Total Maximum Daily Loads for Phosphorus To Address 9 Eutrophic Ponds in Rhode Island

Almy Pond, Newport
Brickyard Pond, Barrington
Gorton Pond, Warwick
North Easton Pond, Middletown, Newport
Roger Williams Park Ponds, Providence
Sand Pond, Warwick
Spectacle Pond, Cranston
Upper Dam Pond, Coventry
Warwick Pond, Warwick

Prepared By:
Office of Water Resources
Rhode Island Department of Environmental Management
235 Promenade St.
Providence, RI 02908
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List of Acronyms and Terms

Best Management Practices (BMP) means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of and impacts upon waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

CFR is the Code of Federal Regulations.

Clean Water Act (CWA) refers to the Federal Water Pollution Control Act (33 U.S.C. § 1251) et seq. and all amendments thereto.

DEM or RIDEM refers to the Rhode Island Department of Environmental Management.

Designated Uses are those uses specified in water quality standards for each waterbody or segment whether or not they are being attained. In no case shall assimilation or transport of pollutants be considered a designated use.

DOT or RIDOT refers to the Rhode Island Department of Transportation.

EPA refers to the United States Environmental Protection Agency.

Hypolimnion means the bottom waters of a thermally stratified lake.

Load allocation (LA) is the portion of a receiving water's loading capacity that is attributed either to one of its nonpoint sources of pollution or to natural background sources.

Loading Capacity means the maximum amount of loading that a surface water can receive without violating water quality standards.

MS4 is a municipal separate storm sewer system. Cities of Providence and North Providence, and the Towns of Smithfield and Johnston, and RIDOT are operators of MS4s.

MOS refers to the Margin of safety.

Nonpoint Source (NPS) means any discharge of pollutants that does not meet the definition of Point Source in section 502.(14). of the Clean Water Act and these regulations. Such sources are diffuse, and often associated with land-use practices, and carry pollutants to the waters of the State, including but not limited to, non-channelized land runoff, drainage, or snowmelt; atmospheric deposition; precipitation; and seepage.

Point source means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel, or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.

Rhode Island Pollutant Discharge Elimination System (RIPDES) is the Rhode Island system for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing point source discharge permits and imposing and enforcing pretreatment requirements pursuant to Title 46, Chapter 12 of the General Laws of Rhode and the Clean Water Act.

Runoff means water that drains from an area as surface flow.

Storm water is that portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility. Stormwater can also refer to rainwater that hits the ground, does not infiltrate at that location and travels to local surface waters without entering a stormwater conveyance system, and 2) rainwater that is collected in stormwater collection systems (pipes or ditches) and is then conveyed to local surface waters.

SWMPP is a storm water management project plan.

Total Maximum Daily Load (TMDL) means the amount of a pollutant that may be discharged into a waterbody and still maintain water quality standards. The TMDL is the sum of the individual waste load allocations for point sources and the load allocations for nonpoint sources and natural background taking into account a margin of safety.

ug/L is a concentration unit of micrograms (one-millionth of a gram) of pollutant (e.g. total phosphorus) per liter solution. One μg/L is equal to one-thousandth of a milligram per liter (mg/l). Hence, the total phosphorus standard of 0.025 mg/l = 25 μg/L.

Waste load allocation is the portion of a receiving water's loading capacity that is allocated to point sources of pollution, including stormwater discharges regulated under the NPDES.

Water quality criteria means elements of the State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use.

Water quality standard means provisions of State or Federal law, which consist of designated use(s) and water quality criteria for the waters of the State. Water Quality Standards also consist of an antidegradation policy.

ABSTRACT

This TMDL addresses phosphorus and phosphorus-related impairments to nine eutrophic ponds scattered throughout the State of Rhode Island. These ponds include Almy (Newport), Brickyard (Barrington), Gorton (Warwick), North Easton (Middletown/Newport), Roger Williams Park (Providence), Sand (Warwick), Spectacle (Cranston), Upper Dam (Coventry), and Warwick (Warwick) Ponds.

These eutrophic ponds range from 8 to 45 hectares in area. Most ponds are shallow, with only four ponds, including Brickyard, Gorton, Spectacle and Warwick Ponds, greater than 5 meters deep.
Most of the ponds included in this study are located in urbanized watersheds and their watershed areas are generally small in area. Residential development (mostly high density development) is the predominant landuse in all of the watersheds. Forest, wetland, and water, the second most common landuse among most of the watersheds, comprises between 9% and 41% of the watersheds.

The goals of this TMDL are to assess total phosphorus, chlorophyll-a, and dissolved oxygen concentrations within these water bodies, to identify and assess sources of the impairment, and to recommend mitigation measures to address the phosphorus related impairments and to restore all designated uses.

Except for limited data collected by RIDEM for North Easton Pond, all water quality data utilized in this study was provided by the University of Rhode Island Watershed Watch program (URIWW). Almy Pond has the most severe nutrient impairment of any of the ponds studied, with a mean total phosphorus concentration of 152 ug/l. The mean total phosphorus concentrations of North Easton and Roger Williams Park Ponds (110 and 82 ug/l, respectively) were also quite elevated relative to the other eutrophic ponds. With the exception of Warwick Pond, with a mean total phosphorus concentration of 27 ug/l, the mean total phosphorus concentrations for the remaining ponds ranged from 42 to 64 ug/l.

Data collected from the four deep (> 5m in depth) ponds generally showed significantly higher total phosphorus concentrations at depth than at the surface. These higher concentrations at depth are probably due to the release of phosphorus from pond sediments caused by stratification and development of anoxic conditions in the hypolimnion. Data collected from the shallow ponds indicates that mean total phosphorus concentrations were highest in the summer. Although most of these ponds are probably not stratified, pond sediments may nevertheless become anoxic in the summer months releasing phosphorus into the mixed water column.

The University of Rhode Island Watershed Watch program (URIWW) measured dissolved oxygen in the hypolimnion of the four deep ponds. The dissolved oxygen concentrations of Brickyard, Gorton, and Warwick Ponds generally fell below 3 mg/l from mid-May and early June through September or October.

Similar pollution sources affect most of the ponds included in this study. Sources of phosphorus are both external and internal (nutrient recycling from the lake sediment). The most significant external source for most of the ponds is stormwater runoff. Animal waste-derived nutrients from waterfowl and other wildlife are also a significant external source for most of the ponds. Other potential external sources to these ponds may include wastewater and erosion/sedimentation and to a lesser extent atmospheric deposition. The release of phosphorus from pond sediments is believed to be the major internal source of phosphorus.

Stormwater runoff has long been recognized as a major source of total phosphorus in urban environments. With the exception of North Easton Pond, a shoreline survey of each of the eutrophic ponds was conducted and all stormwater outfalls discharging directly to the ponds, tributaries, and hydrologically connected wetlands were identified. Outfalls were prioritized for implementation mainly by pipe

diameter, deducing that the culverts were sized according to their drainage areas and the amount of impervious area within the associated catchments.

The primary goal of the Total Phosphorus TMDL is to address the water quality impairments associated with excess phosphorus loadings including increased algal growth/chlorophyll a, and low dissolved oxygen. RIDEM has set a total phosphorus concentration of 25 ug/l as the numeric target for most of the shallow (< 5m deep) ponds included in this study. A numerical target of 20 ug/l was set for total phosphorus for the deep ponds and Spectacle Pond. The total phosphorus target was used as a surrogate for excess algal growth/chlorophyll a, and dissolved oxygen.

Current loads were calculated from in-pond total phosphorus concentrations using an empirical loading-response model. Allowable loadings (TMDLs) were back-calculated using the Reckhow model and the numeric water quality target. A ten percent margin of safety was then subtracted from this value to determine the allowable load or TMDL for each waterbody. Almy and North Easton require the greatest load reductions (80-85%). Roger Williams Park, Sand, Brickyard, Gorton, and Spectacle Ponds require load reductions between 68 and 73%. Upper Dam, and Warwick Ponds require load reductions of 33 and 46 %, respectively.

Eliminating the phosphorus-related impairments to the eutrophic ponds requires a reduction in both external and internal sources of phosphorus. Recommended implementation activities to address external sources to the ponds focus primarily on the control of stormwater runoff to the ponds and to a lesser extent on the control of loadings from waterfowl, stream bank and lakeshore erosion, in some instances wastewater. Control of external sources of phosphorus may not produce immediate or expected water quality benefits in most of the ponds unless internal loading is also addressed in a timely fashion. The use of alum is one option to reduce the release of phosphorus from the ponds' sediments. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments.

To realize water quality improvements in the ponds, both phosphorus concentrations in storm water *and* the volume of storm water discharged to the ponds must be reduced. The implementation of Phase II Stormwater Management Program Plans (SWMPP) including illicit discharge detection and elimination, revision of local ordinances addressing phosphorus from new development and re-development, and the construction of stormwater BMPs at selected locations is expected to, in time, help reduce the nutrient impairments to the ponds. Cities and towns should also consider increasing the frequency of street sweeping and/or stormwater system maintenance.

The control of loading due to excessive populations of waterfowl is also necessary to achieve necessary reductions in some if not most of the ponds. Wastewater management activities include continuing the extension of sewer lines, encouraging homes presently on individual systems to tie-in to the existing sewer systems where available, periodic checking of existing sewer systems to ensure there are no chronic leaks, and adopting wastewater management ordinances in areas without sewers to ensure that septic systems are properly maintained and operated.

Continuing monitoring efforts by University of Rhode Island Watershed Watch volunteers will help track water quality trends, and evaluate pollution control efforts. In accordance with the requirements of this TMDL, monitoring of the eutrophic ponds should continue so that the effectiveness of ongoing remedial activities can be gauged.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act requires the State of Rhode Island to prepare a list of all surface waters in the state for which beneficial uses of the water are impaired by pollutants. Waterbodies placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs) to identify and quantify sources of the impairments and establish acceptable pollutant loads from both point and nonpoint sources of pollution which allow the impaired waterbody to meet water quality standards. TMDLs prepared by RIDEM also include implementation strategies for reducing these point and nonpoint source loads.

This set of TMDLs addresses nine eutrophic ponds identified on the 2006 303(d) List as having phosphorus-related impairments: Almy Pond, Brickyard Pond, Gorton Pond, North Easton Pond, Roger Williams Park Ponds, Sand Pond, Spectacle Pond, Upper Dam Pond, and Warwick Pond. The waterbodies generally lie within urbanized areas and all receive storm water runoff from both point and nonpoint conveyances. Additional sources of phosphorus likely include waterfowl, pet waste, lawn fertilizers, and various upstream and tributary sources.

RIDEM has employed an approach consistent with that in an EPA Region 1 document detailing a procedure for developing lake phosphorus TMDLs (Basile and Voorhees, 1999). The document uses a practical and simplistic approach for lake phosphorus TMDL development. A core component of this methodology is the use of an empirical loading-response model derived by Reckhow, which balances external loadings against the in-lake mean phosphorus concentration. A major benefit of the methodology is that data acquisition and analysis are minimal compared to other widely used techniques. An empirical model was used to relate annual phosphorus load and steady-state in-pond concentration of total phosphorus.

1.1 Scope and Purpose of Eutrophic Pond TMDLs

This set of TMDLs will address nine (9) eutrophic and/or hypereutrophic waterbodies located throughout the State of Rhode Island, within the following cities and towns: Barrington, Coventry, Cranston, Middletown, Newport, Providence, and Warwick**.** These waterbodies are impaired by at least one of the following parameters: phosphorus, excess algal growth/chlorophyll-a, or low dissolved oxygen. The phosphorus-related impairments associated with each of the waterbodies and addressed by this TMDL are listed in Table 1.1. With the exception of North Easton Pond, all the impairments were identified through sampling conducted by volunteers with the University of Rhode Island Watershed Watch Program.

The listed impairments (Table 1.1) are all indicators of nutrient enriched systems, better known as eutrophic systems. In freshwater systems the primary nutrient known to accelerate eutrophication is phosphorus. Therefore, in order to prevent further degradation of water quality and to ensure that each waterbody meets state water quality standards, the TMDLs will establish a phosphorus limit for each waterbody and will outline corrective actions to achieve that goal.

1.2 Pollutants of Concern and Applicable Criteria

The pollutants of concern for these nine eutrophic ponds are phosphorus and related water quality impairments including excess algal growth/chlorophyll-a, and low dissolved oxygen. Total phosphorus is typically the limiting nutrient to algal growth in the freshwater environment. For purposes of this TMDL, the total phosphorus target will also be used as a surrogate for excess algal growth/chlorophyll-a, and low dissolved oxygen, as these impairments, documented in Rhode Island’s 303 (d) list, largely result from excess phosphorus loadings.

Table 1. 1 Eutrophic Pond's Water Quality Classification and 2006 303(d) Listings Addressed by this TMDL.

Waterbody	**Waterbody ID**	**Size (hectares)**	**WQ Classification**	**Impairment(s) 2006 303(d) List**
Almy Pond	RI0010047L-01	20.2	A	Phosphorus
Brickyard Pond	RI0007020L-02	34.0	B	Phosphorus, Low dissolved oxygen
Gorton Pond	RI0007025L-01	23.6	B	Phosphorus, excess algal growth/chl-a, low dissolved oxygen
North Easton Pond	RI0007035L-03	45.1	A	Phosphorus, excess algal growth/chl-a,
Roger Williams Park Ponds	RI0006017L-05	42.4	B	Phosphorus, excess algal growth/chl-a, low dissolved oxygen
Sand Pond	RI0006017L-09	4.9	A	Phosphorus, low dissolved oxygen
Spectacle Pond	RI0006017L-07	15.7	B	Phosphorus, excess algal growth/chl-a
Upper Dam Pond	RI0006014L-04	8.3	B	Phosphorus
Warwick Pond	RI0007024L-02	34.3	B	Phosphorus, excess algal growth/chl-a, low dissolved oxygen

The following criteria for nutrients, which include total phosphorus and nitrogen, excerpted from Table 1 of RIDEM's Water Quality Regulations (RIDEM, 1997), apply to the subject ponds:

10(a). Average Total phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole, or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the Director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication.

10(b). None [nutrients] *in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion of 10(a) above in a downstream lake, pond, or reservoir. New discharges of wastes containing phosphates will not be permitted into or immediately upstream of lakes or ponds. Phosphates shall be removed from existing discharges to the extent that such removal is or may become technically and reasonably feasible.*

Criterion 10(a) states that the total phosphorus concentration shall not exceed 0.025 mg/l (25ug/l) in any lake or pond unless a different value for phosphorus is needed to prevent eutrophication. . The 25 ug/l criterion was used as the target concentration for most of the shallow ponds (5m < in depth) including Almy, North Easton, Roger Williams Park, and Upper Dam Ponds. However, the target concentration was reduced to 20 ug/l for deep ponds including Brickyard, Gorton, Sand, and Warwick Ponds. A separate TMDL addressing the phosphorus-related impairments to Mashapaug Pond located in Providence determined that this decreased target concentration was necessary in order to address the dissolved oxygen impairments to these deep ponds (RIDEM, 2007). Although Spectacle Pond is classified as a shallow pond, its maximum depth exceeds 5 m and measurements by RIDEM staff indicated that dissolved oxygen concentration were low. For these reasons and the fact that Spectacle Pond is located immediately upstream of Mashapaug Pond, the target of 20 ug/l was also used for Spectacle Pond.

Criterion 10(b) states that nutrient concentrations in a waterbody (and hence loadings to the water body) shall not cause undesirable aquatic species (e.g. chlorophyll-a) associated with cultural vegetation. This narrative standard is designed to prevent the occurrence of excessive plant or algal growth. The Department will follow guidelines set by the Nurnberg (1996) Trophic State Index to establish a limit for algal concentrations in the subject ponds.

All of the ponds included in this study are classified as warm water fish habitat (personal communication, Alisa Richardson, RIDEM). The following standards apply for dissolved oxygen:

Warm Water Fish Habitat - Dissolved oxygen content of not less than 60% saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5.0 mg/l. The 7-day mean water column dissolved oxygen concentration shall not be less than 6 mg/l.

1.3 Priority Ranking

All the ponds included in this study are listed as Group 1 water bodies in the DEM 2006 303(d) List of Impaired Waters. Group 1 waters are those not meeting Rhode Island Water Quality Standards, with TMDL development currently underway.

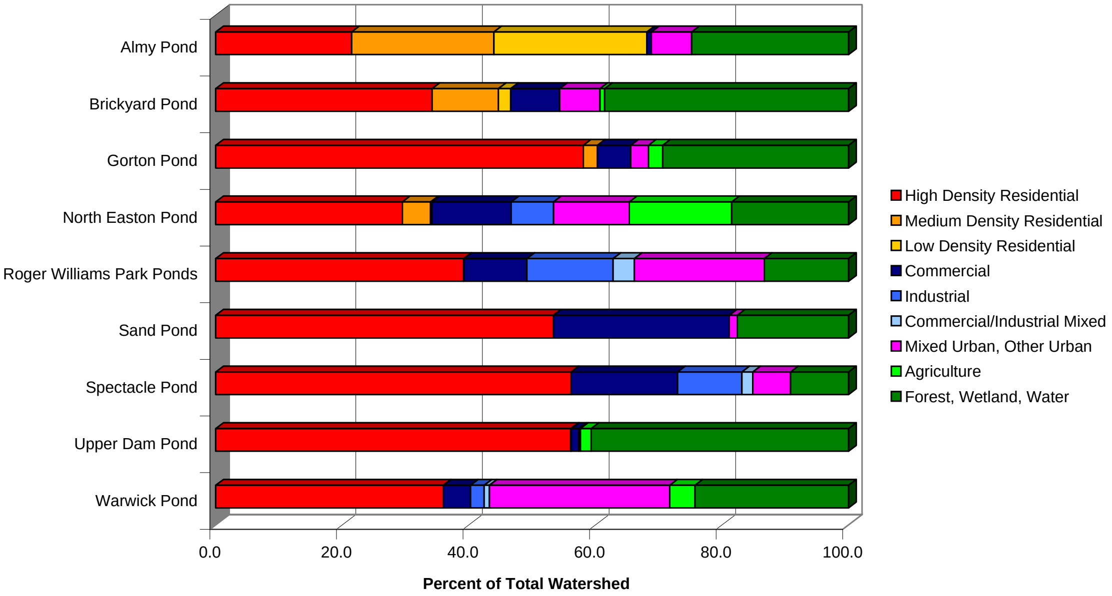
1.4 Antidegradation Policy

Rhode Island’s antidegradation policy requires that, at a minimum, the water quality necessary to support existing uses be maintained (see Rule 18, Tier 1 in the State of Rhode Island’s Water Quality Regulations). If water quality for a particular parameter is of a higher level than necessary to support an existing use, that improved level of quality should be maintained and protected (see Rule 18, Tier 2 in the State of Rhode Island’s Water Quality Regulations).

2.0 WATERSHED/WATERBODY DESCRIPTIONS

Most of the ponds included in this study are located in urbanized watersheds. Landuses within each watershed and watershed boundaries were determined from the 1995 land use and 2005 watershed data sets of the RIGIS database. Since the land use database is twelve years old, some inaccuracies may exist. Residential development was broken down into high (>1 acre), medium (1/4 –1 acre), and low (1/4 acre <) density residential. Residential development (mostly high density development) is the predominant landuse in all of the watersheds (Figure 2.1). Forest, wetland, and water, the second most common landuse among most of the watersheds, comprises between 9% and 41% of the watersheds. Mixed urban landuse generally comprises 12% or less of any watershed. However, both the Warwick Pond and Roger Williams Park Ponds watersheds have significantly more mixed urban landuse. Commercial development occupies less than 13% of most of the watersheds excluding the Sand and Spectacle Pond watersheds. Most of the watersheds have no significant areas of industrial development. Exceptions include the North Easton, Roger Williams Park, Spectacle, and Warwick Pond watersheds. Agriculture occupies no more than 4% of the area of any of the watersheds, except the North Easton Pond watershed.

Figure 2. 1 Percent Land Use within each Watershed.



2.1 Almy Pond

Almy Pond is located on the southern tip of Aquidneck Island in the City of Newport, Rhode Island (Appendix A, Figure 1). This oblong pond is situated only 1200 meters from the Atlantic Ocean. Almy Pond is located immediately north of Ocean Avenue and Bailey's Beach. It is bounded to the west by Carroll Avenue, to the north by Ruggles Avenue, and to the east by Coggleshall Avenue. Almy Pond has a surface area of approximately 20 hectares and a maximum depth of 1.8 meters (RIGIS; Guthrie and Stolgitis, 1977). With an average depth of 1.2 meters, the estimated volume of Almy Pond is 2.42 x 10^5

m^3. Inflow to the pond consists of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The residence time of the pond is approximately 4 months.

The Almy Pond watershed encompasses approximately 135 hectares. The watershed is partially sewered. There are small pumping stations adjacent to the eastern and western shores of the pond at the terminus of Murray Place and on Alpond Drive, respectively. Residential development comprises most of the watershed. Specifically, low, medium and high density residential development make up approximately 24%, 23% and 22% of the watershed, respectively (Figure 2.1). Wetlands and open water make up approximately 25% of the watershed. Most of the remaining watershed is comprised of mixed urban land use. The watershed north and east of the pond is the most densely developed.

A marsh, vegetated almost exclusively by common reed (*Phragmites australis)*, dominates most of the shoreline of the pond. The marsh along the eastern shore is quite narrow, but widens significantly at the northern and southwestern ends of the pond. The marsh is absent along much of the western shore, where the shoreline slopes steeply to the pond. The immediate shoreline of the pond is largely undeveloped, due to the contiguous marsh surrounding it. However, residential development encroaches up to the edge of the marsh at its northern and eastern shores. The western shoreline is more sparsely developed. Aquatic macrophytic vegetation is largely absent. However, an algae problem is apparent and the pond had a pea-green appearance, even late in the growing season.

There is a single tributary, originating at a roadway culvert, which drains into the northern end of the pond. An outlet at the southwest end of the Pond drains to Bailey’s Beach and Rhode Island Sound. The pond does not appear to be tidally influenced as evidenced by the growth of freshwater shrubs within standing water at the pond’s shore.

There are thirteen (13) identified storm drains discharging to Almy Pond, its tributary, or hydrologically connected wetlands. A map of the Almy Pond watershed and the locations of identified point sources are provided in Appendix A, Figure 1.

2.2 Brickyard Pond

Brickyard Pond is located within the Providence River watershed in the Town of Barrington and is bounded to the west by Middle Highway and to the south by Nyatt Road. Brickyard Pond has a surface area of 34 hectares and a maximum depth of 5.5 meters (RIGIS; Guthrie and Stolgitis, 1977). With an average depth of 3.4 meters, the estimated volume of Brickyard Pond is 1.16×10^6 m^3. Inflow to the pond consists primarily of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The residence time of the pond is approximately 6 months.

The Brickyard Pond watershed encompasses approximately 310 hectares. The watershed is sewered. Approximately 39% of the watershed consists of forest, wetland and open water (Figure 2.1). Most of this area consists of a large swamp and upland forest to the east of the pond. High density and medium density residential development makes up 34% and 11% of the watershed, respectively. Most of the remaining watershed is comprised of commercial and mixed urban landuses. The watershed is more densely developed to the north of the pond.

The East Bay Bike Path runs along the northern shoreline and offers excellent views of the pond. The area to the immediate east of the pond is undeveloped and consists of wetland and upland forest. The immediate shoreline of the pond is relatively undeveloped. There are approximately a dozen single-family residences on the southern shoreline, although most have a least some forested buffer. A waste transfer station is located on the western shore.

Brickyard Pond is an artificial pond that was originally excavated as a clay pit. The pond contains several small islands, generally located near the northern shore. Most of the pond appears to be relatively weed free, but isolated coves at the northwest and northeast ends of the pond are characterized by moderately dense growth of aquatic vegetation. This vegetation is dominated by coontail (*Ceratophyllum spp.),* with much lesser amounts of duckweed (*Lemna spp.*) in a few isolated coves.

An unnamed stream drains into the southeast end of the pond. A ditch, along the northern shoulder of the East Bay Bike Path, drains to the pond via two culverts under the former railroad bed. Mussachuck Creek, which originates at the western end of the pond, is its sole outlet. The creek provides an andronomous fish run into Brickyard Pond. Muschechuck Creek discharges directly to the Providence River.

There are twenty four (24) identified storm drains and three (3) areas of concentrated surface flow discharging to Brickyard Pond, its tributaries, or hydrologically-connected wetlands. A map of the Brickyard Pond watershed and the locations of identified point sources are provided in Appendix A, Figure 2.

2.3 Gorton Pond

Gorton Pond is located within the watershed of Greenwich Bay in the City of Warwick and is bounded by Veterans Memorial Drive (Route 1) to the south, Post Road (Route 1) to the east, Main Avenue (Route 113) to the north, and Greenwich Avenue (Route 5) to the west. Gorton Pond has a surface area of 24 hectares and a maximum depth of 13.7 meters (RIGIS; Guthrie and Stolgitis, 1977). With an average depth of 4.9 meters, the estimated volume of Gorton Pond is 1.16 x 10^6 m^3. Inflow to the pond consists primarily of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The residence time of the pond is approximately 6 months.

The Gorton Pond watershed is highly urbanized and encompasses approximately 161 hectares. The watershed is mostly sewered. Approximately 58% of the watershed consists of high density residential development (Figure 2.1). Approximately 30% of the watershed is made up of forested areas and open water. Commercial development accounts for only 5% of the watershed. The remaining portion of the watershed largely consists of nearly equal areas of medium density residential and mixed urban landuses.

The northern shoreline of the pond is characterized by dense residential development. Although steep terrain along most of the immediate northern shoreline provides a narrow forested buffer, a few lawns extend to the water's edge. The southern shore is developed with a few commercial and institutional areas, including the Warwick Police Station. A public beach is located on the eastern shore, which is otherwise undeveloped. There are several single-family dwellings on the western shore, some with lawns extending to the water's edge. One such expansive lawn, near the outlet of the pond, provides a staging area for a large number of waterfowl and seagulls. Keyes Associates et al. (1982) reported 200 sea gulls resting on this lawn adjacent to the outlet. A significant amount of goose fecal material was also observed on the city beach on the eastern shore. Hundreds of gulls and waterfowl were observed on the pond.

Except for a small marsh at the northwest corner of the pond, there are no vegetative wetlands contiguous to the shore. There is significant growth of aquatic vegetation in the shallows of this deep pond. Commonly observed species include eelgrass (*Vallisneria spp.*) and macrophytic algae, with lesser amounts of coontail (*Ceratophyllum spp.)* and white water lily (*Nymphaea odorata*). Aquatic vegetation forms a continuous mat on the surface of the pond in some areas.

An unnamed intermittent stream, associated with a small wetland, discharges into the northwest end of the pond. The outlet of the pond is located at the southwestern end of the waterbody. Water flows from the pond, via culverts under Greenwich Avenue, into an impoundment called Little Gorton Pond. Little Gorton Pond discharges into Hardig Brook and eventually Apponaug Cove.

There are fifteen (15) identified storm drains and five (5) discharge areas of concentrated surface water flows discharging to Gorton Pond, its tributary, or hydrologically connected wetlands. A map of the Gorton Pond watershed and identified point sources is provided in Appendix A, Figure 3.

2.4 North Easton Pond

North Easton Pond (Green End Pond) is located on the southern end of Aquidneck Island only 600 meters north of Newport's First Beach and Easton Bay. The vast majority of the pond is located in the Town of Middletown, but its' southwest corner extends into the City of Newport. Green End Avenue skirts the northern shoreline of the pond. Valley Road (Route 214) closely parallels the eastern shoreline, separated from the pond by a narrow wooded buffer. North Easton Pond has a surface area of 45 hectares and a maximum depth of 3.3 meters (Jay Watts, Newport DPW, written communication). With an average depth of 2.6 meters, the estimated volume of North Easton Pond is 1.17 x 10^6 m^3. Inflow to the pond consists primarily of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The residence time of the pond is approximately 2 months.

The North Easton Pond watershed encompasses approximately 982 hectares. The watershed is mostly sewered. Approximately 30% of the watershed consists of high density residential development (Figure 2.1). Forest, wetland and water and agriculture comprise approximately 19% and 16% of the watershed, respectively. Commercial and mixed urban development each account for approximately 12% of the watershed. Industrial development accounts for approximately 7% of the watershed. The remaining portion of the watershed consists of medium and low density residential development.

The western shoreline of the pond is characterized by an undisturbed wooded area to the north and residential development to the south. Lawns typically extend to the water's edge in the residential area. North Easton Pond is separated from South Easton Pond by an earthen dam. A walking path along the top of the dam is popular with local residents. Water clarity was poor, but aquatic macrophytes appeared to be largely absent. Several hundred geese were observed at the northern end of the pond.

North Easton Pond, along with eight other reservoirs, comprises the drinking water source utilized by the Newport Water Division. Newport's Station 1 Water Treatment Plant is located at the southwestern end of North Easton Pond. Water from North and South Easton Ponds is treated at the Newport Water treatment facility and distributed to Newport, Middletown and the U.S. Navy base.

Bailey's Brook is the main source of surface water into North Easton Pond. The Bailey's Brook watershed is the most urban in the Newport Water Supply system. Bailey's Brook, along with an unnamed perennial stream, discharge into a marsh located to the immediate north of North Easton Pond, opposite Green End Avenue. Inspection of aerial photographs reveals that the marsh was a small body of open water in the 1970's. The area has since filled in with sediment, probably due to erosion from nearby agricultural fields and upstream urban development. Another unnamed perennial stream discharges into the southeast end of the pond less than 100 meters from the outlet of the pond. The submerged outlet structure allows water to enter South Easton Pond. Outflow from South Easton Pond is discharged to Newport's First Beach, via culverts under Memorial Boulevard.

2.5 Roger Williams Park Ponds

The Roger Williams Park Ponds are the most outstanding natural feature of the City of Providence's Roger Williams Park, a 174-hectare Victorian park that offers manicured grounds, an extensive roadway system, a zoo, museum and many other facilities. The Roger Williams Park Ponds are located within the Pawtuxet River watershed. The ponds are bounded by Interstate 95 and Elmwood Avenue (Route 1) to the west, Broad Street and Warwick Avenue (Route 117) to the east, and Park Avenue (Route 12) to the south. Although the Roger Williams Park pond system is essentially one large interconnected body of water, different areas are designated as separate lakes and given the names Roosevelt, Polo, Willow, Pleasure, Edgewood, Cunliff, and Elm (Appendix A, Figure 5). These "lakes" were divided along constrictions, such as those found at roadway bridges. Only two of the park ponds lack a surface connection to the other ponds. An unnamed pond, within the zoo enclosure at the northwest corner of the park, is hydrologically connected to the Polo Lake via a culvert. The only pond lacking a hydrological connection is Deep Spring Lake, which is located at the southwest corner of the park. Due to its hydrological isolation, Deep Spring Lake is the only park pond that is not included in this study.

The Roger Williams Park pond system, not including hydrologically isolated Deep Spring Lake, has a surface area of 42.4 hectares (RIGIS). The ponds have an average and maximum depth of 1.7 meters and 2.7 meters, respectively (Lee Pare & Associates, Inc., 1980). The estimated volume of Roger Williams Park Ponds is $6.79 \times 10^5 \text{ m}^3$. Inflow to the ponds consists primarily of groundwater, surface water runoff, stormwater runoff, tributary inflow (culverted), and direct precipitation. The residence time of the pond system is approximately 6 months.

The Roger Williams Park Ponds watershed is highly urbanized and encompasses approximately 918 hectares. The watershed is sewered. High density residential development accounts for approximately 39% of the watershed (Figure 2.1). Approximately 21% of the watershed consists of mixed urban development or other urban landuses, mostly made up of the park itself. Industrial development and forest, wetland and water each make up approximately 13% of the watershed. Almost all of the forest, wetland, and water landuse in the watershed consists of the Roger Williams Park, Spectacle and Tongue Ponds themselves. Commercial development accounts for approximately 10% of the watershed, with the remaining portion of the watershed comprised of mixed commercial/industrial landuse.

The area immediately adjacent to Roger Williams Park Ponds is typically either forested or maintained lawn. The only significant wetland area is located between Polo Lake and the unnamed pond in the northwest corner of the park. The park service has discontinued the use of fertilizers in their mowed areas, due to concerns about water quality. Both Roosevelt Lake and Deep Spring Lake had a pea-green appearance, indicative of high algae concentrations.

Aquatic macrophytes were absent throughout most of the pond system but formed dense mats of vegetation at the eastern end of Pleasure Lake, the northern end of Edgewood Lake, and to a lesser extent along the western shore of Polo Lake. The vegetation was dominated by white water lily (*Nymphaea odorata*), with much small amounts of duckweed (*Lemna spp.*) also present.

The outlet of the Roger Williams Park Ponds is located at the dam at the southern end of Elm Lake. There are no surface tributaries to the ponds. The main inlet to the ponds, located at the western end of Roosevelt Lake, is culverted flow from Mashapaug Pond, which is located approximately 1300 meters to the northwest of the park.

There are twenty four (24) identified storm drains and two (2) areas of concentrated surface water flow discharging to Roger Williams Park Ponds. A map of the Roger Williams Park Ponds watershed and the locations of identified point sources are provided in Appendix A, Figure 5.

2.6 Sand Pond

Sand Pond is a small urban pond located within the Pawtuxet River watershed, in the City of Warwick. The pond is bounded to the west by Post Road (Route 1), to the north and east by Massasoit Drive and to the south by Sand Pond Road and Puritan Drive. Sand Pond has a surface area of approximately 4.9 hectares (RIGIS). Sand Pond is a kettle hole pond and there are no streams discharging into or draining from the pond, nor are there any contiguous wetlands. Inflow to the pond consists primarily of groundwater, surface water runoff, stormwater runoff, and direct precipitation.

The Sand Pond watershed is highly urbanized and encompasses approximately 25 hectares. The watershed is sewered. The Sand Pond watershed consists of approximately 55% high density residential development and 28% commercial development (Fig. 2.0). The pond itself comprises approximately 18% of the watershed.

Sand Pond is surrounded by dense residential development. There is a narrow forested buffer around most of the pond, but several lawns extend to the water's edge. A small commercial plaza is located to the immediate north of the pond. There is a small public beach at the southeast end of the pond.

Sand Pond is made up of two basins, which are separated by a low narrow earthen berm. It appears that the basins are hydrologically connected for most of the year, but not at times of low water. The diminutive crescent-shaped eastern basin is very shallow and is characterized by extremely dense growth of aquatic vegetation, dominated by coontail (*Ceratophyllum spp.*) and macrophytic algae. Very little aquatic vegetation was observed within the much larger and deeper western basin. At the time of the site inspection, the water clarity appeared to be quite good across the entire pond. Local residents reported that hundreds of geese have periodically over-wintered on the pond.

There are six (6) identified storm drains and one (1) area of concentrated surface water flow discharging to Sand Pond. A map of the Sand Pond watershed and identified point sources is provided in Appendix A, Figure 6.

2.7 Spectacle Pond

Spectacle Pond is located within the Pawtuxet River watershed in a highly urbanized area in northern Cranston, near the Providence border. Spectacle Pond is bounded to the north and west by Cranston Street, to the east by Route 10, and to the south by Park Avenue (Route 12). Spectacle Pond is approximately 15.7 hectares in area (RIGIS). The pond has a maximum depth of approximately 5 meters and an average depth is approximately 2.3 meters (Guthrie and Stolgitis, 1977). The volume of Spectacle Pond is approximately 3.61×10^5 m^3. Inflow to the pond consists primarily of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The outflow from Spectacle Pond was previously estimated at 1.05×10^6 m^3/yr (RIDEM, 2007). The mean hydraulic residence time for the pond is approximately 3 months.

The Spectacle Pond watershed is highly urbanized and is approximately 238 hectares in area. The watershed is sewered. Approximately 53% of the watershed of Spectacle Pond consists of high density residential development (Fig. 2.0). Commercial and industrial land use make up 17% and 10% of the watershed, respectively. Forest, wetland and open water and mixed/other urban landuses comprise approximately 9% and 6% of the watershed, respectively.

The northern and eastern shores of the pond are bounded by commercial and/or industrial uses.

Residential areas characterize the western and southern shores. Steep terrain along the western and eastern shores and small wetlands at the northern and southern ends of the pond provide a vegetated buffer along most of the shoreline.

A manmade ditch connects 2-hectare Tongue Pond, located approximately 330 meters north of Spectacle Pond, to Spectacle Pond at its northern end. There are three small wetland replication areas (e.g. ponds) immediately adjacent to the stream. None of the ponds are hydrologically connected to either the stream or to Spectacle Pond. Spectacle Pond's outlet is a 48-inch highway culvert under Route 10, located in the northeast portion of the pond. The culvert leads to Mashapaug Brook, which discharges into Mashapaug Pond via an underground conduit. Mashapaug Pond discharges to the Roger Williams Park ponds via underground culverts, which then discharge to the Pawtuxet River, which drains into the Providence River, and ultimately into Narragansett Bay.

There are nineteen (19) identified storm drains and thirteen (13) areas of concentrated surface water flow discharging to Spectacle Pond, its tributary and hydrologically-connected Tongue Pond. A map of the Spectacle Pond watershed and identified point sources is provided in Appendix A, Figure 7.

2.8 Upper Dam Pond

Upper Dam Pond is located within the Pawtuxet River watershed, in the Town of Coventry. Upper Dam Pond is bounded to the west by Knotty Oak Road (Route 116), to the north by Gervais Avenue, and to the east by Boston Street. Upper Dam Pond has a surface area of 8.3 hectares. Inflow to the pond consists of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation.

The Upper Dam Pond watershed encompasses approximately 87 hectares. The watershed is not sewered. The Upper Dam watershed consists of approximately 56 % high density residential development (Fig. 2.0). Approximately 41% of the watershed is comprised of forest, wetland, and open water. The remainder of the watershed consists of agricultural, commercial, mixed urban and medium density residential landuses.

Dense residential development characterizes the northeastern and to a lesser extent the southwestern shorelines. Lawns extending to the water's edge are common. The immediate eastern and southern shorelines consist of undisturbed forest. The northwestern end of the pond is predominantly swamp. There is a public beach at the southern end of the pond.

Upper Dam Pond is a small crescent-shaped pond, with a peninsula jutting into the pond's northern end. Aquatic vegetation was observed mainly in shallow coves found along the western and northern shorelines. The submergent vegetation was dominated by macrophytic algae, forming dense mats in places, with lesser amounts of coontail (*Ceratophyllum spp.*), white water lily (*Nymphaea odorata*) and duckweed (*Lemna spp.)*. Water clarity appeared to be quite good across the entire pond. Three intermittent streams discharge into Upper Dam Pond. Two streams are associated with a swamp and drain into a northwestern cove. The third stream discharges into another western cove. All streams originate within 500 meters of the pond. There is an outlet structure the southern end of the pond, which controls the pond's elevation. The outflow drains to Middle Dam Pond and eventually to the South Branch of the Pawtuxet River.

There are eighteen (18) identified storm drains discharging to Upper Dam Pond, its tributaries and hydrologically connected wetlands. A map of the Upper Dam Pond watershed and identified point sources is provided in Appendix A, Figure 8.

2.9 Warwick Pond

Warwick Pond is located in the Buckeye Brook watershed in the City of Warwick. The Warwick Pond area is located east of T.F. Green State Airport, and is bounded to the north by Airport Road and to the east by Warwick Avenue (Route 117A). This 34.3-hectare pond has an average depth of 4.3 meter and a maximum depth of 7.9 meters (RIGIS; Guthrie and Stolgitis, 1977). The estimated volume of Warwick Pond is 1.47×10^6 m^3. Inflow to the pond consists of groundwater, surface water runoff, stormwater runoff, tributary inflow, and direct precipitation. The residence time of the pond is approximately 17 months.

The Warwick Pond watershed is approximately 346 hectares in area. The watershed is sewered. Approximately 36% of the watershed of Warwick Pond consists of high density residential development (Fig. 2.0). Mixed urban land use, mainly consisting of the airport to the west of the pond, comprises 29% of the watershed. Forested areas and open water make up approximately 24% of the watershed. The remainder of the watershed consists of commercial, agricultural, and industrial landuses.

The northern shore of the pond is undeveloped and is dominated by a swamp. Dense residential development surrounds the remainder of the immediate shoreline of the pond. Lawns typically extend to the water's edge along the western and southern shore. Scores of waterfowl were observed on one lawn, located on the southern shore just east of the outlet. Steep topography along the eastern shore generally provides a narrow forested buffer. A small town park is located on the eastern shore, opposite Stanmore Road. Warwick Pond is a popular boating and fishing area, with a public boat ramp located on the western shore, opposite Wells Avenue. The pond supports an andronomous fish population. Aquatic vegetation is generally absent.

An unnamed perennial stream is the main surface inflow to the pond. The main stem of this stream originates approximately 1400 meters north of the pond, flows through Spring Green Pond, and discharges into the northern end of Warwick Pond. Most of the main stem is associated with a wetland corridor, providing a significant forested buffer between the stream and surrounding residential development. A short perennial tributary flows parallel to Airport Road and merges into the main stem of the stream north of the roadway. This tributary is generally bounded by wetland and upland forest, providing a buffer between the stream and nearby commercial development and agriculture uses. A drainage ditch, associated with the airport, empties into the stream within the wetland at the northern end of the pond. A second airport ditch discharges into the southwestern end of the pond. Warwick Pond is drained by Buckeye Brook at its southwestern end. The river empties into Narragansett Bay just south of Conimicut Point.

There are forty four (44) identified storm drains and sixteen (16) areas of concentrated surface water flow discharging to Warwick Pond, its tributaries, and hydrologically connected wetlands. A map of the Warwick Pond watershed and identified point sources is provided in Appendix A, Figure 9.

3.0 CURRENT WATER QUALITY CONDITIONS

Except for limited data collected in North Easton Pond, all water quality data utilized in this study was provided by the University of Rhode Island Watershed Watch program (URIWW). The Watershed Watch Program, initiated in 1986, is led by URI's Cooperative Extension and Department of Natural Resources Science (NRS). The URIWW program is an institutional collaboration between URI, the Cooperative State Research Education Extension Services (CSREES), the Rhode Island Department of Environmental Management (RIDEM), the Narragansett Bay Estuary Restoration Program, municipalities, environmental and sporting organizations, the Narragansett Indian Tribe, lakeside residents and organizations, and various other local, regional, and national partnerships. Program goals are to encourage active citizen participation in water quality protection, to educate the public about water quality issues, and to obtain multi-year surface water quality information. Water quality information is used to ascertain current water quality conditions and to detect trends in order to encourage successful, cost-effective management.

The program is based on the work of volunteers, who conduct the sampling after they receive training for the appropriate field procedures. The sampling schedules are centrally coordinated at URI. The aim of the program is to establish a long-term monitoring program for water bodies all over Rhode Island. The URIWW program typically samples for alkalinity, bacteria, chloride, chlorophyll, ammonium, nitrate, total nitrogen, pH, dissolved phosphorus, total phosphorus and measures secchi depths as well. Through comparison of bi-weekly or monthly sampling over the summer season, long-term changes in the water quality may be detected.

The URIWW program samples for phosphorus three times a year, analyzing for both total and dissolved phosphorus. Waterbodies are typically sampled for phosphorus in May and July. Prior to 1999, the third sample was collected in November, but as of 1999 the last sample for phosphorus is now collected in October. Samples are collected 1 meter below the surface for all waterbodies. A second sample is taken in the deepest portion of the pond at approximately 1 meter above the substrate for ponds that are greater than 4.6 meters deep.

Dissolved phosphorus concentrations for most of the ponds were below detection limits much of the time. Prior to 2001, the detection limit for phosphorus was 4 ug/l. From 2001 onward the detection limit for phosphorus was 3 ug/l. Non-detect measurements were assigned a value of half the detection limit, for the purposes of calculating averages.

The URIWW program typically samples weekly for dissolved oxygen from May through October. URIWW samples for dissolved oxygen in deep ponds only. Samples are generally taken 1 meter below the surface and 1 meter above the substrate at the deepest part of the waterbody.

The URIWW program typically samples for chlorophyll-a once every two weeks, from May through October. Samples are taken 1 meter below the surface at the deepest part of the waterbody. Duplicate samples for the same day are averaged.

Samples were analyzed for chlorophyll-a using solely analog equipment through 2000. In 2001 duplicate samples were analyzed using both analog and digital equipment. Samples were analyzed solely with digital equipment starting in 2002. Analysis of the dual 2001 readings showed that the digital measurements for chlorophyll-a tended to be slightly higher than the analog readings. This difference became more pronounced at higher concentrations of chlorophyll-a. For those ponds that were sampled by both methods, the analog data was converted to digital data to maintain consistency between the readings. This conversion was accomplished by the following regression equation:

$\text{Chlor-a}_d = 1.159\ (\text{Chlor-a}_a) - 0.1232;\ R^2 = 0.9944$

where:
Chlor-a_d = chlorophyll-a concentration (digital); and
Chlor-a_a = chlorophyll-a concentration (analog).

3.1 Almy Pond

Almy Pond has the most severe nutrient impairment of any of the ponds studied. Total phosphorus and chlorophyll-a concentrations for Almy Pond are significantly higher than all other ponds. The URI Watershed Watch data for Almy Pond is limited, and the pond has been monitored only since 2002. The mean total phosphorus concentration for the URIWW sampling period was 152 ug/l. The total phosphorus concentration in the summer, averaged over the three-year sampling period, was 183 ug/l (Table 3.1). The mean total phosphorus concentration in the spring and fall was 130 ug/l and 137 ug/l, respectively. In 2002, the total phosphorus concentration increased from 70 ug/l in the spring to 159 ug/l in the summer months. In 2003, the total phosphorus concentration was about 200 ug/l for all three sampling seasons. The total phosphorus concentration in 2004 is highest in the summer (188 ug/), and lowest in the fall (79 ug/l).

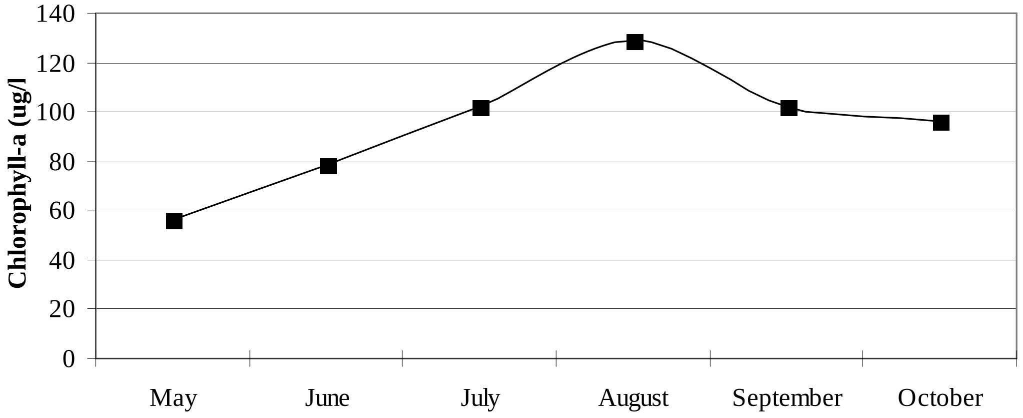
Table 3. 1 Total Phosphorus Concentrations (ug/l) for Almy Pond.

	Spring	Summer	Fall	Mean
2002	70	159		114
2003	199	201	197	199
2004	120	188	76	128
Mean	130	183	137	

The mean dissolved phosphorus concentration for the URIWW sampling period was 8 ug/l, more than an order of magnitude less than the mean concentration of total phosphorus. Dissolved phosphorus concentrations, averaged over the three-year sampling period, were 10 ug/l and 11 ug/l in the spring and summer. The mean dissolved phosphorus concentration decreases to 3 ug/l in the fall.

The mean chlorophyll-a concentration, averaged over the three-year sampling period, was 90 ug/l (Figure 3.1). This represents the highest mean concentration of any of the ponds studied. The maximum recorded chlorophyll-a concentration was 166 ug/l. The mean chlorophyll-a concentration in May was 56 ug/l. The chlorophyll-a concentration more than doubles by August to 129 ug/l. The concentration falls to a mean value of 96 ug/l by October.

Figure 3. 1 Monthly Mean Chlorophyll-a Concentration for Almy Pond (2002-2004).



3.2 Brickyard Pond

Brickyard Pond has been monitored by URI Watershed Watch volunteers since 1994. Since it is a deep pond (> 4.6 meters deep), measurements are taken at the surface and at depth, when appropriate. Deep samples are taken at a depth of 4 meters. The mean total phosphorus concentration (for both shallow and deep samples) for the URIWW sampling period (1994-2004), was 63 ug/l. The mean concentration of total phosphorus for deep samples (111 ug/l) was significantly higher than the mean concentration of surface samples (22 ug/).

In addition to the disparity between total phosphorus concentrations at the surface and at depth, shallow and deep samples also show different patterns in seasonal fluctuations (Table 3.2). The mean total phosphorus concentration at the surface is highest in the spring. The mean springtime total phosphorus concentration at the surface of Brickyard Pond was 30 ug/l. The average surface concentration during the summer and early fall decreased to 14 ug/l and 17 ug/l, respectively. The mean phosphorus concentration at the surface may be highest in the spring because of the complete mixing of the water column that occurs with spring turnover, bringing phosphorus-rich bottom waters to the surface. The similar concentrations of total phosphorus for shallow and deep samples indicate that the water column is thoroughly mixed during the spring. Increased seasonal inflow of urban stormwater may also contribute to the higher total phosphorus concentrations at the surface during the spring. It appears that there is a trend of increasing total phosphorus concentrations at the surface, over the 1994 though 2004 monitoring period.

