# Total Maximum Daily Load for
# Total Phosphorus Loads to
# Stafford Pond

## FINAL

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December 1998

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# INTRODUCTION

The Clean Water Act (CWA) Section 303(d)(1)(C) and federal regulation 40CFR 130.7(c)(1) direct each State to develop Total Maximum Daily Loads (TMDLs) for all impaired waters on the Section 303(d) list of impaired waters. States must take into account seasonal variations and must include a margin of safety (MOS) to account for uncertainty in the modeling and monitoring process. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards. Rhode Island's 1998 303(d) list submitted to EPA by the Rhode Island Department of Environmental Management (RIDEM) lists Stafford Pond as being impaired by "hypoxia, nutrients, and excess algal growth."

Stafford Pond is a 487 acre reservoir in Tiverton, RI, which serves as a drinking water supply for both Tiverton and Portsmouth, RI. Over the past several years, the pond has experienced frequent algal blooms, leading to taste and odor problems, which prompted the Stone Bridge Fire District (SBFD) to upgrade its water treatment practices.

In 1995, RIDEM contracted with Fugro, which later became ENSR, to conduct an in-depth limnological study of the pond. The goals of the study were to assess the water quality of the pond and its tributaries, identify pollution sources, and develop cost-effective solutions for controlling pollution problems. The study was completed in 1996 and the final report was submitted to RIDEM in the summer of 1997 (ENSR, 1997). The results clearly indicate that algal blooms are a result of high phosphorus loadings coming principally from a dairy farm. Additional sources include residential land uses and storm drains.

This TMDL is based on the 1997 report and uses its findings to establish a TMDL for total phosphorus (TP) loads to Stafford Pond. This document extensively quotes the findings in the report, so, for simplicity's sake, individual references are not provided. This TMDL addresses the excess algal growth, high total phosphorus concentrations and low dissolved oxygen levels that were the basis for the Pond being placed on the 303(d) list.

## APPLICABLE WATER QUALITY STANDARDS

As stated in 40 CFR 131.2, "[water quality] standards serve the dual purposes of establishing the water quality goals for a specific waterbody and serve as the regulatory basis for the establishment of water-quality-based treatment controls and strategies beyond the technology-based levels of treatment required by section 301(b) and 306 of the Act." The primary aim of a TMDL is to bring a waterbody back into compliance with applicable water quality regulations. Therefore, it is important to know exactly which regulations apply to the waterbody for which a TMDL is developed. The regulations which are specifically applicable to the impairments which caused Stafford Pond to be listed on the State's 1998 303(d) list are listed below.

Under RIDEM's recently updated Water Quality Regulations (RIDEM, 1997), Stafford Pond is recognized as a drinking water source and is classified as a Class A waterbody. The following excerpt from Rule 8.B of the Regulations describes Class A waters:

> (*a*). *Class A – These waters are designated as a source of public drinking water supply, for primary and secondary contact recreational activities and for fish and wildlife habitat. 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.*

In addition, a footnote in the Regulations states that:

> *Class A waters used for public drinking water supply may be subject to restricted recreational use by State and local authorities.*

Rule 8.D of the Water Quality Regulations establishes physical, chemical, and biological criteria as parameters of minimum water quality necessary to support the water use classifications of Rule 8.B. Therefore, sections of Rule 8.D also are applicable. In particular, Rule 8.D(2) establishes class-specific criterion for freshwaters. For fresh waters of the State that serve as cold water fish habitat, the following dissolved oxygen criteria, excerpted from Table 1, apply:

> *Cold Water Fish Habitat – Dissolved oxygen content of not less than 75% saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5 mg/l.*

For Class A waters, the following Criterion for taste and odor, excerpted from Table 1, apply:

> *None* [tastes and odors ] *other than of natural origin and none associated with nuisance algal species.*

The following criteria for nutrients, excerpted from Table 1, also apply to Stafford Pond:

> *a. Average Total Phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole, or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the Director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication.*
>
> *b. None* [nutrients] *in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion of 10(a) above in a downstream lake, pond, or reservoir. New discharges of wastes containing phosphates will not be permitted into or immediately upstream of lakes or ponds. Phosphates shall be removed from existing discharges to the extent that such removal is or may become technically and reasonably feasible.*

Due to its designation as a drinking water source, Stafford Pond and its first order tributaries are also identified as Special Resource Protection Waters (SRPWs) in the Water Quality Regulations. As an SRPW, Stafford Pond is afforded special protections under Rule 18, *Antidegradation of Water Quality Standards*. Rule 18 protects Stafford Pond from degradation by any new or increased discharge or activity unless the applicant provides adequate technical documentation and engineering plans to prove, to the satisfaction of the Director of RIDEM, that specific pollution controls and/or other best management practices (BMPs) will completely eliminate any measurable impacts to water quality necessary to protect the characteristics upon which the SRPW designation is based. The following excerpt is taken from Rule 18.D:

> *D. Tier 2 ½ -* <u>*Protection of Water Quality for SRPWs*</u> *– Where high quality waters constitute a SRPW, there shall be no measurable degradation of the existing water quality necessary to protect the characteristic(s) which cause the waterbody to be designated as an SRPW. Notwithstanding that all public drinking water supplies are SRPWs, public drinking water suppliers may undertake temporary and short term activities within the boundary perimeter of a public drinking water supply impoundment for essential maintenance or to address emergency conditions in order to prevent adverse effects on public health or safety, provided that these activities comply with the requirements set forth in Rule 18.B (Tier 1 Protection of Existing Uses) and rule 18.C. (Tier 2 Protection of Water Quality in High Quality Waters).*

# DESCRIPTION OF THE WATERBODY

Stafford Pond is located in the northeast corner of Tiverton, RI and lies within the Narragansett Bay Drainage Basin (Figure 1). The pond is approximately 487 acres in size with a watershed of approximately 947 acres. The watershed:lake area ratio is small (less than 2:1), indicating a high potential for successful management.

Stafford Pond is designated as a source of public drinking water supply, and SBFD of Tiverton maintains a water treatment facility on the southwest shore of the pond. The SBFD supplies drinking water to the Town of Portsmouth, the Stone Bridge section of Tiverton, the Tiverton Water Authority, and the North Tiverton Water Authority. The pond supports a viable trout fishery and a self sustaining warmwater fishery, including one of the State's few remaining populations of smallmouth bass. A public boat launch is located on the eastern shoreline.

## Hydrology

Precipitation drives the hydrology of most aquatic systems in the northeastern United States. Data for weather stations in Providence and Newport, RI suggest long-term average annual precipitation of about 45 inches. Providence records for 1996, the year in which the Stafford Pond study was conducted, suggest a near average year, while records for Newport suggest much higher than average precipitation. Precipitation for 1995 was far below normal for each station. The distribution of precipitation tends to be fairly uniform over the months of the year on a long-term average basis, but any individual year is likely to have substantial variability among monthly values.

As shown in Figure 2, two small, unnamed tributaries and two storm drain pipes discharge to Stafford Pond. An outlet structure located along the northern perimeter of the pond controls the outward flow of pond water to Sucker Brook. This rectangular weir is maintained by the Fall River Water Department. However, water rights are actually owned by the Watuppa Reservoir Company. The management goal for the outlet structure has generally been to maintain full capacity in the pond, with the ability to release water during drought conditions.

## Sediments

Average and maximum water depths in the pond are 13 and 25 feet, respectively. As shown in Figure 3, the pond has only one definable basin, with the deepest area slightly northeast of center. Pond volume was calculated at approximately 2.04 billion gallons. Benthic substrates are comprised mostly of boulder, cobble, gravel and sand in water depths less than 15 feet, although some sandy muck is found areas where the bottom slope is more gradual. In depths greater than 15 feet, mucky bottom sediments are more prevalent.

## Groundwater

The results of the limnological study indicate that groundwater exchange, in the form of inseepage, was relatively low along the southwest shoreline and very low along the remaining shoreline segments. Therefore, on an annual basis, groundwater flow will result in a net gain to the pond: more groundwater will flow into the pond than out of it.

