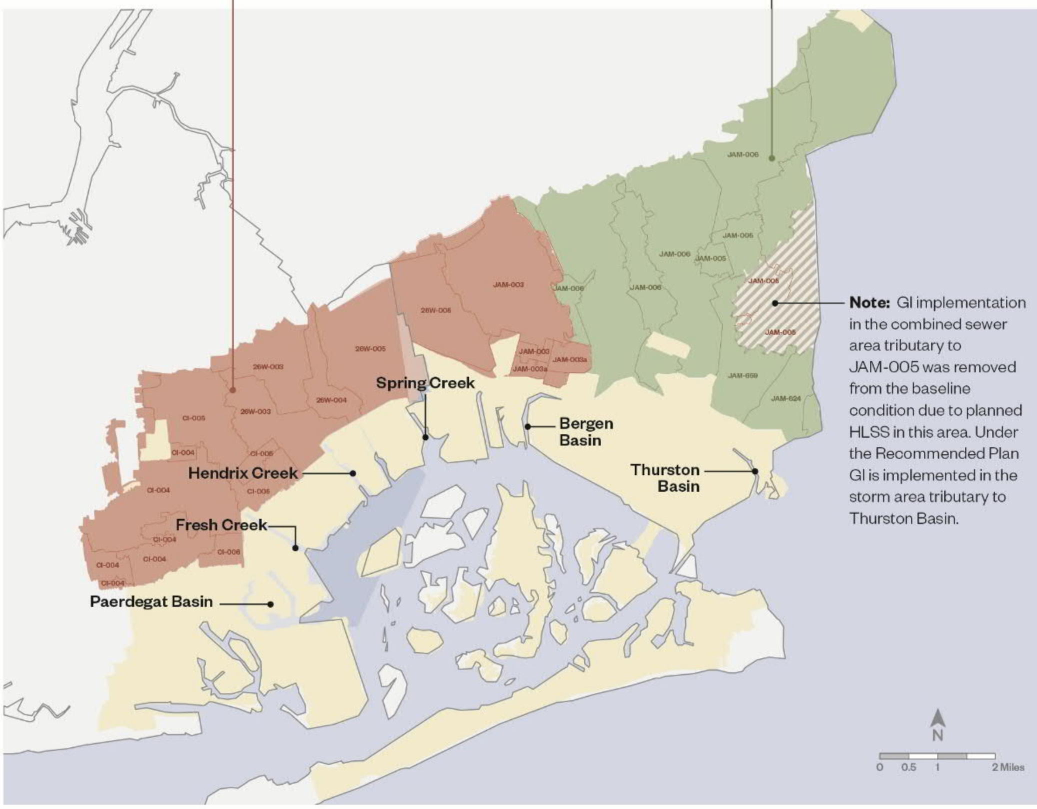


Figure 5-2. GI CSO Baseline and GI Expansion in Recommended Plan

<u>Section 7</u>

<u>The second, third and fourth paragraphs on page 7-5 is hereby deleted and replaced as follows:</u>

"This LTCP further investigated the spatial and temporal attainment with the Amended Enterococci WQ Criteria which will be applicable only to Coastal Primary Contact Recreational Waterbodies that would include Jamaica Bay proper, which is currently classified as a Class SB waterbody. Based on 10-year model simulations with the Recommended Plan conducted as part of this LTCP, Jamaica Bay is currently projected to be in full attainment with the proposed 30-day geometric mean Enterococci criterion of 35 cfu/100mL during the recreational season (May 1st through October 31st). Most of Jamaica Bay is also projected to be in full attainment with the 30-day STV of 130 cfu/100mL during the recreational season (May 1st through October 31st), but some excursions from the 30-day STV are projected near the outlets to the tributaries.*

The Amended Enterococci WQ Criteria does not apply to any of the Jamaica Bay tributaries that are classified as Class I waterbodies. However, DEP did conduct an analysis of attainment with these criteria for informational purposes. Based on this analysis, the Class I waterbodies Paerdegat Basin, Fresh Creek, Spring Creek, and Hendrix Creek are projected to be in full attainment with a 30-day geometric mean Enterococci criterion of 35 cfu/100mL during the recreational season (May 1st through October 31st), but they are not projected to attain a 30-day STV criterion of 130 cfu/100mL.*

The inaccessible portions of Bergen and Thurston Basins, which are also Class I waterbodies, are not projected to be in attainment with either a 30-day geometric mean criterion of 35 cfu/100mL or a 30-day STV value of 130 cfu/100mL during the recreational season (May 1st through October 31st). However, the accessible reaches of those basins are projected to be in attainment of a 30-day geometric mean criterion of 35 cfu/100mL, but not a 30-day STV value of 130 cfu/100mL."

The footnote at the bottom of page 7-5 is hereby deleted and replaced as follows:

*"*Amended Enterococci WQ Criteria only apply to coastal Class SB and SA waters."*

Section 9

The second and third paragraphs on page 9-4 are hereby deleted and replaced as follows:

Table 9-1 presents the projected attainment of existing Class SB Criteria for bacteria for Jamaica Bay and Class I for its tributaries for baseline conditions and the Recommended Plan based on a 10-year simulation. Also presented in Table 9-1 is the projected attainment of the Amended Enterococci WQ Criteria for Jamaica Bay and its tributaries. It should be noted that the Amended Enterococci WQ Criteria* would not apply to non-coastal waters and thus does not include the Jamaica Bay tributaries. However, DEP's assessment for the highest attainable use evaluated both the Amended Enterococci WQ Criteria* and fecal coliform criteria for primary contact recreation. Table 9-2 presents the projected attainment of Existing Class SB Criteria for DO for Jamaica Bay and Class I for its tributaries for baseline conditions and the Recommended Plan based on a 2008 typical year simulation.*

As indicated in Table 9-1, Jamaica Bay is projected to be in attainment with existing Class SB WQ Criteria for fecal coliform bacteria. Among the tributaries to Jamaica Bay, the existing Class I WQ Criteria for fecal coliform bacteria are projected to be attained under the Recommended Plan except in the most upstream reaches of Thurston Basin, Bergen Basin, and Fresh Creek. In the upstream reaches of Thurston and Bergen Basins, unauthorized access is prohibited by JFK International Airport security, and in the case of Thurston Basin, access is further restricted by a chain-link fence that spans the waterway. Modeling indicated that even with 100% CSO control, the upstream reaches of Thurston and Bergen Basins would not be in attainment with the Class I criterion for bacteria. Attainment with the 30-day GM Amended Enterococci WQ Criteria follow a similar trend, except that Fresh Creek is projected to be in attainment with the Recommended Plan. Attainment of the 30-day STV Amended Enterococci WQ Criteria* falls short in all waterbodies except for Jamaica Bay Inner Bay and Rockaway Shore.*

The footnote at the bottom of pages 9-4, 9-5, 9-6, 9-7, 9-8, 9-9 and 9-33 are hereby deleted and replaced as follows:

*"*Amended Enterococci WQ Criteria only apply to coastal Class SB and SA waters."*

The third bullet on page 9-33 is hereby deleted and replaced as follows:

- *The Amended Enterococci WQ Criteria* may result in additional compliance costs for the WWTPs once a water quality based effluent limit is identified.*

Table 9-1 on page 9-5 is hereby deleted and replaced as follows:

Table 9-1. Projected Attainment for Baseline Conditions and the Recommended Plan – Existing and Proposed WQ Criteria* for Bacteria

Station	Baseline(2)				Recommended Plan(2)			
	Fecal Coliform		*Enterococcus*(4)		Fecal Coliform		*Enterococcus*(4)	
	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL
Thurston Basin								
TBH1(1)	77	77	67	5	88	88	69	6
TBH3(1)	89	90	86	12	93	93	87	13
TB9(1)	91	92	89	16	95	95	90	16
TB10(1)	98	100	96	25	100	100	96	25
TB11	100	100	100	89	100	100	100	87
TB12	100	100	100	96	100	100	100	96
Bergen Basin								
BB5(1)	57	59	30	0	72	77	32	0
BB6(1)	89	94	75	7	93	98	73	6
BB7(1)	100	100	95	17	100	100	94	15
BB8	100	100	100	77	100	100	100	57
Spring Creek								
SP1	100	100	100	87	100	100	100	79
SP2	100	100	100	100	100	100	100	95
Hendrix Creek								
HC1	99	100	100	43	98	100	99	32
HC2	100	100	100	50	100	100	98	38
HC3	100	100	100	96	100	100	100	72

Table 9-1. Projected Attainment for Baseline Conditions and the Recommended Plan – Existing and Proposed WQ Criteria* for Bacteria

Station	Baseline(2)				Recommended Plan(2)			
	Fecal Coliform		*Enterococcus*(4)		Fecal Coliform		*Enterococcus*(4)	
	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL
Fresh Creek								
FC1	78	83	99	15	88	97	97	13
FC2	98	98	99	20	100	100	98	17
FC3	100	100	100	63	100	100	100	50
FC4	100	100	100	100	100	100	100	92
Paerdegat Basin								
PB1	97	100	100	39	95	100	96	28
PB2	100	100	100	93	100	100	100	69
Jamaica Bay (Northern Shore)								
J10	100	100	100	99	100	100	100	85
J3	100	100	100	100	100	100	100	97
J9a	100	100	100	100	100	100	100	92
J8	100	100	100	100	100	100	100	92
J7	100	100	100	77	100	100	100	57
JA1	100	100	100	77	100	100	100	86
Jamaica Bay (Inner Bay)								
J2	100	100	100	100	100	100	100	98
J12	100	100	100	100	100	100	100	97
J14	100	100	100	100	100	100	100	100
J16	100	100	100	100	100	100	100	99
Jamaica Bay (Rockaway Shore)								
J1	100	100	100	100	100	100	100	100
J5	100	100	100	100	100	100	100	100

Table 9-1. Projected Attainment for Baseline Conditions and the Recommended Plan – Existing and Proposed WQ Criteria* for Bacteria

	Baseline(2)				Recommended Plan(2)			
Station	Fecal Coliform		*Enterococcus*(4)		Fecal Coliform		*Enterococcus*(4)	
	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL	Annual Monthly GM ≤200 cfu/100mL	Rec. Season(3) Monthly GM ≤200 cfu/100mL	30-day Running GM ≤35 cfu/100mL	30-day Running 90th Percentile STV ≤130 cfu/100mL

Notes:

(1) Monitoring station is located in a portion of the waterbody where unauthorized access is prohibited by signage installed by JFK Airport security and/or a physical barrier.

(2) Based on 10-Year simulation.

(3) The recreational season is from May 1st through October 31st.

(4) Attainment with Amended *Enterococci* WQ* Criteria during the Primary Contact Recreational Season (May 1st through October 31st). These criteria, do not apply to the tributaries to Jamaica Bay. Refer to Section 2 of the LTCP for further description of the Amended *Enterococci WQ* Criteria*.

Appendix A – Supplemental Tables

The Supplemental Tables provided in Appendix A of the Jamaica Bay and Tributaries CSO LTCP are hereby deleted and replaced with the updated Supplemental Tables provided in Attachment H.

Appendix C – Jamaica Bay and Tributaries Use Attainability Analysis

The Use Attainability Analysis (UAA) provided in Appendix C of the Jamaica Bay and Tributaries CSO LTCP is hereby deleted and replaced with the revised UAA provided in Attachment I.

Appendix D – Modeling Approach for Estimating the Pathogen Bioextraction in Jamaica Bay and Tributaries

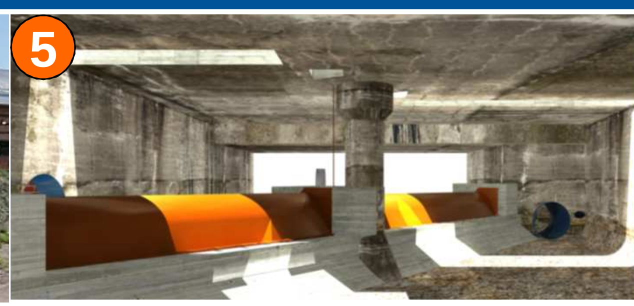
The Modeling Approach provided in Appendix D of the Jamaica Bay and Tributaries CSO LTCP is hereby deleted and replaced with the revised Modeling Approach provided in Attachment J.

Attachment A
Evaluation of CSO Control Alternatives

Evaluation of Retained Alternatives

Jamaica CSO Mitigation Projects

Recommended Project	Status
1 26th Ward WWTP Drainage Area Sewer Cleaning	Completed in 2010
2 Hendrix Creek Canal Dredging	Completed in 2012
3 Spring Creek Auxiliary WWTP Upgrade	In Operation Since 2007
Warnerville Pump Station and Force Main	In Operation Since 2009
4 Paerdegat Basin CSO Facility	In Operation Since 2011
Shellbank Destratification	In Operation Since 2012
5 Bending Weirs	In Operation Since 2017
6 New Parallel Sewer West Interceptor	Construction Completed in 2016
Bergen Basin Lateral Sewer	Ongoing Construction
26th Ward WWTP Wet Weather Stabilization	Ongoing Construction
26th Ward High Level Storm Sewers	Ongoing Construction
Total Cost	**$1.03 Billion**



Jamaica LTCP Alternatives Toolbox

Source Control	Additional GI		High Level Storm Sewers	
System Optimization	Fixed Weir Modifications	Bending Weirs / Control Gates	Pump Station Modifications	Parallel Interceptor
CSO Relocation	Gravity Flow Tipping to Other Watersheds		Flow Tipping with Conduit/Tunnel and Pumping	
Water Quality / Ecological Enhancement	Floatables Control	Environmental Dredging	Mechanical Aeration	Tidal Wetlands, Bioextractors
Treatment *Satellite:*	Outfall Disinfection	Retention Treatment Basin (RTB)		~~High Rate Clarification (HRC)~~
Centralized:	WWTP Upgrades			
Storage	In-System	~~Shaft~~	Tank	Tunnel

Completed or Underway Per WWFP

Completed/Underway Per WWFP & Identified for Evaluation

CSO Controls Identified for Evaluation

Bergen Basin – Alternatives Evaluations

Alt.	Description	Impacted Outfalls	AAOV (MG)	Const. Cost	Recommendations
B-2b	Inline storage with designated pump stations for East and West Interceptors	JAM-003 & 003A	-	-	Abandon due to HGL Increase for West Int.
B-2c	Extend Howard Beach PS force main to Jamaica WWTP	JAM-003 & 003A	-	-	Abandon due to HGL Increase for East Int.
B-2d	Parallel sewer from Regulators JA-03 & JA-14 to the Jamaica WWTP	JAM-003 & 003A	-	-	Abandon - HGL Increase East & West Int.
B-2e	**Abandon Howard Beach PS and construct gravity sewer to 26th Ward WWTP**	**JAM-003 & 003A**	**325**	**$716 M**	**Abandon – High cost to benefit ratio**
B-2f	**Combination of B-2d and B-2e. Parallel sewer along tunnel route.**	**JAM-003 & 003A**	**~260**	**$984 M**	**Abandon – High cost to benefit ratio**
B-2g	**Extend sewer for B-2e to Outfalls JAM-003 and 003A (25% Capture)**	**JAM-003 & 003A**	**277**	**$956 M**	**Abandon – High cost to benefit ratio**
	Extend sewer for B-2e to Outfalls JAM-003 and 003A (50% Capture)	**JAM-003 & 003A**	**185**	**$1,088 M**	**Abandon – High cost to benefit ratio**
	Extend sewer for B-2e to Outfalls JAM-003 and 003A (75% Capture)	**JAM-003 & 003A**	**92**	**$1,348 M**	**Abandon – High cost to benefit ratio**
	Extend sewer for B-2e to Outfalls JAM-003 and 003A (100% Capture)	**JAM-003 & 003A**	**0**	**$1,988 M**	**Abandon – High cost to benefit ratio**
B-2h	Divert all flow from Regulator JA-02 to 26th Ward WWTP Sewer Service Area	JAM-003 & 003A	347	-	Abandon – Insufficient depth differential
B-3	Outfall disinfection of CSO Outfalls JAM-003 & 003A	JAM-003 & 003A	369	-	Abandon – Insufficient contact time
B-4	CSO storage tank along Outfalls JAM-003 and 003A (25% - 100% CSO Control)	JAM-003 & 003A	0-277	-	Abandon – Impacts to JFK Airport facilities
B-6	**CSO tunnel from Outfalls JAM-003/003A to Jamaica WWTP (25% Control)**	**JAM-003 & 003A**	**277**	**$216 M**	**Abandon – High cost to benefit ratio**
	CSO tunnel from Outfalls JAM-003/003A to Jamaica WWTP (50% Control)	**JAM-003 & 003A**	**185**	**$255 M**	**Abandon – High cost to benefit ratio**
	CSO tunnel from Outfalls JAM-003/003A to Jamaica WWTP (75% Control)	**JAM-003 & 003A**	**92**	**$329 M**	**Abandon – High cost to benefit ratio**
	CSO tunnel from Outfalls JAM-003/003A to Jamaica WWTP (100% Control)	**JAM-003 & 003A**	**0**	**$608 M**	**Abandon – High cost to benefit ratio**
B-7	RTB at storage tank sites for Alternative B-4 (25% - 100% Control)	JAM-003 & 003A	0-277	-	Abandon – Impacts to JFK Airport facilities
B-10	Install new regulator along Outfall JAM-006 to divert CSO and SW to the WWTP	JAM-006	-	-	Abandon - HGL Increase in East & West Int.
B-11	Combination of Alternatives B-6 and B-10	JAM-003, 003A & 006	-	-	Abandon - HGL Increase in East & West Int.
B-12	Jamaica WWTP Capacity Upgrade	JAM-003, 003A & 006	369	-	Abandon - No CSO reduction

Thurston Basin – Alternatives Evaluations

Alt.	Description	Impacted Outfall	AAOV (MG)	Const. Cost	Recommendations
T-2a, 2b, 2c	Parallel interceptor from new regulator to Jamaica WWTP	JAM-005/007	-	-	Abandon – HGL increase for West Int.
T-2d, 2e, 2f	Replace East Interceptor from new regulator to Jamaica WWTP	JAM-005/007	-	-	Abandon – HGL increase for West Int.
T-3	Outfall disinfection of CSO and stormwater (25% - 100% Control)	JAM-005/007	611	-	Abandon – Impacts to JFK facilities
T-4a & 4b	CSO storage tank south of 148 Ave or Idlewild Park (25% - 100% Control)	JAM-005/007	0 – 458	-	Abandon – Impacts to wetlands
T-4c	CSO storage tank at site south of Rockaway Blvd (25% - 100% Control)	JAM-005/007	0 - 458	-	Abandon – Impacts to JFK facilities
T-6	**CSO storage tunnel JAM-005/007 to Jamaica WWTP (25% Control)**	**JAM-005/007**	**458**	**$904 M**	**Abandon – High cost to benefit ratio**
	CSO storage tunnel JAM-005/007 to Jamaica WWTP (50% Control)	**JAM-005/007**	**306**	**$913 M**	**Abandon – High cost to benefit ratio**
	CSO storage tunnel JAM-005/007 to Jamaica WWTP (75% Control)	**JAM-005/007**	**153**	**$954 M**	**Abandon – High cost to benefit ratio**
	CSO storage tunnel JAM-005/007 to Jamaica WWTP (100% Control)	**JAM-005/007**	**0**	**$1,204 M**	**Abandon – High cost to benefit ratio**
T-7a & 7b	Retention treatment basins at site south of 148 Ave. or Idlewild Park	JAM-005/007	611	-	Abandon – Impacts to wetlands
T-7c	Retention treatment basin south of Rockaway Blvd (25% - 100% Control)	JAM-005/007	611	-	Abandon – Impacts to JFK facilities
T-9	Laurelton Area high level storm sewers	JAM-005/007	-	-	Abandon – Cannot meet LTCP schedule[1]
T-10	Inline storage	JAM-005/007	-	-	Abandon – HGL increase in East and West Int.
T-11	Wetlands treatment of stormwater	JAM-005/007	-	-	Abandon – Cannot meet LTCP schedule
T-13	**Environmental Dredging**	**JAM-005/007**	**611**	**$27 M**	**Retain – Removes deposited CSO solids**

Notes:
1) Implementation of high level storm sewers requires completion of downstream storm sewer spines to provide sufficient capacity to convey the diverted storm water to Thurston Basin. This work is included in the storm sewer buildout plans for Thurston Basin, but cannot be completed within the 2040 timeline established for the LTCP.

Attachment B
Basis of Modeling Memo

CSO-LTCP: Basis for Modeling	
Location:	**Jamaica Bay and Tributaries**
Version:	**September 22, 2015; Revised July 17, 2018 and August 13, 2019**

The 2012 Combined Sewer Overflow (CSO) Consent Order (DEC Case No. CO2-20110512-25) requires the New York City Department of Environmental Protection (DEP) to develop 11 approvable CSO Long Term Control Plans (LTCPs). One critical step in developing an LTCP is establishing modeling conditions. DEP has had numerous technical meetings with the New York State Department of Environmental Conservation (DEC) over the duration of the project to discuss and confirm the proposed conditions and modeling results that are required in the City's LTCPs. This Basis for Modeling for Jamaica Bay and Tributaries document summarizes modeling assumptions, simulation approaches and post-processing results.

Major points are:

1. The tributaries included in this analysis that received CSO and stormwater discharges were: Paerdegat Basin, Fresh Creek, Hendrix Creek, Spring Creek, Bergen Basin, and Thurston Basin. Tributaries included in the analysis that received stormwater discharges only were: Head of Bay, Shellbank Basin and Hawtree Basin in addition to Jamaica Bay. Waterbodies receiving WRRF effluent included Jamaica Bay, Rockaway Inlet, Bergen Basin, and Hendrix Creek.

2. The CSO flow and quality data collected during 2015, and supplemental data collected in 2016 and 2017, was used to update the model inputs.

3. CSO, DEP MS4 stormwater, airport outfalls, other stormwater discharges, direct drainage, and other component loads were identified. It should be noted that, except as further described below, tributary drainage areas for direct drainage, highway runoff and sources of stormwater had not been fully delineated by DEP or obtained from other agencies. These drainage areas were estimated based on GIS mapping, aerial photographs, land use maps, and topographic maps rather than detailed topographic surveys and sewer maps. The InfoWorks CS™ (IW) watershed model, therefore, had a lumped representation of stormwater areas and features. Hence, urban stormwater flows and loads represented estimates rather than definitive values. BWSO MS4 delineations for the Jamaica and 26th Ward sewersheds were included in the LTCP IW modeling in an effort to provide for better estimates of the stormwater and consistency between DEP's MS4 work and this LTCP work. In addition, the LTCP team re-assessed the JFK airport delineations and created a separate airport/transportation category.

4. The four WRRFs (26th Ward, Coney Island, Jamaica, and Rockaway) were modeled based on the nitrogen removal upgrades specified in the First Amended Nitrogen Consent Judgment.

5. Two CSO retention facilities (Paerdegat Basin and Spring Creek) were explicitly included in the InfoWorks models.

6. Planned High Level Storm Sewers (HLSS) in the Fresh Creek drainage area was included (referred to as "full build-out")

7. The modeling approach and simulations were based on the modified approach approved by DEC on the February 13, 2015 conference call.

8. In cases where high fecal coliform-to-*Enterococci* ratios existed, and the source of high fecal coliform concentrations was not resolved, the bacteria model calibration/validation was based on the *Enterococci* data. Fecal coliform was based on model results using a calibration guided by the *Enterococci* calibration and fecal coliform loads as outlined below.

9. The model included a representation of the potential recommended conveyance alternative for the Jamaica WRRF Drainage Area Facility Planning project, including a limited recalibration based on metered data from the three sanitary trunks feeding the East Interceptor

The results for the modeling are presented in Sections 6 and 8 of the LTCP: Section 6 is entitled "BASELINE CONDITIONS AND PERFORMANCE GAP" and Section 8 is entitled "EVALUATION OF ALTERNATIVES." Both sections of the LTCP include results from the computer modeling work.

The tables and figures that summarized the output from these modeling results, and were included in Sections 6 and 8 and Appendix A, are described in the Post-Processing discussion below.

Modeling Assessment Conditions

Models

The InfoWorks CS™ collection system model was used to generate CSO and stormwater flows and volumes, and the Jamaica Bay Eutrophication Model (JEM) was used to compute pathogen and DO concentrations in the receiving waters. Each of these models is described below.

InfoWorks CS™

- InfoWorks CS™ – The commercially available InfoWorks (IW) model was applied to the sewersheds to develop CSO, stormwater and direct drainage loadings to Jamaica Bay. Three distinct IW models were used to cover the Owls Head, Coney Island, 26th Ward, Jamaica and Rockaway WRRF drainage areas. The Owls Head and Coney Island WRRF areas were integrated into a single IW model network due to certain hydraulic interconnections. Similarly, the 26th Ward and Jamaica areas were integrated into a combined 26th Ward/Jamaica IW model. The starting point for the IW models was the recalibrated (2012) models that include the following updates:
    - The InfoWorks Citywide Recalibration Report, Updates to and Recalibration of the October 2007 Landside Models, New York City, Department of Environmental Protection, June 2012.
    - Latest information on build out for HLSS in the Fresh Creek area.
    - Latest information on the Bergen Basin Parallel Sewer to Jamaica WRRF project (additional sewer crossing Belt Parkway) and Improvements to Regulators JA-03, JA-06 and JA-14 project.
    - Latest information on the Jamaica WRRF Drainage Area Facility Planning project, including a limited recalibration based on metered data from the three sanitary trunks feeding the East Interceptor and the projected additional sanitary flow associated with the rezoning
- While the Owls Head/Coney Island, 26th Ward/Jamaica, and Rockaway IW models contained detailed representations of CSO drainage areas, as well as CSO regulator/outfall dimensions and configurations, they contained a limited, lumped representation of separate storm sewer and direct drainage areas and features. As noted previously, the drainage areas tributary to permitted stormwater outfalls, as well as direct drainage areas (and any other areas contributing separate storm loadings to the receiving water), were not necessarily calibrated to flow monitoring data, nor were they intended to have the same level of detail or resolution as CSO features in the model. In many cases, while the drainage areas were included for loading purposes, multiple stormwater outfall pipes were lumped together in the model as single, larger outfalls for simplicity. This approach provided a means to roughly estimate the loading of stormwater to the receiving water, but

provided a limited ability to extract information pertaining to specific stormwater outfalls located in the study area.

- For the purposes of this LTCP, the project team incorporated BWSO desktop MS4 delineation mapping information for the Jamaica and 26th Ward WRRF sewersheds, which was provided to the LTCP team in October 2017. These delineations were included in the initial modeling assessments and all results provided in LTCP Sections 6 and 8, as well as Appendix A loading tables.
- Updates made as part of the below efforts were also included:
  - The IW models were recalibrated at JAM-001, JAM-003 (at Regulator JA-03), JAM-003A (at Regulator JA-14), JAM-005 (at Regulator JA-06), JAM-007 (at Regulator JA-07), 26W-003 and 26W-004, utilizing flow meter data collected for the LTCP in 2015.
  - The model included a recalibration to support the Jamaica WRRF Drainage Area Facility Planning project.
  - Recalibration activities will be reported in a stand-alone technical memorandum entitled "Jamaica Bay and Tributaries Water Quality and Sewer System Modeling Technical Memorandum." It is anticipated that this document will be submitted in July 2018 after the modeling work and LTCP submission are completed.

Jamaica Bay Eutrophication Model

- The Jamaica Bay Eutrophication Model (JEM), as developed for larval transport analysis and used for post-construction monitoring (PCM) modeling at the Paerdegat Basin CSO Facility and Spring Creek Auxiliary Wastewater Treatment Plant (AWWTP), was the starting point for the water quality modeling of Jamaica Bay and its tributaries. Water quality data used in JEM water quality model recalibration efforts included 2015 DEP Harbor Survey data, DEP Sentinel Monitoring Data, National Park Service and data collected as part of the LTCP project in 2015. Recalibration/verification of the water quality model will also be presented in the "Jamaica Bay and Tributaries Water Quality and Sewer System Modeling Technical Memorandum."

Baseline Conditions

A set of conditions was developed for evaluation of future water quality conditions, with and without additional CSO controls. A separate technical memorandum entitled "LTCP2 Baseline Conditions" describes these baseline conditions and the reasons why they were selected. The following are excerpts from that memo and specifics related to those conditions for Jamaica Bay and Tributaries.

Rainfall Conditions:

- Calendar year 2008 rainfall conditions from JFK Airport rain gauge for single year evaluations.
- Calendar year 2002 through 2011 from JFK Airport rain for continuous water quality simulations.
  - Based on recent LTCPs, the time-to-recovery analysis was based on the 2002 through 2011 JFK rainfall, instead of the August 15, 2008 storm.
- Future alternative analyses used JFK Airport rainfall spread equally to all catchments and subcatchments citywide.

WRRF Projected Sanitary Flows:

- Revised 2040 projected sanitary flow based on BEPA July 2014 projections. (July 14, 2014 memo Angela Licata and Pinar Balci – NYC DEP to Distribution, 2014 Water Demand and Wastewater Flow Projections.)
  - Coney Island WRRF sanitary flow = 78.8 MGD
  - 26th Ward WRRF sanitary flow = 44.9 MGD
  - Jamaica WRRF sanitary flow = 87.7 MGD
    - comprised of the 76.5 MGD 2040 projected sanitary flow plus 11.2 MGD (peak 13 MGD) of flow associated with the rezoning under the Jamaica WRRF Drainage Area Facility Planning project
  - Rockaway WRRF sanitary flow = 20.7 MGD

<u>WRRF Wet Weather Flows:</u>

- Two Times Design Dry Weather Flow (2xDDWF) as plant wet weather flows to estimate CSO capture volumes.

<u>Grey Infrastructure - CSO Controls:</u>

- Existing CSO control structures included the Spring Creek AWWTP and the Paerdegat Basin CSO Facility. Both facilities store CSO that overflows regulator weirs and discharge flow to the receiving waterbody once the storage volume is exceeded. Pump back of the captured CSO volume after a storm event was modeled explicitly for each facility.

- CSO controls included all cost-effective grey (CEG) infrastructure included in the 2012 CSO Order on Consent.
  - For the Jamaica WRRF sewershed these projects included:
    - Regulator Modifications at JA-03, JA-06 and JA-14
      - bending weirs at all three regulators
      - increased orifice opening size at Regulator JA-03 from 36”x48” to 61.5”x74”
    - Bergen Basin Parallel Interceptor Sewer Project
      - relief sewers for existing twin-36” sewers: a new 54” single sewer, followed by twin-36” sewers (in series)
    - Automation of Regulator JA-02
      - actuator to control flow at the regulator; under dry conditions, the regulator conveys flow to the Jamaica WRRF via the Howard Beach Pump Station; under wet weather conditions, the regulator diverts flow to the Spring Creek AWWTP for retention
  - For the 26th Ward WRRF sewershed these projects included:
    - HLSS in Fresh Creek tributary area
  - Infiltration and inflow (I&I) from the storm and combined sewers tributary to the Paerdegat Basin CSO Facility and the Spring Creek AWWTP was included in the analyses. I&I flows were based on existing conditions.

<u>Planned BWSO Sewer Projects:</u>

- The potential gravity trunk sewer to support redevelopment of downtown Jamaica was included in the Baseline Conditions. It is possible that the retained alternative for the Jamaica WRRF Drainage Area Facility Planning project may be a pump station/force main, but no alternative had been selected at the time the Baseline Conditions were finalized. The parameters adjusted during the calibration to support the Jamaica WRRF Drainage Area Facility Planning project were also updated in the Baseline Conditions model.

- It is recognized that BWSO storm sewer build-out planning is ongoing and capital projects planned within the 2040 LTCP Baseline Conditions planning period may change as the LTCP development progresses. Given the uncertainty over the schedule and specific scope of these projects, the Southeast Queens storm sewer buildout was not included in the baseline conditions. However, per DEC's request, conceptual modeling has been performed for the purposes of simulating the changes in CSO and stormwater to Thurston and Bergen Basins upon completion of the SEQ Buildout.

Sewer Sediments:

- Sediment conditions were representative of post cleaning observations from Citywide Interceptor Cleaning Program.

- No sediments in sewers except as measured during model calibration.

Green Infrastructure (GI):

The NYCDEP Bureau of Engineering Design and Construction (BEDC) and the Bureau of Environmental Planning and Assessment (BEPA) have completed or are in the midst of implementing GI projects within a number of sewersheds tributary to Jamaica Bay.

BEPA and their GI modeling consultants provided Hazen and Sawyer with an InfoWorks CS model incorporating all Baseline Condition GI on May 7, 2018. This model included three major types of GI implementation:

1) Lumped detention: Physical location and size of the detention practice has not yet been identified. The total impervious area managed by detention across an outfall is applied to the model. A portion of flow is restricted, so that its release to the sewer system is delayed.

2) Distributed retention: The physical location and size of the retention practice is known and modeled. Additionally, individual infiltration rates obtained during field investigations are applied to each practice. The runoff generated across the impervious area managed by the practice is removed by infiltration and completely bypasses the sewer system.

3) Lumped retention: Physical location and size of the retention practice has not yet been identified. The total impervious area managed by retention across an outfall is applied to the model. The runoff generated across the impervious area managed by the practice is removed by infiltration and completely bypasses the sewer system.

The greened acres associated with GI implementation in this model is summarized in Table 1 below:

Table 1. Baseline Condition: Greened Acres

Waterbody/ Designation/ GI Type	Bergen Basin		Thurston Basin		Fresh /Hendrix Creek	Spring Creek	Paerdegat Basin	Grand Total
	Combined	Storm	Combined	Storm	Combined	Combined	Combined	
Lumped Detention	132.1	0	0	0	117.5	38.0	55.7	343.3
Distributed Retention	130.1	0.2	0	0	146.1	93.5	5.0	374.9
Lumped Retention	5.6	2.8	0	0	8.0	10.0	58.8	85.2
Total Acres Managed by Waterbody	267.8	3.0	**0**	**0**	271.6	141.5	119.5	803.4

Ambient Conditions

- WRRF effluent loadings were assumed to represent future conditions consistent with the Nitrogen Consent Judgment. Effluent limits for BOD and nitrogen at the Jamaica, 26th Ward, Rockaway, and Coney Island WRRFs were set so that nitrogen removal was fully operational.
- For tides, winds and ambient conditions (river flows), used 2008 conditions.
- For 2002 to 2011, continuous bacteria simulations used tides and ambient conditions from 2002-2011.
- Sea Level Rise based on 2050 projections was included only when sea level rise sensitivity was assessed.

Water Quality Standards

- Existing Water Quality (Tributaries) Criteria – Class I
  - Fecal GM ≤ 200 cfu/100mL - calendar month – annual
  - DO never less than 4.0 mg/L at any time
- Primary Contact Water Quality (existing Class SB Criterion in Jamaica Bay and upgraded fishable-swimmable criteria in tributaries)
  - Fecal GM ≤ 200cfu/100mL - calendar month – annual
  - DO Chronic Standard: Daily average ≥ 4.8 mg/l*
  - DO Acute Standard: never less than 3.0 mg/L

* Chronic standard based on daily average. The DO concentration may fall below 4.8 mg/L for a limited number of days, as defined by the formula:

$$\mathrm{DO_i} = \frac{13.0}{2.80 + 1.84e^{-0.1t_i}}$$

where DO_i = DO concentration in mg/L between 3.0 – 4.8 mg/L and t_i = time in days. This equation is applied by dividing the DO range of 3.0 – 4.8 mg/L into a number of equal intervals. DO_i is the lower bound of each interval (i) and t_i is the allowable number of days that the DO concentration can be within that interval. The actual number of days that the measured DO concentration falls within each interval (i) is divided by the allowable number of days that the DO can fall within interval (t_i). The sum of the quotients of all intervals (i …n) cannot exceed 1.0: i.e.

$$\sum_{i=1}^{n} \frac{t_i(\text{actual})}{t_i(\text{allowed})} < 1.$$

- Amended *Enterococci* WQ Criteria[1]
  - o *Enterococci* 30-day rolling GM ≤ 35 cfu/100mL – May 1st through October 31st (Recreational Season)
  - o *Enterococci* standard threshold value (STV) 90th percentile ≤ 130 cfu/100mL (Recreational Season)
- Compliance was defined as being at 95 percent attainment of the standard or higher
- The Amended *Enterococci* WQ Criteria* were not yet been promulgated as of the date of submittal of the LTCP. As such, the assessment of attainment of the Amended *Enterococci* WQ Criteria* was completed for comparison purposes only.

CSO, Stormwater, Highway Runoff, Direct Drainage and other Urban Stormwater Loadings

Bacteria Loading

In order to develop loads for the Jamaica Bay model, the pathogen concentrations were first defined for each of the outfalls that discharge into the model domain. Each outfall has a defined land surface which drains stormwater runoff. Each of these outfall drainage areas was visually inspected using aerial photographs from USDA taken in 2015. The drainage areas were categorized as either residential, impervious non-residential, or undeveloped. Typical concentrations for direct drainage were used for the undeveloped drainage basins. The same concentrations that were used for LaGuardia Airport in the Flushing Bay LTCP model were used for all areas defined as impervious non-residential. The remaining basins were defined as residential, and the stormwater concentrations were dependent on the WRRF sewershed in which they resided.

Pathogen concentration data were collected at several CSO outfalls during the calibration period. For those outfalls, the data was analyzed, and a determination was made as to whether the concentration data was log-normally distributed. A Monte Carlo distribution of 100 unique concentrations was developed based on the mean and the standard deviation of the log of the data from each outfall. The Monte Carlo analysis produced a unique randomized concentration for each hour, with the overall statistical distribution of all the values matching the statistical distribution of the data. Pathogen loadings were calculated for each hour by multiplying the concentration generated by the Monte Carlo analysis by the flow generated by the IW model. The Monte Carlo concentrations were used for all outfalls where the loading was capable of reproducing the receiving water data. In some cases, the data was insufficient to represent the overflow concentrations from certain outfalls. In these cases the mass balance concentrations were applied.

Pathogen data were collected at the Thurston Basin regulators, so the normal loading approach would be to use the Monte Carlo approach at this location. However, due to the interactions between CSO and stormwater in the outfalls to Thurston Basin, and to have a consistent loading approach for the calibration and projection runs, the mass balance approach was used to assign concentrations at the Thurston Basin CSO outfalls.

Loadings to the water quality model were developed from IW flows and associated concentrations:

- Bacteria loading from the WRRFs was based on Monte Carlo analysis of the 2015 plant effluent data for fecal coliform. Since *Enterococci* is not measured in the effluent, a concentration equal to half of the fecal coliform concentration was assigned. The geometric mean of the fecal coliform concentration at each WRRF is presented in Table 2.

Table 2. Geometric Mean Fecal Coliform Concentrations at Each WRRF

* *The amended Enterococci WQ Criteria apply during the recreation season (May 1 to October 31) and do not apply to the tributaries to Jamaica Bay. They are effective November 1, 2019.* They only apply to Class SB and SA waters.

WRRF	Fecal Coliform (#/100mL)
26th Ward	12
Coney Island	21
Jamaica	13
Rockaway	9

- Direct drainage concentrations reflected recent updates to direct drainage bacteria concentrations derived from the low end concentrations from the 2005 Memo (HydroQual 2005, May 4, 2005, NY/NJ Harbor Estuary Program Model Application of Stormwater Sampling Results, Technical Memorandum from Charles Dujardin and William Leo to Chris Villari - NYC DEP), from the NYS Stormwater Manual and from experience in the Charles River watershed.
    - Fecal coliform = 4,000 #/100mL
    - *Enterococci* = 6,000 #/100mL
- The stormwater bacteria concentrations were based upon the HydroQual 2005 Memo for all waterbodies except Bergen and Thurston Basins. The 2005 memo classified the 26th Ward and Coney Island WRRFs as high level urban concentration sewersheds and the Jamaica and Rockaway WRRFs as low level urban concentration sewersheds. Stormwater sampling performed in Bergen Basin and Thurston Basin found bacteria concentrations to be higher than those recommended in the 2005 Memo and were increased accordingly.
- Stormwater loading will be based on the assigned concentrations and calculated flows from InfoWorks.
- IW catchments will be examined to determine whether parks and cemeteries and other open and non-urban areas are properly classified as direct drainage catchments and not stormwater catchments and necessary adjustments will be made.
- The Nassau County drainage area that discharges into Head of Bay and the eastern end of Jamaica Bay will be added to InfoWorks to account for the volume of runoff from Nassau County. Nassau County stormwater concentrations will be based on the direct drainage concentrations used in the calibration process.
- CSO concentrations at outfalls where CSO sampling data were collected were based on 2015 and 2016 measurements:
    - The Monte Carlo approach was used to calculate CSO bacteria concentrations for Outfalls 26W-003, JAM-003, JAM-003A, and PB-CSO.
    - Rounded geometric means of the LTCP sampling results from CSOs that form the basis of the Monte Carlo approach are provided in Table 3.

Table 3. Geometric Means of CSO Sampling Data

Outfall	Fecal Coliform, #/100 ml	*Enterococcus*, #/100 ml
26W-003	215,000	155,000
JAM-003 & JAM-003A	665,000	545,000
PB-CSO	970,000	515,000

- Monitoring data collected at the Paerdegat Basin CSO Facility was used to developed overflow concentrations using the Monte Carlo methodology.

- CSO monitoring covered many of the major CSOs that are expected to overflow. For other CSOs that overflow, the mass balance approach was used based on sanitary concentrations in the HydroQual (2005) memorandum:
  - Sanitary fecal coliform = 4,000,000 cfu/100mL
  - Sanitary *Enterococci* = 1,000,000 cfu/100mL

- For the mass balance modeling simulations, CSO concentrations were calculated using the stormwater and sanitary concentrations, multiplied by the flow calculated by the IW model. The model provided a calculated fraction of flow from stormwater and flow from sanitary sources, as follows:

  $$C_{cso} = fr_{san}*C_{san} + fr_{sw}*C_{sw}$$

  where: C_{cso} = CSO concentration

  C_{san} = sanitary concentration

  C_{sw} = stormwater concentration

  fr_{san} = fraction of flow that is sanitary

  fr_{sw} = fraction of flow that is stormwater

  Further details will be provided in the modeling technical memorandum entitled “Jamaica Bay and Tributaries Water Quality and Sewer System Modeling Technical Memorandum.”

- The flow monitoring at 26W-003, 26W-004, JAM-003, JAM-003A, JAM-005, JAM-007 under this LTCP contract was used to assess the calibration of the InfoWorks model.

Table 4 summarizes the bacteria source concentrations used for water quality modeling.

Table 4. Bacteria Source Concentrations Used for Water Quality Modeling

Source	Fecal Coliform (cfu/100mL)	*Enterococci* (cfu/100mL)	BOD_5 (mg/L)
Urban SW - Bergen Basin(1)	45,000	55,000	15
Urban SW - Rockaway(2)	35,000	15,000	
Urban SW - All Others(2)	120,000	50,000	
Sanitary for Mass Balance CSOs(3)	4,000,000	1,000,000	Mass Balance (Sanitary=110)
CSOs (26W-003, JAM-003, JAM-003A, PB-CSO)(4)	Monte Carlo	Monte Carlo	Mass Balance (Sanitary =110)
CSOs (All others)	Mass Balance	Mass Balance	Mass Balance (Sanitary=110)
Highway/ Airport Runoff (5)	20,000	8,000	15
Direct Drainage(6)	4,000	6,000	15
WRRF Effluent(7)	Monte Carlo	Monte Carlo	Quarterly

Notes:

(1) Stormwater bacteria concentrations based on 2015-2017 Jamaica Bay and Tributaries LTCP measurements. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2012).

(2) Stormwater bacteria concentrations based HydroQual Memo to DEP, 2005a. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2012).

(3) Sanitary bacteria concentrations from the HydroQual Memo to DEP, 2005a. BOD concentrations based on Jamaica Bay Waterbody/Watershed Report (2012).

(4) Monte Carlo based on 2015 LTCP CSO data.

(5) Highway/Airport runoff concentrations based on airport drainage data used in the Flushing Bay LTCP model estimated from NYS Stormwater Manual, Charles River LTCP, National Stormwater Data Base.

(6) Direct drainage bacteria concentrations based on NYS Stormwater Manual, Charles River LTCP, and National Stormwater Data Base for commercial and industrial land uses. Direct drainage BOD_5 concentrations specified as stormwater.

(7) WRRF effluent bacteria concentrations based on 2016 DMR measurements: Monte Carlo selection of daily averages for fecal coliform and median of several months for *Enterococci*. BOD concentrations based on quarterly BioWin model results from the FANCJ analysis.

Eutrophication Loading

- The sanitary and stormwater concentrations used for the eutrophication modeling were based on the previous Jamaica Bay Eutrophication Study. The applied concentrations are shown in Table 5.

Table 5. Sanitary and Stormwater Concentrations for Eutrophication Model

Constituent	26th Ward Sanitary (mg/L)	Coney Island Sanitary (mg/L)	Jamaica Sanitary (mg/L)	Rockaway Sanitary (mg/L)	Stormwater (mg/L)
Organic P	1.22	1.65	1.09	1.34	0.16
Phosphate	2.27	1.63	2.39	1.75	0.11
Organic N	9.28	10.81	12.47	8.00	1.3
Ammonia	16.26	10.85	19.20	10.54	0.27
Nitrite + Nitrate	0.18	0.40	0.28	0.72	0.51
Silica	6.96	7.22	10.03	7.82	1.45
Organic Carbon	58.8	88.0	83.4	42.2	16.5
Dissolved Oxygen	1.0	1.0	1.0	1.0	6.3

- The WRRF effluent concentrations used for the eutrophication modeling were based on BioWin results for the First Amended Nitrogen Consent Judgment and 2015 data. Concentrations varied on a monthly basis and ranges are presented in Table 6.

- Note the model directly modeled carbon and not the indirect measurement of carbon that is BOD. BOD can be calculated based on the carbon concentrations and the carbon oxidation rates used in the model. Conversely, carbon concentrations for loads can be calculated from BOD concentrations using the carbon oxidation rates.

Table 6. WRRF Effluent Concentrations for Eutrophication Model

Constituent	26th Ward WRRF Range (mg/L)	Coney Island WRRF Range (mg/L)	Jamaica WRRF Range (mg/L)	Rockaway WRRF Range (mg/L)
Organic P	0.4-1.5	0.2-1.6	0.3-1.4	0.2-1.6
Phosphate	1.6-4.1	0.8-2.6	0.4-1.8	1.5-2.2
Organic N	1.0-3.7	1.7-8.0	2.0-3.4	0.7-2.1
Ammonia	2.6-11.3	8.8-21.6	1.9-8.8	1.8-7.7
Nitrite + Nitrate	2.3-7.2	0.8-2.6	0.9-3.7	2.9-11.9
Silica	6.96	7.22	10.03	7.82
Organic Carbon	4.9-13.0	7.7-66.7	6.3-15.4	3.9-10.3
Dissolved Oxygen	3.9-6.2	1.3-3.0	4.4-6.4	6.2-7.9

Assessments

IW Model Assumptions

- Runoff coefficients, roughness, etc., were based on the 2012 Recalibration Report (InfoWorks Citywide Recalibration Report, Updates to and Recalibration of the October 2007 Landside Models, New York City, Department of Environmental Protection, June 2012) unless otherwise modified through local calibration as part of LTCP2. These parameters were updated as needed during the IW calibration analysis based on the 2015 flow measurements.

- Evapotranspiration was based on monthly values as per the 2012 Recalibration.

- BEPA and their GI modeling consultants provided Hazen and Sawyer with an InfoWorks CS model incorporating all Baseline Condition GI on May 7, 2018. In July of 2019 BEPA and their GI modeling consultants instructed Hazen to remove 74 greened acres previously implemented within the combined Laurelton area tributary to Thurston Basin; this is the only GI related change that was made to the Baseline Condition model between 2018 and 2019. The Baseline Model includes a total of approximately 803 greened acres managed by GI across all waterbodies tributary to Jamaica Bay

Jamaica Bay WQ Model Assumptions

- The larval transport version of the JEM model was used to calculate water quality in the Bay.

- The model grid was not further refined.

- The WRRFs were modeled based on the nitrogen removal upgrades specified in the First Amended Nitrogen Consent Judgment.

Water Quality Evaluations

- Alternative CSO control evaluations, dissolved oxygen evaluations, Section 6 (Appendix A) loading table, and Section 6 bacteria component analysis were all developed using calendar year 2008 rainfall conditions from JFK Airport rain gauge.

- Fecal coliform and *Enterococci* Baseline and 100% CSO Control evaluations were run for 2008 conditions and continuous water quality simulations using calendar year 2002 through 2011 from JFK Airport rain gauge. The preferred alternative continuous water quality simulations used calendar year 2002 through 2011 from JFK Airport rain gauge.

- Component analyses was performed to develop the fecal coliform (max. month during year) and *Enterococci* (max. 30-day period during recreational season) GM components for 2008 conditions. The components that were evaluated included CSO, DEP MS4 stormwater and direct drainage, and boundary conditions.

- Only CSO load reduction alternatives that provide input to the Knee-of-the-Curve analyses were assessed.

- The gap analysis was completed using a Baseline and a 100% CSO reduction scenario.

- Simulations consisted of the following:

    - 2002-2011 baseline bacteria simulation

- 2002-2011 100% CSO control bacteria simulation
- 2008 baseline DO simulation
- 2008 100% control DO simulation
- 2008 bacteria component analysis
- 2002-2011 recreation binned precipitation time to recover for fecal coliform

- Alternatives analysis included:
  - Up to six one-year bacteria simulations
  - Up to four one-year DO simulations
  - 2002-2011 bacteria simulation for the preferred alternative

Post-Processing

- Models were post-processed for the following:
  - All IW 2008 model simulations were post-processed for annual average CSO, stormwater and direct drainage overflow volumes.
    - Discharge volume (annual average overflow – AAOV) tables were prepared for each CSO outfall, stormwater and direct drainage location.
  - IW model outputs for the 2002 to 2011 preferred alternative run were prepared with water quality outputs and were used to drive the JEM WQ model of Jamaica Bay and its CSO tributaries.
    - No AAOV tables for the 2002 to 2011 run were prepared for use in the report but AAOV tables were prepared for internal use.
  - WQ models were post-processed for annual attainment (fecal coliform and DO) and recreational season attainment (fecal coliform and *Enterococci*) including:
    - Existing WQ Criteria (Tributaries) – Class I
      - Fecal GM ≤ 200cfu/100mL - calendar month – annual and May 1st through October 31st (Recreational Season)
      - DO never less than 4.0 mg/L
    - Primary Contact WQ Criteria (existing Class SB Criterion in Jamaica Bay and upgraded fishable-swimmable criteria in tributaries)
      - Fecal GM ≤ 200cfu/100mL - calendar month – annual and May 1st through October 31st (Recreational Season)
      - DO Chronic Standard: Daily average >= 4.8 mg/L, and
      - DO Acute Standard: never less than 3.0 mg/L

- Amended *Enterococci* WQ Criteria[2]

  - *Enterococci* 30-day rolling GM ≤ 35 cfu/100mL – May 1st through October 31st (Recreational Season)
  - *Enterococci* STV 90th percentile ≤ 130 cfu/100mL (Recreational Season)
  - *Enterococci* was evaluated for comparative purposes only as DEC had not promulgated the *Enterococci* standards as of the submittal of the LTCP.

- Fecal coliform time-to-recovery tables were calculated based on the 2002-2011 recreation season binned precipitation for Baseline Conditions, the 100% CSO control scenario, and the preferred alternative. Results were presented or "binned" based upon a range of storm sizes.

- Preferred alternative WQ results were prepared from the 10-year simulation for bacteria (fecal coliform and *Enterococci*) and from the 2008 simulation for DO.

2 *The amended Enterococci WQ Criteria apply during the recreation season (May 1 to October 31) and do not apply to the tributaries to Jamaica Bay. They are effective November 1, 2019*. They only apply to Class SB and SA waters.

Attachment C
Sewer System and Water Quality Modeling Report

The City of New York
Department of Environmental Protection
Bureau of Wastewater Treatment

CSO Long Term Control Planning II

Jamaica Bay and Tributaries LTCP

Sewer System and Water Quality Modeling

August 2018

AECOM
with Hazen

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1.0 INTRODUCTION

Collection system and receiving-water quality models were used to support the development and evaluation of combined sewer overflow (CSO) control alternatives as part of the process of developing the Long Term Control Plan (LTCP) for Jamaica Bay and its tributaries. These models were initially developed to represent existing conditions in the collection system and in the receiving waters. Flow metering and sampling programs were then undertaken to provide a basis for calibrating the models against actual measured conditions. Once the collection system models were calibrated, they were further modified to represent the LTCP Baseline Conditions. The baseline conditions models provided the basis for comparing the performance of CSO control alternatives, and included a defined set of future conditions including base sanitary flow, implementation of previously-defined cost-effective grey CSO control projects, and implementation of green infrastructure (GI) over a previously-defined percentage of impervious tributary area.

The collection system and receiving-water quality models used to support the Jamaica Bay and Tributaries LTCP were based on versions of previously-calibrated models used as part of earlier CSO planning efforts. These earlier models were updated with new information and validated with flow and water quality data for use in support of the Jamaica Bay and Tributaries LTCP. This report provides information related to the update and validation of the collection system and water quality models for Jamaica Bay and its tributaries. Section 2 covers the collection system model, and Section 3 covers the water quality models.

Figure 1-1 presents the Jamaica Bay watershed area and Figure 1-2 presents the project area. Figure 1-2 presents the drainage area separated into combined sewer areas, separate sewer areas, and direct drainage, and the CSO and storm sewer outfall names and locations are identified. . It should be noted that areas shown in Figure 1-2 as separated (stormwater) and direct drainage are based on information available at the time the model was developed, and should be considered approximate in some locations.

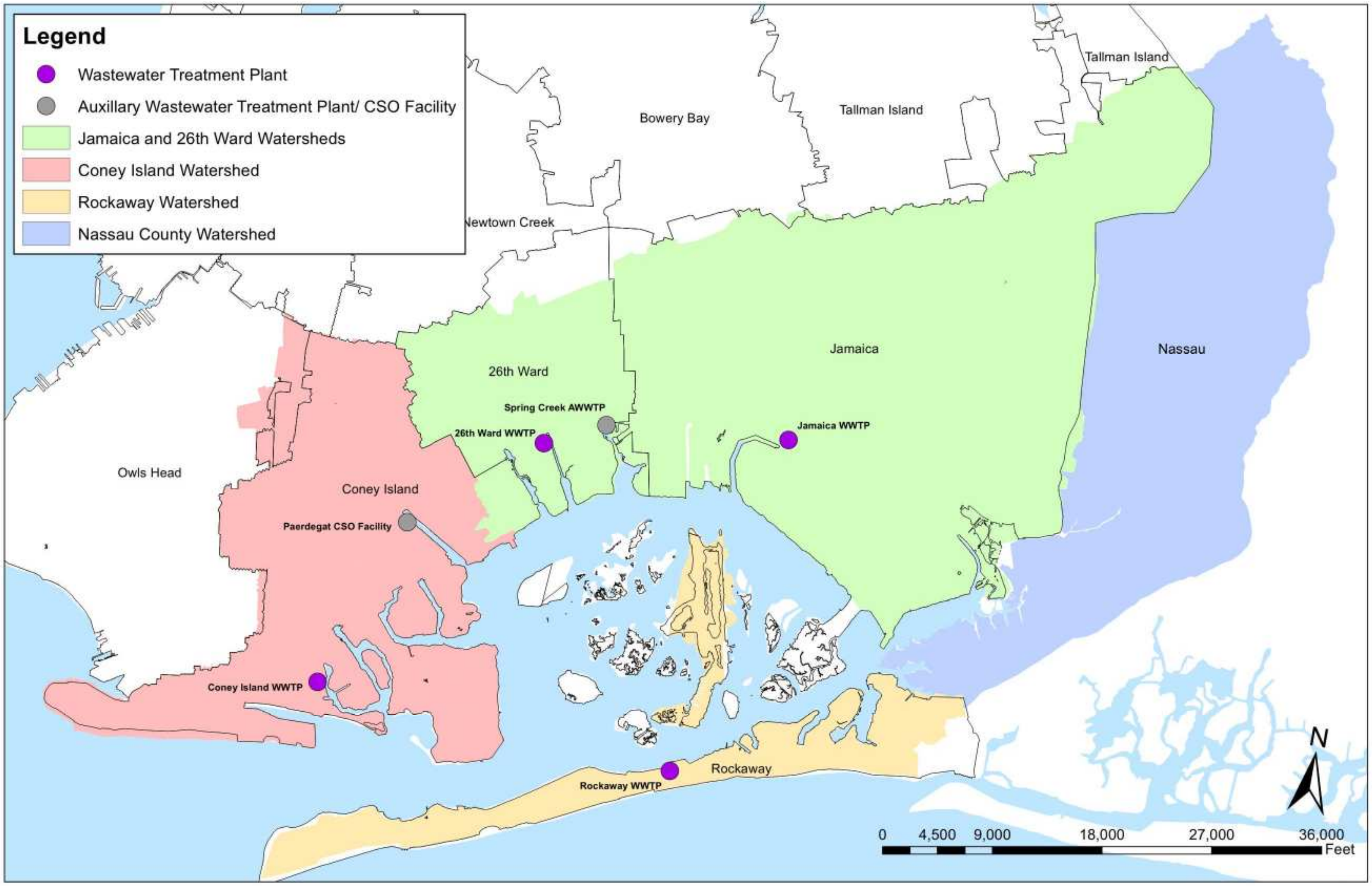

Figure 1-1. Jamaica Bay Watershed Area

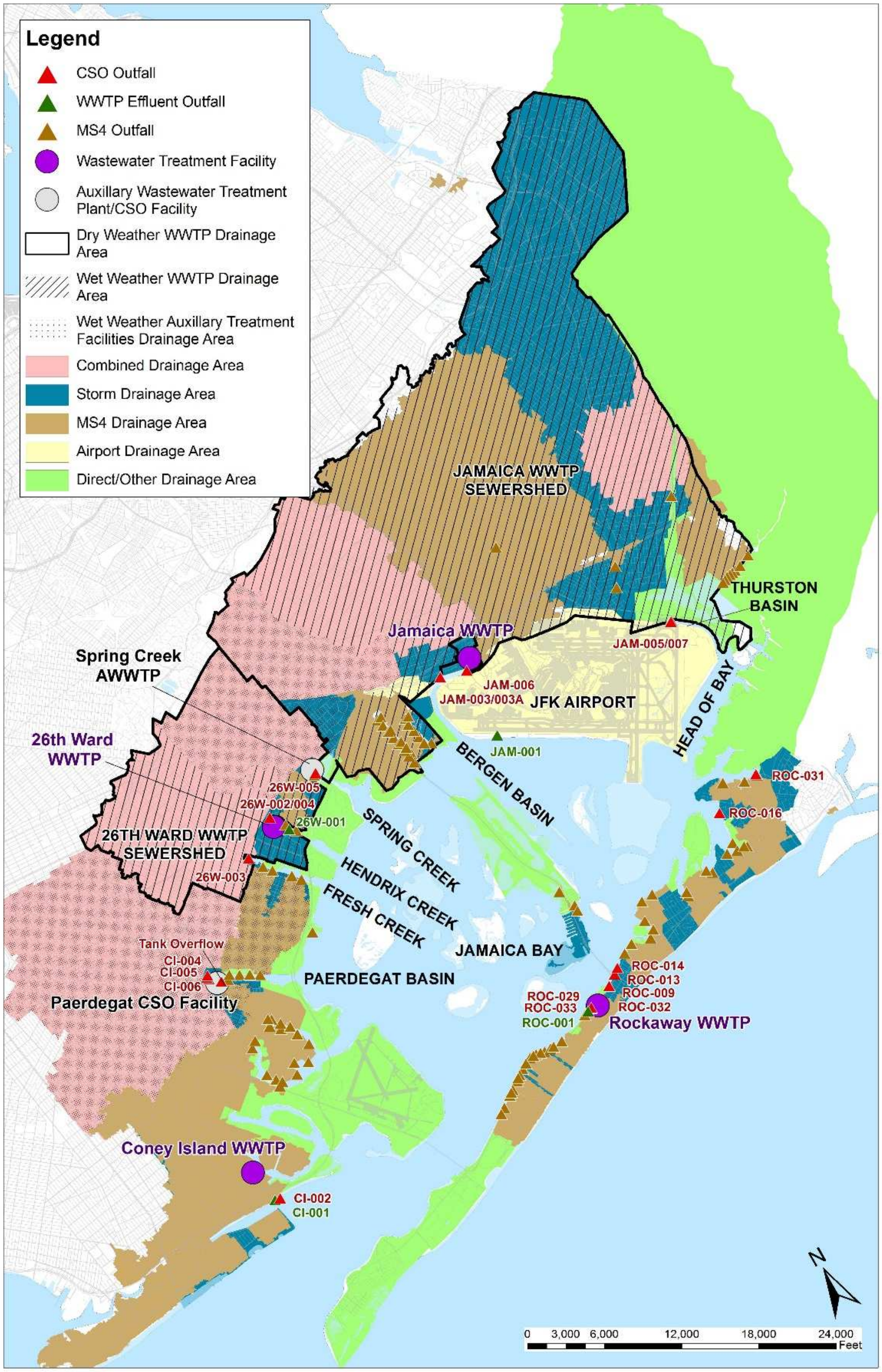

Figure 1-2. Jamaica Bay Project Area

2.0 CSO AND STORMWATER MODELING

2.1 Model Description

The Jamaica, 26th Ward, Rockaway and Coney Island Wastewater Treatment Plant (WWTP) service areas were modeled using InfoWorks CS™ (IW) version 10.5, a link-node hydrologic and hydraulic model that combines a relational database with geographical analysis to provide a single environment for integrated analysis. The hydraulic component of the software incorporates full solution modeling of backwater effects and reverse flow, open channels, sewers, detention ponds, complex pipe connections, and complex ancillary structures such as culverts, orifices, and weirs. The hydrologic component of the IW model incorporates the routines from the U.S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM), a non-linear reservoir routing model developed for the EPA, to route overland runoff. Three distinct IW models were used to cover the Owls Head, Coney Island, 26th Ward, Jamaica and Rockaway WWTP drainage areas. The Owls Head and Coney Island WWTP areas were integrated into a single IW model network due to certain hydraulic interconnections. Similarly, the 26th Ward and Jamaica WWTP areas were integrated into a combined 26th Ward/Jamaica IW model. The Rockaway WWTP service area is addressed as a separate IW model.

All three of the models include: plant headworks, interceptors, branch interceptors, major trunk sewers, all sewers greater than 48 inches in diameter plus other smaller, significant sewers, and control structures such as pump stations, diversion chambers, tipping locations, regulators and tide gates. Figure 2-1, Figure 2-2, and Figure 2-3 present schematics of the model networks.

2.1.a **Previous Modeling Overview**

2007 Model Version

During development of Waterbody/Watershed Facility Plans (WWFP) submitted in the late 2000s to the New York State Department of Environmental Conservation (DEC), IW models were employed for each WWTP service area, as documented in a series of model calibration reports dated October 2007[1]. The reports documented the development process and status of the collection/conveyance system models as of October 2007 and presented results showing the goodness-of-fit between flows and depths calculated by the model and measurements within the collection system conducted at various times prior to 2007. The model versions employed by DEP as documented in these reports were IW versions 6.5 and 7.0.

[1] *There were 14 volumes of the report entitled "City-Wide Long Term CSO Control Planning Project, Landside Modeling Report"; each volume developed for an individual WWTP conveyance system (the 26th Ward, Coney Island, Jamaica, and Rockaway WWTP systems were documented in Volumes 1, 3, 5, and 12, respectively).*

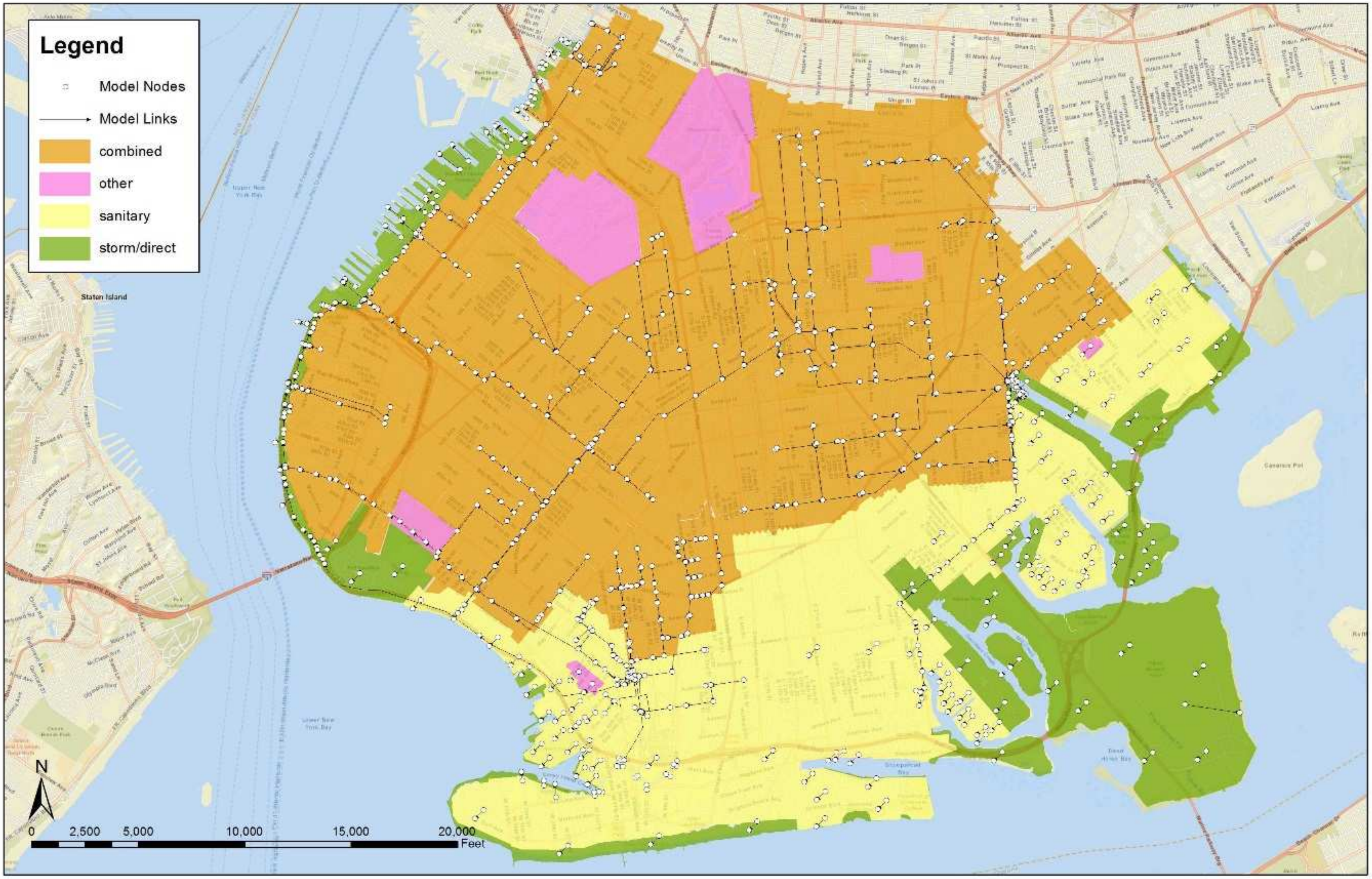

Figure 2-1. Coney Island and Owl's Head WWTP Model Network

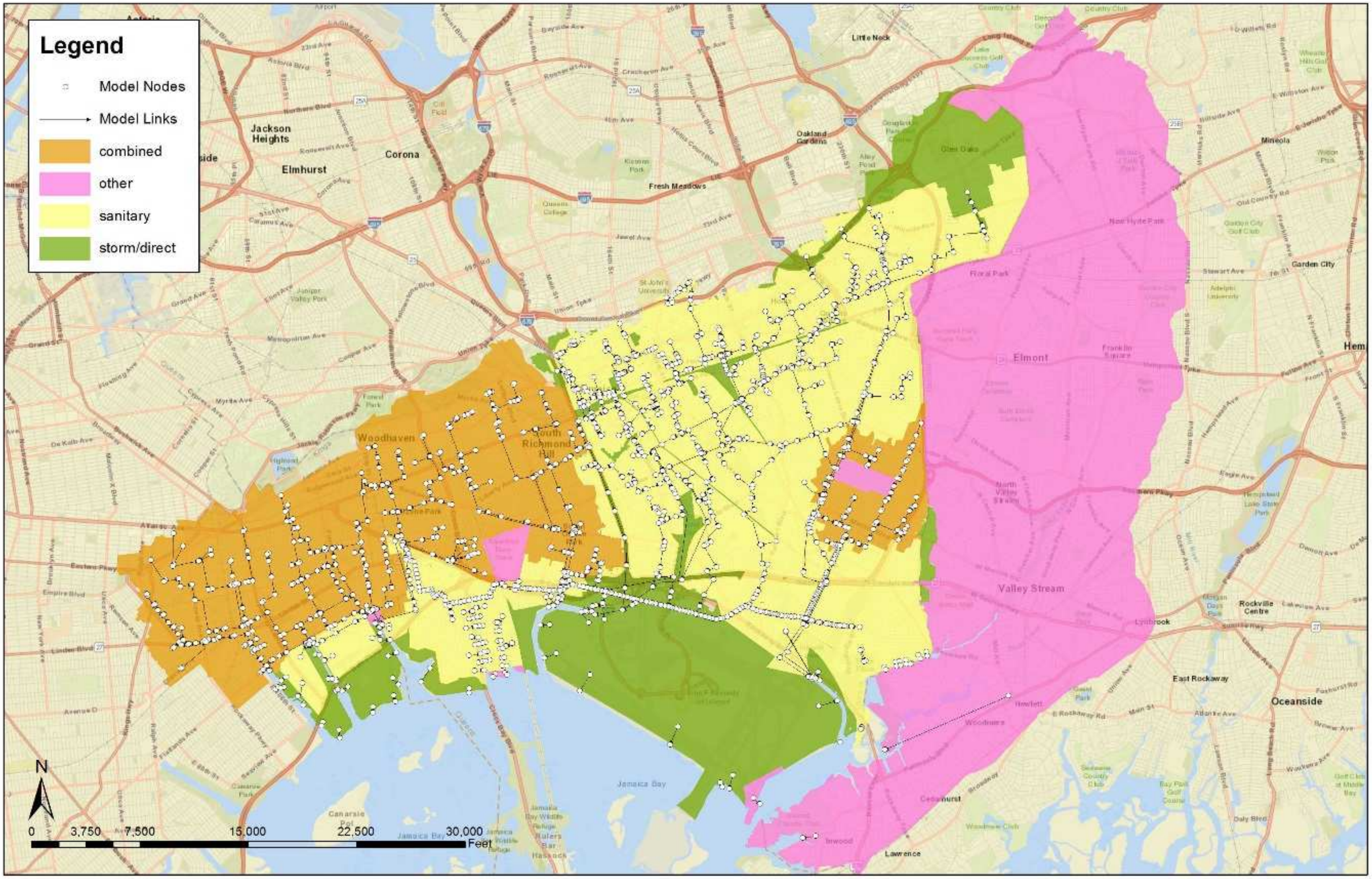

Figure 2-2. Jamaica and 26th Ward WWTP Model Network

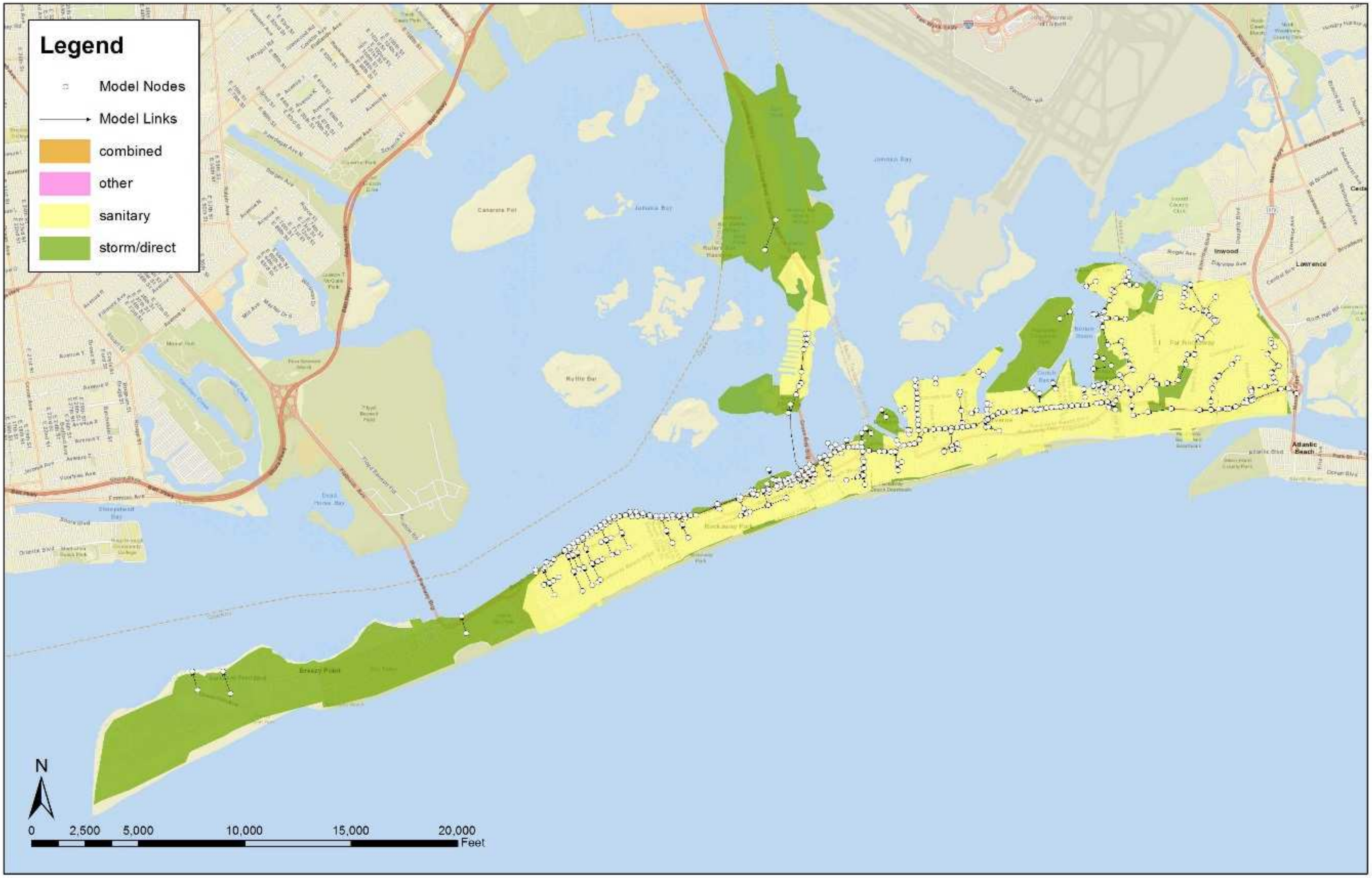

Figure 2-3. Rockaway WWTP Model Network

2012 Model Version

In 2012, the previous models underwent a major recalibration to serve as a better tool for green infrastructure evaluations, among other improvements. The majority of the 2012 model updates focused on the hydrology (i.e., runoff) portion of the model, but other updates were made as described further below. The 2012 update and recalibration is documented in the "InfoWorks Citywide Recalibration Report, Updates to and Recalibration of October 2007 NYC Landside Models, June 2012." The models were recalibrated using a phased approach as follows:

1. Use of site-scale flow monitoring data (to eliminate bias from downstream facilities and hydraulic structures) at a sampling of locations in the City as a localized representation of hydrology only.

2. Use of flow monitoring data located downstream in the system on larger trunk sewers and interceptors as an area-wide representation of both hydrology and hydraulics.

3. Use of facility (e.g., WWTP or CSO storage/treatment facilities) flow data to validate model predictions.

Previously, pervious surfaces were considered to infiltrate rainfall into soils based on the Horton equation. The basic premise of the Horton equation is that the amount of infiltration within the soils is based on the soil properties and that rainfall would continue to infiltrate as long as the intensity was less than the soil absorption capacity. More intense rainfall would produce runoff that would enter the collection system.

In the updated setup, the runoff coefficient approach was adopted for the model after researching the types of soil and infiltration data available from the NYC Water and Soil Conservation Service. In short, the available data would not provide additional insight on surface infiltration characteristics to allow refinement or continued use of the Horton equation approach to characterizing runoff behavior from pervious surfaces. As such, two types of pervious surfaces were developed for each sub-catchment and appropriate land areas developed from Geographical Information System (GIS) analyses: open space pervious surfaces and non-open space pervious surfaces. Open space pervious surfaces included parks, cemeteries, highway medians, and similar surfaces where surface soils were not subjected to consolidation by constant use. Non-open space pervious surfaces were defined as front and back yards in developed areas where soils would likely be consolidated through use. Open space and non-open space pervious surfaces were assigned runoff coefficients consistent with DEP drainage planning design values, as well as common usage in other similar modeling assessments.

In IW, a sub-catchment can have both total impervious area and the fraction of directly connected impervious area (DCIA) specified in the model. DCIA is a term that describes the impervious area that actually produces the runoff that reaches the collection system. Previously, the runoff coefficient for impervious surfaces was assigned an initial value of 1.0, and then the GIS-based imperviousness values were adjusted during calibration. This meant that the total impervious value was adjusted during calibration and it was assumed that all impervious area was directly connected to the sewer system. However, it was recognized that it is more appropriate (particularly to support the future use of the model in evaluating green infrastructure controls) to keep the total impervious area constant and adjust DCIA. This adjustment was made by reducing the runoff coefficient for the total impervious area. The impervious area runoff coefficient was treated as the primary calibration parameter during the recalibration analyses. As a result, the starting value for the impervious surfaces was the area provided by the Columbia University analysis (described in further detail in the 2012 Recalibration Report). This analysis was comprised of procurement of high quality satellite imagery (2.4 meter pixel resolution), followed by translation of each pixel of that imagery to measurements of pervious and impervious fractions. The final value for the DCIA in acres would then be the area provided by the Columbia University analysis multiplied by the final runoff coefficient for the impervious area developed during the recalibration process. This resulted in an approach that utilized the detailed imperviousness data, while controlling the runoff predicted from those surfaces through a coefficient, such that modeled output matched observed data.

In addition, to simulate runoff from impervious areas that have little or no initial rainfall losses (depression storage), one fourth of the impervious areas was assumed to have no initial losses. This assumption was made based on site-scale data analyses (as described above). Thus, the total drainage area in a sub-catchment was subdivided into four types of surfaces: impervious surface without depression storage; impervious surface with depression storage; pervious non-open surface; and pervious open surface.

IW software version 10.5, a more up-to-date version of the model, was employed in the 2012 recalibration effort.

In the 2007 version of the model, an average of 0.1 in/hr evaporation rate was used for model calibration, while no evaporation rate was used in the future condition simulations, as a conservative measure. The Northeast Regional Climate Center (NRCC) affiliated with Cornell University has developed a semi-physical model which estimates hourly evapotranspiration (ET). Continuous hourly ET estimates were obtained from Cornell for the NYC National Oceanic and Atmospheric Administration (NOAA) climate stations (JFK, EWR, CPK and LGA) for an 11-year period from 2000 to 2011. The data were then used to calculate monthly average ET. The monthly average ET rates developed from these long term data were then used in the models. The "June 2012 InfoWorks City-wide Recalibration Report," provides additional information on the revised evaporation rates used in the model.

Finally, detailed pipe sediment data were incorporated into the modeled interceptors to represent a more realistic representation of the pipe conditions after the DEP completed a citywide inspection and cleaning program.

2.1.b **2016 Modifications to Model**

Rainfall and Tides

Previous evaluations of the Jamaica Bay watershed used the 1988 precipitation characteristics as the representative typical precipitation year. However, for this LTCP, the precipitation characteristics for 2008 were used for the baseline condition, as well as for alternative evaluations. In addition to the 2008 precipitation pattern, the observed tide conditions that existed in 2008 were also applied in the models as the tidal boundary conditions at the CSO outfalls that discharge to tidally influenced waterbodies. For longer term 10-year evaluations, the period from 2002 through 2011 was analyzed.

Sanitary Flow Rates

Consistent with previous studies, the dry-weather sanitary sewage flows used in the baseline modeling were escalated to reflect anticipated growth in the City. In the past, flow estimates were based on the 2000 census, and growth rates were estimated by the Mayor's Office and New York City Department of City Planning (DCP), to arrive at projected 2045 sanitary flow rates. These flows were then applied to the model, although they were conservative and did not account for flow conservation measures. The updated analyses uses the 2010 census data to reassign population values to the watersheds in the model and project up to 2040 sanitary flows. These projections also reflect water conservation measures that have already significantly reduced flows to the WWTPs and freed up capacity in the conveyance system.

Other Updates

Certain structures within the Jamaica, 26th Ward, Coney Island, and Rockaway WWTP collection systems have been modeled in more than one configuration, depending on the particular evaluations at the time. Some of these updates are not physically located within the Jamaica Bay watershed, but they may impact flows in this watershed due to hydraulic interconnectivities. Thus, they are summarized below:

- Added two 12" diameter piped interconnections upstream of Regulators JA-03 and JA-14 in the Bergen Basin drainage area of the model.
- Updated the Nassau County drainage area representation in the Jamaica WWTP model.
- Implemented the BWSO drainage area delineations where available in the Jamaica WWTP model.

2.2 Quantity Modeling

2.2.a Monitoring Program and Available Data

Temporary flow monitors were installed to collect flow data at Regulators JA-03 (Bergen Basin), JA-14 (Bergen Basin), JA-06 (Thurston Basin), JA-07 (Thurston Basin), and 26W-01 (Fresh Creek), to validate the current model's CSO discharge predictions. The flow and rainfall monitoring program ran from September 25, 2015 to December 31, 2015. Flow data was obtained at 5-minute intervals. The diagram in Figure 2-4 shows the locations of the flow meters used for the monitoring program.

Rainfall data was collected at the NOAA JFK gauge, as well as at the Jamaica and 26th Ward WWTP rain gauges, and a temporary gauge located near Outfall 26W-003. Radar rainfall data was also obtained and utilized in the model calibration and validation process. Table 2-1 summarizes the storm events observed during the monitoring period for this local gauge.

Figure 2-4. Monitoring Program Overview

Table 2-1. Observed Storm Events at 26W-003 Local (Temporary) Gauge

#	Rain Start	Rain End	Duration (hr)	Peak Intensity (in/hr)	Total Depth (in)
1	9/29/2015 23:20	9/30/2015 5:15	5.9	2.04	1.01
2	10/1/2015 16:55	10/3/2015 13:05	44.2	0.36	2.39
3	10/9/2015 17:45	10/9/2015 19:45	2.0	0.36	0.28
4	10/28/2015 10:50	10/29/2015 8:55	22.1	1.56	1.68
5	11/10/2015 8:55	11/11/2015 8:50	23.9	0.36	0.70
6	11/19/2015 18:00	11/20/2015 1:10	7.2	0.60	0.79
7	12/1/2015 3:25	12/1/2015 22:55	19.5	0.24	0.37
8	12/14/2015 20:15	12/15/2015 2:30	6.2	0.84	0.47
9	12/17/2015 11:05	12/17/2015 17:45	6.7	0.48	1.12
10	12/22/2015 9:05	12/22/2015 16:05	7.0	0.24	0.24
11	12/23/2015 11:00	12/23/2015 23:10	12.2	1.56	1.21
12	12/28/2015 19:20	12/29/2015 11:05	15.8	0.36	0.82
13	12/30/2015 21:00	12/31/2015 0:45	3.8	0.24	0.39

2.2.b **IW Model Quantity Assessment**

The model was used to simulate sewer flows for the rainfall conditions observed during the temporary monitoring period, and calculations were compared to the measured data to evaluate model accuracy. This effort was performed to validate the model's predictive capability for use in typical year LTCP simulations. A validation confirms that the model parameters are appropriate for predicting flows and volumes within reasonable ranges without changing model parameters (as opposed to a calibration, which specifically optimizes model parameters to match measured data).

A "triangulation" approach was utilized, where modeling output, flow monitoring data, and SCADA data (where available), were evaluated with respect to CSO events. Tables 2-2 and 2-3 summarize the comparison for the monitoring period.

Based on the initial comparisons of model-predicted output and measurements, the following modifications were made to the model:

- Dry-weather flow rate was modified to match measured data for the monitoring period.

- Sediment was removed from the Regulator JA-06 influent pipe and branch pipe, to avoid an artificial dry-weather overflow and better match data.

- The runoff coefficient for Thurston Basin upstream separate storm areas where seepage pits were noted was decreased from 0.5 to 0.1. Figure 2-5 shows the approximate locations of seepage pits based on GIS data and conversations with DEP staff.

- The runoff coefficient for a 38-acre local area tributary to JA-06 (influent pipe measured at monitoring location "M2") was decreased from 0.5 to 0.2.

- The runoff coefficient in the 26W-003 tributary area was increased from 0.5 to 0.7.

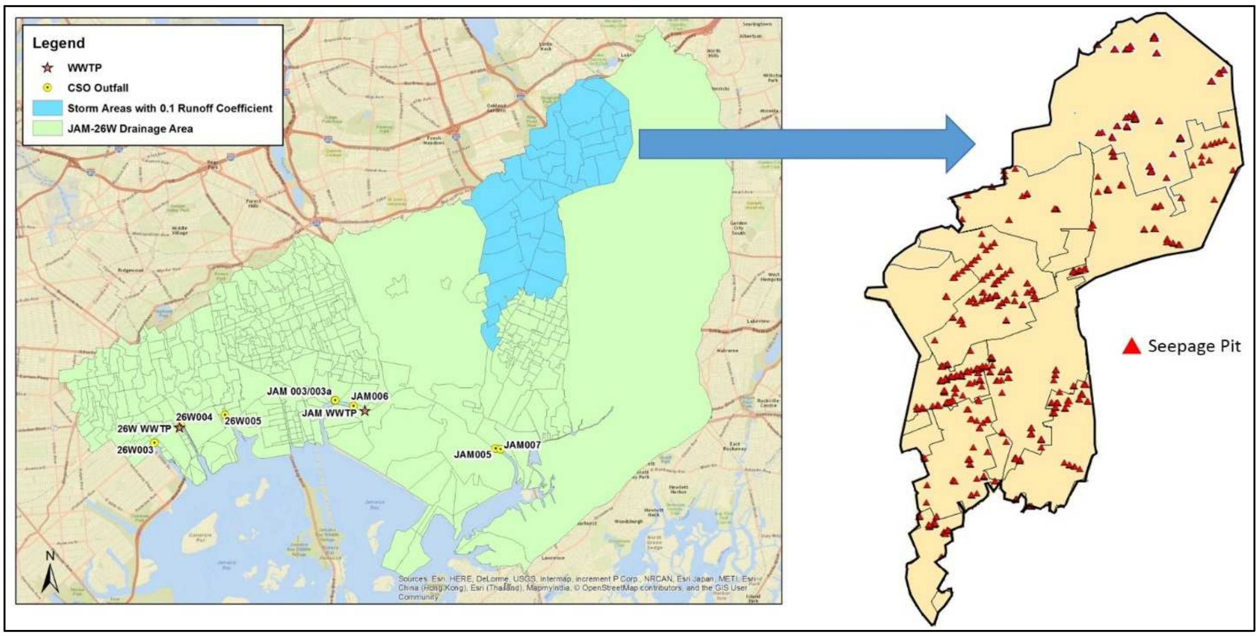

Figure 2-5. Approximate Seepage Pit Locations to Support Model Adjustment

AECOM with Hazen

Table 2-2. Triangulation of Data Sources for Model Calibration

Rain Events During Flow Monitoring Period						CSO Events at 26W-R2 (003)						CSO Events at JA-R6 (005)				CSO Events at JA-R7 (005/007)		
Event #	Rain Start	Rain End	Rain Duration (Hour)	Peak Intensity (Inch/Hour)	Total Depth (Inch)	26W003 Switch1	26W003 Switch2	ADS Metering Data[1]	DEP SCADA[2]	Model Prediction - Local Gauge	Model Prediction - RADAR	ADS Metering Data[5]	DEP SCADA	Model Prediction - Local Gauge	Model Prediction - RADAR	DEP SCADA	Model Prediction - Local Gauge	Model Prediction - RADAR
1	9/29/2015 23:20	9/30/2015 5:15	5.9	2.04	1.01	Y	N	Y	Y	Y	Y	Y		Y	Y		Y	Y
2	10/1/2015 16:55	10/3/2015 13:05	44.2	0.36	2.39	N	N	Y	Y	Y	Y	Y		Y	Y		Y	Y
3	10/9/2015 17:45	10/9/2015 19:45	2.0	0.36	0.28	N	N	N	N	N	N	Y		Y	Y		N	N
4	10/28/2015 10:50	10/29/2015 8:55	22.1	1.56	1.68	N	N	Y	Y	Y	Y	Y		Y	Y		Y	Y
5	11/10/2015 8:55	11/11/2015 8:50	23.9	0.36	0.70	N	N	N	N	N	N	N		Y	Y		N	N
6	11/19/2015 18:00	11/20/2015 1:10	7.2	0.60	0.79	N	N	Y	Y	Y	Y	Y		Y	Y		Y	Y
7	12/1/2015 3:25	12/1/2015 22:55	19.5	0.24	0.37	N	N	N	N	N	N	N	No Data	Y	Y	No Data	N	N
8	12/14/2015 20:15	12/15/2015 2:30	6.2	0.84	0.47	N	N	N	N	N	N	Y		Y	Y		Y	N
9	12/17/2015 11:05	12/17/2015 17:45	6.7	0.48	1.12	N	N	Y	Y	Y	Y	Y		Y	Y		Y	Y
10	12/22/2015 9:05	12/22/2015 16:05	7.0	0.24	0.24	N	N	N	N	N	N	N		Y	Y		N	N
11	12/23/2015 11:00	12/23/2015 23:10	12.2	1.56	1.21	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y	Y
12	12/28/2015 19:20	12/29/2015 11:05	15.8	0.36	0.82	Y	Y	N	N	N	N	Y		Y	Y		Y	N
13	12/30/2015 21:00	12/31/2015 0:45	3.8	0.24	0.39	Y	Y	N	N	N	N	Y		Y	Y		N	N

AECOM with Hazen

Table 2-3. Triangulation of Data Sources for Model Calibration (Continued)

Rain Events During Flow Monitoring Period						CSO Events at JA-R9 (005/007)			CSO Events at JA-R3 (003)				CSO Events at JA-14 (003A)					
Event #	Rain Start	Rain End	Rain Duration (Hour)	Peak Intensity (Inch/Hour)	Total Depth (Inch)	DEP SCADA[2]	Model Prediction - Local Gauge	Model Prediction - RADAR	ADS Metering Data[4]	DEP SCADA	Model Prediction - Local Gauge	Model Prediction - RADAR	JAM003a Switch1	JAM003a Switch2	ADS Metering Data[3]	DEP SCADA[2]	Model Prediction - Local Gauge	Model Prediction - RADAR
1	9/29/2015 23:20	9/30/2015 5:15	5.9	2.04	1.01	N	Y	Y	Y	Data Not Reliable due to Construction	Y	Y	Y	Y	Y	Y	Y	Y
2	10/1/2015 16:55	10/3/2015 13:05	44.2	0.36	2.39	N	N	N	Y		Y	Y	Y	N	Y	Y	Y	Y
3	10/9/2015 17:45	10/9/2015 19:45	2.0	0.36	0.28	N	N	N	Y		Y	Y	Y	Y	Y	Y	Y	Y
4	10/28/2015 10:50	10/29/2015 8:55	22.1	1.56	1.68	N	N	N	Y		Y	Y	Y	No Data	Y	Y	Y	Y
5	11/10/2015 8:55	11/11/2015 8:50	23.9	0.36	0.70	N	N	N	N		Y	Y	Y		N	Y	Y	Y
6	11/19/2015 18:00	11/20/2015 1:10	7.2	0.60	0.79	N	N	N	Y		Y	Y	Y		Y	Y	Y	Y
7	12/1/2015 3:25	12/1/2015 22:55	19.5	0.24	0.37	N	N	N	N		Y	Y	N		N	Y	Y	Y
8	12/14/2015 20:15	12/15/2015 2:30	6.2	0.84	0.47	N	N	N	Y		Y	Y	Y		Y	Y	Y	Y
9	12/17/2015 11:05	12/17/2015 17:45	6.7	0.48	1.12	N	N	N	Y		Y	Y	Y		Y	Y	Y	Y
10	12/22/2015 9:05	12/22/2015 16:05	7.0	0.24	0.24	N	N	N	N		Y	Y	N		N	Y	Y	Y
11	12/23/2015 11:00	12/23/2015 23:10	12.2	1.56	1.21	N	Y	Y	Y		Y	Y	Y		Y	N	Y	Y
12	12/28/2015 19:20	12/29/2015 11:05	15.8	0.36	0.82	N	N	N	Y		Y	Y	Y		Y	Y	Y	Y
13	12/30/2015 21:00	12/31/2015 0:45	3.8	0.24	0.39	N	N	N	Y		Y	Y	No Data		Y	Y	Y	Y

The model was run for the calibration period and the model was evaluated using the criteria suggested in the Wastewater Planning Users Group (WaPUG, 2002) guidance document. The criteria were:

- The timing of the peaks and troughs should be similar, having regard to the duration of the event.
- The difference between observed and modeled peak flow rates at each significant peak should be in the range +25 percent to -15 percent and should be generally similar throughout the complete simulation of each event.
- The differences between observed and modeled volume of flow should be in the range +20 percent to -10 percent.
- The differences between observed and modeled depth of surcharge should be in the range +16 inches to –4 inches.
- The differences between observed and modeled un-surcharged depth at any key points, where un-surcharged depth is important in regard to the objectives of the model (e.g., at combined sewer overflows), should be within the range ±4 inches.

For each validation event, modeled versus observed hydrographs were generated to evaluate the model's performance. In addition, the goodness-of-fit was also examined by comparing the modeled event volume, peak flow and maximum water depth of the events to the observed data in goodness-of-fit scatter plots. The upper and lower WaPUG calibration criteria bounds were marked for comparison in goodness-of-fit plots (see Figure 2-6 for an example).

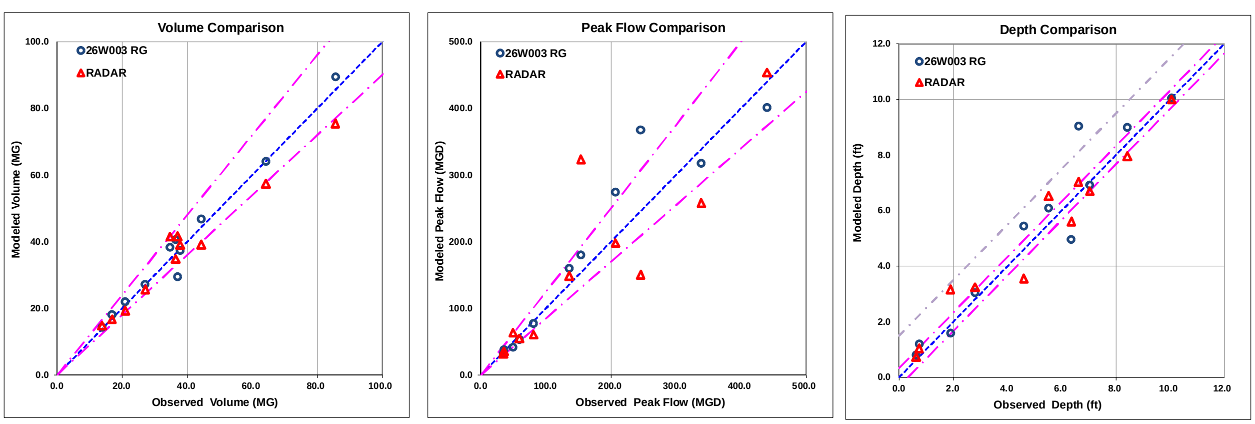

Figure 2-6. Example Model Performance Evaluation (26W-003 Influent)

The validation plots of measured versus modeled data for each monitoring location are presented in Appendix A. Plots showing model performance in comparison to the WaPUG criteria are presented in Appendix B. The validation results at each monitoring location are discussed below.

CSO 26W-003

The model-predicted versus observed influent peak flow, volume, and depth comparisons were almost all within the guidance error tolerances. The CSO comparisons were more scattered, but the volumes were nearly all within the error ranges (except for one storm), when using the local rain gauge. From the triangulation comparison, it can be seen that there was strong agreement and consistency among all three data sources (model output, SCADA data, flow monitoring data), for the occurrence of CSO events.

CSO JAM-003 and 003A

Outfalls 003 and 003A combine together at a common discharge point into the head end of Bergen Basin. Each of these outfalls is fed by overflow from Regulators JA-3 and JA-14, respectively. The model-predicted versus observed influent peak flow and volume comparisons were almost all within the guidance error ranges for influent flow to Regulator 3, but they were on the higher side of the range, while depth was consistently under-predicted. For Regulator JA-14, the opposite was true. This suggests that potentially the flow distribution between the two regulators is less than perfect, but it is greatly improved since the inclusion of the 2-12" diameter interconnections that were located via GIS data review. The CSO comparisons were scattered, but errors were minimized as some events were over-predicted and others under-predicted, at both Outfalls JAM-003 and JAM-003A. It should be noted that the CSO observations are based on a weir equation calculation (using measured depth). Tide gate switches were installed at JAM-003A. From the triangulation comparison, it can be seen that there was generally reasonable agreement and consistency among all three data sources (model output, SCADA data, flow monitoring data), for the occurrence of CSO events. One major factor affecting the comparison of predicted and measured CSOs at these two outfalls is the construction that was ongoing for the bending weir installation contract at each of the CSO regulator structures during the monitoring period.

JAM-005 and 007

Outfalls JAM-005 and JAM-007 receive CSO and separate stormwater flow from upstream tributary areas that are interconnected in many locations (both upstream and downstream of CSO regulators). This discussion focuses on the quantitative comparisons at the regulator structure since that is where the monitoring occurred (versus at the outfalls at the head end of Thurston Basin). Influent flow to Regulator JA-06 was measured at two locations (referred to as “M1” and “M2”). One of these locations (M2) was an influent pipe that served a very small (38-acre) tributary area. At this location, there was reasonable agreement between model-predicted peak flows, volumes and depths and measured values, for most of the storm events. At location M1, the same was true, except volumes were slightly over-predicted. At both locations, the agreement between model-predicted and measured values was closest when using the local point rain gauge (versus radar rainfall data). Influent flow to Regulator JA-7 was also measured at two locations (referred to as “M1P1”and “M1P2”). Comparisons of model-predicted peak flows and volumes for location M1P1 were very close, with nearly all events falling within the error ranges. Depth comparisons were also good for the majority of the storm events. At location M1P2, volume comparisons were well balanced, but peak flow and depth were often under-predicted.

CSO volumes were based on a weir equation calculation (using measured depth). Calculated CSO volumes from Regulator JA-07 were not logical and thus initial comparisons were discarded. Calculations of CSO from Regulator JA-06 produced viable results. Both volume and peak flow were well balanced (some slightly over-predicted and some under-predicted). From the triangulation comparison, it can be seen that all three data sources (model output, SCADA data, flow monitoring data) were never available at any one regulator (only 2 out of 3). For example, SCADA data was not available at either Regulator JA-06 or JA-07, but it was available at Regulator JA-09; thus, comparisons were made between model predictions and SCADA data at this location, for CSO activations. This regulator is further upstream from Regulators JA-06 and JA-07. At Regulators JA-06 and JA-07, comparisons for CSO activations could only be made between model output and flow monitoring data. In total, there was reasonable agreement among data sources for Outfalls JAM-005 and JAM-007, when considering all the available data sources.

3.0 RECEIVING WATERBODY MODELING

3.1 Model Description

Jamaica Bay water quality was simulated using the refined Jamaica Bay Eutrophication Model (JEM), which was originally developed and applied as part of DEP's Jamaica Bay Eutrophication Study in 1996. Updates to the grid were made in 2013 during the development of a larval transport model for the Harbor Estuary Program. The model domain includes Jamaica Bay, its CSO tributaries (Paerdegat Basin, Fresh Creek, Hendrix Creek, Spring Creek, Bergen Basin, and Thurston Basin), as well as the bay's other tributaries and basins. As part of this LTCP work, the model was refined, validated and applied to assess CSO control alternatives.

3.1.a **Previous Modeling Overview**

JEM is a spatially continuous, three-dimensional, time dependent, receiving water model of Jamaica Bay and its tributaries and is comprised of a hydrodynamic model (ECOMSED) coupled to a eutrophication (i.e., water quality) model (RCA). JEM was developed to assess eutrophication and nitrogen controls in Jamaica Bay and has been used as an assessment and prediction tool to support the DEP CSO Long Term Control Planning early 2007 Waterbody Watershed Facility Planning. The original model segmentation of JEM is presented in Figure 3-1. The representation of the Jamaica Bay tributaries was considered too coarse for the analysis of tributaries, so two additional models were used: the North Channel Model (NCM), which includes Fresh, Hendrix and Spring Creeks (Figure 3-2); and a modified JEM segmentation (JEM-BT), which includes finer resolution in Bergen and Thurston Basins (Figure 3-3).

The original calibration and validation of JEM focused on nutrients, chlorophyll-a, and dissolved oxygen (DO) based on data collected during 1995-96 and the model was validated against 1988 data. JEM was later calibrated to bacteria against 2005 data. Both NCM and JEM-BT were also calibrated for bacteria and DO with 2005 data.

Results of the model calibrations can be found in "A Water Quality Model for Jamaica Bay: Calibration of the Jamaica Bay Eutrophication Model (JEM) (2002)," "NYCDEP City-Wide Long Term CSO Control Planning Project, Receiving Water Quality Modeling Report, Volume 5, Jamaica Bay Eutrophication Model (JEM) (October 2007)," and the "City-Wide Long Term CSO Control Planning Project, Receiving Water Quality Modeling Report, Volume 7, North Channel Model (NCM) (October 2007)." This calibrated model was the starting point for the modeling conducted for Jamaica Bay as part of the CSO LTCP. Unless specified differently herein, model coefficients and kinetic coefficients used in the calibration analysis described herein remained unchanged from those described in the calibration reports.

3.1.b **Modifications to the Model**

The primary modifications to JEM for the development of the Jamaica Bay LTCP were the enhancement of the model grid, and the addition of a settling loss term for bacteria. Figure 3-4 presents the model domain used for this analysis. Rather than using three separate models for this analysis, the finer resolution of the model grid developed for larval transport assessment was used. This segmentation has resolution that is similar to, or finer than, the resolution included in the NCM and JEM-BT models. This enhancement to the model grid resulted in finer resolution of water quality impacts in the tributaries and Jamaica Bay.

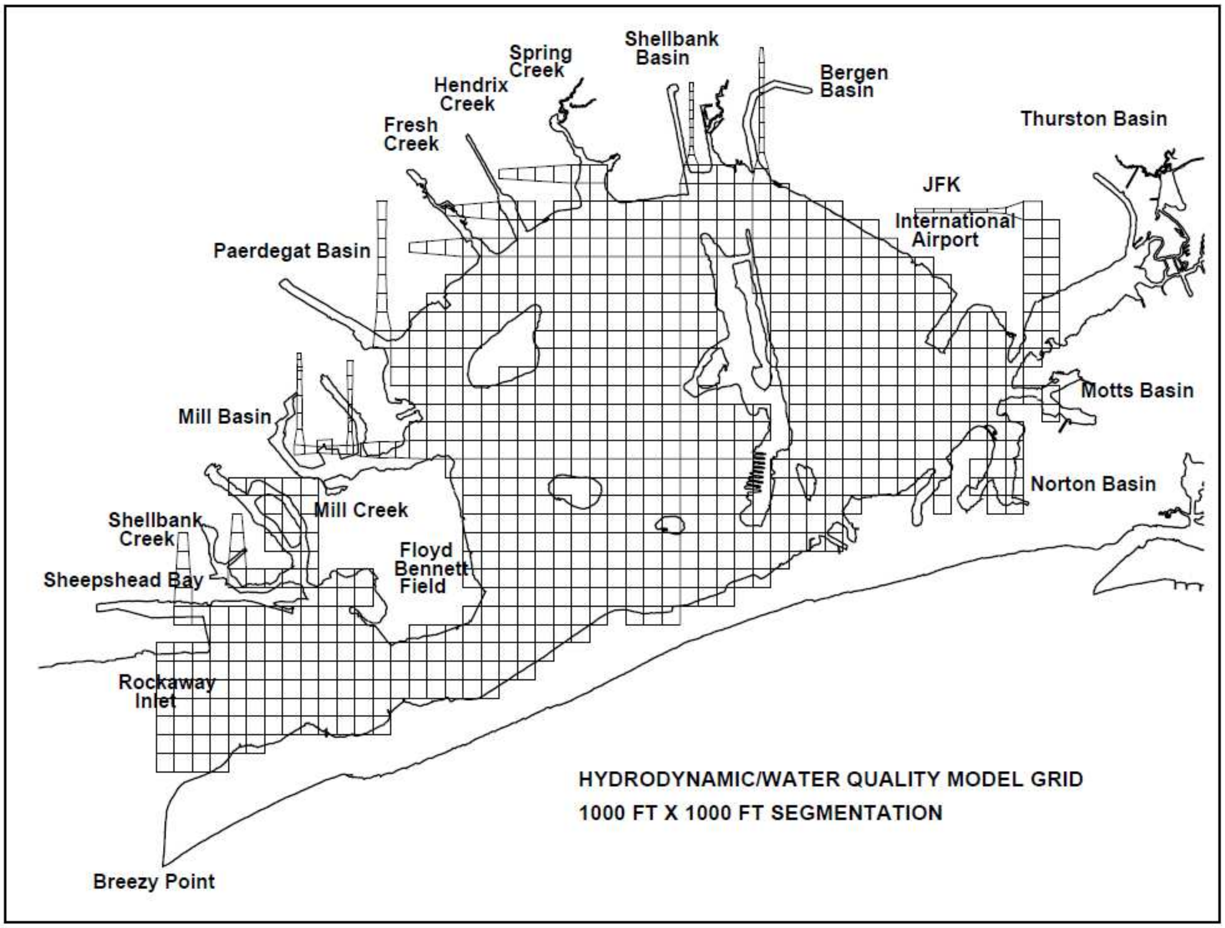

Figure 3-1. Original Jamaica Bay Eutrophication Model (JEM) Domain

During the calibration process, it was noted that the model under-estimated the loss rate of bacteria after rain events, which resulted in over-estimating bacteria concentrations. It is known that sediment mounds form around CSO outfalls, so some fraction of bacteria associated with particulate matter must settle to the sediment. Not all bacteria are associated with particulate matter, and it is likely that during some conditions, sediment can be re-suspended. Rather than trying to estimate the fraction of bacteria associated with particulate matter, the settling rate of the particulate matter, and the amount of resuspension that might occur, a simpler net settling rate was applied. This net settling rate was meant to account for all the factors that affect bacteria associated with settling and resuspension in one term.

The net settling rate (V_{snet}) is a multiplier between 0.0 and 1.0 applied to the settling rate. A V_{snet} of 1.0 represents a condition where all of the bacteria that settles to the bottom is incorporated into the sediment, and none is re-suspended. With a V_{snet} less than 1.0, the value of V_{snet} represents the fraction of the bacteria that settles to the bottom that gets incorporated into the sediment and the rest (1- V_{snet}) remains in the water column (i.e. is re-suspended). Shallower areas, where re-suspension is more likely, were assigned lower values. Deeper areas were assigned higher values. Additional information on the settling rate and impact on bacteria concentrations is presented in Section 3.3.c.

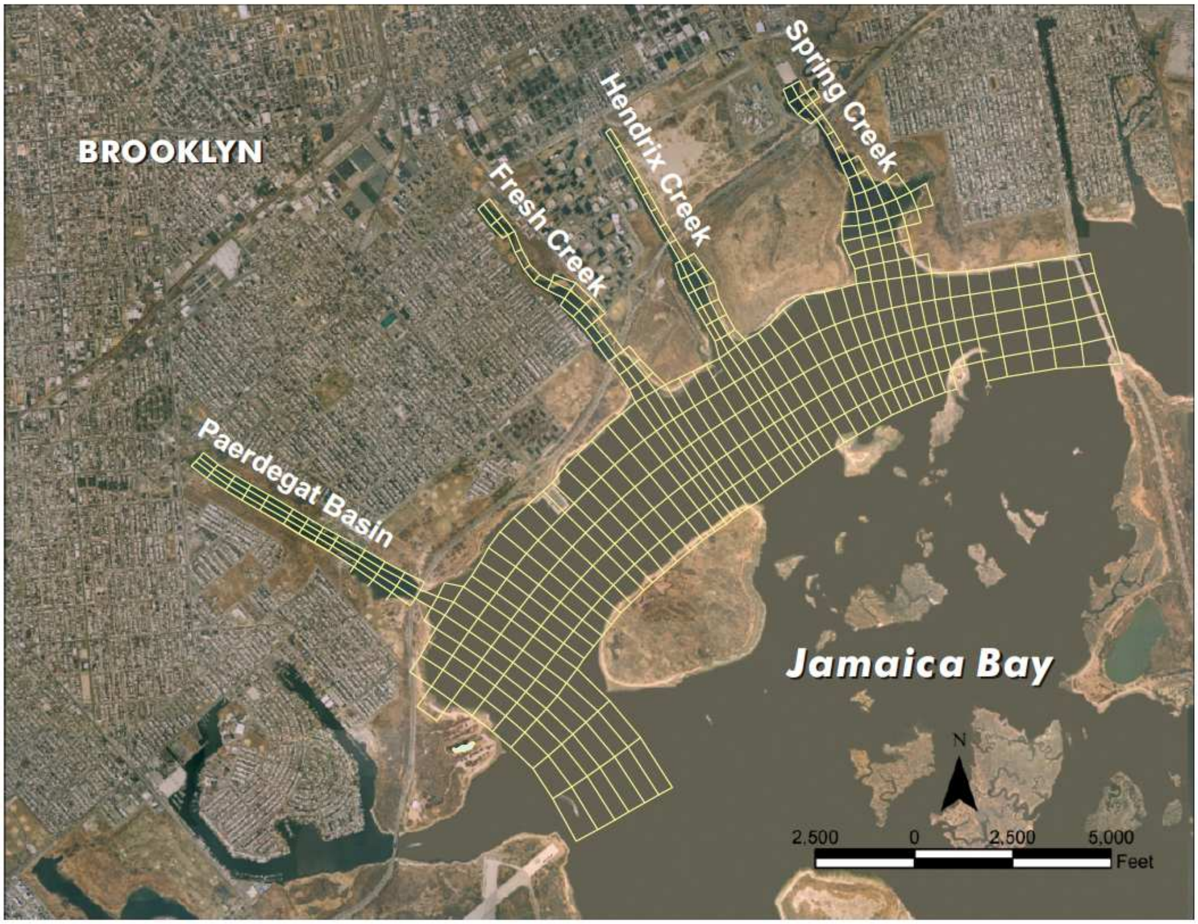

Figure 3-2. North Channel Model (NCM) Domain

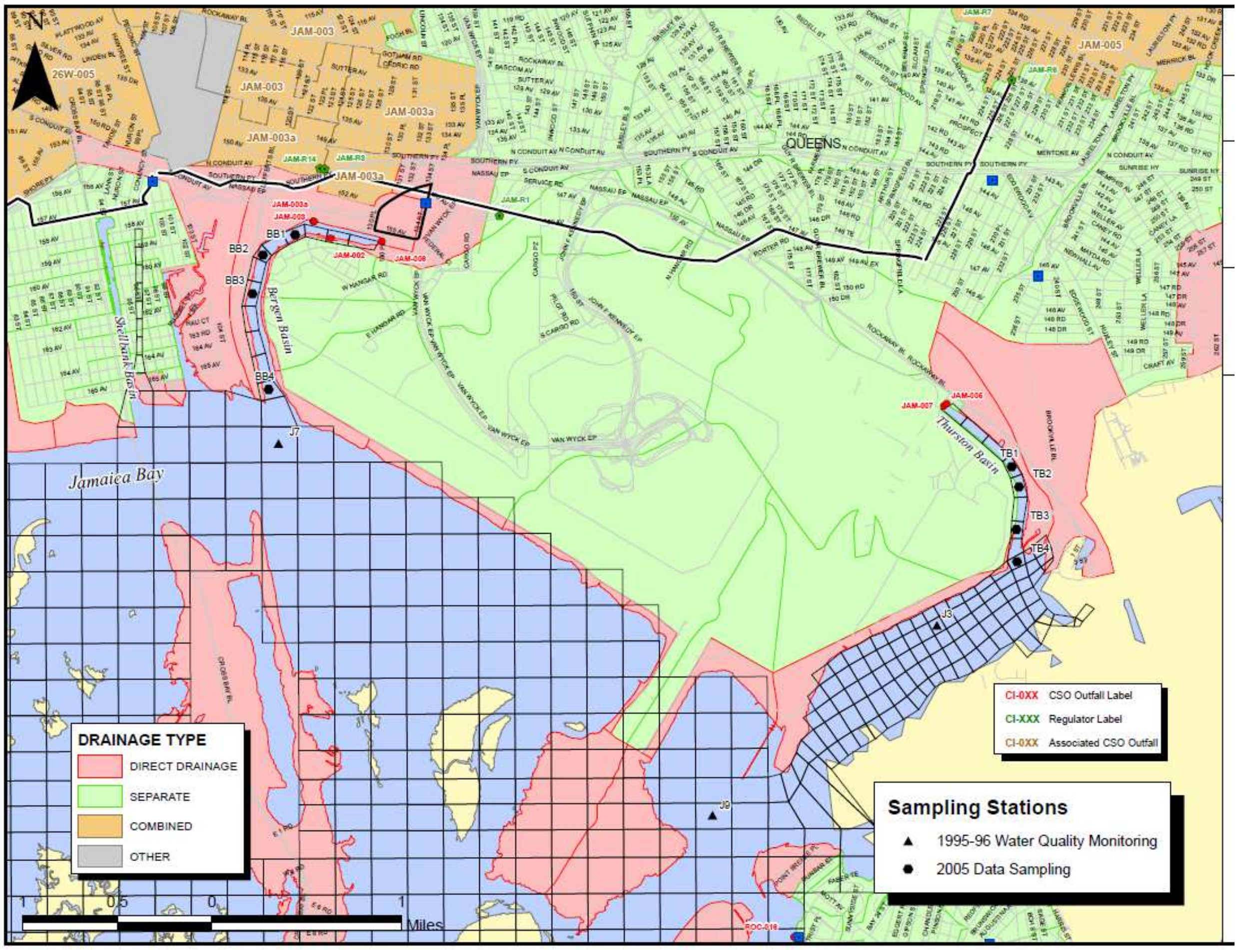

Figure 3-3. JEM-BT Domain

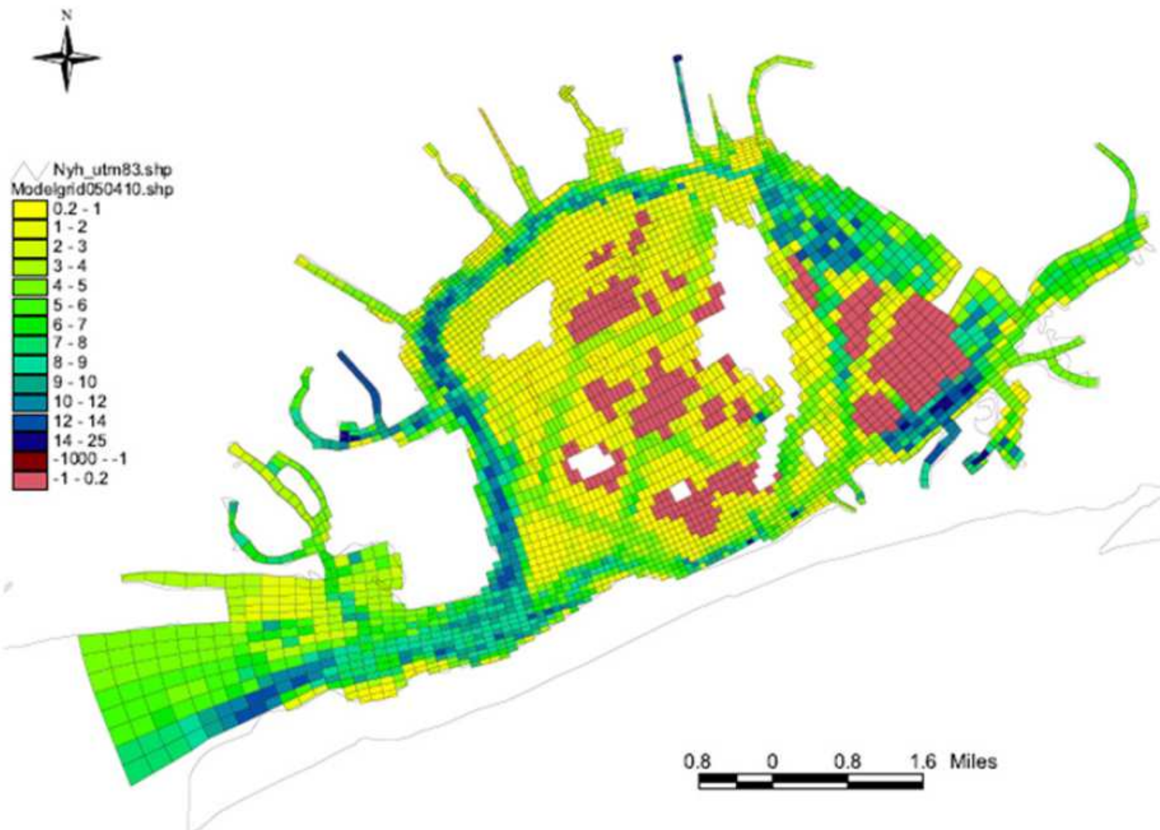

Figure 3-4. Updated Jamaica Bay Eutrophication Model (JEM) Domain

3.2 Hydrodynamic Modeling

3.2.a Monitoring Program and Available Data

Model verification was conducted for the calendar year 2015. Data collected as part of the Harbor Survey Program and data collected as part of the LTCP monitoring program for Fresh Creek, Bergen Basin and Thurston Basin/Head of Bay for this period was used to compare against the model calculations.

The Harbor Survey program collects water quality data for various constituents within the area of interest that can be used to compare against the model. Figure 3-5 shows the locations of the Harbor Survey Stations in Jamaica Bay. Harbor Survey data are collected more frequently during the warmer months at the Harbor Survey Stations and are collected on a predetermined schedule with no regard for trying to capture wet-weather or dry-weather conditions. In 1998, the DEP began supplementing Harbor Survey data with the Sentinel Monitoring Program, in which stations are sampled quarterly for fecal coliform bacteria, and the results are compared with baseline conditions to trigger intensive surveillance of the adjacent shoreline if high fecal coliform concentrations are observed during dry-weather conditions. The Sentinel Monitoring Program includes Stations S76 in Fresh Creek, S27 in Hendrix Creek, S78 in Bergen Basin, and S31 in Thurston Basin.

To supplement the water quality sampling information that is available from DEP, a sampling program was conducted during the development of the LTCP for Jamaica Bay. This sampling was targeted at developing a better understanding of the spatial variability of the water quality along the length of the Fresh Creek, Bergen Basin, and Thurston Basin. Sampling in tributaries was conducted during both Wet-Weather Conditions (WWC) and Dry-Weather Conditions (DWC) at 12 distinct sampling stations. Figure 3-6 through Figure 3-8 show the locations of the LTCP2 stations in Fresh Creek, Bergen Basin, and Thurston Basin, respectively. Samples were collected at these locations in both dry- and wet-weather periodically during October and November 2015. Results of the sampling can be found in the "Data Collection Memorandum for Jamaica Bay" (AECOM, March 1, 2017).

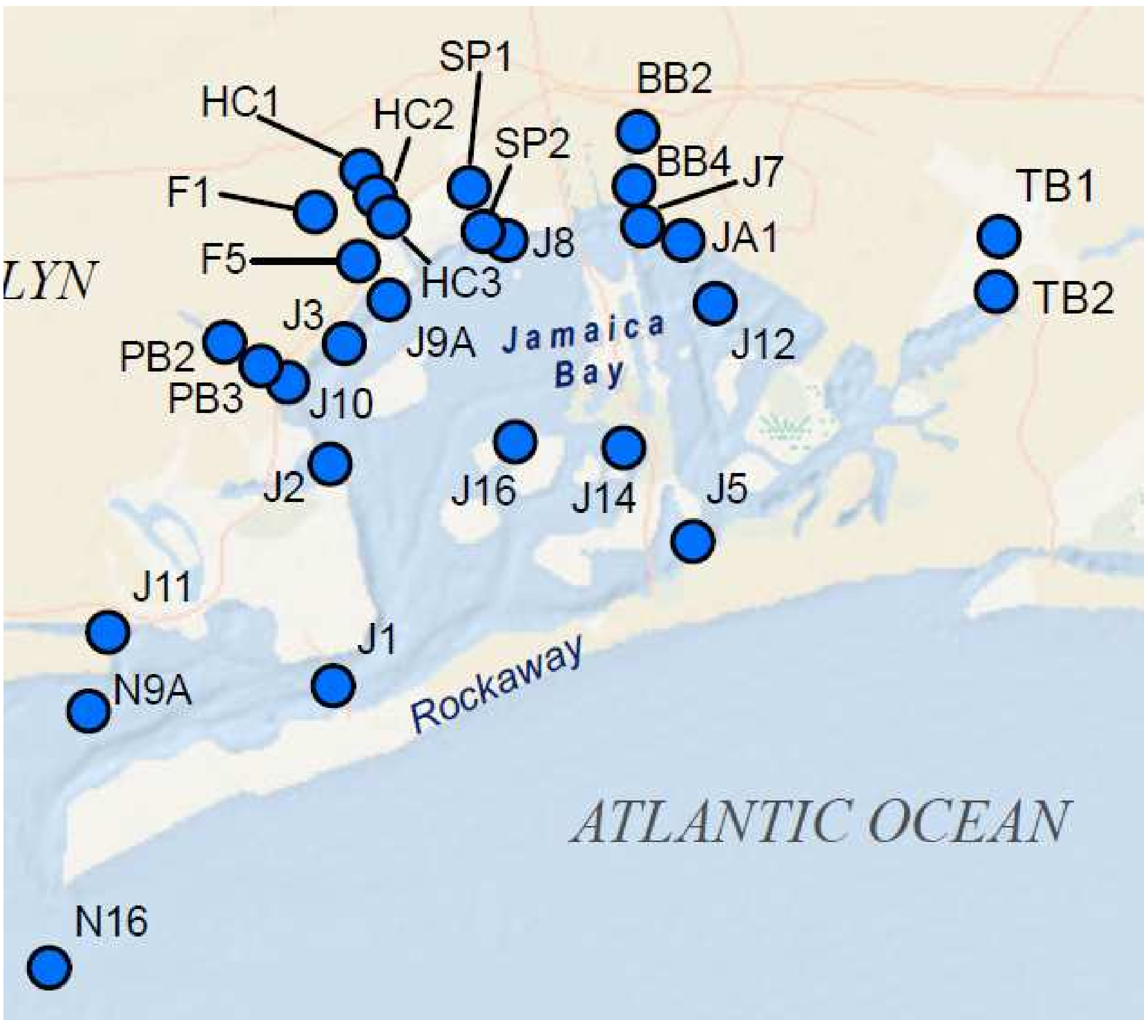

Figure 3-5. Harbor Survey Water Quality Sampling Stations in Jamaica Bay

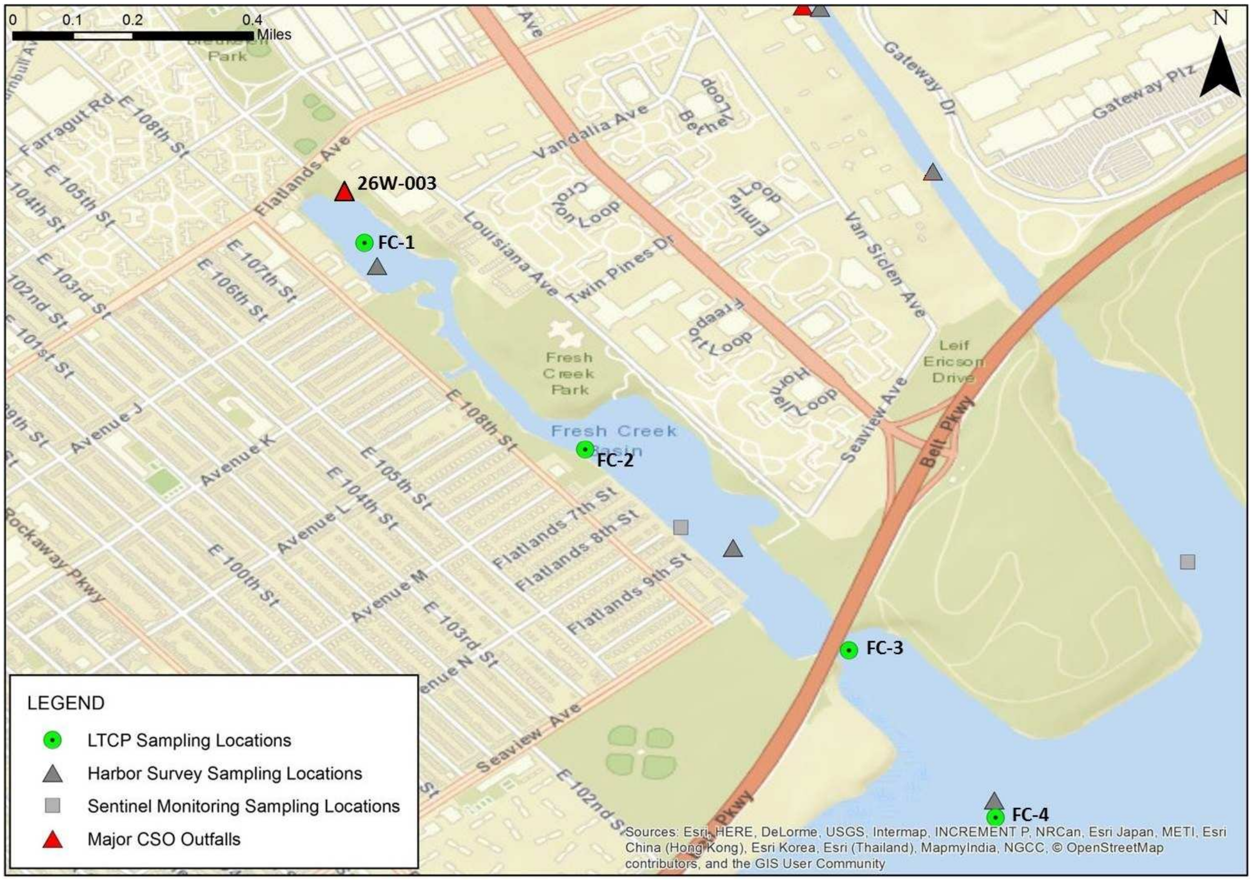

Figure 3-6. LTCP2 Water Quality Sampling Stations in Fresh Creek

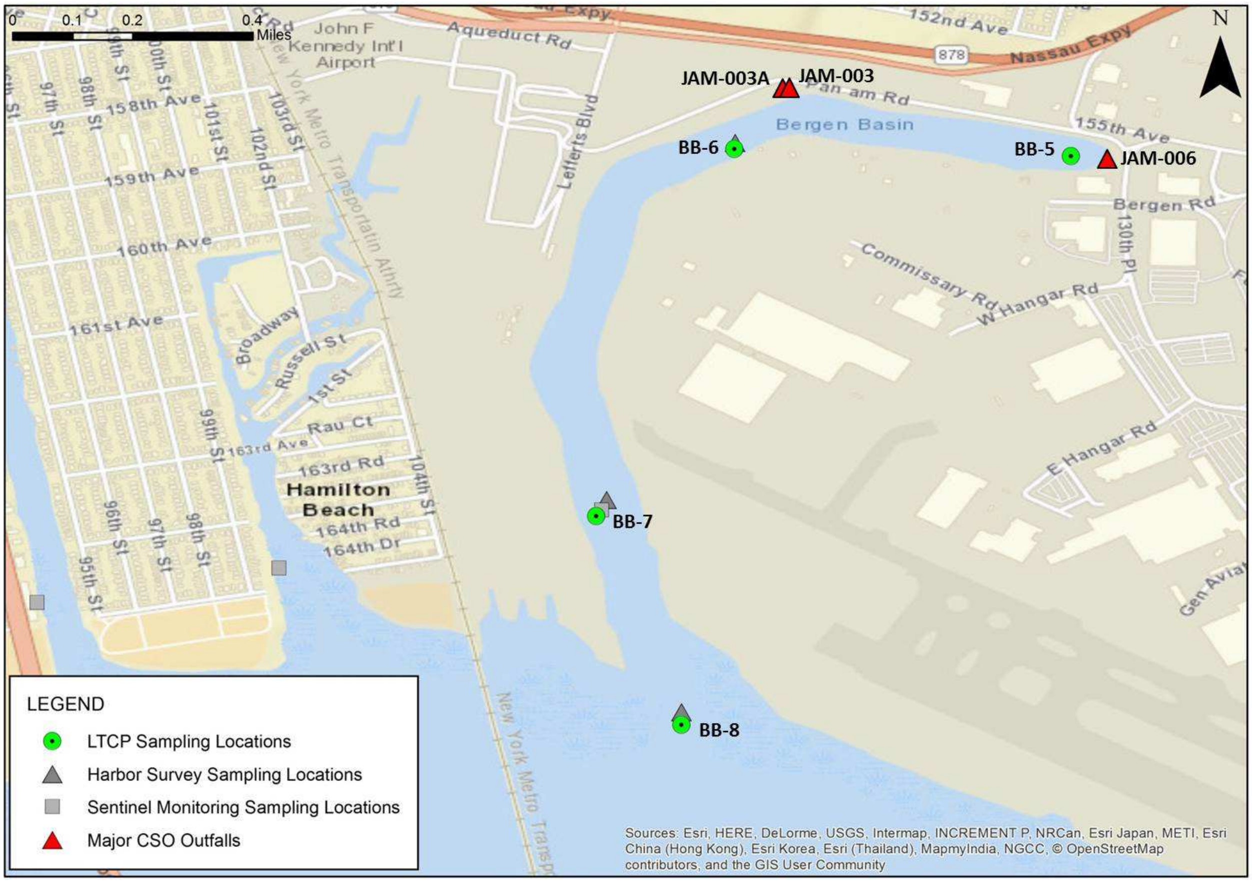

Figure 3-7. LTCP2 Water Quality Sampling Stations in Bergen Basin

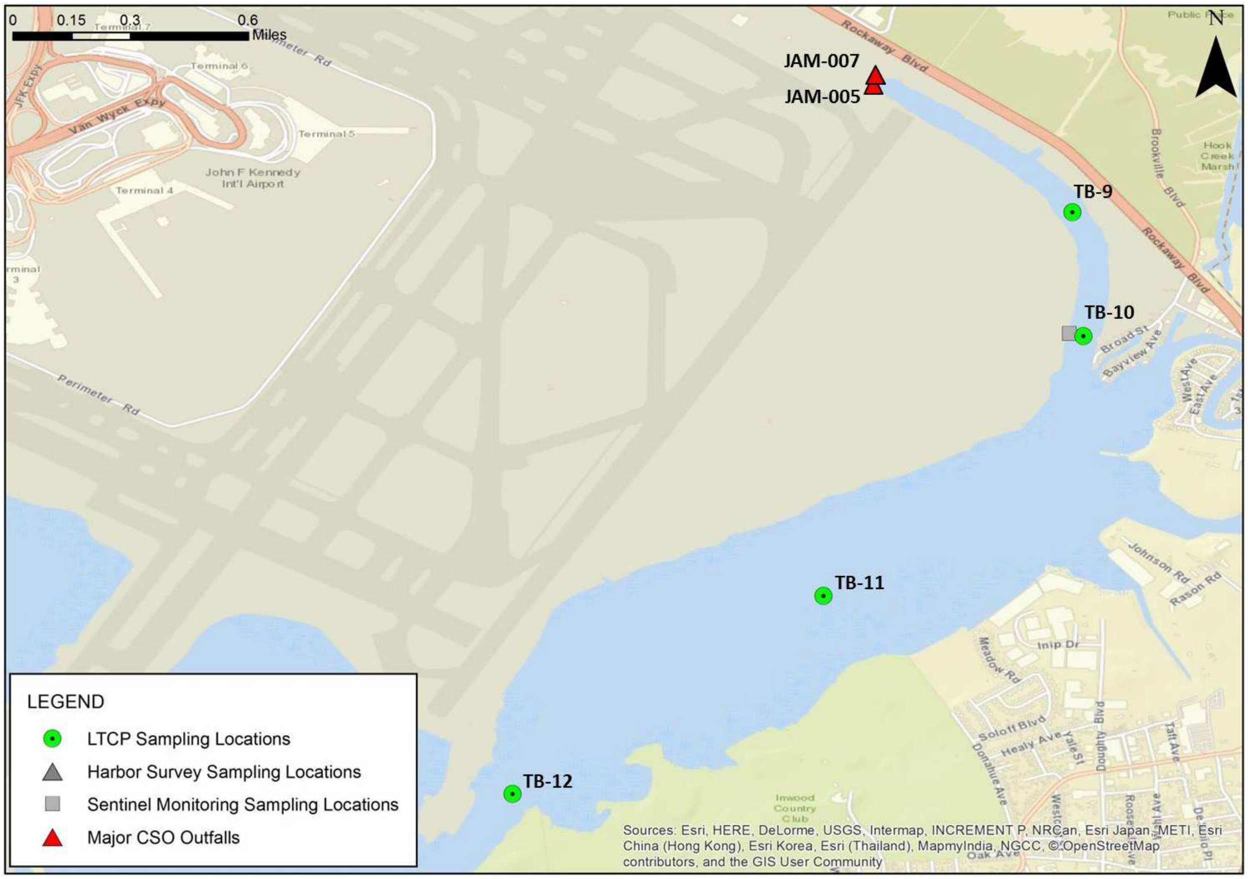

Figure 3-8. LTCP2 Water Quality Sampling Stations in Thurston Basin and Head of Bay

3.2.b **Hydrodynamic Model Inputs**

Input for the hydrodynamic model falls into three general categories: boundary conditions, freshwater flow, and meteorological conditions. Boundary conditions include water elevation, temperature, and salinity. Water elevations were obtained from the regional SWEM model at the Rockaway Inlet. Temperature and salinity boundary conditions were based on U.S. Geographical Survey Floyd Bennett Field measurements. Boundary figures are included in Appendix C.

Freshwater flows from Wastewater Treatment Plants (WWTPs), CSOs, storm sewers and direct drainage for New York City were obtained from the IW model as described in Section 2.

Meteorology input was based on the NOAA's weather station at JFK International Airport (USAF 744860 WBAN_ID 94789). Figures presenting the meteorological inputs are presented in Appendix C.

3.2.c **Hydrodynamic Model Calibration**

The data available to compare against the hydrodynamic model results were somewhat limited. Temperature and salinity data were available from numerous Harbor Survey sampling and LTCP2 sampling stations. Figure 3-9 through Figure 3-16 present model versus data comparisons for temperature in the CSO tributaries and Jamaica Bay proper. The results are presented starting in Paerdegat Basin and then clockwise around the bay in the CSO tributaries followed by results in the bay. The temperature data show a typical seasonal pattern for a temperate region with the highest temperatures observed in August and September. The temperature data show very little temperature difference between the surface and bottom, indicating minimal temperature stratification. The model compares to the temperature data reasonably well throughout the bay. There are a few exceptions where the model over-estimates the summer temperatures, most often in shallow areas at the head ends of tributaries and the center of the bay.

Figure 3-9 presents the temperature calibration for Paerdegat Basin and the stations in Jamaica Bay near Paerdegat Basin. There is some over-estimation by the model of June and July temperatures closer to the head end, but during the other times and locations, the model reproduces the data very well. In Fresh Creek (Figure 3-10) the model also does a good job reproducing the data. The three LTCP2 event surveys are well represented by the model. In some cases, the model over-estimates the temperature during the warmest portion of the year. The data in Hendrix Creek is generally just surface data. As shown in Figure 3-11, the model reproduces the temperature very well. The discharge of wastewater from the 26th Ward WWTP has the impact of moderating the temperatures in Hendrix Creek. Figure 3-12 presents the model versus data comparison for Spring Creek. The model does a good job reproducing the data at these stations.

Bergen Basin model versus data comparisons are presented in Figure 3-13. Here the model can be compared to both Harbor Survey and LTCP2 data. The model compares very favorably to the data on a temporal and spatial basis. Thurston Basin and Head of Bay (Figure 3-14) have only LTCP2 data available, and the model reproduces these three survey events fairly well.

In the open waters of Jamaica Bay (Figure 3-15 and Figure 3-16) the model generally reproduces the temperature data. Over-estimation of the temperature data occurs in deep water at Station J12 and shallow water at Stations J14 and J16.

