Final

Total Maximum Daily Load

For

Dissolved Oxygen and Phosphorus

Mashapaug Pond, Rhode Island

Office of Water Resources
Rhode Island Department of Environmental Management
235 Promenade Street
Providence, Rhode Island

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Acknowledgements

RIDEM would like to acknowledge the assistance of the US Environmental Protection Agency in providing contractor assistance in the development of the Mashapaug Pond Phosphorus and Dissolved Oxygen TMDL. USEPA, in partnership with RIDEM and Tetra Tech began the process of the development of the nutrient TMDL for Mashapaug Pond several years ago. As part of the USEPA work plan, Tetra Tech and its subcontractor ESS developed a QAPP (Quality Assurance Project Plan) and monitoring plan that was submitted to EPA and RIDEM in the spring of 2001. Under contract to US EPA, TetraTech and their subcontractor, ESS assessed available water quality data, conducted supplemental water quality monitoring of Mashapaug Pond, its tributary and stormwater sources discharging into it, and developed a water quality model to determine phosphorus concentrations necessary to resolve the excess algal growth and low dissolved oxygen conditions affecting both recreational uses and ecological health of the pond. RIDEM also wishes to acknowledge the work of Al Basil, EPA's Project Manager for his technical review and contract oversight on this project.

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Aquatic Community	is an association of interacting populations of aquatic organisms in a given waterbody or habitat.
Anoxia	is a complete lack of oxygen (0 mg/L) in an aquatic system.
Bathymetry	is the depth of the bottom of a waterbody relative to sea level or other vertical reference datum.
Bioaccumulation	is the process by which a compound is taken up by an aquatic organism, both from water and through food.
Biological Assessment	is an evaluation of the biological condition of a waterbody using surveys and other direct measurements of resident biota.
CFR	Code of Federal Regulations
Contaminant	is an undesirable substance not normally present or a high concentration of a naturally occurring substance.
CWA	Clean Water Act, also known as the Federal Water Pollution Control Act enacted in 1972. As amended in 1977, this law became commonly known as the Clean Water Act
Epilimnion	the water layer overlying the thermocline of a lake
Erosion	The group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface.
EMC	is the event mean concentration of a pollutant during a storm event.
Eutrophication	the process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen
HUC	Hydrologic Unit Code
Hypolimnion	the part of a lake below the thermocline made up of water that is stagnant and of essentially uniform temperature except during the period of overturn

Hypoxia	means “low oxygen”. In aquatic systems, hypoxia usually means a dissolved oxygen concentration of less than 2 mg/L.
Nutrients	are elements or compounds essential to life usually referring to carbon, nitrogen, and phosphorus although there are others.
Pathogens	An agent that causes disease, especially a living microorganism such as a bacterium or virus
RIDEM	Rhode Island Department of Environmental Management
Sediment	Soil particles having been transported from their natural location by wind, or rain that settle on the bottom of wetlands or other aquatic systems.
Stormwater runoff	The water and associated material resulting from rainstorms that drains into streams and lakes
Suspension	A method of sediment transport in which the turbulence of a fluid is able to keep particles supported in the fluid.
Thermocline	the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth
TMDL	Total Maximum Daily Load
Tributary	A stream which joins another stream or body of water.
URIWW	University of Rhode Island Watershed Watch Program
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
Watershed	An area that slopes toward a waterbody and contributes water to a specified surface water drainage system such as a stream or river.
Wetland	An area that is periodically inundated or saturated by surface or ground water on an annual or seasonal basis and typical supports hydrophytic vegetation.

ABSTRACT

The Mashapaug Pond watershed, located in the Pawtuxet River basin, within an area locally known as the Reservoir Triangle of Providence, Rhode Island is on the state's 303 (d) list of impaired waters for phosphorus, low dissolved oxygen, excess algal growth/chlorophyll a, pathogens, and PCBs. The pond is located in an urban area with high-density residential, commercial and industrial land uses.

Section 303(d) of the Clean Water Act (CWA) requires each state to identify those waters within its boundaries not meeting water quality standards applicable to their waters' designated uses. Total maximum daily loads (TMDLs) for all pollutants violating or causing violation of applicable water quality standards are to be established for each impaired waterbody. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality-based controls to reduce pollution from both point and nonpoint sources, thereby restoring and maintaining the quality of their water resources.

The Mashapaug Pond TMDL was developed to addresses the water quality impairments associated with elevated phosphorus concentrations (low dissolved oxygen and excess algal growth/chl-a). More specifically, excessive phosphorus loads contribute to high plankton concentrations, which in turn contribute to low dissolved oxygen concentrations that impair fish and animal survival and loss of habitat. The phosphorus loads also contribute to the growth of blue-green algae species that have been identified as hazardous to humans (through skin contact), making the pond unsafe for swimming. Uses impaired by these conditions include support of fish propagation and other animal life in the pond, and swimming. The objective of this TMDL is to determine the acceptable amount of phosphorus that the pond can receive in order to restore these designated uses and protect the pond from future degradation

Field monitoring was conducted by an EPA contractor, ESS during 2001 to collect water quality data for the TMDL. Water quality standards for dissolved oxygen and phosphorus are presently not met in Mashapaug Pond. Based on monitoring during 2001, the pond's current mean Total Phosphorus concentration ranges from 30 ug/l to 50 ug/l, which exceeds the state's water quality standard. Dissolved oxygen levels range between 0-4 mg/l in the hypolimnion to 2-12 mg/l in the epilimnion, so the instantaneous dissolved oxygen concentration standard of 5 mg/l is also not met.

A three-dimensional hydrodynamic and water quality model (EFDC) was configured and applied to Mashapaug Pond by Tetra Tech Inc. to develop this TMDL. The model included 54 horizontal grid cells and 5 vertical layers, to allow simulation of the seasonal stratification of the pond. Annual loads were simulated based on precipitation records and literature derived concentrations. Load reduction simulations made using the calibrated model indicate that a 65% reduction in nutrient loads from the manageable sources (i.e., storm drains, direct overland runoff, and base flow from Spectacle Pond) is necessary to meet the TMDL goals:

- Reduce the average Total Phosphorus concentration in the pond to 20 ug/l.
- Eliminate hypoxia (defined as a DO concentration <2 mg/l) in the hypolimnion of the pond to support propagation of fish and other animal life in the pond.
- Reduce algal abundance (chlorophyll-a) to levels consistent with the designated uses.

The 2001 study concluded that the largest single phosphorus source (47%) to Mashapaug Pond is via tributary flow entering from Spectacle Pond. Six storm drain systems contribute 22% of the total phosphorus load, based on estimates derived from land use and data from other areas. Monitoring conducted by ESS also indicate that these same sources also discharge significant fecal coliform concentrations during wet weather. Direct overland runoff from the surrounding watershed is 13% of the total load. Although the sources of phosphorus in runoff from storm drains and direct overland flow are nonpoint in nature, these sources are regulated as point sources and are considered controllable. A combination of upland and end of pipe control structures to treat and reduce runoff volumes, combined with land use management, conservation efforts and source reduction within the watershed is recommended to meet phosphorus reduction targets for these stormwater sources, and to reduce wet weather fecal coliform concentrations. Similar efforts are needed within the Spectacle Pond watershed (Cranston) along with in-lake management techniques to control the release of phosphorus from the sediments to reduce the phosphorus load from Spectacle Pond into Mashapaug Pond. Other nonpoint sources of total phosphorus include atmospheric deposition (11%) and groundwater (7%). Atmospheric deposition and groundwater underflow into the pond are sources that are not controllable at the local level. Continued efforts by regional and national groups to reduce this pollution will result in additional local benefits within the watershed over the long term, but are not considered by this TMDL.

Reversal of the eutrophication of Mashapaug Pond requires reduction of phosphorus inputs. Because this TMDL relies upon the implementation of a combination of BMPs to be applied within the watershed proper, and data available for the success of many of these methods is variable, the implementation approach will be considered as a phased approach to meeting water quality goals. As BMPs and mitigation measures are installed and implemented, the corresponding response in phosphorus concentrations will be measured.

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987, Public Law 100-4, and the United States Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations [Title 40 of the Code of Federal Regulation (40 CFR), Part 130] require each state to identify those waters within its boundaries not meeting water quality standards applicable to the water's designated uses. Total maximum daily loads (TMDLs) for all pollutants violating or causing violations of applicable water quality standards are to be established for each impaired water body. Such loads are established at levels necessary to meet applicable water quality standards with consideration given to seasonal variations and margins of safety. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality-based controls to reduce pollution from both point and nonpoint sources thereby restoring and maintaining the quality of their water resources (USEPA, 1991).

1.1 Study Area

The Mashapaug Pond watershed [RI006017L-06, USGS HUC 01090004] is located in the Pawtuxet River basin, within an area locally known as Reservoir Triangle of Providence, Rhode Island (Figure 1.1). Mashapaug Pond has a long history of development along its banks dating back as early as 1636 when it was included in Roger Williams' original land purchase from the Narragansett Indians. Mashapaug Pond, situated in the southwest quadrant of Providence, bounded by the city of Cranston on the west, Narragansett Avenue to the east and Sinclair Avenue to the south, is the largest freshwater lake in Providence. The pond's surface area is approximately 31 hectares (77 acres) with an average depth of about 3 meters (9.8 feet). Its sources of fresh water are inflow from Spectacle Pond, ground water, and storm water. The Mashapaug Pond physical watershed, including Tongue Pond and Spectacle Pond, encompasses approximately 308 hectares (762 acres) of urban land with a ratio of approximately 2 acres of residential use to 1 acre of industrial use.

1.2 Pollutant of Concern

Mashapaug Pond is on the Rhode Island 2006 303(d) list of impaired waters for hypoxia, nutrients, and pathogens. The primary nutrient of concern is phosphorus since it is the limiting nutrient for algae growth. Hypoxia means "low dissolved oxygen". In aquatic ecosystems, hypoxia is generally defined as a DO concentration of less than 2-3 milligrams of oxygen per liter of water (mg/l) (Ecological Society of America fact sheet at www.esa.org/education/resources/factsheets). A complete lack of oxygen (0 mg/L) is called anoxia. Hypoxia is primarily a problem that occurs in estuaries and coastal waters, but it can also be a problem in stratified freshwater lakes. When the water column of a lake is stratified, oxygen from the upper layer cannot mix with the lower layer, and the oxygen in the lower layer is depleted by oxygen-demanding substances trapped in the hypolimnion as well as by sediment oxygen demand. During the summer months, Mashapaug Pond becomes stratified with a well-defined epilimnion (upper layer) and hypolimnion (lower layer). Vertical profile sampling conducted during the 2001 water quality monitoring program has confirmed stratified DO and temperature conditions in Mashapaug Pond with dissolved oxygen concentrations less than 2 mg/L in the hypolimnion.

The pathogen impairment for Mashapaug Pond was added to the 2002 303(d) list following review of initial fecal coliform data collected as part of the assessment for the phosphorus and dissolved oxygen TMDL. A more complete review of the available dataset (May 2000 – October 2004) which includes the data collected for this TMDL and that collected by URI Watershed Watch volunteers, however reveals a geomean of 40.7 MPN/100ml and compliance with the variability criterion (< 10% exceeding 400) and thus no exceedence of the fecal coliform criteria for this Class B pond.[1] More intensive wet weather monitoring conducted on the pond and its tributaries during one storm on September 25, 2001 including the sampling of first flush, and 4 -, 22 - and 24- hours after the rain event revealed a significant increase in the pond water column concentration of fecal coliform during this rain event. Levels returned to pre-storm concentrations within 24 hours. Though not considered a violation of the primary contact recreation/swimming criteria, the elevation of fecal coliform during wet weather events represents a potential health concern. This TMDL outlines the control measures needed to address this concern.

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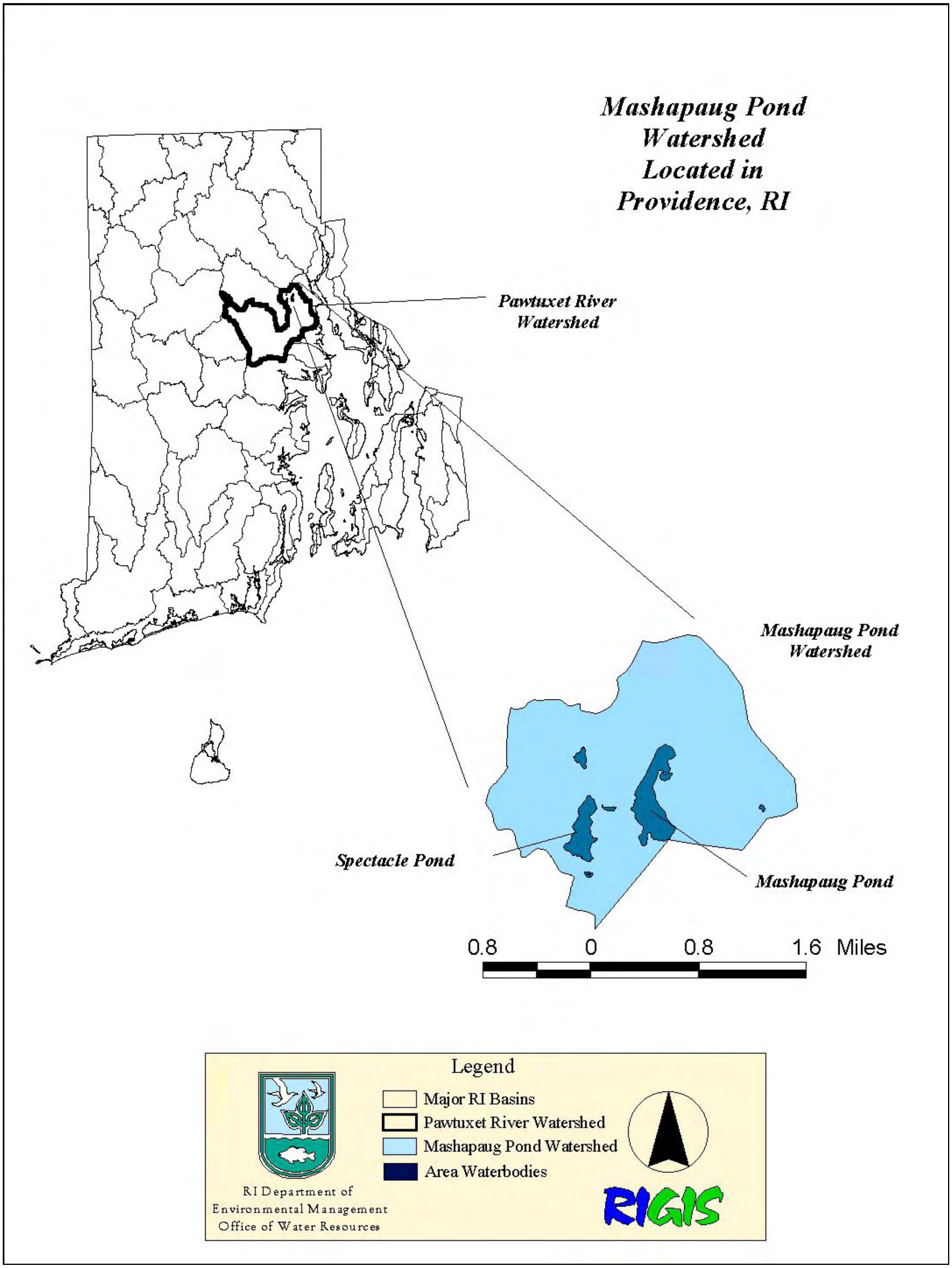
[1] **Primary Contact Recreational/Swimming Criteria-** Not to exceed a geometric mean value of 200 MPN/100 ml and not more than 10% of the total samples taken shall exceed 400 MPN/100 ml, applied only when adequate enterococci data are not available.

Figure 1.1 Map of Study Area



1.3 Priority Ranking

Rhode Island Department of Environmental Management organizes the state's 303(d) list into five groups to describe the progress of the TMDL development process for each impaired waterbody. Group 1 waterbodies are waters that are not meeting Rhode Island's Water Quality Standards and TMDL development is underway. The 2006 303(d) List of Impaired Waters places Mashapaug Pond in Group 1 for hypoxia or low dissolved oxygen, excess algal growth/Chl-a, Phosphorus and pathogens. Pathogens were added as an impairment following the 2001 monitoring program.

1.4 Applicable Water Quality Standards

1.4.1 Designated Uses and Antidegradation

According to Appendix A of the Rhode Island Water Quality Regulations as amended June 23, 2000, Mashapaug Pond (RI0006017), and Mashapaug Brook from the outfall at Spectacle Pond, are Class B waters.

The Class B water use classification is as follows:

Class B – These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.

1.4.2 Numeric Water Quality Criteria

The applicable water quality standards are as follows (DEM, 2006):

- Dissolved Oxygen Warm Water Fish Habitat – DO content not less than 60% saturation, based on a daily average, and an instantaneous minimum DO concentration of at least 5mg/L, except as naturally occurs. The 7-day mean water column DO concentration shall not be less than 6 mg/L.

- Nutrients

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

(b) None [nutrients] in such a concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedence of the criterion of (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.

- Fecal Coliform

  Not to exceed a geometric mean value of 200 MPN/100 ml and not more than 10% of the total samples taken shall exceed 400 MPN/100 ml, applied only when adequate enterococci data are not available.

1.4.3 TMDL Objective

The objective of the Mashapaug Pond TMDL is to identify measures needed to restore the designated uses of Mashapaug Pond. These impaired uses include support of fish propagation and other animal life in the pond, and swimming. The identified cause of the impairment is excessive phosphorus loads that contribute to algae concentrations, which in turn contribute to low dissolved oxygen concentrations that impair fish and animal survival and loss of habitat. The phosphorus loads also contribute to the growth of blue-green algae species *Anabaena planctonica*, *Microcystis aeruginosa*, and *Aphanizomenon flos-aquae* that have been identified as hazardous to humans (through skin contact), making the pond unsafe for swimming. The objectives will be met by meeting the following water quality goals:

- Reduce the average Total Phosphorus concentration in the pond to 20 ug/l.
- Eliminate hypoxia (DO< 2 mg//l) in the hypolimnion to support propagation of fish and other animal life in the pond.
- Reduce algal abundance (chlorophyll-a) to levels consistent with the designated uses.
- Reduce wet weather fecal coliform elevations

2.0 DESCRIPTION OF STUDY AREA

2.1 Land Use

The area surrounding Mashapaug Pond is entirely urban. Two categories of surface water inflows from the land were considered; storms drains, and direct overland runoff. Six storm drains discharge directly into the pond. A map of their drainage areas is presented in Figure 2.1. The area adjacent to the pond shore also contributes runoff sheet flow to the lake. The areas and land uses of these two categories were used to calculate flows and nutrient loads to the pond.

Storm sewer and topographic maps were used to delineate the catchment areas to the six storm drains. RIGIS land use data was used to determine the land uses in each storm drain catchment area. These land uses are presented in Table 2.1.

Table 2-1 Land uses in the Storm Drain Contributing Areas

Land Use Type \ Area (%)	SD1	SD2	SD3	SD4	SD5	SD6
High Density Residential		20.1%				
Medium High Density Residential	16.9%					81.5%
Commercial	6.5%	4.5%				
Industrial	1.2%	75.4%	100.0%	86.6%	77.0%	
Roads	59.8%			2.8%		
Commercial / Industrial Mixed				10.6%		
Developed Recreation					23.0%	3.5%
Deciduous Forest	15.7%					15.2%
Area (acres)	4.1	4.2	5.0	77.0	11.5	9.0

The areas immediately adjacent to the pond shore where no sewers or storm drains exist were assumed to drain directly into the pond. Using the sewer maps, topographic maps, and aerial photography, the direct-runoff drainage area was determined and delineated into six regions based on the land use. A map of the six drainage regions is presented in Figure 2.2. The land uses in each area are presented in Table 2.2.

Table 2-2 Land uses in the Direct Runoff Drainage Areas

Land Use Type \ Area (%)	S1	S2	S3	S4	S5	S6
High Density Residential	46.2%	7.5%				
Medium High Density Residential				11.6%	19.4%	
Commercial	52.0%					
Industrial		92.5%	99.4%	11.1%	62.6%	95.1%
Developed Recreation					18.0%	
Deciduous Forest	1.8%			77.3%		
Wetlands			0.6%			4.9%
Area (acres)	9.2	9.5	16.7	6.1	10.4	10.7

Figure 2.1 Drainage Areas for the Storm Drains Discharging into Mashapaug Pond

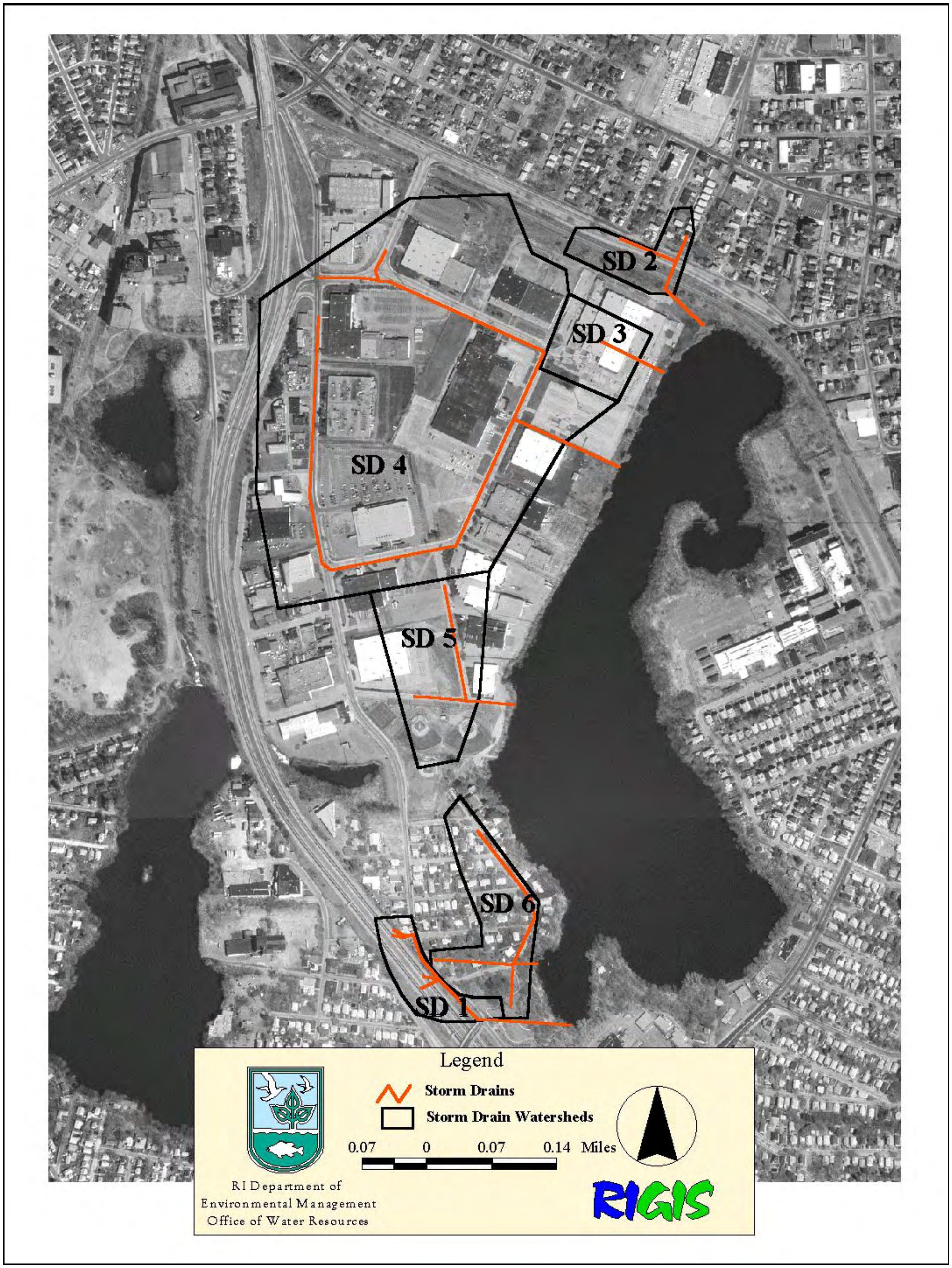
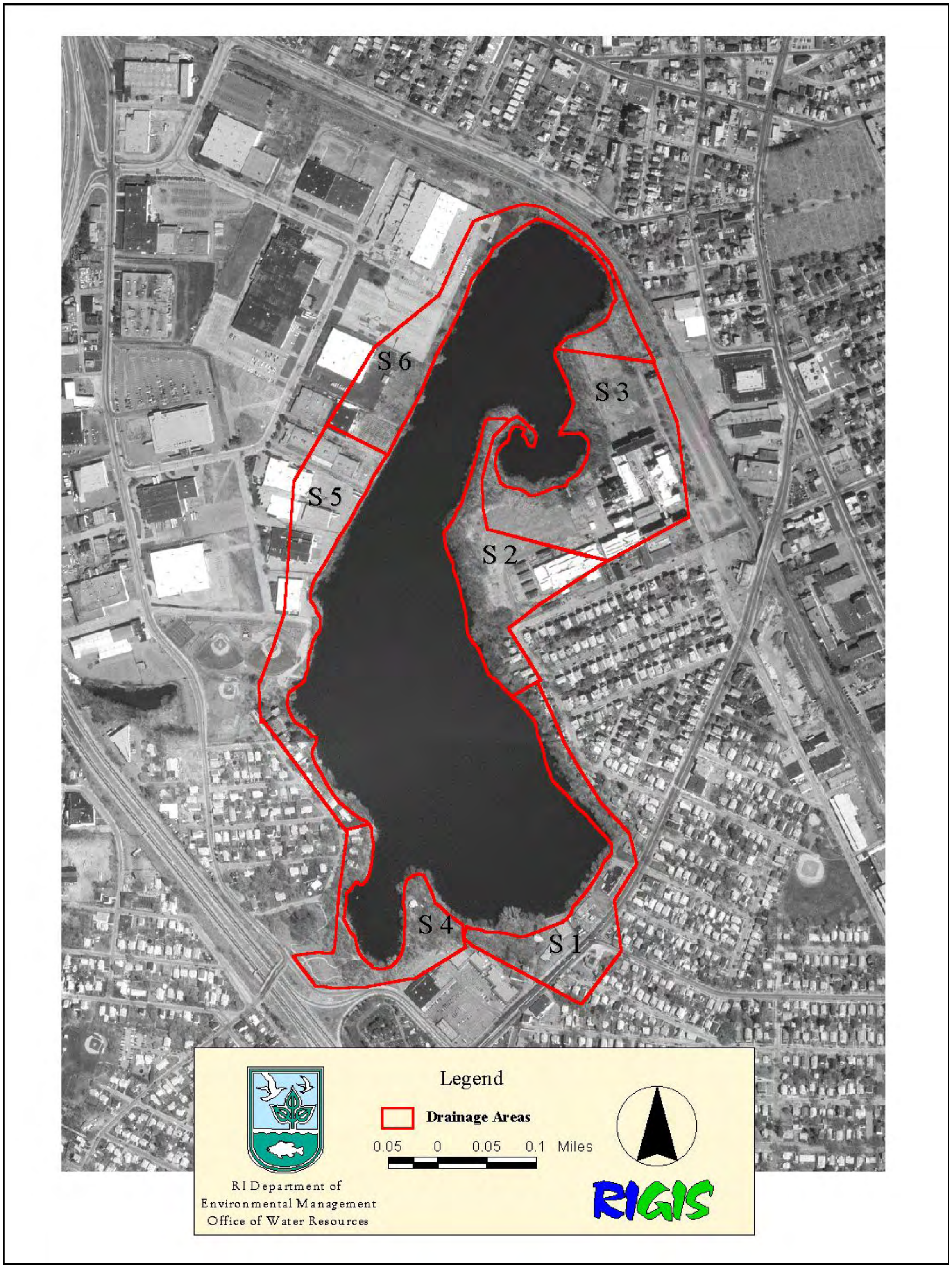


Figure 2.2 Drainage Areas for the Land Adjacent to Mashapaug Pond



2.2 Soils

Soil surrounding Mashapaug Pond was characterized using the State Soil Geographic (STATSGO) Data Base. It was determined that the soil in the storm drain and direct runoff watersheds was of the MUID (Map Unit Identifier) RI006. The RI006 soil series contains Merrimac, Udorthents, Canton, Sudbury, Hinckley, Walpole, and Adrian soil types. Most of these soil types have moderately rapid permeability.

2.3 Pond Hydrology

Inputs of water into Mashapaug Pond include precipitation, storm sewer drainage, direct overland runoff, and ground water. Mashapaug Pond is fed by groundwater discharging into the bottom and edges of the pond. The pond has one tributary, Mashapaug Brook that enters from Spectacle Pond. The outlet is located in the southeast corner of the pond in which a concrete weir structure controls the flow.

During wet weather, the pond receives flow from the six storm drains on its west side, direct runoff from the area adjacent to the pond, Mashapaug Brook, and rain that falls directly onto the surface. Part of the monitoring plan carried out during the summer of 2001 involved the collection of wet weather data. One storm event totaling 0.32 inches of rain was monitored on September 25 and 26, 2001. The flow rate at each storm drain was measured during the storm event. One of the storm drains, SD6, also flowed during dry weather monitoring periods. None of the other storm drains were flowing during the dry weather monitoring dates.

2.4 Bathymetry

A bathymetric map of the pond was produced through field measurements taken during the 2001 data collection effort. The pond depth varies spatially with the deepest depths in the southern portion of the pond ranging from 4 to 5 meters (13 to 16 ft). There is a small area in the northern portion of the pond that is about 4 meters (13 ft) deep. The bathymetry for the pond is presented in Figure 2.4.

2.5 Hydrologic Budget

The estimated annual hydrologic budget (Jan-Dec 2001) for Mashapaug Pond was derived from a combination of inflows (direct precipitation to the pond surface, surface water base flow, surface water storm runoff, groundwater underflow) and outflows (evaporation and outflow through the pond outlet). The average annual inflow rate was estimated as 2.71 cfs. The complete hydrologic budget is presented in Table 2.3.

Table 2-3 Mashapaug Pond Annual Hydrologic Budget (Jan-Dec 2001)

Inflows and Outflows	Annual Volume (m^3)	Average Annual Flow Rate (cfs)
Direct rainfall to pond surface	278,140	0.31
Storm Drain runoff	246,971	0.28
Direct Overland runoff	134,978	0.15
Spectacle Pond base flow	1,044,926	1.17
Spectacle Pond storm runoff	12,254	0.01
Groundwater underflow	701,583	0.79
Total Inflow	2,418,852	2.71
Evaporation	202,912	0.23
Outflow through pond outlet	2,215,940	2.48
Total Outflow	2,418,852	2.71

Figure 2.3 Land Uses for the Area Adjacent to Mashapaug Pond

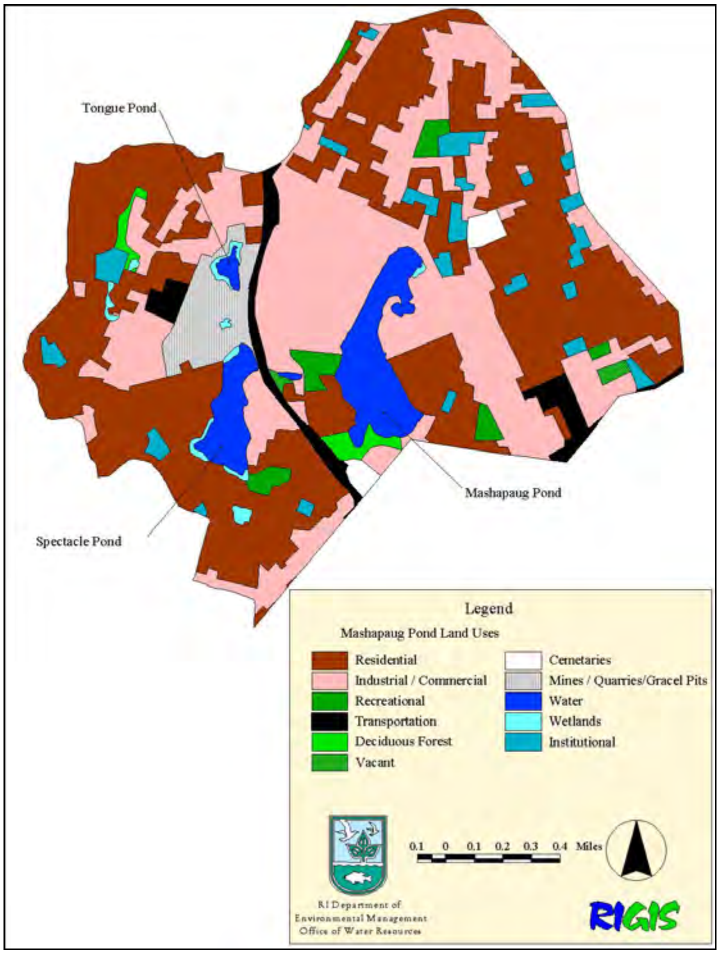
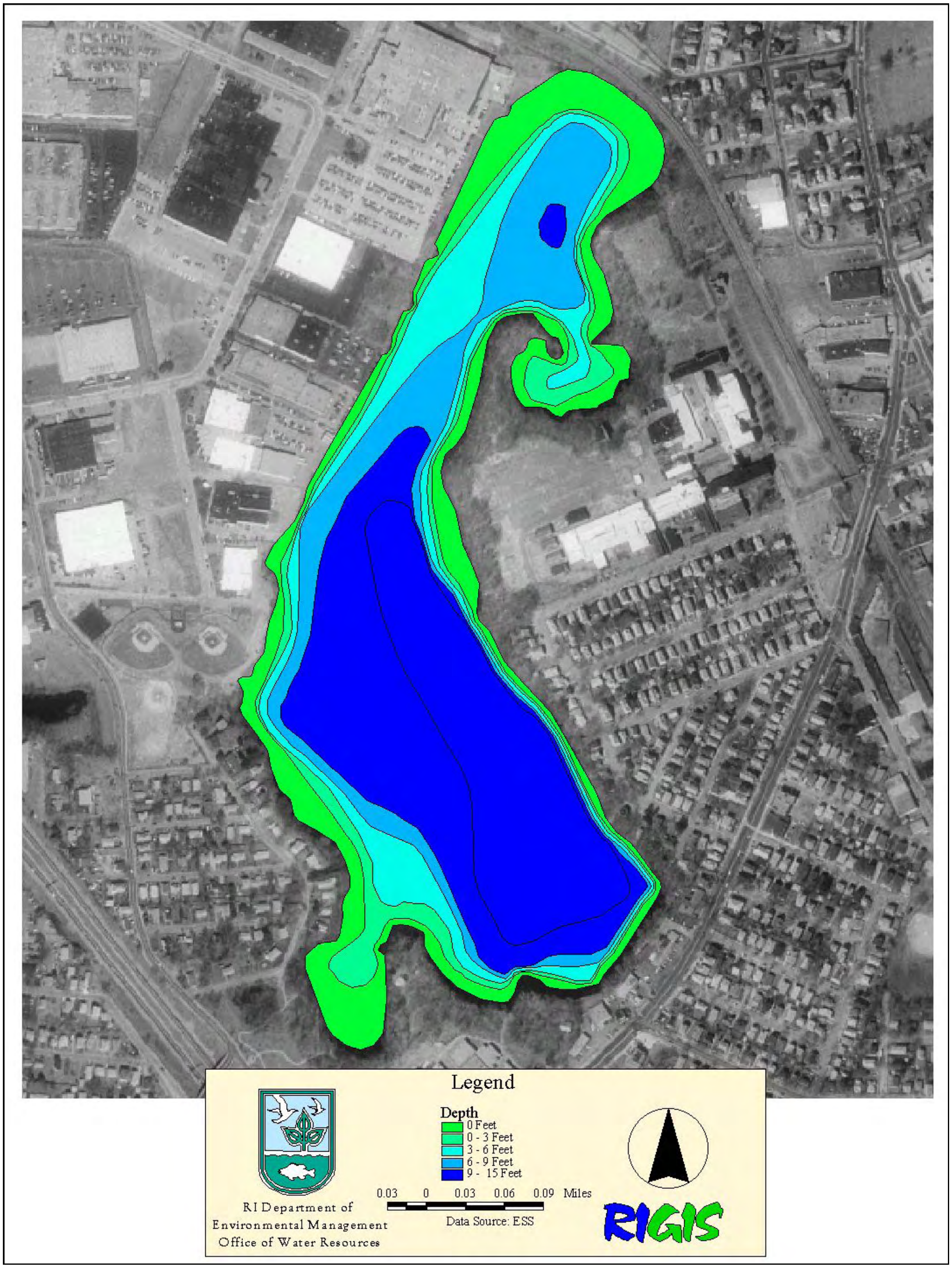


Figure 2.4 Bathymetry of Mashapaug Pond



3.0 PRESENT CONDITION OF WATERBODY

3.1 Current Water Quality Conditions

Water quality standards for dissolved oxygen and phosphorus are not met in Mashapaug Pond under existing conditions. Average total phosphorus levels ranged from 30 –50 ug/l during the summer of 2001 in violation of the states water quality standards. During this same time period dissolved oxygen levels ranged from a low of 0 mg/l in the hypolimnion or bottom waters to 12 mg/l at the surface. Additional information is contained in “Mashapaug Pond Data Report and Analysis, Summer 2001, Mashapaug Pond, Providence, Rhode Island” and “Data Review for Mashapaug Pond, Providence, Rhode Island, August 2001”. Both reports may be found in the Appendices.

A review of the available fecal coliform dataset (May 2000 – October 2004) which includes the data collected for this TMDL and that collected by URI Watershed Watch volunteers, finds a geomean of 40.7 MPN/100ml and compliance with the variability criterion and thus no exceedence of the fecal coliform criteria for this Class B pond. However, wet weather monitoring conducted on the pond and its tributaries during a rain event on September 25, 2001 revealed a significant increase in the pond’s water column concentration of fecal coliform during the storm event – though levels returned to pre-storm concentrations within 24 hours. The fecal coliform concentrations of several of the storm drains and the inlet from Spectacle Pond (Station MP-3) increased thousands of times greater than the background values measured in the pond’s water column.

3.2 Pollutant Sources

Pollutant sources are divided into point and nonpoint categories. Point source pollution includes discrete discharges generated by any discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, or well from which pollutants may be discharged. Nonpoint source pollution represents diffuse sources such as sheet runoff from streets, parking lots, and lawns, groundwater underflow, and atmospheric deposition.

3.2.1 Point Sources

The following table identifies the location of the storm drains that discharge directly to Mashapaug Pond.

Table 3-1 Mashapaug Pond Storm Drains

Storm Drain Identification	Street Location
SD1	Niantic Ave @ southern end of pond
SD2	Dexter Street drain
SD3	DuPont Drive drain
SD4	Parking lot drain from industrial complex on DuPont Drive
SD5	Pawnee Street drain
SD6	Lakeview Drive drain at Westmore Street

Six storm drains (SD1 – SD6) convey storm water runoff directly to Mashapaug Pond (Figure 2.1 and Table 3-1). Results from the empirical based load calculations by Tetra Tech (2001) indicate that these direct discharges contribute 22% of the total phosphorus loading to Mashapaug Pond. The source of pollution to these storm drains is runoff from non-point sources such as streets, parking lots, rooftops, and lawns. SD6 was the only storm drain that flowed during dry weather in 2001. Samples from this drain were taken four times over the course of the 2001 monitoring program. The mean total phosphorus concentration was 67 ug/l, and the mean fecal coliform concentration was 280 col/100ml.

Wet weather samples were taken at five of the six storm drains. Drain SD4 did not flow during the 2001 sampling events including during wet weather. The lack of flow from this drain warrants a recheck of the drainage system flow assumptions and a potential revision to the stormwater system maps. The mean total phosphorus concentration in storm drains contributing wet weather flows ranged from a low of 27 ug/l (SD3) to a high of 150 ug/l at SD5. The mean fecal coliform concentration in storm drains collected over a 24 hour period during a storm on September 25, 2001 ranged from 954 col/100ml (SD3) to a high of 53,288 col/100ml (SD6) and a single sample maximum of 460,000 col/100ml (SD5). The inlet from Spectacle Pond (MP3), which includes runoff from Route 10, was the most significant observed source of fecal coliform to the pond.

