Leesville Lake
2011 Water Quality Monitoring

(Source: http://www.leesvillelake.org)

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Leesville Lake Association

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Funds Supplied by:
American Electric Power
Leesville Lake Association

February 28, 2012

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Table of Contents

List of Tables

List of Figures

List of Maps

List of Acronyms and Abbreviations

AEP	American Electric Power
AFD	Agricultural and Forestal District
BCLP	Bedford Citizens for Land Conservation
BCWPC	Blackwater Creek Watershed Planning Committee
BMP	Best Management Practice
BW	Blackwater
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CVLC	Central Virginia Land Conservancy
Corps	U.S. Army Corps of Engineers
COW	Code and Ordinance Worksheet
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWP	Center for Watershed Protection
DCR	Virginia Department of Conservation & Recreation
DEQ	Virginia Department of Environmental Quality
DGIF	Virginia Department of Game and Inland Fisheries
DO	Dissolved Oxygen
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
ESC	Erosion and Sediment Control
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
FWS	U.S. Fish and Wildlife Service
GIS	Geographical Information Systems
GLEN	Greater Lynchburg Environmental Network
HSPF	Hydrological Simulation Program - FORTRAN
JRA	James River Association
LC	Lynchburg College
Leesville Association	Leesville Lake Association
LID	Low Impact Development
LLA	Leesville Lake Association
MRLC	Multi-Resolution Land Characterization
NEMO	Non-point Education for Municipal Officials
NFWF	National Fish and Wildlife Foundation
NGVD	National Geodetic Vertical Datum
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
NPS	Non Point Source

PDR	Purchase of Development Rights
SAFETEA-LU	Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users
Smith Mountain Association	Smith Mountain Lake Association
SMP	Shoreline Management Plan
SWCD	Soil and Water Conservation District
SWM	Stormwater Management
SCI	Stream Condition Index
TDR	Transfer of Development Rights
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VDCR	Virginia Department of Conservation & Recreation
VDEQ	Virginia Department of Environmental Quality
VDGIF	Virginia Department of Game and Inland Fisheries
VDOT	Virginia Department of Transportation
VOF	Virginia Outdoors Foundation
WHIP	Wildlife Habitat Incentives Program

Executive Summary

The Leesville Lake Association and Lynchburg College in partnership with the American Electric Power Company monitor the water quality of Leesville Lake. This report provides updated information including the results of year 2011 water quality testing for Leesville Lake, providing additional information to be used in creating a long-term plan to protect the health and quality of life in Leesville Lake.

Leesville Lake is a pump storage reservoir in Central Virginia used for Hydro-Electric power generation together with Smith Mountain Lake (SML). Built in the 1960's by American Electric Power (AEP), the lake spans approximately 17 miles from the Smith Mountain Lake Dam to the Leesville Lake Dam (http://www.leesvillelake.org). Located southwest of Lynchburg, the lake covers 3,270 acres, with portions contained within three jurisdictions: Bedford, Campbell, and Pittsylvania Counties. Appalachian Power, a unit of American Electric Power Company, generates power during peak demand hours as water passes from the Smith Mountain Lake through AEP generators to Leesville Lake. During low demands, the generators return the water to the Smith Mountain Lake. Power is also generated when water is released from the Leesville Lake dam. Water levels of Leesville Lake can fluctuate up to 13 feet daily.

Leesville Lake provides economic resources to the Roanoke River basin area. In 2005, Federal Energy Regulatory Commission (FERC) estimated that the Smith Mountain Project accounts for $89 million in earnings throughout Bedford, Campbell, Franklin, and Pittsylvania counties (The Louis Berger Group, 2009). In 2005, Appalachian Power adopted a Shoreline Management Plan to regulate uses along the shoreline to protect and enhance the project's recreational, environmental, cultural and scenic resources according to federal laws. Approximately 80 percent of SML shoreline has been developed (The Louis Berger Group, 2003).

The water quality of Leesville Lake is dependent upon the activities that occur in the lake's tributaries, Smith Mountain Lake, Roanoke River, and the surrounding Roanoke watershed. Shoreline development and development within the watershed causes erosion, sedimentation, agricultural run-off, fertilizer run-off and storm water run-off. As the surrounding land and watershed becomes more urbanized, Leesville Lake's water quality has the potential to decrease and to be further stressed. Healthy and usable water supplies are critical to members of the community and to the greater population of the Roanoke River Basin.

Leesville Lake water quality monitoring provides technical and scientific foundations that will be used for developing a management plan for the Smith Mountain and Leesville Lake reservoirs to protect and improve lake resources for the future while supporting economic growth and development.

Section 1: Introduction

For many years, the Virginia Department of Environmental Quality (DEQ) monitored Leesville Lake water quality either annually or biannually. Beginning in 2006, DEQ placed Leesville Lake on a six-year rotation for water monitoring. However, DEQ collected water quality data in 2009 and 2010.

In an effort to supplement DEQ water quality monitoring, the Leesville Lake Association (LLA) began a Citizen Water Quality Monitoring Program in April 2007. Citizen volunteers monitored bacteria, secchi depth, temperature, dissolved oxygen (DO), pH, and conductivity. LLA outlined four goals for the program: (a) gain a greater understanding of the lake's water quality, (b) supplement the DEQ water quality monitoring, (c) increase the community's awareness of the importance of water quality, and (d) inform residents about harmful factors that damage water quality and age the lake (Lobue, 2010).

The Virginia DEQ provided LLA with a water quality monitoring probe to measure DO, temperature, and pH. With the DEQ Citizen Water Quality Monitoring Grant, LLA purchased Coliscan Easygel® test kits for *E. coli* testing along with Secchi discs and other necessary equipment (Lobue, 2010). Over the next three years, LLA published annual reports of the water quality test results. As part of the water quality monitoring plan required by its new license, Appalachian Power Company committed $25,000/year plus inflation for a water quality monitoring program on Leesville Lake.

Under the Federal Power Act (FPA) and the U.S. Department of Energy Organization Act, the Federal Energy Regulatory Commission has the power to approve licenses for up to 50 years for the management of non-federal hydroelectric projects (FERC, 2009, p. ii). The Commission issued the first license for the Smith Mountain Pumped Storage Project to Appalachian Power on April 1, 1960 with a set expiration date of March 31, 2011 (FERC, 2009).