The average total phosphorus concentration at depth increases as the growing season progresses (Table 3.2). The largest increase in total phosphorus at depth occurs between the spring and summer season. The mean total phosphorus concentration at depth was 44 ug/l in the spring. This increases to 120 ug/l and 190 ug/l in the summer and early fall, respectively. The elevated mean phosphorus concentrations at depth indicate that the pond's sediment may be the most significant source of phosphorus into the water column. This is especially apparent in the summer through early fall when the pond becomes stratified and the hypolimnion becomes anoxic, which encourages the release of phosphorus from the sediment. It appears that, over the 11-year monitoring period, there is a trend of increasing total phosphorus concentrations at depth during the spring. There is no evidence for such a trend during the summer and early fall.

Table 3. 2 Total Phosphorus Concentrations (ug/l) for Brickyard Pond at Surface and Depth.

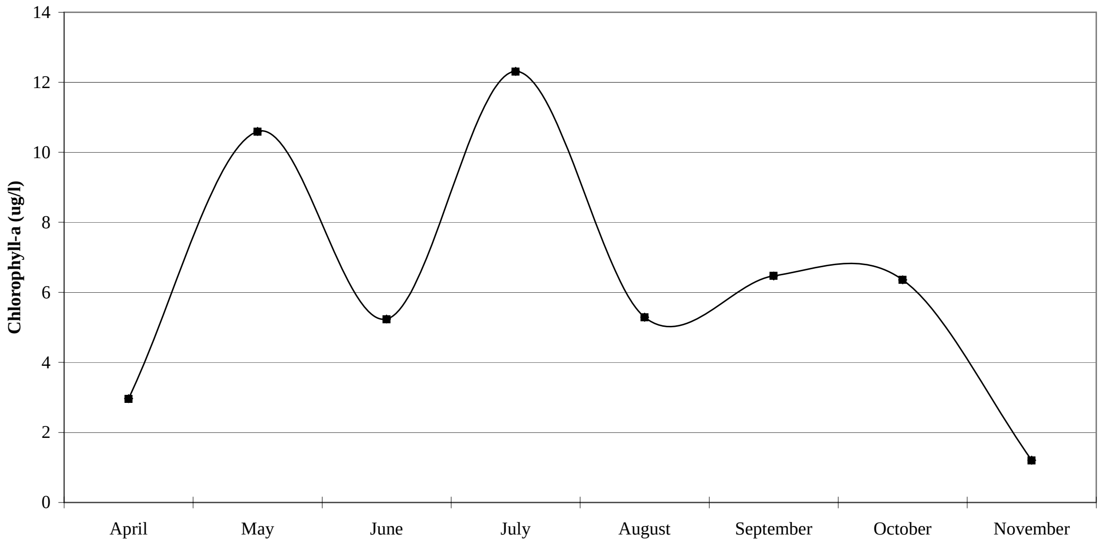
	Surface (1m)				Bottom (4m)			
	Spring	**Summer**	**Fall**	**Mean**	**Spring**	**Summer**	**Fall**	**Mean**
1994	17	13	18	16	18	101	113	77
1995	12	11	13	12				
1996	19	11	8	13	68	90	67	75
1997	16	15	6	12	15	140	324	160
1998	24	6	2	11	24	135	189	116
1999	21	13	36	23	43	321	356	240
2001	40	27	37	35	44	27	88	53
2003	62			62	73			73
2004	61	17		39	69	28		49
Mean	30	14	17		44	120	190	

The mean dissolved phosphorus concentration at the surface was generally below detection levels for the entire monitoring season. Prior to 1999, the dissolved phosphorus concentration was below the detection limit for the entire monitoring season. It appears that nearly all of the phosphorus at the surface is incorporated into algal biomass, and any available phosphorus becomes quickly assimilated. The mean springtime dissolved phosphorus concentration at depth was also generally below the detection limit. However, the mean dissolved phosphorus concentration at depth increased to 145 and 143 ug/l in the summer and fall, respectively. This dramatic increase in dissolved phosphorus at depth is probably the result of phosphorus release from the sediment, facilitated by anoxic conditions in the summer and early fall.

Dissolved oxygen data for Brickyard Pond collected by URIWW from 1995 through 1999 was analyzed. URIWW measured dissolved oxygen levels in Brickyard Pond at a depth of 4.0 to 5.0 meters. Dissolved oxygen concentrations in the hypolimnion waters fell below the 5 and 3 mg/l thresholds in early to mid May and typically remained below this level through at least early to mid October. The 3 mg/l threshold is critical because it is the minimal dissolved oxygen concentration required to support most forms of aquatic life. For the period between 1997 and 1999, dissolved oxygen concentrations fell below the detection limit by mid June to early July and the hypolimnion remained anoxic through October. In 1995 the hypolimnion remained anoxic only until late August. In 1996 dissolved oxygen concentrations were below the detection limit sporadically in June, mid July, and from late August through mid October.

Chlorophyll-a data for Brickyard Pond is available for the entire growing season from 1994 through 1999, and in 2001. No sampling was conducted in 2000 or 2002. In 2003 the pond was sampled for chlorophyll-a in the spring only. In 2004 the pond was sampled in the spring and summer only. During the period in which data is available for the entire growing season, the annual mean chlorophyll-a concentration ranged from 4 ug/l in 1995 to 12 ug/l in 1997. There are two peaks in chlorophyll-a concentrations, one in May and another in July (Figure 3.2). The mean chlorophyll-a concentration of Brickyard Pond from 1994 through 2004 was 8 ug/l. The maximum recorded chlorophyll-a concentration was 75 ug/l. It appears that there is a trend of increasing chlorophyll-a concentrations during May-June and September-October, over the course of the eleven-year monitoring period.

Figure 3. 2 Monthly Mean Chlorophyll-a Concentration for Brickyard Pond (1994-2004).



3.3 Gorton Pond

A comprehensive diagnostic/feasibility study was completed in 1982 by Keyes Associates et al. of Providence, Rhode Island. Both dry and wet weather sampling was conducted, including parameters such as dissolved oxygen, temperature, total phosphorus, chlorophyll-a, water transparency, ammonia, and nitrate. The lake was sampled from March through November of 1981. Samples were also taken at the inlet and outlet, at two wells up-gradient of the pond, and from two stormwater outfalls.

In-lake samples were taken at the deepest portions of the eastern and western basins of the pond. The eastern station was sampled at 0.9 m, 4.6 m, 8.2 m, and 12.2 m. The western station is not as deep and was sampled at 0.9 m, 4.6 m, 7.3 m, and 9.8 m. The overall mean total phosphorus concentration averaged for both stations and all depths was 244 ug/l. The mean total phosphorus concentration at the eastern sampling station (343 ug/l) was significantly higher than the mean concentration at the western station (144 ug/l). The higher concentrations at the eastern station were due mainly to higher total phosphorus concentrations at the bottom sampling depth. (890 ug/l compared to 160 ug/l for the western basin). The highest bottom concentrations for both stations occurred predictably in the summer months when the bottom waters were anoxic.

The total phosphorus concentration at the inlet ranged from 20 to 1830 ug/l. The mean concentration at the inlet (420 ug/l) was significantly higher than the overall in-lake concentration. The mean total phosphorus concentration at the outlet ranged from 10 to 335 ug/l. The mean concentration at the outlet was 140 ug/l.

The total phosphorus concentration of the well samples ranged from 40 to 440 ug/l. The mean concentration for the well samples was 258 ug/l, similar to the overall mean lake concentration.

Stormwater was sampled at two outfalls during two storm events. These outfalls are located at the terminus of Sharon Street and immediately north of the town beach located at the eastern end of the lake. The Sharon Street outfall (identified as GP-B in Appendix A, Figure 3) is a 2-ft. culvert that drains a 41-hectare residential area. The beach outfall (identified as GP-E) drains a 15-hectare commercial area. The outfall was identified as a 12-in. culvert by Keyes Associates et al. (1982). There is currently a 36 X 24-

in. oval culvert at the same location, identified as GP-E in Appendix A, Figure 3. The total phosphorus concentration at the Sharon Street and beach outfalls outfall ranged from 1450 to 9130 ug/l and 45 to 8780 ug/l, respectively. The overall mean total phosphorus concentration for both outfalls was 461 ug/l.

Temperature and dissolved oxygen data indicate that the pond begins to stratify by mid-May, with dissolved oxygen beginning to decline (Keyes Associates et al., 1982). By mid-June the stratified condition is well established and oxygen levels in Gorton Pond are insufficient to support fish populations at depths greater than 3.7 meters, where dissolved oxygen measured 3.23 ug/l. Keyes Associates et al. (1982) stated that the lack of oxygen in the hypolimnion resulted in reducing conditions and the release of phosphorus from the sediment. By mid-October the stratified condition begins to deteriorate, and the dissolved oxygen concentrations are 5.0 mg/l at a depth of 8.2 meters.

Algal concentrations in Gorton Pond generally range between 900 and 11,000 cells/ml (Keyes Associates et al., 1982). Concentrations as high as 67,000 cells/ml were recorded during algal blooms. Chlorophyll-a concentrations ranged from 29 to 894 ug/l, with an overall mean of 346 ug/l. The general seasonal trend for phytoplankton in Gorton Pond is typical of temperate northeastern lakes. Diatoms (*Bacillariophyceae*) and yellow-brown algae (*Chrysophyceae*) are dominant from March through May. Green (Chlorophyceae) and blue-green algae (*Cyanophyceae*) become dominant in June.

Gorton Pond was monitored by URI Watershed Watch volunteers from 1995 to 2000. It is a deep pond and parameters were measured at surface and at depth, when appropriate. Deep samples were taken at a depth of 10 m. The mean total phosphorus concentration for the URIWW sampling period was 56 ug/l, considerably lower than the 244 ug/l reported by Keyes Associates et al. in 1981. Like Brickyard Pond and most of the other deep ponds included in this study, the mean annual concentration of total phosphorus for deep samples (93 ug/l) was significantly higher than the mean concentration of surface samples (24 ug/).

Although mean phosphorous concentrations at the surface and at depth were similar in the spring, the concentrations diverge sharply with depth in the summer and fall (Table 3.3). In the spring, the shallow and deep mean phosphorus concentrations were 29 ug/l and 31 ug/l, respectively. The mean phosphorous concentration at the surface decreases to 17 ug/l in the summer, before rebounding to 24 ug/l in the early fall. The lower total phosphorus concentrations at the surface in the summer is typical of most of the deep ponds studied, and is probably the result of a vegetative uptake and settling and a seasonal decrease in inflow. Since inflow is generally contaminated by urban runoff, a decrease in inflow results in decreased nutrient loading into the pond.

The seasonal fluctuations in total phosphorus concentrations at depth show different dynamics than the surface fluctuations (Table 3.3). Like most of the other deep ponds, the total phosphorus concentrations at depth are lowest in the spring and increase by summer and early fall. The mean phosphorus concentrations at depth increase to 129 ug/l and 118 ug/l in the summer and early fall, respectively. The higher phosphorus concentrations at depth in the summer and early fall appear to be indicative of phosphorus release from the sediment and also may in part be due to settling of algae and plant debris. The total phosphorus concentration at depth in the fall of 1996 and 1998 are similar to surface concentrations, indicating that vertical mixing probably had occurred by the fall reading during these years.

Table 3. 3 Total phosphorus concentrations for Gorton Pond (ug/l) at Surface and Depth.

	Surface (1m)				Bottom (10m)			
	Spring	**Summer**	**Fall**	**Mean**	**Spring**	**Summer**	**Fall**	**Mean**
1995	21	15	33	23				
1996	23		17	20	22	122	23	56
1997	21	27	20	23	20	165	174	120
1998	29	3	18	17	31	91	25	49
1999	27	20	22	23	41	160	153	118
2000	54	21	31	35	42	109	217	123
Mean	29	17	24		31	129	118	

It appears that total phosphorus concentrations during the spring at both the surface and at depth have increased over the course of the six-year monitoring period. It also appears that there may be a trend of increasing total phosphorus concentrations at depth during the fall over the 1995-2002 monitoring period.

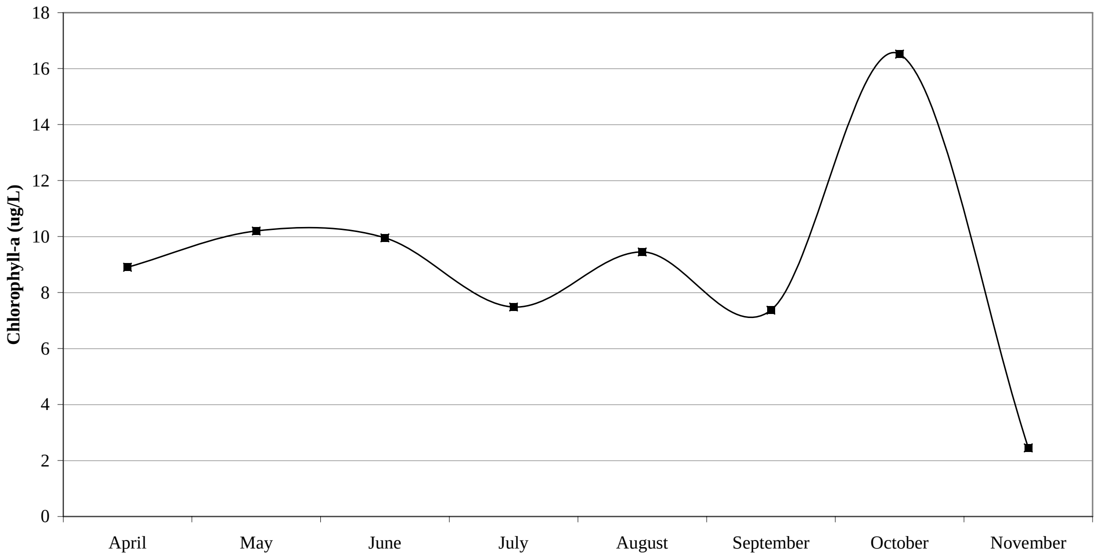
During the 1994 through 2000 sampling seasons, the mean dissolved phosphorus concentration at the surface was below detection levels in all but three of the seventeen measurements taken. The highest recorded dissolved phosphorus concentration at the surface was 6 ug/l.

Dissolved phosphorus data at depth for Gorton Pond is available for 1999 and 2000 only. In 1999, dissolved phosphorus measurements were taken only in the summer and fall. The dissolved phosphorus concentration in the spring of 2000 was 23 ug/l. The mean dissolved phosphorus concentration at depth for the summer and early fall was 62 and 162 ug/l, respectively. This dramatic increase in dissolved phosphorus, over the course of the monitoring season, is typical of the deep ponds in this study.

Dissolved oxygen data for Gorton Pond collected by URIWW from 1996 through 2000 was analyzed. URIWW measured dissolved oxygen levels in Gorton Pond at a depth of 10 meters. Dissolved oxygen concentrations in the hypolimnion waters typically fell below both the 5 and 3 mg/l thresholds in mid to late May and remained below 3 mg/l through October. Dissolved oxygen concentrations were below the detection limit by late June to mid July and typically remained anoxic through October.

The annual mean chlorophyll-a concentration was 12 ug/l, which is well above the eutrophic threshold of 7.2 ug/l. However, the mean chlorophyll-a concentration, reported by Keyes Associates et al. (1982) was 346 ug/l, more than an order of magnitude greater than the mean measured by URIWW between 1995 through 2000. The monthly mean chlorophyll-a concentration peaks in October (Figure 3.3). The mean chlorophyll-a concentration for the month of October, during the 6-year monitoring period, was 17 ug/l. The annual mean chlorophyll-a concentration ranged from 3 ug/l in 1998 to 18 ug/l in 2000. The maximum chlorophyll-a concentration was 54 ug/l, recorded on July 20, 2000. There is no discernable trend in the mean annual chlorophyll-a concentration over the six-year monitoring period.

Figure 3. 3 Monthly Mean Chlorophyll-a Concentration for Gorton Pond (1995-2000).



3.4 North Easton Pond

North Easton Pond is the only waterbody included in this study that is not monitored by the University of Rhode Island Watershed Watch. In partnership with RI. Dept. of Health (HEALTH), the URI Cooperative Extension has assessed pollution threats to major water supplies under the RI Source Water Assessment Program. The focus is on public drinking water "source" areas; the wellhead protection area that recharges a well or the watershed that drains to a surface water reservoir. Assessment results for major community drinking water supplies, including the Newport Water Division, are available as full reports and summary fact sheets.

North Easton Pond was sampled by RIDEM staff for total phosphorus, dissolved phosphorus, chlorophyll, and dissolved oxygen. Sampling was conducted on June 21, August 15, and October 29, 2002. Samples were taken at both the surface and bottom. The sampling results are presented in Table 3.4. The mean total phosphorus concentration was 110 ug/l. The limited data suggest that total phosphorus concentrations increased as the growing season progressed. The mean dissolved phosphorus concentration for the 2002 sampling period was 24 ug/l. The mean chlorophyll-a concentration was 14 ug/l. Dissolved oxygen levels ranged from 7.0 to 11.0 mg/l at the surface and 6.8 to 9.0 mg/l at the bottom.

Table 3. 4 Sampling results for North Easton Pond.

Date	TP surface (ug/l)	TP bottom (ug/l)	DP surface (ug/l)	DP bottom (ug/l)	Chlor-a surface (ug/l)	Chlor-a bottom (ug/l)	DO surface (ug/l)	DO bottom (ug/l
6/21/2002	97	42			17		9.1	
8/15/2002	112	143	13	20	3		7.0	6.8
10/29/2002	144		34	30	15	21	11.0	9.0

3.5 Roger Williams Park Ponds

Lee Pare & Associates conducted a nutrient study on the Roger Williams Park Ponds during the winter of 1979 and 1980. They identified storm water discharge from urban roadways as a major cause of elevated nutrient concentrations in the pond system. They also identified a sedimentation problem in Roosevelt Lake. The study included phosphorus sampling within the park's pond system and also in up-gradient waterbodies, including Spectacle Pond. The total phosphorus concentration at the outlet of the Roger Williams Ponds system (Elm Lake) was generally significantly higher than at the inlet (Roosevelt Lake). The water column was sampled in the winter of 1979 and 1980 and the summer of 1980, during both dry and wet weather. For any given sampling site, the total phosphorus concentration tended to be significantly higher in the summer and during or immediately after wet weather.

Total phosphorus concentrations at the Roosevelt Lake inlet and the Elm Lake outlet during winter dry weather were 15 ug/l and 22 ug/l, respectively (Lee Pare & Associates, 1980). During a period of summer dry weather, the total phosphorus concentrations at the inlet and outlet of the park's pond system increased dramatically to 115 ug/l and 301 ug/l, respectively. During and immediately after storm events, the total phosphorus concentration in the winter at the inlet of Roosevelt Lake and the outlet at Elm Lake was 53 ug/l-64 ug/l and 63-87 ug/l, significantly higher than during winter dry weather. During summer wet weather, the total phosphorus concentration at the Roosevelt Lake inlet and the Elm Lake outlet ranged from 192-290 ug/l and 166-310 ug/l, respectively.

The total phosphorus concentration in the unnamed pond within the zoo enclosure, measured at the beginning of a significant snowmelt, was 122 ug/l. This elevated concentration, especially given that it occurred during the winter, was attributed to waterfowl and run off from an adjoining bison mound. The total phosphorus concentration near a waterfowl congregation area on Willow Lake, measured early during a winter storm, was 101 ug/l.

Lee Pare & Associates (1980) also measured total phosphorus concentrations in the soft sediments of the park ponds. Pare reported that phosphorus concentrations in the pond's sediment were similar to those found in typical silty topsoil. Also, no correlation was found between phosphorus concentrations in the water and those of the sediments. The sediment phosphorus concentrations were highest for both up-gradient and down-gradient ponds. Specifically, the total phosphorus concentrations for Roosevelt, Polo, and Elm Lake sediments were 39-49 mg/g, whereas the phosphorus concentrations for the middle lakes were 4-16 mg/g.

Numerous efforts have been applied over the years to combat the nutrient and algae problems in the park's pond system. The measures have included dredging of bottom sediments, application of algaecides (copper sulfate), and mechanical removal of weeds. These measures have had no lasting affect on the water quality of the Park's pond system.

Lee Pare & Associates (1980) have recommended the dredging of the upper ponds, including Roosevelt, Willow, and Polo Lakes. The application of copper sulfate was recommended in all of the ponds. The application of alum was recommended in Polo, Pleasure, and Deep Spring Lakes. Changes in park landscape management practices, especially those areas near the water's edge, were also recommended. These changes included the discontinuation of mowing in places and allowing these areas to revegetate naturally or replanting with native species. They also recommended areas be cleared of trees and replanted with shrubs, to reduce leaf litter in the park's ponds.

Lee Pare & Associates (1980) noted that, with the exception of the bison mound, all of the zoo wastewater drains are connected to the Providence sewer system. They reported that the trench around the bison mound often fills up with water during periods of high water table and during storms. Park personnel then pump the nutrient-rich wastewater into the pond. They recommended pumping the wastewater to a catch basin that directs flow into the sewer system. The park has since implemented this recommendation.

The Roger Williams Park Ponds were monitored by URI Watershed Watch volunteers in 1993, 1994, and from 2001 through 2003. Roosevelt and Pleasure Lakes, at the up-gradient end of the pond system, were monitored in 1993 and 1994. Cunliff Lake, near the down-gradient end of the pond system, was monitored in 2001-2003. The mean total phosphorus concentrations for Roosevelt and Pleasure Lakes, was 67 and 91 ug/l, respectively. The mean total phosphorus concentration for Cunliff Lake, was 83 ug/l. The mean total phosphorus concentration, averaged for all the separate basins, for the entire URIWW sampling period was 82 ug/l. Mean phosphorous concentrations were significantly higher in the summer than during the spring and early fall sampling periods (Table 3.5). The mean total phosphorous concentration in the summer was 109 ug/l. The mean concentrations for the spring and early fall were 72 ug/l and 58 ug/l, respectively. Although this mean summer concentration is extremely high, it is significantly lower than the 115-310 ug/l reported by Lee Pare and Associates in 1980. The closing of a major brewery at the headwaters of the watershed is the probable reason for the significant reduction in phosphorus loading to the park's ponds. It was estimated that the brewery discharged approximately 3.5 MGD of nutrient-laden water into Tongue Pond, which eventually feeds into the park's pond system.

Table 3. 5 Total Phosphorus Concentrations (ug/l) for Roger Williams Park Ponds.

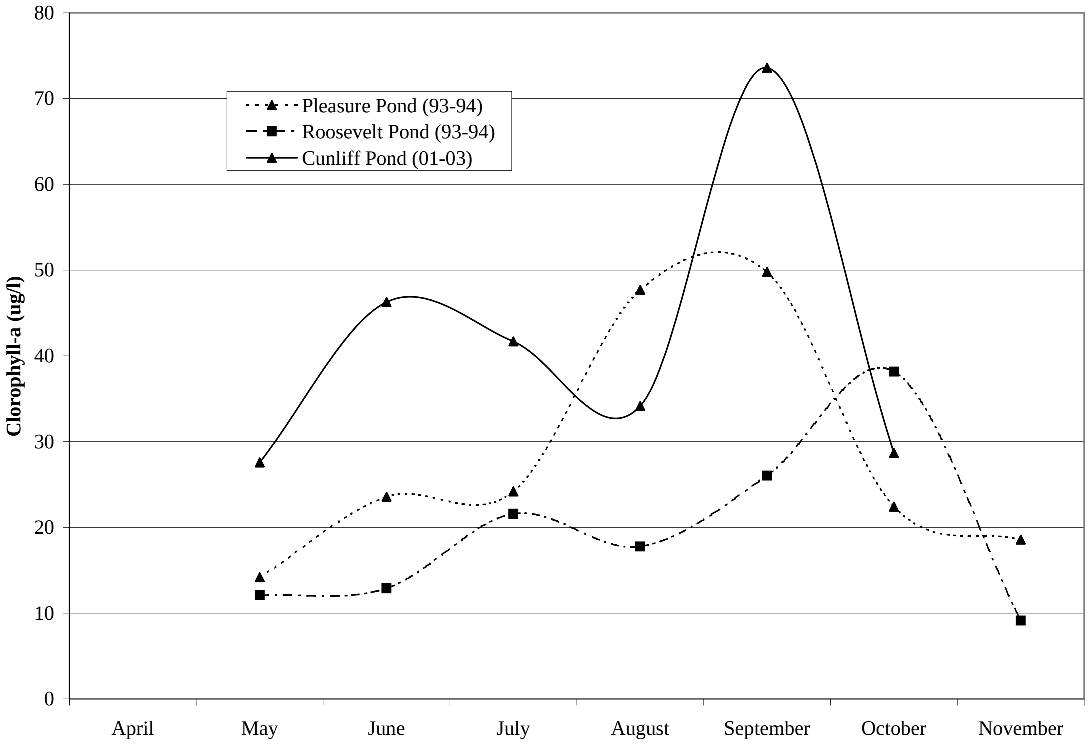
	Pleasure Pond			**Roosevelt Pond**			**Cunliff Pond**			**Mean**
	Spring	**Summer**	**Fall**	**Spring**	**Summer**	**Fall**	**Spring**	**Summer**	**Fall**	
1993	66	140	49		85	44				77
1994	80	143	92	56	85	65				87
2001							70	78	81	76
2002							31	122	40	64
2003							127	113		120
Mean	73	142	71	56	85	55	76	104	61	

The mean dissolved phosphorus concentration for the entire Roger Williams Park Ponds system was 21 ug/l. Although the mean dissolved phosphorus concentration is significantly less than that of the total phosphorus (82 ug/l), it is significantly higher than any other of the shallow ponds included in this study. The mean dissolved phosphorus concentration for Roosevelt and Pleasure Lakes was 12 and 15 ug/l, respectively. The mean dissolved phosphorus concentration for Cunliff Lake was 32 ug/l. Roosevelt and Cunliff Lakes registered peak seasonal mean dissolved phosphorus concentrations in the summer monitoring period. The mean summer dissolved phosphorus concentrations for Roosevelt and Cunliff Lakes were 18 and 64 ug/l. The mean seasonal dissolved phosphorus concentration in Pleasure Lake reached a peak of 26 ug/l in the fall monitoring season.

The mean chlorophyll-a concentration for the entire Roger Williams Park Ponds system, for the URIWW sampling period, was 29 ug/l. This mean concentration is well above the eutrophic threshold of 7.2 ug/l. The annual mean chlorophyll-a concentration ranged from 13 ug/l in 1993 to 57 ug/l in 2003 (Figure 3.4). The maximum recorded chlorophyll-a concentration was 101 ug/l.

RIDEM collected limited dissolved oxygen data in four of the ponds of the Roger Williams Park Ponds system during September and November of 1998 and in April and July of 1999. Samples were taken at an unknown depth. Dissolved oxygen concentrations in both Roosevelt and Elm Lakes remained above 5 mg/l during all four sampling events. The dissolved oxygen concentration in Pleasure Lake was below 5 mg/l in the fall of 1998 and fell below 3 mg/l in the summer of 1999. The dissolved oxygen concentration in Cunliff's Lake fell below 5 mg/l in November 1998 and below 3 mg/l in the early spring of 1999. Dissolved oxygen concentrations in Roosevelt and Elm Lakes may be higher since they are located at the inlet and outlet to the pond system and there may be more mixing of the water column. Pleasure and Cunliff's Lakes are located centrally within the pond system and may be characterized by lower flow velocities leading to low oxygen conditions during stagnant weather conditions.

Figure 3. 4 Monthly Mean Chlorophyll-a Concentration for Roger Williams Park Ponds (1993-2004).



The mean chlorophyll-a concentrations for Roosevelt and Pleasure Lakes in 1993 and 1994 were 23 and 28 ug/l, respectively. Roger Williams Parks has been treating all of its ponds with aquatic herbicides since at least 2000. The algae problem is most pronounced in the three upper ponds of the park pond system (Roosevelt, Willow and Pleasure). The herbicide is typically applied in late May. Despite this treatment, the limited data from Cunliff's Lake indicates that algal concentrations remain high. The mean chlorophyll-a concentration for Cunliff Lake was 39 ug/l. The dissolved phosphorus concentrations for both Pleasure and Cunliff's Lakes reached a peak in the month of September. The peak monthly mean dissolved phosphorus concentrations for Roosevelt Lake occurred in October.

3.6 Sand Pond

Sand Pond has been monitored by URIWW volunteers since 1995. Since it is a deep pond, parameters were measured at surface and at depth, where appropriate. Deep samples were taken at a depth of 7 m. The mean total phosphorus concentration for Sand Pond during the URIWW sampling period (1995-2003), was 64 ug/l. The mean concentration of total phosphorus for deep samples (113 ug/l) was significantly higher than the mean concentration of surface samples (24 ug/).

Total phosphorus concentrations at depth show the same patterns of seasonal fluctuations observed in most of the other deep ponds included in this study (Table 3.6). The total phosphorus concentration at depth increases throughout the monitoring season, with the biggest increase occurring between the spring and summer sampling periods. The average spring total phosphorus concentration at depth was 58 ug/l. The total phosphorus concentration increased to 136 ug/l and 156 ug/l in the summer and early fall, respectively. Inspection of Table 3.6 appears to show that total phosphorus concentrations at depth have increased dramatically since 1999. One possible explanation is that the bottom sediments have recently become anoxic and are now a new source of phosphorus into the water column. Changes in water quality could ultimately be caused by fluctuating numbers of resident waterfowl and/or unknown changes in land use due to redevelopment.

Table 3. 6 Total Phosphorus Concentrations (ug/l) for Sand Pond at Surface and Depth.

	Surface (1m)				**Bottom (7m)**			
	Spring	**Summer**	**Fall**	**Mean**	**Spring**	**Summer**	**Fall**	**Mean**
1995	16	22	30	23				
1996	13	21	16	17	29	65	19	38
1997	22	20	20	21		19	22	21
1998	23	28		26	56	20		38
1999	20	26		23	23	40		32
2000	27	32		30	150	307		229
2001	19	17	21	19	21	73		47
2002	22	31	40	31	17	94	263	125
2003	22	32	27	27		532	349	441
2004	27	29	26	27	112	74	126	104
Mean	21	26	26		58	136	156	

Sand Pond is the only deep pond included in this study in which the total phosphorus concentration at the surface was not the lowest in the summer. Surface total phosphorous concentrations for Sand Pond are lowest in the spring and increase significantly by summer. In the spring, the average phosphorus concentration at the surface was 21 ug/l. This increased to 26 ug/l in the summer and early fall. There appears to be a trend of slightly increasing surface total phosphorus concentrations over the 10-year monitoring period, particularly in the spring and summer.

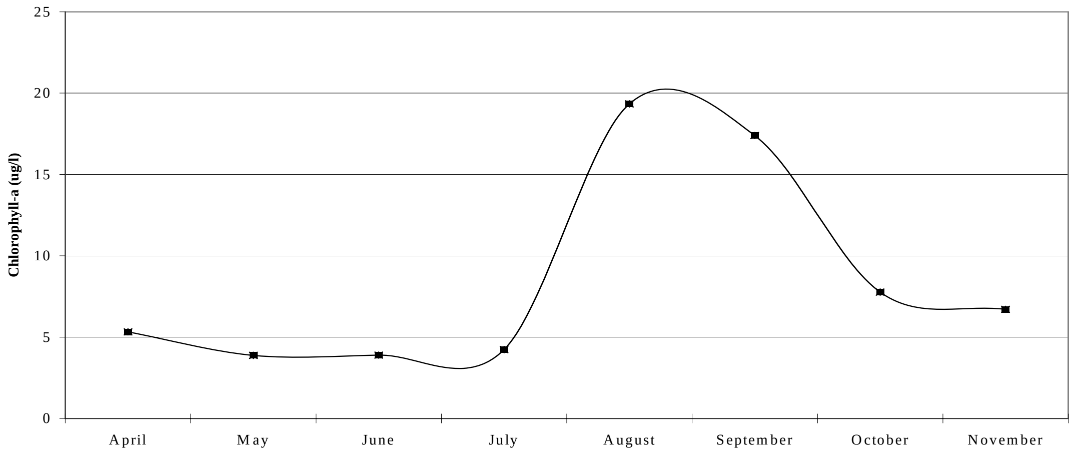
Dissolved phosphorus concentrations displayed many of the same trends as those exhibited by total phosphorus. The mean dissolved phosphorus concentration at the surface averaged over the 10-year monitoring period was 5 ug/l, an order of magnitude less than the mean concentration at depth. The dissolved phosphorus concentration at the surface was most often below detection levels, but reached a maximum of 27 ug/l in the spring of 2004. The mean concentration of dissolved phosphorus at the surface was 8 in the spring and 4 in both the summer and early fall. There appears to be a trend of increasing dissolved phosphorus concentrations at the surface in the spring, but not later in the monitoring season.

The mean dissolved phosphorus concentration at depth, averaged over the ten-year monitoring period, was 54 ug/l. The mean concentration of dissolved phosphorus at depth was 31 and 30 ug/l in the spring and summer, increasing to 144 ug/l in the fall. Dissolved phosphorus concentrations at depth appear to have increased dramatically since 2000, and reached a maximum of 297 ug/l in the fall of 2003.

URIWW data from 2000 through 2004 suggests a trend of decreasing dissolved oxygen concentrations in the hypolimnion of Sand Pond. URIWW measured dissolved oxygen levels in Sand Pond at a depth of 6-7 meters. Dissolved oxygen concentrations in the hypolimnion of Sand Pond tend to fluctuate more than in the hypolimnia of the other three deep ponds included in this study. In 2003 and 2004 hypolimnion waters of Sand Pond were generally below the 3 mg/l threshold for the entire monitoring season (early May through October). In 2002 the dissolved oxygen concentration was below 5 mg/l for the entire monitoring season, falling below 3 mg/l from late May through October. In 2000 the dissolved oxygen concentration in the hypolimnion did not drop below the 3 mg/l threshold until early-mid June. In 2001 the dissolved oxygen concentration in the hypolimnion remained above the 3 mg/l threshold until mid-September. Dissolved oxygen concentrations are generally below the detection limit from mid-September through October in most years. In 2002 levels were also below the detection limit for much of the late summer. In 2003 dissolved oxygen concentrations were below the detection limit intermittently in the early spring and in the mid-late summer as well as the early fall. Summer and fall total phosphorus concentrations in the hypolimnion were highest in 2003, probably due to the prolonged anoxic conditions. Dissolved oxygen concentrations in the hypolimnion were above the detection limit for the entire monitoring season in 2001 and only fell below the detection limit once in 2004, in mid August. The relatively higher oxygen concentrations in the hypolimnion in 2001 and 2004 are probably responsible for the lowest summer phosphorus concentrations in the hypolimnion during the 2000-2004 period.

The mean chlorophyll-a concentration of Sand Pond from 1995 through 2004 was 9 ug/l. The Monthly mean chlorophyll-a concentration reaches a peak of 19 ug/l in August (Figure 3.5). The annual mean chlorophyll-a concentration ranged from 3 ug/l in 1997 and 2001 to 21 ug/l in 2000 and 2002. The chlorophyll-a concentration reached a maximum of 119 ug/l in September of 2002. There appears to be no long-term trend in chlorophyll-a concentrations, despite the trend of increasing phosphorus concentrations over the ten-year monitoring period. Assimilation of phosphorus by dense aquatic macrophytic growth in the eastern basin of the pond may be the reason for the lack of algae growth in response to increasing phosphorus concentrations in the main basin.

Figure 3. 5 Monthly Mean Chlorophyll-a Concentration for Sand Pond (1995-2004).



3.7 Spectacle Pond

Spectacle Pond has been monitored by URI Watershed Watch volunteers since 1999. The mean total phosphorus concentration for Spectacle Pond during the URIWW sampling period was 57 ug/l. The average phosphorus concentration remains fairly constant throughout the monitoring season (Table 3.7).

The average total phosphorus concentration in spring was 50ug/l, increasing to 62 ug/l and 61 ug/l in the summer and fall, respectively. Summer phosphorus concentrations appear to be decreasing slightly over the five-year monitoring period. The drop in summer phosphorus concentrations may be due to the shutdown of a large brewery operation in the early 1980's that previously discharged phosphorus-laden waters into Tongue Pond, which is located upgradient of Spectacle Pond and is connected to it by a manmade ditch. Some of the phosphorus discharged from the brewery was undoubtedly adsorped to the sediments of both Tongue and Spectacle Ponds. Through the passage of time much of this sediment-bound phosphorus is probably seasonally released to the water column through internal cycling (discussed in greater detail in section 4.7), reducing the amount of sediment-bound phosphorus available for release to the water column year over year.

Table 3.7 Total Phosphorus Concentrations (ug/l) for Spectacle Pond.

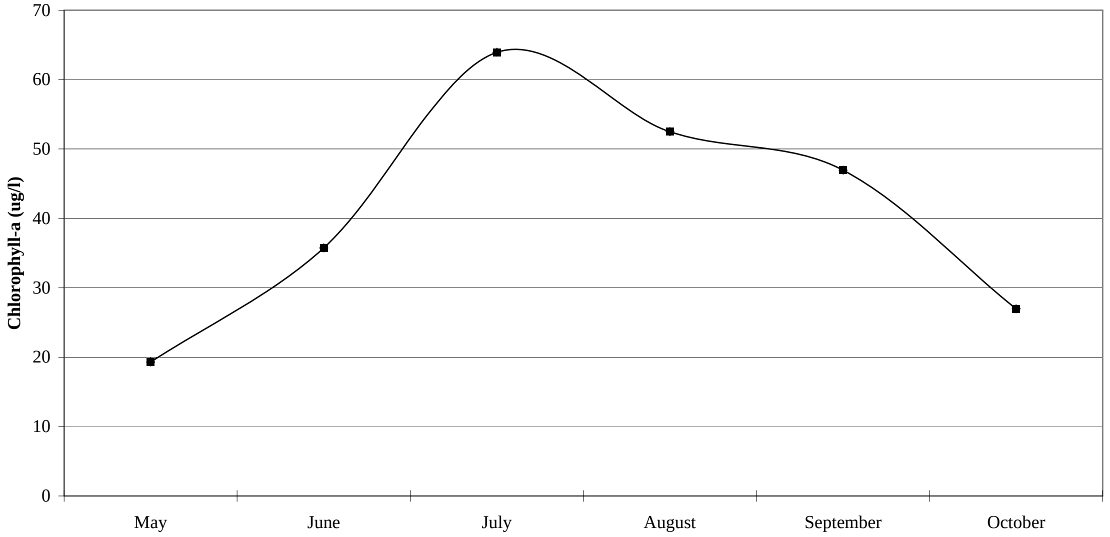
	Spring	**Summer**	**Fall**	**Mean**
1999	47	64	62	58
2000	70	81	61	71
2001	37	61	45	48
2002	58	69	49	59
2003	45	39	86	57
2004	42	56	61	53
Mean	50	62	61	

The mean dissolved phosphorus concentration for Spectacle Pond during the URIWW sampling period was 6 ug/l. Most of measurements for dissolved phosphorus were below the detection limit. The dissolved phosphorus concentration remains fairly constant through the spring and summer, increasing somewhat in the fall. The mean dissolved phosphorus concentration was 5 ug/l and 4 ug/l in the spring and summer, respectively. The mean dissolved phosphorus concentrations increased to 9 ug/l in the fall. There appears to be no discernable trend in dissolved phosphorus concentrations over the five-year monitoring period.

Spectacle Pond was sampled for dissolved oxygen on July 28, 2004 by RIDEM staff. Dissolved oxygen concentrations were measured a depth of 4 meters in three separate areas of the deepest part of the pond, located at its southern end. Concentrations were between 1.2 and 1.5 mg/l. Oxygen concentrations at the same locations 1 meter below the surface were between 5.4 and 5.6 mg/l. Low oxygen conditions at the bottom of Spectacle Pond may result in the release of phosphorus from the sediment.

The mean chlorophyll-a concentration of Spectacle Pond from 1999 through 2004 was 42 ug/l. The annual mean chlorophyll-a concentration ranged from 34 ug/l in 2004 to 56 ug/l in 2000. The monthly mean chlorophyll-a concentration reaches a peak of 64 ug/l in July (Figure 3.6). The chlorophyll-a concentration reached a maximum of 137 ug/l on July 7, 2003. There appears to be a long-term trend of decreasing chlorophyll-a concentrations over the five-year monitoring period.

Figure 3. 6 Monthly Mean Chlorophyll-a Concentration for Spectacle Pond (1999-2004).



3.8 Upper Dam Pond

Only limited monitoring data is available for Upper Dam Pond. The pond was monitored by URI Watershed Watch volunteers from May 1999 through July 2000 and again in 2004. The mean total phosphorus concentration for Upper Dam Pond during the URIWW sampling period was 42 ug/l (Table 3.8). The limited data indicate that the average total phosphorus concentration in the spring is 39 ug/l, increasing to 79 ug/l during the summer and then decreasing dramatically to 11 ug/l by early fall.

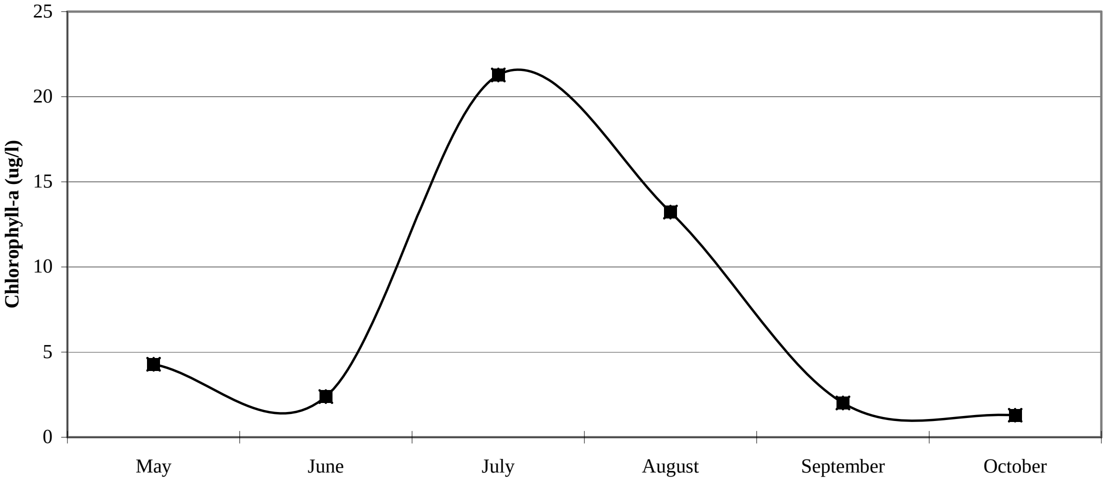
Table 3. 8 Total Phosphorus Concentrations (ug/l) for Upper Dam Pond.

	Spring	Summer	Fall	Mean
1999	21	94	8	41
2000	81			81
2001				
2004	15	63	13	30
Mean	39	79	11	

Five of the six measurements for dissolved phosphorus were below the detection limit. The dissolved phosphorus concentration in July of 2004 was 48 ug/l. Except for Roger Williams Park Ponds, this is the highest dissolved phosphorus concentration recorded in any of the ponds included in this study.

The mean chlorophyll-a concentration of Upper Dam Pond, during the limited monitoring period, was 6 ug/l. The monthly mean chlorophyll-a concentration reaches a peak in July (Figure 3.7). The annual mean chlorophyll-a concentration was 12 ug/l in 1999 and only 3 ug/l in 2004. The chlorophyll-a concentration reached a maximum of 46 ug/l in August of 2004.

Figure 3. 7 Monthly Mean Chlorophyll-a Concentration for Upper Dam Pond (1999-2004).



3.9 Warwick Pond

Warwick Pond has been monitored by URI Watershed Watch volunteers since 1995. Since it is a deep pond, parameters were measured at surface and at depth, where appropriate. Deep samples were taken at a depth of 5.5 m. The mean total phosphorus concentration for the URIWW sampling period (1995-2004) was 27 ug/l, only slightly higher than the state criteria of 25 ug/l. Like most of the other deep ponds included in this study, the total phosphorus concentrations at the surface are generally lowest in the summer (Table 3.9). The mean total phosphorus concentration at the surface during the spring is 35 ug/l. The mean phosphorus concentration decreases to 27 ug/l in the summer, and rebounds to 32 ug/l in the early fall.

Table 3. 9 Total Phosphorus Concentrations (ug/l) for Warwick Pond at Surface and at Depth.

	Surface (1m)				Bottom (5.5 m)			
	Spring	**Summer**	**Fall**	**Mean**	**Spring**	**Summer**	**Fall**	**Mean**
1995	21	20	40	27				
1996	29	32	22	28	21	6	18	15
1997	30	29	36	32	31	20	35	29
1998	48	29	22	33	8	15	24	16
1999	38	16	37	30	26	5	34	22
2000	38	27	23	29	37	5	18	20
2001	31	36	43	37	24	16	38	26
2002	30	24	36	30	29	23	39	30
2003	35	24	38	32	19	27	16	21
2004	47	32	23	34	39	10	10	20
Mean	35	27	32		26	14	26	

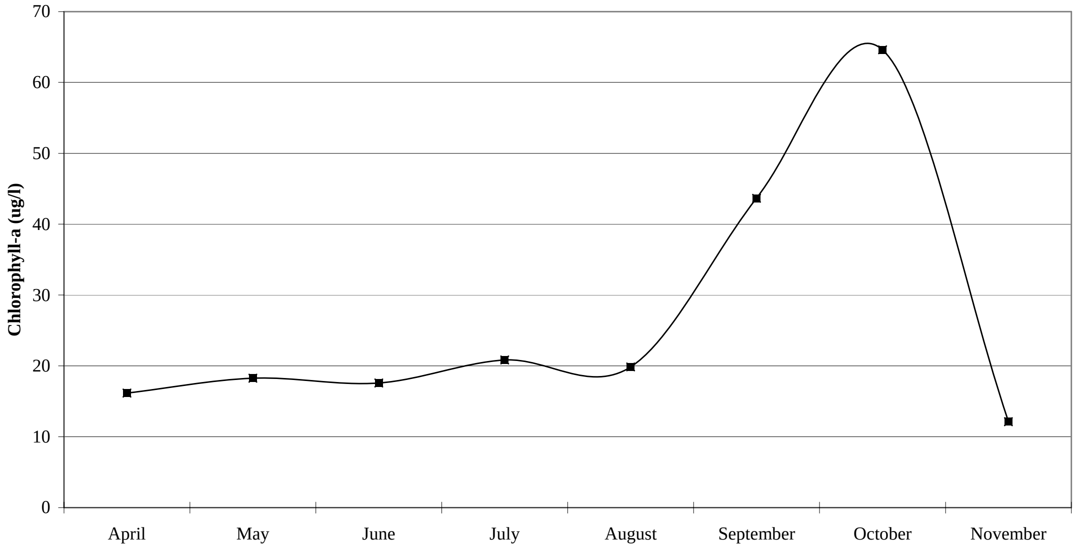
Unlike all the other deep ponds, the mean concentration of total phosphorus for deep samples (22 ug/l) was significantly less than the mean concentration of surface samples (31 ug/). Also, total phosphorus concentrations at depth do not increase dramatically by the summer as observed in all the other deep ponds included in this study. In fact, total phosphorus concentrations at the bottom of Warwick Pond mimic seasonal fluctuations at the surface and are generally lowest in the summer. It appears that the bottom sediments of Warwick Pond are not a major source of phosphorus into the water column.

The mean dissolved phosphorus concentration for Warwick Pond both at the surface and at depth during 1995-2004 time period was 4 ug/l. The vast majority of measurements for dissolved phosphorus were below the detection limit. Dissolved phosphorus concentrations both at the surface and at depth were highest in the summer. However, the mean dissolved phosphorus concentration both at the surface and at depth was only 5 ug/l in the summer months. Unlike all the other deep ponds studied, there was no dramatic increase in dissolved phosphorus concentrations at depth in the summer and early fall.

Dissolved oxygen data from 2000 through 2004 shows that the hypolimnion of Warwick Pond is anoxic for most of the summer. URIWW measured dissolved oxygen levels in Warwick Pond at a depth of 5.5-6 meters. Dissolved oxygen concentrations in the hypolimnion waters fell below 5 mg/l in early May to early June and typically remained below 5 mg/l until late September to early October. The dissolved oxygen levels typically fell below 3 mg/l by early to mid June and remained below this threshold until early to late September. Dissolved oxygen concentrations were below the detection limit by late June to mid September and remained so until early to late September. Despite the prevalent anoxic conditions for most of the summer, examination of the phosphorus data indicates that phosphorus is not being released from the sediment as it is in the three other deep ponds included in this study. The reason for this is not clear.

The mean chlorophyll-a concentration of Warwick Pond from 1995 through 2004 was 29 ug/l. The monthly mean chlorophyll-a concentration reaches a peak of 65 ug/l in October (Figure 3.8). The annual mean chlorophyll-a concentration ranged from 13 ug/l in 1998 to 56 ug/l in 2003. The chlorophyll-a concentration reached a maximum of 153 ug/l in October of 2003.

Figure 3. 8 Monthly Mean Chlorophyll-a Concentration for Warwick Pond.



4.0 POLLUTION SOURCES

4.1 Overview

Similar pollution sources affect most of the eutrophic ponds included in this study. Sources of phosphorus are both external and internal (nutrient recycling from the lake sediment). The most significant external source for most of the ponds is stormwater runoff. Fecally-derived nutrients from waterfowl and other wildlife are also a significant external source for most of the ponds. Other possible external sources may include wastewater and erosion/sedimentation and to a lesser extent atmospheric deposition. The release of phosphorus from pond sediments is the major internal source of phosphorus.

Sections 4.2 through 4.7 present an overview of likely sources of phosphorus to these eutrophic ponds. Sections 4.8 through 4.16 provide more detail on specific sources to each waterbody.

4.2 Stormwater Runoff

Stormwater runoff is a major source of total phosphorus in urban environments. Lee and Jones-Lee (1995) stated that urban stormwater runoff contains about 100 times the total concentrations of phosphorus that are typically derived from stormwater runoff from forested areas. Sampling conducted as part of a TMDL for Mashapaug Pond, located only 450 meters down-gradient of the outlet of Spectacle Pond, found that stormwater was a significant source of total phosphorus. Total phosphorus concentrations measured from six stormwater outfalls discharging to Mashapaug Pond ranged from maximum values at first flush of between 17 and 205 mg/l.

