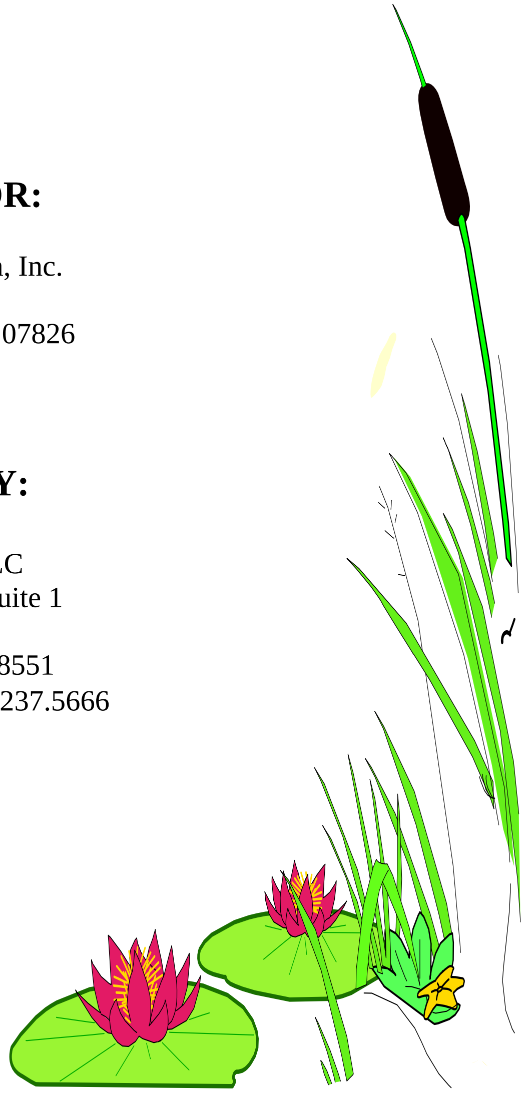
CULVER LAKE
WATER QUALITY MONITORING
AND
ZOOPLANKTON STOCKING PROGRAM
2006 END OF YEAR REPORT



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Executive Summary

- ***Dissolved Oxygen (DO)*** - Data collected from late May through mid-September document that the aeration system did not consistently maintain positive dissolved oxygen concentrations throughout the entirety of the lake's water column. In the early part of the season, it is assumed DO concentrations were acceptable and within the desired range from surface to bottom at the mid-lake station. However, by late May, a DO sag had occurred, resulting in reduced conditions at depths greater than 13 meters. This DO depletion continued throughout the summer and into the late summer, resulting in anoxic conditions at depths greater than 11 meters. Usually anoxic conditions in the deep hypolimnion (water deeper than 8 meters) are not an especially significant concern at this time of year, however low or no dissolved oxygen within the metalimnion layer of the lake has the potential to significantly impact water quality. The data show that increased dissolved oxygen concentration conditions were present within the metalimnetic layer over the course of the later part of the summer as compared to previous monitoring years.

- ***Secchi Transparency*** - The desired target Secchi transparency depth established for Culver Lake is 1 meter. In the summer of 2006, the lake's Secchi depth consistently met or exceeded 1.2 meters, above the target depth. The 2006 average Secchi depth for the mid-lake station was 1.9 meters.

- ***Temperature*** - The Lake became thermally stratified by late May and remained so through late-September. As has been the case historically, three distinct thermal layers were once again present over the course of the summer of 2006. These approximately coincided with the following water depths: 0 - 5 m, 5 m - 10 m, and 10 m to bottom. For the purpose of this report, the epilimnion, metalimnion and hypolimnion will be defined by these depth intervals. The memtalimnetic portion of the lake had corresponding dissolved oxygen concentrations that ranged from 9.5 mg/l in late spring to near anoxic in late summer. This cool thermal layer (metalimnion) should be providing midsummer brown trout habitat. However, the data suggests that the trout "hold over" habitat was only acceptable for the early summer, then marginal at best for the remainder of the summer. Once again, the lake's thermal layering also appeared to affect the development and concentration of algae at or near the lake's thermocline.

- ***Phosphorus*** - Phosphorus concentrations were measured over the 2006 growing season at each of the lake's thermal layers. Phosphorus concentrations were consistently minimal in concentration in the early summer. All three layers, surface, mid-depth and bottom water concentrations were 0.03 mg/L or less. During the mid-summer monitoring event, the three layers concentrations had remained consistent at or below 0.03 mg/L. By late summer, the surface and mid-depth layers were still minimal at 0.02 mg/L; however the deep water concentration had risen to 0.30 mg/L. The consistently dry weather that was observed during the second half of the summer of 2006 allowed the lake to experience a much lower flushing rate then normal, somewhat similar to what was observed in 2005. Thus, when compared to 2005, the 2006 nutrient levels were similar when compared to the previous year.

- ***Ammonia*** - A build up of ammonia was observed in the lake's hypolimnion during the monitoring of 2006. Similar to phosphorous, this was also similar to conditions previously observed during the summer of 2005. This again supports the observation that the persistent dry weather and the subsequent non-flushing of the lake in the second half of the summer of 2006 allowed the nutrient buildup, based on the anoxic conditions.

- ***Chlorophyll a*** - Chlorophyll *a* is a photosynthetic pigment present in all algae. It is commonly used to evaluate and quantify algal community development. For Culver Lake, we have established an acceptable maximum concentration of chlorophyll *a* of 20 mg/m^3. In May, as the lake's algal community is blooming, the concentration of chlorophyll *a* was 4.4 mg/m^3. In July, the epilimnetic concentration of chlorophyll *a* had increased to 14.6 mg/m^3. By late summer, the concentration of chlorophyll *a* had continued to increase to 33.4 mg/m^3. The metalimnetic chlorophyll *a* concentrations remained consistently at or below 5 mg/m^3, unlike the surface concentration. Given the consistency of dry weather experienced in the second half of the summer of 2006, and the decreased flushing rates, the ability of algae to truly bloom may have been the reason for the observed increase in surface chlorophyll *a* concentrations recorded from late spring to late summer.

- ***Phytoplankton*** – The phytoplankton community was monitored both at the surface and at the lake's metalimnion. The blue-green algae where the dominant algae for the majority of the sampling season. The abundances and biomass densities of the blue-greens were considerably higher than observed in 2005.

- ***Macrophyte Growth and Management*** – Macrophyte (weed) growth in the Stehr Tract section of the lake once again continued to pose a significant management problem. Overall, weed growth remained relatively stable as compared to the pattern and densities of weeds recorded during the 2005-growing season.

Introduction

The water quality of Culver Lake has been monitored continuously since the early 1990's by Princeton Hydro. The objective of the annual growing season monitoring program has been two fold; collect and review the data needed to evaluate improvements in the lake's water quality and collect the data needed to evaluate the performance and operation of the lake's Layer Air aeration system. Supplementing Princeton Hydro data are data collected by Ecosystem Consulting Services and Aquatic Analysts. The data collected by the former focus mostly on the performance of the aeration system, while the data collected by the latter pertains exclusively to weed harvesting results. The combination of the data collected and supplied by all three consultants increases the diversity and robustness of the database, thereby increasing the Association's ability to make informed decisions on the management of the lake. This report reviews the findings of the 2006 data, and the implications of these data with respect to management options for Culver Lake.

Methodology

During the 2006 growing season Princeton Hydro monitored the water quality of Culver Lake on three dates; 24 May, 24 July and 19 September. The selected sampling dates enabled us to collect data during critical periods over the course of the growing season, and to make timely observations of weed growth, weed management and thermal stratification processes. During each sampling event, data pertaining to the lake's water chemistry, water clarity and the dynamics of the lake's phytoplankton community were collected. In addition, on each data, observations were made of the lake's weed growth and algal community. Information was also obtained and reviewed regarding the Association's weed control and fishery management efforts. As in past monitoring efforts, three stations were monitored in 2006; mid-lake, Stehr Tract and Causeway Cove. The North Shore was also observed for macrophyte growth.

On each sampling date, Princeton Hydro conducted both *in-situ* and discrete water quality monitoring. At each station the following data were collected in profile, at one-meter intervals from the surface to bottom of the lake:

- Dissolved oxygen
- Temperature
- pH
- Conductivity

In addition, the lake's clarity was measured at each station by means of a Secchi disk. Data pertaining to the occurrence and density of aquatic macrophytes (plants) were recorded on each sampling date.

At the mid-lake station only, water samples were collected from the surface, mid and bottom depths and analyzed for the following parameters:

- Total Phosphorus (TP)
- Nitrate-nitrogen (NO_3)
- Ammonia-nitrogen (NH_3)

In addition, samples were also collected from the surface and mid-depth for chlorophyll *a* analysis, and from the surface and mid-depth for the quantitative analysis of phytoplankton and zooplankton.

Results and Discussion:

1. Water Quality

Temperature/Stratification and Dissolved Oxygen

Somewhat similar to 2005, the summer of 2006 was unseasonably warm and dry from the mid-summer to late summer timeframe. As would be expected, the surface waters of the lake steadily increased in temperature through July and August, then cooled slightly into September, and as a result reached conditions of thermal stratification early on. Similar to previous monitoring years, by mid-summer the thermocline had formed at a depth of approximately five (5) meters (approximately 16 feet). This depth of stratification persisted throughout the summer. It once again appears that weather patterns, and the operation of the aeration system, were responsible for the lake's observed thermal properties. This is significant for Culver Lake, as past data have shown that the shallower the thermocline, the more likely for algae that accumulate at the thermocline to be re-circulated into the lake's epilimnion.