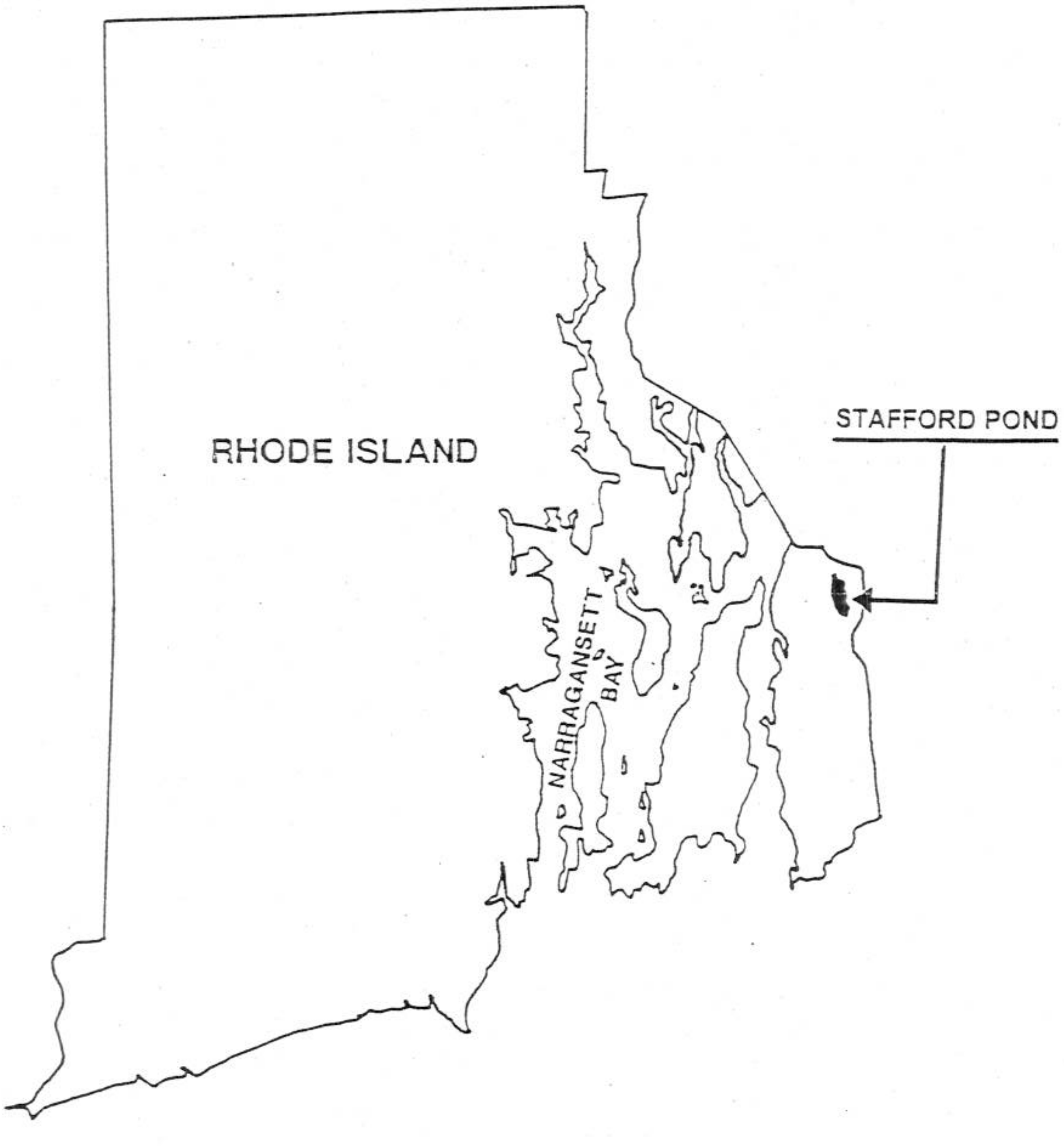
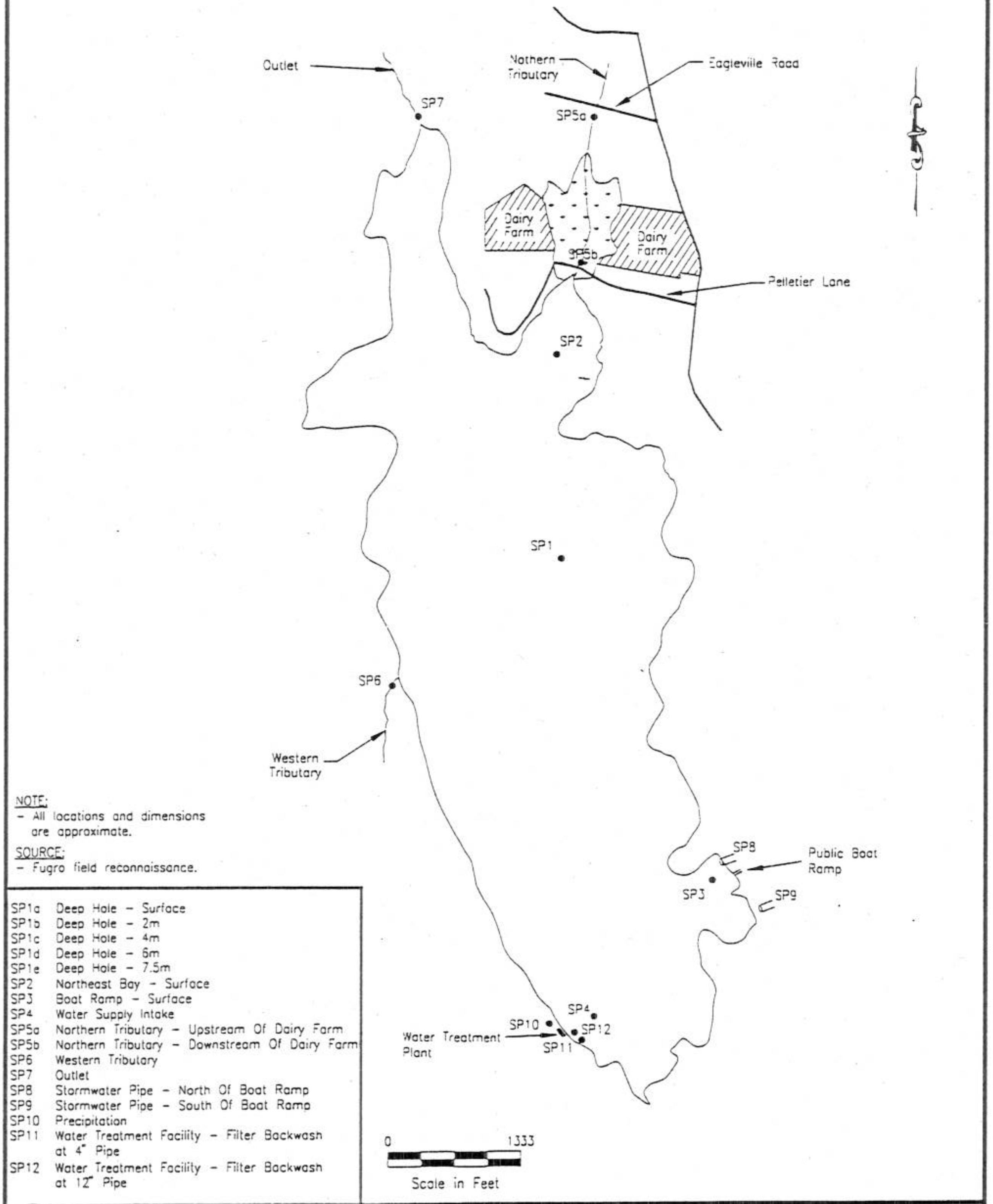


Figure 1 – Location Map

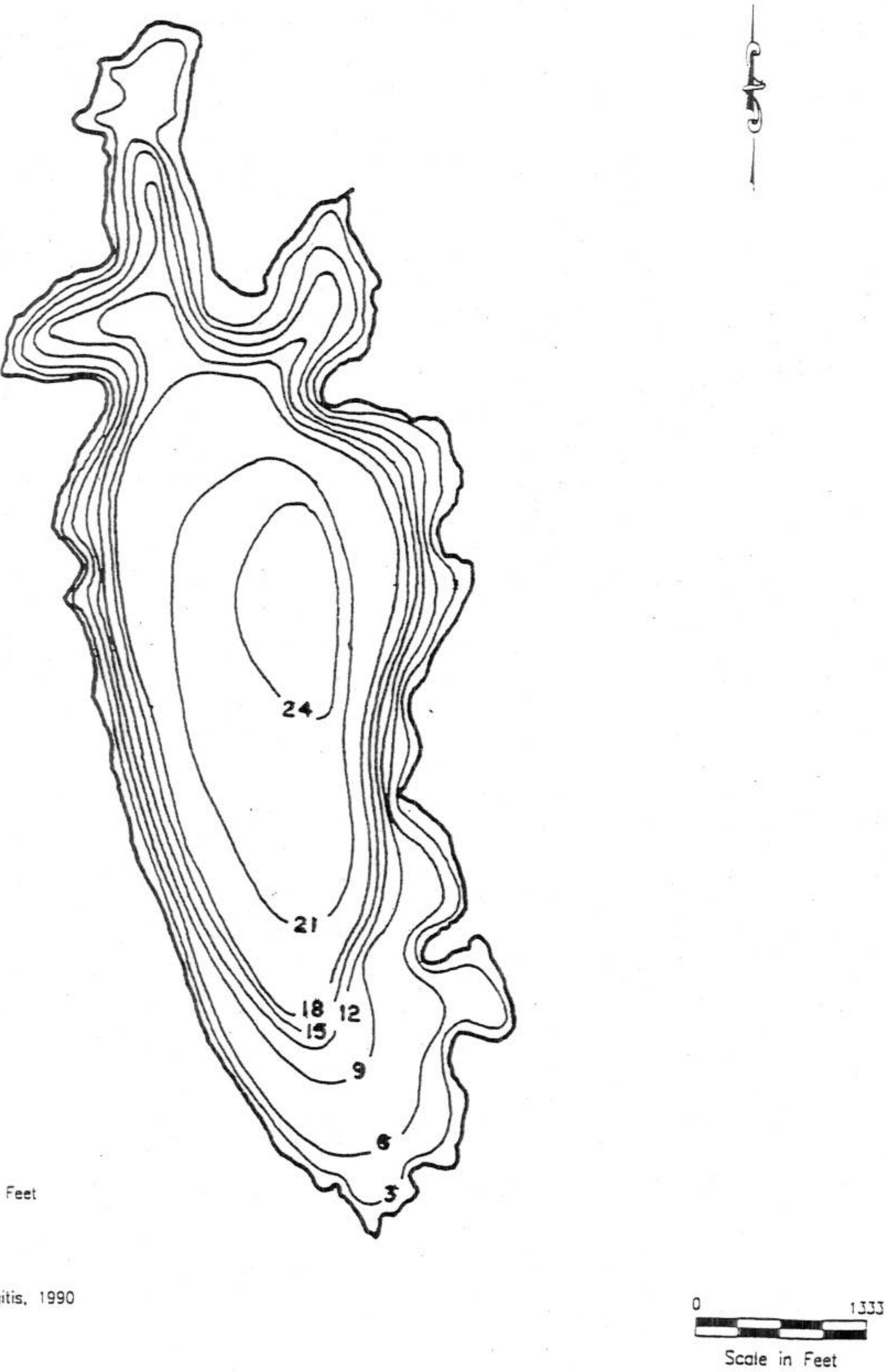


NOTE:
- All locations and dimensions are approximate.