As part of its relicensing process, Appalachian Power was required by the Federal Energy Regulatory Commission to implement a Shoreline Management Plan (SMP). In July 2005, FERC approved a SMP proposed by Appalachian for the Smith Mountain Project. The purpose of this plan is *"to ensure the protection and enhancement of the project's recreational, environmental, cultural, and scenic resources and the project's primary function, the production of electricity."* (FERC, 2009, p. 22). The SMP works to preserve green space, wetlands, and wildlife habitats along the shoreline. Property owners may not remove vegetation within the project boundary unless they have received permission from Appalachian Power. The project boundary for Leesville Lake lies at the 620-foot contour elevation (LLA, 2009).

To renew their license, Appalachian Power Company (Appalachian Power), a unit of American Electric Power (AEP), submitted an application for a new license in March 2008. In August 2009, the Federal Energy Regulatory Commission issued a Final Environmental Impact Statement for the Smith Mountain Project relicensing. While reissuing, the Commission reviewed AEP's methods and proposals for "the protection, mitigation of damage to, and enhancement of fish and wildlife (including related spawning grounds and habitat), the protection of recreational opportunities, and the preservation of other aspects of environmental

quality." (FERC, 2009, p. 1). In the final Environmental Impact Statement (EIS), the FERC endorsed Appalachian Power's proposed $25,000 annually to the LLA to support the on-going water quality monitoring program (FERC, 2009, p. 25). The Commission approved the new license, effective April 1, 2011.

FERC recommended a few modifications to Appalachian Power's *Water Quality Monitoring Plan* including a proposal to develop a lake water quality monitoring plan. FERC determined that the primary water quality issues for Smith Mountain and Leesville lakes arise from nutrients and bacteria. Rather than coming from the dams' operations, the nutrients and bacteria come from shoreline development and overall watershed development. In conclusion, FERC recommended the (a) continuation of water-quality monitoring for Smith Mountain Lake, (b) establishment of a water quality monitoring program for Leesville Lake, and (c) ensuring the future health of the lakes by monitoring lake quality to verify that any changes in operational strategy at the Smith Mountain project do not harm water quality.

In summary, a timeline of significant events is outlined below:

- April 1960: First license for Smith Mountain Project issued
- April 2007: Development of Leesville Lake Citizen Water Quality Monitoring Plan
- 2007-2009: LLA annually reports on water quality
- 2008: AEP proposed $25,000 in 2010 to LLA for water quality monitoring plan
- August 2009: FERC issues a final EIS for Smith Mountain Project relicensing, recommending a water quality plan for Leesville Lake
- April 2011: AP's new license for Smith Mountain Project becomes effective
- June 2011: Lynchburg College begins water quality testing of Leesville Lake
- February 2011: Lynchburg College reports on 2010 water quality
- February 2012: Lynchburg College reports on 2011 water quality

Participants:

In August 2003, a group of Leesville Lake residents formed a non-profit 501(c)(3) corporation called the Leesville Lake Association. The association addresses the issues of debris, shoreline management, environmental and biological health, safety, future development, and fishing for Leesville Lake (LLA, 2003).

In 2007, the Department of Environmental Quality revised the Millennium 2000 Water Quality Monitoring Strategy. The Virginia DEQ maintains the "Water Quality Monitoring and Assessment (WQMA) Program" with the ultimate goal to *"provide representative data that will permit the evaluation, restoration and protection of the quality of the Commonwealth's waters at a level consistent with such multiple uses as prescribed by Federal and State laws (VDEQ, 2007)."*

LLA partnered with Lynchburg College to establish the 2011 Water Quality Monitoring Plan. Lynchburg College agreed to conduct the samplings and testing, and report results.

LLA water monitoring volunteers for 2011 were: Jack & Richard Jenet, Jane & Ron Long, Carmen Perri, Roger Winters and Mike Lobue.

For a description of Leesville Lake and communities, refer to Section 2 of Lynchburg College's report titled *Leesville Lake 2010 Water Quality Monitoring* dated February 28, 2011.

Statement of Goals and Objectives:

Goals and Objectives of the Leesville Lake Water Quality Monitoring Plan:
The Federal Energy Regulatory Commission recommended that a water quality plan for Leesville Lake be developed. In a collaborative approach, Leesville Lake Association and Lynchburg College developed a plan in February 2010 to continue and expand the testing and monitoring of water quality, to monitor nutrients and trophic status, and to supplement data collected by the Virginia Department of Environmental Quality in order to better understand the current state of Leesville Lake.

Leesville Lake Association
The objectives of the Leesville Lake Association, according to its Articles of Incorporation, are as follows (http://www.leesvillelake.org):

- Plan projects and studies that:
  a. Monitor and protect the water quality of Leesville Lake
  b. Contribute to the clean-up and preservation of the lake's shorelines
  c. Promote safe recreational use
  d. Improve the condition of the surrounding land as a high-quality recreational and residential area
  e. Maintain favorable water levels in Leesville Lake for the Smith Mountain Pumped Storage Hydro Project

- Educate to individuals, organizations, and the general public information concerning:
  a. Water quality monitoring results
  b. Management techniques and practices to preserve the environmental quality of Leesville Lake and its watersheds
  c. Safe recreational activities
  d. Commercial and government activities that could harm geographic area of Leesville Lake
  e. How to maintain optimum water levels in Leesville Lake

Section 2: Historical Data

2.1 Sources with Summaries of Historical Data

The annual reports of the Leesville Lake Association's Citizen Water Monitoring Project and the Virginia DEQ data are the two primary sources of historical data.

DEQ compiled the data with the assistance of the Department of Conservation and Recreation (DCR) for its Virginia Water Quality Assessment Reports. Data was collected by the agencies quality control citizen monitoring data. DEQ used Water Quality Management Plans (WQMPs), required by section 303(e) of the Clean Water Act, to establish the link between the required water quality assessment and water quality based controls.