Similar to previous monitoring years, measurable amounts of dissolved oxygen (DO) were not present within the lake's metalimnetic zone (Appendix 1). As will be discussed in further detail in the nutrient sub-section of this report, anoxic conditions within this zone increase the opportunity for phosphorus recycling and an increase in the lake's overall phosphorus budget. It also impacts the lake's ability to sustain acceptable brown trout habitat over the summer months.

With respect to the DO data, from the July through September monitoring dates, metalimnetic DO concentrations were minimal to unacceptable with respect to the maintenance of summer hold-over trout habitat. In July, metalimnetic DO concentrations declined below 4 mg/L at corresponding depths greater than 5 meters. This pattern also held true even in the cooler waters of the lake greater than 12 meters, with DO concentrations holding steady below the 1 mg/L range, anoxia. These data indicate that as of mid-July the lake's hold-over trout habitat was borderline acceptable. This was similar to the conditions observed in the past. For at least the past seven years, the data showed that although some hold-over trout habitat existed, the total volume of summer hold-over trout habitat was once again minimal. Over the course of the summer, the lake's hypolimnion remained anoxic or close to anoxic. This is an acceptable condition and consistent with the management objectives of the lake. The key however, is to ensure that the anoxic portion of the hypolimnion remains well below the lake's thermocline.

pH

The lake's pH changed dramatically with depth (Table 1). In mid-May, the pH of the epilimnion was slightly alkaline (7.84 to 8.01). Once below the thermocline, the pH decreased to slightly basic levels. In July, the pH of the epilimnion was again alkaline (7.70 to 8.35). Once below the thermocline, the pH decreased to essentially neutral levels. The pH levels in September were more prominent in September than observed in July, as elevated epilimnetic pH levels persisted. These elevated pH levels were the direct result of algal productivity and photosynthesis, especially during the dry warm mid to late summer period. The pH values suggest the existence of an algal bloom, and this was further confirmed by elevated chlorophyll a concentrations. However, once below the metalimnetic thermocline, the pH of the lake declined somewhat but did not attain neutral levels as was the case in May and July.

Clarity

The lake's transparency, as measured by Secchi disk remained consistently high from the beginning of the season through the end. In May the lake's Secchi clarity was 2.8 meters; well above the target Secchi depth of 1 meter. In July the lake's clarity had declined to 1.8 meters, but still well above the target depth. A continued decrease in clarity was observed toward the close of the season, as in September the clarity had decreased to 1.2 m.

Nutrients

Phosphorus concentrations were measured over the 2006 growing season at each of the lake's thermal layers. Phosphorus concentrations were fairly consistent from the surface to the bottom of the lake throughout the summer, until the late summer event. Phosphorus concentrations were similar at all three depths in the early summer, with all the depths at or below 0.03 mg/L. During the mid-summer monitoring event, all of the phosphorus concentrations again had remained consistent at or below 0.03 mg/L. By late summer, the deep water concentration was significantly higher than the remaining depths. The surface and mid-depth concentrations were 0.02 mg/L while the deep water concentration had risen to 0.30 mg/L. The consistently dry weather that was observed during the second half of the summer of 2006 allowed the lake to experience a much lower flushing rate then normal, somewhat similar to what was observed in 2005. Thus, compared to 2005, nutrient levels in 2006 were somewhat similar when compared to the previous year.

In May, ammonia concentrations were variable from surface to bottom, ranging from a low of 0.05 mg/L to a maximum of 0.28 mg/L. In July, ammonia concentrations were more consistent from surface to bottom, ranging from a low of 0.01 mg/L to a maximum of 0.05 mg/L. Lastly, in September, ammonia concentrations were again variable from surface to bottom, ranging from a low of 0.02 mg/L to a maximum of 1.30 mg/L. This is consistent with the fact that anoxic conditions (measurable DO) were present below the 5-meter thermocline, specifically at depths greater than 11 meters. Typically, ammonia concentrations increase dramatically under anoxic conditions. This can be seen in the September data, when the hypolimnion was in a continued anoxic condition, an increase in the concentration of ammonia from the early summer concentration was observed in the lake's deepest reaches. Overall, the lakes ammonia concentrations were again higher than those measured during the 2005 season.

Unlike ammonia, the lake's nitrate concentrations remained relatively consistent over the 2006-growing season. As the summer progressed, nitrate concentrations increased markedly in the deepest waters of the lake (depth >14 meters) relative to the concentrations measured at the surface and at the thermocline earlier in the year. This would suggest that a significant amount of bacterial decomposition was occurring near the bottom of the lake. By the end of the summer, nitrate concentrations had again decreased near the bottom and were more consistent with late spring concentrations.

Chlorophyll *a*

For Culver Lake, an acceptable chlorophyll *a* concentration is 20 mg/m^3. It has been determined, on the basis of past data and the consensus of lake users that when concentrations are below this value, the lake, although greenish in color, is aesthetically acceptable. As the concentration of chlorophyll *a* exceeds this target value however, there is an increase in complaints and lower satisfaction with the appearance of the lake. It has been our experience that a concentration of 20 mg/m^3 typically coincides with the development of an algae bloom. As such, we can use this target value to both gauge user satisfaction with the lake as well as identify the onset or existence of an algal bloom.

In May 2006, the concentration of chlorophyll *a* was 4.4 mg/m^3 at the surface and 2.4 mg/m^3 at the thermocline. These are very acceptable concentrations as they are obviously well below the target concentration. This would be expected in the late spring because of the lake's cooler water temperature, limited duration and intensity of sunlight and the predominance of non-surface blooming algal forms. With the onset of the summer, the lake's overall productivity as expected increased. This was somewhat reflected as a measured increase in chlorophyll *a*. At the lake's surface in July the concentration was 14.6 mg/m^3, while at the thermocline it was 4.1 mg/m^3. Again, these conditions are considered acceptable and were well below the target concentration. The fact that the mid-depth concentration was lower than the surface concentration was deemed a positive. Although one would typically expect higher chlorophyll *a* concentrations at the lake's surface due to more favorable light intensity and warmer water temperatures, this has not always been the case in Culver Lake. At times, the blue-green algae *Oscillatoria* has developed to bloom densities near the thermocline. The subsequent upwelling of these algae to the surface has at times in the past caused significant water quality problems. Given that such conditions did not exist in the lake as late as the middle to end of July is a very positive indicator. Later in the summer, due to the dryer, warmer conditions that persisted during most of August and September an increase in the concentration of chlorophyll *a* was then observed as reported in the September data. At that time the lake's surface chlorophyll *a* concentration was 33.4 mg/m^3. This is well above the established target concentration. It should be noted at this same time the chlorophyll *a* concentration measured at the thermocline was only 5.3 mg/m^3. In examining the 2006 to the data collected over previous years it was noted that the 2006thermocline chlorophyll *a* concentrations were similar to those measure over the most recent years; that is relatively low from spring through the end of the summer. This year, much unlike what has been observed in the recent past, the surface chlorophyll *a* concentrations increased as the year progressed to the point of actually exceeding the threshold value. Two important conclusions can be drawn form this. First, the 2006 data shows that the algae present in the mid-layers of the lake were not responsible for the late summer surface bloom. The maintenance of low concentrations at the thermocline supports a conclusion that the transport of deep water algae to the surface was not a primary factor in the September bloom. Second, as based on the analysis of the 2006 chlorophyll *a* with the other discrete and *in-situ* data, and especially the phytoplankton data (Section 2, below), it appears that prevailing (dry, warm) late-summer weather conditions were the driving factor behind the September bloom. As observed in both 2005 and 2006, such conditions allow for the significant growth and development of blue-green algae, leading to the bloom conditions (as reflected in the elevated chlorophyll *a* concentrations) measured at the lake's surface in September.

2. Biota

Phytoplankton

The early season phytoplankton community, as evidenced by the 24 May sample, was typical for most temperate North American lakes with a variety of diatoms, green algae, and golden algae. Surface water phytoplankton samples were markedly higher than those taken at mid depth although still relatively low in comparison to samples taken later in the summer. The dominant algae in terms of abundance was the green algae *Sphaerocystis* while the dominant algae in terms of biomass was the cryptophyte *Cryptomonas*. Mid depth samples were characterized by a relatively low density of phytoplankton in comparison to surface samples, with only 57 cells/ml identified. The dominant algae in terms of abundance and biomass was the diatom *Asterionella* which accounted for 65% of the total phytoplankton community. There were no identified blue-green algae in either the surface water or mid depth sample.

Phytoplankton samples taken on 24 July showed a marked increase in community diversity with a mix of green algae, golden algae, diatoms, and blue-green algae. Surface water samples had a significantly greater concentration of phytoplankton with dominance, both in terms of abundance and biomass, shifted to the blue-green *Anabaena*. In addition to *Anabaena* three (3) other blue-greens were identified, they were *Pseudoanabaena, Aphanizomenon,* and *Chroococcus*. Blue-greens accounted for 95.4% of the total phytoplankton community. The community composition differed significantly from that sampled during a similar time period in 2005 where blue-greens accounted for only 23% of the total phytoplankton community. Along with the increase in phytoplankton abundance was the expected increase in chlorophyll *a* concentration with a shift from 4.4 µg/L measured in May to 14.6 µg/L measured in July. Mid depth samples taken on the same date were characterized with a significantly lower phytoplankton concentration which amounted to only 7% of the surface water abundance. These samples were again dominated both in terms of abundance and biomass by the blue-green algae *Anabaena*. Blue-greens accounted for 99% of the mid depth phytoplankton community. The uneven distribution of blue-greens through the metalimnion to the epilimnion are likely due to the strong stratification patterns and subsequent water density disparities that were observed during the 24 July sampling event. The water density differences between the epilimnion and metalimnion may have been sufficient to prevent vertical migration of blue-greens throughout the water column which is a natural adaptation utilized to optimize light and nutrient acquisition.

