F. X. Browne, Inc.

*Engineers • Planners • Scientists*

December 15, 2011

Kirk Mackey
Twin and Walker Creek Watershed Association
65 Lenape Lane
Twin Lakes, PA 18458

RE: Twin and Walker Creek Watershed Monitoring Program
2011 Water Quality Monitoring Final Report
FXB File No. PA1551-10

Dear Kirk:

The purpose of this letter is to present results of the 2011 Twin and Walker Creek Watershed Monitoring Program. The primary purpose of the monitoring program is to characterize the trophic state within Big Twin Lake, Little Twin Lake, and Walker Lake based on measurements of Secchi depth, total phosphorus, and chlorophyll a. The monitoring program consisted of volunteers from the Twin and Walker Creek Watershed Association collecting lake samples from the photic zone of Big Twin Lake, Little Twin Lake, and Walker Lake and measuring the Secchi depth on four occasions during the 2011 growing season. F. X. Browne, Inc. performed the total phosphorus and chlorophyll a laboratory analysis and analyzed all the 2011 lake monitoring data.

**Results**

Table 1 presents raw and averaged data for the study period. The significance of these results is described in the following sections. In all cases, confidence interval (±) is expressed as twice the standard deviation, equivalent to approximately a 95% confidence interval.

***Phosphorus***

Phosphorus is one of the three main nutrients of life, along with nitrogen and carbon. In the northeast United States, phosphorus is the nutrient that most often controls productivity of lake systems. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are directly related to the trophic condition (water quality status) of a lake. Excessive amounts of phosphorus lead to algae blooms and loss of oxygen in lakes. Epilimnetic (surface water) total phosphorus concentrations less than 10 micrograms per liter (µg/L)/0.010 milligrams per liter (mg/L) are associated with oligotrophic (clean, clear water) conditions and concentrations greater than 25 µg/L (0.025 mg/L) are associated with eutrophic (nutrient-rich) conditions.

The average surface water total phosphorus concentration during 2011 was highest in Walker Lake (0.024 mg/L ± 0.006) and lowest in Little Twin Lake (0.013 mg/L ± 0.014). The highest overall phosphorus concentration was measured in Big Twin Lake. However, this was an atypically high value that was not accompanied by corresponding high chlorophyll a concentrations or low Secchi disk transparencies. Overall, Walker Lake tended to have the highest total phosphorus concentration on each sampling date and experienced the highest overall average total phosphorus concentration.

### *Chlorophyll a*

Chlorophyll a is the green pigment in plants used for photosynthesis, and measuring it provides information on the amount of algae (microscopic plants) in lakes. Chlorophyll a concentrations can also be used to classify lake trophic state. Chlorophyll a concentrations less than 2 micrograms per liter (µg/L) are associated with oligotrophic conditions, while concentrations greater than 10 µg/L are associated with eutrophic conditions.

The average chlorophyll a concentration was highest in Walker Lake (10.8 mg/L ± 14.6) and lowest in Little Twin Lake (5.3 mg/L ± 7.0).

### *Transparency*

Transparency is a measure of water clarity in lakes and ponds. It is determined by lowering a 20 cm black and white disk (Secchi disk) into a lake to the depth where it is no longer visible from the surface. Since algae are the main determinant of water clarity in non-stained lakes that lack excessive amounts of inorganic turbidity (suspended silt), transparency is used as an indicator of lake trophic state. Transparencies greater than 4.6 meters (15.1 feet) are associated with oligotrophic conditions, while transparencies less than 2 meters (6.6 feet) are associated with eutrophic conditions.

The average Secchi disk transparency was highest (most favorable) in Little Twin Lake (3.26 m ± 2.20), and lowest at Walker Lake (1.75 m ± 0.60).

### *Trophic State*

*Trophic state* is a key term used in limnology to describe the amount of algae and macrophytes (aquatic plants) found in a lake. *Oligotrophic* lakes have few algae and macrophytes and appear clean and clear, while *eutrophic* lakes show an overabundance of growth and often have a pronounced green color due to algae. *Eutrophication* is a natural process whereby lakes increase in trophic state over long periods of time. However, the process of eutrophication can be greatly accelerated by human activities (such as watershed development and sewage disposal) which introduce additional nutrients, organic matter and silt into the lake system. This cultural eutrophication can be reversed by controlling human inputs, but in many cases additional in-lake treatments are required in order to accelerate this rehabilitation process.

The Carlson (1977) Trophic State Index (TSI) is an extremely valuable tool for the evaluation of lakes. This index is calculated using summer averages for total phosphorus, chlorophyll a, and/or transparency (Secchi depth) data. In order to calculate this index, each seasonal average is logarithmically converted to a scale of relative trophic state ranging from 1 to 100. This index was constructed such that an increase in ten units represents a doubling in algal biomass. For example, a lake with a chlorophyll TSI of 40 has twice as much algae as a lake with a TSI value of 30. Generally, TSI values less than 37 are considered oligotrophic, while TSI values greater than 51 are considered eutrophic.

Average values for Secchi depth, total phosphorus, and chlorophyll a were used to compute trophic state indices following Carlson, 1977. The TSI values for each lake are shown in Table 1. Figures 1, 2, and 3 compare trophic state indices for 2011 with those calculated for previous years.

### *Dissolved Oxygen and Temperature*

In late spring or the beginning of summer, temperate lakes develop stratified layers of water, with warmer water near the lake's surface (epilimnion) and colder water near the lake's bottom (hypolimnion). As the temperature difference becomes greater between these two water layers, the resistance to mixing increases. Under these circumstances, the epilimnion (top water) is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion (bottom water) may become depleted of oxygen due to oxygen being consumed by organisms decomposing organic matter at the lake bottom.

Conversely, shallow temperate lakes may never develop stratified layers of water. For these shallow lake systems, wave action caused by the wind may be sufficient to keep the entire lake completely mixed for most of the year. In shallow lakes, low dissolved oxygen levels may occur above the lake sediments even though most of the water in the lake is completely mixed. Both shallow and deep temperate lakes can have low dissolved oxygen concentrations near the surface of the lake sediments. If low dissolved oxygen levels occur near the lake bottom, sediments may release significant amounts of nutrients (primarily orthophosphorus and ammonium) back into the lake, thereby allowing for more nutrients for algae and aquatic plant growth.

