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September 11, 2007

Ms. Julia A. Forgue, P.E.
Director of Public Works
City of Newport
70 Halsey Street
Newport, RI 02840-2792

Re: Easton Pond Dam and Moat Study
Final Report

Dear Ms. Forgue:

Enclosed are the following materials:

- Two copies of the final *Easton Pond Dam and Moat Study* (September 2007).
- One copy of the final *Easton Pond Dam and Moat Study* (September 2007) in three parts on compact disk in PDF format.

If you need anything further, please contact me at (401) 861-3070 ext 4571.

Sincerely,

M. James Riordan, AICP
Project Manager

Enclosures (3)

cc: Dean Audet

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Final Report
Easton Pond Dam and Moat Study

City of Newport
Newport, Rhode Island

September 2007

FUSS & O'NEILL
Disciplines to Deliver

Fuss & O'Neill
275 Promenade Street, Suite 350
Providence, RI 02908

EASTON POND DAM AND MOAT STUDY
City of Newport, Rhode Island

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EXECUTIVE SUMMARY

The Easton Pond Dam and Moat system is almost 70 years old after being reconstructed in the late-1930s after the 1938 hurricane. The dam infrastructure forms both North and South Easton Pond Dams that are a critical part of the City's water supply reservoir system. There are three areas of concern associated with this infrastructure:

- The aging dam and moat infrastructure has deteriorated over the past 70 years, which is now resulting in soil loss and threatening the future structural stability of the dam.
- The moat system has limited capacity to manage all of the runoff that discharges to it, which results in localized flooding along the moat.
- The runoff from these neighborhoods as well as activities in and around the dam and moat system new generate significant bacteria loadings that lead result in beach closures at Easton Beach.

Our objective is to provide Newport with a comprehensive approach to resolve or mitigate these problems such that the City has a menu of options from which they can implement future actions.

EVALUATION OF EXISTING SYSTEMS

North and South Easton Pond Dams

The Easton Pond Dam is comprised of earthen embankments and a spillway structure enclosing the South Easton Pond (South Pond) as shown on Figure 1. An earthen embankment forms the northern boundary of this impoundment from the adjacent North Easton Pond (North Pond).

A visual inspection of the North Pond and South Pond embankment and spillway structures was conducted on November 21, 2006 to assess current conditions and identify deficiencies. Historic engineering and construction records on these dams were also reviewed and current maintenance staff were interviewed as part of this evaluation. A visual diving inspection of the South Pond spillway structure, South Pond treatment plant intake structure and North Pond treatment plant intake structure was also performed on this date. Some of the significant deficiencies identified during the inspection is provided below:

- Excessive woody vegetation exists on portions of embankment slopes.
- Portions of existing upstream slope protection (stone riprap) will not provide adequate protection during major storm event.
- Portions of upstream slopes are failing and reducing total embankment cross-section.
- Numerous animal burrows were observed and reported on the embankments.
- Moat channel is encroaching on the downstream bench and embankment slope in several locations, reducing total embankment cross-section and stability.
- Concrete spillway structures exhibit moderate deterioration.

- Worn footpath has developed on embankment crests due to foot traffic, resulting in areas where stormwater runoff channelizes and damages embankments.
- Portions of downstream slope and bench are saturated due to the moat channel and seepage through the embankment.
- Mowing equipment has difficulty operating on portions of embankments due to narrow bench, steep slope and saturated conditions leading to excessive woody vegetation exists on portions of embankment slopes.
- Excessive vegetation in the North Pond emergency spillway channel reduces the capacity of this structure to convey flood flows from the North Pond, if required.

Moat Flooding

The Moat is a manmade channel that surrounds the South Pond on its west, south, and east sides. The southern end of the Moat meets the eastern end of the Moat at the spillway to the South Pond. It then flows under Memorial Boulevard, splitting Easton Beach and Atlantic Beach and enters Easton's Bay between these two beaches.

The entire watershed system that drains to the Moat is about 5.3 square miles in size. This watershed includes Bailey Brook that drains into the North Pond. The North Pond drains into the South Pond which overflows into the Moat via a concrete spillway from time to time, mostly during wetter seasons. Subtracting out the Bailey Brook, North and South Pond watersheds, the watershed that drains directly into the Moat is almost one square mile in size. This watershed is largely built-out with significant amounts of connected impervious surfaces with much of the soils being characterized as poorly draining. As a result, this watershed can generate significant amounts of flow.

In order to evaluate the storm water flows that enter this system, a hydrologic model was developed utilizing the NRCS TR-20 method. Based on this model, peak storm water flows during a 2-year frequency, 24-hour storm event would be about 627 cubic feet per second (cfs) just upstream of the Memorial Avenue bridge. A 50-year frequency storm would generate about 1,460 cfs at that location. These flows exceed the hydraulic capacity of the Moat's conveyance system. This is largely due to how very flat the Moat is.

Easton Beach and Watershed

Easton Beach and Atlantic Beach are located in Newport and Middletown, respectively and on the northern side of Easton's Bay. Over the past five years, these beaches have attracted the attention of City residents, beach goers, and State and City officials due to high bacteria levels that have closed the beaches during and just after rainfall events. There have been a number of questions raised over the past couple of years regarding the potential sources of the bacteria causing these closures. The first portion of this study was to better understand the potential sources of bacteria. In order to accomplish that, the following tasks were completed:

- Conduct a comprehensive storm water monitoring program, including DNA testing of the bacteria found at the beach. While there is a significant amount of historic data collected by the Newport and Middletown, the State and others (e.g. Clean Ocean

Access), there was very little data on potential sources discharging to the moat as well as no flow data.

- Statistically evaluate current and historic water quality data for clues to potential sources.

- Identify potential nonpoint sources of bacteria to the beach based on monitoring data and field observations.

The following paragraphs summarize our conclusions from the evaluation of this data.

Presence of Sanitary Wastewater

Our review of the data found no specific evidence that sanitary wastewater is a source of the closures. There is a concern with potential illicit discharges are two RIDOT storm water outfalls and the Middletown storm drain outfall draining the Esplanade. Water chemistry and/or visual observations at those outfalls were consistent with what can be an illicit discharge to that outfall such as a sanitary or grey water connection.

Animal Waste

Animal wastes are a potentially significant source of bacteria in runoff. Anecdotal evidence suggests that animals such as raccoons and domestic dogs may be a specific source of *Enterococcus* to the beach. Dog wastes were routinely observed on the pond dam embankments. This represents a very large potential load of bacteria to the beach.

Storm Water

Storm water runoff is the predominant source of bacteria to Easton Beach. Storm water runoff sweeps bacteria from impervious surfaces as well as animal wastes into the moat and storm sewer system. This observation is reinforced by the very strong correlation between beach closures and the levels of bacteria measured at the beach with rainfall. A relative loading evaluation has been completed for the Moat and stormwater outfall sampling stations to better understand these sources.

- Bacteria loadings appear to increase as water flows downstream through the Moat. That is, bacteria loadings are highest at the Moat discharge at the beach and lowest at the upstream end of the Moat. That is consistent with loadings increasing as more storm water enters the Moat.

- Aborn Street outfalls S7 and S8, the RIDOT outfall at the Moat crossing under Memorial Boulevard (S10) and the Middletown 36-inch storm drain outfall from the Esplanade have the greatest potential to contribute bacteria loadings for storm water outfalls. However, these are just parts of the entire storm water problem and only happen to drain more runoff than other outfalls.

Bailey Brook

Although, Bailey Brook is known to be impaired for pathogens, it is probably not a significant source of *Enterococcus* to Easton Beach during beach season because flow from the brook does not reach the beach during most events, especially during the summer when water levels in the ponds are lower. When the Ponds are full, Bailey Brook can represent a significant potential load to the beach.

REMEDIAL ALTERNATIVES

A number of alternatives were identified and developed to address the issues found during our investigations. These alternatives include both short- and long-term alternatives, where long-term alternatives are those that require significant design and capital improvements. Opinions of cost were developed to implement/construct each alternative.

Recommended Dam Improvements

Short-Term Dam Improvement Alternatives

There are no short-term alternatives that address the most significant deficiencies identified during the inspections, but there are several that can reduce the continuing deterioration of the dam embankment. These present the most available actions for the City to take to begin efforts. These short-term alternatives are described in the table below that also summarizes advantages, disadvantages and implementation issues.

Table 26
Short-Term Dam Alternatives

Dam STA-1 Clear and Grub Vegetation from Embankment Slopes			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Difficult access to portions of embankments • Erosion and sedimentation controls • Permitting	• Allows future mowing as standard maintenance practice (reduced maintenance costs) • Prevents future hazard from overturned trees • Allows effective visual inspection of embankment surfaces • Low engineering cost	• Does not provide slope protection without additional improvements • Permitting required due to stump removal; likely will not qualify as maintenance • Difficult access to some areas	$236,000
Dam STA-2 Clear and Grub North Pond Emergency Spillway Channel			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate access with normal site activities • Erosion and sedimentation controls • Permitting	• Improves hydraulic capacity of spillway channel • Facilitates visual inspection of spillway structures • Low engineering cost	• Permitting required; likely will not qualify as maintenance • Expense for benefit only realized during relatively rare significant storm events	$21,000

Dam STA-3 Repair North Pond Spillway Concrete Structures			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Erosion and sedimentation controls • Control of water • Permitting	• Relatively low engineering and construction costs • No groundwater dewatering, limited control of surface water required • Limited cost to extend life of existing structures	• Temporary measure to extend life of failing structures	$36,000

Dam STA-4 Conduct Structural Inspection of South Pond Spillway			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Coordinate work with low flows at spillway	• Determine condition of spillway for future repairs or limited/full replacement	• Limited information on actual condition (limited number of samples)	$29,000

Dam STA-5 Repair South Pond Spillway Concrete Structures			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Erosion and sedimentation controls • Control of water • Permitting • Research waterproofing measures	• Limited cost to extend life of existing structures • No groundwater dewatering, limited control of surface water required	• Only delays future need to replace spillway structure	$281,000

Dam STA-6	Construct Stormwater Channel Along East Embankment Slope		
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• May require access through adjoining parcel (otherwise adverse access conditions result) • Erosion and sedimentation controls • Control of water • Permitting	• Addresses rilling of embankment and uncontrolled stormwater discharge into impoundment • Removes standing water at toe of embankment slope	• Possible neighbor opposition due to removal of grassed area (property boundary unknown for this study)	$54,000
Dam STA-7	**Repair North Pond Embankment Settlement Area**		
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$25,000
Dam STA-8	**Repair East Embankment Settlement Area and Footpath**		
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$14,000
Dam STA-9	**Replace Gate Valve in North/South Pond Dividing Embankment**		
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Dewatering • Possible Shoring	• Restores ability to control discharge to South Pond	• May require excavation controls (dewatering, shoring) depending on depth to valve	$45,000

Dam STA-10 Conduct Slope Stability Evaluation			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Access for drill rig	• Evaluates stability of embankments following filling activities by the City	• Expense	$35,000

Dam STA-11 Place Gravel on Bench/Downstream Slope of Accessible Embankments			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Erosion and sedimentation controls	• Previous construction activity, knowledge of procedures by City • Able to access bench and downstream slopes from opposite side of moat	• Limited measure to address deficiencies (does not address embankment deficiencies)	$167,000

Dam STA-12 Install Inlet Screens for Treatment Plant Intake Structures			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Coordinate access with normal site activities	• Low cost to protect structure and plant facilities • Prevents animals and debris from being drawn into the treatment plant works.	• Requires future maintenance to clear accumulate debris	$10,000

Dam STA-13 Implement Rodent Control Program			
Implementation Issues	**Advantages**	**Disadvantages**	**Opinion of Cost**
• Research and develop program • Public education/community relations • Monitoring and reporting	• Limit damage from burrowing animals • Protect future investment in embankment repairs/improvements	• Public opposition from wildlife enthusiasts opposed to lawful management techniques • Abatement methods need to be selected and/implemented to safeguard public users if public is not prohibited from embankments during the program.	$55,000

Dam STA-14 Prepare Emergency Action Plan			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and document resources and contacts • Develop contingency plans for various failure scenarios • Coordination of emergency response agencies • Review and update information periodically	• Provides a prepared plan of action in the event of a failure or unanticipated situation. • Relatively low cost for a measure that could save lives and significant damage to the dam and downstream structures.		$5,000
Dam STA-15 Control Public Access			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and develop program • Public education/ community relations • Monitoring and enforcement	• Limit damage from foot traffic and vandalism • Protect public from dangerous structures • future investment in embankment repairs/ improvements	• Public opposition from current users.	$17,500

Long-Term Dam Improvement Alternatives

Long-term alternatives have been developed to address the long-term stability issues of the dam embankments and will generally require more significant efforts for planning, design and permitting, and significant capital planning to fund their implementation. They are more focused on fundamental conditions affecting the overall ability of the embankments and spillways to withstand extreme loadings during significant storm events. These long-term alternatives are listed in the following table with a brief description of each, listing of primary benefits, an order-of-magnitude opinion of cost, and listing of likely implementation issues.

Long-Term Dam Alternatives

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-1: Realign the East and West Embankments to address significant deficiencies and provide adequate bench width along downstream toe of slopes. Repair upstream slope protection on other embankments.	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides 3H:1V downstream slopes to facilitate mowing equipment. • Provides 10 'wide bench for maintenance access and to facilitate mowing equipment. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from embankment crests.	• Cable-Concrete: $7,592,000 • Bare Riprap $4,358,000 • Grouted Riprap: $4,580,000 • Soil-Filled Riprap (vegetated): $4,412,000 • Cellular Confinement: $4,527,000 • Porta-Dam (add-alternate): $750,000 • Watertube (add-alternate): $640,000 • Reinforced Walking Surface (add-alternate): $96,000	• Control of water required by temporarily lowering impoundment or coffer damming around work areas. • Portion of impoundment storage capacity lost due to relocated embankments. • Significant erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Significant earth volumes to be handled will require stockpiling areas. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-2: Replace upstream slope protection on all embankments and widen embankment crest (no horizontal relocation of downstream slopes).	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from embankment crests.	• Cable-Concrete: $5,280,000 • Bare Riprap $2,888,000 • Grouted Riprap: $3,055,000 • Soil-Filled Riprap (vegetated): $2,867,000 • Cellular Confinement: $3,122,000 • Sheet piling and Cable-Concrete: $7,842,000 • Porta-Dam (add-alternate): $750,000 • Watertube (add-alternate):	• Control of water required by temporarily lower impoundment or coffer damming around work areas. • Small portion of impoundment storage capacity lost due to upstream embankment filling. • Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and ACOE.

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
		$640,000 • Reinforced Walking Surface (add-alternate): $96,000	
Dam LTA-3: Demolish and replace South Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace spillway weir: $289,000 • Porta-Dam (add-alternate): $140,000 • Watertube (add-alternate): $120,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-4: Demolish and replace South Pond downstream concrete apron.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace downstream apron: $234,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-5: Replace North Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure.	• Remove and replace downstream apron: $205,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-6: Rebuild/Regrade all embankment crests.	• Provides 12 'crest width for all embankments for future maintenance/ repair access. • Repairs worn footpath, promotes proper surface drainage from embankment crests. • Provides reinforced surface for public access	• Rebuild/regrade embankment crests: $303,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and possibly ACOE.

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-7: Install moat channel scour protection as described in Flood LTA-2 and LTA-6.	• Reinforces moat channel banks to prevent or reduce further encroachment into benches and downstream slopes.	• Install moat channel scour protection (riprap): $2,500,000 • Install moat channel scour protection (concrete): $3,700,000	• Control of water in moat channels required during work. • Difficult access to some portions of moat channel. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-8: Install embankment toe drains at limited sections of South, West and North Embankments.	• Addresses benches and downstream slopes areas that are wet or saturated.	• Install toe drains: $524,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to portions of West Embankment. • Permits required from CRMC and RIDEM.

Dam Evaluation and Improvements Conclusions/Recommendations

Many of the short- and long-term alternatives presented should be implemented in combination or proper sequence in order to be most effective. The short- and long-term alternatives provided above are listed below in a recommended order of priority based on the significance and urgency of the condition being addressed, ease/relative cost of implementation, and contingency relationships.

<u>Short-Term</u>

1. Dam STA-1: Clear and Grub Woody Vegetation from Embankment Slopes
2. Dam STA-4: Conduct Structural Inspection of South Pond Spillway
3. Dam STA-2: Clear and Grub North Pond Emergency Spillway Channel
4. Dam STA-6: Construct Stormwater Channel Along East Embankment Slope
5. Dam STA-13: Implement Rodent Control Program
6. Dam STA-14: Develop an Emergency Action Plan
7. Dam STA-7: Repair North Pond Embankment Settlement Area
8. Dam STA-8: Repair East Embankment Settlement Area and Footpath
9. Dam STA-15: Develop and Implement Program to Control/Prohibit Public Access Onto Embankments
10. Dam STA-5: Repair South Pond Spillway Concrete Structures
11. Dam STA-11: Place Gravel on Bench/Downstream Slope of Accessible Embankments
12. Dam STA-10: Conduct Slope Stability Evaluation
13. Dam STA-9: Replace Gate Valve in North/South Pond Dividing Embankment
14. Dam STA-3: Repair North Pond Spillway Structures
15. Dam STA-12: Install Inlet Screens for Treatment Plant Intake Structures

Long-Term

1. Dam LTA-1: Realign Portions of Embankments
2. Dam LTA-2: Replace Upstream Slope Protection
3. Dam LTA-7: Install Moat Channel Scour Protection
4. Dam LTA-8: Install Embankment Toe Drains
5. Dam LTA-3: Replace South Pond Concrete Spillway Weir
6. Dam LTA-4: Replace South Pond Downstream Concrete Apron
7. Dam LTA-5: Replace North Pond Concrete Spillway Weir
8. Dam LTA-6: Rebuild/Regrade Embankment Crest

Recommended Moat Improvements

Several alternatives to reduce flooding along the northern section of the Moat, specifically within the Ellery Road and Eustis Avenue neighborhoods, were identified in the *1991 USDA Flood Prevention Evaluation for Ellery Road and Eustis Avenue* (1991 USDA Study). While our study expands from the original USDA study by focusing on flooding throughout the entire length of the Moat, we reconsidered the alternatives proposed by the USDA and identified other alternatives to reduce flooding at Memorial Boulevard and at other local roads adjacent to the Moat.

In order to evaluate the anticipated benefits provided by each of our proposed alternatives, we developed a baseline hydraulic model to determine approximate water surface elevations within the Moat during storm events and to identify existing areas of flooding based on different frequency rainfall events. Hydraulic modeling of the Moat was completed using the US Army Corps of Engineer's model HEC-RAS.

Based on the results obtained from our baseline hydraulic model, the hydraulic capacity of the Moat is inadequate. To put the hydraulic inadequacy of the Moat into perspective, the Moat would need to be more than 50 feet wide to contain all storm events up to the 50-year storm within its banks. However, widening the Moat is not possible given existing physical constraints.

Short-Term Flood Management Alternatives

Although short-term alternatives may slightly increase the hydraulic efficiency of the Moat or the adjacent roadway closed-conduit drainage systems, no short-term alternatives proposed will alleviate flooding or significantly reduce water surface elevations within the Moat during storm events. These alternatives will, however, ensure that flooding conditions do not worsen and will also improve stabilization of the Moat bottom to reduce future erosion/scour. The following summarizes each short-term alternative proposed, the approximate cost of each alternative and lists potential implementation issues associated with each.

Short-Term Flood Management Alternatives

Description	Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood STA-1: Remove areas of sediment deposition within the Moat and install riprap at the outlets of culverts discharging to the Moat.	• Slight improvement of the hydraulic efficiency of the Moat. • Prevents scour at stormwater outlets .	$256,000	Low	• Excavated soil needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • A Maintenance Certificate may be required from the CRMC.
Flood STA-2: Install riprap at the upstream and downstream ends of the Memorial Boulevard culvert	• Stabilized the channel upstream and downstream of the culvert.	$7,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate or Council Assent may be required from the CRMC for work below the mean high water level.
Flood STA-3: Install riprap at the upstream and downstream ends of the pedestrian bridge located in the northwestern corner of the Moat	• Stabilized channel upstream and downstream of the pedestrian bridge.	$6,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate may be required from the CRMC.
Flood STA-4: Remove hydraulic obstruction within the Moat and install culverts below access path	• Improved moat hydraulics.	$40,000	Low	• Improvements must occur during the dry season/weather since the Moat sustains a base flow. • Dewatering will be necessary. • A Maintenance Certificate may be required from the CRMC.
Flood STA-5: Continue to clean and flush existing drainage structures and pipes that	• Reduced roadway flooding during the smaller, more frequent storm events.	$5,000 per Maint. Event	High	• Inspection and maintenance of the closed-conduit drainage systems and components must continue to be performed on a

Description	Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
discharge to the Moat along Ellery Rd., Eustis Ave., Old Beach Rd., and Memorial Blvd.				regular basis (e.g., inspect quarterly and maintain twice a year, at minimum).
Flood STA-6: Continue to implement a regular maintenance / mowing program to control the height of vegetation growing within and adjacent to the Moat	• Improved hydraulic capacity of the Moat.	$107,000 per Clearing Event	High	• Due to the instability of the pond embankment and bench in some locations, maintenance needs to be performed by hand. Mow at least twice a year. • A Maintenance Certificate may be required from the CRMC.

Long-Term Flood Management Alternatives

Several long-term alternatives were developed in order to evaluate their effectiveness to reduce flooding. Each of these alternatives was modeled utilizing HEC-RAS and the resulting water surface profiles were compared with the baseline model to evaluate their flood reduction benefits. No alternatives were identified that will substantially reduce flooding along the entire length of the moat. The alternatives described herein will only have localized benefits. The following table summarizes each long-term alternative, the approximate cost of each alternative, and a list of potential implementation issues.

Long-Term Flood Management Alternatives

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-1: Excavate existing channel bottom to provide a uniform channel slope in sections of the Moat that are adjacent to the identified areas of flooding.	• Minimal flood reduction benefits in areas adjacent to north portion of moat. • Decreases in water surface elevations of 0.2 feet or less would be expected within northern portion of moat during 2- and 5-year storm events only.	$1.4 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-2: Excavate and widen the Moat channel	• Decreases in water surface elevations of 0.3 feet, on average, would	$2.5 Million	Low	• Improvements must occur during dry season and dry weather.

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
throughout its entire length and line the base with riprap.	be expected for 2- thru 10-year storm events in northern portion of moat. As a result, 2 of the 6 flood-prone houses in this location will be above the flood damage elevation during 2- and 10-year storms. • Minimal to no reduction anticipated for storm events greater than the 10-year storm event in all flood-prone areas.			• Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-3: Replace existing Memorial Boulevard culvert with three 5-foot by 10-foot box culverts.	• Flood reduction benefits mainly noted within southeastern corner of moat just upstream of Memorial Boulevard. • Decreases in water surface elevations ranging between 0.9 feet (for 2-year storm) to 0.1 feet (for 50-year storm) would be expected in southeastern portion of moat.	$650,000	Low	• Improvements must occur during dry season and dry weather. • Dewatering will be necessary during construction. • Will require coordination with appropriate utility companies. • Demolition and construction work will cause a disruption to on Memorial Boulevard. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-5: Install 3-5 'x8 ' box culverts at southwestern corner of moat (adjacent to Old Beach Road)	• Flood reduction benefits adjacent to the southern portion of the Moat channel along Memorial Boulevard and Old Beach Road. • Decreases in water surface elevations ranging between 10 inches (for the 2-year storm) to 2 inches (for the 50-year storm) expected within the section of the Moat adjacent to Old Beach Road. Decreases in water surface elevations ranging between 30.7 inches (for the 2-year storm) to 4.9 inches (for the 50-year storm) would be expected in the southwestern portion of the Moat. Decreases in water surface elevations ranging between 29.8 inches (for the 2-year storm) to 6.0 inches (for the 50-year storm) would be expected in the southeastern portion of the Moat.	$1.4 Million	Medium	• The channel width at the inlet of the culverts will need to be increased to 30 feet wide. Retaining walls may be required along both sides of the channel at the culverts. • Will require coordination with appropriate utility companies due to potential conflicts with roadway utilities. The installation of the culvert will cause a disruption to traffic as lane closures on Memorial Boulevard will be most likely be required. • Beach area in the western section of Easton Beach will be lost. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-6: Provide uniform channel slope and cross-section throughout moat and line base of channel with concrete	• Flood reduction benefits in area adjacent to the northern portion of moat. • Decreases in water surface elevations ranging from an average of 1.8 feet (for the 2-year storm) to an average of 0.6 feet (for the 50-year storm) expected in the northern portion of the Moat. • 3 of the 6 flood-prone houses in this location houses will be above the flood damage elevation for storm events up to and including the 10-year storm.	$3.7 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Alternatives such as pre-cast channel sections or shotcrete may be more feasible. • Subdrains or intermittent weepholes may be required to minimize hydrostatic forces on the base and sides of the

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
				channel. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Hydraulic Analysis Conclusions/Recommendations

Flooding along Ellery Road, Old Beach Road, and Memorial Boulevard can be attributed to the insufficient hydraulic capacity of the Moat. Several factors contribute to this deficiency, including:

- The amount of flow discharged to the Moat from numerous closed-conduit storm drain systems and the secondary spillway from North Easton Pond.
- The relatively flat slope of the Moat and restrictive cross-sectional geometry.
- Sediment deposition from scour within the Moat as well as from the interconnected storm drain system, which discharges to the Moat.
- Vegetative growth within the channel of the Moat.

As a result of these factors, no single short-term or long-term alternative that we analyzed will attenuate flooding in all flood-prone areas along the Moat. Each alternative will only have localized effects. For the Memorial Boulevard and Old Beach Road area, the installation of three box culverts in the southwestern corner of the Moat that would span across Memorial Boulevard (Flood LTA-5) did appear to be a moderately cost- effective solution to reduce localized flooding.

Recommended Water Quality Improvements

The Easton Beach watershed has a number of physical limitations that significantly constrain the controls that could be applicable in this watershed. These include significant storm water flows generated in the watershed, little space available to site controls, poor soils available for infiltration and high groundwater which is also prevents use of infiltration. Based on these limitations, a set of potential short- and long-term controls have been identified that could be implemented in the beach-shed to reduce bacteria loads to the beach.

Short-Term Water Quality Alternatives

Several short-term alternatives are available to the City to reduce wet-weather bacteria loadings to the beach. They consist of nonstructural controls and will not require a significant investment or effort to implement. However, none of these short-term alternatives will solve the beach closure problems being currently observed. They would reduce the overall bacteria load discharged.

WQ STA -1 Public Education – The public's behavior has a direct effect on water quality. For example, improperly managed pet waste will contribute significantly to water quality problems. During our fieldwork on Easton Pond Dam, we noted significant quantities of dog waste. We also witnessed dog walking at the beach, where droppings could easily wash into the beach water. In general, this alternative involves adapting existing materials for use at Easton Beach. In part this will involve participation in the Phase II Storm Water Outreach Program that the City has already agreed to participate in this. The opinion of cost for this work is approximately $20,000.

WQ STA-2 Public Participation – Like WQ STA-1, this alternative will also assist the City in complying with Phase II storm water regulations but it will also build public awareness of the water quality problems at the beach and what is contributing to those problems. The City could:

- Continue to work with Clean Ocean Access and wherever possible support their efforts to clean up the beach and conduct water quality sampling.
- The City should also solicit business owner involvement.
- Pet waste is a significant source of bacteria. The City should publicize their existing pet waste ordinance.

The opinion of cost for this work is approximately $10,000.

WQ STA-3 Waste Management at the Beach – Waste management practices at Easton Beach can be improved to reduce sources of bacteria there. Our recommendations are as follows:

- Add trash cans with hoods to prevent seagulls from foraging.
- Develop a regular schedule to remove wrack (i.e., piled-up seaweed) from the beach areas. Wrack is a potential source of bacteria and it has been stockpiled adjacent to the Moat discharge to the beach.

The opinion of cost for this work is approximately $20,000.

WQ STA-4 Illicit Discharge Detection and Elimination (IDDE) – Water quality testing conducted last season showed indications of possible illicit discharges, which could contribute to higher bacteria levels, specifically with three outfalls S9, S10 and S11 that are owned either by RIDOT or the Town of Middletown. The City should coordinate with other entities to remove their illicit discharges. The opinion of cost for this work is approximately $30,000.

WQ STA-5 Wild Animal Management – Urban wildlife can contribute significantly to water quality problems. Animals of concern include birds, raccoons, and rodents.

- Raccoons have been found living in the storm drain system and should be removed.
- The City should also consider developing a waterfowl management plan to control birds around the beach.
- As recommended for the dam, a rodent control plan should be considered.

The opinion of cost for this work is approximately $55,000.

WQ STA-6 Restrict Public Access to Easton Pond Dam – Due to contamination and public health risks, water suppliers do not usually allow public access to or around water supplies. The City should consider prohibiting public access to the dam, especially if efforts to control dog wastes in these areas are not effective. The opinion of cost for this work is approximately $17,500.

Long-Term Water Quality Alternatives

The long-term alternatives proposed herein involve major capital improvements and construction. Long-term alternatives were first screened by reviewing available technologies to identify those that have significant potential to be applied in this watershed. The technologies that were considered have been grouped into filtration/infiltration technologies, disinfection and other technologies and are described below.

- Filtration/infiltration.
  - Infiltration trenches.
  - Disconnected catch basins and proprietary infiltration units.
  - Sand filters.
  - Catch basins with sand filters.
  - Proprietary Filter Media (e.g., Smart Sponge™).
  - Bioretention.
- Disinfection.
  - Chlorination.
  - Ozonation.
  - Ultraviolet disinfection.
- Other Technologies.
  - Stormwater Wetlands.

Long-term alternatives were screened from this list of potential technologies. These alternatives are somewhat unconventional because of the constraints of this watershed. These alternatives are not all equal, they vary significantly with the volumes of storm water they can treat and the areas of runoff that they can manage as well as their treatment efficiency and reliability. As such, long-term alternatives have been organized based on the area that they would be designed to manage. The following table summarizes each potential long-term alternative, which provides size of subwatershed treated, water quality volume treated, treatment efficiency, and cost of alternative in 2007 dollars.

Table 39
Long-Term Water Quality Treatment Alternatives

Treatment Alternative	Subwatershed	Subwatershed Size (acres)	WQV (cubic feet)	Bacteria Removal Efficiency (%)	Cost Benefit Ratio
Easton Beach Parking Lots and Memorial Boulevard					
WQ LTA-1 Infiltration Trenches East Beach Parking Lot	East Beach Parking Lot	4.1	15,078	75-98	$199,000 $13.3-$17.3(/cf)
WQ LTA-2 Infiltration Trenches West Beach Parking Lot	West Beach Parking Lot	2.3	8,600	75-98	$132,000 $15.3-$20.0(/cf)
WQ LTA-3 Infiltration for Memorial Boulevard	Memorial Boulevard	8.6	16,256	75-98	$422,000 $26.5-$34.7(/cf)
WQ LTA-4 Sand Filter East Beach Parking Lot	East Beach Parking Lot Area B	3.1	11,600	40-90	$454,000 $38.8-$50.7(/cf)
Western Residential Neighborhoods Draining to Moat					
WQ LTA-5 Chamber Sand Filters[b]	3-2 3-3 3-4 3-5 3-6 *Total*	232.1 84.6 42.1 21.2 36.6 *416.6*	312,300 143,350 53,060 14,270 24,400 *547,380*	40-90	$4,897,000 $2,109,000 $807,000 $203,000 $351,000 *$8,367,000* $17.8-$40.0(/cf)
WQ LTA-6 Bioretention at Braga Park	3-1 3-2	263.9	335,634	75-98	$2,714,000 $8.2-$10.7(/cf)
WQ LTA-7 Catch Basin Inserts	3-1 3-2 3-3 3-4 3-5 3-6 3-7 3-8 3-9 *Total*	31.8 232.1 84.6 42.1 21.2 36.6 2.2 3.2 4.7 *458.5*	23,300 312,300 143,350 53,060 14,270 24,400 1,200 1,800 2,800 *576,480*	50-75	$14,000 $313,000 $143,000 $58,000 $47,000 $55,000 $5,000 $5,000 $5,000 *$645,000* $1.3-$2/cf

Moat Discharge					
WQ LTA-8 UV Treatment	Easton Beach Watershed[a]	594.3	745,000	99	$3,800,000 $5.1/cf

a. Entire watershed includes flow from Middletown that enters the moat near the discharge point.
b. The sand filters are intended for use in the upland to treat portions of the WQV depending on the length and number installed. Therefore this footprint may be split up amongst several sand filters.
c. The values in the Cost Benefit Ratio column are costs for 2007. The first number is the total cost for the system. The second listing, in BOLD, is the range of dollars per cubic foot of WQV treated, divided by the bacteria removal efficiency (cost/WQV/% removal)

Pilot-Testing of Selected Structural Controls

Several innovative structural controls have been proposed as long-term alternatives. We recommend some pilot testing of the controls before the City makes any significant investment in implementing them. This would allow the City to better understand the relative costs and benefits of the alternatives as a group. The structural controls for which we recommend pilot-testing are:

- Chamber Sand Filters
- Catch Basin Inserts

Pilot testing for these two alternatives would consist of implementing these alternatives on a small scale in the watershed.

In addition to this pilot-testing, more intensive monitoring of both hydraulic and water quality in the Moat area near the Memorial Boulevard bridge is also recommended in order to develop a design for a UV treatment system. The hydraulics in this area is very complicated and need to be better understood in order to ensure that the system will operate without causing additional flooding. Additional water quality testing is recommended in order to define pretreatment needs and sizing of the UV system.

Water Quality Improvements Conclusions/Recommendations

Based on our evaluation, we recommend that the City implement a UV disinfection system for the Moat outfall. This system is the only alternative that could be applied for the entire discharge from the moat. It is also the most reliable in terms of treatment of bacteria and will achieve the greatest reductions in bacteria that are measured at the beach. It is also cost effective compared to other alternatives. Implementation of structural controls such as this is eligible for significant funding opportunities through the Rhode Island Watershed Bond Fund that can provide up to 50% grants for controls such as these. However, this system should be reevaluated after preliminary design to reconfirm expected costs to construct and operate the system and that the system will not significantly impact Moat hydraulics.

Alternatively, the use of catch basin inserts within the watershed to the Moat should be considered if UV disinfection is not implemented. This technology would be the least costly, however, there are many questions regarding its effectiveness. As a result, pilot testing would be recommended for this alternative. Because this technology could only be applied to a portion of the watershed that is draining to the Moat, other structural and non-structural controls will likely be required such as controls for Memorial Boulevard (WQ LTA-3) and removal of dog and animal wastes from the moat and pond dams as a source of bacteria (WQ STA-1, -2, and -5).

1.0 INTRODUCTION

The Easton Pond Dam and Moat system is almost 70 years old after being reconstructed in the late-1930s after the 1938 hurricane. The dam infrastructure forms both North and South Easton Pond Dams that are a critical part of the City's water supply reservoir system. The moat was constructed to manage the storm water that drained from the adjacent neighborhoods and convey that runoff around the ocean at Easton Beach. Since then, the neighborhoods draining to the moat in both Middletown and Newport have been largely built out with development and low have large percentages of connected impervious areas. Runoff from those neighborhoods as well as activities in and around the dam and moat system generates significant bacteria loadings that result in beach closures at Easton Beach. Additionally, the aging dam and moat infrastructure has deteriorated over the past 70 years, which is now resulting in more soil loss and threatening the future structural stability of the dam. Also, the moat system has limited capacity to manage all of the runoff that discharges to it, which results in localized flooding along the moat.

The City of Newport has retained Fuss & O Neill to identify reviewing the causes of these problems and develop potential solutions that the City of Newport can implement in the future. In order to accomplish this, our services included an evaluation of the existing issues including a wet-weather water quality monitoring program of the beach, moat, and storm sewer systems; a comprehensive review of existing data; a visual surface and underwater inspection of the dam system; and hydrologic and hydraulic modeling of the moat system. Once this evaluation was completed, alternatives were identified, screened, and developed to identify those alternatives that could resolve these issues.

This report summarizes the work that we have completed including reviewing the causes of the problems the City is currently facing with this system and potential solutions that can be implemented. We have developed the most viable solutions into short- and long-term alternatives, which are described in terms of their advantages, disadvantages, implementation issues, and cost. Our objective is to provide Newport with an approach to resolve or mitigate these problems such that the City has a menu of options from which they can implement future actions.

2.0 PROJECT BACKGROUND

The Newport Public drinking water supply reservoir system includes North Pond and South Pond. Both of these ponds are located to the north of Easton Beach and are separated from the beach by Memorial Boulevard (see Figure 4).

The ponds straddle the Middletown-Newport boundary. While an earthen impoundment separates the ponds, they connect hydrologically and function as a unit under high flow conditions. The ponds receive the majority of their flow from Bailey Brook, which emanates from Middletown.

A manmade earthen channel, referred to as the Moat, encircles the southern three sides of South Pond and hydrologically separates the ponds from much of what would be their natural watershed. Thus the Moat prevents untreated runoff from the highly urbanized surrounding area from entering and polluting the ponds. The Moat eventually discharges to the eastern side of Easton Beach.

2.1 Easton Pond Dam

The Easton Pond Dam (State ID#585, Federal ID #RI09101) is comprised of earthen embankments and a spillway structure enclosing the South Easton Pond (South Pond) as shown on Figure 1. An earthen embankment forms the northern boundary of this impoundment from the adjacent North Easton Pond (North Pond). The embankments were reportedly completed in 1876 as a municipal water supply. The spillway and portions of the southern embankment were destroyed in a hurricane in 1938 and reconstructed thereafter under a contract issued in 1939. The northern embankment separating the two ponds was damaged and partially breached and reconstructed due to hurricane damage in 1985. Pertinent information describing the structure, as obtained from RIDEM records dated 1995, is provided below:

Table 1
RIDEM Dam Information

Dam Length:	9,708 ft
Dam Height:	13 ft.
Structural Height:	13 ft.
Hydraulic Height:	12 ft.
Spillway Height:	12 ft.
Spillway Width:	45 ft.
Maximum Discharge:	260 cfs
Maximum Storage:	1,375 ac-ft.
Normal Storage	1,225 ac-ft.
Surface Area	147 ac.
Drainage Area:	4 sq. mi.
Downstream Hazard	Low*
Size:	Medium
General Condition:	Good

* - While the dam is currently classified by the Rhode Island Department of Environmental Management as low hazard dam, it has reportedly been considered for reclassification as a high - hazard structure due to its proximity to Kennedy Memorial Boulevard and the Easton Beach recreational area.

The South Pond embankment is constructed of earth and extends from the emergency overflow spillway from the North Pond along the western perimeter of the impoundment and continuing along the southern border along Memorial Boulevard, increasing in height to approximately 13-ft. from toe to crest as it continues downstream toward Easton Bay. The embankment continues along the eastern border of the South Pond in Middletown until joining with the eastern end of the North Pond overflow spillway. The berm/embankment dividing the North and South Ponds serves a water quality function by providing increased detention times in the North Pond, as well as covering pressure mains carrying raw and treated water to the Water Division's service and distribution systems.

A short embankment forming the southwestern boundary of the North Pond adjacent to the treatment plant was also included in this study. This embankment is also earthen, having a height of approximately 5-ft., with grassed downstream slopes along the majority of its length. The remaining shoreline of the North Pond is formed by up gradient land with no embankments.

While the upstream slopes of all embankments were originally armored with riprap or laid stone, significant to severe scarps have formed in many areas and high vegetation is predominant in many areas. Several areas of localized erosion were also noted along the up gradient embankment slopes, which have been and are currently being addressed to the extent possible by the Newport Water Division's maintenance crews. These maintenance crews also are responsible for mowing the embankment crests, downstream slopes and areas along the downstream toe of slope. The proximity of these areas to groundwater and the Moat channel limits access by mowing equipment due to the relatively weak soil strength, and so maintaining these areas becomes a challenge even with specialized mowing equipment.

The main spillway from the North Pond is formed of concrete as a low level-spreader bar tying into abutments and discharging to a laid-stone apron leading to South Pond. The South Pond spillway structure is much higher relative to its downstream floor and is formed of concrete as well with abutments into the embankments. This spillway discharges to an outlet channel that also receives discharge from the moat channel as well as runoff from the channel running along the eastern embankment.

The activities under this portion of the study were to research and investigate the current condition of the dam and appurtenant structures, as outlined below:

- Review previous drawings, reports and studies provided by the City.
- Review data available in RIDEM files.
- Conduct visual inspection of dam structures (embankments, spillways).
- Conduct underwater inspection of South Easton Pond spillway structure.
- Conduct underwater inspection of treatment plant intake piping structures for South Easton Pond and North Easton Pond.

The results of these activities are summarized in Section 3.1 below.

2.2 Easton Pond Moat

The Moat is a manmade channel that surrounds the South Pond on its west, south and east sides. The southern end of the Moat meets the eastern of the Moat at the spillway to the South Pond. It then flows under Memorial Boulevard, splitting Easton Beach and Atlantic Beach and enters Easton's Bay between these two beaches.

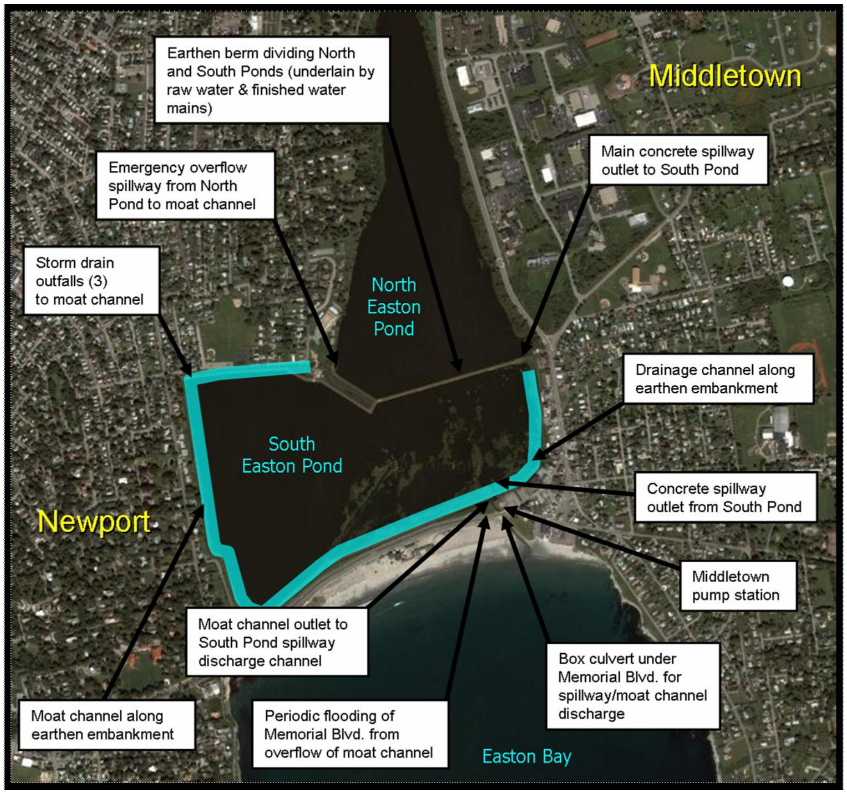
The Moat serves three basic purposes:

- To provide a pathway for stormwater to discharge around the drinking water supply without entering it. Several stormwater outfall pipes collect stormwater from surrounding areas and discharge into this Moat.
- To prevent saltwater intrusion into the drinking water supply. Tidal flow backs up into the Moat, but an impoundment prevents this flow from entering the ponds.
- To provide a discharge path when South Pond reaches its full capacity.

The Moat receives flow from a number of sources including:

- Groundwater discharge
- Tidal backflow
- Storm water discharge from land adjacent to the ponds
- Storm water from Memorial Boulevard
- Overflow from South Pond
- Wave Avenue Pump Station

These flows are cyclical and intermittent. They depend on conditions such as tidal cycle, weather and season. The Moat, therefore, contains a somewhat uncertain mixture of flows from various fluctuating sources.



Land Adjacent to the Moat

Land areas in the drainage catchment of the Moat include parts of Memorial Boulevard as well as several small commercial areas, dense residential neighborhoods and vegetated areas along the ponds. The residents of these neighborhoods use the vegetated areas surrounding the South Pond, including the earthen embankments of the pond, as a recreational area (e.g., dog walking, running, cycling, etc.). The City provides "mutt mitt" stations for residents to use to pick up after their dogs. During several prior investigations by the City, used mutt mitts were found at the bottom of catch basins and along curbs along the western boundary of the Moat. During the same investigation, raccoons were found in several of the storm water manholes. While these observations are anecdotal and circumstantial in nature, they do present very apparent water quality concerns.

Wave Avenue Pump Station

The Wave Avenue Pump Station is located just north of Memorial Boulevard. A large percentage of Middletown's wastewater is pumped through this pump station to Newport's wastewater treatment facility. During large rain events, the combined stormwater and wastewater system may surcharge causing the pump station to releases flow into the Moat, which discharges into the bay near Easton Beach. The pump station is designed to function this way. The overflow causes water quality impairments and is currently being addressed under enforcement action by RIDEM. Future upgrades are planned for this facility to allow the facility to handle larger flow without discharging into the Moat.

Memorial Boulevard

Memorial Boulevard runs between the Moat and Easton Beach. It is a 4-lane, State-owned road with a separate storm drainage system that, in part, drains into the southern side of the Moat via several stormwater outfalls. One outfall from the boulevard also drains directly to Easton Beach (see outfall S9 in Figure 4).

Currently, flooding occurs near Memorial Boulevard and adjacent parking lots and at other local roads adjacent to the Moat during significant storm events. Flooding is often exacerbated by tidal and storm surge influences. Several factors contribute to this flooding, including increases in impervious area, which results in increased runoff volumes and flow rates within the contributing watershed area, sediment deposition in the Moat from the adjacent storm drain system, and vegetative growth within the channel.

2.3 Easton Beach

Easton Beach and Atlantic Beach are located in Newport and Middletown, respectively and on the northern side of Easton Bay. Over the past five years, these beaches have attracted the attention of City residents, beach goers, and State and City officials due to high bacteria levels. Several organizations conduct sampling at these beaches as part of studies as well as for the safety of the public. In addition, community groups such as Clean Ocean Access, City of Newport and the Town of Middletown work together with the State of Rhode Island Department of Health (RIDOH) to conduct beach sampling. Sampling results from all of these organizations continue to validate growing concerns regarding the overall water quality of these areas; specifically, high bacteria levels during periods of heavy rain.

