US Army Corps
of Engineers
Kansas City District

2006 Annual Water Quality Program Report -- Kansas City District

Stockton Lake Site 9 (photo by Steve Fischer)

April 2007

2006 Annual Water Quality Program Report – Kansas City District

Prepared by:

Water Quality Program
Environmental Resources Section
Planning Branch
Planning, Programs and Project Management Division
Kansas City District
U.S. Army Corps of Engineers

April 2007

This document is approved for implementation:

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Vision Statement

Provide a reliable and responsive surface water quality monitoring program to all 18 of the district's lake watersheds, Civil Works projects, and the lower Missouri River.

Mission

Operate in concert with the Planning Branch and Operations Division to form one seamless team. We will provide support and solutions through timely and helpful communication with our customers and partners. We respond to emerging issues by increasing our knowledge through technical courses and training workshops. Program integrity allows us to complete our mission in a reliable manner.

Photo by Mike Watkins (USACE – NWK)

1 Introduction

The Water Quality Program is responsible for surface water quality issues related to all waters under the district's jurisdiction. All groundwater related issues are handled by other programs within the district.

Water quality is an integral component of all Corps civil works missions. The Kansas City District is mandated to meet federal and state water quality standards and stewardship responsibilities at such civil works projects. These standards and responsibilities are described in the Corps Engineering Regulation – *Water Quality and Environmental Management for Corps Civil Works Projects (ER 1110-2-8154, 1995)*, and Corps Environmental Operating Principles.

According to ER 1110-2-8154, an ongoing water quality monitoring program is necessary at all Corps projects. Such data is essential to effectively understand and manage the natural resources of the Corps water projects. Districts must also develop specific water quality management objectives for each project, including an outline of detailed procedures to be implemented to meet stated objectives. Those objectives must be included in the project water control plans, which are reviewed and updated at least once every 10 years. Water quality is an integral part of water control management.

Finally, ER 1110-2-8154 states -- "The water quality program provides one of the greatest opportunities for the Corps to demonstrate its commitment to environmental leadership, conservation, restoration, and stewardship."

1.1 Delivery Team

The Kansas City District's Water Quality Program is comprised of the following individuals:

Program Manager:	Steve Fischer, Limnologist (CENWK-PM-PR-W)
Section Supervisor:	Dr Chris White (CENWK-PM-PR)
Primary Support Staff:	Student Intern
Secondary Support Staff:	USACE, Kansas City District Operations Division – Operations Managers USACE, Kansas City District Operations Division – Park Rangers USACE, Chemical and Materials Quality Assurance Laboratory (CMQA) – Omaha Laboratory

In addition, data generated by this program is shared with the following non-Corps watershed stakeholders:

- State Water Quality Agencies
- State Fisheries Agencies
- Universities

- Watershed alliances

1.2 Connection to Strategic Plan

A Program Management Plan (*Program Management Plan for the Kansas City Districts Water Quality Program (1/07)*) will serve as the operating guidance document for implementation of the US Army Corps of Engineers, Northwest Division, Kansas City District's (NWK) Water Quality Program. Please reference that document regarding specific program goals, objectives and strategies for implementation of the NWK's Water Quality Program.

1.3 Connection to Annual Work Plan and 2006 Accomplishments

Below is a description of accomplishments for the Water Quality Program during the previous calendar year. Accomplishments are divided into seven categories (Monitoring and Assessment, Data Management, Technical Support, Program Development and Evaluation, Interagency Coordination, Staffing, and Miscellaneous) to best track annual activities.

1.3.1 Monitoring and Assessment

Specific details on water quality assessments conducted during the past year are described in detail below and later sections of this report.

1.3.1.1 Lakes

Water quality monitoring was conducted at all 18 NWK lakes from April through September during 2006. The three-year rotational schedule requires categorizing lakes as either 'Ambient' or 'Intensive' in terms of monitoring effort (see WQ Program Management Plan for details). For 2006, 'Intensive' lakes were: Kanopolis, Milford, Rathbun, Longview, Stockton, and Long Branch. The remaining 12 lakes were categorized as 'Ambient' lakes during the past year. In addition, we continued the cooperative monitoring effort with Iowa State University and Iowa DNR in the Rathbun Lake watershed. Details on status and trends of specific water quality variables are provided by lake in sections 2 – 20 of this report.

1.3.1.2 River

No monitoring was conducted on the Missouri River during 2006.

1.3.2 Data Management

Laboratory data currently is entered and stored as Excel files (*.xls), while Hydrolab DataSonde data is downloaded as a *.csv file and stored as a *.xls file. Historic data (1995 – 2005) was located, compiled, consolidated into lake specific folders by year and then stored in P:/KC Water Quality/. The P: drive is accessible via the internal network. In addition, a CD back-up was created and is stored at the Troost Lab. The back-up is updated at least two-times per year. No data was stored nor entered into either DASLER or STORET since training had not been received as of yet.

1.3.3 Technical Support

Technical assistance was requested and provided to the following NWK projects during 2006:

- Tuttle Creek dam modification project (Lisa Rabee)
- Truman Dam DO monitoring system upgrade (Greg Hutinger)
- Upper Turkey Creek (Brian Rast)
- Brush Creek (Brian Rast)
- Blue River (Scott Gard)

Technical assistance and/or data needs were requested and provided externally to the following during 2006:

- KDHE
- Iowa DNR
- Iowa State University
- Smoky Hill / Big Creek WRAPS
- Upper Wakarusa WRAPS
- Smithville Lake Watershed Association
- Missouri Department of Natural Resources
- HNTB for Clinton Lake data
- City Utilities – Springfield – Stockton data
- Kansas State University
- Melvern Lake Watershed Project
- Delaware River WRAPS
- NE DEQ

1.3.4 Program Development and Evaluation

A Program Management Plan (PGmP) was developed and reviewed both internally (David Combs and Dr Chris White) and externally (Dave Jensen, NWO). The PGmP was approved in January 2007. Staffing limitations prevented development of SOP manuals as highlighted in the 2006 Work Plan.

1.3.5 Interagency Coordination

Contact was made with staff at the following federal and state agencies during 2006: EPA, USGS, KDHE, MDNR, MDOC, IDNR, and NEDEQ. Data on district lakes was shared with KDHE, NEDEQ, IDNR and MODNR. Sampling was coordinated with KDHE for lakes in Kansas. Contact was made with watershed groups associated with the following lakes: Kanopolis, Clinton, Tuttle Creek, Milford, Melvern, Hillsdale, Perry, Pomona, Smithville, and Rathbun. One noticeable weakness of watershed protection and restoration efforts by these NGO groups is the lack of data collection and monitoring. Thus, the NWK WQ program can provide a vital service to such efforts by providing status and trend data.

1.3.6 Staffing

Although the NWK Water Quality Program currently only consists of one full-time person (GS-12 Limnologist), two unfilled positions still remain dedicated (GS-12 Limnologist and GS-11 Biologist) to the program. No funding was available for a summer intern during 2006.

1.3.7 Miscellaneous

One of the major miscellaneous activity tracking categories involves communication. Communication is vital to maintain program integrity and exposure, both internally as well as externally. It is the key method of promoting USACE involvement in watershed activities.

1.3.7.1 Communication
1.3.7.1.1 Meetings

The following meetings were attended during the past calendar year:

- Missouri Water Quality Coordination Committee
- University of Kansas, Kansas Biological Survey
- Water and the Future of Kansas
- Rathbun Lake
- Smithville Lake Watershed Association
- Upper Wakarusa WRAPS
- Tuttle Creek WRAPS
- Delaware River (Perry Lake) WRAPS
- Pomona WRAPS
- Smoky Hill River WRAPS
- Kansas WRAPS Conference
- EPA Region 7 Fish Tissue Contaminant Work Group
- NALMS (Madison, WI)

1.3.7.1.2 Presentations

USACE water quality data was presented at the following meetings / conferences:

- Upper Wakarusa WRAPS – rural subcommittee meeting – December 2005
- Missouri Natural Resources Conference (Osage Beach, MO) -- February 2006
- Upper Wakarusa WRAPS – urban subcommittee meeting – March 2006
- Delaware River WRAPS – August 2006

1.3.7.1.3 Articles

An article was written for the University of Missouri Lake Volunteer Monitoring Program's winter newsletter (*The Water Line*). It highlighted the NWK Water Quality program and provided an overview of water quality issues at the seven lakes within Missouri.

1.3.7.2 Training

No training was received during 2006 due to budget limitations.

2 Blue Springs Lake

2.1 General Background

Blue Springs Lake was impounded in 1988, and reached full pool on 18 March 1990. The main threats to the water quality of Blue Springs Lake are nutrients, bacterial contamination, herbicides / pesticides, and other contaminants related to an urban environment. An exotic aquatic plant, Eurasian Milfoil (*Myriophyllum spicatum*), is present in the lake and is a serious concern of Jackson County Parks and Recreation Department (JCPRD). An unsuccessful drawdown was attempted in 2002 to control the plant. As a follow-up, JCPRD and the Missouri Department of Conservation (MDC) conducted a test treatment in one cove during 2005. Although test results were mixed, it was concluded that Sonar would not be a cost effective treatment for milfoil in Blue Springs Lake. Aquatic vegetation control efforts are important to overall lake water quality, as this undesirable plant does serve as a nutrient sink.

2.1.1 Location

A dam located 7.4 river km (4.6 river miles) upstream on the East Fork of the Little Blue River impounds Blue Springs Lake; the dam is 46 river km (28.8 river miles) upstream of the Missouri River. The lake is located approximately 26.8 km (17 miles) east-southeast of downtown Kansas City, in Jackson County, Missouri. Historic water quality sample sites at Blue Springs Lake include 3 lake, 1 outflow, and 0 inflow sites (Figure 2.1).

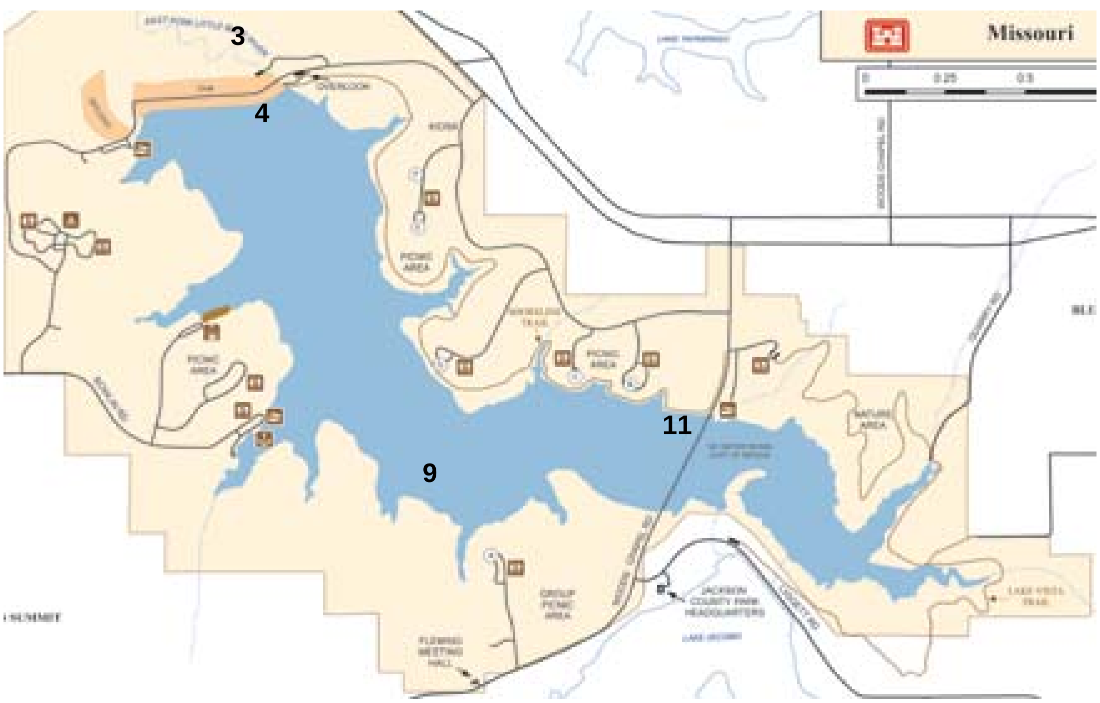


Figure 2.1. Blue Springs Lake area map with sample site locations and numbers.

2.1.2 **Authorized Purposes:** flood control, recreation, and fish and wildlife conservation, and water quality improvement.

2.1.3 **State Use Designations:** Aquatic life, human health / fish consumption, whole-body contact, boating and canoeing, and livestock & wildlife watering.

2.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	820.3	15.8	982	
Multipurpose	802.0	10.8	722	12
Total		26.6		

Total watershed area: 32.8 sq. miles (20,992 A)
Watershed ratio: 21.38 flood control (FC) / 29.07 multipurpose (MP)
Average Annual Inflow: 26,135 acre-ft/yr (1990 – 2006)
Average Annual outflow: 000 acre-ft
Sediment inflow (estimated): 3 acre-ft/yr
Flushing rate: 0.41 years
Water management Plan: Approved 27 January 1994
Historic stage hydrograph: 1996 – 2006 (Figure 2.2)

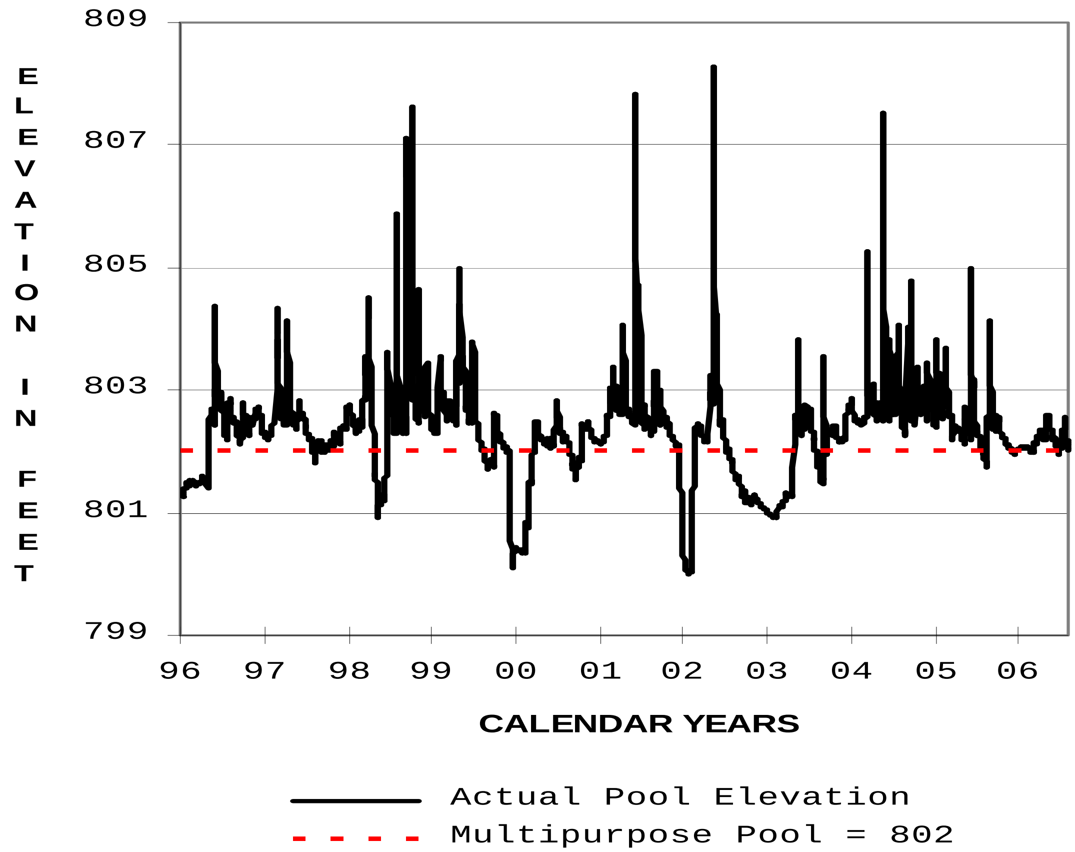


Figure 2.2. Pool elevation hydrograph from 1996 – 2006 (red dashed line is multipurpose pool elevation).

2.2 2006 Activities

Blue Springs Lake was categorized as an ‘ambient’ lake during 2006, thus only surface samples were collected at the three lake sites. Samples were collected from May through September. The mid-lake site (Site 9) was dropped from sampling after July because data was similar to the down-lake site (Site 4) and would be a programmatic cost savings. Todd Gemeinhardt (MO Dept. of Conservation) provided field assistance and a boat at Blue Springs Lake during 2006. Fecal bacteria (*Escherichia coli*) samples were collected weekly at the swimming beach from April through September by JCPRD.

2.3 2006 Data

Comparative historic data is limited to single samples from 1999 (June) and 2002 (July), four monthly samples during 2004 (April - July), and four months of data during 2005 (May through July and September). Samples were collected from May through September during 2006.

2.3.1 Inflow

There is no inflow sample site at Blue Springs Lake because Lake Jacomo dam is immediately above the lake.

2.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. In regards to nutrients, total nitrogen (TN) concentrations from surface samples are relatively consistent between all three lake sites, with median values of samples collected between 1999 and 2005 ranging from 0.72 – 0.78 mg/L (Figure 2.3). Although all samples exceed the proposed EPA nutrient criteria value of 0.36 mg/L TN, these are some of the lowest median values within the district.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Total phosphorus (TP) concentrations are low compared to the other district lakes, with median values ranging from 0.04 – 0.06 mg/L (Figure 2.4). All values exceed EPA’s proposed nutrient criteria value of 0.02 mg/L. However, the exotic milfoil most likely serves as a nutrient sink for phosphorus within the lake. A high flushing rate and presence of aquatic vegetation likely result in lower TP concentrations – even in an urban watershed.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 2.5 as an example from Site 4. Median TN:TP ratios

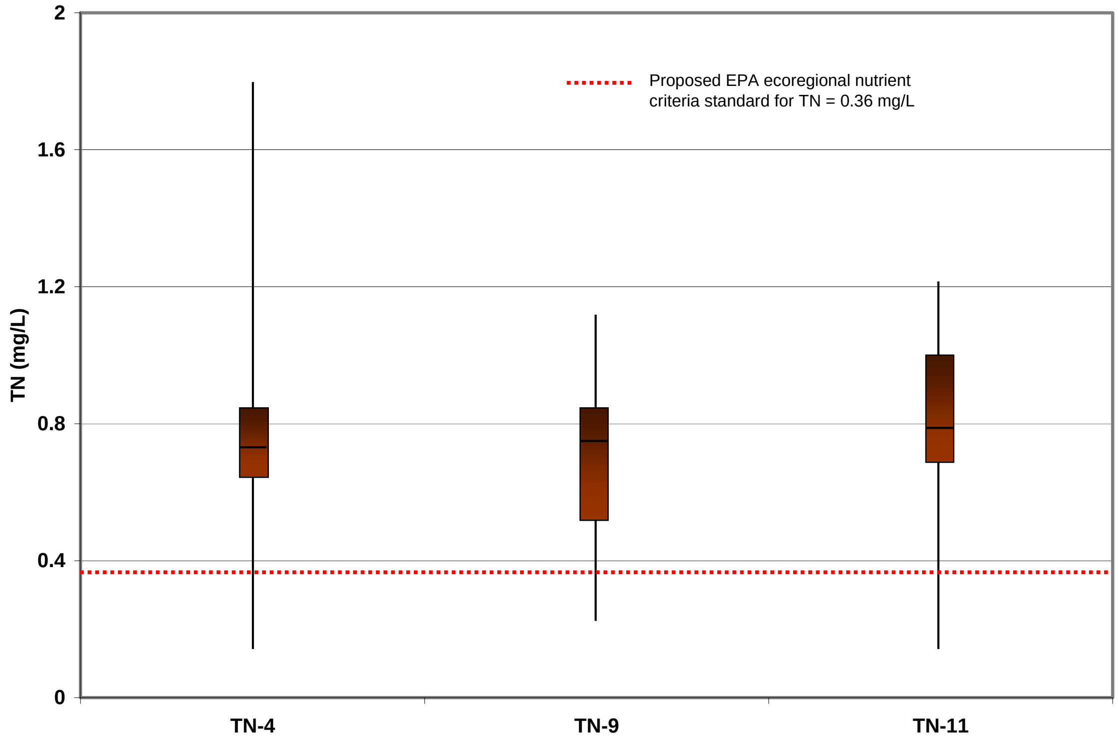


Figure 2.3. Box plots of surface water sample total nitrogen concentrations measured at lake sites from 1999 through 2006 at Blue Springs Lake.

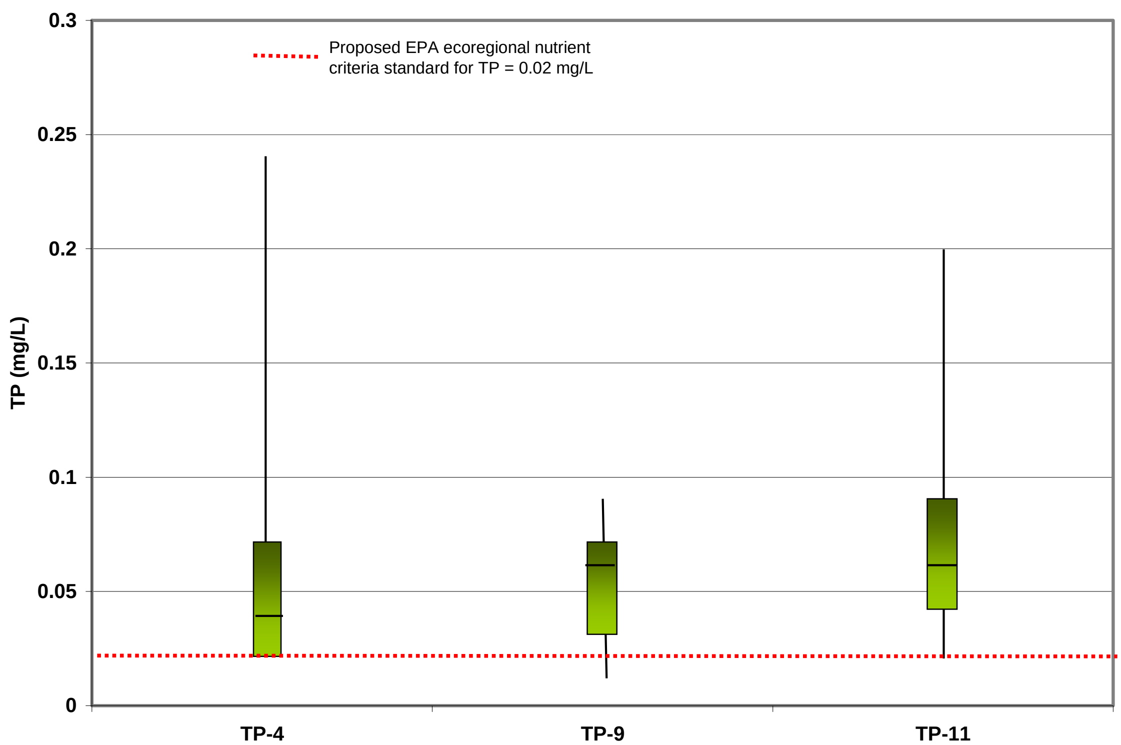


Figure 2.4. Box plots of surface water sample total phosphorus concentrations measured at lake sites from 1999 through 2006 at Blue Springs Lake.

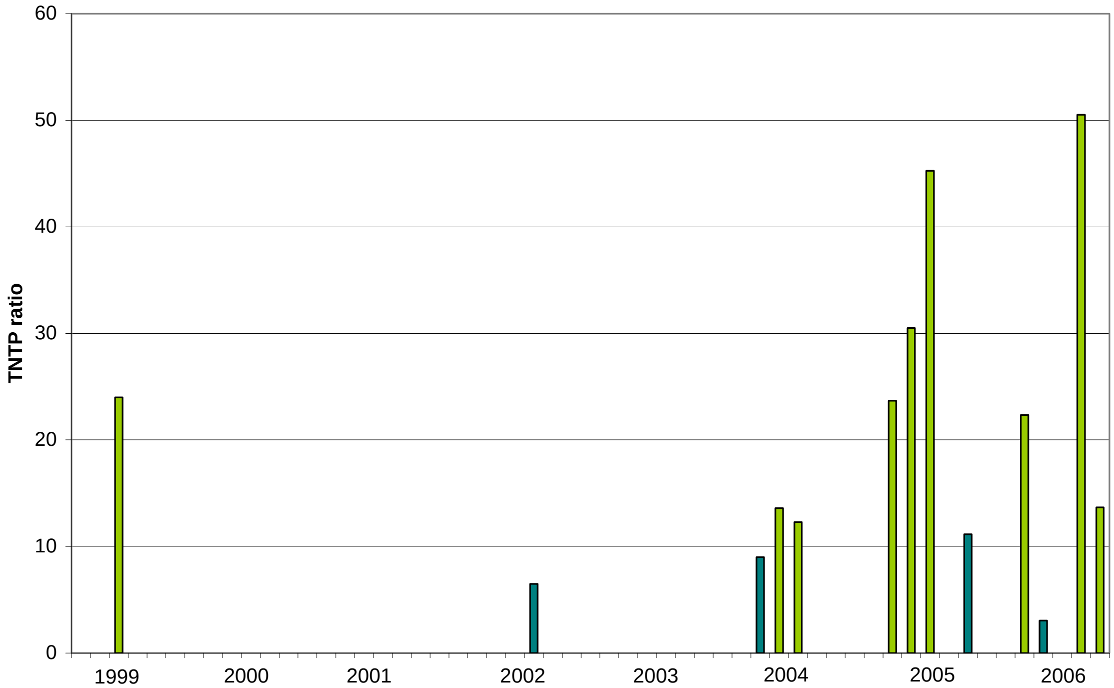


Figure 2.5. Graph of total nitrogen : total phosphorous (TN : TP) ratio by sample date at Site 4 from 1999 through 2006 at Blue Springs Lake.

from the upper lake sites were slightly greater than 12, indicating the lake could potentially be at risk for cyanobacteria blooms.

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 2.6 depicts vertical distribution of phycocyanins measured at Site 4 (Tower) from May through September. Concentrations increased gradually from May into June, but expanded greatly during July and September.

Chlorophyll *a* samples were collected at Sites 4 and 11 during July and August 2006. Mean chlorophyll a values by sample date ranged from 34.18 – 47.5 ug/L, which is indicative of eutrophic waters. Box plots of chlorophyll *a* indicate similar median values between sites (Figure 2.7), although values are variable between months. Mean TSI values averaged 62.4 for both Sites 4 and 11, which further classifies Blue Springs Lake as eutrophic.

Secchi depths indicated relatively good water clarity during May and June at Site 4, but measurements were less than historic summer means during both July and August (Figure 2.8). This was most likely the result of increased algal production, as was measured by both chlorophyll and relative bluegreen algal concentrations (Figure 2.6). As expected, secchi depths were consistently lower at the shallow upper site in comparison to the dam site (Figure 2.8).

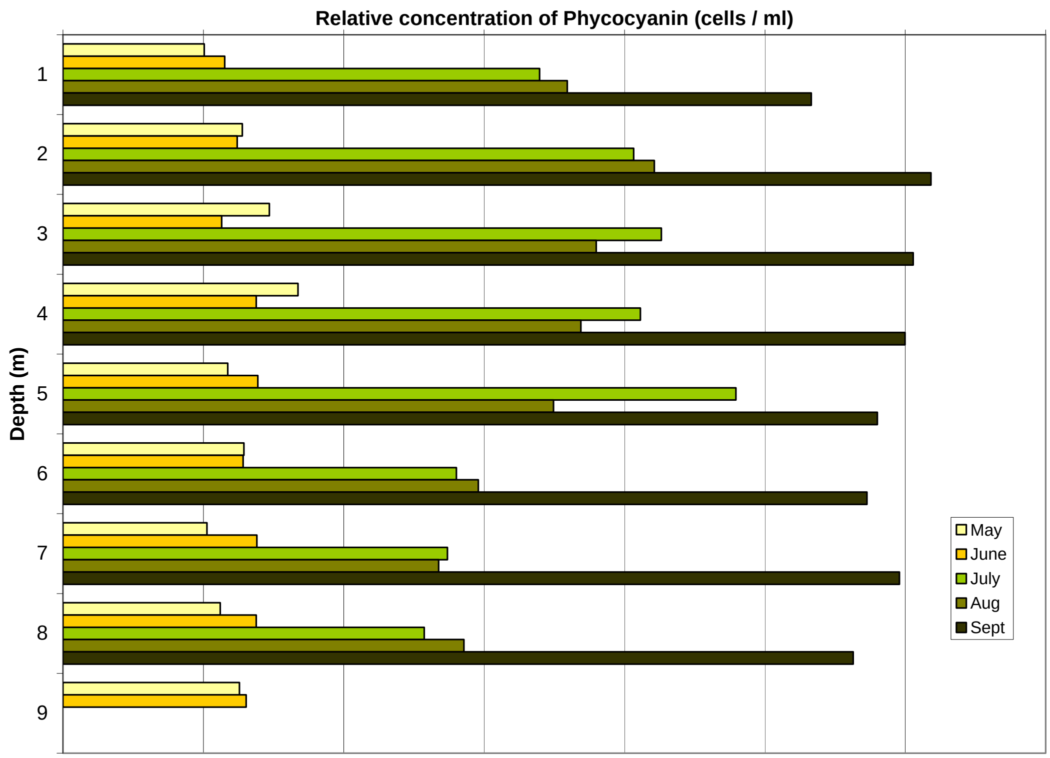


Figure 2.6. Plot of relative phycocyanin (bluegreen algae) concentrations (cells / ml) measured by depth and month at Blue Springs Lake Site 4 during 2006.

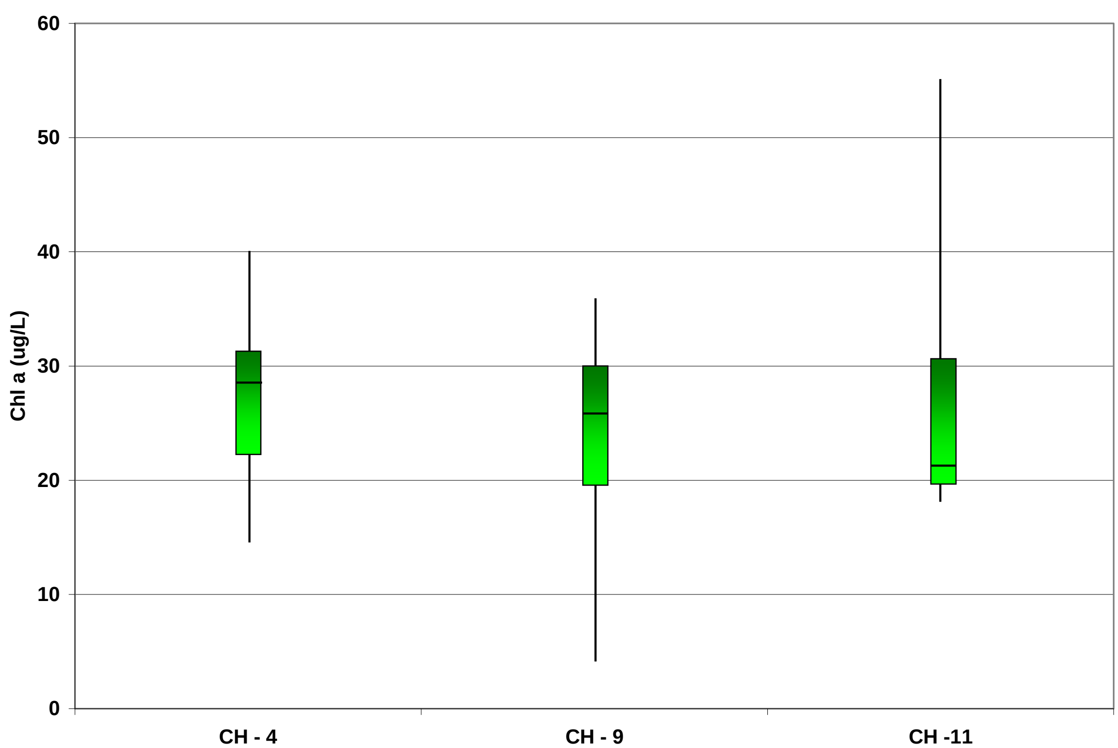


Figure 2.7. Box plots of chlorophyll a concentrations measured at lake sites from 1999 through 2006 at Blue Springs Lake.

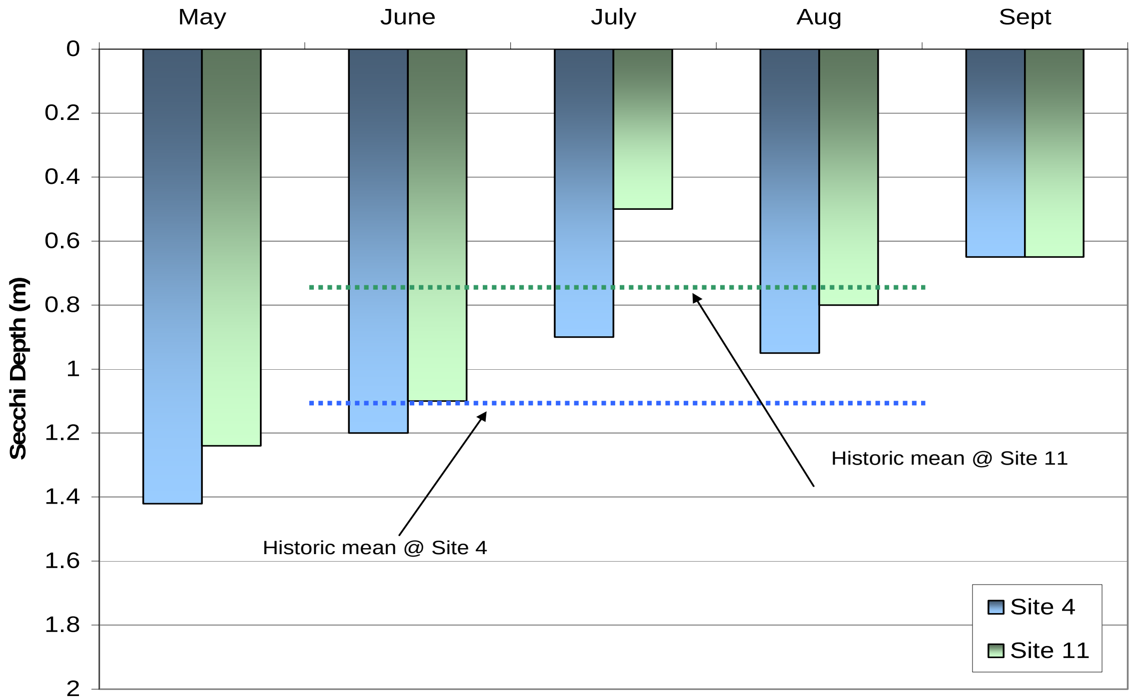


Figure 2.8. Plots of secchi depth measurements by site and sample date during 2006. Dotted lines represent historic mean values by site.

Vertical profiles were recorded during the monthly (May through September) sampling trips. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Typical of smaller, eutrophic reservoirs in Missouri, the lake was stratified both thermally as well as chemically between 4 – 5 m during July (Figure 2.9). The depth of stratification was 1 – 2 m deeper in 2006 than 2005, while the strength of stratification was not as significant or as prolonged as during 2005.

Only August fecal bacteria data was available from beach monitoring during 2006. This composite sample indicated an E coli concentration < 10 colonies / 100 ml sample.

2.3.3 Outflow

No outflow samples were collected from Blue Springs Lake during 2006.

2.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to monthly 'intensive' monitoring from April through September, as well as conducting monthly vertical profiles at both lake sites. Bacteria sampling at the beach will continue on a weekly basis during the summer by JCPRD. Due to elevated phycocyanin concentrations measured during 2006, this lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. A contaminant group of interest is polyaromatic hydrocarbons (PAHs). These compounds are

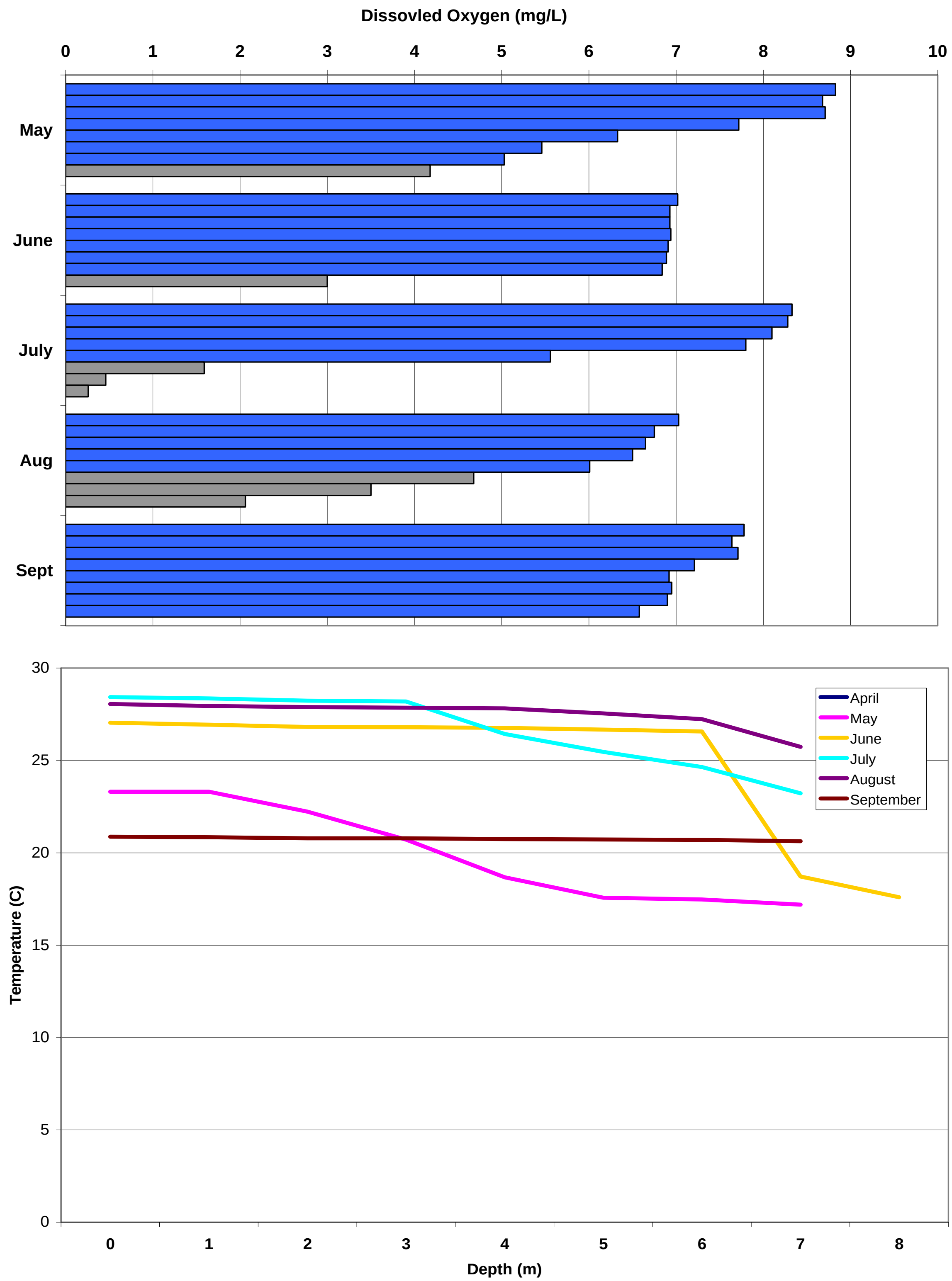


Figure 2.9. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plots from vertical profiles recorded at Site 4 during May through September, 2006 at Blue Springs Lake.

components of asphalt, fuels, oils, and greases. They enter receiving waters from stormwater runoff, industrial and wastewater treatment discharges, and through atmospheric deposition. They do not dissolve, but attach to particulate material and eventually settle out to the substrate. These compounds are highly toxic to aquatic biota, and thus baseline data is desired to track within district lakes. This is a high priority item when future funding becomes available.

3 Clinton Lake

3.1 General Background

Clinton Lake was impounded in 1977 and reached full pool in 1980. The main threats to Clinton Lake's watershed are sedimentation, nutrients and bacterial contamination. The lake is listed on the state's 303(d) list for water quality impairment due to eutrophication and fecal bacteria. Therefore, TMDL's have been developed for the watershed to reduce nutrients, total suspended solids (TSS), and fecal bacteria, and increase dissolved oxygen. Specific TMDL targets are < 100 mg/L TSS at flows < 10 cfs, and total phosphorus (TP) < 0.1 mg/L. The Kaw Valley Heritage Alliance, formed in 1996, is a citizen-based watershed group active within the upper Wakarusa watershed. The Upper Wakarusa Watershed Restoration and Protection Strategy (WRAPS) was approved by the Kansas Department of Health and Environment during 2003. The goals and objectives of this WRAPS are to protect Clinton Lake and ultimately remove it from the 303(d) list of impaired waters.

3.1.1 Location

Clinton Lake is located approximately 6.4 km (4 miles) southwest of Lawrence, Kansas. The dam is located at river km 35.5 (river mile 22.2) of the Wakarusa River, which is a tributary of the Kansas River. The watershed encompasses the counties of Douglas, Shawnee, Osage, and Wabaunsee. Historic water quality samples sites at Clinton Lake include 3 lake, 1 outflow, and 1 inflow (Figure 3.1).

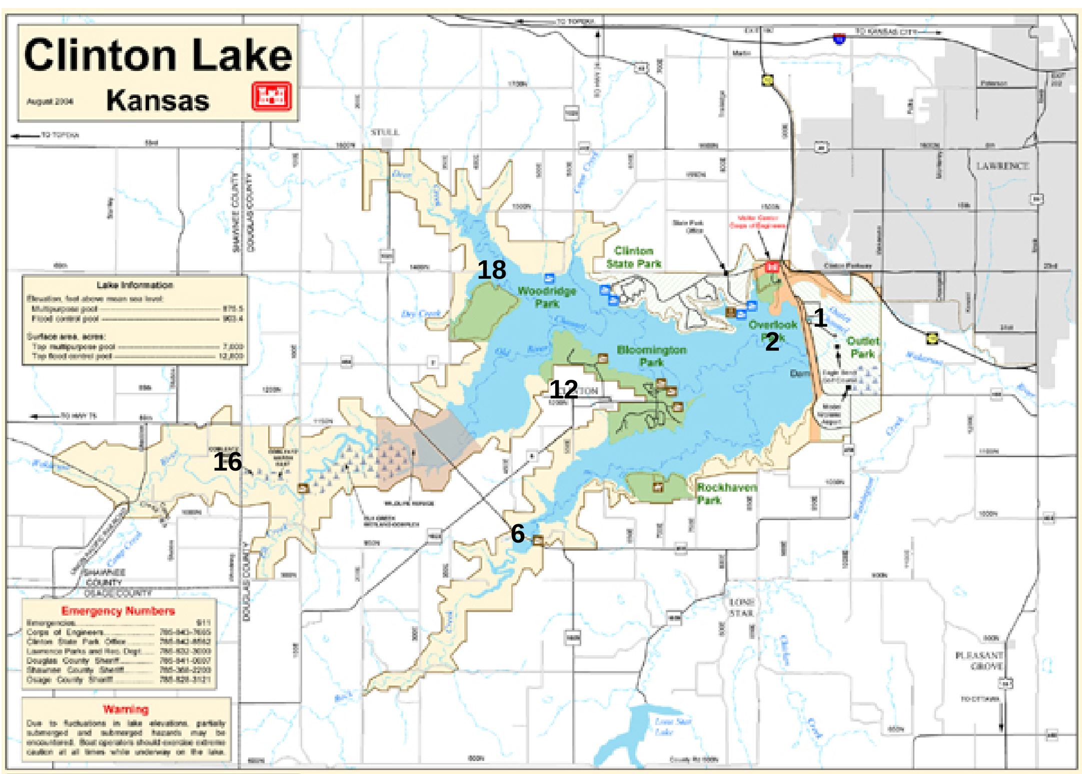


Figure 3.1. Clinton Lake area map with sample site locations and site numbers.

3.1.2 **Authorized Purposes:** Flood control, water supply, low flow supplementation, fish and wildlife conservation, and recreation.

3.1.3 **State Use Designations:** Primary contact recreation, food procurement, domestic water supply, special aquatic life support.

3.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	903.5	268.8	12,891	
Multipurpose	875.5	125.3	7,006	82
Total		394.1		

Total watershed area: 367.0 sq. miles (234,880 A)
Watershed ratio: 18.22 FC / 33.5 MP

Average Annual Inflow: 189,849 acre-feet / yr (1982 – 2006)
Average Annual outflow: 000 acre-feet
Flushing Rate: 0.66 years
Sediment inflow (measured): 3,421 acre-feet (1977 – 1991)
Water management Plan: Approved 12 February 1980
Historic stage hydrograph: 1995 – 2005 (Figure 3.2)

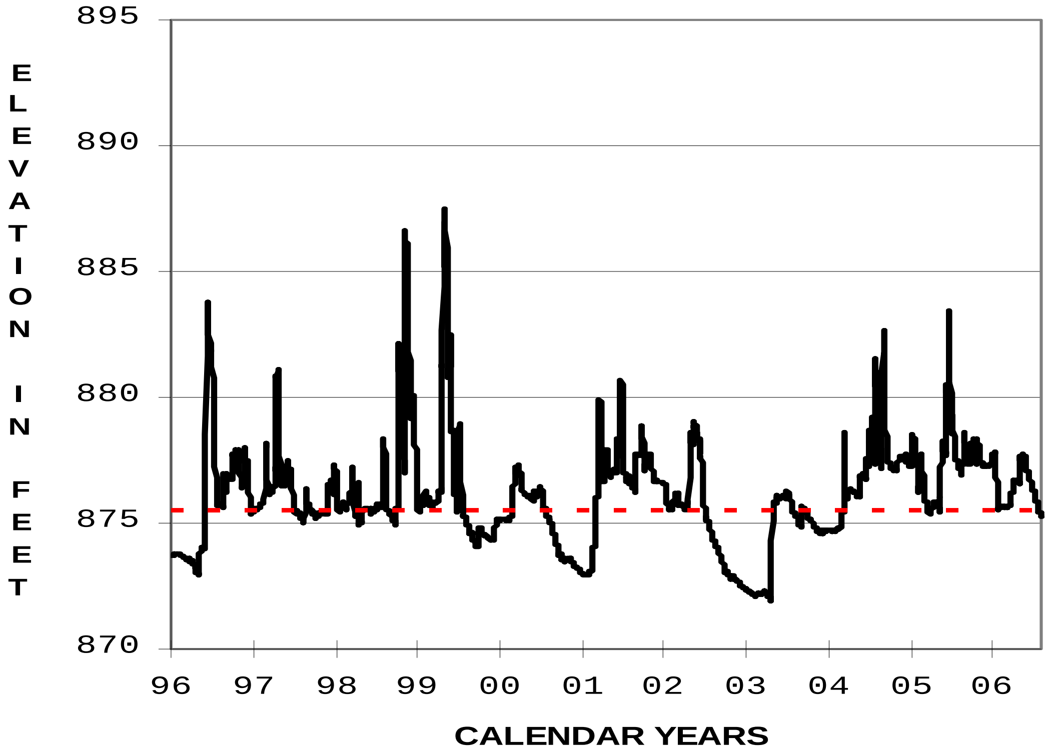


Figure 3.2. Pool elevation hydrograph from 1996 – 2006 (red dashed line is multipurpose level elevation).

3.2 2006 Activities

To address watershed development concerns in Deer Creek, an additional lake site was included during 2006 (Site 18). Clinton Lake was categorized as an 'ambient' lake during 2006, thus only surface samples were collected at the four lake sites. Sample collections occurred from May through September 2006, with vertical profiles recorded at the four lake sites during August. Clinton Lake staff (OF-CL) providing field assistance with the WQP during 2006 included Kipp Walters and Dave Rhoades. Lew Ruona, OF-CL Operations Manager, provided technical insight and background knowledge on Clinton Lake and the Upper Wakarusa watershed. I participated in the Kaw Valley Heritage Alliance's annual meeting, which was held during September. A water quality status and trend poster has been on display in the Clinton Lake visitor center since May.

3.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1996 through 2005. Samples were collected from May through September 2006.

3.3.1 Inflow

No inflow samples were collected from the Clinton Lake watershed during 2006. Historically, nutrient concentrations (nitrogen and phosphorus) are most variable at this site due to influences of runoff events within the watershed. Please see comments for lake sites below on specific parameters.

3.3.2 Lake

Nitrogen and phosphorus are essential nutrients for aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen (TN) and total phosphorus (TP) median concentrations and chlorophyll a values indicate that Clinton Lake is nutrient-rich or eutrophic. Monthly and annual variability in total nitrogen is evident at all sites. Median concentrations range from 0.62 – 0.96 mg/L (Figure 3.2), which is above the proposed EPA nutrient criteria value of 0.36 mg/LTN. The measured values are typical for lakes within this region. Median total phosphorus concentrations (0.06 – 0.13mg/L) for all sites exceed the proposed EPA nutrient criteria value (0.02 mg/L)(Figure 3.3). Currently, the median TP values exceed the WRAPS target value of < 0.1 mg/L at all sites except the tower and outflow sites. The TP concentrations are typical of our district lakes.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 3.4 as an example at Site 2. Median TN:TP ratios at all three lake sites are < 12, indicating the lake is at risk for cyanobacteria blooms (Figure 3.5).

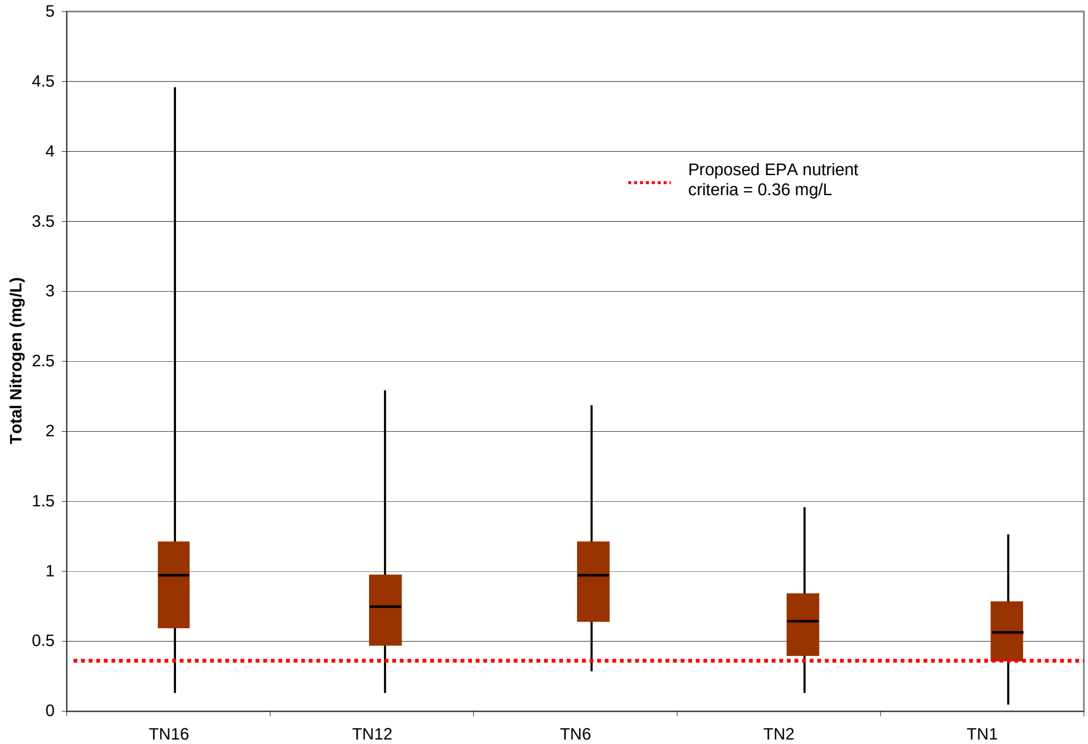


Figure 3.2.	Box plots of surface water sample total nitrogen concentrations measured at lake sites from 1996 through 2006 at Clinton Lake.

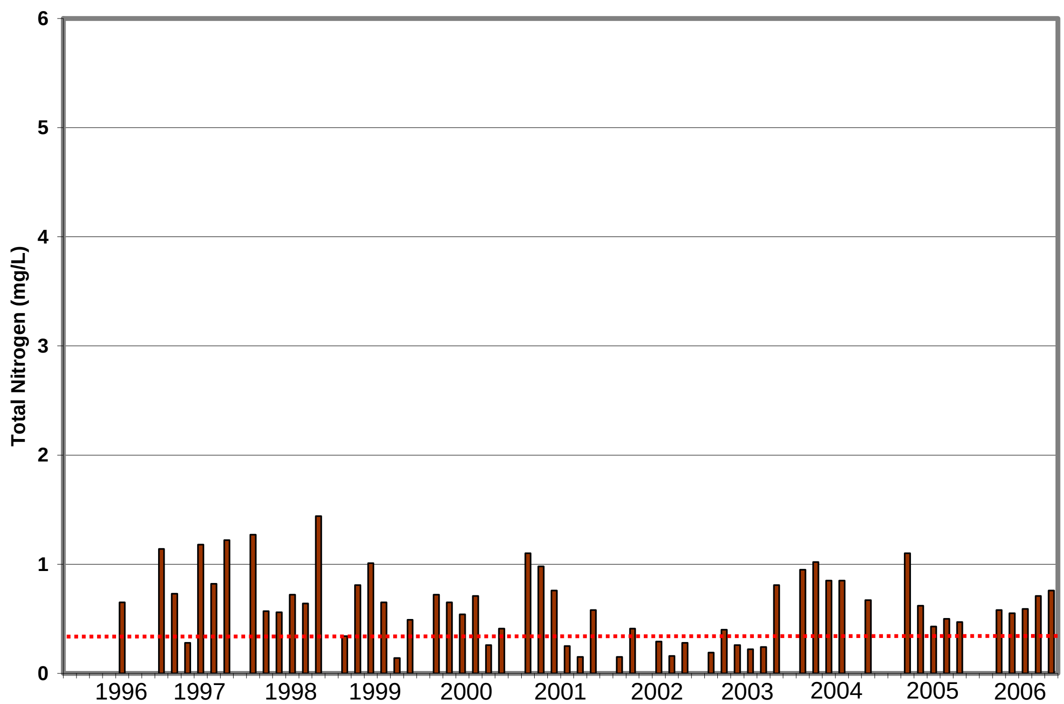


Figure 3.3.	Total Nitrogen concentrations (mg/L) by sample date from 1996 – 2006 at Site 2 (Tower site) in Clinton Lake.

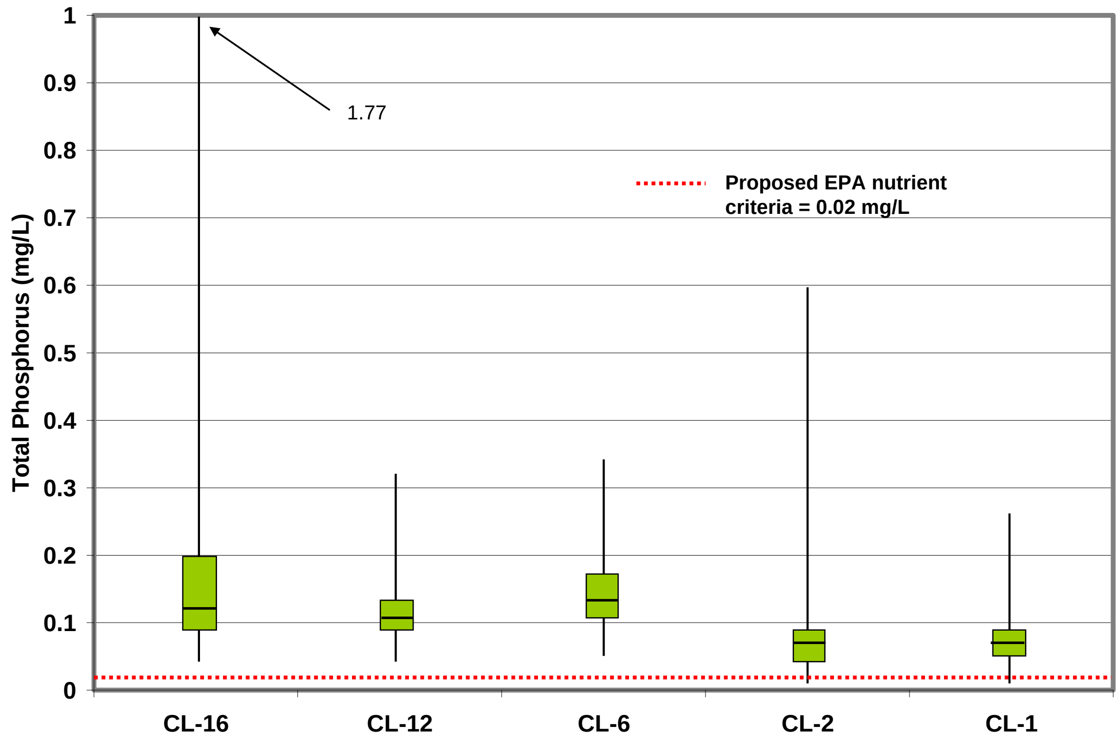


Figure 3.3. Box plots of surface water sample total phosphorus concentrations measured at lake sites from 1996 through 2006 at Clinton Lake.

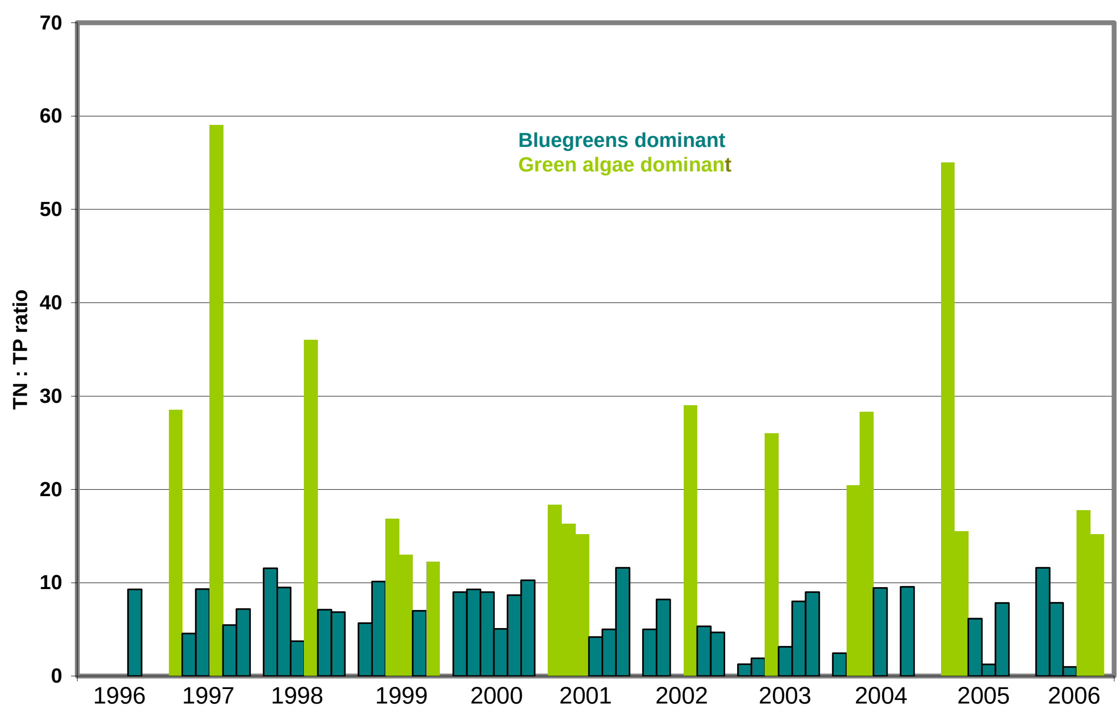


Figure 3.4. Graph of total nitrogen : total phosphorus ratio (TN:TP) by sample at Site 2 of Clinton Lake from 1996 through 2006.

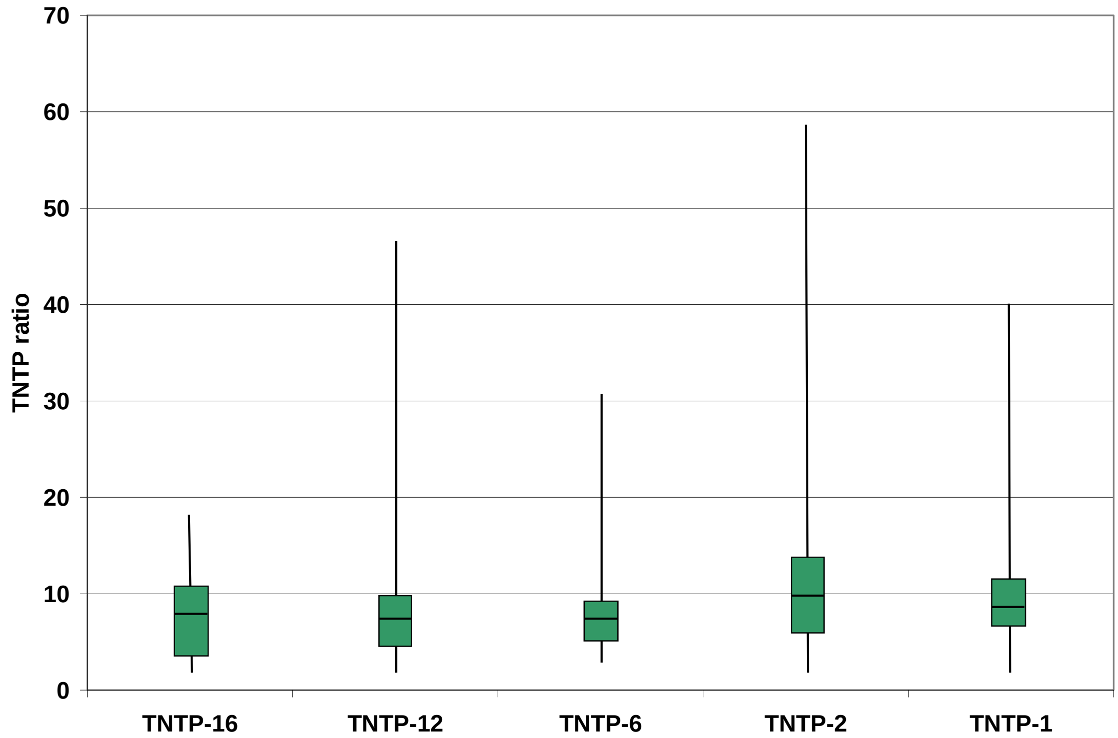


Figure 3.5. Box plots of total nitrogen : total phosphorus (TN:TP) by site from 1996 through 2006 at Clinton Lake.

Chlorophyll was measured monthly from June through August 2006 at all four lake sites. Mean monthly chlorophyll *a* concentration, which was at least 2x greater than during 2005, ranged from 35 – 53 ug/L; median lake concentrations are statistically lower in June than either July or August (Figure 3.6). Mean chlorophyll *a* by sample site and month are plotted in Figure 3.7. Site 2 (Tower) has the lowest mean summer chlorophyll *a* concentration (23.7 ug/L) and lowest monthly variability, while Site 6 (78.7 ug/L) has the highest mean summer chlorophyll *a* concentration (78.7 ug/l) and greatest monthly variability. Mean TSI values range from 61.6 (Site 2) to 73.2 (Site 6), which further classifies Clinton Lake as eutrophic.

Secchi depth was once again measured only during August. Increased algal concentrations during 2006 most likely reduced water clarity compared to 2005 (Figure 3.8). Water clarity was limited in both Deer Creek (Site 18 = 0.45 m) and the Wakarusa arm (Site 12 = 0.55 m), while the tower site was moderately clear (Site 2 = 0.9 m).

Atrazine samples were not collected during 2005. Between 1996 and 2004, median atrazine concentrations (1.3 – 1.7 ug/L) are less than the EPA drinking water maximum contaminant level of 3 ug/L (Figure 3.9). However, individual samples measured during that time period are significant enough to exceed the MCL. Figure 3.10 depicts the individual sample concentrations measured by date at Site 16 (Wakarusa River inflow site).

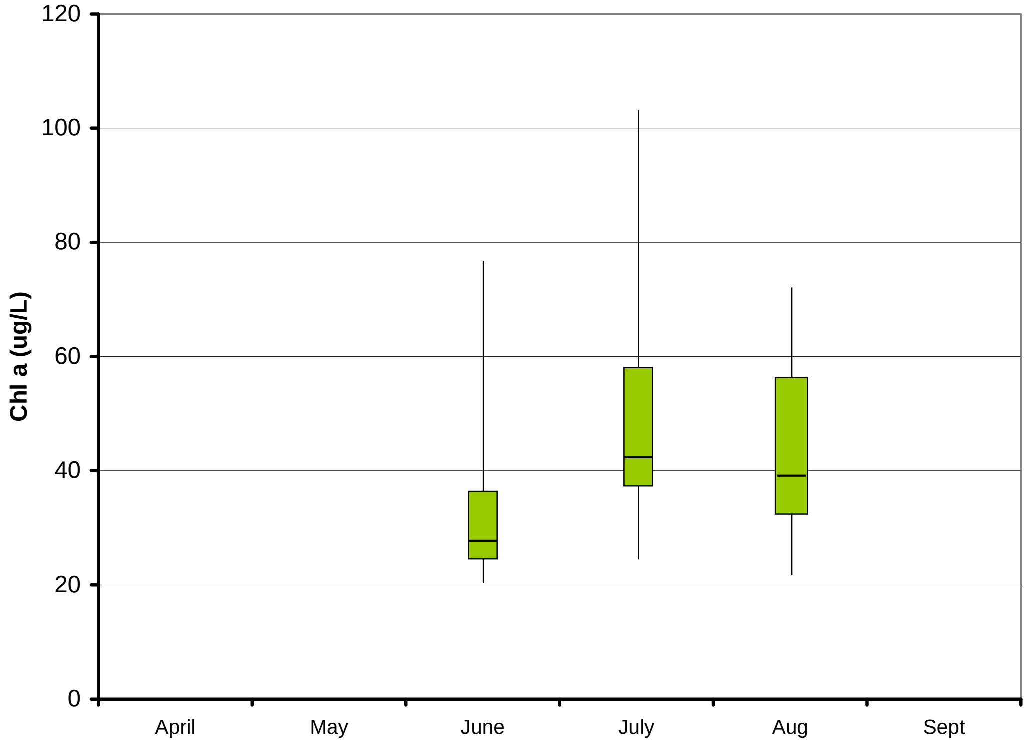


Figure 3.6. Box plots of chlorophyll *a* concentration by site samples collected during 2006 at Clinton Lake.

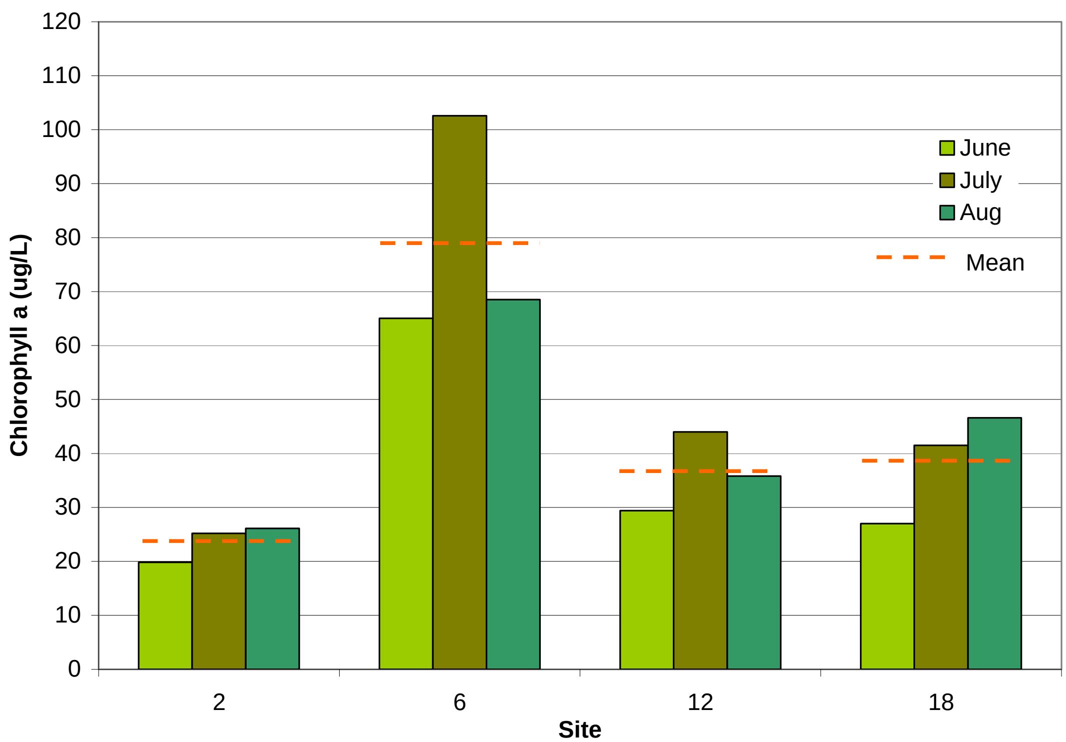


Figure 3.7. Monthly variability and mean chlorophyll *a* by sample site and month in Clinton Lake during 2006.

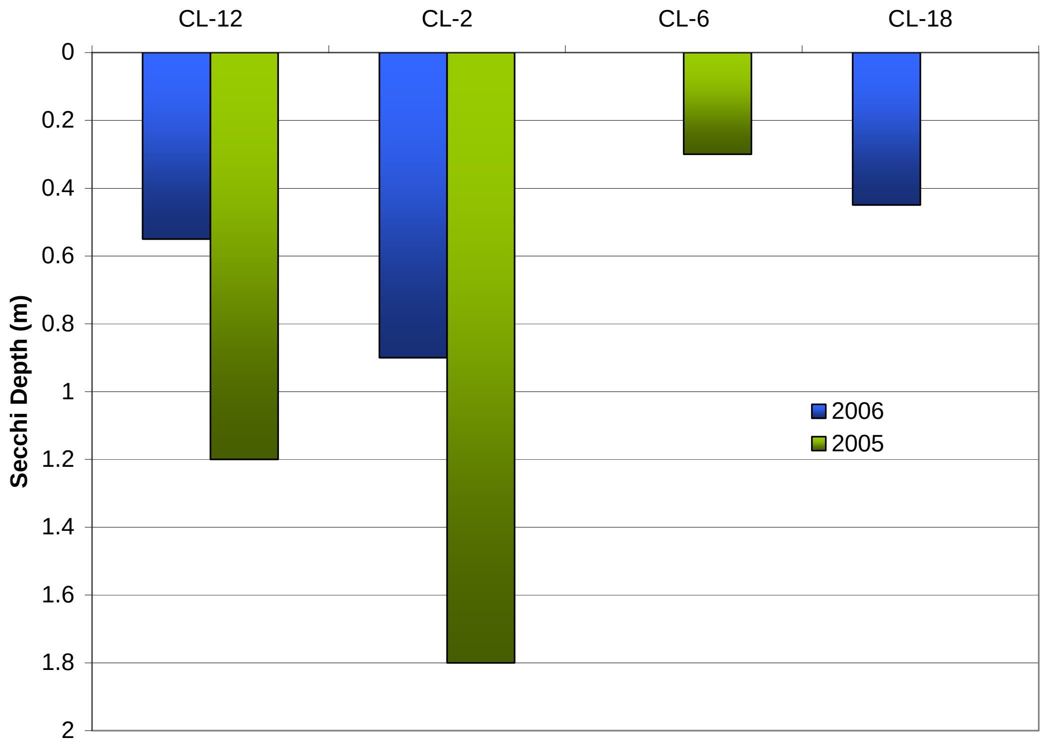


Figure 3.8. Comparative graph of secchi depth (m) measured during August by lake site in Clinton Lake during 2005 and 2006.

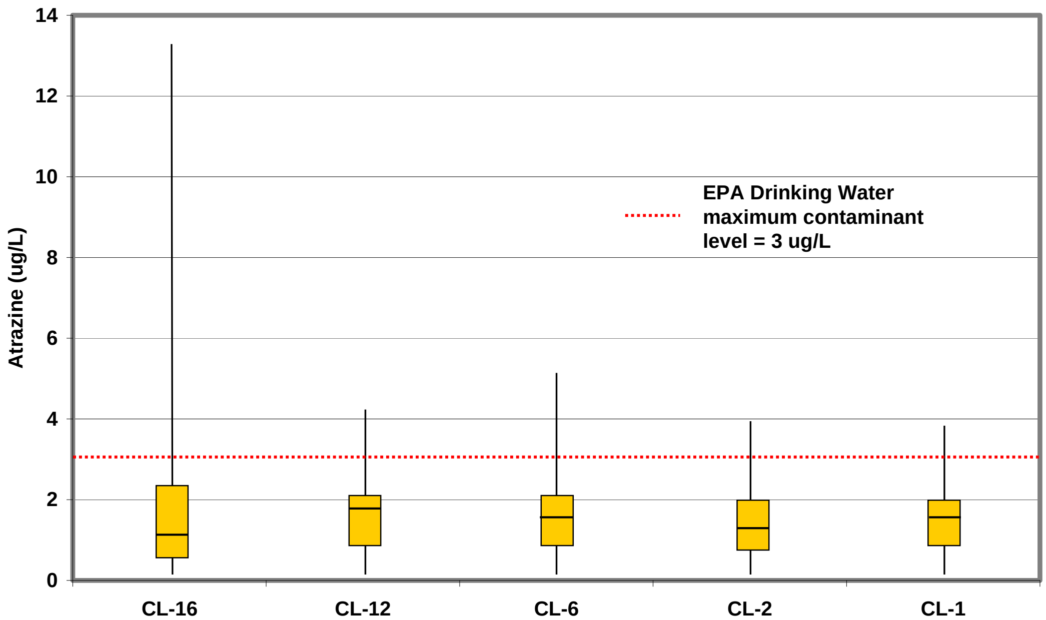


Figure 3.9. Box plots of surface water sample atrazine concentrations measured at lake sites from 1996 through 2004 at Clinton Lake.

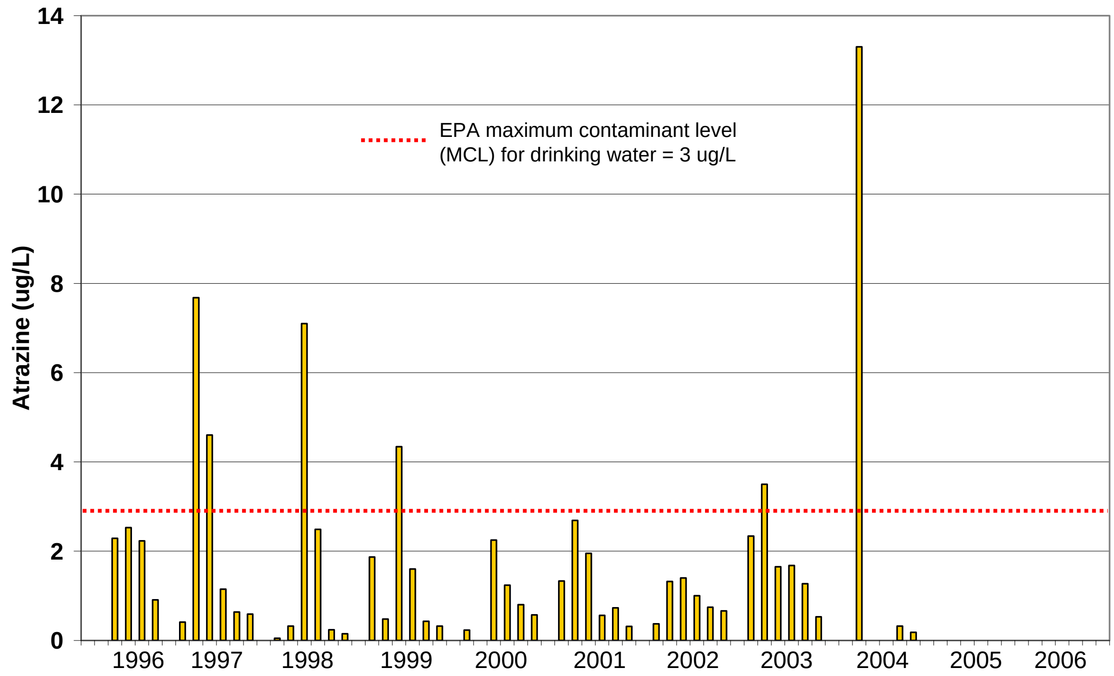


Figure 3.10. Atrazine concentrations by sample date collected at Site 16 (Wakarusa River) inflow to Clinton Lake from 1996 through 2004.

A single vertical profile was recorded at Site 2 (Tower) during the 22 August sampling trip. Parameters included temperature, dissolved oxygen, pH, conductivity, turbidity, chl a, and blue-green algae concentration. In spite of higher chlorophyll concentrations and reduced water clarity, the lake was not as strongly stratified during 2006 as in 2005 (Figure 3.11).

Fecal bacteria samples were collected from three locations at the Corps swimming beach prior to three major holidays (Memorial Day, July 4^{th}, and Labor Day). Although elevated samples were evident prior to Labor Day, all samples were well within compliance limits of 732 colonies / 100 ml for a single sample (Figure 3.12).

3.3.3 Outflow

No outflow samples were from collected from Clinton Lake during 2006.

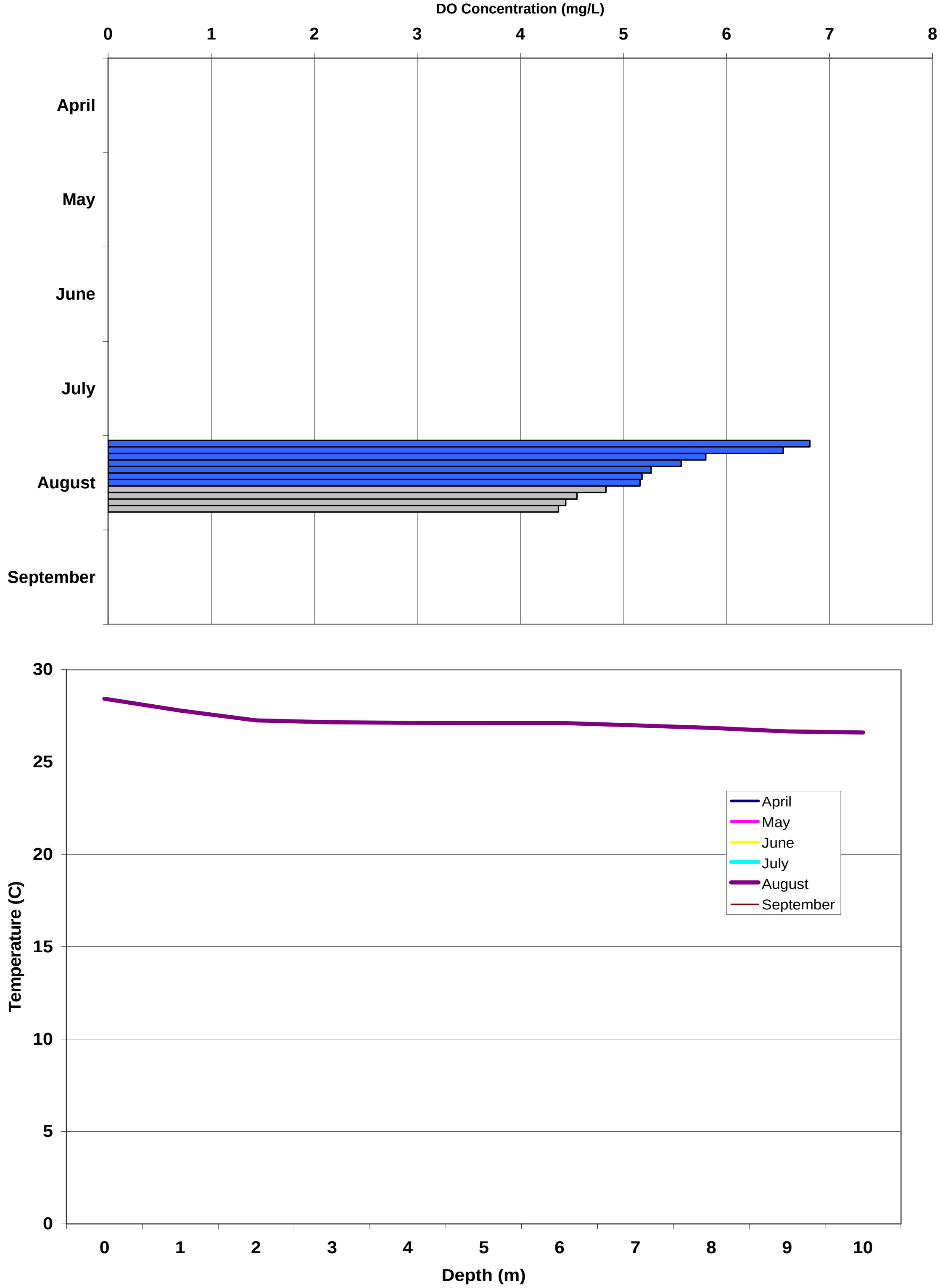


Figure 3.11. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plots from a vertical profile recorded at Site 2 on 22 August 2006 at Clinton Lake.

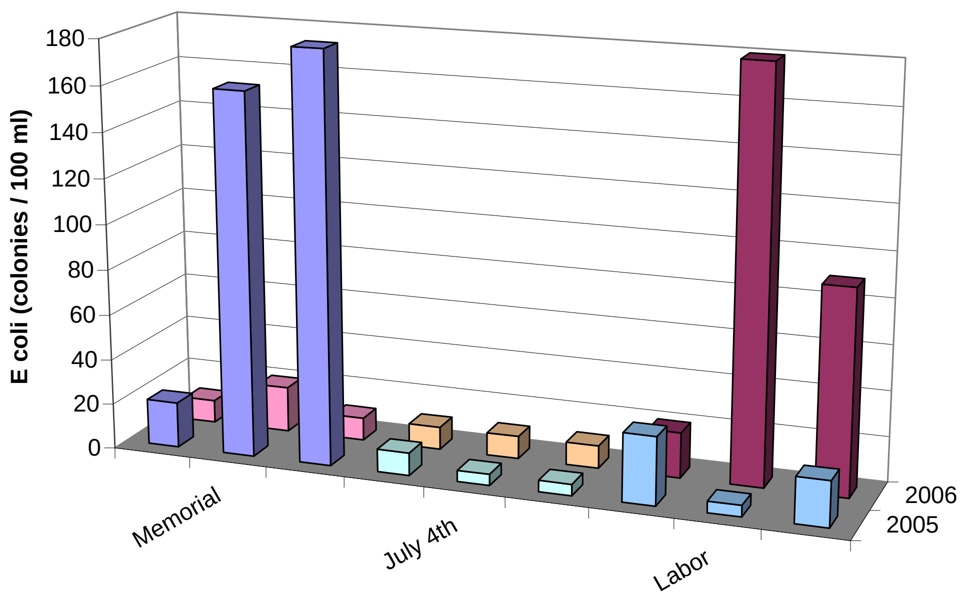


Figure 3.9. Fecal bacteria (E coli) colonies per 100 ml samples collected from three sites at the swimming beach prior to Memorial Day, July 4th, and Labor Day during 2005 and 2006 at Clinton Lake.

3.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition from an ‘ambient’ to an ‘intensively’ monitored lake. This will include monthly sampling from April through September at four lake sites, one inflow site, and one outflow site. Monthly vertical profiles will be recorded at each of the four lake sites. Due to concerns of bluegreen algal toxins, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Sediment – nutrient and metals will be examined during 2007 to provide a comparative point on potential resuspension sources. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP’s, illicit dumping from boats, etc. A contaminant group of interest is polyaromatic hydrocarbons (PAHs). These compounds are components of asphalt, fuels, oils, and greases. They enter receiving waters from stormwater runoff, industrial and wastewater treatment discharges, and through atmospheric deposition. They do not dissolve, but attach to particulate material and eventually settle out to the substrate. These compounds are highly toxic to aquatic biota, and thus baseline data is desired to track within district lakes. This is a high priority item when future funding becomes available.

4 Harlan County Lake

4.1 General Background

Harlan County Lake was impounded on 14 November 1952 and reached full pool on 14 June 1957. The primary water quality threats to Harlan County Lake are nutrients, sediment and toxic cyanobacteria blooms. A drought continues to seriously impact the lake such that it currently contains one-half the surface acreage. Sample site 5 replaced site 7 during 2003 because site 7 was no longer accessible due to the drought. During normal water level years, the lake experiences a 4 – 6 ft drawdown related to irrigation releases (June – August). Dredging has occurred to maintain boat access to both the Patterson Harbor marina and the Gremlin Cove marina. Bluegreen algae blooms have occurred at the lake in the recent past (http://www.deq.state.ne.us/).

4.1.1 Location

The Harlan County Lake is located 12.8 km (8 miles) east of Alma, Nebraska. The dam, located on the Republican River, is located 371.7 km (232.3 miles) upstream of the confluence with the Kansas River. Historic water quality sample sites include 3 lake, 1 outflow, and 1inflow sites (Figure 4.1).

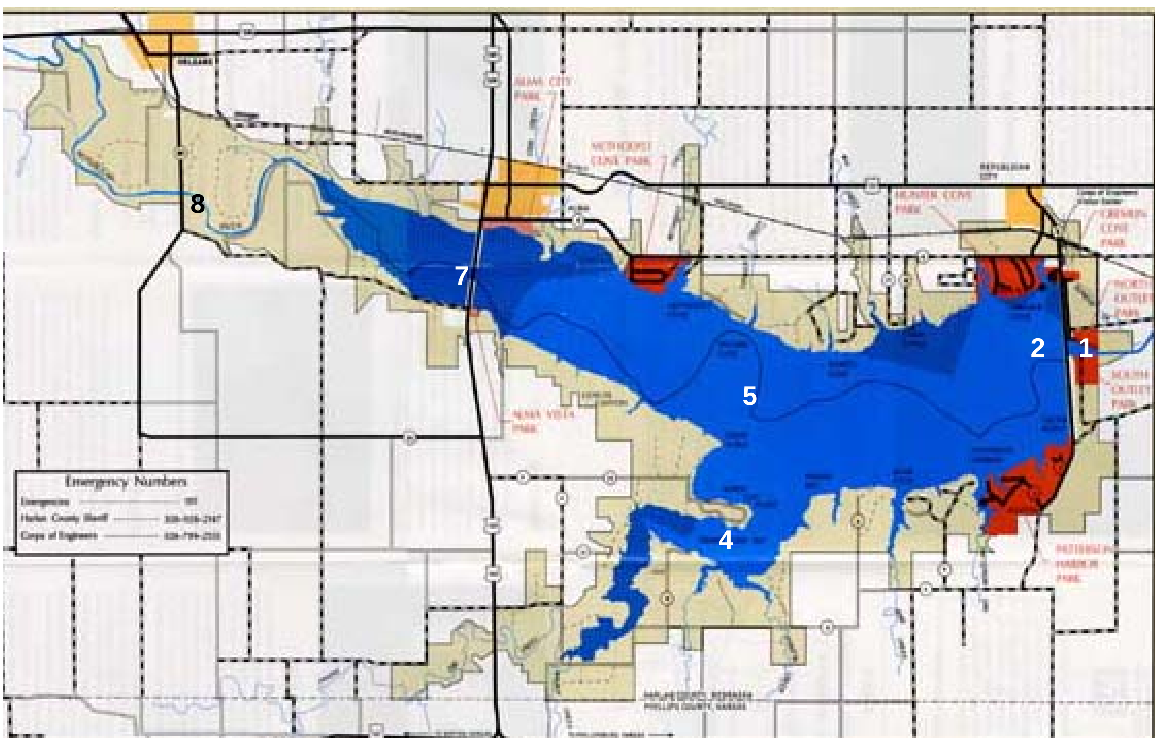


Figure 4.1. Harlan County Lake area map with sample site locations and site numbers.

4.1.2 **Authorized Purposes:** flood control, irrigation, recreation, and fish and wildlife.

4.1.3 State Use Designations: recreation, warmwater aquatic life, agricultural water supply, and aesthetics.

4.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,973.5	500.0	23,431	
Multipurpose	1,946.0	314.1	13,305	54
Total		814.1		

Total watershed area: 13,536 sq miles (total upstream area)
7,169 sq miles (total local drainage below upstream dams; 4,588,160 A)

Watershed ratio: 195.82 FC / 344.84 MP

Average Annual Inflow: 149,984 acre-feet/yr (1982 – 2006)
Sediment inflow (measured): 38,548 acre-feet (1952 – 2000)
Flushing rate: 2.09 years
Water management Plan: Approved 10 May 2001
Historic stage hydrograph: 1995 – 2005 (Figure 4.2)

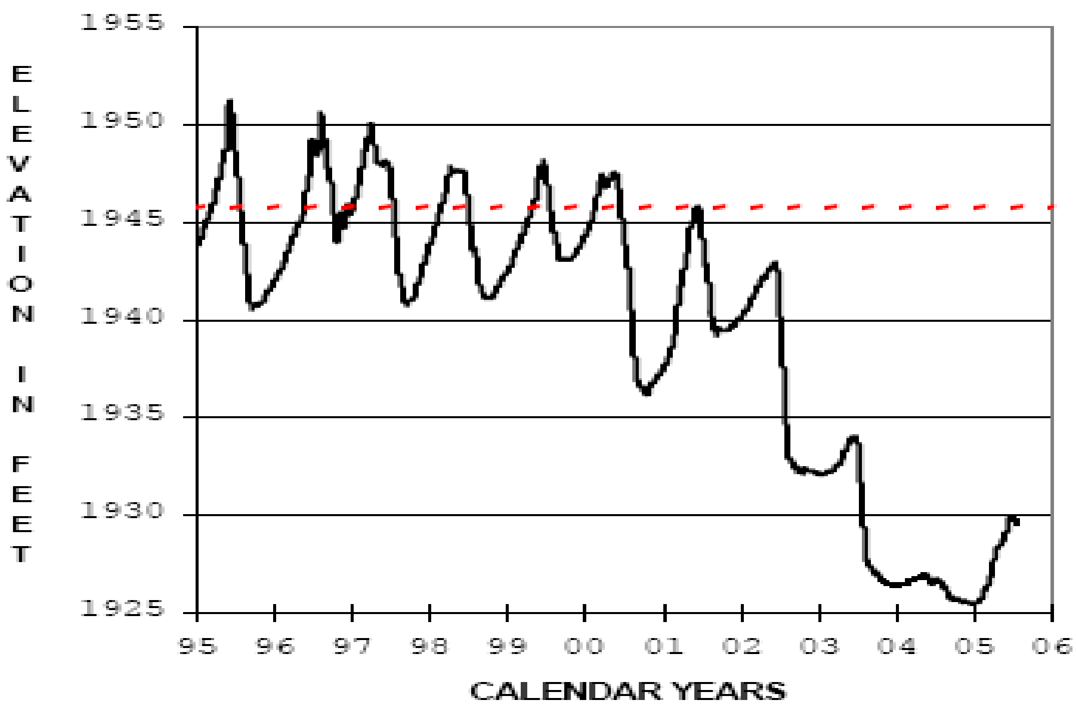


Figure 4.2. Pool elevation hydrograph from 1995 – 2005. Red-dashed line is multipurpose pool elevation.

4.2 2006 Activities

Harlan County Lake was categorized as an 'ambient' lake during 2006, with sample collection occurring from June through September. Surface samples were to be collected from inflow and outflow sites, while surface and bottom samples were collected at the three lake sites. Vertical profiles (temperature, DO, pH, conductivity, and turbidity) were recorded at the three lake sites during each sampling trip. However, because of the drought, no inflow or outflow samples were collected during the year. Harlan County Lake staff (OF-HC) providing field sampling assistance during 2006 included Jim Brown and Larry Janicek. Jim Bowen, OF-HC Operations Manager, provided insight and background information regarding Harlan County Lake.

4.3 2006 Data

Comparative historic data includes samples collected monthly (April – September) from 1996 through 2005. Samples were collected from June through September during 2006.

4.3.1 Inflow

No inflow samples were collected due to the prolonged drought impacts. No visible water was present at site 8 throughout the study period. No samples have been collected at site 8 since July 2003 because of dry conditions.

4.3.2 Lake

Based on TN, TP and chlorophyll a concentrations, Harlan County Lake is classified very eutrophic. Nitrogen is an essential nutrient for aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen concentrations from surface samples are relatively consistent between lake sites, with means ranging from 0.94 – 1.17 mg/L (Figure 4.3). These concentrations are significantly greater than Nebraska Dept of Environmental Quality's (NEDEQ) nutrient criteria target of 0.57 mg/L, and are among the highest median TN concentrations within the district.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. The median total phosphorus values range from 0.12 – 0.17 mg/L (Figure 4.4), which is significantly greater than NEDEQ's nutrient criteria of 0.033 mg/L. The prolonged drought can have some positive impact on water quality, as sediment inflows cease there are less nutrients (i.e., phosphorus) delivered to the lake. As the lake becomes more shallow, wind resuspension of sediment potentially increases the bioavailability of phosphorus; this nutrient is essential for algal blooms.

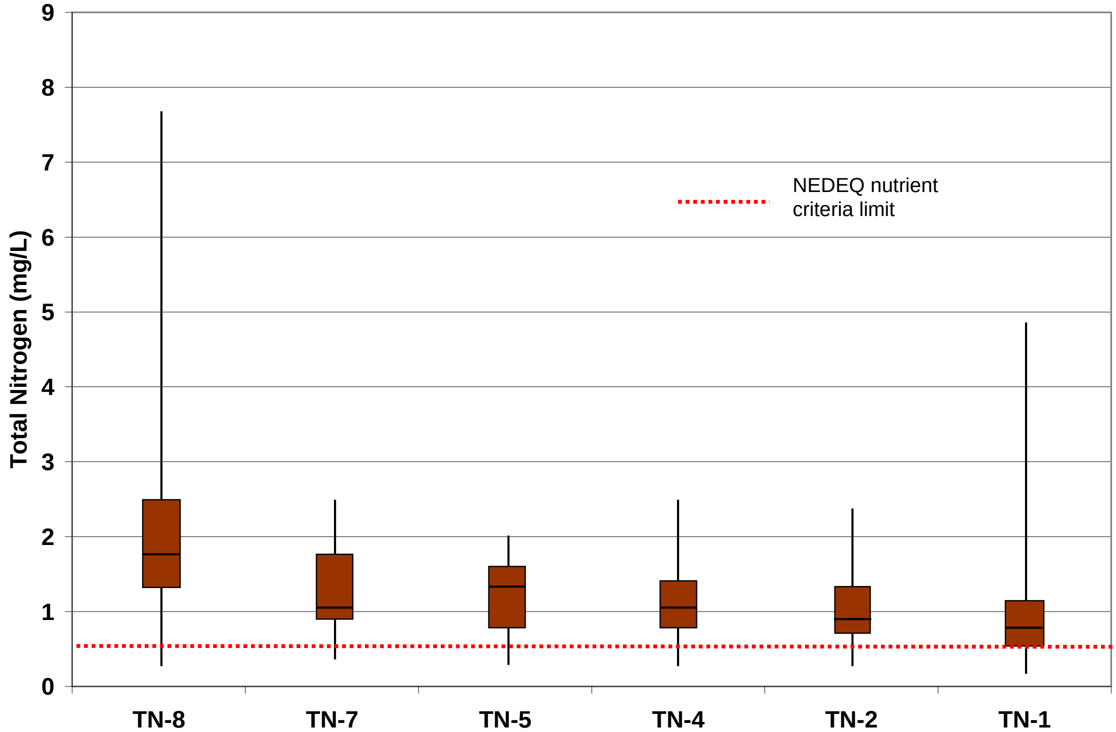


Figure 4.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Harlan County Lake.

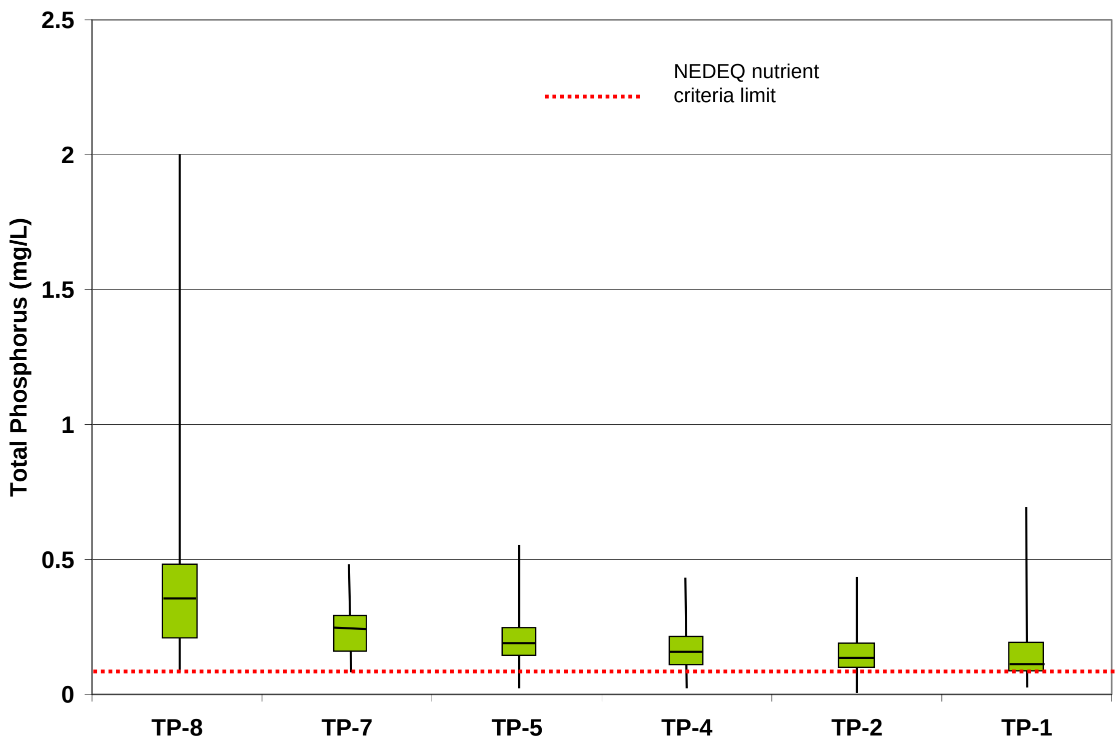


Figure 4.4. Box plots of surface water sample total phosphorus concentrations measured by site from 1996 through 2006 at Harlan Count Lake.

Harlan County experiences some of the lowest median TN : TP ratio values within the district. There is high monthly and annual variability in TN : TP ratios at all sites, with lowest ratios typically present during late summer and fall months. Figure 4.5 depicts such variability as measured at Site 2. Median values range from 5.5 – 7.2 (Figure 4.6), which is strongly indicative for the presence of bloom-forming cyanobacteria (blue-green algae). Thus, this lake is at risk for future cyanobacteria blooms, which pose a serious threat to animals and humans. Recently, lakes in Nebraska have experienced outbreaks of toxic cyanobateria blooms.