In another study, mean total phosphorus concentrations in stormwater runoff in two urban southern Wisconsin watersheds were measured between 140 and 2370 ug/l (Waschbusch et al., 1999; Browman et al., 1979). Waschbusch et al. (1999) determined that lawns and streets were the largest sources of total phosphorus in the watersheds, with lawns contributing more than streets. The street fraction of the phosphorus load was associated with sediment, and to a lesser extent leaf litter. Browman et al. (1979) found that the highest dissolved phosphorus concentrations occurred in the fall and spring, coinciding with leaf and tree seed fall, respectively.

As part of this Eutrophic Ponds TMDL, stormwater outfalls discharging directly to the ponds, tributaries, and hydrologically connected wetlands were identified. A complete shoreline survey of eight of the nine ponds was conducted. Because of the size of its watershed, North Easton Pond was the only waterbody for which a complete shoreline survey was not conducted. Only the shoreline and immediately adjacent areas were inspected for North Easton Pond to try to identify any outfalls discharging directly to the pond, of which none were found. For the remainder of the waterbodies where a complete shoreline survey was conducted, roadways adjacent to the waterbodies, any tributaries, and hydrologically connected wetlands were also investigated to identify low-lying catch basins. Each of these catch basins was inspected to determine if there was an associated outlet to the waterbody. Outfalls were located with a handheld GPS unit and pipe diameters were measured. Outfalls were prioritized for implementation mainly by pipe diameter, deducing that the culverts were sized according to their drainage areas and the amount of impervious area within the associated catchments. Therefore, the vast majority of outfalls targeted as significant sources are greater than 24 inches in diameter. The presence of sedimentation, scouring, dry weather flows, odor, staining, and raccoon sign elevated the prioritization of any given outfall. The prioritization was downgraded if there was evidence that the pipe conveyed significant flow from a tributary or wetland in contrast to stormwater or if the outfall was connected to a water quality structure. Appendix A shows outfall locations mapped on aerial photographs of the watersheds of each of these eutrophic ponds. Appendix B lists all the outfalls for each of the ponds and provides outfall diameters, latitude and longitude, location descriptions, and any comments associated with the outfalls, including the prioritization factors mentioned above and also provides information on blockages of culverts or nearby catch basins. Areas of concentrated surface flows from parking lots and roadways into the ponds, tributaries, or hydrologically connected wetlands are shown in Appendix A and are also listed in Appendix B.

4.3 Waterfowl and Other Wildlife

Fecally derived nutrients have the potential to enrich surface water and thus contribute to the process of eutrophication. There have been a significant number of papers published examining how nutrients from both migratory and resident bird populations can effect water quality and speed the process of cultural eutrophication (Manny et al, 1994; Moore et al. 1998; Purcell, 1999; Portnoy, 1990; Kitchel et al., 1999, and Bland et al., 1996). Even in small numbers, larger waterfowl like geese are likely a significant source of phosphorus. However, studies have shown that the impact of fecally derived nutrient loadings to waterbodies from birds varies with: bird species, bird population density, feeding habits, dilution capacity of the waterbody, and time of year.

In urban and suburban areas throughout Rhode Island, shoreline home development with widespread lawns on lakes and ponds, lack of natural predators, limited hunting, and supplemental feeding have created an explosion in resident waterfowl numbers. Resident and migratory waterfowl can create many problems including excessive nutrient loading to lakes and ponds. Most of the nutrient problems are derived from excessive populations of Canada geese, but ducks, gulls, and swans may be a significant source in some areas.

Manny et al. (1994) estimated that an individual waterfowl contributed approximately 8.2×10^{-3} kg/yr to a lake in southwestern Michigan, mostly during their migration. This is equivalent to 70% of all P that entered the lake from external sources. Manny et al. estimated the annual phosphorus loading per individual Canada goose. This estimate ranged from 0.028 kg/yr (Manny et al., 1975) to 0.179 kg/yr (Manny et al., 1994). At this loading rate, they thought it reasonable to assume that 2100 Canada geese were a significant source of phosphorus to a 15-hectare pond. Portnoy (1990) determined that approximately 42% of phosphorus loading in a Cape Cod pond was attributable to gulls. Migrating geese increased the total phosphorus loading rate in some wetland ponds at the Bosque del Apache National Wildlife Refuge in New Mexico by as much as 75% (Kitchel et al.). Chlorophyll levels increased in proportion to bird densities. Although the eutrophic ponds included in this study have small populations of waterfowl relative to typical wildlife refuges, most of the waterfowl is resident and not just present a few weeks a year. J.K. Bland (1996) reported that 52% of the annual phosphorus budget of Green Lake in Seattle could be traced to waterfowl.

It is difficult to estimate the waterfowl populations that frequent the eutrophic ponds included in this study. In most instances, waterfowl numbers were estimated based on only one day’s observations, and the actual population may differ significantly from the population that was observed on that particular day. However, assuming the more conservative estimate of phosphorus loading of 0.179 kg/yr (Manny et al., 1994) and assuming that all the water birds observed at the eutrophic ponds contributed loads equivalent to geese and that all birds were year-round residents, it is reasonable to assume that water fowl and other birds may be a significant source of phosphorus to some of the ponds.

4.4 Wastewater

Failing septic systems may be a source of phosphorous to receiving waters. Phosphorus from failing individual septic systems is typically adsorped to soil particles within close proximity of the failing system and is not generally found dissolved in groundwater. However, failing systems adjacent to waterbodies, particularly those with surface breakouts, could be a significant source of phosphorus to receiving waters. Illicit tie-ins to storm water systems are probably the most significant potential source of phosphorus associated with failed systems.

Leaking sewer pipes, cross-connections, and force mains are another potential source of phosphorus to these eutrophic ponds. Although groundwater tends to leak into half-empty pipes in up-gradient portions of sewered areas, sewers may be completely full in lower areas and the resulting head differential may force wastewater into the surrounding soil and may even result in a surface breakout. Such breakouts are more likely to occur during storm events and are of particular concern where the sewer system is in close proximity to receiving waters. Force sewer mains are also a significant potential source of phosphorus since wastewater is under pressure. Any leaks in the system would result in the discharge of wastewater into the ground.

The Minnesota Pollution Control Agency (2000) measured phosphate concentrations in ground water in low-high density unsewered residential developments. Phosphate concentrations were generally below 50 ug/l. The maximum concentration was 170 ug/l and only five of 76 samples exceeded 50 ug/l. Phosphate concentrations in septic plumes approached background levels within 40 feet of the system, even in very old systems (MPCA, 1999a).

The USGS has been investigating the subsurface transport of phosphorus introduced by the disposal of treated sewage effluent to ground-infiltration disposal beds at the Massachusetts Military Reservation on Cape Cod. McCobb et al. (2003) recorded ground water dissolved phosphorus concentrations near Ashumet Pond as high as 3000 ug/l near the pond's shoreline and greater than 5000 ug/l of phosphorus farther upgradient. McCobb et al. (2003) found that contaminated ground water contributed as much as 316 kilograms per year of phosphorus to a down-gradient pond. However this scale of loading is probably atypical of individual septic systems. Keyes Associates et al. (1982) estimated that 16% of the phosphorus load to Gorton Pond was due to groundwater recharge, ostensibly from septic systems.

4.5 Streambank and Shoreline Erosion

Streambank and shoreline erosion of phosphorus-containing soils is also a likely source of phosphorus to many of the ponds addressed by this TMDL. Shorelines can erode through many processes. Natural causes of erosion include currents, waves, ice, and rain. Many human activities may significantly increase the rate of erosion. Some common causes include:

- removal of natural vegetation for property development or creation of beaches, both on shore and in the pond;
- improper installation of erosion control structures;
- increased wave action from watercraft traveling close to the shore;
- dredging, filling, or construction on or near the shoreline;
- trampling of banks by human, animal, or vehicle traffic; and
- inadequate protection against stormwater run-off from roofs, driveways, streets, and other developed areas.

Causes of shoreline erosion may differ due to location on the pond, water level changes, and season. Shorelines affected by wind-driven waves and ice damage will be predisposed to more erosive forces. The shallow water zone along the shoreline may dry out and flood seasonally due to natural or controlled fluctuations in lake levels.

DEM staff have observed shoreline erosion on a few of the ponds, particularly Brickyard Pond and North Easton Pond, and to a lesser extent Roger Williams Park Ponds.

Streambank erosion can contribute phosphorus to surface waters and ultimately, receiving waterbodies. Streambank erosion is a dynamic and natural process as streams meander across the landscape. The importance of streambank erosion relative to other nonpoint sources of sediment and phosphorus can be highly variable between stream reaches. Eroded sediment can contribute a significant portion of the phosphorus loads within a watershed, particularly where the soil is fine-grained. Sekely et al. studied the effect of slumping stream banks on phosphorus loading in the Blue Earth River in Minnesota. The percentage of the TP load originating from stream bank slumping was estimated to be from 7% to 10%.

In many places the rate of streambank erosion has increased markedly. The primary reason for this, within the study areas, is extensive clearing of natural vegetation from catchments for urban development. This has resulted in rainfall moving off the land surface at a much faster rate. These increased flows put pressure on stream channels that can no longer contain flood peaks, and bank erosion (as well as bed erosion) is one result. The second factor is the widespread removal of native riparian vegetation along streambanks, primarily through deliberate clearing for development. This weakens the ability of streambanks to resist the erosive forces of increased flood flows and results in eroding streambanks becoming a common feature in many of the eutrophic pond tributaries.

Bank erosion can be pronounced at road-stream crossings, particularly if culverts are undersized. Undersized culverts increase stream velocities, promoting scouring on the downstream side.
Erosion at road-stream crossings, and along streambanks in general, can be quantified using the lateral recession rate method developed by the Natural Resources Soil Conservation Service (NRCS).

Erosion from construction sites can be a significant source of phosphorus to nearby waterways, particularly where the soil is fine-grained. These soils are more erosion-prone and also tend to have higher cation exchange capacities and therefore more adsorped phosphorus. Due to these high erosion rates (lack of vegetation) and high delivery rates (efficient ditches and storm sewers), construction sites were found to be by far the largest source of sediment polluting the water resources of Wisconsin. From an average construction site, 30 tons of sediment per acre is eroded into nearby waterways (Wisconsin DNR, 2006).

4.6 Atmospheric

Atmospheric phosphorus loads are typically divided into wet and dry deposition. Observations of concentrations in rainwater are frequently available, and dry deposition is usually estimated as a fraction of the wet deposition. Wet deposition is typically associated with dissolved substances in rainfall. The settling of particulate matter during non-rainfall events contributes to dry deposition. Ullman et al. (2005) reported that the atmospheric phosphorus load was approximately 3-5% of the total annual phosphorus load to Delaware's inland bays. Wet and dry deposition phosphorus loads were 1.2-1.9 mg/m^2/year and 2.6-5.4 mg/m^2/year, respectively. The atmospheric deposition rates for phosphorus were reported in the Long Island Sound Study (Hydro Qual, 1991) and the Chesapeake Bay Model Study (Cerco and Cole, 1993). The dry atmospheric deposition was 26.7 mg/m^2/year and the wet deposition concentration was 0.061 mg/l.

4.7 Internal Loading

Internal loading, the release of phosphorus from lake sediments, can play an important role in the phosphorus dynamics of lentic systems. Internal phosphorus loading originates from a pool of phosphorus accumulated in the lake sediment. The ultimate source of most of the sediment-bound phosphorus is external (e.g. stormwater). Under certain conditions this sediment-bound phosphorus can be released into the water column resulting in elevated phosphorus concentrations and algal blooms. In some cases, the majority of the phosphorus load to a waterbody can be due to internal loading.

Phosphorus concentrations at the surface and at depth were typically similar in the spring for most of the deep ponds studied, reflecting the physical mixing that occurs in the spring whereby nutrient rich bottom waters are mixed with surface water. After the ponds become thermally stratified in the summer and early fall, oxygen at depth typically becomes depleted because of the decay of organic matter in the sediment and also from the decay of recent algal die-off. The hypolimnion of deep ponds is typically isolated from aerobic surface waters in the summer and early fall, with little occurrence of vertical mixing. Anoxic conditions in the pond sediments favor the release of phosphorus. Along with the release of phosphorus from pond sediments, the addition of phosphorus from the sinking of inorganic particulates and organic material results in a steady increase in dissolved phosphorus in the hypolimnion. Phosphorus concentrations at depth tend to increase dramatically in the summer and early fall, as observed for most of the deep eutrophic ponds included in this study. Søndergaard et al. (1993) found that in a Danish lake phosphorus release mainly occurred from April to October, with little or no phosphorus release occurring during the winter.

Significant amounts of phosphorus in lake sediments may be bound to redox-sensitive iron compounds or fixed in more or less labile organic forms (Søndergaard, 2003). Jensen and Anderson (1992) have shown that iron-bound phosphorus, when present in significant proportions in the sediment, may be a major source for internal phosphorus loading in shallow, eutrophic lakes, just as it may be in deeper, stratified lakes. These phosphorus compounds are potentially mobile and may eventually be released to the lake water once bottom waters become anoxic in the summer, although phosphorus release from the sediment has also been recorded in oxic waters.

Two different mechanisms have to occur nearly simultaneously to result in the release of phosphorus from the sediment. Firstly, phosphorus bound to particles or aggregates in the sediment must be mobilized by being transferred to the pool of dissolved phosphorus (primarily phosphate) in the pore water. Secondly, processes which transport the dissolved phosphorus to the lake water must function. Important mobilization processes are desorption, dissolution, ligand exchange mechanisms, and enzymatic hydrolysis. These processes are affected by a number of environmental factors, of which redox potential, pH and temperature are the most important. Essential transport mechanisms include diffusion, wind-induced turbulence, bioturbation (the disturbance of the bottom sediments by aquatic organisms) and gas convection. Redox-controlled dissolution and diffusion are considered as the dominant mechanisms for phosphorus release from stagnant hypolimnetic bottom areas of deep lakes. All the mobilization and transport processes can theoretically contribute to the overall phosphorus release from sediments in shallow lakes.

Pore water chemistry, especially the Fe:P ratio, can have a significant effect upon the mobility of sediment-bound phosphorus. Jensen et al. (1992) found that internal cycling from aerobic sediments from fifteen Danish lakes was suppressed by Fe:P ratios above 15 (by weight). No correlation was found between the water column total phosphorus concentration and sediment phosphorus concentration alone. Conversely, very high internal loading rates (20-50 mg/m^2/d) have been observed in shallow lakes with low Fe:P ratios, wind mixing/resuspension and high pH (Welch and Cooke, 1995). Phillips et al. (1994) measured higher phosphorus release rates during periods when sulphide from sulphate reduction removed iron [FE(II)] from the sediment pore water.

Although the release of sediment-bound phosphorus is enhanced by anoxic bottom conditions, phosphorus is also released from lake sediments to well aerated water more typical of shallow lakes. Holdren and Armstrong (1980) per Fricker (1981) quoted literature values of sediment phosphorus release rates from several lakes in the United States for aerobic (0 to 13 mg/m^2/day) and anaerobic conditions (0 to 50 [max. 150] mg P mg/m^2/day). Welch and Cooke (1995) reported very high internal loading rates (20-50 mg/m^2/d) in shallow lakes characterized by wind mixing/resuspension. Søndergaard et al. (1992) reported that the rate of phosphorus release from the undisturbed sediment of a shallow eutrophic Danish lake during the summer was 4-12 mg/m^2/day. This rate increased to 150 mg/m^2/day during simulated resuspension events. Phillips et al. (1994) recorded sediment phosphorus release rates as high as 278 mg/m^2/d, in very shallow lakes in the United Kingdom.

While shallow lakes are generally well mixed, they may become weakly or intermittently stratified, resulting in anoxic conditions in the bottom waters. Riley and Prepas (1984) studied two shallow intermittently-stratified lakes in Alberta and found that during periods of stratification water directly overlying sediments was anoxic and total phosphorus increased in deep water, with the sediments being the major source of total phosphorus. After eight of nine mixing events that immediately followed stratified periods, total phosphorus in the surface water increased by 3-52%.

Although hypolimnetic waters of deep lakes are generally stratified in the summer and early fall, thorough mixing of the entire water column may occur during storm events. Soranno et al. (1997) investigated internal phosphorus loading in Lake Mendota, a deep stratified eutrophic lake in Wisconsin during a summer of average rainfall (1992) and a summer of higher than average rainfall (1993). Internal loading accounted for approximately 90% of total phosphorus loading during the wet summer and only 50% during the average summer. Inter-annual variability in internal loading was attributed to a combination of water column stability and weather.

The level of phosphorus concentrations in the water column influences the length of time that phosphorus is released from the sediment. Søndergaard et al. (1999) found that in shallow eutrophic Danish lakes, with total phosphorus concentrations below 100 ug/l, phosphorus was retained in lake sediments for most of the year, except July and August when mean internal loading accounted for 10-30% of external loading. In lakes with total phosphorus above 100 ug/l, phosphorus was retained in lake sediments during the winter but released from April to September.

Experience gained in various lake restoration projects suggests that the history of accelerated eutrophication, that is, the length of time the lake has been eutrophied, has an important bearing on lake behavior with respect to internal loading and phosphorus retention in the sediments. Sediments remain oligotrophic and only become gradually eutrophic, long after the water mass becomes highly eutrophic (Schindler *et al*). Conversely, the highly eutrophic sediment would remain eutrophic long after the external load is reduced and would thus delay the recovery of the lake. In some shallow highly eutrophied lakes with a long history with eutrophication (Ryding and Forsberg), 22 to 400% of the external phosphorus load was released from the sediments after reduction of the external load.

The contribution of internal loading to the total phosphorus load has been quantified in several studies. Keyes Associates et al. (1982) reported that the sediment was the major source of phosphorus to Gorton Pond, contributing 54% of the phosphorus load. In 14 of 17 Washington lakes, where phosphorus budgets were available and internal loading was measurable, internal loading averaged 68% of the total phosphorus loading during the summer (Welch and Jacoby, 2001). Internal phosphorus loads accounted for between 56 and 66% of the total phosphorus load to Spring Lake in southwestern Michigan (Steinman and Rediske, 2003).

With the exception of Warwick Pond, the phosphorus data for the deep eutrophic ponds (over 5 m in depth) included in this study strongly suggest that phosphorus release from the sediments is a major source of the total phosphorus loading. The remaining deep ponds, including Brickyard, Gorton and Sand Ponds, all have elevated phosphorus concentrations in bottom waters relative to surface concentrations during periods of stratification. As previously discussed, stratification results in anoxic conditions in the bottom waters that are conducive to the release of phosphorus from lake sediments. Stratified lake waters cause dissolved phosphorus, released from the sediment, to build up in the hypolimnion. The temperature differential at the thermocline creates a barrier that traps most of the dissolved phosphorus in the hypolimnion and prevents it from reaching the epilimnion. During periods of stratification, total phosphorus concentrations in the bottom waters in the summer and early fall were frequently an order of magnitude greater than concentrations at the surface. The difference between dissolved phosphorus concentrations at the surface and at depth is even more pronounced.

Indirect evidence also indicates that the release of sediment phosphorus is also a significant source in all of the shallow ponds. Phosphorus concentrations in shallow lakes were only measured at the surface and not at the bottom. Therefore there is no direct evidence that the release of phosphorus from sediment occurs in the shallow lakes included in this study. However, all of the shallow eutrophic ponds including Almy, North Easton, Roger Williams Park, Spectacle, and Upper Dam Pond, show significant increases in water column total phosphorus from the spring to the summer. Urban runoff, the main source of external phosphorus to most of the lakes, is typically highest in the spring and lowest in the summer. If internal cycling was not a significant source of phosphorus to the eutrophic ponds, one would expect the total phosphorus concentrations to drop in the summer. Therefore the increase of lake total phosphorus during summer is an indirect indication that internal cycling is a significant source of phosphorus to the lake. Søndergaard et al. (1999) measured the seasonal phosphorus concentrations of 265 shallow, mainly eutrophic Danish lakes and found that total phosphorus concentrations during summer were two to four times higher than winter values in lakes with a mean summer total phosphorus concentration above 200ug/l.

In addition to seasonal variations in total phosphorus concentrations found in the shallow eutrophic ponds, other indirect evidence indicates that internal cycling is likely a significant source of phosphorus for most of the ponds. This other evidence, described in greater detail in sections 4.8-4.16, indicates that bottom waters become anoxic at least in some of the ponds. It appears likely that these shallow lakes are intermittently or weakly stratified during periods of stagnant weather and light wind. During these periods it is probable that the bottom waters become anoxic creating conditions conducive to the release of phosphorus into the water column. As previously discussed, phosphorus release from the sediment can also occur when bottom waters are aerobic, albeit at a lesser rate (Holdren and Armstrong, 1980).

Although internal loading rates have not been quantified in this study, rates could be estimated. In many cases, external phosphorus inputs are either very low or nonexistent during some period of the summer. In these cases, internal loading rates could be estimated by evaluating the increase in lake total phosphorus over time. An alternative method would be to measure phosphorus concentrations of composite sediment cores over time.

The importance of addressing internal phosphorus loading should be clear. The focus of this TMDL's implementation section is the control of identified external sources of phosphorus discharged to these lakes. However, it must be understood that even if external loading is significantly reduced, little improvement may be seen in water quality for decades, because of continued internal loading. Even after wastewater treatment was installed reducing 80% of the external load to Shagawa Lake in Minneapolis, Minnesota, modeling indicates that it would take 80 years to achieve a 90% reduction in summer lake phosphorus, due to internal cycling (Chapra and Canale, RP.1991). Søndergaard et al. (1993) estimated that, even after an 80–90% reduction in external phosphorus loading to a shallow hypereutrophic Danish Lake, phosphorus would continue to be released from the sediment for approximately 20 years. One year after the drastic reduction in external phosphorus loading in 1982, net internal phosphorus loading was 8 g/m^2/y. This rate decreased slowly to 2 g/m^2/y in 1990, 15 years after the reduction in external phosphorus loading. Therefore for most of these eutrophic ponds, the more immediate achievement of water quality improvements will also entail use of in-lake management techniques to control the internal cycling of phosphorus.

4.8 Almy Pond

The major sources of phosphorus to Almy Pond, not necessarily in order of significance, are stormwater, waterfowl, internal cycling and perhaps wastewater.

There are thirteen (13) identified storm drains discharging to Almy Pond, its tributary, or hydrologically connected wetlands (Appendix A, Figure 1; Appendix B, Table 1). Only four of these outfalls are 2 feet in diameter or greater. The most significant culverts are listed in Table 4.1. The highest priority outfall is a 48-inch pipe (AP-L), which discharges to a ditch south of Ruggles Avenue. This outfall appears to conduct the majority of stormwater runoff from neighborhoods to the north of Almy Pond. A 30-inch outfall (AP-C), located at the southeastern end of the pond at the terminus of Wheatland Court, is the main outfall for neighborhoods on the eastern side of the pond. A 24-inch outfall (AP-I), located to the east of Alpond Drive, is the only storm drain discharging to the western shore of the pond. The discharge from this pipe had a slight milky appearance that may be associated with fecal contamination, although there was no discernable odor. Since there is a sewage pump station in close proximity to this pipe, there is reason for concern.

Table 4. 1 Priority Outfalls for Almy Pond

Outfall ID	Diameter (in)	Location	Ownership *
AP-L	48	South of Ruggles Av.	City of Newport
AP-C	30	Wheatland Ct.	City of Newport
AP-I	24	Alpond Dr.	City of Newport

* Ownership inferred from proximity to state or local roadways.

Waterfowl may be a significant source of phosphorus to Almy Pond. Approximately 30-50 Canada geese frequent the pond nightly, with as many as 100 birds on occasion (personal communication, John O'Brien; Fish& Wildlife, RIDEM). There does not appear to be any open areas adjacent to the pond that would be suitable as congregation sites for waterfowl. Most of the shoreline of Almy pond is vegetated with dense reeds (*Phragmites australis*) and the remaining shoreline is characterized by steep slopes.

The mean total phosphorus and chlorophyll-a concentrations in Almy Pond are significantly higher than those recorded in all the other eutrophic ponds. Although the mean fecal coliform concentration for the 2002-2004 monitoring period (14 fc/100 ml) does not appear to yield any definitive evidence of wastewater contamination, there is still a possibility that wastewater is impacting the water quality of Almy Pond. The extremely elevated phosphorus concentrations found in Almy Pond do not appear to be consistent with the surrounding landuse nor does the waterfowl population utilizing the pond appear to be entirely responsible for the phosphorus impairment. Other eutrophic ponds characterized by watersheds with higher density development and by larger waterfowl populations have significantly lower phosphorus concentrations. Thus the possibility that wastewater is a significant source cannot be discounted. Specifically, there is a concern that sewage may be leaking out of force mains located on Alpond Drive and Murray Place or that there may be failing septic systems along the eastern and northern shores. A 24-inch storm drain (AP-I) is located adjacent to the pumping station at Alpond Drive. Any leakage from the force main may infiltrate into the stormwater pipe and flow directly into the pond. Also a possible cross-connection was discovered on Carol Avenue at a sewer manhole, located within the street near telephone pole No. 28. The stormwater drain adjacent to the manhole appears to drain to outfall AP-I.

Because Almy Pond is classified as a shallow pond, URIWW did not sample phosphorus at depth. Although there is no direct evidence of internal cycling, it is entirely probable that phosphorus-laden lake sediments become anoxic in the summer months, releasing phosphorus into the water column. A strong odor of hydrogen sulfide from disturbed bottom sediments was noted by RIDEM staff during a field inspection in shallow pond waters, indicating that the sediment was anoxic. Almy pond is probably very susceptible to the resuspension of mucky bottom sediment due to its extremely shallow depth and exposure to strong winds caused by its proximity to the ocean. Populations of goldfish, brown bullhead, and potentially carp may also cause some resuspension of sediment (personal communication, John O'Brien; Fish& Wildlife, RIDEM). The limited data also suggests that phosphorus concentrations increase during the summer months, another indication that phosphorus is being released from the sediment.

4.9 Brickyard Pond

The major sources of phosphorus to Brickyard Pond, not necessarily in order of significance, are stormwater, waterfowl, shoreline erosion, and internal cycling.

There are twenty four identified storm drains discharging to Brickyard Pond, its tributaries, or hydrologically connected wetlands (Appendix A, Figure 2; Appendix B, Table 2). Eleven of the outfalls are 24 inches in diameter or greater. Only four of the outfalls discharge directly to the pond. Ten outfalls discharge to the ditch located at the northern side of the bike path, adjacent to the northern shore of the pond and the remaining ten outfalls discharge to the extensive wetland area to the east of the pond or to its associated tributary.

The most significant outfalls are located to the north of the pond, conveying storm water from a mixed commercial/residential area (Table 4.2). A 24 x 48-inch box culvert (BrP-E) discharges directly into the pond at the bike path at the pond's northwestern end. A 36-inch outfall (BrP-C) discharges directly into the pond at the bike path at the pond's northeastern end. Twin 24-inch culverts (BrP-I and BrP-J) discharge to a ditch just south of Maple Avenue, which in turn discharges to the ditch alongside the bike path. A second tier of outfalls include two 18-inch culverts (BrP-D and BrP-X) that discharge directly to the pond from a residential area at its southern shore, and three 24-inch culverts (BrP-O, BrP-Q, and BrP-S) that drain into the eastern tributary.

Table 4. 2 Priority Outfalls for Brickyard Pond

Outfall ID	Diameter (in)	Location	Ownership *
BrP-E	24" x 48" box culvert	Bike path near Maple Av.	Town of Barrington
BrP-C	36	Bike path near Maple Av	Town of Barrington
BrP-I and BrP-J	Twin 24" culverts	Maple Av.	Town of Barrington
BrP-D	18	Ferncliffe Rd.	Town of Barrington
BrP-X	18	Broadview Dr.	Town of Barrington
BrP-O	24	South of Half Mile Rd.	Town of Barrington
BrP-Q	24	Near Nyatt Elementary	RIDOT
BrP-S	24	Woodhaven Rd.	Town of Barrington

* Ownership inferred from proximity to state or local roadways.

Waterfowl may be a significant source of phosphorus to the pond. Significant numbers of waterfowl were observed on the pond during each of two site visits. Approximately 25 mute swans were observed on the pond during both site visits. The swans may be congregating near shore along the grassed area along the bike path at the northern edge of the lake or on the many islands dotting the pond, although all of the swans observed during the shoreline survey were in the water. Approximately 55 sea gulls were observed on the pond during the first field inspection. During the second site visit approximately 125 seagulls and 30 ducks were observed on the pond. Residents report that up to 1000 geese and 500 cormorants inhabit the pond, especially in the winter months. The cormorants typically congregate on the many islands within the pond.

Shoreline erosion may be a significant source of phosphorus to Brickyard Pond. Erosion is a significant problem at the northern shore of the pond along the bike path and to a lesser extent the northeastern shore in the general vicinity of the YMCA. Portions of the northern shoreline are characterized by vertical and undercut banks up to 1.5 m high, which is resulting in the undercutting of several large trees in the area. The ongoing erosion problems along the northern shore are probably the result of unstable vertical banks left by the historic clay-mining operation, fine-textured soils that are particularly susceptible to erosion and transport, and the orientation of the shoreline relative to prevailing winds. The clay soils in the area also have the potential to adsorb significantly more phosphorus than coarser sandy soils.

As previously mentioned in Section 3.2, it appears that internal cycling is a significant source of phosphorus for Brickyard Pond. The mean concentration of total phosphorus at the pond bottom was about 5 times greater than the concentration at the surface. The disparity in phosphorus concentrations becomes even more pronounced during the summer and fall. The phosphorus concentrations at the surface and at depth are similar in the spring, but differ by about an order of magnitude in the summer and early fall, when the pond is stratified.

4.10 Gorton Pond

The major sources of phosphorus to Gorton Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

There are fifteen identified storm drains discharging to Gorton Pond, its tributary, or hydrologically connected wetlands (Appendix A, Figure 3; Appendix B, Table 3). Only five of the outfalls discharge directly to the pond. Six outfalls discharge to swales within 20-30 meters of the pond. Two outfalls discharge to the tributary at the northwestern end of the pond and two pipes drain to a ditch leading into the wetland area at the northwestern end of the pond. Most of the outfalls that discharge directly to the pond have significant deltas of transported sediment deposited at their outlets. This sediment is probably a significant source of phosphorus to the pond.

The most significant culverts discharging to Gorton Pond are listed in Table 4.3. Two dual oval outlets, located at the southeastern end of the pond appear to be the most significant point source of stormwater to the pond. Outfalls GP-G and GP-H (52" x 35" and 46" x 30" culverts, respectively) appear to drain the commercial/residential area along Veterans Memorial Drive (Route 1). There is an approximately 40-m^2 delta of transported sediment deposited at these twin outfalls. There are two 24-inch culverts that drain directly into the pond that also carry a significant volume of stormwater. Outfall GP-B is located at the terminus of Sharon Street and drains a residential area to the north of the pond. There is a large plunge pool at the outfall, because the last section of culvert leads nearly vertically from a high hill above the northern shore of the pond. The other 24-inch culvert (GP-K) is located at the western end of the pond and conveys stormwater from residential areas along Greenwich Avenue (Route 5). There is a significant delta of transported sediment at this outfall. Another 24-inch culvert (GP-A) at the terminus of Trinity Street drains a residential area north of the pond, discharging to a short swale. There is a 5-6 meter vertical escarpment at outfall GP-A, approximately 20-30 meters from the pond, which appears unstable with the potential of transporting phosphorus-laden soil to the pond. A 36" x 24" oval outfall (GP-E), located at the eastern end of the pond just north of the public beach, drains a residential/commercial area along Post Road. This outfall drains to a swale, however there is a 100 m^2 delta of transported sediment at its point of discharge into the pond.

Table 4. 3 Priority Outfalls for Gorton Pond

Outfall ID	Diameter (in)	Location	Ownership *
GP-G and GP-H	52" x 35" and 46" x 30" twin oval culverts	Veterans Memorial Dr.	RIDOT
GP-B	24	Sharon St.	City of Warwick
GP-K	24	Greenwich Av.	RIDOT
GP-A	24	Trinity St.	City of Warwick
GP-E	36" x 24" oval culvert	Near Town Beach	RIDOT

* Ownership inferred from proximity to state or local roadways.

Birds may be a significant source of phosphorus to Gorton Pond. Between 100-150 gulls, 50 ducks and up to 30 swans were observed on the pond. Scores of waterfowl were observed congregating on a lawn that stretches to the waters edge. The lawn is located on a small peninsula that juts into the pond immediately north of its outlet. The lawn was also cited as a waterfowl congregation area in 1982 by Keyes and Associates et al. Geese also congregate at the City beach at the eastern end of the pond, as evidenced by abundant scat.

As previously mentioned in Section 3.3, internal cycling is likely a significant source of phosphorus for Gorton Pond. The mean concentration of total phosphorus at the pond bottom was approximately 7 and 5 times higher than the mean concentration at depth in the summer and fall, respectively. Spring phosphorus concentrations are similar at the surface and at depth, due to the thorough mixing of the water column that occurs at that time of year.

4.11 North Easton Pond

The major sources of phosphorus to North Easton Pond, not necessarily in order of significance, are Bailey's Brook and to a lesser extent an unnamed tributary, stormwater, waterfowl, wastewater, erosion/sedimentation internal cycling, and perhaps Rhode Island Nursery properties.

Bailey's Brook is the major tributary to North Easton Pond (Appendix A, Figure 4). Since there are no outfalls discharging directly to the pond, Bailey's Brook appears to be the single biggest source of external phosphorus to the pond. Bailey's Brook was sampled for total phosphorus by RIDEM personnel on 31 occasions between 1991 and 2003. Samples were collected at Kampinar's Clambake, located at the southern end of the river. Total phosphorus concentrations ranged from 15 to 2730 ug/l. The 2730 ug/l concentration appears to be an anomaly, with the second highest value being 150 ug/l. Excluding the highest value of 2730 ug/l, the mean concentration for the remaining 30 values is 42 ug/l.

The only tributary to North Easton Pond other than Bailey's Brook is an unnamed stream that discharges to the southeast corner of the pond. Although this tributary may be a significant source of phosphorus to the pond, its watershed is much smaller than that of Bailey's Brook. Also the unnamed tributary discharges to North Easton Pond in very close proximity to the outlet of the pond, so it may have more impact on the water quality of South Easton rather than North Easton Pond

Stormwater is likely the most significant source of external phosphorus to North Easton Pond. However, a brief survey of a small portion of this urbanized watershed indicates that there are many stormwater outfalls discharging to its major tributary, Bailey's Brook. Due to the length of tributaries feeding the pond, an intensive shoreline survey was not conducted. There are numerous roads that cross the main stem of Bailey's Brook, its tributaries, and another unnamed tributary that drains into the southeast corner of the pond. Most, if not all, of these roads probably have stormwater outfalls associated with them.

Waterfowl may be a significant source of phosphorus to North End Pond. Between 300 and 500 geese were observed in the water at the northern end of the lake near Green End Avenue. Although no waterfowl were observed congregating on the shore at the time of the shoreline survey, geese may congregate at the water treatment plant at the southwest corner of the pond or at neighboring properties to the north where lawn stretches to the water's edge.

An interceptor sewer line that runs along Bailey's Brook may have been a significant source of phosphorus to North Easton Pond. In 2005, Geosyntec Consultants Inc., while conducting a watershed study of the Bailey's Brook watershed, observed several areas where wastewater was surging from sewer manholes in very close proximity to the stream. In other areas they reported odors and organic growth, but no direct evidence of discharge. They also recorded extremely high fecal concentrations within the stream itself. As will be discussed further in section 6.5.4, work done on the sewer line by the Town of Middletown may have significantly reduced or eliminated this source of pollution.

Erosion/sedimentation may be a significant source of phosphorus to North Easton Pond. A study of the Bailey's Brook watershed, conducted by Geosyntec Consultants (2005), revealed that erosion and sedimentation were a significant problem in two of the tributaries to Bailey's Brook. Specifically, eroding landscape material was reported at 245 Oliphant Lane, and sedimentation associated with a sand and gravel operation was reported at Aquidneck Avenue just south of Vierra Terrace. Both instances were reported to the Office of Compliance and Inspection (OCI) at RIDEM. The investigation into these alleged violations is pending. In 2005, Geosyntec Consultants Inc. conducted a habitat analysis of the main stem of Bailey's Brook and its four tributaries. They found that the banks of the streams were generally fairly stable. However, the substrate was found to be unstable in many of the reaches of the main stem and all the tributaries except for the tributary that originates at Aquidneck Avenue. This unstable or constantly shifting bed load significantly curtails epifaunal colonization and may be a contributing factor to the biodiversity impairment of the river. Inspection of areal photographs reveals that a sizeable pond that was present in 1970 immediately north of Green End Avenue at the terminus of Bailey's Brook has been entirely filled in and is now a marsh. This is probably due to improper past agricultural practices, poor sedimentation controls at constructions sites, increased stream flows due to ongoing development resulting in increased impervious area, highly erodable fine-textured soils, and the historic practice of bulldozing down the main tributary to alleviate flooding problems.

The limited dissolved oxygen data for North Easton Pond during 2002 indicates that the pond is well oxygenated. The dissolved oxygen concentration never fell below 6.8 mg/l. However, as previously discussed in Section 4.7, phosphorus release from sediment does occur in shallow oxic hypereutrophic lakes. The limited phosphorus data for North Easton Pond indicates that concentrations of phosphorus increase as the growing season progresses. This is consistent with trends observed in other waterbodies where internal loading is a significant source. Although phosphorus concentrations at depth are similar to those measured at the surface, this is probably due to the lack of stratification in this shallow pond and not because of a lack of phosphorus release from the sediment.

4.12 Roger Williams Pond

The major sources of phosphorus to Roger Williams Pond, not necessarily in order of significance, are Mashapaug Pond, stormwater, waterfowl, erosion, and internal cycling.

Mashapaug Pond discharges to Roger Williams Park Ponds via a 0.4 km subsurface conduit. Mashapaug Pond has been identified as a major source of phosphorus to Roger Williams Park Ponds. The existing or current load from Mashapaug Pond is 232 kg/yr (RIDEM, 2007), which comprises 23% of the total current load (1027 kg/yr) to Roger Williams Park Ponds.

There are twenty four identified storm drains that discharge to Roger Williams Park Ponds (Appendix A, Figure 5; Appendix B, Table 4). Except for three outfalls (RPW-B, RPW-C, and RPW-U) that discharge to short swales, all the outfalls discharge directly to the pond. Eight outfalls appear to conduct drainage from high-density residential areas east of the park. Fifteen outfalls appear to conduct stormwater from the park itself. One outfall conducts stormwater from a large urban area to the west.

The most significant culverts discharging to Roger Williams Park Ponds are listed in Table 4.4. The most significant outfall to the Roger Williams Park Ponds is a 48-inch outfall (RWP-Q) that drains the entire Spectacle Pond and Mashapaug Pond watersheds. This outfall discharges into the pond system at the western end of Roosevelt Lake. The discharge at the outfall was quite turbid at the time of the shoreline survey and there is a significant area of deposited sediment that appears to affect most of Roosevelt Lake. Another 48-inch outfall (RWP-S) apparently drains parks roadways only, discharging into Willow Lake. There was some erosion at the end of the pipe. Outfall RWP-V (a 74-inch x 24-inch box culvert) discharges stormwater into Polo Lake, apparently from a dense residential area to the east of the park. Outfall RWP-H (a 30-inch x 42-inch oval culvert), discharges to the southern end of Edgewood Lake, also from a dense residential area to the east of the park. A 24-inch culvert (RWP-A) drains into Pleasure Lake from a dense residential area and/or from park roadways. Another 24-inch culvert (RWP-D) drains park roadways only, discharging to the eastern end of Pleasure Lake. Outfall RWP-I (a 24-inch culvert) discharges to the southern end of Edgewood Lake, apparently from a dense residential area to the east of the park. Outfall RWP-U discharges to a swale at the northern end of Polo Lake. Some scouring of the swale was observed.

Table 4. 4 Priority Outfalls for Roger Williams Park Ponds.

Outfall ID	Diameter (in)	Location	Ownership *
RWP-Q	48	Eastern end of Roosevelt Lake	RIDOT/City of Providence/Cranston
RWP-S	48	Eastern shore of Willow Lake	City of Providence
RWP-V	74” x 24” box culvert	Eastern shore of Polo Lake	City of Providence
RWP-H	30” x 42” oval culvert	Southern end of Edgewood Lake	City of Providence
RWP-A	24	Northern end of Pleasure Lake	City of Providence
RWP-D	24	Eastern end of Pleasure Lake	City of Providence
RWP-I	24	Southern end of Edgewood Lake	City of Providence
RWP-U	24	Northern end of Polo Lake	City of Providence

* Ownership inferred from proximity to state or local roadways.

Deposited sediment may be a significant source of phosphorus to Roger Williams Park Ponds. A significant sedimentation delta was found at the main inlet to the pond systems (RWPP-Q) at the western end of Roosevelt Lake. Eroded sediment covers much of the pond bottom of Roosevelt Lake. Blocked catch basins near the southern end of Edgewood Lake have caused stormwater to flow across the surface of a grassed area resulting the formation of an eroded channel (RWP-1).

Waterfowl appear to be a significant source of phosphorus to Roger Williams Park Ponds. An estimated 2000 geese and ducks were observed within the park ponds system at any given time. Several hundred waterfowl, mostly geese, were observed congregating in grassed areas next to the ponds, including the southeast end Polo Lake, the southwestern end of Pleasure Lake, and at Roosevelt Lake. Waterfowl densities on the eastern bank of Roosevelt Lake were so great that the area is devoid of grass. Elevated numbers of waterfowl are probably the result of the common practice by the public of feeding the waterfowl.

Erosion was observed near the northern end of Edgewood Lake at Frederick Green Memorial Boulevard opposite Oakland Cemetery. Stormwater catch basins in this area are entirely blocked causing storm water to flow from the roadway across a grassed area resulting in an eroded channel near the northern end of the pond at RWP-1.

Although there is no direct evidence of internal cycling, it is entirely probable that sediments release phosphorus into the water column. The limited data indicates that phosphorus concentrations increase during the summer months, which is typically the period when phosphorus release from the sediment is most significant. The Roger Williams Park Ponds have most likely been eutrophic for a long period of time so its highly probable that sediments are high in phosphorus and are a significant source to the water column.

4.13 Sand Pond

The major sources of phosphorus to Sand Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

There are six identified storm water outfalls discharging to Sand Pond, with only two culverts 24 inches in diameter or greater (Appendix A, Figure 6; Appendix B, Table 5). Except for outfall SdP-D, which discharges to a swale, all outfalls discharge directly to the waterbody. The most significant culverts are listed in Table 4.5. A 36-inch culvert (SdP-F) drains a residential/commercial area along Post Road (Route 1) to the west of the pond. A 24-inch outfall (SdP-B) accepts stormwater runoff from a moderately sized commercial area at the northwest end of the pond. Sedimentation may be a significant source of phosphorus to Sand Pond. An 18-inch outfall (SdP-a) also discharges to the pond from the same commercial area. Deltas of eroded sediment were observed at the larger outfalls, specifically SdP-F, SdP-B and SdP-A. An approximately 100 m^2 delta was observed down-gradient of an area of concentrated surface flow (SdP-1), located at Sand Pond Road.

Table 4. 5 Priority Outfalls for Sand Pond.

Outfall ID	Diameter (in)	Location	Ownership *
SdP-F	36	Post Rd.	RIDOT
SdP-B	24	Commercial Area/Post Rd.	City of Warwick
SdP-A	18	Commercial Area	City of Warwick

* Ownership inferred from proximity to state or local roadways.

Only a few swans and less than ten waterfowl were observed at the time of the shoreline survey. However, a local resident reported that there were approximately 100-200 geese congregating at the pond in the summer of 2001 or 2002, with as many as 500 geese congregating on the ice in the winter. This is a significant population of waterfowl, since the pond is only 5 hectares in area. The resident reported that around 2003 a pair of swans moved in, had a few cygnets, became territorial, and drove off all the geese. The cygnets are now nearing maturity and the adult swans have become much less territorial, however the former population of geese has yet to establish itself. Accumulated scat from geese, especially those congregating on the ice, may have caused the prolonged anoxic conditions in 2003, and the resulting spike in total phosphorus concentrations. Local residents also reported that a family of raccoons lived in culvert SdP-D. Fecal material from the raccoons could also be a source of phosphorus to the pond.

Internal loading is a significant source of phosphorus to Sand Pond, especially since 2000. Concentrations of total phosphorus, measured during the summer and fall, were significantly higher at depth than at the pond surface. This disparity was especially pronounced in 2001 and 2003, when phosphorus concentrations at depth were an order of magnitude or more higher than those measured at the surface.

4.14 Spectacle Pond

The major sources of phosphorus to Spectacle Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

Nineteen outfalls discharge to Spectacle Pond, Tongue Pond, or the ditch that connects the two during brief periods of high water (Appendix A, Figure 7; Appendix B, Table 6). However, only six outfalls discharge directly to Spectacle Pond, with an additional outfall (SpP-D) discharging to the pond from a 70 meter swale.

Four of the seven outfalls, that discharge more or less directly to Spectacle Pond, probably have the most significance in terms of the pond's water quality (Table 4.6). The single most significant outfall is a 48-inch outfall (SpP-F) that drains approximately 98 hectares of mostly high-density residential on the western side of the pond (The Louis Berger Group, Inc., 2001). This catchment area drains approximately 41% of the Spectacle Pond watershed. Also there is a very large sedimentation delta associated with outfall SpP-F, which extends approximately 30-50 meters into the pond. A 36-inch outfall (SpP-E) and a 24-inch outfall (SpP-D) discharge to the pond at the athletic fields at its southeastern corner. The general area adjacent to these outfalls is largely high-density residential bordering Reservoir Avenue (Route 2). However, at least one of these culverts is tied into a french drain system underneath the athletic fields. A 15-inch culvert (SpP-A) at the terminus of Molter Street previously discharged directly to the pond but is now totally blocked. Surging was observed during a rain event from the terminal catch basin with stormwater flowing down the end of Molter Street, across a parking lot and into the pond, causing slight scouring of the bank.

Table 4. 6 Priority Outfalls for Spectacle Pond.

Outfall ID	Diameter (in)	Location	Ownership *
SpP-F	48	Lake St.	City of Cranston
SpP-E	36	Baseball Field	City of Cranston
SpP-D	24	Baseball Field	City of Cranston
SpP-A	15	Molter St.	City of Cranston

* Ownership inferred from proximity to state or local roadways.

Two 4-inch pipes were observed discharging directly to the Spectacle Pond from a waterside restaurant. The effluent was hot and the discharge was reported to the RIDEM's Office of Compliance and Inspection. The discharge was reportedly from a closed system associated with the restaurant's refrigeration units. The restaurant has applied for and obtained a permit for the thermal discharge from the Rhode Island Pollutant Elimination System section (RIPDES) of RIDEM. A 12-inch culvert (SpP-G) discharges directly to the northern end of the pond, from a large commercial center. However, this discharge is treated by an underground detention structure and vortechnics units prior to release.

There are ten outfalls that discharge directly to Tongue Pond, half of which are 24 inches in diameter or greater, including a 36-inch and a 48-inch culvert. Some of these outfalls receive some type of pretreatment prior to release to the pond. There is an underground stormwater storage structure located to the north of Tongue Pond, but it is unclear which of several pipes in the immediate area are connected to the structure. There are an additional two outlet pipes that convey flow from Tongue Pond to the ditch that discharges to Spectacle Pond. Although the volume of stormwater discharged to Tongue Pond is substantial, these outfalls probably do not have the same impact on the water quality as those that discharge directly to Spectacle Pond. Tongue Pond is connected to Spectacle Pond by a 330-meter manmade ditch. During the summer, however, the elevation of the pond was observed to be a meter or more below the outlet invert of Tongue Pond. The ditch appears to flow only during periods of high water, and even then only during or immediately after rain events. There are two outfalls that discharge directly to the ditch down-gradient of Tongue Pond. However, the stormwater from both outfalls receive pretreatment prior to release. In addition to the culverts that discharge to the Spectacle Pond system, there are fourteen areas of concentrated surface flow that discharge into Spectacle Pond. Most of these areas of concentrated surface flow originate at streets that terminate at the steep western shore of the pond.

Deposited sediments may be a significant source of phosphorus to Spectacle Pond. There is an extremely large delta of eroded sedimentation at the end of a ditch that is fed by the major inlet to the pond at the terminus of Lake Street (SpP-A). This delta is by far the largest found in any of the eutrophic ponds surveyed and extends half-way across the pond. Also a blocked culvert at the end of Molter street (SpP-F), is resulting in the surging of stormwater out of the terminal manhole within the street. The stormwater was observed flowing down the street, across a commercial parking lot, and through a 30-foot wide vegetated buffer at the shoreline. This surface flow was causing some relatively minor erosion of the bank.

On average, approximately 20 geese and as many ducks were observed on Spectacle Pond at any given time. On one occasion geese were observed congregating on a commercial parking area at the northern end of the pond. The geese apparently gain access to the pond in this area down a dirt embankment. Due to steep slopes, and to a lesser extent dense vegetation, this dirt embankment appears to be the only waterfowl congregation area adjacent to the shore.

Since Spectacle Pond is classified as a shallow waterbody by URIWW, total phosphorus was measured at the surface only. Although there is no direct evidence of phosphorus release from the sediment, internal cycling probably does occur. Limited data obtained by RIDEM staff showed that dissolved oxygen near the bottom was lower than 1.5 mg/l. It appears probable that the sediment becomes anoxic at least during part of the summer and/or early fall and that these anoxic conditions cause phosphorus release from the mucky organic sediment. Also phosphorus concentrations in the water column tend to be higher in the summer than the spring, an indirect indication that internal cycling is a significant source of phosphorus.

