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Sustainable Environmental Solutions
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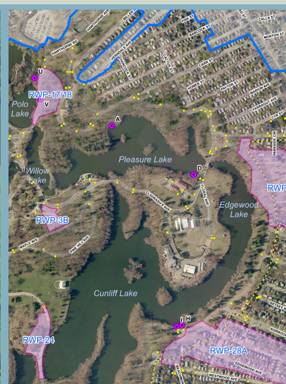
Roger Williams Park Ponds

Water Quality Management Plan

Volume II

June 2013



Prepared for:

The City of Providence
Roger Williams Park
1000 Elmwood Avenue
Providence, RI 02903

Prepared by:

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Acknowledgements

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Karen Marcotte	Save The Lakes
Bernie Beaudreau	Serve Rhode Island
Jimmy Johnson	R.I. Bass Federation
Lou Perrotti	Roger Williams Zoo
Amelia Rose	Environmental Justice League of R.I.
Jessica Blackledge	Eastern R.I. Conservation District
Wendy Nilsson	Partnership for Providence Parks
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Bob Vanderslice	R.I. Department of Health

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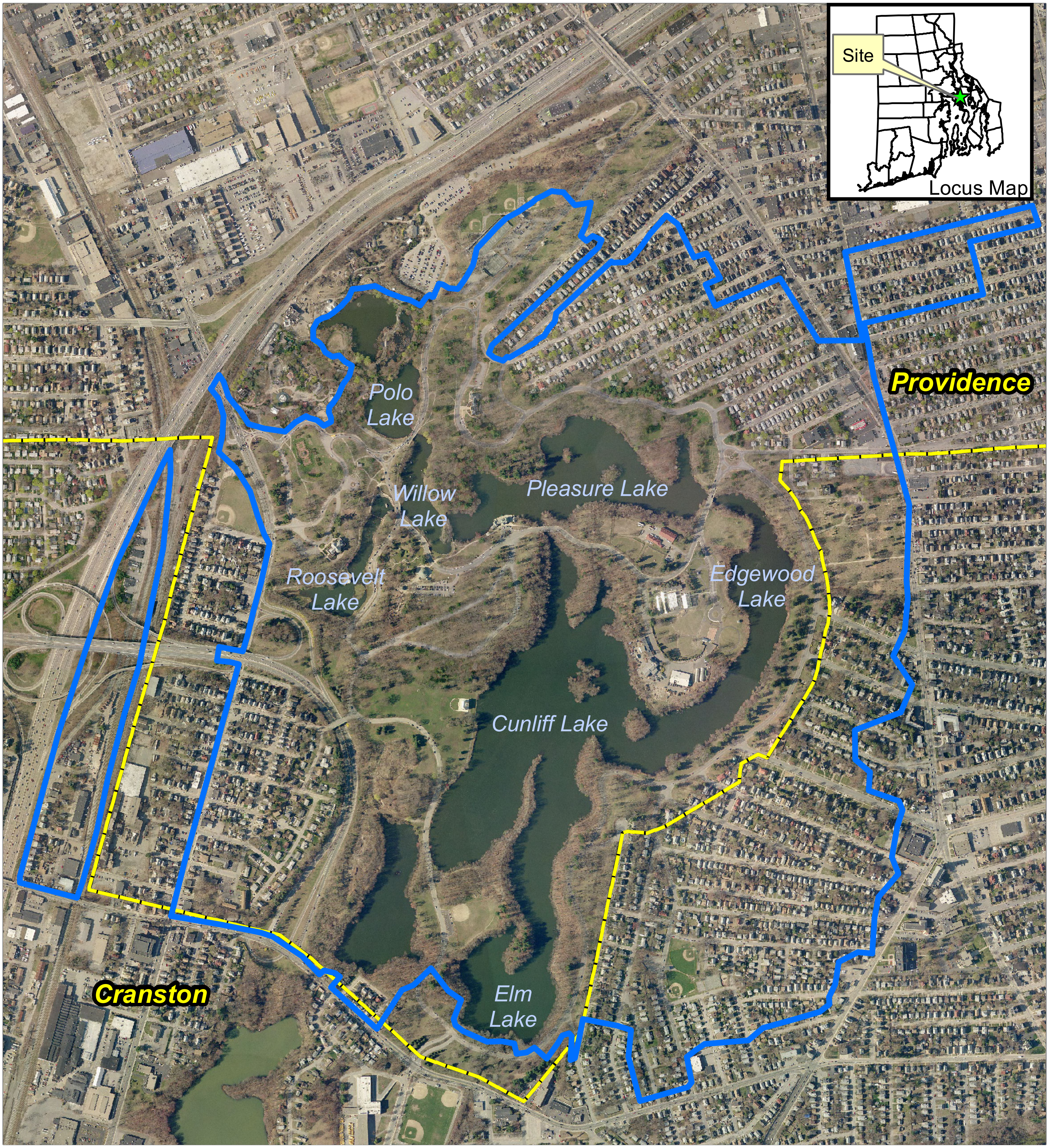
1.0 Introduction

Roger Williams Park (RWP) is considered the crown jewel of the City of Providence Parks and Recreation Department and is a major tourist and cultural attraction for both the City and the State. The 430-acre Victorian park consists of expansive manicured grounds, a system of man-made recreational ponds, public gardens, an extensive roadway/walkway system, the Museum of Natural History and planetarium, a carousel village, and the Roger Williams Park Zoo, as well as many other public facilities. The Park is located in the southeastern portion of Providence, in the South Elmwood neighborhood and the City of Cranston borders the Park to the west, south, and east (see Figure 1.1). It is named for Rhode Island's founding fathers, Roger Williams, and was designed by Horace Cleveland in 1878 followed by construction in the 1880s. It is listed on the National Register of Historic Places, and many of the current roads, bridges and sidewalks were built by the Works Progress Administration (WPA) from 1935 to 1940. Like many of the large city parks constructed across America during the Victorian era, RWP has a long standing history of serving as a "green" oasis within a highly urbanized surrounding environment.

Over the past 130 years, RWP has provided enjoyment and recreational activities for the residents of the surrounding neighborhood and the City of Providence, as well as visitors from across the State of Rhode Island, New England, and beyond. RWP has been identified as one of Rhode Island's most precious treasures and is visited by 1.5 million people per year. Trust for Historic Preservation has designated RWP as one of America's premier historic urban parks. To add to its accolades, the Park most recently received the 2001 "Centennial Medallion Award" presented by the American Society of Landscape Architects as a national landmark of outstanding landscape architecture (www.americangardenmuseum.com).

The most significant natural resource within the RWP is the inter-connected pond system, which covers 100 acres in the Park. Seven Ponds extend from north to south and are named Roosevelt, Polo, Willow, Pleasure, Edgewood, Cunliff, and Elm Ponds (see Figure 1.1). The water quality conditions in the Ponds have been declining over the past several decades. The Ponds were first listed on the RI Department of Environmental Management (DEM) impaired water bodies list (the "303(d)" list) in 1992 due to impacts from low dissolved oxygen. Since then, the Ponds were listed for phosphorus in 1996, and in 1998, were also listed for excessive algal growth/chlorophyll-a and pathogens (fecal coliform). In September of 2011, DEM and the RI Department of Health issued a health advisory for certain Rhode Island Ponds, including Mashapaug Pond and the RWP Ponds, due to blue-green algae (*cyanobacteria*) blooms. People were advised to avoid recreational activities (like swimming, boating, or fishing) in these waters until further notice and to be careful not to ingest water or eat fish from any of the Ponds. Blue-green algae blooms may form naturally-occurring algal toxins, which can cause harm to humans and animals.



*Color Imagery: 2008

Legend

Town Boundaries

Watershed Boundary

N

Feet

1,000

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Vicinity Map
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 1.1

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure1_1_VicinityMap_11058.mxd

To address the impairments in the RWP Ponds, the City of Providence Parks and Recreation Department, with technical support from Narragansett Bay Estuary Program (NBEP), initiated a restoration project to assess water quality conditions and develop a Water Quality Management Plan which would make recommendations for practices to improve water quality.

1.1 Purpose of the Plan

The City of Providence (hereafter, referred to as the City) received funding from the U.S Environmental Protection Agency (EPA) Region 1 to improve the water quality and biodiversity conditions of the RWP Ponds. The Project Team, Horsley Witten Group, Inc. (HW) and Loon Environmental, was contracted by the City to work with the Providence Parks and Recreation Department to develop a Water Quality Management Plan that addresses long-term water quality improvement.

The overarching goals for the long-term improvements of the RWP Ponds include:

- Improve water quality, habitat, and biodiversity within the RWP Ponds;
- Improve the overall environmental quality and user experience of RWP;
- Identify health risks associated with fish consumption; increase public awareness and as warranted; and
- Foster watershed management awareness and environmental stewardship among the Park users and surrounding residents through a public outreach campaign.

The Project Team worked closely with the City, DEM, NBEP, and the Technical Steering Committee to develop a Water Quality Management Plan for restoration of the RWP Ponds. The Technical Steering Committee was established specifically to help guide this project. Members include the following:

- Providence Parks and Recreation Department
- NBEP
- EPA Region 1
- EPA Atlantic Ecology Division
- RI Coastal Resources Management Council
- RI Department of Health
- RI DEM
- RI Department of Transportation
- Save The Bay
- Save The Lakes
- US Fish & Wildlife Service
- USDA Natural Resources Conservation Service
- University of Rhode Island Watershed Watch
- RI Bass Federation
- Environmental Justice League of Rhode Island
- Serve Rhode Island
- Pawtuxet River Authority
- RI Natural History Survey
- Urban Ponds Procession

This plan incorporates short and long-term measures to improve water quality, aesthetics, habitat, and public use of the Ponds. The management plan was developed from information including existing GIS, past design plans, and CAD files (base mapping provided by the City of

Providence). It includes conceptual designs for a set of stormwater best management practices (BMPs) designed in accordance with the 2010 Rhode Island Stormwater Design and Installation

Standards Manual (December 2010) and other non-structural measures such as buffer enhancement. The focus of the plan includes the watershed draining to the RWP Ponds, which includes both the area immediately surrounding the Ponds (referred to as "Lower Watershed", see Figure 1.2) and the nearby contributing watershed ("Upper Watershed"). This plan describes the existing watershed conditions based on a review of existing information; observations made during field assessments; and information derived from project partners, key land owners, and input during a number of agency and public stakeholder meetings. This plan also provides specific recommendations and cost estimates for improving water quality in the short term (one to three years) and in the long term (three to ten years).

The purpose of this Water Quality Management Plan is to:

- Establish short-term and long-term goals to improve the water quality of the RWP Ponds (**Section 1.4**);
- Describe the existing RWP Ponds conditions and identify water quality concerns (**Section 2.0**);
- Characterize the major phosphorus sources contributing to the Ponds (**Section 2.0**);
- Assess the contributing watersheds and identify retrofit options, both structural and non structural (**Section 3.0**);
- Discuss other key activities to improve water quality, such as public education and outreach (**Section 3.0**);
- Provide short-term recommendations to accomplish pollutant loading reduction goals (**Section 4.0**);
- Provide long-term recommendations and watershed-specific strategies to accomplish pollutant loading reduction goals (**Section 5.0**).

Caveats

The following limitations on the information presented in this report should be considered:

- The word "pond" and "lake" are interchangeable in this report.
- While extensive field investigations, Steering Committee meetings, and general public meeting were conducted, the list of stormwater retrofits and restoration opportunities presented here should not be considered exhaustive.
- Project ranking is intended to inform the implementation process. Actual implementation frequently occurs as other opportunities arise, and the ranking should not be viewed as an absolute sequence for implementation.
- Where planning level construction costs are provided, these costs are based upon unit cost data compiled from various sources, including but not limited to Rhode Island Department of Transportation unit costs, R.S. Means unit costs, various construction material providers, and nurseries, as well as bid results from recent similar HW projects. These costs should be used for general planning purposes only.

1.2 Role of the Ponds in the Park Landscape

The RWP Ponds complex is one of the most outstanding and popular features of the Park. The various water bodies comprise approximately 100 acres and provide for recreational activities such as paddle boats, recreation boating, canoeing and kayaking, and fishing. Beyond serving as a valuable park amenity, the Ponds also provide important ecological and environmental benefits. They are an important component in the Pawtuxet River Watershed which discharges to Narragansett Bay, therefore their health and ability to assimilate pollutants important to the whole region.

The pond complex is comprised of man-made impoundments constructed in the old Mashapaug Brook stream bed (Lee & Pare 1980). Although the RWP Ponds are essentially one large interconnected body of water, they are designated as seven separate ponds. The Park also includes two additional bodies of water that lack a surface connection to the Ponds complex, Deep Spring and the Zoo Wetlands. They are not included as part of this water quality management plan. The contributing watershed to the Ponds includes the Lower Watershed, which is the immediately surrounding drainage area from the Park, the adjacent neighborhoods and commercial areas, and the Upper Watershed, which encompasses significant urban areas northwest of Interstate-95, and includes drainage from Reservoir Avenue (Route 2). The Upper Watershed includes Tongue, Spectacle, and Mashapaug Ponds, which eventually drain to the RWP Ponds. It is important to note that while the Ponds are located within RWP, the Park makes up less than 25% of the total land area draining to the Ponds.

1.3 Problems Facing the Ponds

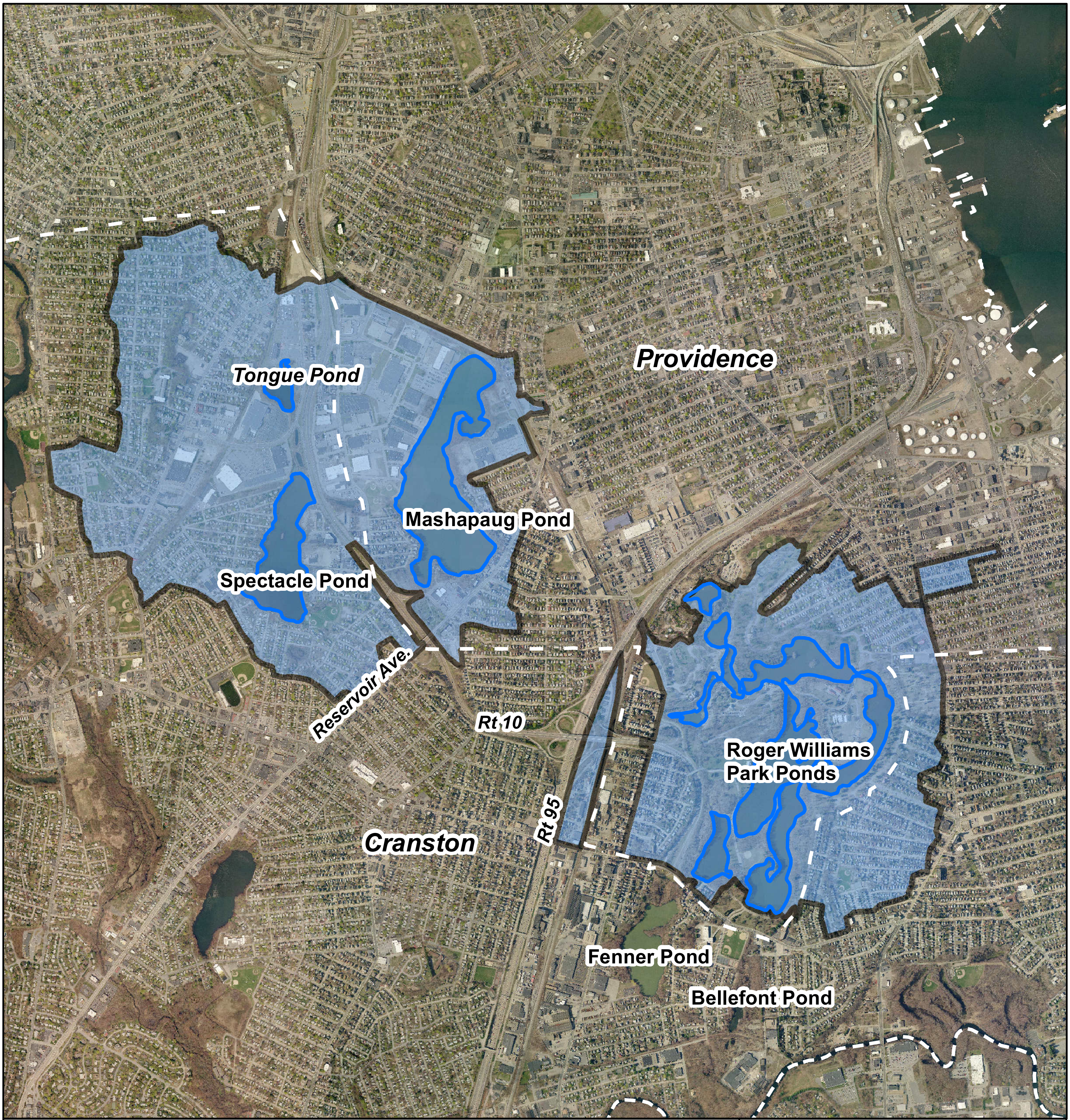
Visitors to RWP during the summer and early fall months can easily see that the Ponds have water quality issues. The water appears murky. There are dense stands of aquatic vegetation, frequent algae blooms, and occasional noxious odors. Posted warnings about toxic blue-green algae and contaminated fish are common occurrences. The causes, however, of these water quality issues are not as apparent to the casual observer. Urban stormwater runoff and an overabundance of waterfowl are the main sources of the pollutants in the Ponds.

The majority of the watershed draining to the RWP Ponds has become highly urbanized since the Park was established, characterized by large amounts of impervious cover (e.g., rooftops, roads, and parking lots) with little to no existing stormwater management. Before development, meadows, forests, and other pervious land covers used to slow, take up, and help infiltrate rainfall into the underlying soils. Now when it rains, runoff from these developed areas carries high levels of pollutants, such as sediment, nutrients, bacteria, oils, and trash, directly into the RWP Ponds by way of a storm drain system or overland flow. In addition, a large waterfowl population lives in RWP. The Park is an ideal habitat and provides a ready source of food, namely, handouts from park visitors. The lack of shoreline buffer vegetation along large sections of the RWP Ponds allows geese and ducks easy access to large lawn areas adjacent to the open water, providing open feeding areas where potential predators are easily seen at a distance. This resident waterfowl population, which includes large numbers of Canada geese, adds to the nutrient and bacteria load in the Ponds, as well as contributing to erosion problems along the shoreline.

The high amount of nutrients (in particular, phosphorus) in the Ponds helps to sustain high algal densities, and reduce water clarity. As the algae decays, dissolved oxygen levels are reduced; this can affect fish and invertebrates within the Ponds. As mentioned above, DEM lists the RWP Ponds, Mashapaug Pond and Spectacle Pond, as impaired for excessive algae growth and total phosphorus concentrations. Spectacle and the RWP Ponds are also listed as impaired for low dissolved oxygen, while Mashapaug and the RWP Ponds are also listed as impaired for fecal coliforms. To address these impairments, the RWP Ponds complex was included in the Total Maximum Daily Loads (TMDL) for *Phosphorus To Address 9 Eutrophic Ponds in Rhode Island* prepared by the DEM Office of Water Resources in September of 2007. This TMDL assessed total phosphorus, chlorophyll-a, and dissolved oxygen concentrations within the water bodies; identified and assessed sources of the impairment, and recommended mitigation measures to address phosphorus-related impairments and to restore all designated uses (DEM 2007). In addition, Mashapaug and the RWP Ponds were included in the Statewide Bacteria TMDL approved by EPA in September 2011.

These water quality problems developed over many decades. For example, the visual appearance of the RWP Ponds has been an issue since at least the 1920s, approximately 50 years after the RWP Ponds existed in their current configuration. Thus, resolving these issues will not happen overnight and will not be a simple or straightforward task. As such, it is important for the City to understand the challenges inherent in managing urban ponds, such as the RWP Ponds, as well as the limitations imposed by urban watersheds. It is not realistic to turn shallow ponds receiving large quantities of stormwater runoff into clear pools resembling natural ponds, but options are available to meet designated and desired uses of the Ponds. Key issues to be addressed to improve the water quality of the RWP Ponds and address the TMDL include:

- Excessive loads of nutrients, sediment and other contaminants, such as fecal coliforms and solid waste, from the urban watershed;
- Erratic flows and flushing rates;
- Lost depth over time from external inputs or internally generated organic matter;
- Possible nutrient cycling from accumulated sediment reserves;
- Low clarity from algae and possibly resuspended sediment;
- Possible resuspension of sediment and nutrient inputs from bottom fish;
- Abundant waterfowl, including geese, with attendant nutrient and bacteria inputs;
- Algal blooms and related occurrences of toxic cyanobacteria;
- Dense rooted plant growths, including native and invasive species; and
- Low oxygen and related water quality impairment.



Legend

City limits

Watershed (Final Nov. 2011)

N

Miles

0.25

Aerial imagery: 2008 Pictometric Licensed Imagery.

Coordinate System: NAD83, Rhode Island State Plane feet

Horsley Witten Group

Sustainable Environmental Solutions

Roger Williams Park Ponds and Watershed

Date: 1/17/2012

Figure: 1-2

File: WatershedBasic

1.4 Water Quality Management Goals

Through working closely with the Project Team, the City, DEM, NBEP and the Steering Committee and based upon data collections, the following short and long-term water quality goals for the RWP were developed.

- Short-term (one to five years);
- Mid- (five to 10 years); and
- Long-term (10 -25 years) water.

These goals were used to establish the general framework for the Water Quality Management Plan and to prioritize the proposed recommendations. Much of the work identified under the short-term goals has been addressed by this WQMP, but additional work will be completed within the next five years.

Short-term

1. Identification of pollutant sources
   a. Both within RWP and larger watershed
2. Quantify targeted pollutant reduction
   a. Phosphorus reduction and others
3. Evaluation of pond management options
   a. Prioritize stormwater BMP locations for maximum pollutant load reduction
      i. Include both structural and non-structural BMPs
   b. Identify potential upstream or in-pond treatment options and locations
      i. Alum dosing and others
   c. Identify locations for enhanced aquatic buffers
4. Implement a water quality sampling plan
5. Completion and implementation of geese management plan (by U.S. Department of Agriculture Animal and Plant Health Inspection Service, USDA APHIS)
6. Installation of six structural BMPs within the Lower Watershed
7. Implementation of non structural BMPs within the Lower Watershed
8. Development of a Park Master Plan and Operation and Maintenance Plan
9. Public outreach/awareness

Mid-term

1. Continue geese management plan implementation
2. Continue water quality sampling
3. Implementation of Park master Plan
4. Further development and installation of structural BMPs within the Lower and Lower Watershed
5. In-pond management Studies
   a. Dredging
   b. In-pond treatments
6. Monitoring of installed BMPs for performance
7. Extend public outreach/awareness in the neighborhoods

Long-term

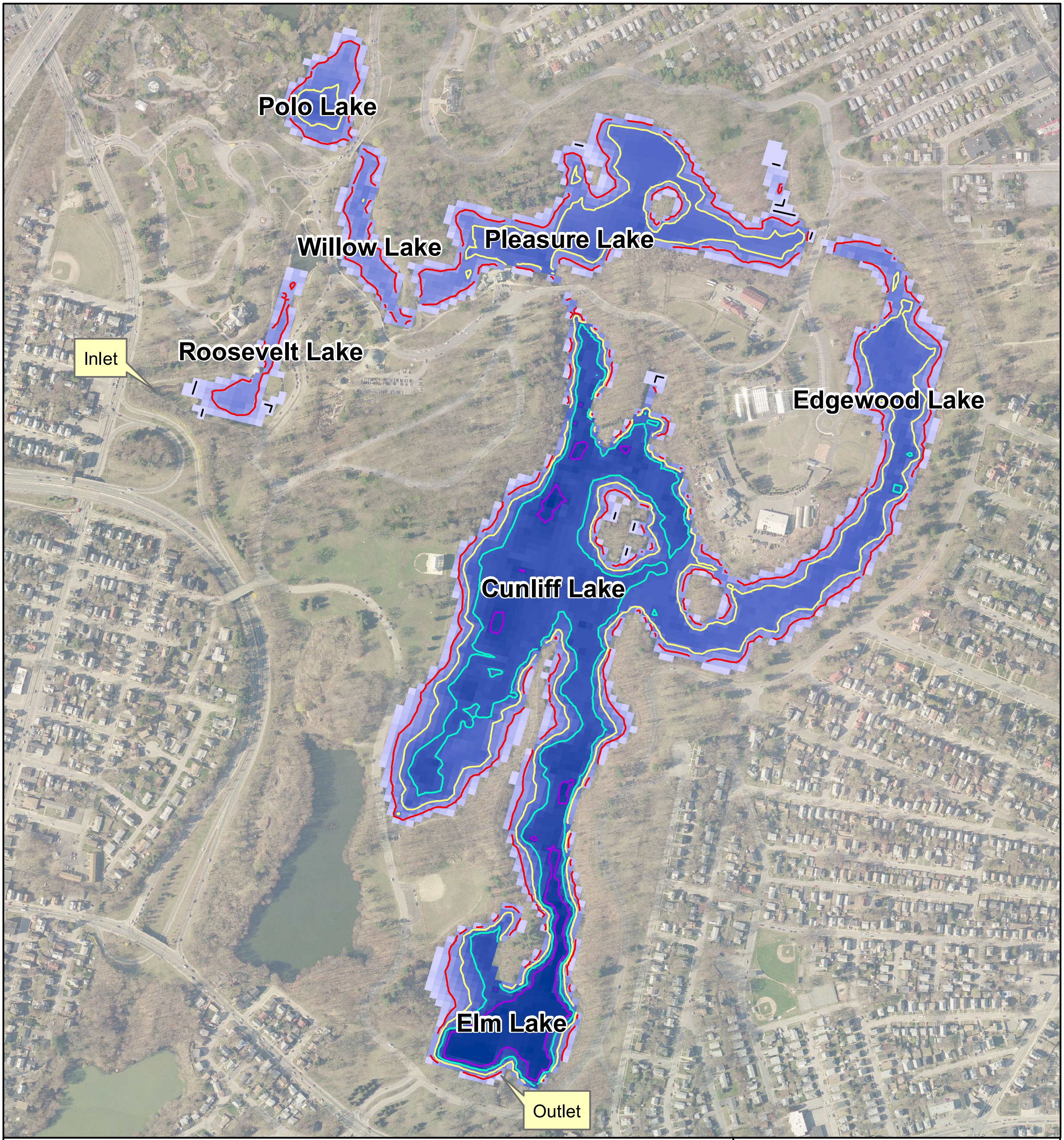
1. Long-term geese management/population control
2. In-pond treatment
3. Continue water quality sampling program
4. Continued monitoring of installed BMPs for performance
5. Explore possibilities of extending herring migration up into the Ponds
6. Phosphorus bans within the Upper and lower watersheds
7. Public support will be a critical and necessary component for the future implementation of projects throughout the watershed; therefore, on-going outreach opportunities should be investigated to make the public aware of the importance of watershed management. This should include highlighting the following:
    a. Potential effects on daily park activities
    b. Wide range of potential benefits of implementing a comprehensive plan to improve water quality

2.0 Characteristics of RWP Watersheds

2.1 RWP Pond Physical Characteristics (Size, Depth, Flow and Uses)

The RWP Ponds consist of a series of seven interconnected water bodies located within Roger Williams Park (RWP) in the City of Providence, Rhode Island. These include: Roosevelt Lake, Willow Lake, Polo Lake, Pleasure Lake, Edgewood Lake, Cunliff Lake, and Elm Lake, and are defined by constrictions between each basin. All the RWP Ponds are man-made; Pleasure, Edgewood, Cunliff and Elm Lakes were created by damming the Old Mashapaug Brook at what is now the terminus of Elm Lake in the 1800's (Lee Pare & Associates, 1980). The remaining lakes, Roosevelt, Willow, Monument and Polo, were dredged out of the Mashapaug Brook streambed between 1872 and 1878 (Lee Pare & Associates, 1980). Monument Lake was later transformed into the Japanese Gardens, which today is a small area between Roosevelt and Willow Lakes that is fed from Willow Lake. The general pattern of flow through the Ponds is from the southern end of Roosevelt Lake where a 48 inch diameter pipe from Mashapaug Pond is located to the dam at the southern end of Elm Pond. Discharge from the RWP Ponds flows into Bellefont Brook into the Pawtuxet River and eventually to Narragansett Bay. Polo Lake is additionally connected to the Zoo Wetland Pond contained within Roger Williams Park Zoo via a culvert (RIDEM, 2007). No outlet flow data are available for the dam at the terminus of Elm Lake and no direct measurements are available for flow entering RWP Ponds from the 48 inch diameter inlet pipe in Roosevelt Lake. Flow rates are likely highly variable due to the large amount of stormwater entering the system. The RWP Ponds are estimated to flush approximately nine times a year based on the results of the Lake Loading Response Model discussed in detail in **Section 2.4**.

Based on a bathymetry survey completed in 2011 by the U.S. Environmental Protection Agency, Atlantic Ecology Division (EPA/AED) under a technical assistance grant to the City of Providence, average pond depth ranged from 1.3 feet in Roosevelt Lake to 4.3 feet in both Cunliff and Elm Lakes (**Table 2.1, Figure 2.1**). From 2003/2004 land use data from the Rhode Island Geographic Information System (RIGIS), the total pond area is estimated at 102.7 acres with a volume of 356 acre feet.



Legend

Depth Contours (ft)

- 0
- 1.6
- 3.3
- 4.9
- 6.6

Depth (feet)

8.2 6.6 4.9 3.3 1.6 0.0

N

Feet

250

Aerial image: 2008 Pictometric licensed image. Depth contours and raster image of depth provided by EPA from data obtained in the summer of 2011, unpublished. Raster image of depth was created with a pixel size of 10x10 meters. Depth data to precision of 0.1 meter.

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2011 Roger Williams Park Ponds Bathymetry

Date: 1/17/2012

Figure: 2.1

Coordinate System: NAD83, Rhode Island State Plane feet

File: Bathy_24x36

Table 2.1. Basic characteristics of the Roger Williams Park Ponds (2011)

Pond	Avg. Depth[1] (ft)	Area[2] (acres)	Volume[3] (acre feet)	Direction of Flow[4]
Roosevelt Lake	1.3	3.8	4.9	West to East-North to South
Willow Lake	2.0	3.4	6.7	South to North and North to South
Polo Lake	2.3	3.6	8.2	South to North
Pleasure Lake	2.6	18.6	48.8	West to East
Edgewood Lake	3.0	19.3	57.0	North to South
Cunliff Lake	4.3	32.3	137.8	North to South
Elm Lake	4.3	21.7	92.7	North to South
Total		102.7	356.2	

Notes:

[1]Calculated from bathymetry data provided by EPA, data collected during summer 2011, unpublished

[2] Area data obtained from RIGIS 2003/2004 Land Use coverage, this data is based on 2003/2004 orthophotography

[3]Volume calculated from area and average depth of each pond.

[4] Direction of flow provided by Providence Parks and Recreation Department.

The Ponds are a key feature of the Park, consisting of approximate a quarter of the total parkland area. Therefore, their potential value as an amenity is integral to the experience of Park users, and the cleaner the water, the more value they add. Current uses include a variety of boating options, including Duck Boat tours and rentals for swan, paddle, and electric boats, and kayaks. Recreational fishing is another activity that occurs in the Ponds. Over the years, fishing tournaments have been conducted at the Park, organized by groups such as the Rhode Island Carp Anglers Group and the Bass Federation of Rhode Island. Finally, the Ponds offer a range of aesthetic appeal including simple shore-line viewing and bird watching, among others.

2.2 Roger Williams Park Ponds Watershed (Lower and Upper)

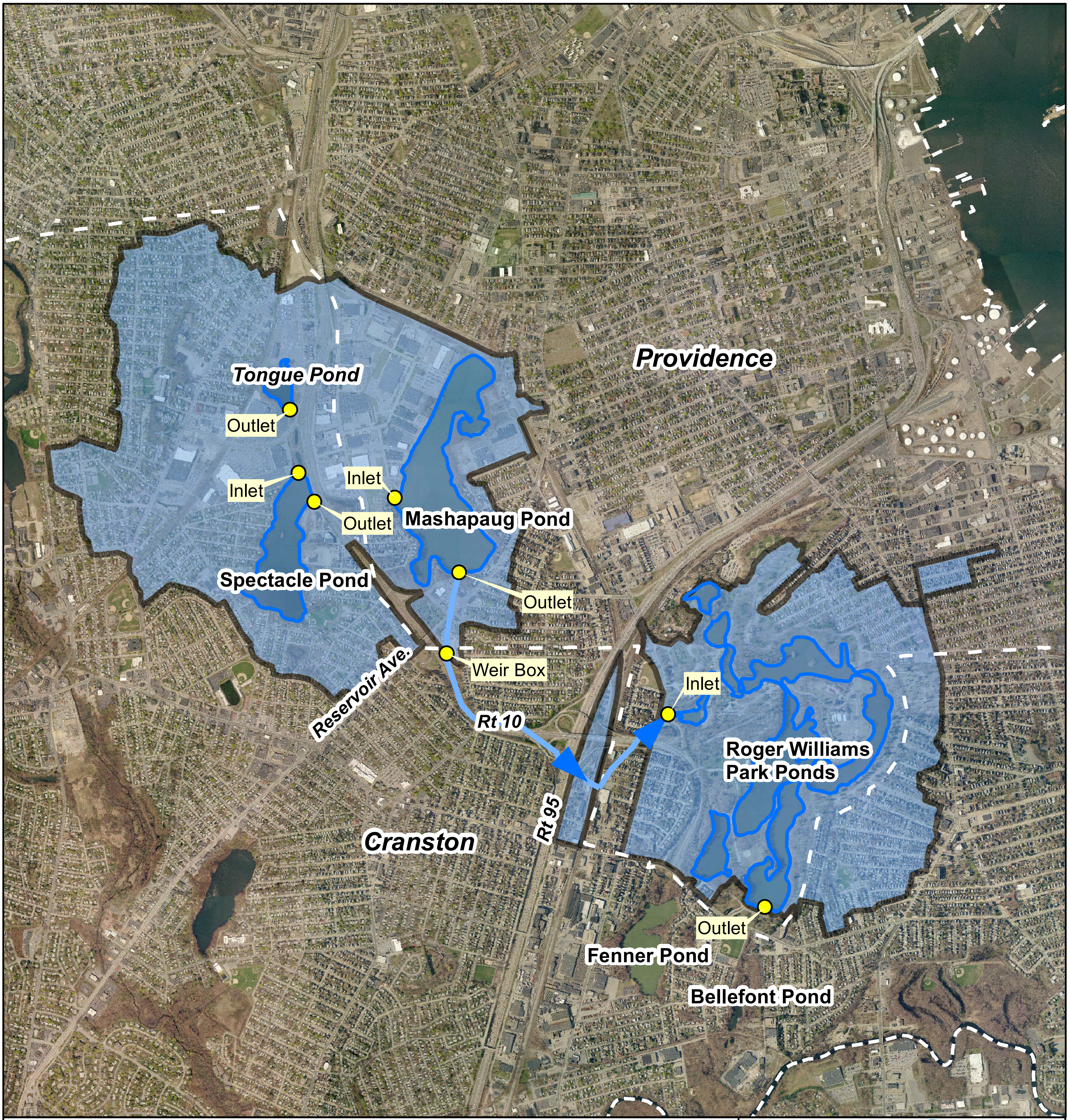
2.2.1 Description

The RWP Ponds watershed is highly modified and consists of a total of approximately 1,625 acres. The topographic watershed, based on the natural slope of the land in the area of the RWP Ponds and used in the preparation of the TMDL for RWP Ponds, was determined to be inaccurate due to the high level human modification of the flow of runoff within this area. Large portions of Providence to the north and west of RWP Ponds are affected by the Narragansett Bay Commission (NBC) Combined Sewer system, which channels runoff to the NBC Wastewater Treatment System and discharges outside of the RWP Ponds watershed. The actual watershed is also affected by the City of Providence, City of Cranston and the Rhode Island Department of Transportation (RIDOT) stormwater conveyance systems. The final delineated watershed takes into account the routing of stormwater by the NBC, City of Cranston, City of Providence and RIDOT stormwater conveyance systems as well as field work completed during the watershed assessment phase of this project and site assessment for structural stormwater practices (described in **Chapter 3**). The watershed consists of two large areas, connected by a single pipe, referred to here as the Upper and Lower Watersheds (**Figure 2.2**).

Table 2.2. Land uses within the Roger Williams Park Ponds Watershed

Land Use	Upper Watershed (acres)	Lower Watershed (acres)	Total Watershed (acres)	% of Total Watershed
High Density Residential (<1/8 acre lot)	308	196	505	31%
Water	118	116	234	14%
Commercial, Institutional (schools, hospitals, churches) and cemeteries	177	50	227	14%
Industrial, mixed commercial/industrial and transportation facilities	195	17	212	13%
Forest	55	142	197	12%
Developed recreation	15	89	104	6%
Medium High Density Residential (1/4 to 1/8 acre lots)	80	15	95	6%
Freeway	23	18	41	3%
Vacant land and brushland	5	7	12	1%
Total	977	649	1,626	100%

Source: RIGIS 2003/2004



Legend

- Pond inlets and outlets
- City limits
- Mashapaug Brook (arrows indicate flow direction)
- Watershed (Final Nov. 2011)

Upper watershed = 977 acres
Lower watershed = 649 acres
Total watershed area = 1626 acres

N

0.25 Miles

Aerial imagery: 2008 Pictometric Licensed Imagery.

Horsley Witten Group
Sustainable Environmental Solutions

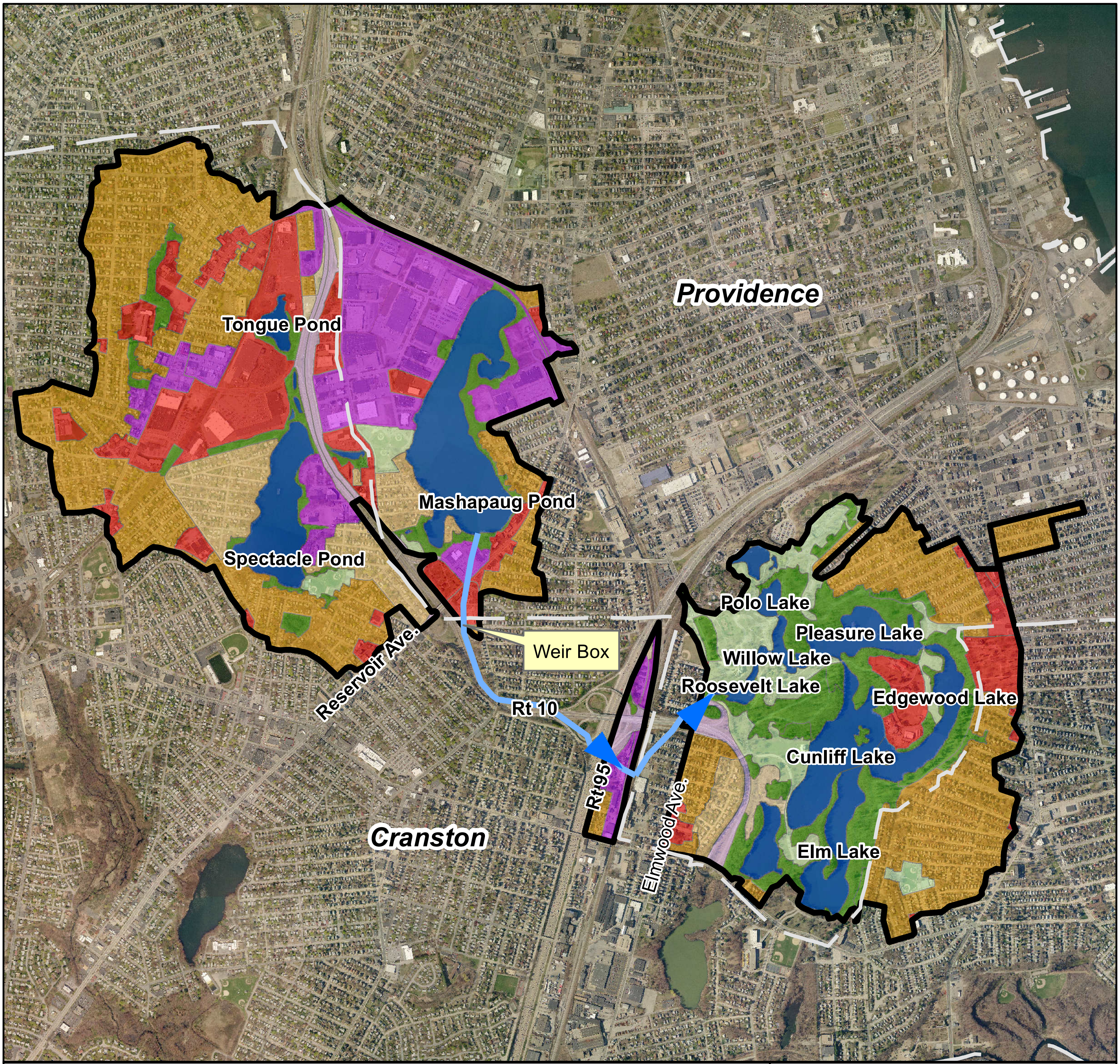
Roger Williams Park Ponds Watershed

Date: 1/17/2012

Figure: 2.2

Coordinate System: NAD83, Rhode Island State Plane feet

File: FinalWatershed_8x11



Land Use

- Medium High Density Residential (1/4 to 1/8 acre lots)
- High Density Residential (<1/8 acre lots)
- Industrial, Mixed Commercial/Industrial and Transportation Facilities (terminals, docks, railroad)
- Freeway
- Commercial, Institutional (schools, hospitals, churches) and Cemeteries
- Developed Recreation
- Vacant Land and Brushland
- Forest
- Water

N

Miles
0.25

Mashapaug Brook (arrows indicate flow direction)
Watershed (Final Nov. 2011)
City limits

Horsley Witten Group
Sustainable Environmental Solutions

Roger Williams Park Ponds Watershed Land Use

Land Use: 2003/2004 RIGIS land use with changes to update land use to exisiting conditions in 2011. Minimum mapped unit for land use is 0.5 acres. City limits from RIGIS. Aerial image: 2008 Pictometric licensed image.

Date: 1/17/2012

Figure: 2.3

Coordinate System: NAD83, Rhode Island State Plane feet

File: LandUse_8x11

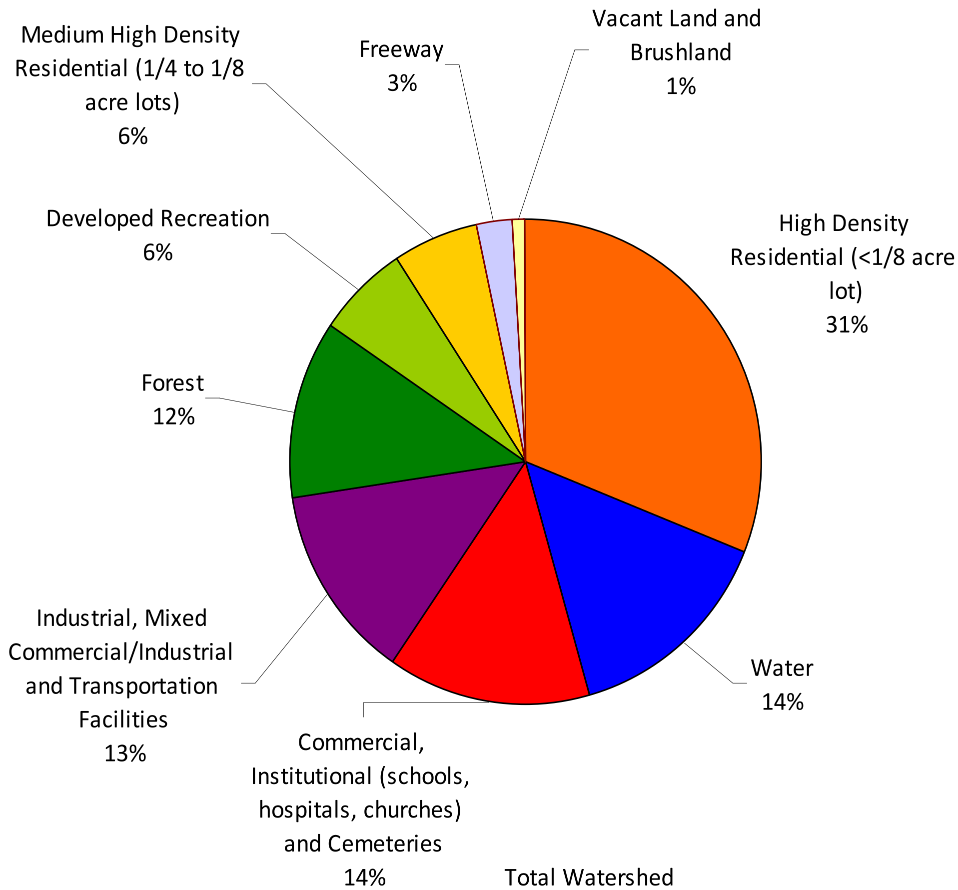


Figure 2.4: *Roger Williams Park Total Watershed Land Uses Pie Chart*

Source: RIGIS 2003/2004

2.2.2 Lower Watershed

The Lower Watershed consists of the area surrounding the RWP Ponds totaling approximately 650 acres. Water enters the RWP Ponds through direct precipitation, overland flow, groundwater flow, and the enclosed storm drainage pipes that discharge to the ponds. Stormwater discharge points to the RWP Ponds are reported in the TMDL to Address 9 Eutrophic Ponds in Rhode Island as well as in documentation of field investigations completed for this study (RIDEM, 2007(2)).

Groundwater is expected to have limited influence on the RWP Ponds as a consequence of storm drainage systems and the disturbed nature of soils in the watershed. The shallow nature of the ponds and the extensive muck sediment accumulated in them also limit the influence of groundwater on the pond system. The ponds are in essence shallow depressions in the landscape, with limited groundwater interaction and dominated by surface stormwater influence. This is not unusual for urban lakes.

High density residential land uses make up 30% of the Lower Watershed, forest makes up 22%, and water at 18%. Impervious surface in the Lower Watershed is 34% of the Lower Watershed land area.

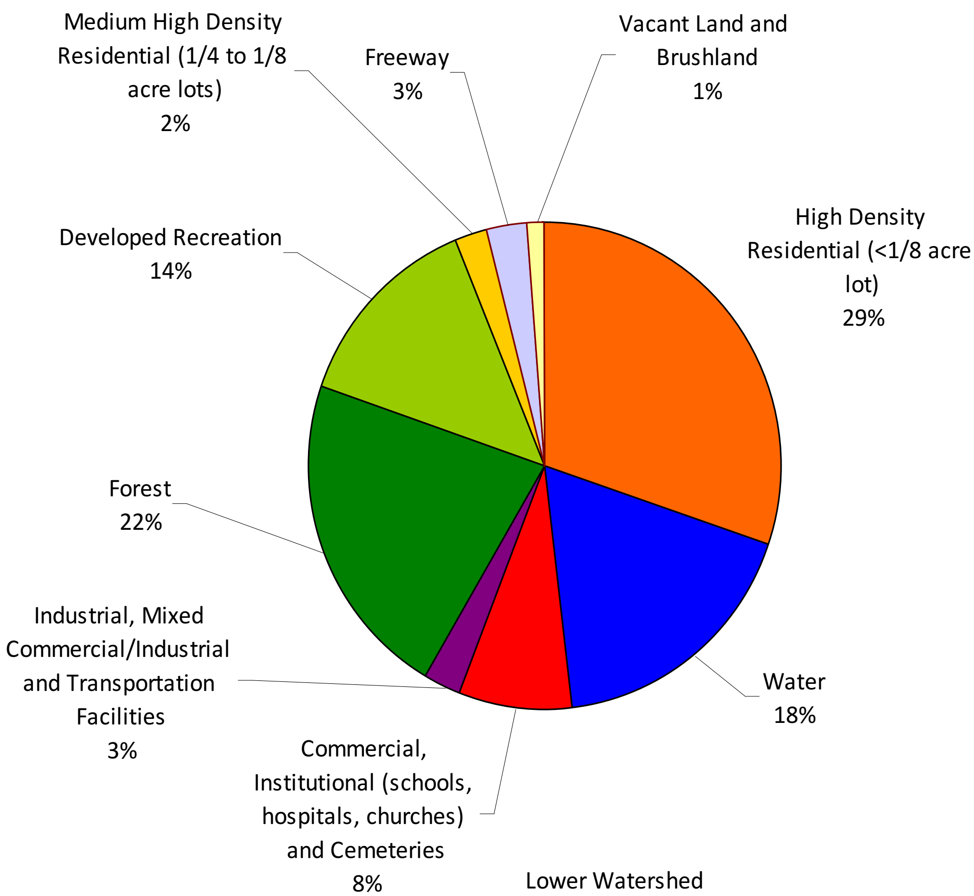


Figure 2.5: *Lower Watershed Land Uses Pie Chart*

Source: RIGIS 2003/2004

2.2.3 Upper Watershed

The Upper Watershed consists of approximately 975 acres encompassing drainage to Tongue Pond, Spectacle Pond, and Mashapaug Pond. Flow is generally from Tongue Pond to Spectacle Pond then to Mashapaug Pond where a concrete weir structure at the southeast corner of the pond controls the outlet flow (RIDEM, 2007). The outflow from Mashapaug Pond discharges through a 48 inch diameter conduit which passes under Reservoir Avenue and empties into a drainage ditch at the edge of the Calart Flower building parking lot located at 400 Reservoir Avenue in the City of Cranston (Lee Pare, 1980). The drainage ditch flows into a weir box structure that allows the base flow from Mashapaug Pond, and storms up to approximately the five year event (4.2 inches in a 24 hour period), to flow into the RWP Ponds while bypassing larger storms to a parallel drainage system that serves Route 10, and eventually discharges outside of the RWP Ponds watershed (RIDEM, 2010). Engineering calculations regarding the sizing of the pipe leading to RWP Ponds and the engineering drawings exhibiting this pipe system are provided in **Appendix A**. Base flow from Mashpaug Pond was calculated based on watershed characteristics, but has not been directly measured.

The delineation of the pipe carrying what was historically Mashapaug Brook was determined from RIDOT as-built plans, NBC sewer maps, information from the City of Providence, and verified during field reconnaissance. Based on these sources, the location of the pipe is well established from the weir box to the Route 10 and Route 95 cloverleaf, after which point, the location is less certain. From our review of existing design plans, field observation, and communications with both RIDOT and the City of Providence Department of Public Works (DPW), it was determined to the best of our knowledge that once the water enters the weir box, the base flow continues along Route 10, passing under Route 95 in the vicinity of the

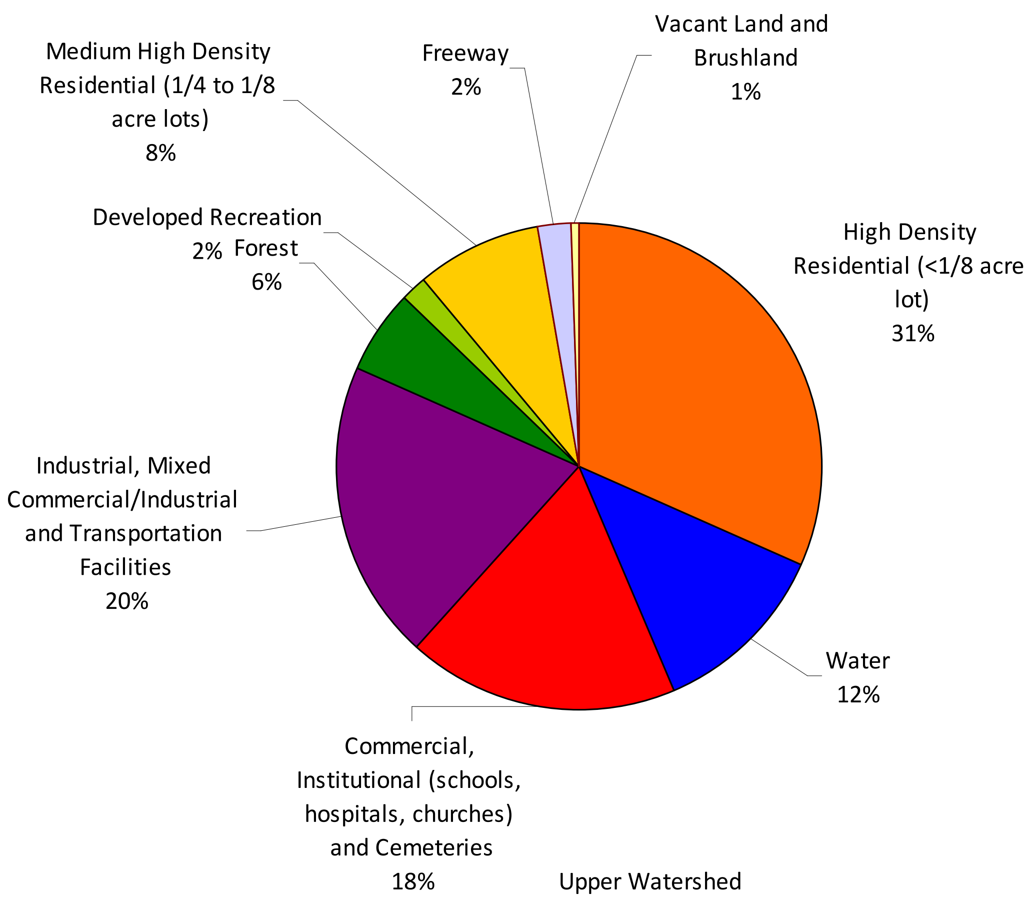


***Figure 2.6:** Upper Watershed Land Uses Pie Chart*

Source: RIGIS 2003/2004

cloverleaf ramps where Route 95 and Route 10 intersect. Once passing under Route 95, the flow appears to cross under a railroad right of way near 250 Station Street in Cranston. Existing plans indicate that the flow then continues under Route 10 picking up additional runoff from a limited section at the Route 10/Route 95 intersection, before discharging at a 48 inch diameter pipe at the head of Roosevelt Lake. Plans provided by the DPW also show a section of the Elmwood Avenue drainage system, between Route 95 overpass to the north and Hamlin Street to the south, also tie into the 48 inch diameter pipe prior to discharge to the pond.

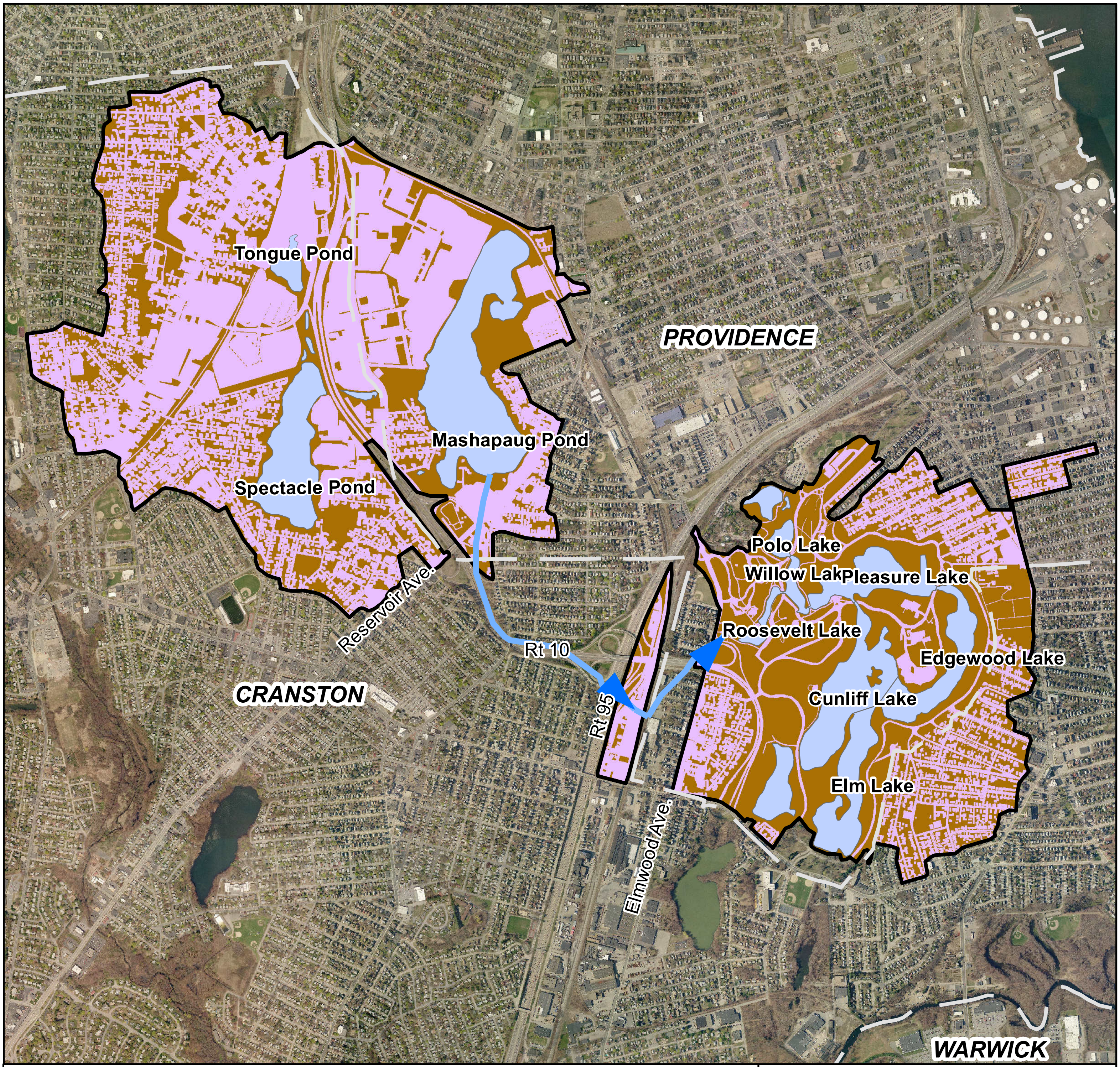
Land uses in the watershed were determined using RIGIS 2003/2004 land use / land cover data. Minor adjustments to the land use data were completed to reflect changes in land use between 2003/2004 and 2011. The largest change was the completion of the commercial development to the north of Tongue Pond, which in 2003/2004 was considered vacant land. Land use categories are presented in groups with similar nutrient loading profiles (**Table 2.2, Figure 2.3, and Figure 2.4**).

High density residential land made up the largest percentage of land use types within the RWP Ponds watershed, comprising 32% of the Upper Watershed. Commercial, Institutional (schools, hospitals, churches) and cemeteries make up 18%; and Industrial, mixed commercial/industrial and transportation facilities make up 20% of the land use. The impervious surface cover of the Upper Watershed is 60% based on 2003/2004 impervious surface data from RIGIS (**Table 2.3 and Figure 2.7**).

Table 2.3. Impervious surfaces in the Roger Williams Park Ponds Watershed[1]

	Upper Watershed (acres)	Lower Watershed (acres)	Total Watershed (acres)	% of Total Watershed
Pervious	270	314	584	36%
Impervious	589	220	808	50%
Water	118	116	234	14%
Total	977	649	1,626	100%

[1]2003/2004 impervious surface from RIGIS adjusted for 2011 conditions



Horsley Witten Group
Sustainable Environmental Solutions

Legend

Mashapaug Brook (arrows indicate flow direction)

City boundary

Watershed (Final Nov. 2011)

Watershed impervious surfaces

Pervious (forest, lawn, non-pavement areas)

Impervious (pavement, roofs, pools)

Water

N

0.25 Miles

Impervious surface: 2x2 ft pixel size, based on 2003/2004 aerial imagery, with adjustment for 2011 data
Aerial: 2008 Pictometric licensed data. Water polygons taken from RIGIS 2003/2004 land use data, which is based on 2003/2004 aerial imagery.

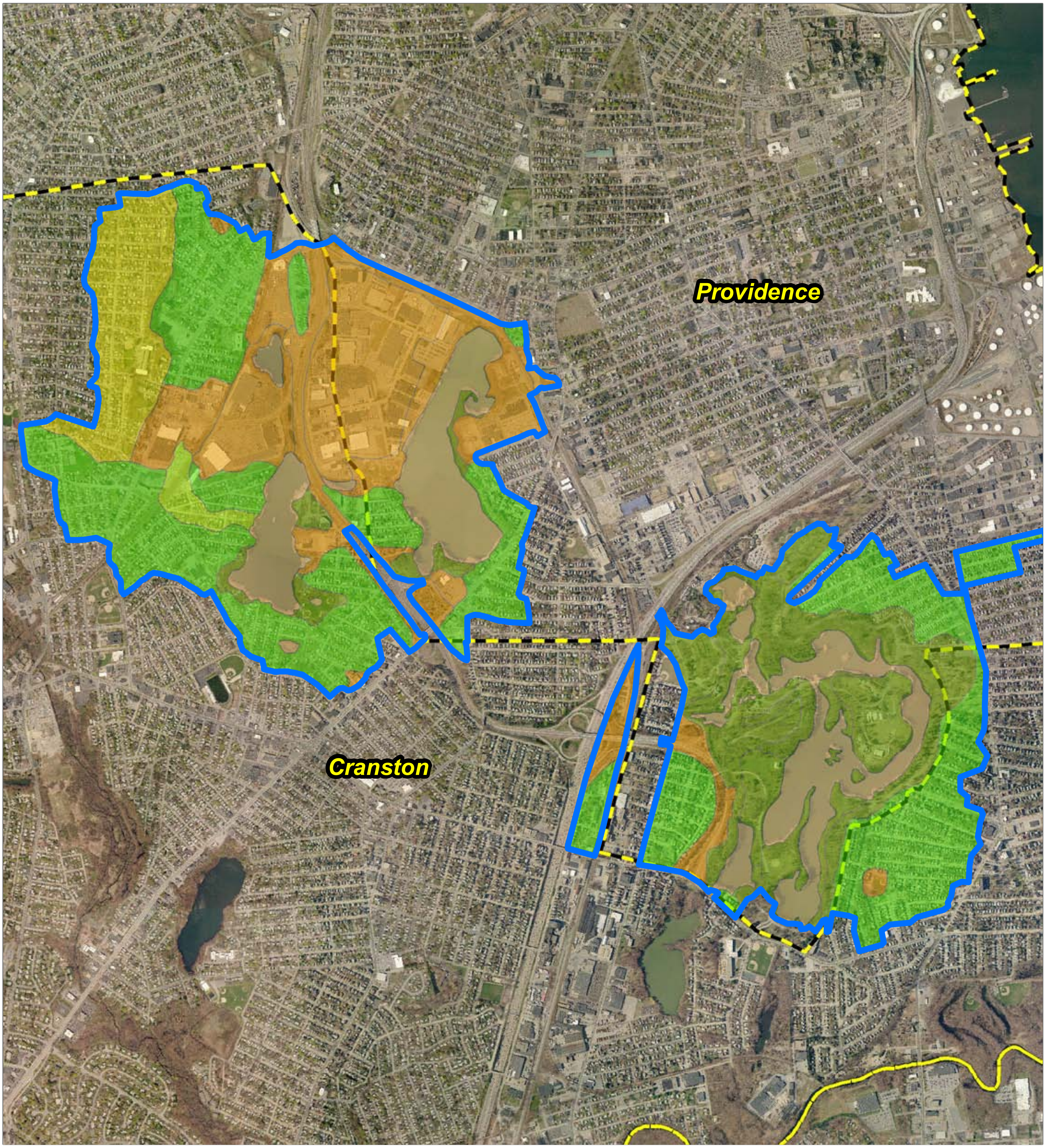
Roger Williams Park Ponds Watershed Impervious Surface

Date: 1/17/2012

Figure: 2.7

Coordinate System: NAD83, Rhode Island State Plane feet

File: Impervious_8x11



*Color Imagery: 2008

Legend

Roger Williams Pond Watershed (Revised October 2011)

Town Boundaries

A
A/VAR
B
B/VAR
Not Rated
Variable

N

2,200 Feet

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Roger Williams Park Ponds
Watershed Soils
Roger Williams Park
Rhode Island

Date: 1/17/2012

Figure 2-8

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_8x11_Soils_11058.mxd

2.3 Current Pond Conditions

The water quality of the RWP Ponds by almost any measure is poor. The observed conditions include indicators such as very poor clarity, frequent algal blooms, and noxious odor in the summer months. In addition, the presence of invasive aquatic vegetation in the summer and fall chokes significant portions of the ponds' surface area to limit boat access, indicating an ecosystem out of balance. The causes and contributors to these conditions are many and varied. This section documents the results of prior monitoring and assessments that relate the sampling data to these observed conditions.