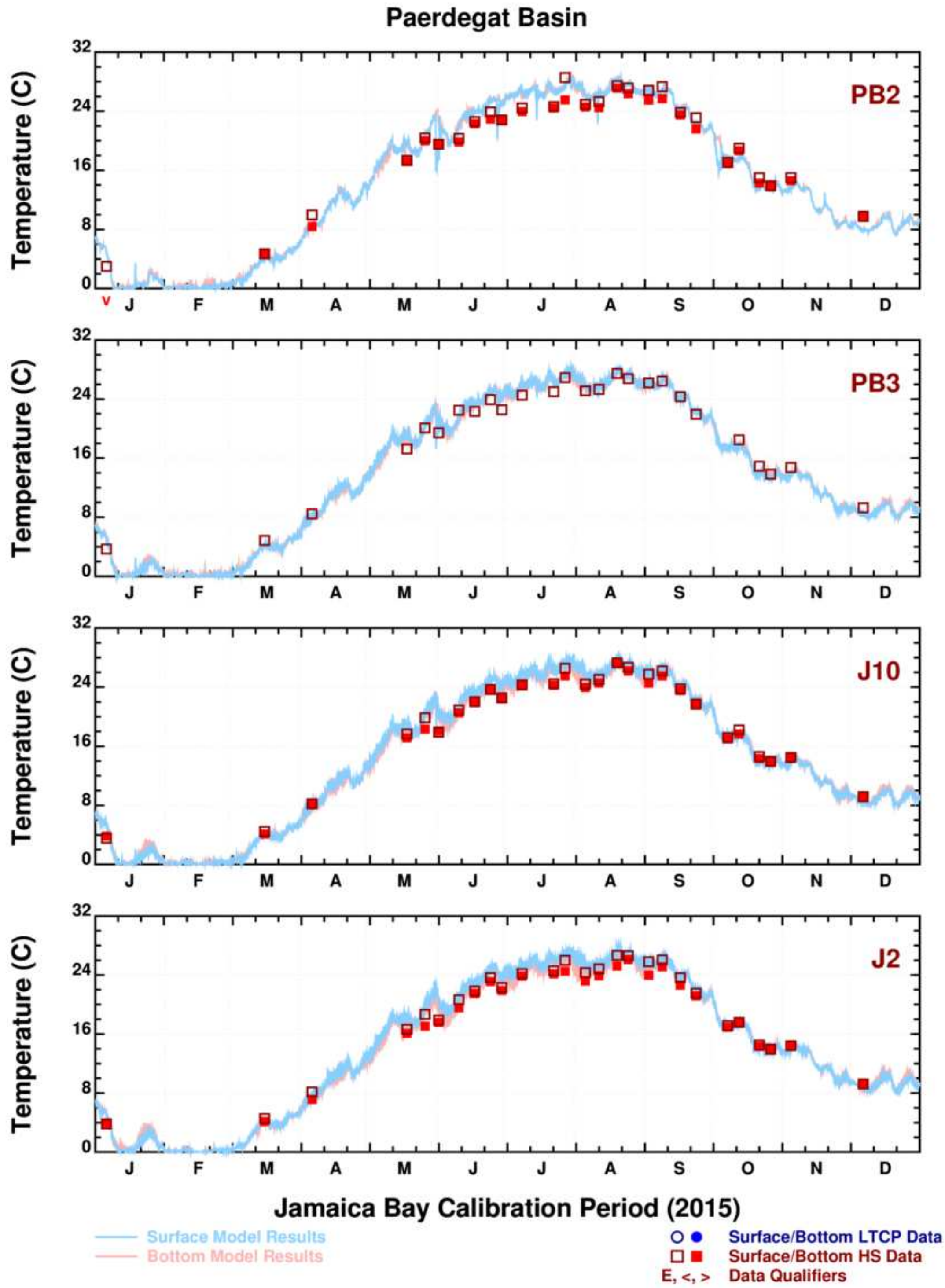

Figure 3-9. 2015 Temperature Calibration in Paerdegat Basin and Nearby Jamaica Bay

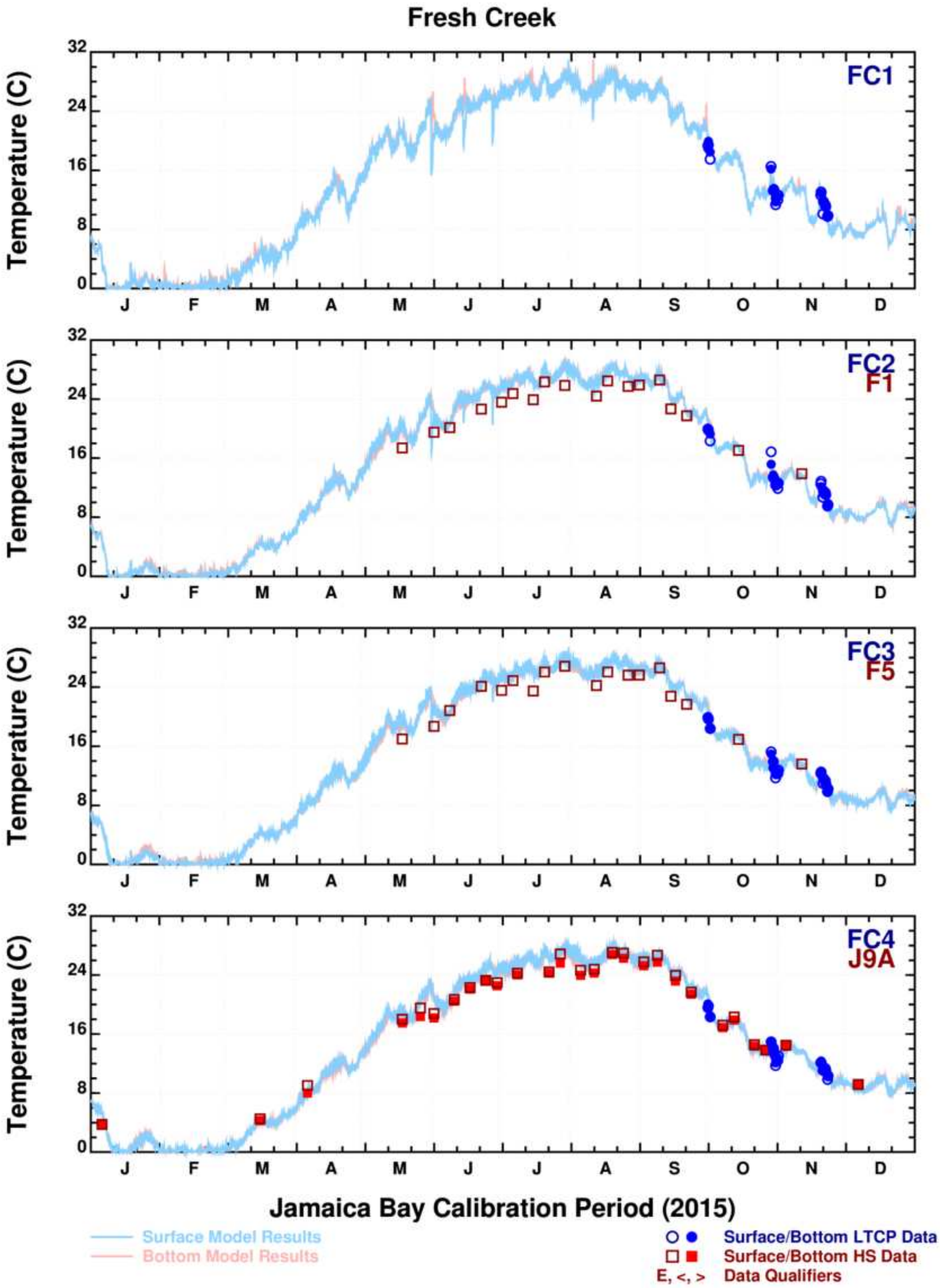

Figure 3-10. 2015 Temperature Calibration Fresh Creek and Nearby Jamaica Bay

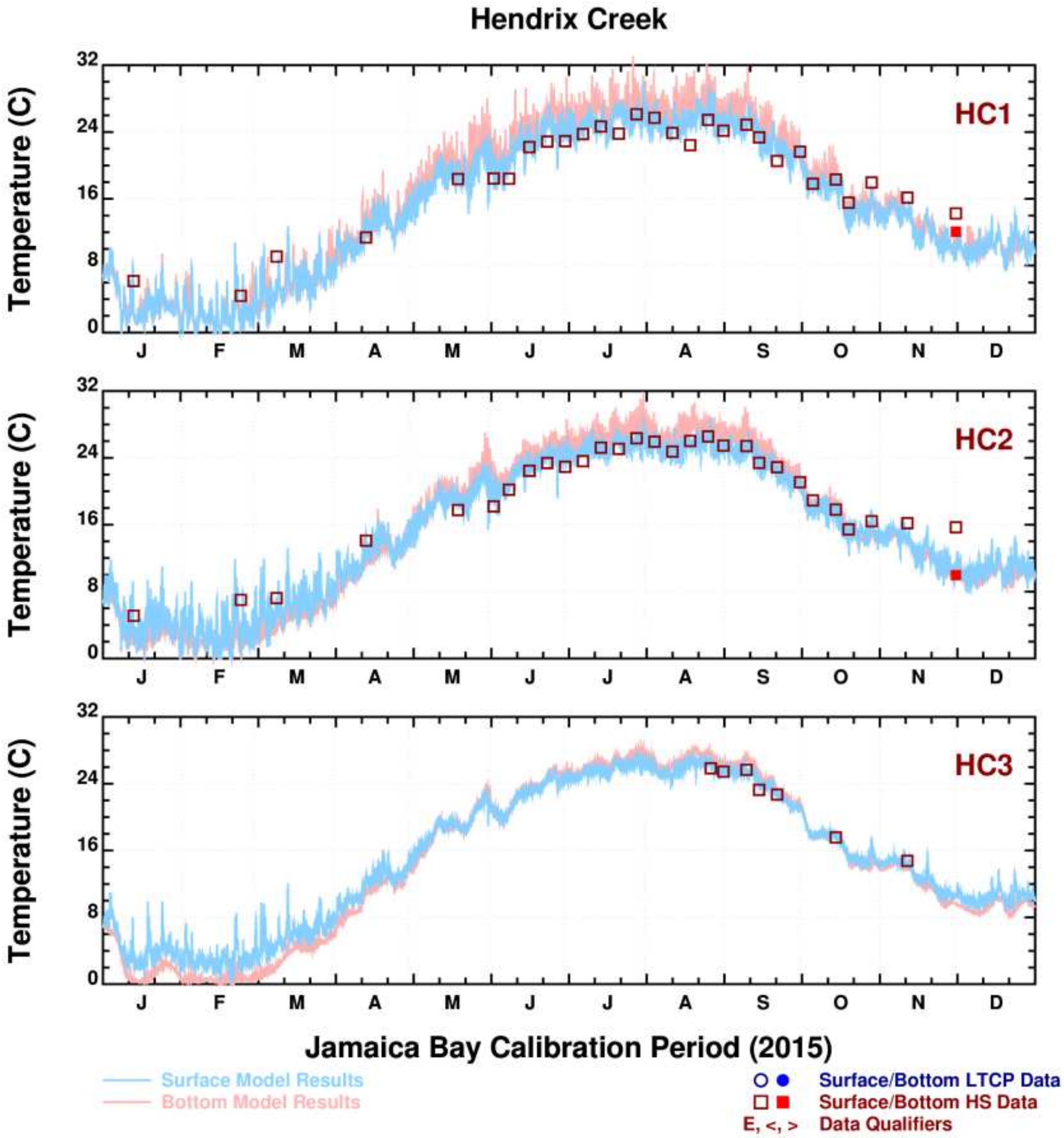

Figure 3-11. 2015 Temperature Calibration in Hendrix Creek

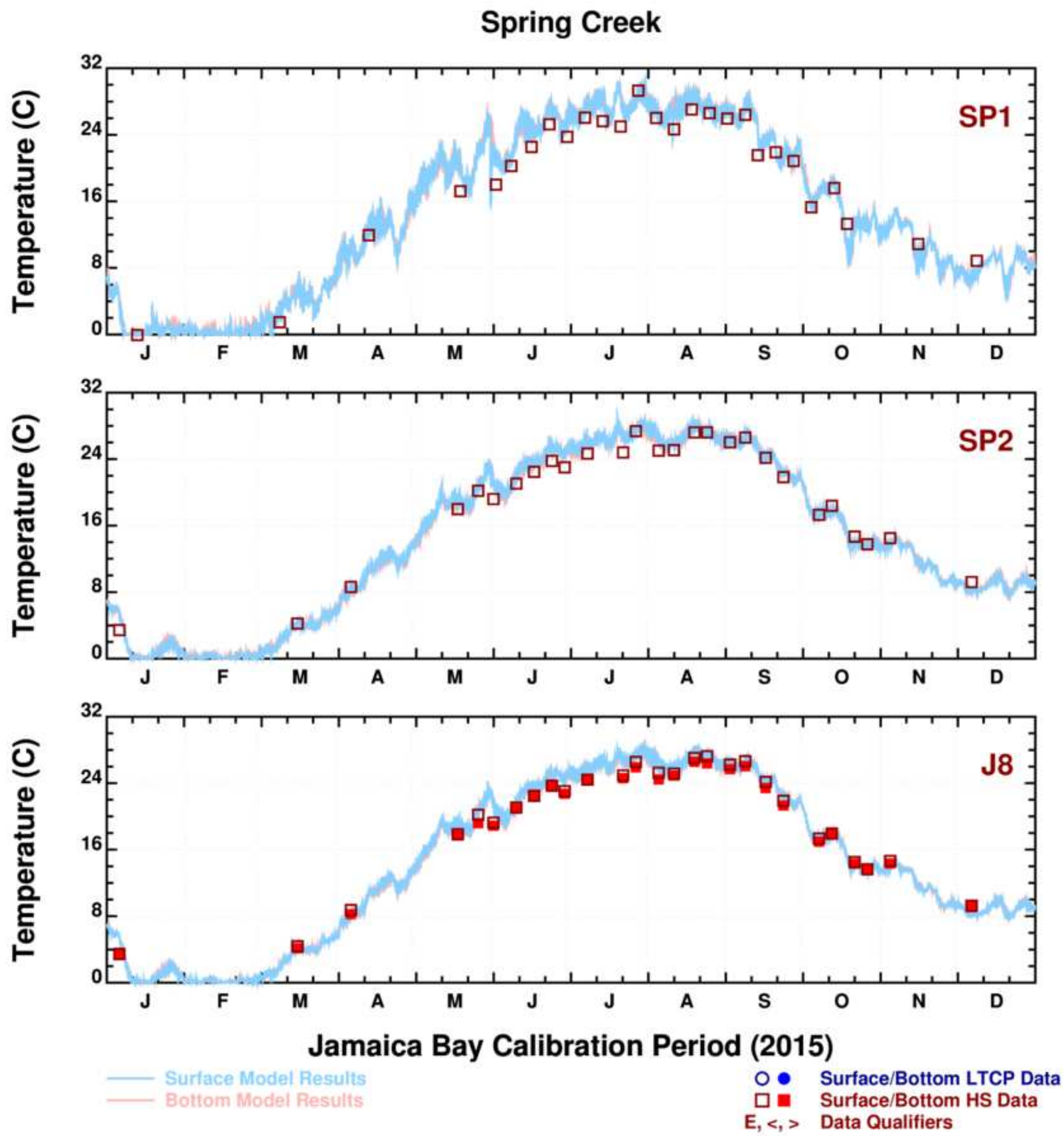

Figure 3-12. 2015 Temperature Calibration in Spring Creek and Nearby Jamaica Bay

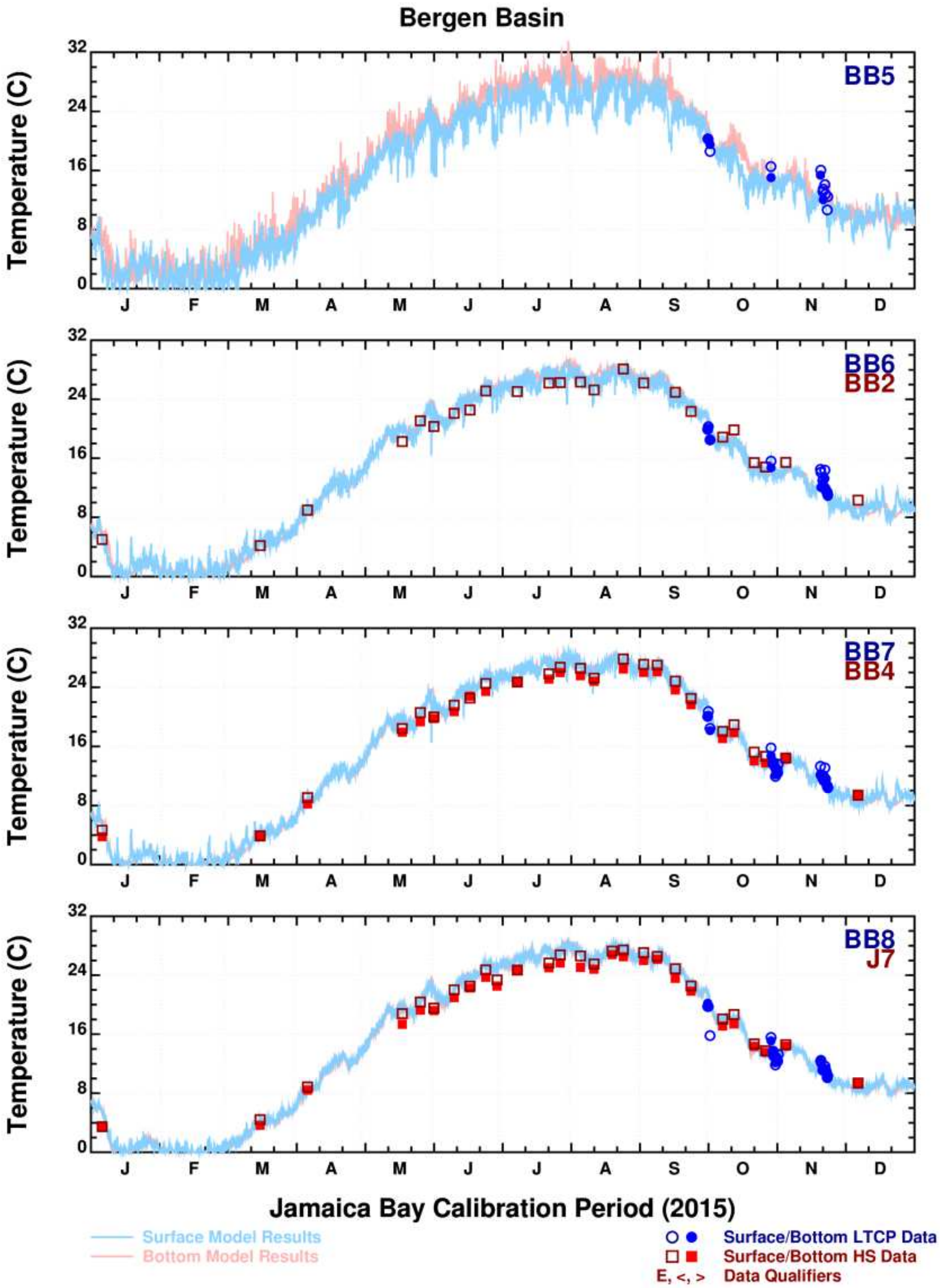

Figure 3-13. 2015 Temperature Calibration in Bergen Basin and Nearby Jamaica Bay

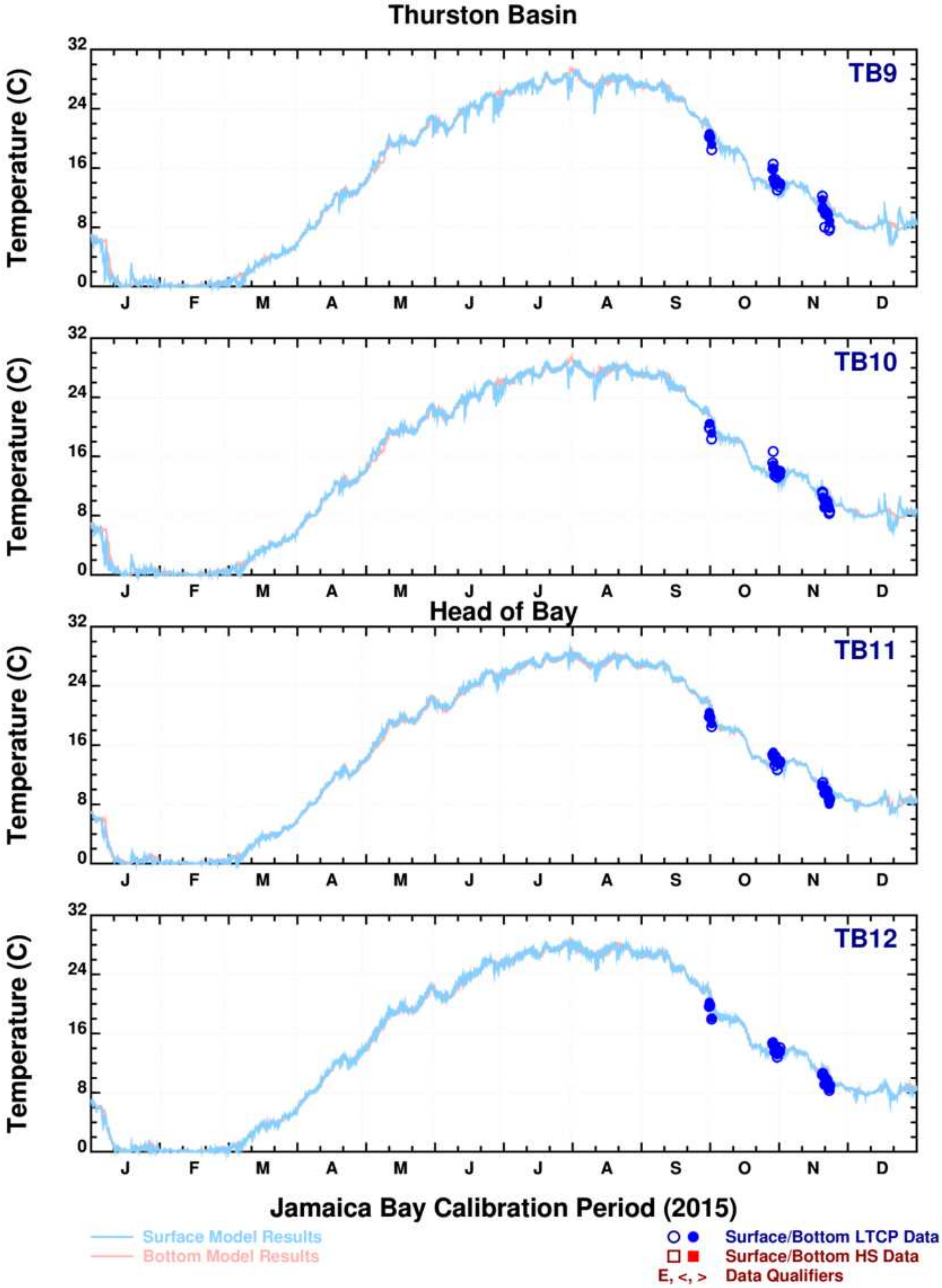

Figure 3-14. 2015 Temperature Calibration in Thurston Basin and Head of Bay

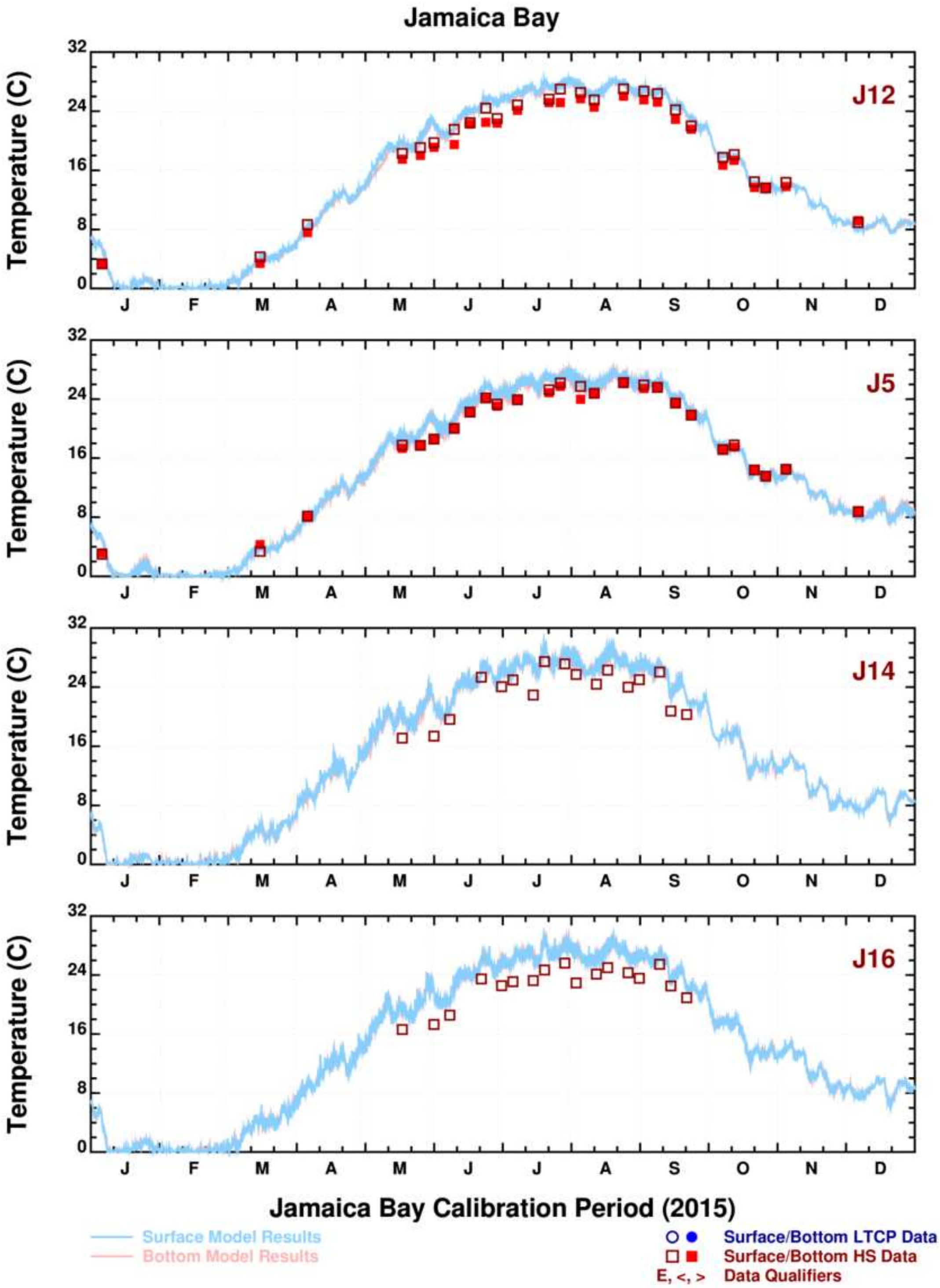

Figure 3-15. 2015 Temperature Calibration in Central and Eastern Jamaica Bay

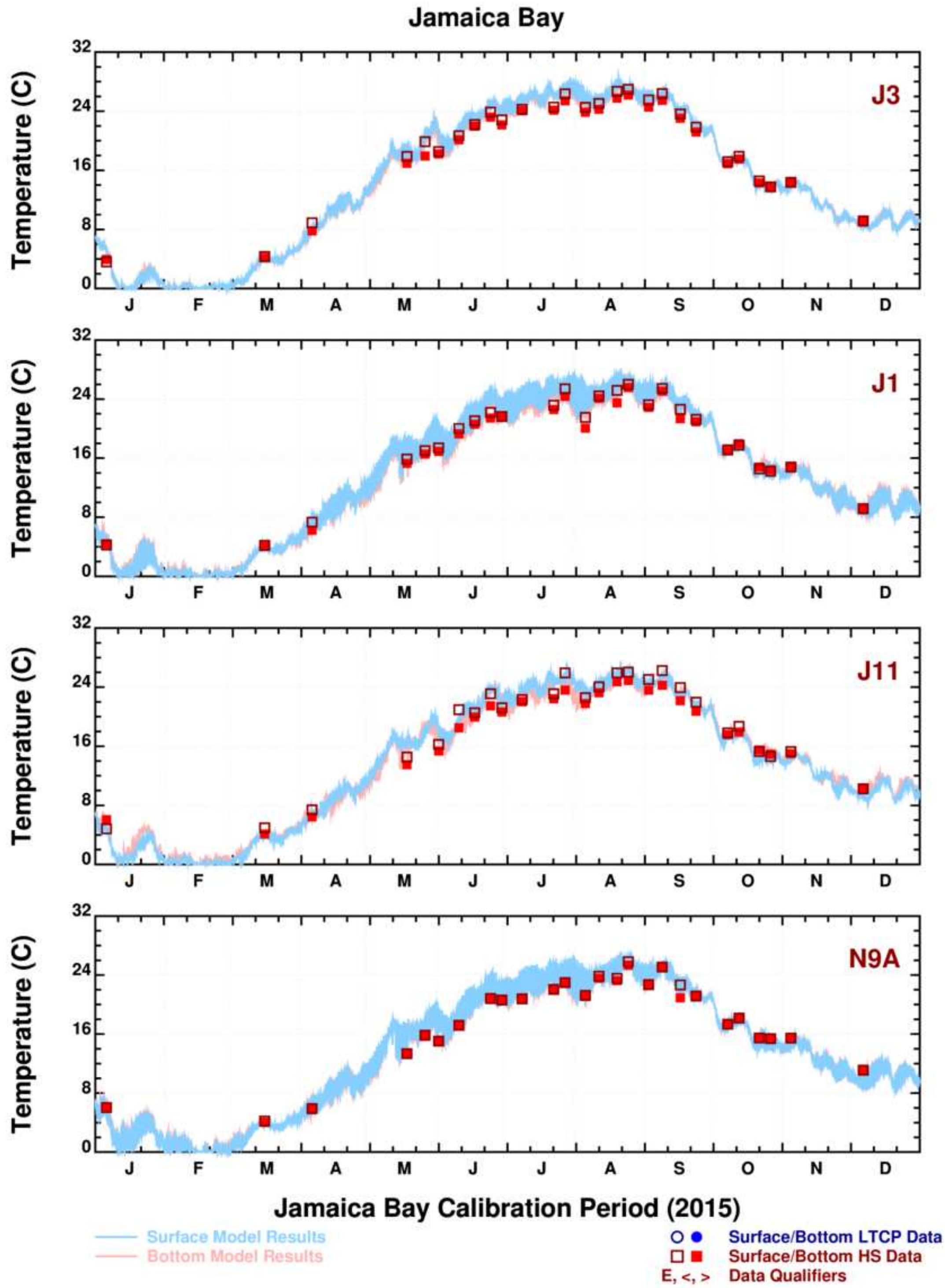

Figure 3-16. 2015 Temperature Calibration in Western Jamaica Bay

The model calibration to salinity data is presented in Figure 3-17 through Figure 3-24. The figures begin with Paerdegat Basin, followed by the other CSO tributaries in a clockwise direction around the bay: Fresh Creek, Hendrix Creek, Spring Creek, Bergen Basin and Thurston Basin. The figures present data from the head end to the mouth and on some occasions into Jamaica Bay. Two additional figures showing the model versus data comparison in the eastern and western bay are then presented. The calibration data includes surface and bottom Harbor Survey data as well as surface and bottom data collected during three, four-day surveys conducted by the LTCP2 Team. The LTCP2 surveys are meant to capture three wet-weather days followed by a dry day.

Figure 3-17 presents the Paerdegat Basin salinity calibration. The Harbor Survey salinity data are fairly consistent at approximately 28 ppt, and very little salinity stratification was measured. The model reproduces the data very well. Occasional low salinity spikes are calculated during the infrequent CSO discharges. The impact on salinity decreases from the head end of Paerdegat Basin towards the mouth and into Jamaica Bay.

The salinity calibration for Fresh Creek is presented in Figure 3-18. In Fresh Creek, the Harbor Survey data is supplemented by three surveys conducted by the LTCP2 Team. The model reproduces the Harbor Survey data very well. The model shows a rapid decrease in salinity during storm events, and low surface salinity during the peak of the storm. The sampling data does not always show these low salinities, but appears to miss the peak of the overflow. The model salinity appears to return to background more quickly than the data.

Figure 3-19 presents the salinity calibration for Hendrix Creek. Hendrix Creek has the freshwater contribution from the 26th Ward Wastewater Treatment Plant (WWTP). While the 26th Ward WWTP outfall is not at the head end of the Creek, the plume appears to trap freshwater in the head end and results in a somewhat chaotic mixture of freshwater and bay water. The model does a reasonable job of reproducing the magnitude and spatial distribution of the Hendrix Creek salinity.

The model calibration to the Spring Creek data is presented in Figure 3-20. The model reproduces the general pattern of the salinity data. Spring Creek does have a small freshwater creek entering the head end, which does contribute some flow, but this creek is not included in the model. The model shows occasional decreases in salinity towards the head end of the Creek during CSO overflow events.

Figure 3-21 shows the salinity calibration for Bergen Basin, which has both Harbor Survey and LTCP2 data available. Bergen Basin receives some freshwater discharge from the Jamaica WWTP. The Harbor Survey data is supplemented by the LTCP2 data in the basin. The salinity data show the effects of the freshwater discharge as is apparent from the greater salinity stratification than is observed in other portions of Jamaica Bay. The model generally reproduces the salinity data, but returns to dry-weather salinity levels more quickly than the data.

The Thurston Basin and Head of Bay model versus salinity comparisons are presented in Figure 3-22. Only LTCP2 data are available at these stations. In Thurston Basin, the model reproduces the timing and magnitude of the data. In Head of Bay, the model over-estimates the salinity during the middle storm and reasonably reproduces the salinity during the other events.

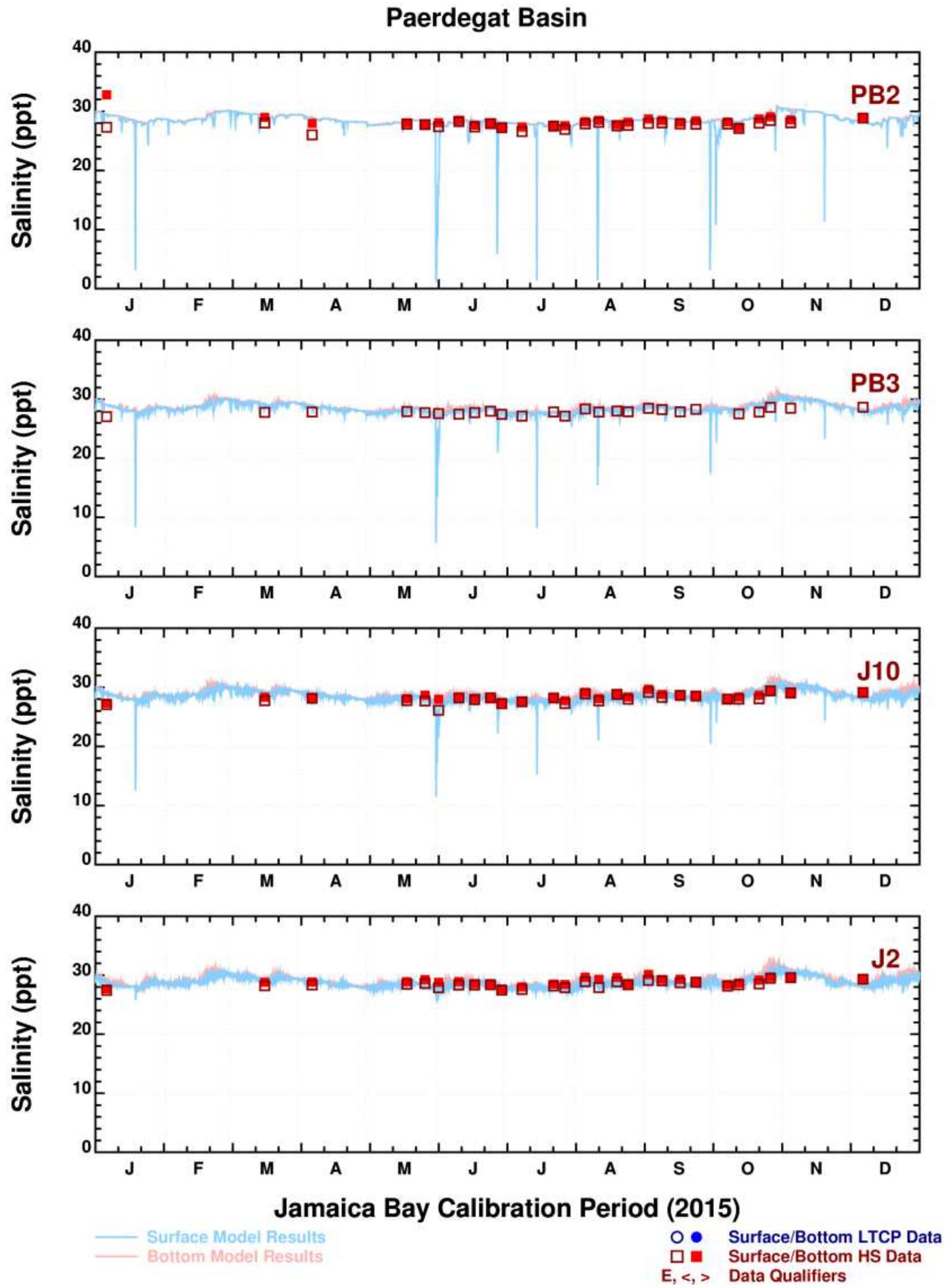

Figure 3-17. 2015 Salinity Calibration in Paerdegat Basin and Nearby Jamaica Bay

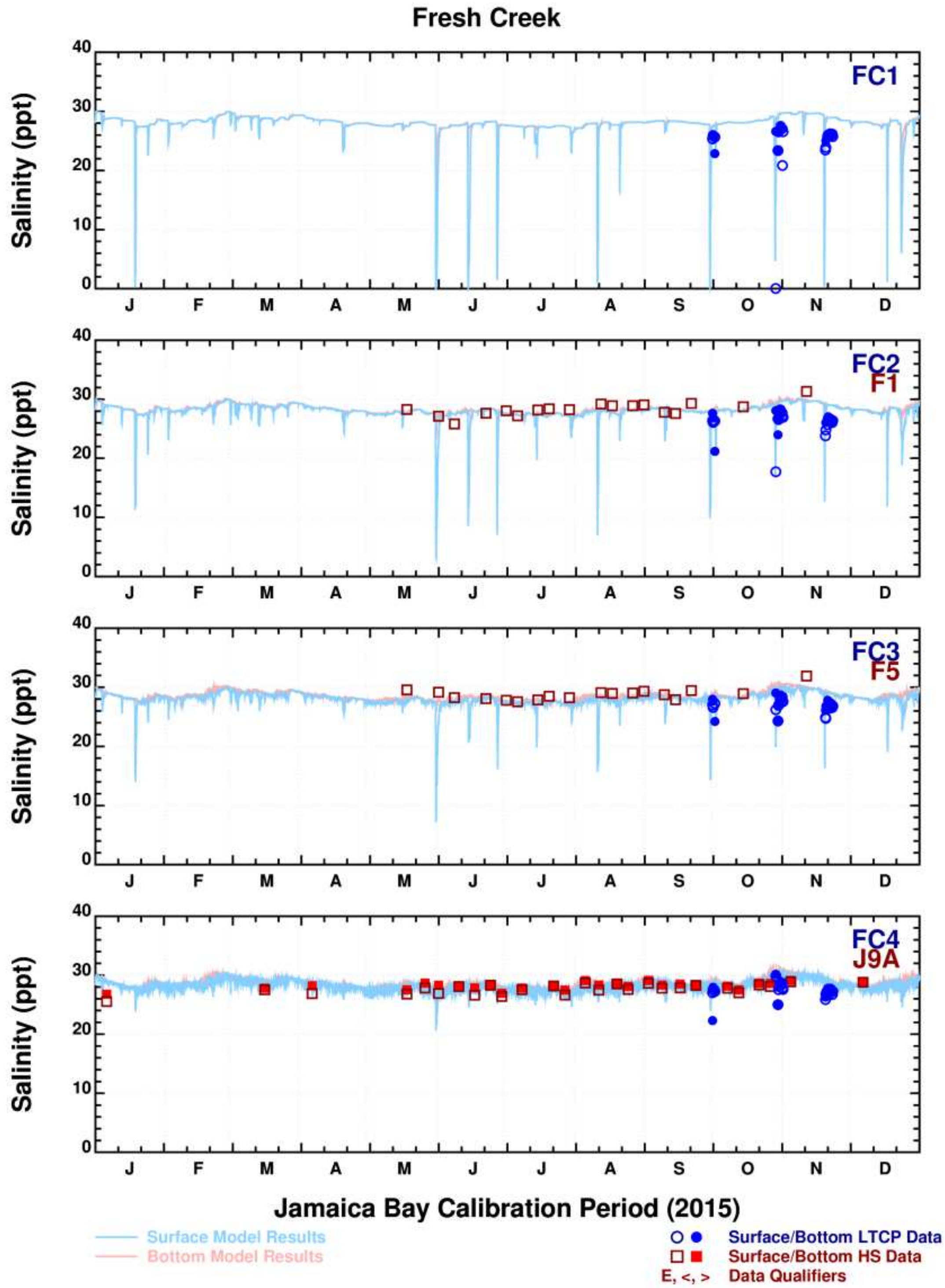

Figure 3-18. 2015 Salinity Calibration Fresh Creek and Nearby Jamaica Bay

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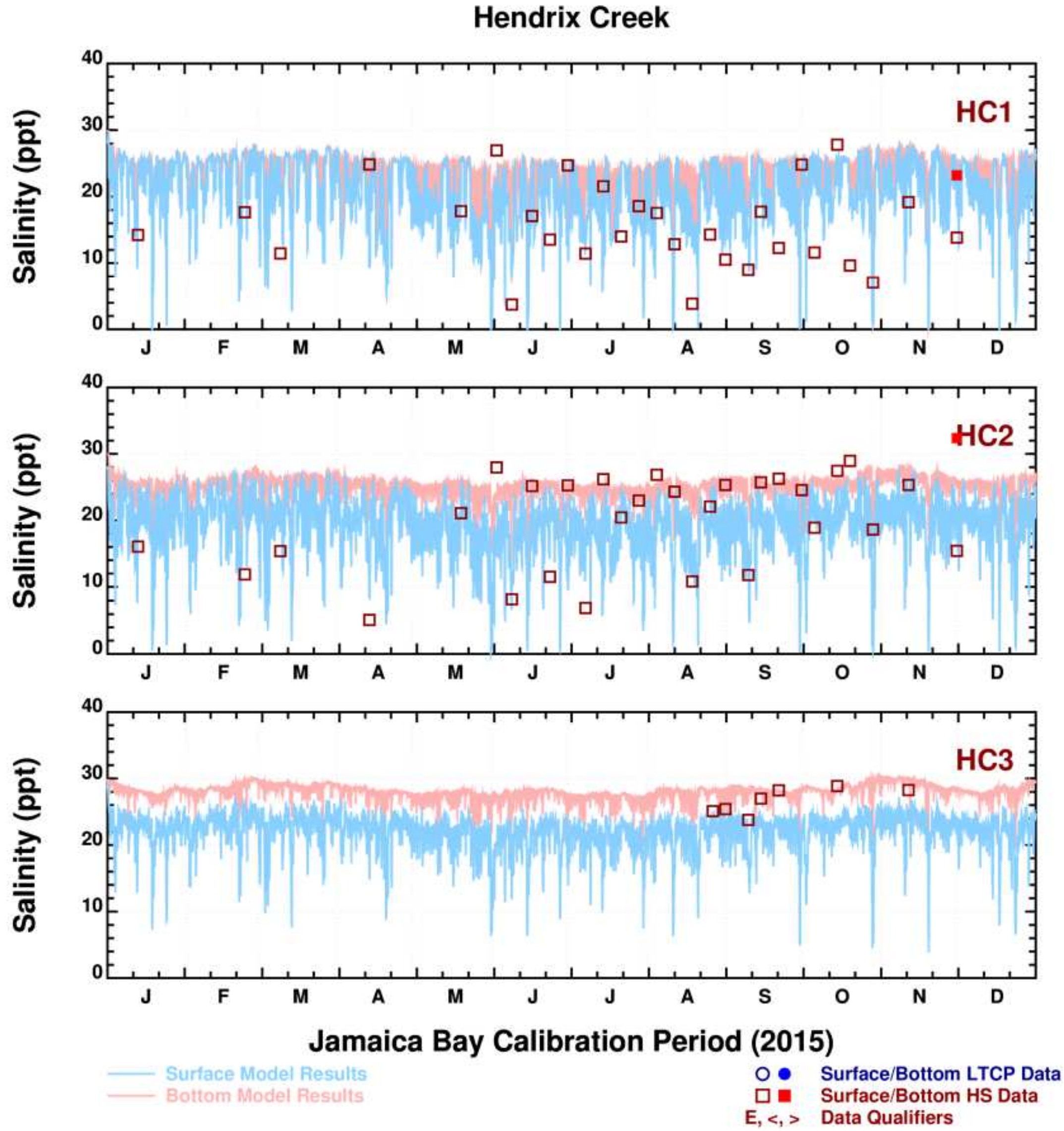

Figure 3-19. 2015 Salinity Calibration in Hendrix Creek

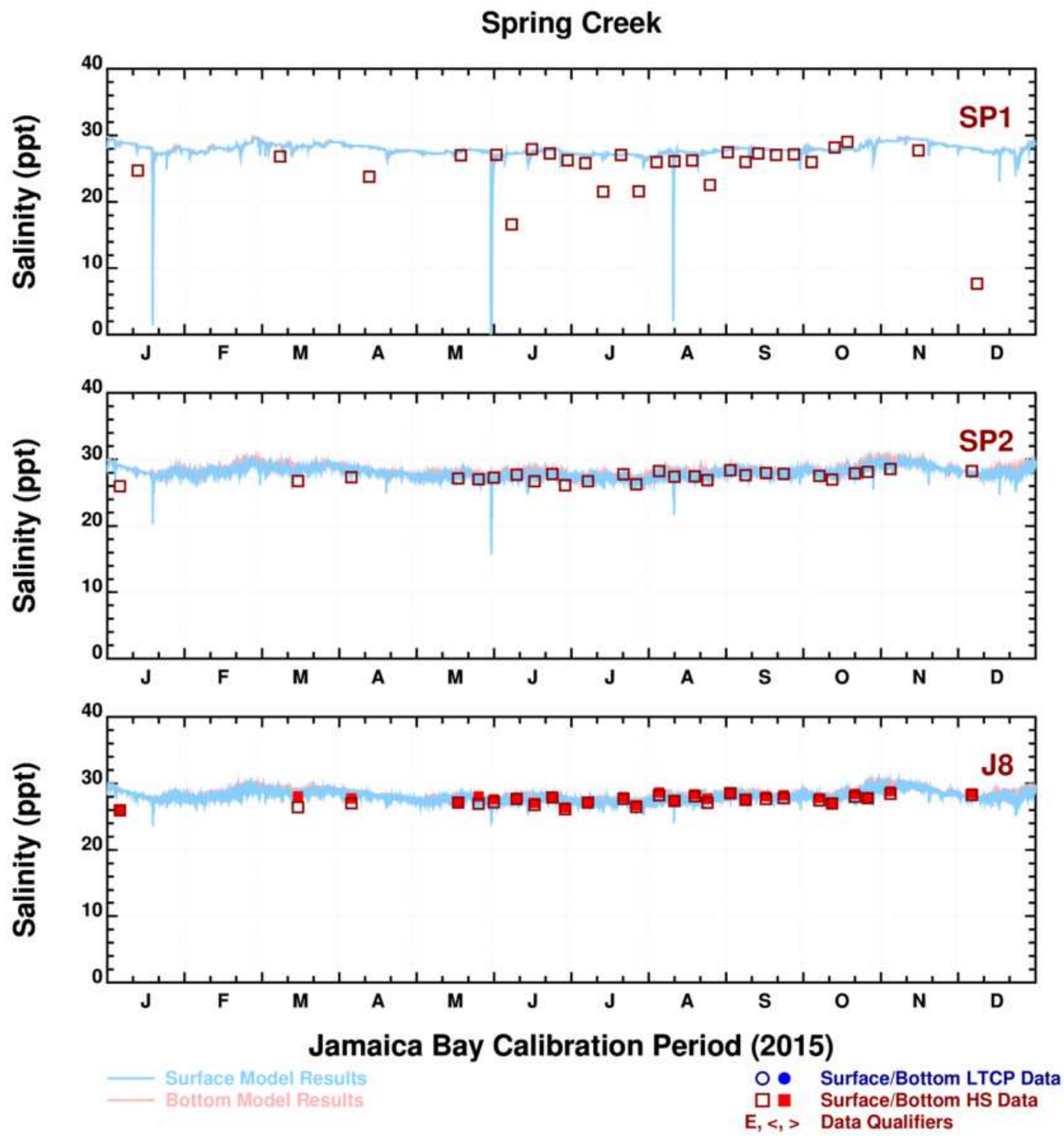

Figure 3-20. 2015 Salinity Calibration in Spring Creek and Nearby Jamaica Bay

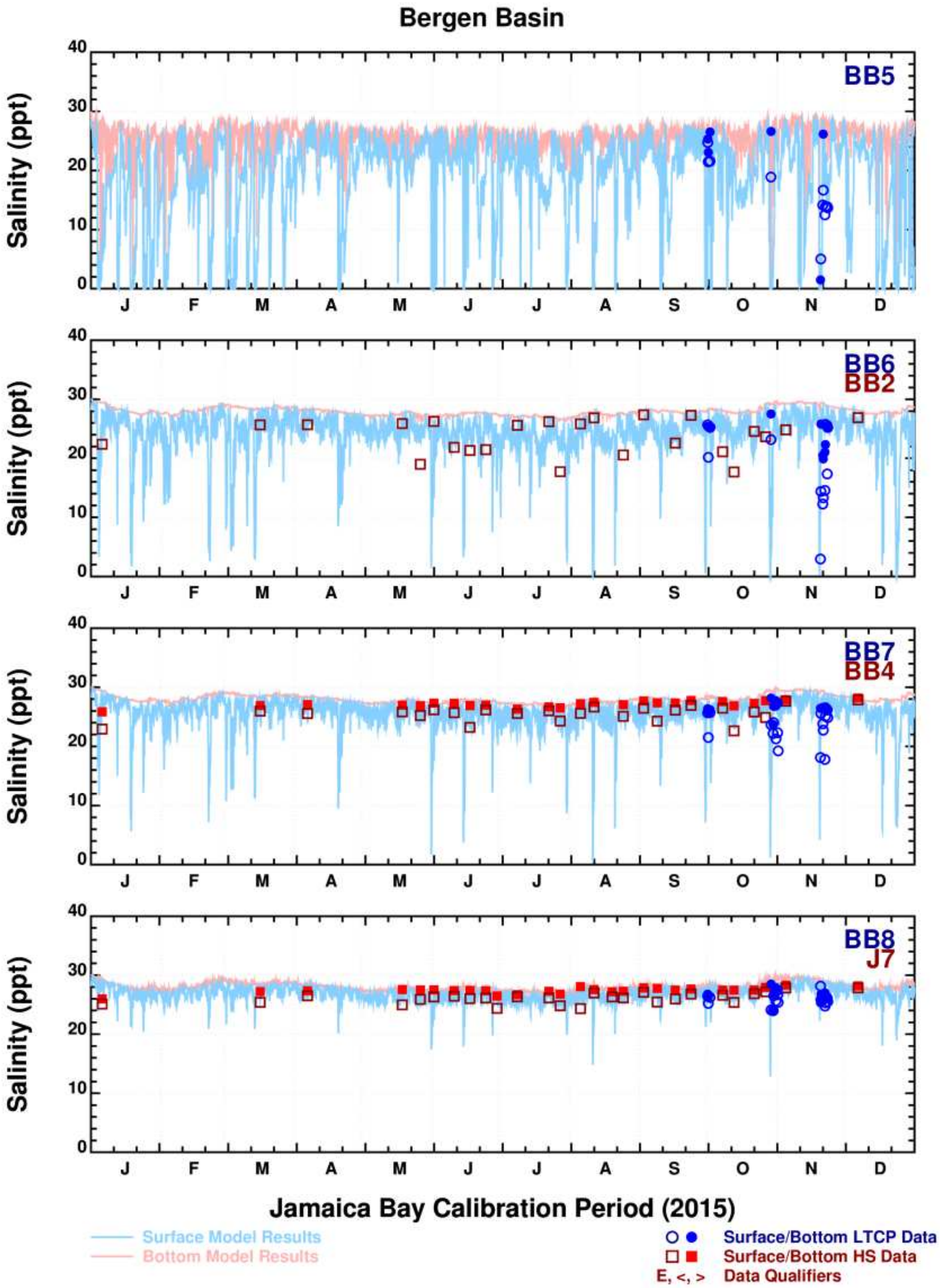

Figure 3-21. 2015 Salinity Calibration in Bergen Basin and Nearby Jamaica Bay

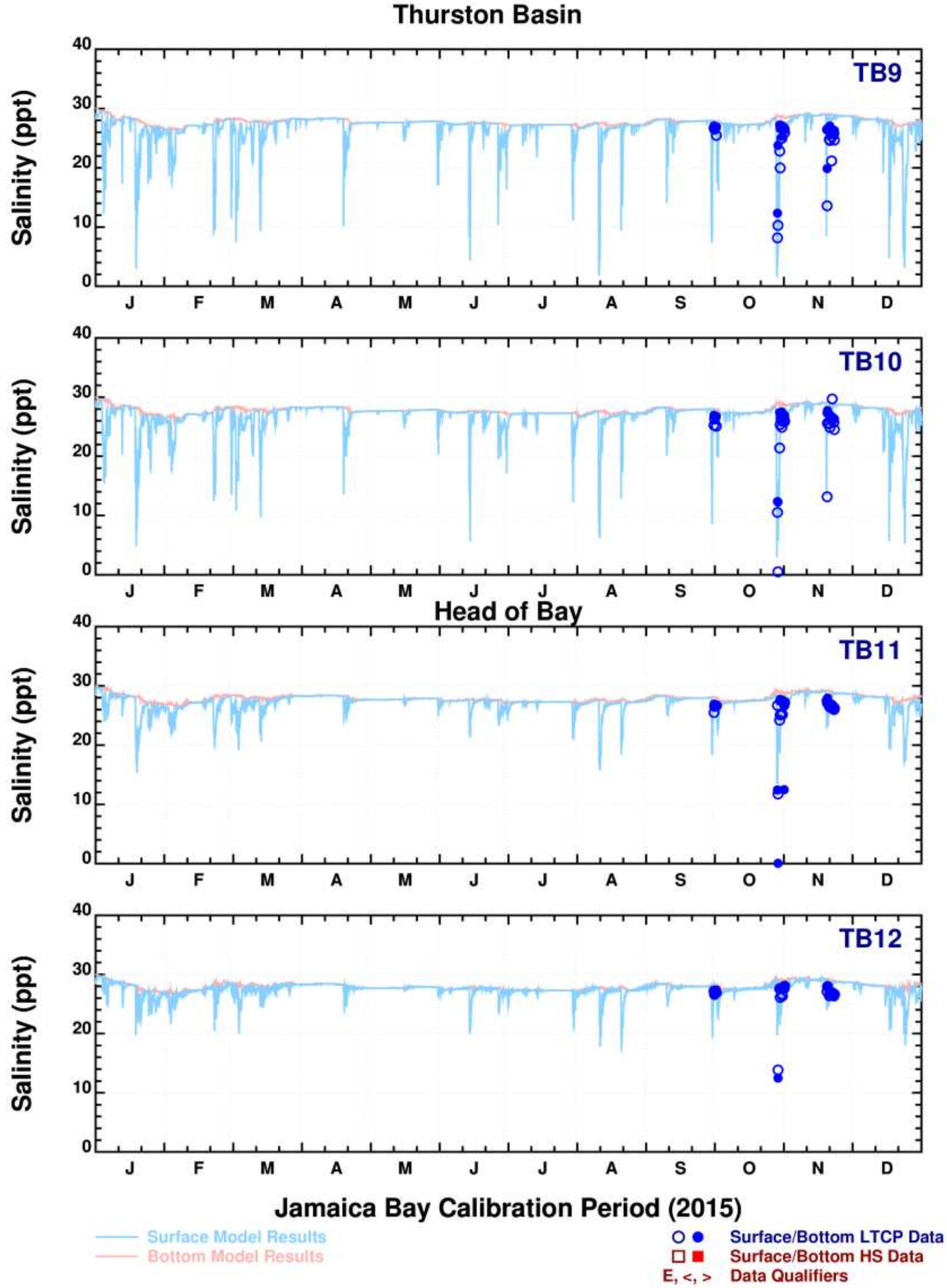

Figure 3-22. 2015 Salinity Calibration in Thurston Basin and Head of Bay

Figure 3-23 presents salinity data versus model results in the eastern, southern and central portions of the open waters of Jamaica Bay. At J12, some of the only observed salinity stratification in the bay is observed, due to the freshwater discharge from the Jamaica WWTP. The model reproduces the data very well. In the southern bay, at Station J5, stratification is generally not observed, and the model reproduces the observed data. In the center of the bay, at Stations J14 and J16, the model under-estimates the data. These salinity data are the highest in the bay, so there may be measurement error, or evaporation is causing higher salinity in the shallower inner portion of the bay.

Figure 3-24 presents salinity data and model comparisons for the western end of the bay. The model reproduces the salinity data very well.

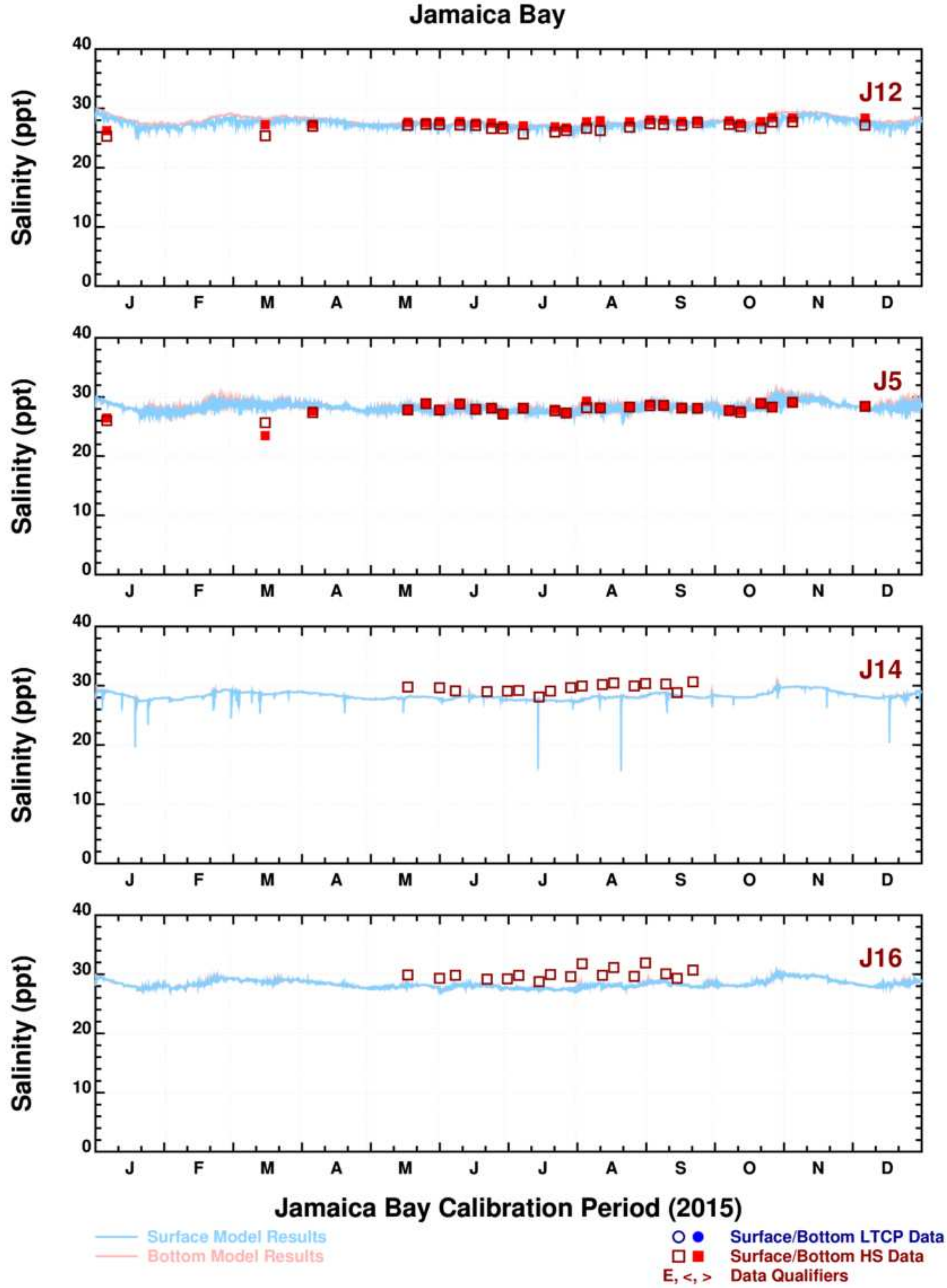

Figure 3-23. 2015 Salinity Calibration in Central and Eastern Jamaica Bay

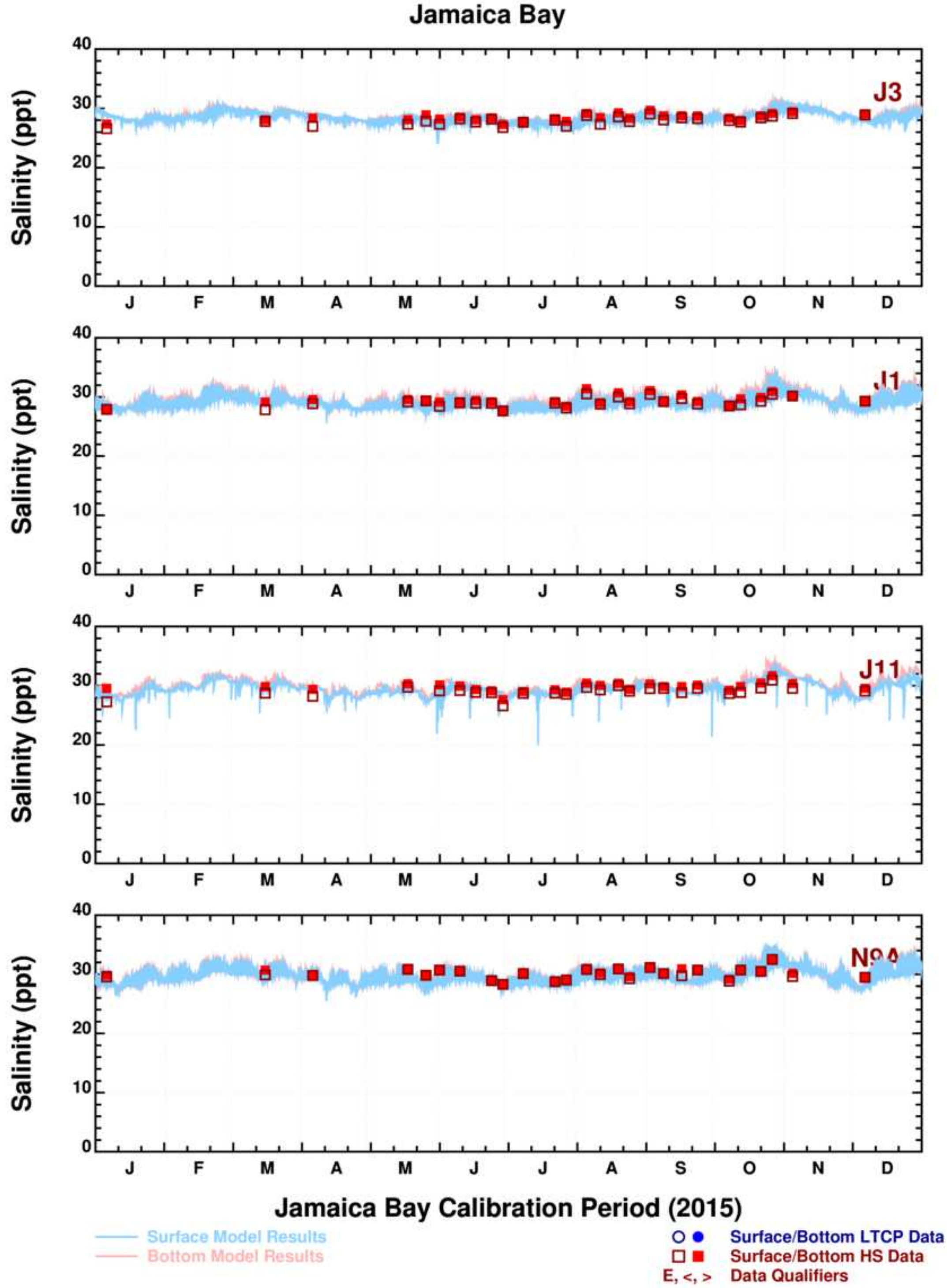

Figure 3-24. 2015 Salinity Calibration in Western Jamaica Bay

3.3 Water Quality Modeling

3.3.a Monitoring Program and Available Data

Data were collected in accordance with the Jamaica Bay FSAP at 12 receiving water sampling locations within Jamaica Bay, representative of wet- and dry-weather conditions. The sampling was conducted during September, October, and November 2015.

Both wet-weather and dry-weather samples were collected for fecal coliform and *Enterococcus* bacteria concentration analysis. Temperature, salinity and dissolved oxygen (DO) were concurrently measured with a multi-parameter water quality probe. Additional information regarding the receiving water sampling can be found in the "Data Collection Memorandum for Jamaica Bay" (AECOM, March 1, 2017).

The Harbor Survey, Sentinel Monitoring, and LTCP data collected during 2015 were used to calibrate the receiving water model.

3.3.b Pathogen Indicator Organism Load Source Sampling and Loading Development

Figure 2-1 presents the locations of existing sources of pollutants to Jamaica Bay including WWTPs, CSOs, stormwater, and direct drainage runoff. Source loads were developed using available and historic data. In addition, sanitary loads were added to the model to improve the model comparison to data during dry periods. These dry-weather loads are subsequently removed for baseline conditions assuming that illicit connections to the stormwater system have been abated.

Wastewater treatment plant effluent data were used to develop the WWTP loads. Fecal coliform bacteria concentrations were available on a daily basis. Very limited *Enterococci* concentration data were available. The sanitary fecal coliform-to-*Enterococci* ratio is estimated to be 4:1, and the disinfection rate of fecal coliform and *Enterococci* using chlorination is assumed to be similar. To be conservative on the higher side of potential concentrations, the *Enterococci* concentrations were assumed to be half of the fecal coliform concentrations.

Stormwater was monitored in several locations in the Jamaica Bay sewershed, but the stormwater results varied considerably in time and by location. To be conservative, most stormwater concentrations were based on previously collected citywide sampling data from the Inner Harbor Facility Planning Study (DEP, 1994) combined with data for the U.S. Environmental Protection Agency Harbor Estuary Program (HydroQual, 2005a). Using a conservative approach, the majority of the stormwater concentrations were based on the high level concentrations, with the exception of the Rockaway sewershed where low level concentrations were applied. An additional exception was Bergen Basin where sufficient data was collected. The IW sewer system model (Section 2) is used to generate the flows from NYC storm sewer outfalls, and concentrations noted in Table 3-1 are applied to the flows to develop pollutant loadings.

Table 3-1. Jamaica Bay Pollutant Source Loadings Characteristics

Source	Fecal Coliform (cfu/100mL)	*Enterococci* (cfu/100mL)	BOD_5 (mg/L)
Urban Stormwater (Bergen Basin)(1)	45,000	55,000	15
Urban Stormwater (Rockaway)(2)	35,000	15,000	15
Urban Stormwater (All Others)(2)	120,000	50,000	15
Sanitary for Mass Balance CSOs(3)	4,000,000	1,000,000	110
CSOs 26W-003, JAM-003, JAM-003A, PB-CSO, CI-004, CI-005 and CI-006(4)	Monte Carlo	Monte Carlo	Mass Balance
All other CSOs	Mass Balance	Mass Balance	Mass Balance
Highway/Airport Runoff (5)	20,000	8,000	15
Direct Drainage(6)	4,000	6,000	15
WWTP Effluent(7)	Monte Carlo	Monte Carlo	Quarterly

Notes:

(1) Stormwater bacteria concentrations based on 2015-2017 Jamaica Bay and Tributaries LTCP measurements. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2011).

(2) Stormwater bacteria concentrations based on HydroQual Memo to DEP, 2005a. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2011).

(3) Sanitary bacteria concentrations from the HydroQual Memo to DEP, 2005a.

(4) MonteCarlo based on 2015 LTCP CSO data.

(5) Highway/Airport runoff concentrations based on airport drainage data used in the Flushing Bay LTCP model estimated from NYS Stormwater Manual, Charles River LTCP, and National Stormwater Data Base.

(6) Direct drainage bacteria concentrations based on NYS Stormwater Manual, Charles River LTCP, and National Stormwater Data Base for commercial and industrial land uses. Direct drainage BOD_5 concentrations specified as stormwater.

(7) WWTP effluent bacteria concentrations based on 2016 DMR measurements: Monte Carlo selection of daily averages for fecal coliform and median of several months for *Enterococci*. BOD concentrations based on quarterly Biowin model results from the FANCJ analysis.

Probability distributions of the calculated and observed data for *Enterococci* and fecal coliform were developed to verify the Monte Carlo distributions. Figure 3-25 shows the calculated and observed distributions at CSO Outfall 26W-003, as well as overflow from the Paerdegat Basin CSO Control Facility. Figure 3-26 shows the calculated and observed distributions at CSO Outfalls JA-003 and JA-003A. Table 3-2 through Table 3-4 compare the characteristics of the observed and Monte Carlo generated distributions. As shown, the Monte Carlo methodology does a very good job of reproducing the observed data and its characteristics.

Table 3-2. Statistical Comparison Between Observed Paerdegat CSO Control Facility Overflow Bacteria Concentrations and Estimated Concentrations from the Monte Carlo Analysis

Statistics	*Enterococci* cfu/100mL		Fecal Coliform cfu/100mL	
	Observed	Estimated	Observed	Estimated
Geometric Mean	515,667	468,787	967,085	1,041,444
Standard Deviation(1)	0.27	0.28	0.30	0.29
Minimum	150,000	104,005	320,000	206,156
Maximum	1,350,000	1,742,642	3,400,000	3,842,722

Note:
(1) Standard deviation of the log of the concentrations.

Table 3-3. Statistical Comparison Between Observed CSO 26W-003 Bacteria Concentrations and Estimated Concentrations from the Monte Carlo Analysis

Statistics	*Enterococci* cfu/100mL		Fecal Coliform cfu/100mL	
	Observed	Estimated	Observed	Estimated
Geometric Mean	154,187	154,983	214,198	210,648
Standard Deviation(1)	0.48	0.49	0.35	0.37
Minimum	17,000	14,315	54,000	39,333
Maximum	1,300,000	4,281,614	790,000	1,714,286

Note:
(1) Standard deviation of the log of the concentrations.

Table 3-4. Statistical Comparison Between Observed CSO JAM-003/003A Bacteria Concentrations and Estimated Concentrations from the Monte Carlo Analysis

Statistics	*Enterococci* cfu/100mL		Fecal Coliform cfu/100mL	
	Observed	Estimated	Observed	Estimated
Geometric Mean	545,248	530,189	668,549	567,173
Standard Deviation(1)	0.39	0.41	0.56	0.57
Minimum	30,000	48,592	60,000	9,804
Maximum	3,000,000	10,919,029	14,700,000	10,697,424

Note:
(1) Standard deviation of the log of the concentrations.

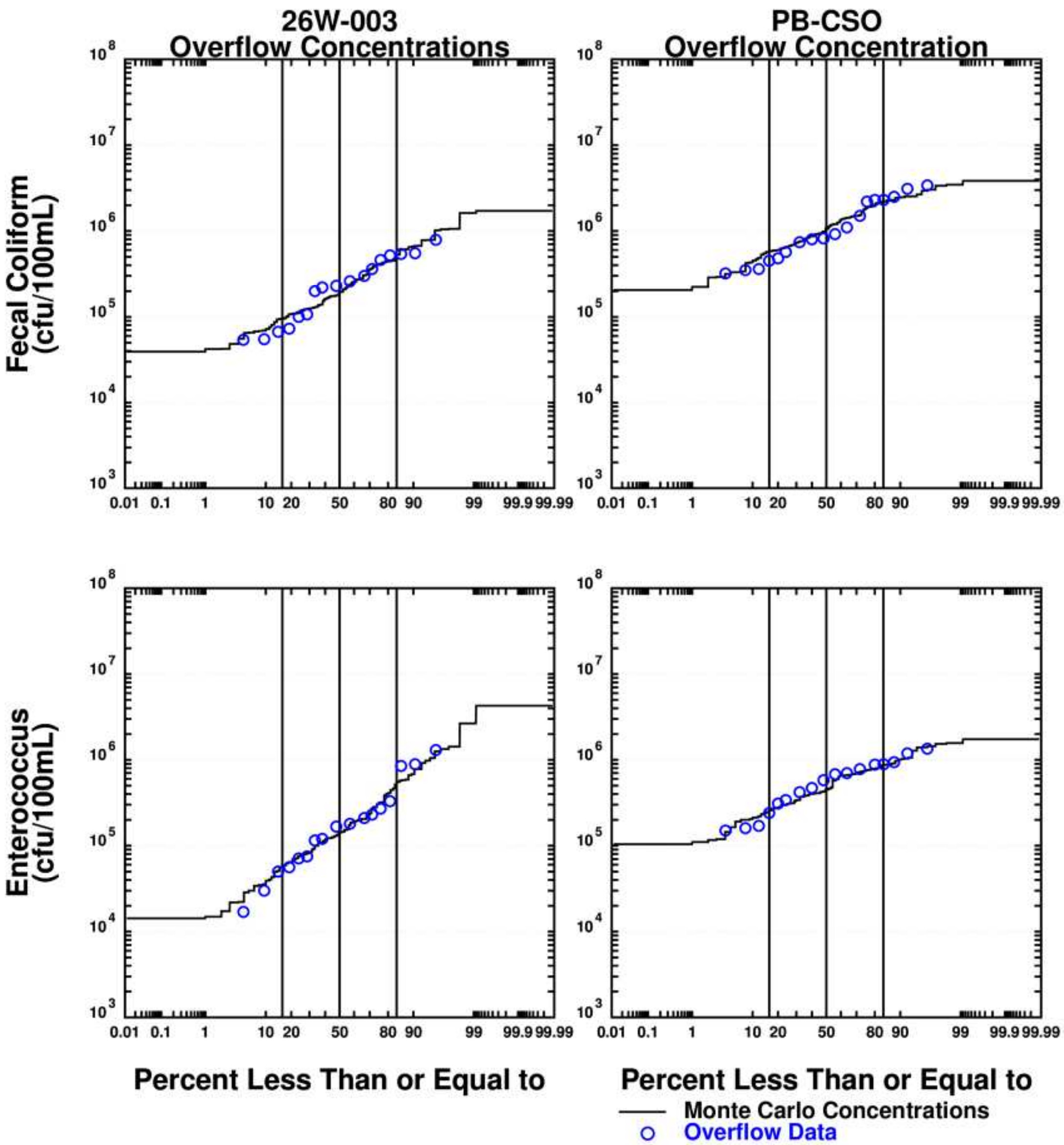

Figure 3-25. Probability Distribution Comparison Between Observed CSO 26W-003 and PB-CSO Bacteria Concentrations and Estimated Concentrations from the Monte Carlo Analysis

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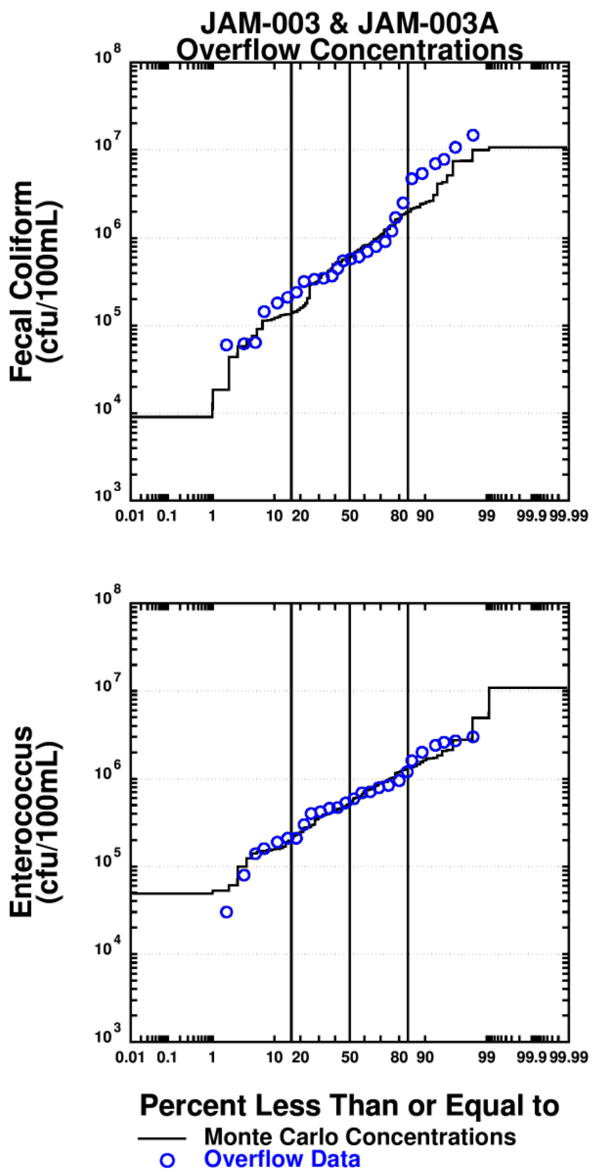

Figure 3-26. Probability Distribution Comparison Between Observed CSO JAM-003 and JAM-003A Bacteria Concentrations and Estimated Concentrations from the Monte Carlo Analysis

3.3.c **Bacteria Modeling Skill Assessment**

The bacteria loadings described above were incorporated into the receiving water quality model to calculate Jamaica Bay bacteria concentrations. Bacteria modeling results for the calibration were compared against both Harbor Survey and LTCP2 monitoring data to assess whether the model was capable of reproducing receiving water bacteria concentrations and whether the model could be used to assess CSO reduction alternatives.

It was noted during the calibration process that the bacteria concentrations in Jamaica Bay decreased more rapidly after precipitation events than the model predicted using the typical bacteria kinetics used in previously modeled LTCP2 waterbodies. Additionally, there is some variability of the bacteria loss rate from tributary to tributary. While it had been noticed that the bacteria concentrations decreased faster than the model predicted in other waterbodies as well, the difference in other waterbodies between the model and data was not as dramatic. After a review of possible mechanisms that would cause a more rapid decline in bacteria concentrations, such as sunlight or an increased bacteria die-off rate, it was decided that particulate settling was the most likely factor. Additionally, *Enterococci* appeared to decline more rapidly than fecal coliform, which is counter to the expectation that *Enterococci* are more resistant to environmental factors than fecal coliform.

Based on an assessment of Coney Island Creek data, where high fecal coliform to *Enterococci* ratios were observed, it was theorized that under certain conditions fecal coliform can survive in the sediment and return to the water column either through resuspension or some other process. In an effort to reproduce that mechanism, the JEM kinetics were modified to include a net settling rate factor (V_{snet}) to replicate resuspension of fecal coliform into the water column. The net settling rate factor reduces the amount of settleable material that is incorporated into the sediment. It is anticipated that re-suspension would occur due to current speed, as well as wind and wave action, so that shallow areas were more likely to have resuspension than deeper areas. To reproduce this resuspension effect, scale factors shown in Table 3-5 were applied based on the depth of the model segment. The application of this scale factor improved the model fit to the data in some shallow areas, as shown in Figure 3-27. Without the net settling rate factor, the model under-estimates the concentrations at the end of the storm. With the net settling rate factor, the model more favorably reproduces the data.

Table 3-5. Assignment of V_{snet} Based on Depth

Model Depth (m)	V_{snet}
< 2.0	0.2
2.0 – 3.0	0.4
3.0 – 4.0	0.6
4.0 – 5.0	0.8
> 5.0	1.0

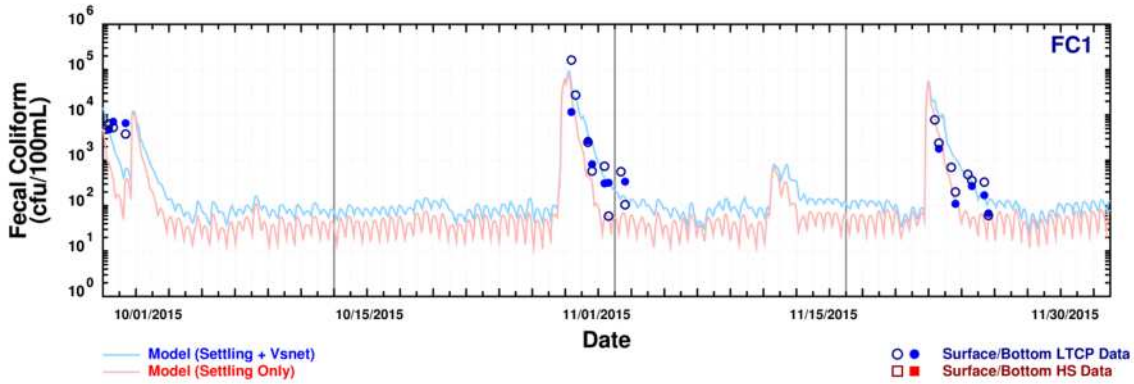

Figure 3-27. Comparison of Fecal Coliform Model Results versus Data for Modeling Scenarios With and Without V_{snet} at Station FC1

The results of the updated calibration are presented in Figure 3-28 through Figure 3-43. Figure 3-28 and Figure 3-29 present the model versus data comparison in Paerdegat Basin for fecal coliform and *Enterococci*, respectively. Like many waterbodies around New York City, there is evidence of an intermittent source of bacteria during dry-weather. To improve the model comparison to data, a small, constant bacteria source, equivalent to a sanitary flow of approximately 6,500 gpd, was applied to the head end of the basin. The model generally matches or exceeds the peak bacteria concentrations measured in the basin. The model is better at reproducing the dry-weather *Enterococci* concentrations than the fecal coliform concentrations, but does reasonably well reproducing both.

Figure 3-30 and Figure 3-31 present model versus data comparisons for fecal coliform and *Enterococci*, respectively, in Fresh Creek. As in Paerdegat Basin, a small constant bacteria load, equivalent to a sanitary flow of approximately 3,200 gpd, was added at the head end of the Creek to reproduce some of the higher bacteria concentrations measured during dry-weather. The model reproduces the high bacteria concentrations very well and also reproduces the lower *Enterococci* concentrations very well. The fecal coliform concentrations remain elevated during dry-weather in Fresh Creek and out into Jamaica Bay, suggesting there are other local sources of fecal coliform.

Model versus data comparisons for fecal coliform and *Enterococci* concentrations in Hendrix Creek are presented in Figure 3-32 and Figure 3-33, respectively. Hendrix Creek bacteria loads include the 26th Ward WWTP, which were based on measured fecal coliform concentrations. *Enterococci* concentrations, which are not measured at the WWTP, were assigned at half of the fecal coliform concentration. Also, a dry, sanitary flow of 320 gpd was assigned to reproduce the dry-weather receiving water concentrations. The model calculates higher peak concentrations than appear in the data, but this may be a function of when samples were collected. The model generally reproduces the bacteria data measured in the Creek.

The Spring Creek model versus data comparisons for fecal coliform and *Enterococci* are presented in Figure 3-34 and Figure 3-35, respectively. A constant dry-weather loading based on 2,600 gpd was added to the head end of the Creek for calibration purposes. The model generally reproduces the measured bacteria data during both dry- and wet-weather; however, toward the mouth of Spring Creek the dry-weather fecal coliform concentrations are sometimes under-estimated. The model accurately reproduces the bacteria concentrations during the larger wet-weather events.

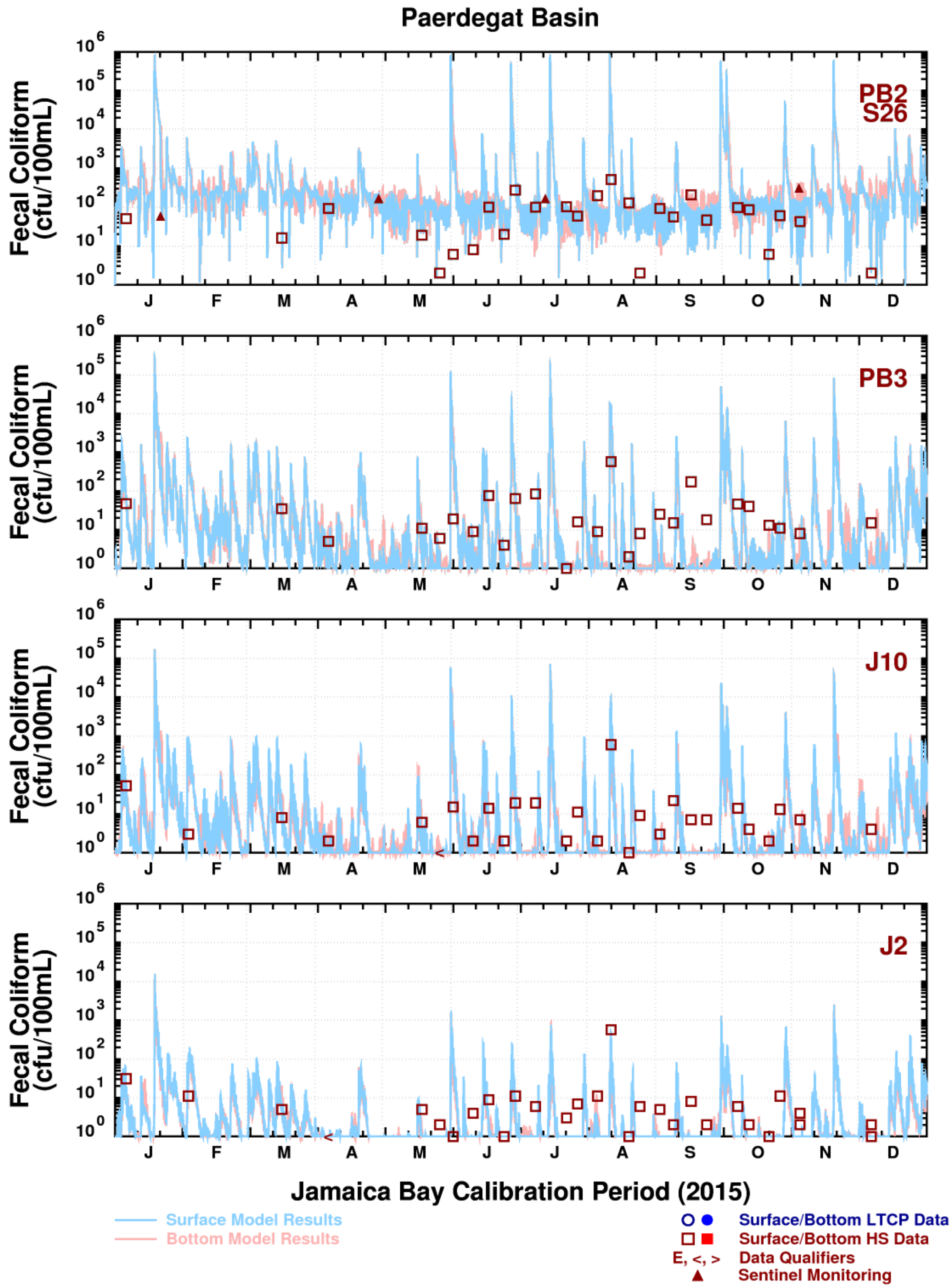

Figure 3-28. 2015 Fecal Coliform Calibration in Paerdegat Basin and Nearby Jamaica Bay Stations

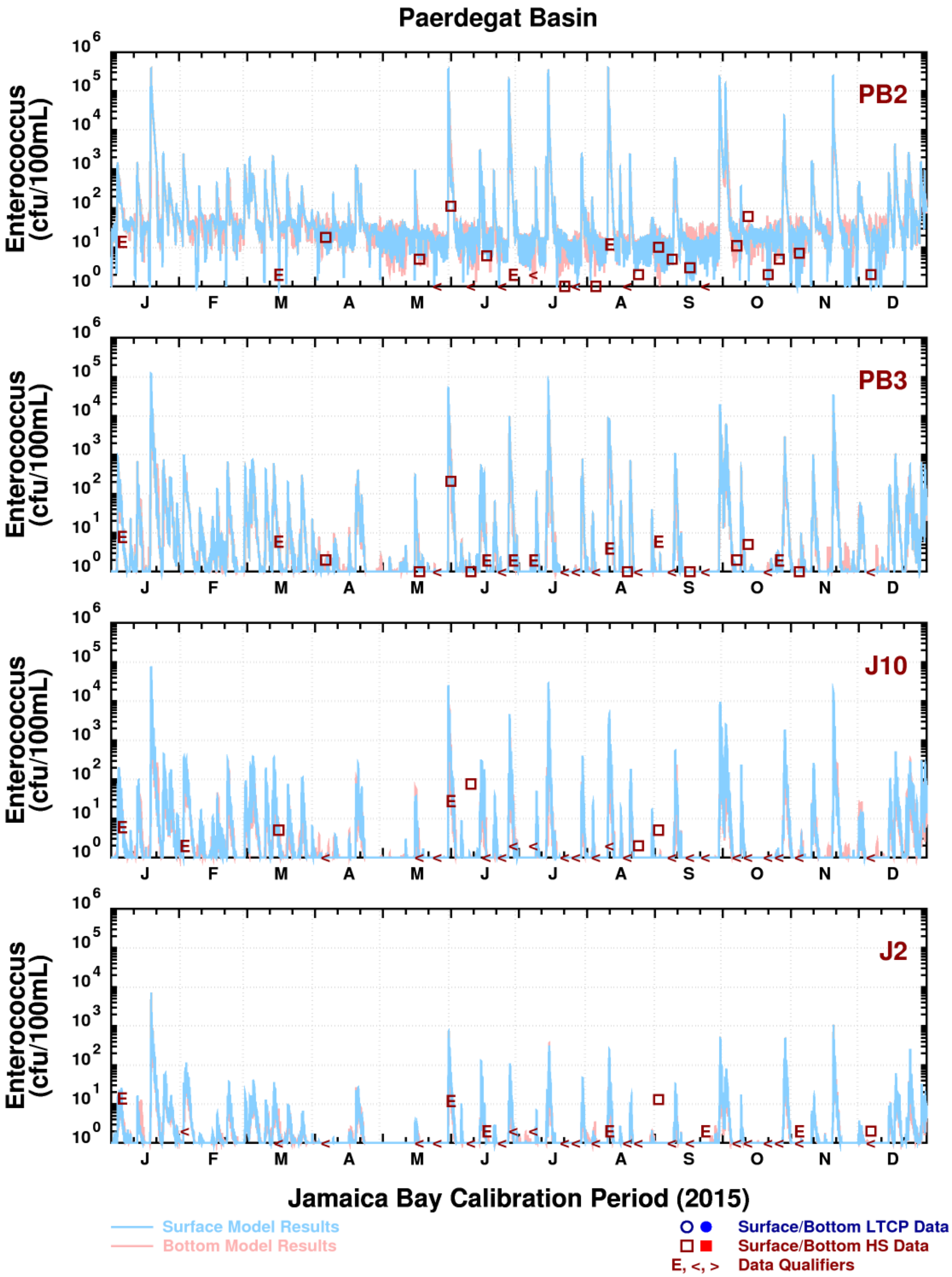

Figure 3-29. 2015 *Enterococci* Calibration in Paerdegat Basin and Nearby Jamaica Bay Stations

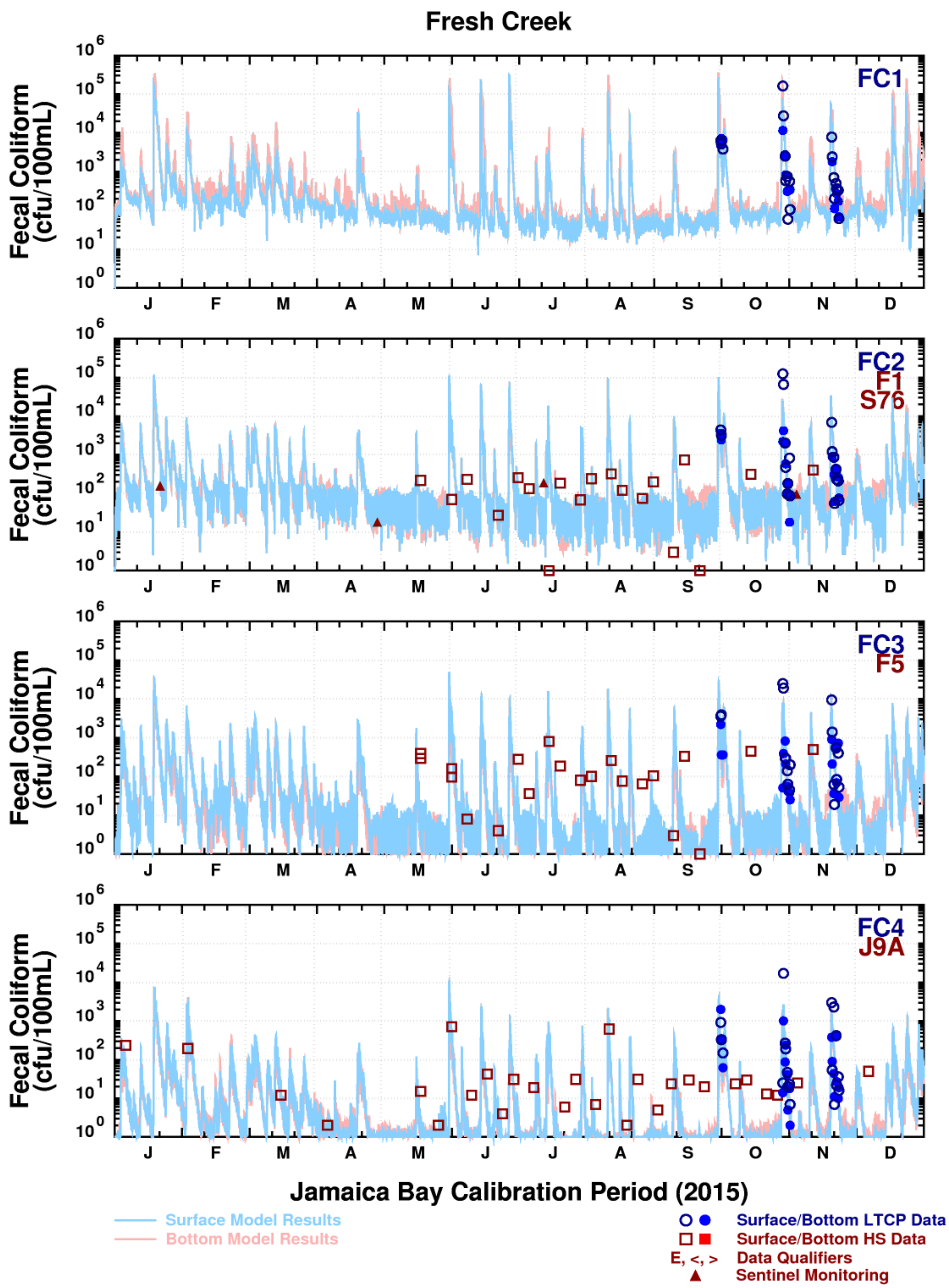

Figure 3-30. 2015 Fecal Coliform Calibration in Fresh Creek and Nearby Jamaica Bay Stations

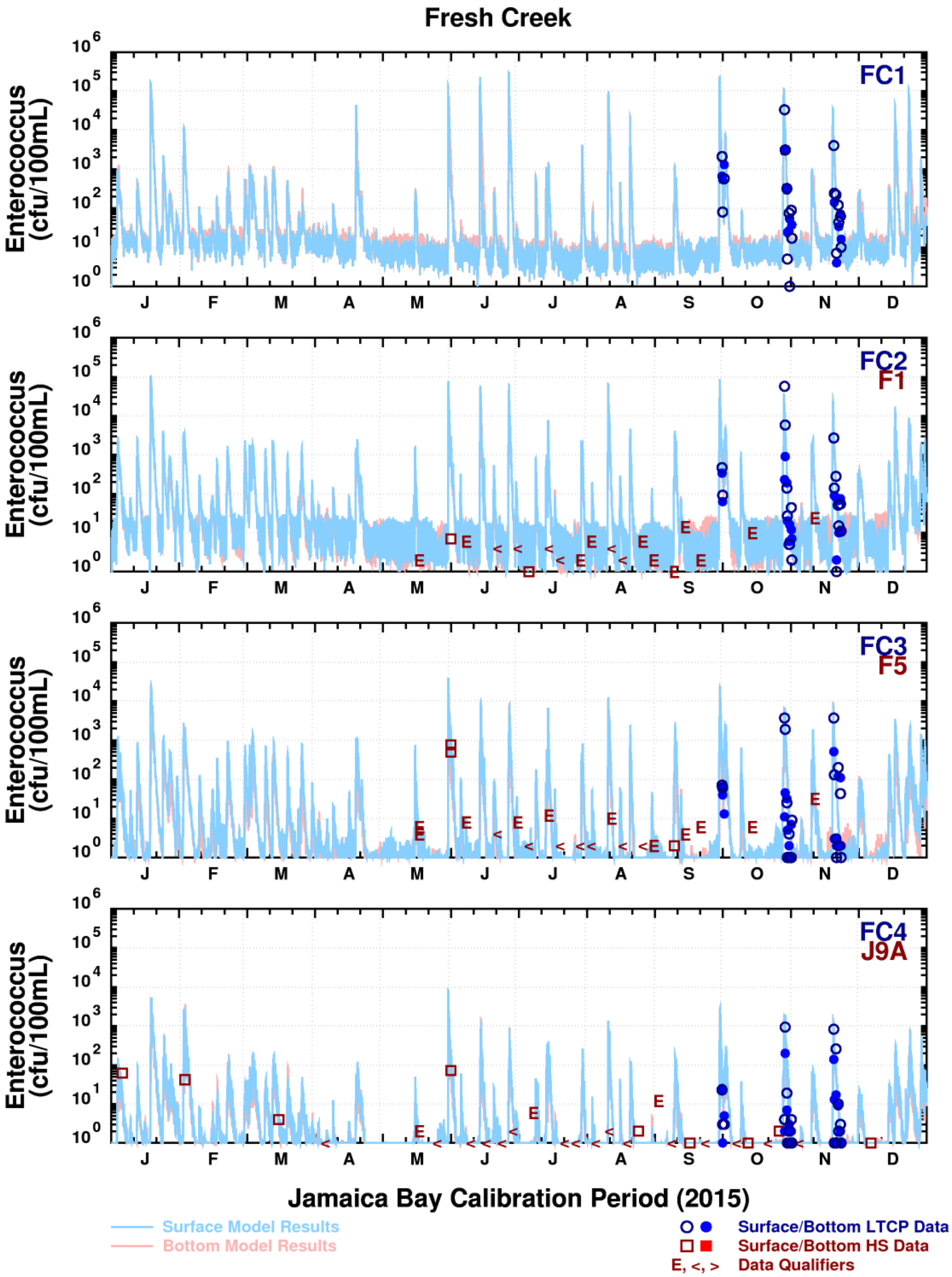

Figure 3-31. 2015 *Enterococci* Calibration in Fresh Creek and Nearby Jamaica Bay Stations

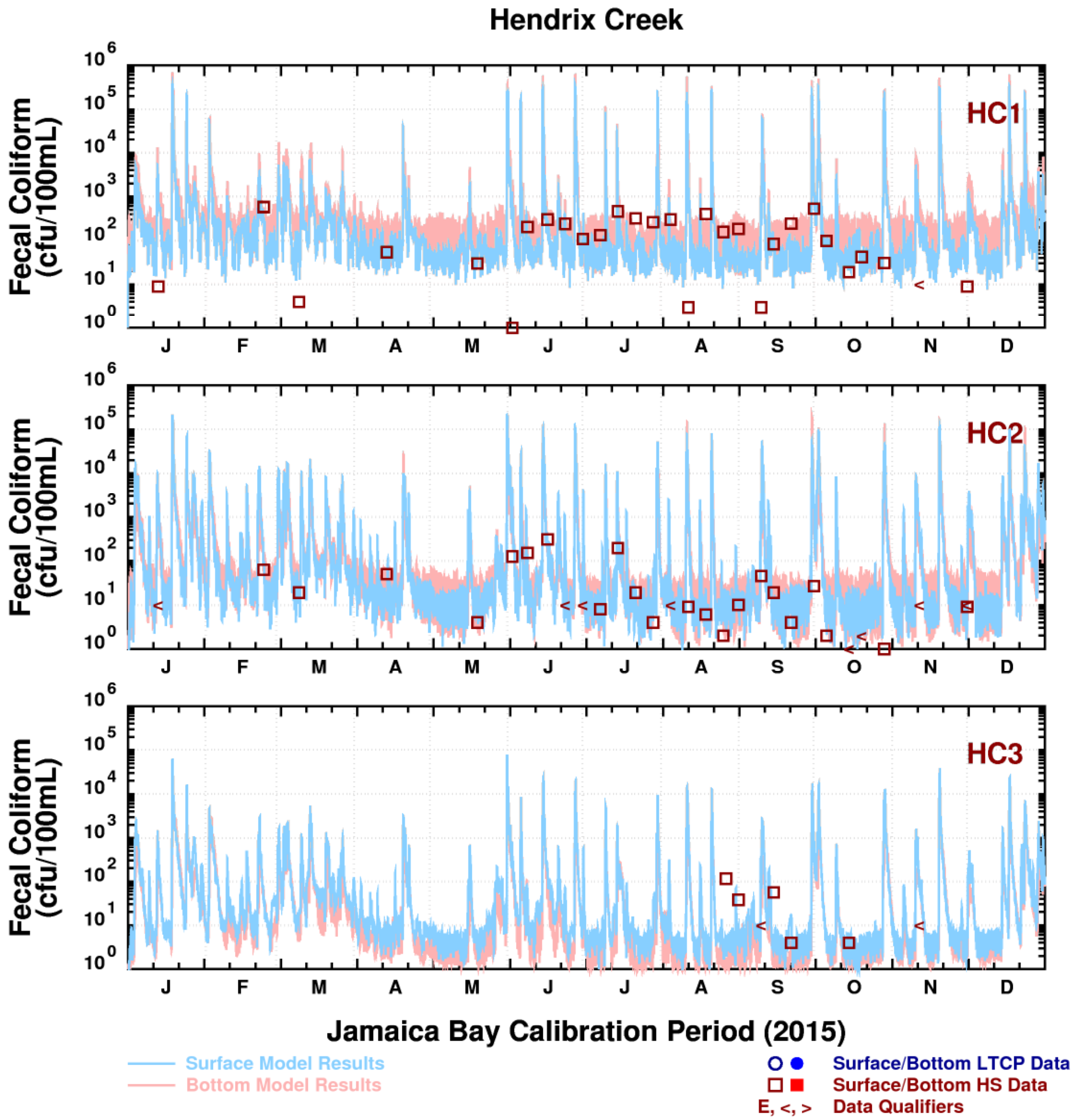

Figure 3-32. 2015 Fecal Coliform Calibration in Hendrix Creek

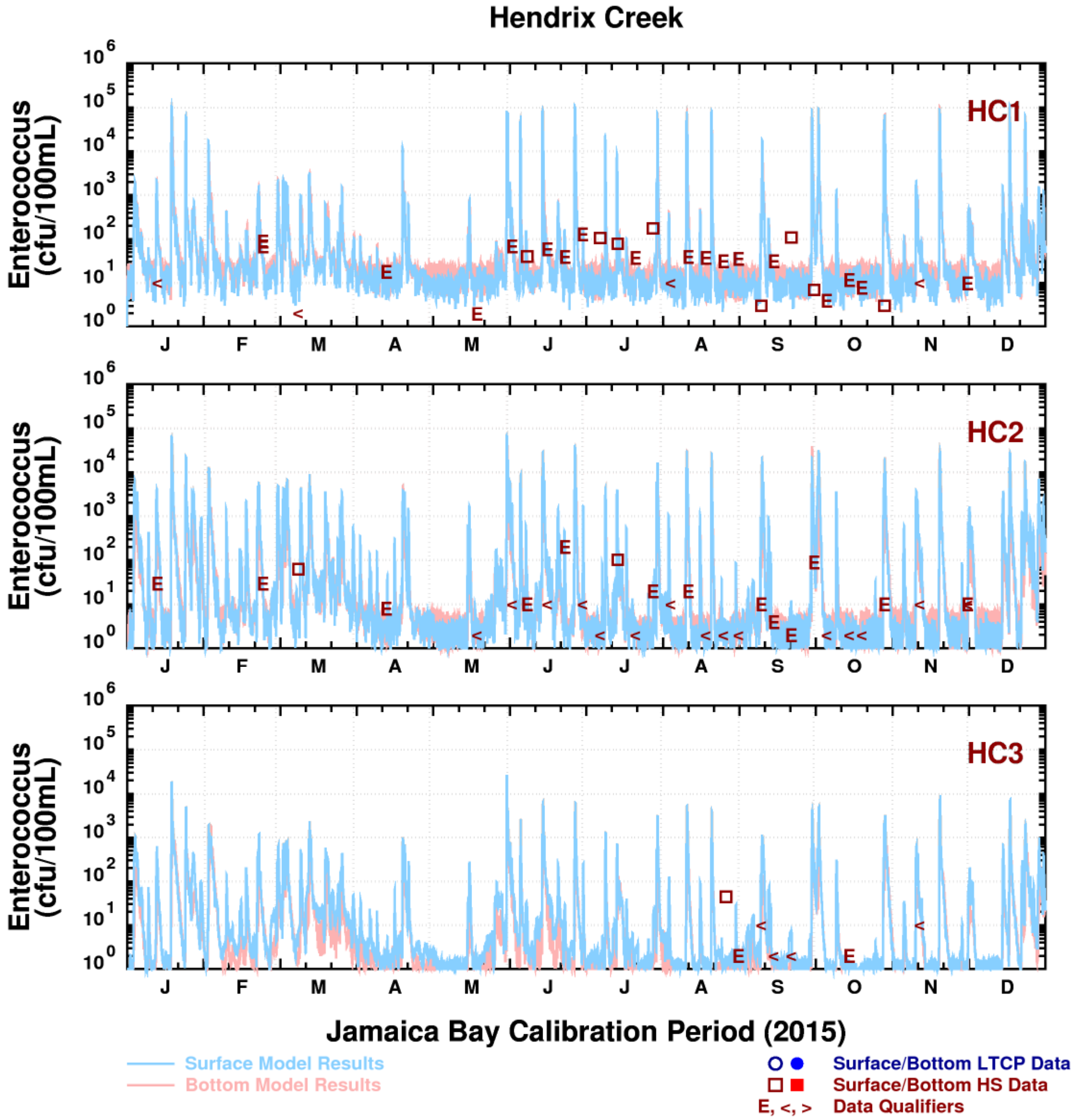

Figure 3-33. 2015 *Enterococci* Calibration in Hendrix Creek

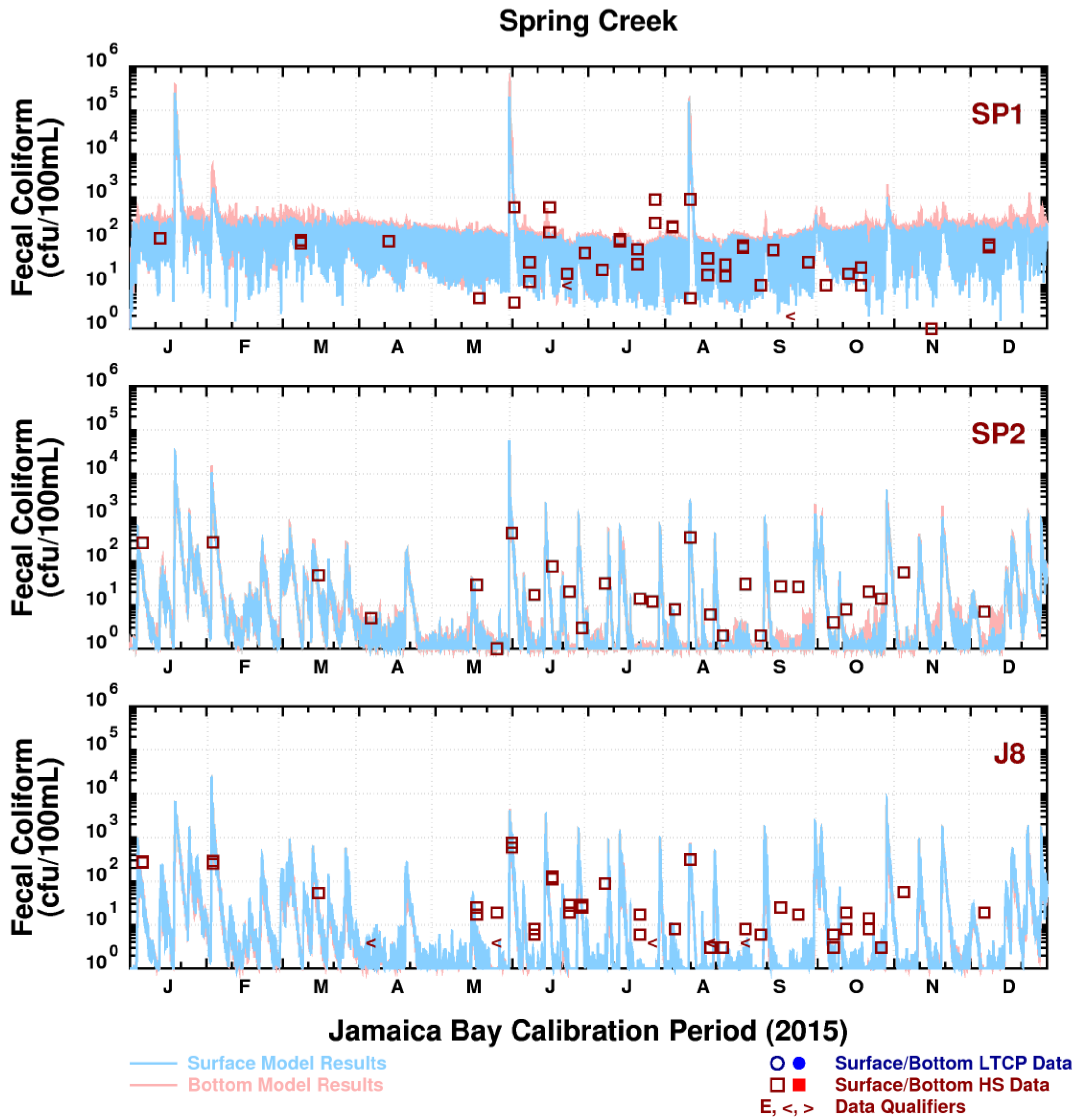

Figure 3-34. 2015 Fecal Coliform Calibration in Spring Creek and Nearby Jamaica Bay Stations

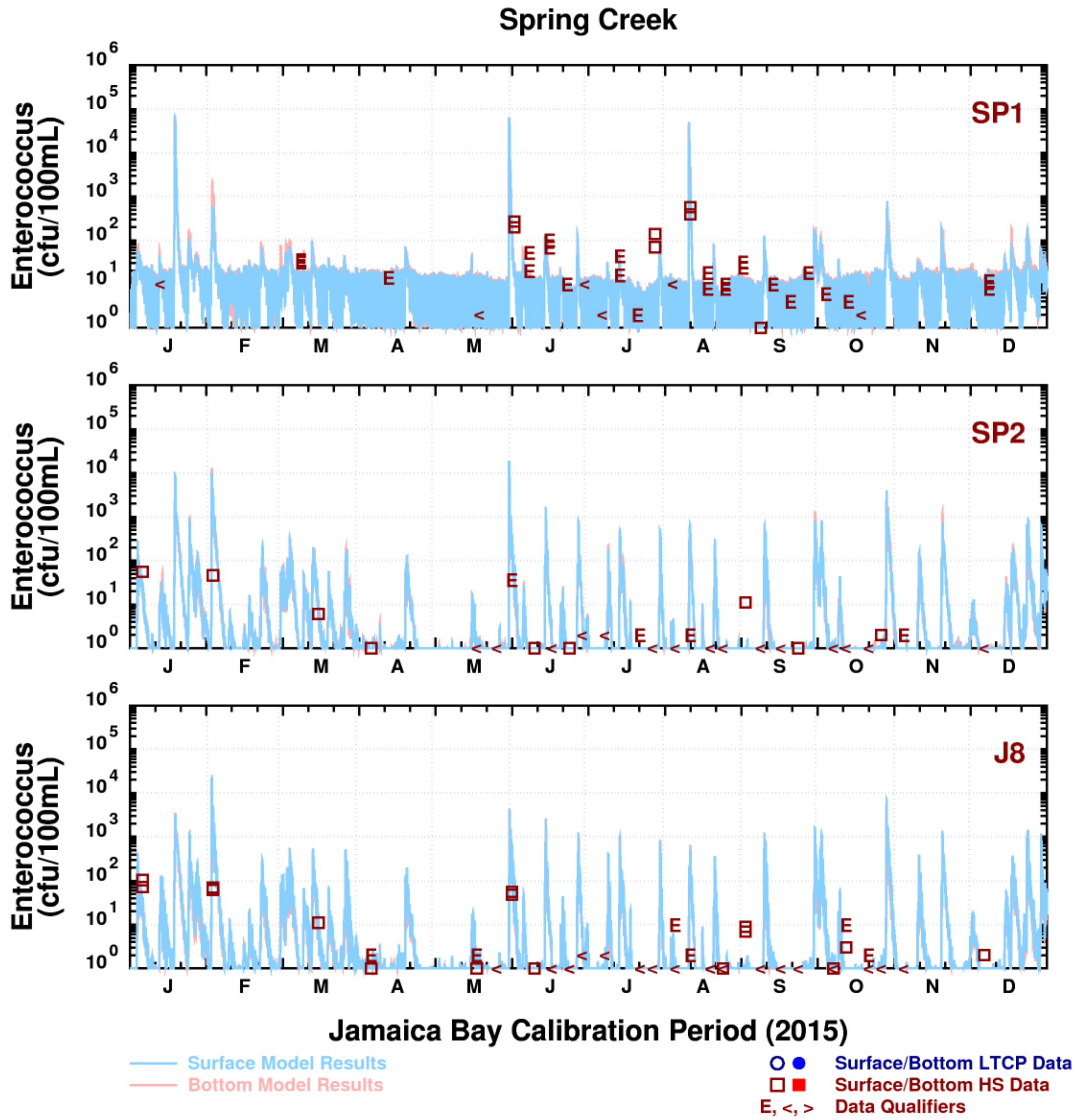

Figure 3-35. 2015 *Enterococci* Calibration in Spring Creek and Nearby Jamaica Bay Stations

The model versus data comparisons for fecal coliform and *Enterococci* in Bergen Basin are presented in Figure 3-36 and Figure 3-37, respectively. Bergen Basin had the largest dry-weather loading assigned to any tributary with a sanitary flow of approximately 32,000 gpd. The model reasonably reproduces the timing and magnitude of the measured wet-weather bacteria concentrations. In general, the measured dry-weather bacteria concentrations fall within the range of concentrations calculated by the model.

The model comparison to fecal coliform and *Enterococci* data collected in Thurston Basin and Head of Bay are presented in Figure 3-38 and Figure 3-39, respectively. Unlike the other tributaries, Harbor Survey does not have stations in Thurston Basin or Head of Bay. Since the typical dry-weather concentrations were unknown, no dry-weather loading was added to the basin. The Sentinel Monitoring Program does have a station at the mouth of Thurston Basin that does suggest elevated fecal coliform concentrations, but since dry-weather loads are removed from baseline conditions, the effort was not made to match the sparse Sentinel Monitoring data. The model generally reproduces the observed wet-weather bacteria concentrations.

Figure 3-40 and Figure 3-41 present the fecal coliform and *Enterococci* model versus data comparisons for eastern and central open waters of Jamaica Bay. Measured fecal coliform and *Enterococci* concentrations are generally low in these regions of the bay, but dry-weather fecal coliform concentrations persist above 1 cfu/100mL whereas dry-weather *Enterococci* data contain many "less–than-detection-limit" values. The model reasonably calculates the peak values observed in the data. The *Enterococci* data are reproduced by the model during wet- and dry-weather. The dry-weather fecal coliform data suggest either a local source such as wildlife or resuspension of sediment or a low level persistent population.

The model versus data comparison for fecal coliform and *Enterococci* are presented in Figure 3-42 and Figure 3-43, respectively, for the western stations in the open water of the bay. The bacteria data in this region of the bay are generally low, with the exception of Station J11 at the mouth of Sheepshead Bay. The fecal coliform data indicate a dry-weather source, but this is less clear in the *Enterococci* data at this station. Since this is not a CSO tributary and dry-weather sources are removed for projection purposes, no effort was made to estimate the size of a potential illicit source. The model reproduces the magnitude of the wet-weather concentrations, but under-estimates some of the dry-weather fecal concentrations. The model reasonably reproduces the *Enterococci* data.

Model versus data probability plots were also created for the fecal coliform and *Enterococci* data, and they are presented in Appendix D.

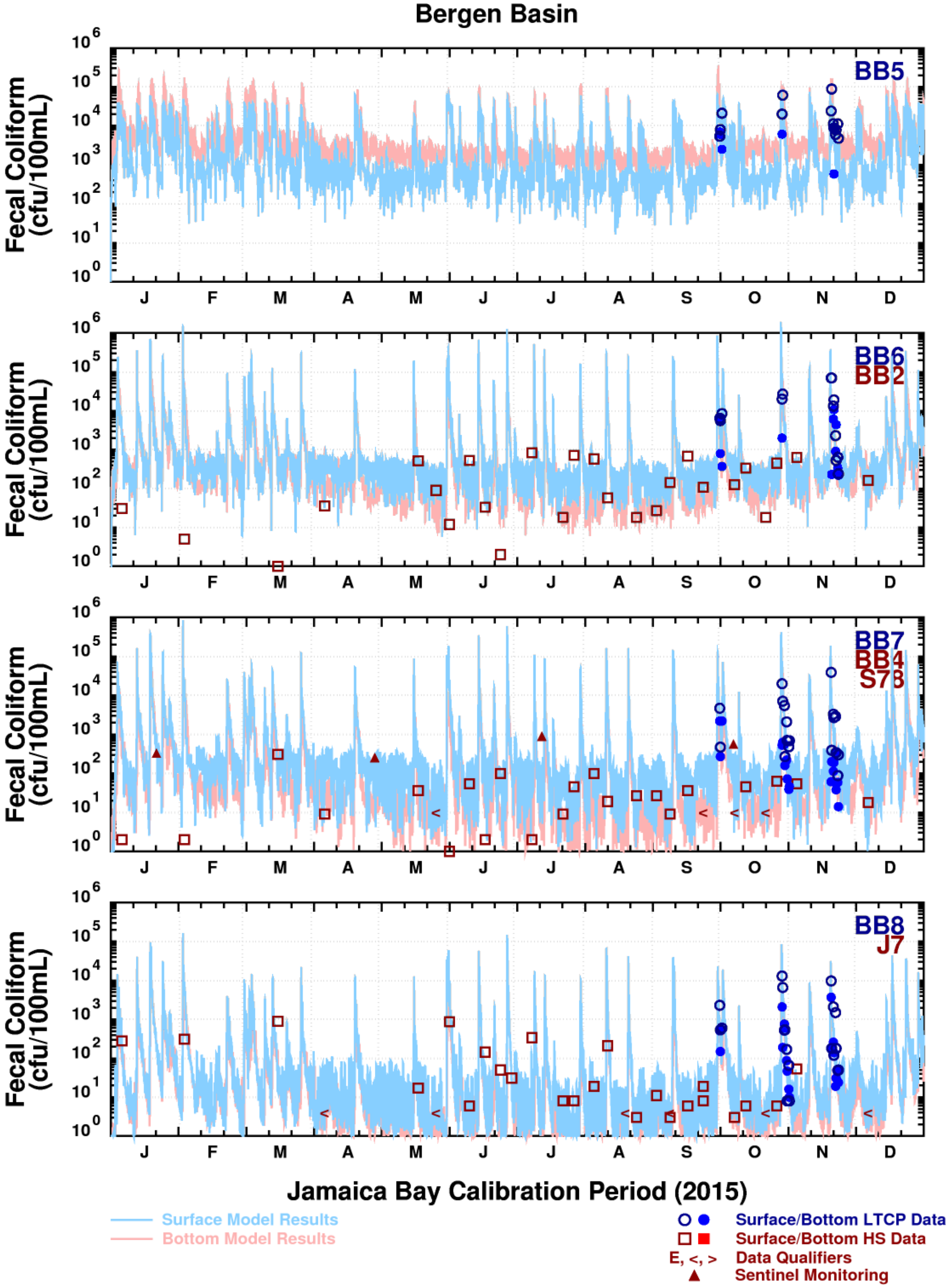

Figure 3-36. 2015 Fecal Coliform Calibration in Bergen Basin and Nearby Jamaica Bay Stations

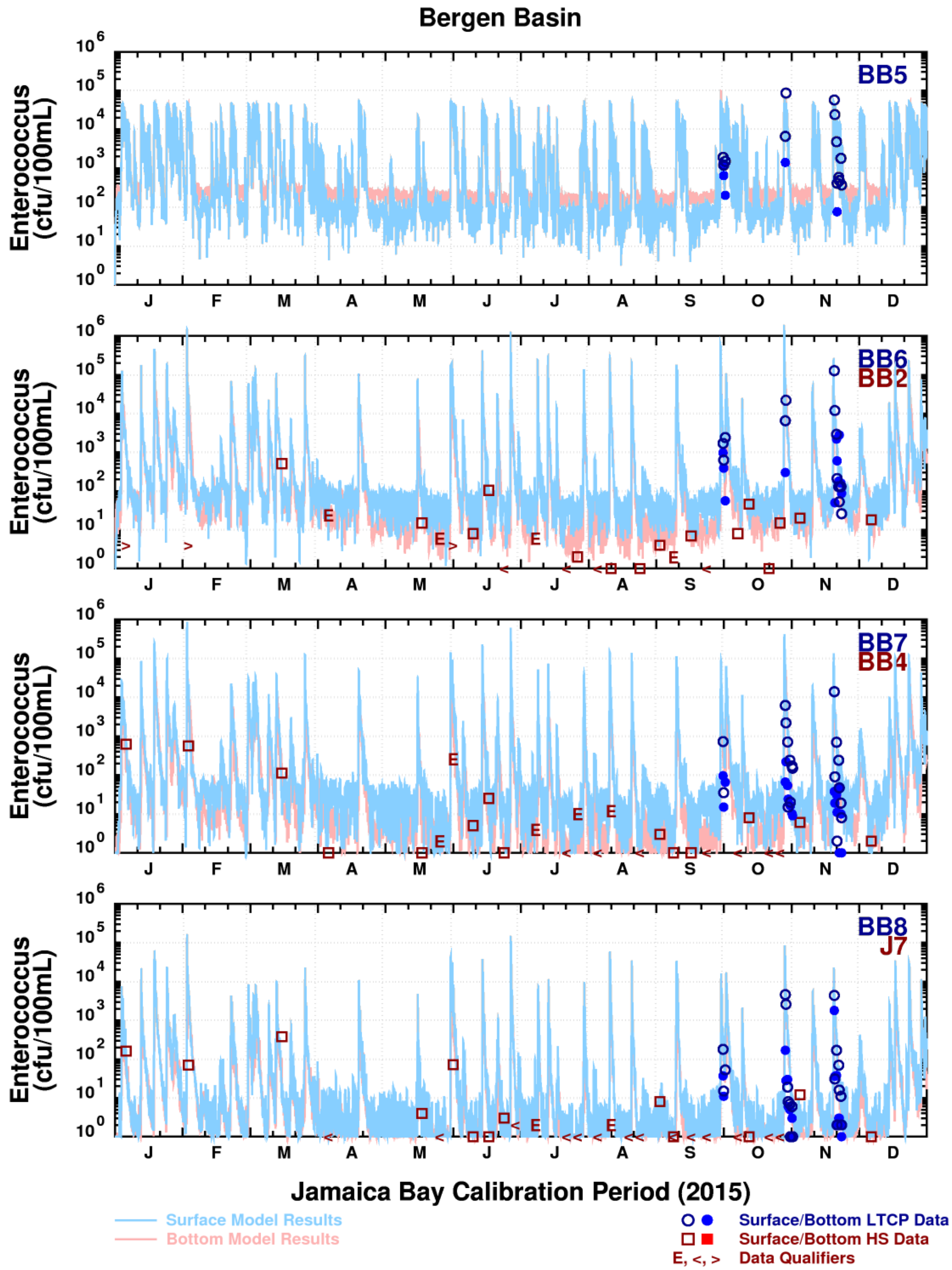

Figure 3-37. 2015 *Enterococci* Calibration in Bergen Basin and Nearby Jamaica Bay Stations

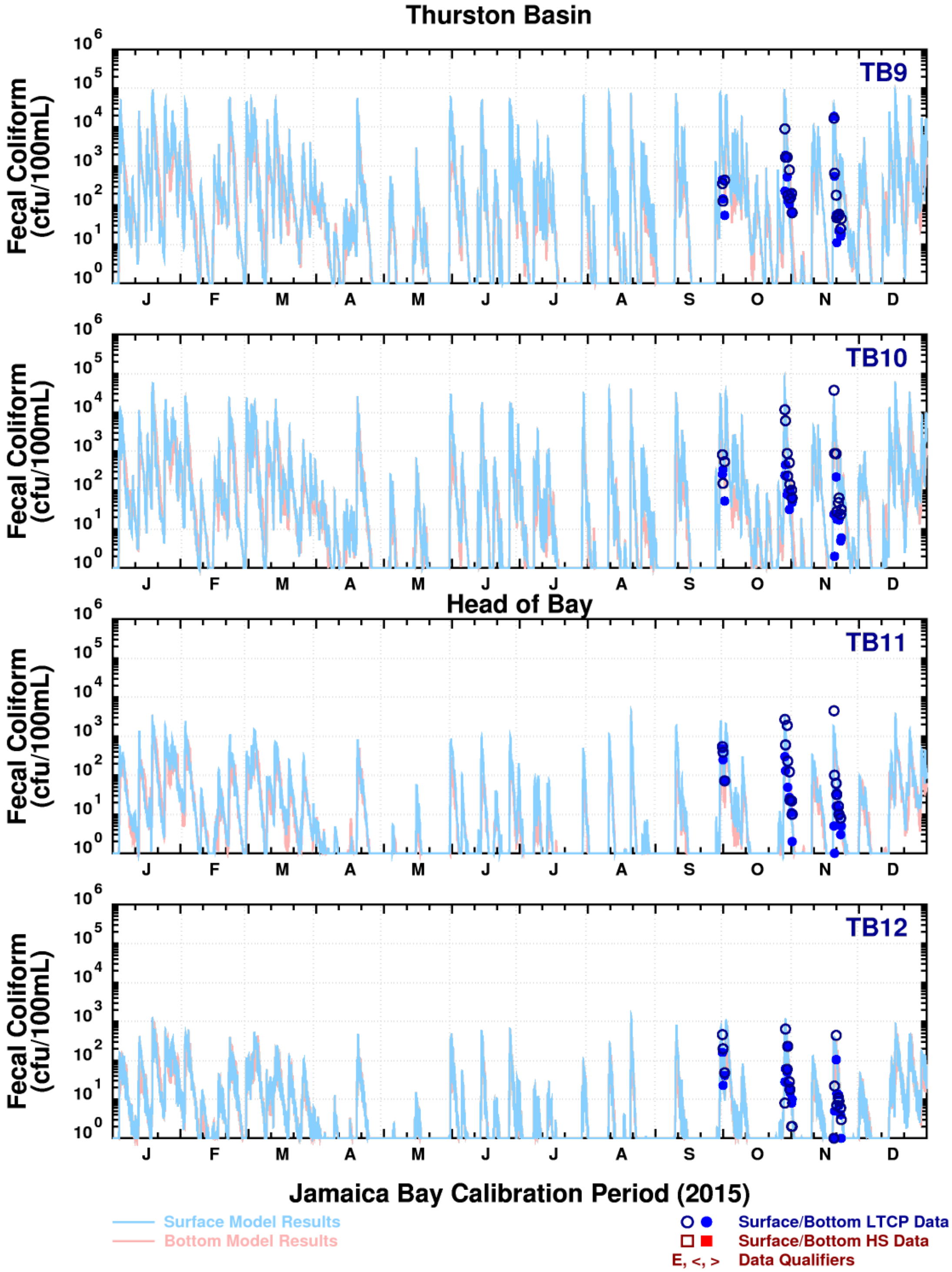

Figure 3-38. 2015 Fecal Coliform Calibration in Thurston Basin and Head of Bay

AECOM with Hazen

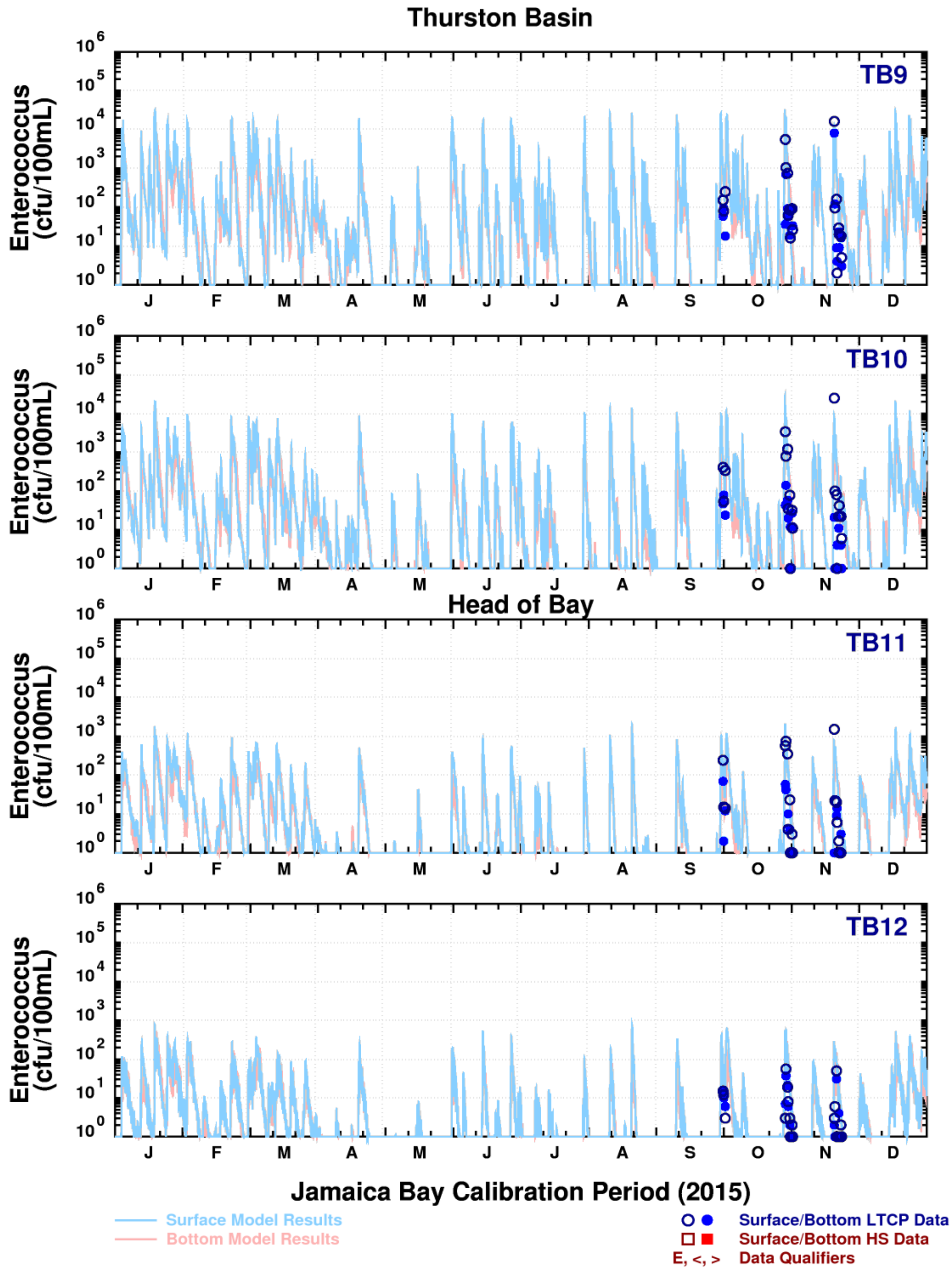

Figure 3-39. 2015 *Enterococci* Calibration in Thurston Basin and Head of Bay

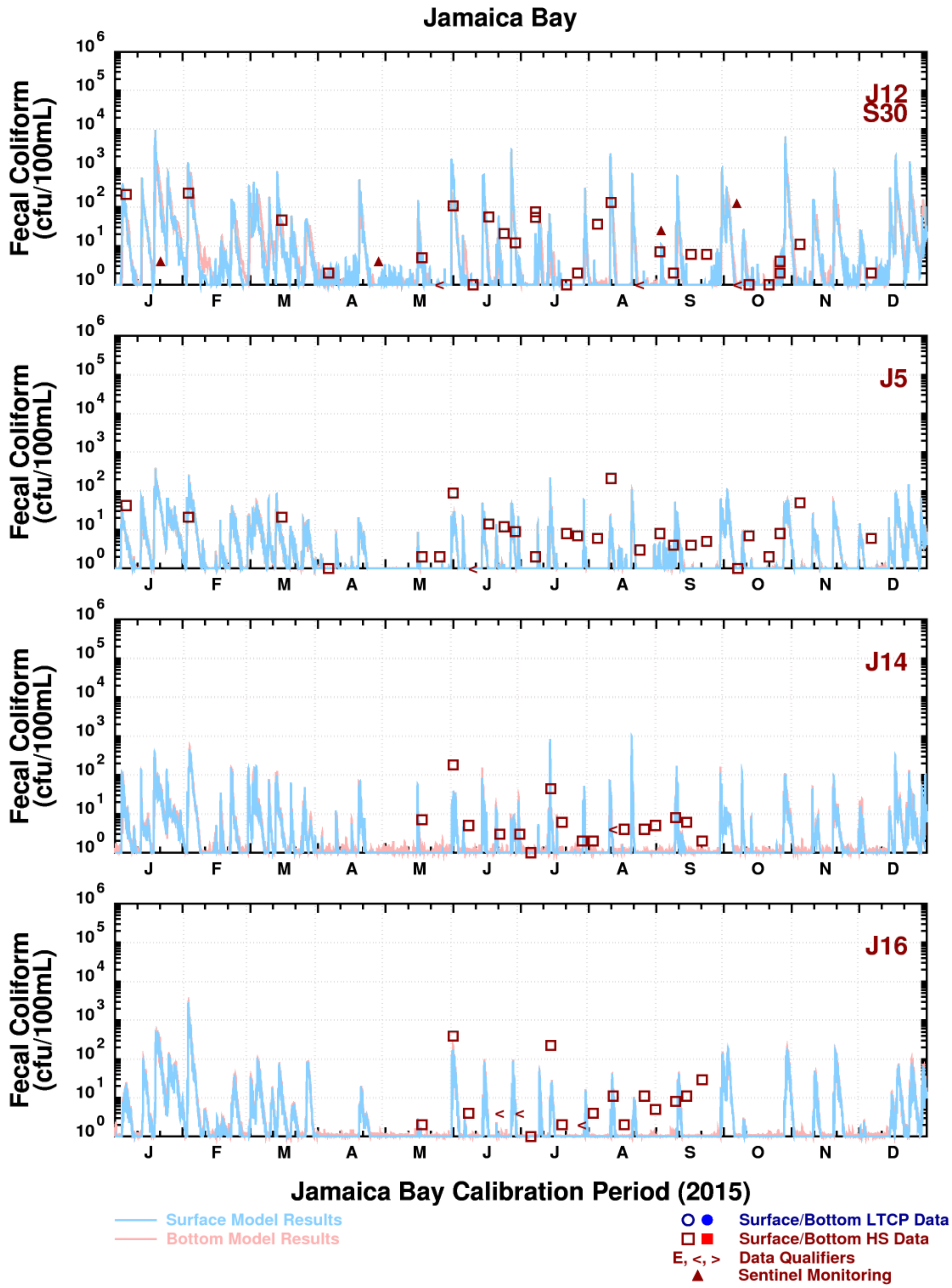

Figure 3-40. 2015 Fecal Coliform Calibration in Central and Eastern Jamaica Bay

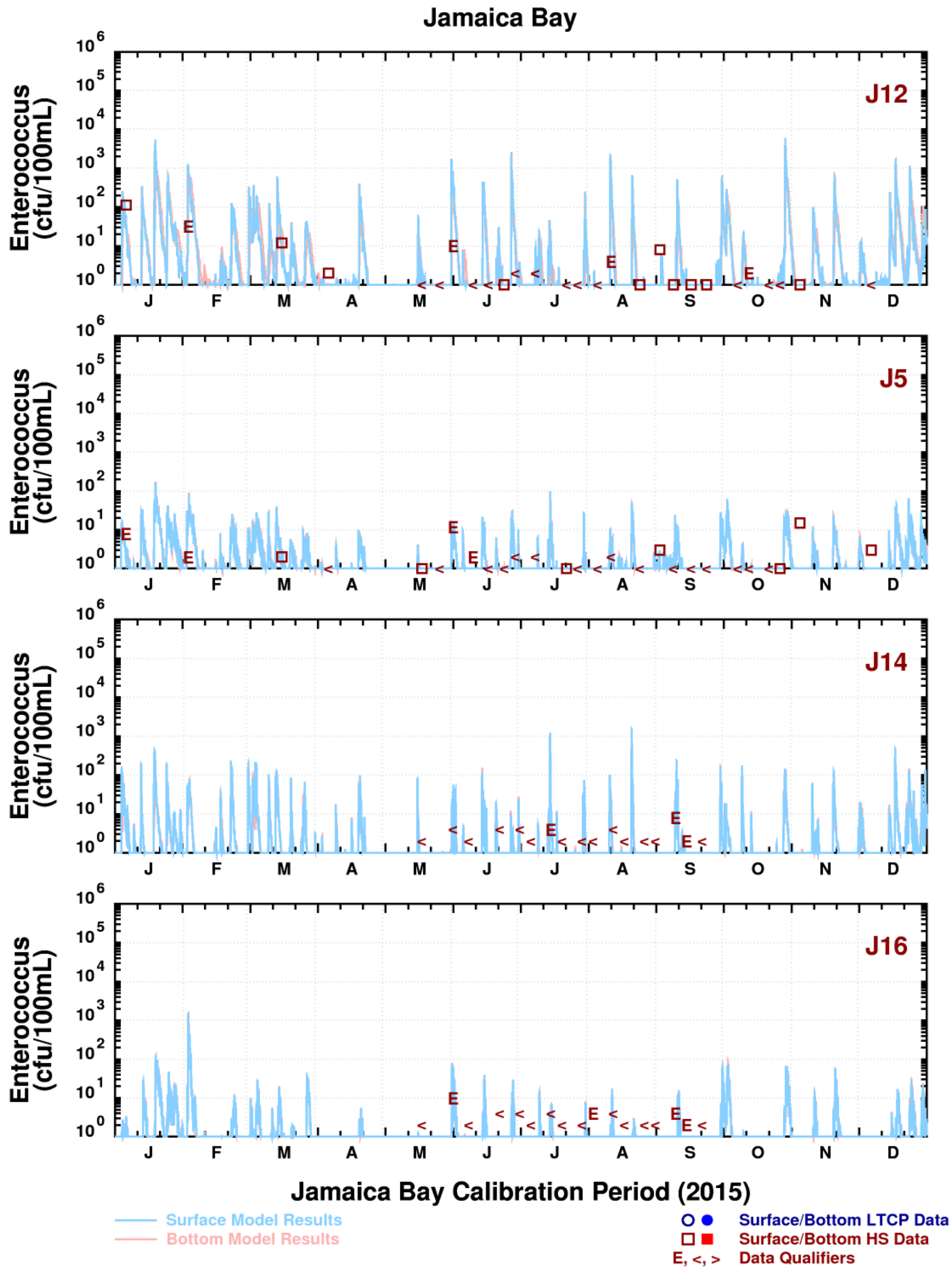

Figure 3-41. 2015 *Enterococci* Calibration in Central and Eastern Jamaica Bay

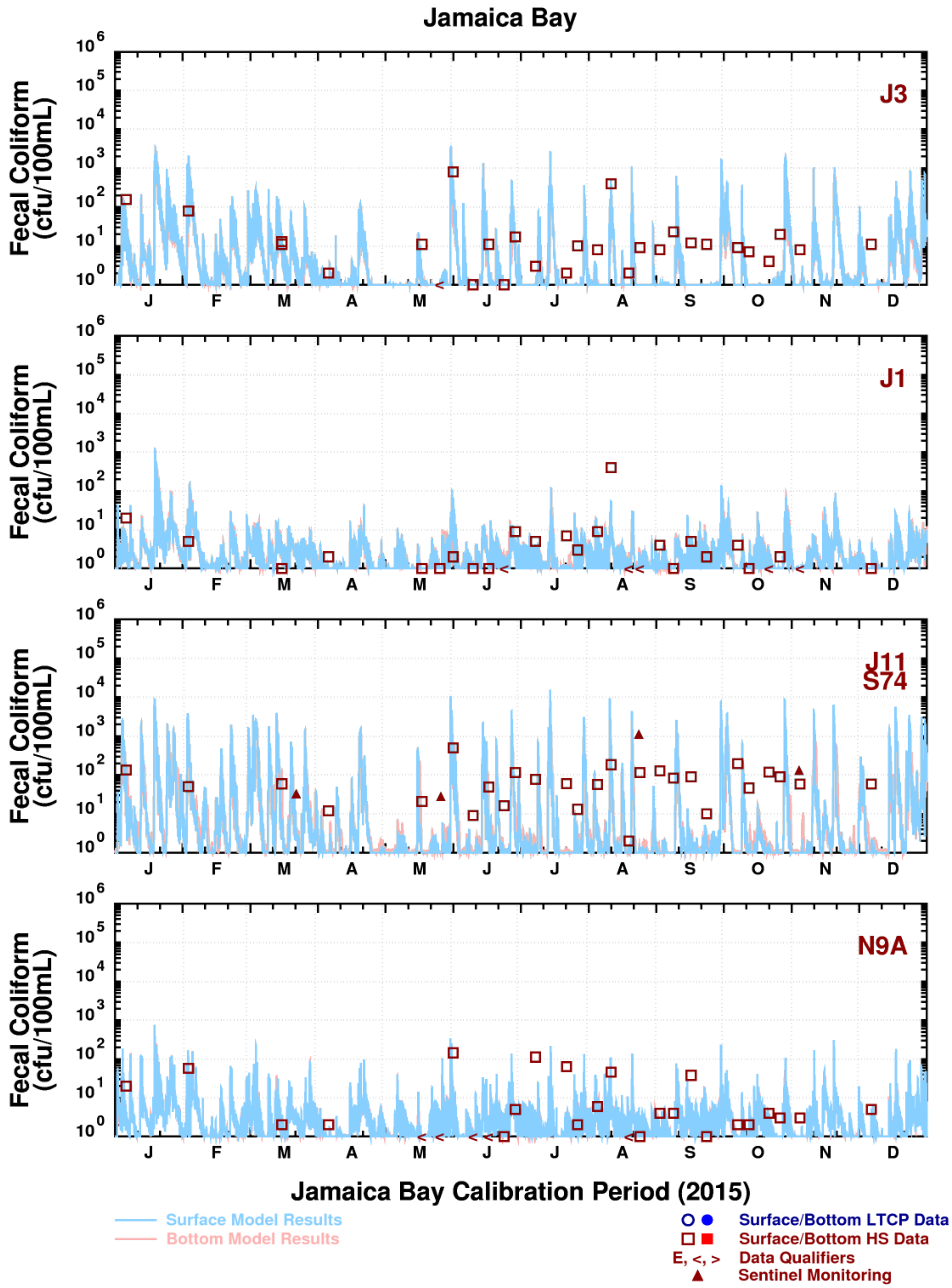

Figure 3-42. 2015 Fecal Coliform Calibration Western Jamaica Bay

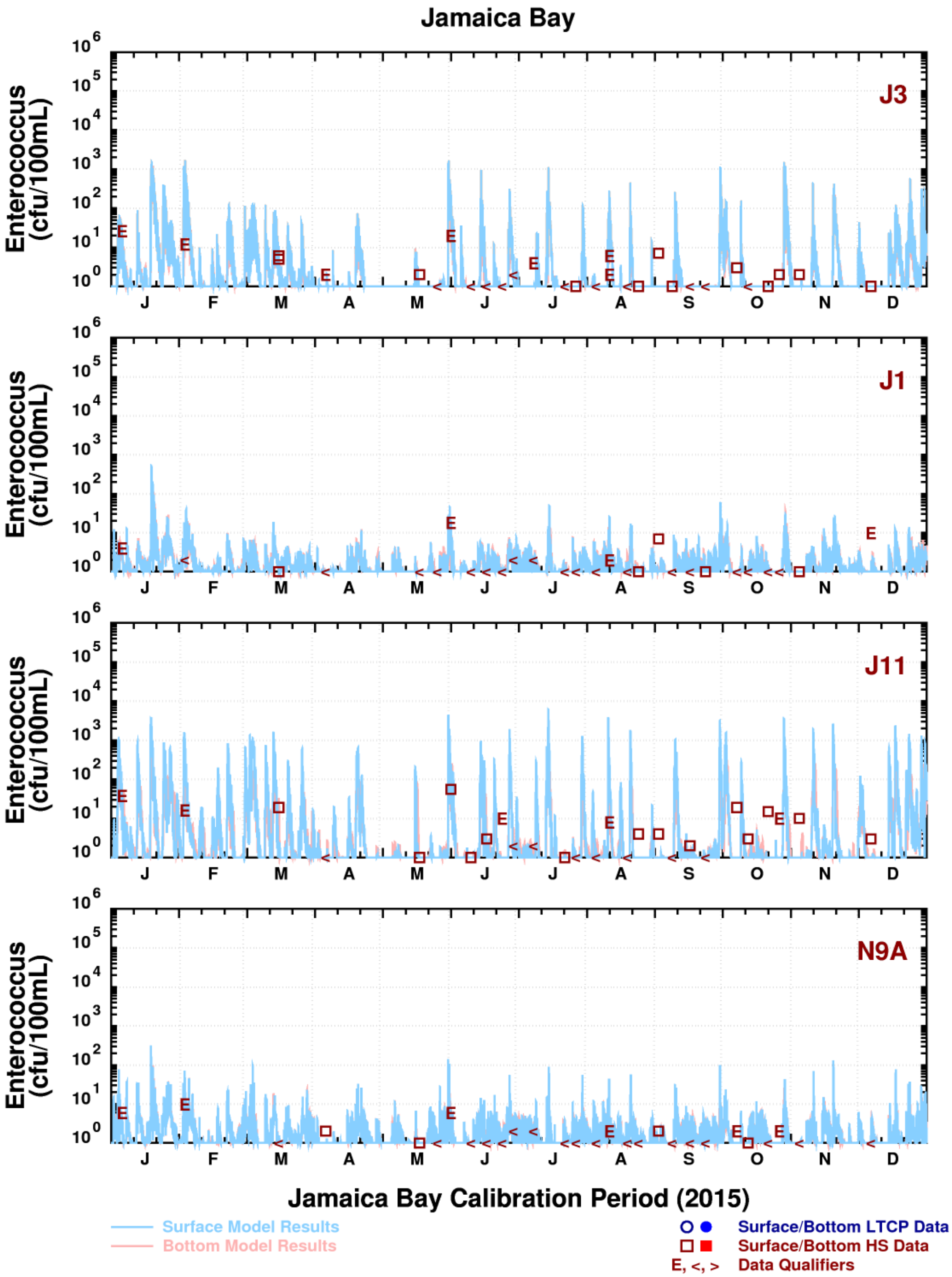

Figure 3-43. 2015 *Enterococci* Calibration in Western Jamaica Bay

3.3.d **Dissolved Oxygen Model Skill Assessment**

The DO validation focused on both the LTCP2 data and the Harbor Survey data. The Harbor Survey sampling is conducted year-round and is more intensive during the summer months. The LTCP2 sampling did not collect data during the critical months for DO. The eutrophication modeling analysis did not involve a model recalibration, so model coefficients were not adjusted from previous modeling efforts. Only model loadings and hydrodynamics were modified for the validation.

The model versus data comparison for DO in Paerdegat Basin and nearby Jamaica Bay is presented in Figure 3-44. In Paerdegat Basin, the model does a better job at reproducing the low DO data than the higher data. There is algal production in the basin that the model does not reproduce. At Station J10, near the mouth of the basin, the model generally reproduces that data, but does not reproduce some of the higher DO concentrations. At Station J2, near the mouth of Mill Basin, the model splits the difference between the surface and bottom data, but does not reproduce the extremes of either.

Figure 3-45 presents the model versus data comparison for DO in Fresh Creek and nearby Jamaica Bay. LTCP2 were collected in Fresh Creek. The model tends to overestimate the lower Harbor Survey DO concentration data. The model does a poor job reproducing the LTCP2 data. However, the majority of the low DO concentrations measured during the wet-weather events appear to be related to eutrophication and algae as the low DO is observed out into North Channel at Station FC4. The wet-weather DO concentrations at Station FC4 are as low as the Station FC1 concentrations near the CSO. This suggests that the low DO is more of a bay-wide phenomenon rather than being caused by CSO discharge.

The comparison between Hendrix Creek model and DO concentration data is presented in Figure 3-46. One of the challenges in modeling the DO concentration in Hendrix Creek is the uncertainty of the DO concentration in the 26th Ward WWTP effluent. At HC1 and HC2, the model generally reproduces the data, but over-estimates some of the lower concentrations. At HC3, the model over-estimates the data.

Figure 3-46 presents the model versus data comparison for Harbor Survey data collected in Spring Creek. The data show very few measurements below the daily average criterion of 4.8 mg/L. There are numerous DO measurements, especially towards the head end of the Creek, indicating supersaturated concentrations associated with an algal bloom. The model generally goes through the middle of the data, not reproducing the extreme highs or lows observed in the data.

The model versus DO data comparison for Bergen Basin is presented in Figure 3-48. The model generally compares favorably to the Harbor Survey data collected along the length of the Creek. The model captures the spatial and temporal variability of the data with the exception of over-estimating the winter concentrations. It is possible that deicing fluid, which has a high BOD load and was not accounted for in the model, could account for some of the differences between the model and sampling data during the colder months. The model also reasonably reproduces the LTCP2 data at Stations BB5 and BB6. However, at stations closer to the mouth of Bergen Basin, the model over-estimates the wet-weather data. As observed in Fresh Creek, this may be a bay-wide event related more to a decrease in algal production than related to CSOs.

Figure 3-49 presents a model versus data comparison for DO concentrations in Thurston Basin and Head of Bay. Thurston Basin and Head of Bay were not sampled by NYCDEP during 2015. The model performs reasonably well against the data from the first two LTCP2 sampling events, but over-predicts the data from the last survey.