Surface water phytoplankton samples taken in September were characterized by a similar community assemblage with blue-greens again accounting for the majority of the community in terms of abundance and biomass. The dominant algae in terms of abundance shifted from the blue-green *Anabaena* to the blue-green *Aphanizomenon*. The dominant algae in terms of biomass was again the blue-green *Anabaena*. Although total abundance was only very slightly elevated, an increase of 2.3%, chlorophyll *a* concentrations rose from 14.6 µg/L to 33.4 µg/L. Mid depth phytoplankton samples again showed a significantly lower abundance and biomass than concomitant surface water samples. The mid depth community assemblage was similar to that of surface waters with the blue-green *Pseudoanabaena* exerting dominance terms of abundance and the blue-green *Anabaena* in terms of biomass. Along with the decreased phytoplankton abundance was a decrease in chlorophyll *a* concentration with a measured concentration of only 5.3 µg/L.

Zooplankton

The surface water zooplankton community sampled on 24 May consisted of a mix of cladocerans and copepods. The dominant zooplankter in terms of abundance was the cladoceran *Bosmina* while the dominant zooplankter in terms of biomass was the copepod *Diaptomus*. There were 302 herbivorous zooplankters enumerated in total which represented 42% of the total surface water community. Mid depth zooplankton abundance was an order of magnitude higher than that enumerated from the surface waters. Zooplankters generally reside in the middle depths of the water column during the daytime in order to evade predation by zooplanktivorous fishes which feed mainly by sight. The mid depth community was dominated by the cladoceran *Bosmina* both in terms of abundance and biomass. Herbivorous zooplankters were enumerated at 18% of the entire zooplankton community. The only herbivore identified in both the surface and mid depth water samples was the cladoceran *Daphnia*. *Daphnia* is characterized as a large-bodied herbivore that feeds almost exclusively on phytoplankton. In large enough densities *Daphnia* may exert top down control on phytoplankton populations, feeding preferentially on the green algae. During the May sampling event Princeton Hydro stocked 132,475 herbivorous zooplankters, this concentration of herbivores was more than twice the level stocked in 2004 and 2005 combined. The mid depth zooplankton community exhibited the highest density of herbivorous zooplankters since stocking began in May 2001. The large density of herbivores, namely *Daphnia*, may be attributed to a high quality food source as well as a lack of zooplanktivorous fishes such as Alewife (*Alosa pseudoharengus*).

The zooplankton community sampled on 24 July showed an increase in community diversity marked by an emergence of several rotifer genera. The surface water zooplankton community was composed of a mix of copepods, cladocerans, and rotifers. The dominant zooplankter both in terms of abundance and biomass was the rotifer *Conochilus. Conochilus* feeds primarily on bacteria, detritus, and other rotifers and as such exhibits little to no control on phytoplankton. There were only 34 herbivorous zooplankters identified which represented 1% of the total zooplankton community. The mid depth zooplankton community had a similar total abundance to that of the surface waters but a greater abundance of herbivorous zooplankters which represented 10% of the total zooplankton community. The dominant zooplankter in terms of abundance was the rotifer *Conochilus* while the dominant zooplankter in terms of biomass was the herbivorous copepod *Diaptomus*. Princeton Hydro stocked 113,550 herbivorous zooplankters during the July sampling event. Stocking provided a substantial boost to the zooplankton community which was markedly lower in abundance to that observed the previous sampling date. Decreases in zooplankton abundances in July may be attributable to a decrease in suitable food sources

Although the zooplankton community was sampled during the September sampling event it was not enumerated due to the use a different sampling device (tow net) which would skew the population numbers. The dominant zooplankters in both the surface and mid depth samples were the herbivorous cladocerans *Ceriodaphnia* and *Diaphanosoma*. The return of dominance to herbivorous cladocerans from a community dominated by rotifers the previous sampling event is a positive sign. The ability of herbivorous cladocerans to repopulate the lake after a temporary population decline is beneficial for continuing control on phytoplankton densities. September zooplankton stocking consisted of 662,375 herbivorous zooplankters, the highest stocking density of the 2006 monitoring season.

The zooplankton stocking program again proved useful in controlling excessive amounts of phytoplankton, namely the green algae. Green algae densities, on average, were much lower in 2006 in comparison to 2005. The abundance of blue-green algae seems to have limited in-lake herbivore concentrations to some extent. As previously mentioned, the blue-green algae are not a preferential food source and are therefore only lightly grazed upon.

Aquatic Macrophytes

In May of 2006, approximately 90%-100% of the Stehr Tract section of the lake was impacted by weed growth. Large amounts of Eurasian water milfoil and Curly-leaved Pondweed were observed growing to a point near the lake’s surface. Weed densities were nominal in the Causeway Cove section of the lake. However, in the Causeway Cove section, as similar to past years, a heavy amount of naiad and elodea were observed along the bottom of the lake.

In July of 2006, the Stehr Tract Cove remained impacted by weed growth, especially Eurasian water milfoil and tapegrass. Weed growth in the other sections of the lake continued to be much more sporadic and patchy, both with respect to that observed in Stehr Tract Cove and that observed throughout the lake in previous years. However, it should be noted that Eurasian watermilfoil was observed in the Causeway Cove portion of the lake, a place where tapegrass is normally dominant. Minimal numbers of yellow and white water lily were observed along the North Shore.

In September of 2006, the Stehr Tract Cove showed the results of the previous two days harvesting activities, as the presence and growth of water milfoil, fanwort, lilies and tapegrass were sporadic in nature. In addition, the Eurasian water milfoil plants that were observed appeared to be brown and decaying. Throughout the summer, both yellow and white water lilies were observed in sporadic patches along the North Shore. The same sporadic plant growth was also observed in the other shallow sections of the lake, the result of the previous two days harvesting activities.

3. Summary

- Between mid May and late July, the lake became strongly stratified. Once again, the thermocline was established at a depth of approximately five (5) meters. This timing of the onset of stratification was similar to that observed in past years. The lake remained strongly stratified through late September.

- Although lake clarity during the beginning of the growing season was consistent with that measured in recent past years (Appendix C), it decreased markedly in the later part of the summer. The lake's clarity in September was lower than observed in the past few years. The less than optimal late summer clarity was due to an intense blue-green algae bloom that developed at the lake's surface.

- The cause for this bloom was concluded to be weather related and a direct function of the dry, warm conditions and subsequent lack of flushing experienced from mid through late summer. There was <u>no</u> evidence to suggest that the bloom was a function of the upwelling or transport of a deep water algae bloom to the lake's surface at the time of the lake turnover. Likewise review of the DO, temperature and TP data do not suggest it was a function of the lake's late-summer destratification and turnover.

- The mean Secchi depth in 2004 was 2.6 meters and in 2005 it was 2.4 meters. In 2006, the lake's mean clarity dropped significantly to 1.9 meters. This is cause for concern. , a continued decrease. It is again possible that the overall dry climatic conditions of the latter portion of 2006 are in part responsible for this value. The mid to late summer's overall dry and warm conditions could be considered favorable for the development of algal blooms.

- As has consistently been the case in the past, in midsummer, dissolved oxygen concentrations at or exceeding saturation were measured in the epilimnion. However, DO concentrations declined rapidly at the thermocline, and anoxic conditions were experienced throughout the deeper portions of the lake's profile. Into the latest part of the summer, the hypolimnion once again remained anoxic. Although this condition did result in the internal release of phosphorus, the released phosphorus remained segregated near the bottom of the lake over the entire course of the 2006 growing season. This was physically achieved by the maintenance of strong thermal profiles into late September. Without a breakdown in stratification, it was possible (as evidenced by the TP data) to contain the phosphorus rich water near the lake bottom.

- With regard to the extent and the maintenance of summer hold-over trout habitat, the lake's thermal and DO properties were less than optimal from the early summer onward. It appears from mid-July through late-September, the DO concentrations measured at or below the thermocline were less than that desired for the maintenance of brown trout.

- Total phosphorus concentrations remained relatively consistent from surface to bottom throughout the early portion of 2006. The late-summer deep water concentrations of TP were significantly elevated; 0.30 mg/L. However, although there significant phosphorus release occurred in the hypolimnion, none of the phosphorus migrated into the metalimnion or the epilimnion. Thus although internal phosphorus release did occur, the maintenance of the lake's thermal properties through the growing season resulted in the segregation of this phosphorus rich water at the bottom of the lake. Thus in essence the lake's internal phosphorus load was controlled.

- Although the annual mean TP concentration measured in 2006 was somewhat lower than that observed in 2005, it was higher than concentrations measured from 1993 to 2004 (Appendix B and C).

- In general (Appendix B and C) mean summer chlorophyll *a* concentrations have declined since 1995. Although the chlorophyll *a* concentration measured in late summer 2006 is the second highest chlorophyll a concentration measured in the last six years, it appears to be a function of weather and external loading factors, not a result of internal processes.

- Form the middle to the end of the summer of 2006, Culver Lake's phytoplankton community was generally dominated by blue-green algae. This is not a positive indicator. The density of blue-greens measured in September was very high and equated to bloom conditions.

- Although the mean annual Secchi depth clarity exceeded the 1.0m threshold, the 2006 mean was far below the means measured in 2004 and 2005. Obviously this decline was strongly influenced by the sharp decline in clarity, and resulting low Secchi disk reading, observed in late September.

- Nutrient and chlorophyll *a* concentrations were very low at the thermocline from the spring through late summer. The data suggest the absence of a 2006 mid-water bloom, but instead the presence of a late summer surface water bloom. The algal and chlorophyll data do not suggest that very much of the algae that developed at or near the thermocline were transported into the epilimnion or were the cause for the late summer surface bloom.