SOURCE:
- Fugro field reconnaissance.

| | |
|---|---|
| SP1a | Deep Hole – Surface |
| SP1b | Deep Hole – 2m |
| SP1c | Deep Hole – 4m |
| SP1d | Deep Hole – 6m |
| SP1e | Deep Hole – 7.5m |
| SP2 | Northeast Bay – Surface |
| SP3 | Boat Ramp – Surface |
| SP4 | Water Supply Intake |
| SP5a | Northern Tributary – Upstream Of Dairy Farm |
| SP5b | Northern Tributary – Downstream Of Dairy Farm |
| SP6 | Western Tributary |
| SP7 | Outlet |
| SP8 | Stormwater Pipe – North Of Boat Ramp |
| SP9 | Stormwater Pipe – South Of Boat Ramp |
| SP10 | Precipitation |
| SP11 | Water Treatment Facility – Filter Backwash at 4" Pipe |
| SP12 | Water Treatment Facility – Filter Backwash at 12" Pipe |

**Figure 2 – Monitoring Locations**



All Contours in Feet

SOURCE:
Guthrie & Stolgitis, 1990

Figure 3 – Bathymetric Map

## Hydrologic Budget

The estimated hydrologic loading to Stafford Pond was derived from a combination of direct precipitation, surface water base-flow, and surface water storm-flow. As discussed earlier, groundwater contributions were considered negligible. Average annual inflow was estimated at 5.5 cfs, assuming normal precipitation conditions. Direct precipitation was the largest of all inputs with a contribution of 2.5 cfs, or 46% of the total water input. This is unusual for water supply lakes in New England and is directly related to the small watershed:lake area ratio. Groundwater inseepage accounted for 18% of all inputs. Surface water base and storm flows accounted for 13% and 23%, respectively, of all inputs.

Pond outputs were derived from a combination of evaporation, groundwater outseepage, surface outflow and withdrawals by the water treatment facility. Surface outflow accounted for the greatest single output at 2.3 cfs, or 42% of the total. Evaporation accounted for 31% of the total, a substantial percentage for this part of the country; again due to the small watershed:lake area ratio. Water treatment facility withdrawals and groundwater outseepage accounted for 24% and 4%, respectively, of all pond outputs.

According to morphometric features and hydrologic data, Stafford Pond has a flushing rate of 0.65 times per year. The flushing rate is the actual number of times in a given year that the entire water volume could be replaced by inputs. The inverse of the flushing rate is the detention time, the average length of time that water remains in the pond. For Stafford Pond, the detention time is 1.54 years. The response time is the amount of time required for the pond to fully respond to inputs and is estimated at 0.65 to 1.08 years, or 237 to 394 days. These values are important indicators of how the system processes pollutant inputs, and they suggest that pollutants stay in the pond long enough to fully impact water quality. Alternatively, if changes in pollutant loading were made, it would take at least most of a year before appreciable changes in water quality became detectable.

## DESCRIPTION OF THE WATERSHED

As stated previously, the watershed draining to Stafford Pond is approximately 947 acres. As shown in Figure 2, two tributaries and two storm drain pipes discharge into the pond. The northern storm drain pipe (sampling station SP8) discharges directly to Stafford Pond and is believed to drain sections of Old Stafford Road. The southern pipe (sampling station SP9) discharges into a forested area within 200 feet of the pond and is believed to drain sections of Route 81. Drainage in the remaining portions of the watershed is a combination of sheet flow and groundwater infiltration. It is important to note that there are no point sources, such as wastewater treatment plants or industrial discharges, in the watershed. All pollutant loadings are from nonpoint sources (NPS).

### Geology

The available information on the geology of the eastern Bay area of Rhode Island indicates that the Stafford Pond watershed is primarily underlain by a thin mantle of till. Till is a compact, unstratified, poorly sorted mixture of clay, silt, sand, gravel, and boulders deposited by glacial activity. The till usually forms a thin discontinuous mantle over the bedrock with frequent outcroppings of the bedrock being present. Because of its clayey character, till generally has a relatively low infiltration capacity, although some soils derived from till can be well drained.

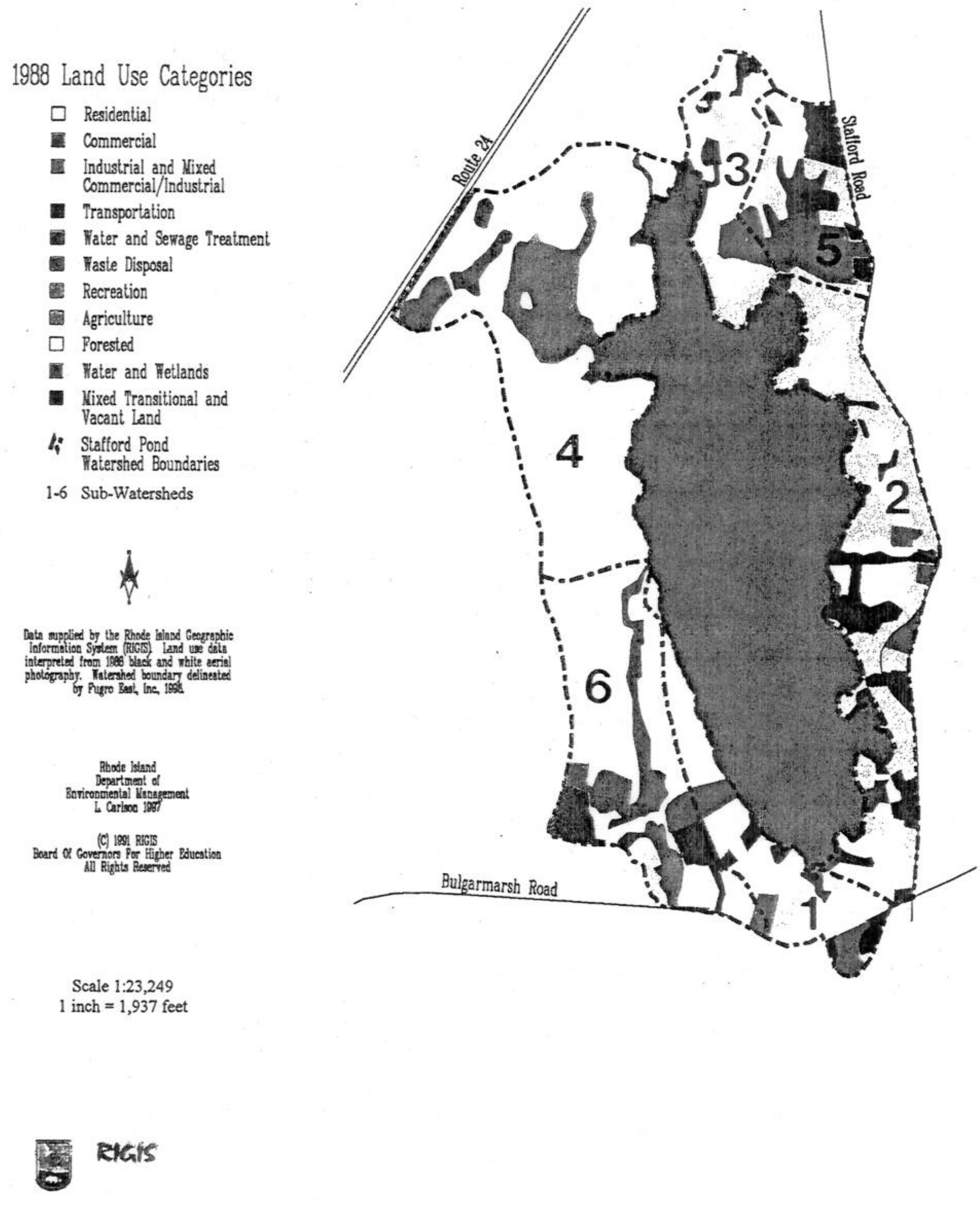
### Soils

The Stafford Pond watershed is primarily composed of well drained and moderately drained soils. Many of these soils are generally suitable for community development. However, on-site sewage disposal systems may require special design and installation considerations. Poorly drained and very poorly drained soils are present throughout the watershed as well. These soils are generally not recommended for community development or on-site sewage disposal.

### Landuse

As shown in Figure 4, forested and residential landuse categories cover the greatest area in the Stafford pond watershed. The most heavily developed area in the watershed is sub-basin 2 that is located along the eastern shore of the pond and includes most of the residential properties and some of the commercial properties. A state boat ramp is located in this sub-basin. Road runoff from this area is discharged to Stafford Pond via two storm drain pipes.

The primary agricultural landuse in the watershed is a 55-acre dairy farm located in sub-basin 5 that drains to the pond's northern tributary. This tributary drains an area of approximately 86 acres and originates in a wetland area just north of Eagleville Road. From this point it flows in a southerly direction, receiving stormwater runoff from Eagleville Road and discharging into a pond located at the north end of the farm. Sample station SP5a is located just below Eagleville Road and upstream of the farm. The northern portion of the farm is well vegetated and not frequented by cattle. The outlet of the pond combines with a groundwater breakout from the west and flows through the southern portion of the farm and into Stafford Pond. The southern portion of the dairy farm, including the stream and associated wetland area, is frequented by cattle, and an unvegetated hillside drains directly into the tributary. Sample station SP5b is located downstream of the dairy farm near the mouth of the northern tributary. Stations SP5a and SP5b were established to



Data supplied by the Rhode Island Geographic Information System (RIGIS). Land use data interpreted from 1986 black and white aerial photography. Watershed boundary delineated by Fugro East, Inc., 1996.