Chlorophyll a concentrations range from 12.15 – 40.08 ug/L from samples collected during 2005, which exceed NEDEQ's nutrient criteria target value of 8 ug/L. These values are indicative of a highly eutrophic environment, and were expected based on a shallow, windswept waterbody.

Atrazine samples were last collected from surface samples at all three lakes sites during 2005. As one would expect with a seasonally applied herbicide, monthly and seasonal variability in concentrations is experienced at all sites. Median atrazine concentrations (0.95 – 1.1 ug/L; Figure 4.7) from samples collected between 1996 and 2005 are less than the EPA drinking water MCL of 3 ug/L. However, spikes measured during spring samples have exceeded the MCL. Highest concentrations historically have been measured at Site 8 (Republican River inflow), with values ranging from 0.08 – 12 ug/L (see Figure 4.8). No inflow samples were collected during 2006 due to drought conditions.

Secchi depths at Site 2 historically range from 0.18 – 0.69 m, which is significantly less than EPA's ecoregional target of 1.3 m. Historically high sediment inflows have impacted water clarity. Resuspension of sediment related to prevailing winds and shallow depth (drought) most likely influence current water clarity. Total suspended solids (TSS) samples corroborate the reduced water clarity, as TSS concentrations from surface samples ranged from 5 – 51 mg/L and near-bottom samples ranged from 21 – 210 mg/L.

No vertical profiles were recorded during 2006. However, profiles recorded during 2005 are presented in Figure 4.9. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake stratified both thermally and chemically between a depth of 3 – 4 m during June and a depth of 6-7 m during July (Figure 4.9). Stratification is typical of eutrophic lakes, and weak stratification is expected in south-central Nebraska lakes due to strong prevailing winds. These winds keep the lake mixed both thermally and chemically. The lake had 'turned over', or destratified, by the mid-September sample trip.

Fecal coliform (*E coli*) bacteria were monitored by lake personnel prior to three major holidays (i.e., Memorial Day, 4th of July, Labor Day) during the 2006 recreational season. None of the median values exceeded NDEQ's single sample maximum (235 colonies / 100 ml) during either 2005 or 2006 (Figure 4.10). In addition, *E coli* samples were last collected by NDEQ at the north swimming beach during 2002. The results were highly variable during the recreational season (Figure 4.11). Two samples exceeded the single

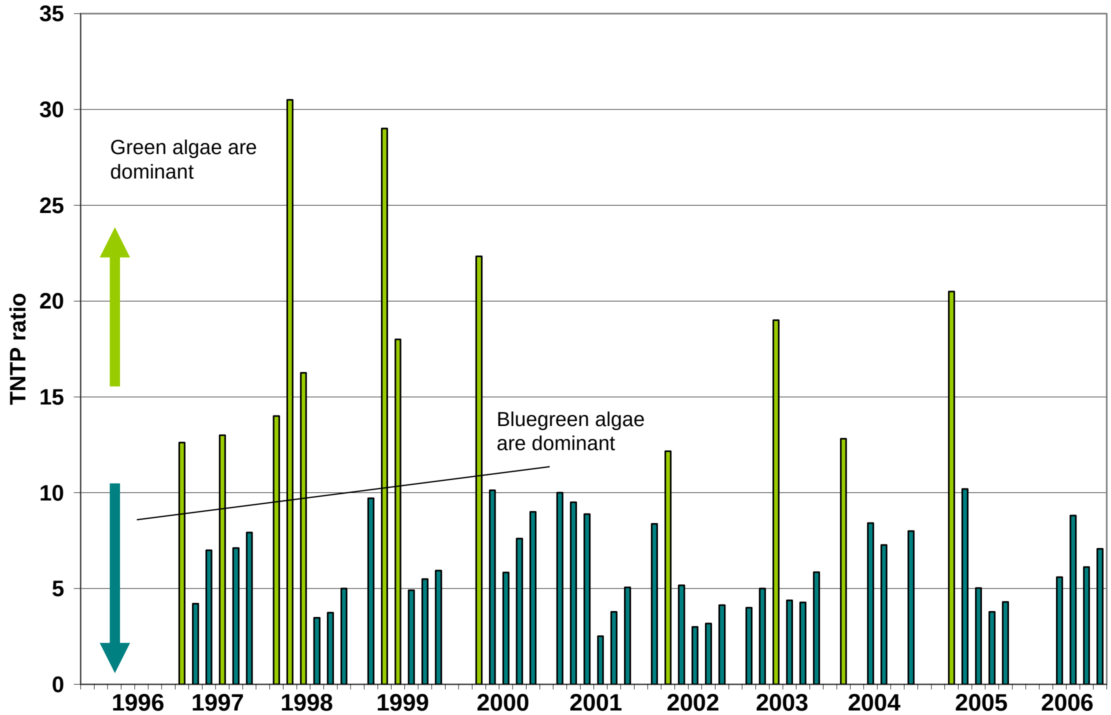


Figure 4.5. Graph of total nitrogen : total phosphorus ratio (TN:TP) by sample at Site 2 of Harlan County Lake from 1996 through 2006.

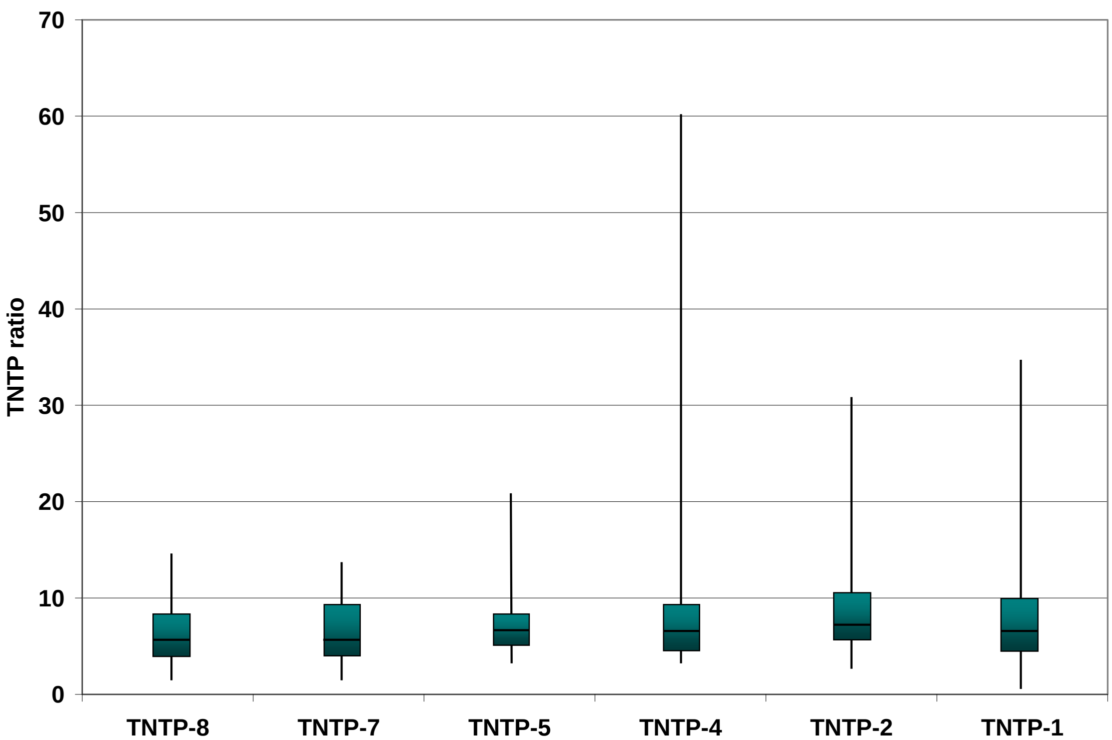


Figure 4.6. Box plots of total nitrogen : total phosphorus ratio from surface water samples by site from 1996 through 2006 at Harlan County Lake.

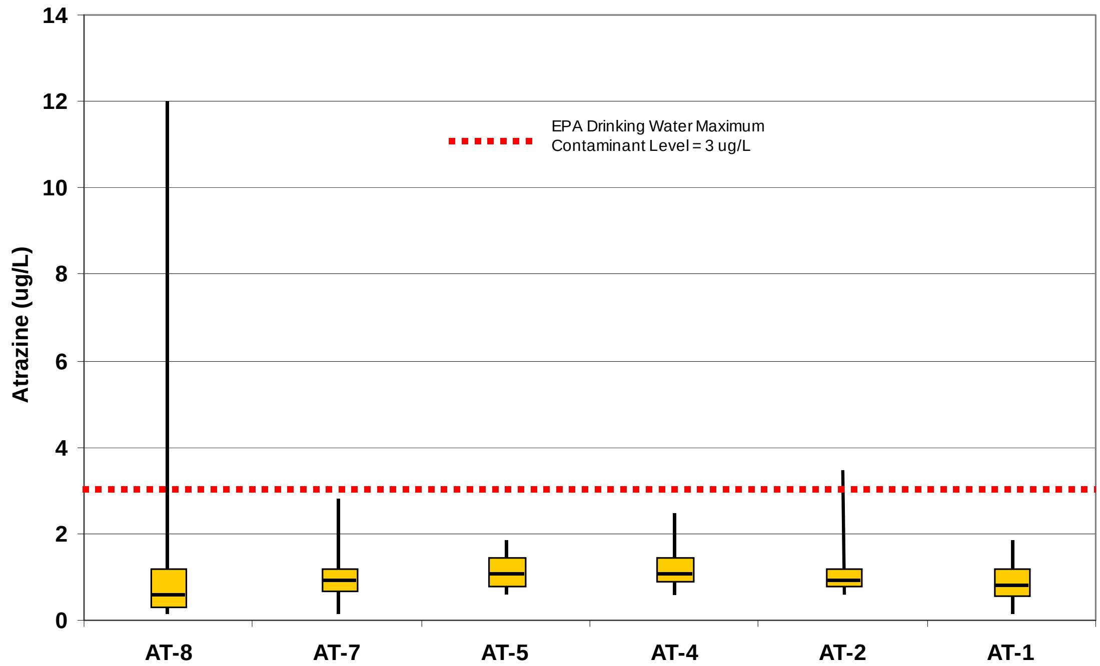


Figure 4.7. Atrazine concentrations by sample site at Harlan County Lake from 1996 through 2005.

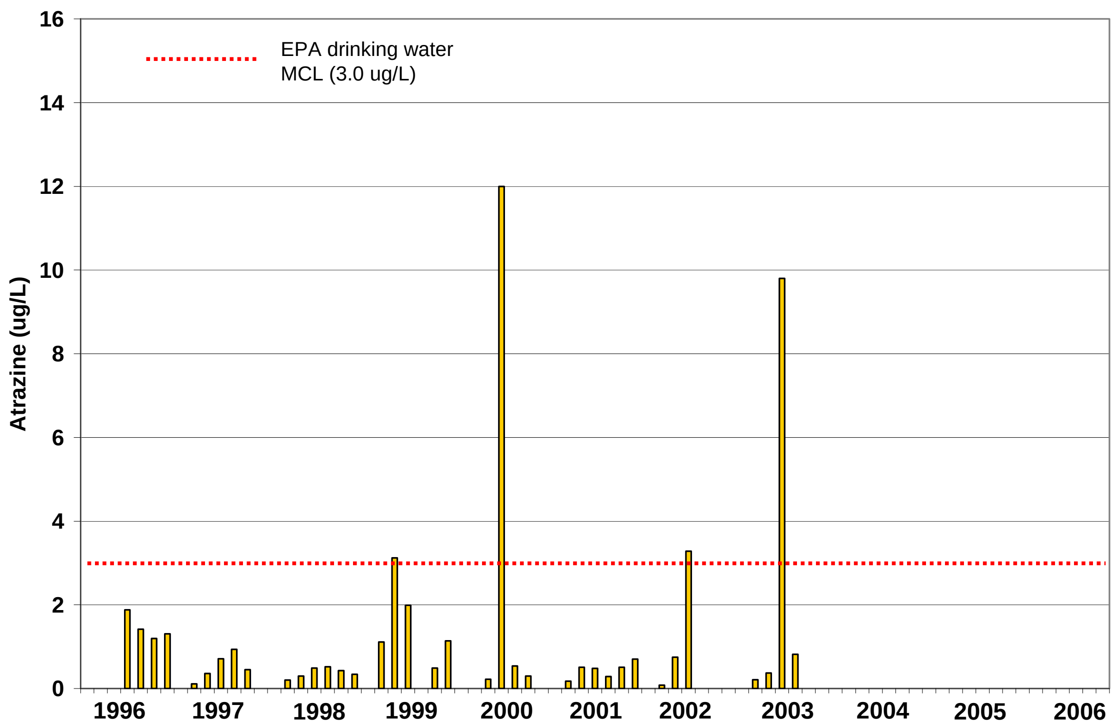
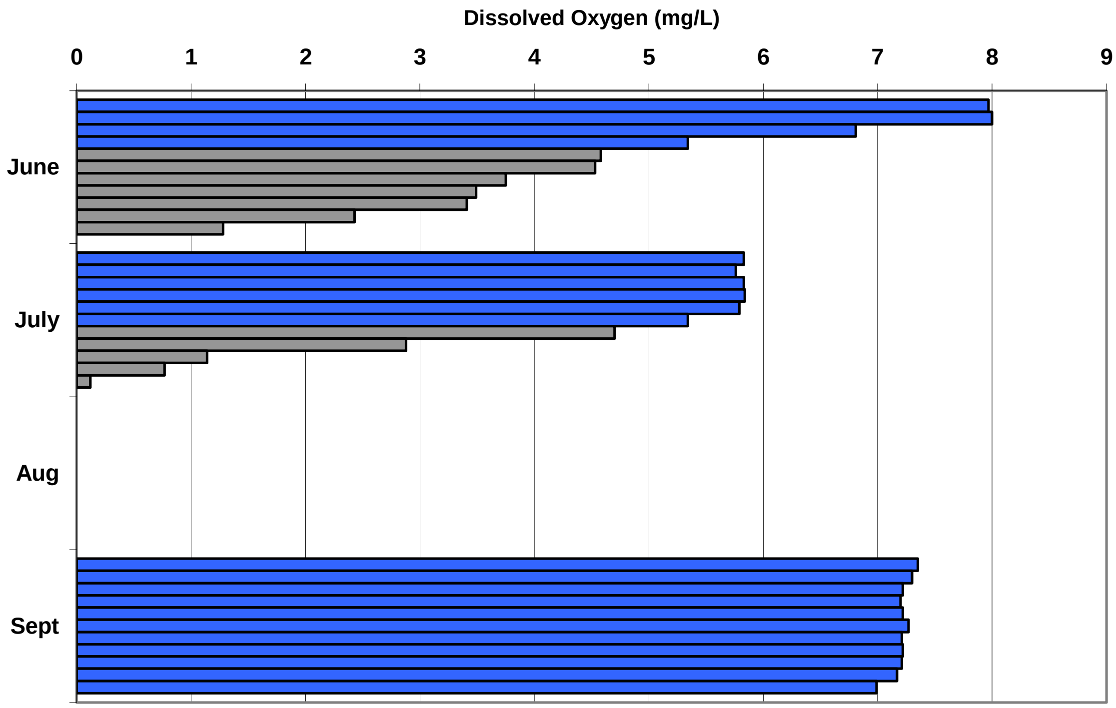


Figure 4.8. Atrazine concentrations by sample date at Harlan County Lake Site 8 (Republican River inflow) from 1996 through 2006.



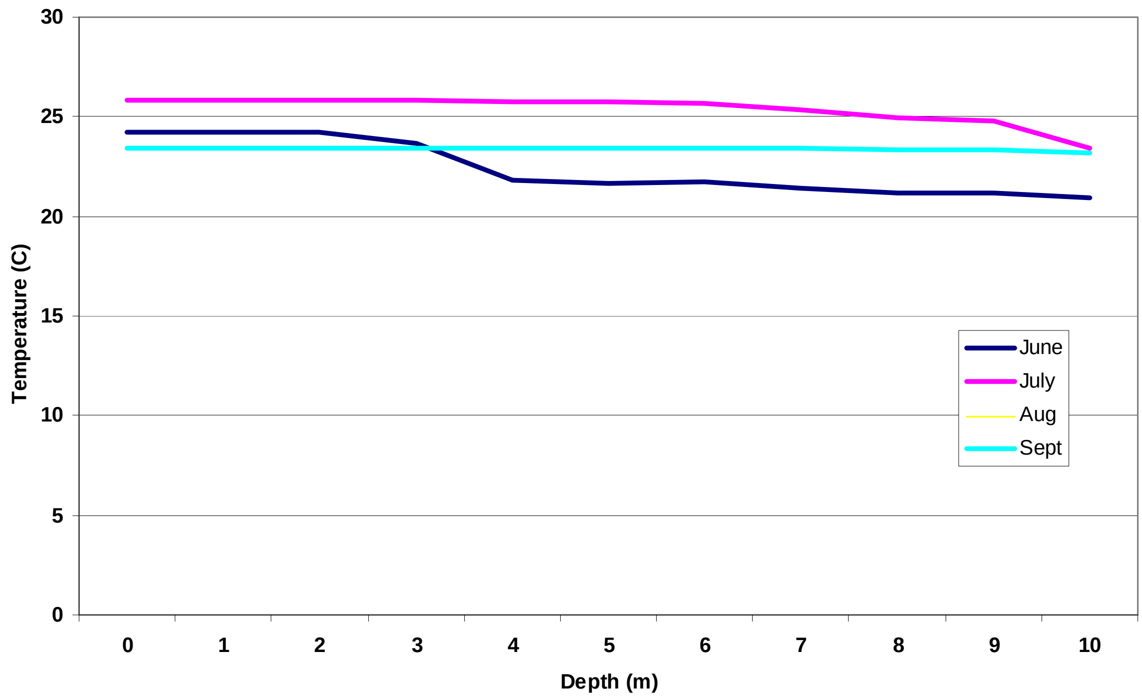


Figure 4.9. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plots by sample dates from vertical profiles recorded at Site 2 during 2005 at Harlan County Lake.

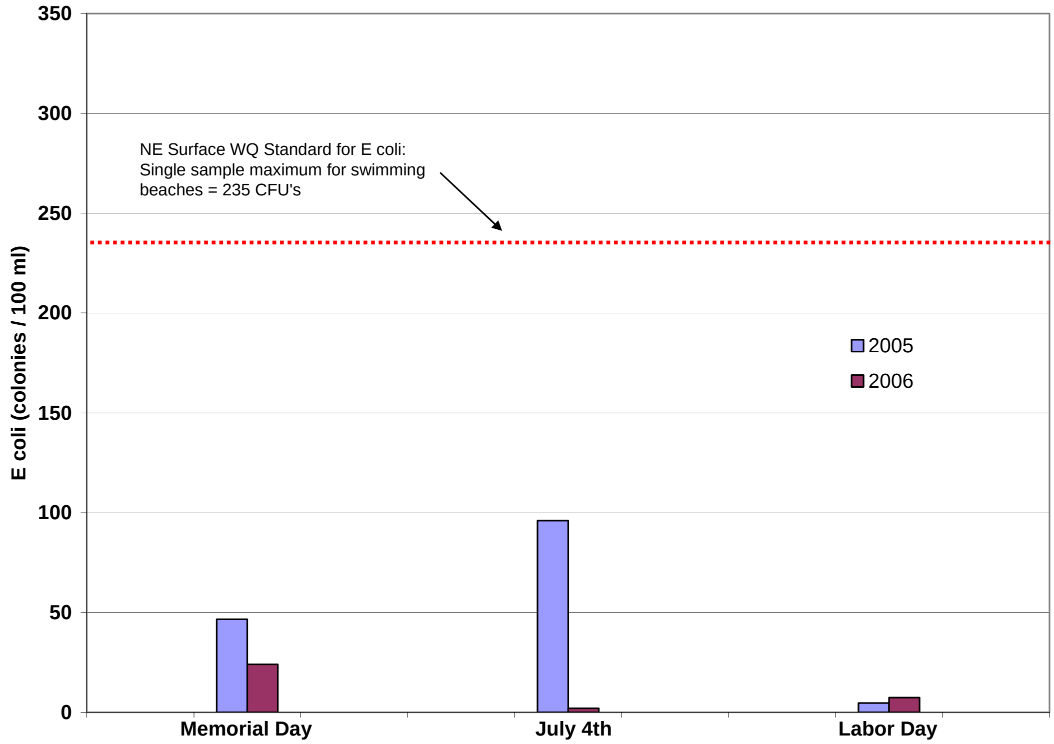


Figure 4.10. Fecal bacteria (E coli) monitoring results from USACE pre-holiday monitoring at Harlan County Lake's north beach during 2005 and 2006.

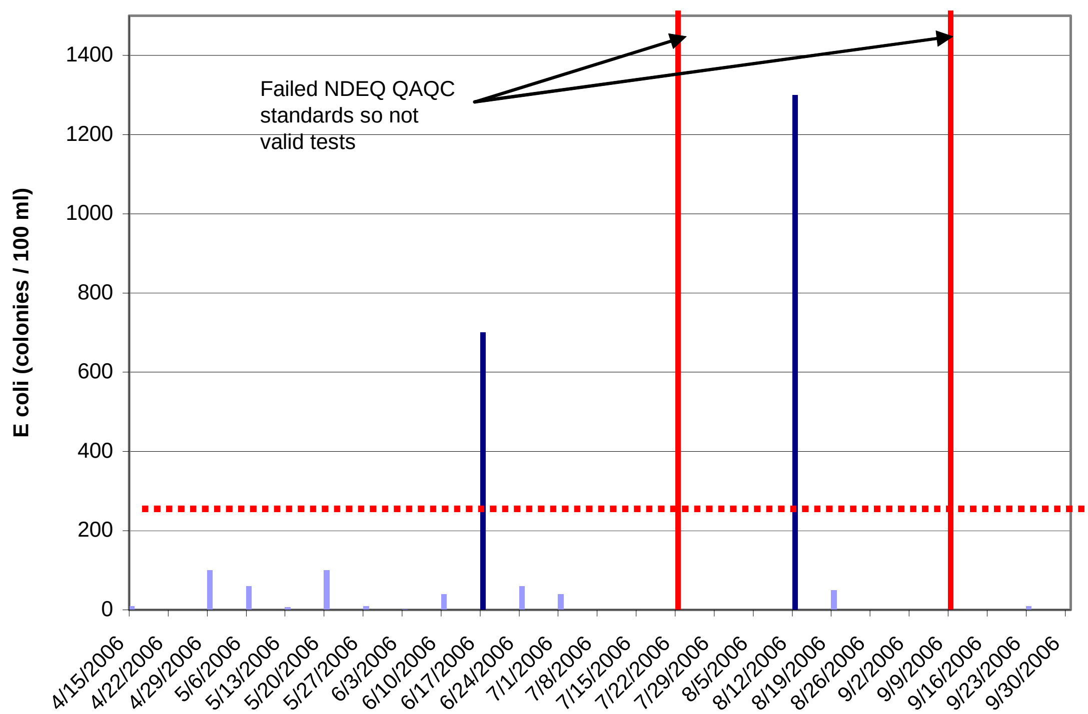


Figure 4.11. Fecal bacteria (E coli) monitoring results from NDEQ 2002 weekly testing at Harlan County Lake's north beach.

sample maximum, while another two samples exceeded the single sample maximum but failed their internal QAQC protocol.

4.3.3 Outflow

Because no water has been released from the lake the past two years, no outflow samples (site 1) have been collected since 2003.

4.4 Future Activities and Recommendations

Sampling activities for 2007 will continue monthly 'ambient' monitoring from May through September, as well as conducting at least one summer vertical profile at each of the three lake sites. Due to elevated TP concentrations and low TN : TP ratios, this lake will be monitored for the cyanotoxin microcystin during August and September. Nebraska Dept of Environmental Quality (NEDEQ) continues to monitor the lake for bluegreen algal blooms. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. NEDEQ is scheduled to conduct intensive monitoring throughout the Republican River watershed during 2007.

5 Harry S Truman Lake

5.1 General Background

Harry S Truman Lake was impounded in October 1979 and reached full pool on 29 November 1979. The primary water quality threats to Truman Lake are sediment, nutrients, bacterial contamination, dissolved oxygen, and herbicides. Currently the lake is listed on the MDNR's 2002 303d list due to elevated concentrations of manganese. As a result a TMDL must be written to deal with the contaminant (MDNR 2002); this is a low priority TMDL for MDNR. Water quality and water quantity issues exist within the upper watershed. Upper watershed issues are beginning to receive some attention as a result of the formation of the Marais des Cygnes, Marmaton, and Little Osage river watershed management plan committee during 2005. There are five Corps lakes (Melvern, Pomona, Hillsdale, Stockton and Pomme de Terre) within the Truman Lake watershed, and when combined, all six lakes comprise 52% of the total surface acres within the district (103,180 A). There are 6 power generation turbines within the Truman Dam, and operation of the turbines historically has been a point of concern in regards to fish mortality (pump-back operation) and water quality standards (i.e., gas supersaturation and dissolved oxygen concentration).

5.1.1 Location

Truman Dam is located on the Osage River 280.2 km (175.1 miles) upstream of the confluence with the Missouri River. The Truman Dam powerhouse is located approximately 2.4 km (1.5 mile) northwest of Warsaw, Missouri. The watershed comprises 15 counties in Missouri and 10 counties in Kansas. Historic water quality sampling sites at Truman Lake include 9 lake, 1 outflow, and 7 inflow sites (Figure 5.1).

5.1.2 **Authorized Purposes:** flood control, hydroelectric power production, fish and wildlife conservation, and recreation.

5.1.3 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	739.6	4,005.4	209,048	
Multipurpose	706.0	1,181.6	55,406	958
Total		5,187.0		

Total watershed area: 11,500 sq miles (total upstream watershed)
8,914 sq miles (total local drainage below upstream dams; 5,704,960 A)

Watershed ratio: 27.29 FC / 102.97 MP
Average Annual Inflow: 7,315,389 acre-ft/yr (1982 – 2006)
Sediment inflow (measured): 22,321 acre-feet (1979 – 1992)
Flushing rate: 0.16 years
Water management Plan: Approved 12 May 1981; minor revision April 1996
Historic stage hydrograph: 1995 – 2005 (Figure 5.2)

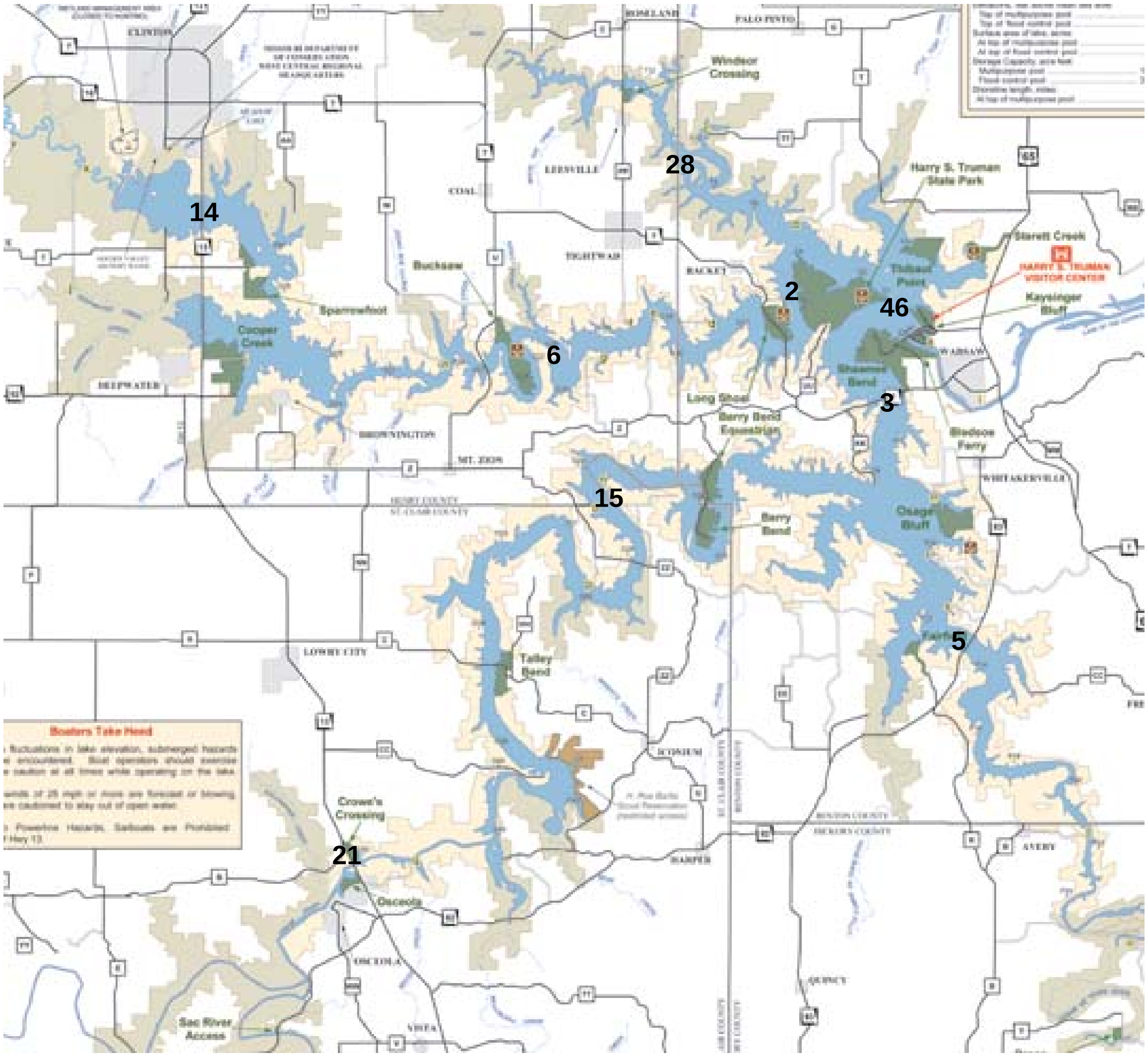


Figure 5.1. Harry S. Truman Lake area map with sample site locations and site numbers.

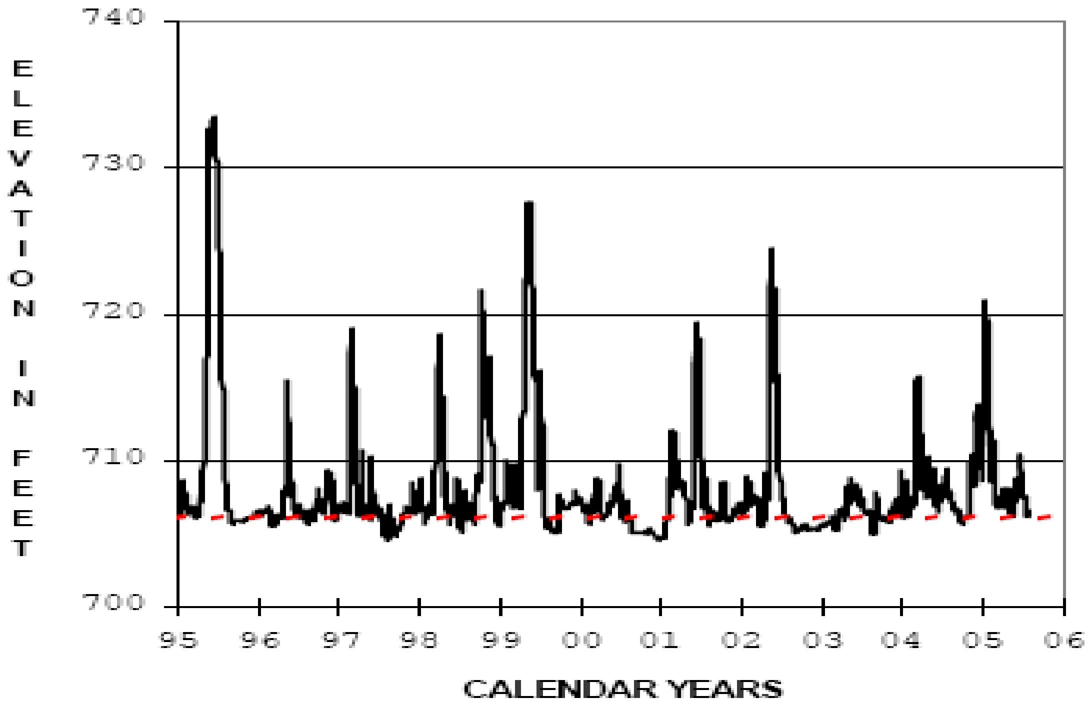


Figure 5.2. Pool elevation hydrograph from 1995 - 2005

5.2 2006 Activities

Harry S. Truman lake was categorized as an ‘ambient’ lake during 2006, thus only surface water quality samples were collected at the nine lake sites (see Figure 5.1). In addition, surface water samples were collected downstream of the lake approximately 600 m downstream of the powerhouse. Samples were collected and vertical profiles were recorded monthly from May through September. The Marais des Cygnes, Marmaton, and Little Osage river watershed committee completed a watershed management plan during late 2006. The committee is headed by Don Schuster (NRCS) and consists of representatives from MDNR, MDC, EPA, and several counties. This group joined with the Marais Des Cygnes Basin Advisory Committee and submitted a grant proposal to EPA for a Targeted Watershed grant in an effort to coordinate water quality and quantity issues between Kansas and Missouri. The NWK’s Water Quality Program has been involved on the periphery to this point, providing input on water quality issues. In addition, the NWK Planning Section proposal -- *Water Resources Analysis Plan for the Upper Osage River Watershed of Kansas and Missouri* – was not selected to receive funding of HQ’s “Comprehensive Analyses of Multi-Jurisdictional Use and Management of Water Resources on a Watershed or Regional Scale” grant program. Presentations on Truman Lake water quality were provided at meetings held by the Lake of the Ozarks Watershed Alliance in Camdenton and Warsaw during October 2006.

Truman Lake staff (OF-HST) providing field assistance during 2006 included: Rich Abdoler, Larry Smith, Erin Cordrey, Jason Hurley and Melissa Herheim. Bob Marchi, OF-HST Operations Manager, provided insight and background on the lake resources.

5.3 2006 Data

Comparative historic data includes single samples collected during 1999 (August), 2001 (May), 2002 (July), and monthly (May – September) sampling during 2005. Samples were collected from May through September during 2006.

5.3.1 Inflow

No inflow data was collected from Truman Lake during 2006.

5.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Longitudinal differences in median total nitrogen (TN) concentrations (0.5 – 1.4 mg/L) were observed between sample sites from data collected between 1996 and 2006 (Figure 5.3). Highest median concentrations were measured from samples collected at the Highway 65 bridge sites on both the South Grand (#14) and Upper Osage (#21) river arms, while the lowest median concentration is from the Tebo Creek branch site (#28). It should be noted that all median values exceed EPA's proposed ecoregional nutrient criteria for TN (0.46 mg/L). The median TN concentration at Site 14 (South Grand River) is one of the highest within the district.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Similar to TN, longitudinal differences in median total phosphorus (TP) concentrations

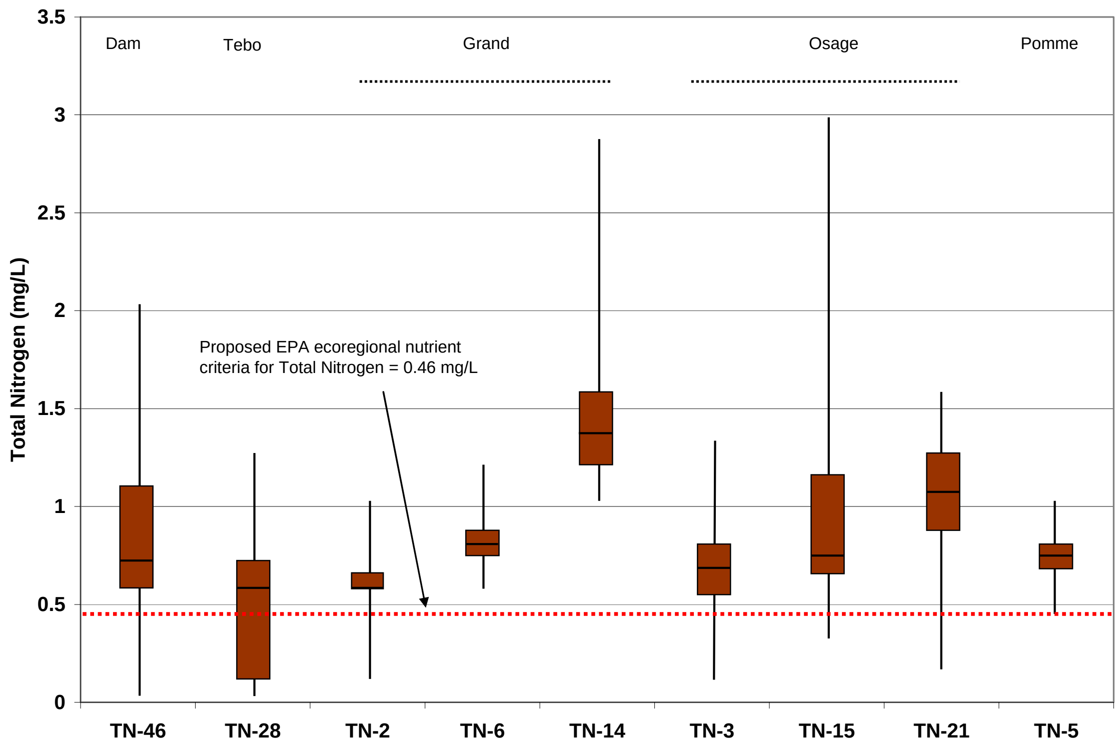


Figure 5.3. Box plots of surface water sample total nitrogen concentrations measured by site during 1999, 2002, and 2005 - 2006 at Harry S. Truman Lake.

(0.04 – 0.19 mg/L) were detected between sample sites at Truman Lake for data collected from 1996 through 2006 (Figure 5.4). The highest concentrations are associated with up-lake sites, with the highest median TP concentration measured at Site 14 (South Grand River). It should be noted that very high concentrations have been measured at Site 2 (lower South Grand River site). The primary source of phosphorus for this site is suspected to be failing septic systems. Median TP concentrations for all nine lake sites currently exceed EPA's proposed ecoregional nutrient criteria.

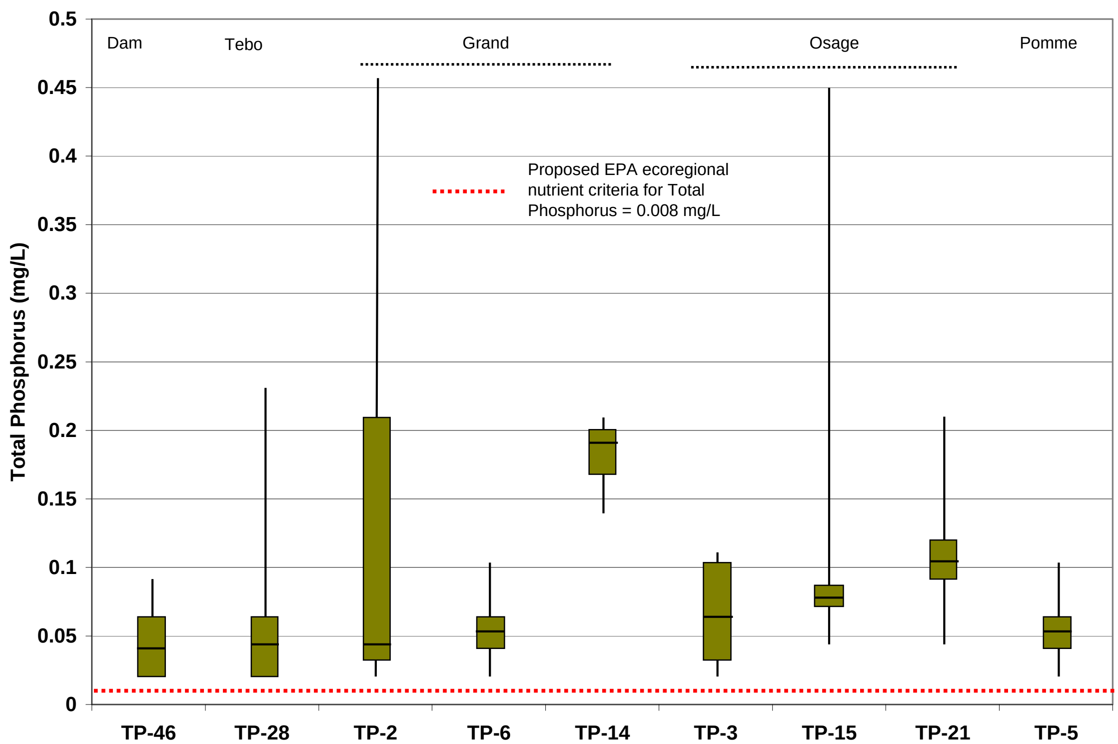


Figure 5.4. Box plots of surface water sample total phosphorus concentrations measured by site during 1999, 2002, and 2005 - 2006 at Harry S. Truman Lake.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a lake. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). Five of the nine sites exhibited median TN:TP ratios < 12, indicating certain sites within the lake are potentially at risk for cyanobacteria blooms (Figure 5.5). Sites 2, 14, and 21 exhibited the highest TP concentrations and also the lowest TN:TP ratios. It should be noted the microcystin toxin has been collected from Harry Truman Lake during 2000 (Dr. Jennifer Graham, USGS, personal communication).

Mean chlorophyll a concentrations for Truman Lake ranged from 20.0 – 33.4 ug/L during 2006 (Figure 5.6), which is indicative of nutrient-rich waters. Highest values were recorded from samples collected at Sites 14 and 21 (uplake). Mean secchi depth measurements ranged from 0.17 – 1.61 m, indicating the variability of sites and tributaries for the large lake (Figure 5.7). A longitudinal gradient was apparent in terms of water clarity, as the poorest clarity existed at both upper lake sites (Sites 14 and 21).

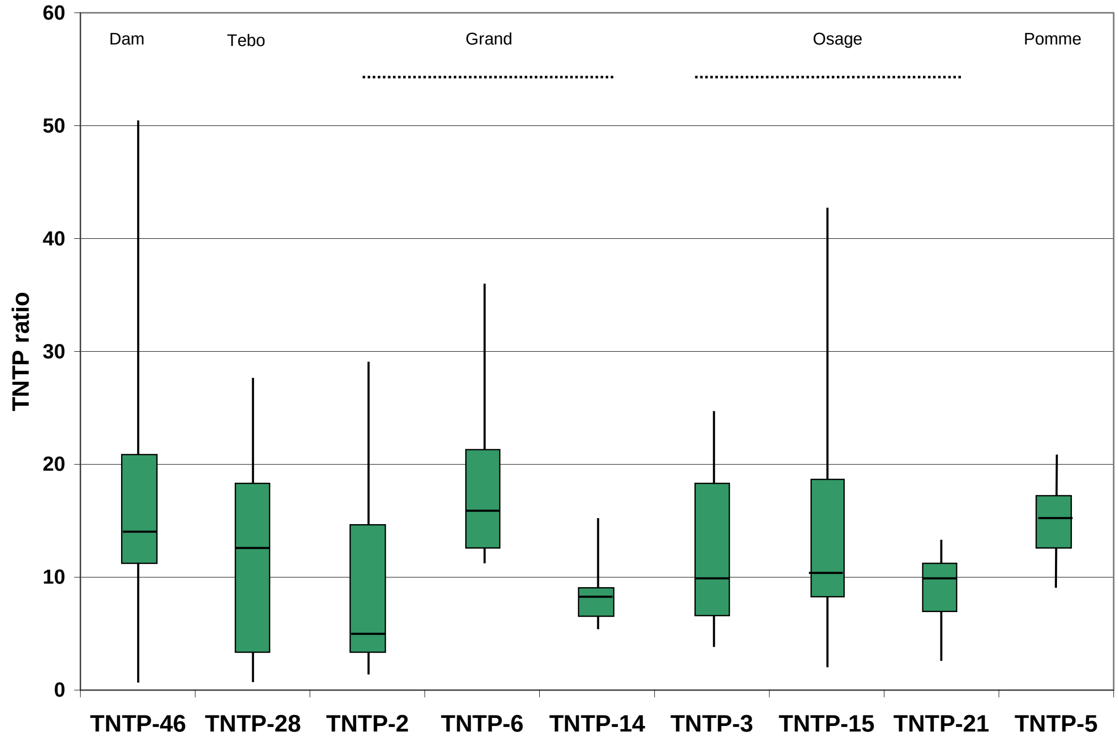


Figure 5.5. Box plots of total nitrogen : total phosphorus ratios from surface water samples measured by site during 2005 - 2006 at Harry S. Truman Lake.

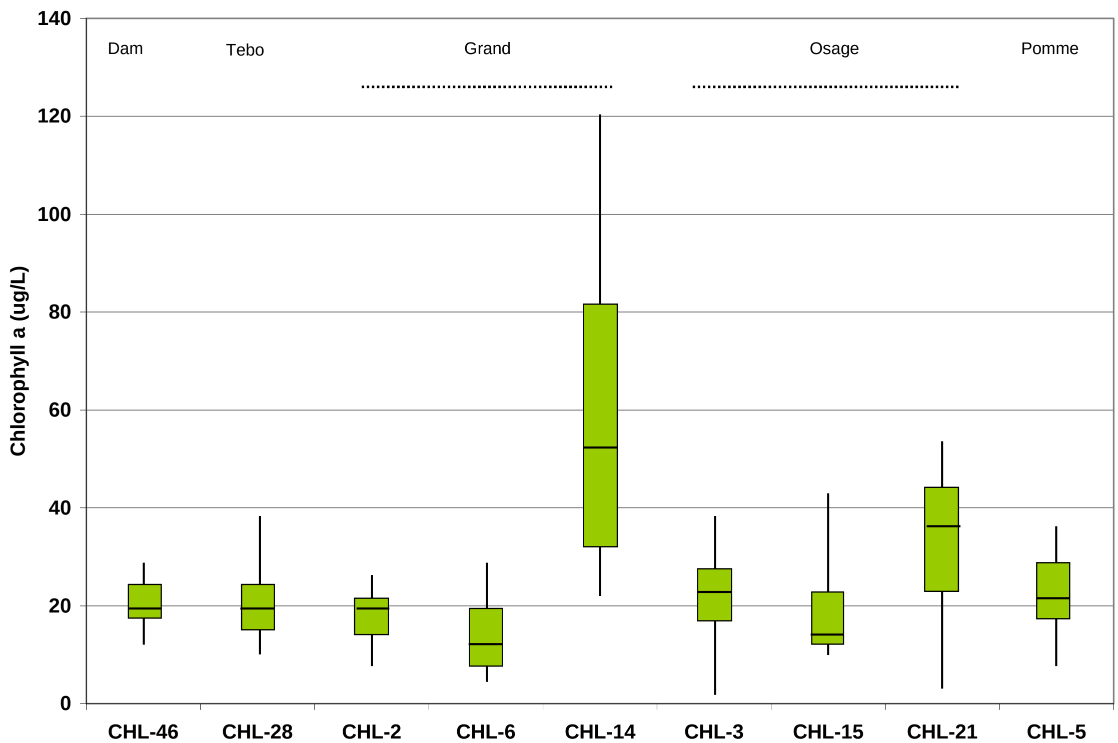


Figure 5.6. Box plots of chlorophyll a concentrations measured by site during 2005 and 2006 at Harry S. Truman Lake.

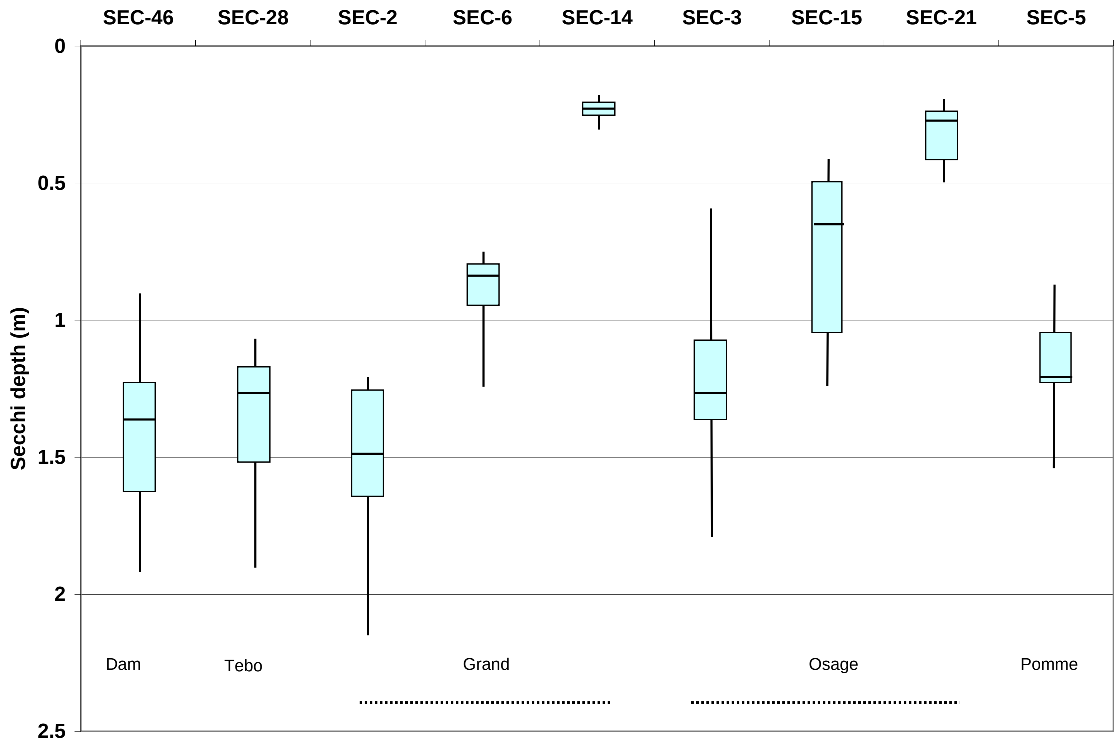


Figure 5.7. Box plots of secchi depth water clarity measured by site during 2005 and 2006 at Harry S. Truman Lake.

This would be expected considering the expansive shallow mud flats in these segments of the lake. Water clarity was higher at all sites during 2006 vs 2005; the lone exception was Site 14 (Figure 5.8). This was most likely a response to drought conditions within the watershed.

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip at Sites 2, 3, 5, 28 and 46. Such profiles provided information on monthly as well as within lake distribution changes. Figure 5.9 depicts vertical distribution of phycocyanins measured at Site 2 (South Grand arm) from May through July and September. Concentrations increased from May into July, before declining slightly in September. The observed peak concentrations were among the lowest detected within the district.

Vertical profiles were recorded at the lower lake sites from June through September. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on this information, the lake was strongly stratified both thermally and chemically between a depth of 5 – 8 m during the summer period at Site 2 (Figure 5.10). Summer stratification occurred at a depth of 4 – 7 m at Site 46 (Figure 5.10).

Fecal bacteria (*E. coli*) samples were collected from three locations at each of six Corp swimming beaches prior to three major holidays (Memorial Day, July 4th, and Labor Day) during 2006. Samples collected from both Thibaut Point and Sparrowfoot prior to Memorial Day exceeded the compliance limits of 126 colonies / 100 ml for a whole-body

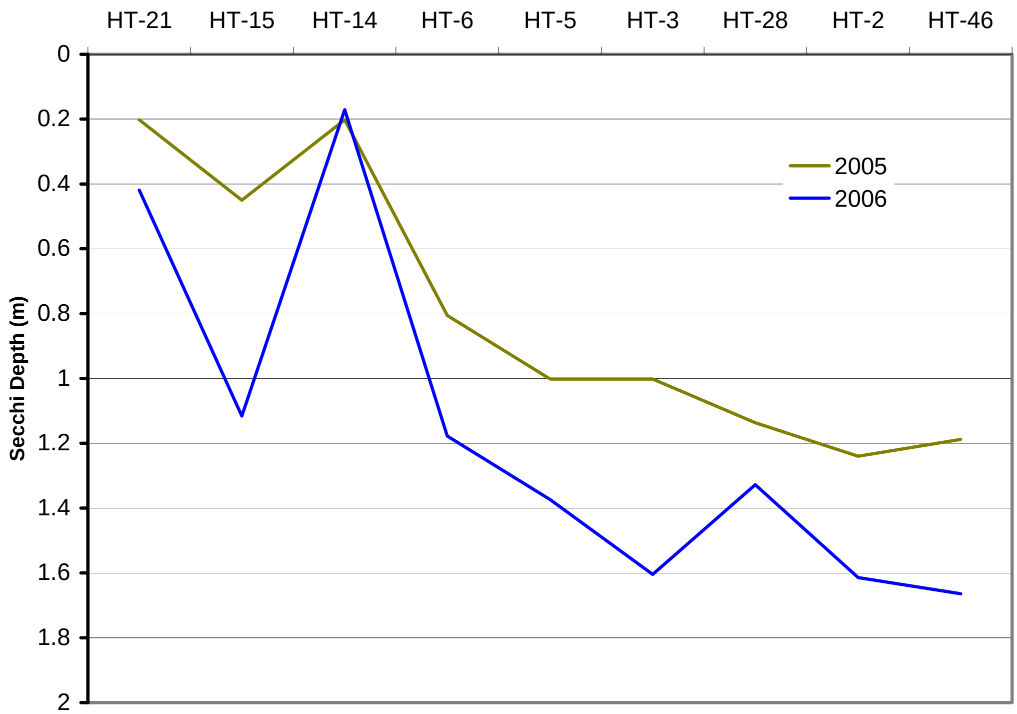


Figure 5.8. Plot of mean summer (June – August) secchi depth water clarity measured by site during 2005 and 2006 at Harry S. Truman Lake.

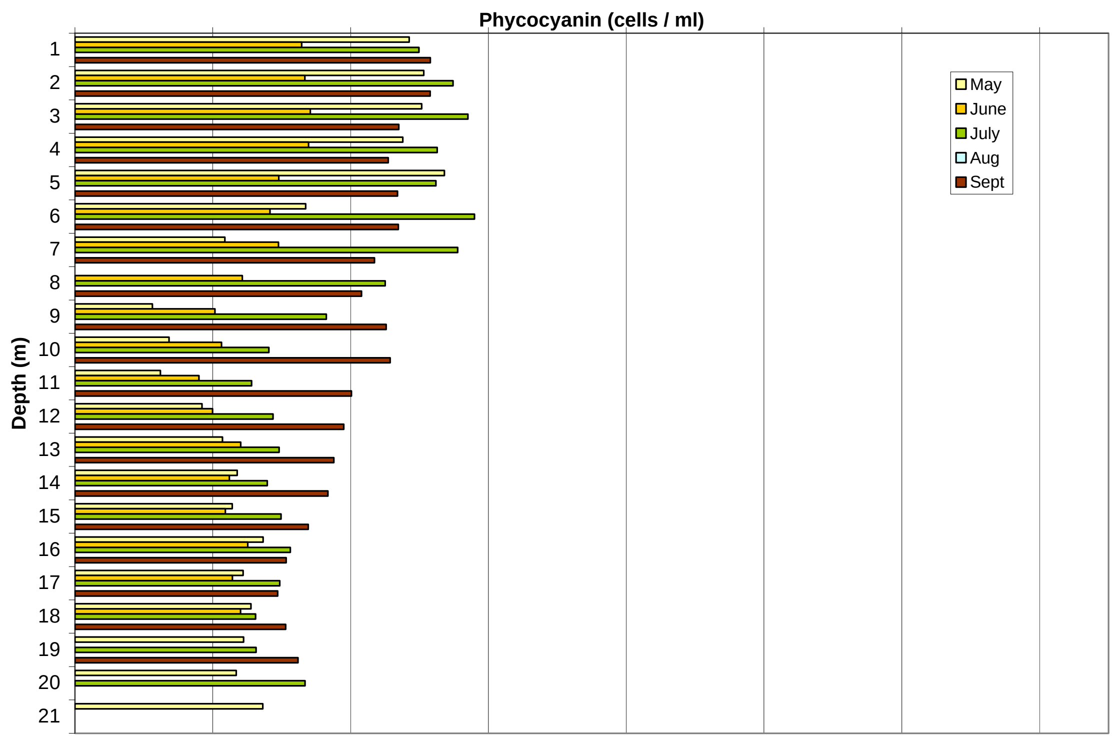


Figure 5.9. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Harry S. Truman Lake Site 2 (South Grand River arm) during 2006.

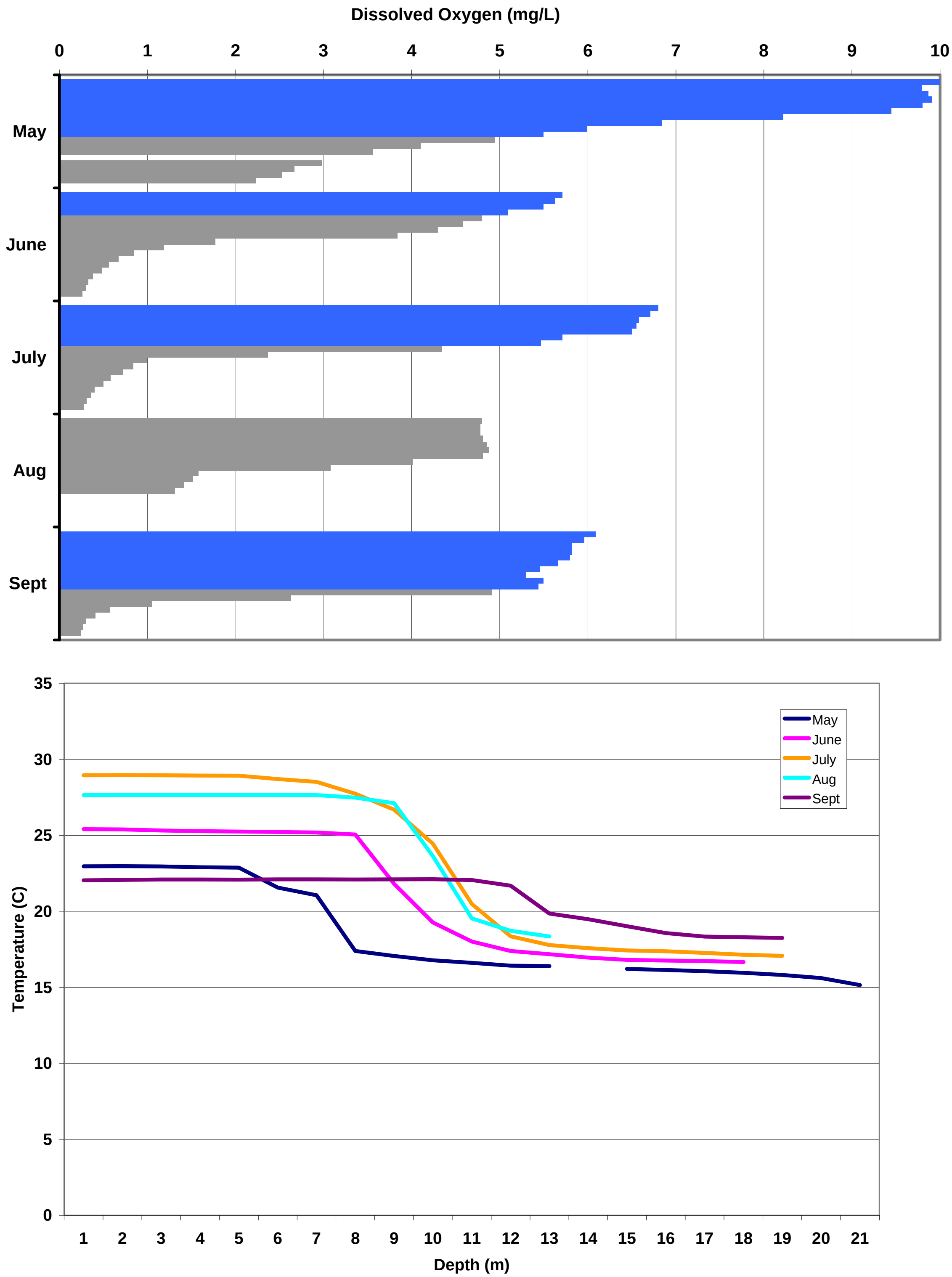


Figure 5.10. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plot from vertical profiles recorded at Site 46 from May – September, 2006 at Harry S. Truman Lake.

contact during the recreational season (Figure 5.11). Thus, both beaches were resampled two days later and were well within compliance limits (means = 6.3 and 48.4 colonies / 100 ml @ Thibaut Point and Sparrowfoot, respectively).

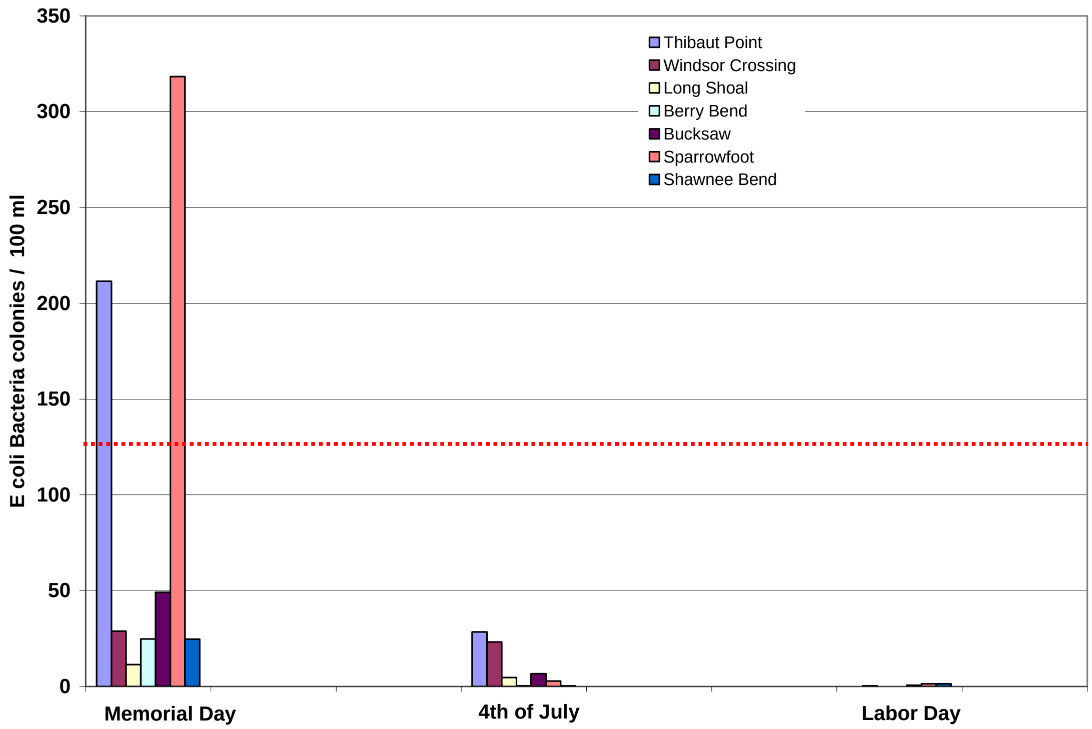


Figure 5.11. Fecal bacteria colonies per 100 ml samples from beach samples collected prior to major holidays at Harry S Truman Lake during 2006.

5.3.3 Outflow

Outflow data was collected from Truman Lake (Site 1) during 2006, but none of it was included in this report.

5.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition from monthly ‘ambient’ monitoring to ‘intensive’ monitoring from April through September. This will also include conducting monthly vertical profiles at each of the nine lake sites. Due to concerns of potentially toxic bluegreen algae, phycocyanin concentrations will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. To more completely understand dissolved oxygen dynamics within the tailrace area, 1 – 2 longterm monitoring instruments (Eureka Midges) will be deployed from June through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP’s, illicit dumping from boats, etc. The Marais des Cynges, Marmaton, and Little Osage Rivers watershed plan committee completed its’ watershed management plan above the lake. Continued interaction with this group could produce a beneficial relationship in regards to lake water quality. In addition, this group is awaiting word on the status of an EPA Targeted Watershed grant submitted during 2006. In addition, a watershed management plan effort focusing on the Pomme de Terre watershed will begin during 2007. Active involvement and data sharing will be coordinated with this multi-agency and citizen-based effort. It is expected that Truman Lake will be added to a future 303(d) list once the Missouri Clean Water Commission approves nutrient criteria.

6 Hillsdale Lake

6.1 General Background

Hillsdale Lake was impounded on 19 September 1981 and reached full pool on 23 February 1985. The main threats to water quality in Hillsdale Lake are nutrients, sedimentation, herbicides, and hydrologic changes related to urban sprawl in the northern reaches of the watershed. The lake is listed on Kansas's 303(d) list for water quality impairment due to eutrophication. Therefore, a TMDL was approved in 2001 to address nutrient control within the watershed. The TMDL goal for Hillsdale Lake is a reduction in the lake's trophic state index (TSI) from fully eutrophic (TSI = 59) to slightly eutrophic (TSI < 55), which would require a 46% reduction in the total annual phosphorus load to the lake. Concerned citizens within the watershed initiated the Hillsdale Water Quality Project (HWQP) in 1991 due to concerns of drinking water protection and recreational use. Since 1993, more than $2 million has been received by the HWQP to improve, monitor, and restore water quality in the lake. In addition, the city of Spring Hill initiated efforts in 2005 to develop a WRAPS project within the upper reaches of Hillsdale Lake watershed to protect their drinking water source. Most recently, Burlington Northern Santa Fe railroad has made overtures to develop a large facility within the upper northern section of the watershed.

6.1.1 Location

The lake is located approximately 8 km (5 miles) northwest of Paola, Kansas.
The dam, built on Big Bull Creek, is located 29.1 km (18.2 miles) upstream of the confluence with the Marais des Cygnes River. The watershed includes southern Johnson County, southwest Douglas County, Franklin County, and Miami County. This area includes the expanding communities of Spring Hill, Edgerton, and Gardner. Historic water quality sample sites at Hillsdale Lake include 3 lake, 1 outflow, and limited inflow data from 3-4 sites (Figure 6.1)

6.1.2 Authorized Purposes: flood control, water supply, water quality improvement, recreation, and fish and wildlife management.

6.1.3 State Use Designations: Primary and secondary contact recreation, special aquatic life support, drinking water supply, industrial water supply, food procurement.

6.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	931.0	83.6	7,413	
Multipurpose	917.0	76.3	4,575	51
Total		159.9		

Total watershed area: 144 sq miles (92,160 A)
Watershed ratio: 12.44 FC / 20.12 MP

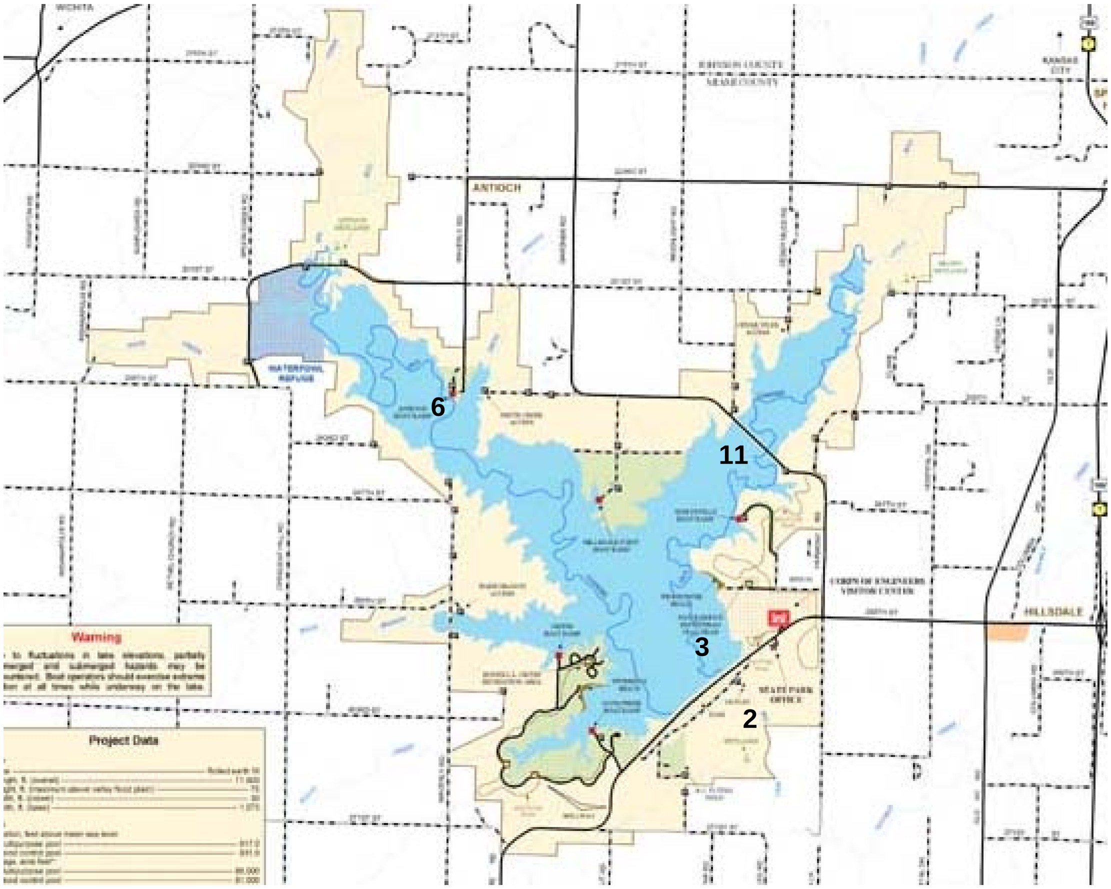


Figure 6.1. Hillsdale Lake area map with sample site locations and sample numbers.

Average Annual Inflow:	91,217 acre-feet (1982 – 2006)
Average Annual outflow:	000 acre-feet
Flushing Rate:	0.84
Sediment inflow:	1,928 acre-feet (1981 – 1991)
Water management Plan:	Submitted for approved 20 May 2005
Historic stage hydrograph:	1995 – 2005 (Figure 6.2)

6.2 2006 Activities

Hillsdale Lake was categorized as an 'ambient' lake during 2006, thus only surface samples were collected at the three lake sites. Sample collections occurred from May through September 2006, with vertical profiles measured at the three lake sites during each monthly sample trip. Jim Bell (OF-HD) provided field sampling assistance during 2006, as well as providing a historic perspective of the lake and watershed. Lew Ruona, OF-CL Operations Manager, provided insight and background regarding Hillsdale Lake.

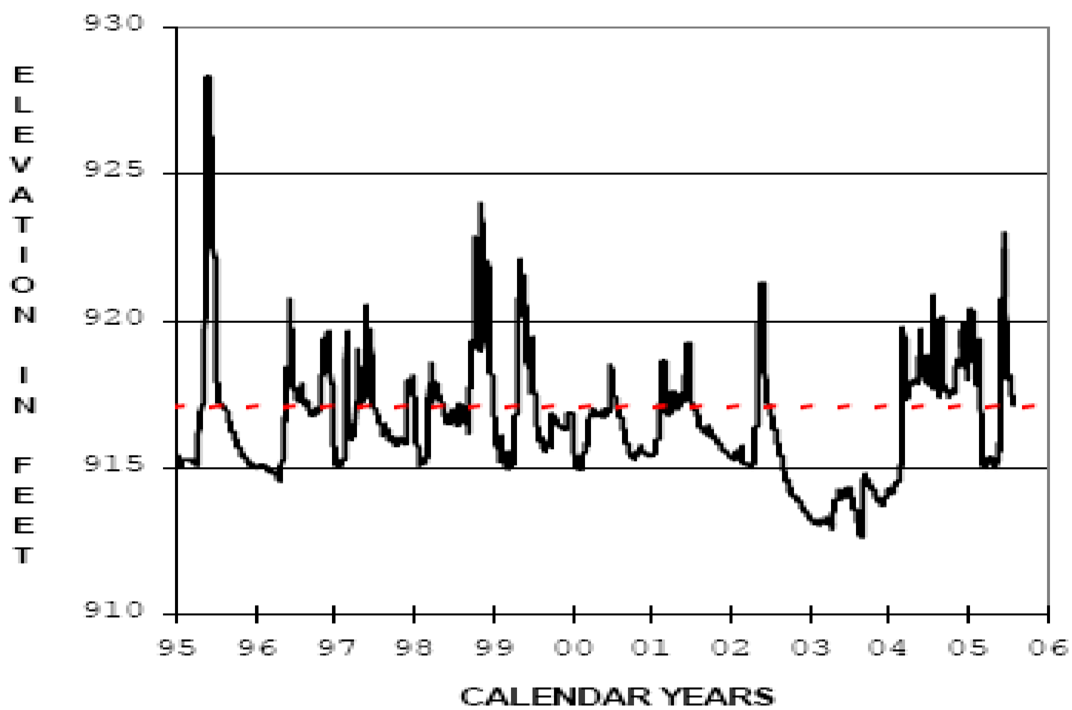


Figure 6.2. Pool elevation hydrograph from 1995 – 2005 (red dashed line is multipurpose pool elevation).

6.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1999 through 2005. Samples were collected from May through September 2006.

6.3.2 Inflow

No inflow samples were collected from Hillsdale Lake during 2006.

6.3.3 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen (TN) concentrations from surface samples are very consistent between the three lake sites, with median values of samples collected between 1999 and 2006 ranging from 0.81 – 0.82 mg/L (Figure 6.3). The median value for samples collected from the outfall was 0.31 mg/L, which is less than the proposed EPA ecoregional nutrient criteria value of 0.36 mg/L TN. As expected, the lake exhibits annual and monthly variability in TN concentrations. Typically, TN concentration peaks in spring following runoff inputs and then declines through summer months as it is assimilated within the lake; see Figure 6.4 for an example from Site 3.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Total phosphorus (TP) concentrations are low compared to other district lakes, with median values ranging from 0.04 – 0.07 mg/L (Figure 6.5). The highest concentrations within

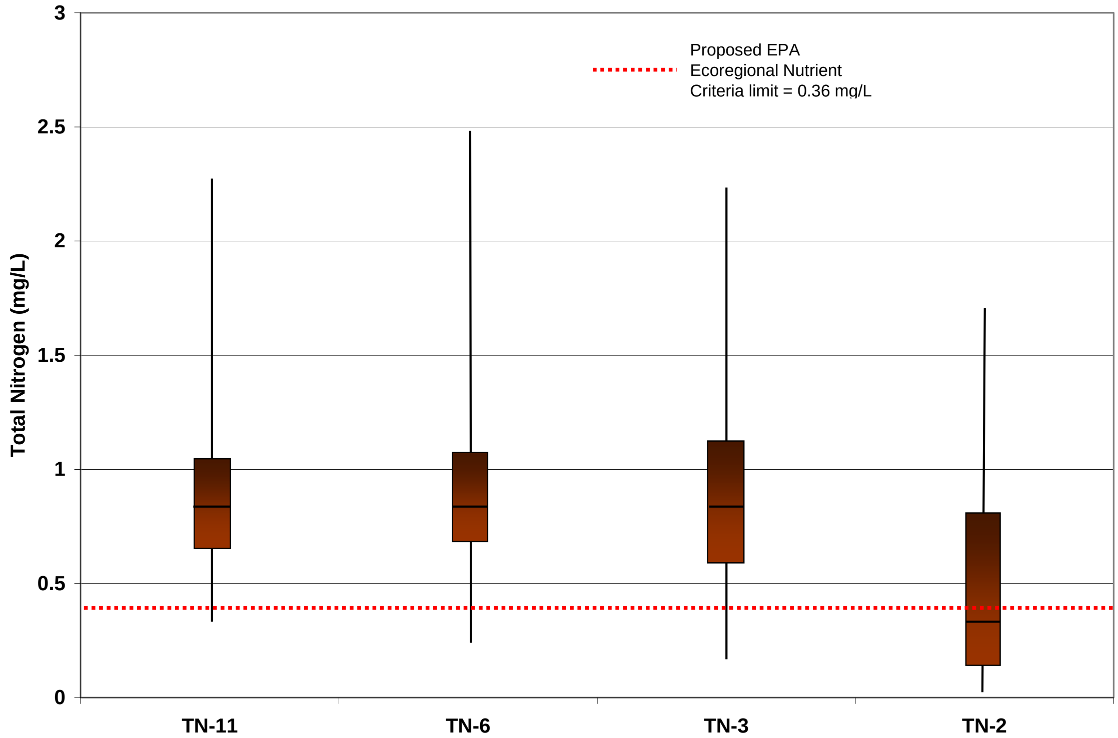


Figure 6.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1999 through 2006 at Hillsdale Lake.

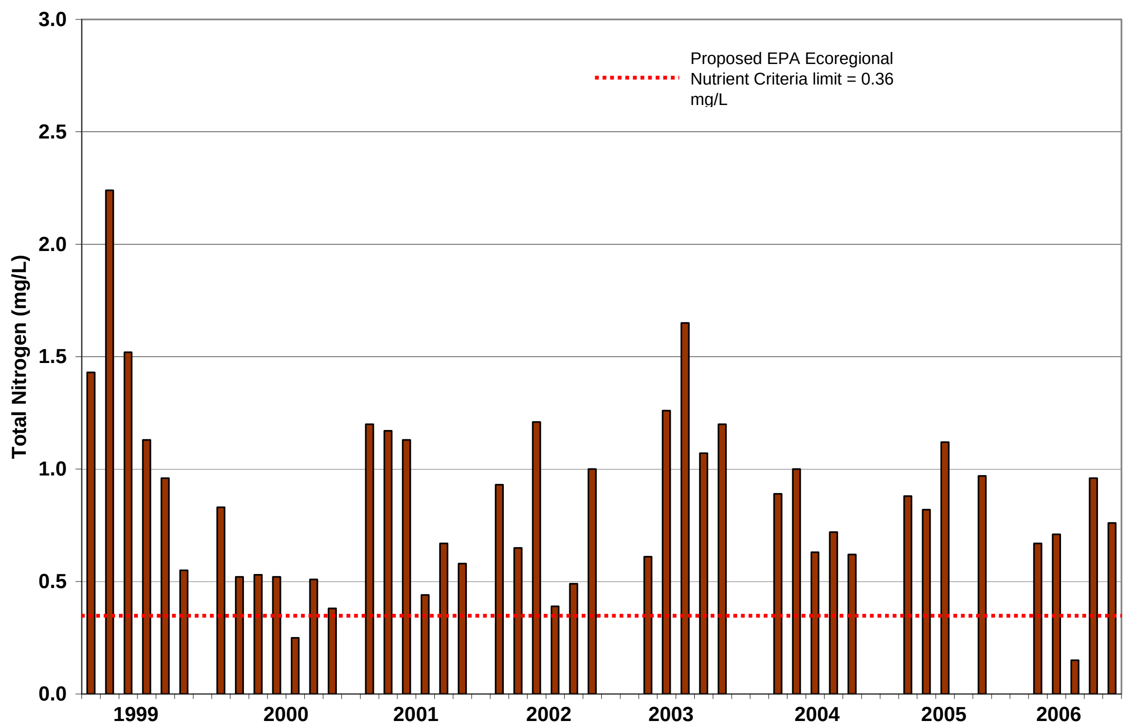


Figure 6.4. Total nitrogen concentrations by sample date collected at Site 3 (Tower) from 1999 through 2006 at Hillsdale Lake.

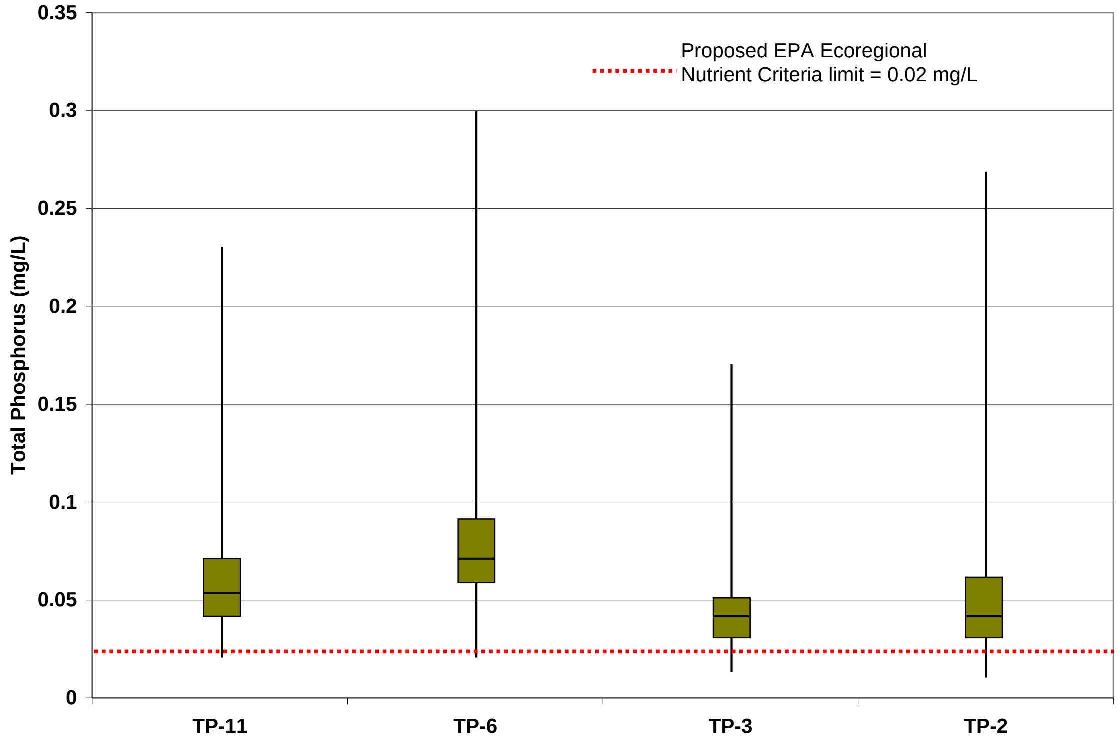


Figure 6.5. Box plots of surface water sample total phosphorus concentrations measured by site from 1999 through 2006 at Hillsdale Lake.

the lake have been measured at Site 6 (Rock Creek). Figure 6.6 depicts annual and monthly variability in TP concentrations measured at Site 6. All values exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 6.7 as an example from Site 3. Median TN:TP ratios from the upper lake sites were slightly greater than 12, indicating the lake could potentially be at risk for cyanobacteria blooms (Figure 6.8). Incidentally, no microcystis toxins were detected in Hillsdale during a single sample collected during 2001 by the University of Missouri – Columbia (Dr. Jennifer Graham – USGS, personal communication).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 6.9 depicts vertical distribution of phycocyanins measured at Site 3 (Tower) from May through September. Concentrations increased from May into August, before declining slightly in September.

An increase in mean annual chlorophyll *a* concentrations is observed at all three lake sites since 2000 (Figure 6.10). A slight decline in mean chlorophyll a at Site 3 during

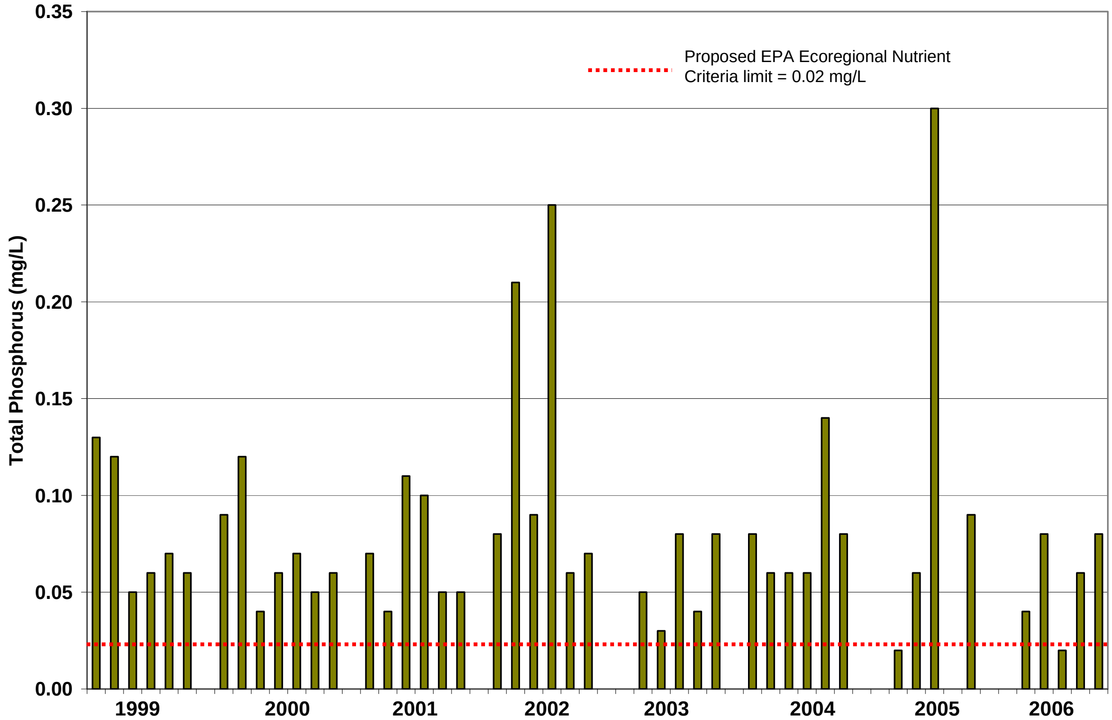


Figure 6.6. Total phosphorus concentrations by sample date collected at Site 6 (Rock Creek) from 1999 through 2006 at Hillsdale Lake.

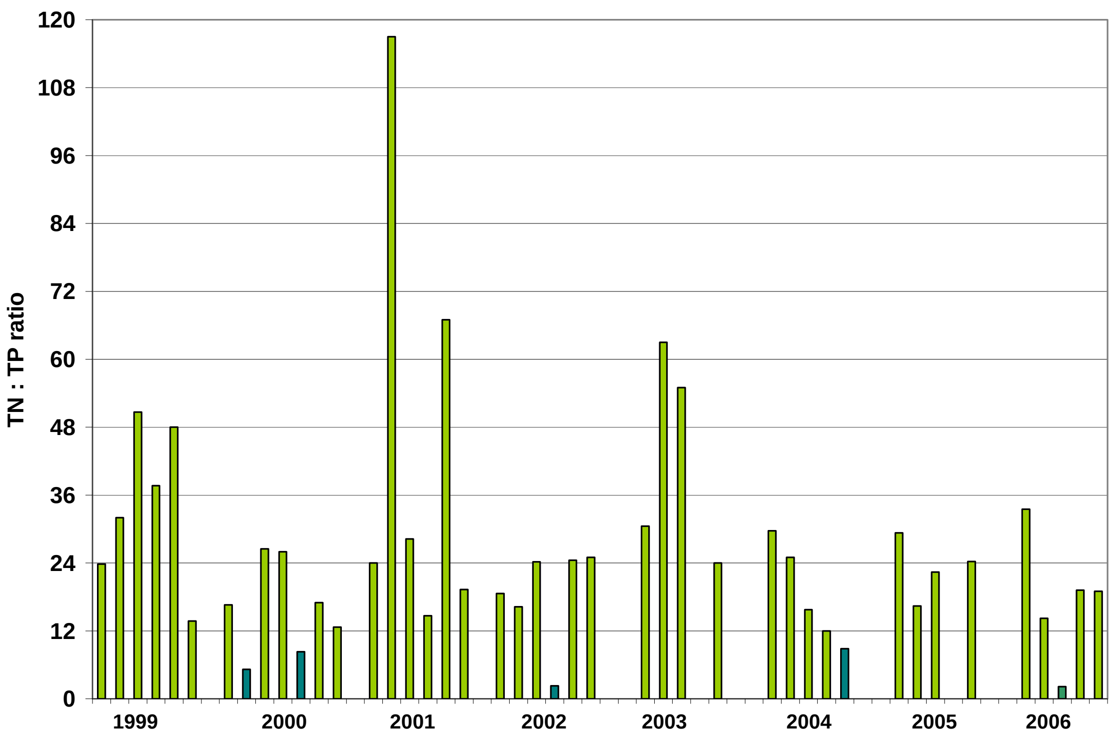


Figure 6.7. Graph of total nitrogen : total phosphorous (TN : TP) ratio by sample date at Site 3 from 1999 through 2006 at Hillsdale Lake.

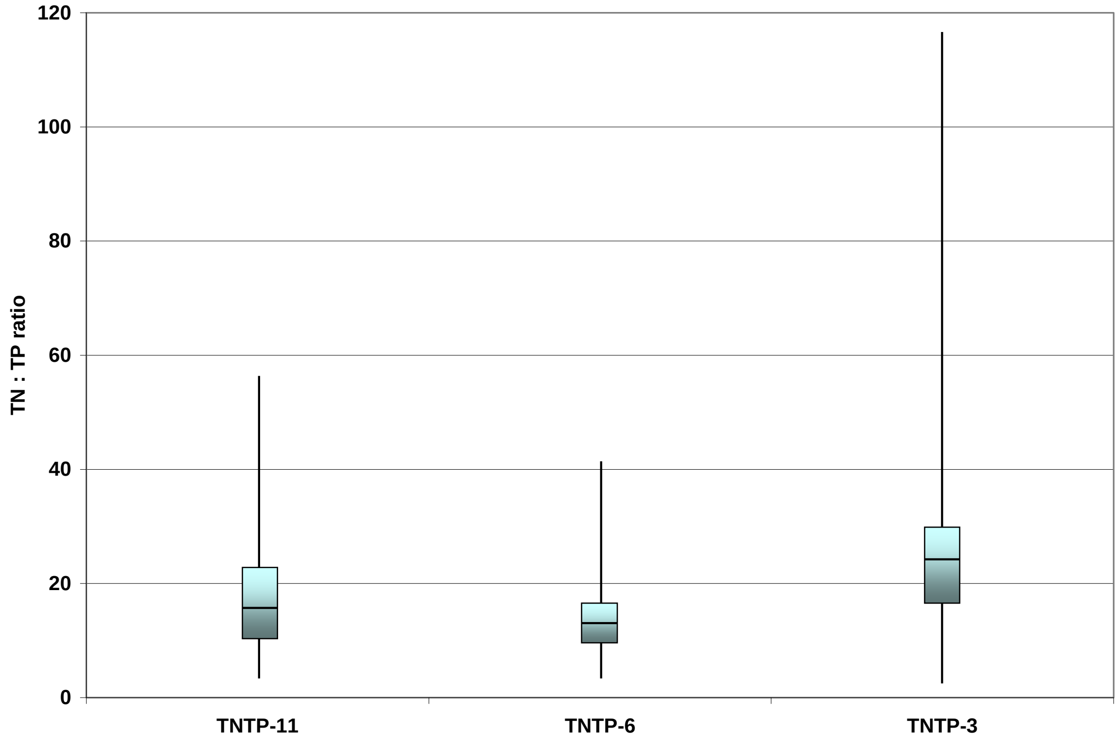


Figure 6.8. Box plots of total nitrogen : total phosphorus ratio (TN:TP) by site from 1999 through 2006 at Hillsdale Lake.

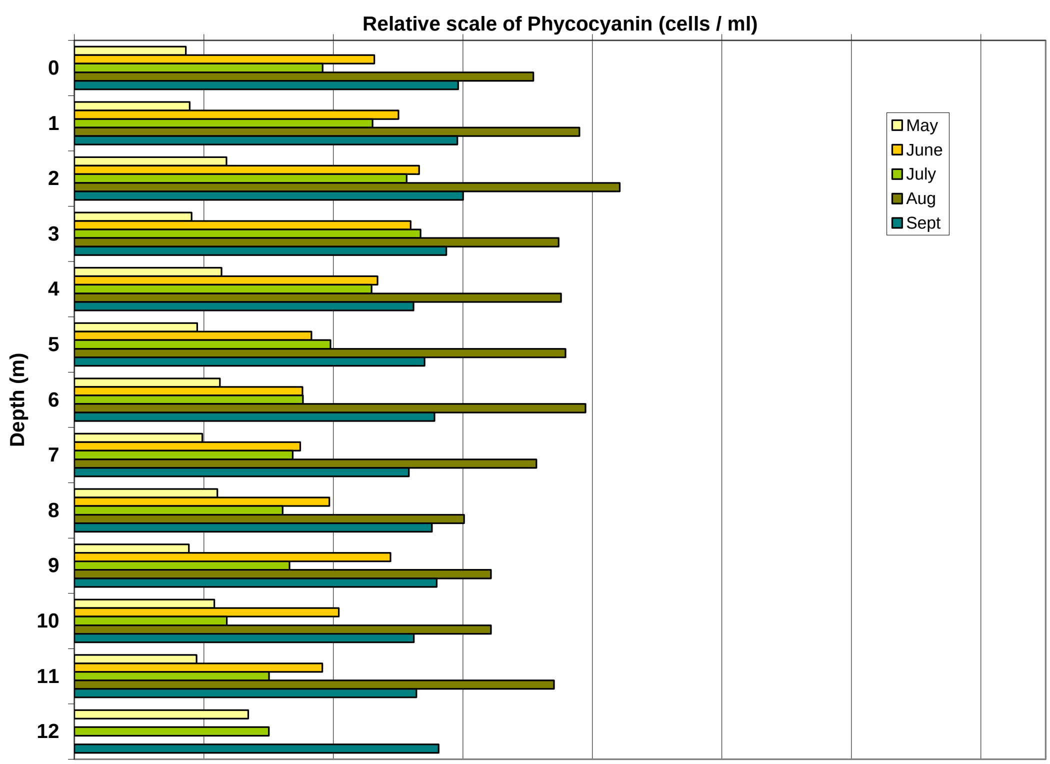


Figure 6.9. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Hillsdale Lake Site 3 (Tower) during 2006.

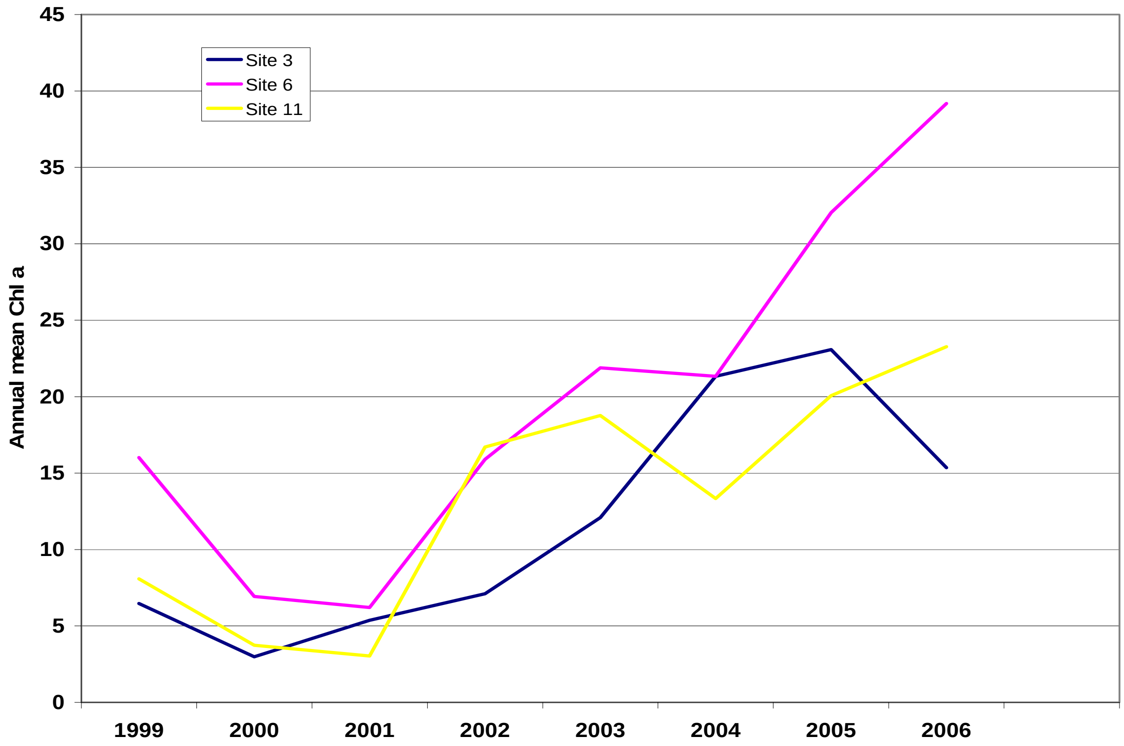


Figure 6.10. Plot of annual mean chlorophyll *a* concentrations measured by site from 1999 through 2006 at Hillsdale Lake.

this past year should be tempered by a high concentration measured in late September. Highest chlorophyll concentrations are routinely measured at Site 6. The increasing trend in chlorophyll *a* at Site 3 during the past four to five years is observed in Figure 6.11. Whether this increasing trend throughout the lake is related to watershed land-use changes is not known at this time.

Differences in secchi depth measurements (0.5 – 0.91 m) were observed between the three lake sites, as depicted in Figure 6.12. The lowest secchi depths are measured at Site 6, which corresponds to the elevated TP and chlorophyll a concentrations. Annual and monthly variability in secchi depth measurements are depicted in Figures 6.13 (Site 3 -- dam) and 6.14 (Site 6 – Rock Creek arm).

The TMDL goal for eutrophication in Hillsdale Lake is a reduction in the lake's trophic state index (TSI) from fully eutrophic (TSI = 59) to slightly eutrophic (TSI < 55). Mean summer TSI values have been increasing at all sites since 2001 (Figure 6.15). An improving trend was detected this past year at Site 3 (Tower) as the mean dropped slightly below 55.

