LAKE HOPATCONG
WATER QUALITY MONITORING
ANNUAL REPORT 2009

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<u>Appendices</u>

1.0 INTRODUCTION

Princeton Hydro, LLC conducted general water quality monitoring of Lake Hopatcong during the 2009 growing season (May through September). This monitoring program represents a continuation of the long-term monitoring program of Lake Hopatcong. The current water quality monitoring program is a modified version of the program that was originally initiated in the Phase I Diagnostic / Feasibility Study of Lake Hopatcong (PAS, 1983) and continued through the Phase II Implementation Project. Both the Phase I and Phase II projects were funded by the US EPA Clean Lakes (314) Program. The modified monitoring program also continued through the development, revision and approval of the TMDL-based Restoration Plan, as well as through the installation of a series of watershed project funded through a NJDEP 319 grant and a US EPA Targeted Watershed grant.

The current water quality monitoring program is valuable in terms of continuing to assess the overall "health" of the lake on a year to year basis, identifying long-term trends or changes in water quality, and quantifying and objectively assessing the success and potential impacts of restoration efforts. In addition, the in-lake water quality monitoring program will be an important component of evaluating the long-term success of the implementation of the phosphorus TMDL-based Restoration Plan, which was approved by NJDEP in April of 2006.

2.0 MATERIALS AND METHODS

In-lake water quality monitoring was conducted at the following eleven (11) locations in Lake Hopatcong (Figure 1 in Appendix A) during the study period:

Station Number	Location
1	Woodport Bay
2	Mid-Lake
3	Crescent Cove/River Styx
4	Point Pleasant/King Cove
5	Outlet
6	Henderson Cove
7	Inlet from Lake Shawnee
8*	Great Cove
9*	Byram Cove
10	Northern Woodport Bay
11	Jefferson Canals

* *In-situ* monitoring only

The 2009 sampling dates were 29 May, 30 June, 30 July, 27 August and 22 September. A Eureka Amphibian PDA with Manta multi-probe unit was used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH, and conductivity during each sampling event. Data were recorded at 1.0 m increments starting at 0.5 m below the water's surface and continued to within 0.5 m of the lake sediments at each station during each sampling date. In addition, water clarity was measured at each sampling station with a Secchi disk.

Discrete water quality samples were collected with a Van Dorn sampling device at 0.5 m below the lake surface and 0.5 m above the sediments at the mid-lake sampling site (Station #2). Discrete samples were collected from a mid-depth position at the remaining six (6) original sampling stations (Stations #1, 3, 4, 5, 6 and 7) and additionally at the Northern Woodport Bay and Jefferson Canals sites (Stations #10 and #11, respectively) on each date. Discrete water samples were appropriately preserved, stored on ice, and transported to a State-certified laboratory for the analysis of the following parameters:

- total suspended solids
- total phosphorous-P
- nitrate-N
- ammonia-N
- chlorophyll *a*

All laboratory analyses were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 18th Edition* (American Public Health Association, 1992). Monitoring at the Great Cove (Station #8) and Byram Cove (Station #9) sampling stations consisted of collecting *in-situ* and Secchi disk data; no discrete water samples were collected from these two stations for laboratory analyses. It should be noted that prior to 2005, Station #10 had been monitored for *in-situ* observations only. However, due to observations made at Station #10 by the Lake Hopatcong Commission operations staff, it was decided that this sampling station should be added to the discrete sampling list.

During each sampling event, vertical plankton tows were also conducted at the deep sampling station (Station #2). A 50-µm mesh plankton net was used to sample the phytoplankton, while a 150-µm mesh plankton net was used to sample the zooplankton. The vertical tows were deployed starting immediately above the anoxic zone (DO concentrations < 1 mg/L) and conducted through the water column to the surface.

Additional Water Quality Data Collected in 2009

In addition to the standard, long-term, in-lake monitoring program, supplemental in-lake data were collected during the 2009 monitoring program. From 2006 to 2008 three, near shore, in-lake sampling sites were established and monitored. These additional in-lake sampling sites were located immediately adjacent to drainage areas that were receiving a structural BMP as part of an existing 319(h) grant. The three near-shore, in-lake sampling stations include:

1. The southern end of Crescent Cove in the Borough of Hopatcong.
2. Ingram Cove, located in the Borough of Hopatcong.
3. Along the eastern shoreline of the lake, in the Township of Jefferson, just south of Brady's Bridge.

Through the course of implementing the 319(h) grant, it was determined that no BMP would be installed in the Ingram Cove drainage basin; the Ingram Cove project was dropped from the grant due to site specific limitations associated with existing utilities. Subsequently, the proposed Ingram Cove project was moved to the Crescent Cove drainage area. However, monitoring of the Ingram Cove sampling station continued through 2008 but was discontinued during the 2009 monitoring program.

For the remaining two supplemental in-lake sampling stations, monitoring occurred during the June through September 2009 monitoring events. Monitoring included collecting *in-situ* data at 0.5 – 1.0 meters from surface to bottom for temperature, dissolved oxygen, pH and conductivity. Water clarity was also measured at each station with a Secchi disk. Discrete mid-depth water samples were collected and analyzed for TP and TSS.

3.0 RESULTS AND DISCUSSION

Thermal Stratification

Thermal stratification is a condition where the warmer surface waters (called the epilimnion) are separated from the cooler bottom waters (called the hypolimnion) through differences in density, and hence, temperature. Thermal stratification separates the bottom waters from the surface waters with a layer of water that displays a sharp decline in temperature with depth (called the metalimnion or thermocline). In turn, this separation of the water layers can have a substantial impact on the ecological processes of a lake (for details see below). Thermal stratification tends to be most pronounced in the deeper portions of a lake. Thus, for convenience, the discussion on thermal stratification in Lake Hopatcong focuses primarily on the deep, mid-lake (Station #2) sampling station.

In-situ measurements during the 2009-growing season were generally consistent with values recorded in previous years' monitoring programs. By late May 2009, the lake was very weakly stratified between 5 and 6 meters. From surface to bottom (12 meters), the temperature decreased from 18.36°C at the surface to 10.28°C at the bottom (Appendix B).

During the remaining four monitoring events the lake was strongly stratified at Station #2 with the thermocline migrating through the water column over the growing season. In June the thermocline was between 5 and 9 meters and by September it was between 8 and 12 meters (Appendix B).

Other than Station #2, the only other long-term monitoring stations that exhibited some degree of thermal stratification were Stations #8 (Great Cove) and #9 (Byram Cove). In addition, in spite of being shallow, the 319 in-lake sampling station Crescent Cove exhibited varying degrees of thermal stratification through the 2009 growing season.

Thermal stratification can effectively "seal off" the bottom waters from the surface waters and overlying atmosphere, which can result in a depletion of dissolved oxygen (DO) in the bottom waters. With the exception of a few groups of bacteria, all aquatic organisms require measurable amounts of DO (> 1 mg/L) to exist. Thus, once the bottom waters of a lake are depleted of DO, a condition termed anoxia, that portion of the lake is no longer available as viable habitat.

Dissolved Oxygen

Atmospheric oxygen enters water by diffusion from the atmosphere, facilitated by wind and wave action and as a by-product of photosynthesis. Adequate dissolved oxygen (DO) is necessary for acceptable water quality. Oxygen is a necessary element for most forms of life. As dissolved oxygen concentrations fall below 5.0 mg/L, aquatic life is put under stress. DO levels that remain below 1.0 – 2.0 mg/L for a few hours can result in large fish kills and loss of other aquatic life. Although some aquatic organisms require a minimum of 1.0 mg/L of DO to survive, the NJDEP State criteria for DO concentrations in surface waters is 5.0 mg/L or greater, for a healthy and diverse aquatic ecosystem.

In addition to a temporary loss of bottom habitat, anoxic conditions (DO < 1 mg/L) can produce chemical reactions that result in a release of phosphorus from the sediments and into the overlying waters. In turn, a storm event can transport this phosphorus to the upper waters and stimulate additional algal growth. This process is called internal loading. Given the temporary loss of bottom water habitat and the increase in the internal phosphorus load, anoxic conditions are generally considered undesirable in a lake.

During the 29 May 2009 sampling event, DO concentrations were above the 5.0 mg/L threshold throughout most of Lake Hopatcong. Only the deepest waters (equal to or greater than 11 meters) of Station #2 (mid-Lake) had depressed concentrations of DO (< 5.0 mg/L).

Lake Hopatcong was oxygenated from surface to bottom and the surface waters of Lake Hopatcong were also generally well oxygenated (> 5.0 mg/L) during the 30 June 2009 sampling event. The exception to this was between 7 and 13.5 meters at Station #2 when the DO concentrations varied between 4.0 and 4.8 mg/L. Similar conditions were observed during the 30 July 2009 sampling event; the lake was generally well oxygenated in the surface waters, with DO concentrations varying between 3.4 and 4.0 mg/L from 8 meters to the bottom at Station #2. In addition, DO concentrations were between 4.5 and 4.8 mg/L in the bottom waters of Station #9.

In contrast to previous monitoring years, no deep water anoxic (DO concentrations less than 1 mg/L) conditions were found in Lake Hopatcong during the August 2009 event. For example, at Station #2, DO concentrations throughout the water column essentially varied from 5.7 to 11.3 mg/L with one depth, 7 meters, having a DO concentration of 4 mg/L. This depressed DO concentration at 7 meters was located within one of the sharpest declines in temperature within the thermocline, which is indicative of an accumulation of organic material and bacteria. In turn, such material can exert a decline in DO due to bacterial decomposition of the organic material.

DO concentrations at Station #2 varied from 1.5 to 7.86 mg/L during the September 2009 sampling event. Thus, while DO concentrations fell below 5 mg/L in the deeper waters, they did not become anoxic (< 1 mg/L). Thus, the unusually wet and cool weather during the 2009 growing reason resulted in weakening the strength of thermal stratification in Lake Hopatcong, which in turn increased mixing and prevented a depletion of DO.

pH

The optimal range of pH for most freshwater organisms is between 6.0 and 9.0. For the most part, the pH throughout the water column of Lake Hopatcong was within this optimal range. The exception to this was during the 29 May 2009 sampling event when the pH at Stations #3 (River Styx / Crescent Cove) and Station #5 (Outlet) exceeded 9 in the surface waters. Such temporarily elevated pH values in the surface waters can be attributed to high rates of algal and/or aquatic plant photosynthesis. As algae and plants photosynthesize, they produce DO as a by-product, as well as increase the pH of their immediate environment. In spite of these temporarily elevated pH values, the pH of Lake Hopatcong through most of the 2009 growing season was within the optimal range for most aquatic organisms. Similar results were observed in 2007 and 2008. It should also be noted that the pH values at the Crescent Cove and Jefferson 319 in-lake sampling stations were within the optimal range for most aquatic life during all five 2009 sampling events.

Water Clarity (as measured with a Secchi disk)

Water clarity or transparency, as measured with a Secchi disk, was generally acceptable at all of the sampling stations during the 2009 sampling season. Based on Princeton Hydro's in-house long-term database of lakes in northern New Jersey, water clarity is considered acceptable for recreational activities when the Secchi depth is equal to or greater than 1.0 m (3.3 ft). Secchi depth measurements throughout most of Lake Hopatcong were greater than 1.0 meter in 2008. For example, at the mid-lake sampling station (Station #2), the Secchi depth varied from 1.2 to 2.5 meters (6.2 to 8.25 ft) through the course of the 2009 sampling season.

