Total Maximum Daily Load to Address the Phosphorus Impairment to Scott Pond

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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 pollution loads.

This TMDL addresses the phosphorus impairment to Scott Pond, as identified on the 2012 303(d) List of Impaired Waters. The vast majority of inflow to the pond, in addition to the phosphorus load, is from the Blackstone River via the Blackstone Canal, with the remainder from the relatively small immediate watershed, that discharges directly to the pond. External sources of phosphorus to the canal include discharge from wastewater treatment plants along the Blackstone River, as well as stormwater runoff, lawn fertilizers, and pet waste. The internal release of phosphorus from the sediments of Scott Pond is potentially another important source of phosphorus. Of course, this internal source of phosphorus is ultimately derived from the watershed.

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 the Scott Pond TMDL

Scott Pond is classified as a Class B waterbody. This TMDL will address the phosphorus and phosphorus-related impairments to Scott Pond (Table 1.1). Scott Pond is also on the 2012 303(d) List of Impaired Waters for low DO and copper. Excess algal growth is also identified as an observed effect for Scott Pond. Both the low DO and excess algal problems ultimately stem from the over-enrichment of Scott Pond waters by phosphorus. The DO impairment and excess algal problems are addressed by this TMDL. Reducing phosphorus levels will result in the reduced frequency, duration and magnitude of hypoxia in the bottom waters, however some hypoxia may still occur naturally despite meeting the phosphorus criteria. The copper impairment to Scott Pond is not addressed by this TMDL, but will be addressed at a future date.

Table 1.1 Water Quality Classification and 2012 303(d) Impairments Addressed by this TMDL.

Waterbody	Waterbody ID	Size (Ha)	WQ Classification	Impairments 2012 303(d) List
Scott Pond	RI0001003L-01	42.7	B	Phosphorus, Low DO

The phosphorus impairment is an indicator of a nutrient enriched system, better known as a eutrophic system. 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 Scott Pond meets state water quality standards, the TMDL establishes a phosphorus allowable load for the pond and outlines corrective actions to achieve that goal.

1.2 Pollutants of Concern and Applicable Criteria

The pollutant of concern for Scott Pond is phosphorus. Total phosphorus is typically the limiting nutrient to algal growth in the freshwater environment.

The following criteria for nutrients, which include total phosphorus and nitrogen, excerpted from Table 1 8.D.(2). Class-Specific Criteria - Fresh Waters of RIDEM's Water Quality Regulations (RIDEM, 2009), apply to the subject ponds:

10(a). Average Total phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettle hole, 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(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 eutrophication. This narrative standard is designed to prevent the occurrence of excessive algal growth as is the case for Scott Pond. The Department will follow guidelines set by the Nurnberg (1996) Trophic State Index to establish a limit for algal concentrations in the subject pond.

Many State Waters are classified as warm or cold water fish habitats in the Rhode Island Water Quality Regulations (Amended May 2010). This classification affects dissolved oxygen criteria, since cold water fish species are more dependent on well oxygenated cooler bottom waters to survive the summer months. Although Scott Pond has not be assessed as a warm or cold water fish habitat, the warm water criteria will be applied to the pond for the purposes of this TMDL, because the pond is part of the Blackstone River system, which is itself classified as a warm water fish habitat. The following standards apply for dissolved oxygen for warm water fish habitat:

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, *except as naturally occurs.* The 7-day mean water column dissolved oxygen concentration shall not be less than 6 mg/l.

Chlorophyll-a levels are often used as a surrogate for algal abundance. RIDEM does not have a numeric criteria for chlorophyll-a. High chlorophyll levels are recognized as observed effects, which are the result of a primary pollutant (e.g. phosphorus). In general, chlorophyll-a levels exceeding 0.010 mg/l have been recognized as characteristic of eutrophic conditions. This threshold level has been used as a guideline in past RIDEM TMDLs.

1.3 Priority Ranking

Scott Pond is listed in Category 5 of the 2012 303(d) List of Impaired Waters and is scheduled for TMDL development in 2013. Category 5 waters are those that are impaired or threatened for one or more designated uses by a pollutant(s), and require a TMDL.

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

Scott Pond is located within the Town of Lincoln, Rhode Island. The pond has a surface area of approximately 17.2 hectares (42 acres). Scott Pond consists of two main basins: a narrow northern basin (herein known as 'the upper basin') and a larger southern basin ('lower basin'). The 3.5-hectare upper basin has a maximum-recorded depth of 11.5 m (Figure 2.1). The 13.8-hectare lower basin has a maximum-recorded depth of 17.4 m. The two basins are connected by a narrow passage, approximately 7.6 m wide and up to approximately 1.5 m deep (Louis Berger Group, Inc., 2008).

The only tributary inflow to Scott Pond is via the remnant Blackstone Canal, which enters the upper basin at the Front Street Bridge. Water flows from the Blackstone River into the Blackstone Canal just upstream of the Ashton Dam, between George Washington Highway (Route 116) and Interstate 295 (Figure 2.2). The canal extends approximately 5 km to the inlet of Scott Pond. The mean flow rate is approximately 6 cfs (Louis Berger Group, Inc. 2008). It appears that water flows in from the canal virtually year-around. The canal appears to be only a few feet deep. Scott Pond does not have any surface water outflow. Stormwater runoff also directly enters the pond via stormwater pipes and as nonpoint runoff. Water exits Scott Pond through groundwater recharge and evaporation.

The surface of Scott Pond is approximately 3 m higher than nearby waterbodies, Valley Falls Pond to the east, and Sayesville Pond to the west. These ponds are located only approximately 100 m from Scott Pond. The steep hydraulic gradient drives regional groundwater flow away from Scott Pond towards the other two waterbodies. However, there may be limited groundwater inflow into Scott Pond, if perched water tables exist in the immediate area.

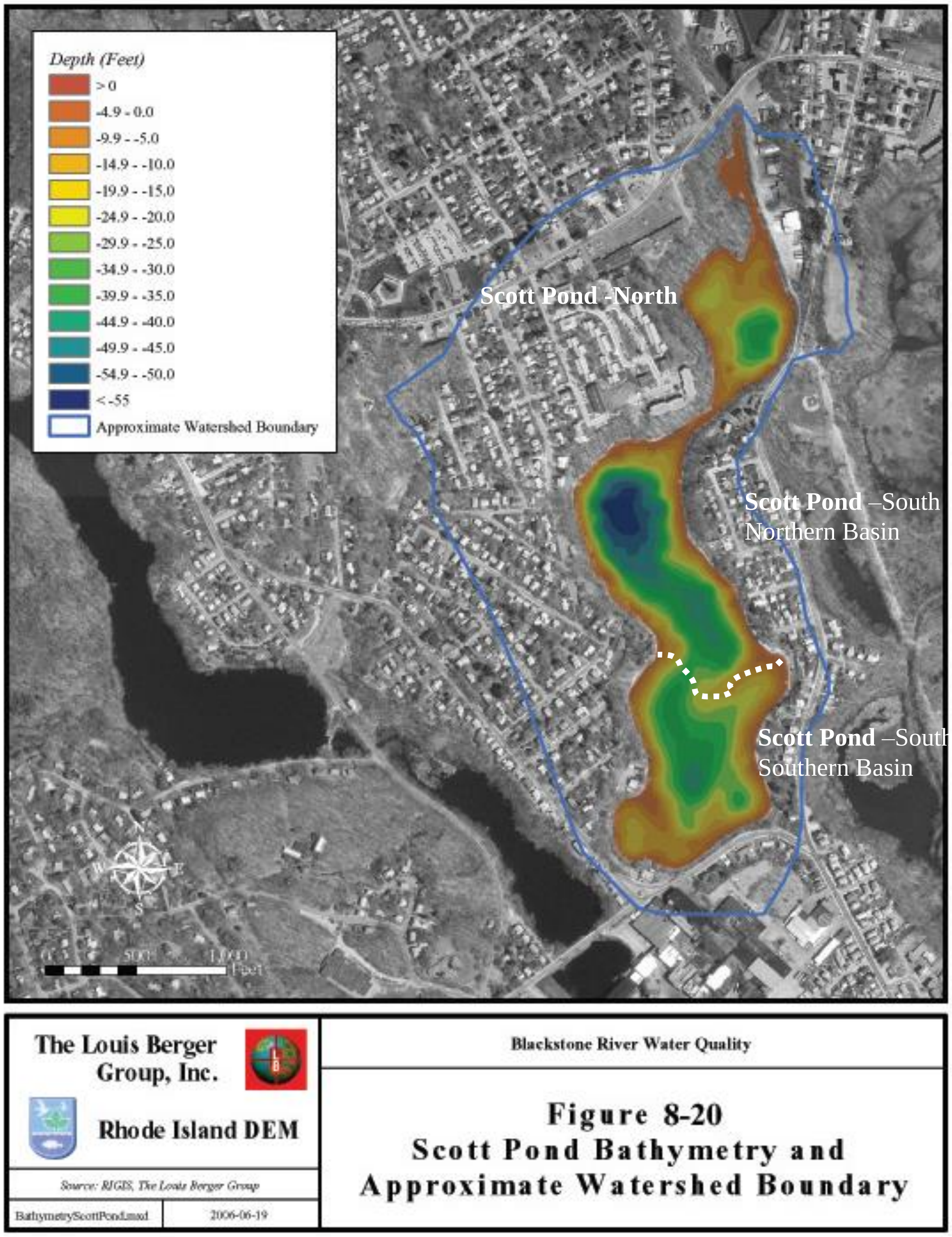
There are two weirs in the Blackstone Canal: one located at the upstream end of the canal, near the Ashton Dam, and the other located approximately 100 m (330 feet) to the north of the former Lonsdale Bleachery. Both weirs are equipped with removable wooden splashboards, which are intermittently operated by the Town of Lincoln to manipulate flow and avoid flooding along the canal. In addition to the weirs, there is an overflow structure from the canal into the Blackstone River in the vicinity of Old River Road in Lincoln, between the intersections of River Road and Dexter Rock Road. This structure cannot be regulated (Louis Berger Group, Inc. 2008).

The watershed of Scott Pond is approximately 49 hectares in area, not including the pond itself. The primary land use in the watershed to Scott Pond is residential development. Some commercial developments exist to the northwest of the northern part of the pond, and a few small industrial developments exist along its northeastern side.

The predominant land use in the Blackstone Canal watershed is also residential development (Louis Berger Group, Inc. 2008). The main exception is the former Lonsdale Bleachery that presently has a number of commercial and industrial uses. The watershed boundary extends approximately 1 km west of the canal. The area is sewered, including the Lonsdale Bleachery, however some residences may not be connected to the sewer system.

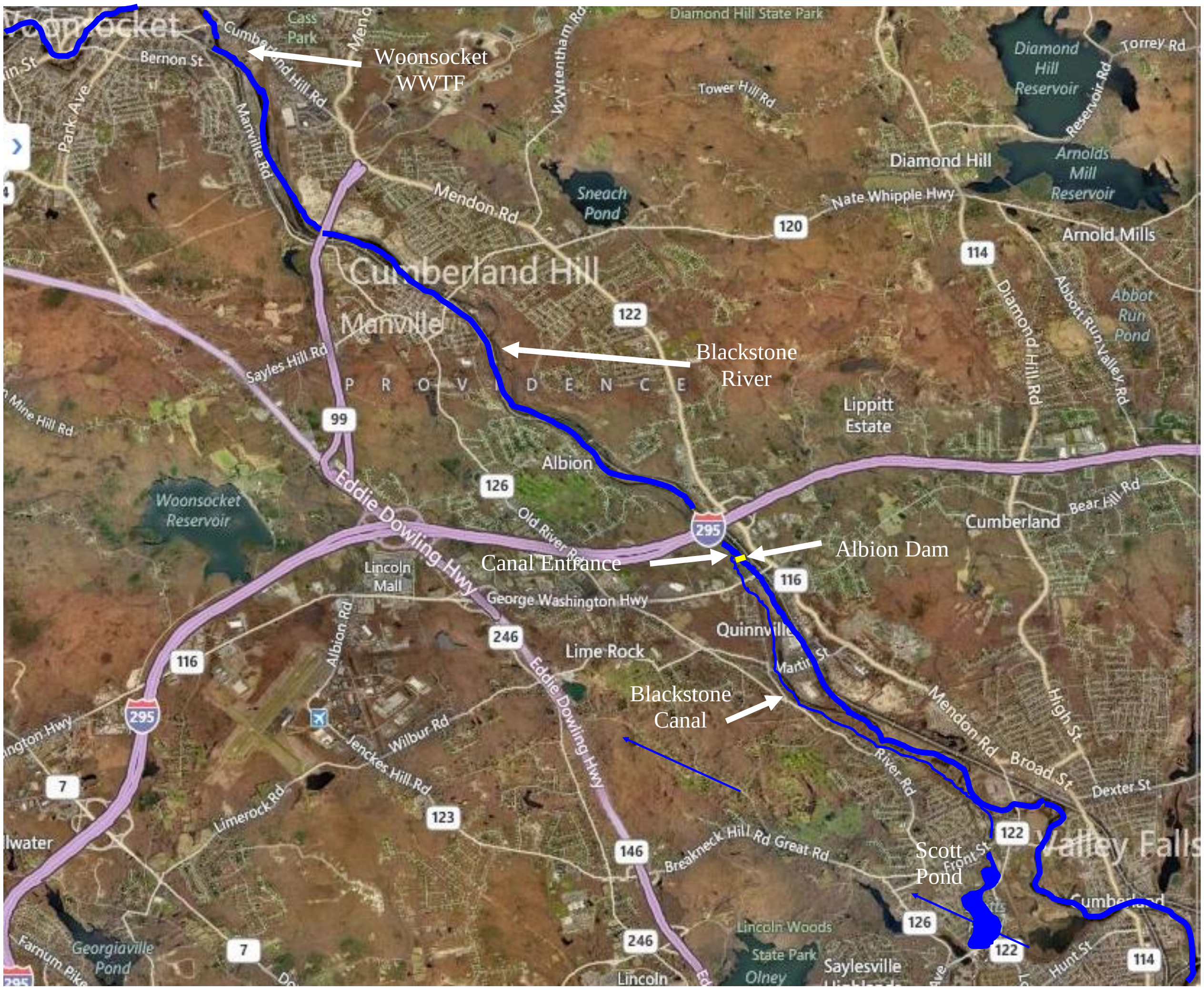
As noted previously, Scott Pond is identified on the 2012 303(d) List of Impaired Waters because of low dissolved oxygen and elevated total phosphorus. Both impairments are associated with nutrient enrichment (eutrophication). Excessive algal growth is listed as an observed effect, in the 2008 Integrated Water Quality Monitoring and Assessment Report. Excessive algal growth is also caused by nutrient enrichment. The pond is anoxic at depth in the summer. Scott Pond is used for recreational fishing and boating.

Figure 2.1 Scott Pond Bathymetry and Approximate Watershed Boundary



(From Louis Berger Group, Inc., 2008)

Figure 2.2. Scott Pond Study Area



3.0 CURRENT WATER QUALITY CONDITIONS

The UMASS-Dartmouth School of Marine Science and Technology staff conducted sampling of Scott Pond in association with the Louis Berger Group. The sampling was done as part of a comprehensive water quality study of the Blackstone River and associated waterbodies (the Louis Berger Group, Inc., 2008). Sampling of Scott Pond was conducted during August and September of 2004 and from July through September of 2005, with additional sampling in December 2004 and April 2005. Sampling and measurements were conducted at two stations in Scott Pond-South (P-08 and P-09), and one station in Scott Pond-North (P-07). Sampling was also conducted at the inflow to Scott Pond underneath the Front Street Bridge (P-11) (Figure 3.1). Water samples were collected during seven of these events of which five were dry weather events and two were wet weather events. The samples were analyzed for total phosphorus as well as several other constituents. The wet weather events were conducted shortly after a storm when maximum wet weather inflow into the pond was believed to have occurred. Water samples from Scott Pond-North were typically collected at: 0.5 and 7m below the surface. The samples for Scott Pond South were typically collected at 1, 7, and 12-13 m below the surface. In-situ measurements (including dissolved oxygen and temperature along with several other parameters) were collected during 11 events.

Chlorophyll a, as well as phytoplankton samples, were also collected in each of the surveys. Samples were collected in the center of Scott Pond North (P-07) and in the center of Scott Pond South (P-12, located in-between Stations P-08 and P-09). Approximately 50% of the volume of the total sample was collected from a water depth of 30 cm (1 foot). The remaining 50% of the sample was collected from the middle of the oxygenated upper zone (i.e., at 1.5 m).

Scott Pond was also sampled for phosphorus, along with several other parameters, by URI Watershed Watch (URIWW) in the 1990’s and again from May 2005 through November 2007. The Pond was generally sampled by URIWW for phosphorus three times per year, in May, July, and November. URIWW volunteers collected samples in the northern portion of Scott Pond-South, near station P-08 (Figure 3.1). Samples were taken at 1m and 9m, below the surface. The mean surface TP of the URIWW surveys was 0.043 mg/l, significantly lower than the mean recorded by the Louis Berger Group (0.067 mg/l). The mean mid-depth TP concentration, logged by URIWW, was 0.152 mg/l, which was similar to the mean mid-level concentration reported by the Louis Berger Group (0.147 mg/l).

The data collected by the URIWW was not used in the TMDL calculations for this study since the data collected by Louis Berger Group was much more extensive. As previously mentioned, URIWW collected data in only one basin and only at the surface and at mid-depth. Since the URIWW is relatively limited, it would be difficult to accurately characterize the water quality of Scott Pond, as a whole. Because the Louis Berger Group sampled at the surface and mid-level depths in three basins of Scott Pond and at the bottom of two basins, only the Louis Berger was used in the TMDL calculations and is presented below.

Total Phosphorus

Total Phosphorus values generally decrease down gradient in the Scott Pond system (Table 3.1 and Figures 3.2-3.4). Water quality, at any given sampling depth, generally improves from the inlet, to Scott Pond-North, and even more significantly from Scott Pond-North to Scott Pond-South. Total phosphorus concentrations also increase with depth in both basins of Scott Pond, which is evidence of phosphorus release from pond sediments.

During the summer months, there is a general trend of improving surface water quality from the Blackstone Canal inlet to Scott Pond-North (Figure 3.2). An exception to this trend occurred on 8/15/2005, when the surface waters of Scott Pond-North were significantly higher in TP than at the inlet.

Surface water quality improves even more significantly from Scott Pond-North to Scott Pond-South. The mean TP at the inlet was 0.164 mg/l. The mean TP in the surface waters of Scott Pond-North, and the northern and southern stations of Scott Pond-South was, 0.144 mg/l and 0.67 mg/l and 0.55 mg/l. This trend reverses during the winter months, when the pond is generally well mixed, introducing phosphorus-rich bottom waters to the surface.

Total phosphorus in the mid water column (7m below the surface), was significantly higher in Scott Pond-North than in Scott Pond-South during all sampling events (Figure 3.3). The mean TP of Scott Pond-North was 0.640 mg/l, compared to 0.147 mg/l at the northern station and 0.116 mg/l at the southern station of Scott pond-South.