- A review of the lake's nitrogen to phosphorous ratios showed that low N:P ratios continue to persist. Such ratios favor the development of blue-green algae. .

- An increase in the densities of herbivorous zooplankton was again observed. The lake's zooplankton community continues to show a positive effect as a result of the zooplankton stocking effort, the maintenance of zooplankton refuge habitat and the control of alewife densities.

- The Stehr Tract section of the lake continued to be impacted by excessive weed growth and continued to be that area of the lake in need of the greatest amount of weed control. Harvesting strategies in this section of the lake were intensified in 2006 to include hydro-raking. The resulting program proved to be very successful. A large amount of weeds and biomat material were removed through the operation. This resulted not only in improved access through this area but also aided in water circulation and improved the area's general aesthetics.

- Overall, weed growth in the <u>entire</u> lake continues to be sporadic and patchy. Weed densities in the Owassa Inlet and Causeway Cove sections of the lake and the along the lake's North Shore were consistent with the conditions documented in these areas in previous years. Although none tend to be as impacted by weed growth as Stehr Tract Cove, each is impaired to some extent with weed densities at times impeding access and usage. As such, they continue to require maintenance. It should also be noted that Eurasian watermilfoil was observed in the Causeway Cove section of the lake in 2006. The spread or density of this weed needs to be tracked. Although rocks and subsurface impediments are more common here than in Stehr Tract Cove, a sharp increase in the density of this weed in the Causeway Cove area may in the future warrant the implementation of a hydro-raking effort.

4. Conclusions and Recommendations:

The data collected during the 2006 season shows that for the most part the Association's management efforts are working. The September algae bloom, the predominance of blue-green algae in the lake from July through September and the less than optimal hold over habitat provided in the metalimnion for brown trout were all negative conditions observed in 2006. The Association needs to continue to track algal species composition and algal densities in both the epilimnetic and metalimnetic regions of the lake. However, with the exception of the late summer algae bloom, the lake's overall conditions were relatively satisfactory. It can be concluded, based on the bulk of the 2006 data, and the relationship of these data to the long-term database, most of the water quality problems documented in the summer of 2006 were weather induced and a function of external loading patterns.

In reviewing the long-term data base it was determined that is time to re-set the lake management water quality thresholds and objectives for Culver Lake. Specifically, the clarity, TP and chlorophyll *a* threshold values need to be reassessed and modified to account for the sustained improvements achieved over the past 6-7 years. In addition, more focus needs to be placed on external loading dynamics, the management of the lake's nitrogen loading (to create N:P ratios that do not favor blue-green algae) and create threshold values for the lake's zooplankton community.

The stocking of herbivorous zooplankton is having a positive impact on the restructuring of the lake's zooplankton community. We do not support the stocking of brown trout other than on a put and take basis. Any fish stocking done by the Association should focus only on species that can exert predatory pressure on the zooplanktivorous fish such as alewives and golden shiner. The limited suitable trout habitat, combined with hybrid Striped Bass predation, may indicate a need to stock larger trout or perhaps another species in its place such as Walleye (*Stizostedion vitreum*) to achieve the same predatory effects of the alewife.

The weed harvesting efforts throughout the lake continues to provide relief from use impairment caused by excessive weed growth. Management of the weed growth in the Stehr Tract section of the lake should continue to include hydro-raking as a supplement to the conventional weed harvesting efforts. Overall, the 2006 hydro-raking project was very successful. Thus, based on the success of this effort, a 2007 hydro-raking program should again be conducted in the Stehr Tract section of the lake. In addition, based on the presence of Eurasian watermilfoil in the Causeway Cove portion of the lake, the feasibility of managing weed growth in this area of the lake by means of hydro-raking should be assessed.

Princeton Hydro still remains guarded in terms of the use of herbicides to control weed growth. We strongly suggest the Association consider implementing a monitoring effort of the lake's weed community using a combination of aerial photographic analysis and in-lake surveys as a means of documenting the spread of different weed species, lake-wide changes in weed composition and density, and the success of different weed management efforts. The data derived through such a survey could be used to direct weed harvesting, hydro-raking or alternative control strategies to problem areas and quantitatively track the resulting improvements.

As such, for 2007 we recommend the following be conducted:

1. Continue with the existing monitoring program and the collection of key water quality parameters from over the course of the 2007 growing season.
2. Conduct a through statistical review of the long-term data base starting with the 2000 data to new lake management water quality thresholds for Secchi clarity, TP and chlorophyll *a*.
3. Use the long-term database to create a new threshold value for nitrogen, specifically the lake' N:P ratios, for the purpose of better controlling environmental conditions that favor blue-green algae.
4. Create a threshold value for the lake's zooplankton community, emphasizing minimum surface and metalimnetic concentrations and size classes for the herbivorous zooplankton standing crops.
5. Model and recompute the watershed pollutant loads to the lake accounting for changes in land development (growth, intensity and in-fill development), the Association's septic management efforts and the new stormwater management rules. Start a shift in focus from internal nutrient control to external nutrient control. Based on observations made over the past three years, external loading dynamics are beginning to have a larger impact on lake water quality than are internal loading dynamics.
6. Implement again a hydro-raking effort in the Stehr Tract area and consider the feasibility of a similar effort in the Causeway Cove area. Continue the conventional harvesting program, and avoid the use of herbicides in the management of the lake's weed growth.
7. Consider the implementation of a weed tracking program that is based on aerial reconnaissance and backed by in-lake field surveys. Princeton Hydro can develop for the Association a work plan and fee for such services.
8. Limit any trout stocking to put and take and consider the introduction of larger brown trout so as to minimize predatory losses to hybrid striped bass. We do not recommend the introduction of additional hybrid striped bass, or other predatory fish, until another fisher survey is conducted.

Appendix A

2006 *In-Situ* Water Quality Data

***In-Situ* Monitoring for Culver Lake 5/24/06**

Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH
	Total	Secchi	Sample	(^{0}C)	(mmhos/cm)	(mg/L)	(units)
Mid-Lake	**14.5**	**2.8**	**Surface**	14.24	0.194	9.54	8.01
			1.0	14.2	0.194	9.49	7.98
			2.0	14.06	0.194	9.45	7.96
			3.0	13.97	0.194	9.37	7.92
			4.0	13.77	0.194	9.36	7.9
			5.0	13.74	0.194	9.29	7.85
			6.0	13.7	0.194	9.25	7.84
			7.0	13.68	0.194	9.22	7.83
			8.0	13.08	0.194	8.83	7.77
			9.0	12.12	0.194	7.8	7.53
			10.0	9.37	0.194	7.72	7.49
			11.0	9.05	0.195	7.16	7.41
			12.0	8.25	0.195	6.25	7.34
			13.0	7.28	0.201	4.52	7.24
			14.0	7.2	0.202	4.09	7.24
Stehr Tract	**2**	**2**	**Surface**	14.94	0.191	10.3	8.22
			1.0	14.74	0.189	10.12	8.17
			2.0	14.19	0.189	9.79	8.04
Causeway Cove	**2**	**2**	**Surface**	15.02	0.195	10.25	8.06
			1.0	14.88	0.195	9.97	8
			2.0	14.73	0.195	9.92	7.96

In-Situ Monitoring for Culver Lake 7/24/06

Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	pH
	Total	Secchi	Sample	(^{0}C)	(mmhos/cm)	(mg/L)	(units)
Mid-Lake	**14.5**	**1.8**	**Surface**	26.33	0.189	9.56	8.35
			1.0	25.81	0.189	9.4	8.48
			2.0	25.55	0.189	8.84	8.22
			3.0	25.34	0.189	8.33	8.03
			4.0	24.59	0.189	6.63	7.7
			5.0	19.1	0.195	2.41	7.14
			6.0	15.79	0.197	2.77	6.83
			7.0	14.67	0.197	3.11	6.64
			8.0	14.14	0.197	2.99	6.5
			9.0	13.59	0.197	2.7	6.51
			10.0	12.56	0.197	2.21	6.57
			11.0	11.18	0.198	0.9	6.59
			12.0	10.09	0.202	0.37	6.65
			13.0	9.17	0.221	0.26	6.72
			14.0	9.12	0.231	0.23	6.85
Stehr Tract	**1.5**	**0.9**	**Surface**	26.22	0.19	8.46	7.82
			1.0	25.38	0.192	8.17	7.7
			1.5	25.03	0.194	7.76	7.57
Causeway Cove	**1.8**	**1.2**	**Surface**	26.84	0.189	9	8.31
			1.0	25.99	0.188	8.82	8.09
			1.5	24.52	0.189	4.41	7.15

***In-Situ* Monitoring for Culver Lake 9/26/05**							
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(mmhos/cm)**	**(mg/L)**	**(units)**
Mid-Lake	**14.7**	**1.2**	**Surface**	20.29	0.189	10.29	8.75
			1.0	20.24	0.188	10.58	9.15
			2.0	20.12	0.188	10.55	9.07
			3.0	19.4	0.187	10.45	8.8
			4.0	18.62	0.187	9.56	8.56
			5.0	18.49	0.187	8.88	8.43
			6.0	18.35	0.187	8.28	8.33
			7.0	17.66	0.189	6.96	8.18
			8.0	16.92	0.191	3.47	8.06
			9.0	16.01	0.191	2.4	7.98
			10.0	13.96	0.199	1.3	7.94
			11.0	13.25	0.201	0.81	8.04
			12.0	12.13	0.207	0.56	8.23
			13.0	11.04	0.228	0.45	8.68
			14.0	10.26	0.242	0.36	9.66
			14.5	10.2	0.247	0.29	10.27
Stehr Tract	**1.8**	**1.5**	**Surface**	20.59	0.184	9.81	7.84
			1.0	19.97	0.18	9.81	7.74
			1.5	19.76	0.18	9.25	7.72
Causeway Cove	**2**	**1.2**	**Surface**	20.78	0.188	10.03	8.19
			1.0	20.59	0.185	9.92	8.02
			2.0	19.33	0.173	4.7	8.02