All Secchi depth values in May and June 2009 were equal to or greater than the 1meter (3.3 ft) established threshold for acceptable "recreational" water quality in Lake Hopatcong. In July 2009 the only station that had a Secchi depth less than a meter was Station #10 (Northern Woodport Bay). However, by late August 2009 four stations has Secchi depths less than 1 meter (Appendix B). These stations included #1, #3, #5 and #10 (Woodport Bay, Crescent Cove / River Styx, Outlet and Northern Woodport Bay, respectively. By late September 2009, the only station that had a Secchi depth value less than 1 meter was Station #5 (the Outlet).

It should be noted that Secchi depths were substantially higher in 2009 at Station #3 relative to 2008. In 2008 Secchi depth values at Station #3 varied from 0.7 to 1.2 m with a mean of 0.9 m, while in 2009 values varied from0.5 to 2.0 m with a mean of 1.2 meters. In addition, over the last few years, Secchi depths in the northern enter of the lake (station #10) have been below the 1 m threshold at least twice during the growing season.

Relative to the 319 in-lake sampling stations, Secchi depth values were generally better at the Crescent Cove sampling station in 2009 relative to 2008, in spite of the higher frequency of storm events. During the 2008 monitoring program, the Secchi depth mean at Crescent Cove was 0.7 m with four of the five events having values below the 1 m threshold. In contrast, during the 2009 monitoring program, the Secchi depth mean at Crescent Cove was 1.0 m with only two of the five events having values below the 1 m threshold. As will be described later, this improved water clarity at Crescent Cove is at least partially attributed to the Aqua-Filter manufactured treatment device installed in the Crescent Cove drainage basin in November of 2008.

Ammonia-Nitrogen (NH_4-N)

Surface water NH_4-N concentrations above 0.05 mg/L tend to stimulate elevated rates of algal growth. During the May 2009 sampling event surface water NH_4-N concentrations varied between < 0.01 and 0.11 mg/L, while during the June 2009 sampling event surface water NH_4-N concentrations were 0.04 mg/L throughout the lake except for Station #3 where the concentration was 0.14 mg/L. During the July 2009 sampling event surface water NH_4-N concentrations varied from 0.02 and 0.12 mg/L, while during the August 2009 sampling event surface water NH_4-N concentrations varied from 0.01 and 0.02 mg/L. Finally, surface water NH_4-N concentrations varied from 0.02 and 0.03 mg/L during the September 2009 sampling event.

Bottom water NH_4-N concentrations were monitored seasonally at the mid-lake sampling site (Station #2). Bottom water NH_4-N concentrations varied between 0.50 and 0.75 mg/L through the 2009 growing season (Appendix C). Bottom water NH_4-N concentrations are typically elevated during the summer season, as a result of a depletion of dissolved oxygen. Under such conditions, bacterial decomposition of organic matter results in an accumulation of NH_4-N. The severe limitation of light in the bottom waters exacerbates these conditions through the negligible uptake of NH_4-N by algae. Thus, this seasonal accumulation of NH_4-N is common occurrence in Lake Hopatcong.

Nitrate-Nitrogen (NO_3-N)

Surface water NO_3-N concentrations throughout the 2009 sampling season of Lake Hopatcong varied between <0.02 mg/L and 0.13 mg/L. While there was a considerable amount of variation both among the sampling stations and between sampling events, the NO_3-N concentrations measured in July and August were generally lower relative to measurements made in May and September. Again, elevated rates of algal growth and associated nutrient demand resulted in a reduction in NO_3-N concentrations in the surface waters at the height of the summer season.

It should be noted as has been identified in past reports, NO_3-N concentrations in the Canal section of the lake (Stations #7 and #11) were generally higher than the rest of the lake. As has been identified, this is primarily due to the high concentration of nearshore, on-site wastewater treatment systems (septic systems) in the Township of Jefferson. Elevated NO_3-N concentrations have been measured at Station #11 during previous monitoring events and these historically high concentrations have been attributed to the horizontal movement of leachate from near-shore septic system leachfields.

Total Phosphorous (TP)

Phosphorus has been identified as the primary limiting nutrient for algae and aquatic plants in Lake Hopatcong. Essentially, a small increase in the phosphorus load will result in a substantial increase in algal and aquatic plant growth. For example, one pound of phosphorus can generate as much as 1,100 lbs of wet algae biomass. This fact emphasizes the continued need to reduce the annual phosphorus load entering Lake Hopatcong, as detailed in the lake's revised TMDL and associated Restoration Plan.

Studies have shown that TP concentrations as low as 0.03 mg/L can stimulate high rates of algal growth resulting in eutrophic or highly productive conditions. Based on Princeton Hydro's in-house database on northern New Jersey lakes, TP concentrations equal to or greater than 0.06 mg/L will typically result in the development of algal blooms / mats that are perceived as a nuisance by the layperson.

The State's Surface Water Quality Standard (SWQS, N.J.A.C. 7:9B – 1.14(c) 5) for TP in the surface waters of a freshwater lake or impoundment is 0.05 mg/L. This established TP concentration is for any freshwater lake or impoundment in New Jersey that does not have an established TMDL. Lake Hopatcong has established a phosphorus TMDL, which was revised and approved by NJDEP in June 2006. Based on its refined phosphorus TMDL, the long-term management goal is to maintain an average, growing season TP concentration of 0.03 mg/L within the surface waters of Lake Hopatcong.

During the 29 May 2009 sampling event, TP concentrations throughout the lake generally varied between <0.01 mg/L and 0.05 mg/L and had a lake-wide mean value of 0.02 mg/L

During the 30 June 2009 sampling event, TP concentrations throughout Lake Hopatcong varied between 0.01 mg/L and 0.03 mg/L with a lake-wide mean value of 0.02 mg/L. In contrast, TP concentrations during the 30 July 2009 event varied between 0.02 and 0.05 mg/L with a lake-wide mean value of 0.03 mg/L.

During the 27 August 2009 sampling event, TP concentrations in the surface waters varied between 0.02 mg/L and 0.06 mg/L with a lake-wide mean value of 0.03 mg/L. Finally, during the 22 September 2009 sampling event, surface water TP concentrations again varied between 0.01 mg/L and 0.03 mg/L with a lake-wide mean value of 0.02 mg/L.

As has been well documented in past reports, Station #3 (River Styx / Crescent Cove) consistently had the highest TP concentrations in Lake Hopatcong. Since the long-term monitoring of Lake Hoaptcong was initiated in the 1980's, elevated TP concentrations In the River Styx / Crescent Cove section of the lake is a re-occurring condition. The elevated TP concentrations at this station are most likely the result of the land use activities within the surrounding sub-watersheds, as well as the minimal amount of seasonal hydrologic flushing. Combined, these factors provide the opportunity for algae and aquatic plants to assimilate available phosphorus and produce the nuisance in-lake conditions typically observed in these portions of the lake.

Bottom water TP concentrations at the mid-lake sampling station (Station #2) varied between 0.16 and 0.31 mg/L from June through September of 2009. The elevated TP concentrations in the deep waters were attributed to the depressed DO concentrations and the lack of mixing with the atmosphere during the summer season.

TP concentrations were generally low at two of the three 319 in-lake sampling stations. Samples were collected monthly from June through September 2009. At the Crescent Cove station TP concentrations varied from 0.03 to 0.06 mg/L, while TSS concentrations varied from < 3 to 15 mg/L. At the Jefferson station TP concentrations varied from 0.02 to 0.03 mg/L, while TSS concentrations varied from < 3 to 5 mg/L.

As part of the existing 319 grant, a large Aqua-Filter Manufactured Treatment Device (MTD) was installed in the southern end of the Crescent Cove drainage basin to reduce a large portion of the TP and TSS loads that enter the lake from this section of the watershed. This MTD was installed in November / December of 2008 and the 2009 growing season was the first post-installation year of monitoring. Thus, the water quality data collected at Crescent Cove in 2009 was compared to the three years of pre-installation data (2006-2008) in order to evaluate if the Aqua-Filter had a positive impact on local water quality conditions. Since no samples were collected in May of 2009 for the 319 sampling stations, these data were not included in the analysis. Table 1 provides a summary of these Crescent Cove water quality data.

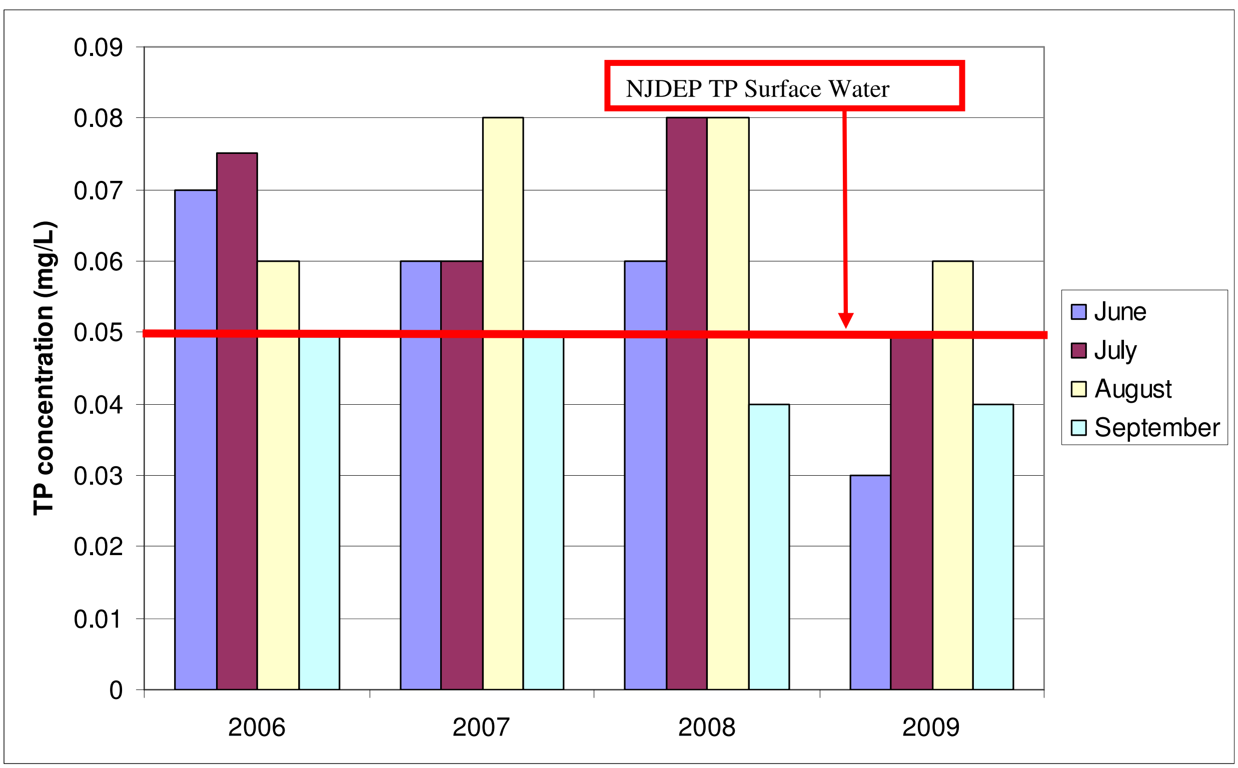
Table 1
The Mean and Range of TP and TSS Concentrations for Crescent Cove From June through September of Each Monitored Year

Monitoring Year	TP mean and range	TSS mean and range
2006 (pre-installation)	0.064 mg/L (0.05 – 0.09 mg/L)	12 mg/L (6 – 15 mg/L)
2007 (pre-installation)	0.063 mg/L (0.05 – 0.08 mg/L)	7 mg/L (3 – 11 mg/L)
2008 (pre-installation)	0.065 mg/L (0.04 – 0.08 mg/L)	18 mg/L (1.5 – 48 mg/L)
2009 (post-installation)	0.045 mg/L (0.03 – 0.06 mg/L)	7 mg/L (1.5 – 8 mg/L)

As shown in Table 1, before the Aqua-Filter was installed the mean TP concentration in Crescent Cove varied between 0.063 to 0.065 mg/L; these mean values are greater than both the State's Surface Water Quality Standard of 0.06 mg/L for standing waterbodies as well as the targeted TMDL concentration of 0.03 mg/L. However, after the Aqua-Filter was installed in late 2008, the mean TP concentration declined to 0.045 mg/L (Table 1). While this value was still greater than the targeted TMDL concentration of 0.03 mg/L, it was below the State's Surface Water Quality Standard of 0.06 mg/L.