The mean TP for the northern and southern sampling stations of Scott Pond-South at 11-12 m were 0.338 and 0.404 mg/l (Figure 3.4). Total phosphorus concentrations were generally similar at the two stations, except in September 2005 and August 2008, when TP was significantly higher at the southern station.

Scott Pond-North
Except for the spike on August 2005, surface concentrations are significantly lower in 2005 than in the late summer of 2004(Figure 3.5). This may be reflective of higher concentrations at the inlet in 2004. The reason for the spike is not known. There is also a trend of increasing phosphorus at 7m from August to September, 2004 and from April through September 2005. Even in December 2004 and April 2005, phosphorus is elevated at 7m relative to surface levels.

Scott Pond-South
Surface TP concentrations were significantly lower during the summer of 2005 than during the late summer of 2004. Again, the relatively high surface TP concentrations in 2004, may be caused by increased phosphorus loads at the inlet. Mid-level and bottom TP concentrations, at the northern station, decrease from August to September 2004. At the southern station, mid-level concentrations remain constant and bottom concentrations decrease, from August to September 2004. There is a trend of decreasing 7m concentrations, and increasing bottom concentrations, from April through September 2005, at both stations of Scott Pond-South. In December 2004 and April 2005, TP concentrations are similar at all depths because of mixing.

Figure 3.1 Scott Pond Sampling Stations.

(From Louis Berger Group, August 2004-September 2005)

Table 3.1 Total Phosphorus Concentrations (mg/l) (from the Louis Berger Group, 2008).

Date	Inlet	Scott Pond-North			Scott Pond-South (Northern Station)				Scott Pond-South (Southern Station)			
	0.5 m	0.5 m	4.5-8	Volumetrically-Weighted Mean	1 m	7 m	10-13 m	Volumetrically-Weighted Mean	1 m	7 m	10-12 m	Volumetrically-Weighted Mean
8/10/2004	0.217	0.147	0.443	0.352	0.073	0.422	0.632	0.320	0.040	0.176	0.348	0.109
9/16/2004	0.377	0.130	0.945	0.352	0.093	0.176	0.484	0.198	0.069	0.171	0.608	0.157
12/6/2004	0.106	0.136	0.568	0.320	0.131	0.159	0.130	0.140	0.138	0.137		0.138
4/19/2005	0.069	0.050	0.299	0.156	0.100	0.108	0.124	0.109	0.062	0.109	0.136	0.086
7/28/2005	0.134	0.061	0.696	0.276	0.026	0.078	0.315	0.098	0.030	0.093	0.673	0.085
8/15/2005	0.130	0.424	0.700	0.594	0.017	0.037	0.285	0.073	0.015	0.081	0.284	0.048
9/16/2005	0.115	0.059	0.832	0.360	0.032	0.046	0.399	0.106	0.030	0.042	0.377	0.054
Means	**0.164**	**0.144**	**0.640**	**0.344**	**0.067**	**0.147**	**0.338**	**0.149**	**0.055**	**0.116**	**0.404**	**0.097**

Figure 3.2 Surface Total Phosphorus.

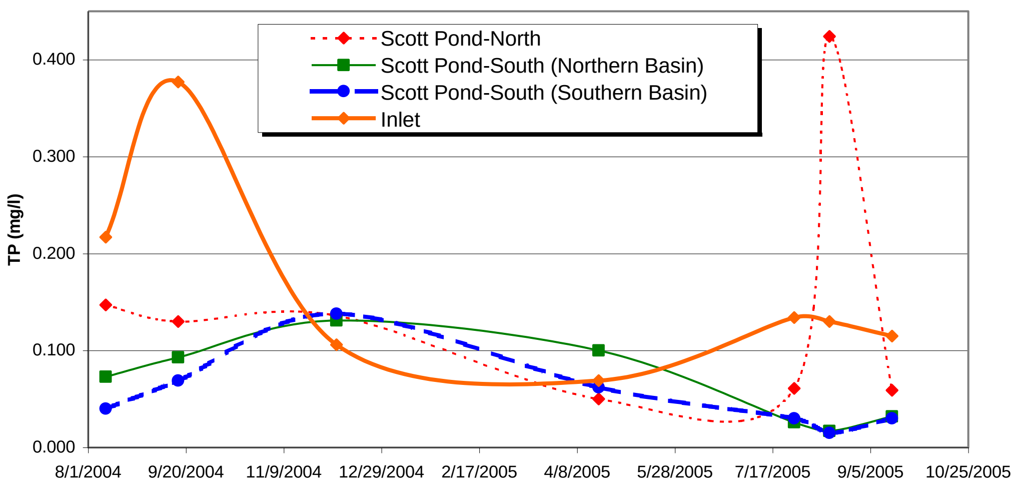


Figure 3.3 Total Phosphorus at 7m.

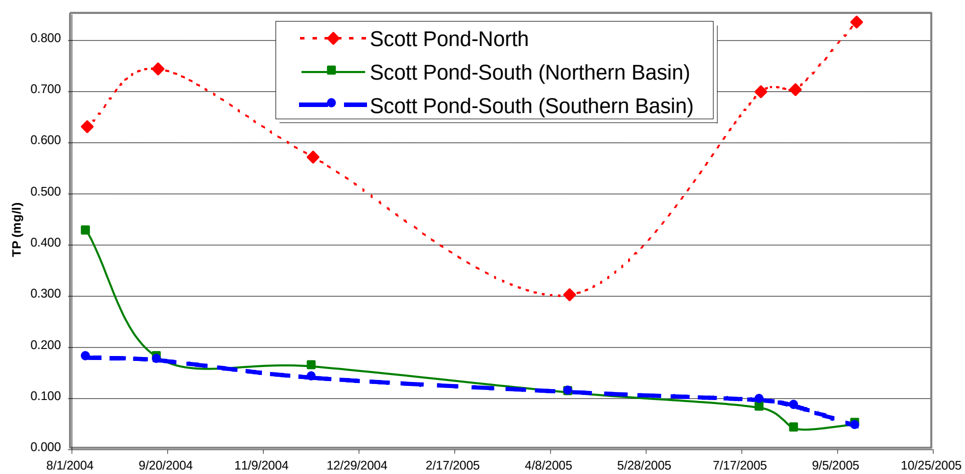


Figure 3.4 Total Phosphorus at 11-12m.

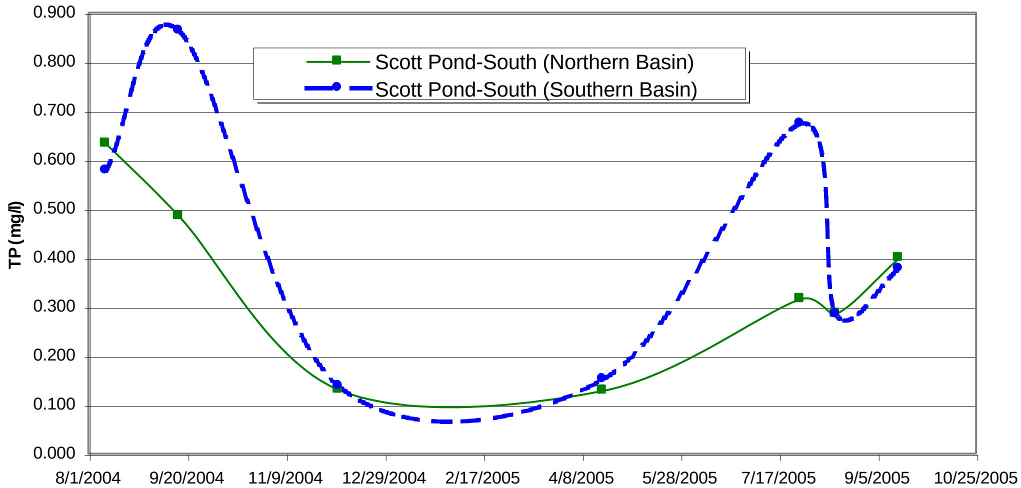


Figure 3.5. Total Phosphorus in Scott Pond-North.

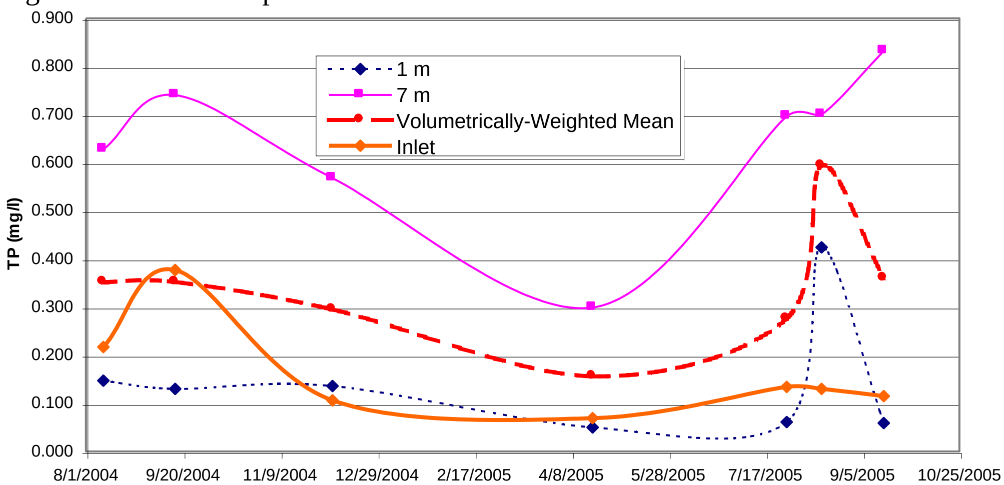


Figure 3.6. Total Phosphorus in Scott Pond-South (Northern Station).

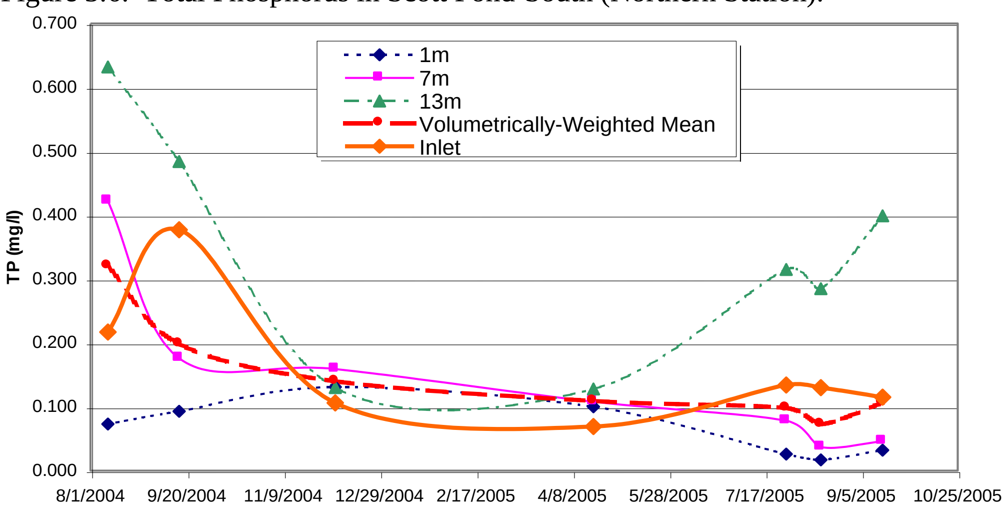
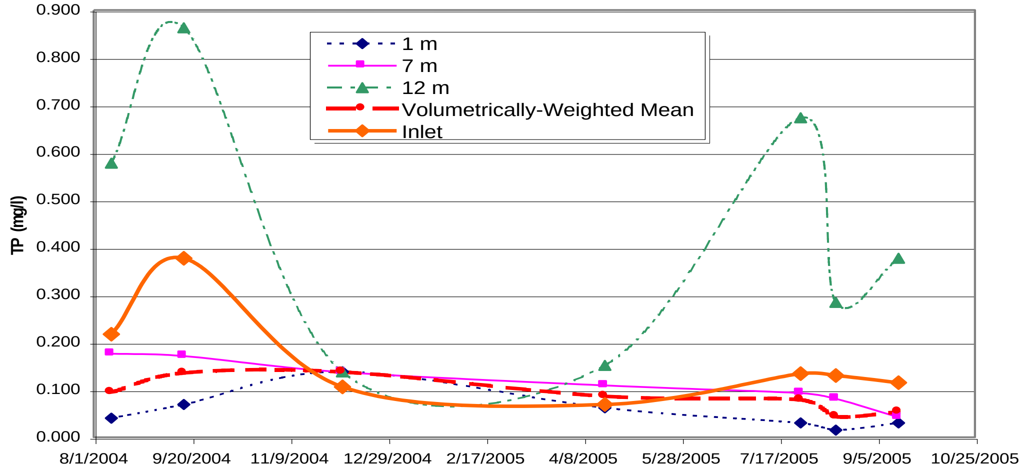


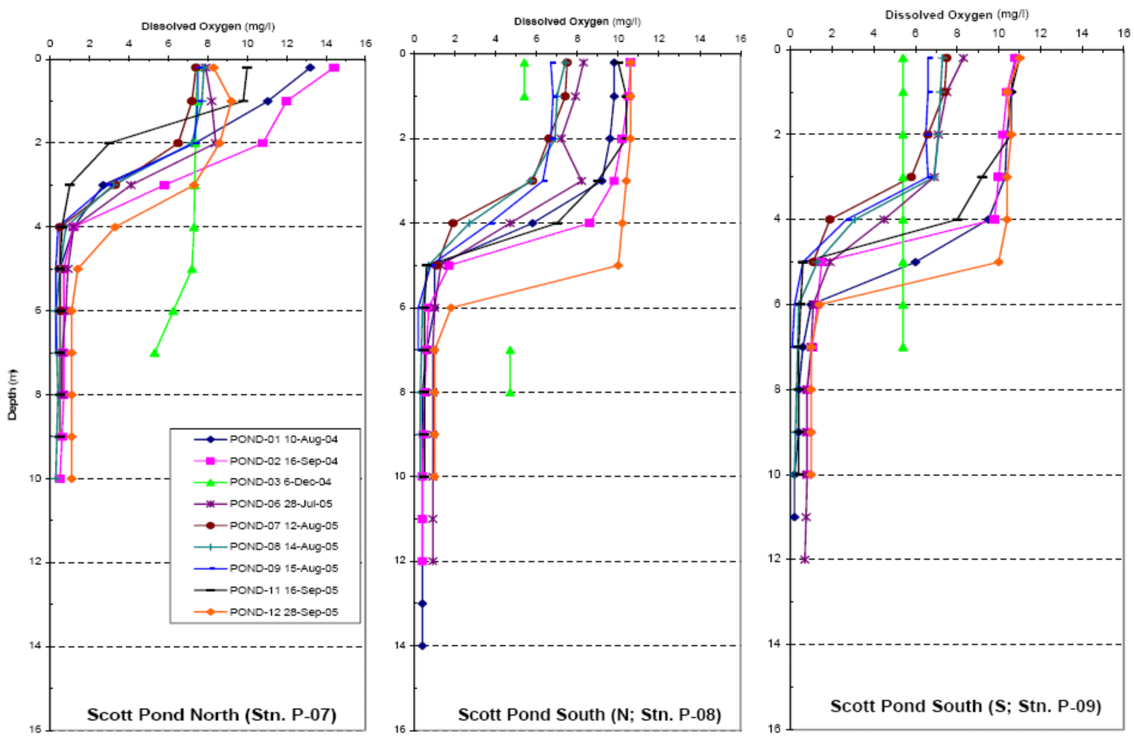
Figure 3.7. Total Phosphorus in Scott Pond-South (Southern Station).



Dissolved Oxygen

During periods of thermal stratification, the bottoms waters of Scott Pond become anoxic. In Scott Pond North, DO generally falls below 1.0 mg//l at approximately 4m below the surface. In Scott Pond South, DO generally falls below 1.0 mg//l at approximately 5-6m below the surface. As previously discussed, the phosphorus samples taken at 7m below the surface are below the top of the hypoxic zone. In December 2004, when the entire water column is well mixed, DO remains above about 5.0 mg/l, to depths of at least 6-8 meters.

Figure 3.8 Dissolved Oxygen in Scott Pond



(From Louis Berger Group, Inc., 2008

Phytoplankton

The water in Scott Pond is often turbid, greenish in color, sometimes approaching a pea soup. The pond becomes relatively clear following copper sulfate treatments.

The algal community composition in Scott Pond North was dominated by the cryptomonad *Chroomonas* nordstedtii, in terms of both density and biovolume (The Louis Berger Group, 2008). Total biovolume was mostly composed of chlorophytes and cryptomonads. Scott Pond South (was numerically dominated by filamentous cyanobacteria belonging to either *Pseudananbaena* or *Limnothrix*. Small unicellular cyanobacteria were also abundant.

The mean chlorophyll *a* concentration in the surface waters of Scott Pond-North was 0.015 mg/l, ranging from 0.002 to 0.027 mg/l (The Louis Berger Group, 2008). The mean chlorophyll *a* concentration in deep water (7-13m) was 0.058 mg/l. The deep water values ranged from 0.008-0.144 mg/l. As previously discussed in section 1.2, RIDEM has no numerical standard for chlorophyll-a, however a threshold level of 0.010 mg/l has been used as guidance in past TMDLs.

The mean chlorophyll *a* concentration in the surface waters of Scott Pond-South was 0.022 mg/l, ranging from 0.001 to 0.087 mg/ l (The Louis Berger Group, 2008). The mean chlorophyll *a* concentration in deep water (4.5-8m) was 0.013 mg/l. The deep water values ranged from 0.002-0.031 mg/l.

Chlorophyll *a* levels were sharply reduced immediately following copper sulfate treatments of the pond. Surface chlorophyll *a* levels, recorded during the July 28, 2005, survey were significantly lower (5-10 fold) than levels recorded during other surveys (The Louis Berger Group, 2008). The July 28, 2005 occurred approximately 1 week after a copper sulfate treatment. However, the effect of copper sulfate treatments appears to be short-lived, as the surface water had a greenish hue on August 10, 2004, despite a recent copper sulfate treatment, which occurred approximately one month prior to the survey.

Cyanobacteria

Cyanobacteria (also known as blue-green algae) are a phylum of photosynthetic bacteria naturally found in surface waters as phytoplankton, floating colonies, or attached to substrate. Under certain conditions, cyanobacteria may grow at high densities, forming blooms. Some species of cyanobacteria release toxins into the water degrading taste and odor and potentially raising public health risks, particularly for contact recreation.

RIDEM's Office of Water Resources has developed a program to screen for, respond to, and characterize cyanobacteria blooms in the state's fresh waters. Screening level monitoring is conducted at select locations known to have a high probability of cyanobacteria bloom. At these locations, water samples are collected and analyzed for cyanobacteria generally once per year in mid-August. If there is visual evidence of a cyanobacteria scum or mat, a high cyanobacteria cell count (> 70,000cells/mL), or high levels of cyanobacteria-related toxins (microcystin $\geq$ 0.014 mg/L), a public health advisory is issued by the RI Department of Health recommending the suspension of recreational activities on that particular water body.