Map 2.1. Leesville Lake Water Quality Monitoring Stations with DEQ Identification (Lobue 2011)

From June through November 2010, Lynchburg College and volunteers from LLA collected Leesville Lake water quality data. Lynchburg College sampled eight sites while LLA sampled seven. Data on water quality parameters included temperature, oxygen (dissolved oxygen and percent saturation dissolved oxygen percentage), conductivity, pH, oxidation-reduction potential, turbidity and more.

Total Maximum Daily Load (TMDL):
The Virginia Total Maximum Daily Load (TMDL) Program, which addresses waters with bacteria levels exceeding state standards, published a report in 2006 on waters around Leesville Lake. This report addressed bacteria levels flowing from the lake's two main tributaries; Pigg River and Old Woman's Creek (Lobue, 2010, p. 10). Story Creek (a tributary to Leesville Lake-Pigg River) and Upper Pigg River have been on Virginia's 303(d) list of impaired waters since 1996. Leesville Lake-Pigg River has been listed as impaired since 1998. Snow Creek (another tributary to Leesville Lake-Pigg River) and Old Woman's Creek have been listed as impaired since 2002.

The TMDL report identified three point sources discharging bacteria into the Pigg River basin, with one located in the Story Creek watershed area. There were no permitted dischargers in the Old Womans Creek watershed. The TMDL reporting specifies nonpoint sources as the primary source for high bacteria levels; including agriculture, land-applied animal waste, and livestock manure are the main nonpoint sources. The report also specifies that cattle and wildlife directly dumping feces into streams cause a large bacteria load. Nonpoint sources from residential areas include straight pipes, failing septic systems, and pet waste (Virginia Tech, 2006).

Section 3: Current Conditions (Year 2011)

3.1 General:

This is the second year Lynchburg College has engaged in monitoring of Leesville Lake. While the data base is increasing, we are using this annual survey of water quality parameters to determine current trophic status and future direction of the lake. We look to continually increase our understanding not only of lake processes but the surrounding watersheds and processes of Smith Mountain Lake that influence water quality. We need good monitoring to predict the influences of changes occurring in the lake. These current conditions reflect our understanding of the current lakes condition. As more information is acquired we will make greater inferences on future trends.

3.2 Methods:

2011 data was collected by Lynchburg College through a series of water samplings and testing from April through October, when lake productivity was high. The following eight sites were sampled, as stated in the Leesville Lake Water Monitoring Plan:

Table 3.0. Leesville Lake 2011 Sampling Sites

Lynchburg College Station	Leesville Lake Association Station	Site ID	DEQ Station ID	Latitude	Longitude
Leesville Lake Dam	11	2636	LVLAROA140.66	37.0916	-79.4039
Pit Stop Marina	5	1275	LVLAOWC000.58	37.05939	-79.39574
Tri County Marina	3	1273	LVLATER000.33	37.05942	-79.44489
Mile Marker 6	8	1373	LVLAROA146.87	37.06320	-79.47110
Mile Marker 9	2	1272	LVLAROA149.94	37.03993	-79.48233
Toler Bridge	1	1271	LVLAROA153.47	37.01090	-79.47530
Pigg River	9	1374	LVLAPGG000.47	37.00430	-79.48590
Smith Tail Waters	12	2637	LVLAROA157.92	37.0382	-79.531306

Volunteers collected samples for testing at each site on June 15 and July 13.

For more detail concerning water quality testing parameters, quality assurance (QA) and quality control (QC), please see Appendix A, B and C.

3.3 Water Quality: Current Test Results (2011)

3.3.1 Temporal Analysis by Station

Background

The analysis of results is divided into three distinct zones representing the zones of the reservoir. In the portion near the dam, we consider the reservoir to be Lacustrine and we have labeled it the Dam site. This classification suggests the reservoir will take on qualities we often see associated with lakes. It is the deepest portion of the reservoir and less likely to be immediately affected by river inputs. It should show the strongest levels of stratification and develop patterns of biology, chemistry and physical processes better understood from lake limnology. However, the lacustrine zone is not isolated from Riverine influences. During high volume storm events stratification is broken down in these areas and the reservoir resembles a river from headwaters to the dam.

The middle portions of the reservoir are considered the transition zones. This is Mile Marker 6 (MM6) in our study. In this area, the Lacustrine portions of the reservoir meet the Riverine dominated sections. This area often exhibits the highest areas of productivity due to river inputs of nutrients yet slows water velocities allowing biological processes to flourish. This defined area may move in the reservoir as Riverine processes exert influence. This is again driven by hydrological inputs. In our best analysis, it is acceptable to observe the transition zone based upon depth, nutrient transport and productivity.

The upper portions of the reservoir are considered Riverine. This is labeled as Toler Bridge in our study. The reservoir's Riverine Section behaves much like a large river system. While nutrients are often elevated so are the sediment inputs. This limits potential limnetic (open water) biological productivity but often creates ideal conditions for littoral (shoreline) production. Nuisance rooted vegetation often takes hold in this portion of the reservoir. Inputs from Riverine areas often determine water quality parameters for the Lacustrine portions.

Additionally, several sites throughout the reservoir were sampled for specific reasons. We sampled marinas at the lake (Pitt Stop and Tri County) due to concern of possible *E. coli* contamination. We sampled Mile Marker 9 to study a point above the transition zone as the lake becomes riveriene. We sampled Pigg River confluence to determine the potential impacts this river has on water quality in the lake. Finally, we sampled Smith Mountain Lake tail waters to see water quality entering from the lake.

The following analysis divides the reservoir into these three sections and then discusses the additional sampling stations on expected and observed results. One of the difficulties for predicting water quality trends in Leesville Lake is the artificially influenced hydrology. While expectations are outlined, Smith Mountain Lake operations are a dominate hydrological feature and create difficulty in predicting the water quality of Leesville Lake.

3.3.2 Dam (Lacustrine)

The area near the dam is considered a Lacustrine section. It exhibits characteristics similar to a lake and can be analyzed for similarities to lake conditions.

Conductivity (Figure 3.1) measures in reservoir often show us changes in hydrology. Depth profiles can demonstrate stratification. We see through several sampling events, particularly in the summer, that the lake will stratify near the dam. We do see changes in conductivity levels between dates, but nothing here is significant.