3.2.2 Non-point Sources

The 2001 monitoring study concluded that the majority of the total phosphorus loading to Mashapaug Pond comes from base flow entering from Spectacle Pond (47%) and direct overland runoff (13%). The study identified six areas shown in figure 2.2 that contribute non-point loads to the pond via sheet runoff. Other non-point sources of total phosphorus include atmospheric deposition (11%) and groundwater (7%).

3.3 Natural Background Conditions

The condition of Mashapaug Pond that would be expected in the absence of human activities in its watershed was estimated from conditions in two similar ponds, Upper Schoolhouse Pond and Wakefield Pond (Tetra Tech, 2001). Data for these ponds was obtained from URI Watershed Watch Program. Upper Schoolhouse Pond is located in a rural area within the Narragansett Indian tribe reservation. Wakefield Pond is also located in a rural area and is primarily wooded. URIWW volunteers have been collecting data on these ponds for a number of years. Data were available for Schoolhouse Pond for the summer of 2001 and for Wakefield Pond for the summer of 1997. Vertical temperature differences in the ponds typically ranged from 3-8^{o} C. (Figures 3.1 and 3.2). The naturally occurring stratification in these ponds lowered dissolved oxygen down to 2.5 mg/l in the hypolimnia. Hypolimnetic DO declines during the summer because it is cutoff from all sources of oxygen, while organisms continue to respire and decay, consuming oxygen.

Figure 3.1 Upper Schoolhouse Pond Temperature and DO Profiles

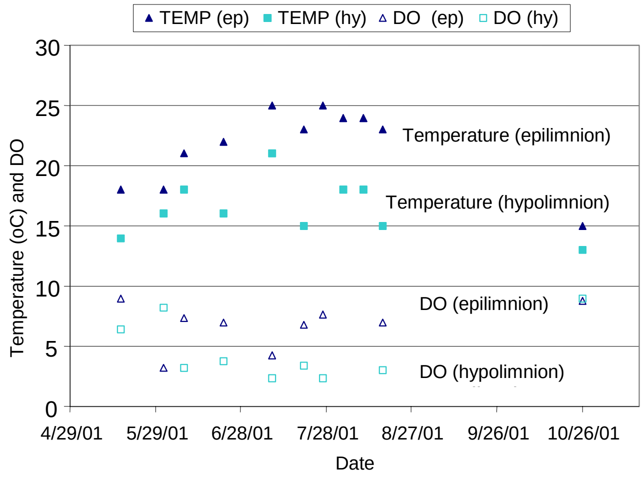
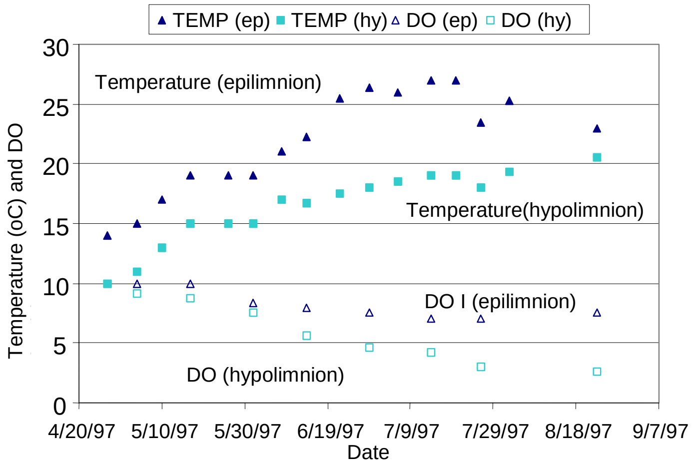


Figure 3.2 Wakefield Pond Temperature and DO Profiles



In addition to the two lakes referenced above, historic DO and temperature profiles were analyzed for several other ponds that had similar bathymetry and comparable acreage to that of Mashapaug Pond. The Rhode Island Division of Fish and Wildlife routinely conducts fishery investigations and collects management data for Rhode Island lakes and ponds (Guthrie and Stolgitis, 1977).

Historic data clearly indicates that many other similar ponds consistently exhibit DO concentrations in the hypolimnion in the 2.0 – 5.0 mg/l range. As shown in Table 3-2 these lakes were in undeveloped watersheds prior to the sampling and would therefore be considered “natural conditions”. For those lakes that do not thermally stratify, DO levels appear to remain above 3 mg/l in the hypolimnia. The two similar lakes, Sucker Pond and Yawgoog Pond that exhibit stratification, display DO levels that fall into the lower range (2-3 mg/l) in their bottom waters.

In some years Mashapaug Pond does not stratify. In other years, dependent upon weather conditions, it does. Pascoag Lake in northern Rhode Island is similarly affected and also demonstrates conditions that do not support a significant thermocline. URIWW data for Pascoag Lake indicate that low DO conditions appear to be dependent upon the presence of stratification. Figures 3.2 and 3.3 show temperature and DO graphs from 1998 and 2002 for Pascoag Reservoir. In 1998 the pond displayed a thermocline that started in June and continued into early August. Correspondingly the dissolved oxygen levels in the pond dropped substantially to anoxic conditions (0 mg/l of DO) as temperatures in the pond rose. Once the pond’s temperatures stabilized or began to decrease, DO levels rose to acceptable levels. For the same time period in 2002, temperatures in the pond remained relatively consistent throughout the entire water column, with minimal thermal stratification. DO levels remain above 6 mg/l throughout the entire 2002 monitoring season.

3.4 Water Quality Impairments

Eutrophication is a natural process characterized by a development towards an environment rich in nutrients and an increase in plant production. Man-made “cultural” eutrophication is caused by excessive discharge of nutrients, especially phosphorus from man-made sources. Observed effects of eutrophication include discolored water, excessive algae and bacteria production, and the demise of aquatic organisms due to oxygen depletion. Biodiversity in these aquatic ecosystems is often low. Low dissolved oxygen, excess phosphorus, and a change in phytoplankton communities are used as indicators of this process.

3.4.1 Dissolved Oxygen

The historical (Guthrie and Stolgitis, 1977) and 2001 data indicate that Mashapaug Pond has low dissolved oxygen concentrations in its hypolimnion. During 2001, dissolved oxygen concentrations in the hypolimnia were below 60% saturation throughout the summer and near zero between late June through late August. Figures 3.5 and 3.6 show the temperature and dissolved oxygen observations over the course of the summer of 2001 in Mashapaug Pond. Figure 3.5 shows data collected in the north section (Station MP-1) of the Pond, while Figure 3.6 shows data collected in the south section (Station MP-2).

Figure 3.3 Pascoag Reservoir URIWW

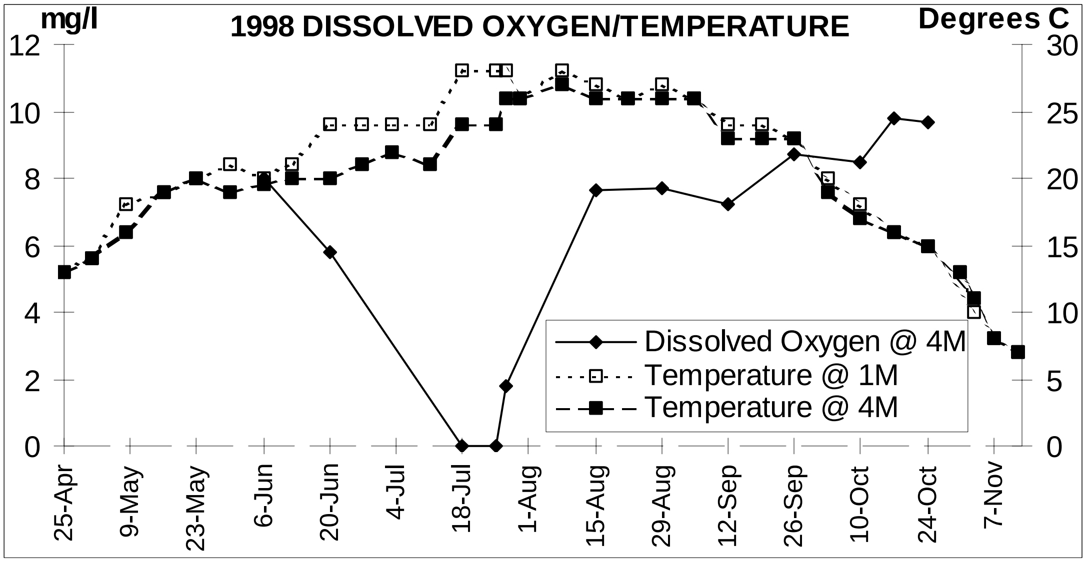


Figure 3.4 Pascoag Reservoir URIWW

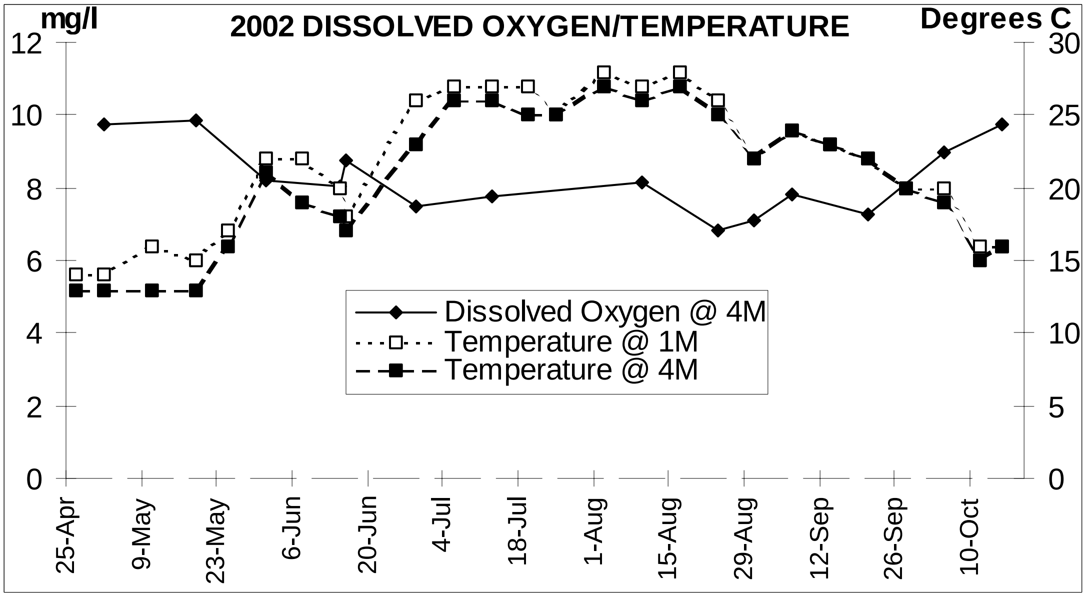


Table 3-2 Historic DO and Temperature Data (Stolgitis and Guthrie, 1977)

	Pond Area (Acres)	Max Depth (Ft.)	Avg. Depth (Ft.)	Sample Date	Thermocline	Temp. Range (C^0)	D.O. @ Surface (mg/l)	D.O. @ Depth (mg/l)	Watershed Description (Yrs. prior to sampling)
Mashapaug Pond	**69**	**17**	**7**	**7/23/57**	**NO**	**22-23**	**11**	**3@13’**	**Developed Residential & Industrial**
Lower Slatersville Res.	72	16	16	8/5/60	MIN/NO	22-23	6	5@13’	Undeveloped
Olney Pond	120	15	15	7/31/67	NO	26-30	9	4.5@13’	Undeveloped
Wenscott Reservoir	78	11	11	8/13/57	NO	21	6	4@9’	Undeveloped
Locustville Pond	83	12	12	8/7/64	MIN/NO	22-24	8	5@13’	Transition from Farm to Residential
Sucker Pond	57	23	10	7/2/68	YES	11-26	7	2@25.6’[1]	Undeveloped
Yawgoog Pond	163	26	16	8/5/55	YES	11-26	7	3@26’	Cleared Farm land

[1] Inconsistent depth data – Limnology states max depth = 23’, Bathymetry and DO/Temperature profile has data @ 7.8m = 25.6’.

Figure 3.5 Mashapaug Pond (Station MP-1) Temperature and DO Profiles

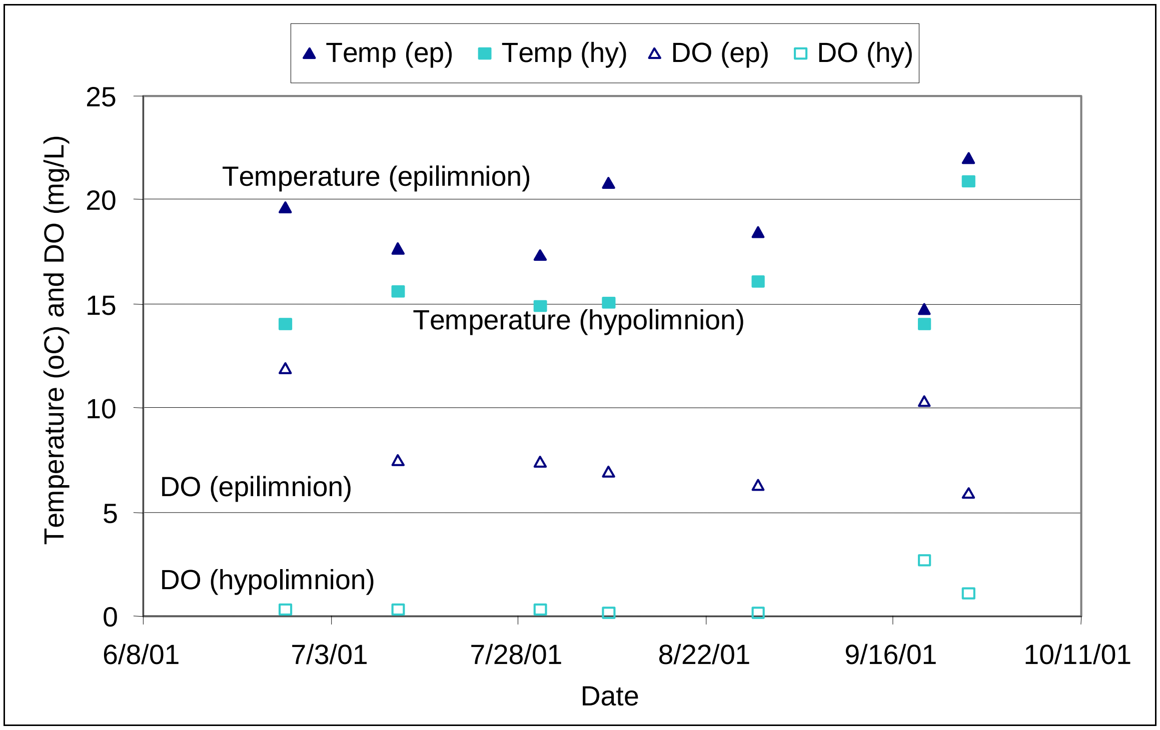
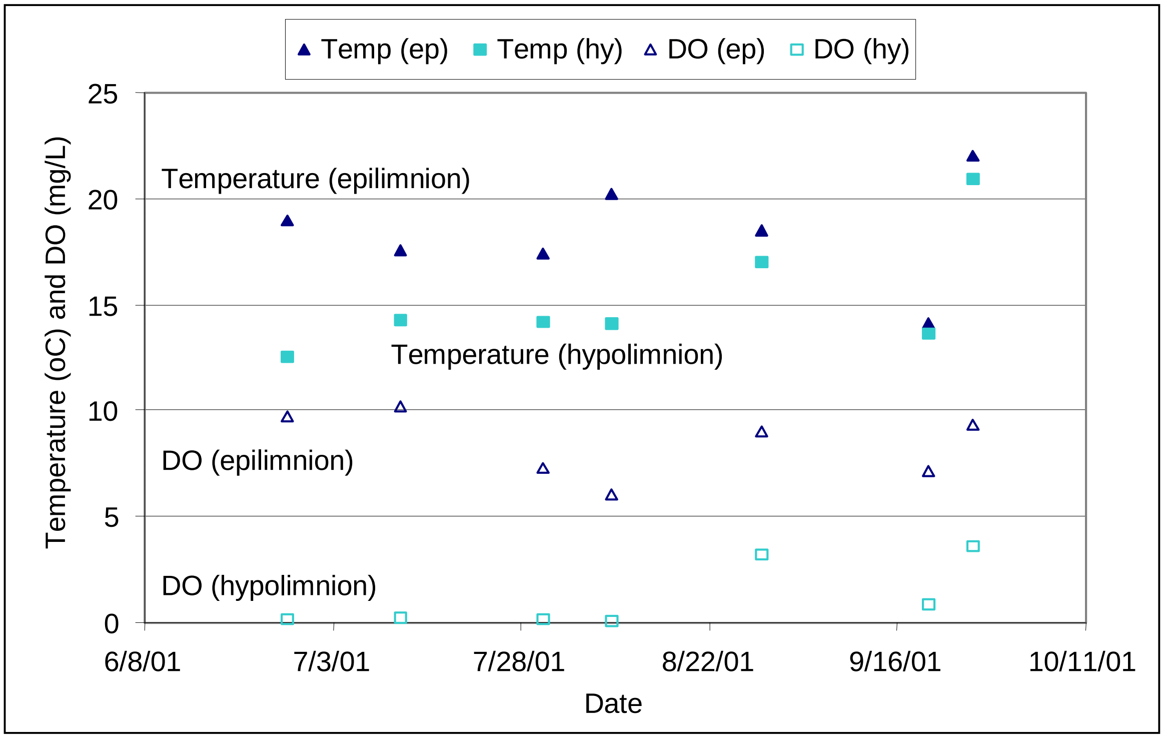


Figure 3.6 Mashapaug Pond (Station MP-2) Temperature and DO Profiles



3.4.2 Phytoplankton Community

Three phytoplankton species that are indicative of eutrophic lakes were identified during the 2001 sampling of Mashapaug Pond. These species are all bluegreen algae (Cyanobacteria or Cyanophyta) and included the species: *Anabaena planctonica*, *Microcystis aeruginosa*, and *Aphanizomenon flos-aquae*. Carlson's Trophic Status Index (TSI), another indicator of eutrophication, was calculated for the pond. TSI uses chlorophyll a as a measure of trophic state. Index values range from 0 (ultraoliogotrophic) to 100 (hypereutrophic). TSI value between 50 and 70 is considered eutrophic while a value above 70 is considered hypereutrophic (Carlson 1977). Mashapaug Pond TSI measurements were 68.6 and 70.5, which places the pond near the hypereutrophic category. The full analysis of Carlson's TSI for Mashapaug Pond may be found in Appendix B.

3.4.3 Nutrients

Either nitrogen or phosphorus typically control eutrophication in freshwater systems. The limiting nutrient is defined as the nutrient that limits plant growth because it is not available in sufficient quantities. Controlling this "limiting" nutrient can often slow the rate of eutrophication and improve lake and pond conditions.

An initial identification of the limiting nutrient can be made by comparing the levels of nutrients in the waterbody with the plant stoichiometry. The mass ratio of nitrogen to phosphorus in biomass is approximately 7.2:1, therefore, an N: P ratio in the water that is less than that suggests that nitrogen is limiting. Alternatively, higher ratios suggest that phosphorus is limiting (Chapra, 1997). The average total nitrogen to total phosphorus ratio for all samples for Mashapaug Pond was 29, indicating that phosphorus is the limiting nutrient. The standard for total phosphorus (0.025 mg/L) was exceeded in 23 of the 26 samples collected at stations MP-1 and MP-2 on seven different dates during the summer of 2001. Total phosphorus at the two stations had an average value of 0.039 mg/L, a minimum of 0.022 mg/L, and a maximum of 0.086 mg/L.

4.0 MODELING

4.1 Eutrophication Modeling

Modeling the physics, chemistry, and biology of streams, lakes, estuaries, and coastal waters requires a model that incorporates all the major processes. Transport processes for this study were simulated using the three-dimensional Environmental Fluid Dynamics Code (EFDC) hydrodynamic model that includes temperature heat flux processes and eutrophication water quality kinetics. The EFDC model was developed by Hamrick (1992). The model formulation is based on the principles expressed by the equations of motion, conservation of mass, and conservation of volume. Quantities computed by the model include three-dimensional velocities, surface elevation, vertical viscosity, temperature, salinity, and sediment transport.

4.1.1 General Description of EFDC Model

EFDC is a general purpose modeling package for simulating three-dimensional flow, transport, and biogeochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is public domain code. Tetra Tech, Inc., currently maintains the model with partial support from USEPA. EFDC is capable of simulating hydrodynamic, salinity and temperature transport, and eutrophication processes.

The EFDC code includes an internal eutrophication submodel for water quality simulation (Park et al., 1995). The full eutrophication model is functionally equivalent to the CE-QUAL-ICM or Chesapeake Bay Water Quality model (Cerco and Cole, 1993). Both water column eutrophication models are coupled to a functionally equivalent implementation of the CE-QUAL-ICM sediment diagenesis or biogeochemical processes model (DiToro and Fitzpatrick, 1993). The eutrophication model is executed simultaneously with the hydrodynamic component of EFDC. The eutrophication model accepts an arbitrary number of point and nonpoint source loadings as well as atmospheric deposition and groundwater loadings.

4.1.2 Modeling Approach

According to the 303(d) listing, Mashapaug Pond is impaired for nutrients and hypoxia. The monitoring data collected in 2001 indicate that hypoxia (i.e., DO less than 2 mg/L) exists in the hypolimnion (bottom layer) of the pond. The epilimnion (surface layer) was characterized by dissolved oxygen concentrations that were consistently above the water quality criteria and, in many samples, were above the DO saturation concentration. The vertical profile of temperature also indicated the pond is highly stratified during the summer months with surface temperatures ranging from 3°C to 10°C higher than bottom temperatures. In order to adequately simulate the vertical temperature and DO characteristics of the pond, EFDC was applied in a 3-d mode. Adequate simulation of the vertical structure of the pond was important if the “natural” conditions of the pond were to be represented in the modeling phase of the project in which hypoxia would be calculated as one of the TMDL endpoints for the pond. Obviously, the use of a depth average model would not be able to resolve the vertical DO profile and hence would not correctly be able to determine whether hypoxic conditions exist in the lower layer of the pond.

Another advanced feature of the EFDC model approach, not available with a simpler model, was the predictive sediment diagenesis. The sediment diagenesis model adjusts benthic flux rates depending on the rate of particulate organic matter deposited to the bed of the pond. One well-known uncertainty with other water quality models revolves around the question: “what should the sediment oxygen demand rate be if the loading to a water body are changed?” The sediment diagenesis model helps minimize this uncertainty by allowing the model to predict the change in sediment oxygen demand due to changes in the loading of particulate organic matter.

4.1.3 Eutrophication Process

Algae in the water column eventually become deposited as organic matter and decay in the bottom sediments, which contributes to oxygen demand. Nutrients in the pond are taken up by alga and predation, which results in the transfer of nutrients to the benthic sediments. As temperature increase during the summer nutrients are mineralized (converted to inorganic form) in the sediments and released back into the water column. Nutrients released from the sediments support the summer algal bloom. Carbon produced by algae settles to bottom waters, decays, and consumes oxygen. Low oxygen in bottom water enhances the release of sediment nutrients, especially ammonia. The nutrient release continues the cycle of benthic release, algal production, and oxygen consumption. This cycle that is simulated by the EFDC predictive sediment processes submodel.

Total phosphorus is conservative in the sediments. The pathways for removal of phosphorus from the sediments are recycling of inorganic phosphorus back to the water column or burial to deep, isolated sediments. On the other hand, a significant fraction of total N may be lost through denitrification to nitrogen gas. The nitrogen loss is such that the nitrogen returned to the water column is roughly half the amount expected based on the nitrogen to phosphorus ratio of the incoming material. The reduced nitrogen to phosphorus ratio of dissolved fluxes leaving the sediments, compared to particle fluxes entering the sediments, acting over lengthy time scales, pushes the water column toward nitrogen rather than phosphorus limitation.

4.1.4 Sediment Water Interactions

Over time scales of years, benthic sediments act as sinks for oxygen, nitrogen, phosphorus, and silica removed from the water column. Oxygen is consumed by the oxygenation of organic carbon and by the nitrification of ammonia. Certain fractions of particulate nitrogen, phosphorus, and silica that settle into bottom sediments are buried to deeper sediment layers from which recycling to the water column is not possible.

Over seasonal time scales, sediments can be significant sources of dissolved nutrients to the overlying water. The role of sediments in the system-wide nutrient budget is especially important during the summer when seasonal low flows diminish tributary nutrient loads. During the summer, warm temperature enhances biological processes in the sediments. The decay (i.e., diagenesis) of organic matter produces phosphate, ammonia, and silica that are released into the overlying water.

4.2 Data to Support Modeling Analysis

4.2.1 Bathymetric and Stream Geometry Data

The Mashapaug Pond EFDC model incorporates a three-dimensional waterbody into its framework. The model consists of 54 grid cells having horizontal dimensions ranging from 55 to 92 meters per side (see Figure 4.1). The model was constructed with 5 vertical layers to resolve the stratification phenomenon observed in the pond. Bathymetric data were measured during the 2001 field survey and were used to develop the model. The deepest point in the southern portion of the pond is at station MP-1 where the water depth was about 4.5 meters (16 feet). The surface area of the pond was $2.96 \times 10^{5} m^{2}$ and the volume was calculated as $8.87 \times 10^{5} m^{3}$. The average depth of the pond was 3.0 meters (9.8 ft). Shoreline information for the pond was obtained from the 1:100,000 Digital Line Graph CD-ROM published by the USGS.

4.2.2 Climatology Data

Meteorological data for Providence, Rhode Island were obtained from the National Climatic Data Center. These data included hourly summaries of atmospheric pressure, air temperature, relative humidity, wind speed, wind direction, cloud cover, and precipitation. Estimates of hourly solar radiation were obtained by using the observed solar radiation from 1961-1990 at Providence. The maximum solar radiation was determined for each hour of each day of the year from the 30-year record. This was assumed to be the clear-sky solar radiation. The hourly cloud cover data were then used to adjust the clear-sky solar radiation to actual solar radiation for each hour of the 2001 calibration period.

4.2.3 Dry-Weather and Wet-Weather Flow Data

There are no USGS stream gaging stations in the Mashapaug Pond watershed. Stream flow measurements were made at the six storm drains and at Mashapaug Brook, which drains Spectacle Pond (see Figure 4.1). During dry weather conditions, flow was observed only at storm drain SD6 and in the Spectacle Pond outlet (MP-3). The average dry weather flow rate measured at SD6 was 0.03 cfs, and the average at the Spectacle Pond outlet was .76 cfs. Flows were also measured during the storm event on September 25-26, 2001 at the six storm drains and at Mashapaug Brook. These stormwater flows are reported in the Mashapaug Pond monitoring data report (ESS, 2002). Wet-weather flows were also estimated for the direct overland runoff areas shown in Figure 4.2. Hourly rainfall-runoff flow rates for each land use area were computed using the rational method ($Q=CiA$) where C is the runoff coefficient of a given land use (see Table 4.1), *i* is the rainfall during a one-hour period, and *A* is the land use area. The individual one-hour rainfall increments were superimposed to build a hydrograph for each catchment contributing to a storm drain or overland runoff area. The event mean TP concentrations for each land use (see Table 5.1) were used to calculate the loadings entering the pond from each catchment during storm events.

Table 4-1 Runoff Coefficient (C) for Different Land Uses in Mashapaug Pond Watershed

Land Use Designation	Runoff Coefficient (*C*)
High density residential (< 1/8 acre lots)	0.65
Medium density residential (1/8 to 1/4 acre lots)	0.55
Commercial (sale of products and services)	0.65
Industrial (manufacturing, design, assembly, etc.)	0.60
Roads (divided highways > 200 ft; related facilities)	0.60
Commercial / Industrial mixed	0.60
Developed recreation (all recreation)	0.40
Deciduous forest (>80% hardwood)	0.25
Wetlands	0.10

4.2.4 Groundwater Data

Estimates of groundwater flow rates and nutrient concentrations were made based on field measurements taken during the 2001 field survey. The average measured groundwater flow rate to the pond was measured as 6.5 L/m^2/day or an average inflow rate of 0.79 cfs. Groundwater concentrations of dissolved phosphorus, ammonia nitrogen, and nitrite+nitrate nitrogen were also measured at six locations along the shoreline of Mashapaug Pond (see Figure 4.3). The concentrations and flow rates were used to estimate groundwater loads to the model.

4.2.5 Water Quality Monitoring Data

Characterization of pond water quality was required for the development of a model that could be used for TMDL analysis. The primary source of water-column water quality data used for the model calibration was collected during the summer of 2001. A detailed description of the Summer 2001 field surveys can be found in the Mashapaug Pond monitoring data report in ESS (2002). Data from the 2001 field monitoring study were compiled into a comprehensive and flexible database (dBase III format) to characterize the existing water quality conditions in Mashapaug Pond. The water quality database was used to compile time-series data sets for comparison to model results.

4.2.6 Atmospheric Deposition Data

Atmospheric loads are typically divided into wet and dry deposition. Wet deposition is typically associated with dissolved substances in rainfall. The settling of particulate matter during nonrainfall events contributes to dry deposition. Observations of concentrations in rainwater are frequently available, and dry deposition is usually estimated as a fraction of the wet deposition. The atmospheric deposition rates reported in the Long Island Sound Study (Hydro Qual, 1991) and the Chesapeake Bay Model Study (Cerco and Cole, 1993) were used to develop both dry and wet deposition loads for the EFDC model of Mashapaug Pond. The dry atmospheric deposition rates are presented in Table 4.2 and the wet deposition concentrations are shown in Table 4.3. The loading rate for wet deposition of nutrients was computed internally by the model by multiplying the rainfall rate times the nutrient concentration during each model time step.

Table 4-2 Atmospheric Dry Deposition Rates used in Mashapaug Pond EFDC Model

Parameter	Deposition Rate ($g/m^2/day$)	Parameter	Deposition Rate ($g/m^2/day$)
Refractory Particulate Organic Carbon	0.000387	Refractory Particulate Organic Nitrogen	0.000530
Labile Particulate Organic Carbon	0.000387	Labile Particulate Organic Nitrogen	0.000530
Dissolved Organic Carbon	0.000773	Dissolved Organic Nitrogen	0.000771
Dissolved Organic Phosphorus	0.000054	Ammonia Nitrogen	0.000214
Orthophosphate	0.000019	Nitrate+Nitrite Nitrogen	0.000393
Available Silica	0.000247		

Table 4-3 Atmospheric Wet Deposition Rates used in Mashapaug Pond EFDC Model

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Refractory Particulate Organic Carbon	0.325	Refractory Particulate Organic Nitrogen	0.0
Labile Particulate Organic Carbon	0.325	Labile Particulate Organic Nitrogen	0.0
Dissolved Organic Carbon	0.650	Dissolved Organic Nitrogen	0.140
Dissolved Organic Phosphorus	0.045	Ammonia Nitrogen	0.222
Orthophosphate	0.016	Nitrate+Nitrite Nitrogen	0.332
Available Silica	0.0		

4.3 Model Calibration

Model calibration involves the adjustment of certain model input quantities and kinetic rate coefficients in an attempt to achieve a specified level of model performance. A representative set of field data were gathered, processed, and displayed for modeling water quality in Mashapaug Pond. The data set included sampling on six dry weather dates and one wet weather date during the summer of 2001. Vertical profile data were collected at two interior pond stations (MP-1 and MP-2). This section presents the results of the calibration of the EFDC hydrodynamic and water quality model. Parameters considered for calibration include a suite of water quality parameters, including phosphorus, nitrogen, chlorophyll-*a*, temperature, and dissolved oxygen.

4.3.1 Model Configuration

The general procedure for application of the EFDC model to Mashapaug Pond followed a sequence of steps beginning with model set up or configuration and continued through model execution of the calibration time period. Model configuration involved the construction of the horizontal grid for the pond, interpolation of bathymetric data to the grid, construction of EFDC input files, and compilation of the FORTRAN source code with appropriate parameter specification of array dimensions. Figures 4.1 – 4.3 delineate the grid structure, locates storm drains and other point sources, monitoring stations, runoff areas and groundwater monitoring zones. The model included a number of nonpoint source discharges, groundwater underflow to each grid cell, and one tributary (Mashapaug Brook).

There was a hydraulic control structure located at grid cell (10,6) at the outlet of the pond (see Figure 4.1). This control structure was configured as an overflow weir which transported water out of the pond when the level of the pond was above the crest of the weir.

4.3.2 Calibration Period

The time period for model calibration, January 1 to December 31, 2001, was selected because it included the most detailed field survey data available for Mashapaug Pond.

4.3.3 Water Quality Calibration Results

Each observation sample from the 2001 field survey was collected at an instant in time and at a single point in space. Time scales realistically represented in the EFDC model were determined by time scales of primary forcing functions: 60-second time step, hourly meteorological updates, constant groundwater and base-flow loading rates, hourly atmospheric wet deposition, and constant atmospheric dry deposition. The minimum model spatial scales were determined by the size of the grid cells, ranging from 55 to 92 meters in the horizontal direction and on the order of 0.5 to 1.0 meter in the vertical direction. The disparity in the temporal and spatial scales between the model and prototype means that individual observations may not be directly comparable with model prediction at a specific time in a given model grid cell.

Model-data comparisons are made using time-series plots for the two pond stations (MP-1 and MP-2). The observed data are shown as circles. The model output results are represented by three lines, the upper layer, a mid-depth layer, and the bottom layer. The model-data comparisons for temperature are presented in Figures 4.4 and 4.5. The model reasonably represents the surface and bottom temperatures during the summer period. The model-data comparisons for dissolved oxygen are presented in Figures 4.6 and 4.7. Again, the surface and bottom simulations in the model agree well with the data measurements. The model representation of chlorophyll-*a*, presented in Figures 4.8 and 4.9, follows the general trend of the measurements which range from about 17 to 36 µg/L. The model-data comparisons for total phosphorus and dissolved orthophosphate (Figures 4.10 to 4.13) indicate good agreement for the majority of observation points.

Another measure of the goodness of the calibration is the hypoxic volume in the pond. The dissolved oxygen profiles at the two pond stations were used to estimate the overall hypoxic volume of the pond (i.e., the volume of the pond which is experiencing DO of less than 2 mg/L). The model-data comparison of hypoxic volume is shown in Figure 4.14. The hypoxic volume was calculated using each station MP-1 and MP-2 independently. The observed data points shown in Figure 4.18 indicate the minimum, maximum, and average hypoxic volumes for these two stations. The model hypoxic volume agrees very well with the observations. This provides additional confidence that the model will provide credible results that can be used to assess changes in hypoxic volume due to changes in load allocations for the TMDL analysis.

4.3.4 Calibration Statistics

The model-data comparisons in Figures 4.4 to 4.18 provide a qualitative evaluation of model performance. A seasoned modeler can examine the plots and form an experience-based judgment on the status of model calibration and verification. In this section, model-data comparisons are presented as quantitative statistical summaries. This presentation provides a different perspective on model-data comparison that numerically quantifies the state of model calibration/verification (sometimes referred to as model “skill assessment”).

Although numerous methods exist for analyzing and summarizing model performance, there is no consensus in the modeling community on a standard analytical suite. A set of basic statistical methods was used to compare model predictions and sampling observations that included the mean error statistic, the absolute mean error, the root-mean-square error, and the relative error. The observations and model predictions were analyzed over the field study period June 27 to September 26, 2001 at the two monitoring stations in Mashapaug Pond.

Mean Error Statistic

The mean error between model predictions and observations is defined in Eq. 4-1. A mean error of zero is ideal. A non-zero value is an indication that the model may be biased toward either over- or under-prediction. A positive mean error indicates that on average the model predictions are less than the observations. A negative mean error indicates that on average the model predictions are greater than the observed data. The mean error statistic may give a false ideal value of zero (or near zero) if the average of the positive deviations between predictions and observations is about equal to the average of the negative deviations in a data set. Because of that possibility, it is never a good idea to rely solely on this statistic as a measure of performance. Instead, it should be used in tandem with the other statistical measures that are described in this Section.

Mean Error Statistic

$$E = \frac{\Sigma(O - P)}{n} \qquad \text{Equation 4-1}$$

where:

E = mean error
O = observation, aggregated by month and over the water column
P = model prediction, aggregated by month and over vertical layers
n = number of observed-predicted pairs

Absolute Mean Error Statistics

The absolute mean error between model predictions and observations is defined in Eq. 4-2. An absolute mean error of zero is ideal. The magnitude of the absolute mean error indicates the average deviation between model predictions and observed data. Unlike the mean error, the absolute mean error cannot give a false zero.

$$E_{abs} = \frac{\Sigma\backslash O - P\backslash}{n} \qquad \text{Equation 4-2}$$

where:

E_{abs} = absolute mean error.

Root-Mean-Square Error Statistic

The root-mean-square error (E_{rms}) is defined in Eq. 4-3. A root-mean-square error of zero is ideal. The root-mean-square error is an indicator of the deviation between model predictions and observations. The E_{rms} statistic is an alternative to (and is usually larger than) the absolute mean error.

$$E_{rms} = \sqrt{\frac{\Sigma(O - P)^2}{n}} \qquad \text{Equation 4-3}$$

where:

E_{rms} = root-mean-square error

Relative Error Statistic

The relative error between model predictions and observations is defined in Eq. 4-4. A relative error of zero is ideal. The relative error is the ratio of the absolute mean error to the mean of the observations and is expressed as a percent.

$$E_{rel} = \frac{\Sigma|O - P|}{\Sigma O} \qquad \text{Equation 4-4}$$

where:

E_{rel} = relative error.

A summary of the error statistics for chlorophyll-*a*, dissolved oxygen, temperature, and total phosphorus for the both surface and bottom layers of the pond during for the 2001 model calibration simulation is given in Table 4.4. The relative error statistic permits comparisons between the various water quality substances. Temperature and dissolved oxygen were the parameters with the smallest relative errors. The results for temperature indicate a relative error of 5.13% in the surface layer and 11.61% in the bottom layer. The relative error for dissolved oxygen was 8.16% in the surface layer and 28.85% in the bottom layer. The large relative error for DO in the bottom layer is somewhat misleading because the observed bottom oxygen concentrations were very small values, generally less than 0.5 mg/L. The absolute mean error for DO in the bottom layer indicates that, on average, the model is simulating bottom DO concentrations within 0.14 mg/L of the observations.

The total phosphorus relative errors were 16.89% in the surface layer and 31.88% in the bottom layer. The relative error for chlorophyll-*a* was 19.38% (only measured in the surface layer). The variability of the chlorophyll-*a* parameter reflects the non-conservative behavior of algal dynamics and the approximate nature of mathematical models of biological processes. A rule of thumb for chlorophyll-*a* monitoring is that at any given station and any given time, the sampled concentrations can vary by a factor of one-half to double. The highly dynamic, short-term variations of the chlorophyll-*a* parameter are extremely difficult to model. Eutrophication models are better suited to simulating the long-term (daily to monthly time scale) chlorophyll-*a* levels rather than the short-term (hourly) concentrations.

According to the *Technical Guidance Manual for Performing Waste Load Allocations* (USEPA, 1990), acceptable relative error statistic criteria are 15% for dissolved oxygen and 45% for nutrient parameters (e.g. phosphorus). The weighted overall relative error statistics for the Mashapaug Pond model were 13.7% for dissolved oxygen and 22.7% for total phosphorus. The relative error statistics for the Mashapaug Pond water quality model meet the general guidance criteria published in USEPA (1990).

Table 4-4 Statistical summary of Mashapaug Pond model 2001 calibration results.