4.15 Upper Dam Pond

The major sources of phosphorus to Upper Dam Pond, not necessarily in order of significance, are stormwater, internal cycling and perhaps wastewater. Waterfowl may also be a significant source.

There are eighteen outfalls that discharge to Upper Dam Pond, its tributaries, and hydrologically connected wetlands (Appendix A, Figure 8; Appendix B, Table 7). Five outfalls discharge directly to the pond, eleven outfalls discharge to tributaries and one outfall discharges to a hydrologically connected wetland. There are only two outfalls that are 24 inches in diameter and none are larger. Priority outfalls are listed in Table 4.7. Outfall UDP-D is a 18-inch culvert that drains a residential area, discharging directly into the northeast cove of Upper Dam Pond. A 24-inch outfall (UDP-P) drains a residential area along Gervais Road and discharges to a tributary. There are also three other outfalls (UDP-Q, UDP-R, and UDP-S) at the same location as outfall UDP-P, with UDP-Q (an 18-inch culvert) being the most significant. Outfall UDP-I is 18 inches in diameter and discharges to a culverted tributary at a catch basin on the eastern side of Knotty Oak Road (Route 116). Culvert UDP-I drains a residential area. A 24-inch outfall (UDP-H) discharges to a culverted tributary at a catch basin on the western side of Knotty Oak Road. A strong odor of sewage was noted at a 5-inch outfall (UDP-L) near the intersection of Knotty Oak Road and Gervais Road. The discharge was reported to the Office of Compliance and Inspection Division (OCI) of RIDEM. Excessive algae growth was observed at another 5-inch outfall (UDP-B) that discharges directly to the northwest cove of the pond. The pipe is apparently associated with a nearby single-family residence and was also reported to the OCI. The cases concerning the two reported discharges have yet to be resolved by the OCI.

Table 4.7 Priority Outfalls for Upper Dam Pond.

Outfall ID	Diameter (in)	Location	Ownership *
UDP-D	18	Pond View Dr.	Town of Coventry
UDP-P	24	Gervais Rd.	Town of Coventry
UDP-Q	18	Gervais Rd.	Town of Coventry
UDP-I	18	Knotty Oak Rd.	RIDOT
UDP-H	24	Knotty Oak Rd.	RIDOT
UDP-L	5	Gervais Rd.	Private
UDP-B	5	Breezy Lake Dr.	Private

* Ownership inferred from proximity to state or local roadways.

Although no waterfowl were observed on the pond during the brief shoreline survey, suitable habitat is present and waterfowl may be utilizing the waterbody in significant numbers. There are several lawns, located on Breezy Lake and Pond View Drives, which extend to the water's edge. Waterfowl may congregate on these lawns and also at the Town Beach on the southern side of the pond.

Limited bacteria data for 2004 and 2005 indicate that Upper Dam fecal coliform levels are generally low. However, the Upper Dam watershed is not sewered, so failing septic systems and illegal tie-ins are a possible source of bacteria and phosphorus. There are many small lots in close proximity to the water on the large peninsula that juts into the northern portion of the lake. These lots are located on Breezy Lake and Pond View Drives. A failing septic system in this area could potentially have a significant impact on this 8 hectare pond.

Although there is no direct evidence of internal cycling taking place in this shallow pond, it is likely that it does occur. A strong odor of hydrogen sulfide was observed when the mucky organic substrate in the shallows was disturbed. Also, the limited phosphorus data shows that phosphorus levels increase dramatically from spring to summer.

4.16 Warwick Pond

The major sources of phosphorus to Warwick Pond, not necessarily in order of significance, are stormwater and waterfowl.There are forty-four identified stormwater outfalls discharging to Warwick Pond, its tributaries, Spring Green Pond, and hydrologically connected wetlands (Appendix A, Figure 9; Appendix B, Table 8). Eleven outfalls discharge directly to Warwick Pond, twenty-four outfalls discharge to tributaries, six outfalls discharge to Spring Green Pond, and three outfalls discharge to hydrologically connected wetlands. In addition to the culverts that discharge to Warwick Pond, there are sixteen areas of concentrated surface flow that discharge into Warwick Pond or its tributaries. These areas are generally asphalt or naturalized swales that originate from concentrated street runoff.

The most significant culverts discharging to Warwick Pond are listed in Table 4.8. Outfall WP-AJ, a 4 x 4 ft box culvert, is the largest outfall in the Warwick Pond watershed. This culvert discharges to the main tributary north of Warwick Pond at Airport Road. Outfall WP-AJ drains a portion of T.F. Green Airport as well as Airport Road and adjacent commercial and perhaps residential areas. A 36-inch culvert (WP-U) drains the only subdivision to the immediate west of the pond. This outfall discharges to a 20-meter swale where some erosion was observed. Outfalls WP-AB and WP-Z (42-inch and 36-inch culverts, respectively) both drain portions of T.F. Green Airport. Both culverts discharge to a ditch that empties into the main tributary to Warwick Pond. Although the airport does not use fertilizers, the stormwater associated with these culverts may carry loads of phosphorus enriched runoff associated with other activities on the airport property including the washing/maintenance of airplanes and vehicles, and use of certain de-icing compounds containing phosphorus. Additionally, data collected by the RI Airport Corporation indicates periodic violations of the dissolved oxygen standards in samples collected at the inlet and outlet of Warwick Pond during the winter months. These violations of the criteria are more likely associated with the discharge of glycol (as the primary de-icing compound at the airport) and not phosphorus from airport property stormdrains. Outfall WP-K (a 24-inch culvert) drains a high density residential area to the east of Warwick Pond. The subject outfall discharges to a grassed swale, with gabion check dams. Some erosion was observed along the swale. Outfall WP-AC (a 30-inch culvert) discharges to a tributary near a commercial/industrial area near Evergreen Avenue.

Table 4. 8 Priority Outfalls for Warwick Pond.

Outfall ID	Diameter (in)	Location	Ownership *
WP-AJ	48” x 48” box culvert	Airport Rd.	R.I. Airport Corp/RIDOT
WP-U	36	Lake Shore Dr.	City of Warwick
WP-AB	42	T.F. Green Airport	R.I. Airport Corp
WP-Z	36	T.F. Green Airport	R.I. Airport Corp
WP-K	24	Stanmore Rd.	City of Warwick
WP-AC	30	Evergreen Av.	City of Warwick

* Ownership inferred from proximity to state or local roadways.

Waterfowl may be a significant source of phosphorus to Warwick Pond. Approximately 70 waterfowl were observed on a waterside lawn just east of the outlet to Warwick Pond. There are several other lawns that extend to the pond’s edge that may serve as congregation areas for geese and ducks.

It does not appear that phosphorus is released from the sediment in Warwick Pond. Warwick Pond is the only pond in this study, for which phosphorus data at depth is available, where the total phosphorus concentration in the hypolimnion is actually less than that at the surface. The reason for this is unclear, especially since the Warwick Pond watershed is as urbanized as many of the other ponds where internal cycling is a significant source.

5.0 TMDL ANALYSIS

As described in EPA guidelines, a TMDL identifies the pollutant loading that a waterbody can assimilate per unit of time without violating water quality standards (40 C.F.R. 130.2). The TMDL is often defined as the sum of loads allocated to point sources (i.e. waste load allocation, WLA), loads allocated to nonpoint sources, including natural background sources (i.e. load allocation, LA), and a margin of safety (MOS). The loadings are required to be expressed as mass per time, toxicity, or other appropriate measures (40 C.F.R. 130.2[I]).

5.1 Margin of Safety (MOS)

The MOS may be incorporated into the TMDL in two ways. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly allocate a portion of the TMDL as the MOS. This TMDL uses the latter approach of allocating an additional 10 percent reduction in allowable total phosphorus loading as an adequate MOS.

5.2 Critical Conditions and Seasonal Variation

Critical conditions for phosphorus occur during the growing season, which in most waterbodies occurs from May though October, when the frequency and occurrence of nuisance algal blooms, low dissolved oxygen, and macrophyte growth are usually greatest. Since these TMDLs are based on information collected during the most environmentally sensitive period (i.e., the growing season) and were developed to be protective of this critical time period, they will also be protective of water quality during all other seasons.

5.3 Numeric Water Quality Target

The primary goal of this Total Phosphorus TMDL is to address the water quality impairments in the eutrophic ponds associated with excess phosphorus loadings including increased algal growth/chlorophyll a, and low dissolved oxygen. Reducing phosphorus is the most effective way to reduce algal abundance, because the growth of algae in freshwater environments is typically constrained by the availability of phosphorus. With algal abundance under control, the variability in dissolved oxygen levels (high daytime values, low nighttime values, and depressed oxygen levels following bloom crashes) will be reduced. As a consequence, dissolved oxygen and algae targets are not set explicitly by the TMDL. The Department believes that these impairments will be addressed by reducing phosphorus to an appropriate level.

RIDEM has set a total phosphorus concentration of 25 ug/l as the numeric target for most of the shallow ponds included in this study. These ponds are less than 5 meters deep and include Almy, North Easton, Roger Williams Park, and Upper Dam Ponds. This 25 ug/l numerical target is consistent with the State's water quality criteria for total phosphorus. Compliance points of shallow ponds are based on historic surface sampling stations.

A numerical target of 20 ug/l was set for deep ponds (> 5 meters deep) to address dissolved oxygen impairments in the hypolimnion. Deep ponds include Brickyard, Gorton, Sand, and Warwick Ponds. A separate TMDL conducted for Mashapaug Pond, located in Providence, concluded that in order to eliminate hypoxia (defined as a DO concentration <2 mg/l) in the hypolimnion of the pond, the mean total phosphorus concentration in the pond had to be reduced to 20 ug/l. Since Mashapaug pond is a deep eutrophic pond and has similar characteristics to the eutrophic ponds included in this study, a reduction of total phosphorus to the 20 ug/l target in the deep eutrophic ponds is expected to address the DO impairment to these ponds. The compliance points for the deep ponds (depth > 5 meters) are the simple averages of the historic surface and deep sampling stations. Although Spectacle Pond is classified as a shallow pond, its maximum depth exceeds 5 m and measurements by RIDEM staff indicated that dissolved oxygen concentration were low. For these reasons and the fact that Spectacle Pond is located immediately upstream of Mashapaug Pond, the target of 20 ug/l was also used for Spectacle Pond. Spectacle Pond was sampled for phosphorus at the surface only.

The URIWW data indicates that the primary water quality problem affecting most of the ponds is an overabundance of algae caused by elevated levels of phosphorus. Although many ponds had mean chlorophyll-a concentrations within an acceptable range, all exhibited extremely elevated maximum chorophyll-a concentrations ranging from 21 to 166 ug/l. The presence of algal blooms diminishes the value of the ponds for virtually all uses and aggravates hypoxic conditions in the bottom waters of the ponds in the summer months. Recreational use is made less appealing, aesthetic enjoyment is impaired, and habitat value is reduced. To support these designated uses, a chorophyll level of 9ug/l is set as an objective of this TMDL.

Dissolved oxygen concentrations are measured by URI Watershed Watch in deep (>5m) lakes only. The deep lakes among these eutrophic ponds include Brickyard, Gorton, Sand, and Warwick Ponds. All of these deep ponds are listed on the 303(d) list as impaired for DO. As previously discussed in sections 3.2, 3.3, 3.6, and 3.9, DO concentrations were measured 1 m from the bottom and typically fell below 3 mg/l (a critical level for most aquatic life) by May and remain below 3 mg/l through October. Dissolved oxygen concentrations were typically below the detection limit from mid-summer through October.

Data collected by RIDEM staff indicates that even shallow ponds can be characterized by low DO concentrations. Dissolved oxygen concentrations were measured on July 28, 2004 in Spectacle Pond. Although classified as shallow, temperature data indicates that the pond does become stratified. As discussed in section 3.7, the DO concentration in the hypolimnion of Spectacle Pond was 1-2 – 1.5 mg/l. Roger Williams Park Ponds, which is also classified as a shallow lake, is listed on the 303(d) list as impaired for DO based on historic data.

The dissolved oxygen condition that would be expected in the deep eutrophic ponds in the absence of human activities in its watershed was estimated from conditions in two similar ponds, Upper Schoolhouse Pond and Wakefield Pond (RIDEM, 2007). Data for these ponds was obtained from URI Watershed Watch Program. Both Upper Schoolhouse Pond and Wakefield Pond are located in rural areas and in the case of the latter, its watershed is primarily wooded. Data from URIWW were available for Schoolhouse Pond for the summer of 2001 and for Wakefield Pond for the summer of 1997. Both waterbodies are classified as deep ponds by URIWW. Vertical temperature differences in the ponds typically ranged from 3-8^{o} C. (Figures 5.1 and 5.2). The naturally occurring stratification in these ponds lowered dissolved oxygen down to 2.5 mg/l in the hypolimnia. Hypolimnetic DO declines during the summer because it is cutoff from all sources of oxygen, while organisms continue to respire and decay, consuming oxygen.

The current Rhode Island water quality criteria for warm water fish habitat are an instantaneous DO concentration of at least 5.0 mg/L at any point in the water column except as naturally occurs and a 7-day mean water column concentration of at least 6.0 mg/L. As previously discussed, the natural process of density stratification due to a vertical temperature gradient can produce low dissolved oxygen concentrations in the hypolimnion (lower layer) of naturally stratifying deep lakes, and even shallower lakes and ponds. Low DO in the hypolimnion can be more distinct in eutrophic lakes (i.e., those having high nutrient and algae levels), but is present in healthy lakes as well.

Figure 5. 1 Upper Schoolhouse Pond Temperature and DO Profiles

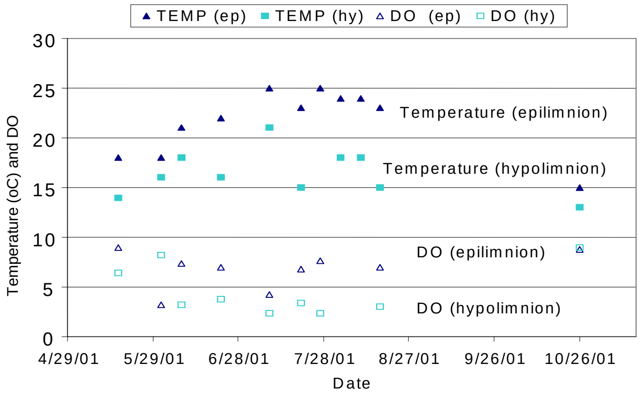
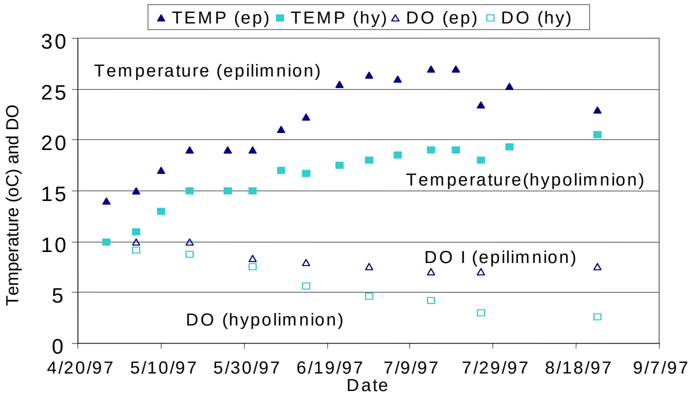


Figure 5. 2 Wakefield Pond Temperature and DO Profiles



DEM's Water Quality Regulations state in the definition for "low quality" or "degraded waters" that "*Waters in their natural hydraulic condition may fail to meet their assigned water quality criteria from time to time due to natural causes, without necessitating the modification of assigned water quality standard(s). Such waters will not be considered to be violating their water quality standards if violations of criteria are due solely to naturally occurring conditions unrelated to human activities.*" The clear intent of the definition is to state that a water body not meeting dissolved oxygen numeric criteria solely due to natural causes is not considered impaired. When a water body naturally does not meet the numeric criteria, as is the case with many freshwater lakes, the levels seen in the natural condition must then become the water quality target for those and similar bodies. The dissolved oxygen concentration measured along a vertical profile (which was greater than 2 mg/L in the hypolimnion) for the two unimpaired reference ponds is selected as the naturally occurring hypolimnetic condition for the deep stratified eutrophic ponds. Thus a DO concentration equal to or greater than 2 mg/l in the hypolimnion of deep eutrophic ponds is set as the goal for DO in these deep eutrophic ponds. For shallow ponds, it is recognized that DO levels of 4.0 mg/l or less may naturally occur. The objective of this TMDL is to restore the ponds to a condition that supports their designated uses and protects them from future degradation. In summary, the goals of this TMDL are to:

- Reduce total phosphorus levels in the ponds to an average level of 25 ug/L for shallow lakes (< 5 meters deep) and 20 ug/l for deep lakes;
- Reduce algal abundance to levels consistent with designated uses, targeting a chlorophyll level of approximately 9 ug/L;

- Improve instantaneous dissolved oxygen levels in the ponds to the maximum extent feasible consistent with naturally occurring conditions; and
- Eliminate hypoxia (defined as a DO concentration <2 mg/l) in the hypolimnion to support the propagation of fish and other animal life in the ponds.

5.4 Technical Analysis

The current annual mean phosphorus load was based on the average TP concentration and areal water loading (see below equation) using the Reckhow model (1979). The Reckhow model was developed from a database of lakes within a north temperate setting, thereby making it applicable for waterbodies within southern New England. The Reckhow model expresses phosphorus concentration (TP in mg/l) as a function of phosphorus loading (L, in g/m^2-yr), areal water loading (q_s, in m/yr), and apparent phosphorus settling velocity (v_s, in m/yr) in the form:

$$\mathbf{TP = L/(v_s + q_s)}$$

Using a least squares regression, it was found that the apparent settling velocity could be fit using a weak function of q_s. This resulted in the fitted model:

$$\mathbf{TP = L/(11.6 + 1.2q_s)}$$

Where:
L = Existing Load; and
q_s = Areal Water Load.

The existing annual load (*L*) for each pond was calculated by substituting the observed total phosphorus concentration, averaged over the sampling period, into the Reckhow equation. With the exception of North Easton Pond, the mean annual total phosphorus concentration was derived from URIWW data. All URIWW data available since 1993 was used. Generally three total phosphorus measurements were taken each year, typically in May, July, and October/November. The mean annual total phosphorus concentration of North Easton Pond was calculated from limited RIDEM data.

The estimation of Areal Water Load (q_s) was calculated in the following manner:

$$\mathbf{q_s = Q/Ao}$$

Where:
Q = Inflow Water Volume; and
A_o = Lake Surface Area.

$$\mathbf{Q = (A_d \times r) + (A_o \times Pr)}$$

Where:
q_s = Areal water loading (m/yr);
Q = Inflow water volume (m^3/yr);
A_d = Watershed area (m^2);
A_o = Waterbody surface area (m^2);
r = total annual unit runoff (m/yr); and
P_r = mean annual net precipitation (m/yr).

Ideally, Q should be determined from direct measurement of inflow or outflow. Since data for Q are not available, it was estimated by regressing mean annual inflows, based on long-term records of gauged streams in Rhode Island against drainage area. This resulted in a value of 2 cfs per square mile (18.9 m^3/d/ha), which was converted into the value Q in m^3/yr. This value was then divided by the waterbody area (A_o) in order to obtain values of q_s for each waterbody.

5.5 Existing Waterbody Loads

Estimated mean annual inflows, mean phosphorus concentrations, and annual current total phosphorus loads to the nine ponds are summarized in Table 5.1. The daily load is the annual load divided by 365. North Easton Pond had the highest estimated mean annual inflow in the study group, followed by Roger Williams Park Ponds, Warwick and Brickyard Ponds, Spectacle and Gorton Ponds, Almy Pond, and Upper Dam Pond. Sand Pond has the lowest estimated mean annual inflow in the study group.

Table 5. 1 Summary of estimated current total phosphorus loads, mean total phosphorus concentrations, and mean annual inflows.

Waterbody	Watershed Area (ha)	Estimated Mean Annual Inflow (m^3/yr)	Mean Annual Total Phosphorus Concentration (ug/l)	Current Load (kg/yr)
Almy Pond	135.4	9.35×10^5	152	526
Brickyard Pond	309.8	2.14×10^6	63	410
Gorton Pond	185.0	1.28×10^6	56	239
North Easton Pond	982.2	6.78×10^6	114	1470
Roger Williams Park Ponds	917.9	6.33×10^6	82	1027
Sand Pond	24.6	1.70×10^5	64	50
Spectacle Pond	237.6	1.64×10^6	57	216
Upper Dam Pond	87.2	6.02×10^5	42	71
Warwick Pond	346.2	2.39×10^6	27	185

At 152 ug/l, Almy Pond has the highest mean annual total phosphorus concentration in the study group. North Easton and Roger Williams Park Ponds have mean annual total phosphorus concentrations of 114 and 82 ug/l, respectively. Brickyard, Gorton, Sand, Spectacle, and Upper Dam Pond have mean annual total phosphorus concentrations in the 42-64 ug/l range. The mean annual phosphorus concentration for Warwick Pond was 27 ug/l.

At 1470 kg/yr, North Easton Pond has the highest current annual phosphorus load of any of the ponds in the study group. Roger Williams Park Ponds have a current mean annual phosphorus load of 1027 kg/yr. Almy Pond has a current mean annual phosphorous of 526 kg/yr. Brickyard Pond has a current mean annual phosphorus load of 410 kg/yr. The annual loads of Gorton, Spectacle and Warwick Pond are in the 180-240-kg/yr range. Upper Dam and Sand ponds both have annual phosphorus loads less than 75 kg/yr.

5.6 Loading Capacity and Allocation of Allowable Loading

In section 5.5, current loads were calculated from in-pond total phosphorus concentrations using the Reckhow model. Allowable loadings (TMDLs) were back-calculated using the Reckhow model and the 25 ug/l or 20 ug/l (0.025 or 0.020 mg/l) numeric water quality target as the load (L). A ten percent margin of safety was then subtracted from this value to determine the Target Load for each waterbody.

TMDL calculations for each of the eutrophic ponds are shown in Appendix C. The necessary load reductions are calculated as follows:

Percent Reduction (%) = [(Current Load – Target Load)/ Current Load] x 100

Allowable phosphorus loads, required load reductions in kg/yr and the percent reduction in loads for each pond are presented below in Table 5.2.

The allowable pollutant load, or TMDL for the ponds can be expressed as follows (EPA, 2002):

TMDL = WLA +LA + MOS

Where:

TMDL = Allowable Pollutant Load
WLA = Waste Load Allocation
LA = Load Allocation, and
MOS = 10% Margin of Safety.

Table 5. 2 Allowable Phosphorus Loads, Required Load Reductions & % Reductions to meet Water Quality Targets.

Waterbody	Current Load (kg/yr)	TMDL * (kg/yr)	Required Load Reduction (kg/yr)	Required Loading Reduction (% Present Value)
Almy Pond	526	78	448	85
Brickyard Pond	410	117	293	71
Gorton Pond	239	77	162	68
North Easton Pond	1470	301	1169	80
Roger Williams Park Ponds	1027	282	745	73
Sand Pond	50	14	36	72
Spectacle Pond	216	68	148	68
Upper Dam Pond	71	38	33	46
Warwick Pond	185	123	62	33

***** Includes a 10% Margin of Safety.

The allocation of loads between stormwater WLAs (point sources) and LAs (non-point sources) was established according to estimates of percent impervious and pervious land cover within separate land use categories specified in Table 5.3. This separation between stormwater WLAs and LAs based on impervious area within land use categories represents the best estimate defined as narrowly as the data allow. For those ponds affected by birds and internal cycling of TP, this methodology of allocating between WLA and LA will over estimate the portion of the total load assigned to point sources. The values of percent impervious cover, assigned to each separate land use, were taken from a study conducted by the Center for Watershed Protection (CWP).

Table 5. 3 Impervious cover (%) for land uses within each waterbody.[1]

Land Use Category	IMPERVIOUS COVER (%)
High density residential	55
Medium density residential	36
Low density- rural residential	22
Commercial	85
Industrial	72
Mixed urban- other urban	46
Agriculture	2
Forest, wetland, water	0

1.Data taken from URI NEMO Program and the Center for Watershed Protection.

Percent impervious area within each of the land use categories was multiplied by the percent of each land use within the watershed in order to calculate a percent impervious value for each watershed. Table 5.4 presents the estimated percent impervious area for each watershed, and the allowable annual loads allocated between point (WLA) and non-point (LA) sources. The daily load is the annual load divided by 365.

Table 5. 4 Allocation of Phosphorus Loads for each Waterbody.

Water Body[1]	Percent Impervious Area in Watershed	TMDL[2][3] (kg/yr)	=	WLA (kg/yr)	+	LA (kg/yr)
Almy Pond	29	78	=	22.4	+	55.4
Brickyard Pond	33	117	=	38.1	+	79.1
Gorton Pond	39	77	=	29.7	+	47.2
North Easton Pond	34	301	=	101.0	+	199.6
Sand Pond	54	14	=	7.5	+	6.5
Spectacle Pond	57	68	=	38.6	+	29.6
Upper Dam Pond	32	38	=	12.1	+	25.8
Warwick Pond	39	123	=	47.8	+	75.4

1. Roger Williams Park Ponds allocations are presented separately.
2. Allowable loads (TMDL) are rounded to the nearest whole number and include a 10% explicit Margin of Safety.
3. The daily load is the annual load divided by 365.

As an example, for Spectacle Pond 57% of the total watershed area is impervious, so the required reductions are allocated between point and nonpoint sources such that 57% of the total reduction will be allocated to point sources (WLA), and 43% of the reduction to nonpoint sources (LA). The existing load for Spectacle Pond based on the Reckhow formula is 216 kg/yr, and the Reckhow formula predicts that the loading capacity is 76 kg/yr. An explicit 10% of the loading capacity is reserved for the MOS, so the TMDL becomes 68 kg/yr. The percent total load reduction is (216-68)/216 = 68%. From above, the WLA is 38.6 kg/yr, and the LA 29.6kg/yr. The fractional reduction assigned to point sources to meet the WLA will be equal to or greater (i.e. PS load reduction ≥ 57%) than that for LA reduction percentage (NPS reduction < or = 57%).

Mashapaug Pond discharges to Roger Williams Park Ponds via a 0.4 km subsurface conduit. Mashapaug Pond has been identified as a major source of phosphorus to Roger Williams Park Ponds. The existing or current load from Mashapaug Pond is 232 kg/yr (RIDEM, 2007), which comprises 23% of the total current load (1027 kg/yr) to Roger Williams Park Ponds (Table 5.5). The current load from the remaining portion of the watershed is 795 kg/yr. The existing point source and non-point source loads associated with the subwatershed that discharges directly to Roger Williams Park Ponds were determined using the estimate of the percent of impervious area within the subwatershed.

Table 5. 5 Current Phosphorus Loads for Roger Williams Park Ponds.

Total Current Load (kg/yr)	Current Load from Mashapaug Pond (kg/yr)	Current Load from Remaining Portion of Watershed (kg/yr)	Percent Impervious Area in Subwatershed	Subwatershed Point Source Current Load (kg/yr)	Subwatershed Nonpoint Source Load (kg/yr)
1027	232	795	39	310	485

The TMDL calculations associated with Roger Williams Ponds differs slightly from those of the remaining ponds. The TMDL assigned to Mashapaug Pond is 108 kg/yr (RIDEM, 2007), which comprises 38% of the entire TMDL of 282 kg/yr assigned to Roger Williams Park Ponds (Table 5.6). The remaining portion of the TMDL assigned to the subwatershed that discharges directly to Roger Williams Park Ponds is 174 kg/yr. The waste load and load allocations were assigned to the subwatershed that discharges directly to Roger Williams Park Ponds and were determined using the estimate of the percent of impervious area within the subwatershed.

Table 5. 6 Allocation of Phosphorus Loads for Roger Williams Park Ponds.

TMDL[12] for Roger Williams Park Ponds	TMDL Assigned to Mashapaug Pond (kg/yr)	Percent Impervious Area in Subwatershed[3]	TMDL Assigned to Subwatershed [3] (kg/yr)	=	WLA (kg/yr)	+	LA (kg/yr)
282	108	19	174	=	33.3	+	140.7

1. Allowable loads (TMDL) are rounded to the nearest whole number and include a 10% explicit Margin of Safety.
2. The daily load is the annual load divided by 365.
3. Subwatershed refers to that portion of the watershed that discharges directly to Roger Williams Park Ponds and excludes that portion that discharges to Mashapaug and Spectacle Ponds.

6.0 IMPLEMENTATION

Eliminating the phosphorus-related impairments to the eutrophic ponds requires a reduction in both external and internal sources of phosphorus. External sources should be mitigated prior to internal sources since internally derived phosphorus is ultimately derived from external sources. However, the implementation of BMPs to control both external and internal phosphorus must be coordinated to achieve ultimate success. Recommended implementation activities for the eutrophic ponds are detailed in the following sections. These implementation activities focus primarily on the control of stormwater runoff to the ponds and to a lesser extent on the control of loadings from waterfowl, stream bank and lakeshore erosion, and in some instances wastewater.

Achieving standards requires that both the volume of storm water and its phosphorus concentration be reduced. Other recommendations include minimizing fecal contamination from domestic animals and wildlife, and the control of erosion and sedimentation. Wastewater management activities include continuing the extension of sewer lines, encouraging homes presently on individual systems to tie-in to the existing sewer systems where available, periodic checking of existing sewer systems to ensure there are no chronic leaks, and adopting wastewater management ordinances in areas without sewers to ensure that septic systems are properly maintained and operated.

The implementation of Phase II Stormwater Management Program Plans (SWMPP) including construction of stormwater BMPs at selected locations is expected to, in time, help reduce the nutrient impairments to the eutrophic ponds. However, control of external sources of phosphorus may not produce immediate or expected water quality benefits in most of the ponds unless internal loading is also addressed in a timely fashion. The use of alum is one option to reduce the release of phosphorus from the ponds' sediments in most of the deep ponds where internal recycling of phosphorus is evident. Although there is no direct evidence of internal cycling in shallow ponds, the control of internal phosphorus may be warranted in these ponds as well. As previously discussed in Section 4.7, phosphorus concentrations in most of the shallow eutrophic ponds increase significantly in the summer, a phenomenon that is consistent with phosphorus release from the sediment.

Continuing monitoring efforts by University of Rhode Island Watershed Watch will help track water quality trends, and evaluate pollution control efforts. In accordance with the requirements of this TMDL, monitoring of the eutrophic ponds should continue so that the effectiveness of ongoing remedial activities can be gauged.

DEM will continue to respond to environmental complaints, conduct inspections, and issue RIPDES permits as part of its responsibilities under state and federal laws and regulations. As resources allow, RIDEM will continue to work with RIDOT, and the local municipalities and watershed groups to identify funding sources and evaluate locations and designs for stormwater control BMPs throughout the watershed.

6.1 Storm Water Management

Municipal and State Stormwater Systems - Phase II – Six Minimum Measures

While other wet weather sources of phosphorus exist, the volume of stormwater generated by the large amounts of impervious areas within the eutrophic pond watersheds suggest that it is the major source of impairments to the eutrophic ponds. Significant stormwater is generated in the mostly urban watersheds within the Cities of Cranston, Providence and Warwick, and the Towns of Barrington, Coventry, and Middletown. Large amounts of stormwater are also generated on RIDOT owned roadways.

The Cities of Cranston, Providence and Warwick, and the Towns of Barrington, Coventry, and Middletown, and the RI Dept. of Transportation operate small Municipal Separate Storm Sewer Systems (MS4s) that discharge to the surface waters of the eutrophic ponds and their tributaries. These entities have applied for and obtained coverage under the RIPDES General Permit and have developed and submitted the required Storm Water Management Program Plans (SWMPPs). The plans contain implementation schedules that include interim milestones, frequency of activities and reporting of results. The SWMPPs describe BMPs for the six minimum measures and include measurable goals and schedules for each measure:

- A public education and outreach program to inform the public about the impacts of stormwater on surface water bodies,
- A public involvement/participation program,
- An illicit discharge detection and elimination program,
- A construction site storm water runoff control program for sites disturbing 1 or more acres,
- A post construction storm water runoff control program for new development and redevelopment sites disturbing 1 or more acres, and
- A municipal pollution prevention/good housekeeping operation and maintenance program.

Storm sewers and ditches associated with stormwater runoff frequently cross municipal boundaries, and have multiple interconnections between MS4s. DEM encourages cooperation between operators of MS4s (including RIDOT) in developing and implementing the six minimum measures and constructing Best Management Practices throughout the drainage area contributing to a discharge, by the way of inter-agency agreements. Communities affected by the Phase II program are encouraged to cooperate on any portion of, or an entire minimum measure when developing and implementing their stormwater programs.

Post-construction storm water management in areas undergoing new development or redevelopment is necessary because runoff from these areas has been shown to significantly effect receiving waterbodies. To meet the requirements of the Phase II minimum control measure relating to Post Construction Runoff Control, the operator of a regulated small MS4 will need to at a minimum:

- Develop and implement strategies which include a combination of structural and/or nonstructural BMPs;
- Develop an ordinance or other regulatory mechanism requiring the implementation of post-construction runoff controls to the extent allowable under State or local law;
- Ensure adequate long-term operation and maintenance of controls;
- Determine appropriate best management practices (BMPs) and measurable goals for this minimum control measure.

Required Amendments to Phase II Stormwater Management Program Plans

Part IV.D of the General Permit states that the operator must address the TMDL provisions in the SWMPP if a TMDL has been approved for any waterbody into which storm water discharges from the

MS4 contribute directly or indirectly the pollutants(s) of concern (Part II.C3). Accordingly, upon approval of this TMDL, the RI Department of Transportation, Cities of Cranston, Providence and Warwick, and the Towns of Barrington, Coventry, and Middletown will be required to submit SWMPP amendments addressing the TMDL provisions within one hundred and eighty (180) days of the date of written notice from the RIPDES Program (Rule 31 (f)(8)(iii), as described in greater detail below.

More specifically, the SWMPPs must be revised to describe the six minimum measures and other additional controls that are or will be implemented to address the phosphorus-related impairments including any specific provisions described herein. The operators must provide measurable goals for the development and/or implementation of the six minimum measures and additional structural and non-structural BMPs that will be necessary to address provisions for the control of storm water identified in this TMDL including an implementation schedule, which includes all major milestone deadlines including the start and finish calendar dates, the estimated costs and proposed or actual funding sources, and the anticipated improvement(s) to water quality. If no structural BMPs are recommended, the operator must evaluate whether the six minimum measures alone (including any revisions to ordinances) are sufficient to meet the TMDL's specified pollutant reduction targets. The revised SWMPP must specifically address the following:

1) Determine the land areas contributing to the discharges identified in TMDL using sub-watershed boundaries as determined from USGS topographic maps or other appropriate means;

2) Address all contributing areas and the impacts identified by the Department;

3) Assess the six minimum control measure BMPs and additional controls currently being implemented or that will be implemented in the SWMPP and describe the rationale for the selection of controls including the location of the discharge(s), receiving waters, water quality classification and other relevant information;

4) Identify and provide tabular description of the discharges identified in the TMDL including:

    a) the location of discharge (latitude/longitude and street or other landmark);

    b) size and type of conveyance (e.g. 15" diameter concrete pipe);

    c) any existing discharge data (flow data and water quality monitoring data);

    d) impairment of concern and any suspected sources(s);

    e) interconnections with other MS4s within the system;

    f) TMDL provisions specific to the discharge;

    g) any BMP(s) that have or will be implemented to address TMDL provisions and phosphorus-related impairments;

    h) schedule for construction of structural BMPs including those for which a Scope of Work (SOW) is to be prepared, as described below.

Among the six minimum measures described earlier is the requirement for operators to establish post construction storm water runoff control programs for new land development and redevelopment sites disturbing one or more acres. It is imperative that land development and re-development projects utilize best management practices if the eutrophic ponds are to be successfully restored. To ensure consistency with the goals and recommendations of the TMDL, the revised SWMPP must also address revisions to the local ordinances to ensure that:

1. **new land development** employ stormwater controls to prevent any net increase in phosphorus and;

2. **redevelopment projects** employ stormwater controls to reduce phosphorus to the maximum extent feasible.

This TMDL has determined that structural BMPs are necessary, therefore all operators of MS4s identified herein must also prepare and submit a **Scope of Work** describing the process and rationale that will be used to select BMPs and measurable goals to ensure that the TMDL provisions will be met. The Scope of Work must also be accompanied with a schedule prioritizing outfalls for the construction of structural stormwater BMPs. A targeted approach to construction of stormwater retrofit best management practices (BMPs) at state and locally-owned stormwater outfalls is recommended. Priority outfalls have been identified in Sections 4.8 through 4.16. Operators of MS4s must work to identify other outfalls that contribute the greatest pollutants loads and prioritize these for BMP construction, as detailed in the following sections.

6.2 The Scope of Work must:

1) Describe the tasks necessary to design and construct BMPs that reduce loads of phosphorus and stormwater volumes to *the maximum extent feasible* including:

    a) the delineation of the drainage or catchment area,

    b) determination of interconnnections within the system and the approximate percentage of contributing area served by each operator's drainage system, as well as a description of efforts to cooperate with owners of the interconnected system, and

    c) completion of catchment area feasibility analyses to determine drainage flow patterns (surface runoff and pipe connectivity), groundwater recharge potentials(s), upland and end-of-pipe locations suitable for siting BMPs throughout the catchment area, appropriate structural BMPs that address the pollutants(s) of concern, any environmental (severe slopes, soils, infiltration rates, depth to groundwater, wetlands or other sensitive resources, bedrock) and other siting (e.g. utilities, water supply wells, etc.) constraints, permitting requirements or restrictions, potential costs, preliminary and final engineering requirements.

2) Establish a schedule to identify and assess all remaining discharges not identified in the TMDL (owned by the operator) contributing to the impaired waters addressed by the TMDL, to delineate the drainage or catchment areas to these discharges, and as needed to address water quality impairments, to design and construct structural BMPS. To determine the prioritization for BMP construction, the assessment of identified discharges shall determine the relative contribution of phosphorus taking into consideration pollutant loads (i.e. concentrations and flows) as indicated by drainage area, pipe size, land use, known hot spots and/or sampling data.

<u>Specific Storm Water Measures</u>

To realize water quality improvements in the eutrophic ponds, both phosphorus concentrations in storm water *and* the volume of storm water discharged to the ponds must be reduced. The large amount of impervious areas within the urban watersheds contributes substantial increases in the amount of runoff and phosphorus entering the ponds during and immediately after rain events. As the amount of impervious area in a watershed increases, the peak runoff rates and runoff volumes generated by a storm increases because developed lands have lost much or all of their natural capacity to delay, store, and infiltrate water. As a result, phosphorus from streets, lawns, wildlife, and domestic pets quickly wash off during storm events and discharge into the nearby waterbodies. In some cases increased runoff rates also result in the transport of eroded phosphorus-rich sediment and organic matter such as leaf litter.

While municipalities and RIDOT must implement the Phase II minimum measures town-wide, they should prioritize implementation of Phase II minimum measures in watersheds of these eutrophic ponds and should target the construction of stormwater BMPs for priority outfalls, identified in Sections 4.8 through 4.16. Addressing priority outfalls would of course first entail the identification of each of the catchments associated with each of these outfalls. Illicit discharge detection and elimination, required by the General Permit, should focus on the outfalls that discharge into the eutrophic ponds or to any of their tributaries.

Municipalities must conduct BMP feasibility studies to identify locations and technologies for installing infiltration basins or equivalent BMPs in these priority catchments. These studies must evaluate the feasibility of distributing infiltration throughout the drainage area of priority outfalls as an alternative to end-of-pipe technologies. This concept is particularly important in highly urbanized areas where rain events increase the storm water flows and pollutant loads as a result of the large amount of impervious surfaces and there is a small amount of undeveloped land available for BMP construction. Water quality improvements identified through ongoing water quality monitoring may result in modifications to the schedule and/or the need for additional BMPs.

There are many opportunities to address both water quality and water quantity and tailor efforts to the local concerns in the SWMPP as follows:

Public Education/Public Involvement

The public education program should focus on both water quality and water quantity concerns within the watershed. Public education material should target the particular audience being addressed. For example, the residential community should be educated about the water quality impacts from residential use and activities and the measures they can take to minimize and prevent these impacts. Examples include minimizing the adverse effects of lawn fertilizers (minimizing use, applying more frequent applications of smaller quantities of fertilizer if current overall quantities are to be maintained, and avoiding fertilizing immediately before anticipated storm events), disposing of pet waste properly, discouraging large waterfowl populations by eliminating human feeding of waterfowl and utilizing plantings and/or fencing adjacent to large tracts of open land near waterbodies where waterfowl land and congregate (see Section 6.3), prohibiting illegal tie-ins to storm drains from failing septic systems or washing machines, and informing residents about disposing wastes improperly (i.e. discouraging the disposal of yard waste immediately adjacent to a waterbody). Public involvement programs should actively involve the community in addressing these concerns. Involvement activities may include posting signs informing the public not to feed waterfowl, stenciling storm drains with *Do Not Dump* labels, and designating and maintaining areas with pet waste bags and containers. Lawn care companies should also be targeted in the case of fertilizer application, by providing educational brochures and/or classes.

The residential community should also be informed about water quantity impacts as a result of large areas of impervious surfaces and what measures they can take to minimize or help offset these impacts. Measures include the infiltration of roof runoff where feasible (green roofs, dry wells, and roof drains redirecting drainage to lawns and forested areas) and landscaping choices that minimize runoff. Some examples of landscaping measures are grading the site to minimize runoff and to promote storm water attenuation and infiltration, the creation of rain gardens, reducing paved areas such as driveways, and to consider porous driveways (cost effective options may include crushed shells or stone). Runoff can also be slowed by buffer strips and swales that add filtering capacity through vegetation. These examples can also be targeted to residential land developers and landscapers.

Other potential audiences include commercial property owners, land developers, and landscapers. BMPs that minimize runoff and promote infiltration should be encouraged when redeveloping or re-paving a site. Examples include minimizing road widths, porous pavement, infiltrating catch basins, breaking up large tracts/areas of impervious surfaces, sloping surfaces towards vegetated areas, and incorporating buffer strips and swales where possible.

RIDOT, in conjunction with RIDEM, has signed an agreement with the University of Rhode Island Cooperative Extension (URI) for a Public Education and Outreach Program. This program will provide participating MS4s the opportunity to use prepared education and outreach programs for their individual use, which could be easily tailored to the TMDL public education recommendations. To date, each of the MS4 designated in the TMDL studies are participating in the Program, except Coventry. More information may be found on the URI NEMO website
http://www.uri.edu/ce/wq/RESOURCES/STORMWATER/index.htm

Illicit Discharge Detection and Elimination

Many of the eutrophic pond watersheds are entirely sewered including those of Brickyard, Roger Williams Park, Sand, Spectacle, and Warwick Ponds. The Upper Dam Pond watershed is not sewered. Almy Pond, Gorton Pond, and North Easton Ponds are mostly sewered, but some areas are still on individual septic systems. There also may be individual residences that have not tied into existing sewage systems even though the neighborhood is sewered. Sewer extension projects are planned for many areas that are not currently sewered. A review of RIDEM’s lists of failed septic systems may alert municipalities to areas prone to failed systems, because of unfavorable soil conditions or the general age of systems. Also municipal sewer lines should be tested for significant leaks. Force mains are of particular concern since the effluent is under pressure, although there is the potential for leaks in gravity-fed pipes when the level of effluent is at a higher elevation than the water table.

Construction/Post Construction

Storm water volume reduction requirements for development and redevelopment of commercial and industrial properties should be considered in the development of ordinances and zoning regulations to comply with the construction and post construction minimum measures (see General Permit Part IV.B.4.a.1 and Part IV.B.5.a.2 respectively consistent with this TMDL’s recommendations). Municipalities are also required to adopt these policies for city-owned facilities and infrastructure (Part IV.B.6.a.2 and Part IV.B.6.b.1 of the Storm Water General Permit). As mentioned previously, examples of acceptable reduction measures include reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, using porous pavement, and installing infiltration catch basins where feasible. Other reduction measures to consider are the establishment of buffer zones, vegetated drainage ways, cluster zoning or low impact development, transfer of development rights, and overlay districts for sensitive areas.

Good Housekeeping/Pollution Prevention

The Storm Water General Permit (see Part IV.B.6.a.2 and Part IV.B.6.b.1) extends storm water volume reduction requirements to operator-owned facilities and infrastructure. Similarly, municipal and state facilities could incorporate measures such as reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, incorporating buffer strips and swales, using porous pavement and infiltration catch basins where feasible. In addition, any new municipal construction project or retrofit should incorporate BMPs that reduce storm water and promote infiltration such as the before-mentioned measures: buffer strips, swales, vegetated drainage ways, infiltrating catch basins, porous roads etc.

As part of its Good Housekeeping/Pollution Prevention requirements, municipalities must investigate the feasibility of increased street sweeping and/or stormwater system maintenance to address sediments loads to these eutrophic ponds. Street sweeping and storm drain cleaning should be conducted in the spring when the last reasonable chance of snowfall has past. Street sweeping in priority areas within the watershed must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls and also with those outfalls associated with large sediment deltas. Both priority outfalls and those outfalls associated with sedimentation deltas are discussed in sections 4.8 through 4.16. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. Cities and towns should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. Municipalities should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin cleaning is also an important activity in controlling phosphorus loads to the eutrophic ponds, by preventing the accumulation of sediment that could hamper settling.

Stormwater from Industrial Activities

Industrial Activities covered by the Statewide Multi-Sector General Permit

The TMDL has documented that stormwater is a major source contributing to the phosphorus and phosphorus-related impairments to the ponds. Stormwater discharges from industrial activities may be discharged to these waters directly or via the MS4s and may contain phosphorus concentrations that contribute to these impairments. Stormwater discharges from facilities that discharge “stormwater associated with industrial activity” are regulated under the statewide general RIPDES permit prescribed in Chapter 46-12, 42-17.1 and 42-35 of the General Laws of the State of Rhode Island.

In accordance with Part I.B.3.j of the RIPDES Multi-Sector General Permit, prior to authorization to discharge stormwater associated with industrial activity, the applicant is required to demonstrate that the stormwater discharge is consistent with the requirements of the TMDL. With completion of this TMDL, consistent with Part I.C. of the general permit, facilities currently authorized to discharge under the permit must either demonstrate that the existing Storm Water Pollution Prevention Plan (SWPPP) is consistent with the TMDL or amend their plan demonstrating consistency with the TMDL. More specifically, the TMDL requires that facilities currently authorized or seeking authorization to discharge to the ponds must demonstrate that their SWPPP reduces phosphorus to the maximum extent feasible. Permittees will have 90 days from written notification by RIDEM to submit this documentation including revised SWMPPs to RIDEM.

The owner/operators of facilities currently authorized to discharge to the ponds and their associated receiving waters are listed below:

- Rhode Island Airport (North Easton Pond via Bailey Brook)
- Freedom Yachts, Inc. (North Easton Pond via Bailey Brook)
- Rhode Island National Guard (Warwick Pond)

The SWPPP must identify the potential sources of pollution, including specifically the TMDL pollutant of concern (phosphorus), which may reasonably be expected to affect the quality of storm water discharges from the facility; and describe and ensure implementation of practices, which the permittee will use to reduce the pollutant in storm water discharges from the facility. The SWPPP must address all areas of the facility and describe existing and/or proposed BMPs that will be used to achieve the maximum extent feasible reduction of the TMDL pollutant of concern. As stated in Part IV.F.7 of the permit, selection of BMPs should take into consideration:

1. the quantity and nature of the pollutants, and their potential to impact the water quality of receiving waters;

2. opportunities to combine the dual purposes of water quality protection and local flood control benefits (including physical impacts of high flows on streams - e.g., bank erosion, impairment of aquatic habitat, etc.); and

3. opportunities to offset the impact of impervious areas of the facility on ground water recharge and base flows in local streams.

For existing facilities, the SWPPP must include a schedule specifying when each control will be implemented. Facilities that are not currently authorized will be required to demonstrate compliance with these requirements prior to authorization.

Industrial Activities covered by Individual Permits

The state airport, T.F. Green Airport operated by the RI Airport Corporation is the only industrial facility covered by an individual stormwater permit which discharges to any of the waters covered by this TMDL.

Three of the priority outfalls that were identified for Warwick Pond drain airport property. The Rhode Island Airport Corporation (RIAC) has applied for and obtained a permit to discharge stormwater to a tributary to Warwick Pond. The permit requires the implementation of the permittee’s existing Storm Water Pollution Prevention Plan (SWPPP) as of the effective date of the permit. The permit establishes a schedule that requires the permittee to amend the SWPPP to include additional BMPs as specified in the permit. The goal of the SWPPP is to help identify the source of pollutants in the discharge of storm water and to ensure practices are being implemented to minimize pollutants associated with industrial activities from entering any storm water discharge. This Plan emphasizes the use of Best Management Practices (BMPs) to provide the flexibility to address different sources of pollutants.

The SWPPP includes required elements and BMPs to mitigate the impacts of the following: aircraft, vehicle, and equipment maintenance, aircraft and pavement deicing/anti-icing fueling and washing, aircraft lavatory service, illicit discharge detection and elimination, pesticide management, building and grounds maintenance, chemical and fuel handling and storage, materials handling, stormwater pollution prevention education, outdoor area and floor wash-down, and water quality monitoring.

The list of BMPs presented in the SWPPP for each of the major airport activities is comprehensive. For instance, the following existing BMPs are listed for aircraft, vehicle, and equipment washing:

- “dry” washing;
- secondary containment for containers of washing and steam cleaning additives;
- covering catch basins with mats during washing;
- keep wash areas clean and free of waste;
- proper signage to prohibit the discharge of waste oils into the drains;
- aircraft vehicles and equipment should be washed indoors at a designated area and wash water should be collected;

- in the event that an indoor wash facility is not available, outdoor rinsing may be performed away from any storm water drains, with rinse water directed to a grassed area;
- consider offsite commercial washing and steam cleaning;
- use designated indoor wash areas and bermed or covered outdoor areas where feasible;
- filter and recycle wash water where practical; and
- conduct berm repair.