2.3.1 Regulatory framework

The RWP Ponds and Mashapaug and Spectacle Ponds are placed in water use classification "B" pursuant to RIDEM Water Quality Regulations (RIDEM, 2010). The RWP Ponds and Mashapaug Pond are additionally classified as warm water fish habitat (RIDEM, 2010). Class B waters are designated for fish and wildlife habitat, primary and secondary contact recreational activities, and shall have good aesthetic value (RIDEM, 2010). Warm water fish habitat must have dissolved oxygen levels not less than 60% of saturation based on a daily average. An instantaneous minimum concentration of at least 5 milligrams per liter (mg/L) and the seven-day mean water column dissolved oxygen concentration shall not be less than 6 mg/L (RIDEM, 2007).

The RWP Ponds and Spectacle and Mashapaug Ponds are included in RIDEM's Section 303(d) and 305(b) reporting of impaired water bodies (**Table 2.4**). RIDEM, as required under Section 303(d) of the Federal Clean Water Act (CWA), prepares a list of all surface waters in the State to which beneficial uses of the water are impaired by pollutants on a biennial basis. An assessment, referred to as a Total Maximum Daily Load (TMDL) study, which identifies and quantifies the source of impairments and determines acceptable pollutant loads that would allow the water body to meet water quality standards, is required for those listed in the 303(d) report. RIDEM, as required by section 305(b) of the CWA, surveys the waters of Rhode Island for attainment of the fishable/swimmable goals of the CWA and reports these data as a water quality assessment.

Beginning in 2008, DEM integrated the state's Section 305(b) Water Assessment Report and Section 303(d) Impaired Waters List into one document, the Integrated Water Quality Monitoring and Assessment Report. There are five assessment categories in the combined report. Category 5 waters are impaired or threatened for one or more designated uses by a pollutant(s), and require a TMDL. This category constitutes the 303(d) List of waters impaired or threatened.

Table 2.4. Summary of Impairments under 303(d)/305(b) reporting requirements (RIDEM, 2011(4) and RIDEM, 2008)

	RWP Ponds	Mashapaug Pond	Spectacle Pond
Assessment Category [1]	5	5	4a
Designated Use	Impairment/Cause		
Fish and wildlife habitat (aquatic life use)	• Excess algal growth • Non-native aquatic plants Dissolved oxygen • Total phosphorus (TMDL addressed this impairment category in 2007, non-native aquatic plants are not recognized as a pollutant)	• Excess algal growth • Dissolved oxygen • Total phosphorus (TMDL addressed this impairment category in 2007)	• Excess algal growth • Total phosphorus
Fish consumption	Not assessed	PCBs in fish tissue (Scheduled to be assessed in 2022)	
Primary contact recreation	fecal coliform (TMDL scheduled for 2011)	fecal coliform (TMDL scheduled for 2011)	
Secondary contact recreation	fecal coliform (TMDL scheduled for 2011)	fecal coliform (TMDL scheduled for 2011)	

[1] Assessment category:
Category 5 – Impaired or threatened for one or more designated uses by a pollutant(s), and requires a TMDL. This Category constitutes the 303(d) List of waters impaired or threatened.
Category 4a – Category 4 waters are impaired or threatened for one or more designated uses but do not require development of a TMDL; the designation of subcategory "A" indicates that a TMDL has been completed.

The primary goal of the completed TMDL for *Phosphorus To Address 9 Eutrophic Ponds in Rhode Island* (including the RWP Ponds and Spectacle Pond) is to address water quality impairments associated with excess phosphorus loadings, including increased algal growth/chlorophyll a and low dissolved oxygen (RIDEM, 2007). Reducing phosphorus is the most effective way to reduce algal abundance since the growth of algae in freshwater systems is typically constrained by the availability of phosphorus (RIDEM, 2007). Reductions in algal abundance will reduce the variability of dissolved oxygen levels, which are typically high during the day when algae are photosynthesizing (producing oxygen), low during the night due to algal respiration (consuming oxygen), and low following death of the algal blooms due to microbial decomposition of the algae (RIDEM, 2007).

Therefore, the TMDL set a total phosphorus target as a surrogate for excess algal growth/chlorophyll a and low dissolved oxygen in the RWP Ponds and Spectacle Pond. The TMDL numerical target for the RWP Ponds is 25 micrograms per liter (ug/L) total phosphorus, which is based on criterion 10(a) of RIDEM's Ambient Water Quality Criteria and Guidelines for Toxic Pollutants (RIDEM, 2010). The *TMDL for Dissolved Oxygen and Phosphorus, Mashapaug Pond, Rhode Island (2007(2))* indicated that the total phosphorus levels in Mashapaug Pond must be reduced to a level of 20 ug/L to eliminate hypoxia in the deep portions of the Pond. The target for Mashapaug Pond was set at 20 ug/L total phosphorus, the same as Spectacle Pond, since it has similar characteristics to Spectacle Pond and is located immediately upstream of Mashapaug Pond (RIDEM, 2007).

In addition to the numeric total phosphorus goal, the TMDL covering the RWP Ponds and Mashapaug Pond lists the following additional goals (RIDEM, 2007):

- Reduction of algal abundance to levels consistent with designated uses with a target chlorophyll a concentration of approximately 9 ug/L; and
- Improvement of instantaneous dissolved oxygen levels in the ponds to the maximum extent feasible consistent with naturally occurring conditions.

Upon approval of both the TMDL covering the RWP Ponds, Spectacle Pond, and Mashapaug Pond, the General Permit for Rhode Island Pollutant Discharge Elimination System (RIPDES) Storm Water Discharge from Small Municipal Separate Storm Sewer Systems (MS4s), also referred to as the Phase II General Permit, and the General Permit for Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s require that the operator must address TMDL provisions in the Stormwater Management Program Plan (SWMPP). The TMDL addressing the RWP Ponds and Mashapaug Pond determined that structural BMPs are necessary, including the retrofitting of priority outfalls to address both bacteria and phosphorus impairments. Therefore, the operators of MS4s identified in the TMDL must prepare and submit a Scope of Work describing the process they will undertake to meet the provisions of the TMDL. The Cities of Cranston and Providence as well as the RIDOT operate MS4s that discharge to water bodies in the RWP Ponds watershed (RIDEM, 2007). It is likely that new Phase II General Permit will include additional language requiring compliance with TMDL studies.

2.3.2 Sedimentation Problems and Internal Phosphorus Recycling

Sedimentation Problems

Average depths of the RWP Ponds were estimated from the bathymetry data reported by EPA/AED in 2011 (unpublished), and comparison of these data with average depths reported by Lee Pare and Associates (Pare) in 1980 indicate that the RWP Ponds appear to have lost water volume during the 30 year period. Lake volume is often estimated by multiplying the average depth by the surface area (this is how the lake volume was calculated in 1980). Surface areas reported in the 1980 data are different than those determined more recently using the 2003/2004 land use data available from RIGIS; therefore, comparison between 2011 and 1980 volume data is more difficult. The most plausible accounting for the differences in pond areas between the 1980 and 2011 data stems from limited access to high quality spatial data in 1980. Images provided for the RWP Ponds in the 1980 Pare reports are less detailed than currently available data. Based on review of the Pare study (1980), it appears that water depths were calculated throughout the ponds using a depth probe, providing reasonable assurance that the depth data as accurate enough for comparison. Assuming the RWP Pond surface areas have not changed much since 1980, the 2011 surface areas and the 1980 lake depths were used to calculate a volume for comparison of the lake volumes between the two periods.

Using these assumptions, a 35% reduction in total RWP Pond volume was determined between 1980 and 2011. This observed reduction in depth is most likely the result of sediment deposits resulting from discharge from the Upper Watershed and Lower Watershed stormwater inputs. However, is does seem unusual that Pleasure, Edgewood, and Elm ponds would have a larger reduction in volume than Roosevelt and Willow Ponds (since these two ponds are upstream, and presumably would have more sediment deposition than downstream ponds).

Table 2.5. Depth, Area, and Volume of the Roger Williams Park Ponds

Pond	Avg. Depth[1] 2011 (ft)	Avg. Depth[2] 1980 (ft)	Area[3] 2011 (acres)	Area[2] 1980 (acres)	Volume[4] 2011 (acre feet)	Volume[2] 1980 (acre feet)	Volume 1980 using 2011 area (acre feet)	Reduction in Volume[5] (%)
Roosevelt Lake	1.3	2.0	3.8	5.1	4.9	10.3	7.4	33%
Willow Lake	2.0	3.0	3.4	3.6	6.7	10.7	10.1	33%
Polo Lake	2.3	3.3	3.6	3.7	8.2	11.9	11.8	30%
Pleasure Lake	2.6	4.9	18.6	21.5	48.8	107.7	91.4	47%
Edgewood Lake	3.0	4.9	19.3	20.6	57.0	103.0	95.0	40%
Cunliff Lake	4.3	5.6	32.3	34.7	137.8	191.0	180.2	24%
Elm Lake	4.3	6.9	21.7	22.3	92.7	156.0	149.7	38%
Total			102.7	111.6	356.2	590.5	545.5	35%

Notes:

[1]Calculated from bathymetry data provided by EPA, data collected during summer 2011, unpublished

[2] Planning Study and Preliminary Recommendations, Improvement of Water Quality in Roger Williams Park, April 1980, Lee Pare & Associates (Table 1). Report indicates that water and soft sediment depths were taken throughout the entire pond system to determine soft sediment and water depths. No detailed information is provided on how surface area was estimated.

[3] Area data obtained from RIGIS 2003/2004 Land Use coverage, this data is based on 2003/2004 orthophotography

[4]Volume calculated from area and average depth of each pond.

[5]Reduction in volume using 2011 surface area and 1980 lake depths to calculate 1980 lake volumes

Internal recycling

Sediment samples were collected by EPA/AED in 2011 (unpublished) and analyzed by Spectrum Analytical of Agawam, Massachusetts, for total iron-bound and loosely sorbed phosphorus as well as percent solids, moisture, and total volatile solids (**Table 2.6**). Loosely sorbed phosphorus is readily available for uptake by organisms through sediment-water column exchange if a diffusion gradient exists. Iron-bound phosphorus is generally available only during anoxic conditions (low or no oxygen) at the sediment-water column interface when iron-phosphorus minerals are broken down due to microbial action. The total phosphorus assay reports all forms of phosphorus in the sediment, those available for release and uptake by algae and plants as well as those forms that are unavailable.

Sediment phosphorus can be a major concern in the management of a water body due to the cyclical nature of the release. Low dissolved oxygen conditions allow the release of phosphorus into the water column, which can stimulate algal growth. Once the algae dies it falls to the bottom and decays, consuming oxygen, which adds to the conditions for phosphorus release while also adding phosphorus to the sediment for release when the next anoxic event occurs. This cycle is referred to as “internal recycling” of phosphorus and will continue to occur even after watershed sources of phosphorus are reduced. -In some lakes, it is the major source of phosphorus to the lake.

Iron-bound phosphorus concentrations can be used to estimate the potential amount of phosphorus that could be released into the water column under the correct conditions, namely low dissolved oxygen. Six of the eight sediment collection sites in the RWP Ponds are considered to be representative of general pond conditions. One site in Cunliff Lake and a second in Elm Lake are deemed unrepresentative due to a very shallow depth of sample collection (less than 1.6 feet). The average ironbound phosphorus in the remaining six sites is 161 milligrams phosphorus/kilogram (mg P/kg) dry weight. Values over 200 mg P/kg dry weight generally signal strong potential for sediment phosphorus release. Loosely sorbed phosphorous is very low at all sites and therefore not expected to contribute a substantial amount to the system. Total sediment phosphorus values are within the range expected for an aquatic system.

Based on EPA/AED 2011 field data, there is a reduction of dissolved oxygen with depth in all the ponds except Roosevelt and Willow Lakes. Roosevelt and Willow Lakes have fairly low (91.4 mg P/kg in Roosevelt and 86.3 mg P/kg in Willow) iron-bound sediment phosphorus, so it will be assumed that the potential for sediment phosphorus release in these lakes is low due to the low values for iron-bound sediment phosphorus and lack of dissolved oxygen stratification. The rest of the ponds exhibit definite dissolved oxygen stratification, with combinations of depths of 3.3 feet or greater and iron-bound sediment phosphorus levels high enough to exhibit release.

Sediment phosphorus release was estimated for all the RWP Ponds in areas with a depth 3.3 feet or greater except Roosevelt and Willow Lakes, for reasons previously described. Sediment data specific to each pond were utilized for Polo and Pleasure Lakes to determine potential levels of phosphorus release from the sediments. Since sediment samples were not available for Elm Lake, the values for Cunliff and Edgewood Lakes were averaged and applied over the these three lakes.

The total mass of sediment phosphorus available for release is estimated at 988 lbs using pond specific data or 1,126 lbs averaging all representative samples across the affected ponds (**Table 2.6**). Typically, 10% of available phosphorus (here only iron-bound phosphorus as loosely sorbed phosphorus levels are very low) is estimated to be released annually, most often during the summer when low dissolved oxygen events correspond with increased microbial and plankton activity due to increased temperatures. This is based on experience with other lakes in southeastern New England, but is not based on published research, and variability is certainly possible. Assuming a release of 10% of the total mass of sediment phosphorus, 113 lbs of phosphorus are estimated to release annually, which corresponds to approximately half of the annual estimated Lower Watershed phosphorus load. If the 113 lbs of phosphorus were released into the water column, the concentration in the five lakes where internal loading was estimated would increase by 11 to 12 ug/L. This is more than enough phosphorus to support algal blooms, and indicates that sediment phosphorus may need to be addressed with in-lake management at some point, even if the other major phosphorus sources are brought under control.

Table 2.6. Estimation of Sediment phosphorus available in RWP Ponds

Lake	Polo	Pleasure	Cunliff, Elm & Edgewood	Using average Iron Bound P number across all 5 lakes
Total mass of sediment P available for release (lbs)	4	88	895	1,126
10% of sediment P available for release (lbs)	0.4	8.8	89.4	113
Increase in water column P (mg/L) if 10% of the available sediment P were released into water column	0.02	0.07	0.11	0.12

Assumptions: Phosphorus in the top 4 centimeters of the sediment interacts with the water column
Release from Roosevelt and Willow Lakes was assumed to be negligible due to lower iron bound phosphorus levels and maintenance of oxygenated water column.

2.3.3 Water Quality

Only a few historical data points are available for water quality in the RWP Ponds. In June of 1980 the total phosphorus values were reported as 115 µg P/L at the Roosevelt Lake inlet and 301 µg P/L at the Elm Lake outlet during a period of hot dry weather (Lee Pare and Associates, 1980(2)). In December 1979, total phosphorus values of 15 µg P/L at the Roosevelt Lake inlet and 22 µg P/L at the Elm Lake outlet were reported (Lee Pare and Associates, 1980(2)). Interestingly, the orthophosphate concentrations reported in December 1979 were essentially the same as the total phosphorus concentrations, indicating that the phosphorus in the system was completely in the dissolved form (Lee Pare, 1980(2)). No orthophosphorus values were reported for the summer sampling.

University of Rhode Island Watershed Watch (URIWW) volunteer monitors collected data over several years spanning 1993 to 2005, which was the only source of data for the TMDL encompassing the RWP Ponds and Mashapaug Pond. These data are collected in the late spring, summer, and early fall. The total phosphorus values reported by URIWW are generally at the same order of magnitude as the summer Roosevelt Lake inlet data, thought they are highly variable (**Table 2.7**). It is difficult to come to a definitive statement regarding changes to water quality with such limited summer total phosphorus values from the 1980s, but it appears that there have been problems with elevated nutrients in the ponds for several decades.

Secchi disk measurements for the RWP Ponds in the summer of 1980 were reported as ranging from one to two feet, within the range observed in the URIWW data (1993-2005), and those values observed by EPA in the summer of 2011 (Lee Pare and Associates, 1980(2); EPA, 2011; URIWW, 2010). Mashpaug and Spectacle Pond data are also provided for comparison to values observed in the RWP Ponds as they both drain into the RWP Ponds (**Table 2.8 and 2.9**).

Total phosphorus, chlorophyll, and Secchi depths reported by URIWW place the RWP Ponds, as well as Mashapaug and Spectacle Ponds, in the eutrophic to hypereutrophic trophic state using Carlsons Trophic State Index (TSI) (**Table 2.10**). Eutrophic systems are characterized by high productivity, high algal growth, poor water clarity, and low dissolved oxygen.

Table 2.7. Summary of Water Quality Data from URI Watershed Watch for Roger Williams Park Ponds (1993-2012)[1]

	WW140 - Pleasure Lake						WW142-Roosevelt Lake			WW37-Cunliff Lake		WW295-Elm Lake	
Months samples taken	**May-Nov**	**May-Oct**	**May-Oct**	**May-Oct**	**June-Aug**	**June-Oct**	**May-Nov**	**May-Oct**	**June-Oct**	**May-Sept**	**June-Oct**	**May-Aug**	**June-Oct**
Year	**1993**	**1994**	**2001**	**2002**	**2005**	**2012[2]**	**1993**	**1994**	**2012[3]**	**2003**	**2012**	**2005**	**2012**
Chlorophyll a (ug/L)													
minimum	0.6	9.0	10.1	6.4	12.8	27.9	4.7	6.6	6.7	11.8	22.4	17.0	19.8
maximum	52.0	63.8	38.3	73.6	87.5	89.6	29.5	57.0	61.5	100.7	87.9	79.8	93.0
average	22.2	27.7	19.7	46.0	56.6	54.7	16.5	25.8	31.3	54.1	55.4	55.9	57.9
count	14	11	14	7	5	11	14	11	22	6	11	5	11
Phosphorus, Total (ug/L)													
minimum	49	80	70	31	53	59	44	56	31	113	40	56	49
maximum	140	143	81	122	194	127	85	85	119	127	115	171	102
average	85	105	76	64	140	100	65	69	76	120	87.4	97	82
count	3	3	3	3	3	5	2	3	6	2	5	6	5
Secchi Depth (m)													
minimum	0.8	1	0.6	0.4	0.2	0.5	1.0	1.4	0.5	0.4	0.4	0.4	0.5
maximum	3.1	2.6	1.1	0.8	1.0	1.4	2.0	1.7	0.6	1.2	1.4	0.8	1.7
average	1.6	1.4	0.9	0.6	0.5	0.8	1.6	1.6	0.5	0.7	0.8	0.6	0.9
count	18	14	12	3	9	11	14	14	11	16	11	9	11

[1] All samples taken 1 meter (m) from surface
[2] 2012 data collected at sampling site 530
[3] 2012 data collected at sampling site 534

Table 2.8. Summary of Water Quality Data from URI Watershed Watch for Mashapaug Pond (1993-2010) [1]

	WW25 - Mashapaug							
Sample month range	May-Oct	May-Oct	May-Nov	May-Oct	May-Aug	May-Oct	May-Oct	May-Oct
Year	1999	2000	2001	2002	2003	2004	2009	2010
Chlorophyll a surface (ug/L)								
minimum	8.3	11.0	3.8	24.8	9.4	8.8	19.1	18.4
maximum	42.1	38.5	38.1	65.3	43.6	44.3	54.0	50.6
average	28.6	25.2	17.5	39.9	25.6	21.0	30.5	35.8
count	8	11	12	10	7	8	10	10
Total Phosphorus -surface (ug/L)								
1999 Min	32	34	37	28	19	25	12	41
1999 Max	45	37	74	41	30	40	44	56
1999 Average	37	36	50	33	25	34	28	48
count	3	3	3	3	2	3	4	3
Total Phosphorus - deep (ug/L)	(deep = 3-7 meters)							
1999 Min	28	30	46	NS[2]	NS	NS	36	45
1999 Max	74	50	185	NS	NS	NS	51	49
1999 Average	45	37	120	NS	NS	NS	43	47
1999 Count	3	3	3	NS	NS	NS	4	2
Secchi depth (m)								
1999 Min	0.5	0.6	0.9	0.7	0.6	0.6	0.7	0.8
1999 Max	1.8	1.3	2.5	1.3	2.1	1.0	2.1	1.5
1999 Average	0.9	0.9	1.5	0.9	1.4	0.8	1.1	1.1
1999 Count	18	12	3	12	8	8	23	19

[1]surface samples collected 1 m from surface
[2]No Sample

Table 2.9. Summary of Water Quality Data from URI Watershed Watch for Spectacle Pond (1993-2010) [1]

	WW49-Spectacle											
Sample month range	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**May-Oct**	**Apr-Oct**	**May-Oct**
year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Chlorophyll surface (ug/L)												
minimum	4.6	12.2	5.2	12.7	14.9	8.6	10.5	8.7	16.8	9.3	7.2	12.6
maximum	88.6	114.5	96.3	57.3	136.8	86.5	106.5	197.8	241.2	124.3	88.7	55.7
average	39.0	48.8	35.6	34.6	43.4	33.9	37.1	35.0	71.5	41.2	45.5	33.4
count	13	17	44	21	17	9	19	19	19	20	22	18
Total phosphorus - surface (ug/L)												
minimum	47	61	37	49	39	42	37	26	26	27	33	34
maximum	64	81	61	69	86	61	74	59	97	63	50	49
average	58	71	48	59	57	53	51	40	61	49	42	45
count	3	3	3	3	3	3	3	3	4	4	4	5
Total phosphorus -bottom (ug/L) Bottom = 3-4 meters												
minimum	NS[2]	NS	NS	NS	NS	NS	NS	NS	18	30	33	21
maximum	NS	NS	NS	NS	NS	NS	NS	NS	367	285	49	122
average	NS	NS	NS	NS	NS	NS	NS	NS	122	112	43	49
count	NS	NS	NS	NS	NS	NS	NS	NS	4	4	3	5
Secchi (m)												
minimum	0.5	0.5	0.6	0.5	0.5	0.6	0.4	0.9	0.7	NS	0.5	0.7
maximum	1.7	1.5	1.6	1.5	3.2	1.6	1.6	1.6	4.6	NS	2.2	1.3
average	0.9	0.8	1.0	0.8	1.2	0.8	1.1	1.2	1.1	NS	1.0	1.0
count	21	19	23	22	18	9	19	19	19	NS	24	18

[1]surface samples collected 1 m from surface
[2]No Sample

Table 2.10. Approximate thresholds for changing trophic state (from Mattson et al. 2004)

Trophic State	Description	Seechi Depth (m)	Chlorophyll a (µg/L)	Total Phosphorus (µg/L)
Oligotrophic	Low productivity; low algal growth; clearer waters	>4 (13 ft)	<2.6	<12
Mesotrophic	Moderate productivity	2 - 4 (6.6 - 13 ft)	2.6-7.2	12-25
Eutrophic	High productivity; high algal growth; poor water clarity; often low dissolved oxygen	0.75 - 2 (2.5 - 6.6 ft)	7.2 - 30	25-65
Hypereutrophic	High productivity; excessive algal growth; very low water clarity	<0.75 (<2.5 ft)	>30	> 65

2.3.4 Rooted Aquatic Plants and Algae Problems

Historically, water quality has been a concern in the RWP Ponds since at least the late 1920s when copper sulfate was applied for algae control purposes and extensive growth of weeds was also reported (Lee Pare & Associates, 1980). In 1936 and 1937 Works Progress Administration (WPA) money was used to draw down Monument and Roosevelt Lakes. Sediments in these two ponds were removed and replaced with sand. Due to recurrence of growth in Roosevelt Lake as well as financial restrictions, this treatment was not duplicated in the remaining ponds. During this time period, weeds were also removed manually with rakes in Willow and Pleasure Lakes (Lee Pare & Associates, 1980). In the 1980s the water quality concern was mainly blue-green algae (Lee Pare & Associates, 1980).

Lycott Environmental has been managing the RWP Ponds since 1997 for nuisance phytoplankton blooms, invasive aquatic vegetation, and excessive levels of white water lily (*Nymphaea odorata)* and yellow water lily (*Nuphar lutea)* growth (Wheaton, 2011). Copper sulfate and/or chelated copper carbonate have been applied periodically to reduce phytoplankton levels in all the ponds except Elm Lake. Treatment is generally conducted in June or early July before water temperatures reach 85°F to reduce the concern of reducing oxygen levels in the water column due to degradation of algae (Wheaton, 2011).

Management of rooted aquatics is assessed annually with treatment focused on areas of heavy plant growth. In the past few years (one to five years) areas with heavy curlyleaf pondweed (*Potamogeton crispus)* growth have been treated with Reward (active ingredient is Diquat) in late May to early June, prior to turion release (Wheaton, 2011). All ponds except Elm Lake were treated with Reward in 2011 to retard *Potamogeton crispus* growth. White water lily management through use of AquaPro (active ingredient is glyphosate) has been performed in areas of heaviest growth in Edgewood Lake, and at the perimeters of Polo, Willow and Pleasure Lakes in 2011, similar treatments were applied in 2012. In 2007, Pleasure, Willow, and Edgewood Lakes and the Japanese Gardens were treated with 2,4-D (2,4-dichlorophenoxyacetic acid) for control of white water lily (Wheaton, 2011).

The Japanese Gardens have most recently been treated with Sonar (active ingredient is fluridone) during 2011 to remove fanwort (*Cabomba caroliniana)* before it becomes a problem due to its status as an invasive species. The 2011 fall survey indicated that Cabomba has been observed in the shallows around the perimeters of Willow, Polo, Pleasure Lakes and the upper portion of Edgewood Lake. These areas of concern were also managed with fluridone in 2012.

Given the shallow depth of all ponds in this system, the potential for rooted plant growth to impair uses including fishing, aesthetics, and overall habitat value is rather high. Given what are expected to be fertile sediments, rooted plant growths could be quite dense, and the relatively new arrival of fanwort represents a major threat to pond integrity. Even with low water clarity due to incoming solids or internally produced algae, the water depth is shallow enough to allow enough light penetration to foster substantial rooted plant growth, so some management action is needed to support designated and desired uses of these ponds.

Two grab samples were collected in September of 2011 by RIDEM as part of their Cyanobacteria Monitoring Program. These samples exhibited high levels of blue-green algae (RIDEM, 2011). RIDEM selected the RWP Ponds as a sampling location in 2011 based on high historical chlorophyll a concentrations in data obtained from URIWW and anecdotal evidence of algae blooms (RIDEM, 2011(2)). This sampling program was designed to provide information on the extent and level of cyanobacteria present in Rhode Island's waters and is not expected to track cyanobacteria extent, concentrations or presence annually in the RWP Ponds (RIDEM, 2011(2)). No other known plankton data for the RWP Ponds exists other than a species list provided in the Lee Pare report in 1980, which utilized a plankton net for sampling and is not likely to give an accurate impression of relative algal abundance or even composition.

Erratic flushing and water chemistry can be expected to cause fluctuations in algal community composition and abundance, but with high nutrient levels, algal blooms are likely, and blue-greens (cyanobacteria) have been cited as a dominant component of the algal community. While there is great variation among cyanobacteria, there is potential for odor and even toxicity problems when cyanobacteria are abundant.

2.3.5 Shoreline Conditions

The pond's shorelines typically fall into one of the following four categories:

1. *Formalized pond edge* – includes a stone or concrete hard pond edge with manicured/mowed lawn up to the water's edge with no shoreline buffer plantings. These areas typically have a gentle to moderate slope. This condition is typically found in the central (most visited) portion of the Park, which includes Roosevelt, Willow and Polo Lakes.

2. Lawn edge – includes mowed lawn area to the water's edge, but does not have the hard formalized edging found in the first category with little to no buffer plantings. These areas typically have a gentle to moderate slope. This condition is also found

mainly in the central portion of the Park, which includes Roosevelt, Willow and Polo Lakes.

3. *Combination lawn and shoreline vegetation* – includes a combination of mowed lawns and some shoreline vegetation. These areas typically have a gentle to moderately steep slope, but can also be found on some of the steeper grass slopes along F.C. Greene Boulevard. This condition can be found along the western shoreline of Edgewood Lake in the area of the Botanical Center, as well as some of the eastern shoreline of Edgewood Lake, the Northern Shoreline of Pleasure Lake and the a portion of the western shoreline (in the area of the Temple of Music) of Cunliff Lake.

4. *Natural buffer* – includes almost exclusively shoreline vegetation with little to no mowed lawn. These are typically the steeper slopes and can be found predominantly in the eastern and sound end of the Park along F.C. Greene Boulevard, which includes portions of Edgewood, Elm and Cunliff Lakes.

Although a complete shoreline study was not part of the scope of this report, visual observations were made by the Project Team during two separate site assessments in the summer and fall of 2011. Site assessments were completed at approximately a dozen shoreline locations to provide sufficient information to prepare a general existing shoreline condition assessment. It should be noted that a more detailed shoreline study, conducted both on land (walking the entire shorelines) and from the water (by boat) would need to be provided to accurately assess the current shoreline conditions of the ponds. The visual observation performed by the Project Team and used for this assessment should be considered as "snap shots" of the current shoreline and not a comprehensive shoreline study.

Based upon random shoreline observation throughout the Park by the Project Team, it was determine that the current shoreline conditions could be grouped into the following three categories:

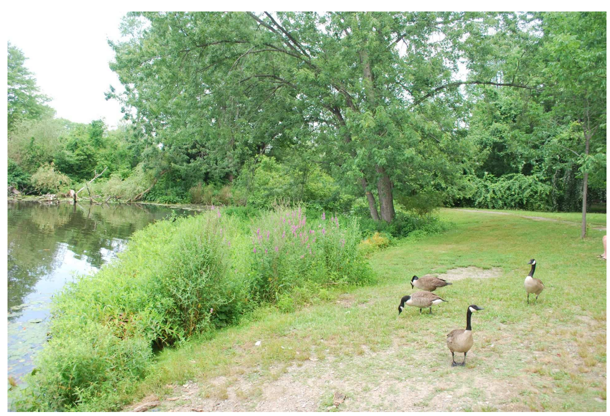
1. Good: Generally healthy plant growth, shoreline stabilized, and little to no lawn.
2. Fair: Shoreline stabilized, minimal shoreline plantings, and mowed lawn potential for Canada Geese habitat.
3. Poor: Degraded shoreline, lawn mowed to pond edge, bare soil present, destabilized shoreline, erosion present, and Canada Geese habitat/feeding area.

Poor

Most of the shorelines that fall into either the formalized pond edge or lawn edge (Roosevelt, Willow and Polo Lakes) have been categorized as poor. These areas are often the most frequently visited and typically provide good Canada Geese habitat as well as feeding locations. The shorelines are typically degraded with little to no vegetation present and the bare surfaces are susceptible to increased erosion. In the areas were lawn has been maintained, there is visible evidence of tire "rutting" caused by mowing equipment as they mow up to the pond edge. These areas would benefit from non structural projects that may include complete shoreline restoration, the addition of shoreline plantings, or the reduction in the frequency of mowing (Section 3.2.3).

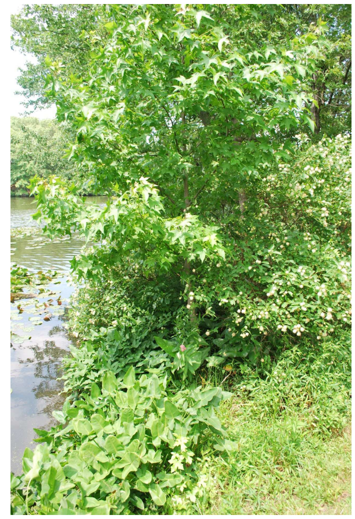

Fair

Most of the shorelines that fall into "Combination of Lawn and Shoreline Vegetation" have been categorized as fair. These areas include open lawn areas leading to a vegetated shoreline buffer that typically could benefit from some stabilization, additional plantings, invasive species removal, or all three. The shorelines typically have evidence of some erosion, a thin covering of vegetation, and invasive species present. The shorelines in these locations are not typically prime geese habitat, but often still provide easy shoreline access from the water. These areas would benefit from non-structural projects, which may include some shoreline restoration, the addition of shoreline plantings, and/or the removal of invasive species. A reduced mowing schedule up-gradient of these areas to create an additional "grass meadow" may also be considered (**Section 3.2.3**).

Good

The shorelines that fall into the "Natural Buffer" classification have been categorized as good. Some of the shorelines classified as "Combination of Lawn and Shoreline Vegetation," in particular in the eastern portion of the Park along F.C. Greene Memorial Boulevard, are included with in the category as well. These areas include heavily vegetated shorelines consisting of mainly native plant species and show little to no disturbance. The shorelines in these locations do not typically provide geese habitat or easy shoreline access from the water.   It should be noted if a shoreline is classified as in good condition, it does not mean that erosion problems do not exist or that the shoreline would not benefit from some buffer restoration. It only indicates that problem sites were not identified or readily visible during the Project Team site visits.



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Lower Watershed
Shoreline Buffer Conditions
Roger Williams Park
Rhode Island

Date: 1/17/2012

Figure 2.9

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure2_9_Shoreline_11058.mxd

2.3.6 Biodiversity

Biodiversity is often defined as the number of different types of organisms within a system. The RWP Ponds have communities of birds, plants (both aquatic and terrestrial), fish, invertebrates, and mammals as well as other organisms such as bacteria.

Little information is available on the number and species of birds found within the RWP Ponds, although the first Bioblitz survey in 2000 identified 41 bird species in the Park. It is known that a large number of resident waterfowl consisting of Canada Geese and ducks are a concern. The RWP Ponds are expected to be frequented by many other bird species that use both the Park grounds and the Ponds. Aquatic plants, both algae and rooted aquatics are both discussed in **Section 2.3.4.** Upland plant data were not available. Invertebrate and mammal use of the RWP Ponds is expected but no data are available.

Due to the Ponds popularity as fishing locations and some past studies, there is some information available on the number and species of fish found within the RWP Pond network. A fish survey conducted in 1996 indicates that white perch were the most abundant species (233 fish collected), with bluegill the next abundant species with 63 fish collected RIDEM, 2011(3)). Recent anecdotal reports of large amounts of carp suggest the fish population may be contributing to the Ponds problems. Carp can stir up the bottom sediments to create turbidity and elevate the nutrient levels. However, the 1996 data reported only 4 common carp within the collected sample (RIDEM, 2011(3)). While the carp were larger and accounted for a proportionally greater part of the fish biomass, the 1996 data do not indicate a major problem. Changes in fish community features over the last 15 years are certainly possible, additional studies are required to determine the potential of carp impacts on the Ponds.

During the development of this report, a fish survey was completed in the spring of 2012 by RIDEM Fish and Wildlife and the EPA/AED. Fish species collected consisted of Black Crappie, Bluegill, Carp, Largemouth Bass, Pumpkin Seed, Golden Shiner, White Perch, and Yellow Perch. As part of this survey fish tissues samples were analyzed to determine the level of toxicity present within the fish. Per the report's findings, "concentrations of metals in fish captured from these Ponds were generally low or not detected, and fall below the range of international limits of safe levels of metals in fish." However, the report found "PCBs were detected in all fish species collected. Largemouth Bass had the highest PCB concentration and Black Crappie had the lowest PCB concentration. Among pesticides, only DDE was at measurable levels and all the other pesticides were at or below detection limits." The full results of this analysis can be found in **Volume III.**

2.4 Sources of Impacts to Pond Conditions

As stated previously, the sources of impacts to the Ponds are many and varied. This section presents the estimated pollutant loads from contributing sources using a simple loading model. The Project Team used the Lake Loading Response Model (LLRM) developed by AECOM (2009) to provide a broad-based assessment of average/ long range conditions.

LLRM uses loading coefficients based on land use and watershed flows for both baseflow and stormflow to calculate watershed loading. The model provides for simple flow and pollutant load attenuation of upstream Mashapaug and Spectacle Ponds and allows for inputs from specific sources including atmospheric deposition, waterfowl, and internal recycling.

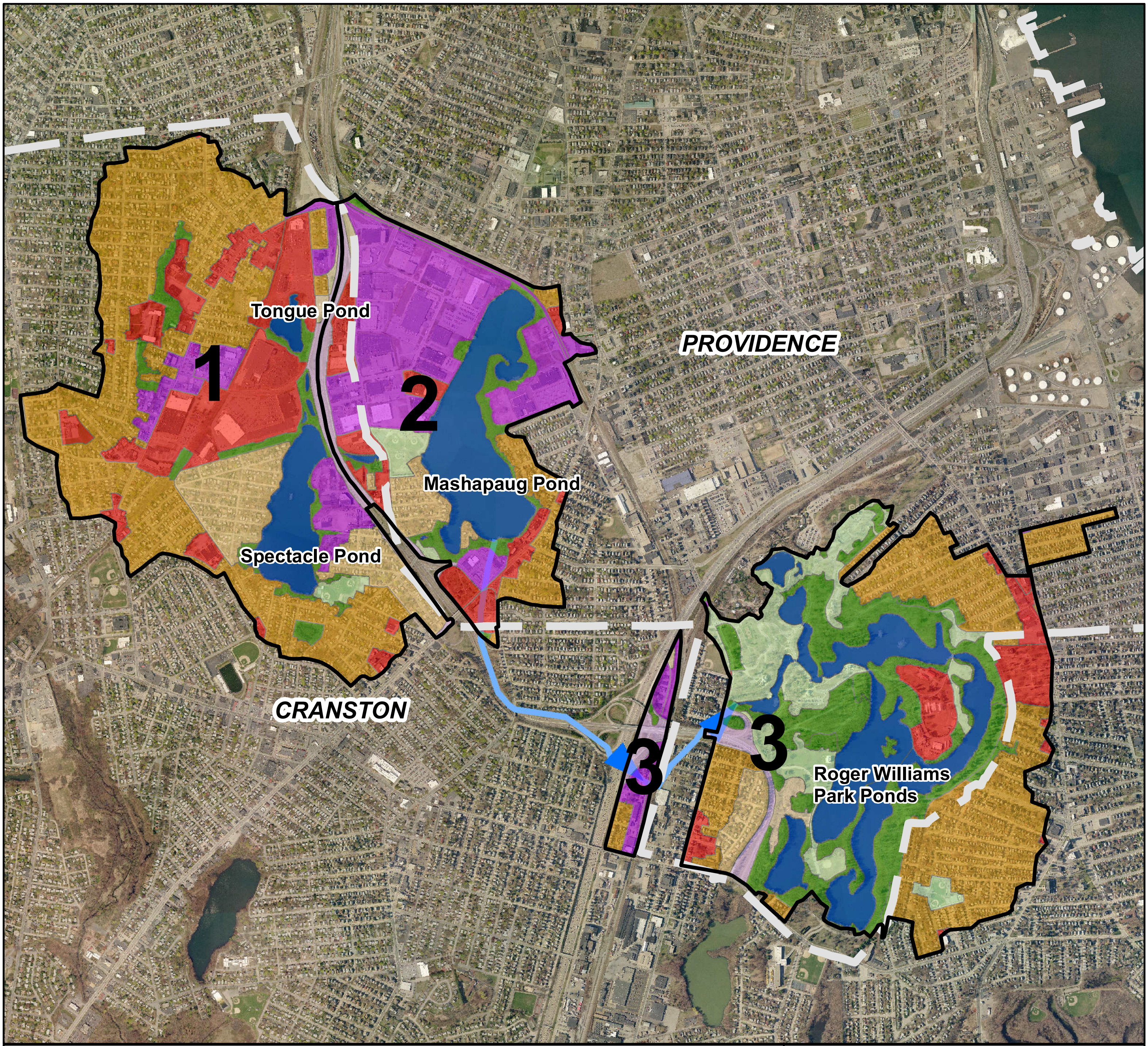
The model was not designed to simulate short-term impacts from temporally fluctuating inputs such as stormwater runoff from single events, but rather provides an indication of steady state conditions. LLRM is used here to predict levels of phosphorus and nitrogen inputs and water body concentrations as well as, chlorophyll a and Secchi disk transparency within the ponds. The model allows for easy evaluation of source control management options and comparison of load reduction benefits to help select the most cost effective measures (see **Appendix B** for model input requirements, reference variables, references, and output spreadsheets)

2.4.1 Sources and Magnitude of Watershed and In-pond Nutrient Loading to the RWP Ponds

Three subwatersheds, one each for Spectacle Pond, Mashapaug Pond, and the RWP Ponds, and designated 1, 2, and 3, were modeled in the RWP Ponds LLRM model (see **Figure 2.10**).

The model was configured to match the flow patterns observed in the field. Water flowing from the Spectacle Pond subwatershed flows into the Mashapaug Pond subwatershed ultimately discharging into the RWP Ponds. The RWP Ponds subwatershed was modeled as draining directly into the pond system. RIGIS land use data from 2003/2004, the most recent land use data available, were used to calculate land use areas within each subwatershed. Nutrient loading and precipitation coefficients, atmospheric deposition, waterflow numbers, and internal recycling inputs selected for use in modeling are described in **Appendix B**.   On-site wastewater disposal and point sources were assumed to be not applicable because the watershed is sewered and there are no known major point sources. Model calibration was performed using data from several sources described in **Appendix B**.

Although all the ideal data were not available to calibrate the LLRM model for the RWP Ponds, the predicted mean chlorophyll a concentration and minimum and average Secchi disk values are very close to measured values (**Table 2.11**). The in-pond predicted total phosphorus values are slightly lower than the measured average in-pond value, but well within acceptable tolerances, and actual values are be expected to fluctuate substantially during a given year and available data may not be sufficient to establish an accurate average. The model should be viewed as a tool to provide guidance on the relative effect



Mashapaug Brook (arrows indicate flow direction)

City limits

LLRM Subwatershed Areas; subwatershed indicated by large bold number

Land Use Grouped by Model Land Use Types

- Medium High Density Residential (1/4 to 1/8 acre lots)
- High Density Residential (<1/8 acre lots)
- Industrial, Mixed Commercial/Industrial and Transportation Facilities (terminals, docks, railroad)
- Freeway
- Commercial, Institutional (schools, hospitals, churches) and Cemeteries
- Developed Recreation
- Vacant Land and Brushland
- Forest
- Water

N

Miles

0.25

Land Use: 2003/2004 RIGIS land use with color palette used to illustrate the groupings used by the LLRM model. Minimum mapped unit for land use is 0.5 acres. City limits from RIGIS. Aerial image: 2008 Pictometric licensed image.

Coordinate System: NAD83, Rhode Island State Plane feet

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Roger Williams Park Ponds Watershed Land Use and Model Watersheds

Date: 1/17/2012

Figure: 2.10

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implementation of management measures will have on the RWP Ponds rather than a specific absolute loading number.

The modeling results indicate that the major sources of phosphorus to the RWP Ponds system are the surrounding subwatersheds, with the Upper Watershed (Spectacle and Mashapaug Pond subwatersheds) contributing almost 40% of the watershed phosphorus load to the RWP Ponds (**Table 2.12**).

Table 2.11. Calibrated model data as compared to actual data

	Existing Conditions	
Parameter	**Calibrated Model Value**	**Actual Data**
Phosphorus (ug/L)	76	92
Nitrogen (ug/L)	998	1116
Mean Chlorophyll (ug/L)	35.7	36.1
Peak Chlorophyll (ug/L)	131.7	100.7
Mean Secchi (m)	0.8	1.0
Peak Secchi (m)	2.9	3.1
Bloom Probability		
Probability of Chl >10 ug/L	99%	89%
Probability of Chl >15 ug/L	96%	75%
Probability of Chl >20 ug/L	86%	60%
Probability of Chl >30 ug/L	65%	34%
Probability of Chl >40 ug/L	43%	25%

Table 2.12. Watershed Phosphorus Loading Summary Derived from LLRM

	Subwatershed			**Total**
	Upper Watershed		**Lower Watershed**	
Phosphorus Load	**Spectacle**	**Mashapaug**	**RWP**	**P (Lbs/YR)**
Direct Loads To RWP Ponds				
Atmospheric	-	-	-	**64**
Internal	-	-	-	**128**
Waterfowl	-	-	-	**154**
Septic System	-	-	-	**0**
WATERSHED LOAD (Lbs/Yr)	200	160	216	**576**
Total Load To Lake (Watershed + Direct Loads)				**922**

3.0 Management Plan: Methods and Options for Improved Water Quality

3.1 Introduction

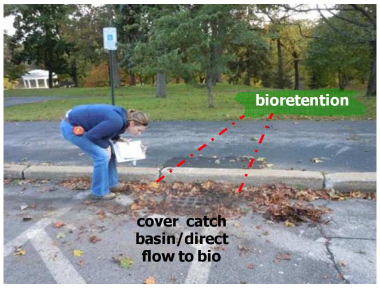
This chapter describes both the methodology used for the watershed assessment and the proposed recommendations to help improve the water quality of the RWP Ponds. The proposed options range from site-specific stormwater retrofits and non-structural best management practices to more general programmatic strategies, including both structural and non-structural control measures. While many of the recommendations focus on activities within the Park, this section also provides pollution prevention suggestions for the surrounding residential and commercial neighborhoods. Public education and outreach programs are also recommended to ensure both the short- and the long-term success of the management

The Project Team, with input from the Steering Committee, undertook a comprehensive watershed assessment of water quality improvement options appropriate for the Lower and Upper Watersheds. This included the following elements:

- GIS mapping to identify surrounding site conditions such as soils, wetlands, storm drainage systems, outfalls, and land use;
- A preliminary site walk with Steering Committee members to identify sites for water quality improvement BMP options;
- A field reconnaissance to assess candidate sites for both structural and non-structural BMPs within the Park;
- A field reconnaissance to assess neighborhoods and Land Uses with a Higher Potential Pollutant Loading (LUHPPLs) restoration opportunities within the Lower and Upper Watershed;
- Assessment of in-pond management options;
- Final selection and ranking of the proposed BMP sites within the Park; and
- A pollutant reduction summary of the proposed water quality management options.

This assessment concentrated on identifying and prioritizing the most cost effective management measures designed to guide the City of Providence Parks and Recreation Department with both short-, mid- term and long-term implementation. Successful implementation of the identified options will reduce stormwater runoff pollution and contribute to improved overall water quality conditions for the RWP Ponds. The various types of restoration opportunities evaluated during the assessment are summarized in **Table 3.1**.

Table 3.1. Summary of Restoration Opportunities Identified

Type	Description
Stormwater Retrofits 	Areas generating stormwater runoff (e.g., parking lots, rooftops, roadways, or compacted pervious areas) were evaluated to determine if new structural stormwater management practices could be installed, or existing facilities modified, to better capture, treat and reduce runoff. Information on existing drainage patterns, surrounding land use, site constraints, and proposed concepts was collected.
Non-Structural Practices 	Non-structural practices generally consist of pollution control techniques or practices that do not involve the construction or installation of stormwater devices. Non-structural opportunities were identified throughout the Park to complement the structural stormwater retrofits described above. These fall into the following categories: site-specific options (buffer restoration, erosion control/slope stabilization, curb removal) and programmatic options (phosphorus bans, long-term park master plan to address pavement reduction, lawn management, leaf litter pick up and a stormwater operation and maintenance plan).
Neighborhood Stewardship 	Neighborhoods were evaluated, generally, to determine the common pollution sources and the type of voluntary watershed stewardship activities that should be targeted to residents (e.g., downspout disconnection, reduced fertilizer use, lawn conversion, septic maintenance, small lot erosion and sediment control, better pet waste management). Average lot size, potential for new development, and road condition were recorded.
LUHPPL Management 	Land uses that have a higher potential pollutant loading (LUHPPLs) are identified as commercial businesses, maintenance facilities, trash collection areas, and other locations where high concentrations of pollutants are likely to come into contact with stormwater. Site activities (e.g., erosion and sediment control, outdoor material storage, waste management, and vehicle maintenance); observed or potential pollutants of concern; and structural and non-structural prevention opportunities were documented for each location.

Type	Description
In-Pond Management 	In addition to assessing the sources of pollution, direct management options in the Ponds themselves was also assessed. These options range from one-time treatments to long-term alterations to the Ponds. Various cost, space, and permitting constraints were analyzed for each option.
Public Education 	A key component to ensuring the success of any management plan is to educate and engage the public. This is particularly true for this project, given the historic nature of the Park and the diverse goals of the many different types of park users. Various public outreach and involvement strategies and activities are reviewed, ranging from passive (signage) to active (enlisting volunteers to do water quality sampling).

3.2 Lower Watershed Assessment and Management Options

As described in **Chapter 2**, the Lower Watershed is the area immediately surrounding the RWP Ponds. A majority of the land use of this watershed is comprised of the Park itself, with some surrounding residential areas to the east and southwest and small portion of commercial land use to the southwest.

3.2.1 Assessment Methods

On July 12, 2011, HW staff met on-site with members of the Steering Committee and representatives from the DEM and EPA to do an initial site walk and identify preliminary retrofit and restoration sites. An initial list of potential restoration sites was developed during this field visit and a summary of the identified sites can be found in **Appendix D.** Following the site walk, HW performed a "desktop analysis" for those preliminary sites, which included using GIS information from RIGIS and the Cities of Providence and Cranston GIS databases to identify soils, wetlands, other site constraints, approximate drainage areas, and any known stormwater infrastructure. This information was used to prepare field forms, aerial plans and overall watershed maps to be used in the field to verify site conditions and complete assessments. In addition, while no park-specific GIS data have been compiled to date on locations and sizes of stormwater infrastructure, HW was able to get a variety of existing plans and reports completed for locations throughout the Park and surrounding area where recent projects have been done and where infrastructure was already identified. These data sources are listed in **Volume III – Technical References**

The full field reconnaissance was conducted on the Lower Watershed on October 21-22, 2011. Field teams used the data collected from the preliminary site walk and desktop analysis, as well as the plans reference above, to assess the previously identified sites. To ensure that a comprehensive assessment was completed, the field teams looked for additional opportunities throughout the Park during the site visits. Restoration opportunities were evaluated using watershed assessment protocols originally developed by the Center for Watershed Protection (Kitchell and Schueler, 2004; Wright et al. 2005; and Schueler et. al., 2007) and adapted by HW for application in Rhode Island. The various types of restoration opportunities evaluated are summarized in **Table 3.1**. These assessments were used to identify potential restoration projects, collect information to further refine priority concepts, and to assist in public education and awareness efforts. The completed field reconnaissance forms can be found in **Volume III** companion document.

Stormwater Retrofits

At each candidate location, the field teams evaluated drainage conditions, identified site constraints, and selected stormwater retrofit options with the best reported pollutant removal capability for the pollutants of concern (phosphorus, bacteria, and sediment) and with the highest runoff reduction potential. Examples include but are not limited to:

- Bioretention (or raingardens, where applicable);
- Dry swales (linear practices that contain amended soils);
- Wet swales (linear practices with emergent wet vegetation);
- Wet vegetative treatment systems (WVTS);
- Infiltration systems;
- Permeable pavement; and
- Downspout disconnections

These practices can be adapted as necessary to several different drainage configurations, including larger open areas, roadside drainage, and parking lots. Additional information and details on the design of each of these practices can be found in the 2010 Rhode Island Stormwater Design and Installation Standards Manual (December 2010).

Ranking

The recommended stormwater retrofits sites identified within this report will not be able to be implemented simultaneously, therefore, each of the evaluated retrofit sites were subject to a ranking procedure in order to help prioritize locations for further evaluation. Not all recommendations are equal when it comes to implementation. Some proposed projects may require additional planning and permitting, both of which will require additional time. Other projects may require a large amount of upfront construction costs. Prioritizing candidate sites allows retrofit sites to be compared to find the most cost-effective and feasible sites within the study area. The ranking system used a 100-point scoring system, where the relative merit of each proposed retrofit BMP was evaluated by assigning points based on the following ranking criteria:

- Pollutant removal potential (40 points)

- Estimated construction cost (20 points)
- Ease of implementation (15 points) including:
    - Wetland impact/permitting;
    - Site accessibility; and
    - Maintenance burden.
- Additional benefits (25 points) including:
    - Public education/demonstrations;
    - Removal of waterfowl habitat/access; and
    - Other funding partners/opportunities.

A relative weight, as indicated above, was assigned to each criterion. After compiling and weighting the screening criteria, we used pertinent information from the retrofit inventory and scored the individual BMP retrofit sites based upon the 100 point scoring system. Scores were entered into a spreadsheet and ranked from highest to lowest to establish the retrofit priority list. Summing the assigned points for each of the factors gave an overall site score. Sites with the highest score represented the best overall candidates for implementation. Highest scoring projects were double-checked to look for hidden "project killers," wherein a project with a high total score has a low or zero score for one or more parameters, suggesting that it may not be feasible. A summary of the site scoring can be found in **Appendix E**.

In consultation with the Steering Committee, the retrofit ranking was used to guide the selection of particular projects to be advanced to the design and permitting phase. A summary of the final site ranking can be found in **Section 3.2.2.** A detailed description of the complete ranking process as well as calculations and summary tables are provided in **Appendix E.**

Non-structural Practices

Although not included in the ranking process, the non-structural options were individually evaluated in the field. The Project Team with the help of Steering Committee members looked for areas where shorelines could be enhanced with vegetated buffers and eroding slopes could be stabilized. Highly used areas in the Park were noted as locations for potential public education efforts. Areas of excess pavement and curbing were identified as well. A summary of the recommended non-structural sites and proposed restoration measures can be found in **Section 3.2.3**.

Based upon the field reconnaissance and evaluation process, some sites identified during the July 12, 2011 site walk were eliminated and additional sites were added. A summary of the sites eliminated and added can be found in **Appendix D**. During the field reconnaissance, plans provided by the City of Providence Parks and Recreation Department (**Volume III – Technical references)** were used to identify additional stormwater infrastructure and outfalls to further refine the watershed boundaries (as described in **Chapter 2**). For example, it was discovered that a large 24-inch combined sewer pipe crosses through the Park, entering near Elmwood Avenue, running along Roosevelt Lake, crossing under/through the north end of Willow Lake, and out the north end of the Park through the zoo. A 24-inch sewer pipe also flows down from the Natural History Museum area, into the 24-inch combined sewer pipe at a manhole on the northeast edge of Willow Lake. While no recent plans of the combined sewer pipe were located, several old plans were used to confirm the general size and location of this pipe, and various manholes were field-verified. In addition, we were able to determine certain areas that currently discharge stormwater into this pipe, and thus, are not contributing to the RWP Ponds (see **Chapter 2**); most notably, much of the zoo property as well as the Casino, and potentially the Natural History Museum, rooftops.

Neighborhood Assessments

Three distinct neighborhoods were delineated within the Lower Watershed based on drainage patterns and include:

- Edgewood North – Includes Montgomery Avenue, Payton Street, Cauctus Street and Fisk Street.
- Edgewood South - Includes Norwood Avenue, Edgewood Avenue, Villa Avenue and Beachmount Avenue.
- Elmwood East – Includes Stamford Avenue, Netop Drive, Potter Drive, Hamlin Street, Dixon Street, Thurston Street, Forestry Circle, Spooner Street, Bissell Street and Hathaway Street.

On October 20th and 21st, HW staff conducted a rapid watershed assessment of neighborhoods within the Lower Watershed. The methodology used was adapted from the Upland Subwatershed and Site Reconnaissance (USSR), Residential Source Assessment (Wright et al., 2004). This assessment evaluates neighborhood pollution potential and weighs the importance of specific sources (e.g., evidence of pet waste, over fertilize lawn, trash and debris) with specific management strategies (e.g., pet waste management, car washing) to help target watershed education and outreach efforts. The assessment also evaluates general conditions of the street and drainage network to determine the relative importance of street sweeping and catchbasin cleanout as potential management priorities. Neighborhood assessments were conducted to help identify and document if the neighborhoods are likely to generate pollutants of concern (e.g., phosphorus, bacteria, sediment), to identify the sources common within each neighborhood, and which areas/sources should be targeted for watershed stewardship activities. A summary of the results of this assessment is described in **Section 3.2.4.**

LUHPPL Assessment

During the rapid watershed assessment, HW staff also identified surrounding land uses that have the potential to contribute a disproportionate level of pollutants to the receiving waters. Sites were then identified as candidates for both structural and non-structural pollution prevention controls. The Rhode Island Stormwater Design and Installation Standards Manual (December 2010). provides a specific description for so-called "land uses with higher potential pollutant loads" (LUHPPLs) that includes a range of industrial use classes including:

- Metal manufacturing facilities;
- Hazardous material storage and handling;
- Landfills (regulated under DEM's RPDES Multi-Sector General Permit for Stormwater Associated with Industrial Activity):
- Auto refueling facilities;
- Exterior vehicle service and maintenance facilities; and

- Road salt storage.

These LUHPPLs are required to meet specific management requirements when applying for new stormwater discharge approvals. A summary of stormwater management opportunities for the identified LUHPPLs in the Lower Watershed are provided in **Section 3.2.5.**

3.2.2 Stormwater Retrofits

Retrofitting involves going back into existing developed areas and installing new, or modifying existing, stormwater management facilities in order to improve water quality treatment and/or reduce runoff volumes to better mimic pre-development land use conditions. Currently, stormwater runoff in the Park is not treated or detained, but quickly conveyed to the Ponds via catchbasins and pipes, as well as direct overland flow.

Table 3.2 summarizes the identified stormwater retrofit opportunities, site ranking, expected benefits of these facilities, and preliminary capital costs for implementation. **Figure 3.1** shows their general locations within the Park. A more detailed description of existing conditions and the proposed retrofit concept at each site is provided in **Appendix F**. Drainage areas to each proposed retrofit practice were confirmed in the field to the extent possible and later refined based on additional plans and GIS information. In areas where catchbasins were completely clogged, drainage areas were delineated under the assumption that they would be cleaned and repaired. In general, practices were roughly sized to treat the first inch of runoff, or the water quality volume, per the criteria in the Rhode Island Stormwater Design and Installation Standards Manual (December 2010).

After completing the watershed field assessment, pollution reduction modeling and stormwater retrofit ranking the stormwater retrofit recommendations were presented to the Steering Committee for review. Based upon available funding and recommendations from the Steering Committee members, the Steering Committee selected the following sites and retrofits for short-term implementation.

- RWP 3B – Carousel Bioretention Area
- RWP-6 – Rain Gardens and Buffer Restoration (changed from a WVTS)
- RWP-12 – Terraced Bioswale
- RWP 17/18 – Wet Swale (changed from a shallow bioretention area)
- RWP-24 - Bioswale
- RWP-28 –Sand Filter (changed from and infiltration basin)

Although RWP-34 was ranked 3rd in the retrofit ranking, this site was not chosen by the Steering Committee for short-term implementation due to the cost and other scheduled park improvements within the proposed retrofit location. The concept for this site should be revisited when the future improvements in the area are undertaken. The retrofits selected are located throughout RWP and include structural control practices including stormwater diversion structures, raingardens, wet and dry swales, and bioretention. Non-structural practices are also proposed as part of the overall concepts and include buffer restoration, removal of geese habitat/feeding areas, and pavement reduction. It should be noted that changes were made during the design and permitting process at sites RWP-6, RWP-17/18 and RWP-28. A more detailed description of each site and proposed retrofit concept is provided in **Appendix F**.

Table 3.2. Stormwater Retrofit Sites and Ranking Summary

Rank	Site I.D.[1]	DEM Priority Outfall	Structural BMP(s)	P Reduction Lbs/yr	Pavement Reduction	Geese Habitat Removal	Planning-level Cost Estimate [2]
1	RWP-17/18	RWP-V	Diversion structure Wet swale	.110	N	Y	$32,500
2	RWP-6	None	Raingardens Buffer restoration	.254	Y	Y	$132,000
3	RWP-34	RWP-D	Bioretention Management plan	1.296	N	N	$129,500
4	RWP-24	None	Bioswale	.128	Y	Y	$49,000
5	RWP-3B	None	Bioretention	.081	N	N	$23,500
6	RWP-28	RWP-H	Sand Filter	8.598	Y	N	$140,000
7	RWP-12	None	Terraced Bioswale	.463	N	N	$89,000
8	RWP-14	None	Diversion Structure Raingarden	.067	N	Y	$18,000
9	RWP-9C/9D	None	Bioretention	.043	N	N	$22,500
10	RWP-37A	RWP-A	Dry Swale	.009	N	N	$7,000
11	RWP-26B	None	Bioretention WVTS	.235	N	N	$9,000
12	RWP-37C	RWP-A	Bioretention	.345	N	N	$49,000
13	RWP-26A	None	Bioretention WVTS	.167	N	N	$6,000
14	RWP-15	None	Terraced Bioretention	.189	N	Y	$67,500
15	RWP-29	None	Vegetated Swales Bioretention Terraced Bioretention	3.796	N	N	$84,500
16	RWP-1C	None	Dry Swale	.087	Y	N	$18,000
17	RWP-1B	None	Bioretention	.019	Y	N	$16,000
18	RWP-1A	None	Bioretention	.018	N	N	$14,000
19	RWP-19B	RWP-U	Diversion structure Dry Swale	.427	N	N	$92,000

Rank	Site I.D.[1]	DEM Priority Outfall	Structural BMP(s)	P Reduction Lbs/yr	Pavement Reduction	Geese Habitat Removal	Planning-level Cost Estimate [2]
20	RWP-19C	RWP-U	Bioretention	.618	N	N	$114,500
21	RWP-7B	None	Diversion Structure WVTS	.494	N	Y	$10,500
22	RWP-9E	None	Bioretention	.033	N	N	$8,500
23	RWP-1F	None	Bioretention	.008	Y	N	$8,000
24	RWP-7A	RWP-Q	Infiltration Basin	.757	N	N	$14,000
25	RWP-3C	None	Bioretention	.060	N	N	$23,000
26	RWP-30B	None	Diversion structure WVTS	7.259	N	N	$213,000
27	RWP-1E	None	Dry Swale	.104	Y	N	$21,000
28	RWP-37B	RWP-A	Diversion Structure Terraced Bioswale	.187	N	N	$58,000
29	RWP-19A	RWP-U	Terraced Bioswale	.355	N	N	$103,000
30	RWP-30A	None	Catchbasin removal Terraced bioretention	1.276	N	N	$203,000
						TOTAL:	**$1,775,500**

[1] Site ID corresponds to locations on watershed maps and to candidate project field form ID's
[2] A detailed cost breakdown is provided in **Appendix G**
Highlighted sites selected for short term implementation.

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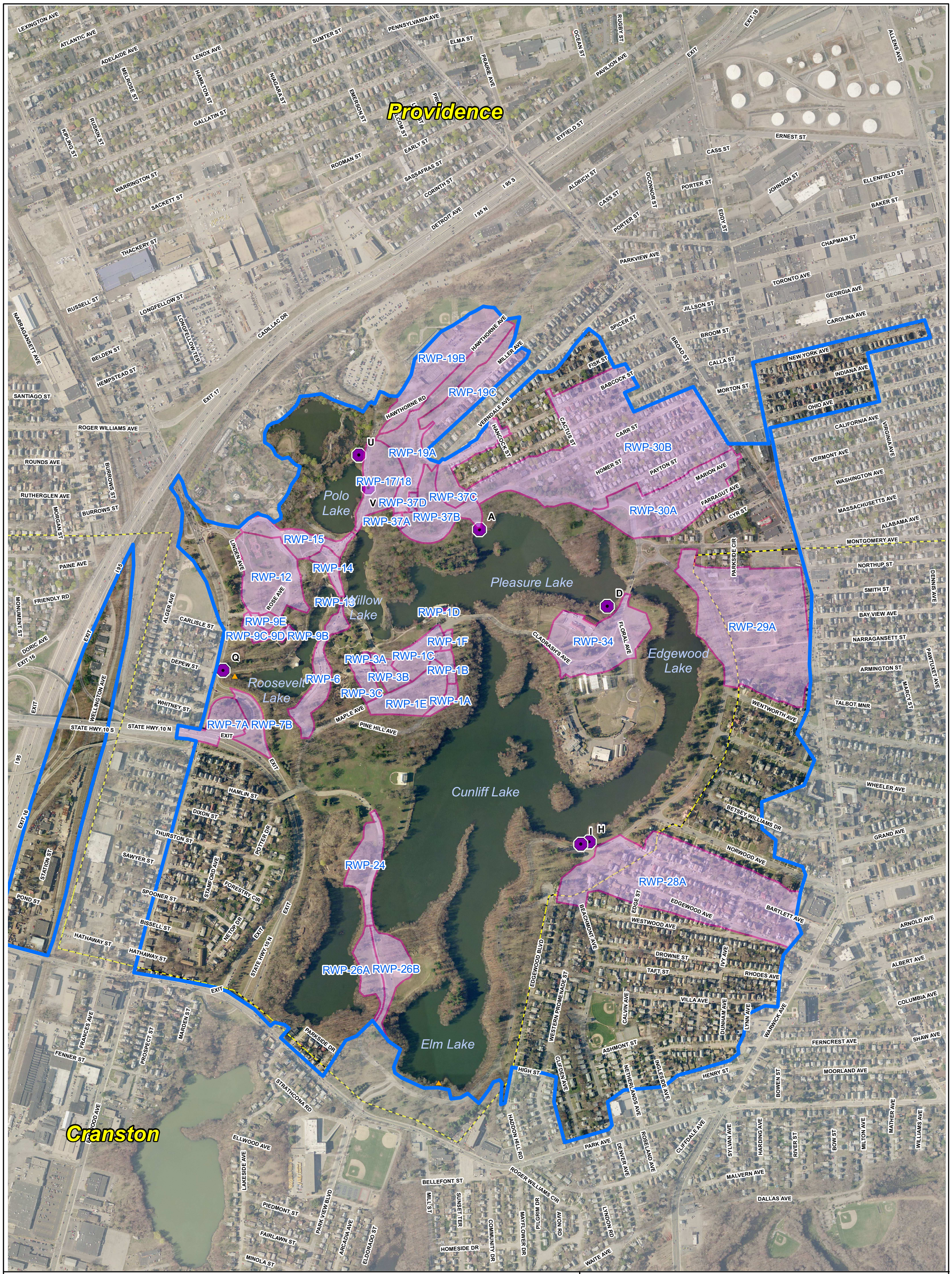

*Color Imagery: 2008

Legend

- Roger Williams Pond Watershed (Revised October 2011)
- Drainage Area to Structural BMP
- Town Boundaries
- RIDEM Priority Outfall
- Pond Inlet/Outlet (Providence GIS)

N

350 Feet

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Sandwich, MA • 02563
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Lower Watershed
Structural Stormwater Retrofit Sites
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.1

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3.2.3 *Non-structural Options*

Non-structural opportunities were identified throughout the Park to complement the structural stormwater retrofits described above. These opportunities fall into the following categories:

- Site-specific options including:
  - Buffer restoration;
  - Erosion control/slope stabilization; and
  - Curb removal.
- Programmatic options including:
  - Park Operation and Maintenance Plan
    - Catchbasin cleaning;
    - Stormwater BMPs;
    - Street sweeping; and
    - Turf mowing.
  - Park Master Plan:
    - Park landscape, use and management;
    - Circulation and pavement reduction;
    - Shoreline buffer plantings and restoration;
    - Additional BMP locations identified and conceptual cost estimates for future funding;
  - Geese management/population control (by others);
  - Leaf litter pick up; and
  - Phosphorus Ban.