Parameter	Mean Error	Absolute Mean Error	RMS Error	Relative Error	No. Samples
Surface (epilimnion)					
Chlorophyll-a (ug/L)	4.6787	4.7582	7.2242	19.38%	10
Dissolved Oxygen (mg/L)	0.6644	0.7693	1.2142	8.16%	79
Total Phosphorus (mg/L)	-0.0017	0.0053	0.0098	16.89%	19
Temperature (degC)	0.4920	0.9910	1.6143	5.13%	77
Bottom (hypolimnion)					
Chlorophyll-a (ug/L)	---	---	---	---	---
Dissolved Oxygen (mg/L)	-0.0902	0.1370	0.2544	28.85%	29
Total Phosphorus (mg/L)	0.0041	0.0151	0.0088	31.88%	12
Temperature (degC)	1.0509	1.6986	2.6444	11.61%	40

Figure 4.1 Mashapaug Pond Model Grid, Storm Drains, and Monitoring Stations

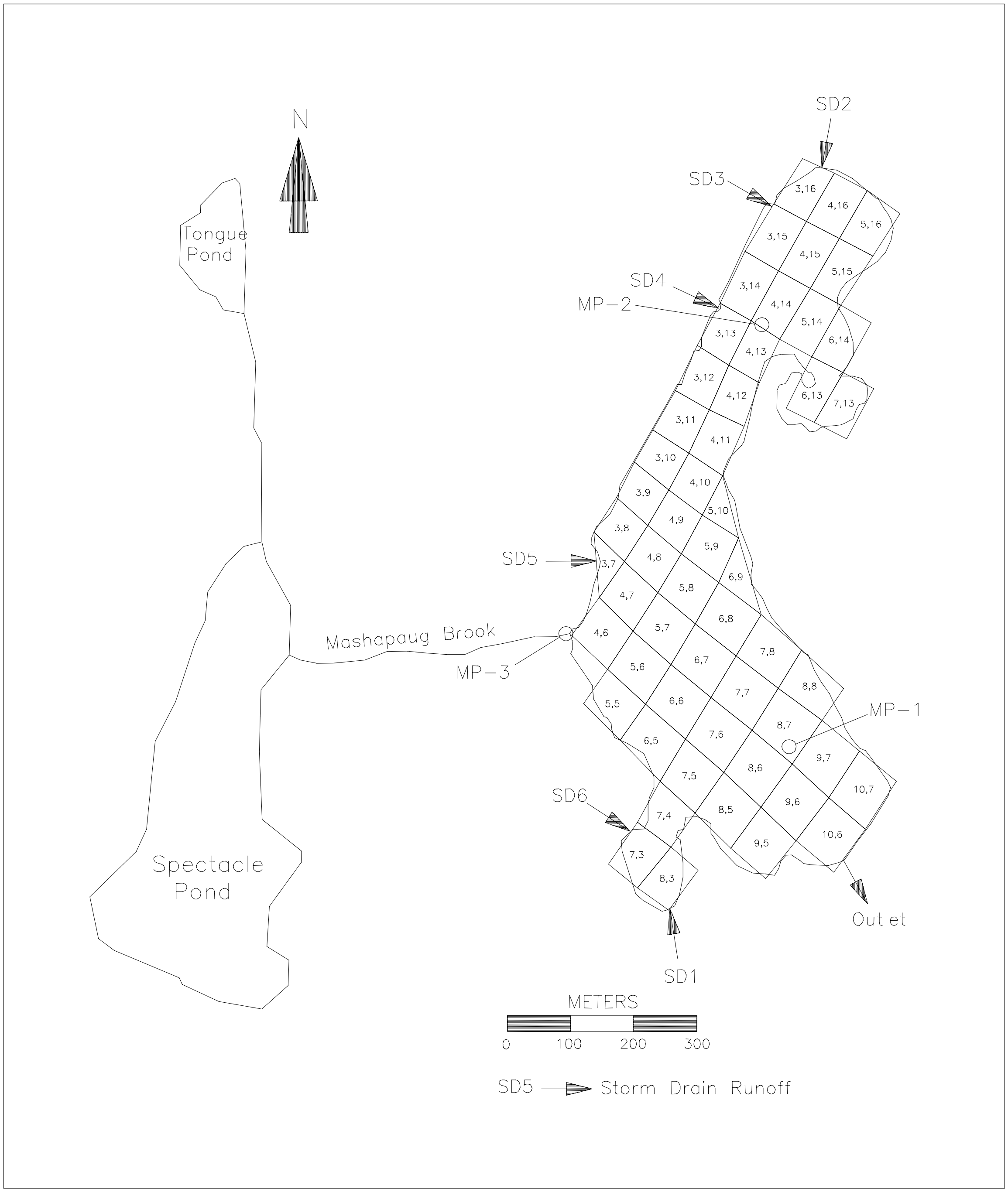


Figure 4.2 Mashapaug Pond, Location of Direct Overland Runoff Contribution Areas

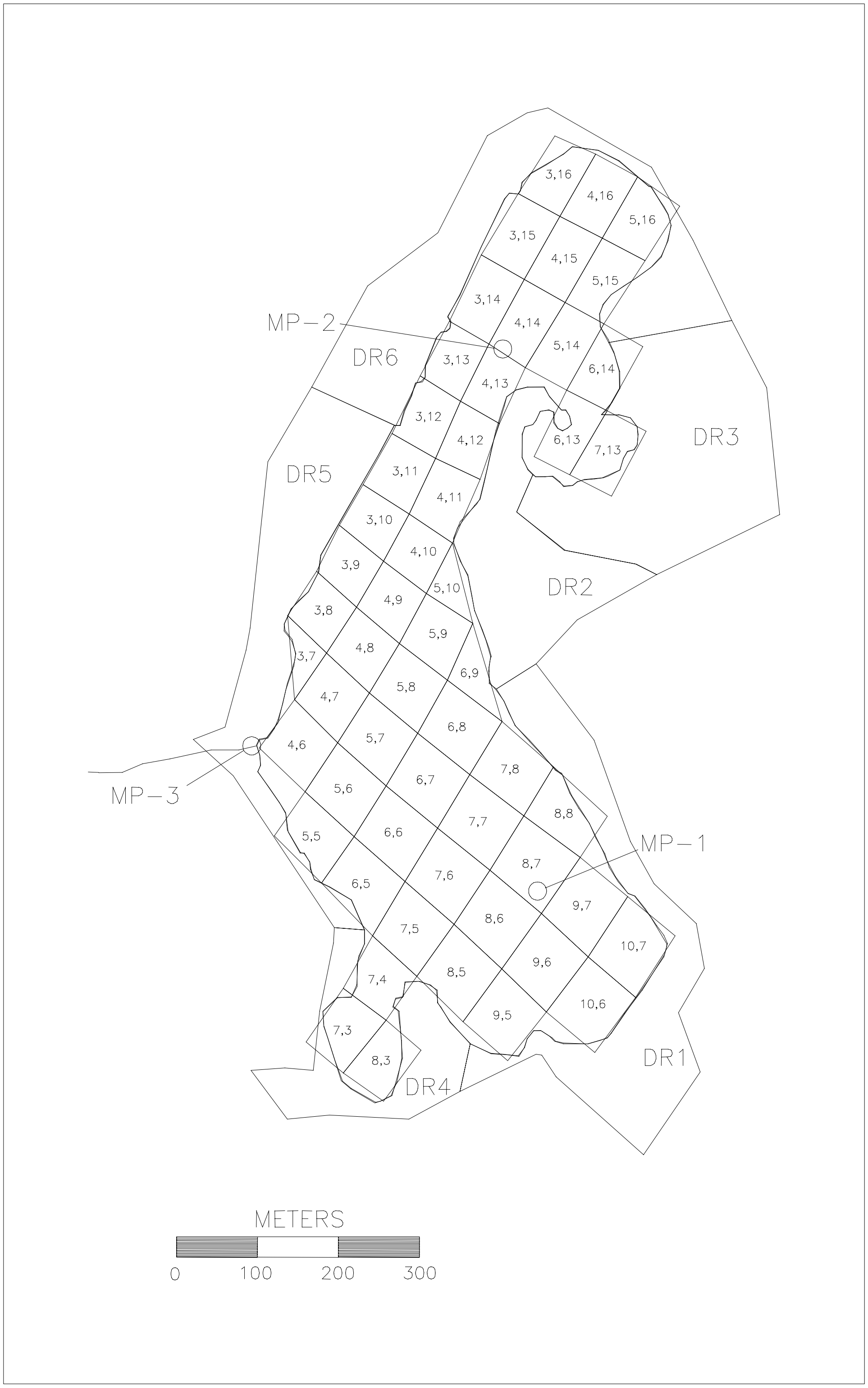


Figure 4.3 Mashapaug Pond, Location of Groundwater Monitoring Zones

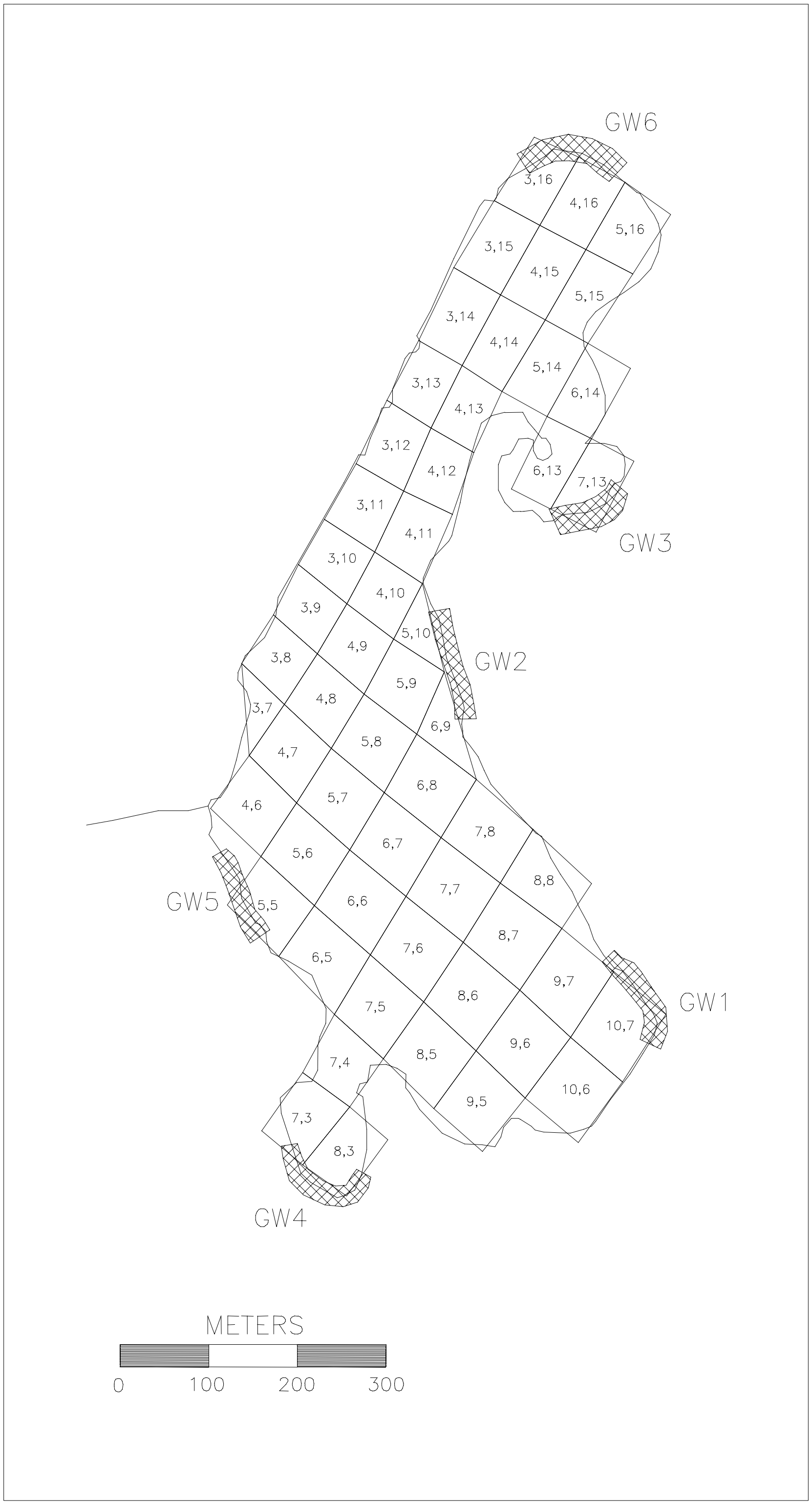


Figure 4.4 Mashapaug Pond Calibration, Temperature at Station MP - 1

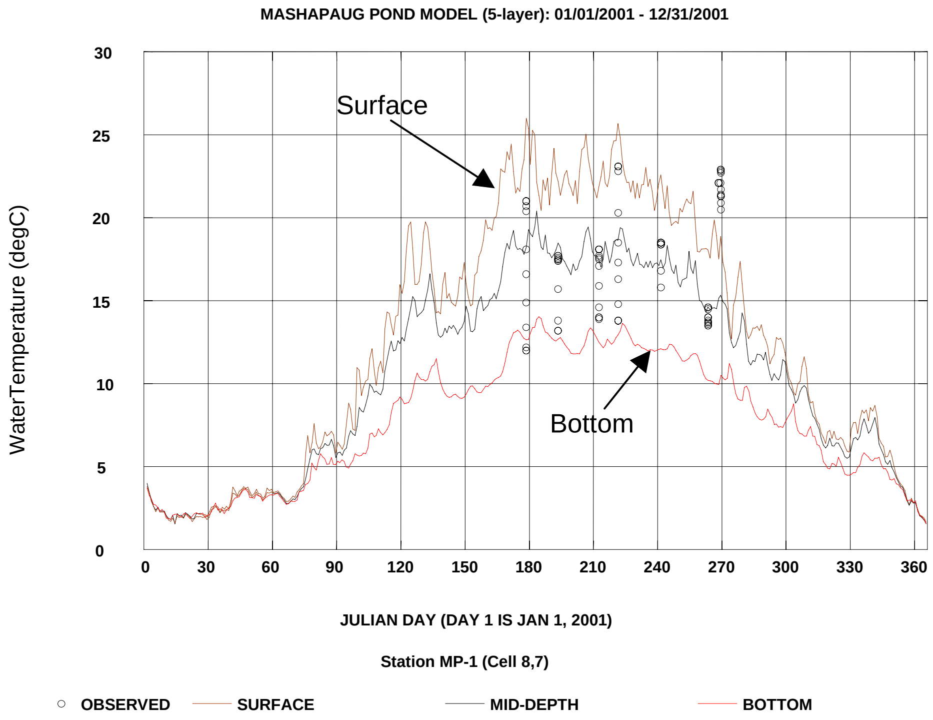


Figure 4.5 Mashapaug Pond calibration, Temperature at Station MP-2

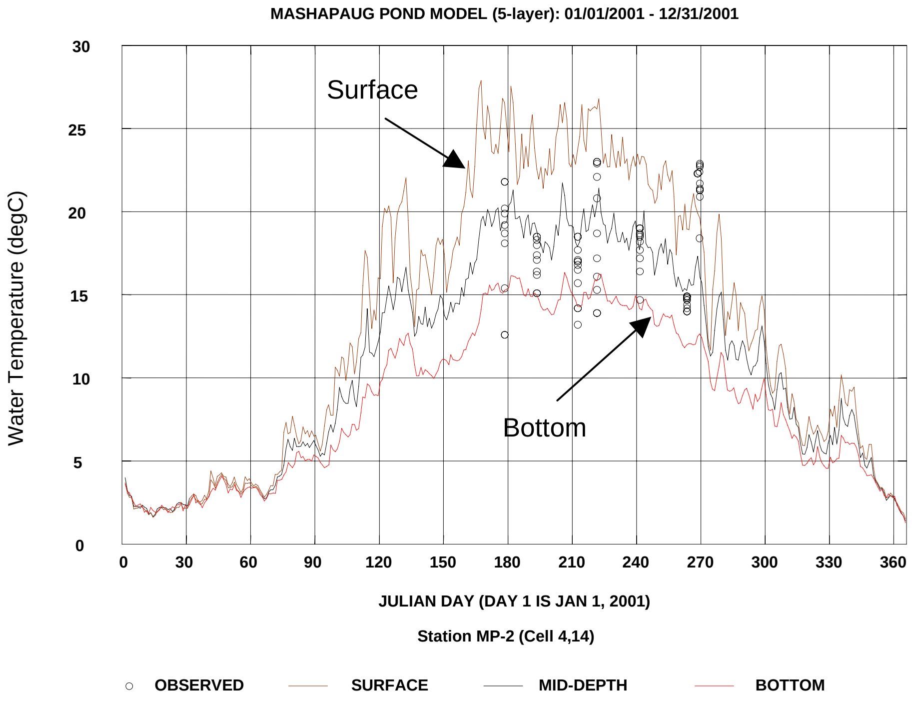


Figure 4.6 Mashapaug Pond Calibration, Dissolved Oxygen at Station MP-1

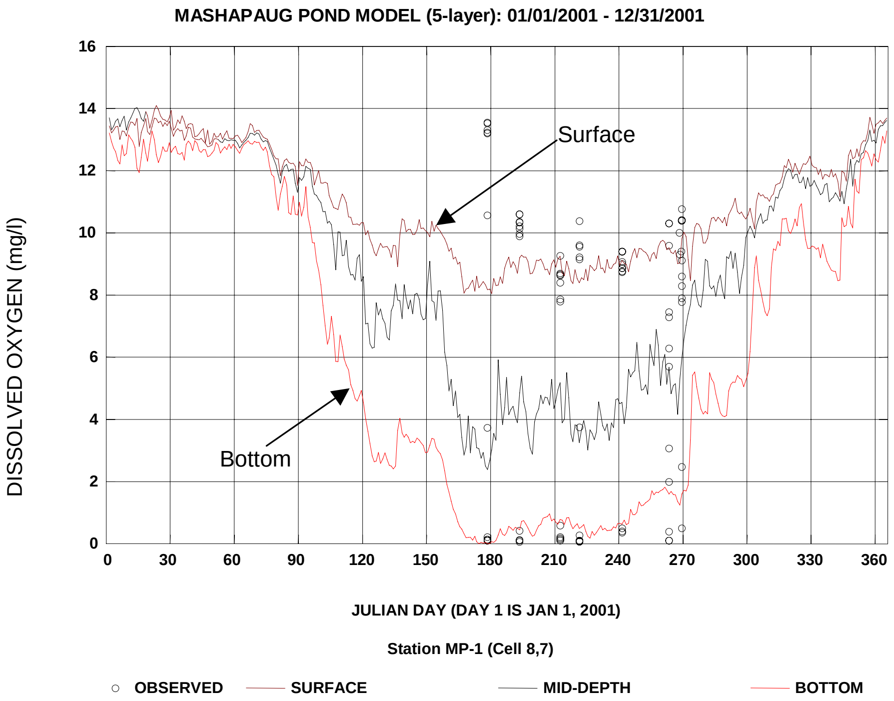


Figure 4.7 Mashapaug Pond Calibration, Dissolved Oxygen at Station MP-2

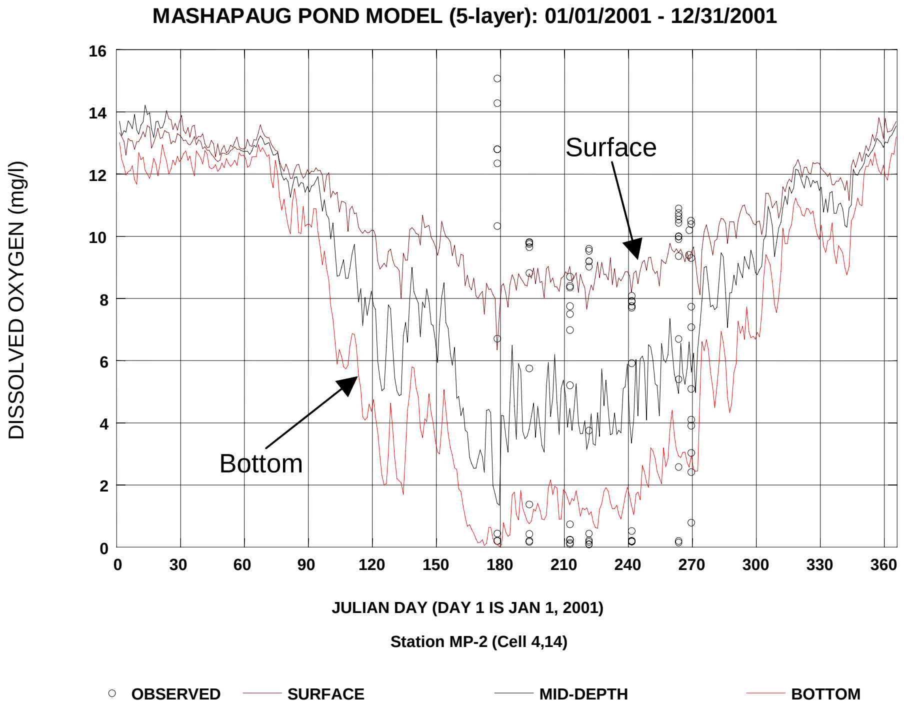


Figure 4.8 Mashapaug Pond Calibration, Chlorophyll – a at Station MP-1

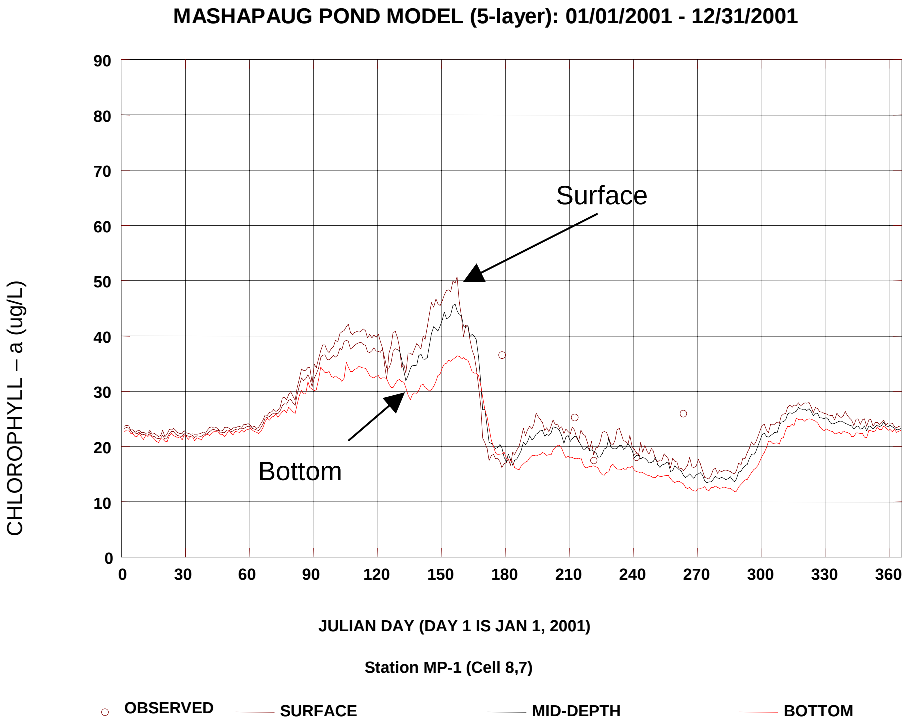


Figure 4.9 Mashapaug Calibration, Chlorophyll – a at Station MP-2

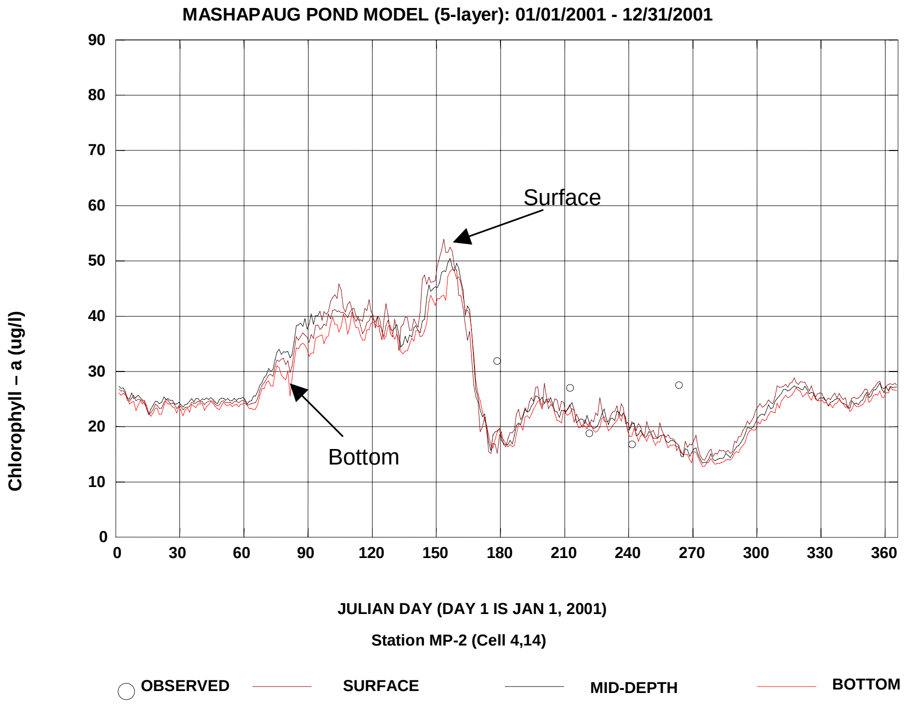


Figure 4.10 Mashapaug Pond Calibration, Total Phosphorus at Station MP –1

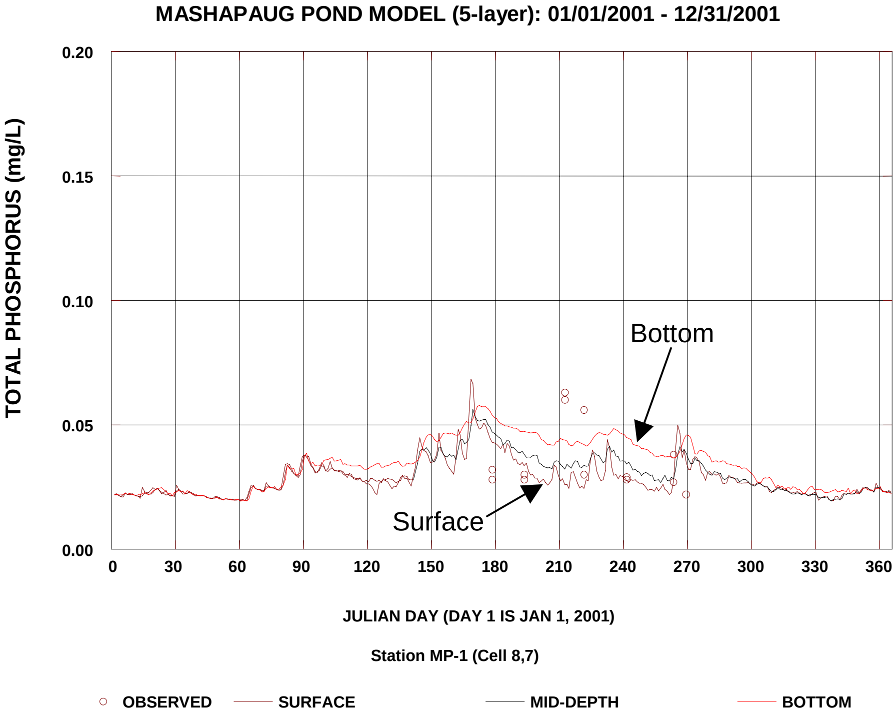


Figure 4.11 Mashapaug Pond Calibration, Total Phosphorus at Station MP –2

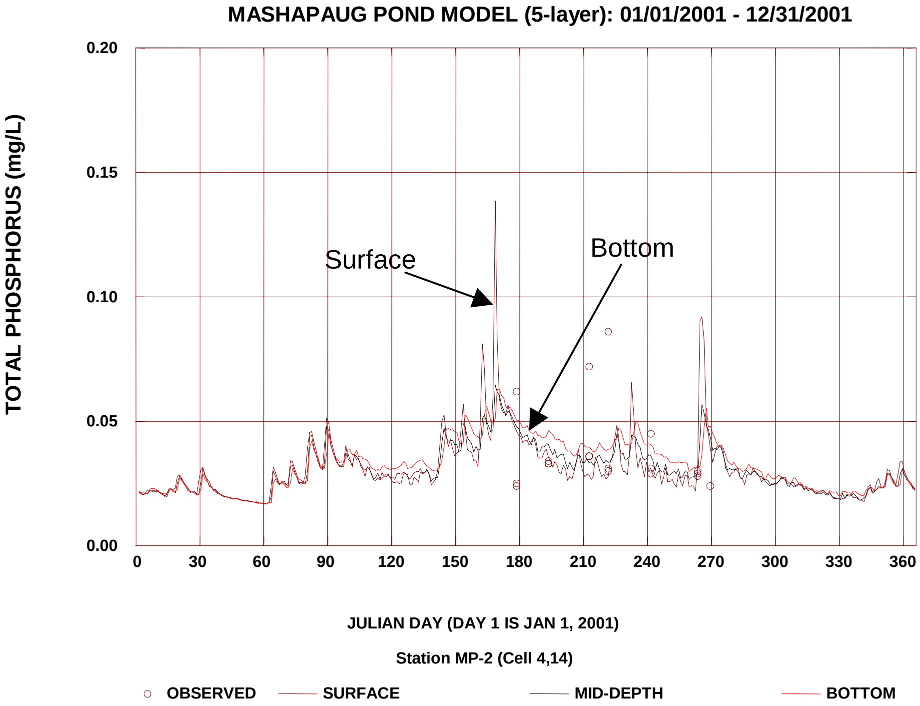


Figure 4.12 Mashapaug Pond Calibration, Dissolved Orthophosphate at Station MP-1

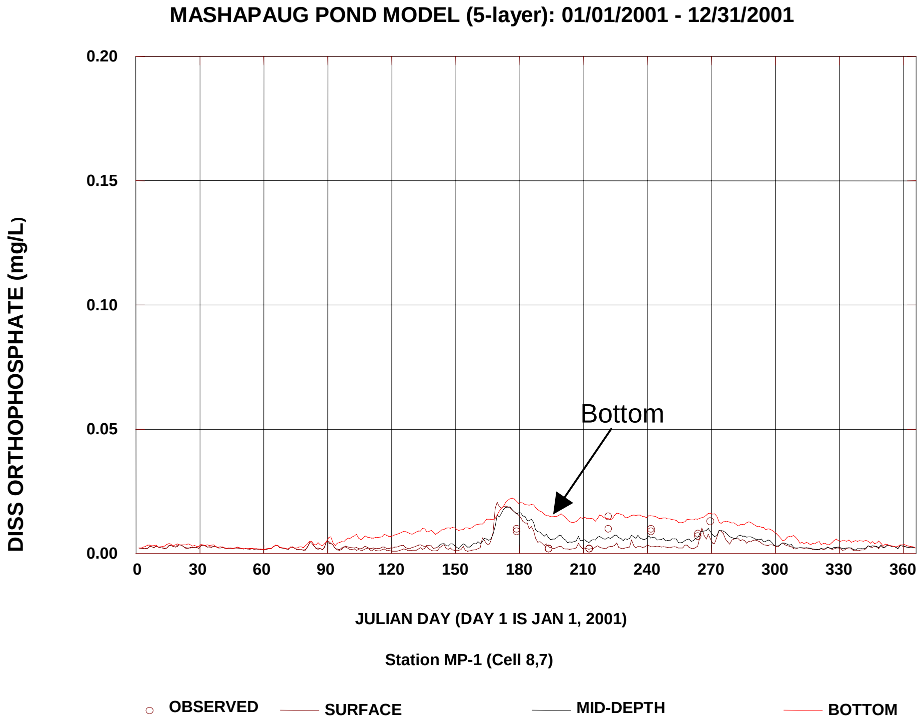


Figure 4.13 Mashapaug Pond Calibration, Dissolved Orthophosphate at Station MP-2

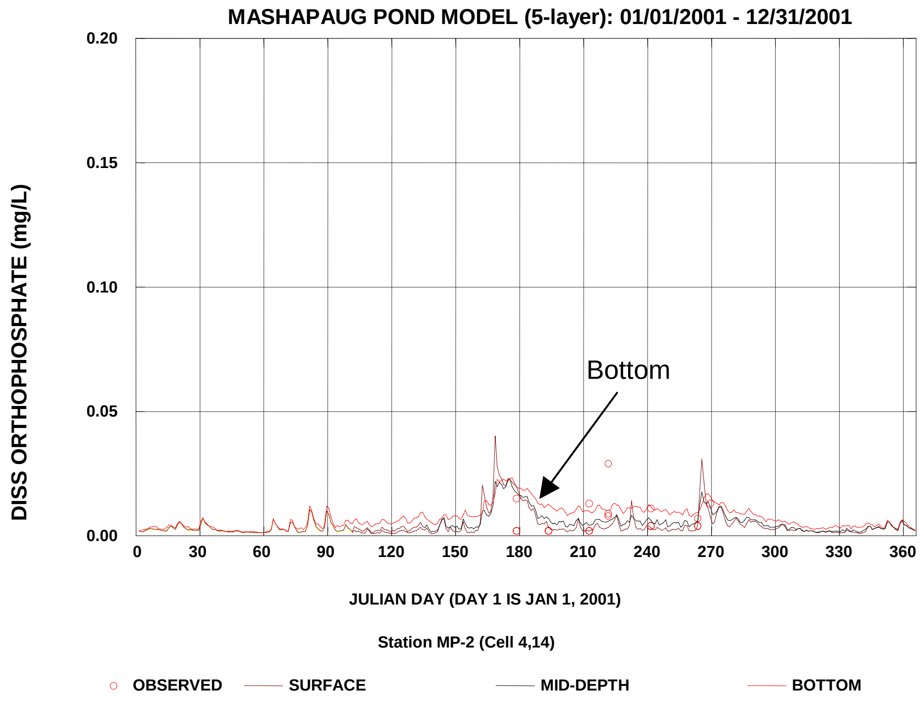
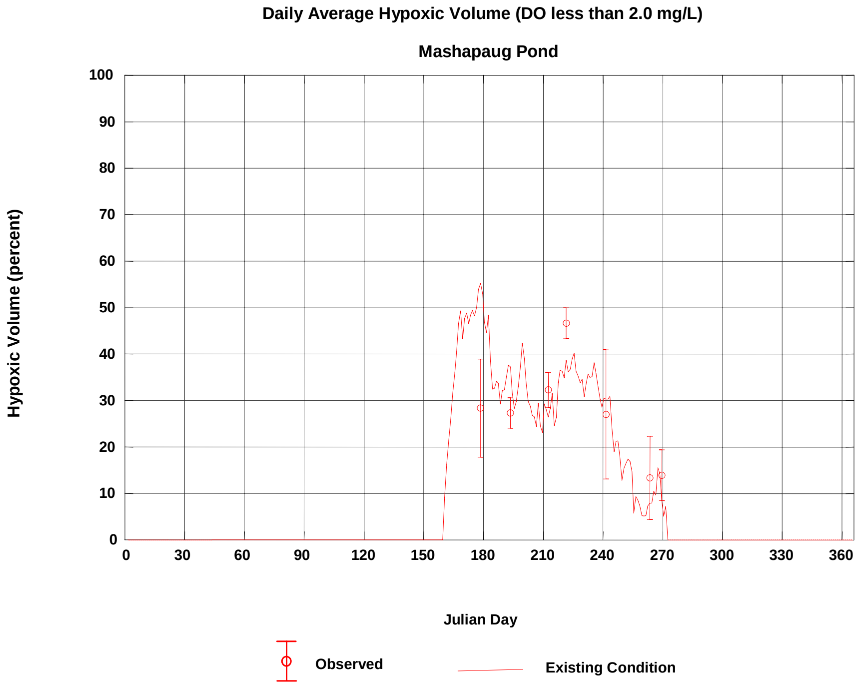


Figure 4.14 Mashapaug Pond Calibration, Hypoxic Volume



5.0 TMDL ANALYSIS

5.1 Establishing the Numeric Water Quality Target

The current Rhode Island water quality criteria are an instantaneous DO concentration of at least 5.0 mg/L at any point in the water column as well as a 7-day mean water column concentration of at least 6.0 mg/L. This standard is applicable to flowing streams, but may not be attainable in the hypolimnia of naturally stratifying ponds and lakes. Section 3.3 documents an evaluation of two unimpaired reference ponds (Upper Schoolhouse Pond and Wakefield Pond) that are located in pristine areas and exhibit healthy water conditions. The analysis concludes that the natural process of density stratification due to a vertical temperature gradient produces low dissolved oxygen concentrations in the hypolimnion (lower layer) of these lakes. Low DO in the hypolimnion can be more distinct in eutrophic lakes (i.e., those having high nutrient and algae levels), but is present in healthy lakes as well. Tetra Tech concluded based on its evaluation that a typical summer season hypolimnetic Dissolved Oxygen level was 2.5 mg/l in these pristine reference ponds.

Rhode Island's Water Quality Regulations (2006) allow dissolved oxygen concentrations to be lower than established criteria if naturally occurring as stated, "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." Additionally, the State's Water Quality Regulations state in the definition for "low quality" or "degraded waters", that waters in their natural hydraulic condition may fail to meet their assigned water quality criteria from time to time due to natural causes. These waters are not considered to violate water quality standards if violations of numeric criteria are due solely to naturally occurring conditions unrelated to human activities. When a water body naturally does not meet the numeric criteria, as is the case with many freshwater lakes, the levels seen in the natural condition must then become the water quality target for those and similar bodies. The dissolved oxygen concentration measured along a vertical profile (which was greater than 2 mg/L in the hypolimnion) for the two unimpaired reference ponds was selected as the naturally occurring hypolimnetic condition for Mashapaug Pond.

The numeric target for DO in the Mashapaug Pond TMDL is a concentration equal to or greater than 2 mg/L in the hypolimnion. This target does not represent a violation of the DO criteria because it has been determined that under certain natural conditions, DO levels of 2.0 mg/l or less may occur in the waters of Mashapaug Pond. To achieve this DO target, the calibrated water quality model of the pond determined that a 62% reduction in modeled existing phosphorus loads was necessary from storm drains and direct overland flow to the pond. The numeric water quality target for Total Phosphorus is set at 20 ug/l, the annual mean concentration associated with these load reductions. Achieving the target of 20 ug/l is also expected to reduce algal abundance (resulting in a shift from dominance of blue-green algae to diatoms and green algae) to levels consistent with the pond's designated uses.

5.1.1 Critical Conditions

Critical conditions for nutrient TMDLs is the summer season when temperatures are the highest and respiration and stratification are greatest. The Tetra Tech modeling analysis predicted a summer season mean Total Phosphorus concentration of 22.2 ug/l; with negligible hypolimnetic DO concentration excursions below 2.0 mg/l during that season. The analysis therefore shows that the reductions are protective during the critical seasonal period.

5.1.2 Margin of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of the fact that there are many uncertainties in the scientific understanding of water quality in natural systems. Specifically, the knowledge is incomplete regarding the exact nature of the magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of natural waterbodies.

The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of protection of the environment. Based on EPA guidance, the MOS can be achieved through one of two methods. One approach is to encompass the MOS as part of conservative assumptions made in the development of the point and nonpoint source load allocations. The second approach is to reserve a portion of the loading capacity as a separate term in the TMDL equation.

An explicit MOS was used for both Total Phosphorus and Dissolved Oxygen in the Mashapaug Pond TMDL. The 20 ug/l numeric target for Total Phosphorus represents a 20% MOS relative to the state water quality standard of 25 ug/l. To account for uncertainty in the modeling exercise and to ensure compliance with the DO water quality target, slightly more than 5% was added to the TMDL, or a 3% load reduction from controllable TP sources.

5.1.3 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and EPA's regulations at 40 CFR 130.7(c)(1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may also be expressed in other terms as appropriate. For the Mashapaug Pond case, the TMDL is expressed in terms of allowable annual loadings of phosphorus. Although critical conditions occur during the summer season when algae growth is more likely to interfere with designated uses, water quality in most lakes and ponds is generally not sensitive to daily or short-term loading. Instead, water quality is more a function of loadings that occur over longer time periods (e.g., annually). In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual, rather than daily, basis. For the reasons stated, annual loads are more appropriate for expressing phosphorus loading goals. However, in order to comply with current EPA guidance, the TMDL is also expressed as a daily load.