Implementation of these and other BMPs outlined in the SWPPP is expected to address the discharge of phosphorus associated with major airport activities, and implementation of the Glycol Management Plan required under the permit is expected to address the airport's contributions to the dissolved oxygen criteria violations observed in data collected by RIAC at the inlet and outlet of Warwick Pond.

The Director may notify the permittee at any time that the Storm Water Pollution Prevention Plan does not meet one or more of the minimum requirements of the permit. After such notification from the Director, the permittee shall make changes to the Plan and shall submit to the Director a written certification that the requested changes have been made. Unless otherwise provided by the Director, the permittee shall have thirty (30) days after such notification to make the necessary changes.

6.2 Structural Stormwater BMPs

A wide range of BMPs are available to control both the quality and quantity of urban storm water runoff entering receiving waters. BMPs should be incorporated into a comprehensive storm water management program. Without proper selection, design, construction, and maintenance, BMPs will not be effective in managing storm water runoff. There are a number of competing factors that must be addressed when selecting the appropriate BMP or suite of BMPs for an area. Site suitability and other factors are crucial in effective BMP selection. Several considerations for BMP selection include: drainage area, land uses, runoff volumes and flow rates, soil types, site slopes, water table elevation, land availability, susceptibility to freezing, community acceptance, maintenance accessibility, long-term maintenance needs, cost, and aesthetics. The combination of these factors make BMP selection difficult, requiring an experienced storm water practitioner. Typical BMP efficiencies are shown in Table 6.1. The University of New Hampshire Storm Water Center and the USEPA both have excellent websites regarding structural BMPs (http://www.unh.edu/erg/cstev/ and http://www.epa.gov/nrmrl/pubs/600r04184/600r04184.pdf). Commonly employed stormwater BMPs are discussed in greater detail in Appendix D.

Table 6. 1 Approximate Pollutant Removal Efficiencies for Common Structural BMPs.

BMP Type	**Typical Pollutant Removal (percent)**	
	Total Suspended Solids	**Total Phosphorus**
Dry extended-detention pond	61	19
Wet retention pond	68 ± 10 (-33 - 99)	55 ± 7 (12 - 91)
Infiltration trench	75	60 - 70
Porous pavement	82 -95	65
Bioretention	80	65-87
Sand or organic media filter	66 - 95	4 - 51
Stormwater wetland	71 ± 35	56 ± 35
Grassed swale	38 ± 31	14 ± 23
Vegetated filter strip	54 - 84	-25 - 40

Source: Adapted from Oak Ridge Institute for Science and Education and USEPA, 2004.

6.3 Waterfowl Control

There are many ways to discourage waterfowl and especially geese from settling adjacent to a nutrient impaired waterbody. No single technique is universally effective and feasible in a suburban or urban setting. Persistent application of a combination of methods is usually necessary and yields the best results. Some methods for controlling goose populations include the following: discontinuing feeding, modifying habitat, installing fencing, using visual scaring devices, applying repellents, using dogs to chase geese, and controlling goose nesting and capturing and removing geese (RIDEM Division of Fish & Wildlife and U.S. Department of Agriculture, written communication). Although the preceding methods pertain to the control of goose populations, many of the methods may also work for other waterfowl and gulls.

Although many people enjoy feeding waterfowl, feeding waterfowl is illegal in the state of Rhode Island and may cause large numbers of geese to congregate in unnatural concentrations. Well-fed domestic waterfowl, often act as decoys, attracting wild birds to the site. Geese that depend on supplemental feeding are also less likely to migrate when winter arrives. Feeding usually occurs in the most accessible areas such as lawns, streets, walkways, and parking areas. Some success in reducing goose feeding may be achieved through simple public education such as “ Do not feed the geese” signs (the Division of Fish & Wildlife will provide examples on request). Further reduction of feeding may require the adoption and enforcement of local ordinances such as fines or community service (cleaning up droppings for example) for violations.

Geese are grazing birds that prefer short, green grass or other herbaceous vegetation for feeding. Well-manicured lawns adjacent to the shoreline provide excellent habitat for these grazing birds. Wherever possible, grass should be allowed to grow to its full height (10-14 in.) around waterbodies. Lawn areas immediately adjacent to the shoreline of ponds may be allowed to revegetate naturally to discourage the congregation of waterfowl. In addition to discontinuing mowing next to ponds, the installation of a buffer of native vegetation is recommended to further discourage waterfowl and to limit the establishment of invasive plant species.

Fencing or other physical barriers installed along the shoreline can be effective where geese tend to land on water and walk up to adjacent lawns to feed. Fencing works best when geese are in their summer molt and unable to fly. Fences must completely enclose a site to be effective. Fencing around large open areas, such as athletic fields, have little effect for free flying birds. Goose fences should be at least 30 inches tall. Wire garden fencing will last for years. Less expensive plastic or nylon fencing could be used, but will have to be replaced more often. Snow fencing or erosion fabric may be used as a temporary barrier to molting geese. As previously discussed, the installation of any fencing adjacent to a pond would require a permit from the Wetlands Permitting office of RIDEM.

Various materials may be used to create a visual image that geese will avoid, especially if they are not already established on a site. Geese are normally reluctant to linger beneath an object hovering overhead. However, visual scaring device are not likely to be effective on suburban lawns where trees or other overhead objects exist and where geese have been feeding for years. One very effective visual deterrent for geese is Mylar tape that reflects sunlight to produce a flashing effect. Also when a breeze catches the tape, it pulsates to produce a humming sound that also repels birds. The tape should be strung at the water’s edge. Some slack should be left in the tape and it should be twisted as it is strung from stake to stake. Another visual scaring technique is the placement of flagging of balloons on poles at the shoreline. Helium-filled bird-scaring balloons with eye spots are sold at some garden supply and party stores. Owl decoys may also be effective. If geese become acclimated to any of these devices, frequent relocation may be necessary. The use of remote control boats can also be used to repel geese, and may be practical if local hobbyists are willing to participate.

The U.S. Environmental Protection Agency has approved the product, ReJeXiT ®, as a goose repellent for lawns. The active ingredient in ReJeXiT ® is methyl anthranilate (MA), which is a human-safe food flavoring derived from grapes. Geese will avoid feeding on treated lawns because they dislike the taste. However geese may still walk across treated areas. The material is available at some garden supply shops and costs about $125 per acre per application. Several applications per year are usually necessary.

Dogs trained to chase but not harm geese have been used effectively to disperse geese from parks, golf courses, and athletic fields. Border Collies or other breeds with herding instincts work best. The dogs must be closely supervised during this activity. Initially, chasing must be done several times a day for several weeks, after which less frequent but regular patrols will be needed. Dogs generally should not be used when geese are nesting or unable to fly, such as during the summer molt or when goslings are present.

The control of goose nesting and the capture and removal of geese are two other methods that could be used to reduce excessive goose populations on lakes and ponds. Both activities require federal permits. The Division of Fish & Wildlife of RIDEM should be contacted if this method is being considered.

Without efforts to reduce nuisance waterfowl populations, these non-lethal methods of control may just shift the populations and their associated negative water quality impacts to other waterbodies. In areas where waterfowl populations are particularly problematic, the involvement of cities and towns working with property owners, and the Division of Fish & Wildlife and USDA Wildlife Services is necessary to develop a more comprehensive and publicly acceptable strategy. Methods to be considered may include where applicable, the extension of the hunting season and/or increased limits for specific waterbodies where waterfowl have been identified as a significant source of pollution in a TMDL.

Some methods of geese control are not recommended because they are ineffective, labor-intensive, or illegal. These include: the use of swans, bird distress calls, scarecrows, dead goose decoys, use of trained birds of prey, sterilization, fountains or aerators, introduction of predators, introduction of disease, and the use of poisons.

6.4 Internal Phosphorus Control

There are four primary techniques to reduce internal loading of phosphorus in waterbodies: dredging, aeration/oxygenation of the hypolimnion, complete circulation/destratification of the entire lake, and the application of alum (or other phosphorus-binding agents). Dredging is the most effective method but is extremely costly (~50 times alum) and may encounter regulatory prohibitions (Welch, 2005). Hypolimnetic aeration/oxygenation treats anoxic phosphorus release only and depends on iron availability to bind phosphorus and iron may not be inactivated itself in highly polluted sediments. Complete circulation/destratification has the same effect on sediment phosphorus as hypolimnetic aeration, but with a greater risk of increasing phosphorus availability in the epilimnion by removing the thermocline barrier. Also shallow lakes are generally already aerated. Aeration techniques also have no lasting effect and once the source of air is shut off the internal loading will return. Alum treatment has proven to be effective in both stratified anoxic and unstratified oxic lakes. While first year costs for alum and aeration/oxygenation are similar (~$1,000-$3000/hectare), alum cost is only one-tenth as much when spread over ten years. As with application of any chemical, the use of alum must be carefully evaluated and controlled to minimize the risk of potential negative chemical and biological impacts. Alum application and its associated risks are discussed in greater detail in Appendix E.

For those ponds identified as having a significant internal cycling of phosphorus, DEM recommends that a professional consultant with experience in the control of phosphorus release from pond sediments be hired to specifically address this source. The consultant should confirm the significance of internal cycling as a source of phosphorus to the pond, and secondly, evaluate the most effective and feasible BMPs to control phosphorus release from the sediment. Lastly, many BMPs used to control the release of internal phosphorus may have undesirable effects on the waterbody if not properly conducted and therefore the consultant should also be retained to oversee implementation of the selected BMPs.

6.5 Specific Implementation Activities

6.5.1 Almy Pond

The major sources of phosphorus to Almy Pond, not necessarily in order of significance, are stormwater, waterfowl, internal cycling and potentially wastewater.

Upon approval of this TMDL, the City of Newport will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. Three stormwater outfalls were identified as the most significant potential sources of phosphorus to Almy Pond. These outfalls, in order of significance, are located off Ruggles Avenue (AP-L), Wheatland Court (AP-C), and Alpond Drive (AP-I) (Appendix A, Figure 1; Appendix B, Table 1). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration, and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The City of Newport must increase street sweeping and/or stormwater system maintenance to address sediment loads to Almy Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the RIPDES Phase II General Permit required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The City of Newport should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The City of Newport should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Almy Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. Sediment-clogged catch basins along Ocean Avenue were observed to cause flooding along the roadway and nearby parking lot (Table 6.2). These catch basins and associated culverts need to be cleaned and properly maintained.

Waterfowl may be a significant source of phosphorus to Almy Pond. Waterfowl appear to congregate mostly at night in the open water of the pond due to a lack of open habitat along the shoreline. Due to this fact, control of the population of 30-50 geese may be difficult.

There is no direct evidence of internal cycling in Almy Pond due to the absence of phosphorus data at depth. However, it is entirely probable that phosphorus-laden lake sediments become anoxic in the summer months, releasing phosphorus into the water column. Indirect evidence such as a strong odor of hydrogen sulfide from disturbed bottom sediments and increased phosphorus concentrations during the summer months, may indicate that phosphorus is being released from the sediment. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

Table 6. 2 Sediment Impacted Storm Water Culverts Within the Almy Pond Watershed.

Outfall/Surface Discharge ID	Culvert Diameter (in.)	Location	Comments	Ownership
AP-F	12	Ocean Av.	Terminal catch basin flooded during wet weather	City of Newport
AP-G	12	Ocean Av.	Terminal catch basin flooded during wet weather	City of Newport
AP-H	12	Ocean Av.	Terminal catch basin flooded during wet weather	City of Newport

There is a concern that leaky force mains associated with pump stations at Murray Place and Alpond Drive and a possible cross-connection at Carol Avenue may contribute to the unusually elevated phosphorus concentrations observed in Almy Pond. Dye studies must be conducted at these three locations to determine if wastewater is a significant source of fecal material and phosphorus to the pond. Any potential leak from the possible cross-connection or the pumping station at Alpond Drive would likely discharge into the pond at outfall AP-I. If the results of the dye tests are positive, then the sewer system must be repaired or reconstructed. There is also a concern that there may be failing septic systems along the pond's eastern and northern shores. The Office of Compliance and Inspection of RIDEM will continue to investigate any reports of failing septic systems. Also the City of Newport is required to identify and eliminate any illegal tie-ins to the storm water system as part of its Phase II Six Minimum Measures requirements.

6.5.2 Brickyard Pond

The major sources of phosphorus to Brickyard Pond, not necessarily in order of significance, are stormwater, waterfowl, shoreline erosion, and internal cycling.

Upon approval of this TMDL, the Town of Barrington and RIDOT will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The Town and RIDOT should coordinate to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the pond. Nine stormwater outfalls were identified as the most significant potential sources of phosphorus to Brickyard Pond. These outfalls, in order of significance, are located at the bike path (BrP-E and BrP-C), Maple Avenue (BrP-I and BrP-J), Ferncliffe Road (BrP-D), Broadview Drive (BRP-X), south of Half Mile Road (BrP-O), near Nyatt Elementary School (BrP-Q), and at Woodhaven Road (BrP-S) (Appendix A, Figure 2; Appendix B, Table 2). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The Town of Barrington and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Brickyard Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup (Table 6.3). The Town of Barrington and RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The Town of Barrington and RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Brickyard Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion.

Table 6. 3 Sediment Impacted Storm Water Culverts Within the Brickyard Pond Watershed.

Outfall/Surface Discharge ID	Culvert Diameter (in.)	Location	Comments	Ownership
BrP-A	18	Maple Ave. Medical Center	Half blocked with sediment	Town of Barrington
BrP-F	8	Bike path; opposite Vineyard Ln.	Mostly blocked with sediment	Town of Barrington

Significant numbers of waterfowl, including mute swans, were observed on the pond. Residents report that up to 1000 geese and 500 cormorants inhabit the pond, especially in the winter months. The Division of Fish and Wildlife is actively monitoring the nests of mute swans and addling eggs at Brickyard Pond to help reduce the swan population (Jason Osenkowski, Division of Fish & Wildlife, personal communication).

Although no feeding was observed during the brief site visits, feeding may occur at the grassed area along the bike path at the northern shoreline of the pond. If this is the case, then signage should be installed instructing the public to refrain from feeding the waterfowl. This no-feeding policy is state law and should be enforced. Residents report that several hundred cormorants congregate on the many islands within the pond. Barriers such as fencing can be installed at the shoreline of these islands, and any other places where large numbers of birds are observed, to discourage the use of these areas by the cormorants or other birds. The installation of such a barrier may require a permit from the RIDEM Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline of the pond and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

Eroded sediment from the northern shore of the pond along the bike path and to a lesser extent the northeastern shore in the general vicinity of the YMCA, may be a significant source of phosphorus to the pond. It appears that the Town of Barrington owns the land within 30 feet of the pond. The Town should prohibit any vegetative cutting and perhaps replant areas that have been previously cleared with native vegetation. It is recommended that erosion controls, such as riprap or gabion, be installed in these areas to minimize the erosion that appears to be ongoing. The installation of riprap would require a permit from RIDEM's Freshwater Wetlands Permitting Program.

It appears that internal cycling is a significant source of phosphorus for Brickyard Pond. Phosphorus concentrations at the surface and at depth differ by about an order of magnitude in the summer and early fall, when the pond is stratified. Since it is likely that internal cycling is a significant source of phosphorus, internal phosphorus BMPs such as those discussed in section 6.4 are recommended. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

6.5.3 Gorton Pond

The major sources of phosphorus to Gorton Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

Upon approval of this TMDL, the City of Warwick and RIDOT will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The City and RIDOT should coordinate to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the pond. Six stormwater outfalls were identified as the most significant potential sources of phosphorus to Gorton Pond. These outfalls, in order of significance, are located at Veterans Memorial Drive (GP-G and GP-H), Sharon Street (GP-B), Greenwich Avenue (GP-K), Trinity Street (GP-A), and Post Road (GP-E) (Appendix A, Figure 3; Appendix B, Table 3). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The City of Warwick and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Gorton Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The City of Warwick/RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The City of Warwick /RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Gorton Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond (GP-G and GP-H). A terminal catch basin associated with another outfall (GP-C) was completely blocked with sediment (Table 6.4). These culverts need to be cleaned and properly maintained. There is also an apparent unstable 15-ft escarpment at the outfall of culvert GP-A. An erosion control BMP should be installed at this location to prevent potential slope failure.

Table 6. 4 Sediment Impacted Storm Water Culverts Within the Gorton Pond Watershed.

Outfall/Surface Discharge ID	**Culvert Diameter (in.)**	**Location**	**Comments**	**Ownership**
GP-A	24	Trinity St.	15-20 ft high vertical escarpment at outfall due to erosion	City of Warwick
GP-C	12[3]	Lodi Ct.	Terminal catch basin blocked with sediment	City of Warwick
GP-G	52” X 35” oval culvert	Post Rd./Veterans Memorial Dr.	Significant sedimentation	RIDOT
GP-H	46” X 30” oval culvert	Post Rd./Veterans Memorial Dr.	Significant sedimentation	RIDOT

Birds may be a significant source of phosphorus to Gorton Pond. Scores of waterfowl including geese, ducks and swans and also gulls were observed congregating on a lawn that stretches to the waters edge. The lawn is located on a small peninsula that juts into the pond immediately north of its outlet. Barriers such as fencing can be installed at the shoreline of the subject lawn to prevent waterfowl from congregating there. Another alternative is to discontinue mowing near the immediate shoreline and allow the area to revegetate naturally. Geese also congregate at the Town beach at the eastern end of the pond. Signage instructing the public not to feed the waterfowl should be installed at the beach and any other public areas where feeding may occur. Fencing could be installed along the shoreline of the beach during the off-season to prevent geese from utilizing this area. The installation of any barrier adjacent to the pond may require a permit from the RIDEM Freshwater Wetlands Program. As previously noted there are numerous areas, especially near outlet of the pond, where lawns extend to the pond’s shoreline providing congregation areas for waterfowl. It is recommended that mowing of the immediate shoreline in these areas be discontinued and the areas be allowed the area to revegetate naturally. The installation of a buffer of native vegetation is also recommended in these areas to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

Internal cycling is likely a significant source of phosphorus for Gorton Pond. The mean concentration of total phosphorus at the pond bottom was approximately 7 and 5 times higher than the mean concentration at depth in the summer and fall, respectively. The control of internal phosphorus is recommended in this pond to mitigate the release of phosphorus from the sediment and to reduce the mean concentration of phosphorus in the water column. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

6.5.4 North Easton Pond

The major sources of phosphorus to North Easton Pond, not necessarily in order of significance, are Bailey's Brook and to a lesser extent an unnamed tributary, stormwater, waterfowl, wastewater, erosion/sedimentation and internal cycling, and perhaps Rhode Island Nursery properties.

Sampling of total phosphorus in Bailey's Brook between 1991 and 2003 shows that the river is a significant source of phosphorus to North Easton Pond. Excluding the highest recorded total phosphorus concentration of 2730 ug/l, the mean concentration was 42 ug/l. It is also highly probable that a second unnamed tributary is also a significant source of phosphorus. However, this other stream may not have as significant effect on the water quality of the pond since it discharges into the pond in very close proximity to its outlet.

Upon approval of this TMDL, the Town of Middletown and RIDOT will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The outfalls discharging to the tributaries North Easton Pond were not identified as part of the development of this TMDL. The Town and RIDOT must coordinate to complete the identification, mapping, and determination of ownership and interconnections for all stormwater outfalls discharging to the pond and its tributaries. The outfalls must then be prioritized consistent with methods discussed in section 4.2, and the catchments of each of the prioritized outfalls must be identified. A feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified catchments to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Locating suitable sites for infiltration BMPs is especially critical in the Town of Middletown where poorly drained soils and high water tables may be problematic. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

As previously discussed in section 6.1, Stormwater discharges from facilities that discharge "stormwater associated with industrial activity" are regulated under the statewide general RIPDES permit prescribed in Chapter 46-12, 42-17.1 and 42-35 of the General Laws of the State of Rhode Island. Two owner/operators of facilities are currently authorized to discharge to Bailey Brook, the major tributary to North Easton Pond. These facilities include Rhode Island Airport and Freedom Yachts, Inc. In accordance with Part I.B.3.j of the RIPDES Multi-Sector General Permit, prior to authorization to discharge stormwater associated with industrial activity, the applicant is required to demonstrate that the stormwater discharge is consistent with the requirements of the TMDL. With completion of this TMDL, consistent with Part I.C. of the general permit, facilities currently authorized to discharge under the permit must either demonstrate that the existing Storm Water Pollution Prevention Plan (SWPPP) is consistent with the TMDL or amend their plan demonstrating consistency with the TMDL. More specifically, the TMDL requires that facilities currently authorized or seeking authorization to discharge to the ponds must demonstrate that their SWPPP reduces phosphorus to the maximum extent feasible. Permittees will have 90 days from written notification by RIDEM to submit this documentation including revised SWMPPs to RIDEM (see section 6.1 for further details).

The Town of Middletown and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to North Easton Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The Town of Middletown /RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The Town of Middletown /RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to North Easton Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond.

Waterfowl may be a significant source of phosphorus to North Easton Pond. Between 300 and 500 geese were observed in the water at the northern end of the lake near Green End Avenue. Although no waterfowl were observed congregating on the shore at the time of the shoreline survey, geese may congregate at the water treatment plant at the southwest corner of the pond or at neighboring properties to the north where lawn stretches to the water's edge. Fencing could be installed at the shoreline to discourage the congregation of waterfowl. The installation of such a barrier may require a permit from RIDEMS Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Signage instructing the public not to feed the waterfowl should be installed at any public areas where feeding may occur, especially also the dike at the southern end of the pond. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

In 2005 the Natural Resources Conservation Services selected Geosyntec Consultants Inc. to conduct a preliminary assessment of the Bailey Brook Watershed. Geosyntec Consultants Inc. reported several areas where wastewater was surging from sewer manholes associated with an interceptor sewer line that runs along Bailey's Brook. This information was forwarded to the Office of Compliance and Inspection (OCI) and to the Town of Middletown for further investigation. The Town of Middletown, through a private contractor, conducted a survey of the sewer system and determined that the pipes themselves were in good shape but the manholes and manhole connections were in a state of disrepair. The Town of Middletown entered into a Consent Agreement with OCI which required the Town to rehabilitate the interceptor system by sealing the manholes and manhole connections, installing risers to increase the elevation of the manhole structures, and installing watertight covers over the manholes to prevent infiltration. Two flow meters were also required to be installed to determine if there is significant infiltration into the system. The rehabilitation of the sewer line has been completed and there have been no additional leaks of sewage along the interceptor to date (personal communication, John O'Loughlin).

Erosion/sedimentation may be a significant source of phosphorus to North Easton Pond. Two instances of eroding stockpiled earth materials, resulting in sedimentation of two tributaries to Bailey's Brook, were identified by Geosyntec Consultants (2005). These sites are located at Oliphant Lane at Aquidneck Avenue just south of Vierra Terrace. Both instances were reported to the Office of Compliance and Inspection (OCI) at RIDEM and their investigation into these alleged violations is pending. OCI will continue to investigate reports of erosion and sedimentation in the watershed.

Geosyntec Consultants Inc. (2005) also found that the substrate was unstable in many of the reaches of the main stem of Bailey's Brook and all its tributaries except for the one that originates at Aquidneck Avenue. This unstable or constantly shifting bed load significantly curtails epifaunal colonization and may be a contributing factor to the biodiversity impairment of the river. Much of this sediment is transported as bedload to the terminus of the main stem of Bailey's Brook, just north of Green End Avenue. Prior to 1970 there was a shallow pond at this location, but the area has since been filled in with sediment and is now a marsh. The sedimentation of Bailey's Brook and its tributaries is in part the result of improper past agricultural practices and also the historic practice of channelizing the streambed with heavy equipment. Currently erosion and sedimentation problems result from inadequate sedimentation controls at construction sites and infrequent street sweeping practices. The implementation of Phase II Minimum Measures is expected to improve both sediment control at construction sites and street sweeping practices. Current erosion problems may also be caused by increased stream flows due to ongoing development and increased impervious area. Stormwater BMPs that encourage infiltration and reduce runoff will result in lower stream flows and less stream streambed instability.

There is no direct evidence of internal cycling in North Easton Pond. However, the limited phosphorus data for North Easton pond indicates that in-pond concentrations of phosphorus increase as the growing season progresses. This is consistent with trends observed in other waterbodies where internal loading is a significant source. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

Concern has been raised by a local official that the Miatonomi Ave. location of Rhode Island Nursery may be a source of phosphorus to North Easton Pond. Apparently irrigation water currently overshoots the nursery and flows down Miatonomi Ave. eventually discharging into the storm drain system and the pond. Inspection of aerial photographs shows that the much larger nursery operation, also owned by Rhode Island Nursery and located between the Newport State Airport and East Main Rd. (Route 138), also may be a source of phosphorus to the pond. Surface water, perhaps rich in phosphorus, can be observed at the southern end of the nursery in very close proximity to a tributary to Bailey's Brook. The potential of these two nursery operations as a phosphorus source to North Easton Pond was discussed in a meeting between RIDEM and National Resources Conservation Service (NRCS) personnel. The NRCS provides leadership in a partnership effort to help private landowners and managers conserve their soil, water, and other natural resources. The NRCS provides technical and financial assistance for many voluntary conservation activities. The NRCS representative was aware of the Rhode Island Nursery operations and agreed to further investigate the potential of these two areas as source of phosphorus to North Easton Pond.

6.5.5 Roger Williams Park Ponds

The major sources of phosphorus to Roger Williams Pond, not necessarily in order of significance, are Mashapaug Pond, stormwater, waterfowl, erosion, and internal cycling.

Mashapaug Pond has been identified as a major source of phosphorus to Roger Williams Park Ponds. . The existing phosphorus load to Roger Williams Park Ponds from Mashapaug Pond is 232 kg/yr (RIDEM, 2007). The TMDL assigned to Mashapaug Pond is 108 kg/yr (RIDEM, 2007), a 53% required reduction in total phosphorus being discharged from Mashapaug Pond into Roger Williams Park Ponds. The BMPs recommended in the implementation section of the Mashapaug Pond TMDL are therefore expected to significantly improve the water quality of Roger Williams Park Ponds.

Upon approval of this TMDL, the Cities of Cranston and Providence, and RIDOT will have 180 days to amend their SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The Cities and RIDOT should coordinate to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the ponds. Eight stormwater outfalls were identified as the most significant potential sources of phosphorus to Roger Williams Park Ponds. These outfalls, in order of significance, are located at Elmwood Avenue (RWP-Q), Frederick C. Green Memorial Boulevard (RWP-S, RWP-V, RWP-H, RWP-A, RWP-I, and RWP-U) and Cladrastis Avenue (RWP-D), (Appendix A, Figure 5; Appendix B, Table 4). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The Cities of Providence and Cranston and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Roger Williams Park Ponds. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition (Table 6.5), Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The Cities of Providence and Cranston and RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The Cities of Providence and Cranston and RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Roger Williams Park Ponds, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A large sedimentation delta that impacts much of Roosevelt Lake is associated with culvert RWP-P. The streets in the catchment area associated with this outfall must cleaned more than twice a year. A culvert discharging into the southern area of Roosevelt Lake was observed to be partially blocked with sediment. This culvert must be cleaned and properly maintained. There are several blocked catch basins along Frederick Green Memorial Boulevard in the vicinity of Edgewood Lake and Oakland Cemetery. Storm water in this area is forced to flow along the surface of the roadway and across a grassed area along the shoreline at RWP-1, causing erosion of the shoreline. This catch basins and the associated culverts need to be cleaned and properly maintained.

Table 6. 5 Sediment Impacted Storm Water Culverts Within the Roger Williams Park Ponds Watershed.

Outfall/Surface Discharge ID	Culvert Diameter (in.)	Location	Comments	Ownership
RWP-P	18	South-central shore of Roosevelt Lake	Partially blocked	City of Providence
RWP-Q	48	Westernmost end of Roosevelt Lake	Significant sand deposition	City of Providence/RIDOT
RWP-1	NA	Edgewood Lake opposite Oakland Cemetery	Erosion due to blocked catch basins	City of Providence

As discussed in Section 4.12, waterfowl appear to be a significant source of phosphorus to Roger Williams Park Ponds. An estimated 2000 geese and ducks were observed within the park ponds system at any given time. The recent installation of signage by the Providence Parks Department discouraging the feeding of waterfowl at all popular feeding areas and enforcement by park police may help to reduce the resident waterfowl population. Unfortunately persistent vandalism of the signs has occurred. The

Providence Parks Department is also planning to deter waterfowl by using broadcasting predatory sounds at strategic areas around the park pond system (oral communication, Robert McMahon, Deputy Superintendent of Parks). If the predatory sounds do not achieve the desired results, the park may employ the use of dogs such as border collies. RIDEM commends these efforts to reduce the waterfowl population within the park and will monitor its success in the future. Other alternatives to discouraging waterfowl would be to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

As previously discussed, stormwater catch basins along Frederick Green Memorial Boulevard near the northern end of Edgewood Lake are entirely blocked causing storm water to flow from the roadway across a grassed area resulting in an eroded channel near the northern end of the pond (RWP-1). The City of Providence must clean out all blocked catch basins and associated storm sewers in this area as required by the Phase II minimum measures.

As discussed in Section 4.12, there is no direct evidence of internal cycling, however it is probable that sediments release phosphorus into the water column. The limited data indicates that phosphorus concentrations increase during the summer months, which is typically the period when phosphorus release from the sediment is most significant. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

Currently the Providence Parks Department has obtained a permit for the application of herbicides to all of the ponds included in this study to reduce the growth of aquatic weeds. Unfortunately, these weeds are left in the pond to decay and eventually reintroduce phosphorus back into the system. Also, one of the permitted herbicides (glyphosate) itself contains phosphorus. The Park administration should consider the mechanical removal of aquatic weeds instead of the use of herbicides in the ponds. The mechanical removal of weeds would be a more long-term solution than herbicide treatment, since it results in removal of phosphorus from the system. Like the application of herbicides, the mechanical removal of weeds from the ponds would require a permit from RIDEM.

6.5.6 Sand Pond

As previously discussed, the major sources of phosphorus to Sand Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

As discussed in Section 4.13, three stormwater outfalls and an area of concentrated surface flow were identified as the most significant potential sources of phosphorus to Sand Pond. These sources, in order of significance are located at Post Road (SdP-F), near a commercial area at the northwest end of the pond (SdP-B, and SdP-A), and at Sand Pond Road (SdP-1) (Appendix A, Figure 6; Appendix B, Table 5). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The City or Warwick and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Sand Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The City of Warwick and RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The City of Warwick and RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Sand Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A significant sedimentation delta was observed at the outfall of culvert SdP-F and also at the terminus of an area of concentrated flow from Sand Pond Rd (Table 6.6). This culvert needs to be cleaned and properly maintained. A sedimentation BMP should be installed at Sd-P-1. The sedimentation BMP should be properly maintained.

Table 6. 6 Sediment Impacted Storm Water Culverts Within the Sand Pond Watershed.

Outfall/Surface Discharge ID	Culvert Diameter (in.)	Location	Comments	Ownership
SdP-F	36	Post Rd	Sand deposition	RIDOT
SdP-1	NA	Sand Pond Rd	Sand deposition	City of Warwick

Although few waterfowl were observed on the pond during the shoreline survey, local residents reported large numbers of waterfowl at the pond in the past (Section 4.13). As many as 200 geese were reported in the summer of 2000 or 2001 and as many as 500 were reported to congregate on the pond ice in the winter of the same time period. Signage instructing the public not to feed the waterfowl should be installed at any public areas where feeding may occur, especially the city beach at the northern shoreline of the pond. There are several lawns that extend to the ponds edge that may provide congregation areas adjacent to the pond. If in the future large numbers of waterfowl return to the pond, fencing can be installed along the shoreline of these lawns to reduce the waterfowl population on the pond. The installation of such a barrier may require a permit from RIDEM’s Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

As discussed in Section 4.13, internal loading is likely a significant source of phosphorus to Sand Pond. Phosphorus concentrations at depth were an order of magnitude or more higher than those measured at the surface during the summer and fall of 2001 and 2003. Internal phosphorus controls are recommended in this pond to mitigate the release of phosphorus from the sediment and to reduce the mean concentration of phosphorus in the water column. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4.

6.5.7 Spectacle Pond

The major sources of phosphorus to Spectacle Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal cycling.

Upon approval of this TMDL, the City of Cranston will have 180 days to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The City should coordinate with RIDOT to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the pond. Four stormwater outfalls were identified as the most significant potential sources of phosphorus to Spectacle Pond. These outfalls, in order of significance, are located at Lake Street (SpP-F), the baseball fields at the southern end of the pond (SpP-E, SpP-D), and Molter Street (SpP-A), (Appendix A, Figure 7; Appendix B, Table 6). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D.

The City of Cranston must increase street sweeping and/or stormwater system maintenance to address sediment loads to Spectacle Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition (Table 6.7), Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The City of Cranston should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The City of Cranston should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Spectacle Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A large sedimentation delta that extends halfway across the pond was observed to be associated with the Lake Street culvert. Also the outfall at Molter Street is completely blocked and stormwater was observed surcharging out of the terminal catch basin. This surging stormwater has caused significant erosion to the shoreline of the pond. These culverts need to be cleaned and properly maintained.

Thirty to forty waterfowl were observed on the pond at any one time. As previously discussed in Section 4.14, geese were observed congregating on a commercial parking area at the northern end of the pond. Signage instructing the public not to feed the waterfowl should be installed at any public areas where feeding may occur. The geese apparently gain access to the pond in this area down a dirt embankment. Due to steep slopes, and to a lesser extent dense vegetation, this dirt embankment appears to be the only waterfowl congregation area adjacent to the shore. Barriers such as fencing can be installed at the shoreline at the base of the dirt embankment to reduce the population of waterfowl frequenting the pond. The installation of such a barrier may require a permit from RIDEM’s Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

Table 6. 7 Sediment Impacted Storm Water Culverts Within the Spectacle Pond Watershed.

Outfall/Surface Discharge ID	**Culvert Diameter (in.)**	**Location**	**Comments**
SpP-A	15	Molter St	Outfall is apparently completely blocked with sediment
SpP-F	48	Lake St	Major sediment delta at end of waste stream

Since Spectacle Pond is classified as a shallow waterbody by URIWW, total phosphorus was measured at the surface only. Although there is no direct evidence of phosphorus release from the sediment, internal cycling probably does occur. Limited data obtained by RIDEM staff on July 28, 2004 showed that dissolved oxygen near the bottom was below 1.5 mg/l. Dissolved oxygen was measured at a depth of 4 m at three locations in the deeper southern portion of the pond. Based on this data, it appears probable that the sediment becomes anoxic at least during part of the summer and/or early fall and that these anoxic conditions cause phosphorus release from the mucky organic sediment. It is recommended that URIWW begin to sample for phosphorus near the lake bottom. It would also be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4. Consideration should be given to the use of in-lake phosphorus management techniques (e.g. alum treatment) – even prior to the significant reduction of identified external sources of phosphorus (i.e. stormwater sources). Such in-lake management techniques would be expected to incrementally improve conditions in Spectacle Pond and reduce the load of phosphorus to Mashapaug Pond.

The TMDL calculated for Spectacle Pond was based on a mean annual in-pond concentration of 20 ug/l. Given an estimated mean annual flow rate of 1.64 x 10^6 m^3/yr, the loading rate from Spectacle Pond to Mashapaug Pond is required to be 32 kg/yr. Since this is less than the TMDL load allotment assigned to Spectacle Pond by the Mashapaug study of 38 kg/yr, the BMPs recommended above will have a significant positive impact not only on the water quality of Spectacle Pond, but also on the water quality of Mashapaug Pond located approximately 0.45 km downstream.

6.5.8 Upper Dam Pond

The major sources of phosphorus to Upper Dam Pond, not necessarily in order of significance, are stormwater, wastewater, internal cycling, and potentially waterfowl.

Upon approval of this TMDL, the Town of Coventry and RIDOT will have 180 days to amend their SWMPP consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The Town and RIDOT should coordinate to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the pond. Seven stormwater outfalls were identified as the most significant potential sources of phosphorus to Upper Dam Pond. These outfalls, in order of significance, are located at Pond View Drive (UDP-D), Gervais Road (UDP-P, UDP-Q and UDP-L), Knotty Oak Road (UDP-I and UDP-H), and Breezy Lake Drive (UDP-B) (Appendix A, Figure 8; Appendix B, Table 7). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D. A feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible.

The Town of Coventry and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Upper Dam Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The Town of Coventry and RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The Town of Coventry and RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Upper Dam Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond.

At least one pipe, discharging wastewater from a failing septic system was found, discharging to a tributary to Upper Dam Pond. This matter is under investigation from the Office of Compliance and Inspection. The presence of other failing septic systems and illegal tie-ins cannot be discounted and are a possible source of phosphorus to Upper Dam Pond. There are many small lots in close proximity to the water on Breezy Lake Drive and the northern portion of the lake. A failing septic system in this area could potentially have a significant impact on this 8 hectare pond. The Office of Compliance and Inspection will continue to investigate any reports of failing septic systems or illegal tie-ins. Also the Town of Coventry is required to identify and eliminate any illegal tie-ins to the storm water system as part of its Phase II Six Minimum Measures requirements.

Although there is no direct evidence of internal cycling taking place in this shallow pond, it is likely that it does occur. A strong odor of hydrogen sulfide was observed when the mucky organic substrate in the shallows was disturbed, indicating that the substrate was anoxic. Also, the limited phosphorus data shows that phosphorus levels increase dramatically from spring to summer. It would be prudent to retain the services of a professional consultant with experience in the control of phosphorus release from pond sediments to develop and implement a pond sediment management strategy as described in Section 6.4. Few waterfowl were observed at the pond during the brief shoreline survey. However, if local knowledge indicates that there is a significant population of waterfowl utilizing the pond, the measures discussed in Section 6.3 should be implemented to control that population.

Although few waterfowl were observed on the pond during the shoreline survey, significant numbers of waterfowl may frequent the pond. Signage instructing the public not to feed the waterfowl should be installed at any public areas where feeding may occur, especially the town beach at the southern end of the pond. There are also several lawns that extend to the pond's edge that may provide congregation areas adjacent to the pond. Fencing can be installed along the shoreline of these lawns to reduce the waterfowl population on the pond. The installation of such a barrier may require a permit from RIDEM's Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

6.5.9 Warwick Pond

As previously discussed, the major sources of phosphorus to Warwick Pond, not necessarily in order of significance, are stormwater and waterfowl.

Upon approval of this TMDL, the City of Warwick and RIDOT will have 180 days to amend their SWMPPs consistent with Part IV.D of the General Permit and more specifically, Section 6.1 of this TMDL. The City and RIDOT should coordinate to confirm the identification, mapping, and ownership, and determine interconnections for all stormwater outfalls discharging directly to the pond. As discussed in Section 4.16, six stormwater outfalls were identified as the most significant potential sources of phosphorus to Warwick Pond. These outfalls, in order of significance, are located at Airport Road (WP-AJ), Lake Shore Drive (WP-U), near T.F. Green Airport (WP-AB and WP-Z), at Stanmore Road (WP-K), and Evergreen Avenue (WP-AC) (Appendix A, Figure 9; Appendix B, Table 8). As discussed in Section 6.1, the catchments associated with each of the priority outfalls must be identified. RIDEM recommends infiltration, filtration and/or retention BMPs throughout the identified subwatersheds to reduce runoff volume and phosphorus loading of stormwater reaching the pond, rather than end-of-pipe solutions. Several BMPs to reduce stormwater volume, and therefore phosphorus load, are discussed in section 6.2 and Appendix D. A feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible.

As previously discussed in section 6.1, stormwater discharges from facilities that discharge "stormwater associated with industrial activity" are regulated under the statewide general RIPDES permit prescribed in Chapter 46-12, 42-17.1 and 42-35 of the General Laws of the State of Rhode Island. The Rhode Island Airport Corporation has applied for and obtained a permit to discharge stormwater from TF Green Airport to a tributary to Warwick Pond. RIAC's Storm Water Pollution Prevention Plan includes required elements and BMPs to mitigate the impacts of major airport activities on these receiving waters – including the phosphorus related impairments discussed herein. The Director may notify the permittee at any time that the SWPPP (and implementation thereof) does not meet one or more of the minimum requirements of the permit (including provisions of this TMDL), at which point the permittee shall make changes to the plan and submit written certification within 30 days of such notification that the requested changes have been made.

The Rhode Island National Guard has obtained a Multi-Sector General Permit and is currently authorized to discharge to Warwick Pond via the storm water system. In accordance with Part I.B.3.j of the RIPDES Multi-Sector General Permit, prior to authorization to discharge stormwater associated with industrial activity, the applicant is required to demonstrate that the stormwater discharge is consistent with the requirements of the TMDL. With completion of this TMDL, consistent with Part I.C. of the general permit, facilities currently authorized to discharge under the permit must either demonstrate that the existing Storm Water Pollution Prevention Plan (SWPPP) is consistent with the TMDL or amend their plan demonstrating consistency with the TMDL. More specifically, the TMDL requires that facilities currently authorized or seeking authorization to discharge to the ponds must demonstrate that their SWPPP reduces phosphorus to the maximum extent feasible. Permittees will have 90 days from written notification by RIDEM to submit this documentation including revised SWMPPs to RIDEM (see section 6.1 for further details).

The City of Warwick and RIDOT must increase street sweeping and/or stormwater system maintenance to address sediment loads to Warwick Pond. Street sweeping and storm drain cleaning should also be conducted in the spring when the last reasonable chance of snowfall has passed. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. For those outfalls having evidence of sediment deposition, Phase II plans must document that twice-annual street sweeping is sufficient to prevent further sediment accumulation and certify that there are no active eroding areas contributing to the sediment buildup. The City of Warwick and RIDOT should also consider acquiring vacuum-assisted street sweeping trucks because of their increased efficiency in removing plant debris and soil. The City of Warwick and RIDOT should also make efficient removal of debris and litter on streets a priority and tailor street sweeping activities accordingly. Catch basin and storm drain system cleaning is also an important activity in controlling phosphorus loads to Warwick Pond, by preventing the accumulation of sediment that could hamper settling or cause flooding and erosion. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A single culvert (WP-Y) at Model Ave. was observed to be completely blocked with sediment (Table 6.8). This culvert needs to be cleaned and properly maintained. Evidence of erosion was observed at a dirt parking area at the southeast corner of Spring Pond. An erosion BMP should be installed in this area to prevent further sedimentation of the pond, which eventually discharges into Warwick pond.
Few waterfowl were observed at the pond during the brief shoreline survey. However, if local knowledge indicates that there is a significant population of waterfowl utilizing the pond, the measures discussed in Section 6.3 should be implemented to control that population.

Table 6. 8 Sediment Impacted Storm Water Culverts Within the Warwick Pond Watershed.

Outfall/Surface Discharge ID	Culvert Diameter (in.)	Location	Comments	Ownership
WP-Y	12	Model Ave	Entirely blocked with sediment	City of Warwick
WP-16	NA	Spring Green Pond parking area	Naturalized channel from dirt parking area; associated erosion and sedimentation	Private

Although few waterfowl were observed on the pond during the shoreline survey, significant numbers of waterfowl may frequent the pond. Signage instructing the public not to feed the waterfowl should be installed at any public areas where feeding may occur. There are several lawns that extend to the ponds edge that may provide congregation areas adjacent to the pond. Fencing can be installed along the shoreline of these lawns to reduce the waterfowl population on the pond. The installation of such a barrier may require a permit from RIDEM’s Freshwater Wetlands Program. Another alternative is to discontinue mowing the immediate shoreline and allow the area to revegetate naturally and to install a buffer of native vegetation to limit the establishment of invasive plant species. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl. Other methods, discussed in Section 6.3, may also be used from discouraging the use of the pond by waterfowl.

As discussed in Section 4.16, it does not appear that internal cycling is occurring in Warwick Pond. Warwick Pond is the only pond in this study, for which phosphorus data at depth is available, where the total phosphorus concentration in the hypolimnion is actually less than that at the surface. Since the sediment does not appear to be a source of phosphorus, the use internal controls is not recommended in this pond.

6.6 IMPLEMENTATION SUMMARY

The recommended implementation measures for each of the eutrophic ponds is summarized in Table 6.9. The implementation of these BMPs is anticipated to address the phosphorus and phosphorus-related impairments to the ponds.

Table 6. 9 Summary of Recommended Implementation Measures and Responsible Parties for the Nine Eutrophic Ponds.

Waterbody	Stormwater BMPs	Local Stormwater Ordinance	Waterfowl Controls	Wastewater Management	Erosion Control BMPs	Internal Phosphorus Controls	Point Source Pollution Controls
Almy Pond	City of Newport	City of Newport	City of Newport	City of Newport *		City of Newport	
Brickyard Pond	Town of Barrington /RIDOT	Town of Barrington	Town of Barrington		Town of Barrington	Town of Barrington	
Gorton Pond	City of Warwick/RIDOT	City of Warwick	City of Warwick			City of Warwick	
North Easton Pond	Town of Middletown/RIDOT	Town of Middletown	Town of Middletown, City of Newport	Town of Middletown	Town of Middletown	City of Newport	
Roger William Park Ponds	Cities of Providence and Cranston/RIDOT	Cities of Providence and Cranston	City of Providence		City of Providence	City of Providence	
Sand Pond	City of Warwick/RIDOT	City of Warwick	City of Warwick			City of Warwick	
Spectacle Pond	City of Cranston	City of Cranston	City of Cranston			City of Cranston	
Upper Dam Pond	Town of Coventry/RIDOT	Town of Coventry	Town of Coventry *	Town of Coventry		Town of Coventry	
Warwick Pond	City of Warwick/RIDOT/R.I. Airport Corp	City of Warwick	City of Warwick				

* Potential unconfirmed source.

7.0 Public Participation

RIDEM presented the draft TMDL plan to the general public and stakeholders, including public officials and other agencies, in a series of public meetings. Because the TMDL addressed impairments to nine different ponds, a series of four meetings were conducted. In an effort to increase public participation the meetings were held in the vicinity of the ponds that were being discussed. Letters were sent to key stakeholders in advance of each of the meetings. In addition, the meetings were publicized in a press release, and public notices which were posted at all Town and City Halls and Public Libraries as well as RIDEM offices in Providence. The draft Eutrophic Ponds TMDL was made available to the public on the RIDEM's website approximately two weeks prior to the first public meeting. Hard copies of the draft were also made available upon request. A public meeting to discuss the phosphorus-related impairments to Brickyard Pond was held at the Barrington Public Library on April 17, 2007. The impairments to Almy and North Easton Ponds were discussed at meeting held at the Middletown Town Hall on April 24, 2007. A public meeting to discuss the phosphorus-related impairments to Gorton, Sand, Upper Dam, and Warwick Ponds was held at the Warwick Public Library on April 30, 2007. The impairments to Spectacle and Roger Williams Park Ponds were discussed at meeting held at the RIDEM offices in Providence on May 2, 2007. The Barrington and Middletown meetings were attended by approximately 14 and 9 individuals, respectively. Approximately 12 and 15 individuals attended the Warwick and Providence meetings, respectively. The public comment period ended on June 1, 2007, thirty days after the final meeting. RIDEM received several comments during the public comment period. These are presented in Appendix F. Meeting notes are presented in Appendix G.

8.0 Future Monitoring

This is a phased TMDL and, as such, additional monitoring is required to ensure that water quality objectives are met as remedial actions are accomplished. Monitoring of eight of the nine ponds has been historically conducted by URI Watershed Watch (URIWW) volunteers. URIWW monitored six of these eight ponds during the 2007 sampling period. RIDEM encourages URIWW to continue monitoring these ponds and reinstate the monitoring of Brickyard and Roger Williams Park Ponds. RIDEM also encourages URIWW to initiate the monitoring of North Easton Pond. In accordance with the requirements of this TMDL, monitoring of the eutrophic ponds is necessary to gauge effectiveness of ongoing remedial activities.