Figure 3.2 shows the locations of the identified site-specific non-structural options. This section does not represent an exhaustive list of all the possible locations for not structural options, but rather provides recommendations for priority locations and examples of more general management options that can be applied throughout the Park. A more detailed description of existing conditions and potential opportunities at each site is provided in **Appendix H.**

Site Specific Options

Buffer Restoration Projects

Much of the shoreline around the Ponds in the interior portion of the Park (Roosevelt, Willow and Polo Ponds) (**Section 2.0**) is maintained as turf bound by a hardened edge. This condition only adds to the water quality issues in the Ponds by providing easy access for waterfowl and the people that feed them, as well as little buffer to attenuate overland flow from uphill sources. In addition, the turf grass is mowed on a regular basis, often leaving bare spots, and "tire rutting" that contribute to erosion and sediment accumulation in the Ponds.

Restoring these shorelines by planting low-maintenance, native species will help to reduce waterfowl impacts and provide a natural filter strip between Park activity and the Ponds. A key function of a natural, vegetated buffer is to slow surface runoff, which will also help reduce the export of pollutants. Native trees, shrubs, and grasses have longer root systems than turf grass and will help to remove additional phosphorus from any stormwater runoff flowing through it by trapping particulate pollutants and reducing export of soluble pollutants through infiltration.

In addition, buffer restoration will reduce erosion by stabilizing the shoreline, as well as reduce park maintenance costs since frequent mowing will not be required. The specific plants used in a buffer restoration project can be adjusted based on hydrologic regime, aesthetics, and viewshed goals (i.e., using low-growing plants in an area where views need to be preserved). Below is a sample list of trees and shrubs that could be incorporated. In addition, **Appendix B** in the 2010 Rhode Island Stormwater Design and Installation Standards Manual (December 2010) has a native plant list.

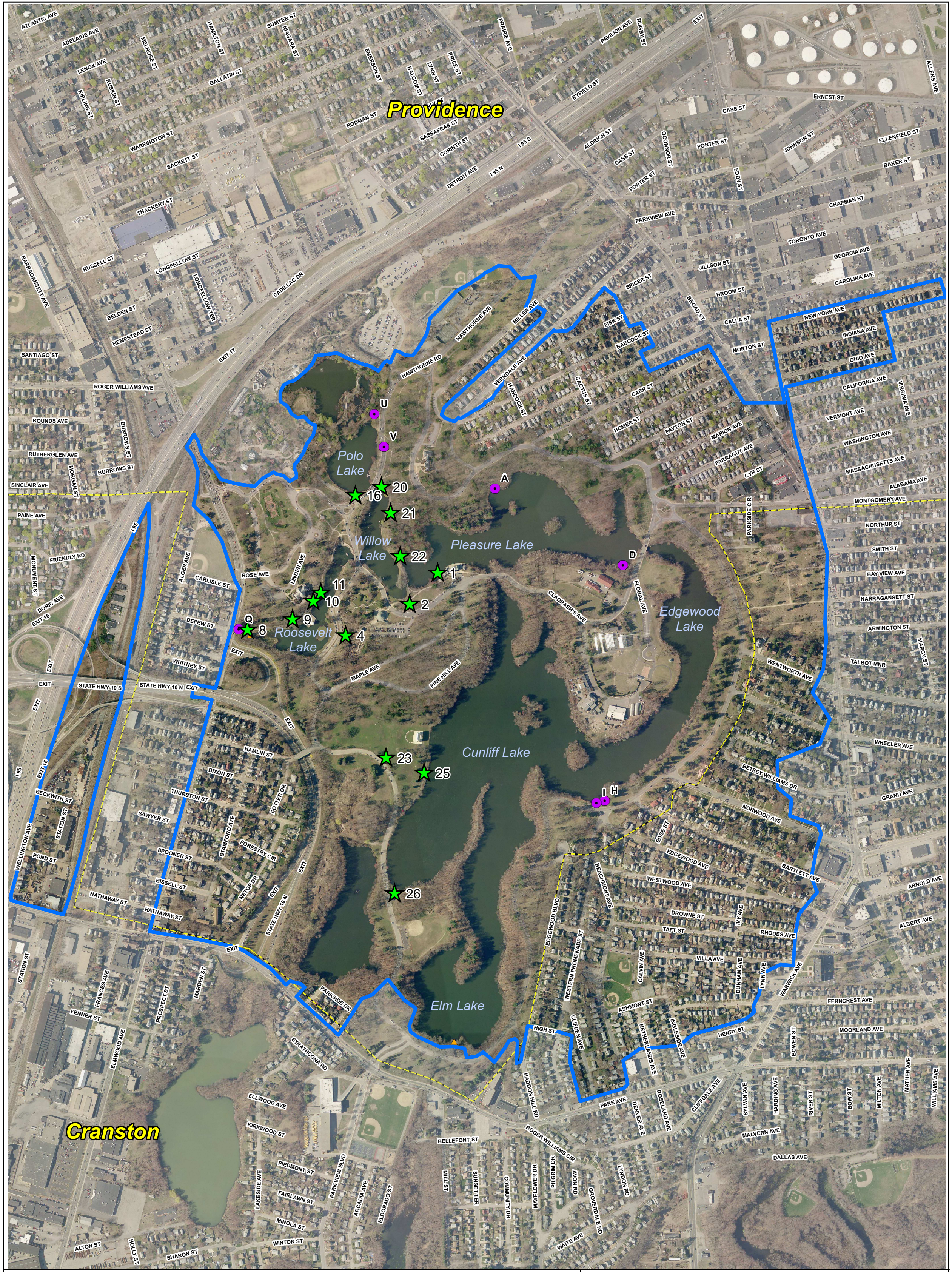
Trees

Amelanchier Canadensis - Shadblow Serviceberry
Betula spp. - Birch
Liquidambar styraciflua - Sweetgum
Taxodium distichum – Bald Cypress

Shrubs

Alnus incana – Speckled Alder
Amelanchier sp. – Serviceberry
Aronia arbutifolia – Red Chokeberry
Aronia melanocarpa – Black Chokeberry
Cephalanthus occidentalis - Buttonbush
Clethra alnifolia – Summer sweet
Cornus sp. – Dogwood
Ilex glabra - Inkberry
Ilex verticillata - Winterberry
Lindera benzoin – Spicebush
Rhododendron viscosum - Swamp Azalea
Salix sp. – Willow
Sambucus canadensis – Elderberry
Viburnum sp. - Viburnum

Table 3.3 lists specific sites where buffer restoration is recommended, with further detail on each site provided below.



*Color Imagery: 2008

Legend

- Roger Williams Pond Watershed (Revised October 2011)
- Town Boundaries
- Non-Structural BMP Retrofit
- RIDEM Priority Outfall
- Pond Inlet/Outlet (Providence GIS)

N

350 Feet

Horsley Witten Group
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Lower Watershed
Non-Structural BMP Retrofit Sites
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.2

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Table 3.3. Buffer Restoration Projects Summary

Site ID[1]	Location	Description	Restoration Area (sf)	Planning Level Cost Estimate [2]
RWP-1G	Shoreline near Boathouse	Re-vegetate buffer area with low-growing grasses and shrubs	2,000 sf	$7,000
RWP-2	Road by Carousel	Plant native material; augment soils and convert low area at yard drain to rain garden; shoreline buffer plantings	1,000 sf for raingarden; 3,000 sf buffer plantings	$19,000
RWP-10	Casino hillside erosion	Repair erosion along slope and stairs and add buffer plantings	1,000 sf	$3,500
RWP-20	Willow Lake near bridge	Re-vegetate buffer area with low-growing grasses and shrubs	2,500 sf	$3,500
RWP-25	Temple of Music Access Road	Create level spreader downhill of grass slope, on uphill side of access road; increase buffer; lawn/open area management with no-mow areas/additional organic matter/erosion control, renovate access road with grass pave.	3,500 sf	$87,000
			TOTAL:	**$120,000**

[1] Site ID corresponds to locations on watershed maps and to candidate project field form ID's
[2] A detailed cost breakdown is provided in **Appendix I**

Slope Stabilization Projects

During the field assessment, the field teams observed several steep slopes that had erosion issues, causing sediment to wash down into the Ponds. In general, these areas tended to be maintained as turf, which has exacerbated the problem. The shallow roots of turf grass do not provide much stabilization, and mowing equipment and frequent mowing can lead to exposed soil. The proposed restoration of these slopes typically includes some re-grading, erosion control matting, seeding, and a long-term turf management plan. Certain sites also require adding a stabilized swale for concentrated runoff and/or additional buffer plantings along the shoreline.

Table 3.4 lists specific sites where slope stabilization is recommended, with further detail on each site provided below.

Table 3.4. Slope Stabilization Projects Summary

Site ID[1]	Location	Description	Planted Area (sf)	Planning-level Cost Estimate [2]
RWP-4	FC. Greene Memorial Blvd.	Replant northeast side of hill along pathway	1,500 sf	$5,000
RWP-8	Island near the Park Entrance	Raingarden in triangle island or possible WVTS along edge of lake; pave or re-vegetate cut-through at entrance near cemetery	1,000 sf slope stabilization; 4,000 sf buffer plantings	$21,000
RWP-9A	Casino hillside erosion	Stabilize slope; formalize a drainage path for runoff from paved area; add buffer plantings	2,000 sf slope stabilization; 2,000 sf buffer plantings	$17,000
RWP-11	Casino hillside erosion	Repair erosion along slope and add buffer plantings	2,500 sf	$12,000
RWP-16	Hillside near Polo Lake	Plant with native, low-growing grasses and shrubs to stabilize and provide vegetated buffer to Polo Lake	4,000 sf	$19,000
RWP-21	Erosion on slope near Willow Lake	Stabilize slope with no-mow vegetation; formalize drainage swale and stabilize with checkdams; create vegetated buffer	7,000 sf slope stabilization; 1,500 sf buffer plantings; 150 ft stabilized swale	$25,000
RWP-22	Hillside erosion near Pleasure Lake	Re-vegetate erosion near stairs; re-plant area of recent storm damage/tree removal; remove area of Japanese knotweed	4,000 sf	$15,000
RWP-26C	F.C. Greene Memorial Blvd by Ball Field	Slope stabilization north of the ball field and interception of runoff prior to pavement.	3,200 sf	$9,500
			TOTAL:	**$123,500**

[1] Site ID corresponds to locations on watershed maps and to candidate project field form ID's
[2] A detailed cost breakdown is provided in **Appendix I**

Curb Removal Projects

The field teams also looked for opportunities where existing roadside curbs could be removed to allow for sheet runoff through existing pervious areas instead of concentrating in a catchbasin. Only one key location was identified for curb removal, as listed in **Table 3.5**, but other opportunities may exist throughout the Park. It is important that curb removal is done on milder slopes where runoff will sheet flow over a stabilized area. Allowing sheet flow of runoff onto steep, bare slopes may lead to slope destabilization and ultimately erosion gullies.

Table 3.5. Curb Removal Projects Summary

Site ID[1]	Location	Description	Planning-level Cost Estimate [2]
RWP-23	F.C. Greene Memorial Blvd by Temple of Music	Curb removal only and create areas of no-mow meadows	$19,500

[1] Site ID corresponds to locations on watershed maps and to candidate project field form ID's
[2] A detailed cost breakdown is provided in **Appendix I**

Programmatic Options

Park Operation and Maintenance Plan

A comprehensive park operation and maintenance plan (O&M Plan) should be developed that includes inspection and maintenance schedules and activities for the entire park as well as the existing stormwater infrastructure, and any future stormwater BMPs installed. An O&M Plan is important to ensure that maintenance crews have a firm understanding of necessary tasks and that a consistent procedure is used among the various crews. This section will address the maintenance items critical for proper operation of both the existing stormwater infrastructure and proposed structural and non-structural practices.

Catchbasin Cleaning

The existing stormwater infrastructure consists of catchbasins, manholes, pipes, and outfalls. During the field assessment, the field teams observed many catchbasins that were clogged with debris to the point that they no longer could accept runoff (e.g., most of the catchbasins along F C Greene Boulevard in the eastern portion of the Park). Many appeared to not have been cleaned in many years. When catchbasins clog, stormwater runoff ponds and ultimately flows to the next down-gradient structure or directly into the Ponds. Many times, runoff has overflowed in pervious areas, causing slope erosion and sedimentation. For those catchbasins that were only partially clogged, the next large storm event will carry that material into the Ponds.

Typical cleaning of a catchbasin includes the removal of trash and sediments collected in the sump using a catchbasin cleaner with a clamshell bucket or a vactor truck. Additional general maintenance activities are performed whenever necessary including repairs to the catchbasin's brickwork, frames, covers, and hoods/traps. Due to the excessive sediment accumulation and clogging observed, some structures and associated pipe may need to reestablish proper drainage flow. We recommend that a regular catchbasin inspection and maintenance program be established and implemented. Currently catchbasin cleaning is the responsibility of the City DPW. Due to the overwhelming amount of catchbasins in need of maintenance within the city, the Parks and Recreation Department has begun to explore alternative arrangements to provide regular cleaning of maintenance of the catchbasins within the Park. It is recommended the followings be undertaken to begin the catchbasin cleaning process:

1) Coordination with the City of Providence and City of Cranston DPW crews to identify responsibilities.
2) An initial inspection should occur to develop a stormwater inventory and prioritize catchbasins to be cleaned first. Catchbasins that are in disrepair should be repaired or replaced.
3) Create a map that shows the location of all existing catchbasins and other stormwater infrastructure. This could be a simple hand-drawn compilation of plans or a comprehensive GIS or CAD map with inverts, material, sizes, etc.
4) Establish a maintenance schedule should to ensure each catchbasin gets inspected at least twice a year, with maintenance performed as necessary. Catchbasins that are outside the Park boundary but connect to one of the Park outfalls need to be maintained as well.
5) Checklists should be created for maintenance crews to use that identify the individual structures inspected and have areas to document any repair and/or maintenance needs. Photographs are also a good way to make visual documentation of any problems at a catchbasin or outfall.

Stormwater BMPs

Many stormwater retrofits have been identified in **Section 3.2.2**. As these retrofits are constructed, specific O&M requirements and checklists should be incorporated into the overall park O&M Plan. Inspections of BMPs and their associated infrastructure (e.g., diversion structures, inlets, overflow structures, underdrains, etc.) should be incorporated into the developed catchbasin inspection/maintenance schedule. Similar to the process described above, maintenance crews should have a map that shows the location of all of the existing BMPs and components and perform regular inspections and maintenance as necessary, per the individual O&M Plans created during final design.

Enhanced Street Sweeping

Enhanced street sweeping involves increasing sweeping frequency, targeting high pollutant or areas and if possible, modernizing sweeping equipment. Regularly scheduled street sweeping of the Park roads can be an effective way to reduce maintenance costs associated with sediment removal from catchbasins, other stormwater BMPs and the Ponds themselves. Sediments and sand accumulated in catchbasin over time can cause system clogging and drainage failures that eventually lead to downstream pollutant discharges. Regularly scheduled street sweeping can also contribute to improved park aesthetics and dust control.

Per the Rhode Island Stormwater Management Resource Center's (SMRC) "Parking Lot and Street Cleaning" guidance document, effective street sweeping programs can remove several tons of debris a year from city streets minimizing pollutants in stormwater runoff. The use of a high efficiency vacuum sweeper is encouraged but may be cost prohibitive if one is not readily available. New studies show that conventional mechanical broom and vacuum-assisted wet sweepers reduce nonpoint pollution by 5 to 30%; and nutrient content by 0 to 15%, but that newer dry vacuum sweepers can reduce nonpoint pollution by 35 to 80%; and nutrients by 15 to 40% for those areas that can be swept (Runoff Report, 1998). While actual reductions in stormwater pollutants have not yet been established, information on the reductions in finer sediment particles that carry a significant portion of the stormwater pollutant load is available. Recent estimates are that the new vacuum assisted dry sweeper might achieve a 50 to 88% overall reduction in the annual sediment loading for a residential street, depending on sweeping frequency (Bannerman, 1999).

At a minimum the SMRC recommends a street sweeping program should address the following:

Street Sweeping Schedule: Designing and maintaining a street sweeping schedule can increase the efficiency of a program. It is recommended that schedules include minimum street sweeping frequencies of at least once a year, but the most effective programs schedule street sweeping to occur twice a year during the spring snowmelt to reduce pollutants in stormwater runoff from road salt, sand and grit accumulated during the winter months and in the fall to collect fallen leaf litter and debris.

Street Sweepings Storage and Disposal: Disposal typically includes sand, salt, leaves, and debris removed from roads. Often the collected debris contains pollutants and disposal must adhere to all federal and state regulations that apply.

Using modern efficient street sweepers or vacuum trucks may reduce the need for other structural stormwater controls. Municipal stormwater managers should compare potential benefits and costs of street sweeping. Street sweeping may prove to be more cost-effective than certain structural controls, especially in more urbanized areas with greater areas of pavement (SMRC, Rhode Island). Additional guidance on effective street sweeping programs can be found on the RIDEM website

The Parks and Recreation Department does not currently own a street sweeper and depends on the DPW to sweep the 10 miles of roads in the Park twice a year. The department may consider supplementing the DPW services with private vendors to increase street sweeping frequency and effectiveness. If excessive sand accumulation is observed at stormwater drainage pipe outfall (as identified at the Roosevelt Lake inlet) catchbasins and stormwater retrofit structures reduced sanding of the Park roads could also be considered as an option to reduce the required street sweeping frequency.

Turf Mowing

During the field assessment, many areas of lawn had only a thin cover of grass or none at all, leading to erosion and sediment accumulation in the Ponds. As part of a Park O&M plan, turf management requirements could be more site-specific, and ongoing inspection and documentation of the areas would produce more healthy and self-sustaining lawns as well as soil structure. Turf management for different areas identified under the Park Master Plan could require various levels of maintenance such as a reduced mowing schedule, and adding soil amendments such as compost. There are woodland areas throughout the Park which currently have manicured lawn beneath the tree cover. The areas with large existing stands of trees could be designated as no-mow areas. The plant litter (leaves and needles) from these trees could be left to create a more naturalistic woodland floor and provide additional nutrient to promote healthy tree growth. The creation of a "woodland floor" would also help reduce the amount of stormwater runoff by reducing lawn and promoting infiltration as well as reduce park maintenance cost associated with leaf removal. The same approach could be applied along the vegetated buffers along the pond edge All of these activities could be paired with plans for on-site composting, using materials collected from park clean-up and maintenance.

Park Staff Training

As stormwater retrofit BMPs are incorporated into the landscape throughout the Park the general park landscape maintenance practices will need to be adjusted accordingly. A person or persons within the Parks and Recreation Department should be designated as the responsible party for implementation and oversight of the O&M Plan. In-house training workshops will also be required to review the inspection and maintenance requirements outlined in the O&M manual and to provide hands on training for all park maintenance staff to ensure the proper implementation of the O&M Plan.

Park Master Plan

An overall Park Master Plan is beneficial for many reasons and may include:

- Planning for long-term maintenance of the Park;
- Ensuring the historical character and design of the Park is maintained while making modifications for future water quality and programmatic needs;
- Identifying specific use areas and circulation patterns (both vehicular and pedestrian);
- Future projects; and
- Funding sources.

The two items described below are most relevant to improving water quality in the Ponds.

Park Use Areas

Much of the Park grounds are currently maintained as turf with regular mowing, even on steep slopes. This has led to erosion in many areas, as well as encouraged waterfowl movement and feeding. While some specifically located areas of open turf are very beneficial for park use (e.g., picnic areas, active recreation, large event, historic viewsheds, etc.), minimizing turf by modifying park use areas and management activities, such as mowing, may be more beneficial in many areas. The highest priority sites for buffer planting and slope stabilization in areas of existing turf have been identified above; however, through the master planning process, park use patterns should be analyzed to determine the best areas to maintain as turf and those that can be converted to more natural landscapes. In some cases, planting and seeding may be appropriate, while in others, a reduced mowing regime may be sufficient. For those areas that do continue to be mowed, a less frequent mowing schedule and a greater blade height should be considered to prevent bare spots from forming and eroding. The Park Master Plan should also identify the important viewsheds throughout the Park and how any turf management in those areas may affect the views. By creating a Park Master Plan, a more specific and sustainable O&M Plan can be produced that reduces unnecessary work and costs and focuses resources on particular tasks and areas based on identified park goals.

Circulation Patterns and Pavement Reduction

Impervious cover is recognized as a source of many water quality issues because it creates more stormwater runoff and its associated pollutants. The field team identified many wide roads in the Park, most with parking available on both sides of the road. Some of the proposed retrofits in **Section 3.2.2** incorporate pavement reductions for specific sites, but additional reductions may be possible throughout the Park. As a part of the master planning process, a traffic study (both vehicular and pedestrian) should be performed to better understand the traffic flow, circulation, and parking patterns during the course of an entire year. This will help park staff identify key sections of pavement (roads, sidewalks, and paths) that could be reduced either as individual projects or as a part of larger road resurfacing or repair projects that address aging infrastructure. For example, while removal of one lane of F C Greene Memorial Boulevard was identified as a part of Retrofit Site RWP-6, it may actually be possible to remove the entire road in this area if traffic can be diverted to another road in the vicinity with available capacity. Having a plan with these key locations identified is often the most efficient way to ensure available funds are used wisely.

Geese Management/Population Control

Due to the excessive Canada Geese population in the Park and their contribution to phosphorous loading within the Ponds, a management plan should be developed by others to decrease the current geese populations.   The plan should be developed in coordination with the U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS).

Leaf Litter Pick Up

Leaf liter has been found to be a contributor to phosphorus in urban runoff. In some studies “cut up” or “mulched” leaves have been found to release as much as three times soluble phosphorus when compared to whole leaves . (Cowen and Lee, 1973). The Parks and Recreation Department should continue their current leaf litter pick up program.   Most importantly leaf litter should be rapidly removed from the roadways within the park during the fall and spring seasons periods to avoid leaf litter breakdown. Leaf litter left in roads and lawn areas for extended periods of time can be carried by stormwater runoff into the drainage system causing clogging and contribute to the ponds phosphorus loading.   A leaf litter pick up program could also be extended into the surrounding neighborhoods of both Cranston and Providence as part of the the catch basin cleaning programs and through neighborhood awareness through public outreach.

Phosphorus Ban

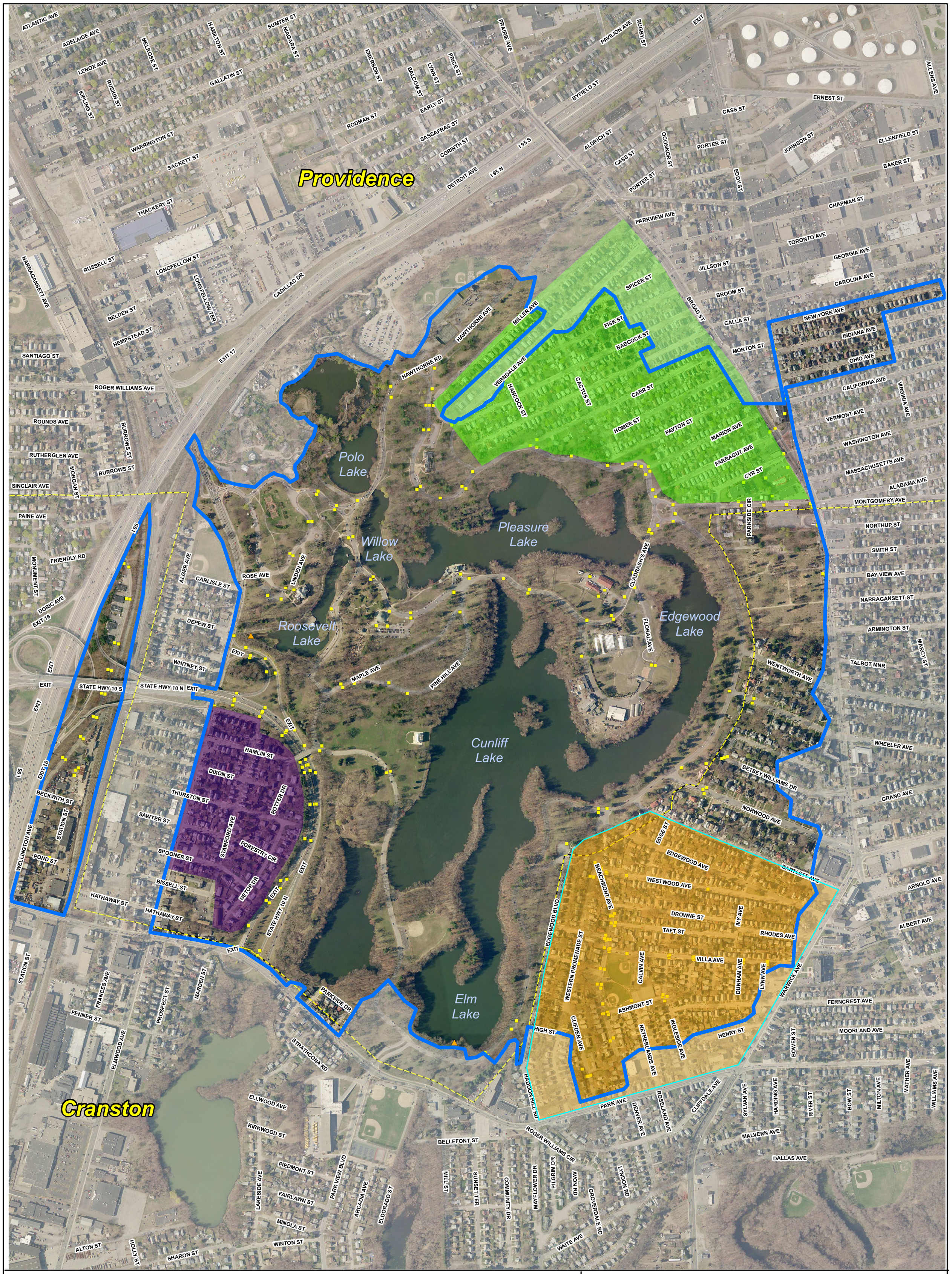
The Parks and Recreation Department should eliminate the use of phosphorus fertilizers in lawn areas. Existing lawns typically need little phosphorus for sufficient growth and lawn fertilizer can be a significant source of phosphorus in urban stormwater runoff. The phosphorus ban could be extended into the surrounding cities of both Cranston and Providence or eventually statewide. Recently Maryland has joined the list of states banning phosphorus in lawn fertilizers used on established lawns. In an effort reduce the cost of stormwater management in Massachusetts, a law will be going into effect on January of 2014 to ban fertilizers with phosphorus. Recent studies have shown that phosphorus a bans on lawn fertilizers can reduce the amount of phosphorus entering the receiving water bodies in the first year. At a minimum, awareness regarding the negative impact of phosphorus use should be included in any public outreach program.

3.2.4 Neighborhood Stewardship Options

A summary of general neighborhood conditions is provided below in order to identify which neighborhoods are likely to generate pollutants of concern, what the common sources are, and which areas/sources should be targeted for watershed stewardship activities. **Table 3.6** is a comparative summary of each neighborhood, and **Figure 3.3** shows the location of each assessed neighborhood. Pollution source is determined by number of observed pollutants (0 = Low; 1-2 = Medium; >2 = High). Individual neighborhood assessments and descriptions are provided in greater detail in **Appendix J.** Field forms for these neighborhoods are included in **Volume III – Technical References**.

Opportunities for pollution prevention within each neighborhood were identified and include the following:

- Regularly scheduled street sweeping or vacuuming to reduce sediment accumulation and minimize maintenance costs of catchbasin cleanings.
- Pavement reduction and storm drain maintenance and repair. Many of the roads within the neighborhood are wider than necessary and street widths at intersections are very wide. Runoff reduction could be achieved by reducing these roadway widths, directing runoff into stormwater BMPs in the areas with open space, and creating “green streets” in the right-of-way to intercept runoff and provide treatment and infiltration
- The cities of both Providence and Cranston should replace failing catchbasins with systems that can trap sediments/organics and provide pretreatment prior to discharge to the RWP Ponds.
- Similarly, many of the existing catchbasins would benefit greatly from more frequent cleaning and maintenance, and storm drains that directly discharge to the Ponds should be stenciled to identify this direct connection. Stenciling the storm drains could increase homeowner awareness of the connection between the roads in their neighborhood and the Park.
- Additionally, homeowners could effectively reduce runoff by redirecting downspouts to pervious areas. Approximately 30 to 50% of the dwellings within the Upper Watershed neighborhoods have downspouts that could be re-directed to pervious portions of the yard.
- There is space for stormwater management practices such as bioretentions or raingardens in the open areas at the end of many of the neighborhood streets. These areas are visually connected to the Park as one drives along F.C. Greene Memorial Boulevard.
- Homeowner education on fertilizer use with emphasis on reduction or elimination, and pet waste bag dispensers and waste receptacles located in public areas could also increase pollution prevention.



Legend

*Color Imagery: 2008

- Upper Watershed (Revised October 2011)
- Town Boundaries
- Pond Inlet/Outlet (Providence GIS)
- Catchbasin (Providence/Cranston GIS)

Assessed Neighborhoods

- Edgewood North
- Elmwood East
- Edgewood South

N

350 Feet

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Sandwich, MA • 02563
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Lower Watershed
Location of Neighborhood Assessments
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.3

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure3_3_RWP_Neighborhoods_11058.mxd

- Pet waste bag dispensers and waste receptacles could be located both within the Park and neighborhood open areas to increase pollution prevention and raise awareness.

Table 3.6. Lower Watershed Neighborhood Inventory Summary

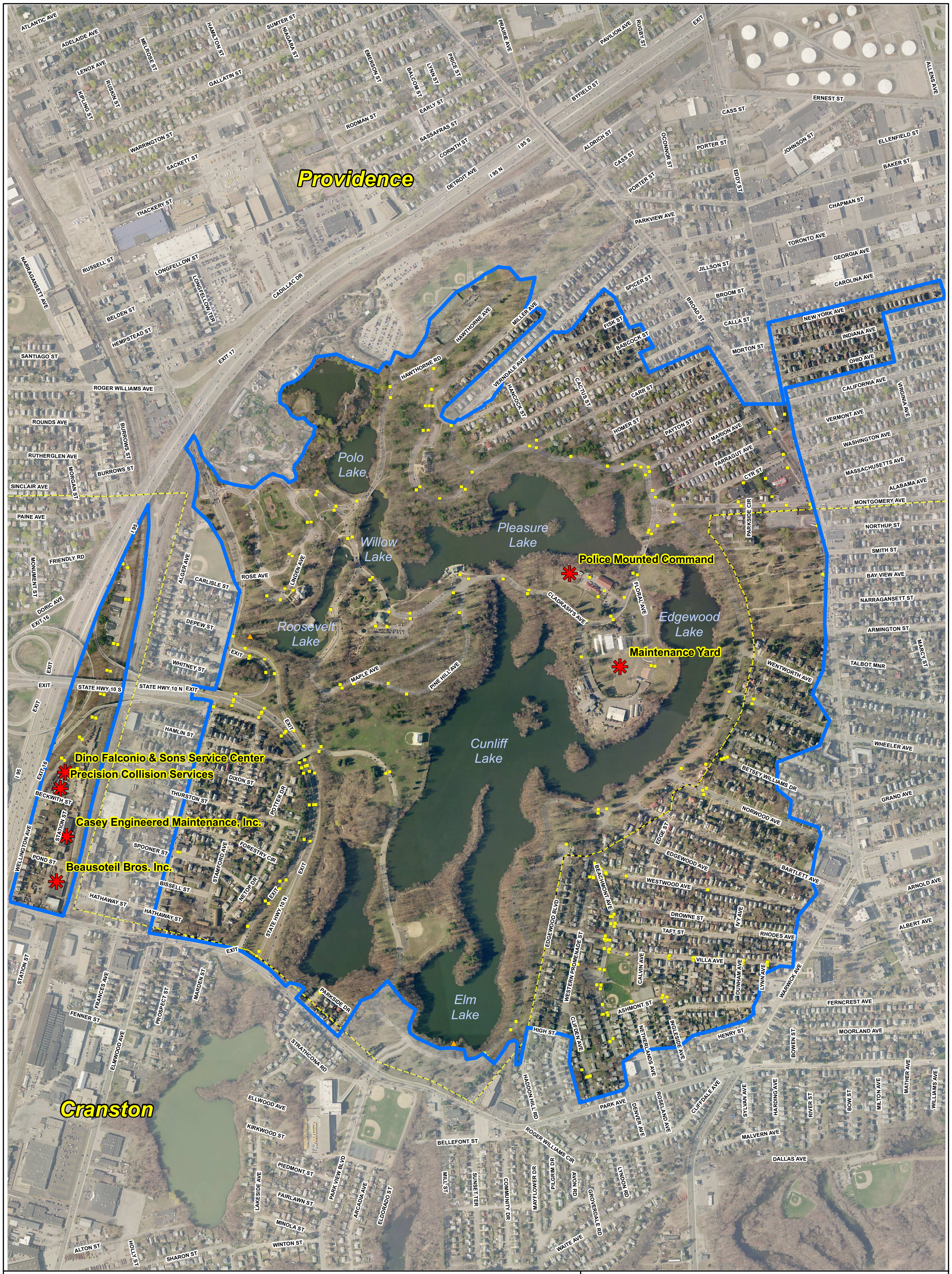
Description	Pollutant Loading	Main Pollutant Source	Stewardship Activities
Edgewood North	Medium	• Sediment • Trash and Litter • Oil and Grease • Nutrients • Bacteria	• Downspout disconnection • Catchbasin maintenance • Pet waste management • Street sweeping • Storm drain stenciling
Edgewood South	Medium	• Sediment • Oil and Grease • Nutrient • Bacteria	• Downspout disconnection • Catchbasin maintenance • Pavement reduction (street width) • Street sweeping • Pet waste management • Storm drain stenciling • Lawn care
Elmwood East	Low	• Sediment • Trash and Litter • Oil and Grease • Nutrients • Bacteria	• Downspout disconnection • Catchbasin maintenance • Pavement reduction (street width) • Street sweeping • Pet waste management • Storm drain stenciling • Lawn care

3.2.5 LUHPPLs Options

A summary of the located potential LUHPPLs, sometimes also referred to as a pollutant hotspot, is provided below in order to identify which ones are likely to generate pollutants of concern, what the common sources are, and which areas/sources should be targeted for pollution control activities. **Table 3.7** is a comparative summary of each LUHPPL and **Figure 3.4** shows the location of each potential LUHPPL. Pollution source is determined by the number of observed pollutants (0 = Low; 1-2 = Medium; >2 = High). Individual LUHPPL assessments and descriptions are provided in greater detail in **Appendix K.**

Table 3.7. Lower Watershed LUHPPL Inventory Summary

Description	Pollutant Loading	Main Pollutant Source	Stewardship Activities
Stables, Training Area and Pens	Medium	• Animal waste • Nutrients • Bacteria • Sediment	• Erosion and sediment control • Stormwater management via swales/trenches • Sustainable pen management • Composting manure • Relocating vehicle and waste storage away from catchbasins
Maintenance Yard	High	• Oil and grease • Compost • Landscape debris • Nutrients • Trash and litter • Sediment	• Management plan • Designated stockpile areas • Restore/re-establish buffer • Erosion and sediment control • Stormwater management via swales and bioretention
Construction Services	Medium	• Oil and grease • Sediment • Animal waste • Nutrients	• Machine and equipment storage • Stockpiled material • Unprotected drains to street storm sewer • Dogs on-site
Auto Repair Services	Medium	• Oil and grease • Trash and litter	• Auto repair business • Car maintenance shop • Open dumpsters • Dogs on-site
General Maintenance Businesses	Low	• Trash and litter • Oil and grease • Landscape debris	• Janitorial and maintenance products and services



Legend

- Upper Watershed (Revised October 2011)
- LUHPPL Location
- Town Boundaries
- Pond Inlet/Outlet (Providence GIS)
- Catchbasin (Providence/Cranston GIS)

N

350 Feet

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Lower Watershed
LUHPPL Locations
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.4

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure3_4_RWP_LUHPPL_11058.mxd

3.2.6 In-pond Management Options

This section presents a suite of possible in-pond management options. Of the many possible options, some are mutually exclusive, and some could be applied in concert for better control. Some options would apply for just the control algae; while others provide control of rooted aquatic plants. The relative shallow depth of the Ponds can only be addressed by removing sediment or raising the water level, limiting options in that regard. Even then, the means by which sediment might be removed covers a substantial range of options and necessitates extensive testing and engineering design work. A broad overview of the various in-pond management options is provided in **Appendix O.**

Crafting a management plan for the Ponds is a function of technical applicability and feasibility, economics, and socio-political factors (including acceptability to park users and regulatory constraints). Given that there is a TMDL for the Ponds, management actions that can help meet the TMDL while also meeting pond condition goals should be considered more favorable. Given the significant phosphorus reduction requirements identified in the TMDL, a mix of watershed-based and in-pond actions seems to be needed.

Implementation of the presented in-pond options should be evaluated in the context of the entire watershed management plan and not considered alone. For example, phosphorus and sediment loads from the contributory watershed should be addressed prior to dredging the Ponds to obtain the maximum benefit from the dredging.

A summary of the potential in-pond management options is presented below, prioritized in the suggested order of implementation:

1. *Continue control of invasive rooted aquatic plants* – Until sediment is removed and phosphorus loads reduced, invasive plant growth can be expected to continue in these shallow ponds. Rooted plants do provide a valued feature of many aquatic habitats, but dominance by invasive species or excessive growth of even native species should be avoided. Physical or chemical means will likely be needed annually for several years to control these aquatic plants. The emphasis should be to focus/prioritize control action in invasive plant rather than all rooted plants. Both white and yellow water lilies are present in the Ponds, and typical common in shallow ponds in the region. These lilies are native and have high aesthetic value and provide good fish habitat.
2. *Continue control of nuisance algal blooms* – Until nutrient levels can be substantially reduced, algal blooms can be expected during periods of higher temperatures and low flow. Some application of algaecides, limited to copper and peroxides, is likely to be necessary to maintain acceptable water clarity. It is important to track clarity and react before blooms form; treatment after bloom formation can have adverse ecological and aesthetic consequence.
3. *Continue to monitor the Ponds for water clarity (Secchi depth), dissolved oxygen, and nutrients several times a year, preferably at least monthly from May through September* – Reliable data are essential to adequate planning and adjustment over time. Existing data

provide some direction, but are not sufficient to facilitate detailed planning or accurate prediction of results.

4. *Reduce waterfowl within RWP per geese management plan* – performed by others.
5. *Evaluate the fishery* - If it is determined carp have become as abundant as suggested by some observers, conduct a carp reduction program. Elimination of carp will be very difficult without damaging other more desirable fish populations, but research has shown that abundant carp can cause elevated turbidity and nutrient levels by their feeding activities.
6. *In the absence of other Upper Watershed management options, chemically treat in-flow from the Upper Watershed at the Roosevelt Lake inlet to reduce total phosphorus and total suspended solids loads* – This approach acknowledges the potential expense and time delay of implementing widespread stormwater management controls in the Upper Watershed, and provides more immediate benefits. While direct chemical treatment is not preferable from the perspective of overall system health or TMDL compliance, inflow treatment has been shown to be effective elsewhere. This could be limited to application only during late spring and summer.
7. *Dredge Roosevelt, Polo, Willow and Pleasure Lakes to remove soft sediment accumulations* – The removal of sediment from the smaller lakes will greatly reduce a variety of in-lake problems, including rooted plant nuisances and internal recycling of nutrients. While expensive and subject to considerable regulation, dredging is a restorative technique, setting the Ponds back in time, removing plants and nutrient reserves, adding depth and volume, changing the character of the bottom, and often affecting the types and quantity of algae present.
8. *Inactivate available sediment phosphorus in Cunliff, Elm and Edgewood Lak*es – While dredging these ponds as well would achieve the same goals cited above, the larger quantity of sediment is likely to be cost prohibitive, and achieving greater depth for these deeper ponds is not as important. Consequently, inactivating available sediment phosphorus may be sufficient, along with other watershed management options, to suitably improve conditions. Rooted plants may still be an issue, and inactivation is not recommended until incoming water quality has been improved, but this approach could provide cost effective progress toward improving existing conditions.

Implementation of all of the suggested in-pond management options is expected to achieve the following:

- Reduction in mean in-pond total phosphorus concentrations;
- Reduction in mean in-pond chlorophyll a concentrations;
- Reduction in the frequency of algae blooms;
- Reduction in the real coverage of rooted aquatic plants;
- Reduction of invasive rooted aquatic plants;
- Removal of accumulated sediment and associated plant propagules, algal spores, nutrient reserves, and oxygen demand;
- Increase in average dissolved oxygen levels; and
- Creation of a long-term record of basic physical (Secchi depth), chemical (dissolved nutrients, dissolved oxygen), and biological (chlorophyll a concentration, algae species and enumeration) data, suitable for guiding future management.

More detail on each recommended element is provided here, but an iterative process of consideration, discussion, prioritization, study, and planning is advised before implementation. The proposed elements are based on current understanding of technical, economic, and socio-political aspects of the project. Additional investigation will be necessary as part of actual implementation, and will likely require additional sediment testing, additional assessment of alternatives, detailed quantify and cost assessment, permitting services, and construction bidding services.

1. Continue control of invasive rooted aquatic plants.

The City of Providence is currently controlling rooted aquatic plants using targeted and some whole pond treatments with aquatic herbicides. The type and location of treatment is assessed on an annual basis with the goals of preventing the spread of potentially aggressive invasive species and targeting especially dense areas of native plant growth. As water clarity increases with the implementation of the suggested management plan, there is potential for rooted aquatic plants to expand in area. Dredging would likely reduce the extent of aquatic plants, but it is also likely that continued management by herbicide and possible mechanical removal will be necessary. The strategy should be to focus on control actions for invasive species as the priority. One concern with the removal of native lilies, for example, is that invasive species may replace those areas. In the future, the Parks and Recreational Department may wish to investigate the use of diver assisted suction harvesting (DASH) for rooted aquatic plant removal in the future, perhaps initially as a pilot project. This will require coordination with RIDEM Freshwater Wetlands Program on permitting.

Herbicides used to date include the active ingredients diquat, fluridone, 2,4-D, and glyphosate. Based on the plants encountered in the Ponds, all of these herbicides are appropriate for one or more target species, but none is effective for all of them. Use of 2,4-D has declined in favor of fluridone in many cases, and for the RWP Ponds, it does not appear that 2,4-D is currently necessary. Fluridone is a systemic herbicide used mainly for fanwort, but will affect other species, notably the water lilies, at a high enough dose. Its greatest limitation is that it requires and extended contact time, and will be less effective when flushing rates are high. Glyphosate is also a systemic herbicide, but is normally sprayed directly on the surface leaves or protruding parts of target plants, not applied to the water. It is therefore more selective, but does not work on completely submerged plants. Diquat is a contact herbicide, effective against a range of plants, which is often used on undesirably dense assemblages on a localized basis. It is not effective on fanwort and is seldom used on water lilies, but can control curlyleaf pondweed.

Applying the format from Mattson et al. (2004), herbicide applications are evaluated as follows:

Benefits

- Complete kill of susceptible vegetation for fluridone and glyphosate;
- Can be used selectively on certain major invasive or nuisance species;
- Slow death of plants minimizes oxygen demand and nutrient release for fluridone;
- Minimal risk of any direct impacts on fauna for fluridone and glyphosate; and

- Can provide vegetation reduction under moderate flushing rates for diquat.

Detriments

- Fluridone acts slowly in the aquatic environment; exposure time of up to 90 days is typically needed but may not be achieved in highly flushed system;
- Diquat will kill only the parts of the plant with which it comes into contact; roots often survive and produce new plants the next year; and
- Treatment rarely kills all target plants or provides control for more than two years.

Information for Proper Application

- Knowledge of system hydrology and detention time;
- Need to provide adequate contact time;
- Mapping of aquatic vegetation with accurate identification of all species and general appraisal of relative abundance and overall cover/biomass;
- Selection of herbicide to match plant susceptibility and local conditions for treatment;
- Inventory of aquatic biota with emphasis on sensitive species;
- Treatment plan to include dose, areas treated, expected alteration of plant community, and follow-up activities;
- Tracking of concentration over intended exposure period for fluridone; and
- Monitoring program for assessing effectiveness and impacts.

Possible Permits

- Review by Rhode Island Natural Heritage Program (further action if protected species are present);
- Permit to Apply Chemicals from RIDEM, with corresponding RIPDES permit; and
- 401 Water Quality Certification Permit through RIDEM.

Next Steps

- Annual written reports on the locations and types of plants treated;
- Locations of invasive species; and
- Quantitative evaluation of plant community conditions and changes (best achieved by having standard inspection points that are checked in spring and late summer).

2. Continue control of nuisance algal blooms.

Currently, the City is using copper sulfate to control nuisance algal blooms, and treatment should continue as needed. Copper is a contact herbicide that is generally considered non-selective, although some species of algae are less sensitive than others. The active ingredient in copper sulfate and copper complexes is the copper ion. The mode of action of copper is to inhibit photosynthesis and it may affect nitrogen metabolism. Copper is by far the most used active ingredient in algaecides.

While copper sulfate is used at concentrations up to 1 part per million (ppm), it appears that control of most target algae can be achieved at very low levels of copper (0.30 mg/L or less). Many blue-green algae appear to be more sensitive to copper than other forms of algae.

Effectiveness of low doses depends on monitoring algal densities and treating prior to the formation of an algal bloom. Once a bloom has formed, higher doses may be required and may still be ineffective if adequate contact with algal cells cannot be achieved. In most cases, treatment of the whole pond is not allowed, with two treatments necessary a week apart, thus limiting effectiveness. In general, bright sunlight appears to enhance the effectiveness of the treatment.

Beyond the susceptibility of the algal species present, the effectiveness of copper-containing aquatic herbicides is dependent in particular on the alkalinity, dissolved solids content, suspended matter, and water temperature. In cases where the alkalinity is high, carbonate and bicarbonate ions and water react with copper and form a precipitate that prevents the uptake of copper by algal cells. In such cases, chelated copper compounds are used instead of copper sulfate. Suspended solids provide additional substrates on which copper sorption can occur, removing it from the water column. Additionally, algae do not respond as well to copper treatments in water less than 10^{o}C (50^{o}F), although some success has been achieved.

Copper sulfate can be applied by towing burlap or nylon bags filled with granules (that dissolve) behind a boat. Other formulations can be applied as broadcast granules or sprayed liquids. The method of delivery, however, is not as important as the duration of effectiveness. Vertical or horizontal mixing can rapidly decrease doses below an effective level, but for these shallow ponds, this should not be an important factor.

Where algaecides are used, effectiveness is enhanced through improved timing of application. Algaecides should be applied early in the exponential growth phase, when algal sensitivity is greatest and the impacts of lysing cells on the aquatic environment are minimized. Proper timing of application requires daily to weekly tracking of algal populations, potentially at greater annual expense than the actual annual treatment cost.

Benefits

- Rapid kill of susceptible algae; and
- Rapidly eliminated from water column, minimizing prolonged adverse impacts.

Detriments

- Toxic to many non-target organisms;
- Releases contents of most killed algal cells back into the water column; this may include nutrients, taste and odor compounds, and toxins;
- Ineffective on some algae; repeated treatments may favor those resistant algae, some of which are major nuisance species;
- Accumulates in sediments, although long-term impacts may not be severe; and
- Must be completed often, timing must be effective.

Information for Proper Application

- Algal monitoring to determine proper timing of treatment;
- Water quality data to evaluate dose needs and likely effectiveness;

- Inventory of non-target biota for potential impact assessment;
- Knowledge of plankton species within the system; and
- Monitoring program to assess impacts and effectiveness.

Possible Permits – This information is preliminary and pending confirmation and additional information from RIDEM

- Review by Rhode Island Natural Heritage Program (further action if protected species are present);
- Permit to Apply Chemicals from RIDEM, with corresponding RIDPES permit; and
- 401 Water Quality Certification Permit through RIDEM.

Cost Considerations

Copper treatments are inexpensive, typically around $100 per acre, although repetitive application, chelated forms, and appropriate monitoring will increase the cost on an annual basis. Assuming treatment of all the RWP Ponds (103 acres), costs would be on the order of $10,000 per treatment. More than one treatment a year may be warranted, but further study is needed.

Next Steps

Complete a study of phytoplankton species and numbers within the RWP Ponds to provide an increased understanding of the type and densities of phytoplankton within the system. This type of study will inform treatment options in the future and will be especially valuable if copper sulfate treatments become ineffective or are not performed. These data will also provide more information on the incidence of potentially toxic cyanobacteria within the RWP Ponds which could become a health risk for humans and animals. Sampling for algae should be accomplished along with the basic water quality testing described below, at the same frequency at each in-lake station.

3. Continue monitoring of RWP Ponds for Secchi depth, dissolved oxygen and nutrients several times a year.

Annual monitoring will build a long-term record of pond health for use in assessing progress toward TMDL water quality goals as well as management goals. Secchi depth is an easily made physical measure that carries only the cost of the Secchi disk (less than $100) and the time to make the measurement. Dissolved oxygen can be measured using a field test kit (approximately $100) or a field meter that will cost at least $1,500, but has limited maintenance costs and could be rented when needed. Nutrients should include ammonium, nitrate, and Kjeldahl nitrogen, and total and dissolved phosphorus. Nutrient data is obtained by contracting with a certified lab which analyzes water samples collected from selected sites, logically one from the deepest point in each pond plus one at any major inlet and one at the outlet of the entire system, so a total of about 10 samples. The cost per sampling round will be approximately $500 to $1,000 to collect the samples and $1,000 to $1,500 for lab testing, so this is not a trivial cost, but proper management is supported by appropriate data. Monitoring monthly from May through September would be desirable, but it may be adequate to monitor for only Secchi depth, dissolved oxygen, total nitrogen, and total phosphorus in late May, early July and early September as a minimum if budgetary restrictions are severe. Contracting with a local university or non-profit for sampling and analysis assistance may afford additional cost savings.

Next Steps
Monitor the RWP Ponds for basic physical and chemical water quality parameters as described above.

4. Evaluate the fishery and consider carp control.
While the only available fishery survey does not indicate that carp are a problem, it is an old survey and local observations suggest that there could be a substantial population of carp that is stirring up the bottom sediments of the Ponds. If so, and this should be verified by a proper survey. A carp biomass reduction study could be implemented by netting. Larger mesh size is used to avoid catching smaller fish, and the process can be labor intensive, but on the scale of the lakes involved, this could be accomplished for under $20,000. Electroshocking would also be possible, at a similar cost. Fish poisons such as rotenone are not recommended, as they will affect other fish populations as well.

Next Steps
Verify carp population by completing a fisheries survey.

5. Chemically treat in-flow from the Upper Watershed at the Roosevelt Lake inlet to reduce total phosphorus and total suspended solids loads.
In the absence of other Upper Watershed management options, investigate the chemical treatment of discharge from the Upper Watershed at the Roosevelt Lake inlet to lower phosphorus and total suspended solids concentrations. Treatment of inlet water for phosphorus can be completed using a drip line feed of one or more aluminum compounds at the discharge point or slightly upstream. As a coagulant, reactive aluminum will bind up phosphorus and most solids, precipitating the resultant floc in the pond. The accumulated material is not extreme in most cases. No maintenance dredging should be necessary, but given the apparently large loss of depth over the last three decades, there could be a need to remove accumulating material in Roosevelt Lake.

The most common aluminum compounds used to treat lakes are aluminum sulfate ($Al_2(SO_4)_3$ xH_2O) and sodium aluminate ($Na_2Al_2O_4\,xH_2O$). The compounds are typically applied to the surface or subsurface, in either solid or liquid form, normally from a boat or barge. In this case, the compounds would be applied in the pipe. When the compounds are applied to the lake, they form aluminum hydroxides (Al(OH)) which appear as a floc. The floc can remove particulates, including algae, from the water column within minutes to hours and precipitate reactive phosphates.

Low doses of aluminum (1 to 5 mg/L) can be used to strip phosphorus out of the water column with limited effects on pH or other water quality variables, even in many poorly buffered waters. If it is not desirable to use a buffer solution the dose is determined by the amount of inactivator (aluminum sulfate) that can be added without causing an undesirable pH shift.

Common rates for aluminum sulfate dosing for water column stripping go up to 20 mg/L, although a buffer may be required. In comparison, 10 to 150 grams per square meter (g/m^2) of aluminum sulfate are commonly required for inactivating surficial sediments. Doses between 1 and 10 mg/L are typically applied to stormwater discharges, and current efforts in stormwater management focus on capturing the floc in detention areas prior to discharge to the lake or stream.

Possible Permits

- Review by Rhode Island Natural Heritage Program (further action if protected species are present);
- Permit to Apply Chemicals through RIDEM's division of Agriculture;
- 401 Water Quality Certification Permit through RIDEM; and
- Possible RIPDES permit for a point water treatment system, but only if water is withdrawn from the pipe to a treatment/dosing system and then discharged back to the pipe or Pond.

The most serious impact is the possibility for fish or invertebrate kills following treatment in low alkalinity lakes, but such impacts are preventable. Minimal adverse impacts are expected to either surface or groundwater supplies. Aluminum is commonly added in water and wastewater treatment facilities with no significant adverse impacts (and generally a marked improvement in water quality).

Next Steps

Prepare an engineering feasibility/design study to determine the best method for treating the inflow from Mashapaug Pond. The study should investigate the construction of an aluminum dosing station as well as monitoring the outflow volume and total phosphorus concentration over time. This would provide a better estimate of actual inputs to inform dosing. Dosing may be year round, applied to specific storm events (e.g., storms less than one inch), or occur only during the summer months depending upon the study results. It seems most likely that treatment from mid-May through August will be sufficient, but adjustments should be expected over time.

Cost is estimated to be on the order of $100,000 to $150,000 for a dosing station. Annual maintenance costs are expected to be on the order of $30,000 to $50,000, which includes the cost of the aluminum compounds (about $1 per gallon for alum, $3per gallon for aluminate). Annual maintenance costs are highly dependent upon the volume of water treated and the time period (summer, fall, all year), if the system is automatically applying chemical or needs to be manually turned on and off. Maintenance will be extremely important as it is assumed that treatment of the Upper Watershed load will be required indefinitely to see results in the RWP Ponds. This management option is integrally linked with implementation of other management options in the Upper Watershed. If BMPs are implemented upstream for the Spectacle and Mashapaug Ponds system or some portion of storm inflows are diverted, the amount of aluminum required to maintain needed phosphorus removals will decline.

6. Dredge Roosevelt, Polo, Willow and Pleasure Lakes to remove soft sediment accumulation and rooted aquatic plants.

Dredging involves the removal of sediment. Dredging falls into three general categories: conventional dry, conventional wet, and hydraulic/pneumatic dredging. Conventional dry and wet dredging will be discussed here as the potential for trash, debris, and heavy plant growth within the RWP Ponds reduces the utility of hydraulic dredging. Dredging is perhaps best known for increasing depth, but dredging can be an effective lake management technique for the control of excessive algae and invasive growth of macrophytes. The management objectives of a sediment removal project are usually to deepen a shallow lake for boating and fishing, or to remove nutrient rich sediments that can cause algal blooms or support dense growths of rooted macrophytes. Several ponds within the RWP Ponds system are currently very shallow and dredging may be required at a future date to maintain open water. Additionally, dredging may be a useful option to limit rooted aquatic plant growth and remove areas of sediment with high potential for internal nutrient loading.

There are a couple of risks to urban ponds from dredging. Increased volume after dredging translates into decreased flushing rates and increased detention times, which can potentially promote algal blooms if nutrient inputs remain high. Also, while dredging would remove oxygen demanding sediments, dredging of the RWP Ponds could expand the duration and extent of anoxia within the Ponds if watershed nutrient loads are not reduced prior to dredging. Continued inputs of oxygen demanding substances to deeper ponds with less mixing would promote oxygen loss near the bottom. The use of the inflow treatment system or flow diversion to address inputs from the Upper Watershed may be adequate to minimize these effects in Roosevelt Lake and some other ponds in the upstream portion of the system, but it is not clear that this will be adequate to prevent problems in Cunliff or Elm Lakes, another reason not to apply dredging to those waterbodies.

A properly conducted dredging program removes accumulated sediment from a lake and effectively sets it back in time, to a point prior to significant sedimentation. Partial dredging projects are possible and may be appropriate depending upon management goals, but for maximum benefit it is far better to remove all “soft” sediment. Failed dredging projects are common, and failure can almost always be traced to insufficient consideration of the many factors that govern dredging success.

Dry Dredging

Dry dredging involves partially or completely draining the lake and removing the exposed bottom sediments with a bulldozer or other conventional excavation equipment and trucking it away. Projects involving silts, sands, gravel and larger obstructions where water level can be controlled favor conventional, dry methodology. Although ponds are rarely dry to the point where equipment can be used without some form of support (e.g., swamp mats or gravel placed to form a road), excavating under “dry” conditions allows very thorough sediment removal and a complete restructuring of the pond bottom. The term “dry” may be a misnomer in many cases, as organic sediments will not dewater sufficiently to be moved like upland soils. For situations such as the RWP Ponds, some provision to allow water passage would be necessary, given the large and unpredictable stormwater inflow component to these ponds.

Control of inflow to the lake is critical during dry excavation. For dry excavation, water can often be routed through the lake in a sequestered channel or pipe, limiting interaction with disturbed sediments. Water added from upstream or directly from precipitation will result in solids content rarely in excess of 50% and often as low as 30%. Consequently, some form of containment area is needed before material can be used productively in upland projects. Where there is an old gravel pit or similar area to be filled, one-step disposal is facilitated, but most projects involve temporary and permanent disposal steps.

Benefits

- Deepening of the lake for many purposes, including increased flood storage, improved recreational uses, enhanced pollutant trapping effectiveness, and dilution of nutrient loads;
- Reduced planktonic algal abundance if internal loading is an important nutrient source and enough sediment is removed;
- Removal of toxic substances or other unwanted materials accumulated in the sediment;
- Reduced sediment-water interactions, with potential improvement in water quality, specifically removal of sediments with high potential for release of phosphorus; and
- Complete removal of soft sediments in any target area.

Detriments

- All possible impacts of drawdown, as the lake is lowered to facilitate dry dredging;
- Loss of most biological components of the drained portion of the lake through physical disturbance;
- Potential for downstream turbidity if through-flow is not controlled;
- Peripheral land disruption for access by equipment;
- Upland area must be provided for sediment disposal, with temporary alteration;
- Contaminated sediments potentially subject to many restrictions on disposal. The Lee Pare and Associations study (1980) documented high levels of metals in lake sediments;
- In the RWP Ponds, will likely increase anoxic areas if water quality is not improved; and
- Effects will not be long-term if the sediment loading from stormwater systems and Upper Watershed is not reduced.

Information for Proper Application

- Sediment quality, which will determine disposal options and cost;
- Sediment quantity, which determines disposal volume needs and greatly affects cost;
- Ability to control the lake level, which affects choice of dredging method;
- Sensitive biological resources, which affects project goals and permitting; and
- Monitoring to track system recovery and overall project impacts.

Possible Permits

- Review by Rhode Island Natural Heritage Program (further action if protected species are present);
- 401 Water Quality Certification Permit and Freshwater Wetland Permit through RIDEM;

- 404 permit through the Corps of Engineers;
- Solid Waste permit for sediment disposal through RIDEM; and
- Possible Dam Safety permit.

Cost Considerations

Because the cost varies depending on the volume of material removed, costs are usually expressed per cubic yard (cy) of material removed. Generally, the larger the project, the lower the cost per cubic yard. The proper way to estimate dredging costs is to consider each element of the project, which may vary dramatically among projects. The total cost can be divided by the total cubic yardage to get a cost per cy, but this may not be especially meaningful in estimating other dredging projects. With that caveat in mind, a typical range of costs for dry dredging projects in recent years is $25 to $50 per cy, with $30 per cy suggested as a rough estimator for considering the general magnitude of a project under initial consideration. It is important, however, to develop a more careful estimate during further project planning, and many smaller projects (less than 50,000 cy) have incurred costs in excess of $50 per cy.

Prior dredging feasibility studies for the RWP Ponds estimated an in-situ volume of 37,500 cy be removed from Roosevelt, Polo and a portion of Willow Lakes with a final average depth for each water body three feet greater than the starting depth (Lee Pare and Associates, 1980(2)). This volume is used here as a minimum; it is assumed that over the ensuing 30 years additional soft sediment accumulations have occurred and Pleasure Lake is also recommended for dredging, which was not addressed in the prior assessment. Using 37,500 cy as a starting point, costs are estimated at a minimum to be $1,125,000. Realistically, with additional sediment accumulation and peripheral restoration work expected, a cost on the order of $1,500,000 is suggested, and that assumes that the quality of the sediment will not compromise disposal options. More investigation is needed before a dredging project can be properly considered.

Conventional Wet Dredging

Wet dredging may involve a partial drawdown, especially to avoid downstream flow of turbid water, but sediment will be excavated from areas overlain by water. Sediment will be very wet, often only 10 to 30% solids unless sand and gravel deposits are being removed. Clamshell dredges, draglines, and other specialized excavation equipment are used. Excavated sediment must usually be deposited in a bermed area adjacent to the pond or into other water-holding structures until dewatering can occur. This approach is most often practiced when water level control is limited.

Conventional wet dredging methods create considerable turbidity, and steps must be taken to prevent downstream mobilization of sediments and associated contaminants. For wet excavation projects, inflows must normally be routed around the lake, as each increment of inflow must be balanced by an equal amount of outflow, and the in-lake waters may be very turbid. It should be noted, however, that more recent bucket dredge designs greatly limit the release of turbid water and have been approved for use in potentially sensitive aquatic settings such as Boston Harbor.

Benefits

- Same as dry dredging.

Detriments

- All the same impacts as dry dredging, although depending upon level of draw-down, some biological components may be less disturbed than with dry dredging; and
- Potentially incomplete dredging as a consequence of not being able to visually appraise underwater sediment conditions and high suspended solids levels that may form a thin muck layer upon settling.

Information for Proper Application

- Same as dry dredging.

Possible Permits

- Same as dry dredging.