Though the preference for technical reasons is to express the TMDL as the allowable annual load, the TMDL is also expressed in daily terms to be consistent with current EPA guidance. The daily load is the annual load divided by 365 days. Therefore, the calculations are based on annual loads. However, in order to comply with current EPA guidance, the TMDL is also expressed as a daily load.

5.2 Current Loading Conditions

Point Sources
Loads from six storm drains that discharge stormwater runoff directly to the pond (Tetra Tech, 2001) were calculated using literature values. The literature and estimated loading event mean concentrations are presented in Table 5.1.

Table 5-1 Loading Event Mean Concentrations Collected From Literature

Land Use Type	Concentration (mg/l)	
	TP	DP
High Density Residential	0.38	0.14
Medium High Density Residential	0.38	0.14
Commercial	0.2	0.08
Industrial	0.21	0.15
Roads	0.22	0.1
Commercial/ Industrial Mixed	0.2*	0.11*
Developed Recreation	0.03	0.03*
Deciduous Forest	0.03	0.03
Wetlands	0.03*	0.03*

Source: Corpus Christi, Tetra Tech, Inc.
*Literature value not found values estimated

Nonpoint Sources
Direct runoff from the land adjacent to the pond shore was factored into the total watershed load. In order to determine the water and nutrient contributions from the runoff, the area around the pond was divided into six regions. These regions are based roughly on the land use types presented in Figure 2.3.

Loads from the direct runoff areas were calculated in a similar manner as the loads from the storm drain areas. The drainage areas were divided by land use and are presented in Table 2.2. The literature loading values were weighted by land use and then multiplied by the runoff flow rate in order to determine the runoff load.

5.3 Allocation of Allowable Loadings

A number of allocation runs were made in which the loads to the pond were successively reduced until the simulated water quality conditions met the water quality targets. A summary of existing loads and the TMDL allocations is presented in Table 5.2 for each source. The TMDL is summarized in Table 5.3. The total existing load (231.60 kg/yr) must be reduced by 53.5% to achieve the TMDL (107.70 kg/yr). Because loads associated with groundwater and atmospheric deposition cannot be easily reduced, a higher percentage of the load reduction must come from the remaining sources. Therefore, a nutrient load reduction of 62% from all storm drains and direct overland runoff areas as well as the base flow from Spectacle Pond was required in order to meet the water quality standard for hypoxia. A margin of safety of slightly more than 5% was added to the TMDL. The MOS requires an additional 3% load reduction from controllable TP sources, which comprise 190.6 kg/yr of the existing load.

Table 5-2 Summary of TMDL Nutrient Reductions for Mashapaug Pond (based on model estimates).

Source	Source type (point/ nonpoint)	Existing Load (kg/yr)	TMDL (kg/yr)	Percent Reduction
		Total P	Total P	Total P
Storm Drain SD1 (Pawnee St.)	P	1.86	0.65	65.0%
Storm Drain SD2 (Dexter St.)	P	2.38	0.83	65.0%
Storm Drain SD3 (DuPont Dr.)	P	2.30	0.80	65.0%
Storm Drain SD4 (Parking Lots)	P	35.15	12.30	65.0%
Storm Drain SD5 (Pawnee St.)	P	4.10	1.43	65.0%
Storm Drain SD6 (Lakeview Dr.)	P	6.19	2.16	65.0%
Direct Runoff S1	P	6.59	2.31	65.0%
Direct Runoff S2	P	4.69	1.64	65.0%
Direct Runoff S3	P	7.56	2.65	65.0%
Direct Runoff S4	P	0.95	0.33	65.0%
Direct Runoff S5	P	4.68	1.64	65.0%
Direct Runoff S6	P	4.64	1.62	65.0%
Spectacle Pond – Storm runoff	P	0.86	0.30	65.0%
Spectacle Pond – base flow	P	108.67	38.03	65.0%
Groundwater Underflow	NP	16.14	16.14	0.0%
Atmospheric Deposition (dry)	NP	7.88	7.88	0.0%
Atmospheric Deposition (wet)	NP	16.97	16.97	0.0%
Total Loading		231.60	107.70	53.5%

Table 5-3 Allocation of the TMDL

TMDL (kg/yr)	=	**WLA** (kg/yr)	+	**LA** kg/yr(kg/yr)	+	**AFG** (kg/yr)	-	**MOS** (kg/yr)
107.7	=	72.4	+	41.0	+	0	-	5.7

The TMDL is a 53.5% reduction in the total loading of phosphorus to the pond. The reduction to meet the TMDL will be accomplished by a 62% reduction in stormwater point source loads (WLA). A 3% explicit MOS is added to the point source load reduction, or slightly more than

5% of the TMDL, to ensure that the TMDL target is met. No reduction is specified for nonpoint sources that include groundwater underflow, atmospheric dry deposition, and atmospheric wet deposition. Management of these three sources requires a regional or national scale effort that is beyond the scope of this localized TMDL. The net phosphorus load reduction was calculated as 53.5% for total phosphorus. The watershed surrounding Mashapaug Pond is highly urbanized and essentially fully developed at the present time. Because the area is built out, the allocation for future growth (AFG) is zero.

The effect of the phosphorus load reductions on hypoxia in Mashapaug Pond can be seen in Figure 5.1. The time series of hypoxic volume shown in Figure 5.1 represents the percent of the total pond volume having a daily average dissolved oxygen concentration under 2.0 mg/l. Under the existing loading condition, the hypoxic volume of the pond reached levels as high as 55% and was regularly above 30% during the summer months. The hypoxic volume for various nutrient load reductions is shown in Figure 5.1. Hypoxia is eliminated throughout the pond with a 62% phosphorus load reduction of controllable sources to achieve the numeric target dissolved oxygen for this TMDL.

The impact of the load reduction on TP is shown in Figure 5.2. The time series indicates that the TP concentration under existing conditions remains above the 0.025 mg/L target concentration for most of the year, in fact, reaching a maximum value of about 0.057 mg/L during the summer months. The annual average TP concentration under existing conditions for the entire pond is 0.031 mg/L and is above the target concentration. TP under the 62% controllable source load reduction is also presented in Figure 5.2, and indicates a maximum TP concentration of about 0.032 mg/L in the summer. The annual average TP concentration for the entire pond is 0.0196 mg/L, below the 0.025 mg/L water quality standard. TP concentrations and water quality standards were also compared to a seasonal index period average. This index period is currently defined as April to November to be consistent with the URIWW sampling schedule. Rhode Island's lake monitoring program relies upon the URIWW to provide lake assessment data. To provide consistent comparison between programs, the seasonal index average TP was also calculated for the 62% reduction scenario. The mean seasonal index period TP concentration is 0.022 mg/L, which is also below the 0.025 mg/l water quality standard.

Time series of hypolimnion dissolved oxygen concentrations for stations MP-1 and MP-2 are shown in Figure 5.3 and 5.4. Under the existing loading conditions, the dissolved oxygen at both locations is well below the 2.0 mg/L target for an extended period of time during the summer months. For the 62% reduction case, the dissolved oxygen levels in the hypolimnion remain above the 2.0 mg/L level.

5.4 Strengths and Weaknesses in the Analytical Process

The strengths of the analytical method used for the Mashapaug Pond TMDL includes the use of a sophisticated hydrodynamic and water quality model that incorporates all the major state variables and kinetic processes of lake eutrophication. The use of a diagenesis sediment flux model allowed the benthic SOD and nutrient flux rates to be predicted rather than specified by the user. The process-oriented model allowed the hypoxic volume in the lake to be computed and the vertical resolution in the hypolimnion that were representative of the observations.

One of the weaknesses of the approach is that a large amount of data and considerable technical expertise are necessary to conduct a modeling study using a complex model. Additional data including storm runoff and loading rates, benthic flux rates, and chlorophyll-a concentrations would have been helpful for calibration of the model. The model simulations outside the summer months were not calibrated due to lack of data during the non-summer months.

Figure 5.1 Mashapaug Pond TMDL Allocations, Hypolimnion DO at Station MP-2

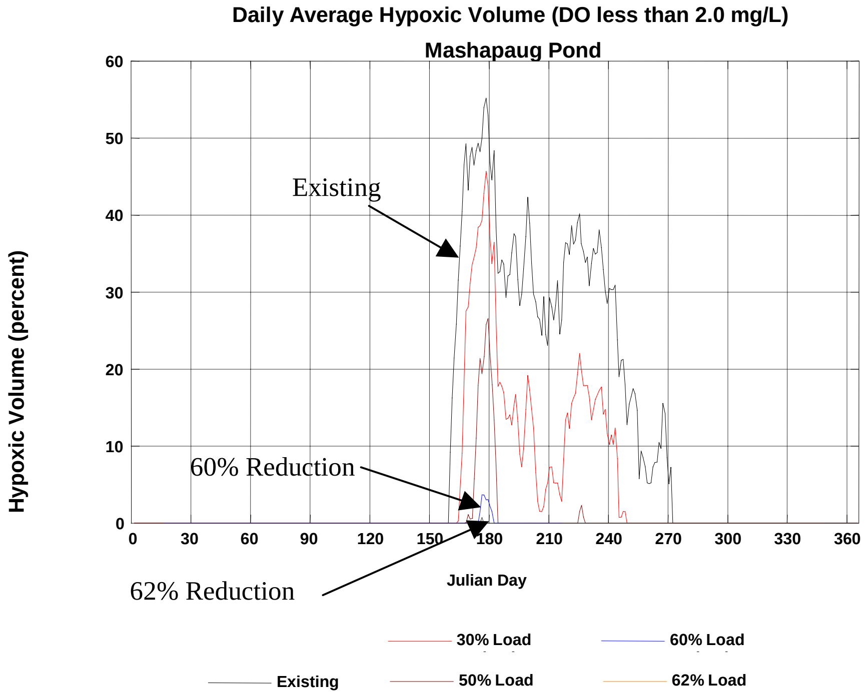


Figure 5.2 Mashapaug Pond TMDL Allocations, Total Phosphorus.

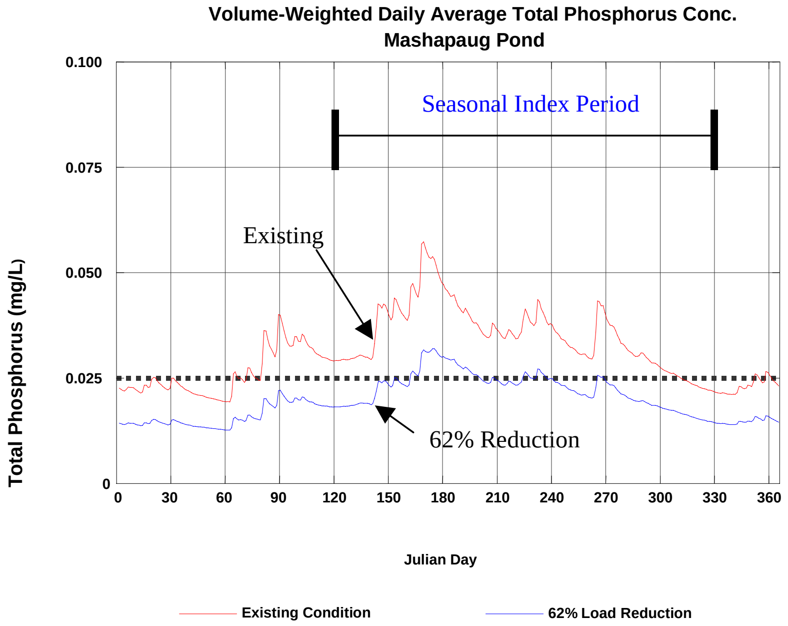


Figure 5.3 Mashapaug Pond TMDL Allocations, Hypolimnion DO at Station MP-1.

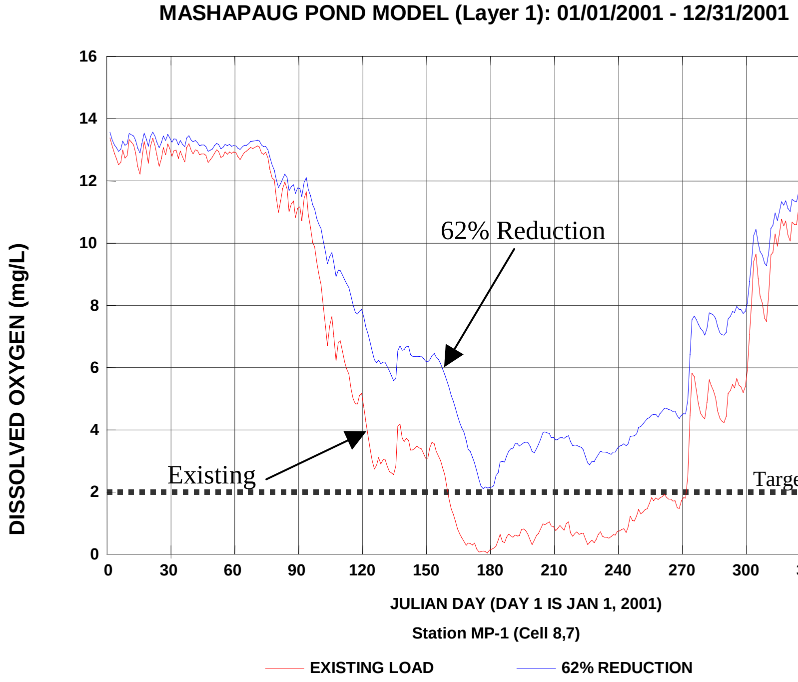
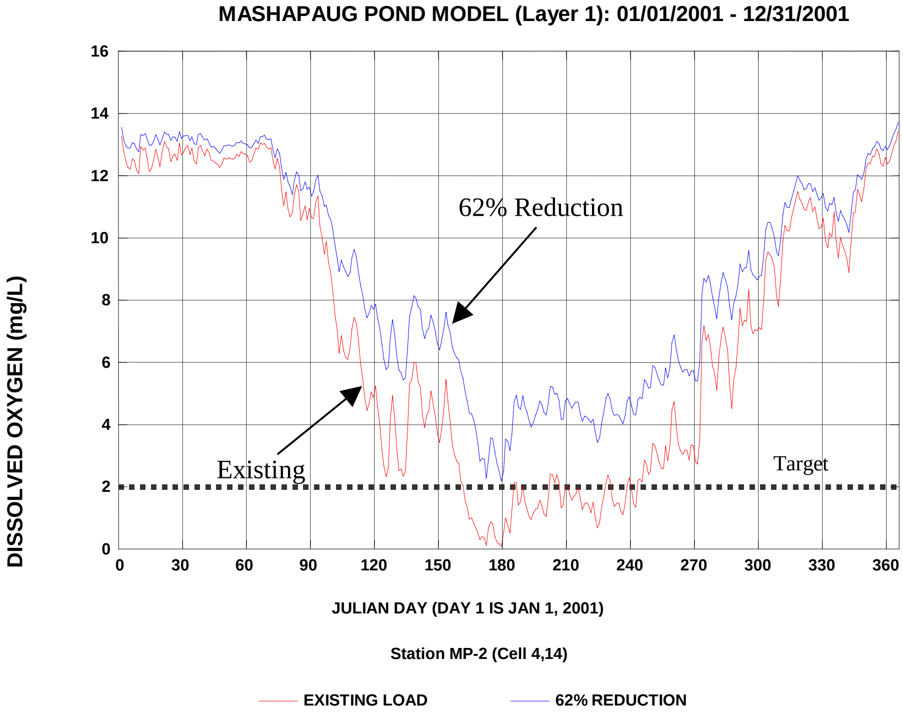


Figure 5.4 Mashapaug Pond TMDL Allocations, Hypolimnion DO at Station MP-2



6.0 IMPLEMENTATION

Runoff from urban activities, including industry and transportation, fertilization, domestic, wildlife waste, and atmospheric deposition are seriously degrading water quality in Mashapaug Pond. This degraded water quality impairs the use of Mashapaug Pond for contact and non-contact recreation, fish habitat and adversely affects the pond's aesthetics. Urban runoff contains elevated concentrations of phosphorus. Excessive amounts of these nutrients cause a wide range of problems including excessive algae growth resulting in potentially toxic blooms, loss of dissolved oxygen that results in fish kills, and loss of bio-diversity. Excess alga levels are also detrimental to the esthetic value of Mashapaug Pond resulting in resultant color (clarity) and odor problems that stem from living and decomposing dead algae.

Reversal of the eutrophication of Mashapaug Pond requires reduction of its phosphorus inputs. Atmospheric deposition of phosphorus onto the pond and its surrounding watershed must be addressed at a regional scale and is beyond the scope of this TMDL. However, there are many technologies and strategies available that can be introduced in the watershed to reduce the local input of nutrients to the pond and meet the goals of this TMDL. Even though stormwater point source discharges to Mashapaug Pond exist, the contributing sources are non-point in nature. The BMPs recommended to achieve the goals of this TMDL will address the non-point sources and will not be assigned to a specific discharge pipe but will represent a reduction of the total overall amount of excess nutrients within the watershed.

Because this TMDL relies upon the implementation of a combination of BMPs to be applied within the watershed, and data describing the success of many of these methods is variable, the proposed implementation approach is considered to be a phased approach to meeting water quality goals. As BMPs and mitigation measures are installed and implemented, the corresponding response in phosphorus concentrations will be measured.

A review of monitoring results and modeling predictions indicate that the Spectacle Pond tributary, which includes runoff from Route 10, contributes the largest single load of phosphorus to Mashapaug Pond. The combined loads from the six identified storm drains comprise the second largest source, followed by overland flow, atmospheric deposition, and groundwater. Though the model predicted storm drain 4 to be the second largest source of phosphorus to the pond, there was no flow observed out of this storm drain over the course of the monitoring program (Mashapaug Pond Data Report and Analysis, Environmental Science Services, Inc 2002). The largest observed wet weather sources of phosphorus to the pond, ranked in decreasing order by load (determined by multiplying concentration times flow), are Spectacle Pond outflow (MP-3, J. T. Owens Park) and then storm drains SD 5 (Pawnee St.), SD 1 (South end of Niantic Ave.), SD 2 (Dexter St.) and SD 6 (Lakeview Dr. at Westmore St.). Relative to fecal coliform, the largest observed sources ranked in decreasing order by load are wet weather flow from the Spectacle Pond outflow (MP-3, J.T. Owens Park), followed by storm drains SD 5 (Pawnee St.), SD 6 (Lakeview Dr.), SD 1 (Niantic Ave.), base flow from Spectacle Pond, and SD 2 (Dexter St.). Storm drain 3 (DuPont Dr.) was not observed to be a significant contributor of either total phosphorus or fecal coliform. Although storm drains are considered point sources, the sources of pollution to these drains are non-point. A combination of upland and end of pipe BMPs combined with land use management, conservation efforts and source reduction within the watershed will be recommended in order to meet the waste load reduction requirements set forth in this TMDL. As stated earlier, atmospheric deposition and groundwater underflow into the pond area make up 18% of the total phosphorus load but are not controllable at the local level, so no recommendation will be made to specifically reduce these loadings. Continued efforts by regional and national groups to reduce this pollution will result in additional local benefits within the watershed over the long term, but are not considered in this TMDL.

6.1 Spectacle Pond

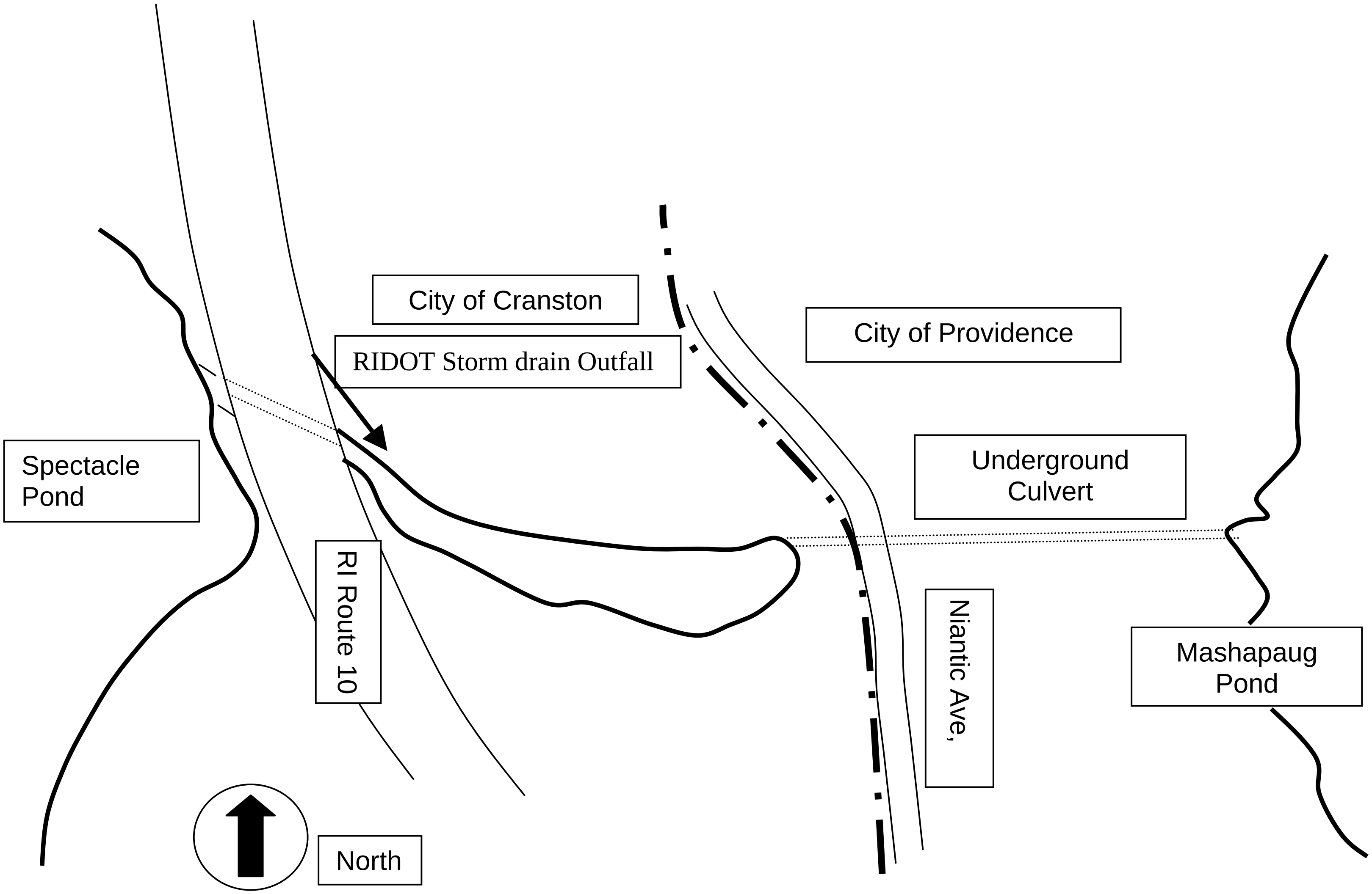
Spectacle Pond represents the single largest source of total phosphorus and fecal coliform loadings to Mashapaug Pond. Spectacle Pond has been placed on Rhode Island's 2002 303(d) List of Impaired Waters for excess algae/ chlorophyll a and phosphorus. These impairments are addressed as part of the "Total Maximum Daily Loads for Phosphorus To Address 9 Eutrophic Ponds in Rhode Island" (hereinafter referred to as the Eutrophic Pond TMDL). This TMDL establishes a target concentration of 42 ug/l for a total load of 38 kg/yr from Spectacle Pond. The Eutrophic Pond TMDL establishes a target concentration of 20 ug/l for Spectacle Pond, which results in a 28.5 kg/yr estimated total load to Mashapaug Pond – assuming an average annual flow of 1.84 cfs. The major sources of phosphorus to Spectacle Pond, not necessarily in order of significance, are stormwater, waterfowl, and internal recycling.

Four stormwater outfalls were identified as the most significant potential sources of phosphorus to Spectacle Pond. These outfalls, in order of significance, are located at Lake Street, two at the baseball fields at the southern end of the pond, and Molter Street. Upon approval of the Eutrophic Pond TMDL, it will be the City of Cranston's responsibility to amend its SWMPP consistent with Part IV.D of the General Permit and more specifically, the Eutrophic Ponds TMDL. As discussed in detail in that TMDL, the catchments associated with each of the priority outfalls must be identified and a feasibility study must be conducted to determine the types and locations of BMPs that will be most effective in reducing stormwater volumes and phosphorus loading to the pond to the maximum extent feasible. The City of Cranston must increase street sweeping and/or stormwater system maintenance to address sediment loads to Spectacle Pond. Street sweeping in priority areas must be conducted more frequently than the required twice-annual schedule. These prioritized areas include catchments that are associated with priority outfalls listed above and also with those outfalls associated with flooding problems, blocked culverts, catch basins and/or sediment deltas. A significant sedimentation delta was observed at twin culverts at the southeast end of the pond. A large sedimentation delta that extends halfway across the pond was observed to be associated with the Lake Street culvert. Also the outfall at Molter Street is completely blocked and stormwater was observed surcharging out of the terminal catch basin. This surging stormwater has caused significant erosion to the shoreline of the pond. These culverts need to be cleaned and properly maintained.

Thirty to forty waterfowl were observed on the pond at any one time and were also observed congregating on a commercial parking area at the northern end of the pond. The geese apparently gain access to the pond in this area down a dirt embankment. Due to steep slopes, and to a lesser extent dense vegetation, this dirt embankment appears to be the only waterfowl congregation area adjacent to the shore. Barriers such as fencing or dense shrubbery can be installed at the shoreline at the base of the dirt embankment to reduce the population of waterfowl frequenting the pond. The installation of such a barrier may require a permit from RIDEM’s Freshwater Wetlands Program.

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

As depicted in the graphic on the following page, water flows from Spectacle Pond into a culvert under Route 10 which then flows into a small impoundment bordered by Niantic Avenue on the downstream end and finally into a underground culvert which discharges into Mashapaug Pond. Further investigation of the area is warranted to determine the presence of any illicit connections or other pollution sources. This area was formerly part of Spectacle Pond, but was significantly altered with the construction of Route 10. The pond is presently a degraded wetland that provides no apparent treatment to the significant stormwater loads that it receives and conveys to Mashapaug Pond. A cooperative effort between the Cities of Cranston and Providence and RIDOT is needed to reduce stormwater loads to the Spectacle Pond tributary, which in turn conveys a sizable fraction of the total pollutant load to Mashapaug Pond.


City of Cranston
RIDOT Storm drain Outfall
City of Providence
Underground Culvert
Spectacle Pond
RI Route 10
Niantic Ave,
Mashapaug Pond
North

6.2 Stormwater Management

Significant stormwater is generated in this urban pond's watershed within the City of Providence and from roadways owned by RI Department of Transportation (RIDOT). The City of Providence and RIDOT operate small Municipal Separate Storm Sewer Systems (MS4s) that discharge to Mashapaug Pond and it's tributaries. These entities have applied for and obtained coverage under the RIPDES General Permit and have developed and submitted the required Storm Water Management Program Plans (SWMPPs). The plans contain implementation schedules that include interim milestones, frequency of activities and reporting of results. The SWMPPs describe Best Management Practices (BMPs) for the six minimum control measures and include measurable goals and schedules for each measure:

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

The SWMPP must include measurable goals for each control measure (narrative or numeric) that may be used to gauge the success of the program. It must also contain an implementation schedule that includes interim milestones, frequency of activities and reporting of results. The DEM Director can require additional permit requirements based on the recommendations of a TMDL.

Public Education/Public Involvement

The public education program must focus on both water quality and water quantity concerns within the watershed. Public education material must target the particular audience being addressed. For example, the residential community must be educated about the water quality impacts from residential use and activities and the measures they can take to minimize and prevent these impacts. Examples include disposing pet waste properly, discouraging large waterfowl populations by eliminating human feeding of waterfowl, eliminating access from water bodies to adjacent open land for waterfowl to congregate and feed, and informing residents about disposing wastes properly (i.e. not disposing yard waste into storm drains or wetlands).

Public involvement programs must actively involve the community in addressing these concerns. Involvement activities may include posting signs informing the public not to feed waterfowl, stenciling storm drains with *Do Not Dump* labels, and designating and maintaining areas with pet waste bags and containers. The residential community must also be informed of measures to reduce runoff, including the use of dry wells or other means to infiltrate roof runoff where feasible and landscaping choices that minimize runoff. Some examples of landscaping measures include using a choice of more tolerant grasses and vegetation that require less fertilizer and watering, grading the site to minimize runoff, and to promote storm water attenuation and infiltration, reducing paved areas such as driveways, and use of porous driveways such as crushed shells or stone. Buffer strips and swales that add filtering capacity through vegetation can also slow runoff. These examples can also be targeted to residential land developers, commercial property owners, and landscapers. BMPs that minimize runoff and promote infiltration must be encouraged when redeveloping or repaving a site. Examples include porous pavement, infiltrating catch basins, breaking up large tracts/areas of impervious surfaces, sloping surfaces towards vegetated areas, and incorporating buffer strips and swales where possible.

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

Illicit Discharge Detection and Elimination

Communities may want to target illicit discharge detection and dry weather flow sampling in the watershed. This requirement is discussed in further detail in the storm drain section 6.3.1.

Construction/Post Construction

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.

As mentioned previously, examples of acceptable reduction measures include reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, using porous pavement, and installing infiltration catch basins where feasible. Other reduction measures to consider are the establishment of buffer zones, vegetated drainage ways, cluster zoning or low impact development, transfer of development rights, and overlay districts for sensitive areas.

Good Housekeeping/Pollution Prevention

The Storm Water General Permit (see Part IV.B.6.a.2 and Part IV.B.6.b.1) extends storm water volume reduction requirements to operator-owned facilities and infrastructure (RIDEM, 2003a). Similarly, municipal and state facilities could incorporate measures such as reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, incorporating buffer strips and swales, using porous pavement and infiltration catch basins where feasible. In addition, any new municipal construction project or retrofit must incorporate BMPs that reduce storm water and promote infiltration such as the before-mentioned measures: buffer strips, swales, vegetated drainage ways, infiltrating catch basins, porous roads etc.

6.3 Required Amendments to Phase II Stormwater Management Program Plans

Part IV.D of the General Permit states that the operator must address the TMDL provisions in the SWMPP if a TMDL has been approved for any waterbody into which storm water discharges from the MS4 contribute directly or indirectly the pollutants(s) of concern (Part II.C3). Accordingly, upon approval of this TMDL, the RI Department of Transportation and City of Providence will be required to submit SWMPP amendments addressing the TMDL provisions within one hundred and eighty (180) days of the date of written notice from the RIPDES Program (Rule 31 (f)(8)(iii), as described in greater detail below. More specifically, the SWMPPs must be revised to describe the six minimum measures and other additional controls that are or will be implemented to address the TMDL pollutants of concern [total phosphorus and fecal coliform] 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 stormwater 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.

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, shellfish growing waters, and other relevant information;
4. Identify and provide tabular description of the discharges identified in the TMDL including:
    a. the location of discharge (latitude/longitude and street or other landmark;
    b. size and type of conveyance (e.g. 15” diameter concrete pipe);
    c. any existing discharge data (flow data and water quality monitoring data);
    d. impairment of concern and any suspected sources(s);
    e. interconnections with other MS4s within the system;
    f. TMDL provisions specific to the discharge;
    g. any BMP(s) that have or will be implemented to address TMDL provisions and pollutants(s) of concern;
    h. schedule for construction of structural BMPs including those for which a 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 Mashapaug 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:

1. **new land development** employ stormwater controls to prevent any net increase in those pollutant(s) of concern [phosphorus and fecal coliform], and
2. **re-development projects** employ stormwater controls to reduce those pollutant(s) of concern [phosphorus and fecal coliform] to the maximum extent feasible.

To achieve the recommended phosphorus reduction rate of 65% and reduce wet weather fecal coliform concentrations, an in-depth analysis of the storm drain systems, availability of treatment sites, and comprehensive design of in-line treatment systems in conjunction with appropriate pre-treatment facilities must be undertaken. Cost, ownership and maintenance issues must be factored into a stormwater management plan that is both feasible and functional in meeting the goals of this TMDL. Since 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.

For those operators for which specific outfalls or discharges are identified in the TMDL, the Scope of Work must:

1. Describe the tasks necessary to design and construct BMPs that reduce loads of pollutant(s) of concern (Total Phosphorus and Bacteria) and stormwater volumes to *the maximum extent feasible* including:
    a. the delineation of the drainage or catchment area,
    b. determination of interconnections within the system and the approximate percentage of contributing area served by each operator’s drainage system, as well as a description of efforts to cooperate with owners of the interconnected system, and
    c. completion of catchment area feasibility analyses to determine drainage flow patterns (surface runoff and pipe connectivity), groundwater recharge potentials(s), upland and end-of-pipe locations suitable for siting BMPs throughout the catchment area, appropriate structural BMPs that address the pollutants(s) of concern, any environmental (severe slopes, soils, infiltration rates, depth to groundwater, wetlands or other sensitive resources, bedrock) and other siting (e.g. utilities, water supply wells, etc.) constraints, permitting requirements or restrictions, potential costs, preliminary and final engineering requirements.

2. Establish a schedule to: identify and assess all remaining discharges not identified in the TMDL (owned by the operator) contributing to the impaired waters addressed by the TMDL, delineate the drainage or catchment areas to these discharges, and as needed to address water quality impairments, design and construct structural BMPs. To determine the prioritization for BMP construction, the assessment of identified discharges shall determine the relative contribution of each to the pollutant(s) of concern 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.

6.4 Specific Storm Drains

Storm drains contribute the second largest source of total phosphorus and fecal coliform to Mashapaug Pond. As stated previously, the City of Providence and RIDOT must map their existing storm drain systems in the Mashapaug Pond watershed – specifically, delineating the areas that contribute stormwater runoff to the pond. As mentioned previously, storm drain SD4 (Parking lot drain) did not flow during the 2001 sampling events. The lack of flow from this drain warrants a recheck of the drainage system to determine if blockages exist, or re-routing has occurred. The stormwater maps must be corrected as necessary. The largest observed wet weather contributions of phosphorus from storm drains to the pond, ranked in decreasing order by load, are storm drains SD 5 (Pawnee St.), SD 1 (Niantic Ave), SD 2 (Dexter St.) and SD 6 (Lakeview Dr.). Relative to fecal coliform, the most significant observed storm drain sources ranked in decreasing order by load are storm drains SD 5 (Pawnee St.), SD 6 (Lakeview Dr.), SD 1 (Niantic Ave.), and SD 2 (Dexter St.). Storm drain 3 (DuPont Dr.) was not observed to be a significant contributor of either total phosphorus or fecal coliform.

The TP reduction target for storm drains is 65%. Several structural BMP technologies are available to treat stormwater, however literature values do not indicate that any one particular system performs at or above the necessary reduction level. Typical total phosphorus removal rates for in line filtration systems such as sand or organic filters are in the 59 – 81% range (CWP, 2004). The higher removal rate is associated with a multi-chambered treatment train, however the data documenting their actual effective removal rates are limited.

In addition to pollutant reduction, the volume of stormwater that directly discharges to Mashapaug Pond must be reduced. The large amount of impervious surfaces within the Mashapaug Pond watershed causes a substantial increase in the volume of stormwater during rain events. The use of BMPs such as pavement reduction, porous pavements, infiltrating catch basins, sub-drains that infiltrate pavement runoff prior to reaching the drainage system and other means of reducing the volume of runoff that discharges directly via the storm drain system to Mashapaug Pond must also be investigated and implemented during redevelopment or re-paving projects – as one means of reducing phosphorus loads to the maximum extent feasible.

Although not identified specifically in any storm drain other than SD6 (Lakeview Dr.), dry weather flows must be investigated and the source of these flows understood. The SWMPPs for the City of Providence and the Department of Transportation must specifically target illicit discharge detection for SD6, and the Route 10 storm drainage system discharging into the Spectacle Pond outlet, respectively. Illicit discharge detection must focus on dry weather flows that are not due to springs, groundwater or other legal connections; any illegal connections to storm drains must be eliminated.

6.5 Direct Runoff

Overland runoff that directly flows to the pond also contributes to water quality degradation in Mashapaug Pond. The following recommendations that address this runoff must be directed to the audience that has the ability to improve the conditions within the watershed. This audience consists of the residents that live along the pond's edge, the people that enjoy the recreational benefits of the pond, the transportation departments that maintain the roadways, and the commercial/industrial tenants that conduct their businesses within the watershed. A comprehensive public education and public involvement program that focuses on both water quality and water quantity concerns must be implemented to minimize the impacts these activities have on the water quality in Mashapaug Pond. Educational material that is targeted to each audience must be developed. The public involvement programs must actively involve all aspects of the community in order to achieve the water quality goals set in this TMDL.

Impervious surfaces within the watershed impact the water quality of Mashapaug Pond. Measures that can be taken to reduce these impacts include the infiltration of roof runoff, landscaping choices that minimize storm runoff, pavement reduction, or use of porous pavement materials or the construction of buffer strips and swales that add filtering capacity through infiltration. Both the residential and industrial communities in the watershed have the potential to incorporate these BMPs into their sites during new construction or redevelopment projects.

Aquatic buffers along the shoreline in which development is restricted or prohibited is one method of physically protecting and separating the pond from future disturbance or encroachment and for improving the water quality of the overland stormwater runoff. If properly designed and maintained, buffers can provide stormwater management, create water pollution hazard setbacks and can act as part of an urban forest, restoring natural habitat for wildlife. A minimum distance of 100 feet is an adequate base (CWP, 2004) width for optimum shoreline protection. Typically three zones based on function, width, vegetative target and allowable land use should be distinguished within the buffer. The functions of the buffer include protecting the physical integrity of the shoreline, providing distance between development and the shoreline, to prevent encroachment on the pond and to providing a filter for stormwater runoff. The width of the zone immediately adjacent to the shoreline should be a minimum of 25 feet and would be increased where applicable to incorporate any existing wetlands or critical habitats. The undisturbed mature forest must be maintained and any grassed areas reforested. Walking paths, utility rights-of-way and other similar uses may be allowed within this zone. The secondary zone or middle zone can vary in width and should take into consideration the slope of the embankment and optimally be between 50 and 100 feet. This could be managed forest with some limited clearing allowed. Recreational uses, some stormwater BMPs, bike paths and other appropriate development could exist within this zone. The outer or third zone should provide a minimum setback of 25 feet from any structure or impervious surface contributing runoff directly to the pond. Turf grass or lawns for residential uses, gardens, and the composting of yard waste and most stormwater BMPs are unrestricted within this zone.