In addition to a reduction in the mean TP concentration, the frequency of the Crescent Cove station violating the State Standard declined after the Aqua-Filter was installed. As shown in Figure 1 below, prior to the installation of the Aqua-Filter (2006-2008) the TP concentration at the Crescent Cove station was above the State Standard three out of four sampling events. In contrast, after the Aqua-Filter was installed (2009) the TP concentration at the Crescent Cove station was above the State Standard in only one of four sampling events (Figure 1).

Figure 1 – TP Concentrations at Crescent Cove



In contrast to TP, the TSS concentrations at the Crescent Cove sampling stations were consistently below the State's Water Quality Standard of 25 mg/L both before and after the Aqua-Filter was installed (Table 1). In fact, the 2007 (pre-installation) and 2009 (post-installation) mean TSS concentrations were the same at 7 mg/L. However, the range of TSS concentrations measured in 2009 was generally lower than those measured during the pre-installation monitoring years. Thus, the resulting TP and TSS data indicate that the Aqua-Filter has had a positive impact on the water quality in the Crescent Cove region of Lake Hopatcong. However, the installation of another stormwater MTD in the Crescent Cove part of the watershed would also contribute toward additional reductions in the in-lake TP concentrations and hopefully result in the Cove being in compliance with the TMDL established mean concentration of 0.03 mg/L.

Chlorophyll a

Chlorophyll *a* is a pigment possessed by all algal groups, used in the process of photosynthesis. Its measurement is an excellent means of quantifying algal biomass. In general, an algal bloom is typically perceived as a problem by the layperson when chlorophyll *a* concentrations are equal to or greater than 30.0 mg/m^3. Based on the findings of the refined TMDL, the existing average seasonal chlorophyll *a* concentration under existing conditions is 15 mg/m^3, while the maximum seasonal value is 26 mg/m^3. In contrast, the targeted average and maximum chlorophyll *a* concentrations, once Lake Hopatcong is in complete compliance with the TMDL, are predicted to be 8 and 14 mg/m^3, respectively.

Only one of the five 2009 lake-wide mean chlorophyll *a* concentrations were less than targeted mean of 8 mg/m^3. However, none of the sampling stations exceeded the targeted seasonal maximum of 14 mg/m^3 during the May and June sampling events. In sharp contrast, all but Stations #7 and #11 (the Canal stations) had chlorophyll *a* concentrations greater than 14 mg/m^3 maximum threshold during the July and August 2009 sampling events. During the September 2009 sampling event, all chlorophyll *a* concentrations except those at Stations #6, #7 and #11 exceeded the maximum threshold of 14 mg/m^3. The lower chlorophyll *a* concentrations in the Jefferson Canal section of the lake was attributed to it being shallow water habitat where macrophyte species such as bladderwort and benthic mat algae competed with the phytoplankton (free-floating, open water algae). These macrophytes were in direct competition with the phytoplankton for the available nutrients.

Finally, it should be noted that as is typically observed at Lake Hopatcong, Station #3 had the highest mean (26.6 mg/m^3) and single (73.6 mg/m^3) highest chlorophyll *a* concentration of the nine discrete sampling stations monitored in 2009. However, it should also be noted that since 2007 the mean chlorophyll *a* concentration at Stations #3 has been less than the perceived nuisance threshold of 30 mg/m^3.

Phytoplankton

Phytoplankton are algae that are freely floating in the open waters of a lake or pond. These algae are vital to supporting a healthy ecosystem, since they are the base of the aquatic food web. However, high densities of phytoplankton can produce nuisance conditions. The majority of nuisance algal blooms in freshwater ecosystems is the result of cyanobacteria, also known as blue-green algae. Some of the more common water quality problems created by blue-green algae include bright green surface scums, taste and odor problems and the generation of cyanotoxins.

Table 1 lists the dominant phytoplankton identified in Lake Hopatcong during each water quality monitoring event in 2009. A bloom of chrysophyte *Dinobryon* was identified on the 29 May 2009 sampling date. A number of green algae and diatoms were also identified in the May sample, as well as the filamentous blue-green alga *Oscillatoria* (Table 1).

Algal diversity and abundance was relatively high during the 30 June 2009 sampling event. Two genera of blue-green algae, *Oscillatoria* and *Anabaena* dominated the algal community at this time. Green algae, diatoms, the chrysophyte *Dinobryon* and the blue-green alga *Aphanizomenon* were also identified in the June sample.

Algal diversity was moderate and abundance was high during the 30 July 2009 sampling event, with the dominant genera continuing to be the blue-green algae *Oscillatoria* and *Anabaena* (Table 1). Other blue-green algae, *Microcystis* and *Coelosphaerium*, were identified in the sample as well as the filamentous diatom *Melosira*, the cryptomonad *Cryptomonas* and a variety of green algae.

Algal abundance was high during the 27 August 2009 sampling event with the dominant alga being the blue-green *Anabaena*. A number of other algae were dominant in Lake Hopatcong during the August 2009 sampling event and included *Aphanizomenon*, *Oscillatoria*, *Microcystis* and *Coelosphaerium*. A large number of green algae, a few diatoms (*Melosira* and *Tabellaria*) and the dinoflagellate *Ceratium* were also identified in the August 2009 sample.

Algal abundance and diversity was relatively high in Lake Hopatcong during the 22 September 2009 sampling event. The blue-green alga *Anabaena* appeared to be the most common genus; other blue-green algae were also identified in the September 2009 sample. A large number of green algae, a few chrysophytes and diatoms and the dinoflagellate *Ceratium* were also identified in the September 2009 sample.

Zooplankton

Zooplankton are the micro-animals that live in the open waters of a lake or pond. Some large-bodied zooplankton are a source of food for forage and/or young gamefish. In addition, many of these large-bodied zooplankton are also herbivorous (i.e. algae eating) and can function as a natural means of controlling excessive algal biomass. Given the important role zooplankton serve in the aquatic food web of lakes and ponds, samples for these organisms were collected at Station #2 during each monitoring event. The results of these samples are provided in Table 2.

Similar to past monitoring years, the zooplankton community of Lake Hopatcong was dominated by small-bodied cladocerans such as *Bosmina*, several genera of rotifers and/or predaceous copepods such as *Cyclops* in May and June 2009. The predaceous copepod *Cylcops* was the dominant zooplankter during the July 2009, while both *Bosmina* and *Cylcops* were the dominant zooplankton during the August and September 2009 sampling events.

While herbivorous zooplankton were not common in Lake Hopatcong, three herbivorous genera were identified through the 2009 sampling season, which included the cladocerans *Diaphanosoma* and *Ceriodaphnia* and the copepod *Diaptomus* (Table 2). Of these zooplankton, *Diaphanosoma* is the most efficient herbivore; this is primarily due to its potential to attain a larger length than *Ceriodaphnia*. The generally low densities of herbivorous zooplankton in Lake Hopatcong observed in 2009 is similar to conditions measured over at least the past 5-6 monitoring years. The relatively low densities of herbivorous zooplankton may indicate that resident zooplankton-eating fishes (i.e. minnows, alewives, young yellow perch, white perch) were heavily grazing on large-bodied zooplankton in 2009.

Finally, it should be noted that the extremely large predaceous cladoceran *Leptodora kindti* was identified in Lake Hopatcong during the 27 August 2009 sampling event. *Leptodora kindti* feeds primarily on other zooplankton, moderate to large-bodied herbivores such as *Ceriodaphnia* and *Daphnia*. Thus, similar to zooplankton-feeding fishes such as alewife and golden shiners, this particular type of zooplankton can have a substantial impact on the open water food web; by feeding on the herbivorous zooplankton, this allows the phytoplankton to grow unchecked through the growing season. Based on Princeton Hydro’s data, no *Leptodora kindti* have been identified in Lake Hopatcong, at least since 1991. Thus, if substantial numbers of this zooplankter are present in the lake, it may be contributing toward the nuisance algal blooms that have plagued the lake.

Table 1
Phytoplankton in Lake Hopatcong during the 2009 Growing Season

Sampling Date	Phytoplankton
29 May 2009	Algal abundance was moderate. Genera of green algae, diatoms and the chrysophyte *Dinobryon* were identified. The blue-green alga *Oscillatoria* was also present.
30 June 2009	Large diversity of algae was identified; total abundance was high. The dominant genera were the blue-green algae *Oscillatoria* and *Anabaena*. Several genera of diatoms and a variety of green algae were identified as well as the chrysophyte *Dinobryon*, the dinoflagellate *Ceratium* and the blue-green alga *Aphanizomenon*.
30 July 2009	Abundance was high and diversity was moderate. The dominant algae were the blue-green algae *Oscillatoria* and *Anabaena*. Other blue-green were identified and included *Coelosphaerium* and *Microcystis.* Other common algae included a number of green algae, the diatom *Melosira* and the cryptomonad *Cryptomonas*.
27 August 2009	The dominant alga was the blue-green alga *Anabaena*; other blue-greens were present such as *Microcystis*, *Aphanizomenon*, *Coelosphaerium* and *Oscillatoria*. A large number of green algae, a few diatoms (*Melosira* and *Tabellaria*) and the dinoflagellate *Ceratium* were also identified.
22 September 2009	The dominant alga was the filamentous diatom *Melosira*. Algal abundance and diversity was high. The blue-green *Anabaena* was common. A large number of green algae and other blue-greens were present. A few diatoms, chrysophytes and the dinoflagellate *Ceratium* were also identified.