Cost Considerations

Cost is likely to be similar to that projected for dry dredging, but any estimate of probable cost is premature at this point without a complete characterization of sediment quality.

Next Steps

Complete a study to determine soft sediment depth within the targeted ponds, and perhaps all the Ponds to confirm which of the Ponds have substantial soft sediment accumulation.

Sample and test areas targeted for dredging for toxics and metals required to determine dredging disposal options.

7. Inactivate sediment available phosphorus in Edgewood, Cunliff and Elm Lakes.

Aluminum treatment of the RWP Ponds that are not dredged (most likely Edgewood, Cunliff and Elm Lakes) after external phosphorus loads are reduced would substantially reduce the expected release of phosphorus into the water column. However, without first addressing the inputs of phosphorus from external sources, dredging and treatment with aluminum cannot be assumed to affect substantial changes in water clarity or nutrient concentrations or algae blooms.

Phosphorus precipitation by chemical complexing removes phosphorus from the water column and can control algal abundance until the phosphorus supply is replenished. Inactivation of phosphorus in surficial lake sediments can greatly reduce the release of phosphorus from those sediments, minimizing the internal load. Treatment of the surficial sediments is most effective after nutrient loading from the watershed is sufficiently reduced, as it acts only on existing phosphorus reserves, not new ones added post-treatment. In-lake treatments are used when studies indicate that the primary source of the phosphorus is internal (recycled from lake sediments). Initial data suggests that the sediments of Cunliff, Elm and Edgewood Lakes may be candidates for phosphorus inactivation.

The most common aluminum compounds used to treat lakes are aluminum sulfate ($Al_2(SO_4)_3$ xH_2O) and sodium aluminate ($Na_2Al_2O_4$ xH_2O). The compounds are applied to the surface or subsurface, in either solid or liquid form, normally from a boat or barge. When the compounds are applied to the lake they form aluminum hydroxides (Al(OH)) which appear as a floc. The floc can remove particulates, including algae, from the water column within minutes to hours and precipitate reactive phosphates. Reactions continue at the sediment-water interface, binding phosphorus that could otherwise be released from the sediment. Because aluminum added as sulfates dissolve to form acid anions along with the formation of the desired hydroxide precipitates, the pH will tend to decrease in low alkalinity waters unless basic salts such as sodium aluminate or lime are also added. It is important to control the lake pH during treatment because concentrations of reactive aluminum (Al^3) are strongly influenced by pH. Aluminum is toxic to fish at levels of 100 to 200 ug/L when the pH is less than 6.0 and greater than 7.5, typically via gill membranes. The "safe" level of dissolved reactive aluminum is considered to be 50 ug/L, but these are not sharp thresholds. Where applied aluminum is less than 5 mg/L and the pH is between 6.0 and 7.5, no toxic effects have been observed in recent treatments on Cape Cod.

Application rates for aluminum dosing range from 10 to 150 g/m^2 for inactivating surficial sediments. Based on the work done to date on the RWP Ponds, rates on the order of 27 g/m^2 would be needed, with a maximum rate up to 60 g/m^2, all within the range of previous treatments in New England.

Benefits

- Rapid removal of available phosphorus from the water column;
- Minimized internal loading of phosphorus; and
- Potential removal of a variety of other contaminants and algae.

Detriments

- Potential for damage to aquatic life at depressed or elevated pH;
- Limited longevity of effects if external loading is significant, in the case of treatment of existing sediments only;
- Potential sediment resuspension for bottom feeding fish (e.g., carp) and wind for shallow ponds; and
- In the case of water column treatment or source treatment, long-term maintenance is required. After construction of the treatment facility, annual maintenance of the facility, monitoring of alum levels and general system upkeep will be required. If the system is not operational then no benefits will be observed.

Possible Permits

- Review by Rhode Island Natural Heritage Program (further action if protected species are present);
- Permit to Apply Chemicals from RIDEM;
- RIDEM Freshwater Wetlands Permit;

- Possible 401 Water Quality Certification Permit through RIDEM; and
- Possible RIPDES permit for a point water treatment system.

The most serious impact is the possibility for fish or invertebrate kills following treatment, but such impacts are preventable. Minimal adverse impacts are expected to either surface or groundwater supplies. Aluminum is commonly added in water and wastewater treatment facilities with no significant adverse impacts (and generally a marked improvement in water quality).

Cost Considerations

Aluminum treatment costs are typically on the order of $1,500 per acre, with the real cost decreasing for larger treatments, unbuffered treatments, and lesser monitoring requirements. Higher costs may result from extreme controls and monitoring. Assuming that the surface area of Cunliff, Elm and Edgewood Lakes are targeted for Alum treatment (approximately 73 acres) costs would be about $110,000, although more set up work would be needed before a definitive cost could be derived.

Recent research by the Steering Committee into alum dosing with a local lake management contractor indicates that dosing may include one to three alum treatments at 1 ppm may be effective in precipitating phosphorus from the water column. This approach might be successful in reducing or ultimately eliminating the blue-green algae. Preliminary planning costs would be approximately $15,000 per treatment. Similar applications in other New England lakes with a history of chronic blooms have shown promising results with a reduction of phosphorus within the lakes of up to 50%. Additional research into this issue is required.

Next Steps

Complete a more comprehensive evaluation of loosely sorbed, ironbound and total phosphorus in the RWP Pond sediments. Samples should be collected from the deepest potions of each pond, perhaps in multiple locations. Lab assays should be conducted to determine the most appropriate dose. Data should be evaluated to determine if the assumptions provided in this document are accurate.

Another consideration, covered previously, is the possibly large carp population. Large numbers of carp in a shallow water body may reduce the effectiveness of an aluminum treatment as continual and large scale disturbance of the layer of alum floc on the surficial sediments could reduce the effectiveness of the treatment. The aluminum floc layer on the surficial sediments is most effective when left undisturbed as a blanket sealing off sediment below from releasing sediment phosphorus. Selective removal of fish species is a difficult task as the most effective methods are non-selective. If large number of carp are confirmed this may need to be addressed. Additionally, the shallow ponds, with a large surface may offer conditions for bottom sediment resuspension from higher winds.

In-Pond BMPs

The creation of in-pond BMPs were considered as a possible option for the pretreatment of the stormwater runoff entering the pond complex at the 48-inch outfall from Mashapaug Pond.

The first BMP considered was the conversion of Roosevelt Lake to a WVTS. This option would provide sediment removal and phosphorus reduction to downstream ponds in the system. Unfortunately, preliminary calculations (**Appendix N)** based upon the Rhode Island Stormwater Design and Installation Standards Manual (December 2010), indicate that a minimum surface area of 15 acres would be required to provide treatment of the 1,003-acre drainage area contributing to the pond at this outfall (the 1,003 acres include 975 acres from the Upper Watershed plus an estimated 28 acres that contribute via the 48-inch pipe upstream of Roosevelt Lake). Since the surface area for Roosevelt Lake of only 3.8 acres, this was not considered to be a feasible option.

The second BMP considered was the conversion of Roosevelt Lake to a gravel WVTS. Preliminary calculations for this practice (**Appendix N**) indicate a minimum surface area of 3.5 acres would be required. Although Roosevelt Lake provides the necessary minimum surface area, serious consideration would have to be given to the impact this would have on the Park design and would significantly alter the landscape in this area of the Park.

The last in-pond BMP option considered was the creation of a sediment forebay at the 48-inch outfall entering the pond. Preliminary calculations for this practice indicate the forebay would require 1.3 acres of the pond (**Appendix N**), or approximately 1/3 of the surface, to be converted to a sediment forebay. Although the implementation of this practice is possible, once again serious consideration would have to be given to the overall impact to the Park and the alteration of a historic landscape. At a minimum, all of the in-pond BMP practices considered would present significant permitting challenges as well as require annual maintenance which could be a financial burden to the City of Providence Parks and Recreation Department. Upstream retention of solids is also highly desirable, but similar to an in-pond practice, any conceivable trapping system upstream of the pond will require substantial land area and annual maintenance.

3.2.7 Public Education and Outreach

A key component to ensuring the success of any management plan is to educate and engage the public. This is particularly true for this project, given the historic nature of the Park and the diverse goals of the many different types of park users. To this end, a targeted education and outreach plan is proposed below to increase awareness of key watershed behaviors that may negatively affect the RWP ponds. The purpose of an education plan is to further implementation of priority projects, and foster broad community awareness of watershed issues. In addition, an education plan is required by EPA in order to be eligible for watershed plan implementation grant funding.

The target audience for the public education and outreach plan includes the following:

- *Residential Audience* - The residents of the surrounding neighborhoods not only visit and use the Park, but also tend to drive on the Park roads frequently as a part of their commute. Flyers, demonstration projects, newspaper articles, radio spots, and road signage are educational activities that could be used to target this audience.

- *Frequent Park Users* - Frequent park users visit the Park regularly to participate in such activities as fishing, walking/jogging, feeding the geese, etc. These visitors are more likely to have hands-on experiences with the Park environment and may be more likely to notice educational items on paths such as signage, brochures, and specific volunteer activities hosted in the Park. However, historically, this has been the most difficult group to target due to their diversity and the transient nature of their visits.
- *Casual Park Visitors* - Casual park visitors include those people who are coming to the Park for specific events or activities, such as to visit the zoo or the carousel. Outreach events held at these locations would be effective in reaching this group. In addition, the zoo already has an effective website and outreach program that could be utilized to help reach this target audience.
- *Park Staff and Other Facilities* - While many people in the Park are just visiting, a few are there as a part of their jobs. This includes staff with park maintenance, the botanical center, police mounted command, City of Providence maintenance, and the Natural History Museum. Education action items should be taken to better target those who work in the Park on a daily basis.

The following actions have been developed to effectively engage the target audience list above. Efforts have been made to identify key messages, delivery mechanisms, and integration opportunities with other education and outreach programs already existing in the Park (e.g., botanical gardens, zoo, etc.). While this is not an exhaustive list, performing these actions will form a solid base for an education and outreach program that can then evolve as park water quality needs and goals change in the future.

Education Action 1: A strong volunteer organization is needed to take the lead on the public education and outreach. Therefore we recommend, the Steering Committee continue with their on-going efforts to develop a volunteer organization (Roger Williams Park Conservancy) to oversee the pollution reduction efforts proposed in and around the RWP Ponds. This group could be active in sponsoring clean-ups and other activities. Continued use of social media networks, such as Facebook and others, could provide an outreach mechanism to strengthen public involvement, increase membership, and raise awareness. Building up a large membership will help reach a larger audience and increase volunteer participation in educational programs and proposed event. Once this organization is fully established and the proper structure is in place many of the following action items could be coordinated and administered through this organization.

Education Action 2: The existing RWP Ponds Restoration project website is hosted by the Narragansett Bay Estuary Program (NBEP). It includes background information on the Ponds, the water quality issues, and links to partnering organizations ranging from governmental (e.g., EPA, RIDEM, etc.) to non-profit (e.g., Save The Bay, Save The Lakes, etc.). This website should evolve into an on-going RWP Ponds watershed education website, potentially hosted by either City of Providence Parks and Recreation Department or the Roger Williams Park Conservancy organization identified in Education Action 1. The website could include additional information such as water quality information and basic homeowner education guidance material.

Education Action 3: An annual RWP Ponds watershed fair should be hosted, potentially by the Roger Williams Park Conservancy, with informational booths and volunteer opportunities, such as helping with a buffer planting or stabilization project or creating a raingarden. Kids' activities such as a fishing derby and a T-shirt design contest with a pond theme can help build stewardship at a young age. These annual events are typically successful in reaching a wide variety of audiences.

Education Action 4: Local media should be utilized to announce volunteer events, inform and educate the public of park management changes (such as the geese control or turf management program), and provide information on what individuals can do to improve water quality in the Ponds. This can range from radio spots to newspaper articles. Publishing a newsletter can also be very effective, particularly if the Roger Williams Park Conservancy can distribute to their membership. Articles congruent with the priorities and goals of the management plan can be very effective in educating the public on topics such as watershed management, stormwater management, landscape practices and vegetation management strategies, proper pet waste disposal, and the benefit of vegetated buffers.

Education Action 5: Create education signage throughout the Park. This signage should be focused on targeted information based on the site. Many of the retrofit and restoration sites identified in this management plan are in great locations for reaching many park users. Signage at these restoration sites would be very effective. For example, the proposed bioretention at Site RWP-17/18 is in a location where many people currently feed the geese. Signage here could be targeted on the negative effects from an overpopulation of geese and why the native vegetated buffer and bioretention installed in this location will be beneficial.

Education Action 6: Host workshops for restoration activities done in the Park so that residents and contractors can learn how to install similar practices in other places. For example, Site RWP-3B (constructing a bioretention facility in front of the Carousel) has been identified as a possible opportunity for an EPA-hosted workshop on bioretention installation. This could be done at other sites as well, from stormwater retrofits to slope stabilization. In addition, workshops could be focused on guest speakers to speak on topics important to the water quality goals of the Park.

Education Action 7: Form a group of volunteers, which may be associated with the Roger Williams Park Conservancy group, to help continue long-term water quality sampling in the Ponds. Having a continuous record will help determine the success of management strategies in improving water quality.

Education Action 8: Host meetings and workshops specifically targeted for the Park staff and others who work within the Park. These meetings should discuss good maintenance practices and include those who work for Parks and Recreation Department, the Carousel, Natural History Museum, the Botanical Center, the Police Mounted Command Stables, the City of Providence Maintenance Yard, and the Roger Williams Park Zoo. The focus of these meetings and continued outreach should be on pollution prevention in the work place.

Education Action 9: Promote a sense of neighborhood pride in the Ponds. This can be done by targeting flyers and activities in the surrounding residential areas that focus on catchbasin stenciling, proper pet waste management, and pond-friendly lawn management, as well as more structural activities like downspout disconnections with rain barrels or raingardens. Events like the Urban Ponds Procession could be held within the Park to raise awareness and generate interest in the restoration of the Ponds.

Table 3.8. Proposed Public Outreach Target Audience Summary

Action Item	Target Audience				
	Residential Audience	Frequent Park Users	Casual Park Users	Park Staff and Other Facilities	General Public
Education Action 1 – Expand Friends of the RWP Ponds	X	X		X	X
Education Action 2 – Educational Website	X	X	X	X	X
Education Action 3 – Host Watershed Fair	X	X	X	X	X
Education Action 4 – Utilize Media	X	X	X		X
Education Action 5 – Create Signage	X	X	X	X	
Education Action 6 – Demonstration Workshops	X	X		X	X
Education Action 7 – Water Quality Sampling					X
Education Action 8 – Meeting and Workshops with Park Staff and Other Facilities				X	
Education Action 9 – Promote Neighborhood Pride in the Ponds	X				

3.3 Upper Watershed Assessment and Management Options

HW field personnel planned for and completed an initial assessment of the Upper Watershed to provide an initial characterization of the pollutant potential of watershed land uses and to identify the key stormwater retrofit locations. The Upper Watershed is comprised of an area of approximately 975 acres and includes three major waterbodies, Tongue Pond, Spectacle Pond, and Mashapaug Pond. Land uses include major areas of commercial, industrial, and medium to high density residential, among others, with impervious cover of approximately 60%. This does not include water surface of the Ponds (Refer to Chapter 2 for more detailed information on the characteristics of the Upper Watershed and a detailed breakout of land use areas).

HW developed GIS derived maps of the Upper Watershed including aerial topography, soils, drainage features, topography, and utilities (where available) to conduct a reconnaissance of the area. A two-day field reconnaissance was completed in mid October 2011. The focus was on initial identification of key source areas of pollutants within neighborhoods, identification of LUHPPLs, and identification of a few key stormwater management retrofit project options. This initial assessment was completed to provide a broad overview of potential options for watershed management and identify a few key specific sites for further investigation as part of the long-term pollutant reduction strategy.

3.3.1 General Reconnaissance of Neighborhoods and Drainage to Tongue, Spectacle, and Mashapaug Ponds

On October 20 and 21, 2011, HW staff conducted a rapid watershed assessment of three different neighborhoods within the Upper Watershed (**Figure 3.5**). This assessment was conducted to help identify and document if these neighborhoods are likely to generate pollutants of concern (e.g., phosphorus, bacteria, sediment), to identify the sources common within each neighborhood, and which areas/sources should be targeted for watershed stewardship activities. The methodology is adapted from the Upland Subwatershed and Site Reconnaissance (USSR), Residential Source Assessment (Wright et al., 2004). This assessment evaluates neighborhood pollution potential and weighs the importance of specific sources (e.g., evidence of pet waste, over fertilized lawns, trash and debris) with specific management strategies (e.g., pet waste management, car washing) to help target watershed education and outreach efforts. The assessment also evaluates general conditions of the street and drainage network to determine the relative importance of street sweeping and catchbasin cleanout as potential management priorities. **Table 3.9** is a comparative summary of each neighborhood, and detailed descriptions of the neighborhoods are described in **Appendix** L . Pollution source is determined by number of observed pollutants (1-2=Medium; >2 = High).

Table 3.9. Upper Watershed Neighborhood Summary

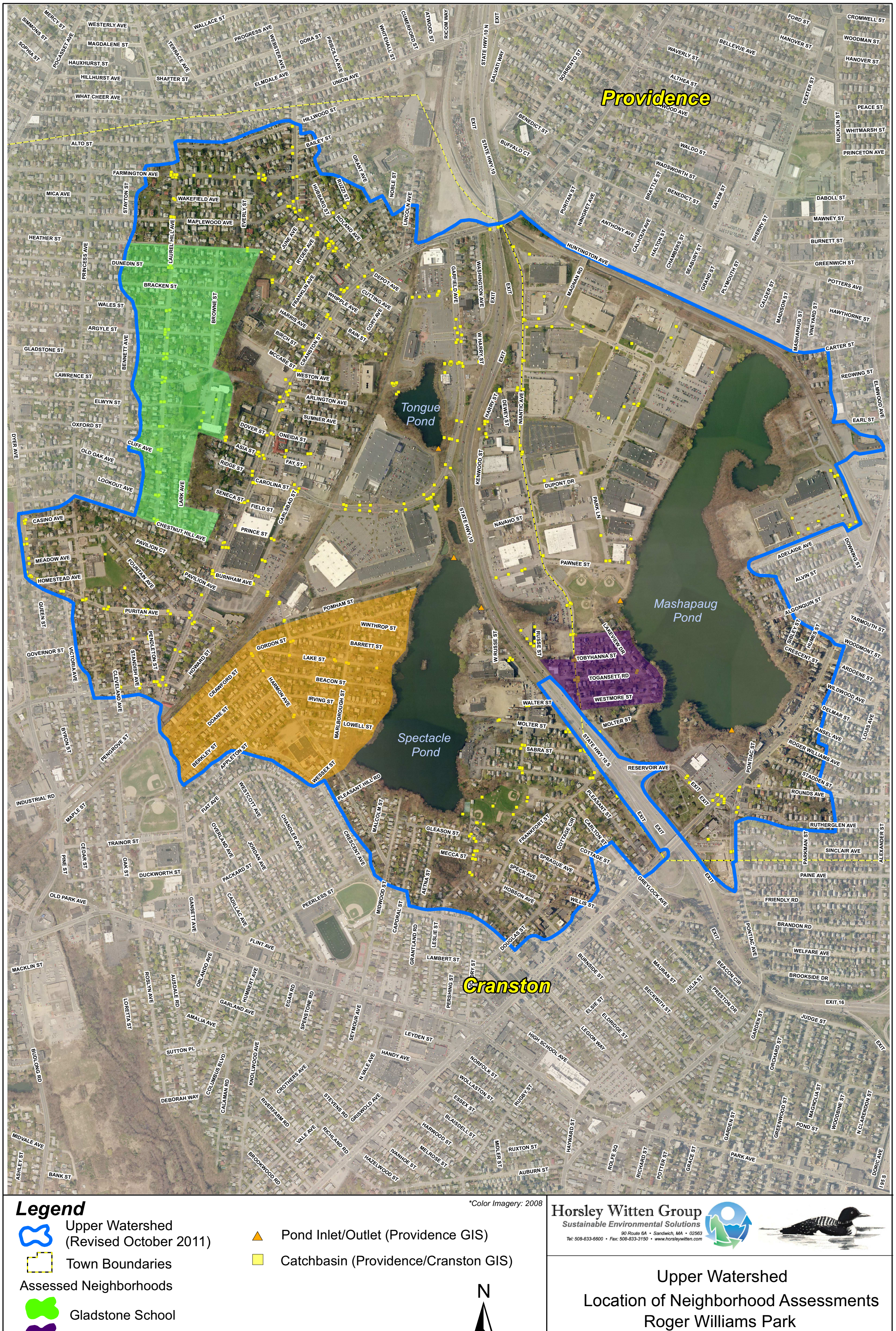
Description	Pollutant Loading Potential	Main Pollutant Source	Stewardship Activities
Gladstone School	High	• Sediment • Oil and Grease • Nutrients	• Downspout disconnection • Catchbasin maintenance • Pavement reduction (street width) • Storm drain stenciling • Street sweeping • Lawn care
Mashapaug West	Medium	• Nutrients	• Downspout disconnection, Catchbasin maintenance • Storm drain stenciling • Street sweeping • Lawn care
Spectacle West	Medium	• Nutrients • Bacteria	• Downspout disconnection • Pet waste management • Street sweeping

3.3.2 Potential Key Stormwater Retrofits

In the Upper Watershed, similar to the Lower Watershed, a set of candidate sites were identified for stormwater retrofitting to help reduce pollutant load delivery to the receiving waters of both watersheds. However, unlike the Lower Watershed, the Project Team concentrated on larger scale and/or higher profile potential projects to act as potential demonstration sites as a starting point for future watershed management. As described in Chapter 2, the Upper Watershed is highly urbanized and has little open space and limited opportunities for large-scale stormwater retrofitting. The methodology included compiling GIS data from both Providence and Cranston, as well as the two TMDL documents (TMDLs for 9 Eutrophic Ponds in Rhode Island, DEM 2007, and Mashapaug Pond, DEM 2007) on the drainage networks and outfall locations.

The drainage in the watershed generally flows northwest to southeast, flowing from Tongue Pond south to Spectacle Pond and east into Mashapaug Pond (**Figure 3.6**). The field team started in the northwest corner of the watershed in Cranston and investigated two drainage networks, one smaller network into Tongue Pond and a much larger system draining from Cranston Street to Burnham Avenue to the outfall on Lake Street into Spectacle Pond. Given the nature of the land uses, density, and drainage system, only one candidate location was identified in this area (site UW-4).

The field team then evaluated the drainage connection and contributing runoff in the vicinity between Tongue Pond and Spectacle Pond. Two large retail projects, anchored by Lowes, Kmart, and Stop and Shop exist immediately west of the stream channel connecting Tongue and Spectacle Ponds. The team evaluated potential retrofits in this location. The field team also evaluated the large area consisting of the Providence Industrial Park as well as other areas between Spectacle Pond and Mashapaug Pond. Several retrofits were identified in the



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Upper Watershed
Location of Neighborhood Assessments
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.5

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northwest corner of Mashapaug Pond in the vicinity of the existing outfalls (site UW-1a, b & c), several sites associated with Dupont Drive and Jewel Case Corp (sites UW-2 a-d), and a site adjacent to the ball fields (site UW-3).

Finally, the team conducted a reconnaissance of the outfall pipe system from Mashapaug Pond to the location of the existing weir box (**Figure 3.6**). The weir box is a large concrete diversion structure that accepts flows from the Mashapaug Pond outfall as well as an incoming 36-inch pipe from the Route 10 drainage system. Two pipes discharge from the weir box, a 36-inch pipe that drains flow from Mashapaug Pond up to approximately the 5-year intensity storm to the Roger Williams Park ponds, and a 72-inch pipe that carries the Route 10 drainage and storms larger than approximately the 5-year storm into the I-95 drainage network, ultimately discharging to the Pawtuxet River. The team reviewed design plans from RIDOT and field verified existing drainage conditions. Two important considerations were derived from the assessment of the weir box: 1) that nearly all pollutant loading from the Upper Watershed flows to the RWP Ponds since the capacity of 36-inch pipe allows for all baseflow and stormflow from almost all storms to flow in that direction; and 2) that the weir box offers potential watershed management options to divert some or all of the smaller storms into the 72-inch pipe to bypass flow around the RWP Ponds, though baseflow should continue to flow to the Ponds. This option is discussed in more detail in **Section 4.3**.

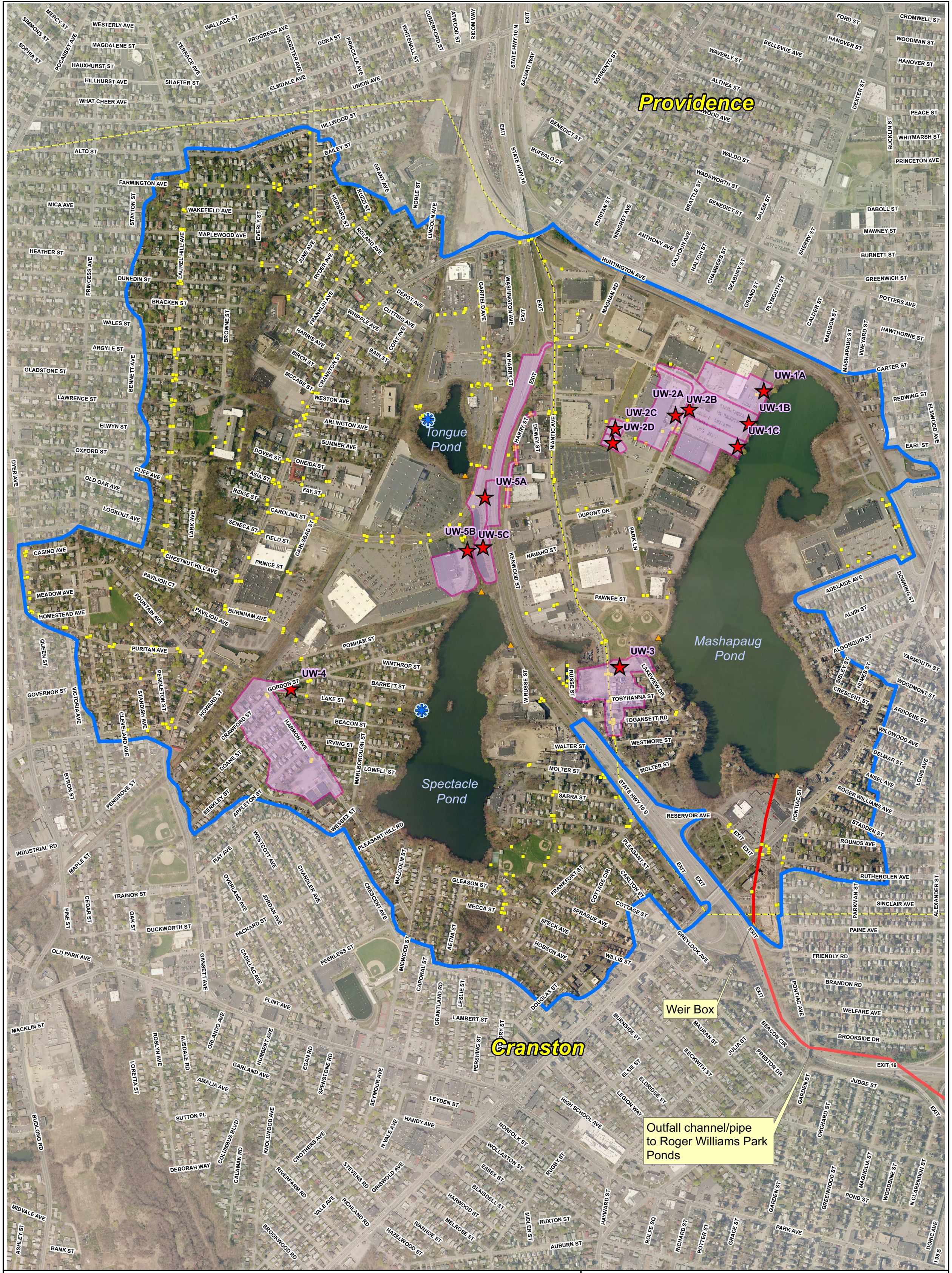
Table 3-10 summarizes the results of the field identified key stormwater retrofits. **Appendix M** includes a description and explanation of the potential retrofits evaluated at each of the identified sites. **Figure 3.6** illustrates the locations of these proposed sites.

Table 3.10. Upper Watershed Potential Retrofit Sites Summary

Site ID*	Location	Description
UW-1(a,b,&c)	City of Providence: Industrial Park - Rear of Bank of America	Construct a swale, bioretention area(s) or WVTS, repave existing flumes for directing flow. Overflow to Mashapaug Pond.
UW-2a	City of Providence: Industrial Park - Dupont Drive	Remove pavement to narrow road from 40' to 28'. Create bump outs on Dupont Drive and construct bioretention areas in the islands with overflow to existing closed drainage system.
UW-2(b&c)	City of Providence: Parking lot off of Dupont Drive – Jewel Case Corp.	Bioretention area in island.
UW-3	City of Providence: Intersection of Niantic Avenue and Swanton Street adjacent to baseball fields	Construct an infiltrating bioretention area or WVTS with paved flumes and structures to direct flow. Overflow to existing closed drainage system.
UW-4	City of Cranston: Intersection of Lake Street, Gordon Street, and Harmon Avenue	Relocate existing sewer pipe leading to pump station. Convert existing structure to diversion structure with flow diverting to bioretention area and underground recharge chambers. Overflow to existing closed drainage system.
UW-5(a&b)	City of Cranston: Adjacent to Stop and Shop Plaza entrance and Rt. 10	Bioretention areas taking runoff from road, Bio serving as pretreatment before entering existing wetland mitigation areas.
UW-5c	City of Cranston: Area of Stop and Shop parking lot	Bioretention area taking runoff from parking lot and building with overflow to existing mitigation area.
*Site ID corresponds to locations on watershed maps and to candidate project field form ID's		

3.3.3 On-site Retrofit Potential and Property Locations of LUHPPLs

As part of the October 21 and 22, 2011 field reconnaissance, HW staff conducted a rapid initial assessment of land uses and properties that contribute a disproportionate level of pollutants to the receiving waters and would, therefore, likely be important implementation sites for both structural and non-structural pollution prevention controls. As previously discussed, the Rhode Island Stormwater Design and Installation Standards Manual (December 2010) provides a specific description for LUHPPLs that includes a range of industrial use classes, such as metal manufacturing facilities, hazardous material storage and handling, and landfills (regulated under DEM's RPDES Multi-Sector General Permit for Stormwater Associated with Industrial Activity) as well as auto refueling facilities, exterior vehicle service and maintenance facilities, and road salt storage. These LUHPPLs are required to meet specific management requirements when applying for new stormwater discharge approvals.



Legend

*Color Imagery: 2008

- Upper Watershed (Revised October 2011)
- Drainage Area to Structual BMP
- Structural BMP Retrofit - Identified on 10/20/2011 - 10/21/2011
- Town Boundaries
- Pond Inlet/Outlet (Providence GIS)
- Catchbasin (Providence/Cranston GIS)
- Outfalls (Field Located)

N

Feet
400

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Upper Watershed
Structural Stormwater Retrofit Sites
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 3.6

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In the Upper Watershed, however, there are a range of land uses and activities that would not fall into the specific category of being a regulated LUHPPL but may contribute disproportionately to the overall pollutant loading to receiving waters. These are areas with high levels of impervious cover and are often combined with land use activities that have elevated levels of pollutants that contribute to degraded water quality. Examples include:

- Large parking lots for commercial/retail activities;
- Warehouses and associated imperviousness;
- Gas stations and auto repair/auto body shops;
- Restaurants;
- Food stores and associated parking;
- Laundry/dry cleaners;
- Car washes; and
- Light industrial/manufacturing/ distributors.

The Providence Industrial Park, in general, would fall into this category with significant levels of impervious cover and a very high runoff coefficient, meaning that almost any pollutant that lands, falls, or comes in contact with a rooftop or paved surface is easily delivered to the receiving waters, namely Mashapaug Pond. **Figure 3.7** illustrates the locations of these properties/activities and is offered to serve as a possible punchlist for future watershed implementation. It is important to note that, other than a rapid visual assessment from the nearest public street, none of the identified properties were field inspected, and therefore the properties identified should not be viewed as "out of compliance" with existing regulatory requirements. While a detailed assessment of these private properties is beyond the scope of this water quality management plan, future detailed assessments are recommended. As discussed in **Chapter 4**, implementation of watershed management strategies will need to be widespread and comprehensive across both the Upper and Lower Watersheds in order to achieve measurable improvements in water quality of Tongue, Spectacle, and Mashapaug Ponds as well as the RWP Ponds.

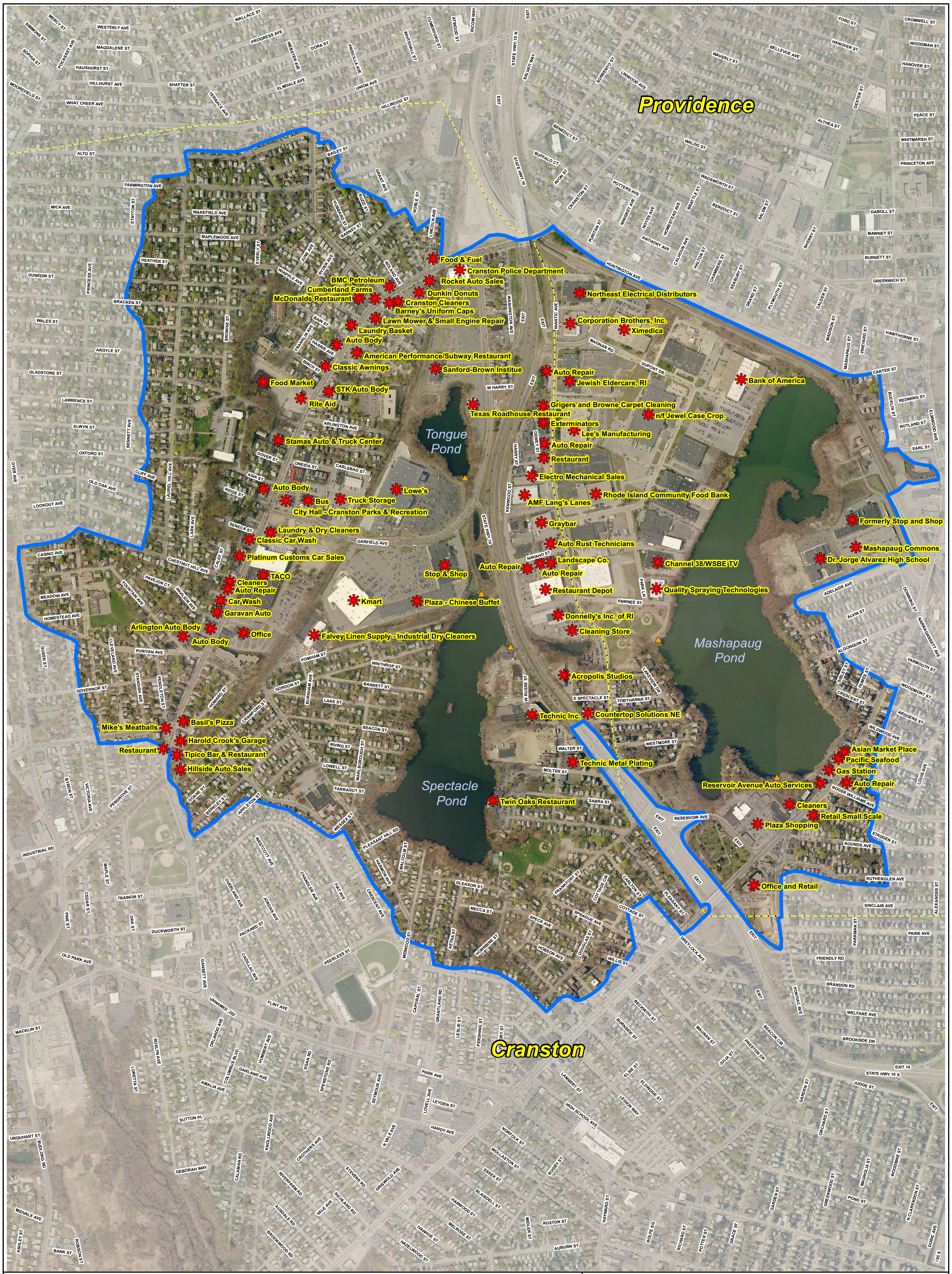
Many of the activities on these properties could easily be modified to reduce the level of pollutant delivery through the application of non-structural good housekeeping activities to minimize the possibility of pollutants coming in contact with precipitation and resulting runoff. The RI Stormwater Manual, Appendix G "Pollution Prevention and Source Controls" contains a suite of guidelines and inexpensive practices that property owners could implement to reduce pollutant loading.

In addition, the document, "Pollution Source Control Practices" (Schueler, et. al, 2004.), published as part of the Urban Subwatershed Restoration Manual Series by the Center for Watershed Protection, contains numerous methods and strategies for pollution prevention.

Based on the Project Team's initial assessment of the Upper Watershed, the following general pollution prevention activities should be considered priorities:

1) *Cover dumpsters and waste materials.* Most commercial and industrial properties have dumpsters and storage piles of a wide range of waste materials. Most dumpsters were either fully or partially open to the atmosphere on the day of our field reconnaissance. Covering dumpsters is probably the most cost effective measures to immediately reduce pollutant loading.
2) *Conduct regular street and parking lot sweeping at a frequency of at least monthly during non-winter months.* Most or the parking lots in the Upper Watershed show signs of mineral and organic materials that are easily conveyed into the nearby ponds. Monthly sweeping during the spring, summer, and fall, even with mechanical sweepers, would collect significant amounts of pollutant loads.
3) *Conduct regular catchbasin sediment removal.* Many of the catchbasins within the Upper Watershed show evidence of partial to full clogging with sediment. Both the City of Providence and the City of Cranston should undertake a systematic catchbasin cleaning program to ensure that collected sediment is removed at least annually.
4) *Ensure that floor drains are not connected to the storm drainage network and implement spill containment and counter measures controls*. A major source of pollutants can be from activities that occur within buildings that are directly connected to the drainage network. In addition, many of the activities within the Upper Watershed involve the use of chemicals and materials that if spilled or released can cause significant impacts. On-site spill prevention and controls is a major program for pollutant reduction.
5) *Manage landscaped areas with low impact techniques and discontinue the use of phosphorus-based fertilizers.* Most commercial properties do not have significant turf areas, but a few key retailers had very plush lawns. Non-phosphorus containing fertilizers should be used in the future, if not already doing so. Landscaping areas should be gradually converted to native species requiring less fertilizers, mulching, and irrigation.
6) *Direct rooftop runoff to pervious surfaces where feasible*. Most of the non-residential rooftops within the Upper Watershed are directly connected to the enclosed drainage network or directly discharging over impervious surfaces to the drainage system. Either way, runoff quickly mixes with pollutants from paved surfaces and discharge to the nearby ponds. Many properties have some level of pervious area that could accept runoff from portions of these roofs that would reduce overall runoff volume and consequently pollutant load.

Finally, nearly all of the properties identified in **Figure 3.7** in the Upper Watershed were built before modern stormwater management requirements and none, to our knowledge, since the adoption of the 2010 RI Stormwater Manual. Many of these properties have large parking lots



Legend

*Color Imagery: 2008

- Upper Watershed (Revised October 2011)
- On-Site Retrofit Property and LUHPPL Location
- Town Boundaries
- Pond Inlet/Outlet (Providence GIS)

N

400 Feet

Horsley Witten Group
Sustainable Environmental Solutions
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Upper Watershed
On-Site Retrofit Properties
and LUHPPL Locations
Roger Williams Park
Rhode Island

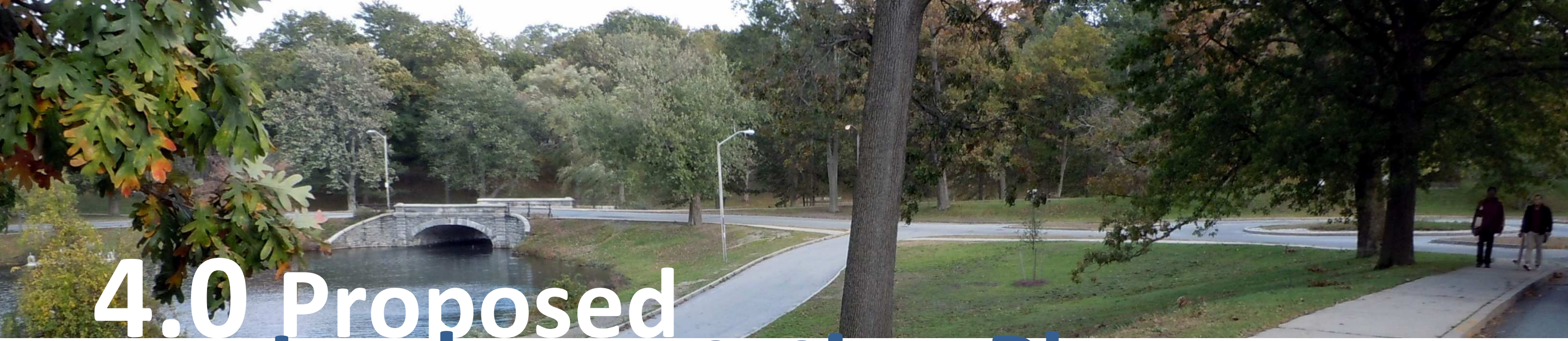
Date: 3/25/2013

Figure 3.7

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure3_7_UpperWS_LUHPPL_11058.mxd

and other impervious surfaces that could be retrofitted with LID stormwater management practices to reduce runoff and pollutant loading. The Providence Industrial Park, in particular, has many large, under-utilized impervious surfaces and road widths that likely exceed travel and turning requirements for freight-carrying trucks (see photo below). As properties are redeveloped and/or improved, or as part of a systematic watershed management strategy, the drainage and stormwater management systems for many of these properties could be dramatically changed to improve stormwater conditions. Refer to **Section 3.3.2** for retrofit examples for Sites UW 1 and UW 2.

Dupont Street in the Providence Industrial Park has a travel width of approximate 40 feet. Reducing the paving to between 28 and 32 feet would result in a significant runoff and pollutant load reduction



4.0 Proposed Implementation Plan

4.1 Introduction

This chapter presents an implementation plan for allocating funds and efforts for the RWP Pond complex water quality improvement for both the Upper and Lower Watersheds. Although the recommendations presented are all viable options for improving water quality over the next decades, some will be easier to implement than others. Therefore, some of the recommended practices are identified as a first step in the quality management process. The long-term improvement of the water quality in the RWP pond complex will require a commitment beyond the next 10 years to not only change current stormwater treatment practices and watershed management, but also to alter the Parks general appearance and maintenance practices to reduce the impacts to the Ponds. This plan identifies both structural and non-structural practices, including programmatic improvements to be implemented within both the Upper and Lower Watersheds.

4.2 Lower Watershed

The measures and recommendations provided for the Lower Watershed take into consideration the Park's historical importance to the City of Providence and its current use by local residents and tourists alike. These recommendations have been developed to be implemented without significant changes to overall park character. Options identified during the watershed assessment and presented within this section include the following:

- Structural BMPs;
- Non-structural BMPs;
- In-pond treatment;
- Public education;
- Water quality monitoring; and
- Additional studies.

4.2.1 Structural BMPs

Table 4.1 provides six individual retrofit opportunities identified during the assessment process and selected by the Steering Committee for short-term implementation. These sites were selected from a list of 30 practices and were chosen using the results of the BMP ranking system provided in (**Section 3.0**) and through assessment of other priorities by the Steering Committee. The retrofits are located throughout the Park (**Figure 4.1**) and include the following structural control practices:

- Stormwater diversion structures;
- Vegetated wet swales;
- Vegetated dry swales;
- Infiltration basins; and
- Bioretention.

Non-structural practices are also incorporated into the overall concepts, and include buffer restoration, removal of geese habitat/feeding areas, and pavement reduction.

Table 4.1. Recommended Stormwater BMP Retrofit Locations

Site ID*	Location	Description
RWP-3B	Carousel Parking Lot	Construct bioretention in existing degraded pervious area at entrance for half of parking lot runoff; overflow into existing closed drainage system
RWP-17/18	F.C. Greene Memorial Blvd	Create paved flume/inlet structure direct road runoff to wet swale; modify box culvert to create diversion structure to divert runoff to bioretention
RWP-24	F.C. Greene Memorial Blvd between Cunliff and Deep Spring Lakes	Increase buffer vegetation and reduce road width/impervious surface; remove curb and add vegetated swale in buffer to capture water before it outfalls through the existing spillway
RWP-28	Intersection of Edgewood, Beachmont and F.C. Greene Memorial Blvd	Remove pavement and add a sand filter; install paved flumes and forbays prior to the main sand filter cell; design overflow structure to connect into existing pipe with outfall into the lake
RWP-6	Roosevelt Lake across from monument	Pavement removal, raingardens, and buffer restoration
RWP-12	Ornamental Bridge at Casino	Diversion structure into a terraced bioretention under the bridge
*Site ID corresponds to locations on watershed maps and to candidate project field form ID's		

As part of this WQMP, the Project Team worked together to design and permit all of the practices listed in Table 4.1. All of the sites, excluding Site 3B, required DEM review and approval of both the BMP design and the proposed disturbance within the perimeter wetland buffer. During the watershed assessment, Site RWP-6 was initially targeted as a suitable site for a Wet Vegetated Treatment System (WVTS). After discussions with the Parks and Recreation Department and their landscape architect, Gardner+Gerrish, it was determined that the portion of F.C Greene Memorial Boulevard which runs through this site would be removed, thereby eliminating most of the stormwater runoff from impervious cover. Due to this change in park design and reduction in impervious cover, it was determined the WVTS would not be necessary for the treatment of stormwater runoff and simple rain gardens and buffer restoration would be a better option for this location. Tim Gardner, RLA (Gardner+Gerrish) developed the plans for permitting of this site.

Upon review and approval from the DEM, and in coordination with the City of Providence and the Parks and Recreation Department, construction drawings and specifications were developed and put out to public bid for the following sites:

- Site RWP 17/18 – Diversion structure and wet swale
- Site RWP 24 – Bioswale
- Site 28 – Sand Filter

Through additional funding secured by Rhode Island Natural History Survey (RINHS), it was determined the following two additional sites would be selected for installation.

- Site RWP-6 - Roosevelt Lake pavement reduction, rain gardens and buffer restoration
- Site RWP-12 - Terraced bioretention facility

Construction drawings and specifications were developed in coordination with RINHS, NBEP and the Parks and Recreation Department.

Local contractors were selected based upon bid price and qualifications. Sites RWP-6, 17/18, 24 and 28 were selected for final construction. Due to bid prices and limited funding, it was determined that Site RWP-12 would not be constructed as part of this funding round, but will be considered for construction at a future date. Construction began at Site RWP-28 and RWP-6 in November 2012. A comparison of the bid price and planning and design level cost estimates is provided in Table 4.2.

Table 4.2. Planning Level and Bid Costs Comparison

Site ID*	Location	Planning Level Cost	Design Level Cost	Bid Price
RWP-3B	Carousel Parking Lot	Demonstration	Demonstration	Demonstration
RWP-17/18	F.C. Greene Memorial Blvd	$32,500	$77,000	
RWP-24	F.C. Greene Memorial Blvd between Cunliff and Deep Spring Lakes	$49,000	$91,000	
RWP-28	Intersection of Edgewood, Beachmont and F.C. Greene Memorial Blvd	$140,000	$113,000	
RWP-6	Roosevelt Lake across from monument	NA	NA	$297,000
RWP-12	Ornamental Bridge at Casino	$89,000	$121,000	$112,000

*Site ID corresponds to locations on watershed maps and to candidate project field form ID's

The 28 remaining stormwater retrofit sites identified in Chapter 3 should also be considered as part of the short-term and mid-term recommendations. As funds become available, or if general site improvements are undertaken in the general vicinity of the remaining sites, the opportunity to construct additional stormwater retrofits may be possible within 10 years. It may not be possible to construct all of remaining sites within the next 10 years; therefore these sites should also be included as part of any long-term plans developed for the Park. Detailed descriptions and planning level cost estimates for the remaining retrofit sites are provided in **Appendix F and G.**

Legend

- Roger Williams Pond Watershed (Revised October 2011)
- Drainage Area to Structural BMP
- Town Boundaries
- RIDEM Priority Outfall
- Pond Inlet/Outlet (Providence GIS)
- Catchbasin (Providence/Cranston GIS)

N

Feet

350

*Color Imagery: 2008

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Lower Watershed
Recommended Structural
BMP Retrofit Locations
Roger Williams Park
Rhode Island

Date: 3/25/2013

Figure 4.1

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure4_1_Struct_Top5_11058.mxd

4.2.2 Non-Structural BMPs

Site Specific

A number of site specific non-structural opportunities were identified to prevent pollution, enhance park appearance, reduce geese habitat, and provide public education and outreach opportunities. **Table 4.4** provides five individual nonstructural opportunities identified during the assessment process for short-term implementation. The five sites were selected from a list of fourteen practices which included:

- Buffer restoration;
- Slope stabilization; and
- Curb removal.

Unlike the stormwater retrofits, these practices were not ranked, but were selected based on visibility and public education outreach potential, practice type, and urgency of implementation. The practices chosen for short-term implementation include buffer restoration and slope stabilization and were selected from the BMP ranking list provided in (**Section 3.0**). The retrofits are located throughout the Park (**Figure 4.2**) and include structural control practices including stormwater diversion structures, vegetated swales, and bioretention. Non-structural practices are also included as part of the overall concepts and include buffer restoration, removal of geese habitat/feeding areas, and pavement reduction.

Table 4.3. Recommended Short-Term Non-structural Locations

Site ID*	Location	Description	Practice
RWP-1G	Shoreline near Boathouse	Re-vegetate buffer area with low-growing grasses and shrubs	Buffer Restoration
RWP-2	Road by Carousel	Plant native material; augment soils and convert low area at yard drain to rain garden; shoreline buffer plantings	Buffer Restoration
RWP-16	Hillside near Polo Lake	Plant with native, low-growing grasses and shrubs to stabilize and provide vegetated buffer to Polo Lake	Slope Stabilization
RWP-22	Hillside erosion near Pleasure Lake	Re-vegetate erosion near stairs; re-plant area of recent storm damage/tree removal; remove area of Japanese knotweed	Slope Stabilization
RWP-23	F.C. Greene Memorial Blvd by Temple of Music	Curb removal only and create areas of no-mow meadows	Curb Removal

*Site ID corresponds to locations on watershed maps and to candidate project field form ID's

The nine remaining non-structural sites identified in Chapter 3 should also be considered as part of the short-term and mid-term recommendations. As funds become available, or if general site improvements are undertaken in the general vicinity of the remaining sites, the opportunity to provide additional improvements may be possible within the next 10 years. However, it may not be possible to construct all of remaining sites within this timeframe;

therefore these sites should also be included in any the long-term plans developed for the Park. Detailed descriptions and planning level cost estimates for the remaining sites are provided in **Appendix H and I.**

Programmatic

The first priority in the implementation of the non structural programmatic practices should be the development of a comprehensive O&M Plan for the existing and recently installed stormwater management practices as described in **Section 3.2.3**. The development of an O&M Plan is critical to not only the long-term proper operation and function of the recently installed stormwater retrofit BMPs, but also to address the neglected existing stormwater conveyance system within the Park. This includes the cleaning of all clogged catch basins and the implementation of an enhanced street sweeping program. During the assessment, numerous catch basins were identified as clogged that have significant impacts on how stormwater runoff is managed within the Park. Specifically, in the section of F.C. Greene Boulevard in the Park's eastern area along Edgewood and Elm Lakes, there are a significant amount of clogged catch basins. Many of the same catch basins along F.C. Greene Boulevard that were identified in the watershed assessment were also identified as clogged in the "Roadway Improvement Project – Roger Williams Avenue – Phase II" plan set dated 1995. In some instances, stormwater runoff travels long distances via overland flow due to clogged basins, thereby inundating the ultimate downstream receiving structures. It should be noted the recommended stormwater retrofits referenced in **Section 4.2.1** have assumed that the existing catch basins will be cleaned and functioning properly and have been sized accordingly. Turf management including fertilization and mowing frequency, and park staff training should also be addressed in the O&M Plan.

As mentioned earlier, the improvement of the water quality in the RWP Ponds will require a long-term commitment to not only changing current stormwater treatment practices and watershed management, but also to altering the Park's general appearance and maintenance practices to reduce the impacts to the Ponds. In order to address these issues and move forward with the implementation of both the short-term and long-term recommendations of this WQMP, it is recommended that a comprehensive park master planning process begin within the next one to five years. At a minimum a comprehensive park master plan is needed to address the current park usage, roads, sidewalks and other paved surfaces (both vehicular and pedestrian) for removal or pavement reduction, parking requirements, modified shoreline access, and park maintenance practices. A master plan for the Park will be instrumental in serving as a guide for the appropriate implementation of stormwater quality control practices and should address not only water quality, but park usage and the implication of any significant changes of the its historical character.

The Park was originally designed in 1878 for a specific use and purpose in the context of that time. Over the years changes have been made to address changing needs, such as the widening of roadways by the WPA in the 1930s to accommodate vehicular traffic, and it seems appropriate that a master plan be developed to more closely reflect modern usage and environmental concerns. The identification of "low mow "areas to create grassy meadows or

Legend

Roger Williams Pond Watershed (Revised October 2011)

Town Boundaries

Non-Structural BMP Retrofit

RIDEM Priority Outfall

Pond Inlet/Outlet (Providence GIS)

*Color Imagery: 2008

N

Feet

350

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Lower Watershed
Recommended Non-Structural
BMP Retrofit Locations
Roger Williams Park
Rhode Island

Date: 1/17/2012

Figure 4.2

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure4_2_Non_Struct_Top5_11058.mxd

the reduction of formal shoreline access are examples of changes that could be undertaken to improve water quality and change current usage detrimental to the overall RWP Ponds appearance and health. The development of an all encompassing master plan would serve as a guiding document to lead the Park and water quality management into the 21st Century.

Geese Management/Population Control

A Geese Control Plan has been developed by USDA APHIS and measures have already been taken within the Park to reduce the overall Canada Geese population. This will be an on-going effort within the Park and should be considered as an integral part of the WQMP.

Leaf Litter Pick Up

The Parks and Recreation Department should continue their current leaf litter pick up program. Spring and fall leaf litter should be scheduled for the road and lawn areas. A leaf litter pick up program should also be discussed with both Cranston and Providence. Information pertaining to the importance of leaf litter pick up should be included in any proposed neighborhood public outreach programs.

Phosphorus Ban

If not already doing so, the Parks and Recreation Department should eliminate the use of phosphorus fertilizers in lawn areas. A phosphorus ban should be considered for the Park's surrounding cities of both Cranston and Providence and eventually statewide. At a minimum, awareness regarding the negative impact of phosphorus use should be included in any public outreach program.

4.2.3 In-Pond Treatment

Completion of any major in-pond treatments, such as dredging, within the next 10 years will require a strong commitment from the City and aggressive action. Additional studies, permitting, and design plans will need to be completed prior to implementation of any in-pond management actions as described in **Section 3.2.6**. The recommended priorities for the next one to five years are based upon the recommendations found in **Section 3.2.6**.

1. **Continue the control of nuisance rooted aquatic plants**
   Obtain annual written reports on the locations and types of plants treated and the locations of invasive species. As part of the plant control the Parks and Recreation Department should begin to complete annual quantitative evaluations of plant community conditions and changes.

2. **Continue the control of nuisance algal blooms.**
   Complete a study of phytoplankton species and numbers within the RWP Ponds and continue to collect data at the same frequency as basic water quality data.

3. **Begin monitoring of RWP Ponds for Secchi depth, dissolved oxygen and nutrients several times a year.**
   See **Section 4.2.5**.

4. **Evaluate the fishery and consider carp control.**
   Verify carp population by completing a fisheries survey.

5. **Treatment of the inflow from the Upper Watershed at the Roosevelt Pond inlet to reduce total phosphorus load by approximately half and reduce the total suspended solids load substantially.**
   The alum dosing station is viewed as a potential priority project that will provide interim relief while other watershed management options are proceeding, and as protection on investments made in other in-pond management approaches. Therefore preparation of an engineering feasibility/design study to determine the best method for treating the inflow from Mashapaug Pond should occur within the next three years. See **Section 4.2.5**.

6. **Dredge Roosevelt, Polo, Willow and Pleasure Ponds to remove soft sediment accumulation and rooted aquatic plants.**
   Complete a study to determine soft sediment depth within the targeted ponds, and perhaps all the Ponds, to confirm which have substantial soft sediment accumulation. Sample and test areas targeted for dredging for toxics and metals required to determine dredging disposal options.

7. **Inactivate sediment available phosphorus in Edgewood, Cunliff and Elm Lakes.**
   Complete a more comprehensive evaluation of loosely sorbed, iron-bound and total phosphorus in the RWP Pond sediments.

4.2.4 Public Education

As identified in **Section 3.2.7,** public education and outreach is an important element of any water quality management plan. Educating the public on the water quality issues and identifying ways for the Park visitors and surrounding neighborhoods to assist in water quality improvement should be the first step. The following short-term recommendations have been developed, based upon **Section 3.2.7**, to lay the foundation for a long-term public education and outreach program for all of the Park users

General Items

The first step should include some general organization and the development of a central watershed volunteer group. Members should include representatives from all user groups and could be used to assist with the creation and implementation of a long-term education and outreach program. A strong volunteer organization is critical to the long-term success of any public outreach program, therefore, the following general recommendations are provided:

1. The Friends of Roger Williams Park Ponds organization should be strengthened and expanded. The creation of the Facebook page and the current project website located on the NBEP website are a strong first step, but the development of a stand-alone park website, or one linked to the City of Providence website, should be considered. It could

provide a central location for the dissemination of all park and pond related information. The following links are examples of both stand-alone and linked park websites:

http://www.centralparknyc.org/

http://www.cityofboston.gov/freedomtrail/bostoncommon.asp

http://www.riparks.com/colt.htm

http://www.ballardpark.org/

A website could also serve as an effective tool to generate more interest in the Park and encourage volunteerism, which could include park clean ups, water sampling and/or monitoring, fish surveys, and other park related efforts.

2. The Parks and Recreation Department, in collaboration with NBEP, should continue the public meetings and consider expanding to include guest speakers to discuss issues related to the Park.

Residential Audience

The Park is surrounded by a diverse spectrum of residential neighborhoods. These neighborhoods have a direct impact on the Ponds through usage from the residents as well as the direct contribution of stormwater runoff to the RWP Ponds. Outreach within these neighborhoods is vital to not only change detrimental park usage patterns, but to encourage stormwater runoff reduction through onsite management at the residential level. The following short-term recommendations are provided to target this group:

1. Conduct a public stormwater retrofit installation demonstration within the Park. This program could benefit the Parks and Recreation Department maintenance crew and local landscape contractors, as well as surrounding residents alike. The design and construction of a raingarden could be explained and demonstrated as well as a discussion on suitable residential applications to disconnect pavement and roof runoff from the storm drainage system. The retrofit demonstration project advertisement should include targeted mailings, local newspaper ad, cable access television stations, radio, and other media outlets in advance of project implementation. Publish a follow-up article in the *Providence Journal* or story on the local news stations. Site RWP-2 (raingarden near the Carousel) would be a good candidate for educational signage.

2. The creation or distribution of an existing informational pamphlet providing an overview of BMPs (e.g., rain gardens and/or rain barrels) that can be installed on individual properties to reduce stormwater runoff. In addition, residents in the surrounding neighborhoods should be targeted for information on catch basin stenciling, proper pet

waste management, and pond-friendly lawn care. This information could also be linked to the Park website proposed under the general recommendations.

3. Install educational signage at select stormwater retrofit sites along the perimeter of the Park and abutting the residential neighborhoods. Sites 28 and 29 would be good candidates for this type of signage.

Frequent Park Users

The Park has a diverse group of frequent users including fisherman, boaters, kayakers, bicyclists, sports enthusiast, and the geese feeders. Due to this group's diversity and transient nature of their visits, public education to this group has proven to be the most difficult. Education targeted to this group will need to be incorporated into the use areas and address the need to alter current behaviors that might be detrimental to the pond water quality or the public health. The following short-term recommendations are provided to target this group:

1. Warning signs should continue to be posted to alert fisherman and boaters on the health risks related to fish consumption and the contact with pond water. This group of park users could also be a valuable resource for a fish inventory through the use of an interactive website.

2. The distribution of up-to-date water quality information through a park website or Facebook page.

3. Educational signage should be installed to explain the link between stormwater runoff, pond water quality, the constructed BMPs, and the health of the fish population. Site RWP 24 or the boat ramp would be a good candidate for educational signage to target this group.

4. The geese feeders are probably the most difficult group to reach, as they comprise all of the Park users and often see the geese as a park attraction. As a first step, educational signage should be installed at the proposed BMP locations identified as geese feeding areas to explain water quality and the importance of reduction of geese habitat. Sites RWP-6, RWP-17/18, and RWP-24 would be good candidates for this type of educational signage.

Casual Park Visitors

The Park is a significant tourist attraction for both in-state residents as well as visitors from around New England and abroad. The high number of visitors to the Park presents a unique opportunity to reach a wide spectrum of park users that can have a significant, yet unknowingly, impact on the water quality of the Ponds. The following recommendations are provided to target this group:

1. Install educational signs highlighting both the structural and non-structural BMPs installed within the most frequently visited areas of the Park (Roosevelt, Willow, and

Polo Lakes). These signs should not only highlight the improved water quality treatment, but also focus on the reduction of geese habitat/feeding areas, the value of a vegetated shoreline, and identification of plants used. The signs should promote awareness of the BMP benefits to the Ponds and their importance to all visitors. Sites RWP-1G and RWP-2 would be good candidates for this type of educational signage.

2. Create an informational pamphlet providing an overview of the water quality issues and to raise awareness. This pamphlet could be distributed to visitors at the Carousel, Boathouse, and Zoo.

3. Linkage of websites between different entities within the Park, such as Roger Williams Park Zoo, local and state agencies such as, RIDEM, City of Providence and the City of Cranston, or informational websites where links to basic homeowner stormwater education guidance material is posted.

Park Staff and Other facilities

This group includes park maintenance and the other facilities that would benefit from educational opportunities related to site maintenance both within the Park and at their individual facilities.

1. Public stormwater retrofit installation demonstration as identified under general recommendations.
2. A maintenance seminar to focus on good stormwater maintenance practices as well as "green" landscape practices.

4.2.5 Water Quality Monitoring

A few programs in Rhode Island are already in place to measure certain relevant water quality indicators. These include:

- The Narragansett Bay Commission (NBC) Environmental Monitoring and Data Analysis;
- The University of Rhode Island (URI) Watershed Watch Program; and
- The EPA/AED.

The NBC is a publicly owned facility treating wastewater from domestic, commercial, and industrial sources in the metropolitan Providence and Blackstone Valley areas. It tracks and publishes the levels of nutrients, totals suspended solids, biochemical oxygen demand, fecal coliform, and other water quality parameters throughout its service areas. Although the NBC monitoring program does not currently include the RWP Ponds, it is a good example of a monitoring program to both measure effectiveness of control measures and provide education and outreach for the general public.

The URI Watershed Watch (URIWW) Program is involved in long-term ecological monitoring of Rhode Island's fresh and salt water resources and provides training, equipment, supplies, and analytical services to local governments, watershed, and other organizations to assess water quality. The URIWW program makes the monitoring data publicly available, improving water quality awareness of local governments as well as the general public.

In addition the EPA/AED (2011) completed a sampling round of the Ponds in 2011. Results of that sampling are to be provided under separate report from EPA.

Several suggested monitoring recommendations have been referenced in previous sections (See **Chapter 2** and **Section 3.2.6**.) as necessary to document changes in water quality over time. Listed below is a summary of these suggestions and additional recommendations for implementation within the next one to three years:

1. EPA/AED should repeat the 2011 monitoring of water quality parameters at least one additional time including, but not limited to Secchi depth, surface dissolved oxygen, surface conductivity, bottom dissolved oxygen, bottom conductivity, and water chemistry parameters.
2. Secchi depth and dissolved oxygen could be monitoring regularly by URIWW in years two and three several times during the spring, summer, and fall (refer to **Section 3.2.6** for specifics).
3. Fish species and population survey should be conducted to establish where bottom dwelling fish are abundant and potentially contributing to sediment resuspension.
4. Citizen volunteer or URIWW monitoring of constructed stormwater structural control practices should occur once annually for physical and aesthetic parameters, including but not limited to evidence of erosion, depth of sediment, and success of plant species growth and development.
5. Citizen volunteer or URIWW monitoring of non-structural vegetative planting success should occur once annually beginning in year two.
6. Monitor geese population (see separate report prepared by Tim Cozine).