9.0 References

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Appendix A: Eutrophic Pond Watersheds and Stormwater Outfall Locations

Figure A. 1 Almy Pond Watershed and Outfalls

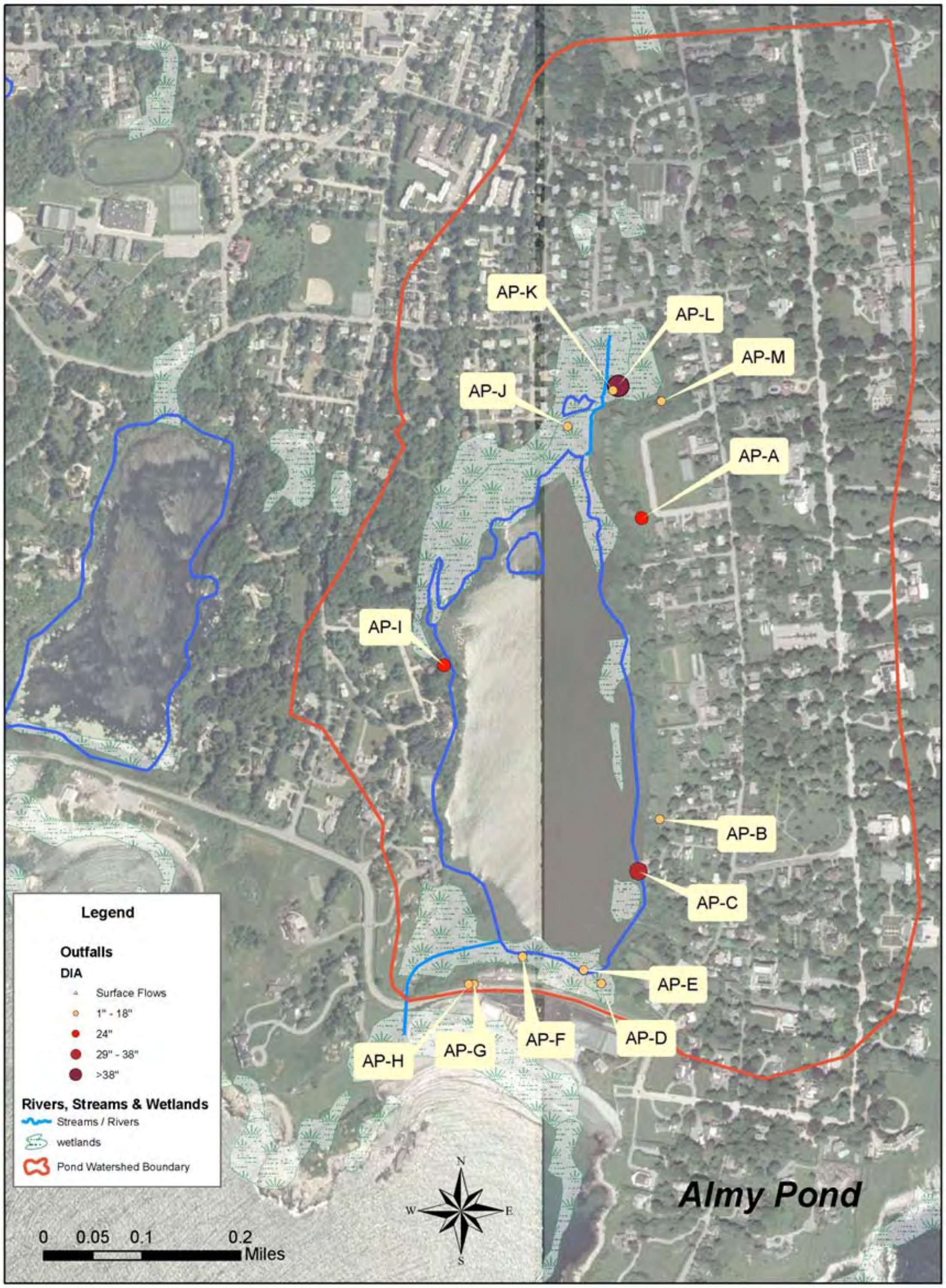


Figure A. 2 Brickyard Pond Watershed and Outfalls

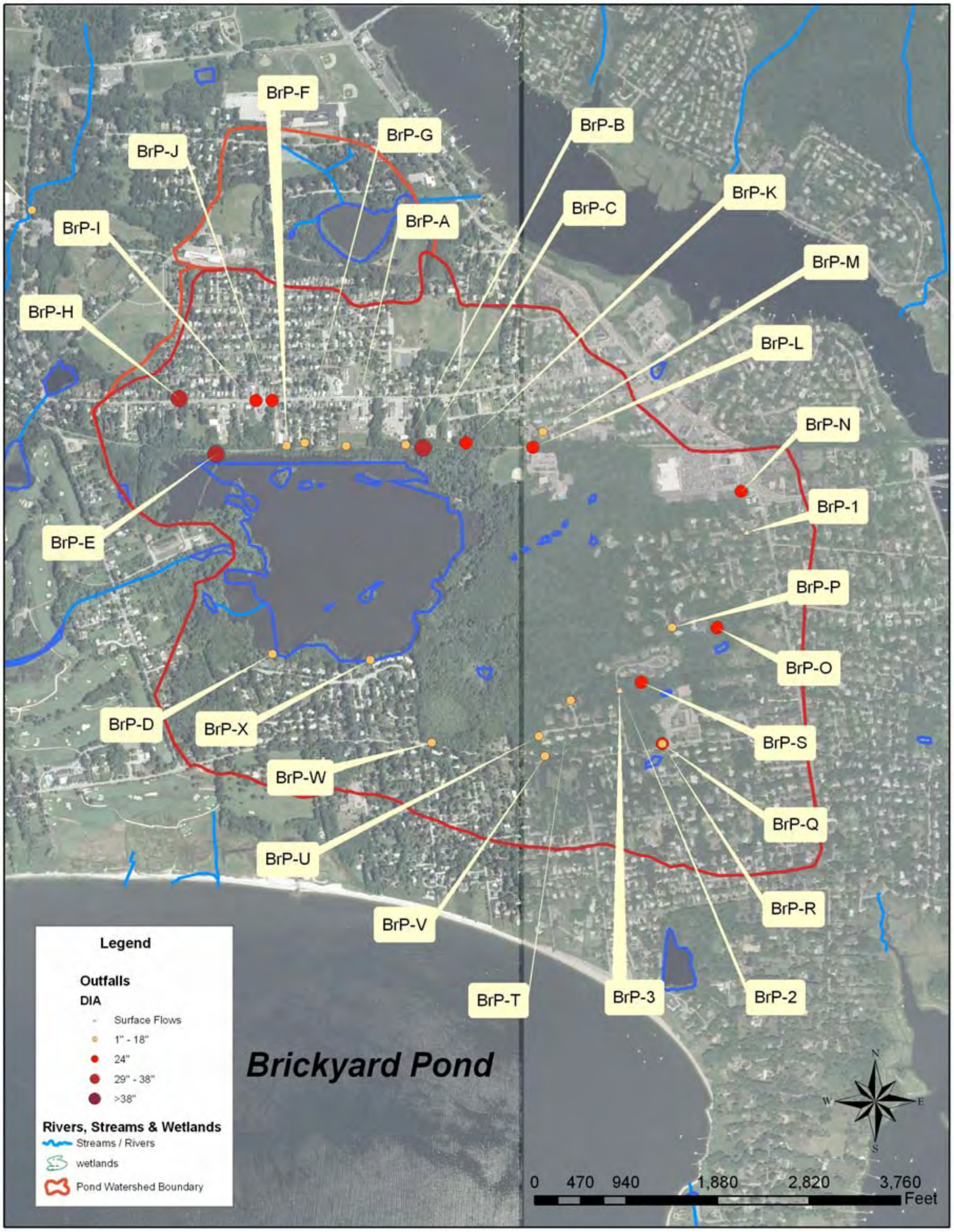


Figure A. 3 Gorton Pond Watershed and Outfalls

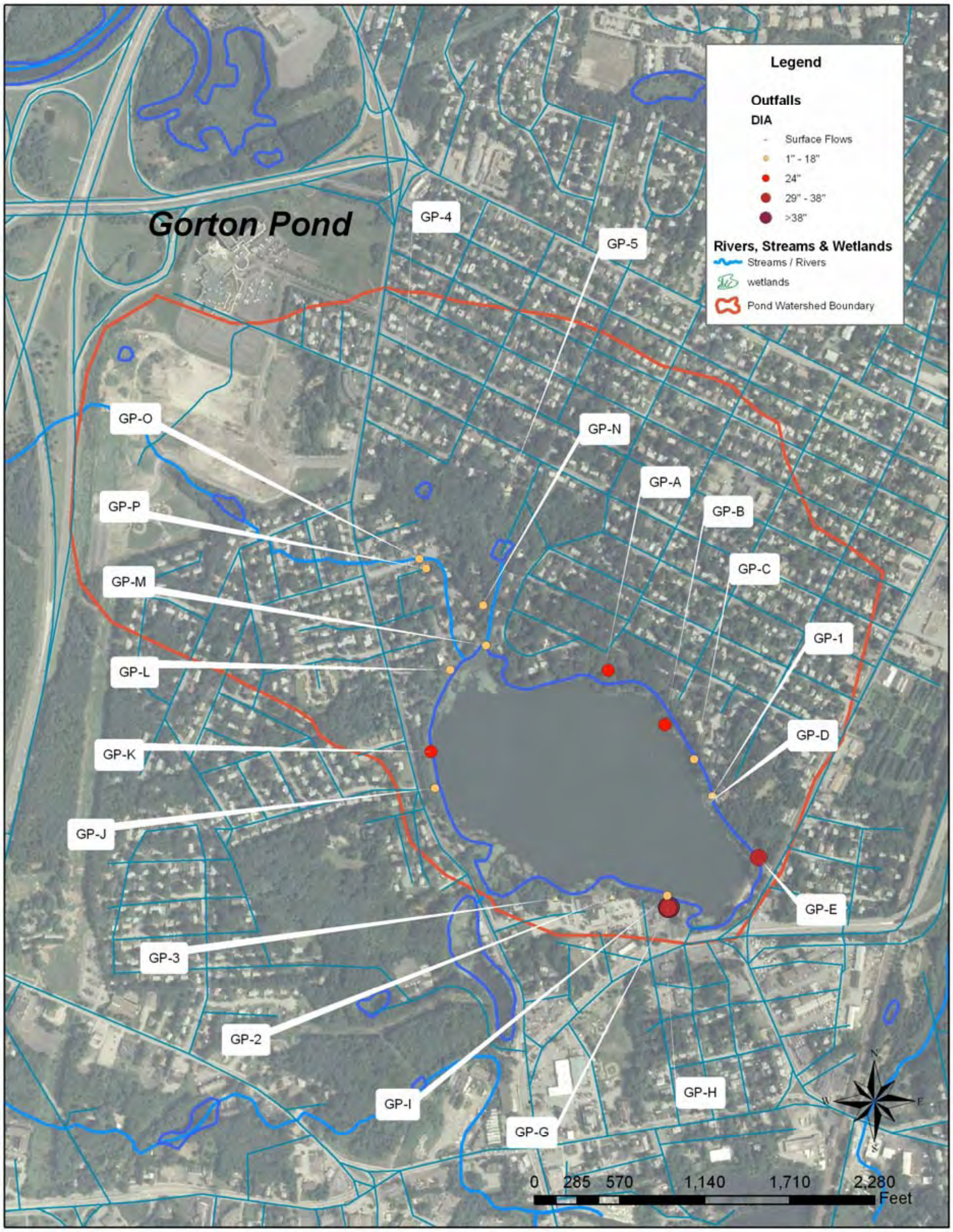


Figure A. 4 North Easton Pond Watershed.

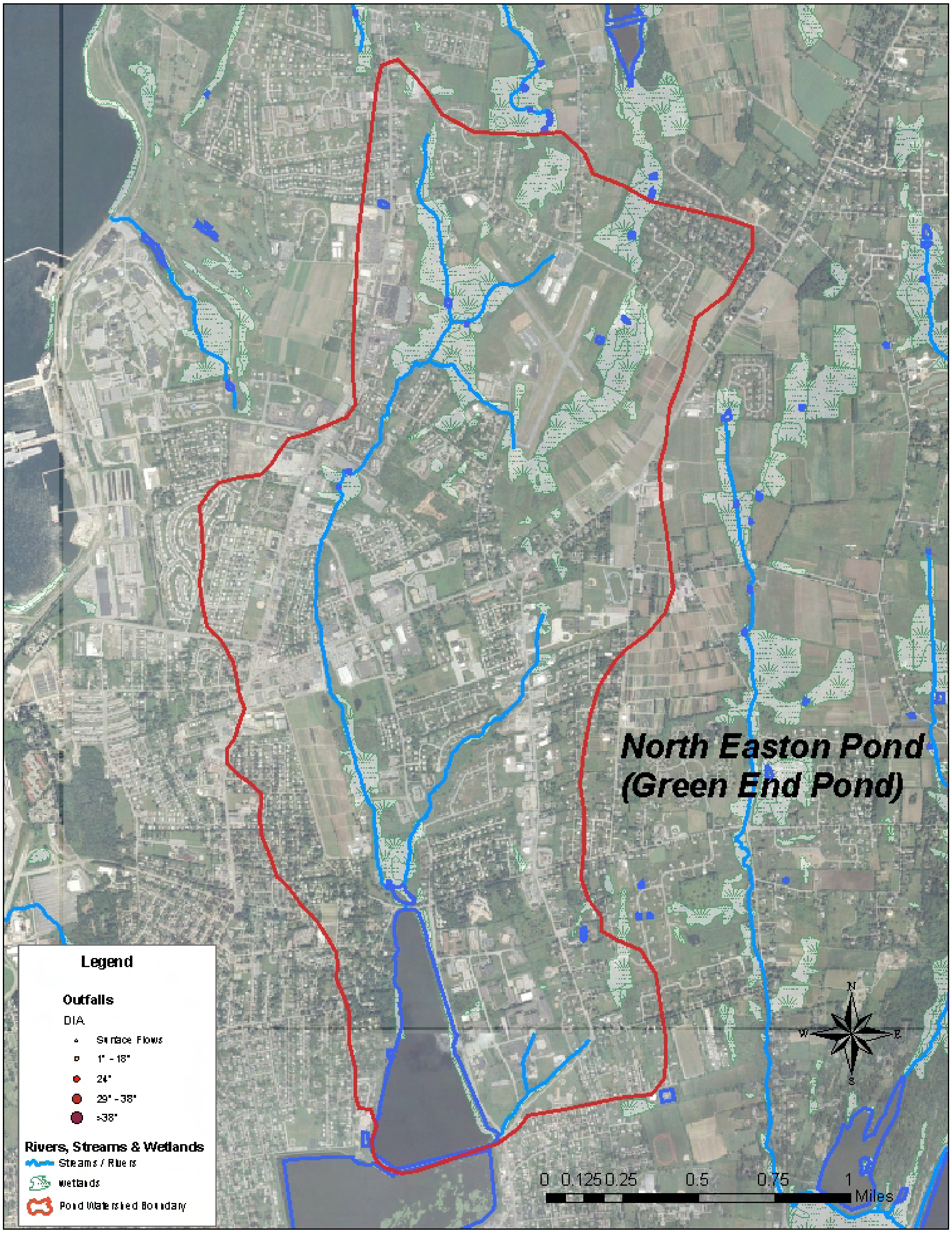


Figure A. 5 Roger Williams Park Ponds Watershed and Outfalls

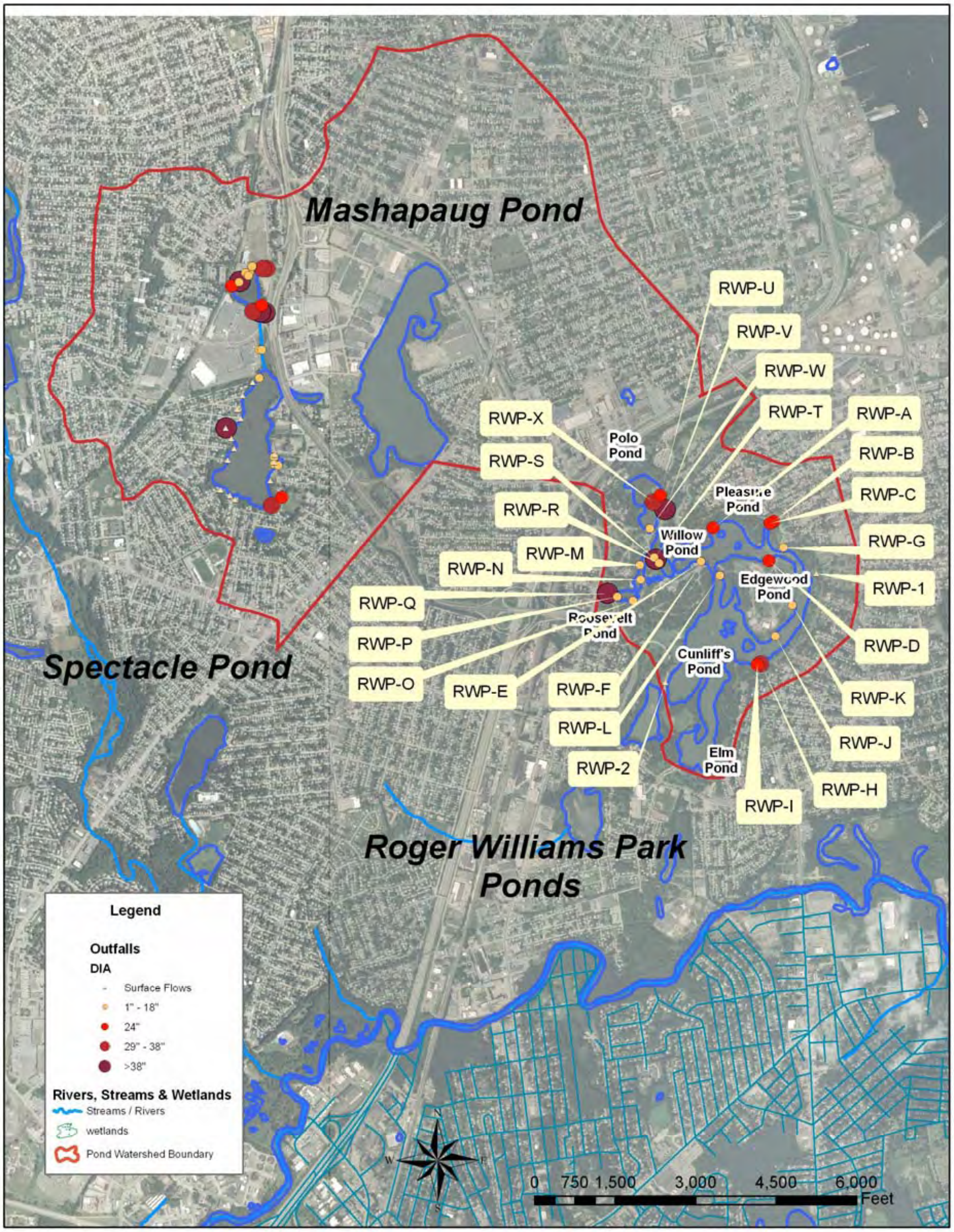
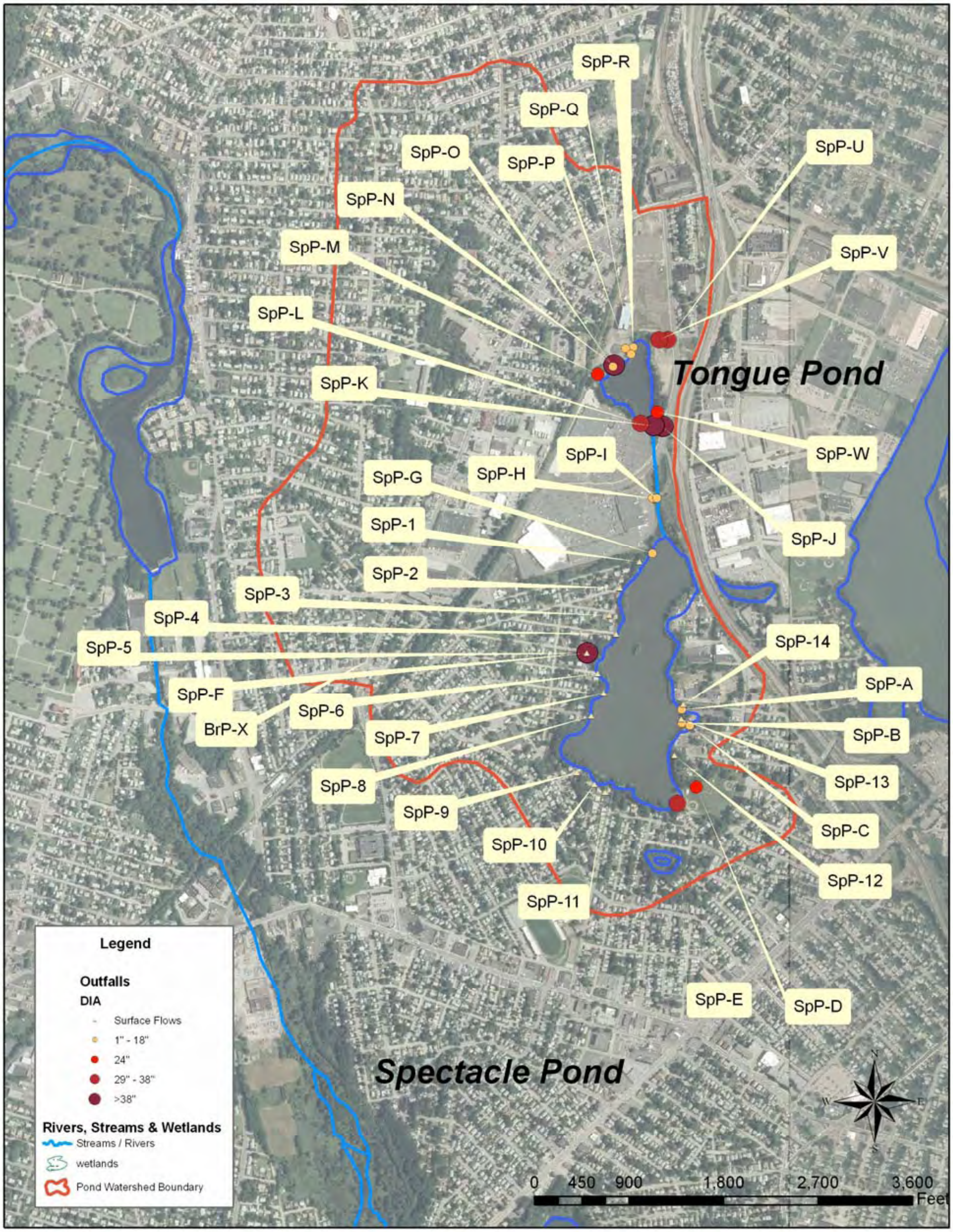


Figure A. 6 Sand Pond Watershed and Outfalls

Figure A. 7 Spectacle Pond Watershed and Outfalls



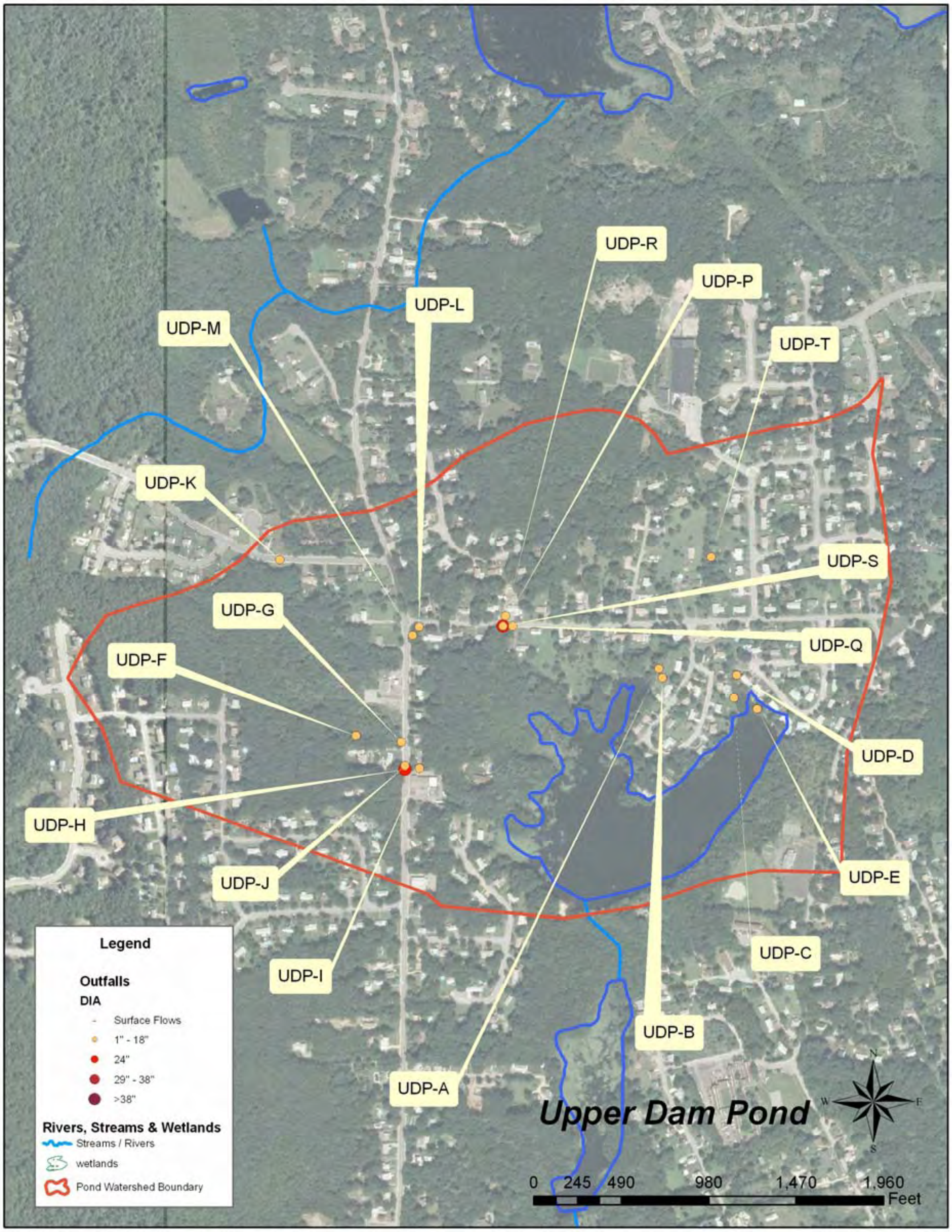
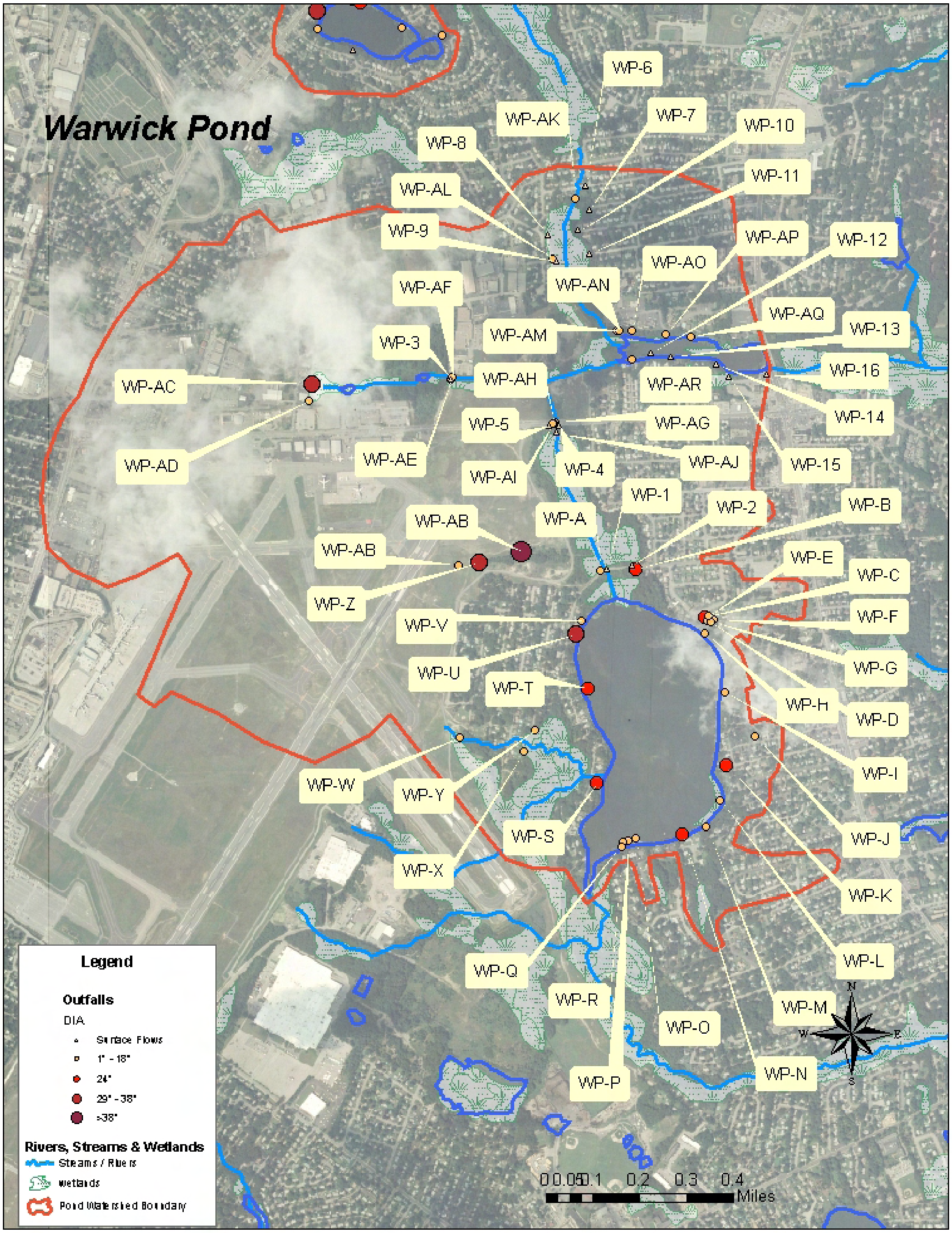


Figure A. 8 Upper Dam Pond Watershed and Outfalls

Figure A. 9 Warwick Pond Watershed and Outfalls



Appendix B: Stormwater Outfall Characteristics and Locations

Table B. 1 Almy Pond Outfalls

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
AP-A	24	41°27.867’ 71°18.631’	Northeast end of the pond; at the southwest corner of Spouting Rock Dr.	No flow; partially submerged
AP-B	6	41°27.600’ 71°18.611’	Eastern shore, at the terminus of Casey Ct	No flow
AP-C	30	41°27.554’ 71°18.636’	Eastern Shore, west of the terminus of Wheatland Ct	Flow [3]
AP-D	12	41°27.455’ 71°18.680’	Southern shore; approximately 400 ft northwest of the intersection of Ocean Av and Coggleshall Av [5]	Outfall not found
AP-E	12	41°27.467’ 71°18.701’	Southern shore; approximately 500 ft northwest of the intersection of Ocean Av and Coggleshall Av	Flowing [3]; outfall submerged
AP-F	12 [4]	41°27.478’ 71°18.772’[5]	Southern shore; approximately 800 ft west-northwest of the intersection of Ocean Av and Coggleshall Av [5]	Outfall not found; terminal catch basin flooded during wet weather
AP-G	12 [4]	41°27.454’ 71°18.830’[5]	Southern shore; approximately 900 ft west-northwest of the intersection of Ocean Av and Coggleshall Av [5]	Outfall not found; terminal catch basin flooded during wet weather
AP-H	12 [4]	41°27.454’ 71°18.836’[5]	Southern shore; approximately 1000 ft west-northwest of the intersection of Ocean Av and Coggleshall Av [5]	Outfall not found; terminal catch basin flooded during wet weather
AP-I	24	41°27.737’ 71°18.864’	West shore; east of Alpond Dr., opposite sewage pumping station	Flowing; slightly milky discharge

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
AP-J	18	41°27.948’ 71°18.718’	Discharges to wetland at northern end of pond; east of southeast corner of McCormick Rd.	Flowing
AP-K	12 [4]	41°27.980’ 71°18.665’[5]	Discharges to contiguous wetland at northern end of pond; approximately 800 ft southwest of the intersection of Ruggles Av. And George St. [5]	Outfall not found; outflow from terminal catch basin [3],
AP-L	48	41°27.984’ 71°18.659’	Discharges to channel at northern end of pond; approximately 700 ft southwest of the intersection of Ruggles Av. And George St.	Flowing [3]; partially submerged
AP-M	12	41°27.970’ 71°18.608’	Discharges to tributary northeast of the pond; north of Spouting Rock Dr.	No flow

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather unless otherwise indicated.
3. Flow was assessed during wet weather.
4. The outfall was not found and conditions at the terminal catch basin precluded the direct measurement of the pipe diameter. Pipe diameter was approximated visually or by inspection of pipes in adjacent catch basins.
5. The outfall was not found. Outfall location was approximated by inspection of terminal catch basin.

Table B. 2 Brickyard Pond Outfalls

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
BrP-A	18	41°44.361’ 71°19.201’	Southwest corner of Maple Ave. Medical Center parking lot	No flow; Half blocked with sediment
BrP-B	8	41°44.256’ 71°19.009’	Discharges to ditch north of bike path; opposite Centennial Ave.	No flow
BrP-C	36	41°44.251’ 71°18.969’	Direct discharge to northeastern portion of pond; opposite Andeozzi Dr.	Flowing; partially submerged
BrP-D	18	41°43.902’ 71°19.311’	Direct discharge to southwest portion of pond; opposite Ferncliffe Rd.	No flow
BrP-E	24” X 48” box culvert	41°44.241’ 71°19.437’	Direct discharge to pond at bikepath; approx. 700’ southeast of the intersection of Maple Ave. and Barrington Ave.	No flow; partially submerged
BrP-F	8	41°44.255’ 71°19.278’	Discharges to ditch north of bike path; opposite Vineyard Ln.	No flow; mostly blocked with sediment
BrP-G	8	41°44.252’ 71°19.009’	Discharges to ditch north of bike path immediately east of Culvert F	Flowing; submerged
BrP-H	30	41°44.336’ 71°19.520’	South of Maple Avenue; approximately 350’ feet east of its intersection with Barrington Ave.	No flow
BrP-I	24	41°44.332’ 71°19.311	South of Maple Av; approximately 200’ feet east of its intersection with Walter St	No flow
BrP-J	24	41°44.332’ 71°19.311’	Adjacent to Culvert I	No flow

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
BrP-K	24	41°44.259' 71°18.873'	Discharges to ditch north of bike path immediately east of terminus of Prince's Hill Av	No flow; partially submerged
BrP-L	24	41°44.251' 71°18.722'	Discharges to culverted portion of ditch; at bikepath, below west side of YMCA drive	Flowing [3]
BrP-M	12	41°44.278' 71°18.699'	Discharges to ditch north of bikepath; east of YMCA drive	No flow
BrP-N	24	41°44.176' 71°18.251'	East of the intersection of Rt. 114 and Rumstick Rd	No flow
BrP-O	24	41°43.945' 71°18.306'	Approximately 500 feet south-southeast of the intersection of Half Mile Rd. and Bayberry La	No flow; almost completely submerged
BrP-P	18	41°43.946' 71°18.408'	Approximately 600 feet south of the intersection of Half Mile Rd and Bayberry La	No flow; submerged
BrP-Q	24	41°43.748' 71°18.431'	Nayatt Rd, just west of Nyatt Elementary	Slight flow; mostly submerged
BrP-R	12	41°43.748' 71°18.431'	Nayatt Rd., just west of Nyatt Elementary	No flow
BrP-S	24	41°43.852' 71°18.477'	South of Woodhaven Rd; approximately 750 feet north-northeast of its intersection with Nyatt Rd	Associated with a water quality structure, Slight flow [3]
BrP-T	18	41°43.822' 71°18.638'	Cul-de-sac of Cranberry Ct	Flowing
BrP-U	18	41°43.761' 71°18.709'	Western terminus of Boxwood Ct	No flow
BrP-V	10	41°43.727' 71°18.696'	Nyatt Ave.; immediately south-southwest of Culvert U	No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
BrP-W	12	41°43.750’ 71°18.951’	North of Nyatt R.; Approximately 300 feet east of Broadview Dr	Flowing [3]
BrP-X	18	---	North of Broadview Drive; Opposite Overlook Road	No flow
BrP-1	NA	41°44.107’ 71°18.238’	North of Woodlawn R.; west of its intersection with Rumstick Rd	Naturalized channel
BrP-2	NA	41°43.839’ 71°18.525’	East of Woodlawn Rd; south of tributary	Asphalt swale
BrP-3	NA	41°43.839’ 71°18.527’	West of Woodlawn Rd; south of tributary	Asphalt swale

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather unless otherwise indicated.
3. Flow was assessed during wet weather.

Table B. 3 Gorton Pond Outfalls

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
GP-A	24	41°42.451’ 71°27.489’	North shore; near the southern terminus of Trinity St.	No flow; 15-20 ft high vertical escarpment at outfall due to erosion
GP-B	24	41°42.248’ 71°27.270’	North shore; near the southern terminus of Sharon St.	No flow, large elevation drop from terminal catch basin; large plunge pool at base of outfall
GP-C	12[3]	41°42.366’ 71°27.398’[3]	North shore; south of Lodi Ct. [3]	Outfall not found; blocked with sediment at catch basin
GP-D	18	41°42.312’ 71°27.336’	North shore; near the southern terminus of Burt St.	No flow
GP-E	36” x 24” oval culvert	41°42.244’ 71°27.267’	Discharges to a ditch at the southeast end of the pond; immediately north of the Town beach	No flow
GP-G	52” X 35” oval culvert	41°42.189’ 71°27.400’	South shore, approximately 500 feet west-northwest of the intersection of Post Rd. and Veterans Memorial Dr.	No flow; significant sedimentation
GP-H	46” X 30” oval culvert	41°42.189’ 71°27.400’	Adjacent to Culvert G	No flow; significant sedimentation
GP-I	6	41°42.202’ 71°27.402’	South shore, approximately 600 feet west-northwest of the intersection of Post Rd. and Veterans Memorial Dr.	No flow
GP-J	15	41°42.321’ 71°27.744’	West shore; opposite Blue Hill Dr.	No flow
GP-K	24	41°42.361’ 71°27.750’	West Shore; opposite Great Oak Dr.	No flow
GP-L	18	41°42.452’ 71°27.721’	Northwest end of the pond; south of the intersection of Carson Av. and Pond View Dr.	No flow
GP-M	8	41°42.479’ 71°27.669’	Discharges to tributary; approximately 300 ft southwest of the intersection of Gorton Lake Blvd. and Birch Glen Av.	No flow

GP-N	8	41°42.523’ 71°27.673’	Discharges to tributary east of the cul-de-sac of Pond View Dr.	No flow
GP-O	8	41°42.575’ 71°27.767’	Discharges to up-gradient end of a ditch approximately 150 ft southwest of the cul-de-sac of Breana La.	No flow
GP-P	8	41°42.564’ 71°27.757’	Discharges to down-gradient end of a ditch approximately 150 ft southwest of the cul-de-sac of Breana La.	No flow
GP-1	NA	41°42.312’ 71°27.336’	North shore; southern terminus of Burt St.	Asphalt/naturalized swale
GP-2	NA	41°42.201’ 71°27.483’	South shore; parking lot to the east of the Police Station	Concrete swale
GP-3	NA	41°42.199’ 71°27.566’	South shore; at the boat ramp to the west of the Police Station	Asphalt swale
GP-4	NA	41°42.649’ 71°27.765’	Discharges to a hydrologically-connected wetland at the eastern terminus of Alvin St.	Natural swale
GP-5	NA	41°42.652’ 71°27.634’	Discharges to hydrologically-connected wetland at the southern terminus of Freeman St.	Natural swale

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather.
3. Outfall was not found. Pipe diameter was determined and the outfall location was approximated by inspection of terminal catch basin.

Table B. 4 Roger Williams Park Pond Outfalls

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
RWP-A	24	41°47.173’ 71°24.673’	Northern end of Pleasure Lake; approximately 250 feet southeast of the intersection of F.C. Green Memorial Blvd and Verndale Av	No flow
RWP-B	24	41°47.192’ 71°24.424’	Discharges to ditch at northeastern end of Pleasure Lake; approximately 350 feet north-northwest of the intersection of F.C. Green Memorial Blvd and Verndale Av	No flow
RWP-C	24	41°47.186’ 71°24.439’	Immediately down gradient of Culvert B	No flow
RWP-D	24	41°47.070’ 71°24.444’	Eastern end of Pleasure Lake; north of the intersection of Cladrastis Av and Floral Av	No flow
RWP-E	18	41°47.068’ 71°24.723’	Discharges to Pleasure Lake to the immediate east of the Boat House	No flow
RWP-F	12	41°47.068’ 71°24.723’	Adjacent to Culvert E	No flow
RWP-G	18	41°47.111’ 71°24.384’	Northern end of Edgewood Pond, on northern side of Cladrastis Av bridge	No flow
RWP-H	30” X 42” oval	41°46.754’ 71°24.477’	Southeastern end of Edgewood Lake; Opposite Bartlett Av	Partially submerged; no flow
RWP-I	24	41°46.751’ 71°24.492’	Southeastern end of Edgewood Lake; Opposite Edgewood Av	No flow
RWP-J	8	41°46.839’ 71°24.417’	Southwestern end of Edgewood Lake; approximately 1050’ feet south of the easternmost intersection of Cladrastis Av and Floral Av	No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
RWP-K	8	41°46.932’ 71°24.348’	West-central shore of Edgewood Lake; approximately 850’ feet south-southeast of the easternmost intersection of Cladrastis Av and Floral Av	No flow
RWP-L	10	41°47.056’ 71°24.706’	Northern end of Cunliff’s Lake; at the Cladrastis Av bridge	No flow
RWP-M	8	41°47.056’ 71°24.975’	Western shore of the northern end of Roosevelt Lake, approximately 450 feet east of the intersection of Lincoln Av and Rose Av	Partially submerged; no flow
RWP-N	8	41°47.012’ 71°24.971’	Central-eastern shore of Roosevelt Lake; approximately 600 feet southeast of the intersection of Lincoln Av and Rose Av	No flow
RWP-O	8	41°46.947’ 71°25.003’	Southernmost end of Roosevelt Lake	Partially submerged; no flow
RWP-P	18	41°46.959’ 71°25.066’	South-central shore of Roosevelt Lake; approximately 650 feet south of the intersection of Lincoln Av and Rose Av	Partially submerged; partially blocked; no flow
RWP-Q	48	41°46.987’ 71°25.069’	Westernmost end of Roosevelt Lake	Flow; major inflow; sand deposition
RWP-R	8	41°47.063’ 71°24.895’	Western shore of Willow Lake; south of the FC Green Memorial Blvd bridge	Partially submerged; No flow
RWP-S	48	41°47.074’ 71°24.910’	Western shore of Willow Lake; south of the FC Green Memorial Blvd bridge	Broken end of pipe; some erosion at outfall; partially submerged; No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
RWP-T	12	41°47.080’ 71°24.915’	Western shore of Willow Lake; north of the FC Green Memorial Blvd bridge	No flow
RWP-U	24	41°47.273’ 71°24.889’	Discharges to ditch 50 feet from the northernmost end of the Polo Lake	No flow
RWP-V	24” X 72” box culvert	41°47.229’ 71°24.872’	Northeastern shore of Polo Lake	No flow
RWP-W	12	41°47.171’ 71°24.933’	Southern end of Polo Lake	Partially submerged; no flow
RWP-X	36	41°47.252’ 71°24.918’	Northwestern shore of Polo Lake	Flowing; connects Willow Lake to unnamed pond to north
RWP-1	NA	41°47.030’ 71°24.249’	Discharges to the northeastern portion of Edgewood Lake; opposite Oakland Cemetery	Naturalized swale, erosion, flow due to blocked catch basins
RWP-2	NA	41°46.696’ 71°24.869’	Southwestern portion of Cunliff’s Lake, immediately north of Deep Spring Lake	Minor concrete swale

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather.

Table B. 5 Sand Pond Outfalls

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
SdP-A	18	41°44.775’ 71°25.496’	North end; South of largest building in shopping plaza	No flow
SdP-B	24	41°44.772’ 71°25.472’	North end; Near southwest corner of shopping plaza parking lot	No flow
SdP-C	12	41°44.725’ 71°25.370’	Northeast end; Near Bigelow Cir	No flow
SdP-D	18	41°44.711’ 71°25.270’	Northeast end of little Sand Pond	No flow; Raccoon sign
SdP-E	12	41°44.722’ 71°25.580’	Southwest corner of Sand Pond	No flow
SdP-F	36	41°44.756’ 71°25.584’	West-central shore; East of Post Rd	No flow; Sand deposition
SdP-1	NA	41°44.684’ 71°25.491’	South-central shore; Sand Pond Rd near Puritan Dr intersection	Sand deposition

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather.

Table B. 6 Spectacle Pond Outfalls

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
SpP-A	15 [3]	41°47.390’ 71°26.475’[3]	Outfall not found; inferred location is eastern shore of Spectacle Pond opposite Molter St [3]	Outfall is apparently completely blocked with sediment; catch basin at the western end of Molter St is often flooded after wet weather
SpP-B	4	41°47.368’ 71°26.475’	Eastern shore of Spectacle Pond; approximately 550 feet east of the intersection of Sabra St and Manhasset Av; at rear of Twin Oaks Restaurant	Flowing, hot effluent; odor; non-contact cooling water, RIPDES permit
SpP-C	4	41°47.368’ 71°26.475’	Adjacent to Culvert B	Flowing, hot effluent; odor; non-contact cooling water, RIPDES permit
SpP-D	24	41°47.268’ 71°26.445’	Southeastern end of Spectacle Pond; discharges to a ditch at the northern edge of athletic fields	No flow
SpP-E	36	41°47.243’ 71°26.484’	Southeastern end of Spectacle Pond; at the western end of athletic fields	No flow
SpP-F	48	41°47.479’ 71°26.674’	Western shore of Spectacle Pond; eastern terminus of Lake St	No flow; submerged; major sediment delta at end of waste stream
SpP-G	12	41°47.635’ 71°26.537’	Northwest corner of Spectacle Pond; southeast corner of Stop & Shop	Flowing, Associated with a water quality structure
SpP-H	18	41°47.722’ 71°26.527’	Located in a ditch that connects Tongue Pond to Spectacle Pond, east of Stop & Shop	No flow, Associated with a water quality structure

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
SpP-I	12	41°47.722’ 71°26.527’	Adjacent to Culvert H	No flow, Associated with a water quality structure
SpP-J	48	41°47.836’ 71°26.534’	At southern end of the Tongue Pond	No flow; outlet of Tongue Pond
SpP-K	48	41°47.836’ 71°26.534’	Adjacent to Culvert J	No evidence of flow, outlet of Tongue Pond pipe invert is approximately 4 ft above the invert of adjacent Culvert J
SpP-L	36	41°47.840’ 71°26.561’	At southern end of Tongue Pond, west of the outlet	No flow
SpP-M	24	41°47.917’ 71°26.651’	At westernmost end of Tongue Pond	Flowing slightly
SpP-N	48	41°47.931’ 71°26.617’	Western part of the northern shore of Tongue Pond	No Flow
SpP-O	12	41°47.929’ 71°26.619’	Adjacent to Culvert N	Flowing slightly
SpP-P	15	41°47.949’ 71°26.581’	Central-north shore of Tongue Pond	No Flow
SpP-Q	15	41°47.949’ 71°26.581’	Adjacent to Culvert P	No Flow
SpP-R	18	41°47.949’ 71°26.581’	Adjacent to Culverts P	No Flow
SpP-U	30	41°47. 972’ 71°26.522’	Located at northeastern end of Tongue Pond	No flow
SpP-V	30	41°47.972’ 71°26.522’	Adjacent to Culvert U	No flow
SpP-W	24	41°47.857’ 71°26.526’	Southern portion of the eastern shore of Tongue Pond	No flow; partially submerged;
SpP-1	NA	41°47.622’ 71°26.564’	Western shore of Spectacle Pond; eastern terminus of Pomham St	
SpP-2	NA	41°47.581’ 71°26.605’	Western shore of Spectacle Pond; eastern terminus of Gordon St	

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
SpP-3	NA	41°47.538’ 71°26.627’	Western shore of Spectacle Pond; eastern terminus of Winthrop St	
SpP-4	NA	41°47.516’ 71°26.652’	Western shore of Spectacle Pond; eastern terminus of Barrett St	
SpP-5	NA	41°47.479’ 71°26.674’	Western shore of Spectacle Pond; eastern terminus of Lake St	
SpP-6	NA	41°47.431’ 71°26.677’	Western shore of Spectacle Pond; eastern terminus of Beacon St	
SpP-7	NA	41°47.416’ 71°26.639’	Western shore of Spectacle Pond; eastern terminus of Irving St	
SpP-8	NA	41°47.380’ 71°26.665’	Western shore of Spectacle Pond; eastern terminus of Lowell St	
SpP-9	NA	41°47.291’ 71°26.695’	Southern shore of Spectacle Pond, northeast terminus of Pleasant Hill Rd	
SpP-10	NA	41°47.273’ 71°26.658’	Southern shore of Spectacle Pond, northern terminus of Malcolm St	
SpP-11	NA	41°47.260’ 71°26.636’	Southern shore of Spectacle Pond, northern terminus of Midwood St	
SpP-12	NA	41°47.325’ 71°26.544’	Eastern shore of Spectacle Pond, southwestern corner of Twin Oaks parking lot	
SpP-13	NA	41°47.375’ 71°26.476’	Eastern shore of Spectacle Pond, immediately north of Twin Oaks Restaurant	

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
SpP-14	NA	41°47.398’ 71°26.472’	Eastern shore of Spectacle Pond, northwestern corner of Twin Oaks parking lot	

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather.
3. Outfall not found. Pipe diameter was determined and the outfall location was approximated by inspection of terminal catch basin.

Table B. 7 Upper Dam Pond Outfalls

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
UDP-A	12	41°42.502’ 71°33.142’	Northern shore; approximately 400 ft southwest of the intersection of Gervais Rd and Breezy Lake Dr	No flow
UDP-B	5	41°42.494’ 71°33.138’	Northern shore; approximately 350 ft southwest of the intersection of Gervais Rd and Breezy Lake Dr	Flowing; submerged; erosion at outfall; dense growth of algae and duckweed
UDP-C	12	41°42.475’ 71°33.050’	Northeast shore; approximately 150 feet east of Breezy Lake Dr; approximately 500 ft south-southeast of its intersection with Gervais St	Flowing; partially submerged
UDP-D	18	41°42.496’ 71°33.046’	Northern shore; approximately 350 ft southeast of the intersection of Gervais Rd and Breezy Lake Dr	Flowing
UDP-E	12	41°42.465’ 71°33.021’	Northeast end of the pond; approximately 600 ft southeast of the intersection of Gervais Rd and Breezy Lake Dr	No flow
UDP-F	5	41°42.440’ 71°33.515’	Discharges to tributary approximately 300 ft west of Knotty Oak Rd (Route 116); approximately 700 feet south-southwest of its intersection with Gervais Rd	No flow, apparently associated with private residence
UDP-G	18	41°42.434’ 71°33.459’	Discharges to culverted tributary at catch basin on the west side of Knotty Oak Rd; approximately 600 feet south of its intersection with Gervais St	No flow
UDP-H	24	41°42.409’ 71°33.455’	Discharges to culverted tributary at catch basin on the west side of Knotty Oak Rd; approximately 850 feet south of its intersection with Gervais St	No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments** [2]
UDP-I	18	41°42. 412’ 71°33.455’	Discharges to culverted tributary at catch basin on the east side of Knotty Oak Rd; approximately 850 feet south of its intersection with Gervais St	No flow
UDP-J	12	41°42. 412’ 71°33.455’	Adjacent to Culvert I	No flow
UDP-K	12	41°42. 602’ 71°33.609’	Discharges to hydrologically connected wetland; approximately 50 feet south of Hunters Crossing Dr; approximately 150 ft east-southeast of its intersection with Silo La	No flow, Associated with a water quality structure
UDP-L	5	41°42. 511’ 71°33.395’	Discharges to tributary approximately 100 ft east of Knotty Oak Rd; approximately 200 ft southeast of the intersection of Knotty Oak Rd and Gervais Rd	Flowing; odor; apparently from a private residence
UDP-M	18	41°42. 533’ 71°33.445’	Discharges to tributary approximately 150 ft east of Knotty Oak Rd; approximately 300 ft southeast of the intersection of Knotty Oak Rd and Gervais Rd	Flowing; apparently culverted stream
UDP-P	24	41°42.541’ 71°33.334’	Discharges to tributary south of Gervais St., approximately 550 feet east of its intersection with Knotty Oak Rd.	Slight flow
UDP-Q	18	41°42.541’ 71°33.334’	Adjacent to Culvert P	No flow
UDP-R	12	41°42.541’ 71°33.334’	Adjacent to Culverts P and Q	No flow
UDP-S	8	41°42.541’ 71°33.334’	Adjacent to Culverts P though R	No flow
UDP-T	15	41°42.605’ 71°33.078’	Conveyance of tributary; approximately 150 ft west of the intersection of LaForge Dr and Viola St	Flowing; probably conveyance for tributary only

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather.