A number of potential bacteria sources exist that could be causing these impacts. These sources include the moat and the storm water runoff as well as other discharges that enter it, Bailey Brook and discharges from the reservoir system. However, during an average year, the City reports that the South Pond discharges to the moat only about a dozen times, typically during wet seasons in the winter and spring.

At the beach itself, the parking and pavilion areas are large impervious areas that have significant potential to contribute pollutants during runoff events. As at most beaches, Easton Beach also supports a large population of seagulls that frequent the parking lots as well as the sandy areas. They are not generally observed around the South or North Ponds, but tend to remain at the beach, proper. No other waterfowl (swans, ducks, etc.) were observed anywhere around the beachshed during sampling events; however, swans and ducks have been observed in the ponds at other times by City officials.

3.0 DAM EVALUATION

Existing Information Reports and records provided by the City of Newport and obtained from RIDEM files for the dam were reviewed prior to the inspection. A summary of this review is provided below, along with anecdotal information obtained during interviews with City staff familiar with the dam's history, current condition and maintenance practices.

3.1 RIDEM Files

- October 18, 1985 RIDEM Inspection Report regarding hurricane damage to dividing embankment
- Sections at former drawdown pipe (20" dia., abandoned in place) at south pond embankment, dated 1898
- June 6, 1995 RIDEM Inventory Data Sheet (reported as completed in 1876, noted in good current condition, low downstream hazard, noted 5/31/95 inspection but no form present in file).

3.2 Reports Provided by City

- 1939 contract manual for reconstruction of portions of south embankment and reinforced concrete spillway provided by City
- 1939 plans of Newport Water Works Spillway (former South Pond spillway) showing boring profiles
- June 28, 1991 engineering report of borings and stability analysis of north embankment and north end of west embankment
    - Noted embankments as in "marginally unstable" condition
    - Noted deepened silty sediment in Moat, increasing effective embankment height and resulting instability
    - Recommended dredging/backfilling Moat (City placed large volume of trap-rock fill, which consolidated into soft underlying material in early 1990's).
    - Identified remedial alternatives:
        - § place culvert in Moat and backfill
        - § move Moat away from toe of slope, flatten downstream slope
        - § construct conc. lined channel further from slope as replacement to Moat
    - Noted wet areas at toe of slope of south embankment, recommended further evaluation regarding effect on stability
    - Recommended continuing inspections and mowing along embankment (trees noted not to exist on embankment)
    - Noted extensive rodent holes along embankment, recommended backfilling as needed. Recommended rodent control program.

- 1978 plans of water plant South Pond inlet reconstruction (for diving inspection)

3.3 Operational Data from Staff Interviews

The following items were noted by City staff during interviews conducted during the inspection.

- Flow in Moat channel is noted to have scoured in places reducing the width of the bench adjacent to the embankment's downstream slope; in some places the Moat channel is noted to be actually encroaching into the embankment toe.
- Compacted gravel has been placed remotely by specialized equipment to reinforce soft/weak/settled areas on downstream slopes and adjacent bench.
- Animal burrows common on embankments, addressed by backfilling with compacted gravel; it was noted that a program formerly existed to address rodents.
- One seep previously noted during high water conditions at west end of southern embankment.
- Access to embankments is very difficult/cost-prohibitive for significant repair or construction projects.
- Brush clearing occurs approximately one or two times per year; cuttings were noted to sometimes be left in the impoundment where cut.
- Riprap gabions and geotextile fabric are often used to repair significant scarps formed on upstream slopes.
- Ability to properly clear vegetation on embankments and repair slopes to original configuration is limited.
- Operating on short-term solutions for upstream slope undermining/scarping.
- Steep/saturated slopes and narrow/saturated benches limit access even for custom mowing equipment.
- Riprap slope protection lost by youths/vandals throwing units onto ice in winter or other loss into impoundment by sliding/settlement.
- South Pond drawdown valve exercised about every 5 years.
- One of two valved drawdown conduits in dividing embankment not operational.

3.4 Limited Field Survey

A limited field survey was conducted to obtain cross-sections of portions of the North, West and South embankments and adjacent moat channel. Survey information was not obtained for other slopes/embankments; however our visual observations did not indicate a large variance from these measurements. Slope angles based on the field survey are summarized below in Table 2.

Table 2
Surveyed Embankment Slope Angles

Location	Slope Range
Down stream slopes on the north end of the West Embankment	2.1H:1V to 2.7H:1V
Up stream slopes on the north end of the West Embankment	1.1H:1V to 1.5H:1V
Down stream slopes on the south end of the West Embankment	2.25H:1V to 3.0H:1V
Down stream slopes on the North Embankment	2.3H:1V to 2.9H:1V
Up stream slopes on the North Embankment	1.5H:1V to 1.9H:1V
Down stream slope on the South Embankment was measured near the spillway	5H:1V

A visual inspection of the North Pond and South Pond embankment and spillway structures was conducted on November 21, 2006 to assess current conditions and identify deficiencies. A visual diving inspection of the South Pond spillway structure, South Pond treatment plant intake structure and North Pond treatment plant intake structure was also performed on this date.

A summary of observations and findings from these inspections is provided below. The diving inspection report is provided in Appendix A. Photographs from the dam inspections are provided in Appendix B.

3.4.1 Spillway Structures

3.4.1.1 South Pond Spillway

Description

- Reinforced concrete spillway and abutments
- Steel sheeting cutoff wall below structure
- Valved drawdown structure at right abutment (operable)
- Weep holes in downstream apron
- Construction joints

Deficiencies

- Spillway
    - Voids detected and/or delamination in progress on top section of concrete spillway (inferred from hollow sound from hammer blows and efflorescence at cracks which is indicative of loss of interior material).
    - Metal guide rails for weir boards in low flow channel not completely secure; joint spalling along rails observed.
    - Efflorescence/horizontal cracking observed along downstream spillway face.
    - Spalling observed on edges of low flow channel.
    - Surface scaling/coarse concrete observed on spillway crest.
- Right Abutment
    - Efflorescence, pattern cracking and spalling observed.
- Left Abutment
    - Faint efflorescence, no pattern cracking.
    - Construction joint on left abutment opening, approx. 1/4" at surface.
    - Fair soil contact (no rilling), large area of settlement adjacent to upstream wall.
- Gate chamber
    - Gate valve operational, demonstrated and flowed full all day to clear sediment.
    - Efflorescence and horizontal cracking inside drawdown gate chamber.
    - Minor spalling on gate chamber exterior concrete.
- Aprons
    - Downstream apron concrete noted as soft (disintegrates easily with hammer blows), covered with approx. 6" soft sediment.
    - Upstream apron appeared in good condition, covered with approx. 6" soft sediment.
    - Weep holes in downstream apron full of sandy sediment.
    - No scouring or undermining of aprons noted.
    - Stone armoring observed on channel bottom immediately downstream of apron.
    - No scour protection observed on south slope of outlet basin immediately downstream of spillway.

- Downstream Channel
  - No scour protection on downstream channel banks.
  - Significant voids exist and actively developing along top of dry stone training wall adjacent to pump station chain link fence and Memorial Avenue box culvert.

3.4.1.2 North Pond Primary Spillway

Description

- Low reinforced concrete spillway bar between reinforced concrete abutments.
- Placed-stone scour protection apron in downstream channel graded to match elevation of spillway bar.
- Some riprap scour protection upstream of spillway bar.
- Significant vegetation in spillway channel (cleared for inspection).
- Void at bottom of left downstream abutment training wall (34"W x 40"D x 12" H, apparently formed by design based on smooth appearance of roof), brick observed at interior wall facing void opening.

Deficiencies

- 2" vertical dislocation at transverse crack in spillway bar approx. 42" from left abutment.
- Significant horizontal cracks (approx. 1/4" wide) on abutment faces.
- Several transverse cracks across spillway bar.
- Several large voids in placed-stone scour protection apron immediately downstream of spillway bar (two observed, each approx. 30" W x 20'L x 2'D); voids apparently resulting from missing scour protection, not sinkholes.
- Minor horizontal deflection of left end of spillway bar.
- Missing upstream riprap scour protection along 10' section near middle of spillway bar.
- Significant brush and vegetation in spillway channel.
- Signs of channelized stormwater runoff (rilling) on earthen embankment adjacent to right abutment; likely due to pedestrian foot-traffic.

3.4.1.3 North Pond Emergency Spillway

Description

- Low riprap spillway bar.
- Mortared field stone abutment walls.
- Low mortared field stone training wall along right downstream channel.
- Significant woody vegetation along spillway and throughout downstream channel.

Deficiencies

- Dislodged cap stone at left abutment.
- Excessive woody vegetation over spillway crest and in downstream channel.
- Downstream channel not clearly defined; adjacent wet areas outside observed channel.

3.4.2 Earthen Embankments

3.4.2.1 South Embankment

Description

- Earthen embankment, crest width approx. 10'.
- Good grass cover on crest (except worn pedestrian footpath), downstream slope and bench.
- Riprap/placed-stone armoring at bottom of upstream slope.
- Approx. 2.5H:1V grassed downstream slope.
- Embankment height approx. 8' (from crest to downstream toe of slope).
- Grassed bench width 10'-15' (between toe of slope to Moat channel), some areas reinforced with gravel fill.
- Limit of bench formed by approx. 12" high scarp to Moat channel bed.
- Limited portions of downstream lower toe of slope and bench along downstream toe of slope reinforced with gravel fill and vegetated.
- 1939 reconstruction drawings show rock-fill toe drain and steel sheeting cutoff at limited portion of west end of embankment.
- 1939 reconstruction drawings show placed-stone armoring on entire upstream slope.

Deficiencies

- Consistent minor scarp along upstream top of slope.

- Significant scarp at portions of upstream top of slope. Likely caused by combination of wave action on insufficiently protected slopes and burrows leading to voids/sloughing of sections of slope.
- Armoring does not extend to upstream top of slope.
- Woody vegetation (brush) on portions of upstream slope.
- Wet areas along majority of lower ¼ downstream slope with saturated bench; evidence of minor seeps observed at some locations.
- Worn footpath along entire embankment crest.
- Some grassed/erosion rills on portions of lower downstream slope.
- Evidence of burrows on downstream slope.
- Portions of bench and lower downstream slope rutted by mowing equipment.
- Minor seep and slough noted on downstream slope near west end of this embankment section.

3.4.2.2 West Embankment

Description

- Earthen embankment, approx. 10' typical crest width.
- Good grass cover on crest (except worn pedestrian footpath), downstream slope and bench.
- Riprap armoring at bottom of upstream slope along waterline.
- Approx. 2.5H:1V grassed downstream slope.
- Embankment height approx. 8' at south end, approx. 4' at north end (from crest to downstream toe of slope).
- Grassed bench width varies between 0-8' (toe of slope to Moat channel), one area noted as reinforced with gravel fill.
- Limited portions of downstream lower toe of slope and bench along downstream toe of slope reinforced with gravel fill and vegetated (near footbridge at Old Beach Road).
- Limit of bench formed by 12"-24" high scarp to Moat channel bed.

Deficiencies

- Consistent significant scarp along upstream top of slope (typically 12"-18" high); no riprap protection.
- Severe scarps (42" high) at limited areas of north end of embankment, crest width narrowing to 3-5' wide (flagged for protection of public at time of inspection); recent repairs completed by placing compacted gravel or riprap gabions on filter fabric. Likely caused by combination of wave action on

insufficiently protected slopes and burrows leading to voids/sloughing of sections of slope.

- Inadequate armoring height on upstream slope; slope subject to erosion by wave action.
- Woody vegetation (brush) on entire upstream slope (north end of embankment recently cleared for inspection).
- Wet areas along majority of lower 1/3 of downstream slope with saturated bench, evidence of some minor seeps.
- Worn footpath along entire embankment crest.
- Moat channel scarp at toe of downstream slope along portions of embankment.
- Portions of bench and lower downstream slope rutted by mowing equipment.
- Erosion at upstream end of left stone masonry training wall along Moat channel.
- Reported animal burrows.

3.4.2.3 North Embankment

Description

- Earthen embankment, approx. 12' crest width.
- Fair grass cover on crest (except worn pedestrian footpath).
- Good grass cover on downstream slope and bench (outside of gravel fill reinforcement to portions of downstream slope and bench).
- Riprap armoring on upstream slope.
- Approx. 2.5H-3H:1V grassed downstream slope (visual estimate).
- Embankment height approx. 4' at west end, approx. 3' at east end (from crest to downstream toe of slope).
- Grassed bench width varies between 1'-5' (toe of slope to Moat channel).
- Limited portions of downstream toe of slope and bench along downstream toe of slope reinforced with gravel fill and vegetated.
- Limit of bench formed by 12"-24" high scarp to Moat channel bed.
- Portion of upstream slope near water treatment plant stock yard reinforced with riprap gabions.

Deficiencies

- Armoring does not fully cover upstream slope (some thin/bare areas); slope subject to erosion by wave action.
- Minor woody vegetation (brush) on entire upstream slope.
- Wet areas along majority of lower 1/3 of downstream slope with saturated bench.

- Worn footpath along entire embankment crest, some widened bare areas.
- Moat channel scarp near toe of downstream slope at portions of embankment.
- Portions of bench and lower downstream slope rutted by mowing equipment.

3.4.2.4 East Embankment

Description

- Earthen embankment, crest width varies from 5 '-10 '.
- Fair grass cover on crest (except worn pedestrian footpath).
- Significant woody vegetation (brush) on slopes and bench along downstream slope.
- Limited riprap armoring at bottom of upstream slope along waterline.
- Approx. 2H:1V downstream slope (visual estimate).
- Embankment height approx. 4 'at north end, approx. 8 'at south end (from crest to downstream toe of slope).
- Bench width varies between 0 '-4 '(toe of slope to drainage ditch.

Deficiencies

- Consistent significant scarp along upstream top of slope (varies 12 "-18 " high).
- Severe scarps (42 " high) at limited areas of embankment, crest width narrowing to 3 '-5 'wide, previous repairs noted at some locations by placing riprap gabions on filter fabric. Likely caused by combination of wave action on insufficiently protected slopes and burrows leading to voids/sloughing of sections of slope.
- Upstream slope settled adjacent to left main spillway abutment.
- Outlet for drainage channel along downstream slope not freely draining near middle of embankment; unstabilized overflow channel over embankment crest resulting in erosion gully.
- Armoring does not extend to upstream top of slope.
- Woody vegetation (brush) on both upstream and downstream slopes.
- Worn footpath along entire embankment crest.
- Channel scarp near toe of downstream slope at portions of embankment.
- Animal burrows and rodents observed.

3.4.2.5 South Pond/North Pond Dividing Embankment

Description

- Earthen embankment, approx. 12 'crest width.
- Good grass cover on crest (except worn pedestrian footpath).

- Riprap armoring on approx. 2H:1V slopes (visual estimate).
- Embankment height approx. 4 '(from crest to downstream waterline).
- Portions of downstream slope reinforced with riprap gabions.

Deficiencies

- Armoring does not fully cover slopes (some thin/bare areas).
- Minor woody vegetation (brush) on slopes (recently cleared for inspection).
- Worn footpath along entire embankment crest.
- Severe scarps at several locations on downstream slope. Likely caused by combination of wave action on insufficiently protected slopes and burrows leading to voids/sloughing of sections of slope.

3.4.2.6 North Pond Embankment

Description

- Earthen embankment, approx. 4 'crest width.
- Good grass cover on crest and downstream slope.
- Riprap armoring on approx. 2H:1V upstream slopes (visual estimate).
- Embankment height approx. 5 '(from crest to downstream toe of slope).
- Significant woody vegetation (brush and trees) on upstream slope.

Deficiencies

- Large void (approx. 15 'L x 3 'W x 2 'D) on upstream side of embankment in area where North Pond intake structure penetrates embankment, adjacent area saturated/ponded with standing water.
- Significant woody vegetation at two outlet structures adjacent to treatment plant; some erosion adjacent to concrete headwall at one structure.
- Trees and woody vegetation at north end of embankment adjacent to treatment plant.

3.4.3 Drawdown Structures

3.4.3.1 South Pond Primary Drawdown Structure

Description

- 24 " cast iron pipe and valve.
- Discharges to downstream spillway apron.
- Gate structure with access chamber adjacent to right spillway abutment.

Deficiencies

- No apparent deficiencies.

- Reported by DPW personnel to have last been operated 5 years ago.
- Opened and closed with normal effort.
- Significant sediment discharged when first opened, allowed to flow full day of inspection.

3.4.3.2 North Pond Drawdown Structures

Description

- Reported 16" or 18" pipe structures penetrating the western and eastern side of the South Pond/North Pond Dividing Embankment.
- Gate boxes in top of embankment.
- West gate valve reported operable.

Deficiencies

- East gate valve near North Pond Spillway reported inoperable in open position.

3.4.4 Water Plant Intake Structures

3.4.4.1 South Pond Intake Structure

Description

- Precast concrete box structure with internal baffle walls.
- 30" intake pipe with bar screen inlet.

Deficiencies

- Screen over top of structure (reportedly formed of chain link fencing) is missing.

3.4.4.2 North Pond Intake Structure

Description

- Precast concrete box structure with internal baffle walls.
- 30" intake pipe with bar screen inlet.

Deficiencies

- Screen over top of structure (formed of chain link fencing) severely deteriorated.

3.4.4.3 Blowoff Structure

Description

- 12" pipe connected to reported 17" raw water line from Paradise Pump Station.
- Pipe opening located near north end of North Pond Emergency Spillway.

Defic1iencies

- Pipe opening discovered with inlet flow forming a small vortex at pond surface.
- Noted as possible location where turtles enter plant piping and raw water system; inlet screen apparently missing.
- Plant staff closed valve to stop inflow during inspection.

3.5 Issues of Concern

A summary of primary issues of concern from the inspections is provided below.

3.5.1 Operational Concerns

3.5.1.1 Vegetation

- DPW workers reported to clear vegetation and leave cuttings in impoundment.
- Saturated slope and bench areas and narrow/eroded bench areas limit mowing. equipment access

3.5.1.2 Construction/Maintenance

- Cannot gain access by heavy equipment in majority of embankment areas due to limited crest width/poor stability, and limited bench width/saturated condition.
- Moat channel scouring bench and encroaching on downstream toe of slope.
- Specialized equipment subcontractor hired by DPW to "sling" gravel across Moat where needed to reinforce bench and slopes.
- Youth/vandals reported to throw slope armor/channel scour units (riprap/placed stone) onto/through ice during winter, resulting in reduced/missing slope protection.

3.5.1.3 Rodent Control

- No formal rodent control program (e.g., trapping).
- Addressing burrows by placing compacted gravel, but cannot address all burrows before they form to voids and contribute to scarping/failure of upstream slopes.

3.5.2 Dam Stability Concerns

3.5.2.1 Downstream Slope Stability

- Partially implemented 1991 report recommendations: filling of Moat channel with riprap units and placing gravel on bench and slope to strengthen soils.
- Saturated and narrowed/missing bench reduces buttress force on downstream embankment slope, reducing slope stability FS.

- Many downstream slopes at 2H:1V or steeper, not in accordance with current dam safety guidelines.
- Severe scarps noted on west embankment and north/south dividing embankment.

3.5.2.2 Upstream Slope Stability

- Consistent scarps noted all embankments.
- Severe scarps noted on west, north and east embankments.
- Missing slope armor units, public foot traffic, animal burrows and woody vegetation all possibly contributing factors.

4.0 MOAT EVALUATION

4.1 Hydrologic Evaluation of Contributing Watersheds

Our hydrologic evaluation of the watershed areas surrounding North Pond and South Pond and the Moat included three major tasks: delineating watershed and/or subwatershed areas, defining basin hydrologic parameters, and establishing a hydrologic model accounting for watershed hydraulic connectivity.

4.1.1 Watershed Delineation

The first task of our hydrologic evaluation was to delineate watershed and subwatershed areas. As part of our evaluation, all watersheds discharging to the Moat and to North and South Ponds were considered and were delineated utilizing topographic information provided by USGS mapping services. Drainage structure mapping provided by the City of Newport was also used to refine overall watershed delineations and further divide the watersheds into subwatersheds.

As depicted in Figure 2, the overall area of land draining to the Moat and to North and South Ponds was divided into three major watershed areas referred to herein as *Watersheds 1, 2,* and *3*. *Watershed 1* is the area of land that drains to North Pond, *Watershed 2* is the area of land that drains to South Pond, and *Watershed 3* is the area of land that drains to the Moat.

Watershed 1 contains several natural and manmade areas of detention and storage. Additionally, two major streams/brooks are located within the watershed that convey runoff to North Pond via several roadway culverts. Consequently, peak flows generated by this watershed (during significant storm events) are most likely influenced by such areas of storage and the numerous hydraulic restrictions within the watershed. Although every area of storage/detention or roadway culvert within the watershed was not accounted for as part of this analysis, impacts to peak flow rates resulting from flow restrictions associated with the Green End Avenue culvert were accounted for. As a result, *Watershed 1* was divided into two subwatersheds: *Subwatersheds 1-A and 1-B*. Storm water runoff generated by *Subwatershed 1-A* is conveyed to the wetland system located immediately upstream of Green End Avenue prior to being discharged to North Pond through an approximate 12-foot wide by 8-foot high box culvert that would function as a hydraulic restriction during significant storm events. Runoff generated by *Subwatershed 1-B* is conveyed directly to North Pond via a combination of closed-conduit drainage systems and overland flow.

Watershed 2 consists of South Pond and the area of land immediately adjacent to the pond that is within the confines of the surrounding dike. Storm water runoff generated by this watershed is discharged to the pond via overland flow.

Storm water runoff generated by *Watershed 3* is directly discharged to the Moat via numerous drain outlets. Consequently, *Watershed 3* was subdivided into 12 subwatersheds corresponding with each outlet where sampling was conducted as part of our water quality analysis.

Although the area draining to both ponds and the Moat have been hydrologically divided into three major watershed areas, all watersheds are hydraulically connected (i.e. during significant storm events). North Pond has been designed with primary and secondary spillways. The pond's primary spillway, located in its southeastern corner, discharges overflow to South Pond when the water level in the pond reaches an elevation of approximately 10.6 feet (as verified by survey). The pond's secondary spillway, located in its southwestern corner adjacent to the Water Department's old water treatment filtration plant, discharges overflow to the Moat when the water level in the pond reaches an approximate elevation of 10.9 feet (as verified by survey). South Pond has also been designed with a spillway, located in its southeastern corner, that discharges overflow to the Moat and ultimately to Easton Bay.

4.1.2 Composite Curve Number and Time of Concentration

The second task of our hydrologic analysis was to define the hydrologic parameters of each watershed and subwatershed analyzed. The various soil types, land uses, and hydrologic cover conditions within a watershed have a significant impact on the amount of flow generated by a watershed. To estimate the composite curve number of each contributing watershed and subwatershed, the following sources were referenced:

- The Soil Survey of Rhode Island (USDA, July 1981). Delineations of the numerous soil hydrologic groups within the numerous watersheds and subwatersheds contributing storm flow to the Moat and to North and South Ponds were imported from the Rhode Island Geographic Information System (RIGIS) website, and are based on soil delineations provided by the Soil Survey of Rhode Island. The majority of soils within the contributing watershed areas have a "Type C" hydrologic classification and consist of Newport silt loams, Newport-Urban land complex, and Pittstown silt loams. For analysis purposes, all areas covered by water were assumed to have an impervious curve number (CN of 98) and any areas underlain by soils with no specific hydrologic group, such as "Udorthents," were assumed to display similar soil characteristics as the most conservative surrounding soil group.

- Rhode Island Geographic Information System Website (1999). Delineations of the numerous land uses within all contributing watershed and subwatershed areas were imported from the RIGIS website. These included land use information such as residential districts of various lot sizes, commercial areas, industrial/institutional areas, recreational areas, wetlands, pond areas, and open space. Refer to Figure 3 for a depiction of the numerous land uses within the watershed and Appendix A for all supporting documentation used in developing the composite curve numbers for each watershed and subwatershed area. This documentation includes a breakdown of approximate percentages of specific land uses within each watershed.

- Technical Release 55 - Urban Hydrology for Small Watersheds (NRCS, 1986). With the soil types, land uses, and hydrologic conditions determined for the watershed, curve numbers for each land use type (underlain by each hydrologic soil group) were obtained from this publication and used to develop the composite curve number of each watershed and subwatershed.

The time of concentration, T_c, is another hydrologic parameter that has an effect on the amount of flow generated by a watershed or subwatershed areas. Several methods have been developed for estimating the time of concentration. The method used in this hydrologic analysis was the Lag Method. The Lag Method requires two input variables: the hydraulic length of the watershed and the average slope of that path. The hydraulic length is the distance from the hydrologically most distant point in the watershed to the watershed outlet point. The path used to calculate the hydraulic length of each watershed and subwatershed analyzed is illustrated in Figure 2 of this report.

4.1.3 Summary of Watershed Hydrologic Characteristics

The following summarizes the hydrologic characteristics (including the composite curve numbers and times of concentration) of each watershed and subwatershed area contributing storm flow to North Pond (*Subwatersheds 1-A and 1-B*), South Pond (*Watershed 2*), and the Moat (*Subwatersheds 3-1 through 3-12*):

Table 3
Summary of Watershed Hydrologic Characteristics

Subwatershed	Area (Acres)	Approximate % of Impervious Area	Composite Curve Number	Time of Concentration
Subwatershed 1-A (To North Easton Pond)	2167.4 Acres	33.4%	84.0	272.3 Minutes
Subwatershed 1-B (To North Easton Pond)	485.6 Acres	33.5%	87.5	64.0 Minutes
Watershed 2 (To South Easton Pond)	140.7 Acres	0.0%	97.0	6.0 Minute (Minimum)
Subwatershed 3-1 (To Moat)	31.8 Acres	34.3%	82.4	23.3 Minutes
Subwatershed 3-2 (Sampling Point S8)	232.1 Acres	57.5%	88.0	55.4 Minutes
Subwatershed 3-3 (Sampling Point S7)	84.6 Acres	66.4%	90.2	30.9 Minutes
Subwatershed 3-4 (Sampling Point S6)	42.1 Acres	54.6%	87.3	30.3 Minutes
Subwatershed 3-5 (Sampling Point S5)	21.2 Acres	31.6%	81.6	24.5 Minutes
Subwatershed 3-6 (Sampling Point S4)	36.6 Acres	31.6%	81.6	18.0 Minutes
Subwatershed 3-7 (Sampling Point S3)	2.2 Acres	23.2%	79.6	6.6 Minutes
Subwatershed 3-8 (Sampling Point S2)	3.2 Acres	24.2%	79.8	6.6 Minutes
Subwatershed 3-9 (Sampling Point S1)	4.7 Acres	27.2%	80.6	8.5 Minutes
Subwatershed 3-10 (To Southern Moat)	8.6 Acres	72.0%	91.0	6.0 Minutes (Minimum)
Subwatershed 3-11 (To Eastern Moat)	8.2 Acres	85.0%	94.0	6.0 Minutes (Minimum)
Subwatershed 3-12 (Sampling Point S10)	119.0 Acres	49.7%	86.1	56.2 Minutes
Subwatershed 4-1* (Sampling Point S11)	116.9 Acres	49.7%	85.9	23.4 Minutes
Subwatershed 4-2[a] (Sampling Point S9)	1.1 Acres	72.0%	91.0	6.0 Minutes (Minimum)

Note
a Note that Subwatersheds 4-1 and 4-2 discharge directly to Easton Beach and do not contribute storm water runoff to North or South Easton Ponds or to the Moat. Hydrologic characteristics associated with these subwatersheds were included for water quality purposes only.

For verification purposes, the composite curve numbers for *Subwatersheds 1-A and 1-B* as computed above were compared with the composite curve numbers provided in the 1991 USDA Flood Prevention Evaluation of Ellery Road and Eustis Avenue for both subwatersheds. As anticipated, the newly computed composite curve numbers for *Subwatershed 1-A* and Subwatershed 1-B (of 84.0 and 87.5, respectively) were higher than those previously computed by the USDA (of 82.4 and 86.0, respectively). These increases in curve numbers can most likely be attributed to an increase in impervious area experienced as a result of development.

4.1.4 Peak Flow Rates and Volumes

The third task of our hydrologic evaluation was to calculate approximate peak flow rates and volumes generated by each watershed and subwatershed discharging to both ponds and the Moat. With the curve numbers and times of concentration calculated, Hydraflow Hydrographs (2002), a program that utilizes the NRCS TR-20 Method to generated hydrographs, was used to calculate peak flow rates generated by each watershed and subwatershed area for the water quality storm event (corresponding to a 1.2-inch rainfall amount over a 24-hour period) and for the 2-, 5-, 10-, 25-, 50-, and 100-year, 24-hour storm events. Rainfall amounts used in the analysis were obtained from Technical Paper No. 40, Rainfall Frequency Atlas of the United States (May 1961).

The following summarizes runoff peak flow rates and volumes generated by each watershed and subwatershed area that contributes storm flow to the Moat and to North and South Ponds. Refer to Appendix A for all existing condition hydrologic calculations and supporting documentation.

Table 4
Peak Flow Rate Summary Table

Subwatershed	Water Quality Storm (1.2-Inches)	2-Year, 24-Hour Storm (3.4-Inches)	5-Year, 24-Hour Storm (4.3-Inches)	10-Year, 24-Hour Storm (4.9-Inches)	25-Year, 24-Hour Storm (5.7-Inches)	50-Year, 24-Hour Storm (6.5-Inches)	100-Year, 24-Hour Storm (7.1-Inches)
Subwatershed 1-A (To North Easton Pond)	78.2 cfs	692.0 cfs	994.5 cfs	1,201.5 cfs	1,481.3 cfs	1,763.8 cfs	1,976.6 cfs
Subwatershed 1-B (To North Easton Pond)	74.0 cfs	481.5 cfs	664.3 cfs	787.0 cfs	950.8 cfs	1,114.3 cfs	1,236.6 cfs
Watershed 2 (To South Easton Pond)	148.6 cfs	474.8 cfs	605.9 cfs	692.9 cfs	808.7 cfs	924.3 cfs	1,010.9 cfs
Subwatershed 3-1 (To Moat)	3.86 cfs	42.3 cfs	61.1 cfs	74.0 cfs	91.3 cfs	108.8 cfs	122.0 cfs
Subwatershed 3-2 (Sampling Point S8)	41.1 cfs	255.6 cfs	350.9 cfs	414.7 cfs	499.8 cfs	584.6 cfs	648.1 cfs
Subwatershed 3-3 (Sampling Point S7)	26.1 cfs	135.1 cfs	181.6 cfs	212.6 cfs	253.7 cfs	294.6 cfs	325.1 cfs
Subwatershed 3-4 (Sampling Point S6)	9.44 cfs	61.9 cfs	85.3 cfs	101.1 cfs	122.1 cfs	143.0 cfs	158.7 cfs
Subwatershed 3-5 (Sampling Point S5)	2.19 cfs	26.5 cfs	38.7 cfs	47.0 cfs	58.3 cfs	69.7 cfs	78.2 cfs
Subwatershed 3-6 (Sampling Point S4)	4.16 cfs	51.5 cfs	75.1 cfs	91.3 cfs	113.2 cfs	135.3 cfs	151.8 cfs
Subwatershed 3-7 (Sampling Point S3)	0.21 cfs	4.07 cfs	6.04 cfs	7.4 cfs	9.25 cfs	11.1 cfs	12.5 cfs
Subwatershed 3-8 (Sampling Point S2)	0.33 cfs	5.97 cfs	8.85 cfs	10.8 cfs	13.5 cfs	16.2 cfs	18.3 cfs

Subwatershed	Water Quality Storm (1.2-Inches)	2-Year, 24-Hour Storm (3.4-Inches)	5-Year, 24-Hour Storm (4.3-Inches)	10-Year, 24-Hour Storm (4.9-Inches)	25-Year, 24-Hour Storm (5.7-Inches)	50-Year, 24-Hour Storm (6.5-Inches)	100-Year, 24-Hour Storm (7.1-Inches)
Subwatershed 3-9 (Sampling Point S1)	0.52 cfs	7.94 cfs	11.7 cfs	14.3 cfs	17.7 cfs	21.2 cfs	23.9 cfs
Subwatershed 3-10 (To Southern Moat)	5.23 cfs	25.1 cfs	33.4 cfs	38.9 cfs	46.3 cfs	53.6 cfs	59.0 cfs
Subwatershed 3-11 (To Eastern Moat)	6.70 cfs	26.0 cfs	33.8 cfs	39.0 cfs	45.9 cfs	52.7 cfs	57.8 cfs
Subwatershed 3-12 (Sampling Point S10)	16.2 cfs	119.7 cfs	167.2 cfs	199.3 cfs.	242.2 cfs	285.1 cfs	317.3 cfs
Subwatershed 4-1* (Sampling Point S11)	24.2 cfs	180.2 cfs	251.6 cfs	299.9 cfs	364.4 cfs	428.9 cfs	477.2 cfs
Subwatershed 4-2* (Sampling Point S9)	0.67 cfs	3.20 cfs	4.26 cfs	4.97 cfs	5.91 cfs	6.84 cfs	7.53 cfs

* Note that Subwatersheds 4-1 and 4-2 discharge directly to Easton Beach and do not contribute storm water runoff to North or South Easton Ponds or to the Moat. Peak flow rates generated by these subwatersheds were included for water quality purposes only.

Table 5
Runoff Volume Summary Table

Subwatershed	Water Quality Storm (1.2-Inches)	2-Year, 24-Hour Storm (3.4-Inches)	5-Year, 24-Hour Storm (4.3-Inches)	10-Year, 24-Hour Storm (4.9-Inches)	25-Year, 24-Hour Storm (5.7-Inches)	50-Year, 24-Hour Storm (6.5-Inches)	100-Year, 24-Hour Storm (7.1-Inches)
Subwatershed 1-A (To North Easton Pond)	40.6 ac-ft	315.7 ac-ft	451.6ac-ft	545.3 ac-ft	673.1 ac-ft	803.1 ac-ft	901.8 ac-ft
Subwatershed 1-B (To North Easton Pond)	14.2 ac-ft	85.3 ac-ft	118.3ac-ft	140.8 ac-ft	171.3 ac-ft	202.0 ac-ft	225.3 ac-ft
Watershed 2 (To South Easton Pond)	10.8 ac-ft	36.9 ac-ft	47.7 ac-ft	54.9 ac-ft	64.6 ac-ft	74.2 ac-ft	81.5 ac-ft
Subwatershed 3-1 (To Moat)	0.54 ac-ft	4.53 ac-ft	6.53 ac-ft	7.92 ac-ft	9.82 ac-ft	11.8 ac-ft	13.2 ac-ft
Subwatershed 3-2 (Sampling Point S8)	7.17 ac-ft	41.8 ac-ft	57.7 ac-ft	68.6 ac-ft	83.3 ac-ft	98.1 ac-ft	109.3 ac-ft
Subwatershed 3-3 (Sampling Point S7)	3.29 ac-ft	16.8 ac-ft	22.8 ac-ft	26.9 ac-ft	32.3 ac-ft	37.9 ac-ft	42.0 ac-ft
Subwatershed 3-4 (Sampling Point S6)	1.22 ac-ft	7.40 ac-ft	10.3 ac-ft	12.2 ac-ft	14.9 ac-ft	17.6 ac-ft	19.6 ac-ft
Subwatershed 3-5 (Sampling Point S5)	0.33 ac-ft	2.94 ac-ft	4.27 ac-ft	5.20 ac-ft	6.46 ac-ft	7.76 ac-ft	8.74 ac-ft
Subwatershed 3-6 (Sampling Point S4)	0.56 ac-ft	5.02 ac-ft	7.30 ac-ft	8.88 ac-ft	11.0 ac-ft	13.3 ac-ft	14.9 ac-ft
Subwatershed 3-7 (Sampling Point S3)	0.03 ac-ft	0.29 ac-ft	0.43 ac-ft	0.52 ac-ft	0.66 ac-ft	0.79 ac-ft	0.90 ac-ft
Subwatershed 3-8 (Sampling Point S2)	0.04 ac-ft	0.42 ac-ft	0.63 ac-ft	0.77 ac-ft	0.96 ac-ft	1.16 ac-ft	1.31 ac-ft

Subwatershed	Water Quality Storm (1.2-Inches)	2-Year, 24-Hour Storm (3.4-Inches)	5-Year, 24-Hour Storm (4.3-Inches)	10-Year, 24-Hour Storm (4.9-Inches)	25-Year, 24-Hour Storm (5.7-Inches)	50-Year, 24-Hour Storm (6.5-Inches)	100-Year, 24-Hour Storm (7.1-Inches)
Subwatershed 3-9 (Sampling Point S1)	0.06 ac-ft	0.63 ac-ft	0.92 ac-ft	1.12 ac-ft	1.40 ac-ft	1.68 ac-ft	1.90 ac-ft
Subwatershed 3-10 (To Southern Moat)	0.37 ac-ft	1.81 ac-ft	2.45 ac-ft	2.88 ac-ft	3.45 ac-ft	4.03 ac-ft	4.47 ac-ft
Subwatershed 3-11 (To Eastern Moat)	0.47 ac-ft	1.93 ac-ft	2.55 ac-ft	2.96 ac-ft	3.52 ac-ft	4.08 ac-ft	4.50 ac-ft
Subwatershed 3-12 (Sampling Point S10)	3.03 ac-ft	19.9 ac-ft	27.9 ac-ft	33.4 ac-ft	40.8 ac-ft	48.3 ac-ft	54.0 ac-ft
Subwatershed 4-1 (Sampling Point S11)	2.90 ac-ft	19.3 ac-ft	27.1 ac-ft	32.4 ac-ft	39.6 ac-ft	46.9 ac-ft	52.5 ac-ft
Subwatershed 4-2 (Sampling Point S9)	0.05 ac-ft	0.23 ac-ft	0.31 ac-ft	0.37 ac-ft	0.44 ac-ft	0.51 ac-ft	0.57 ac-ft

* Note that Subwatersheds 4-1 and 4-2 discharge directly to Easton Beach and do not contribute storm water runoff to North or South Easton Ponds or to the Moat. Peak flow rates generated by these subwatersheds were included for water quality purposes only

5.0 EASTON BEACH AND WATERSHED EVALUATION

Sources of water and flow at Easton Beach include discharge from the Moat, tidal reflux from Easton's Bay and direct discharge from several stormwater pipes. Discharge from the Moat includes flows from a number of intermittent and fluctuating sources that mix together and discharge to Easton's Bay from the Moat's mouth. Therefore the watershed— or beachshed— can be said to include all the sources of the Moat and the ponds.

The purpose of the water quality study portion of the Moat evaluation is to:

- Statistically evaluate current and historic water quality data for clues to potential sources.

- Identify potential nonpoint sources of bacteria to the beach based on monitoring data and field observations.

- Identify best management practices to restore water quality at Easton Beach.

5.1 Historic Water Quality

Historically, some sampling has been conducted at storm water outfalls that discharge directly to the beach, but the focus of most historic sampling has been at locations on the beach itself, not in the beachshed. Lack of water quality data in the Moat and upstream in the beachshed limits our ability to draw precise conclusions regarding potential sources. Notwithstanding, we are able to make some basic comparisons between the sampling stations and these comparisons do indicate direction for further study and investigation.

The questions considered in our analysis of historic water quality data include the following:

1. Do patterns in the water quality data indicate particular problem locations at the beach or in the beachshed?
2. How does water quality at the beach respond to rain events?
3. Have there been any significant changes in water quality at the beach locations from 2003 to 2006?

5.2 Tools Used for Statistical Analysis

In our analysis, we employ the following statistical tools:

- Boxplots
- Cumulative percentage curves.
- Line Graphs
- Correlation Analysis (Pearson's r)

Boxplots
A boxplot, also called a box and whisker plot, provides a graphic depiction of certain data characteristics. The bottom of the box demarks the line separating first and second quartiles of the data. Twenty-five percent of the data values are below the bottom of the box and 75% are

above. The top of the box demarks the line separating the third and fourth quartiles of the data. Twenty-five percent of the data values are above the top of the box and 75% are below. The box itself represents the range of the data between the 25^{th} and 75^{th} percentiles. This is also referred to as the interquartile range (IQR).

In our report, the median value of the data is represented as a line within the box. The split of the box by the median line demonstrates the skew of the data (i.e., whether the box is split evenly by the median line or whether the split leaves the box lopsided). The lines or whiskers are 1.5 times the height of the box, or 1.5 times the interquartile range, and extend from the top and bottom of the box. Values that lie outside the range of the whiskers are termed outliers and are indicated by a "*."

Cumulative Percentage Curves

Cumulative percentage curves (CPCs) are linear plots of data (e.g., *Enterococcus* concentrations) against percentile. CPC graphs generally include a reference line (e.g. the 104 cfu/100 ml swimming standard for *Enterococcus*) to show the percentage of a data set occurring above or below a threshold. Several CPCs may be plotted in a single chart to allow for comparison of related data sets.

CPCs help to insulate data analysis from data anomalies (i.e., outliers) and artificial data boundaries. We use CPCs in our analysis to help us focus on the frequency of violations of the 104 cfu/100 ml *Enterococcus* swimming standard and to protect our analysis from data skewing due to the laboratory upper detection bounds.

Line Graphs

Line graphs compare two variables. Each variable is plotted along an axis. Line graphs help show specific values of data, meaning that given one variable, the other can easily be determined.

Correlation Analysis (Pearson's r)

Correlation analysis is a statistical technique that evaluates the relationship between two variables; i.e., how closely they match each other in terms of their individual mathematical change. Correlation analysis is useful to compare data variable to try to determine if one variable (X) moves or changes in a certain direction, does the second variable (Y) also move or change in a similar or complementary direction.

5.2.1 Available Historical Data

Water quality sampling data collected in the Easton Beach watershed (also called beachshed in this discussion) from 2003 to 2006 was utilized in the analysis of historic water quality impacts. The sources and extent of the historic data are shown in Table 6.

Table 6
Summary of Historic Water Quality Data for the Easton Beach Beachshed

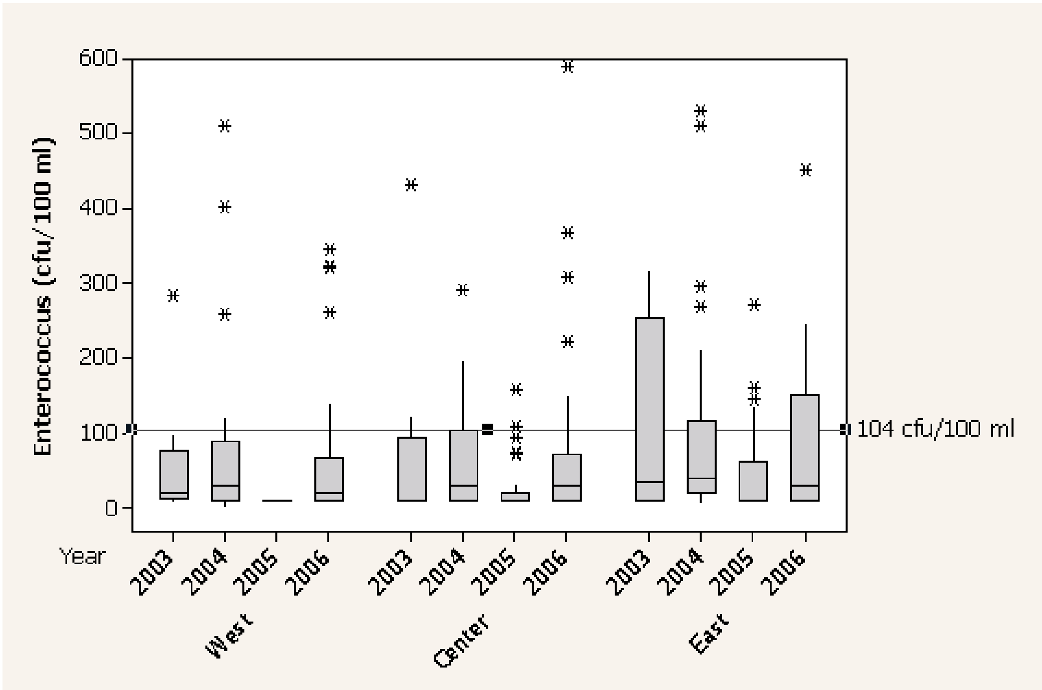
Data Source	Locations(s)	Sampling Period	Frequency	Parameters
RIDOH	Easton Beach, Moat Outlet, Atlantic Beach Club	2003 – 2006 swimming seasons (mid-May through August)	2 times/week or more frequently if violation	*Enterococcus*, daily total rainfall
Newport Recreation Department	Easton Beach, Moat Outlet	June-August 2006	Variable, 13 sampling events	*Enterococcus*
Clean Ocean Access/RIDOH	Easton Beach, Atlantic Beach Club; Surfer's Rick	October 10, 2006 – December 15, 2006 (sampling is on-going)	2 times/week (Tuesday and Friday)	*Enterococcus*, daily rainfall at Newport
Wave Avenue – (unknown collection source)	Easton Beach, Atlantic Beach Club	July 2006	5 consecutive days	*Enterococcus*, daily rainfall at Newport

Some sampling has been conducted at stormwater outfalls that discharge directly to the beach, but the focus of the historic sampling has been at locations on the beach itself, not in the beachshed. While RIDOH samples during the swimming season with the goal of monitoring beach water quality for the protection of public health, the lack of information about water quality in the Moat and upstream in the beachshed limits the ability to draw conclusions about potential sources or identify possible corrective measures based on historic data. However, the multi-year record of microbial water quality at locations at Easton Beach, the Moat Outlet, and the Atlantic Beach Club to allow for meaningful analysis and comparison of the water quality at these stations. The following sections provide analysis of the historic data we have been provided.

5.2.2 Rhode Island Department of Health

RIDOH has collected since 2003. This is the longest record of sampling available from a single entity. Chart 1 shows boxplots of the *Enterococcus* concentrations at the three Easton Beach monitoring locations during the 2003-2006 summer swimming seasons.

Chart 1
Enterococcus Concentrations Measured by RIDOH
at Easton Beach Sampling Stations by Year



While the median concentrations for all stations for the four years of data are below the 104 cfu/100 ml single sample water quality standard, the boxplots in Chart 1 show that the data for all years at all stations are skewed by instances of high measures of *Enterococcus.* The boxplots show a consistent pattern across the sampling locations, that is higher and more variable measures tend to occur on the eastern side of the beach.