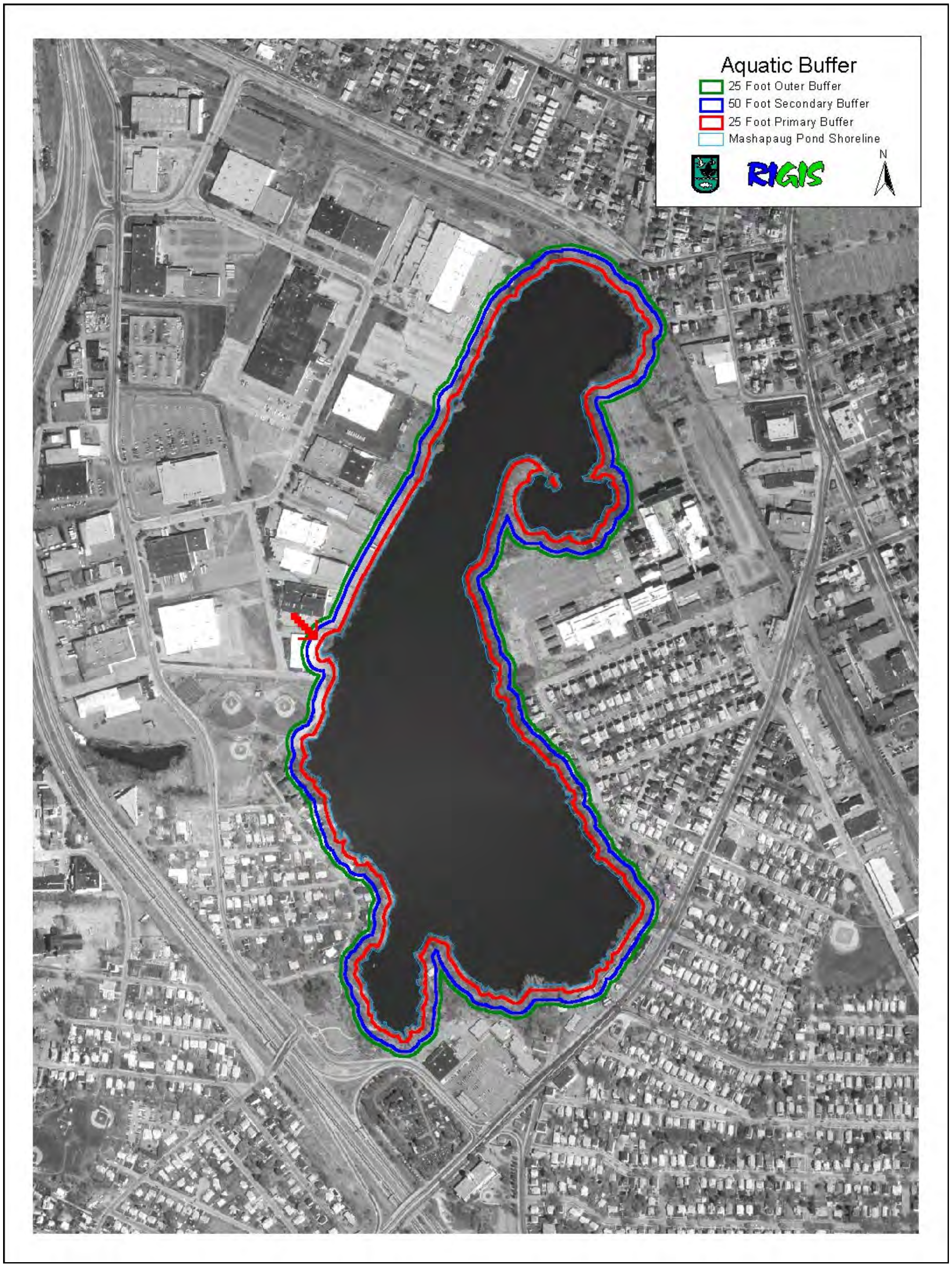
Figure 6.1 is an aerial photograph of the Mashapaug Pond Watershed. The slope-side or primary zone is outlined in red. The middle or secondary zone is located between the red and blue lines, with the outer limits of the buffer zone delineated by the green line. As can be seen very little (less than 1/10th of an acre, 4575 sq. ft.) of the primary zone contains impervious surfaces. This area is shown highlighted by the red arrows. Even though the remaining majority of this buffer zone contains vegetation it is highly unsuitable for stormwater management. The immediate shoreline contains a mixture of poor quality vegetation such as poison ivy, sumac, knotweed, Ailanthus, and briars (Searle and Searle, Oct. 1996). Improving the pollution removal performance of this buffer would require the removal of these invasive species and selective plantings of maples, oaks, willows, shrubbery, and other vegetative improvements. As referenced above the City of Providence Department of Parks and The Providence Plan produced a development and conservation plan for Mashapaug Pond in 1996. This plan suggests a walking trail and other improvements including the same recommendation to improve the general vegetation along the ponds edge that is consistent with the recommendations contained in this report. Particular attention must be paid to that area noted above that contains pavement within the primary zone and attempts should be made to replace this with suitable vegetation. This project has the potential to be an important and successful public involvement project that the city could get credit for under the Phase II program that is outlined in section 6.2.

The City of Providence and property owners along the shoreline would be the responsible parties for achieving this BMP. Commercial and industrial property owners must be educated as to the impacts their activities and/or development practices have on the water quality of Mashapaug Pond. They must be made aware of their responsibility to institute good housekeeping practices and cognizant of the fact that they contribute to the impairment to Mashapaug Pond. Cooperation between business owners and the City is vital to the achievement of the water quality goals established in this TMDL.

Residential property owners are also a critical component of this recommendation. In order to achieve the pollution reduction goals, buffer maintenance, proper fertilizer application, removal of pet waste and other good housekeeping practices on the numerous residential lots directly abutting the pond most be incorporated into this portion of the implementation plan. Failure to educate these stakeholders and engage their cooperation in the attempts to improve water quality in Mashapaug Pond would most likely result in additional failures in meeting the goals of this TMDL.

According to the Center for Watershed Protection fact sheet on aquatic buffers, pollutant removal rates (%) for total phosphorus range from a low of 8% to a high of 88%. The average removal rate based on the results from these ten studies is 50%. This is less than the recommended reduction of 65% outlined in table 5.2 of this report. Three of the studies reported removal rates equal to or above this recommended 65% and discussion within the fact sheet also makes note of the various factors that enhance performance of an aquatic buffer. The addition of organic matter or a mulch layer, the overall length of the buffer, the slope or construction of an intercepting swale, along with a dense grass cover are a few of the enhancements that could be considered in the final design of the buffer. These design components incorporated into a site-by-site basis along the pond's shoreline would more than likely increase performance of the pollutant removal rate to one that does reach the recommended 65% reduction.

Figure 6.1 Mashapaug Pond Aquatic Buffer Delineation



6.6 Waterfowl and Wildlife

Waterfowl and wildlife waste contain high levels of nutrients and fecal coliform that are washed into the pond with stormwater. Although this TMDL did not specifically identify animal waste as a source, reduction of this pollution will benefit the water quality of Mashapaug Pond. An educational component of this TMDL would therefore be to improve the awareness on the part of the general public regarding the adverse effects excess waterfowl populations have on water quality. Options include the distribution of fact sheets and flyers to the users of the parks and public areas around Mashapaug Pond, and signage where appropriate that notifies people that the feeding of wildlife is illegal. The City of Providence is encouraged to work with RIDEM Fish and Wildlife to investigate the options available to discourage the congregation of large populations of Canada Geese at the baseball field and surrounding parks that are adjacent to the pond.

Table 6.1 summarizes the recommended remedial measures discussed above. These measures when implemented should bring about water quality improvements in Mashapaug Pond. This TMDL relies upon phased implementation to reach water quality goals. As BMPs are installed, the corresponding response in total phosphorus concentrations and dissolved oxygen levels will be measured. As appropriate, additional measures may be required to meet the targeted load reductions.

Table 6-1 Summary of corrective measures.

Pollution source	Abatement measure	Location of BMP	Responsible Party
Spectacle Pond	Implementation of Eutrophic Ponds TMDL recommendations including stormwater BMPs, land use controls, in lake phosphorus controls and other non-point sources BMPs	Spectacle Pond Watershed	• City of Cranston • Private Property Owners
Storm drains	• Phase II Stormwater Management Plan, Six Minimum Measures • In line filtration systems, infiltration basins, infiltration trenches and other BMPs • Prioritize BMP implementation for SD1, SD2, SD5 and SD6 (Table 3.1)	Mashapaug and Spectacle Pond Watersheds	• City of Providence • City of Cranston • RIDOT • Private Property Owners
Illicit Discharges	Investigate dry weather flows to SD6 (Table 3.1) and Rt. 10 storm drains into Spectacle Pond outlet	Mashapaug Pond	• City of Providence • Private Property Owners • RIDOT
Direct runoff	Aquatic Buffers	Mashapaug Pond Shoreline	• City of Providence • Private Property Owners
Stormwater volumes	Infiltration, reduction of impervious surfaces	Mashapaug Pond Watershed	• City of Providence • RIDOT • Private Property Owners
Waterfowl and Wildlife	Discourage congregation of large populations of Canada Geese and other waterfowl	Baseball field and surrounding parks	• City of Providence • Citizens and park users

7.0 PUBLIC PARTICIPATION

A critical component of any TMDL is stakeholder involvement. Achieving the goals set forth in a non-point source impaired watershed must include the responsible parties. Public participation is crucial in order to achieve this goal. The following is a summary of the past and future efforts to involve the public in the development and acceptance of this TMDL.

USEPA in partnership with RIDEM and Tetra Tech began the process of the development of an integrated point-nonpoint source nutrient TMDL for Mashapaug Pond several years ago. As part of the USEPA work plan, Tetra Tech and its subcontractor ESS developed a QAPP (Quality Assurance Project Plan) and monitoring plan that was submitted to EPA and RIDEM in the spring of 2001. Monitoring of Mashapaug Pond was completed by the fall of 2001. A stakeholder's identification list was developed which included groups and individuals that had an interest in Mashapaug Pond. This stakeholder's list has been used to notify the public about meetings and presentations regarding the Mashapaug Pond water quality restoration efforts.

On June 5, 2001 an introductory meeting was held in which stakeholders and the public were invited to review the proposed project. The meeting was conducted by staff from RIDEM, USEPA, and Tetra Tech and was well received by the audience in attendance. A general overall explanation of the TMDL process along with the specific plans for the Mashapaug Pond restoration project was presented.

Upon completion of the monitoring and analysis of the preliminary results a meeting was scheduled to present these findings to the public. On June 11, 2002 a meeting was held at the Charles Forte School to present the initial findings from the previous years monitoring. Staff from RIDEM, USEPA, RIDOH, and Tetra Tech's subcontractor ESS presented the data and answered questions.

In the summer of 2002 it became apparent that the message that Mashapaug Pond was not a healthy environment to enjoy contact recreational activities was not getting to the public. Reports were received by RIDEM that people had been observed swimming in the pond. In an effort to educate the public as to the potential human health risks associated with contact with Mashapaug Pond a sign was designed and installed at four access points to the pond. A copy of the sign is shown in figure 7.1.

In addition to the presentations made to an adult audience, RIDEM staff made a presentation to children that participated in the Providence Parks and Recreation Departments summer environmental program at the boathouse located on Mashapaug Pond. Approximately fifty children ranging in age from ten to fourteen participated in a discussion on the impairments to water quality in Mashapaug Pond. The environmental program itself involved the children in water quality sampling, watershed investigation and other educationally based activities that increased water quality and watershed knowledge.

Figure 7.1 Mashapaug Pond Signage

Mashapaug Pond Do's and Don'ts

Enjoy Mashapaug Pond Safely

- Catch and release fish.
- Canoe and boat when pond conditions allow.
- Walk, bicycle or enjoy other recreational activities in the watershed.
- Picnic and bird watch.

WHAT WE KNOW ABOUT MASHAPAUG POND FROM A RECENT STUDY

BACTERIA: Swimming in the Pond is NOT SAFE because Fecal Coliform levels are high following rain storms.

FISH: Analysis of carp & bass samples indicate that fish from the Pond ARE NOT SAFE TO EAT

ALGAE: Some types of Algae (Cyanobacteria) found in the Pond can produce toxins that can harm humans and animals.

To keep you and your family safe until we learn more, Please Do Not:

- Drink pond water.
- Eat fish caught in Mashapaug Pond.
- Swim, wade, play or bathe in pond water.
- Boat whenever thick scum, algae mats, or foul odors occur on the pond.

What Should You Do?

Wash your hands with soap and water if you come in contact with pond water.	DO NOT eat fish caught in the pond.	Watch for increased algae in the pond, and avoid contact with pond water during algae blooms	Wipe your feet after leaving the pond to prevent tracking contaminated sediments into your car or home.

State of Rhode Island
Department of Environmental Management
Office of Water Resources

For More Information Contact:
RI Dept of Health,
Office of Food Protection
Dave Burnett at (401) 222-2749 or
email at RIbeaches@doh.ri.state.us

HEALTHri
Rhode Island Department of Health
Patricia A. Nolan M.D., MPH, Director • Lincoln Almond, Governor

A power point presentation created by RIDEM staff entitled Mashapaug Pond was presented to the Charles Forte Magnet School After School Club in December 2002. Slides representing water quality impairments and sources described the pollution and the sources that are impairing the water quality of Mashapaug Pond. Approximately 20 elementary school children attended this program, watched the presentation, asked questions and were given a word search developed specifically for water quality issues in Mashapaug Pond to complete at home.

RIDEM presented the draft TMDL plan to stakeholders and the general public on May 2, 2007. Approximately two weeks prior to this meeting the draft document was released to the public and also posted to RIDEM's website. The public meeting began the 30-day public comment period, which ended on June 1, 2007. Letters were sent to key stakeholders in advance of the meeting. In addition, the meeting was publicized in a press release, public notices which were posted at Cranston and Providence's City Halls and the Providence Library. The meeting was held at DEM offices in Providence but was sparsely attended by the public, public officials, and other agencies. Total attendance was estimated at 15 individuals, not counting DEM staff. DEM received several comments during the public comment period. These are presented in Appendix C. Meeting notes are presented in Appendix D.

RIDEM encourages the creation of a watershed partnership between stakeholders. Industrial development and redevelopment of the properties surrounding the pond hold a key role in the efforts to improve water quality in Mashapaug Pond. The city's public works and parks departments are also critical players in maintaining and improving stormwater BMPs. The cities will also need to incorporate the recommendations contained in this TMDL into their Phase II Stormwater Management Plan regulated by the RIPDES program. The RI Department of Transportation and the City of Cranston will also need to incorporate the recommendations contained within this report in their Phase II program. Spectacle Pond is located in Cranston and storm drains from RI Route 10 discharge into the impoundment area between Spectacle and Mashapaug Ponds. Both entities will be required to incorporate the aforementioned recommendations into their Phase II stormwater permitting applications.

The residential neighbors to the pond need to be included in the watershed education effort and encouraged to act as catalysts to the improvement of water quality in Mashapaug Pond. These property owners have a vested interest in improving the esthetics of the pond and can play a key role in fostering a partnership with all responsible parties to achieve the goals of this TMDL and the resultant improvement of water quality in Mashapaug Pond.

8.0 FOLLOW-UP MONITORING

This TMDL is presented as a phased approach to achieve the water quality improvements outlined above. Several variations of BMPs could be initiated and constructed within the watershed that will provide varying effects on reducing the pollution to Mashapaug Pond. As there is no one action that will be taken that will meet the goals of this TMDL future monitoring of the water quality will be needed to judge how implemented BMPs are performing.

Currently URI Watershed Watch volunteers conduct routine monitoring of water clarity (secchi depth), temperature, chlorophyll-a, and bacteria sampling. In order to measure the impacts of reducing nutrient loadings from sources in the watershed, sampling for total phosphorus and nitrogen should also be conducted. This sampling should be completed for the waterbody itself at the established monitoring stations and from the identified storm drains for comparison to previous sampling results. As improvements are made within the watershed, subsequent reductions to pollutant loads should be observed. If this does not become a reality, additional recommendations for the reduction of non-point pollution must be considered.

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APPENDIX A
Stratification Analysis and Dissolved Oxygen Standard
Mashapaug Pond, Rhode Island

Stratification Analysis and Dissolved Oxygen Standard
Mashapaug Pond, Rhode Island

Stratification Analysis

Mashapaug Pond in Providence, Rhode Island, is listed on the state's 303(d) list of water quality impaired waterbodies for nutrients and dissolved oxygen (DO). The water quality criteria for dissolved oxygen in Rhode Island is stated as follows:

> Not less than 6.0 mg/L at any place or time except as naturally occurs. Normal seasonal and diurnal variations, which result in in situ concentrations above 6.0 mg/L, not associated with cultural eutrophication processes will be maintained in accordance with the antidegradation implementation policy. Dissolved oxygen content of not less than 60% of saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5.0 mg/L. The 7-day mean water column dissolved oxygen concentration shall not be less than 6.0 mg/L.

The natural stratification processes in a lake are such that it may not be reasonable to expect that all of the above conditions for dissolved oxygen can be achieved, even for a pristine lake. For example, when a lake becomes stratified during the summer season, it is normal for the near-bottom waters experience instantaneous concentrations below 5.0 mg/L. Two reference lakes in Rhode Island with healthy nutrient levels were selected in order to better understand the naturally occurring conditions in Mashapaug Pond. These reference lakes were used to understand how unimpaired waterbodies in Rhode Island behave and to establish a more reasonable DO end-point criteria to be used in a total maximum daily load (TMDL) analysis for Mashapaug Pond.

The process of stratification is a normal and healthy process that occurs in most temperate and northern lakes. Stratification is a well-documented phenomenon in which a lake separates into two distinct layers with very little mixing between them. A warmer, less dense layer forms above a denser cooler lower level during the summer months. Consequently, dissolved oxygen concentration can drop as it gets consumed and nutrients may accumulate out of the sediment in the lower layer. When the air temperature drops in the fall the upper layer cools, falling to the bottom and mixing the lake.

Seasonal stratification is observed in many healthy lakes in Rhode Island. Data from Upper Schoolhouse Pond and Wakefield Pond were analyzed in order to establish reference ponds with hydrology and chemistry similar to that of Mashapaug Pond. Upper Schoolhouse Pond is located in a rural area within the Narraganset Indian tribe reservation. Wakefield Lake is also located in a rural area and has a watershed that is primarily wooded. The Rhode Island Watershed Watch Program, coordinated by Linda Green, has been collecting data on these ponds for a number of years. Data was available for Schoolhouse Pond for the summer of 2001 and for Wakefield Pond for the summer of 1997. Both Ponds display clear stratification during these summers and the data is plotted in Figures 1 and 2.

Figure 1. Upper Schoolhouse Pond Temperature and DO Profiles

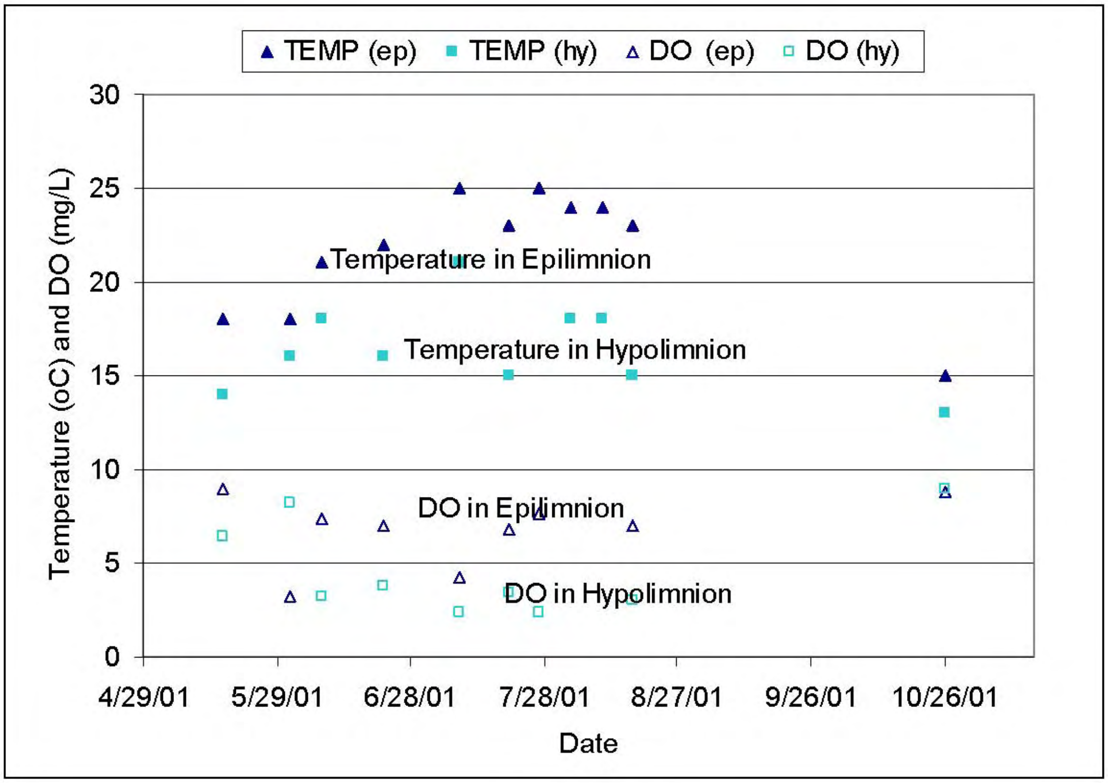
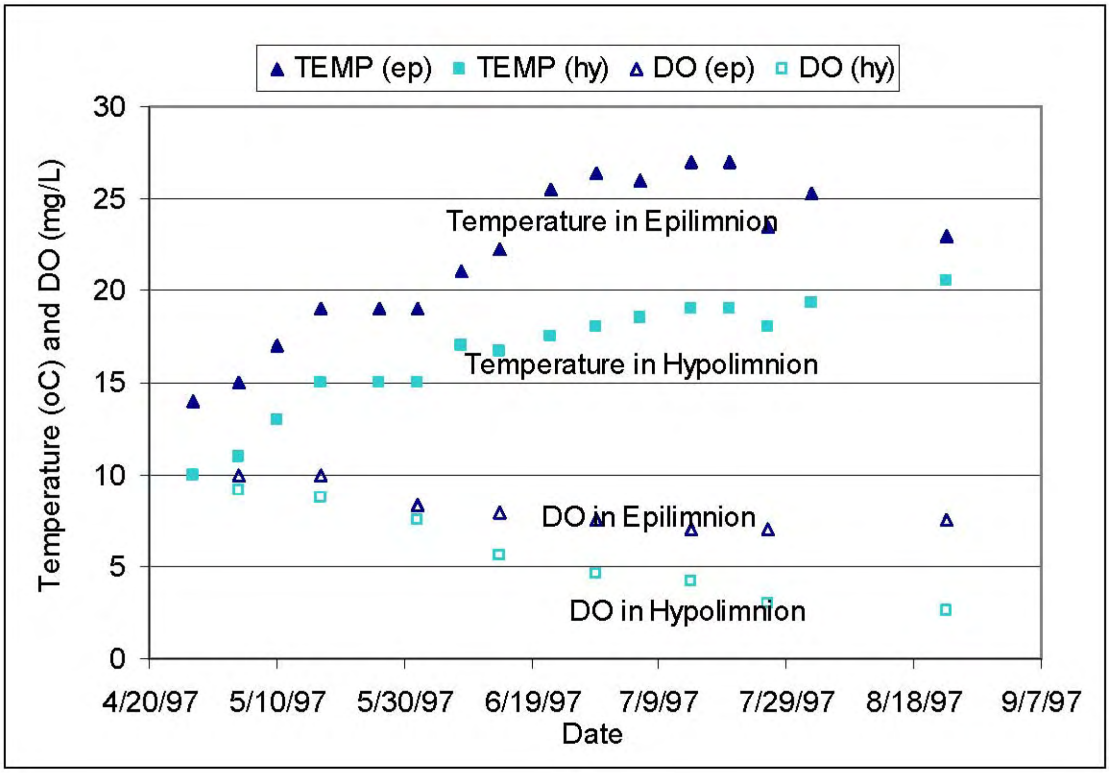


Figure 2. Wakefield Lake Temperature and DO Profiles



Figures 3 and 4 display the same plots of temperature and dissolved oxygen over the course of the summer for Mashapaug Pond. Mashapaug Pond displays a similar stratification process as the one observed in the reference lakes. Figure 3 represents data collected in the north section of the Pond and Figure 4 represents data collected in the south section. The data was collected as part of the monitoring program for the TMDL development during the summer of 2001.

Figure 3. Mashapaug Pond (North Region) Temperature and DO Profiles

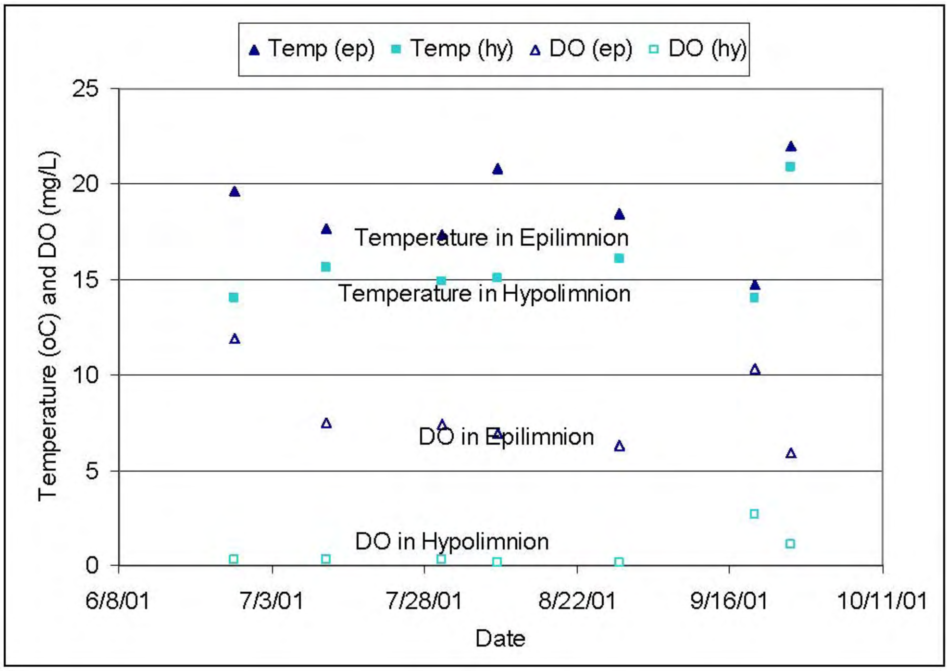
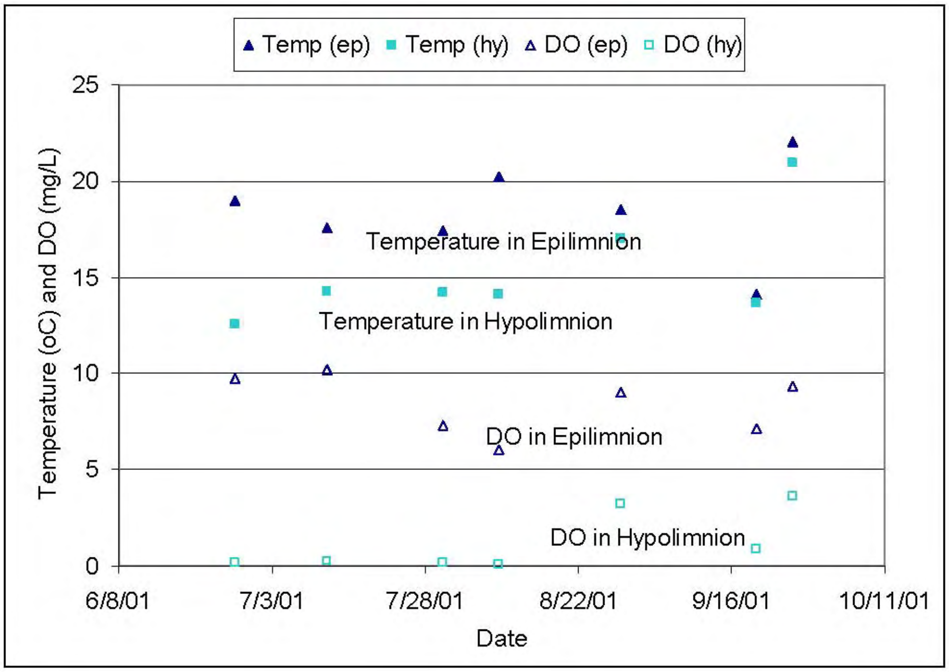
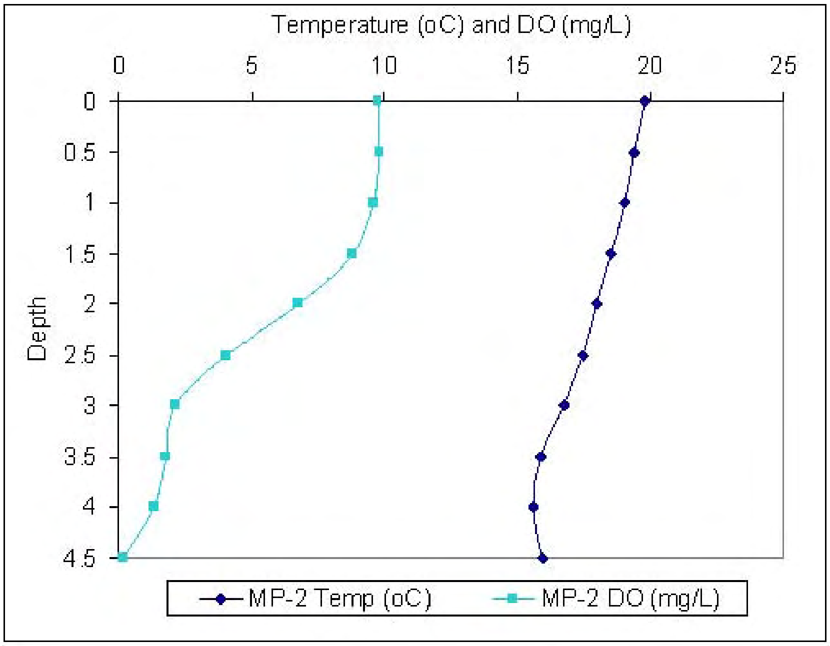


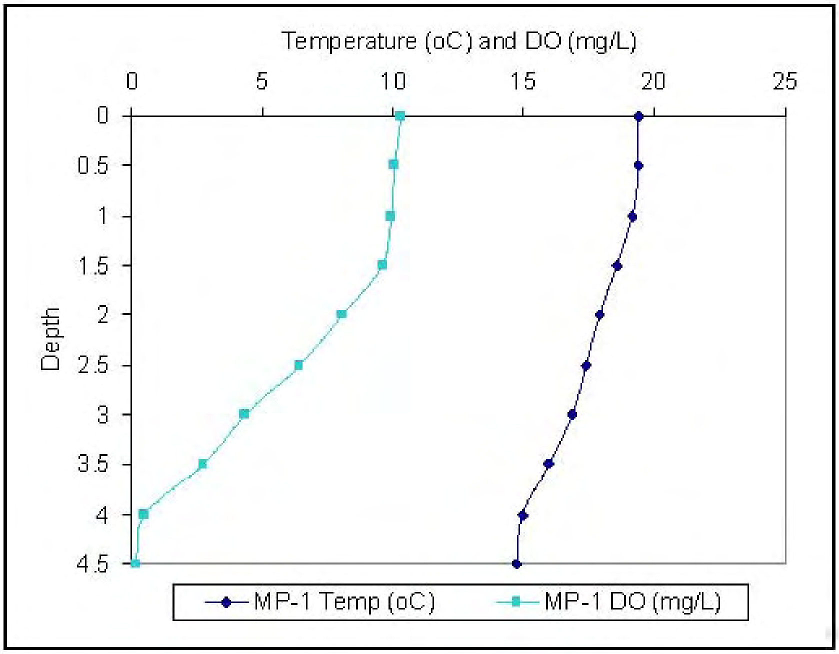
Figure 4. Mashapaug Pond (South Region) Temperature and DO Profiles



An analysis of the dissolved oxygen and temperature profiles of a lake can also help in the understanding of the stratification process. There was not enough data available for the reference lakes to produce profiles as a function of depth. But profiles were produced for Mashapaug Pond and compared to literature data. Figure 5 and 6 show the DO and temperature profiles for the North and South sample stations in Mashapaug Pond. The temperature is in ^{o}C and the DO is in mg/L.

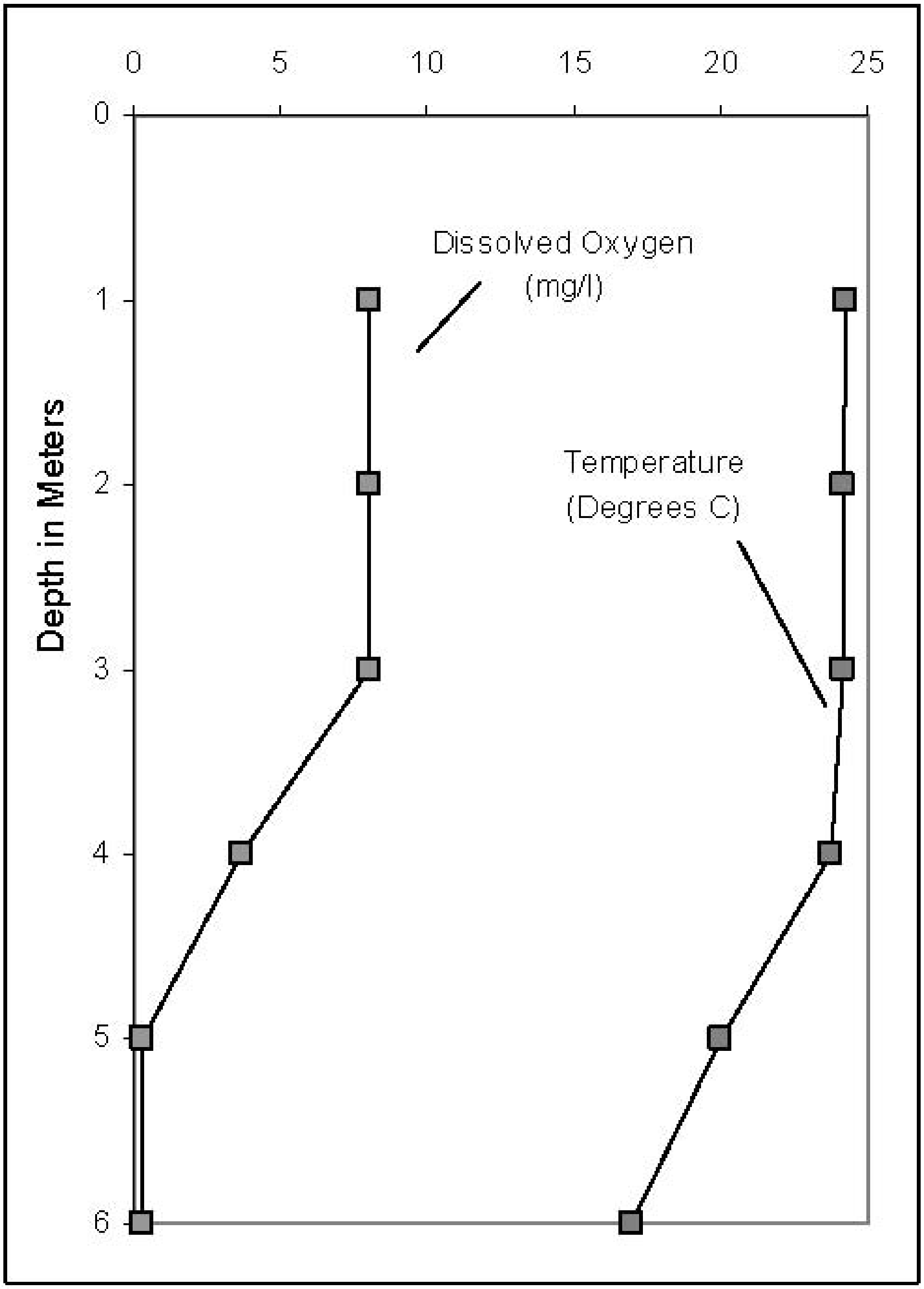
Figure 5. Mashapaug Pond (North Sec.) Figure 6. Mashapaug Pond (South Sec.)





A typical dissolved oxygen and temperature plot for a stressed Rhode Island Lake can be found in Figure 2 of *Dissolved Oxygen and Temperature*, Fact Sheet No. 96-3, Natural Resources Facts, University of Rhode Island at the following URL:
http://www.uri.edu/ce/wq/ww/resources/dotemp.pdf
The profiles, reproduced below in Figure 7, are similar to conditions in Mashapaug Pond.

Figure 7. Typical DO and Temperature Plots for Rhode Island

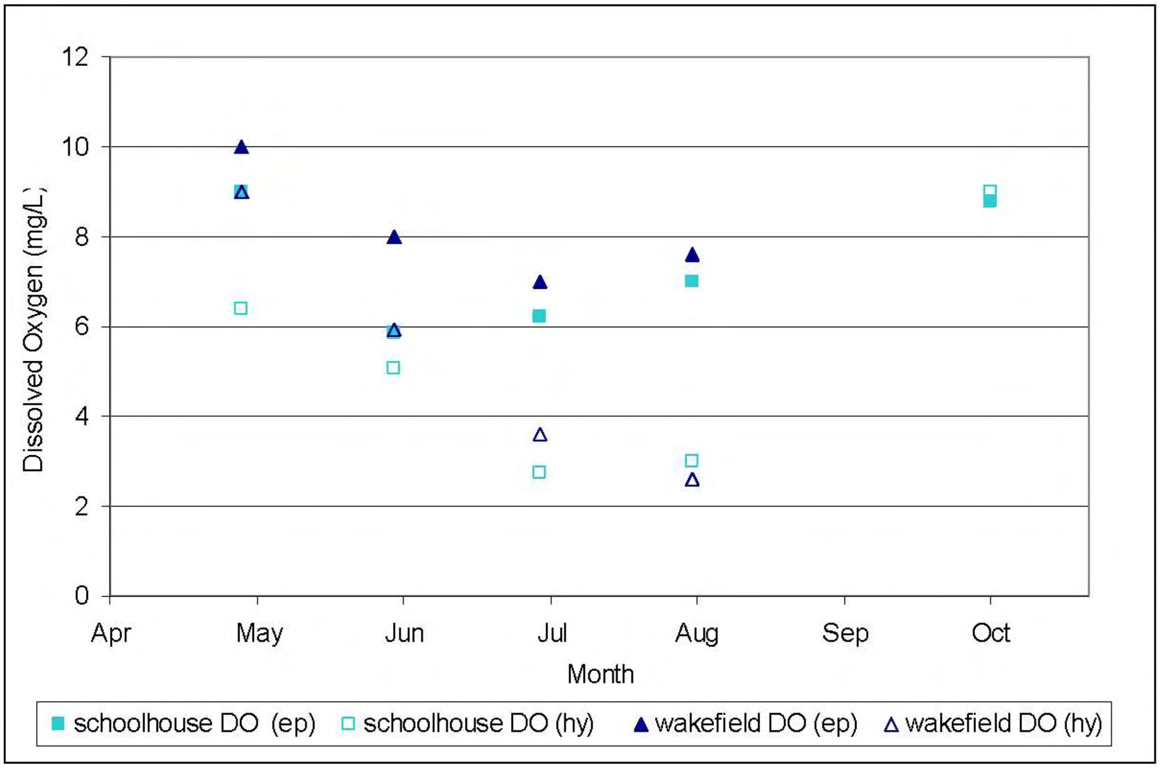


Dissolved Oxygen Standard

As the previous section demonstrated, the process of lake stratification results in lower dissolved oxygen concentrations in the hypolimnion. This is a natural process in most northern lakes. The low DO in the hypolimnion can be more distinct in eutrophic lakes (i.e., those having high nutrient levels), but is present in healthy lakes as well. Therefore, the present numerical water quality standard for DO may be an inappropriate measure of a lake's health.

The current Rhode Island water quality criteria require a water body to have an instantaneous DO concentration of at least 5.0 mg/L at any point in the water column as well as a 7-day mean water column concentration of at least 6.0 mg/L. The two reference lakes have healthy water conditions and neither one is impaired, however, the reference lakes demonstrate a consistent failure to meet the both the instantaneous 5.0 mg/L and the 7-day mean 6.0 mg/L concentration criteria (see Figures 1 and 2) during the summer season. It is recommended that the TMDL endpoint criteria for dissolved oxygen in Mashapaug Pond be representative of the conditions observed in the two reference lakes rather than relying strictly upon numerical values in the DO water quality standard. A reasonable target guideline for use in the Mashapaug Pond TMDL is the dissolved oxygen profile for the two healthy reference lakes (see Figure 8) where the DO concentration in the hypolimnion remains above 2.0 mg/L.

Figure 8. Target Dissolved Oxygen Concentrations for Stratified Lakes



TETRA TECH, INC.