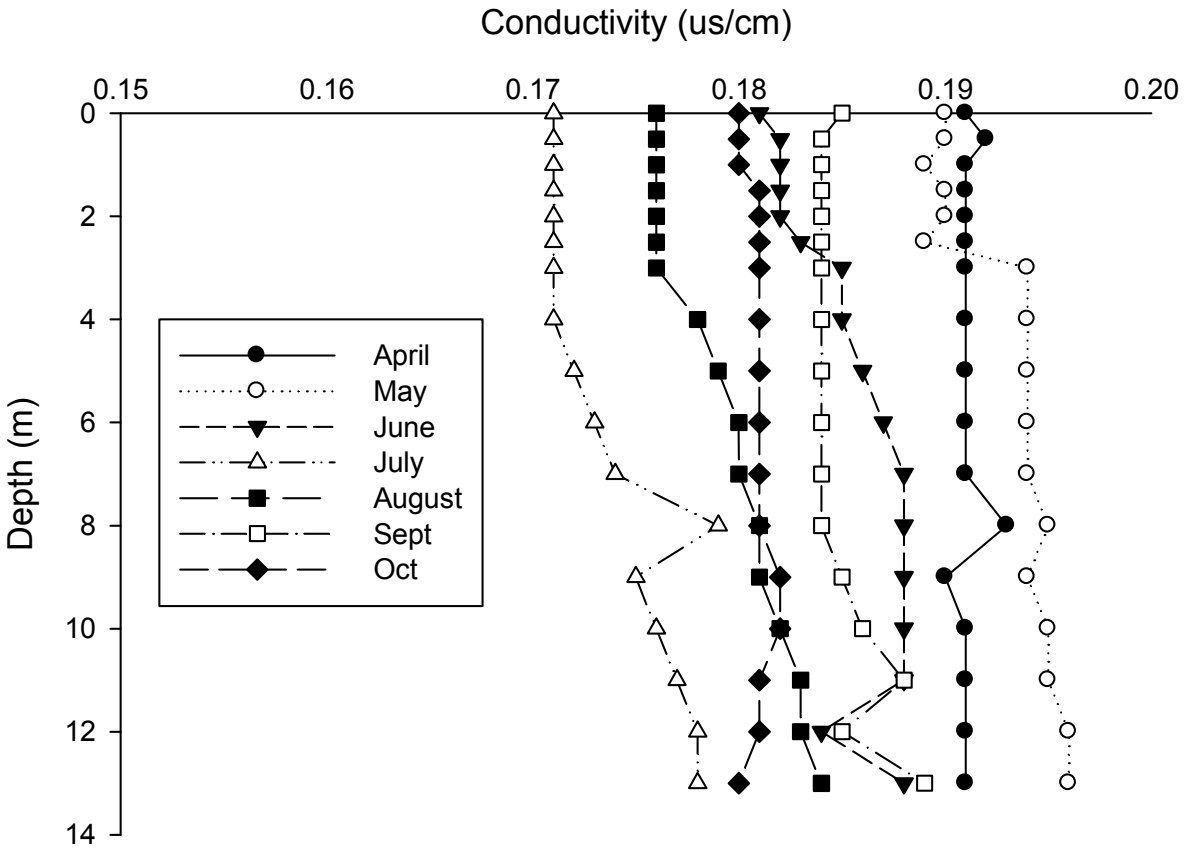

Figure 3.1. Dam (Lacustrine) Conductivity (us/cm) measures over study period (2011).

Table 3.1. Dam (Lacustrine) Conductivity (µs/cm) Measures Over Study Period (2011).

Depth in Meters:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	0.191	0.19	0.181	0.171	0.176	0.185	0.18
0.5	0.192	0.19	0.182	0.171	0.176	0.184	0.18
1	0.191	0.189	0.182	0.171	0.176	0.184	0.18
1.5	0.191	0.19	0.182	0.171	0.176	0.184	0.181
2	0.191	0.19	0.182	0.171	0.176	0.184	0.181
2.5	0.191	0.189	0.183	0.171	0.176	0.184	0.181
3	0.191	0.194	0.185	0.171	0.176	0.184	0.181
4	0.191	0.194	0.185	0.171	0.178	0.184	0.181
5	0.191	0.194	0.186	0.172	0.179	0.184	0.181
6	0.191	0.194	0.187	0.173	0.18	0.184	0.181
7	0.191	0.194	0.188	0.174	0.18	0.184	0.181
8	0.193	0.195	0.188	0.179	0.181	0.184	0.181
9	0.19	0.194	0.188	0.175	0.181	0.185	0.182
10	0.191	0.195	0.188	0.176	0.182	0.186	0.182
11	0.191	0.195	0.188	0.177	0.183	0.188	0.181
12	0.191	0.196	0.184	0.178	0.183	0.185	0.181
13	0.191	0.196	0.188	0.178	0.184	0.189	0.18
14	0.192	0.197		0.179	0.187	0.19	0.181

Dissolved Oxygen (Figure 3.2) further strengthens the idea of stratification in the lake. During July through September, the dam area became stratified and deeper portions of the reservoir exhibited anoxic conditions. This is characteristic of eutrophic reservoirs and Leesville Lake exhibits these characteristics when water mass is stabilized. This is the same pattern the lake exhibited in 2010. Additionally, the June sample exhibited a very strong positive heterograde. This occurs when high biological activity (algal growth) occurs along the thermocline. Because of stratification and the availability of nutrients from the hypolimnion algae tend to accumulate in this zone. This suggests eutrophication may be strengthening in the lake and needs to be closely monitored.