Chart 2
Enterococcus Concentrations Measured by RIDOH by Year
at Sampling Stations Nearby Easton Beach

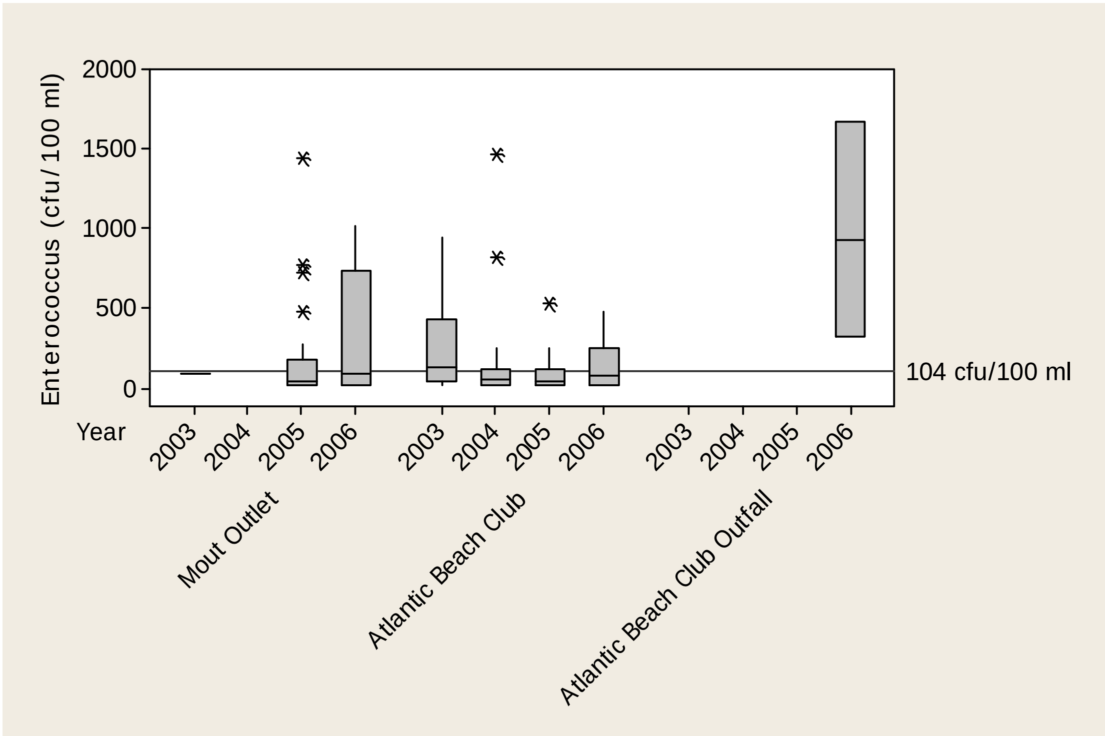


Chart 2 shows boxplots of the *Enterococcus* concentrations from samples collected by RIDOH at the Atlantic Beach Club, the Moat Outlet and the Atlantic Beach Club outfall. Note that data for the Atlantic Beach Club outfall was only available for 2006 and the data for the Moat Outlet was sparse in 2003 and missing in 2004.

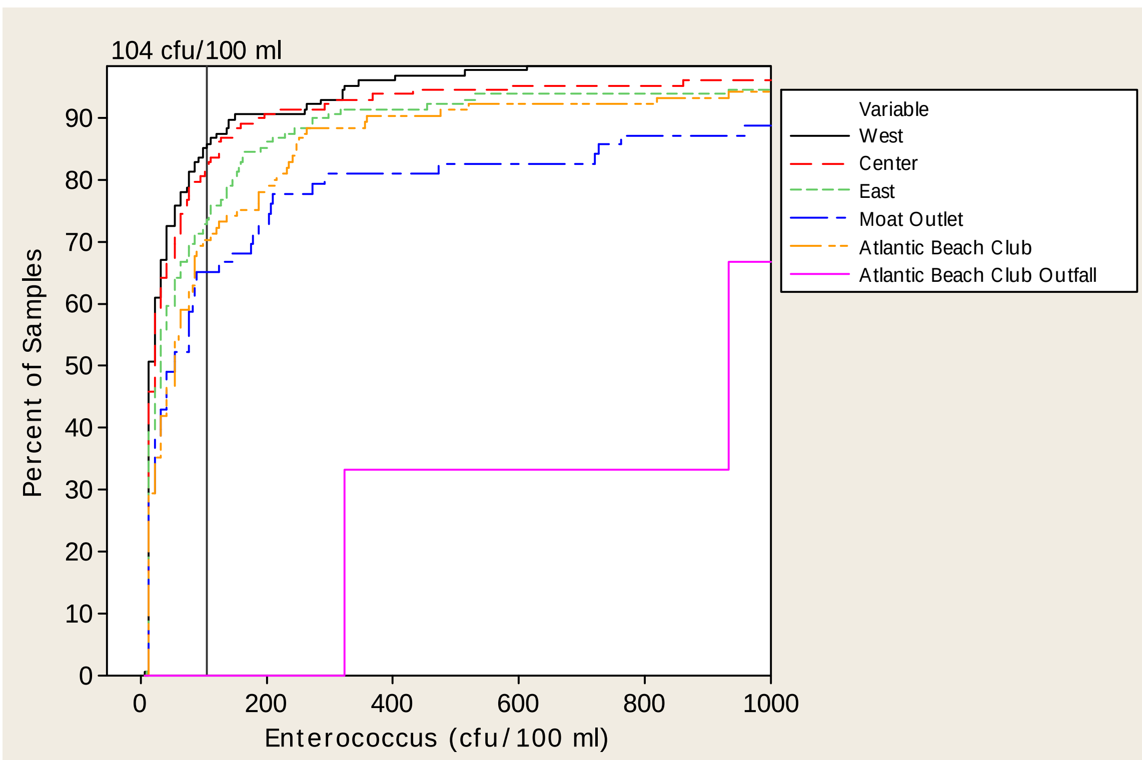
We offer the following observations based on Chart 2:

- Although data for the Atlantic Beach Club Outfall was only available for 2006, it has the highest median and interquartile range of all the stations discussed above.
- Like Chart 1, boxplots for the Moat Outlet and Atlantic Beach Club stations show lower values in 2005.
- The data from these stations have higher median values and a larger range of values than the Easton Beach sampling stations.

Chart 3 shows the cumulative percentage curves (CPCs) of the data collected at the Easton Beach stations, the Atlantic Beach Club, the Moat Outlet and the Atlantic Beach Club Outfall (see Section 6.2 for discussion of how to read CPCs). The vertical line marking the 104 cfu/100 ml *Enterococcus* concentration is included as a point of comparison between data sets for each station. CPCs for each sampling station can be interpreted by noting the point at which it intersects the vertical 104 cfu/100 ml line in relation to the percentages on y-axis.

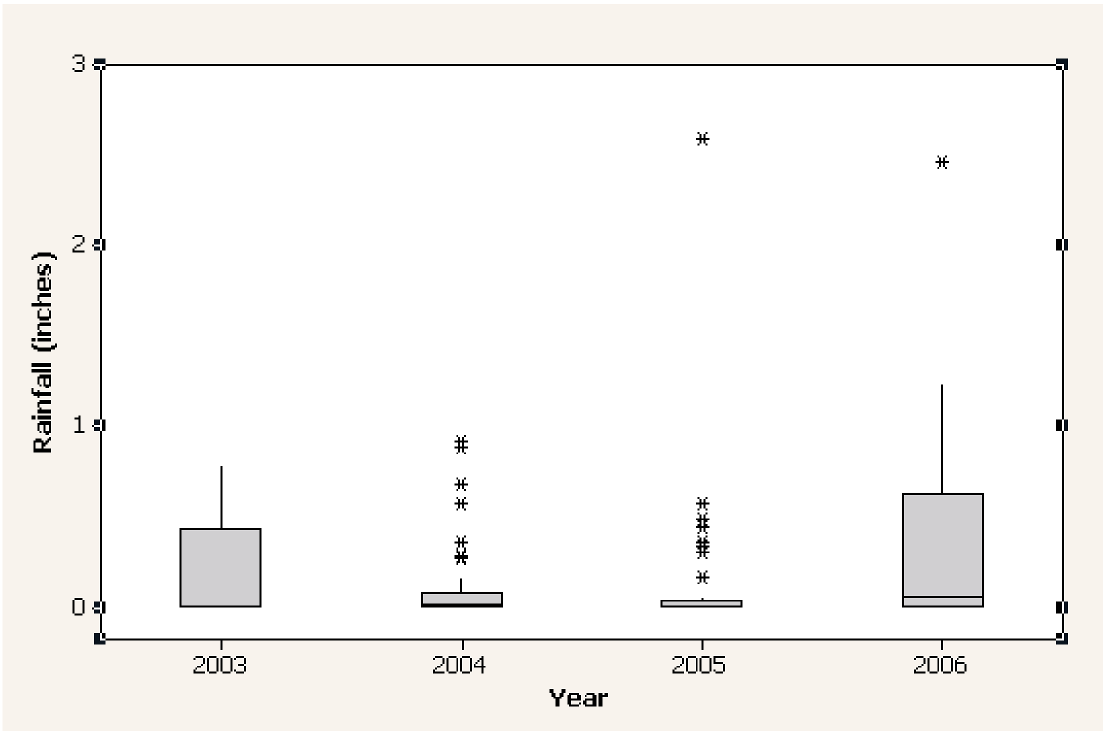
The West and Center Easton Beach stations show the best water quality, with approximately 20% of the samples exceeding 104 cfu/100 ml. Water quality degrades moving east across the beach, with approximately 25% and 29% of the samples exceeding 104 cfu/100 ml at the East Beach Station and Atlantic Beach Club stations, respectively. At the Moat Outlet, approximately 35% of the samples are greater than 104 cfu/100 ml for *Enterococcus*. None of the sample values collected at the Atlantic Beach Club Outfall measured below 104 cfu/100 ml. Note that the x-axis is set to a maximum value of 1000 cfu/100 ml to provide good resolution of the CPCs near the 104 cfu/100 ml threshold.

Chart 3
CPC of the Sampling Stations Monitored by RIDOH during the 2003-2006 Swimming Seasons



In comparison to other years, samples collected during 2005 have lower median values and less variability (see Chart 1 and 2). A boxplot of rainfall over the four-year period (Chart 4) shows overall drier conditions during the 2005 sampling season.

Chart 4
Boxplots of Rainfall on Sampling Days at Easton Beach

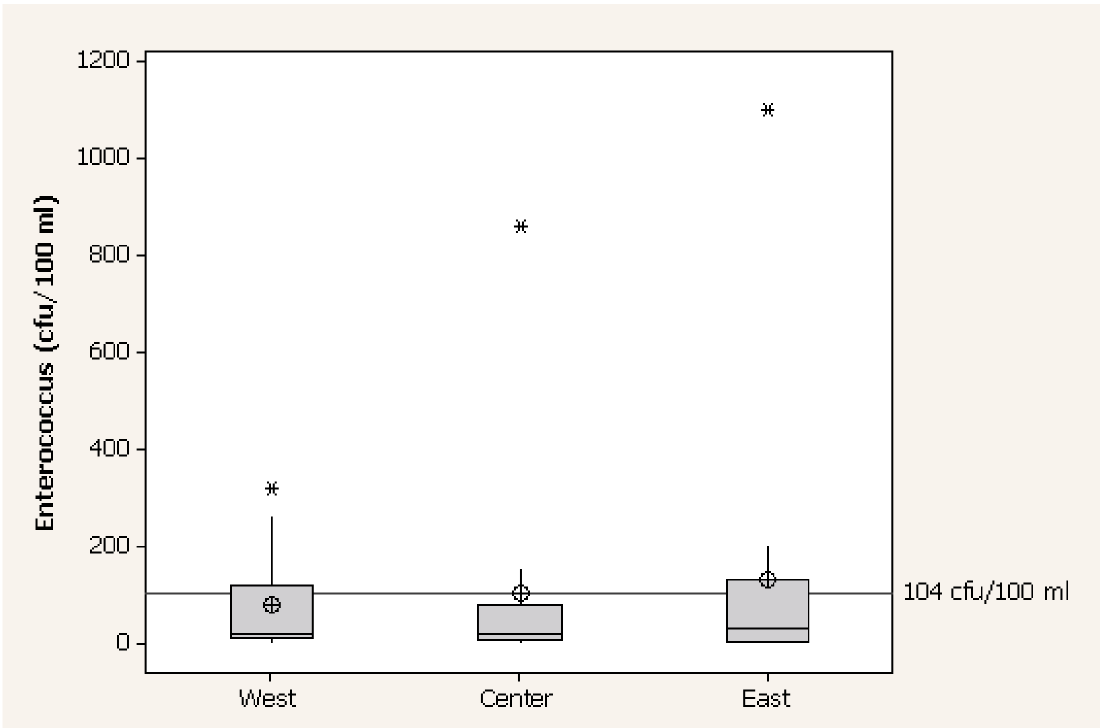


The information in Chart 4 indicates a correlation between rainfall and *Enterococcus* concentrations at the beach. The relationship between rainfall and (*Enterococcus)* and possible seasonal variations is discussed in section 6.2.4, in the analysis of the Clean Ocean Access data.

5.2.3 Newport Recreation Department

Data collected by the Newport Recreation Department on 13 occasions during June, July, and August 2006 shows pattern of *Enterococcus* concentrations at the beach sampling locations that is similar to RIDOH data, namely increasing mean and median values from west to east. (Chart 5)

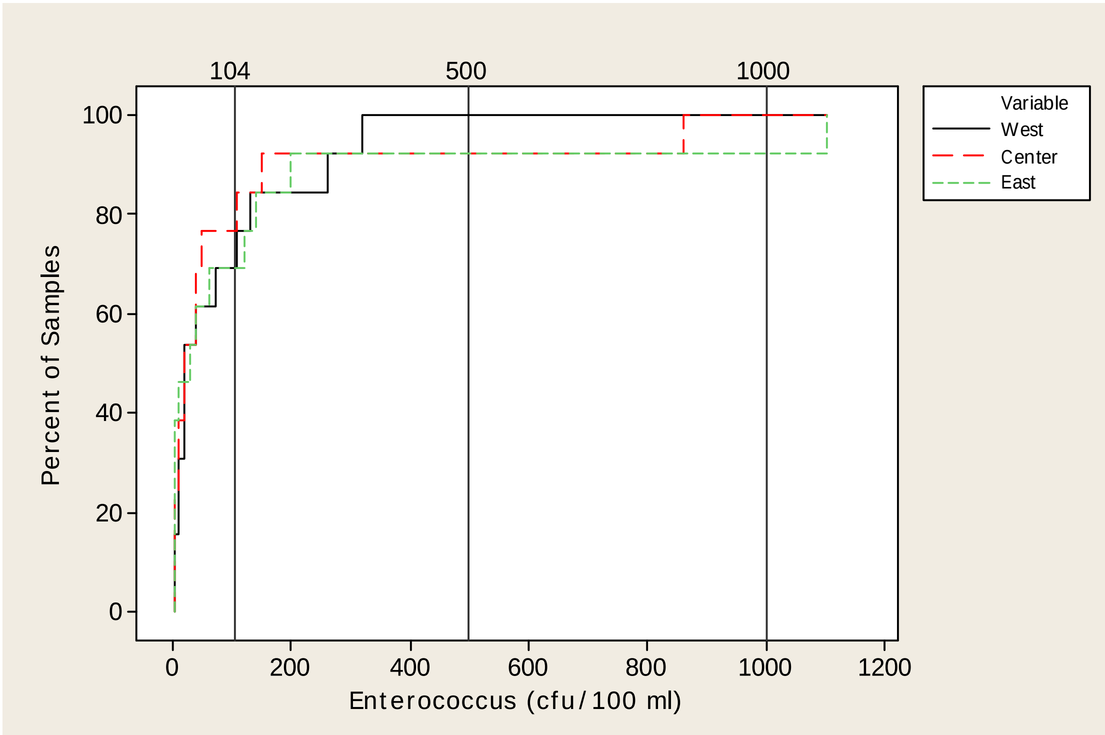
Chart 5
Boxplots of *Enterococcus* Concentrations at Beach Sampling Stations Collected by Newport Recreation Department During Summer 2006



Note:
1. Mean concentrations are indicated by a circle and cross.

Chart 6, which shows CPCs of *Enterococcus* concentrations at the various beach locations, indicates that while all stations exceed the 104 cfu/100 ml concentration, there are an increasing number of high-concentration samples moving across Easton Beach from west to east. The CPC plot of the three beach stations shows that approximately 30% of the samples at the east and west station are greater than the 104 cfu/100 ml standard for *Enterococcus* as compared to the center station that has about 25% of samples exceeding the standard. However, if the concentration increases to 500 cfu/100 ml then all of the samples at the West station are less than 500 cfu/100 ml, but approximately 90% of the observations are less than that value at the other stations. If the CPC threshold line is increased to 1000 cfu/100 ml, 100% of the samples from the West and Center stations are below the concentration, but 10% of the East station samples are above that value.

Chart 6
CPC of *Enterococcus* at Easton Beach Sampling Stations (Summer 2006)



During 2006, *Enterococcus* samples collected at the Moat tended to register higher in concentration than samples collected at the beach. The summary statistics for the beach and Moat Outlet stations are presented in Table 7 and show a significantly higher mean for the Moat Outlet. As with the data discussed above, we found greater overall variability in *Enterococcus* concentrations at the Moat Outlet. This is demonstrated by the greater interquartile range (Table 7).

Table 7
Summary Statistics for *Enterococcus* Data Collected by the Newport Recreation Department (Summer 2006)

Sampling Station	Mean	Median	Interquartile Range
West	79	120	110
Center	102	80	73
East	133	130	125
Moat Outlet	4119	1000	6120

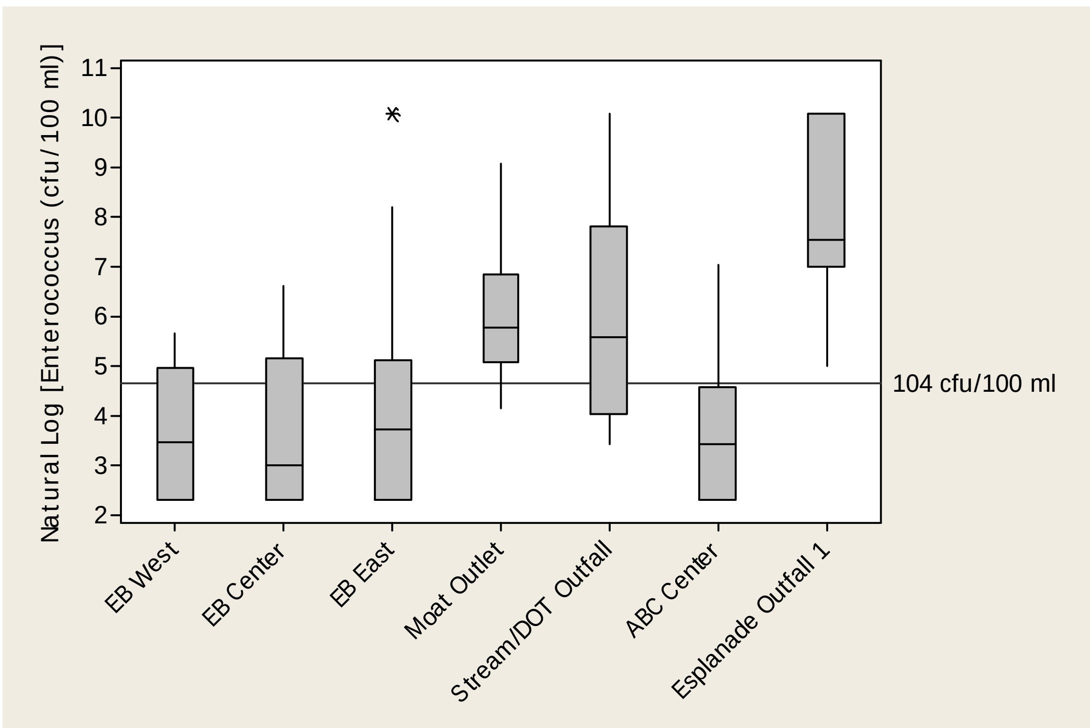
5.2.4 Clean Ocean Access

Clean Ocean Access is a community action group made up of residents who volunteer to perform regular sampling at the beach. The samples are turned over to RIDOH for analysis.

The methods of sample collection have not been confirmed; however, RIDOH accepts these samples are part of their sampling program.

Clean Ocean Access collects water quality data during nonsummer months for Easton Beach and the Atlantic Beach Club and this data is discussed later in this report. The results of the sampling to date are consistent with the observations made at Easton Beach during summer sampling by RIDOH, namely *Enterococcus* concentrations at the storm water outfalls and the Moat Outlet are typically higher than those at the Easton Beach sampling stations. Chart 7 shows boxplots of the nonsummer data collected at the Easton Beach stations and the adjacent Moat Outlet and DOT outfall discharging to the Moat.

Chart 7
Boxplots of Easton Beach and Atlantic Beach Club *Enterococcus* Data Collected by Clean Ocean Access from October – December 2006



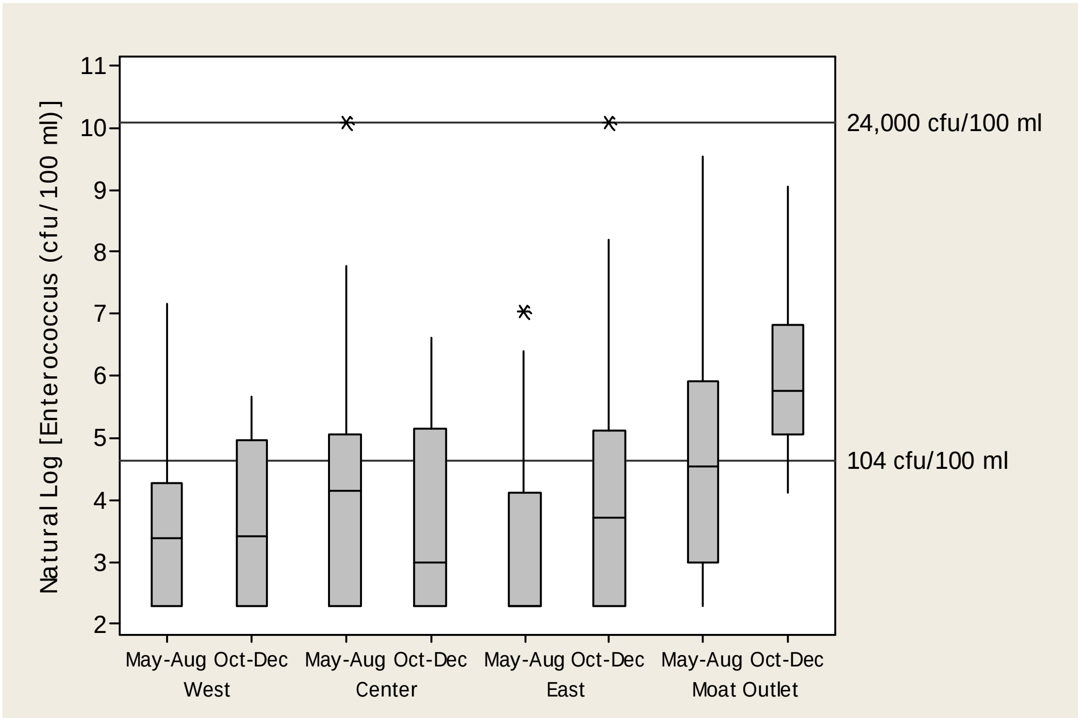
Note:

1. *Enterococcus* concentrations are shown on a natural log scale to allow for easier viewing of the data over a wide range of concentrations.
2. To complete the boxplots, values of <10 cfu/100 ml (10 in data set) were converted to 10 cfu/100 ml and two values of >24,192 cfu/100 ml were converted to 24,192 cfu/100 ml.

Chart 8 shows paired Summer (May – August) and Fall (October – December) 2006 data at the Easton Beach stations and the Moat Outlet. We offer the following observations:

- The east-to-west trend of degrading water quality at the Easton Beach sampling stations is still present in the fall months.
- Higher levels of bacteria were measured during this past fall. This is could be due to high rainfall than normal that was observed this fall.

Chart 8
Boxplot Comparing Summer and Fall *Enterococcus* Concentrations at the Easton Beach West and Center Sampling Stations



We understand this is the first year that samples are being collected during the fall and winter months. Typically, decreased UV light and water temperatures would provide conditions more favorable for bacteria survival. Therefore, because of the change in environmental conditions and the fact that it is an incomplete data set, the data collected this winter cannot be validly compared to the data collected during the summer months.

Combined Data
There is a statistically significant correlation between rainfall and *Enterococcus* which be seen in the data collected from October 2006 through December 2006 and for all the data collected from May 2006 through December 2006. These data sets are combined in Table 8.

The relatively high values of the linear correlation coefficient, Pearson's r, demonstrate that elevated concentrations of *Enterococcus* are associated with higher rainfall amounts. With the exception of the East station, the Easton Beach stations (see Table 6) have higher Pearson's r values for the water quality samples collected in the fall. Chart 9 shows the relationship between high *Enterococcus* concentration and 24-hr rainfall totals greater than 1 inch in October and November.

Table 8

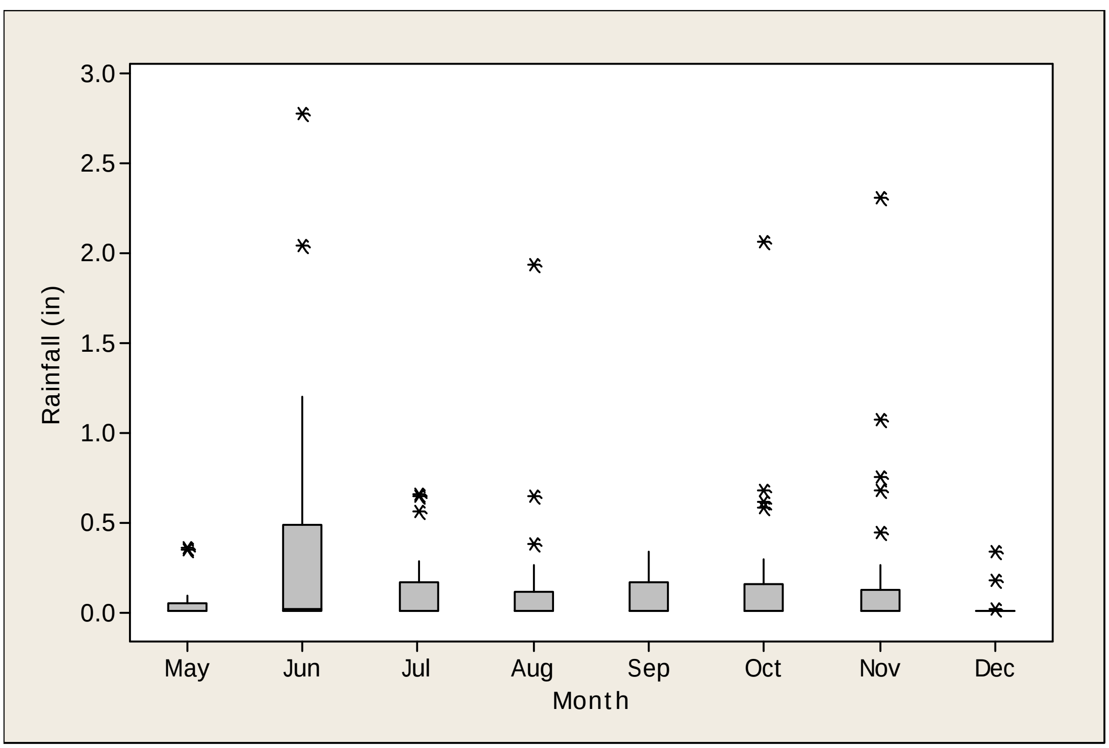
Linear Correlation (Pearson's r) Between 24-hour Rainfall and *Enterococcus* Concentrations for 2006 Easton Beach Sampling Data

Sampling Period	Sampling Stations					
	West	Center	East	Moat Outlet	Atlantic Beach Club	Esplanade Outfall 1
Summer May – August	0.452 (0.004)[1]	0.557 (0.000)	0.512 (0.001)	0.500 (0.001)	0.766 (0.000)[1]	0.59 (0.008)
Fall October – December	0.539 (0.017)	0.579 (0.009)	0.466 (0.045)	0.856 (0.000)	0.606 (0.000)	0.768 (0.000)
May – December (All Data)	0.454 (0.000)	0.558 (0.000)	0.407 (0.002)	0.508 (0.000)	0.668 (0.000)	0.585 (0.000)

Notes:
1. P-values are shown in parentheses.

Chart 9

Boxplot of rainfall for Newport in a 24-hour period (2006)



Note: Data in December is through December 15, 2006

The Clean Ocean Access sampling includes the routine collection of a duplicate and a split sample at the Atlantic Beach Club. Duplicate samples are typically collected in two different containers, at the same location, at the same time. The laboratory is not informed of the duplicate sample, and they are treated and analyzed as two separate samples. Split samples are typically collected in one container and split into two containers at the lab. These samples are then analyzed separately. These are both commonly used and accepted methods of quality control.

Theoretically, if quality control is good, duplicate and split samples should yield identical (or nearly identical) results. Three recently taken duplicate and split-sample sets present unanticipated results. For example, results on October 10, 2006 and November 28, 2006 were the same for the split and duplicate samples (all reported as equal to or <10 cfu/100 ml). However, reported *Enterococcus* results for samples collected on October 17, 2006 varied by as much as 196 cfu/100 ml and as much as 379 cfu/100 ml for samples collected at that location on November 17, 2006. The results from these three samples illustrate potential variability in microbial water quality data

5.2.5 Town of Middletown

The Town of Middletown conducted sampling and investigations between 2004-2006, inclusive.

Louis Berger Group Sampling event (July 11, 2006)

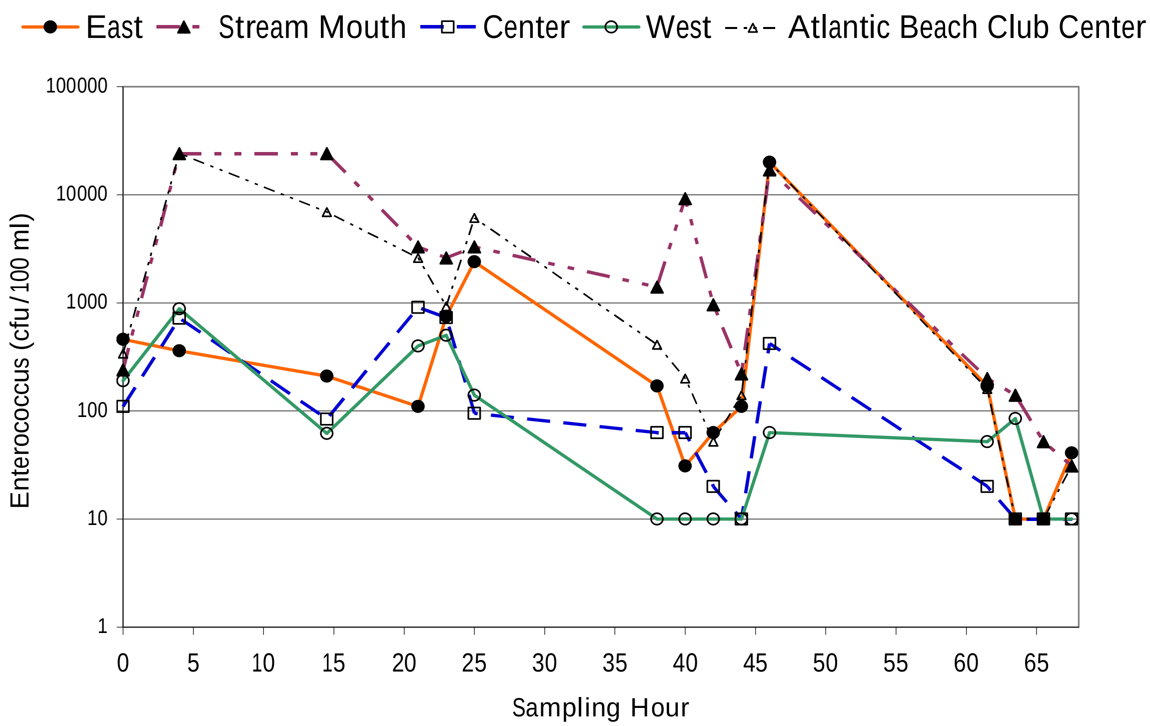
Chart 10 shows data collected during a 68-hour sampling event, at the three Easton Beach stations and the Atlantic Beach Club. Due to the length of the sampling event (over several days) this event is a particularly good representation of the response over time of the beach water quality. Sampling began at 5:00 p.m. July 11, 2006, which is represented as the 0 Hour. Table 9 shows the reported 24-hour rainfall measured and corresponding sampling hours for each calendar day during which sampling took place. Chart 10 shows the *Enterococcus* data in relation to the sampling hours (i.e., hour 0 to hour 68). A logarithmic scale is used on the y-axis to depict *Enterococcus* concentrations.

Table 9
24-Hour Rainfall in Newport During and Before the July 11 –14, 2006 Sampling Event

Calendar Days[1]	Rainfall Depth (inches)
July 10, 2006	0.00
July 11, 2006[2]	0.05
July 12, 2006	0.30
July 13, 2006	0.09
July 14, 2006[3]	0.00

Notes:
1. Calendars days are the four calendar days during which sampling took place and the antecedent calendar day.
2. Sampling took place over 68 hours (0 –68). Sampling began at 5:00 p.m. on July 11, 2006.
3. Sampling ended at 12:00 p.m.

Chart 10
Time series of *Enterococcus* Data at Easton Beach Stations for Period July 11 –July 14, 2006



Notes:
1. Sampling began at 5:00 p.m. on July 11, 2006.

Chart 10 shows that the Moat Outlet and Atlantic Beach Club Center stations show the most rapid response to rainfall and the highest *Enterococcus* concentrations recorded for the sampling event. The East station does not start to increase until after Hour 21. After reaching a peak of 2400 cfu/100 ml at Hour 25, it declines until Hour 40 and rises to another peak of 20,000 cfu/100 ml at Hour 46. The pattern of response is similar to the Atlantic Beach Club Center sampling station, although the concentrations for the Atlantic Beach Club Center station are higher, until Hour 42 when they become similar. The West and Center stations show a similar pattern of response, although *Enterococcus* concentrations are typically higher at the Center station.

These results are consistent with the pattern of water quality observed in the sampling by RIDOH and Clean Ocean Access. Water quality at the Moat Outlet shows a strong response to rainfall, and shows the highest overall concentrations of *Enterococcus*. This is consistent with both the significant correlation between rainfall and *Enterococcus* and the higher overall *Enterococcus* concentrations observed at this station. The East and Atlantic Beach Club Center stations show a similar pattern of response to rainfall and elevated concentrations of bacteria compared to the Center and West stations. This suggests that the influence of the discharge from the Moat Outlet is stronger at the nearby East and Atlantic Beach Club Center stations. As noted in the analysis of the *Enterococcus* concentration data collected over the 2004-2006 summer swimming seasons, microbial water quality tends to decline moving in an easterly direction across Easton Beach.

5.2.6 Earth Tech Storm Sewer Investigation for the City of Newport

In 2004, Newport hired Earth Tech to investigate stormwater drainage pipes to identify any illicit cross-connections with sewers. Earth Tech's study confirmed that there were no cross-connections on the Newport side of the stormwater drainage system. Earth Tech did discover many used "mutt mitts" (plastic gloves for dog owners to use to pick up their animal's waste) discarded at the bottom of several catch basins. Further investigation showed that raccoons were living in several of the storm drainage systems in the Easton Beach Beachshed. Raccoon waste can build up in the storm drainage systems and then be washed out in rain events, carrying bacteria with it.

5.3 Conclusions Based on Analysis of Historic Data

The historic data we have is limited, mostly, to beach sampling and, unfortunately, provides little insight into sources in the beachshed. Notwithstanding, we are able to draw the following conclusions:

- The greatest amount of data is at the beach itself. While this is useful for monitoring water quality for protection of public health, it does not provide insight into sources or relative loading of bacteria upstream of the beach.
- Historic sampling data consistently show higher concentrations and more frequent violations of the single sample 104 cfu/100 ml *Enterococcus* standard at the easterly sampling stations, the stations associated with the Moat Outlet, and near the Atlantic Beach Club.
- High bacteria counts at the Eastons Beach, the Moat, and Atlantic Beach Club sampling stations correlate with rain events.
- Historic data shows that the storm water outfall (S11, aka Esplanade Discharge and Atlantic Beach Club outfall) located at the beaches and the Moat Outlet discharge at concentrations in violation of the single sample bathing beach standard and therefore *have the potential* to adversely affect water quality at the beach. However, the lack of sampling data upstream of these outlets results in uncertainty regarding specific source areas or possible corrective actions.
- Sometimes bathers themselves may be cited as a potential source of bacteria in a swimming area. However, the presence of elevated *Enterococcus* concentrations even after the swimming season has ended, indicates that bathers are unlikely to be the major source of indicator organisms at Easton Beach.

5.4 Water Quality Monitoring

5.4.1 Sampling Program

In order to better evaluate water quality at Easton Beach, a multiphase sampling program is proposed. The sampling program includes two separate sampling events. The first event has been completed and consisted of one 12-hour wet-weather sampling event, which we conducted in September. As an adjunct to this 12-hour event, we conducted a first-flush sampling event two weeks later. This first-flush event included collection of two rounds of samples. A second sampling event is planned to take place late spring of 2007. The following text provides more detail on the two phases of sampling.

Phase 1 Sampling
A 12-hour Phase 1 sampling event was successfully completed on September 29-30, 2006. The additional Phase 1 sampling took place on October 12, 2006. Sampling was conducted during wet weather (after <0.1 inches of rain in the antecedent 48-hour period). Samples were collected once every three hours for 12 hours.

Samples were collected at 26 locations and were analyzed by Rhode Island Laboratories for:

- *Enterococcus*
- Ammonia
- Surfactants

Sampling Event Description
As previously noted, a 12-hour Phase 1 sampling event was successfully completed on September 29-30, 2006. The weather conditions on and around this event, as reported by National Weather Service, were as follows:

Table 10
Weather Conditions-Event 1 Sampling

Date	Rainfall Amount (inches)	Temperature (high/low °F)	Wind Speed (average MPH/peak MPH/direction)
September 26, 2006	0.00	69/48	3/12/WSW
September 27, 2006	0.00	68/46	0/9/SE
September 28, 2006	0.00	68/50	3/13/ESE
September 29, 2006	0.53	64/50	6/14/SW
September 30, 2006	0.00	62/41	4/13/SSE

Sampling stations included seven Newport outfalls, one Middletown outfall, and two Rhode Island Department of Transportation (RIDOT) outfalls. Additionally, three samples were collected at Easton Beach, and one at Atlantic Beach. Two samples were collected from the Easton South Pond and one from the South Pond. Five samples were collected in various locations of the Moat surrounding the North and South Pond. The remaining four samples were collected from puddles in the parking lots of Easton Beach. The locations are shown on the attached Figure 4. The results for the lab analysis for both sampling events are included in Appendix D.

Table 11
Phase 1 – Sampling Stations

Sample Location (abbreviation)	Description
M-1	Moat station on Newport side, just below spillway of the South Pond
M-2	Moat station located at the Moat Outlet between Easton Beach and Atlantic Beach
M-3	Moat station located in Middletown, across from Newport Ave.
M-4	Moat station located in Newport between Eustis and Aborn Streets.
M-5	Moat station located in Newport across from the intersection of Memorial Blvd and Beach Rd.
P-1	South Pond at the southern most spillway
P-2	North Pond at the southern spillway into South pond
P-3	Bailey Brook at the entrance to North Pond
S-1	Newport DPW Outfall pipe just north of M-5
S-2	Newport DPW Outfall pipe north of S-1
S-3	Newport DPW Outfall pipe north of S-2
S-5	Newport DPW Outfall pipe across from Catherine St.
S-6	Newport DPW Outfall pipe across from Champlin St.
S-7	Newport DPW Outfall pipe at the northwest corner of South Pond
S-8	Newport DPW Outfall pipe across from Aborn St.
S-9	RIDOT Outfall pipe at the western end of Easton Beach
S-10	RIDOT Outfall pipe discharging to the Moat beside the Wave Ave pumping station
S-11	Middletown Outfall pipe that drains a section of the esplanade
S-12	Puddle in the east end of the Easton Beach Parking lot
S-13	Puddle in the west end of the Easton Beach Parking lot
S-14	Puddle at the eastern entrance of the Easton Beach Parking lot
S-15	Puddle on Memorial Blvd across from S-9
B-1	Beach station located at the western end of Easton Beach
B-2	Beach station located in the center of Easton Beach
B-3	Beach Station located at the eastern end of Easton Beach
B-4	Beach Station located in the center of Atlantic Beach
MB	Memorial Boulevard Outfall located upstream of M1

Flow data was collected at three of the five Moat stations, and depth of water in the outfall pipes (S Stations) was measured during sampling. Flow at the Moat station at the Moat Outlet (M2) was not measured due to direct tidal and wind influence, and the Moat station on the Middletown side of the Moat (M3) was not measurable because all discharge was flowing via eroded channels into the Moat at an unstable area of the bank separating the Moat from the South Pond. Flow from the outfalls was calculated using the SCS curve number method.

All Moat stations, where flow was measured, were found to have positive flows during the sampling event. Therefore we believe incoming tide was not reversing the Moat's normal flow direction during the sampling event. Although flows were slower during periods of high tide, we conclude that these stations are not affected by saltwater intrusion during rain events.

Additional sampling was performed during the first flush of an event on October 12, 2006. This event (Event 2) consisted of two rounds of samples collected at the Event 1 stations and one additional sample that was collected at outfall MB, a storm drain discharging to the Moat off of Memorial Boulevard. First-flush samples were analyzed for *Enterococcus* only.

During the both events, two samples were collected and were sent to Source Molecular Corporation to determine presence of the *Enterococcus* faecium human gene biomarker. The *Enterococcus* faecium human gene biomarker is a particular genetic pattern that occurs in the DNA of *Enterococcus* that has been excreted with human feces. Presence of the human biomarker indicates sanitary wastewater. Both samples (collected at B3 and M2) during the first event tested negative for this biomarker, and both samples (collected at M2 and S11) during the second event tested positive for this biomarker. It should be noted however, that the samples that tested positive for the human biomarker results were less than 5% of the total amount of *Enterococcus* detected in these samples. These results are included as part of Appendix D.

Table 12
Weather Conditions-Event 1 Sampling

Date	Rainfall Amount (inches)	Temperature (high/low °F)	Wind Speed (average MPH/peak MPH/direction)
October 9, 2006	0.00	70/51	0/10/SSW
October 10, 2006	0.00	71/52	0/13/NNE
October 11, 2006	0.53	63/53	7/13/ENE
October 12, 2006	0.29	61/53	13/20/S
October 13, 2006	0.00	61/52	0/13/NNE

Phase 2 Sampling

As previously discussed, the Phase 2 of the sampling program will be conducted during warmer weather, or active beach season to control for the effect of temperature on bacteria levels.

5.5 Summary of Water Quality Data

Samples were sent to BAL Laboratories to determine concentrations of *Enterococcus* and to New England Testing Laboratories for ammonia and surfactants. All samples were collected and handled in accordance with Fuss & O'Neill storm water sampling practices. Samples were picked up on-site by both labs or dropped off at the labs. The results of the lab analysis for the Phase 1 event are included in Appendix D.

The following sections summarize our findings during the Phase 1 sampling conducted on September 29 2006 and October 11, 2006.

5.5.1 Beach Station Sampling

Beach locations were not tested for ammonia or surfactants as these parameters are highly influenced by saltwater and would not depict accurate results. Beach station results are summarized in the following tables.

Table 13
Event 1 Sampling Results for Beach Locations

Location/Sample	Specific Conductivity [uS/cm]	pH	Temperature [degrees C]	*Enterococcus* [CFU/100mL]
B1				
B1-01	42,674	7.8	18.6	30
B1-02	42,710	7.91	18.65	130
B1-03	42,995	7.83	19.01	<10
B1-04	43,185	8.13	18.74	20
B2				
B2-01	42,370	7.99	18.24	370
B2-02	42,586	8.07	18.52	280
B2-03	42,990	8.7	19.63	<10
B2-04	43,296	8.15	18.45	86
B3				
B3-01	41,780	7.79	18.94	670
B3-02	40,283	8.01	18.62	>25000
B3-03	40,750	8.11	18.94	41
B3-04	43,162	8.09	18.41	61
B4				
B4-01	41,962	7.39	17.7	1600
B4-02	41,268	8.07	18.81	390
B4-03	42,380	8.12	19.04	86
B4-04	42,638	8.09	18.25	63

Note: Beach stations were diluted as part of the laboratories standard procedure as salt levels interfere with the substrate.

Table 14
Event 2 Sampling Results for Beach Locations

Location/Sample	Specific Conductivity [uS/cm]	pH	Temperature [degrees C]	*Enterococcus* [CFU/100mL]
B1				
B1-01	49,110	7.34	17.2	97
B1-02	48,500	7.25	17.4	240
B2				
B2-01	46,300	7.56	17.2	120
B2-02	39,500	7.65	17.4	1100
B3				
B3-01	49,700	7.6	17.2	310
B3-02	29,050	7.03	17.2	6500
B4				
B4-01	50,000	7.6	17.2	58
B4-02	37,400	7.58	17.4	1000

5.5.2 Miscellaneous Sampling Stations

Tables 15 and 16 summarize miscellaneous samples collected in various puddles around Easton Beach Parking lot and Memorial Boulevard.

Table 15
Event 1 Sampling Results for Parking Lot Puddle Locations

Location/Sample	*Enterococcus* [CFU/100mL]
S-12	> 2400
S-13	>2400
S-14	980
S-15	>2400

Table 16
Event 2 Sampling Results for Memorial Boulevard Outfall

Location/Sample	Specific Conductivity [uS/cm]	pH	Temperature [degrees C]	*Enterococcus* [CFU/100mL]
MB				
MB1-01	187	5.9	16.9	97
MB1-02	129	6.45	16.5	2400

5.5.3 *Enterococcus* Data at Storm Water Outfalls, Moat Locations and Pond Locations

Samples collected at the stormwater outfalls (S stations), Moat locations (M stations) and Pond locations (P stations) are summarized in tables below.