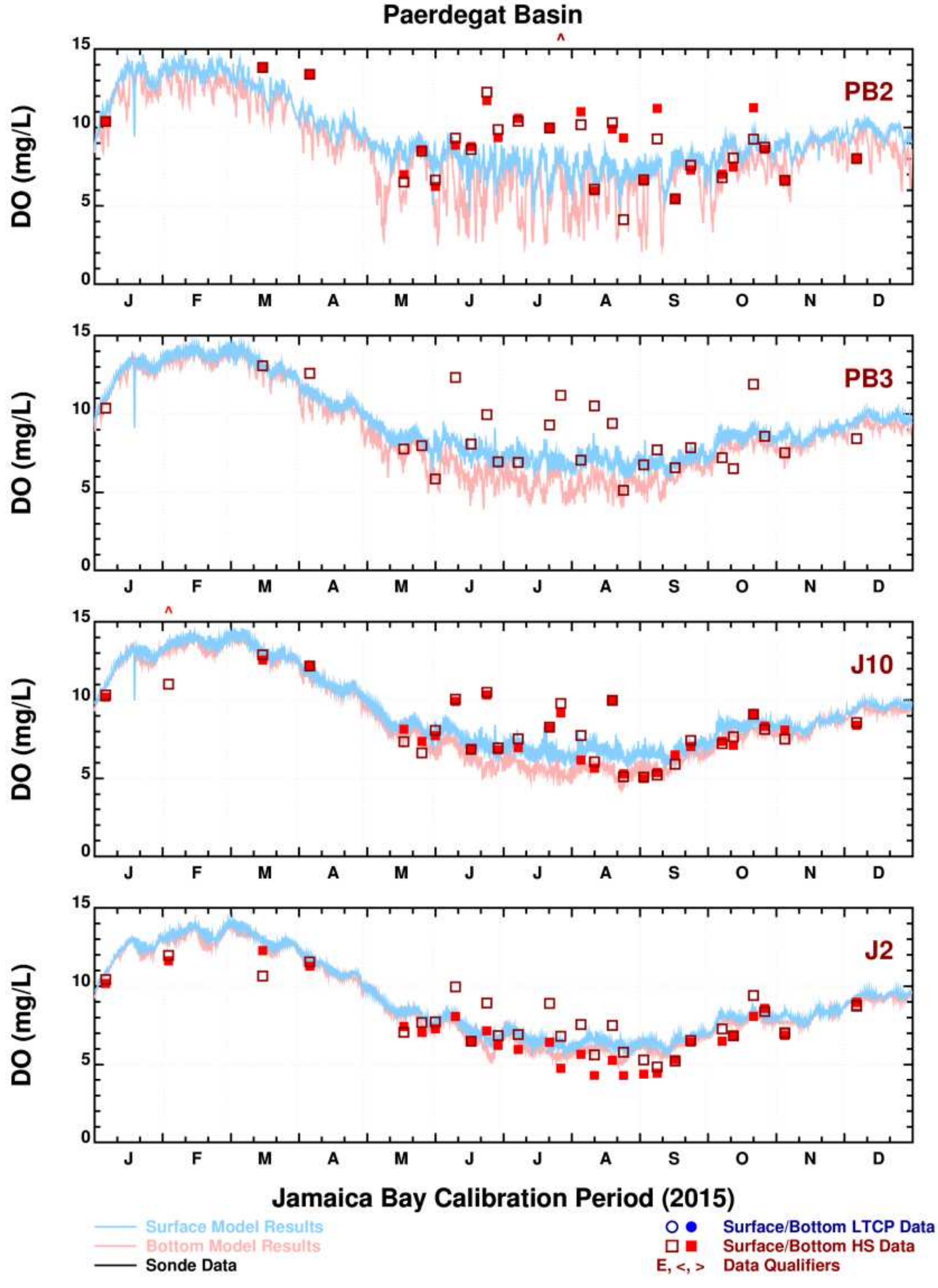

Figure 3-44. 2015 Model Versus Data Comparison for DO in Paerdegat Basin and Nearby Jamaica Bay Stations

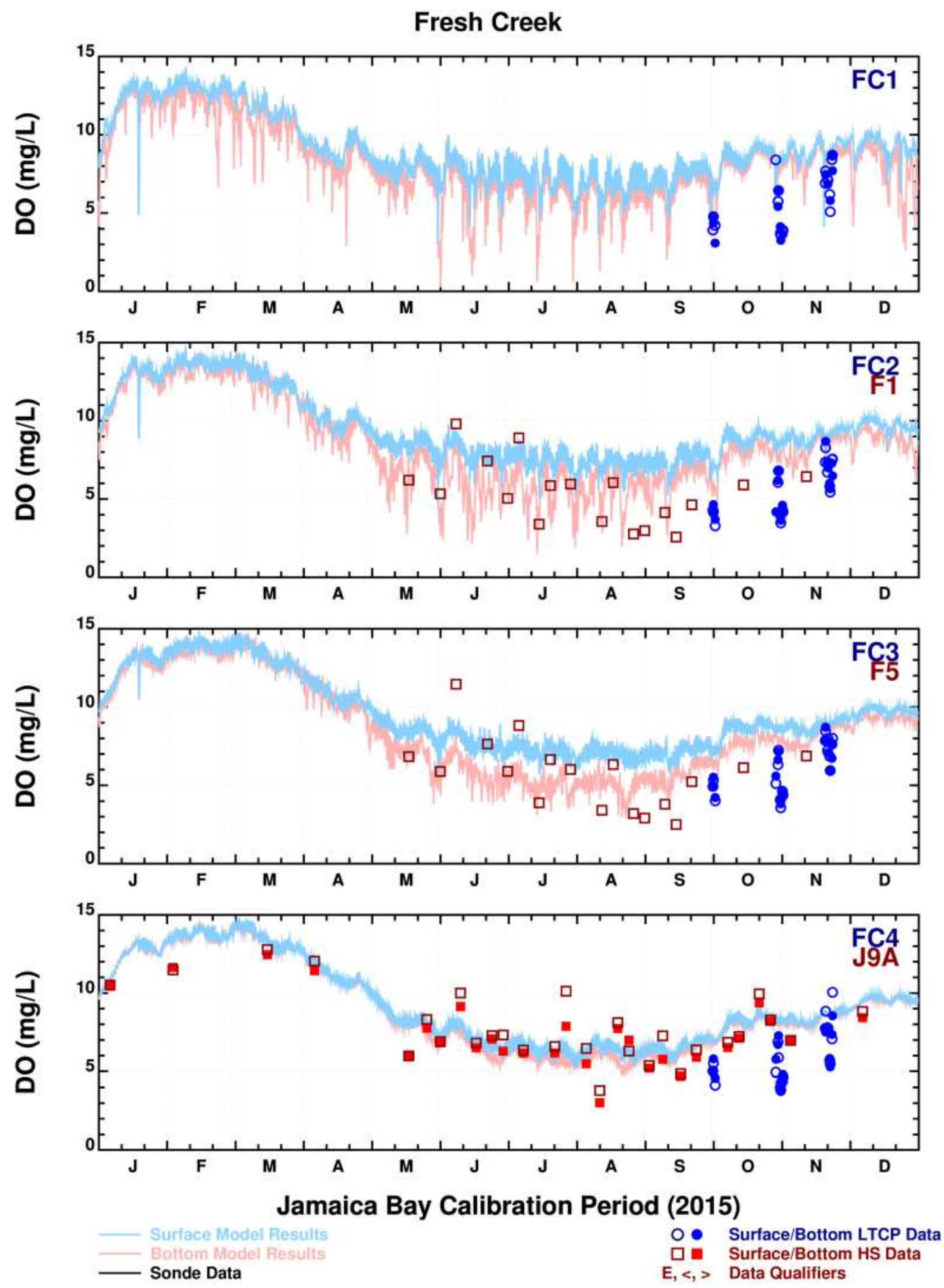

Figure 3-45. 2015 Model Versus Data Comparison for DO in Fresh Creek and Nearby Jamaica Bay Stations

N

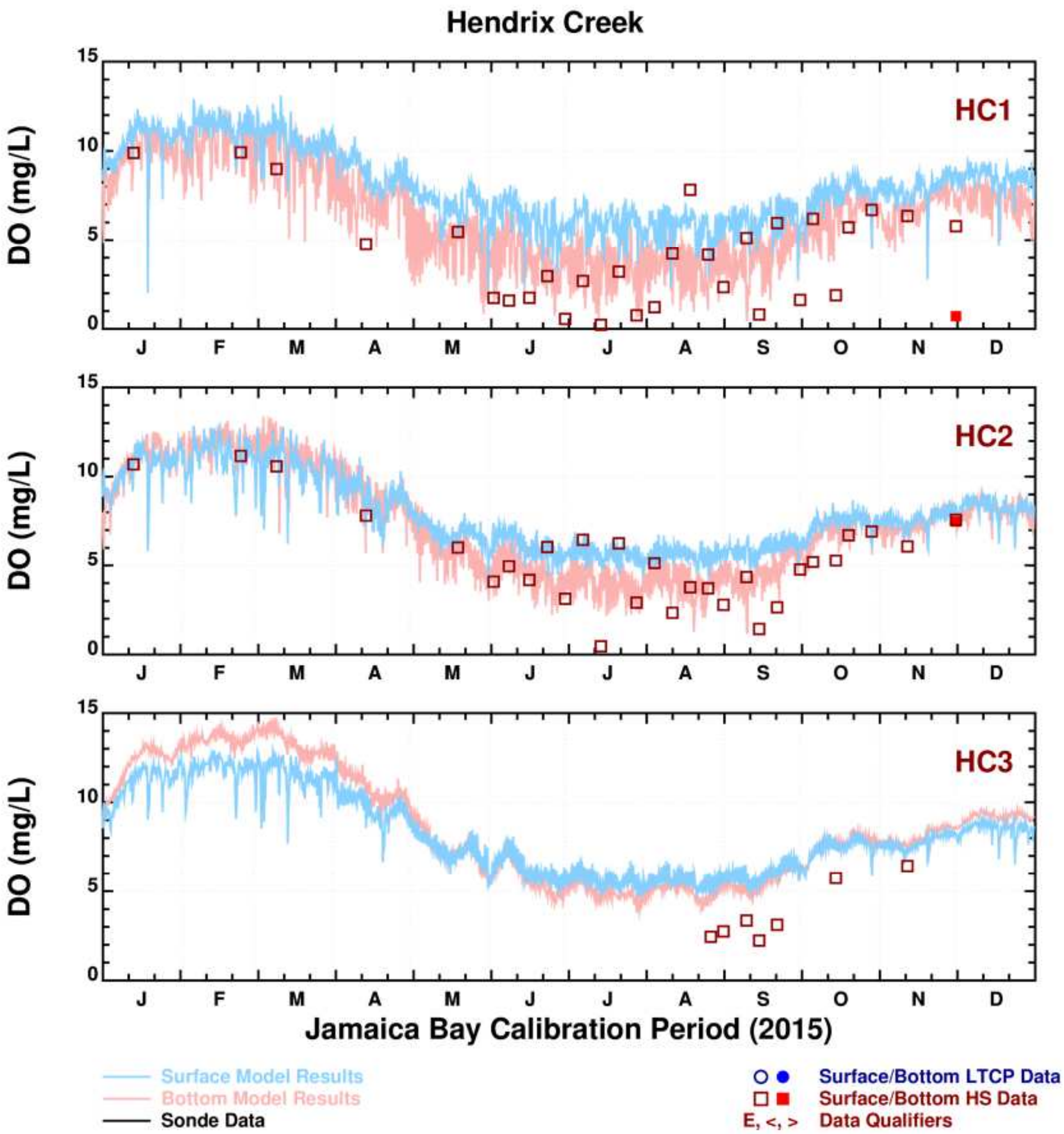

Figure 3-46. 2015 Model Versus Data Comparison for DO in Hendrix Creek

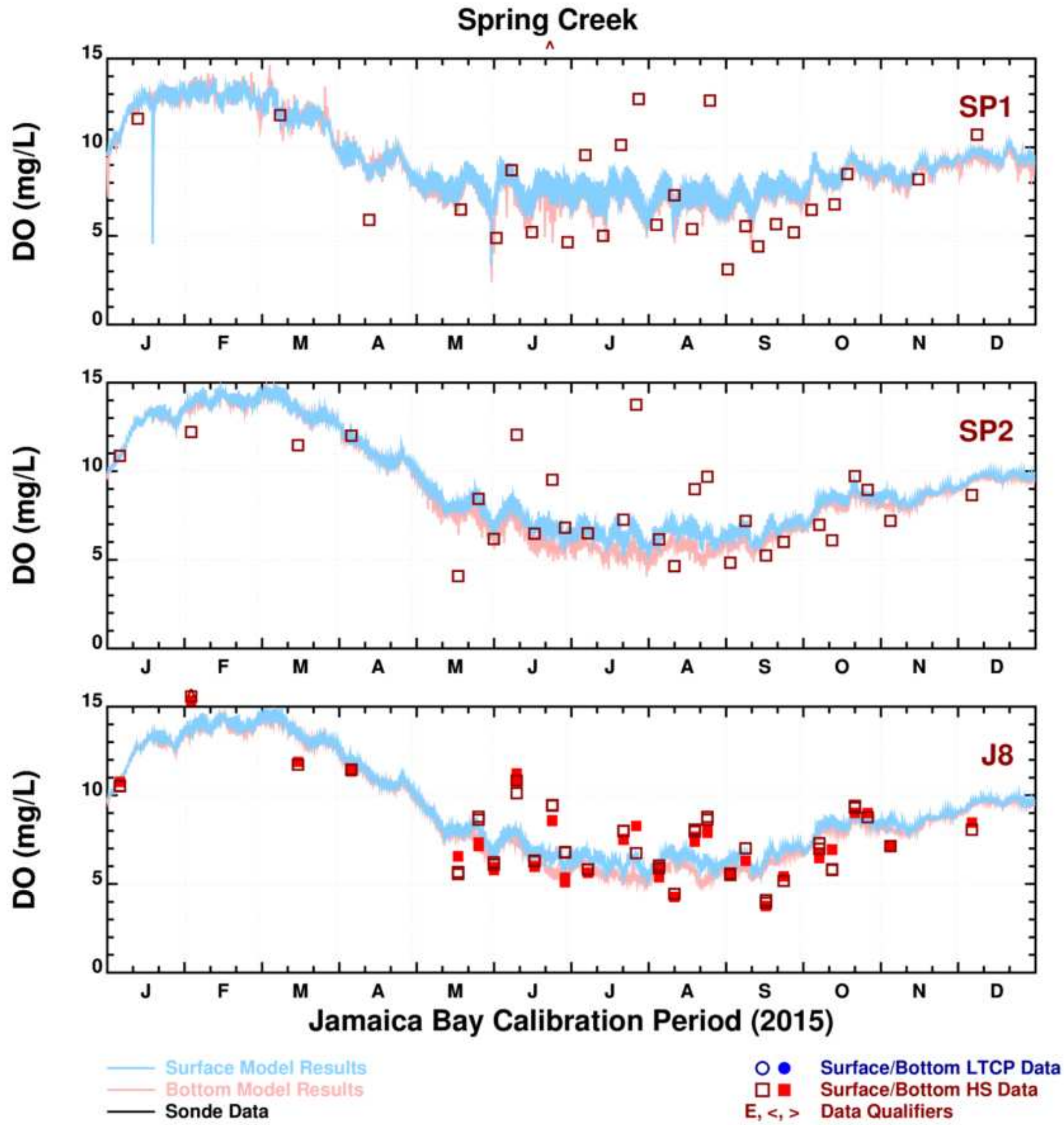

Figure 3-47. 2015 Model Versus Data Comparison for DO in Spring Creek and Nearby Jamaica Bay Stations

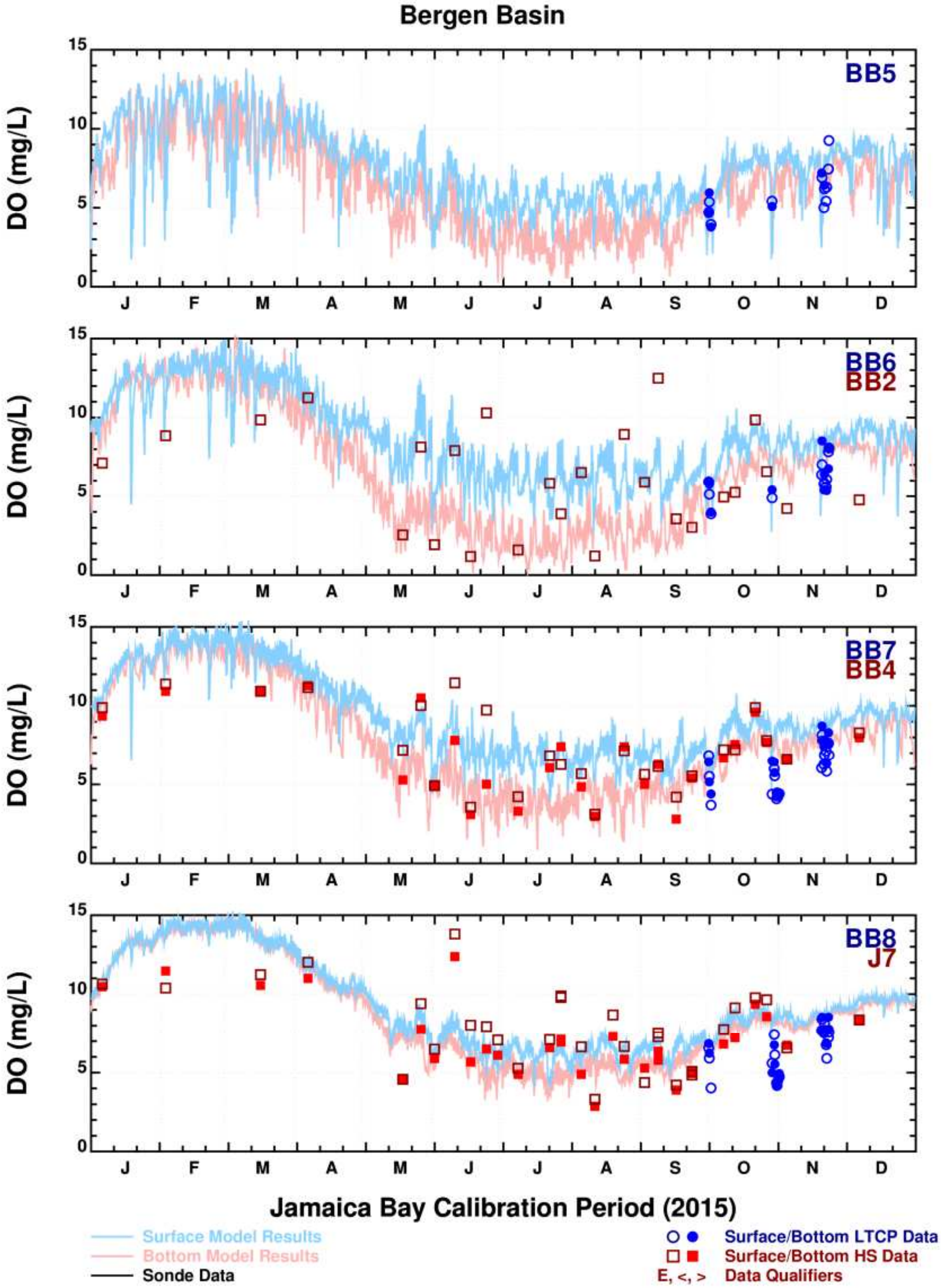

Figure 3-48. 2015 Model Versus Data Comparison for DO in Bergen Basin and Nearby Jamaica Bay Stations

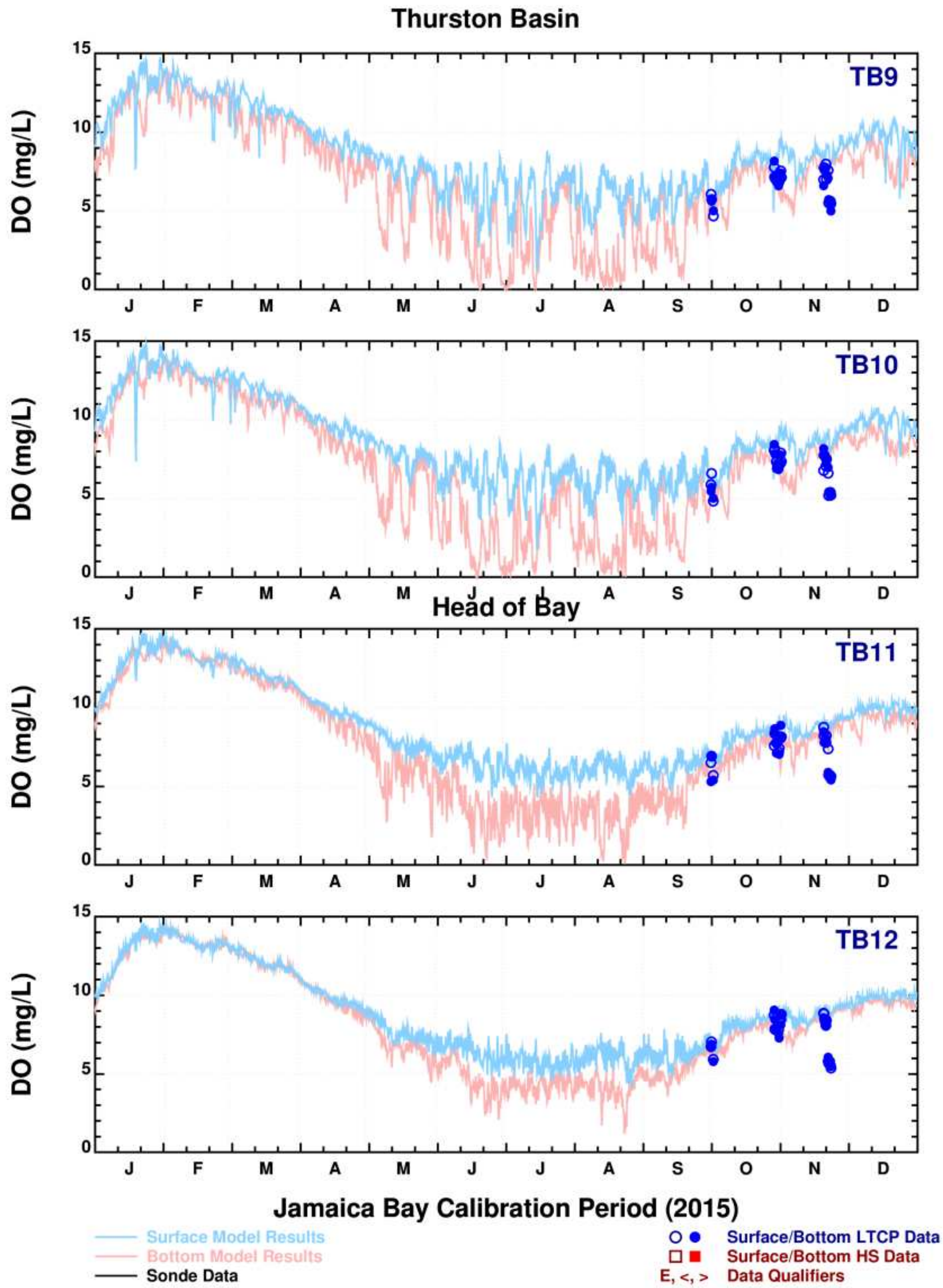

Figure 3-49. 2015 Model Versus Data Comparison for DO in Thurston Basin and Head of Bay

4.0 SUMMARY

The Coney Island, Rockaway, 26th Ward, and Jamaica IW sewer system models, and the JEM hydrodynamic and water quality models, were calibrated extensively as part of the development of the 2011 Waterbody Watershed Plan developed for Jamaica Bay. Since then, recalibration efforts on the Coney Island, Rockaway, 26th Ward, and Jamaica IW models as part of the citywide 2012 recalibration effort have improved the models. Similarly, resizing of the JEM model segmentation and modifying the bacteria kinetics has enhanced the JEM.

The calibration of the JEM to data collected during 2015 shows that the models reasonably reproduce the temperature, salinity, fecal coliform, *Enterococci* and DO observed within Jamaica Bay and its tributaries. The models described herein were used in developing the water quality projections for the baseline and future conditions assessment described in the Jamaica Bay and Tributaries CSO Long Term Control Plan.

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6.0 GLOSSARY

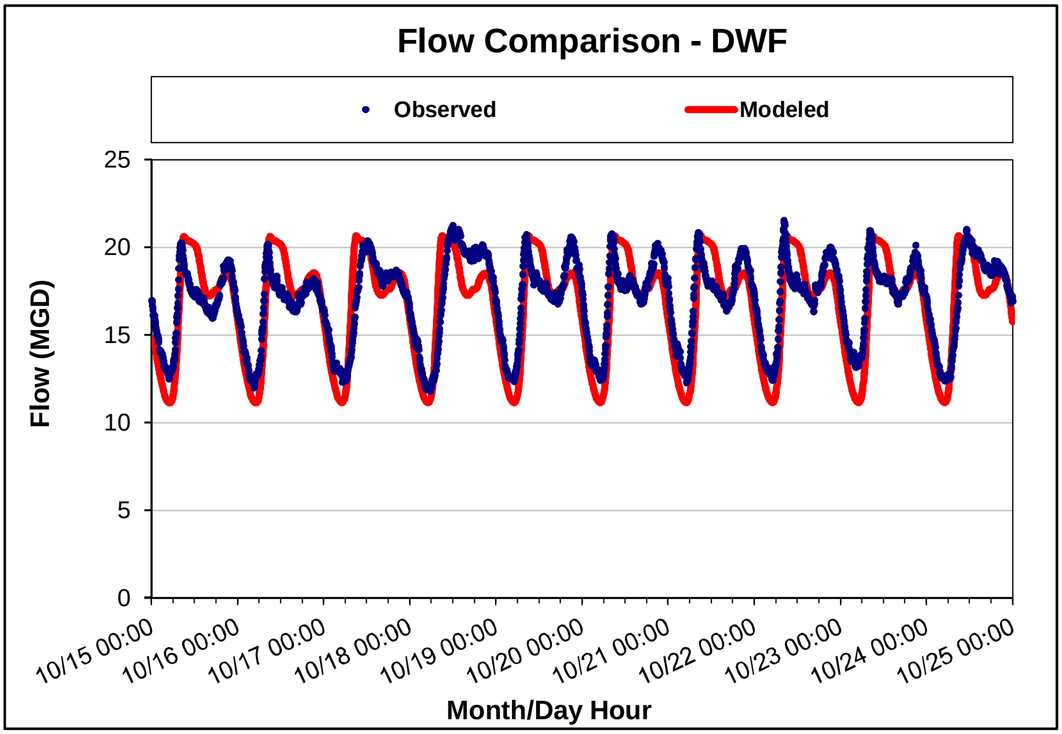
BOD:	Biochemical Oxygen Demand
CPK:	Central Park
CSO:	Combined Sewer Overflow
DCIA:	Directly Connected Impervious Areas
DCP:	New York City Department of City Planning
DEC:	New York State Department of Environmental Conservation
DEP:	New York City Department of Environmental Protection
DO:	Dissolved Oxygen
ET:	Evapotranspiration
EWR:	Newark Liberty International Airport
FSAP:	Field Sampling and Analysis Plan
GIS:	Geographical Information System
in.:	Abbreviation for “Inches”
In/hr	Abbreviation for “Inches per Hour”
IW:	InfoWorks CS™
JFK:	John F. Kennedy International Airport
LGA:	LaGuardia Airport
LTCP:	Long Term Control Plan
NOAA:	National Oceanic and Atmospheric Administration
NRCC	Northeast Regional Climate Center
NYC:	New York City
NYS:	New York State
SWEM:	System-Wide Eutrophication Model
WaPUG:	Wastewater Planning Users Group
WWFP:	Waterbody/Watershed Facility Plan
WWTP:	Wastewater Treatment Plant

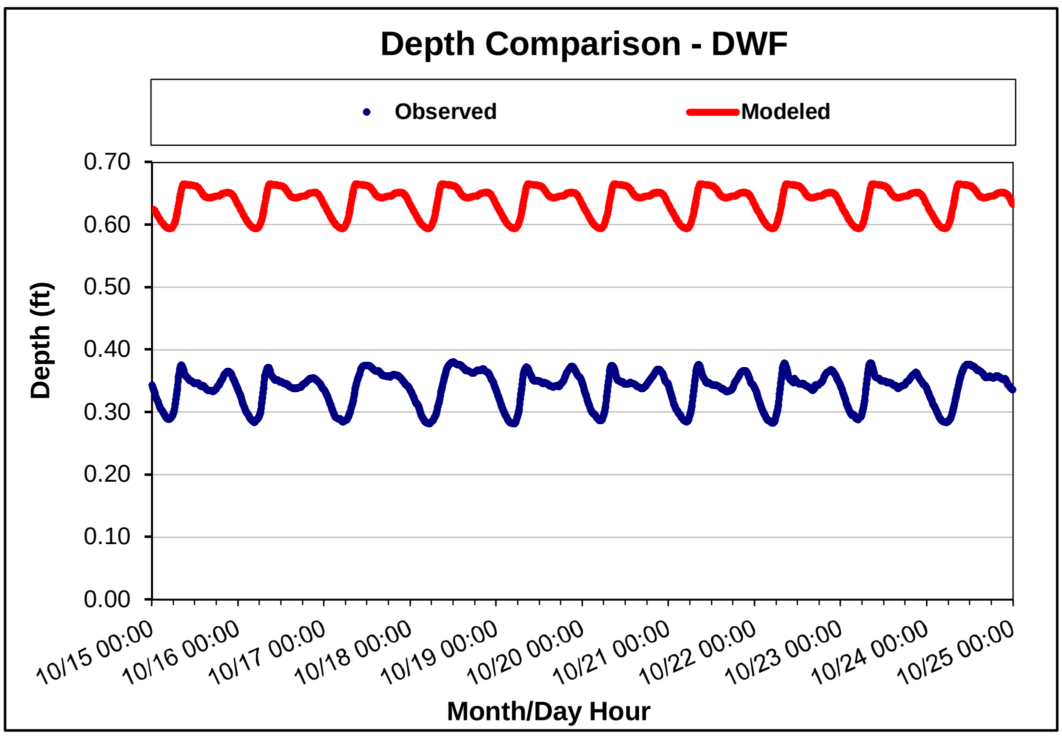
APPENDIX A

INFOWORKS HYDROGRAPHS AND GOODNESS-OF-FIT FIGURES

AECOM
with Hazen

METER 26W-003 M1/M2 INCOMING FLOW





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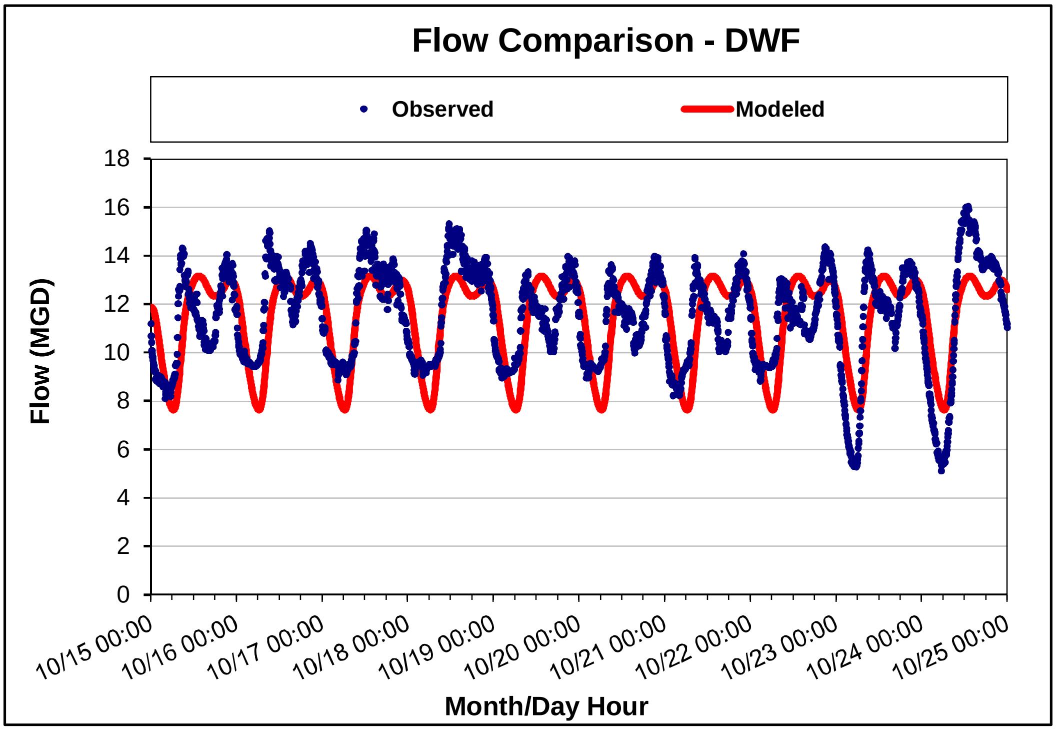

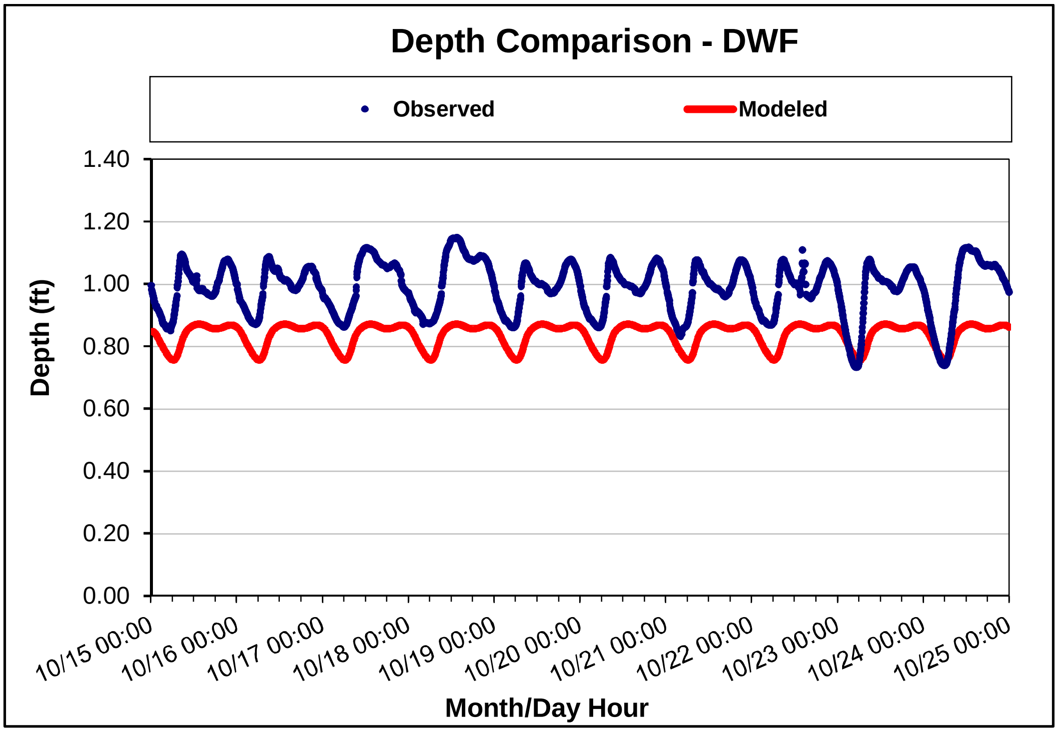

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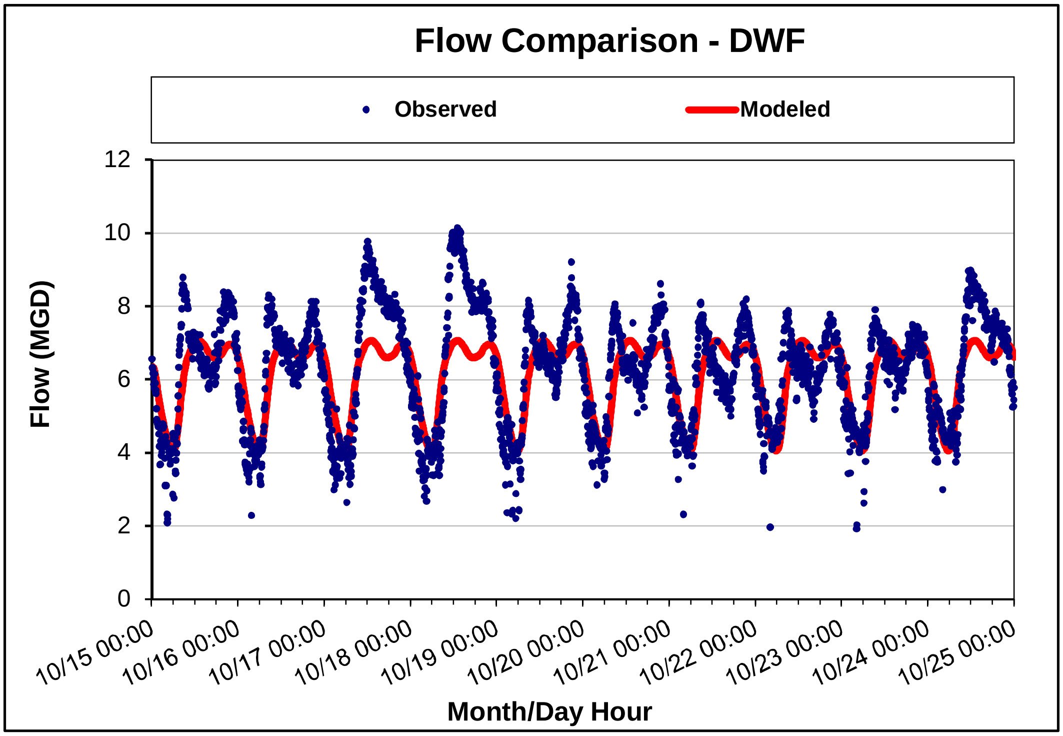

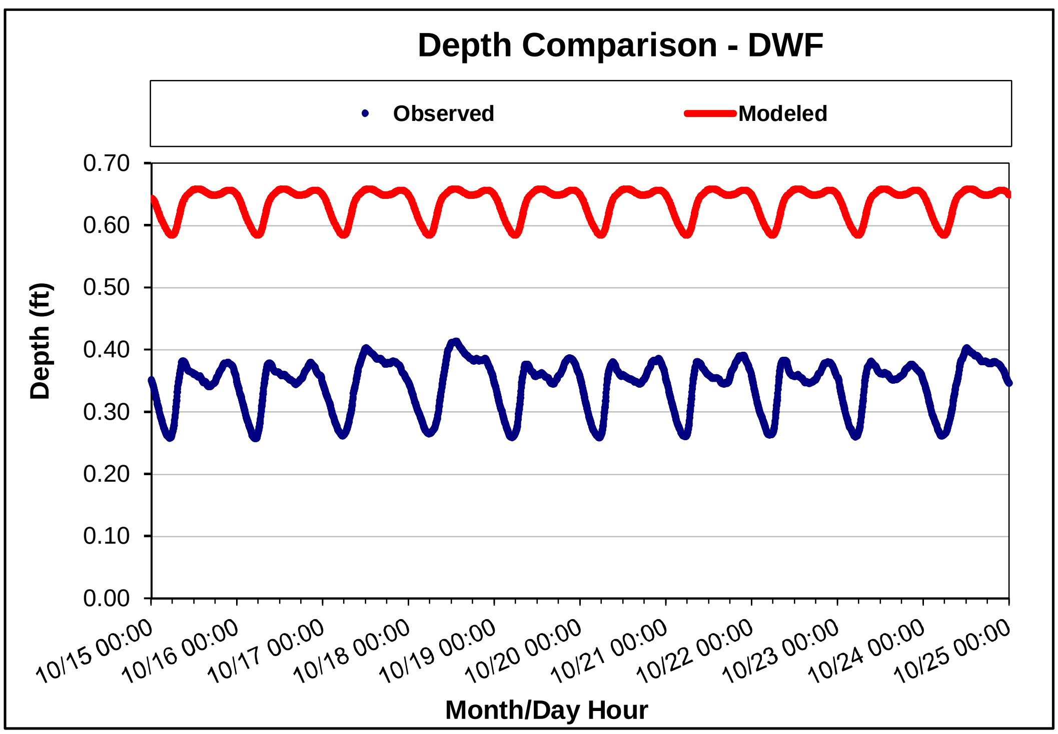

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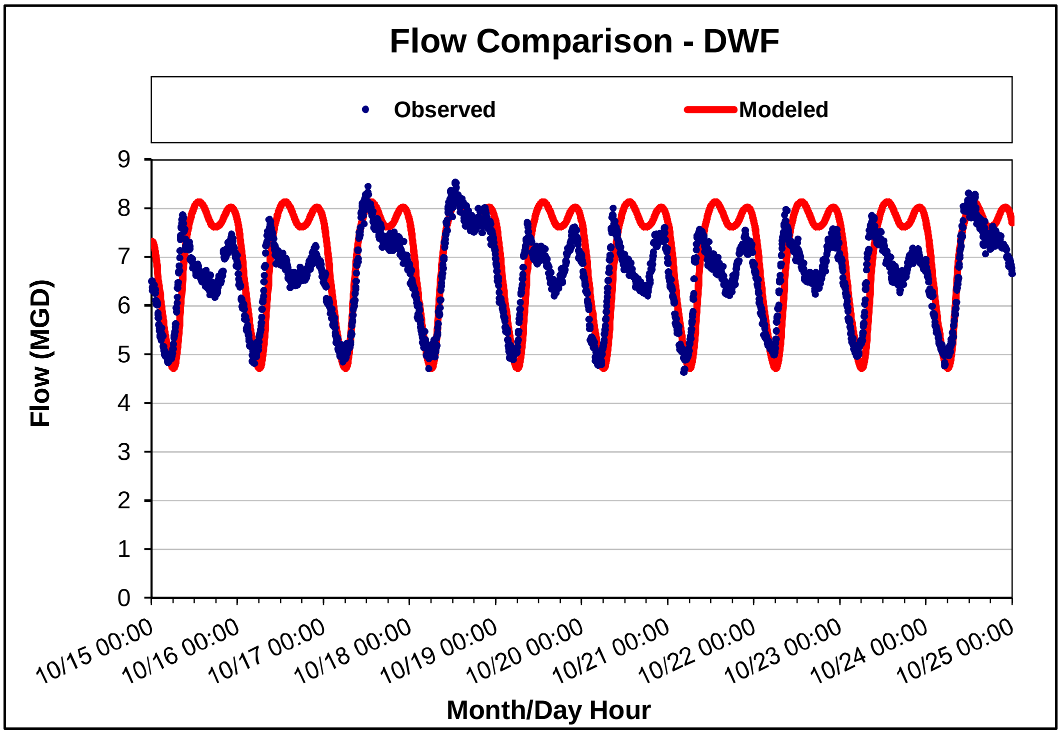

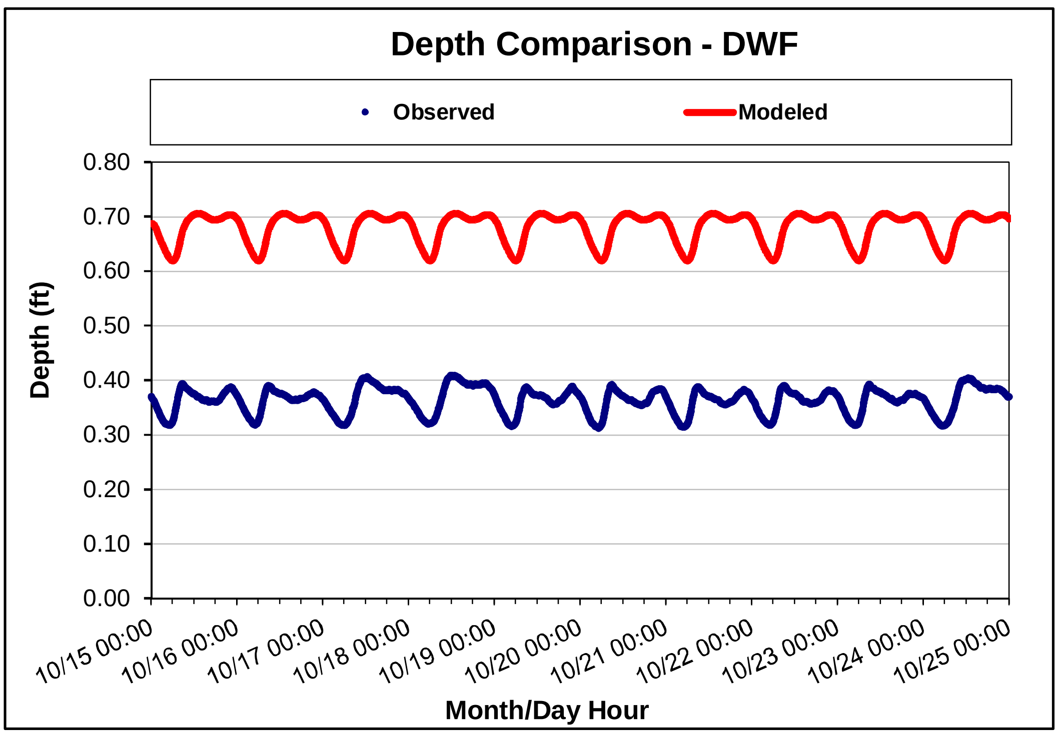

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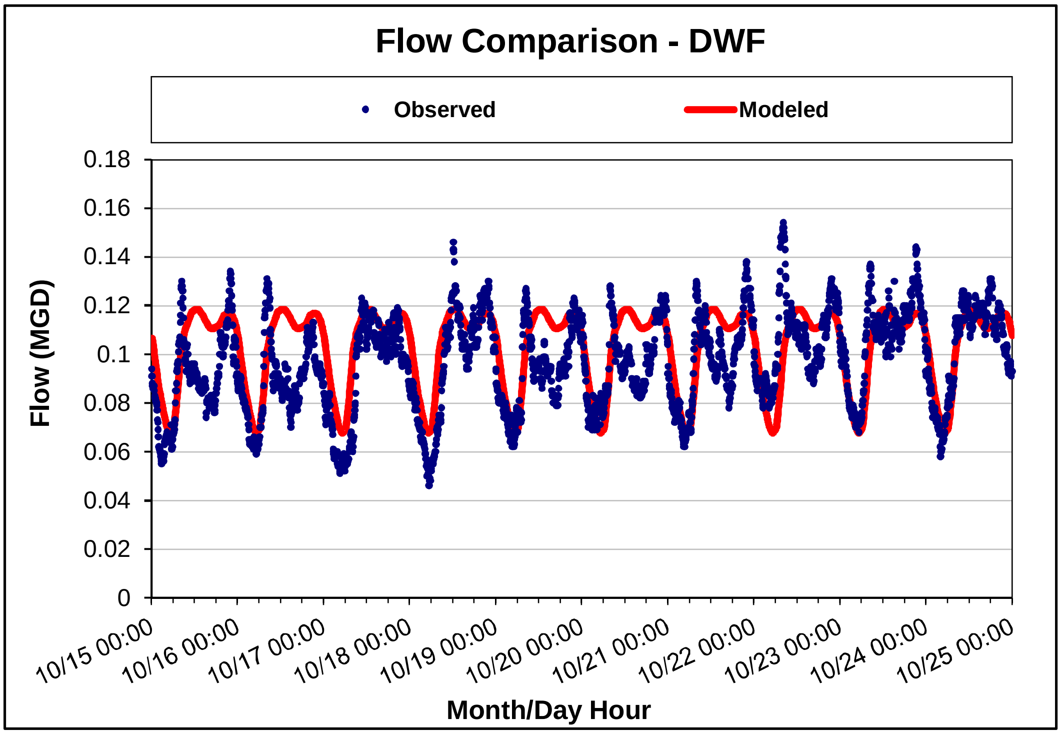

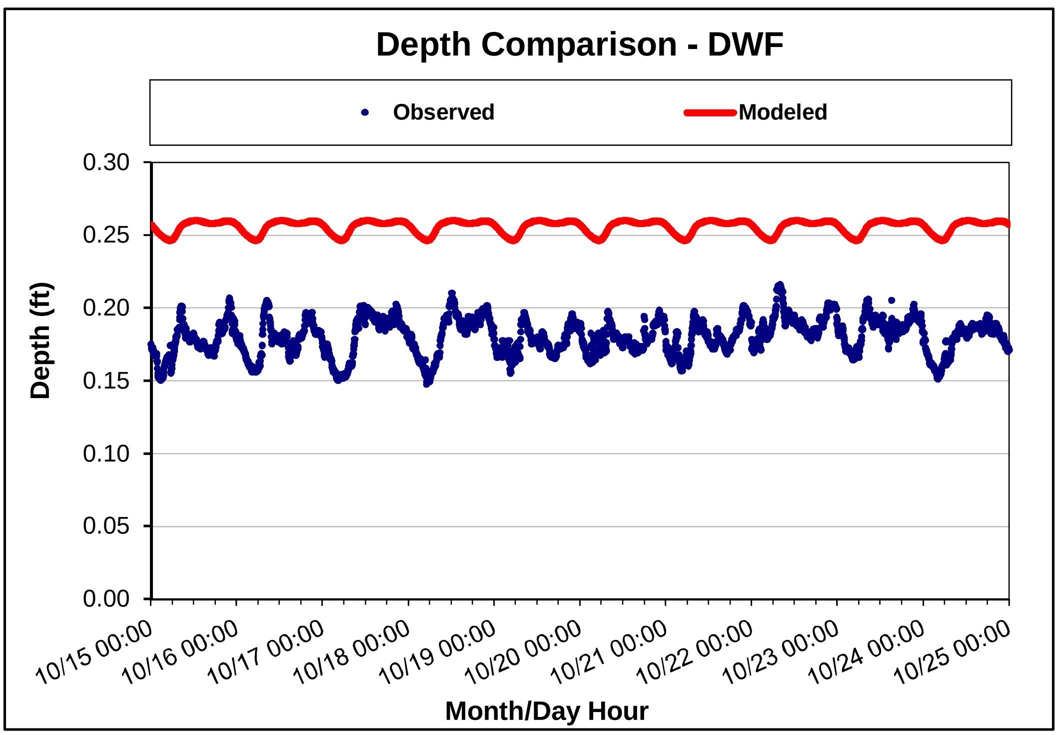

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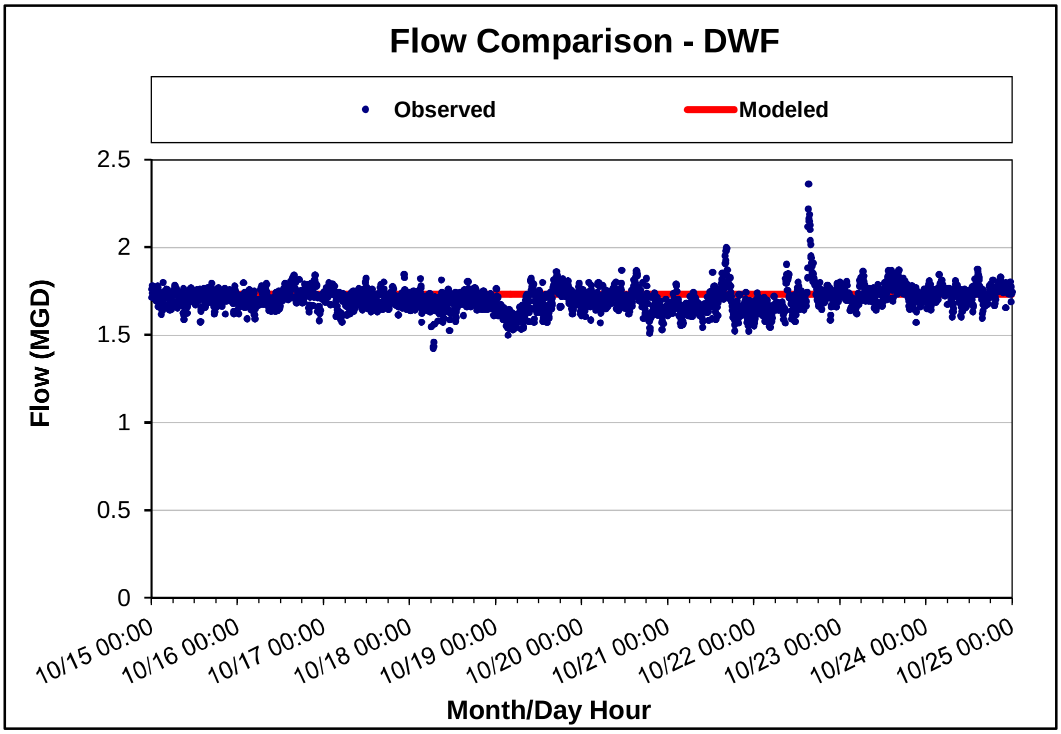

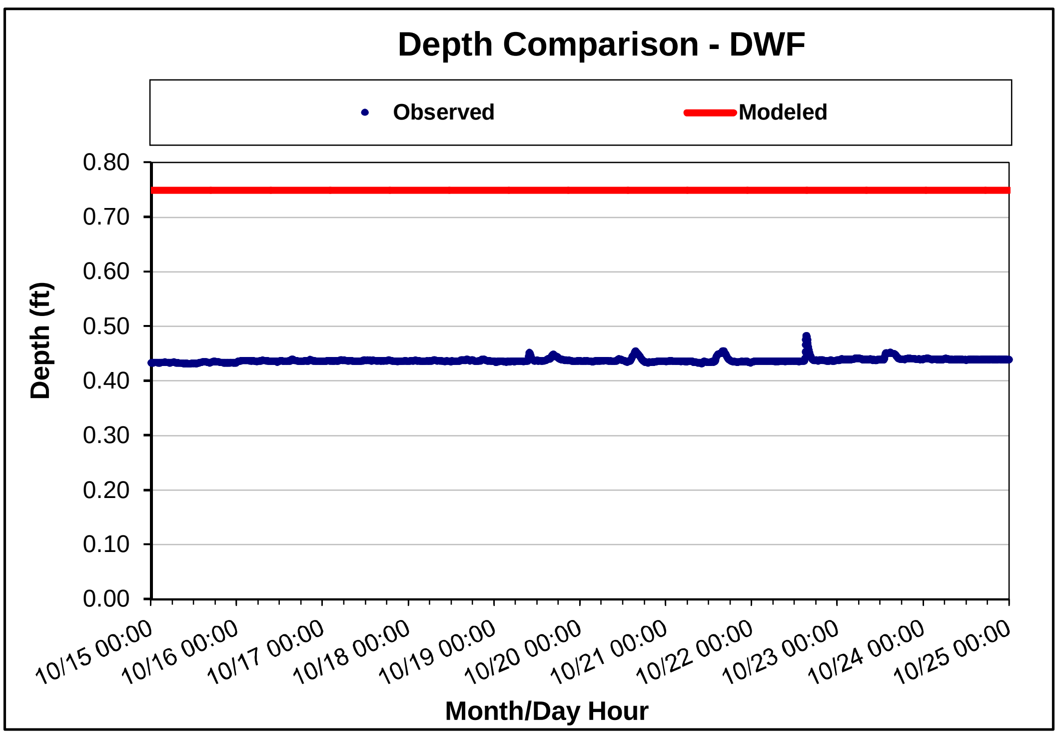

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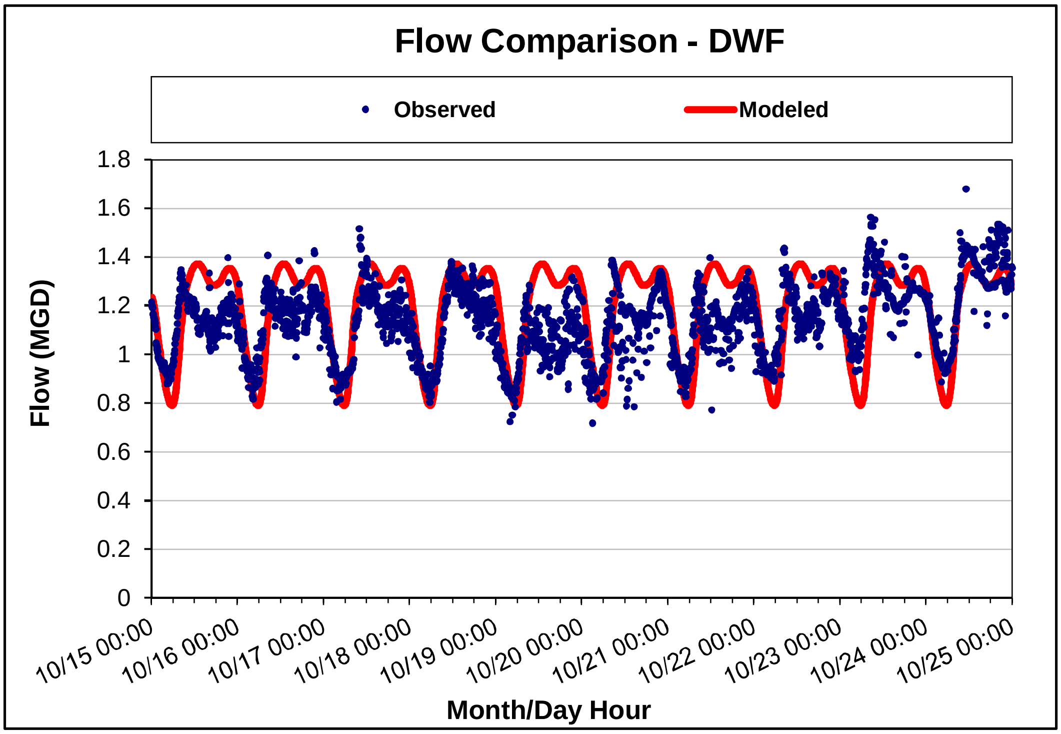
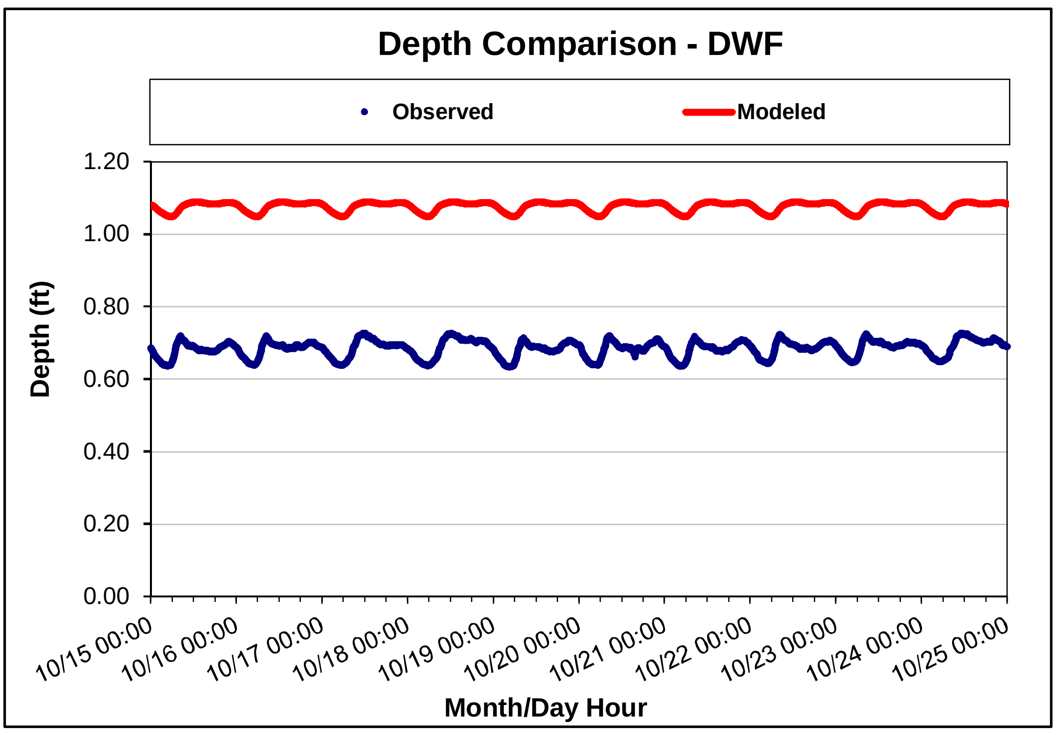
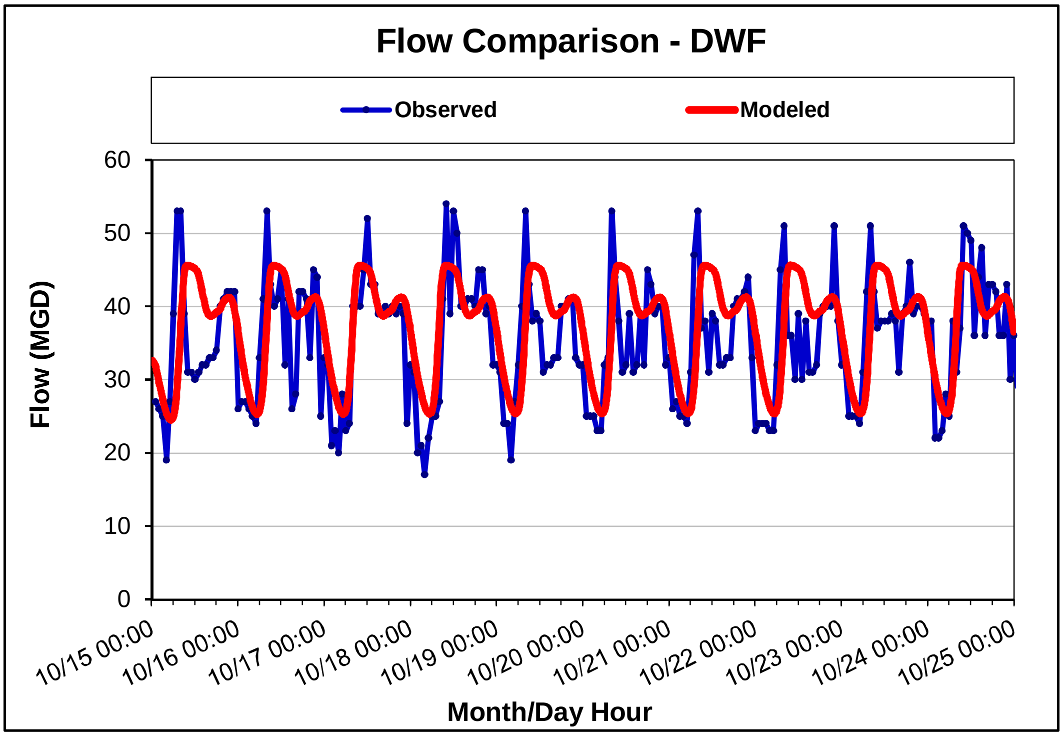
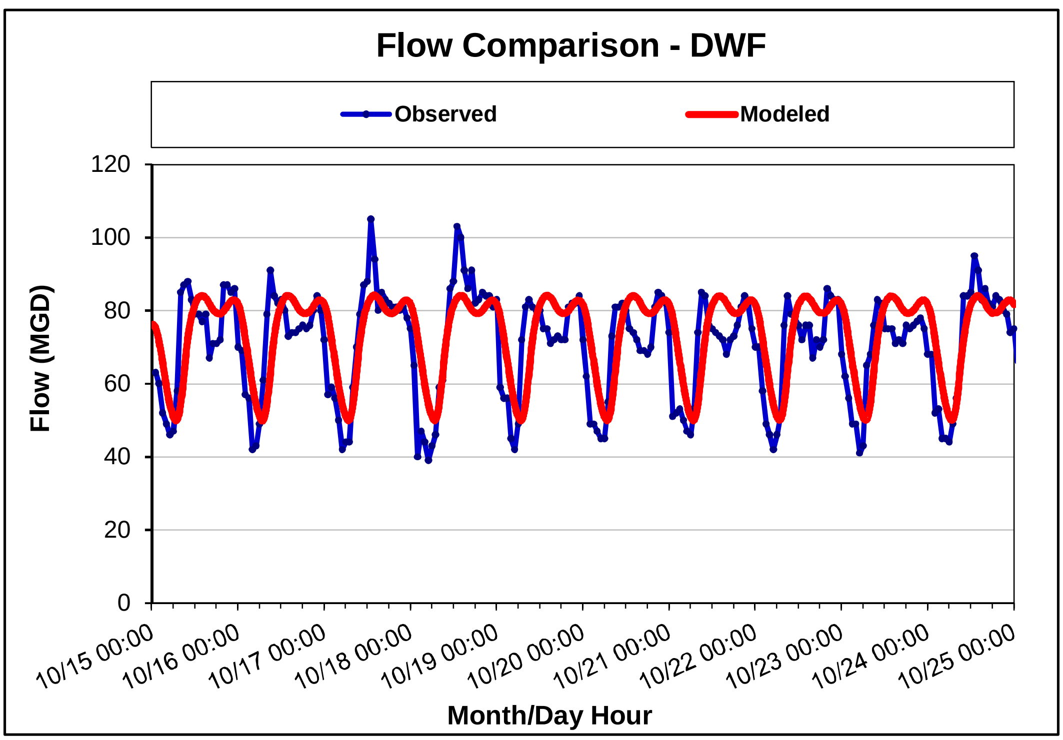




26TH WARD WWTP FLOW



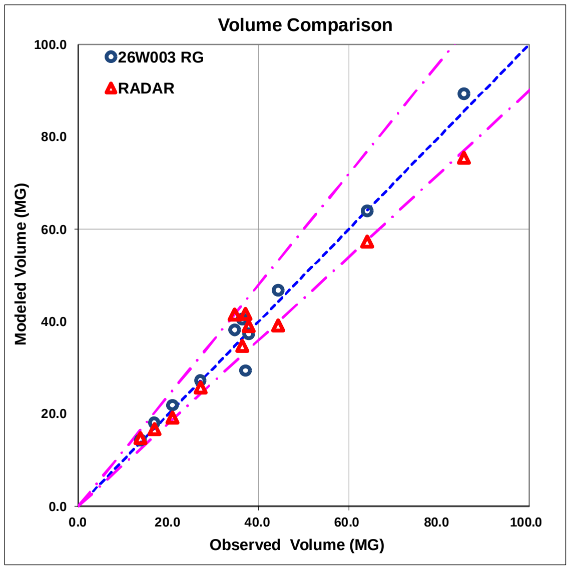
JAMAICA WWTP FLOW

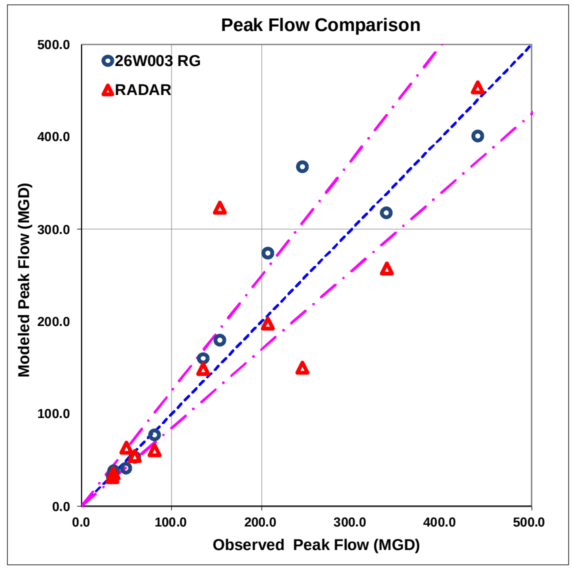


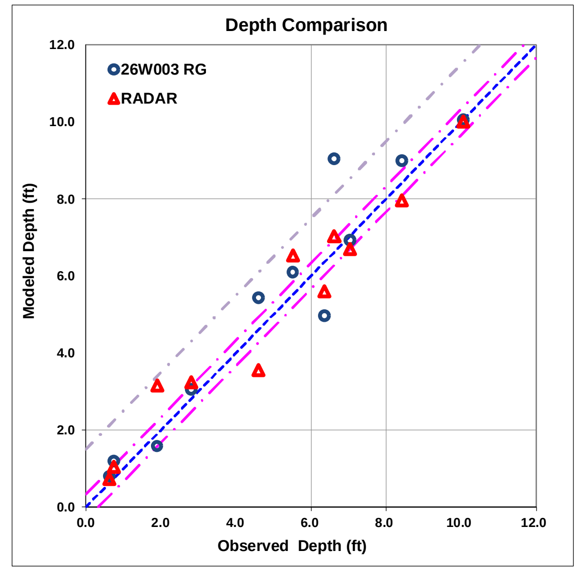
APPENDIX B

WaPUG GOODNESS-OF-FIT FIGURES

METER 26W-003 M1/M2 INCOMING FLOW







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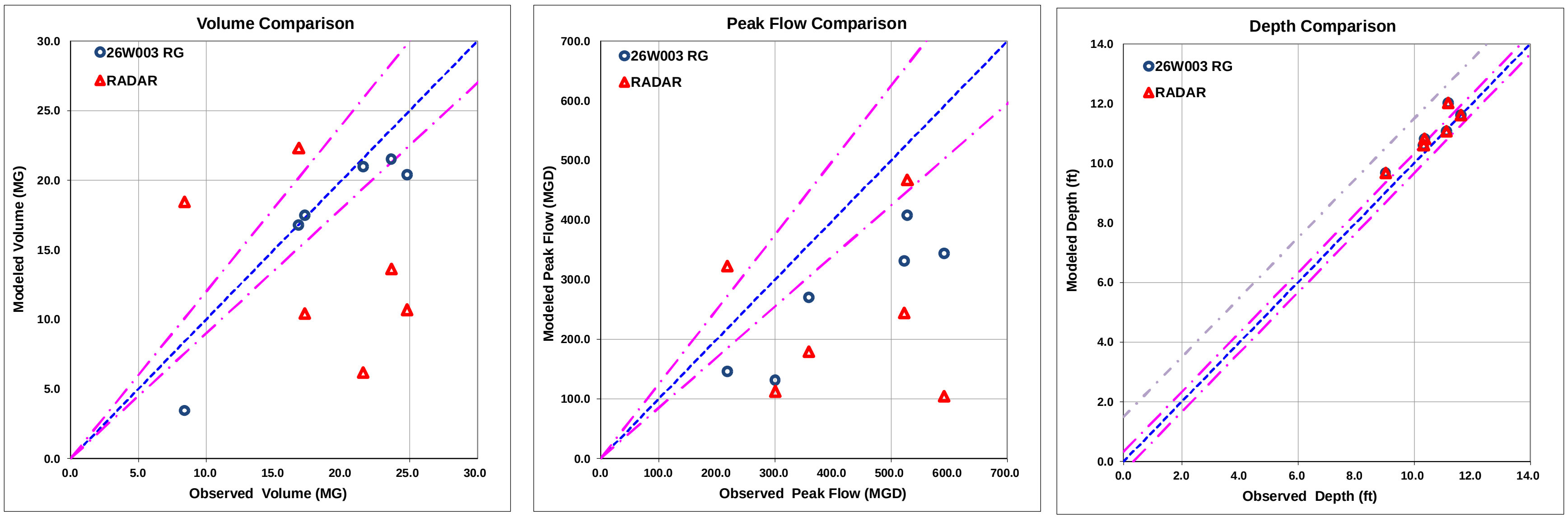

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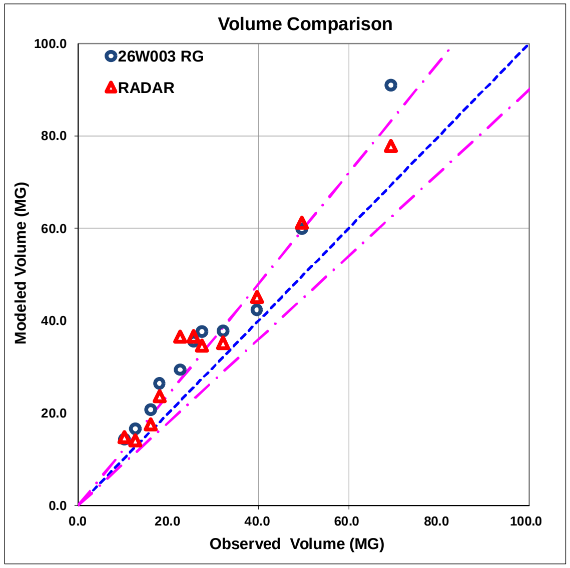

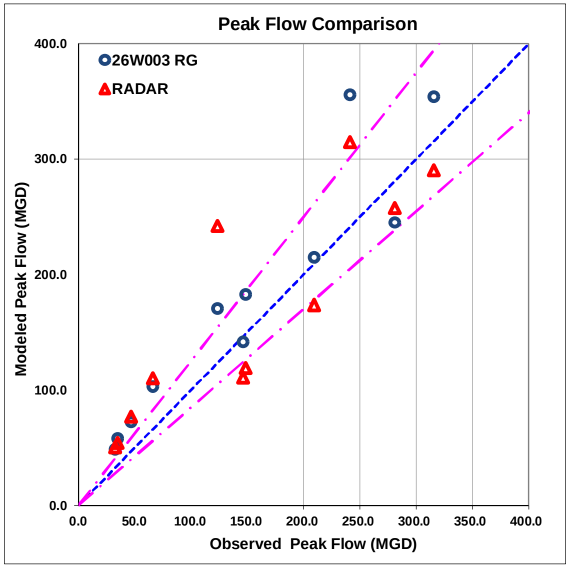

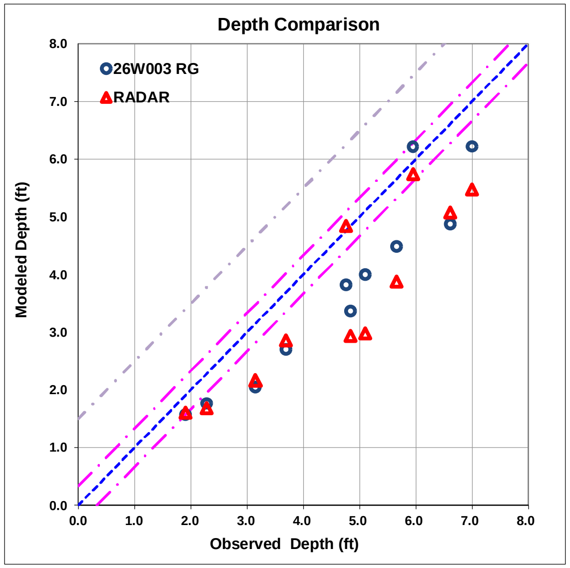

AECOM with Hazen

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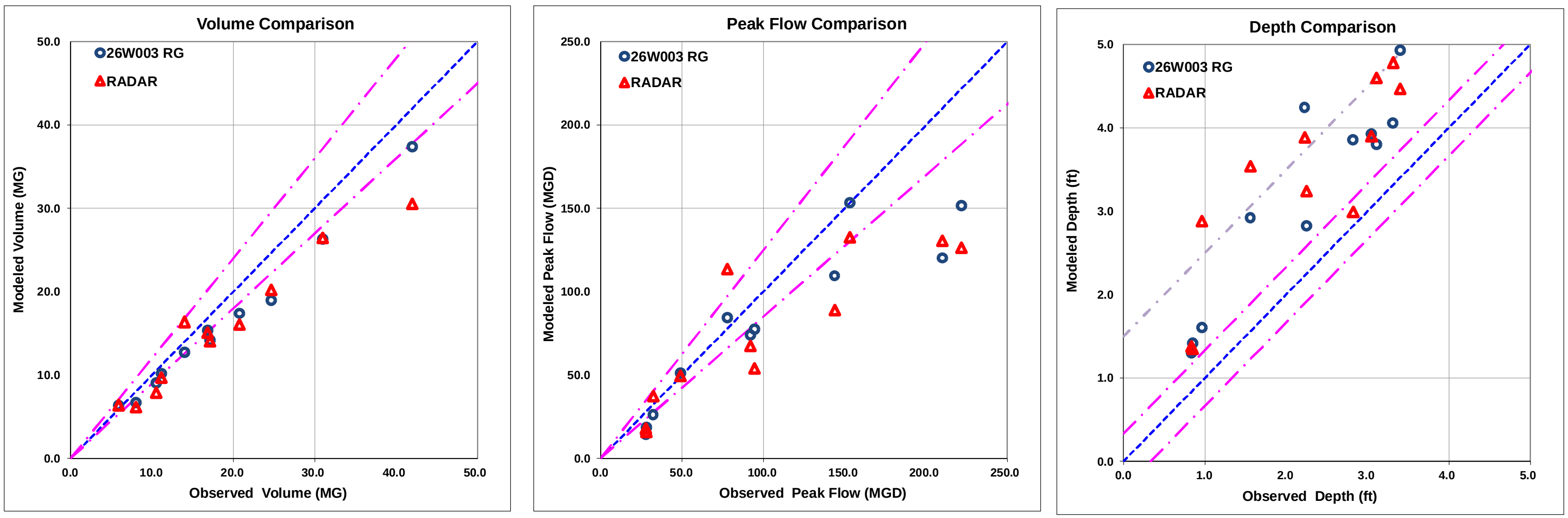

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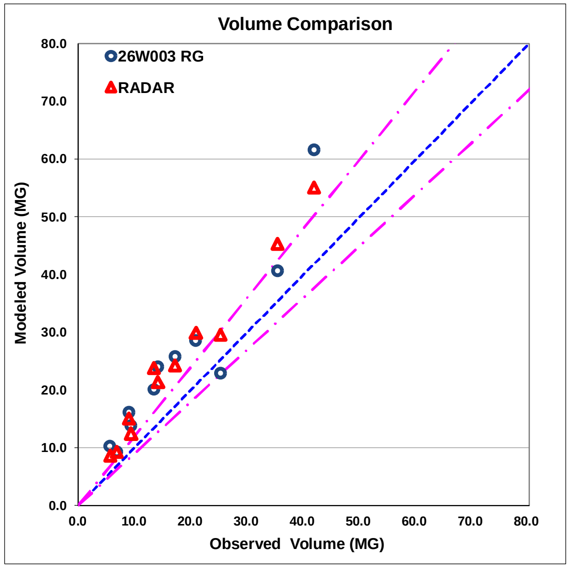

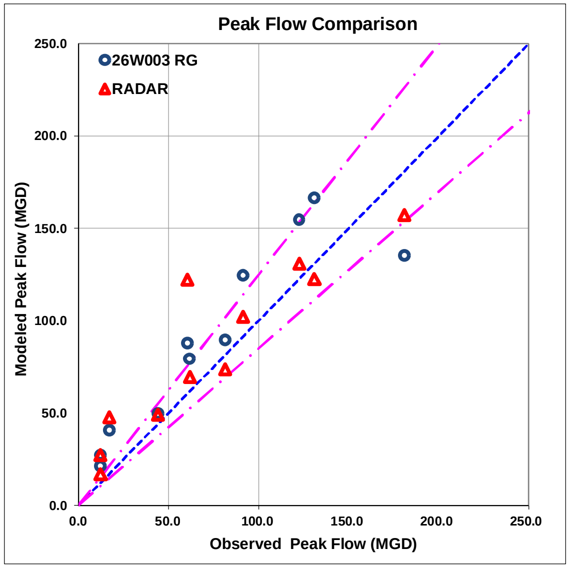

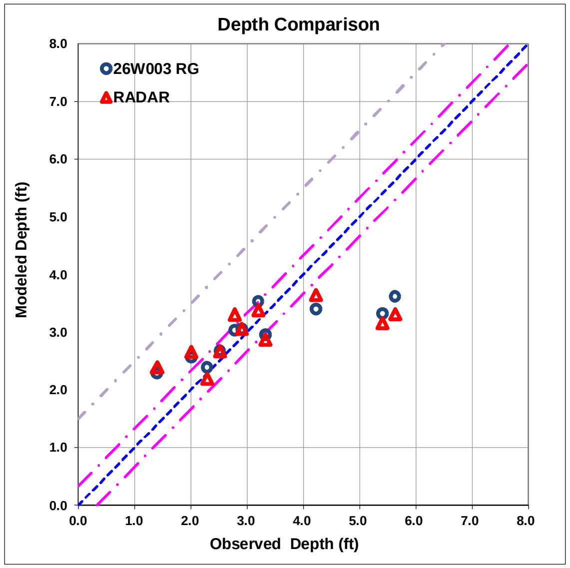

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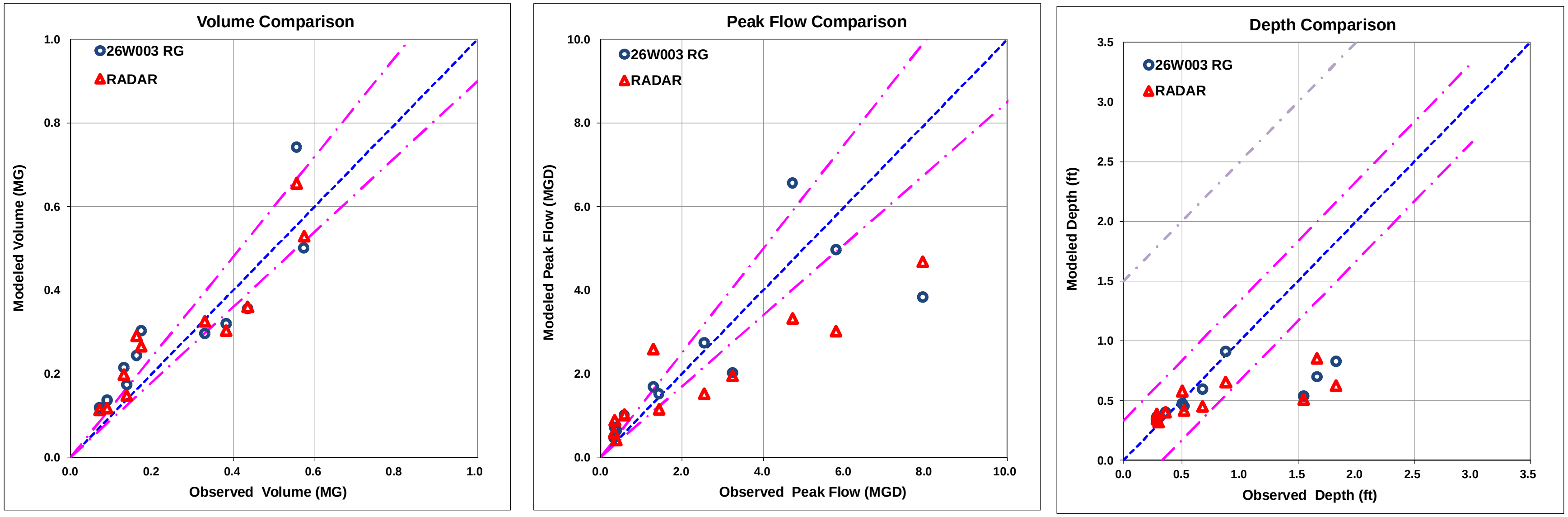

AECOM with Hazen

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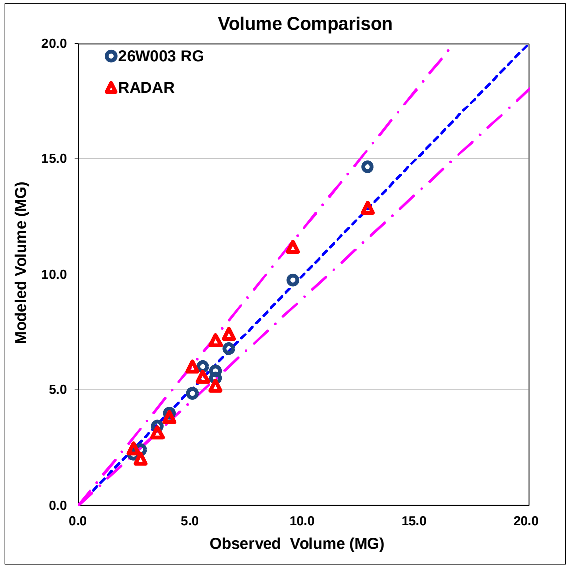

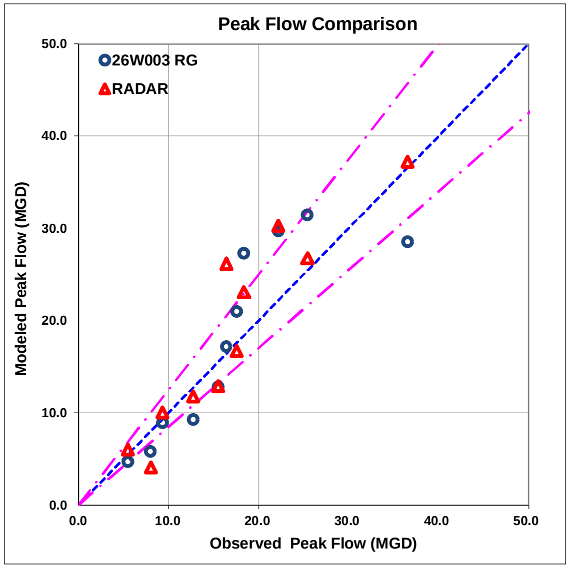

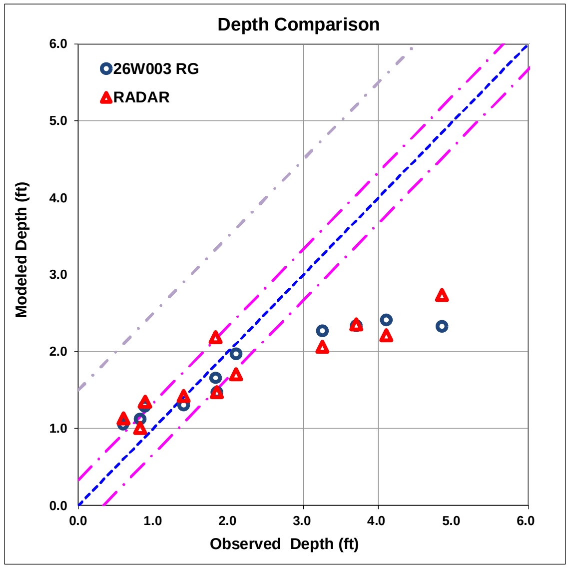

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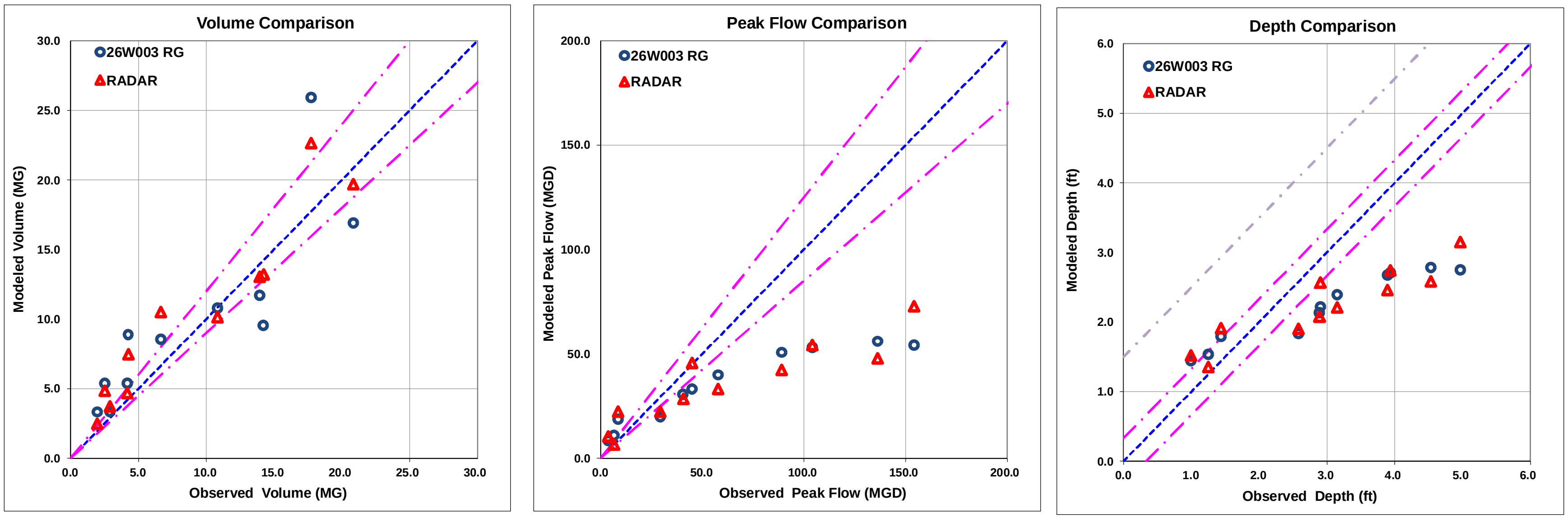

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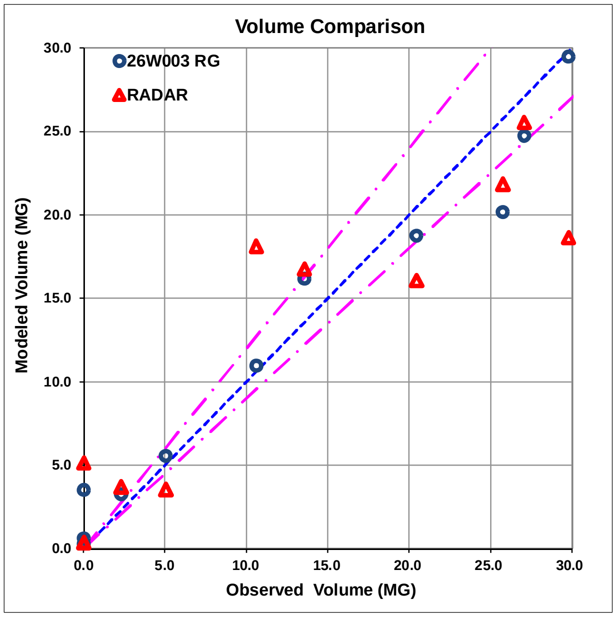

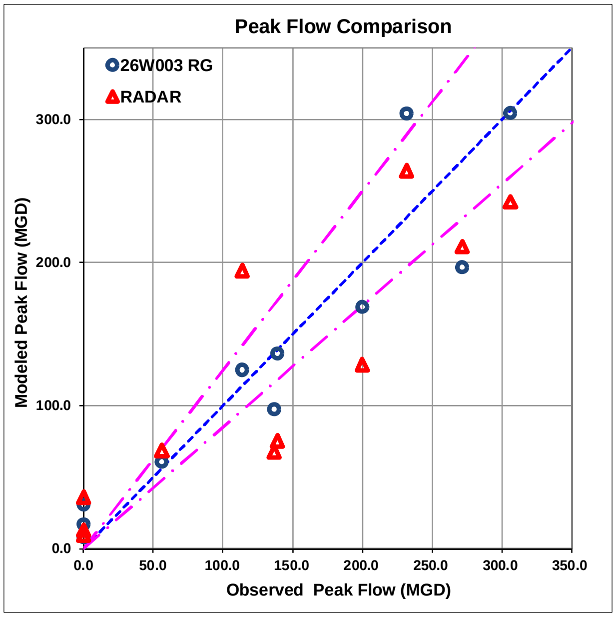

AECOM with Hazen

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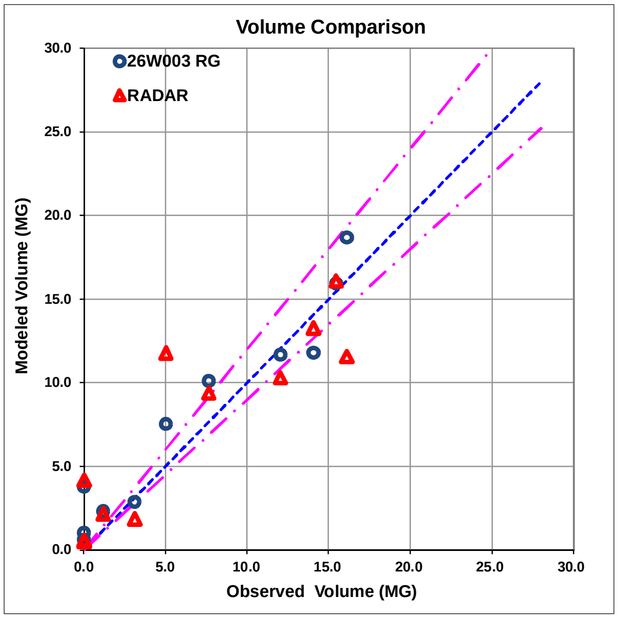

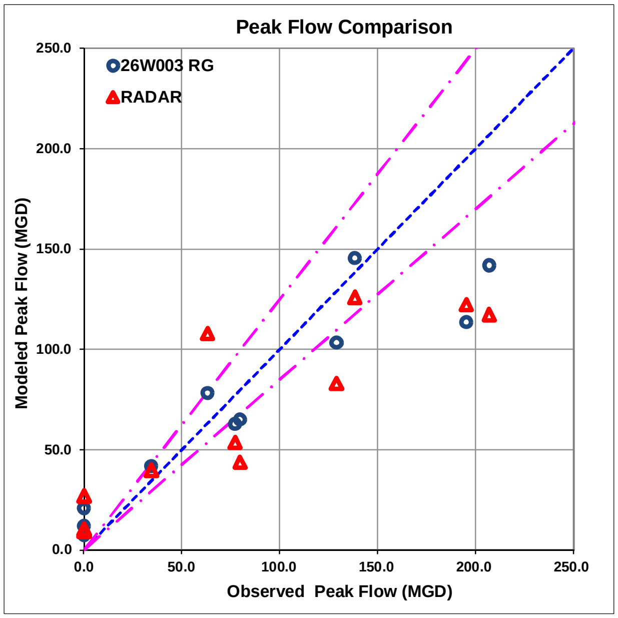

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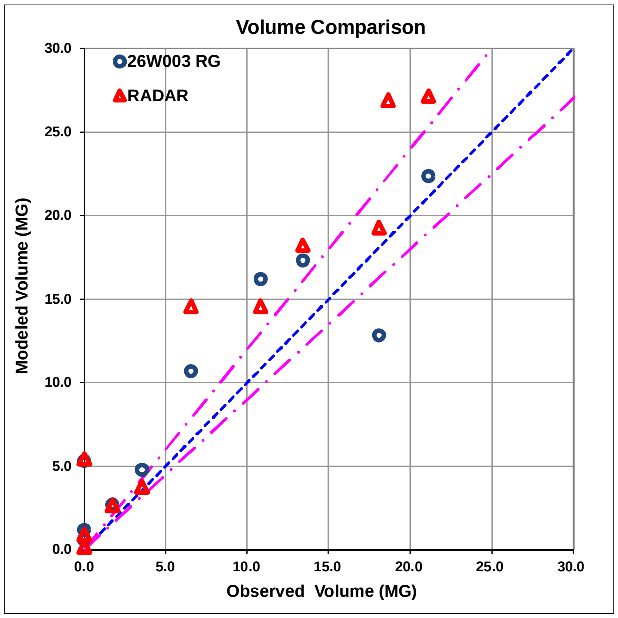
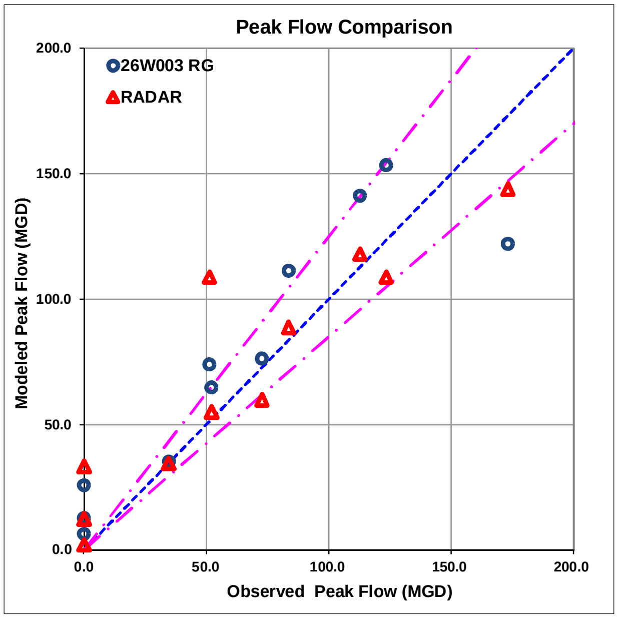
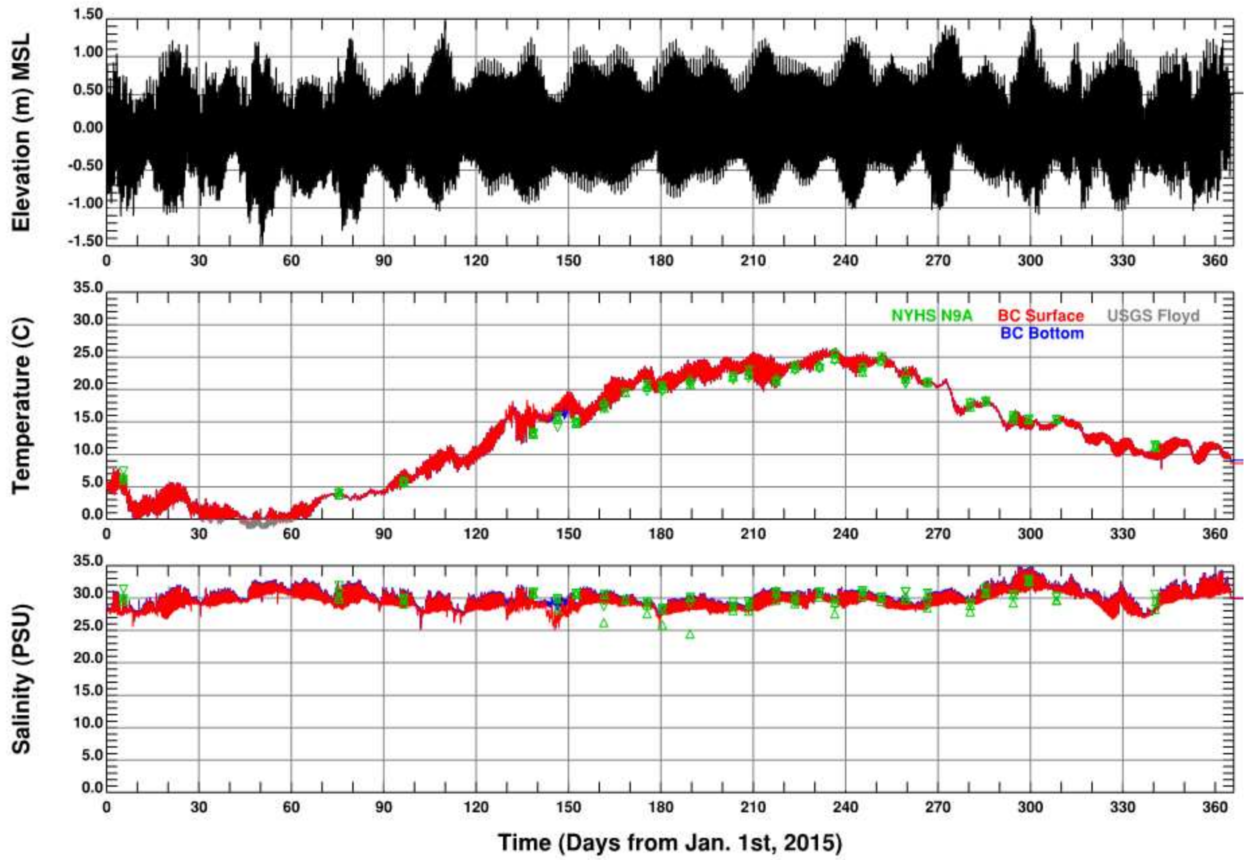


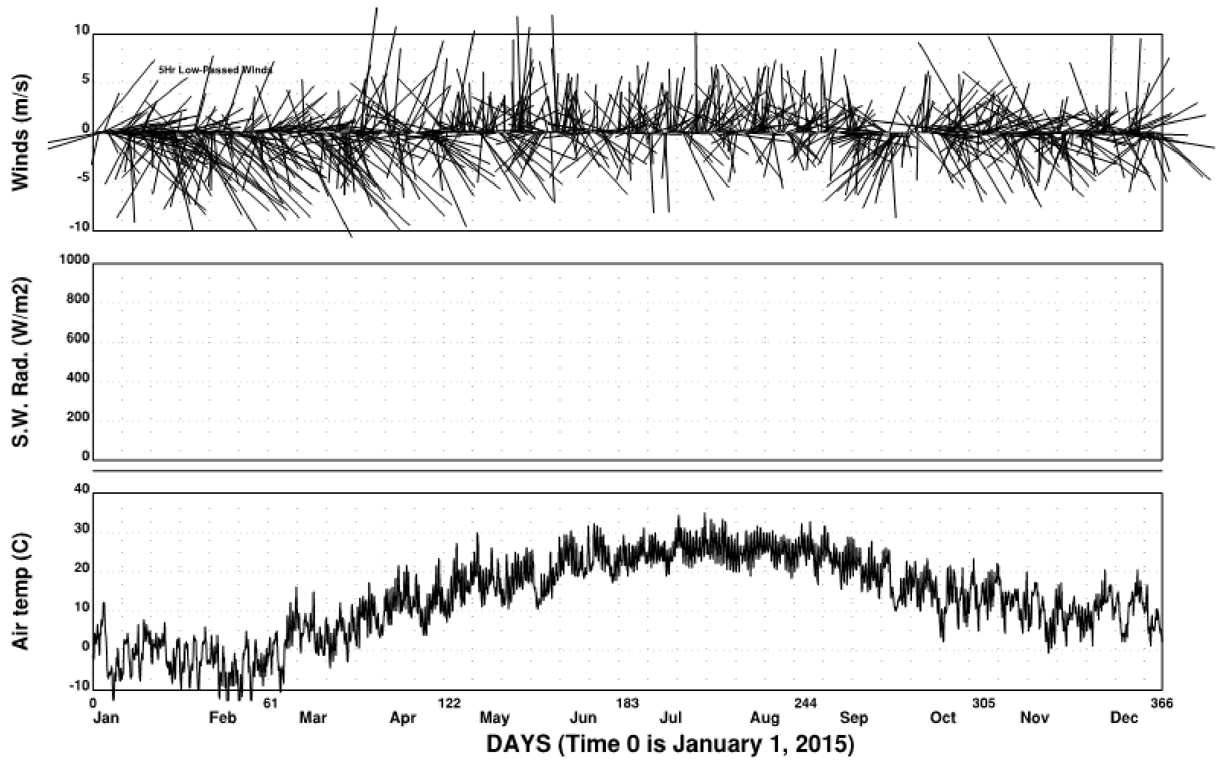


APPENDIX C

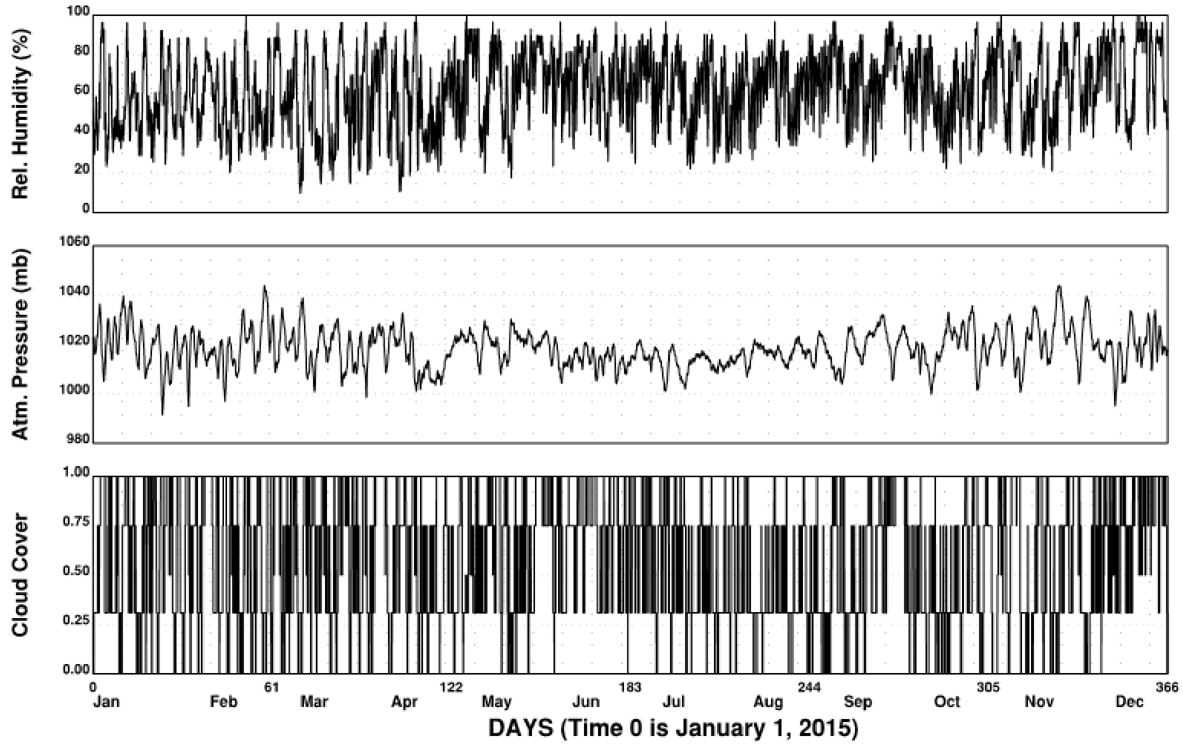
ADDITIONAL HYDRODYNAMIC MODEL FIGURES



HYDRODYNAMIC MODEL BOUNDARY CONDITIONS



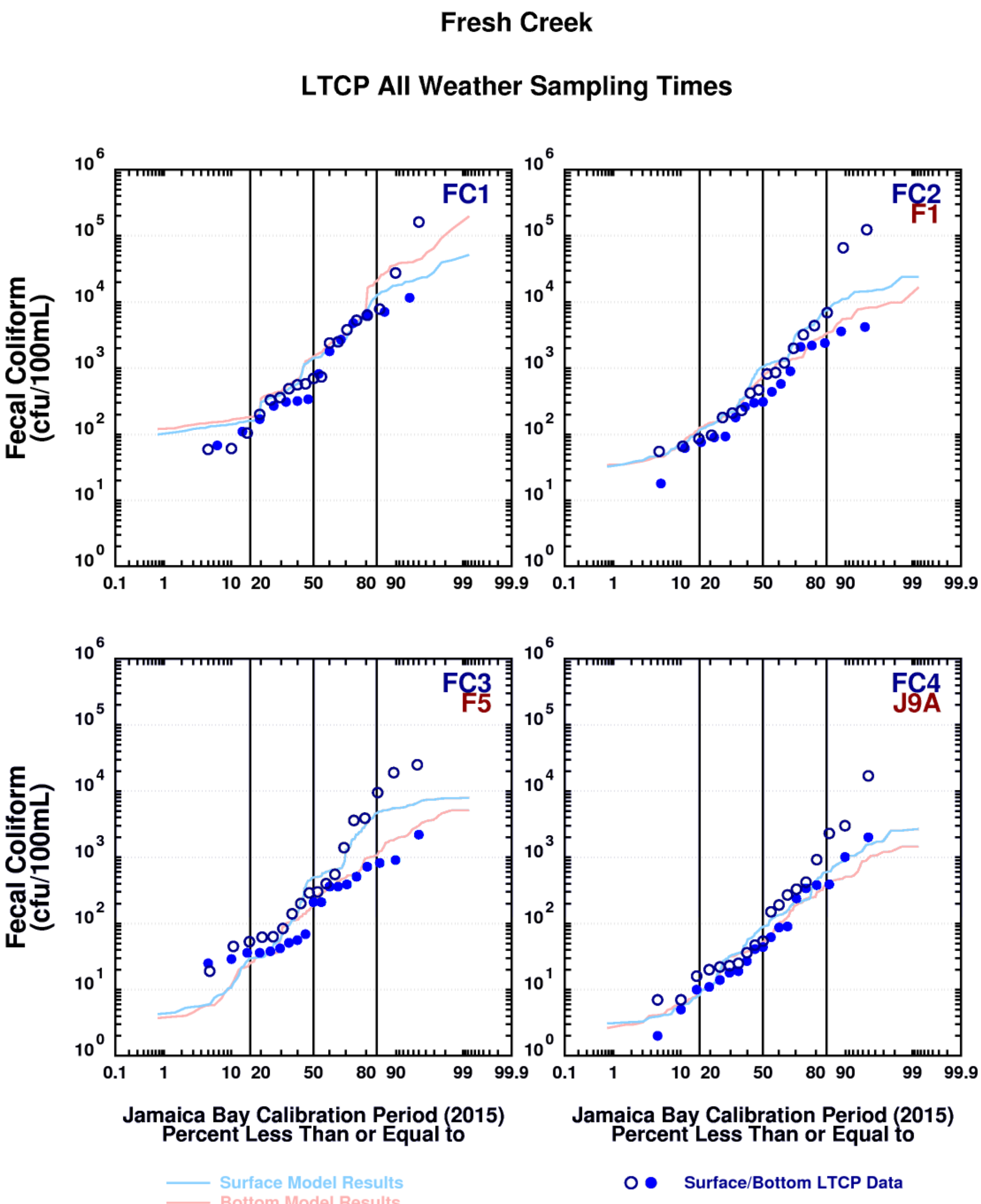
HYDRODYNAMIC MODEL METEOROLOGICAL INPUTS

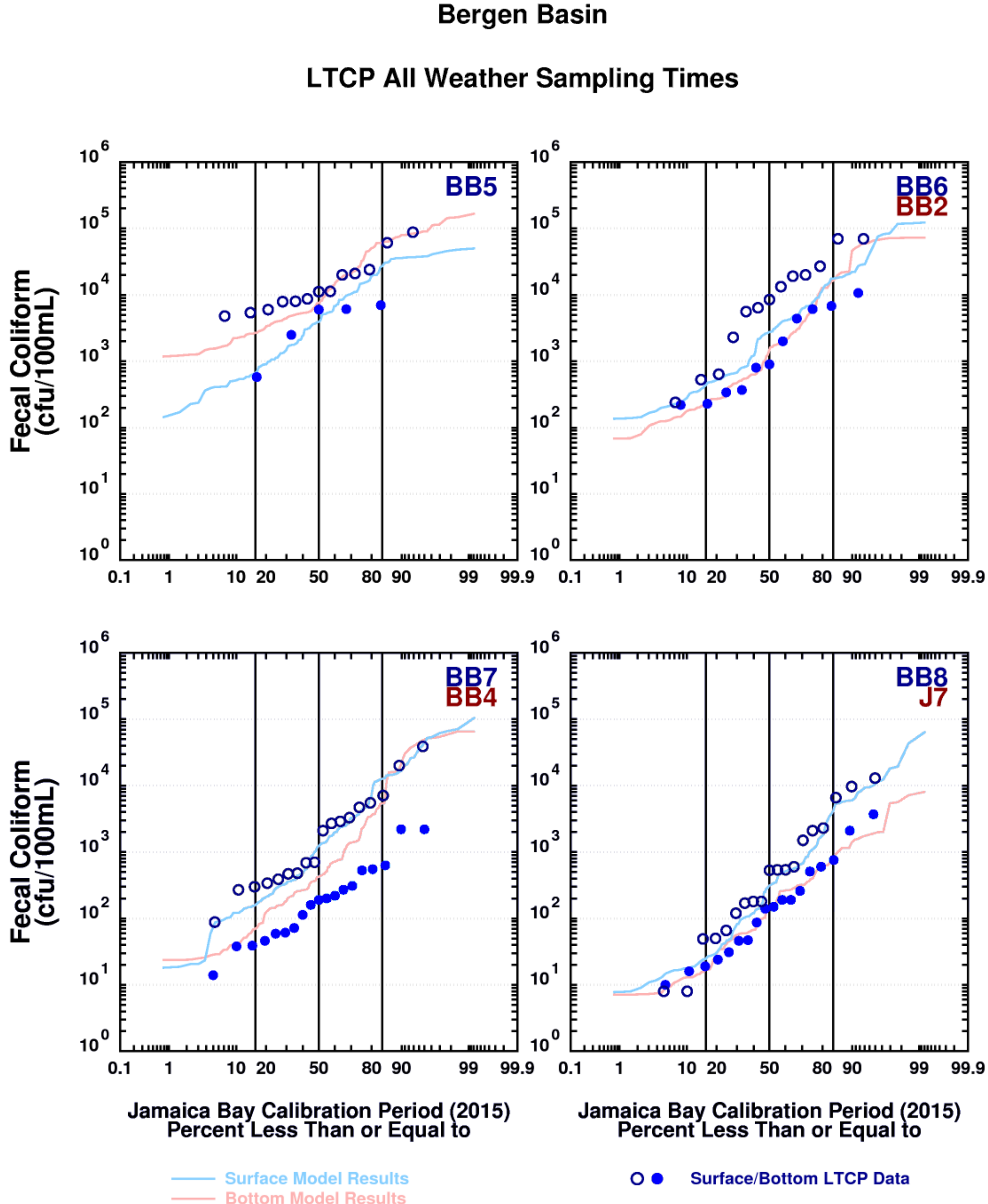


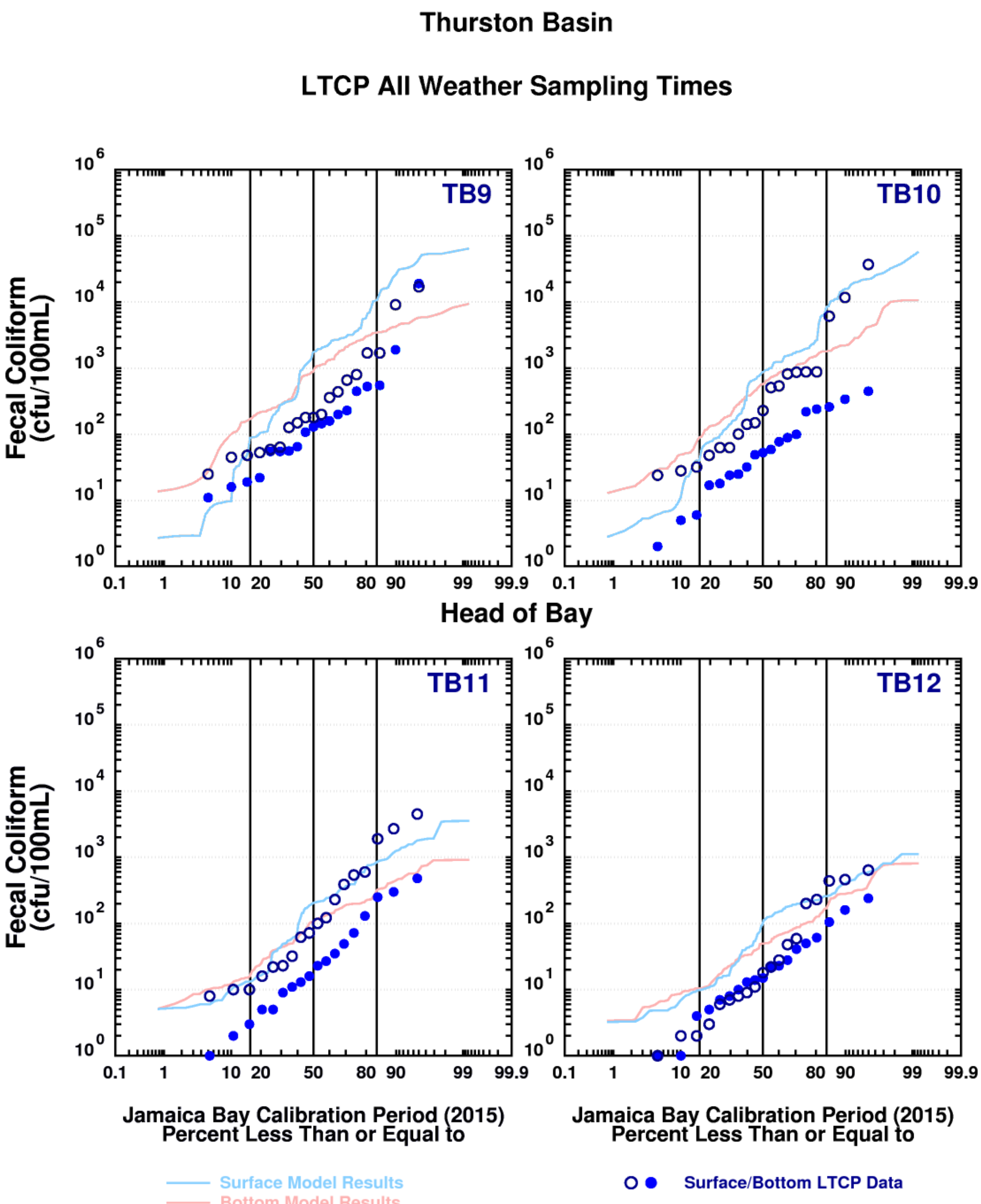
HYDRODYNAMIC MODEL METEOROLOGICAL INPUTS

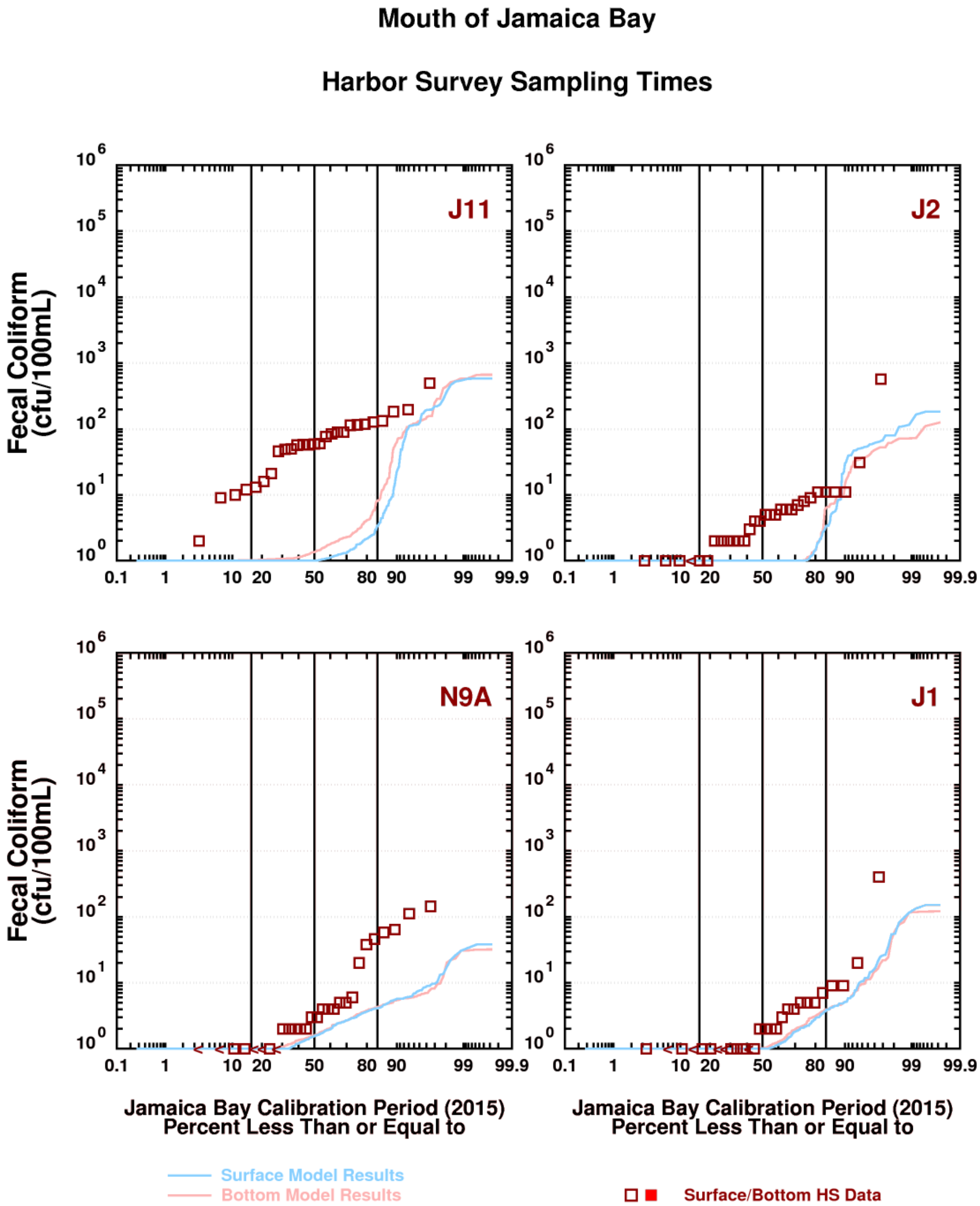
APPENDIX D

ADDITIONAL PATHOGENS CALIBRATION FIGURES


Fresh Creek
LTCP All Weather Sampling Times
Fecal Coliform (cfu/100mL)
FC1
FC2
F1
FC3
F5
FC4
J9A
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data

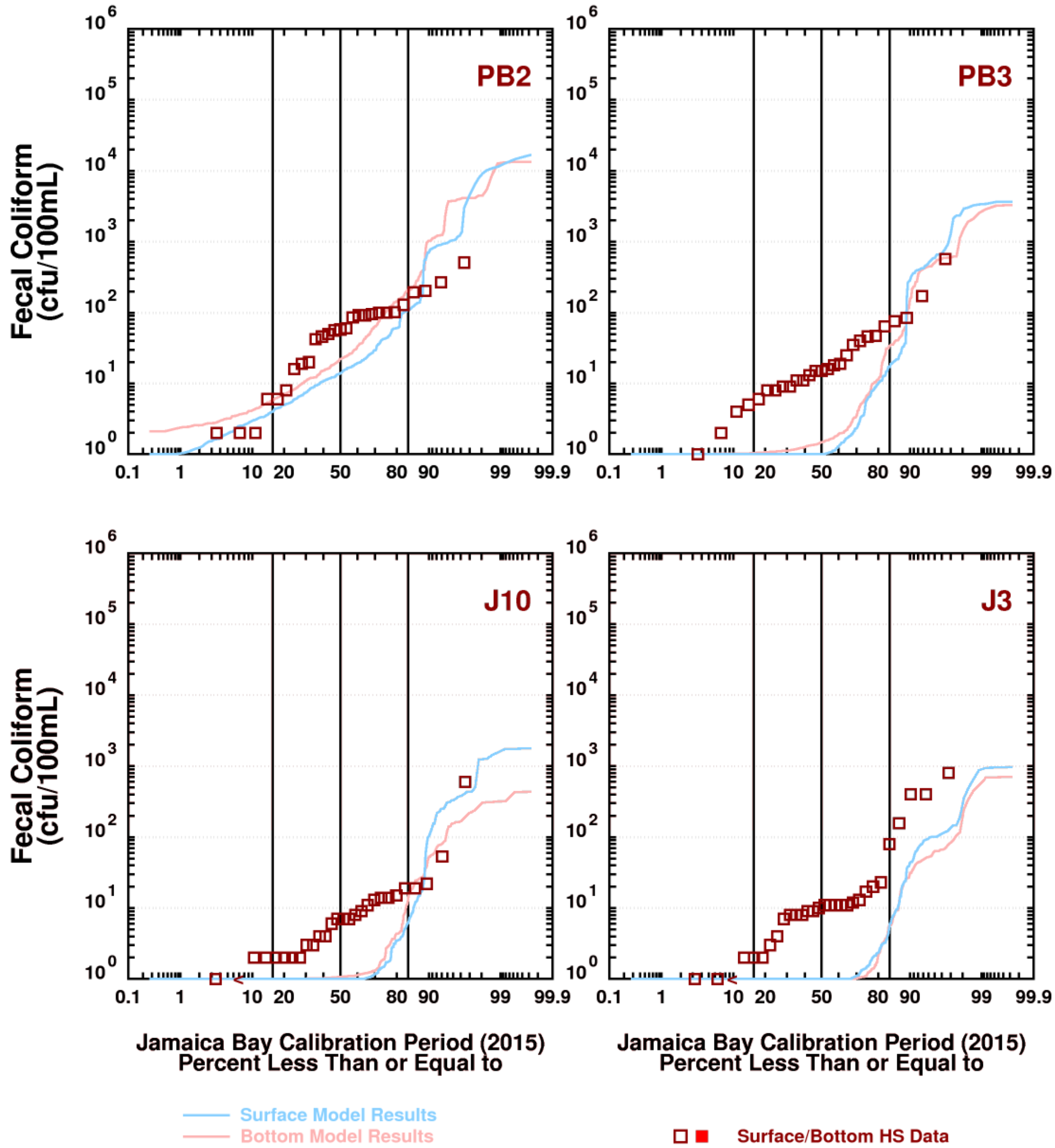

Bergen Basin
LTCP All Weather Sampling Times
BB5
BB6
BB2
BB7
BB4
BB8
J7
Fecal Coliform (cfu/100mL)
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0.1 1 10 20 50 80 90 99 99.9
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data


Thurston Basin
LTCP All Weather Sampling Times
TB9
TB10
Head of Bay
TB11
TB12
Fecal Coliform (cfu/100mL)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0.1
1
10
20
50
80
90
99
99.9
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data


Mouth of Jamaica Bay
Harbor Survey Sampling Times
Fecal Coliform (cfu/100mL)
J11
J2
N9A
J1
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0.1
1
10
20
50
80
90
99
99.9
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data

Paerdegat Basin

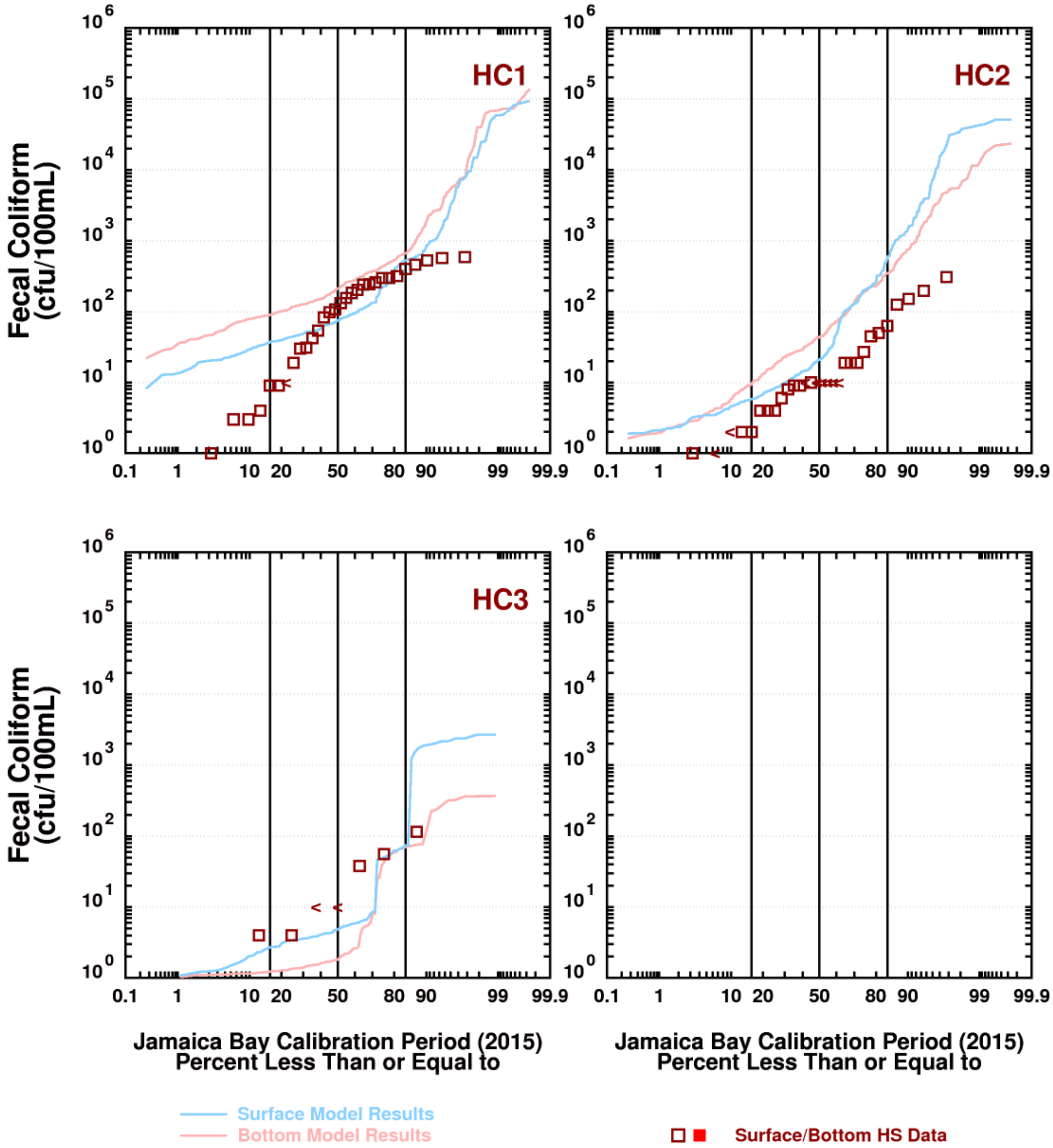
Harbor Survey Sampling Times

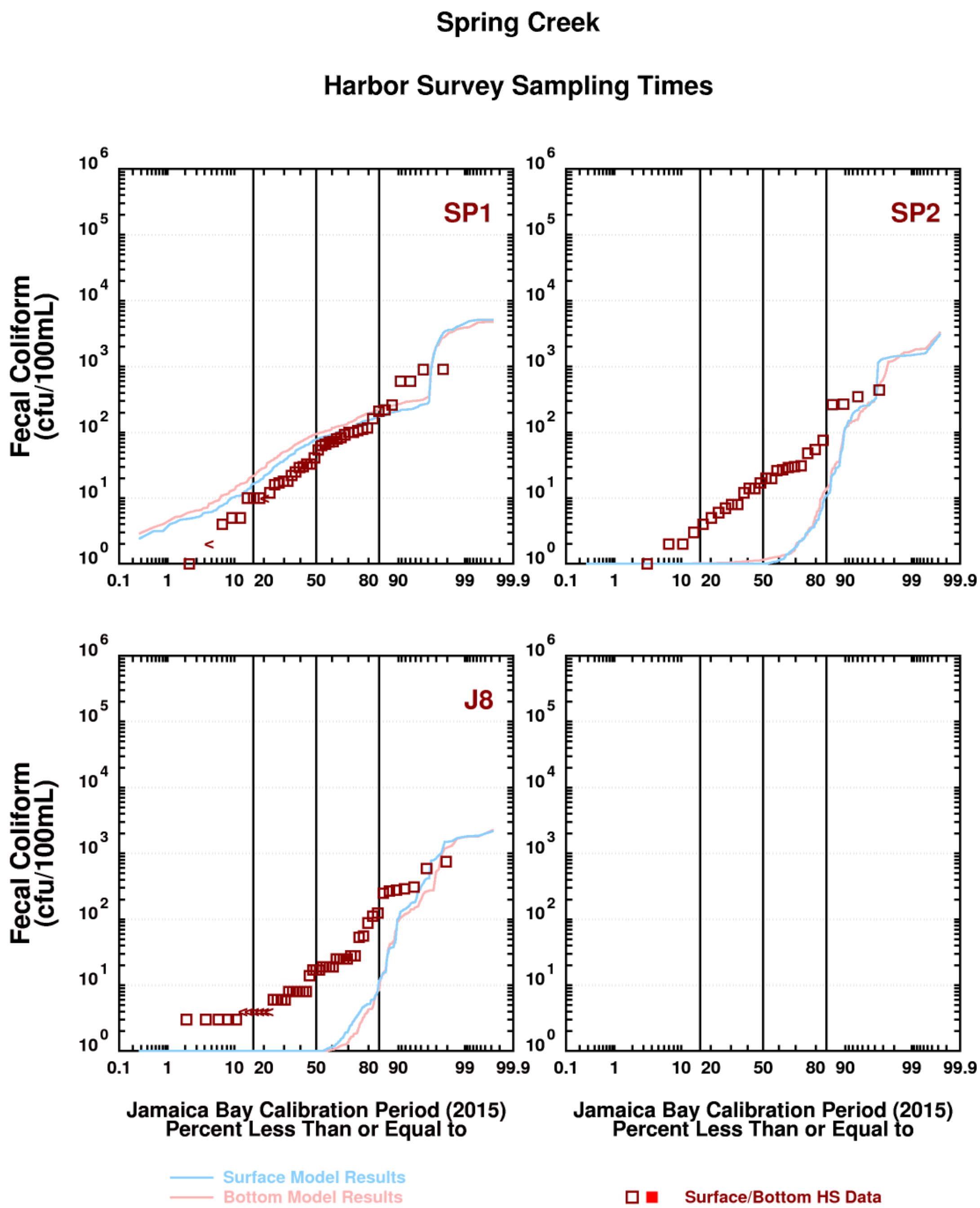


AECOM with Hazen

Hendrix Creek

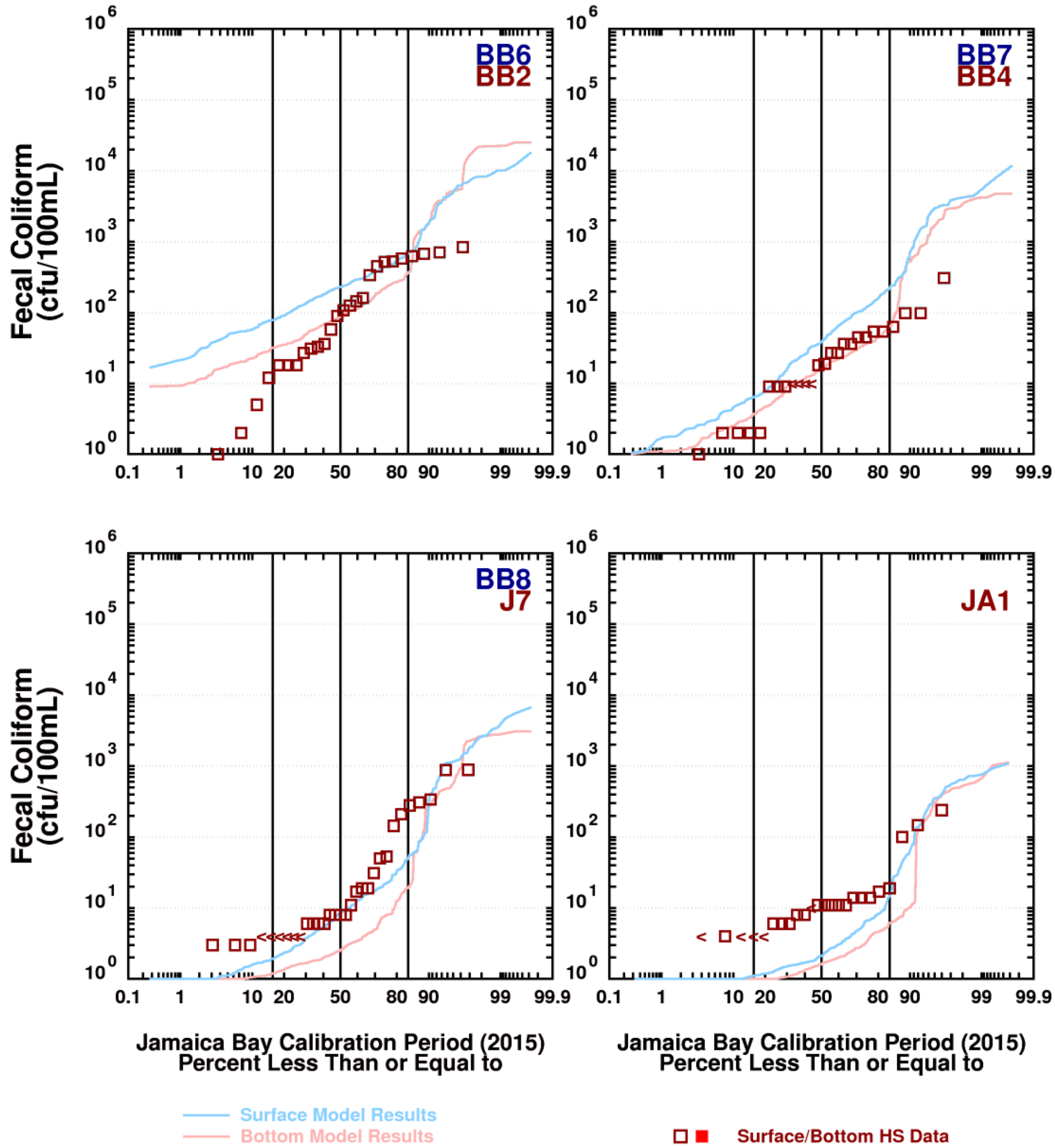
Harbor Survey Sampling Times

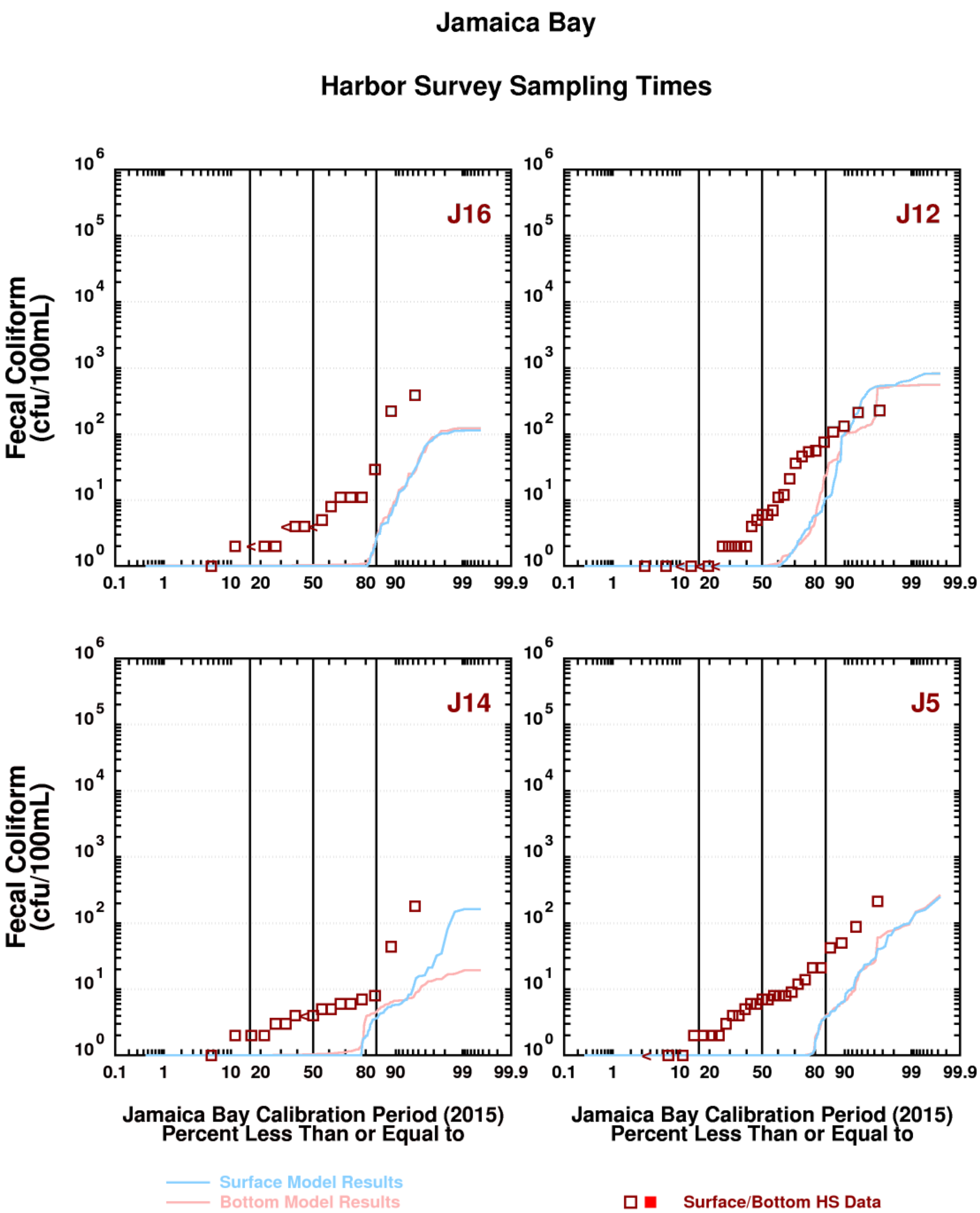


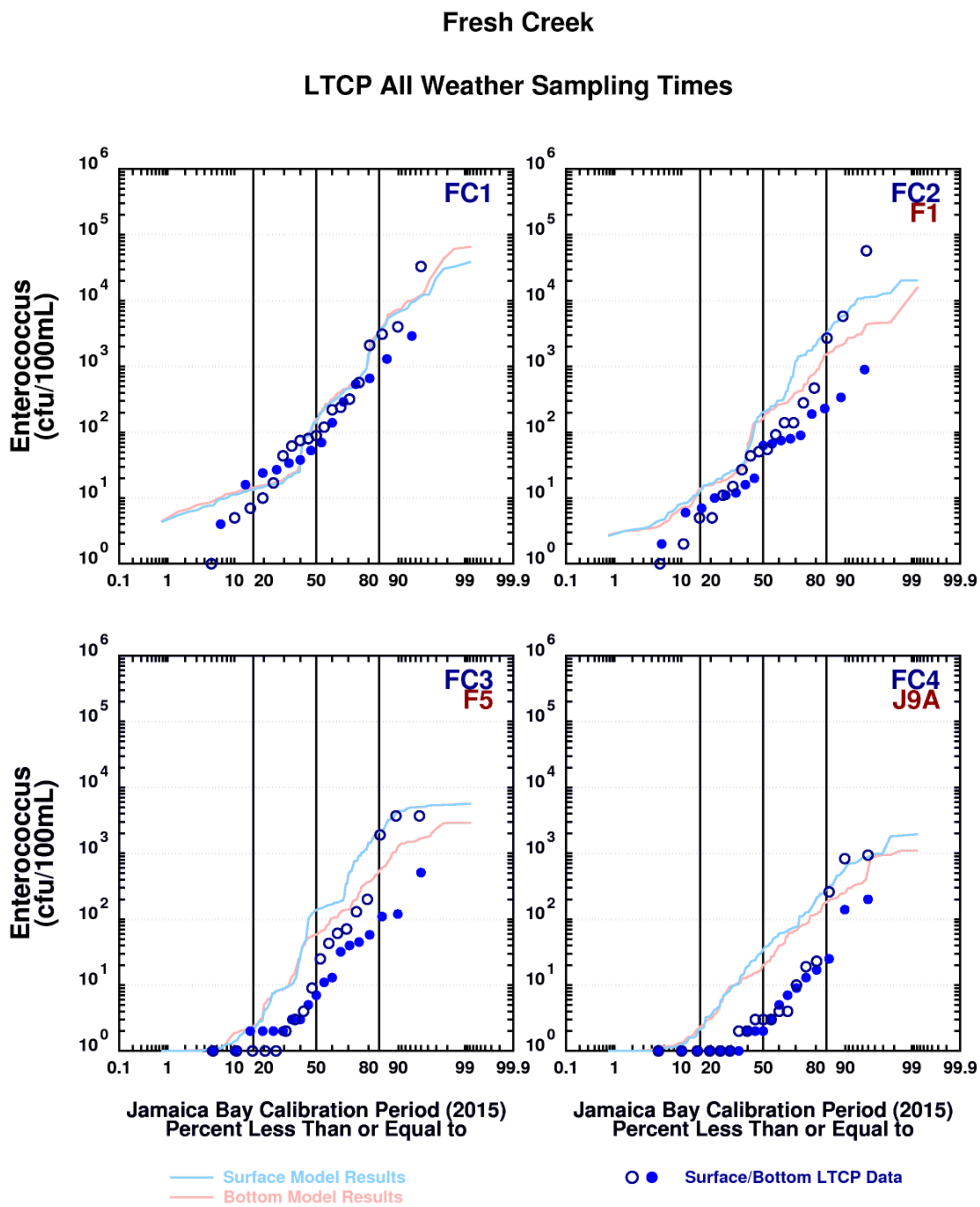

Spring Creek
Harbor Survey Sampling Times
SP1
SP2
J8
Fecal Coliform (cfu/100mL)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0.1 1 10 20 50 80 90 99 99.9
Jamaica Bay Calibration Period (2015)
Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data

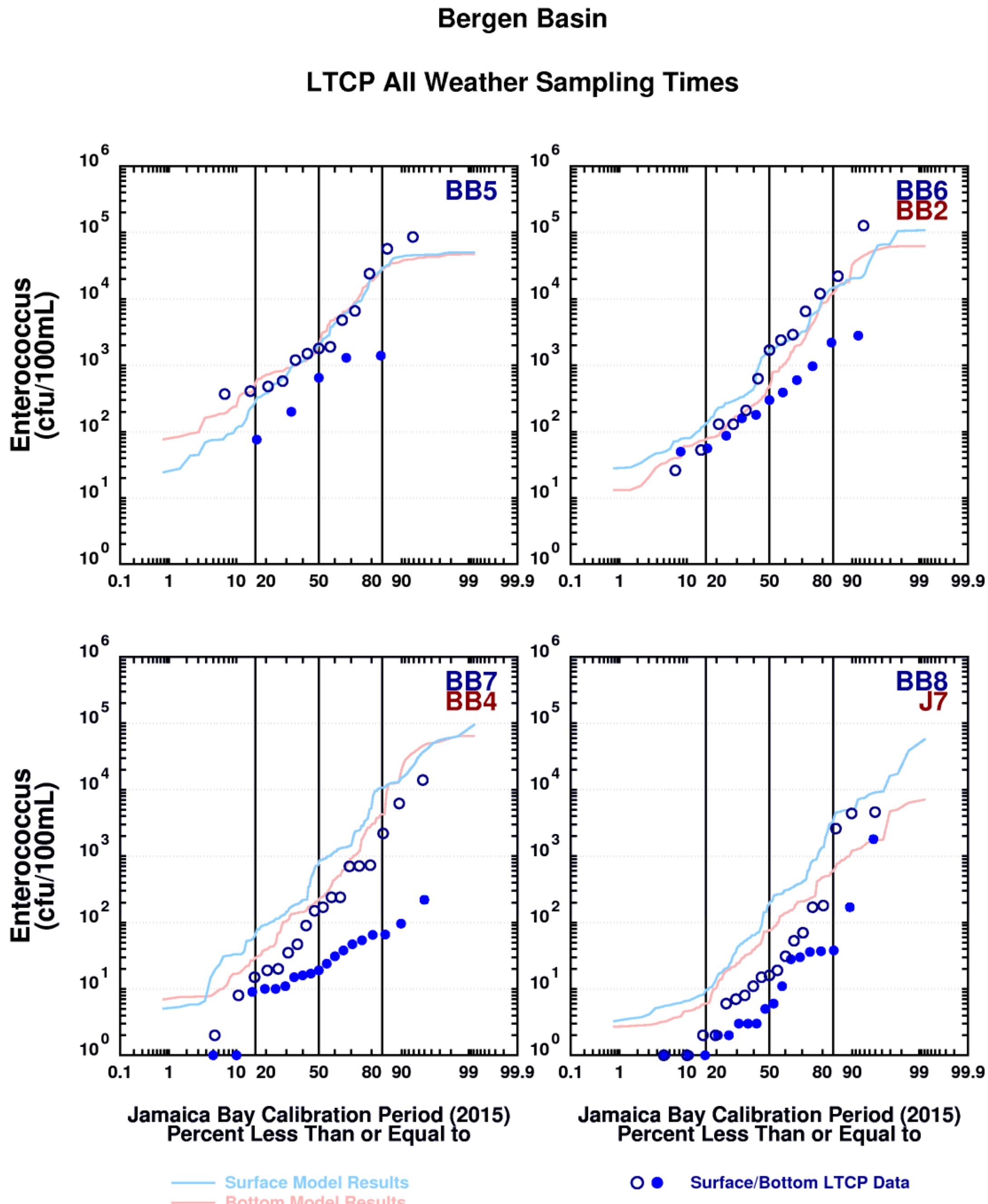
Bergen Basin

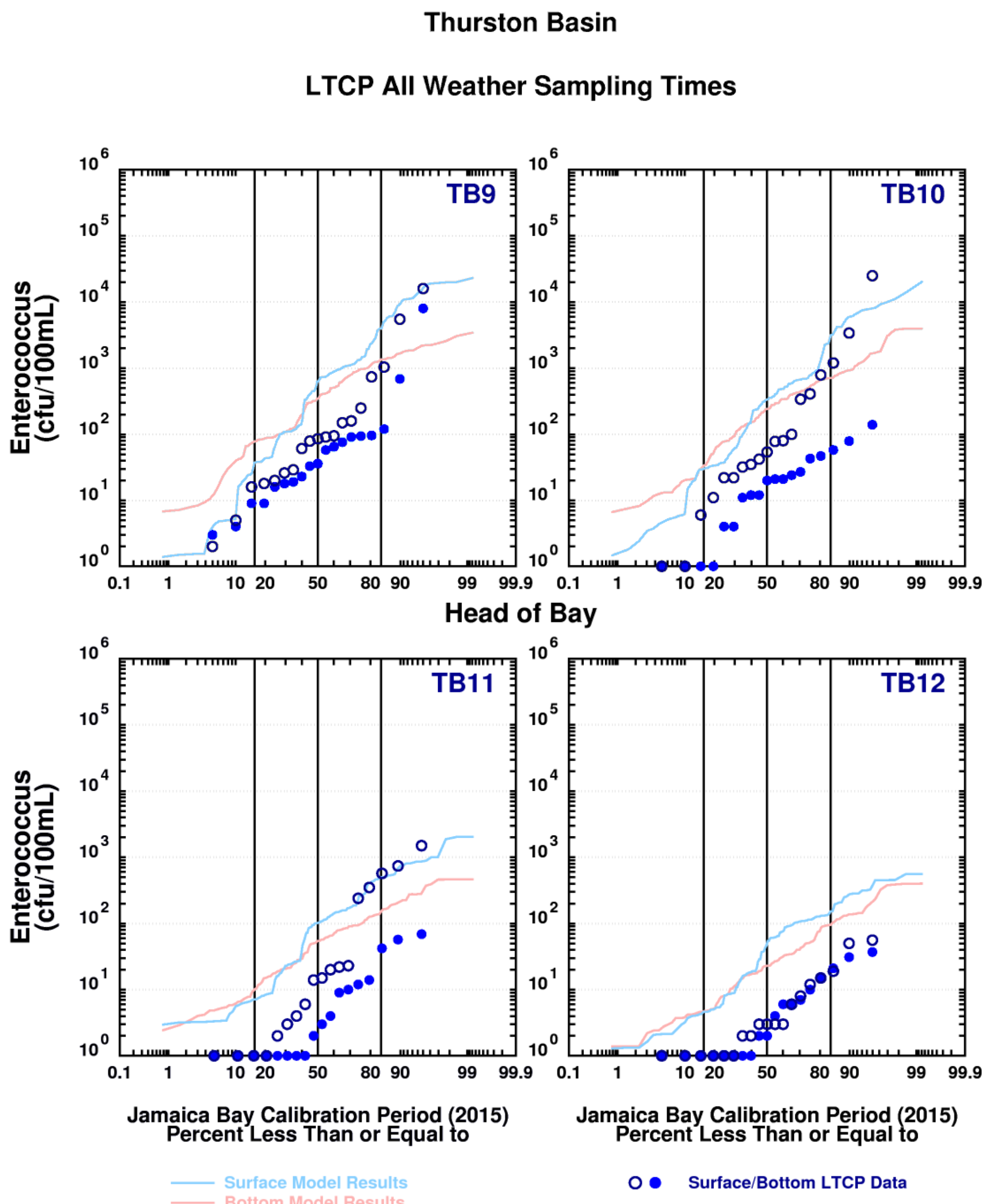
Harbor Survey Sampling Times

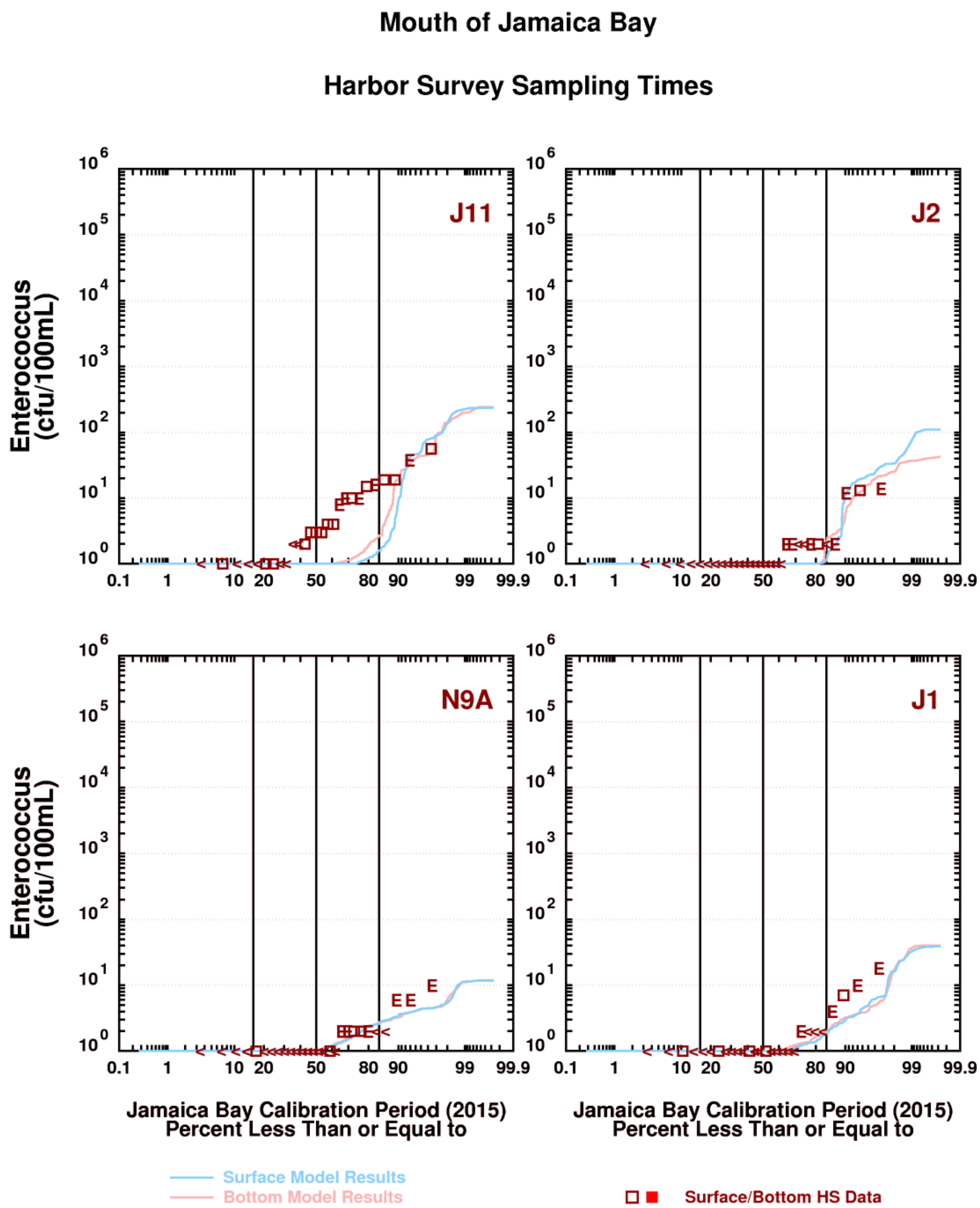



Jamaica Bay
Harbor Survey Sampling Times
J16
J12
J14
J5
Fecal Coliform (cfu/100mL)
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data


Fresh Creek
LTCP All Weather Sampling Times
Enterococcus (cfu/100mL)
FC1
FC2
F1
FC3
F5
FC4
J9A
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data


Bergen Basin
LTCP All Weather Sampling Times
BB5
BB6
BB2
BB7
BB4
BB8
J7
Enterococcus (cfu/100mL)
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0.1
1
10
20
50
80
90
99
99.9
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data


Thurston Basin
LTCP All Weather Sampling Times
TB9
TB10
Head of Bay
TB11
TB12
Enterococcus (cfu/100mL)
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom LTCP Data



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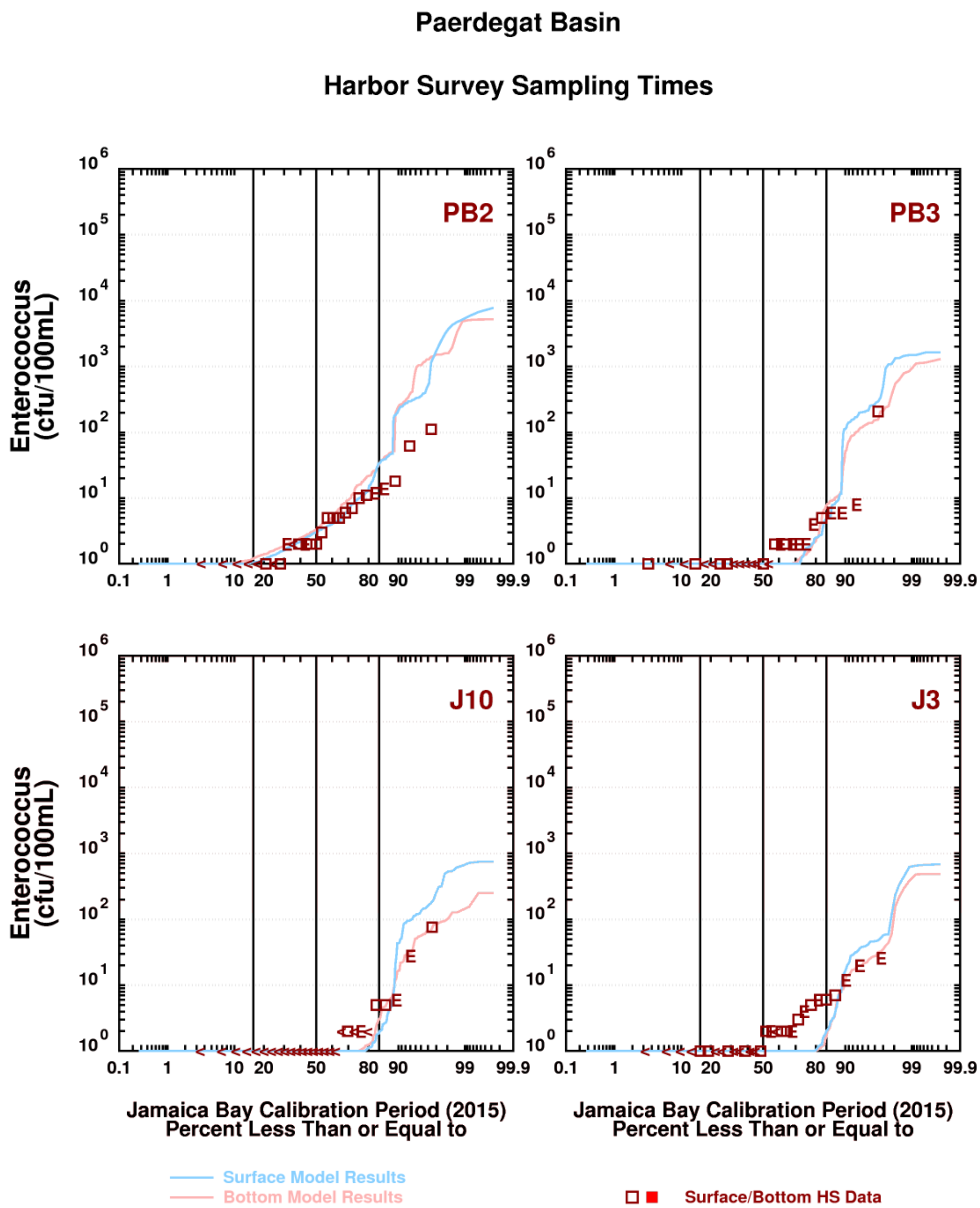

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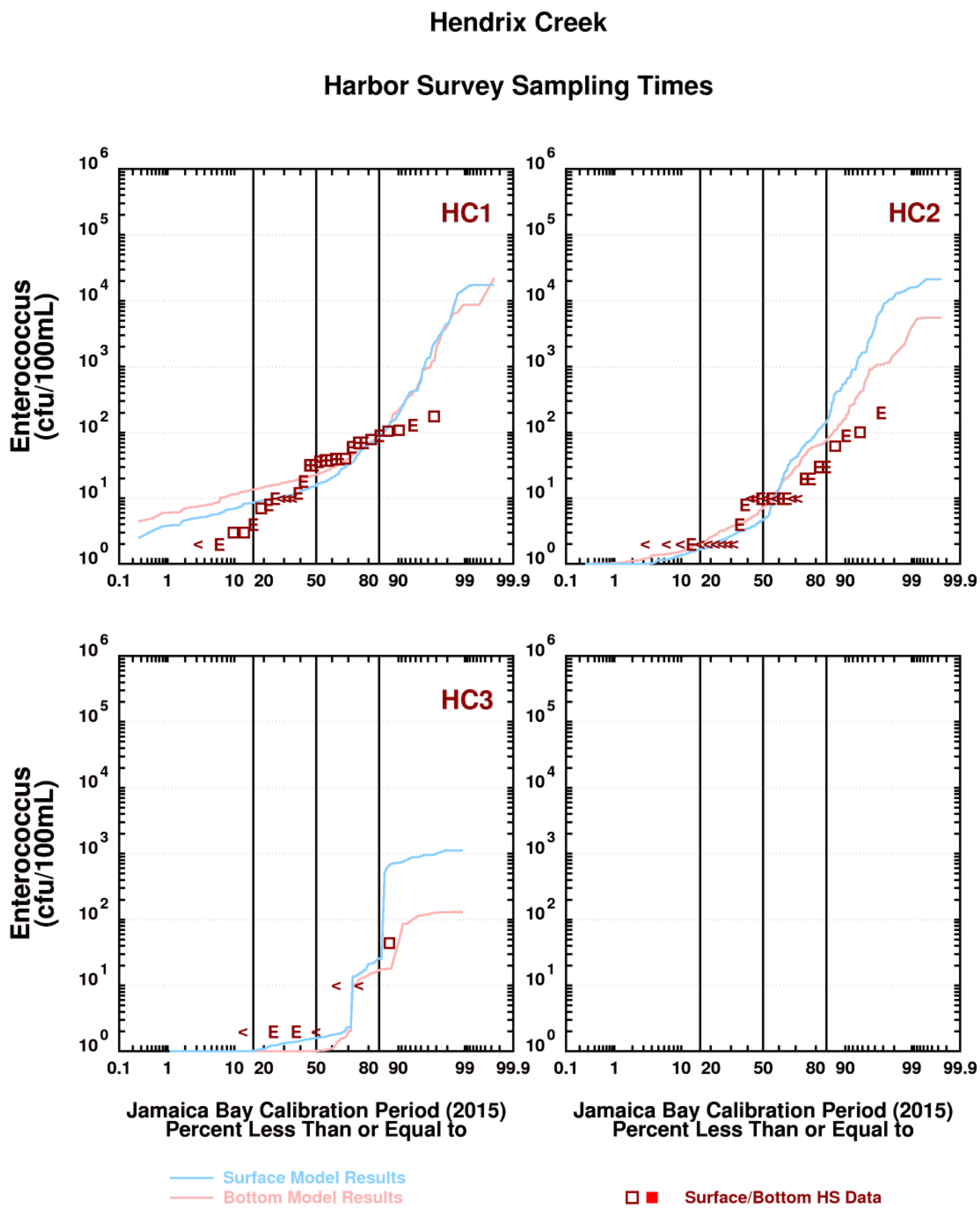
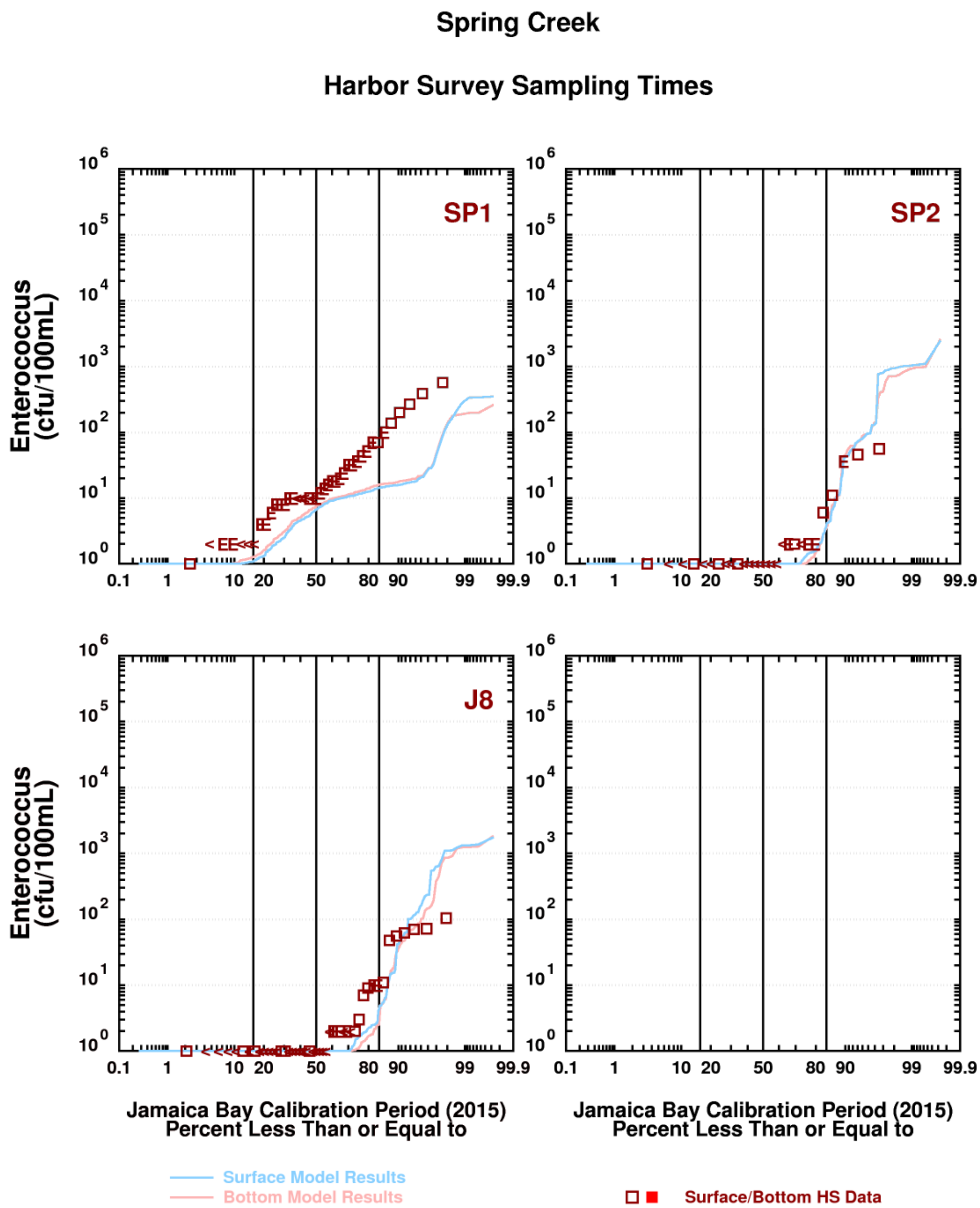
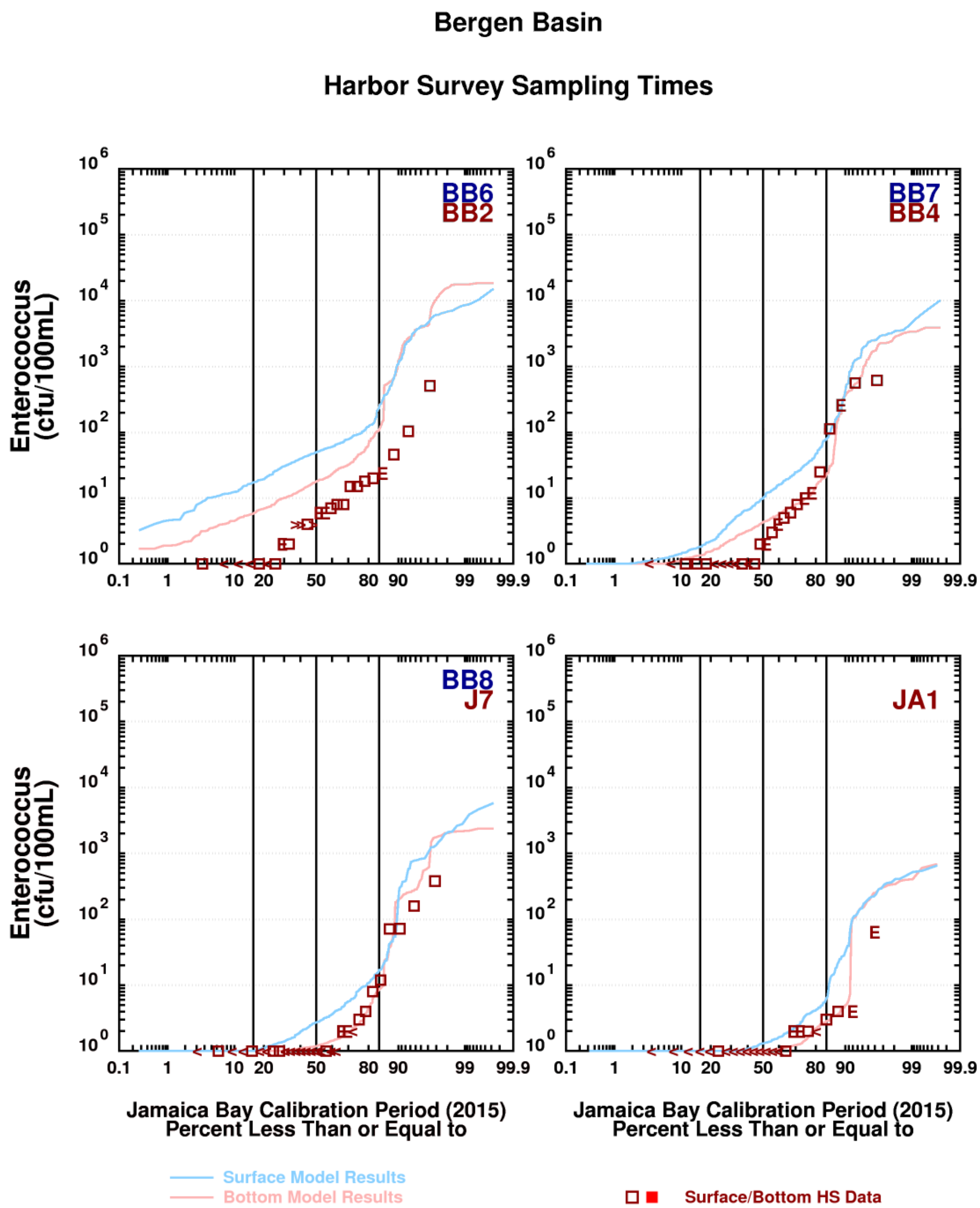

Hendrix Creek
Harbor Survey Sampling Times
HC1
HC2
HC3
Enterococcus (cfu/100mL)
Jamaica Bay Calibration Period (2015)
Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data


Spring Creek
Harbor Survey Sampling Times
SP1
SP2
J8
Enterococcus (cfu/100mL)
Jamaica Bay Calibration Period (2015) Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data


Bergen Basin
Harbor Survey Sampling Times
BB6
BB2
BB7
BB4
BB8
J7
JA1
Enterococcus (cfu/100mL)
10^0 10^1 10^2 10^3 10^4 10^5 10^6
0.1 1 10 20 50 80 90 99 99.9
Jamaica Bay Calibration Period (2015)
Percent Less Than or Equal to
Surface Model Results
Bottom Model Results
Surface/Bottom HS Data

Attachment D
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Attachment E
Executive Summary

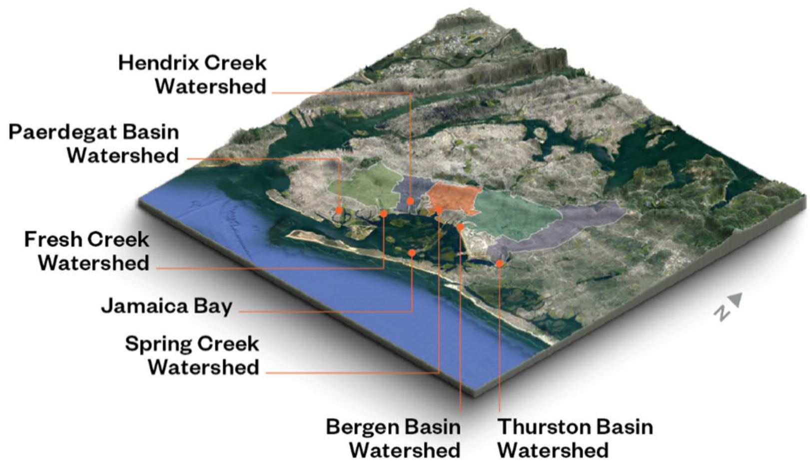
EXECUTIVE SUMMARY

This Executive Summary is organized as follows:

- Synopsis – a high-level summary of this Long Term Control Plan (LTCP);
- Recommended Plan – a summary of the Recommended Plan, water quality (WQ) modeling results, triple-bottom line benefits;
- Background – an overview of the regulations, approach, and characterization of Jamaica Bay and its tributaries; and
- Findings – a summary of the key results of the WQ data analyses, WQ modeling simulations, and alternatives analysis.