June 14, 2002

Mr. Alfred Basile
US Environmental Protection Agency
Region 1
1 Congress Street, Suite 1100
Boston, MA 02114-2023

Dear Al,

Attached please find the document entitled "Stratification Analysis and Dissolved Oxygen Standard, Mashapaug Pond, RI." This document was developed to explain how the hydrologic conditions in Mashapaug Pond effect the water quality criteria applied to the Pond. Specifically, this document describes how the stratification observed in Mashapaug Pond makes it unrealistic to apply uniform dissolved oxygen criteria to the entire water column. The document compares the stratification of Mashapaug Pond with two relatively pristine, stratified lakes in Rhode Island and suggests that the dissolved oxygen concentrations in these lakes should be used as a target during the TMDL development for the Pond.

If you have any questions please do not hesitate to contact me.

Sincerely,

Nancy Sullins
Environmental Engineer

Appendix B
Mashapaug Pond Data Report and Analysis

Mashapaug Pond Data Report and Analysis

Summer 2001
Mashapaug Pond
Providence, Rhode Island
Submitted: 2/25/02

In order to develop a TMDL for Mashapaug Pond, Rhode Island a monitoring plan was implemented during the summer of 2001. Environmental Science Services, Inc. (ESS) carried out the plan. The monitoring plan included the following components: wet and dry weather water quality monitoring; bathymetric survey; ground water and seepage analysis; aquatic vegetation analysis; and fish tissue analysis. This document provides the data gathered by ESS and a discussion of the sampling plan results. This discussion is presented in Chapter 1.

Table of Contents

1.0 Water Quality Data Analysis

1.1 Dry Weather Water Quality Monitoring

In lake analysis of the water column was conducted on six occasions during the summer of 2001 (see Table 1 and Table 3). Two monitoring sites were established in the lake, one in the northern and one in the southern portion (Figure 1). The sampling sites were located in the deepest areas of the lake in order to fully characterize the entire water column. Both the temperature and dissolved oxygen data demonstrate stratification in the water column (see figures 7-10 and Table 5). The thermocline had an average depth of 2m. The dissolved oxygen profile for both sampling locations showed that the lower layer of the lake experiences anoxic conditions during the entire summer, while the upper layer displays adequately high dissolved oxygen values. This type of stratification is a natural condition of many lakes in northern climates. The nitrogen to phosphorus ratio in the lake is much greater than 10 indicating that the water column is limited by phosphorus with respect to algal biomass growth.

Dry weather water quality monitoring of all the inputs to the lake was conducted on the tributary from Spectacle Pond and storm drain #6. These were the only two surface tributaries to drain into the lake during dry conditions. The data shows that the tributary from Spectacle Pond has nitrogen concentrations similar to those in the pond. The phosphorus concentration from the tributary, however, is approximately two fold higher than the values observed in the pond. Storm drain #6, on the other hand, had phosphorus values that were only slightly higher than the values measured in the lake. The nitrogen contributions (nitrate-nitrite) from the storm drain were significantly greater than the values observed in the lake.

Wet Weather Water Quality Monitoring

The original monitoring plan included the monitoring of several wet weather events, unfortunately, the 2001 summer was relatively dry. Wet weather monitoring was conducted on the lake and its tributaries during first flush, 4 hours, 22 hours, and 24 hours after the rain event during one storm on 9/25/01 (see Table 2 and Table 4). The in lake monitoring for dissolved oxygen during the storm showed a stratification consistent with the dry weather conditions although the stratification occurred closer to the bottom of the lake. The temperature stratification was not as noticeable during the wet weather events as it was during the dry weather events. This could be attributed to the fall turnover. The wet weather event was not sampled until late in the season and close to the end of the stratification period typical for northern lakes. The nutrient data for the in lake sampling locations were unavailable for most of the rain event. The fecal coliform and E.coli data were analyzed, however, and both of these parameters demonstrated a significant increase in the lake water column during the storm event. Secchi depth measurements were not taken during the rain events and could not be compared to the dry weather measurements.

The storm drains demonstrated varying magnitudes of nutrient concentrations during the storm event. The nitrogen loading from the various storm drains and the tributary were roughly of the same order of magnitude as the concentrations in the lake. The only exception was storm drain #6, which demonstrated the same high nitrate-nitrite level it had during dry weather. The total phosphorus measurements from the storm drains were higher than the lake values in all drains and particularly in drains #2 and #5. The fecal coliform and E.coli concentrations in the storm drains and the tributary from Spectacle Pond surged during the storm event to values many thousands of times greater than the background values measured in the lake water column.

Fish Tissue Analysis

A fish tissue analysis was conducted to determine if there was any accumulation of organics or metals as a result of the urban watershed surrounding the Pond. No in stream metal data was collected in conjunction with the fish tissue. This analysis does not directly affect the dissolved oxygen impairment but is an indicator of other problems in the water column.

The study found that the carp and bass tissue exhibited high concentrations for certain dioxins and furans. All values exceeded EPA's fish consumption cancer health endpoints for unrestricted consumption based on one meal per month. The measured concentrations of some dioxin/furan congeners (Table 15) exceeded EPA's cancer health endpoint for "no fish consumption" of 1.2 ng/kg . PCB concentrations were greater for carp than bass tissue. Seven PCB congeners were identified in carp tissue and four in bass tissue (Table 10). All of the PCBs in the carp tissue samples were above the unrestricted consumption level of 1.5 ug /kg , one congener fell within the "no greater than one meal a month" range and another fell within the "no greater than half of a meal a month" range. Two of the PCB congeners in the bass tissue were within the level for "no more than sixteen meals per month". The carp tissue had a chlordane concentration that fell within the "no greater than sixteen meals per month" cancer health endpoint although there were no detections in the bass tissue. Both carp and bass tissue had DDT congeners detected (Table 10). One DDT congener in the carp tissue was measured within the "no more than sixteen meal per month" level. The others were within the unrestricted level. Hexachlorobenzene and Endosulfan Sulfate were detected in bass tissue although the level is within the unrestricted consumption level. Arsenic, chromium, copper and mercury were detected in the bass tissue and chromium, tin, aluminum and mercury were detected in the carp tissue (Table 11). None of the levels were greater than those identified as acceptable for unrestricted consumption.

2.0 Groundwater Analysis

An assessment of the quantity and quality of groundwater entering Mashapaug Pond was conducted by ESS on August 22, 2001. This assessment was conducted in order to identify whether particular segments of the pond's shoreline were contributing elevated levels of nutrients (phosphorus and nitrogen) to the pond. This assessment is expected to be of value toward developing an accurate estimate of the nutrient and hydrologic loads that the pond is receiving.

The shoreline of Mashapaug Pond was divided into 6 segments (Figure 3) based on topography and land use features. Consideration of topography is important since shoreline segments with differing slopes are likely to have different hydrologic loadings. Similarly, shoreline segments with differing land use features are likely to contribute differing concentrations of nutrients to the groundwater resulting in different nutrient loadings to the pond.

The actual seepage survey was conducted according to the methods outlined in Mitchell and Wagner (1988) and (1989). Installing two seepage meters per defined shoreline segment and measuring the corresponding change in volume in the attached seepage collection bag estimated seepage quantity. This change in volume is then multiplied by a conversion factor relating the allotted seepage time (in minutes) to an entire day and then multiplying this value by the area of seepage captured by the seepage meter. This yields the total volume (in liters) of in seepage (positive value) or outseepage (negative value) per square meter per day (Table 7). The seepage meters deployed for this study occupied approximately 0.25 square meter and were left in place for between 3.1 and 4.9 hours. Most seepage values were found to be positive, indicating that at the time of sampling, inseepage was occurring (Table 7).

Seepage volume and direction can be affected seasonally, however, since during periods of sustained precipitation the level of water in the pond is typically raised faster than the groundwater elevation. This can result in a net outflow around the sandy edges of the pond. During dry periods, the pond elevation typically would be expected to decline in response to surface water outflow and evaporation, while the groundwater elevation will decline less rapidly, mainly in response to well withdrawal. Since well withdrawal in the Mashapaug Pond watershed is limited to non-existent, it would be expected that groundwater inflows to the pond would be substantial, particularly during the extended dry periods. This is due to the fact that during these periods, the pond elevation is below the groundwater elevation. It should be noted that local variation is possible, allowing groundwater to flow into one part of the pond and out of another.

Also, groundwater flow may change direction throughout the summer, as precipitation changes the pond level more rapidly than the groundwater level, and greater evaporation and surface outflow draw the pond down again. The generally sandy to gravelly substrate on the pond bottom would be expected to allow groundwater to enter or exit most parts of the pond fairly easily. Groundwater seepage into the pond averaged 6.5 L/m^2/D during the August 22, 2001 sampling event (Table 7). It is expected that this average seepage rate would be applicable for a distance of up to 75 feet from Mashapaug Pond's shoreline, beyond that the seepage rate would be expected to decrease considerably as a result of more impermeable substrate materials.

A Littoral Interstitial Porewater (LIP) sampler was used to extract groundwater from the interstitial pore space within the sediments of the pond's bottom. The porewater was collected prior to it reaching the surface water of the pond. Analysis of this porewater provided an assessment of the quality of groundwater entering the pond. Porewater was extracted from multiple (typically three) locations within each pre-defined shoreline segment. The porewater was tested in the field for conductivity and pH and sent to a laboratory for analysis of total dissolved phosphorus (TDP), ammonia nitrogen, nitrate-nitrite nitrogen and dissolved iron.

With the exception of Segment 1 (Figure 3), which exhibited relatively low conductivity levels (83 µmhos/cm), porewater conductivity was elevated (462 – 980 µmhos/cm) along shoreline segments throughout the pond. Conductivity at the higher levels (>400 µmhos/cm) is often indicative of human related impairment but can also be of natural origin.

Total dissolved phosphorus is the concentration of all forms of dissolved phosphorus. "Dissolved" in this case is defined as passing through a 0.45 µm filter. Particles <0.45 µm may move with the groundwater in porous soils. In groundwater, dissolved phosphorus values in excess of 0.05 mg/L are of concern in terms of eutrophication, and values in excess of 0.10 mg/L can be expected to cause serious deterioration of conditions if the phosphorus is biologically available. However, larger values in porewater do not necessarily translate into pond water column values of the same magnitude. High iron levels are known to promote the formation of iron phosphates, which are highly insoluble in oxygenated water. For phosphorus to be available in the water column at a significant level, the ratio of phosphorus to iron must be greater than 5 to 1.

Total dissolved phosphorus in Mashapaug Pond porewater ranged from 0.009 to 0.128 mg/L with a total average of 0.047 mg/L (Table 6). Total dissolved iron levels ranged from 0.2 to 10.6 mg/L with an average of 3.8 mg/L. Five of the six samples had an iron:phosphorus ratio of >5:1, indicating that there are typically sufficient iron levels to counteract the elevated phosphorus values and render them biologically inert. Additionally, phosphorus levels were low (≤0.03 mg/L) in the majority of samples and therefore, the in-pond levels of iron required to sequester dissolved phosphorus from groundwater need not be extremely high. Segment 3 was the only segment sampled, which exhibited an iron:phosphorus ratio of <5:1, suggesting that groundwater flows from this region may be contributing significant sources of biologically available phosphorus. Interestingly, this area also is characterized by dense beds of floating-leaved vegetation (Figures 4 - 6), which presumably thrive in the nutrient rich waters.

Nitrate-nitrite nitrogen values in Mashapaug Pond porewater ranged from <0.02 to 0.53 mg/L with an average value of 0.31 mg/L (Table 6); this average value would not be considered as problematic. Typically, values over 1.0 mg/L are unusual without some form of urban or agricultural influence, while values over 10 mg/L are generally considered a health hazard for human consumption. Segment 6 had the highest levels of nitrate-nitrite nitrogen observed in the study (0.53 mg/L). Based upon the limited number of samples (one sample from a single year), it appears that the level of nitrate-nitrite nitrogen in the groundwater entering Mashapaug Pond is generally acceptable except perhaps in the extreme northern portion of the pond.

Ammonia nitrogen has a similar range of possible values as nitrate-nitrite nitrogen, as the sources are the same. Federal standards for ammonia nitrogen, which estimate the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect, indicate that ammonia standards are variable and are dependent upon ambient pH levels (40 CFR 31 USEPA, 2001; 57 FR 60848 USEPA, 1992; National Recommended Water Quality Criteria USEPA, 1999). For the present analysis, groundwater pH values ranged from 5.5 to 7.9 SU, which translates to a pH dependant ammonia nitrogen threshold ranging from 10 to 57 mg/L.

Measured ammonia nitrogen concentrations in Mashapaug Pond porewater averaged 1.43 mg/L (Table 6) suggesting that ammonia nitrogen levels do not currently pose a toxicity problem for Mashapaug Pond. Despite this relatively low average ammonia value, ammonia nitrogen was observed to be 6.3 mg/L at Segment 3. Although still not a toxicity problem, this level of ammonia nitrogen exceeds the 1.0 mg/L guideline that would typically indicate the presence of significant nutrient loading in this region of the pond.

The sum of nitrate-nitrite nitrogen and ammonia nitrogen, or dissolved inorganic nitrogen (DIN), could be expected to reach up to approximately 1.0 mg/L under natural conditions. Values much over that concentration raise suspicions of contamination from faulty sewage systems or excessive fertilization. DIN values ranged from 0.11 mg/L to 6.30 mg/L with an average value of 1.54 mg/L. DIN values well above 1.0 mg/L were measured in two out of the six segments, with Segment 3, located in the northeast cove and Segment 4, located in the southern cove being the two regions of concern.

3.0 Phytoplankton Community Assessment

Phytoplankton is a term used to describe the algae that live as plankton (or free-floating organisms) in the open waters of a lake or pond. The phytoplankton community of Mashapaug Pond was sampled on July 30, 2001 from sampling station MP-1s (Figure 1). Data collected on the phytoplankton community indicated that Mashapaug Pond is highly eutrophic based on the algae species present and the overall algal abundance (Table 8). Both samples analyzed from July 30, 2001 contained several algal species that are typical of eutrophic waters (Sweet 2002). These phytoplankton are bluegreen algae (Cyanobacteria or Cyanophyta) and included the species: *Anabaena planctonica*, *Microcystis aeruginosa*, and *Aphanizomenon flos-aquae*. All three species are indicative of eutrophic lakes, particularly the *Aphanizomenon flos-aquae*. Algae abundance was very high, with Trophic State Indices (TSI, value calculated from algal bio-volume) of 68.6 and 70.5 for the 2 samples. A TSI value ranging from 50-70 is considered eutrophic while values above that are considered hypereutrophic (Carlson 1977).

There is a potential health risk to swimmers from the three observed bluegreen algae species since all three are known to produce toxins that are capable of making humans sick and potentially killing pets and other animals. It is important to note that not all bluegreen algae blooms are toxic, and even blooms caused by the known toxin producers may not produce toxins or may produce toxins at undetectable levels. Blooms of toxin-producing bluegreen algae are reported to be associated with a stable water column (a stratified condition), increased surface total phosphorus concentrations (>10 μg/L), surface temperatures greater than 22 ºC, high total nitrogen to phosphorus ratios (>30), and increased water column transparency (up to ~5.5 m). All of these conditions, with the exception of the increased water column transparency, were observed to occur in Mashapaug Pond during the July 30, 2001 sampling event.

If a person’s skin comes into contact with toxic blue-green algae through swimming or other activities, the skin may become itchy, rashes may form, eyes and ears may become irritated or a sore throat may develop. If water with toxic bluegreen algae is ingested, nausea, vomiting, abdominal pain, diarrhea, and potentially, liver problems and muscle weakness could develop. It is strongly recommended that additional study and more extensive algal monitoring be conducted at Mashapaug Pond to fully assess the magnitude of the risk to people and animals using this pond.

It may be possible to gather some essential data at a reduced cost through local volunteer monitoring if a citizen or other person is able to measure Secchi depth on a daily basis throughout the summer. Review of this data may be able to provide an early warning of a potentially problematic algal bloom. It would also be beneficial to sample (but not analyze) algae on a daily basis during likely bloom times. Analysis of these collected samples could be performed at a later date to identify the magnitude and the nature of any toxicity problems. If extensive monitoring and a determination of potential risks is not possible due either to a lack of personnel or funding, it would at a minimum be very beneficial to conduct routine bi-weekly phytoplankton sampling and analysis (and if possible, more frequently during bloom times) to track the phytoplankton community cycle in the pond and establish a more extensive set of baseline data. If it is determined that a bluegreen algal bloom is imminent, the pond should be posted accordingly to warn people not to come into contact with its waters.

Ultimately, the most effective means to ensure that the public is protected is to improve conditions within the pond by reducing the nutrients fueling the algal growth. In Mashapaug Pond, phosphorus is expected to be the limiting nutrient and therefore the logical target for management actions. In the absence of a thorough loading analysis, it is expected that the in-pond phosphorus concentration would need to be reduced to a level below 5 μg/L, and preferably below 2.5 μg/L, in order to achieve a noticeable reduction in algal density.

4.0 Quality Assurance/Quality Control

This section documents deviations from Environmental Science Services' (ESS) Quality Assurance and Quality Control (QA/QC) protocols as described in the EPA approved Quality Assurance Project Plan (QAPP) for TMDL Support for EPA New England: Mashapaug Pond, Providence, Rhode Island (ESS, 2001). The following ESS QA/QC review was conducted to ensure that collection, reporting and analysis of data followed approved standard operating guidelines (SOGs) and that data quality objectives as outlined in the QAPP were met. Data subjected to this QA/QC review include both field and laboratory efforts.

Data collected during the course of the study consisted of wet weather water quality samples (collected on September 25 and 26, 2001), dry weather water quality samples (collected on June 27, July 12, July 31, August 9, August 29 and September 20, 2001), groundwater samples (collected on August 22, 2001), macrophyte data (collected on July 5, 2001) phytoplankton community data (collected July 30, 2001) and fish tissue samples (collected on August 8 and September 25, 2001 for carp and bass, respectively). Please refer to attached tables and figures for data collected during the study. Data that fell outside of established QA/QC acceptance criteria were investigated and have been described below.

Field Data Collection:

- In several instances non-flowing conditions at sampling locations were documented, particularly for storm drain locations. Although this was not unexpected, it did prevent collection and analysis of samples from these locations during non-flowing conditions.
- ESS personnel did not conduct pre-dawn dissolved oxygen measurements during the course of the project. Alternatively, an automated YSI dissolved oxygen meter was installed and monitored on a diurnal basis by Rhode Island Department of Environmental Management (RIDEM) personnel. QA/QC of this data has not been performed by ESS.
- Field notebook entries were made in pencil rather than ink as stated in the QAPP.
- Two wet weather events were targeted as specified in the QAPP (September 20 and September 25 – 26, 2001. As pre-directed by EPA Region 1, ESS focused data collection to daylight hours for reasons of safety. Since the storm event began relatively late in the day, wet weather water quality samples were not collected at the pre-determined intervals specified in the QAPP (first-flush, 2 hours, 6 hours, 12 hours, and 24 hours). Rather, wet weather water quality sampling was conducted during first flush, 4 hours, 22 hours and 24 hours during a precipitation event spanning September 25 and 26, 2001.

Laboratory Water Quality Data Analysis:

- The QAPP specified that nitrate (NO_3-N) and nitrite (NO_2-N) should be analyzed jointly (i.e., as NO_2+NO_3-N). ESS Laboratory analyzed nitrate-nitrite as a combined measure for all sampling dates, with the exception of the June 27 and July 12, 2001 sampling dates. Samples collected from these dates were analyzed for NO_3-N (Nitrate) and NO_2-N (Nitrite-N) as two separate analyses. ESS Laboratory Inc. was notified of this discrepancy and conducted the proper analyses for all subsequent sampling events. Site MP-1B on June 27, 2001 was analyzed as a combined measurement. Since nitrate and nitrite values can be combined to attain one result for nitrate-nitrite, the aforementioned discrepancy is not anticipated to affect the validity of the data.
- The July 12, 2001 Chlorophyll *a* samples were improperly diluted in the laboratory with water, rather than the appropriate 90% acetone solution (University of Rhode Island Laboratory, personal communication). As a consequence, the Chlorophyll *a* data from this date have been omitted from the data tables.
- Laboratory *E. coli* analyses were added to the Scope of Work by RIDEM following the June 27, 2001 sampling date and therefore, only fecal coliform values are reported for the initial June 27, 2001 sampling date.
- The 0.05 mg/L Project Quantification Limit for TKN was not met for several of the dry and wet weather water quality samples (Refer to Tables 12 & 13). However, all TKN detection limits were below the 1 mg/L Project Action Limit (ESS Lab data).
- The 0.02 mg/L Project Quantification Limit for NO_2+NO_3-N for sampling location SD-6 was not met on the dry weather water quality sampling events of July 31, August 29 and September 20, 2001, nor was this level of detection met for the first flush wet weather sampling event (SD-6-FF) on September 25, 2001. However, all NO_2+NO_3-N detection limits were below the 1mg/L Project Action Limit.
- The 0.02 mg/L Project Quantification Limit for Ammonium-N was not met in several of the dry and wet weather and groundwater quality samples (Refer to Tables 12, 13 & 14). However, all Ammonium-N detection limits were below the 1 mg/L Project Action Limit.

4.1 Fish Tissue Data Analysis

- Fish (bass and carp) for fish tissue samples were caught primarily by anglers using rod and reel, rather than by the multi-panel gill net as described in the QAPP. Gill nets were initially deployed by ESS (with assistance from EPA Region 1 and RIDEM staff) on July 25, 2001, however, an insufficient number of fish were obtained for the preparation of the composite samples described in the QAPP. Consequently ESS obtained assistance from the Rhode Island Carp Anglers Club and the Bass Club of Rhode Island. These anglers caught carp and Bass on August 8 and September 25, 2001, respectively.
- Carp specimens were not analyzed for Antimony (Sb) as detailed in the QAPP (Environmental Research Institute data).
- Fish samples (bass and carp) were analyzed for furans and dioxins by AXYS Analytical Services Ltd.

4.2 Sampling/Analysis Holding Time

Each laboratory analyte has a standard holding time that has been established to ensure sample/analysis integrity. Refer to the MADEP approved QAPP (ESS, 2001) for a complete listing. If the standard holding time was exceeded, this objective is violated and data would be censored. All holding times for water quality and fish tissue sampling were met throughout the entirety of the study.

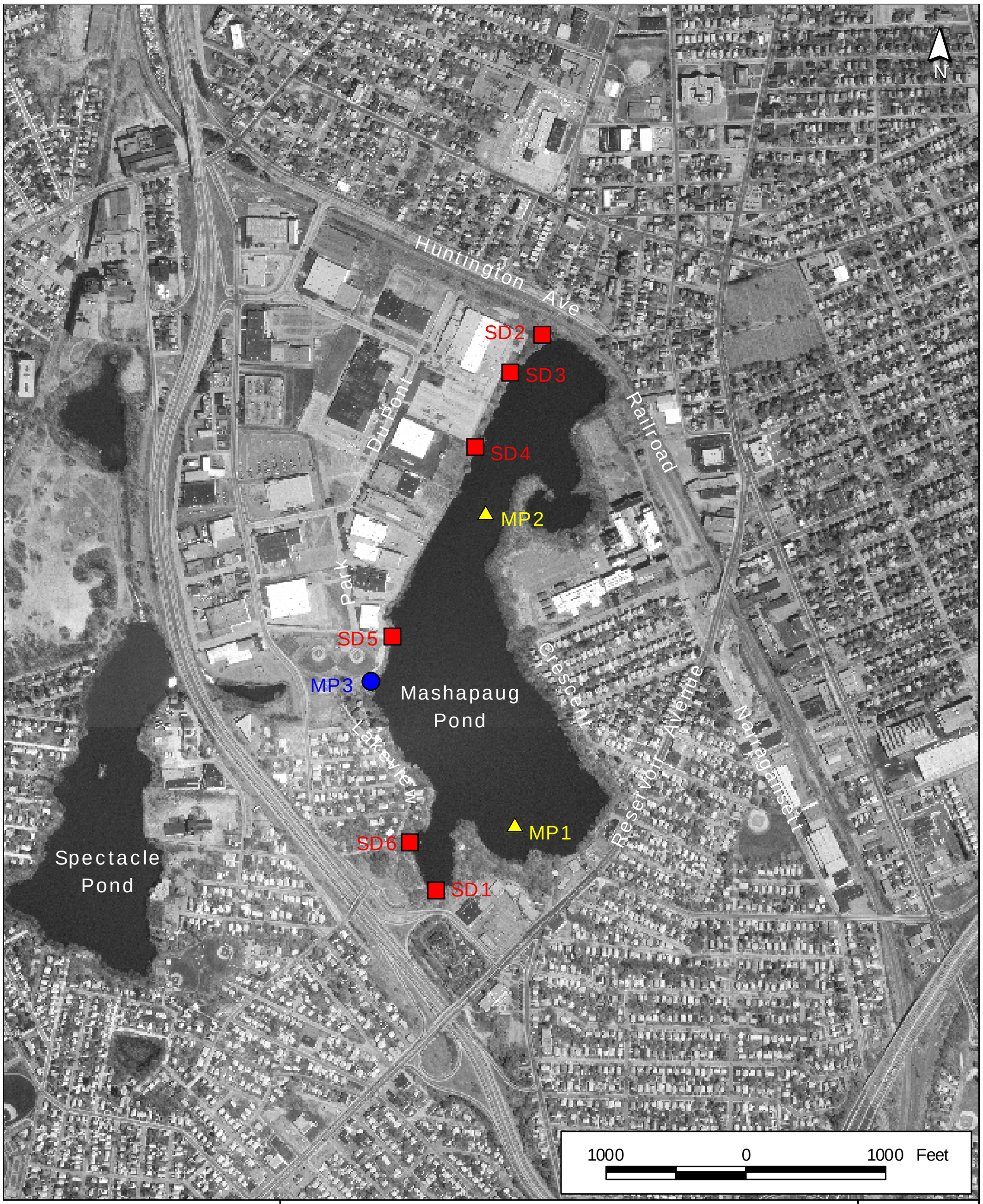
4.3 Duplicate Analysis

According to the QAPP, one field duplicate sample was to be collected for every twenty water quality samples (a frequency representing at least 5% of the total number of samples delivered to the laboratory on any given date). Field duplicate samples were incorporated at a greater frequency for water quality sampling (12%) throughout the entirety of the study.

In addition to the duplicate sampling described above, contracted Laboratories conducted internal replicate sampling. Please refer to Laboratory Quality Assurance (QA) Plans provided in the QAPP for more detailed information.

5.0 Figures and Tables

The following pages contain figures and tables summarizing all of the data collected by ESS for Mashapaug Pond.



Sample Locations

△ In-Pond

🟥 Storm Drain

● Tributary

In-Pond, Tributary, and Storm Drain Sampling Locations

Sources: 1) RIGIS, 5K Ortho Images, 1997
2) ESS, Sample Locations done by GPS (3 Feet Accuracy), 2001

Scale: 1" = 1,000'

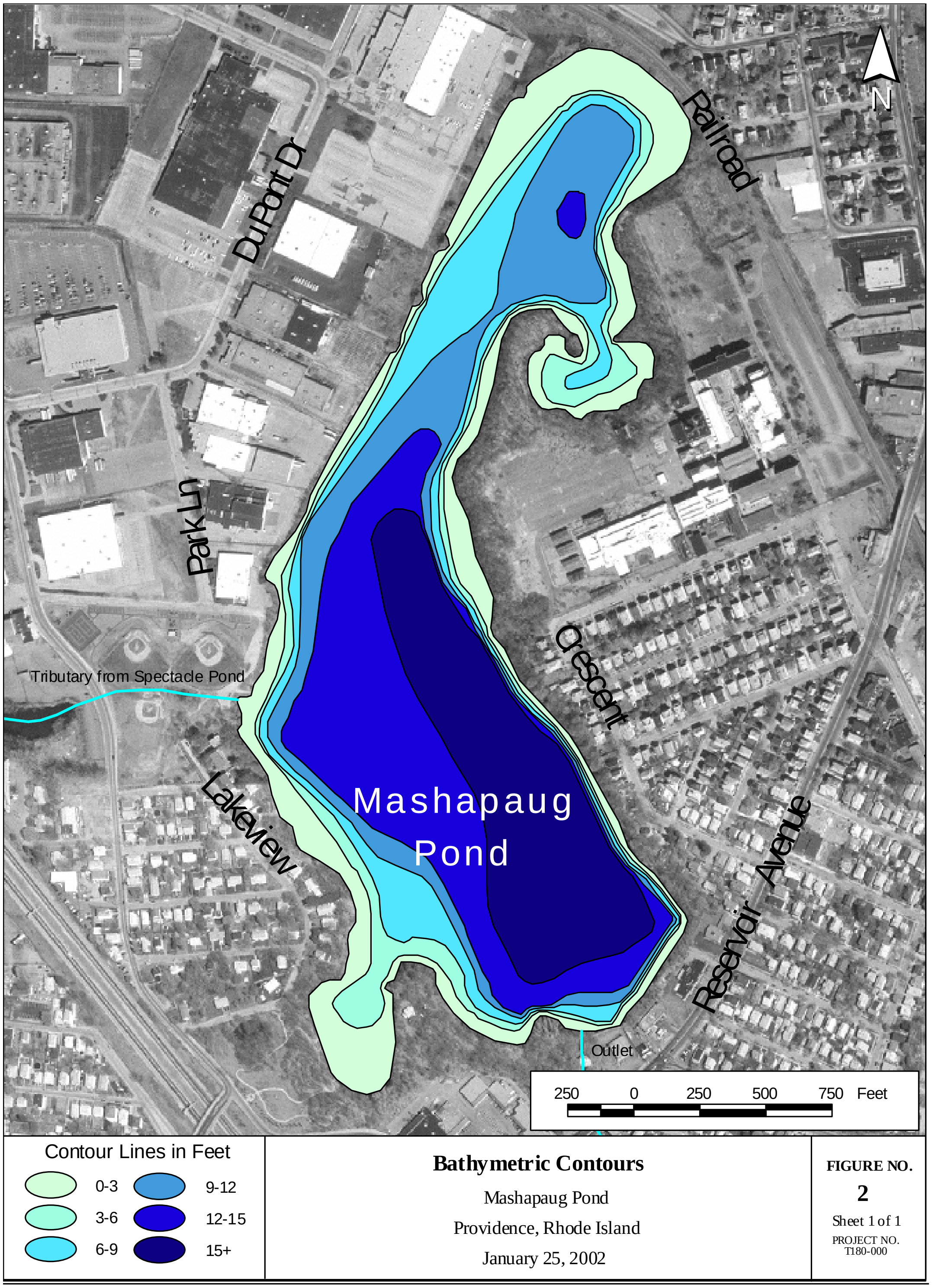
Mashapaug Pond Project

FIGURE NO.

1

Sheet 1 of 1

PROJECT NO.
T180-000



Bathymetric Contours

Mashapaug Pond

Providence, Rhode Island

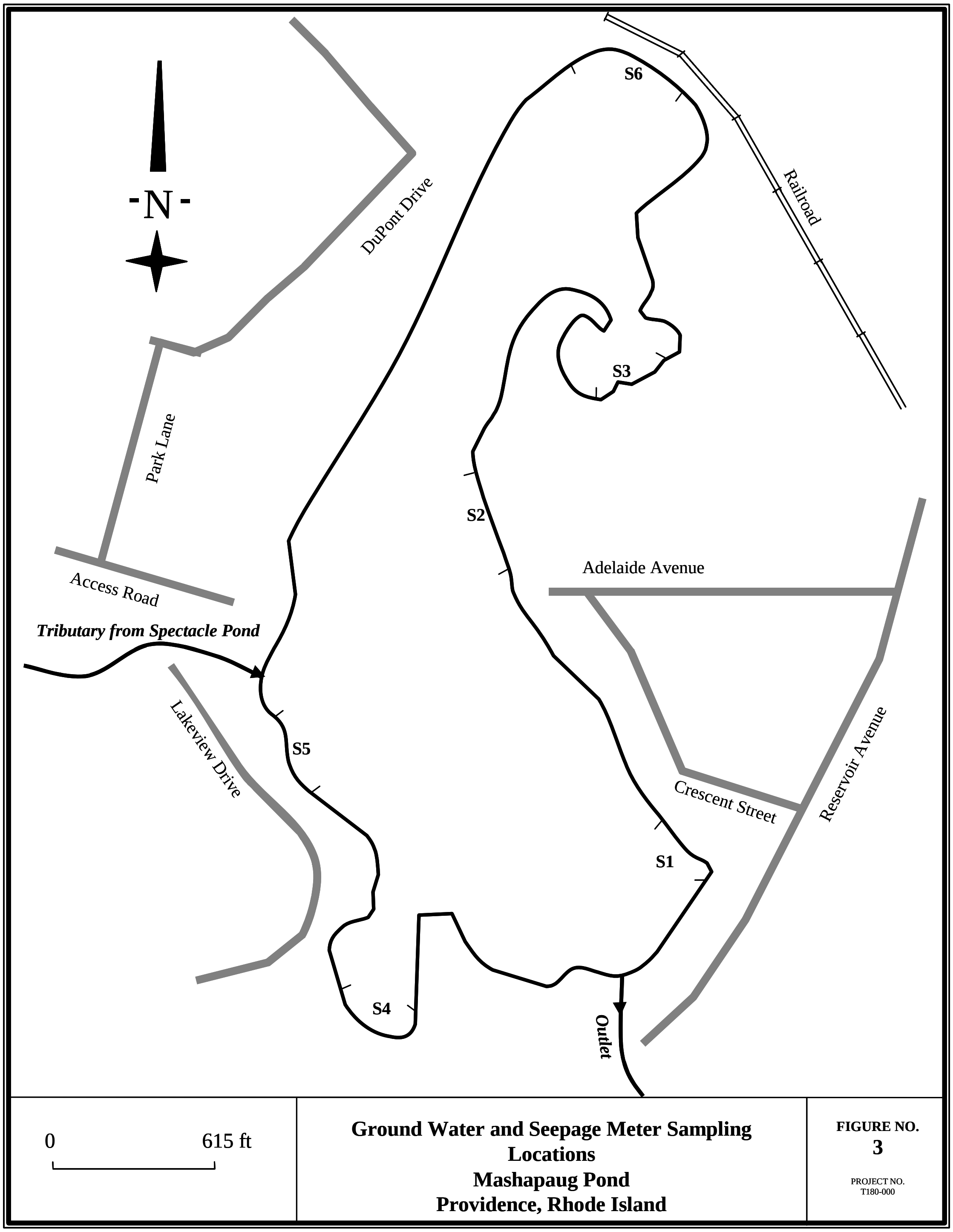
January 25, 2002

FIGURE NO.