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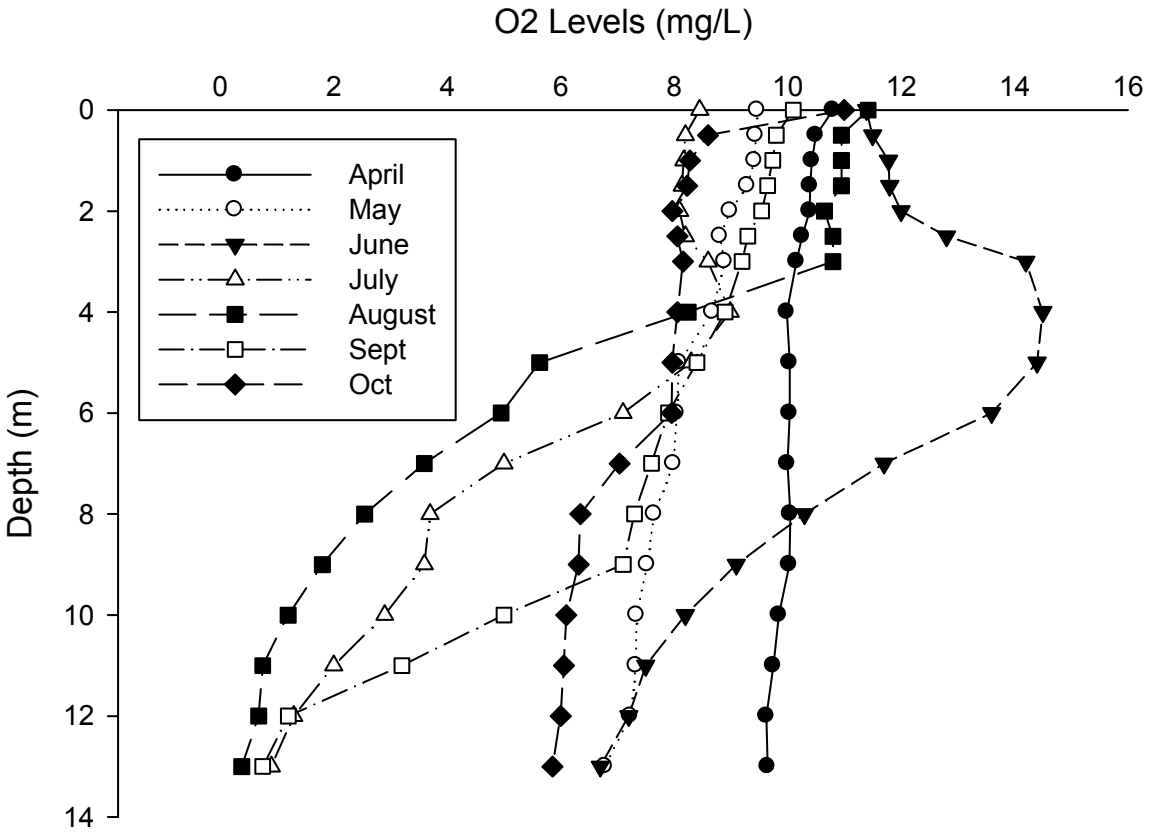

Figure 3.2 - Dam (Lacustrine) Dissolved Oxygen (mg/L) measures over study period (2011).

Table 3.2. Dam (Lacustrine) Dissolved Oxygen (mg/L) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	10.8	9.47	11.39	8.45	11.42	10.1	11
0.5	10.5	9.44	11.5	8.2	10.95	9.8	8.6
1	10.43	9.42	11.78	8.17	10.95	9.74	8.28
1.5	10.4	9.29	11.8	8.14	10.95	9.65	8.23
2	10.39	8.99	12	8.1	10.65	9.54	7.97
2.5	10.26	8.81	12.8	8.2	10.8	9.3	8.06
3	10.16	8.89	14.2	8.6	10.8	9.2	8.16
4	9.99	8.68	14.5	8.99	8.25	8.9	8.06
5	10.04	8.09	14.4	8.3	5.63	8.4	7.97
6	10.04	8.05	13.6	7.1	4.95	7.9	7.96
7	10	7.99	11.7	5	3.6	7.6	7.04
8	10.05	7.65	10.3	3.7	2.55	7.3	6.35
9	10.03	7.53	9.1	3.6	1.8	7.1	6.32
10	9.85	7.34	8.2	2.9	1.2	5	6.1
11	9.75	7.33	7.5	2	0.75	3.2	6.06
12	9.63	7.23	7.2	1.3	0.68	1.2	6
13	9.65	6.78	6.7	0.9	0.38	0.75	5.86
14	9.53	6.6		0.8	0	0.46	5.54

This data should be looked at in conjunction with Temperature (Figure 3.3).

June, July and August are the warmest months and exhibit the greatest degree of stratification. To determine stratification, we look for areas with greater than 1 degree change in temperature over a meter of depth. Stratification occurred beyond three meters in the reservoir this year. This is slightly deeper than in 2010. The stability of the water mass and weather patterns usually account for the strength of stratification in the reservoir here. The important point here is the stratification the lake shows here and the response of oxygen to that stratification.

Looking at the combination of oxygen and temperature we get a good indication that the reservoir is eutrophic. Cooler water would hold more oxygen in the absence of biological activity. In Leesville Lake during the summer months oxygen levels are very low in the hypolimnion. The hypolimnion does warm throughout the season suggesting the lake is polymictic mixing many times throughout the year. This data is also crucial for establishing viable habit for striped bass in the reservoir.