In general, the optimal water temperature for trout is 55 to 60°F (12.8 to 15.6°C). Trout may withstand water temperatures above 80°F (26.7°C) for several hours, but if water temperatures exceed 75°F (23.9°C) for extended periods, trout mortality is expected (Pennsylvania State University). A safe minimum dissolved oxygen concentration for trout is 5 mg/L. Warm water species (i.e. golden shiners, bass, bluegill) grow well when water temperatures exceed 80°F (26.7°C). For many warm water fish species, 3 mg/L is considered a safe minimum dissolved oxygen concentration.

In 2011, volunteers measured profiles of dissolved oxygen and temperature on each of the sampling dates. The dissolved oxygen and temperature profiles for all three lakes are included in Table 2 and Figures 4 and 5.

During the 2011 growing season, the following observations can be made with respect to dissolved oxygen and temperature readings:

- All three lakes were at least weakly thermally stratified during the summer months of June – September.
    - Big Twin Lake exhibited a temperature difference between the surface and bottom that ranged from 10.1°C (June) to 14.3°C (July)
    - Little Twin Lake exhibited a temperature difference between the surface and bottom that ranged from 13.6°C (August) to 16.8°C (July). The temperature difference was 6.6°C in October, outside the growing season.
    - Walker Lake exhibited a temperature difference between the surface and bottom that ranged from 13.4°C (June) to 18.0°C (August).
    - Maximum surface temperatures were 26.8°C in Big Twin Lake in July, 26.1 in Little Twin Lake in July, and 27.3°C in Walker Lake.
- Big Twin Lake and Walker Lake exhibited oxygen depletion in the bottom waters. Little Twin Lake was well oxygenated throughout the water column and exhibited higher oxygen concentrations at mid-depths, which occurs in some oligotrophic and mesotrophic lakes when phytoplankton at mid-depths produce extra oxygen.
- Oxygen values measured during the last two sampling dates (August and September/October) were abnormally low at the lake surface and it is likely the dissolved oxygen meter had not been calibrated properly. These were not used in assessing lake conditions for this report.

### *pH and Conductivity*

The acidity of water (concentration of hydrogen ions in water) is measured as pH and reported in standard units on a logarithmic scale that ranges from one to fourteen. Each pH unit represents a thousand-fold change in the free hydrogen ion concentration. On the pH scale, seven is neutral, lower numbers are more acidic, and higher numbers are more basic. Factors that can significantly affect the pH in a lake include the mineral composition of the surrounding watershed soils and the amount of algal growth occurring in the lake. Intense algal growth can drastically lower carbon dioxide concentrations in the water, which causes a rise in pH and alkalinity. In general, pH values between 6.0 and 8.0 are considered optimal for the maintenance of a healthy lake ecosystem. Many species of fish and amphibians have difficulty with growth and reproduction when pH levels fall below 5.5 standard units (s.u.). In almost all lakes, pH tends to be somewhat lower within the bottom waters due to carbon dioxide released by bacterial decomposition.

Surface pH values were generally between 7 and 7.5 within the three lakes. Surface pH values ranged from 6.6 in Walker Lake on September 17 to 7.8 in Walker Lake on June 19. Big Twin Lake had an average surface pH of 6.99. Little Twin Lake had an average surface pH of 7.39. Walker Lake had an average surface pH of 7.10. Bottom pH values ranged from 5.3 in Big Twin Lake on July 17 to 3.9 in Walker Lake on September 17. Big Twin Lake had an average bottom pH of 6.20. Little Twin Lake had an average bottom pH of 6.67. Walker Lake had an average surface pH of 6.48.

Conductivity (or specific conductance) is a measure of the ability of water to conduct electric current, and is related to the amount of dissolved ions within the water. Higher conductivity values are indicative of pollution by road salt or septic systems and more eutrophic conditions in a lake. Conductivities may be naturally elevated in stained water that drains from swamps and marshes. Clean, clear-water lakes typically have conductivities of around 20 to 30 micro-mhos per centimeter (µmhos/cm) while lakes in developed areas tend to have conductivities between 50 and 150 µmhos/cm.

Big Twin Lake had an average surface conductivity of 59.8 µmhos/cm and a bottom average conductivity of 55.0 µmhos/cm. Little Twin Lake had the highest conductivities overall, with a surface average of 125.0 µmhos/cm and a bottom average conductivity of 102.8 µmhos/cm. Walker Lake had an average surface conductivity of 55.8 µmhos/cm and an average bottom conductivity of 106.5 µmhos/cm. In Big Twin Lake and Little Twin Lake we did see the highest conductivities on the mid-July sampling date, when lake use may be at its highest. In all three lakes, we saw the lowest conductivities during the last sampling dates of the season, September 17 and October 2, presumably when lake use is at its lowest. These results suggest that septic systems, pet waste and fertilizer runoff may be negatively impacting the conductivities of these lakes.

**Table 1. 2011 Twin and Walker Creek Watershed Monitoring Program Lake Monitoring Results**

| *Waterbody Name* | *Date Collected* | *Total Phosphorus (mg/l)* | *Chlorophyll a (mg/l)* | *Secchi Depth (m)* |
|---|---|---|---|---|
| Big Twin-Lake | 6/19/2011 | 0.056 | 2.1 | 2.20 |
| | 7/17/2011 | 0.006 | 6.2 | 2.30 |
| | 8/21/2011 | 0.014 | 8.4 | 2.50 |
| | 10/2/2011 | 0.017 | 6.9 | 1.70 |
| | *Average* | ***0.023*** | ***5.9*** | ***2.18*** |
| | *Standard deviation* | ***0.022*** | ***2.7*** | ***0.34*** |
| | *Trophic State Index* | ***50*** | ***48*** | ***49*** |
| Little Twin Lake | 6/19/2011 | 0.009 | 2.8 | 3.00 |
| | 7/18/2011 | 0.021 | 2.7 | 3.40 |
| | 8/20/2011 | 0.015 | 10.2 | 4.65 |
| | 10/2/2011 | 0.006 | 5.5 | 2.00 |
| | *Average* | ***0.013*** | ***5.3*** | ***3.26*** |
| | *Standard deviation* | ***0.007*** | ***3.5*** | ***1.10*** |
| | *Trophic State Index* | ***41*** | ***47*** | ***43*** |
| Walker Lake | 6/19/2011 | 0.023 | 4.3 | 1.90 |
| | 7/17/2011 | 0.021 | 7.0 | 1.50 |
| | 8/20/2011 | 0.027 | 21.0 | 2.10 |
| | 9/17/2011 | 0.026 | 10.7 | 1.50 |
| | *Average* | ***0.024*** | ***10.8*** | ***1.75*** |
| | *Standard deviation* | ***0.003*** | ***7.3*** | ***0.30*** |
| | *Trophic State Index* | ***50*** | ***54*** | ***52*** |