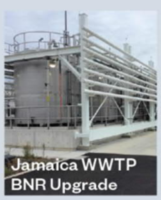
1. SYNOPSIS

Historically, Jamaica Bay has served as an important ecological resource for many flora and fauna. The Bay is a critical ecosystem that supports multiple, diverse habitats, more than 325 bird species, 100 species of fish, and 54 species of moths and butterflies. It also contains one of the largest and most important tidal wetland complexes in New York State, is located along the Atlantic Coastal Flyway bird migration route, and is a component of the National Park Service's Gateway National Recreation Area encompassing 26,000 acres. Approximately 17,000 acres of this area consists of aquatic ecosystems that include estuarine open water, intertidal zones, salt marsh islands, fringing salt marshes, tidal mud and sand flats, and freshwater wetlands, ponds, and tributaries. The Bay is home to many wildlife preserves, parks, marinas, and boat launches, supporting native habitat and recreational boating and fishing. Because of its geographic size and diverse functioning natural habitats, Jamaica Bay is a nationally and internationally renowned New York City (NYC) location.



Rapid urbanization and development resulted in many water quality challenges in Jamaica Bay and the six urban tributaries evaluated in this Combined Sewer Overflow (CSO) LTCP. Those tributaries include Thurston Basin, Bergen Basin, Spring Creek, Hendrix Creek, Fresh Creek, and Paerdegat Basin. Efforts to address water quality in Jamaica Bay and its tributaries date back to the 1900s when NYC was constructing wastewater treatment plants (WWTPs) to treat sewage flow during dry-weather and to capture a portion of the combined storm and sanitary sewage flow generated during wet-weather. Since then, significant water quality improvements have been achieved through several strategic initiatives. These strategic investments, in excess of $3.6B, have led to significant water quality improvements in Jamaica Bay. Water quality attainment is achieved in most tributaries and open waters; however, impairments for fecal coliform remain at the head ends of Fresh Creek, Bergen Basin, and Thurston Basin. The Recommended Plan in this LTCP will build upon these past investments and provide further water quality improvements across Jamaica Bay.

WATER QUALITY IMPROVEMENTS Achieved through Strategic Investments



$600 Million
Biological Nutrient Reduction (BNR) Upgrades across four wastewater treatment plants (JA, 26W, RK, and CI) that discharge to Jamaica Bay

$1 Billion
Past and Existing Grey Infrastructure investments to reduce combined sewer overflows

$300 Million
Existing and Planned Green Infrastructure commitment over the next decade under the OneNYC Plan

$32 Million
Ecosystem Restoration and Research Efforts to support pathogen reduction and DO improvement under the Jamaica Bay Watershed Protection Plan

$1.7 Billion
Southeast Queens Sewer Buildout commitment over the next decade under the OneNYC Plan

LTCP Recommended Plan
will build upon these past investments and provide further water quality improvements.

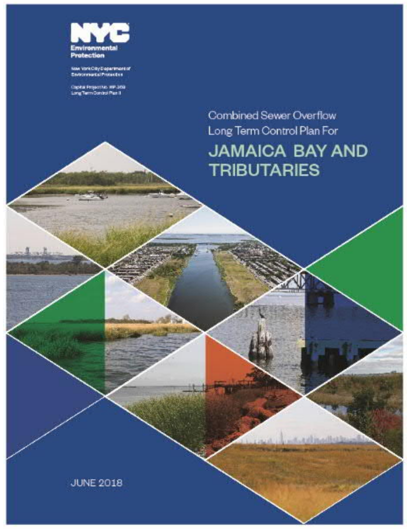
This LTCP has been developed in an effort to better understand and identify cost-effective and implementable projects to reduce CSO impacts to meet water quality standards (WQS) within Jamaica Bay and its tributaries. Throughout the process for developing this LTCP, New York City Department of Environmental Protection (DEP) collected water quality data, performed extensive collection system and water quality modeling, held multiple public meetings and analyzed potential CSO control alternatives based on costs, implementability and model predicted water quality improvement. The selection of the Recommended Plan was based on multiple considerations including public input, environmental and water quality benefits, community and societal impacts, issues related to implementation and operation and maintenance (O&M), as well as cost-performance and cost-attainment evaluations.

The Recommended Plan includes construction of green infrastructure (GI) within separately sewered portions of the Jamaica WWTP collection system in Bergen and Thurston Basins, environmental dredging, ribbed mussel colony creation, and tidal wetlands restoration.

In addition to closing the gap in attainment of Existing WQ Criteria for Jamaica Bay and its tributaries, the Recommended Plan provides economic, social, and environmental benefits that build upon the significant ecological improvements provided by prior grey infrastructure projects. Furthermore, the Recommend Plan can be implemented in 14 years as opposed to the grey retained alternatives, which are projected to take over 25 years to design, construct and activate.

In addition to the co-benefits of the Recommended Plan, which go beyond the requirements of the Clean Water Act, the plan furthers many of the ecosystem goals outlined in Plan OneNYC, including expansion of GI, reduction of pollution from stormwater runoff, expansion in tree planting, urban heat island reduction, resiliency, and habitat improvements for pollinators, wildlife aquatic species.

ELEMENTS OF THE RECOMMENDED PLAN



- Additional 453 greened acres in Bergen and Thurston Basin tributary areas
- 7 acres of ribbed mussel colony creation
- 50,000 CY of environmental dredging in Bergen Basin
- 50 acres of wetland restoration

TRIPLE BOTTOM LINE BENEFITS

- Reduce CSO discharges to Thurston Basin by 8 MGY
- Reduce Stormwater discharges by 241 MGY
- Provide air quality improvement
- Carbon footprint reduction
- Habitat creation
- Heat island construction reduction
- Property value improvement
- Water quality improvement through the filtering of the ribbed mussels

The implementation of the Recommended Plan has an estimated Net Present Worth of $401M, reflecting $91M of annual O&M costs over the course of 100 years and a Probable Bid Cost (PBC) of $310M (design and construction management costs would be additional). Figure ES-1 provides a comparison of the Triple-Bottom-Line benefits that will be realized through the implementation of the Recommended Plan, versus the grey infrastructure alternatives. Full details associated with the alternative evaluations and detailed elements of the Recommended Plan are presented in Section 8 of this LTCP.

Triple Bottom Line Benefits of the Recommended Plan

includes economic, social and environmental co-benefits beyond what can be achieved through a traditional Grey Infrastructure approach of underground CSO Storage Tunnels.

The Recommended plan meets many of the ecosystem goals outlined in Plan #ONENYC

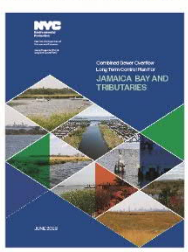
#ONENYC INITIATIVES	RECOMMENDED PLAN	GREY ALTERNATIVE
Expand Green Infrastructure	✓	✕
Reduce Pollution from Stormwater Runoff	✓	✓
Increase Trees Planted	✓	✕
Increase Terrestrial Species	✓	✕
Improve Habitat for Aquatic Species	✓	✕

In addition to water quality benefits, the Recommended Plan provides co-benefits such **as carbon sequestration, air quality improvements, heat island reduction, habitat creation, and property value appreciation.**

TRIPLE BOTTOM LINE BENEFITS*		RECOMMENDED PLAN	GREY
ECONOMIC	Probable Bid Cost ($ Millions)	310	1,560
	Lifetime O&M and Replacement Costs ($ Millions)	91	124
WATER QUALITY BENEFITS	Reduction in Annual CSO Volume (MG)	8	493
	Reduction in Annual Stormwater Volume (MG)	241	0
	Volume of Water Filtered by Ribbed Mussels (MGD)	8,354	0
	Rec. Season Fecal Coliform Attainment (%)	70-100	67-100
ENVIRONMENTAL	Lifetime Carbon Footprint (Construction & Operation)(MT)	-12,806	31,894
	Air Quality (NO_2 Removal) (lbs/yr)	664	0
	Air Quality ($PM_{2.5}$ Removal) (lbs/yr)	46	0
	Ecosystem Habitat Creation (acres)	72	0
	Heat Island Area Reduction (acres)	10	0
	Valuation of Environmental Footprint ($ Millions)	-1.6	1.2
SOCIAL	Offset from Property Value Increase ($ Millions)	-83	0
TOTAL NET PRESENT COST*	Without Co-Benefits	$401M	$1,684M
	With Co-Benefits	$318M	$1,685M

The co-benefits provided by the Recommended Plan reduce its Net Present Cost from $401M to $318M, thereby offsetting its O&M and replacement costs. The Grey Approach provides fewer co-benefits and cost three times more than the Recommended Plan.

Recommended Plan



Triple Bottom Line Benefits

*Based upon a 100 year service life.

Figure ES-1. Triple-Bottom-Line Analysis of the Recommended Plan

AECOM with Hazen

2. RECOMMENDED PLAN

Summary of Recommended Plan

Water quality in Jamaica Bay and its tributaries will be improved through the implementation of the following: (1) currently planned improvements including those recommended in the November 2012 Jamaica Bay Waterbody/Watershed Facility Plan (Jamaica Bay WWFP); (2) current and future GI baseline projects (summarized in Section 5); and (3) the implementation of this Jamaica Bay and Tributaries LTCP Recommended Plan which calls for the design, construction, and maintenance of the projects summarized in Table ES-1:

Table ES-1. Recommended Plan Projects

Waterbody	Project
Thurston Basin	• 221 greened acres of Green Infrastructure Expansion • 3 acres of Ribbed Mussel Colony Creation
Bergen Basin	• 232 greened acres of Green Infrastructure Expansion • 50,000 CY Environmental Dredging • 4 acres of Ribbed Mussel Colony Creation
Spring Creek	• 13 acres of Tidal Wetland Restoration
Hendrix Creek	• 3 acres of Tidal Wetland Restoration
Fresh Creek	• 14 acres of Tidal Wetland Restoration
Paerdegat Basin	• 4 acres of Tidal Wetland Restoration
Jamaica Bay	• 16 acres of Tidal Wetland Restoration

The Recommended Plan for the Jamaica Bay and Tributaries LTCP is projected to reduce CSO discharges to Bergen and Thurston Basins by 8 MGY and stormwater discharges by 241 MGY. The implementation of these elements has an estimated Net Present Worth (NPW) of $401M, reflecting $91M of annual O&M costs over the course of 100 years and a PBC of $310M.

A preliminary constructability analysis has been conducted and DEP has deemed these improvements to be implementable based on information currently available. The Recommended Plan has been developed with input from the public and other stakeholders, and with an awareness of the cost to the citizens of NYC.

Water Quality Modeling Results

Section 8 of this report provides quantitative WQ attainment details for individual WQ monitoring stations under both annual and recreational season (May 1st through October 31st) conditions for the Recommended Plan.

Figure ES-2, ES-3, and ES-4 below summarize the calculated recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform (Monthly geometric mean (GM) ≤200 cfu/100mL) and the Amended *Enterococci* WQ Criteria* (rolling 30-day GM≤35 cfu/100mL with a 90th percentile statistical threshold value (STV) of ≤130 cfu/100mL applied during the recreational season) based on a continuous 10-year model simulation.

As indicated in Figure ES-2, the Recommended Plan will achieve attainment of the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st) for most waterbodies, with the exception of the head ends of Thurston Basin (TBH1, TBH3), Bergen Basin (BB5, BB6), and Fresh Creek (FC1). However, public access to the impacted stations in Bergen Basin and Thurston Basin is prohibited near John F. Kennedy (JFK) International Airport. At Stations TBH3 and BB6, attainment during the recreational season (May 1st through October 31st) is 93 percent or better, falling just short of the 95 percent metric. A more detailed review of the model projected annual attainment at Station FC1 indicates that there are five months outside of the recreational season where geomeans are 215 cfu/100 mL or less. These five months shift the frequency of attainment over the 10-year period of analysis from 93 percent attainment during the recreational season to 85 percent annually.

On June 4, 2019, with an effective date of November 1, 2019, the New York State Department of Environmental Conservation (DEC) adopted Amendments to Water Quality Standards Regulations and the Classification of Upper and Lower New York Bay. Amended *Enterococci* WQ Criteria* for coastal Class SB waters apply to Jamaica Bay (a coastal Class SB waterbody), but not the tributaries (all Class I waterbodies). As requested by DEC, DEP assessed compliance with those amended criteria for all waters considered in this LTCP including the tributaries. As indicated in Figure ES-3, the Amended *Enterococci* WQ GM Criteria* (rolling 30-day GM ≤35 cfu/100mL during the recreational season) would be met for most Jamaica Bay waters under the Recommended Plan, except for Thurston and Bergen Basins. Notably, the stations where attainment falls short of the 95 percent goal were at stations adjacent to JFK International Airport where the Port Authority of New York and New Jersey (PANYNJ) has prohibited public access for security reasons. As indicated in Figure ES-4, the Amended *Enterococci* WQ STV Criteria* (rolling 30-day STV of ≤130 cfu/100mL) would not be attained in each of the tributaries, and in portions of Jamaica Bay adjacent to the tributaries,

Locations of non-attainment of the Class I dissolved oxygen (DO) water quality criteria under the Recommended Plan are limited to the upstream reaches of Bergen and Thurston Basins and Hendrix Creek, while full attainment of the Class SB DO water quality criteria is achieved in Jamaica Bay, as shown in Figure ES-5. The LTCP framework evaluates DO attainment based upon 2008 typical year rainfall conditions.

Table ES-2 presents an overview of the attainment status.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Figure ES-2. Recommended Plan Model Predicted Fecal Coliform Results (Recreational Season)

Figure ES-3. Recommended Plan Model Predicted Enterococcus GM Results (Recreational Season)

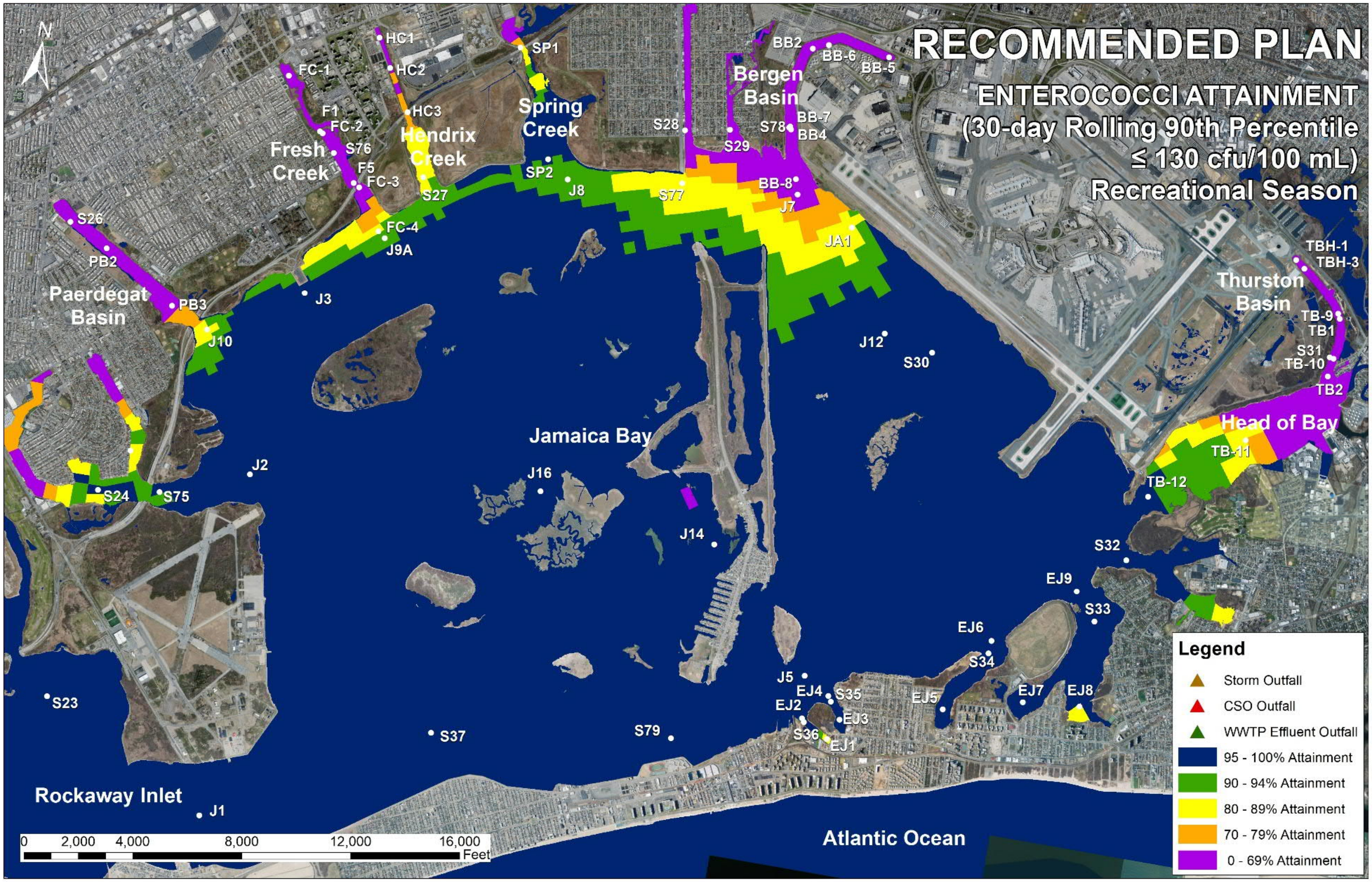


Figure ES-4. Recommended Plan Model Predicted Enterococcus STV Results (Recreational Season)

Figure ES-5. Recommended Plan Model Predicted DO Attainment Results

Table ES-2. Recommended Plan Compliance with Bacteria WQ Criteria

Waterbody	Location	Fecal Coliform Annual Attainment(1)	Fecal Coliform Recreational Attainment(2)	Amended *Enterococci* 30-Day GM(3)	Amended *Enterococci* 30-Day STV(4)	Dissolved Oxygen Annual Attainment(5)
Thurston Basin	Head End(9)	✗	✗	N/A	N/A	✗
	Mid-Point(9)	✗	✓	N/A	N/A	✗
	Mouth	✓	✓	N/A	N/A	✓
Bergen Basin	Head End(9)	✗	✗	N/A	N/A	✗
	Mid-Point(9)	✗	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Hendrix Creek	Head End	✓	✓	N/A	N/A	✗(6)
	Mid-Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Fresh Creek	Head End	✗(7)	✗(7)	N/A	N/A	✓
	Mid-Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Paerdegat Basin	Head End	✓	✓	N/A	N/A	✓
	Mid-Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Jamaica Bay (Grassy Bay)	Northern	✓	✓	✓	✗(8)	✓
	Southern	✓	✓	✓	✓	✓
Jamaica Bay (North Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Beach Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Island Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Rockaway Inlet)	Entire	✓	✓	✓	✓	✓

Notes:

✓ indicates that attainment is projected to occur ≥ 95% of the time.
✗ indicates that attainment is projected to occur < 95% of the time.

(1) Fecal coliform annual attainment is based on a monthly geometric mean (GM) of ≤200 CFU/100mL.
(2) Fecal coliform recreational attainment is based on a monthly GM of ≤200 CFU/100mL from May 1st through October 31st.
(3) The amended 30-day *Enterococci* GM attainment is based on DEC recently adopted 30-day *Enterococci* standard of ≤35 CFU/100mL for coastal recreational waters during recreational season (May 1st through October 31st).
(4) The amended 30-day *Enterococci* STV attainment is based on the DEC recently adopted 30-day *Enterococci* standard that required 90% of the values to be ≤ 130 CFU/100mL during the recreational season (May 1st through October 31st).
(5) The DO standard in the tributaries is never less than 4 mg/L and in Jamaica Bay is never less than 3 mg/L with allowance for duration-based excursions between 3 and 4.8 mg/L.
(6) The projected dissolved oxygen attainment in the head end of Hendrix Creek is 94%.
(7) The projected attainment at the very head end of Fresh Creek is about 85% and 93% for annual and recreational attainment, respectively.
(8) Areas just outside of the various tributaries are projected not to attain the Amended 30-day *Enterococci* STV that required 90% of values to be ≤130 CFU/100mL.
(9) Unauthorized access to these portions of Bergen and Thurston Basins is prohibited by JFK International Airport security.

Triple-Bottom-Line Benefits

In addition to closing the gap in attainment of Existing WQ Criteria for Jamaica Bay and its tributaries, the Recommended Plan provides economic, social, and environmental benefits that supplement prior grey infrastructure improvements. A Triple-Bottom-Line analysis was performed to estimate the monetary value of environmental and social benefits and aggregate them alongside the traditional financial bottom line estimates for the project. The Triple-Bottom-Line analysis is based on estimated magnitude of benefits and an equivalent monetary value per unit benefit, which may be derived by calculation obtained from a representative reference. Although the CSO Policy does not require a Triple-Bottom-Line analysis, or the attainment of such co-benefits, they are worth noting. Details of the analysis are provided in Section 8.

Table ES-3 summarizes and quantifies the Triple-Bottom-Line benefits that DEP anticipates will be realized through the implementation of GI, performance of environmental dredging, creation of ribbed mussel colonies, and restoration of tidal wetlands. Other Triple-Bottom-Line benefits that were not monetized include aesthetic improvements associated with installation of GI and tidal wetland restoration, as well as the reduction of odors associated with exposed organics during low tide. The benefits provided by the Recommended Plan achieve many of the ecosystem goals outlined in Plan OneNYC, including expansion of GI, reduction of pollution from stormwater runoff, expansion in tree planting, increase in terrestrial species, and habitat improvements for aquatic species.

In comparison, the 50 percent Control Tunnel for Bergen and Thurston Basins grey alternative provided none of the environmental or economic benefits of the Recommended Plan. Although the grey alternative had a higher reduction in annual CSO volume, it provided no co-benefits such as improvement in stormwater volume, and would not provide the 24/7 continuous filtering of the water in Bergen and Thurston Basins that would be provided with the ribbed mussel habitat.

Table ES-3. Triple-Bottom-Line Comparison

Triple-Bottom-Line Benefits	Recommended Plan	50% Control Tunnel for Bergen and Thurston Basins
Water Quality Benefits		
Reduction in CSO Volume (MG)	8	493
Reduction in Stormwater Volume (MG)	241	0
Volume of Water Filtered by Ribbed Mussels (MG)	8,354	0
Environmental Benefits		
Lifetime Carbon Footprint Reduction (MT)	12,806(1)	-31,894(1)
Air Quality (NO_2 Removal) (lbs/yr)	664	0
Air Quality PM_{25} Removal) (lbs/yr)	46	0
Ecosystem Habitat Creation (acres)	72	0
Heat Island Reduction (acres)	10	0
Economic Benefit ($ Millions)		
Probable Bid Cost	-$310	-$1,293
Lifetime O&M and Replacement Cost	-$91	-$124
Valuation of Environmental Benefit	+$2	-$1.2
Property Value Appreciation	+$83	0
Total Net Present Cost	-$318	-$1,418

Note:
(1) Positive value indicates reduction in carbon footprint versus baseline; negative value indicates increase in carbon footprint versus baseline.

3. BACKGROUND

DEP prepared this LTCP for Jamaica Bay and Tributaries pursuant to an Order on Consent for CSOs, Case No. CO2-20000107-8 (2005 CSO Order), modified by a 2012 CSO Order on Consent (Case No CO2-20110512-25) (2012 CSO Order) and subsequent modifications (collectively referred to herein as the "CSO Order") overseen by the DEC. Pursuant to the CSO Order, DEP is required to submit 10 waterbody-specific LTCPs and one citywide LTCP to DEC for review and approval. The Jamaica Bay and Tributaries LTCP is the tenth of the waterbody-specific LTCPs.

As described in the LTCP Goal Statement in the CSO Order, the goal of each LTCP is to identify, with public input, appropriate CSO controls necessary to achieve waterbody-specific WQS consistent with the Federal CSO Control Policy and related guidance. In addition, the Goal Statement advises: *"Where existing water quality standards do not meet the Section 101(a)(2) goals of the Clean Water Act, or where the proposed alternative set forth in the LTCP will not achieve existing water quality standards or the Section 101(a)(2) goals, the LTCP will include a Use Attainability Analysis examining whether applicable waterbody classifications, criteria, or standards should be adjusted by the State."* DEP conducted water quality assessments where the data is represented by percent attainment with pathogen targets and associated recovery times. Consistent with guidance from DEC, 95 percent attainment of applicable WQ criteria constitutes compliance with the existing WQS or the Section 101(a)(2) goals conditioned on verification through Post-Construction Compliance Monitoring (PCM).

Regulatory Requirements

The waters of NYC are subject to Federal and New York State (NYS) laws and regulations. Particularly relevant to this LTCP is the U.S. Environmental Protection Agency's (EPA) CSO Control Policy, which provides guidance on the development and implementation of LTCPs, and the promulgation of WQS. In NYS, Clean Water Act (CWA) regulatory and permitting authority has been delegated to DEC.

DEC has designated Jamaica Bay as a Class SB waterbody and the tributaries as Class I waterbodies. The best usages of Class SB waters are primary and secondary contact recreation and fishing, while the best usages of Class I waters are secondary contact recreation and fishing. These waters shall also be "suitable for fish, shellfish, and wildlife propagation and survival. In addition, the water quality shall be suitable for primary contact recreation, although other factors may limit the use for this purpose" (6 NYCRR 701.13). Figure ES-6 shows the Jamaica Bay and its tributaries watershed.

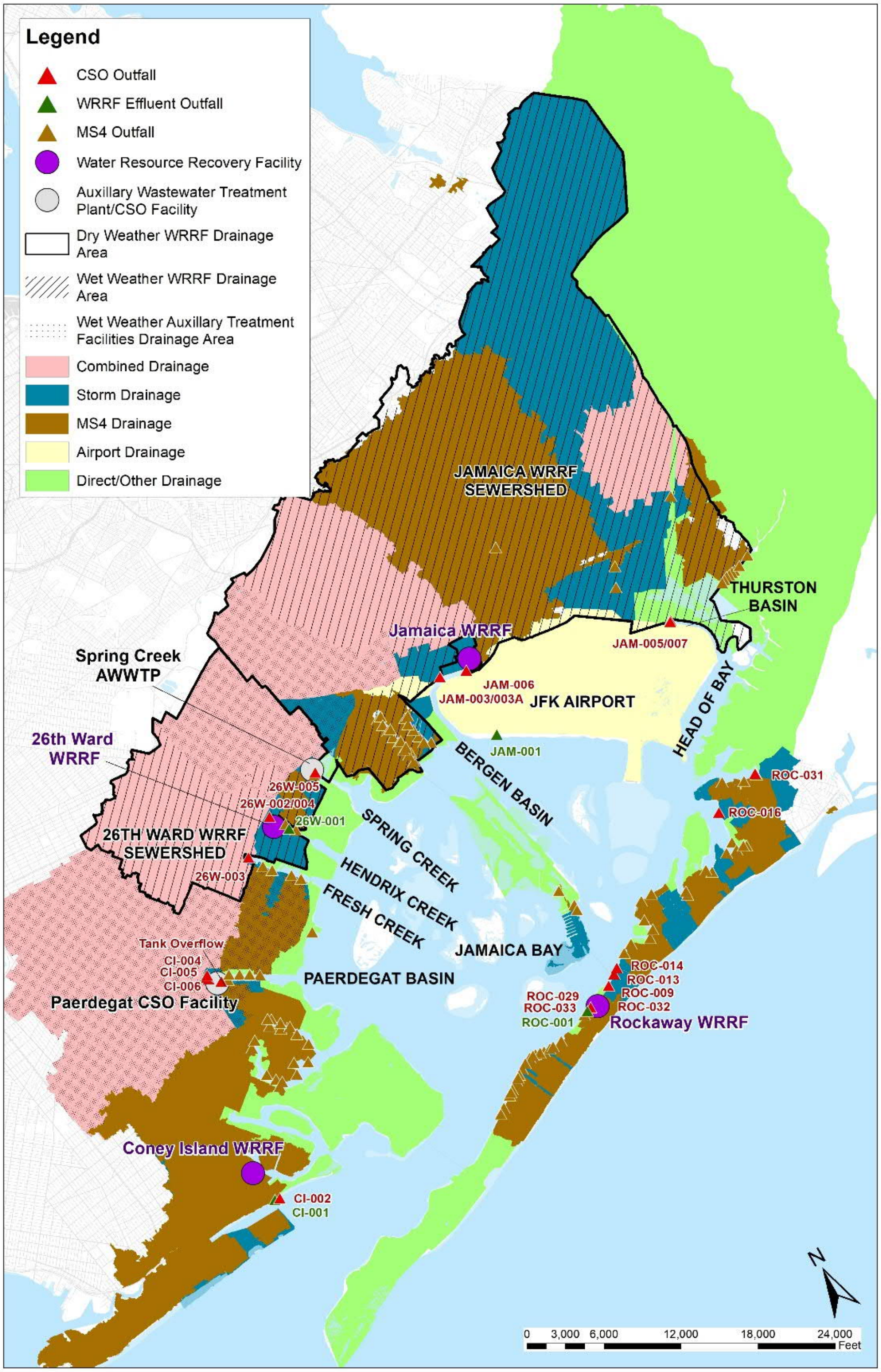


Figure ES-6. Jamaica Bay Watershed Characteristics and Associated WRRF Sewershed

The criteria assessed in this Jamaica Bay and Tributaries LTCP includes the Existing WQ Criteria for fecal coliform and DO (Class SB - Jamaica Bay and Class I - Tributaries). On June 26, 2019, DEC publicly noticed a revision to the WQS that included application of an Amended *Enterococci* WQS for coastal SA & SB waters during the primary contact recreational season (May 1st through October 31st), and a reclassification for the Upper and portion of the Lower New York Bay from Class I to Class SB. Sections 6 and 8 of this LTCP include assessments of attainment with both the Existing WQ Criteria for fecal coliform and DO and Amended *Enterococci* WQ Criteria*. Based on DEC's June 26, 2019 Notice of Adoption, the Amended *Enterococci* WQ Criteria* modeled for this LTCP include a 30-day rolling GM for *Enterococci* of 35 cfu/100mL with a 90th percentile statistical threshold value (STV) of 130 cfu/100mL applied during the recreational season. In accordance with the Notice of Adoption, these criteria would not apply to the tributaries of Jamaica Bay that are non-coastal Class I waters. However, for informational purposes, the LTCP also presents the level of attainment of those criteria for the tributaries in Sections 6 and 8.

Table ES-4 summarizes the Existing WQ Criteria and Amended *Enterococci* WQ Criteria* applied in this LTCP.

Table ES-4. Classifications and Standards Applied

Analysis	Numerical Criteria Applied	
Existing WQ Criteria – Tributaries	Class I	Fecal Monthly GM ≤ 200; DO never <4.0 mg/L
Existing WQ Criteria – Jamaica Bay	Class SB	Fecal Monthly GM ≤ 200; DO between > 3.0 & ≤4.8 mg/L(2); DO never < 3.0 mg/L
Amended *Enterococci* WQ Criteria(1)	Class SB Coastal	*Enterococci*: rolling 30-day GM ≤35 cfu/100mL; STV ≤130 cfu/100mL

Notes:

(1) These amended criteria apply during the recreational season (May 1st to October 31st) and do not apply to the tributaries to Jamaica Bay. They are effective November 1, 2019.

(2) This is an excursion-based limit that allows for the average daily DO concentrations to fall between 3.0 and 4.8 mg/L for a limited number of days as described in more detail on Table 2-7 in Section 2.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Jamaica Bay Watershed

Watershed characteristics for Jamaica Bay and its tributaries, including the NYC CSO and municipal separate storm sewer system (MS4) stormwater outfalls, are shown in Figure ES-6. Jamaica Bay and its tributaries are saline waterbodies surrounding JFK International Airport to the south, east, and west in the Boroughs of Brooklyn and Queens. Jamaica Bay is tributary to Lower New York Bay. Water quality in Jamaica Bay and its tributaries is influenced by multiple sources including stormwater discharges, dry-weather sources, and CSOs. The Jamaica Bay watershed comprises approximately 66,269 acres (in NYC) and the majority of the land immediately surrounding the shoreline is utilized for recreational, transportation, and commercial purposes. The urbanization of NYC and the Jamaica Bay watershed has led to the creation of a large combined sewer system, as well as extensive areas served by separate sanitary and storm sewer systems, with stormwater outfalls that discharge directly to the Bay and tributaries. The Jamaica Bay watershed is served by the Jamaica WRRF, the 26th Ward WRRF, the Coney Island WRRF, and the Rockaway WRRF that are permitted pursuant to DEC issued State Pollution Discharge Elimination System (SPDES) permits. Dry-weather sanitary flow is conveyed to the WRRFs for treatment. During wet-weather, combined storm and sanitary flow is conveyed by the sewer system to the WRRFs. If the sewer system or WRRF is at full capacity, a diluted mixture of combined storm and sanitary flow may discharge through one or more of the 22 SPDES permitted CSO Outfalls to Jamaica Bay or its tributaries.

Table ES-5 summarizes the model projected average annual CSO overflow volume and frequency of overflow for each SPDES-permitted CSO Outfall under the CSO LTCP selected baseline conditions as described herein. A total of 109 DEP owned MS4 outfalls also discharge to Jamaica Bay and its tributaries. Figure ES-7 illustrates the location of the DEP MS4 outfalls as well as 74 New York City Department of Transportation (DOT) outfalls and 347 other stormwater discharge points to Jamaica Bay and its tributaries.

Table ES-5. CSO Discharges Tributary to Jamaica Bay and Tributaries (2008 Typical Year)

Receiving Waters	Combined Sewer Outfalls	Discharge Volume(1) (MGY)	No. of Discharges(1)	Percentage of Total CSO Discharge to Jamaica Bay
Thurston Basin	**JAM-005/007**	**658 (247)**	**73 (26)**	**30.0%**
Bergen Basin	JAM-003	107	17	4.9%
	JAM-003A	223	33	10.2%
	JAM-006	3	14	0.1%
	Subtotal	**333**	**33**	**15.2%**
Spring Creek(2)	**26W-005**	**292**	**6**	**13.3%**
Hendrix Creek	**26W-004**	**85**	**26**	**3.9%**
Fresh Creek	**26W-003**	**232**	**12**	**10.6%**
Paerdegat Basin(3)	Tank Overflow	553	12	25.2%
	CI-004/005/006	38	5	1.7%
	Subtotal	**591**	**12**	**27.0%**
Jamaica Bay	**Rockaway Outfalls(3)**	**0**	**0**	**0.0%**
Jamaica Bay and Tributaries	**Total CSO**	**2,191 (1,780)**	**73 (33) max.**	**100%**

Notes:

(1) CSO volumes and activation frequency are based upon overflow at the respective weirs and do not account for stormwater contributions to the outfall downstream of the regulator with the exception of Thurston Basin, which is based upon the sum of the CSO and stormwater discharges just downstream of Regulators JA-06, JA-07, and JA-08. The values in parentheses are the specific CSO AAOV and frequency of flow that tips over the weirs and diversion structures within the Thurston Basin drainage area.

(2) The Spring Creek Auxiliary Wastewater Treatment Plant (AWWTP) and the Paerdegat Basin CSO Retention Facility provide floatables control and settling prior to overflow of storms exceeding the tank storage capacity.

(3) The Rockaway CSOs do not activate during the typical 2008 rainfall year.

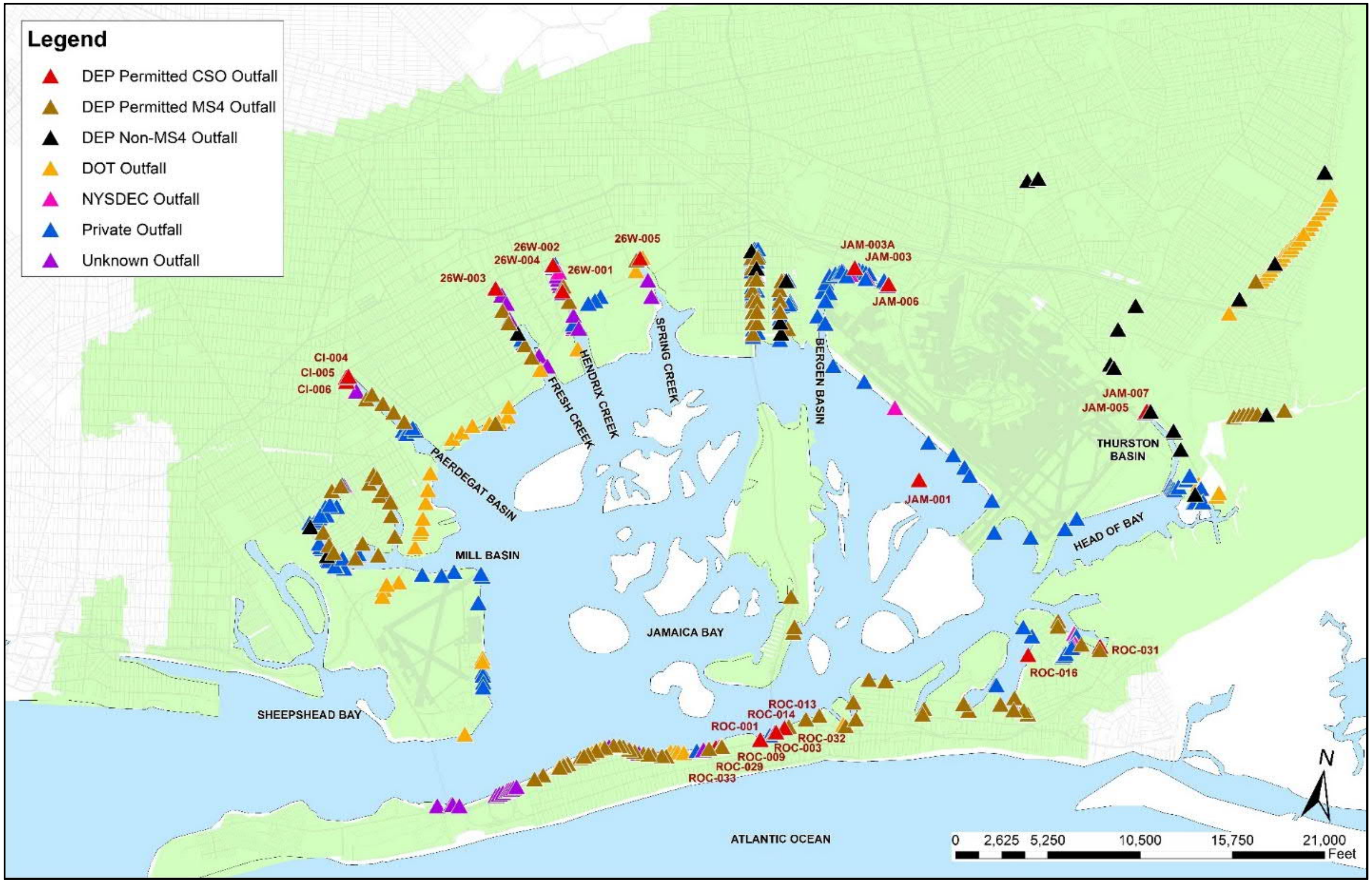


Figure ES-7. Jamaica Bay and Tributaries Outfalls

Southeast Queens Sewer Buildout

Under OneNYC, DEP has commenced an extensive sewer buildout in Southeast Queens that is intended to help alleviate upland flooding and improve the drainage and conveyance of stormwater from the roadways and neighborhoods into the receiving waters. Over the next 10 years, DEP's capital budget includes about $1.7B to continue this long term sewer buildout. Full buildout will go well beyond the 10 year plan and will include installation of about 450 miles of new storm sewers. In addition, there will be approximately an additional 260 miles of new sanitary sewers and an additional 30 miles of combined sewers. Upon completion, this project is expected to greatly alleviate flooding and also significantly reduce CSO discharges into Thurston Basin. Any potential water quality improvements from these future projects were not included in the baseline for this LTCP, and projected water quality improvements from the Recommended Plan do not include any potential improvements from the current planned sewer buildout in Southeast Queens.

Green Infrastructure

Jamaica Bay and its tributaries are priority CSO watersheds for DEP's GI Program, and DEP seeks to saturate priority watersheds with GI based on the specific opportunities each watershed presents. DEP has over 1,000 GI assets in construction, or constructed, including right-of-way (ROW) practices, public property retrofits, and GI implementation on private properties as of 2017 in the Jamaica Bay and Tributaries watershed. In addition, thousands of additional assets are currently planned or in design. Based on the 2008 baseline rainfall condition, all built and planned GI assets under baseline conditions, are projected to result in a CSO volume reduction of approximately 169 MGY.

For the Jamaica Bay and Tributaries LTCP, the baseline reduction is based on GI implementation constructed or planned in the watershed, primarily through retention practices including ROW rain gardens and public property retrofits, but also including an assumption that detention-based GI systems on private property will control runoff from three percent of the combined sewer impervious area tributary to Jamaica Bay and its tributaries. The GI Program will be implemented through 2030 and the final implementation rate will be reassessed as part of the adaptive management approach. Figure ES-8 shows the current contracts in progress in the combined sewer areas tributary to Jamaica Bay and its tributaries. As more information on field conditions, feasibility, and costs becomes known, and as GI projects progress, DEP will continue to report on the progress of the GI in the watershed of Jamaica Bay and its tributaries through 2030.

CSO GREEN INFRASTRUCTURE (GI) BASELINE ASSUMING SEQ BUILDOUT	
Greened Acres	803 ac.
CSO Reduction	169 MGY
Stormwater Reduction	Not applicable

RECOMMENDED PLAN ASSUMING SEQ BUILDOUT		
Additional Benefits	Thurston Basin	Bergen Basin
Greened Acres	221 ac.	232 ac.
CSO Reduction	0 MGY	0 MGY
Stormwater Reduction	209 MGY	239 MGY

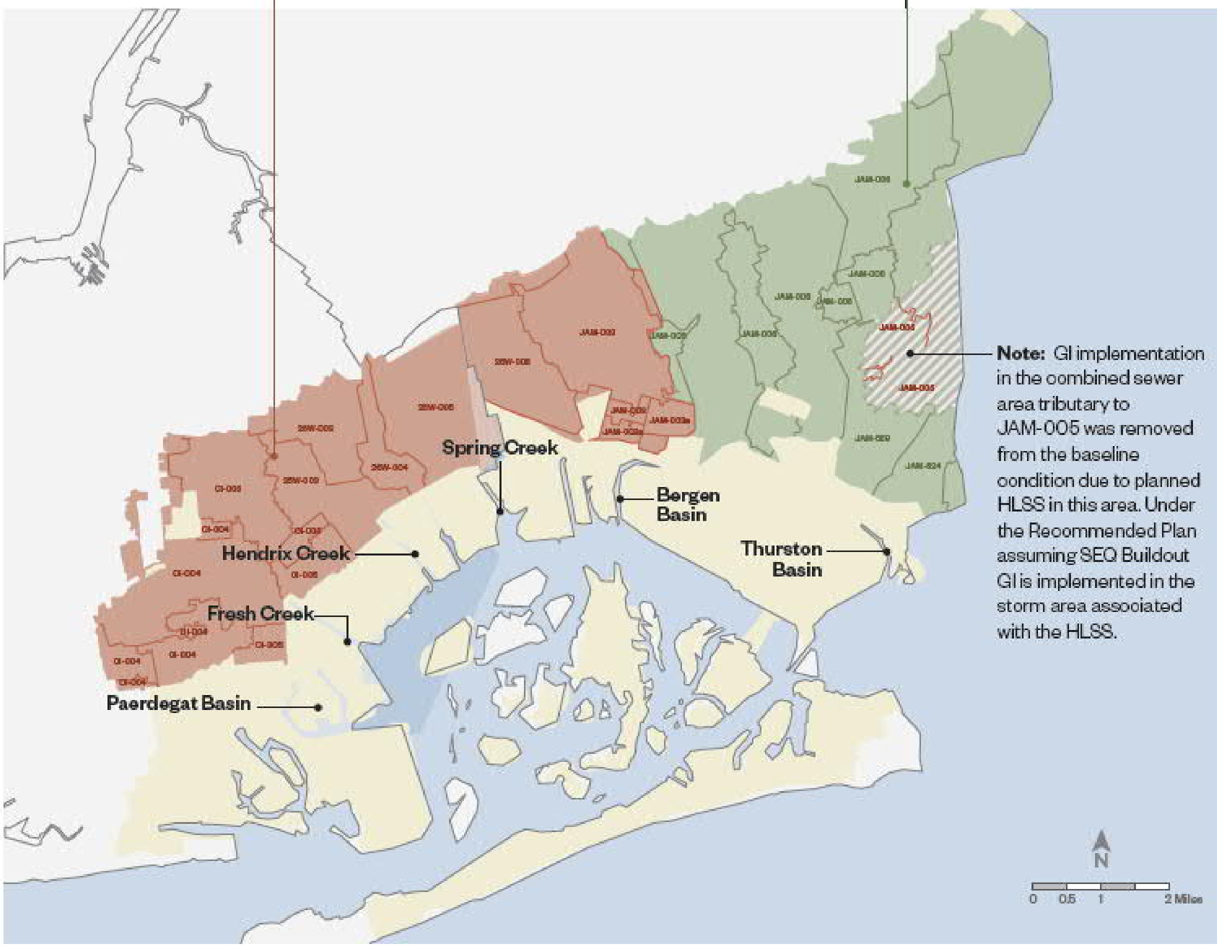


Figure ES-8. GI CSO Baseline and GI Expansion in Recommend Plan

4. FINDINGS

Current Water Quality Conditions

Data collected within Jamaica Bay and its tributaries by DEP's Harbor Survey Monitoring Program (HSM) are available from 2013 to 2016, and data are available from sampling conducted by the LTCP team from October 2015 through November 2015 to support the Jamaica Bay and Tributaries LTCP. The sampling locations for both programs are depicted in Figure ES-9.

Overall, water quality conditions generally fall within standards during dry-weather conditions with the exception of Bergen Basin. The sampling program indicated that pathogen impacts are observed primarily during wet-weather conditions in Bergen Basin, Thurston Basin, and Fresh Creek. DO averages generally achieve standards in all waterbodies with the exception of Bergen Basin, Thurston Basin, and Hendrix Creek during wet-weather conditions.

Full details regarding the sampling results are presented in Section 2 of this report. Figure ES-9 through Figure ES-15 provides a qualitative summary of the sampling results for fecal coliform, *Enterococci*, and dissolved oxygen under dry- and wet-weather conditions.

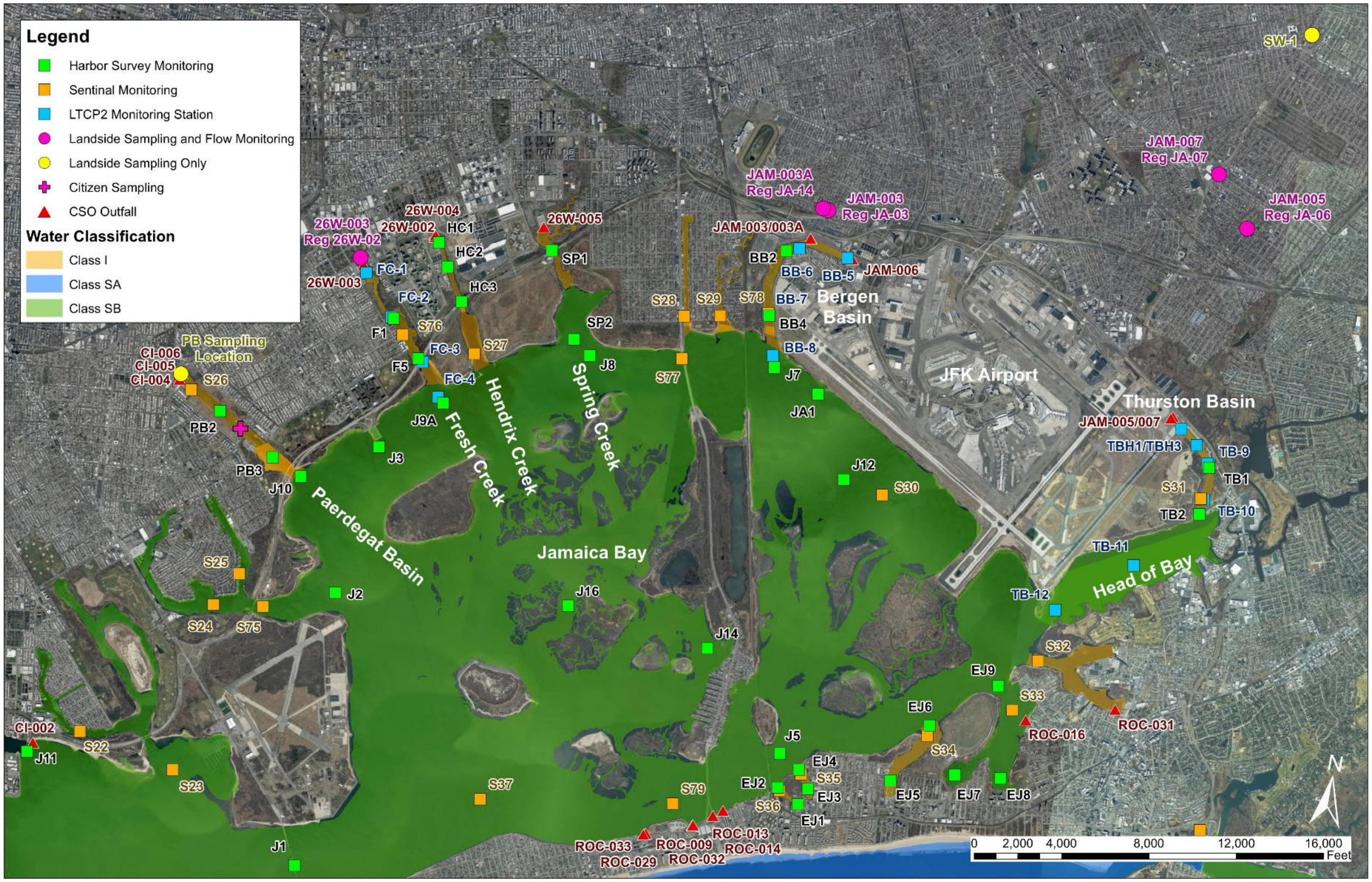


Figure ES-9. Jamaica Bay LTCP Field Sampling Analysis Program and Harbor Survey Monitoring Program and Third Party Sampling Locations

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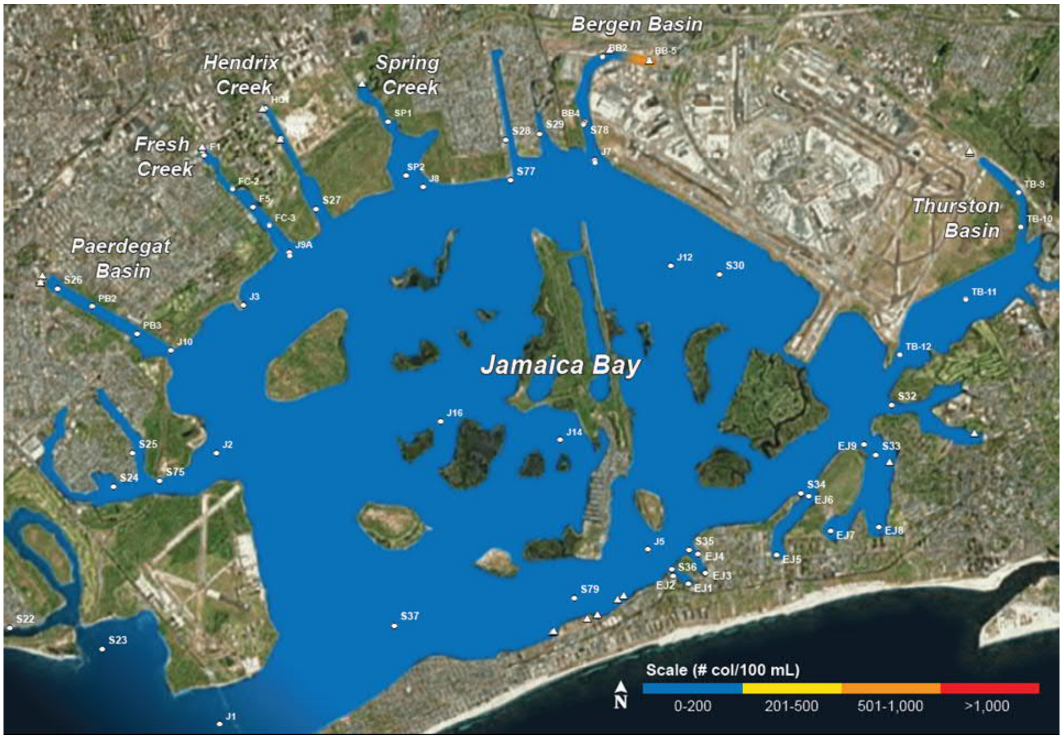

Figure ES-10. Fecal Coliform Sampling Results (1/1/15 – 3/30/16) – Dry-Weather

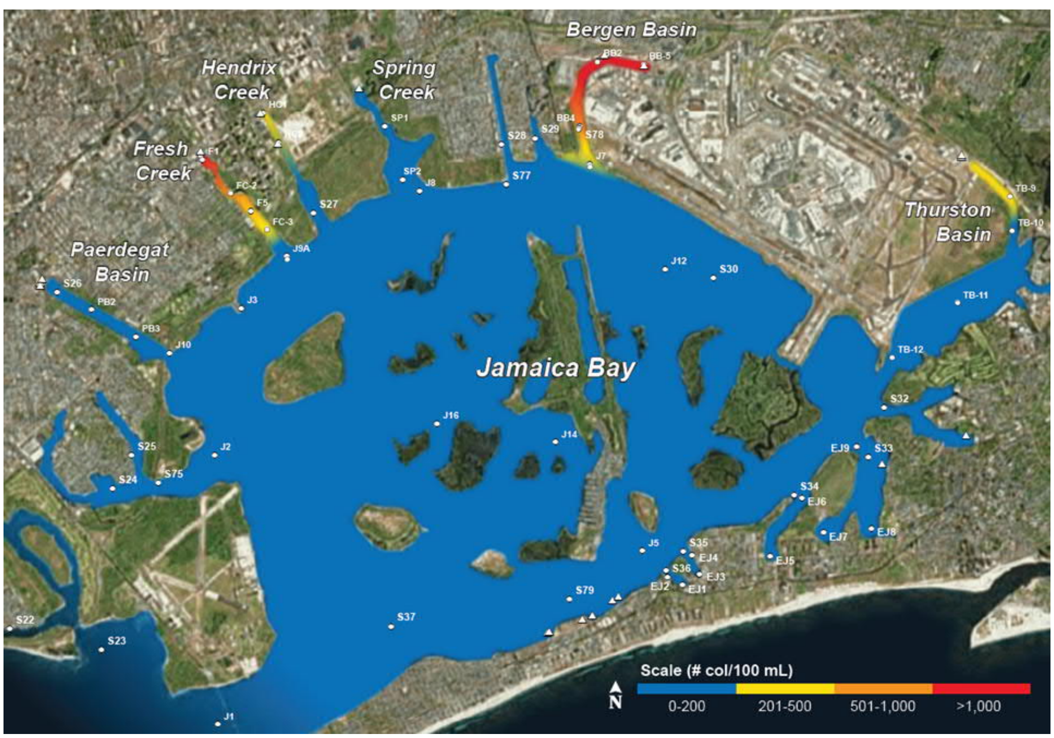

Figure ES-11. Fecal Coliform Sampling Results (1/1/15 – 3/30/16) – Wet-Weather

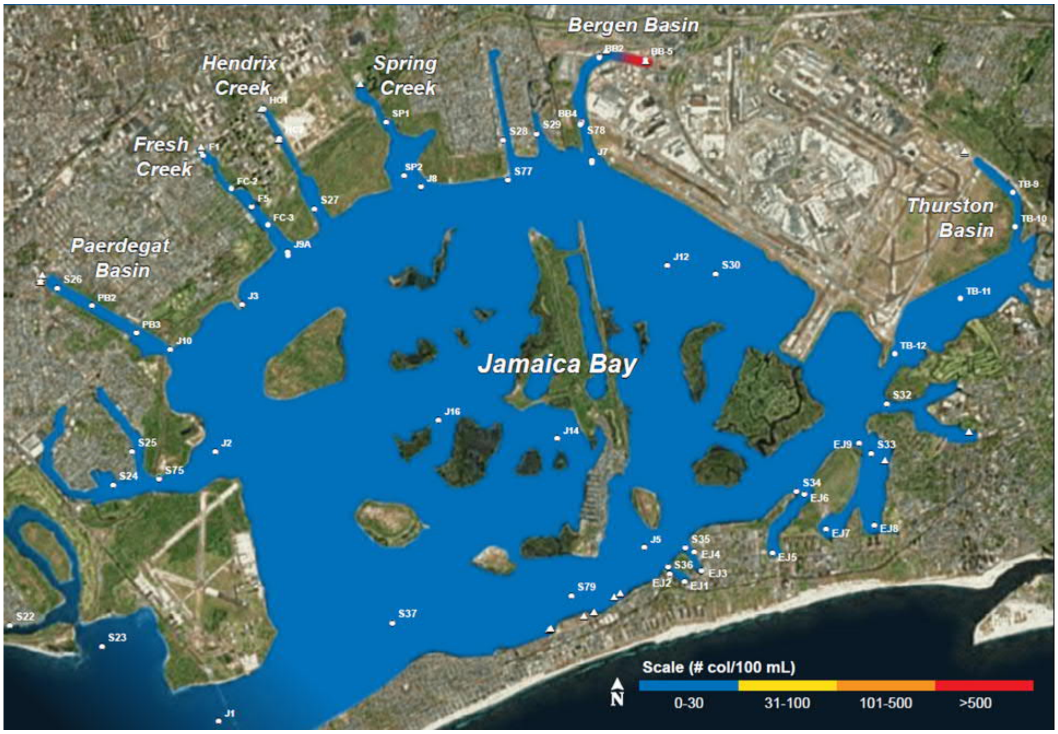

Figure ES-12. *Enterococci* Sampling Results (1/1/15 – 3/30/16) – Dry-Weather

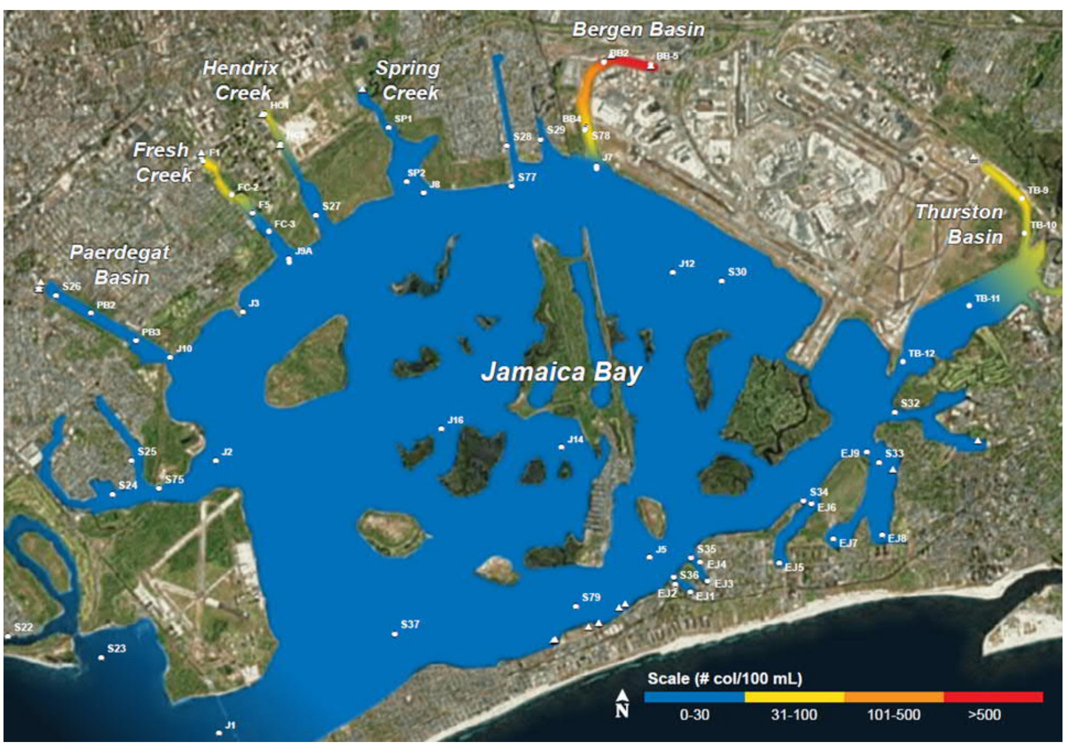

Figure ES-13. *Enterococci* Sampling Results (1/1/15 – 3/30/16) – Wet-Weather

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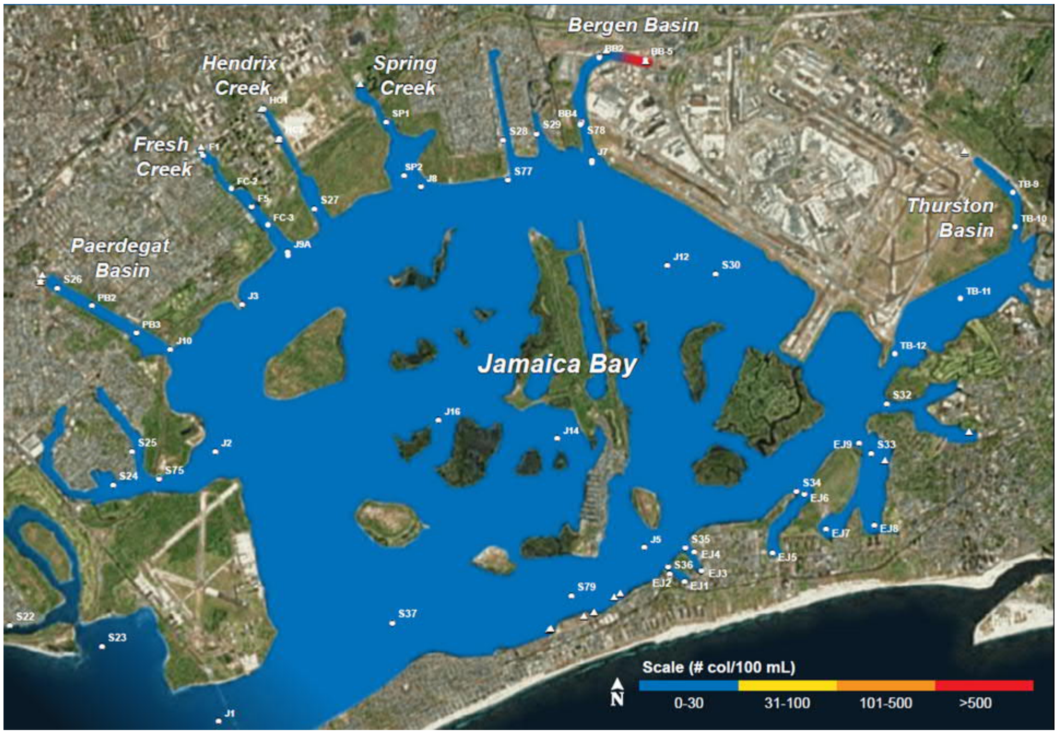

Figure ES-14. Dissolved Oxygen Sampling Results (1/1/15 – 3/30/16) – Dry-Weather

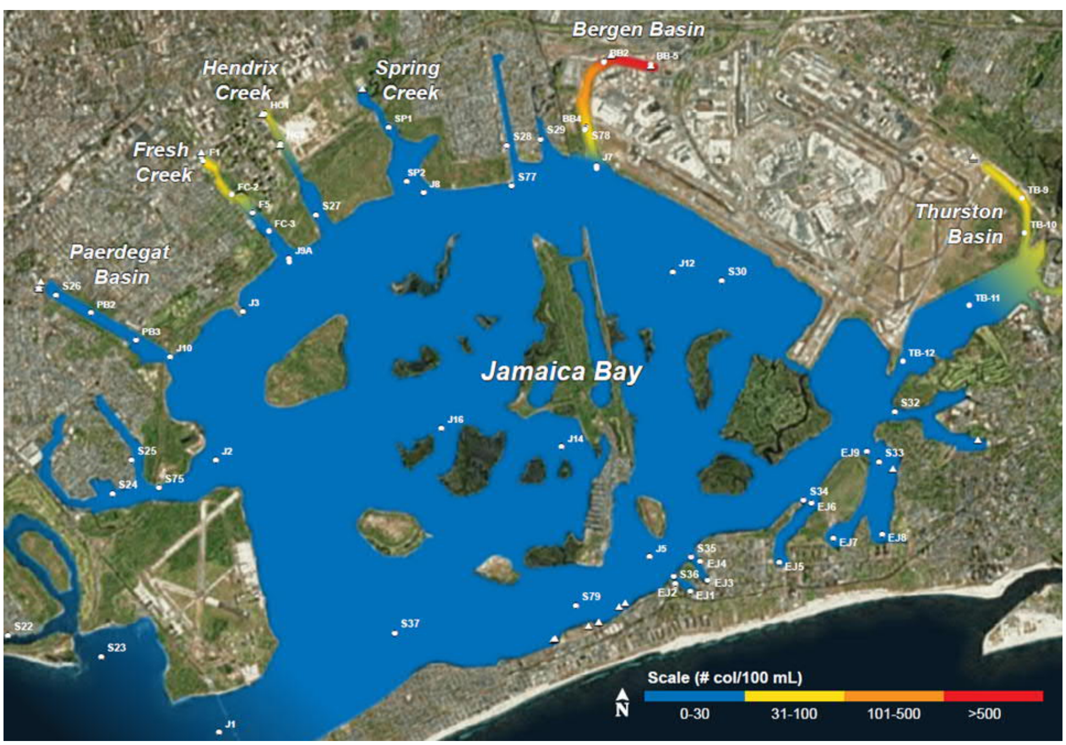

Figure ES-15. Dissolved Oxygen Sampling Results (1/1/15 – 3/30/16) – Wet-Weather

Baseline Conditions, 100% CSO Control and Performance Gap

Computer models were used to assess attainment with Existing WQ Criteria for fecal coliform and DO (Class SB – Jamaica Bay and Class I - Tributaries) and the Amended *Enterococci* WQ Criteria* for Jamaica Bay and its tributaries. The Amended *Enterococci WQ* Criteria* do not apply to non-coastal waters, including the tributaries to Jamaica Bay. The analyses focused on two primary objectives:

1. Determine the levels of compliance with WQ criteria under future baseline conditions. This analysis is presented for Existing WQ Criteria for fecal coliform and DO (Class I and SB) and Amended *Enterococci* WQ Criteria* (coastal Class SB).

2. Determine potential attainment levels without discharge of CSO to the waterbody (100% CSO control), keeping the remaining non-CSO sources. This analysis is based on the criteria shown in Table ES-4.

Details of the baseline conditions and performance gap analyses are covered in Section 6 of this report. Figure ES-16 through Figure ES-23 depict the findings of the gap analysis, which identifies the gap in attainment under baseline conditions in comparison to 100% CSO control (No CSO) conditions. The gap analysis is performed to identify the impact of CSO controls on water quality conditions and provides an indication of whether there are other sources that preclude the attainment of WQ criteria.

As indicated in Figure ES-16 and Figure ES-17, 100% CSO control of the fecal coliform loading results in some improvement in the tributaries. Under baseline conditions, 10-year continuous model simulations indicate the head ends of Fresh Creek, Bergen Basin, and Thurston Basin do not achieve 95 percent attainment of the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st). This is also the case for 100% CSO control, with the exception of the head end of Fresh Creek which improves from 93 to 98 percent attainment. This analysis indicates that CSO controls cannot completely close the gap between attainment and non-attainment of the fecal coliform WQ criteria for Thurston and Bergen Basins. However, these monitoring stations are located within portions of these tributaries that are prohibited from public access by JFK International Airport security.

Under baseline conditions, 10-year continuous model simulations (Figure ES-18) indicate that greater than 95 percent attainment of the Amended *Enterococci* WQ Criteria* (rolling 30-day GM *Enterococci* criterion of 35 cfu/100mL) is achieved during the recreational season (May 1st through October 31st) in Jamaica Bay and its tributaries, except for Thurston and Bergen Basins. With 100% CSO control (Figure **ES-19**), the improvement in attainment is less than 5 percent, with negligible improvement in Thurston and Bergen Basins. Figure ES-20 and Figure ES-21 show the Baseline and 100% CSO Control attainment of the rolling 30-day STV *Enterococci* criterion of 130 cfu/100mL, where some improvement is shown in the Jamaica Bay areas adjacent to the tributaries. However, similar to the gap analysis for fecal coliform, 100% CSO control cannot completely close the gap between attainment and non-attainment of the Amended *Enterococci* WQ Criteria* in Thurston and Bergen Basins.

Figure ES-22 and Figure ES-23 present a comparison of the Class I DO criterion attainment for the tributaries and the Class SB DO criteria attainment for Jamaica Bay, for the 2008 typical year, under baseline conditions and 100% CSO control, respectively. The model generally projects improvements of at most only a few percentage points in attainment with the DO criteria. Thus, CSO loads are not the controlling factor for limiting DO concentrations and CSO controls will not substantially improve DO concentrations.

Figure ES-16. Fecal Coliform Attainment – Baseline Conditions

Figure ES-17. Fecal Coliform Attainment –100% CSO Control

AECOM *with* Hazen

Figure ES-18. *Enterococci* 30-day GM Attainment – Baseline

Figure ES-19. *Enterococci* 30-day GM Attainment – 100% CSO Control

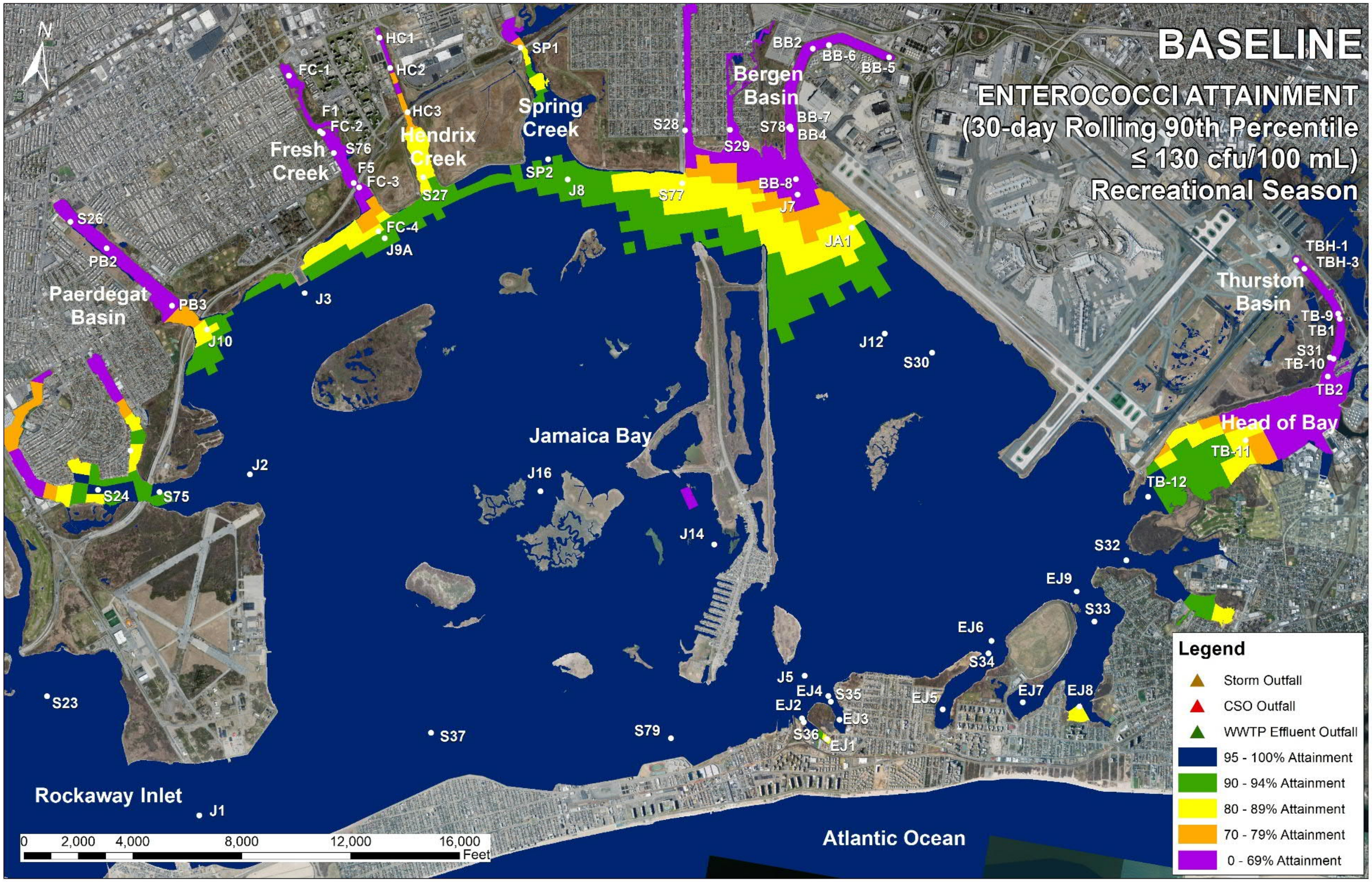

Figure ES-20. *Enterococci* STV Attainment – Baseline

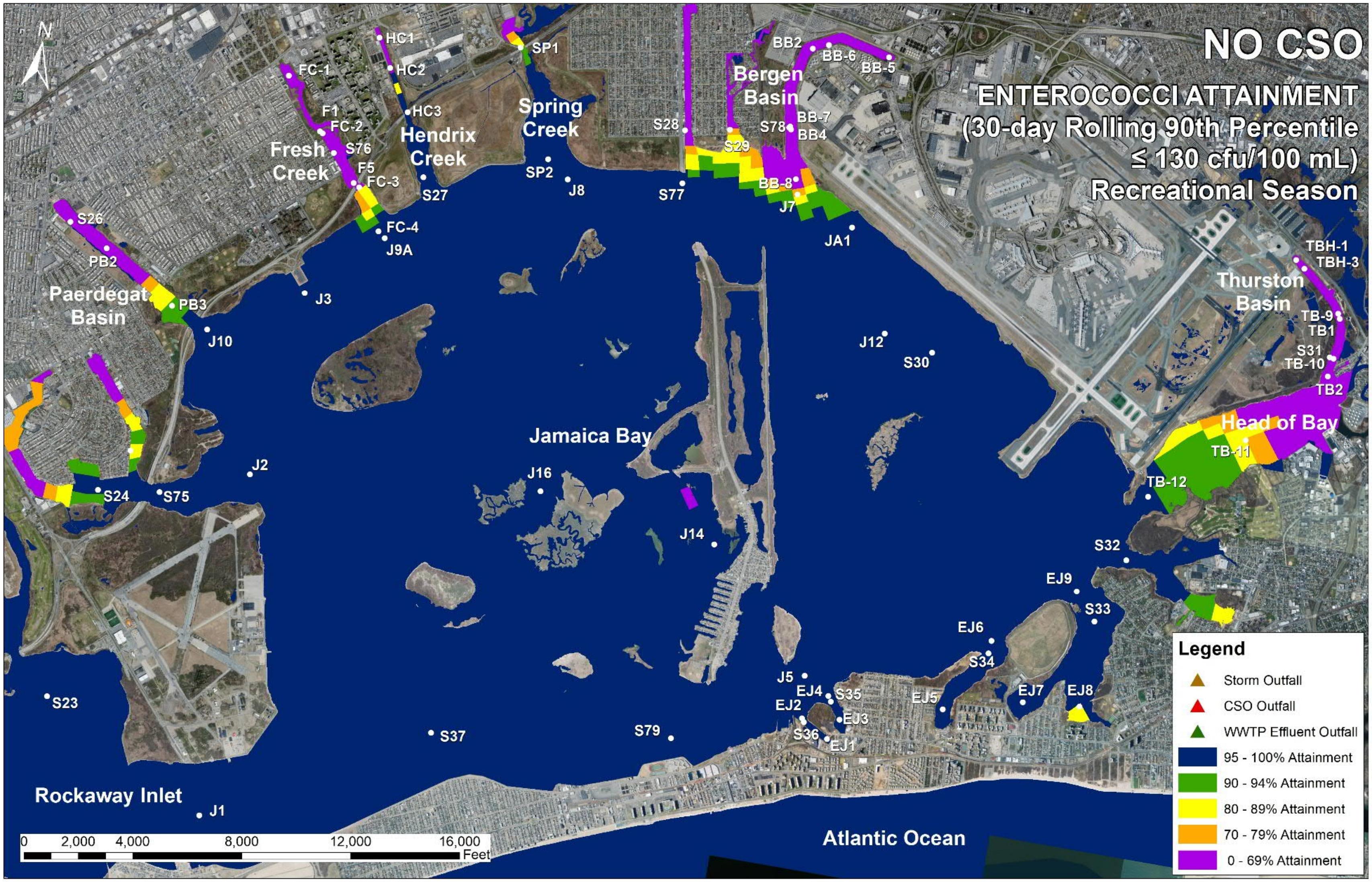

Figure ES-21. ***Enterococci*** **STV Attainment – 100% CSO Control**

Figure ES-22. Dissolved Oxygen – Baseline

Figure ES-23. Dissolved Oxygen –100% CSO Control

AECOM with Hazen

Public Outreach

DEP's comprehensive public participation plan provides the opportunity for interested stakeholders to be involved in the LTCP process. Stakeholders include local residents and citywide and regional groups, a number of whom offered comments at three public meetings held for this LTCP.

On September 22, 2016, DEP hosted a Public Kickoff Meeting to initiate the water quality planning process for the Jamaica Bay and Tributaries LTCP. Approximately 15 stakeholders from different non-profit, community, planning, environmental, economic development, governmental organizations, and the broader public attended the event, as did representatives from DEP. The two-hour event, held at Jamaica Chamber of Commerce, Queens, provided stakeholders with information about DEP's LTCP Program, Jamaica Bay and surrounding tributaries watershed characteristics, GI implementation, and the status of waterbody improvement projects. The presentation is available on DEP's LTCP Program website: http://www.nyc.gov/dep/ltcp.

DEP hosted a Public Status Update Meeting on October 19, 2017 to present information regarding a one-year extension for Jamaica Bay and Tributaries LTCP. Approximately 15 stakeholders from different non-profit, community, planning, environmental, economic development, governmental organizations, and the broader public, attended the event, as did representatives from DEC. The two-hour event, held at the Jamaica Bay Wildlife Refuge Center in Broad Channel, Queens, provided information regarding the one-year time extension for the CSO LTCP for Jamaica Bay and Tributaries, details about planned projects in the Jamaica Bay watershed, an overview of the Southeast Queens Programs Green Infrastructure and Bluebelt Projects, and described additional opportunities for public input and outreach. The presentation is available on DEP's LTCP Program website: http://www.nyc.gov/ dep/ltcp.

On April 18, 2018, DEP hosted a third Public Meeting to continue discussion of the water quality planning process. Approximately 12 stakeholders from the general public attended the event. The purpose of the nearly two-hour event, held at the Jamaica Bay Wildlife Refuge Center in Broad Channel, was to describe the alternatives identification and selection processes, present the Recommended Plan, and solicit public comment and feedback. The presentation is available on DEP's LTCP Program website: http://www.nyc.gov/dep/ltcp.

DEP has received multiple stakeholder emails and comment letters. These documents and additional information on the public outreach activities are available on DEP's website and are also included in Appendix B, Public Participation Materials.

Evaluation of Alternatives

DEP used a multi-step process to evaluate CSO control measures and CSO control alternatives. Section 8 of this report includes DEP's analysis along with figures and descriptions of the conceptual layouts for the CSO control alternatives. These conceptual layouts were prepared for the purposes of developing costs and evaluating the feasibility of the various CSO control alternatives for improving water quality in Jamaica Bay and its tributaries. The final siting of the facilities and other associated details which make up the Recommended Plan presented herein will be further evaluated and finalized during subsequent planning and design stages. The evaluation process considered environmental benefits, community and societal impacts, and issues related to implementation and O&M. Following the comments generated by detailed technical workshops, the retained alternatives were subjected to a functional review and cost-performance and cost-attainment evaluations, where economic factors were introduced.

Table ES-6 presents the retained alternatives that resulted from the evaluation process. As water quality at the head ends of Thurston Basin and Bergen Basin do not attain the 95 percent criterion for fecal coliform, DEP initially focused on waterbody-specific controls (parallel interceptors and tunnels) for Thurston and Bergen Basin (Alternatives 1 through 7). For the remaining Jamaica Bay waterbodies, DEP evaluated a range of regional tunnel configurations for control of CSO discharges throughout the Jamaica Bay watershed (Alternatives 7 through 10). Table ES-7 summarizes the remaining model predicted annual average untreated CSO volumes to Jamaica Bay and its tributaries and the percent reductions in CSO volume and bacteria loads for the retained alternatives.

As the gap analysis provided in Figure ES-17 indicates that attainment of fecal coliform WQ criteria in Thurston and Bergen Basins cannot be achieved under a 100% CSO control scenario, an alternative featuring Additional GI and Environmental Improvements (Alternative 11) was also developed. This alternative includes construction of GI within separately sewered portions of the Jamaica WWTP collection system, environmental dredging, ribbed mussel colony habitat creation, and tidal wetlands restoration. Alternative 11 provides economic, social, and environmental benefits beyond what can be achieved using traditional grey infrastructure approaches for CSO control and further enhances the water quality benefits achieved through the projects previously implemented pursuant to the WWFP. The Additional GI and Environmental Improvements alternative can be implemented in 14 years as opposed to the grey retained alternatives that were evaluated, which are projected to take approximately 25 years to design, construct, and activate.

Table ES-6. Retained Alternatives

Alternative	Description
Thurston Basin Alternatives	
1. CSO Tunnel from JAM-005/007 to Jamaica WWTP (50% Control)	15,200 linear foot (LF), 101-foot diameter CSO tunnel (9 MG) from JAM-005/007 to Jamaica WWTP
2. CSO Tunnel from JAM-005/007 to Jamaica WWTP (75% Control)	15,200 LF, 18-foot diameter CSO tunnel (29 MG) from JAM-005/007 to Jamaica WWTP
3. CSO Tunnel from JAM-005/007 to Jamaica WWTP (100% Control)	15,200 LF, 28-foot diameter CSO tunnel (91 MG) from JAM-005/007 to Jamaica WWTP
Bergen Basin Alternatives	
4. CSO Conveyance from JAM-003/003A to Jamaica WWTP	3,200 LF, 8-foot diameter sewer from Outfalls JAM-003/003A to a 50 MGD pumping station at the Jamaica WWTP
5. CSO Tunnel from JAM--03/003A to Jamaica WWTP (50% Control)	3,200 LF, 21-foot diameter CSO tunnel (8 MG) from JAM-003/003A to Jamaica WWTP

Table ES-6. Retained Alternatives

Alternative	Description
6. CSO Tunnel from JAM-003/003A to Jamaica WWTP (75% Control)	3,200 LF, 32-foot diameter CSO tunnel (19 MG) from JAM-003/003A to Jamaica WWTP
7. CSO Tunnel from JAM-003/003A to Jamaica WWTP (100% Control)	5,400 LF, 49-foot diameter CSO tunnel (45 MG) from JAM-003/003A to Jamaica WWTP
Regional Alternatives	
8. Jamaica WWTP CSO Tunnel (30% Regional Control)	18,500 LF, 35-foot diameter CSO tunnel (133 MG) from JAM-003/003A to JAM-005/007 with Dewatering Pumping Station at Jamaica WWTP
9. Jamaica/26W WWTP CSO Tunnel (70% Regional Control)	40,100 LF, 35-foot diameter CSO tunnel (288 MG) from JAM-005/007 (Thurston Basin) to 26W-003 (Fresh Creek) with Dewatering Pumping Stations at Jamaica WWTP and 26th Ward WWTP
10. North Shore CSO Storage Tunnel (100% Regional Control)	67,000 LF, 35-foot diameter CSO tunnel (482 MG) from JAM-005/007 (Thurston Basin) to the Coney Island WWTP with Dewatering Pumping Stations at Jamaica, 26th Ward and Coney Island WWTPs
11. Additional GI and Environmental Improvements	*Thurston Basin* • Green Infrastructure – 221 greened acres • Ribbed Mussels – 3 Acres *Bergen Basin* • Environmental Dredging – 50,000 cubic yards • Green Infrastructure – 232 greened acres • Ribbed Mussels – 4 acres *Spring Creek* • Tidal Wetlands Restoration – 13 acres *Hendrix Creek* • Tidal Wetlands Restoration – 3 acres *Fresh Creek* • Tidal Wetlands Restoration – 14 acres Paerdegat Basin • Tidal Wetlands Restoration – 4 acres Jamaica Bay • Tidal Wetlands Restoration – 16 acres

Table ES-7. Jamaica Bay Retained Alternatives Summary (2008 Rainfall)

Alternative[1]	Untreated CSO Volume (MGY)[2,6]	Frequency of Overflow[3,6]	Untreated CSO Volume Reduction (%)	Fecal Coliform Reduction (%)[4]	*Enterococci* Reduction (%)[4]
Thurston Basin					
Baseline Conditions	658 (247)	73 (26)	-	-	-
1. CSO Tunnel from JAM-005/007 to Jamaica WWTP (50% Control)	313 (146)	41 (6)	50 (32)	32	32
2. CSO Tunnel from JAM-005/007 to Jamaica WWTP (75% Control)	155 (85)	40 (2)	75 (60)	60	60
3. CSO Tunnel from JAM-005/007 to Jamaica WWTP (100% Control)	0	0	100	100	100
Bergen Basin					
Baseline Conditions	333	33	-	-	-
4. CSO Conveyance from JAM-003/003A to Jamaica WWTP	230	16	32	32	32
5. CSO Tunnel from JAM-003/003A to Jamaica WWTP (50% Control)	165	11	50	50	50
6. CSO Tunnel from JAM-003/003A to Jamaica WWTP (75% Control)	85	7	75	75	75
7. CSO Tunnel from JAM-003/003A to Jamaica WWTP (100% Control)	0	0	75	75	75
Regional Alternatives					
Baseline Conditions	2,191 (1,780)	73 (33)	-	-	-
8. Jamaica WWTP CSO Tunnel (30% Regional Control)	1,490	30	30	30	30
9. Jamaica/26W WWTP CSO Tunnel (70% Regional Control)	640	12	68	68	68
10. North Shore CSO Storage Tunnel (100% Regional Control)	0	0	100	100	100

Table ES-7. Jamaica Bay Retained Alternatives Summary (2008 Rainfall)

Alternative[(1)]	Untreated CSO Volume (MGY)[(2,6)]	Frequency of Overflow[(3,6)]	Untreated CSO Volume Reduction (%)	Fecal Coliform Reduction (%)[(4)]	*Enterococci* Reduction (%)[(4)]
11. Additional GI and Environmental Improvements	2,155 (1,772)	73 (33)	1	10[(5)]	10[(5)]

Notes:
(1) Retained alternatives include waterbody-specific control where water quality attainment is not currently achieved under baseline conditions.
(2) Based upon 2008 typical year rainfall conditions. Rockaway CSOs do not overflow.
(3) Frequency of overflow includes remaining CSO discharges to Jamaica Bay Tributaries that are not captured or receive primary treatment.
(4) Bacteria reduction is computed on an annual basis.
(5) Fecal coliform and *Enterococci* load reductions shown are based on CSO and SW volume reductions associated with Alternative 11. An additional 10 percent reduction in the in-receiving water concentrations within Thurston and Bergen Basins has been assumed to account for the ribbed mussels installed within those basins.
(6) Stormwater connections contribute flow to JAM-005/007 downstream of the regulator weirs in Thurston Basin. As a result, the diversion chambers would direct CSO and stormwater to the tunnel during wet-weather events. The statistics represent the CSO volume and stormwater volume at the point the flow is diverted to the tunnel. Flows in parentheses identify the model predicted CSO volumes overtopping the regulator weirs.

Estimated Costs of Retained Alternatives and Selection of the Recommended Plan

The retained alternatives were reviewed for cost effectiveness, ability to meet WQ criteria, public comments, and operations. The construction costs were developed as Probable Bid Costs (PBC), and the total Net Present Worth (NPW) costs were determined by adding the estimated PBC to the NPW of the projected annual O&M costs at an assumed interest rate of 4 percent over a 100-year life cycle. Design, construction management, and land acquisition costs are not included in the cost estimates. All costs are in June 2018 dollars and are considered Level 5 cost estimates by the Association for the Advancement of Cost Engineering (AACE) International with an accuracy of -50% to +100%. The estimated PBC, annual O&M costs, and total present worth for the retained alternatives are shown below in Table ES-8. The total NPW for the alternatives ranges from $401M to $9,851M.

Table ES-8. Cost of Retained Alternatives

Alternative	PBC(1) ($ Million)	Annual O&M Cost ($/Yr Million)	Total Net Present Worth ($ Million)(2)
Thurston Basin Alternatives			
1. **CSO Tunnel from JAM-005/007 to Jamaica WWTP (50% Control)**	665	1	722
2. **CSO Tunnel from JAM-005/007 to Jamaica WWTP (75% Control)**	939	2	1,020
3. **CSO Tunnel from JAM-005/007 to Jamaica WWTP (100% Control)**	1,509	3	1,637
Bergen Basin Alternatives			
4. **CSO Conveyance from JAM-003/003A to Jamaica WWTP**	633	1	690
5. **CSO Tunnel from JAM-003/003A to Jamaica WWTP (50% Control)**	676	2	736
6. **CSO Tunnel from JAM-003/003A to Jamaica WWTP (75% Control)**	818	2	896
7. **CSO Tunnel from JAM-003/003A to Jamaica WWTP (100% Control)**	1,635	3	1,755
Regional Alternatives			
8. **Jamaica WWTP CSO Tunnel (44% Regional Control)**	2,740	4	2,901
9. **Jamaica/26W WWTP CSO Tunnel (72% Regional Control)**	5,831	11	6,219
10. **North Shore CSO Storage Tunnel (100% Regional Control)**	9,102	23	9,851
11. **Additional GI and Environmental Improvements**	310	2	401

Notes:
(1) The Probable Bid Cost (PBC) for the construction contract based on June 2018 dollars.
(2) The Net Present Worth is based upon a 100-year service life, and is calculated by multiplying the annual O&M cost by a present worth factor of 24.505 and adding this value to the PBC.

As shown in Figure ES-14, most of the areas of Jamaica Bay and the tributaries that are accessible to the public for recreational use would achieve full compliance with the Existing WQ Criteria for fecal coliform under baseline conditions. The one exception was the upstream end of Fresh Creek, where the baseline conditions recreational season (May 1st through October 31st) attainment would be 93 percent. In light of this information, and the costs and potential benefits of the retained alternatives, these alternatives are quite costly as compared to the relatively small improvement of attainment of bacterial and DO WQ criteria.

Selection of the Recommended Plan is based on multiple considerations including public input, environmental and water quality benefits, and costs. A traditional knee-of-the-curve (KOTC) analysis is presented in Section 8.5 of the LTCP. Based on that analysis, the Alternative 11 - Additional GI and Environmental Improvements alternative was identified as the most cost-effective alternative for reducing the frequency and volume of CSOs to Jamaica Bay and its tributaries, and was therefore selected as the Recommended Plan. A more detailed description of the projects included in the Recommended Plan is provided in Section 8 of this LTCP.

The Recommended Plan is projected to result in attainment of the Existing WQ Criteria for fecal coliform in most of the areas of Jamaica Bay and its tributaries that are accessible to the public. The only areas that would not achieve attainment of the Existing WQ Criteria for fecal coliform would be the upstream ends of Thurston and Bergen Basins, where access is prohibited by JFK International Airport security, and the upstream end of Fresh Creek.

While grey infrastructure alternatives were identified for Bergen and Thurston Basins that would provide greater reduction in annual CSO volume than the Recommended Plan, those alternatives were not selected because they carried significantly higher costs, would not significantly improve the attainment of WQ criteria, and would not provide the range of ancillary benefits that would be provided by the Recommended Plan. As described in Section 8, DEP conducted a Triple-Bottom-Line evaluation of the grey alternative versus the Recommended Plan, where the ancillary benefits of the Recommended Plan were monetized. That assessment demonstrated the cost effectiveness of the Recommended Plan more clearly than the traditional cost/performance curves. The benefits that would accrue from the Recommended Plan, beyond reduction in CSO and stormwater discharge volumes, include air quality improvement, carbon footprint reduction, habitat creation, heat island construction reduction, anticipated property value improvement, and water quality improvement through the filtering of the ribbed mussels. For Bergen Basin in particular, the future buildout of the Southeast Queens drainage plan will eventually reduce the volume of CSO discharged to Bergen Basin, and increase the volume of stormwater. Therefore, in the future, the benefits of a grey infrastructure project targeted at CSO control would be reduced, while the benefits of the additional GI would be expected to increase.

In addition, the Recommended Plan would further many of the ecosystem goals outlined in the City's OneNYC Plan, including expansion of GI, reduction of pollution from stormwater runoff, expansion in trees planting, urban heat island reduction, resiliency, and habitat improvements for pollinators, wildlife and aquatic species. Thus, the Recommended Plan is both more cost-effective than the feasible grey infrastructure alternatives with the added benefit of these additional quality of life and ecological improvements. For these multiple reasons, the Recommended Plan consisting of Additional GI and Environmental Improvements was selected over the more traditional grey infrastructure alternatives.

UAA, WQ Compliance and Time to Recovery

The CSO Order Goal Statement stipulates that, in situations where the proposed alternatives presented in the LTCP will not achieve existing WQS or the Clean Water Act (CWA) Section 101(a)(2) goals, the LTCP will include a Use Attainability Analysis (UAA). Because the analyses developed indicate that Bergen Basin, Thurston Basin, and Fresh Creek are not projected to fully meet Existing WQ Criteria for fecal coliform, portions of Jamaica Bay adjacent to the tributaries are not project to meet the Amended *Enterococci* STV WQ Criteria* (rolling 30-day STV of 130 cfu/100mL), and Bergen Basin, Thurston Basin, and Hendrix Creek are not projected to fully attain the Existing DO Criteria, a UAA is included in this LTCP.

DEP has performed an analysis to determine the amount of time following the end of rainfall periods required for Jamaica Bay and its tributaries to recover and return to fecal coliform concentrations of less than 1,000 cfu/100mL. This concentration represents the maximum that the New York City Department of Health and Mental Hygiene (DOHMH) considers safe for primary contact.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Details of this analysis are described in Section 8. The median duration of time within which pathogen concentrations are expected to be higher than 1,000 cfu/100mL varies by location within Jamaica Bay and each of its tributaries. For the Recommended Plan, the median times to recovery are below 24 hours at all of the water quality stations for the storm sizes up to 1.5 inches except for Stations TBH1, TBH3, and TB9 in Thurston Basin, BB5 and BB6 in Bergen Basin, and FC1 in Fresh Creek. The median times to recovery at those stations ranged from 30 to 40 hours. For storms greater than 1.5 inches, the median times to recovery are well above 24 hours at all stations located near the head end of each tributary, except for Hendrix Creek (22 hours). All stations within Jamaica Bay have median times to recovery well below 24 hours.

Attachment F
Section 6 – Baseline Conditions and Performance Gap

6.0 BASELINE CONDITIONS AND PERFORMANCE GAP

A key element in the development of the Jamaica Bay and Tributaries LTCP was the assessment of water quality using applicable WQS within the waterbody. Water quality was assessed using the Jamaica Bay Eutrophication Model (JEM), which was recalibrated using data from the 2015 DEP HSM Program, the DEP Sentinel Monitoring Program, the National Park Service, and data collected as part of the LTCP program in 2015. The JEM water quality model was used to simulate ambient bacteria and DO concentrations within Jamaica Bay for a set of baseline conditions as described in this section. The IW sewer system model was used to provide flows and loads from intermittent wet-weather sources as input to the JEM water quality model.

The assessment of water quality described herein started with a baseline condition simulation to determine future bacterial levels without additional CSO controls beyond those already required under the CSO Order as of the date of this LTCP. Simulations were then performed to determine bacteria and DO levels under the assumption of 100% CSO control. The baseline simulation results were compared to the 100% CSO control simulation results, and the gap between the two scenarios was then assessed to determine whether bacteria and DO criteria could be attained through application of CSO controls. Continuous water quality simulations were performed to evaluate the gap between the calculated baseline bacteria and DO levels and Existing WQ Criteria, including the Amended *Enterococci* WQ Criteria*. As detailed below, a ten-year simulation using 2002-2011 JFK Airport rainfall was performed for bacteria and a one-year simulation using 2008 JFK Airport rainfall was performed for DO. These simulations served as a basis for the evaluation of the control alternatives presented in Section 8.0.

This section of the LTCP describes the baseline conditions, the bacteria, and Biochemical Oxygen Demand (BOD) concentrations and loads calculated by the IW model, and the resulting bacteria and DO concentrations calculated by the JEM water quality model. It further describes the gap between calculated baseline bacteria concentrations and both the Existing WQ Criteria and Amended *Enterococci* WQ Criteria*. This section also assesses whether the gap can be closed through CSO reductions alone (100% CSO control).

It should be noted that the Amended *Enterococci* WQ Criteria* would not apply to non-coastal waters and thus does not include the Jamaica Bay tributaries (such as Thurston Basin, Bergen Basin, Spring Creek, Hendrix Creek, Fresh Creek, and Paerdegat Basin). Therefore, Jamaica Bay tributaries water quality assessments for existing Class I criteria considered the Existing WQ Criteria for fecal coliform criterion only. However, attainment of the Class I waterbodies with the Amended *Enterococci* WQ Criteria* is presented for informational purposes.

6.1 Define Baseline Conditions

Establishing baseline conditions was an important step in the LTCP process because the baseline conditions were used to compare and contrast the effectiveness of CSO controls identified pursuant to the LTCP process and to predict whether water quality goals would be attained after implementation of the identified preferred alternative LTCP. Baseline conditions for this LTCP were established in accordance with guidance set forth by DEC to represent future conditions. Specifically, these conditions included the following assumptions:

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

- Dry-weather flow and loads to the Jamaica, 26th Ward, Coney Island, and Rockaway WRRFs were based on CY2040 projections, as follows:
  - Jamaica Bay WRRF - 87.7 MGD (includes 76.5 MGD 2040 projected sanitary flow plus 11.2 MGD of flow associated with the rezoning under the Jamaica WRRF Drainage Area Facility Planning project
  - 26th Ward WRRF - 44.9 MGD
  - Coney Island WRRF - 78.8 MGD
  - Rockaway WRRF - 20.7 MGD
- The Jamaica, 26th Ward, Coney Island, and Rockaway WWRFs were configured to accept and treat peak flows at two times design dry-weather flow (2xDDWF). The rated wet-weather capacities of each WRRF are as follows:
  - Jamaica Bay WRRF - 200 MGD
  - 26th Ward WRRF - 170 MGD
  - Coney Island WRRF- 220 MGD
  - Rockaway WRRF - 90 MGD
- Constructed or planned GI projects resulting in 169 MGY reduction in baseline annual CSO volume in the watershed were included.
- Cost-effective Grey Infrastructure CSO controls described in the CSO Consent Order and as summarized in Section 4.1 were included.
- Rainfall from 2008 at the JFK rainfall gauge was selected as the typical year rainfall. The 2002-2011 JFK rainfall period was also used to assess performance over a wider range of rainfall conditions. Tide data corresponding to the same timeframes as the rainfall were also incorporated into the IW model.
- The IW model was developed to represent the sewer system on a macro scale, including all conveyance elements generally greater than 48-inches in equivalent diameter, along with all regulator structures and CSO outfall pipes. Small diameter sewers were included for specific areas in downtown Jamaica where greater model definition was desired. Post interceptor cleaning levels of sediments were also included for the interceptors in the collection system to better reflect actual conveyance capacities to the WRRFs.

The IW model was used to develop stormwater flows, conveyance system flows, and CSO volumes for baseline conditions for the Jamaica, 26th Ward, Coney Island, and Rockaway sewersheds. For this LTCP, the baseline conditions were initially developed in a manner consistent with the earlier WWFPs for other waterbodies. However, based on more recent data and public comments received on the preceding WWFPs, it was recognized that some of the baseline condition model input data needed to be updated to reflect more recent meteorological conditions, as well as the current operating characteristics of various collection and conveyance system components. Furthermore, the mathematical models were updated from their configurations and levels of calibration developed and documented prior to this LTCP. IW model modifications for this LTCP reflected a better understanding of dry- and wet-weather pollutant sources, catchment areas, and new or upgraded physical components of the system. In addition, a model recalibration report was issued in 2012 (*InfoWorks Citywide Recalibration Report, 2012a*) that used improved impervious surface satellite data.

Minor improvements made as part of this LTCP to the water quality model included updating and refining the model segmentation. Changes to, and recalibration of, the IW and water quality models are discussed in detail in *CSO-LTCP: Basis for Modeling – Jamaica Bay and Tributaries (Submitted September 2015, Revised May 2018 and August 2019).*

The new IW model network was used to calculate CSO volumes and loads for the baseline conditions and was used as a tool to evaluate the impact of potential alternative operating strategies and other possible physical changes to the collection system on CSO activation frequencies and volumes. The improved water quality model was applied to evaluate the conditions in Jamaica Bay and its tributaries associated with baseline conditions and changes to baseline CSO and/or stormwater volumes associated with LTCP alternatives as represented in the IW model.

6.1.a Hydrological Conditions

For this LTCP, the precipitation characteristics for 2008, based on JFK Airport precipitation data, were used for the baseline condition, as well as for alternatives evaluations, and were considered to be representative of a typical rainfall year. In addition to the 2008 precipitation pattern, the observed tide conditions that existed in 2008 were also applied in the model. Baseline conditions, 100% CSO control (for the gap analysis), and the Recommended Plan were also assessed using 2002-2011 JFK Airport rainfall and the tides from that period.

6.1.b Flow Conservation

Consistent with previous studies, the dry-weather sanitary sewage flows used in the baseline modeling were escalated to reflect anticipated population growth in NYC. In 2014, DEP completed a detailed analysis of water demand and wastewater flow projections. A detailed GIS analysis was also performed to apportion total population among the 14 WRRF sewersheds throughout NYC. For this analysis, Transportation Analysis Zones were overlaid with WRRF sewersheds. Population projections for 2010-2040 were derived from population projections developed by DCP and the New York Metropolitan Transportation Council. These analyses used the 2010 census data to reassign population values to the watersheds in the model and project sanitary flows to 2040. These projections also reflect water conservation measures that already have significantly reduced flows to the WRRFs and freed capacity in the conveyance system.

6.1.c Best Management Practices Findings and Optimization

A list of BMPs pertaining to Jamaica Bay and its tributaries CSOs, along with a brief summary of each and their respective relationship to the EPA Nine Minimum Controls appear in Section 3.0. The BMPs include operation and maintenance procedures, maximum use of existing systems and facilities, and related planning efforts to maximize capture of CSO and reduce contaminants in the combined sewer system, thereby improving water quality conditions.

The following provides an overview of the specific elements of various DEP, SPDES, and BMP activities as they relate to the development of the baseline conditions, specifically in developing and using the IW models to simulate CSO discharges and in establishing non-CSO discharges that impact water quality in Jamaica Bay:

- Sentinel Monitoring: In accordance with BMPs #1 and #5, DEP collects quarterly samples of bacteria water quality at 19 locations in Jamaica Bay and its tributaries (as shown in Figure 6-1) in dry-weather to assess whether dry-weather sewage overflows occur, or whether illicit connections to storm sewers exist. In Bergen Basin, Sentinel Monitoring Program samples, as well as dry-weather samples from the Harbor Survey Monitoring Program and the LTCP sampling program, all suggested the presence of dry-weather sources of bacteria. Since illicit discharges were suspected in Bergen and Thurston Basins, additional dry-weather sampling was conducted at LTCP2 sampling location BB-5 and along CSO JAM-005/007. As DEP is actively investigating and correcting identified illicit connections under a separate consent order, no illicit sources were included in the baseline conditions.

- Interceptor Sediments: Sewer sediment levels determined through the post-cleaning inspections are included in the IW model.

- Combined Sewer Sediments: The IW models assume no sediment in upstream combined trunk sewers in accordance with BMP #2.

- WRRF Flow Maximization: In accordance with BMP #3 and the 2014 CSO BMP Order on Consent, the Jamaica, 26th Ward, Coney Island, and Rockaway WRRFs treat wet-weather flows that are conveyed to the plant up to 2xDDWF. Cleaning of the interceptor sediments has increased the ability of the system to convey 2xDDWF to the WRRF.

- Wet Weather Operating Plan (WWOP): The Jamaica, 26th Ward, Coney Island, and Rockaway WWOPs (BMP #4) establish procedures for pumping at the plant headworks to facilitate treatment of 2xDDWF.

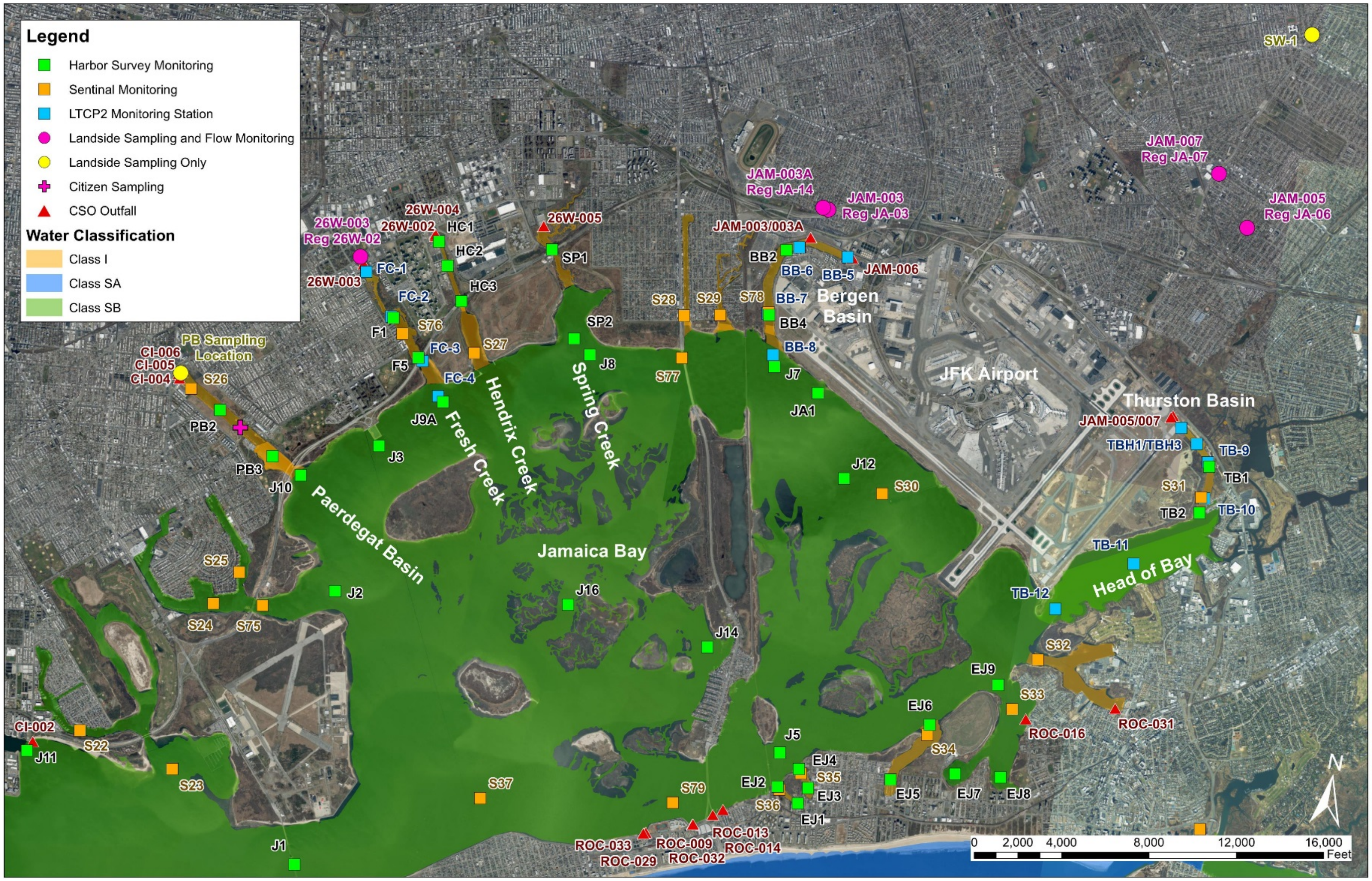

Figure 6-1. Sampling Locations in Jamaica Bay and Its Tributaries

6.1.d Elements of Facility Plan and GI Plan

DEP maintains containment booms to control floatables at CSO Outfalls JAM-006, JAM003/003A, JAM-005/007, 26W-004, and 26W-003. The captured floatables are removed using skimmer vessels. Results of this program are provided in the SPDES Annual CSO BMP Report. The Jamaica Bay and Tributaries LTCP also includes the following projects from the WWFP and other LTCPs which have been expanded upon in Section 4.1:

- Construction of the Paerdegat Basin CSO Facility (50 MG storage)
- Environmental Dredging of Paerdegat Basin
- Meadowmere and Warnerville Dry-Weather Overflow Abatement
- Shellbank Basin Destratification System
- Automation of Regulator JA-02
- Spring Creek Auxiliary Wastewater Treatment Plant (AWWTP) Upgrades
- Sewer Cleaning in the 26^{th} Ward Treatment Plant Drainage Area
- Environmental Dredging of Hendrix Creek
- Installation of a New Parallel Interceptor Sewer
- Regulator Improvements at JA-03, JA-06 and JA-14
- 26^{th} Ward High Level Storm Sewers
- 26^{th} Ward WRRF Wet Weather Stabilization

As discussed in Section 5.0, both the Jamaica and 26^{th} Ward sewersheds have been targeted for GI projects by DEP. The list of GI projects presented in Section 5 has been assumed to be fully implemented in the baseline model.

6.1.e Non-CSO Discharges

Over the past approximately 30 years, DEP has invested heavily in mapping and delineating combined sewer drainage areas and piping systems as part of CSO facility planning and waterbody watershed facility planning efforts. However, non-CSO drainage areas have not received the same level of effort. Non-CSO drainage areas were first identified during WWFP activities as land areas that were not contained within the CSO drainage areas. They were labeled as direct drainage and stormwater drainage areas, but that distinction was inconsequential since both areas were assigned the same runoff characteristics. As part of DEP's LTCP work, these areas were further refined. Direct drainage areas (parks, cemeteries, large un-occupied open areas, etc.) are now assigned lower pathogen runoff concentrations than more urbanized non-CSO drainage areas (residential and/or commercial areas with a separate storm sewer system). In general, highway runoff has been established as a stand-alone category, but in many cases, highway runoff is combined with other stormwater discharges. Figure 6-2 presents the IW subcatchments within the Jamaica Bay drainage area.

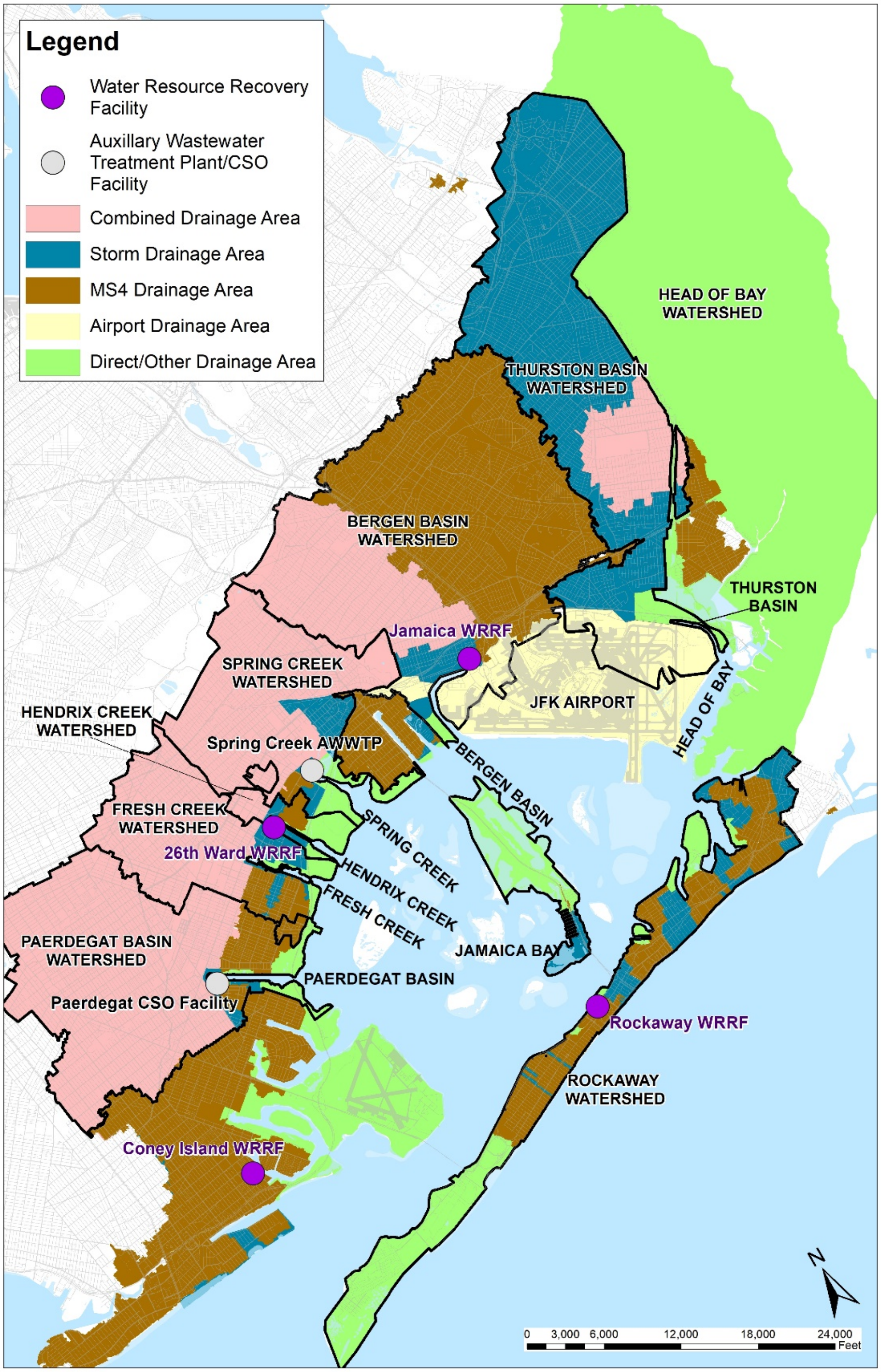

Figure 6-2. IW Subcatchments within Jamaica Bay Drainage Area

In several sections of the Jamaica Bay, 26th Ward, Rockaway, and Coney Island sewersheds, runoff drains directly to receiving waters via overland flow, open channels, or privately-owned pipes, without entering the CSS or separate storm sewer system. These areas were depicted as "Direct/Other Drainage" in Figure 6-2 and were estimated based on topography and the direction of stormwater runoff flow in those areas. In general, shoreline areas adjacent to waterbodies comprise the direct/other drainage category, as they mainly consist of parks. However, JFK Airport covers a large portion of the shoreline area tributary to Bergen Basin, Grassy Bay, Grass Hassock Channel, Thurston Basin, and Head of Bay. In total, these areas comprise approximately 27,694 acres (41 percent) of the 67,718 acres of drainage area to Jamaica Bay.

MS4 areas in the IW model were updated based on desktop analyses conducted by DEP. Non-MS4 stormwater areas and direct drainage areas are meant to represent the remaining parts of the drainage areas not covered by the MS4 delineations. The modeled discharge locations of the non-MS4 and direct drainage areas may not tie to actual locations of individual outfalls, but the loads to the receiving water are appropriately accounted for in the IW model.

6.2 Baseline Conditions – Projected CSO Volumes and Loadings after the Facility Plan and GI Plan

As previously noted, the IW model was used to develop CSO volumes for baseline conditions. The model incorporated the implementation of planned GI and grey infrastructure within the Jamaica Bay, 26th Ward, and Coney Island sewersheds, respectively. Using these overflow volumes, CSO loadings were generated using measured *Enterococci*, fecal coliform, and BOD concentrations. These loadings provided input to the receiving water quality model. Fecal coliform, *Enterococci,* and BOD CSO loadings were developed by employing an hourly Monte Carlo randomization of the measured range of CSO concentrations assigned to the hourly overflows simulated by IW for four outfalls contributing the CSO to Fresh Creek (26W-003), Bergen Basin (JAM-003 and JAM-003A), and the Paerdegat CSO Retention Facility (PB-CSO). Other CSO outfalls were assigned loadings based on a mass balance procedure, described below.

In addition to CSO loadings, storm sewer discharges and direct drainage impact the water quality in Jamaica Bay and its tributaries. The concentrations assigned to the various discharge sources to each waterbody are summarized in Table 6-1. The concentrations represent typical stormwater, direct drainage, and sanitary sewage concentrations, based on water quality data collected for Jamaica Bay and its tributaries. Further details on the modeling validation analyses are provided in the technical memorandum *"Jamaica Bay LTCP Sewer System and Water Quality Modeling Report."*

For the outfalls where a mass balance approach was used, CSO concentrations were calculated using the stormwater and sanitary concentrations assigned in Table 6-2, multiplied by the flow calculated by the IW model.

Table 6-1. Source Concentrations

Source	Fecal Coliform (cfu/100mL)	*Enterococci* (cfu/100mL)	BOD_5 (mg/L)
Urban SW - Bergen Basin(1)	45,000	55,000	15
Urban SW - Rockaway(2)	35,000	15,000	
Urban SW - All Others(2)	120,000	50,000	
Sanitary for Mass Balance CSOs(3)	4,000,000	1,000,000	Mass Balance (Sanitary=110)
CSOs (26W-003, JAM-003, JAM-003A, PB-CSO)(4)	Monte Carlo	Monte Carlo	Mass Balance (Sanitary =110)
CSOs (All others)	Mass Balance	Mass Balance	Mass Balance (Sanitary=110)
Highway/ Airport Runoff (5)	20,000	8,000	15
Direct Drainage(6)	4,000	6,000	15
WRRF Effluent(7)	Monte Carlo	Monte Carlo	Quarterly

Notes:

(1) Stormwater bacteria concentrations based on 2015-2017 Jamaica Bay and Tributaries LTCP measurements. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2012).
(2) Stormwater bacteria concentrations based HydroQual Memo to DEP, 2005a. Stormwater BOD_5 based on Jamaica Bay Waterbody/Watershed Report (2012).
(3) Sanitary bacteria concentrations from the HydroQual Memo to DEP, 2005a. BOD concentrations based on Jamaica Bay Waterbody/Watershed Report (2012).
(4) Monte Carlo based on 2015 LTCP CSO data.
(5) Highway/Airport runoff concentrations based on airport drainage data used in the Flushing Bay LTCP model estimated from NYS Stormwater Manual, Charles River LTCP, National Stormwater Data Base.
(6) Direct drainage bacteria concentrations based on NYS Stormwater Manual, Charles River LTCP, and National Stormwater Data Base for commercial and industrial land uses. Direct drainage BOD_5 concentrations specified as stormwater.
(7) WRRF effluent bacteria concentrations based on 2016 DMR measurements: Monte Carlo selection of daily averages for fecal coliform and median of several months for *Enterococci*. BOD concentrations based on quarterly BioWin model results from the FANCJ analysis.

The IW model provides a calculated fraction of flow from stormwater and flow from sanitary sources, as follows:

$$C_{cso} = fr_{san}*C_{san} + fr_{sw}*C_{sw}$$

where: C_{cso} = CSO concentration

C_{san} = sanitary concentration

C_{sw} = stormwater concentration

fr_{san} = fraction of flow that is sanitary

fr_{sw} = fraction of flow that is stormwater

Baseline volumes of CSO and stormwater to Jamaica Bay and its tributaries for the 2008 typical year by outfall are summarized in Table 6-2 and Table 6-3, respectively. The total baseline volumes of CSO, stormwater, and direct drainage to Jamaica Bay and its tributaries, along with the associated fecal coliform, *Enterococci*, and BOD annual loadings, are summarized in Table 6-4 for the 2008 typical year. The specific SPDES permitted outfalls associated with these sources are shown in Figure 6-1. Additional tables that summarize annual volumes and loadings can be found in Appendix A. The information in these tables is provided for the 2008 rainfall condition.

Table 6-2. 2008 CSO Volume and Overflows per Year

Waterbody	CSO	Volume(1)	Activation Frequency(1)
		Total Discharge (MG/yr)	**Total (No./yr)**
Thurston Basin	JAM-005/007	658 (247)	73 (26)
Bergen Basin	JAM-003	107	17
	JAM-003A	223	33
	JAM-006	3	14
	Subtotal	333	33
Spring Creek(2)	26W-005	292	6
Hendrix Creek	26W-004	85	26
Fresh Creek	26W-003	232	12
Paerdegat Basin(2)	Tank Overflow (PB-CSO)	553	12
	CI-004, CI-005, CI-006	38	5
	Subtotal	591	12
Jamaica Bay	Rockaway Outfalls (3)	0	0
Total		**2,191 (1,780)**	**73 (33) Max.**

Notes:

(1) CSO volumes and activation frequency are based upon overflow at the respective weirs and do not account for stormwater contributions to the outfall downstream of the regulator with the exception of Thurston Basin, which is based upon the sum of the CSO and stormwater discharges just downstream of Regulators JA-06, JA-07, and JA-08. The values in parentheses are the specific CSO AAOV and frequency of flow that tips over the weirs and diversion structures within the Thurston Basin drainage area.

(2) The Spring Creek AWWTP and the Paerdegat Basin CSO Retention Facility provide floatables control and settling prior to overflow of storms exceeding the tank storage capacity.

(3) The Rockaway CSOs do not activate during the typical 2008 rainfall year.

As indicated in Table 6-2, CSO discharges in the typical year occur only within the tributaries to Jamaica Bay. The largest and most active CSO is Outfall JAM-005/007, discharging 73 times for a total of 658 MG, under 2008 conditions. CSOs to Hendrix Creek and Bergen Basin also discharge relatively frequently, on the order of 26 to 33 times per year, respectively. CSO discharges from the Spring Creek AWWTP (26W-005) and the Paerdegat Basin CSO Retention Facility (PB-CSO) discharge relatively large volumes (292 and 553 MG, respectively), but at low frequencies of activation (6 and 12 times per year, respectively). Fresh Creek discharges 12 times for a total annual volume of 232 MG. CSO discharge to JAM-006 is very small (3 MG) and relatively infrequent (14 events) under 2008 conditions. Although

JAM-006 is identified as a permitted CSO outfall, it predominantly conveys stormwater from the collection system serving Southeast Queens.

Table 6-3 summarizes and categorizes the stormwater discharges to Jamaica Bay and its various tributaries. Jamaica Bay is heavily influenced by stormwater. The total volume of stormwater discharged from the Jamaica Bay watershed under 2008 conditions (19,343 MG), is approximately 11 times greater than the CSO volume (1,780 MG). Approximately 6,724 MG of stormwater runoff from Nassau County is discharged to Head of Bay, which can influence the conditions in Jamaica Bay and Thurston Basin. Jamaica Bay receives an additional 6,656 MG of stormwater from other outfalls or direct runoff from Rockaway, Brooklyn, Queens, and JFK Airport. Of the tributaries, Bergen Basin receives the greatest stormwater discharge of 3,276 MG under 2008 conditions. Due to the high frequency of activation, stormwater can influence pathogen and DO attainment in waterbodies despite the lower concentration of pathogens and BOD.

Table 6-3. 2008 Stormwater Volume and Discharges per Year

Waterbody	Total (MG)	DEP MS4 (MG)	SW[4] (MG)	Airport (MG)	Direct[5] (MG)
Jamaica Bay[1]	6,656	2,489	1,243	957	1,967
Bergen Basin	3,276	2, 835	117	302	22
Thurston Basin[3]	782 (1,193)	-	349 (760)	372	61
Fresh Creek	528	216	279	-	33
Hendrix Creek	111	36	41	-	34
Spring Creek	141	26	38	-	77
Paerdegat Basin	352	197	113	-	42
Head of Bay (Nassau Co.)	6,724	291	49	141	6,243
Other Tributaries[2]	362	326	36	-	-
Total	18,932 (19,343)	6,416	2,265 (2,676)	1,772	8,479

Notes:

(1) Grassy Bay, Hassock Creek, Grass Hassock Creek, Shell Bank Creek, Mill Basin, and Rockaway are included with Jamaica Bay.
(2) Other tributaries include Hawtree and Shellbank Basins.
(3) The values shown are the model predicted stormwater volumes assuming the stormwater that discharges just downstream of Regulators JA-06, JA-07, and JA-08 is included in the CSO AAOV for Thurston Basin (i.e., is not counted as separate stormwater). The values in parenthesis are the total estimated stormwater volumes coming out of Outfalls JAM 005/007 excluding the 213 MGY of CSO that tips over the weirs and diversion structures in the upstream sewers.
(4) Stormwater (SW) consists of all outfalls except for DEP MS4 and airport stormwater sources.
(5) Direct drainage consists of all remaining drainage areas not tributary to defined CSO, MS4, and SW subcatchments.

Loadings by source for *Enterococci*, fecal coliform, and BOD are presented in Table 6-4. In tributaries with CSOs, the CSOs are generally the largest contributor of bacteria to the waterbody. While CSOs are a major source of bacteria, they are not always the cause for non-attainment of bacteria standards because other sources discharge more frequently. The major sources of BOD vary from tributary to tributary; for Jamaica Bay as a whole, WRRFs are the major source of BOD.