Rhode Island
Department of
Environmental Management
L. Carlson 1997

Scale 1:23,249
1 inch = 1,937 feet

Figure 4 – Land Use in Stafford Pond Watershed

measure the effects of the dairy farm on the water quality of the tributary.

The western tributary, which empties into the southwest portion of the pond, drains a relatively undeveloped sub-basin 179 acres in size. Forested landuse predominates, with the exception of two significant developed properties: the Tiverton High School and Tiverton Middle School. The Tributary originates near Route 177 and meanders to the pond through a series of wetlands. Runoff from the High School parking lot, and possibly leachate from the wastewater disposal system, appear to reach this tributary.

Landuse data for the different sub-basins is presented in Table 1 shown below.

**Table 1 – Landuse Data for the Stafford Pond Watershed**

| **Sub-basin** | **Landuse Areas (HA)** | | | | |
|---|---|---|---|---|---|
| | **Urban** | **Agriculture** | **Forest** | **Open** | **Total** |
| 1 | 7.91 | 0 | 28.21 | 2.34 | 38.46 |
| 2 | 39.50 | 3.21 | 25.19 | 12.16 | 80.06 |
| 3 | 6.75 | 3.11 | 19.28 | 3.63 | 32.77 |
| 4 | 1.82 | 0 | 98.08 | 24.64 | 124.54 |
| 5 | 11.85 | 7.75 | 7.09 | 8.06 | 34.75 |
| 6 | 14.27 | 0 | 45.64 | 12.57 | 72.48 |
| Total | 82.10 | 14.07 | 223.49 | 63.40 | 383.06 |

## DESCRIPTION OF WATER QUALITY MONITORING ACTIVITIES

During the limnological study conducted in 1996, a variety of monitoring activities were conducted. These activities are summarized below. In addition to the 1996 study, a number of investigations of Stafford Pond and its watershed have been conducted over the past few decades- with the earliest reported study being done in 1966. These different studies are discussed in the 1997 report as part of its "Historical Data Review." For the purposes of this TMDL, however, only the 1997 report by ENSR will be utilized.

### Pond and Tributary Monitoring

As shown in Figure 2, monitoring was conducted at 8 stations in the pond and its tributaries. In addition, two stations ( SP11 and SP12) were established at the water treatment plant's filter backwash pipes, at the two storm drain outlets (SP8 and SP9), and at a precipitation station located near the water treatment plant (SP10).

Routine monitoring was conducted from February through October at the ten stations located in the pond, the tributaries and the filter backwash pipes for the following parameters: dissolved oxygen, temperature, pH, total alkalinity, total hardness, conductivity, turbidity, Secchi disk transparency, chlorophyll a, nitrite+nitrate nitrogen, ammonium nitrogen, inorganic nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, and dissolved phosphorus. Supplemental monitoring was conducted at four locations (stations SP1a, SP1e, SP3, and SP4) during July and September for the following parameters: cadmium, lead, copper, aluminum, calcium, magnesium, sodium, chloride, iron, manganese, total petroleum hydrocarbons, DDT, PCB's, and polynuclear aromatic hydrocarbons. Finally, a single round of monitoring was carried out in October at the surface of the station located in the middle of the pond (station SP1a) to determine concentrations of cadmium, lead, and mercury using very low detection limits.

### Stormwater Monitoring

Three rounds of stormwater monitoring were conducted at up to five locations over the course of the study. Stormwater monitoring locations included SP5b, SP6, SP8, SP9, and SP10. Routine monitoring parameters were evaluated during each round of sampling and, supplemental monitoring parameters were evaluated during a single sampling conducted in September.

### Groundwater Monitoring

A seepage survey was conducted in June 1996 along four shoreline segments to document the role of groundwater on pond hydrology. Shoreline segments were selected to be representative of the pond as a whole. Additionally, two shallow groundwater wells were installed at each of the shoreline segments to further document the effects of groundwater on pond hydrology. The wells were monitored from April through October. For each shoreline segment, one well was established in the shallow littoral zone of the pond and one well was established on-shore.

A ground water quality monitoring investigation was conducted during June and September along four shoreline segments that were consistent with those selected for the seepage and well surveys. A littoral interstitial porewater (LIP) sampler was used to collect three sample from each shoreline segment which were later composited into a single sample per segment. Parameters evaluated included nitrite+nitrate nitrogen, ammonium nitrogen, dissolved phosphorus, dissolved iron, and dissolved manganese.

### Benthic Monitoring

In March, May and July, benthic sediments were collected at three in-pond locations with the aid of an Ekman dredge. Parameters evaluated included grain size analysis, total organic carbon, solids content, total phosphorus, total Kjeldahl nitrogen, total metals (Cd, Cu, Pb, Al, Fe, Mn, Ca), total petroleum hydrocarbons, DDT, PCB's, and polynuclear aromatic hydrocarbons.

### Biological Monitoring

Water samples collected during routine and stormwater monitoring were analyzed for fecal coliform and fecal streptococcus bacteria. Phytoplankton samples were collected every month from February through October at sampling stations in the middle of the pond and at the water treatment plant intake. Cell counts were converted to biomass based on size and species-specific relationships. Chlorophyll a measurements were also made of the same samples. Zooplankton samples were collected during spring, summer and late summer at the sample station in the middle of the pond. Organism counts were converted to biomass based on size and species-specific relationships.

The aquatic vascular plant community of Stafford Pond was surveyed in June and August. During the June survey, a boat and diver equipped with snorkeling gear were used to map species composition and plant density throughout the pond. The August survey was less intense and basically consisted of cruising the shoreline in a boat and documenting any large changes in the plant community.

The fish community in Stafford Pond was determined by reviewing information provided by the Rhode Island Department of Environmental Management, Division of Fish and Wildlife. Additionally, a seining and gill netting survey was conducted during the month of October as a supplement to this information. Fish were identified, examined for external anomalies, enumerated, measured (millimeters), weighed (grams), and released.

## WATER QUALITY CHARACTERIZATION

The findings of the 1996 limnological investigation that are especially pertinent to the “hypoxia, nutrients, and excess algal growth” impairments, which were the basis for Stafford Pond being placed on the 1998 303(d) list, are summarized below.

### Pond and Tributary Monitoring Results

The routine chemical monitoring resulted in the following findings. As shown in Table 2, low levels of dissolved oxygen were recorded in the bottom two meters of the pond, primarily during the summer months. Results of other routine water quality monitoring are shown in Table 3. Total alkalinity, total hardness, and conductivity were low at all sites, except for the station just downstream of the dairy farm. Higher values at this site appear to be a result of inputs from the farm. Values of inorganic and total nitrogen were low at all sites except for the station downstream of the farm, where concentrations were high.

Average Secchi transparency and chlorophyll a concentrations were both indicative of eutrophic conditions in the pond. Chlorophyll a is a green plant pigment essential to photosynthesis. Measuring the concentration of chlorophyll a is a useful indicator of a waterbody’s trophic state or degree of nutrient enrichment. Values in Stafford Pond ranged from 2 to 118 ug/L, with a mean of 22 ug/L at SP-1a and 16 ug/L at SP-4. Higher concentrations predominated during late summer and early fall, when algal blooms were common. In general, values exceeding 10 ug/L are characteristic of eutrophic conditions. Average concentrations exceeded this threshold at both sampling locations, and summer values were consistently above this threshold.

Concentrations of total phosphorus were generally elevated (greater than 0.025 mg/l) and indicative of eutrophic conditions at all sampling stations, except for those at the water treatment backwash pipes. Average total phosphorus concentrations were exceedingly high (greater than 0.1 mg/l) at the stations located downstream of the dairy farm. The total nitrogen:total phosphorus ratio in Stafford Pond was greater than 15:1, indicating that phosphorus is most likely the limiting nutrient for plant growth in this system, although light is probably the most critical limiting factor much of the time.

### Stormwater Monitoring Results

The results of the stormwater monitoring are shown in Table 4. The most salient results are as follows. Average wet weather concentrations of total phosphorus were high (>0.05 mg/L) at all sites except SP10 (precipitation). The highest concentrations were recorded at SP5b. The dissolved phosphorus fraction was typically higher than the particulate phosphorus fraction at most of the stormwater sampling locations.