2

Sheet 1 of 1

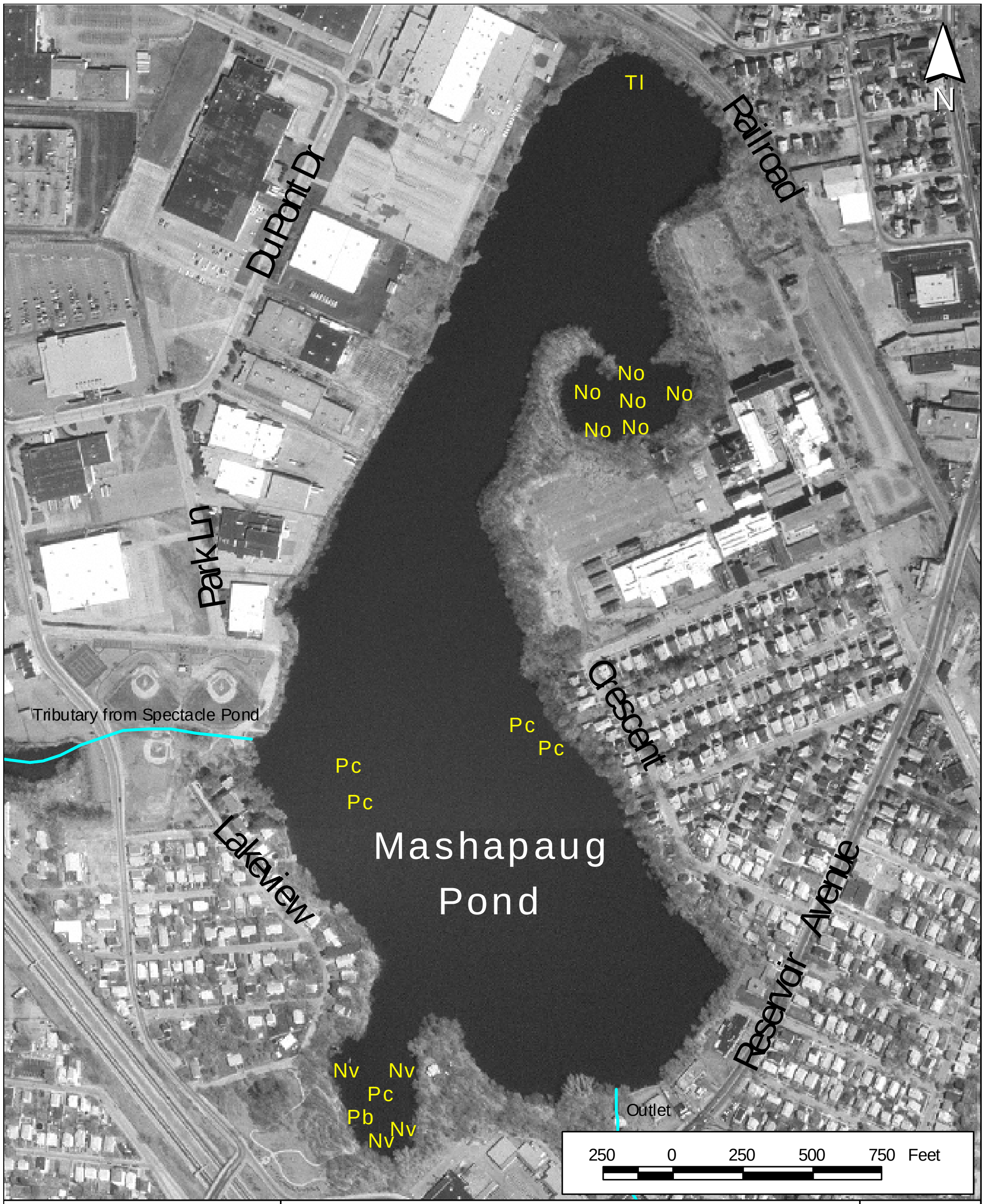
PROJECT NO.
T180-000



Ground Water and Seepage Meter Sampling Locations
Mashapaug Pond
Providence, Rhode Island

FIGURE NO.
3

PROJECT NO.
T180-000



Key to Plant Species:

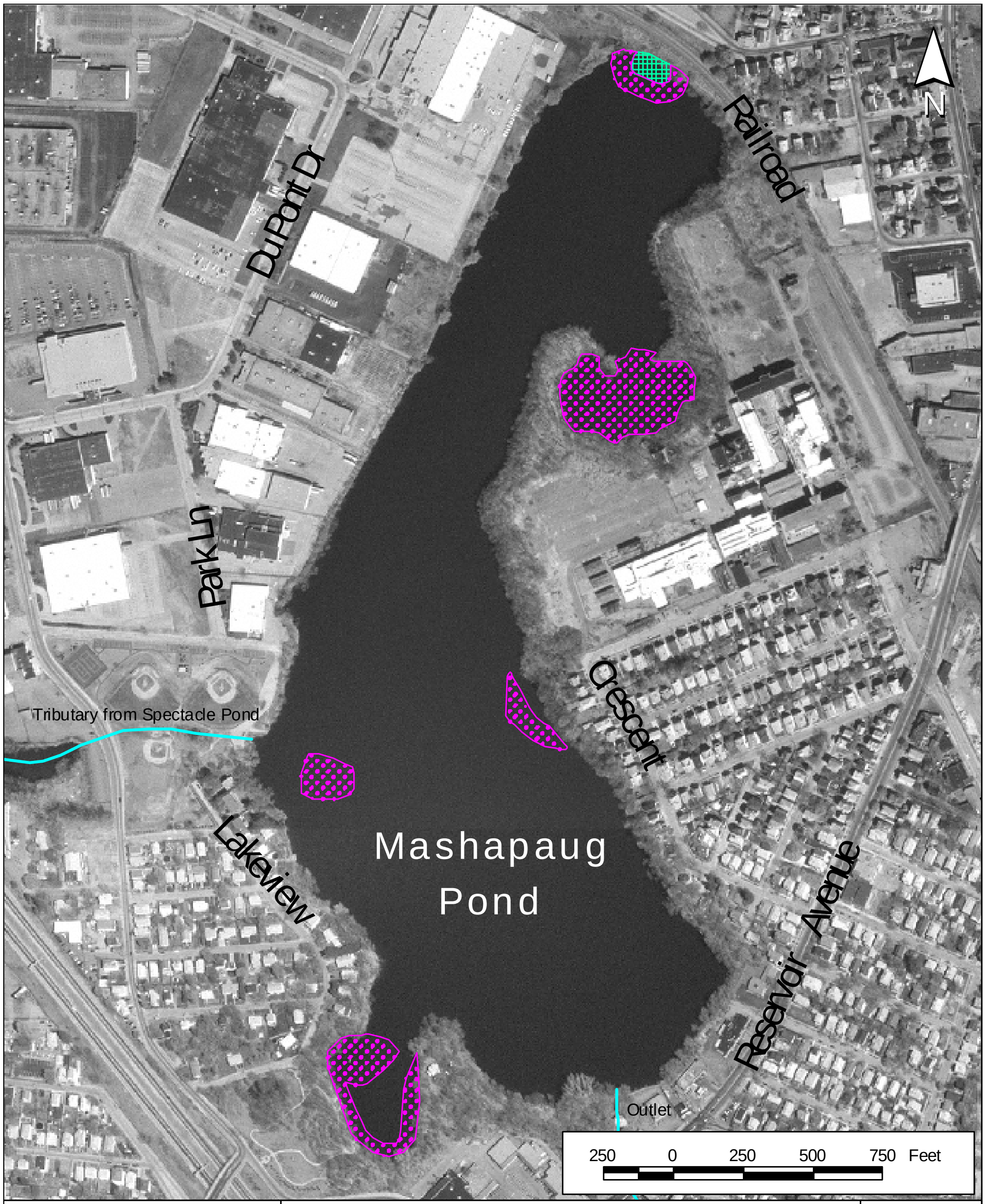
Nv = Nuphar variegatum
No = Nymphaea odorata
Pc = Potomogetan crispus
Pb = Pomatogetan bicupulatus
Tl = Typha latifolia

Distribution of Major Plant Beds
Mashapaug Pond

Providence, Rhode Island

January 25, 2002

FIGURE NO.
4
Sheet 1 of 1
PROJECT NO.
T180-000



Percent Biovolume
- ○ 0%
- ● 1-25%
- ▨ 26-50%
- ▤ 51-75%
- ▦ 76-100%

Biovolume of Aquatic Vegetation
Mashapaug Pond

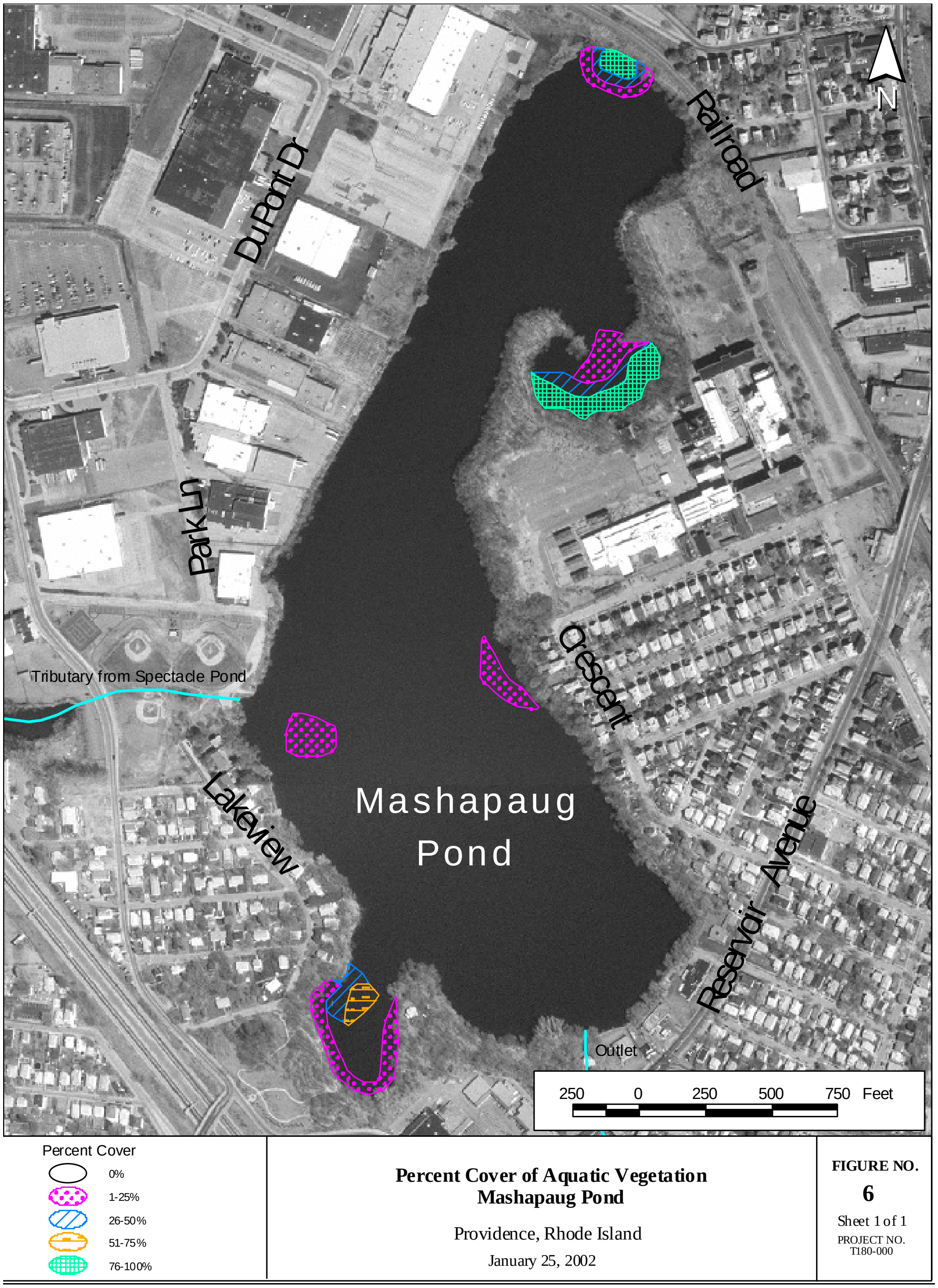
Providence, Rhode Island

January 25, 2002

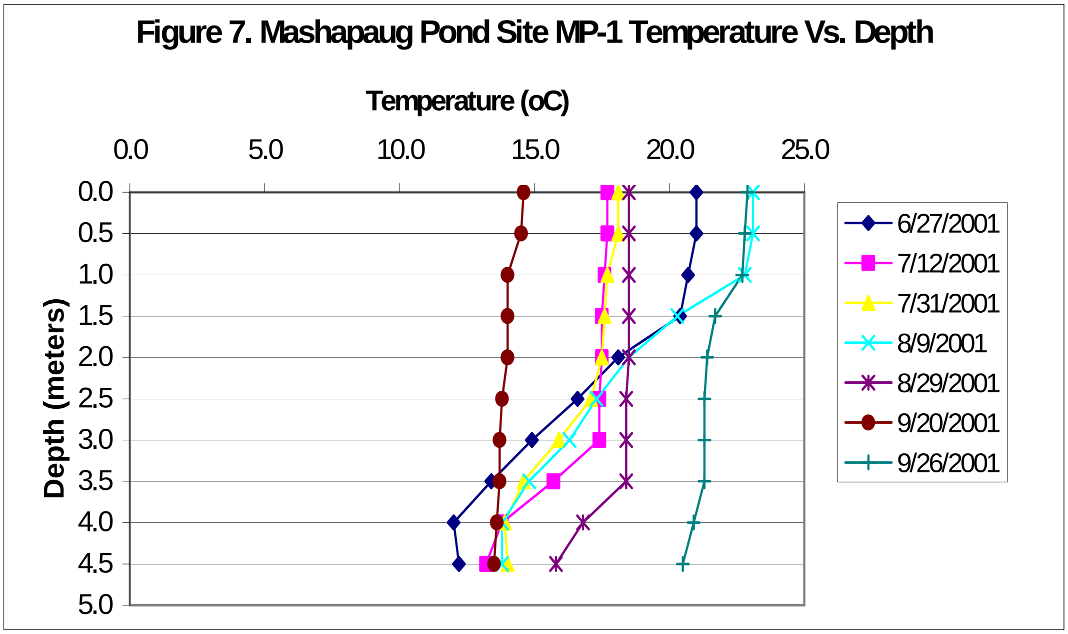
FIGURE NO.
5

Sheet 1 of 1

PROJECT NO.
T180-000



Figures 7 & 8. Temperature and Dissolved Oxygen profiles at Mashapaug Pond MP-1.



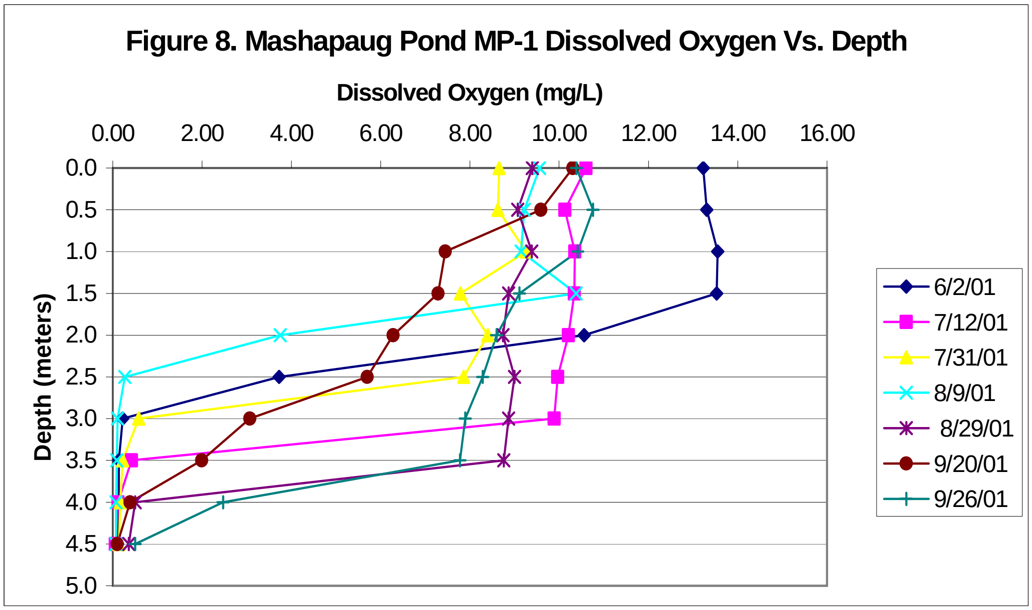


Figure 9 & 10 Temperature and Dissolved Oxygen profiles at Mashapaug Pond MP-2

Figure 9. Mashapaug Pond Site MP-2 Temperature Vs. Depth

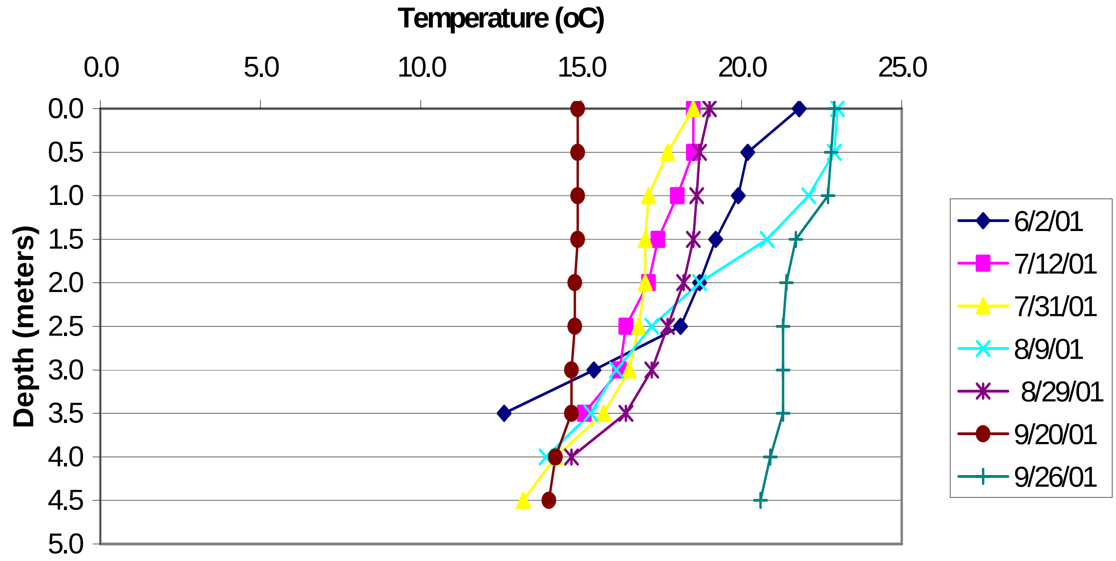


Figure 10. Mashapaug Pond MP-2 Dissolved Oxygen Vs. Depth

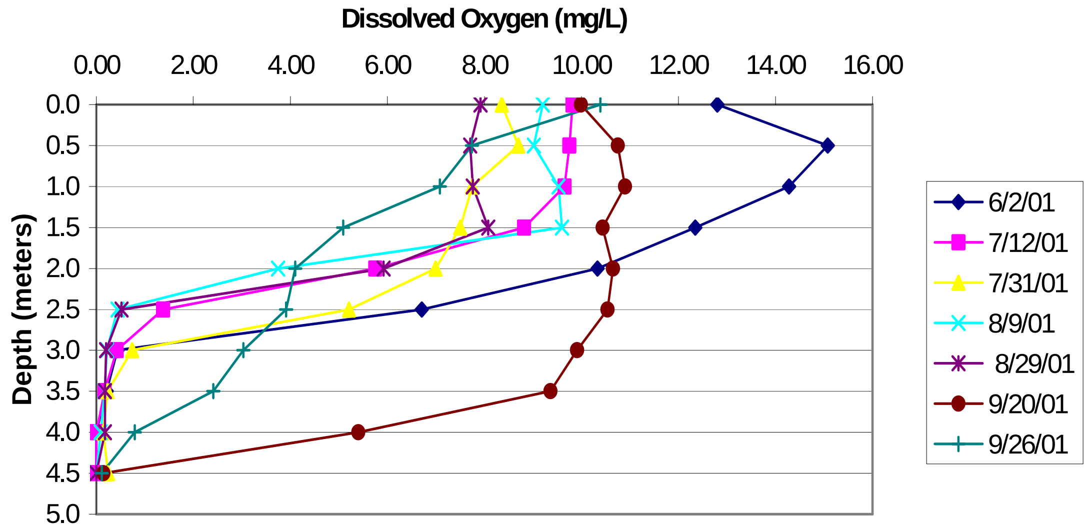


Table 1. Dry Weather Water Quality Laboratory Data for Mashapaug Pond, 2001.
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1. Data preceeded by a less than symbol (<) were divided by 2 before mean values were computed.
Non-detection (ND) data values were incorporated into means by dividing detection limits (Table 12) by 2 before mean values were computed.

Site	Date	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate-Nitrite Nitrogen (mg/L)	Total Phosphorus (µg/L)	Dissolved Phosphorus (µg/L)	Chlorophyll a (µg/L)	Fecal Coliform (col./100 ml)	*E.coli* (col./100 ml)
MP-1S	6/27/2001	0.28	ND	ND	ND	N/A	28	10	36.6	29	*
MP-1S	7/12/2001	ND	ND	0.02	ND	N/A	28	<2	NO DATA	7	7
MP-1S	7/31/2001	0.89	0.08	N/A	N/A	ND	63	<2	25.3	10	10
MP-1S	8/9/2001	0.43	0.06	N/A	N/A	0.02	30	10	17.5	11	10
MP-1S	8/29/2001	0.90	0.03	N/A	N/A	0.04	29	10	18.1	30	24
MP-1S	9/20/2001	0.67	0.26	N/A	N/A	0.10	27	7	26.0	15	13
Mean		**0.53**	**0.08**	**0.02**	**0.01**	**0.04**	**34**	**7**	**24.7**	**17**	**13**
MP-1B	6/27/2001	1.19	0.60	N/A	N/A	0.03	32	9	N/A	N/A	N/A
MP-1B	7/12/2001	0.89	0.26	ND	ND	N/A	30	<2	N/A	N/A	N/A
MP-1B	7/31/2001	3.32	2.26	N/A	N/A	ND	60	<2	N/A	N/A	N/A
MP-1B	8/9/2001	4.29	1.78	N/A	N/A	ND	56	15	N/A	N/A	N/A
MP-1B	8/29/2001	0.59	0.02	N/A	N/A	0.02	28	9	N/A	N/A	N/A
MP-1B	9/20/2001	1.20	0.64	N/A	N/A	0.08	38	8	N/A	N/A	N/A
Mean		**1.91**	**0.93**	**0.01**	**0.01**	**0.03**	**41**	**7**	**N/A**	**N/A**	**N/A**
MP-2S	6/27/2001	0.73	0.02	ND	0.01	N/A	24	<2	31.9	38	*
MP-2S	7/12/2001	0.74	ND	ND	ND	N/A	34	<2	NO DATA	100	70
MP-2S	7/31/2001	0.65	ND	N/A	N/A	ND	36	<2	27.0	30	30
MP-2S	8/9/2001	0.49	ND	N/A	N/A	ND	31	8	18.8	19	19
MP-2S	8/29/2001	0.57	ND	N/A	N/A	ND	31	<4	16.8	27	25
MP-2S	9/20/2001	1.20	0.27	N/A	N/A	0.10	29	7	27.5	38	36
Mean		**0.73**	**0.06**	**0.01**	**0.01**	**0.10**	**31**	**3**	**24.4**	**42**	**36**
MP-2S DUP	6/27/2001	0.65	ND	ND	ND	N/A	25	<2	N/A	34	*
MP-2S DUP	7/12/2001	0.56	ND	ND	ND	N/A	33	<2	N/A	80	70
MP-2S DUP	7/31/2001	0.92	0.10	N/A	N/A	ND	36	<2	N/A	30	30
MP-2S DUP	8/9/2001	0.48	ND	N/A	N/A	ND	30	9	N/A	15	12
MP-2S DUP	8/29/2001	1.50	0.77	N/A	N/A	ND	29	<4	N/A	24	19
MP-2S DUP	9/20/2001	0.59	0.23	N/A	N/A	0.10	30	4	N/A	32	31
Mean		**0.78**	**0.19**	**0.01**	**0.01**	**0.10**	**31**	**3**	**N/A**	**36**	**32**

DUP: Duplicate sample collected in field.
N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.
ND: The analyte was not detected at or above the level of the method reporting limit.
* : *E. coli* testing was added to Scope of Work following 6/27/01 sampling date.

Table 1. Dry Weather Water Quality Laboratory Data for Mashapaug Pond, 2001. (Continued).
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1. Data preceeded by a less than symbol (<) were divided by 2 before mean values were computed.
Non-detection (ND) data values were incorporated into means by dividing detection limits (Table 12) by 2 before mean values were computed.

Site	**Date**	**Total Kjeldahl Nitrogen** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate Nitrogen** (mg/L)	**Nitrite Nitrogen** (mg/L)	**Nitrate-Nitrite Nitrogen** (mg/L)	**Total Phosphorus** (µg/L)	**Dissolved Phosphorus** (µg/L)	**Chlorophyll a** (µg/L)	**Fecal Coliform** (col./100 ml)	***E.coli*** (col./100 ml)
MP-2B	6/27/2001	3.79	0.77	ND	ND	N/A	62	15	N/A	N/A	N/A
MP-2B	7/12/2001	0.74	0.32	ND	ND	N/A	33	<2	N/A	N/A	N/A
MP-2B	7/31/2001	2.18	1.53	N/A	N/A	ND	72	13	N/A	N/A	N/A
MP-2B	8/9/2001	2.44	1.98	N/A	N/A	ND	86	29	N/A	N/A	N/A
MP-2B	8/29/2001	0.75	ND	N/A	N/A	0.02	45	11	N/A	N/A	N/A
MP-2B	9/20/2001	0.66	0.26	N/A	N/A	0.09	28	4	N/A	N/A	N/A
Mean		**1.76**	**0.81**	**0.02**	**0.01**	**0.02**	**54**	**12**	**N/A**	**N/A**	**N/A**
MP-3	6/27/2001	1.05	0.10	0.03	0.01	N/A	64	8	N/A	200	*
MP-3	7/12/2001	0.94	0.12	0.04	ND	N/A	59	14	N/A	290	160
MP-3	7/31/2001	1.36	0.10	N/A	N/A	0.05	138	15	N/A	10	10
MP-3	8/9/2001	1.14	ND	N/A	N/A	0.04	227	36	N/A	80	70
MP-3	8/29/2001	1.13	0.20	N/A	N/A	0.06	88	18	N/A	49	34
MP-3	9/20/2001	1.10	0.28	N/A	N/A	0.19	50	17	N/A	10	10
Mean		**1.12**	**0.14**	**0.04**	**0.01**	**0.09**	**104**	**18**	**N/A**	**107**	**57**
SD-6	7/31/2001	0.71	0.16	N/A	N/A	4.00	9	9	N/A	730	730
SD-6	8/9/2001	1.45	0.23	N/A	N/A	3.90	90	10	N/A	30	30
SD-6	8/29/2001	0.52	0.26	N/A	N/A	3.90	91	13	N/A	110	110
SD-6	9/20/2001	1.20	0.32	N/A	N/A	4.30	78	8	N/A	250	250
Mean		**0.97**	**0.24**	**N/A**	**N/A**	**4.03**	**67**	**10**	**N/A**	**280**	**280**

DUP: Duplicate sample collected in field.
N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.
* : *E. coli* testing was added to Scope of Work following 6/27/01 sampling date.

Table 2. Wet Weather Water Quality Laboratory Data for Mashapaug Pond, 2001.

Sites selected for wet weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Non-detection (ND) data values were incorporated into means by dividing detection limits (Table 13) by 2 before mean values were computed.
Sampling locations are illustrated in Figure 1.

Site	Date	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate-Nitrite Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Fecal Coliform (col./100 ml)	*E.coli* (col./100 ml)
MP-1S-FF	9/25/2001	N/A	N/A	N/A	N/A	N/A	90	80
MP-1S-4	9/25/2001	N/A	N/A	N/A	N/A	N/A	160	140
MP-1S-22	9/26/2001	N/A	N/A	N/A	N/A	N/A	75	71
MP-1S-24	9/26/2001	1.10	0.19	0.11	22	13	93	90
Mean		**1.10**	**0.19**	**0.11**	**22**	**13**	**105**	**95**
MP-2S-FF	9/25/2001	N/A	N/A	N/A	N/A	N/A	70	70
MP-2S-4	9/25/2001	N/A	N/A	N/A	N/A	N/A	1,200	1,200
MP-2S-22	9/25/2001	N/A	N/A	N/A	N/A	N/A	160	150
MP-2S-24	9/25/2001	1.00	0.16	ND	24	13	110	110
Mean		**1.00**	**0.16**	**0.01**	**24**	**13**	**385**	**383**
MP-3-FF	9/25/2001	1.78	0.68	0.25	125	69	560,000	470,000
MP-3-4	9/25/2001	0.42	0.42	0.21	50	15	10,000	9,500
MP-3-22	9/26/2001	1.40	0.46	0.18	49	13	600	300
MP-3-24	9/26/2001	1.40	0.43	0.19	55	12	700	300
*MP-3-24 DUP	9/26/2001	1.20	0.44	0.19	61	N/A	400	300
Mean		**1.25**	**0.50**	**0.21**	**70**	**27**	**142,825**	**120,025**
SD-1-FF	9/25/2001	1.00	0.54	0.54	82	40	4,500	3,900
SD-1-4	9/25/2001	0.71	0.27	0.38	53	29	13,000	10,000
SD-1-22	9/26/2001	1.10	0.08	0.19	50	7	500	100
SD-1-24	9/26/2001	1.40	0.07	0.18	52	8	600	400
Mean		**1.05**	**0.24**	**0.32**	**59**	**21**	**4,650**	**3600**
SD-2-FF	9/25/2001	0.71	0.36	0.34	110	74	2,200	2,000
SD-2-4	9/25/2001	0.84	0.30	0.35	102	65	26,000	17,000
SD-2-22	9/26/2001	No flow						
SD-2-24	9/26/2001	No flow						
Mean		**0.78**	**0.33**	**0.35**	**106**	**70**	**14,100**	**9,500**

DUP: Duplicate sample collected in field.
*MP-3-24 DUP values are not included in calculation of the MP-3 means.
N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.
ND: The analyte was not detected at or above the level of the method reporting limit.

Table 2. Wet Weather Water Quality Laboratory Data for Mashapaug Pond, 2001. (Continued).

Sites selected for sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Non-detection (ND) data values were incorporated into means by dividing detection limits (Table 13) by 2 before mean values were computed.
Sampling locations are illustrated in Figure 1.

Site	Date	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate-Nitrite Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Fecal Coliform (col./100 ml)	*E.coli* (col./100 ml)
SD-3-FF	9/25/2001	0.32	0.20	0.19	17	14	8	5
SD-3-4	9/25/2001	0.79	0.10	0.14	37	8	1,900	1,600
SD-3-22	9/26/2001	No flow						
SD-3-24	9/26/2001	No flow						
Mean		**0.56**	**0.15**	**0.17**	**27**	**11**	**954**	**803**
SD-4-FF	9/25/2001	No flow						
SD-4-4	9/25/2001	No flow						
SD-4-22	9/26/2001	No flow						
SD-4-24	9/26/2001	No flow						
Mean		**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
SD-5-FF	9/25/2001	0.66	0.24	0.16	150	187	460,000	380,000
SD-5-4	9/25/2001	No flow						
SD-5-22	9/26/2001	No flow						
SD-5-24	9/26/2001	No flow						
Mean		**0.66**	**0.24**	**0.16**	**150**	**187**	**460,000**	**380,000**
SD-6-FF	9/25/2001	1.58	0.42	1.02	205	122	210,000	200,000
SD-6-4	9/25/2001	0.56	0.41	3.70	52	20	1,700	1,500
SD-6-22	9/26/2001	0.47	0.42	3.70	24	17	730	710
SD-6-24	9/26/2001	0.60	0.40	3.80	20	14	720	720
Mean		**0.80**	**0.41**	**3.06**	**75**	**43**	**53,288**	**50,733**

N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.
ND: The analyte was not detected at or above the level of the method reporting limit.

Table 3. Dry Weather Water Quality Field Measurements for Mashapaug Pond, 2001.
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1.

Site	Date	Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	Turbidity (NTU)	pH (SU)	Conductivity (µmhos/cm)	Flow (cfs)	Secchi Depth (Feet)
MP-1S	6/27/2001	21.0	13.2	147.6	12.7	9.2	360	N/A	2.1
MP-1S	7/12/2001	17.5	10.6	110.0	8.7	8.2	351	N/A	2.6
MP-1S	7/31/2001	18.1	8.7	92.1	8.0	8.4	365	N/A	2.4
MP-1S	8/9/2001	23.1	9.6	111.8	4.3	8.8	394	N/A	2.6
MP-1S	8/29/2001	18.5	9.4	100.5	4.0	8.0	351	N/A	3.1
MP-1S	9/20/2001	14.6	10.3	102.0	9.1	7.4	376	N/A	3.5
Mean		**18.8**	**10.3**	**110.7**	**7.8**	**8.3**	**366**	**N/A**	**2.7**
MP-1B	6/27/2001	12.0	0.1	1.2	2.8	6.5	430	N/A	N/A
MP-1B	7/12/2001	13.2	0.1	0.7	6.7	7.6	196	N/A	N/A
MP-1B	7/31/2001	14.0	0.1	1.3	7.1	7.6	380	N/A	N/A
MP-1B	8/9/2001	13.8	0.1	0.6	7.1	7.3	397	N/A	N/A
MP-1B	8/29/2001	18.5	0.4	3.6	3.5	8.0	349	N/A	N/A
MP-1B	9/20/2001	13.5	0.1	1.1	5.0	7.0	379	N/A	N/A
Mean		**14.2**	**0.2**	**1.4**	**5.4**	**7.3**	**355**	**N/A**	**N/A**
MP-2S	6/27/2001	21.8	12.8	147.6	5.8	9.1	340	N/A	2.4
MP-2S	7/12/2001	18.3	9.8	101.2	9.8	8.0	352	N/A	2.6
MP-2S	7/31/2001	18.5	8.4	89.7	8.5	8.0	366	N/A	2.4
MP-2S	8/9/2001	23.0	9.2	106.7	5.6	8.8	396	N/A	2.5
MP-2S	8/29/2001	19.0	7.9	85.4	3.4	7.8	350	N/A	3.4
MP-2S	9/20/2001	14.9	10.0	99.2	9.0	7.5	376	N/A	3.1
Mean		**19.3**	**9.7**	**105.0**	**7.0**	**8.2**	**363**	**N/A**	**2.7**

N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.

Table 3. Dry Weather Water Quality Field Measurements for Mashapaug Pond, 2001. (Continued).
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1.

Site	Date	Temperature (^oC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	Turbidity (NTU)	pH (SU)	Conductivity (μmhos/cm)	Flow (cfs)	Secchi Depth (Feet)
MP-2B	6/27/2001	12.6	0.2	2.0	9.2	7.3	418	N/A	N/A
MP-2B	7/12/2001	15.1	0.2	2.3	4.6	7.2	370	N/A	N/A
MP-2B	7/31/2001	14.2	0.1	1.3	11.4	7.2	408	N/A	N/A
MP-2B	8/9/2001	13.9	0.1	0.9	4.1	7.2	412	N/A	N/A
MP-2B	8/29/2001	19.0	0.2	1.8	4.9	7.3	385	N/A	N/A
MP-2B	9/20/2001	14.0	0.2	1.1	9.2	7.4	376	N/A	N/A
Mean		**14.8**	**0.2**	**1.6**	**7.2**	**7.3**	**395**	**N/A**	**N/A**
MP-3	6/27/2001	23.6	8.8	104.9	9.2	7.4	309	1.09	N/A
MP-3	7/12/2001	19.3	7.1	77.7	8.6	6.7	266	2.89	N/A
MP-3	7/31/2001	17.3	3.7	38.4	18.2	6.7	313	0.58	N/A
MP-3	8/9/2001	21.8	1.5	17.2	7.7	6.9	333	0.86	N/A
MP-3	8/29/2001	20.1	4.1	44.8	8.5	7.0	272	0.9	N/A
MP-3	9/20/2001	13.3	4.2	40.4	4.8	6.7	354	0.7	N/A
Mean		**19.2**	**4.9**	**53.9**	**9.5**	**6.9**	**308**	**0.76**	**N/A**
SD-6	7/31/2001	7.2	6.2	51.4	1.8	5.7	692	0.04	N/A
SD-6	8/9/2001	7.7	7.3	63.0	0.8	5.6	697	0.02	N/A
SD-6	8/29/2001	11.8	5.6	51.4	1.2	5.8	890	0.04	N/A
SD-6	9/20/2001	8.0	8.0	66.8	15.8	<5.5*	933	0.01	N/A
Mean		**8.7**	**6.8**	**58.2**	**4.9**	**5.7**	**803**	**0.03**	**N/A**

* = Lower detection limit of pH kit is 5.5 SU.
N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.

Table 4. Wet Weather Water Quality Field Measurements for Mashapaug Pond, 2001.
Sites selected for sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Sampling locations are illustrated in Figure 1.

Site	Date	Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	Turbidity (NTU)	pH (SU)	Conductivity (µmhos/cm)	Flow (cfs)	Secchi Depth (Feet)
MP-1S-FF	9/25/2001	22.1	10.0	110.0	12.5	7.4	324	N/A	N/A
MP-1S-4	9/25/2001	22.1	9.3	108.6	11.4	7.5	328	N/A	N/A
MP-1S-22	9/26/2001	22.1	9.4	107.9	15.5	7.5	330	N/A	N/A
MP-1S-24	9/26/2001	22.9	10.4	120.0	11.2	7.9	333	N/A	3.5
Mean		**22.3**	**9.8**	**111.6**	**12.7**	**7.6**	**329**	**N/A**	**3.5**
MP-2S-FF	9/25/2001	22.3	9.4	106.5	15.1	7.7	321	N/A	N/A
MP-2S-4	9/25/2001	22.3	10.2	123.0	14.7	8	320	N/A	N/A
MP-2S-22	9/26/2001	18.4	10.5	111.6	12.9	7.4	310	N/A	N/A
MP-2S-24	9/26/2001	22.4	9.3	105.0	11.5	7.8	330	N/A	3.1
Mean		**21.4**	**9.8**	**111.5**	**13.6**	**7.7**	**320**	**N/A**	**3.1**
MP-3-FF	9/25/2001	22.8	7.0	82.7	14.1	6.9	199	1.5	N/A
MP-3-4	9/25/2001	22.9	7.7	90.0	12.1	7	230	1.5	N/A
MP-3-22	9/26/2001	21.1	5.7	63.5	11.0	6.9	232	0.04	N/A
MP-3-24	9/26/2001	21.9	6.9	78.3	12.5	6.8	238	0.09	N/A
Mean		**22.2**	**6.8**	**78.6**	**12.4**	**6.9**	**225**	**0.78**	**N/A**
SD-1-FF	9/25/2001	21.5	7.0	83.4	11.9	6.3	60	0.13	N/A
SD-1-4	9/25/2001	21.4	6.6	74.3	8.4	6.8	108	0.045	N/A
SD-1-22	9/26/2001	17.2	5.5	58.2	9.7	7.2	268	0.08	N/A
SD-1-24	9/26/2001	17.5	7.1	75.0	18.7	7.1	275	0.09	N/A
Mean		**19.4**	**6.6**	**72.7**	**12.2**	**6.9**	**178**	**0.09**	**N/A**
SD-2-FF	9/25/2001	22.6	7.2	84.5	14.8	6.3	49	0.19	N/A
SD-2-4	9/25/2001	21.5	5.8	62.6	13.9	6.4	52	0.004	N/A
SD-2-22	9/26/2001	No flow							
SD-2-24	9/26/2001	No flow							
Mean		**22.1**	**6.5**	**73.6**	**14.4**	**6.4**	**50**	**0.10**	**N/A**

N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.

Table 4. Wet Weather Water Quality Field Measurements for Mashapaug Pond, 2001. (Continued).
Sites selected for sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Sampling locations are illustrated in Figure 1.

Site	Date	Temperature (^{o}C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	Turbidity (NTU)	pH (SU)	Conductivity (µmhos/cm)	Flow (cfs)	Secchi Depth (Feet)
SD-3-FF	9/25/2001	22.8	8.6	100.5	1.9	5.8	147	0.02	N/A
SD-3-4	9/25/2001	22.5	9.2	107.4	13.3	7.3	245	0.005	N/A
SD-3-22	9/26/2001	No flow							
SD-3-24	9/26/2001	No flow							
Mean		**22.7**	**8.9**	**104.0**	**7.6**	**6.6**	**196**	**0.01**	**N/A**
SD-4-FF	9/25/2001	No flow							
SD-4-4	9/25/2001	No flow							
SD-4-22	9/26/2001	No flow							
SD-4-24	9/26/2001	No flow							
Mean		**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
SD-5-FF	9/25/2001	23.8	8.3	93.7	3.9	6	20	0.35	N/A
SD-5-4	9/25/2001	No flow							
SD-5-22	9/26/2001	No flow							
SD-5-24	9/26/2001	No flow							
Mean		**23.8**	**8.3**	**93.7**	**3.9**	**6.0**	**20**	**0.35**	**N/A**
SD-6-FF	9/25/2001	20.8	7.7	87.0	17.3	5.7	186	0.06	N/A
SD-6-4	9/25/2001	15.2	4.9	49.1	2.4	6.1	736	0.04	N/A
SD-6-22	9/26/2001	14.3	5.5	54.4	1.8	5.5	777	0.07	N/A
SD-6-24	9/26/2001	14.5	5.5	54.5	2.0	5.7	782	0.07	N/A
Mean		**16.2**	**5.9**	**61.3**	**5.9**	**5.8**	**620**	**0.06**	**N/A**

N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001.
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	Date	Sample Type (Dry vs Wet)	Depth (Meters)	Temperature (oC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
MP-1	6/27/2001	Dry	0.0	21.0	13.23	149.6
			0.5	21.0	13.31	149.0
			1.0	20.7	13.55	150.7
			1.5	20.4	13.53	150.8
			2.0	18.1	10.56	119.7
			2.5	16.6	3.73	39.0
			3.0	14.9	0.22	2.0
			3.5	13.4	0.14	1.3
			4.0	12.0	0.13	1.2
			4.5	12.2	0.11	0.9
MP-1	7/12/2001	Dry	0.0	17.7	10.60	111.6
			0.5	17.7	10.13	106.5
			1.0	17.6	10.35	109.3
			1.5	17.5	10.34	108.6
			2.0	17.5	10.21	106.7
			2.5	17.4	9.97	104.5
			3.0	17.4	9.89	103.5
			3.5	15.7	0.42	6.7
			4.0	13.8	0.12	1.1
			4.5	13.2	0.06	0.7
MP-1	7/31/2001	Dry	0.0	18.1	8.66	92.1
			0.5	18.1	8.63	91.2
			1.0	17.7	9.26	97.5
			1.5	17.6	7.79	81.5
			2.0	17.5	8.40	87.7
			2.5	17.1	7.86	82.3
			3.0	15.9	0.58	6.1
			3.5	14.6	0.22	2.1
			4.0	13.9	0.17	1.6
			4.5	14.0	0.14	1.3

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001. (Continued).
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	Date	Sample Type (Dry vs Wet)	Depth (Meters)	Temperature (oC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
MP-1	8/9/2001	Dry	0.0	23.1	9.56	111.8
			0.5	23.1	9.22	107.2
			1.0	22.8	9.15	106.3
			1.5	20.3	10.38	113.9
			2.0	18.5	3.75	41.3
			2.5	17.3	0.27	2.5
			3.0	16.3	0.11	1.2
			3.5	14.8	0.09	0.9
			4.0	13.8	0.07	0.7
			4.5	13.8	0.07	0.6
MP-1	8/29/2001	Dry	0.0	18.5	9.40	100.5
			0.5	18.5	9.07	96.1
			1.0	18.5	9.39	100.0
			1.5	18.5	8.87	94.8
			2.0	18.5	8.74	93.3
			2.5	18.4	9.00	96.0
			3.0	18.4	8.87	94.3
			3.5	18.4	8.76	93.6
			3.8	16.8	0.50	4.8
			4.0	15.8	0.36	3.6
MP-1	9/20/2001	Wet	0.0	14.6	10.31	102.0
			0.5	14.5	9.59	95.4
			1.0	14.0	7.45	71.7
			1.5	14.0	7.29	70.8
			2.0	14.0	6.28	61.0
			2.5	13.8	5.70	55.5
			3.0	13.7	3.07	29.8
			3.5	13.7	1.99	18.5
			4.0	13.6	0.39	3.9
			4.5	13.5	0.10	1.1

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001. (Continued).
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	**Date**	**Sample Type** (Dry vs Wet)	**Depth** (Meters)	**Temperature** (oC)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (% Saturation)
MP-1	9/26/2001	Wet	0.0	22.9	10.39	120.0
			0.5	22.8	10.76	125.3
			1.0	22.7	10.42	120.5
			1.5	21.7	9.11	103.1
			2.0	21.4	8.60	95.6
			2.5	21.3	8.29	93.5
			3.0	21.3	7.90	88.5
			3.5	21.3	7.78	88.2
			4.0	20.9	2.47	28.0
			4.5	20.5	0.50	5.6
MP-2	6/27/2001	Dry	0.0	21.8	12.80	145.4
			0.5	20.2	15.08	167.5
			1.0	19.9	14.28	155.2
			1.5	19.2	12.35	134.1
			2.0	18.7	10.33	111.4
			2.5	18.1	6.71	71.2
			3.0	15.4	0.44	4.8
			3.5	12.6	0.21	2.0

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001. (Continued).
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	**Date**	**Sample Type** (Dry vs Wet)	**Depth** (Meters)	**Temperature** (oC)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (% Saturation)
MP-2	7/12/2001	Dry	0.0	18.5	9.82	105.0
			0.5	18.5	9.75	104.5
			1.0	18.0	9.65	103.2
			1.5	17.4	8.82	92.0
			2.0	17.1	5.75	59.1
			2.5	16.4	1.38	14.1
			3.0	16.2	0.42	4.3
			3.5	15.1	0.17	2.3
MP-2	7/31/2001	Dry	0.0	18.5	8.36	89.7
			0.5	17.7	8.70	91.9
			1.0	17.1	7.75	81.7
			1.5	17.0	7.50	77.8
			2.0	17.0	6.99	72.2
			2.5	16.8	5.21	53.3
			3.0	16.5	0.74	7.0
			3.5	15.7	0.23	2.6
			4.0	14.2	0.14	1.3
			4.5	13.2	0.24	2.5
MP-2	8/9/2001	Dry	0.0	23.0	9.20	106.7
			0.5	22.9	9.02	104.5
			1.0	22.1	9.53	108.5
			1.5	20.8	9.60	106.1
			2.0	18.7	3.75	39.7
			2.5	17.2	0.44	4.9
			3.0	16.1	0.22	2.3
			3.5	15.3	0.17	1.5
			4.0	13.9	0.09	0.9

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001. (Continued).
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	**Date**	**Sample Type** (Dry vs Wet)	**Depth** (Meters)	**Temperature** (oC)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (% Saturation)
MP-2	8/29/2001	Dry	0.0	19.0	7.92	85.4
			0.5	18.7	7.71	82.7
			1.0	18.6	7.76	83.1
			1.5	18.5	8.08	86.2
			2.0	18.2	5.92	62.4
			2.5	17.7	0.52	5.7
			3.0	17.2	0.20	2.0
			3.5	16.4	0.18	1.9
			4.0	14.7	0.18	1.8
MP-2	9/20/2001	Wet	0.0	14.9	9.99	99.2
			0.5	14.9	10.75	107.2
			1.0	14.9	10.90	108.7
			1.5	14.9	10.44	103.2
			2.0	14.8	10.65	105.2
			2.5	14.8	10.54	104.0
			3.0	14.7	9.91	97.6
			3.5	14.7	9.36	92.9
			3.8	14.4	6.70	67.0
			4.0	14.2	5.40	54.0
			4.3	14.0	2.58	22.1
			4.5	14.0	0.15	1.1

Table 5. Dissolved Oxygen Profile for the In-Lake Sampling Stations (MP-1, MP-2) at Mashapaug Pond, 2001. (Continued).
Sampling locations are illustrated in Figure 1.
Temperature and dissolved oxygen profiles for MP-1 and MP-2 are depicted in Figures 7 & 8 and Figures 9 & 10, respectively.