Table 17
Enterococcus Results for Moat Stations for Events 1 and 2

Event 1 Location / Sample	*Enterococcus* [CFU / 100mL	Event 2 Location / Sample	*Enterococcus* [CFU / 100mL]
M1		M1	
M1-01	>2400	M1-01	240
M1-02	>2400	M1-02	6,500
M1-03	120		
M1-04	1700		
M2		M2	
M2-01	>2400	M2-01	2,400
M2-02	>2400	M2-02	550
M2-03	210		
M2-04	1400		
M3		M3	
M3-01	>2400	M3-01	1,200
M3-02	>2400	M3-02	2,500
M3-03	44		
M3-04	>2400		
M4		M4	
M4-01	>2400	M4-01	24,000
M4-02	2400	M4-02	780
M4-03	70		
M4-04	2400		
M5		M5	
M5-01	>2400	M4-01	370
M5-02	>2400	M4-02	2,000
M5-03	130		
M5-04	870		

Some of the *Enterococcus* concentrations from the September and October sampling were reported as "greater than" values due to the laboratory's use of a single dilution. For these instances, we do not know the actual *Enterococcus* concentrations, but rather that the concentrations were no less than 2,400 cfu/100 ml. With that in mind, M1 and M4 appear high in E2 and also had higher values in E1. (Table 17)

Table 18
Enterococcus Results for Stormwater Outfall Stations for Events 1 and 2

Event 1 Location / Sample	*Enterococcus* [CFU / 100mL	Event 2 Location / Sample	*Enterococcus* [CFU / 100mL
S1		*S1*	
S1-01	>2400	S1-01	340
S1-02	>2400	S1-02	20,000
S1-03	550		
S1-04	290		
S2		*S2*	
S2-01	>2400	S2-01	580
S2-02	>2400	S2-02	17,000
S2-03	>2400		
S2-04	>2400		
S3		*S3*	
S3-01	>2400	S3-01	920
S3-02	>2400	S3-02	1,500
S3-03	29		
S3-04	37		
S5		*S5*	
S5-01	>2400	S5-01	770
S5-02	>2400	S5-02	49
S5-03	920		
S5-04	5		
S6		*S6*	
S6-01	1000	S6-01	920
S6-02	>2400	S6-02	120
S6-03	410		
S6-04	98		
S7		*S7*	
S7-01	>2400	S7-01	1,300
S7-02	>2400	S7-02	570
S7-03	460		
S7-04	2400		
S8		*S8*	
S8-01	>2400	S8-01	2,900
S8-02	>2400	S8-02	10,000
S8-03	34		
S8-04	130		
S9		*S9*	
S9-01	No Flow / No Sample	S9-01	20,000
S9-02	>2400	S9-02	4
S9-03	No Flow / No Sample		
S9-04	No Flow / No Sample		
S10		*S10*	

Event 1 Location/Sample	*Enterococcus* [CFU/100mL	Event 2 Location/Sample	*Enterococcus* [CFU/100mL
S10-01	>2400	S10-01	6,100
S10-02	>2400	S10-02	1
S10-03	No Flow/No Sample		
S10-04	No Flow/No Sample		
S11		*S11*	
S11-01	>2400	S11-01	6,500
S11-02	170	S11-02	2
S11-03	30		
S11-04	1		

Table 18 shows that during Event 2, S1, S2 and S9 (owned by RIDOT) are all high. All values for these stations were >2400 CFU/100ml during the first event.

Charts 11 and 12 show the percentage of concentrations below a particular concentration for each station. The first plot shows the curves for values up to 2400 cfu/100ml. The second plot is limited to concentrations up to 500 cfu/100ml, so the details can be seen at lower concentrations. For a particular concentration (i.e., vertical reference line), the lower the station line, the higher the percentage of samples above that concentration. For example, for a concentration of 500 cfu/100ml, 100% of S2 samples are > 500, approximately 75% of S10 >500, approximately 50% of S6 samples are >500 and approximately 34% of S1, and S11 samples are greater than 500.

Chart 11

Cumulative Percent Curves of S Stations up to 2400 cfu/100 ml for *Enterococcus* for Event 1.

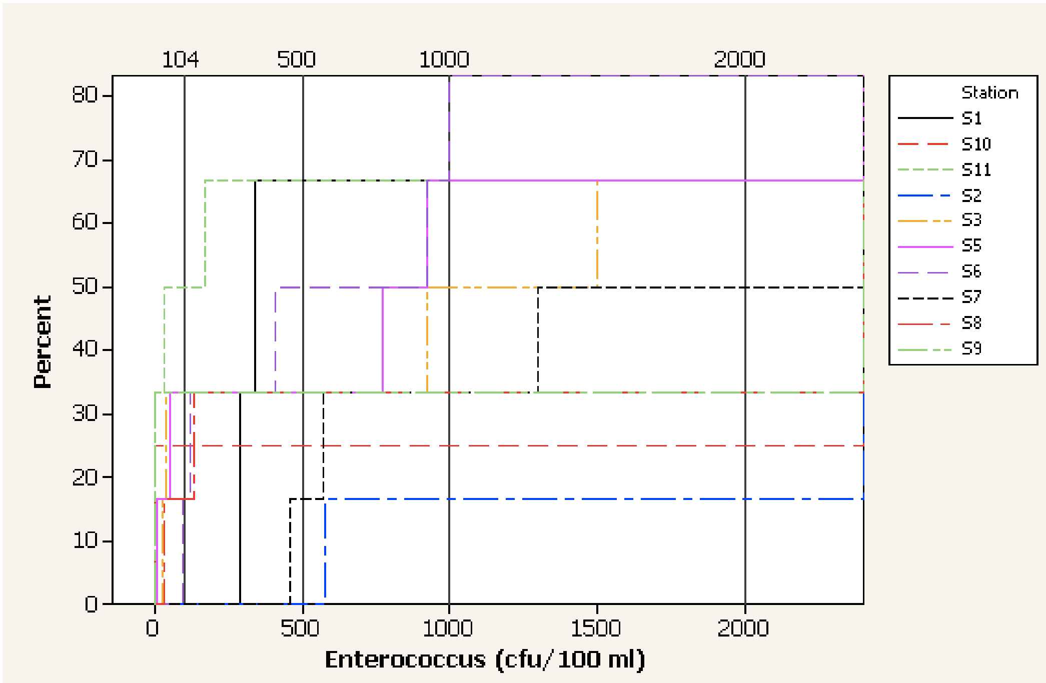


Chart 12

Cumulative Percent Curves of S Stations up to 500 cfu/100 ml for *Enterococcus* for Event 1.

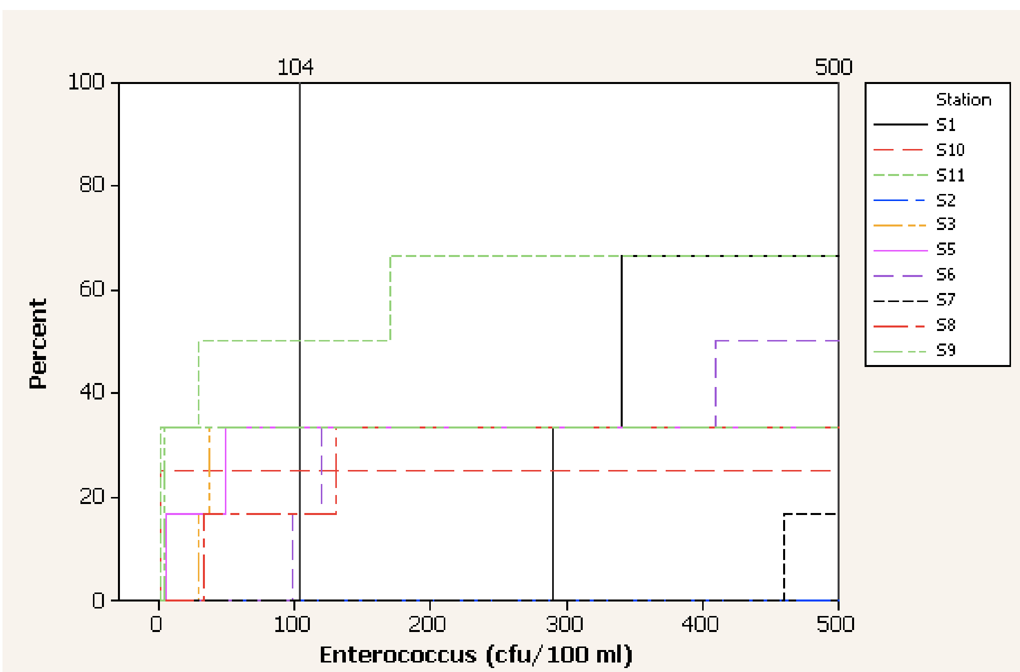
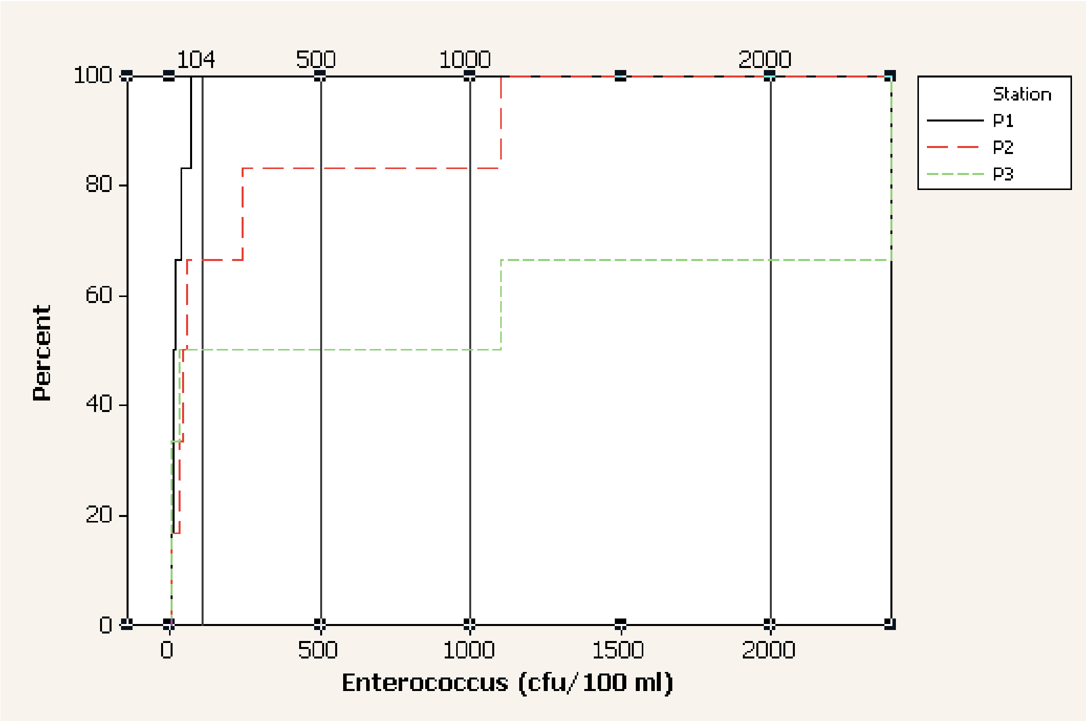


Chart 13 demonstrates that P3 has the highest *Enterococcus* levels and that the samples are progressively cleaner as one moves downstream.

Chart 13
Cumulative Percent Curves of P Stations for *Enterococcus* for Event 1



Specific Conductivity at Storm Water Outfall and Moat Locations
Specific conductivity is a measure of the ability of water to pass an electrical current. Specific conductivity of water may be affected by the presence of dissolved solids, such as salts, which dissociate into anions (ions that carry a negative charge), like chloride, nitrate, sulfate, and phosphate, and cations (ions that carry a positive charge), like sodium, magnesium, calcium, iron and aluminum). Organic compounds, like oil, do not conduct electrical current very well and therefore, have low specific conductivity. Specific conductivity is also affected by temperature--the warmer the water, the higher the specific conductivity. Specific conductivity of distilled water at standard pressure and temperature is used as a reference and has been set at 1.0 uS/cm. The typical range of specific conductivity for stormwater is between 300-500 uS/cm and 2,340 uS/cm for sanitary wastewater. The specific conductivity for the Atlantic Ocean is often reported as 43,000 uS/cm.

Stormwater or illicit discharges to streams can change the specific conductivity depending on their make-up. Illicit discharge that may be infiltrating from a sewer system to a storm drainage system may raise the specific conductivity because of the relatively high concentration of ionic chloride, phosphates, and nitrates; and the opposite affect would happen if oil was spilled into the storm drainage system. The oil has nonconductive organic compounds in it that could lower specific conductivity.

Chart 14 shows that M2 and M4 are high. M2 is tidally influenced and therefore within a normal range for fresh water with saltwater intrusion. M4 is not in a section influenced by salt water. This high level could indicate some discharge of pollution.

Chart 14
Specific Conductivity Results for Moat Stations for Events 1 and 2

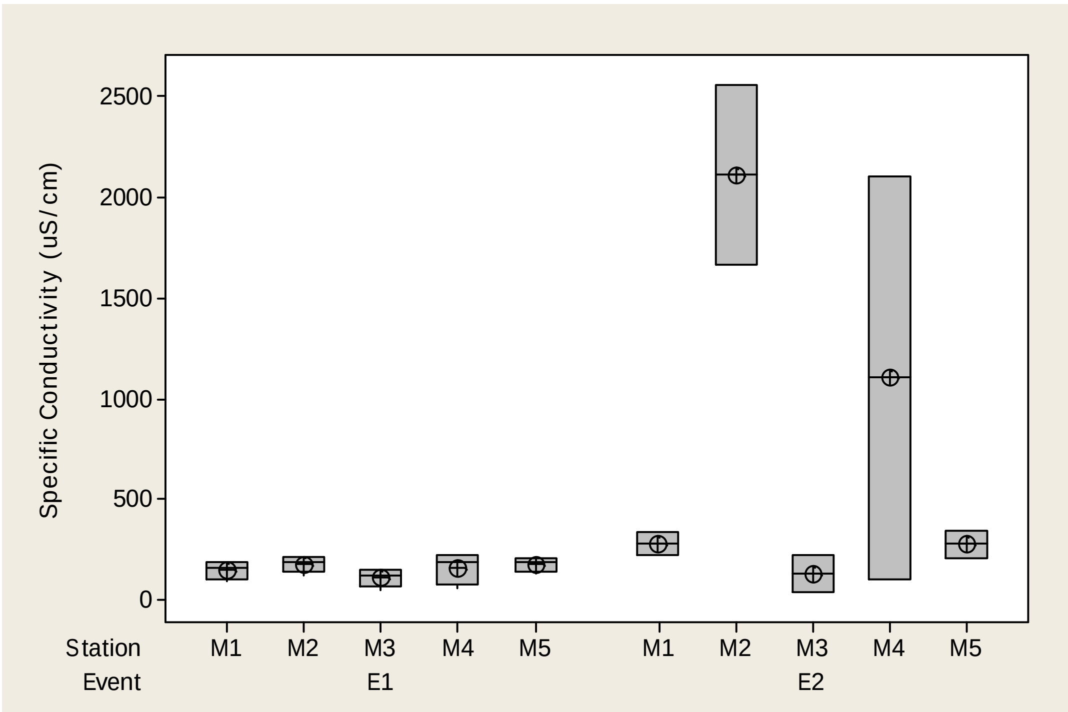
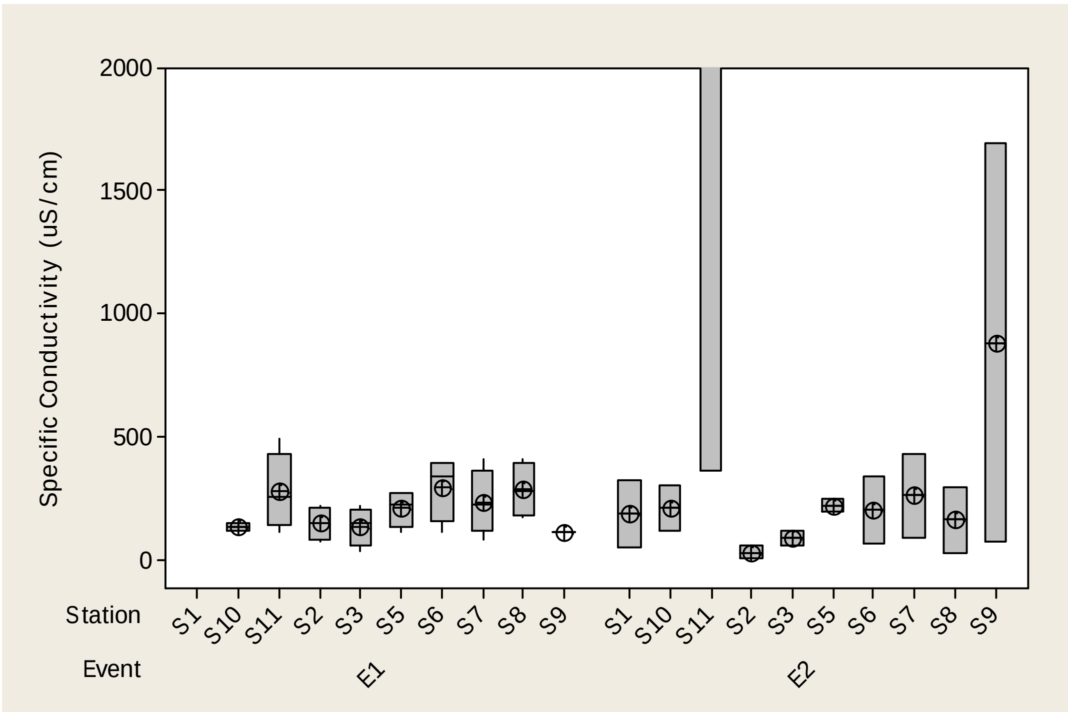


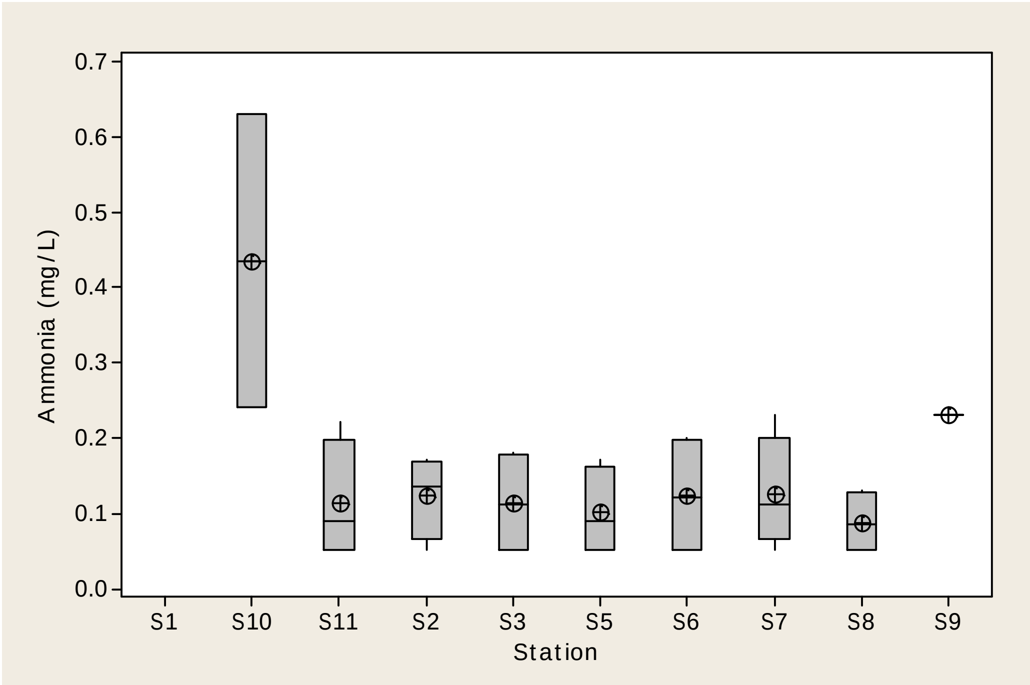
Chart 15 shows that discharge from S11 (Middletown outfall draining a section of the Esplanade) has high specific conductivity. High specific conductivity at the discharge point indicates that there is a potential for up-gradient source of pollution. Discharge from S9 (RIDOT owned) also shows high specific conductivity.

Chart 15
Specific Conductivity results for Stormwater Outfall Stations for Events 1 and 2



Ammonia at Storm Water Outfall and Moat Locations
Ammonia in storm water is typically associated with illicit discharges from sanitary sewage discharges or bacteria from pet waste washed into the storm drains with stormwater. Ammonia concentrations can vary from less than 0.001 mg/L in natural waters to greater than 30 mg/L in raw wastewater. National water quality criteria for ammonia are established for aquatic health and are pH and temperature dependent. As shown in Chart 16, the samples collected at S10 (RIDOT-owned outfall) had a higher mean and median than the samples collected from other stations. This level is higher than what would normally be found in urban runoff.

<u>Chart 16</u>
Ammonia Results for Stormwater Outfall Stations for Event 1



<u>Chart 17</u>
Ammonia Results for Moat Stations for Event 1

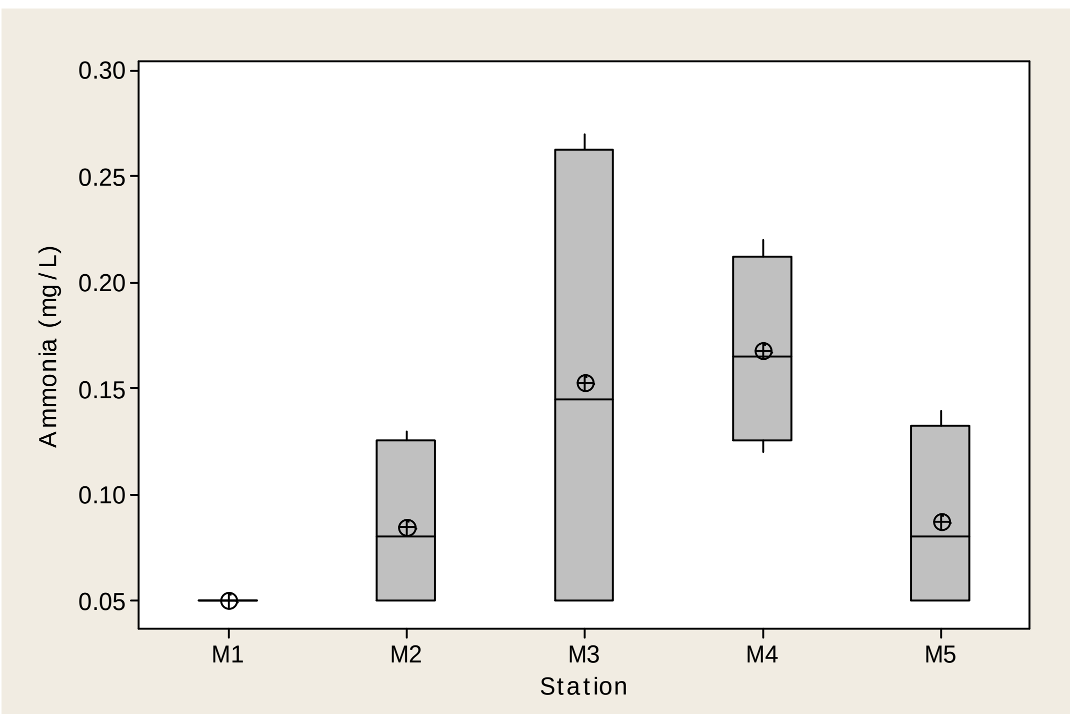


Chart 17 shows that ammonia levels for M4 remain steadily high throughout Event 1 while levels at M3 are also high, with more variability. Although there are relative differences in the levels of ammonia that we found at each outfall, these levels are consistent with levels commonly found in urban runoff. Therefore we conclude that based on ammonia measurements, no significant level of sanitary wastewater or animal waste is present.

Surfactants at Storm Water Outfall and Moat Locations
Surfactants are manmade degreasing agents typically found in detergents. Anionic surfactants are used in shampoo, dish and laundry detergent. As a result, the presence of surfactants can be an indicator of a wastewater discharge.

During Event 1, we measured methylene blue active substances (MBAS) to indirectly measure surfactants. Measure of surfactants is a commonly used method to determine level of anionic surfactants. Levels of surfactants at S10, the RIDOT Outfall, appear to be elevated compared to other sampling locations. In addition, the Moat Outlet station, M2 show relatively higher levels of surfactants, but levels at M1, located upstream from S9, the RIDOT outfall show relatively low levels. Levels at M3, on the Middletown side of the Moat and high overall. Although there are relative differences in the levels of MBAS that we found at each outfall, these levels are consistent with levels commonly found in urban runoff. Therefore we conclude that based on surfactants measurements, no sanitary wastewater is present.

Chart 18
Surfactants Results for Stormwater Moat Stations for Event 1

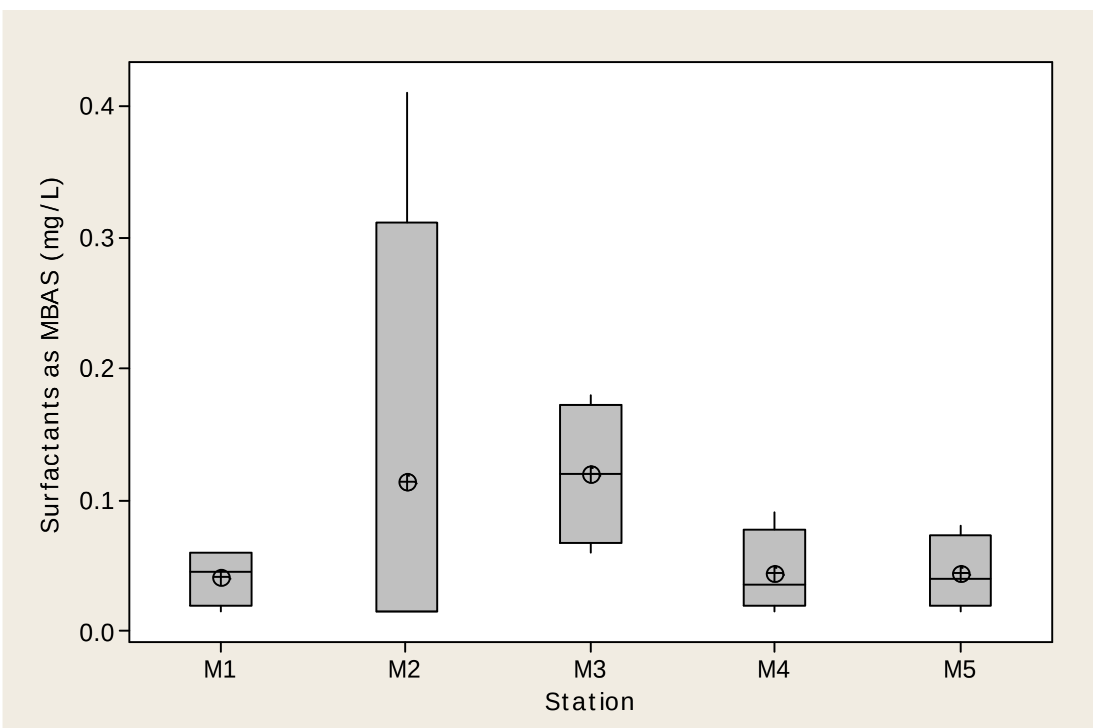
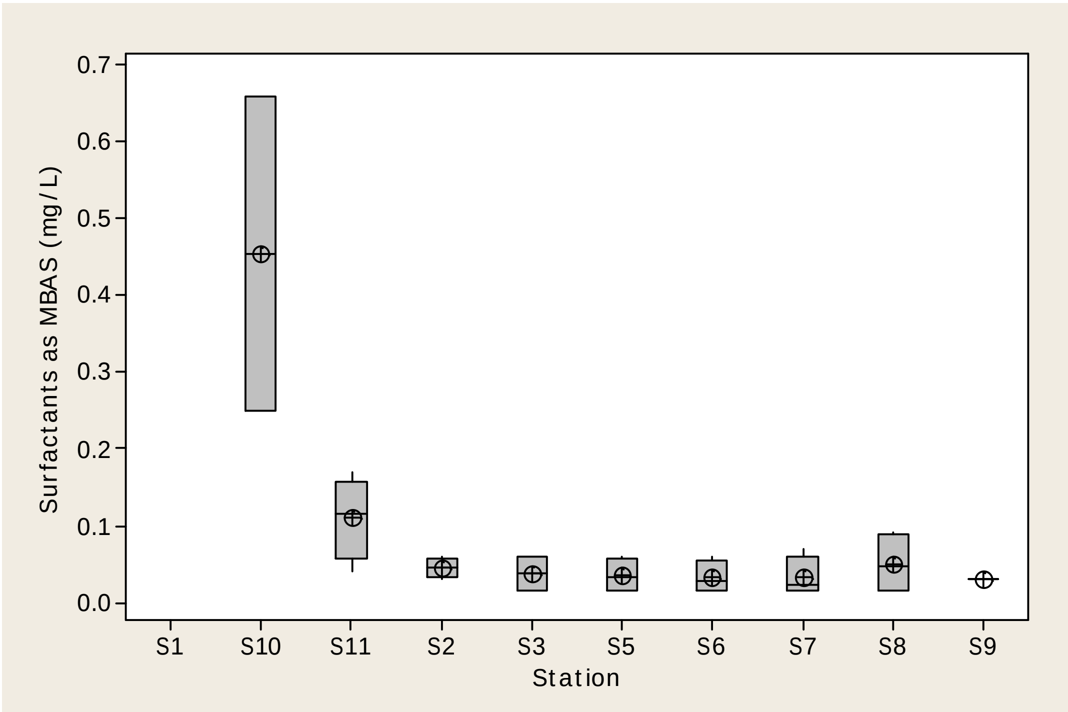


Chart 19
Surfactant results for Stormwater Outfall Stations for Event 1



5.6 Source Evaluation

Mass loading of a pollutant from a discharge point may be determined by multiplying concentration of the pollutant in the discharge by flow rate at the discharge point. Flow from a storm water system typically varies throughout a rain event with intensity of rainfall. Pollutant concentrations also vary throughout a storm event with higher concentrations of pollutants being washed away by runoff during the earlier and more intensive parts of the storm. (This phenomenon is referred to as the "first-flush" effect.) Therefore, a true loading rate requires continuous flow and pollutant monitoring.

In order to simulate mass bacteria loadings, we calculated instantaneous flows and used relative loading assessments which are explained below.

5.6.1 Relative Loading Assessment

Some of the *Enterococcus* concentrations from the September sampling were reported as "greater than" values. For these instances, we do not know the actual *Enterococcus* concentrations, but rather that the concentrations were no less than 2,400 cfu/100 ml. Calculating definitive loading rates from this information is not possible so an alternative method was developed. Relative Loading Assessment, utilizing water quality rankings, incorporates all the sampling data available and provides for meaningful and relatively straightforward comparison of sampling locations.

The ranking involves a five-step process:

1. Use cumulative percentage curves (CPCs) to rank stations at reference concentrations (i.e., 104 cfu/100 ml, 500 cfu/100 ml, 1000 cfu/100 ml, and 2400 cfu/100 ml).
2. Sum the four rank values (for each reference value) for each station to develop aggregate water quality scores.
3. Develop a raw composite score by multiplying the aggregate water quality scores by the water quality volumes for each sampling station's drainage area.
4. Scale the raw composite scores from 0 –1.0. This is done by dividing each of the raw composite scores by the greatest raw composite.
5. Rank each monitoring station by the scaled scores.

The following sections show, specifically, how we ranked the stations.

Step 1— Ranking Sampling Stations using CPCs
As a first step in our relative loading assessment, we used CPCs to rank water quality by percentage of *Enterococcus* exceedances at four reference concentrations. For each station, the water quality data from the September and October sampling events were combined and percentage of samples that exceeded 104 cfu/100 ml, 500 cfu/100 ml, 1000 cfu/100 ml, and 2400/100 ml reference concentrations were calculated.

Table 19 shows the percentages of samples exceeding the *Enterococcus* reference concentrations at each sampling station. Stations that have consistently high percentages of *Enterococcus* samples exceeding these thresholds are considered to have the poorest water quality and receive the greatest rank values (e.g., 5 or 6). Stations with lower percentages of *Enterococcus* concentrations exceeding reference values are considered to have better water quality and receive lower rank values.

Table 19
Sample Station Ranking
Based on Percent Exceedance of Reference *Enterococcus* Concentrations

Station	Number of Samples	Percent > 104 cfu/100 ml (Rank)	Percent >500 cfu/100 ml (Rank)	Percent >1000 cfu/100 ml (Rank)	Percent >2400 cfu/100 ml (Rank)
S1	6	100% (5)	67% (3)	50% (3)	50% (3)
S2	6	100% (5)	100% (6)	83% (6)	83% (6)
S3	6	67% (2)	67% (3)	50% (3)	33% (2)
S5	6	67% (2)	67% (3)	33% (2)	33% (2)
S6	6	83% (4)	50% (2)	17% (1)	17% (1)
S7	6	100% (5)	83% (5)	67% (4)	33% (2)
S8	6	83% (4)	67% (3)	67% (4)	67% (4)
S9	3	67% (2)	67% (3)	67% (4)	67% (4)
S10	4	75% (3)	75% (4)	75% (5)	75% (5)
S11	6	50% (1)	33% (1)	33% (2)	33% (2)

Step 2— Calculating Aggregate Water Quality Scores

Rank values for each station varied somewhat across the four reference concentrations. To account for this variance, we summed the ranks to form an aggregate value. Table 20 shows aggregated scores.

Table 20
Aggregate Water Quality Scores
Based on Percent Exceedance of Reference *Enterococcus* Concentrations

Station	Rank at > 104 cfu/100 ml	Rank at >500 cfu/100 ml	Rank at >1000 cfu/100 ml	Rank at >2400 cfu/100 ml	Aggregate Water Quality Score
S1	5	3	3	3	14
S2	5	6	6	6	23
S3	2	3	3	2	10
S5	2	3	2	2	9
S6	4	2	1	1	8
S7	5	5	4	2	16
S8	4	3	4	4	15
S9	2	3	4	4	13
S10	3	4	5	5	17
S11	1	1	2	2	6

Step 3— Developing Composite Raw Scores

Composite raw scores for each sampling station were developed by multiplying aggregate water quality scores by water quality volumes. Water quality volumes for each station are discussed in Section 4.1.4 Composite raw scores for each station are provided in Table 21, below.

Table 21
Composite Raw Scores for Each Sampling Station

Station	Aggregate Water Quality Score	Water Quality Volume (ac-ft)	Composite Raw Score
S1	14	0.07	0.98
S2	23	0.04	0.92
S3	10	0.03	0.3
S5	9	0.33	2.97
S6	8	1.22	9.76
S7	16	3.29	52.64
S8	15	7.17	107.55
S9	13	0.19	2.58
S10	17	3.03	51.51
S11	6	2.90	17.4

Step 4— Scaling the Raw Composite Scores from 0 –1.0

We converted the composite raw scores to decimal values. Mathematically, this is not an essential step; however, we made this conversion as decimal scales are relatively easy to understand. As can be seen in Table 21, the highest composite raw score 107.55. To scale the raw scores from 0 –1.0, we divided each composite raw score by this value. Table 22 shows the scaled scores for each station.

Table 22
Scaled Scores for Each Sampling Station

Station	Composite Raw Score	Scaled Scores
S1	0.98	0.01
S2	0.92	0.01
S3	0.3	0.00
S5	2.97	0.03
S6	9.76	0.09
S7	52.64	0.49
S8	107.55	1.00
S9	2.58	0.02
S10	51.51	0.48
S11	17.4	0.16

Step 5— Rank Each Monitoring Station by the Scaled Scores

As a final step in our relative loading assessment, we ranked each station by its scaled score. Table 23 shows these scores.

Table 23
Rank of Each Station by Scaled Score

Station	Scaled Scores	Rank
S1	0.01	8
S2	0.01	8
S3	0.00	9
S5	0.03	6
S6	0.09	5
S7	0.49	2
S8	1.00	1
S9	0.02	7
S10	0.48	3
S11	0.16	4

Moat Station Instantaneous Loads

During Event 2, M1 and M4 showed high concentrations of *Enterococcus* and had overall high instantaneous loading rates due to the intensity of their flows. Again, instantaneous loads do not reliably translatable to actual loading data; notwithstanding, these results do provide a snapshot of water quality upstream of each Moat location.

Moat Station Ranking

Moat stations were ranked using the same process that we used to rank the storm water stations. Ranks for the Moat stations are not comparable to rankings for the storm water stations because the Moat receives combined flow from upstream Moat stations as well as discharge from storm water outfalls.

Computation of aggregate water quality score is shown in Table 24. Ranking of the Moat stations is then completed in Table 25. Moat stations M1 and M2 exhibit the highest pollution potential. Station M5 exhibits moderate pollution potential and M4 exhibits relatively low pollution potential.

Table 24
Computation of Aggregate Water Quality Scores for Moat Stations

Station	Number of Samples	Percent>104 cfu/100 ml	Percent>500 cfu/100 ml	Percent>1000 cfu/100 ml	Percent>2400 cfu/100 ml	Aggregate Water Quality Score
M1	6	100% (2)	67% (1)	67% (2)	67% (3)	8
M2	6	100% (2)	83% (2)	83% (3)	33% (1)	8
M4	6	83% (1)	83% (2)	67% (2)	50% (2)	7
M5	6	100% (2)	67% (1)	50% (1)	33% (1)	5

Table 25
Computation of Scaled Scores and Ranks for Moat Stations

Station	Aggregate Water Quality Score	Water Quality Volume (ac-ft)	Composite Raw Score	Scaled Scores	Rank
M1	8	13.77	110.16	0.80	3
M2	8	17.27	138.16	1.00	4
M4	7	0.54	3.78	0.03	1
M5	5	13.24	66.2	0.48	2

5.7 Sampling Conclusions

The following paragraphs summarize our conclusions from the evaluation of the available water quality data.

Presence of Sanitary Wastewater

Our review of the data found no specific evidence of sanitary wastewater. DNA source identification tests were conducted during both the September and October sampling events. The September DNA identification tests were negative for human source markers. The October tests exhibited that approximately 5% of *Entercoccus* originates from human sources. Thus nonhuman Enterococcus sources are predominant in the beachshed.

The following findings support this conclusion:

- Recent investigations by Earth Tech found no evidence of illicit connections to the Newport storm drainage system that discharges to the moat.
- Levels of surfactants and ammonia measured in most of the outfalls owned by the City of Newport were found to be consistent with levels normally found in urban runoff in most of the outfalls.
- Specific conductivity measures are consistent with measures normally found in urban runoff.

Overflows from the Wave Avenue pump station are a potentially significant source of bacteria to the beach. However, based on our findings from a visit to the pump station, it has been equipped such that any overflow would be recorded and reportable. While some beach closures have occurred during overflows from this pump station, most have not, and there is little possibility that overflows are occurring without Middletown being aware of them. As a result, other sources dominate closures at the beach, but the occurrence of overflows should be minimized to reduce the potential for closures.

In all likelihood, these findings rule out sanitary cross-connections to the City's storm drain system and discharge from Wave Avenue as significant contributors of *Enterococcus* to the beach. However, an illicit discharge investigation should be conducted for the two DOT outfalls to the beach (S9 and S10) and for the Middletown storm drain discharge to Atlantic Beach (S11) because of the elevated levels of ammonia, surfactants and/or specific conductivity measured in those outfalls. A bright green discharge was observed from S10 (DOT-owned) in March 2007 site visit, which appeared to be strong visual evidence of an illicit discharge.

Storm Water

Storm water runoff is the predominant source of bacteria to Easton Beach. This observation is reinforced by the very strong correlation between beach closures and the levels of bacteria measured at the beach with rainfall. This observation is also consistent with the fact that beach water quality worsens closer to the Moat and Middletown-Esplanade outfall. These two discharges clearly influence water quality at the beach. Also, given the volume of storm water generated in this watershed, storm water has a tremendous potential to influence beach water quality. Storm water would be conveyed by the Moat, but individual DOT and Middletown outfalls also have significant potential to impact beach water quality.

Animal Waste

Animal wastes are a potentially significant source of bacteria in runoff. Anecdotal evidence suggests that animals such as raccoons and domestic dogs may be a specific source of *Enterococcus* to the beach. This anecdotal evidence includes:

- Sightings of raccoons in the storm drain system during the Earth Tech investigation.
- Mutt-mitts found by EarthTech in the Aborn Street catch basin.
- Use of open areas, directly adjacent to the Moat and Easton's South Pond, for dog walking. Dog litter was frequently observed by our sampling and inspection teams in these areas.
- A significant amount of birds were also observed in the Easton Beach parking lots.

Storm water runoff would be expected to sweep animal droppings into the moat/ponds and eventually to the beach. These droppings are a substantial direct source of bacteria to the beach that can be controlled.

While birds in the North and South Ponds have been a concern, the South Pond does not typically discharge into the Moat especially during the summer season. As a result, these birds are not a significant source of bacteria to the beach.

Relative Significance of Individual Storm Water Discharges

A relative loading evaluation has been completed for both Moat and storm water outfall sampling stations. Based on this loading evaluation and review of the data, we have concluded the following:

- Bacteria loadings appear to increase as water flows downstream through the Moat. That is, bacteria loadings are highest at the Moat discharge at the beach and lowest at the upstream end of the Moat. This is consistent with the storm water discharges and runoff from adjoining areas contributing bacteria loadings to the Moat until it discharges to the beach.
- All of the stormwater outfalls in the beachshed contribute bacteria loadings, largely proportional to their respective drainage areas. While outfalls with larger drainage areas have greater potential to impact water quality, small outfalls represent just smaller parts of the whole.

- Based on comparing these relative loadings, Aborn Street outfalls S7 and S8 as well as the RIDOT outfall at the Moat crossing under Memorial Boulevard (S10) and the Middletown 36" storm drain outfall from the Esplanade (S11) have significant potential to contribute bacteria loadings for storm water outfalls. These loadings are largely driven by relatively large drainage areas with significant impervious areas. However, all storm water outfalls contribute loadings largely proportional to their respective drainage areas. While the outfalls with larger drainage areas have greater potential to impact water quality, smaller outfalls still are parts of the entire storm water load discharged to the beach.

Bailey Brook

Flows from Bailey Brook represent the most significant source of recharge to the North Pond and is the predominant source of bacteria in the overall watershed given the levels of bacteria measured in the Brook and its flows. While the North Pond is connected to the South Pond, the South Pond rarely overtops the spillway to the Moat, thus rarely contributing flow to Easton's Bay and the beach. Although, Bailey Brook is known to be impaired for pathogens, it is probably not a significant source of *Enterococcus* to Easton Beach during beach season because flow from the brook does not reach the beach during most events, especially during the summer when water levels in the ponds are lower. However, Bailey Brook has greater potential to impact beach water quality during wetter months when the South Pond does discharge such as during the winter and spring.

6.0 REMEDIAL ALTERNATIVES

The following paragraphs describe potential alternatives that are available to address the issues existing for North and South Eaton Pond Dams, the Moat and Easton Beach water quality.

6.1 Dam Improvement Alternatives

Based on observations made during the visual inspection of the embankments and underwater portions of the South Pond spillway and treatment plant intake structures (outlined in detail in Section 3.0), the following alternatives are provided for consideration to address identified deficiencies. The alternatives are grouped into short- and long-term categories, which are determined primarily by the timeline and amount of effort associated with engineering design and environmental permitting required for implementation (short-term alternatives require relatively little engineering effort and are, or may be depending on specific design issues, not subject to or otherwise exempt from permitting.

Descriptions of these alternatives are supported with relative advantages, disadvantages, and order-of-magnitude opinions of construction costs in 2007 dollars. These costs are for construction with a 50 percent contingency based on their conceptual basis, and include expected costs for engineering design, environmental permitting and part-time construction administration assistance. It should be noted that assumptions have been made in preparing these costs to reflect the adverse conditions for access at several portions of the embankments due to the adjacent moat channel and properties (most notably the northern portion of the West Embankment and the East Embankment) and are therefore conservatively prepared in this regard. Furthermore, these costs have been prepared under the approach that work would be completed as a large-scale project to address generally-identified deficiencies; it is possible that further inspections, investigations, or surveys - or interim "in-house" improvements by City resources - may determine that a more limited approach for one or more alternatives may be acceptable (e.g., limited replacement of upstream slope protection), thereby reducing the costs provided herein.

The alternatives that we recommend as short-term, are structural/maintenance measures that can be implemented with limited pre-design studies or engineering for construction documents. Some measures may require environmental permitting, which may be dependant on the extent to which RIDEM implements draft regulations prepared by the Dam Safety Task Force and reviewed public workshop. These regulations are intended to streamline environmental permitting requirements for maintenance and repair activities associated with significant- and high-hazard dam structures (low-hazard structures would not be exempt under the proposed regulations and would still require permitting under RIDEM/CRMC Wetland Regulations).

RIDEM's 2006 Annual Report to the Governor on the Activities of the Dam Safety Program reflects the South Pond Dam currently classified as a low-hazard structure, with a recommendation to reclassify as a high-hazard structure. The proposed regulations define the hazard classifications as follows:

- Low-Hazard: A dam where failure or misoperation results in no probable loss of human life and low economic losses.

- Significant-Hazard: A dam where failure or misoperation results in no probable loss of human life but can cause major economic loss, disruption of lifeline facilities or impact other concerns detrimental to the public's health, safety or welfare.

- High-Hazard: A dam where failure or misoperation will result in a probable loss of human life.

This annual report indicates that once RIDEM completes its assessments of the hazard classifications for all dams in the state, it will initiate promulgation of the draft dam safety regulations. In 2006, two amendments to the existing statutes were enacted, one of which requires that by July 1, 2008, an Emergency Action Plan (meeting requirements of the Rhode Island Emergency Management Agency) shall be prepared for each significant- or high-hazard dam by the city or town wherein the dam lies. Presuming that this dam will in fact be reclassified as a high-hazard structure, the short-term recommendations below include the development of such a plan.

Until the draft dam safety regulations are fully promulgated, some short-term alternatives may require authorization under a Coastal Resource Management Council (CRMC) Assent or Certification of Maintenance. If the draft regulations are promulgated as currently written, and assuming that the South Pond Dam is reclassified as a high-hazard structure, the following requirements, among others, would be in effect:

- Dam owners shall register their dam with RIDEM.

- High hazard dams shall be visually inspected by a qualified engineer every two years, or more frequently if required by RIDEM.

- Repairs to a dam shall not be completed until plans and specifications have been filed and approved by RIDEM.

- Maintenance to a dam shall not be completed without approval of RIDEM, unless specifically exempted (certain land-clearing activities are exempt, as described below).

- No new construction, substantial alteration or removal of a dam shall be performed without approval of RIDEM.