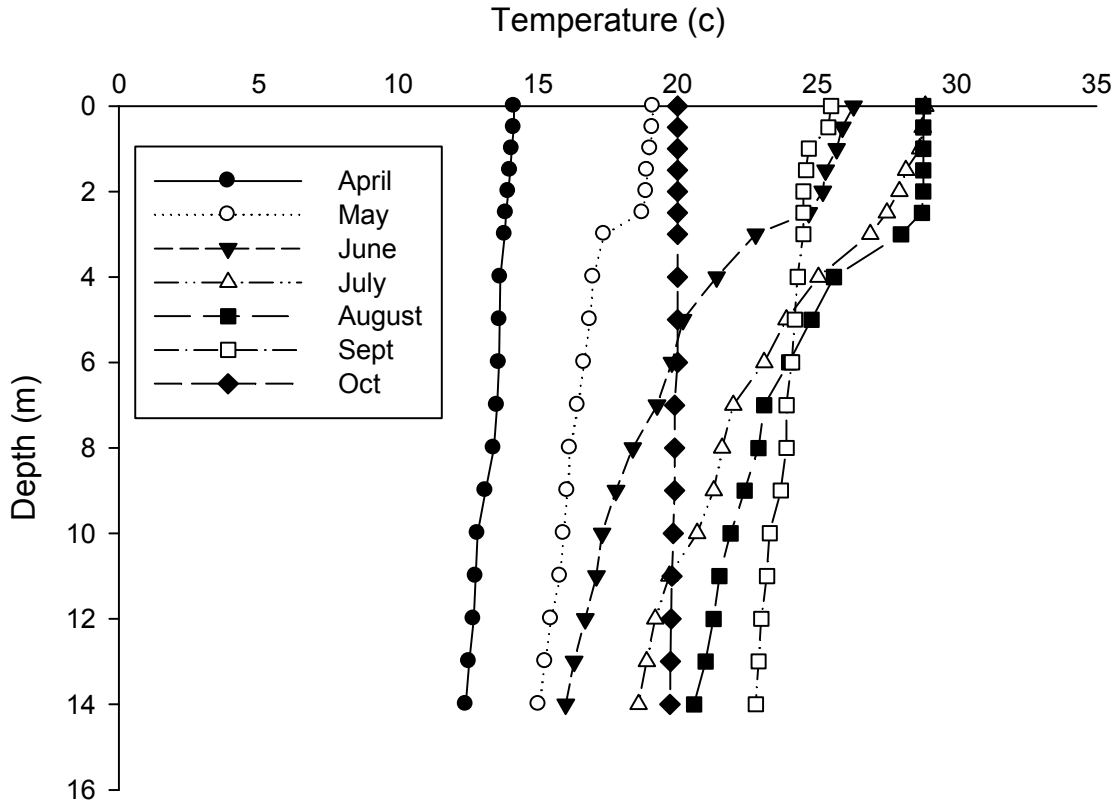

Figure 3.3. Dam (Lacustrine) Temperature (Degrees C) measures over study period (2011).

Table 3.3. Dam (Lacustrine) Temperature (Degrees C) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	14.15	19.13	26.3	28.87	28.8	25.5	20
0.5	14.14	19.11	25.9	28.77	28.8	25.4	20
1	14.07	19.03	25.7	28.68	28.8	24.7	20
1.5	14.01	18.92	25.3	28.18	28.8	24.6	20
2	13.95	18.89	25.2	27.94	28.8	24.5	20
2.5	13.86	18.75	24.7	27.5	28.75	24.5	20
3	13.82	17.38	22.8	26.9	28	24.5	20
4	13.66	16.99	21.4	25.04	25.6	24.3	20
5	13.64	16.87	20.2	23.9	24.8	24.2	20
6	13.61	16.66	19.8	23.1	24	24.1	20
7	13.54	16.43	19.27	22	23.1	23.9	19.9
8	13.42	16.15	18.4	21.6	22.9	23.9	19.9
9	13.13	16.06	17.8	21.3	22.4	23.7	19.9
10	12.85	15.93	17.3	20.7	21.9	23.3	19.85
11	12.78	15.8	10.1	19.7	21.5	23.2	19.8
12	12.7	15.48	16.7	1.2	21.3	23	19.77
13	12.54	15.27	16.3	18.9	21	22.9	19.75
14	12.42	15.03		18.6	20.6	22.8	19.73

The measurement of chlorophyll *a* data through profiles (Figure 3.4) illustrates the productivity patterns in the reservoir. On several sampling occasions high concentrations of chlorophyll a were observed in the metalimnion (transition zone between the epilimnion and the hypolimnion). Elevated chlorophyll a data in June supported the oxygen results. A similar pattern in July occurred but was not as elevated as the June event.

Chlorophyll *a* levels of this magnitude are suggestive of eutrophic conditions (Table 3.4). Often, integrated samples only reflect slight increases during summer month because profiles are not available. Using fluorometric detection in-situ demonstrates this elevated condition and helps us to recognize phytoplankton dynamics in the reservoir. Such bloom conditions need to be analyzed for species composition to determine what type of phytoplankton is involved. This will additionally help with management decision making.

Other measures throughout the year are reflective of a mildly eutrophic reservoir and fall in line with other measured parameters of trophic state. It can be argued that other factors such as turbidity are contributing to lower Secchi depths (when compared to suggested depths in Table 3.9). Yet chlorophyll a levels are at expected levels for phosphorus concentrations.

Table 3.4. Typical trophic state indicators for lakes.

	Organic Matter	TP mg/L	Avg Chl *a* (ppb)	Secchi Depth (M)	TSI
Oligotrophic	low	0.008	4.2	8 - 4	< 40
↓					
Mesotrophic	medium	0.027	16.1	4 - 2	40-50
↓					
Eutrophic	high	0.084	42.6	2 - 1	50-70
↓					
Hypertrophic	very high	0.7-1.2		0.4-0.5	> 70