Table B. 8 Warwick Pond

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
WP-A	12	41°43.732’ 71°24.867’	North of pond; at main tributary at Lakeshore Dr	No flow
WP-B	24	41°43.717’ 71°24.791’	Discharges to hydrologically connected wetland approximately 200 ft west of the intersection of Lake Shore Dr and Hoxie Av	No flow
WP-C	24	41°43.630’ 71°24.611’	Approximately 400 feet south-southwest of the eastern intersection of Zachariah Pl and Sarah La	No flow; discharges to ditch leading to primitive detention basin prior to entering pond
WP-D	5	41°43.630’ 71°24.611’	Adjacent to Culvert C	No flow; appears to be associated with roof drain of single-family dwelling
WP-E	4	41°43.630’ 71°24.611’	Adjacent to Culverts C and D	No flow, appears to be associated with single-family dwelling
WP-F	18	41°43.624’ 71°24.598’	West of the cul-de-sac of Lakecrest Cir	No flow; discharges to ditch leading to primitive detention basin prior to entering pond
WP-G	5	41°43.624’ 71°24.598’	Adjacent to Culvert G	No flow; discharges to ditch leading to primitive detention basin prior to entering pond
WP-H	12	41°43.599’ 71°24.620’	Approximately 600 feet south-southwest of the eastern intersection of Zachariah Pl and Sarah La	No flow; Outlet of rough sedimentation basin, capturing stormwater from Culverts C through G
WP-I	12	41°43.489’ 71°24.571’	Eastern Shore; opposite the intersection of Edgehill Rd and Lake Crest Dr	No flow; discharges to pond via short manmade swale
WP-J	12	41°43.407’ 71°24.497’ [4]	Associated terminal catch basin is located at the intersection of Edgehill Rd and Brewster Dr	Outfall was not found
WP-K	24	41°43.716’ 71°24.794’	Eastern shore; Opposite Stanmore Rd	No flow; discharges to a manmade swale

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
WP-L	5	41°43.289’ 71°24.583’	Southeast corner of pond, approximately 200 feet west-southwest of the intersection of Betsy Williams Dr and Edgehill Rd	No flow
WP-M	10	41°43.238’ 71°24.618’	Southeast end of the pond, opposite the intersection of Yucatan Dr and Betsy Williams Dr	No flow
WP-N	24	41°43.225’ 71°24.677’	Southern shore; approximately 200 ft northwest of the intersection of Betsy Williams Dr and Carant Rd	Flowing; iron staining; conveyance from wetland; stormwater contribution associated with very small drainage area
WP-O	4	41°43.217’ 71°24.792’	Southern shore; approximately 150 feet northeast of the northern terminus of Bowman Dr	No flow
WP-P	12	41°43.290’ 71°24.832’	Southern shore; north of the northern terminus of Bowman Dr	No flow
WP-Q	6	41°43.290’ 71°24.832’	Adjacent to Culvert P	No flow, perforated pipe
WP-R	1	41°43.290’ 71°24.832’	Adjacent to Culverts P and Q	No flow
WP-S	24	41°43.322’ 71°24.888’	Western shore; approximately 900 ft south of the intersection of Lake Shore Dr and Wells Av	Submerged; no flow; conveyance from wetland
WP-T	24	41°43.497’ 71°24.910’	Western shore, at boat ramp opposite Wells Av	No flow
WP-U	36	41°43.637’ 71°24.964’	Western shore; approximately 300 feet south of the intersection of Lake Shore Dr and Rowe Av	No flow; raccoon tracks at pipe
WP-V	12	41°43.621’ 71°24.925’	Western shore; opposite Rowe Av	No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
WP-W	18	NA	T.F. Green Airport; discharges to tributary approximately 1700 ft south of the intersection of Airport Rd and Commerce Dr	Not inspected
WP-X	12	41°43.380’ 71°25.069’	Discharges to hydrologically connected wetland approximately 150 ft east of Wilbur Av; approximately 500 ft south of its intersection with Wells Av	No flow
WP-Y	12	41°43.419’ 71°25.040’	Discharges to hydrologically connected wetland south of the cul-de-sac of Model Av	No flow [5]; entirely blocked with sediment
WP-Z	36	NA	T.F. Green Airport; discharges to tributary approximately 1500 ft south of Airport Rd; approximately 1550 ft south-southeast of its intersection with Commerce Dr	Not inspected
WP-AA	12	NA	Adjacent to Culvert Z	Not inspected
WP-AB	42	NA	T.F. Green Airport; discharges to tributary approximately 1500 ft south of Airport Rd; approximately 1700 ft southeast of its intersection with Commerce Dr	Not inspected
WP-AC	30	41°44.062’ 71°25.595’	Discharges to tributary approximately 550 ft northeast of the intersection of Evergreen Av and Airport Rd	No flow; discharges to headwaters of tributary
WP-AD	12	41°44.033’ 71°25.601’	Discharges to tributary approximately 450 ft northeast of the intersection of Evergreen Av and Airport Rd	Totally blocked with sediment, no sign of recent flow; abandoned?
WP-AE	18 [3]	41°44.072’ 71°25.250’	Discharges to culverted tributary at catch basin at Commerce Dr	No flow

Outfall/Surface Discharge ID[1]	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments [2]**
WP-AF	4	41°44.075’ 71°25.245	Discharges to tributary east of Commerce Dr, approximately 600 ft north-northeast of its intersection with Airport Rd	No flow; apparently associated with small parking area
WP-AG	12	41°43.989’ 71°24.993’	Discharges directly to culverted tributary at northern side of Airport Rd	No flow
WP-AH	12	41°43.989’ 71°24.993’	Discharges directly to culverted tributary at southern side of Airport Rd	No flow
WP-AI	12	41°43.989’ 71°24.993’	Discharges directly to culverted tributary at southern side of Airport Rd	No flow
WP-AJ	54	NA	T.F. Green Airport; discharges to tributary approximately 100 ft south of Airport Rd; approximately 1300 ft east of its intersection with Commerce Dr	Not inspected
WP-AK	12	41°44.407’ 71°24.941’	Discharges to tributary south of Partition St, approximately 250 ft west-southwest of its intersection with Meader St	No flow
WP-AL	18	41°44.295’ 71°24.996’	Discharges to tributary opposite eastern terminus of Way Av	Flowing [5]; submerged
WP-AM	18	41°44.163’ 71°24.846’	Discharges to Spring Green Pond at Four Seasons Apartments; approximately 1650 ft west of the intersection of Warwick Av and Squantum Dr	No flow
WP-AN	18	41°44.163’ 71°24.846’	Adjacent to Culvert AM	No flow

Outfall/Surface Discharge ID$_1$	**Culvert Diameter (in.)**	**GPS Coordinates**	**Location**	**Comments $_2$**
WP-AO	18	41°44.163’ 71°24.799’	Discharges to Spring Green Pond at Four Seasons Apartments; approximately 1350 ft west of the intersection of Warwick Av and Squantum Dr	No flow
WP-AP	18	41°44.155’ 71°24.715’	Discharges to Spring Green Pond at Four Seasons Apartments; approximately 1000 ft west-southwest of the intersection of Warwick Av and Squantum Dr	No flow
WP-AQ	18	41°44.149’ 71°24.652’	Discharges to Spring Green Pond at Four Seasons Apartments; approximately 800 ft west-southwest of the intersection of Warwick Av and Squantum Dr	Flowing $_5$
WP-AR	15	41°44.108’ 71°24.801’	Discharges to Spring Green Pond at the northwest corner of Elberta St	No flow
WP-1	NA	41°43.717’ 71°24.863’	North of pond; east side of main tributary at Lakeshore Dr	Asphalt swale discharging to tributary
WP-2	NA	41°43.725’ 71°24.799’	North of pond, approximately 400 ft west of the intersection of Lake Shore Dr and Hoxie Rd	Naturalized channel that discharges to hydrologically connected wetland
WP-3	NA	41°44.072’ 71°25.250’	Discharges directly to culverted tributary at north side of Commerce Dr	Isolated catch basin discharging directly to culverted tributary
WP-4	NA	41°43.983’ 71°24.984’	South side of Airport Rd, immediately east of tributary	Asphalt/naturalized swale down steep highway embankment
WP-5	NA	41°43.983’ 71°25.004’	South side of Airport Rd, immediately east of tributary	Asphalt/naturalized swale down steep highway embankment
WP-6	NA	41°44.432’ 71°24.914’	Discharges to tributary south of Partition St, opposite its intersection with Meader St	Naturalized/rip rap swale

Outfall/Surface Discharge ID[1]	Culvert Diameter (in.)	GPS Coordinates	Location	Comments [2]
WP-7	NA	41°44.387' 71°24.905'	Discharges to tributary at western terminus of Holiday Av	Asphalt/naturalized swale
WP-8	NA	41°44.339' 71°25.008'	Discharges to hydrologically connected wetland approximately 100 ft east of Waycross Dr; approximately 150 feet east-southeast of its intersection with Potomac Rd	Naturalized channel
WP-9	NA	41°44.291' 71°24.988'	Discharges to tributary at eastern terminus of Way Av	Two asphalt swales
WP-10	NA	41°44.348' 71°24.935'	Discharges to tributary at western terminus of Blanchard Av	Naturalized channel
WP-11	NA	41°44.304' 71°24.906'	Discharges to tributary at western terminus of Bellevue Av	Naturalized channel
WP-12	NA	41°44.120' 71°24.754'	Discharges to Spring Green Pond opposite Etta St	Naturalized channel
WP-13	NA	41°44.114' 71°24.702'	Discharges to Spring Green Pond at the northern terminus of Willard St	Naturalized channel
WP-14	NA	41°44.099' 71°24.592'	Discharges to Spring Green Pond at the intersection of Elberta St and Hargraves St	Asphalt Swale
WP-15	NA	41°44.075' 71°24.561'	Discharges to Spring Green Pond from parking area approximately 700 ft west-northwest of the intersection of Warwick Av and Airport Rd	Naturalized channel from parking area
WP-16	NA	41°44.081' 71°24.465'	Discharges to southeast end of Spring Green Pond from parking area approximately 550 ft north-northwest of the intersection of Warwick Av and Airport Rd	Naturalized channel from parking area; associated erosion and sedimentation

1. Letters represent culvert outfalls; numbers represent discharge points of concentrated surface water flows.
2. Flow was assessed during dry weather unless otherwise indicated

3. Conditions at the terminal catch basin and outfall precluded the direct measurement of the pipe diameter. Pipe diameter was approximated visually or by inspection of pipes in adjacent catch basins.
4. The outfall was not found. Coordinates are given for the terminal catch basin.
5. Flow was assessed during wet weather.

Appendix C TMDL Calculations

(TMDL Calculations for Roger Williams Park Ponds (RWPP) were done by a slightly different method and are not presented in this table. RWPP TMDL calculations are presented in section 5.6.)

Waterbody	Watershed Area (Ha)	Waterbody Area (Ha)	Inflow Water Volume (Q) (m^3/yr)	q_s (m/yr)	Ave. TP (mg/l)	Areal P loading (L) (g/m^{2}-yr)	Areal Loading Capacity (TMDL) (g/m^2-yr)	Current Load (kg/yr)	TMDL (kg/yr)	MOS (kg/yr)	TMDL (kg/yr)	Required Load Reduction (kg/yr)	Percent Reduction	% Imper-vious	WLA (kg/yr)	LA (kg/yr)
Almy Pond	135.4	20.15	9.35E+05	4.64	0.152	2.61	0.43	526	86	9	78	448	85	29	22.4	55.4
Brickyard Pond	309.8	34.03	2.14E+06	6.28	0.063	1.21	0.38	410	130	13	117	293	71	33	38.1	79.1
Gorton Pond	185.0	23.59	1.28E+06	5.41	0.056	1.01	0.36	239	85	9	77	162	68	39	29.7	47.2
North Easton Pond	982.2	45.08	6.78E+06	15.04	0.110	3.26	0.74	1470	334	33	301	1169	80	34	101.0	199.6
Sand Pond	24.6	4.94	1.70E+05	3.44	0.064	1.01	0.31	50	16	2	14	36	72	54	7.5	6.5
Spectacle Pond	237.6	15.70	1.64E+06	10.45	0.057	1.38	0.48	216	76	8	68	148	68	57	38.6	29.6
Upper Dam Pond	87.2	8.30	6.02E+05	7.25	0.042	0.85	0.51	71	42	4	38	33	46	32	12.1	25.8
Warwick Pond	346.2	34.28	2.39E+06	6.97	0.027	0.54	0.40	185	137	14	123	62	33	39	47.8	75.4

Q (m3/yr)= Watershed area (m2) * 1 mi2/ 2,589,988m2 * 1m3/35.31 ft3 * 31,557,600 sec/yr * 2 ft3/(sec * mi2)

qs (m/yr)= Q (m3/yr)/ AO (m2)

L (g/m2-yr) = Ave TP (mg/l)* [11.6+ 1.2 * qs(m/yr)]

TMDL (g/m2-yr) = criteria conc. * [11.6+1.2* qs (m/yr)]

[Criteria concentration (0.025 mg/l) used for most shallow ponds. Concentration of 0.020 mg/l used for deep ponds and Spectacle Pond.]

CL (kg/yr)= L (g/m2-yr) * Water-body area (m2)* 1 kg/1000 g

T
M

TMDL [With-out MOS (kg/yr)] = TMDL (g/m2-yr) * Water-body area (m2)* 1 kg/1000 g

MOS (kg/yr) = TMDL (kg/yr) * 0.10

TMDL [with MOS (kg/yr)] = TMDL (kg/yr) - MOS (kg/yr)

RLR (kg/yr) = CL (kg/yr) - TMDL (kg/yr)

% Reduction = [Current Load (kg/yr)-TMDL (minus MOS)(kg/yr)] / [Current Load (kg/yr)] * 100

WLA (kg/yr)= TMDL (minus MOS (kg/yr) * % Imper-vious * 0.01

LA (kg/yr)= TMDL (minus MOS (kg/yr) * (100 - % Imper-vious) * 0.01

Appendix D: Structural Stormwater BMPs

Infiltration Basins

Infiltration is the most effective means of controlling both water quantity and water quality. Water quantity control can occur by taking surface water and infiltrating it into the underlying soil. This reduces the volume of water that is discharged to receiving streams, thereby reducing potential impacts caused by excess flow such as stream bank erosion and streambed instability as well as increased pollutant concentrations in the receiving waters. Infiltration may have the secondary benefits such as increasing recharge to underlying aquifers and increasing base flow to receiving waters. Infiltration is also an important mechanism for pollutant control. As runoff infiltrates into the ground, particulates and attached pollutants such as nutrients are removed by filtration, and dissolved constituents can be removed by adsorption. These basins are also useful in helping to restore the pre-development hydrology, and can increase the water table and baseflow to streams while reducing the incidence of stream flooding. Infiltration basins may or may not be lined with plants. Vegetated systems may remove pollutants by filtration and roots may increase the permeability of the soil, increasing infiltration. Infiltration basins are designed to intercept only a certain volume of water, perhaps just the first flush, and bypass any excess volume. Infiltration basins are generally designed to empty in 72 hours to prevent mosquito breeding and potential odor problems. The performance of infiltration BMPs is limited in areas of poorly permeable soils and high water tables. Since excessive sediment accumulation can lead to reduced infiltrative capacity, frequent maintenance may be required.

The success of infiltration systems has been mixed. In some areas they have been highly effective, but in other areas these systems have clogged in a very short time. Many failures have been attributed to contractor inexperience, to soil compaction by construction equipment, and to improper design and siting. In order to apply infiltration effectively, the following guidelines should be applied:

Permeability of soils must be verified. A percolation rate of 0.5 inches per hour or more, and a soil layer of at least 4 feet is necessary (Cahill, 1994). Strict sediment controls should be maintained to prevent clogging to the system during construction and the infiltration system should not be placed into service until all disturbed land has been stabilized by vegetation.
A sedimentation basin or forebay should be placed before the infiltration system to remove coarse sediment and extend the life of the system. Filter fabric installed between the recharge bed and the soil interface can prevent migration of soil into the recharge bed. A basin drain should be provided so that the basin drain can be drained and maintenance performed if the basin becomes clogged.

Porous pavements

Porous pavements include porous asphalt, porous concrete, modular perforated concrete, cobble pavers, with porous joints or gaps. Porous pavements are generally not suitable for high traffic areas or areas where heavy equipment is used, but are useful in parking lots, driveways, and residential streets. Sediment may tend to clog the pores of porous pavements and therefore they require maintenance including periodic vacuuming or power-washing. The use of de-icing chemicals and sand on porous pavements should also be limited.

Infiltration Trenches and Wells

An infiltration trench or well is a gravel-filled trench or well designed to infiltrate stormwater into the ground. Trenches are generally designed with a gravel bed that is surrounded with a grass filtering area. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The primary pollutant removal mechanism of this practice is filtering through the soil" (EPA 2002). Typically infiltration trenches and wells can only capture a small amount of runoff and therefore may be designed to capture the first flush of a runoff event only. For this reason, they are frequently used in series with another BMP such as a detention basin. Infiltration trenches are designed for areas not exceeding five acres.

Detention Basins

Detention Basins are designed to intercept a volume of stormwater and temporarily impound it. Detention basins are not designed to retain a permanent volume of water between runoff events, but most are designed to empty in less than 24 hours. The main goal of detention basin design is to reduce the peak flow rate, limiting stream bank scouring and the entrainment of streambed sediments. Detention basins can provide limited settling of suspended solids, reducing associated pollutants such as nutrients, but a large portion of this material can be re-suspended by subsequent rainfall events. The efficiency of detention basins can be increased by constructing a fore bay or settling chamber for the accumulation of coarse sediment, facilitating periodic cleaning to remove pollutant-laden sediment.

Underground Vaults and Tanks

Underground detention basins in that their main purpose is to reduce peak flows. Significant water quality improvements should not be expected from underground detention facilities.

Retention Ponds

Unlike Detention Basins, retention basins (also known as wet ponds) are designed to capture a volume of water and retain that volume until it is displaced in part or in total by the next runoff event. Like detention basins, retention basins reduce peak flows, but also provide a greater amount of water quality improvement. Sediments that accumulate in the pond are less likely to become re-suspended due to the presence of the permanent pool of water. Retention basins also improve water quality through the filtration of suspended solids by aquatic plants, increased infiltration, and the biological uptake of nutrients by aquatic plants and algae. A sediment forebay should be incorporated into the design to allow for the removal of coarse sediments that can degrade the performance of the system.

Retention basins show a wide range of variability in pollutant removal efficiencies due to a number of factors. Drainage area, land use and percent imperviousness, surface area of basin, depth of permanent pool, and hydrologic parameters can have a large effect on efficiency. The most significant parameter controlling infiltration efficiency may be retention time. Studies indicate that residence times on the order of 14 days may be required to allow for sufficient removal of sediment and associated pollutants (Rushton and Dye, 1993). Problems associated with infiltration basins can include resuspension due to intense rainfall events, and changes in water chemistry such as pH, alkalinity and hardness, which can effect the solubility of pollutants such as phosphorus. Ponds can also fail to function properly in the winter when they ice over.

Retention basins can also present a safety hazard to local residents, can attract large numbers of waterfowl, can become a breeding ground for mosquitoes and can create odors if not designed properly.

There are a several design features that can increase the effectiveness of infiltration basins, and reduce maintenance burdens:

- a broad, flat aquatic bench around the perimeter of the basin to allow for the growth of aquatic vegetation;
- a permanent pool volume that provide a long residence time to promote maximum sediment removal;
- an irregular pool shape that increases the sinuosity of flow paths;
- a submerged reversed-slope pipe or other non-clogging low-flow orifice;
- concrete outlet structures; and
- maintenance access to forebays and inlet and outlet structures.

Constructed Wetlands

Wetland basins are similar to retention basins except that a significant portion (generally greater than 50% of the permanent pool area is covered with emergent wetland vegetation. A water balance must be performed to maintain a hydrological regime supportive of the growth of aquatic vegetation. Like other storm water basins, the use of artificial wetlands in urban areas may be limited due to a lack of available land.

Strecker et al. (1997a) indicated that the greatest factor influencing the performance of constructed wetlands is the hydrology of the watershed and the inflow hydraulics. Other factors influencing performance are wetland size and volume, the design of the inlet and outlet structures, flow patterns through the system, vegetational community structure, seasonal productivity and decay of wetland pants, and changes in evapotranspiration rates.

Some important design features that should be incorporated into stormwater wetland design include:

- a pre-settling basin for removal of heavy sediments;
- adjustable level control at the outlet by means of an adjustable weir or orifice;
- design flow path to maximize detention time;
- a broad, densely planted aquatic bench;
- selection of proper species to promote a dense stand of vegetation to increase filtration and uptake; and
- periodic harvesting of excess vegetation to prevent nutrient release.

Filtration Systems

Filtration systems are seeing increased usage in urban areas where space constraints prohibit the use of detention, retention, and constructed wetlands. Filtration systems are primarily a water quality control device used to remove particulate pollutants, but quantity control can also be incorporated into the design. Sand and other media filters are commonly used to treat runoff from small sites such as parking lots and small developments or in areas with high pollutions potential. Filter systems are often designed to intercept and treat only the first half inch or inch of runoff and bypass larger storm water flows. Therefore, during heavy rains the filtration system may lack the capacity to filter all of the water entering the system, and excess water is released through the overflow valve. Several different types of filter media are commonly used. These include filter fabric, sand, gravel, compost, and peat.

The surface sand filter usually incorporates two basins. Runoff first enters a wet or dry sedimentation basin and then flows over a weir or through a riser into the filter basin. The filter bed consists of sand with a gravel and perforated pipe under-drain system to capture the treated water. Bell (1998) reported that significant phosphorus removal could be attributed to reaction and precipitation with sand that contains iron, calcium, or aluminum. Long-term efficiency can be significantly reduced when storm water sediment clogs the sand filter system. Urbonas et al. (1997) reported that the flow rate though a sand filter decreased from 3 ft/hr per square foot of filter area to less than 0.5 ft/hr after only several storm events.

The underground vault sand filter is commonly used in urban areas where there are limitations on land acquisition. Underground sand filters can be constructed under parking lots, but placing filter systems “out of sight” may have implications for the maintenance and longevity of the system. The underground filter design often incorporates three chambers. The first chamber contains a permanent pool of water and serves as a sedimentation chamber. The second chamber contains the filtration bed and the third chamber conducts the treated effluent to the storm drain system via a clear well. There are many variations on this design.

In order to provide adequate efficiency, the following design and operation guidelines should be followed (Urbonas, 1999):

- the filter should be placed off-line;
- a sedimentation basin should be provided above the sand filter;
- the filter should be sized adequately;
- sediment should be controlled during construction; and
- periodic maintenance should be performed to remove accumulated sediments and restore the original flow rate.

Bioretention Systems

Bioretention systems are designed to mimic the functions of the natural forest ecosystem for treated storm water runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed. Biofiltration areas are often incorporated within large parking lots. Existing raised landscape islands within commercial parking lots can be relatively easily converted to sunken bioretention systems. Stormwater flows into the bioretention area as sheet flow often across a grass buffer strips. A central ponding area allows for some storage of stormwater. The ponded stormwater gradually infiltrates into the soil bed and pollutants such as nutrients are removed by filtration, adsorption, and ion exchange. The soil bed is underlain by and sand or gravel layer and sometimes a perforated sub-drain that allows treated water to be discharged to a storm drain system. Plants are a critical component of a bioretention system and reduce stormwater though evapotranspiration and reduce pollutants such as nutrients through uptake. Plants must be carefully selected to withstand both dry and inundated conditions.

The following guidelines should be followed when designing bioretention systems:

- water should not be able to pond for more than 4 days to prevent mosquito breeding and adverse effects on plants;
- plants selected for bioretention should be tolerant to high levels of pollutants, varying wet and dry cycles, and high temperatures;
- native plants should be used when possible; and
- a mulch layer should be included to prevent erosion and retain soil moisture;

Grass Filter Strips

Grass filter strips are densely vegetated areas that intercept sheet runoff from impervious areas such as parking lots, streets and rooftops. Grass filter strips are generally planted with turf grass, but other herbaceous plants or shrubs and trees could be used. These filter strips are often used as pretreatment systems, trapping sediment and inducing some infiltration, prior release to another stormwater BMP.

Vegetated Swales

Vegetated swales are broad, shallow channels with a dense stand of vegetation covering the side slopes and channel bottom. Vegetated swales are designed entrap pollutants, promote infiltration and reduce stormwater flow velocities. Vegetated swales can be designed to be either dry or wet.

Minimizing Directly-Connected Impervious Areas

Minimizing directly-connected impervious areas involves a variety of practices designed to limit the volume of storm water that is directly discharged to the storm water drainage system. Runoff from parking areas, rooftops, driveways and streets, instead is directed to landscaped areas, grass buffer strips, vegetated swales to reduce runoff velocity and volume, attenuate peak flows, and encourage filtration and infiltration of runoff. Street curb-and-gutter systems can be replaced by pervious street shoulders and grassed swales. By incorporating these principles into site designs, the size and number of more convectional and costly BMPs can be reduced.

Miscellaneous Vendor-Supplied Systems

There are a wide variety of proprietary devices used for storm water management. Many of these are “drop-in” systems, and incorporate some combination of filtration media, hydrodynamic sediment removal, oil and grease removal, or screening to remove pollutants from storm water. A few of the available devices include: Baysaver, CDS Technologies, Hydrasep®, Stormceptor®, StormFilter™, StormTreat™ System, and Vortechs™.

Appendix E: Alum Treatment

Alum (aluminum sulfate) is a popular and cost-effective method to inactivate sediment phosphorus. *The use of alum may require a permit from the RIDEM's Division of Fish and Wildlife.* Alum inactivates sediment phosphorus by forming aluminum-bound phosphorus that is not biologically available to algae, even under anaerobic conditions. Welch and Cooke (1999) evaluated the effectiveness and longevity of alum treatment in deep and shallow lakes. They found that the internal recycling rate was reduced in 7 of 7 deep (stratified) lakes and in 6 of 9 shallow (unstratified) lakes. The duration of these effects averaged about 15 years for deep lakes and about 10 years for shallow lakes. The internal loading rate in all the deep lakes and 6 of the shallow lakes was reduced by at least 66% and lake total phosphorus in the trophogenic zone was reduced by about 50% in unstratified lakes and about 40% in stratified lakes. The chlorophyll-a concentration was reduced initially by about 50% and the effectiveness ultimately was similar in the 6 unstratified lakes and by over 50% initially and 40% ultimately in stratified lakes.

Welch (2005) reported that only about 15% of US lake treatments, with adequate evaluation, have failed to be effective at least in the short term. High densities of macrophytes and under-dosing have led either to failure or short-term (one or two years) effectiveness. However, in the majority of alum treatments, many of which were underdosed, the effectiveness of inactivation lasted at least ten years. The effectiveness of treating lakes with high macrophyte densities can be enhanced somewhat by applying the alum in the late winter before the plants have started their vernal growth (Osgood, 2005).

Although alternative coagulants such as calcium and iron exist, neither has proven to be consistently effective in lake applications (Harper 2005). Both iron and calcium salts exhibit minimum solubility in pH ranges that are much higher than typically found in natural lakes. Also iron is highly soluble in anoxic environments and is only effective as a binding agent under anaerobic conditions.

The most common problem with alum application is under dosing, resulting in a shorter period of effectiveness. To avoid under dosing, the alum dose is defined by the amount of mobile phosphorus (iron bound and loose sorbed phosphorus) in the top 4-20 cm of lake sediment and multiplying that phosphorus quantity by 100 to calculate the amount of aluminum needed to inactivate the available sediment phosphorus (Gibbons & Wagner, 2005). Rydin and Welch (1999) and Rydin et al. (2000) also developed methods to determine the dose necessary to inactivate sediment phosphorus. This dose is increased by the amount of water column competition from phosphorus and humic substances, which is determined by jar testing.

As with application of any chemical, the use of alum must be carefully evaluated and controlled to minimize the risk of potential negative chemical and biological impacts. Potential risks and impacts from alum include pH reduction, aluminum toxicity, ecological impairment, and poor treatment effectiveness due to application problems. Fortunately all of these risks can be mitigated by pre-treatment testing, planning and adequate monitoring during application.

Pretreatment testing is an essential component of any alum-related project, to evaluate anticipated impacts to pH, alkalinity, and aluminum concentrations and to observe floc formation and settling and estimate post-treatment water quality characteristics (Harper, 2005). A representative composite water sample is analyzed in the laboratory by conducting a jar test. The sample should be analyzed for alkalinity, soluble reactive phosphorus, chlorophyll-a, dissolved aluminum, and turbidity. Other parameters such as pH, specific conductivity, temperature, dissolve phosphorus, and Secchi depth) should be measured in the field. Varying doses are applied to the jar and changes to water chemistry are recorded. As previously discussed, the alum dose needed to inactivate sediment phosphorus is significantly greater than that required to strip phosphorus from the water column. However, a jar test is useful in evaluating potential negative effects to water chemistry that result from the application of the estimated dose that is required to both strip phosphorus from the water column and inactivate sediment phosphorus.

Perhaps the most significant water quality issue related to alum use is the consumption of alkalinity and decrease in pH, caused by alum addition to surface waters. The maximum change in pH levels generally occurs within one minute after anticipated doses of alum are added to the jar (Harper, 2005). If the water is well buffered (alkalinity > 80 mg/l), then the alum then alum addition may be conducted without significant pH concerns. Unfortunately none of the urban ponds included in this study are well buffered. The pH of alum treated water typically decreases 0.5-1.0 units. The pH of the treated water should not be depressed below 6.0 (although RIDEM Rules and Regulations may hold a stricter standard) to minimize potential aluminum toxicity and biological impacts. Note that the States Water Quality Regulations requires that a waterbody's pH must not be allowed to fall outside the 6 to 9 range, unless it can be shown that the pH as naturally occurs is outside of this specified range.

If laboratory jar tests indicate that an undesirable pH may result from alum application, then several proven options are available. Chemical buffers can be used in combination with alum to adjust the final pH to a pre-selected value. Sodium aluminate (an alkaline salt) is often the buffer of choice since it has a high buffering capacity and provides an additional source of aluminum, which can reduce the alum requirement (Harper, 2005). The specific ratio of alum to buffer required to achieve the required results can be determined by in the laboratory by a jar test. By selecting the proper alum: buffer ratio, virtually any desired final pH can be achieved. Unfortunately sodium aluminate is highly corrosive and requires special handling and equipment. Another method for minimizing pH impacts is to break up the overall alum treatment into a few smaller treatments while monitoring pretreatment and post treatment pH levels. Generally pH recovery occurs within three to six months, at which more alum could be applied. In some instances a third application of alum is required.

Aluminum toxicity is greatest at both low (<5) and high (>9) pH levels (Harper, 2005). The most toxic aluminum species is AL^{+3}, which is the dominant aluminum species under acidic conditions. The equilibrium concentration of Al^{+3} is at a minimum when the final pH is between 5.5-7.5. At this pH, the AL^{+3} concentration is typically less than that found in drinking water. Another concern involves the potential toxicity of alum floc within the sediments. Since aluminum is naturally abundant in sediments, alum application often results in less than a ten-percent increase in sediment aluminum levels. The alum floc which reaches the sediment is primarily $Al(OH)_3$, which is inert under virtually all conditions of pH and redox potential that occur in natural lakes. The floc is extremely stable in lake sediments and forms inert gibbsite crystals over a period of several months. In fact several studies indicate that alum additions to sediments may reduce toxicity by binding heavy metals and other toxic compounds into the inert crystals.

Although aluminum toxicity can easily be controlled by proper pH management, aquatic effects are still possible from physical effects of the application process (Harper, 2005). One of these potential effects involves the attachment colloidal-size floc to fish gill membranes, particularly in fish species that are filter feeders, such as shad. This potential impact is most significant in small lakes, such as those included in this study, where the entire lake may be filled with floc at the same time and the fish are not able to swim away. This impact can be easily avoided by treating only portions of a small lake on a given day. Negative impacts to game fish populations and aquatic plants have not been reported during alum treatments in which the pH has been properly controlled. The most significant potential for aquatic impacts is to the benthic community of the treated lake. However, most studies on benthic populations have found that communities exhibit either no change in density and diversity or exhibit an increase following treatments. Studies in Florida have indicated that there is a decrease in the density of the benthic community following the first year after alum treatment, but the population density begins to increase after one year and the population structure shifts from the original detritivore community to carnivore species that are less pollution tolerant. It is hypothesized that that the aluminum floc in the sediment binds with heavy metals and other pollutants allowing less pollutant-tolerant species to flourish.

Proper floc distribution is essential for the inactivation of sediment phosphorus release. Recent alum applications have relied heavily on the use of GPS to ensure even coverage. Alum should also be applied on windless days so that the floc does not settle unevenly. Another phenomenon that can cause poor floc distribution is the formation of floating floc, which occurs when there are large amounts of cyanobacteria (blue-green algae) that become trapped within the floc. Gas vacuoles within some species of cyanobacteria may cause the entrapped cyanobacteria to float. Under this condition the floc can be easily moved by wind action and generally ends up accumulating on one of the shores. Floating floc can be minimized by performing the alum treatment when cyanobacteria populations are minimal.

Appendix F: Public Meeting Comments

Michelle Komar Written Correspondence.

June1, 2007

Mr. Scott Ribas
RI Department of Environmental Management
Office of Water Resources
235 Promenade Street
Providence, RI 02908

Re: Comments Pertaining to the RIDEM "Total Maximum Daily loads for Phosphorus to Address 9 Eutrophic Ponds in Rhode Island", Final Draft dated 3/30/07

Dear Mr. Ribas:

My comments pertaining to the RIDEM 3/30/07 Final Draft of "Total Maximum Daily loads for Phosphorus to Address 9 Eutrophic Ponds in Rhode Island" are listed below. This RIDEM report is herein is referenced as "the TDML".

1. Warwick Pond: The TMDL states that except for limited data collected by RIDEM for North Easton Pond, all water quality data utilized by RIDEM in the preparation of the TMDL was provided by URI Watershed Watch water quality monitoring program. Does RIDEM have data in their possession (DMRs, RIDEM sampling, etc.) which support that TF Green Airport stormwater outfalls or property is a source of phosphorus?

RIDEM Response: Although RIDEM has water quality data for TF Green Airport stormwater for several other parameters, RIDEM does not have any phosphorus data for airport stormwater outfalls. The RI Airport Corporation's Stormwater Pollution Prevention Plan describes certain activities occurring on the airport property which involve use of phosphorus (including airplane washing and maintenance and use of certain de-icing compounds).

2. Warwick Pond: Only two TF Green Airport stormwater outfalls have been identified in the TMDL. Have all the applicable TF Green Airport stormwater outfalls been identified and addressed in the TMDL?

RIDEM Response: To the best of our knowledge, RIDEM has identified all airport outfalls discharging to Warwick Pond. RIDEM has identified five outfalls that convey stormwater from the airport to Warwick Pond. These outfalls (WP-W, WP-Z, WPAA, WP-AB, and WP-AJ) are shown in Appendix A also listed in Appendix B.

3. The TMDL Table 4.8 identifies two TF Green Airport stormwater outfalls as "Priority Outfalls for Warwick Pond". Does RIDEM have data to demonstrate that Warwick Pond is not impaired by low dissolved oxygen during the months outside of URI Watershed Watch water quality monitoring "season" (typically May-October) and/or has RIDEM determined that there are no

effects of airport stormwater discharges upon low dissolved oxygen during months outside of May-October?

RIDEM Response: RIDEM identifies three TF Green Airport stormwater outfalls as priority outfalls in Table 4.8, including an interconnected outfall (WP-AJ) whose ownership is shared with RIDOT.

RIDEM is not aware of any in-pond DO data collected during the November-April time period. However, dissolved oxygen data collected by RI Airport Corporation at both the inlet and outlet of Warwick Pond has indicated periodic violations of the dissolved oxygen criteria during winter months. These violations are more likely associated with the discharge of glycol (as the primary de-icing compound at the airport) and not phosphorus from airport property storm drains.

Watershed Watch data from 2000-2005 shows that hypoxic conditions (defined as a DO concentration less than 2 mg/l) do not set up in the bottom waters of Warwick Pond until late May to mid-June. Since glycol decays in a matter of days, it appears that it does not exert a significant chemical oxygen demand on Warwick Pond during the critical period from spring late May through the fall. It therefore appears that phosphorus is the main pollutant responsible for low dissolved oxygen in the pond during the critical period.

4. Spring Green Pond in Warwick is not listed on the 2006 303 (d) list (or is listed under another name) and is not included in this TMDL. Has RIDEM determined that Spring Green Pond is not an impaired waterbody? (Spring Green Pond is located to the north of Airport Road and to the west of Warwick Avenue. Activities on the pond include boating and fishing.)

RIDEM Response: RIDEM does not have any water quality data for Spring Green Pond. Therefore the water quality of Spring Green Pond has not been assessed at this time.

5. In addition to state and local agencies subject to Phase II Stormwater Management regulations, the TMDL should also include RIPDES industrial stormwater discharges for those located within the TMDL pond watersheds. Do RIDEM defined industrial stormwater discharges also have 180 days to amend their SWPPPs to be consistent with the TMDL? (If applicable, clarify in the TMDL.)

RIDEM Response: **The TMDL has been revised to specifically identify and address stormwater discharges associated with industrial activities. Stormwater discharges from facilities that discharge "stormwater associated with industrial activity" are regulated under the statewide general RIPDES permit prescribed in Chapter 46-12, 42-17.1 and 42-35 of the General Laws of the State of Rhode Island. In addition to stormwater outfalls from TF Green Airport which discharge into tributaries to Warwick Pond, there are three other facilities currently authorized to discharge to ponds covered by this TMDL:**

- **Rhode Island Airport (North Easton Pond via Bailey Brook)**
- **Freedom Yachts, Inc. (North Easton Pond via Bailey Brook)**
- **Rhode Island National Guard (Warwick Pond)**

Please reference Section 6.2 of the TMDL for the detailed description of the permit requirements

6. The TMDL Abstract and Introduction should clarify that this TMDL addresses phosphorus-related impairments only.

RIDEM Response: The first sentence of the Abstract states that the TMDL addresses phosphorus and phosphorus-related impairments to the nine urban ponds. Table 1.1 in the Introduction lists the specific impairments addressed by this TMDL.

7. The TMDL does not provide pollutant loading allocations for identified outfalls or "priority outfalls". How is RIDEM going to provide data if required to enforce the TMDL, and in particular, cases where industrial stormwater discharges are not assigned a pollutant loading allocation to achieve the pond restoration phosphorus goals?

RIDEM Response: The pollutant allocation for Warwick Pond applies to stormwater load as a whole, not to individual priority outfalls. A 33% load reduction is required for both point and nonpoint sources across the entire watershed. The mean in-pond phosphorus concentration of the pond will serve as the benchmark to determine if the water quality criteria for phosphorus and phosphorus-related parameters have been consistently met. Phase II minimum measures requires the owners and operators stormwater volumes and phosphorus loading to the pond to the maximum extent feasible

Marci L. Cole Ekberg, Ph. D. (Save the Bay). Written Comments.

Scott Ribas
DEM Office of Water Resources
235 Promenade Street
Providence RI, 02908-5767

Re: Eutrophic Pond TMDLs

Dear Mr. Ribas,

Save the Bay has reviewed the Draft Total Phosphorus TMDLs (DTMDLs) for nine eutrophic ponds in Rhode Island. We are pleased to provide these comments:

Save the Bay commends the agency for this study and supports the findings and recommendations for reducing phosphorus loading to the nine listed ponds. We appreciate the efforts of RIDEM to involve the communities in these studies and to educate the public about water quality problems and their solutions.

RIDEM Response: Comment duly noted.

Save the Bay recommends that the major sources for each pond be listed in approximate order of significance as guidance for the towns and cities. Since RIDEM has calculated the relative importance of point vs. non-point sources, this seems feasible. It should also be stated clearly that towns and cities should deal with external sources prior to internal cycling as internally cycled phosphorus is ultimately derived from external sources. On a minor note, in table 5.1 and throughout the document, list concentrations in ug/l instead of mg/l to be consistent.

RIDEM Response: The major sources of stormwater phosphorus or "priority outfalls" for each of the ponds have been identified and are listed in sections 4.8 through 3.9.

A statement that external sources should be mitigated prior to internal sources has been inserted in section 6.0 and the abstract.

All phosphorus concentrations, including those listed in Table 5.1, have been changed to units of ug/l for consistency.

Save the Bay also recommends additional "no feeding the waterfowl" signage in all ponds with potential waterfowl problems. While the TMDL study notes that Roger Williams Park Ponds have signage, a discussion with local residents indicted that they'd never seen any signage. In addition to discontinuing mowing next to ponds, we suggest installation of a buffer of native vegetation to further discourage waterfowl, and to limit the establishment of invasive plant species.

RIDEM Response: The Providence Park system has installed numerous "no feeding the waterfowl" signs around the park only to have the signs repeatedly vandalized. A comment addressing the persistent vandalism was inserted in section 6.5.5.

Language was added in several places in the implementation section of the document recommending the installation of a buffer of native vegetation along the shoreline to limit the establishment of invasive plant species.

Save the Bay continues to support the development of this TMDL, and is committed to working with RIDEM to produce a final TMDL and to develop appropriate nutrient limits to restore water quality. Continued monitoring will be an essential component to this program's success. In addition to field support fro the research, we are also willing to work with the agencies and local conservation organizations to facilitate habitat restoration and protection efforts throughout the watershed.

RIDEM Response: Comment duly noted.

If you have any questions or would like to discuss these comments, you may contact me directly at (401) 272-3540 ext. 113, or by e-mail at mcole@savebay.org.

Sincerely,

Marci L. Cole Ekberg, Ph. D.
Coastal Ecologist

Ronald M. Wolanski (Town Planner, Town of Middletown). Written Comments.

Town of Middletown
Planning Department
350 East Main Rd., Middletown RI 02842 (401) 849-4027

May 29, 2007

Scott Ribas
Office of Water Resources
RI Department of Environmental Management
235 Promenade St.
Providence, RI 02908-5767

Re: TMDL- North Easton Pond (Green End Pond), Middletown & Newport

Dear Mr. Ribas:

In response to your letter of April 3, 2007, I am writing to provide my comments on the draft Total Maximum Daily Load (TMDL) report by prepared by your office for North Easton Pond in Middletown & Newport. I have reviewed the report and I attended the public meeting held at Middletown Town Hall on April 24th. Thank you for your consideration of the following comments:

It appears that water quality data used in establishing the proposed TMDL is based on sampling occurring on only three days in 2002. As was discussed at the public meeting, of the nine ponds studied in this report, only North Easton Pond lacks multi-year data available for analysis. Also discussed was the recent work completed by the town to improve the condition of the main sewer interceptor line which is cited in the report as a potential contributor to phosphorus loading to Bailey Brook. The TMDL and the resulting remediation measures to be imposed on suspected contributors (including the Town of Middletown, City of Newport, RIDOT, and private property owners) are substantially based on data from limited water quality sampling conducted during a single season five years ago. It is possible that phosphorus levels found in 2002 were an anomaly, and do not accurately reflect the actual and current situation. It appears that a more comprehensive water quality analysis should be completed to ensure that sufficient data support the conclusions of the report, and that the resulting remediation burdens placed on the responsible agencies and landowners are justified. *I request that North Easton Pond be removed from the current TMDL study until such a time as adequate and current water quality data are available.*

RIDEM Response:
A potential phosphorus impairment to North Easton Pond was first identified based on anecdotal evidence of algal blooms. North Easton Pond was placed on Group 4 on the 303(d) List of Impaired Waters in 1998. Group 4 includes assessments based on insufficient and/or data that is old. Group 4 waters need further monitoring to determine if there are Water Quality Standards violations. Further monitoring was conducted to definitively characterize the water quality of the pond. The pond was sampled for phosphorus a total of five times in June, August, and October of 2002. The total phosphorus concentration ranged from 42 to 144 ug/l, with a mean total phosphorus concentration of 108 ug/l. Given the extremely elevated phosphorus concentrations within the pond, relative to the Water

Quality Standard of 25 ug/l, it was determined that the data set was sufficient to confirm the pond as impaired for phosphorus. North Easton Pond was placed in Group 1 of the 303(d) List of Impaired Waters. Group 1 lists waters not meeting Rhode Island Water Quality Standards with TMDL development currently underway.

Work done by URI as well as the Eutrophic Ponds TMDL indicates that the phosphorus load to North Easton Pond is in exceedance of the allowable load by a significant margin. The Newport Water and Stone Bridge Fire District Source Water Assessment (2003), conducted by URI for the RI Health Department, used a mass balance model to estimate the total phosphorus load from the Bailey Brook Watershed. The model estimated stormwater runoff assuming an average rainfall of 42 in/yr, evapotranspiration of 21 in/yr and used literature runoff coefficients based on landuse and soil type. The phosphorus load was calculated using the estimated flow and phosphorus concentrations based on literature values for different landuses. The Source Water Assessment estimated that the annual phosphorus load to the Bailey Brook watershed was 2.0 lb/ac/yr or 2601 kg/yr. The Source Water Assessment found that Bailey Brook was at an extreme risk to water quality due to the high estimated phosphorus loads to the river. This exceeds the estimate of the existing phosphorus load to North Easton Pond in the Eutrophic Ponds TMDL (1443 kg/yr). Both estimates of current phosphorus loading significantly exceed the estimated maximum allowable load of 301 kg/yr. The Source Water Assessment also identified the Bailey Brook Watershed as at extreme risk to water quality.

Additional sampling of Bailey Brook also confirms the phosphorus impairment to North Easton Pond. URI Watershed Watch sampled Bailey Brook, the principle tributary to North Easton Pond, from 2004 to 2006. The river was sampled for phosphorus 13 times and the mean total phosphorus concentration was 39 ug/l. RIDEM sampled Bailey Brook for total phosphorus 31 times between 1991 and 2003. The mean total phosphorus concentration was 42 ug/l. Although the mean total phosphorus concentrations for Bailey Brook are considerably lower than that of North Easton Pond, this is to be expected since most of the phosphorus is in particulate form that tends to settle out and accumulate within the pond.

Given both the phosphorus sampling results from both North Easton Pond and Bailey Brook, the persistent excessive algal growth within the pond, and the independent Source Water Assessment conducted by URI, there is ample evidence of a phosphorus impairment of North Easton Pond. Therefore North Easton Pond shall not be excised from the TMDL prior to submittal to EPA for final approval. It should also be noted that regardless of the estimated current load to the pond the target load of 25 ug/l must be met for North Easton Pond to meet the State's Water Quality Standards.

Section 4.11 of the report references the interceptor sewer line as a potential source of phosphorus based on the observations of Geosyntec Consultants, Inc. in 2005. Contrary to the statement in your report, Geosyntec did not conduct an inspection of the sewer line. They were conducting field work for a watershed study funded by NRCS when they observed suspected leaks. To my knowledge these issues have been resolved as part of a recently completed manhole remediation project conducted by Middletown DPW. This information should be included in the report. If necessary, more specific information on the scope of the project can be obtained from Middletown DPW.

RIDEM Response: Sections 4.11 and 6.5.3 have been revised as suggested.

Section 6.1 lists several agencies that will be responsible for revising their Phase II SWMPP and other tasks in order to implement the TMDL requirements. It appears that the City of Newport is omitted from the list. Please explain.

RIDEM Response: The vast majority of the North Easton watershed is located in the Town of Middletown. The portion of the North Easton Pond watershed that is located in the City of Newport includes a 12-acre area of the pond itself at its extreme southwestern corner, and a 4-acre portion of the Friends Drive area, located to the immediate north of the water treatment plant. The 4-acre Friends Drive area comprises only 0.2% of the entire watershed of 2427 acres. There were also no drainage structures observed discharging to North Easton Pond from the Friendship Drive area. Therefore it appears that the stormwater discharge from the Newport stormwater system does not have a significant effect on the water quality of North Easton Pond.

Section 6.5.4 lists specific implementation measures for North Easton Pond. Again the City of Newport appears to be omitted form this discussion.
Regarding SWMPP amendments and related requirements, unless it has been determined that no storm water runoff from the City of Newport is entering the pond, it seems that the city should also be subject to these requirements. The report indicates that a shoreline survey was not completed and outfalls were not identified for the pond. The city should be equally responsible for identifying outfalls and appropriate BMPs to address city runoff.