Median atrazine concentrations ranged from 1.8 – 1.9 ug/L for samples collected from 1999 through 2002, 2004 and once during 2006 (Figure 6.16). Although median values are below EPA's drinking water maximum contaminant (MCL) limit of 3 ug/L, seasonal peaks above this value have been measured from samples at the lake – even during 2006. The peak concentration period within the lake occurred in 2002, when all samples

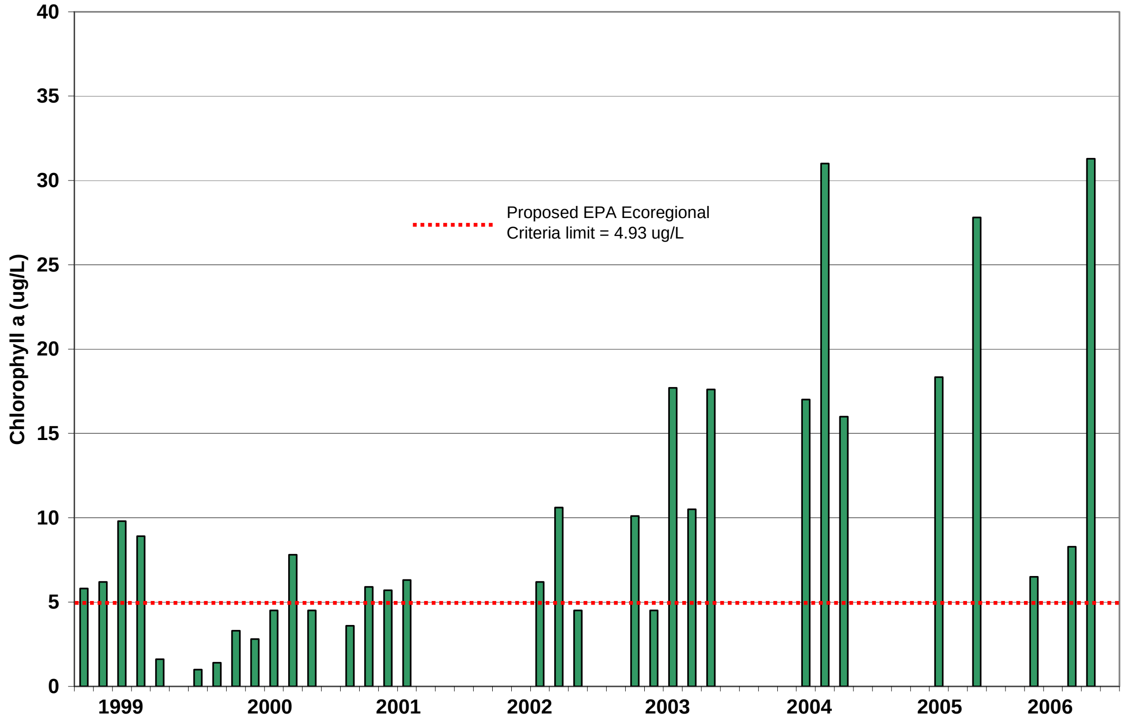


Figure 6.11. Chlorophyll a concentrations by sample date at Site 3 (Tower) from 1999 through 2006 at Hillsdale Lake.

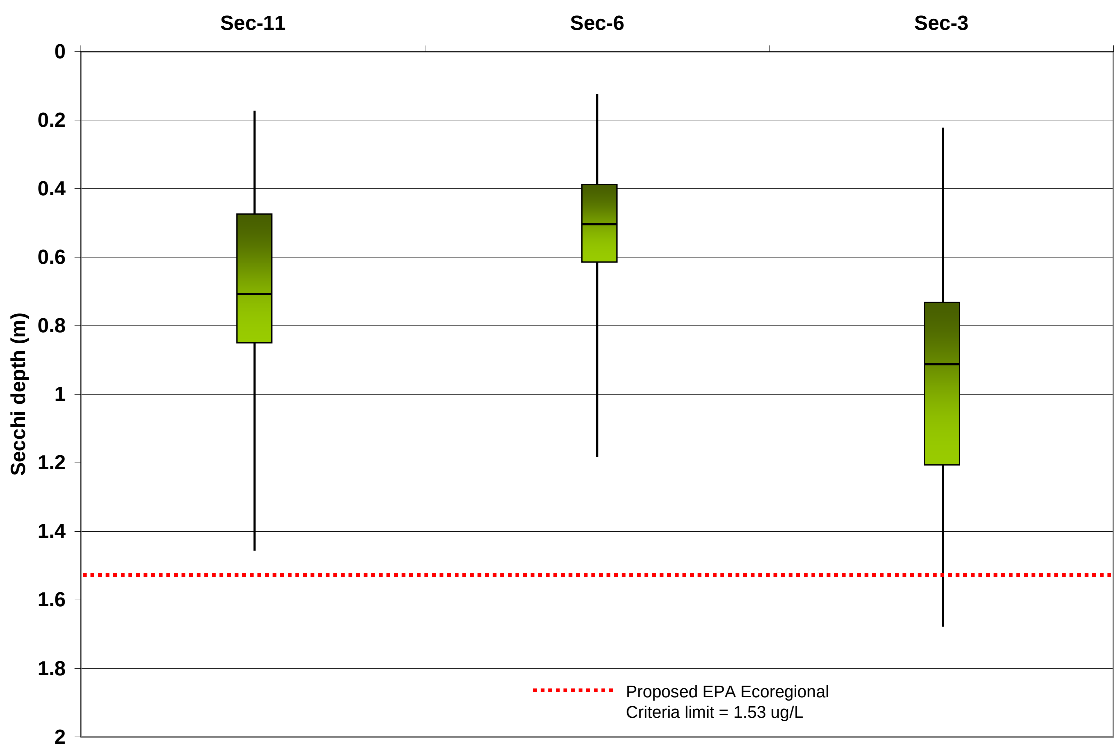


Figure 6.12. Box plots of secchi depth measured by site from 1999 through 2006 at Hillsdale Lake.

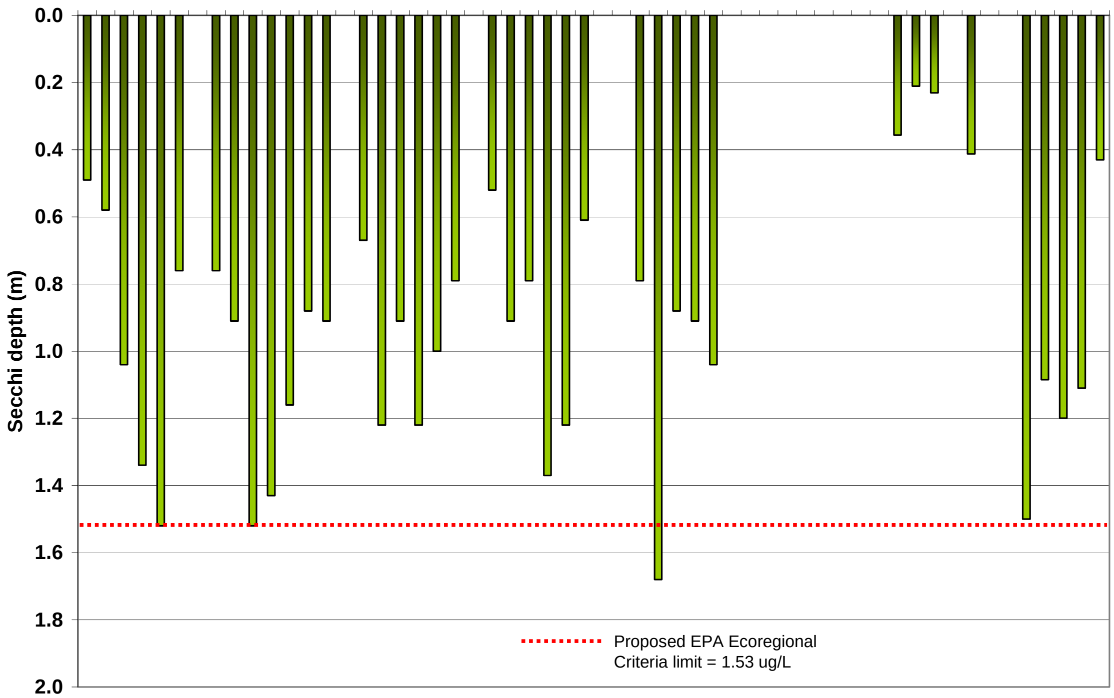


Figure 6.13. Secchi depth measurements by sample date from 1999 through 2006 at Hillsdale Lake Site 3.

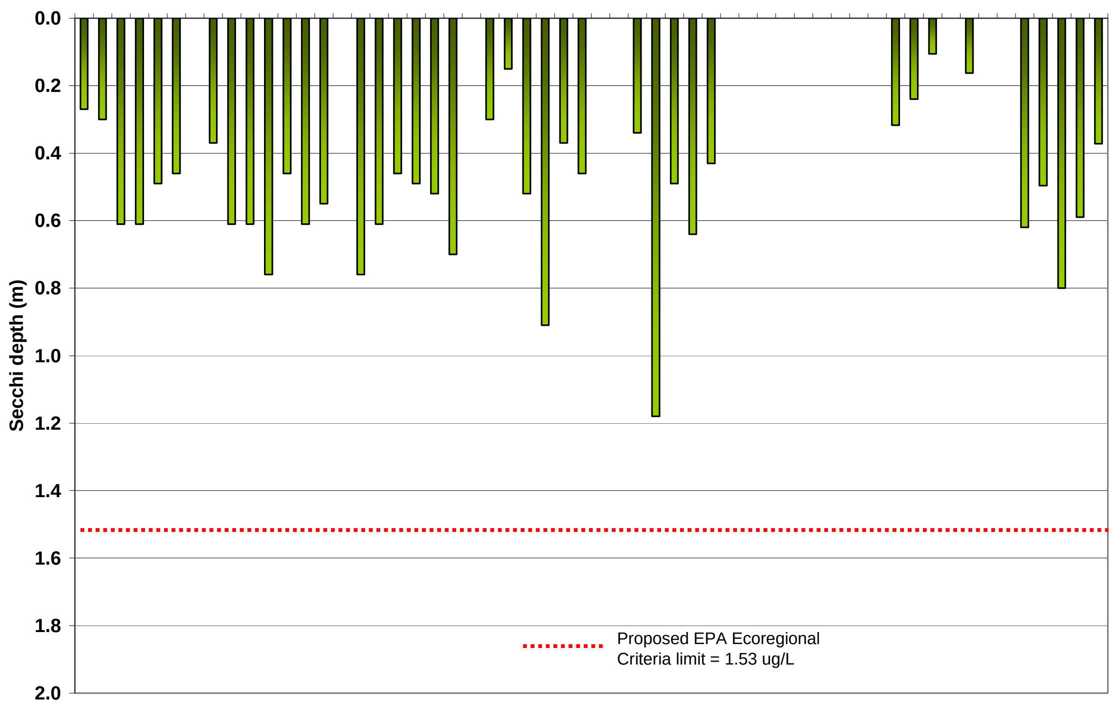


Figure 6.14. Secchi depth measurements by sample date from 1999 through 2006 at Hillsdale Lake Site 6.

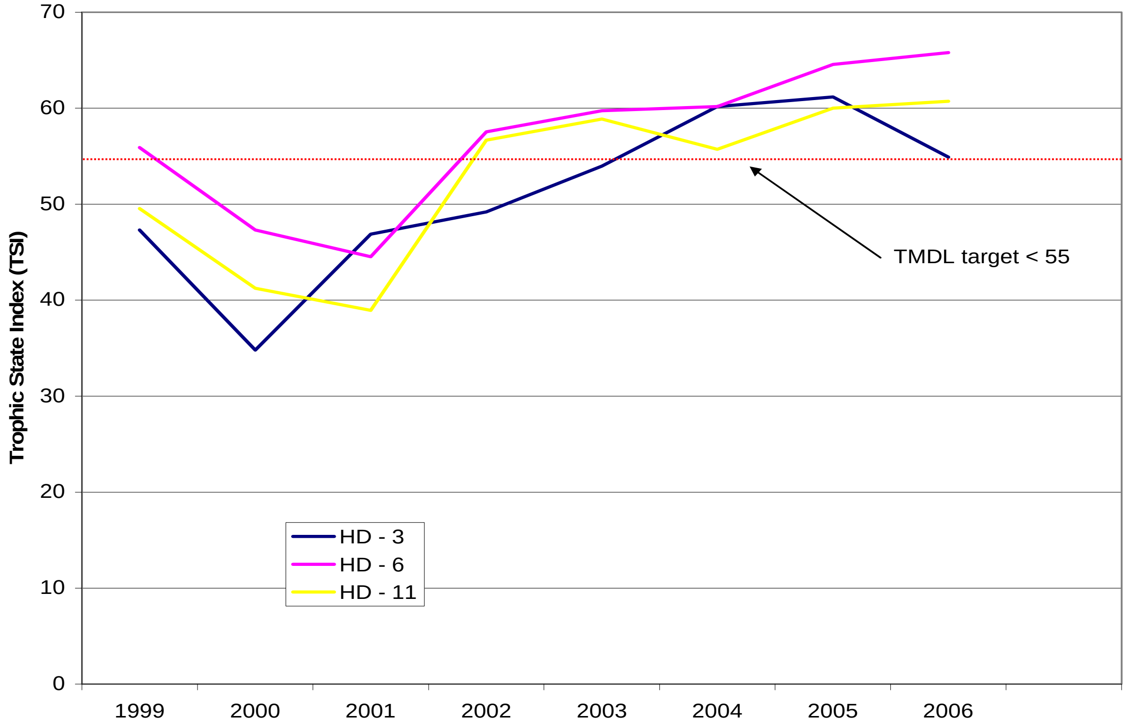


Figure 6.15. Annual mean trophic state index (TSI) scores by year and lake site from 1999 through 2006 at Hillsdale Lake.

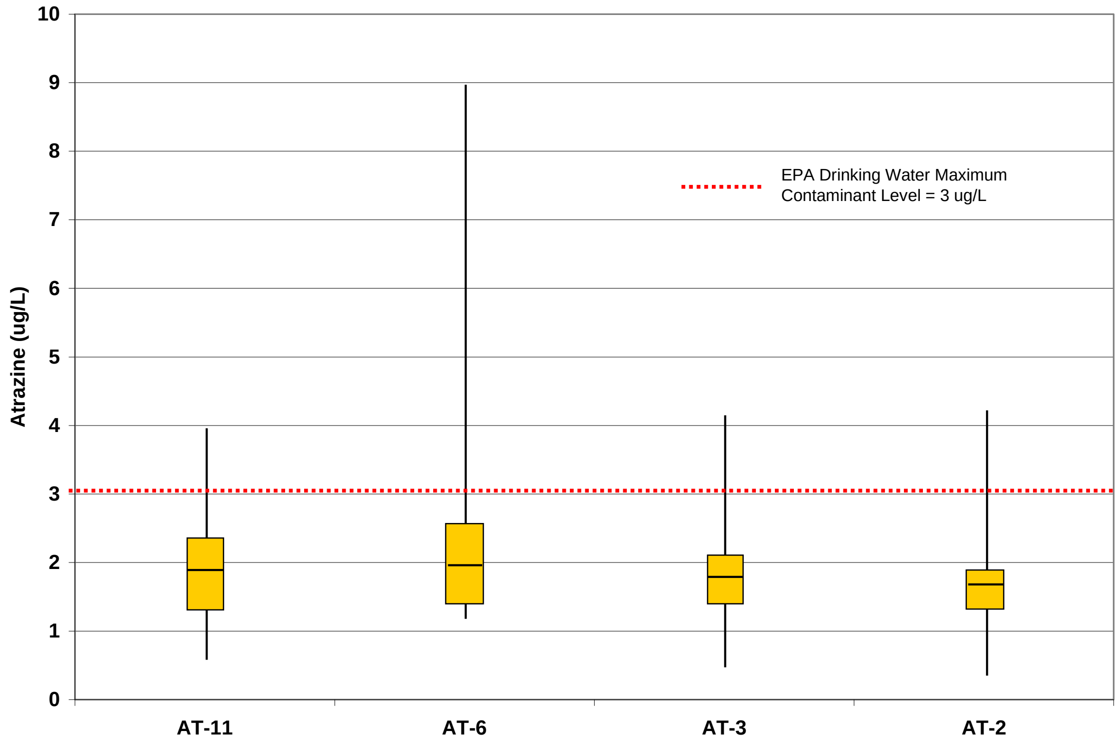


Figure 6.16. Box plots of atrazine concentrations measured from surface lake sites and outflow (Site 2) from 1999 through 2002, 2004, and 2006 at Hillsdale Lake.

collected from Site 6 (Rock Creek arm) during May through September exceeded the MCL (Figure 6.17). A similar annual pattern is observed at Site 11 (Figure 6.18).

Vertical profiles were recorded during monthly sampling trips to Hillsdale Lake in 2006. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Typical of smaller, eutrophic Midwest reservoirs, the lake stratifies both thermally and chemically. Lake stratification began at 5-6 m in depth during June and July, while DO concentrations throughout the entire water column were below 5 ppm during August (Figure 6.19). The lake had undergone fall turn-over prior to the late September sample trip based on temperature and DO measurements.

6.3.4 Outflow

No outflow samples were collected from Hillsdale Lake during 2006.

6.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition from an ‘ambient’ to an ‘intensively’ monitored lake. This will include monthly sampling from April through September at three lake sites, two inflow sites, and one outflow site. Monthly vertical profiles will be recorded at each of the three lake sites. Bluegreen algae vertical distribution within the water column will be examined during the summer and compared to TP concentrations measured from surface samples. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP’s, illicit dumping from boats, etc. A contaminant group of interest at Hillsdale Lake is PAHs, which are typical components of asphalt, fuels, oils, and grease. These compounds enter receiving waters from atmospheric deposition, stormwater runoff, as well as through industrial and wastewater treatment discharges. It is expected that such compounds are likely to increase with a rapidly urbanizing watershed. They do not dissolve, but will attach to particulate material and eventually settle out to the substrate. Samples will be collected in 2008 if funds are available. In an effort to collect baseline phycocyanin toxins (blue green algae), the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Sediment – nutrient and metal samples will be collected from all three lake sites during August 2007. This data will provide a comparative point to identify possible resuspension sources.

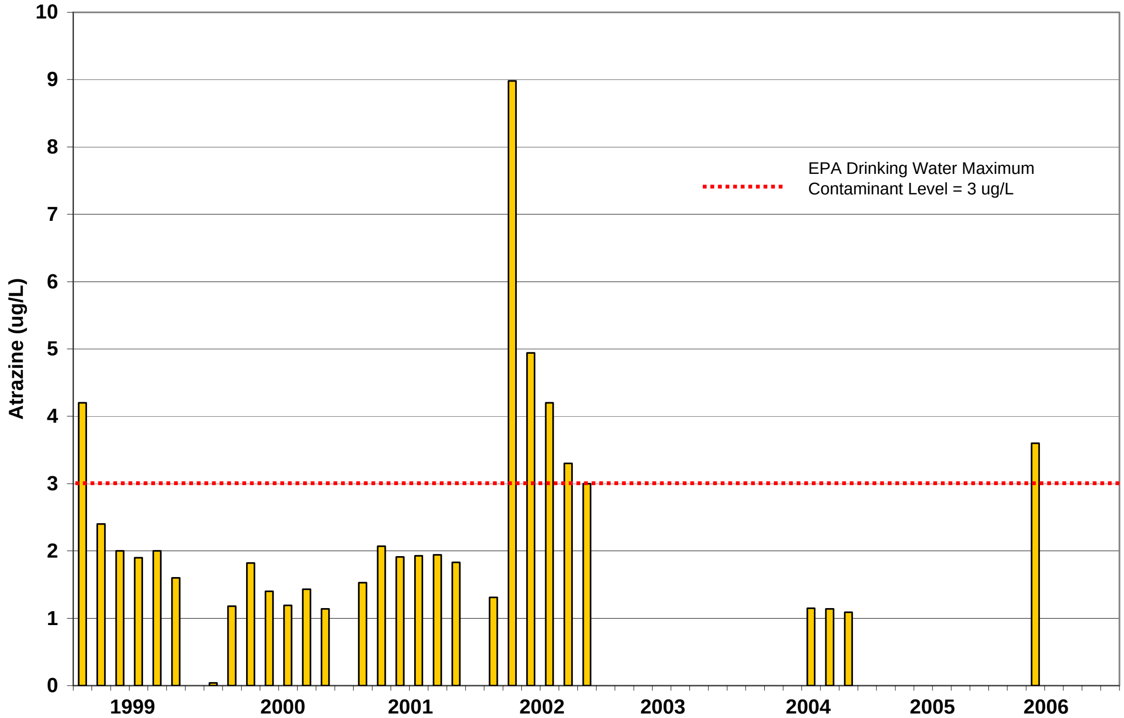


Figure 6.17. Atrazine concentrations by sample date collected at Hillsdale Lake's Site 6 (Big Bull / Rock Creek arm) from 1999 through 2002, 2004, and 2006.

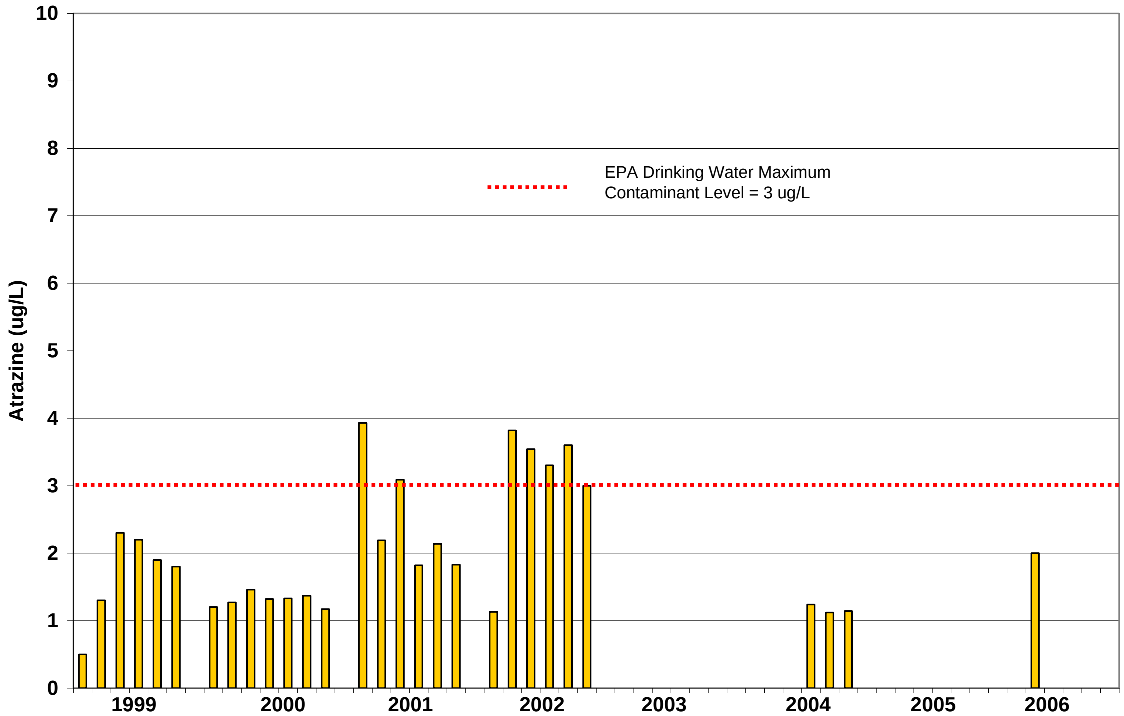


Figure 6.18. Atrazine concentrations by sample date collected at Hillsdale Lake's Site 11 (Little Bull / Spring Creek arm) from 1999 through 2002, 2004, and 2006.

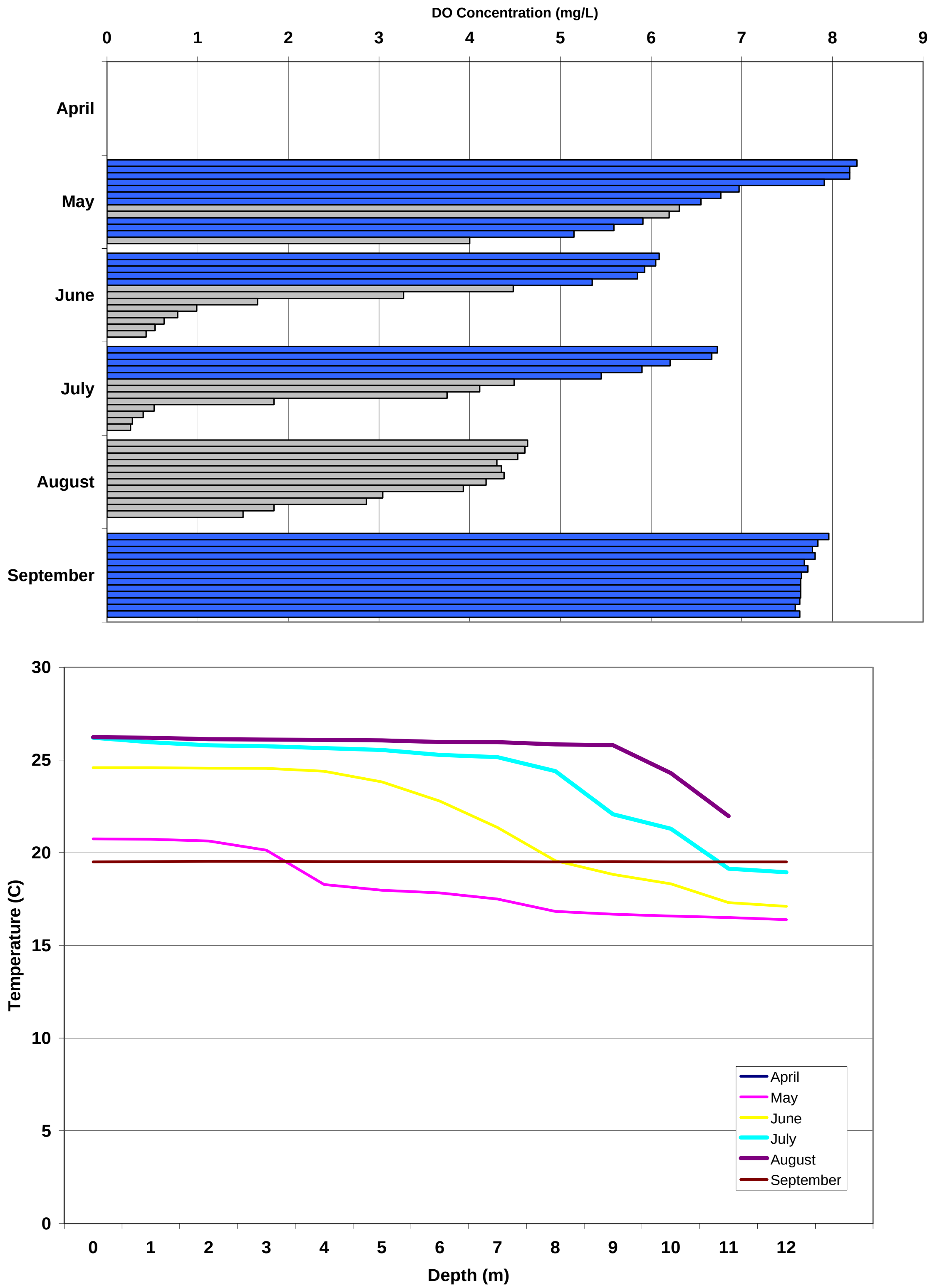


Figure 6.19. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plots by sample dates from vertical profiles recorded at Site 3 during 2005 at Hillsdale Lake.

7 Kanopolis Lake

7.1 General Background

Kanopolis Lake was impounded on 17 February 1948, and reached full pool on 19 July 1948. The primary threats to water quality in Kanopolis Lake are sedimentation, nutrients, and fecal bacteria. Kanopolis Lake is listed on the states 303d – Impaired Waters – list due to eutrophication, chloride, and sulfate. A TMDL was implemented in 2003 to address eutrophication issues, while TMDLs to address chloride and sulfate were approved in 2004. The Smoky Hill / Big Creek WRAPS was approved in 2005 and charged with addressing water quality issues and TMDLs within the Kanopolis Lake watershed. Specific water quality goals for the WRAPS include DO concentrations > 5 mg/L, biological oxygen demand (BOD) < 3.5 mg/L, total dissolved solids (TDS) < 808 mg/L, total suspended solids (TSS) < 101 mg/L, and fecal bacteria ≤ 200 cfu/100 ml for swimming and ≤ 2000 cfu / 100 ml for boating and fishing. These water quality goals hope to be achieved through implementation of best management practices (ie, vegetative buffers, nutrient management plans) throughout the watershed. A rainbow trout fishery is maintained by the Kansas Parks and Wildlife Department in the Kanopolis Lake tailrace area. This winter fishery is supported by stocked fish, and the season runs from 15 October through 15 April.

7.1.1 Location

A dam built 293.9 km (183.7 miles) upstream of the confluence with the Kansas River on the Smoky Hill River formed Kanopolis Lake. The lake is located approximately 27 km (17 miles) southeast of Ellsworth, Kansas, and 48 km (30 miles) southwest of Salina, Kansas. Historic water quality sample sites in the Kanopolis Lake watershed include 2 lake, 1 outflow, and 1 inflow sites (Figure 7.1).

7.1.2 **Authorized Purposes**: flood control, water supply, water quality, supplemental low-water flow, recreation, and fish and wildlife management.

7.1.3 **State Use Designations:** Primary and secondary contact recreation, expected aquatic life support, drinking water supply, food procurement, irrigation.

7.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,508	369.3	13,958	
Multipurpose	1,463	49.5	3,406	41
Total		418.8		

Total watershed area: 7,695 sq miles (total upstream area)
2,330 sq miles (total local drainage area below Cedar Bluff Lake; 1,491,200 acres)
Watershed ratio: 106.81 FC / 437.82 MP

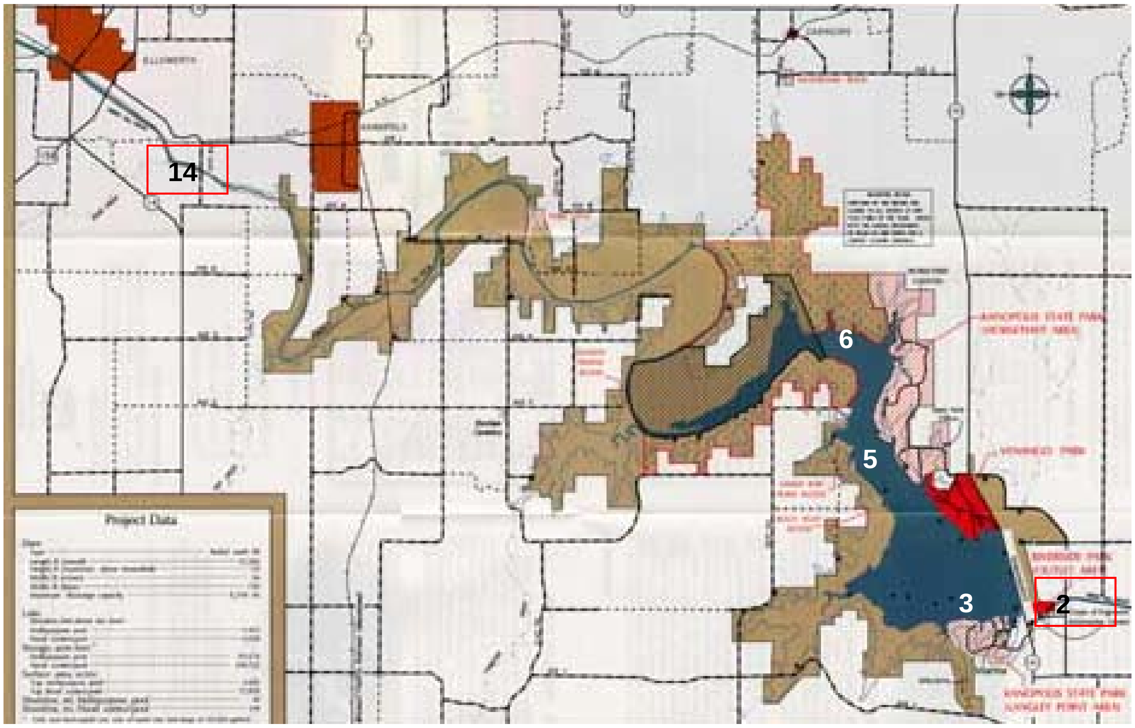


Figure 7.1. Kanopolis Lake area map with sample site locations and site numbers.

Average Annual Inflow: 166,620 acre-feet/yr (1982 – 2006)
Average Annual outflow: 000 acre-feet
Sediment inflow (measured): 28,704 acre-feet (1948 – 1993)
Flushing rate: 0.30 years
Water management Plan: Approved 30 October 1984
Historic stage hydrograph: 1996 – 2006 (Figure 7.2)

7.2 2006 Activities

Kanopolis Lake was categorized as an 'intensive' lake during 2006, thus lake and inflow / outflow sites were all sampled (see Figure 7.1). In addition, Site 20 was added to increases knowledge of watershed contributions; Site 20 is located on the Smoky Hill River at the Hwy 281 bridge in Russell County. Analyses added during 2006 included sulfates and glyphosate. Grab samples were collected monthly from April through September, and vertical profiles were recorded at both lake sites during monthly trips. Kanopolis Lake staff (OF-KA) providing field sampling assistance during 2006 included Nolan Fisher and Jason Hurley. Ken Nelson, OF-KA Operations Manager, provided insight and background regarding Kanopolis Lake.

7.3 2006 Data

Comparative historic water quality data consists of monthly (April – September) data collected from 1996 through 2004 / 2005. Samples were collected from April though September during 2006. An extremely prolonged drought has impacted this western and central Kansas watershed, such that all boat ramps were closed throughout the

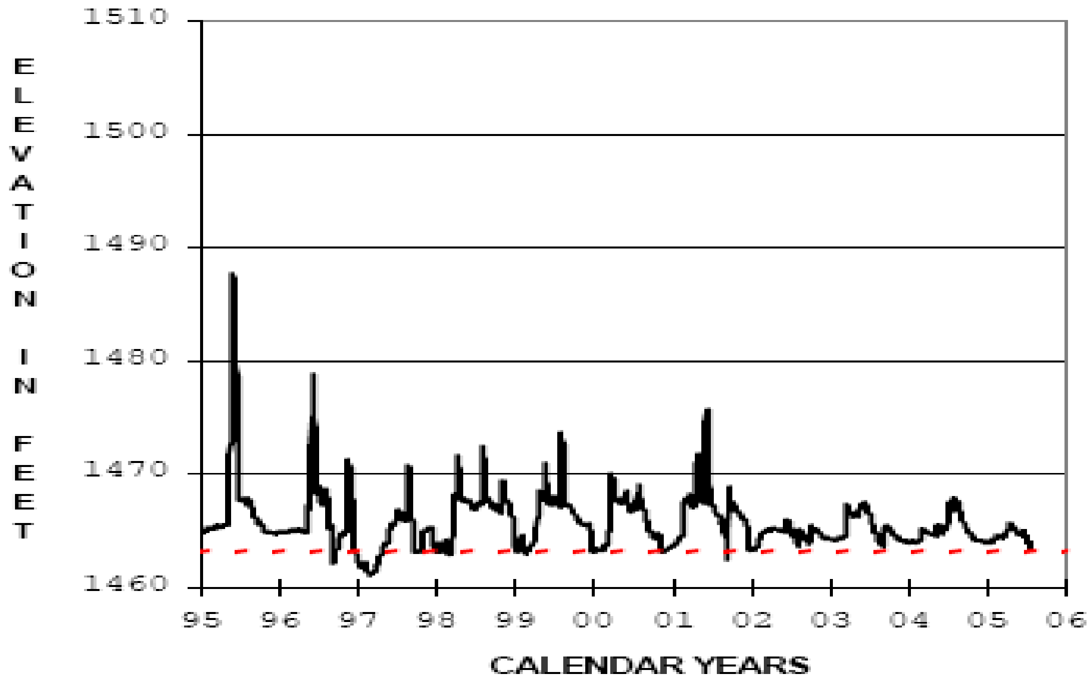


Figure 7.2. Pool elevation hydrograph from 1995 - 2005

recreation season due to extremely low lake levels (Figure 7.2). Such a drought would be expected to impact water quality – both positively and negatively.

7.3.1 Inflow

Kanopolis Lake inflow samples were collected from two sites (Sites 14 and 20) on the Smoky Hill River during 2006.

7.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen (TN) concentrations measured in Kanopolis lake and its' inflow remain some of the highest compared to the other district lakes. Median TN concentrations from samples collected between 1996 and 2006 ranged from 1.0 – 1.1 mg/L (Figure 7.3). Annual and monthly variability in TN concentrations are evident from both inflow (Site 14) and main lake sample (Site 3) sites (Figures 7.4 and 7.5, respectively). With few exceptions, all samples from the Kanopolis Lake watershed exceed EPA's proposed ecoregional nutrient criteria value of 0.56 mg/L TN.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median total phosphorus (TP) concentrations (0.07 – 0.1 mg/L) for all sites monitored exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L (Figure 7.6). The mean TP concentrations (0.126 – 0.179 mg/L) are currently below the WRAPS target goal of 0.26 mg/L, but greatly exceed EPA's proposed ecoregional nutrient criteria of 0.02 mg/L. The elevated TP concentrations are expected due to sedimentation levels

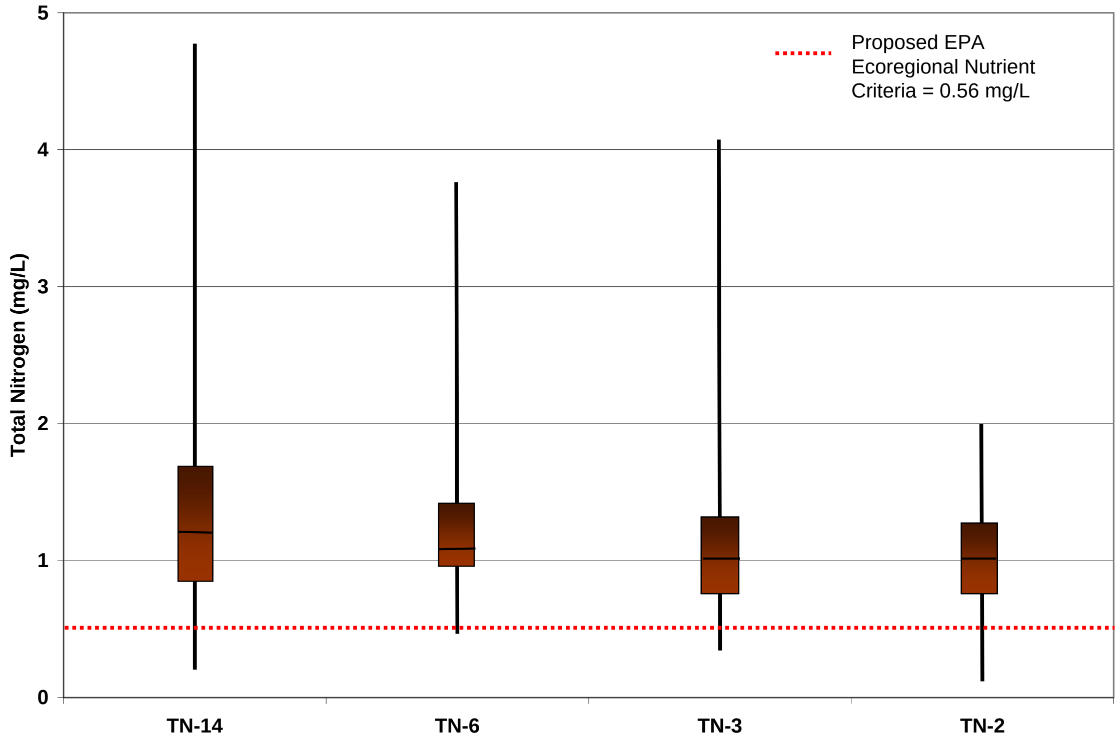


Figure 7.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Kanopolis Lake.

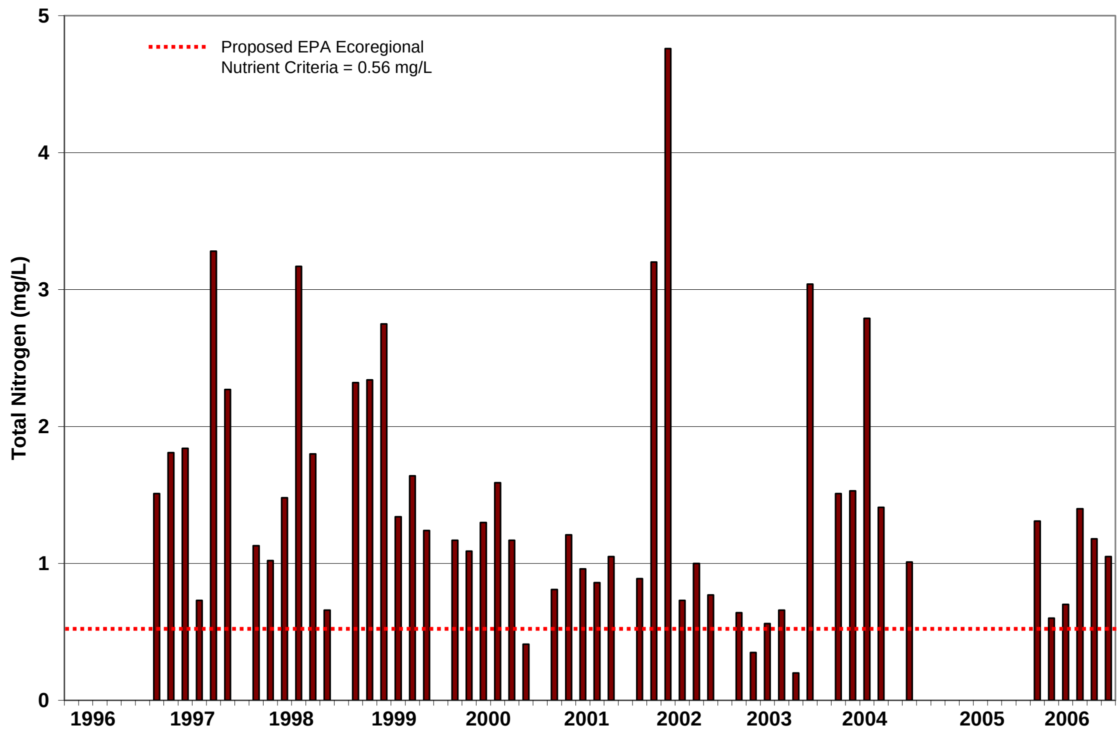


Figure 7.4. Total nitrogen concentrations by sample date collected from 1997 through 2006 at Kanopolis Lake Site 14 (Smoky Hill River inflow).

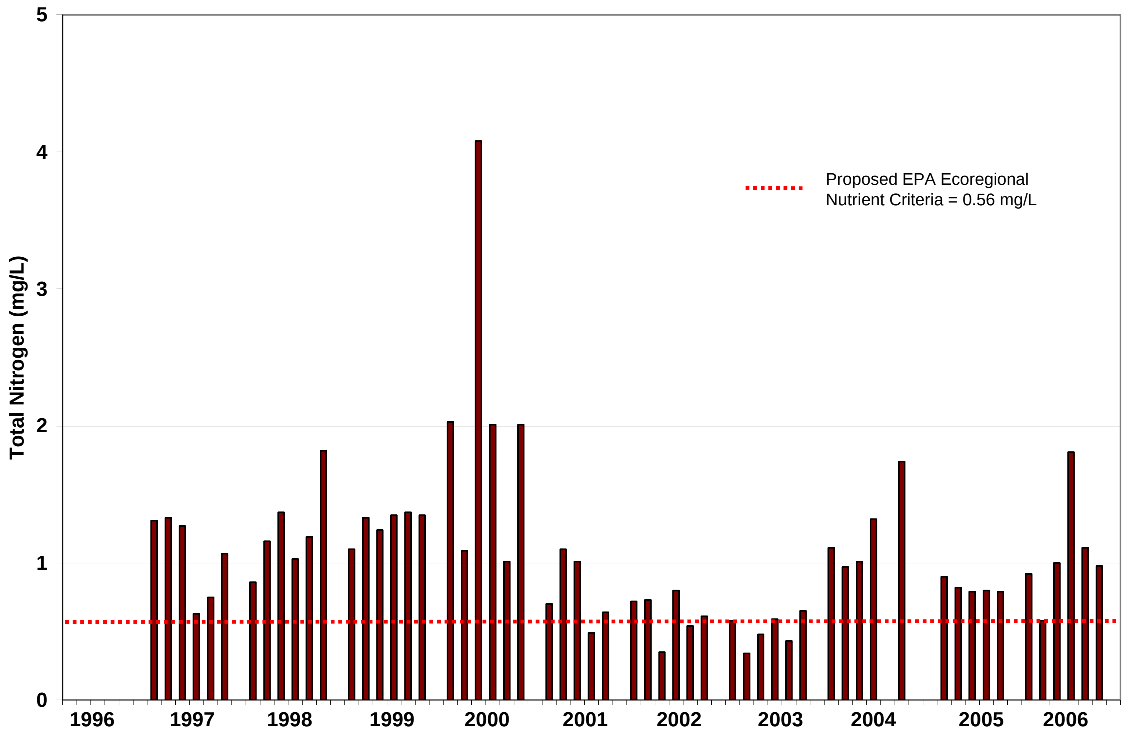


Figure 7.5. Total nitrogen concentrations by sample date collected from 1997 through 2006 at Kanopolis Lake Site 3 (Tower site).

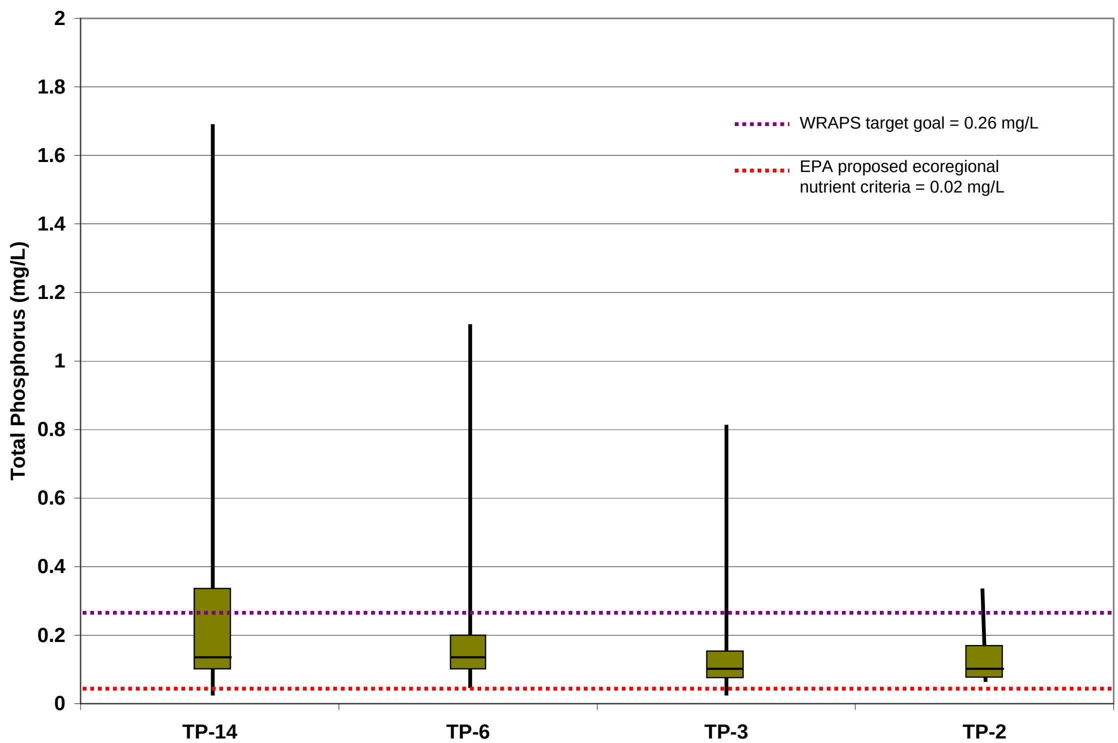


Figure 7.6. Box plots of surface water sample total phosphorus concentrations measured by site from 1996 through 2006 at Kanopolis Lake.

within the lake and wind-driven sediment resuspension. Such TP concentrations are among the highest within the district.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 7.7 as an example at Site 3. Median TN:TP ratios at both lake sites and the Smoky Hill River inflow were ≤ 12, which typically is indicative of a lake at risk for cyanobacteria blooms (Figure 7.8). Kanopolis Lake has the lowest mean TN:TP ratio for lake sites within the district. However, the elevated turbidity level and limited light penetration should act to minimize cyanobacteria blooms.

One target of the Smoky Hill WRAPS is a total suspended solids (TSS) target of < 101 mg/L. Figure 7.9 presents TSS data by site during sampling trips from 2004 through 2006. The data is presented longitudinally from within the watershed -- Site 2 is the outfall and Site 20 is the Smoky Hill River at Hwy 281. Samples of TSS in exceedence of the 101 mg/L target were recorded at Site 5 (upper lake site) during 2004, and from inflows in 2005 (Site 14) and 2006 (Site 20); no samples were collected from Site 20 during either 2004 or 2005. Low measurements were recorded in-lake the past two years, which is an artifact of minimal inflows related to the drought.

Measurements of conductivity (uS/cm), pH, and turbidity (NTU) were recorded during each sampling trip to the inflow and outflow sites during 2006. Inflow samples (Sites 20 and 14) reflected minimal rain event impulses within the upper inflows of Kanopolis Lake (Figure 7.10). For example, at Site 20 a depression in conductivity – indicating overland flow inputs – and rise in turbidity was detected following a rainevent in the upper watershed. This input was not detected downstream at Site 14 due to drought conditions. As expected, outflow (Site 2) measurements of conductivity, pH, and turbidity were very stable.

Monthly variability in mean chlorophyll *a* was detected at both lakes sites (Figure 7.11). Mean chlorophyll *a* concentrations were at least 2x higher at both lakes in 2006 vs 2005 (Figure 7.11), and this is most likely due to reduced turbid inflows and lower TSS (drought impacts). Chlorophyll *a* concentrations ranged from 23 - 48 ug/L at the mid-lake site and 31 - 42 ug/L at the dam site. Secchi depth was variable between months and sites during 2006, with clearest conditions during May (Figure 7.12). Mean summer secchi depths indicated water clarity was limited at both the mid-lake (0.49 m; 1.6 ft) and dam sites (0.57 m; 1.6 ft).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 7.13 depicts vertical distribution of phycocyanins measured at Site 3 (Tower) from May through September. Concentrations in the upper waters peaked in July, but distributions were more consistent throughout the water column during September.

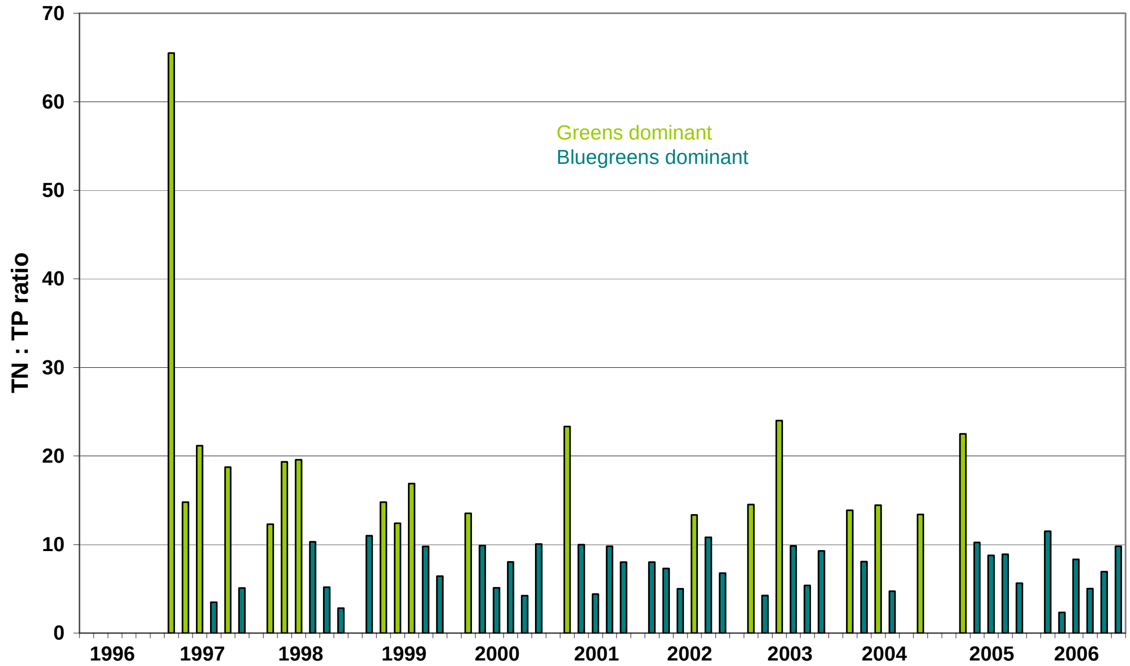


Figure 7.7. Graph of total nitrogen : total phosphorus ratio (TN:TP) by sample from 1997 through 2006 at Kanopolis Lake Site 3 (dam).

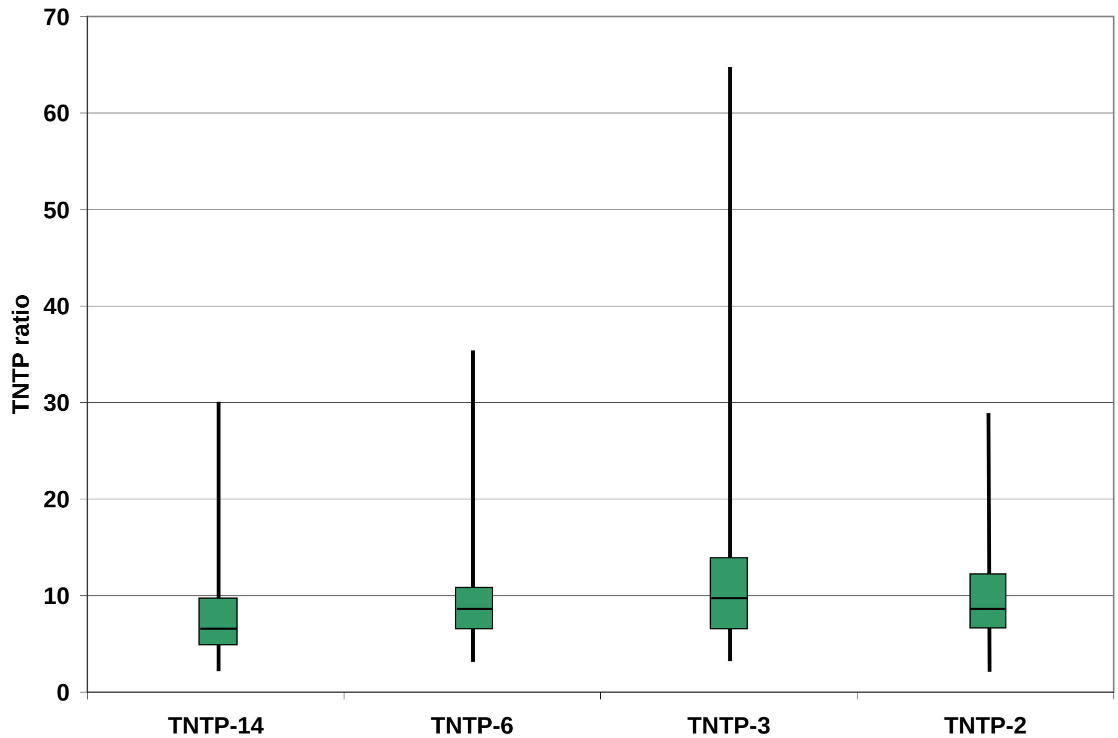


Figure 7.8. Box plots of total nitrogen : total phosphorus (TN : TP) ratio by site from samples collected between 1997 – 2006 at Kanopolis Lake.

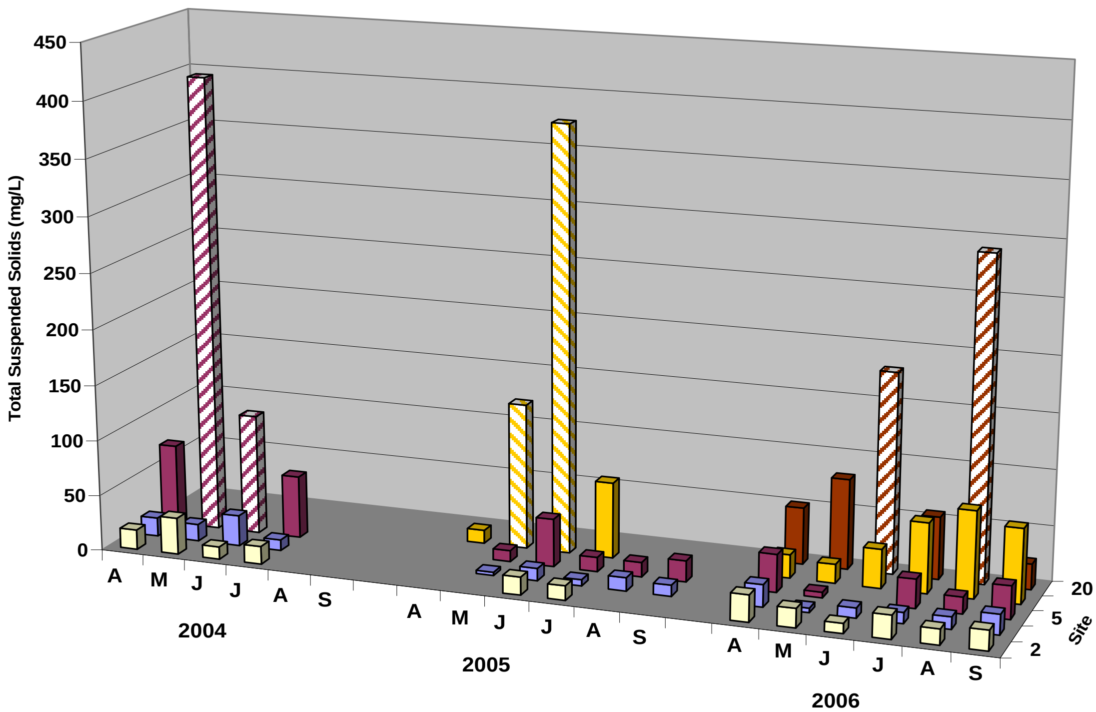


Figure 7.9. Total suspended solids (mg/L) measured by site from 2004 – 2006 at Kanopolis Lake.

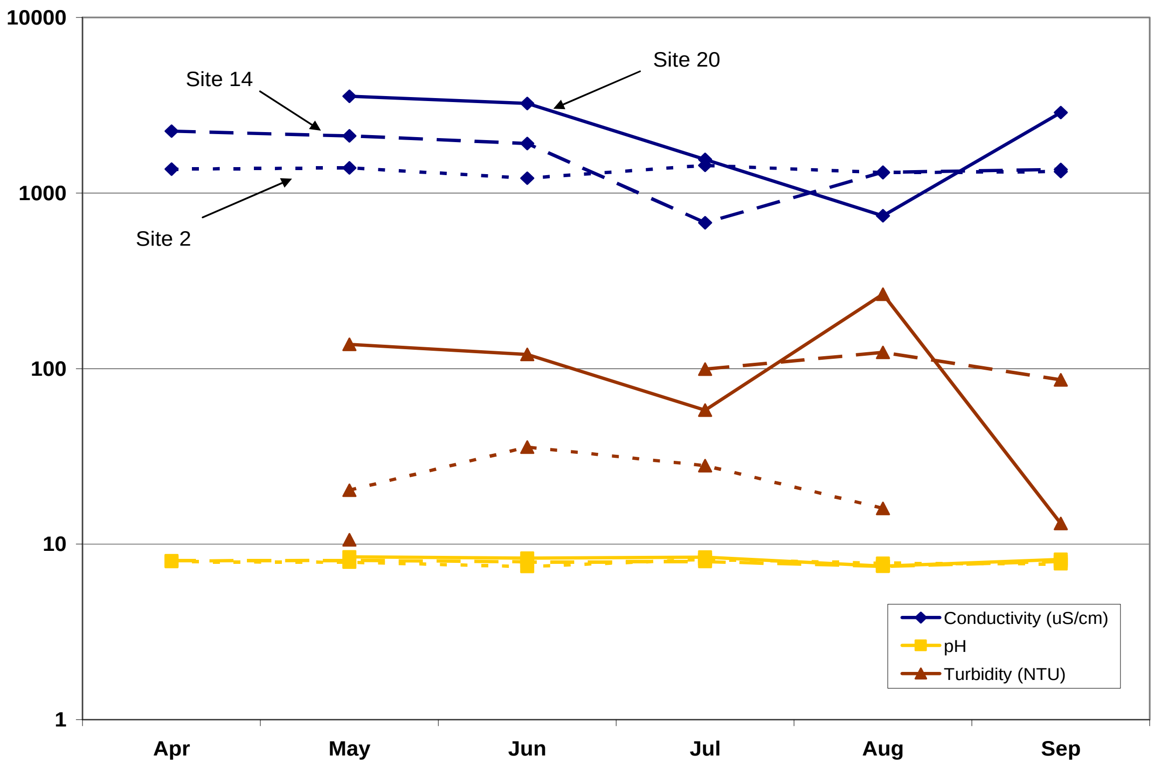


Figure 7.10. Plots of ambient surface water measurements of conductivity (uS/cm), pH, and turbidity (NTU) from inflows (Sites 20 and 14) and outflow (Site 2) in the Kanopolis Lake watershed during 2006.

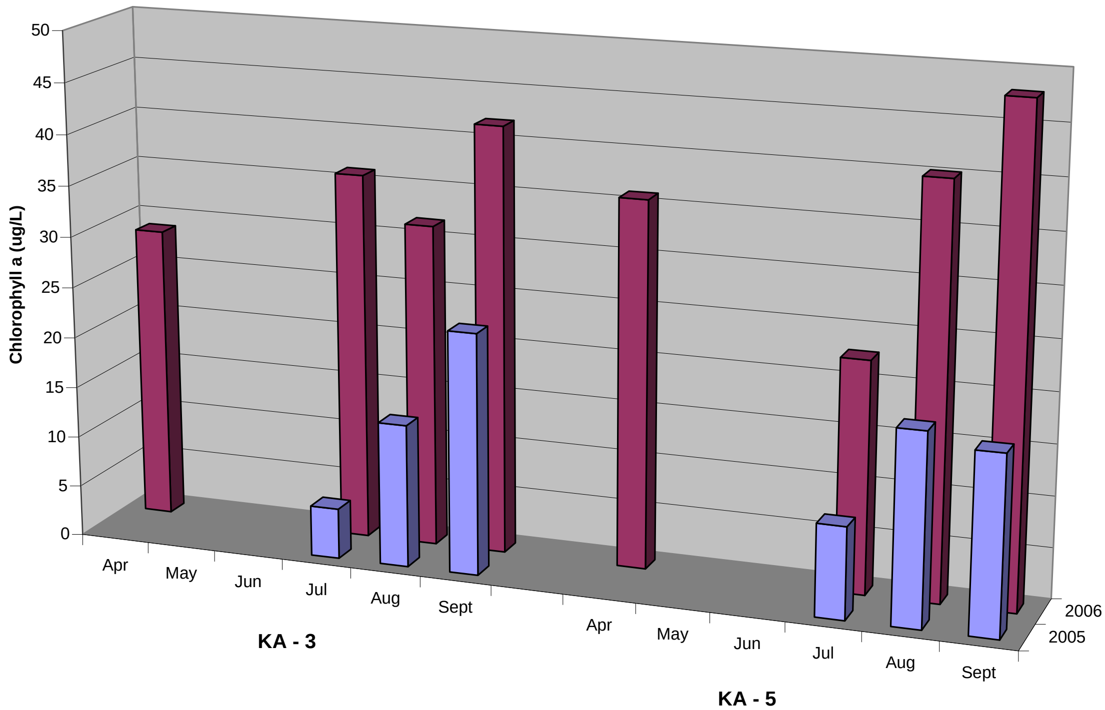


Figure 7.11. Comparison of mean chlorophyll a concentrations (ug/L) by site (3 = Tower; 5 = mid-lake) at Kanopolis Lake during 2005 and 2006.

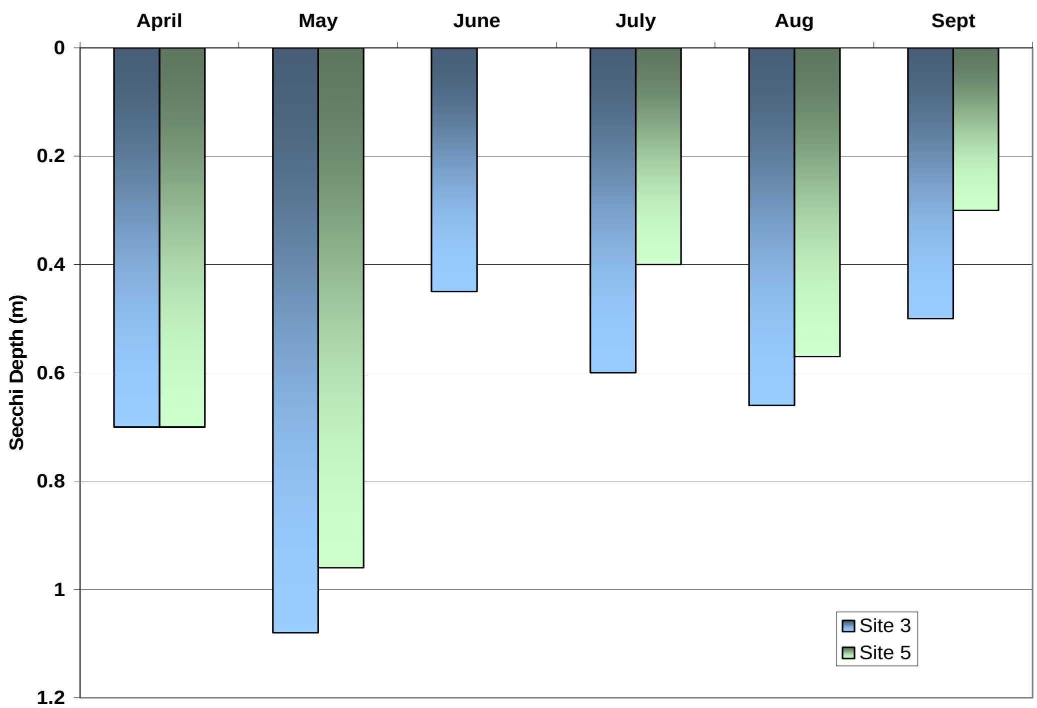


Figure 7.12. Comparison of secchi depth (water clarity) between lake sites from April through September 2006 in Kanopolis Lake.

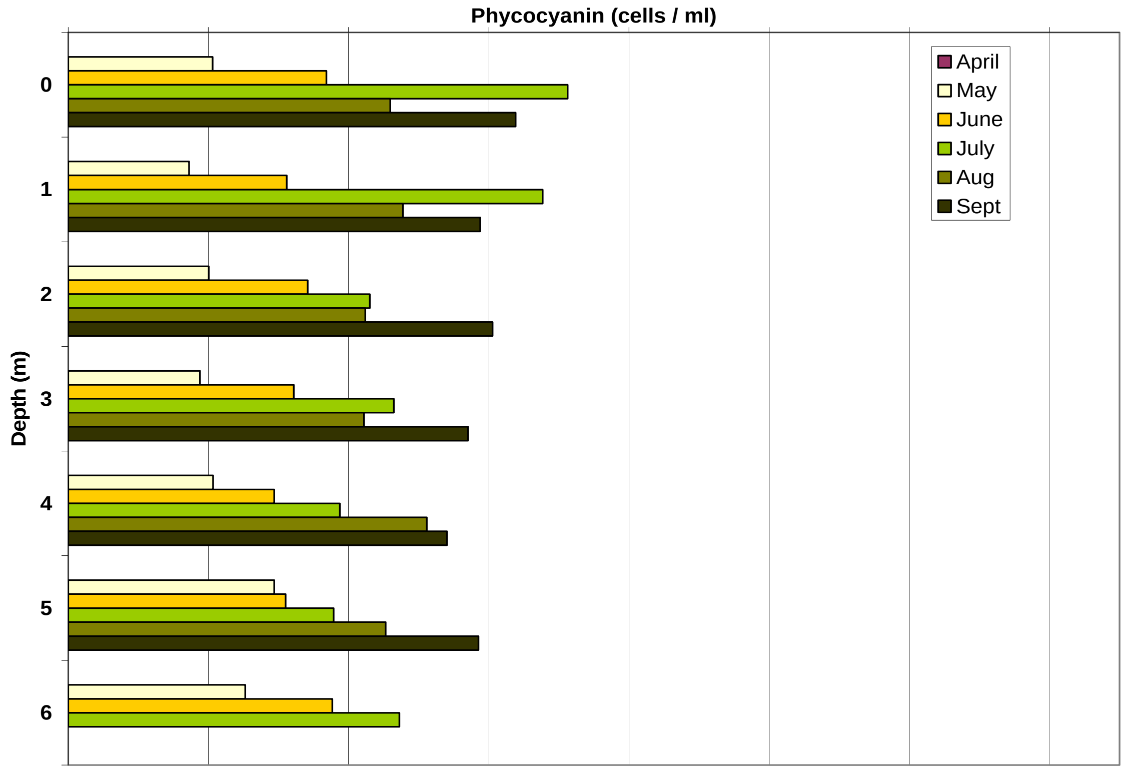


Figure 7.13. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Kanopolis Lake Site 3 (Tower) during 2006.

The median atrazine concentrations from surface water samples collected between 1996 and 2006 (0.7 – 0.73 ug/L) were all below EPA's drinking water maximum contaminant level of 3 ug/L (Figure 7.14). These concentrations are some of the lowest within the district. Interestingly, samples exceeding the drinking water standard have been detected in the Smoky Hill River inflows during June of 2002 and 2003 (Figure 7.15). Median cyanazine concentrations ranged from 0.05 – 0.06 ug/L from lake sites (Figure Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at both inflow sites, the outfall (625 ug/L), and upper lake site (533 ug/L); only the lower lake site did not exceed the SMCL (261 ug/L). Total iron at Site 20 was 7495 ug/L and 2890 ug/L at Site 14. These concentrations reflect local geology and arid conditions in the upper reaches of the watershed. Total iron concentrations ranged from 477 to 683 ug/L for bottom samples collected at Sites 3 and 5, respectively. Elevated levels are directed at drinking water facilities related to taste and staining issues. In addition, surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L) at all sites (range = 67 – 198 ug/L) with the exception of Site 3 (35 ug/L). Implications are directed at drinking water facilities due to taste and stain issues. 7.16).

Monthly variability and longitudinal differences in sulfate concentrations were detected throughout the watershed during 2006 (Figure 7.17). Site 20 exceeded the SMCL in all months except July. A similar pattern was observed at Site 14, which is an inflow site just above the lake. All samples from both lake sites and the outflow were below the

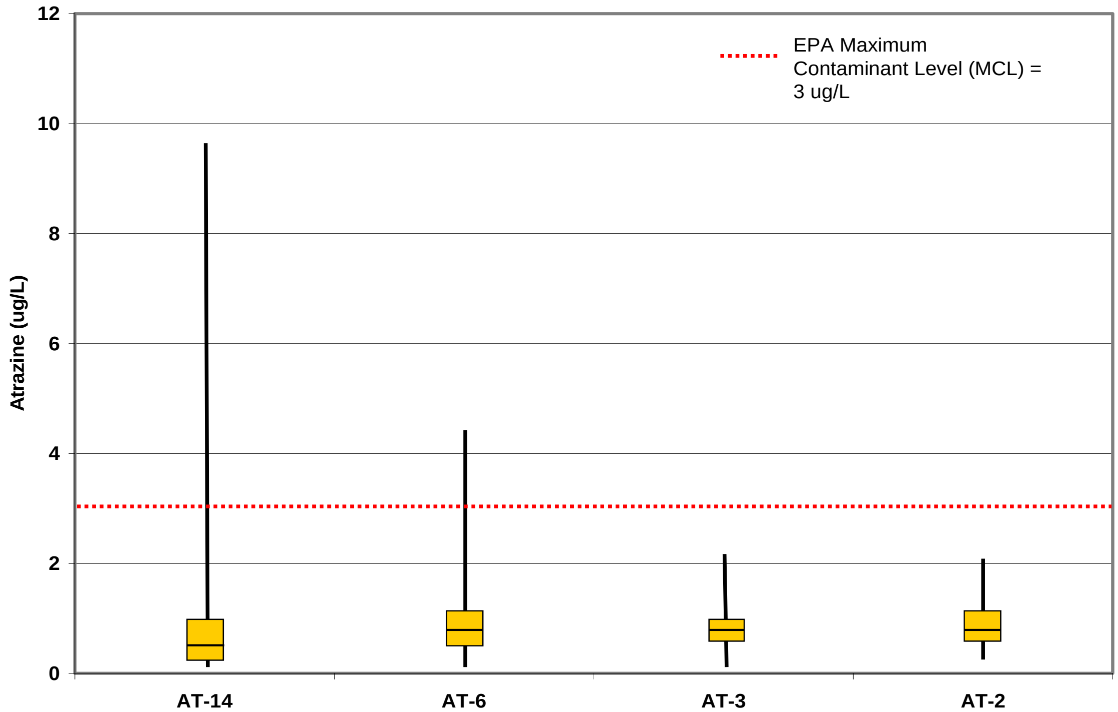


Figure 7.14. Box plot of surface water sample atrazine concentrations measured at lake sites from 1996 through 2006 at Kanopolis Lake.

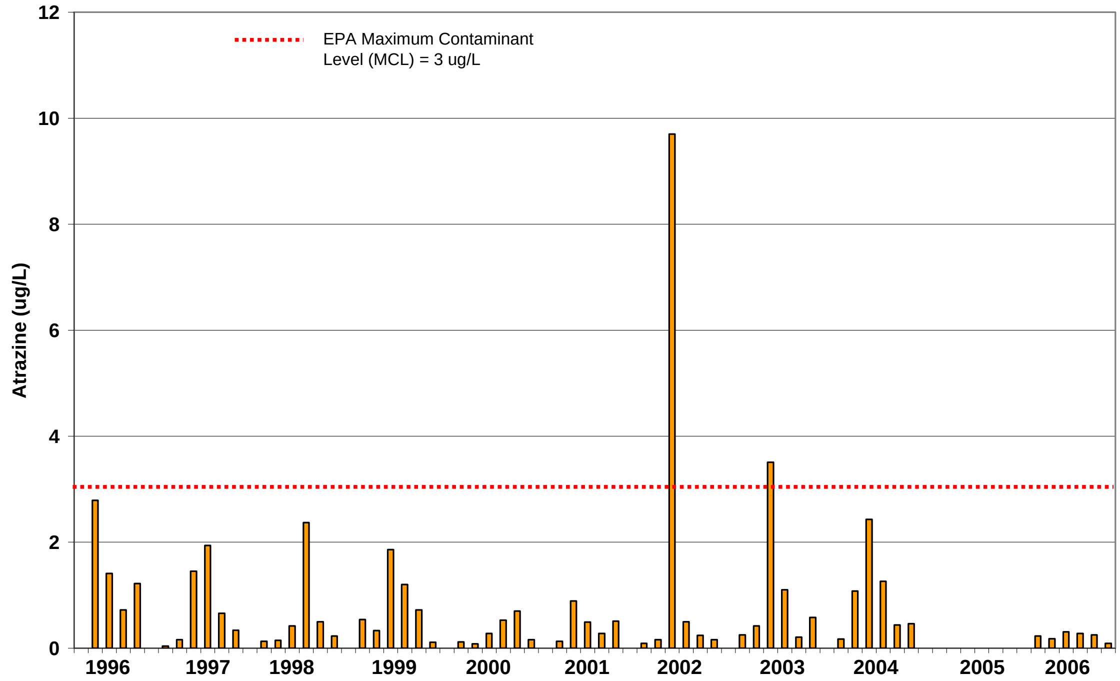


Figure 7.15. Atrazine concentrations by date for samples collected between 1996 and 2006 at Site 14 (Smoky Hill River inflow) in the Kanopolis Lake watershed.

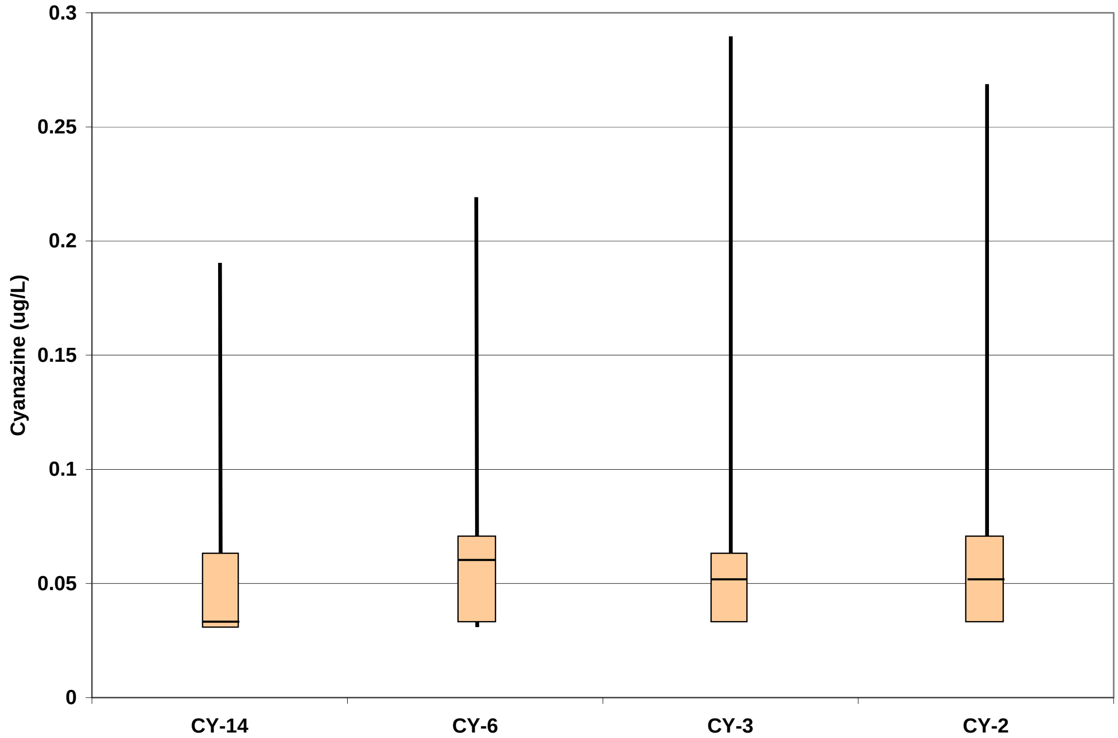


Figure 7.16. Box plot of surface water sample cyanazine concentrations measured at lake sites from 1996 through 2006 at Kanopolis Lake.

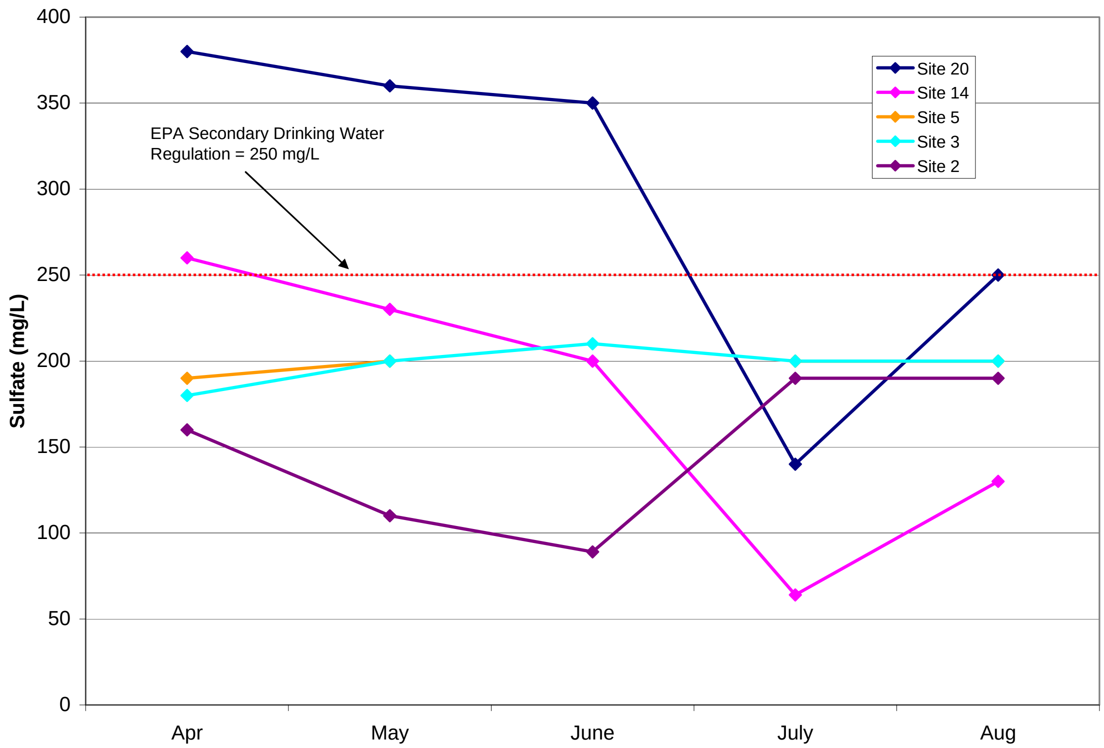


Figure 7.17. Longitudinal plot of sulfate concentrations (mg/L) measured from surface water samples in the Kanopolis Lake watershed during 2006.

SMCL.

Vertical profiles were recorded during monthly sampling trips to Kanopolis Lake in 2006 (Figure 7.18). Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. The lake was stratified both chemically and thermally during July, with stratification beginning at 2 m in depth. The lake was thoroughly mixed during both August and September.

Fecal bacteria (*E. coli*) samples were collected from three locations at Venego beach prior to three major holidays (Memorial Day, July 4^{th}, and Labor Day) during 2006. No samples exceeded the single sample maximum of 732 colonies / 100 ml for a whole-body contact during the recreational season (Figure 7.19). With limited inflows due to prolonged drought conditions, blooms of fecal bacteria would not be expected.

7.3.3 Outflow

Outflow samples were collected from Kanopolis Lake during 2006. Summarized data on Site 2 is included in discussions of lakes sites listed above.

7.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to 'ambient' monitoring from May through September, as well as conducting a single vertical profile at each of the two lake sites during July or August. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Sediment – nutrient and metal samples will be collected from both lake sites during the summer to provide a baseline for possible resuspension sources. This data will also be useful in discussions concerning dredging of lake sediments. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Continue to work with the Smoky Hill / Big Creek WRAPs group to achieve water quality improvements within the Kanopolis Lake watershed.

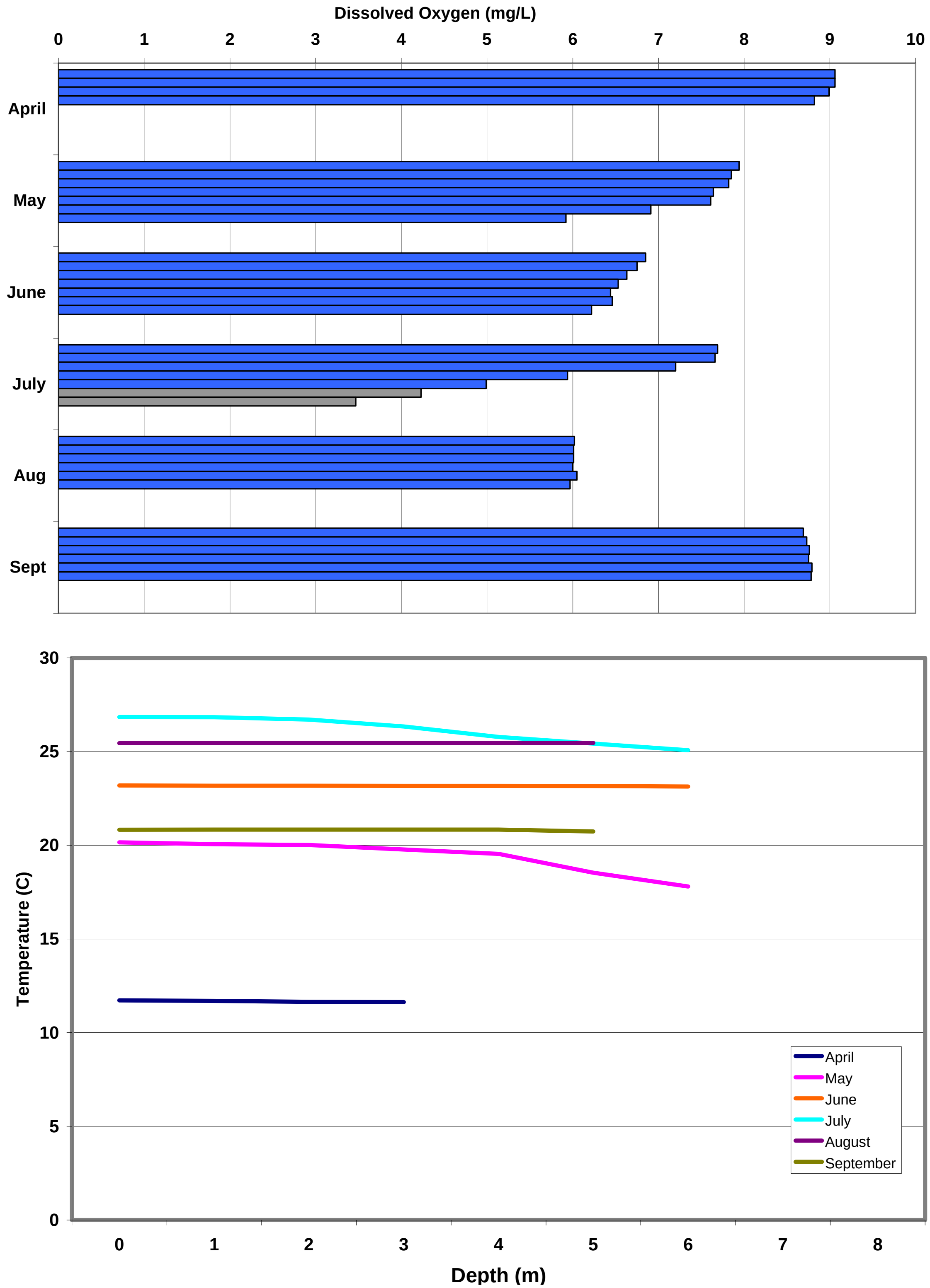


Figure 7.18. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plot from a vertical profile recorded at Site 3 during 20 July 2005 at Kanopolis Lake.

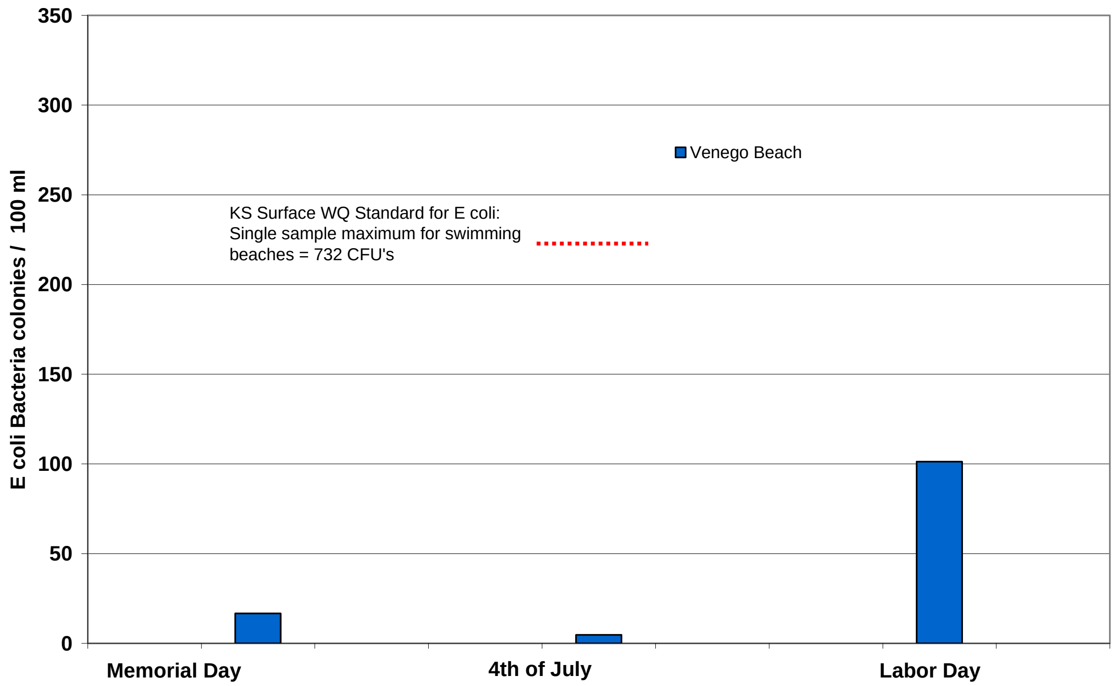


Figure 7.19. Fecal bacteria colonies per 100 ml samples from beach samples collected prior to major holidays at Kanopolis Lake during 2006.

8 Long Branch Lake

8.1 General Background

Long Branch Lake was impounded in 1978 and reached full pool on 19 May 1981. The main threats to water quality at Long Branch Lake are nutrients, herbicides / pesticides, sedimentation, and bacterial contamination. The lake is currently listed on Missouri's 303(d) list of impaired waters due to atmospheric mercury deposition (MDNR 2004). Cyanazine was removed as a pollutant of concern at Long Branch Lake in 2002 (MDNR 2004). The long-term Cyanazine average (0.52 ug/L) dropped below the federal health standard of 1 ug/L. Cyanazine production ceased in 1999.

An AgNPS SALT Project was initiated in 2004 within the Long Branch Lake watershed. This project, designed to operate through 2010, is directed to improve agricultural BMPs and related water quality impairments.

The Corps had an 1135 project slated for Long Branch Lake, but funding limitations prevented development of the project. Another attempt was made with MODOT as part of a wetland mitigation project, but that fell through as well. The lake staff are currently coordinating with the local Army National Guard unit to construct berms in the upper reaches of both lake arms. The focus of in-lake projects are sediment control and bank erosion.

The NWK Water Quality Program was contacted in 2005 by MDNR regarding interest in re-writing the Long Branch Lake watershed management plan. Reassignment of MDNR staff caused this process to stop for the moment.

8.1.1 Location

The dam located on the East Fork of the Little Chariton River impounds Long Branch Lake. The dam is located 110 km (69 miles) upstream of the confluence of the Chariton River with the Missouri River. The lake is located 3.2 km (2 miles) west of Macon, in north-central Missouri. Historic water quality sample sites include 3 lake, 1 outflow, and 2 inflow (Figure 8.1).

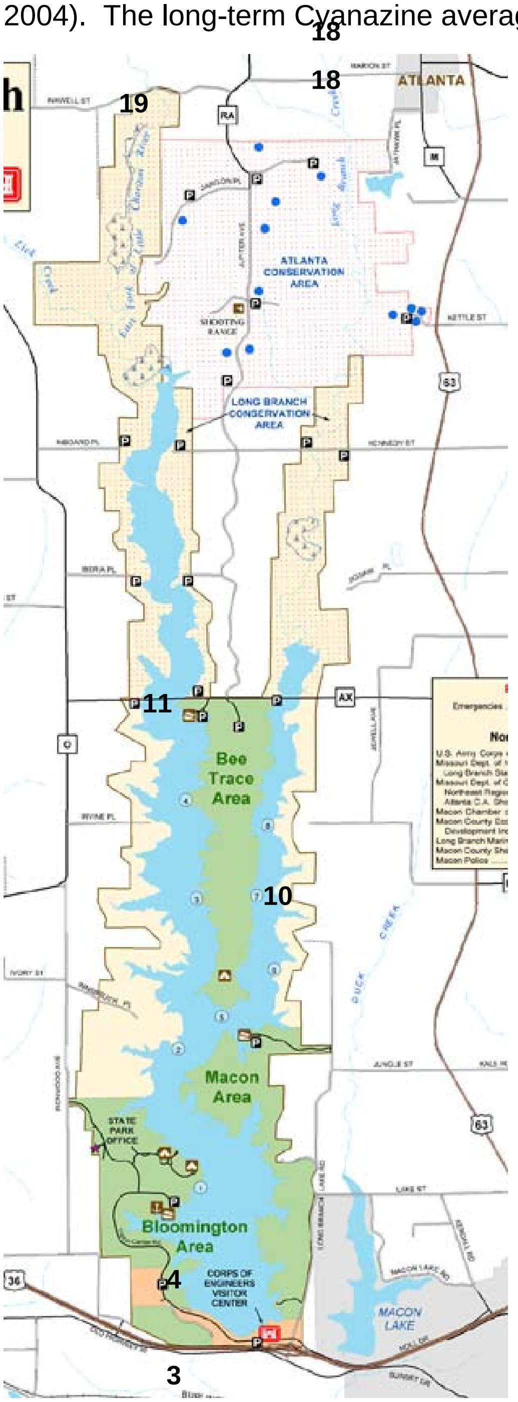


Figure 8.1. Long Branch Lake area map with sample site locations and sample numbers.

8.1.2 Authorized Purposes: Flood control, water supply, fish and wildlife management, and downstream water quality improvement.

8.1.3 State Use Designations: Livestock and wildlife watering, warmwater aquatic life and human health / fish consumption, whole-body contact recreation, boating and canoeing, drinking water supply.

8.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	801.0	30.3	3,670	
Multipurpose	791.0	34.2	2,430	24
Total		64.5		

Total watershed area: 109 sq miles (69,700 A)

Watershed ratio: 19.0 FC / 28.7 MP

Average Annual Inflow: 81,780 acre-feet
Average Annual outflow: 000 acre-feet
Sediment inflow (measured): 483 acre-feet (1978 – 1988)
Flushing rate: 0.47 years
Water management Plan: Interim approved 21 November 1978
Historic stage hydrograph: 1996 – 2006 (Figure 8.2)

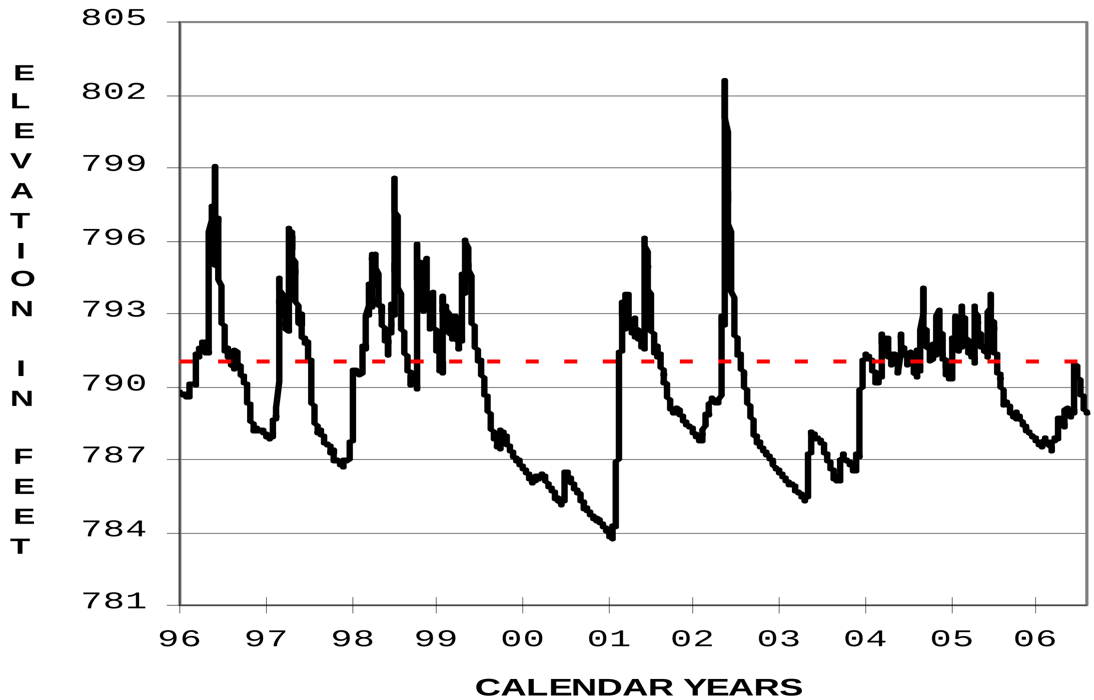


Figure 8.2. Pool elevation hydrograph from 1996 - 2006

8.2 2006 Activities

Long Branch Lake was categorized as an 'intensive' lake during 2006, thus samples were collected from 2 inflows, 3 lake sites, and the outflow (see Figure 8.1). Samples were collected monthly from April through September, and vertical profiles were recorded monthly. Long Branch Lake staff (OF-LB) providing field sampling assistance during 2006 included Mike Monda and Lucius Duerksen. Paul Sampson, OF-LB Operations Manager, provided insight and background regarding Long Branch Lake.

8.3 2006 Data

Comparative historic water quality data consists of monthly (April – September) data collected from 1995 through 2004 / 2005. Samples were collected from April though September during 2006.

8.3.1 Inflow

Long Branch Lake inflow samples were collected from two watershed sites (Sites 18 and 19) during 2006.

8.3.2 Lake

Long Branch Lake is a eutrophic waterbody based upon total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* measurements. Nitrogen is an essential nutrient for aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen mean concentrations for the three lake sites range from 0.96 – 1.27 mg/L, with the highest concentration at Site 11. When inflow sites are included, Site 18 exhibits a significantly higher median TN concentration than any other site (Figure 8.3). Elevated TN concentrations historically have been measured at Site 18 (Figure 8.4). This site is located on Long Branch Creek and is just outside of the City of Atlanta. With few exceptions, all TN measurements have exceeded EPA's proposed ecoregional nutrient criteria value of 0.36 mg/L.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Total phosphorus mean concentrations (0.08 – 0.14 mg/L) at lake sites are typical of Midwestern reservoirs. Similar to TN, significantly elevated TP concentrations exist at Site 18 – Long Branch Creek at Atlanta (Figure 8.5). For a comparative perspective of TP inputs from within the watershed, Figure 8.6 compares TP concentrations between inflow sites – Sites 18 (mean TP = 0.34 mg/L) and 19 (mean = 0.19 mg/L). From this data, efforts to control phosphorus inputs should be focused on Long Branch Creek sources.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 8.7 as an example at Site 4. Median TN:TP ratios at all three lake sites (Sites 11, 10 & 4) are < 10, indicating the lake is at risk for

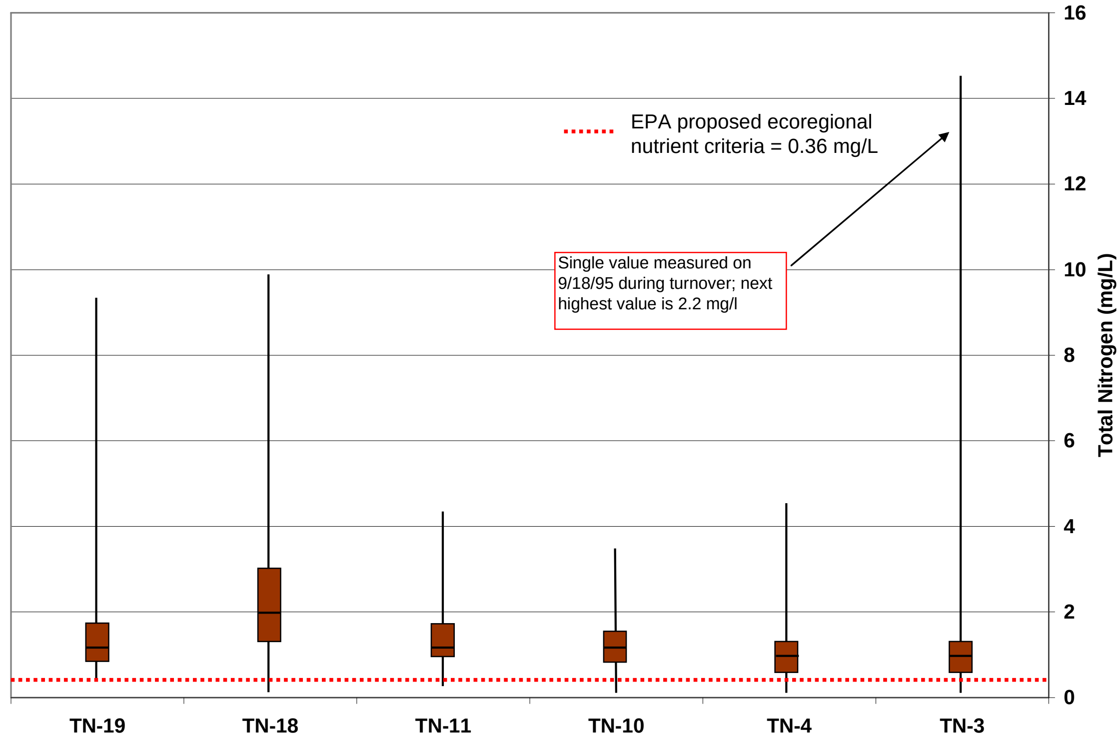


Figure 8.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Long Branch Lake.