**Figure 1. Comparison of Phosphorus-Based Trophic State Index 2002-2011 for Big Twin Lake, Little Twin Lake, and Walker Lake**

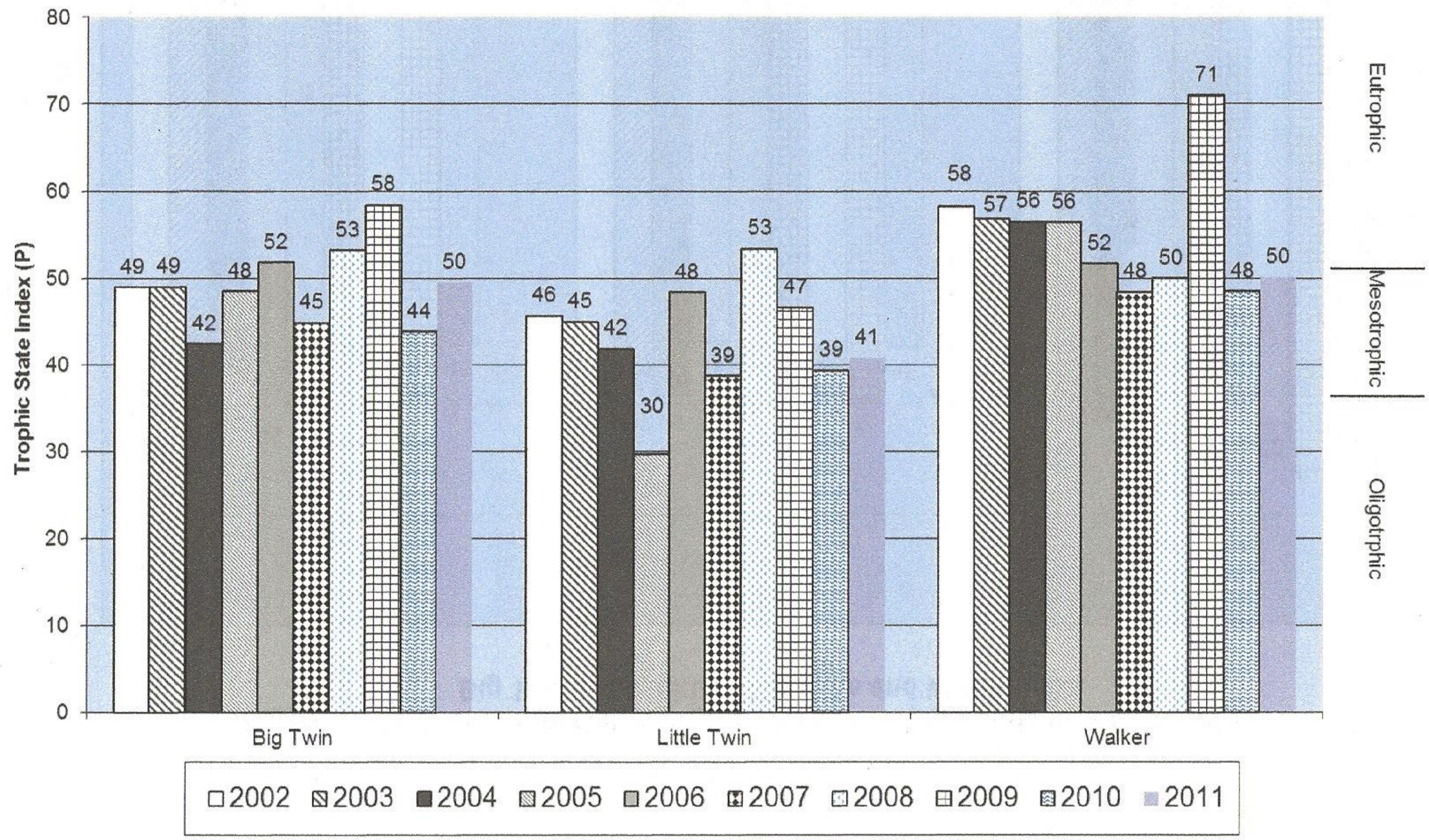


**Figure 2. Comparison of Chlorophyll a - Based Trophic State Index 2002-2011 for Big Twin Lake, Little Twin Lake and Walker Lake**