Table 2
Zooplankton in Lake Hopatcong during the 2008 Growing Season

Sampling Date	Zooplankton
29 May 2009	The dominant zooplankton were the small-bodied cladoceran *Bosmina*. The predatory copepod (*Cyclops*) and juveniles (known as nauplii) were also found in the sample. In addition, several rotifers (*Keratella*, *Conochilus*, *Asplanchna*) were identified.
30 June 2009	The small-bodied cladoceran *Bosmina* was the dominant zooplankter. Several rotifers (*Conochilus*, *Keratella, Polyarthra*) and an herbivorous zooplankton (the cladocerans C*eriodaphnia*) were also identified in the sample. In addition, juvenile copepods, known as nauplii were also identified.
30 July 2009	Zooplankton abundance and diversity was low with the predaceous copepod *Cylcops* being the dominant zooplankter. Several rotifers were observed including *Conochilus* and *Asplanchna*. The herbivores *Ceriodaphnia* and *Diaptomus* were observed as well as the small-bodied cladoceran *Chydorus*.
27 August 2009	Zooplankton abundance and diversity was relatively high at this time; the cladoceran *Bosmina* and the copepod *Cyclops* were the dominant zooplankton. Two herbivorous zooplankton (*Diaptomus*, *Diaphanosoma*) were also observed as well as a number of rotifers. It should be noted that the large, predaceous cladoceran *Leptodora kindti*
22 September 2009	Zooplankton abundance was moderate with the dominant genera being the copepod *Cyclops* and the cladoceran *Bosmina*. The herbivorous zooplankton *Ceriodaphnia* and *Diaptomus* were present as well as juvenile copepods nauplii and several rotifers.

Recreational Fishery and Potential Brown Trout Habitat

Of the recreational gamefish that reside or are stocked in Lake Hopatcong, trout are the most sensitive in terms of water quality. For their sustained management, all species of trout require DO concentrations of at least 4 mg/L or greater. However, the State's designated water quality criterion to sustain a healthy, aquatic ecosystem is a DO concentration of at least 5 mg/L.

While all trout are designated as coldwater fish, trout species display varying levels of thermal tolerance. Brown trout (*Salmo trutta*) have an <u>optimal</u> summer water temperature range of 18 to 24^{o}C (65 to 75^{o}F) (USEPA, 1994). However, these fish can survive in waters as warm as 26^{o}C (79^{o}F) (Scott and Crossman, 1973), defined here as acceptable habitat. The 2009 temperature and DO data for Lake Hopatcong were examined to identify the presence of optimal and acceptable brown trout habitat. As with previous monitoring reports, this analysis focused solely on *in-situ* data collected at the mid-lake sampling station (Station #2).

For the sake of this analysis, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures less than 24^{o}C were considered optimal habitat for brown trout. In contrast, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures between 24 and 26^{o}C were considered carry over habitat for brown trout.

On 29 May 2009 optimal brown trout habitat was identified from the surface to a depth of 10.0 meters (33 feet) in Lake Hopatcong (Appendix B). By 30 June 2009, the optimal brown trout habitat was found from the surface to 6.0 meters (approximately 20 feet).

By 30 July 2009, optimal brown trout habitat was found between 5.0 and 6.0 meters (16 and 20 feet); while carry over brown trout habitat was found from the surface to 4.0 meters (Appendix B). In August 2009, optimal brown trout habitat was limited to between 6.0 and 7.0 meters (20 and 23 feet), while carry over habitat was found from the surface to 5.0 meters. Finally, by 22 September 2009 the lake had optimal brown trout habitat from the surface down to 7.0 meters. Similar to past monitoring years, the *in-situ* data revealed that varying levels of acceptable brown trout habitat persisted through the entire 2009 growing season in Lake Hopatcong.

Mechanical Weed Harvesting Program

Many of the more shallow sections of Lake Hopatcong are susceptible to the proliferation of nuisance densities of rooted aquatic plants. Given the size of Lake Hopatcong, the composition of its aquatic plant community, and its heavy and diverse recreational use, mechanical weed harvesting is the most cost effective and ecologically sound method of controlling nuisance weed densities. Thus, the weed harvesting program has been in operation at Lake Hopatcong since the mid-1980's with varying levels of success. However, one consistent advantage mechanical weed harvesting has over other management techniques, such as the application of herbicides, is that phosphorus is removed from the lake along with the weed biomass. In fact, based on a plant biomass study conducted at Lake Hopatcong in 2006 and the plant harvesting records from 2006 to 2008, approximately 6-8% of the total phosphorus load targeted for reduction under the established TMDL is removed through the mechanical weed harvesting program.

During the 2009 growing season a total of 253 tons of aquatic vegetation was harvested from Lake Hopatcong. This is a substantial reduction in the amount of vegetation that was harvested from the lake relative to the 2006-2008 harvesting years. In fact the amount of weed biomass harvested in 2009 was only 16-22% of the amount of harvested in 2006-2008. The primary reason for this was the fact that the Lake Hopatcong Commission's Operation Staff was laid off in early 2009, with a few of the staff members subsequently re-hired late in the growing season to conduct some maintenance harvesting.

Using the results of the 2006 plant biomass / phosphorus study, it was estimated that the 2009 mechanical weed harvesting program removed 90 lbs (41 kg) of total phosphorus from the lake. This accounted for approximately 1.2% of the amount of phosphorus targeted for removal under the lake's established TMDL. If this removed phosphorus was utilized by filamentous and planktonic algae, it would have the potential to generate approximately 99,000 lbs of wet algae biomass. Again, it is difficult to compare the results of 2009 to past harvesting years since only a fraction of the staff members were operating the equipment and harvesting resumed approximately 1-2 months later relative to previous years.

Inter-annual Analysis of Water Quality Data

Annual mean values of Secchi depth, chlorophyll *a* and total phosphorus concentrations were calculated for the years 1991 through 2009. The annual mean values for Station #2 were graphed, along with the long-term, "running mean" for the lake.

The 2009 mean Secchi depth was less than 2 meters and was the lowest value since the 2005 value and was the fourth lowest mean Secchi depth since 1991 (Figure 2 in Appendix A). However, the 2009 mean Secchi depth was still above the 1 meter (3.3 ft) threshold, below which the layperson perceives the lake and being "dirty". In addition, the long-term mean remains above 2 meters.

The 2009 mean chlorophyll *a* concentration at Station #2 was the highest mean value since 2004 and was the fourth highest mean concentration since 1991 (Figure 3 in Appendix A). While the mean chlorophyll *a* concentration was greater than the targeted mean endpoint of 8 mg/m^3 as per the TMDL, it was below the targeted maximum endpoint of 14 mg/m^3.

Based on the Secchi depth and chlorophyll *a* concentration data, algal productivity was generally higher in Lake Hopatcong during the 2009 growing season, relative to other monitoring years. Based on these results, TP concentrations were expected to be higher but this was not the case. The 2009 mean TP concentration was one of the lowest in the 1991-2009 database (Figure 4 in Appendix A). In addition, the long-term mean TP concentration was higher than the 2009 mean. These seemingly contradictory results, low TP but higher amount of algae and lower water clarity, was attributed to the high frequency of storm events.

The high amount of rain in 2009 washed inorganic soil / sediment particles into the lake, which contributed to the lower water clarity. In addition, some of the other, near shore sampling stations had elevated TP concentrations and produced nuisance algal blooms; this was particularly the case in August when the lake experienced a moderately large bloom. Thus, a substantial portion of the algae at Station #2 may have been transported to the open waters of lake through horizontal, near-shore mixing and/or vertical, deep-water mixing. In any event, the lower Secchi depths and higher abundance of algae in 2009 was attributed the high frequency of storm events experienced through the growing season.

Water Quality Impairments and Established TMDL Criteria

As identified in N.J.A.C. 7:9B-1.5(g)2 "Except as due to natural condition, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation or otherwise render the waters unsuitable for the designated uses." For Lake Hopatcong, these objectionable conditions specifically include both algal blooms and nuisance densities of aquatic vegetation.

Given the undesirable water quality conditions experienced in select portions of Lake Hopatcong, NJDEP conducted a Total Maximum Daily Load (TMDL) analysis for total phosphorus, the primary nutrient limiting algal and plant growth in the lake. This TMDL was revised by Princeton Hydro, who also developed a Restoration Plan for the lake and watershed. The revised TMDL and associated Restoration Plan were approved by NJDEP in 2006 and have been used to obtain grant funding through both NJDEP and US EPA to implement various watershed-based projects to reduce the existing phosphorus loads. Some of these projects were completed in 2008-09 and implementation will continue into 2010. Thus, continuing the long-term monitoring program and augmenting it with near-shore, in-lake and stormwater sampling will provide a means of quantifying the water quality improvements associated with the implementation of these projects.

As described in detail in the TMDL Restoration Plan, a targeted mean TP concentration, as well as mean and maximum chlorophyll *a* ecological endpoints, was established to identify compliance with the TMDL. These criteria are located immediately below Table 3 and of the three criteria the one that is critical in the long-term evaluation of progress made toward compliance with the TMDL, is the mean TP concentration. The chlorophyll *a* ecological endpoints provide the guidance and framework needed to translate the TP concentration into a layperson's perspective on how the lake is responding to the Restoration Plan (i.e. algal blooms).

It should be noted that in addition to the TMDL criteria listed below Table 3, each municipality within the watershed has an existing and targeted annual phosphorus load as per the TMDL. Thus, each municipality is responsible for contributing on a proportional basis toward attaining the overall targeted TP load for the Lake Hopatcong watershed. However, the water quality criteria below Table 3 serve as short-term, year-specific indicators on the progress made toward attaining the overall targeted TP load for the TMDL.

Based on the mean TP concentrations, the Crescent Cove / River Styx section of the lake was out of compliance with the TMDL, where concentrations exceeded the 0.03 mg/L criteria. However, it should be noted that the Crescent Cove mean TP concentration declined from 0.06 mg/L, which is above the State's surface water standard, in 2008 to 0.045 mg/L in 2009. This decline in the Crescent Cove mean TP concentration is at least partially attributed to the Aqua-Filter that was installed in that drainage area.

The targeted mean chlorophyll *a* endpoint for Lake Hoaptcong is 8 mg/m^3, while the targeted maximum chlorophyll *a* endpoint is 14 mg/m^3. With the exception of Stations #7 and #11, the mean and maximum chlorophyll *a* concentrations at all of the stations were above their respective targeted values. Thus, while the TP concentrations were generally low in 2009, TP loading was sufficient to stimulate high amounts of algal growth. Again, this is attributed the high amount of rainfall in 2009. In addition to increased hydrologic and pollutant loading other factors may have contributed to the elevated amount of algal growth, such as the mixing of deep, phosphorus-rich waters with the surface and/or a food web does not favor the growth and development of large-bodied, herbivorous zooplankton.

Table 3
Summary of 2008 water quality data for select sampling stations at Lake Hopatcong

Station	Mean TP	Mean chl. *a*	Maximum chl. *a*
Station #1	0.03	**16.9**	**25.7**
Station #2	0.02	**12.7**	**21.1**
Station #3	**0.04**	**26.6**	**73.6**
Station #4	0.02	**17.9**	**32.5***
Station #5	0.02	**19.5**	**32.3***
Station #6	0.02	**11.1**	**20.6**
Station #7	0.02	**8.5**	13.4
Station #10	0.03	**20.7**	**37.1***
Station #11	0.02	6.4	9.2
Crescent Cove	**0.045**	Not sampled	Not sampled

Please note, any parameter in red indicates the value is above (in violation) the threshold identified under the targeted conditions as described in the TMDL. It should be noted that none of the mean TP concentration exceeded the State's established Surface Water Quality Standard for TP, which is 0.05 mg/L (N.J.A.C. 7:9B – 1.14 (c) 5.). In addition, the * for the maximum chlorophyll *a* concentrations identifies a concentration greater than 30 mg/m^3, which is the threshold when most laypeople perceive the water can being unsuitable or too "scummy" for recreational use.