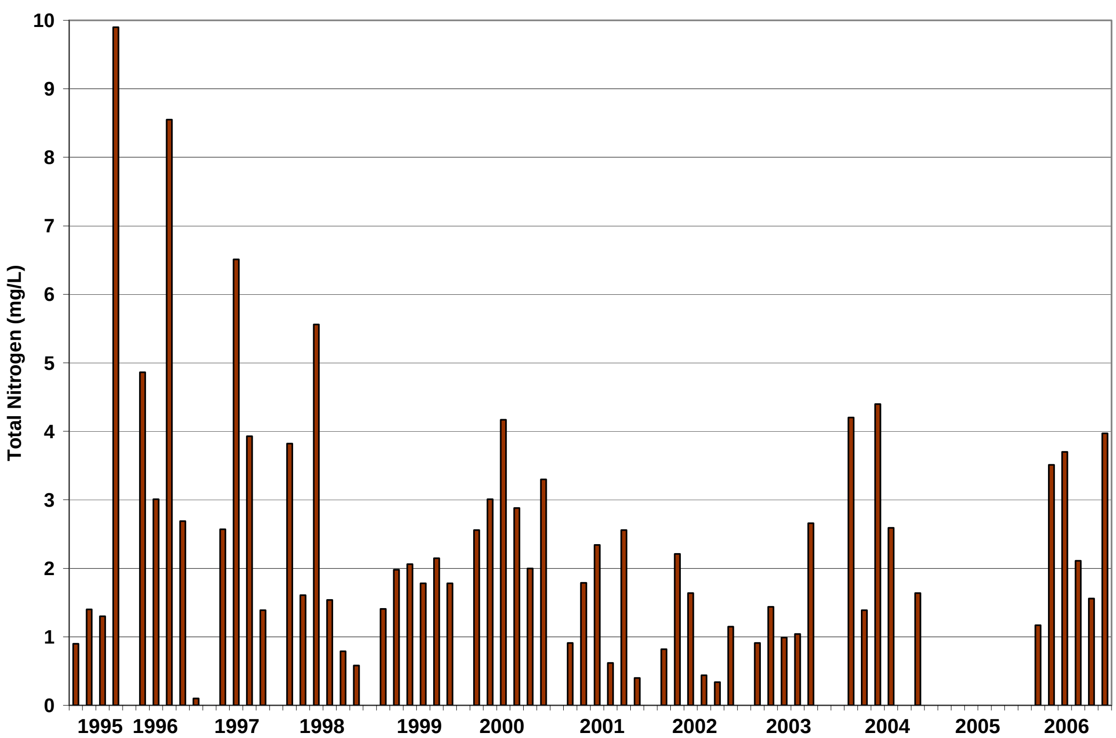


Figure 8.4. Total nitrogen concentrations by sample date at Site 18 (Long Branch Creek) within the Long Branch Lake watershed from 1995 through 2006.

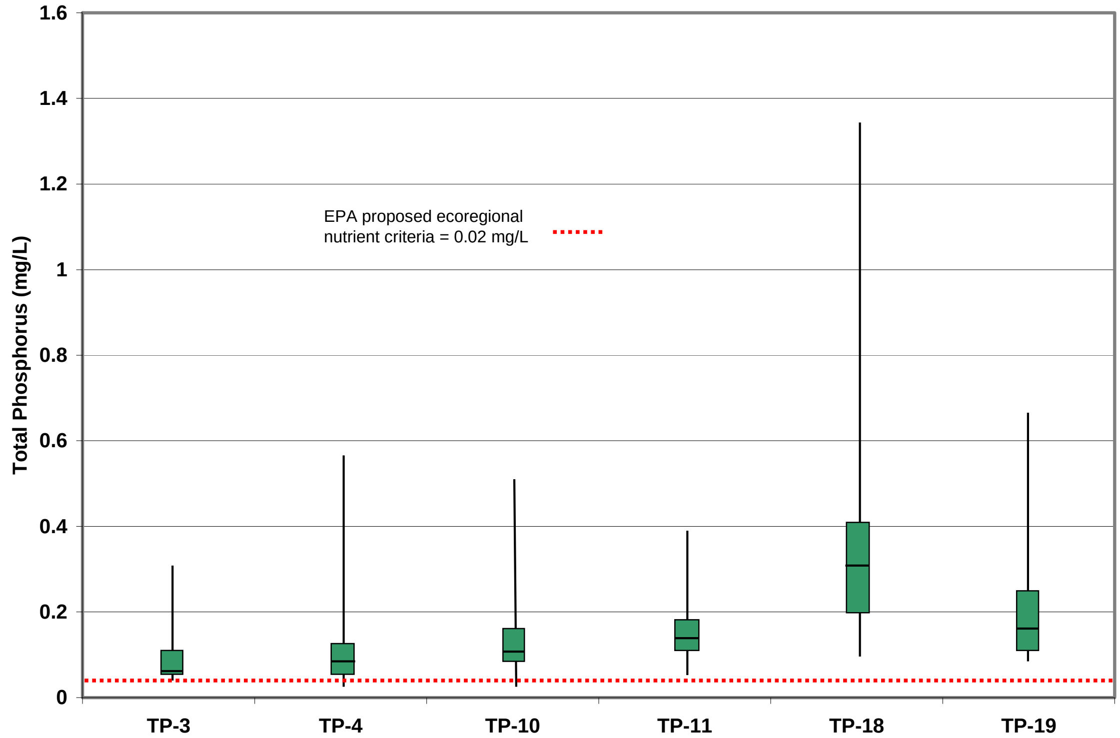


Figure 8.5. Box plot of surface water sample total phosphorus concentrations measured by site from 1996 through 2006 at Long Branch Lake.

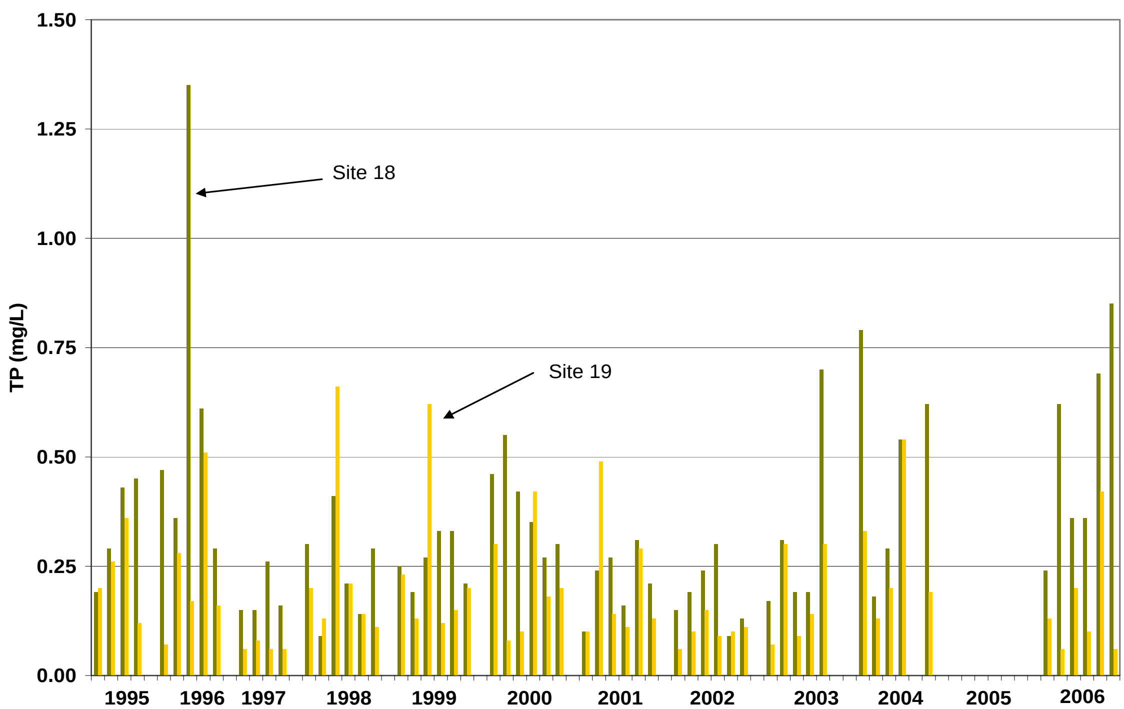


Figure 8.6. Comparison of total phosphorus concentrations by sample date at Site 18 (Long Branch Creek) and Site 19 (East Fork Little Chariton) within the Long Branch Lake watershed from 1995 through 2006.

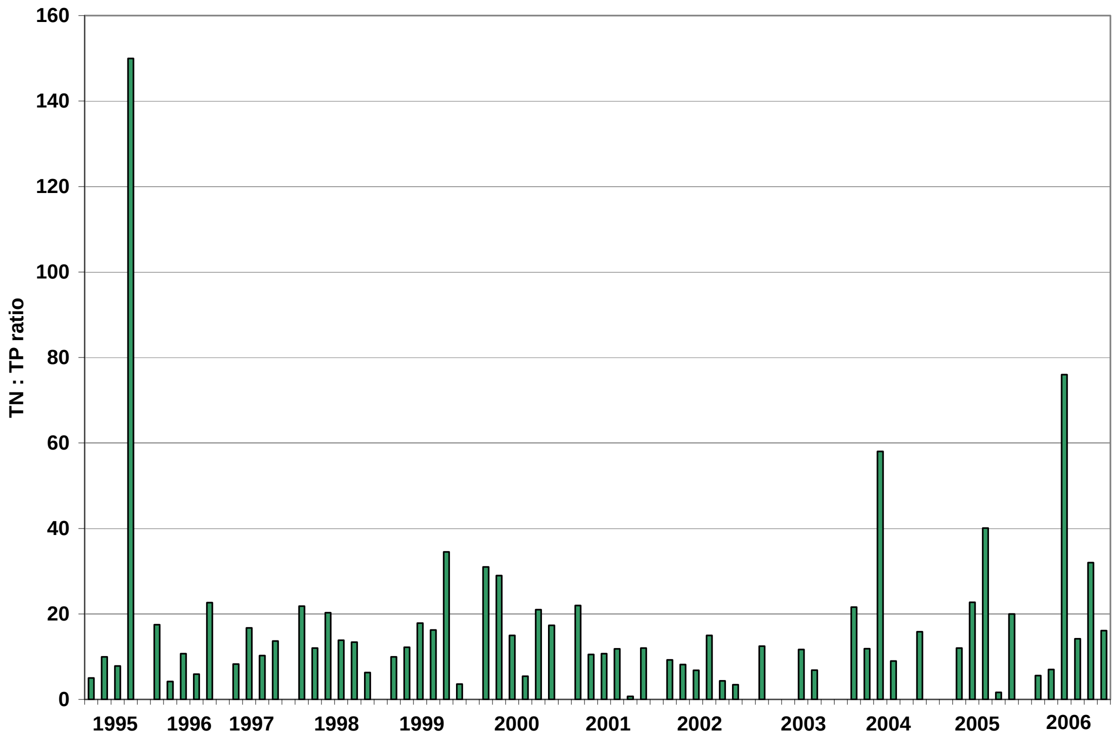


Figure 8.7. Graph of total nitrogen : total phosphorus ratio (TN:TP) by sample at Site 4 of Long Branch Lake from 1996 through 2006.

cyanobacteria blooms (Figure 8.8). The microcystin toxin has been collected from Long Branch Lake during 2000 (Dr. Jennifer Graham, USGS, personal communication).

Mean summer (June – August) chlorophyll *a* concentrations collected in 2006 range from 29.9 - 68 ug/L, with highest values measured at Site 11 (Little Chariton River arm) and lowest values near the dam. The longterm median chlorophyll values (18.0 – 30.3 ug/L; Figure 8.9) are among the highest measured within the district, and indicate the significant nutrient loading within the lake. This is expected due to sediment resuspension in the shallow upper arms and due to elevated TP inputs. Secchi depth ranged from 0.3 to 0.54 m at Site 4 during 2006, indicating limited water clarity within the lake. Figure 8.10 depicts secchi depth variability by month and site during 2006 in Long Branch Lake.

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 8.11 depicts vertical distribution of phycocyanins measured at Site 4 (Tower) from June through September. Concentrations increased significantly during August and September relative the previous months, and distributions were consistent throughout the water column during both months. The concentrations were among the highest measured within the district.

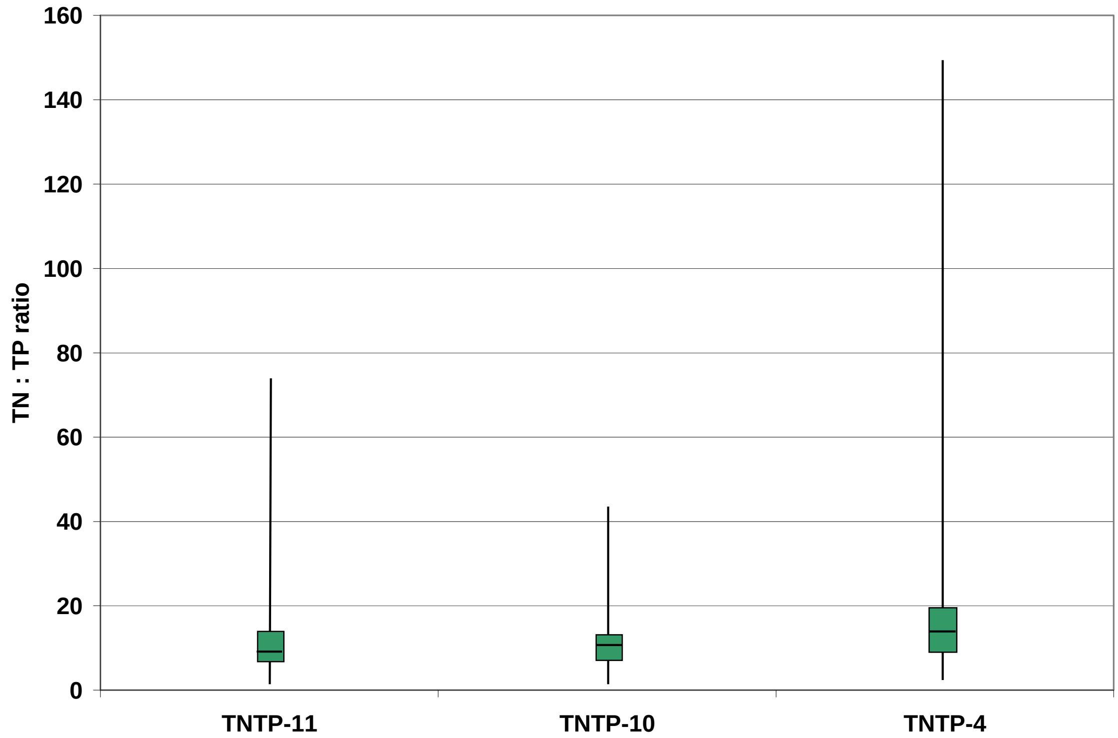


Figure 8.8. Box plots of total nitrogen : total phosphorus (TN : TP) ratio by site from 1996 through 2006 at Long Branch Lake.

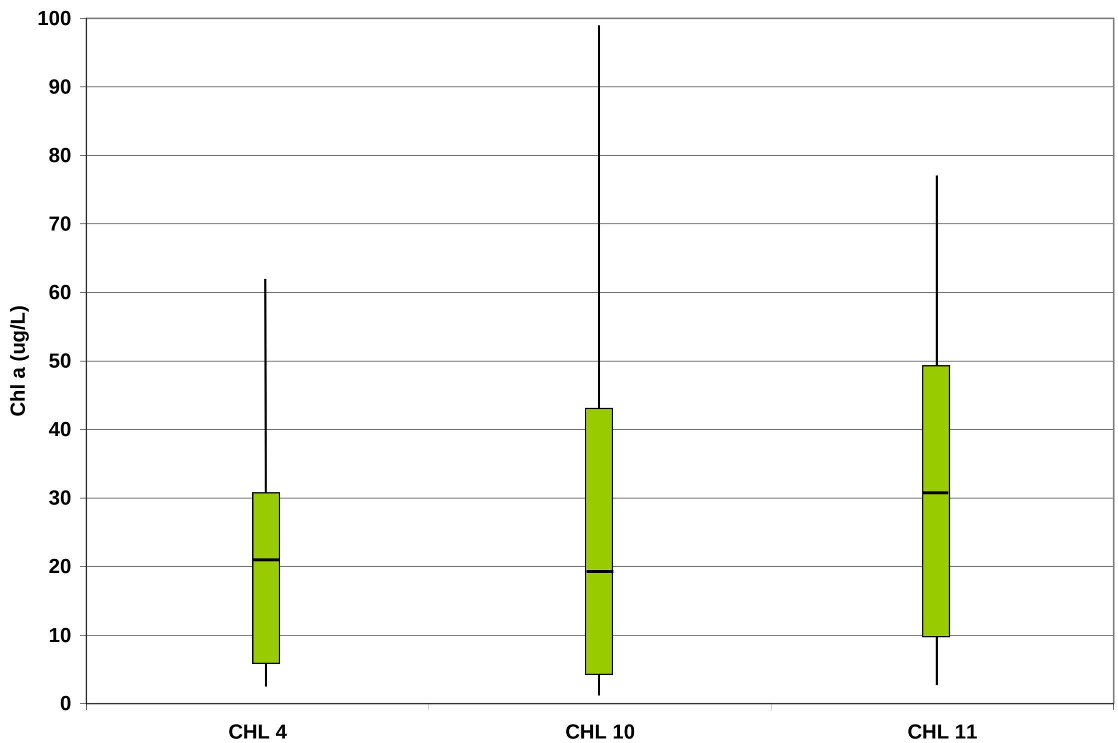


Figure 8.9. Box plots of chlorophyll a concentrations by site from measurements collected from 1996 - 1997 and 2005 - 2006 at Long Branch Lake.

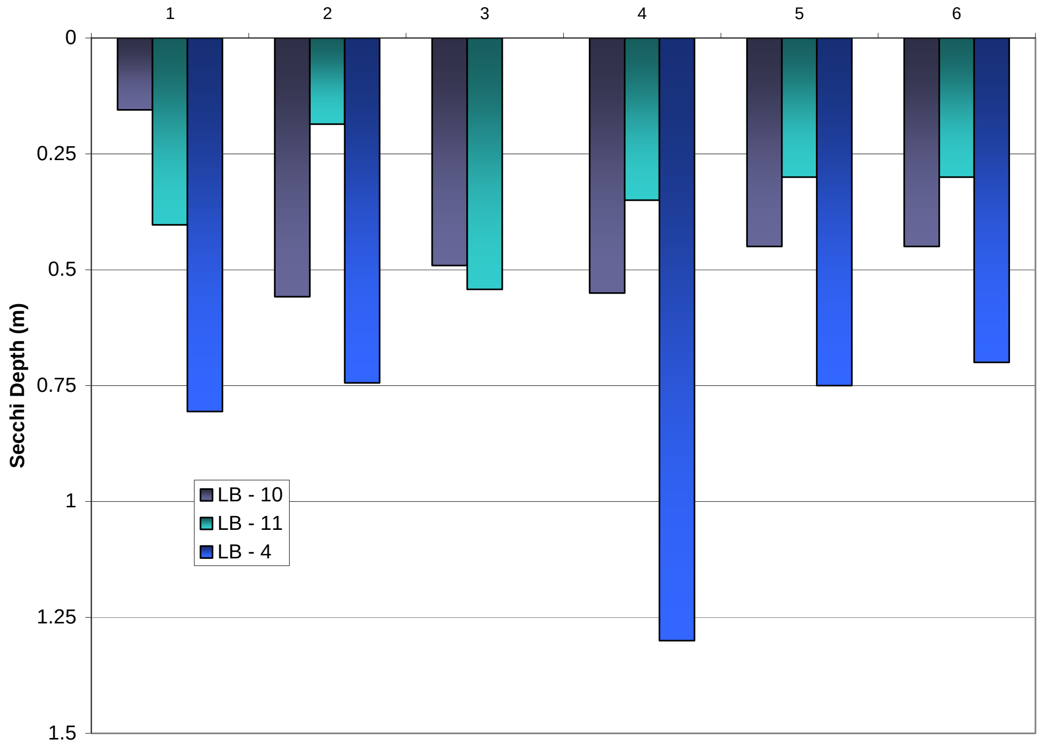


Figure 8.10. Comparison of secchi depth (water clarity) between lake sites from April through September 2006 in Long Branch Lake.

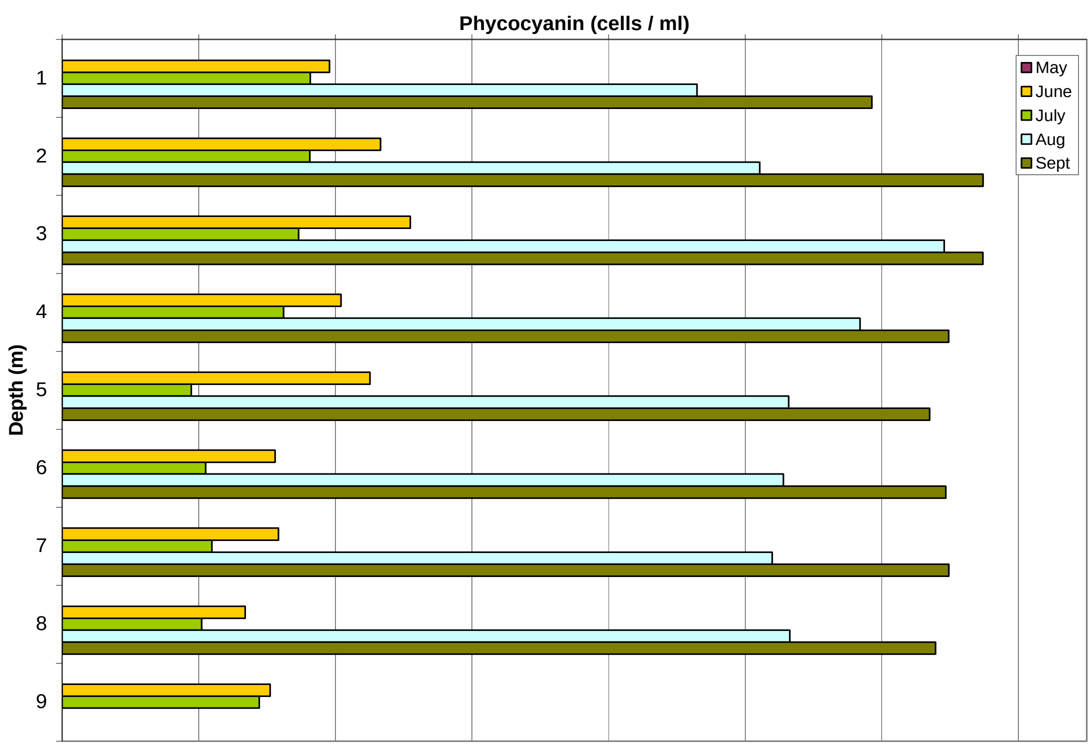


Figure 8.11. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Long Branch Lake Site 4 (Tower) during 2006.

The median atrazine concentrations from lake surface water samples collected between 1996 and 2006 (1.41 – 1.55 ug/L) were all below EPA's drinking water maximum contaminant level of 3 ug/L (Figure 8.12). Median inflow concentrations range from 0.67 (Site 19) to 1.65 (Site 18) are some of the lowest within the district. It should be noted that a samples exceeding the MCL were collected from Site 18 during May (3.32 ug/L) and June (15.0 ug/L), 2006 (Figure 8.13).

Median cyanazine concentrations ranged from 0.06 – 0.08 ug/L from lake sites, and 0.03 ug/L (Site 19) – 0.8 ug/L (Site 18) from inflows (Figure 8.14). Concentrations have declined dramatically following 1998 at all inflow, lake and outflow sample sites.

Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at both inflow sites (Site 18 = 3122 ug/L; Site 19 = 4603 ug/L) and both upper lake sites (Site 10 = 530 ug/L; Site 11 = 1160 ug/L). Total iron concentrations ranged from 1115 to 11951 ug/L for bottom samples collected at Sites 4 and 10, respectively. These values are the highest recorded within the district. Elevated levels are directed at drinking water facilities related to taste and staining issues. In addition, the SMCL for manganese (50 ug/L) was exceeded in all surface samples (range = 103 – 460 ug/L) and lake bottom samples (338 – 661 ug/L) collected during August. Implications are directed at drinking water facilities due to taste and stain issues.

Vertical profiles were recorded during monthly sampling trips to Kanopolis Lake in 2006 (Figure 8.15). Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. The lake was strongly stratified both chemically and thermally during July, and weakly stratified during both June and August.

Fecal bacteria (*E. coli*) samples were collected on a weekly basis from three locations at the State Park beach during the 2006 recreation season (May through August). The geometric mean of the samples never exceeded the state standard of 126 colonies / 100 ml sample for whole-body contact during the recreational season (Figure 8.16).

8.3.3 Outflow

Outflow samples were collected from Long Branch Lake during 2006. Summarized data on Site 3 is included in discussions of lakes sites listed above.

8.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to 'ambient' monitoring from May through September, as well as conducting a single vertical profile at each of the three lake sites during July or August. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Interactions will continue with MDNR on efforts to re-write the watershed management plan.

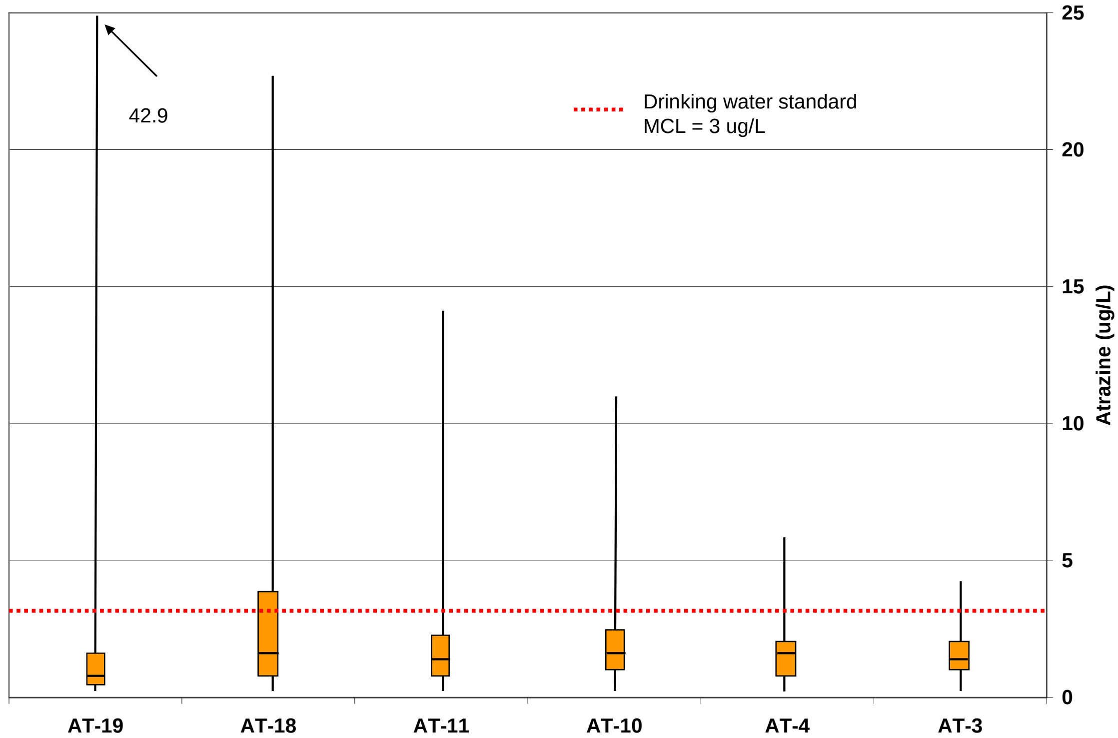


Figure 8.12. Box plot of surface water sample atrazine concentrations measured at lake sites from 1996 through 2005 at Long Branch Lake.

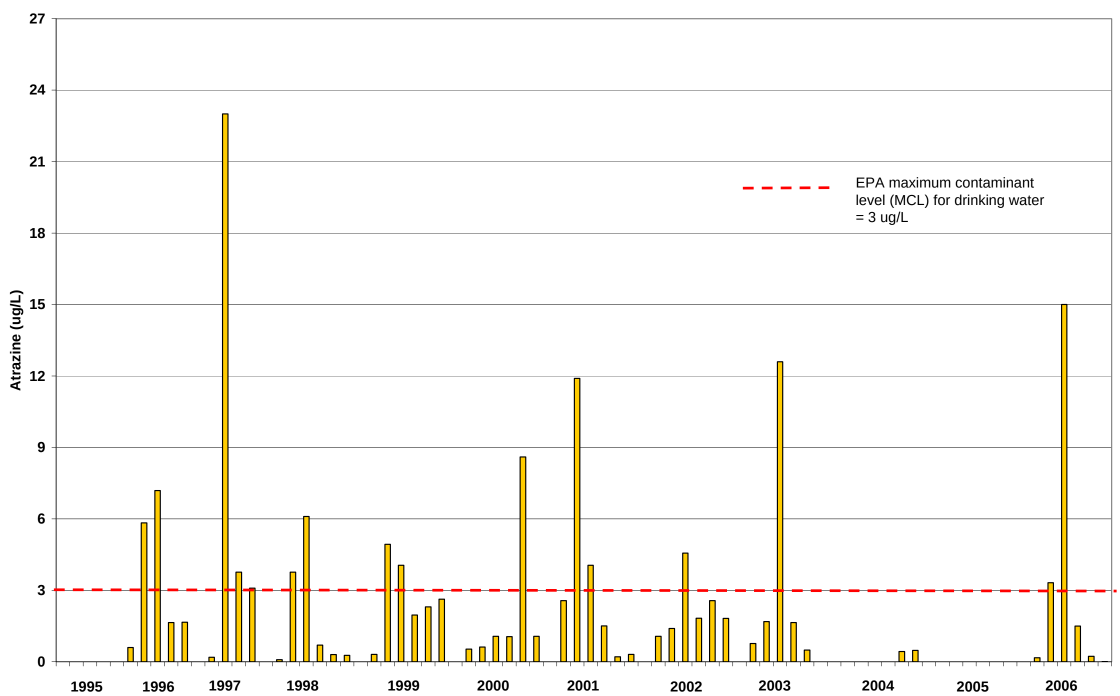


Figure 8.13. Atrazine concentrations by sample date collected at Site 18 (Long Branch Creek) inflow to Long Branch Lake from 1995 - 2006.

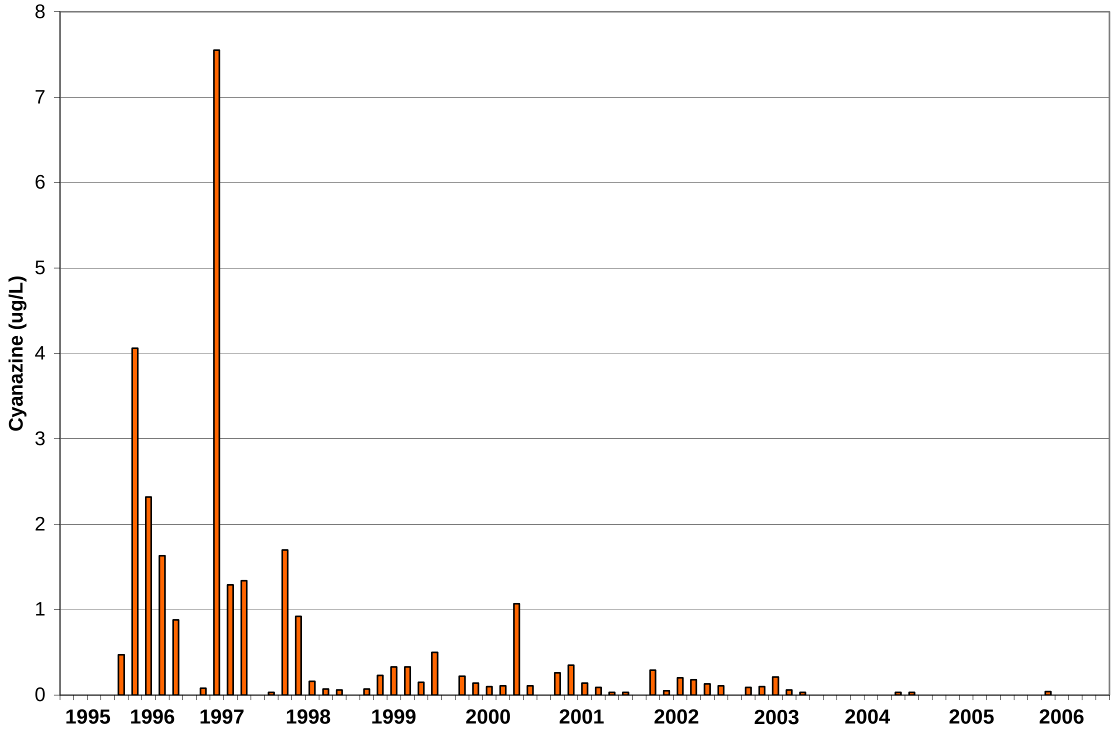
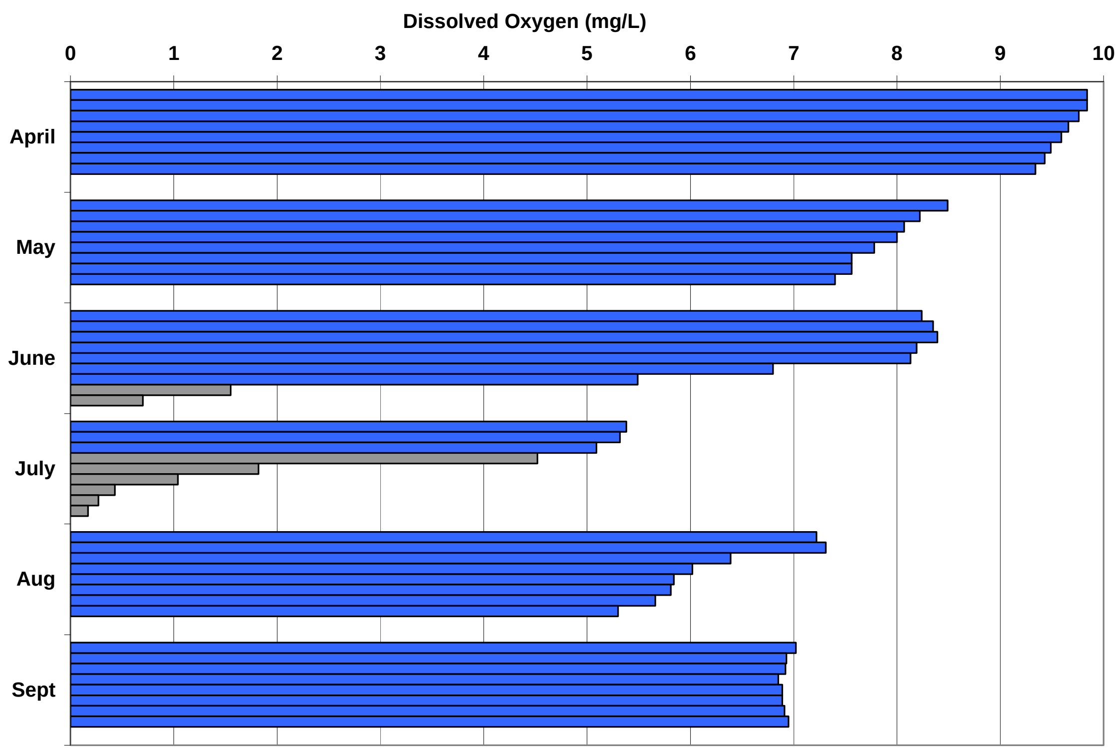


Figure 8.14. Cyanazine concentrations by sample date collected at Site 18 (Long Branch Creek) inflow to Long Branch Lake from 1995 - 2006.



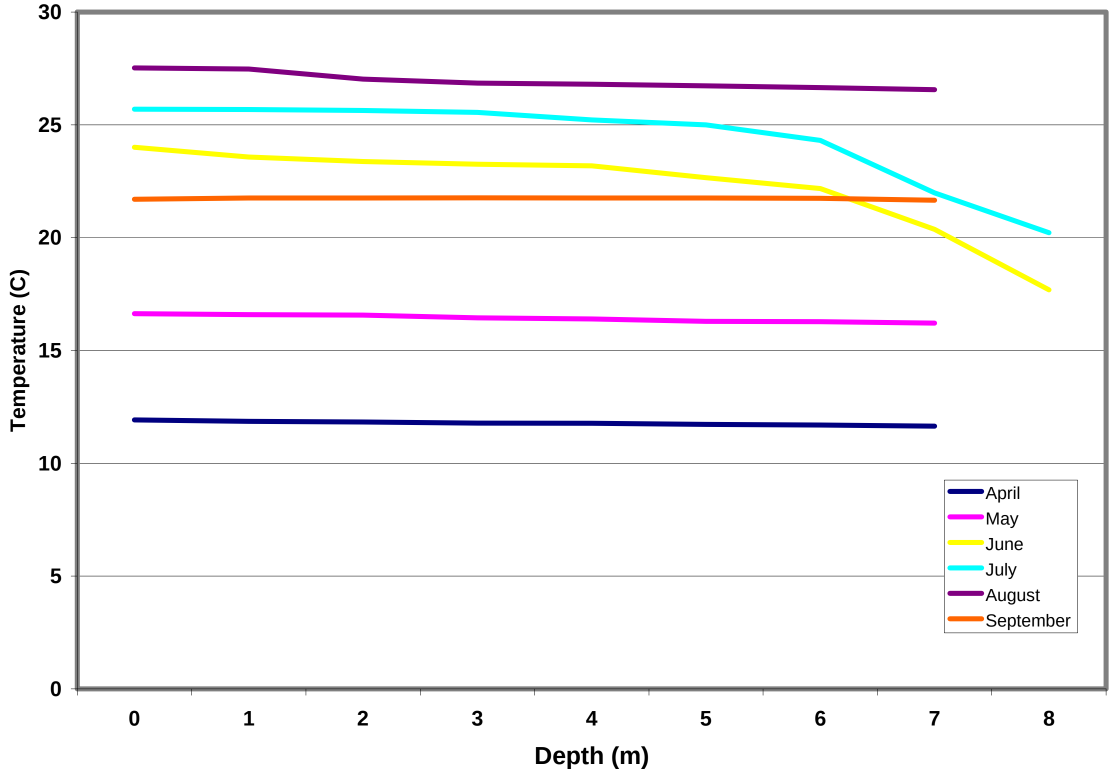


Figure 8.15. Dissolved oxygen concentration (mg/L) histogram and temperature (C) plot from vertical profiles recorded at Site 4 from April through September 2006 at Long Branch Lake.

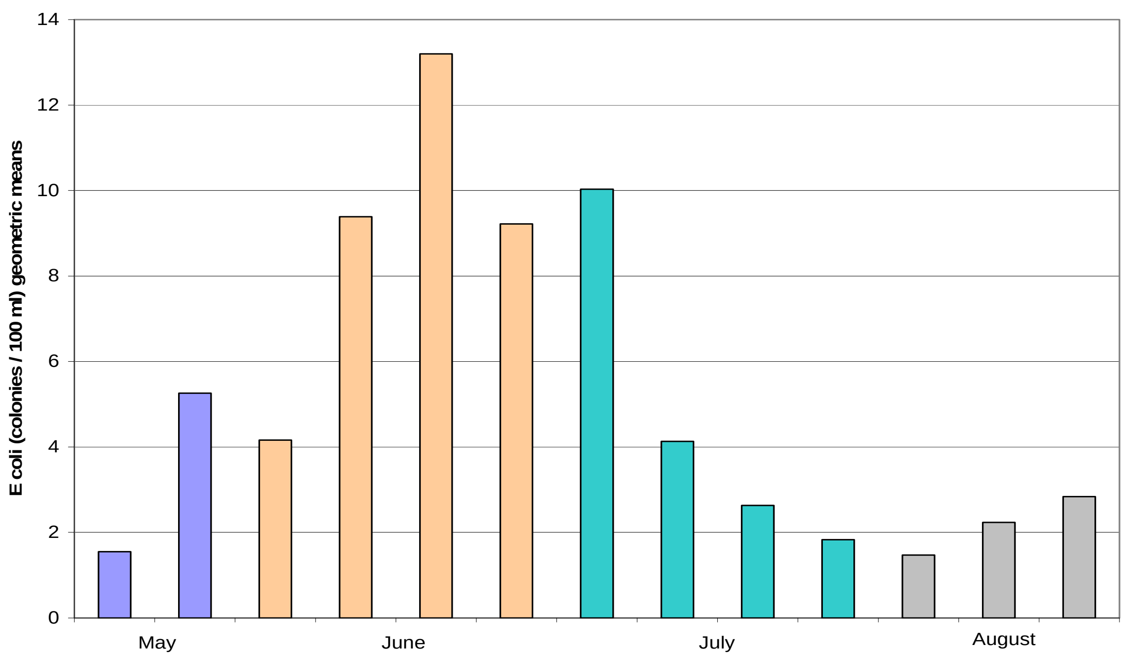


Figure 8.13. Geometric means of fecal bacteria (*E coli*) colonies per 100 ml samples from beach samples collected weekly at Long Branch Lake State Park during 2006.

9 Longview Lake

9.1 General Background

Longview Lake was impounded in 1983, and reached full pool on 23 September 1986. Urban development is occurring throughout the upper reaches of both major tributaries. The main threats to water quality in Longview Lake are nutrients, bacterial contamination, sediment / turbidity related to watershed development, and other contaminants related to an urban environment. The lake is listed on Missouri's 303(d) impaired waters list and an approved TMDL developed for mercury related to atmospheric deposition (MDNR 2004).

9.1.1 Location

A dam on the Little Blue River, located 68 river km (42.9 river miles) upstream of the confluence with the Missouri River, impounds Longview Lake. The lake is located approximately 13.8 km (8.6 miles) southeast of downtown Kansas City, in Jackson County, Missouri. Historic water quality sample sites at Longview Lake include 3 lake, 1 outflow, and 2 inflow sites (Figure 9.1).

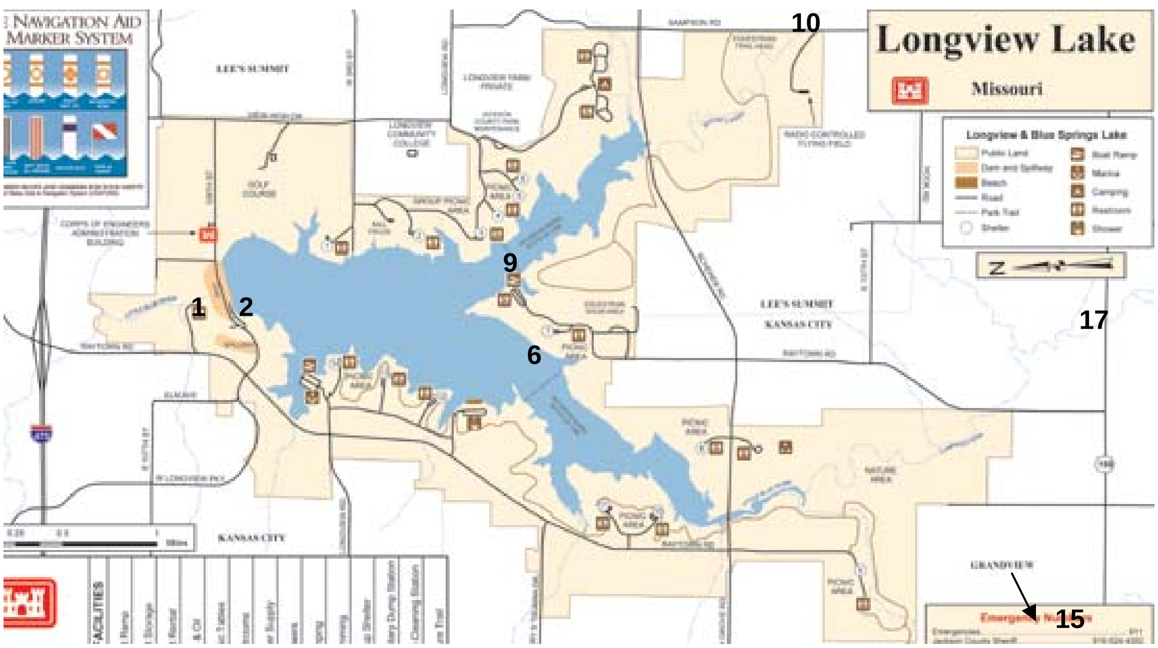


Figure 9.1. Longview Lake area map with sample site locations and site numbers.

9.1.2 **Authorized Purposes:** Flood control, recreation, fish and wildlife conservation, and water quality improvement.

9.1.3 State Use Designations: Livestock and wildlife watering, warmwater aquatic life and human health / fish consumption, whole-body contact recreation, boating and canoeing.

9.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	909.0	24.8	1,960	
Multipurpose	891.0	22.1	930	24
Total		46.9		

Total watershed area: 50 sq miles (32,000 A)

Watershed ratio: 16.3 FC / 34.4 MP

Average Annual Inflow: 34,423 acre-feet/yr (1982 – 2006)
Average Annual outflow: 000 acre-feet
Sediment inflow (measured): 20 acre-feet/yr (1948 – 1993)
Flushing rate: 0.64 years
Water management Plan: Approved 15 February 1994
Historic stage hydrograph: 1996 – 2006 (Figure 9.2)

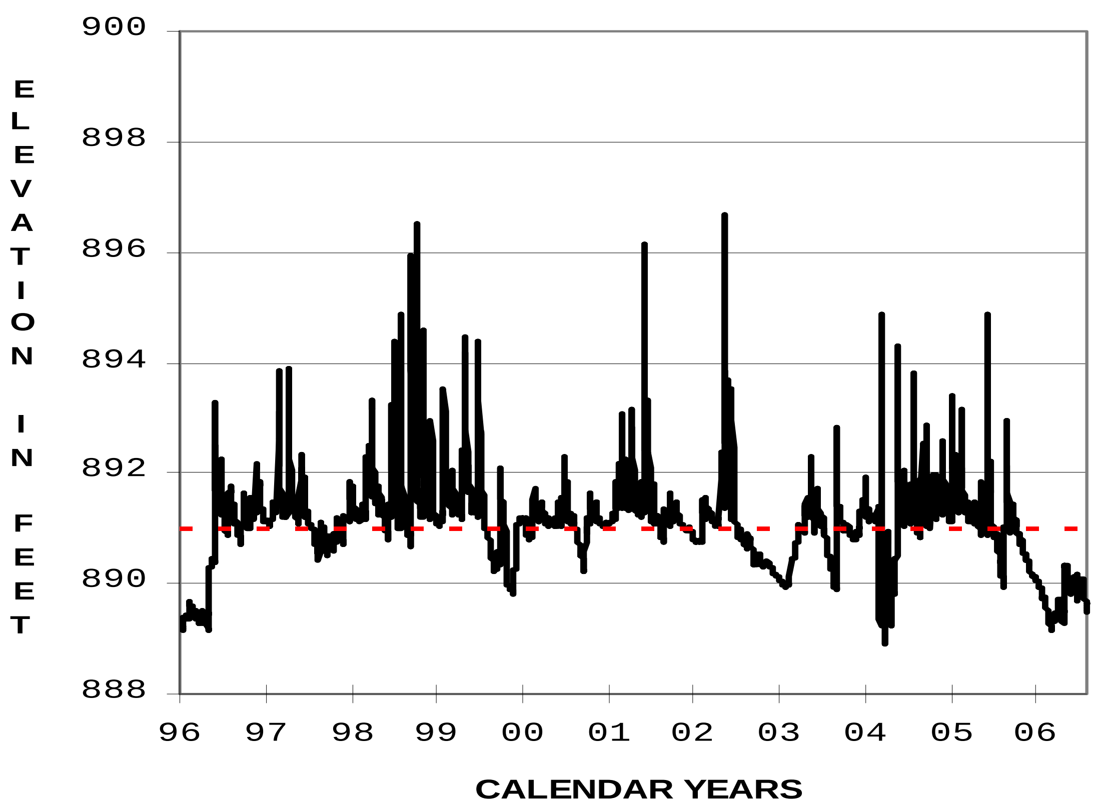


Figure 9.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is multipurpose pool elevation – 891.0 ft)

9.2 2006 Activities

Longview Lake was categorized as an 'intensive' lake during 2006, thus lake and inflow / outflow sites were all sampled (see Figure 9.1). Samples were collected from April through September during 2006. Todd Gemeinhardt (MDC) provided field assistance at Longview Lake during 2006. Fecal bacteria (E. coli) samples were collected weekly at the swimming beach from mid-April through September by JCPRD. The lake was below multipurpose pool elevation throughout the sampling season, which is an indication of the regional drought conditions.

9.3 2006 Data

Comparative historic water quality data consists of a single sample collected during June 1999 and three sampling periods (June, July, and September) during 2005. Samples were collected from April though September during 2006.

9.3.1 Inflow

Longview Lake inflow samples were collected from two sites -- Sites 10 on Mouse Cr and Site 15 on Little Blue River -- during 2006.

9.3.2 Lake

Total nitrogen (TN) and chlorophyll *a* concentrations indicate Longview Lake is eutrophic. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Median TN concentrations from lake site surface samples range from 0.57 – 0.73 mg/L (Figure 9.3), which are above the proposed EPA nutrient criteria value of 0.36 mg/L total nitrogen. The highest median concentration (1.15 mg/L) for an inflow site occurs at Site 10 (Mouse Cr). This site is dominated by high organic-bound nitrogen, which is most likely the result of allochthonous inputs.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Although the median total phosphorus (TP) concentrations (0.023 – 0.04 mg/L) for all sites exceed the proposed EPA nutrient criteria value (0.02 mg/L), Longview has some of the lowest TP concentration within the district (Figure 9.4). The extensive aquatic vegetation introduction efforts by MDC within the littoral zone of Longview Lake is most likely responsible for the reduced TP concentrations. Once again, these results are from a very limited dataset.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). Median TN:TP ratios at all three lake sites are > 20, indicating the lake is at low risk for cyanobacteria blooms (Figure 9.5). This was expected due to low TP concentrations within the lake.

Secchi depth (water clarity) was measured monthly at all three lake sites. When compared between years, secchi depth was slightly higher at both upper lake sites (Sites 6 & 9) during 2006 versus 2005 (Figure 9.6). Conversely, secchi depth measurements at Site 2 (Tower) were consistently lower in 2006 versus 2005. Both the

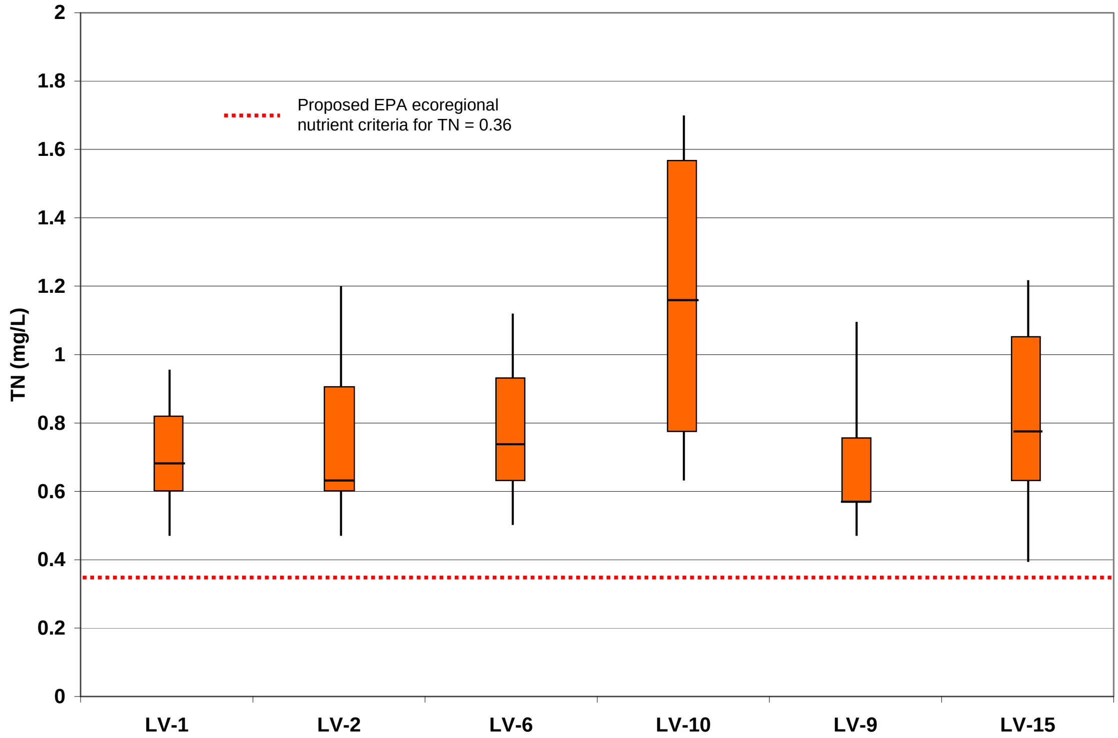


Figure 9.3. Box plots of surface water sample total nitrogen concentrations measured by site during 1999 and 2006 at Longview Lake.

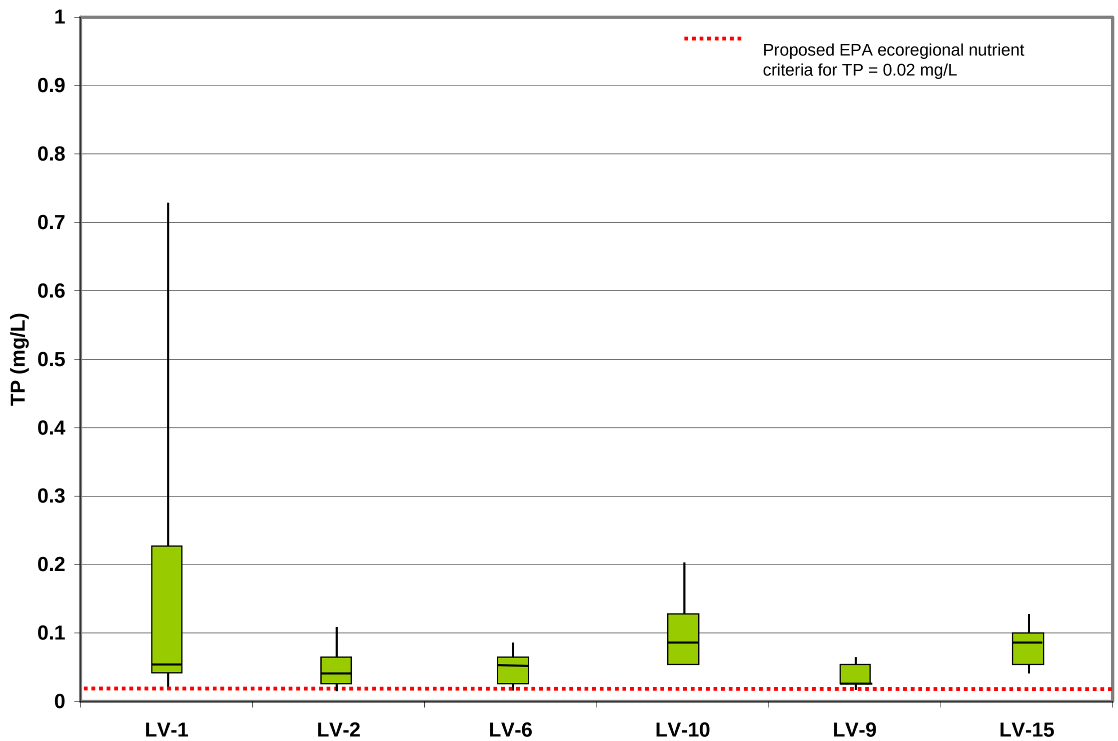


Figure 9.4. Box plots of surface water sample total phosphorus concentrations measured by site during 1999 and 2006 at Longview Lake.

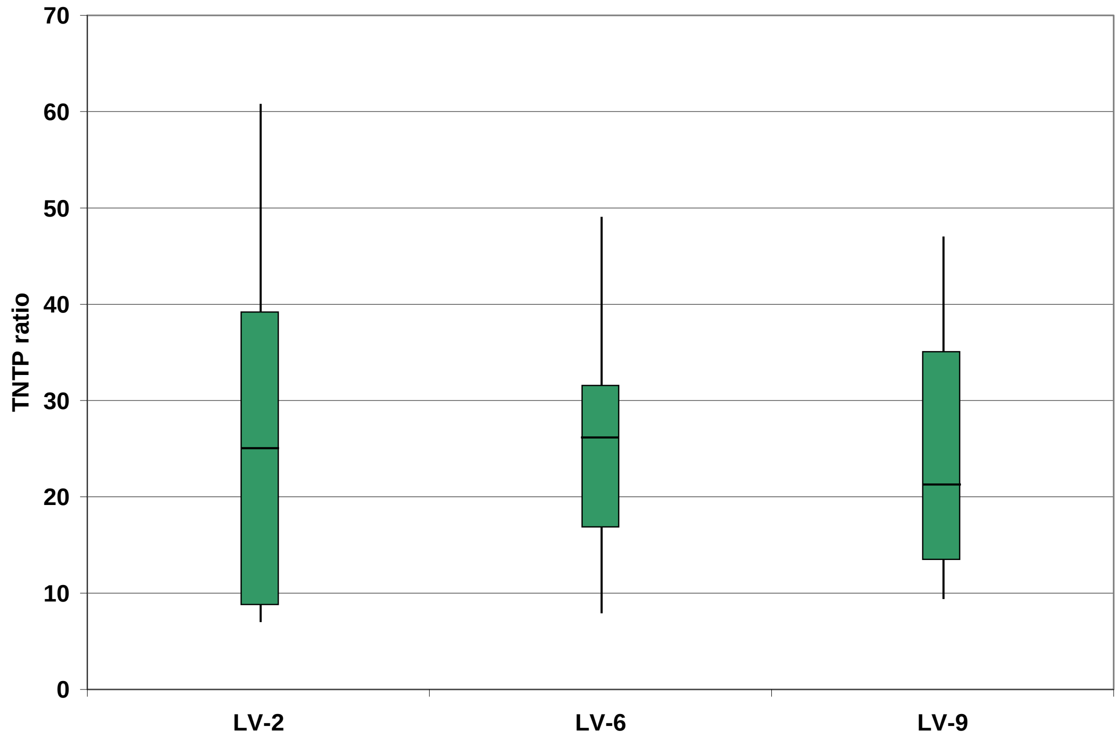


Figure 9.5. Box plots of total nitrogen : total phosphorus (TN : TP) ratios from surface water samples by site from 1999 and 2006 at Longview Lake.

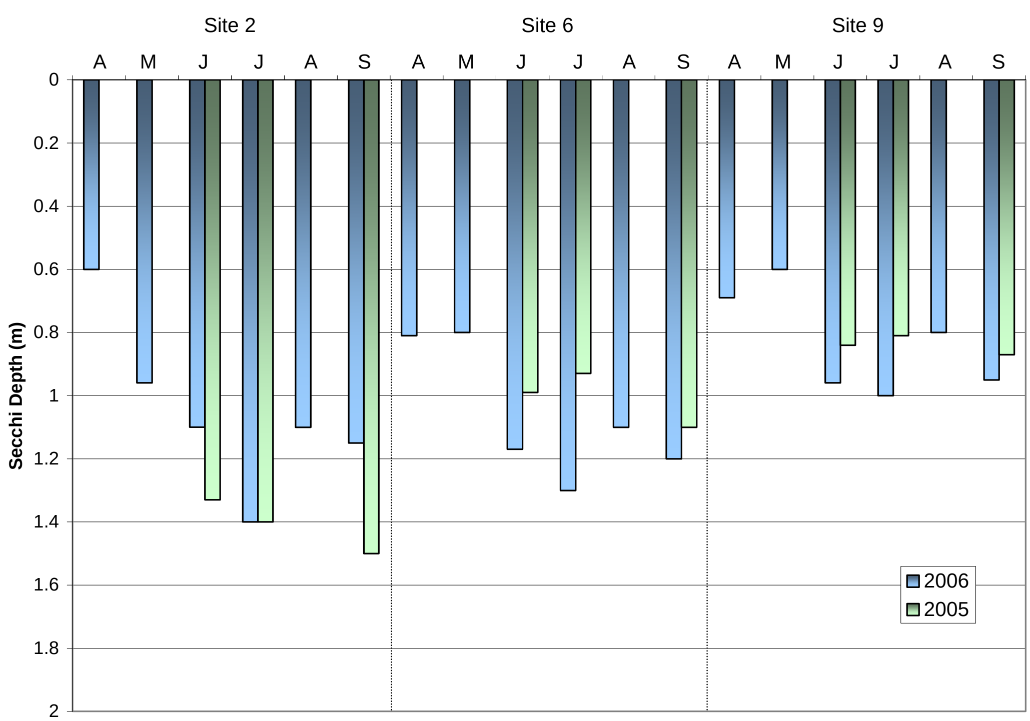


Figure 9.6. Comparison of secchi depth (m) measurements by lake site from 2005 and 2006 at Longview Lake.

main lake (Site 2; median = 1.13 m) and Mouse Creek arm site (Site 6; median = 1.05 m) exhibit good water clarity, while Lumpkin Fork arm (Site 9; median = 0.83 m) exhibits slightly lower water clarity (Figure 9.7).

Monthly variability in mean chlorophyll *a* was detected at all three lakes sites (Figure 9.8). Mean chlorophyll *a* concentrations from the three lake sites ranged from 15 – 18 ug/L during 2006. Median summer chlorophyll *a* concentrations range from 12 – 15.4 ug/L at lake sites during the past two summers (Figure 9.9).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 9.10 depicts vertical distribution of phycocyanins measured at Site 2 (Tower) from May through September. Concentrations in the upper waters peaked in August, but distributions were more consistent throughout the water column during September. Phycocyanin concentrations are lower compared to other district lakes.

The median atrazine concentrations from surface water samples collected in 1999 (1 sample) and 2006 (0.07 – 0.15 ug/L) were all below EPA's drinking water maximum contaminant level of 3 ug/L (Figure 9.11). These concentrations are some of the lowest within the district, which is not unexpected due to the urbanized watershed. It is also important to note that drought conditions may have some impact concentrations measured this year.

Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at both inflow sites (Site 10 = 699 ug/L; Site 15 = 855 ug/L). Total iron concentrations from bottom samples in the lake ranged from 824 – 2889 ug/L, which reflects anoxic conditions throughout the lake. Elevated levels are directed at drinking water facilities related to taste and staining issues. In addition, surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L) at both inflow sites (Site 10 = 811 ug/L; Site 15 = 576 ug/L). The SMCL for total manganese was exceeded in bottom samples from all three lake sites (range = 137 – 1584 ug/L). Implications are directed at drinking water facilities due to taste and stain issues.

Vertical profiles were recorded monthly from April through September. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Typical of smaller eutrophic reservoirs in Missouri, the lake was strongly stratified both chemically and thermally after 7 m during June and August, while stratification began at a depth of 4 – 5 m during (Figure 9.12). Lake stratification had deepened to 7-8 m during September in response to cooling air temperatures.

Weekly samples (April – September) of fecal bacteria (*E. coli*) were collected during 2004 and 2005 (Figure 9.13). Although Longview Lake has a history of elevated fecal samples, the geometric mean from samples collected in 2006 (38 colonies / 100 mg/L) was below the state standard for whole-body contact (200 colonies / 100 ml). Drought conditions could have been responsible for low concentrations measured during 2006.

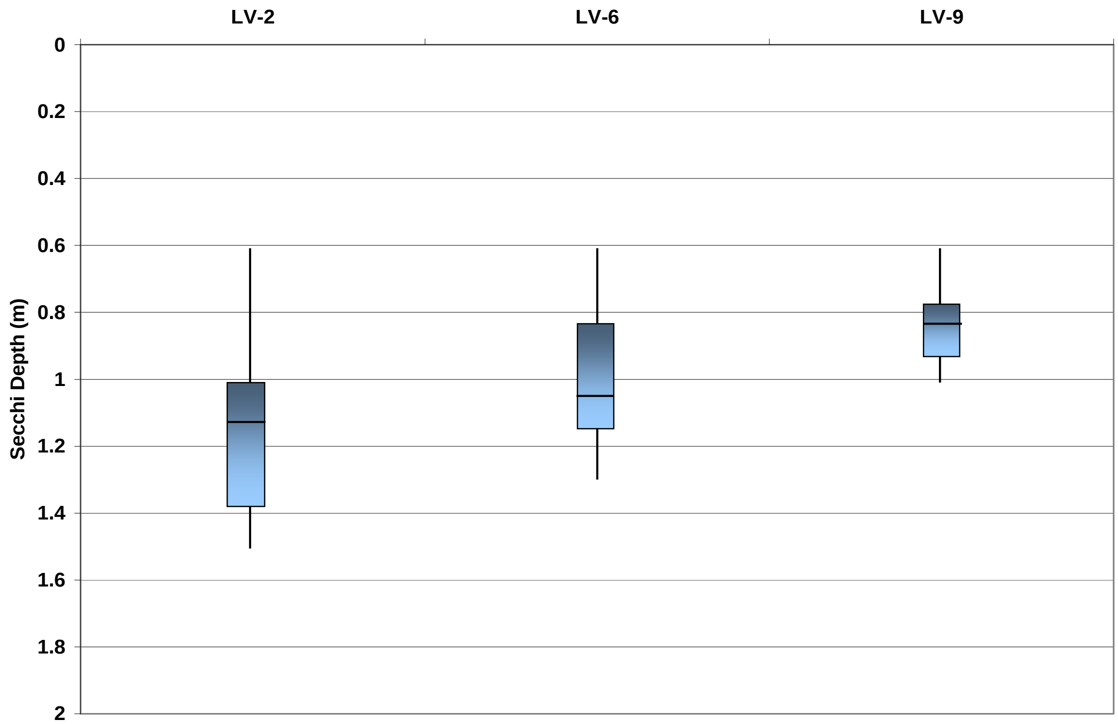


Figure 9.7. Box plots of secchi depth (water clarity) measured at lake sites from 2005 - 2006 at Longview Lake.

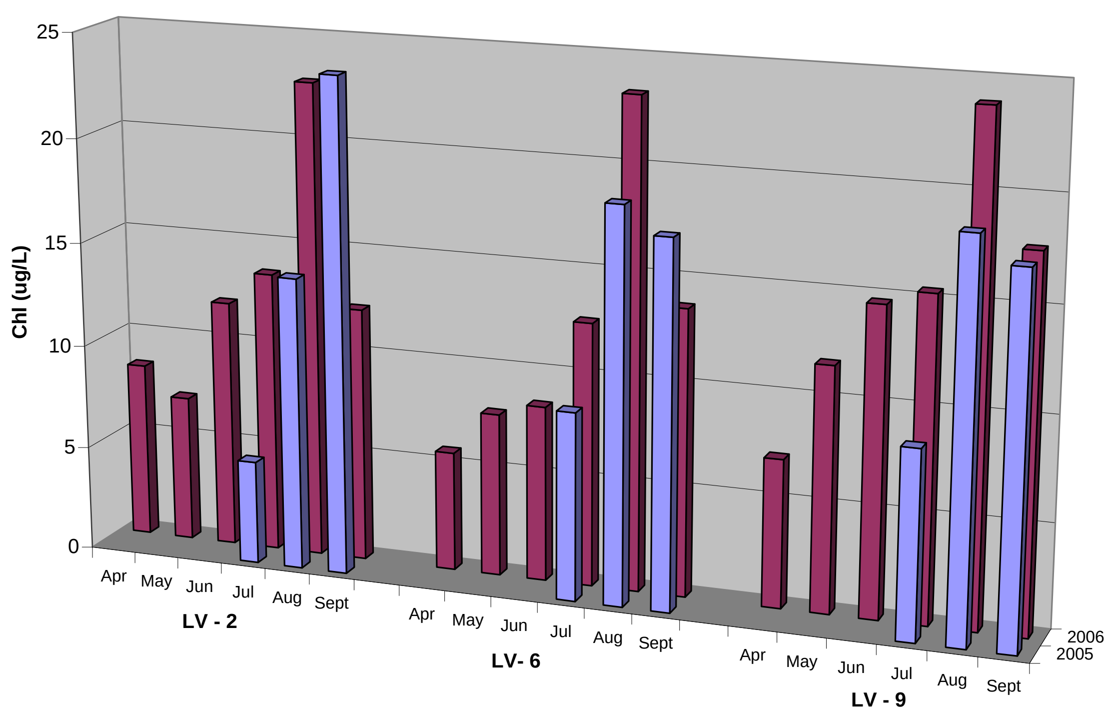


Figure 9.8. Comparison of mean chlorophyll a concentrations (ug/L) by date and site (2 = Tower; 6 = Mouse Cr; 9 = Little Blue arm) at Longview Lake during 2005 and 2006.

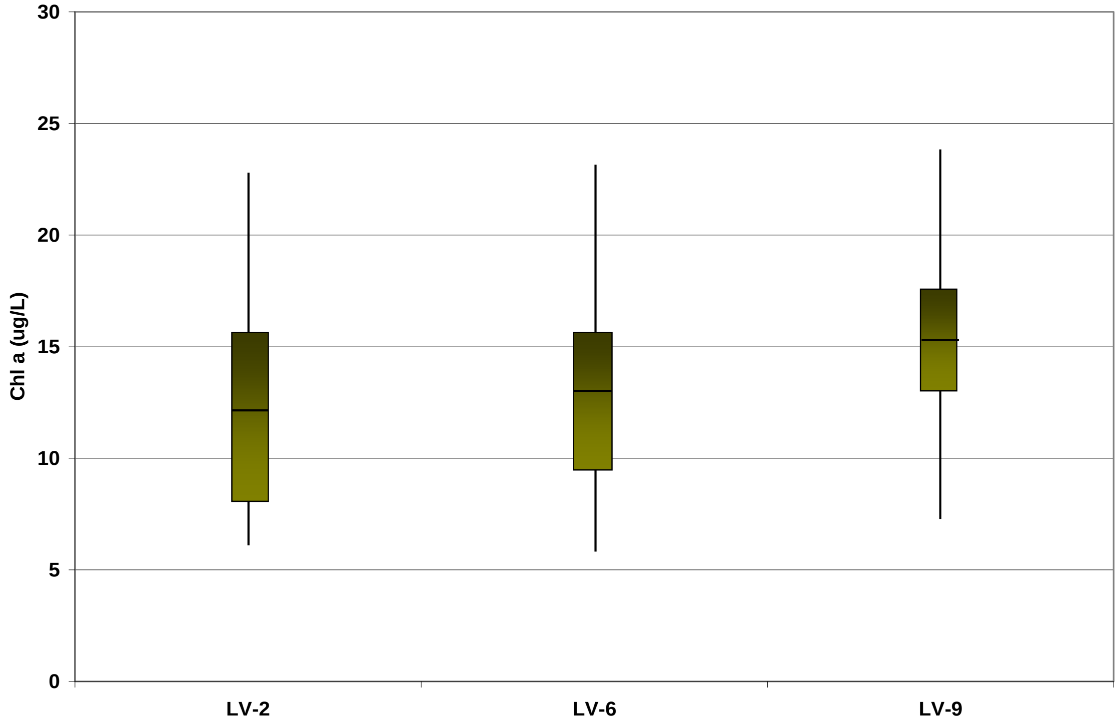


Figure 9.9. Box plots of chlorophyll a concentrations measured at lake sites from 1999 and 2006 at Longview Lake.

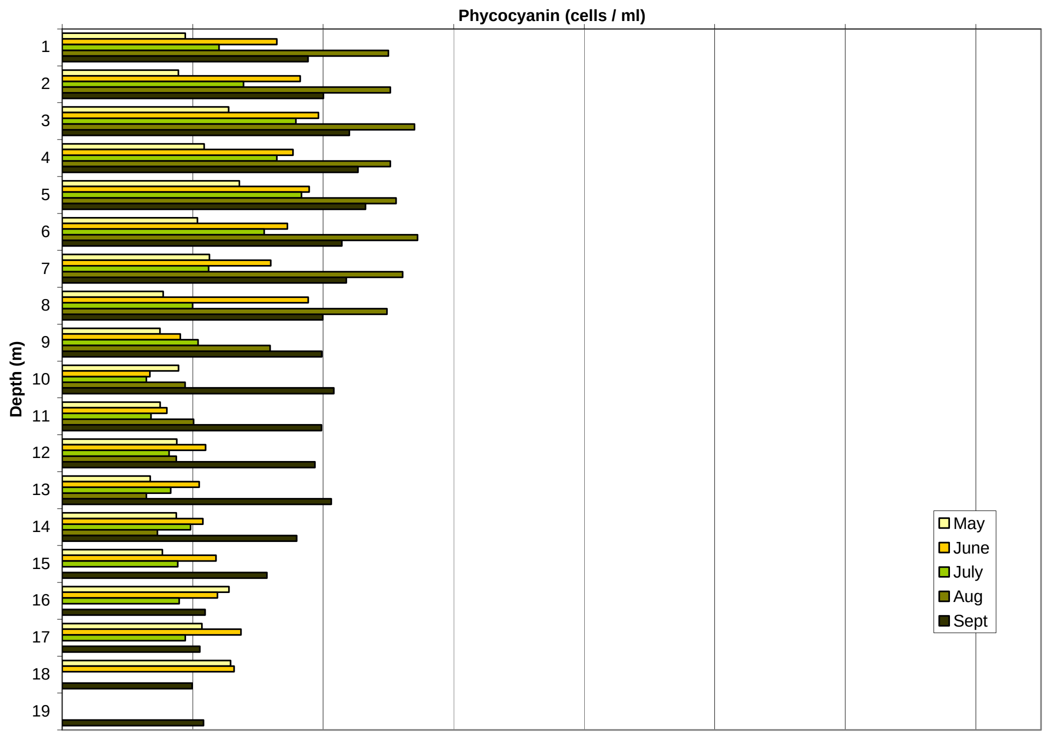


Figure 9.10. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Longview Lake Site 2 (Tower) during 2006.

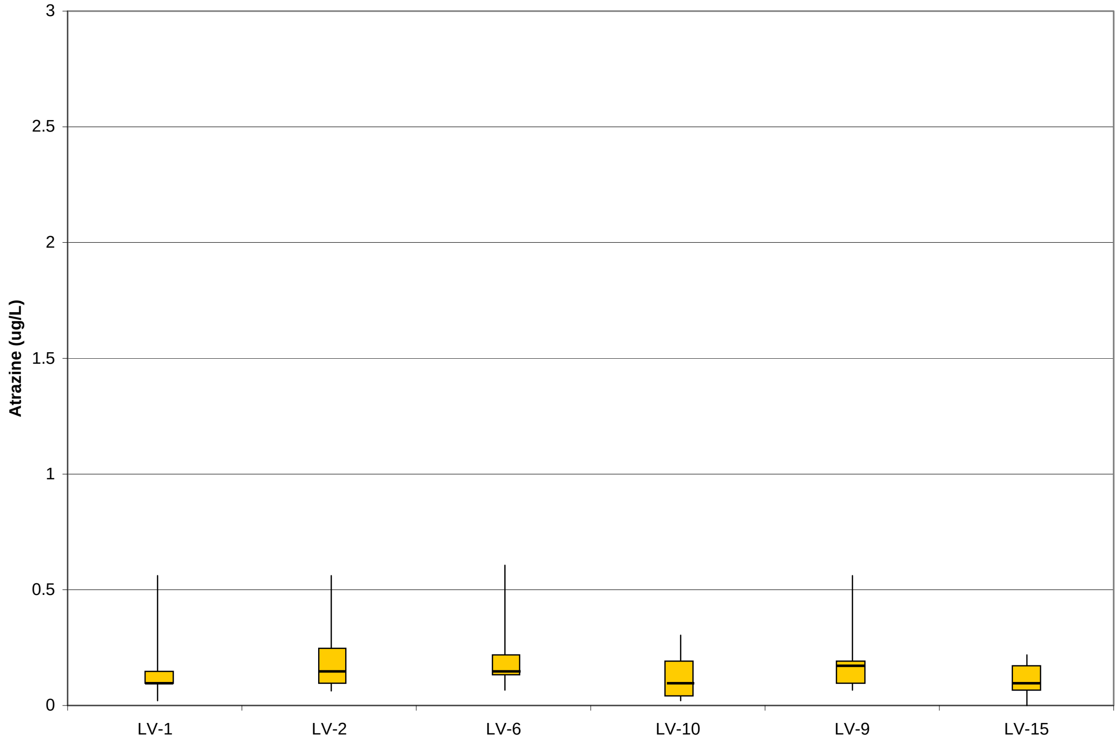
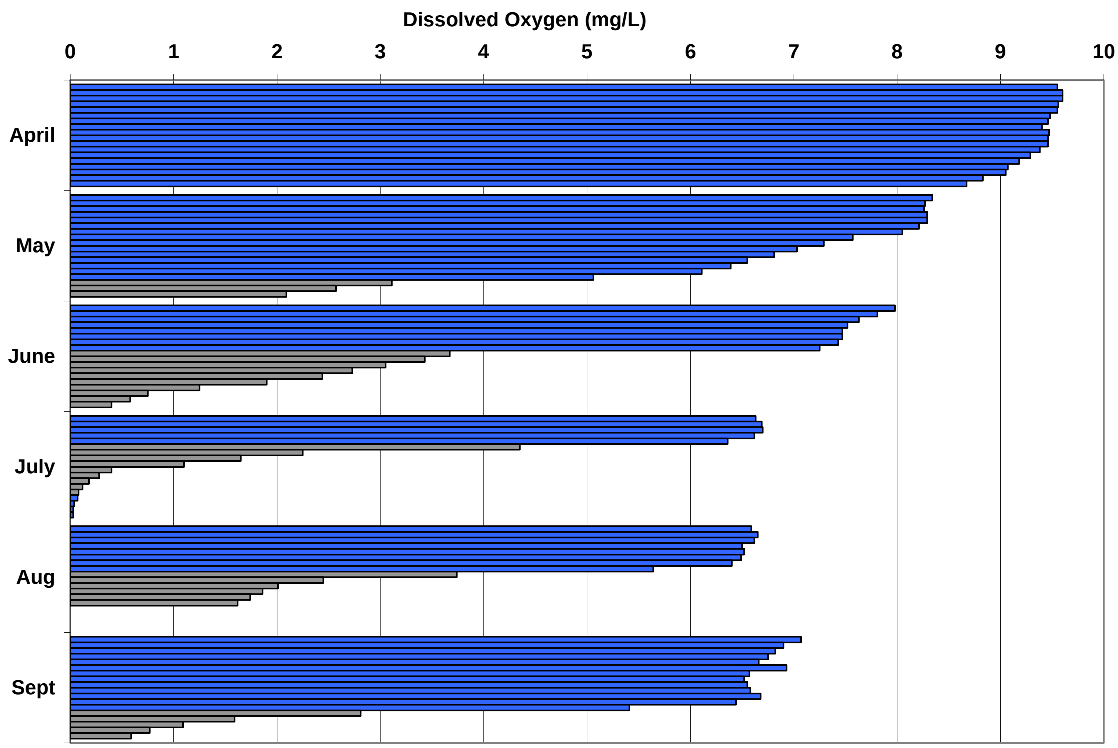


Figure 9.11. Box plots of atrazine concentrations measured by site 1999 and 2006 at Longview Lake.



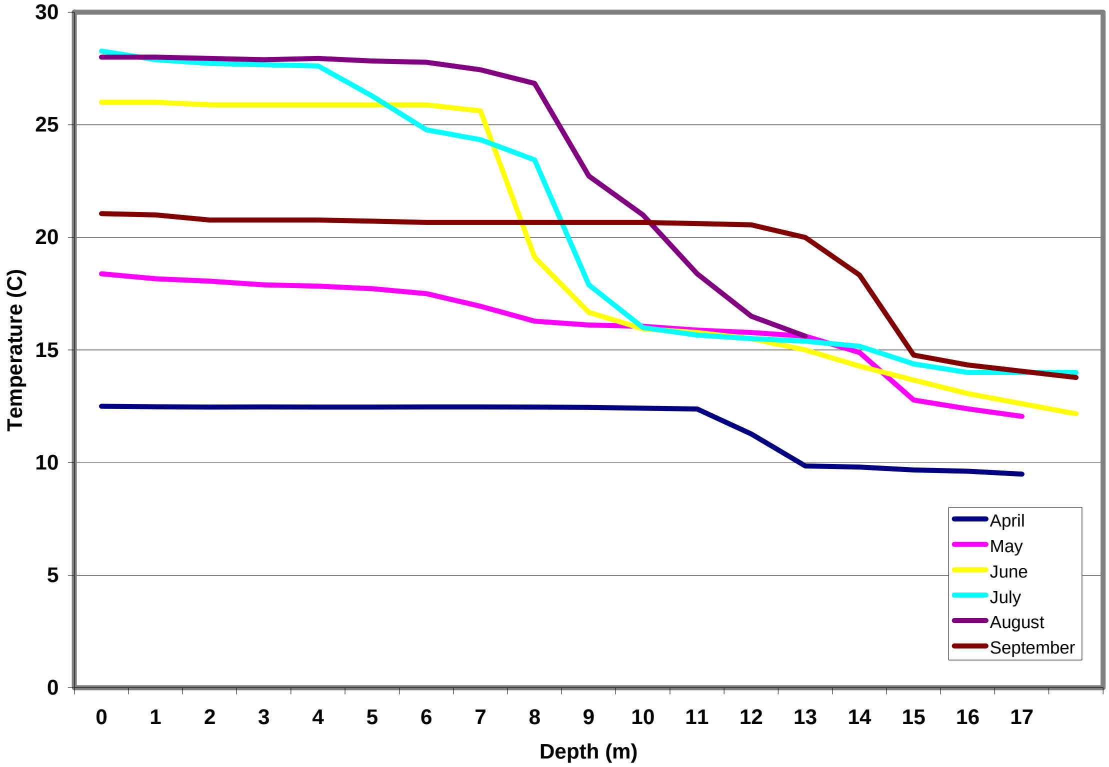


Figure 9.12. Temperature (°C) plots and dissolved oxygen concentration (mg/L) histogram from vertical profiles recorded at Site 2 (dam) from April through September 2006 at Longview Lake.

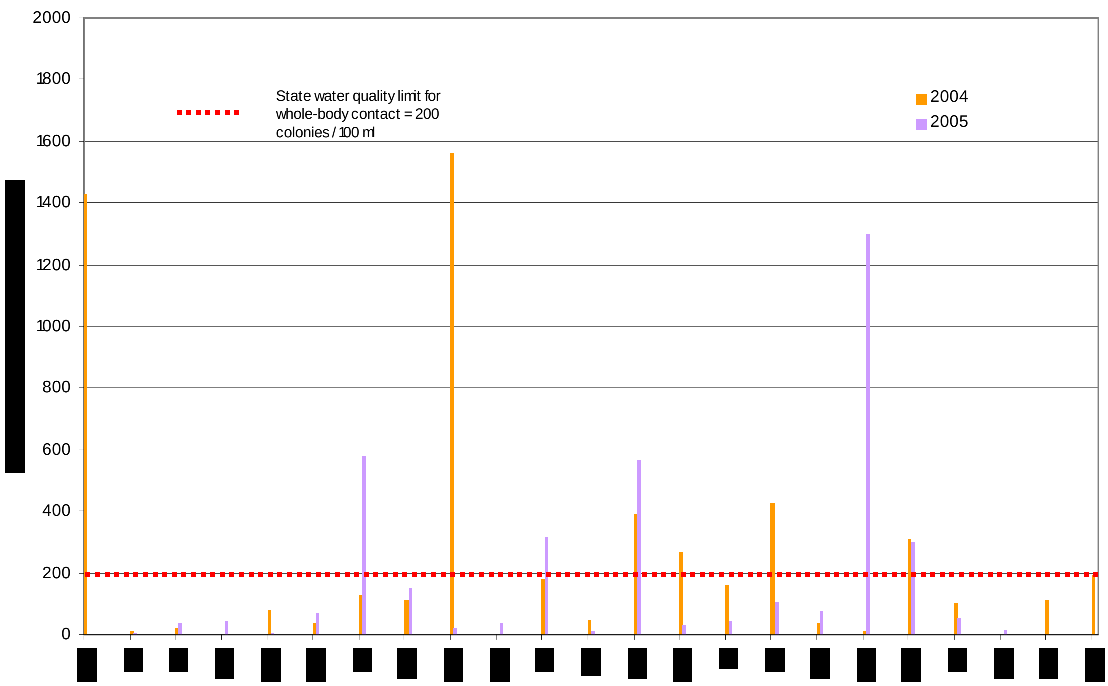


Figure 9.13. Fecal bacteria (E. coli) (colonies per 100 ml) swimming beach samples collected from April through September during 2004 and 2005 at Longview Lake.

9.3.3 Outflow

Outflow samples were collected from Longview Lake during 2006. Summarized data on Site 2 is included in discussions of lakes sites listed above.

9.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to 'ambient' monitoring from May through September, as well as conducting a single vertical profile at each of the two lake sites during July or August. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Due to the urban setting of this lake, sediment contaminant analyses should be conducted when programmatic funds become available in the future to provide status and trend information. Suggest adding Site 17 (Lumpkin Fork) as an inflow monitoring site during next 'intensive' sampling period. Extensive land disturbance due to urban sprawl is occurring upstream of this segment, and baseline / trend data will be beneficial to understanding future changes within the lake. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. A contaminant group of interest is polyaromatic hydrocarbons (PAHs). These compounds are components of asphalt, fuels, oils, and greases. They enter receiving waters from stormwater runoff, industrial and wastewater treatment discharges, and through atmospheric deposition. They do not dissolve, but attach to particulate material and eventually settle out to the substrate. These compounds are highly toxic to aquatic biota, and thus baseline data is desired to track within district lakes. This is a high priority item when future funding becomes available.

10 Melvern Lake

10.1 General Background

Melvern Lake was impounded on 1 August 1970 and reached full multipurpose pool on 4 April 1975. The primary water quality threats to the lake include nutrients, herbicides, bacteria and sedimentation. Approximately 80% of the watershed landuse is grazing, hay or native vegetation, while the remaining 20% is cropland. Soils within the watershed are shallow but high in phosphorus content. The Melvern Lake Water Quality Project was started approximately six years ago, with the specific goals to improve water quality in the lake and tributaries and to reduce nonpoint source pollutants to the lake, tributaries and groundwater. This EPA 319 grant funded project is a cooperative effort between local, state, and federal agencies.

10.1.1 Location

A dam located on the Marais des Cygnes at river mile 175.4 (280.6 km) impounds Melvern Lake. The dam is approximately 6.4 km (4 miles) west of Melvern. The watershed is located in Lyon, Osage, Wabaunsee, and Coffey Counties. Historic water quality sample sites at Melvern include 3 lake, 1 outflow, and 1 inflow (Figure 10.1).

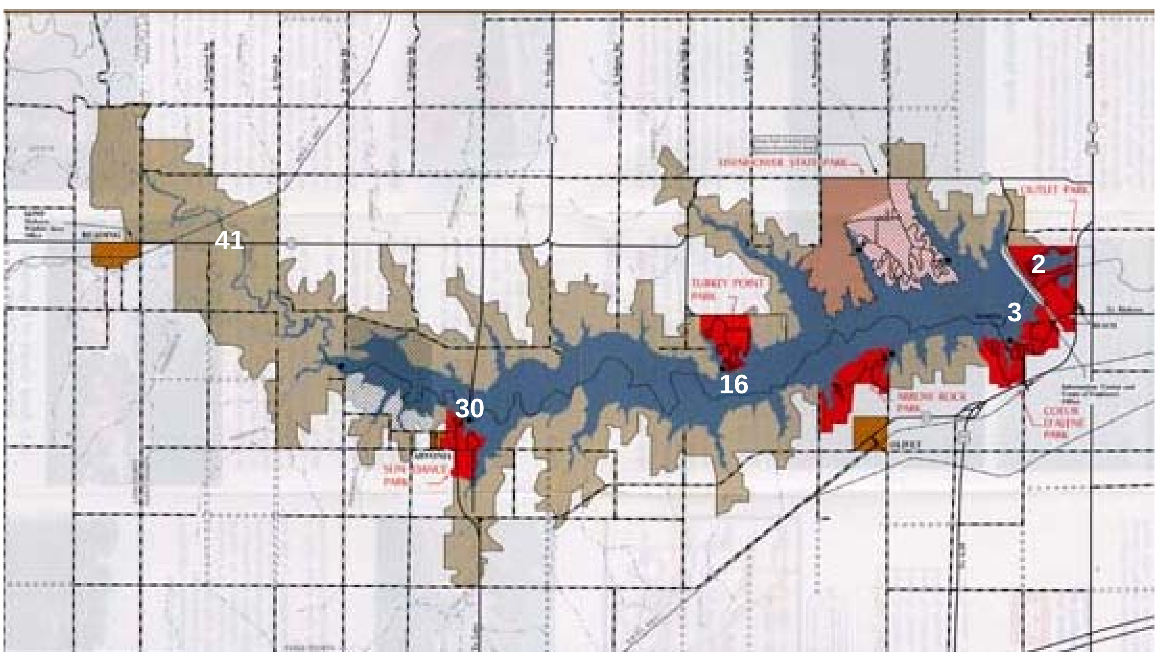


Figure 10.1. Melvern Lake area map with sample site locations and site numbers.

10.1.2 Authorized Purposes: Flood damage reduction, recreation, fish and wildlife management, water supply, and water quality improvement.

10.1.3 State Use Designations: Primary contact recreation, expected aquatic life use, drinking water supply, food procurement, and industrial water supply.

10.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,057	208.2	13,935	
Multipurpose	1,036	152.1	6,912	101
Total		360.3		

Total watershed area: 349 sq miles (223,360 A)

Watershed ratio: 16.0 FC / 32.31 MP

Average Annual Inflow: 164,670 acre-feet
Average Annual outflow: 000 acre-feet
Sediment inflow (measured): 4,064 acre-feet (1972 – 1985)
Flushing rate: 0.88 years
Water management Plan: Approved 27 June 1985

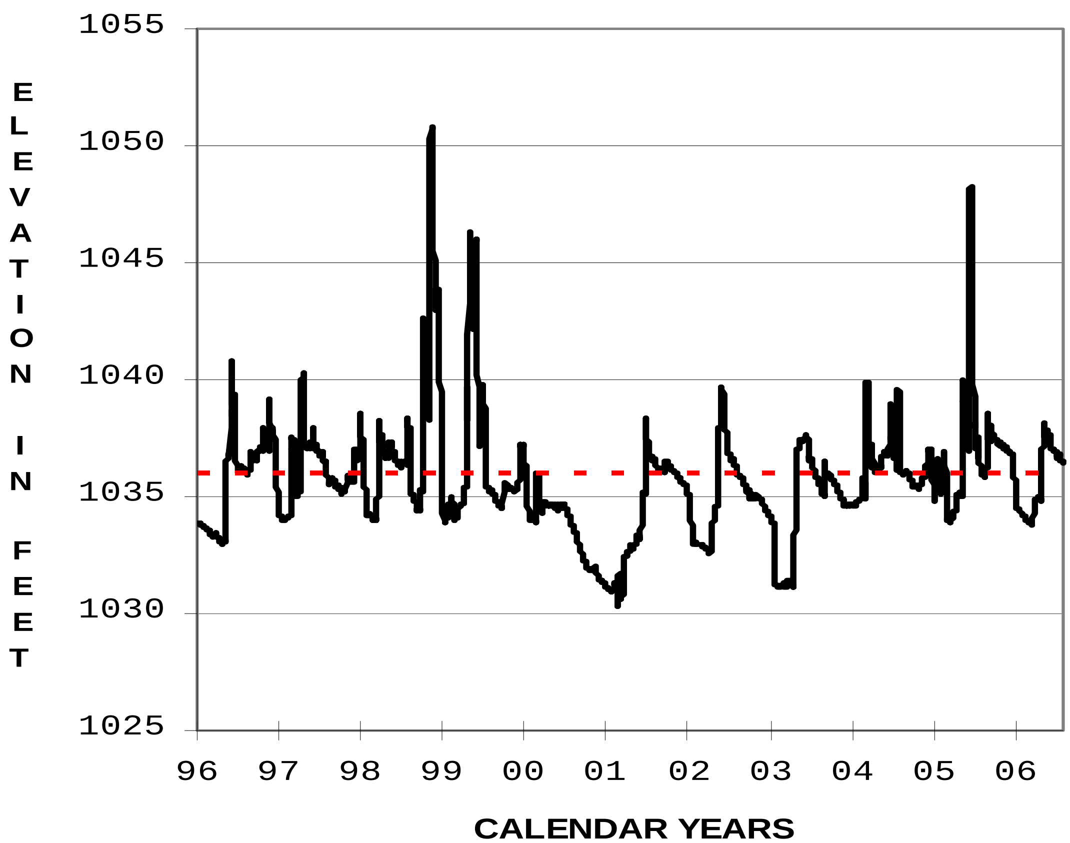


Figure 10.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 1036 ft).

10.2 2006 Activities

Melvern Lake was categorized as an 'ambient' lake during 2006, thus only surface samples were collected at the three lake sites. Sample collections occurred June, August, and September; no samples were analyzed in July due to lost FedEx shipment. Vertical profiles were recorded at each lake site during August. Melvern Lake staff (OF-ME) providing field sampling assistance during 2006 included Charlie Hall, Jim Franz and Scott Rice. Mack Carlisle, OF-ME Operations Manager, provided insight and background regarding Melvern Lake. Historic water quality data was shared with Paul Ingle, Melvern Lake watershed coordinator. Discussions included atrazine trends, sedimentation, and watershed activities being promoted by the watershed program.

10.3 2006 Data

Comparative historic water quality data consists of monthly (April – September) data collected from 1995 through 2004 / 2005. Samples were collected during June, August and September during 2006.

10.3.1 Inflow

No inflow samples were collected from Melvern Lake during 2006.

10.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen median concentrations (0.51 – 0.78 mg/L) measured from Melvern Lake between 1996 and 2006 are some of lowest within the district (Figure 10.3). It should be noted however, these concentrations still exceed EPA's proposed ecoregional nutrient criteria value of 0.36 mg/L total nitrogen. Nitrogen concentrations are highest in the inflow and typicallly lowest near the dam. Monthly and annual variability in total nitrogen is evident at all sites, as is depicted in Figure 10.4 for Site 41. Typically, TN concentration peaks in spring following runoff inputs and then declines through summer months as it is assimilated within the lake.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Total phosphorus median concentrations (0.04 – 0.10 mg/L) measured from Melvern Lake between 1996 and 2006 exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L (Figure 10.5). These concentrations are typical for reservoirs within the district. Highest concentrations are typically found in the shallow upper lake area.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 10.6 as an example at Site 3. Median TN:TP ratios at all three lake sites are ~ 12, indicating the lake is at risk for cyanobacteria blooms (Figure 10.7).

Monthly variability in mean chlorophyll *a* was detected at both lakes sites (Figure 10.8). Monthly mean chlorophyll *a* concentrations were higher at all three sites in 2006 vs

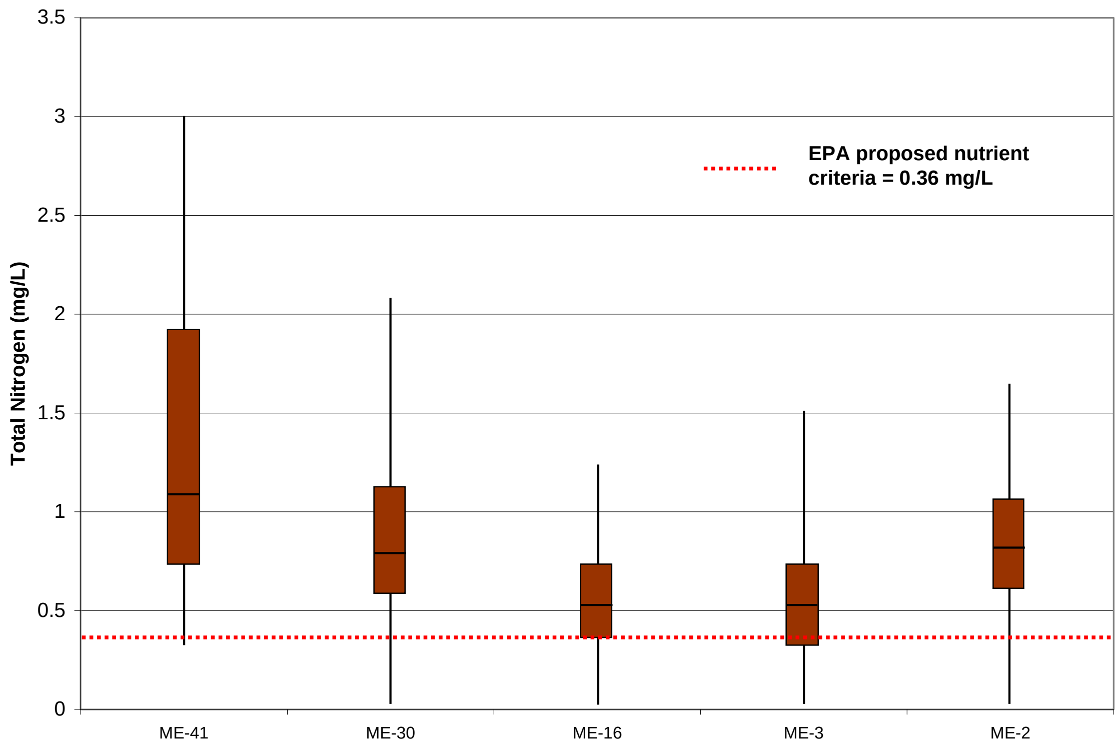


Figure 10.3. Box plots of surface water sample total nitrogen concentrations measured at lake sites from 1996 through 2005 at Melvern Lake.