**Table 2. Dissolved Oxygen/Temperature Profiles at the Deep Hole Sampling Location (SP1) in Stafford Pond (1996)**

| | Depth (m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **7.5** |
| **21-Feb** | | | | | | | | | |
| Dissolved Oxygen | 14.7 | 16.7 | 18.0 | 18.2 | 18.0 | 17.0 | 14.2 | 11.9 | |
| Temperature | 1.9 | 2.4 | 2.5 | 2.5 | 2.5 | 2.7 | 3.0 | 3.1 | |
| **19-Mar** | | | | | | | | | |
| Dissolved Oxygen | 11.4 | 9.9 | 9.3 | 8.8 | 8.6 | 8.5 | 8.5 | 8.7 | |
| Temperature | 3.9 | 3.8 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | |
| **17-Apr** | | | | | | | | | |
| Dissolved Oxygen | 12.4 | 13.2 | 13.4 | 13.3 | 13.0 | 12.8 | 12.7 | 12.3 | 4.4 |
| Temperature | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.8 | 6.8 |
| **14-May** | | | | | | | | | |
| Dissolved Oxygen | 9.2 | 9.7 | 10.1 | 10.2 | 10.0 | 9.8 | 8.9 | 8.0 | 7.3 |
| Temperature | 14.6 | 14.3 | 14.2 | 14.1 | 13.7 | 13.5 | 13.4 | 13.4 | 13.2 |
| **29-May** | | | | | | | | | |
| Dissolved Oxygen | 9.7 | 9.9 | 9.8 | 9.0 | 8.3 | 8.2 | 6.1 | 5.2 | 4.1 |
| Temperature | 17.8 | 17.8 | 17.7 | 17.6 | 17.5 | 16.8 | 15.3 | 15.0 | 14.7 |
| **10-Jun** | | | | | | | | | |
| Dissolved Oxygen | 8.9 | 9.0 | 9.3 | 9.4 | 9.2 | 8.0 | 6.2 | 4.5 | |
| Temperature | 22.5 | 22.5 | 21.0 | 20.7 | 20.2 | 19.1 | 18.3 | 17.8 | |
| **27-Jun** | | | | | | | | | |
| Dissolved Oxygen | 8.6 | 8.7 | 8.5 | 8.4 | 8.2 | 7.8 | 3.9 | 1.0 | |
| Temperature | 22.5 | 22.4 | 22.0 | 21.9 | 21.6 | 21.3 | 20.1 | 18.7 | |

**Table 2. – Continued**

|  | Depth (m) |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **7.5** |
| **17-Jul** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 8.6 | 8.6 | 8.5 | 7.9 | 7.5 | 6.8 | 5.8 | 2.3 |  |
| Temperature | 25.4 | 25.1 | 24.7 | 23.9 | 23.1 | 22.8 | 22.5 | 22.5 |  |
| **30-Jul** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 9.7 | 9.7 | 9.7 | 9.3 | 8.6 | 6.1 | 4.5 | 3.9 | 3.6 |
| Temperature | 24.6 | 24.3 | 24.2 | 23.7 | 23.4 | 22.8 | 22.3 | 22.2 | 22.1 |
| **8-Aug** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 9.3 | 9.3 | 9.3 | 9.3 | 6.5 | 4.8 | 3.9 | 2.2 | 1.0 |
| Temperature | 25.3 | 25.1 | 25.1 | 25.0 | 23.1 | 22.6 | 22.5 | 22.2 | 21.8 |
| **22-Aug** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 8.0 | 8.2 | 7.6 | 7.1 | 6.6 | 5.7 | 4.5 | 2.5 | 1.6 |
| Temperature | 26.0 | 24.0 | 23.5 | 23.5 | 23.5 | 23.0 | 23.0 | 22.5 | 22.5 |
| **5-Sep** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 11.4 | 12.0 | 10.2 | 9.2 | 7.9 | 7.1 | 6.4 | 4.9 | 4.5 |
| Temperature | 24.2 | 23.2 | 22.4 | 22.1 | 21.8 | 21.6 | 21.5 | 21.4 | 21.3 |
| **30-Sep** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 8.7 | 8.4 | 8.5 | 8.6 | 8.7 | 8.6 | 8.2 | 7.8 | 4.8 |
| Temperature | 18.3 | 18.2 | 17.8 | 17.7 | 17.6 | 17.6 | 17.5 | 17.4 | 17.5 |
| **29-Oct** |  |  |  |  |  |  |  |  |  |
| Dissolved Oxygen | 10.0 | 9.5 | 9.2 | 9.2 | 9.3 | 9.3 | 9.2 | 9.2 |  |
| Temperature | 13.2 | 13.2 | 13.1 | 13.1 | 13.2 | 13.2 | 13.2 | 13.2 |  |

## Table 3. Results of 1996 Routine Water Quality Monitoring for Selected Parameters.

| | | Sampling Locations | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **SP1a** | **SP1b** | **SP1c** | **SP1d** | **SP1e** | **SP2** | **SP3** | **SP4** | **SP5a** | **SP5b** | **SP6** | **SP7** | **SP11** | **SP12** |
| **Turbidity** | | | | | | | | | | | | | | | |
| number of samples (n) | | 14 | 2 | 2 | 2 | 14 | 2 | 5 | 14 | 2 | 10 | 10 | | 1 | 1 |
| Mean | NTU | 4.2 | 15.5 | 3.6 | 2.6 | 2.1 | 1 | 5.6 | 2.8 | 1.4 | 5.8 | 0.8 | | 0.6 | 0.4 |
| Minimum | NTU | 0.8 | 1.5 | 1.5 | 2.2 | 0.6 | 0.6 | 0.7 | 0.7 | 1.3 | 1.3 | 0.4 | | 0.6 | 0.4 |
| Maximum | NTU | 21 | 29.5 | 5.7 | 3 | 6.8 | 1.3 | 19.5 | 6.2 | 1.4 | 18.3 | 1.7 | | 0.6 | 0.4 |
| **Secchi Transparency** | | | | | | | | | | | | | | | |
| number of samples (n) | | 13 | | | | | | | | | | | | | |
| Mean | M | 1.5 | | | | | | | | | | | | | |
| Minimum | M | 0.5 | | | | | | | | | | | | | |
| Maximum | M | 2.9 | | | | | | | | | | | | | |
| **Chlorophyll a** | | | | | | | | | | | | | | | |
| number of samples (n) | | 14 | | | | | | | 13 | | | | | | |
| Mean | ug/L | 22 | | | | | | | 16 | | | | | | |
| Minimum | ug/L | 3 | | | | | | | 2 | | | | | | |
| Maximum | ug/L | 118 | | | | | | | 69 | | | | | | |
| **Total Phosphorus** | | | | | | | | | | | | | | | |
| number of samples (n) | | 14 | 2 | 2 | 2 | 14 | 2 | 5 | 14 | 2 | 10 | 10 | 10 | 1 | 1 |
| Mean | mg/L | 0.036 | 0.045 | 0.044 | 0.039 | 0.053 | 0.036 | 0.054 | 0.039 | 0.089 | 0.895 | 0.048 | 0.033 | 0.018 | 0.01 |
| Minimum | mg/L | 0.019 | 0.042 | 0.039 | 0.031 | 0.027 | 0.03 | 0.032 | 0.022 | 0.04 | 0.29 | 0.014 | 0.02 | 0.018 | 0.01 |
| Maximum | mg/L | 0.053 | 0.047 | 0.049 | 0.046 | 0.097 | 0.042 | 0.13 | 0.079 | 0.137 | 2.279 | 0.11 | 0.049 | 0.018 | 0.01 |
| **Dissolved Phosphorus** | | | | | | | | | | | | | | | |
| number of samples (n) | | 12 | 1 | 1 | 1 | 12 | 2 | 4 | 12 | 2 | 9 | 9 | 9 | 1 | 1 |
| Mean | mg/L | 0.023 | 0.037 | 0.038 | 0.017 | 0.033 | 0.023 | 0.038 | 0.027 | 0.065 | 0.618 | 0.038 | 0.024 | 0.005 | 0.005 |
| Minimum | mg/L | 0.009 | 0.037 | 0.038 | 0.017 | 0.017 | 0.015 | 0.024 | 0.01 | 0.02 | 0.01 | 0.014 | 0.01 | 0.005 | 0.005 |
| Maximum | mg/L | 0.046 | 0.037 | 0.038 | 0.017 | 0.081 | 0.03 | 0.055 | 0.045 | 0.109 | 1.9 | 0.075 | 0.044 | 0.005 | 0.005 |

# Table 4. Results of 1996 Storm Water Monitoring for Selected Parameters.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Sampling | Locations | | | |
| **Parameter** | **Units** | **SP5b** | **SP6** | **SP8** | **SP9** | **SP10** |
| **Conductivity** | | | | | | |
| *number of samples (n)* | | 3 | 3 | 2 | 3 | 3 |
| *Mean* | umhos/cm | 280 | 77 | 150 | 7800 | 22 |
| *Minimum* | umhos/cm | 250 | 50 | 110 | 120 | 5 |
| *Maximum* | umhos/cm | 310 | 90 | 190 | 23000 | 40 |
| **Turbidity** | | | | | | |
| *number of samples (n)* | | 3 | 3 | 2 | 3 | 3 |
| *Mean* | NTU | 18.0 | 2.5 | 8.0 | 8.7 | 0.7 |
| *Minimum* | NTU | 5.1 | 1.0 | 5.2 | 8.1 | 0.2 |
| *Maximum* | NTU | 39.0 | 4.9 | 10.8 | 9.9 | 1.1 |
| **Total Phosphorus** | | | | | | |
| *number of samples (n)* | | 3 | 3 | 2 | 3 | 3 |
| *Mean* | mg/L | 2.354 | 0.052 | 0.133 | 0.184 | 0.025 |
| *Minimum* | mg/L | 0.822 | 0.019 | 0.075 | 0.126 | 0.016 |
| *Maximum* | mg/L | 3.170 | 0.073 | 0.190 | 0.294 | 0.043 |
| **Dissolved Phosphorus** | | | | | | |
| *number of samples (n)* | | 3 | 3 | 2 | 3 | 3 |
| *Mean* | mg/L | 1.847 | 0.044 | 0.112 | 0.072 | 0.017 |
| *Minimum* | mg/L | 0.632 | 0.019 | 0.074 | 0.027 | 0.015 |
| *Maximum* | mg/L | 2.700 | 0.058 | 0.150 | 0.097 | 0.020 |

### Groundwater Monitoring Results

As shown in Table 5, dissolved phosphorus concentrations were elevated along all four shoreline segments, but concurrently elevated iron levels minimize the availability of this phosphorus. Only in the southwest segment was there any potentially significant phosphorus input, and low flows limit the magnitude of this input.