The applicability of permitting requirements under current regulations and under the draft regulations, as they currently exist, is discussed further under the descriptions of the respective alternatives.

6.1.1 Short-Term Alternatives

The alternatives described below do not address the most significant deficiencies identified during the inspections, but can be implemented without significant engineering design or permitting, are largely independently of each other and allow subsequent implementation of long-term alternatives. Accordingly, these alternatives present the most available actions for the City to take to begin efforts addressing deficiencies identified during the inspections. Long-term issues related to encroachment of the moat channel toward embankment slopes, structural deficiencies at spillways, saturated benches and downstream slopes, or isolated failures of upstream slopes are addressed in Section 1.1.2.

Refer to Figure STA-1 for the general locations at which these recommendations would apply. These short-term alternatives are listed in Table 26 with a summary of advantages, disadvantages and implementation issues at the end of this section.

Dam STA-1 Clear and Grub Woody Vegetation from Embankment Slopes – Brush and woody vegetation is heavily established on the entire East Embankment and portions of upstream slopes of all other embankments. Trees were also observed within 25 feet of embankment structures. These conditions are a concern because woody vegetation obscures the embankment surface and prevents early and direct observation of deficiencies during inspections, root systems can create seepage pathways through embankments, and overturning of trees can create significant voids when root systems are disrupted, which could create pathways for seepage through the embankment. If left unattended, these conditions could develop into significant seeps with internal piping of soils, leading ultimately to a localized failure of the embankment and posing a potential hazard to downstream persons and property. In addition trees and brush can attract and harbor animals whose burrows can cause serious structural and/or hydraulic deficiencies.

Photograph 1: Vegetation on East Embankment

Additionally, the amount of labor or equipment time required to clear woody vegetation from embankments repeatedly on an annual basis is significant compared to what would be required to regularly mow a stand of grass on slopes and adjacent areas.

This alternative would be to remove woody vegetation and root systems (down to a root diameter of two inches) from the embankment slopes and areas within 15-feet of embankment structures, backfilling resulting voids with appropriate fill material (impervious material on upstream portions of embankments, pervious fill on downstream portions), and establishing grass vegetation on cleared areas such that standard mowing equipment can maintain vegetation on a regular basis. These activities would not include vegetation on the opposite the moat channel, as these are hydraulically isolated from the embankments and would not present a hazard from overturning.

A specific plan for clearing portions of the embankments and adjacent areas should be developed in accordance with accepted guidance manuals specific to dam structures. For example, FEMA Document 535 – Technical Manual for Dam Owners; Impacts of Plants on Earthen Dams identifies specific zones on an embankment for various remedial approaches, depending on the size of tree and significance of impact from uprooting. Under this document's criteria, trees, brush and stumps on up gradient slopes and lower portions of down gradient slopes would be removed backfilled and reseeded, while trees and brush on the middle and upper portions of the down gradient slope would be cut flush to the surface with stumps allowed to remain.

Under the current dam safety regulations, this activity would likely require CRMC approval under a Certificate of Maintenance due to the surface disturbance associated with removing stumps and roots and backfilling the voids with compacted fill in such proximity to a Type I waterbody. Under the draft dam safety regulations, however, this activity would be exempt from RIDEM approval provided that trees have stumps less than six inches in diameter, that their removal does not affect the integrity of the dam structure, and that such cutting and removal is limited to areas within 15 feet of a portion of the dam that have not historically been mowed or otherwise maintained. Based on our observations, there are few, if any, trees having a trunk diameter of greater than six inches, therefore this activity would likely be considered as exempt. This exemption does not preclude requirement for installation and maintenance of erosion and sedimentation controls.

Based on our observations of the extent of woody vegetation at the site, our opinion of construction cost for this activity is approximately $250,000.

Dam STA-2 Clear and Grub North Pond Emergency Spillway Channel – Significant vegetation was observed in the North Pond emergency spillway and immediate downstream channel. This vegetation impedes flow when discharges occur, resulting in surface runoff overflowing the channel banks and surcharging the adjacent downstream area. Recommended practice for dams is to maintain overflow spillways and channels free of vegetation that would obstruct flows.

Photograph 2: Vegetation in North Pond Emergency Spillway Channel

This alternative corresponds to Flood STA-4 which is to remove vegetation from this channel. Similar to the above Dam STA-1, this alternative would be to remove woody vegetation and root systems from the spillway and downstream channel to the treatment facility's access crossing. In addition, non-woody vegetation would be cleared such that grassed plantings can be maintained in the future at a height of six inches or less by periodic mowing. The area to be cleared should extend to 10-feet outside the channel banks to allow future access for inspections and maintenance mowing.

This recommendation would be to remove root systems associated with woody vegetation, backfill affected areas and establish grass vegetation for future mowing. As such, it would likely require a Certificate of Maintenance from CRMC under the current dam safety regulations. Under the current draft dam safety regulations, this activity would qualify under the exemption as the woody vegetation observed during the inspection did not include any trees having a trunk diameter greater than six inches. Erosion and sedimentation controls would still be required.

Based on our observations of the extent of woody vegetation at the site, our opinion of construction cost for this activity is approximately $21,000.

Dam STA-3 Repair North Pond Spillway Structures – Severe cracks were observed on the concrete spillway bar and abutments, and a void was observed at the bottom of the left (east) abutment. In addition, there were several areas along the spillway bar where apron scour stones were missing, resulting in voids that could develop to undermine the spillway bar during significant flows. Finally, worn areas were observed on the embankment immediately adjacent to the right abutment, likely resulting from foot traffic and having developed to a point where they collect and channelize stormwater runoff from the embankment crest. If left unattended, these locations could deteriorate further resulting in significant loss of embankment soils and a possible rupture of the embankment during high water conditions.

Photograph 3: Void at Bottom of Left Abutment

Significant vegetation observed growing in the downstream apron area should also be cleared and maintained free of woody vegetation to prevent future dislodging of apron stones. This work would be included in the clearing and grubbing recommendation above.

In order to extend the lifetime of these structures, cracks should be repaired, the left abutment void should be filled with concrete fill, scour protection along the spillway bar should be restored in the void areas and the worn areas along the right abutment should be evened with topsoil and revegetated.

Due to the proximity of this structure to the impoundments, this activity would be subject to permitting under a CRMC Certificate of Maintenance or Assent under existing dam safety regulations. However, under the draft dam safety regulations, these activities would likely meet the definition of "maintenance" activities and would be subject to approval by RIDEM without a formal application for review. The definition of "maintenance" activities includes minor work to maintain the dam in proper working condition such as filling and repair of minor erosion areas, re-pointing masonry (which would presumably include patching and limited filling of concrete as described above, and clearing vegetation, among others)

The opinion of cost for these activities is approximately $43,000.

Dam STA-4 <u>Conduct Structural Inspection of South Pond Spillway</u> – During the inspection of the spillway, the diving inspector noted several areas along the spillway where concrete appeared to be "hollow" or otherwise unsound. This observation was substantiated by the appearance of efflorescence from cracks on the downstream spillway face, which indicates the loss of internal components (salts) from within the concrete under the hydraulic force of water seeping through the weir crest.

This recommendation would be to perform a more complete structural evaluation of the spillway concrete's competency. This would entail collecting a number of small (i.e., 2-inch diameter) concrete cores from the spillway to assess the presence of void spaces and to allow laboratory tests to be performed which may include compressive strength, presence of chloride ions, and petrographic analysis.

The diving inspection also noted that the concrete forming the downstream apron was not sound when impacted with moderate force with a pointed hammer. A number of concrete cores should also be collected from this area to assess the slab's current thickness in comparison to the original design thickness, presence of voids and overall condition similar to the spillway concrete.

The results of this investigation would help to determine the urgency of replacing the spillway and/or downstream apron concrete. Based on our observations, the concrete forming the abutments and valve bypass chamber appeared to be sound, with minor surface cracking and spalling that would need to be addressed separately under Dam Short-Term Alternative 6 below. This engineering study should include an evaluation and recommendation of potential specific repair alternatives based on the character and extent of deterioration.

These activities would not be subject to environmental permitting as no structures are being materially affected.

The opinion of cost for this recommendation is approximately $30,000.

Dam STA-5 Repair South Pond Spillway Concrete Structures – Significant cracks and areas of spalling were observed on the spillway, abutments, and drawdown gate chamber during the inspection. In addition, the bracing forming the low-level weir board channel at the center of the spillway was found to be secured by weakened concrete exhibiting significant spalling. These conditions will continue to deteriorate in the future and ultimately lead to more significant deficiencies requiring replacement of these structures (replacement is identified in this report as a long-term alternative for the spillway weir only; abutments and the valve chamber were observed to be in satisfactory condition at the time of the inspection).

Photograph 4: Deteriorating Concrete at South Pond Spillway

In addition to repairing the cracks and spalls, this alternative includes the application of a hydraulic barrier on the up gradient surface of the concrete spillway weir. This barrier could be either a typical asphalt sealant applied to a prepared concrete surface (e.g., bitumastic sealants), a spray-applied curing membrane-type sealant (e.g., Liquid-Boot^{TM}), or a conventional synthetic membrane (HDPE, LLDPE, PVC) that could be deployed and secured to the concrete surface. These alternatives would need to be further evaluated in order to determine the most cost-effective means to reduce the movement of water through the concrete weir and limit further degradation of the concrete by efflorescence.

Repairing these cracks would delay the need to complete the more expensive replacement of the spillway. This work entails completing surface repairs (patching and sealing) to cracks and spalls on the spillway, abutments and on/within the bypass valve chamber. Control of water by temporary drawdown of the impoundment and/or coffer damming would be required to allow work on the upstream portions of the spillway weir and abutments under dry conditions.

If only patching and application of liquid sealant were conducted it is likely that permitting would only be required under a CRMC Certificate of Maintenance. However, installation of a synthetic membrane would likely be subject to additional permitting under both existing and current draft dam safety regulations as it would likely be viewed as a modification. In addition, the need for a drawdown or coffer damming would likely require a formal review under the current draft dam safety regulations to demonstrate that the provisions for bypass are adequate to pass flows associated with stipulated storm events corresponding to the expected duration of construction.

The opinion of cost for this work is approximately $305,000 assuming that a drawdown would be performed during the work. It is expected that use of a Porta-Dam system to maintain a full impoundment would increase this cost by approximately $15,000.

Dam STA-6 Construct Stormwater Channel Along East Embankment Slope – A small body of standing water and a submerged stormwater discharge pipe draining from Middletown were observed near the north end of the East Embankment. A significant scarp resulting from stormwater runoff from these features was observed at the embankment crest reflecting previous discharges from these structures entering South Pond (direct stormwater runoff entering South Pond). A grassed area was observed further downstream of this area, separating the standing water and pipe outlet from a drainage channel located approximately 300-feet down gradient, which ultimately discharges to the stilling basin associated with the South Pond spillway.

Photograph 5: Rilling/Scarp on East Embankment (Standing Water Obscured in Background)

Photograph 6: Grassed Area Downstream of Rilling/Scarp

In order to provide a controlled discharge pathway that does not flow into the impoundment, or otherwise cause rilling of the embankment, it is recommended that a formal discharge channel be established to connect this small body of water and discharge from the outlet pipe to the existing down gradient drainage channel. This work would include excavating the graded channel and stabilizing with grass.

This work would be subject to permitting under a CRMC Certificate of Maintenance or Assent. It is likely that a formal permit would not be required under the existing or current draft dam safety regulations due to the fact that this activity is largely unrelated to the embankment structure and only provides for proper drainage in an adjacent area. Activities to address the rilling would require approval as regular maintenance activity.

The opinion of cost for this work is approximately $53,000.

Dam STA-7 Repair North Pond Embankment Settlement Area – A limited area where the embankment crest and adjoining portion of the upstream slope had settled was observed in the general location of where the treatment plant's intake pipe passed below the embankment to the raw water process building. This area extended for approximately 40 feet along the embankment and if not addressed could develop in the future to a point where the embankment crest falls to an elevation at which it would become a preferential pathway during sufficiently high water conditions in the impoundment. This area should be backfilled with impervious fill and topsoil to original grades and revegetated with grass and slope armor protection to match adjacent areas.

Photograph 7: North Pond Embankment Settlement Area

This work would likely be subject to permitting under a CRMC Certificate of Maintenance. It is likely that a formal permit would not be required under the existing or current draft dam safety regulations due to the fact that this is a maintenance activity to restore a structure to original lines and grades. Under the proposed dam regulations this work would require approval from RIDEM.

The opinion of cost for this work is approximately $28,000.

Dam STA-8 Repair East Embankment Settlement Area and Footpath – An area of limited settlement was also observed immediately adjacent to the left upstream abutment of the South Pond spillway. This area extends approximately 50 feet from the abutment on the upstream slope of the embankment. In addition, a worn footpath running from the crest over the downstream slope to a plank over the drainage ditch approximately 100 feet east of the South Pond Spillway has developed as a preferential pathway for stormwater runoff. If left unaddressed, these areas could continue to worsen as from future and/or significant rain events resulting in increased erosion, loss of embankment material, and potential failure of the embankment during high-water conditions in the impoundment. These areas should be backfilled with impervious fill and topsoil to original grades and revegetated with grass and slope armor protection to match adjacent areas.

Photograph 8: Worn Footpath Causing Erosion on East Embankment

Similar to Dam STA-9, this work would likely be subject to permitting under a CRMC Certificate of Maintenance. It is likely that a formal permit would not be required under the existing or current draft dam safety regulations due to the fact that this is a maintenance activity to restore a structure to original lines and grades, but approval from RIDEM would be needed under the proposed dam regulations.

The opinion of cost for this work is approximately $16,000.

Dam STA-9 <u>Replace Gate Valve in North/South Pond Dividing Embankment</u> – During the inspections it was reported by City personnel that the buried gate near the spillway at the east end of the North Pond/South Pond dividing embankment was inoperable, being currently stuck in an open position. This valve should be replaced to restore its function as a limited means (due to the relatively small head differential between the impoundments) to regulate the North Pond water surface elevation below the normal spillway crest discharging to the South Pond.

This work would likely be subject to permitting under a CRMC Certificate of Maintenance. It is likely that a formal permit would not be required under the existing or current draft dam safety regulations however approval from RIDEM would be needed under the proposed dam regulations.

The opinion of cost for this work is approximately $45,000.

Dam STA-10 <u>Conduct Slope Stability Evaluation</u> – A 1991 engineering study was conducted to evaluate the stability of portions of the North and West embankments due to the presence of low-strength materials forming the down gradient bench and moat bed. This study found the embankments to have an insufficient factor of safety under a potential seismic load and provided recommended alternatives to improve their stability. The City conducted activities to place crushed stone fill in a portion of the moat channel, and has since placed gravel fill in areas including on portions of the down gradient bench and embankment slope.

An evaluation should be completed in conjunction with this effort to determine if the work completed to date has sufficiently improved the strength of soils in these areas such that an acceptable factor of safety is provided during seismic load conditions.

Similar to Dam STA-4, these activities would not be subject to environmental permitting as no structures are being materially affected.

The opinion of cost for this work is approximately $35,000.

Dam STA-11 <u>Place Gravel on Bench/Downstream Slope of Accessible Embankments</u> – The City has undertaken activities in recent years to place processed gravel material on bench areas and down gradient embankment slopes in areas where access is provided opposite the moat channel. These areas are primarily along Ellery Drive adjacent to the North Embankment, along Old Beach Avenue adjacent to the south end of the West Embankment, and along Memorial Boulevard adjacent to the South embankment. While this program has addressed limited areas on an as-needed basis, placement of gravel material will continue to improve the strength of bench soils and down gradient benches, allow access by mowing equipment without significant rutting.

This work would likely be subject to permitting under a CRMC Certificate of Maintenance. It is also likely that a formal permit would not be required under the existing or current draft dam safety regulations however approval from RIDEM would be needed under the proposed dam regulations.

Based on our observations of areas where such access if available and where gravel has not already been placed, the opinion of cost for this work is approximately $167,000. This cost is based on published construction costs; the City's actual costs may be different based on its previous contracts to complete similar work at the embankments.

Dam STA-12 <u>Install Inlet Screens for Treatment Plant Intake Structures</u> – During the underwater inspection of the submerged treatment plant raw water intake structures, it was determined that screens depicted on the design drawings for these structures (framed gratings set in channels) were not constructed; instead, chain link fencing was apparently laid over the inlet and secured with bolts to the concrete. During the inspection, small sections of the remaining fencing that had not yet deteriorated were observed.

In addition to the above, a 12-inch diameter submerged blowoff pipe located immediately adjacent to the North Pond emergency spillway was found not to have an inlet screen or other protection to prevent foreign materials from being drawn in. This condition could lead to items being drawn into the intake pipe or otherwise into the structure, causing a blockage or other damage to the pipe.

This recommendation would be to reinstall screen material as originally constructed at the two treatment plant intake structures and to install a new inlet screen for the blowoff pipe.

This work may be subject to permitting under a CRMC Certificate of Maintenance. Because it not a functional part of the impounding embankment or otherwise discharges water to a surface water channel as a low-level control structure, it would not be subject to dam safety regulations. Department of Health requirements may apply.

The opinion of cost for this work is approximately $10,000.

Dam STA-13 Implement Rodent Control Program – Burrows and rodents were observed on the embankments during the inspections, and City personnel noted that current practice is to backfill rodent burrows as they are discovered. However, there is no program currently in place to trap, control, eliminate or otherwise prevent animals from burrowing into the embankment. It was reported that a program was formerly in place decades ago, but that the measures formerly employed were no longer allowed.

This recommendation would be to create a program in accordance with RIDEM's Rules and Regulations Governing Nuisance Wildlife Control Specialists for implementation by a permitted private individual or contractor. A similar program was recently implemented for approximately four miles of dikes along the Connecticut River south of Hartford by initially hiring a wildlife control specialist to conduct an inventory of burrows and animals within the embankments. This initial survey should be completed after the embankments have been cut and cleared of all vegetation so an accurate count of burrow holes can be obtained. This survey included an inventory report with field sketches. Burrows were also staked in the field so they could be subsequently located during program implementation. Following this initial survey, a specification was prepared to implement the program under public bidding. This specification included provisions to protect the public and preclude animals from being driven into adjacent neighborhoods, to prepare a written pest control plan with a number of components detailing the procedures to be used to meet the requirements of the specification, and to meet reporting requirements under state regulations.

Upon implementation for this project, the contractor distinguished active and inactive burrows and set traps or placed fumigant agents or rodenticide in active ones. The burrows were then promptly addressed by excavation and backfilling in using proper dam construction techniques. The wildlife control specialist should continue on to monitor the embankments periodically to identify and promptly address new animals and burrows to limit repopulation and future impacts to the embankments.

One possible measure considered for implementation in concert with installation of armored slope protection would be to underlay the protection system with a layer of continuous metal chain link fencing that would prevent burrowing animals from advancing. While this is not considered further in this recommendation, it may be considered in concert with other long-term alternatives provided in this report; this measure would represent an additional component to the slope protection system.

This work should be implemented in combination with other recommended alternatives which include clearing and removing woody vegetation and replacing with slope protection or grassed surfaces.

The removal of rodents would not be subject to environmental permitting as no structures are being materially affected, however earthwork associated with excavating and backfilling rodents holes would be, as described under other alternatives. As noted above, the program would haven to be developed and implemented in accordance with RIDEM's applicable rules and regulations.

The opinion of cost to research and prepare the specification for bidding and implement the program, excluding backfilling burrow holes, is approximately $55,000.

Table 26
Short-Term Dam Alternatives

Implementation Issues	Advantages	Disadvantages	Opinion of Cost
Dam STA-1 Clear and Grub Vegetation from Embankment Slopes			
• Difficult access to portions of embankments • Erosion and sedimentation controls • Permitting	• Allows future mowing as standard maintenance practice (reduced maintenance costs) • Prevents future hazard from overturned trees • Allows effective visual inspection of embankment surfaces • Low engineering cost	• Does not provide slope protection without additional improvements • Permitting required due to stump removal; likely will not qualify as maintenance • Difficult access to some areas	$250,000
Dam STA-2 Clear and Grub North Pond Emergency Spillway Channel			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate access with normal site activities • Erosion and sedimentation controls • Permitting	• Improves hydraulic capacity of spillway channel • Facilitates visual inspection of spillway structures • Low engineering cost	• Permitting required; likely will not qualify as maintenance • Expense for benefit only realized during relatively rare significant storm events	$21,000

Dam STA-3 Repair North Pond Spillway Concrete Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Relatively low engineering and construction costs • No groundwater dewatering, limited control of surface water required • Limited cost to extend life of existing structures	• Temporary measure to extend life of failing structures	$43,000

Dam STA-4 Conduct Structural Inspection of South Pond Spillway			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate work with low flows at spillway	• Determine condition of spillway for future repairs or limited/full replacement	• Limited information on actual condition (limited number of samples)	$30,000

Dam STA-5 Repair South Pond Spillway Concrete Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting • Research waterproofing measures	• Limited cost to extend life of existing structures • No groundwater dewatering, limited control of surface water required	• Only delays future need to replace spillway structure	$305,000

Dam STA-6 Construct Stormwater Channel Along East Embankment Slope			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• May require access through adjoining parcel (otherwise adverse access conditions result) • Erosion and sedimentation controls • Control of water • Permitting	• Addresses rilling of embankment and uncontrolled stormwater discharge into impoundment • Removes standing water at toe of embankment slope	• Possible neighbor opposition due to removal of grassed area (property boundary unknown for this study)	$53,000

Dam STA-7 Repair North Pond Embankment Settlement Area			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$28,000

Dam STA-8 Repair East Pond Embankment Settlement Area			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$16,000

Dam STA-9 Replace Gate Valve in North/South Pond Dividing Embankment			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Dewatering • Possible Shoring	• Restores ability to control discharge to South Pond	• May require excavation controls (dewatering, shoring) depending on depth to valve	$45,000

Dam STA-10 Conduct Slope Stability Evaluation			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Access for drill rig	• Evaluates stability of embankments following filling activities by the City	• Expense	$35,000

Dam STA-11 Place Gravel on Bench/Downstream Slope of Accessible Embankments			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls	• Previous construction activity, knowledge of procedures by City • Able to access bench and downstream slopes from opposite side of moat	• Limited measure to address deficiencies (does not address embankment deficiencies)	$167,000

Dam STA-12 Install Inlet Screens for Treatment Plant Intake Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate access with normal site activities	• Low cost to protect structure and plant facilities • Prevents animals and debris from being drawn into the treatment plant works.	• Requires future maintenance to clear accumulate debris	$10,000

Dam STA-13 Implement Rodent Control Program			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and develop program • Public education/community relations • Monitoring and reporting	• Limit damage from burrowing animals • Protect future investment in embankment repairs/improvements	• Public opposition from wildlife enthusiasts opposed to lawful management techniques • Abatement methods need to be selected and/implemented to safeguard public users if public is not prohibited from embankments during the program.	$55,000

6.1.2 Long-Term Alternatives

Long-term alternatives generally require more significant efforts for planning, design and permitting, and significant capital planning to fund their implementation as they are generally more focused on fundamental conditions affecting the overall ability of the embankments and spillways to withstand extreme loadings during significant storm events. Depending on whether the dam is reclassified as a high-hazard or significant-hazard structure, environmental permitting may be streamlined through the Office of Compliance and Inspection under the proposed dam safety regulations. If it remains a low-hazard dam, environmental permitting would be through the existing process where applications are reviewed by the Office of Water Resources and/or CRMC due to the dam's proximity to coastal resources.

Refer to Figure DAM LTA-1 for the general locations at which these recommendations would apply.

Dam LTA-1 Realign Portions of Embankments – The moat channel was observed to be scouring the grassed bench area adjacent to the downstream slope at a number of locations along the South, West and North embankments. Further, at some of the locations near the north end of the West Embankment, the scouring has progressed to such a degree that the moat channel is beginning to encroach upon the downstream embankment slope. The moat channel is characterized by an 18-inch to 24-inch deep scarp along its banks as a result of this scouring. Mowing equipment rutting on the downstream slope and bench further exacerbate this condition by pushing soil toward the moat channel, where it ultimately calves in sections into the moat channel due to shear forces during high flows.

Photograph 9: Moat Encroachment and Bench Rutting along West Embankment

In addition, this soil mass functions to control water movement from impoundment through the embankment. As the cross-sectional area of the embankment and down gradient soil mass is reduced, the flow path for water moving through the embankment is also reduced. As the free surface where water emerges from the embankment progresses up gradient (i.e., as scouring and erosion progresses into the bench and the down gradient slope), the energy profile of the groundwater increases such that water emerges from the embankment with greater potential for sufficient velocities to carry soil particles from within the embankment (piping or internal erosion).

This scenario, if not addressed soon after initially developing, can lead to progressive failure of the embankment as further loss of embankment soil leads to a greater potential to lose additional soil at a quickening rate. Further, the loss of soil mass along the downstream toe contributes to the embankments overall instability, as an adequately sized bench composed of soil having a suitable strength serves to buttress the embankment, acting as a restraint to sliding and slip-circle failures. This instability was previously evaluated in a 1991 geotechnical evaluation of the embankments; it is understood that no work (e.g., gravel slinging as conducted on portions of the North Embankment) was subsequently conducted on this portion of the embankment to address the concerns of this report.

Photograph 10: Moat Scouring and Encroaching along West Embankment

In order to restore an appropriate soil mass forming the down gradient bench where it has been eroded, two scenarios were initially considered: relocating the moat channel further from the embankment, and realigning the embankment into the impoundment. Due to space constraints, constructability concerns and environmental permitting issues associated with relocating the moat, this approach was not considered further. Realigning the embankment would displace a portion of the impoundment's storage capacity (discussed below) and would require that a temporary lowering of the impoundment be performed to allow placement of fill material for the new embankments under dry conditions. More specifically, this alternative would entail the following work items:

- Realign the West Embankment as required to provide a minimum bench width of 10-feet along the moat channel, maximum 3H:1V slopes in accordance with current accepted dam construction guidelines, and a minimum crest width of 12-feet. Some portions of this embankment (primarily southern portions) currently have between 4-feet and 8-feet of bench width resulting in a horizontal movement of the embankment of approximately 16 feet. Other portions near the northern end do not have a bench or have a bench less than 4 feet in width, requiring a horizontal movement of approximately 20 feet. Because impoundment

Photograph 11: Upstream Slope Failure and Worn Footpath on West Embankment

bathymetry was not provided for this study, these distances assume a 5 percent bottom slope from the embankment's up gradient toe of slope.

It is noted that significant sections of the northern portion of the embankment are severely compromised by upstream slope failures, so this reconstruction would address this deficiency inherently. Along the same lines, reconstruction of the embankment in general would address a number of other deficiencies addressed elsewhere as alternatives, including increasing the crest width to a standard width in accordance with current dam construction guidelines, providing grading to direct runoff from the crest (where a worn footpath now either ponds runoff or channelizes it to discrete locations where rilling leading to slope failure are more likely to occur), providing upstream slope protection, and providing adequate space for mowing equipment operations.

- Realign the East Embankment as required to provide a minimum 10-foot bench width, maximum 3H:1V slopes and a 12-foot crest width. This work would also result in the removal of trees and other woody vegetation from the embankment, restoration of upgradient slope protection and providing adequate room on the crest and at the downgradient toe of slope for future equipment access. Based on the current embankment dimensions and the recommended embankment configuration noted above, a horizontal movement of approximately 14 feet into the impoundment would result (assuming a 5 percent impoundment bottom slope).

Photograph 12: Narrow Crest Width on East Embankment

- Restore upstream slope protection along the North and South Embankments, both sides of the NorthPond/South Pond Dividing Embankment, and the North Pond Embankment. This work would entail placing a fill to provide a stable base upon which to place the slope protection (several

Photograph 13: Upstream Slope Protection and Worn Footpath on North Embankment

locations along the embankments were noted to exhibit a scarp at the top of slope). This fill would be placed as required on the up gradient side of the embankment to provide a minimum 12-foot wide embankment crest (existing crest width on the South and West Embankments averages approximately 10 feet and the approximately 8 feet on the East Embankment) and a 3H:1V up gradient slope angle. Using the assumed 5 percent slope for the impoundment bottom, this results in a horizontal extension into the impoundment of approximately 7 feet.

There are several options to be considered to restore adequate slope protection as outlined below. These options would apply to the realigned embankment sections as well.

- Cable-Concrete Slope Protection – This approach consists of placing pre-fabricated mats of articulating precast concrete blocks connected by cable on prepared slopes. The precast blocks are typically between 4 inches and 8 inches in dimension, and are strung together in custom-sized mats, typically between approximately 6 feet to 8 feet in width and approximately 12 feet to 20 feet in length. A geotextile typically underlies these mats to control loss of soil by erosion or other hydraulic forces.

  The precast concrete blocks can be either "closed-cell" or "open-cell," depending on whether vegetation if desired on the final surface. Open-cells allow subsequent placement of fill material (e.g., topsoil) and seeding so grass is ultimately established. Closed-cells would provide a continuous surface comprised of the adjoining concrete blocks. The mats would be secured in an anchor trench along the top of slope to prevent a sliding failure.

- Riprap Slope Protection – This approach consists of placing riprap, as originally provided on many of the slopes (with the exception of portions of the South and East embankments, which were constructed with placed-stone armoring, in which nested stones are laid by hand to provide a more or less continuous surface). Compacted fill material would be placed to provide a suitably sloped surface and riprap would be placed on a geotextile fabric. This surface would remain unvegetated, provided no soil washes in to fill over the geotextile fabric which would support germinating seeds blown in.

  This approach has a couple of variants, in which either grout or soil material could be placed to fill the voids between riprap units. Placing grout is relatively common on steep slopes where significant flows are expected, and served to lock the individual riprap units in place, preventing loss of units by ice-plucking or vandalism and deterring burrowing animals. Because grout is placed as a slurry it would self-level to fill the void spaces in a relatively straight-forward construction process. This surface would remain unvegetated because soil would not accumulate on the finished surface. Filling the voids with soil also serves to secure the individual units in place. This finished surface could be vegetated with grass and mowed with suitable equipment.

- Cellular Confinement Slope Protection – This system is comprised of a geotextile fabric overlain by a matrix of geosynthetic strips arranged and connected in a series of cells forming a mat into which various fill materials can be placed. The cells vary in size but are typically in the range of approximately 3 inches to 6 inches in plan dimension and between approximately 2 inches to 8 inches in depth. The recommended fill material for his application would be topsoil to allow grass vegetation to be established. The mats are laid out on a prepared slope surface and anchored to prevent uplifting or sliding. Once vegetation is established the mats are more thoroughly secured and established in the grass root zone to provide a stable surface.

- Regrade embankment crests during this work to remove worn footpaths and direct runoff evenly to the upgradient slopes. These areas would be disturbed anyway during other construction activities, so this work would not present a significant additional cost. An potential addition to this work, discussed further in Dam LTA-9 below, would be to reinforce the center of the regraded crests with a subsurface reinforcement similar to the cellular confinement system described above. This approach would provide a measure of protection to the embankment that is not visible when grassed and in so doing does not formalize access in the same way that a gravel or stone dust path would (it is understood that the City does not wish to provide such formal access). As the embankment is being regraded, this matting (width can be specified but typically 4 feet to 6 feet) is laid and secured onto a compacted subgrade surface, filled and covered with topsoil and seeded to establish grass.

- Install toe drains in wet areas as described in Dam LTA-8 below.

- Clear and grub embankments of trees and woody vegetation and establish grass on disturbed areas.

- Install and maintain erosion and sedimentation controls during construction (silt fence along impoundment edge of water and along moat channel, erosion control blanketing on slopes areas to receive grass vegetation).

- Reuse topsoil stripped from the existing embankments being removed for the surface of the realigned embankments. For purposes of this recommendation and the opinions of construction cost provided below, it was assumed that controlled fill material meeting minimum specification requirements would need to be imported and compacted in place to form the new embankments and upstream slope extensions. Material excavated from the existing slopes that is not suitable for reuse as topsoil is assumed to be hauled to a local fill site.

- Temporarily lower the impoundment to allow placement of fill material for the realigned embankment under dry conditions. The bypass pipe at the South Pond spillway is 30 inches in diameter and has a proposed centerline elevation of 1.00 according to construction drawings provided by the City. The inlet grate elevation for the submerged concrete inlet structure enclosing this intake pipe is shown on the drawing at elevation 4.50. If a drawdown to elevation 5.50 could in fact be achieved and maintained for an estimated 120-day construction period using only the existing bypass conduit at the South Pond spillway (dependent on surface water inputs from stormwater runoff, etc.), an additional bypass culvert would not be required. Otherwise, one or more additional culverts would need to be temporarily installed to provide additional capacity to pass expected storm flows while allowing the work to be conducted in dry conditions while maintaining a sufficient water surface elevation to ensure available inlet water to the intake structure.

  Using the assumed 5 percent bottom slope from the embankment toe, a drawdown to elevation 5.50 would allow the realignment earthwork to be completed outside the edge of water. A temporary cofferdam (e.g., sandbags) would need to be provided for those portions of the embankment where the slope is greater than this assumed bottom slope.

  The estimated loss of impoundment storage in South Pond relative to increasing water surface elevations is provided below (assign the 5 percent pond bottom slope and the horizontal realignments for the respective embankments noted above). Note that RIDEM's 1995 inventory data sheet that was reviewed for the dam files reflects 1,225 acre-feet of storage at normal pool (approx. water surface elevation 8) and 1,375 acre-feet of storage at maximum pool (approx. water surface elevation 11).

Water Surface Elevation	Impoundment Storage Loss (ac-ft.)
8.0	1.6
9.0	4.3
10.0	6.8
11.0	9.3

Alternately, provisions could be employed to temporarily cofferdam areas as work proceeds. Two potential systems that were evaluated were use of Porta-Dam™ and Watertube™ barriers:

- The Porta-Dam™ system is comprised of bracing which supports an impermeable membrane for a portion of the impoundment floor to above the surface. After installation, water behind the barrier is pumped out to allow work under dry conditions.

- The Watertube™ system is comprised of sections of large-diameter tubing that are connected and filled with water along the alignment to be unwatered. Similar to Porta-Dam™, after filling the water behind the barrier is pumped out.

- Project costs are significantly affected by the selected approach: whether sequential areas are to be unwatered along the embankment, whether the entire embankment is to be unwatered at once for the complete project duration, and whether the systems are to be purchased for the project or rented and returned (again depending on the number of reuses allowed by the manufacturer before certification for use is lost). Based on our limited analysis of these alternatives, the expected duration of construction and current costs provided by vendors, it is expected that the most cost-effective approach is to purchase these materials for the project.

This work would be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant disturbance and alterations involved.

Relative advantages and disadvantages for this alternative are provided below along with the opinions of cost for all work including alternative slope protection systems.

Advantages

- Highest level of improvement to address embankment structural deficiencies

- Addresses moat channel encroachment

- Increases bench width and addresses downstream slope wetness to allow mowing equipment access to entire embankments to maintain grassed slopes (all vegetation cleared from embankments and restored with grass)

- Provides adequate crest widths for future access by heavy equipment

- Addresses grading deficiencies on dam crest (worn footpaths)

Disadvantages

- Significant cost
- Loss of impoundment storage volume
- Does not include moat channel stabilization
- Requires temporary lowering of impoundment for construction
- Habitat impact, environmental permitting
- Possible public resistance

Opinions of Cost

The opinion of cost for this work corresponding to the identified slope protection approaches are listed below:

- Cable-Concrete: $7,569,000
- Bare Riprap $4,335,000
- Grouted Riprap $4,559,000
- Soil-Filled Riprap (vegetated) $4,391,000
- Cellular Confinement $4,504,000

Opinions of cost for alternative temporary coffer damming systems to maintain a full impoundment during construction are provided below, which would be in these addition costs.

- Porta-Dam™: $750,000
- Watertube™: $640,000

If the City decides that the embankment crests should be reinforced to resist wearing from pedestrians, the opinion of cost to provide cellular confinement reinforcement is approximately $96,000.

Dam LTA-2 <u>Replace Upstream Slope Protection</u> - Insufficient or nonexistent armored slope protection and some degree of slope failure or excessive vegetation were observed on all South Pond embankment slopes. If it is determined that realigning the embankments to provide minimum bench widths and maximum 3H:1V slopes cannot be provided, this alternative will address one of the primary concerns relating to embankment stability. While this alternative will not by itself address other concerns relating to the downstream slopes, inadequate bench widths and scouring along the moat channel, it could be combined with other short- and long-tern alternatives to address these concerns.

This alternative is to reconstruct the up gradient slopes of all embankments to address observed slope failures, missing/inadequate slope armor protection and trees or other woody vegetation. The following work items would be performed.

- Clear and grub woody vegetation.

- Lower impoundment as required to recede the impoundment's edge of water beyond the proposed toe of slope for the expected 120 day construction period. Alternately, a temporary coffer damming system similar to that described for Dam LTA-1 above could be used. Additional costs for these systems are provided below.

- Install and maintain erosion and sedimentation controls during construction (silt fence along impoundment edge of water and along moat channel, erosion control blanketing on slopes areas to receive grass vegetation). .

- Place fill material on up gradient slopes to fill failure zones and to provide a 3H:1V slope. It is recommended that the crest width be increased to 12 feet by extending the up gradient top of slope toward the impoundment during this work since crews will be mobilized to place fill on the slopes. In addition, it is recommended that fill be placed to grade the embankment crests since these areas will be significantly disturbed due to construction vehicle and equipment traffic, and the existing crest is graded flat or is sunken/channelized due to the worn paths from foot-traffic.

- Place slope armor protection, which could consist of either of the approaches described for Dam LTA-1 above. A more detailed survey of embankment slope armoring conditions and an evaluation of prevailing wind directions and respective fetch lengths for embankment segments during significant storm events, should be completed for final design such that the horizontal and vertical extent of armoring can be better defined.

  One alternative under this recommendation that would be functionally equivalent to providing upstream slope protection while allowing the work to be completed under a full impoundment would be to drive sheet piling along the upstream toe of slope, unwater the area behind the sheeting, and backfilling to provide an widened embankment crest up to the line of sheet piles. This approach would be used on the East and West Embankments. An opinion of cost for this approach is provided below, assuming that cable concrete would be placed on other embankment slopes.

- Install toe drains in wet areas as described in Dam LTA-8 below.

- Place topsoil over disturbed surfaces and establish grass vegetation. This work would include regarding and restoring the embankment crests as described under Dam LTA-6 below since these areas would be disturbed during construction. Similar to Dam LTA-1 above, subsurface reinforcement could be added on the embankment crests to resist wearing from future pedestrians.

Similar to Dam LTA-1 above, this work would be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant disturbance and alterations involved.

Advantages

- Addresses structural deficiencies and lack of armor protection on upstream slopes of embankments
- Minor loss of impoundment storage volume
- Provides adequate crest widths for future access by heavy equipment
- Addresses grading deficiencies on dam crest (worn footpaths)
- Requires minor lowering of impoundment for construction

Disadvantages

- Significant cost
- Does not address moat channel encroachment or scouring
- Does not address excessive woody vegetation on down gradient areas of East embankment
- Limited improvement of access for mowing equipment on downgradient slopes and benches
- Habitat impact, environmental permitting

Opinions of Cost

The opinion of cost for this work corresponding to the identified slope protection approaches are listed below:

- Cable-Concrete: $5,258,000
- Bare Riprap $2,865,000
- Grouted Riprap $3,033,000
- Soil-Filled Riprap (vegetated) $2,845,000
- Cellular Confinement $3,100,000

Opinions of cost for alternative temporary coffer damming systems to maintain a full impoundment during construction are provided below, which would be in addition to these costs.

- Porta-Dam™: $750,000
- Watertube™: $640,000

If sheet piling were to be used in lieu of the above temporary coffer damming and slope protection alternatives for the East and West Embankments, and assuming that cable-concrete slope protection would be placed on other embankment slopes, the opinion of cost for this work would be approximately $7,807,000.

If the City decides that the embankment crests should be reinforced to resist wearing from pedestrians, the opinion of cost to provide cellular confinement reinforcement is approximately $96,000.

Dam LTA-3 Replace South Pond Concrete Spillway Weir - If the testing and structural evaluation recommended above in as Dam STA-4 determines that the spillway is in fact deteriorating, this alternative would be to demolish and replace the entire spillway weir crest between the abutments. While a more detailed engineering evaluation may determine that the deficiencies are limited to specific portions of the weir (e.g., due to poor mix design, preparation or placement during construction in 1939), for the purposes of this alternative replacement of the entire weir between the abutments is recommended.

Any future decision to replace the abutments as well should be followed by an engineering evaluation to verify the hydraulic adequacy of the spillway in accordance with current dam engineering criteria. If it is determined that the spillway is inadequate to pass flows associated with recommended storm for a structure of this size and hazard potential, the length and/or elevation of the spillway weir should be modified to address this inadequacy (since the abutments are being reconstructed, they could be located in a different position during this work). This study was not intended to address the hydraulic adequacy of the current spillway configuration.

The structural evaluation may determine that a more limited approach is appropriate. For example, weather-induced deterioration typically originates at or near the surface and progresses toward the interior, so that it may be possible to mechanically remove the surface portion of the spillway where required, apply a bonding agent to the exposed surface, and reformed the concrete to its original lines and grades. Alternately, it may be determined that a limited length of the spillway needs to be replaced in whole, in which case a similar scope of work would be undertaken to sawcut or remove the deteriorated concrete, apply a bonding agent, and repour the concrete to original lines and grades.

Any partial repair scenario should include use of a waterproofing measure on the up gradient surface of the spillway weir to limit future water intrusion and further degradation of the concrete by efflorescence. In addition, some level of impoundment drawdown and other measures to control water will be required during the work. Because the abutments are not under construction for this alternative, the bypass pipe could be employed to direct water. Whether this alone would adequately pass storm flows would need to be determined during design of the repairs; one or more additional culverts may be required if it is determined to be inadequate for anticipated storm flows. Alternately, a temporary coffer damming system could be employed in concert with one or more bypass culverts to impound water around the work area.

This work would likely be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant alterations involved.

Advantages

- Addresses structural deficiencies associated with weir structure
- If replaced does not delay need to ultimately replace spillway
- Minor environmental permitting issues (no earthwork)

Disadvantages

- Significant cost if entire spillway replaced
- Requires lowering of impoundment and stormwater bypass for construction
- If surficial repairs are completed, replacement of spillway still required in future

Opinion of Cost
The opinion of cost for this work is approximately $289,000.

If a temporary coffer damming system were to be used for this work, this opinion of cost would increase as noted below.

- Porta-Dam™: $140,000
- Watertube™: $120,000

Dam LTA-4 Replace South Pond Downstream Concrete Apron - Similar to the approach for replacement of the spillway above, future structural testing and evaluation may determine that the spillway apron is deteriorating or has lost a portion of its 18-inch design thickness. If these deficiencies are extensive, replacement of the apron may be determined as necessary. This determination may be influenced by the findings on the condition of the spillway weir, as it would be more cost-effective to replace the apron while replacing the weir, rather than having to return to replace the apron separately 10-20 years after replacing the spillway, if required.

This alternative would be to demolish and replace the downstream apron between the abutment and from the spillway weir to the downstream armor protection. As with the spillway, the structural evaluation may determine that a more limited approach can achieve an acceptable level of repair is appropriate. For example, it may be found that the top surface can be removed down to a specific depth, apply a bonding agent and replaced to provide a new surface, or it may be determined that only a limited area of the apron requires replacement whereby it could be sawcut, removed and replaced to the original lines and grades.

This work would likely be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant alterations involved.

Advantages

- Addresses structural deficiencies associated with apron structure
- If replaced does not delay need to ultimately replace apron
- Relatively minor environmental permitting issues (no earthwork)

Disadvantages

- Significant cost if entire apron replaced
- Requires lowering of impoundment and stormwater bypass for construction
- If surficial repairs are completed, replacement of apron still required in future

Opinion of Cost

The opinion of cost for this work is approximately $234,000.

Dam LTA-5 Replace North Pond Concrete Spillway Weir – This alternative would be to remove and replace the concrete spillway weir for this structure if a future evaluation determines the cracks currently observed have progressed to a point where the integrity of the entire structure could be compromised if subjected to significant storm flows. As noted in short-term alternative STA- 3 above, it may be possible to repair this structure to delay the need for ultimate replacement.

The work under this alternative would include the following items:

- Install coffer damming and bypass piping to prevent inundation of the work area and divert storm flows. One of the systems described under Dam LTA-1 could be employed for this purpose, or sandbags if the depth of water in the North Pond immediately up gradient of the work area is small enough.

- Remove stone armor protection and excavate/remove the existing concrete weir between the abutments.

- Implement measures to dewater the excavation as required to form and pour the new concrete weir.

- Backfill the weir and replace stone armor protection. This armoring can either by as originally provided (laid stones on down gradient apron and riprap as the up gradient apron) or could be alternative materials discussed under alternative Dam LTA-1 above.

This work would likely be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant alterations involved.

Advantages

- Addresses structural deficiencies associated with weir structure

Disadvantages

- Requires lowering of impoundment, stormwater bypass and possibly groundwater dewatering for construction
- If surficial repairs are completed, replacement of spillway still required in future

Opinion of Cost

The opinion of cost for this work is approximately $191,000.

Dam LTA-6 Rebuild/Regrade Embankment Crests - This alternative would be to regrade and reestablish grass vegetation with subsurface reinforcement for a walking surface on all embankment crests (with the exception of the section from the dividing embankment to the North Pond emergency spillway) without increasing the crest widths. The reinforced walking path could consist of a geosynthetic product similar in configuration to the cellular confinement slope protection product described in Dam LTA-1. For this application, a matting, consisting of smaller cell sizes would be laid on a subbase, filled and covered with topsoil material and seeded. The topsoil would be supported by the cells and resist rutting from foot traffic. The width of the reinforcing would be defined during design, but has been assumed for purposes of this opinion of cost to be five feet. This improvement would address worn footpaths on the crests if no other work is performed to realign the embankments or reconstruct upstream slope protection.

Photograph 14: Worn Footpath on Crest of South Embankment

As noted in other alternatives described above, these footpaths concentrate stormwater runoff causing rilling where they ultimately outlet to adjacent slopes. In addition, these and other low spots in the embankment crest cause standing water which can enter borrow holes into the embankment. This inflow can further develop voids formed by the burrows, and if extensive enough can create a failure plane for s slip or sliding failure of the up gradient slope (as observed at several locations at the north end of the West Embankment during the inspection).

This work would include placing and grading additional topsoil on the embankment crests such that runoff is directed toward the impoundment, reestablishing grass vegetation and installing/maintaining erosion and sedimentation controls.