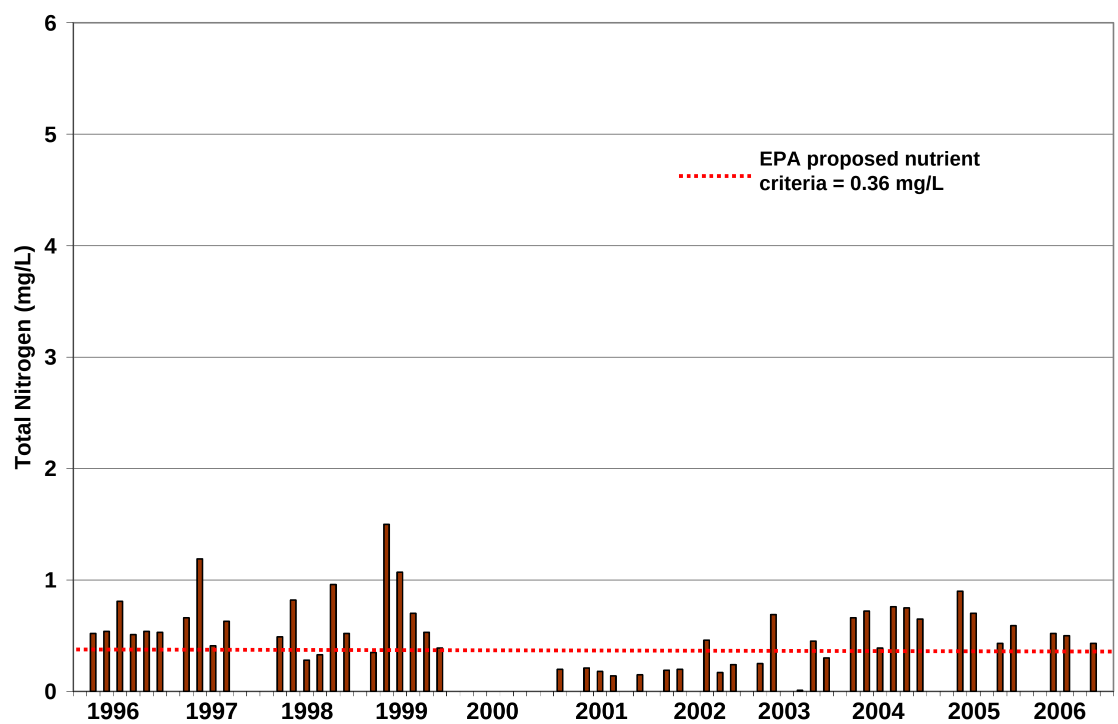


Figure 10.4. Total nitrogen concentrations by sample date from surface water samples collected from Site 3 (tower) in Melvern Lake from 1996 through 2006.

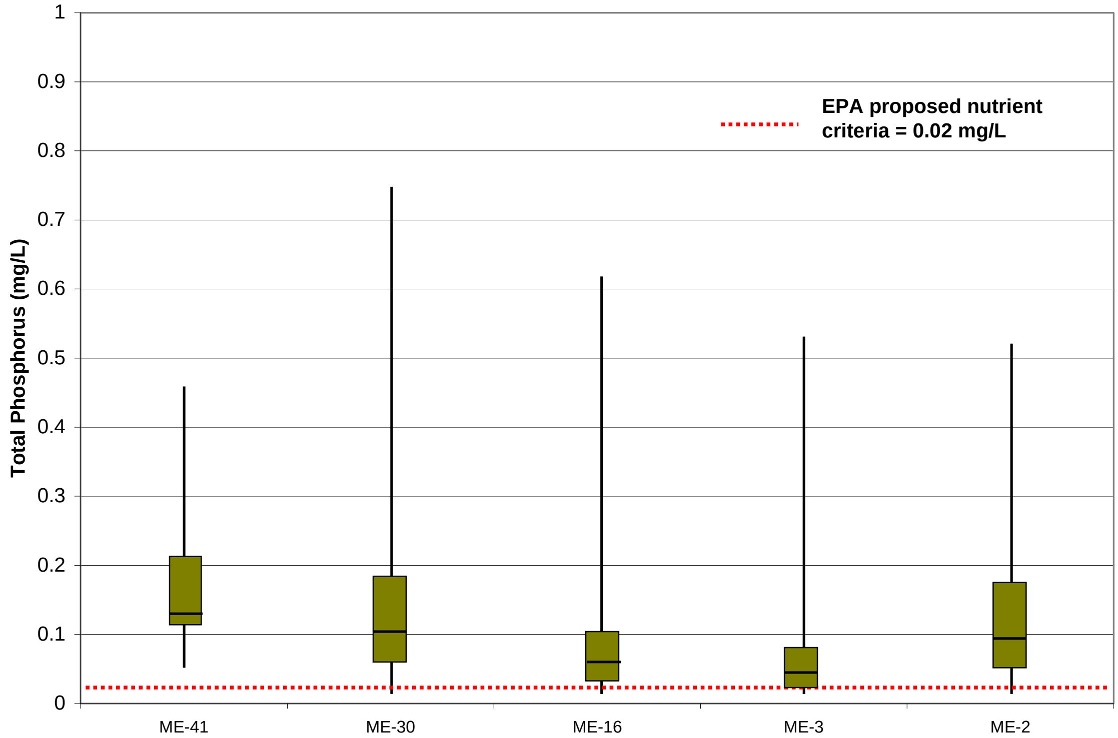


Figure 10.5. Box plots of surface water sample total phosphorus concentrations measured at lake sites from 1996 through 2006 at Melvern Lake.

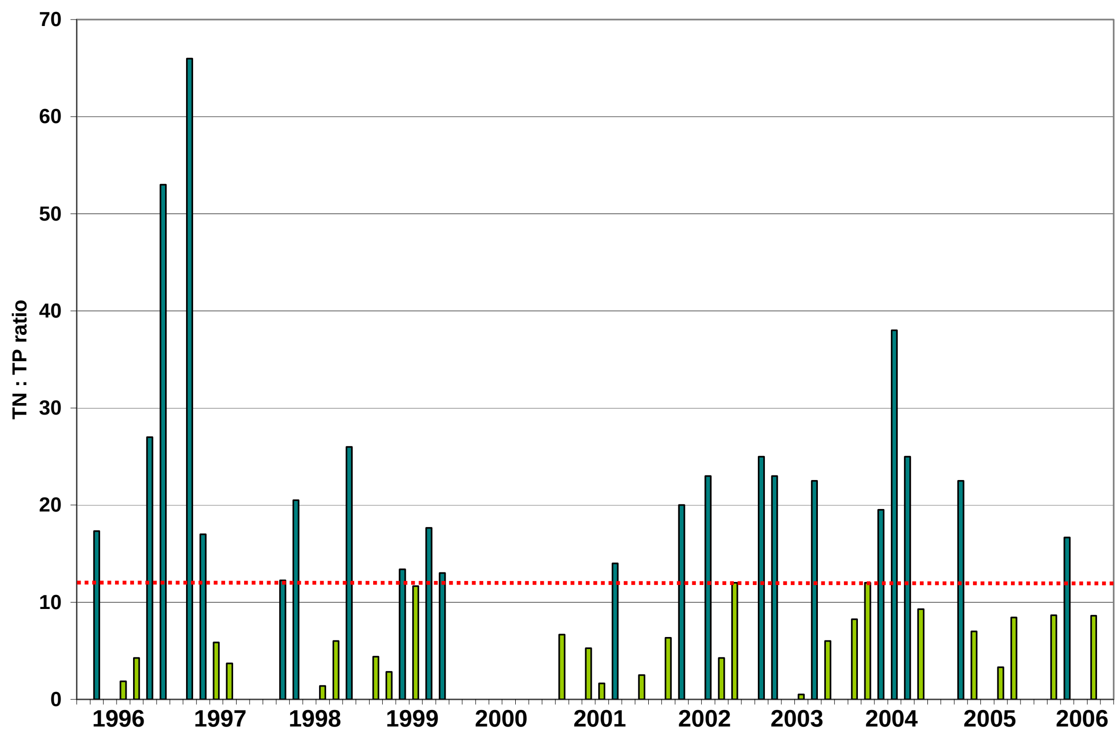


Figure 10.6. Graph of total nitrogen : total phosphorus (TN : TP) ratio by sample date from surface water samples at Melvern Lake Site 3 from 1996 – 2006.

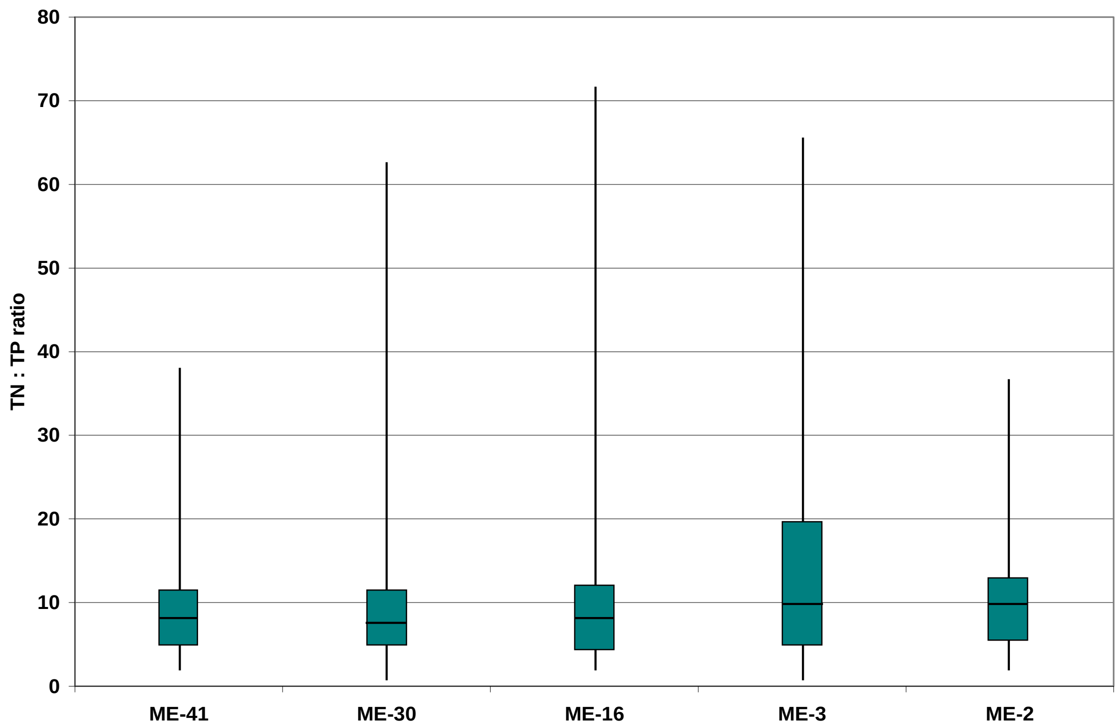


Figure 10.7. Box plots of total nitrogen : total phosphorus (TN : TP) by site from 1996 through 2006 at Melvern Lake.

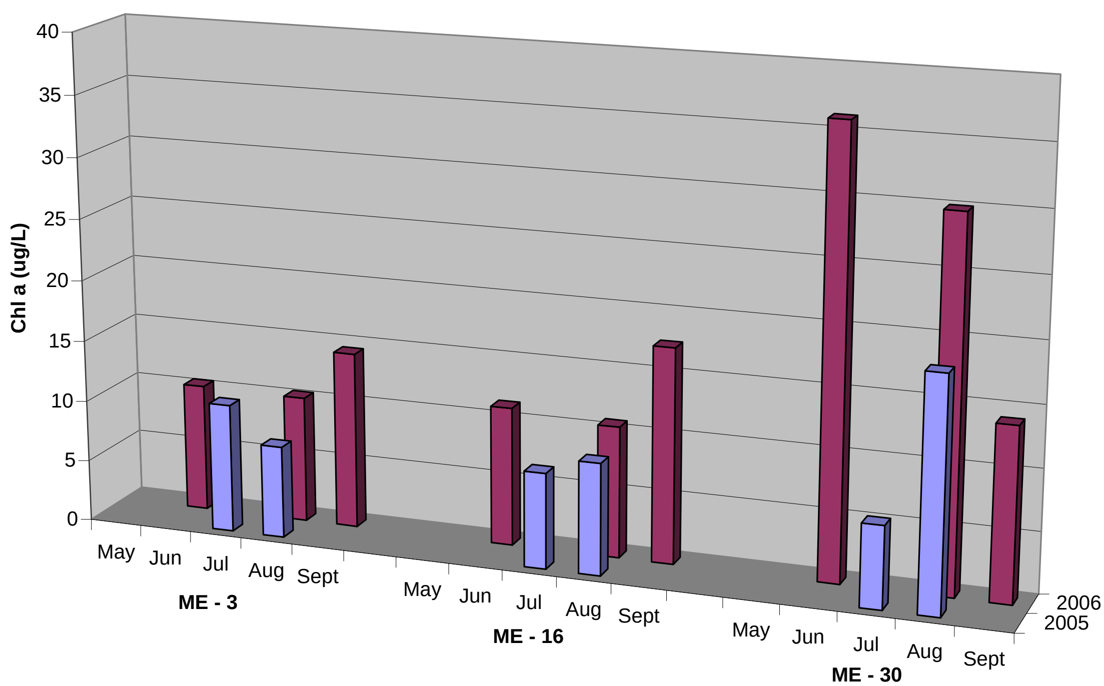


Figure 10.8. Comparison of mean chlorophyll a concentrations (ug/L) by site (3 = Tower; 16 = mid-lake, 31 = upper lake) at Melvern Lake during 2005 and 2006.

2005, and this is most likely due to reduced inflows and lower TSS (drought impacts). Chlorophyll *a* concentrations ranged from 10.4 – 14.4 ug/L at the tower (Site 3), 10.7 – 17.5 ug/L at the mid-lake site and 14.1 – 36.2 ug/L at the dam site.

No secchi depth measurements were made during 2006. However, secchi depth measurements during August 2005 indicated moderately clear water within the main lake (0.93 – 1.02 m).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during the August sample trip. Such profiles provide information on monthly as well as within lake distribution changes. Figure 10.9 depicts vertical distribution of phycocyanins measured at Site 3 (Tower) during August. Although only a single monthly measure, these are the lowest concentrations measured within the district.

Atrazine samples were not collected during either 2005 or 2006. Between 1996 and 2004, median atrazine concentrations (1.1 – 1.7 ug/L) were less than EPA's drinking water maximum contaminant level (MCL) of 3 ug/L (Figure 10.10). However, individual samples measured during that time period are significant enough to exceed the MCL. Figure 10.11 depicts individual sample concentrations measured by date at Site 41, which indicates spikes exceeding the MCL as recent as 2002.

A single vertical profile was recorded at the three lake sites during the 12 August 2005 sampling trip. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on the profile from site 3 (tower), the lake was strongly stratified both chemically and thermally between a depth of 5 –6m (Figure 10.12).

Fecal bacteria (*E. coli*) samples are typically collected from three locations at Coeur D' Alene Park and Outlet Park beaches prior to three major holidays (Memorial Day, July 4th, and Labor Day). However, no samples were collected during 2006 because the contract lab misplaced the sampling order.

10.3.3 Outflow

No outflow samples were collected from Melvern Lake during 2006.

10.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition from an 'ambient' to an 'intensively' monitored lake. This will include monthly sampling from April through September at three lake sites, one inflow site, and one outflow site. Monthly vertical profiles will be recorded at each of the three lake sites. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Interactions with Melvern Lake watershed group and Marais des Cygnes basin advisory committee will continue.

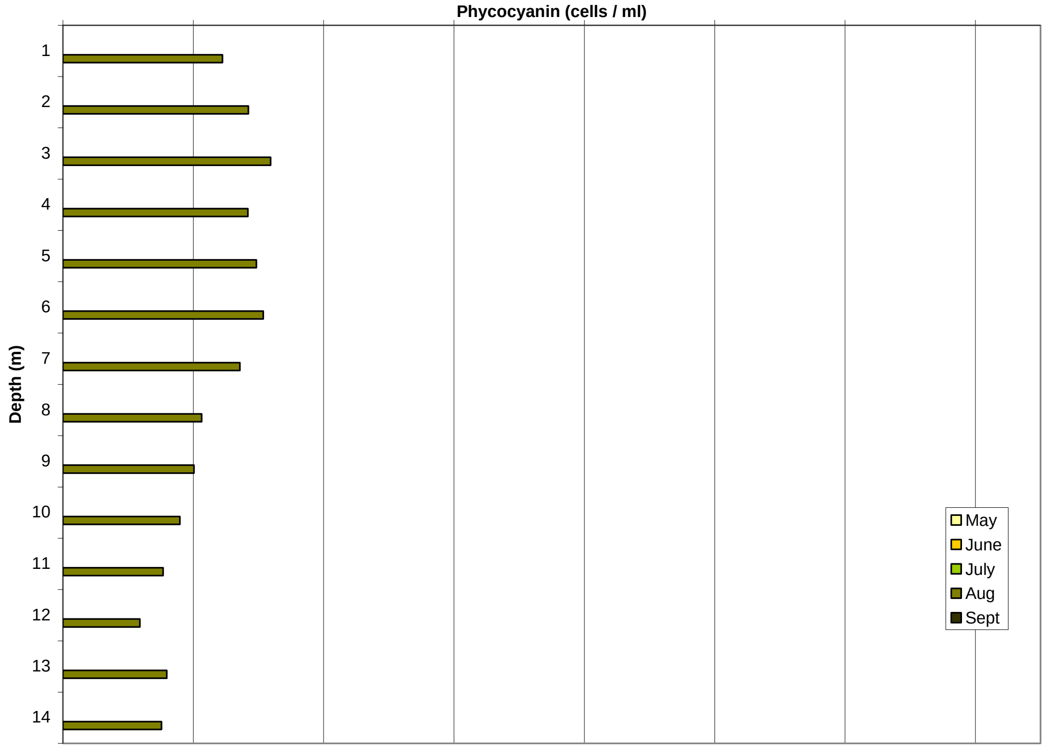


Figure 10.9. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured during August by depth at Melvern Lake Site 3 during 2006.

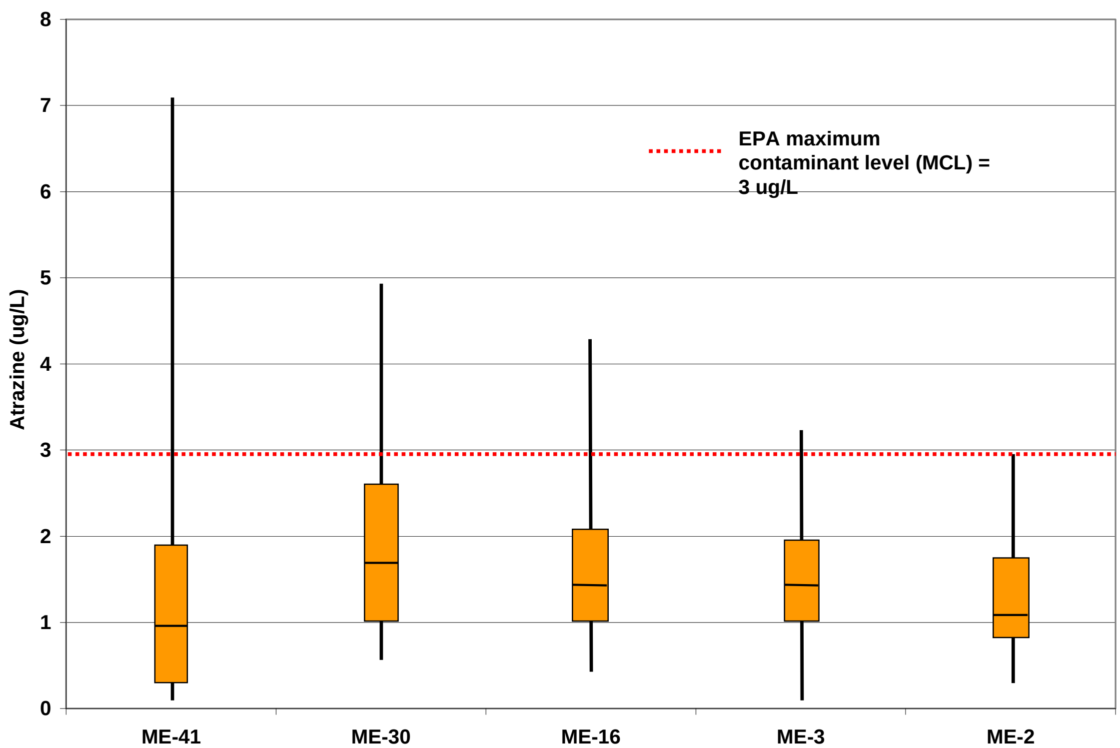


Figure 10.10. Box plots of atrazine concentration by site from 1996 through 2004 at Melvern Lake.

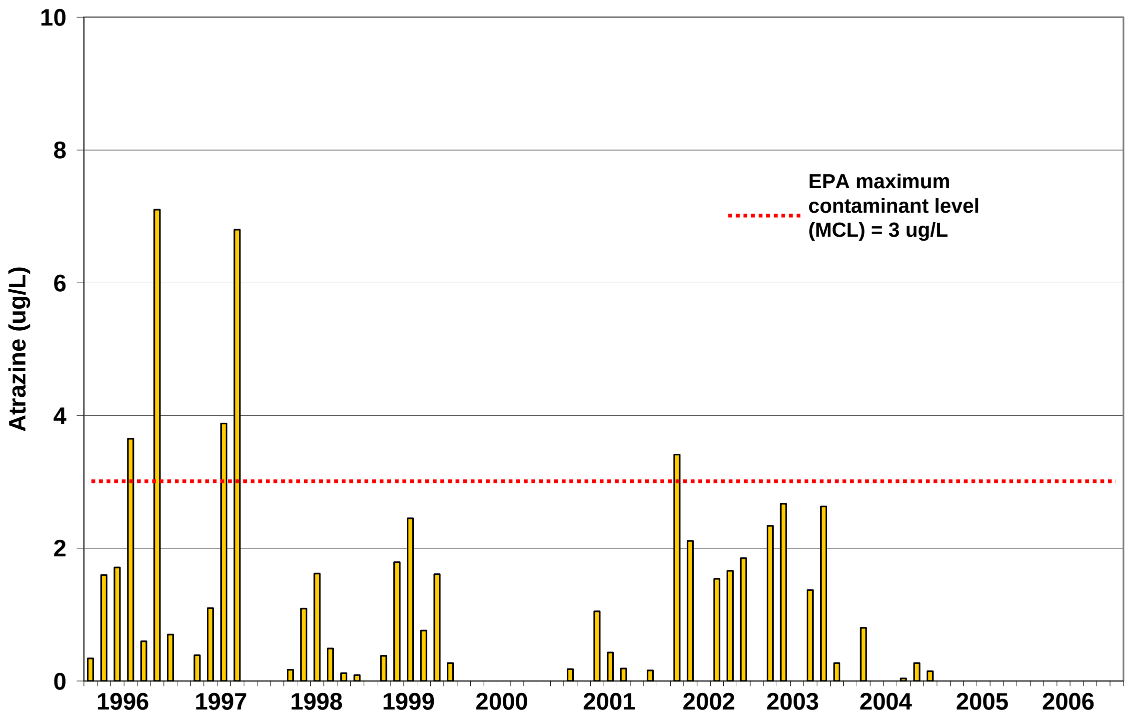
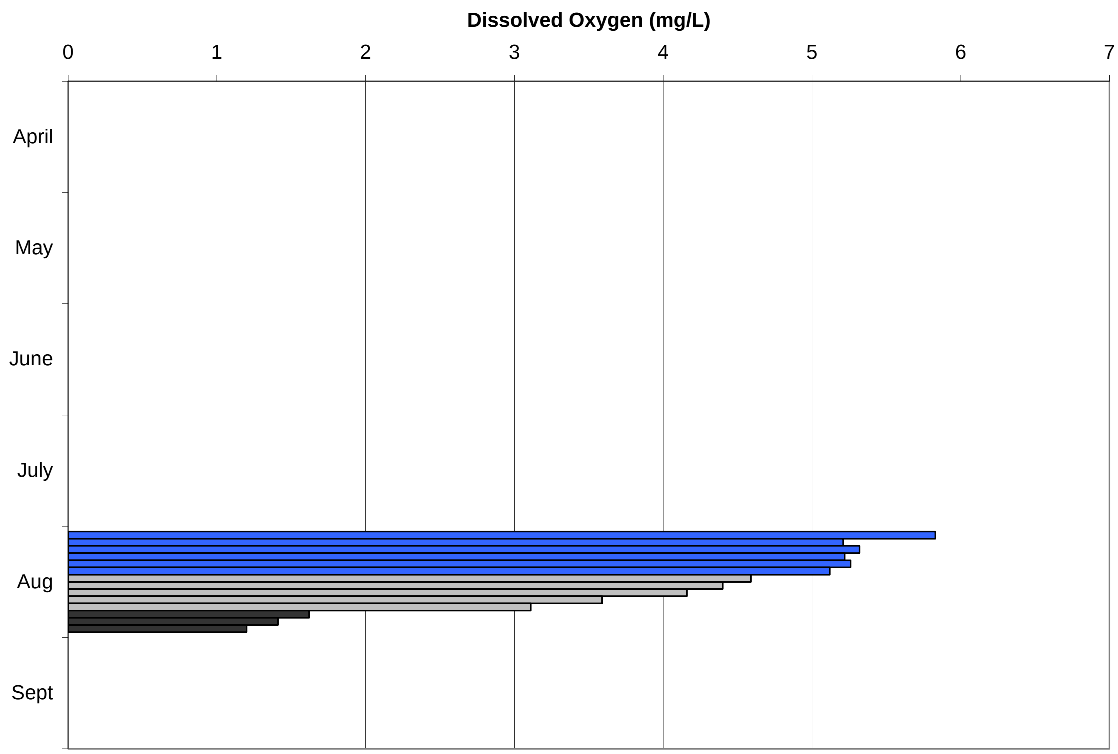


Figure 10.11. Atrazine concentrations by date for samples collected between 1996 and 2004 at Site 41 (Marais des Cygnes River inflow) in the Melvern Lake watershed.



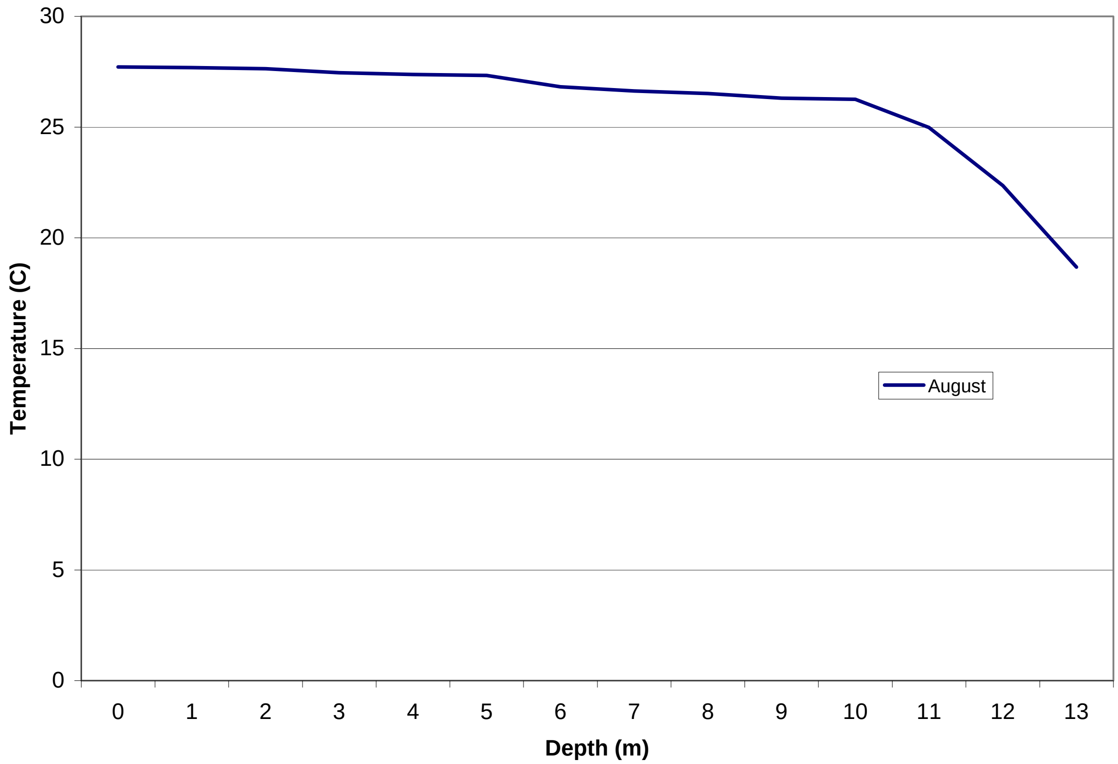


Figure 10.12. Dissolved oxygen concentration (mg/L) histogram and temperature (C plot recorded on 25 August 2006 from Site 3 at Melvern Lake.

11 Milford Lake

11.1 General Background

Milford Lake was impounded and reached conservation pool in 1967. The main threats to Milford Lake's water quality are sedimentation, nutrients, and bacterial contamination. The lake is list on the state's 2004 303(d) list for eutrophication (high) and DO (low). The KDHE is currently developing a TMDL to address the eutrophication listing. Wetland restoration has occurred in the upper reaches of the lake and on the Republican River through the efforts Kansas Wildlife and Parks, KAWS, and Corps Section 1135 program. Additional information on these efforts can be located at http://www.nwk.usace.army.mil/projects/milford/introduction.htm.

11.1.1 Location

Milford Lake is located approximately 6.4 km (4 miles) northwest of Junction City, Kansas. The dam is located at river km 13.3 (river mile 8.3) on the Republican River. Milford Lake is the largest lake in Kansas, based on surface acreage (15,709 acres) and 163 shoreline miles. The watershed includes portions of Clay, Dickinson, and Riley counties, as well as the upper Republican River system. Historic water quality sample sites at Milford Lake include 3 lake, 1 outflow, and 1 inflow (Figure 11.1).

11.1.2 Authorized Purposes: Flood control, water supply, water quality, navigation, recreation, and fish and wildlife conservation.

11.1.3 State Use Designations: Primary contact recreation, expected aquatic life support, drinking water, food procurement, and industrial water supply.

11.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,176.2	752.9	33,000	
Multipurpose	1,144.4	372.3	16,000	163
Total		112.1		

Total watershed area: 24,880 sq miles (15,923,200 A)

Watershed ratio: 482.5 FC / 995.2 MP

Average Annual Inflow: 777,708 acre-feet
Average Annual outflow: 000 acre-feet
Average flushing rate: 0.59 years
Sediment inflow (measured): 47,935 acre-feet (1967 – 1994)
Water management Plan: Approved December 1984; minor revisions January 1995
Historic stage hydrograph: 1996 – 2006 (Figure 11.2)

Figure 11.1. Milford Lake area map with sample site locations and sample numbers.

11.2 2006 Activities

Milford Lake was categorized as an ‘intensive’ lake during 2006, thus lake and inflow / outflow sites were all sampled (see Figure 11.1). Samples were collected from April through September during 2006. An initial meeting of the Milford Lake Watershed Restoration and Protection Strategy (WRAPS) was held in August, 2006. Milford Lake staff (OF-MI) providing field assistance with the WQP during 2006 included Brent Logan and Ken Wenger. R.J. Harms, Operations Manager, provided technical insight and background knowledge on Milford Lake.

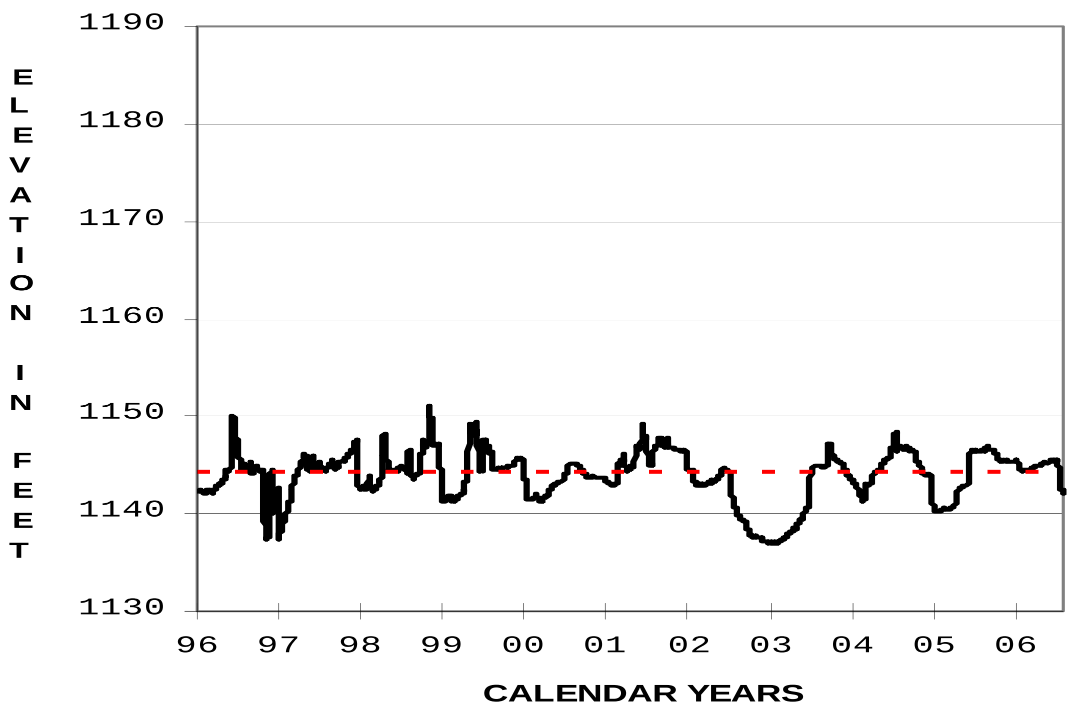


Figure 11.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 1144.4 msl).

11.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from1996 through 2005. Samples were collected at inflow, lake, and outflow sites from April through September, 2006.

11.3.1 Inflow

Milford Lake inflow samples were collected from Sites 24 on the Republican River near Clay Center during 2006. Historically, nutrient concentrations (nitrogen and phosphorus) and contaminants are most variable at this site due to influences of runoff events within the watershed. Please see comments for lake sites below on specific parameters.

11.3.2 Lake

Milford Lake is classified as eutrophic based on total nitrogen (TN) and total phosphorus (TP) median concentrations and chlorophyll *a* values. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Median TN concentrations range from 0.93 – 1.56 mg/L (Figure 11.3), which is above EPA's proposed ecoregional nutrient criteria value of 0.44 mg/L TN. The median TN concentrations, comprising data collected between 1996 and 2006, are the third highest within the district -- only Tuttle Creek and Kanopolis have higher median concentrations. Monthly and annual variability in TN, evident at all sites, is depicted in Figure 11.4 from surface samples collected at Site 5 (upper).

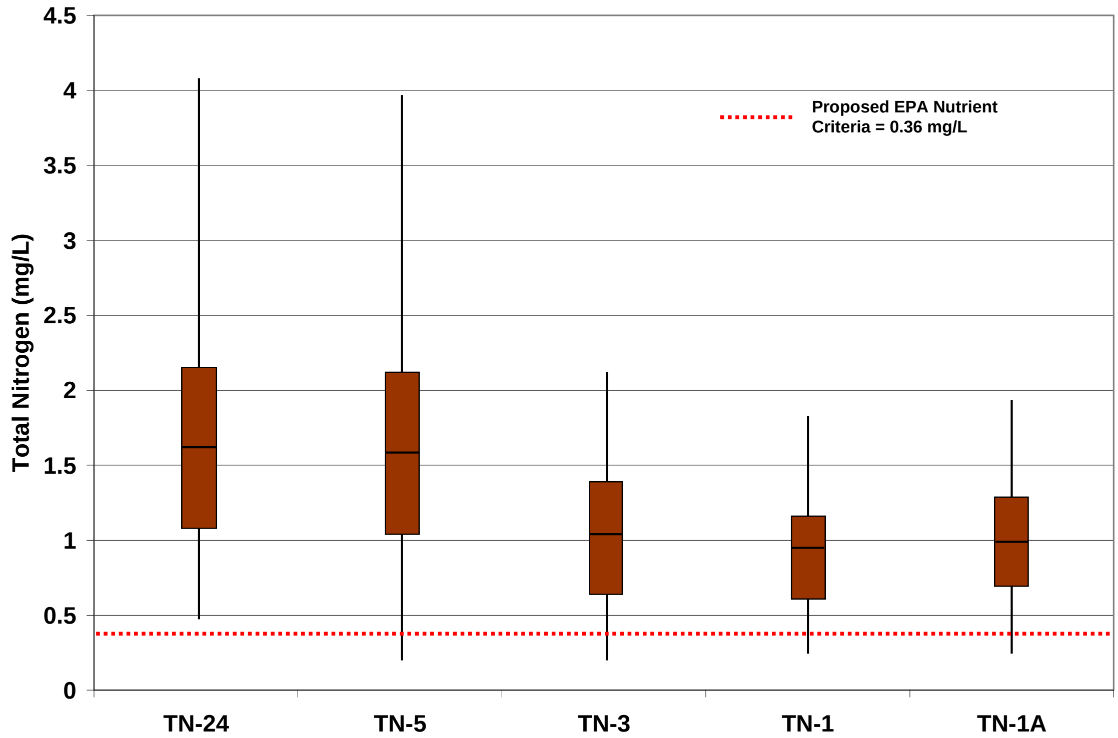


Figure 11.3. Box plots of surface water sample total nitrogen concentrations measured at lake sites from 1996 through 2006 at Milford Lake.

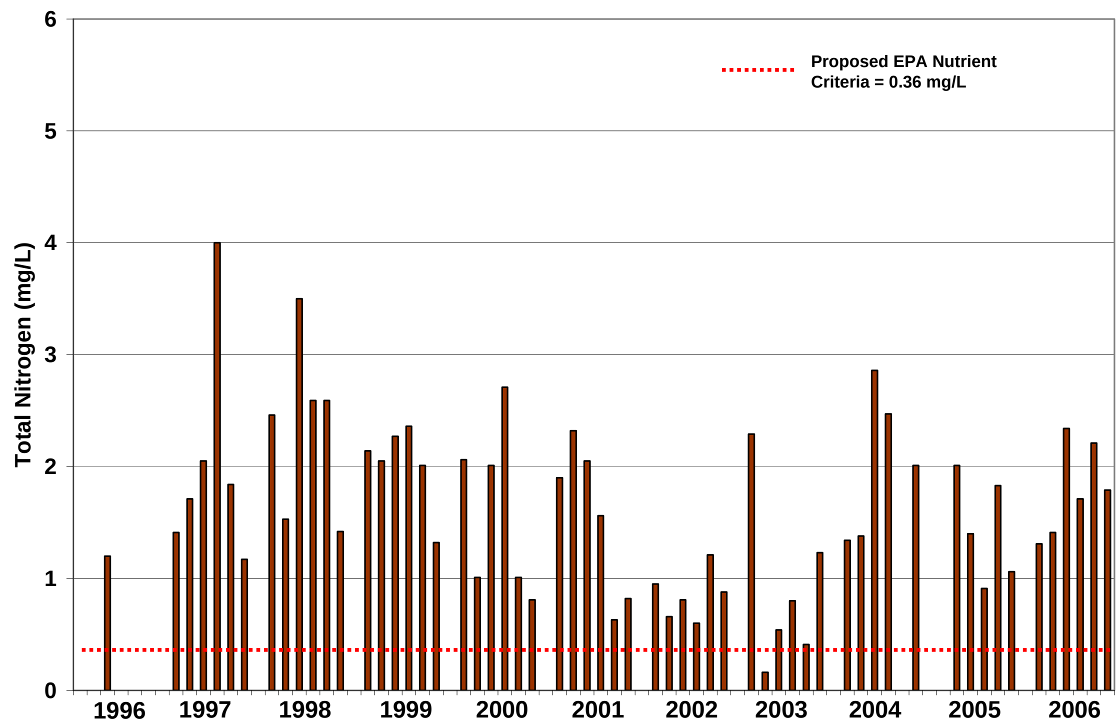


Figure 11.4. Total nitrogen concentrations by surface water sample date collected at Site 5 in Milford Lake from 1996 through 2006.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median TP concentrations range from 0.16 – 0.29 mg/L (Figure 11.5), which is above EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L TP. These median concentrations are also among the highest for district lakes. Longitudinal differences in TP concentration exist between the inflow (Site 24) and upper lake (Site 5) sites in comparison to the mid-lake (Site 3) and lower-lake tower sites (Site 1).

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites, as is depicted by the range of values at Site 1 (Figure 11.6). Median TN:TP ratios at all three lake sites are < 12, indicating the lake is at risk for cyanobacteria blooms (Figure 11.7).

Monthly variability in mean chlorophyll *a* was detected at all three lakes sites (Figure 11.8). Mean summer chlorophyll *a* concentrations from the three lake sites ranged from 25 – 118 ug/L during 2006, with highest values measured from Site 5.

Secchi depth (water clarity) was measured monthly at all three lake sites. Water clarity was significantly lower at Site 5 than Site 1 (Figure 11.9), with very limited clarity at Site 5 (mean = 0.06m) but moderately clear at Site 1 (mean = 1.0; Site 3 exhibited relatively clear water (mean = 0.72m). Secchi depth measurements during May indicated extremely clear water conditions, with a measurement of 3.54 m at Site 1.

The median atrazine concentrations from surface water samples collected from 1996 - 2006 (1.1 – 1.5 ug/L) were all below EPA's drinking water maximum contaminant level of 3 ug/L (Figure 11.10). These concentrations are some of the higher within the district. However, individual samples measured during that time period are significant enough to greatly exceed the MCL – even a sample collected from Site 24 during June 2006 (4.9 ug/L). It is also important to note that drought conditions may have some impact on concentrations measured this year. Figure 11.11 depicts individual sample concentrations measured by date at Site 24 (Republican River inflow site).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 11.12 depicts vertical distribution of phycocyanins measured at Site 1 (Tower) from May through September. Elevated concentrations were prevalent throughout the entire water column during June, declined during July and August, and increased again in September. The highest concentrations within the district were measured at Milford Lake on 22 August as an extremely large bluegreen algal bloom was prevalent and persisted for about 5 days. These concentrations were 45 – 62X background concentrations. Samples were delivered to USGS – Lawrence for analyses. Their preliminary results for specific concentrations of cyanotoxins were as follows: Anatoxin-a (significant), Microcystin RR (significant), Microcystin LR (significant), Microcystin YR (significant), and Microcystin LW (trace).

Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at inflow (Site 24 = 8521 ug/L), upper lake (Site 5; 7271ug/L), midlake (Site 3; 394 ug/L), and outflow (Site 1A = 717 ug/L). Total iron concentrations from bottom samples in the

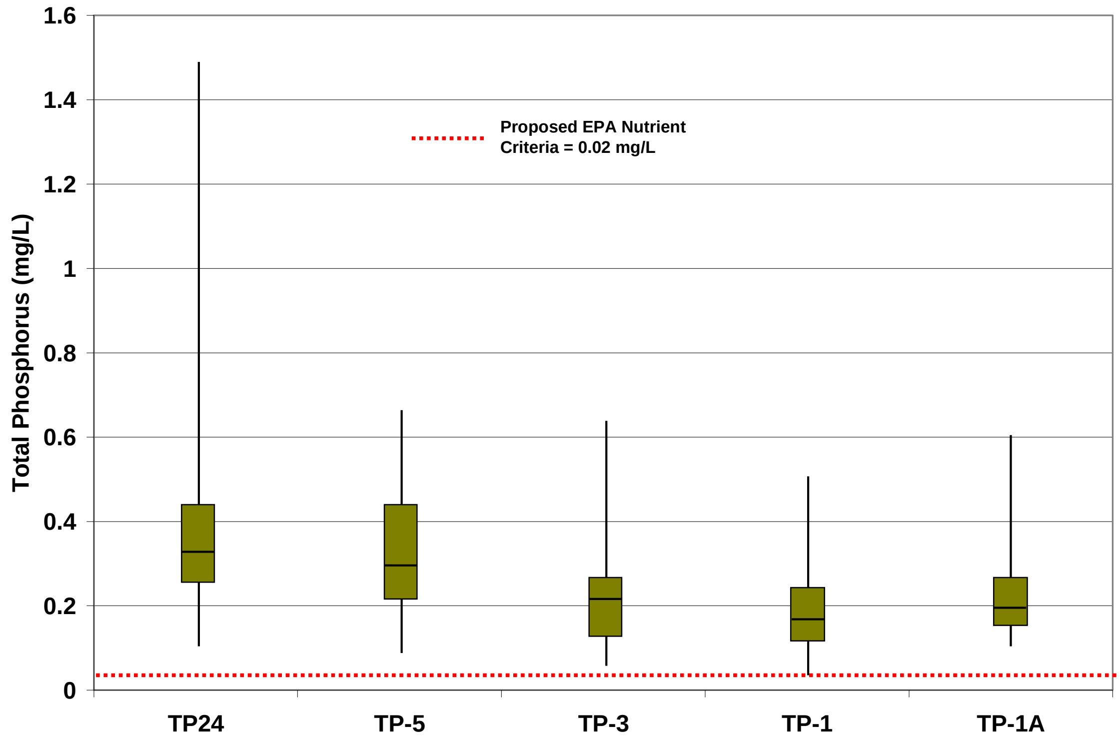


Figure 11.5. Box plots of surface water sample total phosphorus concentrations measured at lake sites from 1996 through 2006 at Milford Lake.

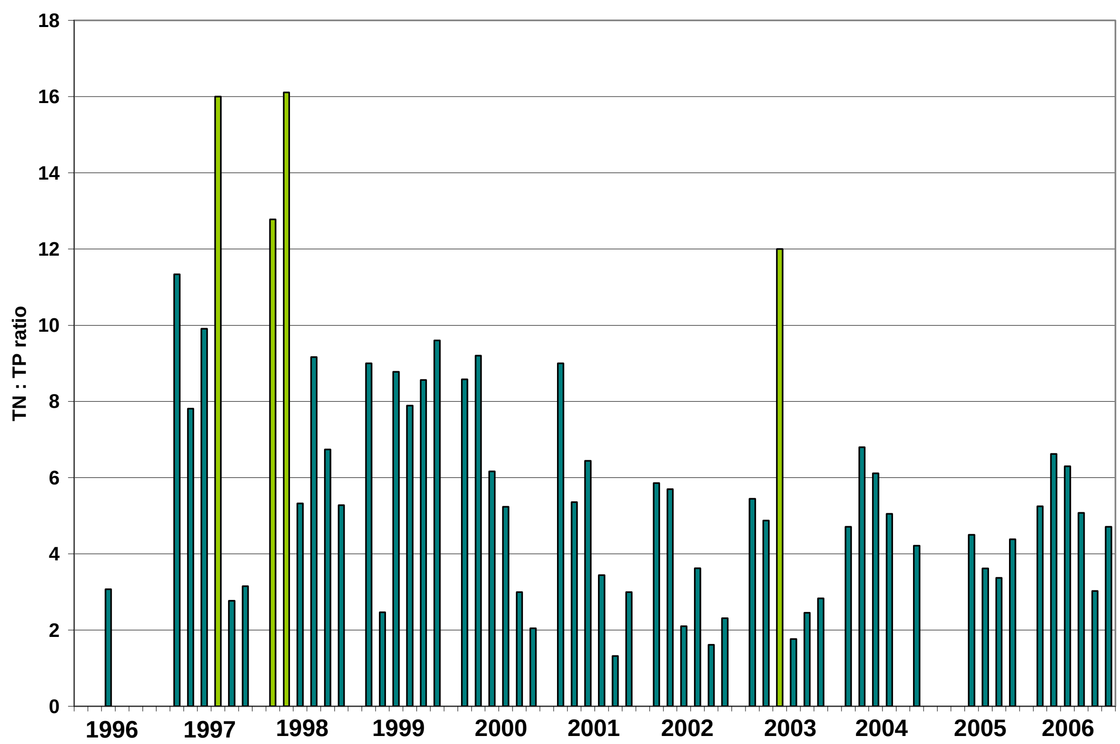


Figure 11.6. Total nitrogen : total phosphorus ratio variability by sample date and year from Site 1 in Milford Lake from 1996 through 2006.

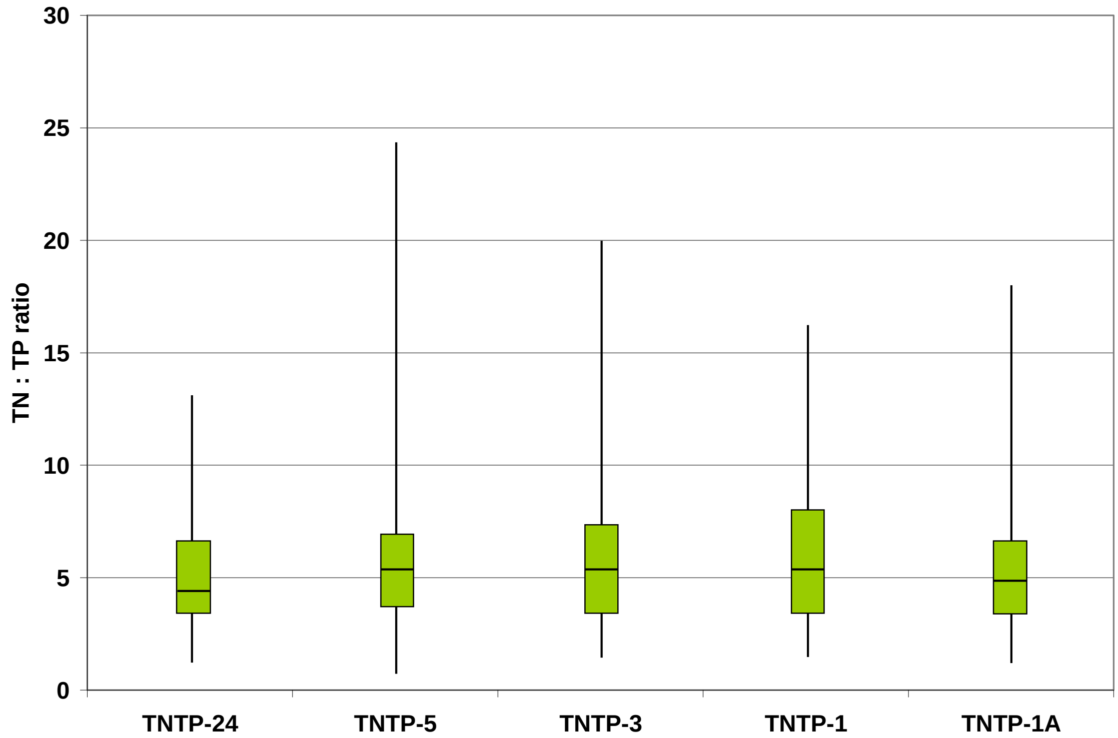


Figure 11.7. Box plots of total nitrogen : total phosphorus (TN : TP) ratio by site from 1996 through 2006 at Milford Lake.

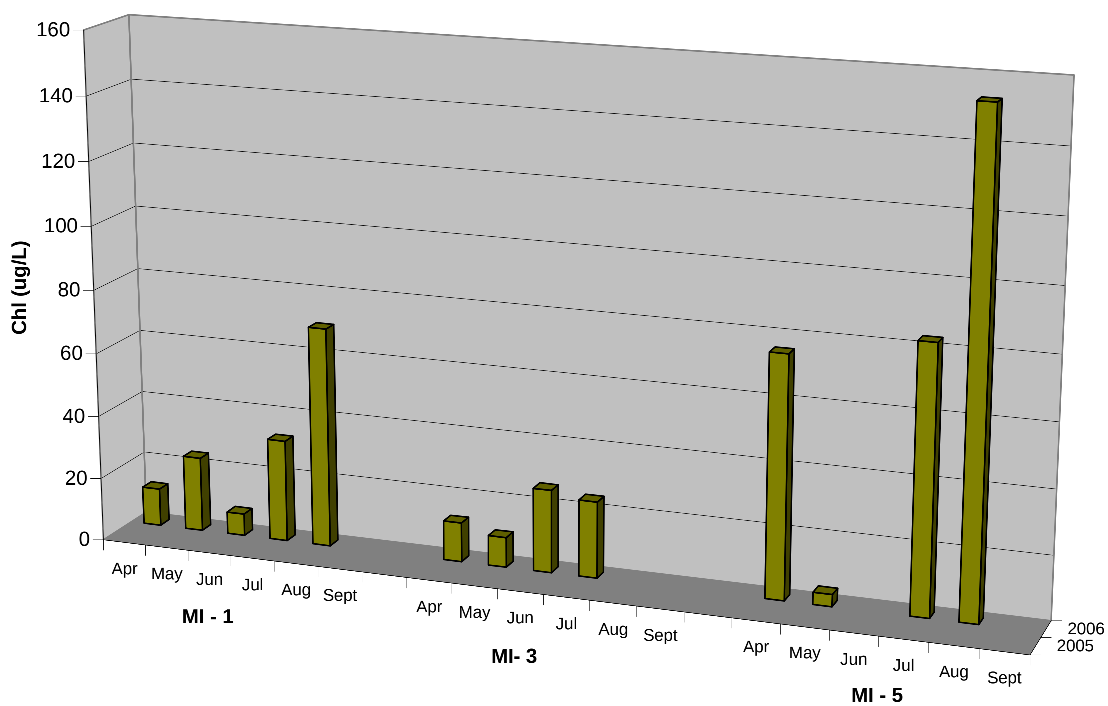


Figure 11.8. Comparison of mean chlorophyll a concentrations (ug/L) by date and site (1 = Tower; 3 = Mid; 5 = Upper) at Milford Lake during 2006.

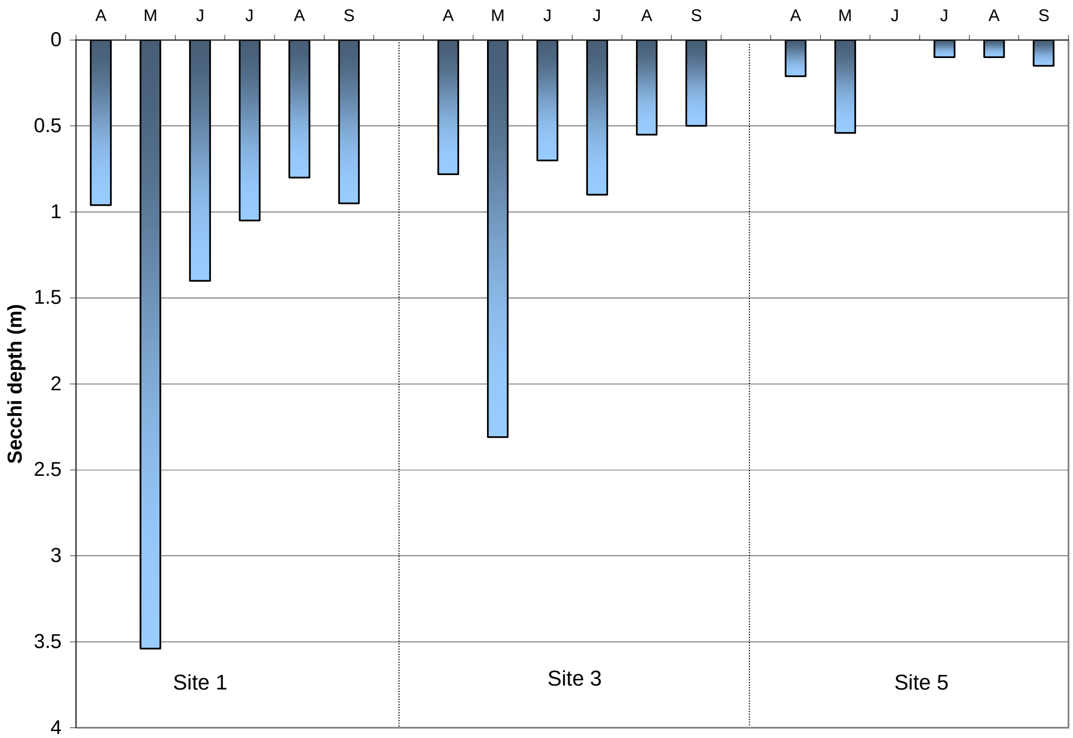


Figure 11.9. Plot of secchi depth (water clarity) measured by date and site during 2006 at Milford Lake.

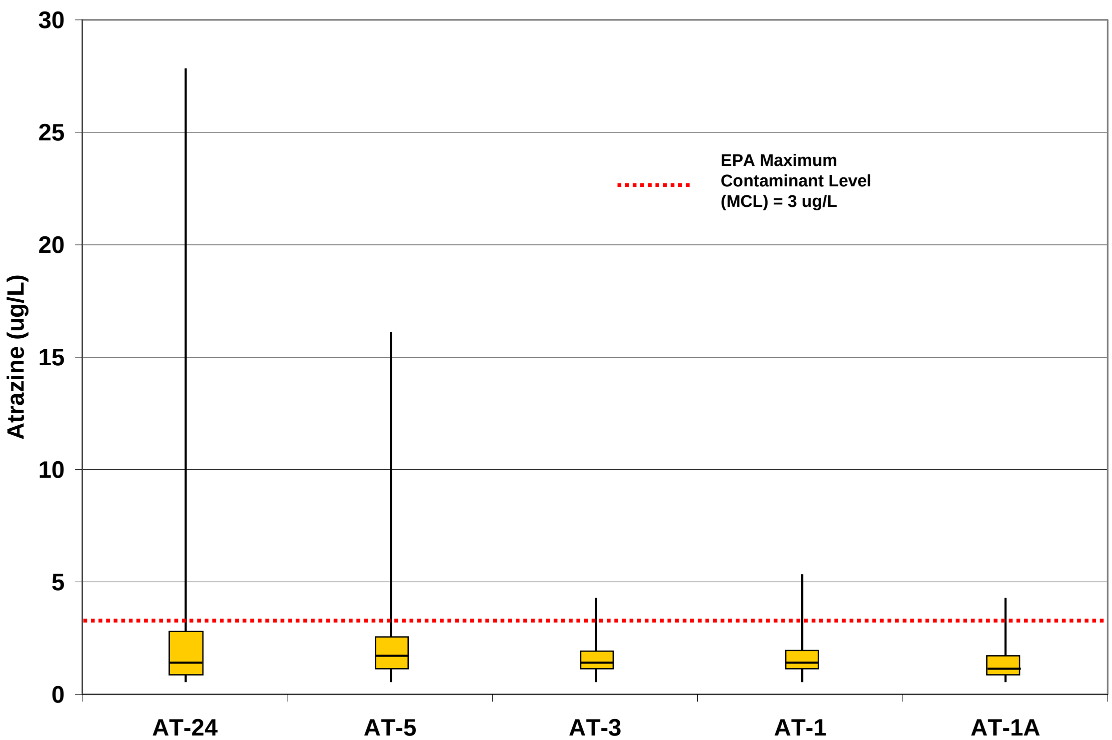


Figure 11.10. Box plots of surface water sample atrazine concentrations measured at lake sites, inflow (Site 24), and outflow (Site 1A) from 1996 through 2006 at Milford Lake.

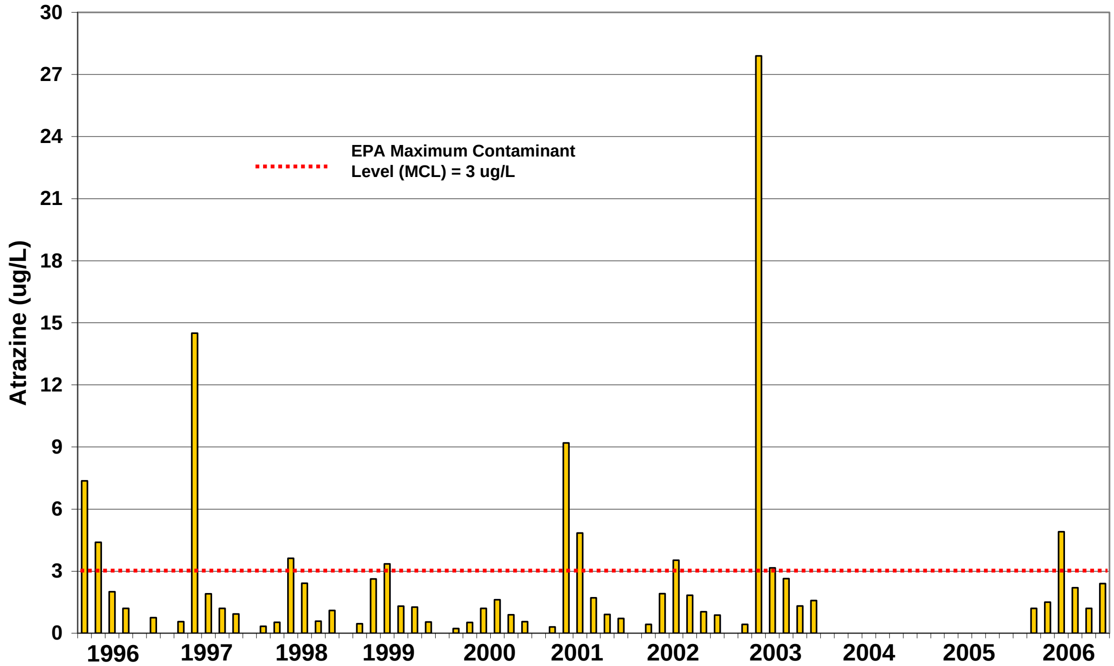


Figure 11.11. Atrazine concentrations by sample date from surface water samples collected at Site 24 (Republican River inflow) in Milford Lake from 1996 through 2006.

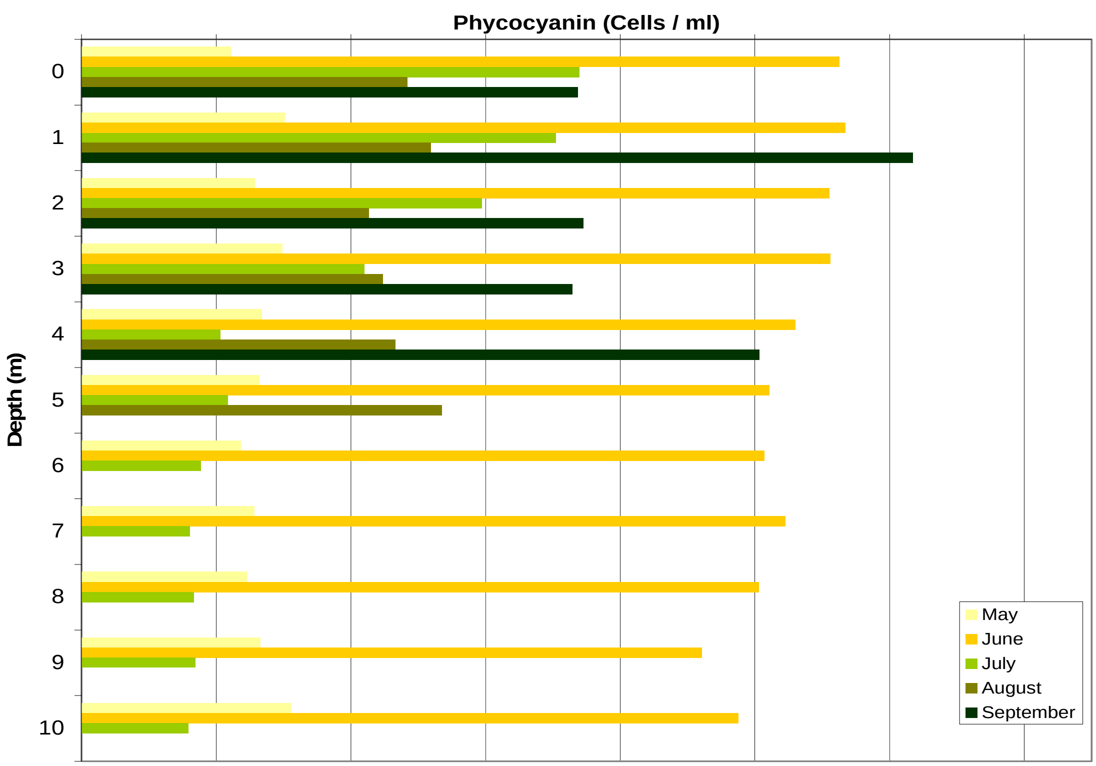


Figure 11.12. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Milford Lake Site 1 (Tower) during 2006.

lake ranged from 194 – 16286 ug/L, which reflects anoxic conditions throughout the lake. Elevated levels are directed at drinking water facilities related to taste and staining issues. In addition, surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L) at both the inflow site (Site 24 = 223 ug/L), upper lake (Site 5; 208 ug/L), mid lake (Site 3; 79), and outflow (Site 1A = 143 ug/L). The SMCL for total manganese was exceeded in bottom samples from midlake and upper lake sites (range = 109 – 371 ug/L). Implications are directed at drinking water facilities due to taste and stain issues.

Vertical profiles were recorded monthly from April through September. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. The lake was stratified chemically from June through August, with stratification beginning around 9 m in depth (Figure 11.13). The lake was weakly stratified thermally, which is typical of large windswept Kansas lakes.

Fecal bacteria (*E. coli*) samples were collected from all three beaches prior to major recreational season holidays during 2006. None of the mean samples exceeded the state standard for single sample whole-body contact (732 colonies / 100 ml)(Figure 11.14).

11.3.3 Outflow

Outflow samples were collected from Milford Lake during 2006. Summarized data on Site 1A is included in discussions of lake sites listed above.

11.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to 'ambient' monitoring from May through September, as well as conducting a monthly vertical profile at each of the three lake sites during July or August. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Future Republican river WRAPS meetings will be attended, and data will be shared for modeling efforts and discussions.

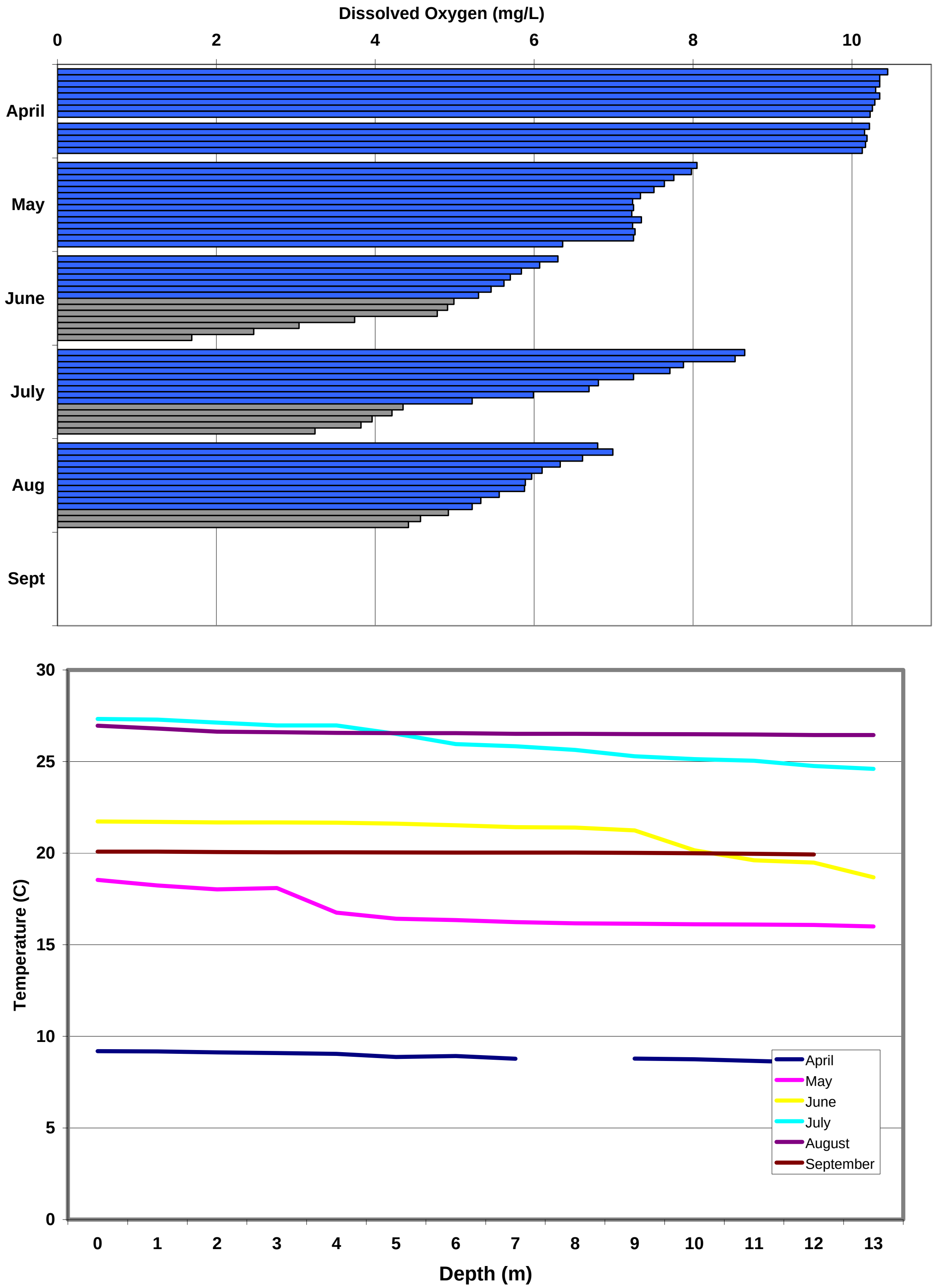


Figure 11.13. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from a vertical profile recorded at Site 1 on 8 August 2006 at Milford Lake.

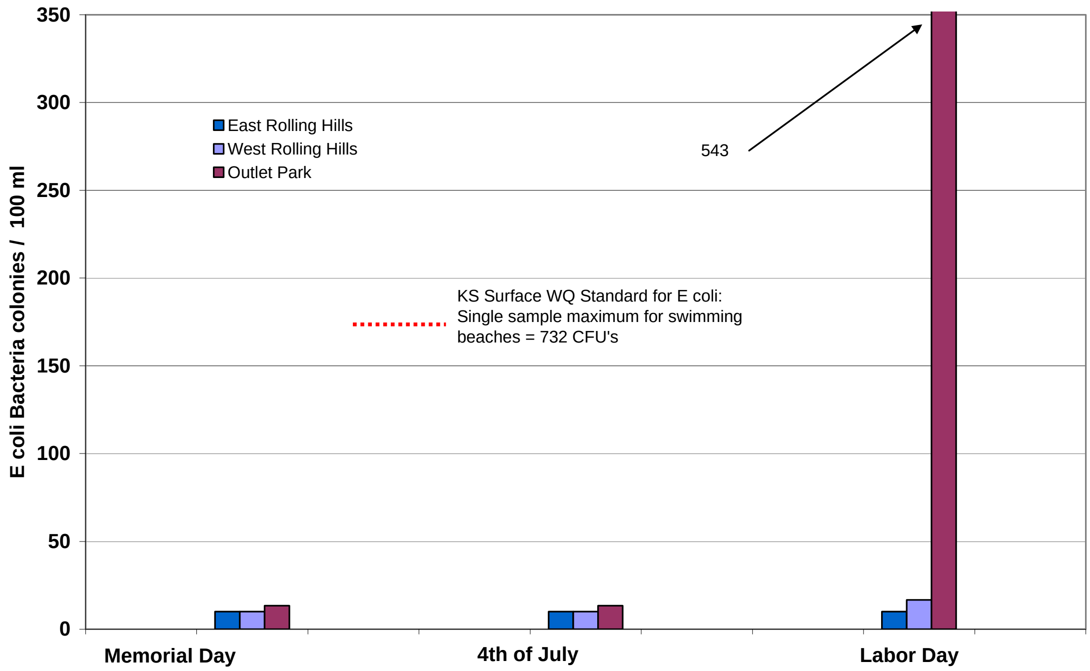


Figure 11.14. Mean fecal bacteria (E. coli) (colonies per 100 ml) results from samples at three swimming beaches collected from April through September during 2006 at Milford Lake.

12 Perry Lake

12.1 General Background

Perry Lake was impounded in 1969 and reached full pool in 1970. The main water quality threats to Perry Lake are sedimentation, nutrients and bacterial contamination. The lake is listed on the state's 2004 303(d) list for water quality impairment due to eutrophication and fecal bacteria (inflows). The Delaware River Watershed Restoration and Protection Strategy (WRAPS), under the direction of Marlene Bosworth, held numerous meetings throughout the past year and is in the process of developing a draft watershed management plan. The purpose of WRAPS is to develop goals and strategies to improve water quality within the watershed over a 10-year period.

12.1.1 Location

Perry Lake, the fourth largest lake in Kansas, is located approximately 20 km (12 miles) northwest of Lawrence, Kansas. The dam is located at river km 8.5 (river mile 5.3) on the Delaware River. The watershed includes portions of Brown, Jefferson, Atchison, Jackson and Nemaha counties. Historic water quality sample sites at Perry Lake include 3

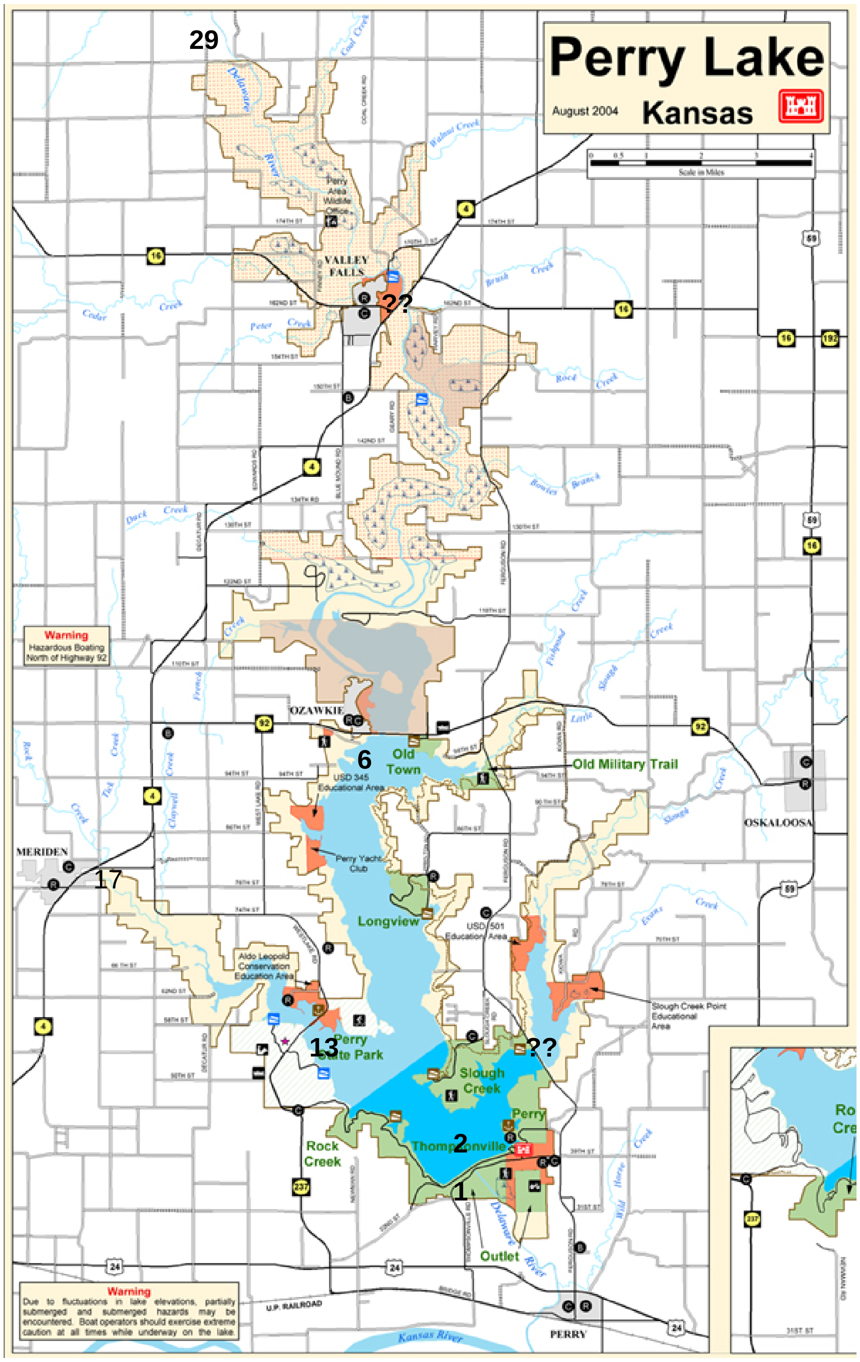


Figure 12.1. Perry Lake area map with sample site locations and site numbers.

lake, 1 outflow, and 2 inflow (Figure 12.1).

12.1.2 Authorized Purposes: Flood control, water storage, fish and wildlife habitat, navigation support, and recreation.

12.1.3 State Use Designations: Primary contact recreation, special aquatic life support, drinking water, food procurement, industrial water supply.

12.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	920.6	509.3	25,347	
Multipurpose	891.5	206.7	11,146	160
Total		716.0		

Total watershed area: 1,117 sq miles (714,880 A)
Watershed ratio: 28.2 FC / 64.14 MP
Average Annual Inflow: 585,391 acre-feet
Average Annual outflow: 000 acre-feet
Average flushing rate: 0.38 years
Sediment inflow (measured): 49,057 acre-feet (1962 – 2000)
Water management Plan: Approved July 1973; minor revisions approved January 1995
Historic stage hydrograph: 1996 – 2006 (Figure 12.2)

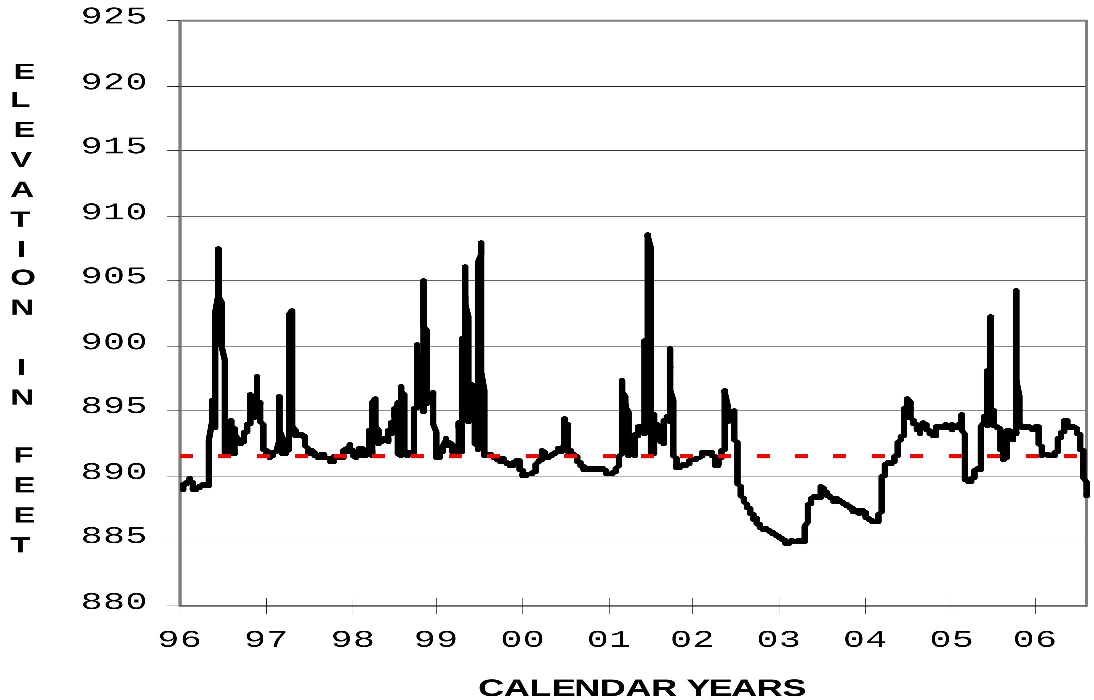


Figure 12.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 891.5 msl).

12.2 2006 Activities

Perry Lake was categorized as an ‘ambient’ lake during 2006, thus only surface samples were collected at three lake sites. Sample collections occurred from May through September 2006, while vertical profiles were recorded at the three lake sites during May and August. Perry Lake staff (OF-PE) providing field assistance with the WQP during 2006 included Bunnie Watkins. Additional assistance was provided by the Jefferson County Sheriffs Department.

12.3 2006 Data

Comparative historic water quality data consists of monthly (April – September) data collected from 1996 through 2005. Samples were collected from May though September during 2006.

12.3.1 Inflow

No inflow samples were collected from the Perry Lake watershed during 2006. Historically, nutrient concentrations (nitrogen and phosphorus) are most variable at these sites due to influences of runoff events within the watershed.

12.3.2 Lake

Based on total nitrogen (TN), total phosphorus (TP), and chlorophyll *a*, Perry Lake is classified as eutrophic. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen concentrations from surface samples are relatively consistent between lake sites ranging from 0.78 – 0.99 mg/L (Figure 12.3). Annual and monthly variability in TN concentrations are evident from both inflow (Site 29) and main lake sample (Site 2) sites (Figures 12.4 and 12.5, respectively). With few exceptions, all samples from the Perry Lake watershed exceed EPA’s proposed ecoregional nutrient criteria value of 0.36 mg/L TN.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median total phosphorus concentrations from lake sites (0.07 – 0.14 mg/L) were typical of other district lakes (Figure 12.6). Similar to TN, greater concentrations and wider monthly and annual variability in TP concentrations were detected at Site 29 (Delaware River). One aspect of the WRAPS is to determine where to focus efforts, so naturally it is important to determine if differences in TP could be differentiated from subwatersheds. According to the data, the mean TP concentration from the Rock Creek inflow was 0.18 mg/L and 0.35 mg/L from the Delaware River. This would indicate that BMP’s targeting TP should be focused along the main tributary of Perry Lake. All median TP concentrations exceed EPA’s proposed ecoregional nutrient criteria value of 0.02 mg/L TP. The TP concentrations are typical of other district lakes.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). Median TN:TP ratios at all three lake sites are < 12, indicating the lake is at risk for cyanobacteria blooms (Figure 12.7). As would be expected, there is high

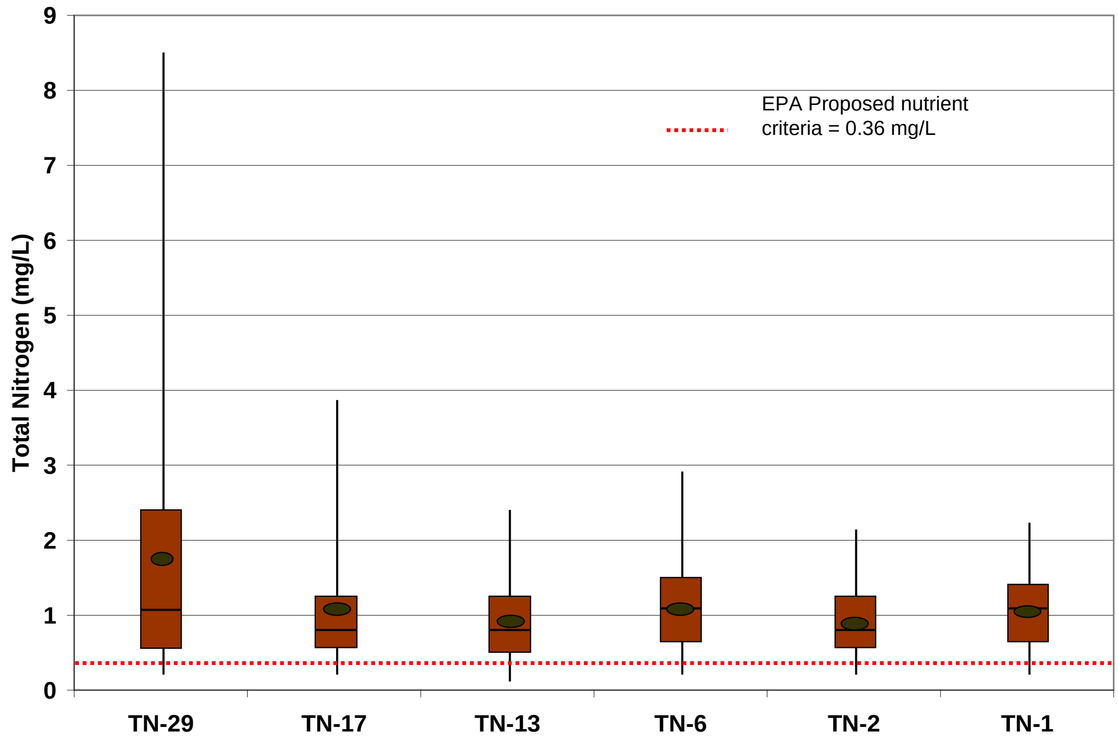


Figure 12.3 Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Perry Lake.

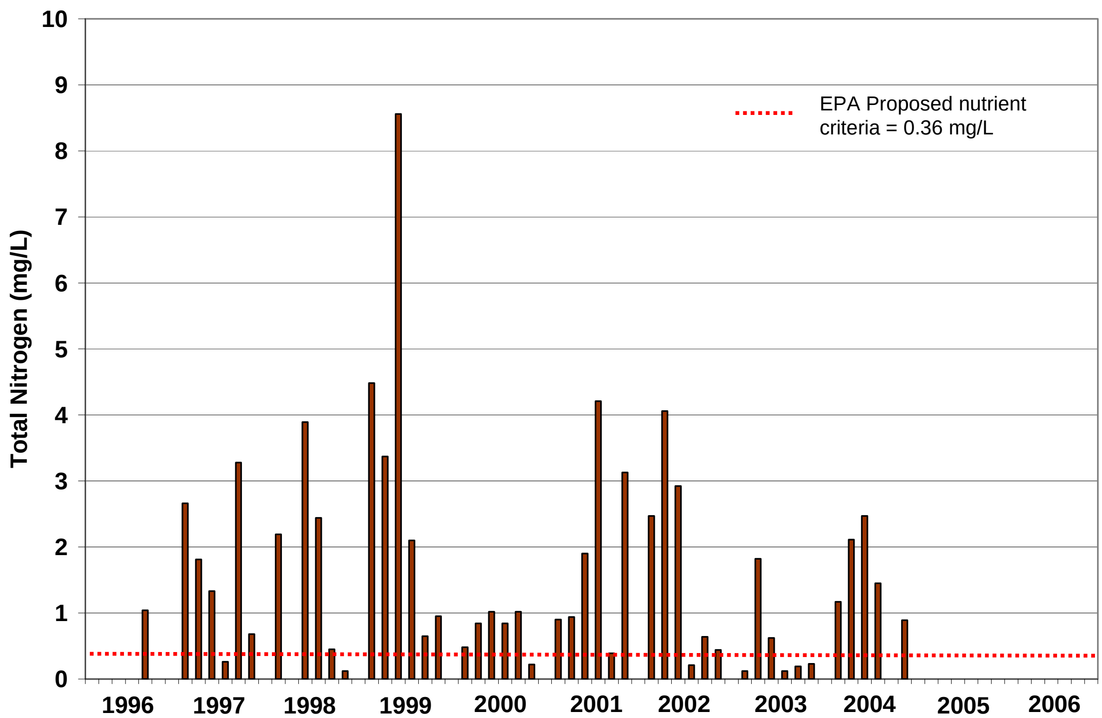


Figure 12.4. Total nitrogen by sample date from surface water samples collected at Site 29 (Delaware River) inflow to Perry Lake from 1996 through 2006.

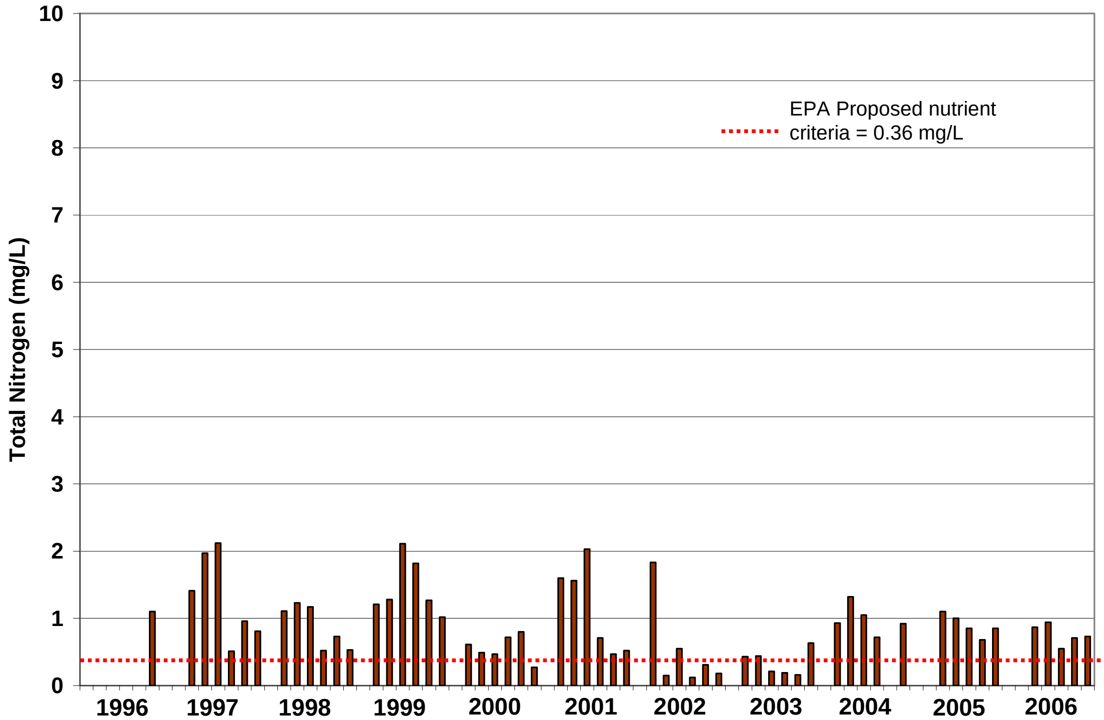


Figure 12.5. Total nitrogen by sample date from surface water samples collected at Site 2 (Tower) in Perry Lake from 1996 through 2006.

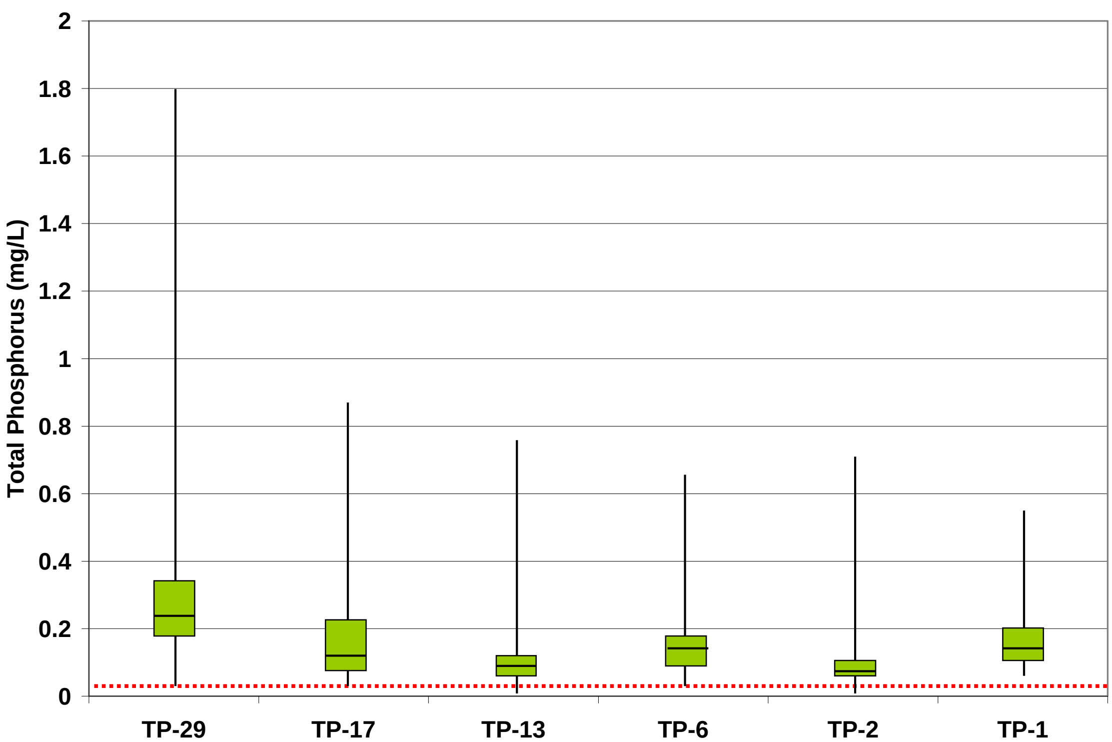


Figure 12.6. Box plots of surface water total phosphorus concentrations measured by site from 1996 through 2006 at Perry Lake.

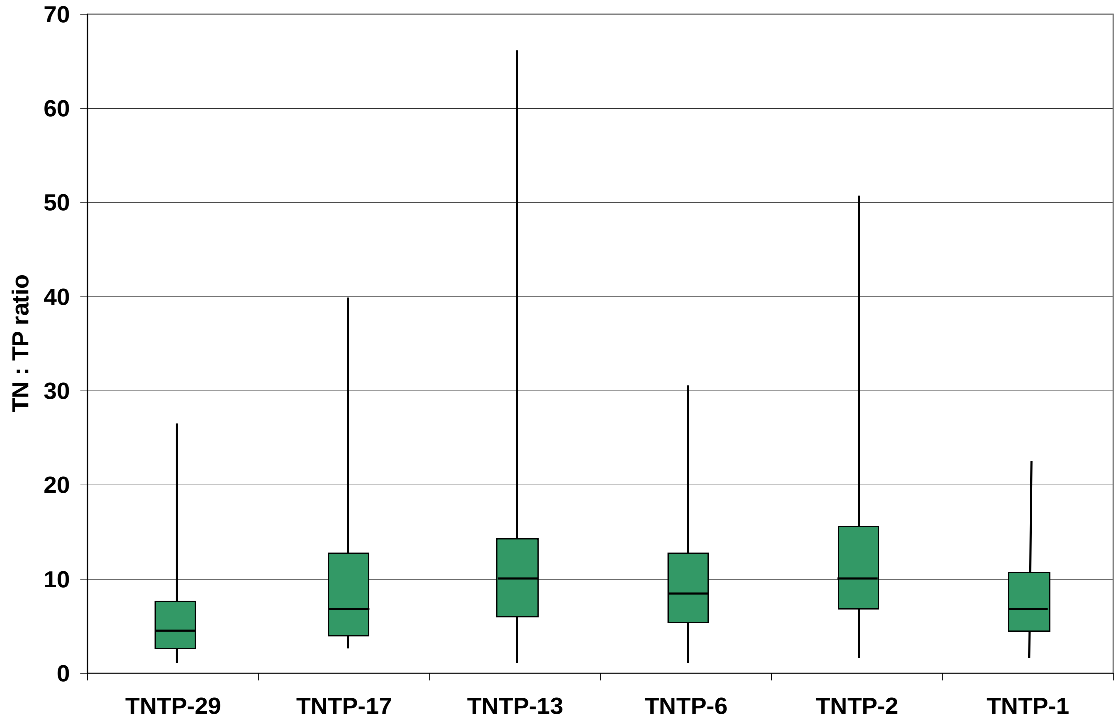


Figure 12.7. Box plots of total nitrogen : total phosphorus ratio (TN : TP) by site from surface water samples collected between 1996 and 2006 at Perry Lake.

monthly and annual variability in the TN:TP ratio at all sites; see Figure 12.8 as an example at Site 13 (Rock Creek arm).

Mean chlorophyll a concentrations ranged from 26 – 28 ug/L for the three lake sites during 2006. Concentrations were consistently more than 2x higher at Site 6 versus the other two lake sites. This data corroborates TP data collected at lake sites.

Secchi depth (water clarity) was measured at all lake sites during May, July, August, and September 2006 (Figure 12.9). Water clarity was relatively clear at Site 2 (1.32 m), slightly clearer at Site 13 (0.68 m), and very limited in the Delaware River arm (Site 6; 0.36 m).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during May and August 2006. Such profiles provided information on monthly as well as within lake distribution changes. Figure 12.10 depicts vertical distribution of phycocyanins measured at Site 2 (Tower). Concentrations were highest in August, and the distribution was relatively consistent throughout the water column during 17 August. A bluegreen algal bloom was observed by lake staff and a sample was collected for algal toxins on 5 September by USGS - Lawrence. Results indicated a concentration of total microtoxins of 3.96 ppb (Total) and 2.22 ppb (Dissolved). World Health Organization protective limits are 1 ug/L for drinking water (dissolved), while recreational protection (total microtoxins) is – low risk range of 1 – 10 ug/L (Chorus and Bartram, 1999).

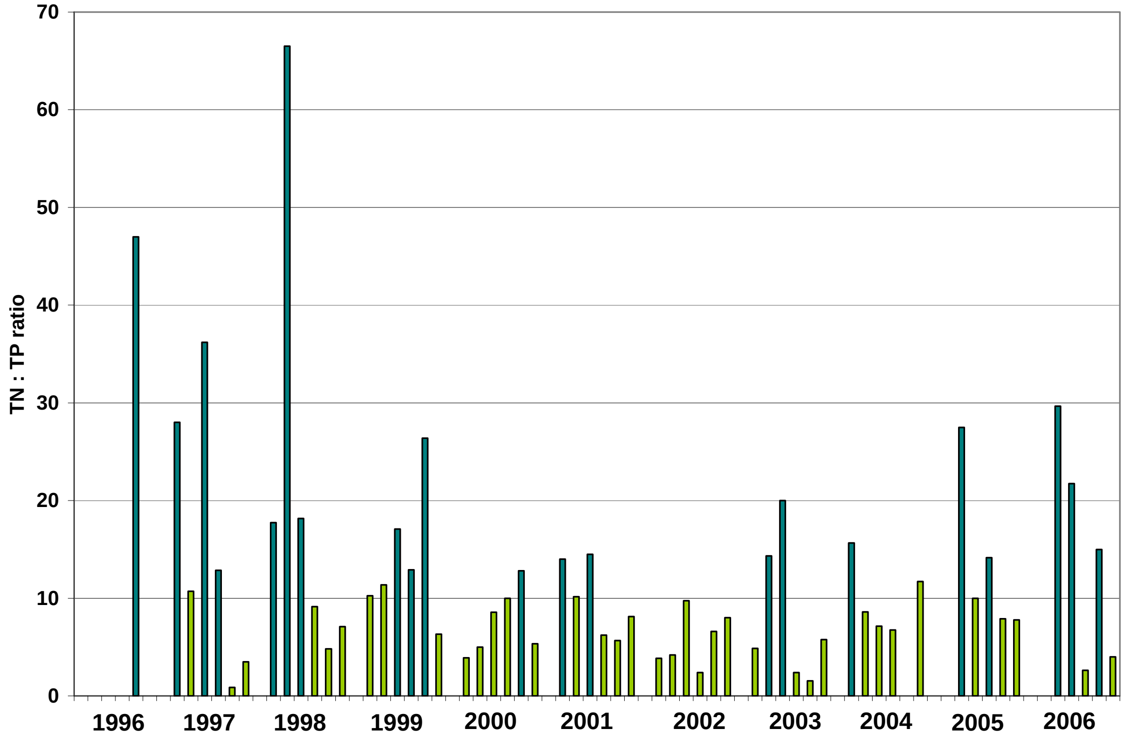


Figure 12.8. Graph of total nitrogen : total phosphorus ratio (TN : TP) by sample date from surface water samples colleted at Site 13 in Perry Lake between 1996 and 2006.