Table 6-4. 2008 Baseline Loading Summary

Totals by Source by Waterbody		Volume	*Enterococci*	Fecal Coliform	BOD
Waterbody	**Source**	**Total Discharge (MG/yr)**	**Total Org (10^12/yr)**	**Total Org (10^12/yr)**	**Total (lbs/yr)**
Thurston Basin	CSO	247	823	2,674	38,935
	MS4 SW	-	-	-	-
	Non-MS4 SW	760	1,508	3,613	99,735
	Airport	372	113	282	46,462
	Direct Drainage	61	14	9	7,621
	Subtotal	**1,440**	**2,458**	**6,578**	**192,752**
Bergen Basin	CSO	333	13,228	17,271	82,569
	MS4 SW	2,835	5,900	4,817	354,211
	Non-MS4 SW	117	243	199	14,602
	Airport	302	92	229	37,839
	Direct Drainage	22	5	3	2,803
	Jamaica WRRF	7,010	5	10	423,351
	Subtotal	**10,619**	**19,473**	**22,530**	**915,375**
Spring Creek	CSO	292	1,444	4,966	62,345
	MS4 SW	26	50	120	3,298
	Non-MS4 SW	38	50	115	4,764
	Airport	-	-	-	-
	Direct Drainage	77	18	12	9,794
	Subtotal	**433**	**1,562**	**5,213**	**80,201**
Hendrix Creek	CSO	85	485	1,710	20,013
	MS4 SW	36	68	164	4,514
	Non-MS4 SW	41	80	191	5,255
	Airport	-	-	-	-
	Direct Drainage	34	8	5	4,391
	26^{th} Ward WRRF	19,685	15	31	952,344
	Subtotal	**19,881**	**656**	**2,101**	**986,517**

Table 6-4. 2008 Baseline Loading Summary

Totals by Source by Waterbody		Volume	*Enterococci*	Fecal Coliform	BOD
Waterbody	**Source**	**Total Discharge (MG/yr)**	**Total Org (10^12/yr)**	**Total Org (10^12/yr)**	**Total (lbs/yr)**
Fresh Creek	CSO	232	4,037	3,318	50,605
	MS4 SW	216	408	978	26,897
	Non-MS4 SW	279	528	1,267	34,854
	Airport	-	-	-	-
	Direct Drainage	33	8	5	4,227
	Subtotal	**760**	**4,981**	**5,568**	**116,583**
Paerdegat Basin	CSO	591	16,113	36,432	148,384
	MS4 SW	197	372	892	24,534
	Non-MS4 SW	113	215	515	14,168
	Airport	-	-	-	-
	Direct Drainage	42	10	7	5,384
	Subtotal	**943**	**16,710**	**37,846**	**192,470**
Jamaica Bay(1)	CSO	0	-	-	-
	MS4 SW	2,489	3,535	8,449	311,973
	Non-MS4 SW	1,243	1,278	3,040	148,865
	Airport	957	290	724	119,549
	Direct Drainage	1,967	452	329	246,506
	Jamaica WRRF	27,327	20	39	1,648,104
	Rockaway WRRF	7,876	6	13	332,734
	Subtotal	**41,859**	**5,581**	**12,594**	**2,807,731**
Head of Bay	CSO	0	-	-	-
	MS4 SW	291	543	1,304	35,855
	Non-MS4 SW	49	94	225	6,197
	Airport	141	43	107	17,645
	Direct Drainage	6,243	1,433	963	787,571
	Subtotal	**6,724**	**2,113**	**2,599**	**847,268**

Table 6-4. 2008 Baseline Loading Summary

Totals by Source by Waterbody		Volume	*Enterococci*	Fecal Coliform	BOD
Waterbody	**Source**	**Total Discharge (MG/yr)**	**Total Org (10^12/yr)**	**Total Org (10^12/yr)**	**Total (lbs/yr)**
Hawtree Basin	CSO	0	-	-	-
	MS4 SW	45	81	195	5,360
	Non-MS4 SW	30	58	139	3,832
	Airport	-	-	-	-
	Direct Drainage	-	-	-	-
	Subtotal	**75**	**139**	**334**	**9,192**
Shellbank Basin	CSO	0	-	-	-
	MS4 SW	281	537	1,289	35,459
	Non-MS4 SW	6	2	4	785
	Airport	-	-	-	-
	Direct Drainage	-	-	-	-
	Subtotal	**287**	**539**	**1,293**	**36,244**
Total		**83,021**	**54,212**	**96,656**	**6,184,333**

Note:
(1) Grassy Bay, Hassock Creek, Grass Hassock Creek, Shell Bank Creek, Mill Basin, and Rockaway are included with Jamaica Bay.

6.3 Performance Gap

Bacteria and DO concentrations in Jamaica Bay and its tributaries are affected by a number of factors, including the volumes of all sources, the concentrations of the respective loadings, flow entering from Head of Bay (Nassau County), man-made features such as the borrow pits excavated in the bottom of Jamaica Bay, and the exchange of tidal flow with the Lower Bay. Because most of the flow and loads discharged into these waterbodies are the result of runoff from rainfall events, the frequency, duration, and amounts of rainfall strongly influence the water quality of Jamaica Bay and its tributaries.

The JEM model was used to simulate bacteria concentrations using 2002-2011 rainfall and tide data and DO concentrations using 2008 rainfall and tide data for the baseline conditions. Hourly model calculations were saved for post-processing and comparison with the Existing WQ Criteria and the Amended *Enterococci* WQ Criteria* for bacteria, as well as designated classifications for DO, as discussed in Section 6.3.c. The performance gap was then developed as the difference between the model calculated baseline waterbody DO and bacteria concentrations and the applicable numerical WQS. The analysis was developed to address the following two sets of criteria:

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

- Existing WQ Criteria (Jamaica Bay - Class SB, Tributaries - Class I);
- Amended *Enterococci* WQ Criteria*.

Within the following sections, analyses are described that reflect the differences in attainment both spatially and temporally. The temporal assessment focuses on compliance with the applicable fecal coliform WQ Criteria over the entire year as well as the recreational season of May 1st through October 31st. For *Enterococci*, the temporal assessment focuses on compliance during the recreational season of May 1st through October 31st. A summary of the criteria that were applied is shown in Table 6-5.

Table 6-5. Classifications and Standards Applied

Analysis	Numerical Criteria Applied	
Existing WQ Criteria - Tributaries	Class I	Fecal Monthly GM ≤ 200; DO never < 4.0 mg/L
Existing WQ Criteria – Jamaica Bay	Class SB	Fecal Monthly GM ≤ 200 DO between > 3.0 & ≤4.8 mg/L(2); DO never < 3.0 mg/L
Amended *Enterococci* WQ Criteria(1)	Class SB Coastal	*Enterococci*: rolling 30-day GM ≤35 cfu/100mL *Enterococci*: STV ≤130 cfu/100mL

Notes:
(1) These amended criteria apply during the recreational season (May 1st to October 31st) and do not apply to the tributaries to Jamaica Bay. They are effective November 1, 2019.
(2) This is an excursion based limit that allows for the average daily DO concentrations to fall between 3.0 and 4.8 mg/L for a limited number of days as described in more detail on Table 2-7 in Section 2.

6.3.a CSO Volumes and Loadings Needed to Attain Current Water Quality Standards

To assess the performance gap, fecal coliform concentrations were calculated under baseline conditions for Jamaica Bay and its tributaries, and DEP analyzed whether any gaps in attainment with WQ Criteria could be closed through reductions to CSO loadings. The water quality monitoring stations are shown in Figure 6-3.

10-Year Annual Rainfall Simulation – Bacteria

A ten-year simulation of bacteria water quality was performed for the 2002-2011 baseline loading conditions, assuming all dry-weather illicit discharges have been eliminated. The results of these simulations are summarized for the Existing WQ Criteria for fecal coliform in Table 6-6. The results shown in this table summarize the highest calculated monthly GM during the 10-year period on an annual basis (recreational and non-recreational seasons) and during the recreational season (May 1st through October 31st). The maximum monthly GM is presented for each sampling location in Jamaica Bay and its tributaries.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

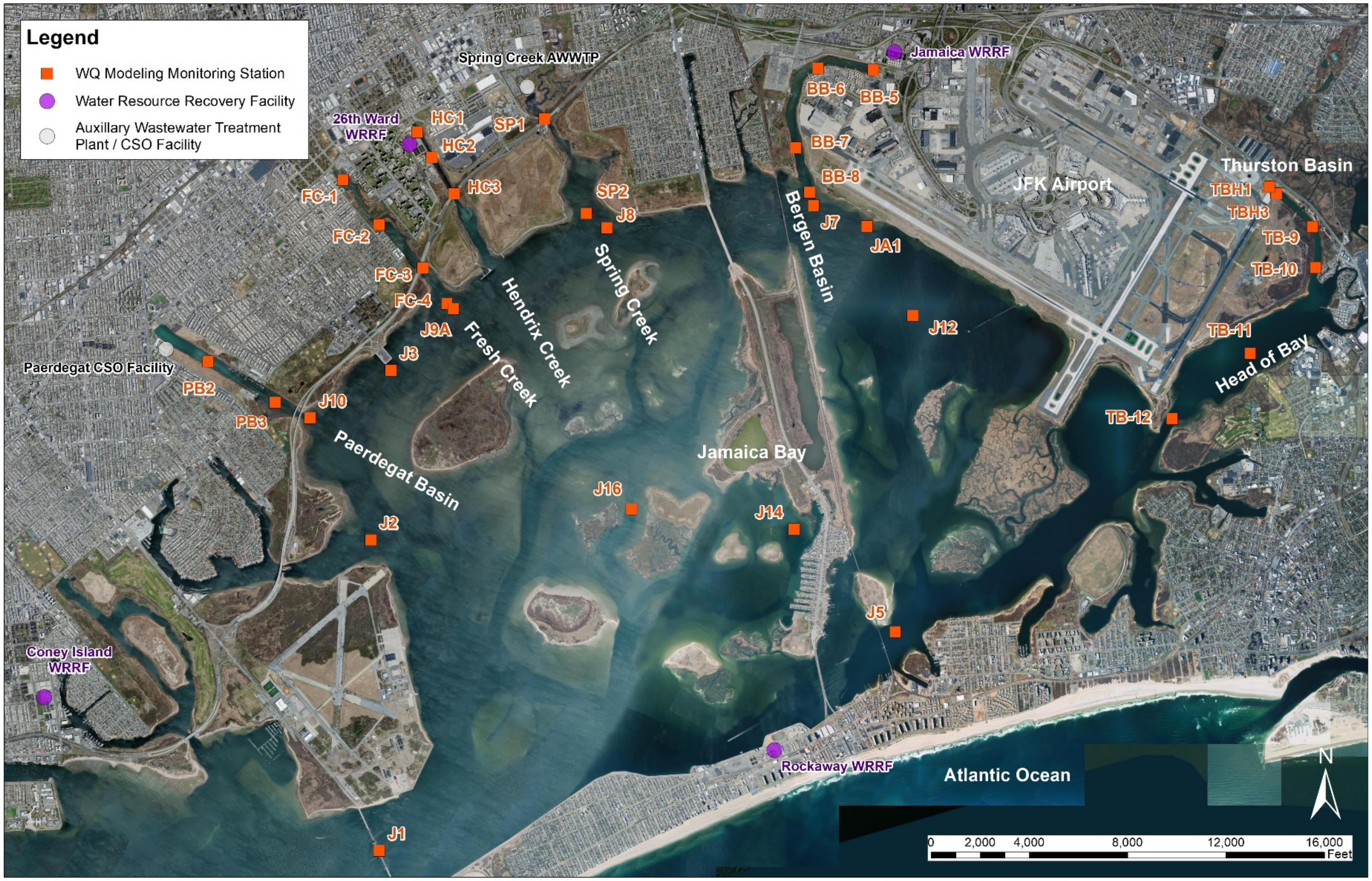

Figure 6-3. LTCP2 Water Quality Monitoring Stations in Jamaica Bay and Its Tributaries

Table 6-6 also presents the percent of time that the fecal coliform monthly GM criterion of 200 cfu/100mL would be attained over the 10-year simulation period. The highest GMs were found to occur in the Bergen Basin and Thurston Basin near the CSOs and stormwater outfalls. However, these monitoring stations are located within portions of these tributaries that are restricted from public access by airport security. Annual and recreational season (May 1st through October 31st) attainment was less than 95 percent at the head ends of Bergen Basin, Thurston Basin, and Fresh Creek. In contrast, 100% attainment is achieved at all of the stations within the Bay and near the confluence of each tributary with the Bay during the recreational season (May 1st through October 31st) and on an annual basis.

Table 6-6. Model Calculated 10-Year Baseline Fecal Coliform Maximum Monthly GM and Attainment of Existing WQ Criteria

Station	Maximum Monthly GMs (cfu/100mL)		% Attainment (GM≤200 cfu/100mL)	
	Annual	Recreational Season(2)	Annual	Recreational Season(2)
Thurston Basin				
TBH1(1)	1,054	1,054	77	88
TBH3(1)	527	527	89	93
TB9(1)	396	396	91	95
TB10(1)	212	186	98	100
TB11	60	52	100	100
TB12	39	37	100	100
Bergen Basin				
BB5(1)	1,195	1,173	57	72
BB6(1)	394	394	89	93
BB7(1)	154	150	100	100
BB8	69	69	100	100
Spring Creek				
SP1	191	191	100	100
SP2	45	45	100	100
Hendrix Creek				
HC1	213	213	99	98
HC2	160	160	100	100
HC3	85	85	100	100
Fresh Creek				
FC1	529	377	85	93
FC2	292	190	98	100
FC3	130	99	100	100
FC4	46	46	100	100
Paerdegat Basin				
PB2	248	222	97	95
PB3	106	106	100	100

Table 6-6. Model Calculated 10-Year Baseline Fecal Coliform Maximum Monthly GM and Attainment of Existing WQ Criteria

Station	Maximum Monthly GMs (cfu/100mL)		% Attainment (GM≤200 cfu/100mL)	
	Annual	Recreational Season(2)	Annual	Recreational Season(2)
Jamaica Bay (Northern Shore)				
J10	62	62	100	100
J3	36	36	100	100
J9A	46	46	100	100
J8	43	43	100	100
J7	69	69	100	100
JA1	54	54	100	100
Jamaica Bay (Inner Bay)				
J2	30	30	100	100
J12	28	26	100	100
J14	21	21	100	100
J16	27	27	100	100
Jamaica Bay (Rockaway Shore)				
J1	19	19	100	100
J5	20	20	100	100

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October 31st.

DEP reran the 10-year baseline condition scenario with the CSO loadings to Jamaica Bay tributaries removed. This projection represents the maximum possible reduction of CSO loads to the tributaries of Jamaica Bay and is referred to as the 100% CSO control scenario. All other conditions from the baseline projection remain unchanged in the 100% CSO control scenario. Table 6-7 presents the maximum monthly fecal coliform GM concentration and the annual and recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform for baseline conditions and the 100% CSO control scenario.

Table 6-7. Comparison of the Model Calculated 10-Year Baseline and 100% Jamaica Bay and Its Tributaries CSO Control Fecal Coliform Maximum Monthly GM and Attainment of Existing WQ for Fecal Coliform Bacteria

Station	Maximum Monthly GMs (Annual - cfu/100mL)		% Attainment - Annual (GM≤200 cfu/100mL)		% Attainment – Recreational Season[2] (GM≤200 cfu/100mL)	
	Baseline	100% CSO Control	Baseline	100% CSO Control	Baseline	100% CSO Control
Thurston Basin						
TBH1[1]	1,054	901	77	77	88	88
TBH3[1]	527	441	89	90	93	93
TB9[1]	396	332	91	92	95	95
TB10[1]	212	199	98	100	100	100
TB11	60	57	100	100	100	100
TB12	39	36	100	100	100	100
Bergen Basin						
BB5[1]	1,195	1,081	57	59	72	77
BB6[1]	394	302	89	94	93	98
BB7[1]	154	108	100	100	100	100
BB8	69	44	100	100	100	100
Spring Creek						
SP1	191	113	100	100	100	100
SP2	45	24	100	100	100	100
Hendrix Creek						
HC1	213	119	99	100	98	100
HC2	160	99	100	100	100	100
HC3	85	47	100	100	100	100
Fresh Creek						
FC1	529	447	85	90	93	98
FC2	292	221	98	98	100	100
FC3	130	94	100	100	100	100
FC4	46	25	100	100	100	100
Paerdegat Basin						
PB2	248	109	97	100	95	100
PB3	106	46	100	100	100	100
Jamaica Bay (Northern Shore)						
J10	62	26	100	100	100	100
J3	36	19	100	100	100	100
J9a	46	25	100	100	100	100
J8	43	24	100	100	100	100
J7	69	44	100	100	100	100
JA1	54	38	100	100	100	100

Table 6-7. Comparison of the Model Calculated 10-Year Baseline and 100% Jamaica Bay and Its Tributaries CSO Control Fecal Coliform Maximum Monthly GM and Attainment of Existing WQ for Fecal Coliform Bacteria

Station	Maximum Monthly GMs (Annual - cfu/100mL)		% Attainment - Annual (GM≤200 cfu/100mL)		% Attainment – Recreational Season(2) (GM≤200 cfu/100mL)	
	Baseline	100% CSO Control	Baseline	100% CSO Control	Baseline	100% CSO Control
Jamaica Bay (Inner Bay)						
J2	30	16	100	100	100	100
J12	28	18	100	100	100	100
J14	21	18	100	100	100	100
J16	27	16	100	100	100	100
Jamaica Bay (Rockaway Shore)						
J1	19	13	100	100	100	100
J5	20	16	100	100	100	100

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October 31st.

As indicated in Table 6-7, 100% CSO control of the bacteria loading results in some improvement in the CSO-affected tributaries. However, on an annual basis, the head ends of Fresh Creek, Bergen Basin, and Thurston Basin do not achieve 95 percent attainment of the criterion even with 100% CSO control. This is also the case for the recreational period with the exception of the head end of Fresh Creek, which improves from 93 to 98 percent attainment. This analysis indicates that CSO controls cannot completely close the gap between attainment and non-attainment of the fecal coliform WQ Criteria.

2008 Annual Rainfall Simulation – Dissolved Oxygen

The average annual attainment of DO criteria based on the water quality model simulation is presented in Table 6-8 for year 2008 conditions. The average annual attainment is calculated by averaging the calculated attainment in each of 10 modeled depth layers, comprising the entire water column. When assessing the water column in its entirety, attainment of the DO criterion is very high, with the exception of the head ends of Bergen Basin, Thurston Basin, and Hendrix Creek. All other monitoring station locations that were assessed have a water column annual attainment of 95 percent or greater for year 2008 conditions.

Table 6-8. Model Calculated Baseline DO Attainment – Existing WQ Criteria (2008)

Annual Attainment (%) (Entire Water Column)				
Tributaries – Class I		**Jamaica Bay - Class SB**		
Station	**Instantaneous (≥4.0 mg/L)**	**Station**	**Instantaneous (≥3.0 mg/L)**	**Daily Ave. (≥4.8 mg/L)**
Thurston Basin		**Jamaica Bay (Northern Shore)**		
TBH1[(1)]	90	J10	100	100
TBH3[(1)]	90	J3	100	100
TB9[(1)]	92	J9a	100	100
TB10[(1)]	92	J8	100	100
TB11	97	J7	100	100
TB12	99	JA1	100	99
Bergen Basin		**Jamaica Bay (Inner Bay)**		
BB5[(1)]	89	J2	100	100
BB6[(1)]	95	J12	99	95
BB7[(1)]	99	J14	100	100
BB8	100	J16	100	100
Spring Creek		**Jamaica Bay (Rockaway Shore)**		
SP1	99	J1	100	100
SP2	100	J5	100	100
Hendrix Creek				
HC1	94			
HC2	98			
HC3	100			
Fresh Creek				
FC1	99			
FC2	100			
FC3	100			
FC4	100			
Paerdegat Basin				
PB2	99			
PB3	100			

Note:

(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.

Table 6-9 presents a comparison of the Class I DO criterion attainment for the tributaries and the Class SB DO criteria attainment for Jamaica Bay under baseline conditions and 100% CSO control. The model generally calculates improvements of at most only a few percentage points in attainment with the DO criteria. Thus, CSO loads are not the controlling factor for DO concentrations and CSO controls will not improve DO concentrations substantially. This finding is not unexpected as DO in Jamaica Bay is influenced by many factors including stormwater loads, tidal flushing, man-made features such as the borrow pits excavated in the bottom of Jamaica Bay, and the nitrogen discharged from WRRFs.

Table 6-9. Model Calculated Baseline and 100% CSO Control DO Attainment – Existing WQ Criteria (2008)

Annual Attainment (%) (Entire Water Column)							
Tributaries – Class I			Jamaica Bay - Class SB				
Station	Baseline	100% Control	Station	Baseline		100% Control	
	Instantaneous (≥4.0 mg/L)			Instantaneous (≥3.0 mg/L)	Daily Ave. (≥4.8 mg/L)	Instantaneous (≥3.0 mg/L)	Daily Ave. (≥4.8 mg/L)
Thurston Basin			**Jamaica Bay (Northern Shore)**				
TBH1[(1)]	90	91	J10	100	100	100	100
TBH3[(1)]	90	91	J3	100	100	100	100
TB9[(1)]	92	93	J9a	100	100	100	100
TB10[(1)]	92	93	J8	100	100	100	100
TB11	97	97	J7	100	100	100	100
TB12	99	99	JA1	100	99	100	99
Bergen Basin			**Jamaica Bay (Inner Bay)**				
BB5[(1)]	89	92	J2	100	100	100	100
BB6[(1)]	95	96	J12	99	95	99	95
BB7[(1)]	99	100	J14	100	100	100	100
BB8	100	100	J16	100	100	100	100
Spring Creek			**Jamaica Bay (Rockaway Shore)**				
SP1	99	100	J1	100	100	100	100
SP2	100	100	J5	100	100	100	100
Hendrix Creek							
HC1	94	95					
HC2	98	98					
HC3	100	100					
Fresh Creek							
FC1	99	100					
FC2	100	100					
FC3	100	100					
FC4	100	100					
Paerdegat Basin							
PB2	99	100					
PB3	100	100					

Note:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.

6.3.b CSO Volumes and Loadings That Would be Needed to Support the Next Primary Contact WQ Criteria or Swimmable/Fishable Uses

Current WQS provide that Class I waterbodies must meet the primary contact (Class SB) bacteria criteria. The primary contact fecal coliform criterion is a monthly GM less than, or equal to, 200 cfu/100mL. Since the Class I bacteria criteria are the same as the Class SB criteria, the performance gap to attain Class SB bacteria criteria would be the same as presented in Table 6-9 above.

6.3.c Amended *Enterococci* WQ Criteria*

As noted in Section 2.0, EPA released its Recreational Water Quality Criteria (RWQC) recommendations in December 2012. That document included recommendations for RWQC for protecting human health in all coastal waters designated for primary contact recreation use, based on *Enterococci*. On March 21, 2018, DEC publicly noticed a proposed rulemaking for revised WQS and re-classifications for certain coastal waterbodies. The formal revision to the WQS was adopted on June 4, 2019 with an effective date of November 1, 2019. The Amended *Enterococci* WQ Criteria* for coastal Class SB waters is a 30-day GM of 35 cfu/100mL and an STV of 130 cfu/100mL. These criteria apply to coastal Class SB waters and do not apply to the tributaries of Jamaica Bay which are non-coastal Class I waters. As requested by DEC, the LTCP has evaluated the level of attainment of the Amended *Enterococci* criteria for the tributaries, for informational purposes. An analysis using the 10-year rainfall baseline and 100% CSO control model simulation results was conducted to assess attainment with the Amended *Enterococci* WQ Criteria*.

6.3.d Load Reductions Needed to Attain the Amended *Enterococci* WQ Criteria*

Additional water quality modeling analyses were performed to assess the extent to which CSO and non-CSO sources impact *Enterococci* concentrations at key locations in Jamaica Bay and its tributaries. Those analyses consisted of first assessing the baseline conditions for *Enterococci* and then determining whether complete CSO reduction (100% CSO control) in the tributaries of Jamaica Bay could close the gap between the baseline conditions and the Amended *Enterococci* WQ Criteria*. Table 6-10 presents the calculated maximum 30-day GM and 90th percentile STV and the percent attainment of the rolling 30-day GM of 35 cfu/100mL and 90th percentile STV of 130 cfu/100mL criteria for baseline conditions at each of the stations in Jamaica Bay and the tributaries. Attainment for the tributaries of Jamaica Bay is shown for informational purposes, as the Amended *Enterococci* WQ Criteria* are not applicable to the tributaries as non-coastal Class I waters. All results are for the attainment of the Amended *Enterococci* WQ Criteria* during the May 1st through October 31st primary contact recreational season defined by the DEC.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 6-10. Model Calculated 10-Year Baseline *Enterococci* Maximum 30-day GM and STV and Attainment of Amended *Enterococci* WQ Criteria*

Station	Maximum Recreational Season(2) 30-day *Enterococci* (cfu/100mL)		% Attainment(3)	
	GM	90th Percentile STV	GM	90th Percentile STV
Thurston Basin				
TBH1(1)	547	7,126	65	5
TBH3(1)	286	4,968	84	11
TB9(1)	225	4,224	89	14
TB10(1)	122	2,639	95	24
TB11	23	699	100	87
TB12	13	462	100	96
Bergen Basin				
BB5(1)	986	26,379	29	0
BB6(1)	448	24,461	69	6
BB7(1)	175	10,450	93	14
BB8	36	3,519	100	57
SP1	22	6,878	100	78
SP2	12	1,302	100	94
Hendrix Creek				
HC1	60	9,157	98	32
HC2	66	7,727	98	38
HC3	36	2,150	100	71
Fresh Creek				
FC1	102	30,855	98	16
FC2	85	14,104	98	17
FC3	37	7,117	100	51
FC4	14	1,263	100	92
Paerdegat Basin				
PB2	136	65,236	96	28
PB3	44	20,622	100	69
Jamaica Bay (Northern Shore)				
J10	19	7,094	100	85
J3	8	663	100	97
J9A	14	1,263	100	92
J8	13	1,244	100	92
J7	36	3,519	100	57
JA1	22	1,468	100	86

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 6-10. Model Calculated 10-Year Baseline *Enterococci* Maximum 30-day GM and STV and Attainment of Amended *Enterococci* WQ Criteria*

Station	Maximum Recreational Season(2) 30-day *Enterococci* (cfu/100mL)		% Attainment(3)	
	GM	90th Percentile STV	GM	90th Percentile STV
Jamaica Bay (Inner Bay)				
J2	6	563	100	98
J12	9	439	100	97
J14	7	116	100	100
J16	4	249	100	99
Jamaica Bay (Rockaway Shore)				
J1	3	57	100	100
J5	4	111	100	100

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October. 31st.
(3) Percent attainment with Amended *Enterococci* WQ Criteria* of 30-day GM of 35 cfu/100mL, and 30-day STV of 130 cfu/100mL, for the recreational season (May 1st through October 31st). These amended criteria do not apply to the tributaries to Jamaica Bay.

Under ten-year baseline conditions, greater than 95 percent attainment of the rolling 30-day GM *Enterococci* criterion of 35 cfu/100mL is achieved during the recreational season (May 1st through October 31st) in Jamaica Bay and its tributaries, except for Thurston and Bergen Basins. Attainment of the rolling 30-day GM criterion ranges from 65 percent to 95 percent between Stations TBH1 and TB10 in Thurston Basin and from 29 percent to 93 percent between Stations BB5 and BB7 in Bergen Basin. Attainment of the 90th percentile STV criterion of 130 cfu/100mL within the tributaries generally ranges from as low as 0 to 96 percent, while Jamaica Bay stations range from 58 to 100 percent. These results indicate that while rainfall events have significant short term impacts, particularly within the tributaries, bacteria impacts generally dissipate before the 30-day GM criterion is exceeded.

Water quality modeling analyses conducted to assess attainment of the Amended *Enterococci* WQ Criteria* with complete removal of the CSO *Enterococci* loadings, as provided in Table 6-11, show that 100% CSO control would result in full attainment of the 30-day rolling GM *Enterococci* criterion in Jamaica Bay and its tributaries, except for Thurston and Bergen Basins. Attainment of the rolling 30-day GM criterion improves at each station by 1 to 2 percent at Stations TBH1 through TB10 in Thurston Basin and from 1 to 7 percent at Stations BB5 through BB7 in Bergen Basin. Improvement in attainment of the 90th percentile STV *Enterococci* criterion is generally less than 10 percent in Thurston Basin, Bergen Basin, and Jamaica Bay, and less than 25 percent in Hendrix Creek, Fresh Creek, and Paerdegat Basin. Most of these areas had generally high stormwater-to-CSO ratios. The low degree of attainment with 100% CSO control indicates that the 90th percentile *Enterococci* concentrations are predominantly influenced by non-CSO sources of bacteria, such as storm sewers, airport runoff, and direct drainage, and therefore will receive limited benefit from CSO control. This finding is further supported by Table 6-5 above, which shows that stormwater is a sizable source of bacteria loading to Jamaica Bay and many of the tributaries.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 6-11. Model Calculated 10-Year 100% CSO Control Maximum 30-day GM and STV, and Attainment of Proposed *Enterococci* WQ Criteria*

Station	Maximum Recreational Season[(2)] 30-day *Enterococci* (cfu/100mL)		% Attainment[(3)]	
	GM	90th Percentile STV	GM	90th Percentile STV
Thurston Basin				
TBH1[(1)]	490	5,929	67	5
TBH3[(1)]	253	3,951	86	12
TB9[(1)]	199	3460	89	16
TB10[(1)]	109	2,171	96	25
TB11	21	628	100	89
TB12	13	412	100	96
Bergen Basin				
BB5[(1)]	910	22,309	30	0
BB6[(1)]	330	7,724	75	7
BB7[(1)]	120	3,009	95	17
BB8	23	712	100	77
Spring Creek				
SP1	11	526	100	85
SP2	6	121	100	100
Hendrix Creek				
HC1	27	1,486	100	43
HC2	33	1,005	100	51
HC3	16	271	100	96
Fresh Creek				
FC1	51	2,636	100	21
FC2	55	2,070	99	21
FC3	22	891	100	64
FC4	6	108	100	100
Paerdegat Basin				
PB2	33	923	100	39
PB3	12	363	100	93
Jamaica Bay (Northern Shore)				
J10	6	186	100	99
J3	4	47	100	100
J9A	6	108	100	100
J8	7	117	100	100
J7	23	712	100	77
JA1	15	220	100	97

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 6-11. Model Calculated 10-Year 100% CSO Control Maximum 30-day GM and STV, and Attainment of Proposed *Enterococci* WQ Criteria*

Station	Maximum Recreational Season(2) 30-day *Enterococci* (cfu/100mL)		% Attainment(3)	
	GM	90th Percentile STV	GM	90th Percentile STV
Jamaica Bay (Inner Bay)				
J2	3	37	100	100
J12	5	83	100	100
J14	6	105	100	100
J16	2	34	100	100
Jamaica Bay (Rockaway Shore)				
J1	2	12	100	100
J5	3	42	100	100

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October. 31st.
(3) Percent attainment with Amended *Enterococci* WQ Criteria* of 30-day GM of 35 cfu/100mL, and 30-day STV of 130 cfu/100mL. These criteria are not applicable to the tributaries to Jamaica Bay.

A load source component analysis was conducted for the 2008 baseline condition using JFK Airport rainfall data, to provide a better understanding of how each source type contributes to bacteria concentrations in Jamaica Bay and its tributaries. The source types include CSOs, stormwater, direct drainage, Airport, WRRF, and other (outfalls not classified as any of the other categories in InfoWorks). Boundary conditions generally contribute an insignificant amount to the concentrations in Jamaica Bay, so they were not included in the table. The analysis included the calculation of fecal coliform and *Enterococci* bacteria GMs in total and from each component. For fecal coliform, a maximum winter month (December) was analyzed because the decay rate is lower in winter, resulting in generally higher fecal coliform concentrations. *Enterococci* was evaluated on a maximum recreational season (May 1st through October 31st) 30-day GM basis. The 30-day period chosen for the *Enterococci* component analysis included both the maximum 30-day period and the 30-day period where the maximum contribution of CSOs to the GM was observed. Since the maximum 30-day period is not always the same in each tributary, the period chosen was based on the maximum 30-day period for Bergen and Thurston Basins, which have the highest calculated bacteria concentrations.

Table 6-12 summarizes the fecal coliform component analysis at selected water quality stations for the maximum winter month during 2008. As indicated in Table 6-12, for 2008, the fecal coliform criterion (monthly GM ≤200 cfu/100mL) is exceeded in Thurston Basin (TBH1, TB9, and TB10), Bergen Basin (BB5), and Fresh Creek (FC1). In each of those cases, the major contributor to the fecal coliform GM is MS4 stormwater or, for Fresh Creek, non-MS4 stormwater. At none of those stations does the CSO fecal coliform component exceed 200 cfu/100mL.

Table 6-12 also summarizes the *Enterococci* component analysis. The rolling 30-day GM of 35 cfu/100mL is exceeded in Thurston Basin (TBH1 and TB9), and in Bergen Basin (BB5). In each case, MS4

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

stormwater is the largest contributor to the rolling 30-day GM. The CSO component does not exceed 35 cfu/100mL at any of the stations shown.

Table 6-12 indicates that the relative impacts of CSO on attainment are most evident within Bergen Basin and Fresh Creek, although the extent of CSO contribution varies both spatially and temporally. In no case does the CSO influence by itself contribute more than 200 cfu/100mL to the fecal coliform GM.

Table 6-12. Fecal Coliform and *Enterococci* GM 2008 Source Components

Source	Station	Fecal Coliform Contribution (cfu/100mL)	*Enterococci* Contribution (cfu/100mL)
		Annual Worst Month December Monthly GM	Max 30-Day Rolling GM during the Recreational Season (May 1st through October 31st)
Thurston Basin			
Airport	TBH1	44	3
CSO	TBH1	91	18
Direct Drainage	TBH1	11	2
MS4	TBH1	2	0
Other	TBH1	0	0
Storm	TBH1	286	72
WRRF	TBH1	0	0
Total	TBH1	**434**	**5596**
Airport	TB9	25	2
CSO	TB9	61	8
Direct Drainage	TB9	16	3
MS4	TB9	2	0
Other	TB9	0	0
Storm	TB9	195	32
WRRF	TB9	0	0
Total	TB9	**300**	**45**
Airport	TB10	15	1
CSO	TB10	37	4
Direct Drainage	TB10	20	3
MS4	TB10	2	0
Other	TB10	0	0
Storm	TB10	127	15
WRRF	TB10	0	0
Total	TB10	**202**	**24**

Table 6-12. Fecal Coliform and *Enterococci* GM 2008 Source Components

Source	Station	Fecal Coliform Contribution (cfu/100mL)	*Enterococci* Contribution (cfu/100mL)
		Annual Worst Month December Monthly GM	Max 30-Day Rolling GM during the Recreational Season (May 1st through October 31st)
Bergen Basin			
Airport	BB5	23	2
CSO	BB5	115	4
Direct Drainage	BB5	1	0
MS4	BB5	1,042	221
Other	BB5	1	0
Storm	BB5	3	1
WRRF	BB5	1	1
Total	BB5	**1,185**	**230**
Airport	BB7	8	1
CSO	BB7	46	2
Direct Drainage	BB7	0	0
MS4	BB7	84	29
Other	BB7	0	0
Storm	BB7	5	1
WRRF	BB7	0	0
Total	BB7	**144**	**33**
Fresh Creek			
Airport	FC1	0	0
CSO	FC1	172	0
Direct Drainage	FC1	34	1
MS4	FC1	106	2
Other	FC1	0	0
Storm	FC1	364	14
WRRF	FC1	0	0
Total	FC1	**677**	**17**

Table 6-12. Fecal Coliform and *Enterococci* GM 2008 Source Components

Source	Station	Fecal Coliform Contribution (cfu/100mL)	*Enterococci* Contribution (cfu/100mL)
		Annual Worst Month December Monthly GM	Max 30-Day Rolling GM during the Recreational Season (May 1st through October 31st)
Hendrix Creek			
Airport	HC1	0	0
CSO	HC1	63	0
Direct Drainage	HC1	1	0
MS4	HC1	29	1
Other	HC1	0	0
Storm	HC1	76	6
WRRF	HC1	3	1
Total	HC1	**173**	**9**
Spring Creek			
Airport	SP1	0	0
CSO	SP1	68	0
Direct Drainage	SP1	4	1
MS4	SP1	43	1
Other	SP1	0	0
Storm	SP1	63	1
WRRF	SP1	0	0
Total	SP1	**178**	**3**
Paerdegat Basin			
Airport	PB2	0	0
CSO	PB2	90	0
Direct Drainage	PB2	0	0
MS4	PB2	53	5
Other	PB2	0	0
Storm	PB2	39	4
WRRF	PB2	0	0
Total	PB2	**181**	**9**

Table 6-12. Fecal Coliform and *Enterococci* GM 2008 Source Components

Source	Station	Fecal Coliform Contribution (cfu/100mL)	*Enterococci* Contribution (cfu/100mL)
		Annual Worst Month December Monthly GM	Max 30-Day Rolling GM during the Recreational Season (May 1st through October 31st)
Jamaica Bay			
Airport	J1	0	0
CSO	J1	3	0
Direct Drainage	J1	0	0
MS4	J1	1	0
Other	J1	0	0
Storm	J1	0	0
WRRF	J1	0	0
Total	J1	**4**	**0**
Airport	J5	0	0
CSO	J5	4	0
Direct Drainage	J5	0	0
MS4	J5	2	0
Other	J5	0	0
Storm	J5	1	0
WRRF	J5	0	0
Total	J5	**7**	**0**
Airport	J7	4	1
CSO	J7	0	0
Direct Drainage	J7	0	0
MS4	J7	20	5
Other	J7	0	0
Storm	J7	3	0
WRRF	J7	0	0
Total	J7	**47**	**7**

6.3.d Time to Recovery

The analyses provided above focused on the long term impacts of wet-weather sources, as is required by Existing Fecal Coliform WQ Criteria and the Amended *Enterococci* WQ Criteria* (monthly GM and 30-day GM, respectively). Shorter-term impacts are not evaluated using these regulatory criteria. Therefore, to gain insight to the shorter-term impacts of wet-weather sources of bacteria, DEP has reviewed the DOH guidelines relative to single sample maximum bacteria concentrations that DOH believes "constitute a potential hazard to health if used for bathing." The presumption is that if the bacteria concentrations are lower than these levels, then the waterbodies do not pose potential hazards if used for primary contact activities.

> **From NYS DOH**
>
> **https://www.health.ny.gov/regulations/nycrr/title_10/part_6/subpart_6-2.htm**
>
> **Operation and Supervision**
>
> 6-2.15 Water quality monitoring
> (a) No bathing beach shall be maintained … to constitute a potential hazard to health if used for bathing. To determine if the water quality constitutes a potential hazard … shall consider one or a combination of any of the following items: results of a sanitary survey; historical water quality model for rainfall and other factors; verified spill or discharge of contaminants affecting the bathing area; and water quality indicator levels specified in this section.
>
> (1) Based on a single sample, the upper value for the density of bacteria shall be: (i) 1,000 fecal coliform bacteria per 100 ml; or …(iii) 104 enterococci per 100 ml for marine water; ….

DOH considers fecal coliform concentrations that exceed 1,000 cfu/100mL to be potential hazards to bathing. Water quality modeling analyses were conducted to assess the amount of time following the end of rainfall required for Jamaica Bay and its tributaries to recover and return to concentrations of less than 1,000 cfu/100mL.

The approach to developing a "Time to Recovery" began with an analysis of LaGuardia Airport rainfall data for the period of 2002-2011. The Synoptic Surface Plotting (SYNOP) model was used to identify each individual storm and calculate the storm volume, duration, and start and end times. Rainfall periods separated by four hours or more were considered separate storms. Statistical analysis of the individual rainfall events for the recreational seasons (May 1^{st} through October 31^{st}) of the 10-year period resulted in a 90^{th} percentile rainfall event of 1.09 inches.

For Jamaica Bay, the JFK Airport rainfall event data was compared against water quality model bacteria results for the 10 recreational seasons to determine how long it took for the water column concentration to return to target threshold concentrations from the end of the rain event. The chosen target threshold concentration was 1,000 cfu/100mL for fecal coliform. The various rainfall events were then placed into rain event size "bins" ranging from less than 0.1 inch to greater than 1.5 inches. Only rain events that reached the target threshold concentrations before the beginning of the next storm were included. The median time to recovery for each bin at each water quality station was calculated. Table 6-13 presents the results for the greater than 1.0 to 1.5 inch rainfall bin, which includes the 90^{th} percentile event.

Table 6-13 presents the time to recovery for the baseline condition and the 100% CSO control scenario for Jamaica Bay and its tributaries. DEC has indicated that it seeks to have a time to recovery of less than 24 hours. Under the baseline conditions, Stations TBH1, TBH3, TB9, BB5, BB6, and FC1 have time to recovery greater than 24 hours, with values ranging from 32 to 39 hours. The other Jamaica Bay and its tributaries stations have time to recovery ranging between 0 and 23 hours.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Removal of CSOs from the Jamaica Bay tributaries (100% CSO control) results in a wide range of reduction in the time to recovery compared to baseline conditions. The time to recovery would be decreased by 0 to 12 hours, with the greatest reduction generally observed at the middle portions of the tributaries. In the head ends of tributaries influenced by other sources (Thurston Basin, Bergen Basin, and Fresh Creek), the time to recovery would still exceed 24 hours despite the removal of all CSO discharges.

Table 6-13. Time to Recovery

Station	Time to Recovery (hours) Fecal Coliform Threshold (1,000 cfu/100mL)(2)	
	Baseline	100% CSO Control
Thurston Basin		
TBH1(1)	38	37
TBH3(1)	36	32
TB9(1)	32	28
TB10(1)	21	17
TB11	0	0
TB12	0	0
Bergen Basin		
BB5(1)	39	37
BB6(1)	34	27
BB7(1)	19	13
BB8	5	0
Spring Creek		
SP1	6	6
SP2	0	0
Hendrix Creek		
HC1	18	11
HC2	17	8
HC3	8	1
Fresh Creek		
FC1	32	29
FC2	22	20
FC3	23	11
FC4	1	0
Paerdegat Basin		
PB2	19	9
PB3	6	3

Table 6-13. Time to Recovery

Station	Time to Recovery (hours) Fecal Coliform Threshold (1,000 cfu/100mL)[(2)]	
	Baseline	100% CSO Control
Jamaica Bay (Northern Shore)		
J10	3	1
J3	0	0
J9a	0	0
J8	0	0
J7	5	0
JA1	1	0
Jamaica Bay (Inner Bay)		
J2	0	0
J12	0	0
J14	0	0
J16	0	0
Jamaica Bay (Rockaway Shore)		
J1	0	0
J5	0	0

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) Time to recovery values presented for 2008 storms in the size range of >1.0 to 1.5-inches of rainfall, which includes the 90th percentile rain event.

In summary, the time to recovery for most of the monitoring stations under baseline conditions appears to be on the order of DEC's desired target of 24 hours, except for the head ends of Thurston Basin, Bergen Basin, and Fresh Creek. However, stations located near the head ends of Thurston Basin and Bergen Basin would still exceed the 24 hour target upon 100% removal of CSO loadings, indicating that non-CSO sources influence time to recovery following wet-weather events.

Attachment G
Section 8 – Evaluation of Alternatives

8.0 EVALUATION OF ALTERNATIVES

This section describes the development and evaluation of CSO control measures and watershed-wide alternatives. A CSO control measure is defined as a technology (e.g., treatment or storage), practice (e.g., NMC or BMP), or other method (e.g., source control or GI) of abating CSO discharges or the effects of such discharges on the environment. Alternatives evaluated are comprised of a single CSO control measure or a group of control measures that will collectively address the water quality objectives for Jamaica Bay and its tributaries.

This section contains the following information:

- Process for developing and evaluating CSO control alternatives that reduce CSO discharges and improve water quality (Section 8.1).
- CSO control alternatives and their evaluation (Section 8.2).
- CSO reductions and water quality benefits achieved by the higher-ranked alternatives, as well as their estimated costs (Sections 8.3 and 8.4).
- Cost-performance and water quality attainment assessment for the higher-ranked alternatives for the selection process of the preferred alternative (Section 8.5).

As presented in Section 6.3, Table 6-5, Classifications and Standards Applied, levels of attainment of fecal coliform and *Enterococci* bacteria WQ criteria and DO WQ criteria were used to evaluate CSO control alternatives. These evaluations included both Existing WQ Criteria for fecal coliform as currently applicable to the waters considered in this LTCP and Amended *Enterococci* WQ Criteria* that only apply to Jamaica Bay (a coastal Class SB waterbody) on a recreation seasonal basis, but not the tributaries (all Class I waterbodies).

8.1 Considerations for LTCP Alternatives Under the Federal CSO Policy

This LTCP addresses the water quality objectives of the CWA and the New York State Environmental Conservation Law. This LTCP also builds upon the conclusions presented in DEP's November 2012 Jamaica Bay WWFP.

As required by the CSO Order, when the proposed alternative set forth in the LTCP will not achieve Existing WQ Criteria or the Section 101(a)(2) goals, a Use Attainability Analysis (UAA) must be prepared. A UAA is the mechanism to examine whether applicable waterbody classifications, criteria, or standards should be adjusted by the State. If deemed necessary, the UAA would assess compliance with the next higher classification that the State would consider in adjusting WQS and developing waterbody-specific criteria. The remainder of Section 8.1 discusses the development and evaluation of CSO control measures and watershed-wide alternatives in accordance with the CWA in general, and with the CSO Control Policy in particular. This section describes the evaluation factors considered for each alternative and a description of the process for evaluating the alternatives.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

8.1.a Performance

A summary of the IW model output data for volume and frequency of discharge of the CSO outfalls to Jamaica Bay and its tributaries is provided in Table 8-1. The locations of these outfalls are shown in Figure 8-1.

Table 8-1. CSO Discharges Tributary to Jamaica Bay and Its Tributaries (2008 Typical Year)

Receiving Waters	Combined Sewer Outfalls	Discharge Volume(1) (MGY)	No. of Discharges(1)	Percentage of Total CSO Discharge to Jamaica Bay
Thurston Basin	**JAM-005/007**	**658 (247)**	**73 (26)**	**30.0%**
Bergen Basin	JAM-003	107	17	4.9%
	JAM-003A	223	33	10.2%
	JAM-006	3	14	0.1%
	Subtotal	**333**	**33**	**15.2 %**
Spring Creek(2)	**26W-005**	**292**	**6**	**13.3%**
Hendrix Creek	**26W-004**	**85**	**26**	**3.9%**
Fresh Creek	**26W-003**	**232**	**12**	**10.6%**
Paerdegat Basin(2)	Tank Overflow	553	12	25.2%
	CI-004/005/006	38	5	1.7%
	Subtotal	**591**	**12**	**27.0%**
Jamaica Bay	**Rockaway Outfalls(3)**	**0**	**0**	**0.0%**
Jamaica Bay and its Tributaries	**Total CSO**	**2,191 (1,780)**	**73 (33) max.**	**100%**

Notes:

(1) CSO volumes and activation frequency are based upon overflow at the respective weirs and do not account for stormwater contributions to the outfall downstream of the regulator with the exception of Thurston Basin, which is based upon the sum of the CSO and stormwater discharges just downstream of Regulators JA-06, JA-07, and JA-08. The values in parentheses are the specific CSO AAOV and frequency of flow that tips over the weirs and diversion structures within the Thurston Basin drainage area.

(2) The Spring Creek AWWTP and the Paerdegat Basin CSO Retention Facility provide floatables control and settling prior to overflow of storms exceeding the tank storage capacity.

(3) The Rockaway CSOs do not activate during the typical 2008 rainfall year.

As indicated in Table 8-1, six CSO discharge points - JAM-005/007, JAM-003, JAM-003A, 26W-003, 26W-005, and tank overflows at Paerdegat Basin - generate approximately 94 percent of the total annual CSO discharge volume. These overflows generally contribute the largest volume of CSO and are located near the head ends of five Jamaica Bay tributaries: Thurston Basin, Bergen Basin, Fresh Creek, Spring Creek, and Paerdegat Basin, respectively.

CSO facilities currently exist at the head ends of Spring Creek and Paerdegat Basin. Under 2008 conditions, the Spring Creek AWWTP discharges approximately 292 MG of CSO, while the Paerdegat CSO Retention Facility discharges 553 MG. While the discharge volumes from these two CSO facilities make up about 41 percent of the total CSO volume, the frequency is 12 events or less per year. Outfalls JAM-005, JAM-007, JAM-003, JAM-003A, and 26W-003 account for 55 percent of the CSO volume and activate 12 to 73 times in response to wet-weather events under 2008 conditions.

DEP's analysis indicates that CSO Outfall 26W-004 discharges an estimated 26 times to Hendrix Creek for a total annual volume of 85 MG under 2008 conditions. CSO discharge from JAM-006 to Bergen Basin is very small (3 MG), primarily stormwater and relatively infrequent (14 events) under 2008 conditions. Although JAM-006 is identified as a permitted CSO outfall, it predominantly conveys stormwater from the collection system serving Southeast Queens.

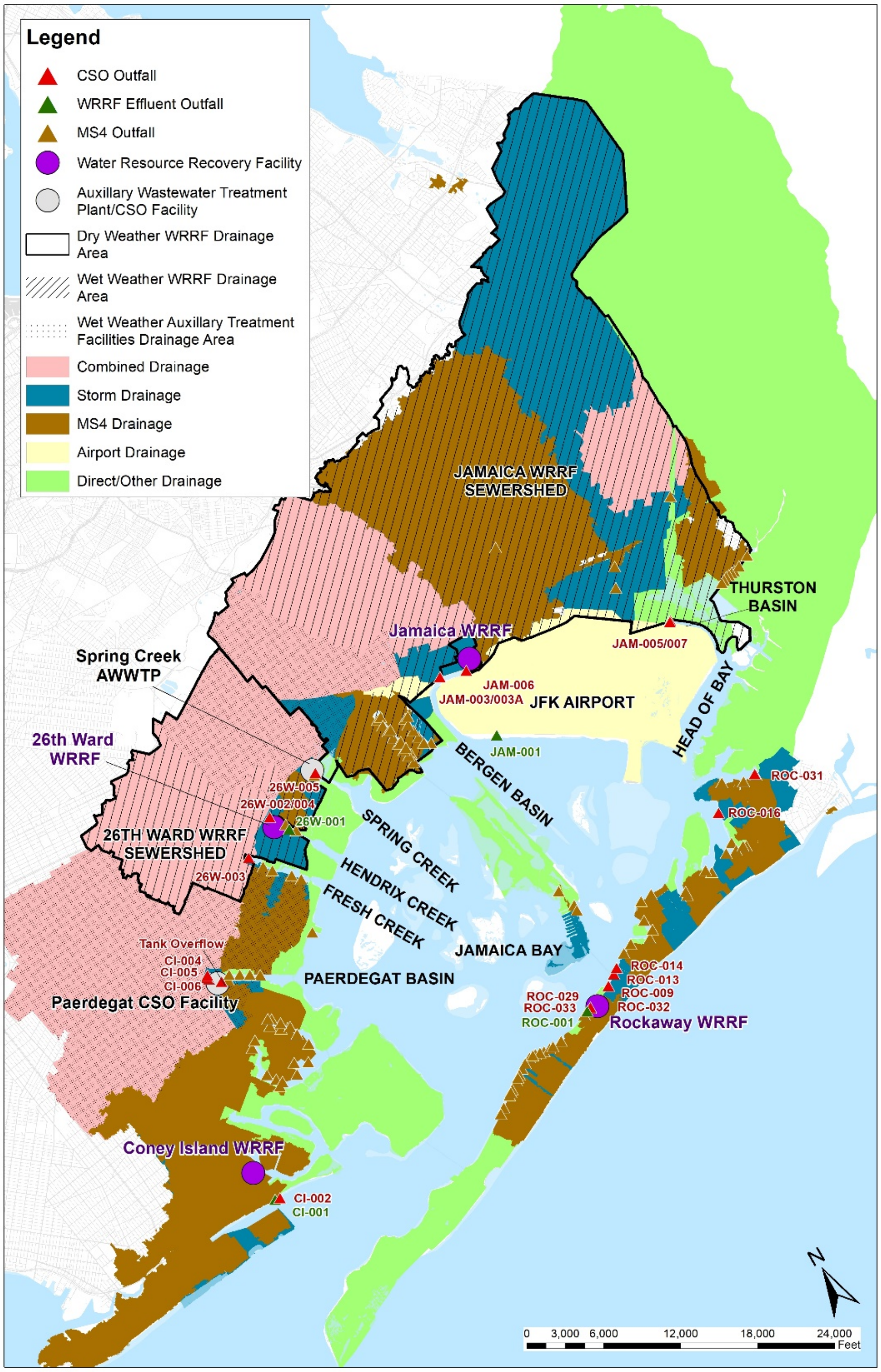

Figure 8-1. CSO Discharges to Jamaica Bay and Its Tributaries

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Stormwater flows also heavily influence Jamaica Bay and its tributaries. Table 8-2 summarizes and categorizes all wet-weather discharges to Jamaica Bay, its tributaries that receive CSO, as well as Head of Bay and other tributaries which only receive stormwater discharges. The total model predicted volume of stormwater discharged to the Jamaica Bay watershed, under 2008 typical year rainfall conditions, is 19,343 MG, which is approximately 11 times greater than the modeled CSO volume (1,780 MG). Approximately 6,724 MG of stormwater runoff from Nassau County is discharged to Head of Bay, which can influence the conditions in Jamaica Bay and Thurston Basin. Jamaica Bay receives an additional 6,656 MG of stormwater from DEP MS4 outfalls, other outfalls, or direct runoff from Rockaway, Brooklyn, Queens, and JFK Airport. Of the tributaries that receive CSO, Bergen Basin receives the greatest stormwater discharge of 3,276 MG under 2008 typical year rainfall conditions. Due to the high frequency of activation, stormwater can influence pathogen and dissolved oxygen (DO) attainment in waterbodies despite the lower concentration of pathogens and biochemical oxygen demand (BOD).

Table 8-2. Estimated Stormwater Discharges Tributary to Jamaica Bay and its Tributaries (2008 Typical Year)

Waterbody	Total (MG)	DEP MS4 (MG)	SW(4) (MG)	Airport (MG)	Direct(5) (MG)
Jamaica Bay(1)	6,656	2,489	1,243	957	1,967
Bergen Basin	3,276	2,835	117	302	22
Thurston Basin(3)	782 (1,193)	-	349 (760)	372	61
Fresh Creek	528	216	279	-	33
Hendrix Creek	111	36	41	-	34
Spring Creek	141	26	38	-	77
Paerdegat Basin	352	197	113	-	42
Head of Bay (Nassau Co.)	6,724	291	49	141	6,243
Other Tributaries(2)	362	326	36	-	-
Total	18,932 (19,343)	6,416	2,265 (2,676)	1,772	8,479

Notes:

(1) Grassy Bay, Hassock Creek, Grass Hassock Creek, Shell Bank Creek, Mill Basin, and Rockaway are included with Jamaica Bay.
(2) Other tributaries include Hawtree and Shellbank Basins.
(3) The values shown are the model predicted stormwater volumes based upon the inclusion of stormwater discharges just downstream of Regulators JA-06, JA-07, and JA-08 in the CSO AAOV for Thurston Basin. The values in parenthesis are the estimated stormwater flow coming out of Outfalls JAM 005/007 excluding the 215 MGY of CSO that tips over the weirs and diversion structures in the upstream sewers.
(4) Stormwater (SW) consists of all outfalls except for DEP MS4 and airport stormwater sources.
(5) Direct drainage consists of all remaining drainage areas not tributary to defined CSO, MS4, and SW subcatchments.

To determine the influence of CSO control on the attainment of existing and amended WQ criteria, a Performance Gap Analysis was performed for Jamaica Bay and the tributaries. The results of the analysis are summarized in Section 6.3. The evaluations concluded that a performance gap exists because, under baseline conditions, the Existing WQ Criteria for fecal coliform bacteria will not be attained in Thurston Basin, Bergen Basin, and Fresh Creek, the Amended *Enterococci* STV WQ Criteria* will not be attained in portions of Jamaica Bay adjacent to the tributaries, and the Class I DO criterion will not be attained in Thurston Basin, Bergen Basin, and Hendrix Creek. As a result, the evaluation of performance for the

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

LTCP alternatives related to bacteria focused on improving the attainment of Existing WQ Criteria for fecal coliform and the designated Class I DO criterion (>4.0 mg/L) for these tributaries. The alternatives evaluations also considered the level of control necessary to achieve the DEC goal for a time to recovery of less than 24 hours after a wet-weather event. Additionally, DEP evaluated projected attainment with the Amended *Enterococci* WQ Criteria*, although the Amended *Enterococci* WQ Criteria* applies only to coastal Class SB waters during the recreational season (May 1st through October 31st) and not to Class I waters.

The analyses in Section 6 showed that under baseline conditions, annual attainment with Existing WQ Criteria for fecal coliform ranged from 57 to 100 percent, with lower attainment projected towards the head end of the receiving waters. While 100% CSO control would be expected to improve overall annual attainment with the Existing WQ Criteria for fecal coliform, modeling still projects non-attainment in Bergen Basin, Thurston Basin, and Fresh Creek, with an annual attainment of 59 percent, 77 percent, and 90 percent, respectively. Under baseline conditions during the recreational season (May 1st through October 31st), attainment with Existing WQ Criteria for fecal coliform ranged from 72 to 100 percent, with lower attainment projected towards the head ends of the waterbodies. While 100% CSO control would improve projected recreational season (May 1st through October 31st) attainment with Existing WQ Criteria for fecal coliform, modeling still projected non-attainment in Bergen and Thurston Basins, with a recreational season (May 1st through October 31st) attainment of 77 percent and 88 percent for these waterbodies.

Annual attainment is achieved at all stations in Jamaica Bay for Existing Class SB bacteria and DO WQ criteria. Annual attainment in the tributaries for the Existing Class I WQ Criteria for DO is projected to range between 89 and 100 percent under baseline conditions. Based on a modeled 100% CSO control, improvements in dissolved oxygen attainment are projected to be in the range of 1 to 3 percent.

The primary goals for the development and evaluation of control alternatives are to achieve bacteria load reduction and to attain applicable WQ criteria. The control of floatables is also an important goal and is a consideration for all alternatives. The evaluation of control alternatives typically follows a two-step process. First, based upon IW watershed model runs for the 2008 typical year rainfall, the level of CSO control of each alternative is established, including the reduction of CSO volume, fecal coliform, and *Enterococci* loading. The second step uses the estimated levels of CSO control to project levels of attainment in the receiving waters. This latter step uses the Jamaica Eutrophication Model (JEM) Water Quality Model. LTCPs are typically developed with alternatives that span a range of CSO volumetric (and loadings) reductions. Accordingly, this LTCP includes alternatives that consider a wide range of reductions in CSO loadings - up to 100% CSO control - including investments in green and grey infrastructure. Intermediate levels of CSO volume control, approximately 25, 50, and 75 percent, are typically also evaluated. Table 8-3 provides a summary of the required storage volume and associated peak flow rates that would have to be diverted from the outfalls for each of these levels of CSO control for the six largest CSO outfalls.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 8-3. Summary of Storage and Peak Flow Rates Required for Each Level of CSO Control for the Six Largest Outfalls

Waterbody	Required Capacity(1)	25% CSO Control	50% CSO Control	75% CSO Control	100% CSO Control
Thurston Basin (JAM-005/007)	Storage Capacity (MG)	6	9	29	91
	Peak Flow (MGD)(2)	5	17	54	280
Bergen Basin (JAM-003/003A)	Storage Capacity (MG)	4	8	19	45
	Peak Flow (MGD)(2)	22	55	121	555
Fresh Creek (26W-003)	Storage Capacity (MG)	6	15	28	53
	Peak Flow (MGD)(2)	35	90	175	710
Spring Creek (26W-005)	Storage Capacity (MG)	11	26	37	72
	Peak Flow (MGD)(2)	71	154	256	454

Notes:
(1) The storage capacity and peak flow rates are based upon the points along the outfall where CSO would be diverted for a storage or treatment alternative.
(2) Peak flow that would have to be conveyed to storage or treatment to provide the targeted level of CSO control.

Figure 8-2 and Figure 8-3 show plots of the required volumes and flow rates for these six outfalls.

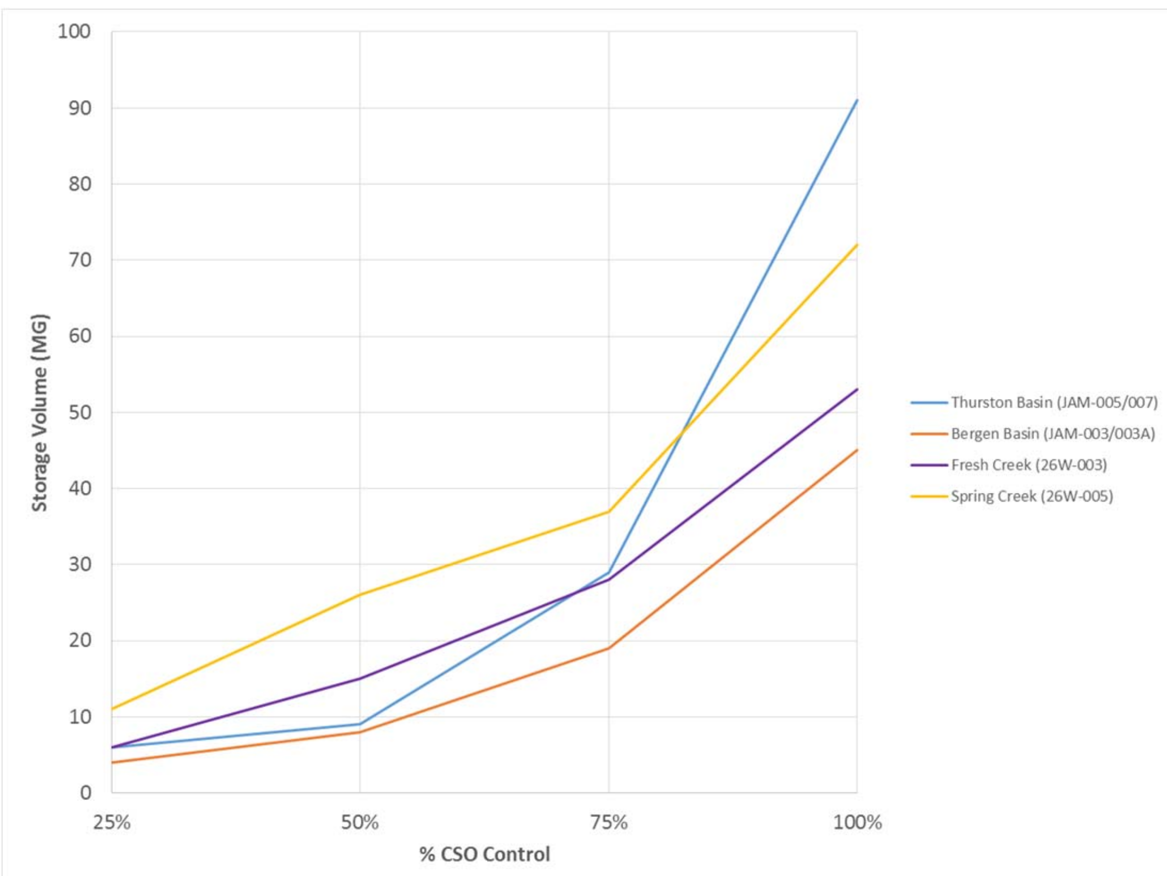

Figure 8-2. Required Storage Volume for Various Levels of CSO Control for Six Largest Outfalls

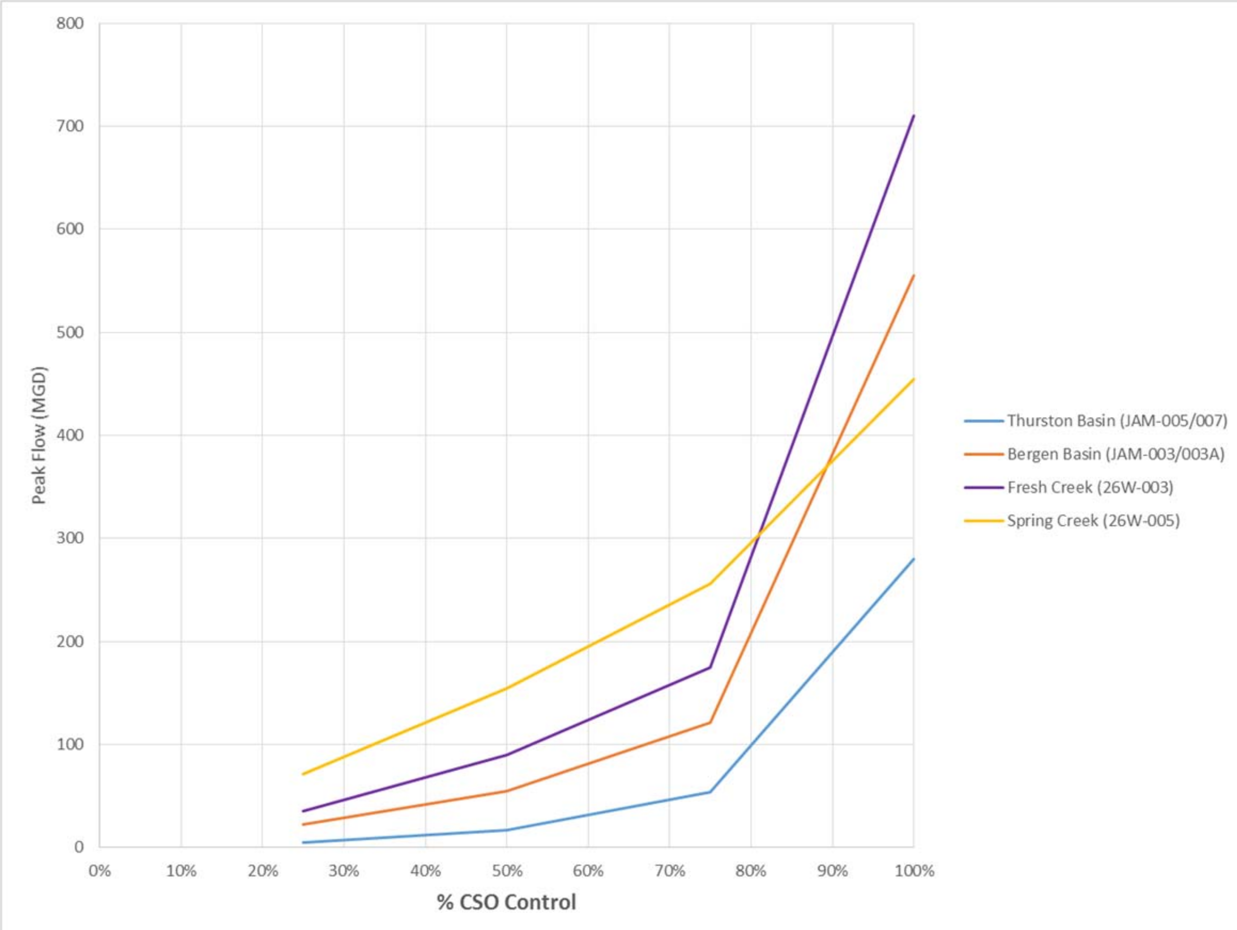

Figure 8-3. Required Flow Rates for Various Levels of Control for Six Largest Outfalls

8.1.b Impact on Sensitive Areas

In developing LTCP alternatives, special effort was made to enhance water quality in sensitive areas and to minimize the impact of construction, to protect existing sensitive areas. As described in Section 2.0, Jamaica Bay and its tributaries were identified as a sensitive area based on the presence of "Threatened or Endangered Species and their Habitat." Jamaica Bay is also classified as a 'Best Use – Primary Contact Recreation' area. Thus, DEP prioritized alternatives based on controlling overflows in the tributaries, while also considering construction impacts, as appropriate. No CSOs currently discharge directly to Jamaica Bay during the typical year.

8.1.c Cost

Cost estimates for the alternatives were computed using a costing tool based on parametric costing data. This approach provides an Association for the Advancement of Cost Engineering (AACE) International Class 5 estimate (accuracy range of minus 20 to 50 percent to plus 30 to 100 percent), which is typical and appropriate for this type of planning evaluation. For the purpose of this LTCP, all cost estimates developed for the evaluation of alternatives are in June 2018 dollars unless specifically noted otherwise.

For the estimate of the construction costs for the LTCP alternatives, DEP used the June 2018 Probable Bid Cost (PBC). Annual operation and maintenance costs were then used to calculate the total or Net Present Worth (NPW) over the projected useful life of the project. A lifecycle of 100 years and an interest rate of 4.0 percent were assumed resulting in a Present Worth Factor of 24.505. A 100-year lifecycle was applied for all alternatives, for consistency with the longer service life of the tunnel alternatives.

To quantify costs and benefits, alternatives were compared based on reductions of both CSO discharge volume and bacteria loading against the total cost of the alternative. These costs were then used to plot the performance and attainment curves. A pronounced inflection point appearing in the resulting graphs, the so-called knee-of-the-curve point, suggests a potential cost-effective alternative for further consideration. In theory, this would reflect the alternative that achieves the greatest appreciable water quality improvements per unit of cost. However, cost/performance or cost/attainment curves do not always identify a distinct “knee,” and if an alternative does fall on a distinct “knee,” it may not necessarily be the Recommended Plan. The Recommended Plan must be capable of improving water quality in a fiscally responsible and affordable manner to ensure that resources are properly allocated across the overall citywide LTCP program. These monetary considerations also must be balanced with non-monetary factors, such as construction impacts, environmental benefits, technical feasibility, and operability, which are discussed below.

8.1.d Technical Feasibility

Several factors were considered when evaluating technical feasibility, including:

- Effectiveness for controlling CSO
- Reliability
- Implementability

The effectiveness of CSO control measures was assessed based on their ability to reduce CSO frequency, volume, and load. Reliability is an important operational consideration, and can have an impact on overall effectiveness of a control measure. Therefore, DEP reviewed past reliability and historical operational records when reviewing the technical feasibility of a CSO control measure.

DEP considered several site-specific factors to evaluate an alternative’s implementability, including available space, neighborhood assimilation, impact on parks and green space, and overall practicability of installing - and later maintaining - CSO controls. In addition, the method of construction was factored into the final selection. Some technologies require specialized construction methods that typically incur additional impacts and costs.

8.1.e Cost-Effective Expansion

All alternatives evaluated were sized to handle the CSO volumes based on the 2008 typical year rainfall and 2040 design year dry-weather flows, with the understanding that the predicted and actual flows may differ. To help mitigate the difference between predicted and actual flows, adaptive management was considered for those CSO technologies that can be expanded in the future to capture or treat additional CSO flows or volumes, should it be needed. In some cases, this may have affected where the facility would be constructed, or gave preference to a facility that could be expanded at a later date with minimal cost and disruption of operation.

Breaking construction into segments allows adjustment of the design of future phases based on the performance of already-constructed phases. Lessons learned during operation of current facilities can be incorporated into the design of future facilities. However, phased construction also exposes the local community to a longer construction period. Where applicable, for those alternatives that can be expanded, the LTCP takes into account the ease of expansion, what additional infrastructure may be required, and if additional land acquisition would be needed.

As regulatory requirements change, other water quality improvements may be required. The ability of a CSO control technology to be retrofitted to address additional pollutant parameters or more stringent discharge limits strengthens the case for application of that technology.

8.1.f Long Term Phased Implementation

Recommended LTCP implementation steps associated with the identification of the Recommended Plan are typically structured in a way that makes them adaptable to change by expansion and modification resulting from possible new regulatory and/or local drivers. If applicable, the project(s) would be implemented over a multi-year schedule. Because of this, permitting and approval requirements must be identified prior to selection of the alternative. With the exception of GI, which is assumed to occur on both private and public property, most of the CSO grey technologies target municipally owned property and right-of-way acquisitions. DEP will work closely with other NYC agencies and, as necessary, with NYS, to ensure proper coordination with other government entities.

8.1.g Other Environmental Considerations

DEP has considered minimizing impacts on the environment and surrounding neighborhood during construction. These impacts could potentially include traffic, site access issues, park and wetland disruption, noise pollution, air quality, and odor emissions. To minimize environmental impacts, they will be identified with the selection of the Recommended Plan and communicated to the public. The specific details on mitigation of the identified concerns and/or impacts, such as erosion control measures and the rerouting of traffic are addressed later as part of a pre-construction environmental assessment.

8.1.h Community Acceptance

As described in Section 7, DEP is committed to involving the public, regulators, and other stakeholders throughout the planning process. Community acceptance of the Recommended Plan is essential to its success. As such, DEP uses the LTCP public participation process to present the scope of the LTCP, background, newly collected data, WQ Criteria and the development and evaluation of alternatives to the public and to solicit its support and feedback. The Jamaica Bay LTCP is intended to improve water quality, and public health and safety are its priorities. The goal of raising awareness of and access to waterbodies was also considered throughout the alternative analysis. Several CSO control measures, such as GI, have been shown to enhance quality of life in communities, as well as increasing local property values. As such, the benefits of GI were considered in the formation of the baseline and the final Recommended Plan. Environmental improvements have been also considered, such as restoration of tidal wetlands and shellfish beds to provide bioextractor elements for improving water quality and to enhance aquatic and wildlife habitat.

8.1.i Methodology for Ranking Alternatives

The multi-step evaluation process DEP used to develop the Jamaica Bay LTCP included meetings with DEP staff, regulators, and stakeholders as listed below:

1. Evaluated benchmarking scenarios, including baseline and 100% CSO control, to establish a range of controls within the Jamaica Bay watershed for consideration. The results of this step are described in Section 6.
2. Used baseline conditions to prioritize the CSO outfalls for possible controls.
3. Developed a list of promising control measures for further evaluation based in part on the prioritized CSO list.
4. Established levels of intermediate CSO control that provide a range between baseline and 100% CSO control for the receiving water quality simulations that were conducted.
5. Held a technical workshop with DEC staff on March 30, 2017, to present water quality sampling results, baseline modeling, WQ Criteria attainment, preliminary gap analysis, and to review the progress to-date on the alternatives development.
6. Evaluated impacts of DEP's Sewer Buildout Program, Downtown Jamaica Rezoning, and GI on the LTCP IW Modeling.
7. Toured the Monroe County (Rochester, NY) CSO tunnel on May 10, 2017, to solicit feedback and lessons learned.
8. Conducted a workshop with DEP operations staff on May 24, 2017, to review the progress to-date on the alternatives development and to solicit input on operability.
9. Conducted a technical workshop with DEC staff on October 18, 2017, to discuss model updates to account for up-zoning in Downtown Jamaica, present water quality modeling results, modeled WQ Criteria attainment projections, and the updated gap analyses.
10. Conducted a workshop with DEP operations staff on November 16, 2017, to review the progress to-date on the alternatives development and to solicit input on operability, and to select a shortlist of retained alternatives.
11. Conducted a DEP Inter-Bureau Workshop on January 26, 2017, to review the progress to-date on the alternatives development and to solicit input on operability.
12. Held an Inter-Bureau Workshop on March 22, 2018 to present the Recommended Plan and solicit comments from DEP operations staff.
13. Conducted a technical workshop with DEC staff on April 4, 2018 to present updated IW and water quality modeling, evaluation of retained alternatives, and present the Recommended Plan.
14. Held a supplemental technical workshop with DEC staff on April 13, 2018 to address comments received at the prior meeting.
15. Conducted a public meeting on April 18th to discuss the Jamaica Bay LTCP Alternatives.
16. Met with various public interest groups and other stakeholders throughout the month of May 2018 to present the Recommended Plan and solicit comments.

17. Conducted an additional technical workshop with DEC staff on May 31, 2018 to present further details on the evaluation of retained alternatives, discuss public comments, and provide additional support for the Recommended Plan.
18. See Section 7 for additional stakeholder meetings.

The focal points of this process were the meetings and workshops listed above. Prior to the first meeting, the control measures evaluated in the Jamaica Bay WWFP were revisited from the perspective of the LTCP goal statement and in light of the implemented WWFP controls. Additional control measures were also identified and assessed. The resultant control measures were introduced at the first meeting. Based on discussions at that meeting, further additional control measures were identified. A preliminary evaluation of these control measures was then conducted including an initial estimation of costs and water quality CWA impacts. During the subsequent meetings, promising alternatives were reviewed in more detail. The LTCP workshops, attended by a broader array of DEP operational and engineering staff, included updated alternative assessments. Meetings with DEC and public interest groups and other stakeholders were held to communicate the status of the LTCP development and solicit feedback on retained alternatives and the Recommended Plan.

Categories of control measures considered include: Source Control, System Optimization, CSO Relocation, Water Quality/Ecological Enhancement, and Treatment and Storage. Specific control measures considered under each category were as follows:

Source Control

- Additional and Existing Green Infrastructure
- High Level Storm Sewers

System Optimization

- Fixed Weir Modifications
- Bending Weirs or Control Gates
- Pumping Station Modifications
- Parallel Interceptor/Sewer

CSO Relocation

- Gravity Flow Tipping to Other Watersheds
- Flow Tipping with Conduit/Tunnel and pumping

Water Quality/Ecological Enhancement

- Floatables Control
- Environmental Dredging
- Mechanical Aeration
- Tidal Wetlands
- Bioextractors (ribbed mussels)

Treatment

- Outfall Disinfection
- Retention Treatment Basin
- High Rate Clarification
- WRRF Upgrades

Storage

- In-System
- Shaft
- Tank
- Tunnel

Figure 8-4 presents these control measures by category.

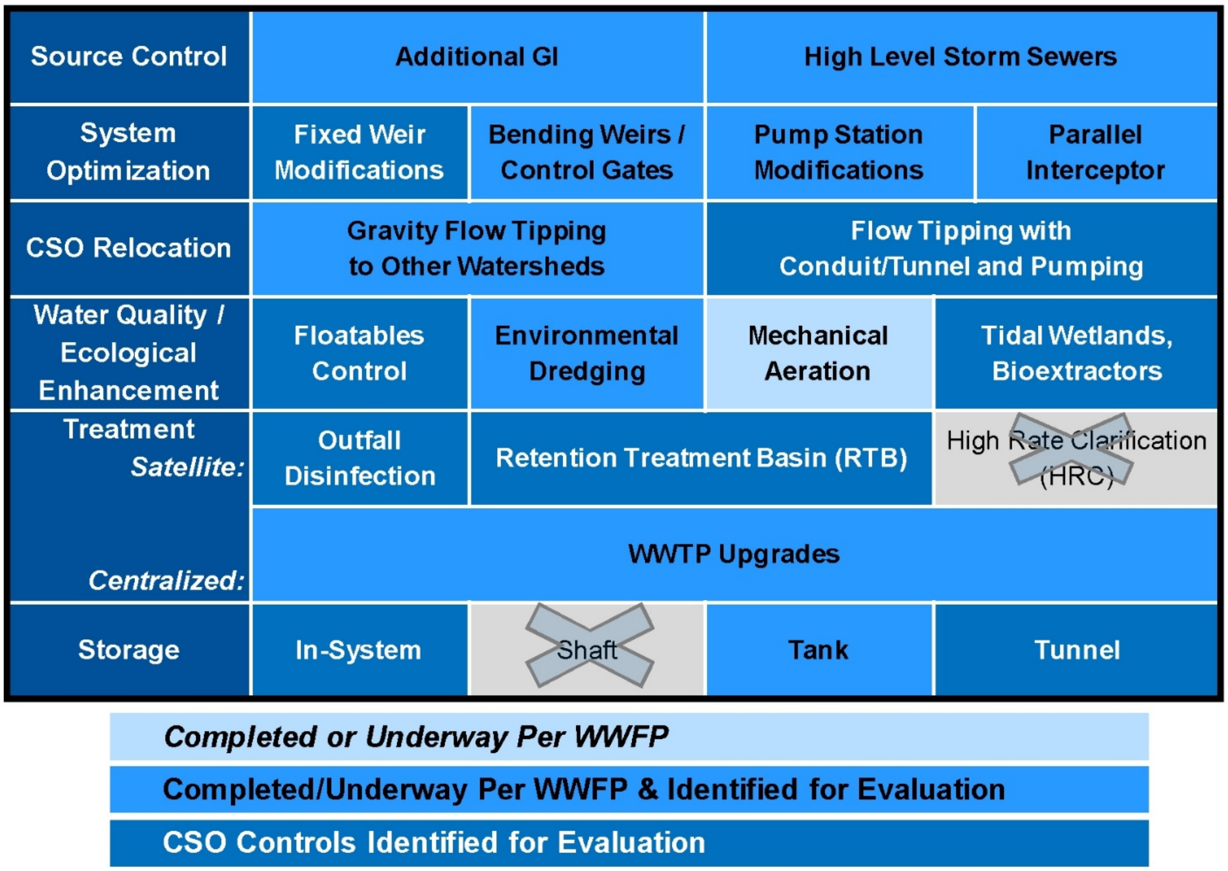

Figure 8-4. Matrix of CSO Control Measures for Jamaica Bay

Following the initial screening meeting, control measures were advanced to a second level of evaluation with the exception of the following (either marked with an "X" or highlighted as an ongoing project in Figure 8-4):

- *Mechanical Aeration*: The Shellbank Basin Destratification System was recommended in the Jamaica Bay WWFP to address DO attainment issues. The project was completed in November 2010. Based on the Water Quality Analysis presented in Section 6, impacts to DO levels in the Jamaica Bay tributaries were not found to be significantly influenced by the CSO discharges in these waterbodies. While attainment results were projected to fall just short of the 95% attainment goal at monitoring stations in Thurston Basin (90% at TBH1 and TBH3), Bergen Basin (89% at BB5) and Hendrix Creek (94% at HC1), modeling of 100% CSO capture had negligible improvements (ranging from 1-3%) for DO attainment. As a result, this alternative was eliminated from further consideration.

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- *High Rate Clarification*: High rate clarification is typically employed for CSO discharges when high levels of suspended solids and BOD reductions are targeted for control in addition to bacteria and floatables. Due to space constraints for remote application and at existing WRRFs, this technology was eliminated form further consideration.
- *Storage Shafts*: Shaft storage involves constructing a deep circular shaft to provide storage, with pump-out facilities to dewater the shaft after the storm event. Shaft storage construction techniques would be similar to those used to construct deep tunnel drop or access shafts. The benefit of shaft storage is that it allows for relatively large storage volumes with relatively small facility footprints. Disadvantages of shaft storage include limits to the depth of shafts, complex dewatering pumping operations, and difficult maintenance. Another disadvantage is that very few operating shaft storage systems exist from which to gain insight on operational issues and experience. Finally, the largest shaft currently in operation is 7.5 MG. Using that size as a maximum, multiple units would be required at the largest Jamaica Bay outfalls. Because the range of levels of CSO control could be provided by more conventional tunnels, storage shafts do not offer advantages sufficient to outweigh their disadvantages. For these reasons, shaft storage was eliminated from further evaluation.

The evaluation of the retained control measures is described in Section 8.2.

8.2 Matrix of Potential CSO Reduction Alternatives to Close Performance Gap from Baseline

Each control measure was initially evaluated on three of the key considerations described in Section 8.1: (1) benefits, as expressed by level of CSO control and attainment; (2) costs; and (3) challenges, such as siting and operations. Using this methodology, the retained control measures listed in Section 8.1 were evaluated on a cost-performance basis and used to develop the basin-wide alternatives.

Following the LTCP outline, these control measures are described under the following categories: Other Future Grey Infrastructure, Other Future Green Infrastructure and subsets thereof.

8.2.a Other Future Grey Infrastructure

For the purpose of this LTCP, "Other Future Grey Infrastructure" refers to potential grey infrastructure beyond existing control measures implemented based on previous planning documents. "Grey infrastructure" refers to systems used to control, reduce, or eliminate discharges from CSOs. These are the technologies that DEP and other wastewater utilities typically have used in their CSO planning and implementation programs. They include retention tanks, tunnels and treatment facilities, including satellite facilities, and other similar capital-intensive facilities.

Grey infrastructure projects implemented under previous CSO control programs and facility plans, such as the Jamaica Bay WWFP, are described in Section 4. To summarize, those projects include:

1. Spring Creek AWWTP Upgrades – provides 20 MG of storage capacity and was completed in April 2007;

2. Meadowmere and Warnerville DWO Abatement – addressed dry- and wet-weather overflows to Jamaica Bay by separating sewers and redirecting flows to the WRRF. The project was completed in 2009;

3. Automation of Regulator JA-02 – installed an electro-hydraulic actuator for automation and was completed in June 2010;

4. Paerdegat Basin CSO Facility – provides 50 MG of storage capacity and was completed in 2011;

5. Paerdegat Basin Dredging – removed approximately 20,000 cubic yards of accumulated sediment mounds at the mouth and head end of the basin. The project was completed in 2014;

6. Hendrix Creek Dredging – removed accumulated sediment mounds exposed at low tide in the area of CSO outfalls. The project was completed in 2012;

7. New 48" Parallel Sewer to Jamaica WRRF – installed to provide supplementary capacity to the existing West Interceptor and improve conveyance of wet-weather combined flow to the WRRF. The 3,500 linear feet (LF) parallel dry-weather sewer was substantially complete in 2016; full functionality of the new parallel sewer is contingent on completion of a new sanitary sewer currently in design, with construction completion scheduled for October 2021.

8. Regulator Improvements at JA-03, JA-06, and JA-14 – installed bending weirs to improve conveyance of wet-weather flow to Jamaica WRRF. The project was completed in 2017;

9. 26th Ward WRRF Wet-Weather Stabilization – will improve flow distribution and increase reliability of preliminary treatment. Construction is ongoing and expected to continue through 2020;

10. 26th Ward High Level Storm Sewers – will divert stormwater from the combined sewer system to reduce CSO discharges and alleviate street flooding. The project is scheduled to be completed in 2022;

11. Laurelton and Springfield Boulevard Storm Sewer Buildout – will reduce inflow sources to the collection system, the volume of CSO discharges and alleviate flooding. The project is ongoing and is expected to take several decades to complete. Given the schedule for this project, it has not been included in the LTCP Baseline Conditions or the LTCP Recommendation Plan.

The technologies identified in the Matrix of CSO Control Measures for Jamaica Bay (Figure 8-4) falls into six broad categories:

Source Controls capture or manage pollutants at their source. DEP monitors and appropriately addresses infiltration/inflow in compliance with its SPDES Permits. By definition, combined sewers receive stormwater inflow from catch basins, yard drains, roof leaders and other sources. The Baseline Conditions for the InfoWorks modeling for the LTCP takes into account the reduction of inflow sources associated with HLSS recommended under the Jamaica Bay WWFP and GI. In addition, infiltration/inflow to the Paerdegat Basin CSO Facility and the Spring Creek AWWTP, as well as each WRRF sewershed, is also accounted for in the InfoWorks modeling. Additional source controls, such as HLSS, additional GI and other measures, were evaluated to further reduce stormwater inflow to the collection systems covered under the LTCP.

The Southeast Queens (SEQ) Storm Sewer Buildout Program is being implemented to address the general lack of stormwater drainage in the areas of Southeast Queens tributary to the Jamaica WRRF. While this project is ongoing and expected to require several decades to complete, it will divert stormwater (inflow sources) from the collection system over time to new storm sewer spines sized to address drainage capacity needs throughout the Jamaica WRRF sewershed.

CSO Relocation, involves the transfer of flow between drainage areas to optimize collection system performance and flow to the WRRF or to divert CSO to other waterbodies that are less sensitive or provide greater dilution/assimilation than the one from which the CSO is being diverted.

Water Quality/Ecological Enhancement alternatives improve water quality through mechanical operations such as floatables control baffles, nets or booms, dredging and aeration. These alternatives also include natural methods such as restoration of tidal wetlands and bioextractors (*Guekensis demissa* aka ribbed mussels). While these alternatives do not reduce CSO volumes to the waterbodies, they provide water quality improvements through extraction and uptake, restore or improve existing habitat, and/or address man-made or naturally occurring conditions that impact the attainment of WQ criteria.

Treatment includes satellite facilities, centralized facilities at the treatment plant, as well as disinfection of CSO. These technologies may not necessarily reduce CSO volumes to the waterbodies, but provide various levels of treatment to reduce pollutant loads and water quality impacts.

Storage may include the modification of existing infrastructure to create in-system storage or off-line shafts, tanks or tunnels. Storage facilities capture CSO during peak flow conditions where the collection system or WRRF treatment capacity is exceeded. Captured CSO is pumped back to the collections system or directly to the WRRF after wet-weather flows subside and capacity becomes available for conveyance and treatment.

Additional grey infrastructure alternatives were evaluated in the development of this LTCP. Considering the varying levels of water quality attainment for each of the Jamaica Bay tributaries and the waterbody and collections system-specific CSO control measures recommended in the Jamaica Bay WWFP, the evaluation of CSO control alternatives were prioritized to focus on Thurston and Bergen Basins, which were found in Section 6 to fall short of the 95 percent attainment goal for Existing WQ Criteria. As a result, alternatives evaluations were performed using the following hierarchy:

1. Optimization of existing collection systems tributary to the Jamaica and 26th Ward WRRFs;

2. Collections system and Jamaica WRRF specific alternatives for control of CSO discharges to Thurston Basin and Bergen Basin; and

3. Regional control measures spanning the collection system and treatment facilities serving Jamaica Bay and each of the tributaries.

8.2.a.1 Source Control

Source control includes technologies that capture sources of pollution before they enter the sewer system. These technologies include green infrastructure and high level storm sewers, which focus on keeping stormwater out of the combined sewer system.

Green Infrastructure: consists of rain gardens, porous pavement, bioinfiltration systems, and other strategies for capturing stormwater runoff and directing it to pervious surfaces for retention and infiltration into the ground. In addition to its primary objective of improving water quality, GI can yield climate change resiliency co-benefits including: improved air quality; urban heat island mitigation; carbon sequestration and biodiversity co-benefits, including increased urban habitat for pollinators and wildlife. EPA's Green Infrastructure for Climate Resiliency handbook also includes managing flooding with infiltration-based practices and spending less energy through managing water by reducing rainwater flows into sewer systems where Green infrastructure can reduce pumping and treatment demands for municipalities. Opportunities for application of additional GI will be addressed for each waterbody under the heading "Other Future Green Infrastructure."

High Level Storm Sewers: remove stormwater from the combined sewer system by diverting catch basins, and other sources of stormwater to new storm sewers. The October 2011 Jamaica Bay and CSO Tributaries WWFP references both High Level Sewer Separation and High Level Storm Sewers. The term "High Level Storm Sewers (HLSS)" is used in relation to partial sewer separation methods that are limited to the diversion of stormwater sources located within public street and rights-of-way. This technology was retained for consideration on a site-specific basis and was believed to be most cost-effective in areas near the shorelines where there is no need to build large diameter and long storm sewers to convey the separated stormwater to the receiving waterbody. The term "sewer separation" includes the diversion of stormwater sources from private residences or buildings such as rooftops and parking lots. Complete separation is almost impossible to attain in the City since it requires re-plumbing of apartment, office, and commercial buildings where roof drains are often interconnected with the building's interior plumbing. Due to the risks and legal issues associated with entering, inspecting, and performing construction on private properties, DEP has limited the practices of diverting stormwater from the combined sewer system to the application of HLSS.

As part of the Jamaica Bay WWFP, HLSS were recommended within the Fresh Creek and Thurston Basin sewersheds. HLSS is currently being implemented in portions of the Fresh Creek sewershed tributary to CSO 26W-003 with an anticipated construction completion date of December 2022. However, HLSS within the Springfield/Laurelton area of the Thurston Basin sewershed cannot be advanced until storm trunk sewers, proposed under the Southeast Queens (SEQ) Storm Sewer Buildout Program, are extended to this area. The SEQ Storm Sewer Buildout is an extensive long-term drainage program covering approximately 7,000 acres, with a primary goal of relieving flooding issues throughout Southeast Queens through the construction of storm sewers. The Springfield/Laurelton HLSS component of the program (as currently envisioned) is expected to result in CSO reductions at JAM 005/007. However, as discussed below, this portion of the SEQ work is not included in DEP's 10-year capital plan, and its primary purpose is not CSO control.

Project phasing, budgetary, and schedule considerations for the SEQ Storm Sewer Buildout must be prioritized based upon expediting relief to areas which have a history of flooding. While $1.9 Billion has been budgeted in DEP's current 10-year capital plan, full buildout of the program is anticipated to cost several billion dollars more and take several decades to complete. As future planning, design and funding will be dependent upon the policy and budgets of future administrations, DEP cannot commit to a schedule for construction of the SEQ Buildout.

The current 10-year capital plan primarily consists of the construction of major storm sewer spines illustrated in Figure 8-5 and neighborhood projects to address localized flooding. No collector storm sewer connections will be made to the major sewer spines under the current 10-year capital plan. Collector sewers will be developed under future phases and are not shown in Figure 8-5. At this point in the project planning, it is not known when the new spines will be activated. The HLSS proposed for the Springfield/Laurelton Area is similarly not included in the current 10-year capital plan, as downstream infrastructure must be constructed first, to accommodate the storm flow to be diverted from the combined sewer system to the new storm sewers.

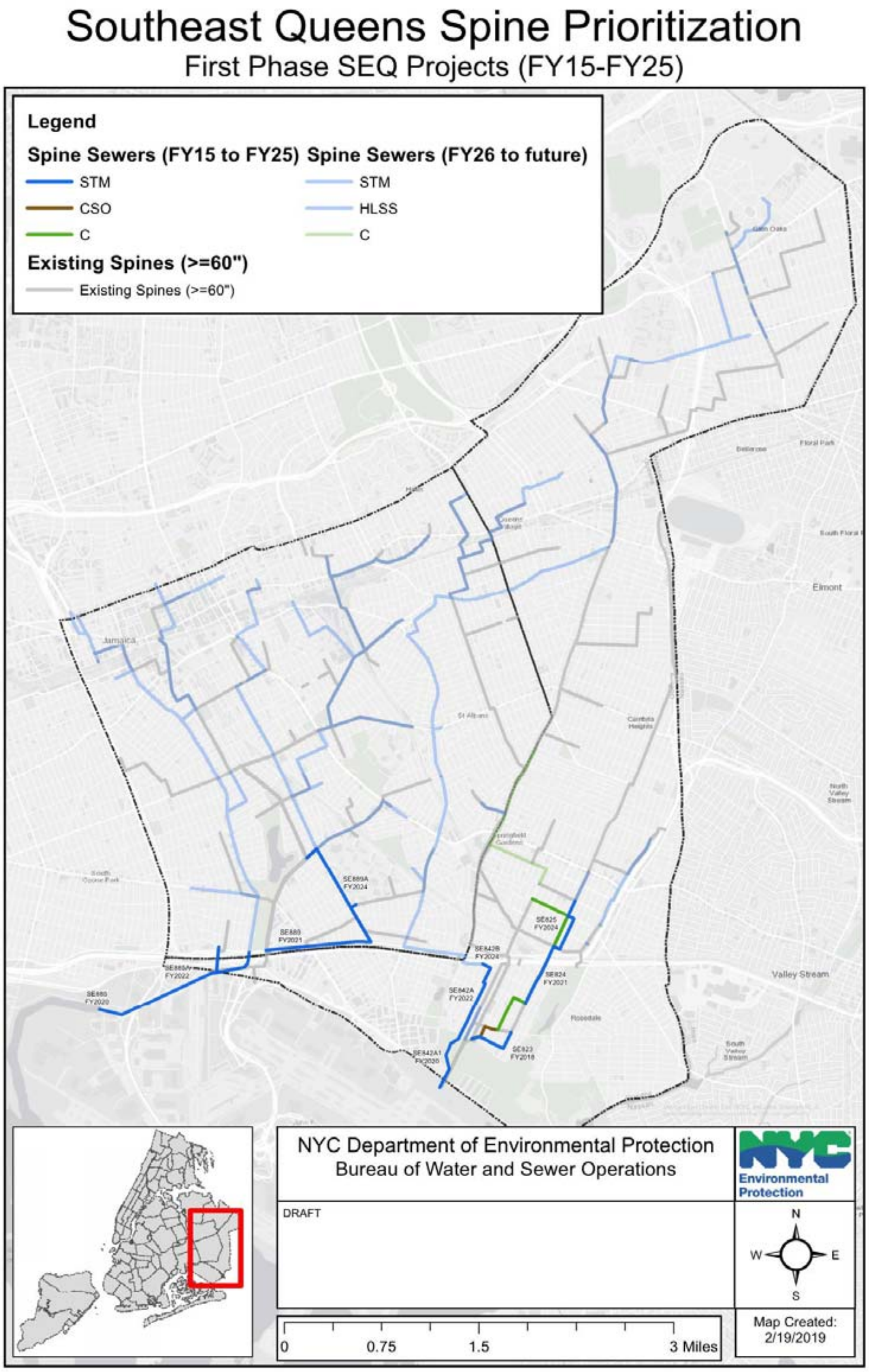

Figure 8-5. Southeast Queens Spine Prioritization

Completion of the major storm sewer spines is not anticipated to initially result in a change in stormwater or CSO volumes, since the collector storm sewers will not be connected and the Springfield/Laurelton HLSS will not be completed under the 10-year capital plan. As implementation progresses beyond the 10-year capital plan, stormwater conveyance capacity is projected to increase as new collector storm sewers are constructed and tied into the new spines. As surface flooding and ponding is reduced, stormwater volumes discharged from the new spines are expected to increase.

Once the Springfield/Laurelton HLSS project is in service, a portion of the stormwater will be redirected from the combined sewers to new storm sewers. The remaining combined flow will be diverted to a new regulator to be constructed at the intersection of 147 Avenue and 229th Street. The SEQ Buildout will result in a redistribution of wet-weather flow throughout the Jamaica WRRF sewershed and ultimately a projected reduction of CSO discharges and a further increase in stormwater discharges.

The primary objective of the SEQ Buildout is to relieve historical flooding throughout Southeast Queens. As a result, any CSO reductions (outside of the Springfield/Laurelton HLSS Project) will be incidental and are not expected to have any impact on attainment of fecal coliform criteria in either Thurston or Bergen Basin. As indicated in the gap analysis summarized in Table 6-7 of Section 6 of the LTCP, water quality standards attainment will not be achieved for fecal coliform in Thurston Basin even with a modeled 100% CSO control. Therefore, the CSO reductions associated with the SEQ Buildout will not result in attainment of water quality standards.

As requested by DEC, conceptual modeling has been performed for the purposes of simulating the changes in CSO and stormwater volume discharges to Thurston and Bergen Basins upon completion of the SEQ Storm Sewer Buildout. The landside modeling was expanded using information available for major sewer spines. Where information was not available, input nodes were added and drainage subcatchments were modified to reflect the capture of runoff throughout the SEQ Buildout drainage area, and runoff coefficients were adjusted to reflect available BWSO drainage plans.

Table 8-4 summarizes the impacts to CSO and stormwater discharges upon implementation of the SEQ Buildout. CSO discharges to Thurston Basin are reduced by 160 MGY as a result of the HLSS proposed within the Springfield/Laurelton Section of Southeast Queens. No CSO reductions are projected by the modeling to Bergen Basin, since 99 percent of the CSO discharge is related to CSO Outfalls JAM-003/003A which are outside of the area impacted by the SEQ Buildout. Stormwater discharge increases by 2,801 MGY for Thurston Basin and by 1,511 MGY for Bergen Basin. While the SEQ Buildout will divert some stormwater from the sewer system (resulting in CSO reduction), the additional stormwater being conveyed to the receiving waters is predominantly attributed to the expansion of the storm sewers to areas with insufficient drainage. The project provides flood relief, conveying stormwater runoff to Thurston and Bergen Basins.

Table 8-4. Comparison of CSO and Stormwater Discharges for SEQ Buildout and Baseline Conditions (2018 Typical Year)

Receiving Waters	Baseline Conditions Discharge Volume(1) (MGY)	SEQ Buildout Discharge Volume (MGY)	Variation in Discharge Volume (MGY)
Combined Sewer Overflows			
Thurston Basin	247	87	-160
Bergen Basin	333	333	0
Total CSO	**580**	**420**	**-160**
Stormwater			
Thurston Basin	1,193	3,994	+ 2,801
Bergen Basin	3,276	4,787	+1,511
Total SW	**4,469**	**8,781**	**+4,312**

The landside modeling results were then incorporated into the water quality model to assess the potential impacts to water quality attainment. A comparison of the model-calculated attainment of Existing WQ Criteria for fecal coliform under Baseline and SEQ Buildout Conditions is provided in Table 8-5. For the 2008 typical year, water quality standards attainment for fecal coliform are not projected to be impacted for Bergen Basin. For Thurston Basin, the geomean concentration at Monitoring Station TBH1 increased from 177 cfu/100mL to 215 cfu/100mL for the month of May resulting in a reduction in the annual and recreational attainment of 8 percent. However, attainment remained unchanged for all of the other monitoring stations.

Table 8-5. Comparison of the Model-Calculated Attainment of Existing WQ for Fecal Coliform Bacteria Baseline and SEQ Buildout Conditions (2008 Typical Year)

Station	% Attainment - Annual (GM<200 cfu/100mL)		% Attainment - Recreational Season(2) (GM<200 cfu/100mL)	
	Baseline Conditions	SEQ Buildout	Baseline Conditions	SEQ Buildout
Thurston Basin				
TBH1(1)	77	75	88	83
TBH3(1)	89	83	93	100
TB9(1)	91	83	95	100
TB10(1)	98	92	100	100
TB11	100	100	100	100
TB12	100	100	100	100
Bergen Basin				
BB5(1)	57	58	72	83
BB6(1)	89	83	93	100
BB7(1)	100	100	100	100
BB8	100	100	100	100

Notes:
(1) Monitoring station is located in a portion of the waterbody that is restricted by airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October 31st.

While the SEQ Buildout is predicted to increase the stormwater discharges to Bergen Basin by about 50 percent, annual and recreational season attainment for fecal coliform is projected to remain unchanged from baseline conditions. For Thurston Basin, modeled CSO is reduced by about 70 percent and stormwater is increased by 230 percent over baseline conditions. The increase in stormwater discharge as a result of the SEQ Buildout is projected to reduce attainment by one month during the typical 2008 year at the head of end of Thurston Basin (TBH1). Annual and recreational season (May 1st through October 31st) attainment at all other monitoring stations are projected to remain unchanged from the baseline conditions. Based upon the full SEQ Buildout model simulations, water quality attainment will remain largely unchanged despite a model projected CSO reduction of 160 MGY.

As the reductions in CSO do not influence fecal coliform attainment and the SEQ Buildout schedule cannot be completed within the time frame of the CSO LTCP, it will be implemented as a separate DEP drainage and flood control project and will not be considered further as a component of this LTCP.

8.2.a.2 Collection System Optimization

System optimization typically includes measures to enhance the sewer system performance by taking advantage of in-system storage capacity to reduce CSO through automated controls or modifications to the existing collection system infrastructure. Examples include: regulator or weir modifications including fixed and bending weirs; control gate modifications; real time control; and increasing the capacity of select conveyance system components, such as gravity lines, pumping stations, and/or force mains. Force main relocation or interceptor flow regulation would also fall under this category. These control measures generally retain more of the combined sewage within the collection system during storm events. The benefits of retaining this additional volume must be balanced against the potential for sewer backups and flooding, or the relocation of the CSO discharge elsewhere in the watershed or to an adjacent watershed. Viability of these control measures is system-specific, depending on existing physical parameters such as pipeline diameter, length, slope, and elevation.

Jamaica WRRF Collection System Optimization

Regulator Improvements: In accordance with the recommendations of the Jamaica Bay WWFP, Regulators JA-02, JA-03, JA-06, JA-07, and JA-14 were modified for the purposes of diverting more wet-weather flow to the Jamaica WRRF and reducing the frequency and volume of CSOs to Thurston and Bergen Basins. Considering the improvements in collection system performance and CSO capture related to these projects, additional opportunities for optimization of the collection system tributary to the Jamaica WRRF were evaluated. Model simulations were performed to assess the performance of system optimization controls in the Matrix of CSO Control Measures for Jamaica Bay (Figure 8-4), such as, fixed weir modifications, bending weirs, control gates, pumping station modifications, floatables control and parallel interceptors as identified to divert additional flow from the CSO outfalls to the interceptor sewer system.

The results for each alternative evaluated and recommendations are summarized in Table 8-6. Many of the alternatives create increases in the hydraulic grade line (HGL) of the East and/or West Interceptor potentially increasing the risk of flooding along upstream contributing sewers. The HGL of the East and West Interceptors is particularly sensitive because no regulator or WRRF bypass is located in close proximity to the Jamaica WRRF. While Regulator JA-01 is the closest overflow point, the weir crest is set at an elevation such that no overflows occur during the 2008 typical year rainfall. During periods of peak wet-weather flow in excess of 2xDDWF at the Jamaica WRRF, the East and West Interceptors surcharge until the wet-weather event subsides. As the peak wet-weather flows tend to range in duration of 1-3 hours, the collection system experiences relatively short duration peaks that result in a backup of the interceptor until the storm event and flow subsides. The optimization alternatives tend to increase the peak flows and create a rise in the HGL, with the exception of Alternative B-2d1. This alternative is discussed in more detail later in this section.

Pumping Station Modifications: During wet-weather events, the convergence of the Howard Beach Pumping Station (HBPS) force main with the West Interceptor is capacity limited, resulting in backups at Regulators JA-03 and JA-14 and overflows to Bergen Basin. As identified in Table 8-6, Alternative B-2c evaluated the benefits of extending this force main directly to the Jamaica WRRF, bypassing the West Interceptor completely. Modeling indicated that during wet-weather events the timing of the peak from the HBPS coincides with the peak from the East Interceptor resulting in surcharging and an increase in the HGL of the East Interceptor. As a result, this alternative was eliminated from further consideration. Other alternatives for modifications to the HBPS involve transferring flows between sewersheds and are discussed further in the “CSO Relocation” section.

Parallel Interceptor/Sewer: Construction of major relief sewers parallel to the existing interceptors was evaluated for Thurston and Bergen Basins. Alternatives T-2a through T-2c evaluated the construction of a sewer parallel to the East Interceptor to allow for additional wet-weather flow to be conveyed to the Jamaica WRRF. Three variations of this alternative were developed to divert existing trunk sewers from the East Interceptor to increase wet-weather capacity to accommodate a new regulator to be installed along Outfall JAM-005/007. Alternatives T-2d through T-2f, evaluated replacing portions of the East Interceptor with larger sewers to improve wet-weather conveyance to the WRRF. Each of these alternatives was modeled as a gravity conveyance that would reconnect to the collection system at the Jamaica WRRF. Model runs indicated that increasing the sewer conveyance capacity of the East Interceptor would result in HGL increases during periods of peak wet-weather flow. In addition, there are concerns with constructability due to the potential for conflicts with existing utilities that cross the proposed sewer alignment, as well as sewers proposed under the Southeast Queens Sewer Buildout Program. As a result, gravity driven parallel interceptor and replacement interceptor options were eliminated from further consideration. However, the sewer alignments will be considered in the evaluation of CSO tunnel options. The deeper tunnel construction avoids conflicts with existing utilities, while the storage within the tunnel equalizes peak flows to the WRRF. In addition, the dewatering pumping station activation can be timed to manage peak flows to the WRRF.

Table 8-6. Jamaica WRRF Collection System Optimization Alternatives

Alternative ID	Description	Impacted Outfalls	Observations	Status
Thurston Basin				
T-1a	Install a new regulator with fixed weir and underflow baffle for floatables along the outfall with an underflow sewer to the existing branch interceptor	JAM-005/007	Reduction in CSOs, but an increase in hydraulic grade line (HGL)	Abandoned due to HGL impacts
T-1b	Installation of a bending weir at the new regulator under Alt T-1a	JAM-005/007	Reduction in CSOs, but an increase in HGL	Abandoned due to HGL impacts

Table 8-6. Jamaica WRRF Collection System Optimization Alternatives

Alternative ID	Description	Impacted Outfalls	Observations	Status
T-1c	Installation of underflow baffles for floatables control at Regulators JA-06, JA-07, JA-08 and JA-09	JAM-005/007	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts
T-2a, 2b, 2c	Construction of a new interceptor parallel to the East Interceptor with a new dedicated pumping station at the Jamaica WRRF	JAM-005/007	Reduction in CSOs, but an increase in HGL	Abandoned due to HGL impacts
T-2d, 2e, 2f	Replacement of the East Interceptor along Rockaway Boulevard and Nassau Expressway with a dedicated pumping station at the Jamaica WRRF. Includes diversion of all connections from the existing interceptor, which is then abandoned.	JAM-005/007	Reduction in CSOs, but an increase in HGL	Abandoned due to HGL impacts
Bergen Basin				
B-1a	Plugging of CSO discharges at Regulator JA-10 to direct all flow to the Merrick Baisley branch interceptor	JAM-006 & JAM-005/007	Minimal reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts
B-1b	Installation of a bending weir at Regulator JA-10	JAM-006 & JAM-005/007	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts
B-1c	Installation of bending weirs at Regulators JA-09 and JA-10	JAM-006 & JAM-005/007	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts
B-1d	Plugging of CSO discharges at Regulator JA-04 to direct all flow to the conveyance system tributary to the West Interceptor	JAM-006 & JAM-003/ 003A	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts
B-1e	Installation of a bending weir at Regulator JA-04	JAM-006 & JAM-003/003A	No reduction in CSOs	Abandoned due to no CSO benefits
B-1f	Real time control of existing private building retention facilities	JAM-006 & JAM-003/ 003A	Limited reduction in CSOs	Abandoned due to limited CSO benefits
B-1g	Installation of underflow baffles for floatables control at Regulators JA-03 and JA-14	JAM-006 & JAM-003/ 003A	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts

Table 8-6. Jamaica WRRF Collection System Optimization Alternatives

Alternative ID	Description	Impacted Outfalls	Observations	Status
B-2a	Modification of upstream sewers to optimize flows between Regulators JA-03 and JA-14	JAM-003/ 003A	No reduction in CSOs and an increase in HGLs	Abandoned due to HGL impacts
B-2c	Redirect HBPS force main from West Interceptor to Jamaica WRRF	JAM-003/ 003A	Reduction in CSO, but an increase in HGL in the East Interceptor	Abandoned due to HGL impacts
B-2d	Construction of a parallel interceptor from Regulators JA-03 and JA-14, along Nassau Expressway to the Jamaica WRRF	JAM-003/ 003A	Reduction in CSO, but an increase in HGL in both the East and West Interceptors	Not constructible due to conflicts at crossings of other utilities
B-2d1	Construction of a parallel interceptor from Regulators JA-03 and JA-14, along Nassau Expressway to the Jamaica WRRF with a 50 MGD pumping station	JAM-003/003A	Reduces CSO with no increase in the HGL of both the East and West Interceptors	Retain for further consideration

Alternative B-2d1: Construct Parallel Sewer from Regulators JA-03 and JA-14 to 50 MGD Pumping Station at Jamaica WRRF

This alternative involves the following elements (Figure 8-6):

- Two new diversion chambers with tide gates constructed on the existing JAM-003 and JAM-003A outfalls downstream of the existing regulators.
- Approximately 150 LF of gravity conveyance piping from the new diversion structure to a launch shaft for the microtunnel.
- Approximately 3,200 LF of 96" gravity sewer to convey flow along Nassau Expressway to the head end of the Jamaica WRRF.
- Manholes at regular intervals along the sewer route based on drive lengths, curvature of the sewer required and crossing of the Nassau Expressway.
- Construction of a new screening and grit chamber and 50 MGD dewatering pumping station and associated force main to convey flows from the microtunnel to the influent distribution box of the primary settling tanks at the Jamaica WRRF.

The diversion chambers, diversion sewers, and the launch shaft would be sited on a city-owned lot subject to a long-term lease with the Port Authority of NY and NJ (PANYNJ). The PANYNJ currently uses this property as a parking lot for JFK Airport. Negotiations to revise the long-term lease of this property, even for the period of construction, would likely be difficult and may not be achievable. The 50 MGD pumping station would be sited on vacant land, which is under DEP jurisdiction and part of the Jamaica WRRF.

Under this alternative, dry-weather flow would continue to the Jamaica WRRF via Regulators JA-03 and JA-14 to the West Interceptor. Under wet-weather conditions, overflow at Outfalls JAM-003 and JAM-003A would be diverted to the new parallel sewer and to the pumping station. Modeling results project a 32 percent reduction in CSO overflow volume to Bergen Basin. As a result, this alternative will be carried forward as a retained alternative for further evaluation.

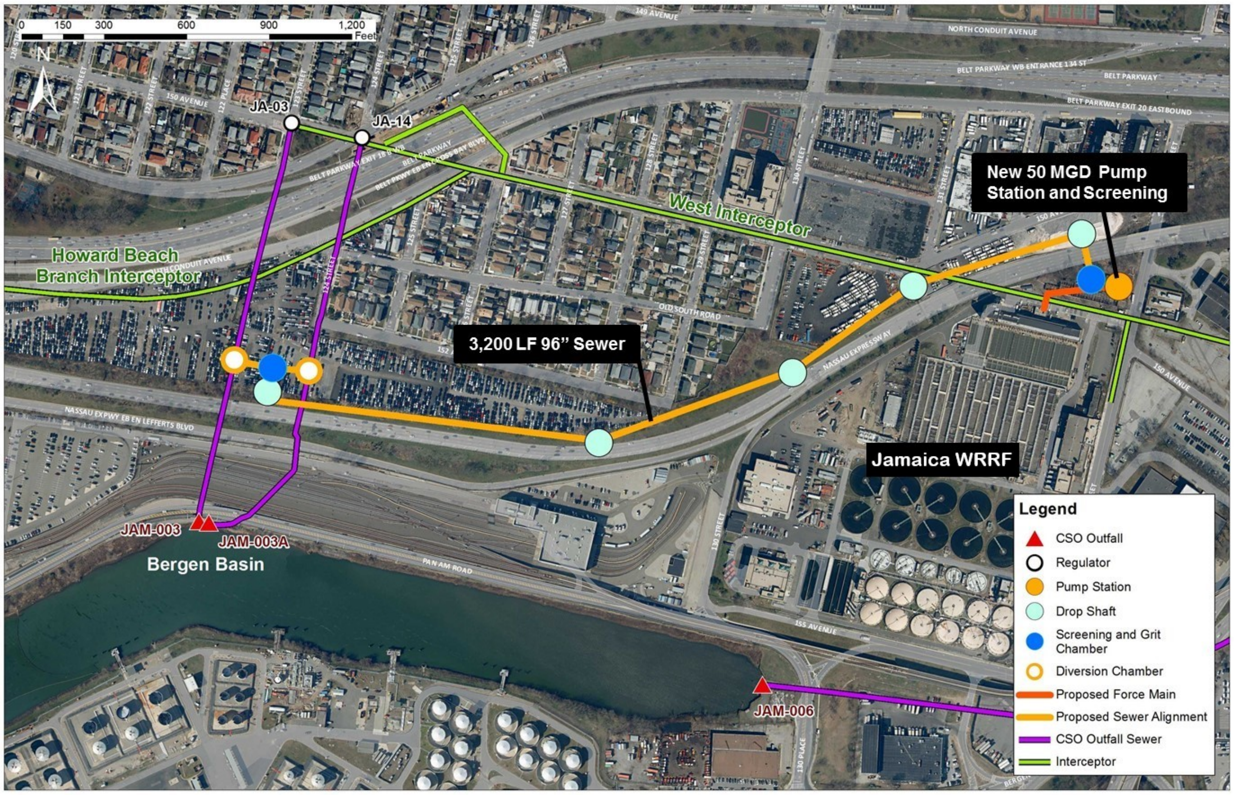

Figure 8-6. Layout of Proposed Parallel Sewer to West Interceptor and Dewatering Pumping Station

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Captures and conveys CSO from JAM-003/003A to the Jamaica WRRF for treatment
- Isolates CSO (by use of a pumping station) to reduce impacts to the West Interceptor

Cost

- The estimated NPW Cost for this control measure is $690M.
- Details of the estimate are presented in Section 8.4.

Challenges

- Limited improvement in Bergen Basin WQ attainment
- Property acquisition and permitting

Other system optimization alternatives evaluated under this LTCP: Many private properties (greater than 5 acres) with large impervious surfaces currently operate and maintain facilities to manage stormwater in conformance with DEP guidelines for the design and construction of stormwater management systems. Implementation of real time control was evaluated for improved management of the wet-weather flows from these privately owned stormwater retention facilities. Model runs were performed to simulate real time control of privately owned stormwater retention systems to more effectively manage the timing of stormwater runoff to the collection sewer system.

The reduction in peak flows contributing to CSOs were found to have a negligible impact on the frequency and volume of CSO discharges. In addition, the practicality of regionally implementing these systems on a large number of privately owned systems is a concern. Property easements or other property rights would need to be developed with private property owners to allow the City to install these systems, as well as outline future responsibilities for operation and maintenance of these systems. "Fail-safe" measures would also need to be incorporated into the designs to eliminate the liability for sewer backups as a result of power outages or system malfunction. Considering the various complexities and risks of operating and maintaining these systems, real time control was not retained for further evaluation for this LTCP.

The benefits and challenges of installing underflow baffles in existing regulator chambers to control floatables were evaluated. As-built plans of the regulators were reviewed to determine the elevations of the weir crests and develop preliminary layouts of the baffles for simulation using the collection system model. Model runs indicated that the baffles would cause increases in the HGL of the sewers upstream of the regulators during higher intensity storm events, thereby increasing the risk of flooding. As a result, floatables baffles were not retained for further evaluation.

26th Ward WRRF Collection System

Alternatives for system optimization within the 26th Ward WRRF sewershed are described below and summarized in Table 8-7. As indicated in Table 8-7, none of the optimization alternatives were carried forward for further evaluation due to either adverse HGL impacts, limited or no CSO reduction benefits, and/or high cost-to-benefit ratio.

Regulator Improvements to the collection system within the 26th Ward WRRF sewershed were not recommended in the Jamaica Bay WWFP, and as a result, they have been revisited under this LTCP to determine whether additional wet-weather flow can be diverted to the WRRF. The results for each alternative evaluated and recommendations are summarized in Table 8-7. Fixed weir modifications were analyzed to reduce overflows to Spring Creek, Hendrix Creek, and Fresh Creek, but preliminary modeling results indicated an elevated hydraulic grade and risk of flooding, resulting in rejection of this alternative. Bending weir alternatives were also evaluated and abandoned for the same reasons.

Pumping Station Modifications recommended in the Jamaica Bay WWFP were limited to replacement of existing emergency pumps at the 26th Ward WRRF to facilitate improved flow distribution to the primary settling tanks. While there are several pumping stations and ejectors throughout the 26th Ward WRRF combined sewer area, flow is regulated downstream of the pumping station force main connections at the trunk sewer connection to the interceptor sewer. Any CSO captured as a result of upgrading the capacity of these pumping stations could overflow at the downstream regulators. To effectively capture the additional wet-weather flow from these pumping stations, capacity improvements would need to be made to the trunk sewers, regulators, and interceptor sewers. As a result, this alternative was not further considered.

Parallel Interceptors/Sewers: Construction of major near-surface sewers would have significant constructability and construction impacts due to the size of the streets, level of traffic and density of existing utilities. As a result, the sewer would need to be constructed using trenchless technologies at sufficient depth to clear the obstructions along the route of the tunnel. A pumping station would also be needed at the downstream end of the sewer to convey the flow to the 26th Ward WRRF. CSO tunnels will be considered in lieu of parallel sewers.

Other system optimization alternatives that were evaluated in this LTCP included implementing real time control to manage discharges from private stormwater retention facilities and installation of underflow baffles within existing regulators for floatables control. Model runs produced similar responses to those observed in the Jamaica WRRF collection system. As a result, these alternatives were eliminated from further consideration.

Other system optimization alternatives evaluated under this LTCP: Similar to the Jamaica WRRF sewershed, implementation of real time control was evaluated for improved management of the wet-weather flows from stormwater retention facilities serving privately owned properties greater than 5 acres. Model runs were performed to simulate real time control of these privately owned stormwater retention systems to more effectively manage the timing of stormwater runoff to the collection sewer system. Considering the negligible impact on the frequency and volume of CSO discharges and the various complexities and risks of operating and maintaining these systems, real time control was not retained for further evaluation for this LTCP.

Table 8-7. 26th Ward Collection System Optimization Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Hendrix Creek	HC-1	Modification of fixed weir at Regulator 26W-01	26W-003 & 26W-004	Slight reduction in CSOs but an increase in HGL	Abandoned due to HGL impacts
Hendrix Creek	HC-2	Construction of parallel interceptor/sewer along either Flatlands Avenue or Vandalia Avenue to divert CSO from Regulator 26W-01 to Spring Creek AWWTP	26W-003 & 26W-004	Limited reduction in CSO with an increase in HGL in the East Interceptor	Abandoned due to high cost-to-benefit ratio
Fresh Creek	FC-1a	Modification of fixed weir at Regulator 26W-02 and 26W-02A	26W-003 & 26W-004	Reduction of CSOs at 26W-003 but increased CSOs at 26W-004, resulting in a net increase in CSOs	Abandoned due to increase in CSO
Fresh Creek	FC-1b	Modification of fixed weir at Regulator 26W-02	26W-003 & 26W-004	Reduction of CSOs at 26W-003 but increased CSOs at 26W-004, resulting in a net increase in CSOs	Abandoned due to increase in CSO

Table 8-7. 26th Ward Collection System Optimization Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Spring Creek, Hendrix Creek & Fresh Creek	26W-1	Real time control of existing private building retention facilities	26W-002, 26W-003, 26W-004 & 26W-005	Limited reduction in CSOs	Abandoned due to limited CSO benefits
Hendrix Creek & Fresh Creek	26W-2	Installation of underflow baffles for floatables control at Regulators 26W-01 & 26W-02	26W-002, 26W-003 & 26W-004	No reduction in CSOs and an increase in HGL	Abandoned due to HGL impacts and no CSO benefits

8.2.a.3 Waterbody Specific Alternatives

The Jamaica Bay and Tributaries LTCP addresses CSO impacts to six tributaries, in addition to Jamaica Bay. As presented in Section 6, annual and recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform was less than 95 percent at the head ends of Thurston Basin, Bergen Basin, and Fresh Creek under baseline conditions. In contrast, 100 percent attainment is achieved at all of the stations within Spring Creek, Hendrix Creek, Paerdegat Basin, and Jamaica Bay (during the recreational season and on an annual basis). Attainment levels of greater than 95 percent were also projected at the confluence of each waterbody with Jamaica Bay. In consideration of the wide range of attainment, the level of CSO control and appropriate technologies will be waterbody specific. As a result, the discussion of the evaluation of CSO control alternatives has been organized by the waterbodies they are targeted to improve.

Bergen Basin Alternatives

Bergen Basin is located in Jamaica, Queens, to the immediate west of JFK Airport and south of the Jamaica WRRF. The Bergen Basin watershed is approximately 10,300 acres in area, of which approximately 2,900 acres is combined drainage area, 5,600 acres is MS4 drainage area, 1,200 acres is separated sewershed and 600 acres is airport drainage area. Small quantities of direct drainage also exist along the banks of the basin. CSO and stormwater flow is discharged to this basin by 3 CSOs and 26 storm outfalls. CSO Outfalls JAM-003, JAM-003A, and JAM-006 are the three biggest outfalls, measuring 8' x 9', double barrel (DBL) 13' x 9', and triple barrel (TBL) 19' x 9', respectively. Under baseline conditions, the model predicted JAM-003 and 003A to discharge to 330 MGY of CSO to Bergen Basin, while JAM-006 contributes 3 MGY of CSO, 3,276 MGY of stormwater, and 5,470 MGY of WRRF effluent. Preliminary modeling also indicated that the primary driving factor for bacterial loading and, consequently water quality impacts, was the significant volume of storm flows entering the waterbody. However, this project is intended to focus on reducing CSOs to the waterbodies of Jamaica Bay; low cost alternatives which provide limited water quality improvements by reduction of these CSOs may fall on the cost-benefit curve and should be evaluated. Thus, each element of the Alternatives Toolbox has been considered and evaluated.

A review of existing land uses near the discharge of Outfalls JAM-003, JAM-003A, and JAM-006 was performed for the purposes of identifying potential sites for new treatment/storage facilities. A 1.5 acre city-owned vacant parcel was identified (see Figure 8-7) near the north end of the Jamaica WRRF, where a building had been demolished. An additional city-owned property was identified along the north edge of the Nassau Expressway which is currently utilized by the New York City Department of Sanitation for parking of fleet vehicles. Other potential parcels for construction include city-owned properties that are leased by the PANYNJ; these properties are subject to a longer team lease and are used for airport long-term parking and car rental. Highway medians and right-of-way are also identified.

The city-owned properties, median strips, and the right-of-way along the northern side of the Nassau Expressway provide sufficient space for construction of sewers, tunnels, or pumping stations for conveyance of CSO to the Jamaica WRRF, but are not of sufficient size to accommodate satellite treatment or off-line storage tanks. While the long-term parking lots are of sufficient size to accommodate most technologies, the lease arrangements and current uses supporting airport operations may prevent them from being considered for technologies that would have impacts to these properties during construction and/or operation of the completed facilities. Property requirements will be considered in assessing the viability of each of the technologies evaluated.

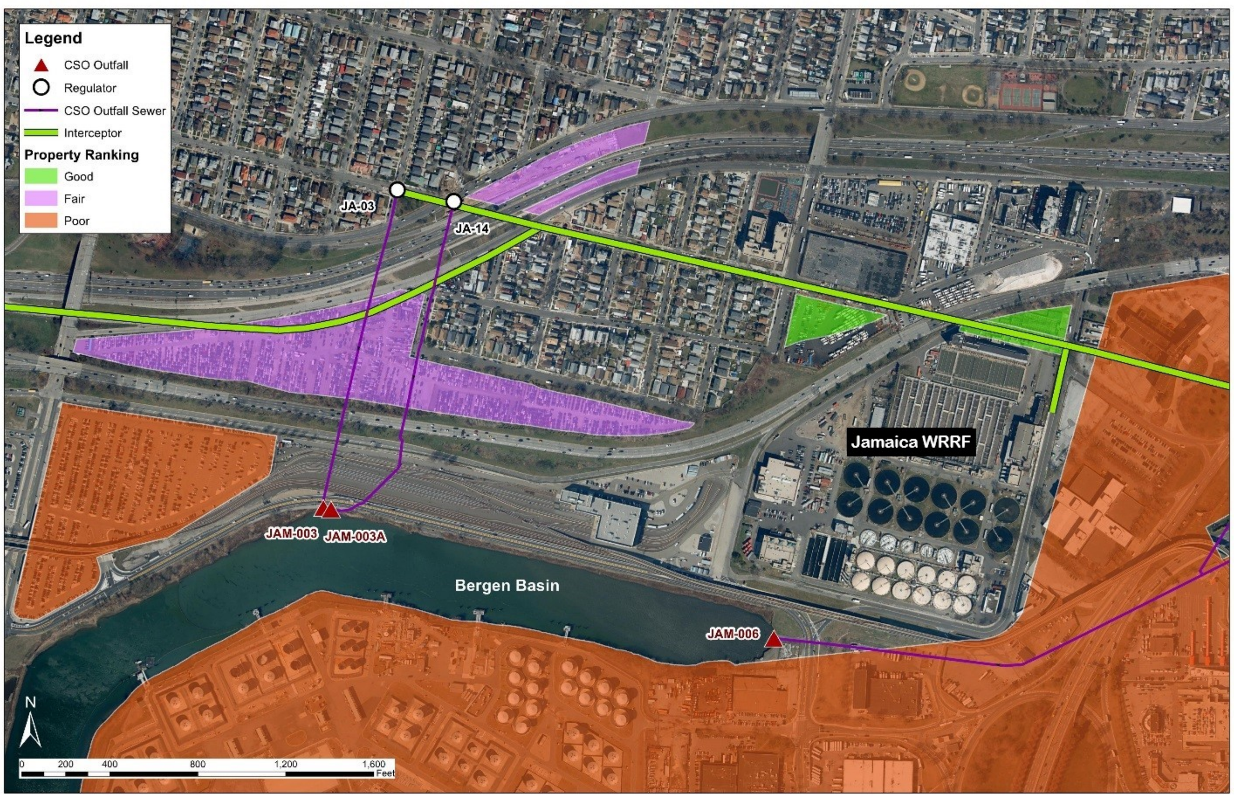

Figure 8-7. Potential Properties Near Bergen Basin CSO Outfalls

CSO Relocation: This concept involves conveying overflows by gravity from one receiving water to another receiving water that would either be less sensitive or provide greater dilution/assimilation. Diversion of the outfall to Jamaica Bay, which has more stringent water quality standards for the promotion of primary contact recreation, is contrary to the intended uses of the Bay and is not recommended for further consideration.

A number of potential CSO Relocation alternatives were identified that involved shifting of overflows between tributaries without increasing discharges directly to Jamaica Bay. These alternatives were initially evaluated, but none were determined to provide significant opportunity to warrant pursuing further. Gravity Flow Tipping to Other Watersheds and Flow Tipping with Conduit/Tunnel and Pumping options evaluated include the following:

Gravity Flow Tipping was implemented in the Jamaica Bay WWFP for Bergen Basin at Regulator JA-02. Installation of an electro-hydraulic actuator enabled flow tipping from the Bergen Basin watershed to the Spring Creek watershed during wet-weather events, reducing overflows to Bergen Basin and maximizing capacity utilization of the Spring Creek AWWTP. The connection of the HBPS force main to the East Interceptor was identified as a potential flow constriction. To reduce wet-weather flow to the pumping station, the East Interceptor, and overflows to Bergen Basin, Alternative B-2e was proposed to redirect dry-weather flow from Regulator JA-02 to the 26th Ward WRRF via the existing CSO outfall sewer from JA-02. A new regulator would be required to divert flow from this CSO line to the existing Vandalia Avenue Interceptor. However, on further analysis it was determined that the new sewer could not be constructed to match the crown of the Vandalia Avenue Interceptor sewer, resulting in a risk of sewer surcharge and settling of solids in the new sewer during peak flow conditions. As a result, this alternative was eliminated from further evaluation.

Flow Tipping with Conduit/Tunnel and Pumping. This control measure would be similar to gravity flow tipping, but the conveyance of flow to another receiving water would require pumping. Diversion of dry- and wet-weather flow was evaluated across the boundary between the subcatchments of Outfalls JAM003/003A and 26W-002/004, which discharge to Bergen Basin and the Hendrix Creek, respectively. Each of the following alternatives evaluated the diversion of flow from the HBPS from the Jamaica WRRF sewer system to the collection system serving the 26th Ward WRRF.

<u>Alternative B-2e: Abandon the HBPS and Construct a Gravity Sewer to the 26th Ward WRRF</u>

InfoWorks CS™ (IW) Modeling indicates that during wet-weather events, flows from the HBPS displace flows from Regulators JA-03 and JA-14 in the West Interceptor, resulting in flooding and increased CSO discharge to Bergen Basin. Alternative B-2e evaluates abandonment of the HBPS and redirection of its flows to the 26th Ward WRRF sewershed via a new gravity sewer (Figure 8-8). The new sewer would convey both dry- and wet-weather flow. A pumping station would be required to continuously convey the diverted flow from the tunneled conveyance to the WRRF. The pumping station would be sited, based on the final alignment, in one of three identified city-owned parcels, The shortest tunnel (Alt. B-2e1) could terminate at the Spring Creek AWWTP and pump to the Vandalia Avenue Interceptor near Regulator 26W-03. A second route alternative (B-2e2) could be terminated at the intersection of Flatlands Avenue and Vandalia Avenue with pumping to the Vandalia Avenue Interceptor or the head of the WRRF. The longest route could terminate at a pumping station to be located at the south end of the WRRF site with a force main constructed to dewater the tunnel to the head of the WRRF. Modeling for Alternative B-2e2, a 14,700 LF, 13 foot diameter tunnel to a pumping station at the intersection of Flatlands and Vandalia Avenues, resulted in a projected 12 percent CSO average annual overflow volume (AAOV) reduction at Bergen Basin.

Construction would largely involve trenchless methods to reduce impacts to sensitive transportation infrastructure and residential housing by utilizing a tunnel boring machine. Each of the three tunnel routes was evaluated to determine the alignment with minimal impacts to existing utilities. All of the proposed routes follow median space along the Shore Parkway from the existing HBPS to the new pumping station sites.

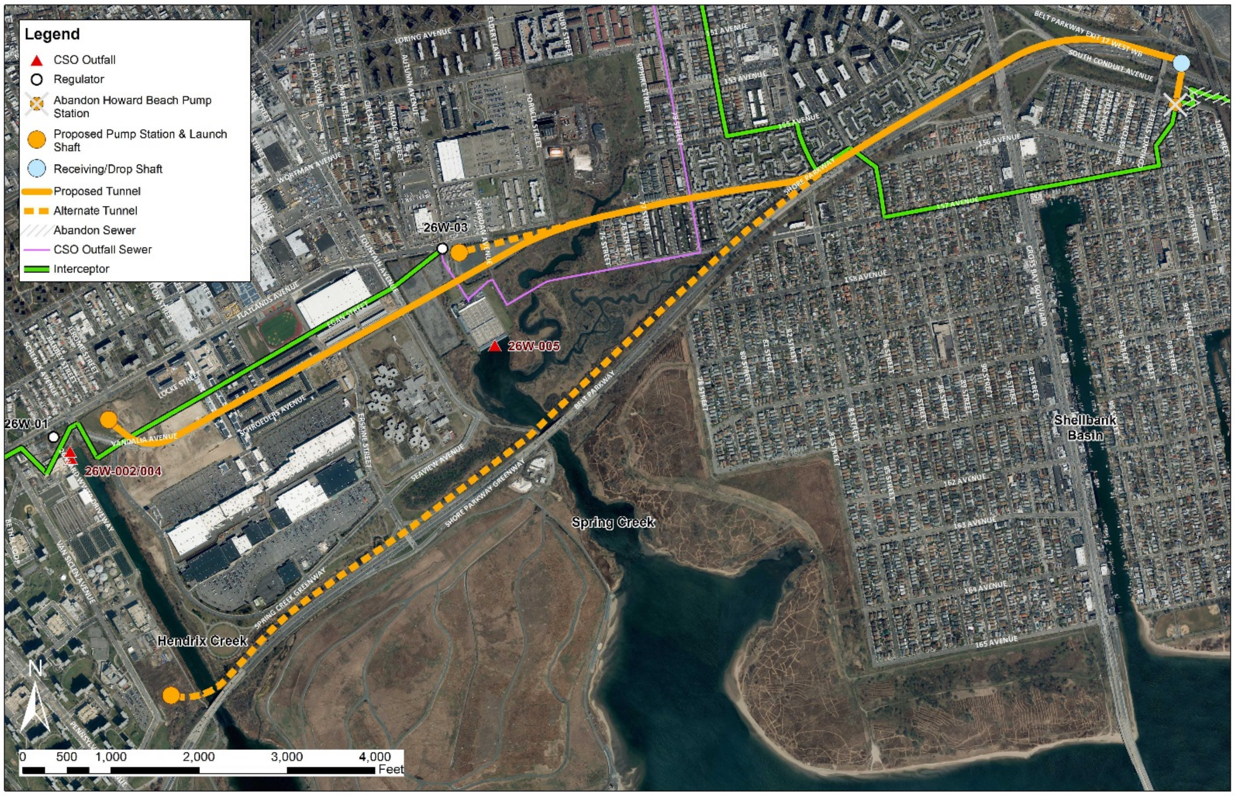

Figure 8-8. Layout of Proposed Gravity Sewer to 26th Ward WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

<u>Benefits</u>

- Utilizes available capacity at the 26th Ward WRRF to provide additional wet-weather capacity at the Jamaica WRRF
- The final tunnel size can be further adjusted during design to help address drainage issues in Howard Beach in addition to controlling CSO discharges

<u>Cost</u>

- The estimated NPW for this control measure is $961M

<u>Challenges</u>

- High cost to CSO volume capture
- Limited improvement in Bergen Basin water quality attainment
- Property acquisitions and permitting
- Crossing of pile supported drainage culverts and highway infrastructure

In consideration of the high cost to implement this alternative in relation to the relatively small reduction in CSO discharged to Bergen Basin annually, this alternative was eliminated from further consideration.

<u>Alternative B-2f: Combination of Alternatives B-2d and B-2e</u>

Alternative B-2f consists of a combination of Alternatives B-2d Bergen Basin Parallel Interceptor and Alternative B-2e Abandon HBPS and the construction of a gravity sewer to 26th Ward WRRF. This alternative, as illustrated in Figure 8-9, includes a 3,200 LF 13 foot diameter parallel interceptor from Outfalls JAM-003 and JAM-003A to the Jamaica WRRF and abandonment of the HBPS by construction of a 14,700 LF, 13 foot diameter gravity sewer to a pumping station located at the intersection of Vandalia and Flatlands Avenues. Modeling of Alternative B-2f2 projects a 34 percent CSO AAOV reduction at Bergen Basin.

Figure 8-9. Layout for Proposed Parallel Interceptor to Jamaica WRRF and Gravity Sewer to 26th Ward WRRF

The benefits, cost and challenges associated with this alternative are as follows:

<u>Benefits</u>

- Utilizes available capacity at the 26th Ward WRRF to provide additional wet-weather capacity at the Jamaica WRRF
- The final tunnel size can be further adjusted during design to help address drainage issues in Howard Beach in addition to controlling CSO discharges

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Cost

- The estimated NPW for this control measure is $1,651M

Challenges

- High cost to CSO volume capture
- Limited improvement in Bergen Basin water quality attainment
- Property acquisition and permitting
- Crossing of pile supported drainage culverts and highway infrastructure

In consideration of the high cost to implement this alternative in relation to the relatively small reduction in CSO discharged to Bergen Basin annually, this alternative was eliminated from further consideration.

Alternative B-2g: Abandon HBPS and Construct CSO Storage Tunnel to 26th Ward WRRF

Alternative B-2g, as shown in Figure 8-10, includes all the elements from Alternative B-2e. Additionally, this alternative proposes an extension of the gravity sewer along the Belt Parkway to divert Outfalls JAM-003 and JAM-003A to capture CSO discharging to Bergen Basin. During dry-weather this tunnel would convey flows diverted from the HBPS only. During storm events, the tunnel would convey wet-weather flows from the HBPS as well as CSO from Regulators JA-03 and JA-14.

IW modeling of the 19,500 LF tunnel indicated that to reduce CSO volumes by 25, 50, 75, and 100 percent at Bergen Basin, 12 foot, 21 foot, 30 foot, and 45 foot diameter tunnels would be required, respectively. However, for Bergen Basin, the gap analysis showed that even with 100% CSO removal, Existing WQ Criteria for fecal coliform would not be achieved. Thus, due to this high cost-to-benefit ratio, this alternative has been eliminated from further evaluation.

Figure 8-10. Layout for Proposed CSO Tunnel to 26th Ward WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Utilizes available capacity at the 26th Ward WRRF to provide additional wet-weather capacity at the Jamaica WRRF
- The final tunnel size can be further adjusted during design to help address drainage issues in Howard Beach in addition to controlling CSO discharges
- Provides storage capacity for equalization of peak flows to the 26th Ward WRRF

Cost

- The estimated NPW for this control measure varies by level of control as follows:
  - 25% CSO control: $1,195M
  - 50% CSO control: $1,573M
  - 75% CSO control: $2,287M
  - 100% CSO control: $4,006M

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Challenges

- High cost to CSO volume capture
- Limited improvement in Bergen Basin water quality attainment
- Property acquisitions and permitting

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing water quality through other approaches. Environmental dredging has been recommended under certain other New York City CSO LTCPs to remove organics and other sediment deposits that can create odors when exposed during low tide. Wetlands Restoration, and bioextraction through ribbed mussel habitat creation can be considered to enhance aquatic and wildlife habitats, manage stormwater runoff, and reduce pathogens and other contaminants.

Floatables Control: A floatables containment boom is located downstream of the CSO outfalls in Bergen Basin for JAM-003/003A. Skimmer boats are utilized to retrieve the floatables captured by the boom. In addition to floatables from CSOs, the boom in Bergen Basin is sited such that floatables are also captured from storm sewers, and the vast majority of wet-weather flow being discharged into Bergen Basin is stormwater. In addition, the Port Authority maintains a containment boom upstream of DEP's boom, which is believed to have resulted in a reduction in the capture recorded at the DEP boom. Replacing the booms with netting facilities or underflow baffles would eliminate these ancillary water quality benefits.

Each of the above floatables control technologies is identified as an accepted practice in the USEPA Guidance for NMCs and Floatables Control Technology Fact Sheet. The fact sheet specifically references boom and skimming operations in Jamaica Bay, as well as catch basin modifications throughout New York City. Considering the well documented effectiveness of the current BMP programs for floatables capture, DEP believes that the existing approach to floatables control in the tributaries to Jamaica Bay meets the intent of the BMP requirements for floatables control, and that additional investment in alternative floatables control technologies would not provide substantial improvements in floatables capture.

However, to be responsive to comments from DEC, DEP has further investigated alternatives for providing end-of-pipe nets in Bergen Basin at JAM003/003A. The following summarizes the findings of these investigations.

Figure 8-11 shows a conceptual sketch of a 12-net end-of-pipe netting arrangement for outfalls JAM003/003A. The sizing was based on providing a design velocity of 5 fps through the nets for the 90th percentile peak flow from the typical year. Published design criteria for the end-of-pipe floating net systems indicate that these systems need a minimum of two to three feet of water depth. It is likely that some dredging would be required at the end of the outfalls at this location to provide the required depth at low tide. The dredging would extend into Bergen Basin until the existing bottom provides two to three feet of depth at low tide.

As indicated in Figure 8-11, limited space is available between Pan Am Road and the shoreline of Bergen Basin for construction and operation of the facilities. Temporary road closures would be required for construction, while access to the nets for replacement would likely be via boat. Access to this reach of Bergen Basin is restricted by JFK Airport security, but the location is just upstream of the floatables control boom across Bergen Basin as shown in Figure 8-12, so access requirements would likely be similar to the requirements for access to the existing boom.

As noted above, if a netting facility for Outfalls JAM003/003A were to replace the existing floating boom, then floatables associated with the stormwater discharges at JAM006 and the airport drain at the upstream end of Bergen Basin would no longer be captured. If the existing boom were to remain in place, then the benefit of a new structural floatables control system for Outfall JAM003/003A in terms of reducing floatables in Bergen Basin would be limited. In summary, although a floating end-of-pipe netting facility for Outfalls JAM003/003A appears to be technically feasible, it is unlikely to provide a significant improvement in the floatables captured by the existing boom in Bergen Basin (26 CY in 2017), and is therefore not recommended.

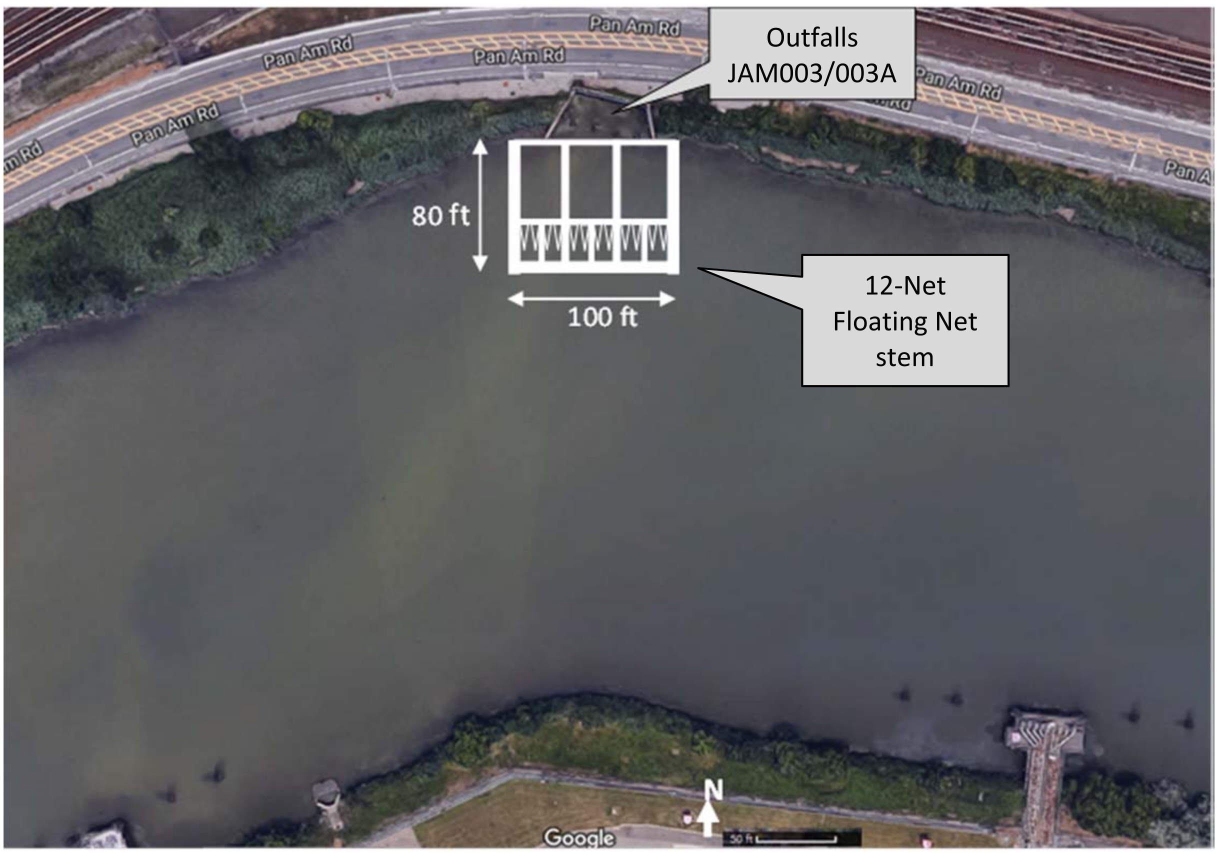

Figure 8-11. Conceptual Layout of Floating Netting Facility for Outfalls JAM003/003A

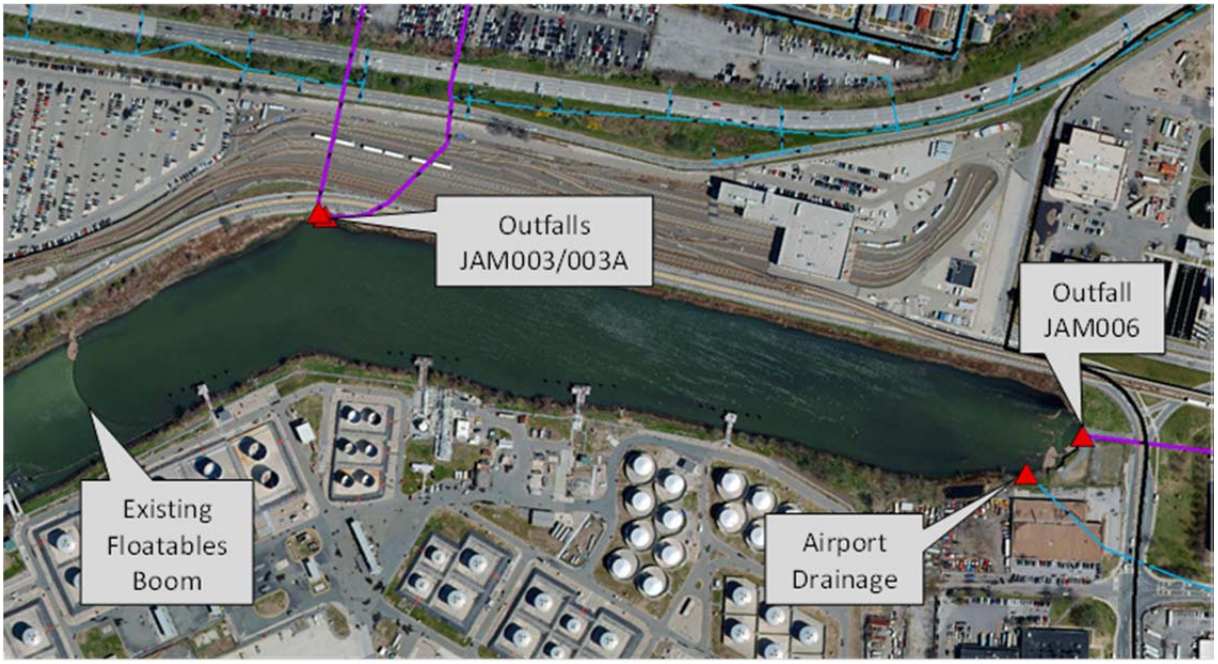

Figure 8-12. Location of Outfalls Relative to Existing Containment Boom in Bergen Basin

Wetlands and Bioextractors: Due to the risk of tidal wetlands attracting birds to waterways adjacent to the airport and the potential hazards associated to aircraft, tidal wetland restoration has been eliminated from further consideration for Bergen Basin and has not been included in Alternative B-13, Additional GI, and Environmental Improvements. Bioextractors, such as ribbed mussels, can provide water quality benefits through the continuous filtration of contaminants and nutrients from the waters in which they reside. Recent studies indicate that ribbed mussels can filter pathogens of various sizes at rates of 25-100 percent, varying with water temperature and mussel density. In order to provide estimates of the reduction in bacteria concentrations due to the influence of filtration by ribbed mussels that could be included in a LTCP, a simplified and conservative approach was applied. Based on the review of literature referenced in Section 10, low end estimates of filtration could support a 10 percent reduction in bacteria where ribbed mussels would be installed. Model runs were completed using Recommended Plan conditions, and then a 10 percent reduction of model-calculated concentrations in the ambient waters was applied as part of post-processing the model output. The literature indicates that the application of a 10 percent reduction could be a conservatively low level of filtration, given that the ribbed mussels would filter the bacteria continuously during dry- and wet-weather. However, a proper design and deployment of ribbed mussels could provide a higher level of bacteria reduction.