### Benthic Monitoring Results

Sediments in the main body of the pond and near the northern tributary were mucky, whereas sediments near the boat launch were sandy. Organic carbon content was especially high near the mouth of the northern tributary, most likely a direct result of inputs from the upstream dairy farm. Total phosphorus concentrations were high in this area and low at the remaining sites. TKN was low near the boat launch, moderate in the main body of the pond, and high at the mouth of the northern tributary.

### Biological Monitoring Results

Results of bacteria monitoring in surface waters at Stafford Pond revealed that concentrations recorded during dry weather were generally low (<100/100 ml) at all sites except SP5b, downstream of the dairy far, where values were consistently high (>500/100 ml). Values recorded during wet weather ranged from low to high, with the highest at SP5b and SP9.

Phytoplankton exhibited spring and late summer peaks, with the diatom *Asterionella* dominating the spring bloom and the bluegreen *Aphanizomenon* dominating the summer bloom. A traditional temperate zone successional pattern was exhibited, interrupted only by reduction of biomass and delay of bluegreen dominance by two early summer copper treatments.

Zooplankton included few forms and low to moderate biomass, but the presence of large bodied *Daphnia* suggests some potential for both grazing control of algae and desirable food for planktivorous fish. The *Daphnia* population crashed in August, however, probably from a combination of predation pressure and poor food quality. Zooplankton size distribution suggested either a balanced fish size structure or a tendency toward older, larger fish; further investigation into the stability of the fish community is warranted.

Results of the aquatic vascular plant surveys revealed that rooted plant growth was minimal in Stafford Pond. Rooted plants only grew near the periphery of the pond and plant densities did not exceed 25 percent. Only seven taxa of aquatic vascular plants were documented in the pond. All seven taxa are native to New England and only one is sometimes considered a nuisance. Rocky substrate in shallow areas is expected to minimize rooted plant growths even in the absence of the current light limitation induced by algal blooms.

The fish community of Stafford Pond is typical of many warm water New England lakes. A gill net and seine survey captured trout, bluegills, yellow perch and white perch, with the latter two species most abundant. Although condition factors were at least average, lack of multiple size classes suggests possible recruitment problems and instability.

**Table 5. Results of 1996 Groundwater Monitoring for Selected Parameters**

| Sample Site | Sampling Date | Dissolved Phosphorus mg/L |
|---|---|---|
| | | |
| Southeast | 10-Jun | 0.210 |
| Southwest | 10-Jun | 0.048 |
| Northeast | 10-Jun | 0.090 |
| Northwest | 10-Jun | 0.047 |
| | | |
| Southeast | 22-Aug | 0.300 |
| Southwest | 22-Aug | 0.180 |
| Northeast | 22-Aug | 0.074 |
| Northwest | 22-Aug | 0.061 |

## WATER QUALITY IMPAIRMENT

The 1996 limnological investigation documents that the primary problem affecting Stafford Pond is an overabundance of algae caused by elevated levels of phosphorus. In addition, the study found violations of water quality criteria for both dissolved oxygen and total phosphorus. This section characterizes the water quality impairments in Stafford Pond and describes specific violations of designated uses and water quality criteria found in the State's Water Quality Regulations.

### Negative Impacts on Designated Uses

The 1996 study found that the presence of the algal blooms diminishes the value of the pond for virtually all of its designated uses, including water supply, recreation, aesthetic enjoyment, and habitat. These negative impacts are summarized below.

**Water Supply Impacts.** A general decline in water quality has also been noted by employees of the SBFD water treatment facility. Prior to 1991, algal blooms were rather sporadic. During the past five years, the frequency and intensity of algal blooms has increased. Three algal taxa have been responsible for most of the bloom conditions. These taxa include *Anabaena, Aphanizomenon, and Asterionella*. The first two are Cyanophytes (bluegreen algae), while the last is a Bacillariophyte (diatom). The algal blooms have caused taste and odor problems and forced SBFD to upgrade its water treatment practices.

**Fishing and Fishery Impacts.** Depending upon how the situation is viewed, present conditions in the pond can either be positive or negative regarding fishing and fisheries. One school of thought holds that nutrient enrichment means greater production and biomass and thus more and bigger fish, suggesting that conditions in Stafford Pond may be favorable. However, nutrient enrichment in the case of Stafford Pond is excessive and has many potential negative impacts on fishing and fisheries.

Excessive nutrient loading is directly related to a high degree of decomposition on the pond bottom. During the summer of 1996, it was noted that stratification and decomposition of organic matter created an oxygen deficit in the bottom two meters of the pond, and this zone could increase in volume during a drier, calmer summer. This area of the pond is crucial habitat for cold water species such as trout as they seek refuge from the warmer upper waters during summer. Additionally, increased nutrient enrichment has resulted in an accumulation of oxygen-demanding organic muck in the pond, thus reducing usable habitat for many invertebrate species and potentially reducing spawning habitat for a self sustaining population of smallmouth bass. Frequent algal blooms can create physical or chemical stress on fish, including irritation and clogging of gill membranes. Finally, frequent algal blooms associated with excessive nutrient enrichment are aesthetically unpleasant to most lake users, including anglers.

Questions of quantity and quality must be considered in lake management for fish production. Greater productivity may not be desirable if it causes longer term instability or if qualitative aspects of the fishery (type and condition of fish) or fishing experience (sense of sight or smell) are impaired. The eutrophication experienced by Stafford Pond does appear to have negative effects on stability, as evidenced by discontinuous size distributions for captured species, and on fishing, as demonstrated by angler dissatisfaction with pond appearance.

**Swimming and Related Contact Recreation Impacts.** Stafford Pond is currently categorized as a Class A waterbody by the State of Rhode Island (RIDEM 1997). Designated uses under the Class A category include both public water supply and primary contact recreation. However, the Rhode Island General Laws (46-14-1) prohibit swimming in public drinking water supplies. Yet it is known that some swimming does occur in Stafford Pond, primarily by waterfront residents. Present conditions in the pond are distinctly undesirable for swimming, especially during algal bloom conditions or anywhere in the vicinity of the northern tributary. Low clarity creates unsafe conditions during much of the swimming season.

**Aesthetic Impacts.** The primary remaining use of the pond is for aesthetic enjoyment. Aesthetic enjoyment and related passive uses are among those most impaired by summer algal blooms. Improvement for water supply purposes and aesthetic appeal are entirely consistent; no conflict exists.

### Violations of Water Quality Criteria

The primary water quality criteria being addressed by this TMDL are minimum standards for dissolved oxygen and total phosphorus. The violations of these standards are described below.

**Dissolved Oxygen.** Due to the fact that it is a cold water fish habitat, the State's Water Quality Regulations require that instantaneous dissolved oxygen concentrations in Stafford Pond be maintained at a minimum of at least 5 mg/l. As shown in Table 2, low levels of dissolved oxygen were recorded in the bottom two meters of the pond, primarily during the late summer months.

**Total Phosphorus.** The State's Water Quality Regulations state that "*Average Total Phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole, or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs…*" As shown in Table 2, the mean concentrations for Total Phosphorus in the in-lake stations, i.e. stations SP1 through SP7, range from a high of 0.895 mg/l at station SP5b downstream of the dairy farm to a low of 0.033 mg/l at station SP7 at the pond outlet. All of these concentrations are in violation of 0.025 mg/l criteria.

## TARGETED WATER QUALITY GOALS

As verified by the 1996 study, the primary problem affecting Stafford Pond is an overabundance of algae caused by elevated levels of phosphorus. The presence of algal blooms diminishes the value of the pond for virtually all uses and leads to hypoxic conditions in the bottom waters of the pond in late summer months. Use as a water supply is made more expensive, recreational use is made less appealing, aesthetic enjoyment is impaired, and even habitat value is reduced.

There are no regulatory standards governing the precise target level of algal abundance, and the ideal level will vary depending upon a waterbody's management goals. Any decrease from current levels is likely to be viewed as an appropriate step, but once average chlorophyll (the green pigment involved in photosynthesis) drops below about 10 ug/L, fish production could be expected to decline. However, for purposes of water supply, the lower the algal abundance the better. As a chlorophyll level of 10 ug/L is not normally perceived by water suppliers as a significant problem, it is a reasonable initial target for algal abundance.

Unfortunately, algal biomass is not consistently correlated with chlorophyll concentration, as the biomass:chlorophyll ratio varies with algal composition. Bluegreen algae, otherwise known as cyanobacteria, have the highest biomass:chlorophyll ratio (up to 300:1), while diatoms have a more moderate ratio and green algae have among the lowest ratios (as low as 50:1). As a consequence, the type of algae present requires attention, in addition to the chlorophyll level. In Stafford Pond, diatoms dominate the spring algal blooms, while bluegreen algae dominate the summer blooms except for brief periods following copper treatments, when green algae appear most abundant.

Although 10 ug/l of chlorophyll, even if associated with bluegreen algae, is likely to cause only limited impairment of use, it would be far more desirable for water treatment, recreation, and habitat value if the algae were dominated by diatoms and green algae. Non-bluegreen algae would yield a lower biomass per unit of chlorophyll and be more easily handled in both the food web and water treatment process. Additionally, certain strains of the types of bluegreen algae found in Stafford Pond can produce and release toxins which can cause illness in human consumers. Consequently, the goal of restoring the pond should reflect both a reduction in chlorophyll level to 10 ug/l and a shift away from blue-green algae as the dominant algal division present during the summer.

In addition to the two goals described above, it is imperative that Stafford Pond also meet the State's Water Quality Criteria for average total phosphorus and instantaneous dissolved oxygen, set at 0.025 mg/l and 5.0 mg/l, respectively.