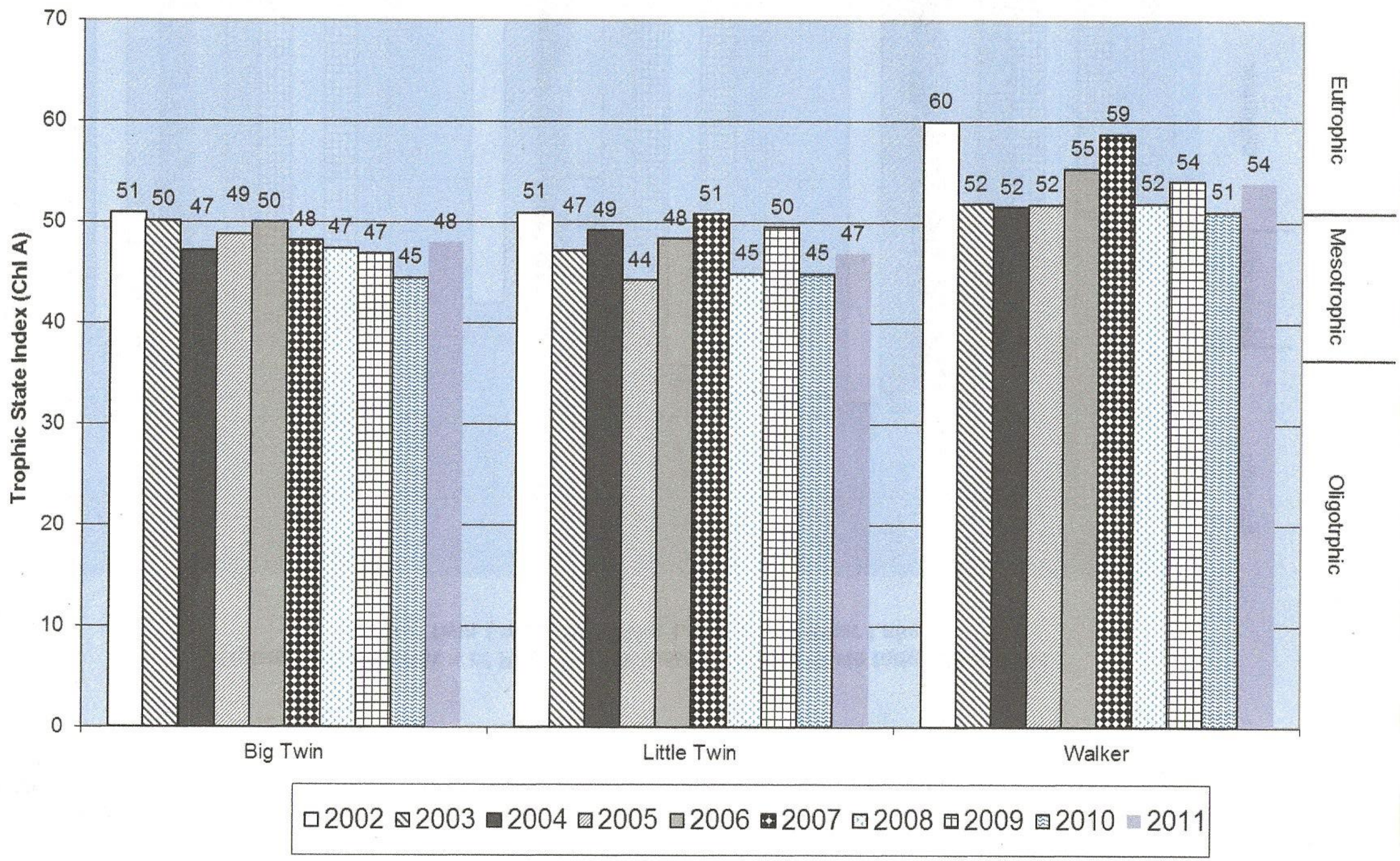
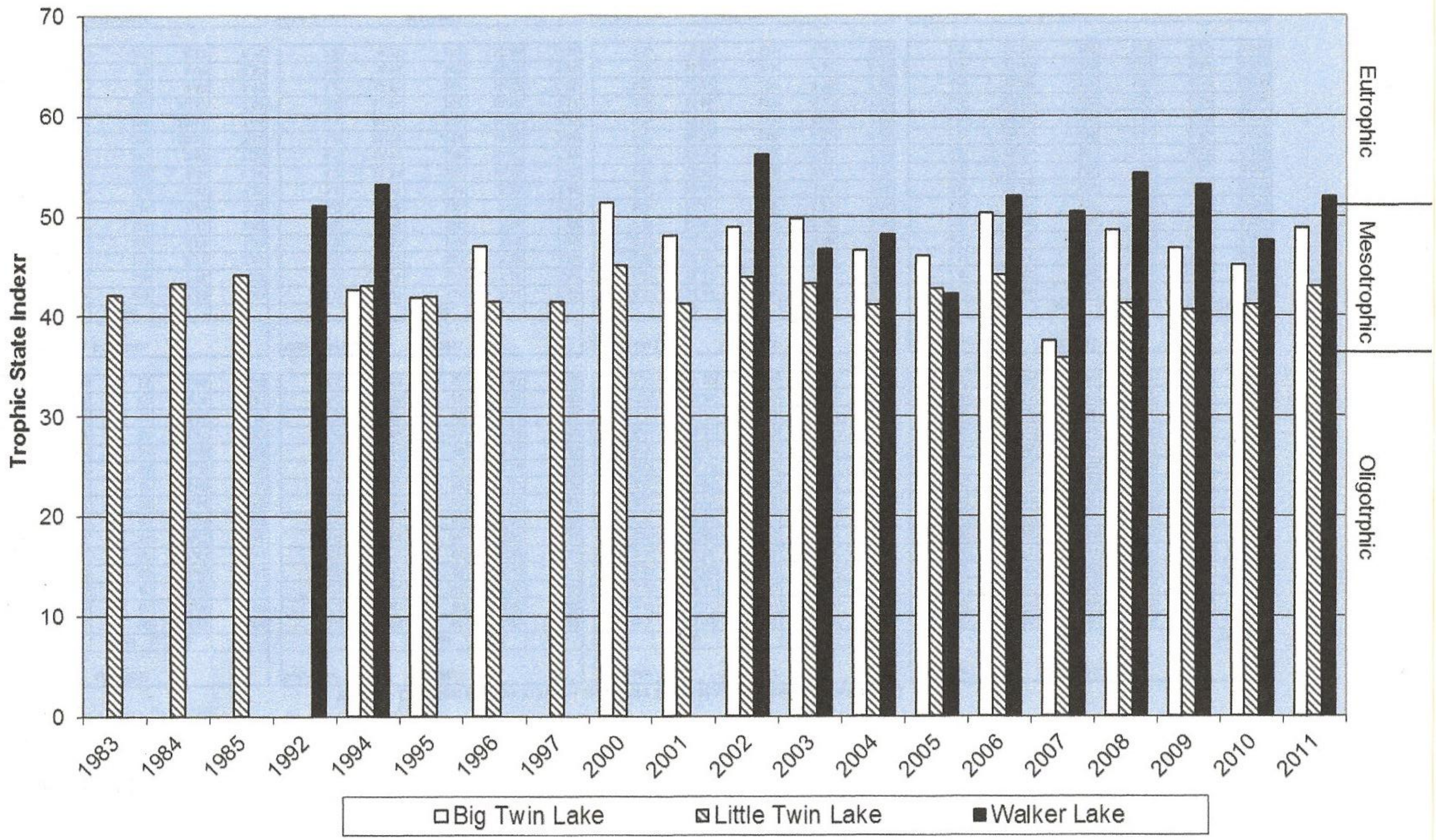


**Figure 3. Comparison of Secchi Depth-Based Trophic State Index for Big Twin Lake, Little Twin Lake, and Walker Lake 1983-2011**