This work would likely be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant alterations involved.

Advantages

- Repairs worn footpaths and low areas
- Maintains sheet flow to minimize the potential for channelization and rilling from stormwater runoff
- Reduces infiltration into embankment
- Provides reinforced surface to support pedestrians

Disadvantages

- Does not address slope stability or inadequate crest width
- Relatively small benefit for large disturbance area and cost as a construction activity by itself

Opinion of Cost

The opinion of cost for this work is approximately $467,000.

Dam LTA-7 <u>Install Moat Channel Scour Protection</u> - The purpose of this alternative would be to install channel scour protection along the moat channel bank adjoining the bench along the South, West and North embankments and benches such that the channel does not continue to erode into these structures. Because other recommended alternatives (Flood LTA-2 and Flood LTA-6) address uneven profile grading resulting in poor hydraulic performance along the entire length of the moat, this recommendation to provide scour protection on the dam-side of the moat channel is only considered further in combination with other work since disturbance of the channel would be significant (all work should be completed for the moat channel while crews are mobilized to perform improvements under environmental permitting).

These alternatives are described under the discussions for Flood LTA-2 and Flood LTA-6 in this report.

Advantages

- Limits future scouring of channel into bench/embankment slopes

Disadvantages

- Does not address slope stability or inadequate crest width
- Environmental permitting

Opinion of Cost
The opinion of cost for this work is included as a portion of Flood LTA-2 and LTA-6.

Dam LTA-8 Install Embankment Toe Drains – Several areas with saturated soil conditions were observed along the South, West and North embankments 'down gradient slopes and adjoining benches. These areas are predominantly if not wholly the result of preferential pathways for water traveling from the impoundment through the embankment and emerging at a point above the down gradient toe of slope. These wet areas exhibit weakened soil conditions and result in displacement of surface soils on the embankment slope due to rutting by mowing equipment and sliding/slumping movement by gravity.

Worsening of these areas would result in additional loss of soil at the toe of slope, which would progressively result in soils failing higher up the embankment until the entire down gradient portion of the embankment was compromised. These areas could then develop as preferential pathways for stormwater runoff, causing significant rilling and a potential rupture of the embankment during significant rain events. Loss of soils from the embankment also reduce the overall cross-section and can progressively develop into worsening internal erosion due to higher hydraulic gradients at the surface as the failure surface moves closer to the center of the embankment.

A 2.5H:1V or steeper slope, which was measured by survey for many of the embankments down gradient slopes, may be found to be stable under properly drained dry conditions (i.e., moisture content below a required soil strength threshold) by an engineering evaluation recommended under Dam STA-11. Similarly, a 3H;1V slope is suitable for most mowing equipment operations under dry conditions. Therefore measures such as a toe drain that properly drain subsoils to limit moisture content will improve the ability of embankment slopes and bench areas to withstand external forces without rutting or other movement. Toe drains provide a preferential pathway for groundwater within embankments to drain freely and in a controlled manner so that soil particles are not carried from within the embankment. This has the effect of lowering the groundwater elevation within the embankment thereby improving the overall strength of the embankment soil mass. This measure may therefore be adequate by itself to adequately improve embankment stability and allow mowing operations without damage to the embankments.

This recommended alternative is to install toe drains along the toe of slope in these areas to provide a controlled discharge for water moving through the embankment. These drains would outlet to the moat channel at a sufficient elevation to prevent backwater during normal flows and should be equipped with rodent screens to prevent them from being occupied by burrowing animals. Based on our observations of wet areas during our inspection, approximately 5,400 feet of toe drain would be installed under this recommendation at limited sections of the three embankments (approximately one-half of the South Embankment, the entire West Embankment, and those portions of the North Embankment that have not been reinforced with compacted gravel, estimated to be one-half of the total length).

This work would likely be subject to permitting under a CRMC Assent and would also require a formal permit under either the existing or current draft dam safety regulations due to the significant alterations involved.

Advantages

- Strengthens soil in typically wet areas to allow operations by mowing equipment.

Disadvantages

- Limited scope in addressing embankment deficiencies
- Adverse access/work conditions on West Embankment if not done in conjunction with embankment realignment (Dam LTA-1).
- Environmental permitting

Opinion of Cost

The opinion of cost for this work is approximately $539,000.

Dam LTA-9 Control Public Access – Open access to the embankments is currently enjoyed by the public including dog-walkers, joggers, walkers, bird watchers, loitering youth, and people fishing from the embankments or spillways. These activities have resulted in the formation of a worn path along the center of the embankment crests, as well as worn paths a certain points on upstream and downstream slopes. In addition, it is our experience at other dam sites where public access is unfettered that rocks placed as slope protection are thrown into the water or onto/through the iced surface during winter freezing over time.

Repairing the worn footpaths by regrading the embankment crests and installing subsurface reinforcement along the center of embankment crests to resist wearing from future pedestrians has been incorporated into Dam LTA-1, Dam LTA-2 and Dam LTA-6 above. This will provide a level of protection to the embankment crests without further formalizing the publicly perceived right-to-access as construction of a stone dust walking surface would.

Considering the fact that sufficient authority currently exists to prohibit public access onto the embankments for reasons of public safety related to the impoundments use as a raw water source for public drinking water, an alternative to the Dam LTA-6 would be to remove the pedestrian bridges currently installed from Ellery Drive at the north end of the West Embankment and from Old Beach Avenue near the south end of the West Embankment. It is understood that these bridges were removed once before but reinstalled due to public pressure and potential liability associated with the hazard faced by those attempting to cross the moat unaided or using an unsafe improvised structure furnished by themselves or others. A public outreach/education program could be implemented in advance of future removal of these bridges to notify users of the lawfully-supported decision by the City to prohibit future access to protect a public drinking water source. This notice could include maps or other information directing users to similar nearby locations for their activities.

Although mentioned in this alternative, construction of the reinforced subsurface walking path is included with the costs the long-term alternatives noted above. This alternative would include implementation of measures to restrict or otherwise prohibit public access. Fencing was discussed as a potential measure, but was not considered further in due to concerns with restricting facility personnel's need for maintenance access, space limitations due to the moat channel, and aesthetic concerns given the site's relatively high profile adjacent to Easton Beach and Memorial Boulevard. Instead, signage at the current footbridge access points could be used to notify users of the City's intent to restrict access, provide the reasons for this closure as identified in this report, and provide alternate locations for activities currently enjoyed on the embankments. This signage could include a date upon which access would be formally closed and upon which the footbridges would be removed. This outreach/public education effort could also include mailers to City residents, or other available means to communicate the reasoning and alternatives.

Advantages

- Prohibition and subsurface reinforcement address damage to the embankment crest and slopes caused by foot traffic
- Prohibition addresses damage to slope protection from loss of riprap units
- Prohibition protects public drinking water supply
- Prohibition removes hazard to public and personal injury liability to City from walking adjacent to slopes, impoundment and moat channel (note caving of upstream slopes and necessity to barricade collapsed area)

Disadvantages

- Public opposition due to perceived right-to-access gained from historical enjoyment of the area from walking embankment crests

Opinion of Cost

The opinion of cost for this work is approximately $17,500.

Table 27
Long-Term Dam Alternatives

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-1: Realign the East and West Embankments to address significant deficiencies and provide adequate bench width along downstream toe of slopes. Repair upstream slope protection on other embankments.	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides 3H:1V downstream slopes to facilitate mowing equipment. • Provides 10 'wide bench for maintenance access and to facilitate mowing equipment. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from embankment crests.	• Cable-Concrete: $7,569,000 • Bare Riprap $4,335,000 • Grouted Riprap: $4,559,000 • Soil-Filled Riprap (vegetated): $4,391,000 • Cellular Confinement: $4,504,000 • Porta-Dam (add-alternate): $750,000 • Watertube (add-alternate): $640,000 • Reinforced Walking Surface (add-alternate): $96,000	• Control of water required by temporarily lowering impoundment or coffer damming around work areas. • Portion of impoundment storage capacity lost due to relocated embankments. • Significant erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Significant earth volumes to be handled will require stockpiling areas. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-2: Replace upstream slope protection on all embankments and widen embankment crest (no horizontal relocation of downstream slopes).	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from	• Cable-Concrete: $5,258,000 • Bare Riprap $2,865,000 • Grouted Riprap: $3,033,000 • Soil-Filled Riprap (vegetated): $2,845,000 • Cellular Confinement: $3,100,000 • Sheet piling and Cable-Concrete: $7,807,000 • Porta-Dam (add-alternate): $750,000	• Control of water required by temporarily lower impoundment or coffer damming around work areas. • Small portion of impoundment storage capacity lost due to upstream embankment filling. • Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
	embankment crests.	• Watertube (add-alternate): $640,000 • Reinforced Walking Surface (add-alternate): $96,000	ACOE.
Dam LTA-3: Demolish and replace South Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace spillway weir: $289,000 • Porta-Dam (add-alternate): $140,000 • Watertube (add-alternate): $120,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-4: Demolish and replace South Pond downstream concrete apron.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace downstream apron: $234,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-5: Replace North Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure.	• Remove and replace downstream apron: $191,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-6: Rebuild/Regrade all embankment crests.	• Provides 12 'crest width for all embankments for future maintenance/ repair access. • Repairs worn footpath, promotes proper surface drainage from embankment crests. • Provides reinforced surface for public access	• Rebuild/regrade embankment crests: $467,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and possibly ACOE.

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-7: Install moat channel scour protection as described in Flood LTA-2 and LTA-6.	• Reinforces moat channel banks to prevent or reduce further encroachment into benches and downstream slopes.	• Install moat channel scour protection (riprap): $2,500,000 • Install moat channel scour protection (concrete): $3,700,000	• Control of water in moat channels required during work. • Difficult access to some portions of moat channel. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-8: Install embankment toe drains at limited sections of South, West and North Embankments.	• Addresses benches and downstream slopes areas that are wet or saturated.	• Install toe drains: $539,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to portions of West Embankment. • Permits required from CRMC and RIDEM.
Dam LTA-9: Develop and implement program to control/prohibit public access onto embankments.	• Prohibition limits future damage to embankment crests and slope protection. • Reinforced walking path limits damage to embankment crests.	• Develop and implement control program:: $17,500	• Potential public opposition.

6.2 Moat Drainage Alternatives

Flooding occurs near Memorial Boulevard and at other local roads adjacent to the Moat during significant storm events. Several alternatives to reduce flooding along the northern section of the Moat, specifically within the Ellery Road and Eustis Avenue neighborhoods, were identified in the *1991 USDA Flood Prevention Evaluation for Ellery Road and Eustis Avenue* (1991 USDA Study). While our study expands from the original USDA study by focusing on flooding throughout the entire length of the Moat, as opposed to flooding only within the residential neighborhoods, we reconsidered the alternatives proposed by the USDA and identified other alternatives to reduce flooding at Memorial Boulevard and at other local roads adjacent to the Moat. The order-of-magnitude cost associated with the implementation of each proposed alternative was then compared to the calculated decrease in water surface elevations to determine which alternatives, if any, would provide the most flood-reduction benefits relative to the costs.

6.2.1 Development of Baseline Hydraulic Model

In order to evaluate the anticipated benefits provided by each of our proposed alternatives, we developed a baseline hydraulic model to identify existing areas of flooding along the Moat and to calculate water surface elevations within the Moat during storm events. The baseline hydraulic model for the Moat was generated using HEC-RAS. HEC-RAS is a PC/Windows-based computer program developed by the United States Army Corps of Engineers that is used to generate water surface profiles for open channels. The analysis was performed using the cross-sectional geometry of the Moat and estimated flows conveyed by the Moat during the 2-, 5-, 10-, 25-, and 50-year storm events. The 100-year storm event was not considered as part of our hydraulic analyses since the entire project area is inundated during this storm event. The 100-year storm surge elevation is approximately 12.9 feet per the Flood Insurance Study (FIS) for the City of Newport.

6.2.1.1 Cross-Section Geometric Data

Topographical information was obtained at numerous locations along the Moat by survey (including adjacent roadway edge of pavement elevations and stormwater structure rim and pipe invert elevations). This information was used to develop channel cross-sections for the baseline hydraulic model. The locations of all cross-sections used in the analysis are included in Appendix F of this report and are depicted in Figure FLOOD XCS-1.

Photograph 15: Moat Along Ellery Road

Channel roughness factors (Manning's *n*) used in the hydraulic analyses were estimated based on field inspection of the channel and overbank areas. With the exception of the Moat channel and overbank areas adjacent to the old filtration plant, a Manning's coefficient of 0.030 (the typical value for excavated, winding and sluggish channels consisting of grass with some weeds) was used. Refer to Photograph 15. A value of 0.080 was used in the Moat channel and overbank areas adjacent to the old filtration plant (consistent with the typical Manning's coefficient value for weedy, unmaintained channels). As shown in Photograph 16, this area is inundated with reeds. Refer to Appendix F of this report for a copy of typical Manning's coefficients used in channel and overbank areas (from HEC-RAS Hydraulic Reference Manual Version 3.0, January 2001). Additionally, photos of the Moat and overbank areas are provided in Appendix G.

Photograph 16: Moat Overbank Areas Adjacent to Old Filtration Plant

6.2.1.2 Steady-Flow Data

Steady-flow data input into the model included peak flows conveyed by the Moat during the 2-, 5-, 10-, 25-, and 50-year storm events. The 100-year storm event was not considered as part of our analysis since the entire area is inundated due to storm surge as documented in the Flood Insurance Study (FIS) for the City of Newport.

Steady-flow data consists of two components: peak discharge and boundary condition information. The steady-flow data was determined from our hydrologic analysis of the drainage areas that contribute to flow in the Moat and the adjacent North and South Easton Ponds. The following table summarizes peak flow values at selected cross-sections throughout the Moat during the specified storm events.

Table 28
Steady-flow Peak Discharge Rates

Cross-Section Location	Cross-Section Description	Peak Flow Rates (cfs) [a]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta. 77+82	Downstream of North Easton Pond Secondary Spillway	150.1	240.7	300.9	364.3	459.6
Sta. 65+34	Downstream of Daniel Street Culvert	151.4	242.6	303.0	366.8	462.7
Sta. 62+71	Downstream of 3-36" Culverts at Northwestern Corner of Moat	278.5	383.6	454.3	548.5	642.5
Sta. 62+57	Downstream of 48" Culvert at Northwestern Corner of Moat	395.3	540.9	638.5	768.6	898.4
Sta. 50+21	Downstream of Catherine Street Culvert	473.1	650.1	768.9	927.5	1085.9
Sta. 33+88	Southwestern Corner of Moat at Old Beach Road/Memorial Boulevard Intersection	513.1	709.4	841.6	1018.3	1195.2
Sta. 02+65	Immediately Upstream of Memorial Boulevard Culvert	627.4	867.3	1028.8	1244.7	1460.6

a. "cfs" refers to cubic feet per second.

The water surface boundary elevations used at the upstream end of the Moat were the water surface elevations for North Easton Pond computed as part of our hydrologic analysis. The water surface boundary elevation used at the downstream end of the Moat for all storm events was the mean higher high water (MHHW) level for the City of Newport by the NOAA at the Newport Naval Station Complex (2.67 feet).

6.2.1.3 Summary of Baseline Water Surface Elevations and Areas of Flooding

The hydraulic analysis of the existing moat indicates that flooding occurs along Ellery Road, Old Beach Road, and Memorial Boulevard during all evaluated storm events.

The following table summarizes the calculated water surface elevations at selected locations throughout the Moat under existing conditions during the specified storm events. The water surface elevations included in parentheses indicate values computed in the 1991 USDA Study, which are provided for model verification.

Table 29
Baseline Water Surface Elevations for Selected Storm Events

Cross-Section Location	Cross-Section Description	Baseline Water Surface Elevations (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta. 77+82	Downstream of North Easton Pond Secondary Spillway	12.1 (11.4[b])	12.6	12.8 (12.7[b])	12.9 (13.2[b])	13.0 (13.4[b])
Sta. 62+57	Downstream of 48" Culvert at Northwestern Corner of Moat	12.0	12.6	12.8	12.9	13.0
Sta. 50+21	Downstream of Catherine Street Culvert	11.1	11.8	12.1	12.5	13.0
Sta. 39+28	Station along Old Beach Road	9.8	10.4	10.5	10.7	10.9
Sta. 33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Int.	9.6	10.2	10.2	10.4	10.6
Sta. 05+55	Upstream of Confluence with Easton Pond Spillway	8.3	9.9	9.4	9.5	9.5
Sta. 02+65	Immediately Upstream of Memorial Boulevard Culvert	7.6	9.8	9.0	9.3	9.1

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under existing conditions (including cross-section input and output).
b. Values in parentheses indicate values computed as part of the *1991 USDA Flood Prevention Evaluation for Ellery Road and Eustis Avenue* as included in Appendix I.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

Based on the results of our hydraulic analysis, the following areas and/or residences are affected by flooding or are inundated during significant storm events:

- Portions of Ellery Road and roadways adjacent to the northern portion of the Moat. The elevation of Ellery Road, in this location, varies between 8.0± and 10.0± feet. The bottom elevation of the Moat in this location varies between 6.1± and 5.3± feet.

- The following six homes adjacent to the northern portion of the Moat:

  - 129 Bliss Mine Road with a ground-level basement window at elevation 9.9±
  - 78 Ellery Road with the garage floor level at elevation 10.5±
  - 70 Ellery Road with basement windows at elevation12.0±
  - 103 Kay Boulevard with a garage floor level at elevation 12.6±
  - 312 Kay Boulevard with the garage floor level at elevation 12.6±
  - 1 Daniel Street with a basement level at elevation 11.6±

  Each home and its associated flood damage elevation were obtained from the 1991 USDA Study.

- Old Beach Road adjacent to the southwestern corner of the Moat (between Sta. 33+88 and Sta. 41+67). A minimum roadway elevation of 7.6± was observed in the roadway in this location. Water surface elevations ranging from 9.8± to 10.8± are anticipated at this location during the 2-year through 50-year, 24-hour storm events based on the results of our hydraulic analysis.

- Memorial Boulevard between the Moat and Easton Beach (between Sta. 33+88 and the Memorial Boulevard culvert). A minimum elevation of approximately 8.6± was measured along Memorial Boulevard. Water surface elevations ranging between 9.5± and 10.4± are anticipated in this location during the 2-year through 50-year, 24-hour storm events.

6.2.1.4 Verification of Baseline Hydraulic Model

For model verification purposes, the water surface elevations obtained as part of our hydraulic analysis were compared to the water surface elevations in the 1991 USDA Study for the northern portion of the Moat. As illustrated in Table 29, differences in water surface elevations calculated in our study are approximately +0.7 feet, +0.1 feet, -0.3 feet, and -0.4 feet compared to the 1991 USDA Study for the 2-year, 10-year, 25-year, and 50-year storm events, respectively.

We contacted the City of Newport to compare our modeled results with actual accounts of flooding. Based on the input provided by the City, it appears that our hydraulic model may be slightly conservative. Although the areas of flooding correspond to reported or observed areas of flooding, the model suggests that flooding occurs in all of these areas during storm events of a magnitude greater than or equal to the 2-year, 24-hour storm event.

The model, however, does closely correlate to actual accounts of flooding experienced by affected homeowners in the area adjacent to the northern portion of the Moat as documented in the 1991 USDA Study. For example, flooding up to the first floor level (El. 12.8) of 129 Bliss Mine Road occurred during a 5.5-inch rainfall event on May 17, 1982. A 5.5-inch rainfall event corresponds to a 25-year storm event. The results of our analysis indicate a 25-year water surface elevation of 12.88 at this location. This correlates closely with the level of flooding recorded on May 17, 1982, and it is our opinion that the model closely reflects actual flooding conditions. The accuracy of the program is dependent on assumptions and limitations such as the accuracy of the geometric data (cross-sections, Manning's *n* values, bridges, culverts, etc.); the accuracy of the flow data and boundary conditions (inflow hydrographs, rating curves, etc...); and the numerical accuracy of the solution scheme.

The curve numbers and times of concentration generated for all subwatersheds that contribute flow to the Moat and North Easton and South Easton Ponds were consistent with the values listed in the 1991 USDA Study. The slightly conservative nature of our analysis may be attributed to small-scale depressions located within the subwatersheds or the limited capacity of the existing of the existing closed-conduit drainage systems. Both of these factors may limit or restrict the amount of flow discharged to the Moat.

A sensitivity analysis was also conducted to determine which variables had the greatest effect on water surface elevations in the Moat. The results of our analysis revealed that flow discharged to the Moat from the three 36-inch culverts and the 48-inch culvert at the northwestern corner of the Moat has a significant effect on water surface elevations. Since the peak flows calculated from these watersheds during the 2- thru 50-year storm events exceed the capacity of the pipes, the peak flows discharged to the Moat from these pipes may be conservative.

6.2.2 Short-Term Flood Management Alternatives

With the baseline model developed and areas of flooding identified, several short-term and long-term alternatives were devised to reduce or alleviate flooding experienced along roadways and at residences adjacent to the northern section of the Moat, along Old Beach Road, and Memorial Boulevard. The alternatives we recommend as "short-term" are best management practices that may be relatively easier and less expensive for the City to implement. We propose these short-term alternatives as positive steps that the City can take immediately.

Although these alternatives may slightly increase the hydraulic efficiency of the Moat or the adjacent roadway closed-conduit drainage systems, there are no short-term alternatives that will completely alleviate flooding or significantly reduce water surface elevations within the Moat during storm events. These alternatives will, however, ensure that flooding conditions do not worsen and will also improve stabilization of the Moat bottom to reduce future erosion/scour. Refer to Figure FLOOD STA-1 for the general locations at which these recommendations would apply.

Flood STA-1: Remove areas of sediment deposition within the Moat and install riprap at the outlets of culverts discharging to the Moat – As illustrated in Figure FLOOD STA-1, the profile of the Moat channel is deteriorated by scour and sediment deposition. These areas contribute to the non-uniform slope of the channel and creation of stagnant pools throughout. Removing areas of sediment build-up will slightly improve the hydraulic efficiency of the Moat in conveying flow from the upstream end of the Moat to the Memorial Avenue Boulevard culvert. Installing riprap at all stormwater outlets to the Moat will prevent scour from occurring at these outlet locations.

The opinion of cost for this work is approximately $256,000.

Flood STA-2: Install riprap at the upstream and downstream ends of the Memorial Boulevard culvert – Based on the topographical information provided by survey, scouring of the Moat channel (approximately 18 inches deep) is occurring at the upstream end of the Memorial Boulevard culvert. Scour is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of the channel. In this case, to the presence of the culvert. The decrease in flow area results in an increase in average flow velocities upstream and downstream of the contraction. Installing riprap at this location will protect the channel from scour.

The opinion of cost for this work is approximately $7,000.

Flood STA-3: Install riprap at the upstream and downstream ends of the pedestrian bridge located in the northwestern corner of the Moat – Extend riprap to encompass the three 36-inch outlets upstream of the bridge and the 48-inch outlet downstream of the bridge.

The opinion of cost for this work is approximately $6,000.

Flood STA-4: Remove obstructions within the Moat adjacent to the Old Filtration Plant to improve the hydraulic efficiency – Photograph 17 shows an existing wall that bisects the Moat adjacent to Sta. 76+89. The removal of this structure will improve hydraulics. Additionally, a paved access path adjacent to the old filtration plant bisects the Moat in the vicinity of Sta. 77+65 as shown in Photograph 18. The installation of culverts to hydraulically connect the Moat upstream and downstream of this path will also slightly improve the hydraulics of the Moat.

The opinion of cost for this work is approximately $40,000.

Photograph 17: Existing Wall at

Photograph 18: Paved Access Path at Sta. 77+65

Flood STA-5: Continue to clean and flush existing drainage structures and pipes that discharge to the Moat along Ellery Road, Eustis Avenue, Old Beach Road, and Memorial Boulevard – This practice will ensure that the roadway drainage systems continue to operate efficiently during the smaller, more frequent storm events.

The opinion of cost for this work is approximately $5,000.

Flood STA-6: Continue to implement a regular maintenance/mowing program to control the height of vegetation growing within and adjacent to the Moat – Limiting the amount of vegetation in and around the Moat will result in lower roughness (Manning's *n*) coefficients in the channel and its overbank areas, thereby limiting energy losses and improving the hydraulic capacity of the Moat. Clippings or cut vegetation should be removed and disposed off-site.

The opinion of cost for this work is approximately $107,000.

Table 30 summarizes each of these short-term alternatives, including the approximate cost, relative cost/benefit rating, and potential implementation issues.

Table 30
Short-Term Flood Management Alternatives

Description	Benefit	Order of Magnitude Costs[a]	Relative Cost / Benefit Rating[b]	Implementation Issues
Flood STA-1: Remove areas of sediment deposition within the Moat and install riprap at the outlets of culverts discharging to the Moat.	• Slight improvement of the hydraulic efficiency of the Moat. • Prevents scour at stormwater outlets .	$256,000	Low	• Excavated soil needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • A Maintenance Certificate may be required from the CRMC.
Flood STA-2: Install riprap at the upstream and downstream ends of the Memorial Boulevard culvert	• Stabilized the channel upstream and downstream of the culvert.	$7,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate or Council Assent may be required from the CRMC for work below the mean high water level.
Flood STA-3: Install riprap at the upstream and downstream ends of the pedestrian bridge located in the northwestern corner of the Moat	• Stabilized channel upstream and downstream of the pedestrian bridge.	$6,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate may be required from the CRMC.
Flood STA-4: Remove hydraulic obstruction within the Moat and install culverts below access	• Improved moat hydraulics.	$40,000	Low	• Improvements must occur during the dry season/weather since the Moat sustains a base flow.

Description	Benefit	Order of Magnitude Costs[a]	Relative Cost / Benefit Rating[b]	Implementation Issues
path				• Dewatering will be necessary. • A Maintenance Certificate may be required from the CRMC.
Flood STA-5: Continue to clean and flush existing drainage structures and pipes that discharge to the Moat along Ellery Rd., Eustis Ave., Old Beach Rd., and Memorial Blvd.	• Reduced roadway flooding during the smaller, more frequent storm events.	$5,000 per Maint. Event	High	• Inspection and maintenance of the closed-conduit drainage systems and components must continue to be performed on a regular basis (e.g., inspect quarterly and maintain twice a year, at minimum).
Flood STA-6: Continue to implement a regular maintenance / mowing program to control the height of vegetation growing within and adjacent to the Moat	• Improved hydraulic capacity of the Moat.	$107,000 per Clearing Event	High	• Due to the instability of the pond embankment and bench in some locations, maintenance needs to be performed by hand. Mow at least twice a year. • A Maintenance Certificate may be required from the CRMC.

a. Refer to Appendix C for a list of items included in the cost estimates and supporting documentation for each short-term alternative.
b. The relative cost/benefit rating value is defined as follows:
High - Highest Benefit (in terms of flood reduction) relative to costs associated with improvements
Medium - Average Benefit (in terms of flood reduction) relative to costs associated with improvements
Low - Minimal Benefit (in terms of flood reduction) relative to costs associated with improvements

Although these short-term alternatives consist mainly of minor improvements or maintenance activities, the Coastal Resource Management Council (CRMC) may require Maintenance Certification, at minimum, for each short-term alternative. CRMC Regulations state that operations occurring on coastal features, or within all directly associated 200-foot contiguous areas, may require a Council Assent or Certification of Maintenance. North and South Easton Ponds are classified as Type 1 waters, and are subject to CRMC jurisdiction.

6.2.3 Long-Term Flood Management Alternatives

Based on the results obtained from our baseline hydraulic model, we concluded that the hydraulic capacity of the Moat is inadequate. To put the hydraulic inadequacy of the Moat into perspective, a rough open channel analysis of the Moat in the areas of Ellery Road, Old Beach Road, and Memorial Boulevard was conducted using FlowMaster. FlowMaster is a Windows-based program that computes flows, water velocities, and depths using several well-known formulas. In this case, the Manning's formula was used. Assuming a channel slope of approximately 0.06% (the average slope of the channel from its upstream to downstream limits) and a Manning's coefficient of 0.030 (the standard coefficient for an excavated channel consisting of grass and some weeds):

- The width of the northern section of moat would need to be increased to approximately 50 feet to eliminate the flooding of adjacent residences for storm events up to, and including, the 50-year storm.

- The width of the northern section of moat would need to be increased to approximately 120 feet to eliminate the flooding of Ellery Road for storm events up to, and including, the 50-year storm.

- The width of the western section of the Moat would need to be increased to approximately 100 feet to eliminate the flooding of Old Beach Road for storm events up to, and including, the 50-year storm.

- The width of the southern section of the Moat channel would need to be widened to approximately 80 feet to eliminate the flooding of Memorial Boulevard for storm events up to, and including, the 50-year storm.

Since the Moat is bounded on one side by the embankment of South Easton Pond and by roadways on the other, it is impractical to consider widening the Moat to the extent listed above without relocating the pond's embankments or realigning adjacent roadways. As a result, several other long-term alternatives were explored. Long-term alternatives generally require more significant efforts for planning, design and permitting, and significant capital investment to fund implementation.

The 1991 USDA Study evaluated several alternatives to reduce or eliminate flooding in the residential neighborhoods adjacent to the northern portion of the Moat. The alternatives included: dredging the Moat; constructing a dike along Ellery Road; relocating the Memorial Boulevard culvert; eliminating pipe flow from adjacent roadway drainage systems; eliminating flow from North Easton Pond's secondary spillway; and re-excavating Braga Memorial Field to allow for flood storage. Based on the conclusions provided within that study, it appeared that costs associated with attempting to reduce or alleviate flooding along Ellery Road would not be justified. The evaluation concluded that flood-proofing the houses susceptible to flood damage adjacent to the northern portion of the Moat was the most reasonable solution.

Our study expands from the 1991 USDA study by focusing on flooding throughout the entire length of the Moat. We reconsidered a number of the alternatives proposed by the USDA and identified other long-term alternatives to reduce flooding along Memorial Boulevard and other local roads adjacent to the Moat. The following is a list of long-term alternatives considered as part of our study:

- Flood LTA-1: Excavate existing channel bottom to provide a uniform channel slope in sections of the Moat that are adjacent to the identified areas of flooding.

- Flood LTA-2: Excavate and widen the existing channel throughout its entire length and line the base of the channel with riprap.

- Flood LTA-3: Replace Memorial Boulevard culvert with three 5-foot by 10-foot box culverts.
- Flood LTA-4: Install a pump station at the southwestern corner of moat (near Memorial Boulevard).
- Flood LTA-5: Install three 5-foot by 8-foot box culverts at southwestern corner of moat (adjacent to Old Beach Road).
- Flood LTA-6: Excavate and widen the existing channel throughout its entire length and line the base of the channel with concrete.

Hydraulic models were developed for each alternative using HEC-RAS to assess the reduction of water surface elevations in existing flood-prone areas along the Moat as a result of the proposed improvements. Refer to Figures FLOOD LTA-1 through FLOOD LTA-6 for illustrations of the proposed long-term alternatives and Appendix F for water surface summary charts showing the anticipated water surface elevations for each proposed alternative.

The following paragraphs provide detailed descriptions of each long-term alternative evaluated and the anticipated benefits associated with each. Since the Moat sustains a year-round base flow, improvements to the Moat for all long-term alternatives will need to be performed during dry weather conditions and during the dry season. Consequently, improvements to the channel will need to be performed in sections since dewatering the entire moat will be impractical.

Flood LTA-1: Excavate existing channel bottom to provide a uniform channel slope in sections of the Moat adjacent to the identified areas of flooding – This alternative will eliminate areas of scour or sediment deposition and improve the hydraulic capacity of the Moat in the areas that flood during significant rainfall events. These areas include Ellery Road and the residential neighborhood adjacent to the northern portion of the Moat, Old Beach Road, and Memorial Boulevard.

As shown in the Table 31, flood reduction benefits from the proposed improvements associated with this alternative were minimal and would not alleviate flooding in any of the flood-prone areas along the Moat. Decreases in water surface elevations of 0.20 feet or less would be expected in the northern portion of the Moat during the 2- and 5-year storms. Decreases in water surface elevations would not be expected in other locations along the Moat or during storm events of a magnitude greater than, or equal to, the 10-year storm. Refer to Figure FLOOD LTA-1 for a depiction of the improvements proposed for this alternative. Improvements adjacent to the old filtration plant included removing the wall bisecting the Moat channel (Sta. 76+89) and installing culverts at the access path (Sta. 77+65).

Table 31:
Anticipated Change in Water Surface Elevations
Resulting From Alternative 1 (Flood LTA-1) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta.77+82	Downstream of North Easton Pond Secondary Spillway	11.8 (-0.3)[b]	12.4 (-0.2)	12.6 (-0.2)	12.8 (-0.1)	12.9 (-0.1)
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	11.8 (-0.2)	12.4 (-0.2)	12.6 (-0.2)	12.8 (-0.1)	12.9 (-0.1)
Sta.39+28	Old Beach Road	10.0 (+0.2)	10.2 (-0.2)	10.4 (-0.1)	10.6 (-0.1)	10.8 (-0.1)
Sta.33+88	Southwest Corner of Moat at Intersection of Old Beach Road & Memorial Boulevard	9.8 (+0.2)	10.0 (-0.2)	10.2 (-0.0)	10.4 (-0.0)	10.5 (-0.1)
Sta.05+55	Upstream of Confluence with Easton Pond Spillway	9.4 (+1.1)	9.2 (-0.7)	9.3 (-0.1)	9.5 (-0.0)	9.5 (-0.0)
Sta.02+65	Immediately Upstream of Memorial Boulevard Culvert	9.4 (+1.8)	9.1 (-0.7)	9.1 (+0.1)	9.3 (-0.0)	9.1 (-0.0)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 1 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the anticipated change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $1.4 Million.

Although slight reductions in flooding were noted in the northern portion of the Moat, the six residential homes affected by flooding in this location will continue to be affected as will Old Beach Road and Memorial Boulevard. This alternative has a low benefit to cost rating.

Flood LTA-2: Excavate and widen the Moat channel throughout its entire length and line the base of the channel with riprap – This alternative will eliminate areas of scour or sediment deposition and improve the hydraulic capacity of the Moat. The proposed channel cross-section used in this analysis has a 10-foot bottom width, a 2-foot minimum depth, and 2:1 side slopes. These dimensions correspond to the average size and

Photograph 19: Sample Photograph of Riprap Channel with Vegetated Sideslopes

depth of the existing moat. Since the channel conveys approximately one foot of base flow year-round, riprap was selected to line the channel bottom and side slopes up to a depth of two feet. Riprap with a median stone diameter of approximately six inches was selected to attain a Manning's coefficient of approximately 0.035 throughout the channel (assuming a depth of flow of 24 inches or greater). Permanent turf reinforcement matting was selected to line the remainder of the channel's slopes to the point where proposed grades match into existing grades. We assumed that the remaining areas adjacent to the Moat that would be affected by construction would receive a layer of loam and be seeded with a native seed mix.

As shown in the Table 32 below, flood reduction benefits associated with this alternative would occur mainly in the area adjacent to the northern portion of the Moat channel. Decreases in water surface elevations ranging between 0.4 feet to 0.2 feet would be expected for the 2- thru 10-year storm events. However, minimal to no reduction is anticipated for storm events of a greater magnitude than the 10-year storm event. Refer to Figure FLOOD LTA-2 for a depiction of improvements proposed for this alternative. Minor improvements such as the removal of the wall that bisects the Moat channel (Sta. 76+89) and the installation of culverts at the access path adjacent to the old filtration plan (Sta. 77+65) are also proposed as part of this alternative.

Table 32
Anticipated Changes in Water Surface Elevations
Resulting from Alternative 2 (Flood LTA-2) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta.77+82	Downstream of North Easton Pond Secondary Spillway	11.7 (-0.4)[b]	12.3 (-0.3)	12.6 (-0.2)	12.8 (-0.1)	13.1 (+0.1)
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	11.6 (-0.4)	12.3 (-0.3)	12.6 (-0.2)	12.8 (-0.1)	13.0 (-0.0)
Sta.39+28	Old Beach Road	10.1 (+0.3)	10.3 (-0.1)	10.5 (-0.0)	10.8 (+0.1)	10.9 (-0.0)
Sta.33+88	Southwest Corner of Moat at Intersection of Old Beach Road & Memorial Boulevard	10.0 (+0.4)	10.1 (-0.1)	10.3 +0.1)	10.5 (+0.1)	10.6 (-0.0)
Sta.05+55	Upstream of Confluence with Easton Pond Spillway	9.5 (+1.2)	9.2 (-0.7)	9.3 (-0.1)	9.5 (-0.0)	9.2 (-0.3)
Sta.02+65	Immediately Upstream of Memorial Boulevard Culvert	9.5 (-0.1)	9.1 (-0.7)	9.1 (+0.1)	9.3 (-0.0)	9.1 (-0.0)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 2 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the computed change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $2.5 Million.

Improvements associated with this alternative will prevent flooding of two of the six houses (103 and 312 Kay Boulevard) adjacent to the northern portion of the Moat during the 2-year and 10-year storms. The remaining four houses, Memorial Boulevard, and Old Beach Road will continue to flood during these significant events. This alternative has a low benefit to cost rating.

Flood LTA-3: Replace existing Memorial Boulevard culvert with three 5-foot by 10-foot box culverts – Based on the results of our hydraulic analysis, the existing Memorial Boulevard culvert is a hydraulic restriction during storm events of a greater magnitude than the 2-year, 24-hour storm event and may be contributing to roadway flooding currently experienced along Memorial Boulevard. A preliminary analysis of the culvert's existing capacity was performed using CulvertMaster assuming maximum headwater and tailwater conditions. We used the elevation of the roadway (when overtopping would occur) as the maximum headwater elevation and the MHHW tide elevation of Easton Beach as the maximum tailwater elevation. Culvert Master is a program developed by Haestad Methods, Inc., that is used to design or analyze culverts under pressure flow conditions.

The results of our analysis indicate that backflow does appear to increase water surface elevations in the southern portion of the Moat during storm events of a magnitude equal to or greater than the 2-year storm event. For example, the approximate capacity of the existing culvert was calculated to be approximately 420 cubic feet per second (cfs). The calculated peak flows conveyed by the Moat at this location are approximately 630cfs for the 2-year storm event and 1,460cfs for the 50-year storm event.

Photograph 20: Sample Photograph of Box Culverts

The widening of the Moat upstream and downstream of the proposed culverts was also proposed to accommodate the proposed width of the three box culverts. Due to the size of the culverts, the channel width will need to be approximately 35 feet wide and retaining walls will be required along both sides of the channel upstream and downstream of the culverts.

As shown in Table 33, flood reduction benefits from the proposed improvements associated with this alternative were noted mainly in the area within the southeastern corner of the Moat just upstream of Memorial Boulevard where decreases in water surface elevations ranging between 0.9 feet (for the 2-year storm) to 0.1 feet (for the 50-year storm) are expected. Although not as significant, reductions of approximately 0.2 feet (for the 2-year storm) to 0.0 feet (for the 50-year storm) are expected within the section of the Moat adjacent to Old Beach Road while decreases in water surface elevations ranging between 0.3 feet (for the 2-year storm) to 0.1 feet (for the 50-year storm) are expected in the southwestern portion of the Moat. Refer to Figure FLOOD LTA-3 for a depiction of improvements proposed under this alternative.

Table 33
Anticipated Changes in Water Surface Elevations
Resulting from Alternative 3 (Flood LTA-3) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta.77+82	Downstream of North Easton Pond Secondary Spillway	12.0 (-0.1)[b]	12.5 (-0.1)	12.6 (-0.2)	13.0 (+0.1)	13.1 (+0.1)
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	12.0 (-0.0)	12.5 (-0.1)	12.6 (-0.2)	13.0 (+0.1)	13.1 (+0.1)
Sta.39+28	Old Beach Road	9.6 (-0.2)	10.1 (-0.3)	10.4 (-0.1)	10.7 (-0.0)	10.9 (-0.0)
Sta.33+88	Southwest Corner of Moat at Intersection of Old Beach Road & Memorial Boulevard	9.3 (-0.3)	9.8 (-0.4)	10.1 (-0.1)	10.4 (-0.0)	10.5 (-0.1)
Sta.05+55	Upstream of Confluence with Easton Pond Spillway	7.4 (-0.9)	8.4 (-1.5)	9.0 (-0.4)	9.3 (-0.2)	9.4 (-0.1)
Sta.02+65	Immediately Upstream of Memorial Boulevard Culvert	6.9 (-0.7)	7.9 (-1.9)	8.6 (-0.4)	8.9 (-0.4)	8.5 (-0.6)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 3 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the computed change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $650,000.

However, the demolition of the existing culvert and the installation of the new culverts across Memorial Boulevard will require coordination with the appropriate utility companies. This cost may increase depending on the extent of utility work required. The installation of the culverts will also cause a disruption to Memorial Boulevard traffic during construction. Road or lane closures, coordinated with RIDOT, will be necessary.

Although reductions in water surface elevations were noted, flooding of Memorial Boulevard, Old Beach Road, and the residential neighborhood in the northern portion of the Moat will not be alleviated. This alternative has a low benefit to cost rating.

Flood LTA-4: Install a pump station within southern portion of moat (adjacent to Memorial Boulevard culvert) – The hydraulic capacity of the Moat channel is severely limited by the minimal slope of the Moat. The slope of the channel and width of the channel cross-section cannot be practicably increased due to the existence of an adjacent pond embankment and roadways. A stormwater pump station was considered for this alternative to quickly remove stormwater from the Moat and discharge to Easton Beach. Installing a pump station would also eliminate the need to replace or widen the existing Memorial Boulevard culvert. However, the use of pump stations are generally recommended only where other systems are not feasible because of high costs associated with construction, operation, and maintenance in addition to the potential problems.

Photograph 21: Sample Photograph of Pump Station

There are two types of pump stations: dry-pit or wet-pit. A wet-pit station was selected for this alternative since they are generally preferred by highway agencies, primarily due to lower station construction costs,. However, the selection of station and pump type is subjective and typically dependent on local preference and experience. The most common types of stormwater pumps are axial-flow (propeller), radial-flow (impeller) and mixed-flow (combination of the two). For this alternative, axial-flow pumps were selected (see Diagram 1). Axial-flow pumps are commonly used for low-head, high-discharge applications and are generally single-stage, vertical flow pumps.

Axial-flow pumps do not handle debris well because the propellers may bend or possibly break if they strike a relatively large, hard object. Using trash racks upstream of the wet well is required to prevent large objects from entering the system and possibly damaging pumps. Additionally, a sediment basin was incorporated into the design upstream of the pump station to capture suspended solids. This will reduce the wear on the pumps and limit deposits in the wet well.

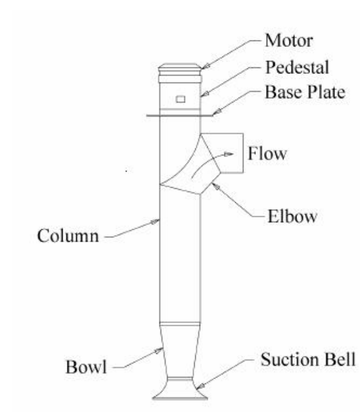


Diagram 1: Vertical, Axial-Flow

A minimum of three pumps is generally preferred; however, two pumps are the required minimum for a pump station. (The third pump is typically installed as a factor of safety should one pump fail.) This alternative includes two 42-inch axial flow pumps and an above-ground structure for the pumps, motors, and other equipment.

Through hydraulic analyses, we determined that the southwestern corner of the Moat was the most effective location to install a pump station. The southeastern corner of the Moat, immediately upstream of the Memorial Boulevard culvert, was also considered as a potential location for a pump station. However, more significant reductions in water surface elevations were noted along Memorial Boulevard and Old Beach Road with the pump station located in the southwestern corner of the Moat.

As shown in Table 34, flood reduction benefits from this alternative were mainly in the area adjacent to the southern portion of the Moat channel along Old Beach Road and Memorial Boulevard. Decreases in water surface elevations ranging between 0.7 feet (for the 2-year storm) to 0.2 feet (for the 50-year storm) are expected along Old Beach Road. Decreases in water surface elevations ranging between 1.2 feet (for the 2-year storm) to 0.3 feet (for the 50-year storm) are expected in the southwestern portion of the Moat along Memorial Boulevard. Refer to Figure FLOOD LTA-4 for a depiction of all other minor improvements proposed for this alternative.

Table 34
Anticipated Changes in Water Surface Elevations
Resulting from Alternative 4 (Flood LTA-4) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta. 77+82	Downstream of North Easton Pond Secondary Spillway	12.0 (-0.1)	12.5 (-0.1)	12.6 (-0.2)	12.9 (-0.0)	13.1 (+0.1)
Sta. 62+57	Downstream of 48" Culvert at Northwest Corner of Moat	11.9 (-0.1)	12.5 (-0.1)	12.6 (-0.2)	12.9 (-0.0)	13.1 (+0.1)
Sta. 39+28	Old Beach Road	9.1 (-0.7)	9.9 (-0.5)	10.2 (-0.3)	10.5 (-0.2)	10.7 (-0.2)
Sta. 33+88	Southwest Corner of Moat at Intersection of Old Beach Road & Memorial Boulevard	8.4 (-1.2)	9.6 (-0.6)	9.9 (-0.3)	10.1 (-0.3)	10.3 (-0.3)
Sta. 05+55	Upstream of Confluence with Easton Pond Spillway	7.6 (-0.7)	9.1 (-0.8)	9.2 (-0.2)	9.4 (-0.1)	9.6 (+0.1)
Sta. 02+65	Immediately Upstream of Memorial Boulevard Culvert	7.3 (-0.3)	8.8 (-1.0)	8.8 (-0.2)	8.5 (-0.8)	7.8 (-1.3)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 4 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the computed change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $6.5 Million.

The new pump station will require the installation of pump discharge pipes across Memorial Boulevard, which will require coordination with the appropriate utility companies. As a result, the cost may increase depending on the extent of utility work that will be required. The installation of the pump discharge pipes will also cause a disruption to Memorial Boulevard traffic during construction. Road or lane closures, coordinated with RIDOT, will be necessary.

The pump discharge pipes will need to outlet to an appropriate erosion control device. We have incorporated a riprap channel at the pipes 'outfalls to effectively and safely convey flow to the mean low tide elevation of Easton Beach. The channel should be located as far to the west as practicable; however, some loss of recreational area will be necessary.

Flooding of Memorial Boulevard, Old Beach Road, and the residential neighborhood in the northern portion of the Moat will not be alleviated by this alternative. Because of minimal reduction in flood elevations and the high costs, the pump station alternative has a low benefit to cost rating.