Appendix B

Discrete Laboratory Data Figures

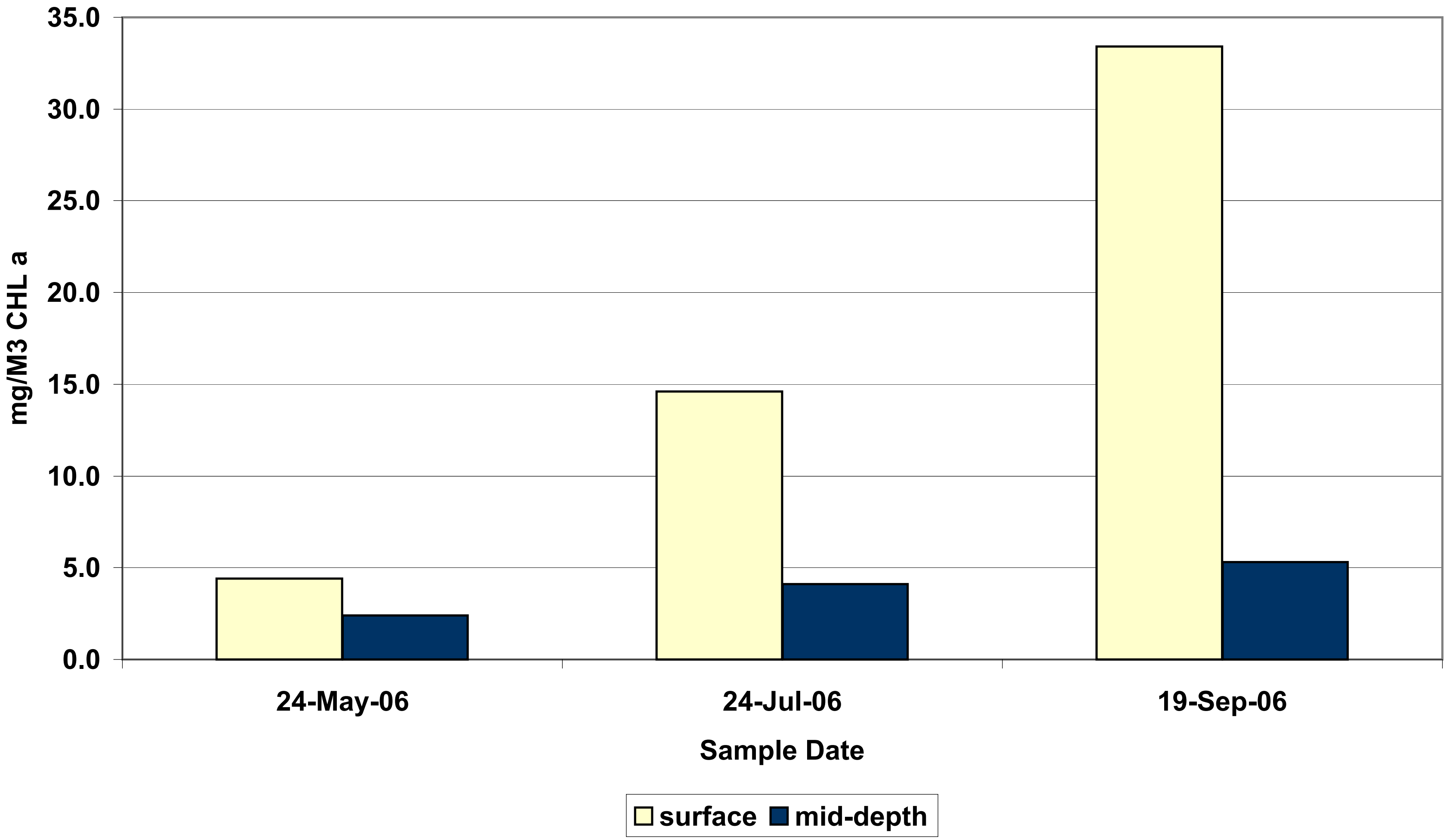

Figure 1 - Chlorophyll a concentrations at the Culver Lake mid-lake sampling station - 2006

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

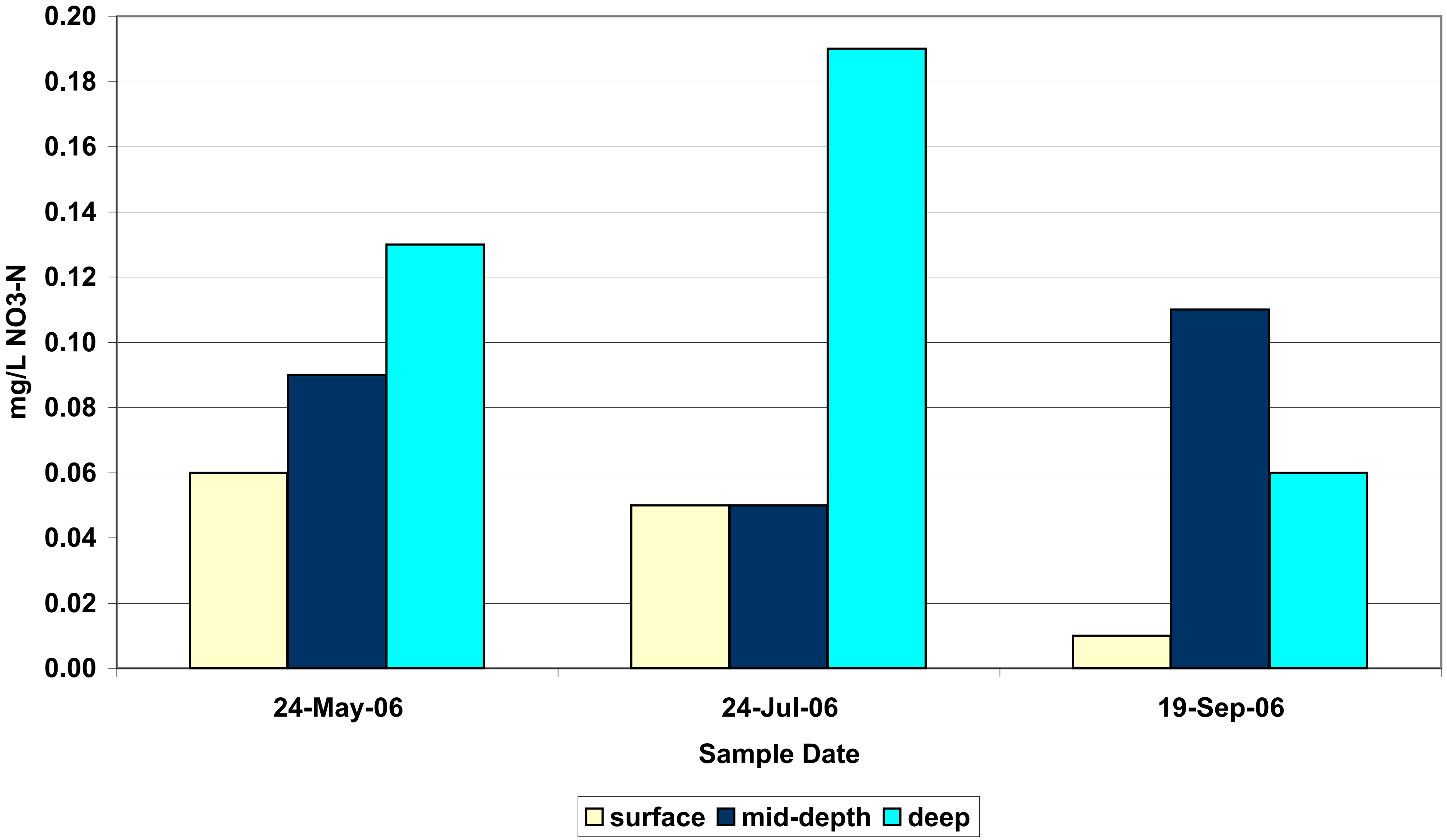

Figure 2 - Nitrate-N concentrations at the Culver Lake mid-lake sampling station - 2006