A surface sample collected on Scott Pond on 8/17/2012 was found to have a total cyanobacteria cell count of 455,079. Since the Rhode Island health advisory guidelines for cell count (70,000 cells/mL) was exceeded, a health advisory was issued for Scott Pond. The dominant genus found were *Pseudanabaena and Aphanizomenon. Aphanizomenon* has the capability of producing microcystin. However, the level of mycrocystin (0.00067 mg/l) was below the health advisory criteria level of 14 μg/l.

Sediment

The bottom sediments are characterized by a low bulk density and high organic carbon content, 10 to 20% (by weight) (The Louis Berger Group, 2008). The sediment organic matter contains very high levels of chlorophyll *a* (60-300 ug/g dry weight). The sediments are also high in phosphorus, which is expected from the high organic matter content. The sediment characteristics are consistent with an organically-enriched sediment resulting from phytoplankton deposition, indicative of an eutrophic aquatic system.

4.0 POLLUTION SOURCES

4.1 Overview

Sources of phosphorus are both external and internal (nutrient recycling from the release of phosphorus from lake sediment). The major source of external phosphorus to Scott Pond is the Blackstone River, via the remnant Blackstone Canal. Stormwater from the immediate watershed, discharging directly to the pond, is a minor external source. Internal cycling (nutrient recycling from the release of phosphorus from lake sediment) is also a significant source. Sections 4.2 through 4.5 present an overview of likely sources of phosphorus to Scott Pond.

4.2 Stormwater Runoff

Most of the stormwater-phosphorus, adversely impacting the water quality of Scott Pond, probably originates from residential areas of the Blackstone River, and to a much lesser extent the immediate watershed of Scott Pond. The ultimate source of stormwater phosphorus includes lawn fertilizers, detergents and cleaners, pet and wildlife waste, some road salts, eroded sediment, and illicit connections.

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 in Providence, 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 0.14 and 2.37 mg/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.

4.3 Blackstone River Watershed

The Blackstone Canal is the major source of external phosphorus, as well as the ultimate source of internal phosphorus, to Scott Pond. The mean TP concentration, measured at the canal inlet was 0.164 mg/l. Based upon simple estimations, discussed in detail in the TMDL section below, it appears that the phosphorus load from the Blackstone Canal makes up approximately 97% of the external load to Scott Pond. This must be taken as an approximate value given the limited inflow sampling and flow estimations that were undertaken (the Louis Berger Group, 2008). In any case, it's clear that the phosphorus load from the canal contributes the vast majority of the external phosphorus load to Scott Pond.

The canal is fed from the Blackstone River with water entering the canal just upstream of the Ashton Dam. Discharges from municipal wastewater treatment facilities have been identified as the primary contributor of eutrophication impacts to the Blackstone River (Louis Berger Group, Inc., 2008). Five wastewater treatment facilities (Woonsocket, RI, Uxbridge, MA, Northbridge, MA, Grafton, MA, and Upper Blackstone Water Pollution Abatement District (UPWPAD) located in Worcester, MA) discharge to the Blackstone River, and ultimately to the canal and Scott Pond. The Woonsocket WWTF is the closest WWTF to the canal entrance to Scott Pond, and is located approximately 8 miles upstream of Scott Pond. More stringent effluent limits for total phosphorus have been established for all wastewater treatment facilities to address eutrophication problems in the receiving water (ie Blackstone River) and in the case of the Woonsocket WWTF, Scott Pond.

In 2006, RIDEM used the QUAL2E model developed as part of the Blackstone River Initiative study to determine effluent limits for the Woonsocket WWTF such that phosphorus concentrations in the Blackstone River at its point of inflow to Scott Pond are protective of the pond's water quality. Using permit limits proposed for the Massachusetts' wastewater treatment facilities at the time, the modeling results found that an effluent limit of 0.10 mg/l for the Woonsocket WWTF was necessary to ensure the Blackstone River does not cause a violation of the RI Water Quality criteria in Scott Pond. The model predicted 0.03 mg/l at the entrance to Scott Pond, as rounded to precision level of the model to the nearest 0.01 mg/l (i.e. the model is accurate to the nearest 0.01 mg/l). This limit is consistent with the requirement to remove phosphorus to the extent that such removal is or may become technically and reasonably feasible, found in Rule 8.D.(2)10.b of the Rhode Island Water Quality Regulations. The results of this analysis are presented in the Woonsocket WWTF Permit Development Document (RIDEM 2008). It is noted that the previous permit issued to Woonsocket WWTF in 2000 had significantly higher total phosphorus limits with a growing season (April-October) limit of 1.0 mg/l and no limit for the cold weather months.

As part of the work to develop this Scott Pond TMDL, the QUAL2E model was re-ran in February 2014 using current permit limits for all wastewater facilities in Massachusetts and Rhode Island. A copy of the model run for the Rhode Island portion of the watershed is presented in Appendix A. The model results confirm that, during 7Q10 conditions, WWTF effluent limits are sufficient to protect Scott Pond with the total phosphorus concentration at the canal inlet to the pond predicted to be 0.03 mg/l (± 0.01 mg/l).

The Louis Berger Group (2008) conducted dry weather sampling at several stations in the Blackstone River in 2005 and early 2006. Phosphorus was sampled at six stations along the main stem of the Blackstone River, between the state line and the entrance to the Blackstone canal, in addition to the outfall of the Woonsocket WWTF. Phosphorus was sampled 3-13 times, depending upon the station. Appendix B provides phosphorus load calculations at each station for each survey. The phosphorus load varies from one dry weather survey to the next sometimes increasing and other times decreasing between Manville Dam (Station W-02) and the George Washington Highway Bridge located just downstream of the canal entrance (Station W-03). , The average growing season load does increase between W-02 and W-03 indicating that there may be dry weather source(s) of phosphorus in this reach. The data also suggest that the impoundments may act as both a sink and a source of phosphorus. Far and away the predominant sources of phosphorus to the canal during dry weather come from Massachusetts sources and the Woonsocket WWTF.

By contrast, wet weather monitoring data indicate that there are significant wet-weather sources of phosphorus, between the RI/MA state line and the canal entrance. Louis Berger (2008) sampled phosphorus, during three wet weather events, in 2005. Phosphorus was sampled near the state line, at the outfall of the Woonsocket WWTF and near the entrance to the Blackstone Canal discharging to Scott Pond. The mean total phosphorus load at the George Washington Highway Bridge located just downstream of the entrance to the Blackstone Canal (843 kg/day) was greater than the combined load from the state line and the Woonsocket WWTF (776 kg/day), indicating that additional nonpoint and/or point sources contribute to the phosphorus load during wet weather (Appendix C). The significance of these sources relative to their contribution to deteriorated water quality in Scott Pond has not been determined at this time.

4.4 Blackstone Canal Watershed

There are 18 outfalls that drain to the Blackstone Canal. The largest of these outfalls is a triple 18 in culvert. There is also a 36 in culvert and three 24 in culverts. The remaining culverts are 18 inches in diameter or less.

Sampling was conducted in 2005, in the Blackstone River and at a station in the Blackstone Canal, during three wet weather events (Louis Berger, 2008). For each of the three storms, the total phosphorus event mean concentration (EMC) at a station in the Blackstone Canal near the inlet to Scott Pond (station W-34) was significantly less than the EMC at a station in the Blackstone River (W-03), located near the up-gradient end of the canal (Appendix D). These results indicate that any potential wet weather sources discharging to the canal, under current conditions, do not represent significant sources of phosphorus to the canal or to Scott Pond.

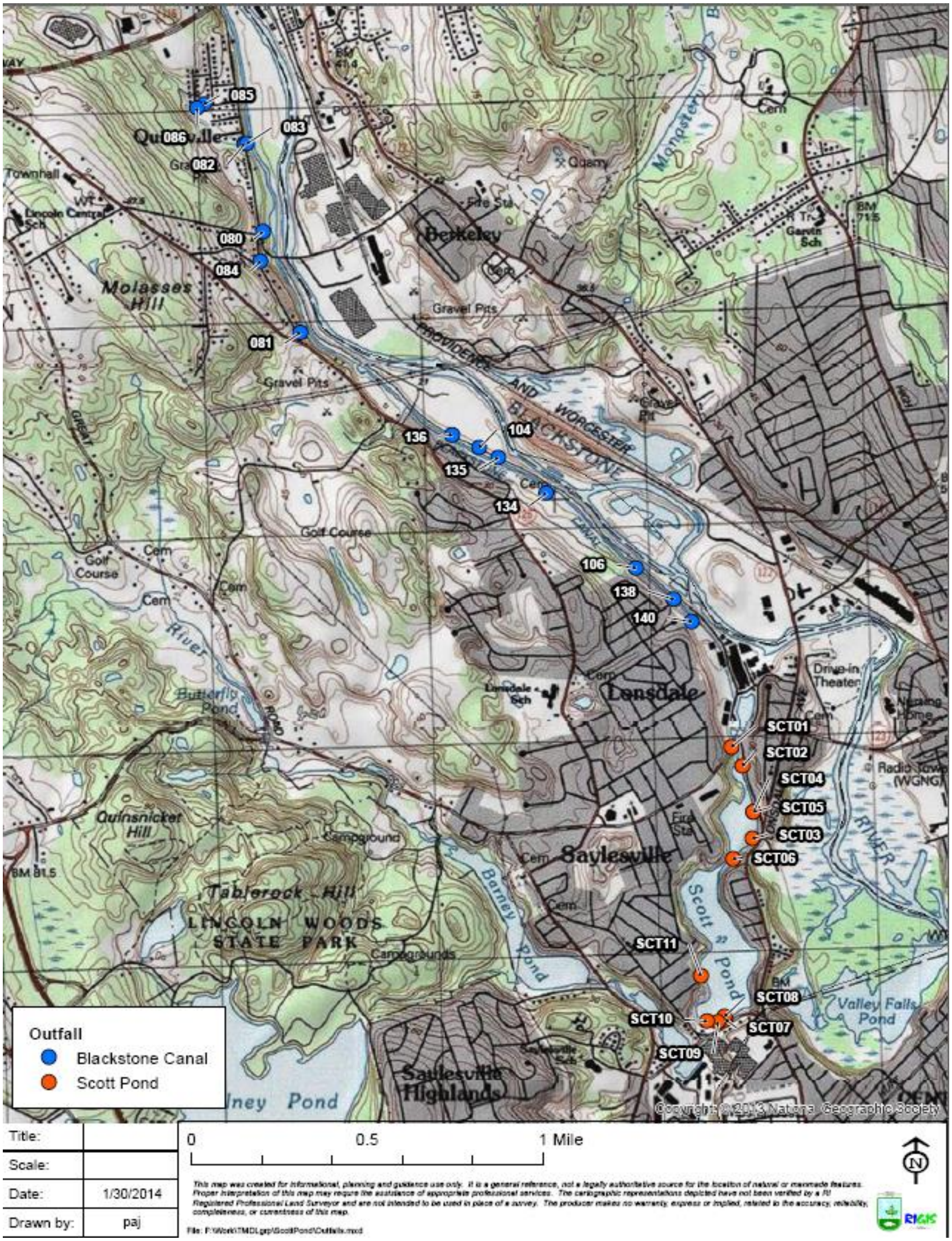
4.5 Immediate/Direct Watershed of Scott Pond

Storm drain mapping information provided by the Town of Lincoln identify seven stormwater culverts and four swales associated with road runoff, that drain directly to Scott Pond (Figure 4.1 and Table 4.1). The largest of the culverts (SCT-07) is a 0.9 x 0.6 m (3 x 2 ft) box culvert that discharges at the southern end of Scott Pond-South. This culvert apparently drains Walker Street as well as Lonsdale Avenue (Route 122). A 24 inch culvert (SCT01) discharges to the northern end of Scott Pond-North. The remaining culverts are 12 inches in diameter or less.

In addition to discharge from stormwater culverts, there is also overland flow from streets on the eastern side of the pond (The Louis Berger Group, 2008). Stormwater from streets between the pond and Lonsdale Avenue also enters the pond via overland flow. Several streets between the pond and Lonsdale Avenue dip toward the southern basin of Scott Pond. Stormwater from these streets enters the ponds as overland flow.

Outfalls were prioritized for pollution reduction activities by pipe diameter, deducing that the culverts were sized according to their drainage areas and the amount of impervious area within the associated catchments. Of the eleven identified direct stormwater discharges to Scott Pond, two priority outfalls, a 3 x 2 ft box culvert (SCT-07) on Walker Avenue and a 24 in. culvert (SCT-01), were identified.

Figure 4.1 Stormwater Outfalls Discharging to Scott Pond and the Blackstone Canal.



Source: Town of Lincoln (Leslie Quish, Town Engineer, electronic communication)

Table 4.1 Stormwater Outfalls Discharging to Scott Pond and the Blackstone Canal.

Outfall ID	Longitude	Latitude	Outfall Type	Diameter (in)	Ownership	MS4 Permit No.
010	-71.463420	41.956988	RCP	18	Town	RIR040021
014	-71.449565	41.947886	RCP	6	Town	RIR040021
015	-71.451246	41.947200	TRCP	18	Town	RIR040021
080	-71.432177	41.927949	CMP	12	Town	RIR040021
081	-71.430114	41.923699	RCP	12	Town	RIR040021
082	-71.433210	41.931650	HDPEP	18	Town	RIR040021
083	-71.433064	41.931665	HDPEP	18	Town	RIR040021
084	-71.432304	41.926693	RCP	24	Town	RIR040021
085	-71.435435	41.933326	PVCP	16	Town	RIR040021
086	-71.435811	41.933157	RCP	16	Town	RIR040021
104	-71.420248	41.918840	RCP	18	Town	RIR040021
106	-71.411599	41.913763	RCP	12	Town	RIR040021
130	-71.447561	41.948446	RCP	24	Town	RIR040021
134	-71.416540	41.916927	RCP	24	Town	RIR040021
135	-71.419183	41.918425	RCP	12	Town	RIR040021
136	-71.421736	41.919379	RCP	18	Town	RIR040021
138	-71.409513	41.912447	RCP	36	Town	RIR040021
140	-71.408527	41.911503	CMP	16	Town	RIR040021
SCT01	-71.406328	41.906222	RCP	24	RIDOT	RIR040036
SCT02	-71.405741	41.905419	RCP	12	Town	RIR040021
SCT03	-71.405181	41.902364	AS	---	RIDOT	RIR040036
SCT04	-71.405117	41.903492	AS	---	Town	RIR040021
SCT05	-71.405117	41.903492	AS	---	RIDOT	RIR040036
SCT06	-71.406253	41.901503	RCP	12	RIDOT	RIR040036
SCT07	-71.406681	41.894731	CBC	36 x 24	RIDOT	RIR040036
SCT08	-71.406728	41.894867	CP	12	RIDOT	RIR040036
SCT09	-71.407097	41.894639	RRS	---	RIDOT	RIR040036
SCT10	-71.407694	41.894661	CMP	12	RIDOT	RIR040036
SCT11	-71.408036	41.896572	CMP	12	Town	RIR040021

(Source: Town of Lincoln (Leslie Quish, Lincoln Town Engineer, electronic communication)
RCP = Reinforced concrete pipe
TRCP = Triple reinforced concrete pipe
CMP = Corrugated metal pipe
HDPEP = High-density polyethylene
PVCP = PVC pipe
AS = Asphalt swale
CBC = Concrete box culvert
CP = Clay Pipe
RRS = Rip Rap Swale

4.6 Internal Loading
Internal loading, the release of phosphorus from lake sediments can play an important role in the phosphorus dynamics of lake systems. Internal phosphorus loading originates from a pool of phosphorus accumulated in the sediment of the lake bed. The ultimate source of most of the sediment-bound phosphorus is external (Blackstone Canal). Under certain conditions this sediment-bound phosphorus can be released into the water column resulting in elevated phosphorus concentrations and algal blooms. The decay of organic matter in the sediment and also the decay of recent algal die-off or aquatic macrophytes may cause anoxic conditions in pond sediments, which favors the release of phosphorus.

Stratification results in the isolation of anoxic bottom waters, which causes dissolved phosphorus, released from the sediment, to build up in the hypolimnion.

In some cases, a significant portion of the phosphorus load to a waterbody can be due to internal loading. 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 located in Warwick, Rhode Island, 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).

The increase in phosphorus levels with depth, in Scott Pond, is evidence of phosphorus release from the sediments. Mean TP, at 10-13m, at the northern station of Scott Pond-South was 0.338 mg/l, compared to 0.067 mg/l at the surface. Mean TP at the southern station of Scott Pond-South, at 10-12m, was 0.404 mg/l, compared to 0.055 mg/l at the surface. The mean TP in Scott Pond-North was 0.640 mg/l at 4.5-8m, and. 0.164 mg/l at the surface.

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 this TMDL is based mainly on information collected during the most environmentally sensitive period (i.e., the growing season) and was developed to be protective of this critical time period, it will also be protective of water quality during all other seasons.

5.3 Numeric Water Quality Target

The primary goal of this TMDL, is to address the phosphorus-related water quality impairments in Scott Pond. Scott Pond is on the 2012 303(d) List of Impaired Waters, because of impairments of total phosphorus and low dissolved oxygen. Excess algal growth is also identified as an observed effect for Scott Pond. Both low dissolved oxygen and excessive algal growth are ultimately caused by excessive total phosphorus. Therefore reductions in total phosphorus are expected to address the low dissolved oxygen impairment, and the excessive algal problem including the occurrence of cyanobacteria blooms.

Reducing phosphorus is the most effective long-lasting way to reduce to reduce algal abundance, because the growth of and algae in freshwater environments is typically constrained by the availability of phosphorus. The presence of algal blooms diminishes the value of the pond for virtually all uses and fosters hypoxic conditions in the bottom waters of the ponds during the summer months. Cyanobacteria, and other algal blooms, may also produce toxic substances that pose a risk to public health. Recreational use is made less appealing, aesthetic enjoyment is impaired, and habitat value is reduced. To support these designated uses, reducing total phosphorus to the criterion concentration will reduce densities of nuisance aquatic vegetation and will also reduce the frequency and duration that the chlorophyll levels are above a nuisance level of 0.010 mg/l.

With algal densities 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 previously discussed, the natural process of density stratification due to a vertical temperature gradient can produce low dissolved oxygen concentrations in ponds. Low DO conditions in Scott Pond occur during the summer months.

RIDEM has set a total phosphorus concentration of 0.025 mg/l as the numeric target for Scott Pond. This numerical target is consistent with the State's water quality criteria for total phosphorus.

The objective of this TMDL is to restore Scott Pond to a condition that supports its designated uses and protects the pond from future degradation. In summary, the goals of this TMDL are to:

- Attain total phosphorus levels in the ponds to an average level of 0.025 mg/l;
- Attain algal abundance to levels consistent with designated uses, by reducing the frequency and duration of chlorophyll-a levels exceeding 0.010 mg/l ;
- Attain 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, except as naturally occurs. The 7-day mean water column dissolved oxygen concentration shall not be less than 6 mg/l.