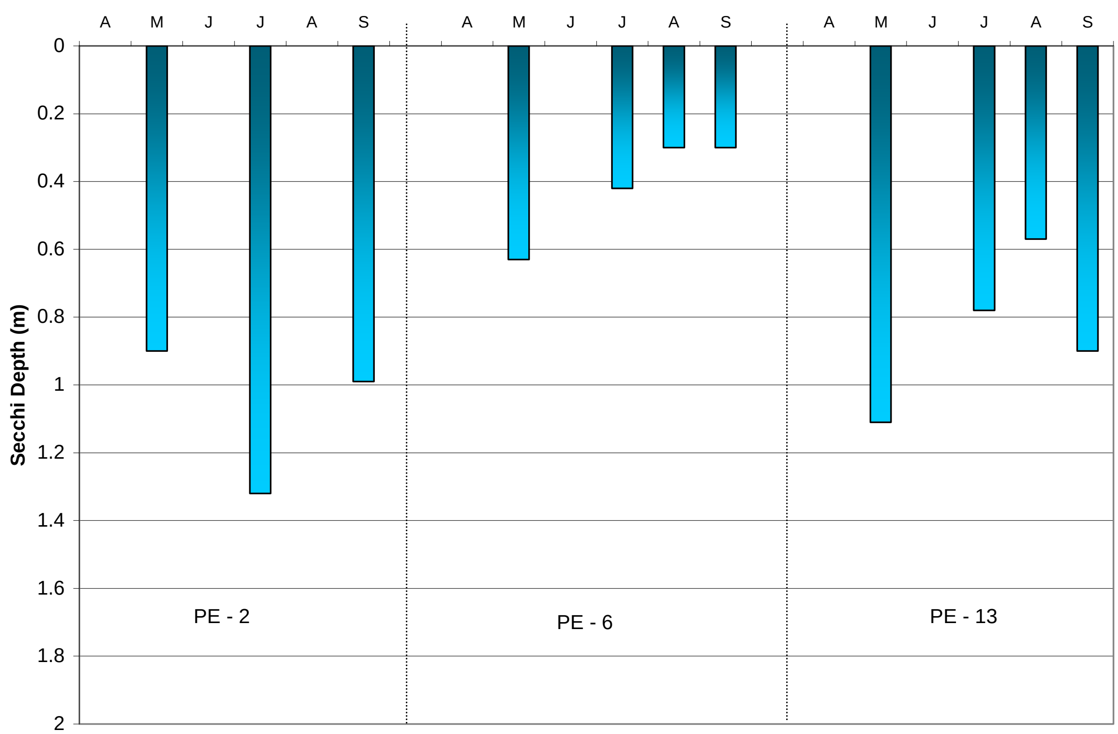


Figure 12.9. Secchi depth (m) measurement by site and sample date at Perry Lake during 2006.

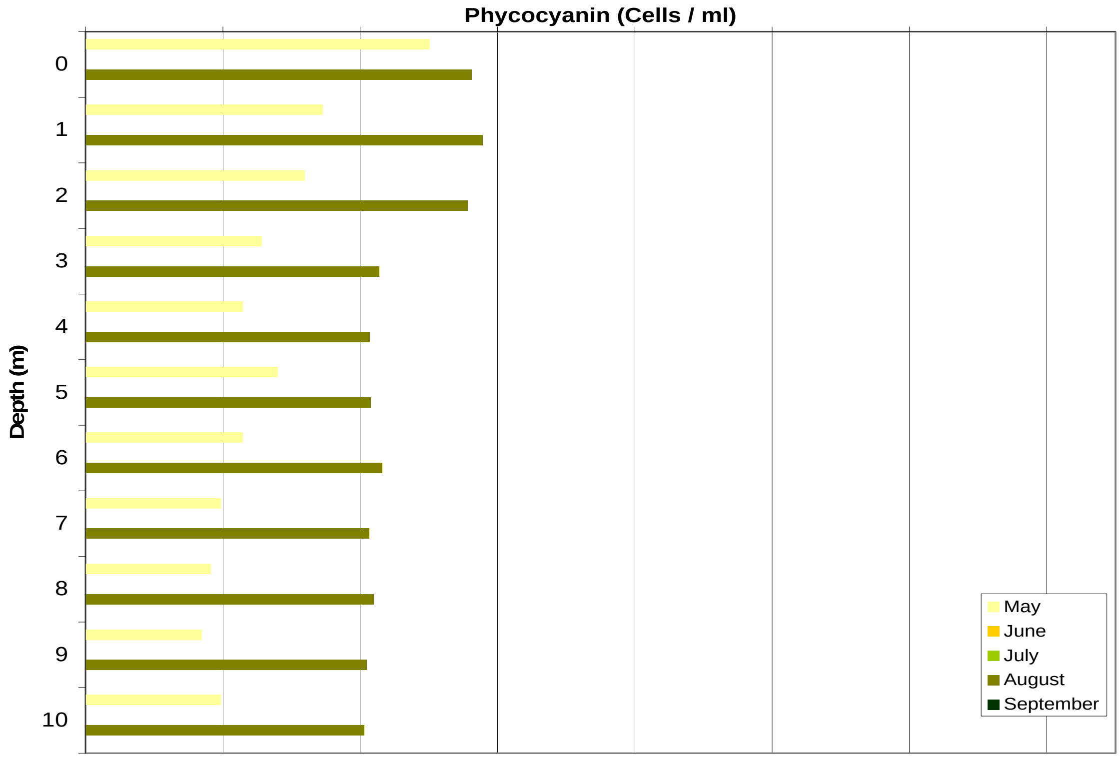


Figure 12.10. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Perry Lake Site 2 (Tower) during 2006.

Atrazine samples were collected from the three lake sites during May 2005. and concentrations ranged from 2.7 (Site 2) – 8.3 ug/L (Site 6). Median atrazine concentrations collected from surface water samples since 1996 range from 0.52 – 1.67 ug/L) (Figure 12. 11). Although less than EPA's drinking water maximum contaminant level of 3 ug/L, individual samples measured even during 2006 still exceed the MCL. Figure 12.12 depicts individual sample concentrations and exceedances of the MCL measured by date at Site 6 (Delaware River arm) from 1996 through 2006.

Perry Lake is the only district lake to exceed the Alachlor MCL of 2 ug/L. As with other contaminants, monthly and annual variability in concentrations is detected; see Figure 12.13 as an example from Site 17 (Rock Creek inflow). Exceedances were detected at both inflow sites as well as Site 6 (Delaware River arm). No exceedances have been detected since 2000, which may be an indication of change in herbicide preference or improved application methods.

Vertical profiles were recorded during May and August sampling trips to Perry Lake. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake stratified both chemically and thermally between 4-7 m depth during May (Figure 12.14). No stratification was observed during August.

Fecal bacteria (*E. coli*) samples were collected from three locations at Perry Park beach prior to three major holidays (Memorial Day, July 4th, and Labor Day) during 2006. No samples exceeded the single sample maximum of 732 colonies / 100 ml for a whole-body contact during the recreational season (Figure 12.15). With limited inflows due to

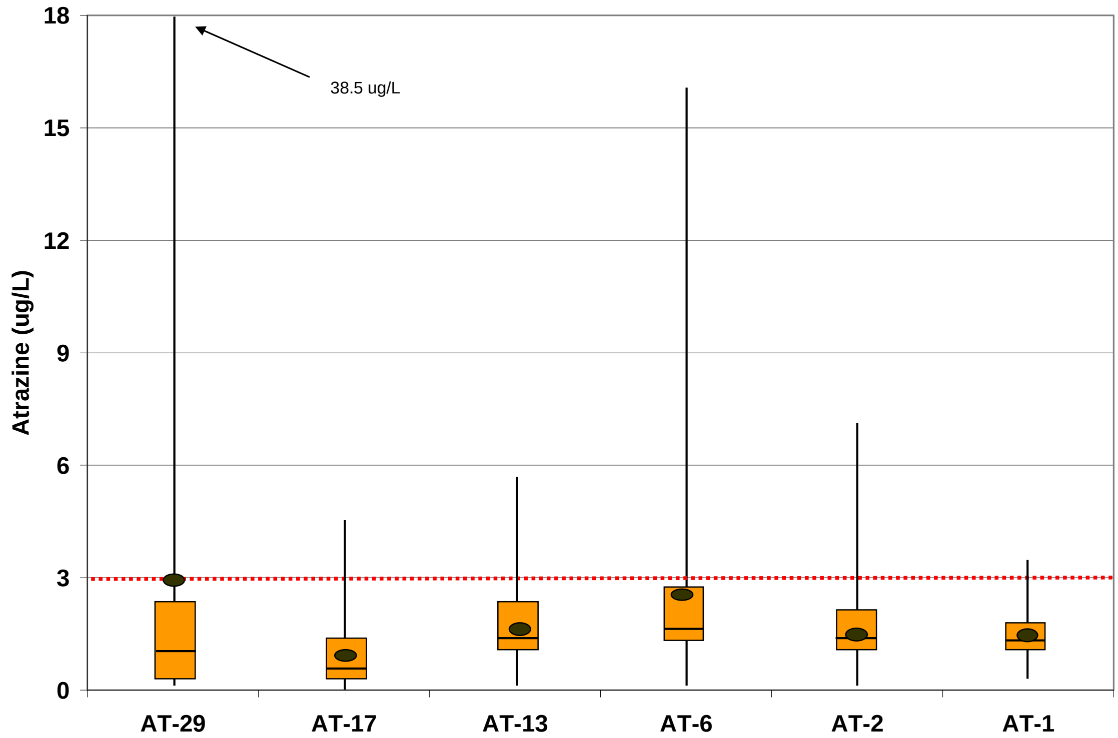


Figure 12.11. Box plots of surface water sample atrazine concentrations measured from 1996 through 2004 at Perry Lake.

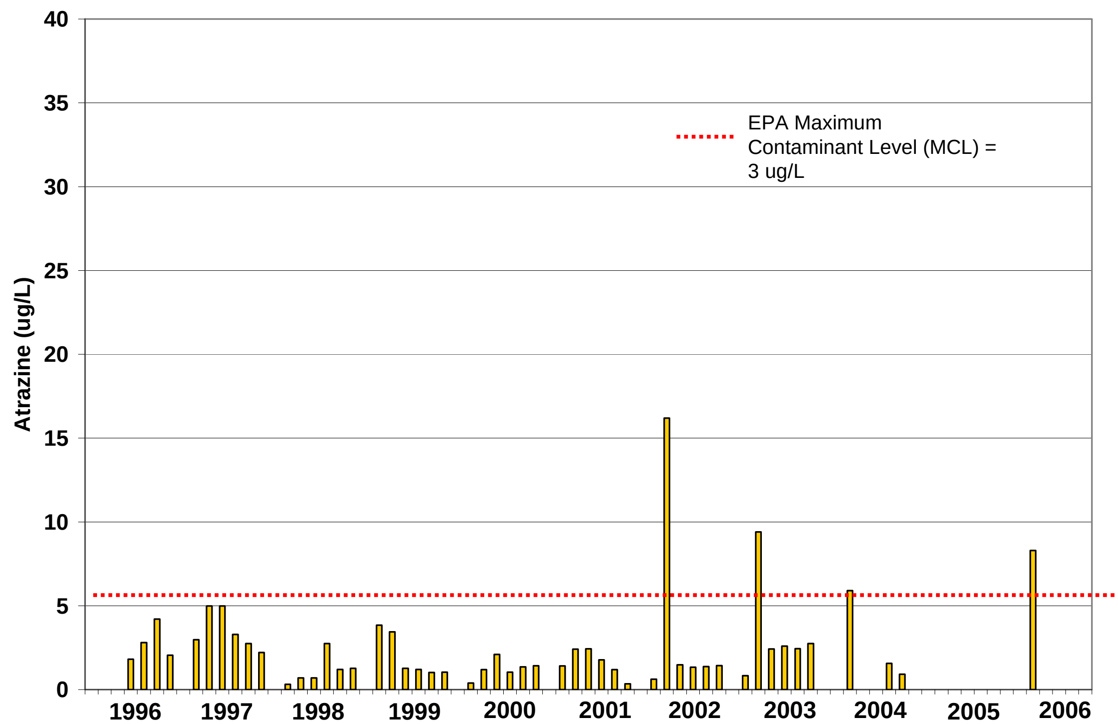


Figure 12.12. Atrazine concentrations by sample date collected from surface water samples at Site 6 -- Delaware River arm -- of Perry Lake between 1996 and 2006.

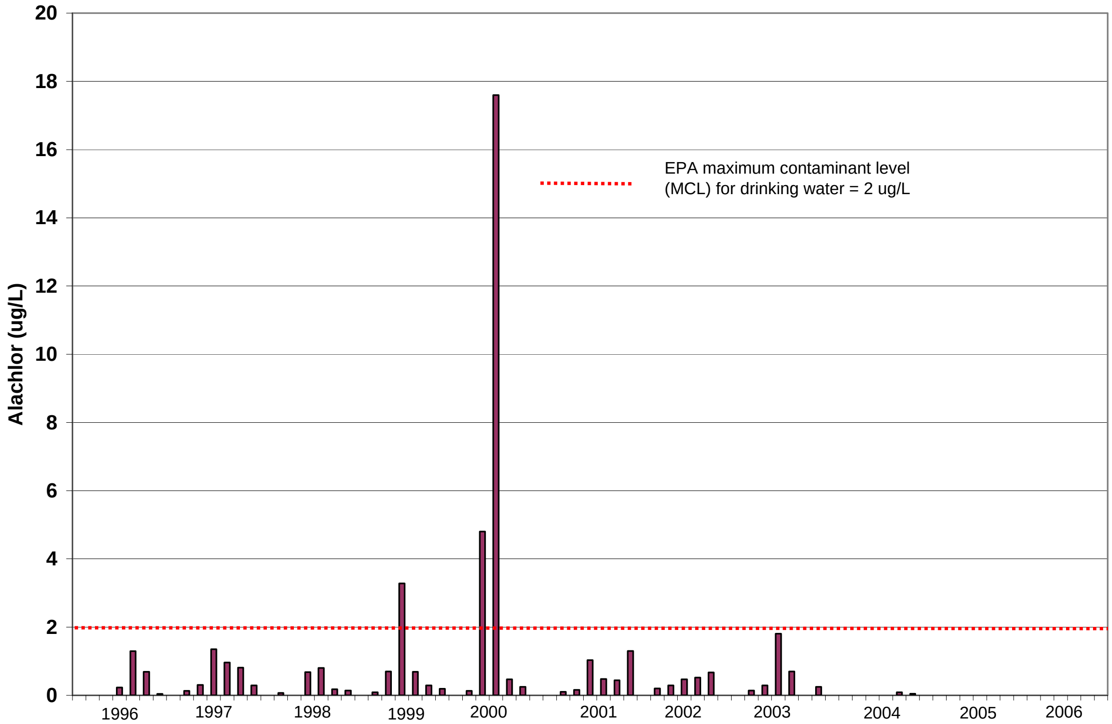
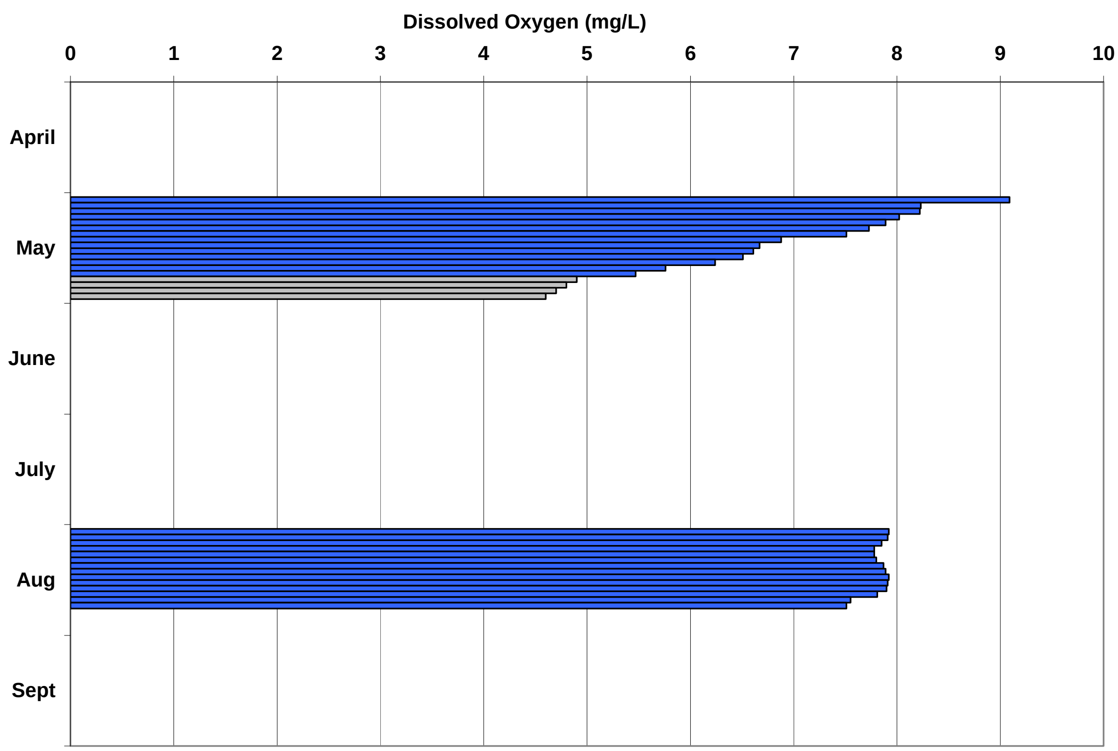


Figure 12.13. Alachlor concentrations by sample date collected from surface water samples at Site 17 (Rock Creek) inflow to Perry Lake between 1996 and 2006.



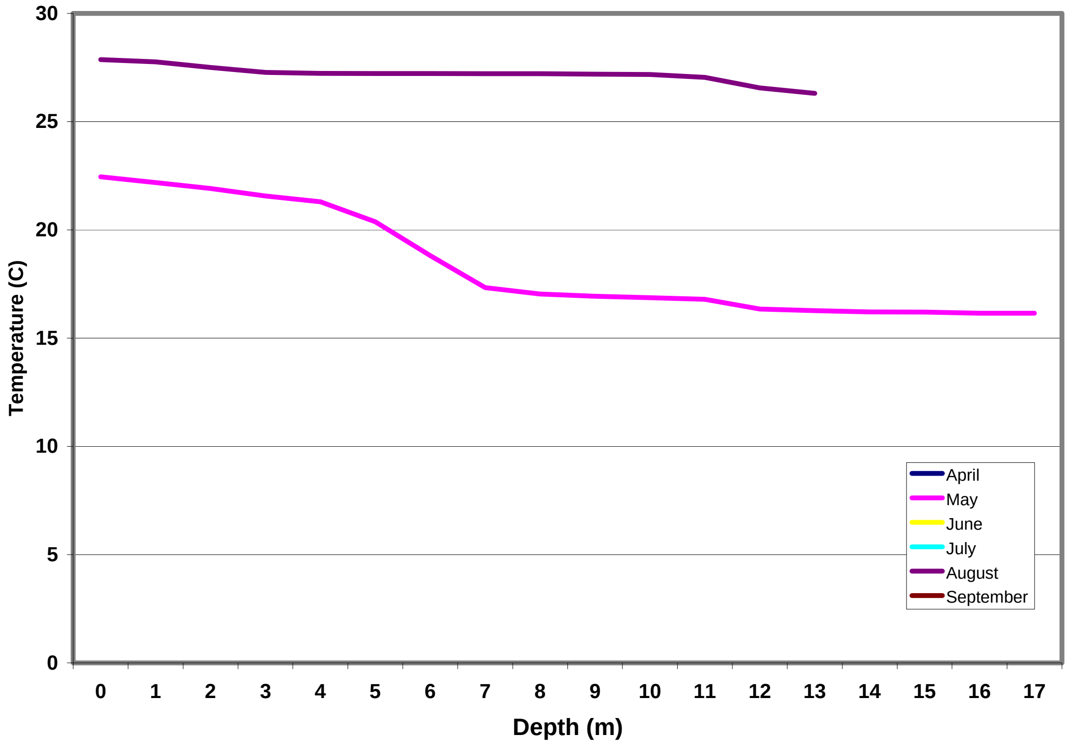


Figure 12.14. Dissolved oxygen concentration (mg/L) histogram and temperature (C plot from vertical profiles recorded at Site 2 (Tower) during 2005 at Perry Lake.

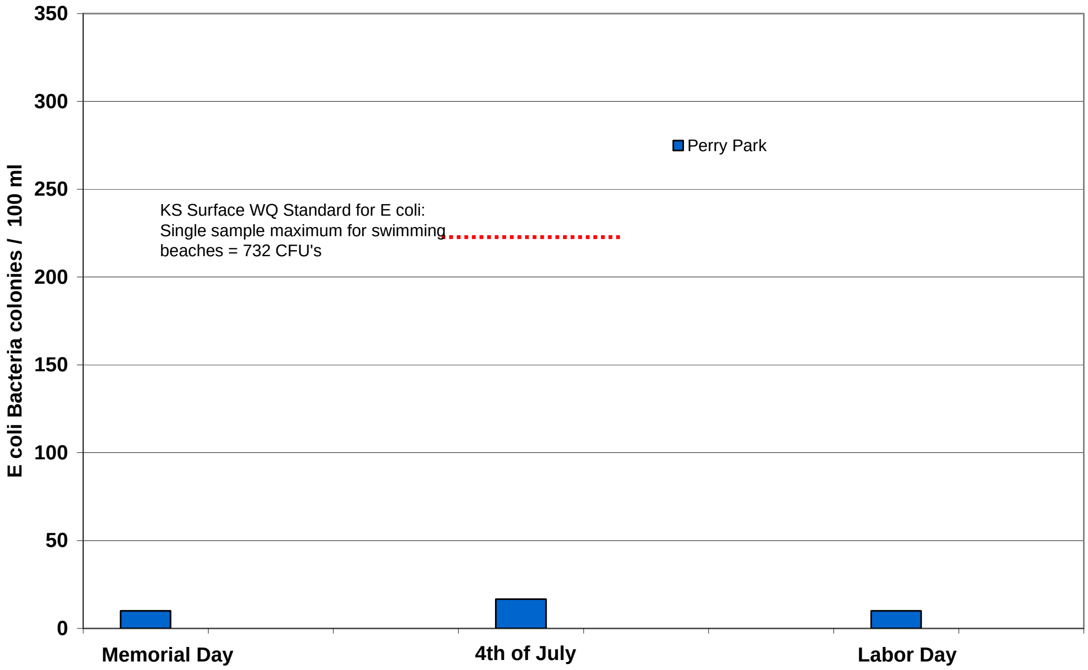


Figure 12.15. Fecal bacteria colonies per 100 ml samples from beach samples collected prior to major holidays at Perry Lake during 2006.

prolonged drought conditions, blooms of fecal bacteria would not have been expected during 2006.

12.3.3 Outflow

No outflow samples were collected from Perry Lake during 2006.

12.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to monthly ‘intensive’ monitoring from April through September, as well as conducting monthly vertical profiles at each of the three lake sites. To gain a better understanding of water quality baseline data both within the lake and the watershed, two additional sites will be added during 2007. The new sites will be Site 4 (lake site at Hwy ?? bridge) and Site (inflow site at Valley F???). Perry Lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP’s, illicit dumping from boats, etc. A contaminant group of interest is polyaromatic hydrocarbons (PAHs). These compounds are components of asphalt, fuels, oils, and greases. They enter receiving waters from stormwater runoff, industrial and wastewater treatment discharges, and through atmospheric deposition. They do not dissolve, but attach to particulate material and eventually settle out to the substrate. These compounds are highly toxic to aquatic biota, and thus baseline data is desired to track within district lakes. This is a high priority item when future funding becomes available. The Delaware River watershed WRAPS is will be developing goals and targets during mid-2006. Data sharing and active involvement with the Delaware River WRAPS group will continue in efforts to achieve water quality improvement within the Perry Lake watershed.

13 Pomme de Terre Lake

13.1 General Background

Pomme de Terre Lake was impounded in 1961 and reached full pool in 1963. The main water quality threats to Pomme de Terre Lake are nutrients and bacterial contamination.

13.1.1 Location

Pomme de Terre Lake is located approximately 96 km (60 miles) north of Springfield, Missouri. The dam is located at river km 73 (river mile 45.6) on the Pomme de Terre River. The watershed includes portions of Hickory, Polk, Green and Webster counties. Historic water quality sample sites at Pomme de Terre Lake include 3 lake, 1 outflow, and 2 inflow (Figure 13.1).

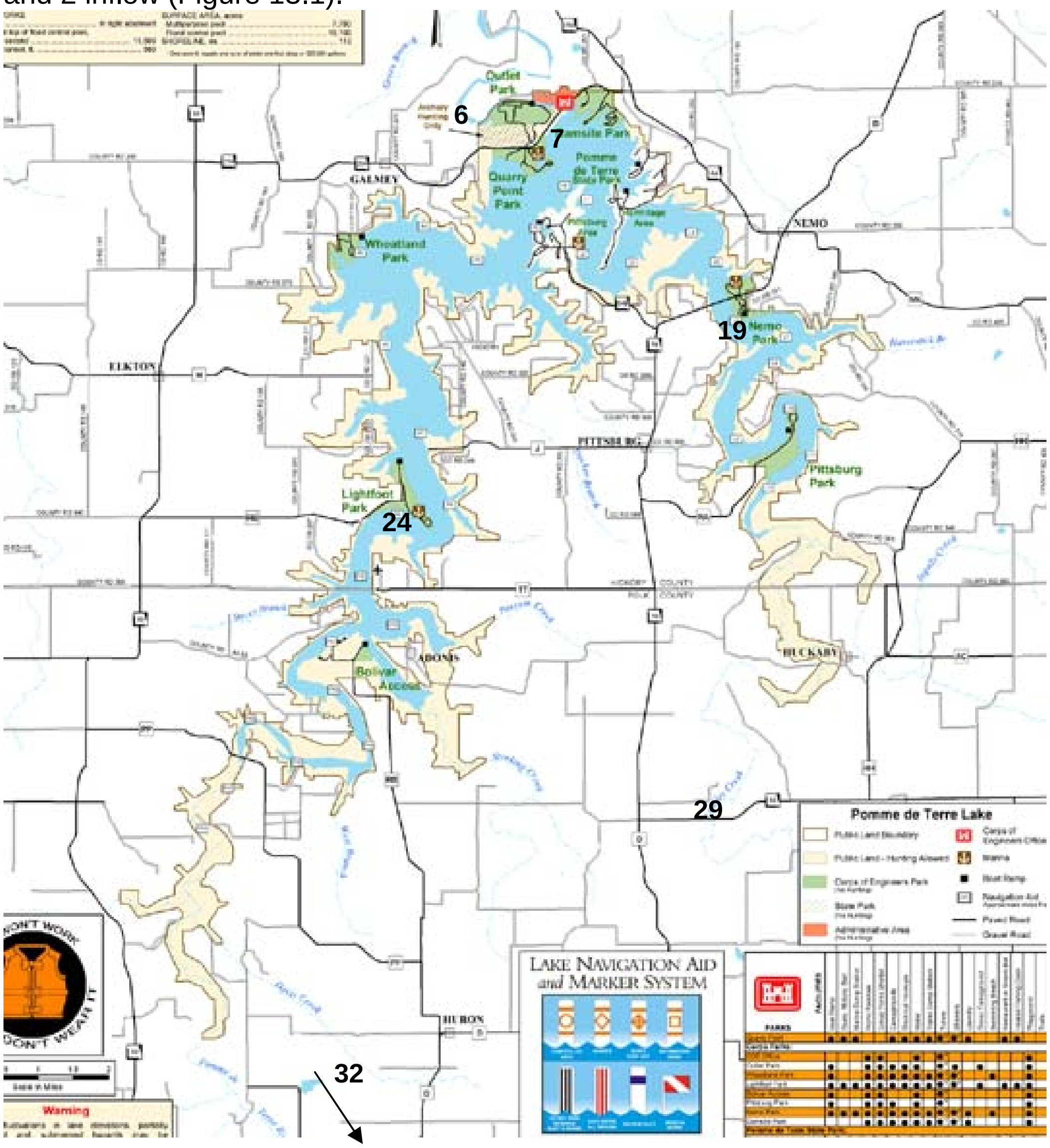


Figure 13.1. Pomme de Terre Lake area map with sample site locations.

13.1.2 Authorized Purposes: Flood control, water quality improvement, supplemental navigation on the lower Missouri and Mississippi Rivers, recreation, and fish and wildlife management.

13.1.3 State Use Designations: Livestock and wildlife watering, protection of warmwater aquatic life and human health / fish consumption, and whole-body contact recreation.

13.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	874.0	406.9	16,100	
Multipurpose	839.0	237.5	7,820	113
Total		644.4		

Total watershed area:	611 sq miles (391,040 A)
Watershed ratio:	24.3 FC / 50.0 MP
Average Annual Inflow:	367,038 acre-feet
Average flushing rate:	
Sediment inflow (measured):	4,358 acre-feet (1961 – 1974)
Water management Plan:	Submitted for approval on 20 May 2005
Historic stage hydrograph:	1996 – 2006 (Figure 13.2)

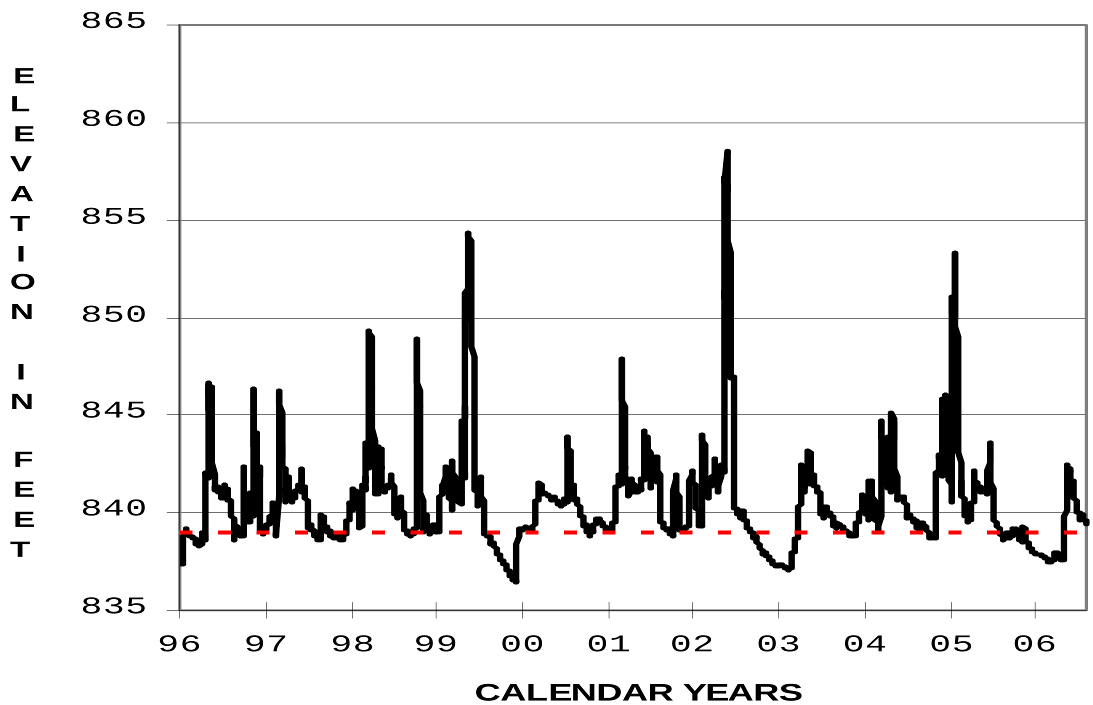


Figure 13.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 839.0 msl).

13.2 2006 Activities

Pomme de Terre Lake was categorized as an 'ambient' lake during 2006, thus surface water samples were to be collected at the three lake sites from May through September 2006. Vertical profiles (temperature, DO) were to be recorded at the three lake sites from June through September. Pomme de Terre Lake staff (OF-PT) providing field assistance with the WQP during 2006 included Glenn Locke and Jon Carlisle. Brad Myers, OF-PT Operations Manager, provided technical insight and background knowledge on Pomme de Terre Lake and surrounding watershed.

13.3 2006 Data

Comparative historic data consists of a single sample collected in 2002, three samples (April – July) during 2004 and five monthly (May - September) samples during 2005. Due to miscommunication, samples were only collected during September 2006.

13.3.1 Inflow

No inflow samples were collected at the two tributary streams during 2006 (Pomme de Terre River [Site 32] downstream of Bolivar, and Site 29 located on Lindley Creek at State Road 64 bridge).

13.3.2 Lake

Based on nutrient concentrations and chlorophyll a values, Pomme de Terre is considered mesotrophic – eurtrophic. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Median total nitrogen concentrations from surface water samples of lake sites range from 0.64 – 0.78 mg/L (Figure 13.3). Although typical of district lakes, these concentrations exceed EPA's proposed ecoregional nutrient criteria value of 0.46 mg/L TN. Historically, the highest TN concentrations are measured at Site 29 (Lindley Creek), which may be indicative of some landuse activities occurring upstream of the site.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median total phosphorus concentrations from surface water samples at lake sites ranged from 0.06 – 0.07 mg/L. These concentrations are typical for district lakes, and are indicative of eutrophic waters (Figure 13.4). These concentrations exceed EPA's proposed ecoregional nutrient criteria value of 0.008 mg/L TP. Inflow TP concentrations were significantly higher than lake sites – nearly 2x the concentration -- indicating opportunities for improvement in landuse practices and nonpoint source nutrient control.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios $\geq$ 20:1 are indicative of desirable algal communities, whereas ratios $\leq$ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites. Median TN:TP ratios at all three lake sites are ~ 12, indicating the lake is at risk for cyanobacteria blooms (Figure 13.5). Microcystin toxins have been detected at Pomme de Terre Lake during 2000 (Dr Jennifer Graham, USGS, personal communication).

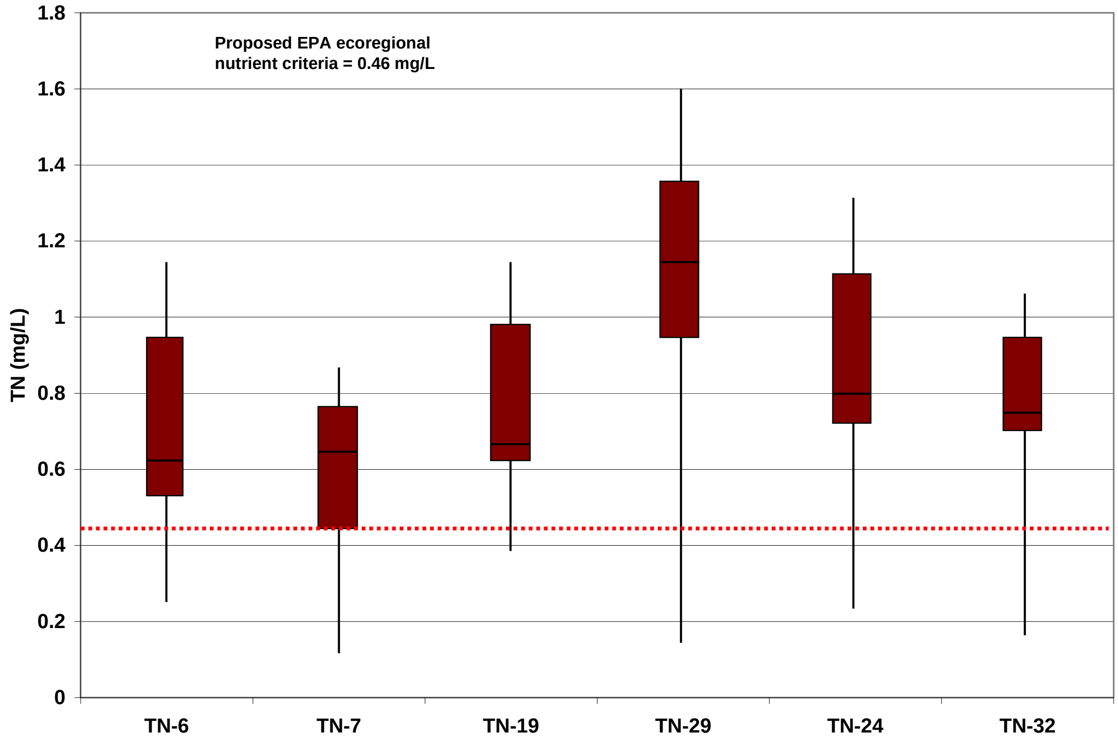


Figure 13.3. Box plots of surface water sample total nitrogen concentrations measured at outflow (TN-6), lake, and inflow (TN-29 & TN-32) sites from 2004 – 2006 at Pomme de Terre Lake.

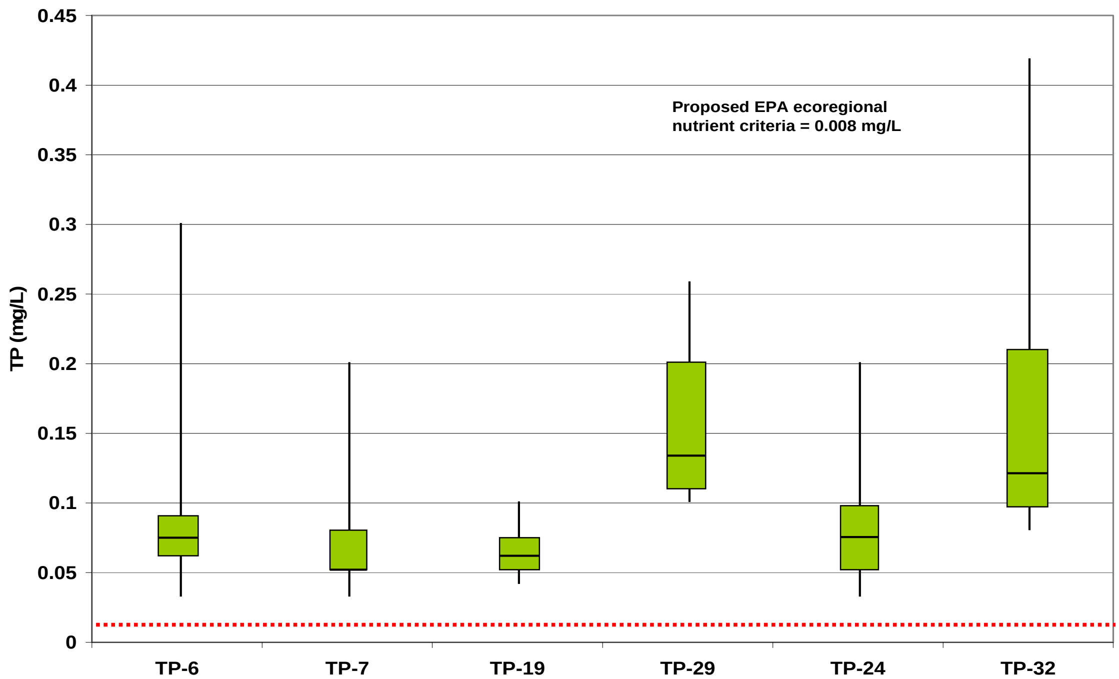


Figure 13.4. Box plots of surface water sample total phosphorus concentrations measured at outflow (TP-6), lake, and inflow (TP-29 & TN-32) sites from 2004 – 2006 at Pomme de Terre Lake.

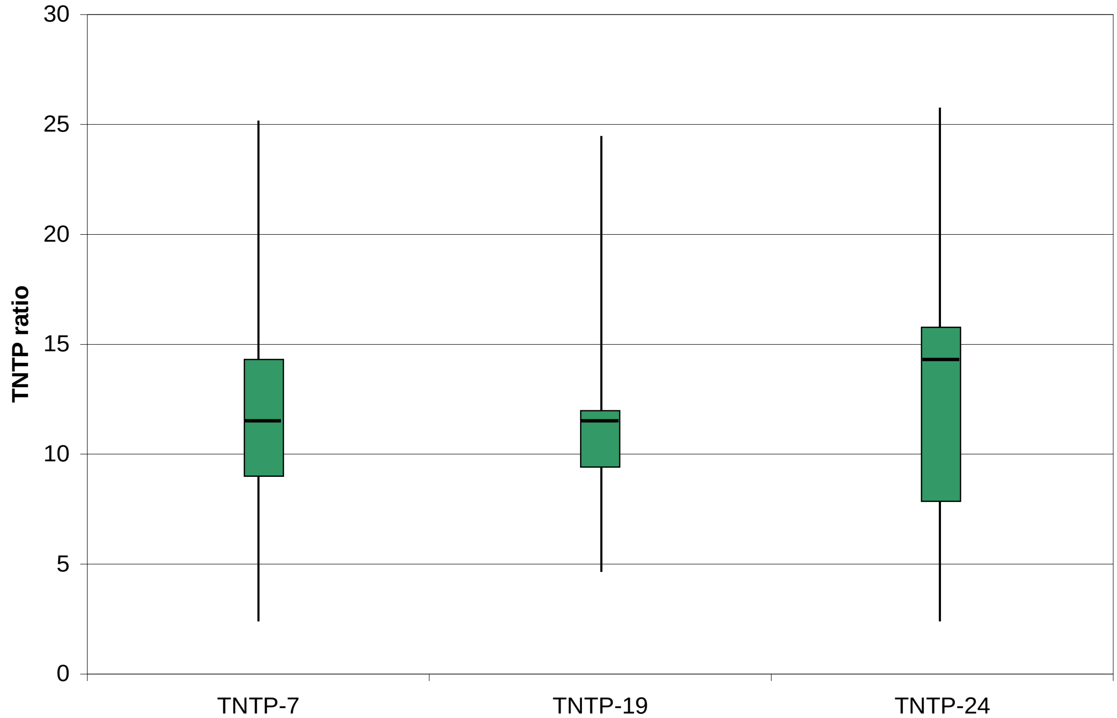


Figure 13.5. Boxplots of total nitrogen : total phosphorus (TN : TP) ratio by site from 2004 – 2006 at Pomme de Terre Lake.

No chlorophyll *a* samples were collected during 2006. However, historic mean chlorophyll *a* concentrations range from 19 – 28 ug/L between July and September at the three lake sites. These values are indicative of eutrophic waters. Secchi depth measured from July through September indicated water clarity was variable between sites and months (Figure 13.6). The clearest water (1.3 – 2 m) was measured at Site 7 (tower), while moderately clear water was measured near Lightfoot Park (0.7 – 0.8 m) in the Pomme de Terre River arm.

No herbicide samples were collected from either inflow, lake or outflow sites during 2006. However, historic atrazine surface water sample concentrations are consistently less than 0.2 ug/L, which is well below EPA's drinking water maximum contaminant level of 3 ug/L. In addition, all other contaminants (ie., alachlor, metolachlor, cyanazine) monitored during 2004 and 2005 were below detection limits from all three lake sites.

Vertical profiles were not recorded during 2006. However, profiles were recorded during June through September 2005. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake stratified both chemically and thermally between 4-5 m depth during July - August (Figure 13.7). The thermocline had extended to nearly 10 m by late September, as the lake water temperatures began to cool and fall turnover was beginning.

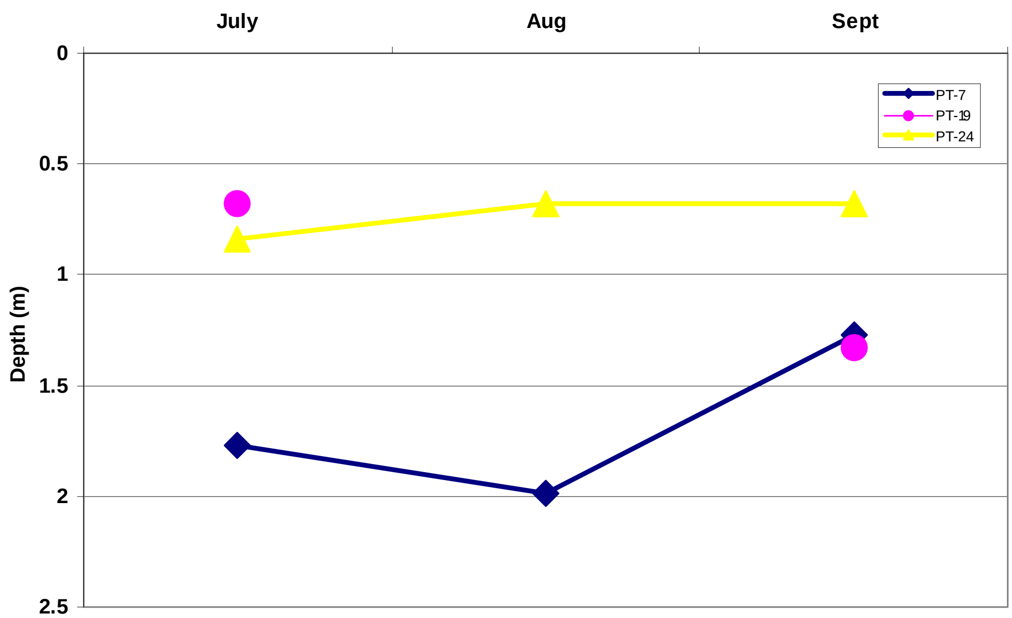
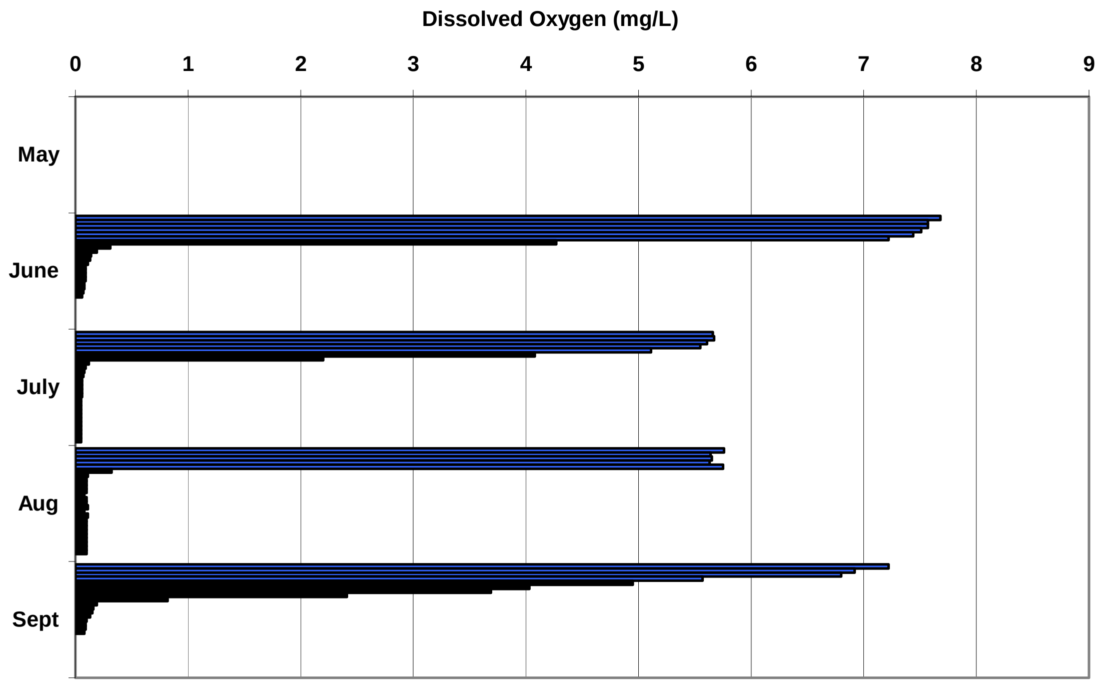


Figure 13.6. Secchi depths measured by site at Pomme de Terre Lake during July, August and September 2005.



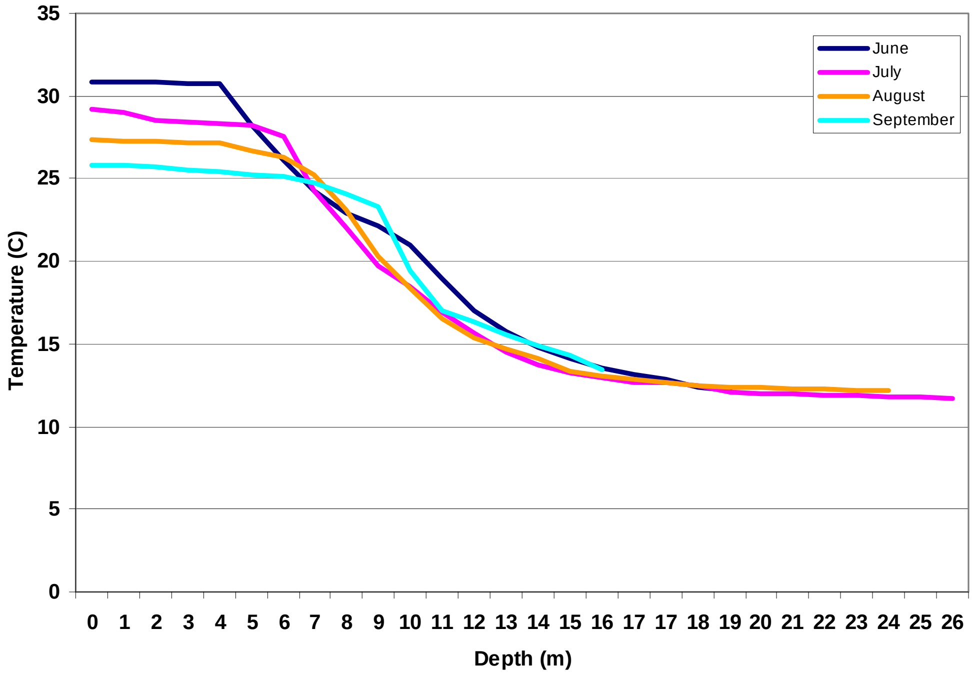


Figure 13.7. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from a vertical profile recorded at Site 7 from June through September 2005.

No metal samples were collected during 2006. However, total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected at both inflow sites during August 2006. Concentrations ranged from 398 – 646 ug/L, with the highest concentration recorded at Site 29 (Lindley Creek). Implications are directed at drinking water facilities related to taste and staining issues. In addition, all surface samples (lake and inflows) collected during August exceeded EPA's SMCL for manganese (50 ug/L). Sample concentrations ranged from 63 – 228 ug/L, with lowest concentrations measured at lake sites. Implications are directed at drinking water facilities due to taste and stain issues.

Fecal bacteria (*E. coli*) samples are typically collected from three locations at both Wheatland and Nemo Park beaches prior to three major holidays (Memorial Day, July 4th, and Labor Day). None of the composite samples exceeded the state standard of 126 colonies / 100 ml sample for whole-body contact during the recreational season (Figure 13.8).

13.3.3 Outflow

No outfall samples were collected from Pomme de Terre Lake during 2006.

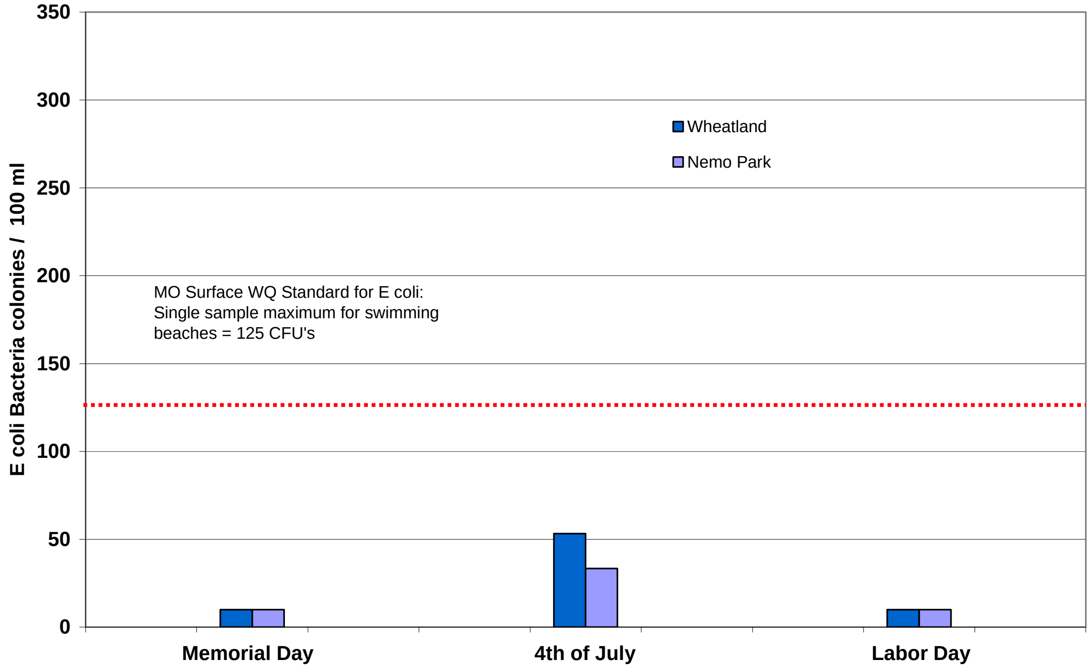


Figure 13.8. Geometric means of fecal bacteria (*E coli*) colonies per 100 ml samples from beach samples collected weekly at Long Branch Lake State Park during 2006.

13.4 Future Activities and Recommendations

Sampling activities for 2007 will include 'ambient' monitoring from May through September, as well as conducting at least one summer vertical profile at each of the three lake sites. In addition, a Hach HQ-10 portable temperature – dissolved oxygen meter with 15 m cable was provided for use at the lake to provide more frequent profile data. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. A watershed management group, directed by the local NRCS and involving federal, state, and local input, will be implemented during 2007. Our water quality dataset will be shared with this group, and input provided during meetings.

14 Pomona Lake

14.1 General Background

Pomona Lake was impounded in 1963 and reached full pool in 1965. The main water quality threats to Pomona Lake are sedimentation, nutrients and bacterial contamination. The lake is listed on the state's 2004 303(d) list for water quality impairment due to eutrophication and silt. Kansas State University (KSU) received a 319 grant to develop a Watershed Restoration and Protection Stragey (WRAPS) project within the Pomona Lake watershed. The WRAPS, chaired by Dr. Bill Hargrove (KSU), has initiated SWAT modeling efforts to help identify priority areas of concern. In addition, the Marais des Cygnes Basin Advisory Committee has begun efforts to develop a watershed management plan and protect the watershed for current and future water needs.

14.1.1 Location

Pomona Lake is located approximately 48 km (30 miles) south of Topeka, Kansas. The dam is located at river km 13.3 (river mile 8.3) on 101 Mile Creek, a tributary of the Marais des Cygnes River. The watershed includes portions of Osage and Wabaunsee counties. Historic water quality sample sites at Pomona Lake include 3 lake, 1 outflow, and 1 inflow (Figure 14.1).

Figure 14.1. Pomona Lake area map with sample site locations.

14.1.2 Authorized Purposes: Flood damage reduction, recreation, water quality improvement, and fish and wildlife management.

14.1.3 State Use Designations: Primary and secondary contact recreation, expected aquatic life support, food procurement, and drinking water supply.

14.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,003	176.1	8,522	
Multipurpose	974	64.2	3,871	52
Total		240.3		

Total watershed area: 322 sq miles (206,080 A)

Watershed ratio: 24.18 FC / 53.24 MP

Average Annual Inflow: 143,721 acre-feet
Average Annual outflow: 000 acre-feet
Average flushing rate: 0.42 years
Sediment inflow (measured): 7,045 acre-feet (1963 – 1989)
Water management Plan: Approved February 1973
Historic stage hydrograph: 1996 – 2006 (Figure 14.2)

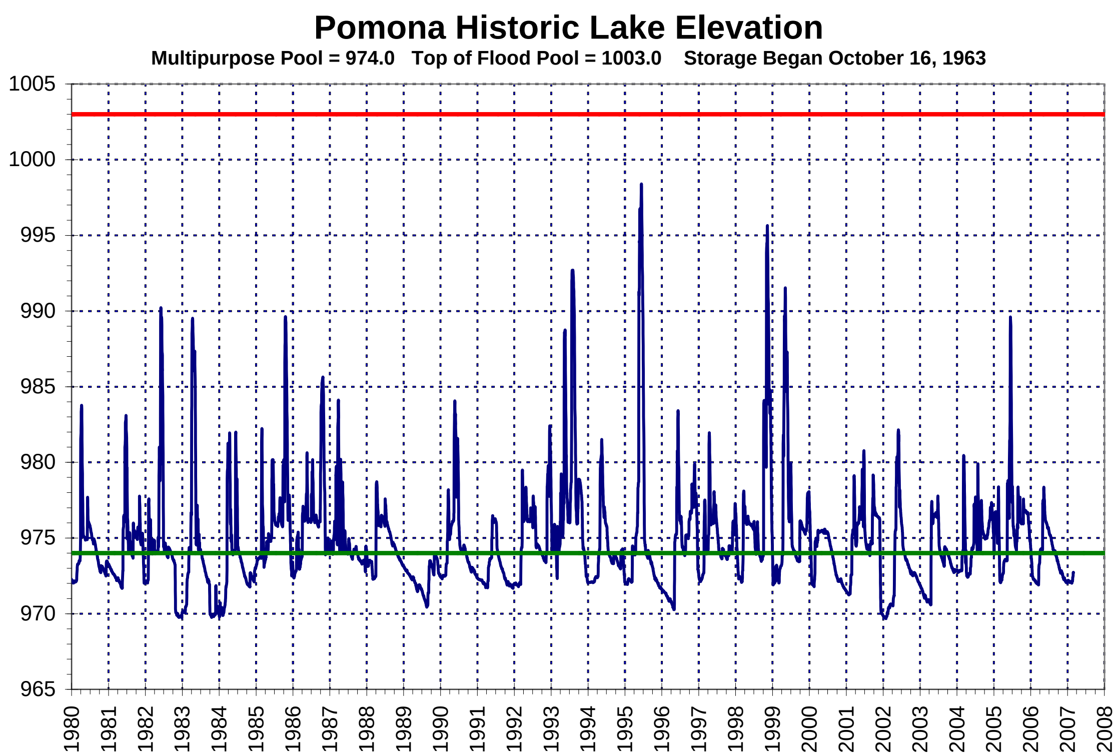


Figure 14.2. Pool elevation hydrograph from 1980 – 2006 (green line is multipurpose pool elevation level; 974.0 msl). Graph provided by Steve Spaulding (CENWK-EC-HC).

14.2 2006 Activities

Pomona Lake was categorized as an 'ambient' lake during 2006, with sample collection occurring from June through September. Surface samples were collected from three lake sites. Vertical profiles (temperature, DO) were recorded at the three lake sites during each monthly sampling trip. Pomona Lake staff (OF-PO) providing field assistance with the WQP during 2006 included David White and Brad Cox. David Green, OF-PO Operations Manager, provided technical insight and background knowledge on Pomona Lake and surrounding watershed.

14.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1996 - 1997, 1999 – 2005. Samples were collected at the three lake sites from June through September during 2006.

14.3.1 Inflow

No Inflow samples were collected during 2006. All data is discussed in context with lake samples below.

14.3.2 Lake

Based on total nitrogen (TN), total phosphorus (TP) and chlorophyll *a* concentrations, Pomona Lake is classified as eutrophic. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Monthly and annual variability in total nitrogen is evident at all sites (Figure 14.2 is an example from Site 3). Median concentrations range from 0.84 – 0.94 (Figure 14.3) for the three lake sites, which exceeds EPA's proposed ecoregional nutrient criteria value of 0.36 mg/L total nitrogen.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median TP concentrations ranged from 0.08 – 0.1 mg/L (Figure 14.4), which exceed EPA's proposed nutrient criteria value of 0.02 mg/L TP. The measured values for TN and TP are typical for reservoirs within the district.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 14.5 as an example at Site 12. Median TN:TP ratios at all three lake sites are < 12, indicating the lake is at risk for cyanobacteria blooms (Figure 14.6). Historically, bluegreen algae blooms have been detected at Pomona Lake.

No metal samples were collected from lakes sites during 2006. No chlorophyll *a* samples or secchi depth measurements were collected during 2006.

Mean atrazine concentrations in Pomona Lake, ranging from 1.67 – 2.03 ug/L, are less than EPA's drinking water maximum contaminant level (MCL) of 3 ug/L (Figure 14.7). However, individual samples measured since 1996 have been significant enough to

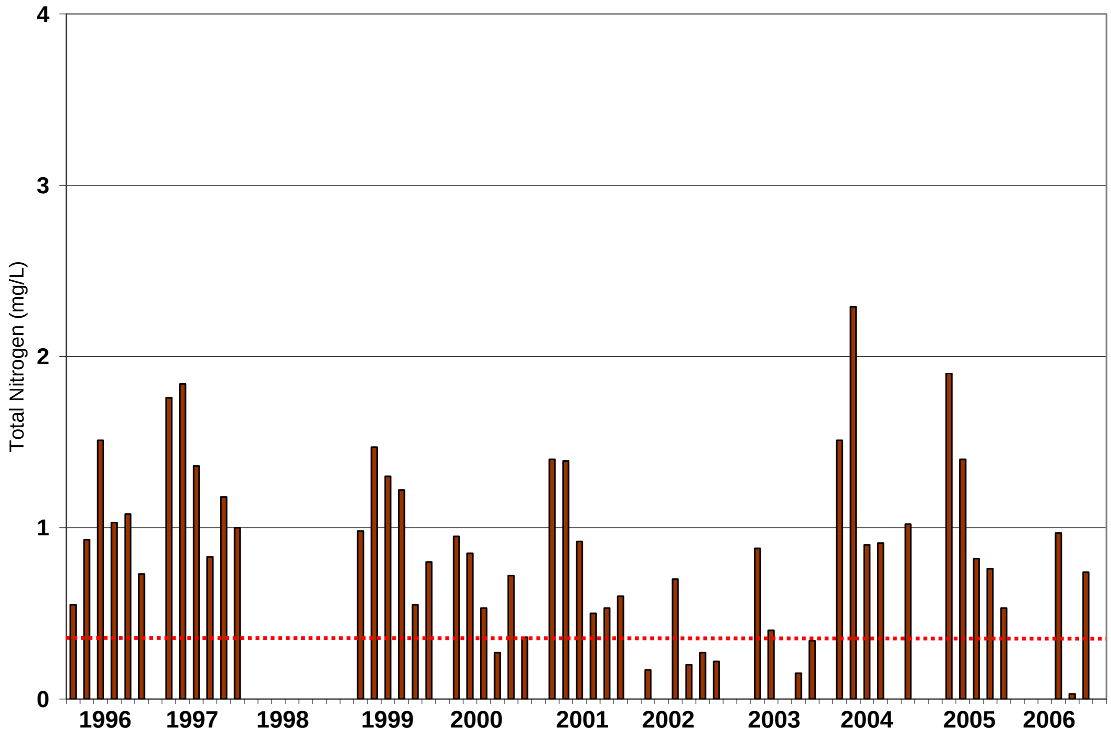


Figure 14.2. Total nitrogen concentrations by sample data collected at Site 3 (Tower) from 1996 through 2006 in Pomona Lake. Red line = proposed EPA ecoregional nutrient criteria value (0.36 mg/L).

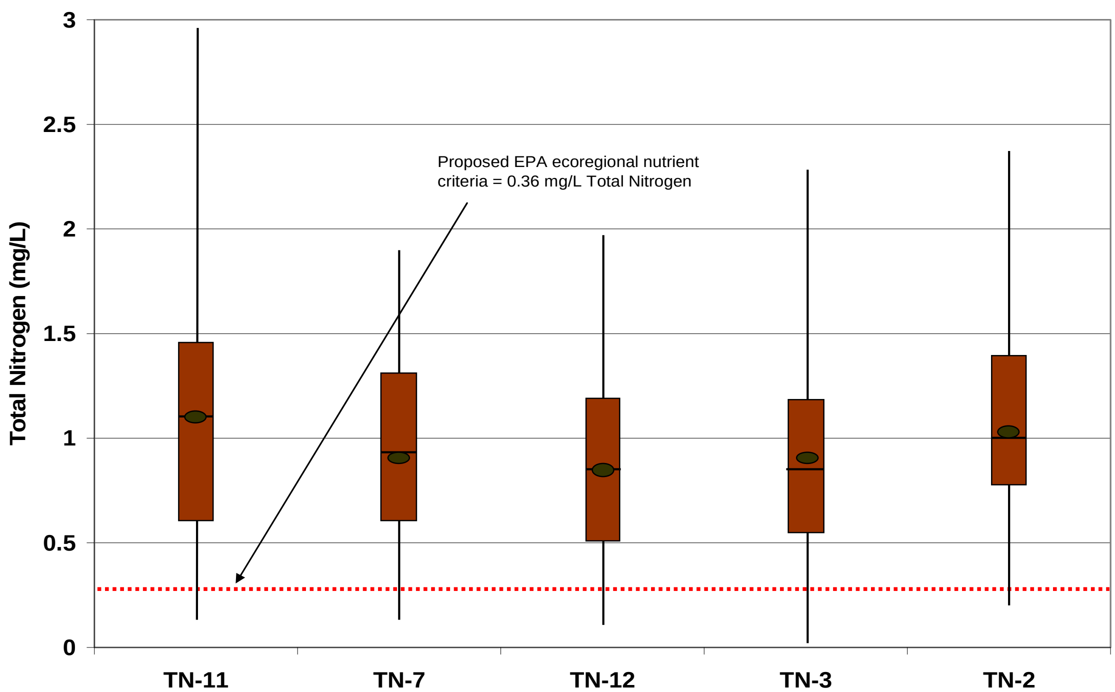


Figure 14.3. Box plots of surface water sample total nitrogen concentrations measured at inflow, lake, and outflow sites from 1996 through 2006 at Pomona Lake.

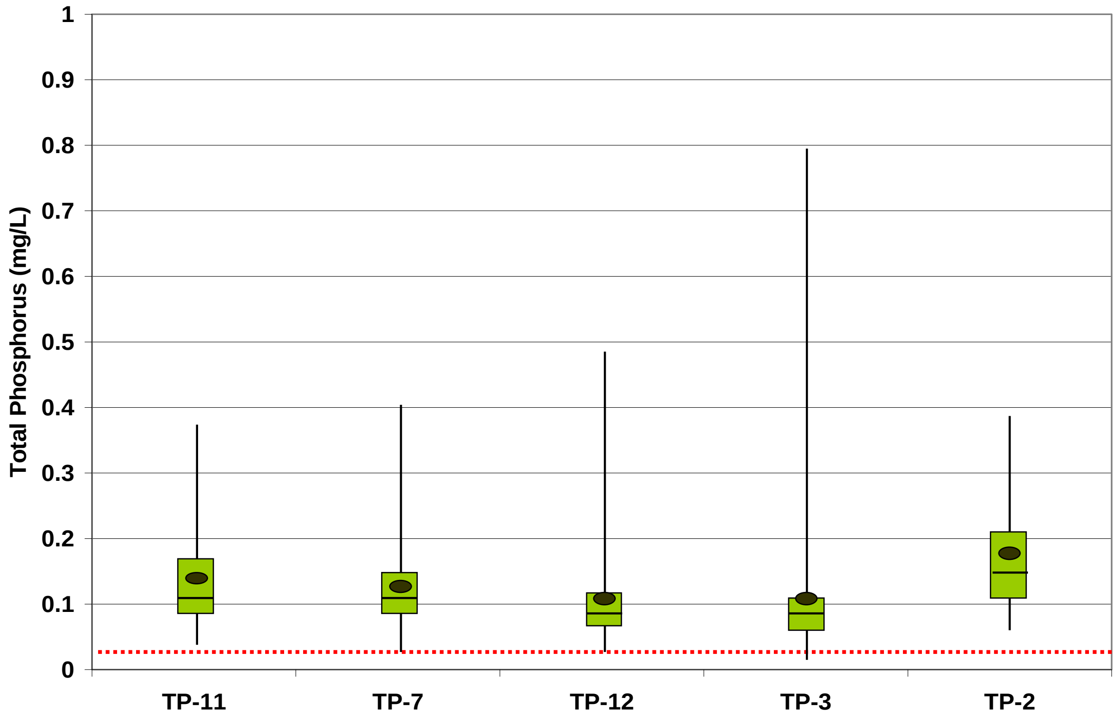


Figure 14.4. Box plots of surface water sample total phosphorus concentrations measured at inflow, lake and outflow sites from 1996 through 2006 at Pomona Lake.

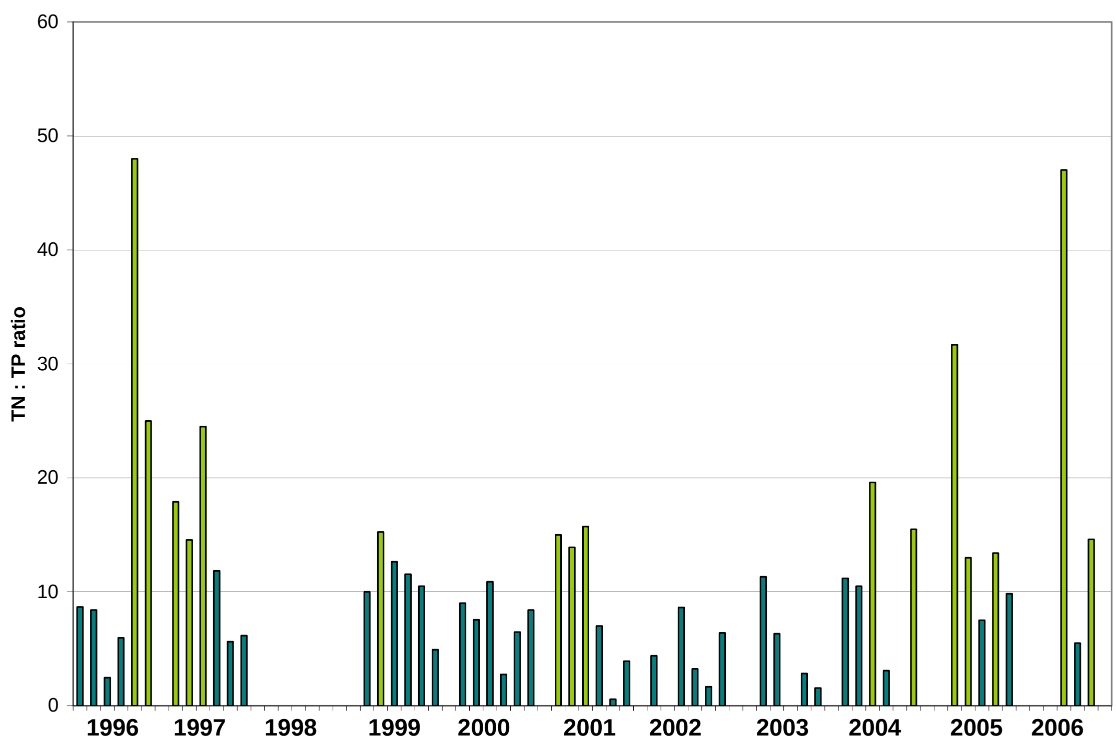


Figure 14.5. Graph of total nitrogen : total phosphorus (TN : TP) ratio by sample date at Site 12 in Pomona Lake from 1996 through 2005.

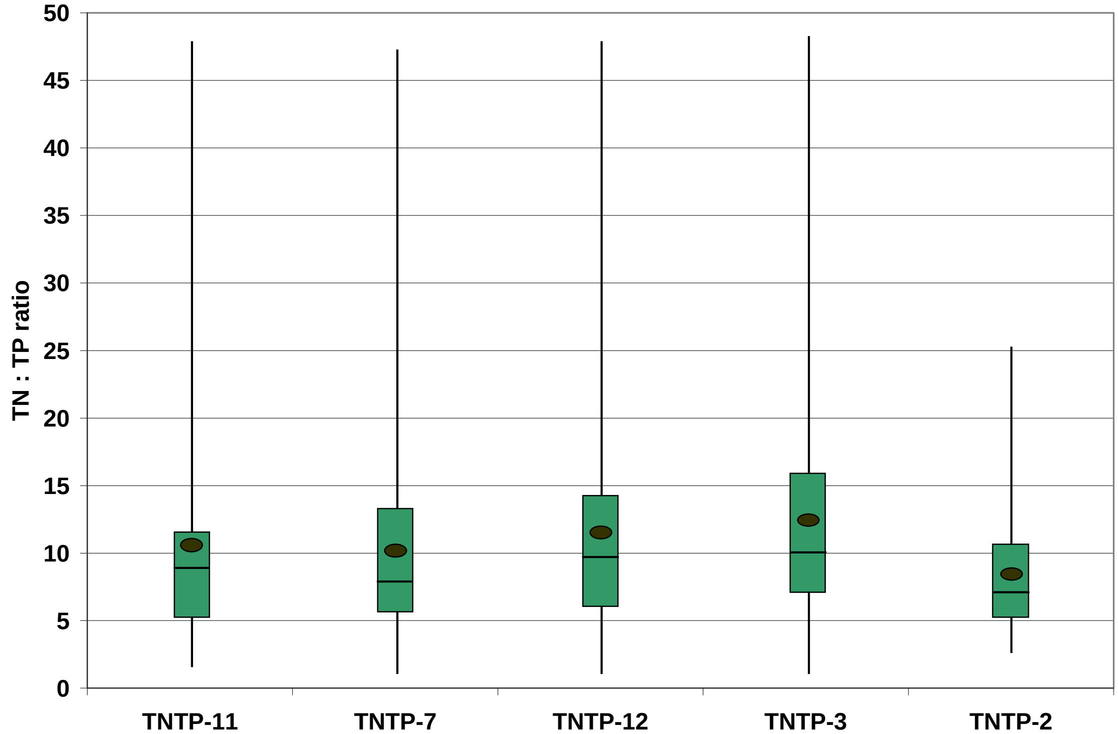


Figure 14.6. Box plots of total nitrogen : total phosphorus (TN : TP) by site from 1996 through 2005 at Pomona Lake.

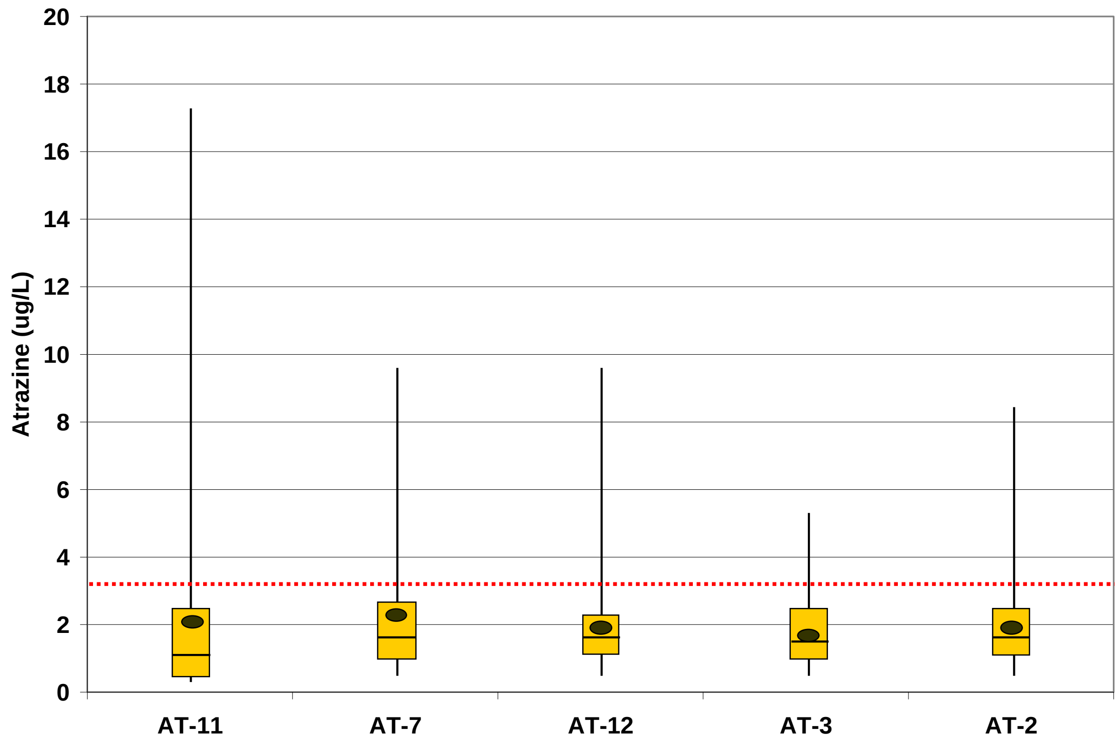


Figure 14.7. Box plots of surface water sample atrazine concentrations measured by site from 1996 through 2005 at Pomona Lake.

exceed the MCL – even exceeding 8 ug/L at Sites 12, 7 and 2 during 2005! Figure 14.8 depicts annual variability in atrazine concentration by sample date at Site 11 (inflow).

Vertical profiles were recorded during sample trips in June and August 2006. Parameters included temperature and dissolved oxygen. Based on these profiles, the lake was stratified both chemically and thermally during June but not during August. (Figure 14.9) Stratification occurred between 5 – 8 m at Site 3 during June 2006.

Fecal bacteria (*E. coli*) samples were collected from three locations at Michigan Valley beach prior to three major holidays (Memorial Day, July 4th, and Labor Day) during 2006. All samples collected were well within compliance limits of 732 colonies / 100 ml for a whole-body contact single sample maximum during the recreational season (Figure 14.10).

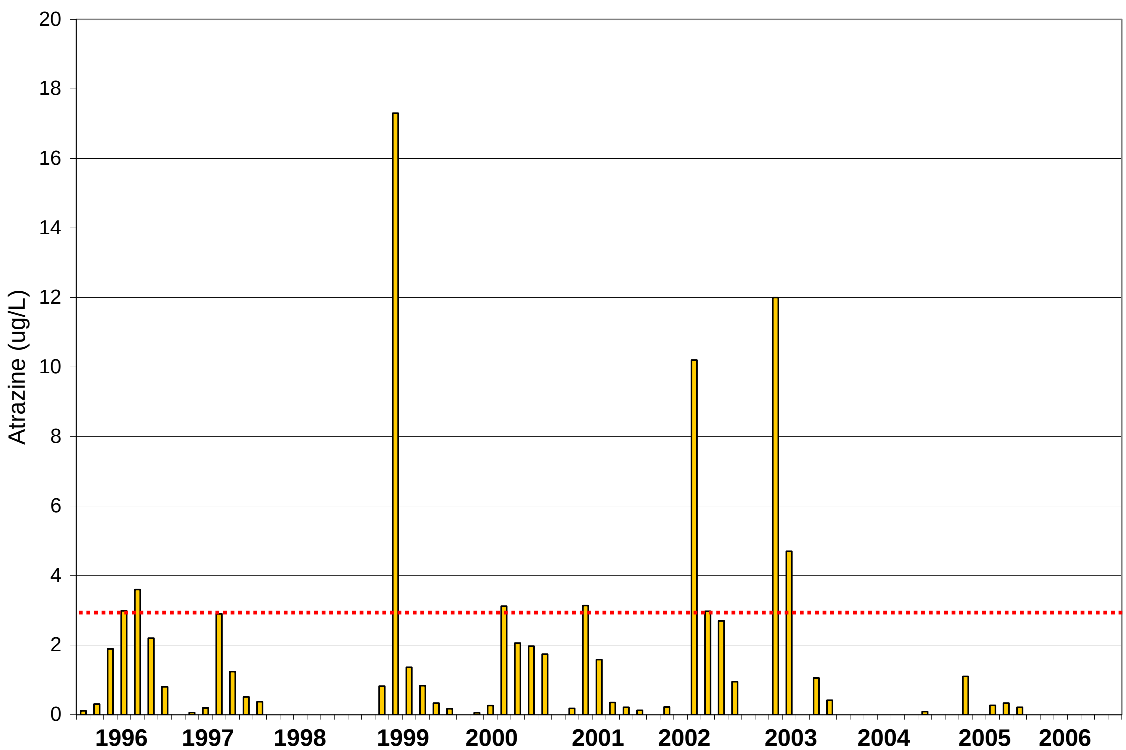
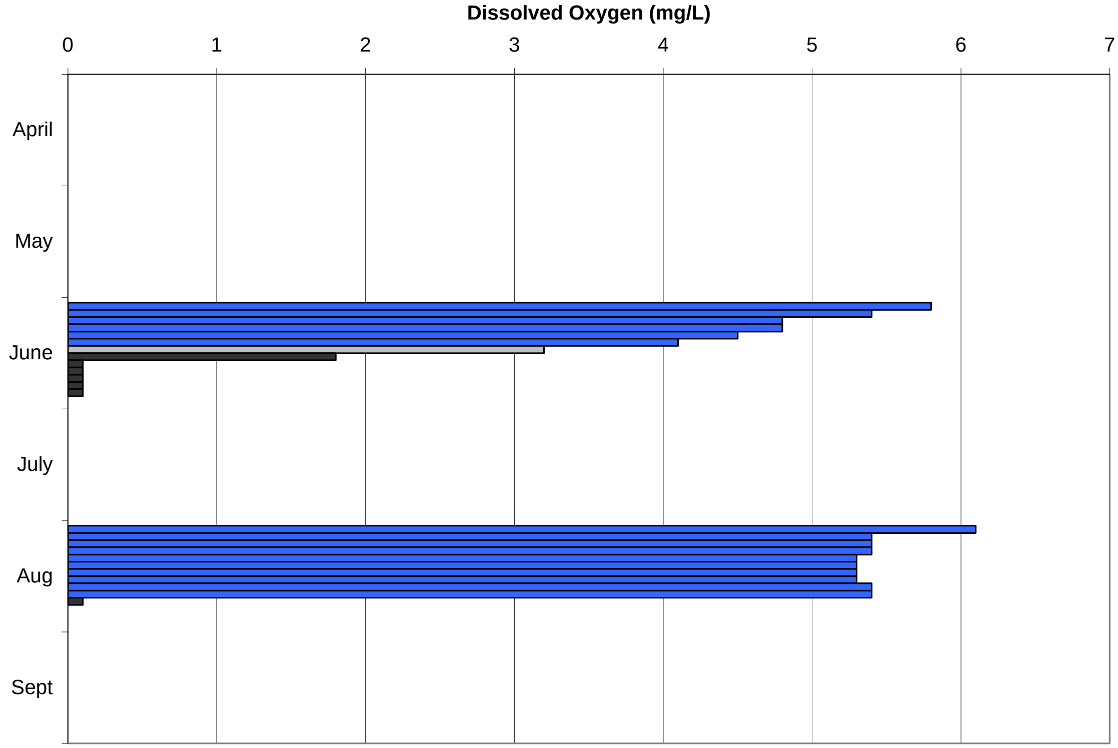


Figure 14.8. Atrazine concentrations by sample date from surface water samples ollected at Site 11 (inflow) of Pomona Lake between 1996 and 2005.



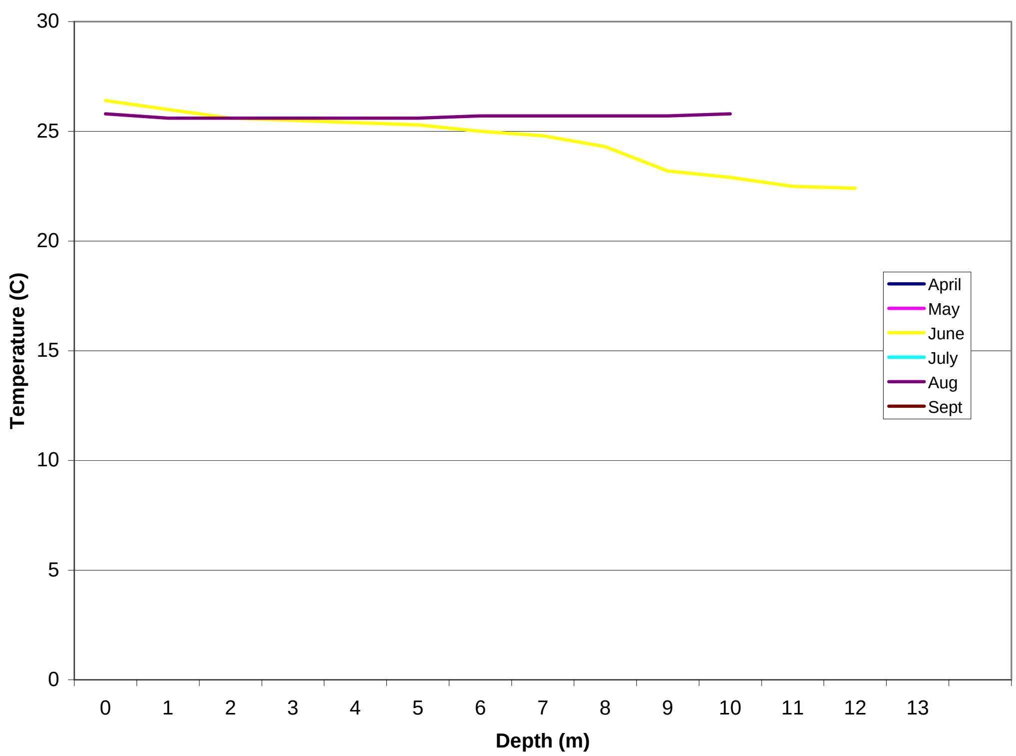


Figure 14.9. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) Plot from vertical profiles recorded at Site 3 (Tower) during June and August 2006.

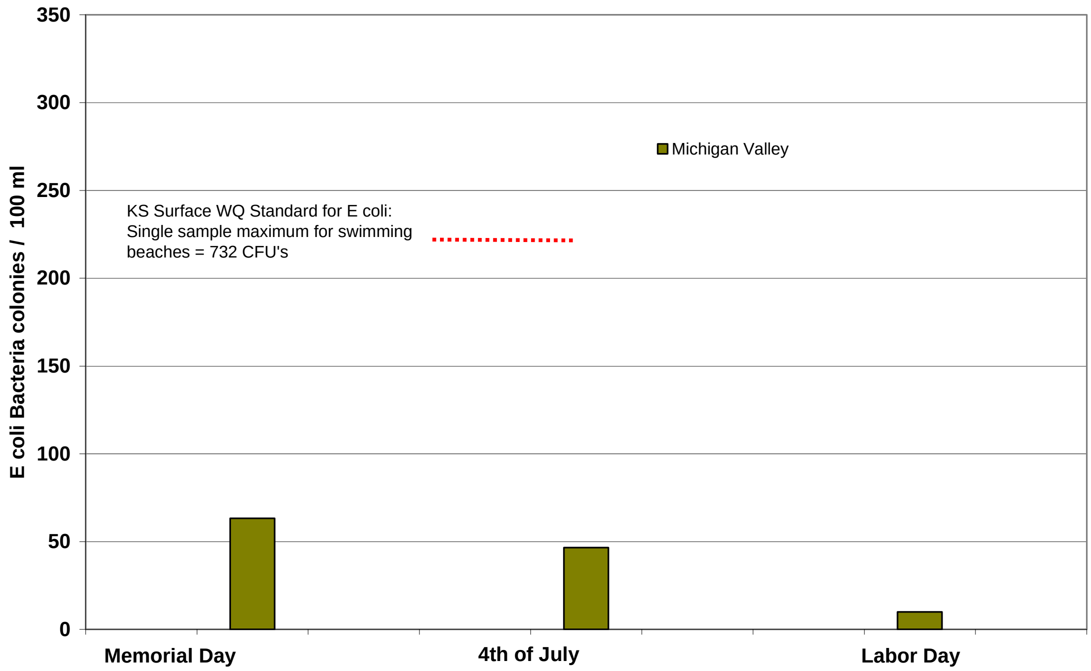


Figure 14.10. Fecal bacteria colonies per 100 ml samples from beach samples collected prior to major holidays at Harry S Truman Lake during 2006.

14.3.3 Outflow

Outfall samples were not collected from Pomona Lake during 2006. All historic data is discussed in context with the lake samples above.

14.4 Future Activities and Recommendations

Sampling activities for 2007 will include continuation of 'ambient' monitoring from May through September, as well as conducting at least one summer vertical profile at each of the three lake sites. To more completely assess specific sub-watershed impacts on Pomona Lake, an additional lake site will be added in 2007. This site (Site 14) will be located in the northeast cove near the confluence of Wolf and Valley Brook Creeks. Due to concerns of potentially toxic bluegreen algae, phycocyanin concentrations will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Participation and data sharing efforts will continue with the Pomona WRAPS group.

15 Rathbun Lake

15.1 General Background

Rathbun Lake was impounded in 1969 and reached multipurpose pool level on 10 October 1970. The main threats to water quality of Rathbun Lake are nutrients, sediment, bluegreen algae, bacterial contamination, and herbicides / pesticides. Rathbun Lake inflows are listed on Iowa's 303(d) impaired waters list due to low dissolved oxygen and nutrients. To address watershed landuse - water quality issues, the Rathbun Land and Water Alliance (RLWA, www.rlwa.org) was formed. Members include the Rathbun Rural Water Association, Soil and Water Conservation Districts and County Governments within the Rathbun Lake watershed. Partners include the Iowa Farm Bureau, Iowa Department of Natural Resources, Iowa Dept of Agriculture, Iowa State University, NRCS, FSA, and the Corps of Engineers. The mission of the Alliance is to 'foster a voluntary approach driven by landowners, water users, and public and private organizations to protect and enhance land, water, and economic resources in the Rathbun region'. The Corps and Iowa DNR are involved in a Section 1135 project at Rathbun Lake. The project, to begin during FY07, is designed to stabilize bank erosion at six sites identified around the lake.

15.1.1 Location

Rathbun Lake is located approximately 120 km (75 miles) southeast of Des Moines in south central Iowa. The dam is located on the Chariton River at river kilometer 227 (river mile 142). The watershed is located in Appanoose, Wayne, and Lucas Counties. Historic water quality sites at Rathbun Lake include 4 lake, 1 outflow, and 15 inflow (Figure 15.1).

15.1.2 Authorized Purposes: Flood damage reduction, water supply, water quality improvement, recreation, and fish and wildlife management.

15.1.3 State Use Designations: Primary contact recreation uses, significant warmwater resource for aquatic life uses, high quality resource water.

15.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	926.0	345.5	21,000	
Multipurpose	904.0	190.7	11,000	155
Total		536.2		

Total watershed area:	549 sq miles (351,360 A)
Watershed ratio:	16.73 FC / 31.94 MP
Average Annual Inflow:	355,704 acre-feet
Average Annual outflow:	000 acre-feet
Average flushing rate:	0.78 years
Sediment inflow (estimated):	240 AF/yr
Water management Plan:	Approved 18 October 1981; revisions September 2005

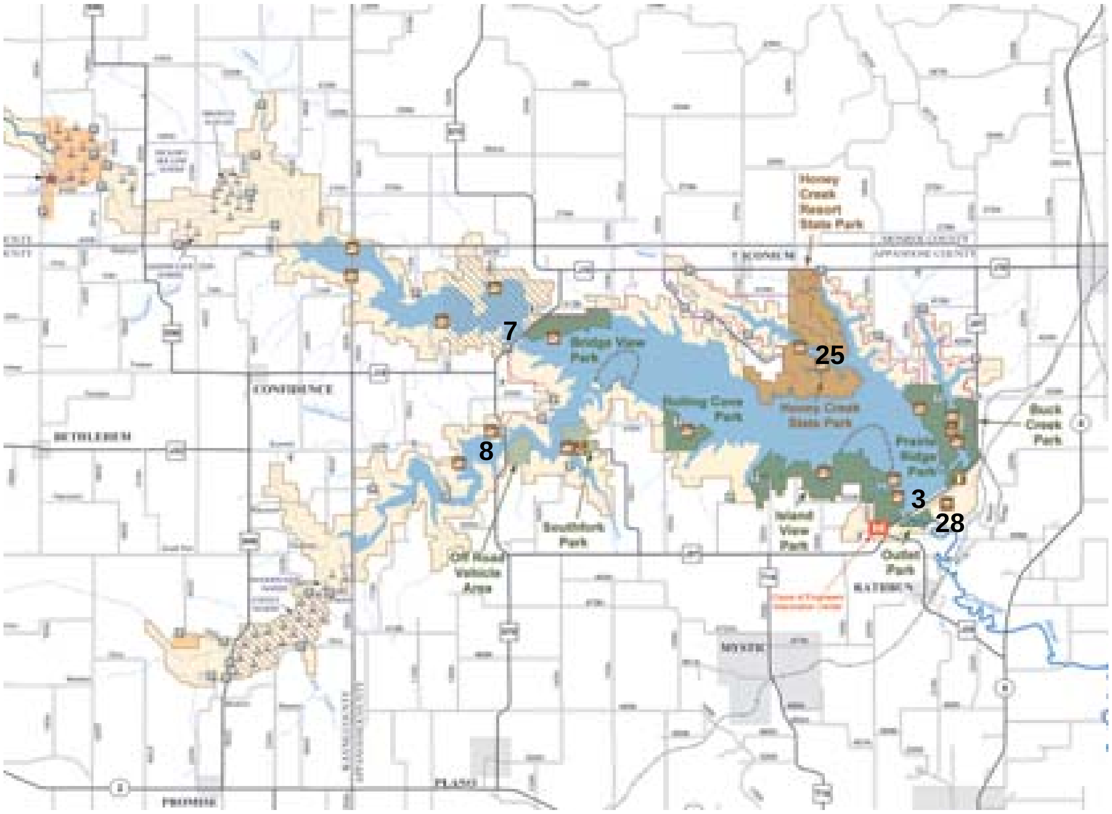


Figure 15.1. Rathbun Lake area map with sample site locations.

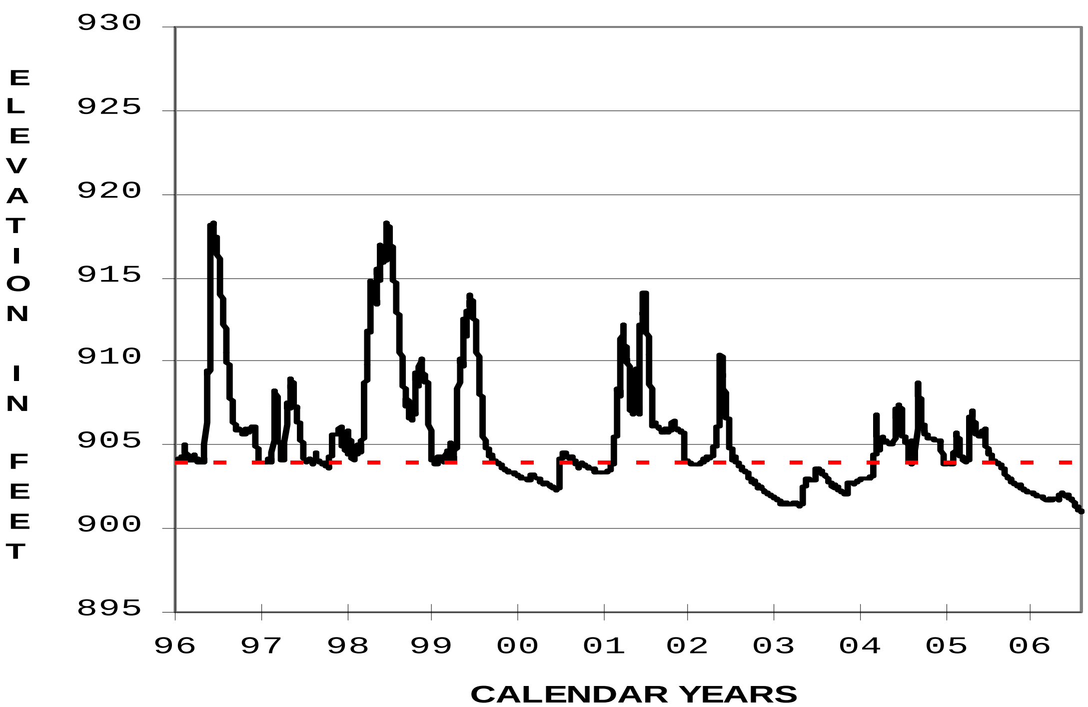


Figure 15.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 904.0 msl).

15.2 2006 Activities

Rathbun Lake was categorized as an 'intensive' lake during 2006, thus surface and bottom samples were collected at the four lake sites and the outlfow. Sample collections occurred from April through September, with vertical profiles recorded at all four sites during each trip. Rathbun Lake staff (OF-RA) providing field sampling assistance during 2005 included Paul Egeland. Bill Duey, OF-RA Operations Manager, provided insight and background regarding Rathbun Lake. Data has been shared with the Rathbun Land and Water Alliance, Iowa State University, and Iowa Dept of Natural Resources. Input has been provided into proposed watershed monitoring efforts and proposed changes in the operations manual.

15.3 2006 Data

Comparative historic water quality data consists of monthly (April – September) samples collected from 1997 through 2006. Samples were collected at inflow, lake, and outflow sites from April through September, 2006.

15.3.1 Inflow

Inflow samples were collected by Iowa State University (Dr John Downing) and analyzed by both Iowa State University Limnology Lab as well as the USACE lab in Omaha. Historically, sediment, nutrient, and herbicide contaminants have been of major concern related to inflows into Rathbun Lake.