RIDEM Response: As previously discussed the Friends Drive neighborhood is the only portion of the North Easton Pond watershed that is located in Newport. A partial shoreline of the watershed was conducted, including the Friends drive neighborhood, and it appears that there are no outfalls discharging into the pond from this area.

Regarding the report's recommendation retention and infiltration of storm water as the preferred BMPs for phosphorus removal in the catchment area. It should be noted in the report that the prevalence of poorly drained soils and high water tables in Middletown limit the feasibility of these options.

RIDEM Response: Section 6.5.4 was revised to acknowledge that the pervasiveness of poorly drained soils and high water tables in the Town of Middletown would make finding suitable sites for infiltration BMPs especially critical.

Please feel free to contact me with and questions or concerns regarding these comments at 401-849-4027 or rwolanski@middletownri.com.

Sincerely,

Ronald M. Wolanski, AICP
Town Planner

Cc: Town Administrator
DPW Director

Helen Tjader (President, The Barrington Land Conservation Trust, Inc.) Written Comments.

Scott Ribas
Environmental Scientist
RI Department of Environmental Management
Office of Water Resources
235 Promenade St.
Providence, RI 02908-5767

Re: Draft Phosphorus TMDL for Brickyard Pond, Barrington

Dear Scott:

Thank you for your presentation last month at the Barrington Library and for the work that you and your department have done to study the eutrophication issues at Brickyard and other ponds. The Barrington Land Conservation Trust (BLCT), as one of the major landowners in the watershed, actively supports efforts to improve water quality in the pond. Our efforts to date have largely been focused on land-protection – a top recommendation of past studies, but we are also working with the Town of Barrington to help develop management plans for town-owned land that has been designated conservation land, including a significant amount of land surrounding Brickyard Pond. In addition, we have proposed establishment of the Sowams National Heritage District, which would serve to advance and coordinate management planning for a larger area, including management of surface and ground water resources.

RIDEM Response: Comments duly noted. RIDEM greatly appreciates the efforts of the Barrington Land Conservation Trust in land preservation and stewardship.

Suggestion: Host a Second Public Meeting in Barrington
We are pleased to see so many neighbors attending last month's meeting as well as Joe Piccerelli of Barrington's DPW. It might be helpful to work with the Town to set up an additional presentation. A variety of Town committees may want to comment on the suggested phosphorus control measures and planning for the pond including: Conservation Commission, Parks and Recreation Commission, Planning Board and perhaps the Ad Hoc Open Space Committee which includes representatives from these and other boards. (The Ad Hoc Committee is also the one focusing on developing management plans.) Several other major private landowners were not represented at the meeting including the Rhode Island Country Club and the Bristol County Water Authority (BCWA). Perhaps with a second meeting you could enlist their attendance and participation. There have been a number of cooperative projects within the creek/pond system including these partners not attending last month's meeting: NOAA, NRCS, National Marine Fisheries, CRMC, RIDEM's Divisions of Planning & Development and Fish & Wildlife, Save the Bay, The Nature Conservancy, Audubon of Rhode Island, RINHS, RI Historical and Heritage Commission, Pokanoket Tribe, Ducks Unlimited and Fish America Foundation. If the majority of improvements will rely on funding from sources in volunteer land management practices, these are the potential partners who have already supported local efforts.

RIDEM Response: Though RIDEM completed the water quality restoration study and has made recommendations to abate the identified sources of phosphorus, responsibility for implementation of the plan rests primarily at the local level. Unfortunately RIDEM does not have the resources to organize additional meetings, however RIDEM staff will gladly attend any future meetings to help provide technical assistance regarding the nutrient

impairment to Brickyard Pond and recommended BMPs. The Town of Barrington, or another interested stakeholder such as the Barrington Land Conservation Trust, would probably be a more appropriate choice in organizing any additional meetings.

Suggestion: Study Salt Water vs Freshwater Inflows and Quality
It is our understanding that Brickyard Pond is very significantly influenced by inflows from Narragansett Bay. We had previously been informed that that connection accounted for much of the poor water quality. The creek system has been extensively studied with the use of computer modeling by NRSC. Significant restoration work has occurred in recent years, with significant support by the Rhode Island Habitat Restoration Team. Replacement of the collapsed culverts under Middle Highway by RIDOT should have restored the connection of Big Mussachuck Creek into Brickyard Pond several years ago, but the project left behind large amounts of sediment in the creek to the west of Middle Highway. Last fall the Rhode Island Country Club (RICC) began a restoration project throughout the Big Mussachuck creek system which was ten years in planning. It included replacement of the broken tide gate with a self-regulating tide gate, dredging the mouth of Big Mussachuck Creek and extensive re-grading, Phragmites treatment and drainage work. All of these projects should improve the connection of the creek with the pond. The cumulative results of these projects on the water quality at Brickyard could be studied this coming year.

RIDEM Response:
As a result of the stakeholder comments during the public meeting regarding a tidal influence on Brickyard Pond, RIDEM staff conducted an investigation of the Mussachuck Creek and the pond to determine if the pond was inundated with brackish water during high tides. RIDEM staff inspected the creek on April 18, 2002 at high tide (high tide at Nyatt Point was at 9:14 A.M.). An astronomical high tide occurred on April 16, 2007. The area was also hit by a severe storm on April 15 and 16, which caused coastal flooding. On the April 18, 2007 high tide, water in the creek was observed flowing westerly away from Brickyard Pond. This westerly flow was observed at the pond outlet and at Middle Highway. The salinity was also measured during this high tide period at several locations around the perimeter of Brickyard Pond, at the pond outlet, and in Mussachuck Creek at Middle Highway. The salinity was 0.5 ppt at all locations, which is well below the range of brackish water (greater than 1 part per thousand but less than 10 parts per thousand). The relatively low salinity is especially significant since it was measured only two days after a severe storm that occurred at an astronomical tide and caused significant coastal flooding. Also only freshwater vegetation, including woody vegetation, was observed within the pond and in Mussachuck Creek upstream of Middle Highway.

NRCS and Division of Fish & Wildlife staff were also contacted to obtain more information about any potential salt water intrusion into Brickyard Pond. The staff from both agencies concurred that Brickyard Pond is a freshwater waterbody and any potential inundation of salt water occurs only on rare occasions during extreme storm events. NRCS staff stated that neither the culvert installation at Middle Highway nor the restoration work completed to the west of the road would have changed flow from Brickyard Pond in any significant way. The floodgate is designed to allow for only westerly flow in the creek (away from Brickyard Pond) once tidal waters reach about 3 feet above mean sea level.

In this context, we also recommend that you coordinate closely with each state and federal program that has been involved with the restoration project, including NRCS, CRMC and the Division of Fish & Wildlife. The extensive data collected for this project, and its implementation, would seem extremely relevant to the objectives of the proposed TMDL. We note the concern that was expressed with impacts from turf management, including the use of pesticides and possible increase in nutrient loading through storm water runoff or other mechanisms; we would hope that these issues were thoroughly addressed during the permitting of the project, and that appropriate best management practices were incorporated to minimize such impacts. We believe it would be helpful to confirm this to the people in the meeting who raised this concern.

RIDEM Response: The storm drain system that drains to Mussachuck Creek was an existing feature of the golf course prior to the project being reviewed by state and federal agencies. The project, which mostly entailed wetland restoration along the creek and other areas owned by the golf course but did include changes to the storm drain system to improve drainage, was reviewed and approved by CRMC and EPA, and also received a Water Quality Certificate from RIDEM. Relative to impacts of this potential source to Brickyard Pond, we note that it is only in rare instances that we would expect the Mussachuck Creek to flow into Brickyard Pond.

Suggestion: Build Upon Existing Frameworks
Figure A.2 – Brickyard Pond Watershed and Outfalls looks very similar to the "Nyatt Wellhead Recharge District". The Town undertook a study of the district back in 1994 with the focus on protecting the water quality of the Nayatt wells owned by BCWA done back in 1994. The study made recommendations including land protection and identified potential hazardous materials within the district. These wells are the only commercially viable wells in the East Bay. Cyndee Fuller of the Barrington Conservation Commission (BCC) has been leading the update of the wellhead district regulations first proposed around 1997. In the late 1990's the BCC did public education about the wellhead district. The BCWA has funding that could be designated in a variety of ways towards wellhead protection, but it has chosen to utilize the available funding in their reservoir watersheds. Perhaps they could be enlisted to help with both the education and other improvements.

RIDEM Response: RIDEM supports the work of the BCWA and BCC in land protection and public education to protect the Nyatt Wellhead Recharge District and the Brickyard Pond Watershed. RIDEM encourages the BCWA to work with the Town and the BCC in helping to provide funding for the implementation of BMPs or assistance in public education.

The BLCT participates on the Town's Ad Hoc Open Space Committee, for which developing management plans is a priority, and which has identified lands surrounding Brickyard Pond as a top priority among other town-owned lands. We believe it would make sense for the Town and RIDEM to coordinate so as to make sure that the management plan is consistent with, and helps optimize, the implementation of the proposed TMDL. Phil Harvey, The Town Planner, is the contact for the Committee.

RIDEM Response: RIDEM will be pleased to review any management plans developed by the Town's Ad Hoc Open Space Committee to ensure consistency with the TMDL implementation recommendations.

The BCLT has also been promoting the Town's adoption of a Sowams National Heritage District. This unique multi-purpose district of about 500 acres of open space is based on the model of the National Park Service's Blackstone River Valley Heritage Corridor. This proposal is being considered through the Town's current process to update its comprehensive plan. Please see the attached proposal presented to the Town's Planning Board last October. Phil Hervey has an accurate map of the proposed district. We have a summary Excel spreadsheet showing 4 phases of projects, including erosion control and public education, and also a more detailed narrative and timeline. These are in need of an update, but they may still be helpful as an overview of the substantial projects completed or underway throughout the proposed district. It is encouraging to know that most of the projects in Phase 1 and 2 and much of Phase 3 are ongoing or completed – quite an effort on the part of many groups, including the Town.

RIDEM Response: RIDEM applauds the efforts of the Town of Barrington and the BLCT in the adoption of the proposed Sowams National Heritage District.

Conclusions
The BCLT supports the study recommendation for a professional consultant to assess pond management options to control phosphorus. Historic maps show Brickyard's progressive development as a man-made pond. Previously, the area contained an extensive wetland system. It would be helpful to know the most effective and practical measures to control phosphorus loading for a clay-based pond including realistic improvement of an 'unnatural' body of water. We recommend close coordination with other programs and agencies, including Fish& Wildlife and the Habitat Coordination Team.

RIDEM Response: RIDEM has identified the release of phosphorus from pond sediments as a significant source of phosphorus to the pond and has recommended that a professional consultant be hired to determine the most effective and appropriate methods to mitigate this source of internal phosphorus. The manmade nature of the waterbody and predominance of clay-sized particles in the lake sediments is not anticipated to preclude effective mitigation of phosphorus release from the sediment.

Erosion control and shoreline re-vegetation are appealing projects that might be underwritten with grants. There may be some cost effective alternatives to rip-rap. Maybe freshwater plant habitat can be restored in targeted areas of the pond. Based on our experiences working with volunteers to remove invasive plants throughout this area, we would recommend planting desired native plants rather than relying on a vegetative re-growth which will assuredly be non-native. According to RINHS there were rare plant species in the area, a survey for any remaining species would be a useful planning component.

RIDEM Response:
RIDEM recommended erosion controls to mitigate the ongoing erosion of the lake shore of Brickyard Pond. Rip-rap was given as one possible example of an appropriate erosion control, however other erosion BMPs may also be appropriate. Kindly note that the installation of erosion controls along the shoreline would require a permit from the Wetlands Permitting program of RIDEM.

Language was added in several places in the implementation section of the document recommending the installation of a buffer of native vegetation along the shoreline to limit the establishment of invasive plant species.

The recommendation for more frequent maintenance of streets and storm drains makes sense as does the clarification of the town's and RIDOT's responsibilities for specific streets and outfalls.

RIDEM Response: Comment duly noted.

If bird population management is needed, the local increase in ospreys and the occasional visits of wintering bald eagles at Brickyard Pond might inspire the construction of roosting and nesting platforms on the overused islands. Some of our volunteers have experience in constructing these and often scouts are available for such projects.

RIDEM Response: RIDEM encourages the construction of roosting and nesting platforms to provide habitat for osprey or other birds of prey on the islands in Brickyard Pond. The presence of these birds of prey may help to keep the populations of problem birds on these islands in check.

Please feel free to contact us for any of the additional information mentioned regarding the proposed district. BLCT looks forward to playing an active role in furthering improvements within the watershed.

Thank you for the opportunity to comment.

Sincerely,

HelenTjader,
President

Cc: Ann Strong, Barrington Conservation Commission
Melissa Horne, Barrington Parks and Recreation Commission
Michael Minardi, Barrington Planning Board
Phil Hervey, Barrington Town Planner

Allison LeBlanc (RIDOT) Written Comments

June 5, 2007

Mr. Scott Ribas, Environmental Scientist
Office of Water Resources
Department of Environmental Management
235 Promenade Street
Providence, RI 02908-5767

RE: TMDLs for Phosphorus to Address 9 Eutrophic Ponds in Rhode Island
TMDL for Dissolved Oxygen and Phosphorus – Mashapaug Pond, Rhode Island

Dear Mr. Ribas:

This letter constitutes the Rhode Island Department of Transportation's (RIDOT's) written comments regarding two Total Maximum Daily Load (TMDL) studies that the Rhode Island Department of Environmental Management (RIDEM) has submitted for Public Comment: the *Total Maximum Daily Loads for Phosphorus to Address 9 Eutrophic Ponds in Rhode Island* and the *Total Maximum Daily Load for Dissolved Oxygen and Phosphorus – Mashapaug Pond, Rhode Island*. RIDOT has reviewed both reports, attended each of the Public Meetings, and offers the following:

<u>Overall</u>

Report technicalities

In the Eutrophic Ponds TMDL, several of the outfall numbers do not match from section to section. For example, in Section 2.7, it is stated that there are 23 outfalls that discharge to Spectacle Pond. In Section 4.14, the report states that there are 21 outfalls that discharge to Spectacle. A similar discrepancy also occurs for Gorton Pond, Roger Williams Park Ponds, and Upper Dam Pond.

RIDEM Response: The document has been revised so that the outfall numbers are consistent throughout the document. In most instances, outfalls were deleted from the document after further consideration showed that they were abandoned (no evidence of flow). Also there some outfalls were deleted from the document because they conducted only stream flow and not stormwater from streets.

In the Eutrophic Ponds TMDL, section 4.2 states that a shoreline survey of each of the nine ponds was conducted and all stormwater outfalls were identified. Section 4.5 goes on to state that due to the extensive size and complexity of North Easton Pond tributaries, the identification of stormwater outfalls was not completed for this Pond.

RIDEM Response: Section 4.2 was revised to reflect the fact that a complete shoreline survey of North Easton Pond was not conducted.

In the Eutrophic Ponds TMDL, there is reference to the 1993 EPA study regarding the effectiveness of structural BMPs. There are re are several newer studies which could be used to update this information. The University of New Hampshire Stormwater Center has published the results of their research on structural BMPs, and comprehensive fact sheets for common BMPs. http://www.unh.edu/erg/cstev/. The EPA has also published **The Use of Best Management Practices (BMPs) in Urban Watersheds** in September 2004, which has more current efficiency data. http://www.epa.gov/nrmrl/pubs/600r04184/600r04184.pdf

RIDEM Response: Both websites have been referenced in section 6.2. The structural BMP efficiency data in Table 6.1 from the 1993 EPA study has been replaced with data from the 2004 EPA publication.

In the Eutrophic Ponds TMDL, the Abstract states that the ponds included in the study are located in urbanized watersheds. Section 1.0 also refers to all ponds included in the study as 'urban ponds'. Section 2.0 goes on to state that *most* of the ponds are in urbanized watersheds. Are any of the ponds not considered to be 'urban'? The term 'Urban' should also be defined, and the Rhode Island Geographic Information System (RIGIS) dataset used to determine the urban areas referenced.

RIDEM Response: All references to "urban ponds have been changed to "eutrophic ponds". The term "eutrophic ponds" is a more apt description of the all the ponds as a whole. The term "urban", as it relates to watersheds, was used in a purely subjective sense and the term does not reflect a classification associated with any specific database such as RIGIS. The term was used as a generalized description of the watersheds since most of them are highly developed. Section 1.0 has been revised to indicate that most and not all of the watersheds are in urbanized areas. For instance, forest and wetland areas comprise approximately 31% of the Upper Dam Pond watershed, so that watershed is arguably not considered urban.

All RIGIS datasets used in both TMDL studies (land use, soils, urban areas) should be listed in References with the creation/revision year noted in the body text.

RIDEM Response: In accordance with this comment, the RIGIS databases have been listed in the reference section as well as cited in section 2.0.

Land Use within each watershed
In the Eutrophic Ponds TMDL, Section 2.0 states that land uses were determined from the RIDGIS database. This database is not included in the Reference section, and there is no mention of what year the dataset was created. If the 1995 Land Use dataset was used (the most recent on the RIGIS website), there should be mention that the dataset is 12 years old and therefore might contain inaccuracies.

RIDEM Response: The 1995 land use and the 2005 watershed data sets were used in the Eutrophic Ponds TMDL. Both databases have been cited in the reference section in response to this comment. The fact that the land use database is 12 years old and that some of the land uses may have changed has been stated in section 2.0.

In the Eutrophic Ponds TMDL, when describing the watershed, the areas categorized as 'water' are grouped with 'forest' and 'wetland'. If the 'Anderson modified Level 2' coding system was used, water could be separated out. As the TMDL is looking at the effects of land use *around* the pond, the pond itself should not be included in the percentages of land use. Especially in the watersheds where 'forest, wetland, water' represents a significant portion of the land use (Brickyard Pond, Upper Dam Pond), reclassifying 'water' could significantly alter the percentages of the other categories. If the intent of including 'water' in the calculations is to account for internal cycling, this may still be accomplished, however, separating it from the other categories will provide a better understanding of the significance of wetland and forested areas.

RIDEM Response: The Level 2 coding system was used, however water, wetland, and forest were lumped together for the sole purpose of estimating percent impervious area within the watershed. The generalized category of forest, wetland, and water was taken from the URI NEMO program and the Center for Watershed Protection, which assigned a value of 0% impervious cover for this combined land use. The only purpose of estimating the percent impervious cover within the watershed was to fulfill an EPA requirement to estimate the waste load (point source) and load (non-point source) allocation of the TMDL. The land use categories did not enter into any of the calculations for the TMDLs or the current loads to the ponds. The TMDLs and current loads were calculated with the Reckhow Model using the areal water load and the target and mean current in-pond concentrations only.

This combined classification was not used in the Mashapaug Pond TMDL (in fact, 'water' was not used as a land use classification at all).

RIDEM Response: The Mashapaug Pond TMDL used an entirely different method in its TMDL calculations than the Eutrophic Ponds TMDL. The hydrodynamic model used for the Mashapaug TMDL used literature loading rates for different land uses to estimate loads to the pond. Therefore a breakdown of the different land uses was critical for the Mashapaug TMDL. As previously discussed, the Eutrophic Ponds TMDL used land use only to calculate the point and non-point source portions of the TMDL. The Eutrophic Ponds TMDLs are calculated solely on the basis of the target concentrations and the areal water loads.

Internal Cycling of Phosphorus

In the Eutrophic Ponds TMDL, lake management strategies such as dredging, aeration/oxygenation of the hypolimnion, complete circulation/destratification of the entire lake, and alum application should be stressed as a secondary solution. These solutions will be short-term (as discussed in Roger Williams Pond section) if nothing is done about the external sources of phosphorus loading. It is already noted that removal of external sources may not provide immediate impact due to internal cycling of phosphorus. It should be stated that removal of both internal and external sources need to be coordinated to achieve success.

RIDEM Response: A statement regarding the need to coordinate implementation of external and internal BMPs has been included in both the Abstract and section 6.0.

In the Eutrophic Ponds TMDL, Section 4.7 states that internal loading rates have not been quantified, though they could be easily estimated. No estimates or equations for developing estimates are given or referenced in the document. It is further stated that internal loading is considered to be a significant source of phosphorus to the most of the Ponds (Sections 4.8 – 4.16). It is unclear if internal loading values were used in creating the TMDL targets for each pond. If not, why was the decision made to exclude these values, especially if they are "easily estimated"?

RIDEM Response: Although an estimation of internal phosphorus loading is attainable, it would require a fairly large supplemental sampling data set that is beyond the resources allocated to this TMDL. The generalized methodology needed to estimate the internal phosphorus load is described in section 4.7. An estimate of the internal load would require either a series of water quality sampling events at variable depths or composite sediment

core sampling over time during a period of time when external phosphorus inputs are negligible.

Public Education and Outreach
RIDOT, in conjunction with RIDEM, has signed an agreement with the University of Rhode Island Cooperative Extension (URI) for a Public Education and Outreach Program. This program will provide participating MS4s the opportunity to use prepared education and outreach programs for their individual use, which could be easily tailored to the TMDL public education recommendations. RIDEM is encouraged to promote the use of this resource. To date, each of the MS4 designated in the TMDL studies are participating in the Program, except Coventry. More information may be found on the URI NEMO website http://www.uri.edu/ce/wq/RESOURCES/STORMWATER/index.htm

RIDEM Response: This information has been included in the Public Education/Public Involvement section of section 6.1.

Illicit Detection and Elimination
RIDOT will continue to prioritize TMDL areas for illicit detection and elimination. As part of Phase II Minimum Measure 3 requirements, RIDOT is locating and inspecting every State-maintained outfall. As part of the inspection, dry weather surveys are conducted, and if flow is present, dry weather sampling of flow, temperature, pH, conductivity, and fecal coliform levels are conducted. Based on analytical results, illicit connections will be investigated. The mapping effort will continue through the summer of 2007, and all TMDL areas that have yet to be mapped will be prioritized for program work. It is anticipated that the 9 Eutrophic Ponds and Mashapaug Pond areas will be mapped this year.

RIDEM Response: Comment duly noted.

Pond Specific Comments

Brickyard Pond

Public Meeting: April 17th, 2007, Barrington Public Library, Barrington

Comments made by the public include:
Storm water runoff from the country club/golf course adjacent to Brickyard Pond may be a significant source of pollutants, and should be included in the TMDL study as a source. They are installing French drains into the herring run from new holes. RIDEM responded that they will investigate and may revise the TMDL accordingly.

RIDEM Response:
The Rhode Island Country Club is located west (downstream) of Brickyard Pond, between Middle Highway and Washington Road. The golf course straddles Mussachuck Creek, downstream of Brickyard Pond. RIDEM staff conducted an investigation of the creek and pond to determine if the pond was inundated with brackish water during high tides. RIDEM staff inspected the creek on April 18, 2002 at high tide (high tide at Nyatt Point was at 9:14 A.M.). An astronomical high tide occurred on April 16, 2007. The area was also hit by a severe storm on April 15 and 16, which caused coastal flooding. On the April 18, 2007 high tide, water in the creek was observed flowing westerly away from Brickyard Pond. This westerly flow was observed at the pond outlet and at Middle Highway. The salinity was also measured during this high tide period at several locations around the perimeter of

Brickyard Pond, at the pond outlet, and in Mussachuck Creek at Middle Highway. The salinity was 0.5 ppt at all locations, which is well below the range of brackish water (greater than 1 part per thousand but less than 10 parts per thousand). The low salinity is especially significant since it was measured only two days after a severe storm that occurred at an astronomical tide and caused significant coastal flooding. Also only freshwater vegetation, including woody vegetation, was observed within the pond and in Mussachuck Creek upstream of Middle Highway. The RI NRCS has also conducted a lot of work restoring the herring run on Mussachuck Creek and NRSC staff do not believe that Brickyard Pond is inundated with brackish water, except possibly during extreme storm events.

Because there was no evidence of reverse (eastward) flow from Mussachuck Creek into Brickyard Pond even during an abnormally high tide, salinity levels within the pond and in the creek upstream of Middle Highway were well below the range recognized by RIDEM as brackish even after a severe storm with coastal flooding, and no vegetation indicative of brackish waters were observed in the pond or nearby creek, it appears that it is highly unlikely that the activities of the Rhode Island Country Club are having any significant impact on the water quality of Brickyard Pond.

Cormorants are more numerous than geese in the area.

RIDEM Response: Sections 4.9 and 6.5.2 has been revised to include a statement that acknowledges that there is a large winter population of cormorants on the pond and to suggest BMP's to address this problem.

Residents are cutting down trees along the Bike Path along the north shore of Brickyard Pond. The Town of Barrington owns 30-feet from the shoreline, and the cutting is allegedly taking place within this right-of-way.

RIDEM Response: The area in question was inspected by RIDEM TMDL staff. The subject area is a grassy lawn area with scattered trees between the bike path and the pond in the vicinity of Joy Street. There was evidence that some trees had been cut in the past, but there was no evidence of any recent cutting. Because there appears to have been no recent activity and the cutting appears to be selective (the area was not clear cut), the matter was not reported to RIDEM's Division of Compliance & Inspection.

Two landfills were situated on either side of Brickyard Pond. The question was raised if this was known by RIDEM and if it would impact the TMDL calculations.

RIDEM Response: **RIDEM's Division of Waste Management has investigated both sites and has files of data associated with both of these historic landfills. One landfill is located north of the pond to the south of Foote Street. Groundwater investigations at this site show that groundwater is flowing to the northeast, away from Brickyard Pond. There is another 10, 000 square foot area located at the outlet of Brickyard Pond that was used in the past for waste disposal. This site was originally used to dispose of waste from a manufacturer of rubber products and later for the disposal of construction debris. Because flow in this area is to the west, away from Brickyard Pond, it appears that the subject site, which has been inactive for decades, is not a significant source of phosphorus to Brickyard Pond. Kindly note that the presence of these landfills does not affect the TMDL calculations in any way. The TMDL or target load for Brickyard Pond was calculated using a target in-pond concentration of 20 ug/l.**

There was no mention of the herring run as a recreational use of this pond in the TMDL. Fishermen report that there were no herring at all this year, and that they all seem to be migrating to a different pond.

RIDEM Response: The andronomous fish run to Brickyard Pond is mentioned in section 2.2. Discussions with RIDEM Fish & Wildlife staff (Phil Edwards and Alan Libby) indicate that herring have been stocked in Brickyard Pond in 2006 and 2007. Prior to 2006 only Echo Pond (also accessible by Mussachuck Creek) was stocked with herring. This may be the reason that more fish were migrating to Echo Pond. Discussions with Fish & Wildlife staff also revealed that herring were present in Brickyard Pond even prior to its being stocked. Since its stocking, herring have been trapped in Brickyard Pond, but at this time its impossible to discern whether they are the same fish that were stocked or returning fish.

RIDOT has not completed outfall mapping in the TMDL area to date. This area will be prioritized for the Summer 2007 mapping program. RIDOT will coordinate with the Town of Barrington in this effort.

RIDEM Response: Comment duly noted.

Almy & North Easton (Green End) Ponds

Public Meeting: April 24th, 2007, Middletown Town Hall, Middletown

Almy Pond

RIDOT has not identified any storm water outfalls within our system which drain into Almy Pond. RIDOT will continue the implementation of the six minimum measure BMPs in the study area, and consider this sufficient action for this portion of the TMDL.

RIDEM Response: Comment duly noted.

North Easton Pond

RIDOT has worked with both the Town of Middletown and RIDEM to locate storm drain outfalls and determine ownership in the vicinity of North Easton Pond. RIDOT has identified 8 outfalls within our system in the vicinity of North Easton Pond. Dry weather surveys have been conducted, and dry weather flow identified. Further investigation has determined that the dry weather flow from RIDOT's outfall was originating from the Town of Middletown's physically interconnected system. RIDOT will continue to coordinate outfall mapping and dry weather surveying with the Town of Middletown.

RIDEM Response: Comment duly noted.

Gorton, Sand, Upper Dam, Warwick Ponds

Public Meeting: April 30th, 2007, Warwick Public Library, Warwick

Public Comments included:
There may be another outfall west of GP-A.

RIDEM Response: In response to this comment, another shoreline inspection of the northern shoreline of the pond, west of Trinity Street, was undertaken and no additional outfalls were found. There are only two catch basins on Gorton Lake Boulevard in this

vicinity and both of their associated outfall pipes (GP-A and GP-M) have been identified in the TMDL document.

Other RIPDES permit holders (the airport and industries) should be included as responsible parties.

RIDEM Response: The RI Airport Corporation is the sole owner of two priority outfalls (WP-AB and WP-Z) and partial owner of the drainage system associated with another priority outfall (WP-AJ) that are identified in section 4.16 and Table 4.8. The RI Airport Corporation was also identified as a responsible party in Table 6.9.

RIDOT has not completed outfall mapping in the TMDL area to date. This area will be prioritized for the Summer 2007 mapping program. RIDOT will coordinate with the Town of Warwick in this effort.

RIDEM Response: Comment duly noted.

Mashapaug, Roger Williams Park, Spectacle Ponds
Public Meeting: May 2nd, 2007, DEM Offices, Providence

Public Comments included:
Tongue Pond should be considered as a wet-weather source of pollutants, and taken into account in calculations.

RIDEM Response: Ten individual stormwater drains that discharge to Tongue Pond have been identified as sources in the TMDL document. Because the ditch that connects Tongue Pond to Spectacle Pond appears to flow only at times of exceptionally high water, none of the direct discharges to Tongue Pond were classified as priority outfalls relative to the water quality of Spectacle Pond. It should also be noted that the TMDL calculations were not affected by individual sources, but were based on in-pond and criteria concentrations and the estimated aerial water loadings.

RIDOT has not completed outfall mapping in the TMDL area to date. This area will be prioritized for the Summer 2007 mapping program, however it may not be completed due to traffic control issues along Route 10 and Route 95. RIDOT will verify ownership of storm drain outfalls in the TMDL study area during the summer of 2007.

RIDEM Response: Comment duly noted.

Implementation

Structural BMPs within these TMDL areas may prove very difficult to design. As noted in both the Mashapaug TMDL (Section 5.3) and the Eutrophic Ponds TMDL (Section 2.0), the areas surrounding these ponds are highly urbanized and most are fully developed. Finding appropriate and sufficient space may prove to be a limiting factor for many of the structural BMPs.

RIDEM Response: RIDEM recognizes the challenge of finding appropriate locations for structural stormwater BMPs in highly developed areas, however it appears there are opportunities for subsurface stormwater structures within roadway right-of-ways, and other state, city, or town-owned properties.

RIDOT will provide an Amendment to its Storm Water Management Program Plan (SWMPP) within the required 180 days of finalization of this TMDL. RIDOT responsibilities and planned actions will be detailed, and will be submitted to the Office of Water Resources for review. RIDOT will also continue to work with the Office of Water Resources, as well as any interconnected MS4s, in implementing both the Storm Drain Retrofit Program and the Storm Water Management Program.

RIDEM Response: Comment duly noted.

Should you have any questions regarding this matter, please contact Ms. Allison LeBlanc of this office at 222-2023, Extension 4097. Thank you.

Sincerely,

Edward S. Szymanski, P.E.
Associate Chief Engineer
Office of Intermodal and Environmental Planning

cc: RIDOT: Bennett, LeBlanc/file, Szymanski
RIDEM: Elizabeth Scott

Donald Pryor (Brown University) Written Comments

From: Donald Pryor [Donald_Pryor@brown.edu]

To: Scott Ribas

CC:

Subject: Ponds TMDLs

Eutrophic Ponds and Mashapaug Pond TMDLs

Focusing almost entirely on the chain of Tongue, Spectacle, Mashapaug and Roger Williams Park ponds.

1. Estimation of Q (inflow water volume) and L (existing loading, g/m2-yr)
Page 51 (Ponds TMDL) erroneously terms Ao as the "watershed area" – it is actually the waterbody surface area. Calculations shown on page 117 confirm.

RIDEM Response: The document (page 52) has been revised accordingly.

The regression result of 2.0 cfs per square mile is given in units jarringly inconsistent with the rest of the document – it should be given in m3/s/ha (18.9 m3/d/ha).

RIDEM Response: Page 52 has been revised accordingly.

This relationship can be checked for consistency in several ways. Spectacle Pond mean annual inflow is estimated as 1.64 x 106 m3/yr (table 5.1, page 52, Ponds TMDL) but the Mashapaug Pond TMDL gives Spectacle Pond baseflow as 1.044 x 106 m3/yr (table 2-3, page 10). Evaporation would account for some of the difference but probably only about 10%. The Mashapaug Pond TMDL estimate appears to be based on measurements and calculation in a Tetra Tech (2001) report (cited on page 12) but no reference is provided in the section 9.0. If Q is overestimated, qs is also overestimated, as is the existing load and loading capacity.

RIDEM Response:
The mean annual inflow to Spectacle Pond estimated in the Eutrophic Ponds TMDL differs from the Spectacle Pond baseflow estimated in the Mashapaug Pond TMDL because flow was estimated by different methods. Without long-term stream gauging, stream flow is a difficult parameter to estimate precisely. Although the estimates do differ, they are fairly similar considering the inherent variability of this parameter. Kindly note that the reference on page 10 was changed to RIDEM, 2007, since the Tetra Tech document was not published and the information is presented in the Mashapaug TMDL.

The inflow estimated in the Eutrophic Ponds TMDL was derived from the regression result of 2 cfs/mi2 (18.9 m3/d/ha). This inflow estimate was based on work done by the Rhode island USGS who estimated streamflow by regressing mean annual inflows, based on long-term records of gauged streams in Rhode Island against drainage area. Although the ratio of streamflow to watershed area of course differed among the different rivers, this ratio was fairly consistent despite different watershed and stream characteristics. Therefore RIDEM

felt comfortable in using the result of this regression to estimate flow to the Spectacle and the other eutrophic ponds.

The Mashapaug TMDL apparently derived its estimate of the baseflow from Spectacle Pond from a Tetra Tech hydrologic model which utilized actual streamflow data supplied by ESS. Stream flow was measured during dry weather conditions on six occasions from June through September 2001 and another four times during a single wet weather event in September 2001. This flow data is presented in Tables 3 and 4 of Appendix B. This estimate of Spectacle Pond outflow may or may not be more accurate than the estimate of Spectacle Pond inflow given in the Eutrophic Ponds TMDL. RIDEM was not able to revise the model inputs as the modeling for Mashapaug Pond was done by an EPA contractor, Tetra Tech Inc. Even if the areal water load has been overestimated, the approach provides the relative magnitude of phosphorus load reductions needed. Through an adaptive management approach, success in achieving the TMDL's objectives will be measured relative to compliance with ambient water quality standards and not whether the calculated load reductions have been achieved.
All Tetra Tech results are presented in the Mashapaug TMDL. Please note that Tetra Tech supplied RIDEM with the results of their hydrologic model only, not a full written report.

Lastly, are there any more current data and information that can be considered? For instance, the Ponds TMDL uses Watershed Watch data through 2004. Can the 2005-2006 data be made available? In the case of Brickyard Pond, for example, P data though 2004 seem to show a declining trend. The last two years of data might clarify any possible trend. Similarly, page 44 notes that RIPDES applications were required for two discharges to Spectacle Pond. Have those permits been issued and, if so, under what conditions? Is the odor noted in table B-6 (page 103) taken care of?

<u>RIDEM Response:</u>
In the case of Brickyard Pond, URIWW did not sample the pond in 2005 or 2006. URIWW only sampled Sand, Spectacle, Upper Dam, and Warwick Ponds in both 2005 and 2006. Almy Pond was sampled in 2005 only and Gorton Pond was sampled in 2006 only, after a six-year hiatus. The 2004 data was the most recent URIWW water quality data available at the time the TMDL calculations were made.

The TMDL could always be updated with new data, however an endpoint must be reached. Recalculating the TMDL figures using the all the available data would change the estimate of the current load only and would not affect the TMDL or target load, which was based on the target concentration of either 20 or 25 ug/l. The benefit of recalculating the current load is not clear, since the enforceable endpoint is the target concentration needed to meet the water quality criteria. Also the additional one or two more years of data that is available for some of the ponds does not appear to significantly elucidate any trends. The 2000-2006 water quality **data is available at the URIWW website at <u>http://www.uri.edu/ce/wq/ww/index.htm</u>.**

A RIPDES Permit was issued in 2005 for the two subject outfalls for noncontact cooling waters. The odor apparently was a secondary and localized affect of the heated discharge waters, and not caused by any chemical pollutant. Since these outfalls are apparently not a source of phosphorus, they have been removed from the list of priority outfalls.

2. Outfall Prioritization

Page 30 of the Ponds TMDL describes prioritization – primarily based on pipe diameter, but adjusted upward if "presence of sedimentation, scouring, dry weather flows, odor, staining, and raccoon sign" were noted, and downward if "there was evidence that the pipe conveyed significant flow from a tributary or wetland in contrast to stormwater or if the outfall was connected to a water quality structure." The table in Appendix B is said to include these prioritization factors. On page 44, under Spectacle Pond it is noted that a 12-inch culvert discharges to the northern end of the pond but "this discharge is treated by an underground detention structure and vortechnics units prior to release." However this is not noted in the table (table B-6, pages 103-106) in Appendix B. Further on page 44, in describing twelve outfalls that discharge directly to Tongue Pond, it is noted that "some of these outfalls receive some type of pretreatment prior to release to the pond." Those are not noted in the table in Appendix B. The document does not appear to give any clues about which of the twelve outfalls are connected to treatment. Including in the Mashapaug TMDL a table similar to those in Appendix B of the Ponds TMDL would be helpful.

RIDEM Response:
With the exception to an association with a water quality structure, all the remaining prioritization factors listed on page 30 were all documented in the Comments Column of Appendix B. Appendix B has been amended to include information on any connection to water quality structures including SpP-G, which is the 12-inch outfall that discharges to the northern end of Spectacle Pond. Regarding the outfalls at Tongue Pond and the connection of some of them to an underground stormwater storage structure, the structure was observed at the northern end of the pond, but it is unclear which pipe(s) are connected to it, since there are several in the immediate vicinity. Section 4.14 has been revised to clarify this difficulty.

Regarding the Mashapaug TMDL, ESS sampled all of the outfalls for nutrients and measured flow on numerous occasions during both dry and wet weather. This data is presented in Appendix B and is probably a better indicator of priority outfalls than the methodology used in the Eutrophic Ponds TMDL. A table that summarizes the priority outfalls and locations has been added to the Implementation section of the Mashapaug Pond TMDL.

3. Nits:
Appendix A, figure 5 should show the names of the RWP ponds mentioned on page 9 (or a supplemental map showing them should be included).

RIDEM Response: The pond labels in Appendix A Figure 5 of the Eutrophic Ponds TMDL have been emboldened to enhance readability.

The Lee Pare & Associates, Inc., 1980 document cited on page 9 is not included in the reference list.

RIDEM Response: The reference list of the Eutrophic Ponds TMDL has been amended accordingly.

Figure 2.0 referred to on page 9 is not included nor is it listed in the list of figures.

RIDEM Response: The reference should have been to Figure 2.1, not Figure 2.0. There is no Figure 2.0 in the document. Page 9 of the Eutrophic Ponds TMDL has been revised accordingly.

The RIDEM, 2004 document cited on page 10 is not included in the reference list.

<u>RIDEM Response:</u> The RIDEM citation on page 10 has been added to the reference list. The year of the citation has also been revised to 2007.

The Louis Berger Group, Inc., 2001 document cited on page 44 is not included in the reference list.

<u>RIDEM Response:</u> The reference list has been amended accordingly.

RWP Ponds TMDL calculations are missing from Appendix C, apparently because of a formatting or printing problem.

<u>RIDEM Response:</u> The formatting problem in Appendix C has been fixed. The PWP Ponds calculations now appear in the table.

Appendix G: Public Meetings Summary

Barrington Meeting Notes (Subject: Barrington Pond)
April 17, 2007
Barrington Public Library

14 people in attendance not including DEM staff.

Approximately 38 stakeholder letters sent out. Meeting public noticed at Barrington Public Library and Town Hall and RIDEM offices in Providence.

Meeting began promptly at 6:30 p.m. DEM staff in attendance were Elizabeth Scott and Scott Ribas.

Elizabeth Scott began the meeting with introductions and project overview.

Scott Ribas: Technical Presentation

Questions and Comments:

Trees have been cut at the northern shoreline of the pond that has caused sloughing off of the shoreline.

RIDEM Response: See response to comments from RIDOT.

Brickyard Pond is tidally influenced and therefore the Rhode Island County Club is a potential source of phosphorus to the pond.

RIDEM Response: See response to the Barrington Land Conservation Trust.

There are approximately 500 cormorants that live on the islands in the pond, and hundreds to one thousand geese that also inhabit the pond, especially in the winter months.

RIDEM Response: Section 4.9 of the TMDL document has been amended with this additional information.

Will RIDEM monitor Brickyard Pond?

RIDEM Response: RIDEM relies almost exclusively on URI Watershed Watch (URIWW) to monitor lakes and ponds statewide. Although URIWW last monitored Brickyard Pond in 2004, we are hopeful that a volunteer(s) will be found that is willing to monitor the pond again to appraise future water quality. This data would help to assess the effectiveness of BMPs employed within the watershed.

In late 2006, Brickyard Pond turned fluorescent yellow and there was also a strong odor emanating from the pond.

RIDEM Response: RIDEM is not certain of the cause of these observed changes in the pond, but these conditions are consistent with an algal bloom.

Several of the outfalls to Brickyard Pond drain to a canal to the immediate north of the East Bay Bike Path.

RIDEM Response: Comment duly noted. The fact that several outfalls discharge to the ditch is noted in section 4.9 and Appendix A of the TMDL document.

Who would fund erosion control?

RIDEM Response: Since the Town of Barrington is the apparent owner of the land around the pond, the Town would be responsible for the funding of erosion controls. However, the Narragansett Bay and Watershed Bond Funds administered by RIDEM may also be available as matching funds for such an effort.

The watershed of Brickyard Pond aligns almost exactly with the Well Head Protection Area for Nyatt Wells, which are a public water supply.

RIDEM Response: Comment duly noted.

The Town of Barrington owns the land around the pond within 30 feet of the waterline and should manage this property to prevent vegetative clearing and erosion.

RIDEM Response: Comment duly noted. Section 6.5.2 has been amended accordingly.

There is a closed landfill behind a ballpark northeast of Brickyard Pond. Could this be a potential source of phosphorus?

RIDEM Response: There is a closed landfill located to the north of Brickyard Pond, immediately south of Foote Street. Groundwater investigations indicate that flow in the area is to the northeast, away from Brickyard Pond.

There are 55-gallon drums in the water at the northeast end of Brickyard Pond. Pronounced iron staining has also been observed in the area.

RIDEM Response: This matter has been reported to the Office of Compliance & Inspection for further investigation.

There may be problems associated with alum treatment regarding the andronomous fishery.

RIDEM Response: Section 6.4 of the document has been amended to include a caveat regarding the potential negative biological impacts of alum application. It is also recommended in Section 6.4 that a professional consultant be hired to determine the most appropriate method of internal phosphorus control and also to oversee implementation of the selected BMP to minimize or avoid any potential negative impacts. Alum application and its associated risks are discussed in some detail in Appendix E of the document. It appears that most of the chemical and biological risks can be avoided by managing the pH and alkalinity of the waterbody.

Sonar is used in Echo Lake every 5 years to control water lilies.

RIDEM Response: Comment duly noted.

Muschechuck Creek, between Brickyard Pond and Middle Highway, is choked off with fallen trees and sediment, which may be a hindrance to the migration of andronomous fish.

RIDEM Response: RI Division of Fish & Wildlife was contacted regarding this matter and their staff stated that although there is some debris in the creek, the herring would not have any difficulty negotiating the stream. Fish & Wildlife staff also noted that the obstacles for andronomous fish to nearby Echo Lake were much more imposing, but the fish had no difficulty reaching that lake either.

Middletown Meeting Notes (Subject: Almy and North Easton Ponds)
April 24, 2007
Middletown Town Hall

9 people in attendance not including DEM staff.

Approximately 47 stakeholder letters sent out. Meeting public noticed at the Middletown and Newport Public Libraries and Town and City Halls as well as RIDEM offices in Providence.

Meeting began promptly at 6:30 p.m. DEM staff in attendance were Elizabeth Scott and Scott Ribas.

Elizabeth Scott began the meeting with introductions and project overview.

Scott Ribas: Technical Presentation

Warwick Meeting Notes (Subject: Gorton, Sand, Upper Dam, and Warwick Ponds)
April 30, 2007
Warwick Public Library

12 people in attendance not including DEM staff.

Approximately 69 stakeholder letters sent out. Meeting public noticed at the Warwick and Coventry Public Libraries and Town and City Halls as well as RIDEM offices in Providence.

Meeting began promptly at 6:30 p.m. DEM staff in attendance were Elizabeth Scott and Scott Ribas.

Elizabeth Scott began the meeting with introductions and project overview.

Scott Ribas: Technical Presentation

Questions and Comments:

Is phosphorus the only limiting nutrient causing the impairment to the eutrophic ponds?

RIDEM Response: Although RIDEM has no direct evidence that phosphorus is the sole limiting nutrient causing the nutrient impairment to these eutrophic ponds, it is generally accepted by the scientific community that phosphorus is the limiting nutrient responsible for eutrophication in freshwater systems. The mean in-pond nitrogen/phosphorus ratio for all the ponds indicates that phosphorus is the limiting nutrient.

There is an outfall located on the north shore of Gorton Pond, west of Trinity Street, which was not identified in the TMDL document.

RIDEM Response: In response to this comment, another shoreline inspection of the northern shoreline of the pond, west of Trinity Street, was undertaken and no additional outfalls were found. There are only two catch basins on Gorton Lake Boulevard in this vicinity and both of their associated outfall pipes (GP-A and GP-M) have been identified in the TMDL document.

There is an ongoing problem with street flooding at Gorton Lake Boulevard.

RIDEM Response: The comment is noted and was forwarded to the city public works department for follow-up.

There is a concern about juvenile herring not being able to exit Gorton Pond through gates leading to Little Gorton Pond.

RIDEM Response: Fish & Wildlife staff inspected Gorton Pond on August 7, 2007 and found large numbers of juvenile herring in the pond. It is apparent that the fish are able to enter and exit the pond at least on a seasonal basis.

Street sweeping and storm drain cleaning often do not occur until summer. These activities should occur in the spring when the last reasonable chance of snowfall has past.

RIDEM Response: A statement addressing the timely commencement of street sweeping and storm drain maintenance activities has been included in several sections of the document.

Providence Meeting Notes (Subject: Spectacle and Roger Williams Park Ponds)
May 2, 2007
RIDEM Offices in Providence

15 people in attendance not including DEM staff.

Approximately 92 stakeholder letters sent out. Meeting public noticed at the Cranston and Providence Public Libraries and City Halls as well as RIDEM offices in Providence.

Meeting began promptly at 6:30 p.m. DEM staff in attendance were Elizabeth Scott and Scott Ribas.

Elizabeth Scott began the meeting with introductions and project overview.

Scott Ribas: Technical Presentation

Questions and Comments:

Roger Williams Park Ponds are treated with chemicals to kill rooted aquatic plants and the dead plants are left to decay, with phosphorus allowed to cycle back into the system.

RIDEM Response: The Providence Parks Department has obtained permits from the Divisions of Fish & Wildlife and Agriculture to apply herbicides to the park's ponds to control aquatic weeds. The permits allow the application of diquat and glyphosate to all of the park ponds addressed in the TMDL. A recommendation that the park administration consider the mechanical removal of aquatic weeds in lieu of herbicide application has been added to section 6.5.5.

Will there still be impairments to Spectacle and Mashapaug Ponds due to Tongue Pond?

RIDEM Response: RIDEM staff documented all stormwater culverts draining to Spectacle Pond, including those discharging to Tongue Pond. Although there are several large-diameter pipes which discharge to Tongue Pond, these pipes were not assessed to be higher priority pipes since they do not discharge directly to Spectacle Pond. It appears that there is limited outflow from Tongue Pond other than during rain events during the spring. From the perspective of the water quality of Spectacle Pond and because of the ephemeral hydrologic connection, the outfalls that discharge directly to Tongue Pond were not deemed as significant as the direct discharges to Spectacle Pond.

There is an underground stormwater treatment system located near Katharine Gibbs College. The system treats stormwater from Cranston Street prior to discharge to Tongue Pond.

RIDEM Response: Comment duly noted. Kindly note that none of the outfalls discharging to Tongue Pond, including the outfall(s) associated with the treatment structure were identified as priority outfalls.

What is the difference in elevation of Tongue, Spectacle and Roger Williams Ponds?

RIDEM Response: According to the USGS topographic map, Tongue Pond is located at an elevation of between 40 and 50 feet above mean sea level. Spectacle and Roger Williams Park Ponds are located at 42 and 40 feet above mean sea level, respectively.

What is the time frame for the implementation of the studies recommendations?

RIDEM Response: The owners and operators of Municipal Separate Storm Sewer Systems (MS4s) must revise their Storm Water Management Program within 180 days of the final approval of the TMDL by EPA. These plans contain a timetable for the completion of the Six Minimum Measures, which include Public Education and Outreach, Public Involvement/Implementation, Illicit Discharge Detection and Elimination, Construction, Post Construction, and Pollution Prevention and Good Housekeeping. Other than the stormwater – related recommendations, implementation of most BMPs recommended in the TMDL study is voluntary. Implementation of waterfowl and internal cycling BMPs, will be accomplished by the responsible parties (generally the cities and towns) as funds become available.

Who is responsible for storm drain retrofits?

RIDEM Response: The cities, towns, RIDOT and any private owners and operators of storm drain systems are responsible for work done on the storm drain systems.

Is the zoo a source of nutrients to the Roger Williams Park Ponds?

RIDEM Response: Robert McMahon, Deputy Superintendent of Parks for the Providence Parks Department was in attendance to address this question. He stated that the storm drains handling waste on the zoo grounds have been hooked up to the Providence sewer system for at least the last ten years. Mr. McMahon also stated that the pond on zoo grounds does not drain into the other ponds of the park's pond system.