5.4 Existing Load To Scott Pond

5.4.1 Estimating Mean TP

Prior to estimating the phosphorus load to Scott Pond, it was necessary to compute a mean TP concentration for the pond as a whole. The mean annual total phosphorus concentration was derived from the UMASS-Dartmouth data. There were seven sampling events from November 2004 through September 2005. As previously discussed, phosphorus samples were taken at one station in Scott Pond-North and two stations in Scott Pond-South. Samples in Scott Pond North were typically taken at 0.5m and 7m. Samples at Scott Pond South were typically taken at 1m, 7m, and 11-12m. Volumetrically weighted mean TP concentrations were calculated for each of the basins associated with the three stations in Scott Pond, using bathymetric data and interpolating TP concentrations vs. depth. The mean TP for the entire pond was then calculated, by weighing each of the basin means by their associated volumes. A detailed discussion of the procedure for estimating the mean total phosphorus concentrations is presented in the Appendix E.

5.4.2 Reckhow Model Estimate

The existing annual load (*L*) was calculated by substituting the mean volumetric TP concentration, discussed above, into the Reckhow equation. The existing annual mean phosphorus load to Scott Pond, was calculated by substituting the mean volumetric TP concentration and areal water loading (see below equation), into the Reckhow equation (1977). 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), and areal water loading (q_s, in m/yr), in the form:

$TP = L/(11.6 + 1.2q_s)$

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

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

$q_s = Q/Ao$

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

The estimated annual inflow (Q) to Scott Pond was 5.55 x 10^6 m^3/yr (6.21 cfs). Annual inflow includes a combined estimate of flow from the Blackstone Canal, stormwater runoff from the immediate watershed of the pond, as well as direct rainfall. The majority of flow, discharged to Scott Pond, is from the Blackstone Canal. The mean annual inflow to Scott Pond, from the Blackstone Canal, was 5.36 x 10^6 m^3/yr (6 cfs). The mean annual flow estimate was based on a simple average of eight measurements, taken at the inlet to Scott Pond, from August 2004 through September 2008 (The Louis Berger Group, Inc., 2008). Annual stormwater runoff, generated from the immediate watershed of Scott Pond, was 1.47 x 10^5 m^3/yr (0.16 cfs). Annual stormwater runoff, was estimated using the AVGWLF model, discussed in greater detail below. Net direct rainfall to Scott Pond was 4.47 x 10^4 m3/yr (0.05 cfs). Net direct rainfall was calculated by estimating the net annual precipitation (precipitation minus evaporation) of 25 cm/yr (10 in/yr).

The estimated annual inflow (Q) was then divided by the waterbody surface area (A_o), to obtain a value for the areal water load $(q)_s$. The areal water load (qs), in addition to the mean TP concentration, was substituted into the Reckhow equation to estimate the existing phosphorus load to Scott Pond (L). The estimated mean annual inflow (Q), the pond's surface area (A_o), and the mean phosphorus concentration (TP), and the current total phosphorus load (L) to Scott Pond are summarized in Table 5.1.

Table 5.1 Summary of Reckhow Model Variables and Existing Load Estimation.

Estimated Mean Annual Inflow (Q) (m3/yr)	Pond Surface Area (Ao) (m2)	Areal Water Load (q_s) (m/yr)	Mean Annual TP (mg/l)	Current Load (kg/yr)
5.55 x 10^6	1.72 x 10^5	32.2	0.159	1374

5.4.3 Existing Loads at the Inlet to Scott Pond.

As discussed in the previous section, the mean annual flow measured at the inlet to Scott Pond, from the Blackstone Canal, was 5.36 x 10^6 m^3/yr (6 cfs). The phosphorus concentration at the terminus of the canal ranged from 0.069-0.377 mg/l. The loading rate at the inlet was calculated by multiplying the mean total phosphorus concentration (0.164 mg/l) by the average flow rate. The mean annual load at the inlet to Scott Pond was 879 kg/yr, 64% of the existing load to Scott Pond (1374 kg/yr), as estimated by the Reckhow Model.

5.4.4 Existing Load from the Immediate Watershed of Scott Pond AVGWLF Model Estimate

The AVGWLF model was used to quantify and categorize non-point nutrient sources within the immediate watershed of Scott Pond, which discharge directly to the pond. The AVGWLF model utilizes GIS software and has been endorsed by EPA, as a good mid-level model with the capacity to simulate most mechanisms controlling nutrient fluxes within a watershed. The model uses daily weather data and a soil layer to simulate runoff. Sediment and nutrient loads are simulated according to runoff and land use. The AVGWLF model predicts runoff, erosion, and sediment yields; subsurface and surface nutrient loads are also calculated. The estimated load was 28.4 kg/yr, about 2% of the total existing load to Scott Pond. A summary of results of the AVGWLF model, and estimated loads from individual land uses are shown in Table 5.2.

Table 5.2 AVGWLF Predicted Existing Loads from the Immediate Watershed of Scott Pond.

Source	Area (Ha)	Total Phosphorus Load (Kg/yr)
High-Intensity Development	38	27
Low-Intensity Development	3	0.2
Forest	8	0.1
Septic Systems		0.8
Stream Bank		0.2
Total	**49**	**28.4**

In section 5.4.2, 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 0.025 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 the waterbody. The necessary load reductions are calculated as follows:

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

The allowable phosphorus load, required load reduction in kg/yr and the percent reduction in load for Scott Pond is presented below in Table 5.3.

Table 5.3 Loading Capacity and Allocation of Allowable Loading.

Current Load (kg/yr)	TMDL (kg/yr)	10% MOS (kg/yr)	TMDL * (kg/yr)	Required Load Reduction (kg/yr)	Required Loading Reduction (% Present Value)
1374	217	22	195	1179	86

*Includes a 10% Margin of Safety.

As shown in Table 5.3, the existing total phosphorus load to Scott Pond must be reduced by 86%, from 1374 to 195kg/yr, to meet water quality standards within the upper basin (Scott Pond-North). The reduction was set for Scott Pond-North because it has the poorest water quality and if the phosphorus criteria is met for the upper basin, it will be met for the entire pond. Rule 8 (D)(2)(Table 1) of Rhode Island's Water Quality Regulations requires that the average total phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole or reservoir, and the average total phosphorus in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria. Therefore, to ensure that the total phosphorus levels in tributary that discharges into Scott Pond do not cause an exceedance of this water quality criteria, the 0.025 mg/l criteria is applied to the Blackstone Canal at the point where it enters Scott Pond.

5.6 Load and Wasteload Allocations

A TMDL is the combination of a wasteload allocation (WLA) that allocates allowable loadings for point sources (stormwater and non-stormwater), a load allocation (LA) that allocates allowable loadings for nonpoint sources and background sources, and a Margin of Safety (MOS). TMDLs can be expressed on a mass loading basis or as a concentration in accordance with provisions in federal regulations [40 CFR 130.2(1)]. This phosphorus TMDL is expressed as a load.

Nonpoint sources of phosphorus to Scott Pond include stormwater from overland runoff, internal loading, air deposition, re-suspension of sediments and/or streambed/bank sloughing, groundwater, and natural background sources. Insufficient data are available to differentiate between nonpoint sources of phosphorus and stormwater point source discharges to Scott Pond, regulated under the RIPDES permitting program. Therefore, this TMDL does not include a separate load allocation; all nonpoint sources are incorporated into the stormwater waste load allocation for Scott Pond.

In addition to reductions in phosphorus loads from Scott Pond's immediate watershed, reductions in phosphorus loads entering Scott Pond from the Blackstone Canal are also necessary. The Blackstone Canal accounts for 97% of the water load to Scott Pond and 64% of the observed phosphorus load to the pond. As discussed previously, the Blackstone Canal receives flow from the Blackstone River just downstream of the Albion Dam. Other studies (Berger et al, 2009) have found wastewater treatment facilities to be the most significant sources of phosphorus to the Blackstone River. The 2008 RIPDES permit issued to the Woonsocket Wastewater Treatment Facility by DEM established a total phosphorus effluent limit of 0.10 mg/l as necessary to achieve compliance with the Gold Book criterion for streams and to ensure the Blackstone River (via the Blackstone Canal) does not cause a violation of the RI Water Quality criterion of 0.025 mg/l phosphorus in Scott Pond. In 2010, EPA issued a permit for the Upper Blackstone Water Pollution Abatement District WWTF in Worcester, MA that also includes a growing season phosphorus limit of 0.10 mg/l.

5.7 Reasonable Assurance

EPA guidance calls for reasonable assurances when TMDLs are developed for waters impaired by both point and nonpoint sources. In a waterbody impaired by both point and nonpoint sources, where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur, reasonable assurance that the nonpoint source reductions will happen must be explained in order for the TMDL to be approvable. This information is necessary for EPA to determine that the load and wasteload allocations will achieve water quality standards.

For this TMDL, reasonable assurance is not required because point sources are not given less stringent wasteload allocations and in fact, there is no separate load allocation assigned. The required load reduction will come from a reduction in the permitted phosphorus levels from wastewater treatment facilities that discharge to the Blackstone River and from BMPs to mitigate stormwater phosphorus sources entering the pond from the immediate watershed. Successful reduction in non-point sources depends on the willingness and motivation of stakeholders to get involved and the availability of private, federal, state, and local funds.

6.0 IMPLEMENTATION

The major sources of phosphorus to Scott Pond are discharge from the Blackstone Canal, stormwater from the immediate watershed of the pond, and internal cycling from the release of phosphorus from lake sediments. Eliminating the phosphorus impairment to Scott Pond will likely require a reduction in both external and internal sources of phosphorus. Recommended implementation activities for Scott Pond are detailed in the following sections.

The five wastewater facilities (Woonsocket, RI, Uxbridge, MA, Northbridge, MA, Grafton, MA, Millbury, MA, and Upper Blackstone Water Pollution Abatement District (UPWPAD), Worcester, MA) that discharge in the Blackstone River are a major source of phosphorus to the river and ultimately to the canal and Scott Pond. More stringent effluent limits for total phosphorus were established for the two larger wastewater treatment facilities, UBWPAD and Woonsocket, in NPDES permits issued by US EPA (2010) and RIDEM (2008). Revised permit limits have also been issued to the three smaller facilities. These permit limits have been established specifically to address eutrophication problems in the receiving water (ie Blackstone River), and in the case of the Woonsocket WWTF, Scott Pond.

As previously discussed in section 4, results from the Louis Berger study (2008) indicate that there may also be dry-weather sources discharging to the main stem of the Blackstone River, between Manville Dam and the entrance to the Blackstone canal Appendix B). While the average growing season phosphorus load increases between Manville Dam and the Blackstone River at the entrance of the canal, no dry weather sources have been specifically identified nor has the role of the impoundment in this phosphorus flux been ascertained. The data do indicate that the Woonsocket WWTF and sources of phosphorus from the Massachusetts portion of the watershed are far and away the most significant dry weather sources of phosphorus to the canal via the Blackstone River at this time.

In addition to the slated upgrades at the Woonsocket WWTF and those facilities in Massachusetts, achieving water quality standards in Scott Pond will require that both the volume of storm water and its phosphorus concentration be reduced. The focus of these enhanced stormwater management efforts are those sources that discharge directly to Scott Pond. The implementation of Phase II Stormwater Management Program Plans (SWMPP) including construction of stormwater BMPs at selected locations is expected to also help reduce the nutrient impairment to Scott Pond.

Available data indicate that there are significant wet-weather sources between the RI/MA state line and the canal entrance. The mean total phosphorus load near the entrance to the Blackstone Canal was greater than the combined load from the state line and the Woonsocket WWTF, indicating that there are significant Rhode Island nonpoint and/or point sources during wet weather (Appendix C). The significance of these sources on the quality of Scott Pond is undetermined at this time, but with completion of upgrades at the WWTF will represent a relatively larger portion of the phosphorus load to the river. There are no specific recommendations for phosphorus reductions from these wet weather sources at this time.

Available data from Scott Pond suggest that control of external sources of phosphorus may not produce immediate or expected water quality benefits unless internal loading is also addressed in a timely fashion. From 2000 through 2009, Scott Pond was treated with copper sulfate to control excessive algal growth. The use of copper sulfate was discontinued after a copper impairment was identified (2010 303(d) List). In addition to contributing to the identified copper impairment, the application of the algaecide does not address the ultimate cause of excessive algal growth, and is only a temporary fix. The focus of efforts to mitigate excessive algal growth should be on the reduction of the watershed phosphorus load. This approach is both more permanent, and more environmentally beneficial.

Monitoring of Scott Pond should be reinstated so that the effectiveness of ongoing remedial activities can be gauged. Monitoring efforts, by University of Rhode Island Watershed Watch (URIWW) volunteers, were conducted in the 1990's and again from 2005 through 2007. Continued monitoring will help track water quality trends, and monitoring by the Woonsocket wastewater Treatment Facility, required by their RIPDES permit, will evaluate pollution control efforts at the facility.

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

6.1 Storm Water Management

6.1.1 RIPDES Phase II Stormwater Management Programs – SWMPPs and Six Minimum Measures

Stormwater runoff is most often carried to waterways by publicly owned drainage networks. Historically, these storm drain networks were designed to carry stormwater away from developed land as quickly as possible to prevent flooding with little to no treatment of pollutants. In 1999, EPA finalized its Stormwater Phase II rule, which required the operators of small municipal separate storm sewer systems (MS4s) to obtain permits and to implement a stormwater management program as a means to control polluted discharges that is based on six minimum measures. Operators develop Stormwater Management Program Plans (SWMPPs) that detail how their stormwater management programs comply with the Phase II regulations. SWMPPs describe BMPs for the six minimum measures, including measurable goals and schedules. The implementation schedules include interim milestones, frequency of activities, and result reporting. Plans also include any additional requirements that are mandated for stormwater that discharges to impaired waters.

In Rhode Island, the RIDEM RIPDES Program administers the Phase II program using a General Permit that was established in 2003 (RIDEM, 2003a). The Town of Lincoln and the Rhode Island Department of Transportation (RIDOT) are regulated under the Phase II program.

The six minimum measures are listed below.

- 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 stormwater runoff control program for sites disturbing 1 or more acres.
- A post construction stormwater runoff control program for new development and redevelopment sites disturbing 1 or more acres.
- A municipal pollution prevention/good housekeeping operation and maintenance program.

The Town of Lincoln (MS4 permit no. RIR040021) and RIDOT (RIR040036) operate MS4s that discharge directly to the surface waters of Scott Pond. In general, municipalities and RIDOT were automatically designated as part of the Phase II program if they were located either completely or partially within census-designated urbanized or densely populated area. Densely populated areas have a population density greater than 1000 people per square mile and a total population greater than 10,000 people. The immediate watershed of Scott Pond is designated as a Phase II Area. The Town and RIDOT have submitted the required Stormwater Management Program Plans (SWMPPs) for the study area.

Storm sewers and ditches associated with stormwater runoff frequently have multiple interconnections between MS4s. DEM encourages cooperation between operators of MS4s (the Town of Lincoln and 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.

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.

6.1.2 Required Amendments to Phase II Stormwater Management Program Plans

In Rhode Island, Part IV.D of the Phase II General Permit requires MS4 operators to address TMDL provisions in their SWMPP if the approved TMDL identifies stormwater discharges that directly or indirectly contain the pollutant(s) of concern (Part II.C3). Operators must comply with Phase II TMDL requirements if they contribute stormwater to identified outfalls, even if they do not own the outfall. Operators must identify amendments needed to their current SWMPP to comply with TMDL requirements. To avoid confusion and to better track progress, the SWMPP amendments should be addressed in a separate TMDL Implementation Plan (TMDL IP). The MS4 operators identified in this TMDL include Lincoln and RIDOT. Consistent with the 2003 RIPDES General Permit, the revisions (i.e. TMDL IP) must be submitted within one hundred and eighty (180) days of the date of written notice from RIDEM that the TMDL has been approved, as described in more detail below (RIDEM, 2003a).

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:

- the location of discharge (latitude/longitude and street or other landmark;
- size and type of conveyance (e.g. 15" diameter concrete pipe);
- any existing discharge data (flow data and water quality monitoring data);
- impairment of concern and any suspected sources(s);
- interconnections with other MS4s within the system;
- TMDL provisions specific to the discharge;
- any BMP(s) that have or will be implemented to address TMDL provisions and phosphorus-related impairments;
- 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 Scott Pond is 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:

- new land development employ stormwater controls to prevent any net increase in phosphorus and;
- re-development 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. Identified outfalls are discussed in Section 4.5 and listed in Table 4.1; two outfalls are prioritized for retrofitting. 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.

The Scope of Work must:

Describe the tasks necessary to design and construct BMPs that reduce loads of phosphorus and stormwater volumes to the maximum extent feasible consistent with pollution reduction targets specified in the TMDL including:

- the delineation of the drainage or catchment area,

- 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

- 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.

- 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.

6.1.3 Specific Storm Water Measures

To realize water quality improvements in Scott Pond, both phosphorus concentrations in storm water and the volume of storm water discharged to the pond must be reduced. The impervious area within the watershed contributes substantial increases in the amount of runoff and phosphorus entering the pond 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.

RIDOT and the Town of Lincoln should prioritize implementation of Phase II minimum measures in the Scott Pond watershed and should target the construction of stormwater BMPs for the priority outfalls (SCT-07 and SCT-01), identified in section 4.5. Outfall SCT-07 was identified as the most significant potential source of stormwater-related phosphorus, discharging directly to Scott Ponds. The 3 x 2 ft box culvert, apparently drains Walker Street as well as Lonsdale Avenue (Route 122) (Figure 4.1, Table 4.1). The remaining priority outfall (SCT-07) is a 24 in. culvert. Illicit discharge detection and elimination, required by the General Permit, should focus on all outfalls that discharge to Scott Pond.

As discussed previously, the catchment area associated with the priority outfall must be identified and delineated. RIDOT and the Town of Lincoln should conduct a BMP feasibility study to identify locations and technologies for installing infiltration/filtration basins or equivalent BMPs. BMP selection should focus on reducing stormwater volumes and phosphorus loading in the priority catchment, to the maximum extent feasible. The study should evaluate the feasibility of distributing infiltration/filtration throughout the drainage area of the priority outfall, as an alternative to end-of-pipe technologies. This concept is particularly important in developed 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.

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 the involvement of an experienced storm water practitioner.

The buildings adjacent to the Blackstone Canal, associated with the former Lonsdale Bleachery, should be inspected closely to assure that there are no illicit discharges to the canal. Dye tests should be performed as appropriate, as some of the discharge points could be below the water surface in the Blackstone Canal or are covered by the buildings constructed right above the canal (Wright, 1997). The former Lonsdale Bleachery is located immediately up-gradient of the inlet to Scott Pond.