TMDL Criteria for Lake Hopatcong

Targeted mean TP concentration	0.03 mg/L
Targeted mean chlorophyll *a* concentration endpoint	8 mg/m^3
Targeted maximum chlorophyll *a* concentration endpoint	14 mg/m^3

4.0 SUMMARY

This report documents the findings of the 2009 Lake Hopatcong water quality monitoring program. This section provides a summary of the 2009 water quality conditions, as well as recommendations on how to preserve the highly valued aquatic resources of Lake Hopatcong.

1. Based on the 2009 water quality database, and similar to past monitoring years, the water quality conditions of Lake Hopatcong were generally consistent with those of a meso- to slightly eutrophic ecosystem.

2. Overall, the surface waters (to approximately 5 meters) of Lake Hopatcong remained well oxygenated (dissolved oxygen concentrations > 5 mg/L) throughout the monitoring season. In contrast to past monitoring years, an anoxic zone (< 1 mg/L) did not develop in Lake Hopatcong. This was attributed to the high frequency of large storm events through the course of the 2009 growing season, mixing the mid- to deep waters with the surface.

3. It has been well documented that phosphorus is the primary limiting nutrient in Lake Hopatcong. That is, a slight increase in phosphorus will result in a substantial increased amount of algal and/or aquatic plant biomass. TP concentrations in the surface waters of Lake Hopatcong typically varied between <0.01 mg/L and 0.06 mg/L. Similar to past monitoring years Station #3 (River Styx/Crescent Cove) and the 319 Crescent Cove station displayed the highest TP concentrations.

4. An Aqua-Filter, a large Manufactured Treatment Device, was installed in the Crescent Cove drainage basin in November / December 2008. Thus, 2009 was the first year the lake was monitored after this stormwater structure was installed. Prior to the installation of the Aqua-Filter (2006-2008), the mean TP concentration in Crescent Cove varied between 0.063 and 0.065 mg/L, while after its installation the mean TP concentration was 0.045 mg/L.

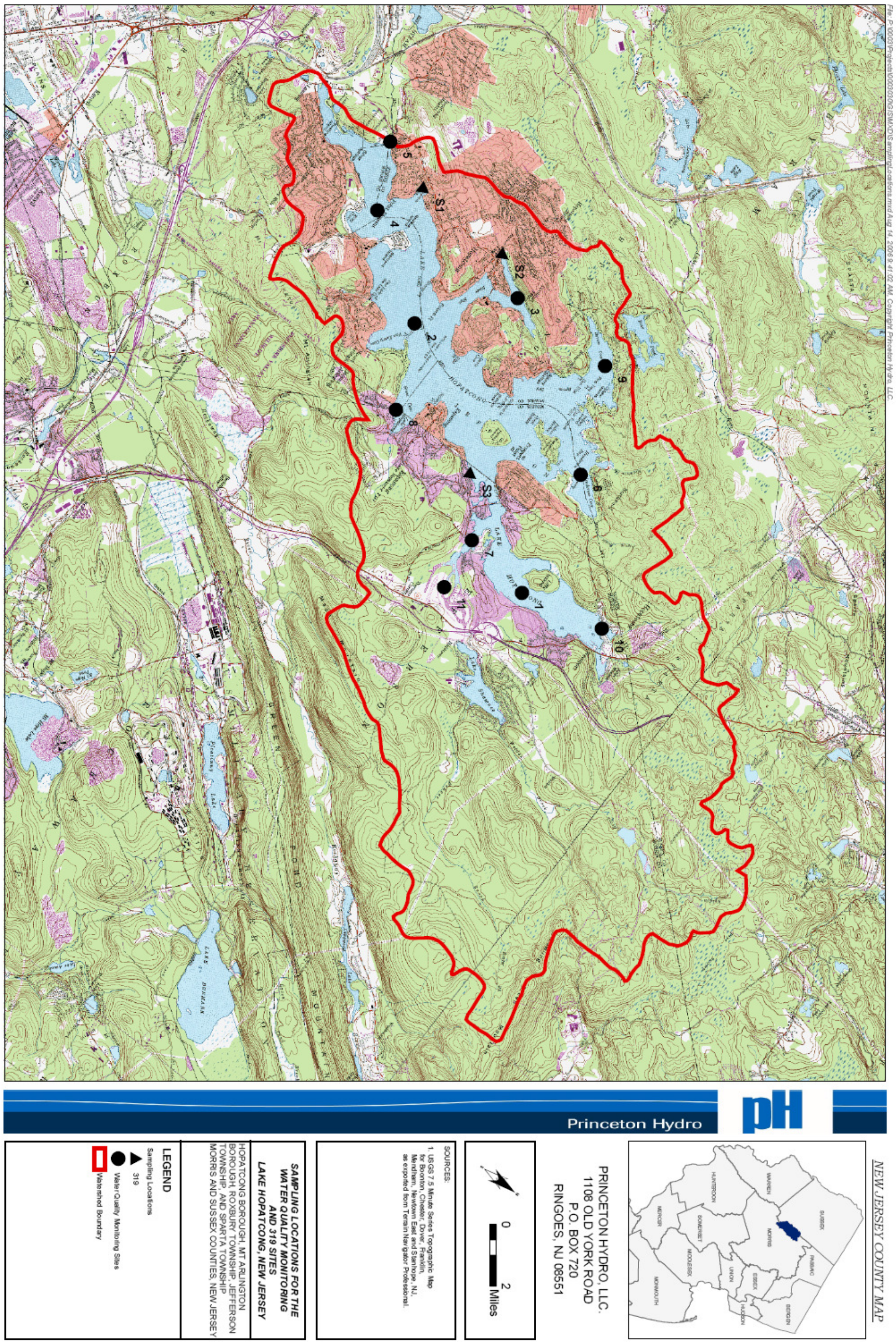
5. Based on the *in-situ* conditions, carry over brown trout habitat was available throughout the entire 2009 growing season. Such results are consistent with those measured in previous monitoring years at Lake Hopatcong.

6. Approximately 253 tons of aquatic plant biomass was removed in 2009, which was only 16-22% of the amount of harvested in 2006-2008. The harvested plant biomass accounted for only 1.2% of the TP load targeted for removal under the TMDL. The lower amount of harvested plant biomass in 2009 was attributed to a substantial reduction in staff operating the harvesters and a later date of initiating the harvesting program.

7. In spite of generally lower TP concentrations in 2009, Secchi depth was lower and chlorophyll *a* concentrations were higher in 2009 relative to past monitoring years. This was attributed to the high amount of rainfall and a food web that does not favor the establishment of a large population of large-bodied, herbivores zooplankton. The identification of *Leptodora kindti*, a large carnivorous zooplankter, provides some support that algal growth is largely unchecked by herbivorous zooplankton in Lake Hopatcong.

APPENDIX A

FIGURES


PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
NEW JERSEY COUNTY MAP
0
2
Miles
SOURCES:
1. USGS 7.5 Minute Series Topographic Map for Boonton, Chester, Dover, Franklin, Mendham, Newfoundland East and Stanhope, NJ, as exported from Terrain Navigator Professional.
SAMPLING LOCATIONS FOR THE WATER QUALITY MONITORING AND 319 SITES
LAKE HOPATCONG, NEW JERSEY
HOPATCONG BOROUGH, MT ARLINGTON BOROUGH, ROXBURY TOWNSHIP, JEFFERSON TOWNSHIP, AND SPARTA TOWNSHIP
MORRIS AND SUSSEX COUNTIES, NEW JERSEY
LEGEND
Sampling Locations
319
Water Quality Monitoring Sites
Watershed Boundary
Princeton Hydro
S1
S2
S3
1
2
3
4
5
6
7
8
9
10
11