Results of all monitoring should be published and posted to the project website and distributed to the public.

4.3 Upper Watershed

In the Upper Watershed (see **Section 3.3**), the assessment of different watershed management strategies was limited to the most obvious stormwater retrofit locations, including an on-site demonstration (Site UW-2), general recommendations for pollution prevention in three neighborhoods and properties with large on-site impervious cover/LUHPPLs. In addition, the field team conducted an initial assessment of the weir box located within the discharge channel/pipe system from Mashapaug Pond. The following implementation recommendations are suggested:

- The cities of Cranston and Providence should investigate funding opportunities for implementation of one or more pilot stormwater retrofit projects. Any of the five project locations identified in the Upper Watershed would serve as a good demonstration project.

Site UW-3, in particular, includes drainage from both municipalities and might be an ideal site for cooperative implementation. Short term implementation would include securing funds to design and construct one or more facilities. Current implementation cost for retrofits within an urban watershed range from approximately $30,000 to as high as $130,000 per acre of impervious cover treated depending on land use, soil type, and site specific factors (HW, 2011). For planning purposes, a cost of $50,000 per impervious acre treated would be a reasonable number for any of the proposed projects identified for the Upper Watershed.

- Since all the low flows and smaller storms are diverted in the weir box to flow towards the RWP Ponds, discharging through the 48-inch pipe into Roosevelt Lake, further investigation is warranted to evaluate the feasibility, costs, and environmental benefits/impacts of modifying this existing diversion. It would be relatively inexpensive to modify the weir box to divert some of the current flows into the 72-inch pipe that bypasses the RWP Ponds. An orifice plate could be constructed at the outlet of the 36-inch pipe discharging to the Park ponds with a small office to allow base flow to continue to flow that way and forcing runoff from storm events to flow into the 72-inch pipe. If there are capacity concerns for the 72-inch pipe, the diversion could be sized only to shunt small frequent storms (say in the range of the one-inch precipitation event) in that direction and allow an overflow back into the 36-inch pipe. For planning purposes, a construction cost of $25,000 to $40,000 would be a reasonable estimate for the implementation of a weir box flow modification. The short-term recommendation would be to conduct further investigation to answer the question of "does this make sense?" and whether or not there would be significant permitting and/or other concerns with a modification of this structure. DEM, RIDOT, the City of Providence, and NBEP, among others may have serious concerns regarding this topic. Completion of a detailed feasibility assessment might cost in the range of $15,000 to $20,000.
- Pollution prevention in the Upper Watershed would require a significant and long-term program of public education, outreach, and engagement to be effective. Conversely, though unlikely in the near-term, the cities of Cranston and Providence could enact one or more ordinances to mandate pollution prevention. As a short-term recommendation, the cities should convene a working group to initiate a pollution prevention program targeted at the businesses and residents of the Upper Watershed. The working group should establish goals for implementation and identify metrics to measure success. A planning level cost for such a program would likely in the range of $10,000 to $20,000.

4.4 Additional Studies

The following additional studies the following will need to be performed to further advance some of the recommendations indentified in implementation plan.

- RWP Ponds dredging study;
- Mashapaug Pond weir box modifications study; and
- Mashapaug in-pond treatment study

In order to better assess the in-pond options both a dredging study and in-pond treatment study will need to be completed prior to any actions being taken. A study will determine soft sediment depth within the targeted ponds, and perhaps all the Ponds, and confirm which of the Ponds have substantial soft sediment accumulation. The City should sample and test areas targeted for dredging for toxics and metals required to determine dredging disposal options. Additional sediment sampling will be needed to better characterize the sediments in all ponds.

In the Upper Watershed, additional studies will be needed to assess the viability of the proposed weir box modifications as well as Mashapaug Pond in-pond treatment options including an outflow alum dosing station. Therefore preparation of an engineering feasibility/design study to determine the best method for treating the inflow from Mashapaug Pond should occur within the next three years. The study should investigate the construction of an alum dosing station as well as monitoring the outflow volume and total phosphorus concentration over time to provide a better estimate of actual inputs to revise dosing amounts.

4.5 Estimated Pollutant Load Reductions

The recommendations provided in this WQMP serve as a guideline for improving the water quality of the RWP pond complex. Although this plan provides recommended improvement for both the upper and lower contributing watersheds, it does not provide detailed solutions for all of the potential pollutant problems and their contributing sources, this is particularly true for Mashapaug Pond. The following goals for the Ponds were developed based upon the required 73% phosphorus load reduction identified in the TMDL and by definition would allow the Ponds to meet water quality standards, and consequently would significantly reduce or eliminate the current seasonal algae problems within the Ponds. In short, the goals are to:

- Reduce phosphorous loadings to the Ponds by 20% in five years;
- Reduce phosphorous loadings to the Ponds by 42% in ten years; and
- Over the long term, continue to work towards the reduction of phosphorus loadings by up to 73%.

The estimated phosphorus load reduction summary provided in **Table 4.5** below outlines an aggressive strategy based upon these goals. The load reductions provided assume that all recommendations outline in the WQMP are implemented, including the short-, mid- and long-term management measures. In addition, other more-global management measures, such as improvements in regional air quality and regional or state-wide bans on phosphorus fertilizers, are offered as means to achieve the water quality goals of the TMDL. To meet the reductions identified in **Table 4.5**, the following additional assumptions are provided:

- 20% reduction of the internal pond recycling;
- Implementation of a wide array of structural and non structural BMPs within the Upper Watershed to improve the water quality of the contributing Mashpaug Pond and Spectacle Pond;

- Implementation of a weir box modification or major constructed wetland in Mashapaug Pond to improve the water quality of incoming water between Mashpaug Pond and Roosevelt Lake;
- Implementation of a statewide phosphorus ban or at a minimum a ban within both the Upper and Lower Watersheds;
- Implementation of an aggressive leaf litter pickup and catchbasin cleaning program within both the Upper and Lower Watersheds.
- Additional reductions for atmospheric deposition reductions based upon the continuing trends of improved air quality and the addition of more stringent future environmental regulations.

In order to achieve the identified goals the following short-, mid- and long-term recommendations are provided:

Short-Term (1-5 Years)

- Lower Watershed
    - Structural BMPs: 6 BMPs installed (#s 3B, 6, 12, 17/18, 24 and 28)
    - Non-Structural BMPs:
        - 7.5% reduction due to partial phosphorus ban and leaf litter pickup.
        - Waterfowl: Geese population reduced to 50 birds.
- Upper Watershed
    - Non-Structural BMPs: 7.5% reduction due to partial phosphorus ban and leaf litter pickup.

Mid-Term (5-10 Years)

- Lower Watershed Non-Structural:
    - 10% reduction due to phosphorus ban, leaf litter pickup and catch basin cleaning.
    - Waterfowl: Geese population reduced to 50 birds.
    - Structural BMPs: All 30 BMPs in RWP installed.
- Upper Watershed
    - Structural BMPs: 50% reduction due to weir box modification or major constructed wetland in Mashapaug Pond.
    - Non-Structural BMPs: 15% reduction due to phosphorus ban, leaf litter pickup and catch basin cleaning.
- Internal Pond Recycling: 20% load reduced due to lower incoming loads (from waterfowl and Upper Watershed).

Long-Term (10-25 Years)

- Lower Watershed
    - Non-Structural BMPs: 20% reduction due to phosphorus ban, leaf litter pickup and regular catch basin cleaning and regular street sweeping Structural BMPs: All 30 BMPs in RWP installed + additional BMPs beyond RWP, resulting in 50% load reduction.

  - Waterfowl: Geese population reduced to 50 birds.
- Upper Watershed
  - Structural BMPs: 60% reduction due to weir box modification or major constructed wetland in Mashapaug Pond, plus additional BMPs
  - Non-Structural BMPs: 20% reduction due to phosphorus ban, leaf litter pickup, regular catch basin cleaning, and regular street sweeping.
- Atmospheric deposition: 5% load reduced due to cleaner air quality nationally.
- Internal Pond Recycling: 35% load reduced due to lower incoming loads (from waterfowl and Upper Watershed) and 35% of load reduced due to dredging.

Table 4.4. Estimated Phosphorous Load Reduction Summary

Source Area	Current Loading to Ponds		Phosphorus Reduction Over Time by Management Activity						
				Short Term (5 Yrs)		Mid Term (10 Yrs)		Long term (25 Yrs)	
	Load #	%		Load #	% of Total	Load #	% of Total	Load #	% of Total
Atmospheric Deposition	64	6.9	Air quality improvement	0	0	0	0	3.2	0.3
Pond Internal Recycling	128	13.9	Lower incoming load	0	0	25.6	2.8	44.8	4.9
			Dredging	0	0	0	0	44.8	4.9
Waterfowl	154	16.7	Removal/Habitat Alteration	132	14.3	132	14.3	132	14.3
Upper Watershed Stormwater	360	39.0	Non-Structural	27	2.9	54	5.9	72	7.8
			BMPs (includes weir box or other structure)	0	0	126	13.7	216	23.4
Lower Watershed Stormwater	216	23.5	Non-Structural	16.2	1.8	21.6	2.3	43.2	4.7
			BMPs	9.2	1.0	27.5	3.0	108	11.7
Totals	922	100		184.4	20.0	386.7	41.9	664.0	72.0

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Appendix A

Mashapaug Pond Weir Box Calculations

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MEMORANDUM

TO: Marie Evans Esten

FROM: Brian Kuchar / Kristopher Houle

DATE: November 23, 2011

RE: Roger Williams Park Water Quality Management Plan:
Upper Watershed Modeling

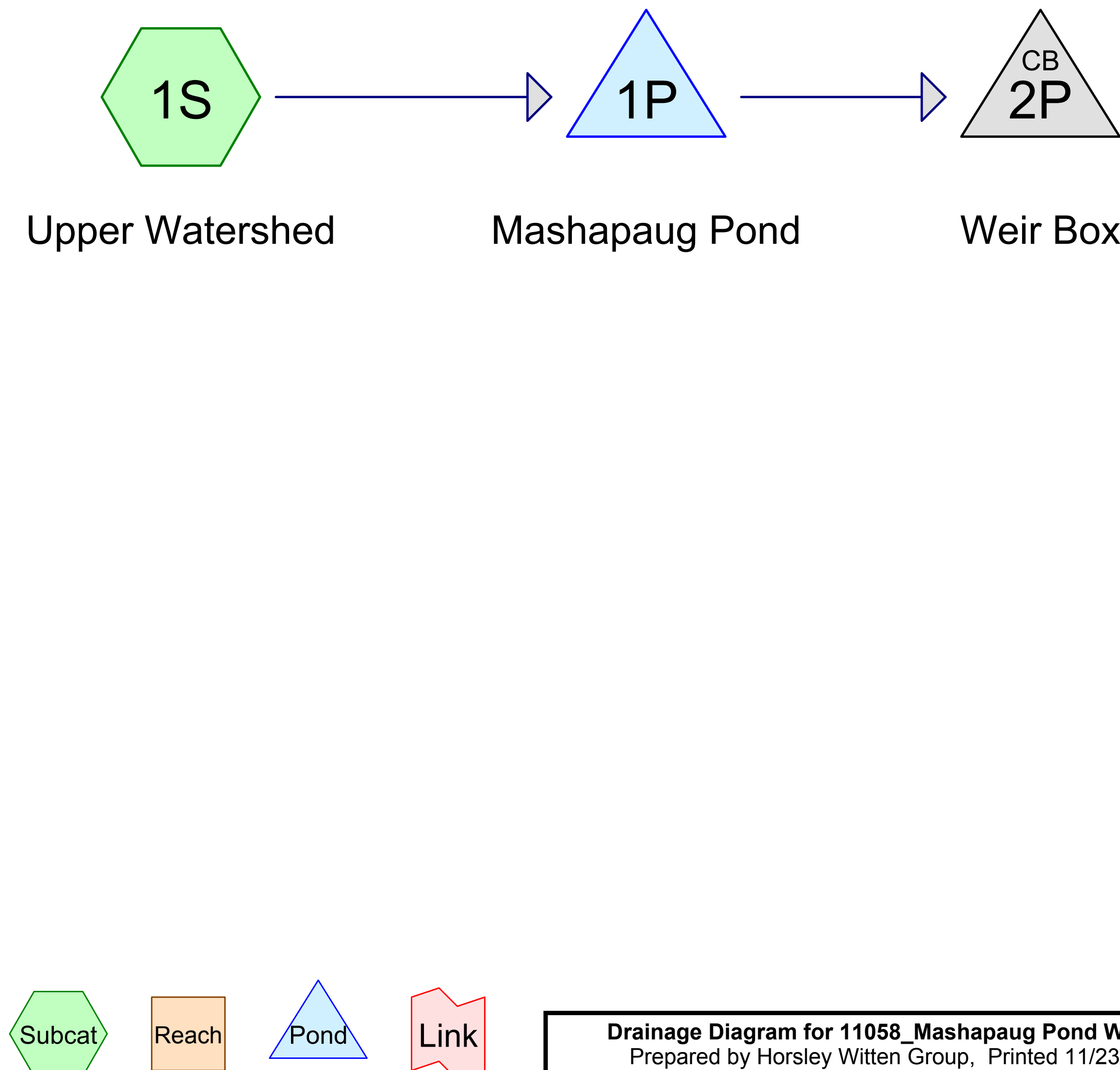
CC: Rich Claytor

In order to determine the amount of runoff that discharges into Roosevelt Pond from the Roger Williams Park Upper Watershed, a basic hydrologic model was created using HydroCAD 9.00 (2009). Land use data was obtained by Loon Environmental to model the Upper Watershed runoff characteristics. Construction drawings were obtained from the Rhode Island Department of Transportation (RIDOT) for the Huntington Expressway Project that describes the design of the Mashapaug Brook Weir Box Structure.

The weir box structure controls the amount of the water that passes to Roosevelt Pond via a 36-inch diameter reinforced concrete pipe (RCP). Once the capacity of the 36-inch RCP is reached, excess runoff passes over a 20-foot long, broad-crested weir and through a 72-inch RCP bypass culvert.

According to the model results, the design capacity of the 36-inch RCP is approximately 40 cubic-feet per second (cfs). When this flow rate is exceeded, the 72-inch RCP begins to carry runoff. This design flow rate of 38.5 cfs corresponds with an approximate 7 year recurrence interval design storm, or 4.64 inches of rainfall. In order to determine these results, the following assumptions were necessary.

- It was assumed that all runoff from the Mashapaug watershed flows into the Mashapaug Pond and is not attenuated by any other ponds or detention areas.
- The available storage of Mashapaug Pond was assumed to be approximately 2.5 feet based on available topographic information.
- The outlet structure for Mashapaug Pond was assumed to be a 48-inch RCP culvert based on the best available data provided by the RIDOT.



Drainage Diagram for 11058_Mashapaug Pond Watershed
Prepared by Horsley Witten Group, Printed 11/23/2011

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
20.752	39	>75% Grass cover, Good, HSG A (1S)
55.092	43	Woods/grass comb., Fair, HSG A (1S)
80.130	61	1/4 acre lots, 38% imp, HSG A (1S)
29.689	70	Institutional (1S)
308.251	77	1/8 acre lots, 65% imp, HSG A (1S)
4.991	77	Newly graded area, HSG A (1S)
168.408	81	Urban industrial, 72% imp, HSG A (1S)
156.718	89	Urban commercial, 85% imp, HSG A (1S)
34.744	98	Paved roads w/curbs & sewers, HSG A (1S)
118.246	98	Water Surface, HSG A (1S)
977.021		**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Goup	Subcatchment Numbers
947.332	HSG A	1S
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
29.689	Other	1S
977.021		**TOTAL AREA**

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)
1	1P	39.00	31.70	1,392.0	0.0052	0.011	48.0	0.0

Summary for Subcatchment 1S: Upper Watershed

Runoff = 963.77 cfs @ 13.02 hrs, Volume= 203.090 af, Depth= 2.49"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-144.00 hrs, dt= 0.05 hrs
Type III 24-hr DESIGN Rainfall=4.64"

	Area (ac)	CN	Description
	118.246	98	Water Surface, HSG A
	55.092	43	Woods/grass comb., Fair, HSG A
	168.408	81	Urban industrial, 72% imp, HSG A
	156.718	89	Urban commercial, 85% imp, HSG A
	34.744	98	Paved roads w/curbs & sewers, HSG A
	20.752	39	>75% Grass cover, Good, HSG A
	308.251	77	1/8 acre lots, 65% imp, HSG A
	80.130	61	1/4 acre lots, 38% imp, HSG A
	4.991	77	Newly graded area, HSG A
*	29.689	70	Institutional
	977.021	79	Weighted Average
	338.754		34.67% Pervious Area
	638.267		65.33% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.8	50	0.0270	0.17		**Sheet Flow, Sheet** Grass: Short n= 0.150 P2= 3.40"
4.4	582	0.0120	2.22		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.8	603	0.0760	5.60		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	406	0.0940	6.22		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
18.0	1,568	0.0051	1.45		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
16.5	1,048	0.0050	1.06		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
26.8	1,082	0.0055	0.67	0.05	**Pipe Channel, Channel** 5.0" x 2.0" Box Area= 0.1 sf Perim= 1.2' r= 0.06' n= 0.025 Rubble masonry, cemented
0.3	215	0.0050	12.52	353.91	**Pipe Channel, culvert** 72.0" Round Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.011 Concrete pipe, straight & clean
0.8	622	0.0050	12.52	353.91	**Pipe Channel, culvert** 72.0" Round Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.011
1.8	1,392	0.0052	12.77	360.92	**Pipe Channel,** 72.0" Round Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.011
76.3	7,568	Total			

Summary for Pond 1P: Mashapaug Pond

Inflow Area = 977.021 ac, 65.33% Impervious, Inflow Depth = 2.49" for DESIGN event
Inflow = 963.77 cfs @ 13.02 hrs, Volume= 203.090 af
Outflow = 38.48 cfs @ 23.86 hrs, Volume= 154.578 af, Atten= 96%, Lag= 650.3 min
Primary = 38.48 cfs @ 23.86 hrs, Volume= 154.578 af

Routing by Stor-Ind method, Time Span= 0.00-144.00 hrs, dt= 0.05 hrs
Peak Elev= 41.30' @ 23.86 hrs Surf.Area= 3,227,561 sf Storage= 7,408,472 cf

Plug-Flow detention time= 2,384.5 min calculated for 154.578 af (76% of inflow)
Center-of-Mass det. time= 2,297.4 min (3,190.4 - 892.9)

Volume	Invert	Avail.Storage	Storage Description
#1	39.00'	8,068,903 cf	**Custom Stage Data (Irregular)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
39.00	3,227,561	13,230.0	0	0	3,227,561
41.50	3,227,561	13,230.0	8,068,903	8,068,903	3,260,636

Device	Routing	Invert	Outlet Devices
#1	Primary	39.00'	**48.0" Round Culvert** L= 1,392.0' RCP, square edge headwall, Ke= 0.500 Outlet Invert= 31.70' S= 0.0052 '/' Cc= 0.900 n= 0.011

Primary OutFlow Max=38.48 cfs @ 23.86 hrs HW=41.30' (Free Discharge)
└—**1=Culvert** (Inlet Controls 38.48 cfs @ 5.16 fps)

Summary for Pond 2P: Weir Box

Inflow Area = 977.021 ac, 65.33% Impervious, Inflow Depth > 1.90" for DESIGN event
Inflow = 38.48 cfs @ 23.86 hrs, Volume= 154.578 af
Outflow = 38.48 cfs @ 23.86 hrs, Volume= 154.578 af, Atten= 0%, Lag= 0.0 min
Primary = 38.48 cfs @ 23.86 hrs, Volume= 154.578 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-144.00 hrs, dt= 0.05 hrs
Peak Elev= 34.26' @ 23.86 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	31.50'	**36.0" Vert. Orifice/Grate** C= 0.600
#2	Device 3	34.50'	**20.0' long x 1.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 Coef. (English) 2.69 2.72 2.75 2.85 2.98 3.08 3.20 3.28 3.31 3.30 3.31 3.32
#3	Secondary	26.07'	**72.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=38.49 cfs @ 23.86 hrs HW=34.26' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 38.49 cfs @ 5.66 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=26.07' (Free Discharge)
↑—**3=Orifice/Grate** (Controls 0.00 cfs)
  ↑—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Appendix B

Lake Loading Response Model (LLRM)

Lake Loading Response Model (LLRM)

Description and Calibration

LLRM is a spreadsheet-based loading model which requires that the contributing watershed surrounding the water body of interest be divided into one or more subwatersheds for each up-gradient water bodies and for which land use data are available to estimate input loadings.

Each land use within the subwatersheds is assigned a precipitation, nitrogen and phosphorus export coefficient for runoff and baseflow. These precipitation export coefficient values are the fraction of precipitation that becomes runoff or baseflow. The selection of the final precipitation export coefficients used in the model is based on best professional judgment, comparison between modeled basin water volume outputs and actual measured stream flows, as well as comparison between modeled basin water volume outputs and calculations using the standard areal water yield. Export coefficients for nitrogen and phosphorus load are expressed in nitrogen or phosphorus load to baseflow and runoff in kg per hectare per year. The reference variables provided with the LLRM model include a mean, median, maximum and minimum reported nitrogen and phosphorus export coefficient for baseflow and runoff from a variety of referenced sources.

Routing and attenuation of subwatershed loads is adjustable within the model. Direct loads to the water body of interest including atmospheric deposition, internal nutrient loading, waterfowl and other wildlife, on-site wastewater disposal systems and point sources are entered into the model, where applicable. Point sources for the purposes of the model are specific inputs for discharges with known quantity and quality, such as a wastewater treatment plant or industrial discharge. Reference variables (mean, median, maximum and minimum) are provided for the direct loads. The land uses are used to generate estimates of baseflow volume, runoff volume and nutrient loads in both baseflow and runoff to the water body of interest which are added to the direct loads to provide an estimate of water quality (nitrogen and phosphorus concentrations, chlorophyll a and Secchi depth) to the water body of interest. Ideally the model is calibrated based on actual data obtained for inflows and outflows from the various subwatersheds as well as the lake of interest.

RIGIS land use data from 2003/2004, the most recent land use data available, were used to calculate land use areas within each subwatersheds. Several small changes were made to the land use data to reflect changes observed since 2003/2004. The largest change was the adjustment of land use north of Tongue Pond identified in the 2003/2004 data from vacant to commercial, as this area has been recently redeveloped. Nitrogen and phosphorus loading coefficients selected for use in modeling the RWP Ponds system were selected from the reference variables provided in the LLRM model and the Charles River TMDL (CRWA, 2011). Precipitation export coefficients were based on best professional judgment, comparison of modeled basin water volume outputs and actual measured stream flows, as well as comparison between modeled basin water volume outputs and calculations using the standard areal water yield. Atmospheric deposition load was based on the assumption that the watershed receives deposition from the South and West including the New York and New Jersey areas, which contain mixed land use types. Internal loading in the model used default values for N and P rate of release (see reference variables in the LLRM) and a 75 days of potential release. Waterfowl load was estimated at 350 birds based on a RIDEM estimate of 300-400 resident birds (Ardito, 2011). On-site wastewater disposal and point sources were assumed to be not applicable as the watershed is sewered and there are no known major point sources (e.g., wastewater treatment plant).

Model calibration data were obtained from several sources:

- Water outflow volumes from Spectacle Pond and Mashapaug Pond were obtained from the Mashapaug TMDL (RIDEM, 2007a). The Mashapaug TMDL reported outflow from Spectacle Pond was determined based on standard water yield calculations using land uses for Spectacle Pond as well as some inlet flow data (RIDEM, 2007a). The watershed delineated in the Mashapaug TMDL for Spectacle Pond is similar to that used in this study, therefore it is reasonable to use this estimate as a comparison point in the model for RWP Ponds. Outflow data for Mashapaug Pond reported in the TMDL was determined by calculation; total inflow (determined using various sources) was assumed to equal total outflow, a reasonable assumption, allowing this data to be used as a comparison point for the RWP Ponds model (RIDEM, 2007a).
- Outflow total nitrogen and phosphorus data for Spectacle Pond were obtained from the Mashapaug Pond TMDL (RIDEM, 2007a). Reported data were obtained by direct measurement in 2001 (RIDEM, 2007a).
- Total phosphorus data for the RWP Pond outlet were unavailable, the Elm Lake total phosphorus values obtained from URIWW were used instead. (Ideally the actual outlet concentration as well as an outflow volume would have been utilized in the model).
- Average total phosphorus and total nitrogen values, mean and peak chlorophyll a and, minimum and average Secchi depth were obtained from URIWW data.

Several key pieces of information that would allow for better calibration of the model were not available, including:

- Inflow nutrient concentration from Mashapaug Pond; and
- Outflow volume and nutrient concentration for RWP Ponds.

Calibration of the model was accomplished by varying the flow attenuation and pollutant attenuation of Masapaug and Spectacle Ponds to achieve reasonable agreement between variables predicted by the model and the average of observed parameters. Although all the ideal data were not available to calibrate the LLRM model for RWP Ponds, the predicted average chlorophyll a concentrations and minimum and average Secchi disk values are very close to measured values. The in-pond predicted total phosphorus values are slightly lower than the measured average in-pond value, but well within acceptable tolerances and actual values are be expected to fluctuate substantially during a given year and available data may not be sufficient to establish an accurate average.

PREDICTIONS

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE TERMS

PHOSPHORUS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models	To Be Predicted	**Marie Esten:** Elm Pond TP value (one year only); not actual output value, Elm lake is last pond in the series
KG	Phosphorus Load to Lake	kg/yr	From export model	419	
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A	1.007	
TPin	Influent (Inflow) Total Phosphorus	ppb	From export model	110	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available	58	Enter Value (TP out)
I	Inflow	m3/yr	From export model	3808463	
A	Lake Area	m2	From data	415600	
V	Lake Volume	m3	From data	439319	Enter Value (V)
Z	Mean Depth	m	Volume/area	1.057	**Marie Esten:** 771,647 From Lee Pare Report 1980.. New number based on 2011 summer survey
F	Flushing Rate	flushings/yr	Inflow/volume	8.669	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.528	
Qs	Areal Water Load	m/yr	Z(F)	9.164	
Vs	Settling Velocity	m	Z(S)	0.558	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.429	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.254	
				771647	m3 volume Lee Pare
					1980

NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE
TN	Lake Total Nitrogen Conc.	ppb	From in-lake models	To Be Predicted
KG	Nitrogen Load to Lake	kg/yr	From export model	4854
L1	Nitrogen Load to Lake	g N/m2/yr	KG*1000/A	11.68
L2	Nitrogen Load to Lake	mg N/m2/yr	KG*1000000/A	11680
C1	Coefficient of Attenuation, from F	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	2.29
C2	Coefficient of Attenuation, from L	fraction/yr	2.7183^(0.71(ln(L2))-6.426)	1.25
C3	Coefficient of Attenuation, from L/Z	fraction/yr	2.7183^(0.594(ln(L2/Z))-4.144)	4.00

PREDICTIONS

THE MODELS					PREDICTED CHL AND WATER CLARITY			
	PHOSPHORUS	**PRED.**	**PERMIS.**	**CRITICAL**				
		CONC.	**CONC.**	**CONC.**				
NAME	**FORMULA**	**(ppb)**	**(ppb)**	**(ppb)**	**MODEL**	**Value**	**Mean**	**Measured**
Mass Balance	TP=L/(Z(F))*1000	110						
(Maximum Conc.)					**Mean Chlorophyll (ug/L)**			
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	63	19	38	Carlson 1977	46.2		
(K-D)					Dillon and Rigler 1974	38.7		
Vollenweider 1975	TP=L/(Z(S+F))*1000	104	31	62	Jones and Bachmann 1976	45.1		
(V)					Oglesby and Schaffner 1978	40.6		
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	82	25	49	Modified Vollenweider 1982	35.7	41.3	36.1
(L-M)					**Peak Chlorophyll (ug/L)**			
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	86	26	52	Modified Vollenweider (TP) 1982	120.5		
(J-B)					Vollenweider (CHL) 1982	134.1		
Reckhow General (1977)	TP=L/(11.6+1.2(Z(F)))*1000	45	13	27	Modified Jones, Rast and Lee 1979	140.5	131.7	100.7
(Rg)					**Secchi Transparency (M)**			
					Oglesby and Schaffner 1978 **(Avg)**	0.8		1.0
Average of Model Values		76	23	46	Modified Vollenweider 1982 **(Max)**	2.9		3.1
(without mass balance)								
Measured Value		92			**Bloom Probability**			
(mean, median, other)					Probability of Chl >10 ug/L **(% of time)**	99.5%		89%
					Probability of Chl >15 ug/L **(% of time)**	96.2%		75%
From Vollenweider 1968					Probability of Chl >20 ug/L **(% of time)**	88.5%		60%
Permissible Load (g/m2/yr)	Lp=10^(0.501503(log(Z(F)))-1.0018)	0.30			Probability of Chl >30 ug/L **(% of time)**	65.1%		34%
Critical Load (g/m2/yr)	Lc=2(Cp)	0.60			Probability of Chl >40 ug/L **(% of time)**	42.6%		25%
	NITROGEN							
Mass Balance	TN=L/(Z(F))*1000	1275						
(Maximum Conc.)								
Bachmann 1980	TN=L/(Z(C1+F))*1000	1008						
Bachmann 1980	TN=L/(Z(C2+F))*1000	1114						
Bachmann 1980	TN=L/(Z(C3+F))*1000	872						
Average of Model Values		998						
(without mass balance)								
Measured Value		1116						
(mean, median, other)								

Marie Esten: average of all Chlorophyll a data in all ponds

Marie Esten: Cunliff in 2003

Marie Esten: average of all ponds

Marie Esten: Pleasure in 1993

Marie Esten: Average of all TP values for Park ponds - 28 values from 1993 to 2005. Minimum is 31 ug/L. Maximum is 194 ug/L

Marie Esten: Avearge of TN in all ponds. 1993-2005. Min 180 ug/L TN. Maximum 2210 ug/L TN

PREDICTIONS

BLOOM FREQUENCY CALCULATIONS

ln(std dev of C)	Threshold level ppb	Z*	Normsdist	Freq.
0.5	10	-2.585	0.005	0.995
0.5	15	-1.774	0.038	0.962
0.5	20	-1.199	0.115	0.885
0.5	30	-0.388	0.349	0.651
0.5	40	0.188	0.574	0.426

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EXPORT MODEL INPUT AND CALCULATIONS

Cells shaded like this must have values entered or verified

Cells shaded like this are notes to aid processing

COEFFICIENTS

STD. WATER YIELD (CFSM)	1.5	(low - based on watershed being located in sandy coastal area)
PRECIPITATION (METERS)	1.18	(NOAA National Climatic Data Center)

	RUNOFF EXPORT COEFF.			BASEFLOW EXPORT COEFF.			
LAND USE	Precip Coefficient (Fraction)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	Precip Coefficient (Fraction)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	
Urban 1 (LDR)							NOTE: Precipitation runoff and baseflow coefficients will sum to <1.0
Urban 2 (MDR)	0.40	0.56	5.50	0.10	0.010	5.00	
Urban 3 (HDR)	0.60	0.80	5.50	0.05	0.010	10.00	
Urban 4 (Ind, com/Ind mixed, transport otl	0.60	0.90	5.50	0.05	0.010	2.50	
Urban 5 Institutional, cemetary & Commer	0.40	1.00	5.50	0.10	0.010	7.50	
Agric 1 (Cvr Crop)							
Agric 2 (Row Crop)							
Agric 3 (Grazing)							
Agric 4 (Feedlot)							
Forest 1 (Upland)	0.10	0.13	2.46	0.40	0.004	0.50	
Forest 2 (Wetland)							
Open 1 (Wetland/Lake)	0.05	0.20	2.46	0.40	0.004	0.50	
Open 2 (Meadow)							
Open 3 (vacant and Brushland)	0.30	0.14	1.48	0.20	0.004	0.50	
Other 1 (freeway)	0.90	0.90	5.50	0.05	0.010	10.00	
Other 2 (developed recreation)	0.35	0.30	5.50	0.25	0.010	5.00	
Other 3							
					(Median)	(Median)	

AREAL SOURCES

	Affected Lake Area (ha)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	P Load (from coeff) (kg/yr)	N Load (from coeff) (kg/yr)	Period of Release (days)	P Rate of Release (mg/m2/day)	N Rate of Release (mg/m2/day)	P Load (from rate) (kg/yr)	N Load (from rate) (kg/yr)
Direct Atmospheric Deposition	41.56	0.70	16.00	29.092	664.96					
Internal Loading	38.6	1.50	3.75	57.9	144.75	75	2.00	5.00	57.9	144.75

NON-AREAL SOURCES

	Number of Source Units	Volume (cu.m/yr)	P Load/Unit (kg/unit/yr)	N Load/Unit (kg/unit/yr)	P Conc. (ppm)	N Conc. (ppm)	P Load (kg/yr)	N Load (kg/yr)
Waterfowl	350		0.20	0.95			70	332.5
Point Sources								
PS-1		0			3.00	12.00	0.0	0.0
PS-2		0			3.00	12.00	0.0	0.0
PS-3		0			3.00	12.00	0.0	0.0

Basin in which Point Source occurs (0=NO 1=YES)

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
PS-1	0	0	0	0	0	0	0	0	0	0
PS-2	0	0	0	0	0	0	0	0	0	0
PS-3	0	0	0	0	0	0	0	0	0	0

DIRECT SEPTIC SYSTEM LOAD

Septic System Grouping (by occupancy or location)	Days of Occupancy/Yr	Distance from Lake (ft)	Number of Dwellings	Number of People per Dwelling	Water per Person per Day (cu.m)	P Conc. (ppm)	N Conc. (ppm)	P Attenuation Factor	N Attenuation Factor	Water Load (cu.m/yr)	P Load (kg/yr)	N Load (kg/yr)
Group 1 Septic Systems	0	<100	25	2.5	0.25	8	20	0.2	0.9	0	0.0	0.0
Group 2 Septic Systems	0	100 - 300	75	2.5	0.25	8	20	0.1	0.8	0	0.0	0.0
Group 3 Septic Systems	0	<100	50	2.5	0.25	8	20	0.2	0.9	0	0.0	0.0
Group 4 Septic Systems	0	100 - 300	100	2.5	0.25	8	20	0.1	0.8	0	0.0	0.0
Total Septic System Loading										0	0.0	0.0

BASIN AREAS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP direct								
LAND USE	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)
Urban 1 (LDR)											0.0
Urban 2 (MDR)	25.2										25.2
Urban 3 (HDR)	112.6	19.4	85.3								217.3
Urban 4 (Ind, com/Ind mixed, transport oth	17.7	61.2	6.8								85.7
Urban 5 Institutional, cemetary & Commer	53.1	18.5	20.4								92.0
Agric 1 (Cvr Crop)											0.0
Agric 2 (Row Crop)											0.0
Agric 3 (Grazing)											0.0
Agric 4 (Feedlot)											0.0
Forest 1 (Upland)	12.1	10.2	57.4								79.7
Forest 2 (Wetland)											0.0
Open 1 (Wetland/Lake)	17.0	30.8	5.3								53.2
Open 2 (Meadow)											0.0
Open 3 (vacant and Brushland)	1.2	0.9	2.7								4.7
Other 1 (freeway)	4.3	5.1	7.4								16.8
Other 2 (developed recreation)	2.2	4.1	35.8								42.1
Other 3											0.0
TOTAL	245.3	150.1	221.2	0.0	0.0	0.0	0.0	0	0		616.6

WATER LOAD GENERATION: RUNOFF											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
LAND USE	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
Urban 1 (LDR)	0	0	0	0	0	0	0	0	0	0	0
Urban 2 (MDR)	119117	0	0	0	0	0	0	0	0	0	119117
Urban 3 (HDR)	796936	137193	604156	0	0	0	0	0	0	0	1538286
Urban 4 (Ind, com/Ind mixed, transport otl	125382	432943	48192	0	0	0	0	0	0	0	606517
Urban 5 Institutional, cemetary & Commer	250448	87371	96391	0	0	0	0	0	0	0	434210
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	0	0	0	0	0	0	0	0	0	0	0
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	14285	12023	67679	0	0	0	0	0	0	0	93987
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	10045	18189	3153	0	0	0	0	0	0	0	31386
Open 2 (Meadow)	0	0	0	0	0	0	0	0	0	0	0
Open 3 (vacant and Brushland)	4098	3052	9611	0	0	0	0	0	0	0	16761
Other 1 (freeway)	45219	54271	79016	0	0	0	0	0	0	0	178505
Other 2 (developed recreation)	9000	16816	147953	0	0	0	0	0	0	0	173769
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL (CU.M/YR)	1374529	761858	1056152	0	0	0	0	0	0	0	3192539
TOTAL (CFS)	1.54	0.85	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.58

LOAD GENERATION: RUNOFF P											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 2 (MDR)	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1
Urban 3 (HDR)	90.0	15.5	68.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.8
Urban 4 (Ind, com/Ind mixed, transport otl	15.9	55.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.1
Urban 5 Institutional, cemetary & Commer	53.1	18.5	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	1.6	1.3	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4
Forest 2 (Wetland)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 1 (Wetland/Lake)	3.4	6.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6
Open 2 (Meadow)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 3 (vacant and Brushland)	0.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Other 1 (freeway)	3.8	4.6	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.1
Other 2 (developed recreation)	0.7	1.2	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6
Other 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	182.8	102.5	121.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	406.5

LOAD GENERATION: BASEFLOW P											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban 2 (MDR)	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Urban 3 (HDR)	1.13	0.19	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17
Urban 4 (Ind, com/Ind mixed, transport otl	0.18	0.61	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86
Urban 5 Institutional, cemetary & Commer	0.53	0.19	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92
Agric 1 (Cvr Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 2 (Row Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 3 (Grazing)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 4 (Feedlot)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest 1 (Upland)	0.05	0.04	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
Forest 2 (Wetland)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open 1 (Wetland/Lake)	0.07	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Open 2 (Meadow)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open 3 (vacant and Brushland)	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Other 1 (freeway)	0.04	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Other 2 (developed recreation)	0.02	0.04	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42
Other 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2.27	1.25	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.34
ROUTING PATTERN											
	(Basin in left hand column passes through basin in column below if indicated by a 1)										
1=YES 0=NO XXX=BLANK	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	Spectacle	Mashapaug	RWP								
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	
INDIVIDUAL BASIN	1	1	1	1	1	1	1	1	1	1	
BASIN 1 OUTPUT	XXX	1	0	0	0	0	0	0	0	0	
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0	
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0	
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0	
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0	
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0	
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0	
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0	
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0	
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX	

CUMULATIVE DRAINAGE AREAS										
	(Total land area associated with routed water and nutrients)									
1=YES 0=NO XXX=BLANK	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	Spectacle	Mashapaug	RWP							
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	245.3	150.1	221.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	245.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
TOTALS	245.3	395.4	221.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WATER ROUTING AND ATTENUATION										
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	Spectacle	Mashapaug	RWP							
SOURCE	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	1692951	1041879	1547027	0	0	0	0	0	0	0
BASIN 1 OUTPUT	XXX	1269713	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX
CUMULATIVE TOTAL	1,692,951	2,311,592	1547027	0	0	0	0	0	0	0
BASIN ATTENUATION	0.75	0.90	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT VOLUME	1,269,713	2,080,433	1237622	0	0	0	0	0.0	0.0	0.0
Reality Check from Flow Data	1,044,926	2,215,940					800000.0			
Calculated Flow/Measured Flow	1.215	0.939	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.000	#DIV/0!	#DIV/0!	#DIV/0!
Reality Check from Areal Yield X Basin Area	1270132.9	2047354.2	1145577.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calculated Flow/Flow from Areal Yield	1.000	1.016	1.080	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

LOAD ROUTING AND ATTENUATION: PHOSPHORUS											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	Spectacle	Mashapaug	RWP								
	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	
BASIN 1 INDIVIDUAL	185.1	103.7	123.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN 1 OUTPUT	XXX	129.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	
CUMULATIVE TOTAL	185.1	233.3	123.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
BASIN ATTENUATION	0.70	0.70	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
OUTPUT LOAD	129.6	163.3	98.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	Spectacle	Mashapaug	RWP								
OUTPUT (CU.M/YR)	1269713	2080433	1237622	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	129.6	163.3	98.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT (MG/L)	0.102	0.078	0.079	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC. (FROM DATA)	0.104	0.036									
CALCULATED CONC./MEASURED CONC.	0.981	2.180	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
BASIN EXPORT COEFFICIENT	0.53	0.41	0.44	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
TERMINAL DISCHARGE?	2	1	1	1	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											TOTAL
WATER (CU.M/YR)	0	2080433	1237622	0	0	0	0	0	0	0	3318055
PHOSPHORUS (KG/YR)	0.0	163.3	98.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	261.7
PHOSPHORUS (MG/L)	0.000	0.078	0.079	#DIV/0!	0.000	0.000	0.000	0.000	0.000	0.000	0.079

LOAD SUMMARY

DIRECT LOADS TO LAKE	P (KG/YR)	N (KG/YR)	WATER (CU.M/YR)
ATMOSPHERIC	29.1	665.0	490408
INTERNAL	57.9	144.8	0
WATERFOWL	70.0	332.5	0
SEPTIC SYSTEM	0.0	0.0	0
WATERSHED LOAD	261.7	3711.9	3318055
TOTAL LOAD TO LAKE	418.7	4854.1	3808463
(Watershed + direct loads)			
TOTAL INPUT CONC. (MG/L)	0.110	1.275	

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WATER LOAD GENERATION: BASEFLOW											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
Urban 1 (LDR)	0	0	0	0	0	0	0	0	0	0	0
Urban 2 (MDR)	29779	0	0	0	0	0	0	0	0	0	29779
Urban 3 (HDR)	66411	11433	50346	0	0	0	0	0	0	0	128190
Urban 4 (Ind, com/Ind mixed, transport otl	10448	36079	4016	0	0	0	0	0	0	0	50543
Urban 5 Institutional, cemetary & Commer	62612	21843	24098	0	0	0	0	0	0	0	108553
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	0	0	0	0	0	0	0	0	0	0	0
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	57141	48094	270715	0	0	0	0	0	0	0	375950
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	80357	145512	25222	0	0	0	0	0	0	0	251091
Open 2 (Meadow)	0	0	0	0	0	0	0	0	0	0	0
Open 3 (vacant and Brushland)	2732	2035	6407	0	0	0	0	0	0	0	11174
Other 1 (freeway)	2512	3015	4390	0	0	0	0	0	0	0	9917
Other 2 (developed recreation)	6428	12012	105681	0	0	0	0	0	0	0	124121
Other 3	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL (CU.M/YR)	318422	280021	490876	0	0	0	0	0	0	0	1089318
TOTAL (CFS)	0.36	0.31	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.000	1.22

LOAD GENERATION: RUNOFF N											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 2 (MDR)	138.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	138.8
Urban 3 (HDR)	619.1	106.6	469.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1195.0
Urban 4 (Ind, com/Ind mixed, transport otl	97.4	336.3	37.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	471.2
Urban 5 Institutional, cemetary & Commer	291.8	101.8	112.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	506.0
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1 (Upland)	29.8	25.1	141.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	195.9
Forest 2 (Wetland)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 1 (Wetland/Lake)	41.9	75.8	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	130.9
Open 2 (Meadow)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 3 (vacant and Brushland)	1.7	1.3	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0
Other 1 (freeway)	23.4	28.1	40.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.4
Other 2 (developed recreation)	12.0	22.4	197.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	231.4
Other 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	1255.9	697.4	1015.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2968.6

LOAD GENERATION: BASEFLOW N											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	Spectacle	Mashapaug	RWP								
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban 2 (MDR)	126.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.18
Urban 3 (HDR)	1125.62	193.78	853.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2172.72
Urban 4 (Ind, com/Ind mixed, transport otl	44.27	152.88	17.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	214.17
Urban 5 Institutional, cemetary & Commer	397.96	138.83	153.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	689.95
Agric 1 (Cvr Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 2 (Row Crop)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 3 (Grazing)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agric 4 (Feedlot)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest 1 (Upland)	6.05	5.09	28.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.83
Forest 2 (Wetland)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open 1 (Wetland/Lake)	8.51	15.41	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.60
Open 2 (Meadow)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open 3 (vacant and Brushland)	0.58	0.43	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.37
Other 1 (freeway)	42.58	51.10	74.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	168.08
Other 2 (developed recreation)	10.90	20.36	179.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	210.37
Other 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1762.65	577.88	1309.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3650.27

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LOAD ROUTING AND ATTENUATION: NITROGEN

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	Spectacle	Mashapaug	RWP							
	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
BASIN 1 INDIVIDUAL	3018.6	1275.3	2325.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	1811.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	3018.6	3086.4	2325.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.60	0.60	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	1811.1	1851.8	1860.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: NITROGEN

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	Spectacle	Mashapaug	RWP								
OUTPUT (CU.M/YR)	1269713	2080433	1237622	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	1811.1	1851.8	1860.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	1.426	0.890	1.503	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC. (FROM DATA)	1.12	0.9									
CALCULATED CONC./MEASURED CONC.	1.274	0.989	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
BASIN EXPORT COEFFICIENT	7.38	4.68	8.41	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
TERMINAL DISCHARGE?	2	1	1	1	0	0	1	1	1	1	
(1=YES 2=NO)											
LOAD TO RESOURCE											TOTAL
WATER (CU.M/YR)	0	2080433	1237622	0	0	0	0	0	0	0	3318055
NITROGEN (KG/YR)	0.0	1851.8	1860.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3711.9
NITROGEN (MG/L)	0.000	0.890	1.503	#DIV/0!	0.000	0.000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.119

EXPORT MODEL VARIABLES AND INPUT RANGES

VARIABLE	DESCRIPTION	FOR SOUTHERN NE AREA HIGH	MEDIUM	LOW	SOURCE	APPLICATION NOTES
HYDROLOGIC FACTORS						
Standard Water Yield	Rate of water yield in CFSM by watershed	2.0	1.7	1.5	Sopper and Lull 1970, Higgins and Colonell 1971	Increases with increasing runoff; range will vary substantially by region; NE range shown
Precipitation	Annual rainfall in meters	1.53	1.14	0.81	NOAA Precipitation Records through 2008	Range will vary substantially by region; NE range shown. Also, while values will vary by year, model is focused on longer term, steady state conditions
Runoff Coefficient	Portion of rainfall converted to overland flow	0.95	0.40	0.10	Dunn and Leopold 1978	Increases with steeper slope and lowered permeability
Baseflow Coefficient	Portion of rainfall converted to baseflow	0.40	0.20	0.01	Dunn and Leopold 1978	Increases with flatter slope and higher permeability

PHOSPHORUS AND NITROGEN EXPORT COEFFICIENTS FOR RUNOFF

LAND USES		PHOSPHORUS EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	SOURCE	NITROGEN EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	
Urban 1 (LDR)	Low density residential (>1 ac lots)	6.23	1.91	1.10	0.19	Omernik 1976, Reckhow et al. 1980, Frink 1991, Sharpley et al. 1992, Line et al. 1998, Clark et al. 2000, Rohm et al. 2002, unpublished AECOM data	38.47	9.97	5.50	1.48	All urban lands given same range; differences between and within them result from differences in lawn area (increased coeff with increased lawn area), fertlizer use (increased coeff with increased use, tends to be linked to lawn area), soils (increased coeff with less permeable soils), slope (increased coeff with increased slope), and application of local BMPs (decreased coeff with LID technique application or fertilizer regulations).
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	6.23	1.91	1.10	0.19		38.47	9.97	5.50	1.48	
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	6.23	1.91	1.10	0.19		38.47	9.97	5.50	1.48	
Urban 4 (Ind)	Industrial	6.23	1.91	1.10	0.19		38.47	9.97	5.50	1.48	
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	6.23	1.91	1.10	0.19		38.47	9.97	5.50	1.48	
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	2.90	1.08	0.80	0.10		7.82	5.19	6.08	0.97	Increases with fertilizer use, slope, duration of open conditions, and lack of conservation tillage application.
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	18.60	4.46	2.20	0.26		79.60	16.09	9.00	2.10	
Agric 3 (Grazing)	Agricultural pasture with livestock	4.90	1.50	0.80	0.14		30.85	8.65	5.19	1.48	Increases with animal density, slope, lack of vegetative cover, imperviousness of soils.
Agric 4 (Feedlot)	Concentrated livestock holding area	795.20	300.70	224.00	21.28		7979.90	3110.70	2923.20	680.50	Increases with animal density, slope, and lack of manure management practices.
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.83	0.24	0.20	0.02		6.26	2.86	2.46	1.38	Increases with decreased canopy layer, ground cover, or soil permeability, and with increased slope.
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.83	0.24	0.20	0.02		6.26	2.86	2.46	1.38	Increases with greater channelization of flows, slope, flushing effect and pH.
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.83	0.24	0.20	0.02		6.26	2.86	2.46	1.38	Increases with decreased detention time, increased pH.
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.83	0.24	0.20	0.02		6.26	2.86	2.46	1.38	Increases with decreased ground cover and increased slope.
Open 3 (Barren)	Mining or construction areas, largely bare soils	4.90	1.50	0.80	0.14		30.85	8.65	5.19	1.48	Increases with increased slope and lack of depression area storage.
Other 1	Define:	0.83	0.24	0.20	0.02		6.26	2.86	2.46	1.38	
Other 2	Define:	6.23	1.91	1.10	0.19		38.47	9.97	5.50	1.48	
Other 3	Define:	18.60	4.46	2.20	0.26		79.60	16.09	9.00	2.10	

PHOSPHORUS AND NITROGEN EXPORT COEFFICIENTS FOR BASEFLOW

LAND USES		PHOSPHORUS EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	SOURCE	NITROGEN EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	
Urban 1 (LDR)	Low density residential (>1 ac lots)	0.050	0.010	0.010	0.001	Uttormark et al. 1974, Mitchell et al. 1989, Miller et al. 1997, AECOM Unpublished Data, some reliance on runoff references as well	20.00	5.00	5.00	1.00	P increases mainly with soil permeability and higher ground water table. N increases mainly with presence of on-site wastewater disposal systems and decreases with dilution from rainfall or uncontaminated water inputs.
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	0.050	0.010	0.010	0.001		40.00	10.00	10.00	2.00	
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	0.050	0.010	0.010	0.001		80.00	20.00	20.00	4.00	
Urban 4 (Ind)	Industrial	0.050	0.010	0.010	0.001		20.00	5.00	5.00	1.00	
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	0.050	0.010	0.010	0.001		20.00	5.00	5.00	1.00	
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	0.050	0.010	0.010	0.001		10.00	2.50	2.50	0.50	Increases with fertilizer use, soil permeability, flushing from irrigation.
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	0.050	0.010	0.010	0.001		10.00	2.50	2.50	0.50	
Agric 3 (Grazing)	Agricultural pasture with livestock	0.050	0.010	0.010	0.001		20.00	5.00	5.00	1.00	Increases with animal density and duration of use, soil permeability.
Agric 4 (Feedlot)	Concentrated livestock holding area	0.100	0.030	0.030	0.001		100.00	25.00	25.00	5.00	Increases with animal density and duration of use, lack of manure handling techniques, increased soil permeability.
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	Increases with increased soil permeability, high water table and groundwater anoxia.
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	Increases with increased soil permeability, high water table and groundwater anoxia.
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	Increases with increased baseflow through area.
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	Increases with increased soil permeability, high water table and groundwater anoxia.
Open 3 (Barren)	Mining or construction areas, largely bare soils	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	Increases with increased soil permeability, high water table and groundwater anoxia.
Other 1	Define:	0.010	0.004	0.004	0.001		1.00	0.50	0.50	0.05	
Other 2	Define:	0.050	0.010	0.010	0.001		20.00	5.00	5.00	1.00	
Other 3	Define:	0.050	0.010	0.010	0.001		80.00	20.00	20.00	4.00	

OTHER AREAL SOURCES		PHOSPHORUS EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	SOURCE	NITROGEN EXPORT (KG/HA/YR) MAXIMUM	MEAN	MEDIAN	MINIMUM	
Direct Atmospheric Deposition	Wet and dry deposition from aerial sources										
from Forested Area	Deposition originating in largely forested area	0.54	0.27	0.20	0.07	Reckhow et al. 1980, Dillon et al. 1991	11.30	5.96	6.50	0.99	Increases with increased sources. However, note that contributory area is likely to be much larger than the immediate watershed, and requires consideration of regional sources and wind direction.
from Agricultural/Rural Area	Deposition originating in largely agricultural area	0.97	0.45	0.30	0.12		38.00	20.98	13.10	10.49	
from Urban/Industrial Area	Deposition originating in largely urban area	3.67	1.27	1.00	0.26		24.80	18.51	21.40	7.40	
Internal Loading	Release from sediments or macrophytes, oxic or anoxic	10.00	1.00	1.00	0.10	Nurnberg 1984, Nurnberg and LaZerte 2004,	10.00	1.00	1.00	0.10	Increases with available sediment P and N (forms assessed by extraction assays) and anoxia.
	(duration of anoxia must be specified)	PHOSPHORUS EXPORT (MG/M2/YR)					NITROGEN EXPORT (MG/M2/YR)				
	For calculation with # of days and areal release	40.00	6.00	2.00	0.10		40.00	12.00	5.00	0.30	
		PHOSPHORUS INPUT					NITROGEN INPUT				
NON-AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	P SOURCE	MAXIMUM	MEAN	MEDIAN	MINIMUM	

Waterfowl	Direct inputs from birds (kg/bird/yr)	1.86	0.23	0.20	0.06	Brezonik 1973, Uttormark et al. 1974, Gould & Fletcher 1978, Portnoy 1990	5.80	1.00	0.95	0.48		Increases with bird size.
Point Sources	Direct discharge from facility											Varies by treatment technology and details within treatment (e.g., holding time, chemical additions).
	Wastewater - primary treatment (ppm)	6.00	4.00	4.00	1.00	Metcalf & Eddy	70.00	45.00	45.00	20.00		
	Wastewater - secondary treatment (ppm)	4.00	2.00	2.00	0.40	1991, DMR data	10.00	5.00	5.00	1.00		
	Wastewater - tertiary treatment (ppm)	1.00	0.50	0.50	0.10	from EPA for many	5.00	2.00	2.00	1.00		
	Cooling water (ppm)	5.00	1.00	1.00	0.05	WWTF	1.00	0.05	0.05	0.02		
SEPTIC SYSTEM INPUTS		PHOSPHORUS INPUT					NITROGEN INPUT					
		MAXIMUM	MEAN	MEDIAN	MINIMUM	SOURCE	MAXIMUM	MEAN	MEDIAN	MINIMUM		
Domestic Wastewater Inputs												
	Concentration (ppm)	15.00	8.00	8.00	4.00	Metcalf & Eddy 1991	85.00	40.00	40.00	20.00		Varies by tank sizing and leachfield features
	People per dwelling	10.00	2.50	2.50	1.00							
	Cubic meters of water per person per day	0.45	0.25	0.25	0.13							
	Days of occupancy per year	365	180	180	1							
	Attenuation factor (portion that reaches lake)	0.50	0.10	0.10	0.01		0.95	0.80	0.80	0.50		Increases with increasing soil permeability, high ground water table, anoxia.

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LOAD SUMMARY

PHOSPHORUS LOAD

	Spectacle	Mashapaug	RWP	Direct to lake P (lbs/yr)	Total P (lbs/yr)
DIRECT LOAD TO LAKE					
ATMOSPHERIC	-	-	-	64	64
INTERNAL	-	-	-	128	128
WATERFOWL	-	-	-	154	154
SEPTIC SYSTEM	-	-	-	0	0
WATERSHED LOAD	200	160	216		
TOTAL LOAD TO LAKE					922
(Watershed + Direct Load)	360				

NITROGEN OAD

	Spectacle	Mashapaug	RWP	Direct to lake P (lbs/yr)	Total P (lbs/yr)
DIRECT LOAD TO LAKE					
ATMOSPHERIC	-	-	-		1466
INTERNAL	-	-	-		319
WATERFOWL	-	-	-		733
SEPTIC SYSTEM	-	-	-	0	0
WATERSHED LOAD	2396	1687	4100		
TOTAL LOAD TO LAKE					8193
(Watershed + Direct Load)	4083				

Appendix C

Algae Pond Management Table

Algae management options review

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
IN-LAKE PHYSICAL CONTROLS				
1) Circulation and destratification	♦ Use of water or air to keep water in motion ♦ Intended to prevent or break stratification ♦ Generally driven by mechanical or pneumatic force	♦ Reduces surface build-up of algal scums ♦ May disrupt growth of blue-green algae ♦ Counteraction of anoxia improves habitat for fish/invertebrates ♦ Can eliminate localized problems without obvious impact on whole lake	♦ May spread localized impacts ♦ May lower oxygen levels in shallow water ♦ May promote downstream impacts	♦ Low ♦ Not likely to counteract all loading impacts ♦ Lake too shallow to get even and consistent mixing, internal loading isn't believed to be a major source of phosphorus. ♦ May support other techniques, but inadequate by itself as an algal control in this case.
2) Dilution and flushing	♦ Addition of water of better quality can dilute nutrients ♦ Addition of water of similar or poorer quality flushes system to minimize algal build-up ♦ May have continuous or periodic additions	♦ Dilution reduces nutrient concentrations without altering load ♦ Flushing minimizes detention; response to pollutants may be reduced	♦ Diverts water from other uses ♦ Flushing may wash desirable zooplankton from lake ♦ Use of poorer quality water increases loads ♦ Possible downstream impacts	♦ Low ♦ No ready source of water at key time (summer)
3) Drawdown	♦ Lowering of water over autumn period allows oxidation, desiccation and compaction of sediments ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Algae are affected mainly by reduction in available nutrients.	♦ May reduce available nutrients or nutrient ratios, affecting algal biomass and composition ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ May provide rooted plant control as well	♦ Possible impacts on non-target resources ♦ Possible impairment of water supply ♦ Alteration of downstream flows and winter water level ♦ May result in greater nutrient availability if flushing inadequate	♦ Low ♦ Has benefits for rooted plant control and sediment compaction, but will not likely impact key areas of nutrient reserves.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
4) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Nutrient reserves are removed and algal growth can be limited by nutrient availability	♦ Can control algae if internal recycling is main nutrient source ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging	♦ Moderate ♦ Sediment P is minimal compared to other P sources. ♦ Ponds will become deeper, increase potential for low dissolved oxygen events and reduce flushing, which has potential for increasing duration of blooms. More low DO events may lead to internal recycling becoming more of an issue. ♦ Ponds have lost substantial volume since 1980's and therefore may eventually have to be dredged to maintain open water. ♦ Very expensive proposition, considerable additional investigation needed to plan project ♦
4a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging	♦ Moderate ♦ Easiest way to conduct a thorough dredging in this case ♦ Would impact fish and other biological elements of lake being dredged but would be possible to re-route discharges around lake during dredging, making it possible to drain only one lake at a time.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
4b) “Wet” excavation	♦ Lake level may be lowered, but sediments not substantially exposed ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve aquatic biota	♦ Usually creates extreme turbidity ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May disrupt ecological function ♦ Use disruption	♦ Moderate ♦ Although creates much turbidity, may be possible to section off portions of the ponds to keep turbidity in affected location.
4c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area	♦ Moderate ♦ Minimizes downstream impacts ♦ Allows pumping of sediment slurry to location away from lake, could use part of RWP park ♦ Requires substantial engineering and disposal arrangement ♦ More expensive when simpler options would be available.
5) Light-limiting dyes and surface covers	♦ Creates light limitation	♦ Creates light limit on algal growth without high turbidity or great depth ♦ May achieve some control of rooted plants as well	♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water	♦ Low ♦ Will not prevent all blooms ♦ May be perceived as unappealing ♦ System already has fairly low transparency.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
5.a) Dyes	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting algal growth ♦ Dyes remain in solution until washed out of system.	♦ Produces appealing color ♦ Creates illusion of greater depth	♦ May not control surface bloom-forming species ♦ May not control growth of shallow water algal mats ♦ Altered thermal regime	♦ Low ♦ Big storm could flush dye out of system ♦ Public acceptability in question ♦ System already has fairly low transparency
5.b) Surface covers	♦ Opaque sheet material applied to water surface	♦ Minimizes atmospheric and wildlife pollutant inputs	♦ Minimizes atmospheric gas exchange ♦ Limits recreation	♦ Low ♦ Prevents most uses
6) Mechanical removal	♦ Filtering of pumped water for water supply purposes ♦ Collection of floating scums or mats with booms, nets, or other devices ♦ Continuous or multiple applications per year usually needed	♦ Algae and associated nutrients can be removed from system ♦ Surface collection can be applied as needed ♦ May remove floating debris ♦ Collected algae dry to minimal volume	♦ Filtration requires high backwash and sludge handling capability ♦ Labor and/or capital intensive ♦ Variable collection efficiency ♦ Possible impacts on non-target aquatic life	♦ Moderate ♦ Filtering arrangement would have to be large, expensive, and space intensive ♦ Could target upstream watershed inputs. ♦ Depending upon system used, may only remove algae and not reduce nutrient loads.
7) Selective withdrawal	♦ Discharge of bottom water which may contain (or be susceptible to) low oxygen and higher nutrient levels ♦ May be pumped or utilize passive head differential	♦ Removes targeted water from lake efficiently ♦ May prevent anoxia and phosphorus build up in bottom water ♦ May remove initial phase of algal blooms which start in deep water ♦ May create coldwater conditions downstream	♦ Possible downstream impacts of poor water quality ♦ May promote mixing of remaining poor quality bottom water with surface waters ♦ May cause unintended drawdown if inflows do not match withdrawal	♦ Low ♦ No selective withdrawal capacity; requires major outlet overhaul ♦ Lake not strongly stratified and very shallow

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
8) Sonication	♦ Sound waves disrupt algal cells	♦ Supposedly affects only algae (new technique) ♦ Applicable in localized areas	♦ Unknown effects on non-target organisms ♦ May release cellular toxins or other undesirable contents into water column	♦ Moderate ♦ Technique gaining acceptance, does control many cyanobacteria ♦ Would need many units ♦ Does not control nutrient levels. ♦ Yearly maintenance required.
IN-LAKE CHEMICAL CONTROLS				
9) Hypolimnetic aeration or oxygenation	♦ Addition of air or oxygen provides oxic conditions ♦ Maintains stratification ♦ Can also withdraw water, oxygenate, then replace	♦ Oxic conditions reduce P availability ♦ Oxygen improves habitat ♦ Oxygen reduces build-up of reduced cpds	♦ May disrupt thermal layers important to fish community ♦ Theoretically promotes supersaturation with gases harmful to fish	♦ Low No real hypolimnion

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
10) Algaecides	♦ Liquid or pelletized algaecides applied to target area ♦ Algae killed by direct toxicity or metabolic interference ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid elimination of algae from water column , normally with increased water clarity ♦ May result in net movement of nutrients to bottom of lake	♦ Possible toxicity to non-target species ♦ Restrictions on water use for varying time after treatment ♦ Increased oxygen demand and possible toxicity ♦ Possible recycling of nutrients	♦ High ♦ Not the preferred approach, but helps maintain clarity as interim measure ♦ Frequent applications increase cost and probability of non-target impacts ♦ Used in the past
10a) Forms of copper	♦ Cellular toxicant, disruption of membrane transport ♦ Applied as wide variety of liquid or granular formulations	♦ Effective and rapid control of many algae species ♦ Approved for use in most water supplies	♦ Possible toxicity to aquatic fauna ♦ Accumulation of copper in system ♦ Resistance by certain green and blue-green nuisance species ♦ Lysing of cells releases nutrients and toxins	♦ High ♦ Current algaecide used when needed
10b) Peroxides	♦ Disrupts most cellular functions, tends to attack membranes ♦ Applied as a liquid or solid. ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid action ♦ Oxidizes cell contents, may limit oxygen demand and toxicity	♦ Much more expensive than copper ♦ Limited track record ♦ Possible recycling of nutrients	♦ High ♦ Less potential negative impact than copper, but more expensive
10c) Synthetic organic algaecides	♦ Absorbed or membrane-active chemicals which disrupt metabolism ♦ Causes structural deterioration	♦ Used where copper is ineffective ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on water use	♦ High ♦ Not necessary if copper is effective.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
11) Phosphorus inactivation	♦ Typically salts of aluminum, iron or calcium are added to the lake, as liquid or powder ♦ Phosphorus in the treated water column is complexed and settled to the bottom of the lake ♦ Phosphorus in upper sediment layer is complexed, reducing release from sediment ♦ Permanence of binding varies by binder in relation to redox potential and pH	♦ Can provide rapid, major decrease in phosphorus concentration in water column ♦ Can minimize release of phosphorus from sediment ♦ May remove other nutrients and contaminants as well as phosphorus ♦ Flexible with regard to depth of application and speed of improvement	♦ Possible toxicity to fish and invertebrates, especially by aluminum at low pH ♦ Possible release of phosphorus under anoxia or extreme pH ♦ May cause fluctuations in water chemistry, especially pH, during treatment ♦ Possible resuspension of floc in shallow areas ♦ Adds to bottom sediment, but typically an insignificant amount	♦ High ♦ Treatment should focus on addition to watershed loading from upper watershed which would be a continual process and required annual maintenance. ♦ Treatment of sediments within the ponds, the traditional approach for applying aluminum salts would not provide major benefit to water quality as this is not the major source of phosphorus. ♦ Additional information on volumes and quality of waters entering RWP ponds from the upper watershed through the outfall in Roosevelt Pond must be quantified. ♦ Must maintain pH between 6 and 8 SU to minimize non-target impacts
12) Sediment oxidation	♦ Addition of oxidants, binders and pH adjustors to oxidize sediment ♦ Binding of phosphorus is enhanced ♦ Denitrification is stimulated	♦ Can reduce phosphorus supply to algae ♦ Can alter N:P ratios in water column ♦ May decrease sediment oxygen demand	♦ Possible impacts on benthic biota ♦ Longevity of effects not well known ♦ Possible source of nitrogen for blue-green algae	♦ Low ♦ Applicable, but rarely implemented in the USA ♦ Will not counteract external load; substitute for P inactivation treatment ♦ Internal P load is not believed to be major source of P.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
13) Settling agents	♦ Closely aligned with phosphorus inactivation, but can be used to reduce algae directly too ♦ Lime, alum or polymers applied, usually as a liquid or slurry ♦ Creates a floc with algae and other suspended particles ♦ Floc settles to bottom of lake ♦ Re-application typically necessary at least once/yr	♦ Removes algae and increases water clarity without lysing most cells ♦ Reduces nutrient recycling if floc sufficient ♦ Removes non-algal particles as well as algae ♦ May reduce dissolved phosphorus levels at the same time	♦ Possible impacts on aquatic fauna ♦ Possible fluctuations in water chemistry during treatment ♦ Resuspension of floc possible in shallow, well-mixed waters ♦ Promotes increased sediment accumulation	♦ Moderate ♦ Aluminum use for P inactivation also fills this function ♦ Alternative coagulants exist, but may not inactivate P to desired extent ♦ Would need to be applied numerous times/year
14) Selective nutrient addition	♦ Ratio of nutrients changed by additions of selected nutrients ♦ Addition of non-limiting nutrients can change composition of algal community ♦ Processes such as settling and grazing can then reduce algal biomass	♦ Can reduce algal levels where control of limiting nutrient not feasible ♦ Can promote non-nuisance forms of algae ♦ Can improve productivity of system without increased standing crop of algae	♦ May result in greater algal abundance through uncertain biological response ♦ May require frequent application to maintain desired ratios ♦ Possible downstream effects	♦ Low ♦ Not usually implemented where nutrient loading is high ♦ Often used to promote green algae over blue/green algae. This system is believed to have low incidences of blue-green algae scums.
IN-LAKE BIOLOGICAL CONTROLS				
15) Enhanced grazing	♦ Manipulation of biological components of system to achieve grazing control over algae ♦ Typically involves alteration of fish community to promote growth of grazing zooplankton	♦ May increase water clarity by changes in algal biomass or cell size without reduction of nutrient levels ♦ Can convert unwanted algae into fish ♦ Harnesses natural processes	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms	♦ Moderate, with native species ♦ Reliability over time tends to be low, however; biological controls are not stable ♦ Limited consumption of cyanobacteria by possible grazers ♦ Would need more plankton information for the RWP ponds system.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
15.a) Herbivorous fish	♦ Stocking of fish that eat algae	♦ Converts algae directly into potentially harvestable fish ♦ Grazing pressure can be adjusted through stocking rate	♦ Typically requires introduction of non-native species ♦ Difficult to control over long term ♦ Smaller algal forms may be benefited and bloom	♦ Low ♦ Non-native species introductions generally inappropriate ♦ Possible permitting issues
15.b) Herbivorous zooplankton	♦ Reduction in planktivorous fish to promote grazing pressure by zooplankton ♦ May involve stocking piscivores or removing planktivores ♦ May also involve stocking zooplankton or establishing refugia	♦ Converts algae indirectly into harvestable fish ♦ Zooplankton response to increasing algae can be rapid ♦ May be accomplished without introduction of non-native species ♦ Generally compatible with most fishery management goals	♦ Highly variable response expected; temporal and spatial variability may be high ♦ Requires careful monitoring and management action on 1-5 yr basis ♦ Larger or toxic algal forms may be benefitted and bloom	♦ Moderate ♦ More large zooplankton would help suppress algae ♦ Limited consumption of cyanobacteria ♦ Limited by fish community composition; may consume added zooplankton
16) Bottom-feeding fish removal	♦ Removes fish that browse among bottom deposits, releasing nutrients to the water column by physical agitation and excretion	♦ Reduces turbidity and nutrient additions from this source ♦ May restructure fish community in more desirable manner	♦ Targeted fish species are difficult to control ♦ Reduction in fish populations valued by some lake users (human/non-human)	♦ Moderate ♦ Unclear if bottom feeding fish are a problem, more data needed. ♦ If carp are present, could be appropriate
17) Microbial competition	♦ Addition of microbes, often with oxygenation, can tie up nutrients and limit algal growth ♦ Tends to control N more than P	♦ Shifts nutrient use to organisms that do not form scums or impair uses to same extent as algae ♦ Harnesses natural processes ♦ May decrease sediment	♦ Minimal scientific evaluation ♦ N control may still favor cyanobacteria ♦ May need aeration system to get acceptable results	♦ Moderate ♦ Little documented success, but no known adverse impacts ♦ Relatively inexpensive option for experimentation

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
18) Pathogens	♦ Addition of inoculum to initiate attack on algal cells ♦ May involve fungi, bacteria or viruses	♦ May create lakewide "epidemic" and reduction of algal biomass ♦ May provide sustained control through cycles ♦ Can be highly specific to algal group or genera	♦ Largely experimental approach at this time ♦ May promote resistant nuisance forms ♦ May cause high oxygen demand or release of toxins by lysed algal cells ♦ Effects on non-target organisms uncertain	♦ Low ♦ No commercially available forms ♦ Results not impressive to date
19) Competition and allelopathy by plants	♦ Plants may tie up sufficient nutrients to limit algal growth ♦ Plants may create a light limitation on algal growth ♦ Chemical inhibition of algae may occur through substances released by other organisms	♦ Harnesses power of natural biological interactions ♦ May provide responsive and prolonged control	♦ Some algal forms appear resistant ♦ Use of plants may lead to problems with vascular plants ♦ Use of plant material may cause depression of oxygen levels	♦ Low ♦ Potential for dense rooted plant community high, not desirable
19a) Plantings for nutrient control	♦ Plant growths of sufficient density may limit algal access to nutrients ♦ Plants can exude allelopathic substances which inhibit algal growth ♦ Portable plant "pods" , floating islands, or other structures can be installed	♦ Productivity and associated habitat value can remain high without algal blooms ♦ Can be managed to limit interference with recreation and provide habitat ♦ Wetland cells in or adjacent to the lake can minimize nutrient inputs	♦ Vascular plants may achieve nuisance densities ♦ Vascular plant senescence may release nutrients and cause algal blooms ♦ The switch from algae to vascular plant domination of a lake may cause unexpected or undesirable changes	♦ Low ♦ Potential for dense rooted plant community high, not desirable
19b) Plantings for light control	♦ Plant species with floating leaves can shade out many algal growths at elevated densities	♦ Vascular plants can be more easily harvested than most algae ♦ Many floating species provide waterfowl food	♦ Floating plants can be a recreational nuisance ♦ Low surface mixing and atmospheric contact promote anoxia	♦ Low ♦ Shallow lake, not likely to get enough light control with plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO ROGER WILLIAMS PARK PONDS
19c) Addition of barley straw	♦ Input of barley straw can set off a series of chemical reactions which limit algal growth ♦ Release of allelopathic chemicals can kill algae ♦ Release of humic substances can bind phosphorus	♦ Materials and application are relatively inexpensive ♦ Decline in algal abundance is more gradual than with algaecides, limiting oxygen demand and the release of cell contents	♦ Success appears linked to uncertain and potentially uncontrollable water chemistry factors ♦ Depression of oxygen levels may result ♦ Water chemistry may be altered in other ways unsuitable for non-target organisms	♦ Low ♦ Not registered as an algaecide ♦ Unreliable results in other systems ♦ Has had some success with cyanobacteria which do not appear to be the main concern in these lakes.