6.2 Blackstone Canal Discharge

As previously discussed, inflow from the Blackstone River via the Blackstone Canal is responsible for the vast majority of the external phosphorus load to Scott Pond. In 2006, RIDEM used the QUAL2E model developed as part of the Blackstone River Initiative to determine that an effluent limit of 0.10 mg/l for the Woonsocket WWTF is necessary to ensure the Blackstone River does not cause a violation of the RI Water Quality criteria in Scott Pond. As previously discussed in section 4, the QUAL2E model that was re-run, in February 2014, using current permit limits for all wastewater facilities in Massachusetts and Rhode Island (Appendix A). The results showed that, during 7Q10 conditions, the total phosphorus concentration at the canal inlet to Scott Pond are predicted to be 0.03 mg/l (± 0.01 mg/l). Therefore it appears that the point source controls, that are slated to take effect in the near future, are sufficient to protect the water quality of Scott Pond during dry weather.

The 2008 Rhode Island Pollution Discharge Elimination System (RIPDES) permit issued to the Woonsocket WWTF establishes the lower effluent limits for total phosphorus. During the growing season from April 1 through October 31, considered the critical time for phosphorus-induced eutrophication, the total phosphorus limit is set at 0.1 mg/l. This lower limit represents a 81% reduction in the growing season WWTF phosphorus load, relative to the April through October current load measured between 2000 and 2008 (Louis Berger, 2008). The permit also sets a cold weather limit from November 1 through March 31 of 1.0 mg/l. A higher phosphorus effluent discharge limitation in the winter period is appropriate because the predominant form of phosphorus (dissolved fraction), lacking plant growth to absorb it, will likely remain dissolved and flow out of the system. Imposing a limit on phosphorus during the cold weather months is, however, necessary to ensure that phosphorus discharged during the cold weather months does not result in the accumulation of phosphorus in the sediments, and subsequent release during the warm weather growing season.

To ensure DEM's understanding of the anticipated behavior of dissolved and particulate phosphorus is correct, a monitoring requirement for orthophosphorus has been included for the cold weather months (November 1st – March 31st) in order to determine the dissolved particulate fraction. Technological upgrades to the wastewater treatment facility and compliance with the lower phosphorus limits are slated to be completed in 2017. The lowered permit limit for phosphorus is anticipated to address the required load reduction to the inlet of Scott Pond.

As mentioned previously, NPDES permits requiring lower phosphorus limits have also been issued to the wastewater treatment facilities discharging to the Blackstone River in Massachusetts. The most significant of these is UBWPAD; the 2010 NPDES permit establishes a growing season limit of 0.1 mg/l TP and cold weather limit of 1.0 mg/l. In 2013, EPA issued permits to the other smaller WWTFs, (Grafton, Northbridge, and Uxbridge). All three facilities have a growing season limit of 0.2 mg/l TP and cold weather limit of 1.0 mg/l.

It appears that, under current conditions, there are no significant wet weather sources of phosphorus discharged directly to the Blackstone Canal. The results of three wet weather monitoring events in 2005 found the total phosphorus event mean concentration (EMC) at a station in the Blackstone Canal near the inlet to Scott Pond (station W-34) was significantly less than the EMC at a station in the Blackstone River (W-03), located near the up-gradient end of the canal Appendix D) (Louis Berger, 2008). These results indicate that any potential wet weather sources discharging to the canal, under current conditions, do not result in increased phosphorus concentrations in-stream.

6.4 Internal Phosphorus Control

Control of external sources of phosphorus may not produce immediate or expected water quality benefits to the pond unless internal loading is also addressed in a timely fashion. Thus, in addition to reducing external sources of phosphorus discharged to the pond, it is strongly recommended that a lake management study be done to determine the most effective and environmentally safe method to determine the extent to which internal phosphorus recycling is influencing algal growth ands as appropriate to reduce internal phosphorus loading.

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. 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.

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, 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.

Scott Pond has been treated with herbicide in the past to control excessive algal growth. Treating Scott Pond with herbicide may reduce excessive algal growth, however since phosphorus from decaying herbicide-treated algae would just be released back into the system, the problems associated with elevated phosphorus would be expected to continue. For these reasons along with the preference to not introduce additional chemicals into the environment, herbicide treatments are the less desirable treatment option. A permit from the Division of Agriculture must be obtained prior to any chemical treatment.

6.6 IMPLEMENTATION SUMMARY

The recommended implementation measures for Scott Pond are summarized in Table 6.2. As discussed previously, implementation of these BMPs is anticipated to address the ponds' phosphorus and phosphorus-related impairments.

Table 6.1 Summary of Recommended Implementation Measures and Responsible Parties.

Abatement Measure	Responsible Party	Notes
WWTF Upgrade	Woonsocket Wastewater Treatment Facility	RIDEM issued a revised RIPDES permit with more stringent phosphorus limits in 2008; upgrades are scheduled to be completed 2017
Stormwater Phase II Minimum Measures	Town of Lincoln (RIR040021) & RIDOT (RIR040036)	Revised Plans submitted to RIDEM as required.
Stormwater BMPs	RIDOT (RIR040036) & the Town of Lincoln (RIR040021)	Recommend BMP feasibility studies to identify locations and technologies for installing infiltration basins or equivalent BMPs in priority catchments.
Internal Phosphorus	Town of Lincoln	It is strongly recommended that a lake management study be done to determine the most effective and environmentally safe method to reduce internal phosphorus loading and control excessive algal growth

7.0 PUBLIC PARTICIPATION

The Rhode Island Department of Environmental Management held a public meeting on February 27th to discuss the draft water quality restoration plan for Scott Pond. At the meeting, RIDEM presented the draft TMDL plan to the general public and stakeholders, including public officials and other agencies. Letters were sent to key stakeholders approximately two weeks in advance of the meeting. In addition, the meeting was publicized in a press release, and public notices which were posted at the Town Hall and Public Library. The draft Scott Pond TMDL was made available to the public on the RIDEM's website approximately two weeks prior to the first public meeting. The meeting was attended by approximately 15 individuals. The public comment period ended on March 31, 2014, thirty days after the final meeting. RIDEM received comments from only one party (Steven Winnett, USEPA). These comments and responses are presented in Appendix F.

8.0 FUTURE MONITORING

Future monitoring should be designed to track water quality improvements as remedial actions are accomplished. Monitoring of Scott Pond has been historically conducted by URI Watershed Watch (URIWW) volunteers. URIWW has monitored the upper basin of Scott Pond-South, however no monitoring activities have taken place since 2007. RIDEM encourages URIWW to reinstitute monitoring at its historic station in Scott Pond-South. RIDEM also encourages URIWW to initiate the monitoring of Scott Pond-North and the Blackstone Canal near its inlet to Scott Pond. Monitoring of Scott Pond-North is essential in fully characterizing the water quality of Scott Pond. Scott Pond-North is separated from Scott Pond-South by a narrow constriction, and the two basins have distinctly different water quality characteristics. Since the Blackstone Canal discharges into Scott Pond-North, its water quality is significantly worse than that of Scott Pond-South. Monitoring of the Blackstone Canal, near its inlet to Scott Pond, is essential in evaluating water quality improvements resulting from upgrades to the Woonsocket Wastewater Treatment Facility, and the four WWTFs located in Massachusetts, as well as any other improvements conducted in the watershed.

9.0 REFERENCES

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APPENDIX A QUAL2E Stream Quality Routing Model Results for the Rhode Island Portion of the Blackstone River Watershed-RIDEM-Febuary 2014

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                                   * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                              * * * EPA/NCASI VERSION * * *

 $$$ (PROBLEM TITLES) $$$
CARD TYPE                            QUAL-2E PROGRAM TITLES
TITLE01              STREAM QUALITY MODEL--QUAL2E; BLACKSTONE RIVER, RI
TITLE02              SURVEY # 2 - AUGUST 14-15, 1991. BDOR7Q1.DAT     RI SEGMENT  February 10, 2014 Model Run
TITLE03  YES         CONSERVATIVE MINERAL   I   CHLORI  MG/L
TITLE04   NO         CONSERVATIVE MINERAL  II          Scenario 9 WQ
TITLE05   NO         CONSERVATIVE MINERAL III          River at 7Q10 Flow
TITLE06   NO         TEMPERATURE                       SOD Reduced 25%
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND   Woonsocket Diss-P=0.10
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L     DIURNAL FILE:SRAUG01.DAT
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORM IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$
CARD TYPE                                          CARD TYPE
LIST DATA INPUT               0.00000                                            0.00000
WRITE OPTIONAL SUMMARY        0.00000                                            0.00000
NO FLOW AUGMENTATION          0.00000                                            0.00000
NO STEADY STATE               0.00000                                            0.00000
NO TRAP CHANNELS              0.00000                                            0.00000
PRINT LCD/SOLAR DATA          0.00000                                            0.00000
NO PLOT DO AND BOD            0.00000                                            0.00000
FIXED DNSTM CONC (YES=1)=     0.00000          5D-ULT BOD CONV K COEF  =         0.25000
INPUT METRIC            =     0.00000          OUTPUT METRIC           =         0.00000
NUMBER OF REACHES       =    10.00000          NUMBER OF JUNCTIONS     =         0.00000
NUM OF HEADWATERS       =     1.00000          NUMBER OF POINT LOADS   =         4.00000
TIME STEP (HOURS)       =     1.00000          LNTH. COMP. ELEMENT (MI)=         0.20000
MAXIMUM ROUTE TIME (HRS)=   198.00000          TIME INC. FOR RPT2 (HRS)=         6.00000
LATITUDE OF BASIN (DEG) =    42.50000          LONGITUDE OF BASIN (DEG)=        83.30000
STANDARD MERIDIAN (DEG) =    75.00000          DAY OF YEAR START TIME  =       196.00000
EVAP. COEF.,(AE)        =     0.00068          EVAP. COEF.,(BE)        =         0.00027
ELEV. OF BASIN (METERS) =   150.00000          DUST ATTENUATION COEF.  =         0.13000
ENDATA1                       0.00000                                            0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$
CARD TYPE                                             CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.5000         O UPTAKE BY NO2 OXID(MG O/MG N)=    1.0700
O PROD  BY ALGAE (MG O/MG A)   =    1.6000         O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.1000         P CONTENT OF ALGAE (MG P/MG A) =    0.0500
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.5000         ALGAE RESPIRATION RATE (1/DAY) =    0.2000
N HALF SATURATION CONST  (MG/L)=    0.1500         P HALF SATURATION CONST  (MG/L)=    0.0250
LIN ALG SHADE CO (1/FT-UGCHA/L=)    0.0110         NLIN SHADE(1/FT-(UGCHA/L)**2/3)=    0.0170
LIGHT FUNCTION OPTION (LFNOPT) =    1.0000         LIGHT SAT'N COEF (BTU/FT2-MIN) =    0.0600
DAILY AVERAGING OPTION (LAVOPT)=    2.0000         LIGHT AVERAGING FACTOR (AFACT) =    0.9200
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0000         TOTAL DAILY SOLR RAD (BTU/FT-2)= 1639.0000
ALGY GROWTH CALC OPTION(LGROPT)=    1.0000         ALGAL PREF FOR NH3-N (PREFN)   =    0.0000
ALG/TEMP SOLR RAD FACTOR(TFACT)=    0.4500         NITRIFICATION INHIBITION COEF  =    0.6000
ENDATA1A                            0.0000                                             0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$
CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA        1.047     DFLT
THETA( 2)      BOD SETT        1.024     DFLT
THETA( 3)      OXY TRAN        1.024     DFLT
THETA( 4)      SOD RATE        1.060     DFLT
THETA( 5)      ORGN DEC        1.047     DFLT
THETA( 6)      ORGN SET        1.024     DFLT
THETA( 7)      NH3 DECA        1.020     USER
THETA( 8)      NH3 SRCE        1.074     DFLT
THETA( 9)      NO2 DECA        1.020     USER
THETA(10)      PORG DEC        1.047     DFLT
THETA(11)      PORG SET        1.024     DFLT
THETA(12)      DISP SRC        1.074     DFLT
THETA(13)      ALG GROW        1.047     DFLT
THETA(14)      ALG RESP        1.047     DFLT
THETA(15)      ALG SETT        1.024     DFLT
THETA(16)      COLI DEC        1.047     DFLT
THETA(17)      ANC DECA        1.000     DFLT
THETA(18)      ANC SETT        1.024     DFLT
THETA(19)      ANC SRCE        1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$
CARD TYPE          REACH ORDER AND IDENT                R. MI/KM             R. MI/KM
STREAM REACH     1.0  RCH= MAIN STREET       FROM        18.2     TO          17.4
STREAM REACH     2.0  RCH= BRANCH RIVER      FROM        17.4     TO          16.6
STREAM REACH     3.0  RCH= ST. PAUL ST       FROM        16.6     TO          14.4
STREAM REACH     4.0  RCH= THUNDERMIST DAM   FROM        14.4     TO          12.8
STREAM REACH     5.0  RCH= HAMLET AVE.       FROM        12.8     TO          10.0
STREAM REACH     6.0  RCH= MANVILLE DAM      FROM        10.0     TO           8.2
STREAM REACH     7.0  RCH= ALBION DAM        FROM         8.2     TO           6.8
STREAM REACH     8.0  RCH= WASHINGTON HW     FROM         6.8     TO           3.8
STREAM REACH     9.0  RCH= LONSDALE AVE      FROM         3.8     TO           2.0
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STREAM REACH	10.0	RCH= BROAD STREET	FROM	2.0	TO	0.0
ENDATA2	0.0			0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	4.	1.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	2.	4.	6.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	11.	2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	8.	2.2.2.2.2.6.6.2.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	5.	14.	2.6.2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.
FLAG FIELD	6.	9.	2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	7.	7.	2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	8.	15.	2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.
FLAG FIELD	9.	9.	2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	10.	10.	2.2.2.2.2.2.2.2.2.5.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	300.00	0.012	0.581	1.452	0.400	0.040
HYDRAULICS	2.	300.00	0.012	0.581	0.854	0.400	0.040
HYDRAULICS	3.	300.00	0.012	0.581	1.554	0.400	0.040
HYDRAULICS	4.	300.00	0.071	0.523	0.351	0.400	0.040
HYDRAULICS	5.	300.00	0.010	0.581	1.037	0.400	0.040
HYDRAULICS	6.	300.00	0.012	0.581	0.644	0.400	0.040
HYDRAULICS	7.	300.00	0.007	0.710	0.642	0.400	0.040
HYDRAULICS	8.	300.00	0.008	0.870	0.638	0.400	0.040
HYDRAULICS	9.	300.00	0.008	0.701	0.638	0.400	0.040
HYDRAULICS	10.	300.00	0.009	0.746	0.638	0.400	0.040
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF OR FOR OPT 8	EXPQK2 OR SLOPE FOR OPT 8
REACT COEF	1.	0.10	0.00	0.110	3.	0.00	0.000	0.00000
REACT COEF	2.	0.10	0.00	0.110	3.	0.00	0.000	0.00000
REACT COEF	3.	0.10	0.00	0.110	3.	0.00	0.000	0.00000
REACT COEF	4.	0.10	0.00	0.110	3.	0.00	0.000	0.00000
REACT COEF	5.	0.10	0.00	0.280	3.	0.00	0.000	0.00000
REACT COEF	6.	0.10	0.00	0.250	3.	0.00	0.000	0.00000
REACT COEF	7.	0.10	0.00	0.250	3.	0.00	0.000	0.00000
REACT COEF	8.	0.10	0.00	0.250	3.	0.00	0.000	0.00000
REACT COEF	9.	0.10	0.00	0.250	3.	0.00	0.000	0.00000
REACT COEF	10.	0.10	0.00	0.250	3.	0.00	0.000	0.00000
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000	0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.20	0.05	0.10	5.00	0.20	0.35	0.05	0.50
N AND P COEF	2.	0.20	0.05	0.10	5.00	0.20	0.35	0.05	0.50
N AND P COEF	3.	0.20	0.05	0.10	5.00	0.20	0.35	0.05	0.50
N AND P COEF	4.	0.20	0.05	0.10	5.00	0.20	0.35	0.05	0.50
N AND P COEF	5.	0.20	0.05	0.30	5.00	0.60	0.35	0.05	0.50
N AND P COEF	6.	0.20	0.05	0.54	5.00	1.08	0.35	0.05	0.50
N AND P COEF	7.	0.20	0.05	0.73	5.00	1.46	0.35	0.05	0.50
N AND P COEF	8.	0.20	0.05	0.73	5.00	1.46	0.35	0.05	0.50
N AND P COEF	9.	0.20	0.05	1.00	5.00	2.00	0.35	0.05	0.50
N AND P COEF	10.	0.20	0.05	1.00	5.00	2.00	0.35	0.05	0.50
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	4.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	5.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	6.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	7.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	8.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	9.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	10.	3.00	1.00	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	77.00	6.60	1.40	68.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	77.00	8.20	1.20	60.20	0.00	0.00	0.00	0.00

INITIAL COND-1	3.	77.00	8.20	1.20	60.00	0.00	0.00	0.00	0.00
INITIAL COND-1	4.	77.00	7.50	1.10	58.10	0.00	0.00	0.00	0.00
INITIAL COND-1	5.	77.00	7.50	1.10	58.60	0.00	0.00	0.00	0.00
INITIAL COND-1	6.	77.00	8.00	1.05	58.30	0.00	0.00	0.00	0.00
INITIAL COND-1	7.	77.00	7.55	1.00	58.00	0.00	0.00	0.00	0.00
INITIAL COND-1	8.	77.00	7.55	0.90	57.80	0.00	0.00	0.00	0.00
INITIAL COND-1	9.	77.00	5.60	0.80	57.60	0.00	0.00	0.00	0.00
INITIAL COND-1	10.	77.00	7.00	0.80	56.90	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	15.85	0.07	0.09	0.05	2.57	0.00	0.23
INITIAL COND-2	2.	18.00	0.07	0.08	0.05	2.57	0.00	0.26
INITIAL COND-2	3.	19.20	0.06	0.07	0.04	2.43	0.00	0.26
INITIAL COND-2	4.	19.20	0.06	0.94	0.20	2.34	0.00	0.11
INITIAL COND-2	5.	25.20	0.06	0.93	0.39	2.62	0.00	0.11
INITIAL COND-2	6.	22.25	0.06	0.58	0.36	2.96	0.00	0.19
INITIAL COND-2	7.	22.10	0.06	0.44	0.32	3.13	0.00	0.18
INITIAL COND-2	8.	22.10	0.06	0.32	0.28	3.24	0.00	0.18
INITIAL COND-2	9.	4.95	0.05	0.28	0.24	3.28	0.00	0.15
INITIAL COND-2	10.	12.20	0.05	0.28	0.24	3.28	0.00	0.16
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.003	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.384	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.386	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	1.342	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	5.	1.049	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	6.	0.310	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	7.	0.576	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	8.	0.284	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	9.	0.112	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
INCR INFLOW-1	10.	1.889	77.00	5.20	0.00	17.40	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	2.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	3.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	4.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	5.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	6.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	7.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	8.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	9.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
INCR INFLOW-2	10.	0.00	0.00	0.05	0.00	0.18	0.00	0.06
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT	UPSTRM	JUNCTION	TRIB
ENDATA9	0.	0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	**MAIN ST.**	**123.50**	**77.00**	**7.42**	**2.19**	**82.33**	**0.00**	**0.00**
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS, COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	**0.00**	**0.00**	**1.55**	**0.02**	**0.50**	**0.00**	**6.45**	**0.01**	**0.08**
ENDATA10A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	BRANCH RIVER	0.00	13.76	77.00	7.30	1.30	21.75	0.00	0.00
POINTLD-1	2.	MILL RIVER	0.00	1.97	77.00	7.30	1.60	23.97	0.00	0.00
POINTLD-1	3.	PETERS RIVER	0.00	1.00	77.00	5.60	1.20	37.00	0.00	0.00
POINTLD-1	4.	WOONSOC WWTP	0.00	24.64	77.00	5.00	10.00	127.50	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS, COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00	2.40	0.00	0.20	0.00	0.26	0.00	0.05
POINTLD-2	2.	0.00	0.00	4.60	0.00	0.20	0.00	0.35	0.00	0.04
POINTLD-2	3.	0.00	0.00	3.10	0.00	0.20	0.00	0.74	0.00	0.03
POINTLD-2	**4.**	**0.00**	**0.00**	**0.00**	**0.00**	**2.00**	**0.00**	**3.00**	**0.00**	**0.10**
ENDATA11A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