Flood LTA-5: Install three new 5-foot by 8-foot box culverts at the southwestern corner of moat (adjacent to Old Beach Road) – Based on the results of our hydraulic analysis, the existing Memorial Boulevard culvert is a hydraulic restriction during storms greater than the 2-year, 24-hour storm event and may contribute to roadway flooding. The installation of three new box culverts in the southwestern corner of the Moat would convey flow to Easton Beach upstream of the Memorial Boulevard culvert.

Flow within the Moat will need to be redirected to the proposed culverts by a diversion channel. The channel will need to be approximately 30 feet in width to accommodate the overall width of the three box culverts. Due to space constraints at the upstream end of the culverts, the channel may need to be lined on both sides with concrete walls.

As shown in Table 35 below, flood reduction associated with this alternative occurs primarily in the area adjacent to the southern portion of the Moat channel along Old Beach Road and Memorial Boulevard. Decreases in water surface elevations ranging between 1.1 feet (for the 2-year storm) to 0.2 feet (for the 50-year storm) are expected along Old Beach Road. Decreases in water surface elevations ranging between 2.6 feet (for the 2-year storm) to 0.4 feet (for the 50-year storm) are expected in the southwestern portion of the Moat along Memorial Boulevard. Decreases in water surface elevations ranging between 2.5 feet (for the 2-year storm) to 0.5 feet (for the 50-year storm) are expected in the southeastern portion of the Moat upstream of the Memorial Boulevard culvert. Refer to Figure FLOOD LTA-5 for a depiction of improvements proposed for this alternative.

Table 35
Anticipated Changes in Water Surface Elevations
Resulting from Alternative 5 (Flood LTA-5) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta. 77+82	Downstream of North Easton Pond Secondary Spillway	12.0 (-0.1)[b]	12.5 (-0.1)	12.6 (-0.2)	12.9 (-0.0)	13.1 (+0.1)
Sta. 62+57	Downstream of 48" Culvert at Northwest Corner of Moat	11.9 (-0.1)	12.5 (-0.1)	12.6 (-0.2)	12.9 (-0.0)	13.1 (+0.1)
Sta. 39+28	Old Beach Road	8.9 (-1.1)	9.5 (-0.9)	9.8 (-0.7)	10.2 (-0.5)	10.7 (-0.2)
Sta. 33+88	Southwest Corner of Moat at Intersection of Old Beach Road & Memorial Boulevard	7.0 (-2.6)	8.1 (-2.1)	8.8 (-1.4)	9.4 (-1.0)	10.1 (-0.4)
Sta. 05+55	Upstream of Confluence with Easton Pond Spillway	5.8 (-2.5)	6.2 (-3.7)	6.6 (-2.8)	7.8 (-1.7)	9.0 (-0.5)
Sta. 02+65	Immediately Upstream of Memorial Boulevard Culvert	4.7 (-2.9)	5.3 (-4.5)	5.9 (-3.1)	7.4 (-1.9)	8.9 (-0.2)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 5 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the computed change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $1.4 Million.

The installation of these culverts across Memorial Boulevard will require coordination with the appropriate utility companies, which may increase costs depending on the extent of utility work that will be required. The installation of the culverts will also cause a disruption to Memorial Boulevard traffic during construction. Road or lane closures, coordinated with RIDOT, will be necessary.

Flow conveyed by the box culverts will need to discharge to an appropriate erosion control device. We have incorporated a riprap channel at the culverts' outfalls to effectively and safely convey flow to the mean low tide elevation of Easton Beach. The channel should be located as far to the west as practicable; however, some loss of recreational area will be necessary.

Of the six long-term alternatives considered, this alternative appears to be the most effective solution to reduce flooding in the project area. Reductions in water surface elevations are not expected in the northern portion of the Moat; however, flooding along Memorial Boulevard will be alleviated. This alternative has a medium benefit to cost rating.

Flood LTA-6: Excavate and widen the Moat channel throughout its entire length and line the base of the channel with concrete – This alternative will eliminate areas of scour and improve the hydraulic capacity of the Moat. The proposed channel cross-section used in this analysis has a 10-foot bottom width, a 2-foot minimum depth, and 2:1 side slopes. The dimensions correspond to the average size and depth of the existing moat. Concrete has a low Manning's coefficient, approximately 0.013, and will improve the hydraulic efficiency of the channel. Since concrete linings should be placed on a well-consolidated subgrade, approximately two feet of material below the base of the channel must be excavated. Preparation should include filling all voids with suitable material, ensuring adequate compaction of the rest of the foundation by rolling, tamping or vibrating, and trimming the foundation to the correct shape.

Permanent turf reinforcement matting is proposed to protect the remainder of the channel's side slopes up to the point where the proposed grades match into existing grades. All slope areas that will be affected by construction, excluding the channel, will receive a layer of loam and be seeded with a native seed mix.

As shown in Table 36, flood reduction benefits associated with this alternative are mainly in the area adjacent to the northern portion of the Moat channel where decreases in water surface elevations range from an average of 1.3 feet (for the 2-year storm) to an average of 0.4 feet (for the 50-year storm). Refer to Figure FLOOD LTA-6 for a depiction of all improvements proposed for this alternative. Minor improvements such as the removal of the wall that bisects the Moat channel adjacent to the old filtration plant (Sta. 76+89) and the installation of cross-culverts at the access path adjacent to the old filtration plan (Sta. 77+65) are also proposed as part of this alternative.

Table 36:
Anticipated Changes in Water Surface Elevations
Resulting from Alternative 6 (Flood LTA-6) Improvements

Cross-Section Location	Cross-Section Description	Anticipated Water Surface Elevation (ft.)[a,c]				
		2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm
Sta. 77+82	Downstream of North Easton Pond Secondary Spillway	10.8 (-1.3)[b]	11.5 (-1.1)	11.9 (-0.9)	12.3 (-0.6)	12.6 (-0.4)
Sta. 62+57	Downstream of 48" Culvert at Northwest Corner of Moat	10.7 (-1.3)	11.3 (-1.3)	11.7 (-1.1)	12.3 (-0.6)	12.6 (-0.4)
Sta. 39+28	Station along Old Beach Rd	9.9 (+0.2)	10.1 (-0.3)	10.3 (-0.2)	10.5 (-0.2)	10.7 (-0.2)
Sta. 33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Int.	9.9 (+0.3)	9.9 (-0.3)	10.1 (-0.1)	10.3 (-0.1)	10.4 (-0.2)
Sta. 05+55	Upstream of Confluence with Easton Pond Spillway	9.5 (+1.2)	9.2 (-0.7)	9.2 (-0.2)	9.4 (-0.1)	9.2 (-0.3)
Sta. 02+65	Immediately Upstream of Memorial Boulevard Culvert	9.5 (+1.9)	9.1 (-0.7)	9.1 (+0.1)	9.3 (-0.0)	9.1 (-0.0)

a. Refer to Appendix F for complete list of computed water surface elevations at all cross-sections under Alternative 6 (including cross-section output and supporting documentation).
b. Values in parentheses indicate the computed change in elevation as a result of improvements.
c. All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

The opinion of cost for this alternative, including materials and installation, is approximately $3.7 Million.

The water surface elevations within the northern portion of the Moat would decrease to levels below the lowest flood elevations of three houses (103 Kay Boulevard, 312 Kay Boulevard, and 70 Ellery Road) for storm events up to and including the 10-year storm. However, the remaining three houses (129 Bliss Mine Road and 78 Ellery Road), Memorial Boulevard, and Old Beach Road would continue to be affected by flooding during storm events. Due to the relatively high cost associated with lining the channel with concrete, this alternative has a low benefit to cost rating.

6.2.4 Summary of Long-Term Flood Management Alternatives

The following table summarizes each alternative, the approximate cost of each alternative, the relative cost to benefit ratio of each alternative, and a list of potential implementation issues associated with each long-term alternative.

Table 37
Long-Term Flood Management Alternatives

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-1: Excavate existing channel bottom to provide a uniform channel slope in sections of the Moat that are adjacent to the identified areas of flooding.	• Minimal flood reduction benefits in areas adjacent to north portion of moat. • Decreases in water surface elevations of 0.2 feet or less would be expected within northern portion of moat during 2- and 5-year storm events only.	$1.4 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits will be needed from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-2: Excavate and widen the Moat channel throughout its entire length and line the base with riprap.	• Minimal flood reduction benefits in areas adjacent to northern portion of the Moat channel. • Decreases in water surface elevations of 0.3 feet, on average, would be expected for 2- thru 10-year storm events in northern portion of moat. • 2 of the 6 houses in this location houses will be above the flood damage elevation during 2- and 10-year storms. • Minimal to no reduction anticipated for storm events greater than the 10-year storm event in all flood-prone areas.	$2.5 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits will be needed from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-3: Replace existing Memorial Boulevard culvert with three 5-foot by 10-foot box culverts.	• Flood reduction benefits mainly noted within southeastern corner of moat just upstream of Memorial Boulevard. • Decreases in water surface elevations ranging between 0.9 feet (for 2-year storm) to 0.1 feet (for 50-year storm) would be expected in southeastern portion of moat.	$650,000	Low	• Improvements must occur during dry season and dry weather. • Dewatering will be necessary during construction. • Will require coordination with appropriate utility companies. • Demolition and construction work will cause a disruption to on Memorial Boulevard. • Permits will be needed from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-4: Install a pump station within southern portion of moat (adjacent to Memorial Boulevard culvert).	• Flood reduction benefits noted mainly in area adjacent to southern portion of moat channel along Memorial Boulevard and Old Beach Road. • Decreases in water surface elevations ranging between an average of 1.0 feet (for 2-year storm) to 0.3 feet (for 50-year storm) within section of moat adjacent to Old Beach Road and southwestern portion of moat. • Decreases in water surface elevations ranging between 0.7 feet (for 2-year storm) to 0.0 feet (for 50-year storm) in southeastern portion of moat.	$6.5 Million	Low	• Architectural and landscaping decisions will need to be made in regards to appearance of pump station. • Operation and maintenance of pump stations involves frequent inspection, monitoring, and maintenance. • Will require coordination with appropriate roadway utility companies in addition to cause a disruption to traffic. • Dewatering will be necessary during construction. • Permits will be needed from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-5: Install 3-5 x8 ' box culverts at southwestern corner of moat (adjacent to Old Beach Road)	• Flood reduction benefits adjacent to the southern portion of the Moat channel along Memorial Boulevard and Old Beach Road. Decreases in water surface elevations ranging between 10 inches (for the 2-year storm) to 2 inches (for the 50-year storm) expected within the section of the Moat adjacent to Old Beach Road. Decreases in water surface elevations ranging between 30.7 inches (for the 2-year storm) to 4.9 inches (for the 50-year storm) would be expected in the southwestern portion of the Moat. Decreases in water surface elevations ranging between 29.8 inches (for the 2-year storm) to 6.0 inches (for the 50-year storm) would be expected in the southeastern portion of the Moat.	$1.4 Million	Medium	• The channel width at the inlet of the culverts will need to be increased to 30 feet wide. Retaining walls may be required along both sides of the channel at the culverts. • Will require coordination with appropriate utility companies due to potential conflicts with roadway utilities. The installation of the culvert will cause a disruption to traffic as lane closures on Memorial Boulevard will be most likely be required. • Beach area in the western section of Easton Beach will be lost. • Permits will need to be obtained by RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-6: Provide uniform channel slope and cross-section throughout moat and line base of channel with concrete	• Flood reduction benefits in area adjacent to the northern portion of moat. • Decreases in water surface elevations ranging from an average of 1.8 feet (for the 2-year storm) to an average of 0.6 feet (for the 50-year storm) would be expected in the northern portion of the Moat. • 3 of the 6 houses in this location houses will be above the flood damage elevation for storm events up to and including the 10-year storm.	$3.7 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Cast-in-place concrete may be difficult to construct. Alternatives such as pre-cast channel sections or shotcrete may be more feasible. • Subdrains or intermittent weepholes may be required to minimize hydrostatic forces on the base and sides of the channel.

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
				• Permits will be needed from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Notes

a. The relative cost/benefit rating value is defined as follows:
High - Highest Benefit (In Terms of Flood Reduction) Relative to Costs Associated with Improvements
Medium - Average Benefit (In Terms of Flood Reduction) Relative to Costs Associated with Improvements
Low - Minimal Benefit (In Terms of Flood Reduction) Relative to Costs Associated with Improvements

6.2.5 Other Long-Term Alternatives Considered

The following alternatives were also considered in this study, but not modeled:

Flood LTA-7: <u>Floodproof the six residential homes within the residential neighborhood adjacent to the northern portion of the Moat –</u> As stated in the 1991 USDA Study, "floodproofing is the planning and installation of measures that are a combination of changes or the addition of features to individual buildings, structures, or properties to reduce or eliminate flooding." Various measures such as water stops or flood shields, elevating and/or enclosing appliances, bagging appliances, installing relief drains and sump pumps, sandbagging, levees, floodwalls, and the use of water tolerant construction materials were previously suggested. Since extensive and costly channel improvements would be required to alleviate the flooding of these homes during storm events, floodproofing these individual homes will be more cost-effective.

Flood LTA-8: <u>Reroute flow that is currently discharged to the Moat from the three 36-inch culverts and 48-inch culvert in the northwestern corner of the Moat directly to Easton Beach</u> – We determined through our hydraulic model sensitivity analysis that flows discharged to the Moat from the three 36-inch culverts and the 48-inch culvert did have a major effect on water surface elevations in the Moat during significant storm events. However, the slope of the proposed trunk drain that would be required to divert these flows to Easton Beach would be approximately 0.07%. Because of the relatively flat slope, the size of the pipe(s) required to safely convey flows to Easton Beach would be extremely large and would need to be installed within or parallel to Eustis Avenue and/or Old Beach Road. Since the elevation of the roadway increases in the direction of Easton Pond, excavation depths in excess of ten feet would be required to install trunk drain. The costs associated with this improvement would far exceed the anticipated benefits.

Flood LTA-10: <u>Eliminate the secondary/emergency spillway of North Easton Pond –</u> Flow discharged to the Moat from the secondary spillway does affect water surface elevations within the Moat, but the time at which peak flows are discharged from the secondary spillway far exceeds the time at which peak flows are discharged from the adjacent closed-conduit drainage systems. As a result, flow discharged to the Moat from the adjacent drainage systems was determined to have a greater effect on water surface elevations within the Moat than flow discharged from the secondary spillway.

Flood LTA-11: Do not attempt to alleviate flooding within flood-prone areas along the Moat – If no action is taken, flooding will continue to affect Ellery Road and the six residential houses along the northern section of the Moat, Old Beach Road, and Memorial Boulevard. The City would need to continue its normal maintenance of the Moat and surrounding drainage structures to ensure that flooding conditions do not worsen.

6.2.6 Summary

Several potential alternatives were identified and developed to reduce Moat flooding. However, none of the alternatives would have a significant affect on water surface profiles during flood events in the Moat. This is largely due to the fact of the limited capacity of the Moat itself and the lack of space and hydraulic slope available to significantly increase the capacity along the Moat. Even to provide localized improvements, significant investments would be required.

6.3 Water Quality Alternatives

A wide range of structural and nonstructural controls exist to address the wet-weather related bacteria loadings that may contribute to the closure of Easton Beach. A number of limitations exist which significantly constrain the set of controls that are practical for this watershed. Limitations include high groundwater, poor soils, large flows, and little space. Our analysis addresses these limitations.

We have organized the controls into both short- and long-term alternatives. The following paragraphs provide a detailed description of these alternatives. As part of our review of long-term alternatives, a discussion of available technologies is included as well as a detailed description of the alternatives that we think are viable for this watershed.

6.3.1 Short-Term Water Quality Alternatives

Several short-term alternatives are available to the City to reduce wet-weather bacteria loadings to the beach. They are nonstructural and should be able to be implemented immediately. Because short-term alternatives do not require new construction, they are less costly, do not require permitting, and will be relatively easy to implement.

The following paragraphs describe short-term alternatives that we anticipate will reduce bacteria loadings to the beach. However, with the amount of data that is available, it is not possible to quantify the actual reduction in bacteria loading. We have classified each alternative as having a "high" or "low" potential to reduce bacteria loadings. The alternative descriptions also include a discussion of how each alternative should be implemented and its anticipated cost.

WQ STA -1 Public Education – The public's behavior has a direct effect on water quality. For example, improperly managed pet waste will contribute significantly to water quality problems. During our fieldwork on Easton Pond Dam, we noted significant quantities of dog waste. We also witnessed dog walking at the beach, where droppings could easily wash into the beach water.

During field visits, we noted flocks of gulls and other birds in and around the beach. Bird waste is also a source of bacteria loadings. Feeding birds encourages them to congregate. Litter and open trash receptacles may also attract birds.

During a recent investigation of the City of Newport's storm sewer system, Earth Tech reported a large number of "mutt-mitts" disposed in the catch basins near the entrance to the Moat walking paths. Apparently, some dog walkers use the catch basins for pet waste disposal. These catch basins discharge to the Moat, which in turn outlets at Easton Beach. This is probably another significant source of bacteria loadings to the beach.

Public education and participation is a required element of the *General Permit for Rhode Island Pollution Elimination Discharge System Storm Water Discharge from Small Municipal Separate Storm Sewer Systems and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s* (Storm Water Phase II General Permit). Implementing a public education and outreach program will assist the City in meeting Storm Water Phase II requirements.

We recommend the following actions to encourage improved public stewardship:

- Distribute educational materials to the community–To assist with Phase II implementation, Rhode Island Department of Transportation (RIDOT), Rhode Island Department of Environmental Management (RIDEM) and the University of Rhode Island (URI) have teamed to develop a statewide public education and outreach program. The City is currently participating in development of the program and consider utilizing materials and approaches developed by that process.

- Use existing education materials–Many public outreach materials already exist. The City may wish to examine public education materials currently available from RIDEM and other agencies and to adapt them for local use. Materials should focus on actions that will reduce pathogenic inputs (e.g., pet waste, litter, and bird feeding). The City could distribute these materials with water bills or other planned mailings.

- Post prominent signage and messages–The City should also consider installing prominent signs, stencils and other forms of written messages to:

    - Encourage dog walkers to scoop dog droppings.
    - Discourage bird feeding.
    - Discourage littering and providing sources of food for birds.
    - Discourage improper waste disposal into catch basins, including stenciling.
    - Remind the public that an ordinance requires collection of dog wastes.

Stenciling in particular, seems to have a considerable affect on public behavior. Some commonly used stencils include:

- Don t dump! Drains to the Ocean.
- Please! Don't Pollute! Drains to Ocean.
- Dump no waste – Drains to Ocean.

This alternative has relatively high potential to reduce bacteria loadings compared to other short-term alternatives since the public s activities in this watershed have a direct impact on water quality at the beach. These activities are also required to comply with the RIDEM s general permit for storm water discharges.

The opinion of cost for this work is approximately $20,000.

WQ STA-2 Public Participation – Studies show that stewardship messages alter behavior most effectively when delivered by peers. Individuals who help to deliver these messages tend to internalize them, which also results in behavior change. Public participation (i.e., volunteerism) will encourage behavior that will lead to better water quality at the beach.

Currently, Clean Ocean Access organizes several beach clean-ups in Middletown and Newport. Clean Ocean Access is a very active community group that focuses on the overall quality of the beach as a resource. The City should considering coordinating with Clean Ocean Access and may wish to provide equipment and other assistance for beach cleanups.

One example of a public participation program is "Adopt-Your-Watershed," which was developed by the USEPA. This campaign encourages citizens and groups to work at protecting and restoring surface and groundwater quality in their watershed. The networking and training resources available from this program can help educators, communities, or private citizens improve water quality. RIDEM, RIDOT, and URI will be developing similar programs through the Storm Water Outreach Program, discussed in WQ STA 1 "Distribute educational materials to the community" (above). The City should consider these or similar public participation programs for Easton Beach.

The City should also solicit business owner involvement. Businesses tend to benefit from the aesthetics of a clean beach area and will likely share the City s interest in managing water quality. Some local businesses may consider adopting sections of the beaches to patrol and clean on a regular basis.

This alternative has a higher potential to reduce bacteria loadings compared to other short-term alternatives since the public s activities in this watershed have a direct affect on water quality at the beach. These activities are also required to comply with the RIDEM s Storm Water Phase II General Permit.

The opinion of cost for this work is approximately $10,000.

WQ STA-3 Waste Management at the Beach – Waste management practices at Easton Beach can be improved to reduce sources of bacteria there. We propose focusing on the two areas–solid waste management and wrack management. Our recommendations are as follows:

- Add trash cans with hoods–Add trash cans with hoods or some form of cover to prevent rain from entering and also to prevent birds from accessing the trash. Seagull waste contains concentrated levels of pathogens and can contribute significantly to water quality problems.

- Improve Wrack Management–Develop a regular schedule to remove wrack (i.e., piled-up seaweed) from the beach areas. During field visits we noted several large piles of seaweed at the east end of the beach, next to the Moat discharge. Any piles of wrack should be removed on a regular basis, ideally as it is raked. Various studies around New England have shown that piles of seaweed create a breeding ground for bacteria, which can get washed onto the beach and into the water when it rains.

  This alternative has a lower potential to reduce bacteria loadings. While these sources contribute bacteria, existing data implies that these sources are relatively small in comparison bacteria contributions from stormwater runoff. Nevertheless, they represent good management practices to minimize the overall loads.

  The opinion of cost for this work is approximately $20,000.

WQ STA-4 Illicit Discharge Detection and Elimination (IDDE) – Municipal storm sewer system discharges may include polluted non-storm water sources that can adversely affect water quality. Sanitary sewage, process wastewater, flows from floor drains and other wastewaters have been documented in storm sewer systems throughout the country. Water quality testing conducted last season showed indications of possible illicit discharges, which could contribute to higher bacteria levels, specifically with three outfalls S9, S10 and S11 that are owned either by RIDOT or the Town of Middletown. The locations of these outfalls are shown on Figure 4. During a field visit on March 21, 2007, a bright green substance was observed discharging from S10. This is a clear illicit discharge to the storm sewer system that needs to be investigated.

We understand that the City has already completed an IDDE program for the storm sewers that drain to Moat. This program did not find any illicit connections from those outfalls. Similarly, our monitoring program found no indication of illicit discharges in those outfalls.

This alternative has a higher potential to reduce bacteria loadings compared to other short term alternatives because illicit connections can contribute tremendous bacteria loads to the beach as well as other health impacts depending on what is actually being discharged. Both Middletown and RIDOT are required by the RIDEM Storm Water Phase II General Permit to complete IDDE inspections of their outfalls.

The opinion of cost for this work is approximately $30,000.

WQ STA-5 Wild Animal Management – Urban wildlife can contribute significantly to water quality problems. Animals of concern include birds, raccoons, and rodents.

- Raccoon Management–Raccoons have been found living in the storm drain system and should be removed. Raccoon waste can build up in the storm drainage systems and then be washed out in rain events, carrying bacteria with it. It is also possible that raccoons may die in storm drains during heavy rains. Degrading animal carcasses will contribute high levels of bacteria. Once raccoons are removed from the storm drains, structures can be installed at the ends of the outfall pipes to prevent raccoons from reentering. This does not require specific permitting.

- Water Fowl Management–The City should also consider developing a waterfowl management plan. During our field work, we have observed a significant number of birds on the Easton Beach parking lot. Birds may directly contribute sources of bacteria to an impervious surface that discharges to the beach without treatment. One method of deterring birds is stringing monofilament line from high points around parking areas. The actual reason that monofilament line repels birds is not clear; however, it has been speculated that because monofilament line seems to appear and disappear, birds are repelled by the uncertainty of whether a barrier exists. The monofilament line does not pose a physical barrier to the birds and the lines are spaced far enough apart that the birds could easily pass between strands. Other options also exist, but some field testing of options would be needed to determine effectiveness. Effectiveness of controls also varies between locations.

- Rodent Control–As recommended in the Section 6.1.1, a rodent control plan should be considered. During site visits, burrowing rodents were observed in the moat. The waste from animals such as muskrats, which spend most of their time in and around the moat, can be a significant source of bacteria.

This alternative has a high potential to reduce bacteria loadings. While these sources contribute bacteria, existing data implies that these sources are relatively small given the bacteria contributions from pet waste and storm water runoff in the watershed. Nevertheless, they represent good management practices to minimize the overall loads. Animal control along the moat and dam embankments would also be valuable in reducing the sloughing and weakening of that structure increasing its benefit as an alternative.

The opinion of cost for this work is approximately $55,000.

WQ STA-6 Restrict Public Access to Easton Pond Dam – The dam has been a recreational resource to Easton Beach neighborhood for decades, allowing people a quiet place to walk and jog. However, some of the people that access these trails are not good stewards and leave their pet wastes behind. As mentioned earlier, these activities appear to increase bacteria loads to both the beach and the public water supply.

Public access on this embankment has led to the creation of preferential flow paths leading to rilling and weakening of its structural integrity

At this time, we would recommend that the City implement other short-term alternatives including public education before implementing this alternative. However, if the other alternatives are not effective in reducing the amount of pet waste on the embankments, the City should consider restricting public access consistent with other public water supplies.

The opinion of cost for this work is approximately $17,500.

Table 38
Short-Term Water Quality Alternatives

WQ STA-1 Public Education				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Easy to implement • Relatively low cost • Also required to comply with RIDEM storm water general permit • Can also address other public environmental issues.	• None	$20,000	• Maybe difficult to quantify water quality benefits • Change in attitude/awareness does not necessarily result in behavior change	High
WQ STA-2 Public Participation				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Existing organizations such as Clean Ocean Access can provide an immediate start to a public participation program • Relatively low cost	• This alternative will require the City to participate with and track activities of these groups.	$10,000	• Maybe difficult to quantify water quality benefits	High

WQ STA-3 Beach Management				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Relatively low cost • No structural changes	• Additional regular work for City	$20,000	• None	Low

WQ STA-4 Illicit Discharge Detection and Elimination				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Useful information for the City to have	• Can be a high cost • May be some structural changes • Cooperation with DOT and Middletown may be difficult • May be a high cost without expected results	$30,000	• Requires coordination with state and other municipalities	High

WQ STA-5 Wild Animal Management				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Relatively low cost • No structural changes	• Public criticism • Permitting	$55,000	• Animal control strategies may raise special interest group concerns.	High

WQ STA-6 Restrict Public Access to Easton Pond Dam				
Advantages	Disadvantages	Opinion of Cost	Implementation Issues	Anticipated Effectiveness
• Relatively low cost • No structural changes	• Public criticism • Permitting	$17,500	• Animal control strategies may raise special interest group concerns.	High

6.3.2 Long-Term Water Quality Alternatives

The long-term alternatives proposed herein involve major capital improvements and construction. They will require significant permitting effort and will be more difficult to implement than the short-term alternatives. The long-term alternatives are also more directly focused on treatment of the stormwater that is discharged to the beach as opposed to source reduction.

This section first describes the general technologies that would have some potential to reduce bacteria loadings and then considers the feasibility of their implementation in the Easton Beach watershed. Feasible alternatives are then discussed in terms of size, location, cost and implementation issues.

Wherever possible, the alternatives proposed in this technical memorandum are based on descriptions, terminology and standards in the draft *Rhode Island Stormwater Design and Installation Standards Manual* (RIDEM, 2006). Some alternatives, such as disinfection, are not addressed in that manual. In these cases, we have employed manufactures 'design specifications and best available engineering standards.

6.3.2.1 Potential Technologies

There are several challenges in reducing bacteria loads in stormwater runoff that limit the effectiveness of structural controls. For example, bacteria in settling basins behave much like very small (colloidal) particles. As a result, conventional gravity separation (i.e., sedimentation), which is common in stormwater controls, is not effective for removing bacteria. Infiltration and filtration practices are better suited to this task, but they require more space. Additionally, while disinfection practices are very commonly used to reduce, or eliminate bacteria, in water or waste water treatment plants, stormwater treatment works differently because flows are highly variable and intermittent. Managing flows of this nature requires either very large systems or large areas where water can be stored.

In the Easton Beach watershed, there are a number of physical constraints that further limit the controls that are feasible. These physical constraints include the following:

- High groundwater exists in the area between the beach and South Easton Pond. Based on high tide elevations and grades, less than five feet of separation exists in this area, which includes the beach parking lot and Memorial Boulevard. This significantly limits the ability to infiltrate water in this location with subsurface structures, since a typical separation of three feet between the bottom of an infiltration device and high groundwater is recommended for bacteria removal. This small change in elevation also imposes a significant hydraulic limitation that limits feasibility of many alternatives.

- Poor soils exist in the upland areas of Newport that drain to this system. The soils in the Newport neighborhoods to the west of the Moat are classified as HSG C by the Soil Conservation Service. These soils are typically poor draining making infiltration in these areas infeasible. Alternatively, the soils at the beach drain well.

- Hydraulic loadings in this watershed are very large. The discharge from the Newport side of the moat is about 96 cubic feet per second for a 24-hour storm with 1.2 inches of precipitation.

The following paragraphs describe the technologies that were considered under this evaluation, and viability in the Easton Beach Watershed. The technologies that were considered have been grouped into filtration/infiltration technologies, disinfection and other technologies.

- Filtration/infiltration.[1]
  - Infiltration trenches.
  - Disconnected catch basins and proprietary infiltration units.
  - Sand filters.
  - Catch basins with sand filters.
  - Proprietary Filter Media (e.g., Smart Sponge™).
  - Bioretention.
- Disinfection.
  - Chlorination.
  - Ozonation.
  - Ultraviolet disinfection.
- Other Technologies.
  - Stormwater Wetlands.

Filtration/Infiltration

Both filtration and infiltration practices employ percolating runoff through a media, such as graded sand, in order to strain out particulates such as bacteria. Filtration best management practices discharge treated water through a subdrain to a surface discharge point. Infiltration practices discharge water through native soils to groundwater. Filtration and infiltration practices have been well documented as effective mechanisms for treatment of bacteria found in stormwater.

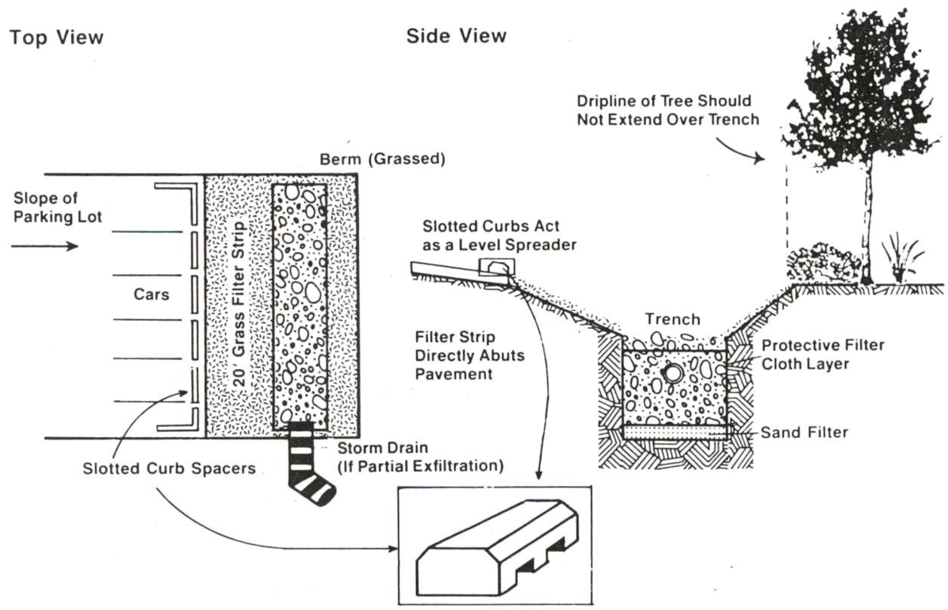
The capacities of filtration and infiltration practices are limited by their ability to drain water. The size of these structures is dependant on the hydraulic load they receive and the infiltration rate of the filtering media (i.e., sand or soil) and its surface area. We consider the following infiltration and filtration practices to be appropriate for the watershed of Easton Beach.

Infiltration Trenches

An infiltration trench (Diagram 2) is an excavated trench that has been back-filled with stone to form a subsurface collection area. Stormwater runoff is diverted into the trench where it is detained until it can be infiltrated into the soil. Infiltration trenches are very adaptable and the availability of many practical configurations makes them ideal for small urban drainage areas.

[1] Filtration and infiltration alternatives are generally considered to be different categories of alternative; however, this memorandum groups them together as they use the same basic pollution removal mechanism (i.e., filtering) and may be converted (i.e., infiltration to filtration or filtration to infiltration) with the addition or deletion of an underdrain system.

Diagram 2
Infiltration Trench



Source: Adapted from Scheuler, 1987.

Advantages

- Particularly appropriate for application around the perimeter of parking lots or in parking lot islands.
- Are unobtrusive and have little adverse affect on site aesthetics.
- Significant bacteria removal efficiency.
- Very simple technology and easy to construct.
- Little maintenance is required.

Limitations

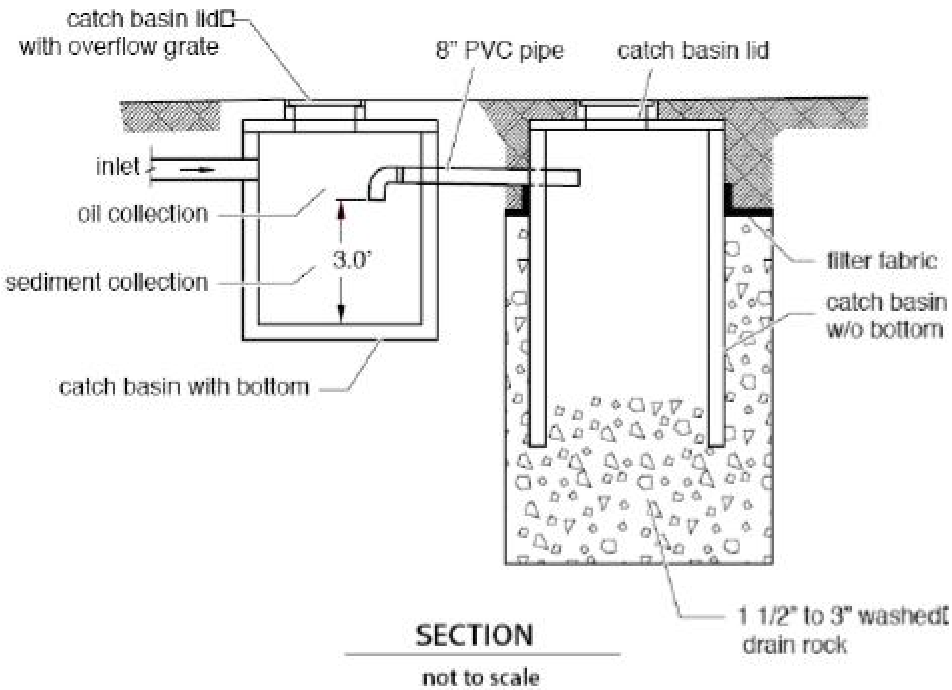
- Inappropriate for tight soils and soils with high ground water (i.e., Hydrologic Soil Groups C and D).
- Most appropriate for relatively flat slopes.
- Most appropriate for small drainage areas (i.e., 10 acres or less).
- Difficult to restore function after clogging occurs.

This technology would be applicable to the beach parking lot and Memorial Boulevard areas where there are sandy, flat, well-drained soils and we selected it to be further developed into a long-term alternative.

Disconnected Catch Basins

Conventionally, storm sewer networks employ catch basins to collect surface water runoff, skim floatables and settle larger sediment particles such as road sand, and convey runoff to drain pipes. Disconnected catch basins perform all these functions except that they do not connect to a pipe network and instead, infiltrate collected runoff through galleys, flow diffusers or proprietary infiltration units (e.g., Cultec, Stormceptor, Infiltrator, etc.). Disconnected catch basins are commonly sized to capture the water quality volume. When runoff exceeds the volume of disconnected catch basins, flows simply bypass treatment. Disconnected catch basins may also be designed as off-line alternatives.

Diagram 3
Disconnected Catch Basin



Source: Adapted From Atlanta Regional Commission, 2001

Advantages

- Require little space.
- Have been very effective in reducing bacteria loads.

Limitations

- Inappropriate for tight soils and soils with high groundwater (i.e., Hydrologic Soil Group Type C and D).
- Difficult to restore function if clogging occurs.
- These systems typically require 3 feet of depth to groundwater to meet regulatory requirements which may be difficult to attain due to their profile.

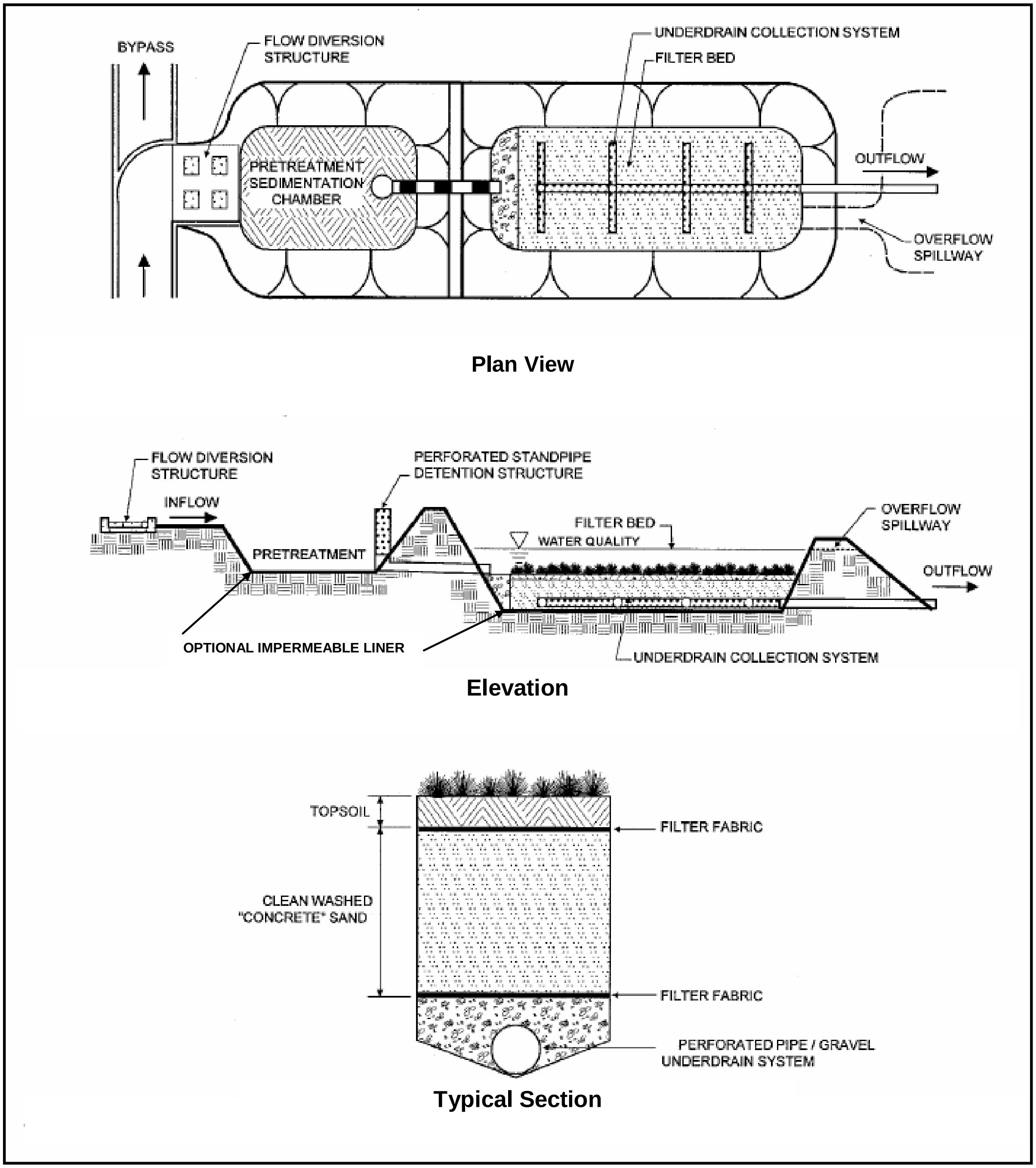
Given soil types and depth to groundwater, this technology is not appropriate for this watershed. While well-drained soils exist near the beach, groundwater is too close to the surface for this practice to function properly.

Sand Filters

Sand filters employ of an engineered filter media (e.g., sand) for pollutant removal. Sand filters may be constructed at grade or subsurface. Sand filters are usually designed as off-line systems with a bypass for flows larger than WQV. In the storm drainage network, the water quality volume is diverted into a pretreatment settling chamber or forebay where coarse solids are allowed to settle. This reduces the amount of sediment that reaches the filter and improves filter efficiency. Water flows to the filter surface, where finer sediment and attached pollutants are trapped or strained out; and breakdown, and conversion of pollutants such as nitrogen may occur. A subdrain collects the effluent and discharges it to the conveyance system.

Sand filters are most commonly used to treat runoff from small drainage areas; however, they can be adapted for use in larger drainage areas. Some typical applications include parking lots and small developments, areas with high pollution potential such as industrial sites, and highly urbanized areas where space is limited. A number of surface and underground stormwater filter design variations have been developed for these types of applications. Underground filters can be placed under parking lots or roadways and are well suited to highly urbanized areas or space-limited sites since they do not consume much surface area.

Diagram 4
Earthen Surface Sand Filter



Source: Adapted from Center for Watershed Protection, 2000.

Advantages

- Applicable to use under roadways and parking lots.
- Highly effective for a wide range of pollutants found in urban runoff including pathogens and TSS.
- May be installed subsurface and, therefore, can work where there are significant site constraints.

Limitations

- Pretreatment is generally required to prevent sand media from clogging.
- Frequent maintenance is required— generally, twice a year. Maintenance costs tend to be higher than other filtration/infiltration management practices.

This technology would be applicable to the Newport neighborhoods to the west of the moat where infiltration is impractical. This technology could also work to treat runoff from the beach parking lot where enough vertical space between the parking lot and high tide may exist. As a result, it was selected to be further developed into a long-term alternative.

Proprietary Filter Media (e.g., Smart Sponge™)

Filter media is a relatively new form of treatment for pathogen removal in stormwater. This practice employs materials such as polymer that are coated with an antibacterial liquid. At the microscopic level, the media resembles a layer of stiff fibers extending outward in all directions. These fibers carry a slight electrical charge. As the stormwater passes through the foam and the bacteria come into contact with the stiff fibers, the fibers puncture the cell membrane and an electrical charge shocks the cell.

Filter media is placed in catch basin inserts that are attached to its frame under the grate. These inserts can be placed in any catch basin.

Advantages

- Can be inserted into a catch basin over a large area or a small area to targeted known areas from which high bacteria loads emanate.
- Relatively inexpensive.
- Not a major infrastructure change.

Limitations

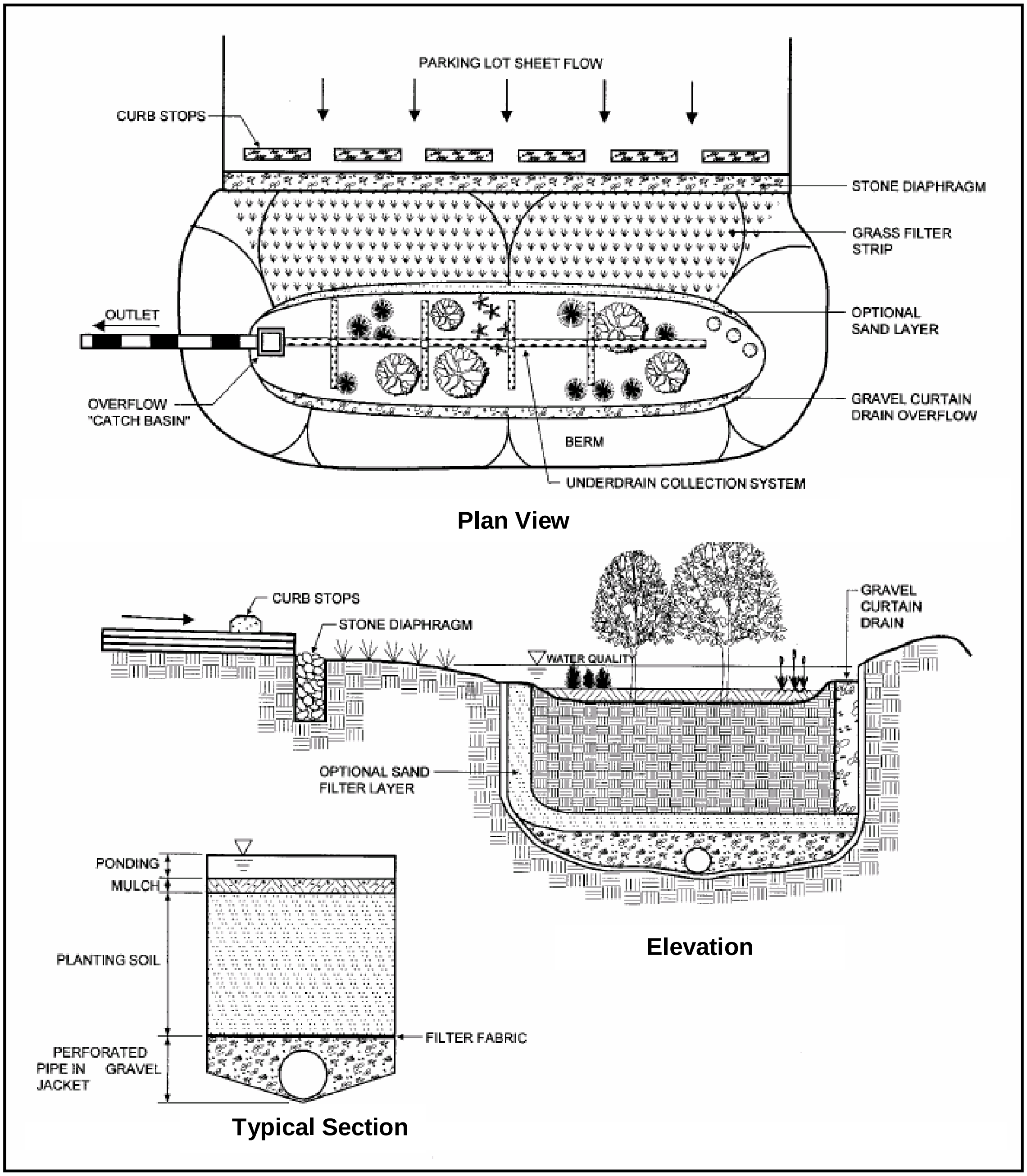
- New technology, little data on effectiveness.
- Needs semi-annual maintenance and replacement at 18 months.
- May change the hydraulics of catch basins and other stormwater infrastructure.