Appendix D

Project Candidate Sites

The following is a summary table of all the potential candidate sites and proposed Best Management Practices (BMP) sites identified during the initial Steering Committee site walk and subsequent field reconnaissance of the Lower Watershed. The table includes the site identification name, location and brief description of the BMP(s) proposed. It also identifies the sites which were determined to be outside of the watershed and therefore eliminated from consideration. Detailed description of the sites and proposed management are provided in **Appendix F** and **H** of this report.

Table D.1. Summary of Candidate retrofit/ Restoration Project Sites

Initial Site Walk Site (7/15/11) Structural BMPs

Initial Site Walk Site (7/15/11) Non Structural BMPs

Additional Site – Structural BMP

Additional Site – Non Structural BMP

Eliminated from consideration

	Site ID[1]	Location	Description[2]
	RWP-1A	Pine Hill Ave	Construct bioretention area(s) on and Install paved flumes to direct flows
	RWP-1B	Intersection of Pine Hill and Maple Ave	Remove pavement at intersection, construct bioretention with overflow to existing closed drainage system
	RWP-1C	Cladrastis Ave (near Boathouse)	Construct dry swale along or within roadway; overflow to existing closed drainage system.
	RWP-1D	Boathouse	Direct roof downspouts into stormwater planters or rain gardens.
	RWP-1E	Maple Avenue	Construct dry swale along or within roadway; overflow to existing closed drainage system.
	RWP-1F	Cladrastis Avenue - intersection	Remove pavement at intersection, construct bioretention with overflow to existing closed drainage system
	RWP-1G	Boathouse	Revegetate shoreline between Boathouse and Bridge
	RWP-2	Road by Carousel	Plant native material; augment soils and convert low area at yard drain to rain garden; shoreline buffer plantings
	RWP-3A	Carousel Roof	Collect roof runoff in stormwater planters
	RWP-3B	Carousel Parking Lot	Construct bioretention in existing degraded pervious area at entrance for half of parking lot runoff; overflow into existing closed drainage system
	RWP-3C (also RWP-5)	Carousel Parking Lot	Construct bioretention at edge of parking lot or within adjacent Japanese gardens for half of parking lot runoff; overflow into existing closed drainage system
	RWP-4	FC. Greene Memorial Blvd.	Replant northeast side of hill along pathway

	RWP-5	(See RWP-3C)	See RWP-3C
★	RWP-6	Roosevelt Lake – across from monument	Pavement removal; WVTS at low point; buffer plantings along shoreline and on island; repair erosion/settlement at sidewalk
★	RWP-7A	Route 10 on-ramp	Modify existing depression near outfalls for infiltration area with sediment forebays
★	RWP-7B	Outfall at Roosevelt Lake	Construct WVTS; install diversion structure upstream of outfall to direct runoff to WVTS
★	RWP-8	Island near Park Entrance	Rain garden in triangle island or possible WVTS along edge of lake; pave or re-vegetate cut-through at entrance near cemetery
★	RWP-9A	Casino hillside erosion	Create formalized swale to direct runoff
★	RWP-9B	Casino roof	Disconnect rooftop downspouts into rain gardens / planters around building
★	RWP-9C/D	Casino Parking Lot and portion of Linden Ave	Construct bioretention in grass area near parking lot; install paved flume to divert runoff into bioretention
★	RWP-9E	Casino Entrance	Construct bioretention in grass island near entrance; install paved flume to divert runoff into bioretention
★	RWP-10	Casino hillside erosion	Repair erosion along slope and stairs and add buffer plantings
★	RWP-11	Casino hillside erosion	Repair erosion along slope and add buffer plantings
★	RWP-12	Ornamental Bridge	Daylight outfall pipe into a terraced bioswale under bridge; maintain original outfall for large storm events
★	RWP-13	Seal House	Direct roof runoff into rain gardens / planters
★	RWP-14	Catchbasins on north side of Roosevelt Lake	Modify catchbasin to create diversion structure to direct runoff into rain garden for small storms
★	RWP-15	Polo Lake Outfall rear rotary	Modify existing closed drainage system to intercept road runoff into a terraced bioretention area
★	RWP-16	Hillside near Polo Lake	Plant with native, low-growing grasses and shrubs to stabilize
★	RWP-17/18	FC Greene Memorial Blvd	Create paved flume / inlet structure direct road runoff to bioretention; Modify box culvert to create diversion structure to divert runoff to bioretention
★	RWP-19A	Outfall into Polo Lake (Museum)	Daylight outfall pipe into a terraced bioswale along slope; maintain original outfall for large storm events
★	RWP-19B	Outfall into Polo Lake (Tennis Courts)	Install diversion structure to direct runoff into WVTS; maintain original outfall for large storm events
★	RWP-19C	Miller Avenue	Direct road runoff into bioretention in the adjacent turf area
★	RWP-20	Willow Lake near bridge	Re-vegetate area with low-growing grasses and shrubs to stabilize

	RWP-21	Erosion on slope near Willow Lake	Formalize drainage with terraced, stabilized swale down slope
	RWP-22	Hillside erosion near Pleasure Lake	Re-vegetate erosion near stairs; re-plant area of recent storm damage/tree removal; remove area of Japanese knotweed
	RWP-23	FC Greene Memorial Blvd by Temple of Music	Curb removal only and create areas of no-mow meadows
	RWP-24	FC Greene Memorial Blvd between Cunliff and Deep Spring Lakes	Increase buffer vegetation and reduce road width/impervious surface; remove curb and add vegetated swale in buffer to capture water before it outfalls through the existing spillway.
	RWP-25	Temple of Music Access Road	Create infiltration trench downhill of grass slope, on uphill side of access road; increase buffer; lawn/open area management with no-mow areas/additional organic matter/erosion control, renovate access road with grass pave.
	RWP-26A	FC Greene Memorial Blvd by Ball Field	Cut curb into flumes to vegetated swales leading to bioretention/WVTS on west side of road.
	RWP-26B	FC Greene Memorial Blvd by Ball Field	Cut curb into flumes bioretention/WVTS on east side of road.
	RWP-26C	FC Greene Memorial Blvd by Ball Field	Slope stabilization north of the ball field and interception of runoff prior to pavement.
	RWP-27-ELIMINATED	Fish Passage at Elm Lake	Cut curb into flumes to bioretention areas by intersection; add curb bulb with bioretention by parking on North side of road; all overflow to existing CBs; restore streambank and increase buffer plantings.
	RWP-28	Intersection of Edgewood, Beachmont and FC Greene Memorial Blvd.	Remove pavement and add a bioretention/infiltration basin; install a diversion structure from pipe with outfall to lake so that it discharges to bioretention area with overflow to infiltration.
	RWP-29	Oakland Cemetery and Wentworth Ave	Retrofit existing concrete swale into a tiered bioretention system with outfall to lake; intercept pipes going from catchbasins to outfall pipes and direct into bioretention areas
	RWP-30A	Intersection of Marion Ave and FC Greene Memorial Blvd.	Take one or more CBs offline and direct sheet flow into flume and tiered bioretention system above existing outfall.
	RWP-30B	FC Greene Memorial Blvd. at the end of Payton Street	Intercept existing pipe with diversion structure to WVTS; overflow back to pipe.

	RWP-31 ELIMINATED	Zoo Parking Lot-Back Entrance	Create a vegetated swale to an infiltration basin; use erosion and sediment control in the maintenance area and create a management plan.
	RWP-32 ELIMINATED	Zoo-Overflow Parking Lot	Replace asphalt for pervious paving; conduct invasive removal and restore the vegetated swale along the parking lot; cap any CBs and create flumes to vegetated swales; build weirs in the existing swale uphill from the parking lot and re-vegetate; restore existing low point with a forebay, bioretention plantings; direct overflow to vegetated swale along parking lot; create a no-mow area; add erosion control to steep slope.
	RWP-33 ELIMINATED	Zoo Parking Lot	Create WVTS in existing detention area; add planters to overflow parking lot to reduce impervious surface; create bioretention area in parking lot island in front of zoo entrance that overflows to existing CB; (pervious paving in future).
	RWP-34	Police Mounted Command Center/Botanical Center and Cladrastis Ave.	Intercept street runoff and direct into a vegetated swale and bioretention area downhill from Floral Ave.
	RWP-34B (LUHPPL section)	Police Mounted Command Center and Cladrastis Ave.	Create horse pen management plan; build vegetated swales along the downhill side of the pens; collect, cover, and compost manure; relocate vehicular operations and waste management away from existing CBs;
	RWP-35 (LUHPPL section)	Maintenance Yard	Create a maintenance yard management plan that includes stormwater management practices; increase the vegetated buffer; decrease impervious area; designate areas for stockpiles; use erosion and sediment control practices.
	RWP-37A	Natural History Museum - Parking	Construct dry swale for approximately half of parking lot
	RWP-37B	Natural History Museum – Memorial Blvd.	Create / modify existing drainage structure to diversion structure; Construct terraced bio swales for road runoff
	RWP-37C	Natural History Museum – Babcock Street	Create bioretention for road runoff
	RWP-37D	Natural History Museum -Roof	Planters or rain gardens for roof runoff

Notes: [1] Site ID corresponds to locations on watershed maps and to candidate project field form ID's
[2] Detailed descriptions of the site and proposed BMP options can be found in **Appendix F** and **H**.

Legend

*Color Imagery: 2008

- Roger Williams Pond Watershed (Revised October 2011)
- Initial Site Walk Site (7/15/11) - Structural BMP
- Additional Site - Structural BMP
- Initial Site Walk Site (7/15/11) - Non Structural BMP
- Additional Site - Non Structural BMP
- Sites Removed Based on Field Recon.
- Town Boundaries
- Outfalls (Providence GIS)
- Outfalls (RIDEM Priority Outfall)
- Outfalls (Field Located)
- Pond Inlet/Outlet (Providence GIS)
- Catchbasin (Providence/Cranston GIS)

N

350 Feet

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Lower Watershed
Structural and Non-Structural BMP
Sites Considered
Roger Williams Park
Rhode Island

Date: <dyn type="date" format="short"/>

Figure D.1

Path: H:\Projects\2011\11058 Providence-Roger William Park\GIS\Maps\ForReport\120117_Figure3_1_Struct_Nonstruct_11058.mxd

Appendix E

Stormwater Retrofit Site Ranking

The following is a detailed description of the stormwater retrofit site ranking procedure used to prioritize the implementation of the Lower Watershed stormwater retrofit options summarized in **Table 3.2** of the Water Quality Management Plan.

Stormwater Retrofit Site Ranking

Based on the information gathered, the ranked retrofit sites were refined down to 30 individual structural best management practice (BMP) concepts throughout the Park (not including concepts for rooftop runoff, which were not ranked).

The ranking system places an emphasis on pollutant removal potential by weighting it more heavily. Specifically, 40% of the total points were allocated to this category (impervious area treated, water quality volume treated, and pollutant reduction). Estimated construction costs were allocated 20% of the points. The cost estimates are based on a combination of compiled data and best professional judgment based on experience. The exact costs will vary from these estimates based on final engineering design, permitting and contingencies. Contingency costs can be generally estimated at approximately 30% of the base construction costs (CWP, 2007). Ease of implementation of the retrofits at each site was allocated 15% and additional benefits were allocated 25% of the total points.

The following is a breakdown of the ranking criteria categories:

1) Pollutant Removal Potential (40 points)

This category was allotted the highest number of possible points based on the main goal of the project - to improve water quality in the Park's lakes. We analyzed this category based on water quality volume treated (with a goal of 1 inch per impervious cover), as well as removal efficiencies of the proposed practices.

- Water Quality Volume Treated - The site with the maximum volume treated received 30 points, while the minimum received 10 points, and the remaining sites were ranked accordingly.
- Removal Efficiency – The practice with the highest removal efficiency was given 10 points, and the remaining practices were weighted accordingly.

2) Estimated Construction Cost (20 points)

Construction costs were estimated for each concept based on literature sources and recent experience with implementation of local projects. The costs were then ranked based on the cost ranges below. The lower-cost projects received the most points to maximize the number of quality project constructed under the current grant in a reasonable timeframe. The cost categories are as follows:

- $ = 20 points (<$50,000)
- $$ = 15 points (Between $50,000 and $100,000)
- $$$ = 10 points (Between $100,000 and $150,000)
- $$$$ = 5 points (Between $150,000 and $200,000)
- $$$$$ = 0 points (>$200,000)

3) *Ease of Implementation (15 points)*

This category compared the concepts based on the following implementation factors:

- Potential required permitting
  - Low (L) = 5 points (Minimal to no permitting required)
  - Medium (M) =2.5 points (Some permitting likely)
  - High (H) =0 points (Complicated permitting likely)
- Access issues
  - Low (L) = 5 points (Site easily accessed)
  - Medium (M) = 2.5 points (Some difficulty getting equipment to the site)
  - High (H) = 0 points (Site is difficult to access)
- Maintenance burden
  - Low (L) = 5 points (Low maintenance requirements)
  - Medium (M) = 2.5 points (Average maintenance requirements)
  - High (H) = 0 points (High maintenance requirements)

4) *Additional benefits/factors (25 points)*

This category helps compare the proposed concepts based on additional factors of interest to this project, as listed below:

- Public Education/Demonstration
  - High (H) = 10 points (Site is located in a high visibility area and provides an excellent opportunity for reaching the public)
  - Medium (M) = 5 points (Site provides moderate visibility and located where some portion of park users could benefit)
  - Low (L) = 0 points (Site provides low visibility and is located in an area few park users will visit)
- Removal of Waterfowl Habitat/Access
  - Concept will remove an area frequently used by geese/ducks for feeding = 10 points;
  - Concept will remove an area occasionally used by geese for feeding = 5 points; and
  - Site is not in an area preferred by geese = 0 points.
- Other Partners for Funding
  - Low = 5 points;
  - Medium = 2.5 points; and
  - High = 0 points.

  Zero points were given to those sites that have a high potential to be constructed with funding from other sources beyond the current project grant.

The following tables show the preliminary BMP sizing and ranking calculations (**Table E.1.)**, BMP scoring calculations (**Table E.2.)** and BMP Scoring Results (**Table E.2.)**. This data was used to determine the final overall ranking for the proposed stormwater retrofit sites.

Table E.1. BMP Preliminary Sizing and Ranking Calculations

#	Project	% Imp.	Drainage Area		Imp. Area		WQv Required	WQv provided	WQv provided	TP removed	Pavement Removal	Repaving	Total Cost $	Total Cost Rank	Ease of Implementation: Wetlands/ Permitting	Ease of Implementation: Access Issues	Ease of Implementation: Maintenance Burden	Additional Benefits/Factors: Public Ed	Additional Benefits/Factors: Waterfowl Removal	Additional Benefits/Factors: Other Partners
		%	ac	sf	ac	sf	cf	%	cf	%	sf	sf	$							
RWP-1A	Pine Hill Avenue - Bioretention	63%	0.61	26,572	0.38	16,671	1,389	100.0	1389	30	0	0	$ 13,892.50	$	L	L	L	M	L	L
RWP-1B	Pine Hill and Maple Avenue Intersection - Bioretention	58%	0.66	28,750	0.38	16,763	1,397	100.0	1397	30	4000	0	$ 15,969.17	$	L	L	L	M	L	L
RWP-1C	Cladrastris Avenue - near boathouse - Dryswale	25%	2.21	96,268	0.55	24,073	2,006	100.0	2006	30	4000	0	$ 18,048.67	$	L	L	L	M	L	L
RWP-1E	Maple Avenue - Dryswale	17%	3.60	156,816	0.60	26,269	2,189	100.0	2189	30	7000	0	$ 21,012.67	$	L	L	L	L	L	L
RWP-1F	Cladrastris Avenue Intersection - Bioretention	80%	0.27	11,761	0.22	9,397	783	100.0	783	30	500	0	$ 8,080.83	$	L	L	L	M	L	L
RWP-3B	Carousel Parking Lot -Bioretention (1/2 of lot)	38%	1.40	60,984	0.54	23,424	1,952	100.0	1952	30	0	0	$ 23,424.00	$	L	L	L	H	M	L
RWP-3C	Carousel Parking Lot -Bioretention (1/2 of lot)	48%	1.10	47,916	0.53	22,924	1,910	100.0	1910	30	0	0	$ 22,924.00	$	L	M	L	M	L	L
RWP-6	F.C. Greene Memorial Blvd - Across from Monument - WVTS	47%	3.43	149,411	1.61	70,250	5,854	100.0	5854	48	40600	30400	$ 131,989.58	$$$	L	L	L	H	H	L
RWP-7A	Route 10 off-ramp - Infiltration Basin/Dry Swale	35%	2.67	116,305	0.93	40,644	3,387	100.0	3387	65	0	0	$ 13,548.00	$	L	L	L	L	L	H
RWP-7B	Outfall at Roosevelt Lake from Route 10 - WVTS	36%	1.86	81,022	0.67	29,292	2,441	100.0	2441	48	0	0	$ 10,252.20	$	M	M	L	L	H	H
RWP-9C/9D	Casino Parking Lot -Bioretention	74%	0.69	30,056	0.51	22,206	1,851	100.0	1851	30	0	0	$ 22,206.00	$	L	L	L	H	L	L
RWP-9E	Casino Entrance - Bioretention	46%	0.50	21,780	0.23	10,075	840	100.0	840	30	0	0	$ 8,395.83	$	L	L	L	M	L	L
RWP-12	Ornamental Bridge - Terraced Bioswale	26%	6.54	284,882	1.70	74,108	6,176	100.0	6176	30	0	0	$ 88,929.60	$$	L	M	M	H	M	L
RWP-14	North side of Roosevelt Lake - Shallow Bioretention	54%	1.01	43,996	0.54	23,600	1,967	100.0	1967	30	0	0	$ 17,700.00	$	L	L	L	L	H	L
RWP-15	Polo Lake outfall near Rotary - Terraced Bioswale	45%	2.85	124,146	1.29	56,250	4,688	100.0	4688	30	0	0	$ 67,500.00	$$	L	L	M	M	M	L
RWP-17/18	F.C. Greene Memorial Blvd - Polo Lake - Shallow Bioretention	26%	3.83	166,835	1.00	43,383	3,615	100.0	3615	30	0	0	$ 32,537.25	$	L	L	L	H	H	L
RWP-19A	Outfall into Polo Lake (Museum) - Terraced Bioswale	17%	11.65	507,474	1.97	85,638	7,137	100.0	7137	30	0	0	$ 102,765.60	$$$	L	M	M	M	L	L
RWP-19B	Outfall into Polo Lake (Tennis Courts) - Dry Swale	43%	7.96	346,738	3.44	149,913	12,493	76.5	9554	30	0	0	$ 91,720.32	$$	L	M	L	L	L	L
RWP-19C	Miller Ave - Bioretention	50%	5.24	228,254	2.63	114,439	9,537	100.0	9537	30	0	0	$ 114,439.00	$$$	L	L	M	M	L	L
RWP-24	F.C. Greene Memorial Blvd between Cunliff and Deep Spring Lakes - Bioswale	33%	3.15	137,214	1.043	45,437	3,786	100.0	3786	30	5500	0	$ 48,737.00	$	L	L	M	M	H	L
RWP-26A	F.C. Greene Memorial Blvd by Ball Field - WVTS	18%	2.11	91,912	0.374	16,281	1,357	100.0	1357	48	0	0	$ 5,698.35	$	L	L	L	M	L	L
RWP-26B	F.C. Greene Memorial Blvd by Ball Field - WVTS	21%	2.86	124,582	0.590	25,721	2,143	100.0	2143	48	0	0	$ 9,002.35	$	L	L	L	M	L	L
RWP-28	Edgewood, Beachmont and F.C. Greene Memorial Blvd.- Infiltration Basin	50%	22.20	967,032	11.175	486,769	40,564	70.2	28463	65	5500	0	$ 139,920.00	$$$	L	L	H	M	L	L
RWP-29	Oakland Cemetery and Wentworth Ave - Terraced/Shallow Bioretention	13%	20.37	887,317	2.578	112,302	9,359	100.0	9359	30	0	0	$ 84,226.50	$$	M	L	M	M	L	L
RWP-30A	Marion Ave and F.C. Greene Memorial Blvd.-Terraced Bioswale	58%	9.19	400,316	5.350	233,037	19,420	72.5	14083	30	0	0	$ 202,800.00	$$$$$	H	M	M	M	L	L
RWP-30B	Marion Ave and F.C. Greene Memorial Blvd.-WVTS	66%	28.54	1,243,202	18.726	815,692	67,974	74.5	50667	48	0	0	$ 212,802.12	$$$$$	L	H	L	M	L	L
RWP-34	Botanical Center/Stables - Bioretention	38%	7.83	341,075	2.973	129,500	10,792	100.0	10792	30	0	0	$ 129,500.00	$$$	L	L	M	H	M	L
RWP-37A	History Museum Parking - Dry Swale	97%	0.20	8,712	0.19	8,441	703	100.0	703	30	0	0	$ 6,752.80	$	L	L	L	H	L	L
RWP-37B	History Museum - Memorial Blvd. - Terraced Bioswale	25%	4.43	192,971	1.11	48,189	4,016	100.0	4016	30	0	0	$ 57,826.80	$$	L	M	M	M	L	L
RWP-37C	History Museum - Babcock Street - Bioretention	45%	2.97	129,373	1.35	58,771	4,898	100.0	4898	30	0	0	$ 48,975.83	$	L	L	M	M	L	L

Table E.4. BMP Score Results

	Pollutant Removal Potential (Total = 40 points)			Cost (Total = 20 points)		Ease of Implementation (Total = 15 points)				Additional Benefits/Factors (Total = 25 points)				
Site #	Total WQv treated Score **(30)**	Pollutant Reduction Score **(10)**	**Removal Score (40)**	Total Cost $	**Cost Score (20)**	Wetlands/ Permitting Score **(5)**	Accessibility Score **(5)**	Maintenance Burden Score **(5)**	**Implement Score (15)**	Public Education/ Demonstration Score **(10)**	Removal of Waterfowl Habitat/ Access Score **(10)**	Other Partners/ Funding Score **(5)**	**Additional Benefits Score (25)**	**TOTAL SCORE (100)**
RWP-1A	11.03	4.6	**15.6**	$ 13,893	**20**	5	5	5	**15**	5	0	5	**10**	**60.6**
RWP-1B	11.04	4.6	**15.7**	$ 15,969	**20**	5	5	5	**15**	5	0	5	**10**	**60.7**
RWP-1C	11.95	4.6	**16.6**	$ 18,049	**20**	5	5	5	**15**	5	0	5	**10**	**61.6**
RWP-1E	12.22	4.6	**16.8**	$ 21,013	**20**	5	5	5	**15**	0	0	5	**5**	**56.8**
RWP-1F	10.12	4.6	**14.7**	$ 8,081	**20**	5	5	5	**15**	5	0	5	**10**	**59.7**
RWP-3B	11.87	4.6	**16.5**	$ 23,424	**20**	5	5	5	**15**	10	5	5	**20**	**71.5**
RWP-3C	11.80	4.6	**16.4**	$ 22,924	**20**	5	2.5	5	**12.5**	5	0	5	**10**	**58.9**
RWP-6	17.70	7.4	**25.1**	$ 131,990	**10**	5	5	5	**15**	10	10	5	**25**	**75.1**
RWP-7A	14.01	10.0	**24.0**	$ 13,548	**20**	5	5	5	**15**	0	0	0	**0**	**59.0**
RWP-7B	12.60	7.4	**20.0**	$ 10,252	**20**	2.5	2.5	5	**10**	0	10	0	**10**	**60.0**
RWP-9C/9D	11.71	4.6	**16.3**	$ 22,206	**20**	5	5	5	**15**	10	0	5	**15**	**66.3**
RWP-9E	10.20	4.6	**14.8**	$ 8,396	**20**	5	5	5	**15**	5	0	5	**10**	**59.8**
RWP-12	18.18	4.6	**22.8**	$ 88,930	**15**	5	2.5	2.5	**10**	10	5	5	**20**	**67.8**
RWP-14	11.89	4.6	**16.5**	$ 17,700	**20**	5	5	5	**15**	0	10	5	**15**	**66.5**
RWP-15	15.96	4.6	**20.6**	$ 67,500	**15**	5	5	2.5	**12.5**	5	5	5	**15**	**63.1**
RWP-17/18	14.35	4.6	**19.0**	$ 32,537	**20**	5	5	5	**15**	10	10	5	**25**	**79.0**
RWP-19A	19.62	4.6	**24.2**	$ 102,766	**10**	5	2.5	2.5	**10**	5	0	5	**10**	**54.2**
RWP-19B	23.23	4.6	**27.8**	$ 91,720	**15**	5	2.5	5	**12.5**	0	0	5	**5**	**60.3**
RWP-19C	23.20	4.6	**27.8**	$ 114,439	**10**	5	5	2.5	**12.5**	5	0	5	**10**	**60.3**
RWP-24	14.61	4.6	**19.2**	$ 48,737	**20**	5	5	2.5	**12.5**	5	10	5	**20**	**71.7**
RWP-26A	10.98	7.4	**18.4**	$ 5,698	**20**	5	5	5	**15**	5	0	5	**10**	**63.4**
RWP-26B	12.15	7.4	**19.5**	$ 9,002	**20**	5	5	5	**15**	5	0	5	**10**	**64.5**
RWP-28	30.00	10.0	**40.0**	$ 139,920	**10**	5	5	0	**10**	5	0	5	**10**	**70.0**
RWP-29	22.94	4.6	**27.6**	$ 84,227	**15**	2.5	5	2.5	**10**	5	0	5	**10**	**62.6**
RWP-30A	30.00	4.6	**34.6**	$ 202,800	**0**	0	2.5	2.5	**5**	5	0	5	**10**	**49.6**
RWP-30B	30.00	7.4	**37.4**	$ 212,802	**0**	5	0	5	**10**	5	0	5	**10**	**57.4**
RWP-34	25.08	4.6	**29.7**	$ 129,500	**10**	5	5	2.5	**12.5**	10	5	5	**20**	**72.2**
RWP-37A	10.00	4.6	**14.6**	$ 6,753	**20**	5	5	5	**15**	10	0	5	**15**	**64.6**
RWP-37B	14.95	4.6	**19.6**	$ 57,827	**15**	5	2.5	2.5	**10**	5	0	5	**10**	**54.6**
RWP-37C	16.27	4.6	**20.9**	$ 48,976	**20**	5	5	2.5	**12.5**	5	0	5	**10**	**63.4**

Table E.5. BMP Scoring Summary

	Ranking Criteria Summary:									
	1. Pollutant Removal Potential (40 pts)		2. Cost (20 points)		3. Ease of Implementation (15 points)		4. Additional Benefits/Factors (25 points)		Overall Site Ranking	
Rank	Site	Score	Site	Score	Site	Score	Site	Score	Site	Score
1	RWP-28	40.0	RWP-1A	20	RWP-1A	15	RWP-6	25	RWP-17/18	**79.0**
2	RWP-30B	37.4	RWP-1B	20	RWP-1B	15	RWP-17/18	25	RWP-6	**75.1**
3	RWP-30A	34.6	RWP-1C	20	RWP-1C	15	RWP-3B	20	RWP-34	**72.2**
4	RWP-34	29.7	RWP-1E	20	RWP-1E	15	RWP-12	20	RWP-24	**71.7**
5	RWP-19B	27.8	RWP-1F	20	RWP-1F	15	RWP-24	20	RWP-3B	**71.5**
6	RWP-19C	27.8	RWP-3B	20	RWP-3B	15	RWP-34	20	RWP-28	**70.0**
7	RWP-29	27.6	RWP-3C	20	RWP-6	15	RWP-9C/9D	15	RWP-12	**67.8**
8	RWP-6	25.1	RWP-7A	20	RWP-7A	15	RWP-14	15	RWP-14	**66.5**
9	RWP-19A	24.2	RWP-7B	20	RWP-9C/9D	15	RWP-15	15	RWP-9C/9D	**66.3**
10	RWP-7A	24.0	RWP-9C/9D	20	RWP-9E	15	RWP-37A	15	RWP-37A	**64.6**
11	RWP-12	22.8	RWP-9E	20	RWP-14	15	RWP-1A	10	RWP-26B	**64.5**
12	RWP-37C	20.9	RWP-14	20	RWP-17/18	15	RWP-1B	10	RWP-37C	**63.4**
13	RWP-15	20.6	RWP-17/18	20	RWP-26A	15	RWP-1C	10	RWP-26A	**63.4**
14	RWP-7B	20.0	RWP-24	20	RWP-26B	15	RWP-1F	10	RWP-15	**63.1**
15	RWP-37B	19.6	RWP-26A	20	RWP-37A	15	RWP-3C	10	RWP-29	**62.6**
16	RWP-26B	19.5	RWP-26B	20	RWP-3C	12.5	RWP-7B	10	RWP-1C	**61.6**
17	RWP-24	19.2	RWP-37A	20	RWP-15	12.5	RWP-9E	10	RWP-1B	**60.7**
18	RWP-17/18	19.0	RWP-37C	20	RWP-19B	12.5	RWP-19A	10	RWP-1A	**60.6**
19	RWP-26A	18.4	RWP-12	15	RWP-19C	12.5	RWP-19C	10	RWP-19B	**60.3**
20	RWP-1E	16.8	RWP-15	15	RWP-24	12.5	RWP-26A	10	RWP-19C	**60.3**
21	RWP-1C	16.6	RWP-19B	15	RWP-34	12.5	RWP-26B	10	RWP-7B	**60.0**
22	RWP-14	16.5	RWP-29	15	RWP-37C	12.5	RWP-28	10	RWP-9E	**59.8**
23	RWP-3B	16.5	RWP-37B	15	RWP-7B	10	RWP-29	10	RWP-1F	**59.7**
24	RWP-3C	16.4	RWP-6	10	RWP-12	10	RWP-30A	10	RWP-7A	**59.0**
25	RWP-9C/9D	16.3	RWP-19A	10	RWP-19A	10	RWP-30B	10	RWP-3C	**58.9**
26	RWP-1B	15.7	RWP-19C	10	RWP-28	10	RWP-37B	10	RWP-30B	**57.4**
27	RWP-1A	15.6	RWP-28	10	RWP-29	10	RWP-37C	10	RWP-1E	**56.8**
28	RWP-9E	14.8	RWP-34	10	RWP-30B	10	RWP-1E	5	RWP-37B	**54.6**
29	RWP-1F	14.7	RWP-30A	0	RWP-37B	10	RWP-19B	5	RWP-19A	**54.2**
30	RWP-37A	14.6	RWP-30B	0	RWP-30A	5	RWP-7A	0	RWP-30A	**49.6**

Table E.1 shows the overall ranking for each site. The final ranking for the projects was used to guide the steering committee in choosing the initial retrofits to carry forward for final design and construction in the immediate future. The full ranking spreadsheets have also been included in this appendix. These sites are described in greater detail in **Appendix F**.

Table E.4. Overall Ranking for the Proposed Stormwater Retrofits

Overall Site Ranking	Site #	Site Description
1	RWP-17/18	FC Green Memorial Blvd - Polo Lake - Shallow Bioretention
2	RWP-6	FC Green Memorial Blvd - Across from Monument - WVTS
3	RWP-34	Botanical Center/Stables - Bioretention
4	RWP-24	FC Green Memorial Blvd between Cunliff and Deep Spring Lakes - Bioswale
5	RWP-3B	Carousel Parking Lot -Bioretention (1/2 of lot)
6	RWP-28	Edgewood, Beachmont and FC Green Memorial Blvd.- Infiltration Basin
7	RWP-12	Ornamental Bridge - Terraced Bioswale
8	RWP-14	North side of Roosevelt Lake - Shallow Bioretention
9	RWP-9C/9D	Casino Parking Lot -Bioretention
10	RWP-37A	History Museum Parking - Dry Swale
11	RWP-26B	FC Green Memorial Blvd by Ball Field - WVTS
12	RWP-37C	History Museum - Babcock Street - Bioretention
13	RWP-26A	FC Green Memorial Blvd by Ball Field - WVTS
14	RWP-15	Polo Lake outfall near Rotary - Terraced Bioswale
15	RWP-29	Oakland Cemetery and Wentworth Ave - Terraced/Shallow Bioretention
16	RWP-1C	Cladrastris Avenue - near boathouse - Dryswale
17	RWP-1B	Pine Hill and Maple Avenue Intersection - Bioretention
18	RWP-1A	Pine Hill Avenue - Bioretention
19	RWP-19B	Outfall into Polo Lake (Tennis Courts) - Dry Swale
20	RWP-19C	Miller Ave - Bioretention
21	RWP-7B	Outfall at Roosevelt Lake from Route 10 - WVTS
22	RWP-9E	Casino Entrance - Bioretention
23	RWP-1F	Cladrastris Avenue Intersection - Bioretention
24	RWP-7A	Route 10 off-ramp - Infiltration Basin/Dry Swale
25	RWP-3C	Carousel Parking Lot -Bioretention (1/2 of lot)
26	RWP-30B	Marion Ave and FC Green Memorial Blvd.-WVTS
27	RWP-1E	Maple Avenue - Dryswale
28	RWP-37B	History Museum - Memorial Blvd. - Terraced Bioswale
29	RWP-19A	Outfall into Polo Lake (Museum) - Terraced Bioswale
30	RWP-30A	Marion Ave and FC Green Memorial Blvd.-Terraced Bioswale

Pollutant Loading Analysis

In addition, the HW team evaluated the phosphorus and nitrogen loading to the Roger Williams Park Ponds (see **Chapter 2**) as well as the potential phosphorus removal for each of the proposed structural controls. The breakdown of pollutant removal for all 30 ranked sites is included in **Table E.5**.

Table E.5. Pollutant Removal from Ranked Retrofits

		Existing		With BMP		% Reduction of Total Load	
Rank	Site I.D.	P load lbs/yr	N load lbs/yr	P load lbs/yr	N load lbs/yr	P	N
1	RWP-17/18	0.368	8.157	0.110	4.486	0.01%	0.04%
2	RWP-6	0.529	15.873	0.254	4.762	0.03%	0.05%
3	RWP-34	4.321	56.438	1.296	31.041	0.16%	0.30%
4	RWP-24	0.428	11.464	0.128	6.305	0.02%	0.06%
5	RWP-3B	0.271	8.818	0.081	4.850	0.01%	0.05%
6	RWP-28	13.228	251.106	8.598	163.219	1.08%	1.57%
7	RWP-12	1.543	48.943	0.463	26.918	0.06%	0.26%
8	RWP-14	0.223	7.496	0.067	4.123	0.01%	0.04%
9	RWP-9C/9D	0.143	4.850	0.043	2.668	0.01%	0.03%
10	RWP-37A	0.031	0.882	0.009	0.485	0.00%	0.00%
11	RWP-26B	0.489	15.212	0.235	4.564	0.03%	0.04%
12	RWP-37C	1.151	22.487	0.345	6.746	0.04%	0.06%
13	RWP-26A	0.348	10.803	0.167	3.241	0.02%	0.03%
14	RWP-15	0.631	21.385	0.189	11.762	0.02%	0.11%
15	RWP-29	12.655	174.606	3.796	96.033	0.48%	0.93%
16	RWP-1C	0.291	8.157	0.087	4.486	0.01%	0.04%
17	RWP-1B	0.062	1.323	0.019	0.728	0.00%	0.01%
18	RWP-1A	0.060	1.323	0.018	0.728	0.00%	0.01%
19	RWP-19B	1.422	47.179	0.427	25.948	0.05%	0.25%
20	RWP-19C	2.061	41.667	0.618	22.917	0.08%	0.22%
21	RWP-7B	1.030	18.298	0.494	5.490	0.06%	0.05%
22	RWP-9E	0.110	3.748	0.033	2.061	0.00%	0.02%
23	RWP-1F	0.026	0.661	0.008	0.364	0.00%	0.00%
24	RWP-7A	1.164	20.503	0.757	13.327	0.10%	0.13%
25	RWP-3C	0.198	6.173	0.060	3.395	0.01%	0.03%
26	RWP-30B	15.124	284.396	7.259	85.319	0.91%	0.82%
27	RWP-1E	0.346	7.716	0.104	4.244	0.01%	0.04%
28	RWP-37B	0.624	17.637	0.187	9.700	0.02%	0.09%
29	RWP-19A	1.182	36.817	0.355	20.249	0.04%	0.20%
30	RWP-30A	4.255	83.114	1.276	45.713	0.16%	0.44%
	Totals	**64.432**	**1241.201**	**27.520**	**618.054**	**3.5%**	**6.0%**

Appendix F

Stormwater Retrofit Site Descriptions

The following are the detailed descriptions of the recommended Lower Watershed stormwater retrofits identified in **Section 3.2.2** of the Water Quality Management Plan.

Stormwater Retrofits Site Descriptions

The Boathouse Area

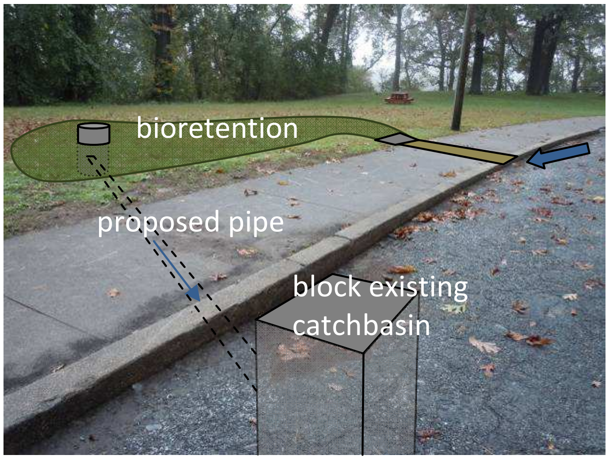
The roadways in the general area of the Boathouse (Cladrastris Avenue, Maple Avenue, and Pine Hill Avenue) range from 36 to 45 feet in width. It appears that parking is allowed on both sides of most roads and the roads merge at large intersections. The roads are crowned with curbs on either side with an existing closed drainage system consisting of a series of catchbasins, trench drains, and manholes which discharge to Pleasure Lake through one or more outfall pipes.

Several retrofits are proposed in this area. Proposed BMPs include pavement removal, bioretention areas, dry swales, and downspout disconnection. Detailed site descriptions and retrofit options are provided below.

RWP-1A: Pine Hill Avenue

Pine Hill Avenue is a 36-foot wide paved roadway, crowned with curbs on both sides of the road. Catchbasins are located on either side of the street and are connected to an outfall into Pleasure Lake. The drainage area to this site is 0.6 acres, with 63% impervious cover. Open, pervious areas maintained as turf are present all along the roadway.

The concept for this site is to construct paved flumes leading to bioretention areas on both sides of the street to intercept stormwater prior to its entering the closed drainage system. The plan is to block the existing catchbasin grates, but leave the structures in place for overflow from the bioretention area during large storm events.



*Roadway reduction should be evaluated in the context of an overall "master plan assessment" for the Park where uses, traffic volumes, pedestrian linkages, and historic elements, among other factors are evaluated in an inclusive process. For more information, see non-structural practices in **Section 3.2.3**.

For future consideration, we recommend removing a travel lane from this section of roadway, creating a one-way road with parking allowed on only one side of the street. The other direction of travel would be on Maple Avenue (see RWP-1E). This reduction in impervious cover reduces the amount of stormwater created, as well as the associated pollutants. The estimated planning level cost for this project is $13,900 (see **Appendix G** for the full cost table).

RWP-1B: Intersection of Pine Hill and Maple Avenue

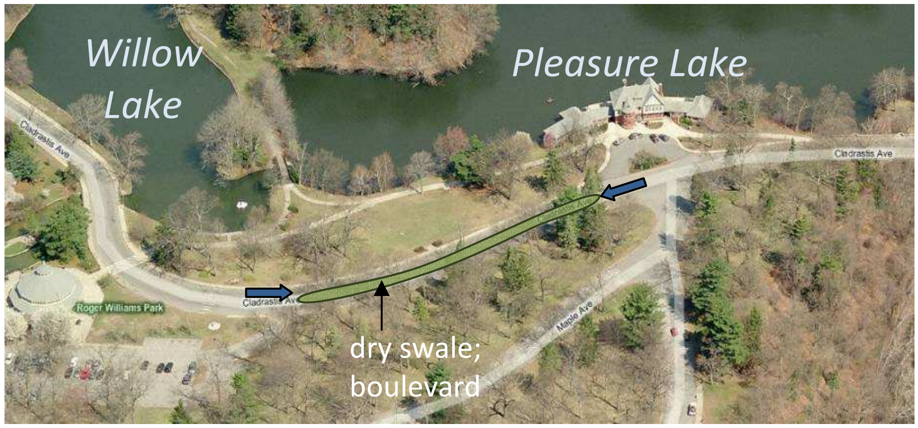
The intersection of Pine Hill and Maple Avenue is over 70 feet wide. Catchbasins and manholes are located at the intersection and connect to the closed drainage system that discharges to Pleasure Lake. During the site visit, the catchbasins were clogged with woodchips and debris. It was difficult to fully assess this site due to the large wood chipping operation that was in progress during our site visit. However, aerial photographs and GIS information helped identify a potential retrofit at this location. It appears that the contributing drainage area to the intersection is approximately 0.7 acres, with 58% impervious cover.

The concept for this site is to remove pavement from the center of the intersection, creating a traffic island where a bioretention area could be installed. Convert the existing catchbasins to diversion structures, thereby allowing runoff from small storms to be directed to the bioretention area. The bioretention area would have underdrains connected to the existing closed drainage system. Additionally, a management plan should be implemented to ensure adequate protection of any existing and proposed drainage infrastructure during any future chipping operations in this area. The estimated planning level cost for this project is $16,000 (see **Appendix G** for the full cost table).

RWP-1C: Cladrastris Avenue

The width of pavement of Cladrastris Avenue is approximately 45 feet in the area between the Boathouse and the Carousel. It appears that parking is allowed on both sides of the street. Catchbasins located along the road connect to the outfall in Pleasure Lake. The contributing drainage area is approximately 2.2 acres, with 25% impervious cover.

The proposed retrofit for this site includes the removal of pavement in the center of the street where a 10-foot wide dry swale could be constructed, creating a boulevard. This removes parking on one side of the street. The dry swale would overflow to the existing closed drainage system for large storm events. In addition to treating stormwater, the boulevard would provide the added benefit of traffic calming in this busy area. The estimated planning level cost for this project is $18,000 (see **Appendix G** for the full cost table).



RWP-1D: The Boathouse Roof Runoff

The southern half of the Boathouse roof area is a little over 3,000 square feet. The roof leaders appear to be directly connected to the existing drainage system that discharges to Pleasure Lake.

There are several areas around the boathouse that could be utilized for stormwater planters or raingardens. This would allow the roof runoff to be infiltrated instead of discharging directly to the pond. In addition, this would be a good opportunity to provide a demonstration project with educational signage so visitors to this area could learn what practices they could implement at their own homes. The public could also be involved in the actual construction of these retrofits as additional outreach.

RWP-1E: Maple Avenue

Maple Avenue is 36 feet wide and has curbing along both sides. This street was being utilized as a storage area for a wood chipping operation during the site visit, making it difficult to fully assess this area. There was a large amount of debris on the road surface, as shown in the photo. However, aerials and GIS data were used to determine an appropriate retrofit for the site, which has an approximately 3.6-acre drainage area with 17% impervious cover.

The recommended retrofit for this site includes removing pavement along the northern edge of the road to create space for a dry swale. Overflows during large storm events would be directed into the existing closed drainage system by converting the existing catchbasin near the intersection of Pine Hill and Maple Avenues (see photo) into an overflow structure. This option would have little impact on the many mature trees along Maple Avenue since it is in an area of existing impervious cover. To accommodate the pavement removal, roadside parking would be eliminated along this stretch. Alternatively, Maple Avenue could be converted to a one-way road with the other direction of traffic flow on Pine Hill Avenue (see RWP-1A). The estimated planning level cost for this project is $21,000 (see **Appendix G** for the full cost table).

RWP-1F: Cladrastris Avenue Intersection

The intersection of Cladrastris Avenue and Pine Hill Avenue is over 100 feet at its widest point. Catchbasins are located on Cladrastris Avenue that connect to the existing outfall in Pleasure Lake. The drainage area to this location is almost 0.3 acres, with 80% impervious cover.

Similar to the proposed retrofit at the intersection of Pine Hill and Maple Avenues (RWP-1B), pavement could be removed from the intersection in order to create a bioretention island. Overflow from the proposed practice would discharge into the existing closed drainage system, discharging to Pleasure Lake. The estimated planning level cost for this project is $8,000 (see **Appendix G** for the full cost table).

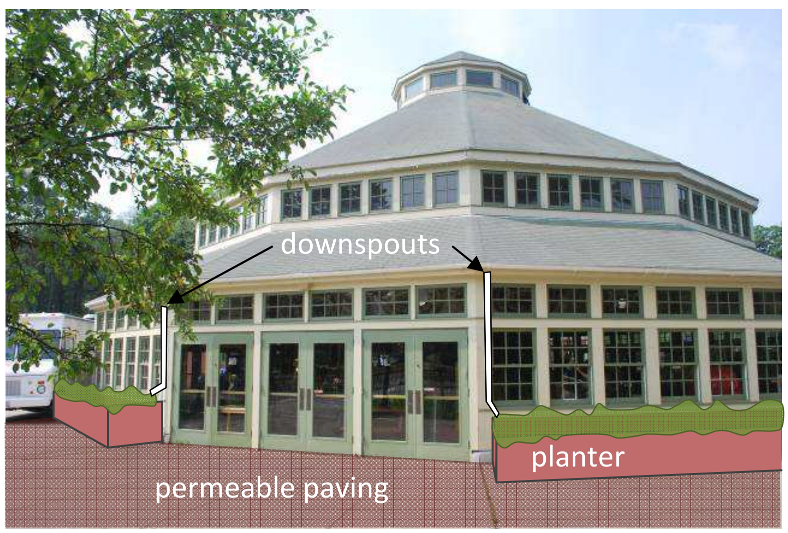
The Carousel Area

The Carousel is a popular spot for year-round park users. It has an off-street parking lot for more than eighty cars that slopes gently toward the northwest corner, near the Japanese Garden. The parking lot is paved with curbing and a series of catchbasins that discharge into the Japanese Garden via a 12-18 inch outfall (assumed). It has reasonably sized parking spaces and drive aisles, and a few small landscaped islands located within the parking area. Low points with visible ponding were observed during the field visit.

RWP-3A: Carousel Roof

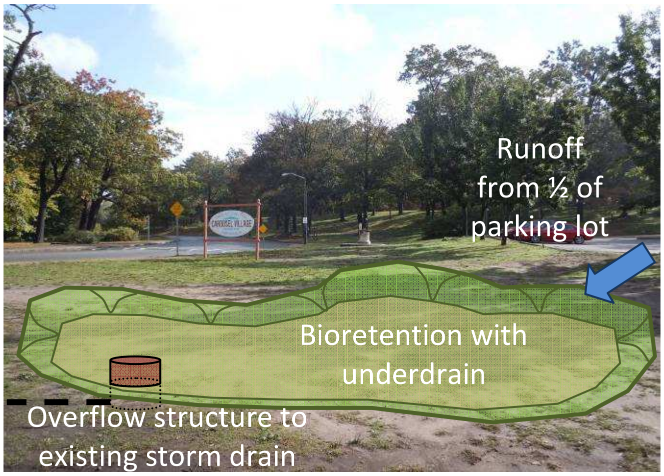
The Carousel roof is approximately 6,300 square feet. Downspouts currently discharge onto the surrounding concrete walkway. In many cases, the downspouts are damaged and/or disconnected from the gutter (see photo below). Based upon the foot traffic observed, there also appears to be an excessive amount of impervious cover surrounding the Carousel.

Stormwater planters are the proposed retrofit for this site. There are several potential locations around the building. It is recommended that an alternative surface material, such as pervious pavement or pavers, be considered for the existing impervious area around the Carousel. This location provides a good opportunity for public outreach.



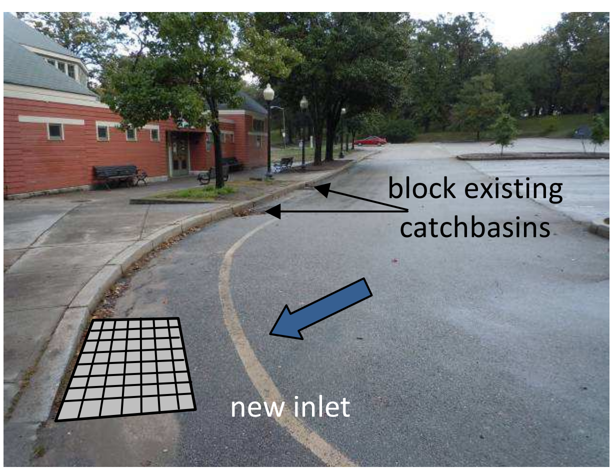
RWP-3B: Carousel Parking Lot

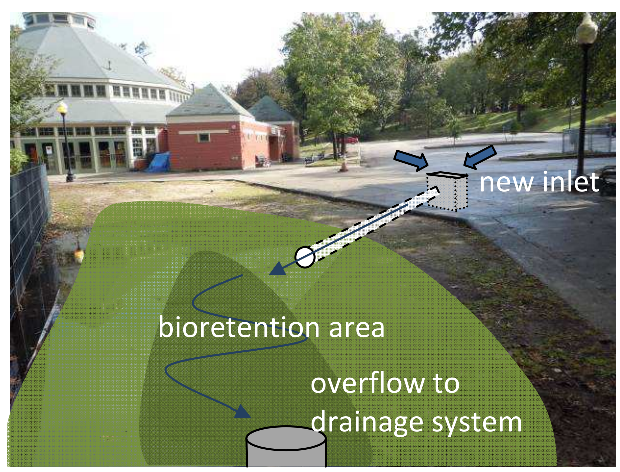
The proposed retrofit for the eastern half of the parking lot (drainage area 1.4 acres, 38% impervious) is to create a bioretention area in the open grassed area between the parking lot and Cladrastris Avenue, near the sign for the Carousel. The bioretention area would be located to minimize the impact to the turf area closest to the carousel where temporary tents are erected for various events held throughout the year. A new inlet structure would need to be constructed at the existing low point in the parking lot to direct stormwater into the proposed bioretention area through a pipe. Underdrains would connect to the existing closed drainage system in Cladrastris Avenue that discharges to Willow Lake via a 12-inch outfall. This location is a highly visible site because it is located on a major park road and also because the Carousel is an attraction that many people visit all year. Thus, it would be a great location for a demonstration project with signage to educate the public, as well as a good opportunity to provide an educational workshop during installation. The estimated planning level cost for this project is $23,400 (see **Appendix G** for the full cost table).



RWP-3C: Carousel Parking Lot

A retrofit similar to RWP-3B is proposed for the western half of the Carousel parking lot. The contributing drainage area to this site is 1.1 acres with almost 50% impervious cover. Stormwater from this portion of the parking lot would be directed to a bioretention area along the fence adjacent to the Japanese Garden (or within the Japanese Garden, depending on soil conditions here). The existing catchbasins would be blocked, and a new inlet structure would be required at the existing low point to direct stormwater into the bioretention area through a pipe. The bioretention area would have underdrains connected to the existing closed drainage system that outfalls into the Japanese Garden. The estimated planning level cost for this project is $22,925 (see **Appendix G** for the full cost table).



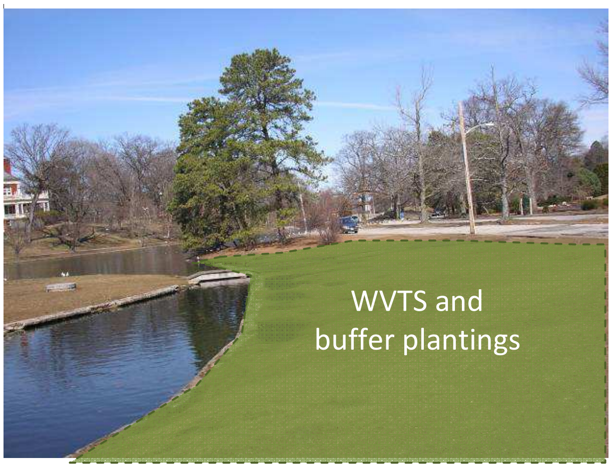


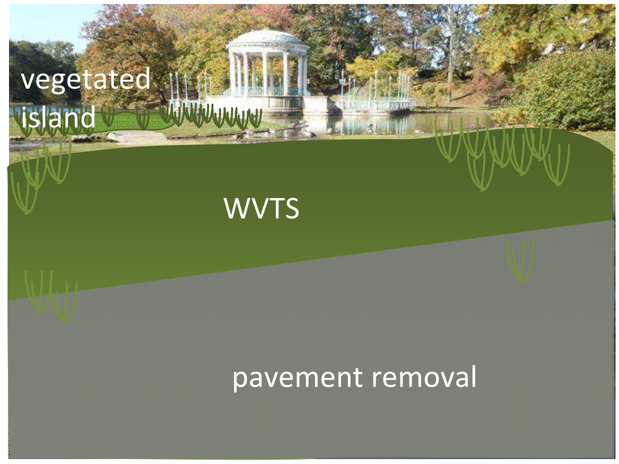
RWP-6: Roosevelt Lake – Across from the Monument

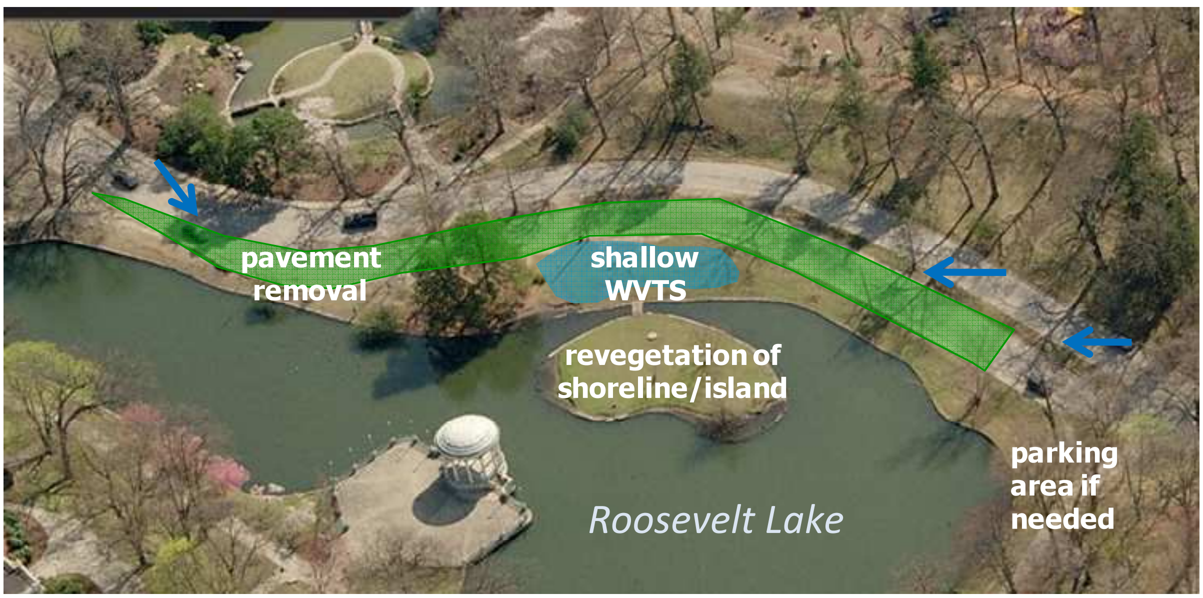
Across from the monument, F.C. Greene Memorial Boulevard is a divided roadway with each lane measuring approximately 22 feet in width, allowing for a travel lane as well as parking on each side of the road. The contributing drainage area is 3.4 acres, with 47% impervious cover.