	DAM	RCH	ELE	ADAM	BDAM	FDAM	HDAM
DAM DATA	1.	3.	2.	1.60	0.70	1.00	4.00
DAM DATA	2.	4.	2.	1.60	0.70	1.00	18.00

DAM DATA	3.	5.	1.	1.60	0.70	1.00	10.00
DAM DATA	4.	6.	2.	1.60	0.70	1.00	17.00
DAM DATA	5.	7.	2.	1.60	0.70	1.00	6.00
DAM DATA	6.	8.	2.	1.60	0.70	1.00	4.00
DAM DATA	7.	8.	15.	1.60	0.70	1.00	4.00
DAM DATA	8.	10.	2.	1.60	1.05	1.00	4.00
DAM DATA	9.	10.	7.	1.60	0.70	1.00	4.00
ENDATA12	0.	0.	0.	0.00	0.00	0.00	0.00

$$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

CARD TYPE TEMP D.O. BOD CM-1 CM-2 CM-3 ANC COLI

ENDATA13 DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

$$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

CARD TYPE CHL-A ORG-N NH3-N NO2-N NH3-N ORG-P DIS-P

ENDATA13A DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

SYSTEM STATUS AFTER 198.00 HOURS OF DYNAMICOPERATION

**** HYDRAULICS SUMMARY ****

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S	
1	1	1	18.20	18.00	123.50	0.00	0.00	0.197	0.062	9.969	62.892	662.05	87.47	626.94	61.31	
2	1	2	18.00	17.80	123.50	0.00	0.00	0.197	0.062	9.969	62.892	662.05	87.47	626.95	61.31	
3	1	3	17.80	17.60	123.50	0.00	0.00	0.197	0.062	9.969	62.892	662.06	87.47	626.95	61.31	
4	1	4	17.60	17.40	123.50	0.00	0.00	0.197	0.062	9.969	62.892	662.06	87.47	626.95	61.31	
5	**2**	**1**	**17.40**	**17.20**	**137.36**	**13.76**	**0.10**	**0.210**	**0.058**	**6.118**	**107.147**	**692.22**	**126.07**	**655.51**	**43.43**	**Branch R**
6	2	2	17.20	17.00	137.45	0.00	0.10	0.210	0.058	6.120	107.148	692.42	126.07	655.70	43.45	
7	2	3	17.00	16.80	137.55	0.00	0.10	0.210	0.058	6.121	107.150	692.63	126.08	655.90	43.48	
8	2	4	16.80	16.60	137.65	0.00	0.10	0.210	0.058	6.123	107.151	692.83	126.08	656.09	43.51	
9	3	1	16.60	16.40	137.68	0.00	0.04	0.210	0.058	11.143	58.885	692.90	85.72	656.16	71.66	
10	3	2	16.40	16.20	137.72	0.00	0.04	0.210	0.058	11.144	58.886	692.98	85.72	656.23	71.67	
11	3	3	16.20	16.00	137.75	0.00	0.04	0.210	0.058	11.145	58.886	693.05	85.72	656.30	71.69	
12	3	4	16.00	15.80	137.79	0.00	0.04	0.210	0.058	11.146	58.886	693.12	85.72	656.37	71.71	
13	3	5	15.80	15.60	137.82	0.00	0.04	0.210	0.058	11.148	58.886	693.20	85.73	656.44	71.73	
14	3	6	15.60	15.40	137.86	0.00	0.04	0.210	0.058	11.149	58.887	693.27	85.73	656.51	71.74	
15	3	7	15.40	15.20	137.89	0.00	0.04	0.210	0.058	11.150	58.887	693.35	85.73	656.58	71.76	
16	3	8	15.20	15.00	137.93	0.00	0.04	0.210	0.058	11.151	58.887	693.42	85.74	656.65	71.78	
17	3	9	15.00	14.80	137.96	0.00	0.04	0.210	0.058	11.152	58.888	693.49	85.74	656.72	71.79	
18	3	10	14.80	14.60	138.00	0.00	0.04	0.210	0.058	11.153	58.888	693.57	85.74	656.79	71.81	
19	3	11	14.60	14.40	138.03	0.00	0.04	0.210	0.058	11.154	58.888	693.64	85.74	656.86	71.83	
20	4	1	14.40	14.20	138.20	0.00	0.17	0.935	0.013	2.521	58.648	156.11	67.26	147.83	92.57	
21	4	2	14.20	14.00	138.37	0.00	0.17	0.935	0.013	2.522	58.654	156.20	67.26	147.92	92.66	
22	4	3	14.00	13.80	138.54	0.00	0.17	0.936	0.013	2.523	58.659	156.29	67.27	148.00	92.76	
23	4	4	13.80	13.60	138.70	0.00	0.17	0.937	0.013	2.524	58.664	156.38	67.28	148.09	92.85	
24	**4**	**5**	**13.60**	**13.40**	**138.87**	**0.00**	**0.17**	**0.937**	**0.013**	**2.526**	**58.670**	**156.47**	**67.29**	**148.17**	**92.95**	**Mill R**
25	**4**	**6**	**13.40**	**13.20**	**141.01**	**1.97**	**0.17**	**0.945**	**0.013**	**2.541**	**58.739**	**157.61**	**67.40**	**149.26**	**94.17**	**Peters R**
26	4	7	13.20	13.00	142.18	1.00	0.17	0.949	0.013	2.549	58.776	158.24	67.45	149.84	94.84	
27	4	8	13.00	12.80	142.35	0.00	0.17	0.949	0.013	2.551	58.782	158.33	67.46	149.93	94.94	
28	5	1	12.80	12.60	142.42	0.00	0.07	0.178	0.069	7.537	105.959	843.35	127.81	798.63	43.97	
29	**5**	**2**	**12.60**	**12.40**	**167.13**	**24.64**	**0.07**	**0.196**	**0.062**	**8.035**	**106.282**	**901.84**	**129.20**	**854.01**	**50.90**	**Woonsocket WWTF**
30	5	3	12.40	12.20	167.21	0.00	0.07	0.196	0.062	8.037	106.283	902.01	129.21	854.17	50.92	
31	5	4	12.20	12.00	167.28	0.00	0.07	0.196	0.062	8.038	106.284	902.18	129.21	854.34	50.94	
32	5	5	12.00	11.80	167.36	0.00	0.07	0.196	0.062	8.040	106.285	902.35	129.22	854.50	50.96	
33	5	6	11.80	11.60	167.43	0.00	0.07	0.196	0.062	8.041	106.286	902.52	129.22	854.66	50.98	
34	5	7	11.60	11.40	167.51	0.00	0.07	0.196	0.062	8.043	106.286	902.69	129.22	854.82	51.00	
35	5	8	11.40	11.20	167.58	0.00	0.07	0.196	0.062	8.044	106.287	902.86	129.23	854.98	51.02	
36	5	9	11.20	11.00	167.66	0.00	0.07	0.196	0.062	8.045	106.288	903.02	129.23	855.14	51.05	
37	5	10	11.00	10.80	167.73	0.00	0.07	0.196	0.062	8.047	106.289	903.19	129.24	855.30	51.07	
38	5	11	10.80	10.60	167.81	0.00	0.07	0.196	0.062	8.048	106.290	903.36	129.24	855.46	51.09	
39	5	12	10.60	10.40	167.88	0.00	0.07	0.196	0.062	8.050	106.291	903.53	129.24	855.62	51.11	
40	5	13	10.40	10.20	167.96	0.00	0.07	0.196	0.062	8.051	106.292	903.70	129.25	855.78	51.13	
41	5	14	10.20	10.00	168.03	0.00	0.07	0.196	0.062	8.053	106.293	903.87	129.25	855.94	51.15	
42	6	1	10.00	9.80	168.07	0.00	0.03	0.236	0.052	5.001	142.632	753.29	161.18	713.34	41.28	
43	6	2	9.80	9.60	168.10	0.00	0.03	0.236	0.052	5.002	142.633	753.35	161.18	713.40	41.29	
44	6	3	9.60	9.40	168.14	0.00	0.03	0.236	0.052	5.002	142.633	753.42	161.19	713.46	41.30	
45	6	4	9.40	9.20	168.17	0.00	0.03	0.236	0.052	5.003	142.634	753.48	161.19	713.53	41.31	
46	6	5	9.20	9.00	168.21	0.00	0.03	0.236	0.052	5.003	142.634	753.55	161.19	713.59	41.31	
47	6	6	9.00	8.80	168.24	0.00	0.03	0.236	0.052	5.003	142.635	753.61	161.19	713.65	41.32	
48	6	7	8.80	8.60	168.28	0.00	0.03	0.236	0.052	5.004	142.635	753.68	161.19	713.71	41.33	
49	6	8	8.60	8.40	168.31	0.00	0.03	0.236	0.052	5.004	142.636	753.74	161.19	713.77	41.34	
50	6	9	8.40	8.20	168.34	0.00	0.03	0.236	0.052	5.005	142.637	753.81	161.19	713.83	41.34	
51	7	1	8.20	8.00	168.43	0.00	0.08	0.267	0.046	4.990	126.608	667.15	144.24	631.77	46.62	
52	7	2	8.00	7.80	168.51	0.00	0.08	0.267	0.046	4.991	126.601	667.25	144.23	631.86	46.65	
53	7	3	7.80	7.60	168.59	0.00	0.08	0.267	0.046	4.992	126.595	667.34	144.23	631.95	46.67	
54	7	4	7.60	7.40	168.67	0.00	0.08	0.267	0.046	4.993	126.588	667.44	144.22	632.04	46.70	
55	7	5	7.40	7.20	168.76	0.00	0.08	0.267	0.046	4.994	126.581	667.53	144.22	632.13	46.72	
56	7	6	7.20	7.00	168.84	0.00	0.08	0.267	0.046	4.995	126.574	667.62	144.21	632.22	46.74	
57	7	7	7.00	6.80	168.92	0.00	0.08	0.267	0.046	4.996	126.567	667.72	144.21	632.31	46.77	
58	**8**	**1**	**6.80**	**6.60**	**168.94**	**0.00**	**0.02**	**0.694**	**0.018**	**4.965**	**49.046**	**257.15**	**62.28**	**243.51**	**120.82**	**Scott Pond Canal Inlet**
59	8	2	6.60	6.40	168.96	0.00	0.02	0.694	0.018	4.965	49.044	257.15	62.28	243.51	120.84	
60	8	3	6.40	6.20	168.98	0.00	0.02	0.694	0.018	4.965	49.043	257.15	62.28	243.52	120.86	
61	8	4	6.20	6.00	169.00	0.00	0.02	0.694	0.018	4.966	49.041	257.16	62.28	243.52	120.87	
62	8	5	6.00	5.80	169.01	0.00	0.02	0.694	0.018	4.966	49.040	257.16	62.27	243.52	120.89	
63	8	6	5.80	5.60	169.03	0.00	0.02	0.694	0.018	4.966	49.038	257.16	62.27	243.53	120.91	
64	8	7	5.60	5.40	169.05	0.00	0.02	0.694	0.018	4.966	49.037	257.17	62.27	243.53	120.92	

65	8	8	5.40	5.20	169.07	0.00	0.02	0.694	0.018	4.966	49.035	257.17	62.27	243.53	120.94	
66	8	9	5.20	5.00	169.09	0.00	0.02	0.694	0.018	4.967	49.034	257.18	62.27	243.54	120.95	
67	8	10	5.00	4.80	169.11	0.00	0.02	0.694	0.018	4.967	49.032	257.18	62.27	243.54	120.97	
68	8	11	4.80	4.60	169.13	0.00	0.02	0.694	0.018	4.967	49.031	257.18	62.27	243.54	120.99	
69	8	12	4.60	4.40	169.15	0.00	0.02	0.695	0.018	4.967	49.030	257.19	62.27	243.55	121.00	
70	8	13	4.40	4.20	169.17	0.00	0.02	0.695	0.018	4.968	49.028	257.19	62.27	243.55	121.02	
71	8	14	4.20	4.00	169.19	0.00	0.02	0.695	0.018	4.968	49.027	257.19	62.26	243.56	121.04	
72	8	15	4.00	3.80	169.20	0.00	0.02	0.695	0.018	4.968	49.025	257.20	62.26	243.56	121.05	
73	9	1	3.80	3.60	169.22	0.00	0.01	0.292	0.042	4.968	116.685	612.18	133.71	579.71	50.86	
74	9	2	3.60	3.40	169.23	0.00	0.01	0.292	0.042	4.968	116.685	612.19	133.71	579.73	50.87	
75	9	3	3.40	3.20	169.24	0.00	0.01	0.292	0.042	4.968	116.684	612.21	133.71	579.74	50.87	
76	9	4	3.20	3.00	169.25	0.00	0.01	0.292	0.042	4.969	116.683	612.22	133.71	579.75	50.88	
77	9	5	3.00	2.80	169.27	0.00	0.01	0.292	0.042	4.969	116.682	612.23	133.71	579.77	50.88	
78	9	6	2.80	2.60	169.28	0.00	0.01	0.292	0.042	4.969	116.681	612.25	133.71	579.78	50.88	
79	9	7	2.60	2.40	169.29	0.00	0.01	0.292	0.042	4.969	116.680	612.26	133.71	579.79	50.89	
80	9	8	2.40	2.20	169.30	0.00	0.01	0.292	0.042	4.969	116.679	612.27	133.71	579.80	50.89	
81	9	9	2.20	2.00	169.32	0.00	0.01	0.292	0.042	4.969	116.678	612.29	133.71	579.82	50.89	
82	10	1	2.00	1.80	169.51	0.00	0.19	0.414	0.030	4.972	82.314	432.15	97.42	409.23	72.22	
83	10	2	1.80	1.60	169.69	0.00	0.19	0.415	0.029	4.974	82.301	432.27	97.41	409.35	72.30	
84	10	3	1.60	1.40	169.88	0.00	0.19	0.415	0.029	4.976	82.288	432.39	97.41	409.46	72.39	
85	10	4	1.40	1.20	170.07	0.00	0.19	0.415	0.029	4.978	82.274	432.52	97.40	409.58	72.48	
86	10	5	1.20	1.00	170.26	0.00	0.19	0.416	0.029	4.980	82.261	432.64	97.39	409.69	72.56	
87	10	6	1.00	0.80	170.45	0.00	0.19	0.416	0.029	4.983	82.248	432.76	97.38	409.81	72.65	
88	10	7	0.80	0.60	170.64	0.00	0.19	0.416	0.029	4.985	82.234	432.88	97.37	409.93	72.74	
89	10	8	0.60	0.40	170.83	0.00	0.19	0.417	0.029	4.987	82.221	433.00	97.36	410.04	72.82	
90	10	9	0.40	0.20	171.02	0.00	0.19	0.417	0.029	4.989	82.208	433.12	97.35	410.16	72.91	
91	**10**	**10**	**0.20**	**0.00**	**171.21**	**0.00**	**0.19**	**0.417**	**0.029**	**4.991**	**82.195**	**433.25**	**97.34**	**410.27**	**73.00**	**End of River**