Bioretention

A bioretention system consists of a soil bed planted with native vegetation located above a sand layer that can be subdrained if the native soil is unable to accept effluent. . Bioretention may be designed in two forms–infiltrating and exfiltrating. Infiltrating bioretention systems discharge to in-situ soils. Where soil discharge is inappropriate, a subdrain may be employed. Subdrained bioretention is referred to as exfiltrating. Due to the nature of the soils in the Easton Beach watershed, we anticipate that any proposed bioretention system will be subdrained. Diagram 5 depicts an exfiltrating bioretention system.

Bioretention systems are used to remove a wide range of pollutants, such as suspended solids, nutrients (including nitrogen), and bacteria from stormwater runoff. Bioretention can also be used to provide a reduction in peak runoff rates. Like sand filters, bioretention systems are most commonly used to treat runoff from small drainage areas, but can be adapted for use in larger drainage areas. Bioretention systems can be designed to receive and treat runoff from a variety land uses. The systems can be installed in virtually any open area including parks, lawns, median strips, parking lot islands, unused lot areas, and easements.

Diagram 5
Bioretention



Source: Adapted from Center for Watershed Protection, 2000.

Advantages

- Very high solids, nutrient, metals, and bacteria removal efficiency.
- Applicable for use in open spaces, such as parks.
- Can be planted with various types of vegetation to maintain the existing open space use and aesthetics.

Limitations

- Some studies indicate bioretention to be less effective during the winter months due to freezing of the filter bed.
- More expensive to construct than other filtration/infiltration management practices.

Exfiltrating bioretention would be applicable to the Newport neighborhoods to the west of the moat where infiltration is impractical. Braga Memorial Field is a large open area that has good potential for installation of a bioretention system. As a result, we selected biorentention to be further developed into a long-term alternative.

Disinfection

The process of disinfection refers to the elimination of pathogens, either by killing or disabling of their infectious mechanisms. Disinfection may include chemical methods, physical methods, and irradiation (e.g., exposure to certain frequencies of ultraviolet light). Some disinfection methods have been proven practical (i.e., safe and effective) for stormwater management at sites such as Easton Beach. In this report, we analyze three options that have some potential:

- Chlorination
- Ozonation
- Ultraviolet disinfection

Chlorination

Chlorine treatment is commonly used as the final process of treating drinking water. It is also used to treat wastewater effluent, and combined sewer overflows (CSOs). It can be applied in either a gaseous form or as a solid. The gas can present a significant safety hazard and is highly corrosive.

Chlorine disinfection is heavily dependant on the contact time between the chlorine and pathogens. Because suspended solids can inhibit the chlorine from reacting with the bacteria, disinfection is usually used in conjunction with an additional technology that specifically reduces the suspended solids. Potential pre-treatment could consist of a hydrodynamic separator or a constructed wetland in the moat area to offer TSS removal.

When chlorine is added to the stormwater, it forms a residual, which remains in the water after the initial application. In some cases, it is necessary to remove the chlorine. This process is called dechlorination. Dechlorination may be needed to protect sensitive receptors from the corrosive and harmful effects of chlorine exposure.

Advantages

- Can remove pathogens to very low levels.
- A chlorine treatment unit, for the entire watershed, could be housed at a single location.

Limitations

- Requires pretreatment to remove TSS.

- Requires a separate system to manage peak flows.
- Expensive to construct.
- Halogenated organics, which are toxic, may be a byproduct of the chlorination process
- May require dechlorination to protect sensitive ecologies.
- Chlorine is toxic and may be hazardous to humans and the environment if managed improperly.
- May be difficult to permit in a system such as the Moat that is regulated as a natural system.

This technology was not considered further, because it poses a significant risk and may be difficult to permit. It is also expensive compared to other disinfection technology.

Ozonation

Ozone is a strong oxidizer and is commonly used to treat bacteria in wastewater. Its use for disinfection of stormwater is relatively new in the United States, and there are few facilities currently using ozone for disinfection. As a disinfectant, ozone is as effective or superior to chlorine and it does not cause the formation of halogenated organics, which may be carcinogenic or otherwise toxic.

Because ozone must be generated on-site, and the amount generated is dependent on demand, ozone is not currently considered practical for intermittent use (i.e., in situations where the system would be frequently turned on and off or where there are wide fluctuations in flow rate and disinfection demand, such as in stormwater treatment applications).

Advantages

- Ozone is generated on site and does not have to be stored.
- Low doses are required to complete disinfection.
- Treatment unit needs a relatively small footprint.
- Does not require pre-treatment to remove TSS.

Limitations

- Requires a separate system to manage peak flows.
- Requires pretreatment to remove TSS.
- Very expensive to construct.
- Ozone escaping to the atmosphere may contribute to air pollution problems.
- Requires a start-up period to treat pollutants effectively; therefore, a detention area will be required to hold polluted runoff while the system activates.

This technology was not considered further because of its cost. Also, feasibility appears to be limited by required start-up periods.

Ultraviolet Light

UV disinfection works by exposing pathogens to UV light for a period of time in a detention area. The UV light penetrates the cell walls of pathogenic organisms and structurally alters their

DNA, preventing the cells from reproducing, or functioning (e.g., infecting other organisms). No hazardous chemicals are produced or released while treating stormwater with UV.

UV is not a chemical disinfection method, it disinfects without altering the physical or chemical properties of water. However, like chlorination, UV efficiency is affected by suspended solids in the wastewater, which can block the light from being absorbed by the pathogens. Thus, UV disinfection needs some level of pretreatment in order to be more effective. Potential pretreatment could consist of a constructed wetland in the moat area to offer TSS removal.

Advantages

- Does not alter the physical or chemical properties of the stormwater.
- Capable of providing pathogen treatment to very low levels.
- Once constructed, a UV treatment facility can treat all stormwater at a single site.

Limitations

- Requires a bypass system to manage high flows.
- Expensive to construct.

This technology has potential to be applied near the Moat outfall, upstream of the Memorial Boulevard crossing. It presents excellent economies of scale and will likely be cost effective for treating stormwater flows observed near the discharge of the moat. As a result, this technology was further developed into a long-term alternative.

Other Technologies

Constructed Wetlands

Constructed wetlands have long been used in the final treatment of municipal wastewater and in the last decade have been used increasingly for treating stormwater. Wetlands remove pollutants through sedimentation, plant uptake, microbial decomposition, sorption, filtration, and exchange capacity.

Constructed wetlands incorporate the natural functions of wetlands to aid in pollutant removal from stormwater. In part, constructed wetlands work by retaining stormwater in a vegetated "permanent" pool where particulates settle between storms, and plants uptake pollutants. Water is displaced from the permanent pool by incoming runoff during storm events. The newly entering runoff is stored in the wetland until the next storm. This dynamic creates long detention times and high treatment effectiveness. Constructed stormwater wetlands may provide some of the ecological functions of natural wetlands as well.

A constructed wetland (Diagram 6) consists of a soil bed planted with native vegetation located above liner or suitable soils. Constructed wetlands are especially appropriate where groundwater levels are close to the surface, as groundwater can supply the necessary water required for sustaining the wetland system during dry periods (e.g., July and August).

We have examined the potential use of these controls and have determined that they are not feasible for several reasons some of which are described in the study. The following summarizes some of these reasons.

- A constructed wetland system sized to treat the Water Quality Volume (runoff generated from 1.2" of precipitation) from the Moat would need to be more than 10 acres in size. This is a large area of land and there is no space available outside of the ponds available to construct this.

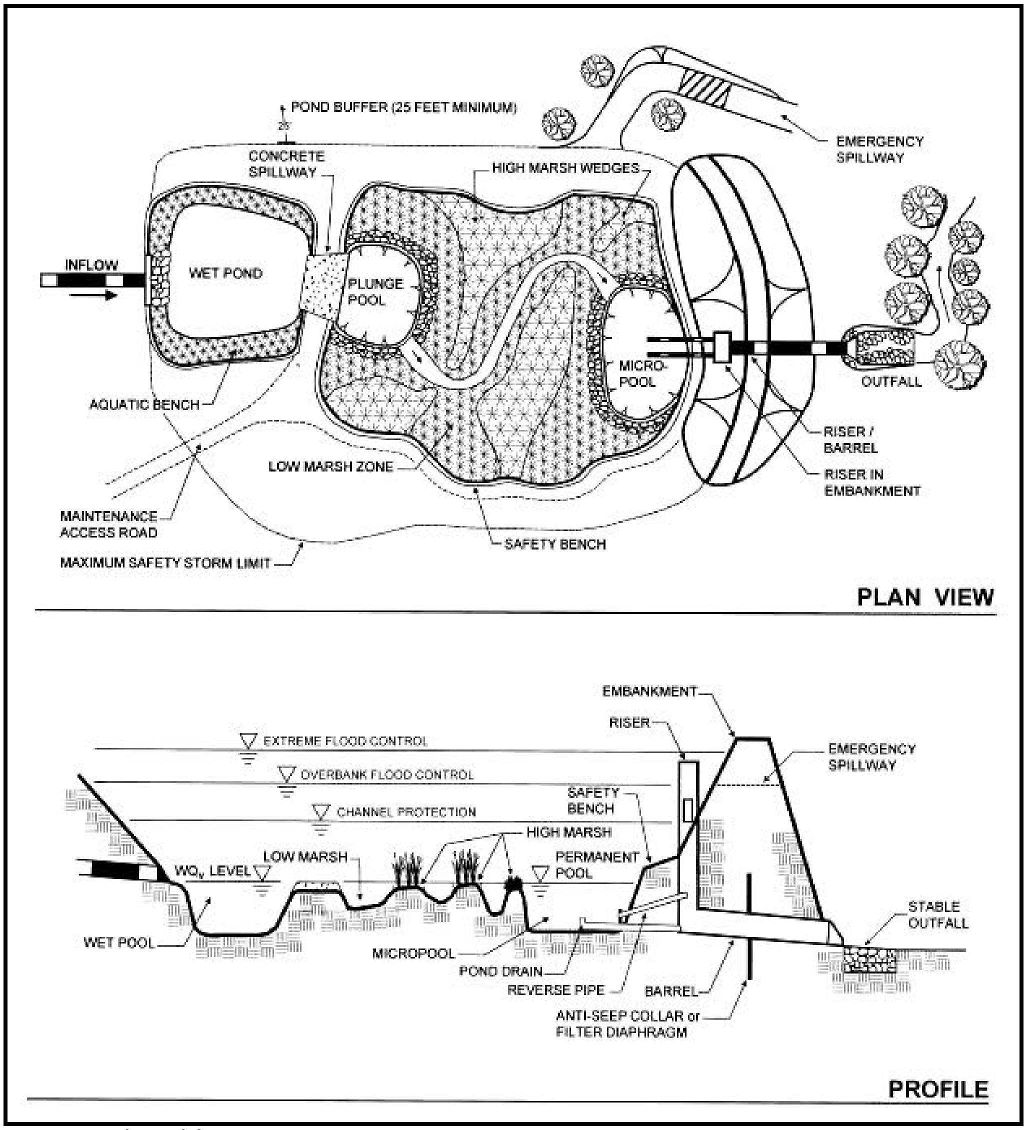
- From discussions with CRMC, the ponds are regulated as Type 1 waters. As a result, "filling" these waters for the construction of storm water controls will be difficult if not impossible. Relocating the embankment of the pond to would also reduce the reservoir system's capacity and ultimately its yield capacity. While relocation of the embankment is recommended in the report for dam repair, the embankment relocation for dam repair would be less extensive than would be required for a constructed wetland.

- Constructed wetlands discharge pollutants at certain irreducible levels. Pathogens are noted to discharge at levels up to ten times greater than water quality standards for recreational waters. As a result, it cannot provide the same level of reliability that alternatives, such as UV disinfection can provide.

- Using a detention basin or constructed wetland to temporarily store water such that it could be pumped into the ponds would also not be recommended. If the water is not acceptable for swimming, we cannot recommend that it be introduced into a public water supply.

Therefore, constructed wetlands are not recommended as stand-alone treatment systems at Easton Beach. Notwithstanding this concern, constructed wetlands do provide an excellent pretreatment option preceding disinfection.

Diagram 6
Constructed Wetland System



Source: Adapted from NYDEC, 2001

Advantages

- Sedimentation of particulate pollutants.
- Enhancement of vegetation diversity and some wildlife habitat.
- Can provide significant water quality improvement across a broad spectrum of constituents.

Limitations

- Expensive to construct.
- Very difficult to permit in-situ.
- May not achieve desired bacteria reductions.
- Hydraulics will be very difficult to work given the lack of elevation and slope near the end of the Moat.

- Typically requires a large contributing drainage to ensure maintenance of the permanent pool and aquatic vegetation during dry periods of the year.
- Not effective for pathogen treatment to limits of beach standards.

6.3.2.2 Recommended Long-Term Alternatives

The following paragraphs outline our recommendations for use of long-term water quality alternatives in the Easton Beach watershed with the objective of reducing bacteria loadings. The evaluation of alternatives summarized herein is based on limited information. As such, some modifications in layouts, designs, and costs should be expected as the City moves to completing final design. Pilot testing is also recommended for alternatives before full-scale implementation to better understand treatment efficiency, maintenance needs, and sizing. In order to account for the uncertainty inherent at this stage of the project, opinions-of-construction costs include a 50% contingency.

All of the controls described herein have been sized to manage the water quality volume as defined in the *Rhode Island Storm Water Design and Installation Standards Manual*; that is, the first inch of runoff from impervious surfaces. This is equivalent to the volume of runoff generated from impervious surfaces during a 1.2-inch rain event. For the purposes of determining the total hydraulic loads to these controls, a 1.2 inch storm was applied across both pervious and impervious portions of the watershed.

The following paragraphs describe specific applications, implementation issues, design issues, and costs. The long-term alternatives have been organized based on the area that they would be designed to manage. Following the descriptions of each specific application, we summarize alternatives in Table 39, which provides size of subwatershed treated, water quality volume treated, treatment alternative footprint, and cost of alternative in 2007 dollars.

Easton Beach Parking Lots and Memorial Boulevard

The Easton Beach and Memorial Boulevard area is largely underlain by well-drained sands. As a result, we have recommended several alternatives for this area that rely on infiltration technologies to take advantage of these soils. A sand filter has also been proposed as an alternative to the infiltration practices for the east parking lot where existing elevations would likely provide adequate change in elevation to allow this technology to work.

This area manages a relatively small percentage of the total WQV that is discharged to the beach. The east parking lot discharges about 15,000 cubic feet of runoff the west parking lot discharges 9,000 cubic feet and Memorial Boulevard discharges about 16,000 cubic feet during a WQV event. This is compared to a WQV of 745,000 cubic feet that is discharged by the Moat. While this area is a relatively small contributor, it is still a potential source of bacteria immediately adjacent to the beach. These controls should be considered as follow-up actions following implementation of the larger scale controls that follow.

Lastly, controls are not contained herein for the pavilion area as that area drains through weep holes into the sand. Based on our visual observations, there is an adequate separation to groundwater above the weeps to control bacteria from the parking areas. However, any of the controls proposed for the parking lot could also be implemented in the pavilion area.

The following design considerations were used to size and locate the infiltration alternatives:

- The locations of the infiltration surfaces are based on the existing low areas and grading of the parking lots and road. Since regrading the parking lots and road represents a significant cost, we located the infiltration systems in existing low areas. The locations are shown in Figures WQV LTA-1 through 3.

- In the parking lot, the proposed trenches will be located in the existing low spots, between the catch basins. Under this alternative, the catch basins and an 8-foot wide section of pavement around each catch basin will remain in place. Concrete curb will be installed between the asphalt cut and the infiltration trench to provide the grade transition. Once the trench storage area is filled, runoff in excess of the WQV will bypass into the catch basins and be conveyed using the existing conveyance system.

- Field measurements will be required to determine the actual infiltration rate of in-situ soils. If the infiltration rate is less than 7 feet per day, the footprint or storage depth may need to be increased. For purposes of our analysis, we assumed an infiltration rate of seven feet per day, which is the maximum allowable rate according to the *Rhode Island Stormwater Design and Installation Standards Manual*. We assumed that the soil will be amended to reduce the infiltration rate to seven feet per day if the native soil has a higher infiltration rate.

- The proposed trenches were sized to handle beach sand sedimentation without lessening the effectiveness of the trenches in treating the WQV for bacteria. Over time, as the trenches become filled with sand, the ability of the runoff to be stored in the trench storage area will be constrained by the infiltration rate of the sand, in which case, the runoff will pond in the parking lot above the trench.

- Pretreatment for floatables, such as oil and grease, is not included in our design. While infiltration provides some removal of these pollutants, direct infiltration does create a conduit for pollutants to enter and contaminate groundwater.

- Depth to groundwater is not definitively known. If groundwater is within 3.25 feet of the surface, infiltration may become infeasible. The trenches we propose are designed with the infiltration surface at three inches below ground surface. Three feet of separation between the infiltration surface and the seasonally high groundwater table is typically required by state regulation.

- Sand tends to accumulate at vertical surfaces, such as at retaining walls or curbs. To increase sediment-removal maintenance interval, a curb with curb-cut inlets could be installed along trenches that are located at the edge of the parking lots; however, this would reduce the size of the parking lot and may, where the trenches are wider, reduce the number of parking spaces.

- Maintenance for the infiltration systems will include the following:

- Remove sediment from infiltration surfaces when sediment accumulation has reduced the available storage area or restricted overflow devices.

- Till or add gravel as necessary to maintain the proposed slopes. As use in the parking lot increases, settling may occur over time.

- Replant and mow vegetation for infiltration swales and adjacent vegetated slopes.

- Sweep parking lots and roads.

WQ LTA-1 Trenches for the East Beach Parking Lot –For the east beach parking lot, we propose installing three infiltration trenches along the length of the lot to treat its runoff. Figure WQV LTA-1 presents a detail of the infiltration trench as well as the trench layouts and contributing areas.

Infiltration trenches are proposed as exposed trenches that would bare vehicular traffic as well as collect and directly infiltrate runoff that sheet flows into from adjacent paved surfaces. The trenches we propose include the following design features:

- Six inches of crushed stone surrounded on the sides and bottom by six inches of amended soil (i.e., soil altered for use in infiltration) with geotextile surrounding the amendment soil. The amended soil is required to enhance the treatment of soils that are too well-drained.

- The surface of the trench will be three inches lower than the surrounding paved area. This three-inch depth above the trench will serve as storage for stormwater before it infiltrates through the trench. As a result, during large storm events there may be standing water in the trenches.

- Where the trenches meet asphalt surfaces, a one-foot wide concrete transition curb sloped to match grades will be required.

- Normally, infiltration trench design assumes that both the sides and the bottom can accept infiltrate; and that incoming water may be stored in the void above the infiltrating surface. We assumed the infiltration surface was at the top of the trench, and storage was only above the top of the infiltration surface to account for the fact that wind-blown beach sand will clog the pore spaces of the crushed stone.

We propose using infiltration trenches in three of the east parking lot areas:

East Beach Area A

Area A is the western most portion of the parking lot, north of the building area. In this area, we propose an 8-foot by 220-foot trench located in between the catch basins.

East Beach Area B
Area B makes up most of the remaining parking lot area. We propose a 15.5-foot by 645-foot trench located in between the catch basins. In Areas A and B, we propose installing trenches around the existing catch basins, which would remain to convey runoff volumes greater than the WQV.

East Beach Area C
Area C is a 20-foot wide strip along the southern edge of the parking lot. We propose a 1.5-foot by 845-foot trench. In this area, the trench would be installed along the edge of the parking lot.

The opinion of cost for this work is approximately $199,000.

WQ-LTA-2 Trenches for the West Beach Parking Lot – The west beach parking lot does not have catch basins. Our observations indicate that runoff flows overland toward the north and south edges of the parking lot where openings in the concrete walls that surround the lot allow runoff to flow to the beach (to the south) or road (to the north). The trenches would be designed as described WQ-LTA-1. For the west parking lot, we propose two infiltration trenches as follows:

West Beach Area A
Area A consists of a 20-foot wide section along the northern edge. The trench for this area is located between Memorial Boulevard and the parking lot, at the same elevation as the road, so that flow from Memorial Boulevard could also be directed to the trench (resized to handle additional flow from Memorial Boulevard, this trench would be 6 feet by 590 feet). We also consider this part of the road area as part of LTA-3.

West Beach Area B
The main trench would treat Area B (as shown on Figure WQV LTA-2) and would be located along the southern edge of the parking lot. This trench would need to be 11 feet wide by 480 feet long.

The opinion of cost for this work is approximately $132,000.

WQ LTA-3 Swales and Trenches at Memorial Boulevard – In order to manage runoff from the portion of Memorial Boulevard between Easton Pond and Easton Beach, we propose a combination of trenches and, swales. This alternative consists of utilizing low impact design techniques that are commonly used on site. That is, these controls will consist of allowing runoff to sheet flow from the road to be infiltrated into the ground either through vegetated swales (bioretention) or infiltration trenches.

We divided the subwatershed into three smaller areas, which consist of the south-side eastbound lane (Area A), the north-side east bound lane (Area B), and the westbound lanes (Area C). The eastbound lanes are crowned in the middle, directing flow to both sides. The westbound lanes are sloped down toward the north side of the road. Therefore, we made the following general assumptions:

- 25 percent of the WQV is generated from Area A.
- 25 percent of the WQV is generated from Area B.
- 50 percent of the WQV is generated from Area C.

Figure WQ LTA-3 shows the subwatershed boundary and general layout of the proposed controls. These controls include:

Memorial Boulevard Area A (Eastbound Lane— South Side)
Area A drains to the south side of Memorial Boulevard, which, beyond the curb, consists of a concrete sidewalk that extends to the parking lot retaining walls. On this side, we propose installation of curb inlets at regular intervals between catch basins to direct the flow to an infiltration trench. The trench would have dimensions of 1.5 feet wide by 2,900 feet long to manage the WQV from this area. The trench would be approximately one foot lower than the top of the road curb and the sidewalk. The existing catch basins in the road would remain in place to manage larger storms.

To match grades between the trench and sidewalk, we include a grass slope. To properly size and install the trench and grass slope, approximately 5 feet of the sidewalk would need to be converted to the trench and slope. Based on visual observation, this would appear to leave approximately half of the existing sidewalk. Alternatively, the sidewalk could be replaced and lowered, which would decrease the amount of sidewalk lost to between 1.5 and 2 feet. However, there would be an additional cost to replace the sidewalk that has not been included.

Memorial Boulevard Area B (Eastbound Lane— North Side)
Area B drains to catch basins on the north side of the road. The ground surface north of the curb consists of a median between the eastbound and westbound lanes. Curb inlets would be installed at regular intervals on the south side of the median, and the median would be converted to an infiltration swale. The infiltration swale would function like an infiltration trench, but would consist of seeded topsoil instead of gravel. The storage area would still be above the ground surface but would only be one inch deep (instead of three inches as allowed for the trenches). To construct the swale, the ground surface of the median would be lowered to allow for a storage depth of 1 inch across the median. The surface would be vegetated. The area of the required swale in the median is 30,140 square feet. The depth of the swale can be increased to decrease the size of the swale surface area.

Memorial Boulevard Area C (Westbound Lane)
Area C drains to catch basins on the north side of the road. Beyond the curb is a grassed area, which separates the road from the Moat. In this area, either trenches, swales or a combination of both could be used. We used trenches to size this alternative. Trenches can be designed with greater storage depth than

swales; and have the capacity to treat a greater volume of water in a given footprint.

We sized the infiltration trench to be 2.5 feet by 2,900 feet. To construct this alternative, the ground surface north of the curb will need to be regarded and curb inlets will need to be installed at regular intervals. Our proposed regrading accounts for lowering the infiltration surface directly adjacent to the curb by about one foot and then sloping the ground surface beyond the trench back to the existing grade. The majority of the grassed area between the road and the Moat in this area is wider than 10 feet, which appears to provide enough space to construct the trenches in most cases. However, there is a 600-foot portion of the 2,900-foot length that appears to be less than 10 feet wide. Existing grades may make construction of trenches infeasible in this area.

The opinion of cost for this work is approximately $422,000.

WQ LTA-4 Sand Filter for the East Beach Parking Lot Area B

A sand filter consists of a structure which contains energy dissipaters, a sedimentation chamber, a filtration basin, and an underdrain discharge. The sand filter would be open-topped to allow for maintenance and inspection.

We propose a sand filter to treat Area B of the east beach parking lot (refer to WQ LTA-1 for a description of Area B). Our design includes a trench drain to convey flow to the sand filter installed at the east end of the parking lot. We also propose the removal of the catch basins in the parking lot. Our design allows for storms larger than the WQV to overtop the sand filter and discharge to the Moat. We anticipate the footprint of this alternative to be less than 4,000 square feet.

As discussed above, the sand filters include a sedimentation chamber. This part of the system allows for settling of larger suspended particles. The sediment chamber will not control floatables such as oil and grease. To prolong the useful life of the filter media, an oil absorbent may be added into the filter chamber. These materials are available commercially. The absorbent is not a design requirement for a sand filter.

The opinion of cost for this work is approximately $454,000.

Western Residential Neighborhoods Draining to Moat

The residential neighborhoods that drain to the moat in Newport are characterized by poor soils that have poor drainage characteristics and slope. As a result, infiltration technologies are not appropriate in these neighborhoods. Instead filtration technologies have been proposed for these neighborhoods including sand filters and bioretention that do not rely on the underlying soils for hydraulic capacity. Space is also a significant constraint as these areas are largely built out with residential development. Braga Park is the only significant open space in these neighborhoods.

This area manages a significant part of the total Water Quality Volume (WQV) that is discharged to the beach. These neighborhoods discharge about 524,000 cubic feet of runoff compared to a WQV of 745,000 cubic feet that is discharged to the beach during a storm event. The following design considerations were used to determine the sizing and location of the sand filters.

- Depth to groundwater should be determined during later stages of design. Two feet of separation between the sand filter and the seasonally high groundwater table is desirable. If this depth cannot be met, an impervious liner may be installed around the system to prevent groundwater from infiltrating into the system and disrupting treatment dynamics.

- The sand filters should be installed according to the manufacturer's requirements for infiltration chambers. Portions of the system such as the access and maintenance ports may need to be modified to allow inspection of the sand filter and underdrain.

- The filter media in the subsurface sand filters cannot be replaced without removing and replacing the entire filter system. This is a significant constraint to this design. As a result, pilot testing of the system would be recommended beforehand to better understand maintenance frequency.

- We propose sand as the filter media. Sand has an infiltration rate of 8 feet per day. A proprietary filter media (such as Smart Sponge™) could be substituted. The infiltration and bacteria removal rates of the proprietary media depend on the packing density. This may alter the size of the system. Additional information about proprietary filter media is provided in Section 6.3.2.1. The filter media in the parking lot sand filter could also be replaced with the proprietary media.

- Maintenance considerations for the sand filters include the following items.

    - Ensure proper operation of the pretreatment device.

    - Remove sediment and debris from bottom of storage area (and other accumulation areas).

    - Replace filter media as needed.

    - Follow manufacturer's recommended maintenance program for proprietary equipment, such as infiltration chambers.

WQ LTA-5 Subsurface Sand Filters on the West Side of the Watershed – This alternative consists of a sand filter, which employs proprietary infiltration chambers (e.g., Stormtech Chambers), partially filled with filtration media and underdrained. The proposed sand filters were designed using SC-740 Stormtech™ Chambers. Each filter will have a filtration surface width of 6.25 feet. Where necessary an impervious liner may also be included to prevent infiltration by groundwater. Figure WQV LTA-5 illustrates the cross-sectional and side view of the sand filter.

We propose the sand filters for use in parts of Subwatersheds 3-2, 3-3, 3-4, 3-5, and 3-6. We envision retrofitting multiple sand filters where catch basins are currently installed. The sand filters will work most effectively if installed as close to the source (i.e., the catch basin collecting the runoff) as possible. As a result, this alternative will consist of installing a number of small sand filters for individual groups of catch basins. The area treated per linear foot of sand filter for each subwatershed was estimated as presented in Table 39. The total length of sand filter needed to treat an area of watershed depends on the curve number of the drainage area and is also outlined in that table. This is a total area for the subwatershed that would then be divided between catch basins.

Pretreatment may be achieved using deep-sump catch basins with floatable controls (e.g., hooded outlets); however, other pretreatment systems (e.g., proprietary hydrodynamic separators) would reduce the need for maintenance and increase the useful life of the filter media. A minimum of four feet between the inlet and outlet of the catch basin leading to the sand filter is required to divert the WQV to the sand filter and to drain the treated runoff back in to the catch basin from the underdrain while still allowing bypass of the larger storms without restricting the flow from the underdrain.

If this alternative is selected, the sand filters will be sited based on the location of existing utilities and catch basin invert elevations. The sand filters are gravity-driven systems and require certain pipe slope (i.e., elevation difference between inlet and outlet) in order to work properly.

The opinion of cost for this work is approximately $4,897,000 if applied to the entire watershed to the west of the moat. This cost would be reduced if only applied to smaller subwatersheds in that area.

WQ LTA-6 Bioretention at Braga Memorial Field – Bioretention is a versatile practice and can be sited on large or small sites with subdrains or infiltrating to the soil. Because of space constraints, bioretention is appropriate only at Braga Memorial Field.

We propose a bioretention area planted with grass to allow for continuation of existing recreational use after its installation. Installation may also be phased to allow for recreational use during construction. This design will result in the field flooding during storm events but then draining and being reusable after a 24-hour period. This system will not eliminate current flooding problems, but will allow the field to drain more quickly. The proposed system is not expected to significantly impact activities that take place at the park; however, establishment of new vegetation will limit use of the field during the establishment period, which could take up to two growing seasons. Construction of the bioretention system should be phased so it is established before runoff is routed to it.

Bioretention requires incoming flow to be in the form of sheet flow (i.e., very shallow even runoff, such as that which occurs on gently sloping lawn). Therefore, we propose redirecting the existing runoff to outfall protection outlets (reinforced, turf-covered outlets) and subsequently to swales that will function as level spreaders. Level spreaders are structures designed to convert stream flow to sheet flow.

The bioretention requires elevation differences to function properly. The underdrain should discharge to the Moat above the water surface elevation during the design storm.

Three feet of separation between the bioretention surface and the seasonal high groundwater table is required. If this depth cannot be met, it will be necessary to install an impervious liner under the underdrain to prevent groundwater from infiltrating into the system.

Based on field observation, we propose converting approximately 3.4 acres of Braga Memorial Field to bioretention. The bioretention area was sized to treat the entire WQV from Subwatersheds 3-1 and 3-2; however, it may not be possible to capture the entire WQV of both subwatersheds, specifically the portions that are south or down-gradient of the bioretention area. The actual size of the bioretention area and portions of the contributing subwatersheds that will be diverted to the bioretention area should be determined during final design. Subwatersheds 3-1 and 3-2 contribute 336,000 cubic feet of the total WQV that is discharged to the beach area. This the volume for which the bioretention area was sized. Figure WQV LTA-6 shows the conceptual layout for bioretention at Braga Memorial Field.

The opinion of cost for this work is approximately $2,714,000.

WQ LTA-7 Catch Basins Inserts with Proprietary Filter Media West Side of the Watershed

As an alternative, we have proposed the use of catch basin inserts with a proprietary filter media (e.g., Fabco, SmartSponge, etc.). This alternative simply involves insertion of a tub below the grate of a standard catch basin. In general, water that enters the catch basin is trapped in a tub. The incoming water then drains through one or two filter cartridges. The system includes a bypass that can manage flow in excess of the cartridge filter flow rate. These structures have a reported initial filtration rate of 120 gallons per minute per cartridge which may be reduced to 60 gallons per minute before replacement. With a two cartridge system, the operating flow rate would be 0.52 cubic feet per second per catch basin.

The filter media used with these inserts are a relatively new and innovative practice for pathogen management. The inserts are purported to achieve good removal of pathogens— an average 77 percent of *fecal coliform* and *e coli*. However, testing data is very limited and largely supplied by vendor-initiated studies, which yet to be independently verified. Before this alternative is fully implemented, we recommend implementing a pilot-testing program to confirm bacteria removal efficiencies and maintenance requirements. This pilot testing program would be recommended to be implemented on at least a half dozen catch basins where removal efficiencies and long-term hydraulic capacity can be evaluated.

Semi-annual inspections are recommended in March and November, to coincide with seasonal sanding and cleaning of roads. Maintenance considerations for the catch basin inserts are limited to inspection, cleaning, and replacement of clogged media. Cleaning involves seasonal removal of sand and debris. We anticipate replacement will be approximately every 18-24 months. Current materials costs for replacing cartridges are $100 a piece, $200 per catch basin if two cartridges are used. This would be equivalent to an annual material replacement cost of 31,000 for 235 catch basins.

If the City decides to implement this alternative, inserts would be installed in all of the catch basins in the neighborhoods draining to the western Moat These include subwatersheds 3-1, 3-2, 3-3, 3-4, 3-5, 3-6, 3-7, 3-8, and 3-9. For the purposes of developing a comparative cost, these neighborhoods were estimated to have about 235 catch basins, but that needs to be confirmed, using a detailed survey, if this alternative is selected.

The opinion of cost for installing these inserts is approximately $645,000.

Moat Discharge

The Moat discharges most of the stormwater runoff that appears to be causing the water quality impairments at the beach. As a result, a single control that can substantially reduce bacteria loadings in this discharge could significantly improve beach water quality. The constraints related to the Moat include high hydraulic loads (96 cfs) for the water quality storm (i.e., the storm that generates the WQV), and limited space for installation of a treatment system. Ultraviolet disinfection could provide excellent bacteria treatment despite these constraints.

WQ LTA-8 Ultraviolet Treatment at the Moat Outlet – Ultraviolet disinfection is a highly effective means of pathogen reduction in stormwater. We propose to implement UV disinfection as an end-of-pipe treatment near the Moat outfall, upstream of the Memorial Boulevard crossing.

A UV treatment system can treat all of the WQV of all Newport subwatersheds contributing flow to the Moat (runoff from approximately 600 acres of land). The WQV associated with the flow in the Moat at this point is 600,000 ft^3 with a peak flow of 96 cfs (62 MGD). For the purposes of developing this alternative, we conceptually sized this system to remove 99% of the pathogens in the discharge, which will yield a 30-day geometric mean below 104 cfu/100 ml (i.e., the beach closure standard).

We propose constructing a weir across the Moat to divert flows and the WQV into the UV system. The weir will allow flows greater than the WQV to bypass the UV system.

The UV system outlet weir will keep the lamps submerged regardless of flow. After the disinfected water flows over the UV system outlet weir, it will discharge via two outlet pipes. The pipes will cross under Memorial Boulevard and discharge to the downstream side of the Memorial Boulevard Bridge. In order to manage the WQV, twin 30-inch HDPE storm drains would be required. The UV system has a total head loss of about 10 inches at the design flow. Upstream of the Memorial Boulevard Bridge, the Moat does not provide enough head differential to allow gravity flow. In order for the discharge to flow via gravity, the UV system outlet must be piped to a lower water surface elevation beyond the Memorial Boulevard Bridge.

As part of this study, we sampled water in the Moat in the vicinity of the Memorial Boulevard Bridge. The samples were collected on March 16, 2007 during a storm event and the results are as follows:

UV transmittance:	79% without filtration
Total suspended solids:	11 mg/l
UV transmittance:	84% with filtration

These samples are cleaner than what would be expected. We based our design on more conservative numbers in keeping with typical stormwater quality. The UV system was sized for a UV transmittance of 55% and total suspended solids of 30 mg/l.

We propose a UV system consisting of an 8-foot by 50-foot diversion channel, leading to an 8-foot by 39-foot UV reactor channel. The UV reactor channel will contain one UV reactor configured in a two-stage arrangement that houses 336 lamps. The footprint area of the UV system along with the diversion channel and the outlet piping are pictured in Figure WQ LTA-7. This system would be constructed of 304L stainless steel that may be passivated, if required, due to its proximity to the coast. Passivation of stainless steel enhances steel's resistance to the corrosive effects of salt.

The UV system control center requires an electrical service of one 120 volt, 1 phase, 2 wire (plus ground), 16.7 amps. Each power distribution center requires an electrical service of one 277/480 volt, 3 phase, 4 wire (plus ground), 568.9 kVA. Each UV reactor has one hydraulic system center and requires an electrical service of one 120 volt, 2 phase, 1 wire (plus ground), 50 amps. Electrical requirements will be evaluated during later design phases.

This system could operate automatically with feedback from a rain gauge and/or outlet flow meter. The intensity of the UV lights may be varied to optimize treatment and minimize cost. Operator attention will be limited to semi-annual inspection of the UV system's control-panel display. Lamp replacement may be deemed necessary from these inspections, but lamps are estimated to need replacement an average of once every three years. For the purposes of this evaluation, we assumed that an annual average of 40 storms would be treated for duration of 48 hours.

Before implementation, we recommend pilot testing as follows in order to confirm that pretreatment will not be required. Specifically, the pilot testing and monitoring proposed includes:

- Sampling of a set of storm events to better understand flow, moat hydraulics, and water quality, specifically TSS, UV transmittance and collimated beam evaluations.
- Settling tests.
- Hydraulic monitoring of the moat, specifically using data loggers to measure water elevations during storm events.

The opinion of cost for the construction and installation of this alternative is approximately $3.8 million, not including pretreatment. The opinion-of-cost for operation and maintenance is up to $206,000 per year of power costs ($0.10/kwh) assuming that the system operates at maximum current upon startup and for 40 storm events per year (48 hour duration per storm). Operational practices that would reduce power requirements include scaling lamp intensities based on volumes treated. Also, approximately $37,500 should be budgeted annually for lamp replacement, which does not include labor. These costs are presented in 2007 dollars.

6.3.3 Summary of Water Quality Long-Term Treatment Alternatives

Table 39, "Long-Term Water Quality Treatment Alternatives," provides a summary of the alternatives discussed in Section 6.3.3. It provides size of the subwatershed treated, water quality volume treated, treatment-alternative footprint, and cost of alternative in 2007 dollars.

We also estimated cost per cubic foot for each alternative. Most alternatives will cost approximately $13 - $15 per cubic foot of WQV treated. Because we developed opinions of cost with limited information, we believe these costs ratios to be essentially equal. Two alternatives had much higher costs per cubic foot of WQV treated— WQ LTA-3 trenches and swales at Memorial Boulevard ($26/cubic foot), and WQ LTA-4 sand filter near the east side beach parking lot ($38/cubic foot). If the City selects these alternatives, we recommend waiting until later in the implementation process to install them in order to keep cost-benefit efficiencies high.

Table 39
Long-Term Water Quality Treatment Alternatives

Treatment Alternative	Subwatershed	Subwatershed Size (acres)	WQV (cubic feet)	Bacteria Removal Efficiency (%)	Cost Benefit Ratio
Easton Beach Parking Lots and Memorial Boulevard					
WQ LTA-1 Infiltration Trenches East Beach Parking Lot	East Beach Parking Lot	4.1	15,078	75-98	$199,000 $13.3-$17.3(/cf)
WQ LTA-2 Infiltration Trenches West Beach Parking Lot	West Beach Parking Lot	2.3	8,600	75-98	$132,000 $15.3-$20.0(/cf)
WQ LTA-3 Infiltration for Memorial Boulevard	Memorial Boulevard	8.6	16,256	75-98	$422,000 $26.5-$34.7(/cf)
WQ LTA-4 Sand Filter East Beach Parking Lot	East Beach Parking Lot Area B	3.1	11,600	40-90	$454,000 $38.8-$50.7(/cf)
Western Residential Neighborhoods Draining to Moat					
WQ LTA-5 Subsurface Sand Filters[b]	3-2 3-3 3-4 3-5 3-6 *Total*	232.1 84.6 42.1 21.2 36.6 *416.6*	312,300 143,350 53,060 14,270 24,400 *547,380*	40-90	$4,897,000 $2,109,000 $807,000 $203,000 $351,000 *$8,367,000* $17.8-$40.0(/cf)
WQ LTA-6 Bioretention at Braga Park	3-1 3-2	263.9	335,634	75-98	$2,714,000 $8.2-$10.7(/cf)
WQ LTA-7 Catch Basin Inserts	3-1 3-2 3-3 3-4 3-5 3-6 3-7 3-8 3-9 *Total*	31.8 232.1 84.6 42.1 21.2 36.6 2.2 3.2 4.7 *458.5*	23,300 312,300 143,350 53,060 14,270 24,400 1,200 1,800 2,800 *576,480*	50-75	$14,000 $313,000 $143,000 $58,000 $47,000 $55,000 $5,000 $5,000 $5,000 *$645,000* $1.3-$2/cf
Moat Discharge					
WQ LTA-8 UV Treatment	Easton Beach Watershed[a]	594.3	745,000	99	$3,800,000 $5.1/cf

d. Entire watershed includes flow from Middletown that enters the moat near the discharge point.
e. The sand filters are intended for use in the upland to treat portions of the WQV depending on the length and number installed. Therefore this footprint may be split up amongst several sand filters.

f. The values in the Cost Benefit Ratio column are costs for 2007. The first number is the total cost for the system. The second listing, in BOLD, is the range of dollars per cubic foot of WQV treated, divided by the bacteria removal efficiency (cost/WQV/% removal)

Based on our evaluation, we recommend that the City implement a UV disinfection system for the Moat outfall. This system is the only alternative that could be applied for the entire discharge from the moat. It is also the most reliable in terms of treatment of bacteria and will achieve the greatest reductions in bacteria that are measured at the beach. It is also cost effective compared to other alternatives. Implementation of structural controls such as this is eligible for significant funding opportunities through the Rhode Island Watershed Bond Fund that can provide up to 50% grants for controls such as these. However, this system should be reevaluated after preliminary design to reconfirm expected costs to construct and operate the system and that the system will not significantly impact Moat hydraulics.

Alternatively, the use of catch basin inserts within the watershed to the Moat should be considered if UV disinfection is not implemented. This technology would be the least costly, however, there are many questions regarding its effectiveness. As a result, pilot testing would be recommended for this alternative. Because this technology could only be applied to a portion of the watershed that is draining to the Moat, other structural and non-structural controls will likely be required such as controls for Memorial Boulevard (WQ LTA-3) and removal of dog and animal wastes from the moat and pond dams as a source of bacteria (WQ STA-1, -2, and -5).

6.3.3.1 Pilot-Testing of Selected Structural Controls

Several innovative structural controls have been proposed as long-term alternatives. We recommend some pilot testing of the controls before the City makes any significant investment in implementing them. This would allow the City to better understand the relative costs and benefits of the alternatives as a group. The structural controls for which we recommend pilot-testing are:

- Subsurface Sand Filters
- Catch Basin Inserts

Pilot testing for these two alternatives would consist of implementing these alternatives on a small scale in the watershed. For example, install catch basin inserts in 4 or 5 catch basins, or install 20 feet of a subsurface sand filter. These structures should then be monitored such that hydraulic performance and influent and effluent quality is measured. Based on the results of this analysis, the effectiveness and sizing of these structures can be better defined.

In addition to this pilot-testing, more intensive monitoring of both hydraulic and water quality in the Moat area near the Memorial Boulevard bridge is also recommended in order to develop a design for a UV treatment system. The hydraulics in this area is very complicated and need to be better understood in order to ensure that the system will operate without causing additional flooding. Additional water quality testing is recommended in order to define pretreatment needs and sizing of the UV system.

6.3.3.2 Water Quality Management Implementation

Implementation of a water quality management program commonly occurs over the course of several years. Time frames vary for many reasons including, but not limited to, financing, public concern, interagency coordination, construction delays and complications, and technical issues.

While incidence of beach closure can be reduced with the controls proposed herein, no control or set of controls will completely eliminate all beach closures. That is, there will always be some storm event or set of circumstances that will cause closures at the beach. As a result, implementation of controls should be stepwise, that is, implement a round of controls and evaluate their effectiveness before implementing a second round of controls.

The following paragraphs outline a recommended plan to implement the water quality controls for Easton Beach.

Year 1

- Conduct additional hydraulic and water quality monitoring required to develop preliminary design of UV system at Easton Beach. (WQ LTA-8)
- Begin coordination with state agencies on permitting. This should include DOT, DEM, and CRMC.
- Begin coordination with the media regarding development of anticipated controls for the watershed.
- Develop plan with Middletown to develop controls for the watershed. These include both shared controls such as a UV system as well as controls that need to be implemented by Middletown such as illicit discharge and detection program and structural controls for their outfall at S-11. Newport and Middletown should consider cost-sharing for controls such as the UV system based on the water quality volume that they would both contribute. (WQ STA-5 and LTA-8)
- Coordinate with DOT on implementation of an illicit discharge detection program and the potential to relocate their Moat discharge at the Memorial Boulevard Bridge to a point that can be managed by the UV system. Also, begin discussions on cost-sharing for a potential future UV system. (WQ STA-5 and LTA-8)
- Develop public education program for the watershed. This is an item that should also be coordinated between Middletown and Newport. The program should be focused on activities that lead to increased bacteria loads and storm water pollution (e.g., pet waste management, activities on the pond dams). (WQ STA-1)
- Coordinate with local groups to develop and implement public-participation activities such as beach cleanup to continue to improve public awareness of the issues. (WQ STA-2)

- Develop preliminary (30% complete) design of UV system (WQ LTA-8). The purpose of this preliminary design will be to:
    - Confirm that Moat hydraulics will work with this system.
    - Size the system based on updated data.
    - Develop a more accurate opinion-of-cost for both construction and operation and maintenance.
    - Make a final decision as to whether or not UV disinfection is the preferred alternative.

- Pilot-test catch basin inserts as described herein as a fall back strategy if UV disinfection is not advanced beyond preliminary design.

- Advance the preliminary design plans for the UV system to 70% complete. Update opinions-of-cost.

- Prepare permit applications to CRMC and RIDEM water quality certification.

- Apply for funding to RIDEM to the Nonpoint Source Bond Fund for the selected alternatives.

- Prepare construction documents for the UV disinfection system.

Year 2

- Follow-up on RIDEM grant funding.

- Bid construction of capital improvements after grant awards are made.

- Construct capital improvements. The scheduling of the construction of these improvements will be dependant upon RIDEM's schedule to make these awards.

Year 3

- Consider the implementation of other improvements. We suggest that the City implement an adaptive management approach where the success of implemented controls is evaluated based on their impact on beach closures. The City would continue to select and implement controls until beach closures are reduced to the point that would be acceptable based on the scale of investment that the City wants to make.