## Table 2 - Chemical Profiles in Twin Lake, Little Twin Lake, and Walker Lake for 2011

**Twin Lake — 6/19/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 21.64 | 60 | 7.53 | 7.04 |
| 1.0 | 21.63 | 61 | 7.54 | 7.08 |
| 1.5 | 21.61 | 60 | 7.53 | 6.94 |
| 2.0 | 21.59 | 60 | 7.49 | 6.92 |
| 2.5 | 21.56 | 60 | 7.42 | 6.84 |
| 3.0 | 20.81 | 59 | 7.41 | 6.80 |
| 3.5 | 20.50 | 58 | 7.04 | 6.66 |
| 4.0 | 19.67 | 58 | 6.54 | 6.53 |
| 4.5 | 18.61 | 57 | 5.00 | 6.37 |
| 5.0 | 16.15 | 54 | 3.30 | 6.26 |
| 5.5 | 15.54 | 54 | 2.48 | 6.29 |
| 6.0 | 14.69 | 53 | 2.47 | 6.35 |
| 6.5 | 14.05 | 53 | 2.31 | 6.44 |
| 7.0 | 12.31 | 51 | 1.36 | 6.41 |
| 7.5 | 11.50 | 51 | 1.09 | 6.30 |

**Twin Lake — 7/17/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 26.75 | 68 | 7.25 | 7.07 |
| 1.0 | 25.87 | 66 | 7.48 | 7.03 |
| 1.5 | 25.50 | 65 | 7.36 | 6.99 |
| 2.0 | 25.40 | 65 | 7.40 | 6.93 |
| 2.5 | 25.32 | 65 | 7.25 | 6.85 |
| 3.0 | 25.08 | 65 | 6.92 | 6.71 |
| 3.5 | 24.32 | 63 | 7.09 | 6.57 |
| 4.0 | 22.92 | 61 | 6.03 | 6.43 |
| 4.5 | 20.39 | 59 | 2.47 | 6.26 |
| 5.0 | 17.34 | 58 | 0.13 | 6.30 |
| 5.5 | 15.47 | 59 | 0.13 | 6.31 |
| 6.0 | 14.64 | 59 | 0.14 | 6.32 |
| 6.5 | 14.20 | 60 | 0.17 | 6.20 |
| 7.0 | 13.44 | 59 | 0.26 | 5.93 |
| 7.5 | 12.46 | 59 | 1.01 | 5.30 |

**Twin Lake — 8/21/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 23.51 | 62 | 3.72 | 7.01 |
| 1.0 | 23.46 | 62 | 3.67 | 7.01 |
| 1.5 | 23.23 | 62 | 3.59 | 6.95 |
| 2.0 | 23.05 | 61 | 3.47 | 6.93 |
| 2.5 | 22.94 | 61 | 3.35 | 6.94 |
| 3.0 | 22.90 | 61 | 3.22 | 6.84 |
| 3.5 | 22.84 | 61 | 3.12 | 6.78 |
| 4.0 | 22.70 | 61 | 2.67 | 6.71 |
| 4.5 | 21.99 | 60 | 1.56 | 6.67 |
| 5.0 | 20.14 | 62 | 0.77 | 6.83 |
| 5.5 | 17.97 | 68 | 0.51 | 6.77 |
| 6.0 | 16.12 | 69 | 0.44 | 6.76 |
| 6.5 | 14.33 | 65 | 0.56 | 6.75 |
| 7.0 | 13.25 | 65 | 0.82 | 6.78 |
| 7.5 | 12.59 | 64 | 1.05 | 6.53 |

**Twin Lake — 10/2/2011**

| z | temp | cond | DO | pH | TDS (g/L) |
|---|---|---|---|---|---|
| 0.0 | 17.76 | 49 | 3.63 | 6.85 | 0.037 |
| 1.0 | 17.77 | 49 | 3.62 | 6.85 | 0.037 |
| 1.5 | 17.77 | 49 | 3.65 | 6.95 | 0.037 |
| 2.0 | 17.77 | 49 | 3.48 | 6.84 | 0.037 |
| 2.5 | 17.75 | 49 | 3.47 | 6.82 | 0.037 |
| 3.0 | 17.75 | 49 | 3.39 | 6.83 | 0.037 |
| 3.5 | 17.74 | 49 | 3.31 | 6.83 | 0.037 |
| 4.0 | 17.74 | 49 | 3.23 | 6.88 | 0.037 |
| 4.5 | 17.74 | 49 | 3.19 | 6.80 | 0.037 |
| 5.0 | 17.74 | 49 | 3.24 | 6.84 | 0.037 |
| 5.5 | 17.69 | 49 | 3.00 | 6.77 | 0.037 |
| 6.0 | 17.53 | 48 | 2.91 | 6.70 | 0.037 |
| 6.5 | 17.43 | 48 | 2.81 | 6.68 | 0.037 |
| 7.0 | 17.11 | 47 | 2.57 | 6.62 | 0.036 |
| 7.5 | 16.55 | 46 | 2.41 | 6.66 | 0.035 |

**Little Twin Lake — 6/19/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 21.98 | 128 | 7.59 | 7.42 |
| 1.0 | 21.97 | 128 | 7.68 | 7.43 |
| 1.5 | 21.87 | 127 | 7.72 | 7.57 |
| 2.0 | 21.71 | 126 | 7.64 | 7.33 |
| 2.5 | 21.23 | 124 | 7.71 | 7.32 |
| 3.0 | 20.67 | 124 | 7.99 | 7.32 |
| 3.5 | 17.74 | 121 | 9.32 | 7.25 |
| 4.0 | 17.56 | 120 | 9.33 | 7.16 |
| 4.5 | 15.20 | 115 | 9.81 | 7.14 |
| 5.0 | 13.44 | 109 | 10.13 | 7.12 |
| 5.5 | 11.68 | 105 | 10.11 | 7.09 |
| 6.0 | 10.02 | 101 | 10.12 | 7.09 |
| 6.5 | 9.17 | 99 | 9.47 | 6.97 |
| 7.0 | 8.47 | 99 | 9.07 | 6.80 |
| 7.5 | 8.09 | 100 | 9.12 | 6.71 |