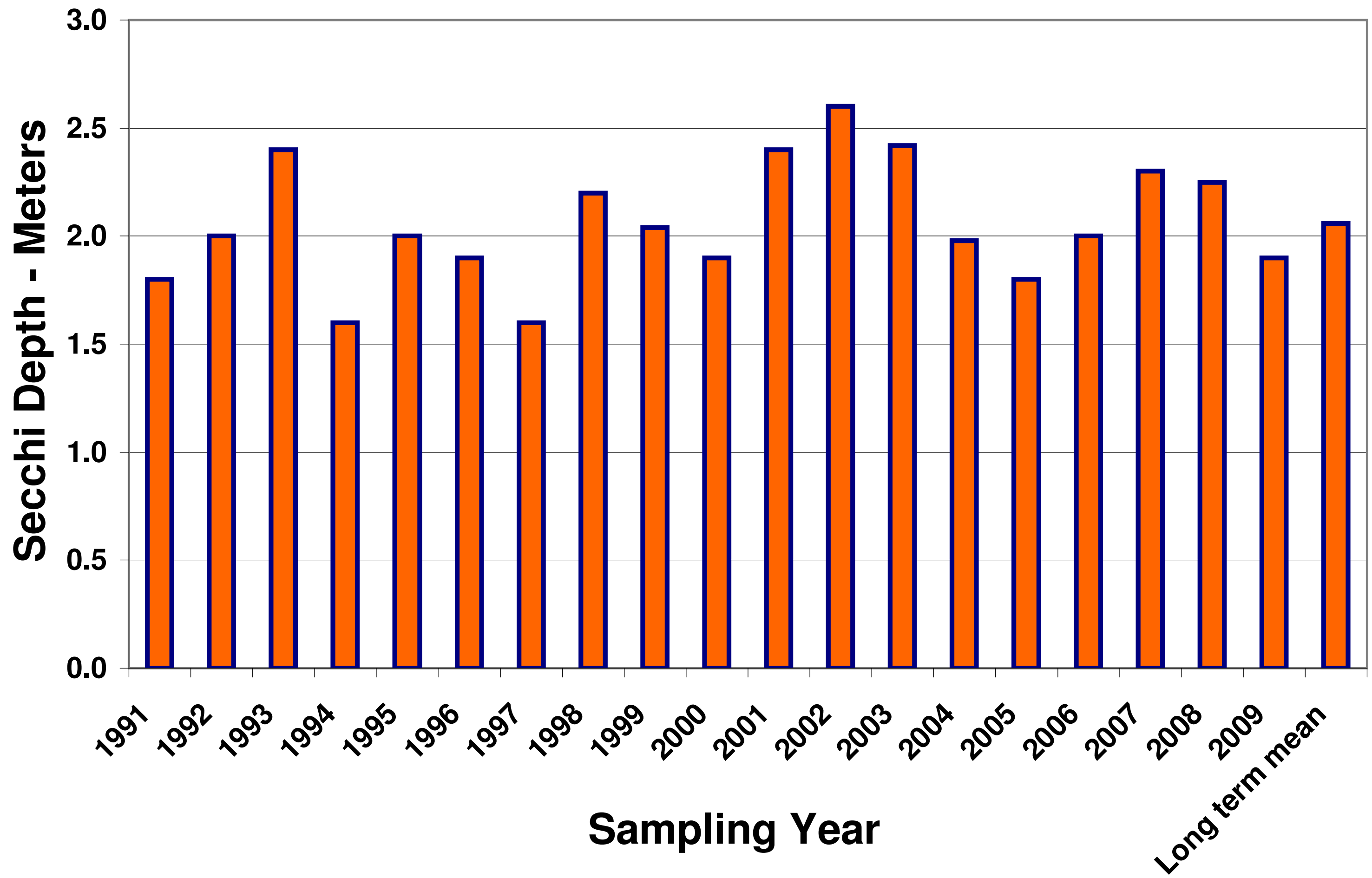


Figure 2 - Lake Hopatcong Long Term Secchi Depth Values at Station #2

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N. J. 08551

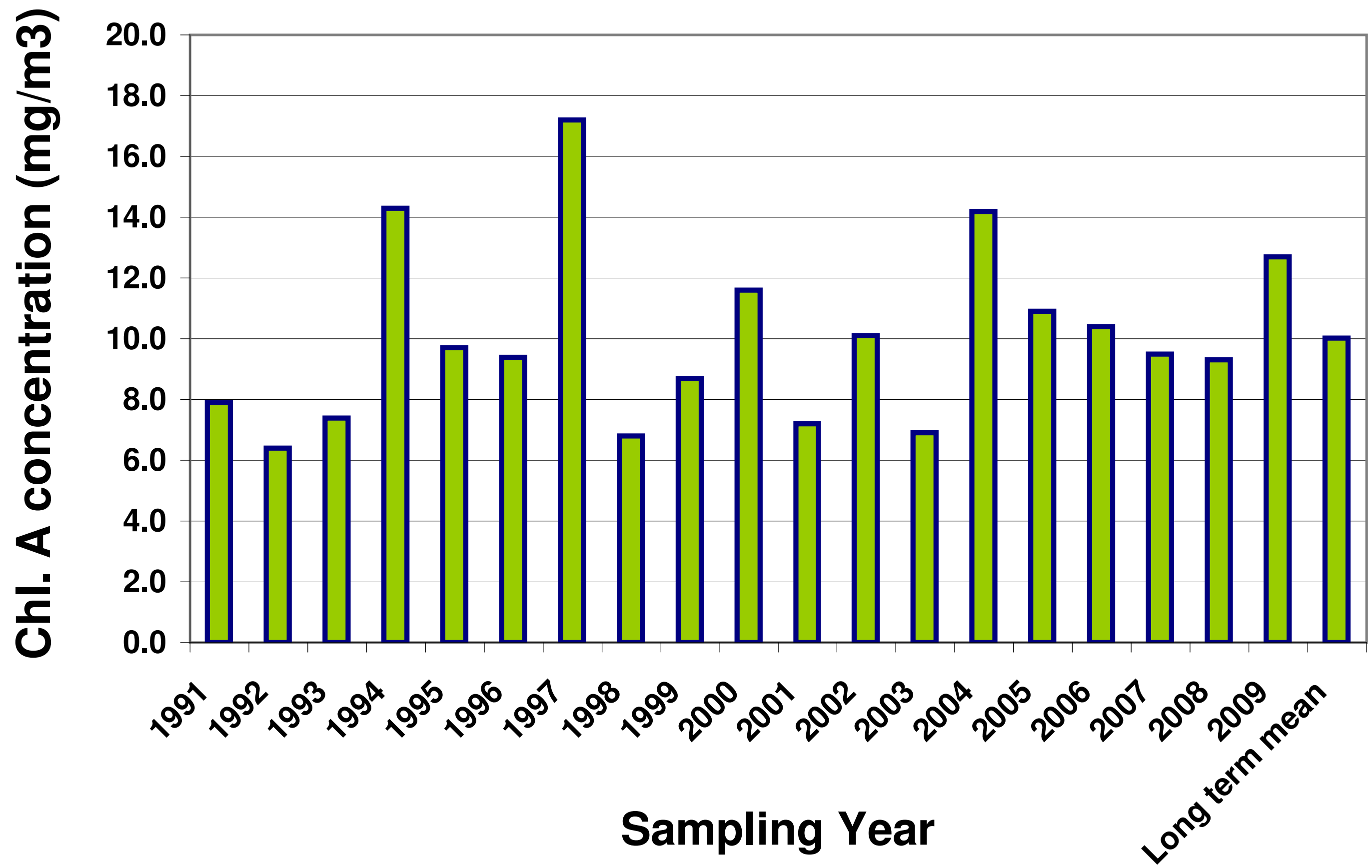


Figure 3 - Lake Hopatcong Long Term Chl A concentrations at Station #2

pH

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N. J. 08551

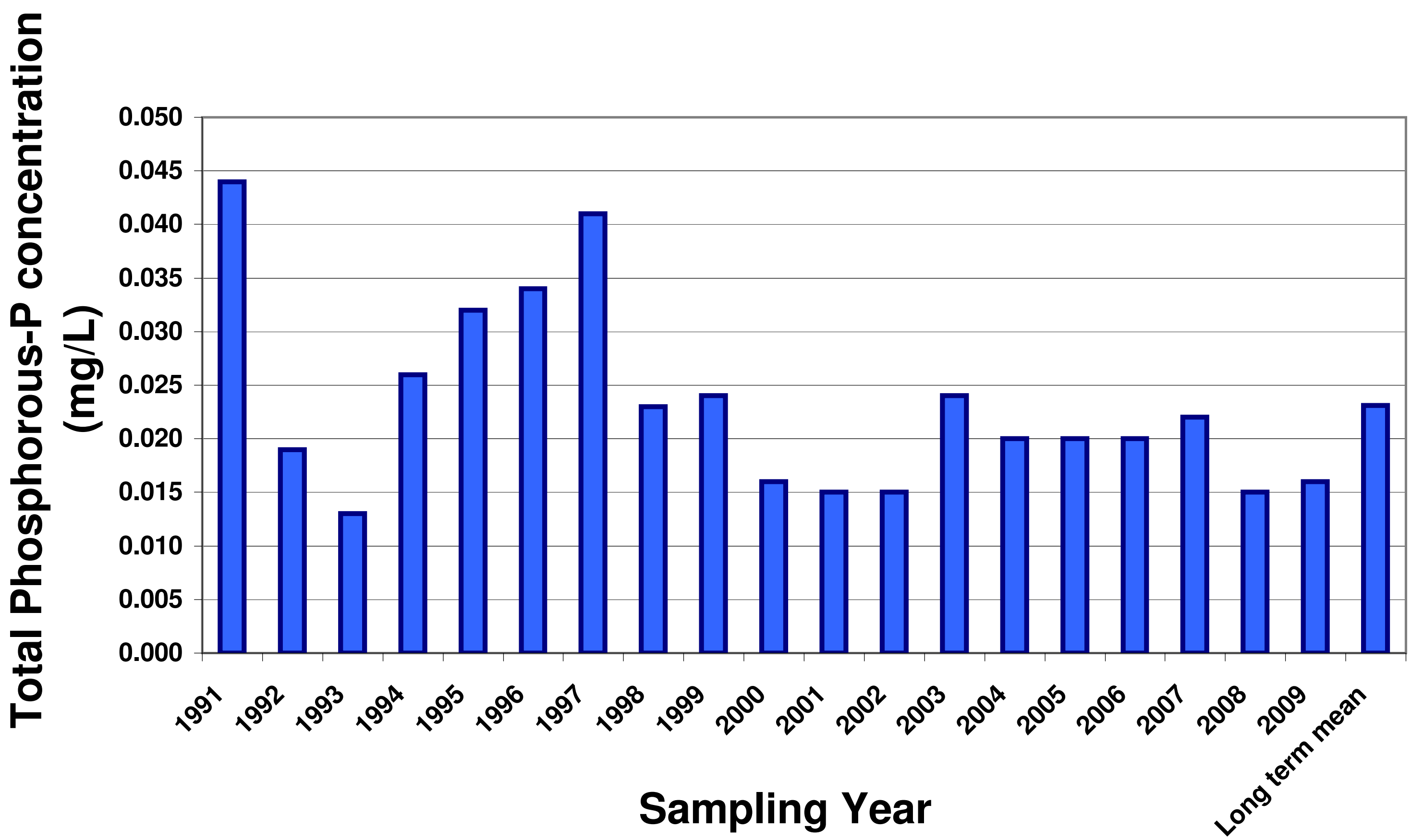


Figure 4 - Lake Hopatcong Long Term TP concentrations at Station #2

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N. J. 08551

APPENDIX B

IN-SITU DATA

In-Situ Monitoring for Lake Hopatcong 5/29/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(°C)	(mmhos/cm)	(mg/L)	(units)	(%)
ST-1	1.25	1.25	Surface	19.33	0.379	8.15	7.76	89.88
			1.0	18.63	0.393	8.52	7.81	92.66
ST-2	12.5	2.5	Surface	18.36	0.371	7.51	8.35	81.25
			1.0	18.23	0.371	7.6	8.32	82.05
			2.0	18.01	0.37	7.71	8.31	82.81
			3.0	17.9	0.37	7.76	8.21	83.12
			4.0	16.74	0.368	8.01	8.05	83.84
			5.0	16.04	0.368	7.96	7.91	82.13
			6.0	15.05	0.367	7.77	7.76	78.4
			7.0	14.41	0.368	7.11	7.59	70.82
			8.0	13.53	0.368	6.17	7.38	60.24
			9.0	12.77	0.368	5.8	7.28	55.72
			10.0	11.9	0.369	5.02	7.13	47.24
			11.0	11.13	0.37	4.49	7.05	41.58
			12.0	10.28	0.372	4.39	7.03	39.86
ST-3	1.6	1.6	Surface	19.13	0.61	9.62	9.52	105.77
			1.0	18.82	0.645	9.96	9.47	108.84
ST-4	2.5	2.5	Surface	18.71	0.378	7.19	8.95	78.36
			1.0	18.42	0.377	7.24	8.89	78.41
			2.0	18.31	0.377	7.16	8.86	77.43
ST-5	3	2.3	Surface	18.52	0.386	8.72	9.22	94.69
			1.0	18.24	0.386	8.59	9.3	92.74
			2.0	18.09	0.385	8.3	9.26	89.32
ST-6	1.9	1.3+	Surface	19.1	0.367	8.85	8.32	97.17
			1.0	18.24	0.366	9	8.46	97.15
			1.5	18.14	0.367	8.7	8.07	93.73
ST-7	0.75	0.75	Surface	18.22	0.252	7.5	7.26	80.84
			0.5	17.87	0.254	7.56	7.22	80.93
ST-8	6.6	2.5	Surface	18.43	0.37	7.63	8.21	82.7
			1.0	18.17	0.37	7.82	8.27	84.24
			2.0	18.06	0.369	7.82	8.21	84.07
			3.0	18.02	0.369	7.86	8.18	84.44
			4.0	17.57	0.382	7.93	8.03	84.46
			5.0	15.69	0.367	7.99	7.83	81.72
			6.0	14.66	0.367	7.8	7.67	78.09
ST-9	7.3	2.1	Surface	19.02	0.37	8.96	8.3	98.22
			1.0	18.66	0.37	9.18	8.28	99.88
			2.0	18.44	0.371	9.14	8.13	99.02
			3.0	18.34	0.37	9.01	8.03	97.4
			4.0	18.26	0.369	8.93	7.99	96.42
			5.0	18.2	0.369	8.93	7.98	96.31
			6.0	15.9	0.369	8.31	7.63	85.42
			7.0	13.92	0.37	7.15	7.37	70.44
ST-10	1.5	1.3	Surface	19.18	0.41	8.45	8.17	92.97
			1.0	18.61	0.41	8.36	7.98	90.89
ST-11	0.6	0.6	Surface	18.11	0.242	7.81	7.25	84.03