Ribbed mussels provide continuous filtering of the waterbody to remove pollutants and enhance native habitat. As shown in Figure 8-13, Alternative B-13 includes 4 acres of ribbed mussel beds to be created within Bergen Basin. The final locations and configuration of the ribbed mussel beds would be refined during the implementation phase. The WQ model was run (see Appendix D for a memo detailing the modeling approach) to assess the impact of adding the ribbed mussels to the other components of Alternative B-13, Additional GI and Environmental Improvements. Under 2008 typical year rainfall conditions, model predictions indicate that implementation of ribbed mussels improves attainment of Existing WQ Criteria for fecal coliform at the head of the Bergen Basin by 5 percent on an annual basis and during the recreational season (May 1st through October 31st). That improvement would be on top of the improvement in attainment associated with the additional GI component. In contrast, the gap analysis indicated that 100% CSO control would improve fecal coliform attainment by 2 percent on an annual basis and 5 percent during the recreational season. The level of attainment resulting from the ribbed mussels can be attributed to the continuous filtration of the water column through dry- and wet-weather conditions, while CSO control is limited to larger wet-weather events when CSOs are activated (33 times/year for JAM-003A, 17 times/year for JAM-003 and 14 times/year for JAM-006). As the ribbed mussels and tidal wetlands provide low cost water quality and ecological benefits that address impacts of CSO and stormwater discharges, in addition to naturally occurring sources of pathogens and other contaminants, this alternative will be retained for further consideration.

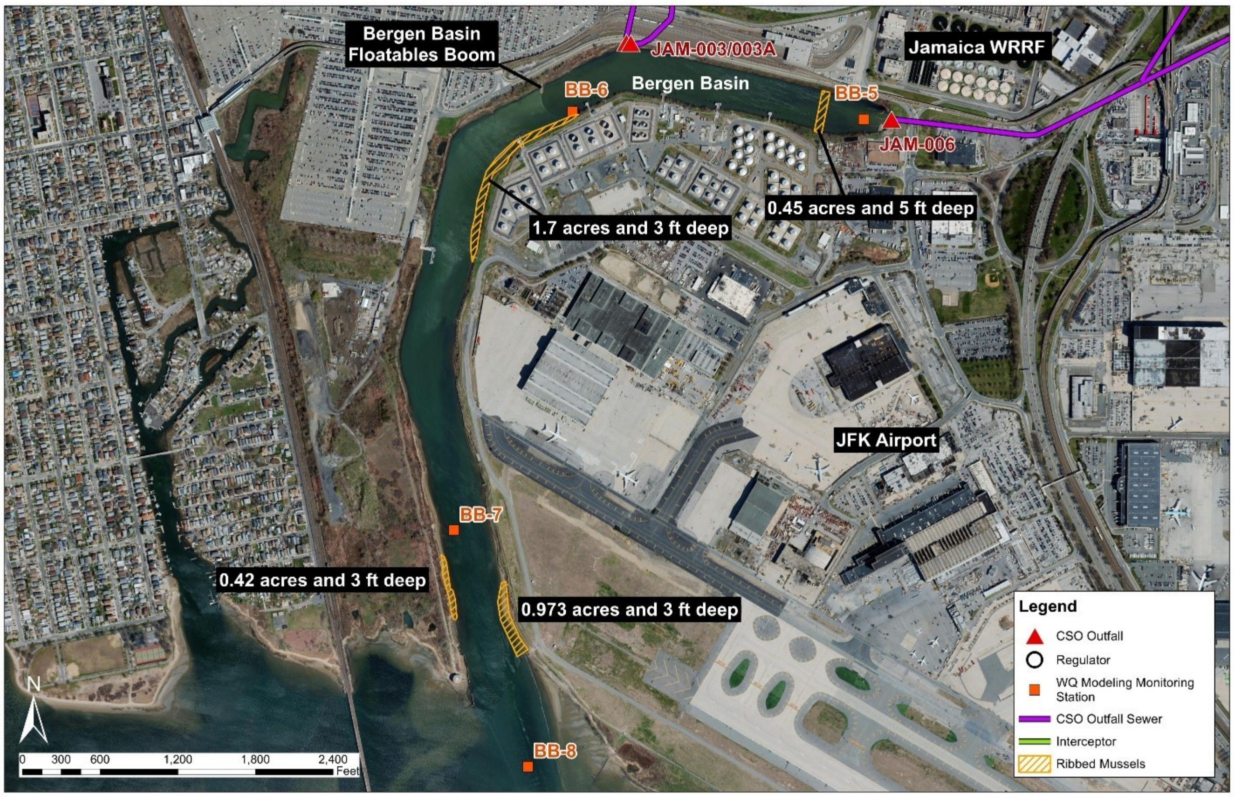

Figure 8-13. Ribbed Mussel Installation in Bergen Basin

Environmental Dredging: Based upon NOAA navigation charts and field visits during low tide, mounds of sediment were observed during low tide at the head end of Bergen Basin. In consideration of documented odor complaints in the area of Bergen Basin, notwithstanding the recent upgrades to the Jamaica WRRF odor control systems, dredging of exposed sediment at Outfall JAM-006 would be performed. An estimate of 50,000 CY of dredged material was developed based upon the dredging limits shown in Figure 8-14. Dredging depths, final grading of the stream bottom and restorative measures would need to be coordinated with the ribbed mussel bed design and PANYNJ airport operations. While this alternative provides no reduction in CSO discharge, it does address ancillary issues of CSO discharges through the removal of odor causing sediments, as well as aesthetic benefits of stream bottom restoration. Environmental dredging has been included in Alternative B-13 and retained for further consideration.

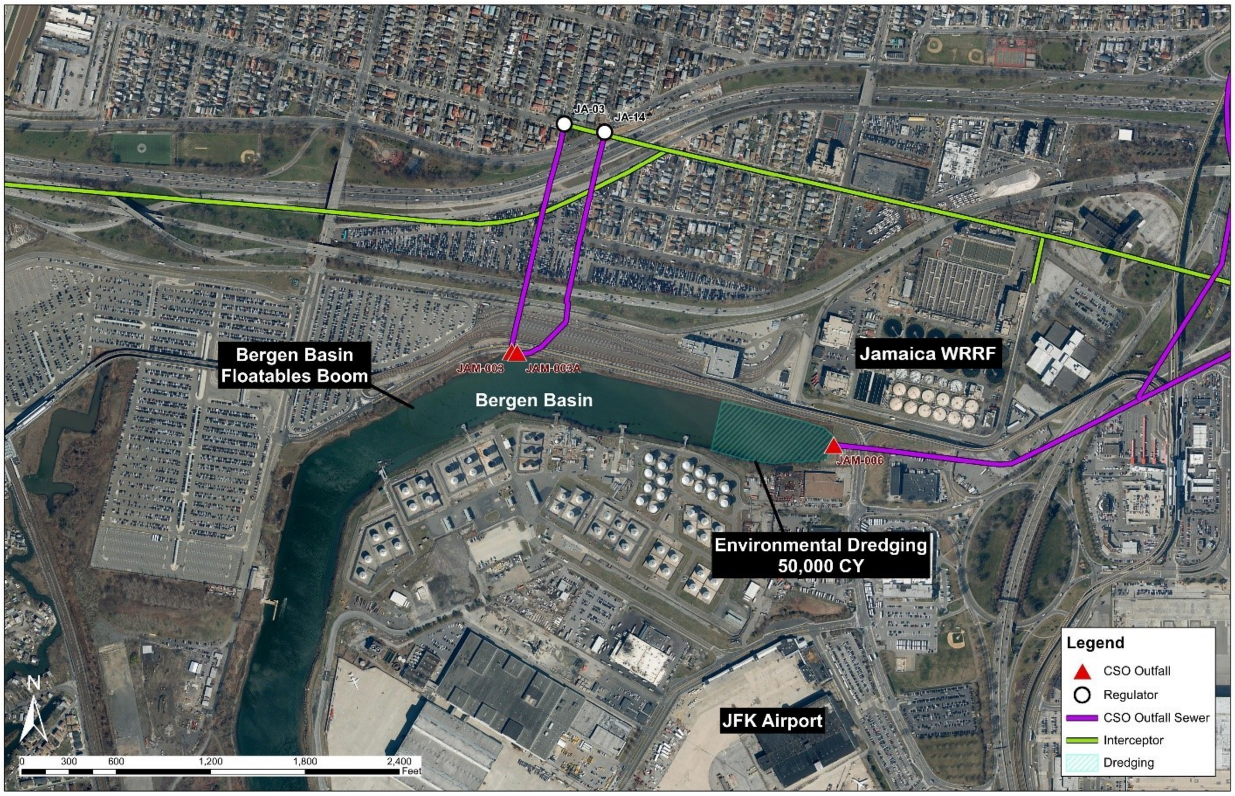

Figure 8-14. Environmental Dredging of Bergen Basin

Treatment/Storage Alternatives: A number of the control measures considered for Bergen Basin fall under the dual category of treatment and storage. These control measures include in-line or in-system storage, off-line tanks, and deep tunnel storage. Treatment refers to disinfection in either CSO outfalls or at Retention Treatment Basins (RTBs). A discussion of the treatment and storage alternatives evaluated for Bergen Basin follows.

<u>Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Treatment/Storage</u>

Initial evaluations focused on optimizing the performance of existing infrastructure to capture and/or treat CSO discharges. *In-System storage* is limited due to the lack of existing infrastructure large enough to accommodate sufficient volumes to make the alternatives cost-effective. Storage in the CSO outfalls was not considered feasible due to the relatively short length of the outfalls, and the volume of stormwater that also discharges through the outfalls downstream of the regulators.

An alternative was evaluated utilizing in-line storage within the East and West Interceptors, with designated pumping stations at the treatment plant for each interceptor; however, modeling indicated that HGLs in the West Interceptor would be raised increasing the risk of flooding along contributing trunk and collector sewers. As a result, In-System Storage was eliminated from further evaluation for this waterbody.

WRRF Upgrades were determined to be infeasible for the Jamaica WRRF due to limited available space for installing additional primary settling tanks and expansion of disinfection facilities. In addition, IW modeling indicated that WRRF capacity upgrades would negligibly reduce CSO discharges to Bergen

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Basin without providing storage capacity to equalize peak wet-weather flow. This alternative was eliminated from further evaluation for the Jamaica WRRF.

Outfall Disinfection was determined to be non-viable for Bergen Basin due to the lack of available contact time within the two largest outfall sewers. The outfall for JAM-003 is a 1,500 foot long single barrel 9' x 8' sewer, and the outfall for JAM-003A is a 1,500 foot long double barrel 13.5' x 9' sewer. While disinfection and dechlorination facilities (if needed) could both be sited along the outfall, the contact time cannot be achieved at the peak flow rates predicted by the model for many storm events. As these sewers are tidally influenced, new tide gates would need to be installed at the discharge end of the outfall sewers. In addition, a siphon exists under the Belt Parkway, as well as several storm sewer connections, further impacting the hydraulic complexity of designing and effectively operating disinfection facilities along this outfall. In consideration of the site characteristic and associated design and operational complexities, this alternative has been eliminated from further evaluation for Bergen Basin.

Evaluation of New Treatment/Storage Facilities

Treatment/Storage Alternatives require dewatering of stored CSO volumes after wet-weather events. Table 8-8 provides a summary of the total storage volume and the associated dewatering rate assuming a 24-hour dewatering period for storage facilities providing 25, 50, 75, and 100 percent levels of CSO Control for Outfalls JAM-003 and JAM-003A.

Table 8-8. Storage and Dewatering System Capacity for Storage Alternatives for Outfalls JAM-003 and JAM-003A

Level of Control	Storage Volume (MG)	Dewatering PS Capacity(1) (MGD)
25%	4	4
50%	8	10
75%	19	20
100%	45	50

Note:

(1) Assumes pump-back of stored CSO within a 24 hour period with peak flow limited to 1.5xDDWF.

During wet-weather conditions, the Jamaica WRRF's SDPES permit requires the WRRF to treat up to 1.5xDDWF (150 MGD) through all treatment processes and up to 2xDDWF through preliminary, primary and disinfection processes. In sizing CSO storage tanks and tunnels for the Jamaica CSO LTCP, it was assumed that dewatering would only be performed when peak flows were less than 150 MGD, so that all captured CSO would receive full treatment. Flow logic was built into the model to adjust the dewatering pumping station discharge rate to convey the difference between 1.5xDDWF and the incoming flow from the interceptor system. For example, if the flow entering the Jamaica WRRF from the East and West Interceptors totaled 120 MGD, the dewatering pumping station could pump up to 30 MGD. If the incoming flow was 100 MGD, the pump rate would increase to 50 MGD. In the case of back-to-back storm events, the tunnel dewatering pumps would shut off when peak flows exceeded 150 MGD.

RTB and storage concepts evaluated for control of CSO from JAM-003 and JAM-003A included a conveyance conduit with an RTB and CSO storage tunnels. Further description and discussion relating to these alternatives follows.

Retention Treatment Basins: As discussed earlier and illustrated in Figure 8-15, a number of viable sites for the installation of new treatment or storage facilities were identified in the vicinity of Bergen Basin. A 1.5 acre city-owned vacant parcel was identified near the north end of the Jamaica WRRF, where a building had been demolished. Other potential parcels for construction included city-owned properties leased by PANYNJ for long-term parking and car rental.

The only parcels large enough to accommodate RTBs were the long-term parking and car rental leased by PANYNJ. Figure 8-15 illustrates the plan view for the proposed RTB sited on this parcel, for 25, 50, 75, and 100 percent levels of CSO control. The challenges associated with siting this facility include significant loss of JFK parking spaces over a five to six year construction period, as well as property acquisition/access challenges while providing minimal water quality benefits to Bergen Basin. As a result, this alternative has been eliminated from further evaluation under this LTCP.

Storage tanks require a larger footprint than RTBs, resulting in a greater impact to the long-term parking and car rental parcel. Thus, this alternative has also been eliminated from further evaluation under this LTCP.

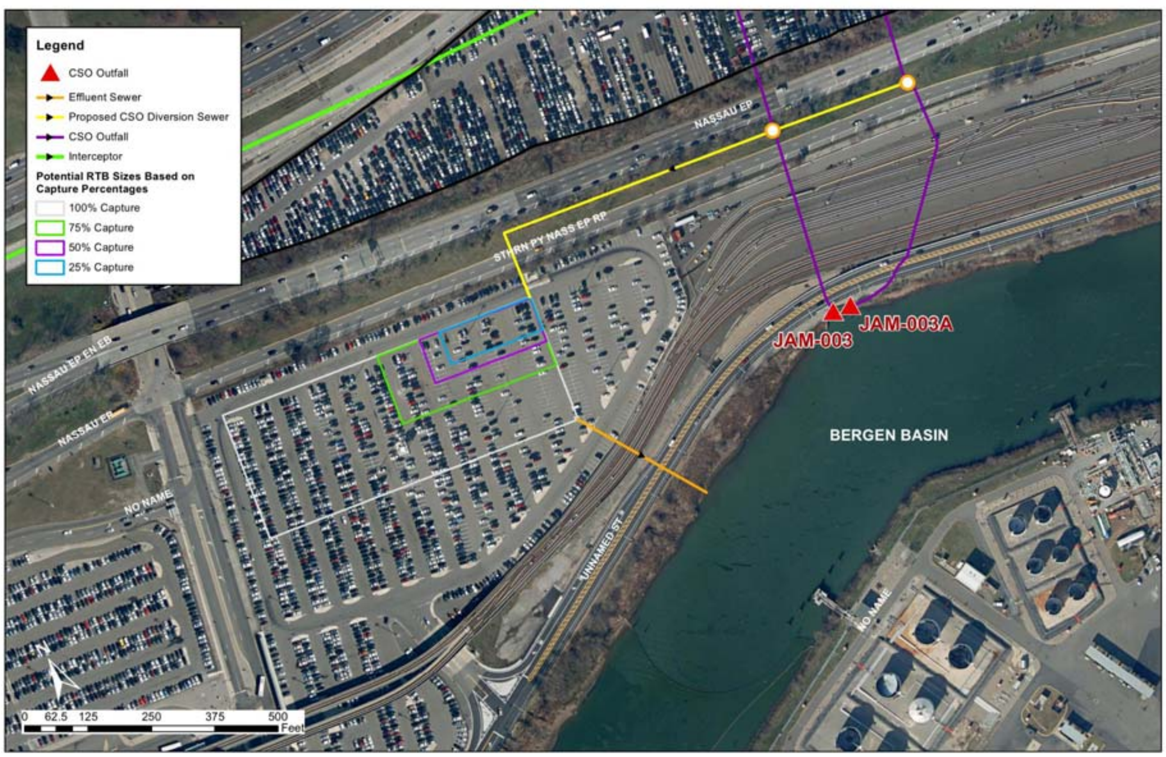

Figure 8-15. Layout for Proposed Retention Treatment Basin

Alternative B-2c1: Extend HBPS Discharge to a RTB at Jamaica WRRF

This alternative, shown in Figure 8-16, includes the elements of Alternative B-2c: Abandonment of the force main connection of the HBPS to the West Interceptor, and redirection of this force main to the head end of the Jamaica WRRF. A new 50 MGD RTB sited at the head end of the Jamaica WRRF would receive flow and discharge its effluent to the chlorine contact tanks at the treatment plant.

This alternative removes the flow constriction at the West Interceptor, preventing backups at Regulators JA-03 and JA-14 during wet-weather events, reducing the HGL of the West Interceptor and thereby reducing CSOs to Bergen Basin. IW modeling projects a 13 percent CSO reduction at Bergen Basin, which is small in consideration of the cost to implement this alternative.

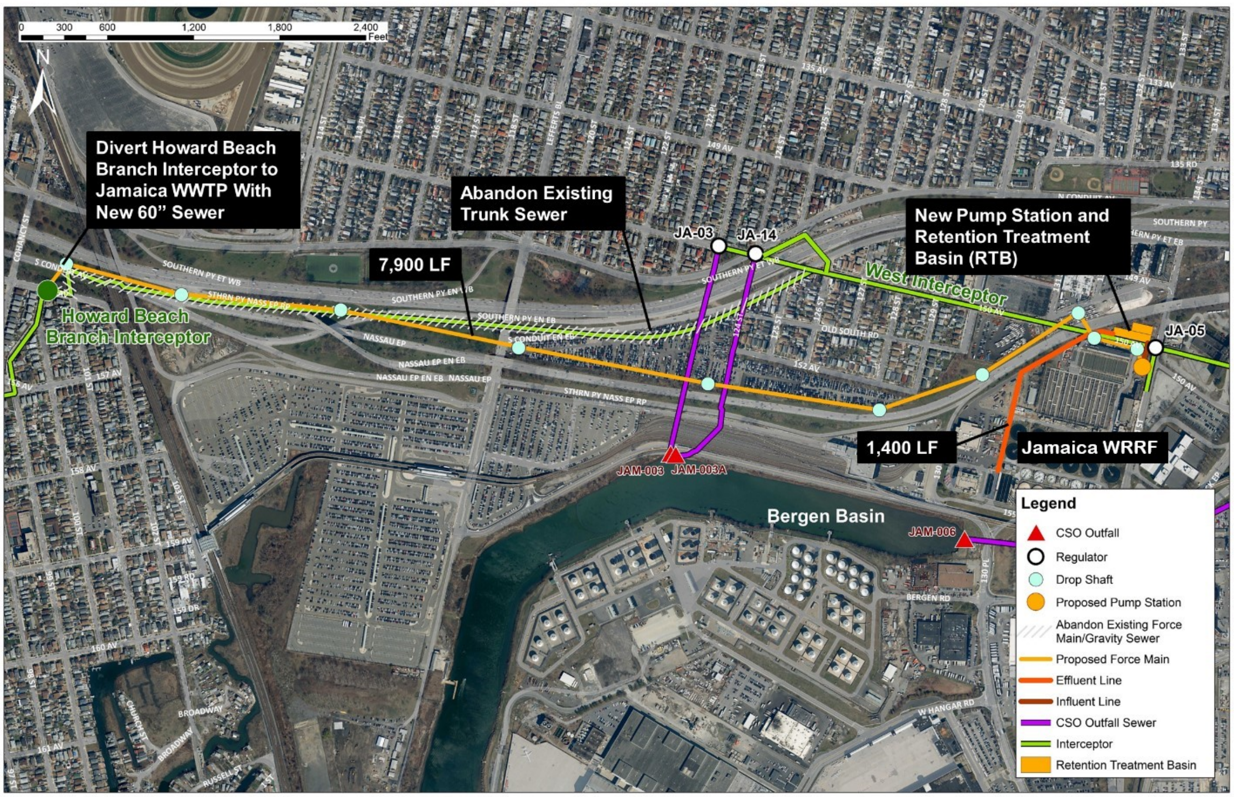

Figure 8-16. Layout for Diversion of the HBPS Discharge to a RTB at the Jamaica WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Provides additional capacity in West Interceptor for conveyance of JAM-003/003A CSO to the Jamaica WRRF
- The final sewer size could be further adjusted in conjunction with HBPS upgrades during final design to help address drainage issues in Howard Beach in addition to controlling CSO discharges

Cost

- The estimated NPW for this control measure is $985M.

Challenges

- High cost to CSO volume capture
- Requires continuous pumping to address dry and wet-weather flow conveyed by the diverted trunk sewer
- Limited improvement in Bergen Basin water quality attainment
- Property acquisition and permitting
- Limited space for construction of RTB and pumping station
- Highway and West Interceptor crossings
- Construction of RTB effluent sewer to chlorine contact tank

Alternative B-2d2: Construct a Parallel Sewer From Regulators JA-03 and JA-14 to a 50 MGD RTB at the Jamaica WRRF

Alternative B-2d2 includes the components of Alternative B-2d with a new 50 MGD RTB sited at the head end of the Jamaica WRRF. The RTB would receive flow and discharge its effluent to the chlorine contact tanks at the treatment plant, as shown in Figure 8-17. Under this alternative, dry-weather flow would continue to the Jamaica WRRF via Regulators JA-03 and JA-14 and the West Interceptor. Under wet-weather conditions, overflow at Outfalls JAM-003 and JAM-003A would be diverted to the new parallel sewer and to the RTB. Modeling results project a 63 percent reduction in CSO overflow volumes to Bergen Basin.

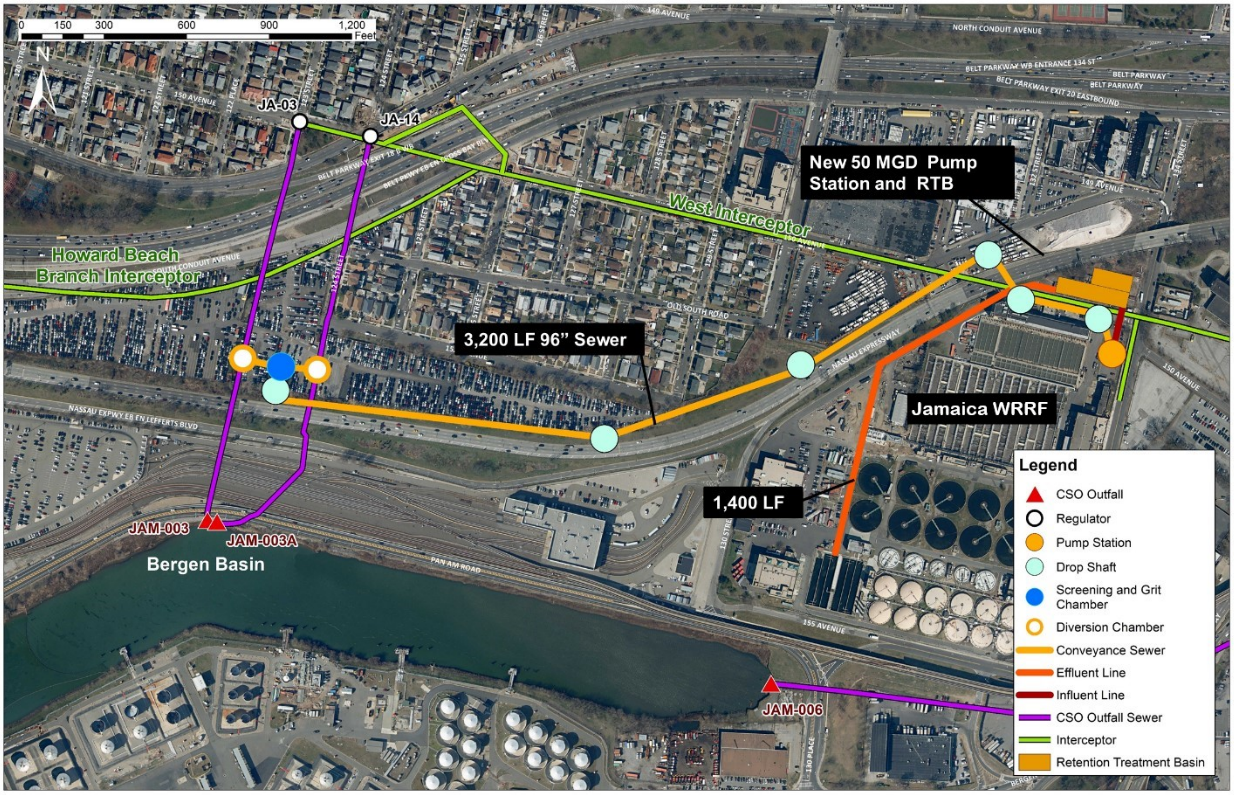

Figure 8-17. Layout for the Diversion of JAM-003/003A to a RTB at Jamaica WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Captures and conveys CSO from JAM-003/003A to a RTB
- Isolates CSO to reduce HGL impacts to the East and West Interceptors
- Mechanical components are located at the Jamaica WRRF to facilitate O&M
- Staff familiar with RTB Operations and Maintenance

Cost

- The estimated NPW for this control measure is $882M.

Challenges

- Limited improvement in Bergen Basin water quality attainment
- Property acquisition and permitting
- Tight site for construction of facilities
- Potential for sewer conflicts on WRRF site
- Highway and West Interceptor crossings
- Construction of RTB effluent sewer to chlorine contact tank

As a result of the high cost to water quality benefit ratio, this alternative has been eliminated from further evaluation.

CSO Storage Tunnels: As a result of the limited availability of suitable sites for traditional storage and satellite treatment technologies within the Bergen Basin sewershed, tunnel alternatives were developed further. Unlike traditional tanks, tunnels:

1. Can provide for both conveyance and storage of CSO;
2. Require less permanent above-ground property per equivalent unit of storage volume;
3. Minimize surface construction impacts;
4. Reduce construction related groundwater pumping and treatment costs; and
5. Reduce the volume of near-surface spoil material to be treated, handled, and transported for disposal during construction.

These benefits make tunnel storage more practical for highly developed sewersheds such as Bergen Basin.

Alternative B-6: CSO Storage Tunnel from Outfalls JAM-003 and JAM-003A with a Dewatering Pumping Station at the Jamaica WRRF

Tunnel construction would involve the boring of a linear storage conduit underground using a tunnel boring machine. Shafts would be installed during construction for the connection of CSO diversion pipes and O&M access. A tunnel dewatering pumping station (TDPS) would also be included at the downstream end of the tunnel with pumped discharges being conveyed to the Jamaica WRRF for treatment after wet-weather events. A mechanical ventilation system would be provided with an activated carbon odor control system. Additional passive odor control systems and/or backdraft dampers would be provided at the drop shafts.

As shown in Figure 8-18, two diversion chambers, a screening/grit chamber, and a receiving/drop shaft would be sited along Outfalls JAM-003 and JAM-003A, causing temporary disturbances to PANYNJ facilities. Two gravity sewers would convey flows from these diversion chambers through the screening and grit chamber to the storage tunnel. The 3,200 LF tunnel would generally follow the northern edge of the Nassau Expressway until crossing it at the head end of the Jamaica WRRF. A launch shaft, screening chamber, and 50 MGD TDPS would be sited at the head end of the WRRF.

This system would remain inactive during dry-weather only seeing flows during wet-weather events, when the hydraulic capacity of the West Interceptor is exceeded and the weirs at Regulators JA-03 and JA-14 are overtopped. Flows would then be diverted to this tunnel, which would retain these CSOs until the wet-weather event has receded and the Jamaica WRRF could handle the CSO pump-back.

Modeling determined that a 21 foot diameter single barrel 8 MG tunnel would be required for 50 percent capture, a 32 foot diameter single barrel 19 MG tunnel would be required for 75 percent capture and a 49 foot diameter 2,200 LF double barrel and 1,200 LF single barrel 91 MG tunnel would be required for 100% CSO capture.

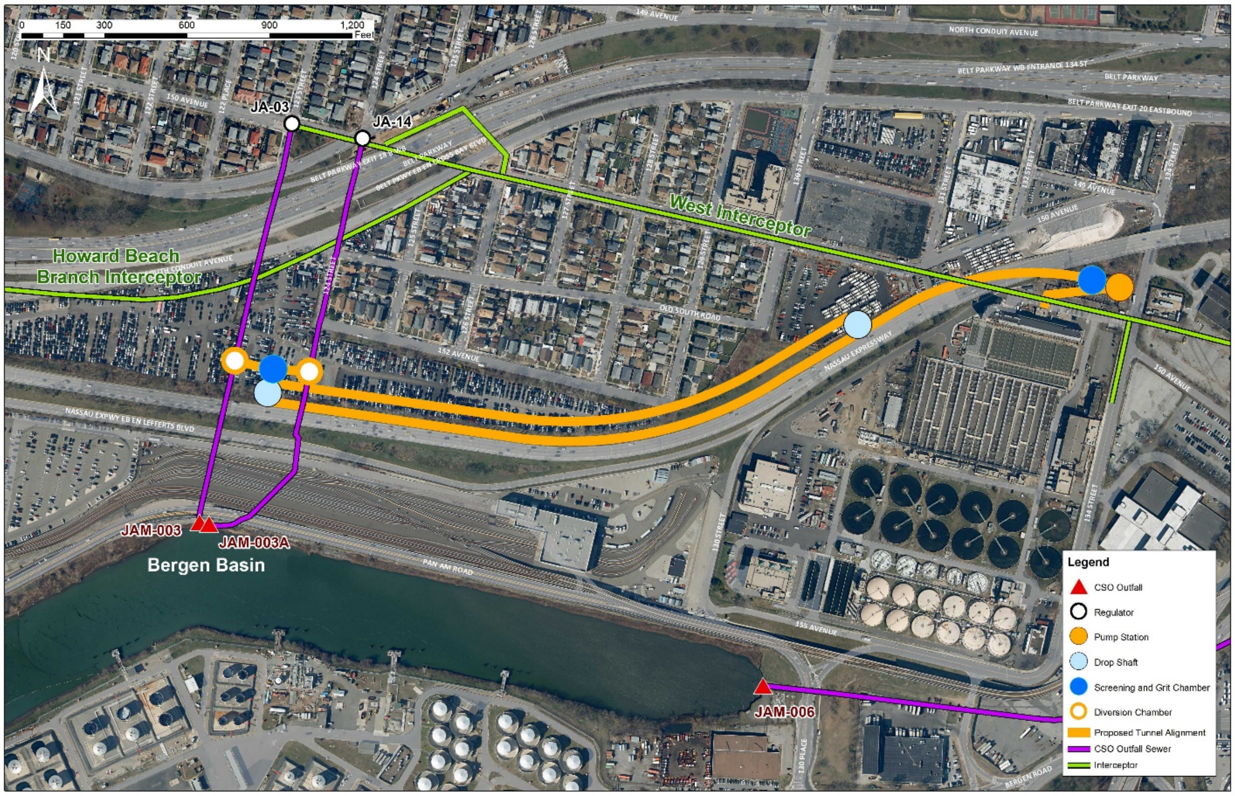

Figure 8-18: Layout of CSO Storage Tunnel and 50 MGD Dewatering Pumping Station at Jamaica WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Can provide high level of CSO capture and treatment
- Provides storage and conveyance for control of wet-weather peak flows from Regulators JA-03 and JA-14

Cost

- The estimated NPW for this control measure varies by level of control is as follows:
  - 50% CSO control: $736M
  - 75% CSO control: $896M
  - 100% CSO control: $1,755

  Details of the cost estimates are presented in Section 8.4.

Challenges

- Limited improvement in Bergen Basin water quality attainment

- Temporary relocation of parking and businesses during construction
- Crossings of the Nassau Expressway and the West Interceptor
- The 100% CSO control tunnel is near the limit of current TBM technology and may not be constructible

As previously stated, preliminary gap analysis showed that the water quality benefits from reducing CSOs in Bergen Basin are insignificant compared to the water quality impacts associated with storm and WRRF effluent flows. Thus, due to a high cost-to-benefit ratio, this alternative has been eliminated from further evaluations.

8.2.b Other Future Green Infrastructure (Bergen and Thurston Basins)

Jamaica Bay and its tributaries are priority watersheds for DEP's GI Program, which seeks to saturate priority watersheds with GI based on the specific opportunities each watershed presents. DEP plans to construct approximately 803 greened acres of GI by 2030, including ROW practices, public property retrofits, and compliance with stormwater connection regulations on private property within the Jamaica and 26th Ward WRRF sewersheds. As discussed in Section 5, DEP projects that baseline GI should result in a CSO volume reduction to Jamaica Bay and its tributaries of approximately 169 MGY, based on 2008 typical year rainfall conditions. This projected GI has been included as part of the baseline model projections, and is thus not categorized as an LTCP alternative.

For the purpose of this LTCP, "Other Future Green Infrastructure" is defined as GI alternatives that are in addition to those implemented under previous facility plans and those included in the baseline conditions. Under Alternative T-12, an additional 8 MGY CSO reduction is projected due to the increased capacity in the interceptors in CSO portion of system. GI will also provide additional co-benefits, such as property value appreciation, carbon sequestration, air quality improvements, urban heat island reduction, and habitat creation in addition to reductions in CSO and stormwater pathogen loads. Thus, this alternative will be retained for further evaluation.

8.2.c Hybrid Green/Grey Alternatives (Bergen Basin)

Hybrid green/grey alternatives are those that combine traditional grey control measures with GI control measures, to achieve the benefits of both. However, as discussed above, the SEQ Storm Sewer Buildout Program is ongoing and will significantly impact the drainage patterns throughout the collections system tributary to the Jamaica WRRF. Therefore, no controls in this category are proposed for the Jamaica Bay and Tributaries LTCP.

8.2.d Retained Alternatives (Bergen Basin)

The goal of the previous evaluations was the development of a list of retained control measures for Outfalls JAM-003, JAM-003A, and JAM-006 to Bergen Basin. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in Table 8-9. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures include the CSO storage tunnels and the Additional GI and Environmental Improvements. Measures for additional and/or improved floatables control are addressed within the retained alternatives.

Table 8-9. Summary of Bergen Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Recommendations
Bergen Basin	B-2b	In-line storage within the East and West Interceptors along with designated pumping stations at the Jamaica WRRF	JAM-003 & JAM-003A	Limited reduction in CSOs and an increase in HGL in the West Interceptor	Abandoned due to HGL impacts
Bergen Basin	B-2c1	Redirect the HBPS force main to a new RTB located at the Jamaica WRRF	JAM-003 & JAM-003A	Slight reduction in CSO with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Bergen Basin	B-2d2	Construction of a parallel sewer to convey CSO from JA-03 and JA-14 to a new 50 MGD RTB at the Jamaica WRRF	JAM-003 & JAM-003A	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Bergen Basin	B-2e	Abandon HBPS and construct a new gravity sewer and dewatering pumping station at 26th Ward WRRF	JAM-003 & JAM-003A	Slight reduction in CSO with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Bergen Basin	B-2f	Abandon HBPS, construction of a new gravity sewer, dewatering pumping station at 26th Ward WRRF and construction of a new parallel sewer from JA-03 and JA-14 to the Jamaica WRRF	JAM-003 & JAM-003A	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Bergen Basin	B-2g	Abandon HBPS, construction of a new CSO Storage Tunnel from Outfalls JAM-003 & JAM-003A with a dewatering pumping station at 26th Ward WRRF. Diverts flow from HBPS Drainage Area.	JAM-003 & JAM-003A	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Bergen Basin	B-2h	Diversion of all flow from Regulator JA-02 to 26th Ward WRRF Sewer Service Area	JAM-003 & JAM-003A	This alternative was not modeled. Insufficient grade differential to construct new sewer.	Abandoned. Not constructible.

Table 8-9. Summary of Bergen Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Recommendations
Bergen Basin	B-3	Outfall disinfection of CSO Outfalls JAM-003 and JAM-003A	JAM-003 & JAM-003A	Insufficient contact time and tidal impacts	Abandoned due to insufficient contact time
Bergen Basin	B-4	Construction of a CSO storage tank to receive flow from Outfalls JAM-003 and JAM-003A with a dewatering pumping station and force main to return flows to the system after the wet-weather event has receded	JAM-003 & JAM-003A	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio and significant impacts to JFK Airport facilities due to a large footprint
Bergen Basin	B-6	Construction of a CSO storage tunnel from Outfalls JAM-003 and JAM-003A with a dewatering pumping station at Jamaica WRRF	JAM-003 & JAM-003A	Significant reduction in CSO but with limited Water Quality Benefits. Equalizes peaks and provides operational benefits during wet-weather	Retain. Provides CSO conveyance, storage, and treatment at WRRF.
Bergen Basin	B-7	Construction of a RTB at the Port Authority leased Parking Lot to receive flows from Outfalls JAM-003 and JAM-003A	JAM-003 & JAM-003A	Limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio and significant impacts to JFK Airport facilities
Bergen Basin	B-10	Construction of a new regulator along Outfall JAM-006 to divert CSO and stormwater to Jamaica WRRF	JAM-006	Limited CSO reduction and Water Quality Benefits	Abandoned due to tidal flows seen in outfall sewer as well as HGL impacts to the interceptors
Bergen Basin	B-11	Construction of a new regulator along Outfall JAM-006 to divert CSO and stormwater to Jamaica WRRF, and construction of a CSO storage tunnel from Outfalls JAM-003 and JAM-003A with a dewatering pumping station at Jamaica WRRF	JAM-003, JAM-003A & JAM-006	Significant reduction in CSO but with limited Water Quality Benefits and an increase in HGLs in the East and West Interceptor	Abandoned due to high cost-to-benefit ratio and increased HGL impacts

Table 8-9. Summary of Bergen Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Recommendations
Bergen and Thurston Basin	B-12	Jamaica WRRF capacity upgrade	JAM-003, JAM-003A & JAM-006	No CSO reduction	Abandoned due to lack of available space for installation of new primary tank and due to lack of CSO reduction
Bergen and Thurston Basin	B-13	Additional GI and Environmental Improvements	JAM-003, JAM-003A & JAM-006	Low CSO reduction, but provides SW reduction. Dredging removes odor causing sediments. Ribbed mussels provide filtration of tide cycles and CSO/SW discharges.	Retain. Low cost-to-benefit ratio. Co-benefits.

Thurston Basin Alternatives

Thurston Basin is located in Jamaica, Queens to the immediate east of JFK Airport. It receives runoff from approximately a 9,220 acre drainage area, out of which approximately 1,170 acres is combined drainage area, 6,870 acres is separated sewershed, and 970 acres is airport drainage area. About 210 acres of direct drainage also exist along the banks of the basin. CSO and stormwater is discharged to this basin by two CSO and seven storm outfalls. CSO Outfalls JAM-005 and JAM-007 are the two biggest outfalls, measuring quadruple barrel (QBL) 16' x 8' and QBL 17' x 6', respectively.

Based on 2040 projected flows, with all proposed Jamaica Bay WWFP projects constructed, the model projects discharges to Thurston Basin in the amount of 247 MGY of CSO and 1,193 MGY of stormwater. Baseline loading, as summarized in Table 6-4, indicates that pathogen and BOD loading from stormwater sources ranges from 2.5 to 3 times the load of CSOs. This is reflected in the gap analyses, which indicates that 100% CSO control fails to achieve attainment of pathogen and DO WQ Criteria for Thurston Basin. In consideration of these findings, the cost-to-benefit ratio of CSO control is expected to be very high. As a result, it will be desirable to consider technologies and approaches that reduce stormwater contributions to both the combined and separate portions of the collection system.

A review of existing land uses near the discharge of Outfalls JAM-005 and JAM-007 was performed for the purposes of identifying potential sites for new treatment/storage facilities. Figure 8-19 illustrates the location of the sites in relation to the CSO outfalls and Thurston Basin. The most suitable locations identified were a 15 acre privately owned parking lot on Rockaway Boulevard and a number of small vacant city-owned lots near 148 Avenue, which total less than an acre. Other viable parcels for construction include a few privately owned vacant lots near 148 Avenue. However, wetlands cover sizable portions of these lots thereby limiting their use. While the outfalls pass through Idlewild Park, park alienation relating to construction of above-grade facilities would likely be an issue.

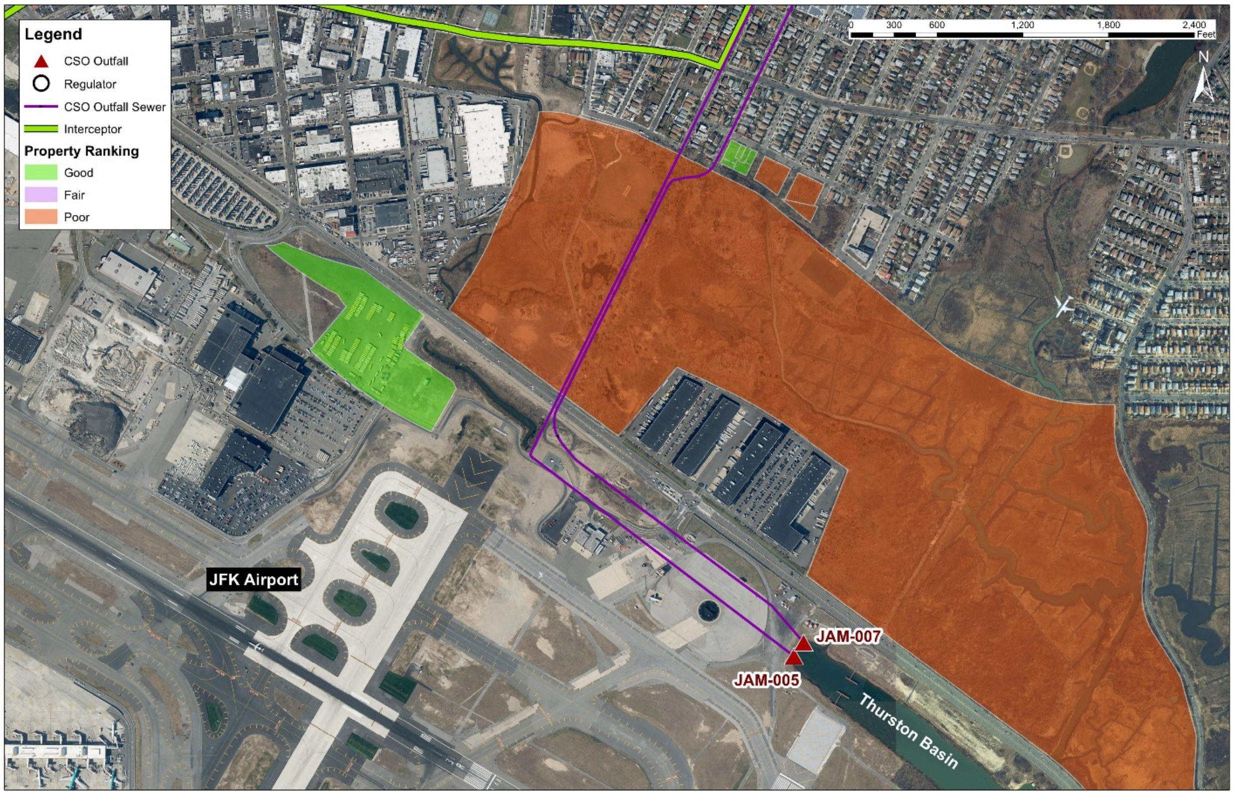

Figure 8-19. Potential Properties near Thurston Basin CSO Outfalls

CSO Relocation: This concept involves conveying overflows by gravity from one receiving water to another receiving water, where the second receiving water would either be less sensitive or provide greater dilution/assimilation than the one from which the CSO is being diverted. Neither Gravity Flow Tipping nor Flow Tipping with Conduit/Tunnel and Pumping were recommended in the WWFP for Thurston Basin. Based on preliminary water quality modeling, Bergen Basin was determined to be just as sensitive, if not more so, than Thurston Basin. In addition, diversion of the outfall to Jamaica Bay, which has more stringent water quality standards for the promotion of primary contact recreation, is contrary to the intended uses of the Bay. As a result, these alternatives have not been pursued further under the LTCP.

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing the water quality through other approaches.

Floatables Control: A floatables containment boom is located downstream of the CSO outfalls in Thurston Basin for JAM-005/007. Skimmer boats are utilized to retrieve the floatables captured by the boom. In addition to floatables from CSOs, the boom in Thurston Basin is sited such that floatables are also captured from storm sewers, and the vast majority of wet-weather flow being discharged into Thurston Basin is stormwater. The Thurston Basin boom also provides floatables capture for two unnamed streams conveying runoff from areas surrounding Springfield Park and Idlewild Park. Replacing the boom with netting facilities or underflow baffles would eliminate these ancillary water quality benefits.

Each of the above floatables control technologies is identified as an accepted practice in the USEPA Guidance for NMCs and Floatables Control Technology Fact Sheet. The fact sheet specifically references boom and skimming operations in Jamaica Bay, as well as catch basin modifications throughout New York City. Considering the well documented effectiveness of the current BMP programs for floatables capture, DEP believes that the existing approach to floatables control in the tributaries to Jamaica Bay meets the intent of the BMP requirements for floatables control, and that additional investment in alternative floatables control technologies would not provide substantial improvements in floatables capture.

However, to be responsive to DEC's comments during the development of this LTCP, DEP has further investigated alternatives for providing end-of-pipe nets in Thurston Basin at JAM005/007. The following summarizes the findings of these investigations.

Figure 8-20 indicates the location of the JAM005/007 outfalls relative to other key features of Thurston Basin. An end-of-pipe netting system would extend approximately 80 feet into Thurston Basin from the outfall headwall at the upstream end of Thurston Basin. As noted above, a minimum of two to three feet of water depth is needed for the netting system. Based on available information, dredging would likely be required at the end of the outfalls at this location to provide the required depth at low tide. The dredging would have to extend into Thurston Basin until the existing bottom provides two to three feet of depth at low tide.

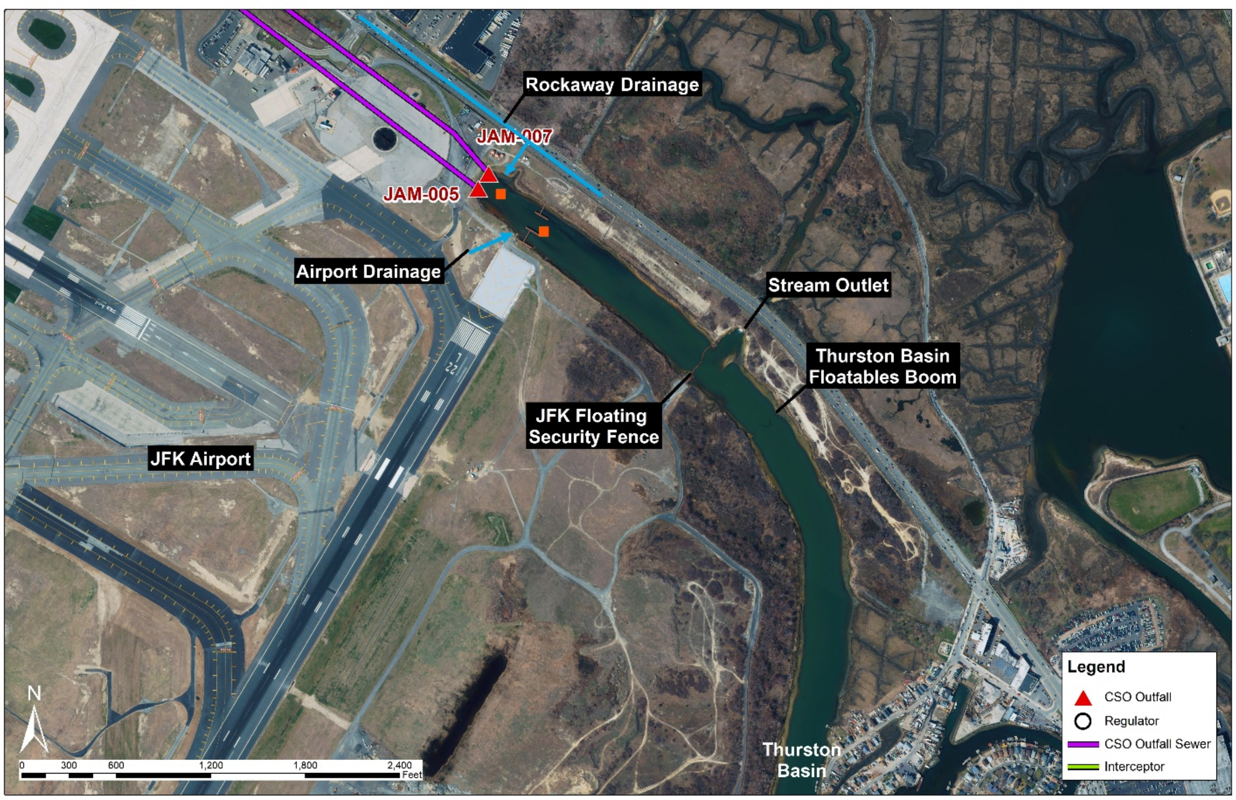

Figure 8-20. Location of Outfalls in Thurston Basin

This location is immediately adjacent to an active runway from JFK Airport. The floating security fence shown in Figure 8-20 prevents access to this location by water, so the nets would need to be replaced from the land side. The only access road to this location is on JFK Airport property, where access is restricted due to its proximity to the runway. The nets need to be pulled out of their frames using a jib crane or boom truck, and this type of operation would also be severely restricted in such close proximity to the active runway. In summary, the physical location of a floating net system for Outfall JAM005/007 creates severe restrictions in terms of access and equipment use for regular maintenance activities. For these reasons, a floating netting system is not recommended for JAM005/007. The existing containment boom located downstream of the floating security fence would continue to provide floatables control for these CSO outfalls, as well as for storm drain outfalls and a stream that discharge to Thurston Basin upstream of the boom as indicated in Figure 8-20.

Environmental Dredging: Based upon NOAA navigation charts and field observations, sediment deposition does not appear to be an issue in this waterbody. In addition, a review of historical complaint records does not indicate an issue with odors in the area. As a result, this technology will not be retained for further consideration.

Wetlands and Bioextractors: Due to the risk of tidal wetlands attracting birds adjacent to the airport and the potential hazards to aircraft, tidal wetland restoration has been eliminated from further consideration for Thurston Basin and has not been included in Alternative T-12, Additional GI, and Environmental Improvements. Ribbed mussels provide continuous filtering of the waterbody to remove pollutants and enhance native habitat. Alternative T-12 includes 3 acres of ribbed mussel beds to be created within Thurston Basin as shown in Figure 8-21. As this alternative provides low cost water quality benefits that address impacts of CSO and stormwater discharges, in addition to naturally occurring sources of pathogens and other contaminants, Alternative T-12 will be retained for further consideration.

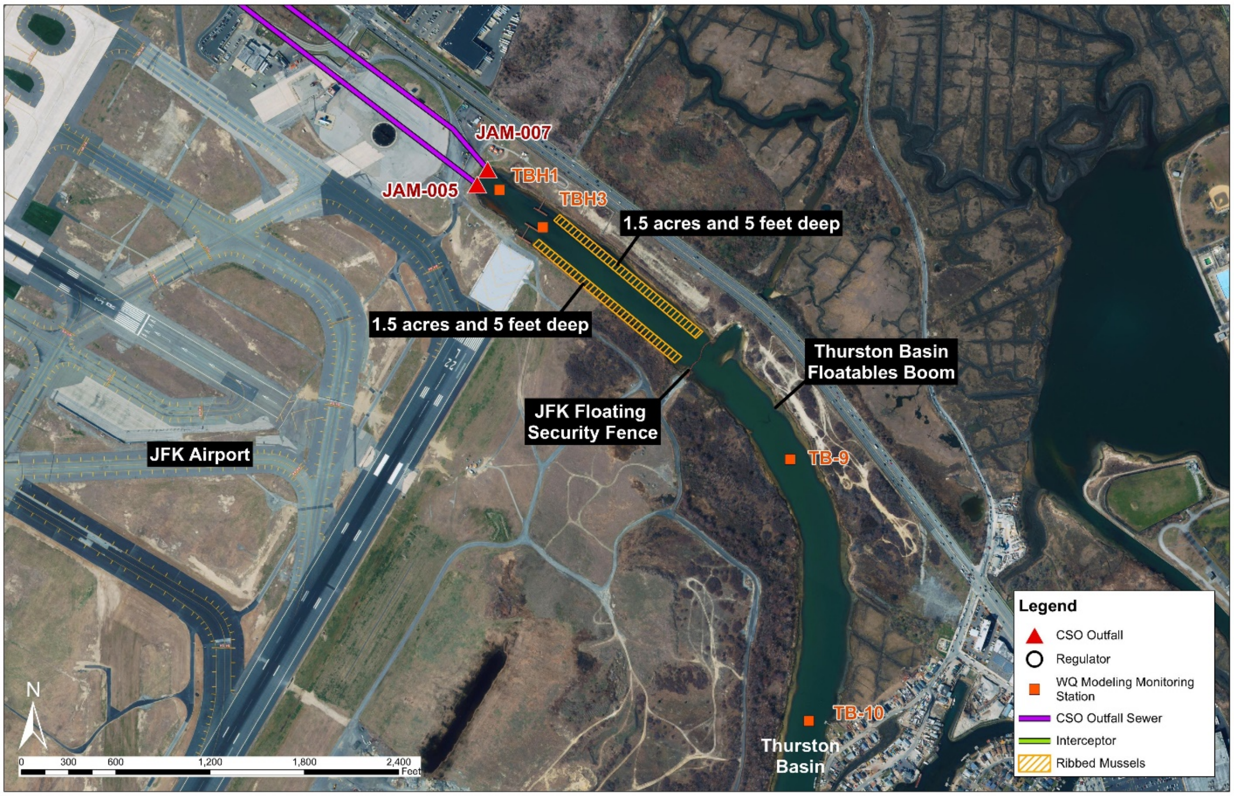

Figure 8-21. Ribbed Mussel Installation in Thurston Basin

WRRF Upgrades were determined to be infeasible for the Jamaica WRRF due to limited available space for installing additional primary settling tanks and expansion of disinfection facilities. In addition, IW modeling indicated that WRRF capacity upgrades would negligibly reduce CSO discharges to Bergen Basin unless storage capacity is provided to equalize peak wet-weather flow. As a result, this alternative was eliminated from further evaluation for the Jamaica WRRF.

Treatment/Storage Alternatives: A number of the control measures considered for Thurston Basin fall under the categories of treatment and storage. These control measures include in-line or in-system storage, off-line tanks and deep tunnel storage. Treatment refers to disinfection in either CSO outfalls or at RTBs. A discussion of the treatment/storage alternatives evaluated follows.

Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Treatment/Storage

In-system Storage: Initial alternatives evaluations focused on maximizing the performance of existing infrastructure to capture and/or treat CSO discharges. CSO JAM-005 consists of a 4,750 LF QBL 17' x 6' box culvert, while JAM-007 is a 4,500 LF DBL 16' x 8' box culvert. In-line Storage was assessed for Thurston Basin as Alternative T-10.

Alternative T-10: In-line Storage of CSO and Stormwater Within Outfall JAM-005/007

Installation of gates would be required at multiple locations as indicated in Figure 8-22 to isolate tidal inflow from Thurston Basin, as well as an existing unnamed stream that connects to Outfall JAM-005 approximately 2,200 feet upstream of the outfall discharge. The gates would be located at the discharge

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end of each of the four barrels of JAM-007 and on two outfall sewer barrels of JAM-005 just upstream of the connection of the unnamed stream as shown in Figure 8-22. The gates on JAM-005 are necessary to prevent backflow of the stream along the outfall which would reduce in-line storage capacity during high tide conditions and increase the risk of deposition of debris and sediment. Deposition of stream debris within the outfall will also increase the risk of clogging the dewatering pumps and reduce storage and conveyance capacity.

To create and maximize in-line storage within the outfall over the range of tides, mechanically operated gates and controls would be necessary, rather than the traditional hinged tide gates used at most of the City's CSO outfalls. During low tide conditions, the design would need to include automated or remote gate controls to induce storage of CSO within the outfall until the stored CSO can be pumped back to the interceptor. During large storms, which generate runoff in excess of storage capacity of the outfalls or when a 5 year storm occurs, automated control or remote operation of the gates would be needed to open the gates to release the flow to the receiving waters when depths reach a maximum set point. Malfunction of mechanically operated gates poses a high risk for sewer backup and flooding as experienced at the Spring Creek AWWTP on April 30, 2014. Failure of the mechanically operated gates resulted in basement backups and flooding in parts of the New Lots and Lindenwood neighborhoods. As a result, DEP is removing the mechanically operated sluice gates at this facility and replacing them with standard passive hinged tide gates.

Considering the potential for similar equipment malfunctions and the history of flooding throughout SEQ, DEP will not consider CSO control alternatives that would require automated electro-mechanical systems to store or control flow within a sewer or tank. Maintaining existing drainage to this community is a high priority for DEP as evidenced by the SEQ Storm Sewer Buildout Program.

Outfall disinfection has been recommended in prior LTCPs where the outfall length provides the necessary contact time to kill bacteria and remove residual chlorine. To accommodate a wide range of flow conditions, the outfalls are often retrofitted to prevent tidal inflow, manage contact time, provide chemical mixing, or address other process needs. Outfall disinfection was assessed for Thurston Basin as Alternative T-3.

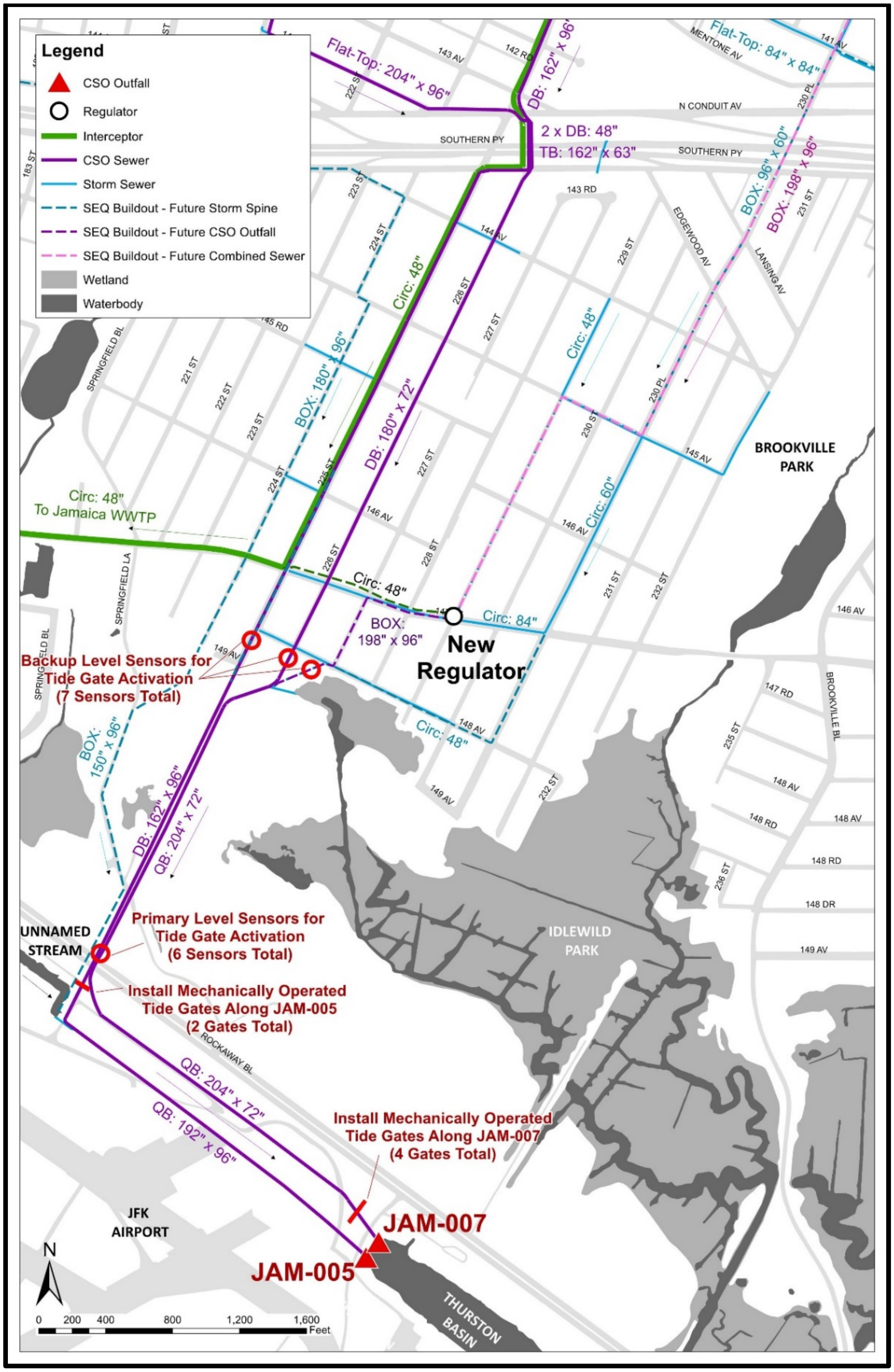

Figure 8-22. Layout for In-line Storage of CSOs JAM-005/007

Alternative T-3: Outfall Disinfection of CSO and Stormwater in CSOs JAM-005 and JAM-007

A desktop analysis of outfall disinfection opportunities was performed to determine the feasibility of utilizing the length and in-line capacity of CSOs JAM-005 and JAM-007. The concept for this alternative, as shown in Figure 8-23, includes the installation of a sodium hypochlorite feed system with introduction of disinfectant to the outfalls barrels near 148 Avenue. The chlorination building would be constructed within a vacant lot located at the intersection of 148 Avenue and 226th Street. An above-ground dechlorination facility would be sited near the outfall discharge point in Idlewild Park. The dechlorination feed line would be located along the outfall to provide enough contact time to control the residual chlorine before the flows are discharged to Thurston Basin. To address the tidal impacts, a tide gate chamber would be installed with tide gates on all eight of the sewer barrels.

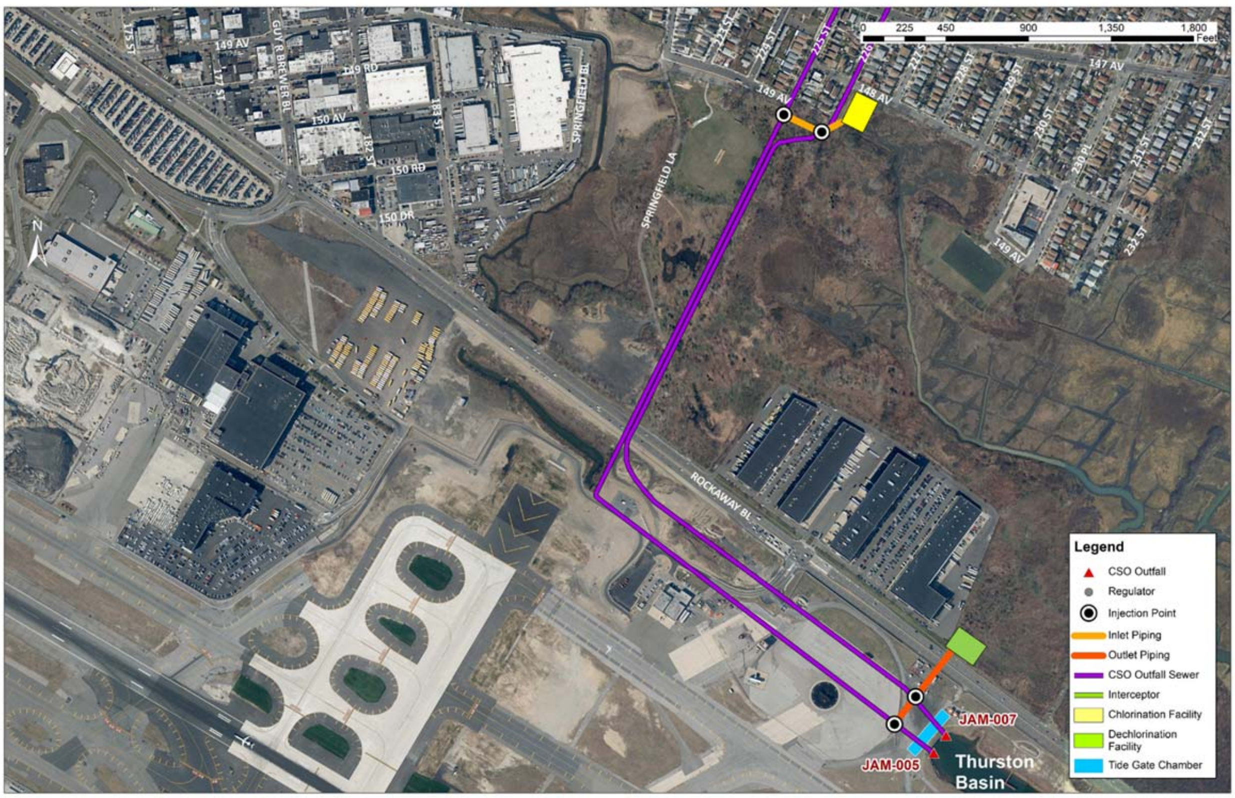

Figure 8-23. Layout for Outfall Disinfection of CSOs JAM-005/007

The benefits cost and challenges associated with this alternative are as follows:

Benefits

- Disinfects both CSO and stormwater in JAM-005 and JAM-007
- Low cost pathogen control

Cost

- The estimated NPW Cost for this control measure is $25M.

Challenges

- Property acquisitions and permitting
- Potential impacts to parkland
- Tidal influence
- Control of total residual chlorine
- Additional storm sewer and open stream connections exist along the outfall downstream of the hypochlorite feed point
- Transition from dual barrel sewers to quadruple barrels
- Process control challenges associated with flow in multiple barrels, and the streamflow/stormwater connections downstream of the disinfectant dosing location.
- Access for operation and maintenance
- Community opposition
- Potential impacts to shellfish restoration projects in Head of Bay and Thurston Basin

There are numerous siting and operational challenges to overcome for the successful installation and operation of disinfection facilities along Outfalls JAM-005 and JAM-007. While the chlorination building could be sited in a vacant lot, permitting for impacts to wetlands and buffers would be needed for the chemical feed piping, and an access road for installation and periodic maintenance of mixers or other equipment located along the outfall. The dechlorination facilities would need to be sited in Idlewild Park, which would likely require State legislation, or within a secure area of the airport property, which would require agreement from the PANYNJ. The transition of the outfalls from dual barrel to quadruple barrel configurations, the introduction of additional stormwater and surface streams at points along the outfall and the impacts of tidal action create highly variable operating conditions that will make it extremely difficult to achieve the required bacteria kills and satisfy total residual chlorine limits that would be included in a future SPDES permit for this facility. These challenges create potentially unmanageable challenges and risks, some of which are beyond the control of DEP or the City, that eliminate this alternative from further consideration.

Based on technical discussions with DEC, DEP conducted further review of these challenges as discussed below and documented in a technical memorandum attached hereto as Appendix E.

The following text further emphasizes the concerns with successful operation of this CSO control alternative and addresses the request to evaluate application of disinfectant at points closer to Regulators JA-06 and JA-07, as well as a new regulator to be constructed at 147 Avenue and 229th Street under the SEQ Storm Sewer Buildout Program. While moving the disinfection application point upstream increases available contact time, it further complicates system operation as a result of the additional storm sewers that connect to the multiple barrel sewers between the points for application of chlorination and dechlorination chemicals.

Figure 8-24 provides a scaled map of the collection system downstream of Regulators JA-06, JA-07, and JA-08. The figure identifies over a dozen interconnections (48" or larger) contributing CSO and stormwater to the multiple barrel CSO Outfalls JAM-005 and JAM-007. In addition, numerous smaller connections (not shown in the figure) exist along each of the outfalls. Due to the configuration of the collection system, siting of chemical storage and feed equipment will require multiple property acquisitions. Potential sites for chlorination and dechlorination facilities are shown. Sites for tide gates are also shown for each outfall.

Controlling the application of chlorination and dechlorination chemicals will be a major operations issue for the following reasons:

- As there are several points where CSO and stormwater enter the outfalls, there would be a need to introduce disinfectant at numerous upstream locations or heavily dose with disinfectant at the upstream end to achieve the required contact times.
- Since the flow rates and composition of CSO and stormwater may vary significantly within each sewer barrel, multiple pumps and feed lines would be required, each with meters and controls to pace application of disinfectant at each injection point.
  - Sensors and means of estimating CSO discharges over regulator weirs would also need to be incorporated in the disinfectant feed control logic to adjust feed for the higher load associated with CSO.
  - Dechlorination chemicals would need to be introduced to multiple outfall barrels, all having varying flow rates. The dechlorination system will require similar chemical feed equipment and operations as used for the application of disinfectant.
  - Due to the intermittent application, chemical feed equipment and distribution lines must be flushed following each storm event to prevent crystallization of chemicals and blockage of the feed lines. As flushing will be performed during dry-weather conditions, procedures will need to be developed to minimize the introduction of chemicals to the outfalls and the impact of chlorination byproducts.
- As the outfalls are tidally influenced, the discharge will be impacted by the tide level and storm surge. These conditions will be highly variable within each of the outfall barrels and would require potential safeguards to prevent activation of chemical feed equipment as a result of the movement of water within the outfall barrels as CSO and stormwater enter the outfall during high tide. The chemical feed control logic would need to account for negative or extremely low flow rates that will occur in the outfalls until there is sufficient head to overcome the tide and open downstream tide gates.

During the typical rainfall year (2008), CSO discharges occur about 25 times annually, while stormwater is introduced during each of the 118 rain events. To achieve the bacteria and total residual chlorine limits that are expected to be included in future SPDES permits, DEP will likely need to activate these facilities for the majority of precipitation events to avoid the risk of missing a CSO event. This increases the level of maintenance by nearly five times that of a typical off-line tank installation. The multiple injection points further increase the level of maintenance.

The disinfection system will need to consider future phased expansion and/or modification to account for the wide variations in flow and load as future connections are made as the SEQ Buildout is implemented. For example, as the storm sewer buildout program advances, additional stormwater will be contributed to the upstream sewers and CSO will be reduced and ultimately eliminated from some of the outfall sewer barrels.

In summary, the primary challenges and risks include:

- Chemical feed facilities that would need to be constructed and maintained at multiple locations;
- As these facilities would be located in residential and commercial areas, the health and safety risk of spills and public exposure is much higher in comparison to a typical WRRF application, and public opposition to siting is also likely to be higher;
- The trunk and outfall sewers consist of multiple barrel pipes with additional connecting sewers along their alignments resulting in highly variable flow conditions from event to event;
- Multiple feed lines must be provided and individually controlled for application of chemicals to each of the individual sewer barrels;
- To address the highly variable flow conditions and multiple feed points, an extremely high degree of system automation and sophistication will be required to operate this facility;
- As the chemicals are being applied to multiple sewers in comparison to a tank with multiple channels, it is virtually impossible to simulate the highly variable operational conditions for accurate calibration of instrumentation and controls;
- There is a high risk of overdosing to overcome operational complexities and achieve anticipated permit limits for pathogens and chlorine residual;
- Thorough flushing of multiple chemical feed lines will be required after each storm event with management of flush water to protect against contaminating the downstream waterbody;
- The gap analysis indicated that even with 100% control of CSOs, recreational season (May 1st through October 31st) water quality attainment for fecal coliform is not achieved at the upstream end of Thurston Basin. As a result, outfall disinfection will not achieve water quality attainment for pathogens.

In consideration of the highly variable operating conditions, successful operation of an outfall disinfection system for Thurston Basin would be extremely complicated and pose a high risk of failing to consistently achieve permit limits. As a result, outfall disinfection is not considered to be feasible for Thurston Basin.

Therefore, DEP is not recommending this technology for further consideration.

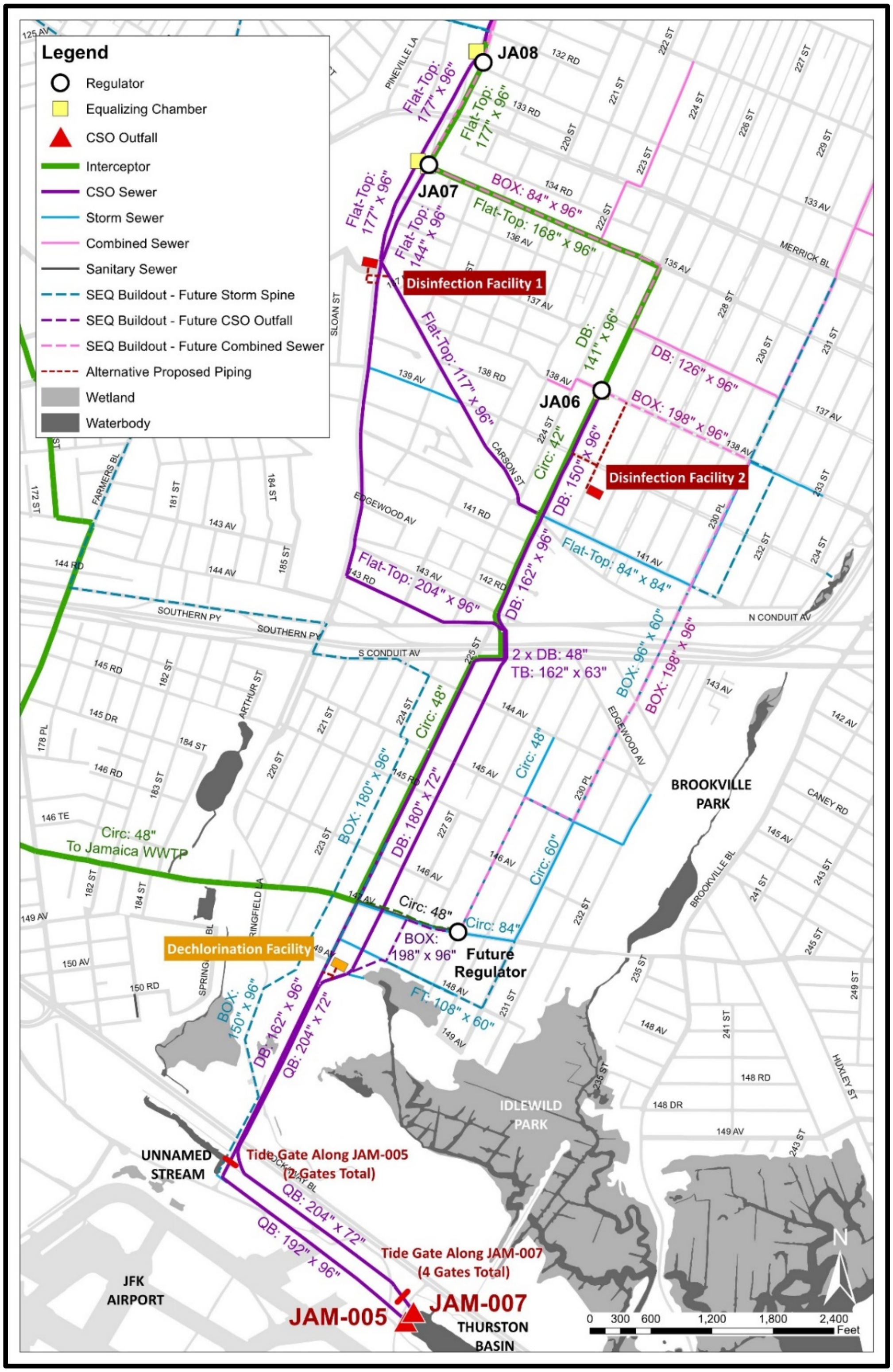

Figure 8-24. Alternative Layout for Outfall Disinfection of CSOs JAM-005/007

Evaluation of New Treatment/Storage Facilities

CSO Storage Tank and Tunnel alternatives require dewatering of stored CSO volumes as wet-weather events subside and WRRF capacity becomes available. Table 8-10 provides a summary of the total storage volume and the associated dewatering rate assuming a 24-hour dewatering period for storage facilities providing 25, 50, 75, and 100 percent levels of CSO control for Outfalls JAM-005 and JAM-007.

Table 8-10. Storage and Dewatering System Capacity for Storage Tunnel Alternatives for Outfalls JAM-005 and JAM-007

Level of Control	Storage Volume (MG)	Dewatering PS Capacity[(1)] (MGD)
25%	4	5
50%	9	10
75%	29	30
100%	91	100

Note:
(1) Assumes pump-back of stored CSO within a 24 hour period with peak flow limited to 1.5xDDWF.

During wet-weather conditions, and in accordance with the WRRF SPDES permit, the Jamaica WRRF can treat up to 1.5xDDWF (150 MGD) through all treatment processes and up to 2xDDWF through preliminary, primary, and disinfection processes. In sizing CSO storage tunnels for the Jamaica CSO LTCP, it was assumed that tunnel dewatering would only be performed when peak flows were less than 150 MGD, so that all captured CSO would receive full treatment. Flow logic was built into the model to adjust the dewatering pumping station discharge rate to the difference between 1.5xDDWF and the incoming flow from the interceptor system. For example, if the flow entering the Jamaica WRRF from the East and West Interceptors totaled 120 MGD, the dewatering pumping station could pump up to 30 MGD. If the incoming flow was 100 MGD, the pump rate would increase to 50 MGD. In the case of back-to-back storm events, the tunnel dewatering pumps would shut off when peak flows exceeded 150 MGD.

As mentioned earlier and illustrated in Figure 8-19, a number of viable sites for the installation of new treatment or storage facilities were identified in the vicinity of Thurston Basin. The most suitable locations identified were a privately owned parcel on Rockaway Boulevard and a number of small city-owned lots near 148 Avenue, which amount to less than an acre and are currently un-utilized. Siting of facilities at Idlewild Park would require park alienation. Acquisition of the private site would be difficult and would be accomplished either through negotiation or eminent domain.

In consideration of the limited availability of vacant or undeveloped properties*, CSO Storage Tanks* were determined to be non-viable. Properties of sufficient size to accommodate a storage tank are limited to PANYNJ or Idlewild Park. In addition, portions of the park and smaller private properties were found to fall within JFK Airport flight patterns, resulting in severe height restrictions for buildings and construction equipment. In consideration of the site constraints and a high cost-to-benefit ratio, this alternative has been eliminated from further evaluation.

Though *Retention Treatment Basins* require a smaller footprint than *CSO Storage Tanks*, they are also subject to the same site constraints and limitations. Because of this, the alternative has been eliminated from further evaluation.

Alternative T-6: CSO Storage Tunnel from Outfalls JAM-005 and JAM-007 to the Jamaica WRRF

As a result of the limited availability of suitable sites for traditional storage and treatment technologies within the Thurston Basin watershed, tunnel alternatives were developed further (Figure 8-25). Unlike traditional tanks, tunnels:

1. Can provide for both conveyance and storage of CSO;
2. Require less permanent above-ground property per equivalent unit of storage volume;
3. Minimize surface construction impacts;
4. Reduce construction related groundwater pumping and treatment costs; and
5. Reduce the volume of near-surface spoil material to be treated, handled, and transported for disposal during construction.

Tunnel construction would involve the boring of a linear storage conduit using a tunnel boring machine. Shafts would be installed along the tunnel route for connection of the CSO diversion sewers and O&M access. A TDPS would also be included at the downstream end of the tunnel with pumped discharges conveyed to the Jamaica WRRF for treatment when influent flow from the interceptors drops below 1.5xDDWF. A mechanical ventilation system would be provided with an activated carbon odor control system. Additional passive odor control systems and/or backdraft dampers would be provided at the drop shafts.

Diversion chambers, a screening/grit chamber and a receiving/drop shaft would be sited along Outfalls JAM-005 and JAM-007, at the city-owned vacant lands identified. Two gravity sewers would convey flows from these diversion chambers through the screening and grit chamber to the storage tunnel. The 15,200 LF tunnel would generally follow the southern edge of Rockaway Boulevard and the Nassau Expressway until it reaches the Jamaica WRRF. A launch shaft, screening/grit chamber and 50 MGD dewatering pumping station would be sited in a vacant lot located at the north end of the WRRF.

This system would remain inactive during dry-weather, only seeing flows during wet-weather events, when the hydraulic grade has topped the weirs at Regulators JA-06, JA-07, and JA-08. Flows would then be diverted to this tunnel, which would retain these CSOs until the wet-weather event has receded and capacity is available at the Jamaica WRRF to dewater the tunnel.

Modeling for the CSO tunnel determined that a 10 foot diameter 9 MG tunnel would be required for 50 percent capture, an 18 foot diameter 29 MG tunnel would be required for 75 percent capture, and a 28 foot diameter 70 MG tunnel would be required for 100% CSO capture. The difference between the two smallest capture alternatives is minimal due to the fact that the tunnel diameter for the 25 percent and 50 percent capture are essentially dominated by the sanitary flow, while the sizing of the higher percent capture tunnels are driven by more intense longer duration rainfall events that contribute large volumes of stormwater.

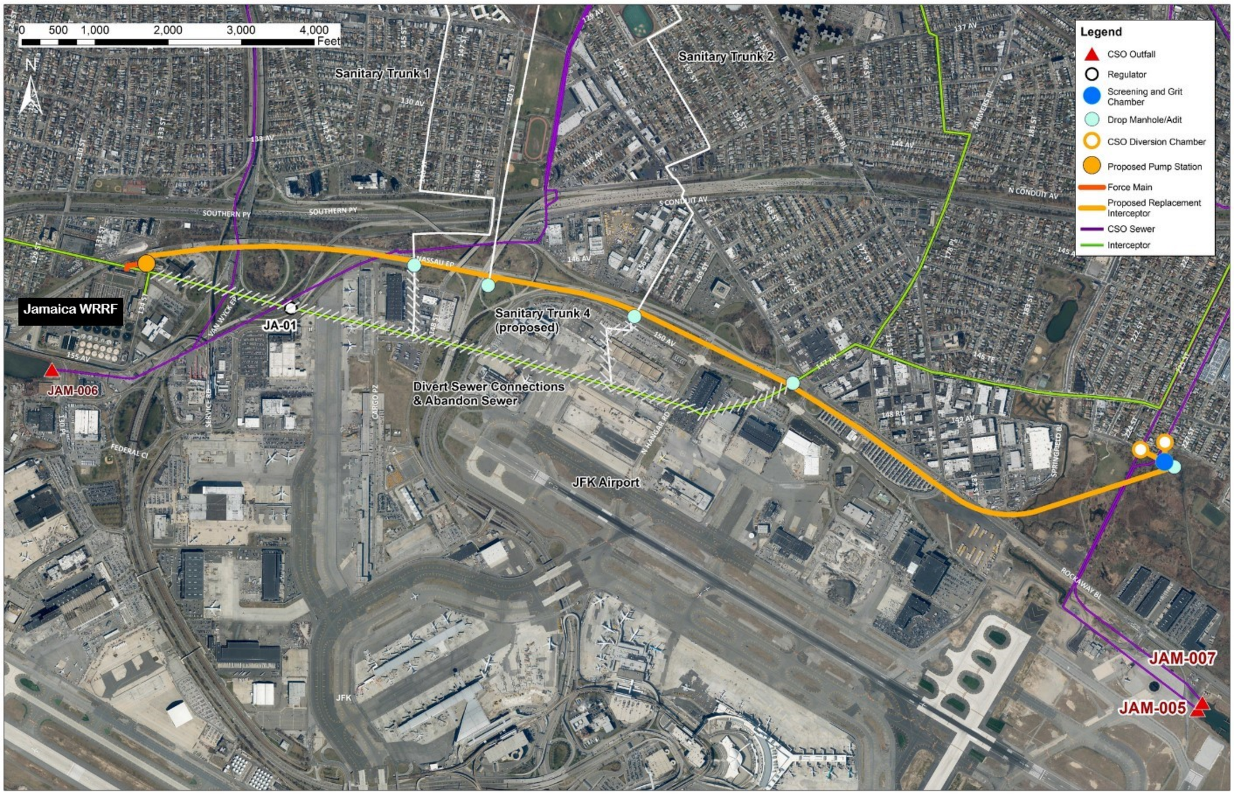

Figure 8-25. Layout for Proposed CSO Tunnel From JAM-005/007 to Jamaica WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

<u>Benefits</u>

- Diverts CSO from JAM-005 and JAM-007 to the Jamaica WRRF for treatment
- Provides equalization of peak wet-weather flows and allows for flexibility in WRRF operations

<u>Cost</u>

- The estimated NPW for this control measure varies by level of control as follows:
  - 50% CSO control: $721M
  - 75% CSO control: $1,020M
  - 100% CSO control: $1,637M

  Details of the estimates for each level of CSO control are presented in Section 8.4.

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Challenges

- Limited improvement in Thurston Basin water quality attainment
- Property acquisitions and permitting
- Neighborhood impacts associated with diversion chamber construction
- Highway ramp crossings

The gap analysis showed that the water quality benefits from 100% CSO capture for Thurston Basin results in a four percent increase in fecal coliform attainment annually and a two percent improvement during the recreational season (May 1st through October 31st) for 2008 typical year rainfall conditions. Despite the limited water quality benefits, Alternative T-6 isolates the captured CSO from the East and West Interceptor and does not impact the hydraulic grade line of the existing trunk and collector sewers. As a result, this alternative has been retained for further evaluation.

8.2.e Other Future Green Infrastructure (Thurston Basin)

See Section 8.2b.

8.2.f Hybrid Green/Grey Alternatives (Thurston Basin)

Hybrid green/grey alternatives are those that combine traditional grey control measures with GI control measures, to achieve the benefits of both. However, as discussed above, the SEQ Storm Sewer Buildout Program is ongoing and will significantly impact the drainage patterns throughout the collections system tributary to the Jamaica WRRF. Therefore, no controls in this category are proposed for the Jamaica Bay and Tributaries LTCP.

8.2.g Retained Alternatives (Thurston Basin)

The goal of the previous evaluations was the development of a list of retained control measures for Outfalls JAM-005 and JAM-007 to Thurston Basin. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in Table 8-11. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures include the CSO storage tunnels and the Additional GI and Environmental Improvements. Measures for additional and/or improved floatables control are addressed within the retained alternatives.

Table 8-11. Summary of Thurston Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Thurston Basin	T-3	Construction of disinfection and dechlorination facilities along Outfalls JAM-005 and JAM-007	JAM-005/007	Limited water quality benefits, operational complexity, public opposition	Abandoned due to operational concerns and site accessibility concerns

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Table 8-11. Summary of Thurston Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Thurston Basin	T-4a & 4b	Construction of a CSO storage tank at vacant lots south of 148 Ave or at Idlewild Park with a dewatering pumping station and force main to the East Interceptor	JAM-005/007	Significant reduction in CSO but limited water quality benefits, limited property available	Abandoned due to high cost-to-benefit ratio and impacts to wetlands
Thurston Basin	T-4c	Construction of a CSO storage tank at private parking lot south of Rockaway Boulevard with a dewatering pumping station and force main to the East Interceptor	JAM-005/007	Significant reduction in CSO but with limited water quality benefits	Abandoned due to high cost-to-benefit ratio
Thurston Basin	T-6	Construction of a CSO storage tunnel/replacement interceptor from Outfalls JAM-005 and JAM-007 with a dewatering pumping station at the Jamaica WRRF	JAM-005/007	Significant reduction in CSO but with limited water quality benefits. Equalizes peaks and provides operational benefits during wet-weather.	Retain. Provides CSO conveyance, storage, and treatment at WRRF.
Thurston Basin	T-7a & 7b	Construction of an RTB at vacant lots south of 148 Ave or at Idlewild Park with an effluent sewer back to Outfalls JAM-005 and JAM-007	JAM-005/007	Limited availability of property and water quality benefits, park alienation	Abandoned due to high cost-to-benefit ratio and impacts to wetlands
Thurston Basin	T-7c	Construction of an RTB at vacant lots south of Rockaway Blvd with an effluent sewer back to Outfalls JAM-005 and JAM-007	JAM-005/007	Limited water quality benefits, effluent return line through PANYNJ	Abandoned due to high cost-to-benefit ratio and impacts to JFK facilities
Thurston Basin	T-9	Springfield/Laurelton area high level storm sewer buildout	JAM-005/007	Storm sewer capacity not available	Abandoned because project cannot meet LTCP schedule
Thurston Basin	T-10	In-line storage	JAM-005/007	Limited reduction in CSO. Limited water quality benefits.	Abandoned due to HGL impacts in the East and West Interceptor and the high risk of failure of automated electro-mechanical tide gates.
Thurston Basin	T-11	Construction of wetlands to treat stormwater	JAM-005/007	Grade issues for discharge of outfall, wetland impacts, park alienation	Abandoned. Cannot daylight outfall in wetland.

Table 8-11. Summary of Thurston Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Thurston Basin	T-12	Additional GI and Environmental Improvements	JAM-005/007	Limited water quality benefits, reduced SW volume, improved habitat, low cost	Retain. Low cost-to-benefit ratio. Co-benefits.

Spring Creek Alternatives

Spring Creek straddles the boundary of Brooklyn and Queens and is located immediately south of the Spring Creek AWWTP. It receives discharges from approximately a 4,250 acre drainage area, of which approximately 3,300 acres is combined drainage area and 600 acres is separated sewershed. About 300 acres of direct drainage exists along the banks of the basin. Flows enter this basin through 1 CSO, 1 MS4, and 6 other storm outfalls. CSO Outfall 26W-005 is the tank overflow which has 72 tide gates measuring 7'-6" x 2'-5" each. Based on 2040 projected flows, with all proposed WWFP projects constructed, the model predicted discharges to Spring Creek to amount to 292 MGY of CSO and 141 MGY of storm flow. Water quality modeling indicates that Existing WQ Criteria for fecal coliform and DO are attained under baseline conditions.

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing the water quality through other approaches.

Environmental Dredging: Based upon NOAA navigation charts and field observations, sediment deposition does not appear to be an issue in this waterbody. In addition, a review of historical complaint records does not indicate an issue with odors in the area. As a result, this technology will not be retained for further consideration.

Floatables Control: The Spring Creek AWWTP includes floatables controls at the head end of the facility. As a result, this technology will not be considered further.

Wetlands and Bioextractors: As Spring Creek is in attainment with Existing WQ Criteria for fecal coliform under baseline conditions, ribbed mussels will not be retained for further consideration. However, preliminary field investigations indicate that approximately 13 acres of tidal wetlands could be restored along the shoreline of Spring Creek. As implementation of tidal wetlands will help to build upon the water quality improvements associated with the implementation of the WWFP recommendations through enhancement of fish and wildlife habitats, promote filtering of direct drainage and other co-benefits, tidal wetland restoration will be retained for further consideration.

Since the only source of CSO into this waterbody is the overflow from the Spring Creek AWWTP, only *Treatment* alternatives for modifications to this existing facility were considered.

Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Retention/Treatment

The Jamaica Bay WWFP recommended upgrades to the Spring Creek AWWTP consisting of floatables control, high rate settling, and in-line CSO storage. Thus, alternatives evaluations in the LTCP focused on outfall disinfection only. DEP recently completed a CSO chlorination study at this facility in order to optimize sodium hypochlorite dosage needed to achieve a two-log kill (99 percent bacteria reduction), to minimize residuals to near non-detect and to avoid the need for dechlorination. The conclusions of the June 2018 report were as follows:

The disinfection Demonstration Study was successful in providing critical information by defining protocols for data collection characterization, bench scale testing and sampling, which could be useful during the planning and design of any future CSO disinfection facilities. For example, sudden and unexpected changes in the weather presented unique challenges for sample collection, which proved to be extremely time sensitive. Main conclusions of the study are included in Table 8-12.

Table 8-12. Summary of Spring Creek Disinfection Demonstration Study

Observation	Main Conclusion
During the Demonstration Study, chlorine dosages significantly varied mainly due to the differences in water quality from the distinct drainage area characteristics.	Each drainage area is unique and it is recommended that for any future projects a site-specific sampling plan be developed to determine dosing requirements.
Each storm presented different challenges for dosage control. Variability of flows entering the facility created a wide range of events for targeted disinfection.	Any future projects must be designed to accommodate significant flow and quality variability.
Dosages used during the study did not produce significant bacteria reduction nor did they result in significant effluent TRC levels.	Due to high variability of the drainage areas and rain events, chlorine dosages cannot be standardized and will be specific to each CSO treatment facility and receiving waterbody.

Under baseline conditions, the Spring Creek AWWTP discharges six times annually with a total AAOV of 292 MGY under 2008 typical year rainfall conditions. Of the six overflow events annually, four of those events occur during the recreational season (May 1st through October 31st). Despite the infrequent overflow, operators would need to activate the chlorination process for the majority of storm events to avoid the risk of discharging untreated effluent from the tank. As a result, large volumes of chemicals would be applied to the flow entering the tank without any concomitant benefit.

A review of the gap analysis indicates that Existing WQ Criteria are attained in Spring Creek with no appreciable improvement in attainment (one percent annually and two percent during the recreational season) with 100% CSO control. In consideration of the limited water quality benefit, this alternative was eliminated from further consideration.

8.2.h Retained Alternatives (Spring Creek)

The goal of the previous evaluations was the development of a list of retained control measures for Outfall 26W-005 to Spring Creek. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in **Table 8-13**. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures were limited to Environmental Improvements.

Table 8-13. Summary of Spring Creek Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Modeling Results	Status
Spring Creek	SC-3	Construction of disinfection and dechlorination facilities (if needed) at the Spring Creek AWWTP	26W-005	Limited water quality benefits, community opposition, concerns with operational effectiveness	Abandoned. Negligible water quality benefit.
Spring Creek	SC-4	Environmental Improvements	All CSO and SW Outfalls	Builds upon past WWFP projects. Enhances fish and wildlife habitat and other co-benefits.	Retain for further evaluation.

<u>Hendrix Creek Alternatives</u>

Hendrix Creek is located in Brooklyn, to the immediate East of the 26th WRRF. It receives discharges from approximately a 450 acre drainage area, out of which approximately 250 acres is combined drainage area, 100 acres is MS4 drainage area, and 100 acres is separately sewered. Small quantities of direct drainage also exist along the banks of the basin. Flows discharge to this basin through one WRRF effluent outfall, one WRRF plant bypass sewer, one CSO, two MS4 and 21 other storm outfalls. CSO Outfalls 26W-002, 26W-004, and 26W-001 are the three biggest outfalls, measuring QBL 11' x 7.5', QBL 11' x 7.5' and 10' x 6', respectively. Based on 2040 projected flows, with all proposed WWFP projects constructed, the model predicted discharges to Hendrix Creek to amount to 85 MGY of CSO and 111 MGY of storm flow, in addition to the 19,622 MGY of WRRF effluent flows.

Under baseline conditions, water quality modeling projects that this waterbody is in attainment of Existing WQ Criteria for fecal coliform over a typical year. However, Existing WQ Criteria for DO (Class I) would not be achieved for the 95 percent attainment metric. The gap analysis indicates that attainment can be improved by one percent from 94 percent under baseline conditions to 95 percent with 100% CSO control. Considering the limited benefit of 100% CSO control, cost-to-benefit ratios for CSO control are expected to be high.

A review of existing land uses near the discharge of Outfall 26W-004 was performed for the purposes of identifying potential sites for new retention/treatment facilities. As indicated in Figure 8-26, the most suitable location identified was an 18 acre, partially vacant lot at the southern end of the 26th Ward

WRRF, under the jurisdiction of DEP. Other viable parcels for construction included two acre and 40 acre lots under the jurisdiction of the New York City Department of Parks and Recreation, and a two acre lot under the jurisdiction of the New York City Department of General Services, all on the east side of the Creek, across from the WRRF.

Figure 8-26. Potential Properties near Hendrix Creek CSO Outfalls

CSO Relocation: This concept involves conveying overflows by gravity from one receiving water to another, where the second receiving water would either be less sensitive or provide greater dilution/assimilation than the one from which the CSO is being diverted. Neither *Gravity Flow Tipping* nor *Flow Tipping with Conduit/Tunnel and Pumping* were recommended in the WWFP for Hendrix Creek. Based on modeling, Fresh Creek and Spring Creek were both determined to be just as sensitive, if not more so, than Hendrix Creek. In addition, diversion of the outfall to Jamaica Bay, which has more stringent water quality standards for the promotion of primary contact recreation, is contrary to the intended uses of the Bay. As a result, these alternatives will not be evaluated further under the LTCP.

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing the water quality through other approaches.

Floatables Control: A floatables containment boom is located downstream of the CSO outfalls in Hendrix Creek for 26W-004. Skimmer boats are utilized to retrieve the floatables captured by the boom. Floatables containment booms are identified as an accepted practice in the USEPA Guidance for NMCs and Floatables Control Technology Fact Sheet. The fact sheet specifically references boom and skimming operations in Jamaica Bay, as well as catch basin modifications throughout New York City. Considering the well documented effectiveness of the current BMP programs for floatables capture, DEP believes that the existing approach to floatables control in the tributaries to Jamaica Bay meets the intent of the BMP requirements for floatables control, and that additional investment in alternative floatables control technologies would not provide substantial improvements in floatables capture.

However, to be responsive to comments from DEC's during the LTCP development process, DEP has further investigated alternatives for providing end-of-pipe nets in Hendrix Creek at 26W-004. The following summarizes the findings of these investigations.

As noted above, published design criteria for floating end-of-pipe netting installations call for having a minimum water depth of two to three feet at the nets. Outfall 26W-004 is located at the upstream end of Hendrix Creek (see Figure 8-27), where a previous dredging project established the creek bed at an elevation of -6.1 BSD, which approximately matches the minimum low tide elevation during the typical year. Under lowest tide conditions, the depth in Hendrix Creek at the end of the outfall would be less than two to three feet, and therefore a floating end-of-pipe netting system would require extensive re-dredging of the upstream end of Hendrix Creek. Since the existing boom across Hendrix Creek effectively provides floatables control for Outfall 26W-004 (5 CY in 2017), a floating end-of-pipe net system is not recommended.

Figure 8-27. Location of Outfall 26W-004 and Existing Floatables Boom in Hendrix Creek

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Environmental Dredging: Based upon NOAA navigation charts and field observations, sediment deposition does not appear to be an issue in this waterbody. As a review of historical complaint records does not indicate an issue with odors in the area, this technology will not be retained for further consideration.

Wetlands and Bioextractors: As Hendrix Creek attains Existing WQ Criteria for fecal coliform under baseline conditions, ribbed mussels will not be retained for further consideration. However, preliminary field investigations indicate that approximately three acres of tidal wetlands could be restored along the shoreline of Hendrix Creek. As implementation of tidal wetlands will help to build upon the water quality improvements associated with the implementation of the Jamaica Bay WWFP recommendations through enhancement of fish and wildlife habitats, promoting filtering of direct drainage and other co-benefits, tidal wetland restoration will be retained for further consideration.

WRRF Upgrades: Model runs were performed to simulate a 20 percent increase in treatment capacity at the 26th Ward WRRF. IW modeling indicated that WRRF capacity upgrades would negligibly reduce CSO discharges unless storage capacity is provided to equalize peak wet-weather flow. As a result, this alternative was eliminated from further evaluation for the 26th Ward WRRF.

Retention / Treatment: A number of the control measures considered for Hendrix Creek fall under the dual category of treatment and retention/storage. These control measures include in-line or in-system storage, off-line tanks and deep tunnel storage. Treatment refers to disinfection in either CSO outfalls or at RTBs. A discussion of the retention/treatment alternatives evaluated follows.

Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Retention/Treatment

Initial evaluations focused on maximizing the performance of existing infrastructure to capture and/or treat CSO discharges. *In-system storage* is problematic due to the lack of existing infrastructure large enough to accommodate such volumes; though the sewer to Outfall 26W-004 is a large quad barrel, 11' x 7.5', it has a short run of only about 250 LF between the regulator and the outfall, which does not provide sufficient CSO storage capacity to reduce the frequency of volume of discharge. In addition, optimization alternatives evaluated for the collection system tributary to 26th Ward WRRF indicate hydraulic grade line impacts increasing the risk of flooding. As a result, *In-system storage* has been eliminated from further consideration.

Outfall disinfection was determined to be non-viable for Hendrix Creek due to the lack of available contact time within the CSO outfall sewer. The outfall for 26W-004 is only 250 feet long providing insufficient contact time. Thus, this alternative has been eliminated from further evaluation for Hendrix Creek.

Evaluation of New Retention/Treatment Facilities

As mentioned earlier and illustrated in Figure 8-27, a number of viable sites for the installation of new treatment or storage facilities were identified in the vicinity of Hendrix Creek. The most suitable location identified was an 18 acre partially vacant lot at the southern end of the 26th Ward WRRF, under DEP's jurisdiction. Other viable parcels for construction included a two acre and 40 acre lots under the jurisdiction of New York City Department of Parks and Recreation, and a two acre lot under the jurisdiction of the New York City Department of General Services, all on the east side of the Creek, across from the WRRF. However, unless all facilities are constructed below grade, park alienation concerns would eliminate the New York City Department of Parks and Recreation properties from further consideration.

Based on the identified properties, *CSO Storage Tanks* could be sited at the southern end of the WRRF or at the head end of Hendrix Creek, with minimal impacts to existing utilities or above-grade infrastructure. A diversion chamber would be required along the sewer to Outfall 26W-004 to convey wet-weather flow to the tank. Influent flow would be screened of large solids and floatable material. Following each storm event, the tank would be dewatered and cleaned and prepared for the next event. Flushing gates, tipping buckets, nozzle systems, and/or high pressure hoses would be provided to facilitate cleaning of the tank bottom. Flushed grit and solids would be conveyed in a channel to a wet well containing dewatering pumps for pump down of the facilities to the Vandalia Avenue Interceptor for conveyance to the 26th Ward WRRF. Due to its proximity to residential and commercial properties, odor control facilities using activated carbon would be provided. Due to a very high cost-to-benefit ratio, this alternative has been eliminated from further evaluation.

Retention Treatment Basins could be sited in similar locations at similar cost to the tank alternative, without providing any additional water quality benefits. Thus, due to a very high cost-to-benefit ratio, this alternative has been eliminated from further evaluation.

The *CSO Storage Tunnel* alternative described below requires dewatering of stored CSO volumes after wet-weather events occur. Table 8-14 provides a summary of the total storage volume and the associated dewatering rate assuming a 24-hour dewatering period for storage facilities providing 25, 50, 75, and 100 percent levels of CSO Control for Hendrix Creek.

Table 8-14. Storage and Dewatering System Capacity for Storage Alternatives for Hendrix Creek

Level of Control	Storage Volume (MG)	Dewatering PS Capacity(1) (MGD)
25%	2	5
50%	4	5
75%	8	10
100%	18	15

Note:
(1) Assumes pump-back of stored CSO within a 24 hour period.

Alternative HC-6: CSO Storage Tunnel from Outfall 26W-004 with a Dewatering Pumping Station at Spring Creek AWWTP

As a result of the limited availability of suitable sites for traditional storage and satellite treatment technologies within the Hendrix Creek sewershed, tunnel alternatives were developed further. As illustrated in Figure 8-28, tunnel construction would involve the boring of a linear storage conduit under Flatlands or Vandalia Avenues. Shafts would be installed during construction for the connection of CSO diversion pipes and O&M access. A tunnel dewatering pumping station (TDPS) would also be included at the downstream end of the tunnel with pumped discharges being conveyed to the Spring Creek AWWTP for treatment after wet-weather events. A mechanical ventilation system would be provided with an activated carbon odor control system. Additional passive odor control systems and/or backdraft dampers would be provided at the drop shafts.

A diversion chamber, a screening/grit chamber and a receiving/drop shaft would be sited along Outfall 26W-004, causing temporary disturbances to the 26th Ward WRRF lot. A gravity sewer would convey flows from this diversion chamber through the screening and grit chamber to the storage tunnel. Two alignments of the 5,000 LF tunnel were evaluated – one following Flatlands Avenue (Alternative HC-6a) and the other following Vandalia Avenue (Alternative HC-6b), both of which convey flow to the head end of the Spring Creek AWWTP. A launch shaft, screening chamber and 50 MGD TDPS would be sited at the head end of the AWWTP.

This system would remain inactive during dry-weather, only seeing flows during wet-weather events, when the hydraulic capacity of the interceptor is exceeded and the weir at Regulators 26W-01 is overtopped. Flows would then be diverted to this tunnel, which would retain these CSOs until the wet-weather event has receded and the Spring Creek AWWTP could handle the CSO pump-back.

Modeling determined that a 7 foot diameter single barrel 1.5 MG tunnel would be required for 25 percent capture of CSOs, a 11 foot diameter single barrel 3.4 MG tunnel would be required for 50 percent capture, a 17 foot diameter single barrel 7.7 MG tunnel would be required for 75 percent capture and a 25 foot diameter single barrel 18 MG tunnel would be required for 100% CSO capture.

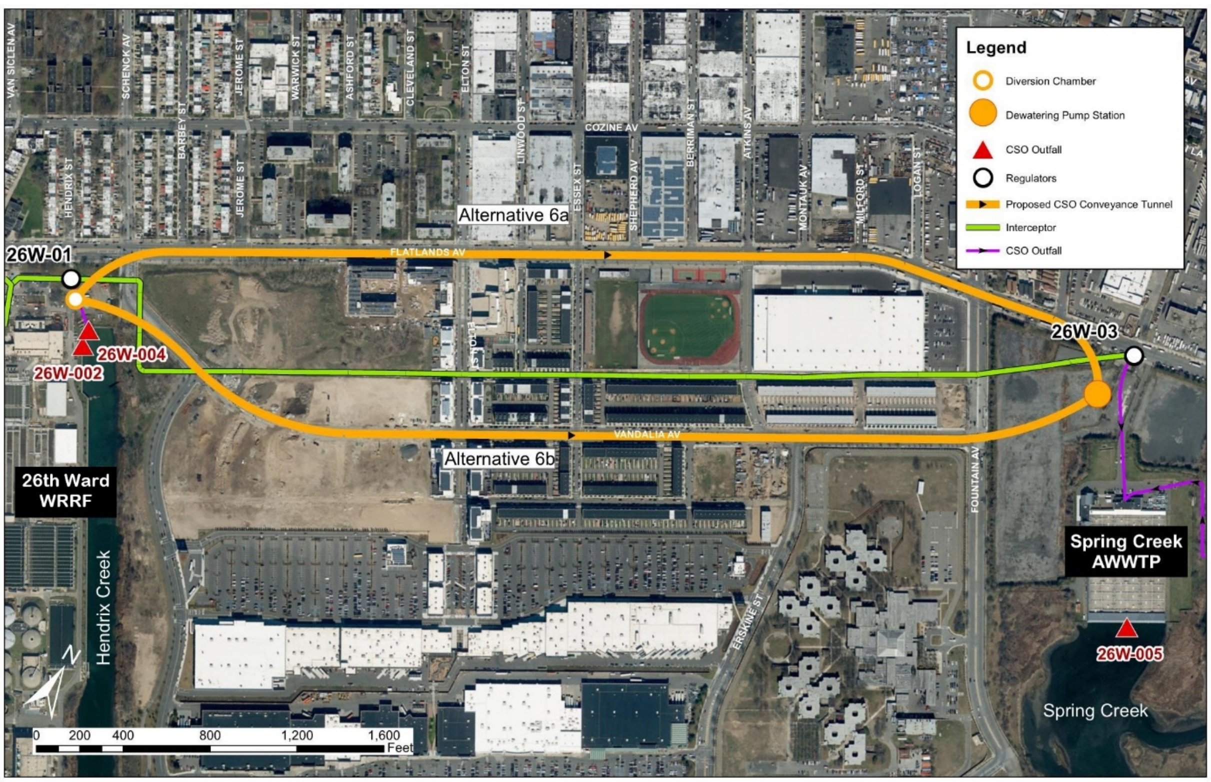

Figure 8-28. Layout of CSO Storage Tunnel and 50 MGD Dewatering Pumping Station at the Spring Creek AWWTP

The benefits, cost, and challenges associated with this alternative are as follows:

Benefits

- Can provide high level of CSO capture and treatment
- Provides storage and conveyance for control of wet-weather peak flows from Regulator 26W-01

Cost

- The estimated NPW for this control measure varies by level of control as follows:
  - 25% CSO control: $716M
  - 50% CSO control: $747M
  - 75% CSO control: $758M
  - 100% CSO control: $868M

Challenges

- Limited improvement in Hendrix Creek water quality attainment
- Site constraints for construction of diversion chamber and tunnel receiving shaft at head of 26^{th} Ward WRRF
- Park alienation for construction of dewatering pumping station near Spring Creek AWWTP

As previously stated, the preliminary gap analysis showed that water quality benefits from reducing CSOs in Hendrix Creek were minimal even with 100% CSO capture. Thus, due to a high cost-to-benefit ratio, this alternative has been eliminated from further evaluations.

8.2.i Retained Alternatives (Hendrix Creek)

The goal of the previous evaluations was the development of a list of retained control measures for Outfall 26W-004 to Hendrix Creek. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in **Table 8-15**. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures were limited to Environmental Improvements.

Table 8-15. Summary of Hendrix Creek Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Hendrix Creek	HC-3	Construction of disinfection and dechlorination facilities (if needed) at CSO outfall	26W-004	Insufficient contact time to enable significant reduction in bacteria loading	Abandoned due to insufficient contact time
Hendrix Creek	HC-4	Construction of a CSO storage tank at vacant lot south of 26th Ward WRRF with a dewatering pumping station and force main to the head end of the WRRF	26W-004	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Hendrix Creek	HC-6	Construction of a CSO Storage Tunnel from 26W-004 to the Spring Creek AWWTP	26W-004	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Hendrix Creek	HC-7	Construction of a RTB at the south end of 26th Ward WRRF	26W-004	Significant reduction in CSO bacteria loadings but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Hendrix Creek	HC-8	Environmental Improvements	All CSO and SW Outfalls	Builds upon past WWFP projects. Enhances fish and wildlife habitat and other co-benefits.	Retain for further evaluation

<u>Fresh Creek Alternatives</u>

Fresh Creek is located in Brooklyn, to the West of the 26th WRRF. The combined collection system receives stormwater runoff from approximately a 4,250 acre drainage area, out of which approximately 3,300 acres is combined drainage area, 50 acres is MS4 drainage area, 600 acres is separately sewered, and 300 acres is direct drainage to the basin. Wet-weather flow is discharged to Fresh Creek through one CSO, four MS4, and 14 other storm outfalls. Outfall 26W-003 is the biggest sewer, measuring quadruple barrel (QBL) 15' x 10'. Based on 2040 projected flows, with all proposed WWFP projects constructed, the model predicted discharges to Fresh Creek to amount to 232 MGY of CSO and 528 MGY of storm flow. Water quality analysis showed that this waterbody achieves dissolved oxygen attainment for the 2008 typical year rainfall. Attainment of the Existing WQ Criteria for fecal coliform is not achieved in the most upstream end of Fresh Creek, but the remainder of the Creek is in attainment with those criteria. A review of the gap analysis indicates that annual attainment for fecal coliform can be improved from 85 percent to 90 percent and recreational season (May 1st through October 31st) attainment can be improved from 93 percent to 98 percent with 100% CSO control. A more detailed review of the model projected annual attainment at Station FC1, indicates that there are five months outside of the recreational season where geomeans are 215 cfu/100mL or less. These five months shift the frequency of attainment over the 10-year period of analysis from 93 percent attainment during the recreational season to 85 percent annually.

A review of existing land uses near the discharge of Outfall 26W-003 was performed for the purposes of identifying potential sites for new retention/treatment facilities. Figure 8-29 indicates that the only suitable location identified was a privately owned parcel at the head end of Fresh Creek. Based on field inspection in the winter of 2017, it is believed that the site is being developed. Properties to the north are under the jurisdiction of the NYC Department of Parks and Recreation and the New York City Housing Authority. Due to the lack of vacant city-owned property, acquisition of private properties would need to be considered to accommodate additional CSO controls.

Figure 8-29. Potential Properties near Fresh Creek CSO Outfalls

CSO Relocation: This concept involves conveying overflows by gravity from one receiving water to another receiving water, where the second receiving water would either be less sensitive or provide greater dilution/assimilation than the one from which the CSO is being diverted. Neither *Gravity Flow Tipping* nor *Flow Tipping with Conduit/Tunnel and Pumping* were recommended in the WWFP for Fresh Creek. Based on water quality modeling, Hendrix Creek and Paerdegat Basin were both determined to attain Existing WQ Criteria for fecal coliform just above the 95 percent metric. Diversion of additional CSO to these waterbodies would impact attainment within these waterbodies. In addition, diversion of the outfall to Jamaica Bay, which has more stringent water quality standards for the promotion of primary contact recreation, is contrary to the intended uses of the Bay. As a result, *CSO Relocation* has been eliminated from further consideration under this LTCP.

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing the water quality through other approaches.

Floatables Control: DEP operates and maintains a netting facility at CSO Outfall 26W-003 (located at the upstream end of Fresh Creek near Monitoring Station FC-1). The 2017 and 2018 CSO BMP Annual Reports indicate that 21.25 cubic yards (CY) and 3 CY of floatables were captured, respectively, by the existing floatables containment nets in Fresh Creek.

Floatables downstream of the nets are in part associated with tidal changes in the Creek and non-CSO discharges. Floatables have also been observed in the Creek in relation to shoreline erosion downstream of the nets. As the existing floatables control facilities are performing well and consistent with accepted practices, alternative floatables technologies will not be considered.

Environmental Dredging: Based upon NOAA navigation charts and field observations, sediment deposition does not appear to be an issue in Fresh Creek. In addition, a review of historical complaint records does not indicate an issue with odors in the area. As a result, this technology will not be retained for further consideration.

Wetlands and Bioextractors: Under baseline conditions, most of Fresh Creek except the very upstream end attains the Existing WQ Criteria for fecal coliform. As a result, ribbed mussels will not be retained for further consideration. However, preliminary field investigations indicate that approximately 14 acres of tidal wetlands could be restored along the shoreline of Fresh Creek. As implementation of tidal wetlands will help to build upon the water quality improvements associated with the implementation of the Jamaica Bay WWFP recommendations through enhancement of fish and wildlife habitats, promoting filtering of direct drainage and other co-benefits, tidal wetland restoration will be retained for further consideration.

WRRF Upgrades: Model runs were performed to simulate a 20 percent increase in treatment capacity at the 26^{th} Ward WRRF. IW modeling indicated that WRRF capacity upgrades would negligibly reduce CSO discharges unless storage capacity is provided to equalize peak wet-weather flow. As a result, this alternative was eliminated from further evaluation for the 26^{th} Ward WRRF.

Retention / Treatment: A number of the control measures considered for Fresh Creek fall under the dual category of treatment and retention/storage. These control measures include in-line or in-system storage, off-line tanks and deep tunnel storage. Treatment refers to disinfection in either CSO outfalls or at RTBs. A discussion of the retention/treatment alternatives evaluated follows.

Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Retention/Treatment

Initial evaluations focused on maximizing the performance of existing infrastructure to capture and/or treat CSO discharges. *In-System storage* is problematic due to the lack of existing infrastructure large enough to accommodate such volumes; though the sewer to Outfall 26W-003 is a large QBL15' x 10', it has a short run of only about 350 LF between regulator and outfall, which does not provide sufficient CSO storage capacity to reduce the frequency of volume of discharge. In addition, optimization alternatives evaluated for the collection system tributary to 26^{th} Ward WRRF indicate hydraulic grade line impacts increasing the risk of flooding. As a result, *In-system storage* has been eliminated from further consideration.

Outfall disinfection was determined to be non-viable for Fresh Creek due to the lack of available contact time within the CSO outfall sewer. The outfall for 26W-003 is only 350 feet long providing insufficient contact time within the outfall sewer. As a result, *In-system storage* has been eliminated from further consideration.

Evaluation of New Retention/Treatment Facilities

As mentioned earlier and illustrated in Figure 8-29, no vacant city-owned properties were identified in the vicinity of Fresh Creek and DEP would thus have to consider acquisition of private property. Acquisition of any private sites is challenging and would require either negotiated acquisition or the use of eminent domain.

IW modeling performed to estimate the size of *CSO Storage tanks* for 25, 50, 75, and 100 percent CSO control indicated that at least 1.1 acres would be required to accommodate a tank and related facilities. While Retention Treatment Basins typically require a smaller footprint, a RTB sized for 25 percent CSO control was estimated to require 0.5 acres. Due to the unavailability of properties of sufficient size to accommodate a tank or RTB in close proximity to Fresh Creek, *CSO Storage Tanks and RTBs* were eliminated from further consideration.

The *CSO Storage Tunnel* alternative described below requires dewatering of stored CSO volumes after wet-weather events occur. Table 8-16 provides a summary of the total storage volume and the associated dewatering rate assuming a 24-hour dewatering period for storage facilities providing 25, 50, 75, and 100 percent levels of CSO Control for Outfall 26W-003.

Table 8-16. Storage and Dewatering System Capacity for Storage Alternatives for Outfall 26W-003

Level of Control	Storage Volume (MG)	Dewatering PS Capacity(1) (MGD)
25%	6	10
50%	15	15
75%	28	30
100%	53	50

Note:
(1) Assumes pump-back of stored CSO within a 24 hour period.

Alternative FC-6: CSO Storage Tunnel from Outfall 26W-003 with a Dewatering Pumping Station at 26th Ward WRRF

As a result of the limited availability of suitable sites for traditional storage and satellite treatment technologies within the Fresh Creek sewershed, tunnel alternatives were developed further. Tunnel construction, as shown in Figure 8-30, would involve the boring of a linear storage conduit along Flatlands Avenue. Shafts would be installed during construction for the connection of CSO diversion pipes and O&M access. A TDPS would also be included at the downstream end of the tunnel with pumped discharges being conveyed to the 26th Ward WRRF for treatment after wet-weather events. Mechanical ventilation would be provided with an activated carbon odor control system. Additional passive odor control systems and/or backdraft dampers would be provided at the drop shafts.

A diversion chamber, a screening/grit chamber and a receiving/drop shaft would be sited along Outfall 26W-003. A gravity sewer would convey flows from this diversion chamber through the screening and grit chamber to the storage tunnel. The alignment generally follows Flatlands Ave for approximately 3,500 LF and conveys flow to the head end of the 26th Ward WRRF. A launch shaft, screening chamber and 50 MGD TDPS would be sited at the head end of the WRRF.

This system would remain inactive during dry-weather, only seeing flows during wet-weather events, when the hydraulic capacity of the interceptor is exceeded and the weir at Regulators 26W-02 is overtopped. Flows would then be diverted to this tunnel, which would retain these CSOs until the wet-weather event has receded and the WRRF could handle the CSO pump-back.

Modeling determined that a 16 foot diameter single barrel 6 MG tunnel would be required for 25 percent capture of CSOs, a 27 foot diameter single barrel 15 MG tunnel would be required for 50 percent capture, a 39 foot diameter single barrel 31 MG tunnel would be required for 75 percent capture and a 51 foot diameter single barrel 54 MG tunnel would be required for 100% CSO capture.

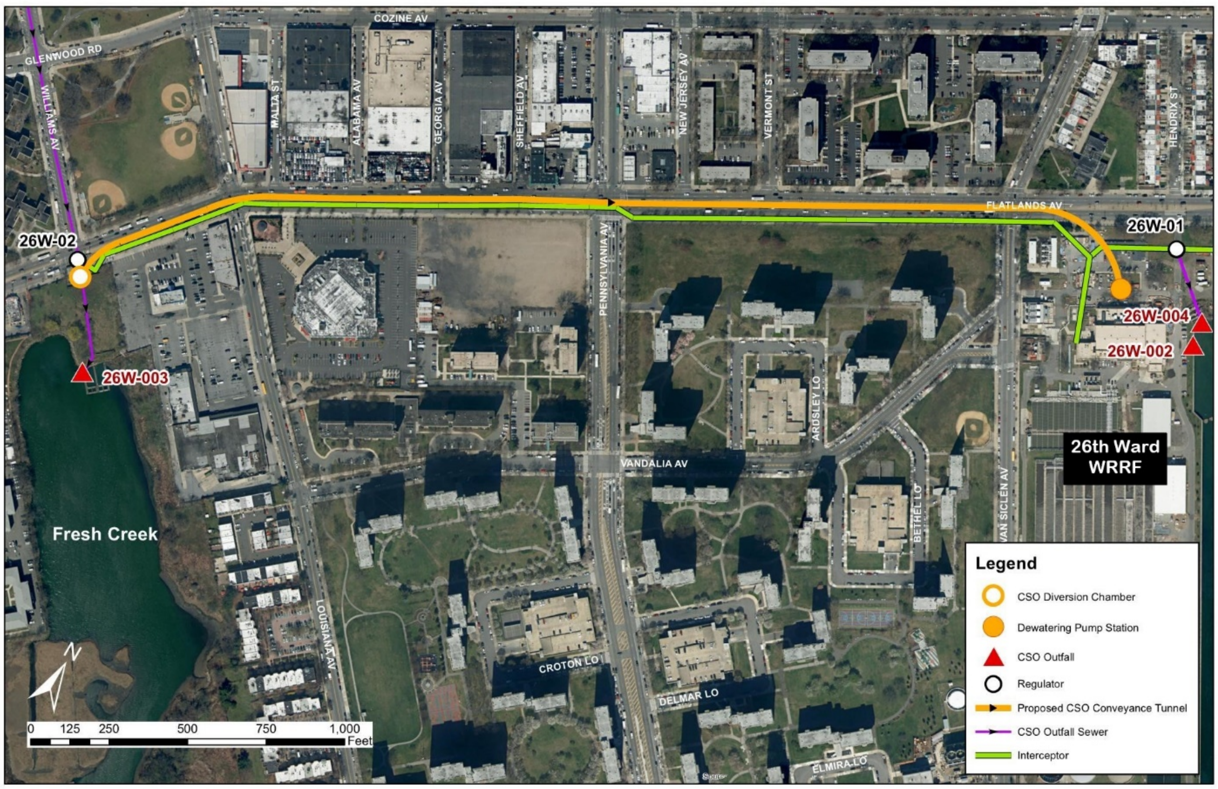

Figure 8-30. Layout of CSO Storage Tunnel and Dewatering Pumping Station at the 26th Ward WRRF

The benefits, cost, and challenges associated with this alternative are as follows:

<u>Benefits</u>

- Can provide high level of CSO capture and treatment
- Provides storage and conveyance for control of wet-weather peak flows from Regulator 26W-02

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Cost

- The estimated NPW for this control measure varies by level of control as follows:
  - 25% CSO control: $738M
  - 50% CSO control: $840M
  - 75% CSO control: $1,067M
  - 100% CSO control: $1,471M

Challenges

- Limited improvement in Fresh Creek water quality attainment
- Limited space at the head of the WRRF to accommodate the dewatering pumping station
- The 100% CSO control tunnel is near the limit of current TBM technology and may not be constructible

As previously stated, preliminary gap analysis showed that water quality benefits from reducing CSOs in Fresh Creek were limited even with 100% CSO capture. Thus, due to a high cost-to-benefit ratio, this alternative has been eliminated from further evaluations.

8.2.j Retained Alternatives (Fresh Creek)

The goal of the previous evaluations was the development of a list of retained control measures for Outfall 26W-003 to Fresh Creek. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in **Table 8-17**. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures include Environmental Improvements.

Table 8-17. Summary of Fresh Creek Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Fresh Creek	FC-6	Construction of a CSO Storage Tunnel from 26W-003 to the 26th Ward WRRF	26W-003	Significant reduction in CSO but with limited Water Quality Benefits	Abandoned due to high cost-to-benefit ratio
Fresh Creek	FC-8	Environmental Improvements	All CSO and SW Outfalls	Builds upon past WWFP projects. Enhances fish and wildlife habitat and other co-benefits.	Retain for further evaluation

Paerdegat Basin Alternatives

The head end of Paerdegat Basin is located, near the intersection of Ralph and Flatlands Avenues in Brooklyn. The waterbody receives discharges from approximately a 5,950 acre drainage area, of which approximately 5,200 acres is combined drainage area, 300 acres is MS4 drainage area, and 200 acres is separated sewershed. In addition, about 250 acres of direct drainage passes along the ground surface and down the stream banks to Paerdegat Basin. Flow is discharged to this waterway through the Paerdegat Basin CSO Retention Facility overflow, three CSO, five MS4, and nine other storm outfalls. CSO Outfalls CI-004, CI-005, and CI-006 are the three largest of these outfalls, measuring DBL 12' x 9', DBL 10' x 9' and DBL 7', respectively.

Based on 2040 projected flows, with all proposed WWFP projects constructed, the model predicted discharges to Paerdegat Basin to amount to 591 MGY of CSO and 352 MGY of storm flow. Continuous 10-year water quality modeling indicates that Existing WQ Criteria for fecal coliform and dissolved oxygen are achieved under baseline conditions.

Water Quality/Ecological Enhancements: The control measures under the category of Water Quality/Ecological Enhancements are not CSO reduction measures but, rather, focus on enhancing the water quality through other approaches.

Floatables Control: The Paerdegat Basin CSO Retention Facility includes floatables controls at the head end of the facility. As a result, this technology will not be considered further.

Environmental Dredging: Based upon NOAA navigation charts and field observations, sediment deposition does not appear to be an issue in this waterbody. In addition, a review of historical complaint records does not indicate an issue with odors in the area. As a result, this technology will not be retained for further consideration.

Wetlands and Bioextractors: As Paerdegat Basin is in attainment with Existing WQ Criteria for fecal coliform under baseline conditions, ribbed mussels will not be retained for further consideration. However, preliminary field investigations indicate that approximately four acres of tidal wetlands could be restored along the shoreline of Paerdegat Basin. As implementation of tidal wetlands will help to build upon the water quality improvements associated with the implementation of the Jamaica Bay WWFP recommendations through enhancement of fish and wildlife habitats, promote filtering of direct drainage and other co-benefits, tidal wetland restoration was retained for further consideration.

Since the majority of the CSO into this waterbody is the overflow from the Paerdegat CSO Retention Facility, only *Treatment* alternatives for modifications to this facility were considered.

Evaluation of Re-purposing or Upgrading of Existing Infrastructure for Retention/Treatment

The Paerdegat Basin CSO Facility already provides floatables control and CSO storage, in tanks and the influent sewers. Thus, initial evaluations in the LTCP focused on outfall disinfection only.

Under baseline conditions, the Paerdegat Basin CSO Retention Facility discharges 12 times annually with a total AAOV of 553 MGY under 2008 typical year rainfall conditions. Of the 12 overflow events annually, eight of those events occur during the recreational season (May 1st through October 31st). Despite the infrequent overflow, operators would need to activate the chlorination process for the majority of storm events to avoid the risk of discharging undisinfected effluent from the tank. As a result, large volumes of disinfection chemicals would be applied to the flow entering the tank without any concomitant benefit.

A review of the gap analysis indicates that Existing WQ Criteria for fecal coliform are attained in Paerdegat Basin, and analysis of a modeled 100% CSO control provided limited improvement in attainment (three percent annually and five percent during the recreational season). In consideration of the limited water quality benefit, this alternative was eliminated from further consideration.

8.2.k Retained Alternatives (Paerdegat Basin)

The goal of the previous evaluations was the development of a list of retained control measures for the Paerdegat CSO Retention Facility overflow and Outfalls CI-004, CI-005, and CI-006. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in **Table 8-18**. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measures include Environmental Improvements.

Table 8-18. Summary of Paerdegat Basin Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Paerdegat Basin	PB-3	Construction of disinfection and dechlorination facilities (if needed) at the Paerdegat Basin CSO Retention Facility	Tank Overflow Outfall	Limited water quality benefits, community opposition, concerns with operational effectiveness	Abandoned. Limited water quality benefit.
Paerdegat Basin	PB-4	Environmental Improvements	All CSO and SW Outfalls	Builds upon past WWFP projects. Enhances fish and wildlife habitat and other co-benefits.	Retain for further evaluation

Jamaica Bay Alternatives

Jamaica Bay receives discharges from an approximately 66,269 acre drainage area, of which approximately 15,287 acres is combined sewer area, 13,396 acres is MS4 drainage area, 10,643 acres is separated sewershed and about 22,934 acres is direct drainage. Stormwater is discharged to the Bay via 109 MS4 and 26 other storm outfalls.

Based on 2040 projected flows, with all proposed WWFP projects constructed, the model indicates that no CSO discharges occur under 2008 typical year rainfall conditions from the six Rockaway CSOs. Model predicted stormwater discharges to Jamaica Bay amount to 6,656 MGY of storm flow. Water quality modeling indicates that Existing WQ Criteria for fecal coliform and DO (Class SB) are achieved under baseline conditions. In addition, attainment of Amended *Enterococci* WQ Criteria* (GM<35 cfu/100mL) is achieved during the recreational season (May 1st through October 31st). While the Amended *Enterococci* WQ Criteria* (STV<130 cfu/100mL) is attained at most stations within the Bay, stations located near the outlets of the various tributaries fall below 95 percent.

Wetlands and Bioextractors: As Jamaica Bay is in attainment with Existing WQ Criteria for fecal coliform and Amended *Enterococci* WQ Criteria* (GM<35 cfu/100mL) under baseline conditions, ribbed mussels will not be retained for further consideration. However, preliminary field investigations indicate that approximately 16 acres of tidal wetlands could be restored in addition to current USACE funded projects. Tidal wetlands would be restored throughout the Bay including the Northern Channel, Inner Bay, and

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Rockaway Shore. As implementation of tidal wetlands will help to build upon the water quality improvements associated with the implementation of the Jamaica Bay WWFP recommendations through enhancement of fish and wildlife habitats, promoting filtering of direct drainage and other co-benefits, tidal wetland restoration will be retained for further consideration.

8.2.l Retained Alternatives (Jamaica Bay)

The goal of the previous evaluations was the development of a list of retained control measures for Jamaica Bay. These control measures, whether individually or in combination, formed the basis of basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in Table 8-19. The reasons for excluding the non-retained control measures from further consideration are also noted in the table. As shown, the retained control measure is Environmental Improvements.

Table 8-19. Summary of Jamaica Bay Specific Alternatives

Waterbody	Alternative ID	Description	Impacted Outfalls	Observations	Status
Jamaica Bay	JB-1	Environmental Improvements	All CSO and SW Outfalls	Builds upon past WWFP projects. Enhances fish and wildlife habitat and other co-benefits.	Retain for further evaluation

Regional Planning Alternatives

In addition to developing alternatives for each waterbody individually, this LTCP also considers implementing alternatives which span across multiple basins to provide consolidation of flows for storage and treatment.

Three regional tunnel alternatives were evaluated for capture CSO from each of the existing active CSO outfalls for conveyance to existing treatment facilities. The regional CSO storage tunnels require dewatering of stored CSO volumes after wet-weather events and can utilize available capacities at the Jamaica, 26th Ward, and Coney Island WRRFs. Table 8-20 provides a summary of the total storage volume and the respective TDPS capacities assuming a 48-hour dewatering period for facilities providing 100% levels of CSO control for the Jamaica WRRF only (Thurston and Bergen Basins), Jamaica and 26th Ward WRRFs (Thurston Basin, Bergen Basin, Spring Creek, Hendrix Creek, and Fresh Creek) and Jamaica, 26th Ward and Coney Island WRRFs (all Jamaica Bay tributaries).

Table 8-20. Storage and Dewatering System Capacity for Regional Tunnel Storage Alternatives

Level of Control	Storage Volume (MG)	Dewatering PS Capacity$^{(1)}$ (MGD)
RP-1A: Jamaica only	133	75
RP-1B: Jamaica and 26th Ward	288	75, 75
RP-1C: Jamaica, 26th Ward and Coney Island	482	75, 75, 75

Note:
(1) Assumes pump-back of stored CSO within a 48 hour period with peak WRRF flow limited to 2xDDWF.

Alternative RP-1a: Jamaica WRRF CSO Tunnel

This alternative would involve the following elements (Figure 8-31):

- Four new diversion chambers with tide gates constructed on the existing JAM-003, JAM-003A, JAM-005, and JAM-007 outfalls downstream of the existing regulators.

- Approximately 150 LF of gravity conveyance piping from the diversion structures in Bergen Basin to a launch shaft for the CSO tunnel.

- Approximately 700 LF of gravity conveyance piping from the diversion structures in Thurston Basin to a launch shaft for the CSO tunnel.

- Approximately 18,250 LF of 35 foot diameter tunnel to convey flow along Nassau Expressway to the head end of the Jamaica WRRF.

- Construction of a new screening and grit chamber and 75 MGD dewatering pumping station and associated force main to convey flows from the CSO tunnel to the influent distribution box of the primary settling tanks at the Jamaica WRRF.

The diversion chambers, diversion sewers and the launch shaft for Outfalls JAM-003 and JAM-003A would be sited on a city-owned lot currently leased to the PANYNJ, and utilized as a parking lot for JFK Airport. Similar structures for Outfalls JAM-005 and JAM-007 would be sited on city-owned vacant property, which may have some wetland impacts. The 75 MGD pumping station would be sited on vacant land, which is DEP owned and part of the Jamaica WRRF.

Under this alternative, dry-weather flow would continue to the Jamaica WRRF via the interceptors. Under wet-weather conditions, overflow at Outfalls JAM-003, JAM-003A, JAM-005, and JAM-007 would be diverted to the new CSO tunnel and to the pumping station. Modeling results project a 30 percent reduction in CSO overflow volumes regionally. As a result, DEP retained this alternative for further evaluation.

Figure 8-31. Layout of Proposed CSO Tunnel and Dewatering Pumping Station

The benefits, costs, and challenges associated with this alternative are as follows:

Benefits

- Captures and conveys CSO from JAM-003/003A/005/007 to the Jamaica WRRF for treatment
- Isolates CSO (by use of a pumping station) to reduce impacts to the East and West Interceptors

Cost

- The estimated NPW Cost for this control measure is $2,901M.
- Details of the estimate are presented in Section 8.4.

Challenges

- Limited improvement in Bergen Basin and Thurston Basin water quality attainment
- Property acquisition and permitting
- Parkland alienation and wetland impacts in Thurston Basin
- Protection of highway ramps and infrastructure

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Alternative RP-1b: Jamaica/26th Ward WRRF CSO Tunnel

This alternative would include the following elements (Figure 8-32):

- All elements from Alternative RP-1a.
- Three new diversion chambers with tide gates constructed on the existing 26W-003, 26W-004, and 26W-005 outfalls downstream of the existing regulators.
- Gravity conveyance piping from the diversion structures to a launch/receiving shaft for the CSO tunnel.
- In addition to the 18,250 LF of 35 foot tunnel from Alternative RP-1a, approximately 23,000 LF of 35 foot diameter tunnel to convey flow along Shore Parkway and Flatlands Avenue to the head end of the 26th Ward WRRF.
- Construction of a new screening and grit chamber and 75 MGD dewatering pumping station and associated force main to convey flows from the CSO tunnel to the influent distribution box of the primary settling tanks at the 26th Ward WRRF.

The diversion chambers, diversion sewers and the launch shaft for Outfall 26W-003 would be sited on privately owned property. For Outfall 26W-004, such structures would be sited on property under DEP's jurisdiction, which is part of the 26th Ward WRRF. Similar structures for Outfall 26W-005 would be sited on city-owned vacant property, which is currently a part of the Spring Creek AWWTP. The 75 MGD pumping station would be sited on vacant land, which is currently under the jurisdiction of the New York City Department of Parks and Recreation or New York City Department of General Services.

Under this alternative, dry-weather flow would continue to the Jamaica and 26th Ward WRRFs via the interceptors. Under wet-weather conditions, overflow at Outfalls JAM-003, JAM-003A, JAM-005, JAM-007, 26W-003, 26W-004, and 26W-005 would be diverted to the new CSO tunnel and to the pumping station. Modeling results project a 70 percent reduction in CSO overflow volumes regionally. As a result, DEP retained this alternative for further evaluation.

Figure 8-32. Layout of Proposed CSO Tunnel and Dewatering Pumping Stations

The benefits, costs, and challenges associated with this alternative are as follows:

<u>Benefits</u>

- Captures and conveys CSO from JAM-003/003A/005/007 and 26W-003/004/005 to the Jamaica WRRF and 26th Ward WRRF for treatment
- Isolates CSO (by use of a pumping station) to reduce impacts to the interceptors

<u>Cost</u>

- The estimated NPW Cost for this control measure is $6,219M.
- Details of the estimate are presented in Section 8.4.

<u>Challenges</u>

- Limited improvement in Bergen Basin and Thurston Basin water quality attainments
- Property acquisition and permitting
- Parkland alienation and wetland impacts
- Site constraints for construction of dewatering pumping station at head of 26th Ward WRRF
- Construction of diversion chambers along outfalls

Alternative RP-1c: North Shore CSO Storage Tunnel

This alternative would involve the following elements (Figure 8-33):

- All elements from Alternative RP-1b.
- Three new diversion chambers with tide gates constructed on the existing CI-004, CI-005, and CI-006 outfalls downstream of the existing regulators.
- Gravity conveyance piping from the diversion structures to a launch/receiving shaft for the CSO tunnel.
- In addition to the 41,300 LF of 35 foot diameter tunnel from Alternative RP-1b, approximately 26,500 LF of 35 foot diameter tunnel to convey flow along Ralph Avenue, Avenue T and Knapp Street to the head end of the Coney Island WRRF.
- Construction of a new screening and grit chamber and 75 MGD dewatering pumping station and associated force main to convey flows from the CSO tunnel to the influent distribution box of the primary settling tanks at the 26th Ward WRRF.

Under this alternative, dry-weather flow would continue to the Jamaica, 26th Ward, and Coney Island WRRFs via the interceptors. Under wet-weather conditions, overflow at Outfalls JAM-003, JAM-003A, JAM-005, JAM-007, 26W-003, 26W-004, 26W-005, CI-004, CI-005, and CI-006 would be diverted to the new CSO tunnel and to the pumping station. Modeling results project a 100% reduction in CSO overflow volumes regionally. As a result, DEP retained this alternative for further evaluation.

Figure 8-33. Layout of Proposed CSO Tunnel and Dewatering Pumping Stations

The benefits, costs, and challenges associated with this alternative are as follows:

Benefits

- Captures and conveys CSO from JAM-003/003A/005/007, 26W-003/004/005 and CI-004/005/006 to the Jamaica WRRF, 26th Ward WRRF, and Coney Island WRRF for treatment
- Isolates CSO (by use of a pumping station) to reduce impacts to the interceptors

Cost

- The estimated NPW Cost for this control measure is $9,851M.
- Details of the estimate are presented in Section 8.4.

Challenges

- Limited improvement in Bergen Basin and Thurston Basin water quality attainments
- Property acquisition and permitting
- Parkland alienation and wetland impacts

8.2.m Other Future Green Infrastructure (Regional Alternatives)

Jamaica Bay and its tributaries are priority watersheds for DEP's GI Program, which seeks to saturate priority watersheds with GI based on the specific opportunities each watershed presents. DEP plans to construct approximately 803 greened acres of GI by 2030, including ROW practices, public property retrofits, and compliance with stormwater connection regulations on private property within the Jamaica and 26th Ward WRRF sewersheds. As discussed in Section 5, DEP projects that baseline GI should result in a CSO volume reduction to Jamaica Bay and its tributaries of approximately 169 MGY, based on 2008 typical year rainfall conditions. This projected GI has been included as part of the baseline model projections, and is thus not categorized as an LTCP alternative.

Note that the Alternative B-13 and T-12 will enable DEP to build GI in the combined sewer area within Thurston Basin (see Figure 5-2), which has been assumed in the GI baseline. However, without the alignment with the GI expansion, DEP will not be able to build in this area due to its distance from the other GI baseline assets and maintenance will be costly and impractical.

For the purpose of this LTCP, "Other Future Green Infrastructure" is defined as GI alternatives that are in addition to those implemented under previous facility plans and those included in the baseline conditions. Under Alternative B-13 and T-12, an additional 8 MGY reduction in CSO volume is projected due to the increased capacity in the interceptors in CSO portion of system. As GI will provide additional co-benefits, such as property value appreciation, carbon sequestration, air quality improvements, urban heat island reduction, and habitat creation in addition to reductions in CSO and stormwater pathogen loads, this alternative will be retained for further evaluation.

8.2.n Hybrid Green/Grey Alternatives

Hybrid green/grey alternatives are those that combine traditional grey control measures with GI control measures, to achieve the benefits of both. However, as discussed above, the SEQ Storm Sewer Buildout Program is ongoing and will significantly impact the drainage patterns throughout the collections system tributary to the Jamaica WRRF. Therefore, no controls in this category are proposed for the Jamaica Bay and Tributaries LTCP.

8.2.o Retained Alternatives

The goal of the previous evaluations was the development of a list of retained control measures for CSOs to Jamaica Bay and its tributaries. These control measures, whether individually or in combination, formed the basis of the basin-wide alternatives that DEP assessed using the more rigorous cost-performance and cost-attainment analyses. That list is presented in Table 8-21. The reasons for excluding the non-retained control measures from further consideration are also identified in the table.

Table 8-21. Summary of Next Level of Control Measure Screening

Control Measure	Category	Drainage Area	Retained for Further Analysis?	Remarks
Additional GI	Source Control	Jamaica WRRF	YES	Additional sites in separately sewered areas were identified.
		26th Ward WRRF	NO	Additional sites were not identified.
High Level Storm Sewers	Source Control	Jamaica WRRF	NO	Recommended and in construction under the WWFP and SEQ SSBP. Was not evaluated further under the LTCP.
		26th Ward WRRF	NO	Recommended and in construction under the WWFP. Was not evaluated further under the LTCP.
Fixed Weir Modifications	System Optimization	Jamaica WRRF	NO	Increases HGL and provides minimal CSO reduction benefit
		26th Ward WRRF		
Bending Weirs/Control Gates	System Optimization	Jamaica WRRF	NO	Recommended and implemented under the WWFP. Increases HGL and provides minimal CSO reduction benefit.
		26th Ward WRRF	NO	Increases HGL and provides minimal CSO reduction benefit
Parallel Interceptor Sewer	System Optimization	Jamaica WRRF	YES	Alternative B-2d2 evaluated a sewer paralleling the West Interceptor to a designated pumping station at the WRRF. Other alternatives increased the collection system HGL.
		26th Ward WRRF	NO	Increases HGL within collection system
Pumping Station Modifications	System Optimization	Jamaica WRRF	NO	Recommended in the WWFP leading to the installation of a new pumping station for Meadowmere and Warnerville; No other sensitive pumping stations were identified for modification under the LTCP.
		26th Ward WRRF	NO	Recommended for the influent pumps at the 26th Ward WRRF under the WWFP. No other sensitive pumping stations were identified for modification under the LTCP.

Table 8-21. Summary of Next Level of Control Measure Screening

Control Measure	Category	Drainage Area	Retained for Further Analysis?	Remarks
Gravity Flow Tipping to Other Watersheds	CSO Relocation	Thurston Basin	NO	No opportunity for flow tipping due to sensitivity of adjacent waterbodies
		Bergen Basin	NO	Recommended and implemented to divert CSO from Regulator JA-04 to the Spring Creek AWWTP under the WWFP. No additional opportunities were identified under the LTCP.
		Spring Creek	NO	No opportunity for flow tipping due to sensitivity of adjacent waterbodies
		Hendrix Creek		
		Fresh Creek		
		Paerdegat Basin		
Flow Tipping with Conduit/Tunnel and Pumping	CSO Relocation	All Tributaries	NO	No opportunity for flow tipping due to sensitivity of adjacent waterbodies
Floatables Control	Water Quality / Ecological Enhancement	All Tributaries	NO	Existing controls have been very effective. Additional control provides no CSO reduction benefit with increased HGL.
Environmental Dredging	Water Quality/ Ecological Enhancement	Thurston Basin	NO	No odor complaints
		Bergen Basin	YES	Retained. Addresses odor complaints.
		Spring Creek	NO	No odor complaints
		Hendrix Creek	NO	Recommended and completed under the WWFP
		Fresh Creek	NO	No odor complaints
		Paerdegat Basin	NO	No odor complaints
Mechanical Aeration	Water Quality/ Ecological Enhancement	All Tributaries	NO	In-stream aeration was recommended and implemented at Shellbank Basin under the WWFP. This technology was not considered further under this LTCP.