**** WATER QUALITY VARIABLES **** **7Q10 Flows**

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 CHLO MG/L	CM-2 cena	CM-3 iver	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L	
1	1	77.00	82.32	0.00	0.00	7.45	2.17	0.02	0.50	0.00	6.44	6.96	0.01	0.08	0.09	0.00	0.00	1.72	
1	2	77.00	82.26	0.00	0.00	7.49	2.16	0.02	0.50	0.01	6.43	6.95	0.01	0.07	0.08	0.00	0.00	1.92	
1	3	77.00	82.02	0.00	0.00	7.53	2.14	0.02	0.50	0.01	6.39	6.92	0.01	0.07	0.08	0.00	0.00	2.12	
1	4	77.00	80.95	0.00	0.00	7.57	2.10	0.02	0.49	0.01	6.28	6.80	0.01	0.07	0.08	0.00	0.00	2.33	
2	**1**	**77.00**	**76.24**	**0.00**	**0.00**	**7.59**	**2.03**	**0.02**	**0.47**	**0.01**	**5.79**	**6.29**	**0.01**	**0.06**	**0.07**	**0.00**	**0.00**	**2.52**	**Branch R**
2	2	77.00	76.20	0.00	0.00	7.63	2.01	0.02	0.47	0.02	5.78	6.28	0.01	0.06	0.07	0.00	0.00	2.72	
2	3	77.00	76.16	0.00	0.00	7.68	1.99	0.02	0.47	0.02	5.77	6.28	0.01	0.05	0.06	0.00	0.00	2.90	
2	4	77.00	76.12	0.00	0.00	7.72	1.98	0.02	0.47	0.02	5.76	6.27	0.01	0.05	0.06	0.00	0.00	3.08	
3	1	77.00	76.10	0.00	0.00	7.82	1.96	0.02	0.46	0.03	5.75	6.26	0.01	0.05	0.06	0.00	0.00	3.25	
3	2	77.00	76.09	0.00	0.00	8.03	1.95	0.03	0.46	0.03	5.74	6.26	0.01	0.04	0.06	0.00	0.00	3.39	
3	3	77.00	76.07	0.00	0.00	8.07	1.93	0.03	0.46	0.03	5.73	6.25	0.01	0.04	0.05	0.00	0.00	3.53	
3	4	77.00	76.06	0.00	0.00	8.11	1.92	0.03	0.46	0.03	5.73	6.25	0.01	0.04	0.05	0.00	0.00	3.65	
3	5	77.00	76.04	0.00	0.00	8.14	1.90	0.03	0.46	0.04	5.72	6.24	0.01	0.04	0.05	0.00	0.00	3.76	
3	6	77.00	76.03	0.00	0.00	8.16	1.89	0.03	0.46	0.04	5.71	6.24	0.01	0.03	0.05	0.00	0.00	3.86	
3	7	77.00	76.01	0.00	0.00	8.18	1.88	0.03	0.46	0.04	5.71	6.24	0.01	0.03	0.05	0.00	0.00	3.97	
3	8	77.00	76.00	0.00	0.00	8.19	1.86	0.03	0.46	0.04	5.70	6.23	0.01	0.03	0.04	0.00	0.00	4.07	
3	9	77.00	75.98	0.00	0.00	8.20	1.85	0.03	0.46	0.04	5.69	6.23	0.01	0.03	0.04	0.00	0.00	4.17	
3	10	77.00	75.96	0.00	0.00	8.20	1.83	0.03	0.46	0.05	5.69	6.22	0.01	0.02	0.04	0.00	0.00	4.27	
3	11	77.00	75.94	0.00	0.00	8.20	1.82	0.03	0.46	0.05	5.68	6.22	0.01	0.02	0.04	0.00	0.00	4.35	
4	1	77.00	75.86	0.00	0.00	8.21	1.81	0.03	0.46	0.05	5.67	6.21	0.02	0.02	0.04	0.00	0.00	4.36	
4	2	77.00	75.79	0.00	0.00	8.24	1.81	0.03	0.46	0.05	5.66	6.20	0.02	0.02	0.04	0.00	0.00	4.36	
4	3	77.00	75.72	0.00	0.00	8.23	1.80	0.04	0.46	0.05	5.65	6.20	0.02	0.02	0.04	0.00	0.00	4.36	
4	4	77.00	75.64	0.00	0.00	8.22	1.80	0.04	0.46	0.05	5.64	6.19	0.02	0.02	0.04	0.00	0.00	4.37	
4	5	77.00	75.51	0.00	0.00	8.20	1.79	0.04	0.46	0.05	5.63	6.17	0.02	0.02	0.03	0.00	0.00	4.37	
4	**6**	**77.00**	**74.77**	**0.00**	**0.00**	**8.18**	**1.78**	**0.04**	**0.45**	**0.05**	**5.55**	**6.09**	**0.02**	**0.02**	**0.03**	**0.00**	**0.00**	**4.37**	**Mill R**
4	**7**	**77.00**	**74.46**	**0.00**	**0.00**	**8.16**	**1.77**	**0.04**	**0.45**	**0.05**	**5.51**	**6.05**	**0.02**	**0.02**	**0.03**	**0.00**	**0.00**	**4.37**	**Peters R**
4	8	77.00	74.46	0.00	0.00	8.14	1.78	0.04	0.46	0.05	5.50	6.05	0.02	0.02	0.03	0.00	0.00	4.37	
5	1	77.00	75.11	0.00	0.00	8.09	1.87	0.04	0.47	0.06	5.47	6.03	0.02	0.02	0.03	0.00	0.00	4.37	
5	**2**	**77.00**	**81.49**	**0.00**	**0.00**	**7.65**	**2.84**	**0.03**	**0.65**	**0.06**	**5.16**	**5.90**	**0.01**	**0.02**	**0.04**	**0.00**	**0.00**	**3.98**	**Woonsocket WWTF**
5	3	77.00	81.46	0.00	0.00	7.59	2.82	0.03	0.64	0.07	5.15	5.89	0.01	0.02	0.04	0.00	0.00	4.11	
5	4	77.00	81.43	0.00	0.00	7.53	2.80	0.04	0.63	0.08	5.14	5.89	0.02	0.02	0.03	0.00	0.00	4.22	
5	5	77.00	81.41	0.00	0.00	7.45	2.77	0.04	0.62	0.09	5.14	5.88	0.02	0.02	0.03	0.00	0.00	4.33	
5	6	77.00	81.38	0.00	0.00	7.36	2.75	0.04	0.61	0.10	5.14	5.88	0.02	0.01	0.03	0.00	0.00	4.41	
5	7	77.00	81.35	0.00	0.00	7.26	2.73	0.04	0.60	0.10	5.13	5.87	0.02	0.01	0.03	0.00	0.00	4.48	
5	8	77.00	81.32	0.00	0.00	7.14	2.71	0.04	0.59	0.11	5.13	5.87	0.02	0.01	0.03	0.00	0.00	4.52	
5	9	77.00	81.29	0.00	0.00	7.00	2.68	0.04	0.58	0.12	5.13	5.87	0.02	0.01	0.03	0.00	0.00	4.56	
5	10	77.00	81.26	0.00	0.00	6.86	2.66	0.04	0.57	0.12	5.13	5.87	0.02	0.01	0.03	0.00	0.00	4.58	
5	11	77.00	81.23	0.00	0.00	6.71	2.64	0.04	0.56	0.13	5.13	5.86	0.02	0.01	0.03	0.00	0.00	4.58	
5	12	77.00	81.21	0.00	0.00	6.55	2.62	0.05	0.55	0.14	5.13	5.86	0.02	0.01	0.03	0.00	0.00	4.58	
5	13	77.00	81.18	0.00	0.00	6.40	2.60	0.05	0.55	0.14	5.13	5.86	0.02	0.01	0.02	0.00	0.00	4.56	
5	14	77.00	81.15	0.00	0.00	6.27	2.58	0.05	0.54	0.15	5.13	5.86	0.02	0.00	0.02	0.00	0.00	4.54	
6	1	77.00	81.14	0.00	0.00	6.27	2.56	0.05	0.52	0.15	5.14	5.86	0.02	0.00	0.02	0.00	0.00	4.50	
6	2	77.00	81.13	0.00	0.00	7.24	2.54	0.05	0.51	0.16	5.14	5.86	0.02	0.00	0.02	0.00	0.00	4.46	
6	3	77.00	81.11	0.00	0.00	7.07	2.52	0.05	0.50	0.16	5.15	5.86	0.02	0.00	0.02	0.00	0.00	4.42	
6	4	77.00	81.10	0.00	0.00	6.91	2.51	0.05	0.49	0.17	5.16	5.86	0.02	0.00	0.03	0.00	0.00	4.37	
6	5	77.00	81.09	0.00	0.00	6.75	2.49	0.05	0.48	0.17	5.16	5.87	0.02	0.00	0.03	0.00	0.00	4.33	
6	6	77.00	81.07	0.00	0.00	6.61	2.47	0.05	0.47	0.18	5.17	5.87	0.02	0.00	0.03	0.00	0.00	4.28	
6	7	77.00	81.06	0.00	0.00	6.46	2.46	0.05	0.46	0.18	5.18	5.87	0.02	0.00	0.03	0.00	0.00	4.24	
6	8	77.00	81.05	0.00	0.00	6.33	2.44	0.06	0.45	0.18	5.19	5.87	0.02	0.00	0.03	0.00	0.00	4.19	
6	9	77.00	81.03	0.00	0.00	6.21	2.43	0.06	0.44	0.18	5.20	5.87	0.02	0.00	0.03	0.00	0.00	4.14	
7	1	77.00	81.00	0.00	0.00	6.22	2.41	0.06	0.42	0.19	5.21	5.87	0.02	0.00	0.03	0.00	0.00	4.10	
7	2	77.00	80.97	0.00	0.00	7.05	2.39	0.06	0.41	0.19	5.22	5.87	0.02	0.00	0.03	0.00	0.00	4.06	
7	3	77.00	80.94	0.00	0.00	6.90	2.38	0.06	0.40	0.19	5.23	5.87	0.02	0.00	0.03	0.00	0.00	4.02	
7	4	77.00	80.91	0.00	0.00	6.75	2.36	0.06	0.39	0.19	5.24	5.87	0.02	0.00	0.03	0.00	0.00	3.97	
7	5	77.00	80.88	0.00	0.00	6.60	2.35	0.06	0.38	0.19	5.24	5.87	0.02	0.00	0.03	0.00	0.00	3.94	
7	6	77.00	80.85	0.00	0.00	6.47	2.34	0.06	0.37	0.19	5.25	5.87	0.02	0.00	0.03	0.00	0.00	3.90	

7	7	77.00	80.82	0.00	0.00	6.37	2.32	0.06	0.36	0.19	5.26	5.87	0.02	0.00	0.03	0.00	0.00	3.86	
8	**1**	**77.00**	**80.81**	**0.00**	**0.00**	**6.51**	**2.31**	**0.06**	**0.35**	**0.19**	**5.27**	**5.87**	**0.02**	**0.00**	**0.03**	**0.00**	**0.00**	**3.83**	**Scott Pond Canal Inlet**
8	2	77.00	80.80	0.00	0.00	7.19	2.31	0.06	0.35	0.19	5.28	5.87	0.02	0.00	0.03	0.00	0.00	3.82	
8	3	77.00	80.80	0.00	0.00	7.13	2.30	0.06	0.34	0.18	5.28	5.87	0.02	0.00	0.03	0.00	0.00	3.80	
8	4	77.00	80.79	0.00	0.00	7.07	2.30	0.06	0.34	0.18	5.28	5.87	0.02	0.00	0.03	0.00	0.00	3.79	
8	5	77.00	80.78	0.00	0.00	7.02	2.29	0.06	0.34	0.18	5.29	5.87	0.02	0.00	0.03	0.00	0.00	3.78	
8	6	77.00	80.77	0.00	0.00	6.96	2.28	0.06	0.33	0.18	5.29	5.87	0.02	0.00	0.03	0.00	0.00	3.76	
8	7	77.00	80.77	0.00	0.00	6.91	2.28	0.06	0.33	0.18	5.30	5.87	0.02	0.00	0.03	0.00	0.00	3.75	
8	8	77.00	80.76	0.00	0.00	6.86	2.27	0.06	0.33	0.18	5.30	5.87	0.02	0.00	0.03	0.00	0.00	3.74	
8	9	77.00	80.75	0.00	0.00	6.81	2.27	0.06	0.32	0.18	5.30	5.87	0.02	0.00	0.03	0.00	0.00	3.72	
8	10	77.00	80.75	0.00	0.00	6.76	2.26	0.06	0.32	0.18	5.31	5.87	0.02	0.00	0.03	0.00	0.00	3.71	
8	11	77.00	80.74	0.00	0.00	6.72	2.26	0.06	0.32	0.18	5.31	5.87	0.02	0.00	0.03	0.00	0.00	3.70	
8	12	77.00	80.73	0.00	0.00	6.67	2.25	0.06	0.31	0.18	5.31	5.87	0.02	0.00	0.03	0.00	0.00	3.68	
8	13	77.00	80.72	0.00	0.00	6.64	2.25	0.06	0.31	0.18	5.32	5.87	0.02	0.00	0.03	0.00	0.00	3.67	
8	14	77.00	80.72	0.00	0.00	6.69	2.24	0.06	0.31	0.18	5.32	5.87	0.03	0.00	0.03	0.00	0.00	3.66	
8	15	77.00	80.71	0.00	0.00	7.28	2.24	0.06	0.30	0.18	5.33	5.87	0.03	0.00	0.03	0.00	0.00	3.64	
9	1	77.00	80.71	0.00	0.00	7.16	2.23	0.06	0.30	0.18	5.34	5.88	0.03	0.00	0.03	0.00	0.00	3.63	
9	2	77.00	80.70	0.00	0.00	7.02	2.22	0.06	0.29	0.17	5.35	5.88	0.03	0.00	0.03	0.00	0.00	3.60	
9	3	77.00	80.70	0.00	0.00	6.88	2.21	0.06	0.28	0.17	5.36	5.88	0.03	0.00	0.03	0.00	0.00	3.57	
9	4	77.00	80.69	0.00	0.00	6.75	2.19	0.06	0.27	0.17	5.38	5.88	0.03	0.00	0.03	0.00	0.00	3.54	
9	5	77.00	80.69	0.00	0.00	6.62	2.18	0.07	0.26	0.16	5.39	5.88	0.03	0.00	0.03	0.00	0.00	3.52	
9	6	77.00	80.68	0.00	0.00	6.50	2.17	0.07	0.25	0.16	5.40	5.88	0.03	0.00	0.03	0.00	0.00	3.49	
9	7	77.00	80.68	0.00	0.00	6.39	2.16	0.07	0.24	0.16	5.42	5.88	0.03	0.00	0.03	0.00	0.00	3.46	
9	8	77.00	80.67	0.00	0.00	6.28	2.15	0.07	0.24	0.15	5.43	5.89	0.03	0.00	0.03	0.00	0.00	3.44	
9	9	77.00	80.66	0.00	0.00	6.20	2.14	0.07	0.23	0.15	5.44	5.89	0.03	0.00	0.03	0.00	0.00	3.41	
10	1	77.00	80.58	0.00	0.00	6.29	2.12	0.07	0.22	0.15	5.44	5.88	0.03	0.00	0.03	0.00	0.00	3.39	
10	2	77.00	80.51	0.00	0.00	7.19	2.11	0.07	0.22	0.15	5.45	5.88	0.03	0.00	0.03	0.00	0.00	3.37	
10	3	77.00	80.44	0.00	0.00	7.10	2.10	0.07	0.21	0.14	5.45	5.87	0.03	0.00	0.03	0.00	0.00	3.35	
10	4	77.00	80.37	0.00	0.00	7.01	2.09	0.07	0.21	0.14	5.45	5.87	0.03	0.00	0.03	0.00	0.00	3.33	
10	5	77.00	80.30	0.00	0.00	6.94	2.08	0.07	0.20	0.14	5.45	5.86	0.03	0.00	0.03	0.00	0.00	3.31	
10	6	77.00	80.23	0.00	0.00	6.93	2.07	0.07	0.20	0.14	5.45	5.86	0.03	0.00	0.03	0.00	0.00	3.30	
10	7	77.00	80.16	0.00	0.00	7.39	2.06	0.07	0.20	0.13	5.46	5.85	0.03	0.00	0.03	0.00	0.00	3.28	
10	8	77.00	80.10	0.00	0.00	7.30	2.05	0.07	0.19	0.13	5.46	5.85	0.03	0.00	0.03	0.00	0.00	3.26	
10	9	77.00	80.03	0.00	0.00	7.22	2.04	0.07	0.19	0.13	5.46	5.84	0.03	0.00	0.03	0.00	0.00	3.25	
10	**10**	**77.00**	**79.98**	**0.00**	**0.00**	**7.15**	**2.04**	**0.07**	**0.18**	**0.13**	**5.46**	**5.84**	**0.03**	**0.00**	**0.03**	**0.00**	**0.00**	**3.23**	**End of River**

ENDATA3 0. 0. 0.0 0. 0. 0. 0. 0. 0.

APPENDIX B . Dry Weather Total Phosphorus Loads along the Main Stem of the Blackstone River.

Station ID	Location	Total Phosphorus Loads (kg/day)																			
		2005																**2006**		**Mean (7/21, 8/11, 9/14)**	**Mean (All Growing Season[1])**
		3/16	4/20	5/11	5/23	6/9	6/27	7/21	8/3	8/11	8/25	9/14	9/26	10/7	10/22	11/29	12/22	1/27	2/17		
W-01	Millville (MA/RI border)	290	242	422	345	260	123	159	97	118	60	90	162	119	509	420	1081	998	1470	122	208
W-21	Singleton Street							111		95		49								85	85
W-22	Below Thundermist Dam							117		174		63								118	118
W-17	Hamlet Avenue	644				286		138		58		60					1400			85	136
W-24	Woonsocket WWTF							6				55								31	31
W-02	Manville Dam	804	262	680	329	497	204	161	201	107	50	99	166	9	736	1119	1474	1688	2907	122	269
W-03	George Washington Hwy Bridge	520	338	703	322	595	145	171	196	186	22	54	110	9	754	827	1498	1898	2767	137	277

(Adapted from Louis Berger, 2008)

1 Growing Season defined as April – October

APPENDIX C. Wet Weather Total Phosphorus Loads along the Main Stem of the Blackstone River.

Station ID	Location	WW01			WW03			WW04			Mean Load (kg/day)
		Mean Flow (cfs)	EMC TP (mg/l)	**Load (kg/day)**	Mean Flow (cfs)	EMC TP (mg/l)	**Load (kg/day)**	Mean Flow (cfs)	EMC TP (mg/l)	**Load (kg/day)**	
W-01	Millville, MA	909	0.22	**498**	663	0.45	**728**	1,610	0.21	**845**	**690**
W-24	Woonsocket WWTF	11.4	1.54	**43**	17.7	3.70	**160**	17.7	1.24	**54**	**86**
W-02	Manville Dam	1,147	0.21	594	897	0.38	844	2,433	0.17	1003	814
W03	George Washington Hwy Bridge	1,187	0.21	**611**	1,120	0.39	**1070**	2,161	0.16	**847**	**843**

(Adapted from Louis Berger, 2008)

APPENDIX D. Summary of Event Mean Concentrations (EMC) for Total Phosphorus.

Station ID	Location	Total Phosphorus (mg/l)			
		Storms			Mean
		WW-01 (7/8/05-7/12/05)	WW-03 (10/7/05-10/11/05)	WW-04 (10/22/05-10/25/05)	
W-03	George Washington Hwy Bridge	0.21	0.39	0.16	0.25
W-34	Blackstone Canal at Lonsdale	0.13	0.24	0.13	0.17

(Adapted from Louis Berger, 2008)

APPENDIX E. Estimating Mean Total Phosphorus

Prior to estimating the phosphorus load to Scott Pond, it was necessary to compute a mean TP concentration for the pond as a whole. The mean annual total phosphorus concentration was derived from the UMASS-Dartmouth data. There were seven sampling events from November 2004 through September 2005. As previously discussed, phosphorus samples were taken at one station in Scott Pond-North and two stations in Scott Pond-South. Samples in Scott Pond North were typically taken at 0.5m and 7m. Samples at Scott Pond South were typically taken at 1m, 7m, and 11-12m.

Scott Pond is typical of eutrophic ponds that exhibit clinograde phosphorus curves during periods of stratification, exhibiting a marked increase in phosphorus concentration with depth. During periods when lake sediments become anoxic, phosphorus is released from the sediment into the water column where it is largely trapped in the anoxic zone of the hypolimnion. As a result, phosphorus concentrations at the bottom of the pond are elevated relative to the surface. Typically the phosphorus concentration is fairly uniform from the surface to the top of the anoxic zone, where it reaches an inflection point, where the phosphorus concentration increases steadily with depth.

Volumetrically weighted mean TP concentrations were calculated for each of the basins associated with the three stations in Scott Pond, using bathymetric data and interpolating TP concentrations vs. depth. The mean TP for the entire pond was then calculated, by weighing each of the basin means by their associated volumes. Mean TP concentrations were estimated first for the two stations in Scott-Pond-South, since both were sampled at three depths (typically 1m, 7m, and 10-13m). Since the station located at Scott Pond-North was typically only sampled at 0.5m and 7m, an additional preliminary step was added, to estimate an 11m TP value, prior to performing the regression. The regression equations for Scott Pond-South are presented in Table A.1. In most cases, the best fit was a correlation of the natural log of TP with depth.

Table A1. Scott Pond South: Regression equations relating TP concentration and depth.