15.3.2 Lake

Total nitrogen (TN) median concentrations and chlorophyll a values indicate Rathbun Lake is eutrophic. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Monthly and annual variability in total nitrogen is evident at all sites (see Figure 15.3 for Site 8 as an example). Median concentrations range from 0.81 – 1.49 mg/L TN (Figure 15.4), with highest concentrations present in samples from the South Fork Chariton River arm (Site 8). All median values exceed EPA's proposed ecoregional nutrient criteria value of 0.36 mg/L TN. The measured values are typical for agricultural watersheds within the district.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median total phosphorus concentrations ranged from 0.04 – 0.12 mg/L for surface samples collected between 1997 and 2005 at Rathbun Lake (Figure 15.5). These values do exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L. Monthly and annual variability in total phosphorus is evident at all sites, as is depicted in Figure 15.6 (Site 8). Mean TP concentrations from the lower lake sites are typical of clearer district lakes.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the

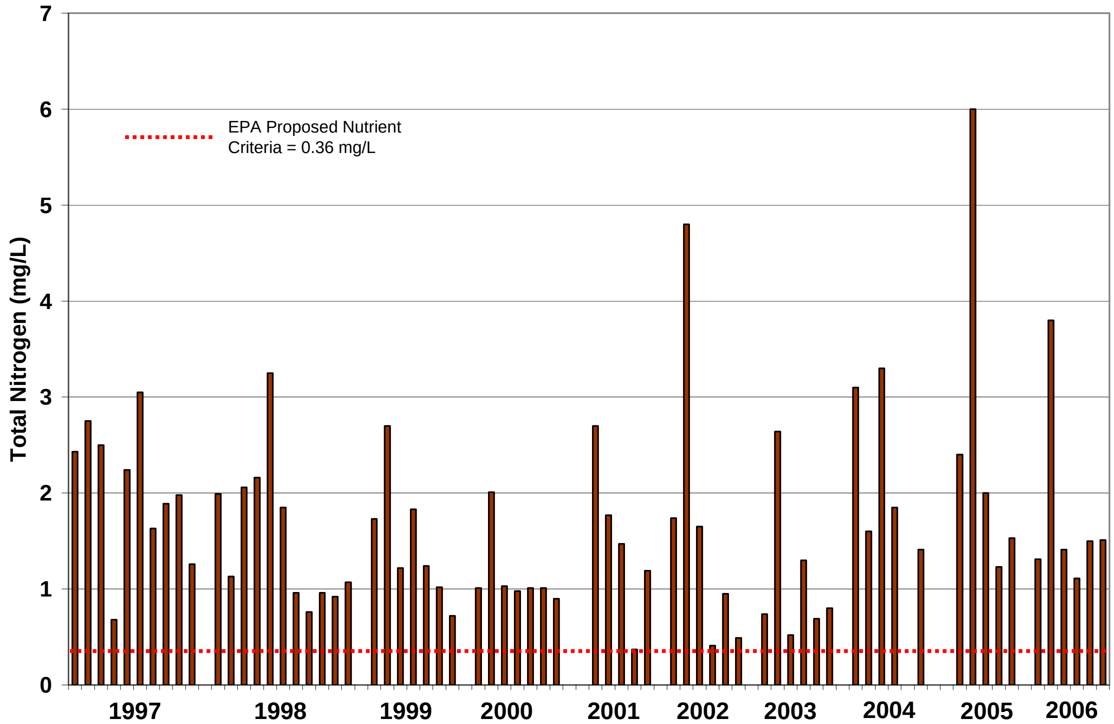


Figure 15.3 Total nitrogen concentrations by sample date collected from surface water samples at Site 8 (Southfork of Chariton River arm) in Rathbun Lake from 1997 through 2006.

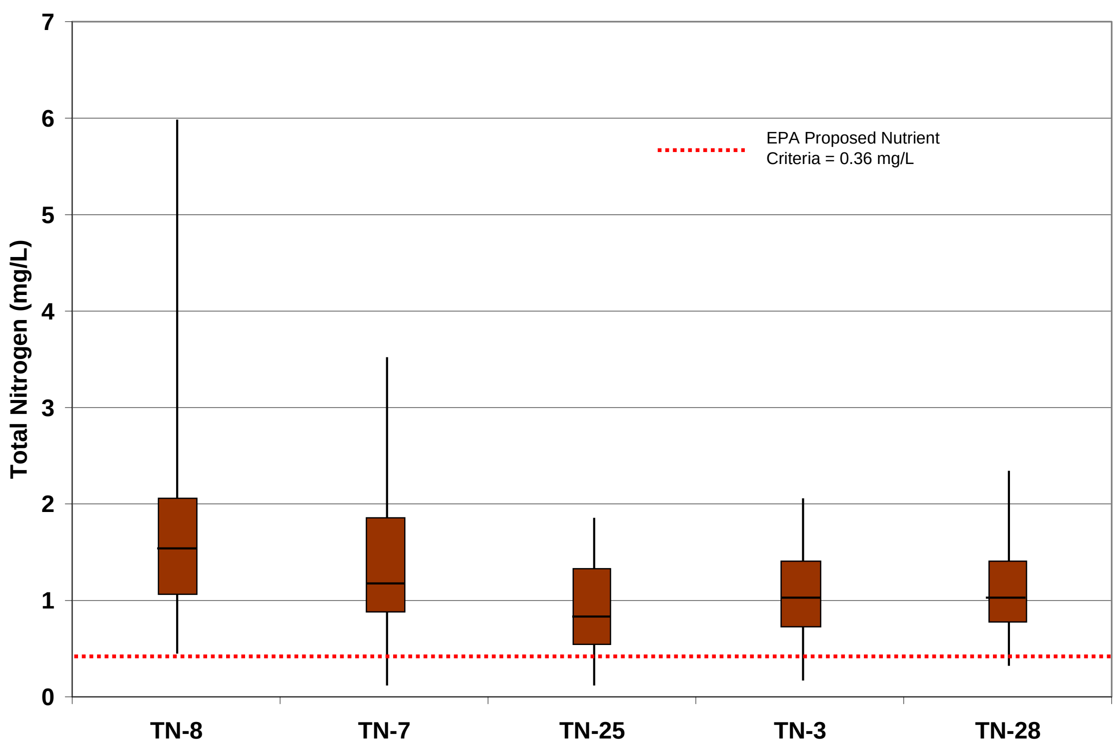


Figure 15.4. Box plots of surface water sample total nitrogen concentrations measured by site from 1997 through 2006 at Rathbun Lake.

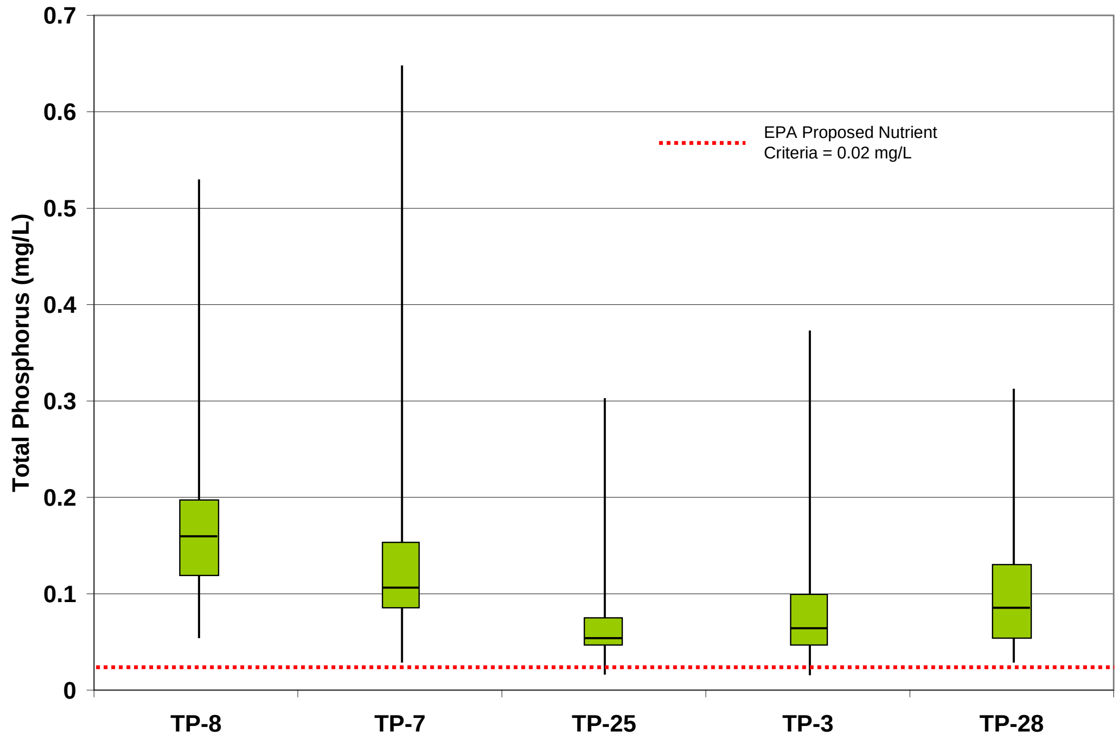


Figure 15.5. Box plots of surface water sample total phosphorus concentrations measured by site from 1997 through 2006 at Rathbun Lake.

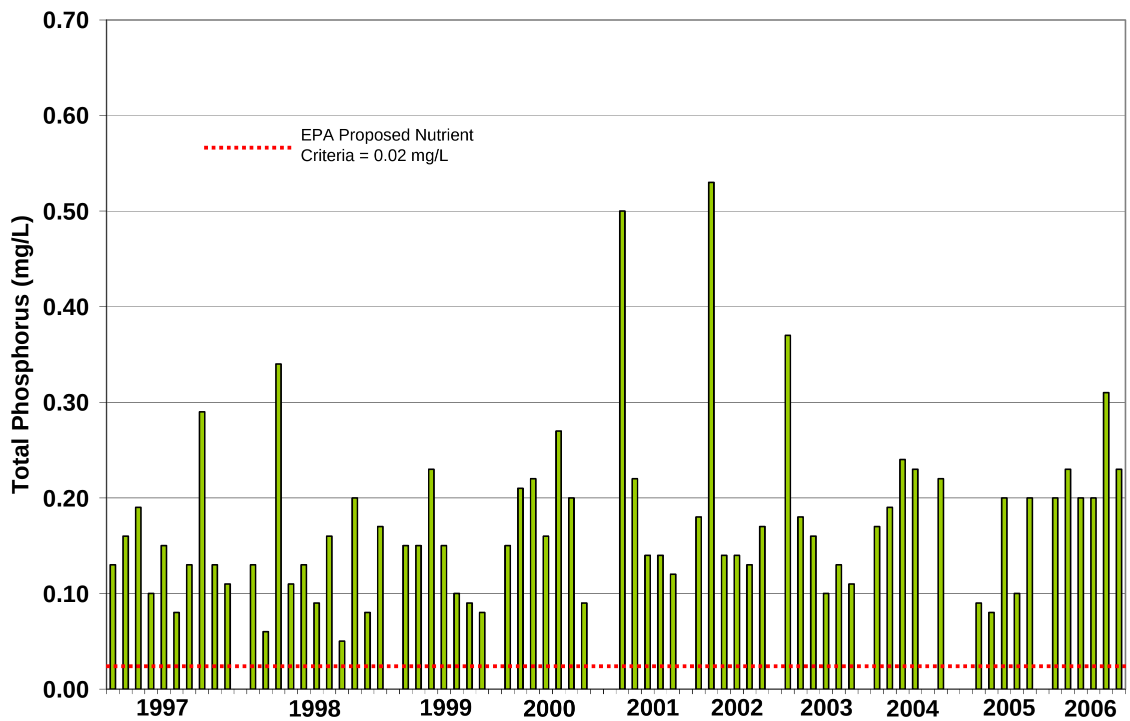


Figure 15.6 Total phosphorus concentrations by sample date collected from surface water samples at Site 8 (Southfork of Chariton River arm) in Rathbun Lake from 1997 through 2006.

TN:TP ratio at all sites; see Figure 15.7 as an example at Site 3. Median TN:TP ratios were < 12 at both upper lake sites (Sites 7 and 8) but slightly higher at lower lake sites (Figure 15.8). These values indicate the lake is at risk for cyanobacteria blooms. Microcystin toxins were detected at Rathbun Lake during 2000 and 2001 (Dr. Jennifer Graham, USGS, personal communication).

Rathbun Lake exhibited longitudinal differences in chlorophyll *a* concentrations by site from uplake to lower lake (Figure 15.9), which would be expected due to sediment and nutrient inflows. The highest chlorophyll *a* concentrations are consistently measured at Site 8 (median = 19.1 ug/L), while Site 7 and Site 25 are similar in median concentrations (median = 12.4 and 10.7 ug/L, respectively).

Secchi depth measurements (water clarity) also exhibited a longitudinal gradient from uplake to downlake (Figure 15.10). Significantly higher water clarity (0.78 m) was measured at Site 3 (Tower) and Site 25 (Honey Creek arm), whereas very limited clarity (0.24 – 0.37 m) was measured Site 8 (South Fork Chariton) and 7 (Chariton River arm), respectively.

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 15.11 depicts vertical distribution of phycocyanins measured at Site 3 (Tower) from June through September. Elevated concentrations were prevalent throughout the entire water column during June, and declined during July and September. The highest concentrations were typical of other lakes within the district.

Between 1997 and 2006, median atrazine concentrations (1.12 – 1.54 ug/L) were less than EPA's drinking water maximum contaminant level (MCL) of 3 ug/L (Figure 15.12). However, individual samples measured from surface samples during this period were significant enough to exceed the MCL. Figure 15.13 depicts sample concentrations measured by sample date at Site 8 (South Fork Chariton River) between 1997 and 2006. Concentrations exceed the MCL during most spring run-off events at Site 8; concentration of 24 ug/L was measured from Site 8 during 2006. The MCL has only been exceeded at Site 7 on limited occasions, while samples have never exceeded the MCL at Site 25.

Cyanazine exceeded EPA's drinking water maximum contaminant level (1 ug/L) at all sites during 1997 and up lake sites during 1998. No value has exceeded 1 ug/L at any site since 1998.

Glyphosate was monitored at all lake and outflow sites during 2006 to provide background data. Concentrations ranged from 0.13 – 0.23 ug/L, which well below EPA's drinking water MCL of 700 ug/L.

Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August 2006 at all lake sites (371 – 2475 ug/L) except Site 3 (299 ug/L); Site 28 (outfall) exceeded the SMCL (31 ug/L. Bottom samples exceeded the SMCL at all lake sites (311 – 2931), with highest concentrations measured at Sites 7 and 8. Implications are directed at drinking water facilities related to taste and staining issues. In addition,

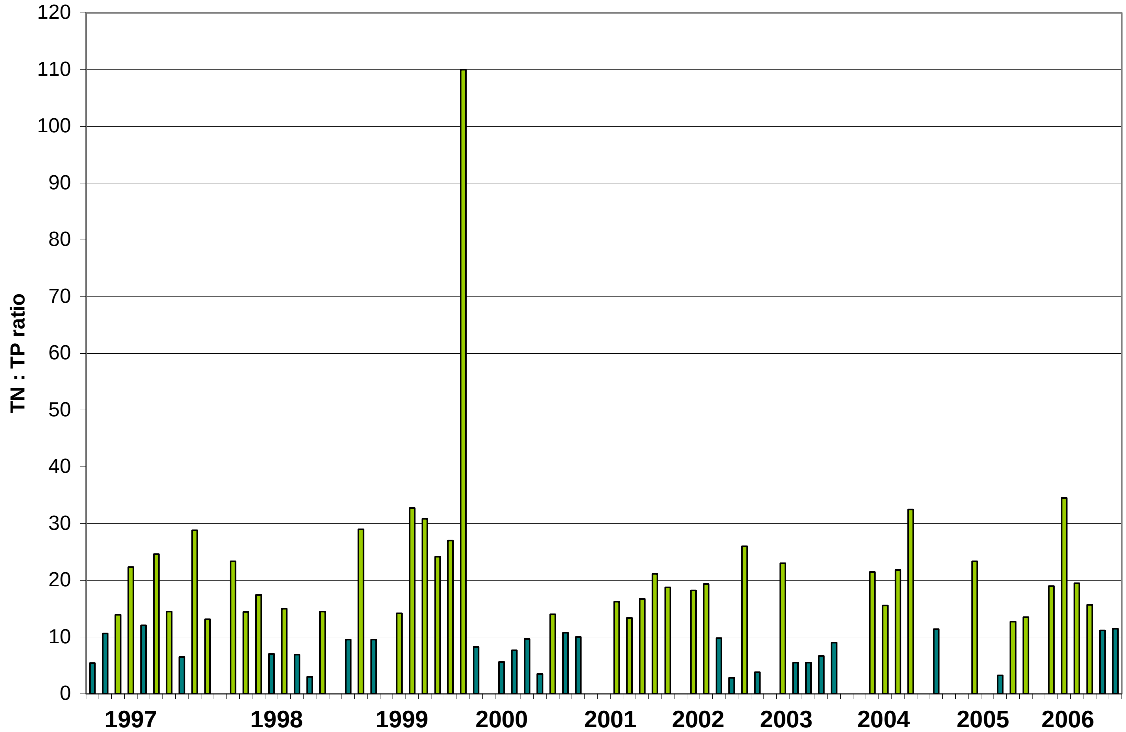


Figure 15.7. Graph of total nitrogen : total phosphorus ratio (TN : TP) by sample date from 1997 through 2006 at Site 3 (Tower) in Rathbun Lake.

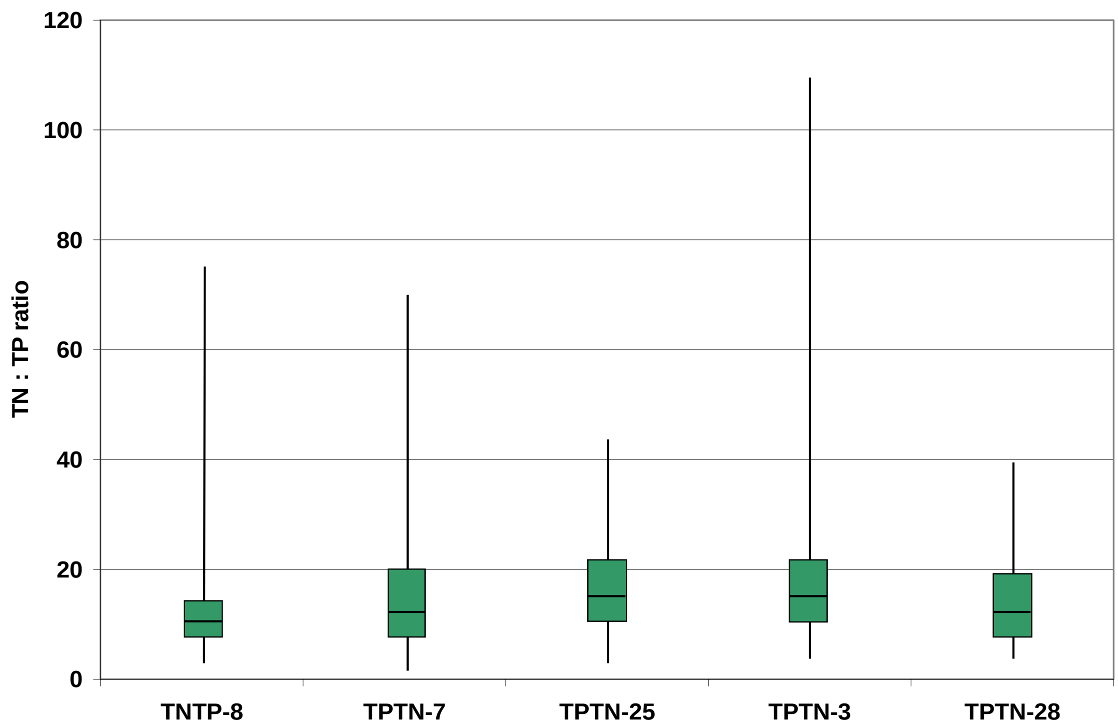


Figure 15.8. Box plots of total nitrogen : total phosphorus (TN : TP) ratio by site from 1997 through 2006 at Rathbun Lake.

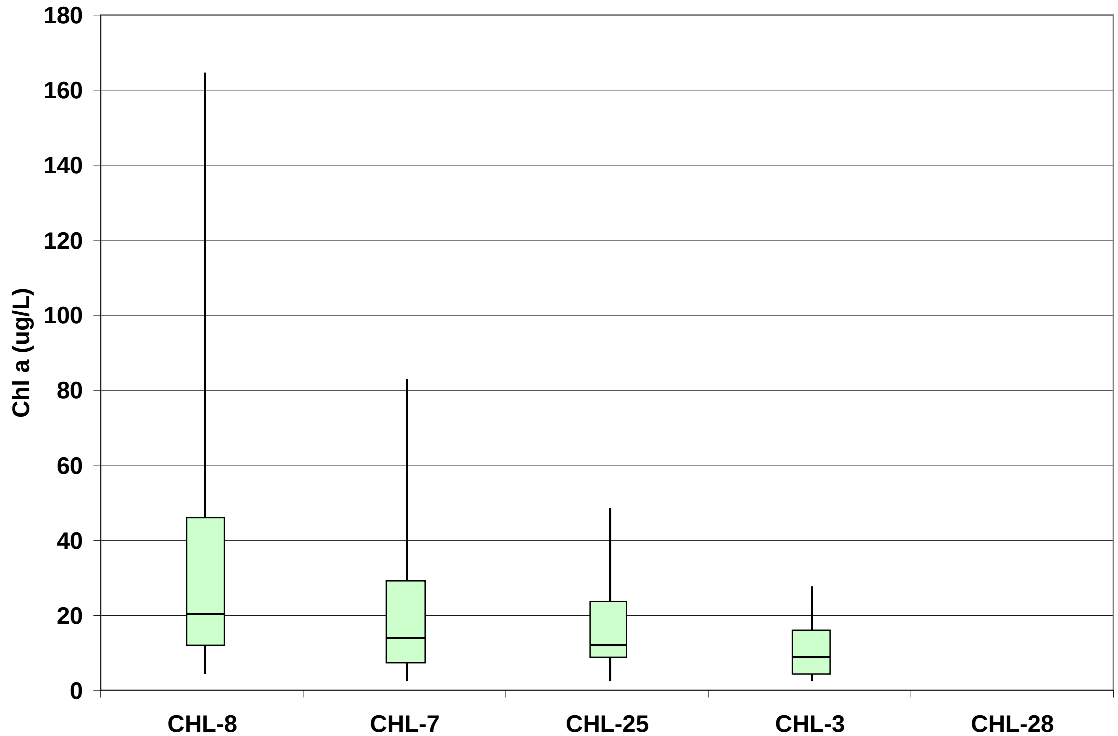


Figure 15.9. Box plots of chlorophyll a concentration measurements by site from 1997 through 2006 at Rathbun Lake.

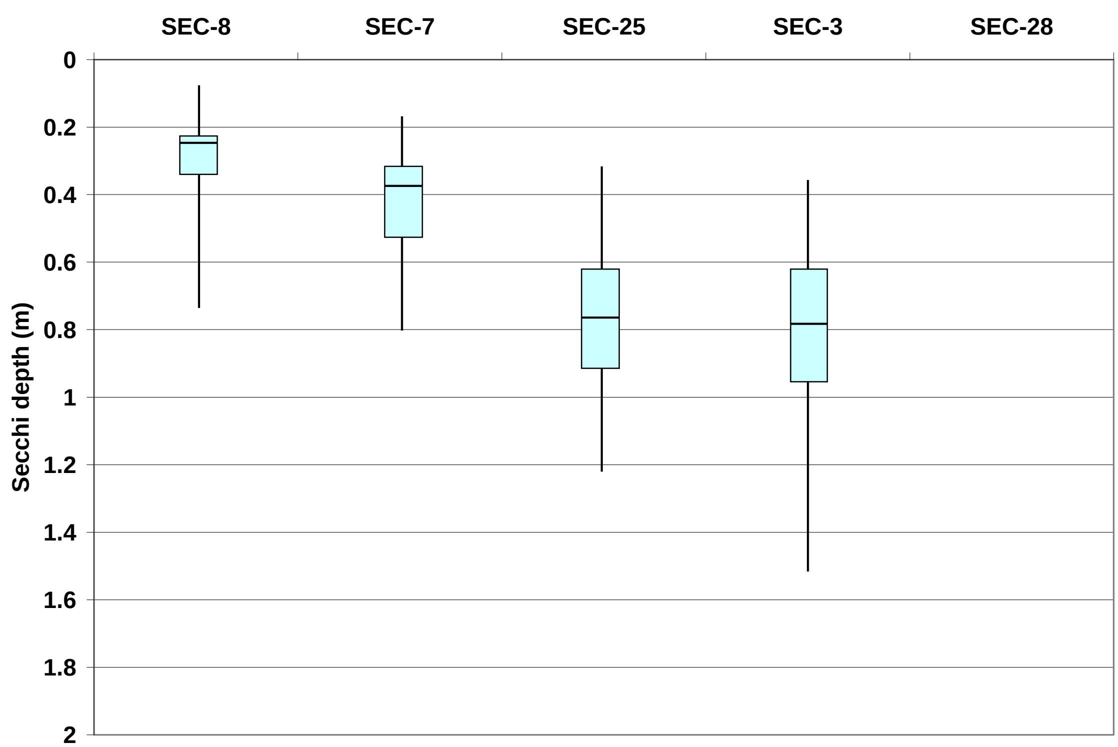


Figure 15.10. Box plot of secchi depth by site from 1997 through 2006 at Rathbun Lake.

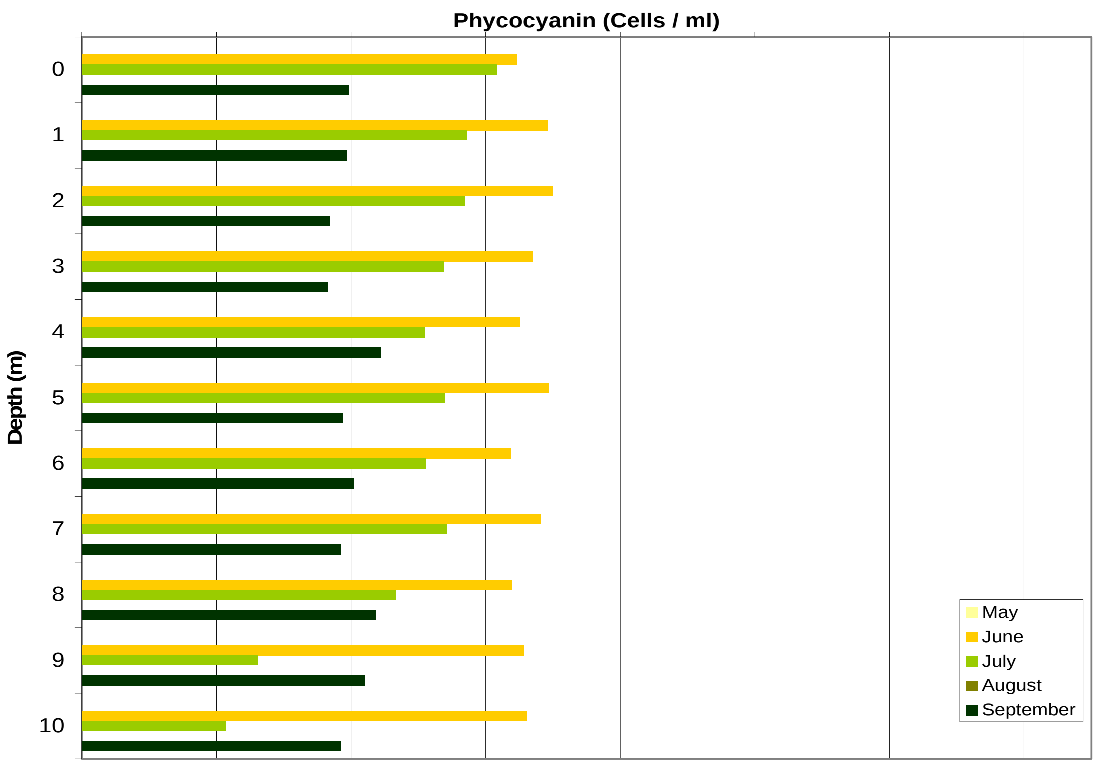


Figure 15.11. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Rathbun Lake Site 3 (Tower) during 2006.

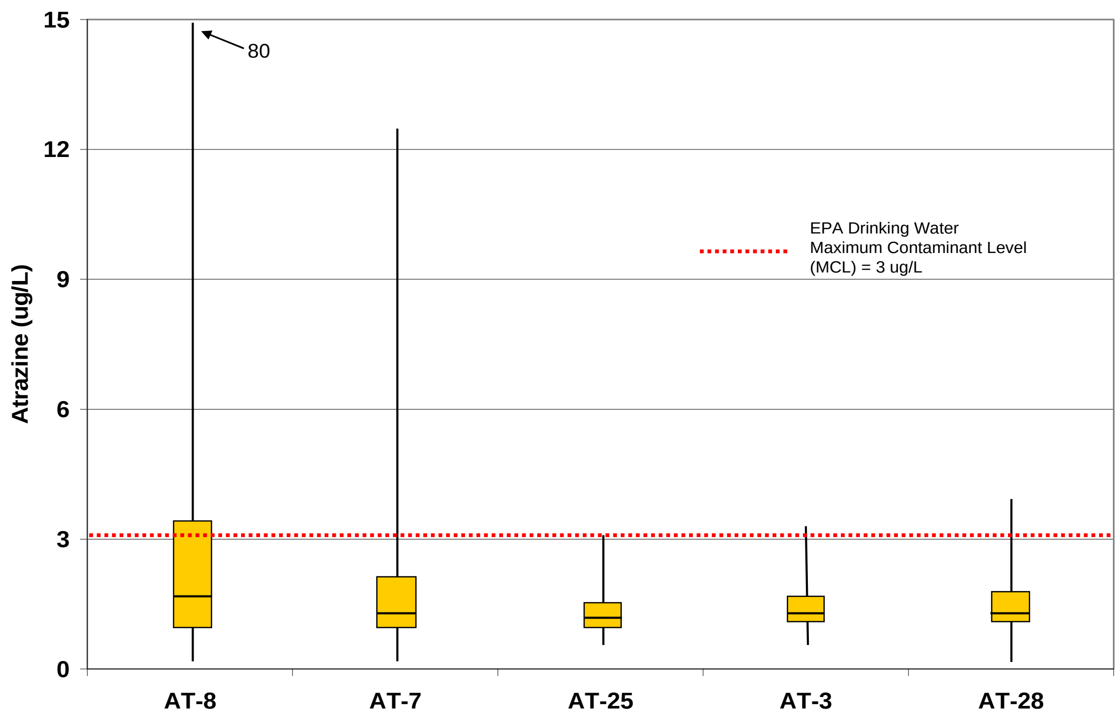


Figure 15.12. Box plots of atrazine concentrations from surface samples collected by site at Rathbun Lake from 1997 thorugh 2006.

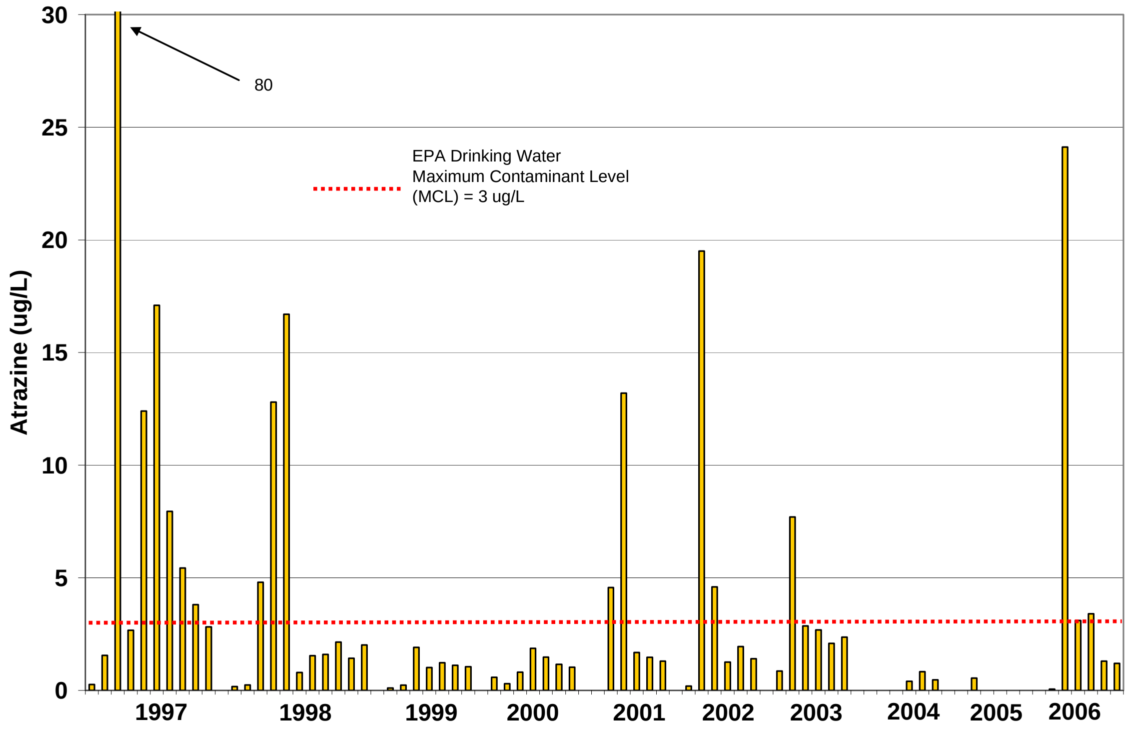


Figure 15.13 Atrazine concentrations from surface water samples by sample date at Site 8 (South Fork Chariton River arm) in Rathbun Lake from 1997 through 2006.

surface samples collected at lake sites and outflow during August 2006 exceeded EPA's SMCL for manganese (50 ug/L). Sample concentrations ranged from 81 – 564 ug/L, with highest concentrations measured at up lake sites. Implications are directed at drinking water facilities due to taste and stain issues. Bottom samples also exceeded the SMCL at all lake sites (86 – 605 ug/L).

Vertical profiles were recorded during sample trips in April through July and September 2006. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake at Site 3 was weakly stratified both thermally and chemically during July (Figure 15.14). Lake stratification occurred between 8 – 10 m in depth. The lake was rather homogenous in terms of both temperature and dissolved oxygen during September.

Fecal bacteria (*E. coli*) samples were collected from all three beaches prior to major recreational season holidays during 2006. None of the mean samples exceeded the state standard for single sample whole-body contact (235 colonies / 100 ml)(Figure 15.15).

15.3.3 Outflow

Outflow samples were collected at Rathbun Lake from Site 28 during 2006. Summarized data from this site is included in discussions of lake sites listed above.

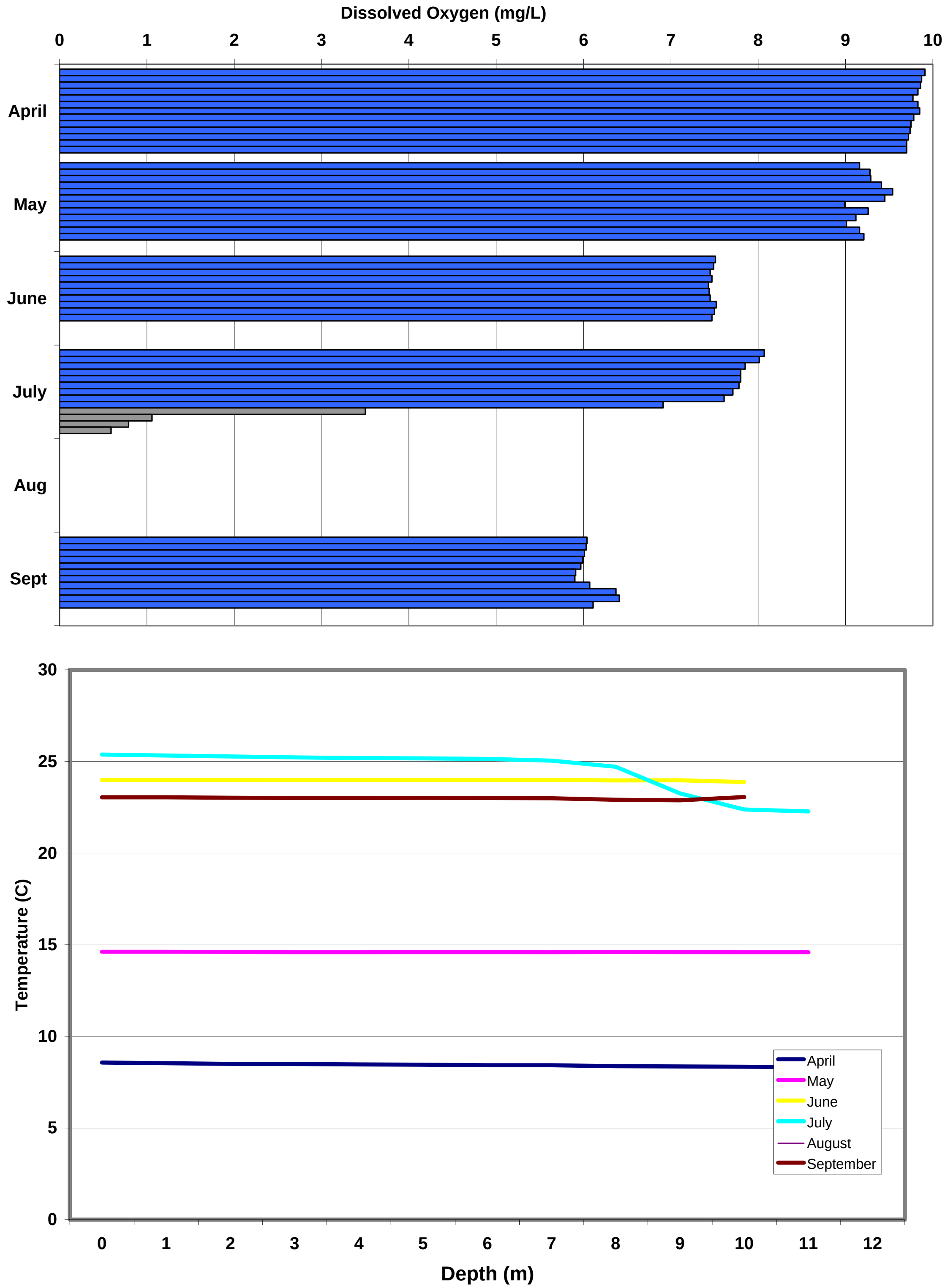


Figure 15.14. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from vertical profiles recorded at Site 3 (Tower) from June through September 2006.

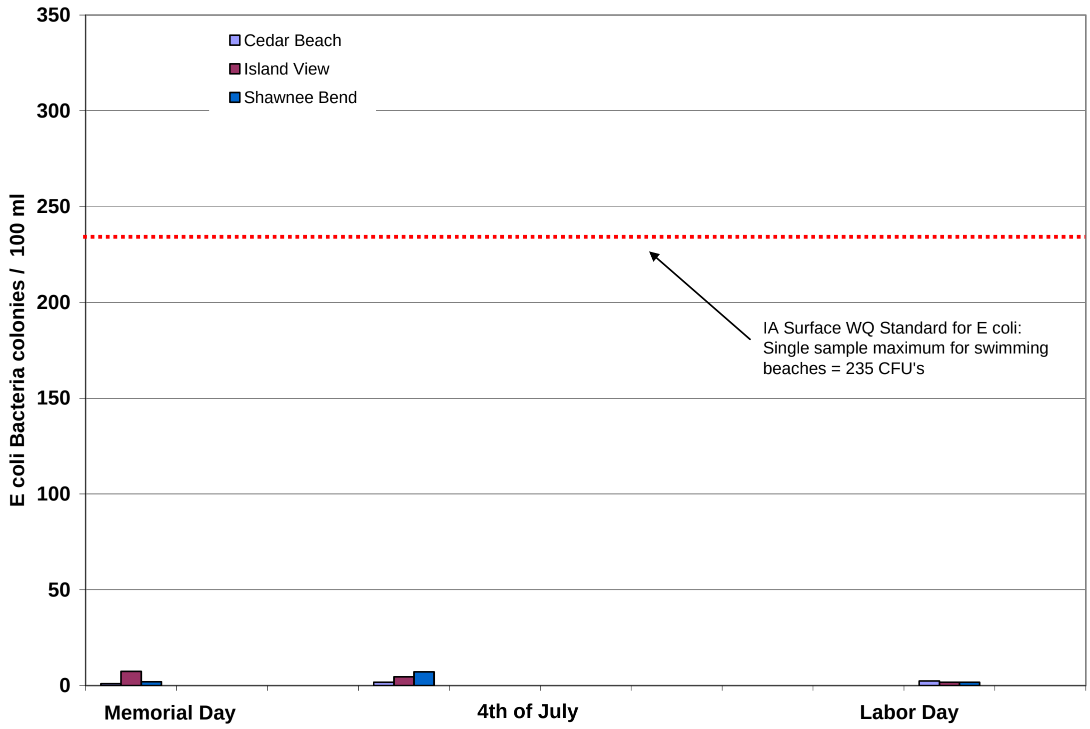


Figure 15.15. Mean fecal bacteria (E. coli) (colonies per 100 ml) results from samples at three swimming beaches collected from April through September during 2006 at Rathbun Lake.

15.4 Future Activities and Recommendations

Continue to cooperate with Iowa State University, Iowa DNR, and Rathbun Land and Water Alliance to monitor water quality parameters relative to BMP improvement programs within the watershed. Work with our partners to redesign the overall monitoring scheme for both lake and inflows to best capture ambient conditions present within the watershed. Sampling activities for 2007 will include transition to monthly 'ambient' monitoring from April through September, as well as conducting monthly vertical profiles at each of the four lake sites. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Beach monitoring will be conducted by the NWK Water Quality Program prior to main holidays during the recreational season. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc.

16 Smithville Lake

16.1 General Background

Smithville Lake was impounded in 1979 and reached multipurpose pool elevation on 11 June 1982. The primary water quality threats in the Smithville Lake watershed include nutrients, herbicides, sedimentation, and bacterial contamination. The lake is listed on the state's 303(d) list for water quality impairment due to mercury contamination. The Smithville Lake Watershed Coalition (SLWC), formed in 1997, is a citizen-based watershed group active within the Smithville Lake watershed. The SLWC developed a Missouri DNR approved watershed management plan during 2005 to address water quality issues related to nutrients, contaminants, sediment, and bacterial contamination. The Missouri Department of Conservation has conducted aquatic vegetation introduction efforts at the lake to since 1998. The Corps of Engineers Waterways Experiment Station and the Missouri Department of Conservation have worked together to reduce shoreline erosion resulting from water level fluctuations and wave action. Techniques include planting willow wattling bundles and coyier rolls along the shoreline to dissipate wave energy. This not only reduces shoreline erosion but also protects newly planted aquatic vegetation. Additional benefits of the aquatic vegetation plantings include creating spawning and nursery habitat for fish, as well as uptake of excess nutrients in the water. Enclosures are used around the plantings to reduce wave action and reduce damage by foraging rough fish, namely carp. Woody plant species, primarily willow, will be planted at higher elevations in hopes of holding soil in place in times when the lake pool fluctuates above multipurpose pool. A variety of woody tree and shrub species will be experimented with to determine which species are best adapted to the lake shore environment. The effort expended will pay great dividends in the future to improved water quality, fishing habitat, and the aesthetic value for Smithville Lake.

16.1.1 Location

Smithville Lake is located approximately 32 km (20 miles) north of Kansas City, Missouri (Figure 16.1). The dam is located at river kilometer 20.6 (river mile 12.9) on the Little Platte River, a tributary of the Platte River. The watershed covers over 126,000 acres within the counties of Clay, Clinton, and Dekalb. Historic water quality sample sites include 1 inflow, 3 lake, and 1 outlfow.

16.1.2 Authorized Purposes: Water supply, flood control, water quality improvement, recreation, and fish and wildlife management.

16.1.3 State Use Designations: Livestock and wildlife watering, protection of warmwater aquatic life and human health / fish consumption, whole-body contact recreation, boating and canoeing, drinking water supply.

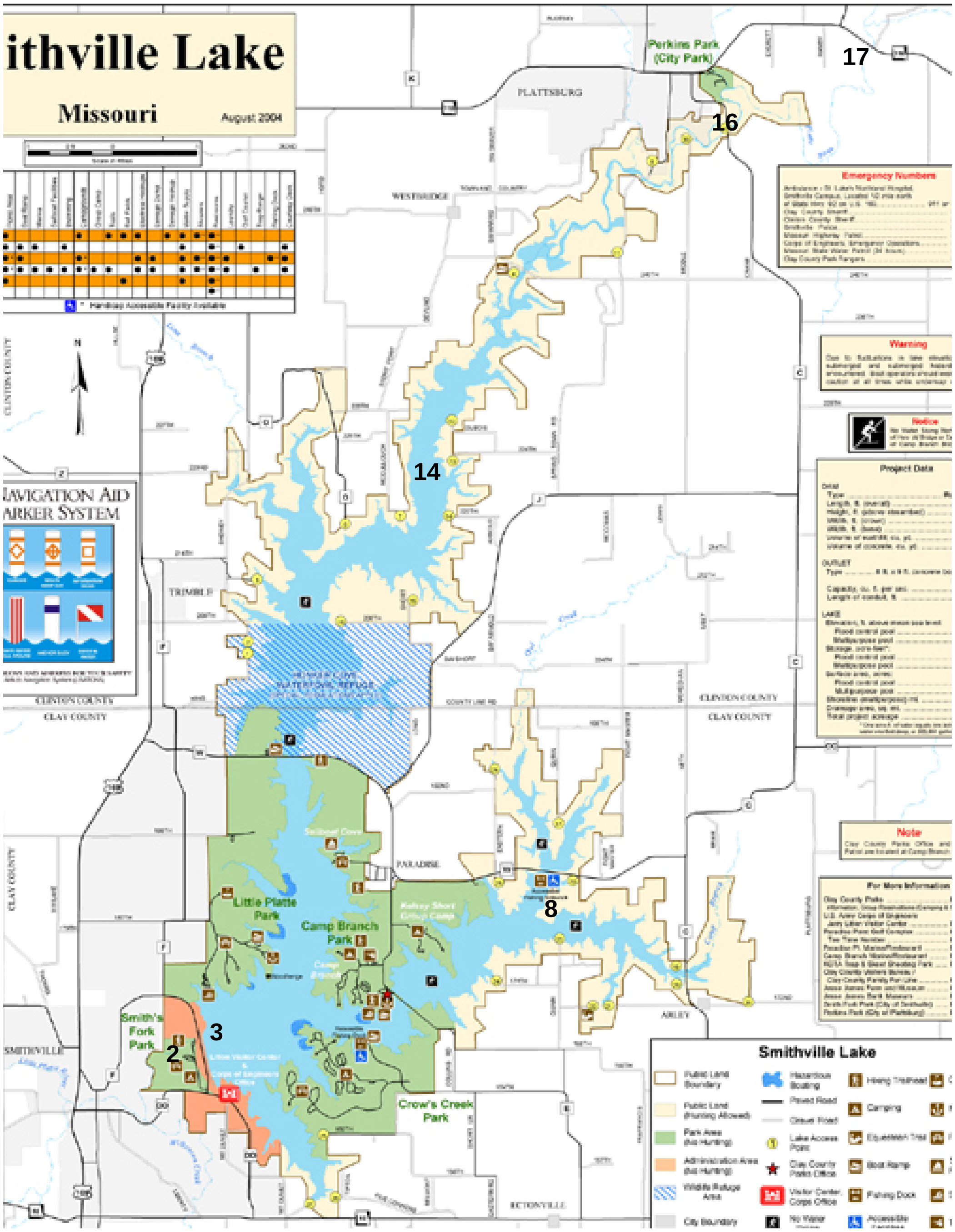


Figure 16.1.   Smithville Lake area map with sample site locations.

16.1.4   Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	876.2	101.7	10,000	
Multipurpose	864.2	139.8	7,190	175
Total		241.5		

Total watershed area:	213 sq miles (136,320 A)
Watershed ratio:	13.62 FC / 18.96 MP
Average Annual Inflow:	133,248 acre-feet
Average flushing rate:	1.18 yrs
Sediment inflow (measured):	4,987 acre-feet (1979 – 1993)
Water management Plan:	Approved 12 August 1979
Historic stage hydrograph:	1996 – 2006 (Figure 16.2)

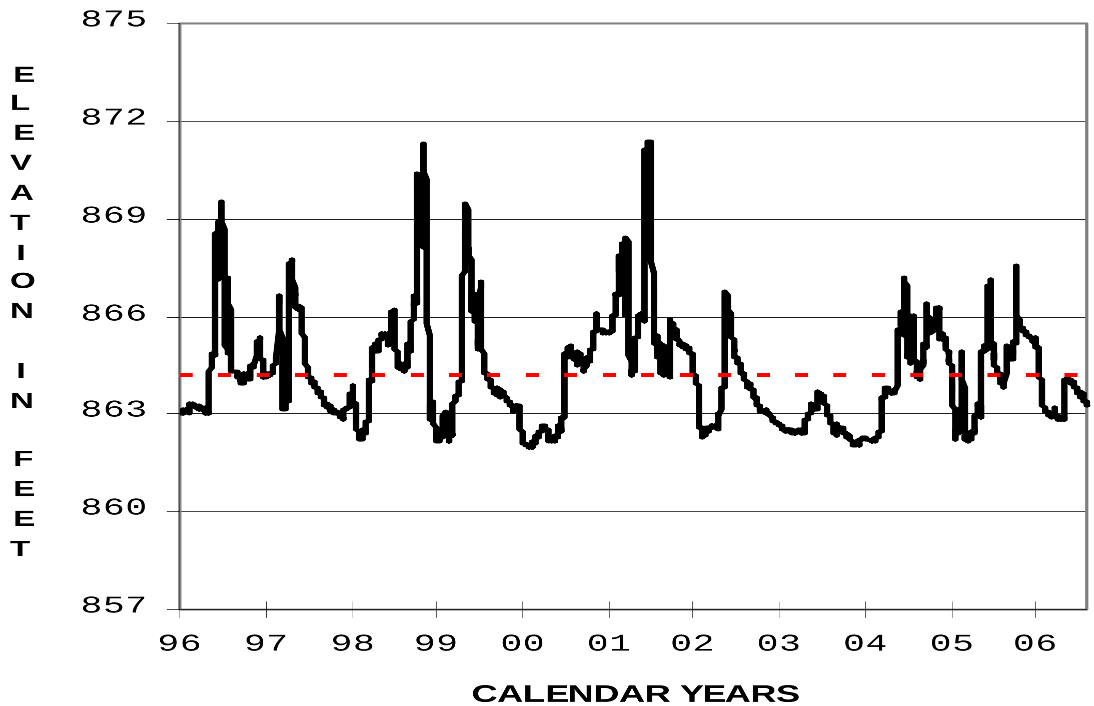


Figure 16.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 904.0 msl).

16.2 2006 Activities

Smithville Lake was categorized as an 'ambient' lake during 2006, thus lake and inflow sites were sampled (see Figure 11.1). An additional inflow site – Site 17 – was added during 2006 to provide additional data on water quality above Plattsburg. Samples were collected from April through September during 2006. Smithville Lake staff (OF-SM) providing field sampling assistance during 2006 was Derek Dorsey, Federal Park Ranger. Bruce Clark, OF-SM Operations Manager, provided insight and background regarding Smithville Lake.

16.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1997 through 2005. Samples were collected at inflow and lake sites from April through September, 2006.

16.3.1 Inflow

Inflow samples were collected from a two inflow sites -- Site 16 is located downstream from the city of Plattsburg, Missouri, while Site 17 is located just above Plattsburg. Data results will be discussed with lake specific data below.

16.3.2 Lake

Nitrogen is one of the most critical elements related to water quality. Sources of nitrogen within the watershed include: fertilizers, septic tanks / lagoons, and WWTP. Median total nitrogen (TN) concentrations from surface samples collected between 1997 and 2006 range from 0.74 – 0.91 mg/L (Figure 16.3). The highest median concentration and most variability are attributed to inflows from the upper watershed (Site 16). Although these median values are some of the lowest measured in the district, they do exceed EPA's proposed ecoregional nutrient criteria (0.36 mg/L). As expected, annual and monthly variability is very apparent for TN concentrations – see Figure 16.4 as an example from Site 14 (Little Platte arm).

Phosphorous is the other critical element related to water quality issues, especially related to algal communities. Phosphorous sources within the watershed include fertilizers (primarily bound to sediment), soaps / detergents, and waste byproducts. Median total phosphorus (TP) concentrations range from 0.05 – 0.1 mg/L from surface water samples collected from 1997 through 2006 (Figure 16.5). Similar to TN, the highest median concentrations and most variability are measured at the upper end of the lake (Site 16). All median TP concentrations exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L. Smithville Lake TP concentrations are typical of other large reservoirs in northern Missouri (LMVP 2004) and within the district.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites; see Figure 16.6 as an example at Site 3 (Tower). Median TN:TP ratios are < 12 for Sites 14 (Little Platte arm) and 8 (Camp Branch arm), indicating the lake is at risk for cyanobacteria blooms (Figure 16.7). Microcystin toxins have been detected at Smithville Lake during 2000 and 2001 (Dr. Jennifer Graham, USGS, personal communication).

Mean summer chlorophyll *a* concentrations collected during 2006 ranged from 27 to 42 ug/L, with highest concentrations measured at Site 14. These values are much higher than the long-term median values (11.5 ug/L - 22.5 ug/L)(Figure 16.8).

Differences in water clarity, as measured my secchi depth, exist between lake sites (Figure 16.9). Longterm median secchi depths range from 1.1 m (Site 3; Tower) to 0.62 m (Site 14; Little Platte arm). Water clarity measured during 2006 was very similar to long-term means by site. The only difference occurred during April when secchi depth measurements were more than 2x greater than average, which was an indication of a dry spring.

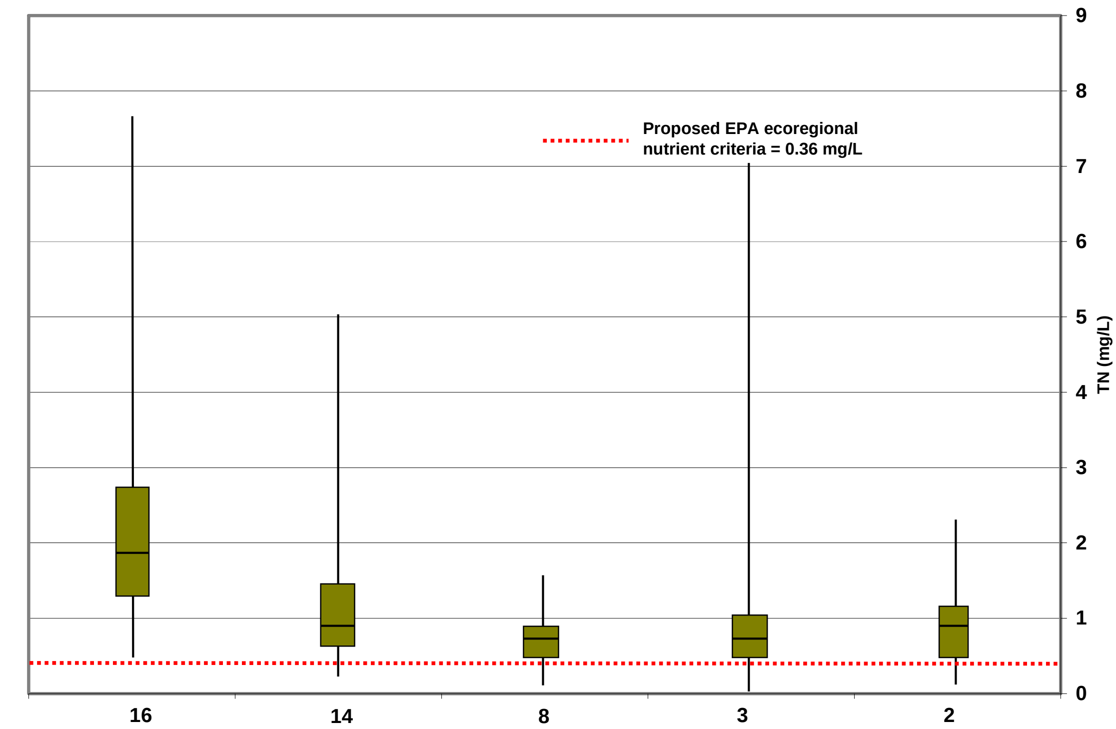


Figure 16.3. Box plots of surface water sample total nitrogen (TN) concentrations measured by site at Smithville Lake from 1997 through 2006.

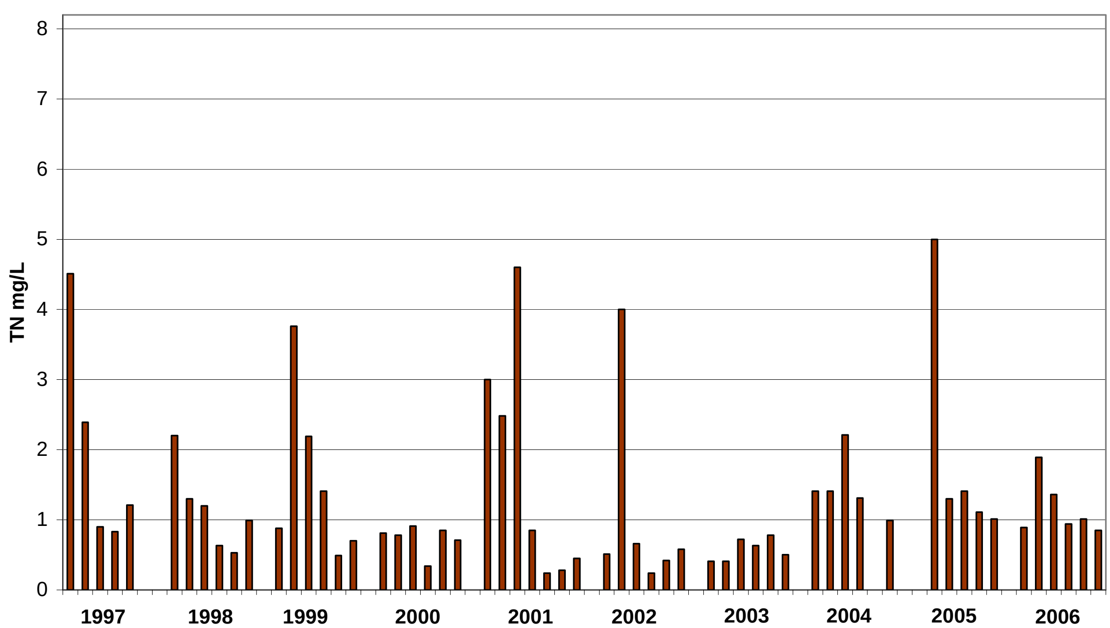


Figure 16.4. Total nitrogen (TN) concentrations from surface samples by date and year from Site 14 (Little Platte arm) in Smithville Lake from 1997 through 2006.

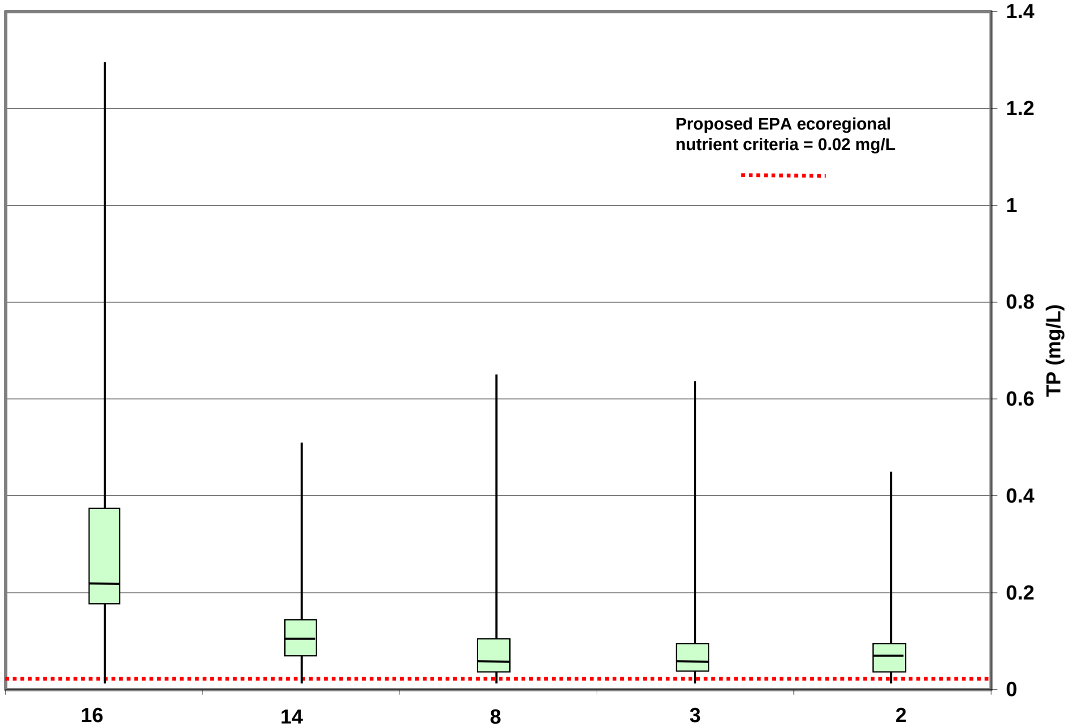


Figure 16.5. Box plots of surface water sample total phosphorus concentrations measured by site from 1997 through 2006 at Smithville Lake.

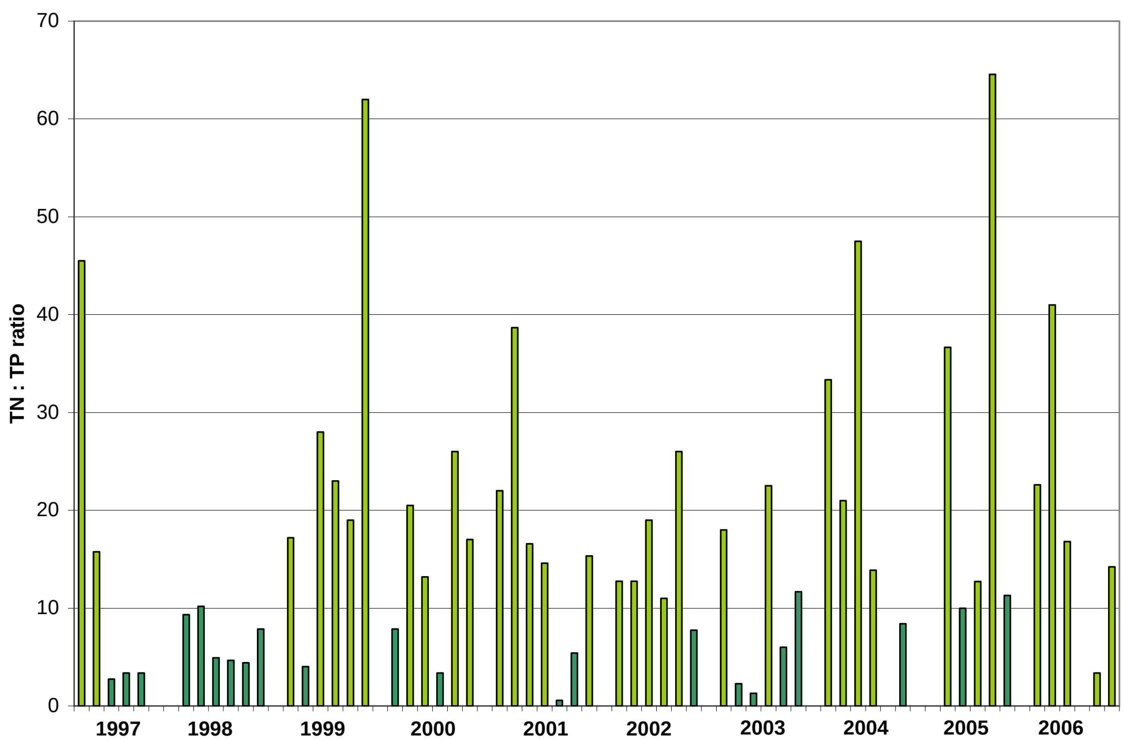


Figure 16.6. Graph of total nitrogen : total phosphorus (TN : TP) ratio by sample date from 1997 through 2006 at Site 3 (Tower) in Smithville Lake.

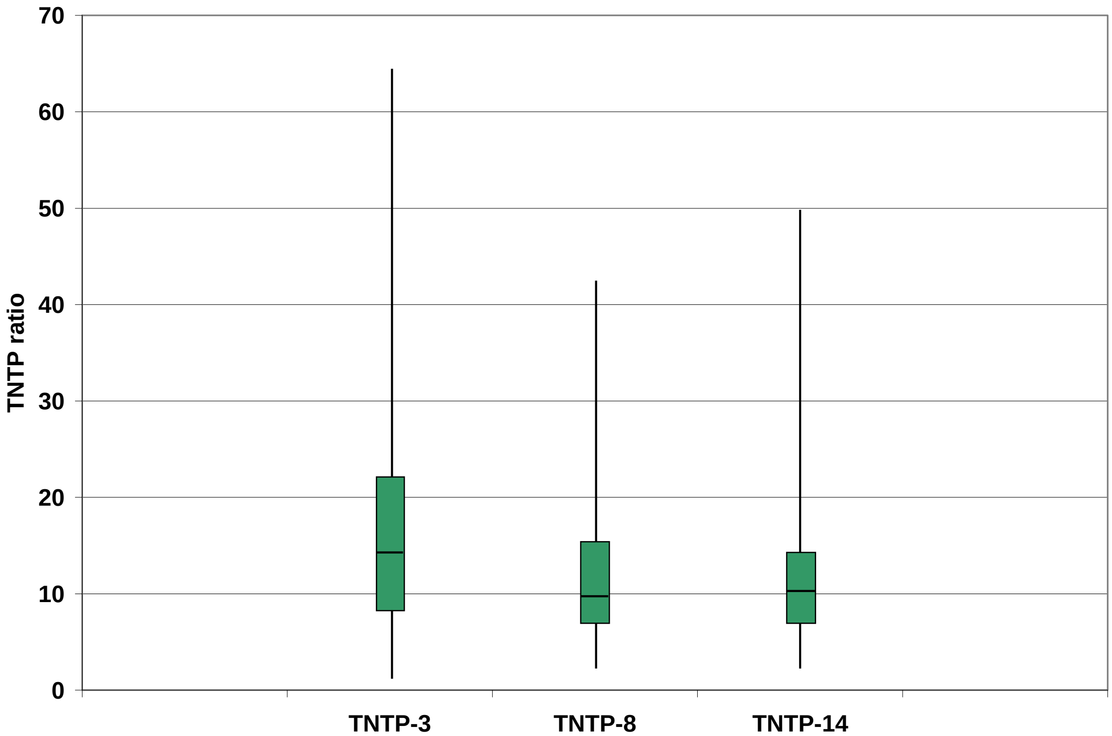


Figure 16.7. Box plots of total nitrogen : total phosphorus (TN : TP) concentrations by site from 1997 through 2006 at Smithville Lake.

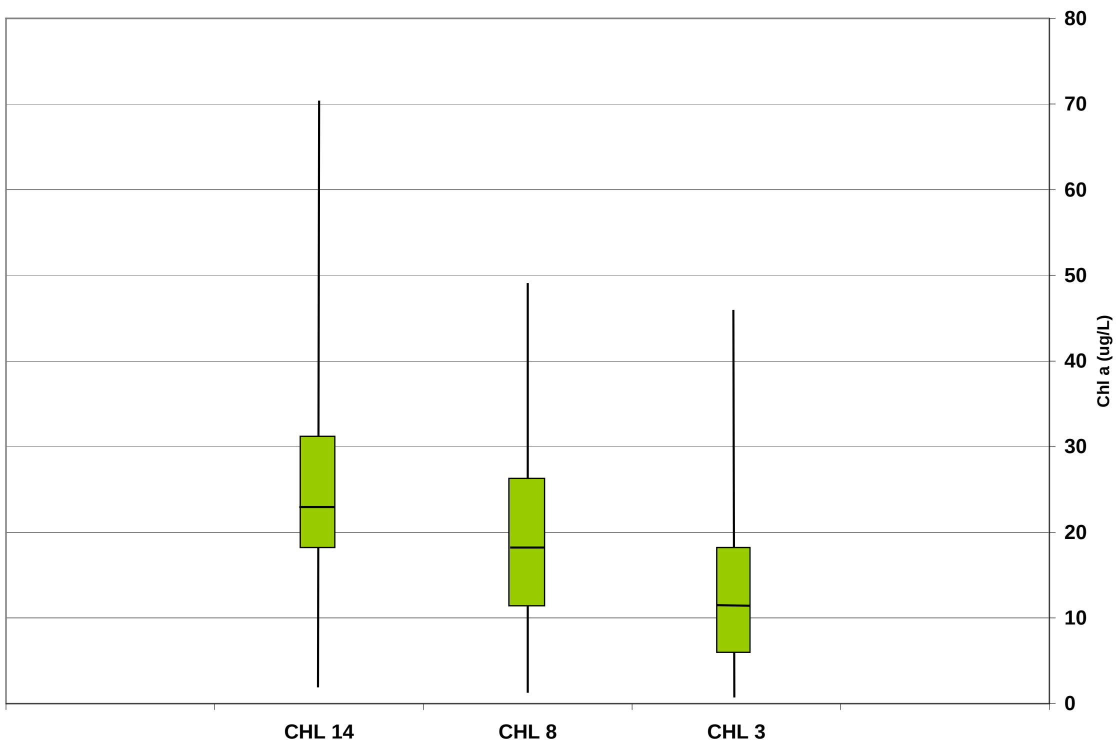


Figure 16.8. Box plots of chlorophyll a values measured by site at Smithville Lake from 1997 through 2006.

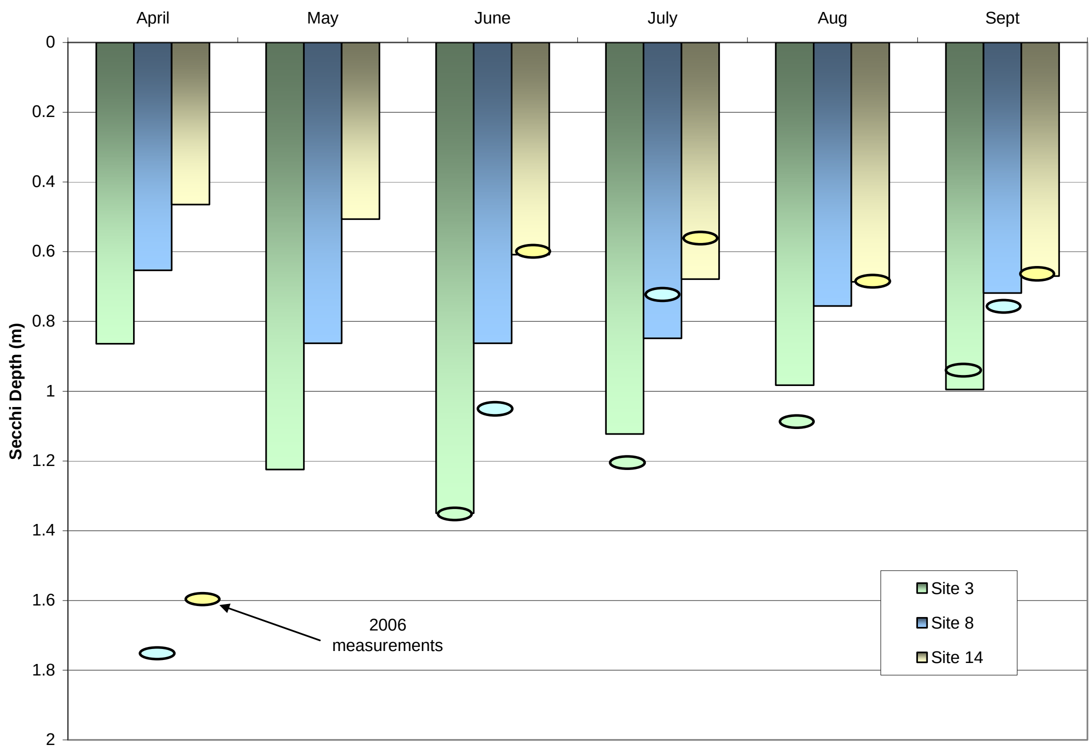


Figure 16.9. Plot of mean secchi depth measurements by site and month (bars 1997 - 2005) and 2006 measurements (circles) by site in Smithville Lake.

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column from May through September 2006. Such profiles provided information on monthly as well as within lake distribution changes. Figure 16.10 depicts vertical distribution of phycocyanins measured at Site 3 (Tower). Concentrations were highest in August, with higher concentrations above the thermocline. Concentrations in September were slightly lower, but distribution was more uniform throughtout the water column. These concentrations were some of the highest recorded within the district during 2006.

Major reductions in atrazine application rates (from 4.0 to 1.6 - 2.5 lbs active ingredient per acre), have resulted in improved water quality at Smithville Lake. The mean atrazine levels in Smithville Lake's raw water have declined from 2.37 ug/L in 1997 to 1.68 ug/L in 2004, which is less than EPA's drinking water maximum contaminant level (MCL) of 3 ug/L. Differences in median concentrations of atrazine from 1997 - 2006 are very noticeable between water quality monitoring sites at Smithville Lake (Figure 16.11). For reference, Site 2 is located just below the dam outflow, Site 3 is located within the lake near the dam (deep water site), Site 8 is located in the Camp Branch arm of the lake, Site 14 is located near Trimble, and Site 16 is located on the Little Platte River prior to the confluence of the lake. (Figure 16.1). The highest concentrations and most variability in data are from the Plattsburg site (Site 16), with median concentrations decreasing in a down-lake progression. When examined on a monthly basis during this time period, highest concentrations are measured during spring, which coincides with application, rainevents, and runoff. Figure 16.12 depicts monthly and annual

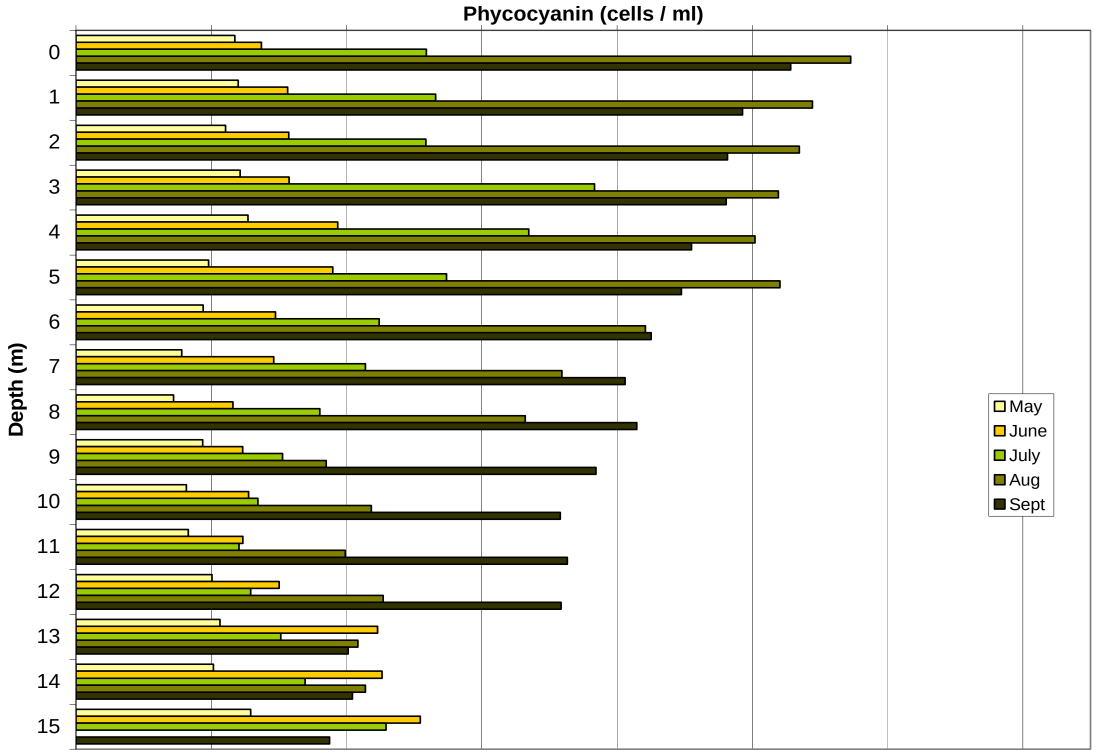


Figure 16.10. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Smithville Lake Site 3 (Tower) during 2006.

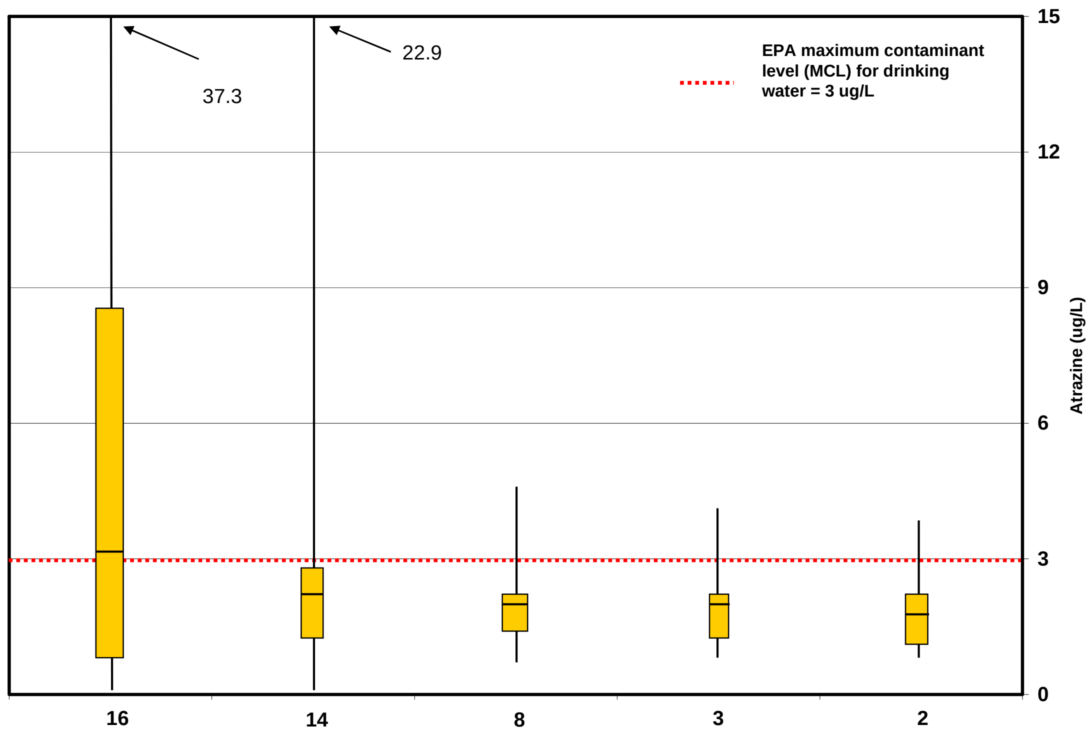


Figure 16.11. Box plots of surface water sample atrazine concentrations measured by site from 1997 through 2006 at Smithville Lake.

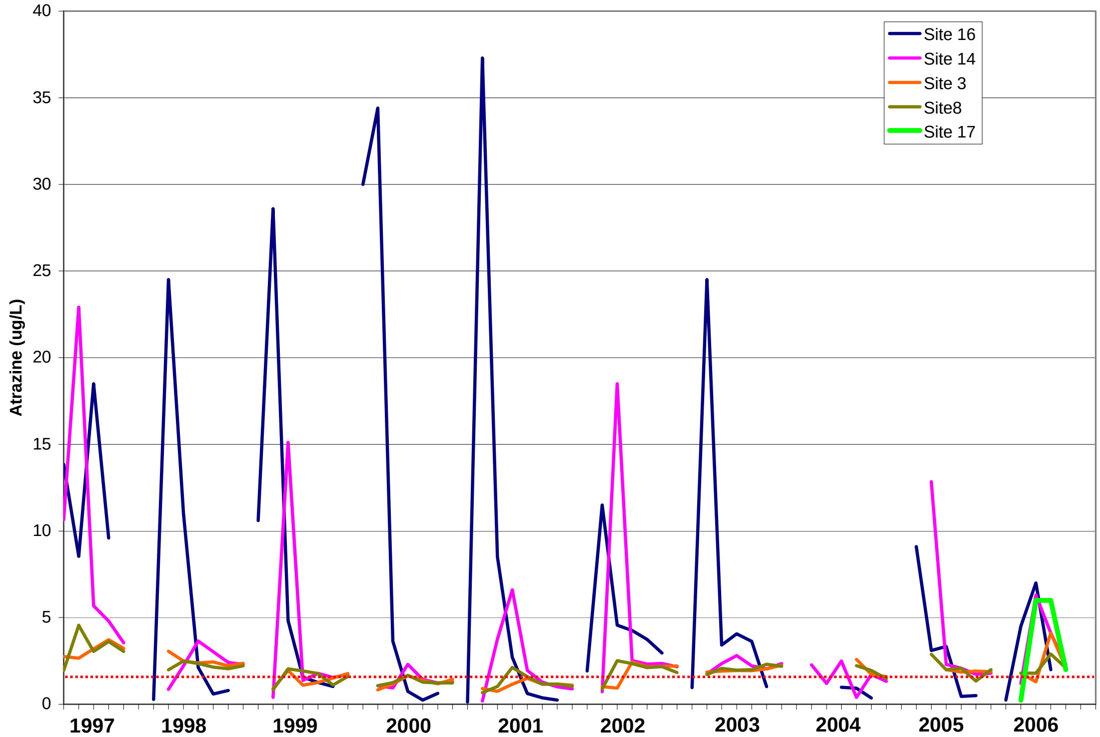


Figure 16.12. Atrazine concentrations by sample date collected by site (lake and inflows at Smithville Lake from 1997 through 2006.

differences in atrazine concentrations measured at all sites from 1997 through 2006. Spring rain events still produce concentrations that exceed the MCL, especially near the Plattsburg drinking water intake. This indicates that additional BMP's need to be installed in the upper watershed to reduce future herbicide runoff.

No metals data was collected during 2006. However, in 2005 total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August from Sites 2 (outflow), 14 (Little Platte arm) and 16 (Little Platte inflow). Concentrations ranged from 222 (Site 8) to 3648 (Site 16), indicating possible inputs upstream of the lake in the Little Platte. Implications are directed at drinking water facilities related to taste and staining issues. In addition, all surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L). Sample concentrations ranged from 59 – 240 ug/L, with highest concentrations measured at Site 16 (Little Platte inflow). Implications are directed at drinking water facilities due to taste and stain issues.

A lake profile can provide insight into depth of lake stratification and mixing depending upon the time of year and location within the lake. Profile parameters include temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on monthly profiles in 2006, stratification was prevalent from May through September (Figure 16.13). Both dissolved oxygen and temperature graphs indicate the lake was solidly stratified at a depth of 4m during both June and July. This transition from warm to cool waters is the thermocline – an area important to fishermen as well as water supply intakes! Within

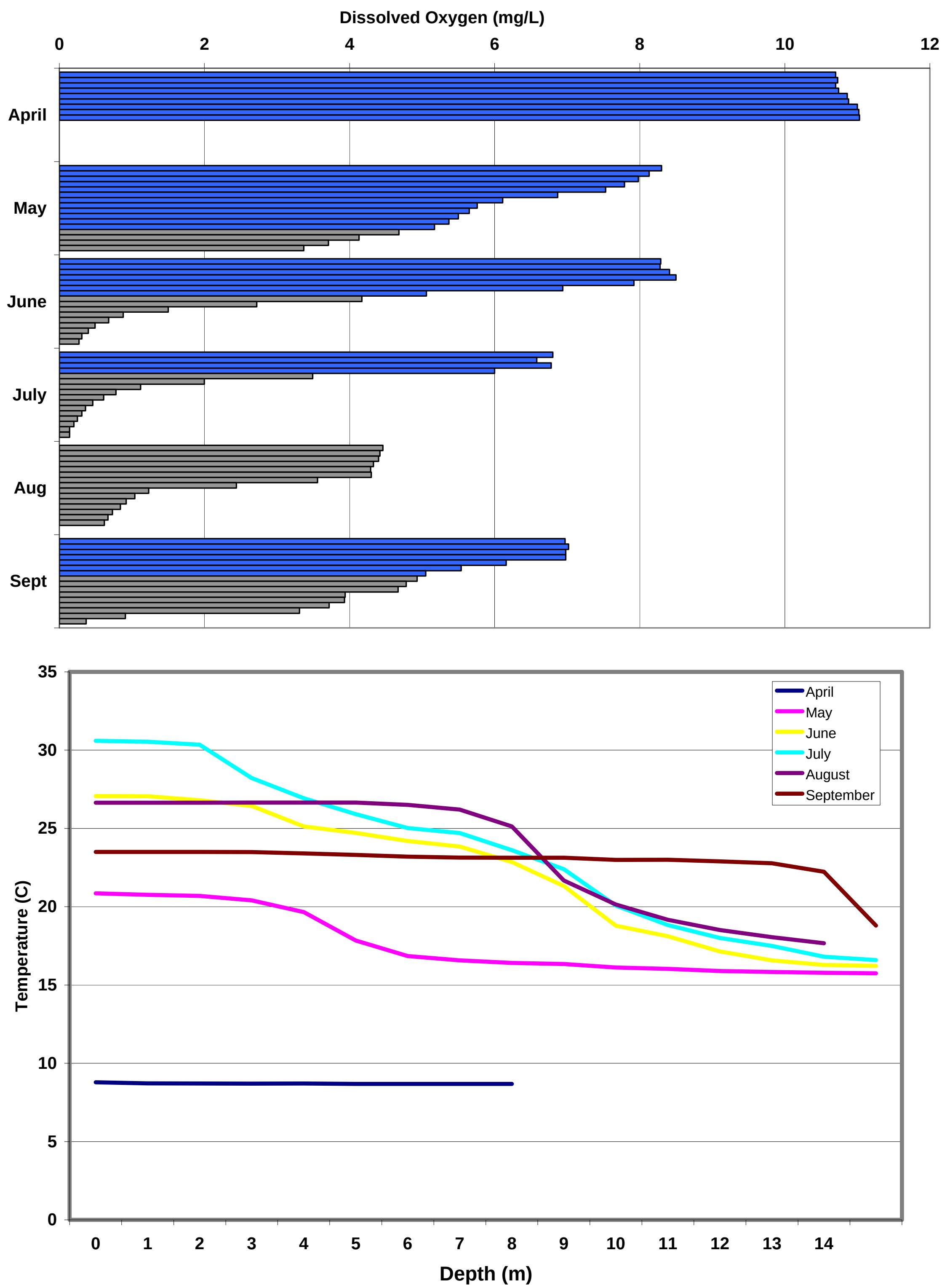


Figure 16.13. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from vertical profiles conducted during 2005 at Site 3 (Tower) in Smithville Lake.

this transition zone, available oxygen rapidly declines from 6-8 mg/L to nearly 0 mg/L. This anoxic layer (no oxygen) drives many water quality functions within the lake, including phosphorous release and ammonia buildup — these are released in fall when the lake undergoes 'turnover'. An increase in nutrients inputs into the lake ultimately reduces the depth at which the lake stratifies. This will impact depths at which fish can occupy (resulting in loss of habitat), and impacts quality of drinking water (ie, flavor, filtration, cyanobacteria).

16.3.3 Outflow

Outflow samples were not collected during 2006 (Site 2).

16.4 Future Activities and Recommendations

Sampling activities for 2007 will include continuation of 'ambient' monitoring from April through September, as well as conducting monthly vertical profile at each of the three lake sites. Due to concerns of potentially toxic bluegreen algae, phycocyanin concentrations will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. A contaminant group of interest is polyaromatic hydrocarbons (PAHs). These compounds are components of asphalt, fuels, oils, and greases. They enter receiving waters from stormwater runoff, industrial and wastewater treatment discharges, and through atmospheric deposition. They do not dissolve, but attach to particulate material and eventually settle out to the substrate. These compounds are highly toxic to aquatic biota, and thus baseline data is desired to track within district lakes. This is a high priority item when future funding becomes available. A Section 1135 aquatic habitat project will be initiated during 2007. This project is designed to provide bank stabilization and fish habitat structure along windswept, exposed banks in the Camp Branch area. Continue interactions with the Smithville Lake Watershed Coalition, NRCS, and Missouri Department of Conservation to improve water quality conditions within the lake and throughout the watershed.

17 Stockton Lake

17.1 General Background

Stockton Lake was impounded in 1969 and multipurpose pool reached on 18 December 1971. The primary water quality threats to Stockton Lake are nutrients, bacterial contamination, and urban sprawl from the Springfield metro area. Stockton Lake serves as a drinking water source for the Springfield metropolitan area (City Utilities), with a water intake located on the Little Sac arm. Stockton and Truman dams are the only hydropower generation facilities within the district. Stockton contains a single turbine-generator unit, which is marketed by Southwest Power Administration for distribution.

17.1.1 Location

Stockton Lake is located approximately 82 km (51 miles) northwest of Springfield, Missouri in the rolling hills of the Ozarks. The dam is located 82 km (51 miles) above the confluence with the Little Osage River (Truman Lake). The watershed encompasses areas of Cedar, Polk, and Dade Counties. Historic water quality sample sites at Stockton Lake include 3 inflow, 3 lake, and 1 outflow (Figure 17.1).

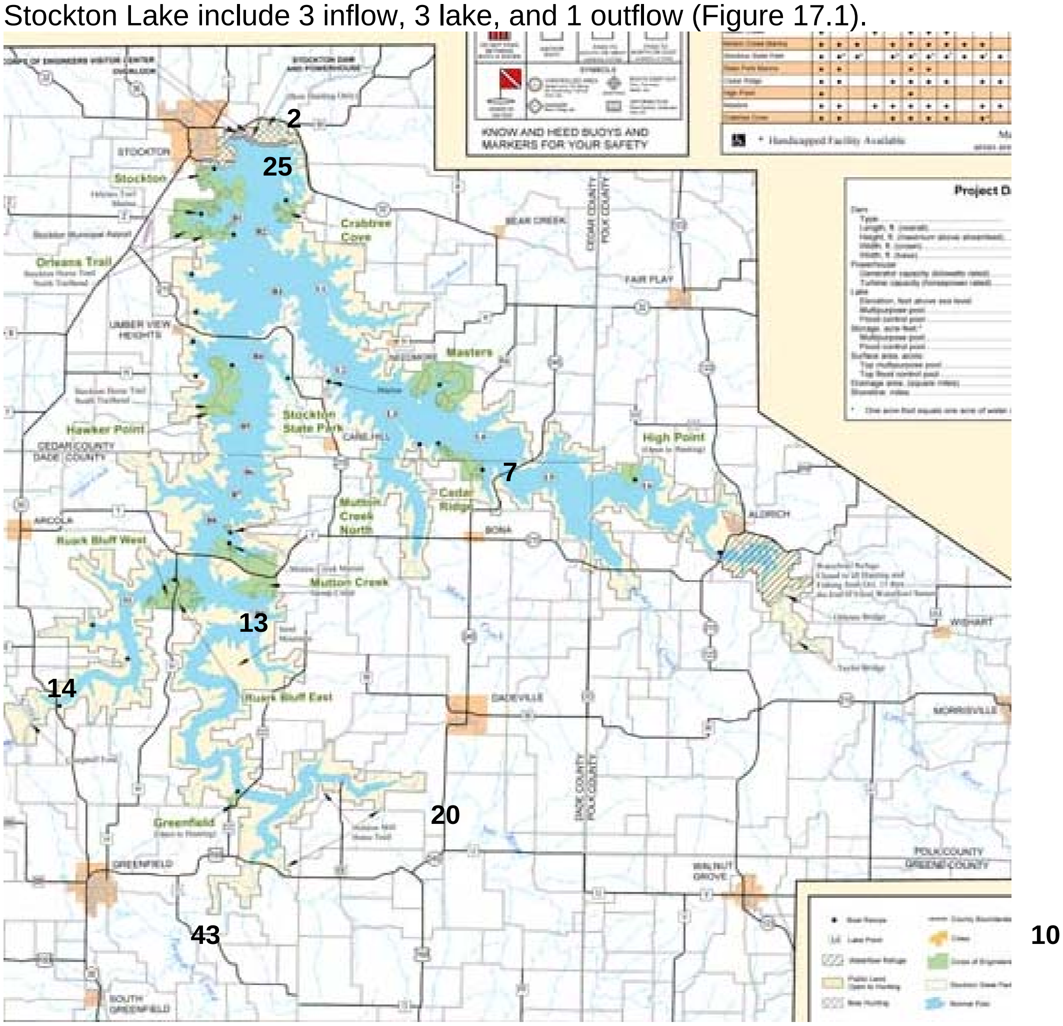


Figure 17.1. Stockton Lake area map with sample site locations.

17.1.2 Authorized Purposes: Flood control, water quality improvement, hydroelectric power generation, recreation, and fish and wildlife management.

17.1.3 State Use Designations: Livestock and wildlife watering, protection of warmwater aquatic life and human health / fish consumption, whole-body contact recreation, drinking water supply.

17.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	892.0	779.4	38,200	
Multipurpose	867.0	878.3	24,900	300
Total		1,657.7		

Total watershed area: 1,160 sq miles (742,400 A)
Watershed ratio: 19.43 FC / 29.82 MP
Average Annual Inflow: 832,679 acre-feet
Average flushing rate: 1.01 years
Sediment inflow (measured): 8,953 acre-feet (1969 – 1987)
Water management Plan: Approved 21 August 1975
Historic stage hydrograph: 1996 – 2006 (Figure 17.2)

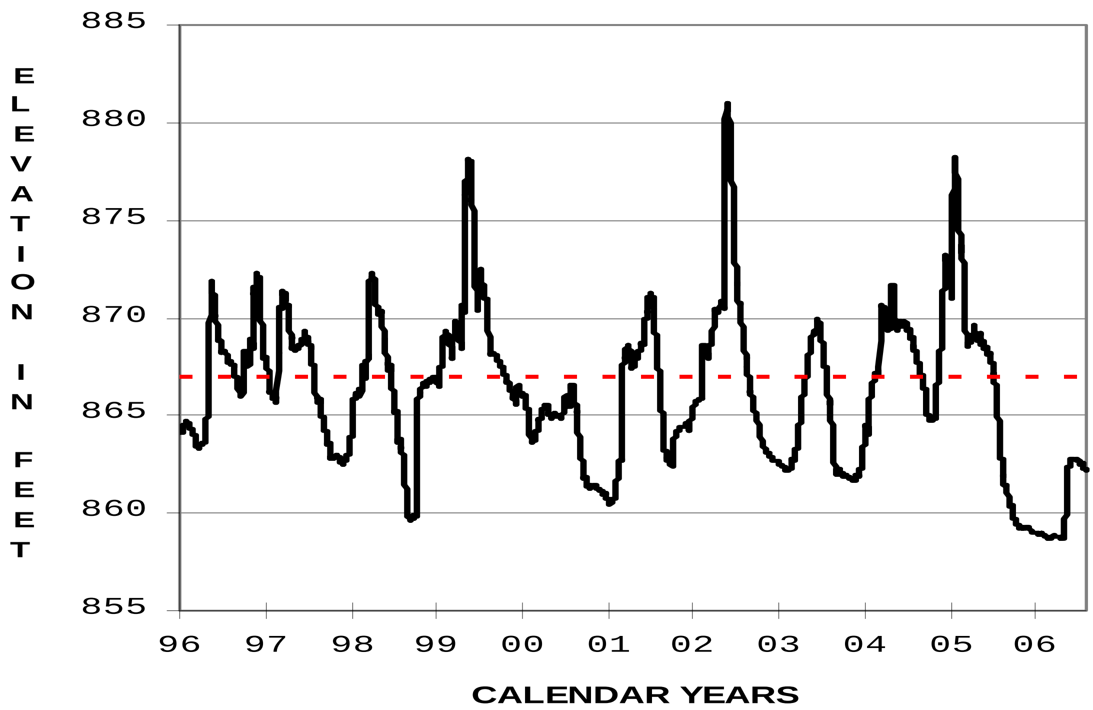


Figure 17.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line s the multipurpose pool elevation – 867.0 msl).

17.2 2006 Activities

Stockton Lake was categorized as an 'intensive' lake during 2006, thus inflow, lake (surface and bottom), and outflow sites were sampled (see Figure 17.1). Samples were collected from April through September 2006, while vertical profiles were recorded at the three lake sites during monthly trips. Stockton Lake staff (OF-ST) providing field sampling assistance during 2006 was Stanton Rains and Greg Thomas. Tom Long, OF-ST Operations Manager, provided insight and background regarding Stockton Lake.

17.3 2006 Data

Comparative historic data consists of single sample trips in 1999 (July) and 2002 (August) and monthly data from May through September 2005. Samples were collected at inflow, lake, and outflow sites from April through September, 2006.

17.3.1 Inflow

Inflow samples were collected at three sites – Turnback Creek, Sac River, Little Sac River --- in the Stockton Lake watershed during 2006. Please see comments for lake sites below on specific parameters.

17.3.2 Lake

Stockton Lake is considered a meso-trophic lake based on nutrients and chlorophyll data. Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen (TN) median concentrations ranged from 0.52 – 0.72 mg/L (Figure 17.3), which exceeds EPA's proposed nutrient criteria value of 0.46 mg/L TN. Highest median concentrations are measured at the upper lake sites. These values are typical for other lakes within the district.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Median total phosphorus (TP) concentrations ranged from 0.01 – 0.02 mg/ (Figure 17.4), which are the lowest TP values within the district and typical for mesotrophic Ozark waters. EPA has proposed a nutrient criteria value of 0.008 mg/L TP for this ecoregions, and thus the lake would be in exceedence of such nutrient criteria. Watershed samples were collected during 2006, with significantly higher concentrations measured at both Site 20 (Sac River) and Site 43 (Turnback Creek). However, very elevated TP concentrations (median = 0.30 mg/l) were measured at Site 10 (Little Sac River). These TP concentrations are a concern for the overall water clarity, drinking water, and water quality concerns at Stockton Lake. Watershed efforts should be focused in this area to reduce nutrient inputs. It is important to determine possible sources – failing septic systems, WWTP inputs, animal waste.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal

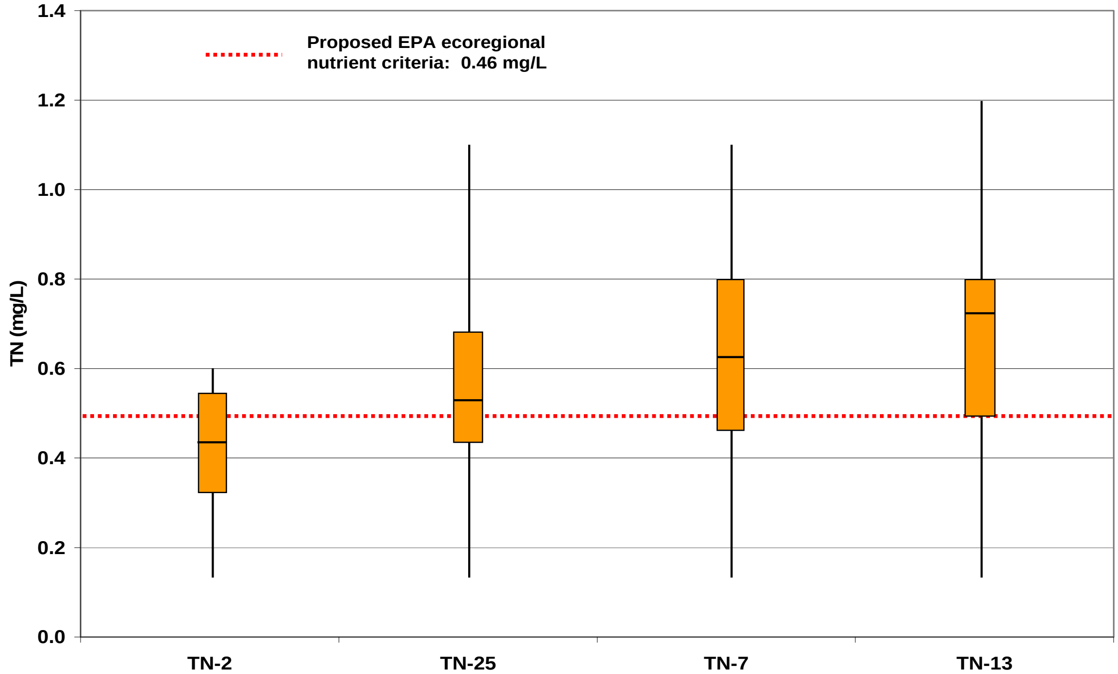


Figure 17.3. Box plots of surface water sample total nitrogen (TN) concentrations measured at lake sites from 1999, 2002, 2005, and 2005 in Stockton Lake.