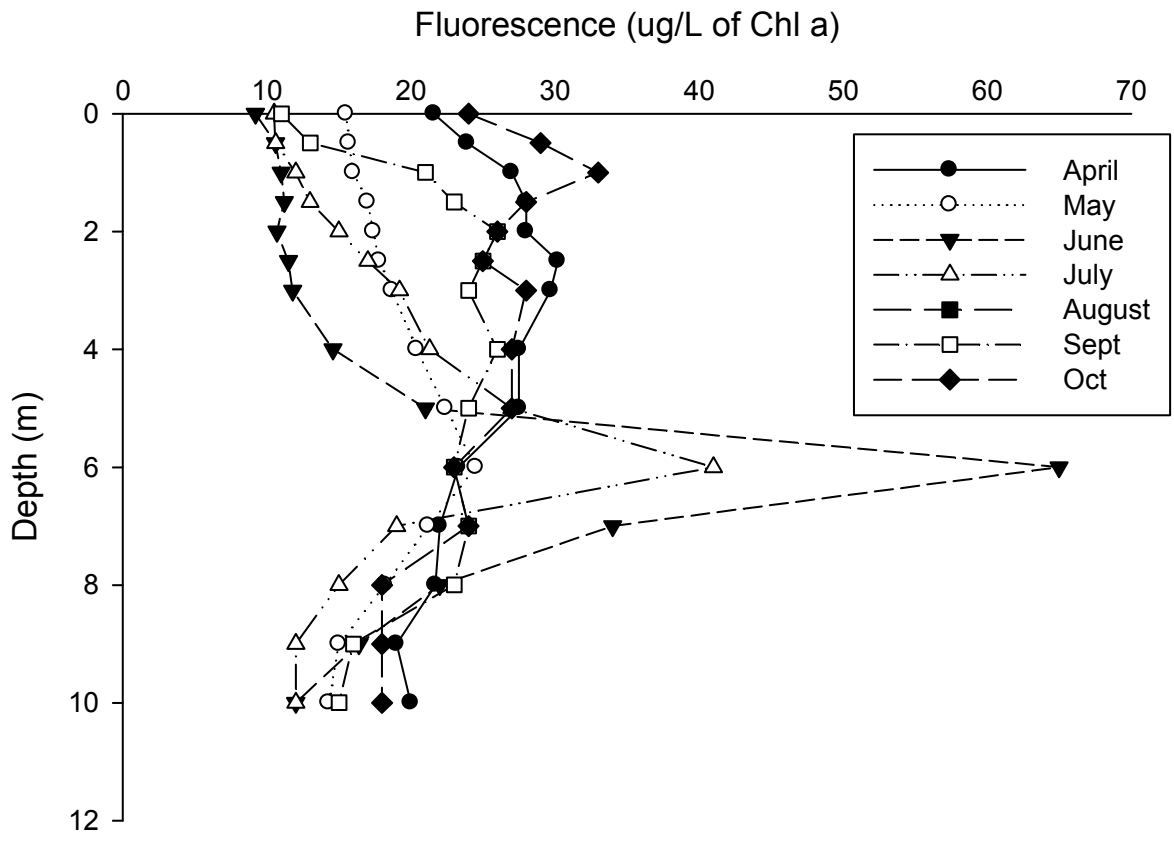

Figure 3.4. Dam (Lacustrine) Fluorometer measured Chlorophyll *a* (ppb) measures over study period (2011).

Table 3.5. Dam (Lacustrine) Fluorometer measured Chlorophyll *a* (ppb) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	21.6	15.5	9.2	10.5	n/a	11	24
0.5	23.9	15.7	10.6	10.6	n/a	13	29
1	27	16	11	12	n/a	21	33
1.5	28	17	11.2	13	n/a	23	28
2	28	17.4	10.7	15	n/a	26	26
2.5	30.2	17.8	11.5	17	n/a	25	25
3	29.7	18.7	11.8	19.2	n/a	24	28
4	27.5	20.4	14.6	21.3	n/a	26	27
5	27.5	22.4	21	27	n/a	24	27
6	23.3	24.5	65	41	n/a	23	23
7	22	21.2	34	19	n/a	24	24
8	21.7	18.2	22	15	n/a	23	18
9	19	15	16.4	12	n/a	16	18
10	20	14.3	12	12	n/a	15	18
11	18.3	13	10	12	n/a	13	
12	19.4	13.4			n/a	13	
13	19.4	13.4			n/a	13	
14	19.4	13.4			n/a	13	

Measures of pH (Figure 3.5) are typical of reservoirs. We see elevated pH during times and in the profiles during high phytoplankton populations. Elevated pH occurs from phytoplankton productivity removing CO_2 from water. Carbon dioxide acts as a weak acid in water and its removal elevates pH. The August readings were elevated and this corresponded well with elevated Chlorophyll *a* readings in this portion of the reservoir. Mixing conditions appear to influence the concentrations of phytoplankton in the water column.

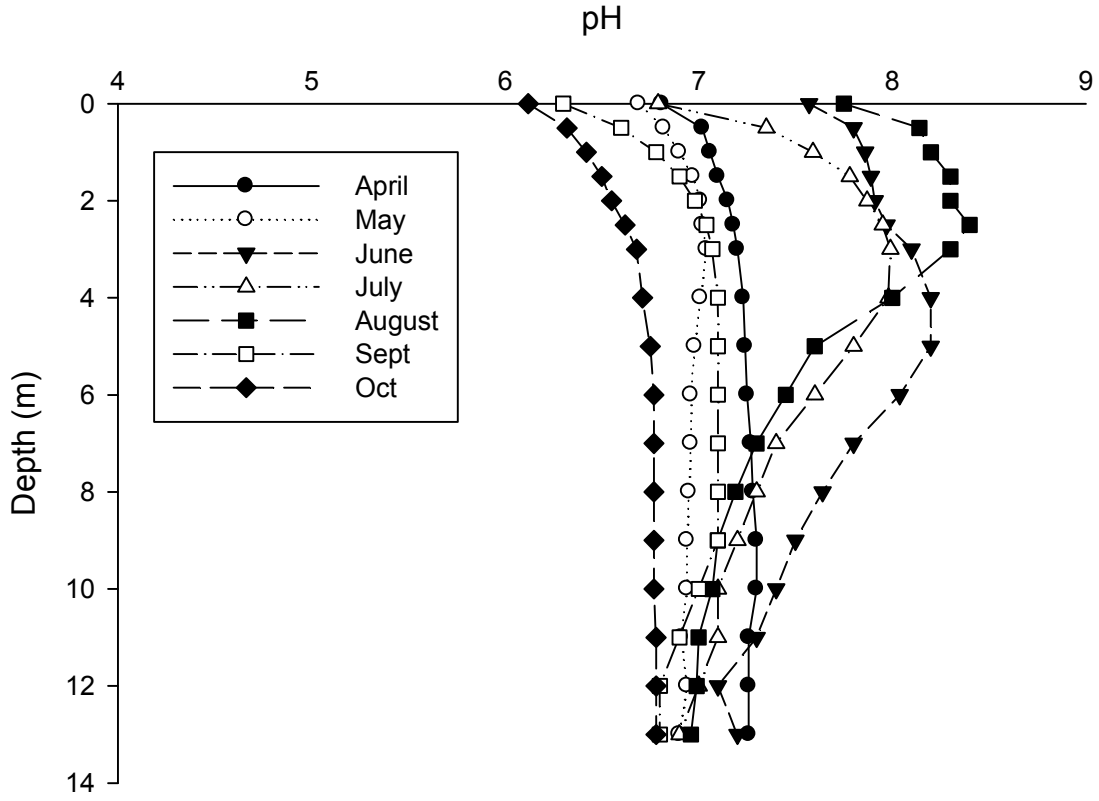

Figure 3.5. Dam (Lacustrine) pH measures over study period (2011).