There does not appear to be any formalized drainage. Runoff sheet flows to a low point in the roadway and then into Roosevelt Lake, causing erosion of the shoreline and settlement of the roadway and sidewalk. This location also appears to be a popular spot to feed the waterfowl, which has contributed to shoreline erosion.

A Wet Vegetated Treatment System (WVTS), pavement removal, and buffer restoration are proposed for this site. The concept includes removing the western travel lane and center island to provide greater separation from the impervious cover to Roosevelt Lake and a larger space for a WVTS to be constructed to treat the road runoff. A WVTS was chosen for this site due to the anticipated high groundwater along the low-lying shoreline. The remaining eastern travel lane would be repaired and widened slightly from its existing 22 foot width to provide an adequate width for comfortable two-way traffic. The parking area near the top of the hill on Hillside Avenue could be expanded to include an area for approximately ten additional cars, allowing for more appropriate access to the area. Buffer planting along the shoreline should consist of native, low-growing wildflowers, grasses, shrubs, and emergent vegetation to stabilize the area as well as to deter geese from congregating. The buffer restoration plantings would be designed to seamlessly blend with the WVTS plantings, improving aesthetics in the area while not affecting the viewshed. Small, inconspicuous fencing could also be incorporated into the planting area for additional waterfowl control.   The estimated planning level cost for this project is $132,000 (see **Appendix G** for the full cost table).



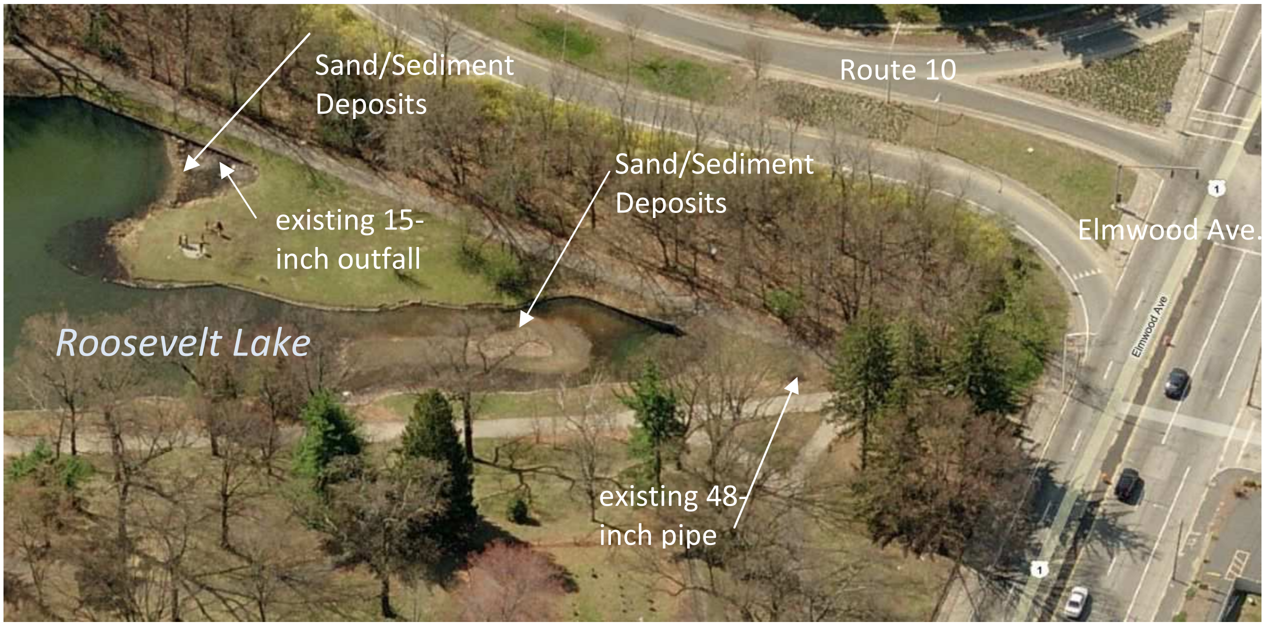




Route 10/Elmwood Avenue Area (U.S. Route 1)

All of the drainage areas within the Route 10/Elmwood Avenue area are outside of the Park boundaries. Route 10 and Elmwood Avenue (U.S. Route 1) are designated highways and under the Rhode Department of Transportation (RIDOT) jurisdiction. There are a series of catchbasins located on the Route 10 and Elmwood Avenue, which drain to Roosevelt Lake via a 48-inch pipe in the southwest corner of the lake and a 15-inch pipe east of the 48-inch outfall. Large amounts of sand deposits were observed at both outfalls during the field assessment. This is attributed to excessive road sanding during the winter months along both Elmwood Avenue and the Route 10 on ramp. Several retrofits are proposed in the area of the Route 10/Elmwood Avenue area. Proposed BMPs include diversion structures, dry swales, infiltration basins and WVTS. Detailed site descriptions and retrofit options are provided below.

The implementation of a reduced sanding/salting program should be considered for the for the contributing drainage area. This would help reduce the annual maintenance required for sand removal for both pond outfalls and proposed BMPs.



RWP-7A: Route 10 On-Ramp

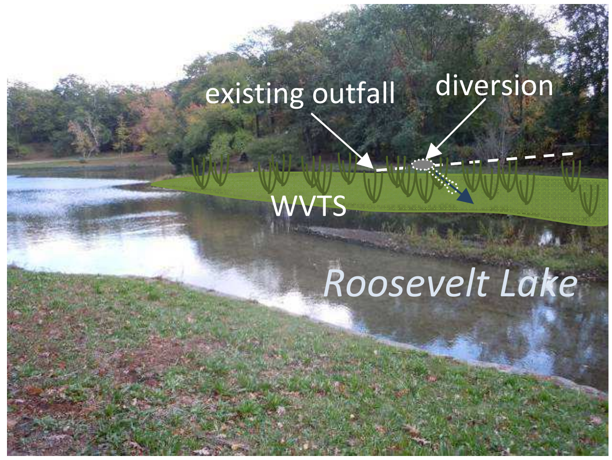
Catchbasins located within the travel lanes for Route 10 and the Elmwood Avenue on-ramp discharge at two separate outfalls into a paved swale located in the open vegetated island area of the on-ramp. The drainage area to the swale is 2.7 acres, with 35% impervious cover. This swale then discharges to the existing closed drainage system that eventually outfalls into Roosevelt Lake via a 48-inch pipe. This outfall has been identified as priority outfall RWP-Q in the "9 Eutrophic Ponds in Rhode Island" TMDL (TMDL report) (see **Figure 3.1**). .

The proposed retrofit concept for this site is to fully utilize the existing turf area adjacent to the swale. Sediment forebays would be constructed at both outfalls to trap sands/sediments prior to discharging to Roosevelt Lake. An infiltration basin would be constructed in the open lawn area to provide groundwater recharge and stormwater treatment for the first inch of runoff. Additionally, the remaining paved swale would be converted into a dry swale for increased infiltration before discharging into the 48-inch pipe. It should be noted that this area is located within the highway layout, and any proposed work would need to be permitted and constructed in coordination with RIDOT. The estimated planning level cost for this project is $13,500 (see **Appendix G** for the full cost table).

RWP-7B: 15-inch Outfall at Roosevelt Lake (RWP-7B)

There is an existing 15-inch outfall into Roosevelt Lake that receives untreated stormwater from several catchbasins located within the on and off-ramps of the Elmwood Avenue Exit of Route 10. The contributing drainage area is almost 2 acres, with 36% impervious cover.

The peninsula of land just to the north of the outfall presents a great location for constructing a WVTS. This area has high groundwater and would also benefit from the WVTS vegetation, which would provide the additional benefit of deterring waterfowl in this area. A diversion manhole would be installed to direct the first inch of runoff to the proposed BMP. A sediment forebay would be constructed to allow the settling of heavy sands and sediments prior to entering the proposed BMP. The existing outfall would remain in place for overflow during large storm events.   The estimated planning level cost for this project is $10,250 (see **Appendix G** for the full cost table).



The Casino Area

The Casino is considered a Rhode Island landmark and serves as one of the gateways to the Park. It hosts special events throughout the year and is available for private functions. Since there are year round visitors to the facility, this area provides great public outreach opportunities. Paved parking areas are located along the western side of the building with stormwater runoff managed with traditional curb and gutter. A series of catchbasins carry runoff from the parking lot and roadways to outfalls into Roosevelt Lake. Roof runoff from the Casino building is directed to downspouts that currently discharge into a combined sewer system located along Roosevelt Lake.

The roadways surrounding the Casino include Rose, Linden and Lincoln Avenue and merge at the large entrance “roundabout”. The roads range in width from 34 to 36 feet wide, crowned with curbs on both side, and drains via an existing closed drainage system. A series of catchbasins, and manholes discharge to Roosevelt Lake through one or more outfall pipes.

Several retrofits are proposed in this area including downspout disconnections, bioretention areas and bio swales. Detailed site descriptions and retrofit options are provided below.

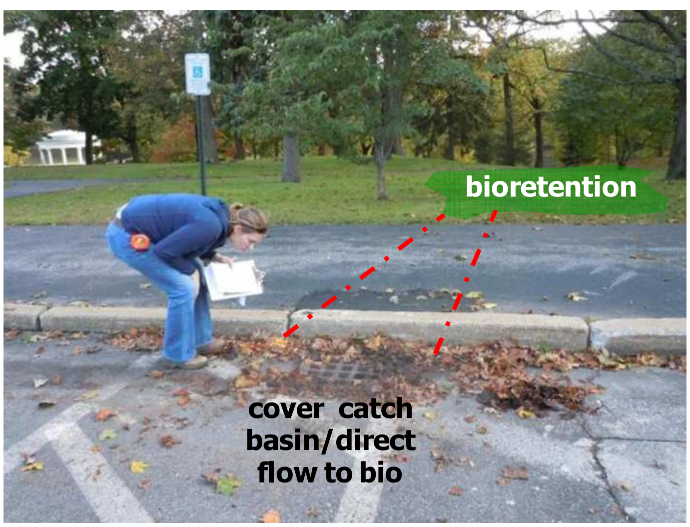
RWP-9B: Casino Roof Runoff

The Casino roof is approximately 9,400 square feet. Currently, eight downspouts carry roof runoff into the combined sewer system that is located along Roosevelt Lake. The proposed retrofit for this site is to disconnect the downspouts from the combined sewer system and redirect them into raingardens or raised planters around the building. This proposed retrofit location would provide a great opportunity for public education and outreach.

RWP-9C/9D: Casino Parking Lot and portions of Linden and Rose Avenues

Portions of Linden and Rose Avenues slope down toward the Casino parking lot. Both roads are crowned, with curbs. The total drainage area to this site is 0.7 acres, with 74% impervious cover. Stormwater enters the closed drainage system via two catchbasins in the parking lot. The drainage system currently discharges to Roosevelt Lake.

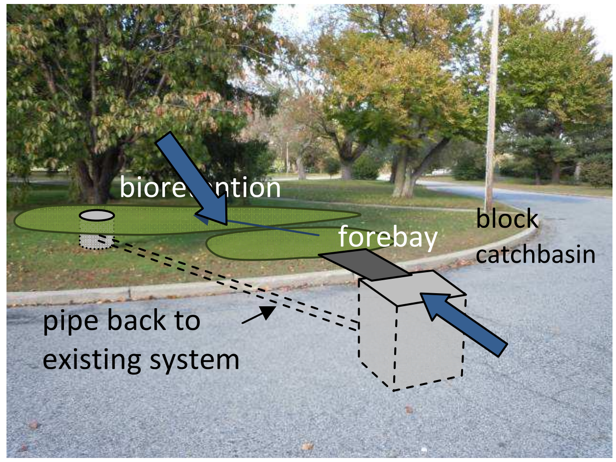
The concept for this site is to direct runoff into a bioretention area in the open area just south of the catchbasin closest to the Casino via a paved flume and a sediment forebay. The existing catchbasins would be blocked, or adjusted to be used only as an overflow for large storm events. The bioretention area would have underdrains that would connect back into the existing closed drainage system. The estimated planning level cost for this project is $22,200 (see **Appendix G** for the full cost table).



RWP-9E: Casino Entrance

A catchbasin located near the Casino entrance receives runoff from a portion of Linden Avenue (0.5-acre drainage area; 46% impervious). Similar to the other surrounding catchbasins, it connects to the closed drainage system that discharges to Roosevelt Lake.

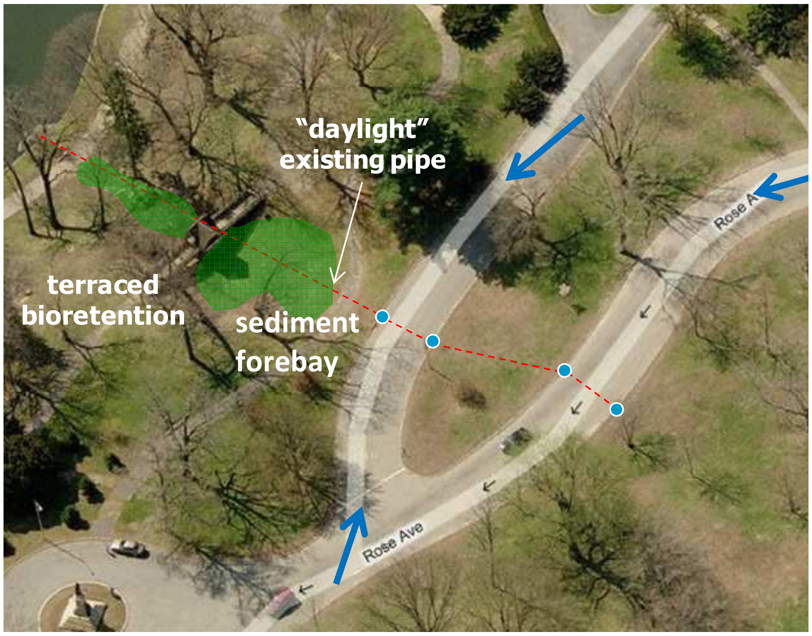
The open island area between Linden and Rose Avenues could be utilized as a bioretention area. The existing catchbasin would be blocked, and stormwater would enter the proposed BMP through a paved flume to a sediment forebay. The bioretention would have underdrains and an overflow structure that connect back into the existing closed drainage system. The estimated planning level cost for this project is $8,400 (see **Appendix G** for the full cost table).

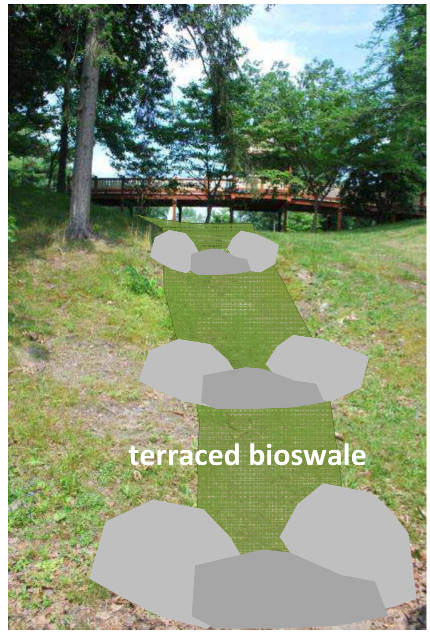


RWP-12: Ornamental Bridge

In this area Linden and Rose Avenues discharge to an outfall to Roosevelt Lake via three pairs of existing catchbasins. Overland flow has caused some erosion down the slope under the ornamental bridge. The contributing drainage area to this site is approximately 6.6 acres, with 26% impervious cover.

The proposed retrofit for this site is to daylight the existing pipe to an area just upgradient of the ornamental bridge into a sediment forebay for pretreatment, and then to a terraced bioswale under the bridge. The existing outfall would be maintained for overflow during large storm events. The bioswale would be planted with native landscaping, and the adjacent area should be planted with low growing native grasses and shrubs to help stabilize the slope and prevent erosion. This location provides a great opportunity for educational signage. The estimated planning level cost for this project is $89,000 (see **Appendix G** for the full cost table).

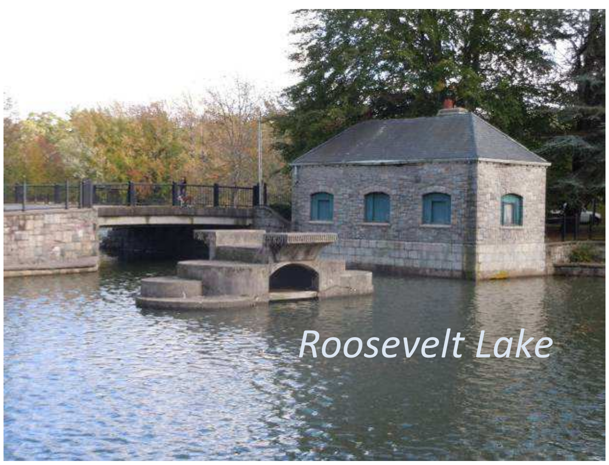


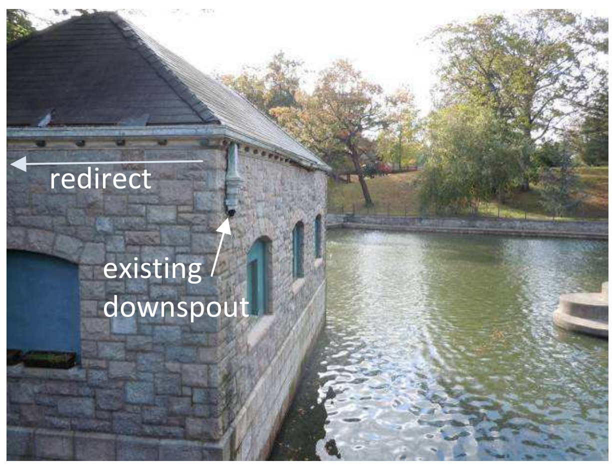


The Seal House Area

RWP-13: Seal House

The Seal House, located on the edge of Roosevelt Lake is approximately 700 square feet with existing downspouts that discharge directly to the lake. Although the building is in disrepair and a large hole exists in the top of the roof, the building has been considered for future educational or public outreach purposes. If the building is renovated in the future it is recommended the downspouts be directed to rain barrels or planters which could serve as a demonstration practices within the Park. This could be a great opportunity to provide educational outreach.

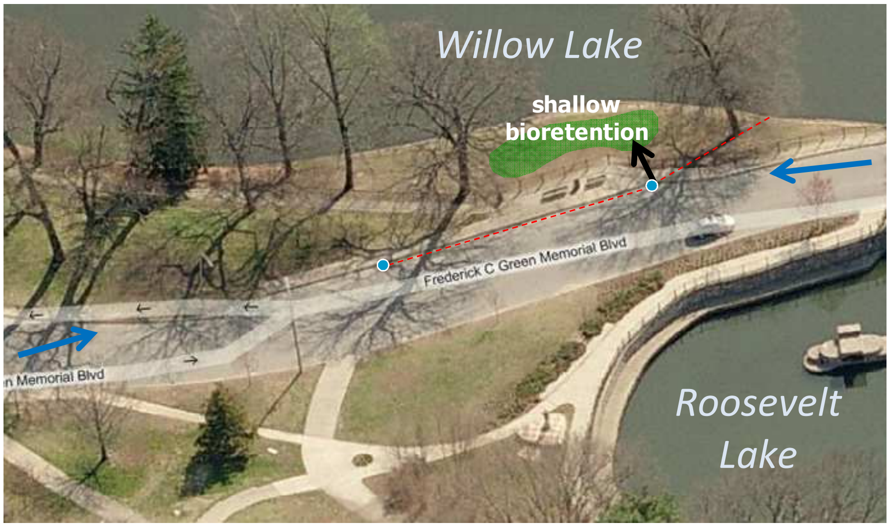




RWP 14: Catchbasins on north side of Roosevelt Lake

There are several catchbasins located on F.C. Greene Memorial Boulevard near the bridge crossing Roosevelt Lake/Willow Lake that discharge to Willow Lake. The contributing drainage area to this location is 1 acre, with 54% impervious cover. The slope from the roadway to Willow Lake is fairly steep, but it does not appear that erosion is a problem at this location.

The concept for this site is to utilize an area along the western shoreline of Willow Lake for a shallow bioretention. The existing catchbasin would be modified to divert stormwater from the small storms while maintaining the original 8-inch outfall for large storm events. The estimated planning level cost for this project is $17,700 (see **Appendix G** for the full cost table).

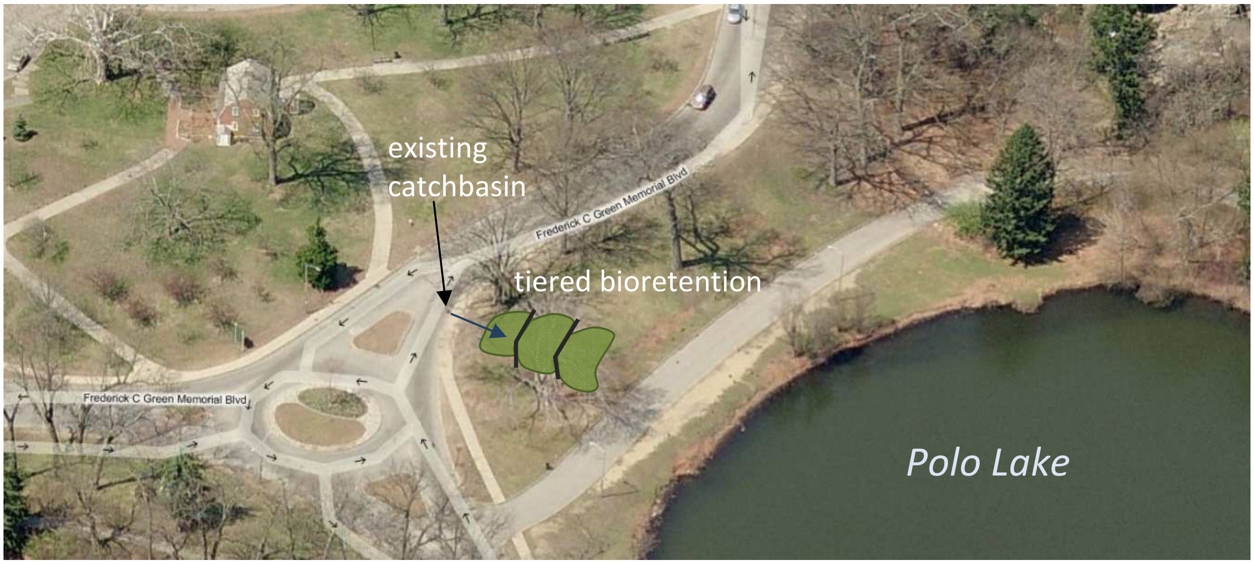


Polo Lake Area

RWP 15: Polo Lake Outfall near rotary

Three sets of catchbasins collect runoff from F.C. Greene Memorial Boulevard near the rotary. The existing catchbasins are connected by PVC pipes and are directed to two leaching basins that then overflow into Polo Lake through a 12-inch pipe. The drainage area to this site is 2.9 acres, with 45% impervious cover. Although the slope to the water is fairly steep, erosion does not appear to be a problem at this location.

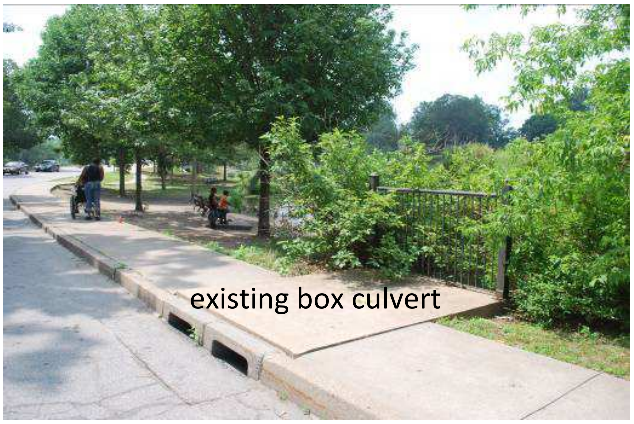
The concept for this site is to construct a terraced bioretention facility in the open grassy area between F.C. Greene Memorial Boulevard and the access road to the zoo. A diversion structure would need to be installed upgradient of the leaching structures, or convert the leaching structures into diversion structures, to direct the first inch of runoff to the bioretention area. The bioretention area would have underdrains connecting back to the closed drainage system to Polo Lake. The estimated planning level cost for this project is $67,500 (see **Appendix G** for the full cost table).



RWP-17/18: F. C. Greene Memorial Boulevard

This section of F.C. Greene Memorial Boulevard is very busy, serving as both a main route for the surrounding neighborhoods and park/zoo users. It is a popular spot within the Park due to multiple uses at one location. The main zoo entrance is just to the north, the swan boat launch to the south, and there are several park benches along the shoreline where visitors feed the waterfowl. As a result, the area has become degraded, and the ground is bare in some areas (see photos below). Shoreline erosion is also occurring here. Runoff currently sheet flows down F.C. Greene Memorial Boulevard into a box culvert inlet before discharging into Polo Lake. The box culvert was identified as a priority outfall RWP-V in the TMDL report (see **Figure 3.1**). . The contributing drainage area to this location is 3.8 acres, with 26% impervious cover.

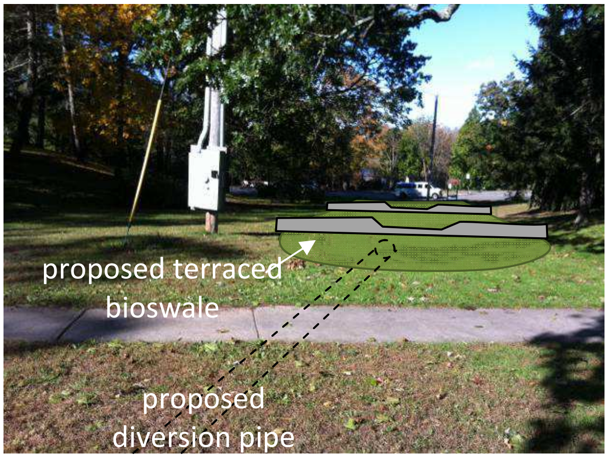
The concept for this site is to convert the shoreline area (between the sidewalk and the lake) into a shallow bioretention facility with a shallow, engineered filter media and only a simple spillway (no underdrain) to convey overflows into the lake. The existing box culvert structure would need to be modified to allow stormwater to be diverted into the proposed BMP. An existing curb cut located near the swan boat launch area appears to direct stormwater to this area. This curb cut could be formalized to direct runoff into the proposed BMP. Any remaining degraded shoreline would be planted and stabilized. It is a great location for public education regarding the negative impacts of geese feeding, waterfowl habitat removal, and improved aesthetics in an area with an important park vista. The estimated planning level cost for this project is $32,550 (see **Appendix G** for the full cost table).

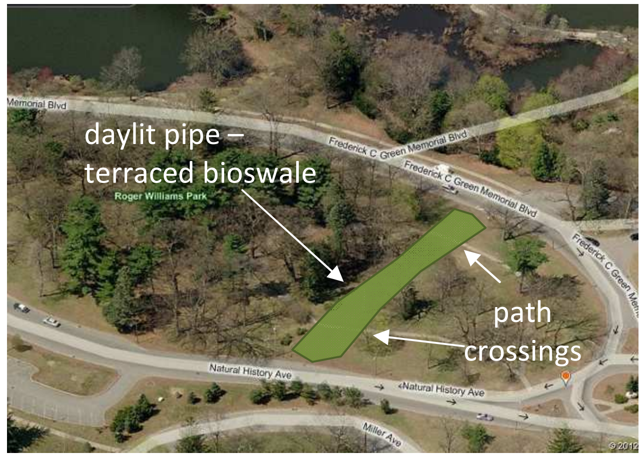


RWP-19A: Outfall into Polo Lake (Museum)

The drainage area for this site encompasses 11.7 acres with 17% impervious and includes the parking lot for the Natural History Museum and a portion of Natural History Avenue. Stormwater enters catchbasins located in the parking lot and along the road and is conveyed through the closed drainage system to a 24-inch outfall into Polo Lake. This outfall was identified as a priority outfall RWP-U in the TMDL report (see **Figure 3.1**).

Space is available along the slope between F.C. Greene Memorial Boulevard and Natural History Museum Avenue for a stormwater retrofit. Currently, this is where the existing stormwater pipe is located, before it connects with the closed drainage system from RWP-19B along Polo Lake near the outfall. Runoff from the drainage manhole in the road would be diverted to a terraced bioswale along the slope and "daylighting" the pipe to create a surface swale. Tiers at different elevations would be constructed using large boulders. Flow would either be conveyed under the existing two paths via a culvert or bridges could be constructed in these locations for additional aesthetics. The original outfall pipe would be maintained for overflow from large storm events. The estimated planning level cost for this project is $102,800 (see **Appendix G** for the full cost table).





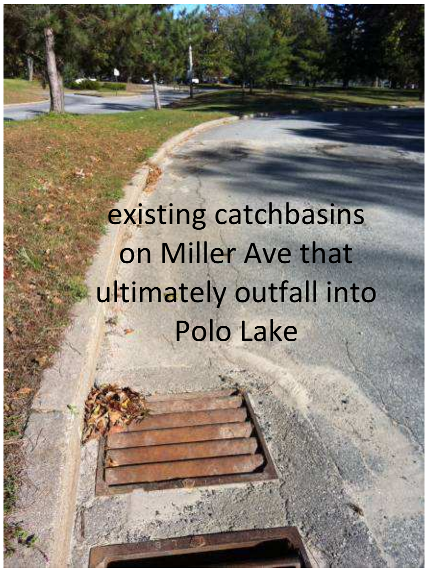
RWP-19B: Outfall into Polo Lake (Tennis Courts)

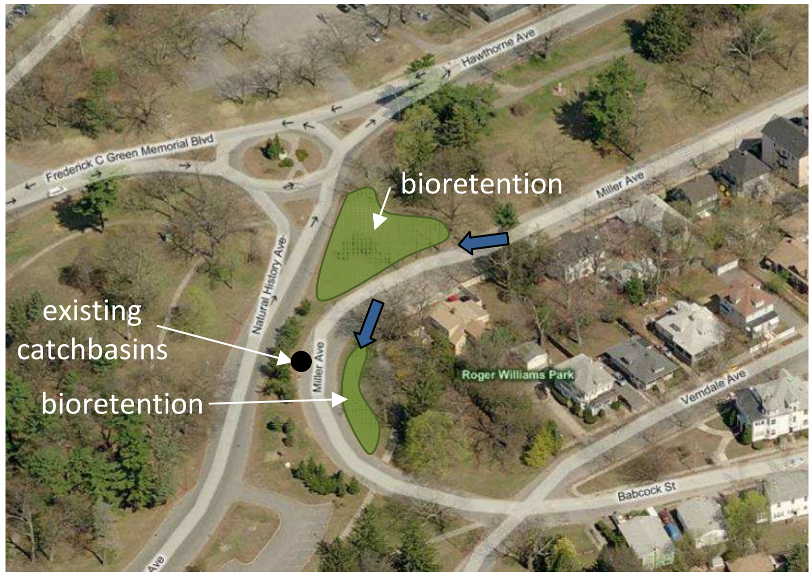
RWP-U, the priority outfall from the TMDL report (see **Figure 3.1**) mentioned in the previous site description, also receives runoff from Hawthorne Avenue, the tennis courts on Hawthorne Avenue, and their adjacent parking lot. A series of catchbasins and manholes directs stormwater to the outfall in Polo Lake. The contributing drainage area is almost 8 acres, with 43% impervious.

The retrofit opportunity for this site is a proposed dryswale along the southeastern edge of Hawthorne Road. There is currently an existing swale that runs along the edge of the roadway, but it is separated from the roadway by curbing. A diversion structure would be required to direct the first inch of runoff into the proposed practice from the existing drainage structures; overflow from large storm events would continue to flow to the existing outfall. The estimated planning level cost for this project is $91,700 (see **Appendix G** for the full cost table).

RWP-19C: Outfall into Polo Lake (Miller Avenue)

The outfall mentioned in sites RWP-19A and 19B (RWP-U) also receives runoff from Miller Avenue via a double catchbasin shown in the photo below. There are curb inlets all along the northern side of Miller Avenue. All are currently clogged and the runoff currently overflows down to the double catchbasin. The contributing drainage area to this site is 5.2 acres, with 50% impervious cover. The retrofit opportunity for this site is to divert runoff into two proposed bioretention facilities along the northwestern side of Miller Avenue as well as on the inside of the curve, as shown below. Overflow from large storm events would continue to flow to Polo Lake. The estimated planning level cost for this project is $114,500 (see **Appendix G** for the full cost table).

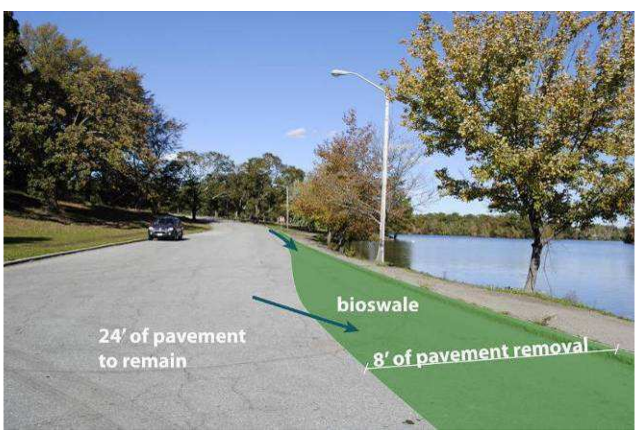




F. C. Greene Memorial Boulevard

RWP-24: F.C. Greene Memorial Boulevard between Cunliff and Deep Spring Lakes

This site is located along F.C. Greene Memorial Boulevard in the section of road between Cunliff and Deep Spring Lakes. The drainage area is 3.15 acres and 33% impervious. The road runoff travels by overland flow into a direct spillway to Cunliff Lake. The shoreline has been degraded over the years from geese activity and serves as a popular feeding spot for park users. The concept for the site is to create a bioswale, through the removal of existing pavement along the eastern side of road. This would provide water quality treatment for the first inch of runoff as well as reduce on-street parking and shoreline habitat for geese. The site is located in a high visibility area and a great location for public education. The estimated planning level cost for this project is $48,750 (see **Appendix G** for the full cost table).



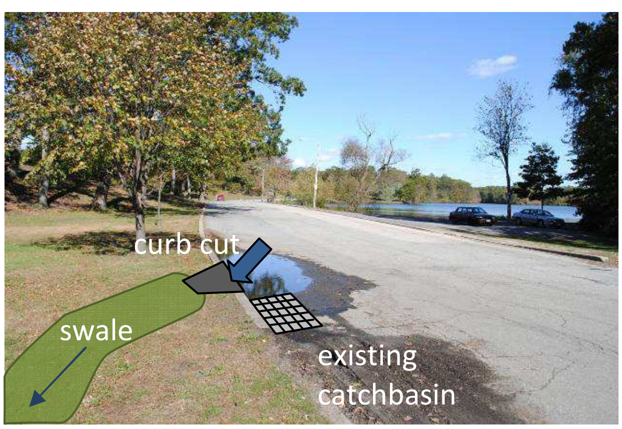
RWP-26A/26B: F.C. Greene Memorial Boulevard by Ball Field

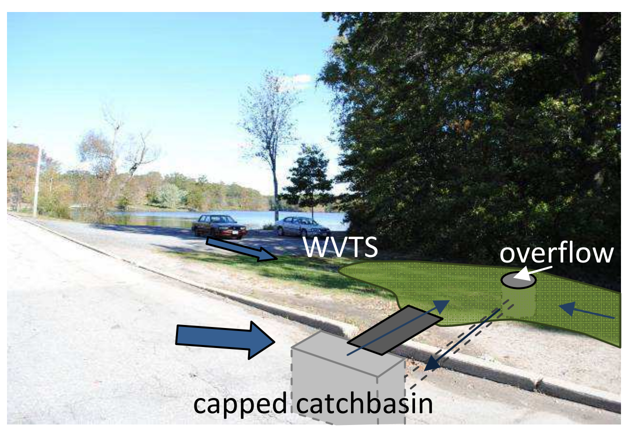
This site is located south of RWP-24, along F.C. Greene Memorial Boulevard, in the area of the existing baseball fields and has a contributing drainage area of approximately 5 acres, with 19% impervious cover.   The road in this area is 30' wide and crowned with a defined curbed gutter line on both sides.   There is a parking lot for the ball field located along the east side of the road, separated by a vegetated island, which drains via a paved flume through the island onto the road. Stormwater runoff travels from both the North and South along the gutter lines to a low point just south of the existing boat ramp. A traditional drainage design is currently used with catchbasins located on either side of the road at the low point. At the time of the site visit, both catchbasins were clogged and ponding on both sides of the road was visible. During storms, runoff accumulates at the low point and overtops the curbs, flowing into the grass areas along both sides of the road. It appears the curb on the east side of the road has been cut at the low point to alleviate some of this ponding on the east side of the road and allow the stormwater to flow down into a grass depression east of the road and south of the boat ramp parking. Standing water was observed in this depression on the day of the site visit and this area appears to remain wet for extended periods of time.

Proposed BMP retrofits for this site can be divided into two separate practices. One located in the grass depression along the east side of the road (RWP-26A) and one located in the open field along Deep Spring Lake to the west (RWP-26B). At RWP-26A, the existing curb cut would be incorporated into a formalized paved flume discharging into the existing grass depression, which would be converted into a WVTS. The existing catchbasin could be capped and serve as the overflow outlet for the WVTS. The boat ramp could also be re-graded to direct runoff into this BMP.

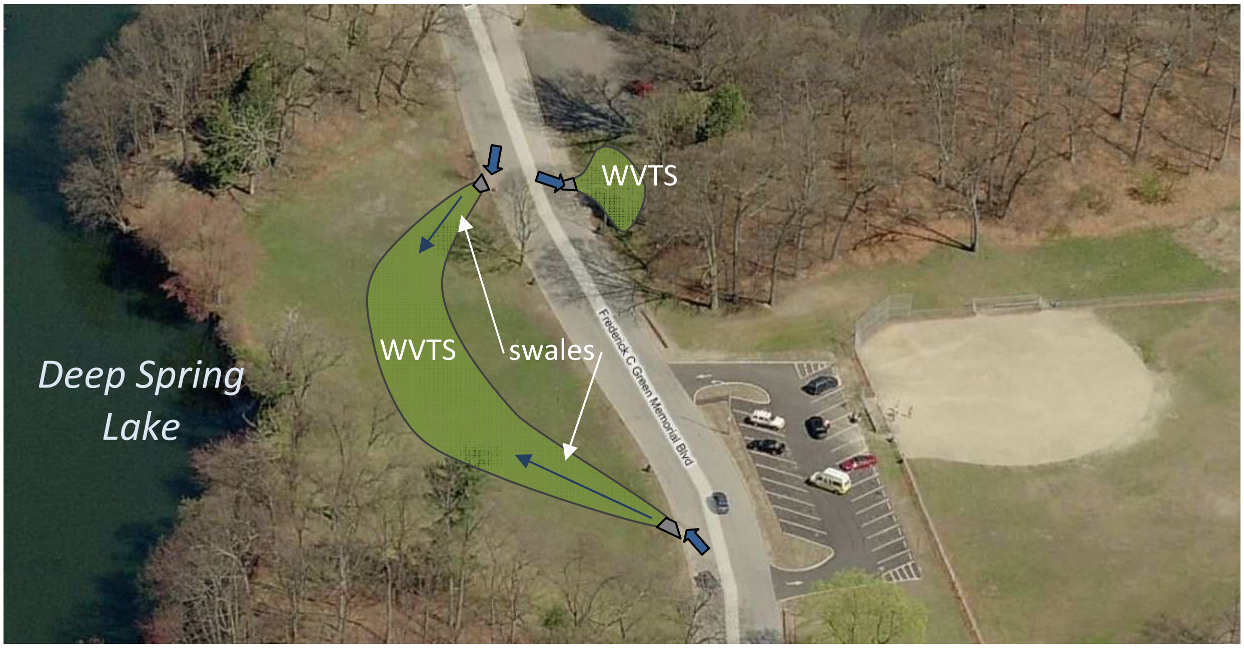
RWP-26B, located on the west side of the road, would include curb cuts installed uphill of the abandoned (capped) catchbasins, thereby directing water, via paved flumes, into vegetated swales. The swales would lead to a WVTS created in the large open grass area beside Deep Spring Lake. Overflow from the WVTS could be discharged to Deep Spring Lake or connected to the capped catchbasins.

These practices would provide water quality treatment for the first inch of runoff and the site is located in a high visibility area providing a great opportunity for public education.





There may be an additional opportunity to remove pavement in this area along the east side of F.C. Greene Memorial Boulevard. The estimated planning level cost for this project is $5,700 (excluding pavement removal) for A and $9,000 for B (see **Appendix G** for the full cost table).



RWP-28: Intersection of Edgewood, Beachmont and F.C. Greene Memorial Boulevard.
This site is located at the intersection of Edgewood Boulevard, Beachmont Avenue, Edgewood Avenue and F.C. Greene Memorial Boulevard. The contributing drainage area is 22.2 acres, with 50% impervious cover. Two catchbasins are located on either side of F.C. Greene Memorial Boulevard and drain to a 24-inch corrugated metal outfall pipe at the southern end of Edgewood Lake. This outfall has been identified as priority outfall RWP-I in the TMDL report (see **Figure 3.1**). Just east of the 24-inch outfall there is a larger 30-inch oval corrugated outfall pipe that takes water from a catchbasin on F.C. Greene Memorial Boulevard and Edgewood Avenue. This outfall has been identified as priority outfall RWP-H in the TMDL report (see **Figure 3.1**). During field observations, water was observed flowing down Bartlett onto Edge Street and finally to Edgewood Avenue/F.C Greene Memorial Boulevard where it then flowed over the clogged catchbasin and into the catchbasins at the retrofit site.

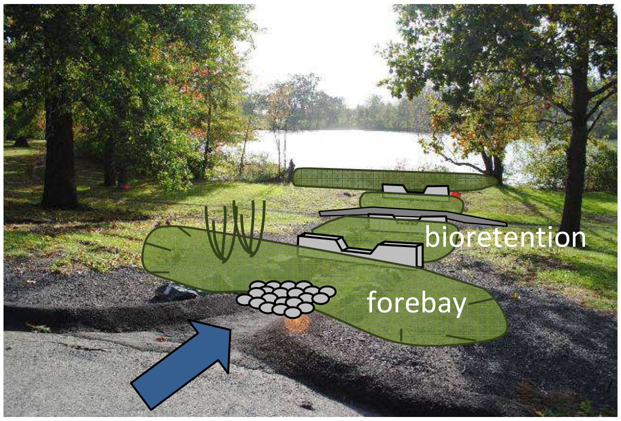
The concept requires the removal of a significant amount of pavement, to decrease the existing opening at this intersection, consistent with the Garofalo & Associates, Inc. "Roadway Improvement Project Plans" dated February 1995. The pavement removal would allow the creation of an infiltration basin/bioretention area to be located in the large grass area to the west of the intersection, which would increase in size due to the pavement removal. Stormwater runoff could be diverted into this area through overland flow via paved flumes. An outlet structure would be provided to allow for overflow during the larger storm events and be reconnected to the existing 30-inch outlet pipe. Due to its location along the eastern park perimeter, the site provides low visibility and less of an opportunity for public education when compared with other sites located within the Park. The estimated planning level cost for this project is $140,000 (see **Appendix G** for the full cost table).

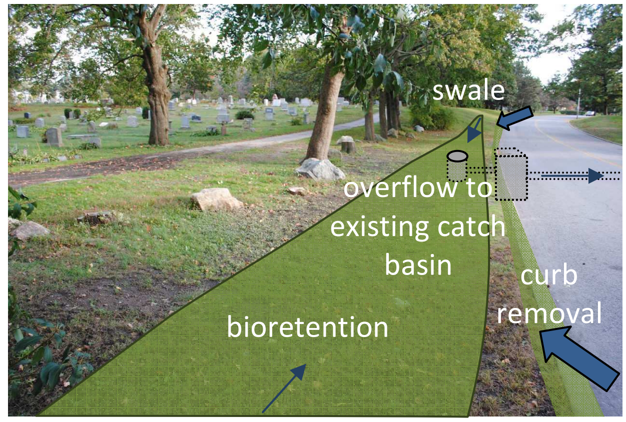
RWP-29: Oakland Cemetery and Wentworth Avenue

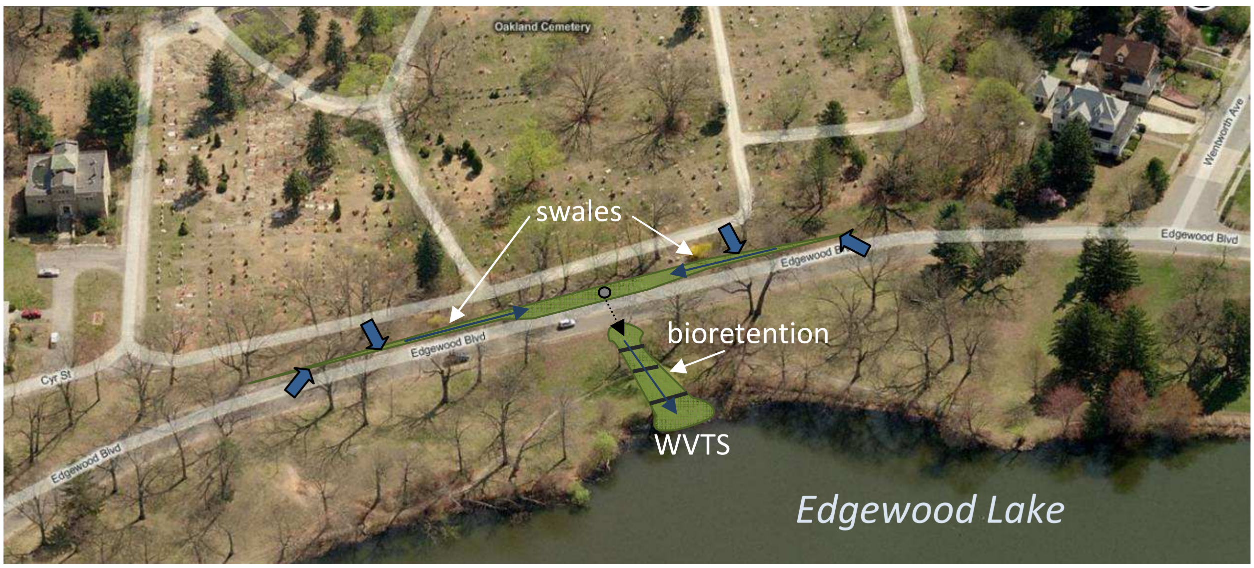
This site is located north of RWP-28, along F.C. Greene Memorial Boulevard., in the section of the Oakland Cemetery. It has a contributing drainage area of approximately 20.4 acres, with 13% impervious cover. The road in this area is 30' wide and crowned with a defined curbed gutter line on both sides. On the section of F.C. Greene Memorial Boulevard that passes Oakland Cemetery, stormwater runoff from both the east and the west drains along the eastern and western gutter lines to a low point which drains via a concrete/stone lined swale along the western side. A catchbasin along the eastern side of the road also drains into the swale. Currently, this system conveys the stormwater runoff directly to the lake without any pre-treatment.

The proposed retrofit includes reconstructing the existing concrete swale into a tiered, shallow vegetated bioretention system with sediment forebay. Stormwater runoff from the eastern side of the road, as well as from the deteriorated road in the Cemetery, would flow overland into vegetated swales in the areas between the road and path. The swales would meet at a bioretention area and overflow into the existing catchbasin and discharge into the tiered bioretention system. Curb removal may also be considered along the eastern side of the road to allow for runoff to enter the proposed vegetated swale.

It should be noted that stormwater runoff from the 40' wide Wentworth Avenue and surrounding watershed currently bypasses the clogged catchbasins and drains via overland flow down the F.C. Greene Memorial Boulevard to the RWP-29 outfall. It has been assumed that these catchbasins will be cleaned, and this runoff will no longer reach the outfall; therefore, this additional drainage area has not been included in the sizing calculations. The estimated planning level cost for this project is $84,250 (see **Appendix G** for the full cost table).



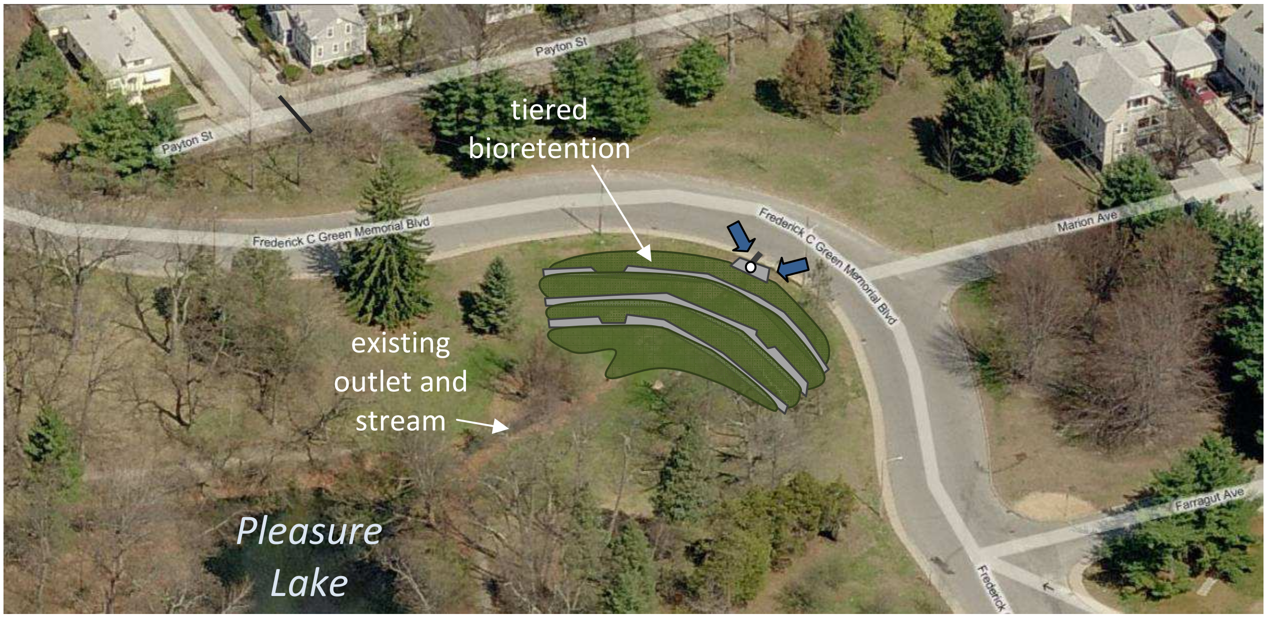




RWP-30A: Intersection of Marion Avenue and F.C. Greene Memorial Boulevard

This site is located at the intersection of F.C. Greene Memorial Boulevard and Marion Avenue and has a contributing drainage area of approximately 9.2 acres, with 58% impervious cover. The road in this area is 30' wide and crowned with a defined curbed line on both sides. Many catchbasins along F.C. Greene Memorial Boulevard and the intersecting streets in this area, such as Marion Avenue, drain to existing outfalls downhill from the boulevard. During field observations, many of the catchbasins were clogged. The hill between the boulevard and the outfalls is a large, steep, grassy slope. At the outfall pipes, a small stream forms and flows into Pleasure Lake.

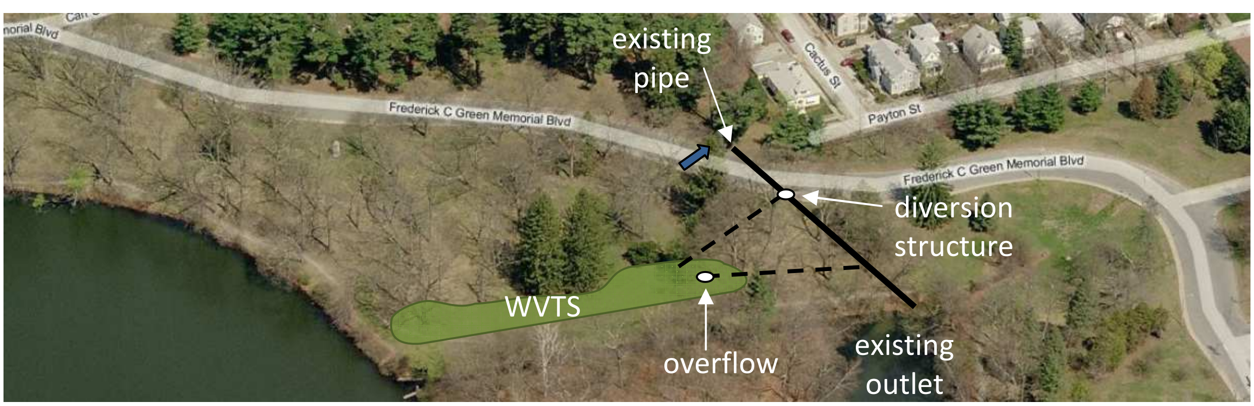
The proposed retrofit would divert runoff in the existing catchbasin on F.C. Green Memorial Boulevard across from Marion Avenue. The catchbasin would be converted to a manhole and curb cuts would be installed on either side, allowing the water to pass through trench drains in the sidewalk and down a stone swale into a tiered bioretention system on the hill. The wide, tiered system would overflow into the grass near the base of the hill before the water reached the stream. The estimated planning level cost for this project is $202,800 (see **Appendix G** for the full cost table).



RWP-30B: F.C. Greene Memorial Boulevard/Payton Neighborhood (RWP-30B)

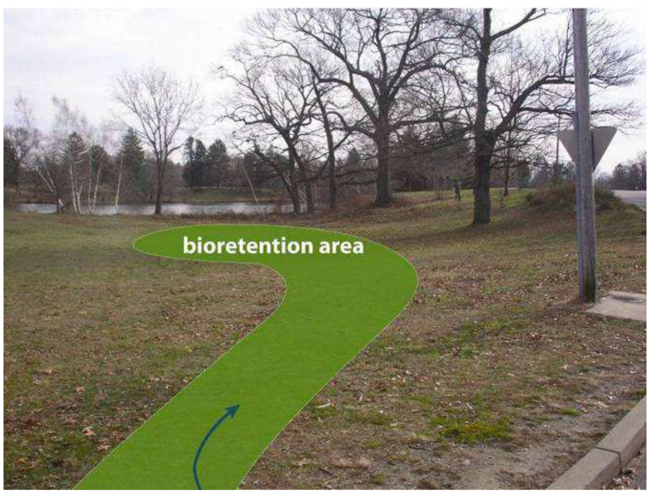
RWP-30B is located south of F.C. Greene Memorial Boulevard., in the area southwest of Payton Street and west of site RWP-30A. The contributing drainage area is 28.54 acres, with 66% impervious cover and includes portions of Payton, Homer and Carr Streets. Runoff from this neighborhood travels towards the Ponds along the gutter lines in the streets and collects in a closed drainage system. Visual observations and research indicate the runoff from this area is connected to the drainage system under F.C. Greene Memorial Boulevard. Additional inspections and testing should to be performed to verify this connection.

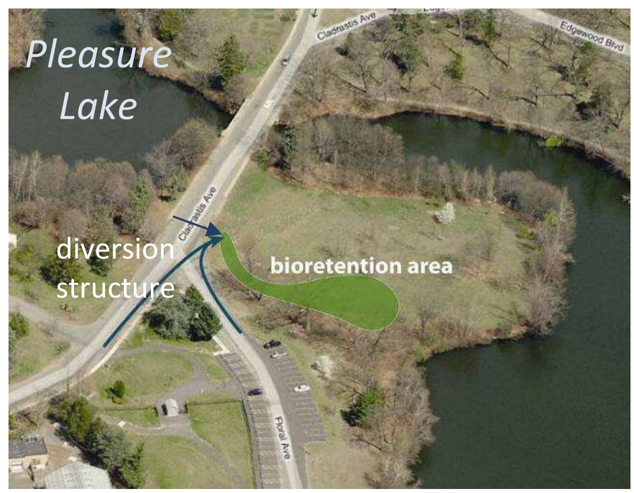
This concept proposes to create a WVTS in a grass depression downgradient and south of F.C. Greene Memorial Boulevard. The proposed retrofit would include the construction of a diversion manhole to intercept the 18-inch PVC drain pipe and divert the first inch of runoff into the treatment system. Overflow from the WVTS could be tied back into the 18-inch line prior to discharge. Due to its location along the eastern park perimeter and being located downgradient of the road, the site could present a maintenance challenge and provides low visibility and less of an opportunity for public education when compared with other sites located within the Park. The estimated planning level cost for this project is $212,800 (see **Appendix G** for the full cost table).



RWP-34: Intersection of Cladrastis and Floral Avenue (RWP-34)

This site is located at the intersection of Cladrastis Avenue and Floral Avenue and has a contributing drainage area of approximately 7.8 acres, with 38% impervious cover. The roads in this area are 30' wide and crowned with a defined curbed gutter line on both sides. The existing drainage system collects stormwater runoff, via a closed pipe system, for portions of Cladrastis and Floral Avenues (Botanical Center parking lot) and the Providence Police Department Mounted Command Facility. The system discharges at the eastern end of Pleasure Lake via 24-inch pipe identified as priority outfall RWP-D in the TMDL report (see **Figure 3.1**). It includes a large area of open lawn east of Cladrastis Avenue, which would be suitable for a bioretention area. A diversion structure could be installed within the existing drainage system to divert the first inch of runoff to the proposed bioretention area. The site is located in a high visibility area, which makes it a great location for public education and can be incorporated into the Botanical Center's plans for a future community garden and edible forest in this area. The estimated planning level cost for this project is $129,500 (see **Appendix G** for the full cost table).





Natural History Museum Area

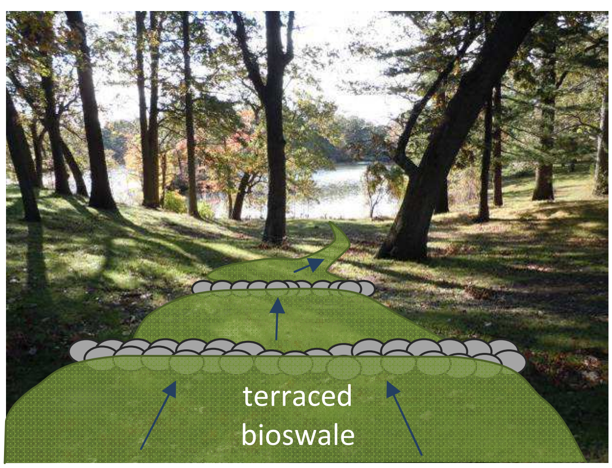
RWP-37A: Natural History Museum - Parking (RWP-37A)

The eastern parking areas for the Natural History Museum drain to a series of catchbasins and manholes that currently discharge to an 18-inch outfall in Pleasure Lake, identified as priority outfall RWP-A in the TMDL report (see **Figure 3.1**). The parking area is surrounded by curbing, and the parking spaces and drive aisle are an acceptable width (aisle reductions not recommended). The contributing drainage area is 0.2-acre with 97% impervious cover and limited to the high point in the parking area to the first set of catchbasins.

There is an open area to the west of the catchbasins that is available for a dry swale. The existing catchbasin could be modified into a diversion structure to allow small storms to be conveyed into the proposed BMP. Larger storm events would continue to discharge into the closed drainage system into Pleasure Lake. The dry swale would be planted with native grasses to ensure that the historic viewshed is maintained. The estimated planning level cost for this project is $6,750 (see **Appendix G** for the full cost table).

RWP-37B: Natural History Museum – Memorial Boulevard

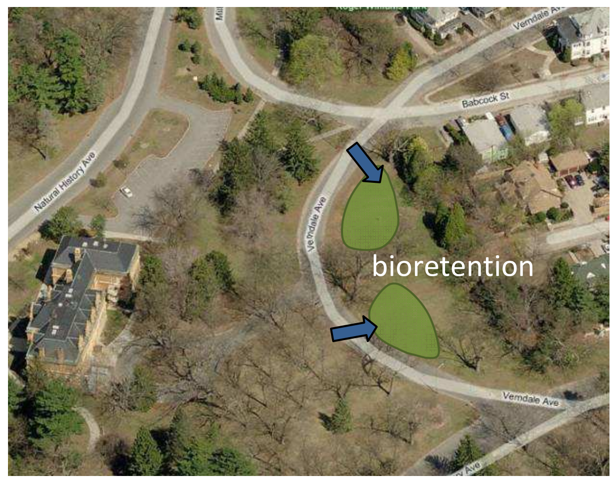
The location of this proposed retrofit is along the slope leading down to Pleasure Lake in the location of the existing 18-inch outfall identified as priority outfall RWP-A in the TMDL report (see **Figure 3.1**). The contributing drainage area to this site is 4.4 acres with 25% is impervious. The proposed practice is to convert the existing drain manhole into a diversion structure to divert the first inch of runoff into a terraced bioswale down the slope to the lake. Overflows from larger storm events would continue to flow to the existing leaching structures before discharging to the lake. The estimated planning level cost for this project is $57,825 (see **Appendix G** for the full cost table).



RWP-37C: Natural History Museum – Verndale Avenue

A portion of Babcock Street and Verndale Avenue drains to an existing catchbasin that is also connected to the closed drainage system that outfall into Pleasure Lake. This outfall has been identified as priority outfall RWP-A in the TMDL report (see **Figure 3.1**). The contributing drainage area to this site is 3 acres with 45% impervious cover.

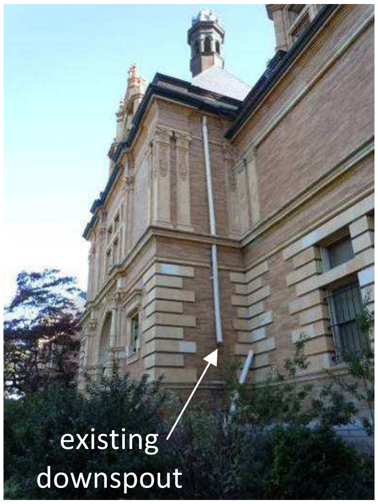
There is an open area at the intersection of Verndale and F.C. Greene Memorial Boulevard that is available for a bioretention area to be constructed. Runoff would be conveyed from Verndale into the bioretention via paved flumes. In addition, the existing catchbasin at the intersection would be blocked and a paved flume would convey stormwater into the bioretention area. Overflow from larger storm events would be directed into the existing drainage system. Careful consideration should be paid to the type of landscape proposed in order to be consistent with the historic viewsheds in the area. The estimated planning level cost for this project is $49,000(see **Appendix G** for the full cost table).

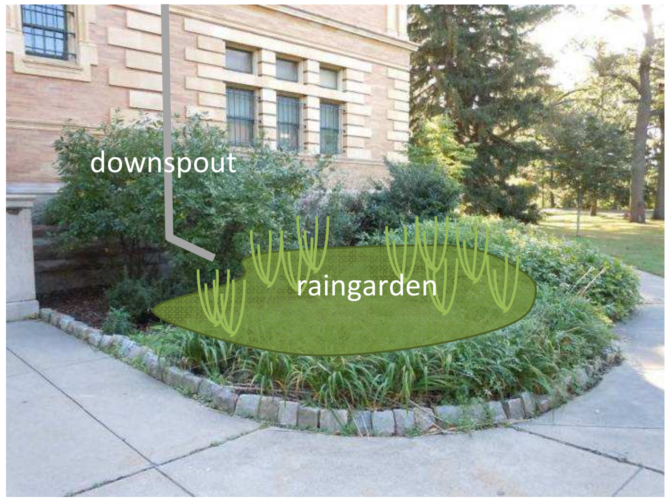


RWP-37D: Natural History Museum – Roof

The existing roof drains for the 9,000 square foot building discharge directly into the ground, presumably connected into the CSO pipe that traverses the Park. Several downspouts were observed to be in need of repair at the time of our field visit.

The proposed retrofit for the roof runoff is to direct the downspouts to rain gardens and/or planters at various locations around the building. As with other locations around the museum, careful consideration would be given to the proposed plantings in order to be consistent with the historic viewsheds. This would be a good location for public education by using signage and volunteer labor to install and maintain the practices.


existing
downspout


downspout
raingarden

Appendix G

Planning Level Estimated Cost Summary for Stormwater Retrofits

The following is a cost breakdown of the proposed stormwater retrofits summarized in **Table 3.2** of the Water Quality Management Plan. The estimates provided are based upon unit cost data compiled from various sources, including but not limited to Rhode Island Department of Transportation unit costs, R.S. Means unit costs, various construction material providers, nurseries as well as bid results from recent similar HW projects.