**Little Twin Lake — 7/17/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 26.07 | 138 | 7.21 | 7.56 |
| 1.0 | 26.05 | 137 | 7.16 | 7.60 |
| 1.5 | 26.07 | 137 | 7.13 | 7.58 |
| 2.0 | 26.06 | 138 | 7.29 | 7.56 |
| 2.5 | 25.99 | 136 | 7.18 | 7.59 |
| 3.0 | 25.68 | 136 | 7.65 | 7.55 |
| 3.5 | 24.75 | 136 | 8.71 | 7.49 |
| 4.0 | 21.74 | 133 | 10.28 | 7.43 |
| 4.5 | 19.03 | 126 | 10.57 | 7.33 |
| 5.0 | 16.56 | 118 | 10.61 | 7.30 |
| 5.5 | 14.30 | 111 | 11.07 | 7.25 |
| 6.0 | 12.56 | 107 | 10.50 | 7.12 |
| 6.5 | 10.92 | 103 | 10.23 | 6.98 |
| 7.0 | 9.95 | 102 | 10.01 | 6.78 |
| 7.5 | 9.23 | 101 | 10.68 | 6.85 |

**Little Twin Lake — 8/21/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 23.44 | 128 | 3.36 | 7.38 |
| 1.0 | 23.44 | 128 | 3.42 | 7.36 |
| 1.5 | 23.46 | 129 | 3.48 | 7.36 |
| 2.0 | 23.43 | 129 | 3.48 | 7.37 |
| 2.5 | 23.42 | 129 | 3.50 | 7.36 |
| 3.0 | 23.41 | 129 | 3.52 | 7.36 |
| 3.5 | 23.40 | 129 | 3.52 | 7.36 |
| 4.0 | 23.40 | 129 | 3.54 | 7.35 |
| 4.5 | 22.57 | 129 | 3.61 | 7.19 |
| 5.0 | 20.01 | 130 | 4.52 | 7.01 |
| 5.5 | 17.50 | 123 | 5.05 | 7.09 |
| 6.0 | 14.85 | 115 | 5.10 | 7.12 |
| 6.5 | 12.32 | 109 | 4.70 | 7.00 |
| 7.0 | 11.11 | 105 | 4.37 | 6.89 |
| 7.5 | 9.80 | 101 | 4.23 | 6.82 |

**Little Twin Lake — 10/2/2011**

| z | temp | cond | DO | pH | TDS (g/L) |
|---|---|---|---|---|---|
| 0.0 | 18.34 | 106 | 2.97 | 7.20 | 0.079 |
| 1.0 | 18.32 | 106 | 2.94 | 7.17 | 0.079 |
| 1.5 | 18.34 | 105 | 2.80 | 7.15 | 0.079 |
| 2.0 | 18.33 | 106 | 2.79 | 7.16 | 0.079 |
| 2.5 | 18.33 | 106 | 2.65 | 7.12 | 0.079 |
| 3.0 | 18.33 | 105 | 2.54 | 7.10 | 0.079 |
| 3.5 | 18.32 | 105 | 2.37 | 7.13 | 0.079 |
| 4.0 | 18.24 | 105 | 2.38 | 7.03 | 0.078 |
| 4.5 | 18.23 | 105 | 2.21 | 6.99 | 0.078 |
| 5.0 | 18.16 | 104 | 2.13 | 6.90 | 0.078 |
| 5.5 | 18.11 | 105 | 1.91 | 6.78 | 0.078 |
| 6.0 | 17.22 | 110 | 1.54 | 6.64 | 0.084 |
| 6.5 | 15.46 | 114 | 1.31 | 6.54 | 0.090 |
| 7.0 | 13.45 | 113 | 1.21 | 6.46 | 0.094 |
| 7.5 | 11.78 | 109 | 1.20 | 6.28 | 0.095 |

**Walker Lake — 6/19/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 21.77 | 60 | 6.78 | 7.80 |
| 1.0 | 21.30 | 58 | 6.81 | 7.70 |
| 1.5 | 20.77 | 58 | 6.68 | 7.67 |
| 2.0 | 20.60 | 58 | 6.62 | 7.63 |
| 2.5 | 19.52 | 45 | 6.52 | 7.59 |
| 3.0 | 17.67 | 51 | 4.56 | 7.29 |
| 3.5 | 15.54 | 47 | 2.46 | 6.95 |
| 4.0 | 13.32 | 45 | 1.86 | 6.78 |
| 4.5 | 11.44 | 43 | 1.18 | 6.66 |
| 5.0 | 10.31 | 42 | 0.56 | 6.59 |
| 5.5 | 9.20 | 47 | 0.27 | 6.51 |
| 6.0 | 8.63 | 58 | 0.24 | 6.47 |
| 6.5 | 8.39 | 70 | 0.22 | 6.52 |

**Walker Lake — 7/17/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 25.13 | 61 | 7.20 | 7.02 |
| 1.0 | 24.86 | 61 | 8.22 | 7.03 |
| 1.5 | 24.68 | 61 | 7.20 | 7.01 |
| 2.0 | 24.42 | 59 | 6.81 | 6.95 |
| 2.5 | 22.95 | 53 | 5.08 | 6.67 |
| 3.0 | 19.81 | 51 | 1.32 | 6.18 |
| 3.5 | 17.59 | 52 | 0.36 | 5.95 |
| 4.0 | 14.90 | 48 | 0.27 | 5.87 |
| 4.5 | 12.46 | 45 | 0.18 | 5.78 |
| 5.0 | 10.82 | 47 | 0.15 | 5.78 |
| 5.5 | 9.80 | 54 | 0.13 | 5.86 |
| 6.0 | 9.05 | 71 | 0.13 | 6.03 |
| 6.5 | 8.68 | 91 | 0.11 | 6.29 |

**Walker Lake — 8/21/2011**

| z | temp | cond | DO | pH |
|---|---|---|---|---|
| 0.0 | 27.32 | 65 | 3.23 | 6.97 |
| 1.0 | 23.67 | 60 | 3.47 | 6.88 |
| 1.5 | 22.98 | 58 | 3.49 | 6.85 |
| 2.0 | 22.47 | 58 | 3.55 | 6.88 |
| 2.5 | 21.62 | 47 | 3.35 | 6.73 |
| 3.0 | 20.60 | 44 | 3.04 | 6.49 |
| 3.5 | 19.12 | 52 | 2.29 | 6.18 |
| 4.0 | 16.26 | 52 | 1.58 | 6.00 |
| 4.5 | 14.60 | 49 | 1.25 | 5.90 |
| 5.0 | 12.63 | 51 | 1.06 | 5.84 |
| 5.5 | 11.35 | 64 | 0.80 | 5.85 |
| 6.0 | 10.08 | 81 | 0.69 | 6.00 |
| 6.5 | 9.35 | 120 | 0.69 | 6.24 |