pH

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

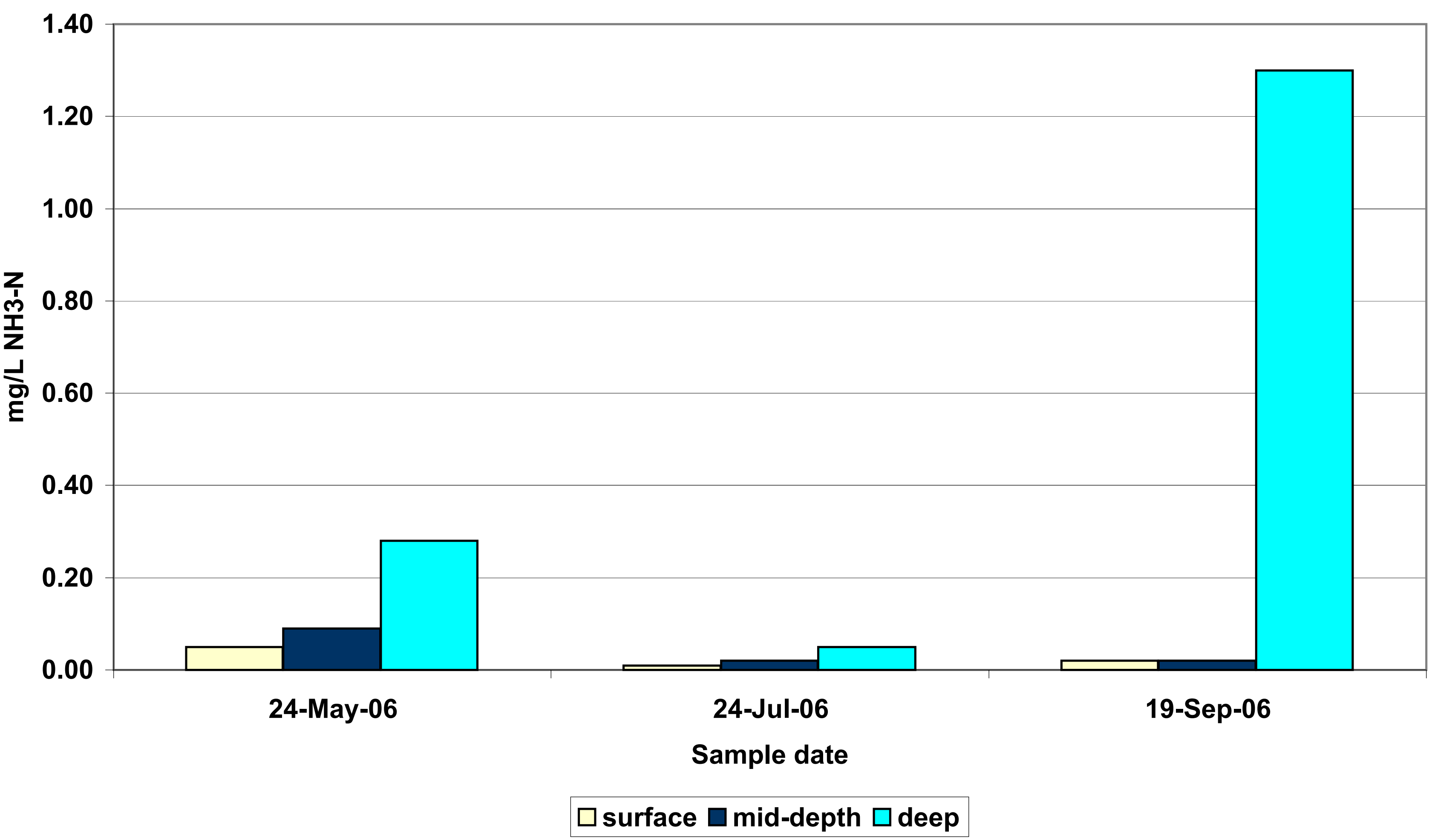

Figure 3 - Ammonia-N concentrations at the Culver Lake
mid-lake sampling station - 2006

pH

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

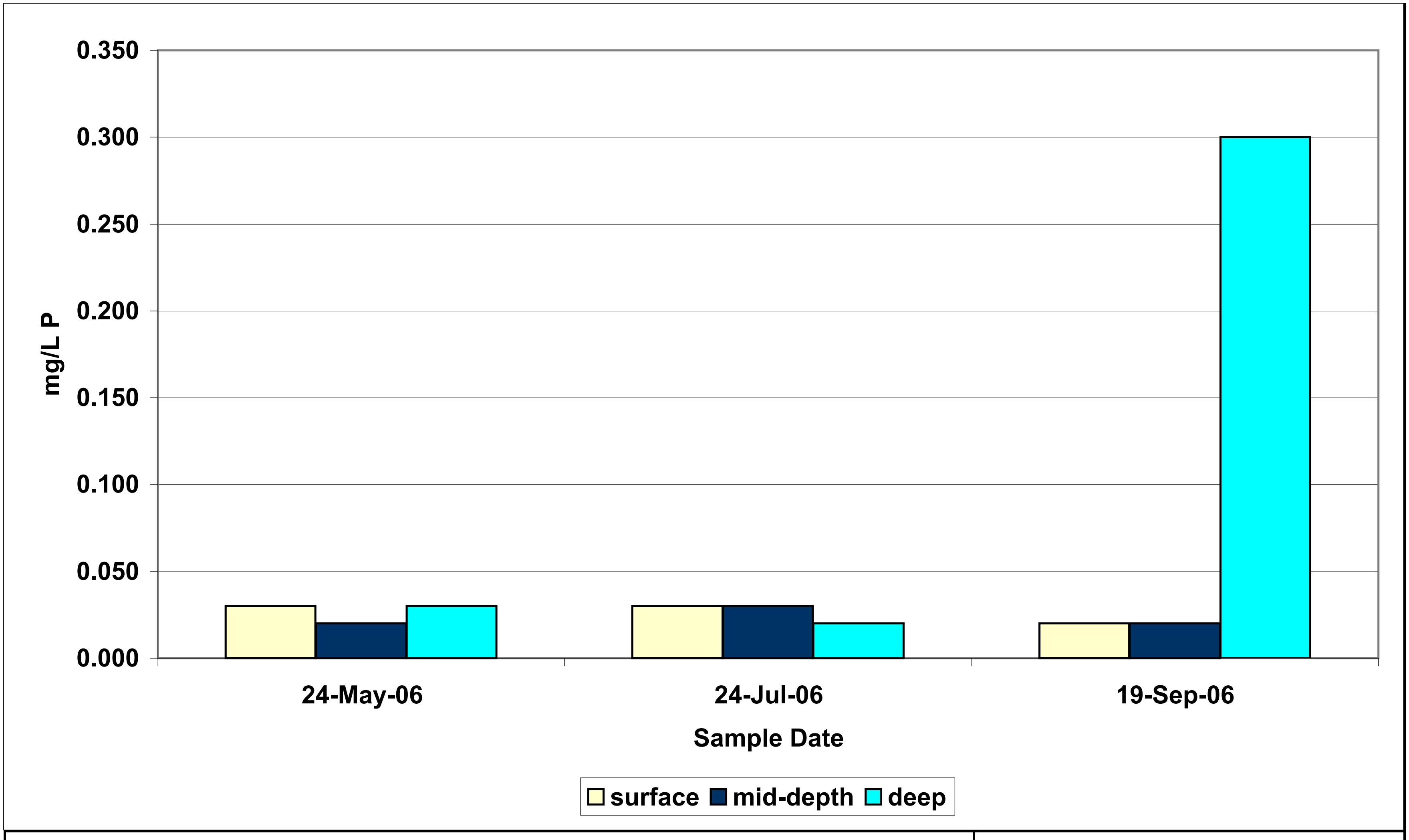

Figure 4 - Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station - 2006

pH

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

Appendix C

Discrete Laboratory Data Long Term Trend Figures

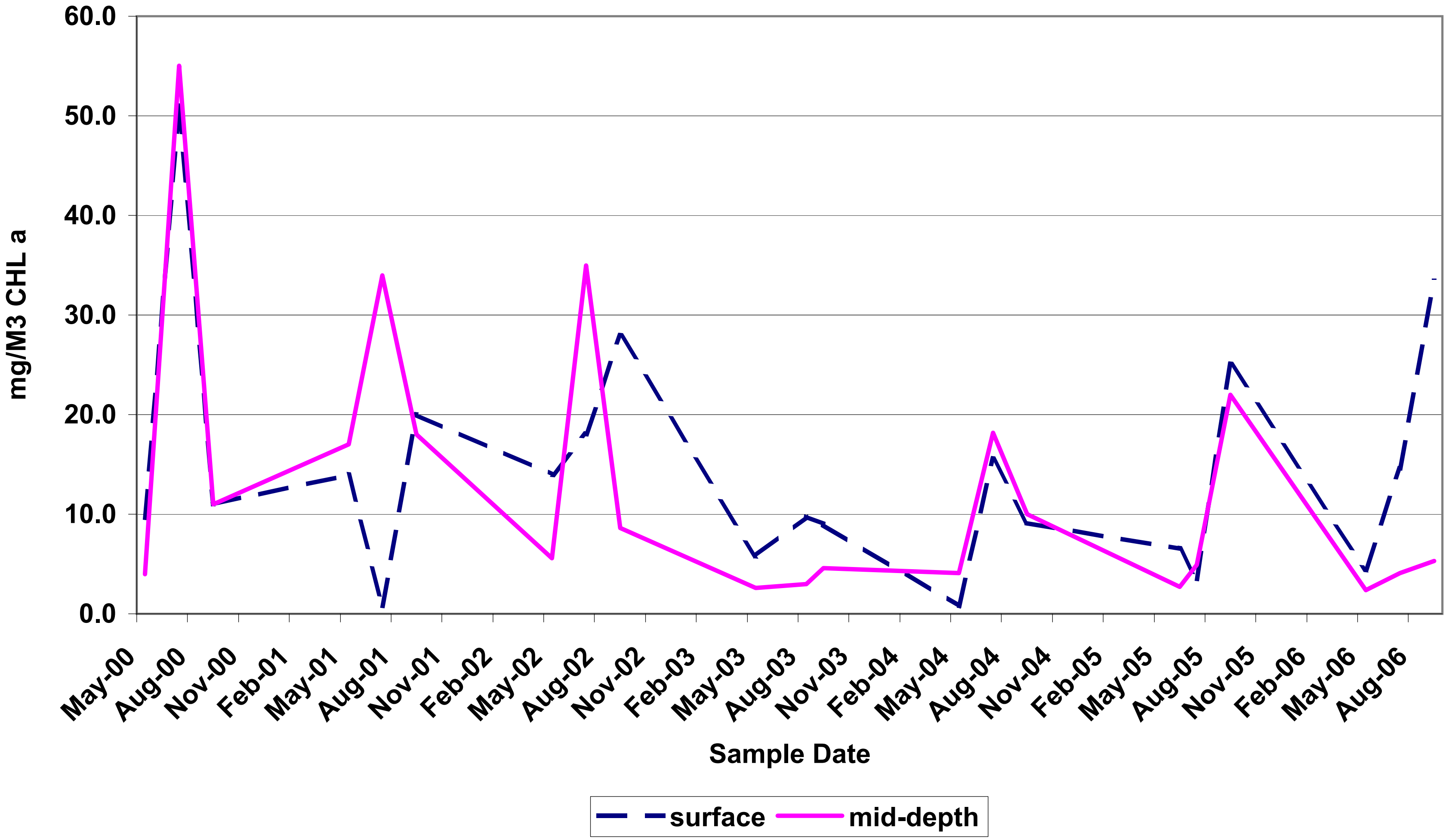

Figure 5 - Long-Term Trend of Chlorophyll a concentrations at the Culver Lake mid-lake sampling station