In-Situ Monitoring for Lake Hopatcong 6/30/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(^{0}C)	(mmhos/cm)	(mg/L)	(units)	(%)
ST-1	1.9	1.2	Surface	24.84	0.339	9.96	7.8	122.15
			1.0	24.61	0.341	10.05	7.74	122.7
			1.5	23.46	0.352	9.39	7.46	112.24
ST-2	13.8	2.3	Surface	23.82	0.348	9.11	8.16	109.61
			1.0	23.79	0.348	9.15	8.14	110.08
			2.0	23.29	0.348	9.36	8.16	111.55
			3.0	23.06	0.349	9.32	8.04	110.6
			4.0	21.8	0.349	8.93	7.63	103.44
			5.0	20.19	0.351	7.49	7.24	84.07
			6.0	18.72	0.352	7.33	7.15	79.92
			7.0	16.18	0.354	4.21	6.8	43.56
			8.0	14.68	0.355	3.97	6.75	39.81
			9.0	13.43	0.356	3.97	6.73	38.68
			10.0	12.68	0.357	4	6.74	38.32
			11.0	11.81	0.362	4.12	6.75	38.75
			12.0	11.05	0.366	4.53	6.8	41.82
			13.0	10.56	0.376	4.76	6.88	43.44
			13.5	10.54	0.376	4.84	7.02	44.2
ST-3	2	2	Surface	24.98	0.634	10.08	8.59	123.98
			1.0	24.92	0.633	10.94	8.6	134.45
			1.5	23.63	0.732	11.45	8.13	137.47
ST-4	2.9	2.1	Surface	24.46	0.369	8.78	7.83	106.97
			1.0	24.2	0.368	8.86	7.82	107.37
			2.0	23.81	0.364	8.56	7.63	103.03
			2.5	22.99	0.356	5.85	7.08	69.29
ST-5	3.2	2.1	Surface	24.46	0.363	8.73	7.72	106.34
			1.0	24.29	0.363	8.64	7.63	104.93
			2.0	23.54	0.365	7.63	7.43	91.42
			3.0	20.93	0.39	3	7.03	34.24
ST-6	2.5	2	Surface	24.13	0.346	9.52	7.89	115.28
			1.0	24.09	0.346	9.66	7.81	116.89
			2.0	23.17	0.344	9.4	7.56	111.79
ST-7	2.5	1.4	Surface	25.91	0.184	10.18	7.53	127.22
			1.0	24.01	0.176	10.76	7.41	129.89
			2.0	23.24	0.184	9.87	7.14	117.43
ST-8	7.5	2.3	Surface	24.16	0.343	9.81	8.02	118.76
			1.0	23.72	0.344	10.07	8.07	120.97
			2.0	23.45	0.348	10.23	8.09	122.27
			3.0	22.59	0.347	10.23	7.83	120.33
			4.0	22.04	0.347	10.2	7.72	118.7
			5.0	20.45	0.351	9.4	7.43	106.06
			6.0	19.29	0.352	8.96	7.27	98.77
			7.0	16.7	0.355	7.11	7.04	74.36
ST-9	7.8	2.3	Surface	23.77	0.349	9.61	8.06	115.5
			1.0	23.3	0.349	10.04	8.11	119.68
			2.0	22.99	0.35	10.3	8.14	122.06
			3.0	22.8	0.352	10.55	8.15	124.55
			4.0	22.66	0.359	10.67	8.03	125.67
			5.0	21.07	0.35	11.05	7.8	126.16
			6.0	19.26	0.353	10.85	7.56	119.47
			7.0	17.01	0.357	10.01	7.26	105.35
ST-10	1.5	1.5	Surface	24.94	0.352	10.65	8.2	130.86
			1.0	24.38	0.354	11.21	8.45	136.28
ST-11	1	1	Surface	23.55	0.144	11.17	7.67	133.62
			0.5	23.54	0.144	11.04	7.42	132.12

In-Situ Monitoring for Lake Hopatcong 7/30/09

Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(^{0}C)	(mmhos/cm)	(mg/L)	(units)	(%)
ST-1	1.9	1	Surface	25.89	0.366	8.89	7.5	111.23
			1.0	25.78	0.367	8.93	7.49	111.51
			1.5	25.44	0.366	8.81	7.44	109.29
ST-2	13.8	2	Surface	24.71	0.372	8.62	7.87	105.46
			1.0	24.7	0.372	8.61	7.96	105.36
			2.0	24.64	0.372	8.65	8.02	105.77
			3.0	24.58	0.372	8.69	8.06	106.06
			4.0	24.33	0.373	8.52	7.9	103.55
			5.0	23.82	0.373	7.56	7.49	91.04
			6.0	22.31	0.372	5.3	7.03	62.01
			7.0	20.83	0.371	3.71	6.78	42.2
			8.0	17.73	0.373	3.4	6.71	36.38
			9.0	13.95	0.379	3.6	6.74	35.55
			10.0	12.76	0.383	3.65	6.77	35.05
			11.0	12.09	0.387	3.71	6.86	35.15
			12.0	11.61	0.39	3.78	6.9	35.35
			13.0	10.82	0.4	3.94	6.98	36.24
			13.5	10.76	0.401	4.04	7.04	37.09
ST-3	2.1	1	Surface	27.07	0.643	9.42	8.21	120.47
			1.0	25.72	0.613	9.66	8.17	120.48
			2.0	24.84	0.645	5.54	7.28	68.03
ST-4	2.8	1.2	Surface	25.23	0.383	8.22	7.57	101.62
			1.0	25.02	0.386	7.92	7.45	97.43
			2.0	24.82	0.385	7.51	7.33	92.14
			2.5	24.26	0.383	5.21	7.05	63.3
ST-5	3.1	1.1	Surface	25.71	0.392	8.97	7.8	111.78
			1.0	25.2	0.393	8.76	7.74	108.22
			2.0	24.9	0.395	5.57	7.1	68.47
			3.0	23.14	0.416	3.24	6.77	38.59
ST-6	2.4	1.5	Surface	26.53	0.367	9.77	8.35	123.59
			1.0	26.2	0.367	9.43	8.24	118.64
			2.0	25.66	0.367	9.19	8.21	114.47
			2.4	25.33	0.368	8.3	7.74	102.73
ST-7	1.5	1.5	Surface	25.5	0.287	8.41	7.19	104.4
			1.0	25.18	0.291	8.56	7.17	105.68
			1.5	25.1	0.292	8.62	7.17	106.18
ST-8	7	1.9	Surface	24.9	0.371	9.58	8.25	117.65
			1.0	24.91	0.37	9.74	8.26	119.65
			2.0	24.83	0.37	9.8	8.27	120.24
			3.0	24.74	0.37	9.83	8.27	120.38
			4.0	24.68	0.371	9.8	8.22	119.81
			5.0	24.42	0.372	9.54	7.95	116.11
			6.0	21.81	0.372	6.24	7.19	72.31
			7.0	21.33	0.378	5.44	6.94	62.48
ST-9	8.1	1.5	Surface	26.41	0.37	9.92	8.76	125.27
			1.0	25.87	0.37	10.24	8.77	127.99
			2.0	25.26	0.37	10.22	8.65	126.26
			3.0	24.76	0.37	9.24	8	113.22
			4.0	24.19	0.372	8.16	7.54	98.89
			5.0	22.36	0.371	5.61	7.02	65.66
			6.0	19.49	0.37	4.47	6.79	49.48
			7.0	15.23	0.386	4.81	6.83	48.8
			8.0	14.66	0.404	4.78	6.92	47.87
ST-10	1.6	0.8	Surface	26.41	0.376	9.42	8.03	118.91
			1.0	25.7	0.374	8.83	7.59	110.06
			1.5	25.51	0.373	8.52	7.43	105.8
ST-11	1.1	1.1	Surface	25.46	0.209	9.88	7.25	122.53
			1.0	23.94	0.215	5.69	6.67	68.63

In-Situ Monitoring for Lake Hopatcong 8/28/09

Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(°C)	(mmhos/cm)	(mg/L)	(units)	(%)
ST-1	2	0.9	Surface	26.27	0.365	9.63	7.59	117
			1.0	26.12	0.364	9.07	7.52	109
			1.5	25.89	0.363	8.39	7.37	101
ST-2	13.5	1.2	Surface	25.56	0.373	7.01	7.61	86
			1.0	25.6	0.373	6.98	7.56	86
			2.0	25.58	0.373	6.98	7.54	86
			3.0	25.55	0.373	6.86	7.51	84
			4.0	25.52	0.373	6.83	7.48	84
			5.0	25.48	0.373	6.85	7.46	84
			6.0	24.15	0.368	5.58	7.14	67
			7.0	19.62	0.382	4.03	6.85	44
			8.0	15.93	0.388	7.38	6.79	75
			9.0	14.71	0.387	10.85	6.78	107
			10.0	13.74	0.388	11.33	6.77	110
			11.0	12.66	0.392	9.96	6.81	94
			12.0	11.88	0.397	9.22	6.83	86
			13.0	11.22	0.404	8.38	6.88	77
ST-3	2	0.5	Surface	26.36	0.559	10.4	8.62	126
			1.0	25.71	0.555	10.18	8.52	122
			2.0	25.41	0.528	8.46	7.7	101
ST-4	2.5	1	Surface	25.66	0.383	6.51	7.36	80
			1.0	25.68	0.383	6.51	7.27	80
			2.0	25.62	0.382	6.52	7.22	80
ST-5	3.5	0.8	Surface	25.43	0.384	5.43	7.2	66
			1.0	25.45	0.384	5.36	7.15	66
			2.0	25.45	0.384	5.34	7.13	65
			3.0	24.91	0.401	2.8	6.9	34
ST-6	2.5	1	Surface	26.5	0.373	9.56	7.52	116
			1.0	26.18	0.372	9.6	7.45	116
			2.0	25.94	0.372	9.21	7.36	111
			2.4	25.89	0.372	8.66	7.27	104
ST-7	2	1.75	Surface	25	0.233	9.28	6.98	110
			1.0	24.64	0.229	9.39	6.94	110
			1.5	24.46	0.231	9.26	6.92	108
ST-8	7.5	1.25	Surface	25.95	0.375	12.15	7.84	146
			1.0	25.95	0.375	11.48	7.81	138
			2.0	25.88	0.375	11.17	7.74	134
			3.0	25.75	0.373	10.5	7.67	126
			4.0	25.25	0.372	9.18	7.34	109
			5.0	24.57	0.371	6.85	6.93	80
			6.0	23.2	0.367	5.46	6.66	62
			7.0	19.62	0.383	5.39	6.67	57
ST-9	8	1.6	Surface	26.09	0.374	11.43	7.46	141
			1.0	25.71	0.374	11.32	7.45	139
			2.0	25.55	0.374	11.15	7.47	137
			3.0	25.5	0.375	10.93	7.5	134
			4.0	25.45	0.375	10.58	7.47	129
			5.0	24.56	0.373	8.75	7.05	105
			6.0	21.87	0.365	6.88	6.67	79
			7.0	20.41	0.376	6.42	6.65	71
			8.0	18.79	0.424	6.31	6.69	68
ST-10	1.5	0.8	Surface	26.12	0.381	10.53	8.31	127
			1.0	25.93	0.379	10.39	8.2	125
			1.5	25.67	0.377	10.1	7.96	121
ST-11	1	1	Surface	25.09	0.17	9.09	7.15	108
			1.0	24.76	0.17	9.59	6.97	113