Table 8-21. Summary of Next Level of Control Measure Screening

Control Measure	Category	Drainage Area	Retained for Further Analysis?	Remarks
Wetlands and Bioextractors	Water Quality/ Ecological Enhancement	Thurston Basin	YES	Opportunities for tidal wetland restoration and ribbed mussel habitat creation were identified
		Bergen Basin		
		Spring Creek		
		Hendrix Creek		
		Fresh Creek		
		Paerdegat Basin		
Outfall Disinfection	Treatment: Satellite	Thurston Basin	NO	Siting and operability challenges
		Bergen Basin	NO	Insufficient outfall length to provide the required contact time
		Spring Creek		
		Hendrix Creek		
		Fresh Creek		
		Paerdegat Basin		
Retention/Treatment Basins	Treatment: Satellite	All Tributaries	NO	Insufficient land available
In-System Storage (Outfalls)	Storage	All Tributaries	NO	Increases HGL within collection system while providing limited level of CSO control
Off-line Storage (Shafts)	Storage	All Tributaries	NO	Limited capacity would require multiple shafts. Limited number of existing facilities from which to judge performance/ operational issues.
Off-line Storage (Tanks)	Storage	All Tributaries	NO	Insufficient land available.
Off-line Storage (Tunnels)	Storage	All Tributaries	YES	Tunnels were retained for Alternatives B-6, T-6, RP-1a, RP-1b, and RP-1c

As shown, the retained control measures include the CSO storage tunnels, additional GI, environmental dredging, tidal wetland restoration, and bioextractors (ribbed mussels). Measures for additional and/or improved floatables control are also addressed within the retained alternatives.

8.3 CSO Reductions and Water Quality Impact of Retained Alternatives

To evaluate effects on the loadings and water quality impacts, DEP analyzed the retained alternatives listed in Table 8-22 using both the Jamaica Bay-26th Ward watershed (IW) and receiving water quality (JEMWQM) models. Evaluations of levels of CSO control for each alternative are presented below. In all cases, the predicted reductions shown are relative to the baseline conditions using 2008 JFK typical year rainfall as described in Section 6. The baseline assumptions were described in detail in Section 6 and assume that the grey infrastructure projects from the Jamaica Bay WWFP have been implemented, along with the GI projected implementation identified in Section 5.

The 11 retained alternatives shown in Table 8-22 were then analyzed on the basis of their cost-effectiveness in reducing loads and improving water quality. These more advanced analyses are described in Sections 8.3, 8.4, and 8.5.

Table 8-22. Retained Alternatives with New Sequential Numbering

Alternative	Description
Thurston Basin Alternatives	
1. CSO Tunnel from JAM-005/007 to Jamaica WRRF (50% Capture)	15,200 LF, 10-foot diameter CSO tunnel (9 MG) from JAM-005/007 to Jamaica WRRF
2. CSO Tunnel from JAM-005/007 to Jamaica WRRF (75% Capture)	15,200 LF, 18-foot diameter CSO tunnel (29 MG) from JAM-005/007 to Jamaica WRRF
3. CSO Tunnel from JAM-005/007 to Jamaica WRRF (100% Capture)	15,200 LF, 28-foot diameter CSO tunnel (91 MG) from JAM-005/007 to Jamaica WRRF
Bergen Basin Alternatives	
4. CSO Conveyance from JAM-003/003A to Jamaica WRRF	3,200 LF, 8-foot diameter sewer from Outfalls JAM-003/003A to a 50 MGD pumping station at the Jamaica WRRF
5. CSO Tunnel from JAM--03/003A to Jamaica WRRF (50% Capture)	3,200 LF, 21-foot diameter CSO tunnel (8 MG) from JAM-003/003A to Jamaica WRRF
6. CSO Tunnel from JAM-003/003A to Jamaica WRRF (75% Capture)	3,200 LF, 32-foot diameter CSO tunnel (19 MG) from JAM-003/003A to Jamaica WRRF
7. CSO Tunnel from JAM-003/003A to Jamaica WRRF (100% Capture)	5,400 LF, 49-foot diameter CSO tunnel (45 MG) from JAM-003/003A to Jamaica WRRF

Table 8-22. Retained Alternatives with New Sequential Numbering

Alternative	Description
Regional Alternatives	
8. Jamaica WRRF CSO Tunnel (30% Regional Capture)	18,500 LF, 35-foot diameter CSO tunnel (133 MG) from JAM-003/003A to JAM-005/007 with Dewatering Pumping Station at Jamaica WRRF
9. Jamaica/26W WRRF CSO Tunnel (70% Regional Capture)	40,100 LF, 35-foot diameter CSO tunnel (288 MG) from JAM-005/007 (Thurston Basin) to 26W-003 (Fresh Creek) with Dewatering Pumping Stations at Jamaica WRRF and 26th Ward WRRF
10. North Shore CSO Storage Tunnel (100% Regional Capture)	67,000 LF, 35-foot diameter CSO tunnel (482 MG) from JAM-005/007 (Thurston Basin) to the Coney Island WRRF with Dewatering Pumping Stations at Jamaica, 26th Ward and Coney Island WRRFs
11. Additional GI and Environmental Improvements	*Thurston Basin* • Green Infrastructure – 221 greened acres • Ribbed Mussels – 3 Acres *Bergen Basin* • Environmental Dredging – 50,000 cubic yards • Green Infrastructure – 232 greened acres • Ribbed Mussels – 4 acres *Spring Creek* • Tidal Wetlands Restoration – 13 acres *Hendrix Creek* • Tidal Wetlands Restoration – 3 acres *Fresh Creek* • Tidal Wetlands Restoration – 14 acres Paerdegat Basin • Tidal Wetlands Restoration – 4 acres Jamaica Bay • Tidal Wetlands Restoration – 16 acres

8.3.a CSO Volume and Bacteria Loading Reductions of Basin-Wide Retained Alternatives

Table 8-23 summarizes the projected performance of the retained Jamaica Bay alternatives in terms of CSO volume, fecal coliform and *Enterococci* load reduction. The bacteria loading reductions shown in Table 8-23 were computed on an annual basis. These data are plotted on Figure 8-34 through Figure 8-36.

Table 8-23. Jamaica Bay Retained Alternatives Summary (2008 Typical Year)

Alternative[(1)]	Untreated CSO Volume (MGY) [(2,6)]	Frequency of Overflow[(3,6)]	Untreated CSO Volume Reduction (%)	Fecal Coliform Reduction (%)[(4)]	*Enterococci* Reduction (%)[(4)]
Thurston Basin					
Baseline Conditions	658 (247)	73 (26)	-	-	-
1. CSO Tunnel from JAM-005/007 to Jamaica WRRF (50% Capture)	313 (146)	11 (6)	50 (32)	32	32
2. CSO Tunnel from JAM-005/007 to Jamaica WRRF (75% Capture)	155 (85)	10 (2)	75 (60)	60	60
3. CSO Tunnel from JAM-005/007 to Jamaica WRRF (100% Capture)	0	0	100	100	100
Bergen Basin					
Baseline Conditions	333	33	-	-	-
4. 96"CSO Conveyance from JAM-003/003A to Jamaica WRRF	230	16	32	32	32
5. CSO Tunnel from JAM-003/003A to Jamaica WRRF (50% Capture)	165	11	50	50	50
6. CSO Tunnel from JAM-003/003A to Jamaica WRRF (75% Capture)	85	7	75	75	75
7. CSO Tunnel from JAM-003/003A to Jamaica WRRF (100% Capture)	0	0	100	100	100
Regional Alternatives					
Baseline Conditions	2,191 (1,780)	73 (33)	-	-	-
8. Jamaica WRRF CSO Tunnel (30% Regional Capture)	1,490	30	30	30	30
9. Jamaica/26W WRRF CSO Tunnel (70% Regional Capture)	640	12	68	68	68
10. North Shore CSO Storage Tunnel (100% Regional Capture)	0	0	100	100	100

Table 8-23. Jamaica Bay Retained Alternatives Summary (2008 Typical Year)

Alternative(1)	Untreated CSO Volume (MGY) (2,6)	Frequency of Overflow(3,6)	Untreated CSO Volume Reduction (%)	Fecal Coliform Reduction (%)(4)	*Enterococci* Reduction (%)(4)
11. Additional GI and Environmental Improvements	2,155 (1,772)	73 (33)	1	10(5)	10(5)

Notes:

1. (1) Retained alternatives include waterbody-specific control where water quality attainment is not currently achieved under baseline conditions.
2. (2) Based upon 2008 typical year rainfall conditions. Rockaway CSOs do not overflow.
3. (3) Frequency of overflow includes remaining CSO discharges to Jamaica Bay tributaries that are not captured or receive primary treatment.
4. (4) Bacteria reduction is computed on an annual basis.
5. (5) Fecal coliform and *Enterococci* load reductions shown are based on CSO and SW volume reductions associated with Alternative 11. An additional 10 percent reduction in the in-receiving water concentrations within Thurston and Bergen Basins has been assumed to account for the ribbed mussels installed within those basins.
6. (6) Stormwater connections contribute flow to JAM-005/007 downstream of the regulator weirs in Thurston Basin. As a result, the diversion chambers would direct CSO and stormwater to the tunnel during wet-weather events. The statistics represent the CSO volume and stormwater volume at the point the flow is diverted to the tunnel. Flows in parentheses identify the model predicted CSO volumes overtopping the regulator weirs.

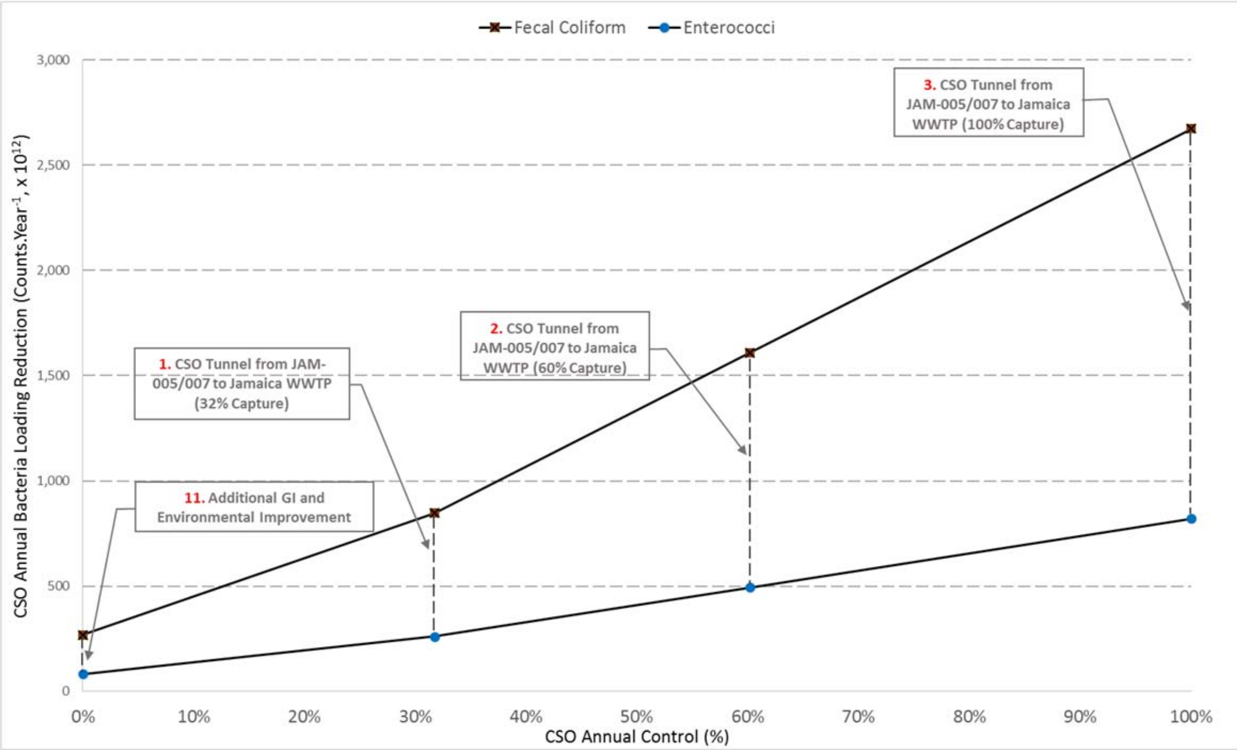

Figure 8-34. Untreated CSO Volume Reductions (as Percent CSO Annual Control) vs. Annual CSO Bacteria Loading Reduction (2008 Typical Year) for Thurston Basin

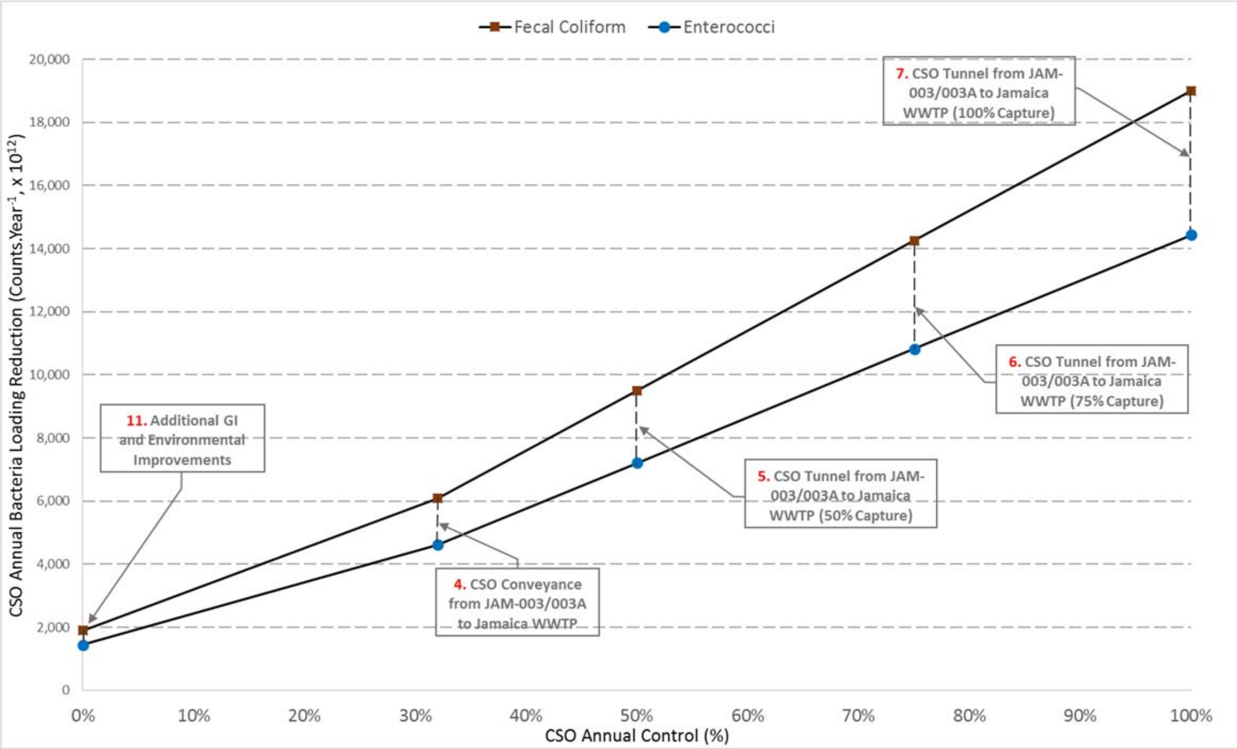

Figure 8-35. Untreated CSO Volume Reductions (as Percent CSO Annual Control) vs. Annual CSO Bacteria Loading Reduction (2008 Typical Year) for Bergen Basin

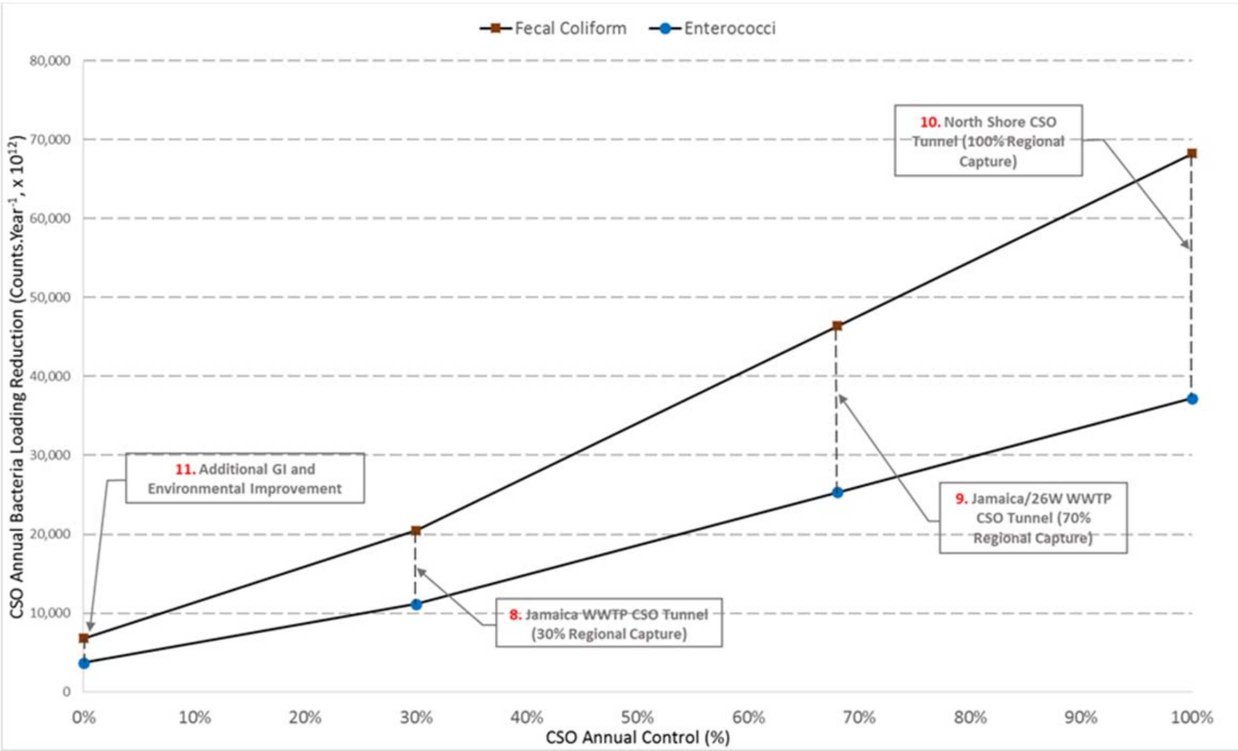

Figure 8-36. Untreated CSO Volume Reductions (as Percent CSO Annual Control) vs. Annual CSO Bacteria Loading Reduction (2008 Typical Year) for Jamaica Bay and its Tributaries

Because the retained alternatives for Jamaica Bay and its tributaries primarily provide volume reduction and not treatment, the predicted bacteria loading reductions of the alternatives are very closely aligned with their projected CSO volume reductions. However, Alternative 11 includes stormwater reductions associated with the green infrastructure and ribbed mussels that provide additional pathogen load reductions beyond the reduction in CSO loading.

8.3.b Water Quality Impacts within Jamaica Bay

Due to the geographic location of Jamaica Bay relative to the other tributary branches, the analysis of water quality impacts to the waterbody was segmented accordingly below:

Water Quality of Jamaica Bay

Jamaica Bay is a coastal Class SB waterbody. Based on the analysis presented in Section 6.0, and supported by the 10-year JEMWQM runs, historic and recent water quality monitoring, along with baseline condition modeling, all locations assessed within the waterbody are currently in attainment with the Existing WQ Criteria for fecal coliform and DO (Class SB) and Amended *Enterococci* GM WQ Criteria* (GM<35 cfu/100mL). Portions of the Bay adjacent to the tributaries are not in attainment with the Amended *Enterococci* STV WQ Criteria* (STV<130 cfu/100mL).

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

CSO Reductions and Water Quality of Tributaries to Jamaica Bay

Tributaries to Jamaica Bay are all classified as Class I waterbodies. Based on the analysis presented in Section 6.0, and supported by the 10-year JEMWQM runs, historic and recent water quality monitoring, along with baseline condition modeling, locations within Bergen Basin, Thurston Basin and Fresh Creek waterbodies do not meet the Class I criterion for fecal coliform, with annual and recreational season (May 1st through October 31st) attainments less than 95 percent at the head ends of these basins.

The 10-year baseline condition scenario was rerun with the CSO loadings to Jamaica Bay tributaries removed. This projection represents the maximum possible reduction of CSO loads to the tributaries of Jamaica Bay and is referred to as the 100% CSO control scenario. All other conditions from the baseline projection remain unchanged in the 100% CSO control scenario. On an annual basis, the head ends of Fresh Creek, Bergen Basin, and Thurston Basin do not achieve 95 percent attainment of the criterion even with 100% CSO control. This is also the case for the recreational period (May 1st through October 31st) with the exception of the head end of Fresh Creek, which improves from 93 to 98 percent attainment. This analysis indicates that CSO controls cannot completely close the gap between attainment and non-attainment of the fecal coliform water quality criterion for Bergen and Thurston Basins.

Based on 2008 typical year rainfall conditions, the upstream ends of Bergen Basin, Thurston Basin, and Hendrix Creek are not in attainment with the Class I criterion for DO under baseline conditions. With 100% CSO control, the upstream ends of Bergen and Thurston Basins would still not be in attainment for DO, while the DO attainment in the upstream end of Hendricks Creek would increase from 94 to 95 percent. This analysis indicates that CSO controls cannot close the gap between attainment and non-attainment of the Class I DO water quality criterion for Bergen and Thurston Basins.

8.4 Cost Estimates for Retained Alternatives

Evaluation of the retained alternatives requires cost estimation. The methodology for developing these costs is dependent upon the type of technology and its O&M requirements. The construction costs were developed as PBC and the total NPW costs were determined by adding the estimated PBC to the NPW of the projected annual O&M costs at an assumed interest rate of 4 percent. As the majority of the alternatives consist of tunnels, a 100-year life cycle was used in computing the NPW. Design, construction management, and land acquisition costs are not included in the cost estimates. All costs are in June 2018 dollars and are considered Level 5 cost estimates by AACE International with an accuracy of -50 percent to +100 percent.

8.4.a Alternative 1 – 50 Percent Control CSO Tunnel from JAM-005/007 to Jamaica WRRF

The costs for Alternative 1 include planning-level estimates for the construction of a deep tunnel for 50 percent CSO control for Outfalls JAM-005 and JAM-007, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 1 is $699M, as shown in Table 8-24.

Table 8-24. Costs for Thurston Basin Alternative 1

Item	June 2018 Cost ($ Million)
Probable Bid Cost	665
Annual O&M Cost	1
Net Present Worth	699

8.4.b Alternative 2 – 75 Percent Control CSO Tunnel from JAM-005/007 to Jamaica WRRF

The costs for Alternative 2 include planning-level estimates for the construction of a deep tunnel for 75 percent CSO control for Outfalls JAM-005 and JAM-007, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 2 is $1,020M, as shown in Table 8-25.

Table 8-25. Costs for Thurston Basin Alternative 2

Item	June 2018 Cost ($ Million)
Probable Bid Cost	939
Annual O&M Cost	2
Net Present Worth	1,020

8.4.c Alternative 3 – 100 Percent Control CSO Tunnel from JAM-005/007 to Jamaica WRRF

The costs for Alternative 3 include planning-level estimates for the construction of a deep tunnel for 100% CSO control for Outfalls JAM-005 and JAM-007, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 3 is $1,637M, as shown in Table 8-26.

Table 8-26. Costs for Thurston Basin Alternative 3

Item	June 2018 Cost ($ Million)
Probable Bid Cost	1,509
Annual O&M Cost	3
Net Present Worth	1,637

8.4.d Alternative 4 – CSO Conveyance from JAM-003/003A to Jamaica WRRF

The costs for Alternative 4 include planning-level estimates for the construction of a microtunneled CSO conveyance for Outfalls JAM-003 and JAM-003A, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 4 is $690M, as shown in Table 8-27.

Table 8-27. Costs for Bergen Basin Alternative 4

Item	June 2018 Cost ($ Million)
Probable Bid Cost	633
Annual O&M Cost	1
Net Present Worth	690

8.4.e Alternative 5 – 50 Percent Control CSO Tunnel from JAM-003/003A to Jamaica WRRF

The costs for Alternative 5 include planning-level estimates for the construction of a deep tunnel for 50 percent CSO Control for Outfalls JAM-003 and JAM-003A, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 5 is $736M, as shown in Table 8-28.

Table 8-28. Costs for Bergen Basin Alternative 5

Item	June 2018 Cost ($ Million)
Probable Bid Cost	676
Annual O&M Cost	2
Net Present Worth	736

8.4.f Alternative 6 – 75 Percent Control CSO Tunnel from JAM-003/003A to Jamaica WRRF

The costs for Alternative 6 include planning-level estimates for the construction of a deep tunnel for 75 percent CSO Control for Outfalls JAM-003 and JAM-003A, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 6 is $895M, as shown in Table 8-29.

Table 8-29. Costs for Bergen Basin Alternative 6

Item	June 2018 Cost ($ Million)
Probable Bid Cost	818
Annual O&M Cost	2
Net Present Worth	895

8.4.g Alternative 7 – 100 Percent Control CSO Tunnel from JAM-003/003A to Jamaica WRRF

The costs for Alternative 7 include planning-level estimates for the construction of a deep tunnel for 100% CSO Control for Outfalls JAM-003 and JAM-003A, and reflect the description provided in Section 8.2. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 7 is $1,755M, as shown in Table 8-30.

Table 8-30. Costs for Basin-Wide Alternative 7

Item	June 2018 Cost ($ Million)
Probable Bid Cost	1,636
Annual O&M Cost	3
Net Present Worth	1,755

8.4.h Alternative 8 – 30 Percent Control CSO Tunnel from JAM-003, JAM-003A, JAM-005 and JAM-007 to Jamaica WRRF

The costs for Alternative 8 include planning-level estimates for the construction of a deep tunnel for Outfalls JAM-003, JAM-003A, JAM-005, and JAM-007, and reflect the description provided in Section 8.2. The alternative provides 30 percent control of all CSO discharges to Jamaica Bay and its tributaries. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 8 is $2,901M, as shown in Table 8-31.

Table 8-31. Costs for Basin-Wide Alternative 8

Item	June 2018 Cost ($ Million)
Probable Bid Cost	2,740
Annual O&M Cost	4
Net Present Worth	2,901

8.4.i Alternative 9 – 70 Percent Control CSO Tunnel from JAM-003/003A, JAM-005/007 and 26W-003/004/005 to Jamaica WRRF and 26th Ward WRRF

The costs for Alternative 9 include planning-level estimates for the construction of a deep tunnel for Outfalls JAM-003, JAM-003A, JAM-005, JAM-007, 26W-003, 26W-004 and 26W-005, and reflect the description provided in Section 8.2. The alternative provides 70 percent control of all CSO discharges to Jamaica Bay and its tributaries. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 9 is $6,219M, as shown in Table 8-32.

Table 8-32. Costs for Basin-Wide Alternative 9

Item	June 2018 Cost ($ Million)
Probable Bid Cost	5,831
Annual O&M Cost	11
Net Present Worth	6,219

8.4.j Alternative 10 – 100% Control CSO Tunnel from JAM-003/003A, JAM-005/007, 26W-003/004/005 and CI-003/004/005 to Jamaica WRRF, 26 Ward WRRF and Coney Island WRRF

The costs for Alternative 10 include planning-level estimates for the construction of a deep tunnel for Outfalls JAM-003, JAM-003A, JAM-005, JAM-007, 26W-003, 26W-004, 26W-005, CI-003, CI-004 and

CI-005, and reflect the description provided in Section 8.2. The alternative provides 100 percent control of all CSO discharges to Jamaica Bay and its tributaries. Site acquisition costs are not included. The total cost, expressed as NPW, for Alternative 9 is $9,851M, as shown in Table 8-33.

Table 8-33. Costs for Basin-Wide Alternative 10

Item	June 2018 Cost ($ Million)
Probable Bid Cost	9,102
Annual O&M Cost	23
Net Present Worth	9,851

8.4.k Alternative 11 – Additional GI and Environmental Improvements

The costs for Alternative 11 include planning-level estimates for the expansion of the Green Infrastructure Program within the separately sewered areas of the Bergen Basin and Thurston Basin watersheds. Additionally, this alternative also recommends wetlands restoration and creation of ribbed mussel colonies in the Jamaica Bay tributaries. The total cost, expressed as NPW, for Alternative 11 is $401M, as shown in Table 8-34.

Table 8-34. Costs for Basin-Wide Alternative 11

Item	June 2018 Cost ($ Million)
Probable Bid Cost	310
Annual O&M Cost	2
Net Present Worth	401

The cost estimates of these retained alternatives are summarized below in Table 8-35 and are then used in the development of the cost-performance and cost-attainment plots presented in Section 8.5.

Table 8-35. Cost of Retained Alternatives

Alternative	PBC(1) ($ Million)	Annual O&M Cost ($/Yr Million)	Total Net Present Worth ($ Million)(2)
Thurston Basin Alternatives			
1. CSO Tunnel from JAM-005/007 to Jamaica WRRF (50% Capture)	665	1	722
2. CSO Tunnel from JAM-005/007 to Jamaica WRRF (75% Capture)	939	2	1,020
3. CSO Tunnel from JAM-005/007 to Jamaica WRRF (100% Capture)	1,509	3	1,637
Bergen Basin Alternatives			
4. CSO Conveyance from JAM-003/003A to Jamaica WRRF	633	1	690
5. CSO Tunnel from JAM-003/003A to Jamaica WRRF (50% Capture)	676	2	736

Table 8-35. Cost of Retained Alternatives

Alternative	PBC(1) ($ Million)	Annual O&M Cost ($/Yr Million)	Total Net Present Worth ($ Million)(2)
6. CSO Tunnel from JAM-003/003A to Jamaica WRRF (75% Capture)	818	2	896
7. CSO Tunnel from JAM-003/003A to Jamaica WRRF (100% Capture)	1,635	3	1,755
Regional Alternatives			
8. Jamaica WRRF CSO Tunnel (30% Regional Capture)	2,740	4	2,901
9. Jamaica/26W WRRF CSO Tunnel (70% Regional Capture)	5,831	11	6,219
10. North Shore CSO Storage Tunnel (100% Regional Capture)	9,102	23	9,851
11. Recommended Plan	310	2	401

Notes:
(1) The Probable Bid Cost (PBC) for the construction contract based on June 2018 dollars.
(2) The Net Present Worth is based upon a 100-year service life, and is calculated by multiplying the annual O&M cost by a Present Worth Factor of 24.505 and adding this value to the PBC.

8.5 Cost-Attainment Curves for Retained Alternatives

The final step of the analysis is to evaluate the cost-effectiveness of the basin-wide retained alternatives based on their NPW and projected impact on CSO loadings and attainment of applicable WQ criteria. Those retained alternatives that did not show incremental gains in performance (shown in red in the figures) were not included in the development of the best-fit curve.

8.5.a Cost-Performance Curves

Cost-performance curves were developed by plotting the costs of the retained alternatives against their predicted level of CSO control. For the purposes of this section, CSO control is defined as the degree or rate of bacteria reduction through volumetric capture. Both the cost-performance and subsequent cost-attainment analyses focus on bacteria loadings and bacteria WQ criteria.

A best-fit cost curve was developed based on those alternatives judged most cost-effective for a defined level of CSO control as estimated by IW modeling for the 2008 typical year rainfall.

DEP also evaluated the level of bacteria loadings reductions to the receiving waters. Figure 8-37 shows the percent reductions on a volumetric basis achieved by each alternative, whereas Figure 8-38 illustrates the CSO events remaining upon implementation of each alternative. Bacteria load reduction plots are presented in Figure 8-39 (*Enterococci*) and Figure 8-40 (fecal coliform). These curves plot the cost of the alternatives against their associated projected annual CSO *Enterococci* and fecal coliform loading reductions, respectively. The primary vertical axis shows percent CSO bacteria loading reductions. The secondary vertical axis shows the corresponding total bacteria loading reductions, as a percentage, when loadings from other non-CSO sources of bacteria are included.

The evaluation of the retained alternatives focused on cost-effective reduction of the frequency of CSO discharge, in addition to CSO volume and pathogen load reductions, to address current impacts to waterbody uses and issues raised by the public.

8.5.b Cost-Attainment Curves

This section evaluates the relationship of the costs of the retained alternatives versus their expected level of attainment of fecal coliform Primary Contact WQ Criteria and Amended *Enterococci* WQ Criteria* as modeled using JEMWQM with 2008 typical year rainfall. The cost-performance plots shown in Figure 8-37 through Figure 8-40 indicate that most of the retained alternatives represent incremental gains in marginal performance. Those retained alternatives that did not show incremental gains in marginal performance on the cost-performance curves are not included in the cost-attainment curves as they were deemed not to be cost-effective relative to other alternatives.

In addition to the fecal coliform Primary Contact WQ Criteria, the cost-attainment analysis considered Amended *Enterococci* WQ Criteria*. As was noted in Section 2.0, the Amended *Enterococci* WQ Criteria* do not apply to the tributaries of Jamaica Bay, which are not coastal recreation waters and do not have primary contact recreation as a designated use. However, as requested by DEC, DEP assessed compliance with those proposed criteria for all waters considered in this LTCP including the tributaries. The resultant curves for the Existing WQ Criteria for fecal coliform and Amended *Enterococci* WQ Criteria* are presented as Figure 8-41 through Figure 8-50 for ten locations (Stations BB5 through BB8, TBH1, TBH3, and TB9 through TB12,) within Bergen Basin and Thurston Basin.

Based on the continuous 10- year water quality model simulations for this LTCP, annual or seasonal attainment of the Existing WQ Criteria or Primary Contact WQ Criteria for fecal coliform under baseline conditions are not satisfied 100 percent of the time near the head end of Bergen and Thurston Basins.

Based on 10-year model runs with no CSO loadings, it was determined that the head ends of Fresh Creek, Bergen Basin, and Thurston Basin do not achieve 95 percent attainment of the Existing WQ Criteria for fecal coliform even with a 100% CSO control scenario. This is also the case for the recreational period with the exception of the head end of Fresh Creek, which improves from 93 to 98 percent attainment. This analysis indicates that CSO controls cannot completely close the gap between attainment and non-attainment of the fecal coliform water quality criterion for Bergen and Thurston Basins.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

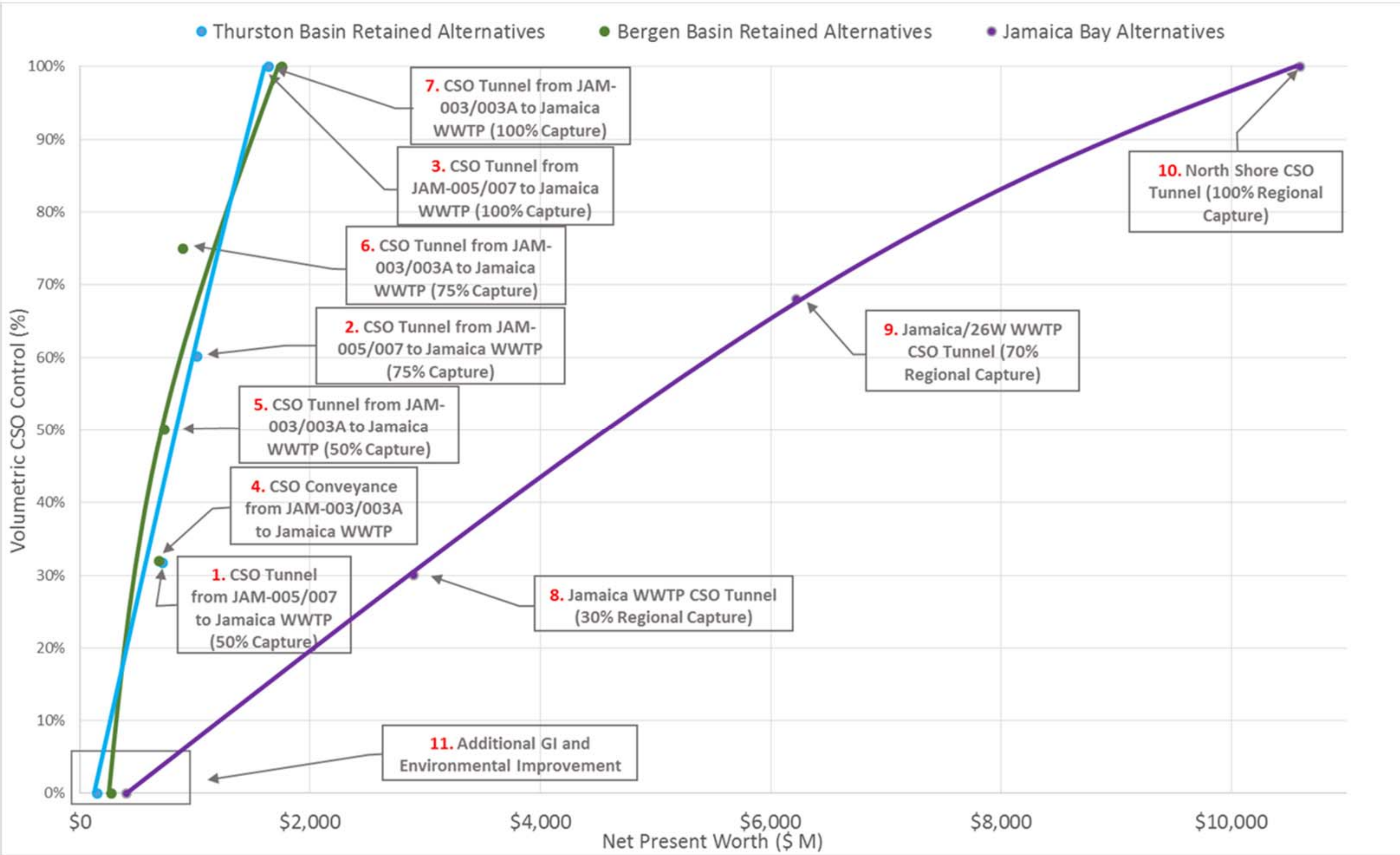

Figure 8-37. Cost vs. CSO Control (2008 Typical Year)

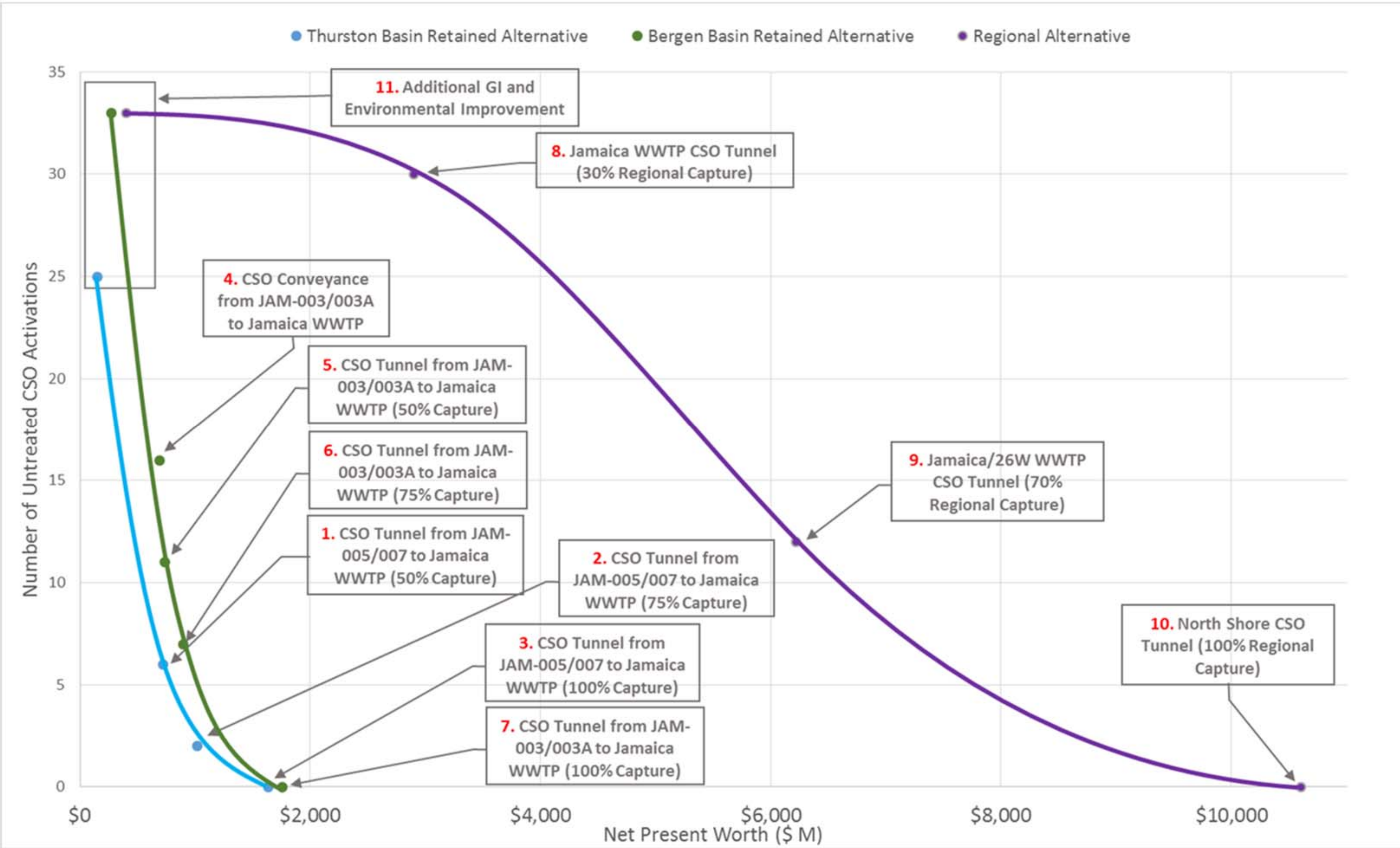

Figure 8-38. Cost vs. Remaining CSO Events (2008 Typical Year)

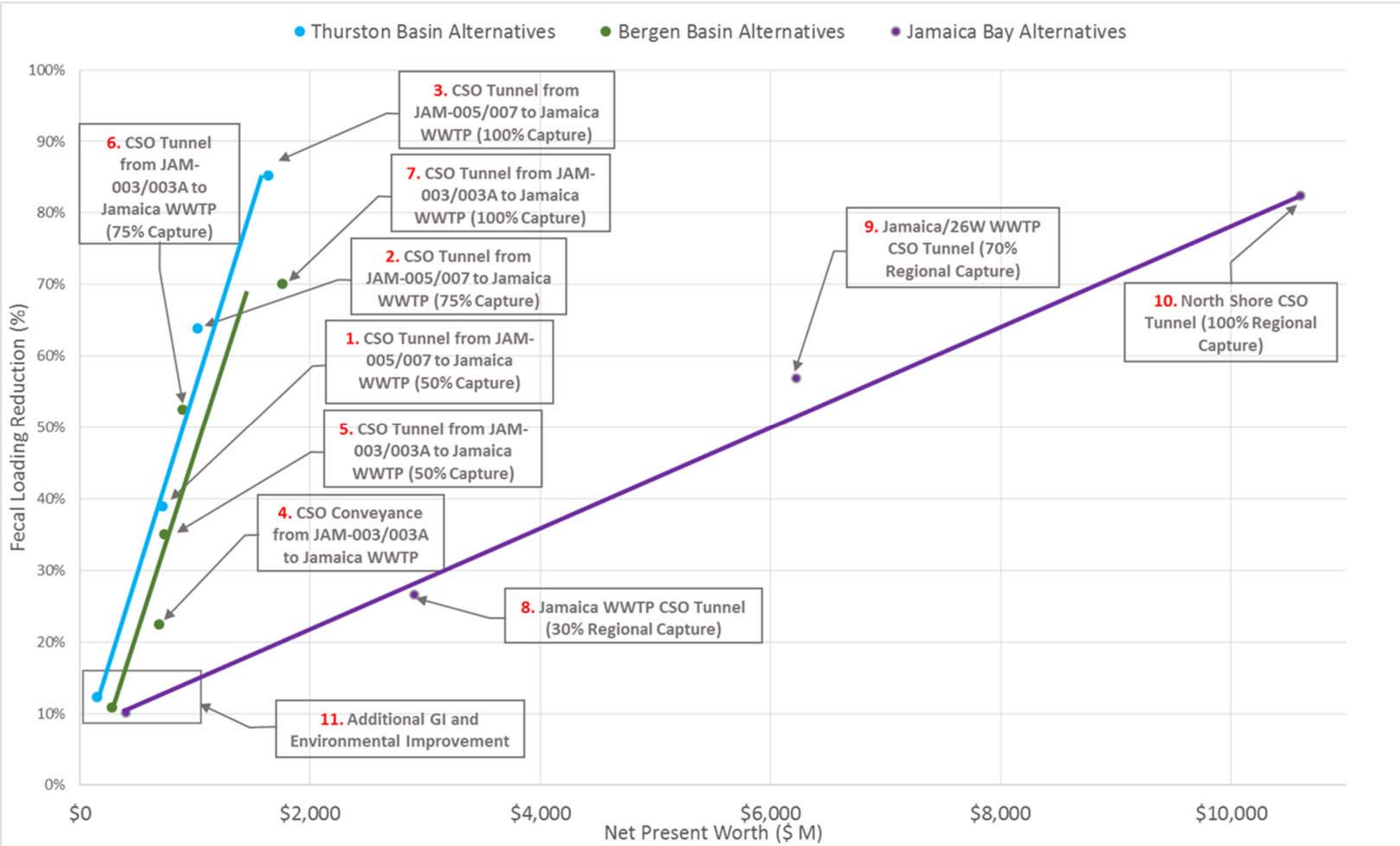

Figure 8-39. Cost vs. *Enterococci* Loading Reduction (2008 Typical Year)

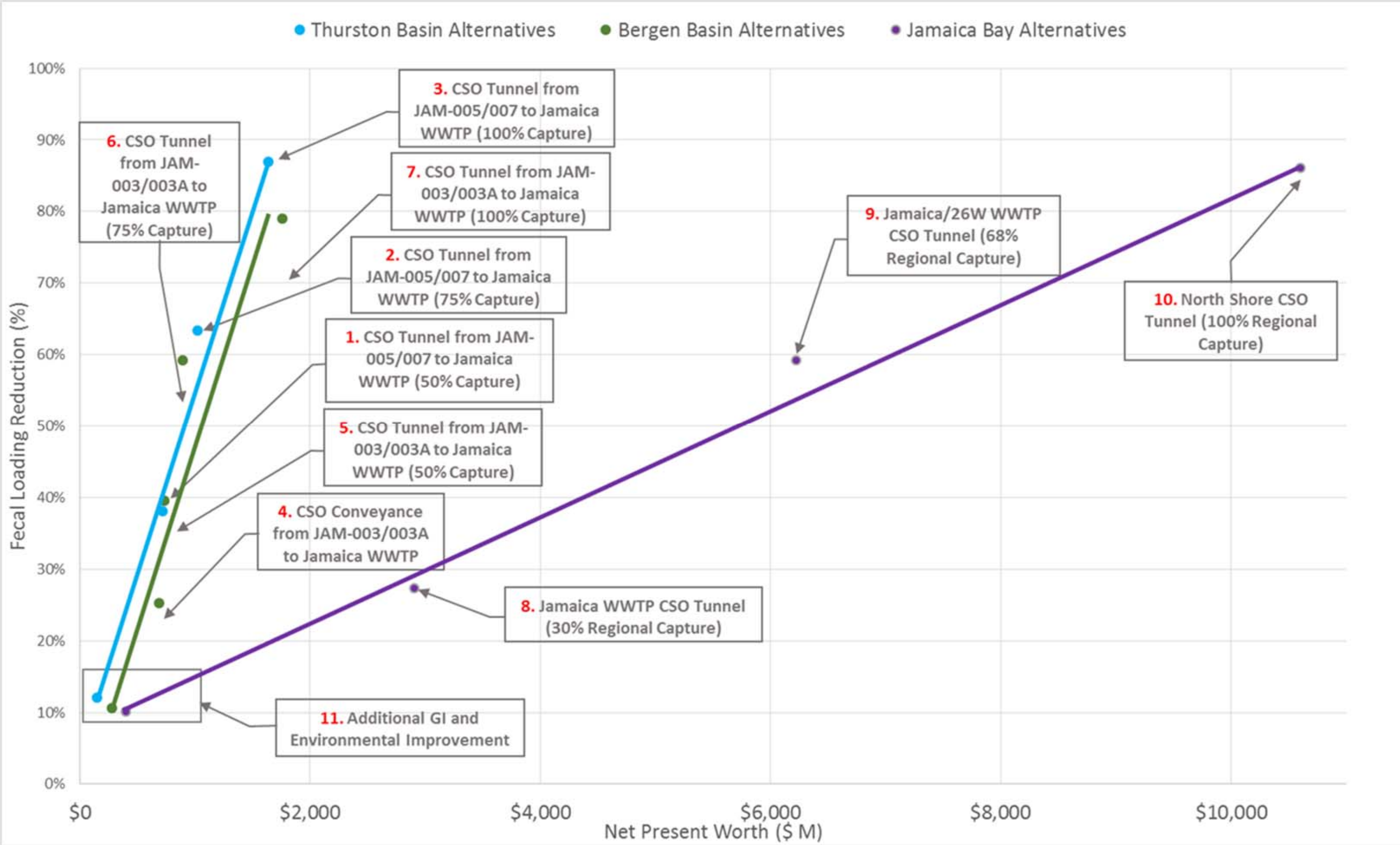

Figure 8-40. Cost vs. Fecal Coliform Loading Reduction (2008 Typical Year)

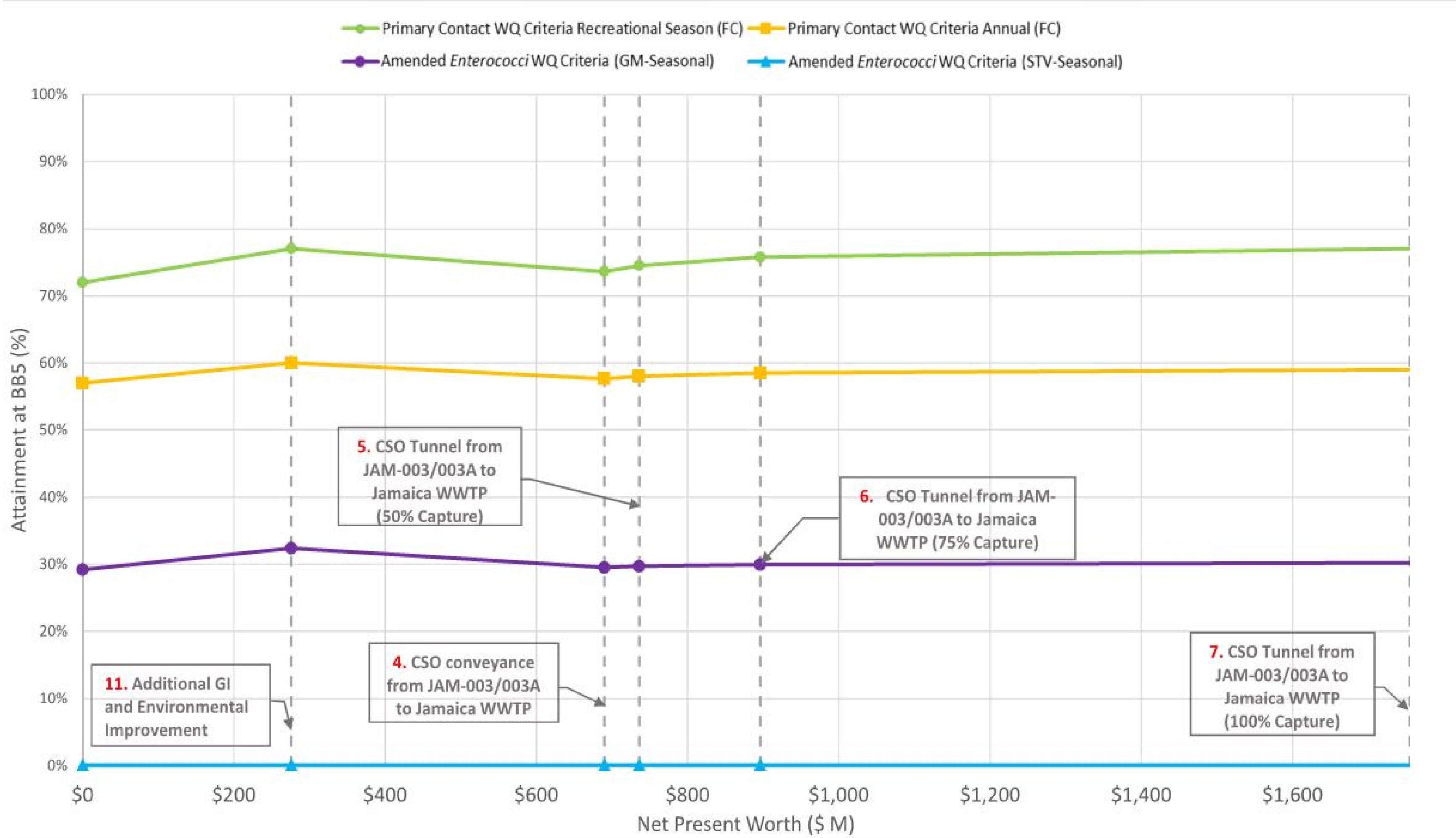

Figure 8-41. Cost vs. Bacteria Attainment at Station BB5 (2008 Typical Year)

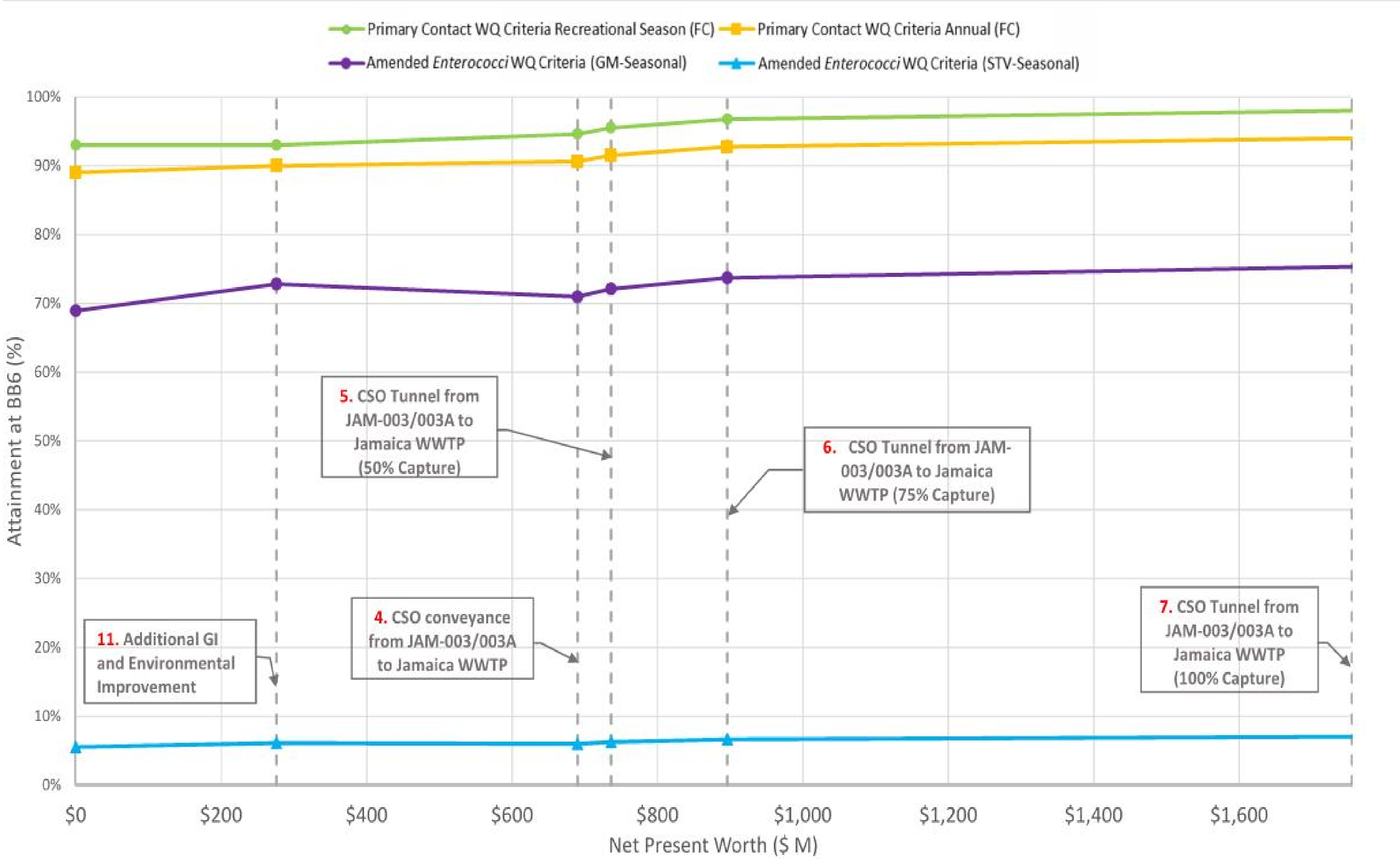

Figure 8-42. Cost vs. Bacteria Attainment at Station BB6 (2008 Typical Year)

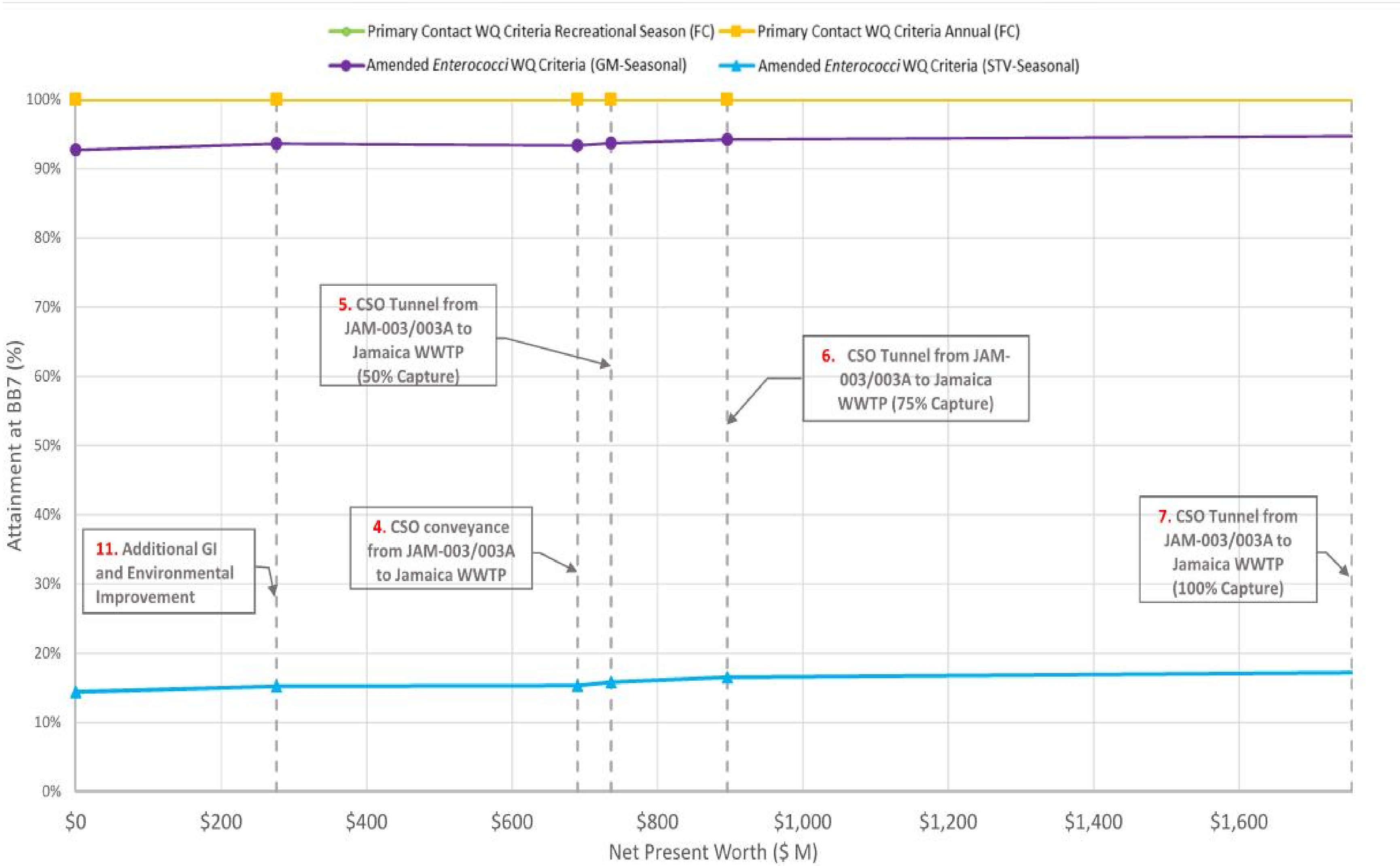

Figure 8-43. Cost vs. Bacteria Attainment at Station BB7 (2008 Typical Year)

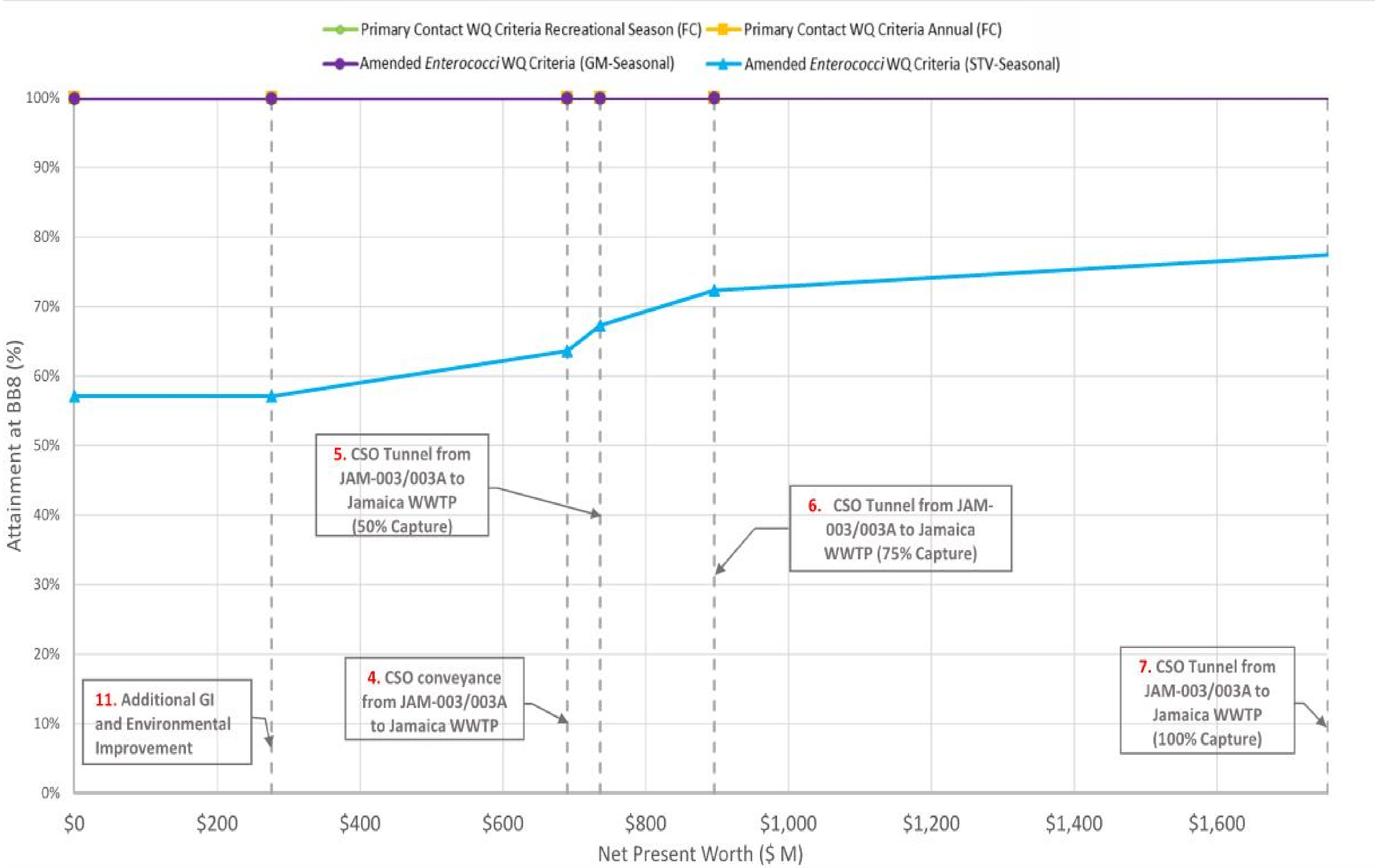

Figure 8-44. Cost vs. Bacteria Attainment at Station BB8 (2008 Typical Year)

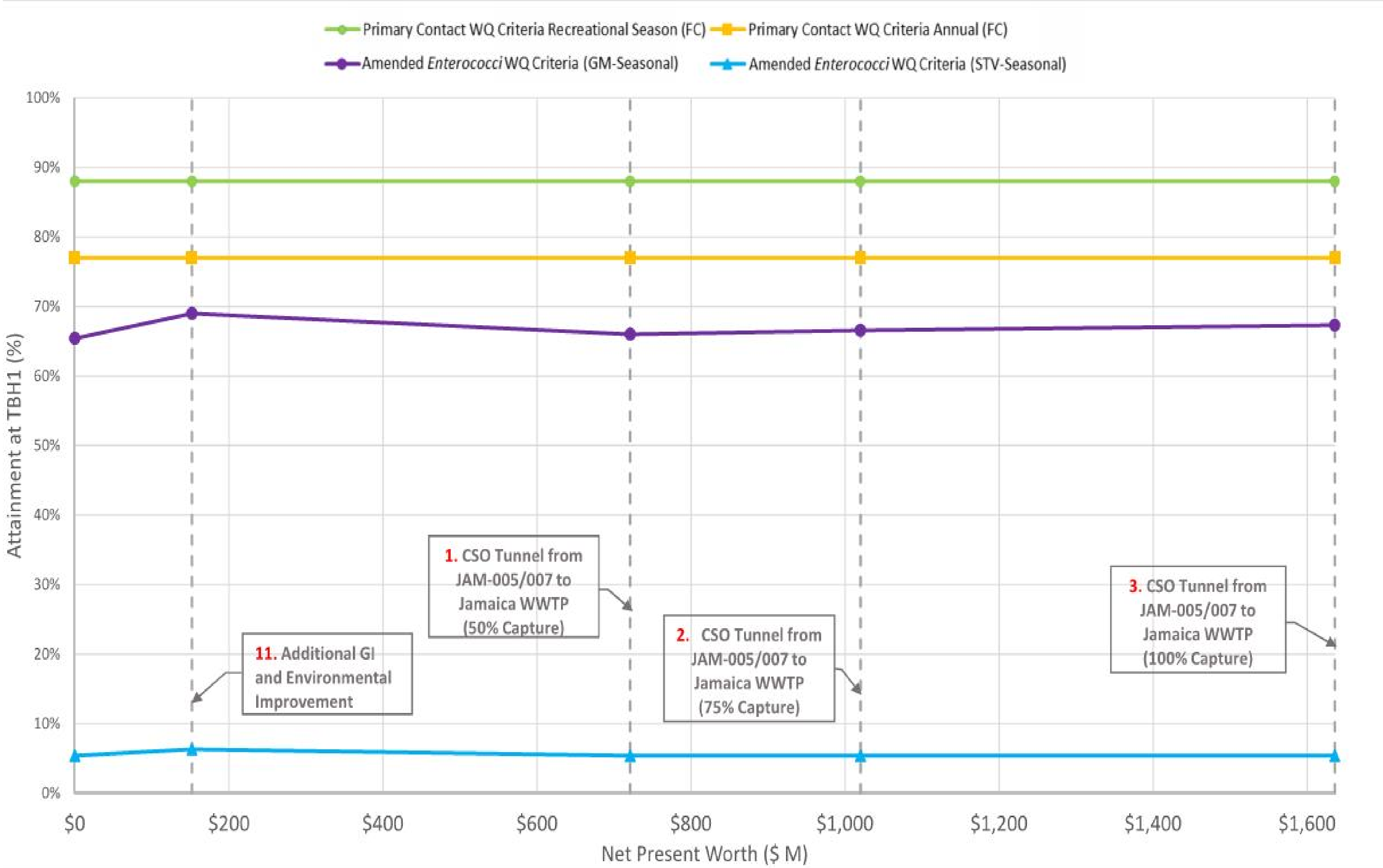

Figure 8-45. Cost vs. Bacteria Attainment at Station TBH1 (2008 Typical Year)

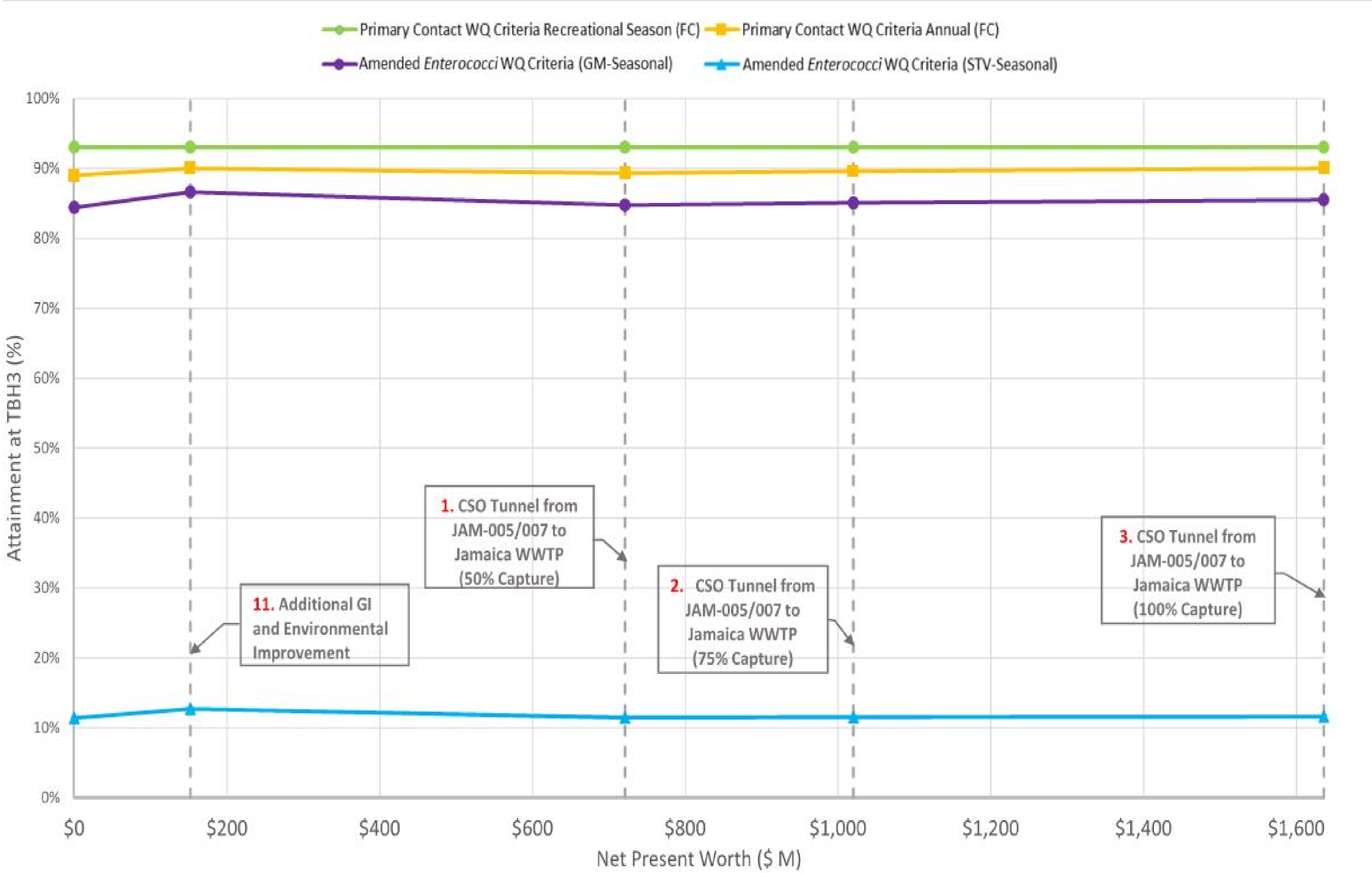

Figure 8-46. Cost vs. Bacteria Attainment at Station TBH3 (2008 Typical Year)

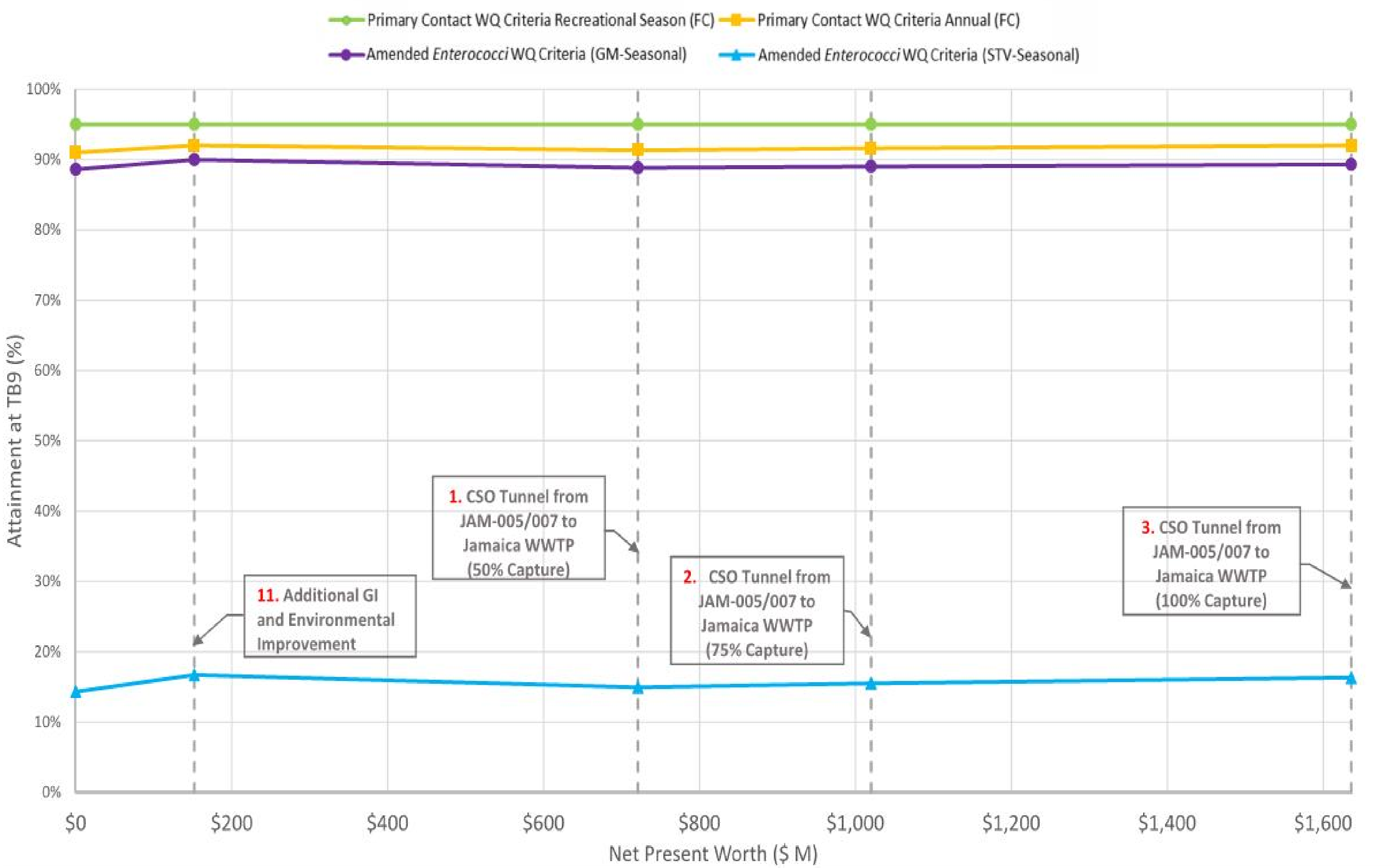

Figure 8-47. Cost vs. Bacteria Attainment at Station TB9 (2008 Typical Year)

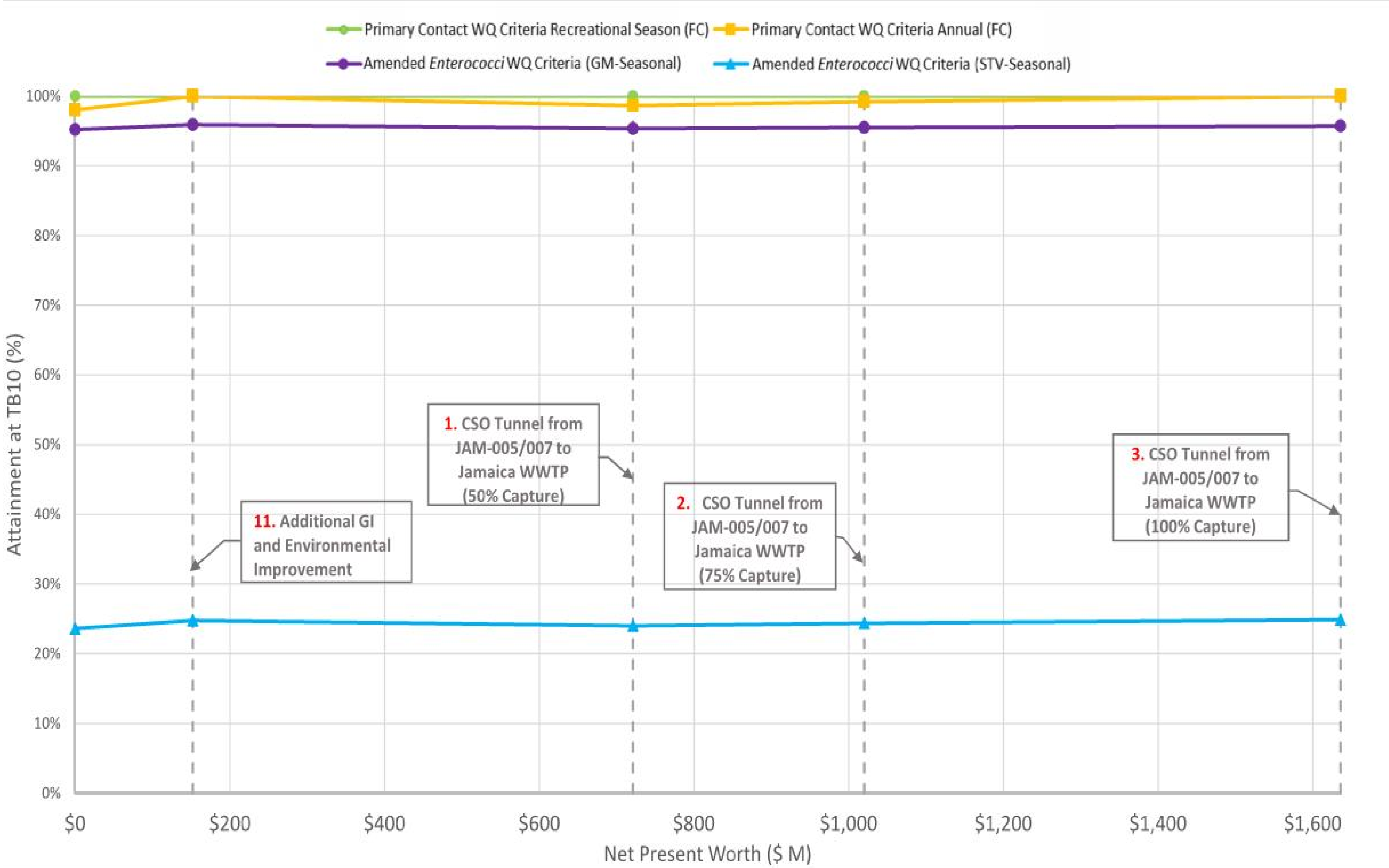

Figure 8-48. Cost vs. Bacteria Attainment at Station TB10 (2008 Typical Year)

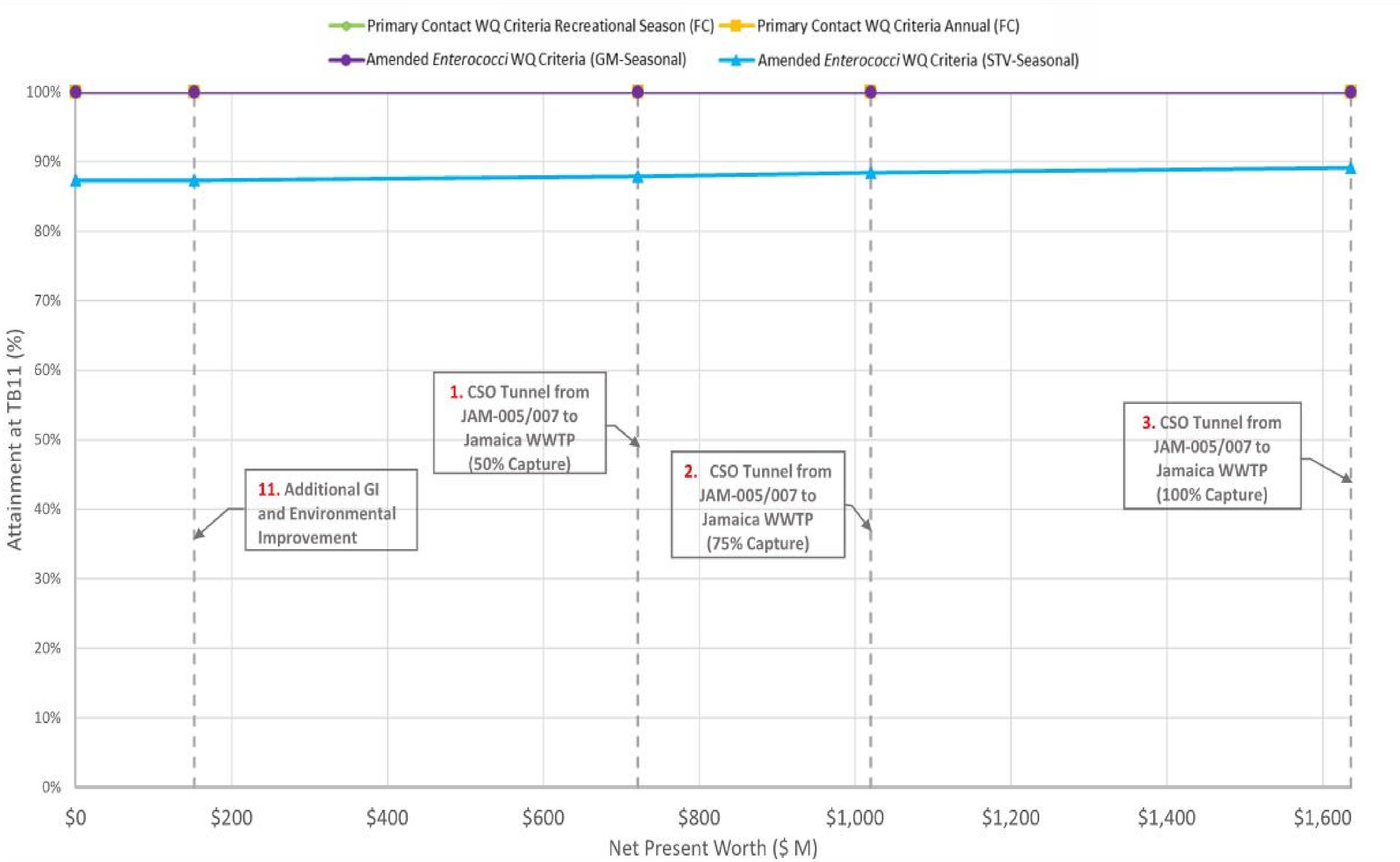

Figure 8-49. Cost vs. Bacteria Attainment at Station TB11 (2008 Typical Year)

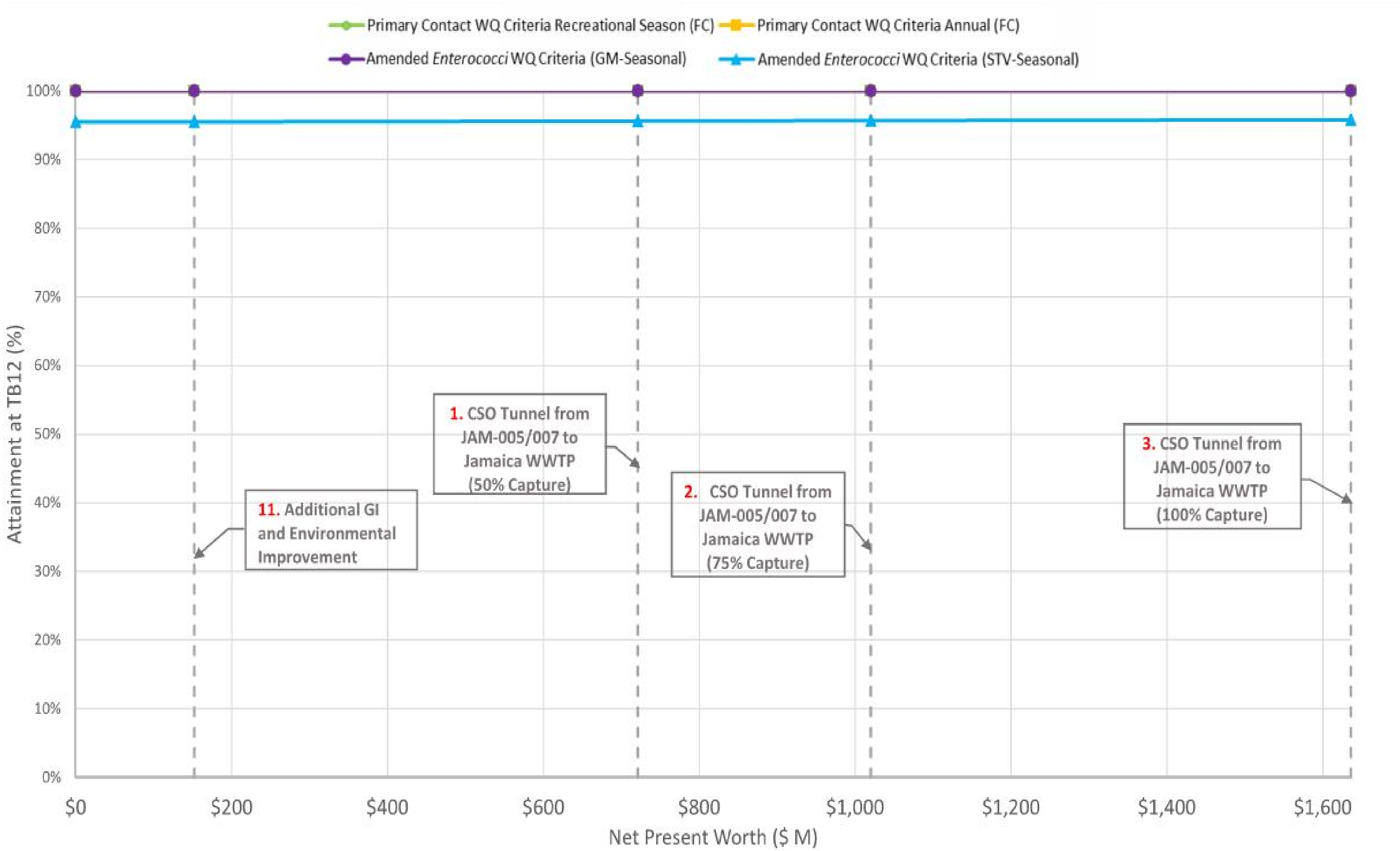

Figure 8-50. Cost vs. Bacteria Attainment at Station TB12 (2008 Typical Year)

8.5.c Conclusion on Recommended Plan

The alternatives were reviewed for cost-effectiveness, ability to meet Existing WQ Criteria and Amended *Enterococci* WQ Criteria*, public comments and operations. The construction costs were developed as Probable Bid Costs (PBC), and the total Net Present Worth (NPW) costs were determined by adding the estimated PBC to the NPW of the projected annual O&M costs at an assumed interest rate of 4 percent over a 100-year life cycle. Design, construction management, and land acquisition costs are not included in the cost estimates. All costs are in June 2018 dollars and are considered Level 5 cost estimates by Association for the Advancement of Cost Engineering (AACE) International with an accuracy of -50 to +100 percent.

The selection of the Recommended Plan is based on multiple considerations including public input, environmental and water quality benefits, and cost. The traditional KOC analysis for cost versus attainment indicates that the Recommended Plan (Alternative 11 – Additional GI and Environmental Improvements) is the most cost-effective approach for CSO control in Bergen and Thurston Basins. This alternative includes expansion of GI to include an additional 453 greened acres in the Bergen and Thurston Basin tributary areas beyond the baseline levels of GI, seven acres of ribbed mussel colony creation distributed between Bergen and Thurston Basins, 50,000 CY of environmental dredging in Bergen Basin, and 50 acres of wetland restoration, distributed among Spring Creek, Hendrix Creek, Fresh Creek, Paerdegat Basin, and Jamaica Bay. Evaluations indicated that the expansion of the GI program in separately sewered areas would help capture stormwater for smaller storms, reducing bacterial loading to Bergen and Thurston Basins. These GI assets would generally be sited in the public right-of-way with minimal impact to private properties. Additionally, wetland restoration and ribbed mussel colony creation along the banks of the tributary basins would provide in-stream concentration reductions of bacteria, improving attainment. Wetland restoration would also enhance wildlife habitat along the shoreline. Environmental dredging in Bergen Basin will improve aesthetics and reduce odors. The specific dimensions and configurations of the ribbed mussel beds, limits of environmental dredging, areas identified for restoration of tidal wetlands and details of the GI to be implemented will be finalized during the design phase.

The Additional GI and Environmental Improvements alternative is projected to result in attainment of the Existing WQ Criteria for fecal coliform in the areas of Jamaica Bay and its tributaries that are accessible to the public. The only area that would not achieve attainment of the Existing WQ Criteria for fecal coliform would be the upstream ends of Thurston and Bergen Basins and Fresh Creek. Public access to upstream ends of Thurston and Bergen Basins is prohibited due to JFK Airport security, and in the case of Thurston Basin, a chain link fence across the waterbody further restricts access. In addition, the gap analysis for Jamaica Bay's tributaries presented in Section 6 indicated that even with a modeled 100% CSO reduction, Existing WQ Criteria for fecal coliform and DO would not be met at the head end of Thurston and Bergen Basins.

While DEP identified grey infrastructure alternatives for Bergen and Thurston Basins that would provide greater reduction in annual CSO volume than the Additional GI and Environmental Improvements alternative, those grey alternatives carried significantly higher costs, would not significantly improve the attainment of WQ criteria, and would not provide the range of ancillary benefits that would be provided by the Additional GI and Environmental Improvements alternative. To further support the evaluation of alternatives, DEP conducted a Triple-Bottom-Line evaluation of the 50 percent control storage tunnel grey alternatives for Bergen and Thurston Basins versus the Additional GI and Environmental Improvements

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

alternative, where the ancillary benefits of the Additional GI and Environmental Improvements alternative were monetized. The Triple-Bottom-Line evaluation is presented below.

Triple-Bottom-Line Benefits

In addition to closing the gap in attainment of Existing WQ Criteria for Jamaica Bay and its tributaries, the Additional GI and Environmental Improvements alternative provides economic, social, and environmental benefits that supplement prior grey infrastructure improvements. A Triple-Bottom-Line analysis was performed to estimate the monetary value of environmental and social benefits and aggregate them alongside the traditional financial bottom line estimates for the project. The Triple-Bottom-Line analysis is based on estimated magnitude of benefits and an equivalent monetary value per unit benefit, which may be derived by calculation of obtained from a representative reference. Although the CSO Policy does not require a Triple-Bottom-Line analysis, or the attainment of such co-benefits, they are worth noting.

Table 8-36 summarizes and quantifies the Triple-Bottom-Line benefits that DEP anticipates will be realized through the implementation of GI, performance of environmental dredging, creation of ribbed mussel colonies, and restoration of tidal wetlands. Co-benefits that were monetized are listed below with their basis of valuation:

- Appreciation of property value – associated with improved curb appeal and drainage improvements and based on one property for each GI practice appreciating by 3 percent from a median property value in Jamaica Bay drainage area of $458,600. The value of 3 percent is the median from the potential range indicated by NYC DEP's Green Infrastructure Co-Benefits Calculator.

- Carbon sequestration – based on carbon sequestration into plant per square foot of wetland and GI area, as detailed by NYC DEP's Water Energy Nexus tool. Carbon offsets are monetized according to NYC Local Law 6 of 2016.

- Air quality improvements – based on NO_2 and $PM_{2.5}$ removal by urban GI, as detailed by NYC DEP's Green Infrastructure Co-Benefits Calculator. Reductions were monetized using the Autocase TBL-CBA software, developed by Impact Infrastructure.

- Heat island reduction – based on grey area replaced by vegetated area. Reductions were monetized using the Autocase TBL-CBA software, developed by Impact Infrastructure.

Other Triple-Bottom-Line benefits that were not monetized include aesthetic improvements associated with installation of GI and tidal wetland restoration, as well as the reduction of odors associated with exposed organics during low tide.

The benefits provided by the Additional GI and Environmental Improvements alternative achieve many of the ecosystem goals outlined in Plan OneNYC, including expansion of GI, reduction of pollution from stormwater runoff, expansion in tree planting, increase in terrestrial species, and habitat improvements for aquatic species.

The Triple-Bottom-Line of the Additional GI and Environmental Improvements alternative was evaluated over a 100 year service life and the benefits were monetized to estimate the life cycle costs and to determine the economic benefits to the community. Property value appreciation was estimated at $83M. The value of environmental benefits such as air quality improvement, carbon footprint reduction, habitat creation, and urban heat island reduction was estimated at $2M. The $85M in Triple-Bottom-Line benefits was found to be almost equal to the $91M in operation and maintenance costs over the 100 year life cycle. In comparison, the 50 percent Capture Tunnel for Bergen and Thurston Basins grey alternative provided none of the environmental or economic benefits of the Additional GI and Environmental Improvements alternative. Although the grey alternative had a higher reduction in annual CSO volume, it provided no co-benefits such as improvement in stormwater volume, and would not provide the 24/7 continuous filtering of the water in Bergen and Thurston Basins that would be provided with the ribbed mussel habitat.

Table 8-36. Triple-Bottom-Line Comparison

Triple-Bottom-Line Benefits	Additional GI and Environmental Improvements	50% Capture Tunnel for Bergen and Thurston Basins
Water Quality Benefits		
Reduction in CSO Volume (MG)	8	493
Reduction in Stormwater Volume (MG)	241	0
Volume of Water Filtered by Ribbed Mussels (MG)	8,354	0
Environmental Benefits		
Lifetime Carbon Footprint Reduction (MT)	12,806(1)	-31,894(1)
Air Quality (NO_2 Removal) (lbs/yr)	664	0
Air Quality PM_{25} Removal) (lbs/yr)	46	0
Ecosystem Habitat Creation (acres)	72	0
Heat Island Reduction (acres)	10	0
Economic Benefit ($ Millions)		
Probable Bid Cost	-$310	-$1,293
Lifetime O&M and Replacement Cost	-$91	-$124
Valuation of Environmental Benefit	+$2	-$1.2
Property Value Appreciation	+$83	0
Total Net Present Cost	**-$318**	**-$1,418**

Note:
(1) Positive value indicates reduction in carbon footprint versus baseline; negative value indicates increase in carbon footprint versus baseline.

As shown in the cost/attainment figures above, the percent attainment of WQ criteria at the stations in Bergen and Thurston Basins for the Additional GI and Environmental Improvements alternative would be either slightly higher or about the same as the 50 percent capture grey alternative. Since the Additional GI and Environmental Improvements alternative would provide equal or slightly higher WQ criteria attainment at a significantly lower cost than the 50 percent capture grey alternative, and would provide extensive ancillary environmental benefits that the 50 percent capture grey alternative would not provide, Alternative 11 "Additional GI and Environmental Improvements" was identified as the Recommended Plan for Jamaica Bay and its tributaries.

Water Quality Benefits

Figure 8-51 identifies each of the water quality monitoring stations evaluated within Jamaica Bay and its tributaries. The water quality modeling results associated with this Recommended Plan for Jamaica Bay and its tributaries are shown in Table 8-37 and Table 8-38. Table 8-37 provides the calculated annual and recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform and Table 8-38 presents the recreational season attainment of the Amended *Enterococci* WQ Criteria*. The results presented in Table 8-37 and Table 8-38 are based on the 10-year simulation.

As indicated in Table 8-37, the Recommended Plan will achieve attainment of the Existing WQ Criteria for fecal coliform annually and during the recreational season (May 1st through October 31st) for most waterbodies, with the exception of Thurston Basin (TBH1, TBH3), Bergen Basin (BB5, BB6), and Fresh Creek (FC1). However, the impacted stations in Bergen Basin and Thurston Basin are prohibited to access by the public by JFK Airport security. In Thurston Basin, access is also prohibited by a floating chain link fence across the waterbody. At Stations TBH3 and BB6, attainment during the recreational season (May 1st through October 31st) is 93 percent or better, falling just short of the 95 percent metric. In addition, the gap analysis presented in Section 6 demonstrated that the upstream ends of Thurston Basin and Bergen Basin would not be in attainment with the Existing WQ Criteria for fecal coliform even with 100% CSO control.

As indicated in Table 8-38, the Amended *Enterococci* WQ Criteria* (rolling 30-day GM <35 cfu/100mL) are met for most waterbodies, except for Thurston and Bergen Basins. However, the stations where attainment falls short of the 95 percent goal are in areas that are prohibited to public access. Attainment of the 90th percentile STV of <130 cfu/100mL ranges between 0 and 100 percent with the lowest levels of attainment occurring at the head ends of Thurston Basin, Bergen Basin, Fresh Creek and Hendrix Creek. Attainment of the STV standard ranges between 57 and 100 percent within Jamaica Bay and at the confluence of each tributary with the Bay.

*Amended *Enterococci* WQ Criteria would only apply to coastal Class SB and SA waters.

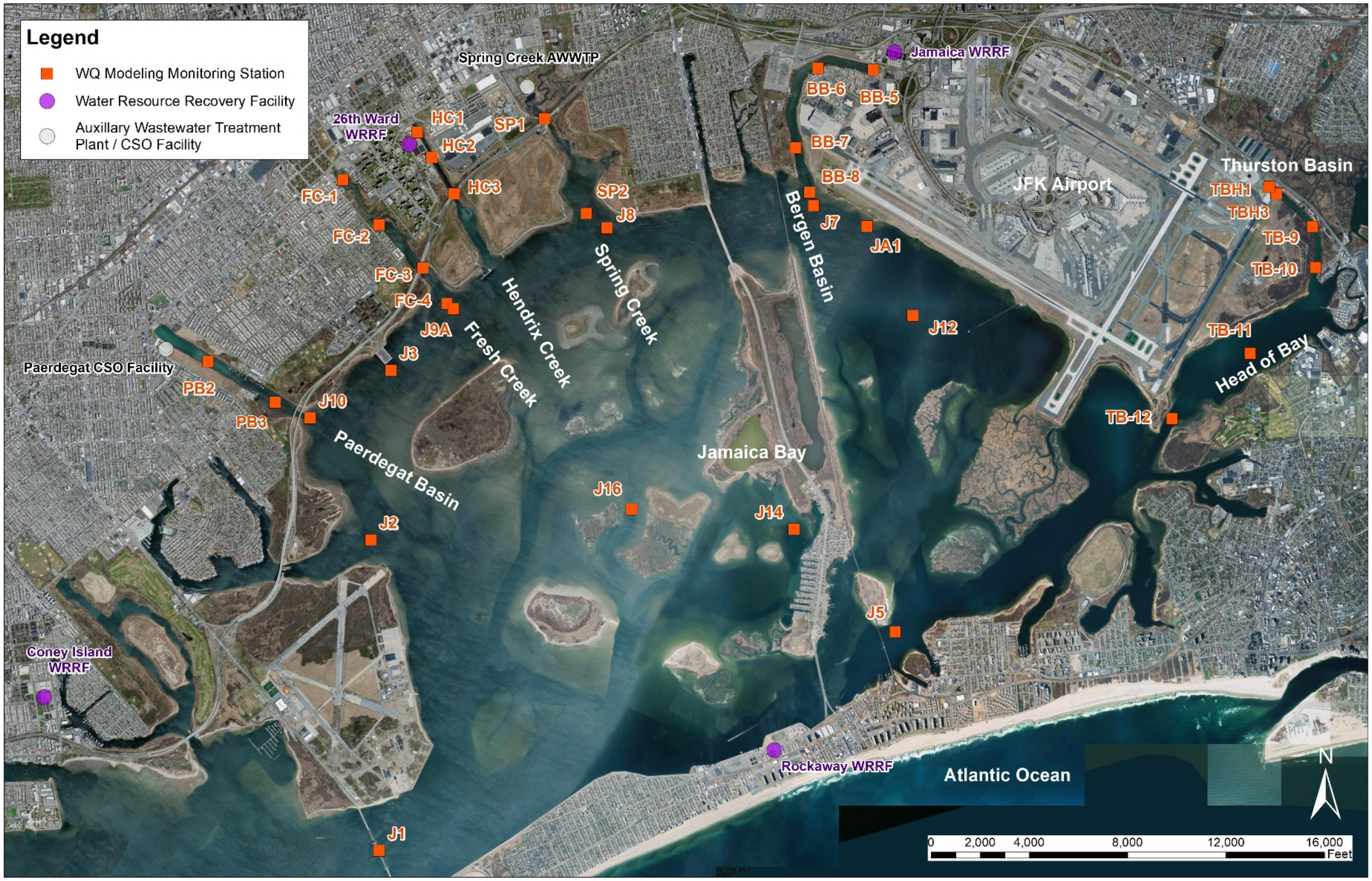

Figure 8-51. LTCP2 Water Quality Monitoring Stations in Jamaica Bay and its Tributaries

Table 8-37. Model Calculated Recommended Plan Fecal Coliform Percent Attainment of Existing WQ Criteria and Primary Contact WQ Criteria

Station	10-Year Percent Attainment (GM<200 cfu/100mL)[(3)]	
	Annual	Recreational Season[(2)]
Thurston Basin		
TBH1[(1)]	77	88
TBH3[(1)]	89	93
TB9[(1)]	91	95
TB10[(1)]	98	100
TB11	100	100
TB12	100	100
Bergen Basin		
BB5[(1)]	57	72
BB6[(1)]	89	93
BB7[(1)]	100	100
BB8	100	100
Spring Creek		
SP1	100	100
SP2	100	100
Hendrix Creek		
HC1	99	98
HC2	100	100
HC3	100	100
Fresh Creek		
FC1	85	93
FC2	98	100
FC3	100	100
FC4	100	100
Paerdegat Basin		
PB2	97	95
PB3	100	100
Jamaica Bay (Northern Shore)		
J10	100	100
J3	100	100
J9A	100	100
J8	100	100
J7	100	100
JA1	100	100

Table 8-37. Model Calculated Recommended Plan Fecal Coliform Percent Attainment of Existing WQ Criteria and Primary Contact WQ Criteria

Station	10-Year Percent Attainment (GM<200 cfu/100mL)(3)	
	Annual	Recreational Season(2)
Jamaica Bay (Inner Bay)		
J2	100	100
J12	100	100
J14	100	100
J16	100	100
Jamaica Bay (Rockaway Shore)		
J1	100	100
J5	100	100

Notes:

(1) Monitoring station is located in a portion of the waterbody where unauthorized access is prohibited by JFK Airport security and/or a physical barrier.

(2) The recreational season is from May 1st through October. 31st.

(3) As described in Section 8.2, the ribbed mussels proposed for Bergen and Thurston Basins were assumed to provide an additional 10 percent reduction in in-water bacteria concentrations in Bergen and Thurston Basins. The attainment values in this table take into account that 10-percent reduction in concentration. Without the 10 percent reduction associated with the ribbed mussels, the percent attainment in Bergen and Thurston Basins would be in the range of 1 to 5 percent lower, depending on the station.

Table 8-38. Model Calculated Recommended Plan Percent Attainment of the Amended *Enterococci* WQ Criteria*

Station	10-Year Recreational Season(2) Percent Attainment(3)(4)	
	30-day Rolling GM <35 cfu/100mL	90th Percentile STV <130 cfu/100mL
Thurston Basin		
TBH1(1)	65	5
TBH3(1)	84	11
TB9(1)	89	14
TB10(1)	95	24
TB11	100	87
TB12	100	96
Bergen Basin		
BB5(1)	29	0
BB6(1)	69	6
BB7(1)	93	14
BB8	100	57
Spring Creek		
SP1	100	78
SP2	100	94
Hendrix Creek		
HC1	98	32
HC2	98	38
HC3	100	71
Fresh Creek		
FC1	98	16
FC2	98	17
FC3	100	51
FC4	100	92
Paerdegat Basin		
PB1	96	28
PB2	100	69
Jamaica Bay (Northern Shore)		
J10	100	85
J3	100	97
J9A	100	92
J8	100	92
J7	100	57
JA1	100	86
Jamaica Bay (Inner Bay)		
J2	100	98
J12	100	97
J14	100	100
J16	100	99

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 8-38. Model Calculated Recommended Plan Percent Attainment of the Amended *Enterococci* WQ Criteria*

Station	10-Year Recreational Season(2) Percent Attainment(3)(4)	
	30-day Rolling GM <35 cfu/100mL	90th Percentile STV <130 cfu/100mL
Jamaica Bay (Rockaway Shore)		
J1	100	100
J5	100	100

Notes:

(1) Monitoring station is located in a portion of the waterbody where unauthorized access is prohibited by JFK Airport security and/or a physical barrier.
(2) The recreational season is from May 1st through October. 31st.
(3) The Amended *Enterococci* WQ Criteria* do not apply to non-coastal Class I waters, including the tributaries of Jamaica Bay.
(4) As described in Section 8.2, the ribbed mussels proposed for Bergen and Thurston Basins were assumed to provide an additional 10 percent reduction in in-water bacteria concentrations in Bergen and Thurston Basins. The attainment values in this table take into account that 10-percent reduction in concentration. Without the 10 percent reduction associated with the ribbed mussels, the percent attainment of the 90-day Rolling GM criterion in Bergen and Thurston Basins would be in the range of 1 to 5 percent lower, depending on the station.

The average annual attainment of DO criteria for the Recommended Plan based on the water quality model simulation is presented in Table 8-39 for 2008 typical year rainfall conditions (the LTCP framework does not evaluate DO attainment under a 10-year simulation). The average annual attainment is calculated by averaging the calculated attainment in each of 10 modeled depth layers, comprising the entire water column. When assessing the water column in its entirety, attainment of the DO criterion is very high, with the exception of the head ends of Bergen Basin, Thurston Basin, and Hendrix Creek. All other monitoring station locations that were assessed have a water column annual attainment of 95 percent or greater for 2008 typical year rainfall conditions.

Table 8-39. Model Calculated Recommended Plan DO Attainment – Existing WQ Criteria (2008 Typical Year)

Annual Attainment (%) (Entire Water Column)				
Tributaries – Class I		**Jamaica Bay - Class SB**		
Station	**Instantaneous (>=4.0 mg/L)**	**Station**	**Instantaneous (>=3.0 mg/L)**	**Daily Ave. (>=4.8 mg/L)**
Thurston Basin		**Jamaica Bay (Northern Shore)**		
TBH1(1)	90	J10	100	100
TBH3(1)	90	J3	100	100
TB9(1)	92	J9a	100	100
TB10(1)	92	J8	100	100
TB11	97	J7	100	100
TB12	99	JA1	100	99

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 8-39. Model Calculated Recommended Plan DO Attainment – Existing WQ Criteria (2008 Typical Year)

Annual Attainment (%) (Entire Water Column)				
Tributaries – Class I		**Jamaica Bay - Class SB**		
Station	**Instantaneous (>=4.0 mg/L)**	**Station**	**Instantaneous (>=3.0 mg/L)**	**Daily Ave. (>=4.8 mg/L)**
Bergen Basin		**Jamaica Bay (Inner Bay)**		
BB5(1)	89	J2	100	100
BB6(1)	95	J12	100	100
BB7(1)	99	J14	100	100
BB8	100	J16	100	100
Spring Creek		**Jamaica Bay (Rockaway Shore)**		
SP1	99	J1	100	100
SP2	100	J5	100	100
Hendrix Creek				
HC1	94			
HC2	98			
HC3	100			
Fresh Creek				
FC1	99			
FC2	100			
FC3	100			
FC4	100			
Paerdegat Basin				
PB2	99			
PB3	100			

Note:
(1) Monitoring station is located in a portion of the waterbody where unauthorized access is prohibited by JFK Airport security and/or a physical barrier.

The key components of the Recommended Plan include:

- Thurston Basin
  - 147 greened acres of GI Expansion
  - 3 acres of Ribbed Mussel Colony Creation
- Bergen Basin
  - 232 greened acres of GI Expansion
  - 50,000 CY Environmental Dredging
  - 4 acres of Ribbed Mussel Colony Creation
- Spring Creek
  - 13 acres of Tidal Wetland Restoration

- Hendrix Creek
  - 3 acres of Tidal Wetland Restoration
- Fresh Creek
  - 14 acres of Tidal Wetland Restoration
- Paerdegat Basin
  - 4 acres of Tidal Wetland Restoration
- Jamaica Bay
  - 16 acres of Tidal Wetland Restoration

DEP will identify the specific locations and layouts of the proposed projects in each of the tributaries during subsequent planning and design phases. The implementation of these elements has a NPW of approximately $401M, reflecting $91M of O&M for a 100-year service life.

The proposed schedule for the implementation of the Recommended Plan is presented in Section 9.2.

8.6 Use Attainability Analysis

The CSO Order requires that a UAA be included in a LTCP "where existing WQS do not meet the Section 101(a)(2) goals of the CWA, or where the proposed alternative set forth in the LTCP will not achieve existing WQS or the Section 101(a)(2) goals." The UAA shall "examine whether applicable waterbody classifications, criteria, or standards should be adjusted by the State." The UAA process specifies that States can remove a designated use that is not an existing use if the scientific assessment can demonstrate that attaining the designated use is not feasible for at least one of six reasons:

1. Naturally occurring loading concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by Sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

As part of the LTCP, elements of a UAA, including the six conditions presented above, will be used to determine if changes to the designated use are warranted, considering a potential adjustment to the designated use classification as appropriate.

As noted in previous sections, even with the implementation of the Recommended Plan, Bergen Basin, Thurston Basin, and Fresh Creek are not projected to fully meet Existing WQ Criteria for fecal coliform, portions of northern Jamaica Bay are not projected to meet the Amended *Enterococci* 30-day STV criteria*, and Bergen Basin, Thurston Basin, and Hendrix Creek are not projected to fully attain the Existing WQ Criteria for DO (Class I). Thus, a UAA has been included in this LTCP.

8.6.a Use Attainability Analysis Elements

The objectives of the CWA include providing for the protection and propagation of fish, shellfish, wildlife, and recreation in and on the water. Cost-effectively maximizing the water quality benefits associated with CSO reduction is a cornerstone of this LTCP.

To simplify this process, DEP and DEC have developed a framework that outlines the steps taken under the LTCP in two possible scenarios:

1. Waterbody meets water quality requirements. This may either be the Existing WQ Criteria (where primary contact is already designated) or for an upgrade to the Primary Contact WQ Criteria (where the existing standard is not a Primary Contact WQ Criteria). In either case, a high-level assessment of the factors that define a given designated use is performed, and if the level of control required to meet this goal can be reasonably implemented, a change in designation may be pursued following implementation of CSO controls and Post-Construction Compliance Monitoring.

2. Waterbody does not meet water quality requirements. In this case, if a higher level of control is not feasible, the UAA must justify the shortcoming using at least one of the six criteria (see Section 8.6 above). It is assumed that if 100% elimination of CSO sources does not result in attainment, the UAA would include factor number 3 at a minimum as justification (human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied, or would cause more environmental damage to correct than to leave in place).

As indicated in Table 8-37 and Table 8-39, upon implementation of the LTCP Recommended Plan, the fecal coliform and DO criteria for the Class I waters of the tributaries to Jamaica Bay are not projected to be achieved on a recreational season (May 1st through October 31st) basis. The non-attainment is predominantly due to stormwater, direct drainage and other urban sources of pathogens to these waterbodies. As indicated in Table 6-7 of Section 6.3, the criteria would not be attained even with a 100% CSO control scenario, thus supporting the influence that non-CSO sources have on the ability to achieve attainment of WQ criteria.

8.6.b Fishable/Swimmable Waters

The goal of this LTCP is to identify appropriate CSO controls necessary to achieve waterbody-specific WQS, consistent with EPA's CSO Control Policy and subsequent guidance. DEC considers that compliance with Class SB WQS for Jamaica Bay and Class I WQS for the tributaries, as fulfillment of the CWA's fishable/swimmable goal.

Based on the 10-year continuous simulations, as presented in Table 8-37, the Recommended Plan would result in attainment of the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st) for Jamaica Bay and Existing WQ Criteria for fecal coliform for Spring Creek, Hendrix Creek, and Paerdegat Basin. However, Existing WQ Criteria for fecal coliform for Thurston Basin,

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Bergen Basin, and Fresh Creek would not be achieved, and the Amended *Enterococci* 30-day STV criteria* would not be achieved in portions of northern Jamaica Bay. As indicated in Table 8-39, the Existing WQ Criteria for DO (Class SB) would be met for Jamaica Bay on an annual average basis. In addition, the Existing WQ Criteria for DO (Class I) would be met for all tributaries except for Thurston Basin, Bergen Basin, and Hendrix Creek.

As discussed in Section 6, 100% CSO control does not result in attainment of the Existing WQ Criteria for fecal coliform or DO for these tributaries, and does not result in attainment with the Amended *Enterococci* 30-day STV criteria* in all stations in northern Jamaica Bay. Thus, CSO loads are not the controlling factor for bacteria or DO concentrations and CSO controls will not substantially improve WQ criteria attainment. This finding is not unexpected as the DO and bacteria concentrations in the Jamaica Bay tributaries are influenced by many non-CSO factors including stormwater loads, tidal flushing, and the nitrogen discharged from WRRFs (DO impact, only).

8.6.c Assessment of Highest Attainable Use

The CSO Order Goal Statement stipulates that, in situations where the proposed alternatives presented in the LTCP will not achieve the CWA Section 101(a)(2) goals, the LTCP will include a UAA. Because the analyses developed herein indicate that some of the Jamaica Bay tributaries are not projected to fully attain the Class I fecal coliform or DO criteria on an annual basis, and the Amended *Enterococci* 30-day STV criteria* would not be achieved in portions of northern Jamaica Bay, a UAA is required under the CSO Order. Table 8-40 summarizes the compliance with Existing, Primary Contact, and Amended *Enterococci* WQ Criteria* for the Recommended Plan. The UAA is included as Appendix C.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 8-40. Recommended Plan Compliance with Bacteria WQ Criteria

Waterbody	Location	Fecal Coliform Annual Attainment (1)	Fecal Coliform Recreational Attainment (2)	Amended Enterococcus 30-Day GM (3)	Amended Enterococcus 30-Day STV (4)	Dissolved Oxygen Annual Attainment (5)
Thurston Basin	Head End(9)	✗	✗	N/A	N/A	✗
	Mid Point(9)	✗	✓	N/A	N/A	✗
	Mouth	✓	✓	N/A	N/A	✓
Bergen Basin	Head End(9)	✗	✗	N/A	N/A	✗
	Mid Point(9)	✗	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Hendrix Creek	Head End	✓	✓	N/A	N/A	✗ (6)
	Mid Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Fresh Creek	Head End	✗ (7)	✗ (7)	N/A	N/A	✓
	Mid Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Paerdegat Basin	Head End	✓	✓	N/A	N/A	✓
	Mid Point	✓	✓	N/A	N/A	✓
	Mouth	✓	✓	N/A	N/A	✓
Jamaica Bay (Grassy Bay)	Northern	✓	✓	✓	✗ (8)	✓
	Southern	✓	✓	✓	✓	✓
Jamaica Bay (North Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Beach Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Island Channel)	Entire	✓	✓	✓	✓	✓
Jamaica Bay (Rockaway Inlet)	Entire	✓	✓	✓	✓	✓

Notes:

✓ indicates that attainment is projected to occur ≥ 95% of the time

✗ indicates that attainment is projected to occur < 95% of the time

(1) Fecal coliform annual attainment is based on a monthly geometric mean of ≤200 cfu/100mL.

(2) Fecal coliform recreational attainment is based on a monthly geometric mean of ≤200 cfu/100mL from May 1st through October 31st.

(3) The amended 30-day *Enterococcus* GM attainment is based on DEC recently adopted 30-day *Enterococcus* standard of ≤35 cfu/100mL for coastal recreational waters during recreational season (May 1st through October 31st).

(4) The amended 30-day *Enterococcus* STV attainment is based on the DEC recently adopted 30-day *Enterococcus* standard that required 90% of the values to be ≤ 130 cfu/100mL during the recreational season (May 1st through October 31st).

(5) The DO standard in the tributaries is never less than 4 mg/L and in Jamaica Bay is never less than 3 mg/L and a allows for duration-based excursions between 3 and 4.8 mg/L.

(6) The projected dissolved oxygen attainment in the head end of Hendrix Creek is 94%.

(7) The projected attainment at the very head end of Fresh Creek is about 85% and 93% for annual and recreational attainment, respectively.

(8) Areas just outside of the tributaries are projected not to attain the amended 30-day *Enterococcus* STV that required 90% of values to be ≤130 cfu/100mL.

(9) Unauthorized access to these portions of Bergen and Thurston Basins is prohibited by JFK Airport security.

8.7 Water Quality Goals

Based on the analyses of Jamaica Bay, its tributaries and the WQ criteria associated with the designated uses, the following conclusions can be drawn:

8.7.a Existing Water Quality

Jamaica Bay, excluding the tributaries, is classified as suitable for primary and secondary contact recreation and fishing. Numerous public access points that facilitate primary and secondary contact activities within Jamaica Bay exist at federal, State, and City parklands. Approximately 66 percent of the publicly accessible parkland is within the GNRA. The bulk of the remaining waterfront access is provided by the New York City Department of Parks and Recreation operated parks and open space areas and includes four kayak/canoe launch sites. Only one public boat launch ramp is located within Jamaica Bay, adjacent to the Rockaway WRRF.

Under baseline conditions, Spring Creek and Paerdegat Basin are in attainment with the bacteria and DO criteria associated with their current classification (Class I), while Thurston Basin, Bergen Basin, Fresh Creek, and Hendrix Creek are not. Jamaica Bay, itself, is in attainment with the fecal coliform and DO criteria associated with its current classification (Class SB). Jamaica Bay is also in attainment with the Amended *Enterococci* WQ GM Criteria* (GM≤35 cfu/100mL), but portions of northern Jamaica Bay near the tributary outlets are not in attainment with the Amended *Enterococci* WQ STV Criteria* (GM≤130 cfu/100mL),

8.7.b Primary Contact Water Quality Criteria

As presented in Section 8.5, this LTCP incorporates assessments for attainment with Primary Contact WQS, as the Existing WQ Criteria for fecal coliform are the same as the Primary Contact WQS. DEP assessed attainment both spatially and temporally using the 2008 typical year rainfall and a 10-year simulation for bacteria. For the Recommended Plan, projected bacteria levels show that Jamaica Bay and its tributaries (with the exception of the stations at the head ends of Thurston Basin, Bergen Basin, and Fresh Creek) will meet the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st). The same is true for the Primary Contact WQ Criteria for bacteria. The stations near the head ends of Thurston and Bergen Basins (TBH1 and BB5) are not projected to achieve attainment of the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st) even with 100% CSO control. These stations, however, are prohibited from public access. The stations within these waterbodies that are accessible to the public (TB11 and BB8) achieve both annual and recreational season (May 1st through October 31st) attainment for the fecal coliform criteria. These stations also achieve attainment for the Amended *Enterococci* WQ Criteria* (GM≤35 cfu/100mL) although this amended criteria is not applicable to Class I waters. While Fresh Creek does not achieve 95 percent annual or recreational season (May 1st through October 31st) attainment of Existing WQ Criteria for fecal coliform under baseline conditions, Fresh Creek does achieve the Amended *Enterococci* WQ Criteria* (GM≤35 cfu/100mL) although this amended criteria is not applicable to Class I waters.

8.7.c Amended *Enterococci* WQ Criteria*

DEP is committed to improving water quality in Jamaica Bay and its tributaries. Toward that end, DEP has identified instruments that will allow DEP to continue to improve water quality in the system over time. Wet-weather advisories based on time to recovery analysis are recommended for consideration while

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

advancing towards the numerical criteria established, or others under consideration by DEC, including Amended *Enterococci* WQ Criteria*.

8.7.d Time to Recovery

Although Jamaica Bay and the accessible areas in the tributaries could be protective of primary contact use during the recreational season (May 1st through October 31st), they will not be capable of supporting primary contact 100 percent of the time. Even with anticipated reductions in CSO and stormwater volumes resulting from the Recommended Plan, the waterbodies cannot support primary contact during, and, for a certain period of time, following rainfall events. Toward the goal of maximizing the amount of time that Jamaica Bay and its tributaries can achieve water quality levels to support primary contact, DEP has performed an analysis to assess the amount of time following the end of a rainfall event required for Jamaica Bay and its tributaries to recover and return to fecal coliform concentrations less than 1,000 cfu/100mL. This concentration represents the maximum that the New York City Department of Health and Mental Hygiene (DOHMH) considers safe for primary contact.

The analyses consisted of examining the water quality model-calculated bacteria concentrations in Jamaica Bay and its tributaries for recreational periods (May 1st through October 31st) abstracted from 10 years of model simulations. The time to return (or "time to recovery") to a fecal coliform concentration of 1,000 cfu/100mL for each water quality station within the waterbody was then calculated for each storm within the various size categories. The median time after the end of rainfall was then calculated for each rainfall category. Table 8-41 presents the results of these analyses for Jamaica Bay and its tributaries, for the storms that fell within the range of 1.0 to 1.5 inches of rainfall. Approximately 90 percent of the storms are 1.5-inches or less on an average annual basis. As described in Section 8, results presented for the Recommended Plan for the 10-year model simulations were interpolated from available results for the alternatives that included the 0 and 50 percent CSO control tunnels for Bergen and Thurston Basins. As indicated in Table 8-41, the median duration of time within which pathogen concentrations are expected to be higher than 1,000 cfu/100mL varies by location within Jamaica Bay and each of its tributaries. For the Recommended Plan, the median times to recovery are below 24 hours at all of the water quality stations for the storm sizes up to 1.5 inches except for Stations TBH1, TBH3, and TB9 in Thurston Basin, BB5 and BB6 in Bergen Basin and FC1 in Fresh Creek. The median times to recovery at those stations ranged from 30 to 40 hours. For storms greater than 1.5 inches, the median times to recovery are well above 24 hours at all stations located near the head end of each tributary, except for Hendrix Creek (22 hours). All stations within Jamaica Bay have median times to recovery well below 24 hours.

Table 8-41. Time to Recovery – Recommended Plan

Station	Time to Recovery (hours) Fecal Coliform Threshold (1,000 cfu/100mL)(1)
Thurston Basin	
TBH1(2)	38
TBH3(2)	35
TB9(2)	30
TB10(2)	16
TB11	0
TB12	0
Bergen Basin	
BB5(2)	40
BB6(2)	33
BB7(2)	18
BB8	6
Spring Creek	
SP1	6
SP2	0
Hendrix Creek	
HC1	18
HC2	17
HC3	8
Fresh Creek	
FC1	32
FC2	22
FC3	23
FC4	1
Paerdegat Basin	
PB1	19
PB2	6
Jamaica Bay (Northern Shore)	
J10	3
J3	0
J9a	0
J8	0
J7	5
JA1	1
Jamaica Bay (Inner Bay)	
J2	0
J12	0
J14	0
J16	0

Table 8-41. Time to Recovery – Recommended Plan

Station	Time to Recovery (hours) Fecal Coliform Threshold (1,000 cfu/100mL)[(1)]
Jamaica Bay (Rockaway Shore)	
J1	0
J5	0

Notes:
(1) Median values for storms in the 1.0 to 1.5-inch range, for the 10-year recreational periods.
(2) Monitoring station is located in a portion of the waterbody where unauthorized access is prohibited by JFK Airport security and/or a physical barrier.

8.8 Recommended LTCP Elements to Meet Water Quality Goals

Water quality in Jamaica Bay will be improved with the Recommended Plan (NPW = $401M, PBC = $310M) and other actions identified herein.

The actions identified in this LTCP include in the following waterbodies:

- Thurston Basin (PBC = $109.8M)
    - 147 greened acres of GI Expansion ($106.0M)
    - 3 acres of Ribbed Mussel Colony Creation ($5.8M)

- Bergen Basin (PBC = $138.0M)
    - 232 greened acres of GI Expansion ($106.4M)
    - 50,000 CY Environmental Dredging ($27.0M)
    - 4 acres of Ribbed Mussel Colony Creation ($4.6M)

- Spring Creek (PBC = $16.3M)
    - 13 acres of Tidal Wetland Restoration

- Hendrix Creek (PBC= $3.1M)
    - 3 acres of Tidal Wetland Restoration

- Fresh Creek (PBC= $17.0M)
    - 14 acres of Tidal Wetland Restoration

- Paerdegat Basin (PBC = $5.6M)
    - 4 acres of Tidal Wetland Restoration

- Jamaica Bay (PBC = $20.5M)
    - 16 acres of Tidal Wetland Restoration

AECOM with Hazen

Furthermore, the Recommended Plan will result in an additional 8 MGY reduction in CSO volume due to the increased capacity in the interceptors in the CSO portion of system. Table 8-42 provides a breakdown of the Probable Bid Cost for the Recommended Plan.

DEP is committed to improving water quality in these waterbodies, which will be advanced by the improvements and actions identified in this LTCP. These identified actions have been balanced with input from the public and awareness of the cost to the citizens of NYC.