The overall objectives of the Stafford Pond TMDL are to restore the pond to a condition that supports its designated uses and to protect the pond from future degradation. More specifically, the targeted water quality goals for this TMDL are as follows:

- Reduce algal abundance, targeting a chlorophyll level of around 10 ug/l.
- Shift away from bluegreen algae as the dominant algal division in the summer.

- Reduce total phosphorus levels in the pond to an average level of 0.025 mg/l.
- Increase instantaneous dissolved oxygen levels in the pond to 5.0 mg/l.

It is quite possible to address all of these objectives more or less simultaneously. This is due to the fact that reducing phosphorus is the most effective way to control algal abundance, which would lead to improved dissolved oxygen levels and a shift away from dominance by bluegreen algae. Therefore, total phosphorus was chosen as the pollutant of concern for which this TMDL was developed. As discussed in the following section, reducing total phosphorus levels in the pond to 0.025 mg/l, the State's water quality standard, is projected to allow the pond to meet all four of the water quality goals outlined above.

# TOTAL MAXIMUM DAILY LOAD AND ALLOCATIONS

This section describes the TMDL load allocations that were developed for Stafford Pond. A brief description of the different allocations provided for in a TMDL is provided. Next, the different methods used to estimate current and projected phosphorus loadings are discussed.

## Definition of a TMDL

As defined by EPA regulations, a TMDL is the sum of the pollution loads allotted to point sources (i.e. waste load allocation) plus loads allotted to nonpoint sources, including natural background sources (i.e. load allocation) plus a margin of safety. The sum of all the loads is equal to the assimilative capacity of the waterbody such that applicable water quality standards are met.

Point sources include industries and municipal wastewater treatment plants that discharge to a waterbody. In the case of the Stafford Pond watershed, there are no significant point sources to consider. Nonpoint sources include stormwater runoff from urban and agricultural landuses, contributions from ground water, and deposition of pollutants from the air. Finally, the margin of safety accounts for the scientific uncertainty found in making these types of projections. Therefore, a TMDL can be represented by the following equation:

$$\mathbf{TMDL = WLA + LA + MOS}$$

Where:

TMDL = Assimilative capacity of the waterbody
WLA = Waste Load Allocation (Point source loads)
LA = Load Allocation (Nonpoint source loads)
MOS = Margin of Safety

## Estimation of Current Phosphorus Loads

The authors of the 1997 report detailing the results of the limnological investigation of Stafford Pond utilized three approaches to estimate phosphorus loading. In the first approach, existing data for water flows and phosphorus concentrations were used to calculate approximate inputs for sources with available data, and to derive rough estimates for unsampled sources through comparison. The second approach incorporated empirical models that utilize hydrologic lake features and known in-lake concentrations to back-calculate annual loading. A variety of such models are available, and four were chosen to represent the range of possible conditions. Such models can also be used to calculate the expected in-lake concentration from a provided loading value. The third approach to phosphorus loading incorporated the use of a land use export coefficient model. This model was also combined with an expanded version of the empirical model approach to provide predictions on in-lake water quality.

Application of the first approach to Stafford Pond included itemization of nutrient inputs from direct precipitation, ground water inseepage, surface water storm flow, surface water base flow, waterfowl, and internal recycling (Table 6). The discharge from the water treatment facility (periodic backwash) was excluded, as it contained only nutrients removed from the pond in the

## Table 6. Current (1996) Phosphorus Loads Estimated from Existing Data.

| SOURCE | WATER (CU.M/YR) | AVERAGE TOTAL P CONC. (MG/L) | TOTAL P LOAD (KG/YR) | ESTIMATED AVAILABLE P CONC. (MG/L) | ESTIMATED AVAILABLE P LOAD (KG/YR) |
|---|---|---|---|---|---|
| **Direct Precipitation** | **2250000** | **0.025** | **56** | **0.017** | **38** |
| | | | | | |
| **Watershed Sources** | | | | | |
| Ground Water Inseepage | 893000 | 0.126 | 113 | 0.023 | 21 |
| Surface Water Flow | | | | | |
| Baseflow | | | | | |
| Basin #1 | 0 | | | | |
| Basin #2 | 0 | | | | |
| Basin #3 | 0 | | | | |
| Basin #4 | 0 | | | | |
| Basin #5 | 286000 | 0.385 | 110 | 0.267 | 76 |
| Basin #6 | 348000 | 0.053 | 18 | 0.035 | 12 |
| Stormflow | | | | | |
| Basin #1 | 116000 | 0.030 | 3 | 0.015 | 2 |
| Basin #2 | 313000 | 0.159 | 50 | 0.092 | 29 |
| Basin #3 | 107000 | 0.047 | 5 | 0.047 | 5 |
| Basin #4 | 268000 | 0.020 | 5 | 0.010 | 3 |
| Basin #5 | 116000 | 1.608 | 187 | 1.255 | 146 |
| Basin #6 | 196000 | 0.047 | 9 | 0.047 | 9 |
| | | | | | |
| **Watershed Total** | **4893000** | | **500** | | **302** |
| | | | | | |
| *Additional Sources* | *Approach* | *(Unit Load)* | *(kg/yr)* | *(Unit Load)* | *(kg/yr)* |
| **Waterfowl** | **65 Bird-Years** | **0.20 kg P/B-Y** | **13** | **0.14 kg P/B-Y** | **9** |
| **Internal Recycling** | **Average** | **0.078 g/m2/yr** | **60** | **0.077 g/m2/yr** | **55** |
| | | | | | |
| **Grand Total** | | | **629** | | **405** |
| Notes: | | | | | |

1. There may be substantial overlap between internal and total basin loads, as much of the basin load may be rapidly assimilated into the sediment base.

2. Baseflow concentrations are based on data for days with no precipitation for at least 72 hrs prior to sampling, while stormflow values are an average of all other data.

3. Available concentrations estimated as the sum of all soluble concentrations, except for phosphorus in ground water, where all values for samples with Fe:P ratios > 5:1 were excluded as well.

first place and was far “cleaner” than any other input to the pond. Flow values in Table 6were taken directly from the hydrologic budget developed in the 1997 report, with some rounding for simplicity.

The resultant dissolved and total phosphorus loads were estimated to be 405 and 629 kg/yr, respectively. Loading allocations included approximately 75% to 79% from watershed sources, 10% to 14% from internal loading, 9% from direct precipitation, and 2% from waterfowl. Considering only the load from watershed sources, about 52% to 64% was associated with storm flow, 26% to 29% was attributable to base flow in the two tributaries, and 7% to 22% was related to ground water inputs. Of particular note, is that over half of the entire watershed load comes from sub-basin 5 which contains the only active dairy farm in the entire watershed. Based upon phosphorus chemistry and the forms present, it is expected that the effective phosphorus load (portion of the total phosphorus load that will be truly available for algal uptake) will be between the total and dissolved loads and closer to the dissolved load; much of the particulate phosphorus is incorporated into the sediment shortly after entry into Stafford Pond.

The second approach utilized by the authors of the 1997 report incorporated the use of empirical models to back-calculate annual phosphorus loading. The in-lake total phosphorus concentration predicted from the empirical models ranged between 27 and 66 ug/L, with an average of 46 ug/L. This is higher than the observed average value of 39 ug/L at the drinking water plant intake or 36 ug/L at station SP1a (pond surface). Use of the low end phosphorus load of 405 kg/yr resulted in a predicted in-lake total phosphorus concentration of 36 ug/L, more in line with observed values.

The third approach utilized by the authors of the 1997 report incorporated the use of a landuse export coefficient model to estimate annual phosphorus loading. A fairly simple but extensive spreadsheet model was created for Stafford Pond to employ the export coefficient approach, and was combined with an expanded version of the empirical model approach to provide predictions on in-lake water quality. The resulting phosphorus load estimates, shown in Table 7, were consistent with previous estimates. Since actual data was used to calibrate the model, this should not be surprising or impressive. However, the known limits for export coefficients were adhered to in constructing this model, so it does not unnaturally mimic the real system. The estimated effective phosphorus load from the combined model was 445 kg/yr, within the range from Table 6 and equating to an average input concentration of 91 ug/L.

**Table 7. Loading Summary from Watershed Export Model**

| LOAD SOURCE | WATER (CU.M/YR) | PHOSPHORUS (KG/YR) |
|---|---|---|
| DIRECT LOADS TO LAKE | | |
| ATMOSPHERIC | 2246940 | 59 |
| INTERNAL | 0 | 58 |
| WATERFOWL | 0 | 13 |
| WATERSHED LOADS | | |
| BASIN #1 | 271635 | 16 |
| BASIN #2 | 568117 | 53 |
| BASIN #3 | 227282 | 12 |
| BASIN #4 | 838709 | 20 |
| BASIN #5 | 233122 | 191 |
| BASIN #6 | 495410 | 23 |
| Total | 2634275 | 315 |
| | | |
| TOTAL LOAD TO LAKE | | |
| (Watershed + direct loads) | 4881215 | 445 |
| TOTAL INPUT CONC. (MG/L) | | 0.091 |

The constructed model for current Stafford Pond conditions predicts an in-lake total phosphorus concentration of 23 to 58 ug/L (average = 40 ug/L), an average chlorophyll concentration of 15 to 20 ug/L, a "maximum" (about 90th percentile) chlorophyll level of 56 to 61 ug/L, an average secchi depth of 1.4 m, and a maximum secchi depth of 3.5 m. Although not identical to other predictions, these values are in-line with known values for Stafford Pond. Within the range of plausible variability, the constructed model appears to appropriately represent the Stafford Pond system.

In conclusion, the total phosphorus load to Stafford Pond is as high as 629 kg/yr, but loss of particulate phosphorus to the sediment causes the pond to function as if it is receiving a load closer to 445 kg/yr.