In-Situ Monitoring for Lake Hopatcong 9/22/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(^{0}C)	(mmhos/cm)	(mg/L)	(units)	(%)
ST-1	2	1.2	Surface	19.2	0.369	11.02	7.7	121.27
			1.0	19.18	0.369	10.64	7.63	117.09
			2.0	19.04	0.373	9.24	7.41	101.37
ST-2	14	1.7	Surface	19.44	0.378	7.86	7.42	86.96
			1.0	19.41	0.378	7.83	7.39	86.54
			2.0	19.41	0.378	7.78	7.38	85.97
			3.0	19.39	0.378	7.71	7.37	85.23
			4.0	19.37	0.378	7.59	7.35	83.87
			5.0	19.35	0.378	7.45	7.32	82.27
			6.0	19.34	0.378	7.25	7.28	80.06
			7.0	18.96	0.379	6.03	7.15	66.01
			8.0	18.42	0.38	4.37	7	47.42
			9.0	17.5	0.378	1.5	6.78	15.95
			10.0	14.06	0.394	1.49	6.81	14.77
			11.0	12.86	0.397	1.57	6.84	15.15
			12.0	11.73	0.403	1.97	6.87	18.48
			13.0	11.24	0.408	4.08	6.9	37.86
			13.5	11.01	0.417	3.76	6.91	34.67
ST-3	2	1	Surface	19.88	0.448	12.27	8.06	136.9
			1.0	19.75	0.47	12.15	8.13	135.22
			2.0	19.01	0.531	8.42	7.44	92.4
ST-4	3	1.3	Surface	19.61	0.388	8.85	7.66	98.15
			1.0	19.62	0.388	8.82	7.63	97.92
			2.0	19.6	0.388	8.7	7.6	96.52
			3.0	19.38	0.385	5.61	7.25	61.98
ST-5	2.5	0.9	Surface	19.59	0.392	8.71	7.61	96.62
			1.0	19.55	0.392	8.62	7.51	95.47
			2.0	19.23	0.394	6.61	7.27	72.76
ST-6	2.3	1.5	Surface	20.16	0.377	10.9	7.82	122.29
			1.0	19.91	0.378	11.11	7.92	123.99
			2.0	19.76	0.379	10.71	7.74	119.19
ST-7	1.7	1.7	Surface	19.45	0.299	9.95	7.37	110.05
			1.0	19.44	0.299	9.97	7.32	110.15
ST-8	7.5	1.3	Surface	20.22	0.378	10.98	7.81	123.3
			1.0	20.2	0.378	10.79	7.78	121.07
			2.0	20.08	0.378	10.41	7.68	116.61
			3.0	19.81	0.379	9.65	7.5	107.47
			4.0	19.64	0.378	9.47	7.42	105.19
			5.0	19.59	0.379	9.25	7.35	102.55
			6.0	19.3	0.382	8.55	7.25	94.23
			7.0	18.46	0.38	5.68	6.9	61.61
ST-9	8	1.7	Surface	20.23	0.376	11.3	7.72	126.95
			1.0	20.19	0.376	11.08	7.68	124.3
			2.0	20.06	0.376	10.74	7.62	120.19
			3.0	20.01	0.377	10.43	7.55	116.62
			4.0	19.89	0.376	10.1	7.46	112.64
			5.0	19.65	0.377	9.85	7.39	109.36
			6.0	19.51	0.377	9.74	7.35	107.89
			7.0	19.38	0.377	9.41	7.29	103.91
			8.0	19.02	0.378	7.24	7.04	79.43
ST-10	1.5	1.1	Surface	19.83	0.387	11.6	8.33	129.21
			1.0	19.82	0.387	11.51	8.33	128.24
			1.5	19.81	0.387	11.28	8.3	125.64
ST-11	1.2	1.2	Surface	18.25	0.224	9.69	7.21	104.54
			1.0	18.13	0.222	9.37	7.08	100.87

In-Situ Monitoring for Hopatcong 319 Stations 5/29/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(⁰C)	(mmhos/cm)	(mg/L)	(units)	(%)
Crescent Cove	1	1	Surface	19.46	0.972	9.01	8.46	99.79
			1.00	18.4	1.021	9.92	8.56	107.65
Jefferson	1.8	1.4	Surface	18.56	0.347	8.08	7.7	87.75
			1.00	18.21	0.347	7.58	7.58	81.72
			1.50	18.14	0.347	7.37	7.53	79.34

In-Situ Monitoring for Hopatcong 319 Stations 6/30/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(⁰C)	(mmhos/cm)	(mg/L)	(units)	(%)
Crescent Cove	1.6	1.6	Surface	24.71	0.809	10.24	8.01	125.48
			1.00	23.12	0.838	10.77	7.88	128.12
Jefferson	3	2	Surface	25.5	0.264	9.63	7.66	119.5
			1.00	24.77	0.264	10.43	8.1	127.71
			2.00	21.9	0.277	8.29	7.22	96.21
			2.50	20.03	0.3	6.37	6.95	71.32

In-Situ Monitoring for Hopatcong 319 Stations 7/30/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(⁰C)	(mmhos/cm)	(mg/L)	(units)	(%)
Crescent Cove	1.5	1	Surface	27.35	0.647	9.66	8.36	124.15
			1.00	25.93	0.661	9.8	8.25	122.73
			1.50	24.64	0.651	8.83	7.74	107.96
Jefferson	2.1	1.5	Surface	26.39	0.327	8.89	7.84	112.2
			1.00	25.39	0.325	9.4	8.06	116.43
			2.00	24.82	0.328	6.8	7.19	83.42

In-Situ Monitoring for Hopatcong 319 Stations 8/27/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(⁰C)	(mmhos/cm)	(mg/L)	(units)	(%)
Crescent Cove	1.5	0.5	Surface	25.59	0.58	10.47	8.66	125
			1.00	24.75	0.604	10.34	8.55	122
			1.50	24.38	0.619	9	8.25	105
Jefferson	2.5	1.1	Surface	25.79	0.322	9.61	7.23	115
			1.00	25.66	0.322	8.95	7.11	107
			2.00	25.51	0.325	6.18	6.82	74

In-Situ Monitoring for Hopatcong 319 Stations 9/22/09								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH	Dissolved Oxygen
	Total	Secchi	Sample	(⁰C)	(mmhos/cm)	(mg/L)	(units)	(%)
Crescent Cove	1.2	0.9	Surface	19.47	0.531	12.3	8.2	136.19
			1.00	18.51	0.562	10.92	7.78	118.53
Jefferson	1.3	1.3	Surface	19.44	0.373	11.61	8.39	128.36
			1.00	19.43	0.373	11.13	8.42	123.07

APPENDIX C

WATER QUALITY DATA

HOPATCONG
29-May-2009

STATION	Chlorophyll *a* (mg/m3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	6.9	0.01	0.03	0.02	5
ST-2	3.1	0.07	ND <0.02	0.02	7
ST-3	3.3	ND <0.01	0.04	0.05	ND <3
ST-4	ND <0.6	0.10	0.03	ND <0.01	4
ST-5	ND <0.6	0.11	ND <0.02	0.02	4
ST-6	ND <0.6	0.03	ND <0.02	0.03	ND <3
ST-7	9.1	0.06	0.08	0.03	4
ST-10	12.0	ND <0.01	0.03	ND	7
ST-11	6.2	0.07	0.08	0.02	5
ST-2 DEEP					
MEAN	**4.6**	**0.05**	**0.04**	**0.02**	**4.3**

HOPATCONG
30-Jun-09

STATION	Chlorophyll *a* (mg/m3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	11.5	0.04	0.04	0.03	4
ST-2	6.6	0.04	ND <0.02	0.01	3
ST-3	5.5	0.14	0.21	0.02	ND <3
ST-4	8.8	0.04	0.02	0.02	3
ST-5	7.6	0.04	ND <0.02	0.02	ND <3
ST-6	5.9	0.04	0.05	0.02	3
ST-7	13.4	0.04	0.09	0.03	4
ST-10	13.8	0.04	0.04	0.03	5
ST-11	9.2	0.04	0.13	0.03	3
ST-2 DEEP		0.75	0.13	0.16	4
MEAN	**9.1**	**0.05**	**0.07**	**0.02**	**3.1**

HOPATCONG 30-Jul-09 STATION	Chlorophyll *a* (mg/m3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	22.3	0.02	0.04	0.04	3
ST-2	15	0.04	0.02	0.02	ND <3
ST-3	25.2	0.04	0.04	0.05	ND <3
ST-4	24.9	0.08	0.02	0.03	3
ST-5	27.4	0.08	0.03	0.02	4
ST-6	20.6	0.10	0.03	0.04	ND <3
ST-7	4.3	0.14	0.06	0.02	ND <3
ST-10	37.1	0.10	0.05	0.05	ND <3
ST-11	4.8	0.12	0.06	0.02	ND <3
ST-2 DEEP		0.50	0.11	0.15	4
MEAN	**20.2**	**0.08**	**0.04**	**0.03**	**2.1**

HOPATCONG 27-Aug-09 STATION	Chlorophyll *a* (mg/m3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	25.7	0.01	ND <0.02	0.04	8
ST-2	21.1	0.01	ND <0.02	0.02	ND <3
ST-3	73.6	0.02	0.09	0.06	8
ST-4	32.5	0.01	ND <0.02	0.02	4
ST-5	32.3	0.01	ND <0.02	0.03	ND <3
ST-6	17	0.02	ND <0.02	0.02	ND <3
ST-7	8.4	0.02	0.04	0.03	ND <3
ST-10	28	0.02	0.05	0.04	7
ST-11	4.7	0.02	0.11	0.02	ND <3
ST-2 DEEP		0.50	0.19	0.26	6
MEAN	**27.0**	**0.02**	**0.04**	**0.03**	**3.8**

HOPATCONG
22-Sep-09

STATION	Chlorophyll *a* (mg/m3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	18.1	0.01	0.05	0.03	4
ST-2	17.6	0.01	ND <0.02	0.02	ND <3
ST-3	25.3	0.01	0.04	0.03	3
ST-4	22.9	0.02	0.02	0.02	4
ST-5	30.1	0.01	0.04	0.02	4
ST-6	11.6	0.02	0.03	0.01	ND <3
ST-7	7.1	0.02	0.03	0.01	ND <3
ST-10	22.5	0.02	0.04	0.02	3
ST-11	7	0.03	0.04	0.02	ND <3
ST-2 DEEP		0.75	0.21	0.31	8
MEAN	**18.0**	**0.02**	**0.05**	**0.02**	**2.7**

319 Sampling

6/30/2009

Station	TP (mg/L)	TSS (mg/L)
Crescent Cove	0.03	ND <3
Jefferson	0.02	ND <3

319 Sampling

7/30/2009

Station	TP (mg/L)	TSS (mg/L)
Crescent Cove	0.05	ND <3
Jefferson	0.03	ND <3

319 Sampling

8/27/2009

Station	TP (mg/L)	TSS (mg/L)
Crescent Cove	0.06	15
Jefferson	0.03	5

319 Sampling

9/22/2009

Station	TP (mg/L)	TSS (mg/L)
Crescent Cove	0.04	8
Jefferson	0.02	ND<3