Site	**Date**	**Sample Type** (Dry vs Wet)	**Depth** (Meters)	**Temperature** (oC)	**Dissolved Oxygen** (mg/L)	**Dissolved Oxygen** (% Saturation)
MP-2	9/26/2001	Wet	0.0	22.9	10.39	110.0
			0.5	22.8	7.74	89.4
			1.0	22.7	7.08	81.3
			1.5	21.7	5.09	58.0
			2.0	21.4	4.10	47.0
			2.5	21.3	3.91	44.2
			3.0	21.3	3.03	34.2
			3.5	21.3	2.41	27.0
			4.0	20.9	0.79	8.0
			4.5	20.6	0.11	1.4

Table 6. Groundwater Quality Field and Laboratory Measurements for Mashapaug Pond, August, 2001.

Groundwater sampling segments are illustrated in Figure 3.

Non-detection (ND) data values were incorporated into means by dividing detection limits (Table 14) by 2 before mean values were computed.

Segment I.D.	**Dissolved Phosphorus** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate-Nitrate Nitrogen** (mg/L)	**Iron** (mg/L)	**ty** (μmhos/cm)	**pH** (SU)
1	0.012	0.25	ND	10.6	1350.0	6.5
2	0.023	0.33	ND	7.5	83.0	5.9
3	0.096	6.30	ND	0.2	886.0	7.0
4	0.011	1.60	ND	2.4	462.0	7.3
5	0.128	0.06	0.08	0.8	530.0	5.5
6	0.011	0.06	0.53	1.2	980.0	6.7
6-DUP	0.009	0.11	ND	2.5	N/A	N/A
Mean	**0.047**	**1.43**	**0.15**	**3.8**	**715.2**	**6.5**

DUP: Duplicate sample collected in field. Duplicate values are not included in calculation of mean.

N/A: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.

ND: The analyte was not detected at or above the level of the method reporting limit.

Table 7. Groundwater Seepage Data (water quantity inflow or outflow) for Mashapaug Pond, August, 2001.
Shallow (A) and deep (B) samples were collected for each groundwater sampling segment and all sites are graphically depicted in Figure 3.

Segment I.D.	Depth to base (inches)	Time In	Time Out	Seepage Time (hrs)	Volume In (ml)	Volume Out (ml)	Volume Change (ml)	Seepage (L/m^2/D)
1A	16.2	8:21	11:28	3.1	250	420	170	7.3
1B	23.4	8:24	11:29	3.1	250	275	25	0.8
2A	9.8	8:36	11:50	3.2	250	350	100	3.1
2B	27.0	8:41	11:52	3.2	250	275	25	0.8
3A	19.8	9:00	12:21	3.4	250	540	290	8.7
3B	20.5	9:04	12:20	3.3	250	424	174	7.1
4A	18.4	9:47	14:40	4.9	250	130	-120	-2.5
4B	23.0	9:50	14:41	4.9	250	232	-18	-0.5
5A	18.0	10:11	13:17	3.1	250	172	-78	-2.5
5B	23.0	10:14	13:20	3.1	250	390	140	4.5
6A	26.6	10:45	14:00	3.3	250	1430	1180	48.4
6B	28.8	10:48	14:03	3.3	250	330	80	2.5
Mean								**6.5**

Table 8. Phytoplankton Sample Analysis, Mashapaug Pond, 2001.
Sample and duplicate were collected from in-pond surface sampling station (MP-1).
Sampling locations are graphically depicted on Figure 1.

Date	Division	Species	Relative Density (#/mL)	Relative Density (Percent)	Relative Biovolume (µm3/mL)	Relative Biovolume (Percent)
7/30/2001	Chlorophyta (Green algae)	*Chlamydomonas sp.*	423	10.4	137,414	0.8
		Ankistrodesmus falcatus	35	0.9	3,523	0.0
		Oocystis pusilla	35	0.9	7,611	0.0
		Pediastrum duplex	35	0.9	9,584	0.1
7/30/2001	Cryptophyta (Cryptomonads)	*Rhodomonas minuta*	388	9.5	7,752	0.0
		Cryptomonas erosa	176	4.3	91,609	0.5
		Chroomonas sp.	35	0.9	2,290	0.0
7/30/2001	Cyanophyta (Blue Green algae)	*Anabaena planctonica*	2,114	51.7	15,937,917	91.0
		Microcystis aeruginosa	599	14.7	1,126,091	6.4
		Aphanizomenon flos-aquae	176	4.3	105,703	0.6
7/30/2001	Euglenophyta (Euglenoids)	*Trachelomonas volvocina*	35	0.9	66,417	0.4
7/30/2001	Pyrrhophyta (Dinoflagellates)	*Glenodinium sp.*	35	0.9	24,664	0.1
		Totals **Trophic State Index = 70.5**	**4,086**	100	**17,520,575**	100

Duplicate Sample

Date		Species	Relative Density (#/mL)	Relative Density (Percent)	Relative Biovolume (µm3/mL)	Relative Biovolume (Percent)
7/30/2001	Chlorophyta (Green algae)	*Chlamydomonas sp.*	421	11.0	136,803	1.0
		Dictyosphaerium ehrenbergianum	30	0.8	7,216	0.1
		Ankistrodesmus falcatus	30	0.8	752	0.0
7/30/2001	Chrysophyta (Yellow green algae)	*Melosira ambigua*	60	1.6	177,093	1.3
7/30/2001	Cryptophyta (Cryptomonads)	*Cryptomonas erosa*	241	6.3	125,077	0.9
		Chroomonas sp.	60	1.6	3,909	0.0
		Rhodomonas minuta	451	11.8	9,020	0.1
7/30/2001	Cyanophyta (Blue Green algae)	*Anabaena planctonica*	1,684	44.1	11,847,421	88.1
		Microcystis aeruginosa	511	13.4	817,813	6.1
		Aphanizomenon flos-aquae	210	5.5	126,280	0.9
7/30/2001	Euglenophyta (Euglenoids)	*Trachelomonas volvocina*	90	2.4	170,027	1.3
7/30/2001	Pyrrhophyta (Dinoflagellates)	*Glenodinium sp.*	30	0.8	21,047	0.2
		Totals **Trophic State Index = 68.6**	**3,818**	100	**13,442,458**	100

Table 9. Aquatic and semi-aquatic plants observed at Mashapaug Pond, July 5th, 2001.

Common Name	Scientific Name
Groundnut	*Apios americana*
Umbrella sedge	*Cyperus strigosus*
Swamp-Loosestrife	*Decodon verticillatus*
Spike-Rush	*Elecharis spp.*
Water horehound	*Lycopus americanus*
Swamp candles	*Lysimachia terrestris*
Yelow water lily	***Nuphar variegatum***
White water lily	***Nymphaea odorata***
Reed-Canary Grass	*Phalaris arundinacea*
Pondweed	***Pomatogetan bicupulatus***
Curly pondweed	***Potomogetan crispus***
Bittersweet nigtshade	*Solanum dulcamara*
Cattail	***Typha latifolia***

Note: Dominant species are in bold and correspond to those depicted on Figure 4.

Table 10. Pesticide and PCB Fish Tissue Analysis for Mashapaug Pond, 2001.

Parameter	Carp		Bass	
	Concentration (μg/Kg)	Detection Limit (μg/Kg)	Concentration (μg/Kg)	Detection Limit (μg/Kg)
PCB 8	ND	0.47	ND	0.44
PCB 18	ND	0.47	ND	0.44
PCB 28	1.89	0.47	ND	0.44
PCB 44	ND	0.47	ND	0.44
PCB 52	6.67	0.47	ND	0.44
PCB 66	ND	0.47	ND	0.44
PCB 77	ND	0.47	ND	0.44
PCB 101	ND	0.47	ND	0.44
PCB 105	ND	0.47	ND	0.44
PCB 118	ND	0.47	1.94	0.44
PCB 126	ND	0.47	0.57	0.44
PCB 128	6.60	0.47	ND	0.44
PCB 138	ND	0.47	1.11	0.44
PCB 153	54.93	0.47	1.61	0.44
PCB 170	4.96	0.47	ND	0.44
PCB 180	17.00	0.47	ND	0.44
PCB 187	8.26	0.47	ND	0.44
PCB 195	ND	0.47	ND	0.44
PCB 206	ND	0.47	ND	0.44
PCB 209	ND	0.47	ND	0.44
alpha-Chlordane	11.70	0.47	ND	0.44
o,p'-DDE	ND	0.47	ND	0.44
p,p'-DDE	35.06	0.47	0.93	0.44
o,p'-DDD	ND	0.47	ND	0.44
p,p'-DDD	5.16	0.47	ND	0.44
o,p'-DDT	ND	0.47	ND	0.44
p,p'-DDT	ND	0.47	0.62	0.44
Aldrin	ND	0.47	ND	0.44
Dieldrin	ND	0.47	ND	0.44
Endrin	ND	0.47	ND	0.44
Hexachlorobenzene	ND	0.47	1.36	0.44
alpha-BHC	ND	0.47	ND	0.44
beta-BHC	ND	0.47	ND	0.44
gamma-BHC	ND	0.47	ND	0.44
delta-BHC	ND	0.47	ND	0.44
Heptachlor	ND	0.47	0.52	0.44
Heptachlor Epoxide	ND	0.47	ND	0.44
Oxyochlordane	ND	0.47	ND	0.44
gamma-Chlordane	ND	0.47	ND	0.44
Mirex	ND	0.47	ND	0.44
trans-Nonachlor	14.21	0.47	ND	0.44
cis-Nonachlor	7.55	0.47	0.52	0.44
Endrin Ketone	ND	0.47	ND	0.44
Endrin Aldehyde	ND	0.47	ND	0.44
Endosulfan I	ND	0.47	ND	0.44
Endosulfan II	ND	0.47	ND	0.44
Endosulfan Sulfate	ND	0.47	1.24	0.44
Methoxychlor	ND	0.47	ND	0.44

Table 11. Metals Fish Tissue Analysis for Mashapaug Pond, 2001.

Parameter	Symbol	Carp		Bass	
		Concentration (µg/g)	Detection Limit (µg/g)	Concentration (µg/g)	Detection Limit (µg/g)
Arsenic	**As**	ND	2.00	0.87	0.06
Silver	**Ag**	ND	0.10	ND	0.06
Cadmium	**Cd**	ND	0.20	ND	0.06
Chromium	**Cr**	0.74	0.10	0.87	0.12
Copper	**Cu**	ND	5.00	0.25	0.12
Nickel	**Ni**	ND	0.50	ND	0.12
Lead	**Pb**	ND	0.10	0.07	0.06
Antimony	**Sb**	-	-	ND	0.06
Selenium	Se	ND	1.00	-	-
Tin	Sn	0.50	0.50	-	-
Aluminum	Al	67.57	10.00	-	-
Iron	Fe	ND	50.00	-	-
Zinc	Zn	ND	50.00	-	-
Mercury	**Hg**	0.12	0.01	0.17	0.01

Metals in bold font are those included in Scope of Work and are detailed in Quality Assurance Project Plan.
Supplemental analyses, which were conducted by UCONN Environmental Research Laboratory, are presented in normal font.
Hyphen indicates that the analysis was not conducted.

Table 12. Detection Limits for Dry Weather Water Quality Laboratory Data for Mashapaug Pond, 2001.
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1.

Site	**Date**	**Total Kjeldahl Nitrogen** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate Nitrogen** (mg/L)	**Nitrite Nitrogen** (mg/L)	**Nitrate-Nitrite Nitrogen** (mg/L)	**Total Phosphorus** (µg/L)	**Dissolved Phosphorus** (µg/L)	**Chlorophyll a** (µg/L)	**Fecal Coliform** (col./100 ml)	***E.coli*** (col./100 ml)
MP-1S	6/27/2001	0.05	0.02	0.02	0.01	NA	2.0	2.0	0.1	<1col./100 ml	*
MP-1S	7/12/2001	0.05	0.02	0.02	0.01	NA	2.0	2.0	NO DATA	<1col./100 ml	<1col./100 ml
MP-1S	7/31/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-1S	8/9/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-1S	8/29/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-1S	9/20/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-1B	6/27/2001	0.25	0.10	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-1B	7/12/2001	0.10	0.02	0.02	0.01	NA	2.0	2.0	NA	NA	NA
MP-1B	7/31/2001	0.60	0.20	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-1B	8/9/2001	1.50	0.10	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-1B	8/29/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-1B	9/20/2001	0.30	0.04	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-2S	6/27/2001	0.13	0.02	0.02	0.01	NA	2.0	2.0	0.1	<1col./100 ml	*
MP-2S	7/12/2001	0.10	0.02	0.02	0.01	NA	2.0	2.0	NO DATA	<1col./100 ml	<1col./100 ml
MP-2S	7/31/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-2S	8/9/2001	0.03	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-2S	8/29/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-2S	9/20/2001	0.10	0.02	NA	NA	0.02	2.0	2.0	0.1	<1col./100 ml	<1col./100 ml
MP-2S DUP	6/27/2001	0.13	0.02	0.02	0.01	NA	2.0	2.0	NA	<1col./100 ml	*
MP-2S DUP	7/12/2001	0.10	0.02	0.02	0.01	NA	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-2S DUP	7/31/2001	0.12	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-2S DUP	8/9/2001	0.03	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-2S DUP	8/29/2001	0.30	0.04	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-2S DUP	9/20/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml

DUP: Duplicate sample collected in field.
NA: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
* : *E. coli* testing was added to Scope of Work following 6/27/01 sampling date.

Table 12. Detection Limits for Dry Weather Water Quality Laboratory Data for Mashapaug Pond, 2001. (Continued).
Sites selected for dry weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and a storm drain (SD6).
Sampling locations are illustrated in Figure 1.

Site	**Date**	**Total Kjeldahl Nitrogen** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate Nitrogen** (mg/L)	**Nitrite Nitrogen** (mg/L)	**Nitrate-Nitrite Nitrogen** (mg/L)	**Total Phosphorus** (µg/L)	**Dissolved Phosphorus** (µg/L)	**Chlorophyll a** (µg/L)	**Fecal Coliform** (col./100 ml)	***E.coli*** (col./100 ml)
MP-2B	6/27/2001	0.50	0.08	0.02	0.02	NA	2.0	2.0	NA	NA	NA
MP-2B	7/12/2001	0.10	0.02	0.02	0.01	NA	2.0	2.0	NA	NA	NA
MP-2B	7/31/2001	0.60	0.20	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-2B	8/9/2001	0.60	0.10	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-2B	8/29/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-2B	9/20/2001	0.06	0.02	NA	NA	0.02	2.0	2.0	NA	NA	NA
MP-3	6/27/2001	0.25	0.02	0.02	0.01	NA	2.0	2.0	NA	<1col./100 ml	*
MP-3	7/12/2001	0.20	0.02	0.02	0.01	NA	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-3	7/31/2001	0.12	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-3	8/9/2001	0.12	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-3	8/29/2001	0.15	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
MP-3	9/20/2001	0.10	0.02	NA	NA	0.02	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
SD-6	7/31/2001	0.15	0.02	NA	NA	0.10	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
SD-6	8/9/2001	0.15	0.02	NA	NA	0.20	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
SD-6	8/29/2001	0.15	0.02	NA	NA	0.20	2.0	2.0	NA	<1col./100 ml	<1col./100 ml
SD-6	9/20/2001	0.10	0.02	NA	NA	0.20	2.0	2.0	NA	<1col./100 ml	<1col./100 ml

DUP: Duplicate sample collected in field.
NA: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
* : *E. coli* testing was added to Scope of Work following 6/27/01 sampling date.

Table 13. Detection Limits for Wet Weather Water Quality Laboratory Data for Mashapaug Pond, 2001.
Sites selected for wet weather sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Sampling locations are illustrated in Figure 1.

Site	Date	Total Kjeldahl Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate-Nitrite Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Fecal Coliform (col./100 ml)	*E.coli* (col./100 ml)
MP-1S-FF	9/25/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-1S-4	9/25/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-1S-22	9/26/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-1S-24	9/26/2001	0.10	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
MP-2S-FF	9/25/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-2S-4	9/25/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-2S-22	9/25/2001	NA	NA	NA	NA	NA	<1col./100 ml	<1col./100 ml
MP-2S-24	9/25/2001	0.10	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
MP-3-FF	9/25/2001	0.15	0.04	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
MP-3-4	9/25/2001	0.12	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
MP-3-22	9/26/2001	0.10	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
MP-3-24	9/26/2001	0.10	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
*MP-3-24 DUP	9/26/2001	0.20	0.03	0.02	2.0	NA	<1col./100 ml	<1col./100 ml
SD-1-FF	9/25/2001	0.15	0.04	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-1-4	9/25/2001	0.06	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-1-22	9/26/2001	0.20	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-1-24	9/26/2001	0.30	0.03	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-2-FF	9/25/2001	0.15	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-2-4	9/25/2001	0.12	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-2-22	9/26/2001	No flow						
SD-2-24	9/26/2001	No flow						

DUP: Duplicate sample collected in field.
NA: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.

Table 13. Detection Limits for Wet Weather Water Quality Laboratory Data for Mashapaug Pond, 2001. (Continued).
Sites selected for sampling include in-pond (MP-1, MP-2) surface (S) and bottom (B) stations, the inlet from Spectacle Pond (MP-3), and up to 6 storm drains, (SD1-SD6).
Wet weather sampling was conducted during first flush (FF), at 4 hours (4), at 22 hours (22) and at 24 hours (24) during the precipitation event.
Sampling locations are illustrated in Figure 1.

Site	**Date**	**Total Kjeldahl Nitrogen** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate-Nitrite Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**Dissolved Phosphorus** (mg/L)	**Fecal Coliform** (col./100 ml)	***E.coli*** (col./100 ml)
SD-3-FF	9/25/2001	0.06	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-3-4	9/25/2001	0.15	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-3-22	9/26/2001	No flow						
SD-3-24	9/26/2001	No flow						
SD-4-FF	9/25/2001	No flow						
SD-4-4	9/25/2001	No flow						
SD-4-22	9/26/2001	No flow						
SD-4-24	9/26/2001	No flow						
SD-5-FF	9/25/2001	0.06	0.02	0.02	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-5-4	9/25/2001	No flow						
SD-5-22	9/26/2001	No flow						
SD-5-24	9/26/2001	No flow						
SD-6-FF	9/25/2001	0.15	0.02	0.04	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-6-4	9/25/2001	0.12	0.02	0.10	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-6-22	9/26/2001	0.15	0.03	0.10	2.0	2.0	<1col./100 ml	<1col./100 ml
SD-6-24	9/26/2001	0.20	0.03	0.10	2.0	2.0	<1col./100 ml	<1col./100 ml

NA: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.
No flow: Non-flowing conditions at sampling locations prevented sample collection.

Table 14. Detection Limits for Groundwater Quality Field and Laboratory Measurements for Mashapaug Pond, August, 2001. Groundwater sampling segments are illustrated in Figure 3.

Segment I.D.	**Dissolved Phosphorus** (mg/L)	**Ammonia Nitrogen** (mg/L)	**Nitrate-Nitrate Nitrogen** (mg/L)	**Iron** (mg/L)
1	0.002	0.02	0.02	0.1
2	0.002	0.02	0.02	0.1
3	0.002	0.40	0.02	0.1
4	0.002	0.08	0.02	0.1
5	0.002	0.02	0.02	0.1
6	0.002	0.02	0.02	0.1
6-DUP	0.002	0.02	0.02	0.1

DUP: Duplicate sample collected in field.

NA: Not applicable, sampling of parameter not required at this location or time per Quality Assurance Project Plan.

Table 15. Dioxin and Furan Fish Tissue Analysis for Mashapaug Pond, 2001.

Parameter	Carp		Bass	
	Concentration (wet weight) (ng/Kg)	Detection Limit (ng/Kg)	Concentration (wet weight) (ng/Kg)	Detection Limit (ng/Kg)
2,3,7,8-TCDD	0.15	0.10	ND	0.10
1,2,3,7,8-PeCDD	0.47	0.10	0.19	0.10
1,2,3,4,7,8-HxCDD	0.23	0.10	ND	0.10
1,2,3,6,7,8-HxCDD	ND	0.10	ND	0.10
1,2,3,7,8,9-HxCDD	ND	0.10	ND	0.10
1,2,3,4,6,7,8-HpCDD	1.23	0.10	0.12	0.10
OCDD	1.47	0.10	ND	0.12
2,3,7,8-TCDF	1.07	0.10	1.48	0.10
1,2,3,7,8-PeCDF	ND	0.10	0.20	0.10
2,3,4,7,8-PeCDF	1.05	0.10	ND	0.10
1,2,3,4,7,8-HxCDF	0.13	0.10	ND	0.10
1,2,3,6,7,8-HxCDF	ND	0.10	ND	0.10
1,2,3,7,8,9-HxCDF	ND	0.10	ND	0.10
2,3,4,6,7,8-HxCDF	ND	0.10	ND	0.10
1,2,3,4,6,7,8-HpCDF	0.23	0.10	ND	0.10
1,2,3,4,7,8,9-HpCDF	ND	0.10	ND	0.10
OCDF	0.25	0.10	0.12	0.10

ND: The analyte was not detected at or above the level of the method reporting limit.

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Appendix C

30-Day Public Notice Comments

Please note that this TMDL and the TMDL entitled "Total Maximum Daily Loads for Phosphorus To Address 9 Eutrophic Ponds in Rhode Island" were presented jointly to the public due to the interconnections between Spectacle Pond, Mashapaug Pond and the ponds within Roger Williams Park. The comments in bold refer to Mashapaug Pond issues and the responses by RIDEM to these comments are included in this report. The reader is referred to the Total Maximum Daily Loads for Phosphorus To Address 9 Eutrophic Ponds in Rhode Island for responses that pertain to that TMDL.

June 5, 2007

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

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

Dear Mr. Ribas:

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

Overall

Report technicalities

- In the Eutrophic Ponds TMDL, several of the outfall numbers do not match from section to section. For example, in Section 2.7, it is stated that there are 23 outfalls that discharge to Spectacle Pond. In Section 4.14, the report states that there are 21 outfalls that discharge to Spectacle. A similar discrepancy also occurs for Gorton Pond, Roger Williams Park Ponds, and Upper Dam Pond.
- In the Eutrophic Ponds TMDL, section 4.2 states that a shoreline survey of each of the nine ponds was conducted and all stormwater outfalls were identified. Section 4.5 goes on to state that due to the extensive size and complexity of North Easton Pond tributaries, the identification of stormwater outfalls was not completed for this Pond.
- In the Eutrophic Ponds TMDL, there is reference to the 1993 EPA study regarding the effectiveness of structural BMPs. There are re are several newer studies which could be used to update this information.
  The University of New Hampshire Stormwater Center has published the results of their research on structural BMPs, and comprehensive fact sheets for common BMPs. http://www.unh.edu/erg/cstev/.
  The EPA has also published **The Use of Best Management Practices (BMPs) in Urban Watersheds** in September 2004, which has more current efficiency data. http://www.epa.gov/nrmrl/pubs/600r04184/600r04184.pdf
- In the Eutrophic Ponds TMDL, the Abstract states that the ponds included in the study are located in urbanized watersheds. Section 1.0 also refers to all ponds included in the study as 'urban ponds'. Section 2.0 goes on to state that *most* of the ponds are in urbanized watersheds. Are any of the ponds not considered to be 'urban'? The term 'Urban' should also be defined, and the Rhode Island Geographic Information System (RIGIS) dataset used to determine the urban areas referenced.

- **In the Mashapaug Pond TMDL, Section 6.1 cites the 2002 303(d) listing of Spectacle Pond. Is the more recent 2006 list supposed to be referenced? Or was 2002 the first 303(d) listing? It could be informative to provide the first 303(d) listing of each pond in the background information.**
    - **RIDEM Response: Section 1 was revised citing the most recent 303(d) list. The dissolved oxygen impairment was first "listed" in 1992.**
- **In the Mashapaug Pond TMDL, Section 6.1 incorrectly cites the Eutrophic Pond TMDL as the *Total Maximum Daily Loads for Phosphorus to Address 10 Eutrophic Ponds in Rhode Island.***
    - **RIDEM Response: The citation has been changed to "*Total Maximum Daily Loads for Phosphorus To Address 9 Eutrophic Ponds in Rhode Island*".**
- **All RIGIS datasets used in both TMDL studies (land use, soils, urban areas) should be listed in References with the creation/revision year noted in the body text.**
    - **RIDEM Response: In accordance with this comment, the RIGIS databases have been listed in the reference section**

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

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

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

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

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

Internal cycling is not mentioned as a source in the Mashapaug TMDL. As this Pond is similar (in depth, urbanization, land use, and water chemistry) to many of the Ponds in the Eutrophic Ponds TMDL, why is internal loading not considered a significant source of phosphorus?

> **RIDEM Response: URIWW has sampled Mashapaug Pond for total phosphorus 1m above the bottom and 1m below the surface and the data does not definitively support phosphorus release from the sediment.**

Public Education and Outreach

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

Illicit Detection and Elimination

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

Pond Specific Comments

Brickyard Pond

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

Comments made by the public include:

- Storm water runoff from the country club/golf course adjacent to Brickyard Pond may be a significant source of pollutants, and should be included in the TMDL study as a source. They are installing French drains into the herring run from new holes.
  RIDEM responded that they will investigate and may revise the TMDL accordingly.
- Cormorants are more numerous than geese in the area.
- Residents are cutting down trees along the Bike Path along the north shore of Brickyard Pond. The Town of Barrington owns 30-feet from the shoreline, and the cutting is allegedly taking place within this right-of-way.
- Two landfills were situated on either side of Brickyard Pond. The question was raised if this was known by RIDEM and if it would impact the TMDL calculations.

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

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

Almy & North Easton (Green End) Ponds
Public Meeting: April 24th, 2007, Middletown Town Hall, Middletown

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

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

Gorton, Sand, Upper Dam, Warwick Ponds
Public Meeting: April 30th, 2007, Warwick Public Library, Warwick

Public Comments included:

- There may be another outfall west of GP-A.
- Other RIPDES permit holders (the airport and industries) should be included as responsible parties.

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

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

Public Comments included:

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

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

The Mashapaug Pond TMDL recommends a location for a constructed wet pond or stormwater wetland between Spectacle Pond and Mashapaug Pond. At the Public Meeting on May 2nd, it was indicated by RIDEM that this, and other BMPs, would pose 'significant permitting hurdles', even though RIDEM recommends the activity. RIDOT requests that any activities specifically recommended by RIDEM TMDL studies be coordinated internally to remove these 'hurdles', or, alternatively, that the recommendations be amended.

> **RIDEM Response: A project of this nature that is proposed within an existing wetland will require a permit from the Wetlands program of RIDEM, even if recommended in a TMDL to improve water quality. While there are situations that may merit going forward with such projects, further investigation by RIDEM has determined, in this case, that in-lake treatment options (e.g. alum treatments) in addition to construction of BMPs (as recommended in the Eutrophic Ponds TMDL) represent a more viable and likely more effective strategy to not only address phosphorus related impairments in Spectacle Pond but to also control phosphorus loading from Spectacle Pond into Mashapaug Pond. As such, RIDEM has deleted reference to this recommendation in the TMDL.**

The Mashapaug Pond model predicted storm drain 4 to be the second largest source of phosphorus to the pond, however, no flow (either wet or dry) was observed out of the storm drain over the course of the monitoring program. Was the model changed to correct for this?

> **RIDEM Response: As noted in sections 3.21 and 6.4 in the Mashapaug TMDL, drain SD4 did not flow during the 2001 wet weather sampling events. The model was not modified to correct for this lack of flow, however this would not affect the total TMDL or the total existing load. The load associated with SD4 would simply be allocated to the load (non-point source) portion of the current load and not the waste load (point source) portion.**

Implementation

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

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

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

Sincerely,

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

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

Donald Pryor (Brown University) Written Comments received by email

Eutrophic Ponds and Mashapaug Pond TMDLs

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

1. Estimation of Q (inflow water volume) and L (existing loading, g/m2-yr)

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

<u>RIDEM Response:</u> The mean annual inflow to Spectacle Pond estimated in the Eutrophic Ponds TMDL differs from the Spectacle Pond baseflow estimated in the Mashapaug Pond TMDL because flow was estimated by different methods. Without long-term stream gauging, stream flow is a difficult parameter to estimate precisely. Although the estimates do differ, they are fairly similar considering the inherent variability of this parameter.

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

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

measured relative to compliance with ambient water quality standards and not whether the calculated load reductions have been achieved.

All Tetra Tech results are presented in the Mashapaug TMDL. Please note that Tetra Tech supplied RIDEM with the results of their hydrologic model only, not a full written report.

For another consistency check, the Mashapaug Pond watershed is given (page 1 of Mashapaug TMDL) as 1967 ha including the watershed of Tongue and Spectacle Ponds. Using the regression relation, this watershed area would produce a mean annual inflow of 13.5 x 106 m3/yr – much larger than the 2.42 x 106 m3/yr total inflow estimated in table 2-3, page 10 of the Mashapaug Pond TMDL. There appears to be large areas of the Mashapaug Pond watershed, particularly to the east, that are not accounted as contributing to the pond (perhaps because of combined sewers that convey the flow out of the watershed?). Tables 2-1 and 2-2 (page 6 of Mashapaug TMDL) show only ~170 acres (~70 ha) in storm drain and direct runoff areas. The watershed of Spectacle and Tongue ponds is 238 ha but the Mashapaug pond TMDL does not appear to account for contributions from more than 1500 ha of the reported watershed.

<u>RIDEM Response:</u> **The area of the Mashapaug Pond watershed as stated on Page 1 of the Mashapaug TMDL (1967 ha) is an error. Page 1 of the Mashapaug TMDL has been revised accordingly. The actual watershed area of Mashapaug Pond is approximately 308 ha and is comprised of the Tongue and Spectacle Pond watershed areas (a total of 238 ha) in addition to the 70 ha subwatershed that contributes direct discharge to Mashapaug Pond. It appears that Tetra Tech modeled the 308 ha watershed area shown in Tables 2-1 and 2-2, not the larger "area adjacent to Mashapaug pond" depicted in Figure 2.3, which is approximately 707 ha in area. This 707-ha area appears to have been the historic watershed to Mashapaug Pond, but it appears that storm sewers have diverted stormwater from much of the area to the east of Mashapaug Pond depicted in Figure 2.3 outside of this historic watershed area. Using the regression equation and a watershed area of 308 ha, the total annual inflow to Mashapaug Pond is 2.1 x 106 m3/yr, which is similar to the inflow estimated in Table 2.3.**

For yet another check, the Reckhow model can be compared to the estimates in the Mashapaug TMDL. Based on inflow water volume of 2.42 x 10^6 m^3 (table 2-3, page 10) and waterbody surface area of 31 ha, q_s for Mashapaug Pond would be 7.8 m/yr. Using that and a phosphorus concentration of 0.039 mg/l (page 19), the existing loading to Mashapaug Pond would be estimated at 245 kg/yr as compared to the 231.6 kg/yr estimate given in table 5-3 (page 42 of Mashapaug TMDL) – quite close agreement. The assumptions underlying the estimate in table 5-3, however, are not clear. The Tetra Tech document missing from the references might provide that information.

<u>RIDEM Response:</u> It is noted that the total annual phosphorus loading to Mashapaug Pond as estimated by the Reckhow model is quite similar to the estimate in Table 5-3 of the Mashapaug TMDL.

As previously mentioned Tetra Tech did not produce a separate document. Tetra Tech reported only the results of their water quality study to RIDEM. The assumptions underlying the estimate in Table 5-3 are presented in various sections of the Mashapaug TMDL. Both point and nonpoint stormwater flows were estimated by the rational method (section 4.2.3), using landuse areas within each subwatershed (Tables 2-1 and 2-2), literature runoff coefficients (Table 4-1), and meteorological data for Providence from the National Climatic Data Center. Loads were estimated by multiplying estimated flows by the mean total phosphorus concentrations measured by ESS and listed in Tables 1 and 2 of Appendix B. Phosphorus loading from groundwater was estimated based on flow rates and nutrient concentrations from the ESS data presented in Tables 6 and 7 of Appendix B. Literature atmospheric deposition rates (Tables 4-2 and 4-3) and climatic data were used to develop atmospheric loadings for the EFDC model employed by Tetra Tech.

A different check can be done by comparing the Mashapaug Pond measured inputs to the load estimates based on land use presented in table 5-3. Unfortunately neither the assumptions for the table nor the rainfall profile needed to apply the rational method to the wet weather measurements of September 2001 seem to be available. However, it is worth noting that the contribution from storm drain SD4 was estimated to be the second largest input when, in fact, there was no flow observed from this storm drain. Page 55 states: “The lack of flow from this drain warrants a recheck of the drainage system to determine if blockages exist or re-routing has occurred.” However, storm drain maps (presumably complied from the city of Providence and RIDOT) are not included. Hopefully maps and other files underlying the TMDLs can be made available to support the analysis of storm drain systems and treatment alternatives called for on page 54 and elsewhere in the document.

<u>RIDEM Response:</u> Figure 2.1 of the Mashapaug TMDL shows the storm water drainage systems associated with each of the six catchment areas. The drain lines are clearly visible in the color version of the document, however they are difficult to discern in a black and white copy.

2. Outfall Prioritization

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

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

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

Appendix D

Public Meeting Notes

Public Meeting Notes
May 2, 2007, 6:00 pm
RIDEM Offices, Providence

Meeting began promptly at 6:00 pm, RIDEM staff in attendance were Elizabeth Scott, Russell Chantenauf, Joseph Martella, Scott Ribas and Lucinda Hannus.

Elizabeth Scott began the meeting with introductions and an overview of the two TMDL projects.

Scott Ribas gave a technical presentation of the projects.

The following comments in bold apply to the Mashapaug Pond TMDL project.

Roger Williams Park Ponds are treated with chemicals to kill rooted aquatic plants and the dead plants are left to decay, with phosphorus allowed to cycle back into the system.

RIDEM Response: The Providence Parks Department has obtained permits from the Divisions of Fish & Wildlife and Agriculture to apply herbicides to the park's ponds to control aquatic weeds. The permits allow the application of diquat and glyphosate to all of the park ponds addressed in the TMDL. A recommendation that the park administration consider the mechanical removal of aquatic weeds in lieu of herbicide application has been added to section 6.5.5.

Will there still be impairments to Spectacle and Mashapaug Ponds due to Tongue Pond?

<u>RIDEM Response:</u> RIDEM staff documented all stormwater culverts draining to Spectacle Pond, including those discharging to Tongue Pond. Although there are several large-diameter pipes which discharge to Tongue Pond, these pipes were not assessed to be higher priority pipes since they do not discharge directly to Spectacle Pond. It appears that there is limited outflow from Tongue Pond other than during rain events during the spring. From the perspective of the water quality of Spectacle Pond and because of the ephemeral hydrologic connection, the outfalls that discharge directly to Tongue Pond were not deemed as significant as the direct discharges to Spectacle Pond.

There is an underground stormwater treatment system located near Katharine Gibbs College. The system treats stormwater from Cranston Street prior to discharge to Tongue Pond.

RIDEM Response: Comment duly noted. Kindly note that none of the outfalls discharging to Tongue Pond, including the outfall(s) associated with the treatment structure were identified as priority outfalls.

What is the difference in elevation of Tongue, Spectacle and Roger Williams Ponds?

RIDEM Response: According to the USGS topographic map, Tongue Pond is located at an elevation of between 40 and 50 feet above mean sea level. Spectacle and Roger Williams Park Ponds are located at 42 and 40 feet above mean sea level, respectively.

What is the time frame for the implementation of the studies recommendations?

RIDEM Response: The owners and operators of Municipal Separate Storm Sewer Systems (MS4s) must revise their Storm Water Management Program within 180 days of the final approval of the TMDL by EPA. These plans contain a timetable for the completion of the Six Minimum Measures, which include Public Education and Outreach, Public Involvement/Implementation, Illicit Discharge Detection and Elimination, Construction, Post Construction, and Pollution Prevention and Good Housekeeping. Other than the stormwater – related recommendations, implementation of most BMPs recommended in the TMDL study is voluntary. Implementation of waterfowl and internal cycling BMPs, will be accomplished by the responsible parties (generally the cities and towns) as funds become available.

Who is responsible for storm drain retrofits?

RIDEM Response: The cities, towns, RIDOT and any private owners and operators of storm drain systems are responsible for work done on the storm drain systems.

Is the zoo a source of nutrients to the Roger Williams Park Ponds?

RIDEM Response: Robert McMahon, Deputy Superintendent of Parks for the Providence Parks Department was in attendance to address this question. He stated that the storm drains handling waste on the zoo grounds have been hooked up to the Providence sewer system for at least the last ten years. Mr. McMahon also stated that the pond on zoo grounds does not drain into the other ponds of the park’s pond system.