### Estimation of Assimilative Capacity

As previously discussed, the TMDL for phosphorus loading to Stafford Pond must be such that it meets the water quality goal of reducing average chlorophyll concentrations to ≤10 ug/L. In order to reach this goal, authors of the 1997 report determined that the effective phosphorus load should be reduced to 315 kg/yr, resulting in an average in-lake total phosphorus concentration of 28 ug/L. However, this did not meet the State's water quality standard of 25 ug/L, so the results of the study had to be refined. Additional analysis, utilizing several empirical models used in the study, found that the effective phosphorus load should be reduced from 315 to 292 kg/yr (Wagner, 1998) in order for the pond to meet the water quality standard.

Results of the 1997 report indicated that the effective phosphorus load (445 kg/yr) to Stafford Pond was approximately 71% of the total phosphorus load (629 kg/yr). With this estimation in mind, the Stafford Pond TMDL for total phosphorus was set at 411 kg/yr. In order to reach this goal, a total phosphorus reduction of at least 218 kg/yr must be achieved.

### Seasonality

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 Stafford 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 of a function of loadings that occur over longer periods of time (e.g. annually). In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual, rather than a daily, basis.

### 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 and technical understanding of water quality in natural systems. Specifically, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, 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 incorporate 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.

For the Stafford Pond TMDL for total phosphorus, a combination of the two approaches was taken. First of all, the uncertainties in estimating the current phosphorus loads to the pond and the required reductions were minimized in this case by an intensive monitoring effort that addressed a wide range of loadings from the watershed, including groundwater contributions, as well as internal loads from sediments. In addition, the authors of the 1997 report predicted that reducing the effective phosphorus load to the pond to 315 kg/yr would allow the pond to reach the primary goal of the TMDL which is the reduction of nuisance algal blooms to acceptable levels. This TMDL further reduces the effective phosphorus load by 23 kg/yr, to 292 kg/yr, in order to reach the water quality criteria of 25 ug/L. The water quality standard for phosphorus itself is fairly conservative and is designed to prevent cultural eutrophication in lakes, ponds and impoundments. The State water quality standard and the Stafford Pond TMDL are both presented as total phosphorus.

In addition to the conservative assumptions outlined above, it was decided that a margin of safety of 5%, or 21 kg/yr of total phosphorus, would be set aside as a precaution to account for any remaining uncertainties.

**Summary of Total Maximum Daily Load**
The total phosphorus TMDL for Stafford Pond is:

| **TMDL** | **=** | **WLA** | **+** | **LA** | **+** | **MOS** |
|---|---|---|---|---|---|---|
| **411** | **=** | **0** | **+** | **390** | **+** | **21** |

## PUBLIC PARTICIPATION

The public participation associated with this TMDL has three components. The first component is the series of outreach activities that surrounded the planning, implementation and review of the limnological study that resulted in the 1997 report that is the basis of this TMDL. At both the beginning and end of the study, DEM sponsored well attended public meetings in the watershed to solicit input from local residents.

DEM staff also established a steering committee of stakeholders that included representatives from local municipalities, watershed residents, the Stone Bridge Fire District, the Eastern Rhode Island Conservation District, the University of Rhode Island (URI) Watershed Watch program, and other State and federal agencies. The steering committee has met often since its formation in 1996 and has worked to ensure that the various stakeholders' concerns were addressed in the study and the report. Now that the report has been finalized and a TMDL developed, the steering committee will continue to play an important role by helping to guide implementation activities in the watershed.

The second component of the public outreach process for this TMDL is the public comment period associated with the review of the draft TMDL prior to its submittal to EPA by DEM. At a minimum, a 30-day public comment period will be provided. Also, DEM staff will present the TMDL to the local Stafford Pond steering committee and discuss its content and implications. If there is sufficient public interest, a public meeting will be held in or near the Stafford Pond watershed to solicit further public input.

The third, and final, component of the public outreach process associated with this TMDL is the public outreach activities funded by DEM and carried out by the Eastern Rhode Island Conservation District (ERICD). As described in the following section, ERICD will be performing a number of activities designed to heighten public awareness of water quality issues in Stafford Pond. The Stafford Pond TMDL for total phosphorus is a key component of the State's protection measures for the pond and, as such, will be included in ERICD's presentations and workshop discussions.

## ASSURANCE OF IMPLEMENTATION

EPA guidance on the development of TMDLs states that implementation plans may be submitted to EPA as revisions to State water quality management plans, coupled with a proposed TMDL, or as part of an equivalent watershed or geographic planning process. Implementation plans should include "*reasonable assurances that the nonpoint source load allocations established in TMDLs (for waters impaired solely or primarily by nonpoint sources) will in fact be achieved. These assurances may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs.*" (EPA, 1991) For the Stafford Pond TMDL, the State of Rhode Island can provide the necessary assurances that the nonpoint source load reductions are achievable. Plans are already in place to reduce a large portion of the current load. The three key areas in which progress is already underway are described below. In addition, a summary of the load reductions projected to date is provided.

### Agricultural BMPs

DEM is working with the Natural Resources Conservation Service (NRCS) to see that a runoff management system is put in place on the Aruda dairy farm. The farm contributes approximately 267 kg/yr of total phosphorus to the pond, out of a total of 500 kg/yr from the entire watershed. DEM is providing funding for construction through the Nongovernmental Water Pollution Control Facilities Fund which is part of the RI Clean Water Act Environmental Trust Fund, a bond fund approved by Rhode Island voters in the 1980's. NRCS is providing technical expertise by designing the facilities and providing additional federal funding for BMP implementation.

The proposed NRCS plan calls for better manure management practices on the farm, as well as a number of structural BMPs. These include better site grading, stream bank fencing and a vegetated swale containing six check dams and two settling basins with concrete-lined bottoms for easy maintenance. Upon construction of these BMPs, as well as additional BMPs planned for the near future, the total load reduction from the farm is expected to be approximately 400 lbs/yr, or 182 kg/yr.

### Stormwater BMPs

As noted earlier in this report two 18-inch storm drains empty into the southeast corner of Stafford Pond near the public boat ramp. These outfalls are the only direct discharges of stormwater runoff to the pond. The northern storm drain pipe (sampling station SP8) drains sections of Old Stafford Road. The southern pipe (sampling station SP9) drains sections of Route 81 and discharges to a small wetland area within 200 feet of the pond. Sub-basin 2, which contains these two storm drain systems, delivers the second largest of the sub-basin loads, so it is an important source to control.

DEM is presently working with the Rhode Island Department of Transportation (DOT) to support the implementation of stormwater BMPs at both outfalls. In order to expedite the installation of these BMPs, DEM is working with DOT to add these two sites to a pre-existing design contract with an outside consultant. DEM is using funding from the CWA Section 319 Nonpoint Source program to pay for the design and construction of these facilities. Due to the tight constraints on available land, the design engineer will focus on in-line BMPs, such as the

“Stormtreat” or “Vortechnic” type systems, rather than traditional detention or retention ponds (CEI, 1998). Since the BMPs have yet to be assigned, it is not possible to assign a load reduction to them. However, given that the DOT storm sewers drain less than half of the sub-basin, which contributes an total load of 50 kg/yr, it is not expected that the BMPs could reduce loads by more than 10 to 15 kg/yr.

**Public Outreach**

The third component of the implementation plan for the Stafford Pond TMDL is a watershed-wide public education and outreach program. In March 1998, DEM provided CWA Section 319 Nonpoint Source funds to the Eastern Rhode Island Conservation District (ERICD). The ERICD has agreed to develop a public outreach program for residents of the Stafford Pond watershed with the following components:

- Create an education and outreach committee formed from members of the existing Stafford Pond Committee made up of community volunteers and other interested parties.
- Develop a public information fact sheet based on the results of the 1997 report that would be mailed to all residents and property owners in the watershed.
- Create a “travelling” display to be used in workshops, schools and libraries.
- Develop a brochure, similar to the Narrow River handbook, highlighting the protection of the watershed, potential citizen involvement, and opportunities.
- Hold two workshops on protecting the watershed.
- Hold one workshop on applicable State regulations for town officials and interested citizens.

**Summary of Projected Load Reductions**

Based on the estimated annual load of 629 kg/yr and the TMDL load allocation of 390 kg/yr, a load reduction of approximately 239 kg/yr is required in the watershed. As described above, structural BMPs already under development are projected to reduce nonpoint source loads to the pond by approximately 195 kg/yr. Given the uncertainties in quantifying changes in loading due to the public outreach program, no reduction was allocated to this program. This results in a shortfall of about 44 kg/yr that still needs to be controlled.

**Additional Activities**

DEM, in partnership with local stakeholders, will continue to look for further opportunities in the watershed for reducing phosphorus loads to the pond. DEM will work closely with NRCS to facilitate further reductions, where possible, on the dairy farm. For example, the farmer has recently agreed to implement a restoration plan developed by NRCS for a wetland area on the farm that was illegally filled. As the project progresses, DEM will work with NRCS to quantify the resulting reductions in total phosphorus loads to the pond.

The Town of Tiverton has approved a local ordinance requiring home owners in the Stafford Pond watershed to upgrade their septic systems by 2005. DEM will work with the Town to determine how these improvements will impact the pond. Based on the fact that many older systems will be replaced, a net reduction in nutrient loads to the pond from this source may result.

In addition to the activities described above, DEM will continue to support the long-term monitoring of the pond and its tributaries to evaluate the performance of installed BMPs and to judge the effectiveness of this TMDL in restoring water quality in Stafford Pond.  DEM will also incorporate this TMDL into its Continuing Planning Process and will take the phosphorus-loading cap into account when reviewing future permit applications for activities in the watershed.

# REFERENCES

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