Date	Scott Pond-South (northern station)		Scott Pond-South (southern station)	
	Regression Equation	R^2	Regression Equation	R^2
8/10/04	TP=Log((D/20.752)/1.1646)	0.9968	TP=e^(D-14.301/4.1424)	0.9996
9/16/04	TP=e^((D-18.535)/7.1526))	0.9832	TP=e^((D-12.621/4.0228)	0.9206
12/6/04	N/A	N/A	N/A	N/A
4/19/05	TP=e^((D-104.26)/44.408))	0.9248	TP=(D+6.515)/122.3	0.9988
7/28/05	TP=e^((D-18.74)/4.788))	0.9953	TP=e^(D-13.828/3.4224)	0.9572
8/15/05	TP=e^((D-18.471)/3.9892))	0.9372	TP=e^((D-16.579/3.7302)	0.9990
9/16/05	TP=e^((D-17.088)/4.0678)	0.8553	TP=e^((D-15.855/3.6022)	0.8082

TP = Total Phosphorus (mg/l)
D=Depth (m)
N/A = The water column in December was well mixed and TP is relatively consistent with depth. Mean TP was calculated from a simple average.

In a few cases, the phosphorus profile, for Scott Pond-South, did not fit a natural log distribution (Table A.1). In December 2004, TP was fairly uniform with depth, and the mean TP concentration was calculated by taking a simple average of the three sample depths. The uniform concentration is typical of winter periods, when deep eutrophic ponds are well mixed. The TP profile at the southern station of Scott Pond-South, in April 2005, fit a linear relationship. Apparently phosphorus was being released from pond sediments in April 2005, but the thermocline was not sufficiently developed to trap all the phosphorus in the hypolimnion (DO data was not available for this sampling event). The TP profile at the northern station of Scott Pond-South, in August 2004, fit a power (nearly linear) regression. Although the pond was well stratified and the thermocline well developed, phosphorus released from the pond sediments was not trapped in the hypolimnion. The cause of the near-linear TP profile in August 2004 is unclear, however an application of herbicide (copper sulfate) in July 2004 could have modified the typical TP profile expected at that time of year.

The TP concentration, interpolated for each 1m segment of the water column, was multiplied by the volume associated with each corresponding 1m depth interval, to yield a mass of TP in each meter of the water column. The masses were then summed and divided by the total volume of each basin of Scott Pond-South to yield the mean concentration, weighted by volume, for the specific sampling event (Tables A.2 and A.3). Of course, the surface concentrations exert more influence on the volumetric mean, because most of the volume is contained near the surface. The sampling event means were then averaged to calculate the annual mean TP for each basin of Scott Pond-South. The calculation, for the mean volumetric TP concentration, is shown in the equation below.

$$TP_{vm} = \sum_{i=0-1m}^{n} (TP_i)(V_i)$$

Where:
TP_{vm} =Volumetric mean TP concentration
TP_i= Interpolated TP concentration of specified meter of water (mg/l)
V_i= Volume of specified meter of water (mg/l)
V_T=Total volume of basin
n = Bottom meter of water column

Table A.2. Scott Pond-South (northern station): Mean volumetric TP (mg//l) calculated from regressed concentrations and incremental volumes.

Depth Interval (m)	Area (m^2)	Volume (l)	8/10/2004		9/16/2004		4/19/2004		7/28/2005		8/15/2005		9/16/2005	
			TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)
0-1	7.15E+04	7.15E+07	0.040	2.89	0.080	5.74	0.097	6.91	0.022	1.58	0.011	0.79	0.017	1.21
1-2	7.15E+04	7.15E+07	0.104	7.47	0.092	6.60	0.099	7.07	0.027	1.95	0.014	1.01	0.022	1.55
2-3	6.83E+04	6.83E+07	0.162	11.08	0.106	7.25	0.101	6.91	0.034	2.30	0.018	1.25	0.028	1.89
3-4	6.30E+04	6.30E+07	0.217	13.65	0.122	7.69	0.103	6.51	0.041	2.61	0.023	1.48	0.035	2.23
4-5	5.81E+04	5.81E+07	0.269	15.63	0.140	8.16	0.106	6.15	0.051	2.97	0.030	1.75	0.045	2.63
5-6	5.31E+04	5.31E+07	0.320	16.96	0.162	8.58	0.108	5.74	0.063	3.34	0.039	2.05	0.058	3.07
6-7	4.85E+04	4.85E+07	0.369	17.89	0.186	9.01	0.111	5.37	0.078	3.76	0.050	2.41	0.074	3.59
7-8	4.41E+04	4.41E+07	0.417	18.40	0.214	9.42	0.113	4.99	0.096	4.21	0.064	2.82	0.095	4.17
8-9	3.99E+04	3.99E+07	0.464	18.54	0.246	9.81	0.116	4.62	0.118	4.70	0.082	3.27	0.121	4.83
9-10	3.57E+04	3.57E+07	0.511	18.24	0.283	10.09	0.118	4.22	0.145	5.18	0.105	3.76	0.155	5.52
10-11	3.09E+04	3.09E+07	0.557	17.21	0.325	10.04	0.121	3.74	0.179	5.52	0.135	4.18	0.198	6.11
11-12	2.61E+04	2.61E+07	0.602	15.73	0.374	9.76	0.124	3.23	0.220	5.75	0.174	4.55	0.253	6.61
12-13	1.96E+04	1.96E+07	0.647	12.68	0.430	8.42	0.127	2.48	0.271	5.32	0.224	4.38	0.323	6.34
13-14	1.34E+04	1.34E+07	0.691	9.25	0.494	6.62	0.130	1.73	0.334	4.48	0.287	3.85	0.413	5.53
14-15	1.10E+04	1.10E+07	0.735	8.10	0.568	6.26	0.132	1.46	0.412	4.54	0.369	4.07	0.529	5.82
15-16	7.26E+03	7.26E+06	0.778	5.65	0.654	4.75	0.135	0.98	0.508	3.69	0.474	3.45	0.676	4.91
16-17	4.42E+03	4.42E+06	0.821	3.63	0.752	3.32	0.139	0.61	0.626	2.77	0.609	2.69	0.864	3.82
17-18	1.07E+03	1.07E+06	0.864	0.92	0.865	0.92	0.142	0.15	0.771	0.82	0.783	0.84	1.105	1.18
Totals		**6.67E+08**		**213.91**		**132.46**		**72.89**		**65.48**		**48.59**		**71.01**
Means			**0.320**		**0.198**		**0.109**		**0.098**		**0.073**		**0.106**	

Table A.3. Scott Pond-South (southern station): Mean volumetric TP (mg//l) calculated from regressed concentrations and incremental volumes.

Depth Interval (m)	Area (m^2)	Volume (l)	8/10/2004		9/16/2004		4/19/2004		7/28/2005		8/15/2005		9/16/2005	
			TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)
0-1	6.62E+04	6.62E+07	0.036	2.363	0.049	3.249	0.057	3.795	0.020	1.346	0.013	0.888	0.014	0.931
1-2	6.54E+04	6.54E+07	0.045	2.974	0.063	4.118	0.065	4.286	0.027	1.782	0.018	1.147	0.019	1.215
2-3	6.24E+04	6.24E+07	0.058	3.606	0.081	5.031	0.074	4.593	0.036	2.274	0.023	1.429	0.025	1.528
3-4	5.52E+04	5.52E+07	0.074	4.068	0.103	5.715	0.082	4.521	0.049	2.698	0.030	1.655	0.032	1.787
4-5	4.67E+04	4.67E+07	0.094	4.379	0.133	6.196	0.090	4.205	0.065	3.055	0.039	1.830	0.043	1.994
5-6	3.92E+04	3.92E+07	0.119	4.677	0.170	6.667	0.098	3.849	0.088	3.434	0.051	2.008	0.056	2.209
6-7	3.31E+04	3.31E+07	0.152	5.023	0.218	7.212	0.106	3.518	0.117	3.880	0.067	2.215	0.074	2.460
7-8	2.70E+04	2.70E+07	0.193	5.217	0.280	7.544	0.115	3.090	0.157	4.240	0.088	2.363	0.098	2.649
8-9	2.07E+04	2.07E+07	0.246	5.097	0.359	7.423	0.123	2.541	0.211	4.358	0.115	2.370	0.130	2.683
9-10	1.53E+04	1.53E+07	0.313	4.801	0.460	7.043	0.131	2.005	0.282	4.319	0.150	2.293	0.171	2.621
10-11	1.02E+04	1.02E+07	0.399	4.070	0.589	6.013	0.139	1.419	0.378	3.852	0.196	1.997	0.226	2.304
11-12	3.35E+03	3.35E+06	0.508	1.704	0.756	2.535	0.147	0.494	0.506	1.696	0.256	0.858	0.298	1.000
12-13	1.12E+03	1.12E+06	0.647	0.727	0.969	1.089	0.155	0.175	0.677	0.761	0.335	0.376	0.393	0.442
13-14	8.36E+01	8.36E+04	0.824	0.069	1.243	0.104	0.164	0.014	0.907	0.076	0.437	0.037	0.519	0.043
Totals		**4.46E+08**		**48.77**		**69.94**		**38.50**		**37.77**		**21.47**		**23.87**
Means			**0.109**		**0.157**		**0.086**		**0.085**		**0.048**		**0.054**	

With the exception of an added initial step in some cases, the mean volumetric TP concentration for Scott Pond-North was estimated in the same manner as Scott Pond-South. Unless the data for Scott Pond-North indicated a linear TP profile, it was necessary to estimate a bottom TP concentration for Scott Pond-North, prior to regressing the TP data. Unlike Scott Pond-South, there was no bottom phosphorus sample taken in Scott Pond-North. Scott Pond-North was sampled at 0.5m and 7 m, only. Experimentation with regressing only the1m and 7 m data from Scott Pond South, resulted in consistently lower estimates of the mean TP concentration, compared to means derived by regressing all three available data points. Accordingly it was necessary to estimate an 11m TP concentration for Scott Pond-North, prior to regressing the TP data.

For those sampling events where a logarithmic TP profile was indicated for Scott Pond-North, the ratio of the 11m vs the 7m TP concentrations was calculated for both stations of Scott Pond South, for each of the sampling events. The two ratios were then averaged and the mean 11m/7m TP ratio for Scott Pond-South was multiplied by the 7m concentration of Scott Pond-North, to estimate the 11m value in the northern basin, for each of the sampling events (Table A.4). A regression was then performed on the 0.5m, 7m and the estimated 11m concentrations, and the mean volumetric TP concentration for Scott Pond-North was calculated in the same manner as Scott Pond-South (Table A.5 and A.6).

Table A.4. Estimation of TP (mg/l) @ 11m for Scott Pond-North.

	Scott Pond-South (Northern Station)			Scott Pond-South (Southern Station)			Scott Pond-South Mean	Scott Pond-North	
	TP@7m (mg/l)	T @11m (mg/l)[a]	TP@11m/ TP@7m	TP@7m (mg/l)	T @11m (mg/l)[a]	TP@11m/ TP@7m	TP@11m/ TP@7m	TP@7m (mg/l)	TP@11m (mg/l)[b]
08/10/04[c]	---	---	---	---	---	---	---	---	---
09/16/04	0.176	0.349	1.985	0.171	0.673	3.934	2.959	0.731	2.164
12/6/2004[c]	---	---	---	---	---	---	---	---	---
4/19/2005[c]	---	---	---	---	---	---	---	---	---
07/28/05	0.078	0.199	2.557	0.093	0.442	4.749	3.653	0.696	2.543
08/15/05	0.037	0.155	4.181	0.081	0.226	2.788	3.485	0.700	2.439
09/16/05	0.046	0.225	4.898	0.042	0.262	6.237	5.567	0.832	4.632

a. Regressed values.
b. Estimated values derived my multiplying TP @ 7m by the ratio of TP @ 11m and TP @ 7m.
c. Ratio not calculated because TP vs. depth relationship appears to be linear not logarithmic.

Table A.5. Scott Pond North: Regression equations relating TP concentration and depth.

Date	Scott Pond-North	
	Regression Equation	R^2
8/10/04	TP=(D+1.4865)/13.514	a
9/16/04	TP=e^((D-8.1535)/3.7429)	0.9999
12/6/04	TP=(D+1.5463)/15.046	a
4/19/05	TP=(D+0.8052)/26.104	a
7/28/05	TP=e^((D-8.2414)/2.7962)	0.9986
8/15/05	TP=e^((D-6.7554)/5.466)	0.8636
9/16/05	TP=e^((D-7.3566)/2.4106)	0.9998

a. Linear regression of two points yields r^2 of 1.

Table A.6 . Scott Pond-North: Mean volumetric TP (mg//l) calculated from regressed concentrations and incremental volumes.

Depth Interval (m)	Area (m^2)	Volume (l)	8/10/2004		9/16/2004		12/6/2004		4/19/2004		7/28/2005		8/15/2005		9/16/2005	
			TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)	TP (mg/l)[1]	TP (kg)
0-1	34649	3.46E+07	0.147	5.1	0.129	4.5	0.136	4.7	0.050	1.7	0.063	2.2	0.318	11.0	0.058	2.0114
1-2	34055	3.41E+07	0.221	7.5	0.169	5.7	0.202	6.9	0.088	3.0	0.090	3.1	0.382	13.0	0.088	2.9933
2-3	30769	3.08E+07	0.295	9.1	0.221	6.8	0.269	8.3	0.126	3.9	0.128	3.9	0.459	14.1	0.133	4.095
3-4	25381	2.54E+07	0.369	9.4	0.288	7.3	0.335	8.5	0.165	4.2	0.183	4.6	0.551	14.0	0.202	5.1145
4-5	18348	1.83E+07	0.443	8.1	0.376	6.9	0.402	7.4	0.203	3.7	0.262	4.8	0.661	12.1	0.305	5.5982
5-6	13796	1.38E+07	0.517	7.1	0.492	6.8	0.468	6.5	0.241	3.3	0.374	5.2	0.794	11.0	0.462	6.3733
6-7	8816	8.82E+06	0.591	5.2	0.642	5.7	0.534	4.7	0.280	2.5	0.535	4.7	0.953	8.4	0.699	6.1669
7-8	6438	6.44E+06	0.665	4.3	0.839	5.4	0.601	3.9	0.318	2.0	0.766	4.9	1.145	7.4	1.059	6.8186
8-9	4942	4.94E+06	0.739	3.7	1.096	5.4	0.667	3.3	0.356	1.8	1.095	5.4	1.375	6.8	1.604	7.9256
9-10	3475	3.47E+06	0.813	2.8	1.431	5.0	0.734	2.5	0.395	1.4	1.566	5.4	1.651	5.7	2.428	8.4363
10-11	2100	2.10E+06	0.887	1.9	1.869	3.9	0.800	1.7	0.433	0.9	2.239	4.7	1.982	4.2	3.676	7.7188
11-12	474	4.74E+05	0.961	0.5	2.442	1.2	0.867	0.4	0.471	0.2	3.201	1.5	2.380	1.1	5.566	2.6374
Totals		**1.83E+08**		**64.5**		**64.5**		**58.7**		**28.6**		**50.5**		**108.8**		**65.9**
Means			**0.352**		**0.352**		**0.320**		**0.156**		**0.276**		**0.594**		**0.360**	

If the data for Scott Pond-North indicated a linear TP profile, a linear regression was performed on the two available data points, and the mean volumetric TP concentration was calculated in an identical manner as the mean TP for the two stations in Scott Pond-South. A linear profile was indicated for Scott Pond-North in August and December 2004, and April 2005.

In August 2004, TP at 4.5 m below the surface was significantly elevated relative to the concentration at 0.5m, despite the fact that the 4.5 m sampling depth appears near the top of the thermocline. Because there does not appear to be a physical or chemical barrier, between the surface and 4.5m depths, it appears that there is nothing to account for a change in the rate of TP increase with depth. Therefore it appears that the TP profile in Scott Pond-North was linear in August 2004. As discussed previously, the TP profile at the northern station of Scott-Pond-South, in August 2004, was nearly linear.

Although the TP concentrations in Scott Pond-South, in December 2004, were fairly uniform with depth, the TP concentration at 7m in Scott Pond-North was significantly higher than the surface concentration. Because the waterbody was well mixed and not stratified in December, it appears that there was no physical or chemical barrier to account for a change in the rate of TP increase with depth. It therefore appears that the TP profile in Scott Pond-North in December 2004, was linear.

Although there is no temperature or DO data from April 2005, Scott Pond-North was probably not stratified this early in the year, despite the fact that TP was elevated at depth. Since the waterbody was probably well mixed, it appears that the TP profile was linear and not logarithmic. As discussed previously, the TP profile at the southern station of Scott-Pond-South, in April 2005, was nearly linear.

The mean volumetric TP concentration, for Scott Pond as a whole, was calculated by taking a volumetrically weighted average of the mean TP values calculated for the three sampling stations. The mean volumetric TP concentration, for Scott Pond was 0.159 mg/l. The calculation of the volumetric mean is shown below:

$TP_{SP} = [(TP_{SP\text{-}S\text{-}nb})(V_{SP\text{-}S\text{-}nb}) + (TP_{SP\text{-}\ S\text{-}sb})(V_{SP\text{-}\ S\text{-}sb)} + (TP_{SP\text{-}N})(V_{SP\text{-}N})] / V_{SP}$

Where:
TP = Volumetric mean TP concentration of basin or pond (mg/l)
V = Total Volume of basin or pond (l)
SP = Scott Pond (in its entirety)
SP-S-ns n = Scott Pond-South (northern basin)
SP- S-sb = Scott Pond-South (southern basin)
SP-N sb = Scott Pond-North

APPENDIX F. Public Comments and Responses.

Steven Winnett, USEPA Region 1

Thank you for the opportunity to review the public review draft of DEM's Scott Pond TMDL for phosphorus. EPA has only a few comments but please let me know if you need clarification on any of them.

1. P. 2, para 5, line 2, you may mean "cultural *eutrophication*."

RIDEM Response: The document was revised, accordingly.

Chapter 2: it would be very helpful to have a larger, more detailed map which shows the entire pond-canal system, including the location of the important landmarks such as the Woonsocket WWTF, Ashton Dam, and canal inlet.

RIDEM Response: An additional figure (Figure 2.2, Page 6) was inserted into the document, accordingly.

Figure 3, Can you show on the map the approximate dividing line between the Scott Pond South northern and southern basins?

RIDEM Response Figure 2.1 (Page 5) was revised, accordingly.

P. 12, Phytoplankton section: What is the healthy or target concentration of chlorophyll-a? We have no frame of reference to understand the levels discussed in paragraphs 2 & 3.

RIDEM Response: The document was revised, accordingly (Section 1.4 and third paragraph, Page 13).

P. 14, last line: What is the significance of the Woonsocket WWTF? Is it immediately upstream from the canal inlet?

RIDEM Response: The document was revised accordingly. (last paragraph, page 15).

P. 15, 1st para, 3rd sentence: The language here needs some clarification around the subject of precision.

RIDEM Response The document was revised accordingly. (first paragraph, page 16).

Figure 4.1: See comment above about a larger, more detailed map. This one is very hard to read and understand, especially as it appears to be distorted horizontally.

RIDEM Response: Figure 4.1 was revised accordingly.

Chapter 5 and 6. Somewhere in these chapters we need to have the permit numbers for the MS4s which discharge into the Scott Pond system.

RIDEM Response: The document was revised accordingly (Table 4.1, Page 19; last paragraph Page 27; and Table 6.1, Page 33).