**Walker Lake — 9/17/2011**

| z | temp | cond | DO | pH | TDS (g/L) |
|---|---|---|---|---|---|
| 0.0 | 17.86 | 37 | 1.78 | 6.60 | 0.028 |
| 1.0 | 17.91 | 37 | 1.81 | 6.63 | 0.028 |
| 1.5 | 17.72 | 37 | 1.80 | 6.62 | 0.028 |
| 2.0 | 17.71 | 37 | 1.75 | 6.56 | 0.028 |
| 2.5 | 17.47 | 36 | 1.74 | 6.54 | 0.028 |
| 3.0 | 17.41 | 36 | 1.77 | 6.50 | 0.028 |
| 3.5 | 16.97 | 36 | 1.62 | 6.40 | 0.028 |
| 4.0 | 16.53 | 36 | 1.49 | 6.29 | 0.028 |
| 4.5 | 15.89 | 39 | 0.12 | 6.20 | 0.030 |
| 5.0 | 14.84 | 43 | 0.80 | 6.20 | 0.034 |
| 5.5 | 12.32 | 78 | 0.66 | 6.32 | 0.067 |
| 6.0 | 11.12 | 114 | 0.56 | 6.58 | 0.100 |
| 6.5 | 9.98 | 145 | 0.51 | 6.87 | 0.132 |

**Figure 4. Temperature Profiles in 2011 for Big Twin Lake, Little Twin Lake and Walker Lake**

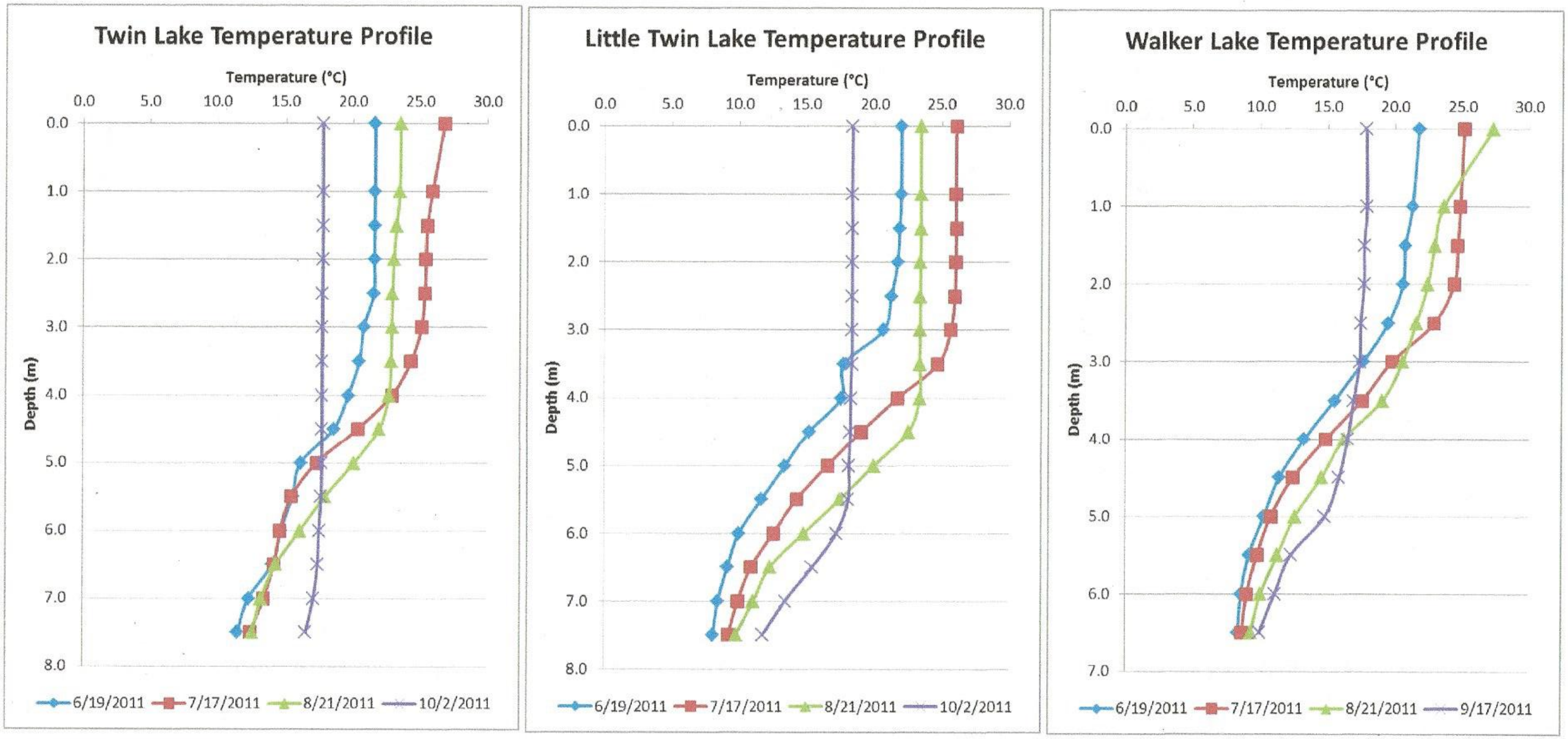
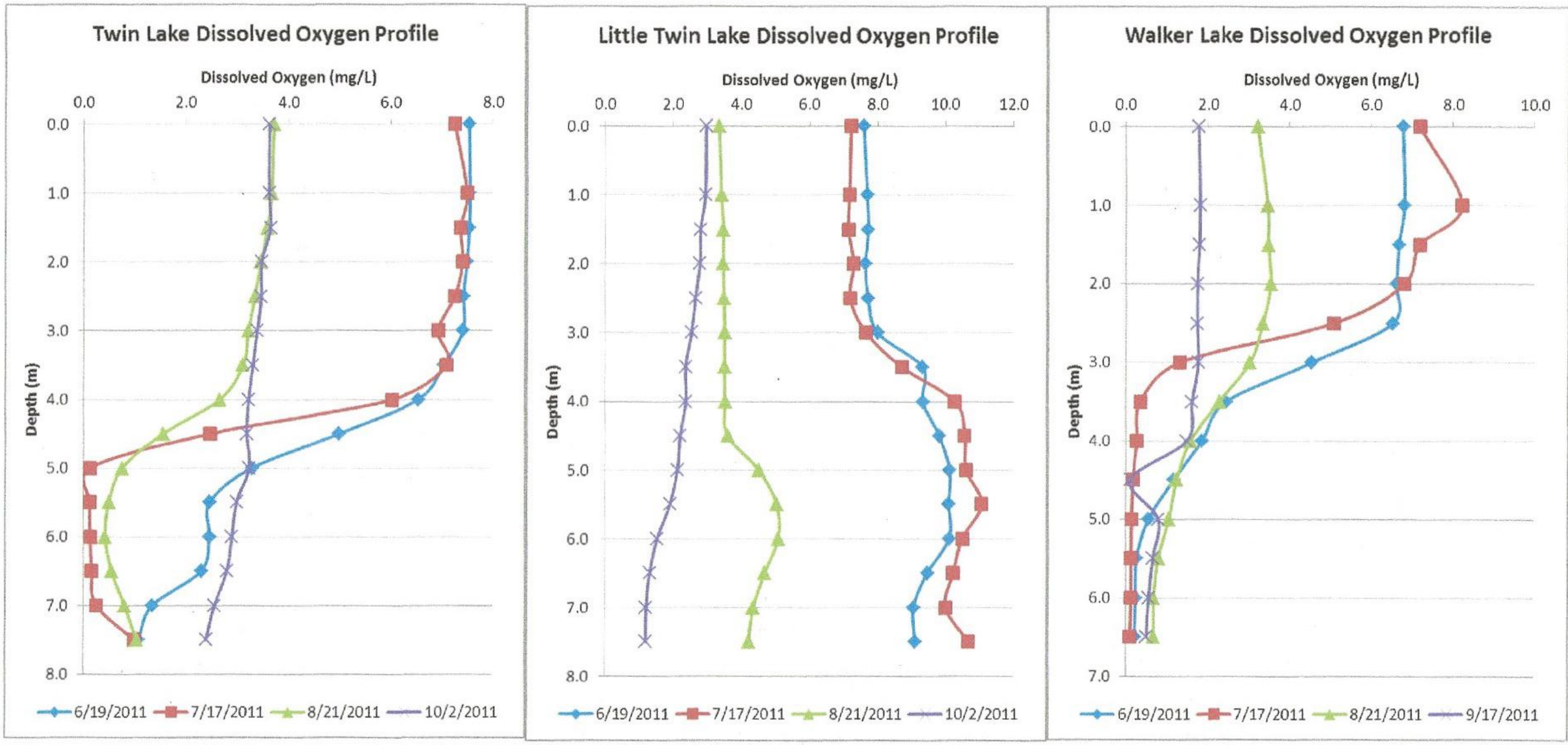