Table 8-42. Recommended Plan Breakdown of Probable Bid Cost

Waterbody	GI Cost ($ Millions)	Environmental Dredging Cost ($ Millions)	Ribbed Mussel Cost ($ Millions)	Tidal Wetlands Restoration Cost ($ Millions)	Total Cost ($ Millions)
Thurston Basin	$104.0	$0.0	$5.8	$0.0	**$109.8**
Bergen Basin	$106.4	$27.0	$4.6	$0.0	**$138.0**
Spring Creek	$0.0	$0.0	$0.0	$16.3	**$16.3**
Hendrix Creek	$0.0	$0.0	$0.0	$3.1	**$3.1**
Fresh Creek	$0.0	$0.0	$0.0	$17.0	**$17.0**
Paerdegat Basin	$0.0	$0.0	$0.0	$5.6	**$5.6**
Jamaica Bay	$0.0	$0.0	$0.0	$20.5	**$20.5**
PBC Total (2018 $)	**$210.4**	**$27.0**	**$10.4**	**$62.5**	**$310.3**

Attachment H
Appendix A – Supplemental Tables

Appendix A: Supplemental Tables

Combined Sewer Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge (MG/Yr)**
Paerdegat Basin	CI-004	12
Paerdegat Basin	CI-005	18
Paerdegat Basin	CI-006	8
Paerdegat Basin	CI-CIT	553
Bergen Basin	JA-003/003A	330
Bergen Basin	JA-006	3
Thurston Basin	JA-007/JA-005	247
Jamaica Bay	RO-030	0
Jamaica Bay	RO-029	0
Jamaica Bay	RO-015	0
Jamaica Bay	RO-014	0
Jamaica Bay	RO-012	0
Jamaica Bay	RO-011	0
Jamaica Bay	RO-010	0
Jamaica Bay	RO-009	0
Jamaica Bay	RO-008	0
Jamaica Bay	RO-007	0
Jamaica Bay	RO-006	0
Jamaica Bay	RO-005	0
Jamaica Bay	RO-004	0
Fresh Creek	26-003	232
Hendrix Creek	26-004	85
Spring Creek	26-005	292
	Total CSO	**1,780**

MS-4 Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Jamaica Bay	CI-603	24
Jamaica Bay	CI-604	3
Jamaica Bay	CI-605	298
Jamaica Bay	CI-607	3
Jamaica Bay	CI-608	2
Jamaica Bay	CI-609	2
Jamaica Bay	CI-610	404
Jamaica Bay	CI-611	8
Jamaica Bay	CI-612	10
Jamaica Bay	CI-613	251
Jamaica Bay	CI-614	2
Jamaica Bay	CI-615	54
Jamaica Bay	CI-616	9
Jamaica Bay	CI-617	12
Jamaica Bay	CI-618	16
Jamaica Bay	CI-619	12
Jamaica Bay	CI-620	16
Jamaica Bay	CI-621	7
Jamaica Bay	CI-622	25
Jamaica Bay	CI-623	14
Jamaica Bay	CI-624	38
Jamaica Bay	CI-625	27
Jamaica Bay	CI-626	27
Jamaica Bay	CI-627	33
Paerdegat Basin	CI-628	30
Paerdegat Basin	CI-629	40
Paerdegat Basin	CI-630	48
Paerdegat Basin	CI-632	78
Jamaica Bay	CI-633	121
Fresh Creek	CI-634	114
Fresh Creek	CI-636	51
Fresh Creek	CI-637	50
Jamaica Bay	CI-642	11
Jamaica Bay	CI-656	5
Jamaica Bay	CI-657	83
Jamaica Bay	CI-667	9

MS-4 Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Jamaica Bay	CI-668	5
Jamaica Bay	CI-669	9
Jamaica Bay	CI-670	7
Jamaica Bay	CI-671	11
Jamaica Bay	CI-672	20
Jamaica Bay	CI-673	5
Jamaica Bay	CI-674	2
Jamaica Bay	CI-676	15
Bergen Basin	JA-006	2,811
Bergen Basin	JA-140	25
Shellbank Basin	JA-114	4
Shellbank Basin	JA-115	7
Shellbank Basin	JA-116	4
Shellbank Basin	JA-117	6
Shellbank Basin	JA-081	5
Hawtree Basin	JA-523	4
Shellbank Basin	JA-601	10
Shellbank Basin	JA-603	54
Shellbank Basin	JA-604	6
Shellbank Basin	JA-605	9
Shellbank Basin	JA-607	41
Shellbank Basin	JA-609	34
Shellbank Basin	JA-630	12
Hawtree Basin	JA-636	5
Hawtree Basin	JA-638	3
Head of Bay	JA-640	6
Head of Bay	JA-649	256
Head of Bay	JA-652	0
Head of Bay	JA-653	11
Head of Bay	JA-654	1
Head of Bay	JA-655	6
Hawtree Basin	JA-656	20
Hawtree Basin	JA-657	3
Hawtree Basin	JA-658	4
Shellbank Basin	JA-802	48
Head of Bay	JA-661	11

MS-4 Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Shellbank Basin	JA-607A	41
Hawtree Basin	JA-877	5
Jamaica Bay	RO-680	59
Jamaica Bay	RO-679	9
Jamaica Bay	RO-678	9
Jamaica Bay	RO-676	12
Jamaica Bay	RO-675	5
Jamaica Bay	RO-672	10
Jamaica Bay	RO-671	11
Jamaica Bay	RO-670	3
Jamaica Bay	RO-669	2
Jamaica Bay	RO-661	4
Jamaica Bay	RO-660	8
Jamaica Bay	RO-659	16
Jamaica Bay	RO-658	14
Jamaica Bay	RO-657	61
Jamaica Bay	RO-656	9
Jamaica Bay	RO-653	45
Jamaica Bay	RO-652	48
Jamaica Bay	RO-651	48
Jamaica Bay	RO-649	15
Jamaica Bay	RO-648	50
Jamaica Bay	RO-642	60
Jamaica Bay	RO-641	21
Jamaica Bay	RO-640	4
Jamaica Bay	RO-638	6
Jamaica Bay	RO-637	6
Jamaica Bay	RO-636	34
Jamaica Bay	RO-635	14
Jamaica Bay	RO-634	37
Jamaica Bay	RO-633	8
Jamaica Bay	RO-632	27
Jamaica Bay	RO-631	9
Jamaica Bay	RO-630	45
Jamaica Bay	RO-629	9
Jamaica Bay	RO-627	12

MS-4 Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Jamaica Bay	RO-625	40
Jamaica Bay	RO-624	8
Jamaica Bay	RO-622	10
Jamaica Bay	RO-620	7
Jamaica Bay	RO-619	9
Jamaica Bay	RO-618	8
Jamaica Bay	RO-617	24
Jamaica Bay	RO-614	23
Jamaica Bay	RO-610	32
Hendrix Creek	26--062	23
Hendrix Creek	26-601M	12
Spring Creek	26-603M	26
	Total MS-4	**6,415**

Stormwater Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Jamaica Bay	CI--64	56
Jamaica Bay	CI--65	19
Jamaica Bay	CI--66	96
Jamaica Bay	CI--67	17
Paerdegat Basin	CI--96	62
Paerdegat Basin	CI--98	41
Paerdegat Basin	CI--99	10
Jamaica Bay	CI-113	272
Thurston Basin	JA-005/007	578
Hawtree Basin	JA--064	0
Bergen Basin	JA--065	117
Head of Bay	JA--079	49
Hawtree Basin	JA--082	2
Thurston Basin	JA--083	182
Shellbank Basin	JA-530	6
Hawtree Basin	JA-DD09	27
Spring Creek	JA-S001	25
Jamaica Bay	RO--16_1	70
Jamaica Bay	RO--10	52
Jamaica Bay	RO-016	10
Jamaica Bay	RO-031	72
Jamaica Bay	RO-130	16
Jamaica Bay	RO--14	94
Jamaica Bay	RO--12	10
Jamaica Bay	RO--11	10
Jamaica Bay	RO--08	29
Jamaica Bay	RO--05	34
Jamaica Bay	RO--04	84
Jamaica Bay	RO--02	64
Jamaica Bay	RO--01	206
Jamaica Bay	RO--60	9
Jamaica Bay	RO--61	4
Jamaica Bay	RO--62	8
Jamaica Bay	RO--63	11
Fresh Creek	26-HS1	0
Fresh Creek	26-HS2	72

Stormwater Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Fresh Creek	26-HS3	98
Fresh Creek	26--061	108
Spring Creek	26--084	13
Hendrix Creek	26--092	18
Hendrix Creek	26--093	11
Hendrix Creek	26--094	13
	Total Stormwater	**2,675**

Direct Runoff Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Fresh Creek	CI--54	10
Fresh Creek	CI--55	11
Jamaica Bay	CI--56	21
Jamaica Bay	CI--57	19
Paerdegat Basin	CI--58	7
Paerdegat Basin	CI--59	8
Paerdegat Basin	CI--60	3
Jamaica Bay	CI--68	28
Jamaica Bay	CI--69	10
Jamaica Bay	CI--70	14
Jamaica Bay	CI--71	4
Jamaica Bay	CI--72	20
Jamaica Bay	CI--73	24
Jamaica Bay	CI--74	18
Jamaica Bay	CI--75	3
Jamaica Bay	CI--76	7
Jamaica Bay	CI--77	13
Jamaica Bay	CI--78	31
Jamaica Bay	CI--79	42
Jamaica Bay	CI--80	86
Jamaica Bay	CI--82	65
Jamaica Bay	CI--83	147
Jamaica Bay	CI--84	15
Jamaica Bay	CI--85	11
Jamaica Bay	CI--86	13
Jamaica Bay	CI--87	10
Jamaica Bay	CI--88	13
Jamaica Bay	CI--89	10
Jamaica Bay	CI--90	4
Jamaica Bay	CI--91	15
Jamaica Bay	CI--92	6
Jamaica Bay	CI--93	8
Jamaica Bay	CI--94	7
Paerdegat Basin	CI--95	20
Paerdegat Basin	CI--97	3
Spring Creek	JA--060	38

Direct Runoff Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge, (MG/Yr)**
Jamaica Bay	JA--061	0
Jamaica Bay	JA--062	2
Bergen Basin	JA--066	22
Head of Bay	JA--067	14
Thurston Basin	JA--077	61
Head of Bay	JA--078	106
Head of Bay	JA-888	5,900
Head of Bay	JA-999	178
Head of Bay	JA-BCK	45
Jamaica Bay	RO--17	20
Jamaica Bay	RO--16	300
Jamaica Bay	RO--15	288
Jamaica Bay	RO--13	513
Jamaica Bay	RO--09	119
Jamaica Bay	RO--07	12
Jamaica Bay	RO--06	10
Jamaica Bay	RO--03	22
Spring Creek	26--083	13
Spring Creek	26--085	3
Spring Creek	26--086	19
Spring Creek	26--087	4
Jamaica Bay	26--088	2
Jamaica Bay	26--089	8
Hendrix Creek	26--090	22
Hendrix Creek	26--091	6
Hendrix Creek	26--095	7
Jamaica Bay	26--096	7
Fresh Creek	26--097	4
Fresh Creek	26--098	5
Fresh Creek	26--099	3
	Total Direct Runoff	**8,419**

Airport/Transport Outfalls - Volumes		
Waterbody	**Outfall**	**Total Discharge (MG/Yr)**
Jamaica Bay	JA--074	23
Head of Bay	JA--075	114
Bergen Basin	JA-615	111
Bergen Basin	JA-617	62
Bergen Basin	JA-03aH	25
Jamaica Bay	JA-618	552
Jamaica Bay	JA-620	314
Bergen Basin	JA-639	104
Thurston Basin	JA-659	372
Jamaica Bay	JA-806	68
Head of Bay	JA-663	27
	Total Airport	**1,772**

WWTP Discharges - Volumes		
Waterbody	**Outfall**	**Total Discharge (MG/Yr)**
Jamaica Bay	JA-WWTP-1	27,326
Jamaica Bay	RO-WWTP-1	7,876
Hendrix Creek	26-WWTP-1	19,685
Bergen Basin	JA-WWTP-2	7,010
	Total WWTP	**61,897**

Totals by Waterbody - Volumes		
Waterbody	**Outfall**	**Total Discharge (MG/Yr)**
Bergen Basin	NA	10,620
Fresh Creek	NA	758
Hawtree Basin	NA	73
Head of Bay	NA	6,718
Hendrix Creek	NA	19,882
Jamaica Bay	NA	41,860
Paerdegat Basin	NA	941
Shellbank Basin	NA	287
Spring Creek	NA	433
Thurston Basin	NA	1,379

Totals by Source - Volumes		
Source	**Outfall**	**Total Discharge (MG/Yr)**
Airport	NA	1,772
CSO	NA	1,780
Direct Runoff	NA	8,418
MS4	NA	6,409
Storm	NA	2,675
WWTP	NA	61,897

Totals by Source by Waterbody - Volumes		
Waterbody	**Source**	**Total Discharge (MG/Yr)**
Paerdegat Basin	CSO	591
	MS4	196
	Storm	113
	Direct Drainage	41
	Airport/Transport	NA
	WWTP	NA
Fresh Creek	CSO	232
	MS4	215
	Storm	278
	Direct Drainage	33
	Airport/Transport	NA
	WWTP	NA
Jamaica Bay	CSO	0
	MS4	2,491
	Storm	1,243
	Direct Drainage	1,967
	Airport/Transport	957
	WWTP	35,202
Bergen Basin	CSO	333
	MS4	2,836
	Storm	117
	Direct Drainage	22
	Airport/Transport	302
	WWTP	7,010

Totals by Source by Waterbody - Volumes		
Waterbody	**Source**	**Total Discharge (MG/Yr)**
Thurston Basin	CSO	247
	MS4	NA
	Storm	760
	Direct Drainage	61
	Airport/Transport	372
	WWTP	NA
Spring Creek	CSO	292
	MS4	26
	Storm	38
	Direct Drainage	77
	Airport/Transport	NA
	WWTP	NA
Hawtree Basin	CSO	NA
	MS4	44
	Storm	29
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Head of Bay	CSO	NA
	MS4	285
	Storm	49
	Direct Drainage	6,243
	Airport/Transport	141
	WWTP	NA
Shellbank Basin	CSO	NA
	MS4	281
	Storm	6
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Hendrix Creek	CSO	85
	MS4	35
	Storm	42
	Direct Drainage	35
	Airport/Transport	NA
	WWTP	19,685

Combined Sewer Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Paerdegat Basin	CI-004	419
Paerdegat Basin	CI-005	869
Paerdegat Basin	CI-006	563
Paerdegat Basin	CI-CIT	34,582
Bergen Basin	JA-003/003A	17,253
Bergen Basin	JA-006	17
Thurston Basin	JA-005/007	2,674
Jamaica Bay	RO-030	0
Jamaica Bay	RO-029	0
Jamaica Bay	RO-015	0
Jamaica Bay	RO-014	0
Jamaica Bay	RO-012	0
Jamaica Bay	RO-011	0
Jamaica Bay	RO-010	0
Jamaica Bay	RO-009	0
Jamaica Bay	RO-008	0
Jamaica Bay	RO-007	0
Jamaica Bay	RO-006	0
Jamaica Bay	RO-005	0
Jamaica Bay	RO-004	0
Fresh Creek	26-003	3,318
Hendrix Creek	26-004	1,710
Spring Creek	26-005	4,966
	Total CSO	**66,371**

MS-4 Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI-603	108
Jamaica Bay	CI-604	16
Jamaica Bay	CI-605	1,349
Jamaica Bay	CI-607	15
Jamaica Bay	CI-608	11
Jamaica Bay	CI-609	10
Jamaica Bay	CI-610	1,828
Jamaica Bay	CI-611	35
Jamaica Bay	CI-612	44
Jamaica Bay	CI-613	1,135
Jamaica Bay	CI-614	10
Jamaica Bay	CI-615	244
Jamaica Bay	CI-616	42
Jamaica Bay	CI-617	54
Jamaica Bay	CI-618	73
Jamaica Bay	CI-619	53
Jamaica Bay	CI-620	72
Jamaica Bay	CI-621	33
Jamaica Bay	CI-622	114
Jamaica Bay	CI-623	66
Jamaica Bay	CI-624	174
Jamaica Bay	CI-625	121
Jamaica Bay	CI-626	123
Jamaica Bay	CI-627	149
Paerdegat Basin	CI-628	138
Paerdegat Basin	CI-629	184
Paerdegat Basin	CI-630	218
Paerdegat Basin	CI-632	352
Jamaica Bay	CI-633	548
Fresh Creek	CI-634	517
Fresh Creek	CI-636	232
Fresh Creek	CI-637	229
Jamaica Bay	CI-642	52
Jamaica Bay	CI-656	22
Jamaica Bay	CI-657	376
Jamaica Bay	CI-667	41

MS-4 Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI-668	21
Jamaica Bay	CI-669	43
Jamaica Bay	CI-670	32
Jamaica Bay	CI-671	51
Jamaica Bay	CI-672	90
Jamaica Bay	CI-673	24
Jamaica Bay	CI-674	11
Jamaica Bay	CI-676	68
Bergen Basin	JA-006	4,775
Bergen Basin	JA-140	42
Shellbank Basin	JA-114	19
Shellbank Basin	JA-115	31
Shellbank Basin	JA-116	19
Shellbank Basin	JA-117	29
Shellbank Basin	JA--081	24
Hawtree Basin	JA-523	19
Shellbank Basin	JA-601	47
Shellbank Basin	JA-603	245
Shellbank Basin	JA-604	28
Shellbank Basin	JA-605	43
Shellbank Basin	JA-607	187
Shellbank Basin	JA-609	156
Shellbank Basin	JA-630	55
Hawtree Basin	JA-636	23
Hawtree Basin	JA-638	0
Head of Bay	JA-649	1,165
Head of Bay	JA-652	3
Head of Bay	JA-653	51
Head of Bay	JA-654	6
Head of Bay	JA-655	28
Hawtree Basin	JA-656	93
Hawtree Basin	JA-657	13
Hawtree Basin	JA-658	21
Shellbank Basin	JA-802	220
Head of Bay	JA-661	50
Shellbank Basin	JA-607A	187

MS-4 Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Hawtree Basin	JA-877	25
Jamaica Bay	RO-680	78
Jamaica Bay	RO-679	13
Jamaica Bay	RO-678	13
Jamaica Bay	RO-676	17
Jamaica Bay	RO-675	7
Jamaica Bay	RO-672	13
Jamaica Bay	RO-671	15
Jamaica Bay	RO-670	4
Jamaica Bay	RO-669	3
Jamaica Bay	RO-661	6
Jamaica Bay	RO-660	10
Jamaica Bay	RO-659	21
Jamaica Bay	RO-658	18
Jamaica Bay	RO-657	80
Jamaica Bay	RO-656	12
Jamaica Bay	RO-653	59
Jamaica Bay	RO-652	64
Jamaica Bay	RO-651	63
Jamaica Bay	RO-649	20
Jamaica Bay	RO-648	66
Jamaica Bay	RO-642	79
Jamaica Bay	RO-641	28
Jamaica Bay	RO-640	6
Jamaica Bay	RO-638	9
Jamaica Bay	RO-637	8
Jamaica Bay	RO-636	46
Jamaica Bay	RO-635	18
Jamaica Bay	RO-634	49
Jamaica Bay	RO-633	11
Jamaica Bay	RO-632	36
Jamaica Bay	RO-631	12
Jamaica Bay	RO-630	59
Jamaica Bay	RO-629	12
Jamaica Bay	RO-627	17
Jamaica Bay	RO-625	53

MS-4 Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	RO-624	11
Jamaica Bay	RO-622	13
Jamaica Bay	RO-620	10
Jamaica Bay	RO-619	13
Jamaica Bay	RO-618	11
Jamaica Bay	RO-617	31
Jamaica Bay	RO-614	31
Jamaica Bay	RO-610	42
Hendrix Creek	26--062	107
Hendrix Creek	26-601M	57
Spring Creek	26-603M	120
	Total MS-4	**18,208**

Stormwater Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI--64	253
Jamaica Bay	CI--65	85
Jamaica Bay	CI--66	433
Jamaica Bay	CI--67	77
Paerdegat Basin	CI--96	283
Paerdegat Basin	CI--98	186
Paerdegat Basin	CI--99	46
Jamaica Bay	CI-113	1,231
Thurston Basin	JA-07S	2,758
Hawtree Basin	JA--064	4
Bergen Basin	JA--065	199
Head of Bay	JA--079	225
Hawtree Basin	JA--082	12
Thurston Basin	JA--083	829
Shellbank Basin	JA-530	4
Thurston Basin	JA-640	27
Hawtree Basin	JA-DD09	124
Spring Creek	JA-S001	113
Jamaica Bay	RO--16_1	93
Jamaica Bay	RO--10	69
Jamaica Bay	RO-016	69

Stormwater Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	RO-031	96
Jamaica Bay	RO-130	21
Jamaica Bay	RO--12	8
Jamaica Bay	RO--11	8
Jamaica Bay	RO--08	38
Jamaica Bay	RO--05	45
Jamaica Bay	RO--04	111
Jamaica Bay	RO--02	86
Jamaica Bay	RO--01	273
Jamaica Bay	RO--60	13
Jamaica Bay	RO--61	5
Jamaica Bay	RO--62	11
Jamaica Bay	RO--63	15
Fresh Creek	26-HS1	0
Fresh Creek	26-HS2	327
Fresh Creek	26-HS3	447
Fresh Creek	26--061	493
Spring Creek	26--084	2
Hendrix Creek	26--092	81
Hendrix Creek	26--093	48
Hendrix Creek	26--094	62
	Total Stormwater	**9,304**

Direct Runoff Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Fresh Creek	CI--54	2
Fresh Creek	CI--55	2
Jamaica Bay	CI--56	3
Jamaica Bay	CI--57	3
Paerdegat Basin	CI--58	1
Paerdegat Basin	CI--59	1
Paerdegat Basin	CI--60	1
Jamaica Bay	CI--68	4
Jamaica Bay	CI--69	1
Jamaica Bay	CI--70	2
Jamaica Bay	CI--71	1
Jamaica Bay	CI--72	3
Jamaica Bay	CI--73	4
Jamaica Bay	CI--74	3
Jamaica Bay	CI--75	1
Jamaica Bay	CI--76	1
Jamaica Bay	CI--77	2
Jamaica Bay	CI--78	5
Jamaica Bay	CI--79	6
Jamaica Bay	CI--80	13
Jamaica Bay	CI--82	10
Jamaica Bay	CI--83	22
Jamaica Bay	CI--84	12
Jamaica Bay	CI--85	8
Jamaica Bay	CI--86	10
Jamaica Bay	CI--87	8
Jamaica Bay	CI--88	2
Jamaica Bay	CI--89	2
Jamaica Bay	CI--90	1
Jamaica Bay	CI--91	2
Jamaica Bay	CI--92	1
Jamaica Bay	CI--93	1
Jamaica Bay	CI--94	1
Paerdegat Basin	CI--95	3
Paerdegat Basin	CI--97	1
Spring Creek	JA--060	6

Direct Runoff Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	JA--061	0
Jamaica Bay	JA--062	0
Bergen Basin	JA--066	3
Head of Bay	JA--067	10
Thurston Basin	JA--077	9
Head of Bay	JA--078	16
Head of Bay	JA-888	893
Head of Bay	JA-999	27
Head of Bay	JA-BCK	7
Jamaica Bay	RO--17	3
Jamaica Bay	RO--16	45
Jamaica Bay	RO--15	44
Jamaica Bay	RO--13	78
Jamaica Bay	RO--09	18
Jamaica Bay	RO--07	2
Jamaica Bay	RO--06	1
Jamaica Bay	RO--03	3
Spring Creek	26--083	2
Spring Creek	26--085	0
Spring Creek	26--086	3
Spring Creek	26--087	1
Jamaica Bay	26--088	0
Jamaica Bay	26--089	1
Hendrix Creek	26--090	3
Hendrix Creek	26--091	1
Hendrix Creek	26--095	1
Jamaica Bay	26--096	1
Fresh Creek	26--097	1
Fresh Creek	26--098	1
Fresh Creek	26--099	1
	Total Direct Runoff	**1,324**

Airport Outfalls – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Bergen Basin	JA-03aH	19
Jamaica Bay	JA--074	17
Head of Bay	JA--075	86
Bergen Basin	JA-615	84
Bergen Basin	JA-617	47
Jamaica Bay	JA-618	418
Jamaica Bay	JA-620	238
Bergen Basin	JA-639	79
Thurston Basin	JA-659	282
Head of Bay	JA-663	21
Jamaica Bay	JA-806	52
	Total Airport	**1,342**

WWTP Discharges – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	JA-WWTP-1	39
Jamaica Bay	RO-WWTP-1	13
Hendrix Creek	26-WWTP-1	31
Bergen Basin	JA-WWTP-2	10
	Total WWTP	**92**

Totals by Waterbody – Fecal Coliform		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Bergen Basin	NA	22,530
Fresh Creek	NA	5,568
Hawtree Basin	NA	334
Head of Bay	NA	2,590
Hendrix Creek	NA	2,101
Jamaica Bay	NA	12,594
Paerdegat Basin	NA	37,846
Shellbank Basin	NA	1,293
Spring Creek	NA	5,213
Thurston Basin	NA	6,569

Totals by Source – Fecal Coliform		
Source	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Airport	NA	1,342
CSO	NA	66,371
Direct Runoff	NA	1,324
MS4	NA	18,208
Other	NA	0
Storm	NA	9,309
WWTP	NA	92

Totals by Source by Waterbody – Fecal Coliform		
Waterbody	**Source**	**Total Load (10^{12} cfu/Yr)**
Paerdegat Basin	CSO	36,432
	MS4	892
	Storm	515
	Direct Drainage	7
	Airport/Transport	NA
	WWTP	NA
Fresh Creek	CSO	3,318
	MS4	978
	Storm	1,267
	Direct Drainage	5
	Airport/Transport	NA
	WWTP	NA
Jamaica Bay	CSO	0
	MS4	8,449
	Storm	3,040
	Direct Drainage	329
	Airport/Transport	724
	WWTP	52
Bergen Basin	CSO	17,271
	MS4	4,817
	Storm	199
	Direct Drainage	3
	Airport/Transport	229
	WWTP	10

Totals by Source by Waterbody – Fecal Coliform		
Waterbody	**Source**	**Total Load (10^{12} cfu/Yr)**
Thurston Basin	CSO	2,674
	MS4	NA
	Storm	3,586
	Direct Drainage	9
	Airport/Transport	282
	WWTP	NA
Spring Creek	CSO	4,966
	MS4	120
	Storm	115
	Direct Drainage	12
	Airport/Transport	NA
	WWTP	NA
Hawtree Basin	CSO	NA
	MS4	195
	Storm	139
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Head of Bay	CSO	NA
	MS4	1,304
	Storm	225
	Direct Drainage	963
	Airport/Transport	107
	WWTP	NA
Shellbank Basin	CSO	NA
	MS4	1,289
	Storm	4
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Hendrix Creek	CSO	1,710
	MS4	164
	Storm	191
	Direct Drainage	5
	Airport/Transport	NA
	WWTP	31

Combined Sewer Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Paerdegat Basin	CI-004	186
Paerdegat Basin	CI-005	387
Paerdegat Basin	CI-006	251
Paerdegat Basin	CI-CIT	15,288
Bergen Basin	JA-003/003A	13,219
Bergen Basin	JA-006	9
Thurston Basin	JA-005/007	823
Jamaica Bay	RO-030	0
Jamaica Bay	RO-029	0
Jamaica Bay	RO-015	0
Jamaica Bay	RO-014	0
Jamaica Bay	RO-012	0
Jamaica Bay	RO-011	0
Jamaica Bay	RO-010	0
Jamaica Bay	RO-009	0
Jamaica Bay	RO-008	0
Jamaica Bay	RO-007	0
Jamaica Bay	RO-006	0
Jamaica Bay	RO-005	0
Jamaica Bay	RO-004	0
Fresh Creek	26-003	4,037
Hendrix Creek	26-004	485
Spring Creek	26-005	1,444
	Total CSO	**36,129**

MS-4 Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI-603	45
Jamaica Bay	CI-604	7
Jamaica Bay	CI-605	562
Jamaica Bay	CI-607	6
Jamaica Bay	CI-608	4
Jamaica Bay	CI-609	4
Jamaica Bay	CI-610	762
Jamaica Bay	CI-611	15
Jamaica Bay	CI-612	18
Jamaica Bay	CI-613	473
Jamaica Bay	CI-614	4
Jamaica Bay	CI-615	102
Jamaica Bay	CI-616	17
Jamaica Bay	CI-617	23
Jamaica Bay	CI-618	30
Jamaica Bay	CI-619	22
Jamaica Bay	CI-620	30
Jamaica Bay	CI-621	14
Jamaica Bay	CI-622	47
Jamaica Bay	CI-623	27
Jamaica Bay	CI-624	73
Jamaica Bay	CI-625	50
Jamaica Bay	CI-626	51
Jamaica Bay	CI-627	62
Paerdegat Basin	CI-628	57
Paerdegat Basin	CI-629	76
Paerdegat Basin	CI-630	91
Paerdegat Basin	CI-632	147
Jamaica Bay	CI-633	228
Fresh Creek	CI-634	216
Fresh Creek	CI-636	97
Fresh Creek	CI-637	95
Jamaica Bay	CI-642	22
Jamaica Bay	CI-656	9
Jamaica Bay	CI-657	157
Jamaica Bay	CI-667	17

MS-4 Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI-668	9
Jamaica Bay	CI-669	18
Jamaica Bay	CI-670	13
Jamaica Bay	CI-671	21
Jamaica Bay	CI-672	38
Jamaica Bay	CI-673	10
Jamaica Bay	CI-674	5
Jamaica Bay	CI-676	28
Bergen Basin	JA-006	5,848
Bergen Basin	JA-140	51
Shellbank Basin	JA-114	8
Shellbank Basin	JA-115	13
Shellbank Basin	JA-116	8
Shellbank Basin	JA-117	12
Shellbank Basin	JA--081	10
Hawtree Basin	JA-523	8
Shellbank Basin	JA-601	20
Shellbank Basin	JA-603	102
Shellbank Basin	JA-604	12
Shellbank Basin	JA-605	18
Shellbank Basin	JA-607	78
Shellbank Basin	JA-609	65
Shellbank Basin	JA-630	23
Hawtree Basin	JA-636	10
Hawtree Basin	JA-638	0
Head of Bay	JA-649	485
Head of Bay	JA-652	1
Head of Bay	JA-653	21
Head of Bay	JA-654	3
Head of Bay	JA-655	12
Hawtree Basin	JA-656	39
Hawtree Basin	JA-657	6
Hawtree Basin	JA-658	9
Shellbank Basin	JA-802	92
Head of Bay	JA-661	21
Shellbank Basin	JA-607A	78

MS-4 Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Hawtree Basin	JA-877	10
Jamaica Bay	RO-680	34
Jamaica Bay	RO-679	5
Jamaica Bay	RO-678	6
Jamaica Bay	RO-676	7
Jamaica Bay	RO-675	3
Jamaica Bay	RO-672	6
Jamaica Bay	RO-671	7
Jamaica Bay	RO-670	2
Jamaica Bay	RO-669	1
Jamaica Bay	RO-661	3
Jamaica Bay	RO-660	4
Jamaica Bay	RO-659	9
Jamaica Bay	RO-658	8
Jamaica Bay	RO-657	34
Jamaica Bay	RO-656	5
Jamaica Bay	RO-653	25
Jamaica Bay	RO-652	28
Jamaica Bay	RO-651	27
Jamaica Bay	RO-649	9
Jamaica Bay	RO-648	28
Jamaica Bay	RO-642	34
Jamaica Bay	RO-641	12
Jamaica Bay	RO-640	3
Jamaica Bay	RO-638	4
Jamaica Bay	RO-637	4
Jamaica Bay	RO-636	20
Jamaica Bay	RO-635	8
Jamaica Bay	RO-634	21
Jamaica Bay	RO-633	5
Jamaica Bay	RO-632	15
Jamaica Bay	RO-631	5
Jamaica Bay	RO-630	25
Jamaica Bay	RO-629	5
Jamaica Bay	RO-627	7
Jamaica Bay	RO-625	23

MS-4 Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	RO-624	5
Jamaica Bay	RO-622	6
Jamaica Bay	RO-620	4
Jamaica Bay	RO-619	6
Jamaica Bay	RO-618	5
Jamaica Bay	RO-617	13
Jamaica Bay	RO-614	13
Jamaica Bay	RO-610	18
Hendrix Creek	26--062	45
Hendrix Creek	26-601M	24
Spring Creek	26-603M	50
	Total MS-4	**11,494**

Stormwater Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	CI--64	105
Jamaica Bay	CI--65	36
Jamaica Bay	CI--66	180
Jamaica Bay	CI--67	32
Paerdegat Basin	CI--96	118
Paerdegat Basin	CI--98	78
Paerdegat Basin	CI--99	19
Jamaica Bay	CI-113	513
Thurston Basin	JA-07S	1,152
Hawtree Basin	JA--064	2
Bergen Basin	JA--065	243
Head of Bay	JA--079	94
Hawtree Basin	JA--082	5
Thurston Basin	JA--083	345
Shellbank Basin	JA-530	2
Thurston Basin	JA-640	11
Hawtree Basin	JA-DD09	52
Spring Creek	JA-S001	47
Jamaica Bay	RO--16_1	40
Jamaica Bay	RO--12	3
Jamaica Bay	RO--11	3

AECOM with Hazen

Stormwater Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	RO--10	30
Jamaica Bay	RO-016	29
Jamaica Bay	RO-031	41
Jamaica Bay	RO-130	9
Jamaica Bay	RO--08	16
Jamaica Bay	RO--05	19
Jamaica Bay	RO--04	48
Jamaica Bay	RO--02	37
Jamaica Bay	RO--01	117
Jamaica Bay	RO--60	5
Jamaica Bay	RO--61	2
Jamaica Bay	RO--62	5
Jamaica Bay	RO--63	7
Fresh Creek	26-HS1	0
Fresh Creek	26-HS2	136
Fresh Creek	26-HS3	186
Fresh Creek	26--061	206
Spring Creek	26--084	3
Hendrix Creek	26--092	34
Hendrix Creek	26--093	20
Hendrix Creek	26--094	26
	Total Stormwater	**4,056**

Direct Runoff Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Fresh Creek	CI--54	2
Fresh Creek	CI--55	2
Jamaica Bay	CI--56	5
Jamaica Bay	CI--57	4
Paerdegat Basin	CI--58	2
Paerdegat Basin	CI--59	2
Paerdegat Basin	CI--60	1
Jamaica Bay	CI--68	6
Jamaica Bay	CI--69	2
Jamaica Bay	CI--70	3
Jamaica Bay	CI--71	1
Jamaica Bay	CI--72	4
Jamaica Bay	CI--73	5
Jamaica Bay	CI--74	4
Jamaica Bay	CI--75	1
Jamaica Bay	CI--76	2
Jamaica Bay	CI--77	3
Jamaica Bay	CI--78	7
Jamaica Bay	CI--79	9
Jamaica Bay	CI--80	19
Jamaica Bay	CI--82	15
Jamaica Bay	CI--83	33
Jamaica Bay	CI--84	5
Jamaica Bay	CI--85	3
Jamaica Bay	CI--86	4
Jamaica Bay	CI--87	3
Jamaica Bay	CI--88	3
Jamaica Bay	CI--89	2
Jamaica Bay	CI--90	1
Jamaica Bay	CI--91	4
Jamaica Bay	CI--92	1
Jamaica Bay	CI--93	2
Jamaica Bay	CI--94	2
Paerdegat Basin	CI--95	5
Paerdegat Basin	CI--97	1
Spring Creek	JA--060	9

Direct Runoff Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	JA--061	0
Jamaica Bay	JA--062	0
Bergen Basin	JA--066	5
Head of Bay	JA--067	4
Thurston Basin	JA--077	14
Head of Bay	JA--078	24
Head of Bay	JA-888	1,340
Head of Bay	JA-999	40
Head of Bay	JA-BCK	10
Jamaica Bay	RO--17	5
Jamaica Bay	RO--16	68
Jamaica Bay	RO--15	65
Jamaica Bay	RO--13	117
Jamaica Bay	RO--09	27
Jamaica Bay	RO--07	3
Jamaica Bay	RO--06	2
Jamaica Bay	RO--03	5
Spring Creek	26--083	3
Spring Creek	26--085	1
Spring Creek	26--086	4
Spring Creek	26--087	1
Jamaica Bay	26--088	1
Jamaica Bay	26--089	2
Hendrix Creek	26--090	5
Hendrix Creek	26--091	1
Hendrix Creek	26--095	2
Jamaica Bay	26--096	2
Fresh Creek	26--097	1
Fresh Creek	26--098	1
Fresh Creek	26--099	1
	Total Direct Runoff	**1,933**

Airport Outfalls - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Bergen Basin	JA-03aH	8
Jamaica Bay	JA--074	7
Head of Bay	JA--075	34
Bergen Basin	JA-615	34
Bergen Basin	JA-617	19
Jamaica Bay	JA-618	167
Jamaica Bay	JA-620	95
Bergen Basin	JA-639	32
Thurston Basin	JA-659	113
Head of Bay	JA-663	8
Jamaica Bay	JA-806	21
	Total Airport	**537**

WWTP Discharges - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Jamaica Bay	JA-WWTP-1	20
Jamaica Bay	RO-WWTP-1	6
Hendrix Creek	26-WWTP-1	15
Bergen Basin	JA-WWTP-2	5
	Total WWTP	**46**

Totals by Waterbody - *Enterococci*		
Waterbody	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Bergen Basin	NA	19,473
Fresh Creek	NA	4,980
Hawtree Basin	NA	139
Head of Bay	NA	2,099
Hendrix Creek	NA	656
Jamaica Bay	NA	5,580
Paerdegat Basin	NA	16,709
Shellbank Basin	NA	539
Spring Creek	NA	1,562
Thurston Basin	NA	2,444

Totals by Source - *Enterococci*		
Source	**Outfall**	**Total Load (10^{12} cfu/Yr)**
Airport	NA	537
CSO	NA	36,129
Direct Runoff	NA	1,933
MS4	NA	11,494
Other	NA	0
Storm	NA	4,056
WWTP	NA	46

Totals by Source by Waterbody - *Enterococci*		
Waterbody	**Source**	**Total Load (10^{12} cfu/Yr)**
Paerdegat Basin	CSO	16,113
	MS4	372
	Storm	215
	Direct Drainage	10
	Airport/Transport	NA
	WWTP	NA
Fresh Creek	CSO	4,037
	MS4	408
	Storm	528
	Direct Drainage	8
	Airport/Transport	NA
	WWTP	NA
Jamaica Bay	CSO	0
	MS4	3,535
	Storm	1,278
	Direct Drainage	452
	Airport/Transport	290
	WWTP	26
Bergen Basin	CSO	13,228
	MS4	5,900
	Storm	243
	Direct Drainage	5
	Airport/Transport	92
	WWTP	5

Totals by Source by Waterbody - *Enterococci*		
Waterbody	**Source**	**Total Load (10^{12} cfu/Yr)**
Thurston Basin	CSO	823
	MS4	NA
	Storm	1,508
	Direct Drainage	14
	Airport/Transport	113
	WWTP	NA
Spring Creek	CSO	1,444
	MS4	50
	Storm	50
	Direct Drainage	18
	Airport/Transport	NA
	WWTP	NA
Hawtree Basin	CSO	NA
	MS4	81
	Storm	58
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Head of Bay	CSO	NA
	MS4	543
	Storm	94
	Direct Drainage	1,433
	Airport/Transport	43
	WWTP	NA
Shellbank Basin	CSO	NA
	MS4	537
	Storm	2
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Hendrix Creek	CSO	485
	MS4	68
	Storm	80
	Direct Drainage	8
	Airport/Transport	NA
	WWTP	15

Combined Sewer Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Paerdegat Basin	CI-004	1,697
Paerdegat Basin	CI-005	3,500
Paerdegat Basin	CI-006	2,336
Paerdegat Basin	CI-CIT	140,852
Bergen Basin	JA-003/003A	82,144
Bergen Basin	JA-006	425
Thurston Basin	JA-007	38,935
Jamaica Bay	RO-030	0
Jamaica Bay	RO-029	0
Jamaica Bay	RO-015	0
Jamaica Bay	RO-014	0
Jamaica Bay	RO-012	0
Jamaica Bay	RO-011	0
Jamaica Bay	RO-010	0
Jamaica Bay	RO-009	0
Jamaica Bay	RO-008	0
Jamaica Bay	RO-007	0
Jamaica Bay	RO-006	0
Jamaica Bay	RO-005	0
Jamaica Bay	RO-004	0
Fresh Creek	26-003	50,605
Hendrix Creek	26-004	20,013
Spring Creek	26-005	62,345
	Total CSO	**402,851**

MS-4 Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	CI-603	2,957
Jamaica Bay	CI-604	438
Jamaica Bay	CI-605	37,109
Jamaica Bay	CI-607	420
Jamaica Bay	CI-608	295
Jamaica Bay	CI-609	273
Jamaica Bay	CI-610	50,269
Jamaica Bay	CI-611	963
Jamaica Bay	CI-612	1,214
Jamaica Bay	CI-613	31,220
Jamaica Bay	CI-614	276
Jamaica Bay	CI-615	6,709
Jamaica Bay	CI-616	1,147
Jamaica Bay	CI-617	1,491
Jamaica Bay	CI-618	1,995
Jamaica Bay	CI-619	1,463
Jamaica Bay	CI-620	1,976
Jamaica Bay	CI-621	912
Jamaica Bay	CI-622	3,124
Jamaica Bay	CI-623	1,812
Jamaica Bay	CI-624	4,789
Jamaica Bay	CI-625	3,324
Jamaica Bay	CI-626	3,374
Jamaica Bay	CI-627	4,091
Paerdegat Basin	CI-628	3,795
Paerdegat Basin	CI-629	5,048
Paerdegat Basin	CI-630	6,001
Paerdegat Basin	CI-632	9,689
Jamaica Bay	CI-633	15,081
Fresh Creek	CI-634	14,224
Fresh Creek	CI-636	6,382
Fresh Creek	CI-637	6,291
Jamaica Bay	CI-642	1,433
Jamaica Bay	CI-656	605
Jamaica Bay	CI-657	10,345
Jamaica Bay	CI-667	1,118

MS-4 Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	CI-668	589
Jamaica Bay	CI-669	1,178
Jamaica Bay	CI-670	874
Jamaica Bay	CI-671	1,408
Jamaica Bay	CI-672	2,484
Jamaica Bay	CI-673	646
Jamaica Bay	CI-674	314
Jamaica Bay	CI-676	1,868
Bergen Basin	JA-006	351,128
Bergen Basin	JA-140	3,083
Shellbank Basin	JA-114	516
Shellbank Basin	JA-115	854
Shellbank Basin	JA-116	521
Shellbank Basin	JA-117	797
Shellbank Basin	JA--081	672
Hawtree Basin	JA-523	529
Shellbank Basin	JA-601	1,298
Shellbank Basin	JA-603	6,729
Shellbank Basin	JA-604	769
Shellbank Basin	JA-605	1,187
Shellbank Basin	JA-607	5,137
Shellbank Basin	JA-609	4,284
Shellbank Basin	JA-630	1,505
Hawtree Basin	JA-636	644
Hawtree Basin	JA-638	0
Head of Bay	JA-649	32,043
Head of Bay	JA-652	81
Head of Bay	JA-653	1,394
Head of Bay	JA-654	167
Head of Bay	JA-655	783
Hawtree Basin	JA-656	2,556
Hawtree Basin	JA-657	370
Hawtree Basin	JA-658	572
Shellbank Basin	JA-802	6,055
Head of Bay	JA-661	1,386
Shellbank Basin	JA-607A	5,134

MS-4 Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Hawtree Basin	JA-877	688
Jamaica Bay	RO-680	7,384
Jamaica Bay	RO-679	1,182
Jamaica Bay	RO-678	1,212
Jamaica Bay	RO-676	1,574
Jamaica Bay	RO-675	655
Jamaica Bay	RO-672	1,272
Jamaica Bay	RO-671	1,457
Jamaica Bay	RO-670	399
Jamaica Bay	RO-669	246
Jamaica Bay	RO-661	588
Jamaica Bay	RO-660	970
Jamaica Bay	RO-659	2,022
Jamaica Bay	RO-658	1,737
Jamaica Bay	RO-657	7,585
Jamaica Bay	RO-656	1,146
Jamaica Bay	RO-653	5,581
Jamaica Bay	RO-652	6,066
Jamaica Bay	RO-651	5,958
Jamaica Bay	RO-649	1,875
Jamaica Bay	RO-648	6,257
Jamaica Bay	RO-642	7,487
Jamaica Bay	RO-641	2,602
Jamaica Bay	RO-640	569
Jamaica Bay	RO-638	808
Jamaica Bay	RO-637	779
Jamaica Bay	RO-636	4,309
Jamaica Bay	RO-635	1,740
Jamaica Bay	RO-634	4,625
Jamaica Bay	RO-633	1,062
Jamaica Bay	RO-632	3,348
Jamaica Bay	RO-631	1,146
Jamaica Bay	RO-630	5,605
Jamaica Bay	RO-629	1,104
Jamaica Bay	RO-627	1,581
Jamaica Bay	RO-625	5,032

MS-4 Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	RO-624	1,070
Jamaica Bay	RO-622	1,269
Jamaica Bay	RO-620	956
Jamaica Bay	RO-619	1,213
Jamaica Bay	RO-618	1,059
Jamaica Bay	RO-617	2,959
Jamaica Bay	RO-614	2,900
Jamaica Bay	RO-610	4,001
Hendrix Creek	26--062	2,946
Hendrix Creek	26-601M	1,568
Spring Creek	26-603M	3,298
	Total MS-4	**802,101**

Stormwater Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	CI--64	6,950
Jamaica Bay	CI--65	2,345
Jamaica Bay	CI--66	11,900
Jamaica Bay	CI--67	2,125
Paerdegat Basin	CI--96	7,785
Paerdegat Basin	CI--98	5,129
Paerdegat Basin	CI--99	1,255
Jamaica Bay	CI-113	33,862
Thurston Basin	JA-07S	76,205
Hawtree Basin	JA--064	100
Bergen Basin	JA--065	14,602
Head of Bay	JA--079	6,197
Hawtree Basin	JA--082	320
Thurston Basin	JA--083	22,795
Shellbank Basin	JA-530	785
Thurston Basin	JA-640	735
Hawtree Basin	JA-DD09	3,412
Spring Creek	JA-S001	3,112
Jamaica Bay	RO--16_1	8,729
Jamaica Bay	RO--10	6,515
Jamaica Bay	RO-016	6,465
Jamaica Bay	RO-031	9,027
Jamaica Bay	RO-130	1,982
Jamaica Bay	RO--12	1,259
Jamaica Bay	RO--11	1,292
Jamaica Bay	RO--08	3,582
Jamaica Bay	RO--05	4,266
Jamaica Bay	RO--04	10,479
Jamaica Bay	RO--02	8,064
Jamaica Bay	RO--01	25,788
Jamaica Bay	RO--60	1,209
Jamaica Bay	RO--61	516
Jamaica Bay	RO--62	1,054
Jamaica Bay	RO--63	1,455
Fresh Creek	26-HS1	0
Fresh Creek	26-HS2	8,996

Stormwater Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Fresh Creek	26-HS3	12,287
Fresh Creek	26--061	13,571
Spring Creek	26--084	1,652
Hendrix Creek	26--092	2,237
Hendrix Creek	26--093	1,326
Hendrix Creek	26--094	1,693
	Total Stormwater	**333,057**

Direct Runoff Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Fresh Creek	CI--54	1,260
Fresh Creek	CI--55	1,359
Jamaica Bay	CI--56	2,642
Jamaica Bay	CI--57	2,446
Paerdegat Basin	CI--58	934
Paerdegat Basin	CI--59	1,075
Paerdegat Basin	CI--60	433
Jamaica Bay	CI--68	3,520
Jamaica Bay	CI--69	1,221
Jamaica Bay	CI--70	1,749
Jamaica Bay	CI--71	524
Jamaica Bay	CI--72	2,468
Jamaica Bay	CI--73	2,980
Jamaica Bay	CI--74	2,297
Jamaica Bay	CI--75	471
Jamaica Bay	CI--76	915
Jamaica Bay	CI--77	1,597
Jamaica Bay	CI--78	3,929
Jamaica Bay	CI--79	5,209
Jamaica Bay	CI--80	10,677
Jamaica Bay	CI--82	8,106
Jamaica Bay	CI--83	18,339
Jamaica Bay	CI--84	1,944
Jamaica Bay	CI--85	1,344
Jamaica Bay	CI--86	1,697
Jamaica Bay	CI--87	1,263

Direct Runoff Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	CI--88	1,669
Jamaica Bay	CI--89	1,240
Jamaica Bay	CI--90	587
Jamaica Bay	CI--91	1,928
Jamaica Bay	CI--92	767
Jamaica Bay	CI--93	1,001
Jamaica Bay	CI--94	850
Paerdegat Basin	CI--95	2,529
Paerdegat Basin	CI--97	414
Spring Creek	JA--060	4,707
Jamaica Bay	JA--061	0
Jamaica Bay	JA--062	229
Bergen Basin	JA--066	2,803
Head of Bay	JA--067	1,727
Thurston Basin	JA--077	7,621
Head of Bay	JA--078	13,235
Head of Bay	JA-888	737,047
Head of Bay	JA-999	22,235
Head of Bay	JA-BCK	5,706
Jamaica Bay	RO--17	2,579
Jamaica Bay	RO--16	37,528
Jamaica Bay	RO--15	35,930
Jamaica Bay	RO--13	64,134
Jamaica Bay	RO--09	14,927
Jamaica Bay	RO--07	1,487
Jamaica Bay	RO--06	1,230
Jamaica Bay	RO--03	2,755
Spring Creek	26--083	1,699
Spring Creek	26--085	392
Spring Creek	26--086	2,434
Spring Creek	26--087	562
Jamaica Bay	26--088	316
Jamaica Bay	26--089	1,095
Hendrix Creek	26--090	2,771
Hendrix Creek	26--091	772
Hendrix Creek	26--095	848

Direct Runoff Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	26--096	915
Fresh Creek	26--097	535
Fresh Creek	26--098	644
Fresh Creek	26--099	428
	Total Direct Runoff	**1,060,676**

Airport Outfalls - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Bergen Basin	JA-03aH	3,142
Jamaica Bay	JA--074	2,866
Head of Bay	JA--075	14,219
Bergen Basin	JA-615	13,840
Bergen Basin	JA-617	7,802
Jamaica Bay	JA-618	68,924
Jamaica Bay	JA-620	39,257
Bergen Basin	JA-639	13,055
Thurston Basin	JA-659	46,462
Head of Bay	JA-663	3,425
Jamaica Bay	JA-806	8,501
	Total Airport	**221,493**

WWTP Discharges - BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Jamaica Bay	JA-WWTP-1	1,648,104
Jamaica Bay	RO-WWTP-1	332,734
Hendrix Creek	26-WWTP-1	952,344
Bergen Basin	JA-WWTP-2	423,351
	Total WWTP	**3,356,533**

Totals by Waterbody – BOD		
Waterbody	**Outfall**	**Total Load (Lbs/Yr)**
Bergen Basin	NA	915,375
Fresh Creek	NA	116,583
Hawtree Basin	NA	9,191
Head of Bay	NA	839,646
Hendrix Creek	NA	986,518
Jamaica Bay	NA	2,807,731
Paerdegat Basin	NA	192,470
Shellbank Basin	NA	36,244
Spring Creek	NA	80,201
Thurston Basin	NA	185,131

Totals by Source – BOD		
Source	**Outfall**	**Total Load (Lbs/Yr)**
Airport	NA	221,493
CSO	NA	402,851
Direct Runoff	NA	1,060,676
MS4	NA	802,101
Other	NA	0
Storm	NA	333,057
WWTP	NA	3,356,533

Totals by Source by Waterbody – BOD		
Waterbody	**Source**	**Total Load (Lbs/Yr)**
Paerdegat Basin	CSO	148,384
	MS4	24,534
	Storm	14,168
	Direct Drainage	5,384
	Airport/Transport	NA
	WWTP	NA
Fresh Creek	CSO	50,605
	MS4	26,897
	Storm	34,854
	Direct Drainage	4,227
	Airport/Transport	NA
	WWTP	NA
Jamaica Bay	CSO	0
	MS4	311,973
	Storm	148,865
	Direct Drainage	246,506
	Airport/Transport	119,549
	WWTP	1,980,838
Bergen Basin	CSO	82,569
	MS4	354,211
	Storm	14,602
	Direct Drainage	2,803
	Airport/Transport	37,839
	WWTP	423,351
Thurston Basin	CSO	38,935
	MS4	NA
	Storm	99,735
	Direct Drainage	7,621
	Airport/Transport	46,462
	WWTP	NA
Spring Creek	CSO	62,345
	MS4	3,298
	Storm	4,764
	Direct Drainage	9,794
	Airport/Transport	NA
	WWTP	NA

Totals by Source by Waterbody – BOD		
Waterbody	**Source**	**Total Load (Lbs/Yr)**
Hawtree Basin	CSO	NA
	MS4	5,360
	Storm	3,832
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Head of Bay	CSO	NA
	MS4	35,855
	Storm	6,197
	Direct Drainage	787,571
	Airport/Transport	17,645
	WWTP	NA
Shellbank Basin	CSO	NA
	MS4	35,459
	Storm	785
	Direct Drainage	NA
	Airport/Transport	NA
	WWTP	NA
Hendrix Creek	CSO	20,013
	MS4	4,514
	Storm	5,255
	Direct Drainage	4,391
	Airport/Transport	NA
	WWTP	952,344

Attachment I
Appendix C – Use Attainability Analysis

Appendix C: Jamaica Bay and Tributaries Use Attainability Analysis

EXECUTIVE SUMMARY

The New York City Department of Environmental Protection (DEP) has performed a Use Attainability Analysis (UAA) for Jamaica Bay and Tributaries in accordance with the Combined Sewer Overflow (CSO) Order. Jamaica Bay and its tributaries are tidal waterbodies spanning the Boroughs of Brooklyn and Queens and exchange waters with the Lower Bay (Figure 1). The Jamaica Bay watershed is located throughout south Brooklyn and south Queens and is served by the Rockaway, Jamaica, 26th Ward, and Coney Island Wastewater Resource Recovery Facilities (WRRFs). The waters of Jamaica Bay and its tributaries are saline and receive freshwater input from groundwater, stormwater, direct drainage, and CSO discharges.

The gap analyses performed as part of the Jamaica Bay and Tributaries Long Term Control Plan (LTCP) concluded that under baseline conditions, the Existing Water Quality (WQ) Criteria for fecal coliform in this waterbody would be attained at all of the monitored water quality stations on an annual basis, and during the recreational season (May 1st through October 31st) for Jamaica Bay, Paerdegat Bay, Hendrix Creek, and Spring Creek. However, attainment is not achieved at the head ends of Thurston Basin, Bergen Basin, and Fresh Creek. The gap analyses also indicated that the Existing WQ Criteria for fecal coliform would not be attained at all stations in Thurston Basin, Bergen Basin, and Fresh Creek on an annual basis, even with the implementation of 100% CSO control. This finding is not unexpected, as bacteria levels in Thurston Basin, Bergen Basin, and Fresh Creek are also affected by stormwater loads and poor tidal flushing, largely due to man-made conditions.

The gap analyses also demonstrated that Class SB dissolved oxygen (DO) criteria is attained under baseline conditions at least 95 percent of the time on an annual average basis for Jamaica Bay. Class I DO criteria are attained for all monitoring stations within Paerdegat Basin, Fresh Creek, and Spring Creek. Attainment of Class I DO criteria are met at most monitoring stations within Thurston Basin, Bergen Basin, and Hendrix Creek with the exception of TBH1, TBH3, TB9, TB10, BB5, and HC1. With the implementation of 100% CSO control, monitoring Station HC1 would achieve attainment, while the others would all continue to fall below the 95 percent metric.

The Recommended Plan includes the following projects:

- Thurston Basin
  - 147 greened acres of Green Infrastructure (GI) Expansion
  - 3 acres of Ribbed Mussel Colony Creation
- Bergen Basin
  - 232 greened acres of GI Expansion
  - 50,000 CY Environmental Dredging
  - 4 acres of Ribbed Mussel Colony Creation
- Spring Creek
  - 13 acres of Tidal Wetland Restoration
- Hendrix Creek
  - 3 acres of Tidal Wetland Restoration
- Fresh Creek
  - 14 acres of Tidal Wetland Restoration
- Paerdegat Basin
  - 4 acres of Tidal Wetland Restoration

Figure 1. Overview of Water Quality Stations and Permitted Outfalls in Jamaica Bay and Its Tributaries

- Jamaica Bay
  - 16 acres of Tidal Wetland Restoration

The LTCP assessment shows that the Recommended Plan would achieve recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform bacteria at all sampling locations in Jamaica Bay and its tributaries with the exception of TBH1, TBH3, BB5, BB6, and FC1 for the 10-year continuous model run. Annual attainment of the Existing WQ Criteria for fecal coliform would be achieved at all stations except TBH1, TBH3, TB9, BB5, BB6, and FC1. Assessment of compliance using a 10-year continuous model run indicated that recreational season (May 1st through October 31st) compliance for those stations that do not achieve attainment would be in the range of 77 to 93 percent, and annual compliance would range from 60 to 92 percent.

With the Recommended Plan, the existing Class SB DO criteria is predicted to be met at least 95 percent of the time at all stations within Jamaica Bay on an annual average basis. Class I DO criteria are attained at least 95 percent of the time at all stations within the tributaries, with the exception of monitoring stations in Thurston Basin (TBH1, TBH3, TB9, TB10), Bergen Basin (BB5) and Hendrix Creek (HC1).

In June 2019, New York State Department of Environmental Conservation (DEC) released Amended *Enterococci* WQ Criteria* for coastal recreational waters, which are effective November 1, 2019. These criteria apply to Jamaica Bay (a coastal Class SB waterbody), but not the tributaries (all Class I waterbodies). The Amended *Enterococci* WQ Criteria* includes a 30-day rolling geometric mean (GM) for *Enterococci* of 35 cfu/100mL with a 90th percentile statistical threshold value (STV) of 130 cfu/100mL.

The UAA addresses the attainability of these criteria at each of the applicable modeled water quality stations in Jamaica Bay. For the Recommended Plan, the 30-day GM≤35 cfu/100mL Amended *Enterococci* WQ Criteria* are attained at all monitoring stations within Jamaica Bay, while the STV criteria are attained for all stations except JA1, J7, J8, J9A and J10, which are located at the confluence of Bergen Basin, Spring Creek, Fresh Creek, and Paerdegat Basin with Jamaica Bay. Amended *Enterococci* WQ Criteria* do not apply to the tributaries.

Each applicable criterion is discussed below for the waterbodies where Existing WQ Criteria are not predicted to be met at least 95 percent of the time.

Fecal Coliform

Water quality modeling analyses performed during the Jamaica Bay and Tributaries LTCP concluded that under baseline conditions for a 10-year continuous model simulation, attainment of the Existing WQ Criteria for bacteria during the recreational season (May 1st through October 31st) is 72, 88, and 93 percent, respectively, at the head ends of Bergen Basin, Thurston Basin, and Fresh Creek. Attainment increases towards the mouth of each waterway, reaching 100 percent before the confluence with Jamaica Bay. Annual attainment ranges from 56 percent at the head end of Bergen Basin, to 76 percent for Thurston Basin and 85 percent for Fresh Creek. Attainment reaches 100 percent before the confluence of each waterway with Jamaica Bay.

The Recommended Plan was also modeled for a 10-year continuous model simulation. Recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform bacteria ranges from 77 percent at the head end of Bergen Basin, to 88 percent for Thurston Basin, 88 percent for Fresh Creek, and 100 percent at the confluence of each of these waterbodies with Jamaica Bay.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

However, annual attainment of the Existing WQ Criteria for fecal coliform is predicted to range from 60 percent at the head end of Bergen Basin, to 77 percent for Thurston Basin, 78 percent for Fresh Creek, and 100 percent at the confluence with Jamaica Bay based on the 10-year continuous model simulation.

Dissolved Oxygen

Under baseline conditions for the 2008 rainfall year, water quality modeling analysis projects attainment of Existing WQ Criteria for DO (Class SB) at all monitoring stations within Jamaica Bay. For the Class I tributaries, Existing WQ Criteria for DO are attained at all monitoring stations in Spring Creek, Fresh Creek, and Paerdegat Basin. However, attainment at the head ends of Bergen Basin, Thurston Basin, and Hendrix Creek were projected to be 89, 90 and 94 percent, respectively. Attainment progressively increases towards the mouth of each of these waterways, reaching 100 percent before the confluence with Jamaica Bay. Modeling for the Recommended Plan for the 2008 rainfall year indicates no improvement in DO attainment.

Waterbody Access and Uses

Bergen Basin and Thurston Basin are navigable waterways that primarily support recreational boating, shipping traffic associated with JFK International Airport, and the servicing of the DEP floatables booms with skimmer boats. Public access to these waterbodies is prohibited by JFK Airport security at points near their confluence with Jamaica Bay. In addition, access to the head ends of these waterways is limited due to physical barriers. Floatables and oil containment booms prevent access of small watercraft to the head end of both waterways. The head end of Thurston Basin is also blocked by a floating chain link fence at a point downstream of an airport runway. As shown on Figure 2, public access is not available to these waterways except for private boat docks near the confluence of Thurston Basin with Jamaica Bay. In addition, no Department of Health and Mental Hygiene (DOHMH) certified bathing beaches are located along Bergen and Thurston Basins.

Hendrix Creek is a navigable waterway that primarily supports recreational boating and skimmer boat access for servicing the floatables boom. The 26th Ward WWTP traverses the western shoreline and head end of the Creek, limiting public access. While Fountain Avenue Park bounds the eastern shoreline of Fresh Creek, heavy vegetation along the banks limits access. No docks or certified bathing beaches exist along Hendrix Creek or near its confluence with Jamaica Bay.

Portions of Fresh Creek are navigable; however, narrow stretches and shallow water depths limit access to the head end of the waterway to small watercraft. At the head end of Fresh Creek, access is limited by heavy commercial, institutional, and residential development. While Figure 2 identifies Fresh Creek Park, Canarsie Park, and Pennsylvania Avenue Landfill as access areas, heavy vegetation along the shorelines limits access to the waterway. No docks or certified bathing beaches exist along Fresh Creek or near its confluence with Jamaica Bay.

As illustrated in Figure 3, the shorelines of Bergen and Thurston Basins are composed of a mix of natural areas, riprap, marina docks, and bulkheads. The shoreline adjacent to the JFK Airport fuel tanks is armored with riprap and piers for docking fuel delivery vessels. The shoreline along Pan Am Road is armored with bulkheads adjacent to CSO Outfalls JAM-003/003A and JAM-006. The Thurston Basin shoreline is primarily composed of natural areas, except the head end which is bulkheaded and armored with riprap. Three docks exist off the rear yards of private residences near the confluence of Thurston Basin with Jamaica Bay.

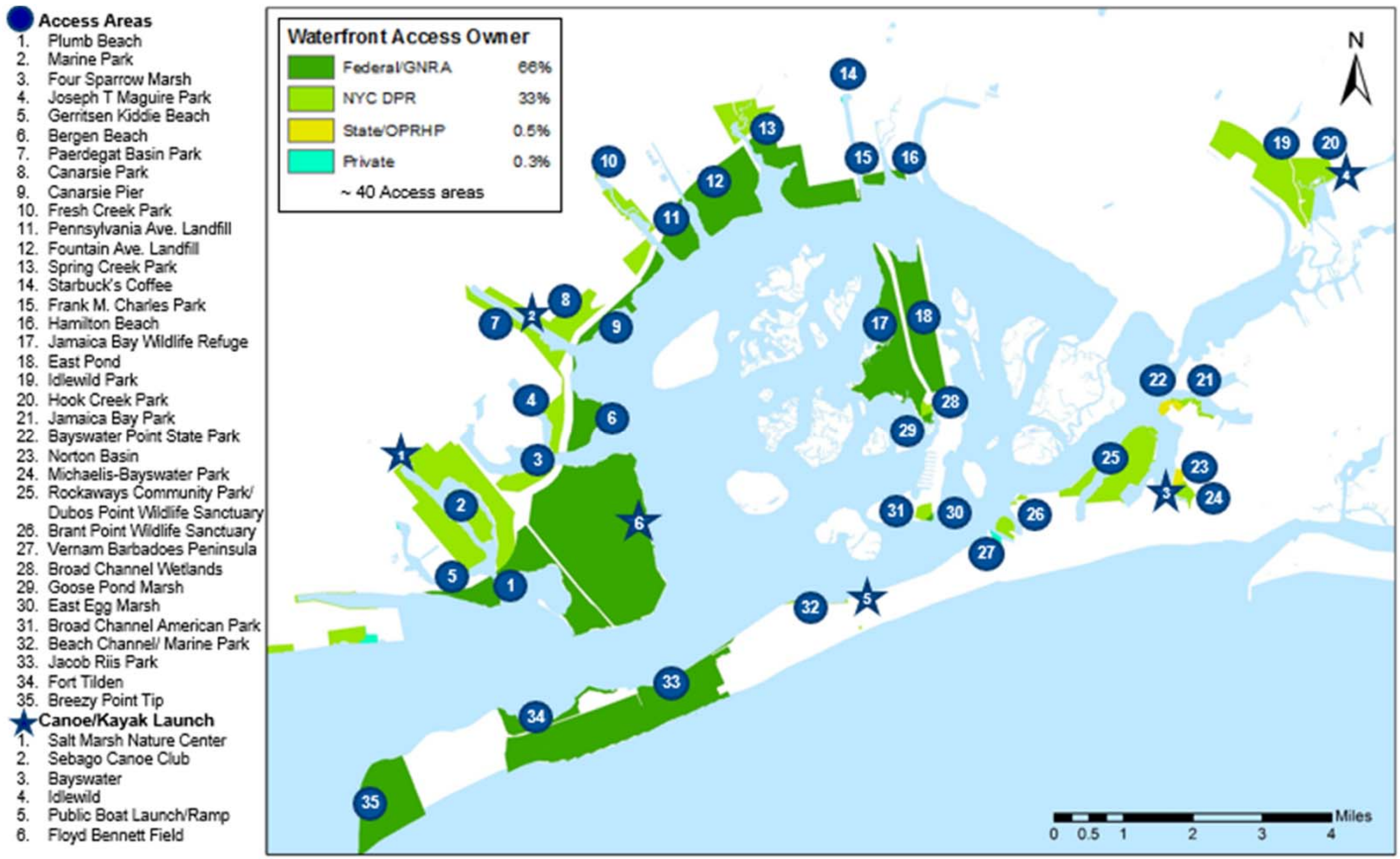

Figure 2. Shoreline Access Locations Along Jamaica Bay and Its Tributaries

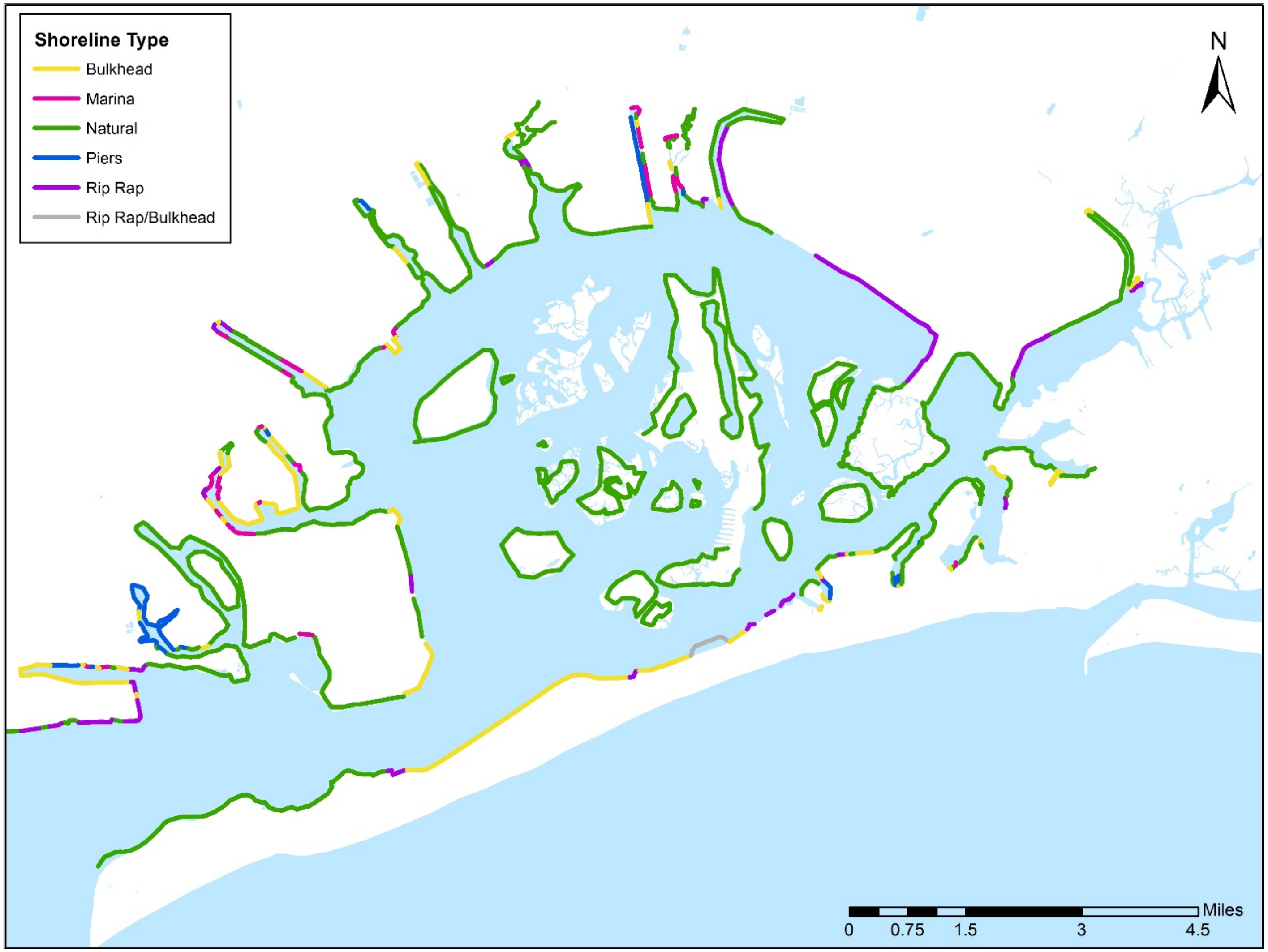

Figure 3. Jamaica Bay Shoreline Characteristics

The Hendrix Creek shoreline is composed of a mix of natural areas, riprap, and bulkhead. Most of the Hendrix Creek shoreline is composed primarily of natural shoreline except for bulkhead along the head end and the western shoreline adjacent to the 26th Ward WWTP. Docks for sludge transport vessels span the western shoreline of the confluence of Hendrix Creek with Jamaica Bay.

The shoreline of Fresh Creek is composed of a mix of natural areas, riprap, and bulkhead. Most of the Fresh Creek shoreline is composed primarily of natural shoreline except for pockets of development with riprap shoreline and small pockets of bulkhead.

Based on the analyses summarized above, projected fecal coliform levels do not meet the Existing WQ Criteria on an annual or recreational season (May 1st through October 31st) basis for portions of Bergen Basin and Thurston Basin to which public access is prohibited by JFK Airport security. Station FC1 in Fresh Creek falls just short of the 95 percent metric. Non-attainment of the Existing WQ Criteria at these stations appears to be primarily related to stormwater sources discharging at the head end of these tributaries. This is supported by the gap analysis which indicates that even 100% CSO control would not achieve annual compliance at all of the stations. It is recommended that the current designated uses of the tributaries and Class I classification be maintained after implementation of the LTCP Recommended Plan. After implementation, future data collection efforts will provide data that could be used to re-assess the attainment of Class I WQ Criteria and the best use of the tributaries could be revised accordingly. DEP will continue to issue wet-weather advisories informed by the time to recovery analyses presented in the Jamaica Bay and Tributaries LTCP. However, it should be noted that although the water quality is projected to be protective of primary contact in the publicly accessible portions of the tributaries during the recreational season (May 1st through October 31st) based on the 10-year continuous model simulation, other factors, such as adjacent land use, prohibited access by JFK Airport security, current marine industrial uses, and safety, must be taken into account in considering appropriate uses of the waterbody.

For the Recommended Plan, the 30-day GM≤35 cfu/100mL Amended *Enterococci* WQ Criteria* are attained at all monitoring stations within Jamaica Bay, while the STV criteria are attained for all stations except JA1, J7, J8, J9A and J10, which are located at the confluence of Bergen Basin, Spring Creek, Fresh Creek, and Paerdegat Basin with Jamaica Bay. For 100% CSO control conditions, Station J7 would still not achieve attainment with the STV criteria. Amended *Enterococci* WQ Criteria* do not apply to the tributaries.

INTRODUCTION

Regulatory Considerations

The DEC has designated Jamaica Bay as a Class SB waterbody and the tributaries as Class I waterbodies. The best usages of Class SB waters are primary and secondary contact recreation and fishing, while the best usages of Class I waters are secondary contact recreation and fishing. These waters shall also be “suitable for fish, shellfish, and wildlife propagation and survival. In addition, the water quality shall be suitable for primary contact recreation, although other factors may limit the use for this purpose” (6 NYCRR 701.13).

Federal policy recognizes that the uses designated for a waterbody may not be attainable, and the UAA has been established as the mechanism to modify the water quality standard (WQS) in such a case. Jamaica Bay is projected to achieve attainment with Class SB WQ Criteria for fecal coliform, and the

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Amended *Enterococci* 30-day GM criteria*, but portions of the Bay do not meet the Amended *Enterococci* 30-day STV criteria* with the implementation of the LTCP Recommended Plan for a continuous 10-year model simulation. Thurston Basin, Bergen Basin, and Fresh Creek do not meet the Existing WQ Criteria (Class I) for bacteria on an annual or recreational season (May1st through October 31st) basis with the implementation of the LTCP Recommended Plan for a continuous 10-year model simulation. Under baseline conditions, Existing WQ Criteria for DO (Class SB) are projected to be achieved in Jamaica Bay for a 2008 typical year continuous model simulation. However, Existing WQ Criteria for DO in the tributaries (Class I) is projected to be achieved in Paerdegat Basin, Fresh Creek, and Spring Creek. DO attainment in Hendrix Creek (94 percent) falls just short of the 95 percent metric. DO at the upstream ends of Bergen Basin and Thurston Basin are projected to achieve 89 and 90 percent attainment, respectively.

This UAA identifies the attainable and existing uses of Jamaica Bay and its tributaries and compares them to those designated by DEC in order to provide data to establish appropriate water quality goals for this waterway. An examination of several factors related to the physical condition of the waterbody and the actual and possible uses suggests that annual attainment of bacteria and DO criteria associated with existing Class SB and I standards is not projected to occur, and even 100% CSO reduction would not bring the waterbody into compliance on an annual basis. Under Federal regulations (40 CFR 131.10), six factors may be considered in conducting a UAA:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent or low flow conditions, or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original conditions or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the waterbody, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by Sections 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.

The UAA shall "examine whether applicable waterbody classifications, criteria, or standards should be adjusted by the State." The UAA process specifies that States can remove a designated use which is not an existing use if the scientific assessment can demonstrate that attaining the designated use is not feasible for at least one of six factors listed above.

Identification of Existing Uses

The waterfront area surrounding Bergen and Thurston Basins is predominantly altered along its banks throughout its length to protect Port Authority of New York and New Jersey (PANYNJ) JFK Airport infrastructure. Due to JFK Airport security restrictions, public access to these waterbodies is prohibited.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

The majority of the property on either side of Bergen and Thurston Basin is owned by PANYNJ and is fenced to prevent unauthorized access and to secure airport operations. Due to the presence of altered shorelines (piers, bulkheads, and riprap), floatables and fuel/oil containment booms, a security fence, and industrial maritime uses, the bulk of Bergen and Thurston Basins is not conducive to primary contact or secondary contact recreation. While secondary contact recreation has been observed at the confluence of these waterbodies with Jamaica Bay, Existing WQ Criteria are being achieved at these locations on an annual and recreational season (May 1st through October 31st) basis. No DOHMH certified bathing beaches exist anywhere within Bergen and Thurston Basins. Figure 4 and Figure 6 illustrate the typical shoreline conditions along Bergen and Thurston Basins. Figure 5 shows the headwall for CSO Outfall JAM-003/003A and riprap armor protection along the banks of Bergen Basin to either side of the outfall. Figure 7 shows the floating airport security fence downstream of CSO Outfall JAM-005/007. An airport security vehicle can be seen in the background monitoring use of the waterway. Permission from the U.S. Coast Guard was required to access the upstream reaches of both Bergen and Thurston Basins for each site visit during the development of the LTCP.

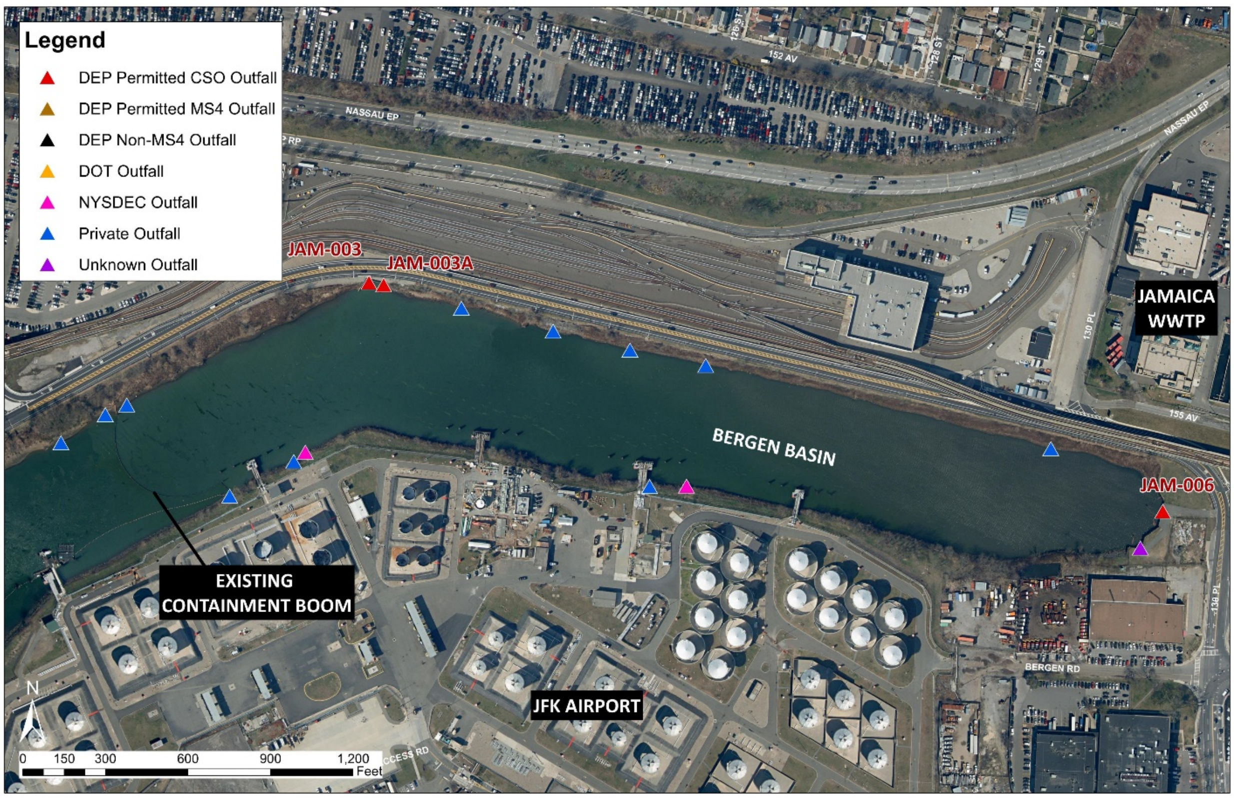

Figure 4. Bergen Basin Shoreline

Figure 5. Bergen Basin Shoreline
(Armored Banks and Headwall for JAM-003/003A)

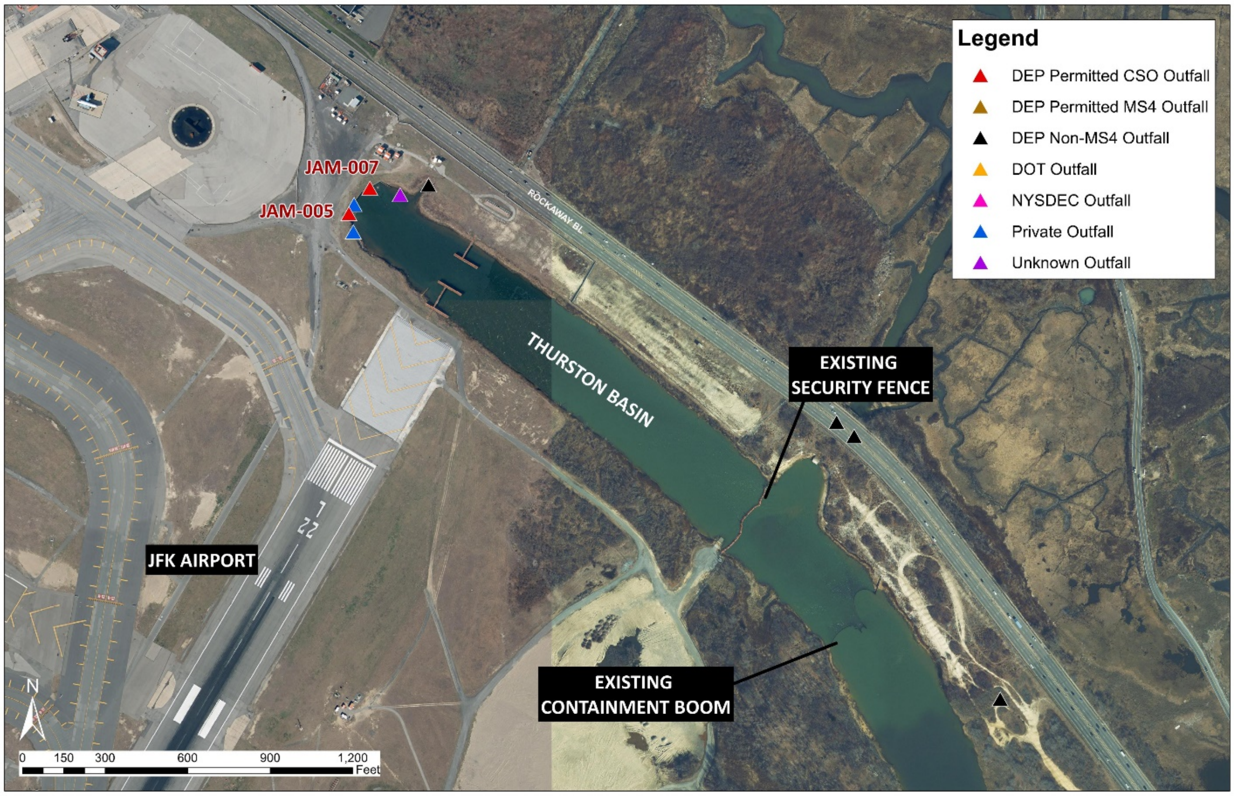

Figure 6. Thurston Basin Shoreline

Figure 7. Thurston Basin Shoreline
(Airport Security Fence with Bulkhead and CSO Outfalls JAM-005/007 in Background)

As shown in Figure 8, Hendrix Creek passes between two parks that were created from former landfills at its confluence with Jamaica Bay. The Pennsylvania Avenue Landfill Park is located along the western shoreline, while the Fountain Avenue Landfill Park is located along the eastern shoreline. The Creek measures approximately 600 feet wide between the landfills, but narrows to about 190 feet upstream of the Belt Parkway. National Oceanic and Atmospheric Administration (NOAA) charts indicate that the depth of the waterway becomes much shallower (less than 2 feet deep) as the waterway narrows, thereby limiting access to the narrower stretch to small watercraft, particularly during low tide. However, the closest dock or boat launch is the Sebago Canoe Club located in Paerdegat Basin. Existing WQ Criteria at the confluence of Hendrix Creek with Jamaica Bay are attained on an annual and recreational season (May 1st through October 31st) basis, thereby supporting secondary contact recreation activities. The shallow depth and presence of the WWTP along the western shoreline of the upstream reaches discourage secondary recreation. In addition, a floatables boom exists at the upstream end of the Creek which prevents small watercraft from accessing the head end of the Creek. No DOHMH certified bathing beaches exist anywhere along Hendrix Creek or portions of the northern shore of Jamaica Bay.

Fresh Creek, as shown in Figure 9, is of similar configuration to Hendrix Creek. The width of the waterway ranges from about 300 to 400 feet at the downstream end, but narrows to about 150 feet at a point approximately 2,500 feet north of the Belt Parkway overpass. While the downstream segment is supportive of secondary contact recreation, the depth becomes shallow (less than 3 feet deep) at the point where the Creek narrows, significantly limiting access to the upstream reaches of the waterway for boating and fishing. These limitations were confirmed during a field visit by the LTCP2 staff, where the boat's sonar system indicated extremely shallow conditions preventing access to the upstream reaches of the waterway. No docks, marinas, or boat launches exist along Fresh Creek. In addition, no DOHMH certified beaches exist along the Creek.

Figure 8. Hendrix Creek Shoreline

Figure 9. Fresh Creek Shoreline

AECOM with Hazen

ATTAINMENT OF DESIGNATED USES

The Jamaica Bay tributaries are Class I waterbodies, whose best uses are aquatic life protection, as well as secondary contact recreation. As noted previously, physical features of Thurston Basin, Bergen Basin, Hendrix Creek, and Fresh Creek create obstacles to secondary contact recreation. However, the Recommended Plan includes ecological improvement projects to enhance fish and wildlife habitats.

As part of this LTCP, an analysis was performed to assess the level of attainment of the Existing WQ Criteria for fecal coliform associated with Class I waters, although other factors may preclude the attainment of the use. Water quality modeling analyses performed during the Jamaica Bay and Tributaries LTCP concluded that for a 10-year simulation under baseline conditions, attainment of the Existing WQ Criteria for bacteria during the recreational season (May 1st through October 31st) ranges from 72 percent in the upstream reach of Bergen Basin to 88 and 93 percent in the upstream reaches of Thurston Basin and Fresh Creek, respectively. Attainment in the downstream monitoring stations within these tributaries is 100%. Annual attainment ranges from 56 percent to 76 percent and 85 percent, respectively, in Bergen Basin, Thurston Basin, and Fresh Creek in the upstream reaches. Attainment is 100% in the downstream monitoring stations approaching the confluence with Jamaica Bay. The non-attainment is due to CSO, direct drainage, airport runoff and other stormwater discharges accruing within these tributaries due to poor tidal flushing conditions, largely due to man-made conditions.

Assessment of compliance upon implementation of the Recommended Plan was evaluated using a 10-year continuous model run. While the Recommend Plan will not achieve annual or recreational season (May 1st through October 31st) attainment of the Existing WQ Criteria for fecal coliform bacteria at all sampling locations in Bergen Basin and Thurston Basin, attainment is achieved at those stations that are not prohibited from public access by JFK Airport security. These accessible stations achieve greater than 95 percent attainment of the Existing WQ Criteria for fecal coliform. Fresh Creek was predicted to achieve 88 percent attainment of the Existing WQ Criteria for fecal coliform during the recreational season (May 1st through October 31st) at the head of the waterbody. However, all other downstream stations are projected to achieve 100% attainment and fully support the intended uses of the waterbody.

Table 1 presents the attainment levels for the Existing WQ Criteria for fecal coliform (monthly GM≤200 cfu/100mL) and, for stations in Jamaica Bay only, the Amended *Enterococci* WQ Criteria*, as determined using the 10-year simulation for the Recommended Plan. Table 1 also presents the attainment with the Class I DO criteria in the tributaries for the 2008 rainfall year. All of the stations in Jamaica Bay meet the Class SB DO criteria. As described in Section 8 of the LTCP, the values presented in Table 1 for the 10-year simulation were post-processed to estimate the water quality attainment benefits associated with the installation of ribbed mussels in Bergen and Thurston Basins.

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

Table 1. Projected Attainment of WQ Criteria for the Recommended Plan

Waterbody	Station	10-Year Simulation				2008 Rainfall Year
		Fecal Coliform Annual Monthly GM ≤200 cfu/100mL	Fecal Coliform Recreational Season(2) Monthly GM ≤200 cfu/100mL	*Enterococci* Recreational Season(2)(4) 30-day GM ≤35 cfu/100mL	*Enterococci* Recreational Season(2)(4) 90th Percentile STV ≤130 cfu/100mL	Dissolved Oxygen Class I (≥4.0 mg/l)
Thurston Basin(1)	TBH1(3)	77	88	N/A	N/A	90
	TBH3(3)	90	93	N/A	N/A	90
	TB9(3)	92	95	N/A	N/A	92
	TB10(3)	100	100	N/A	N/A	92
	TB11	100	100	N/A	N/A	97
Bergen Basin(1)	BB5(3)	60	77	N/A	N/A	89
	BB6(3)	90	93	N/A	N/A	95
	BB7(3)	100	100	N/A	N/A	99
	BB8	100	100	N/A	N/A	100
Hendrix Creek	HC1(3)	99	98	N/A	N/A	94
	HC2	100	100	N/A	N/A	98
	HC3	100	100	N/A	N/A	100
Fresh Creek	FC1(3)	78	88	N/A	N/A	99
	FC2	98	100	N/A	N/A	100
	FC3	100	100	N/A	N/A	100
	FC4	100	100	N/A	N/A	100
Paerdegat Basin	PB1	97	95	N/A	N/A	99
	PB2	100	100	N/A	N/A	100

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Table 1. Projected Attainment of WQ Criteria for the Recommended Plan

Waterbody	Station	10-Year Simulation				2008 Rainfall Year
		Fecal Coliform Annual Monthly GM ≤200 cfu/100mL	Fecal Coliform Recreational Season(2) Monthly GM ≤200 cfu/100mL	*Enterococci* Recreational Season(2)(4) 30-day GM ≤35 cfu/100mL	*Enterococci* Recreational Season(2)(4) 90th Percentile STV ≤130 cfu/100mL	Dissolved Oxygen Class I (≥4.0 mg/l)
Jamaica Bay (Northern Shore)	J10	100	100	100	85	N/A
	J3	100	100	100	97	N/A
	J9A	100	100	100	92	N/A
	J8	100	100	100	92	N/A
	J7	100	100	100	57	N/A
	JA1	100	100	100	86	N/A
Jamaica Bay (Inner Bay)	J2	100	100	100	98	N/A
	J12	100	100	100	97	N/A
	J14	100	100	100	100	N/A
	J16	100	100	100	99	N/A
Jamaica Bay (Rockaway Shore)	J1	100	100	100	100	N/A
	J5	100	100	100	100	N/A

Notes:
(1) Values were post-processed from 10-year simulations to estimate the water quality attainment benefits associated with the installation of ribbed mussels in Bergen and Thurston Basins.
(2) The recreational season is from May 1st through October 31st.
(3) Monitoring station is located in a portion of the waterbody where access is prohibited by JFK Airport security and/or prevented by a physical barrier.
(4) These criteria do not apply to the tributaries to Jamaica Bay.

Upon implementation of the LTCP Recommended Plan, Existing WQ Criteria for DO (Class I) is projected to be attained on an annual basis at least 95 percent of the time for the accessible portions of Bergen Basin, Thurston Basin, and Hendrix Creek. DO attainment at the inaccessible portions of these waterways ranges from 89 to 99 percent.

Table 1 shows that the 30-day GM≤35 cfu/100mL Amended *Enterococci* WQ Criteria* are attained at all monitoring stations within Jamaica Bay, while the STV criteria are attained for all stations except JA1, J7, J8, J9A, and J10, which are located at the confluence of Bergen Basin, Spring Creek, Fresh Creek, and Paerdegat Basin with Jamaica Bay. Attainment of the GM criteria indicates that water quality is supportive of the designated uses. However, the lower percent attainment of the STV criteria at Station JA1, J7, J8, J9A, and J10 indicates that wet-weather events may peridically impact designated uses in the vicinity of that station.

CONCLUSIONS

Bergen Basin, Thurston Basin, and Fresh Creek do not attain the Existing WQ Criteria (Class I) for bacteria under baseline conditions. These waterbodies cannot fully achieve the Existing WQ Criteria for fecal coliform on an annual basis, even with 100% CSO control. However, the analyses show that with the Recommended Plan, Existing WQ Criteria for fecal coliform is projected to be attained in the unrestricted segments of these waterways throughout the recreational season (May 1st through October 31st) based on continuous 10-year simulation. Regardless of the timeframe used to assess compliance, bacteria levels will be elevated during and after rain events. No permitted swimming locations exist along these waterways. Thus, the non-attainment of swimmable standards during and after rainfall or during the non-recreational season (November 1st through April 30th) would not impact such uses. Secondary contact recreation has been reported in these waterbodies, although physical features limit the extent of those activities.

Under baseline conditions, Bergen Basin, Thurston Basin, and Hendrix Creek do not attain the Existing WQ Criteria (Class I) for DO. Under 100% CSO control conditions, DO attainment in Hendrix Creek improves from 94 to 95 percent; however, Bergen and Thurston Basins do not achieve attainment. The analysis of the Recommended Plan projects DO attainment in Bergen and Thurston Basins to be 89 and 90 percent, respectively, at the head ends of these waterways. Attainment of DO standards in the unrestricted segments of the Bergen and Thurston Basins exceeds the 95 percent metric and is supportive of aquatic life.

Non-attainment of the Existing Class I WQ Criteria in the tributaries, and the Amended *Enterococci* STV criteria* in Jamaica Bay stations adjacent to the tributaries, is attributable to the following UAA factors:

Fecal Coliform:

- Human caused conditions (direct drainage and urban runoff) create high bacteria levels that prevent the attainment of the use and that cannot be fully remedied for large storms (UAA factor #3).

DO:

- Human caused conditions (direct drainage and urban runoff) create low DO levels that prevent the attainment of the use and that cannot be fully remedied for large storms (UAA factor #3).

*Amended *Enterococci* WQ Criteria only apply to coastal Class SB and SA waters.

It should be emphasized that the Bergen Basin, Thurston Basin, and Fresh Creek watersheds, although surrounded by commercial and industrial uses in most areas, provide very few shoreline access points for on-shore and in-water recreation, limiting the ability of the public to take advantage of the recreational uses of these waterways. These uses should be protected in recreational periods, with the exception of during rain events when advisories will be in place.

RECOMMENDATIONS

The head ends of Bergen Basin, Thurston Basin, and Fresh Creek are not projected to attain the Existing WQ Criteria for fecal coliform (Class I) on an annual or recreational basis, even with 100% CSO control. Upon implementation of the Recommended Plan, Existing WQ Criteria is attained in the unrestricted portions of these waterways on an annual and recreational seasonal basis (based on a 10-year continuous model run). Recreational season (May 1st through October 31st) compliance in the segments of these waterways to which public access is prohibited by JFK Airport security would be in the range of 77 to 100 percent, and annual compliance would be slightly lower. However, as noted above, no DOHMH sanctioned locations for primary contact recreation exist along these waterbodies, and physical features limit the extent of secondary contact recreation. The current uses are primarily associated with on-shore activities at specific access locations, as well as boating/kayaking facilitated by the Sebago Canoe Club boat launching location.

The Class I criteria for DO are projected to be attained in the tributaries to Jamaica Bay except for the upstream ends of Bergen and Thurston Basin and Hendrix Creek. The locations in Bergen and Thurston Basin would not achieve attainment even with 100% CSO control, while Hendrix Creek attainment would go from 94 to 95 percent with 100% control. Under the Recommended Plan, DO attainment in Bergen and Thurston Basins is projected to be 89 and 90 percent, respectively, at the head ends of these waterways. Attainment of the Class I criteria for DO in the publicly accessible segments of Bergen and Thurston Basins exceeds the 95 percent metric and is supportive of aquatic life.

The above conclusions support that Bergen Basin, Thurston Basin, Fresh Creek, and Hendrix Creek should remain as designated Class I waterbodies after the implementation of the LTCP Recommended Plan. Future Post-Construction Compliance Monitoring data collection efforts may later support a revision of the best uses and designated WQ classification for these waterways.

Attachment J
Appendix D – Modeling Approach for Estimating the Pathogen Bioextraction in Jamaica Bay and Tributaries

Appendix D: Modeling Approach for Estimating the Pathogen Bioextraction in Jamaica Bay and Tributaries, June 19, 2018

The New York City Department of Environmental Protection (DEP) has proposed the use of nutrient and pathogen bioextraction methods through the placement of *Geukensia demissa* (ribbed mussels) in two of the tributaries to Jamaica Bay that receive combined sewer overflows (CSOs) during wet-weather. The proposed introduction of ribbed mussels to Thurston and Bergen Basins is a component of the Recommended Plan to be presented in the Jamaica Bay and Tributaries CSO Long Term Control Plan (LTCP). Potential benefits of installing ribbed mussels include bacteria and nutrient reduction, improved water clarity, and improving ecological habitat. These benefits would accrue during both dry- and wet-weather conditions, as the filtering action would occur continuously and potentially provide greater benefits as the population density increases over time. Additionally, the application of ribbed mussels in these specific basins provides a unique approach to CSO and stormwater pathogen control considering the long term plans for build-out of the storm sewer system throughout Jamaica, Queens and the reduction of CSO discharges through the construction of high level storm sewers in some of the remaining areas of Jamaica served by combined sewers. The ribbed mussels provide a pathogen control that can adapt to the transition in sources of pathogens from CSO to stormwater that will take place over the next several decades.

Studies of the use of ribbed mussels in the Bronx River in New York and in the Chesapeake Bay area have indicated that ribbed mussels may be effective in nutrient and pathogen bioextraction, and demonstrate the bivalve's capabilities of overall water filtration capacity and how this compared in an urban subtidal deployment. While the configuration of mussels differs from what is proposed for Bergen and Thurston Basins, the Ribbed Mussel Pilot Study in the Bronx River, New York reported the following relevant findings (http://longislandsoundstudy.net/our-vision-and-plan/clean-waters-and-healthy-watersheds/nutrient-bioextraction-overview/2-bronx-mussel-project-info-002-julie20-july-revised-docx/):

- Laboratory experiments with ribbed mussels showed that after three days of submersion, there were no differences in feeding between the intertidal and submerged mussels. These results support the use of ribbed mussels for bioextraction purposes using traditional mussel aquaculture techniques.

- The native ribbed mussel populations were studied by a shellfish pathologist and compared to a population in a suburban environment to look at occurrence of physiological abnormalities and disease. There were no significant differences in the health of the urban and suburban mussels.

- The ribbed mussels demonstrated a high tolerance of a wide range of environmental conditions. For this reason, researchers believe the ribbed mussel is a good candidate for use in future nutrient bioextraction projects.

- Researchers were also able to use measurements of mussel feeding to determine that a fully stocked, one-acre raft of ribbed mussels would filter 19 million gallons of water every day, removing 1,358 pounds of particulate matter. These filtration rates will vary depending on the density of ribbed mussels, temperature, TSS, and salinity.

A study of biofiltration potential of ribbed mussel populations conducted by the Virginia Institute of Marine Science characterized the ribbed mussel population along the York River, Virginia, and estimated their water processing potential (https://scholarworks.wm.edu/cgi/viewcontent.cgi?referer=https://www.bing.com/&httpsredir=1&article=1703&context=reports).

The findings from this Chesapeake Bay area study included the following:

- Ribbed mussels were most abundant within the first meter of the marshes. Mussel abundance was highly variable among marsh types/position.
- Fringing marshes along the main stem of the River possessed the highest average number of mussels. Fringing marshes along the Creek possessed a smaller number of mussels but had the highest average biomass (0.7 g dry weight [DW] of tissue) compared to other marsh types (0.24 g DW).
- The mussel population on the York River was estimated to be approximately 197 million animals (range: 8.3 to 313 million, 95 percent Confidence Interval). The water filtration potential of mussels on the York River is between 111 and 464 million liters per hour (mean: 286 million L/hr) on the basis of observed biomass and previously estimated clearance rates. These filtration rates will vary depending on the density of ribbed mussels.

Other literature indicates that ribbed mussels are effective at filtering bacteria sized particles from the water column and is summarized below under Approach Option 3. DEP is interested in quantifying the effect of ribbed mussels if they were deployed as a means to reduce bacteria and nutrients in NYC waters. DEP, in collaboration with Cornell Cooperative Extension of Suffolk County, has started bench-scale testing to determine actual ribbed mussel filtration efficiency rates. These experiments have indicated a 62 percent to 88 percent efficiency removal rate of *E. coli*. Additional research is currently underway that will build on the knowledge gathered during the bench-scale testing phase of the project to perform targeted experiments for evaluating the ability of ribbed mussels to clear coliform bacteria from contaminated seawater under different environmental and biological conditions. The City intends to look more closely at the effects of various biological and physio-chemical factors (e.g., temperature, salinity, TSS, mussel size) on clearance rates of two bacteria strains: *E. coli* and *E. faecalis*. The fate of the cleared bacteria will also be identified by analyzing the material rejected after clearance (i.e., feces and pseudofeces). These experiments will quantify key measures of the capabilities of ribbed mussels to sequester and remove the bacteria during a CSO event.

During the Jamaica Bay LTCP development, several modeling approaches were considered in an effort to quantify the effect of bioextraction methods on bacteria concentrations in order to estimate water quality improvements of the Recommended Plan. The discussion of Approach Options 1 and 2 present the modeling strategies considered and is followed by a detailed description of Approach Option 3, which has been selected as the approach to be used in the LTCP. The proposed model will be updated with additional data from the various experiments.

Approach Option 1 – Modify Existing Filter Feeder Model

The first approach that was considered was to modify an existing filter feeder model to represent the filtration processes of ribbed mussels. HDR has a filter feeder model that was developed for use in the Jamaica Bay Eutrophication Model (HydroQual, 2002), but the model is set up based on the filtration of phytoplankton by hard clams (*Mercenaria mercenaria*), which have different filtering rates and efficiency than ribbed mussels. Without the data to calibrate the existing model, this approach was seen as too complicated and time consuming to pursue for the Jamaica Bay and Tributaries LTCP, given time constraints and limited data to calibrate and validate the model.

Approach Option 2 – Represent Filtering as an Effective Settling Rate

The second approach to modeling involved calculating an effective settling rate that would represent the bacteria loss due to filtering. The effective settling rate would then be incorporated into the existing Jamaica Bay Eutrophication Model.

Based on available data for ribbed mussel filtration rates, a filtering rate of 5.1 L/hr-g was estimated by Kreeger (unpublished data as reported in Bilkovic and Mitchell, 2014) along with ribbed mussel biomass of 0.7 g DW per individual. Riisgaard (1988) developed a power function for ribbed mussel filtration of:

$$F = 6.15W^{0.83}$$

where F is filtration in L/hr and W is the dry weight biomass of the ribbed mussels. These rates indicate that filtration rates change with the size of the organism, but rates can also change with temperature, oxygen levels, and available food (Wilbur et al., 1989; Jorgensen et al., 1990; Aldridge et al., 1995; Kittner and Riisgard, 2005; Galimany et al., 2013). Using an estimated weight of 0.7 g, an individual ribbed mussel could filter approximately 100 L/d or 0.1 m^3/d.

DEP reviewed several ribbed mussel density levels for placement in Bergen and Thurston Basins. For planning purposes, a moderate ribbed mussel density of 2,000 mussels/m^2 was selected for consideration in the modeling analysis (the final configuration of the ribbed mussel colonies will be determined during the implementation phase). Using the filtration rate of 0.1 m^3/d, an effective settling rate can be calculated that can be applied as a loss term in a model.

$$V_{se} = \text{Density*Filtration Rate} = 2{,}000 \text{ mussels/m}^2 * 0.1 \text{ m}^3\text{/ mussel-day} = 200 \text{ m/day}$$

where V_{se} is the effective settling velocity in m/day.

Ribbed mussels do not filter bacteria with 100% efficiency. That is, not all of the bacteria that are filtered by ribbed mussels will be retained. Riisgard (1988) reported that ribbed mussels could filter down to a particle size of 4 µm with close to 100% efficiency, and down to 2 µm with 35-70 percent efficiency. *E. coli* is approximately 1 to 3 µm in size. *Clostridium perfringens* is approximately 4 to 8 µm, and *Enterococcus* are approximately 1 to 2.5 µm in size. These sizes are within the particle size filtering capability of ribbed mussels, although at different uptake efficiencies for each. Ribbed mussels are known to filter particle sizes less than 2 µm (e.g., clay particle sizes down to 1 micron) with lower efficiencies. *Clostridium* would be filtered at closer to the 100 percent efficiency range, and the *E. coli* and *Enterococcus* would be filtered closer to the 35 to 70 percent efficiency range. Fecal coliform covers a group of bacteria, which includes bacteria from non-feces origins. *E. coli* is included within the fecal coliform group, so it can be expected that filtering efficiencies for fecal coliform bacteria would be similar to *E. coli.* Langdon and Newell (1990) estimated that ribbed mussels can filter unattached bacteria with an efficiency of 15.8 percent of the efficiency of larger particle filtration. Kemp et al. (1990) estimated the efficiency of filtration of bacteria by ribbed mussels to be 25-56 percent/hr.

Kemp's estimates of filtration efficiency, which include a time component, bring up other uncertainties as to how much water in a tributary flows within the area of influence of filtration by ribbed mussels and how long the water remains within the area of influence. Based on the filtering efficiency and water contact efficiency of ribbed mussel deployment, the actual effective settling rate could be less than the estimated effective settling calculated above. However, it should be noted that the filtering effects of the ribbed mussels for Bergen and Thurston Basins would be occurring constantly, in both dry- and wet-weather conditions, providing constant benefits in terms of reduction in bacteria and nutrient concentrations in the waterbody.

To provide some insight as to how effective ribbed mussels could be in reducing bacteria concentrations, two model sensitivities were conducted using the Jamaica Eutrophication Model. The Bergen Basin portion of the Jamaica Eutrophication Model is represented by a series of connected model cells or segments. In both cases, an effective settling rate was applied to one model segment downstream of the CSO outfall in Bergen Basin to replicate the deployment of ribbed mussel racks. One model sensitivity run used an effective settling rate of 5 m/day, and the other used an effective settling rate of 50 m/day. The current formulation of the model allows bacteria to settle up to 5 m/day, so the model sensitivities provide insight into the effect of doubling the rate of settling or increasing it by approximately an order of magnitude while staying within the theoretical maximum of 200 m/day. If the model showed the additional settling representing the ribbed mussel filtering had no impact on percent attainment of water quality criteria, then the concept of using ribbed mussels could be discarded. If the model showed the potential for improved attainment, then the concept could move forward. The impact was assessed on the existing Class I water quality criteria for bacteria (fecal coliform monthly geometric mean (GM) less than or equal to 200 cfu/100mL), For informational purposes, the impact was also assessed on a 90-day *Enterococci* GM of 35 cfu/100mL and a 90-day, 90^{th} percentile statistical threshold value [STV] for *Enterococci* of 130 cfu/100mL). *Enterococci* criteria are not applicable to Bergen and Thurston Basin.

The results of the model sensitivity analyses are presented in Table 1. As indicated in Table 1, the model sensitivities showed that ribbed mussels could be effective in reducing bacteria concentrations and improving the percent attainment with GM concentration bacteria water quality criteria. The additional settling had no impact on 90^{th} percentile STV criteria attainment. However, due to the uncertainties in the calculations, and since no data were available to confirm the use of an equivalent settling rate to represent the removal of bacteria by ribbed mussels, this methodology was not adopted for the Jamaica Bay and Tributaries LTCP.

Table 1. Calculated 2008 Attainment at BB5 Based on Effective Settling Sensitivities

Criteria	Percent Attainment of Criteria at Station BB5		
	Baseline[(1)]	Additional 5 m/day Settling	Additional 50 m/day Settling
Fecal Coliform Monthly GM (200 cfu/100mL)	50%	58%	100%
Enterococci 90-day GM (35 cfu/100mL)[(2)]	0%	26%	100%
Enterococci 90-day STV (130 cfu/100mL)[(2)]	0%	0%	0%

Notes:

(1) Note the final LTCP baseline was not completed at the time these sensitivities were conducted. Results were based on an earlier baseline configuration, but the relative performance should not be significantly affected.

(2) These criteria do not apply to the tributaries to Jamaica Bay.

The model used in Approach Option 2 was applied to assess what effective settling velocity would need to be assigned in order to achieve a 10 percent reduction in bacteria concentrations under ribbed mussel bed conceptual configurations. Since the model grid cells are larger than the areas proposed for the mussel beds, scale factors based on the ratio of the mussel bed to cell size were applied to the effective settling rates assigned in the model. Additionally, since the basins are deeper than the depths assigned to the mussel beds, and the model contains only one cell laterally across the width of each basin, the impact of the effective settling was generally applied to only one to three bottom layer cells (the model contains 10 layers). One exception is the head end of Bergen Basin, which has essentially the same depth as the mussel bed. Table 2 presents the distribution of where additional effective settling was applied in the model.

Table 2. Ribbed Mussel Configuration in the Model

Ribbed Mussel Placement				Model Cell Dimensions		Fraction of Model Cell Affected by Ribbed Mussels	Model Layer(s) Affected by Ribbed Mussels
Waterbody	Location	Area (acre)	Depth (feet)	Area (acre)	Depth (feet)		
Bergen Basin	Head End	0.45	5	5.15	5.51	0.09	1-10
	Middle	0.85	3	6.05	15.19	0.14	9-10
	Middle	0.85	3	4.94	14.53	0.17	9-10
	Near Mouth	0.42	3	3.77	17.49	0.11	9-10
	Near Mouth	0.97	3	2.91	22.08	0.33	10
Thurston Basin	Near Head End	1.4	5	3.45	18.14	0.41	8-10
	Near Head End	1.6	5	4.03	21.10	0.40	8-10

Once the ribbed mussels were assigned to the appropriate model grid cells, model sensitivity runs were performed to evaluate the additional effective settling rate attributed to the mussels. To simulate a 10 percent reduction in bacteria concentrations, the model sensitivity runs indicate that additional effective settling associated with the ribbed mussels ranged from 5 m/d to 20 m/d. Table 3 presents the results which are based on *Enterococci* concentrations on an annual basis. The reductions were also assessed for wet and dry conditions. Wet conditions were defined as the 24-hr period from the beginning of a precipitation event. The results show that if ribbed mussels can achieve an effective settling rate of between 10 m/d and 20 m/d they can remove 10 percent of the bacteria in Bergen and Thurston Basins on an annual basis. These rates seem achievable based on the theoretical maximum rate of 200 m/d calculated above. The results also show that the ribbed mussels remove a higher fraction of bacteria during dry-weather than wet-weather. This is probably due to the reduced retention time and greater density stratification during wet-weather.

Table 3. Percent of Enterococci Remaining Compared to Baseline with the Addition of Ribbed Mussels

Percentage of Enterococci Remaining Compared to Baseline										
		Effective Settling Rate								
		5 m/d			10 m/d			20 m/d		
Waterbody	Station	All Days	Wet Days	Dry Days	All Days	Wet Days	Dry Days	All Days	Wet Days	Dry Days
Bergen Basin	BB5	95.4	96.8	94.6	91.6	94.3	90.0	85.0	89.8	82.4
	BB6	95.1	95.9	94.7	91.1	92.9	90.1	84.3	87.8	82.4
	BB7	96.1	96.9	95.8	93.2	94.9	92.3	88.1	91.3	86.4
	BB8	97.9	98.1	97.9	96.5	97.0	96.4	94.1	95.1	93.7
Thurston Basin	TBH1	91.5	93.7	90.4	86.4	89.9	84.6	79.9	84.7	77.5
	TBH2	91.9	93.8	90.9	87.0	90.1	85.4	80.8	85.0	78.5
	TB9	95.8	97.1	95.2	93.5	95.6	92.4	90.3	93.6	88.6
	TB10	97.5	98.3	97.2	96.3	97.6	95.8	94.7	96.6	93.8

Approach Option 3 – Simplified Approach Applying a Percent Reduction to Completed Model Results

In order to provide estimates of bacteria concentrations due to the influence of filtration by ribbed mussels that could be included in the LTCP, a simplified and conservative approach was applied. Rather than directly model the effects of ribbed mussels, a percent reduction in bacteria concentration was applied to existing model output to approximate the reduction of bacteria due to filtering. Based on the review of literature referenced above, low end estimates of filtration could justify a 10 percent reduction in bacteria where ribbed mussels would be installed. Model runs were completed using the LTCP preferred alternative conditions, and then a 10 percent reduction of model calculated concentrations in the waterbodies, where the ribbed mussel colonies would be located, was applied as part of post-processing the model output to represent the impact of the ribbed mussel colonies.

The succeeding description outlines the completed research and intended experiment design to further test the efficiency of ribbed mussel filtration capacities. It is anticipated that the proposed experiments will provide supporting data to demonstrate that the 10 percent reduction in bacteria assumed for by the LTCP performance is conservative and can likely be exceeded with the proposed installation. The discussion focuses specifically on:

- A completed literature review that show cases filtration capabilities supporting the assumed level of bacteria reduction.
- Completed initial bench-scale experiments that confirm the literature review.
- Proposed lab and *in-situ* experiments of increasing complexity, simulating the conditions of Bergen and Thurston Basins, to inform the design of full-scale engineering application.
- Timeframes and milestones for completing proposed experiments, culminating in the submittal of an approvable engineering report.
- Cultivation techniques that were studied and partnerships that were secured with multiple hatcheries for spawning large mussel populations.

Literature Review

DEP has completed a literature review to explore and confirm the water filtration capabilities of ribbed mussels. Papers that were referenced include research studies on the general biology and ecology of ribbed mussels and other similarly functioning bivalves, filtration capabilities that focused on bacteria uptake, and aquaculture techniques for spawning mussels. General takeaways from the compilation of this research show the *extensive filtration capabilities of ribbed mussels, pointedly to their abilities to filter smaller particle sizes in the range of fecal coliform,* and these studies would be used to direct a series of lab experiments to inform the ultimate design of the proposed deployment. Between the compilation of literature and results of preliminary bench-scale testing, the City believes that *a 10 percent removal efficiency is a conservative estimate* and is eager to explore the range of possibilities of this biofiltration system.

An extensive array of research literature exists focusing on the ecological role of the ribbed mussel. To contextualize this data within the localities of interest, DEP reviewed several papers that examined ribbed mussel populations in Jamaica Bay (Franz, 1993, 1997, and 2001) and in a subtidal setting in the Bronx River Estuary at Hunts Point (Galimany et al., 2013a and b, 2017), another highly eutrophic, urban waterbody. The natural presence of the mussel populations in these waterbodies, combined with the aforementioned studies, *demonstrate the suitability of the proposed waterbodies to accommodate the large-scale engineering application of ribbed mussels.*

A few notable studies have been conducted that look specifically at the filtration of bacteria by ribbed mussels. Based on these papers, (Kemp et al., 1990; Langdon and Newell, 1990; Newel and Krambeck, 1995; Riisgard 1988; and Wright et al., 1982) it has become accepted that ribbed mussels are capable of filtering out smaller particles (<2µm) with greater efficiency than other species such as oyster and clam, with *efficiency rates as high as 86 percent* (Wright et al., 1982) also analyzed the gill structure of ribbed mussel in comparison with other bivalve species and inferred that the structural differences are what enables the ribbed mussel to filter out particles as small as 0.2µm in size. Kemp et al. (1990) looked at the ranges of mussel size classes and how their filtration rates changed in response to different particle size. Other studies, as noted above, also corroborated the findings of Wright et al. and examined how the bacteria were being removed by the ribbed mussel. A table of particle sizes and associated efficiency rates for various studies can be seen below in Table 4. These studies are invaluable in demonstrating the efficacy of ribbed mussels in the proposed application and will help to form the design of microcosm bench-top testing, mesocosm lab testing, the *in-situ* pilot study, and the full-scale engineering application.

Table 4. Filtration Efficiency Rates of Specific Particle Sizes from Literature Review

Reference	Particle Size(1)	Efficiency
Langdon & Newell (1990)	< 2 µm	15.8%
Newell & Krambeck (1995)	Not specified	30-35%
Riisgard (1988)	2 µm	70%
Wright et al (1982)	0.2-0.4µm	30%
	0.4-0.6µm	86%

Note:
(1) For comparison, *E. coli* ranges in size from 1-3 µm and Enterococcus ranges in size from 1-2.5 µm.

A study by Bernard (1989) was influential and informative as it studied metrics and variables that were directly related to preliminary bench-scale testing completed in a joint effort by Cornell Cooperative Extension (CCE) and Stony Brook University (SBU). Bernard looked at the capabilities of various species of bivalve in filtering *E. coli* specifically, and included water temperature as a variable to observe the trends of filtration. It is important to note that while this west-coast study was conducted with bivalves native to the Pacific Northwest including the blue mussel, *Mytilus edulis*, the research of Wright et al. (1982) documented that the ribbed mussel gill structure has a greater density of gill filaments than the blue mussel and is likely to filter out *E. coli* more effectively.

The compilation of these studies serves to confirm that *ribbed mussels have been looked to as an efficient and effective biofiltration method for decades* and infers that filtration rates could far exceed what has been displayed in deployments of other bivalve species in similar efforts. These studies have informed and propelled the next step of lab testing that will be used to design the full-scale engineering application of ribbed mussels in Thurston and Bergen Basins.

Completed Laboratory Experiments

A multi-phased approach has been proposed to further the study of water filtration with ribbed mussels and inform the design of the full-scale engineering application; initial bench-scale testing has already been completed.

The initial bench-scale experiments focused on determining the filtration of *E. coli* bacteria by the ribbed mussel using small-scale laboratory experiments to identify baseline levels of clearance rates. Once prepped, a single mussel was suspended in 12 separate, two liter replicate beakers containing 1600 mL of filtered and sterilized seawater. Two additional treatments were tested as controls: (A) live ribbed mussel with no bacteria to provide a reference for filtration capabilities and test whether or not natural levels of bacteria may have been introduced by the ribbed mussels themselves; and (B) empty ribbed mussel shell with the same bacterial introduction as the experimental beakers to identify whether or not the bacterial loads and microcapsule concentration in experimental containers change over time as a result of particle settling and bacteria natural multiplication or decay, if any. Each experiment ran for six hours after a brief acclimation period for the live mussels.

The design of the initial bench-scale experiments was set up in a way to isolate and capture the experience of (1) a pulsed addition of bacteria (to simulate a CSO flow), (2) a constant flow of bacteria (to simulate normal tidal flow), and (3) the combination of constant flow and pulsed bacteria. This last experiment's settings most closely mimic the relationship of mussels and bacteria in the vicinity of a CSO outfall. The results of these experiments displayed *E. coli* removal efficiency rates at 88 percent for experiment (1), and 62 percent for experiments (2) and (3). While this testing was acknowledged by all to be a preliminary, isolated experiment without hydrodynamic engineering controls, it served to confirm the impressive filtration capabilities of these bivalves and verify some of the filtration efficiencies as per the literature on similarly sized particles in the range of fecal coliform (<2 µm). With the acknowledgement of the contact time and other variable distinctions between bench-top testing and the full-scale engineering application, *the 62-88 percent removal efficiency results far exceed the 10 percent removal efficiency that was proposed as part of the Jamaica Bay and Tributaries LTCP.* This experiment also provided a baseline framework to move forward with further experiments that include the addition of a host of variables that are key physical and biological components of the proposed field setting.

Discussion of Scale-Up Strategies

As highlighted by DEC, "the City needs to include a plan to undertake a series of experiments and studies that will gradually build upon each other and establish a solid basis for the design of a full-scale engineering application of ribbed mussels for improving water quality in Bergen and Thurston Basins." Accordingly, DEP proposes a comprehensive series of experiments guiding the scale up towards a full-scale deployment of ribbed mussels in Bergen and Thurston Basins. These series of experiments consist of additional microcosm experiments (bench-top tests), mesocosm experiments to simulate field conditions, and an *in-situ* pilot study. Throughout this process, DEC will be briefed on the results of each phase and suggest edits before proceeding to the next phase of research. Data and results gathered from these studies will be used to shape the design of the full-scale engineering application. Figure 1 presents the overall plan, sequencing, and expected outcomes from the laboratory to the field. *Throughout this process, regular meetings and workshops will be scheduled with interested stakeholders and DEC so that decisions can be made collaboratively.*

Microcosm Bench-Top Experiments

Additional microcosm experiments would be conducted prior to and in concurrence with mesocosm experiments to study the effects of individual variables on the filtration capabilities of ribbed mussels (see Table 5). These variables include:

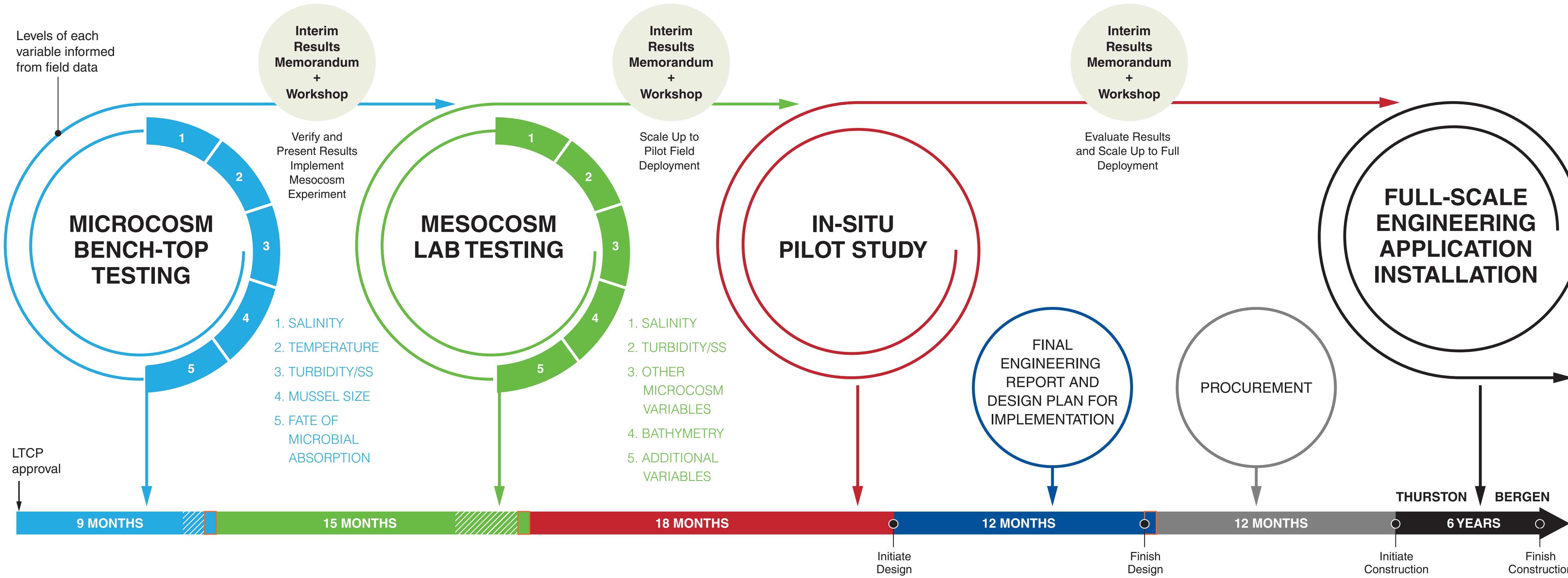
1. salinity
2. temperature
3. turbidity
4. mussel size
5. fate of microbial absorption (composition of feces and pseudofeces for *E. coli* assimilation)

Scale-Up Strategies For Full-Scale Engineering Application of Ribbed Mussels

DEP is proposing a comprehensive series of experiments guiding the scale up towards a full-scale engineering application of ribbed mussels in Bergen and Thurston basins. Periodic workshops would be held, concurrent with the studies, throughout the entire timeline.

Development of Interim Results Memorandum

DEC Review of Memorandum



MICROCOSM

- Purpose of Microcosm (lab) experiments is to study the effects of individual variables on the filtration efficiency of ribbed mussels.
- Test individual variables in isolated setting.
- Will inform design of Mesocosm experiments.

MESOCOSM

- Establish the flowrates and retention times to replicate the bathymetry and hydrodynamics of Bergen/Thurston basins.
- Vary the salinity and turbidity to emulate the ambient and CSO events to inform the placement of mussels.

IN-SITU

- Will take results of Microcosm and Mesocosm experiments and will verify filtration rates in similar site conditions (including all environmental/water quality variables).
- Additionally, mussels will be installed in cages to document the adaptability, recruitment, and mortality within Bergen and Thurston basins.

FINAL ENGINEERING REPORT

- Detailed engineering report will document the basis for the design of the full scale application.
- Will include refined projected water quality improvements.
- DEC will review the report prior to procurement phase.

INSTALLATION

- Mussels will be installed in stages throughout the six years, achieving the full complement of mussels by the end of the proposed timeline.
- Thurston Basin will be completed first, followed by Bergen Basin.

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Figure 1

Each of these variable parameters would be determined by site conditions at Bergen and Thurston Basins. To start, three-to-four levels of each variable would be tested to determine if a strong correlation appears between the variable and mussel filtration rates (see Figure 2). Levels of dissolved oxygen will also be measured at the beginning and end of each experiment. For any variables that could be altered through the design of the full-scale engineering application, a feedback loop would be established to determine if additional levels should be tested at the microcosm scale. Bacterial strains introduced in the microcosm experiments will include *Escherichia coli* (*E. coli*) at a concentration of 25,000 cfu/mL and a lab-safe strain of *Enterococcus faecalis* at a concentration of 8,000 cfu/mL.

Table 5. Microcosm Experiment Variables and Implications

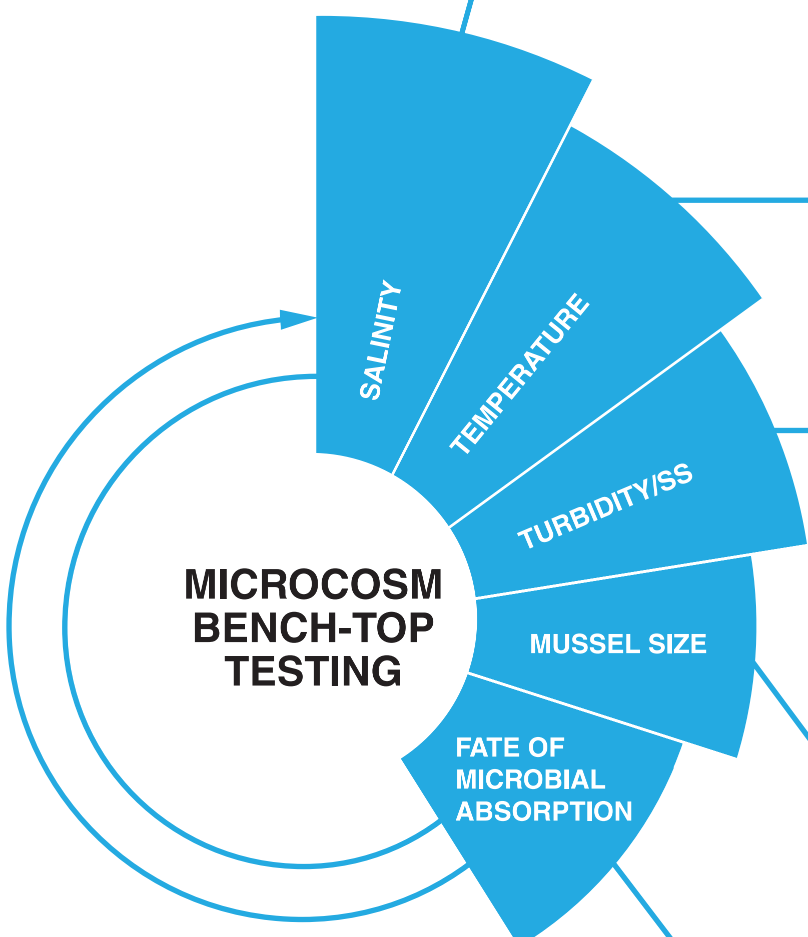
Microcosm			
Parameter	**Variables**	**Implications**	**Impact Design? (Full-scale engineering application)**
Salinity	5 ppt	Define lower limit efficacy and establish efficiency pattern	Yes
	12.5 ppt		
	20 ppt		
	25 ppt (stable concentration)		
Temperature	15˚C	Define lower limit efficacy and establish efficiency pattern	No
	21˚C		
	24˚C (stable temperature)		
	28˚C		
Turbidity/SS	3 levels representing the range as informed by survey data	Define upper limit efficacy and establish efficiency pattern	Yes
Mussel Size	30mm	Establish mussel size in relation to particle size filtration and efficiency	Yes
	50mm		
	70mm		
Fate of Microbial Absorption	None	Will speak to feasibility of experiment	No

1. **Salinity** - Tests would be designed using three levels informed by field data that capture salinity concentrations that would be lowered, as it would follow a CSO event both close to the outfall and further out in the basin, and would be complemented by the average salinity of the basin during the recreational season (May 1st to October 31st) as a point of comparison. Results of these tests would aid in the determination of the ideal placement of the full-scale engineering application in regards to distance from the CSO outfall and the anticipated physiological response of the ribbed mussels.

Microcosm Bench-Top Experiments

MICROCOSM MESOCOSM IN-SITU

Microcosm experiments will be conducted to study the effects of individual variables on the filtration capabilities of ribbed mussels in a laboratory setting. Each of these variable parameters would be determined by site conditions at Bergen and Thurston basins.



FACTORS	SAMPLES	RESULTS
SALINITY Expect that this could be a significant factor, which would affect placement and engineering applications for field deployment	• 5 ppt • 12.5 ppt • 20 ppt • 25 ppt	Define lower limit efficacy and establish efficiency pattern → MESOCOSM LAB TESTING
TEMPERATURE Not expected to be a significant factor, however, at lower temperatures the filtration efficiency may be reduced. Establish performance under range of ambient temperatures capturing the recreation season.	• 15°C • 21°C • 24°C • 28°C	Define lower limit efficacy and establish efficiency pattern → MESOCOSM LAB TESTING
TURBIDITY/SS Define impact of turbidity/ss on ribbed mussel filtration efficiency. Identify any upper thresholds that render the filtration ineffective. The results from this would inform the placement and design of the full-scale deployment.	• 3 levels representing range as informed by survey data • Will study the sensitivity towards different ratios of organic and inorganic particulate matter	Define upper limit efficacy and establish efficiency pattern → MESOCOSM LAB TESTING
MUSSEL SIZE Will only govern how we will deploy mussels. Three specific sizes tested at microcosm scale	• 30mm • 50mm • 70mm	Establish mussel size in relation to particle size filtration and efficiency → MESOCOSM LAB TESTING
FATE OF MICROBIAL ABSORPTION Will speak to feasibility of the proposed full-scale deployment and will inform the modeling of water quality benefits. Will only be tested in microcosm.		

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2. **Temperature -** Tests on temperature would include levels informed by data gathered from Bergen and Thurston Basins isolated to include only logged temperatures during the recreational season (May 1st to October 31st). While the results of this experiment would not affect the overall design of the full-scale engineering application, the variable temperature experiments would enhance the resolution of expected efficiency rates, which are expected to be above the 10 percent removal rate.

3. **Turbidity** – The experiments would also include survey-data informed levels but would be further broken down to isolate different combinations of turbidity particulate matter. Different mixes of organic and inorganic suspended solids will be tested, as it is understood that every CSO flow is unique. The results from this experiment will define the upper limit efficacy of the ribbed mussels in response to a turbid CSO flow and would inform the ideal distance from the outfalls of the full-scale design in both basins.

4. **Mussel Size -** Three different mussel sizes would be tested at the microcosm scale to determine the overall filtration capacities of mussels at different life stages. It is also expected that smaller sized mussels are capable of filtering smaller particulate matter due to their gill structure, so these experiments would serve to further that understanding. The results of these experiments would implicate the design of the full-scale engineering application in facilitating the stage at which the mussels would be moved from the hatcheries to the field site.

5. **Fate of microbial absorption -** Microcosm bench-top experiments would also be conducted to look at the fate of microbial absorption. While this test would not hold implications for the design of the final engineering application, it is necessary in understanding the cycle and final fate of the bacteria, and would address the feasibility of the overall experiment and guide the subsequent larger-scale experiments.

After the completion of microcosm bench-top experiments, a detailed report including an analysis of results will be prepared to provide the basis of design for the mesocosm experiments. A workshop will also be scheduled to discuss results and strategy with DEC and other stakeholders. It is expected that further resolution may be needed for specific parameters that would weigh heavily on the design of the full-scale engineering application. As needed, these additional microcosm experiments will be conducted simultaneously with mesocosm experiments.

Mesocosm Experiments

Once the preliminary results of the microcosm tests are produced, the mesocosm experiments would be carried out. Designs for a large, custom-built mesocosm setup are progressing and include features such as bathymetry, flow rates, and retention times all scaled proportionately from data gathered at Bergen and Thurston Basins. 3D printing options based on NOAA navigational charts are being considered to accurately capture cross sections of the bathymetry of each basin. Experiments in the custom-built, flume system would involve multiple key variables at levels informed from microcosm results.

The purpose of these mesocosm tests is to develop specific design parameters by isolating independent variables in a laboratory setting. As the middle step of the scale-up strategy, these experiments will bring the field conditions into the laboratory. Data from Bergen and Thurston Basins will be run through existing engineering models to develop the flow rates and retention times that will be represented in the mesocosm set up. Ultimately, as discussed in the following scale-up step, these experiments will be replicated in the *in-situ* pilot study to verify the results in the actual field conditions.

As seen in Figure 3**,** mesocosm experiments would be carried out in three rounds, first to expose the microcosm variables in conjunction with the site-specific bathymetry while varying the retention times and flow rates. The retention times and flow rates would be developed using existing models and data to map the hydrodynamics of Bergen and Thurston Basins. The next mesocosm experiment would keep the retention times and flow rates constant while varying the turbidity and salinity. Isolating these parameters would determine the expected efficacy and efficiency at the flow rates and retention times during ambient and CSO events, and would hold valuable information for the design of the full-scale engineering application, which could be widely varied based on its placement in each basin. The third round would include testing the positioning of mussels in different locations and physical orientations in the modeled systems to optimize bacterial uptake under the replicated hydrodynamics of Bergen and Thurston Basins.

Again, similar to the completion of the microcosm bench-top testing, a detailed analysis report will be prepared to present the findings from the mesocosm experiments and discuss how they will impact the full-scale engineering application of ribbed mussels in Bergen and Thurston Basins. A workshop will also be conducted with DEC and other stakeholders to inform the implementation of the *in-situ* pilot testing and the full-scale engineering application.

In-situ Pilot Study

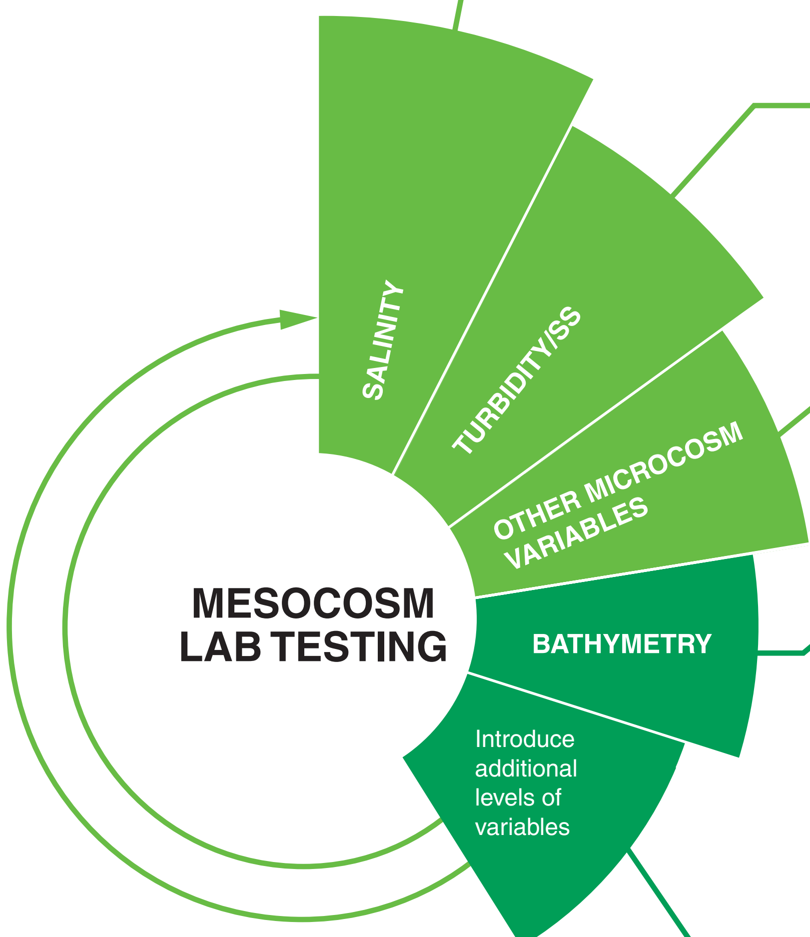
The next phase of experimental testing toward final design would be to design an *in-situ* pilot study (see Figure 4). The primary objective of the *in-situ* pilot study would be to replicate and verify the filtration rates and bacterial removal rates achieved in the mesocosm (lab) testing in Bergen and/or Thurston Basins. Based on the prior mentioned literature review, experimental flow-through systems or other similar installations will be evaluated to isolate the inflow and outflow to test for removal efficiency and would include parallel setups within the aforementioned basins, as well as control setups with no mussels. These parallel setups with isolated inflow and outflow would provide verifiable results and a much better understanding of the quantifiable water quality benefits that can be scaled up to represent the full-scale engineering application. Additionally, individual groups (lots) of mussels with varying ratios of juveniles to adults would be installed in cages, or other structures as deemed appropriate, and best for the practice to document adaptability and examine recruitment and mortality trends within Bergen and Thurston Basins. *These in-situ pilot studies, planned in either Bergen or Thurston Basins, would provide real-world simulations and would allow the testing of different locations and strategies for the full-scale engineering application.* This would also finalize the design basis and document the various environmental factors that would be considered and addressed as part of the full-scale engineering application.

Throughout all testing on ribbed mussels, regular meetings between DEP and DEC would allow for informed decision making and collaborative progression of the proposed project.

Mesocosm Laboratory Experiments

MICROCOSM MESOCOSM IN-SITU

Using the results of the microcosm laboratory experiments, these tests will expose the ribbed mussels to modeled conditions replicating the conditions at Bergen and Thurston basins.



FACTORS	ROUND 1	ROUND 2	ROUND 3
SALINITY Use conditions as defined by the microcosm experiments.	Constant	Vary	Constant
TURBIDITY/SS Will experiment with implementing a quick onset of high suspended solids to simulate CSO flow conditions to understand the length of time the mussel filtration ability is lessened.	Constant	Vary	Constant
OTHER MICROCOSM VARIABLES Use conditions as defined by the Microcosm experiments for other variables such as temperature and mussel size.	Constant	Constant	Constant
BATHYMETRY Will be a constant throughout experiment. Will use NOAA navigation charts and potentially 3D print technology to replicate the waterbody bathymetry.	Scaled Representation	Scaled Representation	Scaled Representation
FLOW RATE Based on field data replicating the hydrodynamics of the waterbodies.	Vary	Constant	Constant
RETENTION TIMES Based on field data replicating the hydrodynamics of the waterbodies.	Vary	Constant	Constant
PHYSICAL PLACEMENT/ ORIENTATION OF MUSSELS Will experiment with orientation of mussels within the waterbody using the scaled simulation.	Constant	Constant	Vary

RESULTS

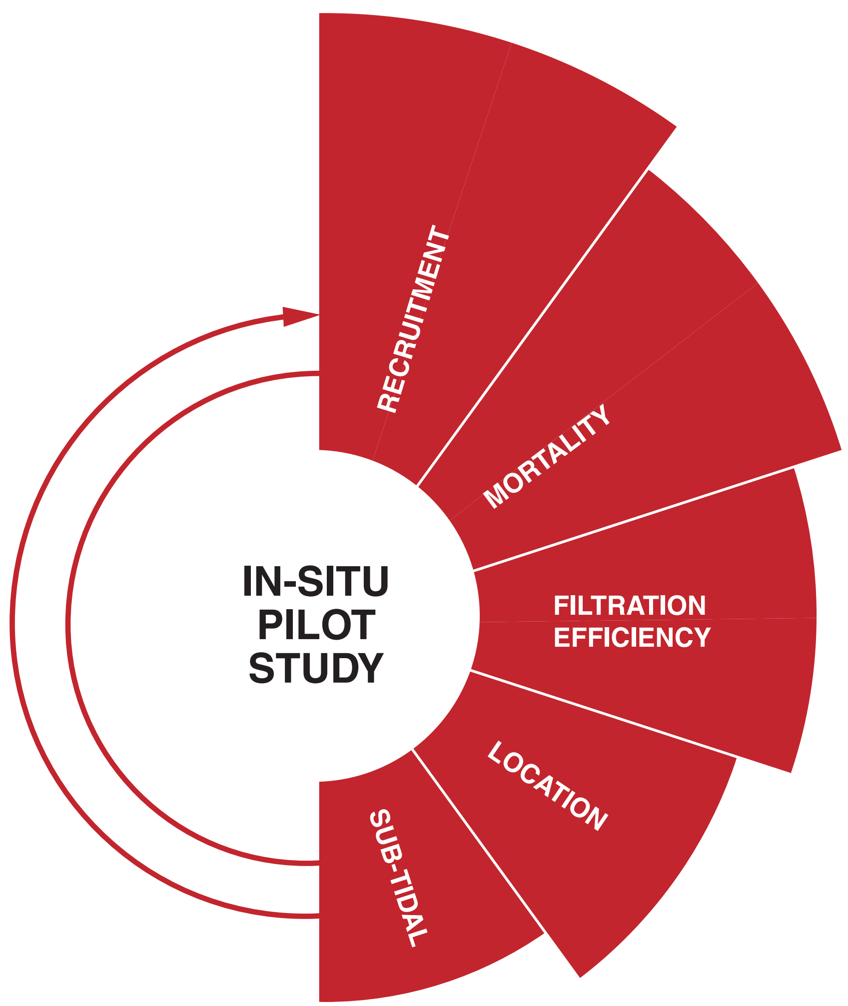
- We will establish the flowrates and retention times to simulate the conditions in Bergen and Thurston basins.
- We will verify the efficiencies at the various flowrates and retention times.
- Following that we will also vary the turbidity and salinity to simulate the time variable patterns incorporating the hydrodynamics in the basins.
- We shall use the existing models and data to inform the experimental parameters.
- We will bracket the location range for deploying mussels within the water column.

IN-SITU PILOT STUDY

In-Situ Pilot Study Experiments

MICROCOSM MESOCOSM IN-SITU

This phase of experimental testing towards final design would be to conduct in-situ testing using an experimental flow-through system installed in the waterbodies to verify the filtration and removal efficiencies.



- Will take results of micro and mesocosm experiments and will test filtration rates in site-specific conditions (all environmental/water quality variable combined).
- Will be done in limited areas of basin (one or both). At this point we will have a good understanding of expected results based on prior two phases, then in-situ serves as a check to the prior experiments

Planning and Design for Full-Scale Development

Key design parameters for the full-scale engineering application would be informed by all prior experiment phases, as described above. Additionally, variables such as filtration capacity in relation to mussel size and mussel survivability will be explored to have a firm understanding of what maintenance and operations would be required once installation is complete. Concerns regarding bird attraction would be eliminated through the use of a subtidal deployment, which as an added benefit would maximize the effectiveness of filtration, both during CSO events and in ambient conditions. The subtidal deployment strategy will continue to be used at the mesocosm scale, so results gathered from that phase of testing and replicated in the *in-situ* pilot will properly inform the full-scale engineering application. This will be achieved by using a similar channel flow system design that was used in a previous DEP experiment with oysters to determine nitrogen uptake using fluorometry measurements. As for options for housing the mussels, plastic mesh bags, oyster cages, and gabion cages are being explored and our recommendations will be documented in the approvable engineering report. Navigation issues and hazards will be evaluated as part of the design as needed.

The sizing of the mussel beds was developed using the information from the existing hydrodynamic model of Jamaica Bay and its tributaries (provided by HDR) on the volume of water that is exchanged within each basin for each tidal cycle. Knowing that volume for each tidal exchange and the filtering capacity of a single adult mussel to be 5.1 L/hour and assuming a medium-low density of 2,000 mussels per square meter produces the calculated number of acres needed to filter that entire water volume. It is important to note that the density of mussels in Jamaica Bay can reach 10,000 mussels per square meter, so 2,000 mussels per square meter is a very reasonable density.

$$\text{1 Mussel Filtration Capacity} = \frac{5.1\,L}{1\,hour} = \frac{61.2\,L}{\substack{Tidal\ Cycle \\ (12\ hours)}} \rightarrow \frac{3{,}000{,}000{,}000\,L\ (apprx.)}{\substack{Tidal\ Cycle \\ (Bergen\ and\ Thurston\ Basins)}} \approx \text{50,000,000 mussels}$$

$$50{,}000{,}000\ mussels\ \div\ \frac{\substack{2{,}000\ mussels \\ (med - low\ density)}}{1\ sq\ meter} = 25{,}000\ sq\ meters\ \approx\ 6.2\ acres \rightarrow\ rounded\ to\ 7\ acres$$

Following the interim results memoranda from the experimental phases, the estimated pathogen removal efficiencies will be refined. The initial 10 percent removal efficiency rate has been informed from multiple factors. First, as the mussel installations would be subtidal, the contact time of the bivalves would be 100%. Second, the number of mussels for the full-scale deployment was calculated to filter the full tidal cycle of Bergen and Thurston Basins. And lastly, these details, paired with the literature review showing removal efficiency rates up to 86 percent, informed the decision of the conservative 10 percent removal efficiency rate. Furthermore, the final engineering report and design plan will include a knee-of-the-curve analysis to provide the highest water quality benefit with the lowest cost. Assuming the described experimental phases will serve to prove that ribbed mussel filtration rates are above 10 percent, this analysis will be used in consultation with DEC to inform the optimum number of mussels and their associated acreage for the deployment.

Timeframes and Milestones

The proposed timeline begins with the approval of the LTCP and ends with the full complement of mussels installed for the full-scale engineering application. First, microcosm bench-top testing would be initiated. This experiment phase would be carried out over a period of 9 months. The final month of the microcosm bench-top tests would be dedicated to producing an interim results memorandum, which would be disseminated to DEC and other stakeholders. Next, the mesocosm lab testing would be carried out over a period of 15 months, with an interim results memorandum produced in the final three months. The *in-situ* pilot study would follow and is expected to be carried out over 18 months. Following the *in-situ* pilot study, a detailed engineering report will be developed and DEP will initiate procurement prior to the start of construction. The report, produced over the course of 12 months, would document the basis for the design of the full-scale application along with projected water quality improvements. Construction procurement will be initiated following the DEC approval of the engineering report. The remaining six years would then be utilized for installation and deployment of the ribbed mussels for the full-scale engineering application. Installation would occur first in Thurston Basin, followed by Bergen Basin. Mussels would be installed in stages throughout the six years, ultimately achieving the full complement of mussels by the end of the proposed timeline.

The milestone of initiating design would officially begin at the completion of the *in-situ* pilot study; however, preliminary designs have already commenced following the completion of initial bench-scale experiments. The final engineering design will be completed with the delivery of the final engineering report, and construction will be initiated following procurement. These schedule milestones are presented in Figure 1. Concurrent with the studies, periodic workshops would be held quarterly, or as needed, with DEC and other stakeholders.

The full engineering design report will document the results of all experiments. Based on these results it will provide a basis of design including a set of input design parameters, detailed description of all environmental factors and a schedule of implementation for the full-scale engineering application. The design report will also include the projected water quality benefits for the full-scale application and document the mussel procurement and culturing strategy to reach the desired mussel numbers for the full-scale engineering application.

Initiatives for Culturing and Procuring Large Ribbed Mussel Populations

DEP agrees with DEC that the first key step is developing a reliable method for culturing the mussels. Accordingly, Cornell Cooperative Extension (CCE) and Stony Brook University (SBU) scientists have been developing methodologies on large scale cultivation techniques to ensure adequate stock is available per the proposed installation schedule. The research team will be refining multiple annual spawning cultivation techniques at CCE's hatchery, while simultaneously engaging other hatcheries in conversation on a collaborative spawning effort. In addition, CCE's newly constructed hatchery in Southold will enable for mass production of ribbed mussels once the cultivation techniques have been optimized. To achieve the full required population of ribbed mussels for the full-scale engineering application, a ramping-up strategy would be utilized where mussels would be installed in stages over the course of several years. This strategy is beneficial in many ways as it maximizes available square footage devoted to mussel cultivation at the participating hatcheries, diversifies the sizes of mussels in the field, and it allows for mussel recruitment. Additionally, this technique will provide a production buffer in case small numbers of larvae are produced from each spawn. The approach outlines the potential for consistent spawning to provide continuous batches for production.

Collaborations with other hatcheries have already been established and these partnerships would allow for exponential spawning growth opportunities, as needed. They include the Aquatic Innovation Center (AIC) at Rutgers University and Martha's Vineyard Shellfish Group. Canvassing of additional facilities is ongoing, and the collection of partnerships is expected to produce an adequate supply of ribbed mussels for the proposed full-scale deployment. Some of the additional hatcheries include the Aquatic Research and Environmental Assessment Center (AREAC) at Brooklyn College, Roger Williams University in Rhode Island, and the Aquaculture Research Corporation in Massachusetts.

In summation, DEP has undertaken a significant effort to showcase the significant filtration capacity of ribbed mussel populations and is confident in the applicability of the proposed full-scale engineering application in reducing a conservative 10 percent of bacterial concentrations in Bergen Basin and Thurston Basin. DEP looks forward to frequent communication and requests for feedback from DEC throughout the proposed experiment and design process.

Conclusions

The installation of ribbed mussels as a bioextraction method has good support in literature and preliminary bench-top testing. Ribbed mussels have high filtration rates and are more efficient than other bivalves at filtering small particles. In addition, they are native to Jamaica Bay and would not be considered an attractive nuisance since they are not consumed by humans. Modeling suggests that the placement of ribbed mussels in waterbodies with high bacteria concentrations would be effective in reducing bacteria concentrations and would improve attainment with water quality standards. As CSO and stormwater flows in these tributaries are anticipated to change over the coming decades, the application of ribbed mussels represents an adaptable method of improving water quality. The literature review and preliminary bench-top testing indicate that it is reasonable to apply a 10 percent reduction to the modeled bacteria concentrations in Bergen and Thurston Basins to account for the placement of ribbed mussels in those Jamaica Bay tributaries. This approach is the basis for the performance of the ribbed mussel colonies presented in the Jamaica Bay and Tributaries LTCP. The additional studies and analyses presented in this appendix will provide further support of the design and performance of the ribbed mussel colonies.

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Attachment K
Appendix H – Sensitive Areas Analysis

Appendix H: Sensitive Area Analysis

Introduction

The Jamaica Bay and Tributaries Long Term Control Plan (Jamaica Bay LTCP) is being prepared by the New York City Department of Environmental Protection (DEP) in furtherance of the water quality goals of the Federal Clean Water Act and the State Environmental Conservation Law. The Jamaica Bay LTCP will evaluate water quality improvement projects, consisting of both grey and green infrastructure, which will build upon the implementation of the U.S. Environmental Protection Agency's (EPA) Nine Minimum Controls and the existing Waterbody/Watershed Facility Plan (WWFP) projects.

Federal CSO Policy requires that the LTCP give the highest priority to controlling overflows to Sensitive Areas (USEPA, 1995). The Policy defines Sensitive Areas as:

1. Designated Outstanding National Resource Waters (ONRW)
2. National Marine Sanctuaries
3. Waters with threatened or endangered species and their habitat
4. Waters with primary contact recreation
5. Public drinking water intakes and their designated protection areas
6. Shellfish beds

This Sensitive Areas evaluation includes an analysis of Jamaica Bay (Figure 1).

Assessment of Sensitive Areas

Information and data regarding Sensitive Areas within Jamaica Bay were obtained via online websites, databases, and consultations with regulatory agencies. The following sources were used to compile information on the presence of Sensitive Areas located within the project area:

- United States Fish and Wildlife Service
  - Information for Planning and Consultation (IPaC) database search
- National Oceanic and Atmospheric Association
  - Section 7 (threatened and endangered species) mapper
  - 2016 Environmental Sensitivity Index Maps
- United States Environmental Protection Agency
  - Outstanding Natural Resource Waters
- Office on National Marine Sanctuaries
- New York State Department of Environmental Conservation
  - Natural Heritage Program for State listed threatened and endangered species and critical habitat
  - Environmental Resource Mapper

A complete list of sources used to obtain information on Sensitive Areas can be found in the References section.

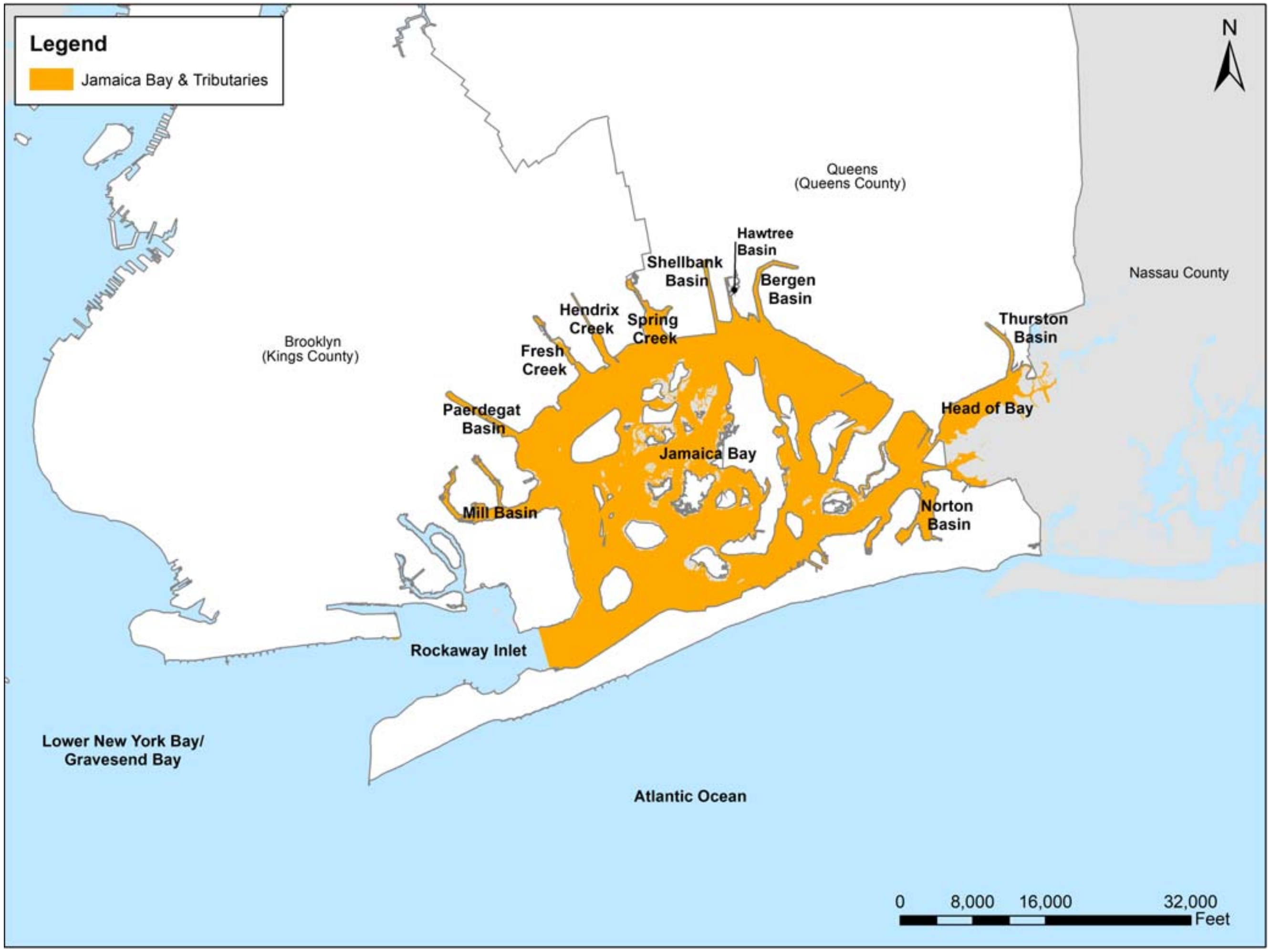

Figure 1. Waterbodies Included in the Jamaica Bay LTCP

Designated Outstanding National Resource Waters

Under the Clean Water Act, Outstanding National Resource Waters (ONRW) are provided Tier 3 level protection by the USEPA's Anti-degradation Policy whereby only minor and temporary decreases in water quality are allowed. Only waters of "exceptional ecological significance" qualify for designation as ONRW and States and Tribes are the responsible parties for determining whether a water body is classified as an ONRW. The USEPA does not list any ONRW within or adjacent to Jamaica Bay. In addition, the DEC Protection of Waters Program and Environmental Resource Mapper do not list any ONRW within or adjacent to the Jamaica Bay project area.

Office of National Marine Sanctuaries

The Office of National Marine Sanctuaries (ONMS), part of the National Oceanic and Atmospheric Administration (NOAA), manages a national system of 14 underwater-protected areas. Since 1972, the ONMS has worked cooperatively with the public and federal, state, and local officials to promote conservation while allowing compatible commercial and recreational activities. Increasing public awareness of our marine heritage, scientific research, monitoring, exploration, educational programs, and outreach are just a few of the ways the ONMS fulfills its mission to the American people.

Sanctuaries are established to protect areas that encompass unique or significant natural and cultural features. The primary objective of the program is to protect the natural and cultural features of the sanctuary while allowing people to use and enjoy the ocean in a sustainable way. Local, state, and federal agencies may have overlapping regulations or other management authorities aimed at protecting specific marine resources. However, no other federal agency is directly mandated to comprehensively conserve and manage special areas of the marine environment like the ONMS. Coordination and cooperation among the responsible government agencies is key to successful sanctuary management.

There are no National Marine Sanctuaries located within or adjacent to Jamaica Bay.

Waters with Threatened or Endangered Species and Their Designated Critical Habitat

The Federal CSO Policy states that waters with threatened or endangered species or their designated critical habitat are considered a Sensitive Area (USEPA, 1995). Information on federally listed threatened and endangered species and their designated critical habitat was obtained through online database searches of the USFWS and the NOAA. The USFWS' Information for Planning and Consultation (IPaC) web site identified six (6) threatened or endangered species within Jamaica Bay (Table 1). NOAA's Endangered Species Act Section 7 Mapper for the Greater Atlantic Region identified six (6) threatened or endangered species within Jamaica Bay (Table 2).

Information on New York State listed threatened and endangered species and significant natural communities was obtained through a formal request for information to the DEC's New York Natural Heritage Program (NYNHP). The response from NYNHP identified twenty-two (22) threatened or endangered species within the Jamaica Bay project area (Table 3). The NYNHP also identified two significant natural communities within Jamaica Bay project area (Table 4). The information provided by the NYNHP includes records from their database. Further information from on-site surveys or other sources may be required to fully assess biological resources depending upon the nature of alternatives proposed in the Jamaica Bay LTCP and site-specific conditions.

Table 1. USFWS Listed Threatened and Endangered Species with the Potential to Occur in Jamaica Bay

Common Name	Scientific Name	Federal Status	Critical Habitat Present within Project Area
Birds			
Piping Plover	*Charadrius melodus*	Threatened	No
Red Knot	*Calidris canutus rufa*	Threatened	No
Roseate Tern	*Sterna dougallii dougalli*	Endangered	No
Mammals			
Northern Long-eared Bat	*Myotis septentrionalis*	Threatened	No
Plants			
Sandplain Gerardia	*Agalinis acuta*	Endangered	No
Seabeach Amaranth	*Amaranthus pumilus*	Threatened	No

Table 2. NOAA Listed Threatened and Endangered Species with the Potential to Occur in Jamaica Bay

Common Name	Scientific Name	Federal Status	Critical Habitat Present within Project Area
Fish			
Atlantic Sturgeon	*Acipenser oxyrhynchus oxyrhynchus*	Endangered	No
Shortnose Sturgeon	*Acipenser brevirostrum*	Endangered	No
Reptiles			
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Endangered	No
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	No
Green Sea Turtle	*Chelonia mydas*	Threatened	No
Loggerhead Sea Turtle	*Caretta caretta*	Threatened	No

Table 3. NYNHP Listed Threatened and Endangered Species with the Potential to Occur in Jamaica Bay

Common Name	Scientific Name	State Status
Birds		
Peregrine Falcon	*Falco peregrinus*	Endangered
Piping Plover	*Charadrius melodus*	Endangered
Northern Harrier	*Circus hudsonius*	Threatened
Upland Sandpiper	*Bartramia longicauda*	Threatened
Short-eared Owl	*Asio flammeus*	Endangered
Common Tern	*Sterna hirundo*	Threatened
Least Tern	*Sternula antillarum*	Threatened
Least Bittern	*Ixobrychus exilis*	Threatened
Pied-billed Grebe	*Podilymbus podiceps*	Threatened
Insects		
Little Bluet	*Enallagma minusculum*	Threatened
Plants		
Retrorse Flatsedge	*Cyperus retrorsus*	Endangered
Yellow Flatsedge	*Cyperus flavescens*	Endangered
Roland's Sea Blite	*Suada rolandii*	Endangered
Narrow-leaf Sea Blite	*Suaeda linearis*	Endangered
Willow Oak	*Quercus phellos*	Endangered
Cut-leaved Evening Primrose	*Oenothera laciniata*	Endangered
Seaside Bulrush	*Bolboschoenus maritimus spp. paludosus*	Threatened
Sedge Rush	*Juncus scirpoides var. scirpoides*	Endangered
Fringed Boneset	*Eupatorium torreyanum*	Threatened
Northern Gama Grass	*Tripsacum dactyloides var. dactyloides*	Threatened
Dune Sandspur	*Cenchrus tribuloides*	Threatened
Red Pigweed	*Oxybasis rubra var. rubra*	Threatened

Table 4. NYNHP Listed Significant Natural Communities within Jamaica Bay

Significant Natural Community Type
Marine Back-barrier Lagoon
Low Salt Marsh

State and Federal resource agencies do not provide discrete locations of threatened and endangered species as a protective measure; therefore, it is assumed that each of the threatened and endangered species could occur throughout the Jamaica Bay study area.

A total of thirty-three (33) threatened and endangered species occur within the waters and adjacent uplands of the Jamaica Bay project area. Therefore, the entire Jamaica Bay project area can be considered a Sensitive Area and the LTCP will need to assess potential impacts to the identified threatened and endangered species.

Waters with Primary Contact Recreation

Jamaica Bay waters are saline and tidally influenced. New York State classifies Jamaica Bay as Class SB Bathing, and the tributaries to Jamaica Bay as Class I Boating/Fishing. The Codes, Rules, and Regulations of the State of New York (6 CRR-NY 701) define the best usages of Class SB saline waters as primary and secondary contact recreation and fishing. The best usages of Class I saline waters are secondary contact recreation and fishing. Both water classifications are suitable for fish, shellfish, and wildlife propagation and survival (Figure 2). There are no bathing beaches within Jamaica Bay that are permitted by the Department of Health and Mental Hygiene.

Public Drinking Water Intakes or Their Designated Protection Areas

There are no Sensitive Areas associated with public drinking water intakes or their designated protection areas within Jamaica Bay.

Shellfish Beds

Shellfishing within New York State is governed by 6 CRR-NY Part 41: Sanitary Condition of Shellfish Lands within New York State. 6 CRR-NY Part 41.1 regulates shellfishing in Westchester, Bronx, Kings, New York, Richmond, and Queens Counties. All shellfish lands in Westchester, Bronx, Kings, New York, Richmond, and Queens Counties are in such sanitary condition that the shellfish thereon shall not be taken for use as food and as such are designated as uncertified areas. Therefore, there are no certified shellfish beds within Jamaica Bay.

Summary of Sensitive Areas Analysis

An extensive search of federal, state, and local municipality online databases and web sites was conducted to identify potential Sensitive Areas within the Jamaica Bay LTCP project area. The results are summarized below and in Table 5:

1. Designated Outstanding National Resource Waters
    - There are no Outstanding Natural Resource Waters in Jamaica Bay.

2. National Marine Sanctuaries
    - There are no National Marine Sanctuaries in Jamaica Bay.

New York State Saline Surface Water Quality Standards				
Class	Bacteria			Dissolved Oxygen
	Total Coliform(1)	Fecal Coliform(1)	*Enterococcus*(2)(3)	
SA	Median ≤ 70 MPN/100mL	-	GM ≤ 35/100mL STV 90% ≤ 130 cfu/100mL	> 4.8 mg/L (daily avg) ≥ 3.0 mg/L
SB	Monthly Median ≤ 2,400 cfu/100mL 80% ≤ 5,000 cfu/100mL	Monthly GM ≤ 200/100mL	GM ≤ 35/100mL STV 90% ≤ 130 cfu/100mL	> 4.8 mg/L (daily avg) ≥ 3.0 mg/L
I	Monthly Median ≤ 2,400 cfu/100mL 80%≤ 5,000 cfu/100mL	Monthly GM ≤ 200/100mL	-	≥ 4.0 mg/L
SD	Monthly Median ≤ 2,400 cfu/100mL 80%≤ 5,000 cfu/100mL	Monthly GM ≤ 200/100mL	-	≥ 3.0 mg/L

Notes:
(1) Assessed on an annual basis
(2) Assessed during primary contact recreational season or as necessary to protect human health
(3) Applicable to coastal recreational waters only

Figure 2. Current Water Quality Standards

AECOM with Hazen

3. Waters with threatened or endangered species and their habitat
   - A total of thirty-three (33) federal and state listed threatened and endangered species are associated with Jamaica Bay. Therefore, Jamaica Bay can be considered a Sensitive Area for threatened and endangered species and the LTCP will need to assess potential impacts to the identified threatened and endangered species. Additionally, the NYNHP identified two (2) significant natural communities within Jamaica Bay.

4. Waters with primary contact recreation
   - There are no permitted bathing beaches within Jamaica Bay.

5. Public drinking water intakes
   - There are no Sensitive Areas associated with public drinking water intakes or their designated protection areas within Jamaica Bay.

6. Shellfish beds
   - There are no certified shellfish beds open to harvest in Jamaica Bay.

Table 5. Sensitive Area Classification/Designation of Jamaica Bay

Presence of Sensitive Area Classification/Designation					
Outstanding National Resource Water	**National Marine Sanctuary**	**Threatened or Endangered Species/Critical Habitat**	**Best Use-Primary Contact Recreation**	**Public Water Supply Intake***	**Shellfish Beds**
No	No	Yes	Yes	No	No

* Including designated protection areas

References

Outstanding National Resource Waters

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