pH

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

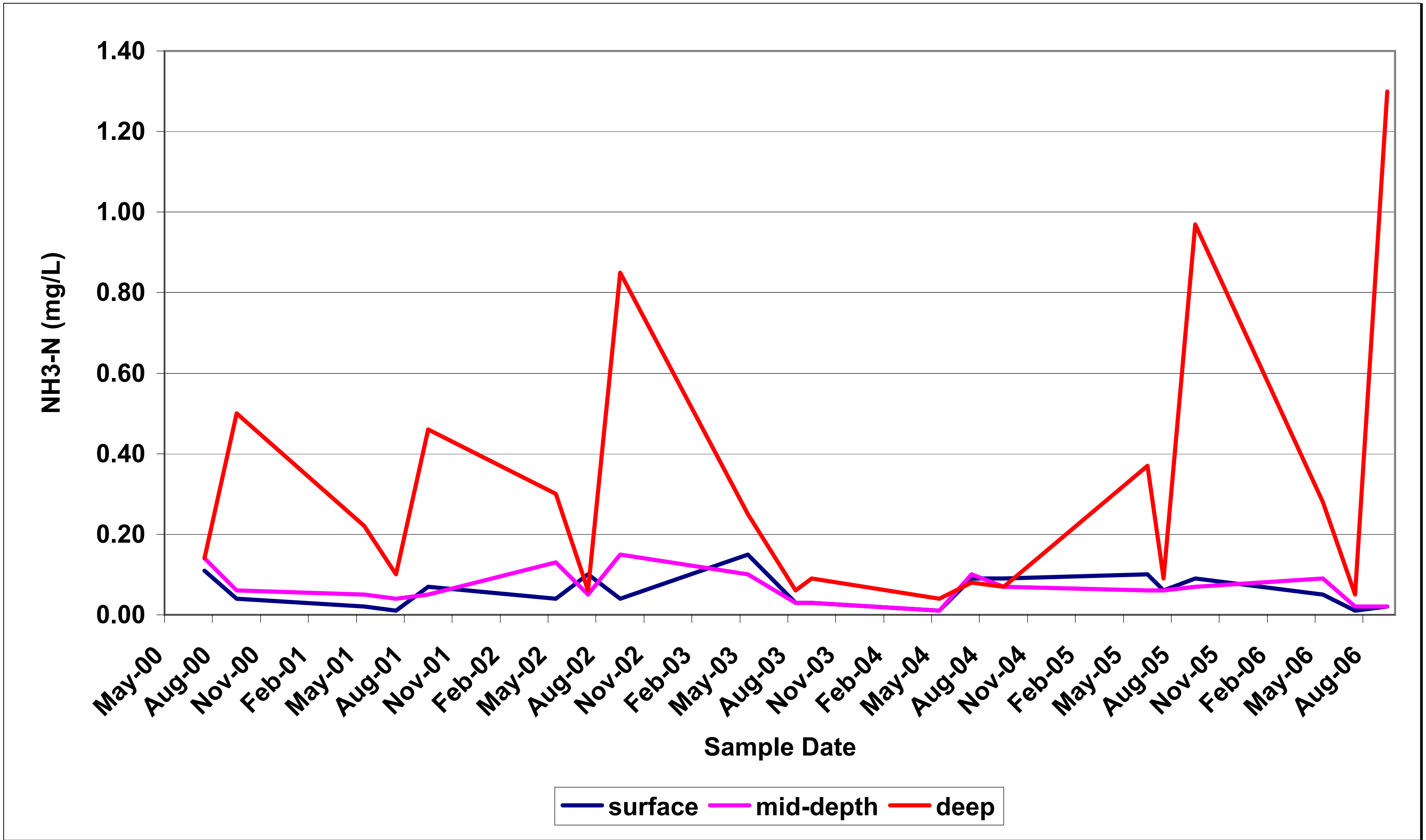

Figure 6 - long Term Trend of Ammonia-N concentrations at the Culver Lake mid-lake sampling station

pH

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

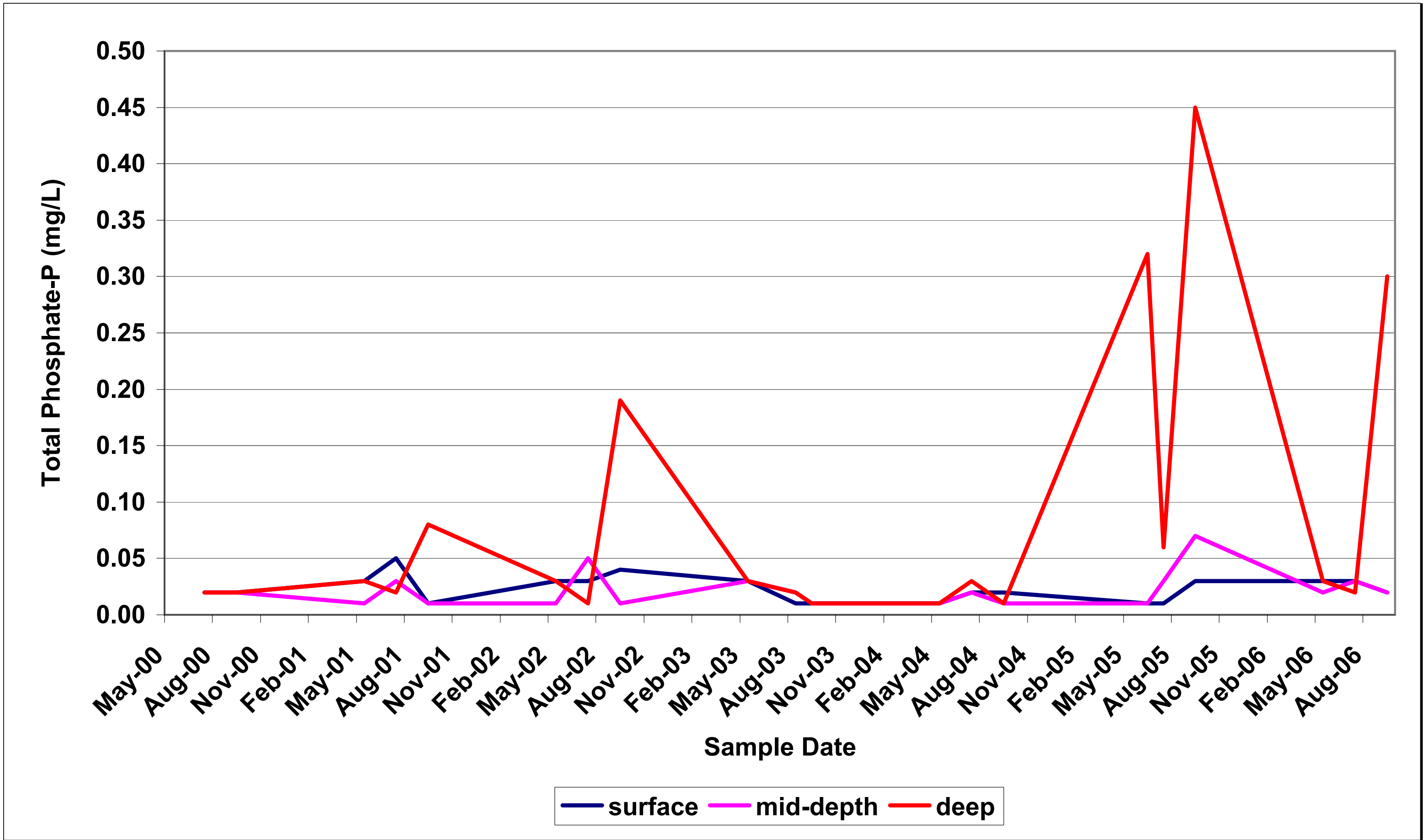

Figure 7 - Long Term Trend of Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station