**Figure 5. Dissolved Oxygen Profiles in 2011 for Big Twin Lake, Little Twin Lake and Walker Lake**



Big Twin Lake
Big Twin Lake can be classified as mesotrophic with respect to total phosphorus, chlorophyll a and transparency during 2011. Overall, conditions were similar to the past number of years. Based upon oxygen and temperature profiles, Big Twin Lake would not be capable of sustaining a cold-water fishery but warm-water fish should do well within the lake. The pH level of the lake was excellent.

Little Twin Lake
Little Twin Lake was mesotrophic with respect to total phosphorus, chlorophyll a and transparency during 2011. Little Twin continued to have the best water quality of the three lakes. The Secchi depth and chlorophyll a TSI value in Little Twin Lake was similar to prior years, while total phosphorus TSI values remain quite low compared to the last several years. Based upon oxygen and temperature profiles, Little Twin Lake may be capable of supporting a cold-water fishery, especially using the less sensitive cold-water fish, such as brown trout and rainbow trout. An analysis of the existing fish within the lake would be advisable before any stocking program is attempted. The pH level of the lake was excellent.

Walker Lake
Walker Lake was mesotrophic based on the total phosphorus TSI during 2011, and eutrophic based upon the Secchi depth and chlorophyll a TSI values. Overall, Walker Lake would be classified as eutrophic for 2011. Chlorophyll a, in particular, was in the eutrophic range and similar to previous years. Based upon oxygen and temperature profiles, Walker Lake would not be capable of sustaining a cold-water fishery but warm-water fish should do well within the lake. The pH level of the lake was excellent.

***Conclusions and Recommendations***

In general, Walker Lake had the worst water quality in 2011 while Little Twin Lake had the best water quality in 2011. In general, water quality was slightly worse in 2011 with respect to total phosphorus, chlorophyll a and transparency values. However, year to year variability indicates the lakes are sensitive to any increase in nutrient inputs. Evidence of higher conductivities during periods of increased lake usage and lower conductivities during decreased lake usage suggest that septic systems and runoff from lawns may be a factor in affecting the water quality of these three lakes. Dissolved oxygen and temperature profiles have indicated that Big Twin Lake and Walker Lake experience oxygen depletion in the bottom waters, while Little Twin Lake does not and may be capable of supporting a cold-water fishery.

Nutrient reduction strategies that reduce the introduction of nutrients into the lakes should be implemented to maintain or reestablish mesotrophic conditions. Such strategies include septic system upgrades, diversion and/or treatment of storm water, and the control of Canada geese populations. An educational program for lakefront property owners should be put in place in order to instruct those homeowners on proper lakefront best management practices for protecting and restoring good water quality. This program can include lectures and educational materials on lakefront landscaping, proper use of fertilizer, pet waste management, runoff control, and the identification and management of invasive species, aquatic plants, and algae.

In 2012, volunteers need to be retrained on calibrating the dissolved oxygen meter, stressing the importance of calibrating the meter each time sample collection occurs.

Thank you again for choosing F. X. Browne, Inc. for your lake consulting needs. We look forward to continuing our work together in the future. If you should have any questions concerning the 2011 report, please contact me at mmartin@fxbrowne.com at any time.

NALMS
Certified Lake Manager
#93-02M Date 12/15/11

Sincerely,

**F. X. Browne, Inc.**

Michael R. Martin, CLM
Senior Project Scientist