Table G.1. Planning Level Estimated Cost Summary for Stormwater Retrofits

I.D.	Project	WQv Provided	WQv Provided	TP Removed	Pavement Removal	Repaving	Planning Level Estimated Unit Costs: BMP	Planning Level Estimated Unit Costs: Pavement Removal	Planning Level Estimated Unit Costs: Repaving	Total Cost $[1]
		%	cf	%	(sf)		$/cf	$/sf	$/sf	$
RWP-1A	Pine Hill Avenue - Bioretention	100.0	1389	30	0	0	$10.00	$0.50	$3.00	$ 13,892.50
RWP-1B	Pine Hill and Maple Avenue Intersection - Bioretention	100.0	1397	30	4000	0	$10.00	$0.50	$3.00	$ 15,969.17
RWP-1C	Cladrastris Avenue - near boathouse - Dryswale	100.0	2006	30	4000	0	$8.00	$0.50	$3.00	$ 18,048.67
RWP-1E	Maple Avenue - Dryswale	100.0	2189	30	7000	0	$8.00	$0.50	$3.00	$ 21,012.67
RWP-1F	Cladrastris Avenue Intersection - Bioretention	100.0	783	30	500	0	$10.00	$0.50	$3.00	$ 8,080.83
RWP-3B	Carousel Parking Lot -Bioretention (1/2 of lot)	100.0	1952	30	0	0	$10.00	$0.50	$3.00	**$ 23,424.00**
RWP-3C	Carousel Parking Lot -Bioretention (1/2 of lot)	100.0	1910	30	0	0	$10.00	$0.50	$3.00	**$ 22,924.00**
RWP-6	F.C. Greene Memorial Blvd - Across from Monument - WVTS	100.0	5854	48	40600	30400	$3.50	$0.50	$3.00	$ 131,989.58
RWP-7A	Route 10 off-ramp - Infiltration Basin/Dry Swale	100.0	3387	65	0	0	$4.00	$0.50	$3.00	$ 13,548.00
RWP-7B	Outfall at Roosevelt Lake from Route 10 - WVTS	100.0	2441	48	0	0	$3.50	$0.50	$3.00	**$ 10,252.20**
RWP-9C/9D	Casino Parking Lot -Bioretention	100.0	1851	30	0	0	$10.00	$0.50	$3.00	**$ 22,206.00**
RWP-9E	Casino Entrance - Bioretention	100.0	840	30	0	0	$10.00	$0.50	$3.00	$ 8,395.83
RWP-12	Ornamental Bridge - Terraced Bioswale	100.0	6176	30	0	0	$12.00	$0.50	$3.00	**$ 88,929.60**
RWP-14	North side of Roosevelt Lake - Shallow Bioretention	100.0	1967	30	0	0	$7.50	$0.50	$3.00	**$ 17,700.00**
RWP-15	Polo Lake outfall near Rotary - Terraced Bioswale	100.0	4688	30	0	0	$12.00	$0.50	$3.00	**$ 67,500.00**
RWP-17/18	F.C. Greene Memorial Blvd - Polo Lake - Shallow Bioretention	100.0	3615	30	0	0	$7.50	$0.50	$3.00	**$ 32,537.25**
RWP-19A	Outfall into Polo Lake (Museum) - Terraced Bioswale	100.0	7137	30	0	0	$12.00	$0.50	$3.00	**$ 102,765.60**
RWP-19B	Outfall into Polo Lake (Tennis Courts) - Dry Swale	76.5	9554	30	0	0	$8.00	$0.50	$3.00	**$ 91,720.32**
RWP-19C	Miller Ave - Bioretention	100.0	9537	30	0	0	$10.00	$0.50	$3.00	**$ 114,439.00**
RWP-24	F.C. Greene Memorial Blvd between Cunliff and Deep Spring Lakes - Bioswale	100.0	3786	30	5500	0	$10.00	$0.50	$3.00	**$ 48,737.00**
RWP-26A	F.C. Greene Memorial Blvd by Ball Field - WVTS	100.0	1357	48	0	0	$3.50	$0.50	$3.00	**$ 5,698.35**
RWP-26B	F.C. Greene Memorial Blvd by Ball Field - WVTS	100.0	2143	48	0	0	$3.50	$0.50	$3.00	**$ 9,002.35**
RWP-28	Edgewood, Beachmont and F.C. Greene Memorial Blvd.- Infiltration Basin	70.2	28463	65	5500	0	$4.80	$0.50	$3.00	**$ 139,920.00**
RWP-29	Oakland Cemetery and Wentworth Ave - Terraced/Shallow Bioretention	100.0	9359	30	0	0	$7.50	$0.50	$3.00	**$ 84,226.50**
RWP-30A	Marion Ave and F.C. Greene Memorial Blvd.-Terraced Bioswale	72.5	14083	30	0	0	$9.00	$0.50	$3.00	**$ 202,800.00**
RWP-30B	Marion Ave and F.C. Greene Memorial Blvd.-WVTS	74.5	50667	48	0	0	$3.50	$0.50	$3.00	**$ 212,802.12**
RWP-34	Botanical Center/Stables - Bioretention	100.0	10792	30	0	0	$12.00	$0.50	$3.00	**$ 129,500.00**
RWP-37A	History Museum Parking - Dry Swale	100.0	703	30	0	0	$8.00	$0.50	$3.00	**$ 6,752.80**
RWP-37B	History Museum - Memorial Blvd. - Terraced Bioswale	100.0	4016	30	0	0	$12.00	$0.50	$3.00	**$ 57,826.80**
RWP-37C	History Museum - Babcock Street - Bioretention	100.0	4898	30	0	0	$10.00	$0.50	$3.00	$ 48,975.83

Notes: 1. Costs in **Purple** carry an additional 20% due to the increased complexity of the proposed BMP.

Appendix H

Non-Structural Site Descriptions

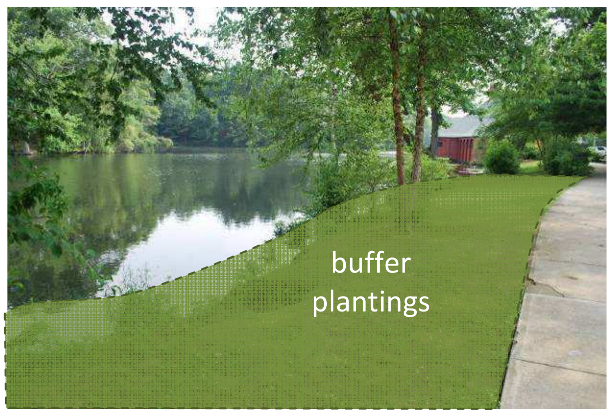
The following are the detailed descriptions of the recommended Lower Watershed non structural BMPs identified in **Section 3.2.3** of the Water Quality Management Plan.

Non-structural Site Descriptions

Buffer Restoration

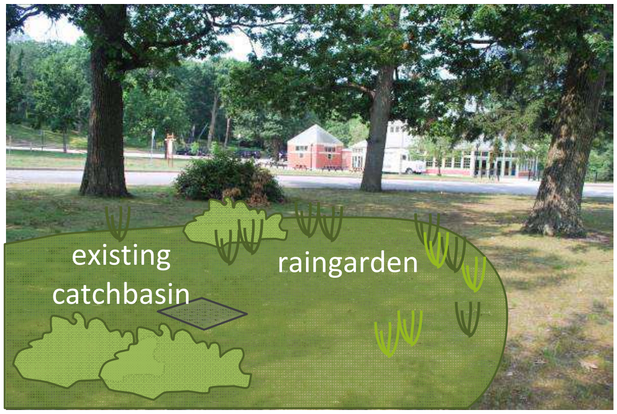
RWP-1G: The Boathouse shoreline plantings

The shoreline around the Boathouse is currently maintained as mowed turf. We recommend planting the area (2,000 sf) between the path and the water with low-growing native shrubs and grasses to improve the buffer while maintaining the viewshed. Given its location near the boathouse and carousel, this site has a great opportunity for public education and involvement. The estimated planning level cost for this project is $6,600 (see **Appendix I** for the full cost table).



RWP-2: Cladrastris Avenue near Carousel

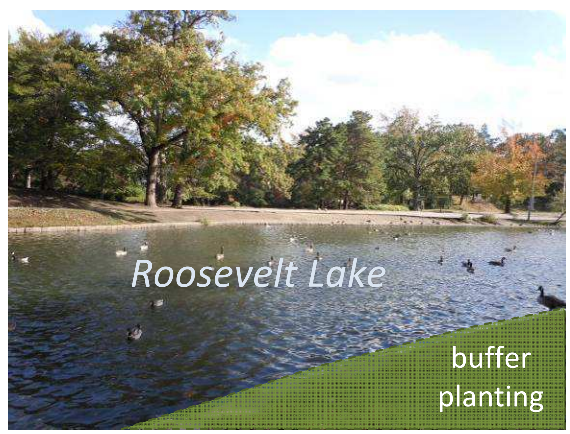
An existing yard drain is located in the lawn area between Cladrastris Avenue and the path, across from the Carousel. The existing drain is located at a low point and connects to the closed drainage system that discharges to Pleasure Lake. The concept for this area is to convert the existing depression into a raingarden by minimally augmenting the existing soils with compost, plant the area (~1,000 sf) with native shrubs, grasses, and wildflowers, and raise the rim of the existing yard drain to allow for additional storage and infiltration. Additionally, the entire southern shoreline of Pleasure Lake is currently maintained as mowed turf. This area is approximately 3,000 sf and should be revegetated with low growing shrubs and grasses to provide a native buffer and to discourage geese. Any restoration plantings installed in this area would be visible to carousel visitors, users of the path/footbridge, and those driving along Cladrastris Avenue. Therefore, this site would be a good candidate for educational signage and outreach. The estimated planning level cost for this project is $18,600 (see **Appendix I** for the full cost table).



RWP-10: Shoreline Planting

The shoreline along Roosevelt Lake adjacent to the monument is predominantly mowed turf. This is one of the areas in which geese congregate and are regularly fed by visitors.

A new seed mix that is less favored by geese and a less frequent mowing regime are recommended for this area along with enhanced buffer plantings (~1,000 sf). This would discourage geese, reduce the direct runoff from the grass area, and stabilize the shoreline to prevent erosion. This proposed landscape is a relatively low-maintenance option that will provide enhanced protection for the pond. The estimated planning level cost for this project is $3,300 (see **Appendix I** for the full cost table).



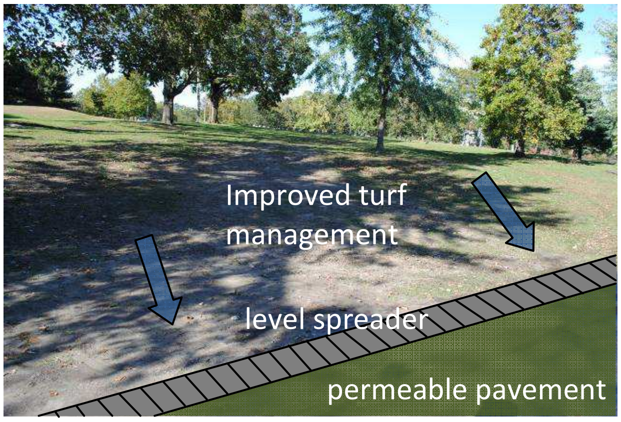
RWP-20: North shore of Willow Lake near bridge on F.C. Greene Memorial Boulevard

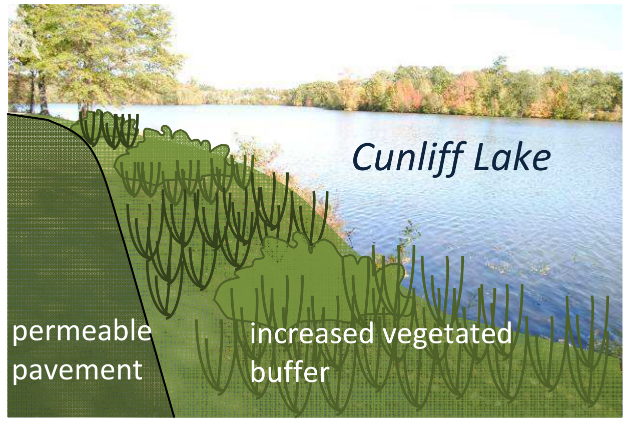
This site is located across the bridge from Site RWP-17/18, along Willow Lake. The shoreline area is currently maintained as mowed turf. Additionally, a large willow tree was damaged in a recent storm, and the equipment used to clean up debris from this tree has caused some "tire rutting" and erosion. If this is not stabilized, the area will continue to deteriorate. This is not a heavily used area by many park visitors, and geese do not appear to be a problem at this site. However, it is located in a historically important part of the park, and any restoration done at this site should keep the historic viewshed and use in mind. The recommendation for this site is to plant the slope with native grasses and shrubs to provide a vegetated shoreline buffer to remove the direct connection of the lawn to pond and stabilize the slope. The estimated planning level cost for this project is $3,300 (see **Appendix I** for the full cost table).

RWP-25: Temple of Music Access Road

On F.C. Greene Memorial Boulevard, just uphill of the low point at RWP-24, the curb is replaced with a shallow asphalt berm at the beginning of an old gravel and asphalt road. Sediment from the boulevard has washed over the berm onto the bare soil and gravel at the entrance to the access road, creating erosion into Cunliff Lake. The entire access road is in poor condition and is located a few feet from the water's edge, providing very little buffer. Trees, grass, and patches of bare soil line the edge of the lake downgradient of the access road. Upgradient of the access road is a grassy slope, which flattens out into a large open lawn area in front of the Temple of Music. Runoff from the lawn carried down this slope has created some erosion problems causing bare patches in the grass and sediment accumulation on the road and beside the lake.

Recommendations for this site include reconstructing the access road with pervious pavement/reinforced turf to allow stormwater to infiltrate into the soil. Using a product such as turf reinforced matting or a similar product would also mend the visual break of the asphalt cutting in between the grass and lakeside buffer by the Temple of Music. A level spreader between the road and the bottom of the grass slope would allow water to collect and spread evenly as sheet flow instead of causing erosion on the path. An increased strip of vegetated buffer (~3,500 sf) would reduce erosion and geese gathering options on the water's edge. Improved turf management in the area around the Temple of Music would greatly reduce the amount of bare soil and erosion that can cause sediment and nutrient accumulation in the lake. The estimated planning level cost for this project is $86,850 (see **Appendix I** for the full cost table).





Slope Stabilization Projects

RWP-4: Hill alongside F.C. Greene Memorial Boulevard

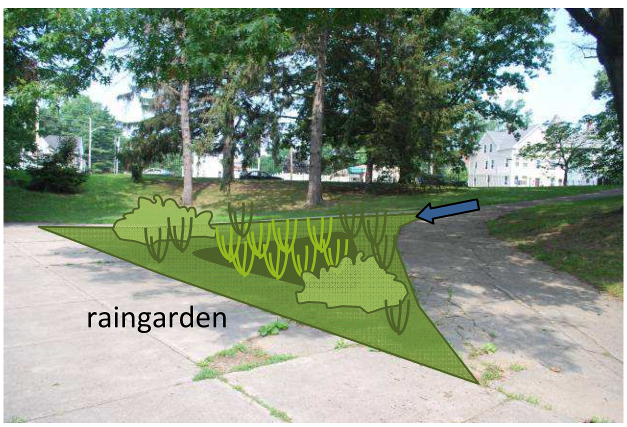
A gravel pathway runs from the back of the Carousel and Japanese Garden area up to and along the ridge of the hill adjacent to F.C. Greene Memorial Boulevard. There are several areas along the path that are eroding due in part to the steep slope and also due to mowing practices. The western side of the hill also contributes to retrofit site RWP-6.

This area (~1,500 sf) should be replanted with native, low-growing grasses and shrubs to stabilize the slope. Additionally, for any areas maintained as turf, the mowing schedule should be modified to allow the grass to grow to a greater height. The estimated planning level cost for this project is $4,950 (see **Appendix I** for the full cost table).

RWP-8: Path Landscaped Triangle Island

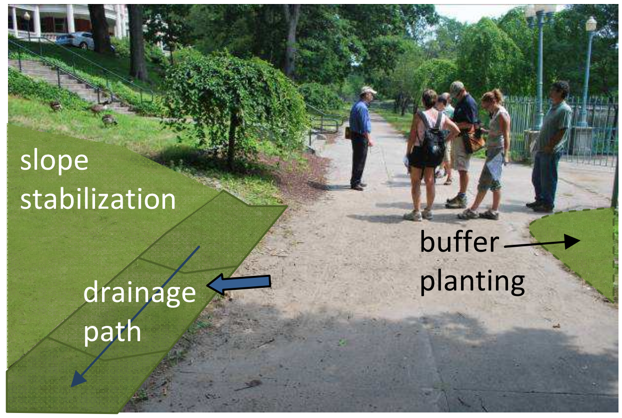
A gully and a small area of erosion has formed from the stormwater that sheet flows down the paved walkway leading from the Elmwood Avenue park entrance near the cemetery down to Roosevelt Lake. The drainage area is fairly small but the slope is quite steep, which contributes to the erosion.

The slope in this area (~1,000 sf) should be stabilized with native no-mow vegetation. Efforts should be made to convert concentrated runoff into sheet flow down the slope. In addition, a raingarden could be planted at the triangle in the pathway to help dissipate erosive flows and provide an opportunity for increased infiltration. A vegetated buffer (~4,000 sf) should also be planted between the path and Roosevelt Lake. This location is a good area for public outreach as it is very visible from the Elmwood Avenue park entrance. The estimated planning level cost for this project is $20,640 (see **Appendix I** for the full cost table).



RWP-9A: Path/Hillside Erosion

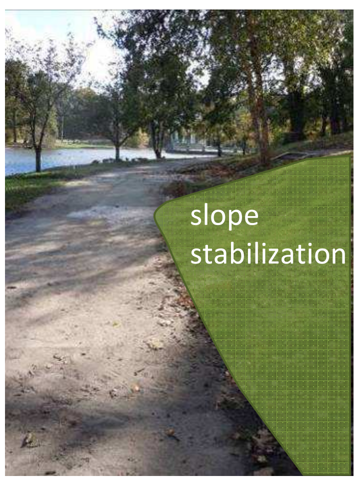
Erosion has left gullies and areas of exposed soil along the steep slope and paved paths that lead down to the main path along Roosevelt Lake. Geese also add to the erosion on the slope. The slope in this area (~2,000 sf) should be stabilized with soil amendments, native no-mow vegetation, and a formalized, stable drainage path for runoff from the paved walkways. Additionally, the shoreline (~2,000 sf) should be revegetated to create an enhanced buffer for the pond. Consideration should be given to the elimination of one of the paths down the slope in this area to reduce impacts. The estimated planning level cost for this project is $16,680 (see **Appendix I** for the full cost table).

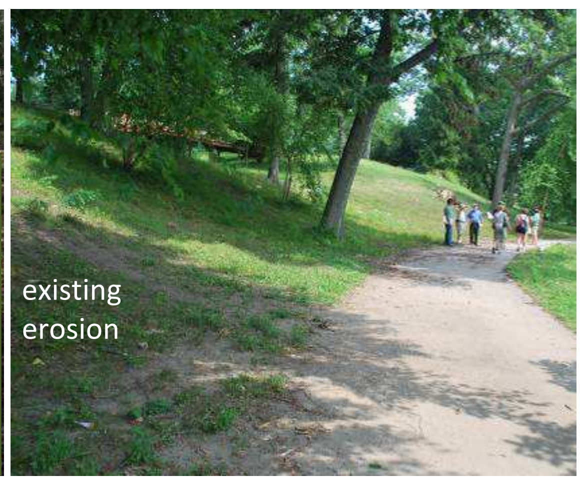


RWP-11: Erosion on Stairs/Path

A paved walkway leads from the Casino towards Roosevelt Lake and ends at a stairway that connects to the path that loops around the pond. There is evidence of erosion at several locations down the steep grass slope as well as along the sides of the stairway. Sediment is washing across the pond loop path and down into the pond. This site is located next to the site RWP-10, along the shoreline of Roosevelt Lake.

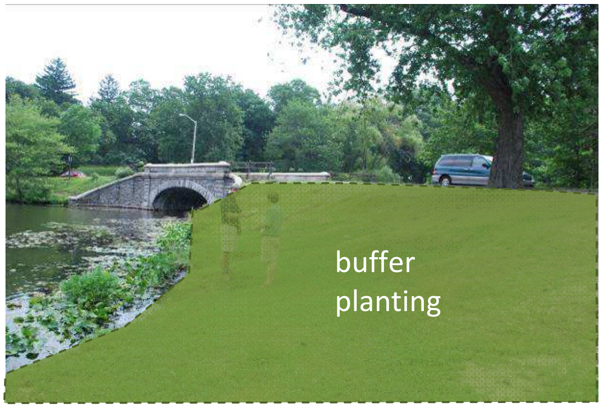
Stormwater at this site should be directed towards a more formalized channel rather than being allowed to flow down the slope creating rills and causing erosion. A paved berm could be added along the path just above the stairway to direct stormwater to this channel, away from the stairway, to help alleviate the erosion along the sides of the stairs. Finally, a new seed mix and a less frequent mowing regime are recommended for this area along with enhanced buffer plantings (2,500 sf). The estimated planning level cost for this project is $11,850 (see **Appendix I** for the full cost table).





RWP-16: Hillside Erosion along Polo Lake near Zoo Maintenance Road

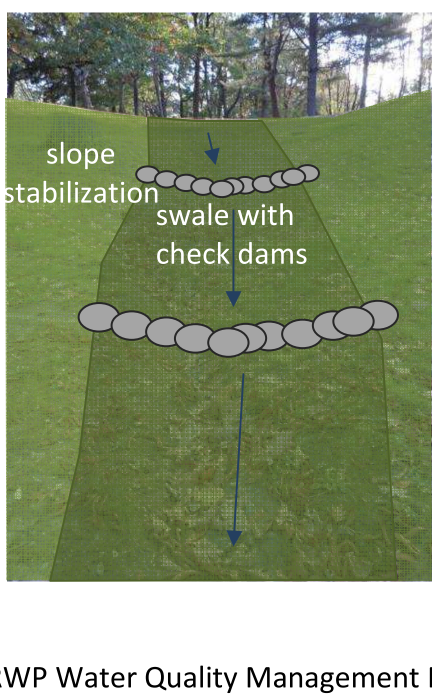
The shoreline of Polo Lake adjacent to F.C. Greene Memorial Boulevard is currently maintained as mowed turf down to the water's edge, creating prime geese habitat. In addition, the slope down from the road is steep, and in some areas, erosion gullies have formed. This site should be planted with native, native grasses and shrubs to stabilize the slope and to discourage geese. The total area of proposed buffer and stabilization planting for this site is approximately 4,000 square feet. The estimated planning level cost for this project is $18,960 (see **Appendix I** for the full cost table).



RWP-21: Eroded slope along northeastern edge of Willow Lake

The eastern shoreline of Willow Lake has a very steep slope leading down to the water. This slope is maintained as mowed turf and has several areas of exposed soil. Stormwater runoff concentrates on this slope, creating an eroded gully from the top of the hill to edge of the water. The resulting sediment washes across the shoreline path and into the pond.

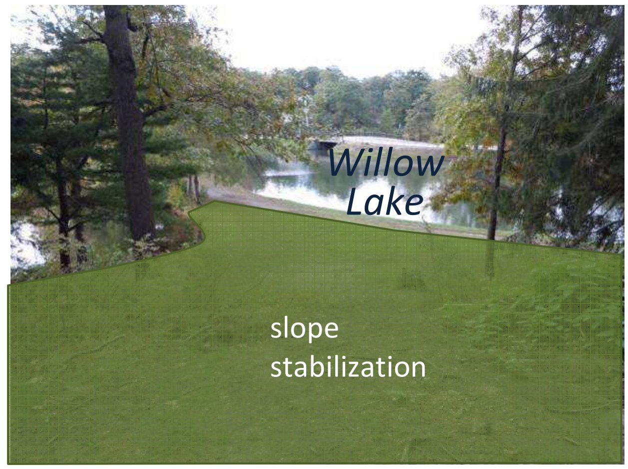
The recommendation for this site is to stabilize the slope with native no-mow vegetation (~7,000 sf) and create a formal, stable swale (~150 ft) for runoff. The swale should have checkdams installed at intervals down the slope, using rock to dissipate erosive energy. In addition, the shoreline should be revegetated to create a low-growing buffer (~1,500 sf) between the path and the water that will connect with the restored buffer at site RWP-20. The estimated planning level cost for this project is $24,990 (see **Appendix I** for the full cost table).



RWP-22: Path Intersection by Willow and Pleasure Lakes

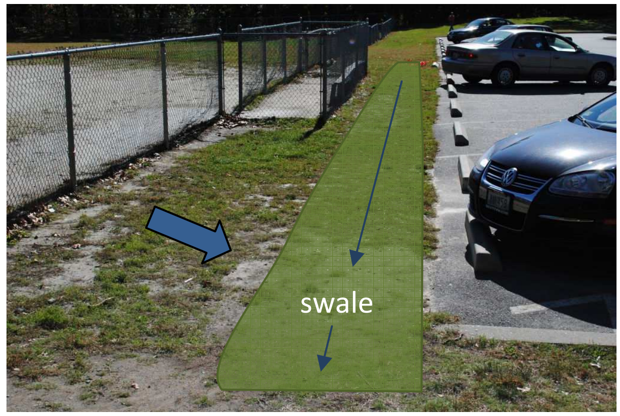
Erosion has left a significant amount of bare soil at this location. Similar to the other shorelines throughout the park, the steep slopes are the main cause of the erosion. There are gullies and rills along the side of the stairs' Additionally, a large section of the slope has bare soil, possibly due to people using this as a cut-through. A small area of Japanese Knotweed was observed near the top of the stairs. Also in this area, recent storm damage and the equipment used to clean up debris from that storm has damaged the vegetation, particularly, the top of the hill adjacent to Pleasure Lake.

This is another area (~4,000 sf) that would benefit from low-growing grasses and shrubs to stabilize the slope and the top of the hill adjacent to Pleasure Lake. The rills and gullies along the stairs should be repaired and a maintenance plan should be created and implemented to remove the Japanese Knotweed and to prevent it from spreading further. The estimated planning level cost for this project is $15,020 (see **Appendix G** for the full cost table).



RWP-26C: F.C. Greene Memorial Blvd by Ball Field

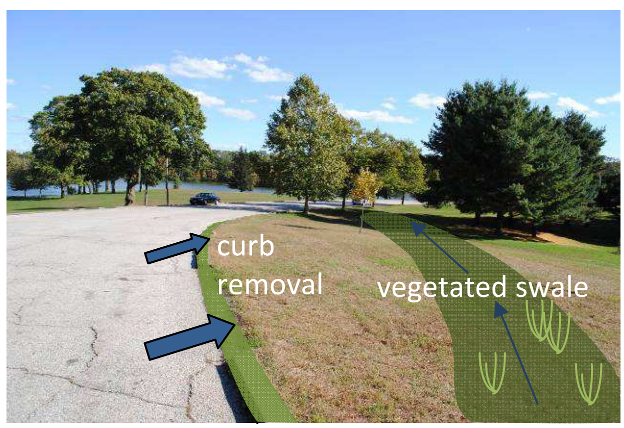
An erosion problem was identified north of the ball field and parking lot along F.C. Greene Memorial Boulevard. Erosion on a bare slope and runoff from the baseball field infield has contributed to sediment accumulation along the northern edge of the parking lot. It is recommended that this area be stabilized and reseeded, and drainage from the infield should be intercepted via a swale/infiltration trench outside of the ball field fence to prevent sediment accumulation on the paved surfaces. Erosion has also occurred along the southern side of the ball field where significant gullying has occurred. This area should also be considered for shoreline stabilization. The estimated planning level cost for this project is $12,000 (see **Appendix I** for the full cost table).



Curb Removal Projects

RWP-23: F.C. Greene Memorial Blvd by Temple of Music

The section along F.C. Greene Memorial Boulevard in the area of the Temple of Music curves around the rolling grass landscape. It is a wide, crowned road in fair to good condition with short curbs on both sides that are in poor condition or missing altogether. On the north and east side of the road there is a steep grass slope that descends towards the Temple of Music. On the south and west side of the road, a more shallow slope goes down through grass and into a densely vegetated area. Currently, stormwater flows down the road into catchbasins (which drain to Cunliff Lake). The recommendation is to remove the curbing on both sides of the road so that runoff can sheet flow into the large areas of existing lawn, which should be converted into no-mow stormwater filter strips. Careful consideration should be given to the parking patterns in this area. By removing the curb, vehicles would then be allowed to drive unobstructed onto the grass areas. The estimated planning level cost for this project is $19,100 (see **Appendix I** for the full cost table).



Appendix I

Planning Level Estimated Cost Summary for Non Structural Practices

The following is a cost breakdown of the proposed non-structural practices summarized in **Table 3.3, 3.4 and 3.5** of the Water Quality Management Plan. The estimates provided are based upon unit cost data compiled from various sources, including but not limited to Rhode Island Department of Transportation unit costs, R.S. Means unit costs, various construction material providers, nurseries as well as bid results from recent similar HW projects.

Table I.1. Planning Level Estimated Cost Summary for Non-Structural Practices

#	Project	Estimated Area	Unit	Unit Costs[1]	Planning Level Estimated Cost
Buffer Restoration Projects					
RWP-1G	Shoreline Near Boathouse				
	Buffer Planting and reseeding	2,000	sf	$ 2.75	$ 5,500.00
	Contingency 20%				$ 1,100.00
	Total Cost				$ 6,600.00
RWP-2	Road by Carousel				
	Buffer Planting and reseeding	2,000	sf	$ 2.75	$ 5,500.00
	Raingarden	1,000	sf	$ 10.00	$ 10,000.00
	Contingency 20%				$ 3,100.00
	Total Cost				$ 18,600.00
RWP-10	Casino Hillside Erosion				$ -
	Buffer Planting and reseeding	1,000	sf	$ 2.75	$ 2,750.00
	Contingency 20%				$ 550.00
	Total Cost				$ 3,300.00
RWP-20	Willow Lake Near Bridge				
	Buffer Planting and reseeding	1,000	sf	$ 2.75	$ 2,750.00
	Contingency 20%				$ 550.00
	Total Cost				$ 3,300.00
RWP-25	Temple of Music Access Rd				
	Bank clearing, fine grading, stabilization, erosion control and seeding	3,500	sf	$ 4.70	$ 16,450.00
	Planting Estimate (Plants Only)	3,500	sf	$ 1.75	$ 6,125.00
	Level Spreader	400	lf	$4.50	$ 1,800.00
	Grasspave	8,000	sf	$ 6.00	$ 48,000.00

	Contingency 20%				$ 14,475.00
	Total Cost				$ 86,850.00
Slope Stabilization					
RWP-4	F. C. Greene Memorial Blvd.-East of the				
	Buffer Planting and reseeding	1,500	sf	$ 2.75	$ 4,125.00
	Contingency 20%				$ 825.00
	Total Cost				$ 4,950.00
RWP-8	Island Near Park Entrance				
	Fine grading, stabilization, erosion control and seeding	1,000	sf	$ 2.20	$ 2,200.00
	Raingarden	400	sf	$ 10.00	$ 4,000.00
	Buffer Planting and reseeding	4,000	sf	$ 2.75	$ 11,000.00
	Contingency 20%				$ 3,440.00
	Total Cost				$ 20,640.00
RWP-9A	Casino Hillside Erosion-South of Casino				
	Fine grading, stabilization, erosion control and seeding	2,000	sf	$ 2.20	$ 4,400.00
	Buffer Planting and reseeding	2,000	sf	$ 1.75	$ 3,500.00
	Pathway removal	1,000	sf	$ 6.00	$ 6,000.00
	Contingency 20%				$ 2,780.00
	Total Cost				$ 16,680.00
RWP-11	Casino Hillside Erosion - East of Casino				
	Fine grading, stabilization, erosion control and seeding	2,500	sf	$ 2.20	$ 5,500.00
	Buffer Planting and reseeding	2,500	sf	$ 1.75	$ 4,375.00
	Contingency 20%				$ 1,975.00
	Total Cost				$ 11,850.00
RWP-16	Hillside South of Polo Lake				
	Fine grading, stabilization, erosion control and seeding	4,000	sf	$ 2.20	$ 8,800.00
	Buffer Planting and reseeding	4,000	sf	$ 1.75	$ 7,000.00
	Contingency 20%				$ 3,160.00
	Total Cost				$ 18,960.00
RWP-21	Hillside Erosion Near Pleasure Lake				
	Fine grading, stabilization, erosion control and seeding	7,000	sf	$ 2.20	$ 15,400.00
	Buffer Planting and reseeding	1,500	sf	$ 1.75	$ 2,625.00

	Swale	150	lf	$ 12.00	$ 1,800.00
	Stone Check Dams	2	ea	$ 500.00	$ 1,000.00
	Contingency 20%				$ 4,165.00
	Total Cost				$ 24,990.00
RWP-22	Path Intersection by Willow and Pleasure Lakes				
	Fine grading, stabilization, erosion control and seeding	4,000	sf	$ 2.20	$ 8,800.00
	Knotweed Removal	1,000	sf	$ 2.75	$ 2,750.00
	Contingency 20%				$ 3,465.00
	Total Cost				$ 15,015.00
RWP-26	Ballfield Erosion				
	Fine grading, stabilization, erosion control and seeding	4,200	sf	$ 2.20	$ 9,240.00
	Contingency 20%				$ 2,772.00
	Total Cost				$ 12,012.00
Curb Removal					
RWP-23	F.C. Greene Memorial Blvd by Temple of Music				
	Concrete Curb removal	1,000		$ 4.80	$ 4,800.00
	Fine grading, erosion control and seeding (5' either side of road)	5,000	sf	$ 2.20	$ 11,000.00
	Contingency 20%				$ 3,300.00
	Total Cost				$ 19,100.00

Total Non Structural Costs **$262,847.00**

[1]The estimates provided are based upon unit cost data compiled from various sources, including but not limited to Rhode Island Department of Transportation unit costs, R.S. Means unit costs, various construction material providers, nurseries as well as bid results from recent similar HW projects.

Appendix J

Lower Watershed Neighborhood Descriptions

The following are detailed descriptions of the Lower Watershed neighborhoods and proposed stewardship options identified during the field assessment described in **Section 3.2.4** of the Water Quality Management Plan.

Lower Watershed Neighborhood Descriptions

Edgewood North (Montgomery Avenue, Payton Street, Cactus Street, Fisk Street)

Edgewood North is an older neighborhood comprised of three-story multi-family houses and detached single-family houses that appear to be around 80-100 years old. The paved roads are cracked, with sidewalks on both sides. The overall size of the neighborhood bordered by Broad Street, Montgomery Avenue, Verndale Avenue, and F.C. Greene Memorial Boulevard is approximately 83 acres. None of the neighborhood is forested; however, there are permeable strips in the right-of-way and areas of open space at the end of the blocks on the side closest to Roger Williams Park. A typical lot is approximately <1/8 of an acre, made up of 80% impervious cover, 15% grass cover and 5% landscaped beds. The lawns in the neighborhood do not appear to be irrigated or fertilized and are therefore considered low maintenance. In general, the neighborhood was free of visible pet waste or illegal dumping; however, there were dog-walkers and a small amount of trash on the sidewalks and streets.

Stormwater runoff is collected via storm drains, some of which connect to a storm system, while others connect to a combined sewer system. The streets have few catch basins and most were clogged with accumulated sediment and organic matter. As a result, runoff is bypassing upgradient basins in the neighborhood study area and entering catch basins downgradient that directly discharge to the RWP ponds. 90% of the driveways are impervious and drained down to the road. Half of the gutters in the neighborhood were disconnected from storm drains or sewer lines, and 40% of those downspouts are directed to an impervious surface such as the driveway.

Opportunities for pollution prevention within the neighborhood include street sweeping. Moving forward, the City of Providence should replace failing catch basins with systems that can trap sediments/organics and provide pretreatment prior to discharge to Pleasure and Edgewood Lake. Stenciling the storm drains could increase homeowner awareness of the connection between the roads in their neighborhood and RWP. There is space for BMPs such as bioretention areas or raingardens in the open areas at the end of many of the neighborhood streets. These areas are visually connected to the Park as one drives along F.C. Greene Memorial Boulevard. Pet waste bag dispensers and waste receptacles could be located in the open areas as well. Additionally, homeowners could effectively reduce runoff by disconnecting directly connected impervious areas. Approximately 50% of the dwellings have downspouts that could be re-directed to pervious portions of the yard.

The proposed retrofit (RWP-30, see **Section 3.2.2**) takes runoff from F.C. Greene Memorial Boulevard, Marion Avenue and Farragut Avenue in the Edgewood North neighborhood. The retrofit includes taking a catchbasin off-line and intercepting the water in a tiered bioretention area before it outfalls into Pleasure Lake.

Edgewood South (Norwood Avenue, Edgewood Avenue, Villa Avenue, Beachmont Avenue)

Edgewood South is an older neighborhood of single-family detached dwellings that appear to be approximately 90 to 120 years of age. Part of the neighborhood falls within a National Historic District. The roads are in good condition, and there are sidewalks on both sides of some roads, while there are no sidewalks along others. The overall size of the neighborhood is approximately 93 acres, none of which is forested. The typical lot is approximately between 1/8 to 1/4 of an acre, made up of 60% impervious area, 30% grass cover, and 10% landscaped beds. The majority of the yards appear to have low maintenance requirements, with 15% having medium maintenance requirements from irrigating and fertilizing. There is public open space in the neighborhood, and numerous dog-walkers were observed.

The stormwater system consists of catch basins that lead to two outfalls into Edgewood Lake identified by the DEM as priority outfalls RWP-H and RWP-I. RWP-I is a 24 inch outfall pipe connected to catch basins in the adjacent intersection of Edgewood Avenue, Beachmont Avenue and F.C. Greene Memorial Boulevard. RWP-H is a, 30-inch oval corrugated outfall pipe connected to a larger drainage area of the neighborhood. Many catch basins in the study area are in poor or failing condition due to high accumulations of sediment and organic matter. As a result, runoff is bypassing upgradient basins and flowing down to other catch basins that connect to Edgewood Lake.

Opportunities for pollution prevention within the neighborhood include addressing pavement reduction and storm drain maintenance and repair. While many of the roads within the neighborhood are in good condition, they are wider than necessary, measuring 28 to 30 feet. Street widths at intersections, especially those onto F.C. Greene Memorial Boulevard, are very wide, measuring up to 60 feet. Runoff reduction could be achieved by reducing these roadway widths, directing runoff into stormwater practices in the areas with open space, and creating "green streets" in the right-of-way to intercept runoff and provide treatment and infiltration. Moving forward, the City of Cranston should replace failing catch basins with systems that can trap sediments/organics and provide pretreatment prior to discharge to Edgewood Lake. Similarly, many of the existing catch basins would benefit greatly from more frequent cleaning and maintenance, and storm drains that directly discharge to the lake should be stenciled to identify this direct connection. Homeowner education regarding fertilizer use with emphasis on reduction or elimination, and pet waste bag dispensers and waste receptacles located in public parks could also increase pollution prevention. Additionally, homeowners could effectively reduce runoff by redirecting downspouts to pervious areas; approximately 30% of the dwellings have downspouts that could be re-directed to pervious portions of the yard.

The proposed retrofit (RWP-28, see **Section 3.2.2**) takes runoff from roads in the Edgewood South neighborhood including Edgemont Avenue and Bartlett Avenue. The retrofit includes pavement removal and the construction of an infiltration basin to capture and treat runoff at the intersection of F.C. Greene Memorial Boulevard, Edgemont Avenue, and Beachmont Avenue.

Elmwood East (Stamford Avenue, Netop Drive, Potter Drive, Hamlin Street, Dixon Street, Thurston Street, Forestry Circle, Spooner Street, Bissell Street, Hathaway Street)

Elmwood East is a residential neighborhood comprised of a mixture of single-family attached, single-family detached and multifamily dwellings that appear to be approximately 50 years of age. The roads are in fair condition, with numerous cracks apparent and sidewalks along both sides of most roads. On street parking is permitted. The overall size of the neighborhood is 29.6 acres, none of which is forested. The typical lot is approximately between 1/8 to 1/4 of an acre, made up of 60% impervious area, 30% grass cover, and 10% landscaped beds. Approximately 75% of the yards appear to have medium maintenance requirements from irrigation and fertilizing. Dog-walkers were observed in the neighborhood. The stormwater system consists of catchbasins that lead to an outfall into Deep Spring Lake. Also connected to this outfall is runoff from the Route 10 highway on- and off-ramp.

Opportunities for pollution prevention within the neighborhood include addressing pavement reduction and storm drain maintenance and repair. Many of the roads within the neighborhood are in fair condition. However, they are wider than necessary, and street widths at intersections are very wide. Runoff reduction could be achieved by reducing these roadway widths and creating “green streets” in the right-of-way to intercept runoff and provide treatment and infiltration. Moving forward, the City should replace failing catchbasins with systems that can trap sediments/organics and provide pretreatment prior to discharge to Deep Spring Lake. Similarly, many of the existing catchbasins would benefit greatly from more frequent cleaning and maintenance, and storm drains that directly discharge to the lake should be stenciled to identify this direct connection. Homeowner education on fertilizer use with emphasis on reduction or elimination, and pet waste bag dispensers and waste receptacles located in public areas could also increase pollution prevention. Additionally, homeowners could effectively reduce runoff by redirecting downspouts to pervious areas; approximately 50% of the dwellings have downspouts that could be re-directed to pervious portions of the yard.

Appendix K

Lower Watershed LUHPPL Descriptions

The following are the detailed descriptions of the management options for the Upper Watershed Land Uses with Higher Potential Pollutant Loading (LUHPPLs), as identified during the field assessment described in **Section 3.2.5** of the Water Quality Management Plan.

Lower Watershed LUHPPL Descriptions

Police Mounted Command Stables, Training Area and Pens (North side of Noonan Island)

The Police Mounted Command Area is identified as a potential pollutant hotspot of medium severity due to the observation of erosion and sediment runoff from the areas of bare soil within the horse pens as well as trucks and dumpsters parking on and next to a catchbasin. The runoff from the pens goes down the steep slope into Pleasure Lake, and the existing catchbasins also drain to a 24-inch outfall into the lake.

Pollution prevention could be provided by adding vegetated swales along the side of the pens to intercept the runoff before it flows downhill. The pens themselves should be re-graded and stabilized with a grass mix. Pen rotation, keeping horses off wet soil/grass, adding materials such as wood chips, sand, or a geotextile layer with soil on top, will help to reduce erosion and wet conditions in the pens. Collecting manure often, covering any manure piles, and composting manure could reduce bacteria loading. Vehicular operations and waste management should be moved to an area away from existing catchbasins. Stormwater retrofit opportunity identified near this site as described in **Section 3.2.2**, RWP-34.

Maintenance Yard (South side of Noonan Island)

The Maintenance Yard is identified as a pollutant hotspot due to the numerous uncovered stock piles of waste, mulch, and machinery, vehicular storage and maintenance at, and adjacent to, the water's edge. Large stock piles of landscape and trash debris are stockpiled up to the ponds edge. The existing native vegetated buffer has been reduced in width over the years resulting in large stand of knotweed along the southeastern bank. It is recommended to re-establish a vegetated buffer between the ponds edge and the stock pile. A fence should be installed along the re-established buffer edge to delineated the area as protected and prevent encroachment into the restored buffer.

Only two catchbasins were seen on site and there is an overall lack of stormwater management at the facilities. The watershed area contains large amounts of impervious surfaces consisting of pavement and roofs. The potential for pollutant loading from sediment, nutrients, oil and grease, trash and bacteria is high.




It is recommended that a site-specific management plan be prepared for this area that focuses on reducing pollutant loading with stormwater management and identifying designated areas to stockpile various materials. Practices that could help reduce pollution include providing a larger vegetated buffer, decreasing the impervious area, using erosion and sediment control around stock-piled materials, covering stockpiled materials, installing stormwater management practices that include vegetated swales, bioretention areas, and oil and grease separators.

Construction Services

These business locations are identified as a potential pollutant hotspot due to uncovered stock piles of pavement and gravel, pavement recycling, and vehicular storage on-site. Stormwater from these sites typically drains into the storm sewer system in the street. Also, dogs are sometimes present at these sites. The potential for pollutant loading from sediment, nutrients, oil and grease, trash, and bacteria is high.

It is recommended that a site-specific management plan for these sites focus on reducing pollutant loading with stormwater management and identifying designated areas to stockpile various materials. Practices that could help reduce pollution include managing runoff on-site, using dust control fabric to entirely surround the area of pavement recycling operations, covering stockpiled material, properly disposing of pet waste, and ensuring that all vehicle maintenance is done in a covered location.

Auto Repair Services

These business locations are identified as a potential pollutant hotspot due to the storing of various vehicles and associated parts within salvage yards. The potential for pollutant loading from sediment, nutrients, oil and grease, and trash is estimated to be medium.

It is recommended that a site-specific management plan be prepared for these facilities that focuses on reducing pollutant loading with stormwater management and identifies designated covered maintenance areas. Practices that could help reduce pollution include managing runoff on-site, covering areas where vehicles are maintained and stored, properly disposing of pet waste, providing a cover for the dumpster, and ensuring that all hazardous materials are properly stored and disposed of.

General Maintenance Businesses

These business locations typically provide landscape services, janitorial services, and maintenance supplies as well as a machine repair service. Since the types of equipment supplies and debris associated with these types of businesses may be harmful to the ponds if left exposed to stormwater, we recommend that a site-specific assessment be performed for each business.

Appendix L

Upper Watershed Neighborhood Descriptions

The following are the detailed descriptions of the Upper Watershed Neighborhoods and proposed stewardship options identified during the field assessment described in **Section 3.3.2** of the Water Quality Management Plan.

Upper Watershed Neighborhood Descriptions

Gladstone School Neighborhood (Laurel Hill Avenue, Chestnut Hill Avenue, Heather Street, Browne Street)

The Gladstone School neighborhood is a high density residential land use in an older area dominated by single family detached homes on approximately 1/2 acre lots. Many of the paved roads are cracked and/or have patches from prior utility work and many of the sidewalks are in disrepair. Sidewalks are present on both sides of the street along the main roads and on side streets there are typically only sidewalks on one side. During the field reconnaissance, lawn clipping debris and leaves were observed to cover many of the sidewalks. A typical lot in the neighborhood is made up of approximately 50 to 60% impervious cover, with 20 to 30% grass cover, 5 to 10% landscaping, and 5 to10% bare soil, though there is a fair amount of variability. The neighborhood does not contain forested areas with the exception of the area of the Gladstone Street School which includes some forested area and open space. The lawns in the neighborhood show no evidence of irrigation and therefore are considered relatively low maintenance. The overall size of the neighborhood as delineated in GIS (**Figure 3.5**) is approximately 55 acres.

Stormwater runoff is collected via an enclosed storm drain system though the number of inlets/catchbasins appears to be too few to adequately convey typical stormwater events. Approximately 90% of the driveways in the area are impervious and drain directly into the road drainage network. About 45% of downspouts in the neighborhood are directly connected to storm drain system, approximately 50% are directed to impervious surfaces such as a driveway or sidewalk, and the remainder discharge to pervious areas on the lots.

Gladstone School Neighborhood. Several roads and sidewalks with deferred maintenance and recent utility construction (e.g., Laurel Hill Road), left; and many directly connected downspouts, right

Opportunities for pollution prevention include pavement reductions, street sweeping, and catchbasin maintenance/repair, and on-lot impervious cover disconnection. Many of the streets are cracked and in need of repair. Many roads are wider than necessary, including Laurel Hill Road, which measures 34 feet wide. This road is one example of where a "green streets" program could be implemented through a reduction in width during future repaving or streetscape projects. The pavement removal would result in runoff reduction and create larger areas for stormwater treatment and infiltration. Stormwater runoff could be directed to stormwater practices along the streetscape and in the newly created open space area. The property owners with directly connected impervious cover could redirect their downspout runoff from impervious to pervious surfaces, effectively reducing roof runoff. Practices such as rain gardens, cisterns and rain barrels should also be considered in the neighborhood. Catchbasin cleaning would be beneficial, allowing for pretreatment before reaching the ponds. Stenciling the storm drains could be beneficial, making homeowners aware of the drainage system connection to Spectacle Pond.

Mashapaug West (Niantic Avenue, Swanton Street, Lakeview Drive, Molter Street)

The Mashapaug neighborhood is a medium density residential land use consisting of single family detached residences on lots that are approximately 1/4 acre in size. The neighborhood appears to be around 40 to 50 years old. A typical lot consists of approximately 40% impervious cover, 45% grass cover, and 15% landscape area. About 10% of the lots have measurable tree cover with lots along Molter Street containing significant forest cover. Forested areas and open space are located to the south of Molter Street, along Mashapaug Pond. The neighborhood includes a park along Mashapaug Pond and ball fields north of Swanton Street. Approximately 90% of the lawns appear to show a moderate amount of maintenance while the remaining 10% appear to have low maintenance with no evidence of permanent irrigation systems. The roads are in good condition with minor cracking and there are no sidewalks present. During the field reconnaissance there was no visible evidence of illegal dumping or pet waste. The overall size of the neighborhood as delineated in GIS (**Figure 3.5**) is approximately 15 acres.

The stormwater runoff from the area is collected via storm drains and connects to the storm drain system. Nearly all of the driveways, most being clean, are impervious and drain to the road. Approximately 50% of downspouts are directed to impervious surfaces.

Pollution prevention opportunities within the neighborhood include street sweeping, maintaining and repairing catchbasins, and stenciling the storm drains to show the neighborhood's connection to Mashapaug Pond. Directly connected downspouts could be redirected from impervious to pervious surfaces, effectively reducing runoff. Nearly all of the lots have lawns present downgradient of roof leaders showing potential for rain gardens.

Typical neighborhood street in Mashapaug West, left; Signage of water quality warning in neighborhood park, right.

Spectacle West (Harmon Avenue, Crescent Avenue, Gordon Street, Lake Street)

The Spectacle West neighborhood is a medium density residential land use consisting of single family detached homes in an area that appears to be approximately 50 years old. A typical lot is approximately 1/4 acre in size and consists of approximately 50% impervious cover, 35% grass cover, 10% landscaping and 5% tree canopy. The neighborhood is well maintained with approximately 15% of lawns exhibiting high management, 75% showing medium management, and only 10% showing low management. The roads are in fair condition with only modest visible cracking and no sidewalks exist. On the day of our field reconnaissance, there were numerous dog-walkers observed but no visible pet waste. The overall size of the neighborhood as delineated in GIS (**Figure 3.5**) is approximately 65 acres.

Stormwater runoff is collected through a few catchbasins which appear to be connected to the existing storm drainage system that flows to the outfall at the end of Lake Street. Approximately 80% of the neighborhood driveways are impervious and direct runoff to the road. It appears that approximately 10% of downspouts are directly connected to the storm drain system, but approximately 50% of the downspouts are directed to impervious surfaces, and 40% of downspouts discharge to pervious areas.

Pollution prevention opportunities include homeowner education on fertilizer use with emphasis on reduction or elimination, street sweeping, and downspout disconnections. Directly connected downspouts could be redirected from impervious to pervious surfaces, effectively reducing runoff. Many lots have lawns present downgradient of roof downspouts. Practices such as rain gardens, cisterns and rain barrels would be appropriate in the neighborhood. The neighborhood may also benefit from pet waste bag dispensers, waste receptacles, and educational signage in vacant lots/road dead ends.

Typical street within Spectacle West neighborhood with some steeply sloping streets and mix of curbed and non-curbed streets, left; Paved flume at Beacon Street with direct discharge to Spectacle Pond and possible location for pet waste management.

Appendix M

Upper Watershed Stormwater Retrofit Site Descriptions

The following are the detailed descriptions of the recommended Upper Watershed stormwater retrofits identified in **Section 3.3.2** of the Water Quality Management Plan.

Upper Watershed Stormwater Retrofit Site Descriptions

UW-1: Rear of Bank of America parking lot along Mashapaug Pond

Located directly west of the Mashapaug Pond, the Bank of America Building and parking lot consists mostly of impervious surfaces. Runoff from the parking lot and buildings currently flows directly to the Mashapaug Pond via paved flumes located along the pond. These paved flumes are in poor condition with cracking and breaks. There are signs of scouring and erosion where stormwater runoff is not reaching these flumes and is flowing directly to the pond. A relatively large area of lawn/meadow immediately bordering the pond offers an excellent opportunity for stormwater retrofits to provide pretreatment.

Retrofit location for Bank of America. Upper left, bioretention or WVTS. Upper right, diversion weir structure. Damaged paved flume, lower left and view of contributing drainage area, lower right.

The proposed retrofit on the western border of the Mashapaug Pond is to direct stormwater flows from the parking lot and building to bioretention areas/WVTS before entering the Mashapaug Pond. The stormwater treatment areas would run parallel to the pond shoreline, where stormwater runoff would be diverted from the upper end of the paved flumes into the proposed facilities. The runoff would be treated in the bioretention areas/WVTS before overflowing to the pond. The proposed drainage structures within the paved flumes would be sized only to divert the water quality treatment volume to the proposed practices; larger storms would remain in the flumes and discharge directly to Mashapaug Pond. We also recommend bank stabilization practices in this area.

UW-2: Dupont Drive in front of Jewel Case Corporation (now or formerly)

Dupont Drive is 40 feet in width and located to the west of Mashapaug Pond within the Providence Industrial Park. The road is in poor condition with visible cracks and breaks. Stormwater runoff between Magnan Road and Park Lane is collected in catchbasins along the road. The runoff appears to be conveyed to an outfall at Mashapaug Pond, though additional drainage assessment would be necessary to confirm this.

The existing road width of 40 feet offers an ideal “green street” retrofit opportunity. The road could be reduced to a width of 28 feet and still accommodate the vehicular traffic of the industrial park. Removing 6 feet of pavement on both sides of the road would create an opportunity for road “bump outs” where stormwater treatment practices can be placed on each side of the road. Stormwater runoff from the road would be directed to the bump outs through curb cuts or flumes to a bioretention swale. This would reduce runoff volume, increase recharge, and provide stormwater treatment. Existing catchbasins along the road would be utilized as outlets to allow for overflow to be directed back to the existing drainage system. Landscaping islands immediately adjacent to the road right of way could be converted to bioretention areas to capture and treat runoff from upgradient areas (see photos below, Upper left and right, and lower left).

The former Jewel Case Corporation building includes extensive parking areas along the south side and to the rear of the building. Depending on future uses, this area could be retrofitted with drive islands containing swales and bioretention area to manage runoff (See photo below, lower right). Currently the parking lots have no formal drive or parking areas and thus could be easily retrofitted to provide stormwater treatment. The existing enclosed drainage system would be utilized to convey larger storms and overflow from the retrofit facilities.

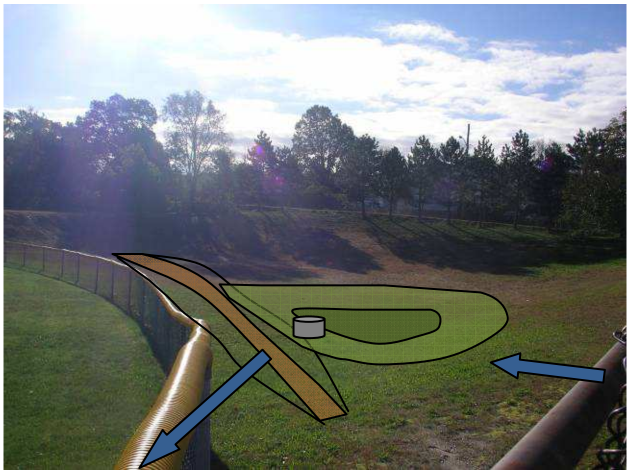
Retrofit locations for Dupont Drive and adjacent Jewel Case Corporation building. Upper left, bioretention bump outs. Upper right, lower left and, lower right, bioretention areas treating parking lot runoff.

UW-3: Intersection of Niantic Avenue and Swanton Street Adjacent to Baseball Fields

This site is located adjacent to the west-central portion of Mashapaug Pond, lying between Spectacle and Mashapaug

Ponds. Just North of Swanton Street, an open area is located beyond the active baseball fields. A portion of the neighborhood south of the ball fields drains towards this area. Niantic Avenue lies to the west of the proposed site and has an existing drainage system that collects runoff from Togansett Road to Swanton Avenue, including runoff from a vacant lot, a few side streets, and Niantic Avenue itself. This system currently discharges to the connecting pipe between Spectacle and Mashapaug Ponds

The area that lies beyond the outfield fence of the baseball fields offers an ideal location for a stormwater retrofit. This area currently receives some runoff from the residential neighborhood and streets south of the site, and has an existing low point. This open space would be used to create a WVTS or infiltration basin. According to GIS information, some of the underlying soil in this area is classified as hydrologic soil group A. Therefore, infiltration may be utilized here (but site specific soils and depth to groundwater constraints would need to be verified). Runoff would be directed to this area from the existing piping system in Niantic Avenue, into a sediment forebay before entering the infiltrating bioretention/WVTS.



Off-Line WVTS or Infiltration Basin south of ball fields and east of Niantic Avenue.

The treatment area would overflow to an outlet that would connect to the existing closed drainage system. A berm along the north side of the area would provide additional storage and act as an emergency overflow to the baseball fields for very large storms.

UW-4: Intersection of Lake Street, Gordon Street, and Harmon Avenue near existing pump station

The site of the existing pump station at the intersection of Lake Street and Burnham Street is at the eastern end of a triangular parcel. The western tip of the property is currently open space and could be a possible location for a stormwater retrofit. Runoff from the surrounding area is currently collected in an existing drainage system which outfalls at the end of Lake street into Spectacle Pond. The outfall pipe is submerged and there are current flooding problems along the conveyance path that affects the surrounding neighborhood (See photos below, lower left and right). A retrofit could reduce the amount of runoff that reaches the outfall while also providing some stormwater treatment.

Gordon Street and Lake Street intersection open space, upper left; pump station, upper right; Lake Street towards outfall, lower left; and submerged outlet into Spectacle Pond, lower right.

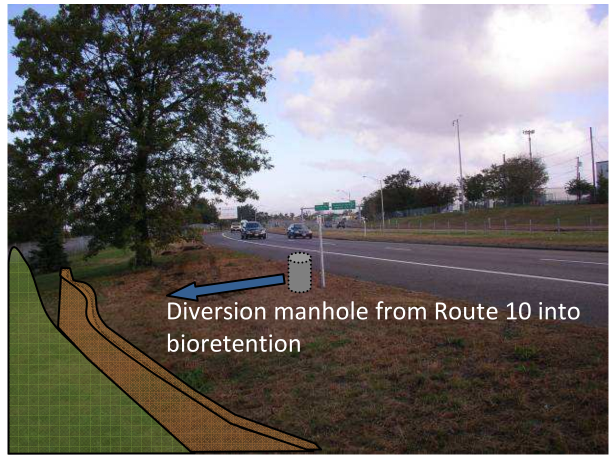
The proposed retrofit for this site would include a bioretention area with overflow to recharge chambers in the field, west of the existing pump station. If infiltration is not feasible (site specific soils and depth to groundwater constraints would need to be verified) direct discharge back to the drainage system is recommended. An existing sanitary sewer line runs through the open field and would have to be relocated to connect to the pump station at a different location. This would allow for the construction of the bioretention area and recharge field. Runoff from the existing drainage system would be directed into this area by converting an existing drainage structure into a diversion manhole. Runoff would be treated in the bioretention area and larger storms would remain in the existing system. Overflow from the bioretention area would flow to the underground recharge system for treatment.

UW-5: Route 10 and Garfield Ave intersection adjacent to Stop & Shop

The Stop and Shop Plaza borders Spectacle Pond to the southwest with Tongue Pond located to the north. According to DEM, the Stop and Shop Plaza was redeveloped in recent years and required to address stormwater management requirements and provide wetland mitigation for unavoidable impacts. There are currently Vortechnic units provided for pretreatment before runoff enters Spectacle Pond. There are also three mitigation ponds which border the existing connecting stream from Tongue Pond to Spectacle Pond (two on the east side, and one to the west). Based on field observations, the mitigation ponds appear to exhibit fair to poor water quality conditions (existing algae and evidence of stagnation). The pond to the west, immediately adjacent to the Stop and Shop plaza appears to be the worst. Proposed retrofits for this site include a bioretention area and a WVTS used as pretreatment for runoff from Route 10 prior to discharge into the mitigation areas. Runoff from a northern portion of Route 10 and a portion of Garfield Avenue would be directed to a bioretention area located in the median between Garfield Avenue and Route 10. The stormwater would be directed to this area by converting an existing structure to a diversion manhole, allowing larger storms (greater then water quality flow) to remain within existing drainage system. The bioretention would provide pretreatment before the runoff enters the existing mitigation pond.

A second facility would be located between the two existing mitigation ponds, east of the stream, and would collect runoff from another portion of Route. 10. This would be done by converting an existing structure to a diversion structure to direct stormwater runoff to the proposed retrofit. This retro fit that could be designed as either a bioretention area or a WVTS (depending on site specific groundwater constraints) with larger storms remaining in the existing drainage system. The bioretention/WVTS will provide pretreatment to the runoff before being directed to the second mitigation pond. A third potential retrofit could be a bioretention area or a WVTS that would provide more pretreatment before entering Spectacle pond. This facility would be located west of the stream where runoff from the Stop and Shop plaza parking lot would be directed into the facility via a paved drainage flume (for surface runoff) and a diversion manhole (for runoff from the enclosed drainage network). This would divert water that is currently flowing to the Vortechnic units to the proposed bioretention/WVTS to provide additional pretreatment and enhance phosphorus removal before ultimately discharging to Spectacle Pond.

Two wetland mitigation ponds upstream of Spectacle Pond. Algal blooms in western pond, left; open water with emerged aquatic vegetation, right.



Bioretention area at intersection of Route 10 on-ramp and Garfield Avenue. Facility would collect runoff from both Route 10 and Garfield Avenue via diversion structures.

Bioretention or WVTS proposed to capture runoff from Route 10, left, and Stop and Shop plaza parking lot, right.

Appendix N

Calculations for In-Pond (Roosevelt Lake) Options

Project Name:	Roger Williams Park	Project No.:	11058
Prepared by:	BRK	Date:	1/13/2012
Reviewed by:	RAC	Date:	1/13/2012

Calculations for In-pond (Roosevelt) BMP Options:

Wet Vegetated Treatment System (WVTS) Conceptual Calculations

Upper Watershed Area:	975	acres
Upper Watershed Area:	28	acres
Lower Watershed Contributing Area:	1003	acres
Surface Area Required[1]:	15.0	acres
Pond Surface area:	3.8	acres

[1] Per the Rhode Island Stormwater Design and Installation Standards Manual, the surface area for a shallow WVTS shall be at least 1.5% of the contributing drainage area

Gravel Wetland Conceptual Calculations

Upper Watershed Area:	975	acres
Contributing Lower Watershed Area:	28	acres
Total Contributing Drainage Area:	1003	acres
Surface Area Required[1]:	3.5	acres
Pond Surface area:	3.8	acres

[1] Per the Rhode Island Stormwater Design and Installation Standards Manual, the surface area for a gravel WVTS shall be at least .35% of the contributing drainage area

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Project Name:	Roger Williams Park	Project No.:	11058
Prepared by:	BRK	Date:	1/13/2012
Reviewed by:	RAC	Date:	1/13/2012

Sediment Forebay Conceptual Calculations

Upper Watershed Impervious Area:	589	acres
Contributing Lower Watershed Impervious Area[1]:	17	acres
Total Contributing Drainage Area:	606	acres
Water Quality Volume (WQv)[2]	50.5	acre-feet
10% of WQv[3]	5.05	acre-feet
Assumed Forebay Depth[3]	4	feet
Surface Area Required:	1.3	acres
Pond Surface area:	3.8	acres

[1] It was assume that 60% of the contributing lower watershed is impervious

[2] Per the Rhode Island Stormwater Design and Installation Standards Manual, the WQv is calculated by WQv=(1")/12*(Impervious Area)

[3] Per the Rhode Island Stormwater Design and Installation Standards Manual, the forebay shall be sized to contain at least 10% of the contributing WQv and be of an adequate depth to prevent resuspension of collected sediments during the design storm, often 4 to 6 feet deep.

[4] Per the Rhode Island Stormwater Design and Installation Standards Manual, the surface area for a gravel WVTS shall be at least .35% of the contributing drainage area

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