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

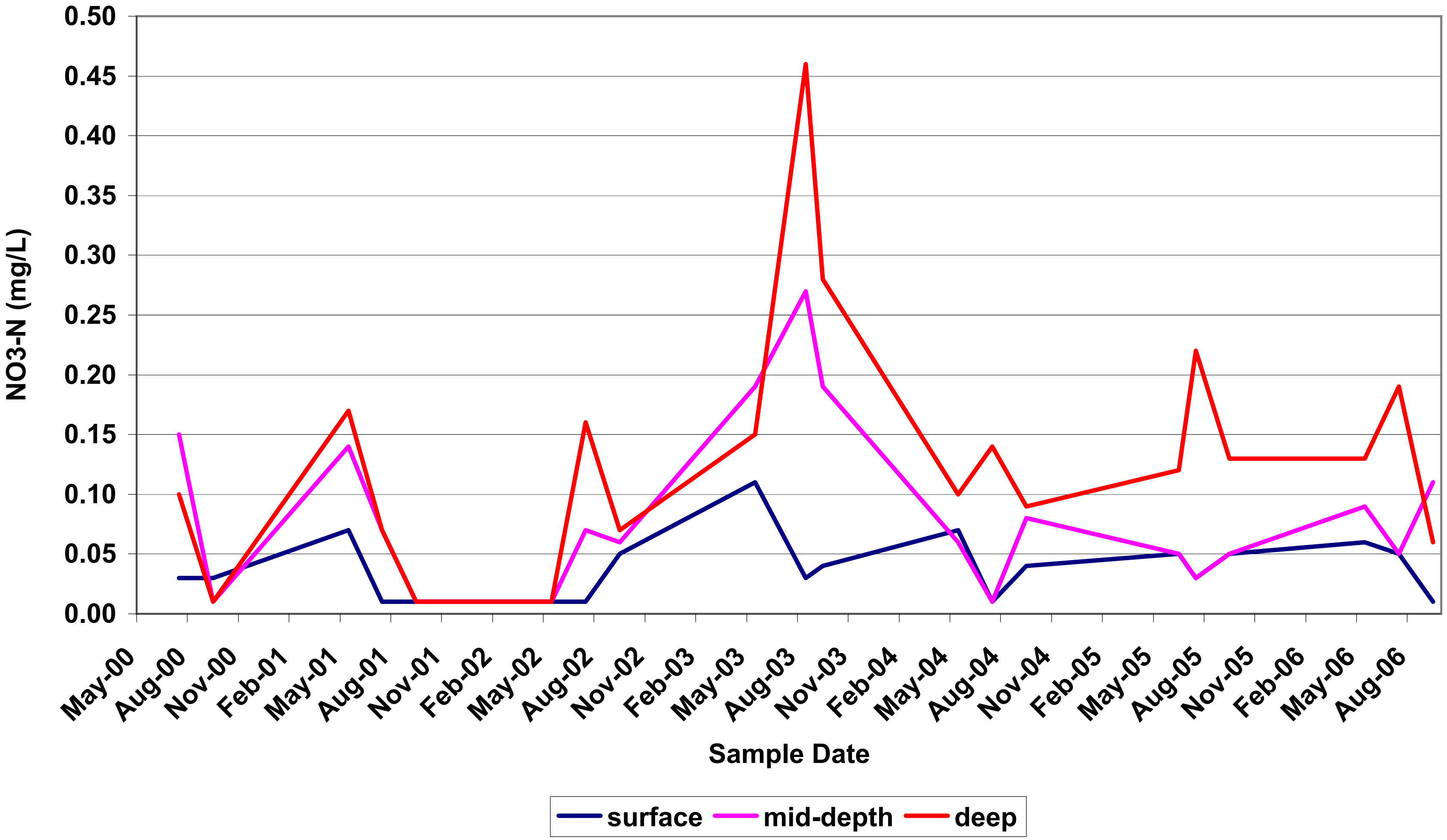

Figure 8 - Long Term Trend of Nitrate-N concentrations at the Culver Lake mid-lake sampling station

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

Appendix D

2006 and Long Term Zooplankton Population Data

Culver Lake

Mid-depth

24-May-06

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Chlamydomonas	4	0.42
Chlorella	2	1.58
Ankistrodesmus	2	0.04
Total	**8**	**2.04**
Chrysophyta		
Ochromonas	8	1.74
Diatoms		
Asterionella	37	53.62
Synedra	4	13.74
Total	**41**	**67.37**
Total	**57**	**71.14**

Culver Lake

Surface waters

24-May-06

Organism	Cells / ml	ug per Liter
Green Algae		
Chlamydomonas	28	2.92
Chlorella	8	6.33
Ankistrodesmus	16	0.33
Elaktothrix	24	4.00
Sphaerocystis	179	12.44
Coelastrum	95	6.60
Total	**350**	**32.63**
Chrysophyta		
Ochromonas	44	9.56
Cryptophyta		
Cryptomonas	63	60.97
Diatoms		
Synedra	4	13.74
Total	**461**	**116.89**

Culver Lake
Surface waters

24-Jul-06

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Chlamydomonas	98	10.22
Chlorella	17	13.46
Gloeocystis	833	463.11
Cosmarium	6	1.73
Oocystis	23	3.20
Sphaerocystis	324	1.60
Coelastrum	93	22.52
Staurastrum	12	932.46
Gonium	23	2.40
Total	**1429**	**1450.7**
Chrysophyta		
Ochromonas	12	2.61
Mallomonas	12	29.74
Total	**24**	**32.35**
Cryptophyta		
Cryptomonas	6	5.81
Diatoms		
Frgilaria	208	831.17
Cyclotella	6	2.75
Total	**214**	**833.91**
Blue-green Algae		
Anabaena	20255	48281.76
Pseudoanabaena	434	25.42
Aphanizomenon	2627	153.84
Chroococcus	69	54.62
Total	**23385**	**48515.64**
Total	**25058**	**50838.39**
% Blue-greens		**95.4**

Culver Lake

Mid-depth

24-Jul-06

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Chlamydomonas	42	4.38
Chlorella	8	6.33
Oocystis	46	6.39
Pleodorina	61	6.36
Total	**157**	**23.46**
Chrysophyta		
Chromulina	27	6.33
Cryptophyta		
Rhodomonas	8	1.56
Diatoms		
Cyclotella	8	3.66
Blue-green Algae		
Anabaena	1442	3437.29
Pseudoanabaena	152	8.90
Total	**1594**	**3446.19**
Total	**1794**	**3481.22**
% Blue-greens		**99.0**

Culver Lake

Surface waters

19-Sep-06

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Chlamydomonas	172	17.93
Chlorella	11	8.71
Sphaerocystis	92	0.76
Arthrodesmus	11	138.00
Staurastrum	46	110.29
Total	**332**	**275.69**
Cryptophyta		
Cryptomonas	23	22.26
Diatoms		
Cyclotella	11	5.04
Dinoflagellates		
Peridinium	23	68.53
Blue-green Algae		
Anabaena	6887	16416.51
Pseudoanabaena	7461	436.92
Aphanizomenon	10904	638.54
Total	**25252**	**17491.97**
Total	**25641**	**17863.49**
% Blue-greens		**97.9**

Culver Lake

Mid-depth

19-Sep-06

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Chlorella	6	4.75
Ankistrodesmus	130	2.71
Gloeocystis	45	25.02
Total	**181**	**32.48**
Chrysophyta		
Ochromonas	6	1.30
Chromulina	28	6.57
Chrysosphaera	28	22.16
Total	**62**	**30.04**
Diatoms		
Tabellaria	23	69.14
Dinoflagellates		
Peridinium	6	17.88
Euglenoids		
Trachelomonas	6	35.70
Blue-green Algae		
Anabaena	502	1196.62
Pseudoanabaena	689	40.35
Aphanizomenon	56	3.28
Total	**1247**	**1240.24**
Total	**1525**	**1425.47**
% Blue-greens		**87.0**

Culver Lake

Surface

Zooplankton

24-May-06

Cladocerans	**Number per Liter**	**ug / L**
Daphnia	131	207.6
Bosmina	202	204.0
Total	**333**	**411.5**
Copepods		
Cyclops	71	14.4
Diaptomus	171	413.9
nauplii	151	118.0
Total	**393**	**546.3**
Total	**726**	**957.8**
Herbivores	**302**	
% Herbivores	**42**	

Culver Lake

Mid-depth

Zooplankton

24-May-06

Cladocerans	**Number per Liter**	**ug / L**
Daphnia	875	1386.4
Bosmina	3938	3976.6
Total	**4813**	**5363.0**
Copepods		
Cyclops	583	118.5
Diaptomus	438	1060.2
nauplii	1021	797.6
Total	**2042**	**1976.2**
Rotifers		
Keratella cochlearis	583	19.4
Total	**7438**	**7358.6**
Herbivores	**1313**	
% Herbivores	**18**	

Culver Lake

Surface

Zooplankton

24-Jul-06

Cladocerans	**Number per Liter**	**ug / L**
Diaphniosoma	11	9.9
Bosmina	11	11.1
Chydorus	283	205.4
Total	**305**	**226.4**
Copepods		
Cyclops	34	6.9
Diaptomus	23	12.9
nauplii	170	132.8
Total	**227**	**152.6**
Rotifers		
Keratella cochlearis	23	0.8
Conochilus	1813	223.0
Trichocerca pilla	23	9.5
Total	**1859**	**233.3**
Total	**2391**	**612.3**
Herbivores	**34**	
% Herbivores	**1**	

Culver Lake

Mid-depth

Zooplankton

24-Jul-06

Cladocerans	**Number per Liter**	**ug / L**
Daphnia	21	43.4
Diaphniosoma	31	95.4
Bosmina	21	21.2
Chydorus	146	106.0
Total	**219**	**266.0**
Copepods		
Cyclops	33	6.6
Diaptomus	150	193.5
nauplii	111	86.3
Total	**293**	**286.4**
Rotifers		
Keratella cochlearis	83	2.8
Conochilus	1271	156.3
Trichocerca pilla	63	26.2
Polyarthra	104	100.7
Asplanchna	10	13.3
Total	**1531**	**299.3**
Total	**2043**	**552.4**
Herbivores	**202**	
% Herbivores	**10**	

Culver Lake Zooplankton Analysis

24-May-06

# of herbivores	35	per ml
concentrate	1	gallons
concentrate	3.785	liters
concentrate	3785	mls
zoops	**132,475**	**number**

Culver Lake Zooplankton Analysis

24-Jul-06

# of herbivores	30	per ml
concentrate	1	gallons
concentrate	3.785	liters
concentrate	3785	mls
zoops	**113,550**	**number**

Culver Lake Zooplankton Analysis

19-Sep-06

# of herbivores	175	per ml
concentrate	1	gallons
concentrate	3.785	liters
concentrate	3785	mls
zoops	**662,375**	**number**

TOTAL

908,400