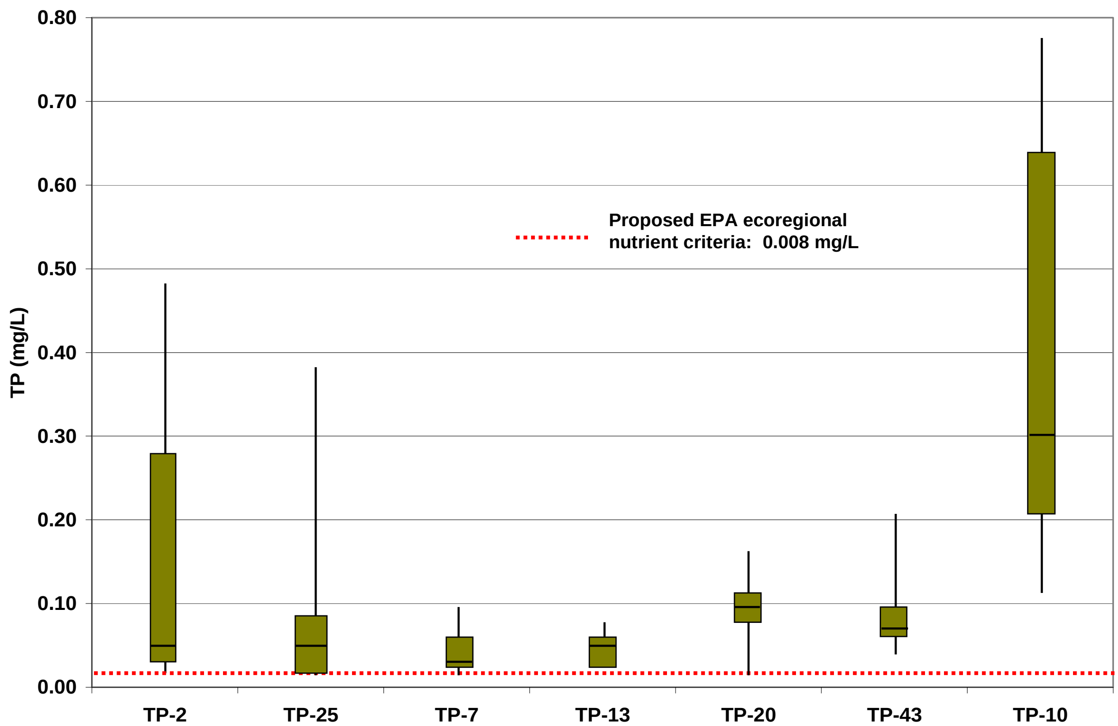


Figure 17.4. Box plots of surface water sample total phosphorus (TP) concentrations measured at lake sites from 1999, 2002, 2005 and 2006 at Stockton Lake.

communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). Median TN:TP concentrations range from 9.1 (Site 25) to 13.1 (Site 7), indicating all sites could be influenced by blue-green algae (Figure 17.5). As would be expected, there is high monthly variability in the TN:TP ratio at all sites, with lowest values recorded during late summer and early fall (Figure 17.6). Sites with TN:TP ratios < 12 are at risk for cyanobacteria blooms, however, no microcystin toxins were detected at Stockton Lake during sampling in 2000 (Dr. Jennifer Graham, USGS, personal communication). Cyanotoxins are a concern related to both drinking water and recreational use.

Median chlorophyll *a* concentrations ranged from 8 – 19 ug/L from lake sample sites collected during 1999, 2005 and 2006 (Figure 17.7). Lowest chlorophyll concentrations were measured at Site 25 (main lake – tower), while significantly higher concentrations are measured at both upper lake sites.

Secchi depth (water clarity) was measured monthly at all three lake sites. Differences in water clarity were detected between sites, as is evident in Figure 17.8. Water clarity is very high at Site 25 (mean = 2.99 m), while moderately clear water clarity is measured at both Sites 7 (mean = 1.8 m) and Site 13 (mean = 1.55 m).

Relative concentrations of phycocyanins, or bluegreen algae, were measured vertically throughout the water column during each monthly sample trip. Such profiles provided information on monthly as well as within lake distribution changes. Figure 17.9 depicts vertical distribution of phycocyanins measured at Site 25 (Tower) from June through September. Highest lake concentrations were measured during June at a depth of 9 – 11 m. Overall, concentrations in Stockton Lake were the lowest measured within the district.

Atrazine samples from surface water samples have only been collected 1x in 1999 and April – September 2006. The mean concentrations ranged from 0.03 – 0.06 ug/L from lake sites, and from 0.03 – 0.07 ug/L at inflow sites. These concentrations are the lowest measured within the district. None of the samples collected during 2006 exceeded the MCL (3 ug/L). It is also important to note that drought conditions may have some impact on concentrations measured this year.

Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at all inflow sites (range = 386 – 3663 ug/L). The highest concentration was measured at Site 10. Total iron concentrations from bottom samples in the lake ranged from 3663 – 4571 ug/L, which reflects anoxic conditions throughout the lake. Elevated levels are directed at drinking water facilities related to taste and staining issues. In addition, surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L) at all inflow site (range = 70 - 1696 ug/L). Once again, the highest inflow concentrations was measured at Site 10 (Little Sac River). The SMCL for total manganese was exceeded in bottom samples from all lake sites (range = 1559 – 2074 ug/L). Implications are directed at drinking water facilities due to taste and stain issues.

Fecal bacteria (*E. coli*) samples were collected from all five beaches (Stockton, Orleans Trail, Ruark Bluff, Cedar Ridge, and Masters) prior to major recreational season holidays during 2006. Samples prior to July 4th exceeded single sample whole-body contact

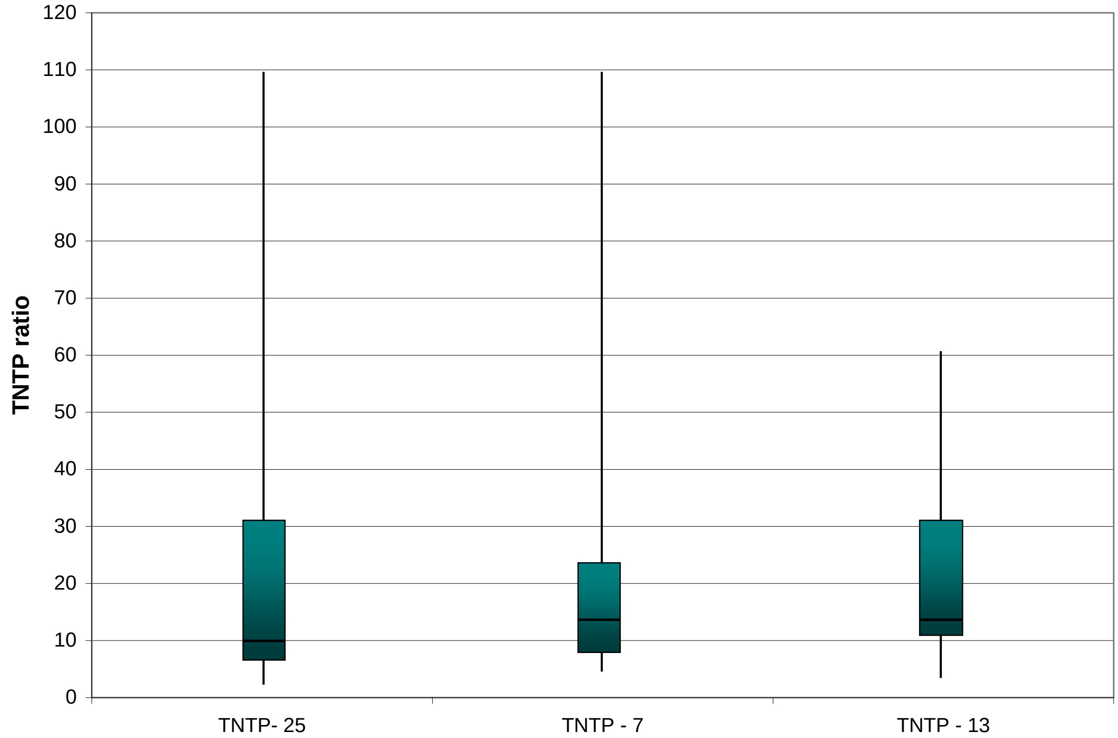


Figure 17.5 Box plots of total nitrogen : total phosphorus (TN : TP) ratio by site from 1996 through 2006 at Stockton Lake.

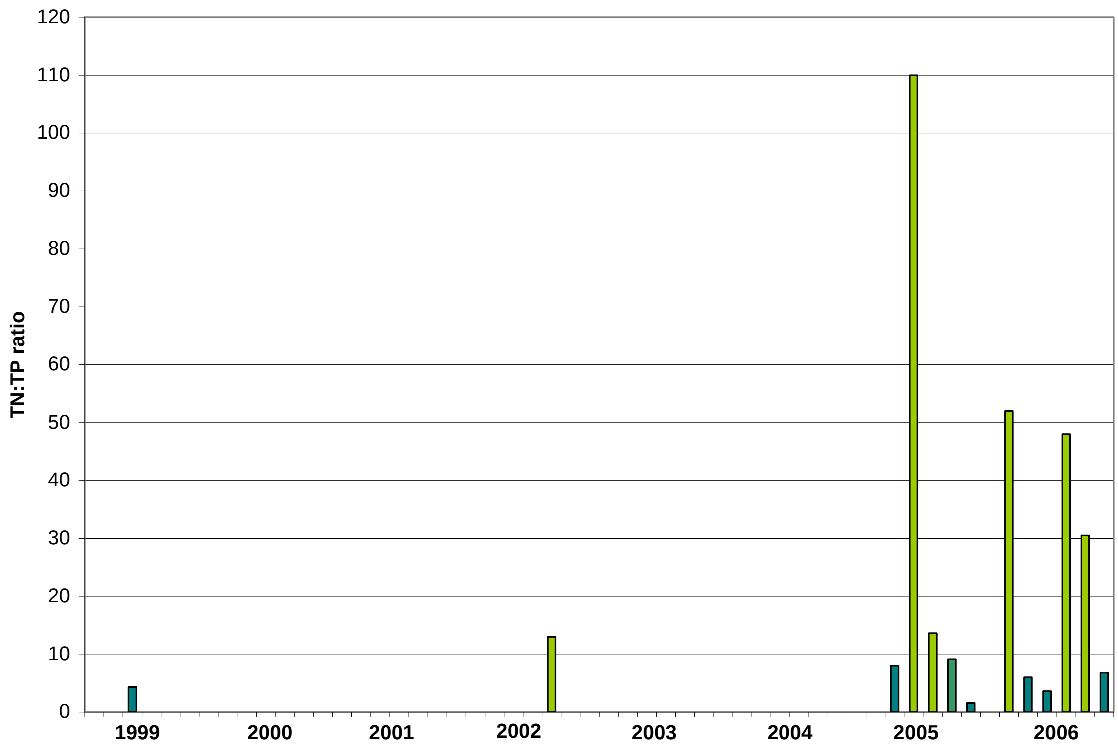


Figure 17.6. Total nitrogen : total phosphorus ratio variability by sample date and year from Site 25 in Stockton Lake from 1996 through 2006.

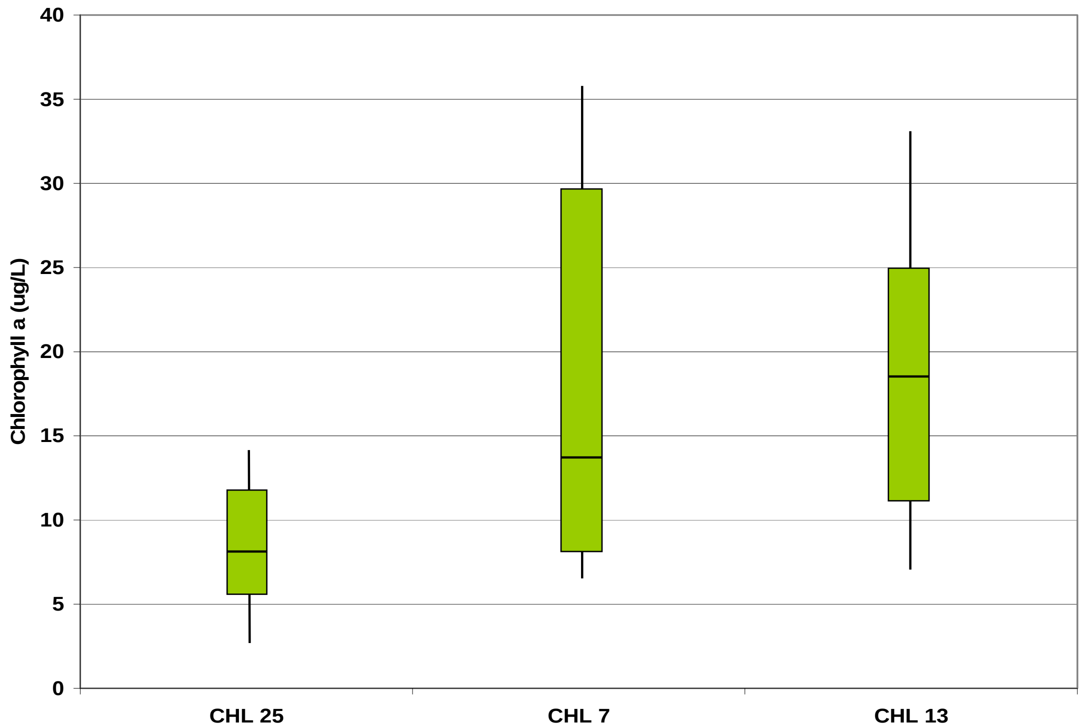


Figure 17.7. Box plots of chlorophyll a concentrations from samples collected by site during 1999 and 2005 at Stockton Lake.

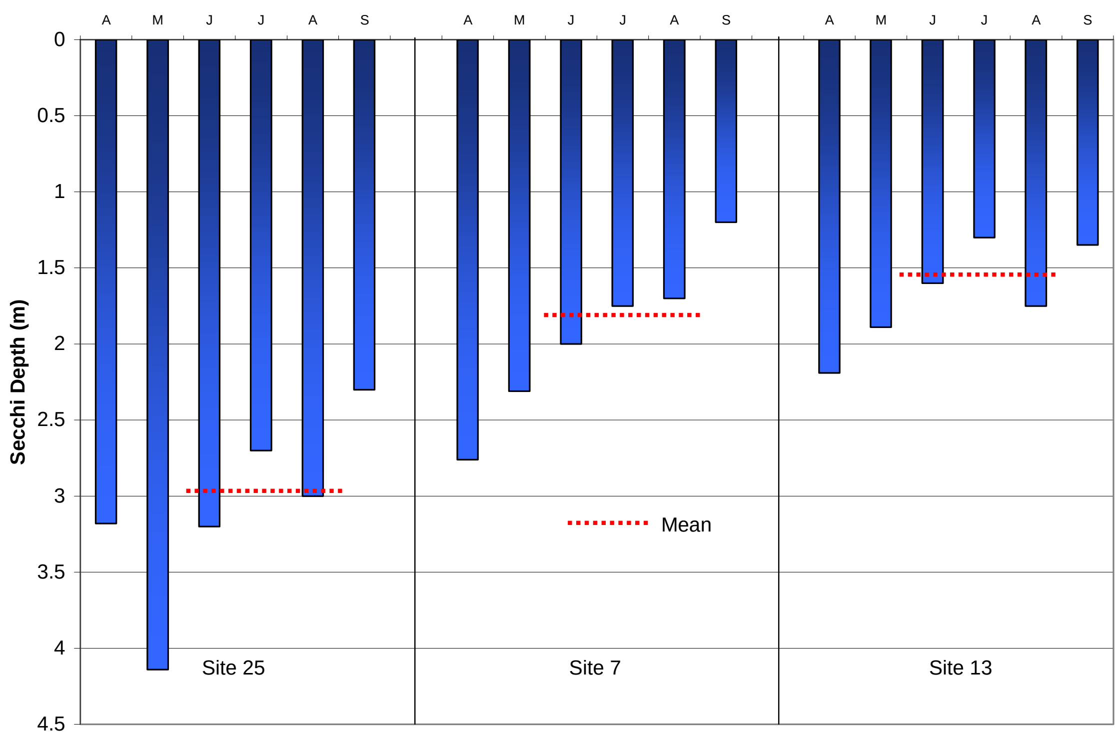


Figure 17.8. Plot of secchi depth (water clarity) measured by date and site during 2006 at Stockton Lake.

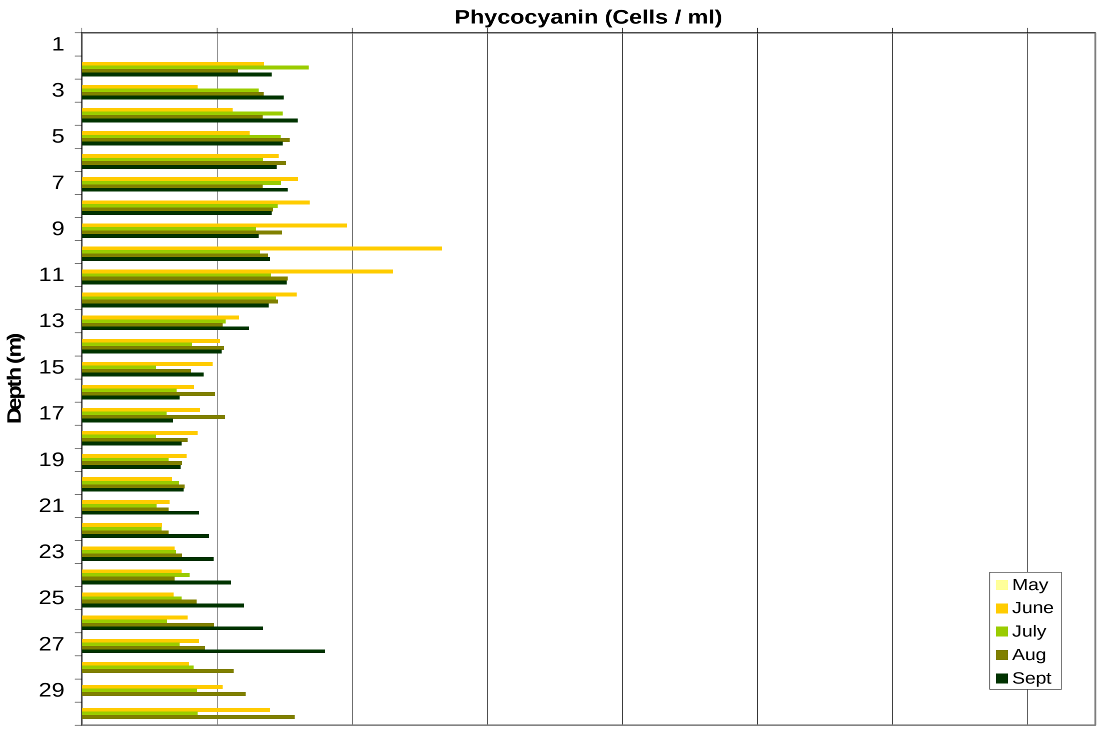


Figure 17.9. Relative concentrations of phycocyanin (bluegreen algae) (cells / ml) measured monthly by depth at Stockton Lake Site 25 (Tower) during 2006.

criteria (126 colonies / 100 ml) at Stockton, Orleans Trail, and Ruark Bluff beaches (Figure 17.10).

Vertical profiles were recorded at the three lake sites from April through September 2006. Parameters included temperature, dissolved oxygen, pH, conductivity, chlorophyll a, phycocyanins, and turbidity. Based on this information, the lake was strongly stratified both thermally and chemically. Stratification occurred between a depth of 7 – 9 m during June, and this increased to 11 – 14 m during August (Figure 5.10).

17.3.3 Outflow

Outflow samples were collected at Site 2 from Stockton Lake during 2006. Summarized data from Site 2 is included in discussions of lake sites listed above.

17.4 Future Activities and Recommendations

Sampling activities for 2007 will include transition to 'ambient' monitoring from May through September, as well as conducting a monthly vertical profile at each of the three lake sites during July or August. In an effort to gather baseline phycocyanin data, the lake will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be

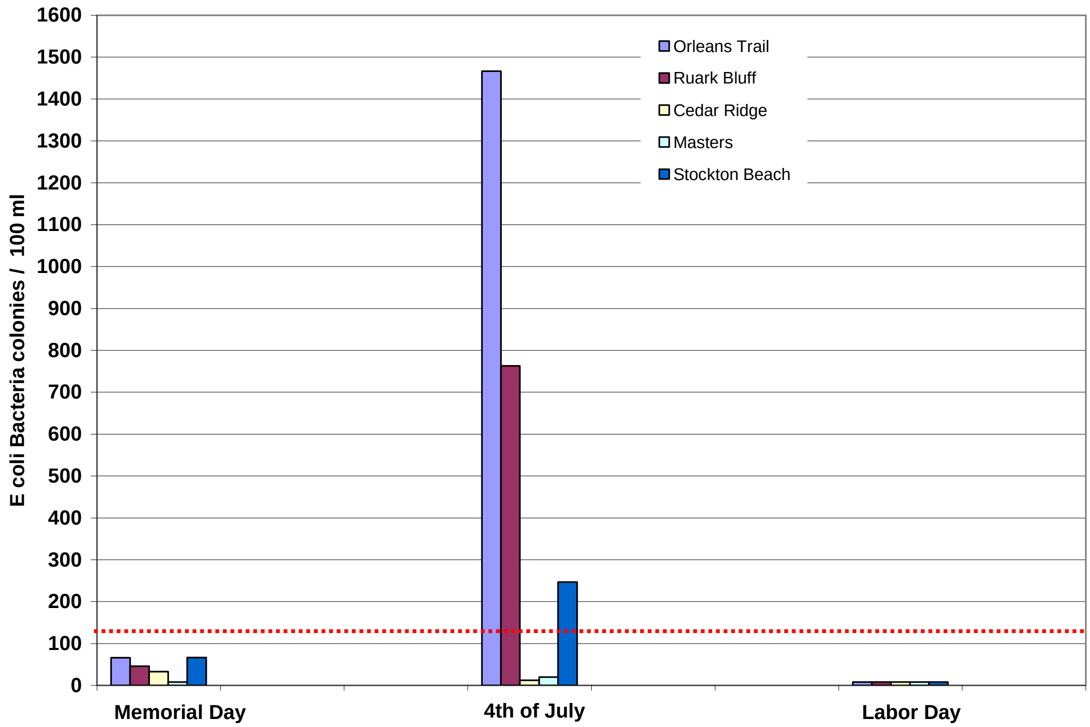
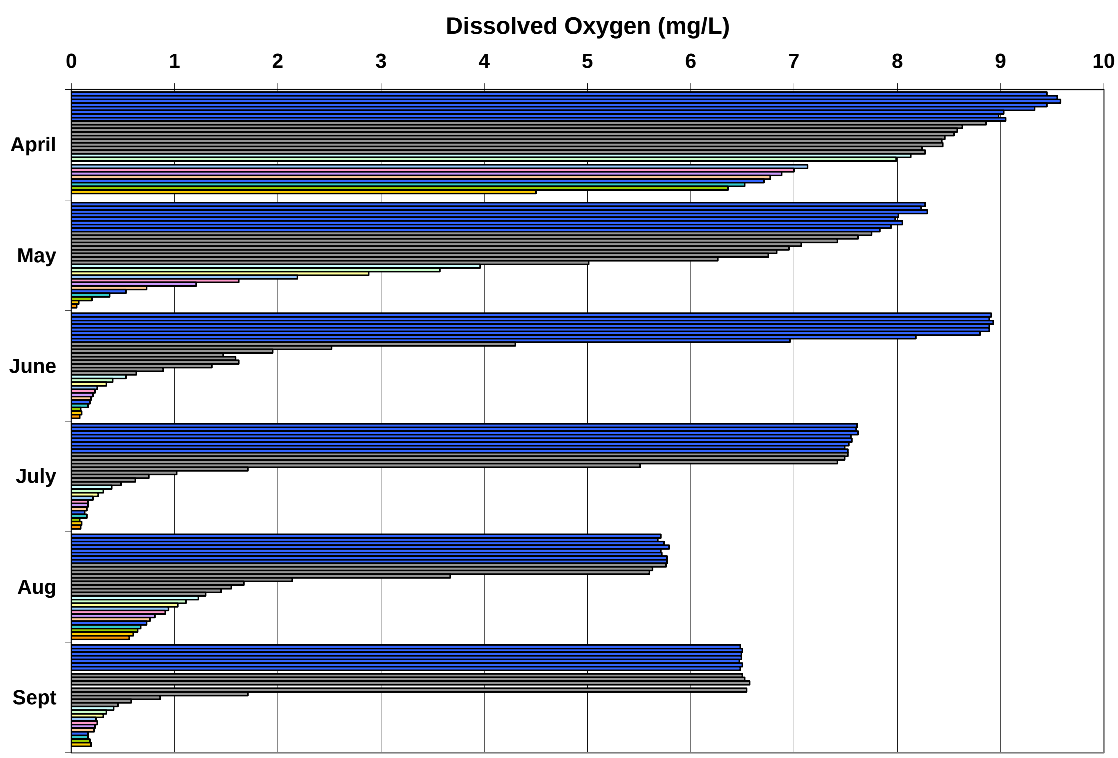


Figure 17.10. Fecal bacteria (E. coli) colonies per 100 ml samples from beach samples collected prior to major holidays at Stockton Lake during 2006.



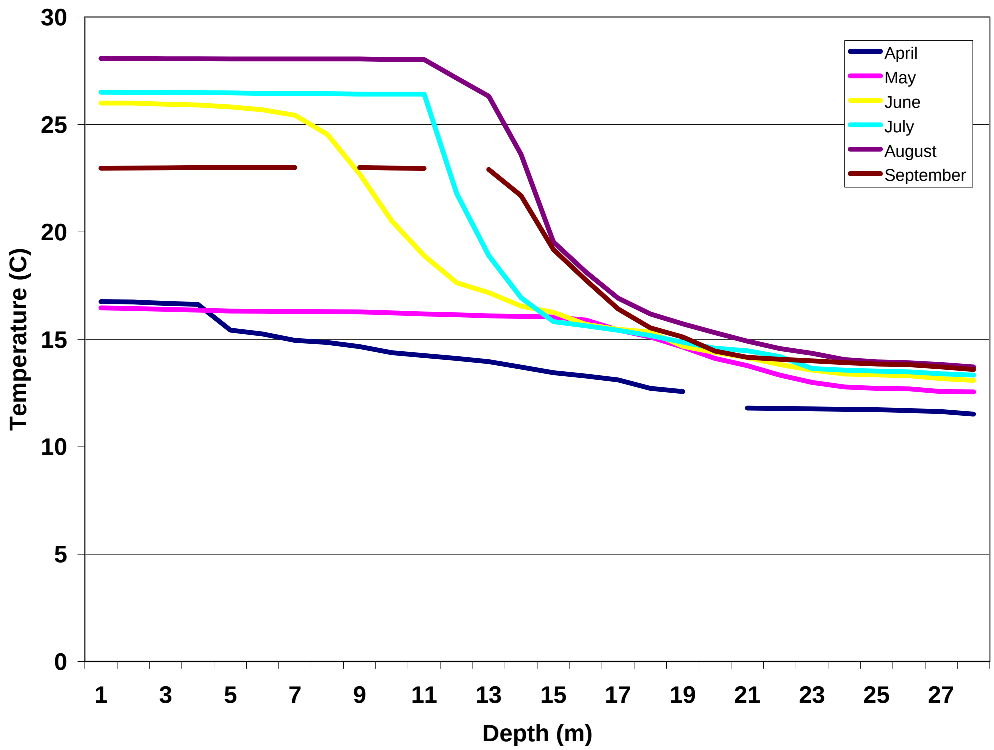


Figure 17.11. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from vertical profiles recorded at Stockton Lake Site 25 during 2006.

measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Two additional sites are proposed to provide additional lake and watershed information. Both sites are located in Sons Creek – an inflow site at the Hwy 39 bridge (Site 14), and a lake site (Site X) in the historic channel just west of the Ruark Bluff Recreation Area.

18 Tuttle Creek Lake

18.1 General Background

Tuttle Creek Lake was impounded in 1962 and reached full pool on 29 April 16963. The primary water quality threats to Tuttle Creek Lake and its' watershed are sedimentation, herbicides, nutrients, and bacterial contamination. The lake is listed on Kansas's 303(d) list for water quality impairment due to eutrophication, atrazine, alachlor, pH, copper, silt, and *E. coli* (inflows). The atrazine TMDL was approved in 2005 by KDHE, while the other TMDLs were implemented in 1999. A watershed restoration and protection strategy (WRAPS) group formed during 2006. The goals and objectives of the WRAPS group will be to protect Tuttle Creek Lake and ultimately remove it from the 303(d) list of impaired waters.

18.1.1 Location

Tuttle Creek Lake is located 8 km (5 miles) north of Manhattan, Kansas. The dam is located on the Big Blue River at river km 16 (river mile 10) above the confluence with the Kansas River. The watershed flows south from Nebraska and includes counties of . Historic water quality sample sites at Tuttle Creek Lake include 3 lake, 1 outflow, and 2 inflow (Figure 18.1).

Figure 18.1. Tuttle Creek Lake area map with sample site locations.

18.1.2 Authorized Purposes: Flood control, recreation, navigation, water quality improvement, and fish and wildlife management.

18.1.3 State Use Designations: Primary contact recreation, drinking water supply, expected aquatic life support, food procurement.

18.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,136.0	1,903.4	53,600	
Multipurpose	1,075.0	299.5	14,000	112
Total		2,202.9		

Total watershed area: 9,600 sq miles (6,144,00 A)

Watershed ratio: 114.63 FC / 438.86 MP

Average Annual Inflow: 1,860,074 acre-feet
Average Annual outflow: 000 acre-feet
Average flushing rate: 0.15 years
Sediment inflow (measured): 216,145 acre-feet (1962 – 2000)
Water management Plan: Approved 16 April 1974; minor revisions January 1995
Historic stage hydrograph: 1996 – 2006 (Figure 18.2)

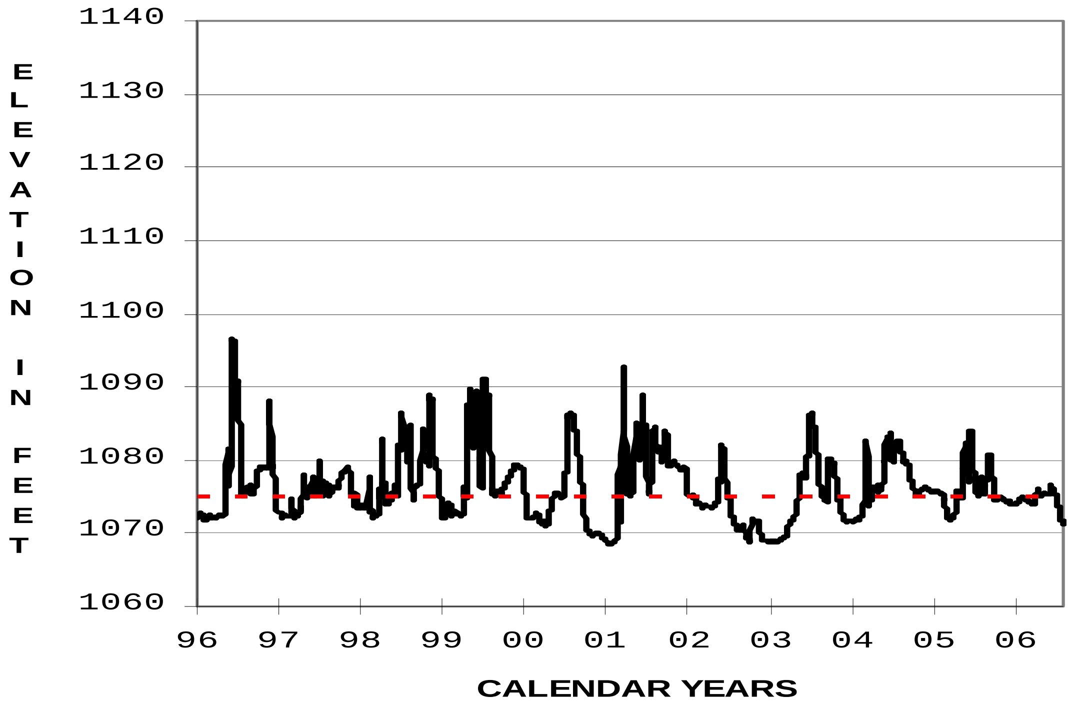


Figure 18.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 1075.0 msl).

18.2 2006 Activities

Tuttle Creek Lake was categorized at an 'ambient' lake during 2006, thus samples were collected from the three lake sites (Sites 3, 8 & 11). In addition, the two inflow sites (Site 30 and 32) were sampled to collect data for the bi-state atrazine watershed project. See Figure 18.1 for specific locations. Sample collections occurred from May through September 2006, with monthly vertical profiles (temperature, DO, pH, conductivity, and turbidity) recorded at the three lake sites. Tuttle Creek Lake staff (OF-TC) providing field sampling assistance during 2006 included Gene Scherer and Paul Weidhaas. Brian McNulty, OF-TC Operations Manager, provided insight and background regarding Tuttle Creek Lake. Multiple meetings were attended to participate in the WRAPS group.

18.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1996 through 2005. Samples were collected from April through September 2006.

18.3.1 Inflow

Inflow samples were collected from two watershed sites located on the Big Blue River at Highway 77 (Site 30) and Black Vermillion River (Site 32). Historically, water quality parameters are most variable at these sites due to influences of runoff events and climatic variations within the watershed.

18.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Tuttle Creek Lake holds the distinction of having the highest median concentration for total nitrogen (TN) and second highest for total phosphorus (TP) within the district. Therefore, the influx of such large quantities of nutrients leads to a very eutrophic lake. Median concentrations range from 2.1 – 2.3 mg/L within the lake (Sites 3, 8 & 11) , 1.6 – 2.6 mg/L at the inflows (Sites 30 and 32, respectively), and 2.3 mg/L in the outfall (Site 27)(Figure 18.3). These concentrations exceed EPA's proposed ecoregional nutrient criteria value of 0.36 mg/L TN. Monthly and annual variability in TN is evident at all sites within the watershed, as depicted in Figure 18.4 for Site 30.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Surface water sample median TP concentrations collected from 1996 through 2006 range from 0.27 – 0.33 mg/L at lake sites, 0.3 – 0.56 mg/L at the inflows (Sites 32 and 30, respectively), and 0.25 mg/L in the outflow (Site 27)(Figure 18.5). These median values exceed EPA's proposed ecoregional nutrient criteria value of 0.02 mg/L TP.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios $\geq$ 20:1 are indicative of desirable algal communities, whereas ratios $\leq$ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). As would be expected, there is high monthly and annual variability in the TN:TP ratio at all sites. Median TN:TP ratios at all three lake sites are < 12, indicating the lake is at risk for cyanobacteria blooms (Figure 18.5). High turbidity rates may moderate the expected high risk during wet inflow years.

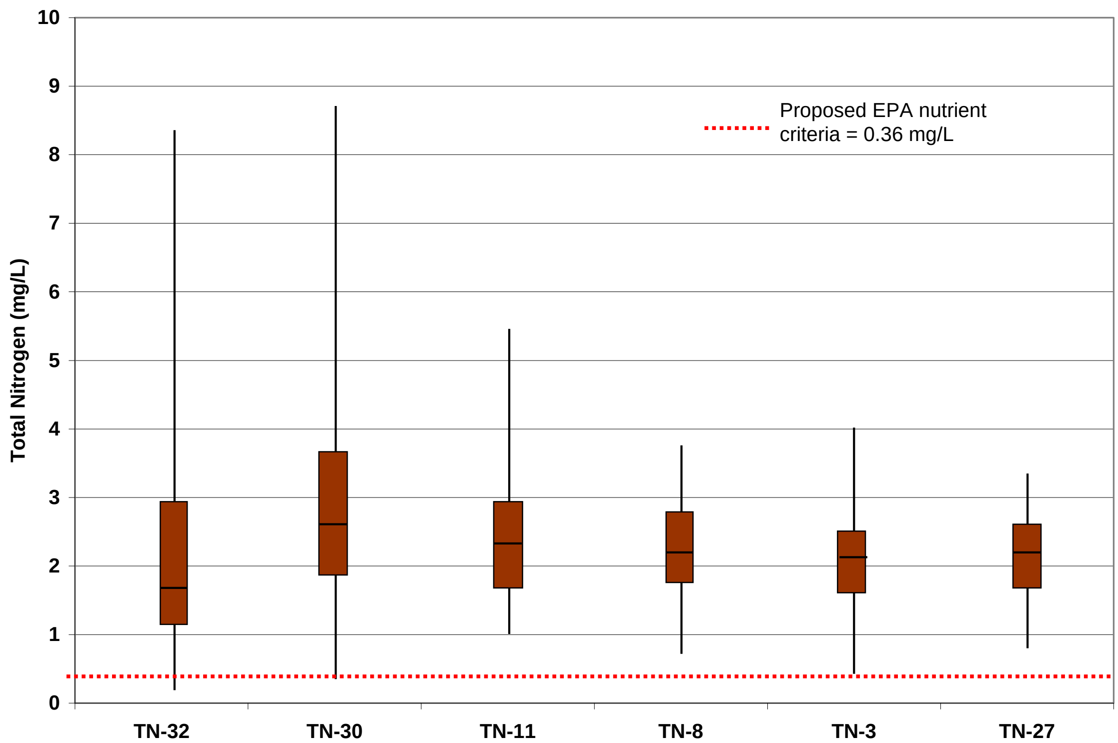


Figure 18.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Tuttle Creek Lake.

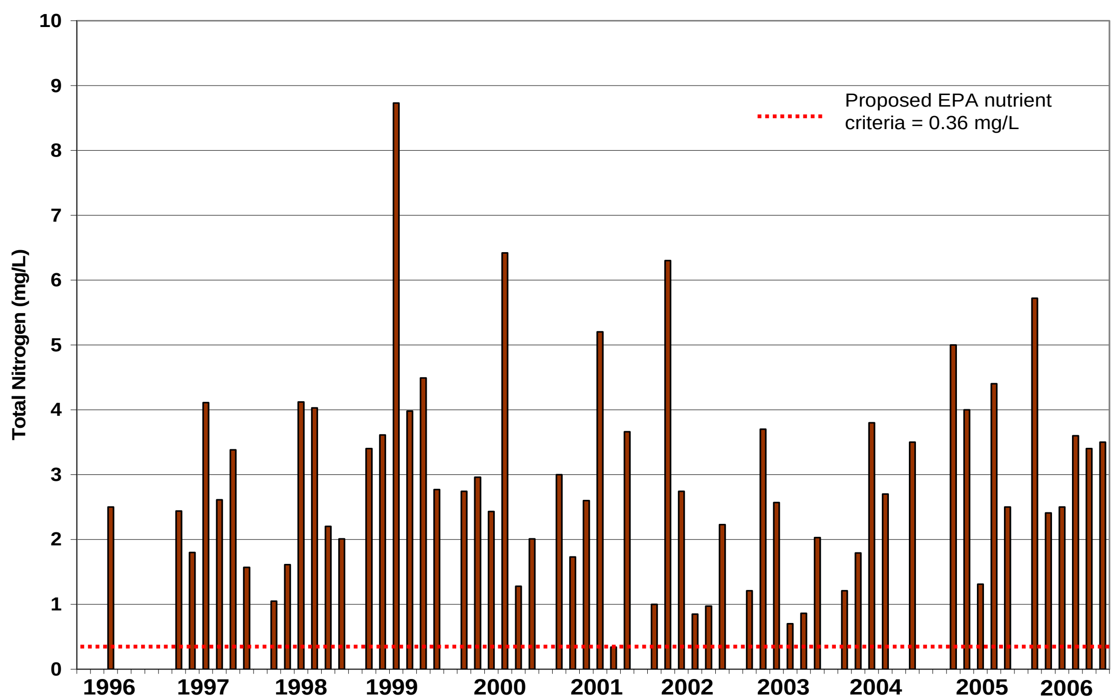


Figure 18.4. Graph of surface water sample total nitrogen concentrations by sample at Tuttle Creek Site 30 (Big Blue River) from 1996 through 2006.

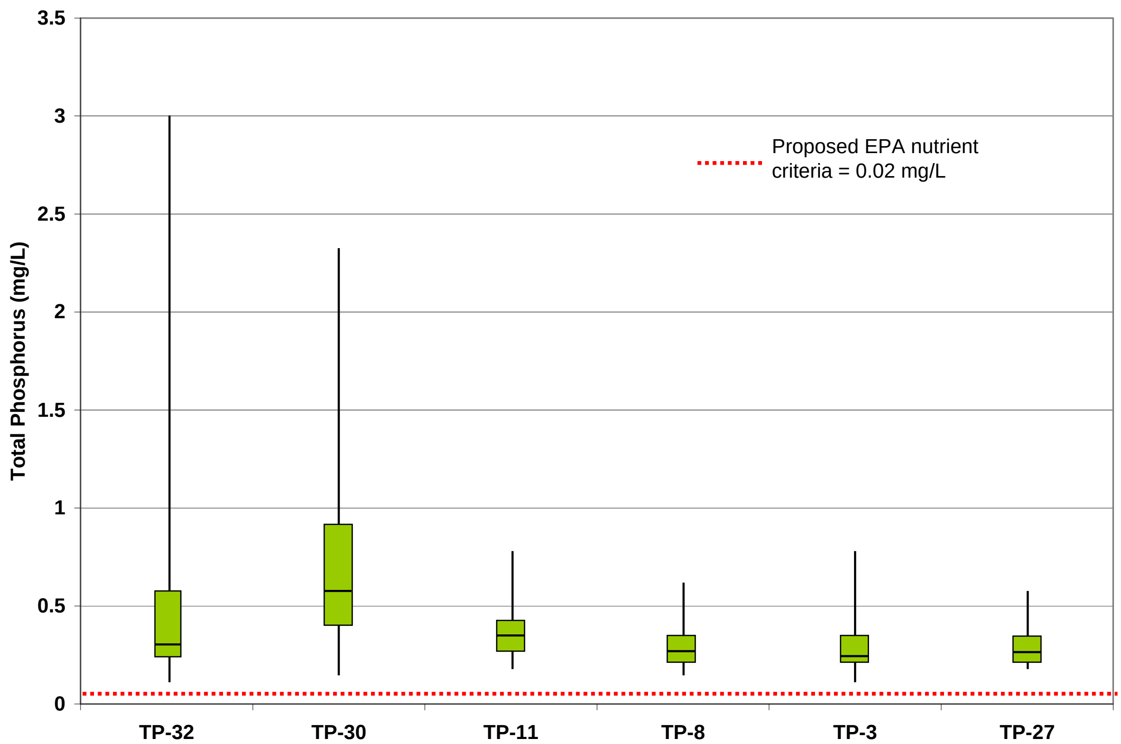


Figure 18.5. Box plots of surface water sample total phosphorus concentrations by site from 1996 through 2006 at Tuttle Creek Lake.

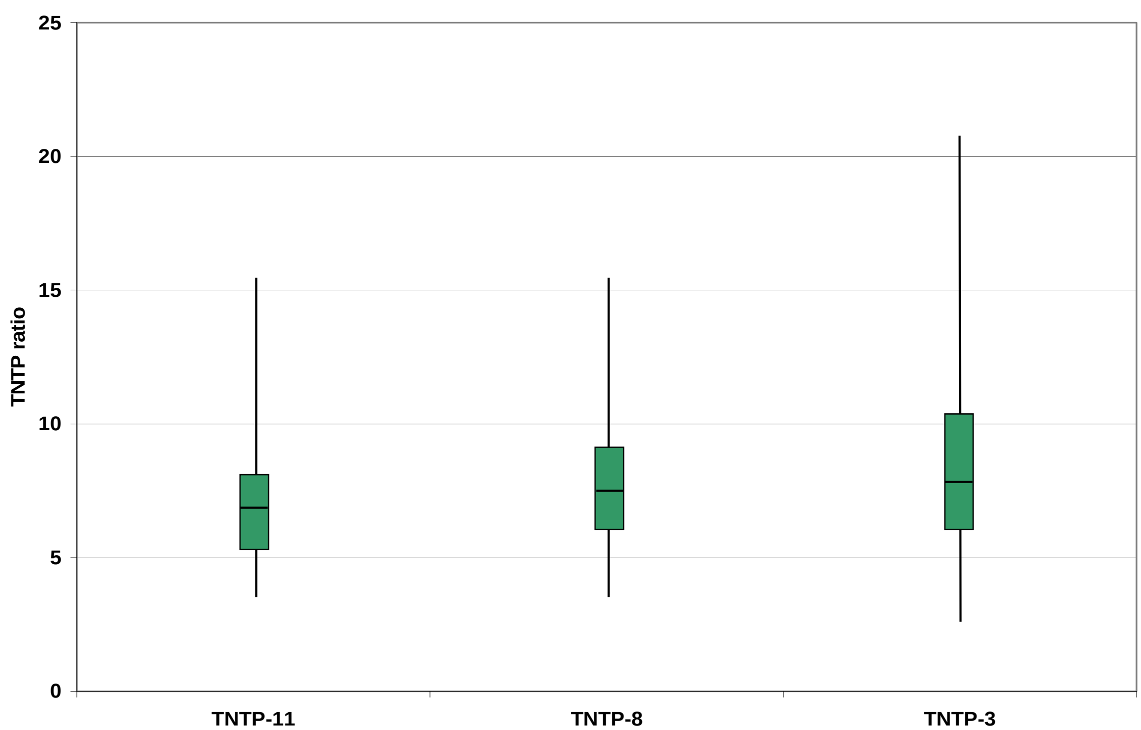


Figure 18.6. Box plots of total nitrogen : total phosphorus (TN : TP) by site from 1996 through 2006 at Tuttle Creek Lake.

Secchi depth was measured in April, June, August and September. Variability was detected between and within sites and between years by site (Figure 18.7). In contrast to 2005, greater water clarity was observed at lower (Site 3) and mid lake (Site 8) during most months of 2006. This would be expected due to the prolonged drought and limited inflows, which would allow suspended sediment to settle out of solution. Very limited water clarity was measured at Site 11 (uplake; mean = 0.23 m), while limited water clarity was measured at Sites 8 (mid-lake; mean = 0.6 m) and 3 (tower; mean = 0.61 m).

Mean chlorophyll a concentrations ranged from 9 to 14 ug/L during July and August 2005. Chlorophyll concentrations responded to increased water clarity during 2006, as July concentrations ranged from 53 – 62 ug/L. This is expected in a lake with very high nutrient concentrations, especially in years of reduced inflow and greater light penetration.

Concentrations of the herbicides atrazine and alachlor have been significant enough to warrant listing of the waters on the states 303d list. Median atrazine concentrations (1.1 – 1.6 ug/L) are less than EPA's drinking water maximum contaminant level (MCL) of 3 ug/L (Figure 18.8). However, individual samples measured from 1996 through 2006 are significant enough to exceed the MCL. Figure 18.9 depicts the individual sample concentrations measured by date at Site 32 (Black Vermillion River) inflow. Median alachlor concentrations from surface water samples collected at lake sites range from 1.0 – 1.1 ug/L, which are less than EPA's drinking water MCL of 2 ug/L (Figure 18.10).

Metals were not analyzed from samples collected during 2006. However, samples were collected in 2005. Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at all three lake sites (1057 – 5269 ug/L), inflows (2071 – 33,624 ug/L) and outflow (1091 ug/L). The extremely elevated levels on the Big Blue River at Blue Rapids is a concern to the lake. Implications are directed at drinking water facilities related to taste and staining issues. In addition, surface samples collected during August exceeded EPA's SMCL for manganese (50 ug/L) at the inflow sites, upper lake and mid-lake sites. Sample concentrations ranged from 60 – 718 ug/L, with the highest concentrations measured at Site 30 (Big Blue River). Implications are directed at drinking water facilities due to taste and stain issues. Lead was also exceeded at Site 30 (20 ug/L).

Vertical profiles were recorded during sample trips in April and June through September 2006. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake was weakly stratified thermally during June and September, and nearly iso-thermal during August (Figure 18.11). Chemical stratification was most pronounced during July, and relatively homogenous across depths during August and September.

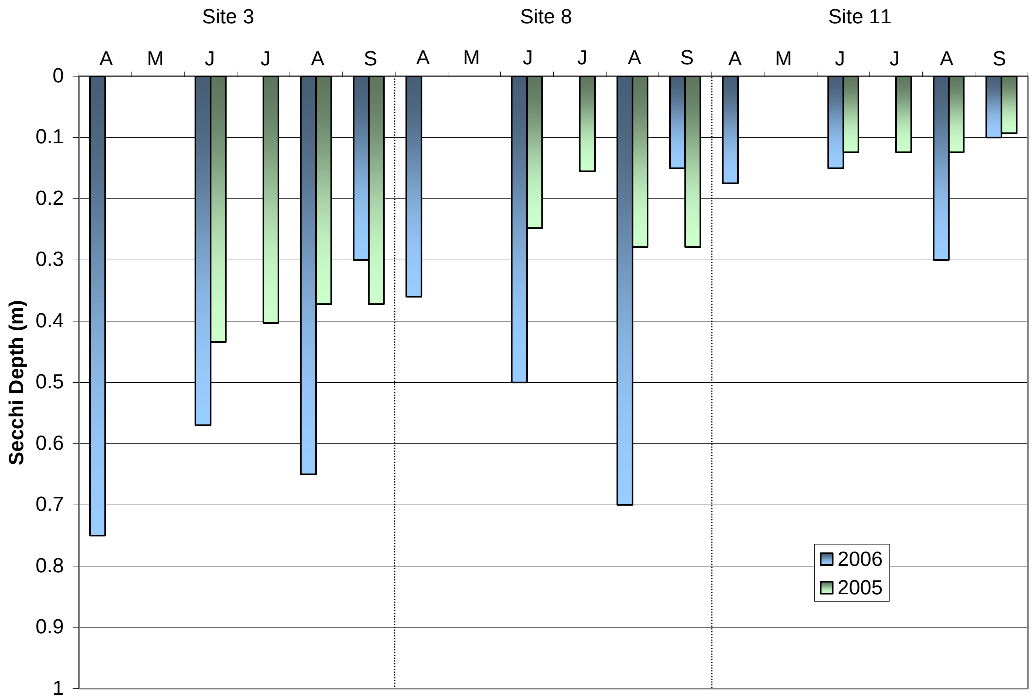


Figure 18.7. Secchi depth measurements by site from April through September 2006 at Tuttle Creek Lake.

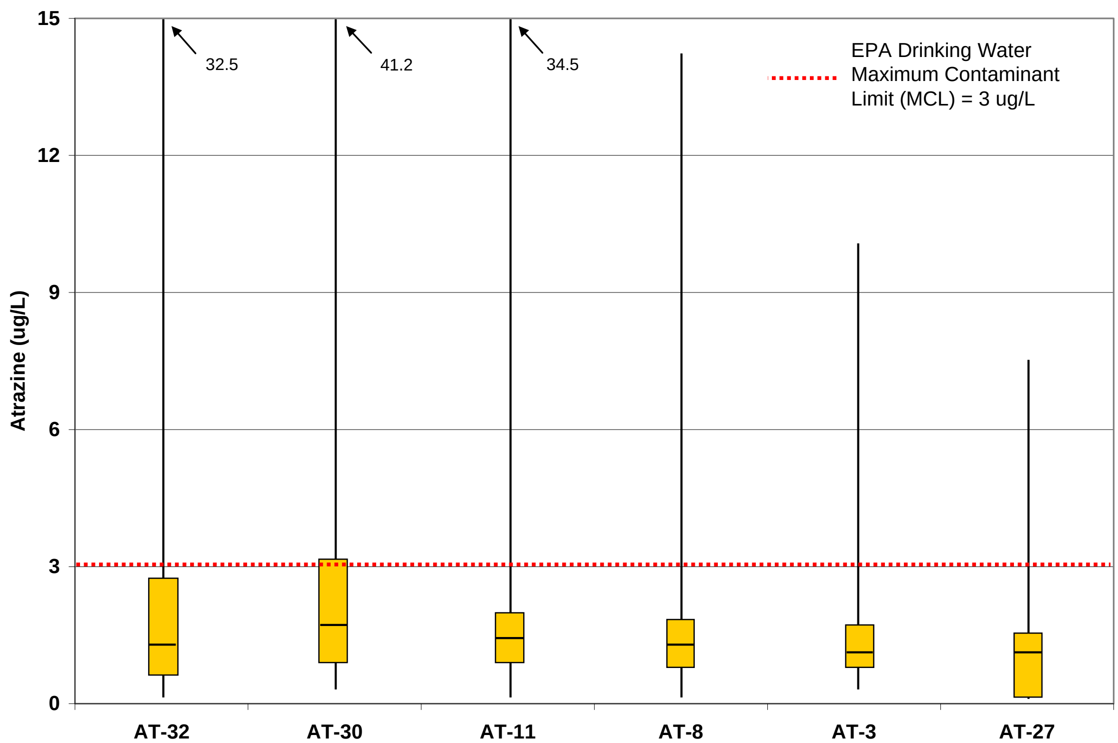


Figure 18.8. Box plots of surface water sample atrazine concentrations measured by site from 1996 through 2006 at Tuttle Creek Lake.

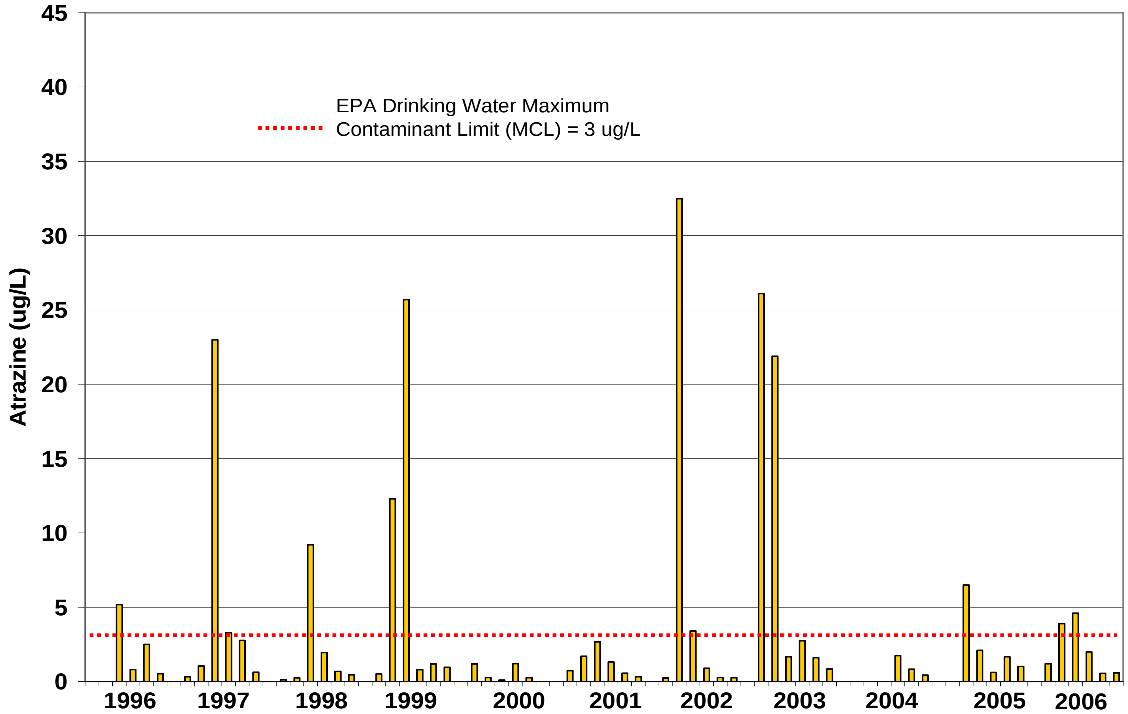


Figure 18.9. Atrazine concentrations from surface water samples by sample date collected at Site 32 (Black Vermillion River) inflow to Tuttle Creek Lake from 1996 through 2006.

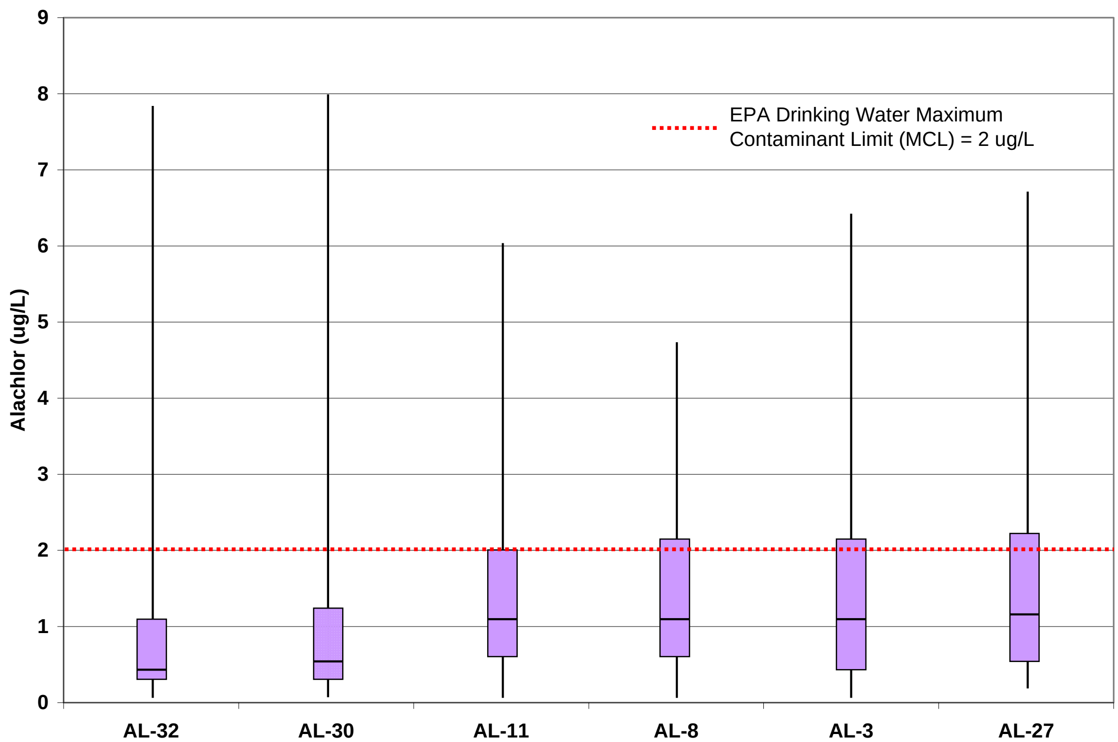
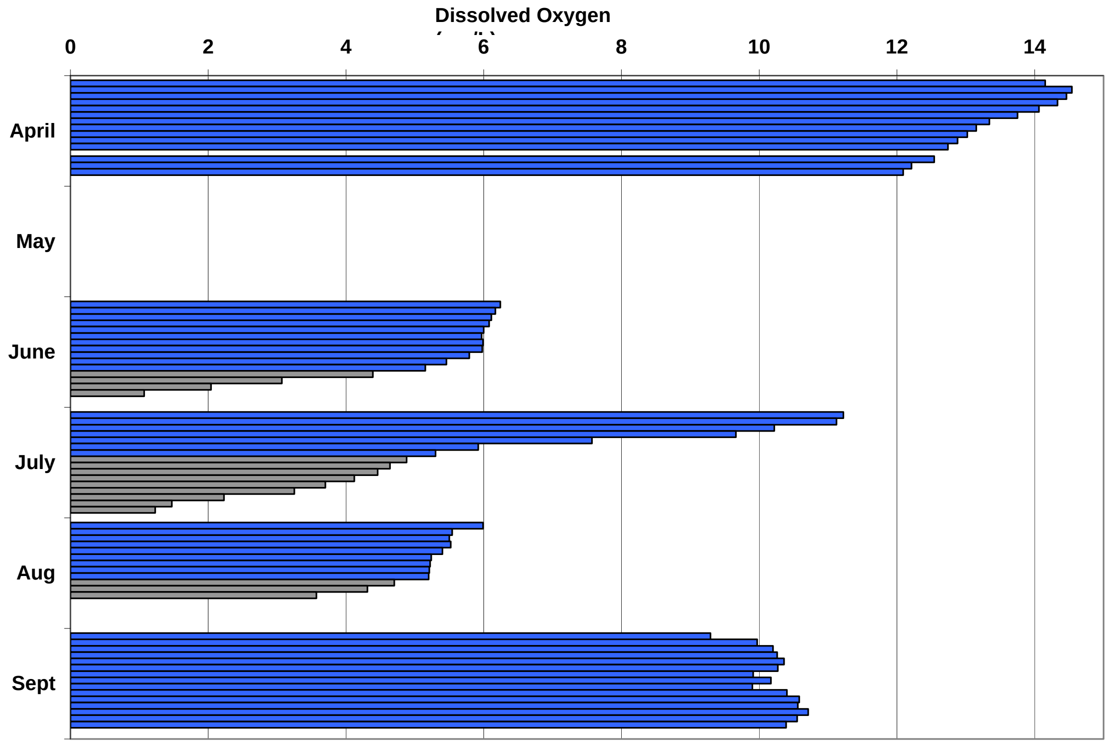


Figure 18.10. Box plots of surface water sample alachlor concentrations measured by site from 1996 through 2006 at Tuttle Creek Lake.



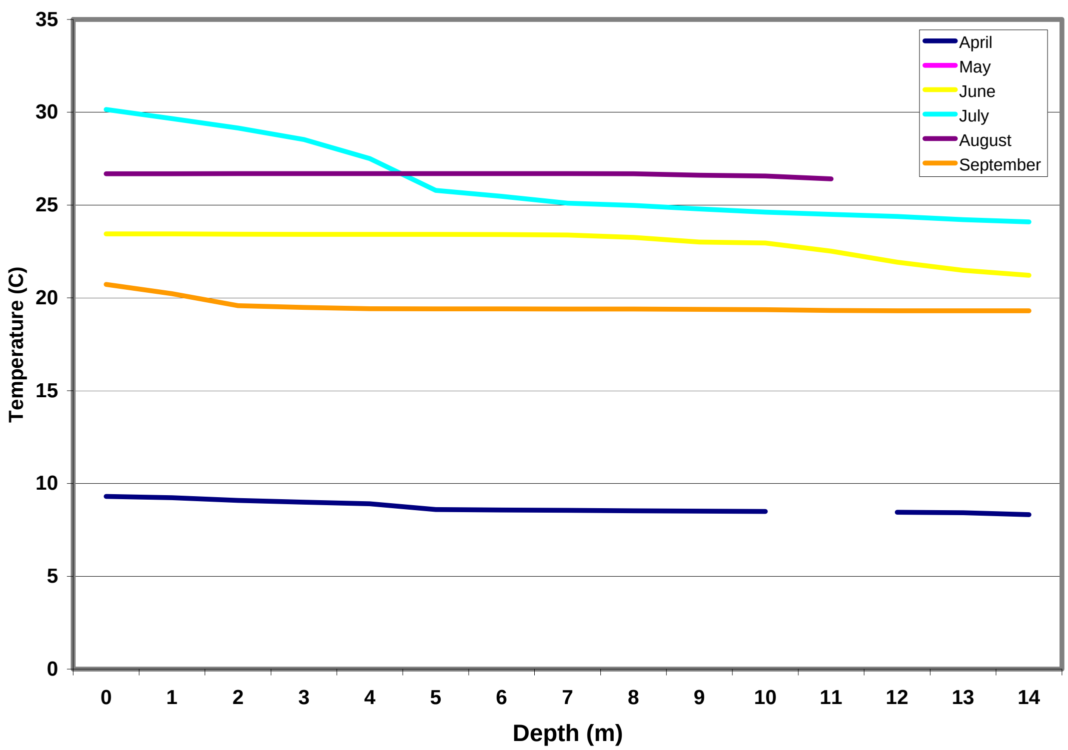


Figure 18.11. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from vertical profiles recorded at Site 3 (Tower) during June, July and September 2006 at Tuttle Creek Lake.

18.3.3 Outflow

Outflow samples were not collected during 2006 from the stilling basin (Site 27).

18.4 Future Activities and Recommendations

Sampling activities for 2007 will include continuation of ‘ambient’ monitoring from April through September, as well as conducting monthly vertical profile at each of the lake sites. As part of the bi-state EPA Targeted Watershed grant project (2006 – 2010) within the Tuttle Creek watershed, funds will be spent during the next few years to promote conservation agricultural practices and education programs related to water quality improvements. No-till farming and riparian buffer strips are two of the cost-effective conservation practices designed to reduce agricultural runoff. For our part, CENWK will continue to sample inflow sites monthly (April – September) for nutrients and herbicides. Due to concerns of potentially toxic bluegreen algae, phycocyanin concentrations will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Sediment – nutrient and metals will be examined during 2007 to provide a comparative point on potential resuspension sources. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP’s, illicit dumping from boats, etc. Involvement with the Blue River WRAPS group will continue. Monitoring and consultation regarding the projected 10-year dam modification project at Tuttle Creek will also continue during the next year. The inclusion of another inflow site is proposed for Mill Creek. This site would provide additional watershed data, especially in an area more likely to develop in future years. Due to shallow water conditions at Site 11, this upper lake sampling site will be relocated to Site 10.

19 Wilson Lake

19.1 General Background

Wilson Lake was impounded in 1964 and reached full multipurpose pool on 12 March 1973. The primary water quality threats to Wilson Lake are nutrients and runoff / groundwater contamination from the Russell landfill. Wilson Lake has the nickname as the 'Clearest Lake in Kansas'. The lake is listed on the state's 303(d) list for water quality impairment due to sulfates and chlorides. The discharge of groundwater from the Dakota aquifer is the primary source of chloride in surface waters flowing into Wilson Lake. Because achievement of the chloride water quality standard (250 mg/L) is not possible due to natural inputs, an alternative endpoint has been proposed. The TMDL, developed by KDHE, will seek to maintain chloride concentrations < 860 mg/L (acute chronic life criteria) during normal flow conditions and higher concentrations will be allowed during drought conditions. The target value for sulfate is 480 mg/L, and similar to chloride is strongly correlated with inflows due to natural regional geology.

19.1.1 Location

Wilson Lake is located approximately 32 km (20 miles) east of Russell, Kansas. The dam is located at river kilometer 208.6 (river mile 130.4) of the Saline River. The watershed encompasses Russell, Ellis, Rooks, Osborne, and Trego Counties. Historic water quality sample sites at Wilson Lake include 1 inflow, 3 lake, and 1 outflow (Figure 19.1).

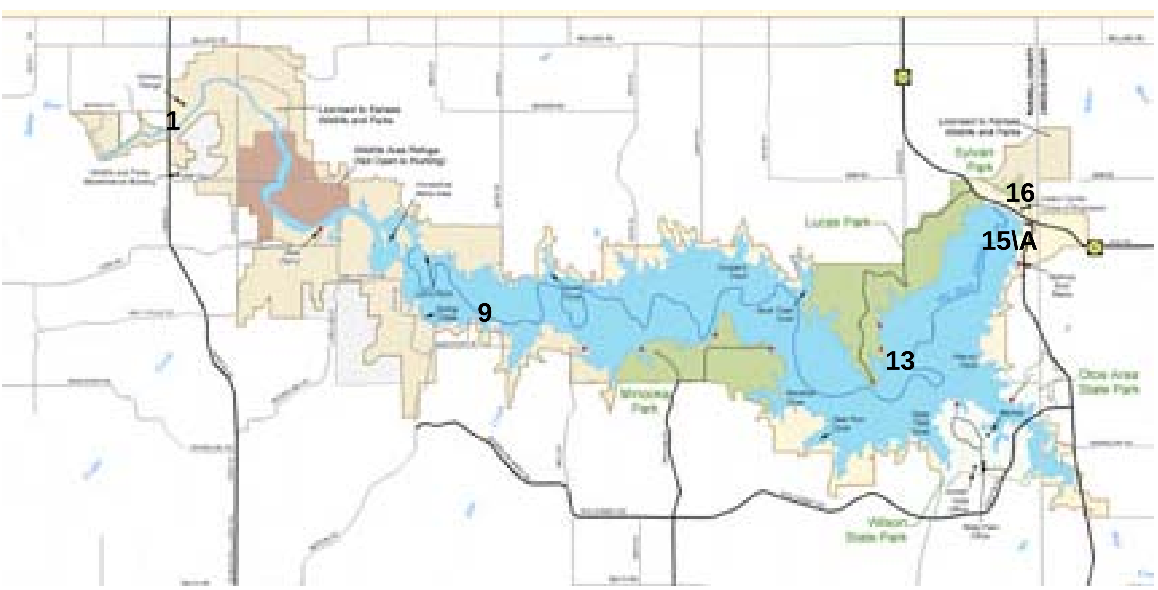


Figure 19.1. Wilson Lake area map with sample site locations.

19.1.2 Authorized Purposes:

Authorized Purposes: Flood control, recreation, fish and wildlife management, water supply, water quality improvement.

19.1.3 State Use Designations: Primary and secondary contact recreation, expected aquatic life support, and food procurement.

19.1.4 Lake and Watershed Data

Pools	Surface Elevation (ft. above m.s.l.)	Current Capacity (1000 AF)	Surface Area (A)	Shoreline (miles)
Flood Control	1,554.0	529.8	20,000	
Multipurpose	1,516.0	233.6	9,000	100
Total		763.4		

Total watershed area: 1,917 sq miles (1,226,880 A)
Watershed ratio: 61.34 FC / 136.32 MP
Average Annual Inflow: 97,845 acre-feet
Average flushing rate: 2.18 years
Sediment inflow (measured): 15,066 acre-feet (1964 – 1993)
Water management Plan: Approved 13 June 1997
Historic stage hydrograph: 1996 – 2006 (Figure 19.2)

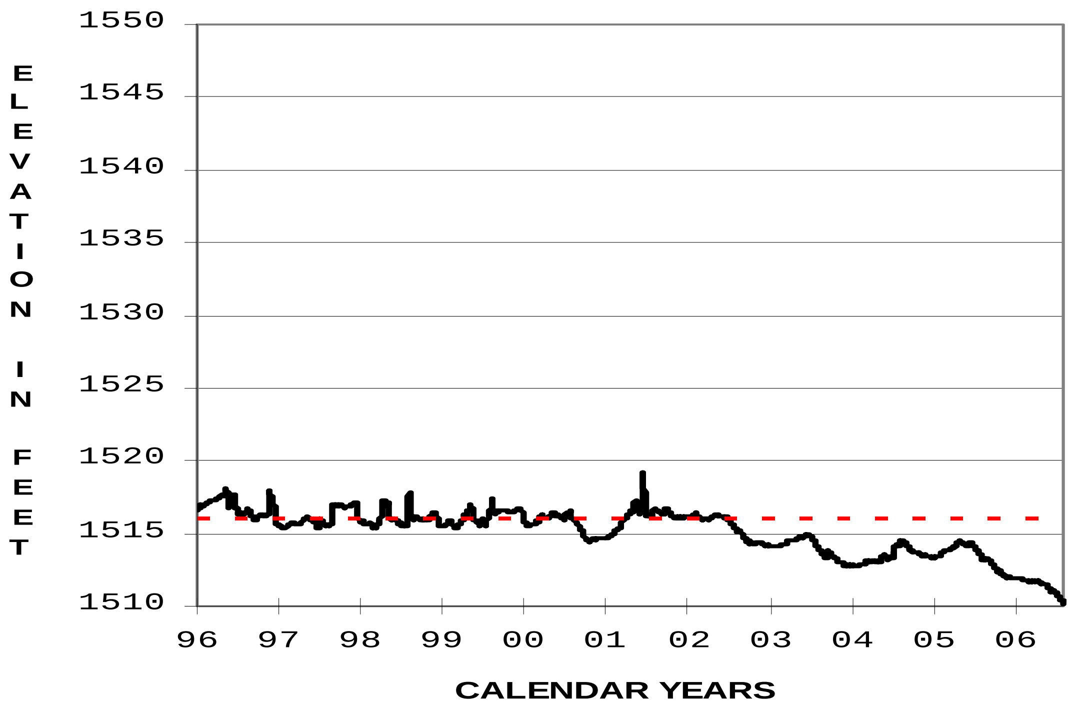


Figure 19.2. Pool elevation hydrograph from 1996 – 2006 (red-dashed line is the multipurpose pool elevation – 1516.0 msl).

19.2 2006 Activities

Wilson Lake was categorized at an 'ambient' lake during 2006, thus samples were only collected from the surface at the three lake sites (Figure 19.1 for specific locations).

Sample collections occurred from May through July and September 2006, with a single vertical profile (temperature, DO, pH, conductivity, and turbidity) recorded at the three lake sites during August. No samples were collected during August due to boat engine issues. Sulfates were added to the sample analyte list in 2006 due to the TMDL developed within the watershed. An extremely prolonged drought has impacted this western and central Kansas watershed. Such a drought would be expected to impact water quality – both positively and negatively. Wilson Lake staff (OF-WI) providing field sampling assistance during 2005 included Ryan Williams and Curtis Keller. Ken Nelson, OF-WI Operations Manager, provided insight and background regarding Wilson Lake.

19.3 2006 Data

Comparative historic data consists of monthly (April – September) data collected from 1996 through 2005. Samples were collected at the three lake sites from May through July and September during 2006.

19.3.1 Inflow

Inflow samples were not collected from the watershed site located at the Highway 281 bridge crossing (Site 1) during 2006. Historically, water quality parameters are most variable at this site due to influences of runoff events and climatic variations within the watershed.

19.3.2 Lake

Nitrogen is an essential nutrient to aquatic life. However, excessive concentrations can result in algal blooms, low DO levels, taste and odor issues in drinking water, and even fish kills. Total nitrogen (TN) median concentrations from surfaced water samples collected from 1996 through 2006 range from 0.79 – 0.9 from lake sites and 1.21 mg/L from the inflow (Site 1)(Figure 19.3). Although low in respect to other district lakes, these values exceed EPA's proposed ecoregional nutrient criteria value of 0.56 mg/L.

Phosphorus is another essential nutrient for aquatic life, and it limits algal growth. Total phosphorus (TP) median concentrations from surface water samples collected from 1996 through 2006 range from 0.03 – 0.05 mg/L from lake sites and 0.11 mg/L from the inflow (Site 1)(Figure 19.4). These concentrations greatly exceed EPA's proposed ecoregional nutrient criteria of 0.02 mg/L.

The ratio of TN:TP can be used as a surrogate to determine the dominant algal community within a waterbody. Ratios ≥ 20:1 are indicative of desirable algal communities, whereas ratios ≤ 12:1 are indicative of bloom-forming cyanobacteria (blue green algae). Median TN:TP ratios at all three lake sites range from 17 - 21, indicating the lake is not at risk for cyanobacteria blooms (Figure 19.5). These are among the highest TN : TP ratios measured within the district.

Metals were not analyzed from samples collected during 2006. However, samples were collected in 2005. Total iron exceeded EPA's Drinking Water Standard of Secondary Maximum Contaminant Levels (SMCL) of 300 ug/L from surface samples collected during August at both the inflow (Site 1) and outfall (Site 16) but was only between 60 – 175 g/L from lake sites. Concentrations were 516 ug/L at Site 16 and 1250 ug/L at Site 1. Implications are directed at drinking water facilities related to taste and staining issues, but neither exceedence site served as a drinking water source. In addition, surface samples collected from both inflow and outflow during August exceeded EPA's SMCL for manganese (50 ug/L). Those concentrations were 390 ug/L (Site 1) and 63 ug/L (Site 16), while lake sites only ranged from 15 – 24 ug/L. Implications again are directed at drinking water facilities due to taste and stain issues.

Sulfates were measured from surface water samples collected at lake sites during 2006. Concentrations ranged from 720 – 800 mg/L, which exceeds the TMDL target of 480 mg/L. The elevated concentrations could be the direct result of extended drought conditions within the watershed. The discharge of saline groundwater is dominant during drought conditions, which results in elevated sulfate and chloride concentrations.

Mean monthly (June – September) chlorophyll *a* concentrations ranged from 7 – 18 ug/L, which indicates the lake is boarderline mesotrophic – eutrophic. Highest values are measured at Site 9 (upper lake), while the lowest measurements are recorded at Site 15a (Tower).

Secchi depth, a measure of water clarity, ranged from 0.8 – 1.7 m during July. These measures were within the range measured during 2005. Site 9 (upper lake) consistently had the lowest water clarity measurements, while the highest water clarity was measured near the tower at Site 15a (Figure 19.6). The secchi depths measured at Site 15a are some of the deepest within the district. This coincides with the low chlorophyll *a* measurements, and is expected based on watershed landuse.

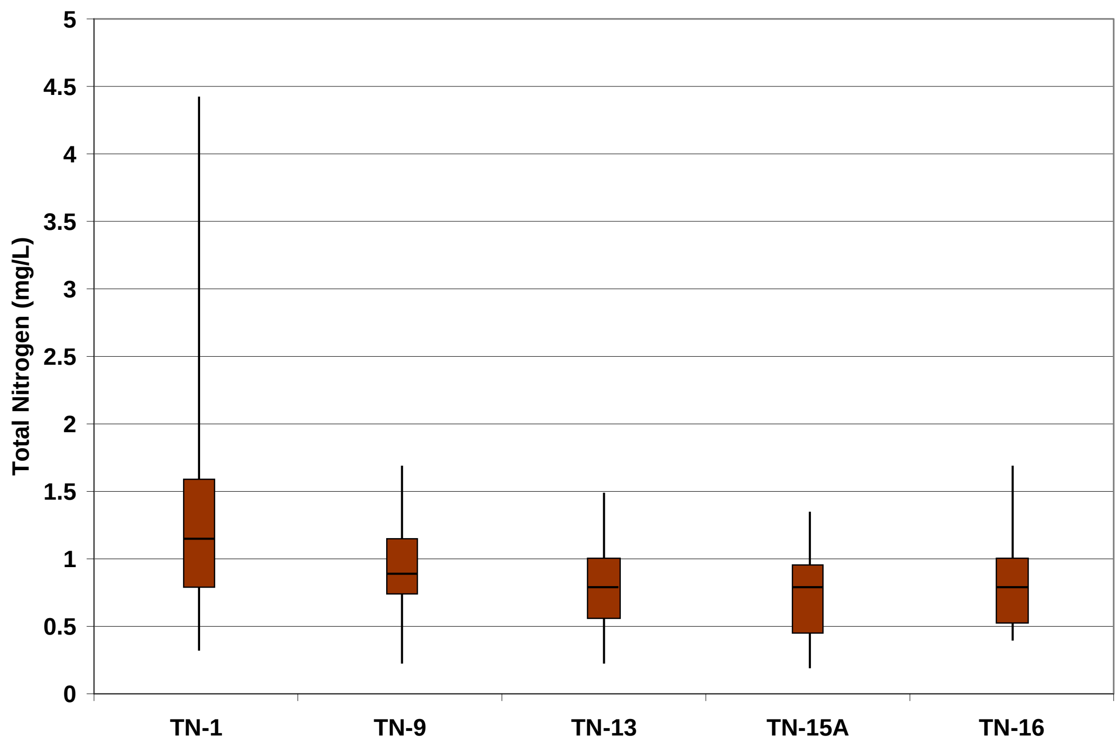


Figure 19.3. Box plots of surface water sample total nitrogen concentrations measured by site from 1996 through 2006 at Wilson Lake.

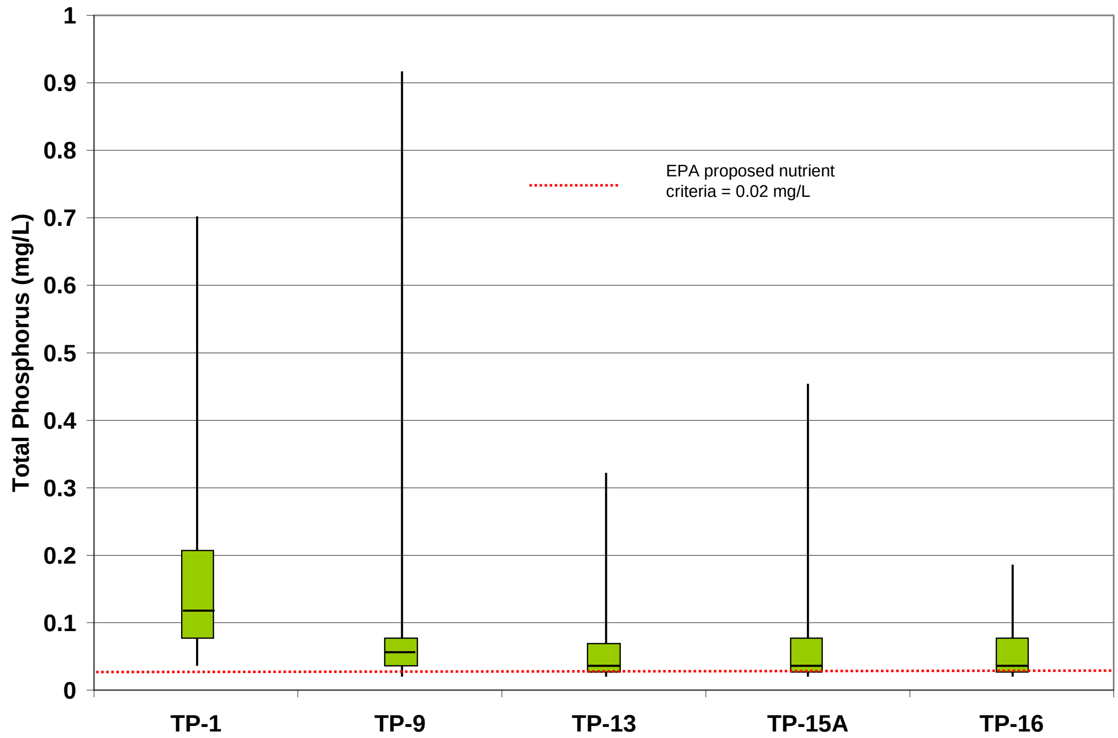


Figure 19.4. Box plots of surface water sample total phosphorus concentrations measured by site from 1996 through 2006 at Wilson Lake.

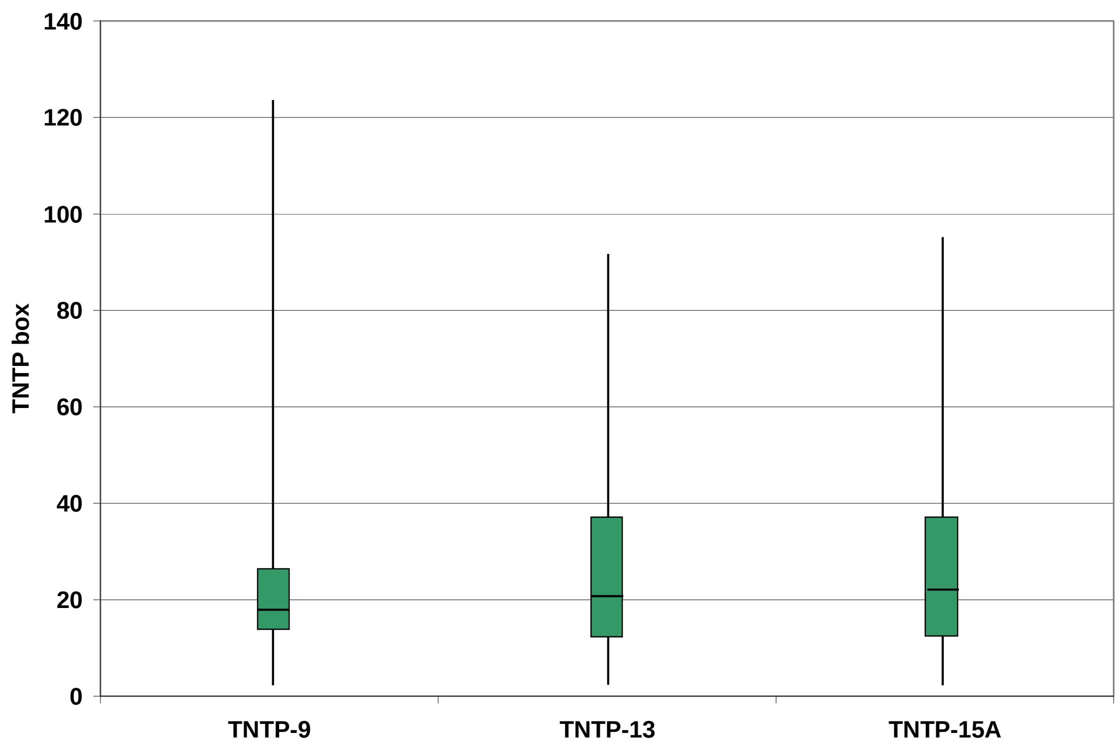


Figure 19.5. Box plots of total nitrogen : total phosphorus (TN : TP) ratio from surface samples collected by site from 1996 through 2006 at Wilson Lake.

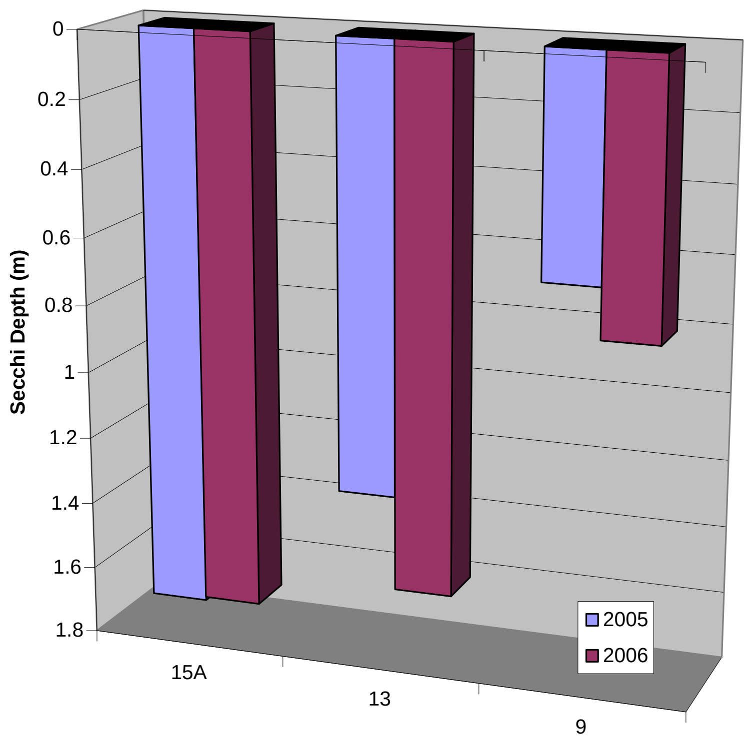


Figure 19.6. Comparisoin of secchi depth measurements by site from June through August 2005 and 2006 at Wilson Lake.

No herbicides were analyzed from any site within the watershed during 2006. However, the median atrazine concentrations collected from surface water samples between 1996 and 2005 ranged from 0.33 – 0.43 ug/L. These values are the lowest within the district (Figure 19.7). This would be expected due to landuse practices within the watershed. In fact, individual samples have never exceeded EPA's drinking water maximum contaminant level of 3 ug/L.

Vertical profiles were recorded at all three lake sites during the July sample trip in 2006. Parameters included temperature, dissolved oxygen, pH, conductivity, and turbidity. Based on these profiles, the lake was weakly stratified thermally and chemically during July between a depth of 5 and 7 m (Figure 19.8). Such conditions were expected due to the prolonged drought and decrease in water level within the lake.

Fecal bacteria (*E. coli*) samples were collected from both beaches (Minooka and Lucas) prior to major recreational season holidays during 2006. All samples were well below the Kansas Surface Water Quality Standard of *E coli* for a single sample maximum value of 732 CFU's (Figure 19.9).

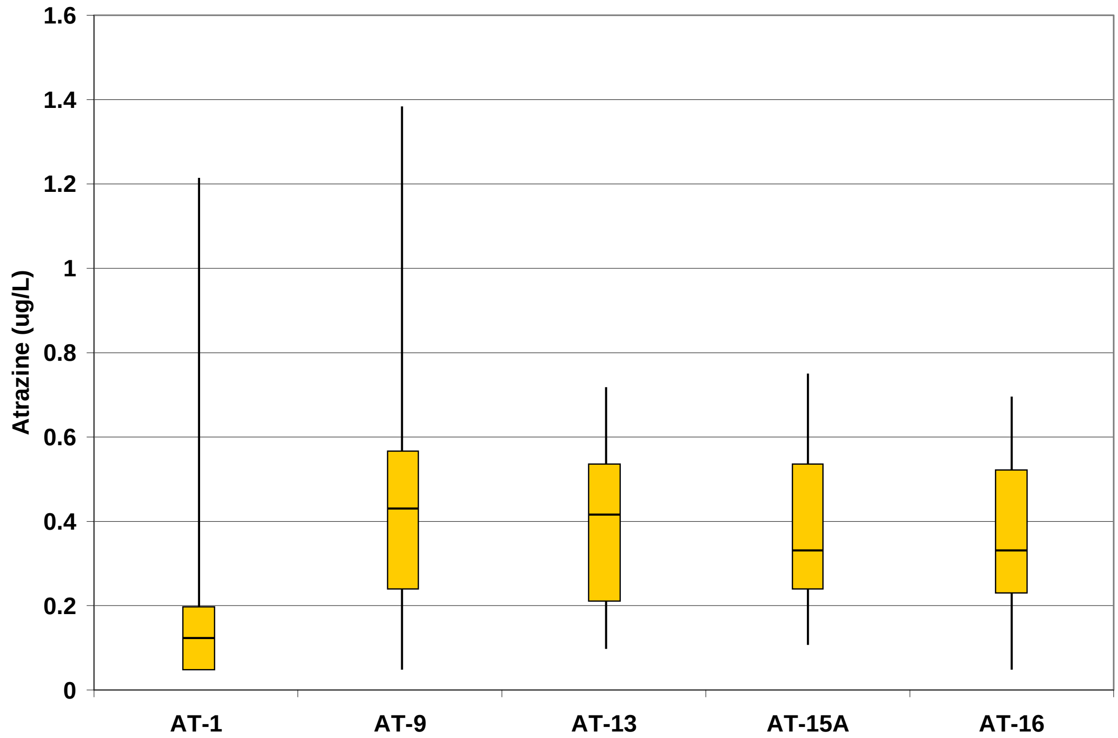
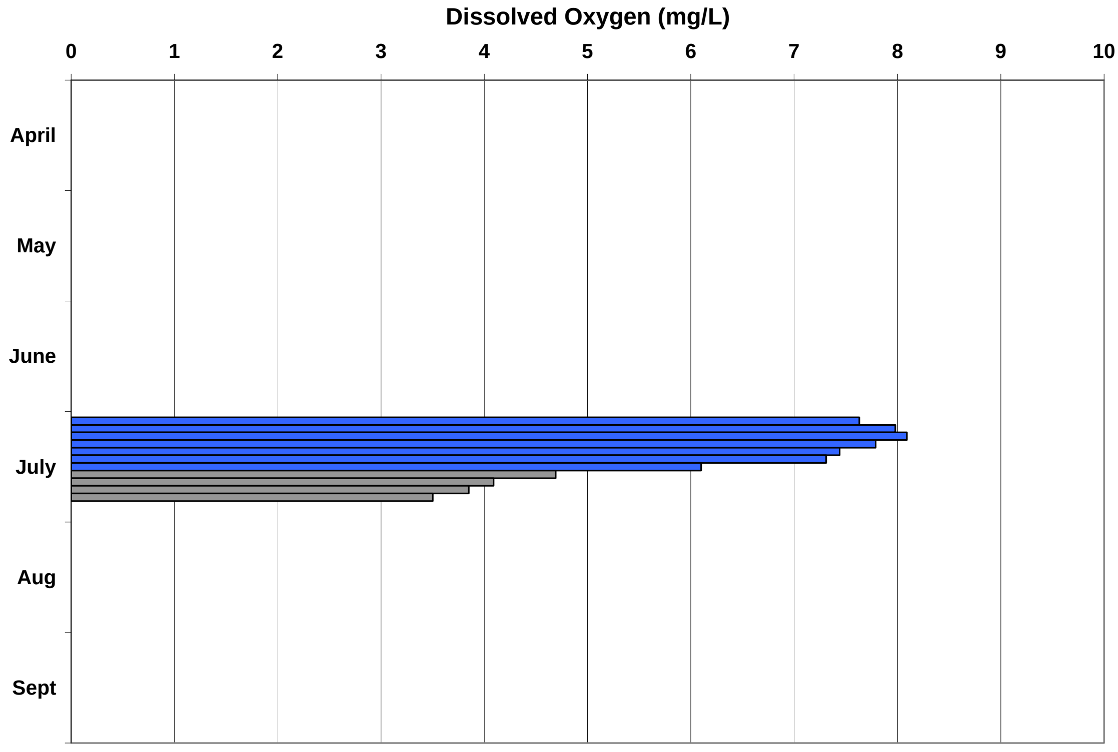


Figure 19.7. Box plots of surface water sample atrazine concentrations measured by site from 1996 through 2006 at Wilson Lake.



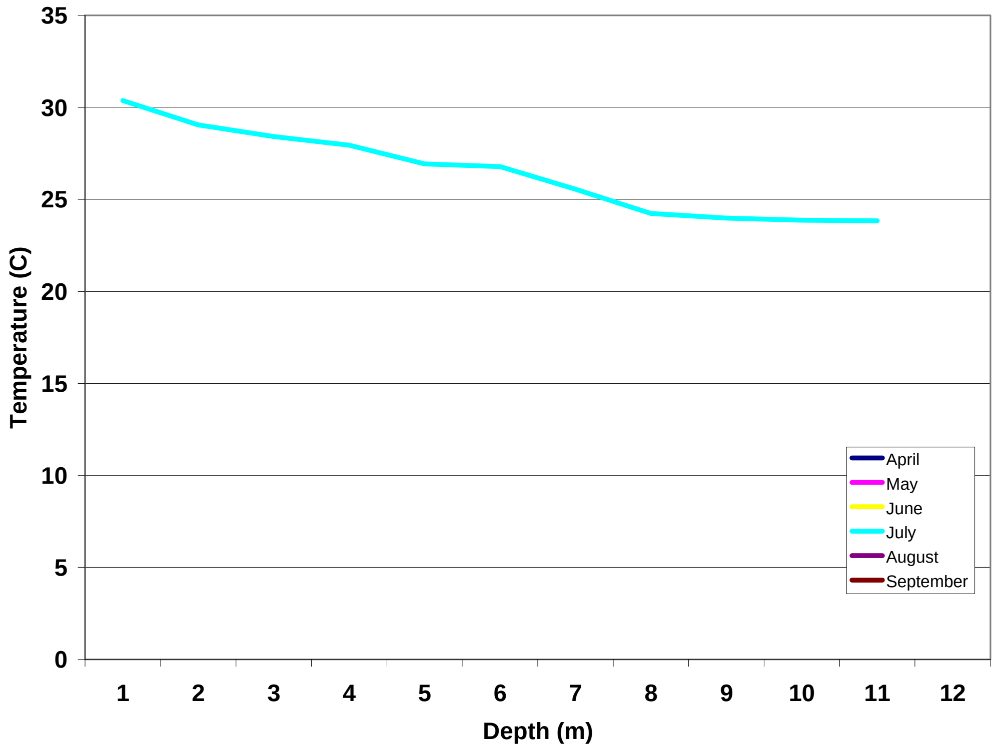


Figure 19.8. Dissolved oxygen concentration (mg/L) histogram and temperature (°C) plot from vertical profiles recorded at Site 15A (tower) from June through September 2006 at Wilson Lake.

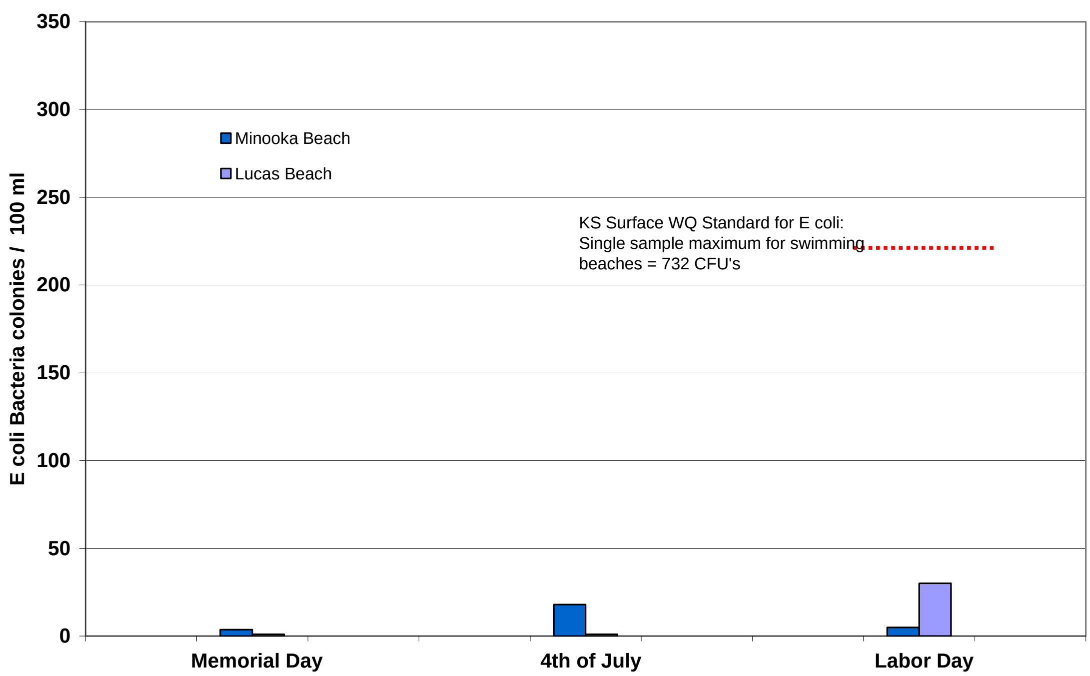


Figure 19.9. Fecal bacteria (E. coli) colonies per 100 ml samples from beach samples collected prior to major holidays at Wilson Lake during 2006.

19.3.3 Outflow

Outflow samples were collected during 2005 from the stilling basin (Site 16). This data is discussed in concert with lake specific sites above.

19.4 Future Activities and Recommendations

Sampling activities for 2007 will include continuation of 'ambient' monitoring from May through September, as well as conducting at least one summer vertical profile at each of the three lake sites. Due to concerns of potentially toxic bluegreen algae, phycocyanin concentrations will be monitored for the cyanotoxin microcystin during August and September. Geosmin, associated with taste and odor issues in drinking water, will be examined from samples collected near the tower from July through September. Caffeine will be measured at several sites around the lake as a surrogate for human impacts resulting from failing septic systems, WWTP's, illicit dumping from boats, etc. Participation and data sharing