Table 3.6. Dam (Lacustrine) pH Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	6.81	6.69	7.57	6.79	7.75	6.3	6.12
0.5	7.02	6.82	7.8	7.35	8.14	6.6	6.32
1	7.06	6.9	7.86	7.59	8.2	6.78	6.42
1.5	7.1	6.97	7.89	7.78	8.3	6.9	6.5
2	7.15	7.01	7.91	7.87	8.3	6.98	6.55
2.5	7.18	7.02	7.97	7.95	8.4	7.04	6.62
3	7.2	7.04	8.1	7.99	8.3	7.07	6.68
4	7.23	7.01	8.2	7.98	8	7.1	6.71
5	7.24	6.98	8.2	7.8	7.6	7.1	6.75
6	7.25	6.96	8.04	7.6	7.45	7.1	6.77
7	7.27	6.96	7.8	7.4	7.3	7.1	6.77
8	7.28	6.95	7.64	7.3	7.19	7.1	6.77
9	7.3	6.94	7.5	7.2	7.1	7.1	6.77
10	7.3	6.94	7.4	7.1	7.07	7	6.77
11	7.26	6.91	7.3	7.1	7	6.9	6.78
12	7.26	6.94	7.1	7	6.99	6.8	6.78
13	7.26	6.9	7.2	6.9	6.96	6.8	6.78
14	7.26	6.88		6.9	6.9	6.8	6.77

Oxidation Reduction Potential (ORP) measured in Figure 3.6 is information related to chemical transformations in the reservoirs. Patterns measured this season show a more oxidized environment during the spring sampling periods with increased reduction potential later in the season. Patterns were consistent throughout the profile.

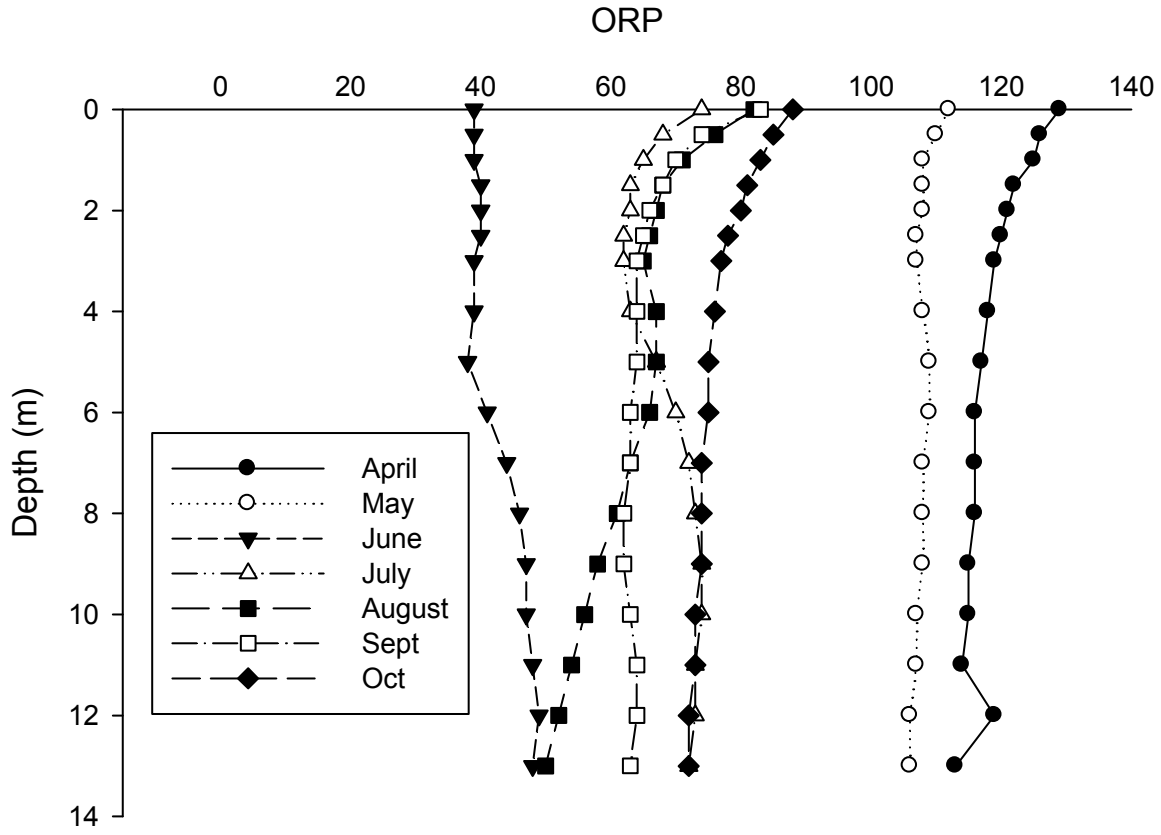

Figure 3.6. Dam (Lacustrine) ORP measures over study period (2011).

Table 3.7. Dam (Lacustrine) ORP Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	129	112	39	74	82	83	88
0.5	126	110	39	68	76	74	85
1	125	108	39	65	71	70	83
1.5	122	108	40	63	68	68	81
2	121	108	40	63	67	66	80
2.5	120	107	40	62	66	65	78
3	119	107	39	62	65	64	77
4	118	108	39	63	67	64	76
5	117	109	38	67	67	64	75
6	116	109	41	70	66	63	75
7	116	108	44	72	63	63	74
8	116	108	46	73	61	62	74
9	115	108	47	74	58	62	74
10	115	107	47	74	56	63	73
11	114	107	48	73	54	64	73
12	119	106	49	73	52	64	72
13	113	106	48	72	50	63	72
14	115	106		71	48	63	72

Turbidity (Table 3.7) is a combination of both phytoplankton growth and sediment entering the reservoir. In the Dam area it is more a demonstration of phytoplankton turbidity and should mimic Chlorophyll a measures if phytoplankton is the primary driver of turbidity. The high turbidity readings in August certainly reflect phytoplankton growth but other contributors must also be considered. The measured data for June shows elevated turbidity but not as high as would be expected from the chlorophyll a data. Turbidity data is helpful in quantifying additional inputs to the reservoir but other measures provide more reliable indicators of trophic condition.

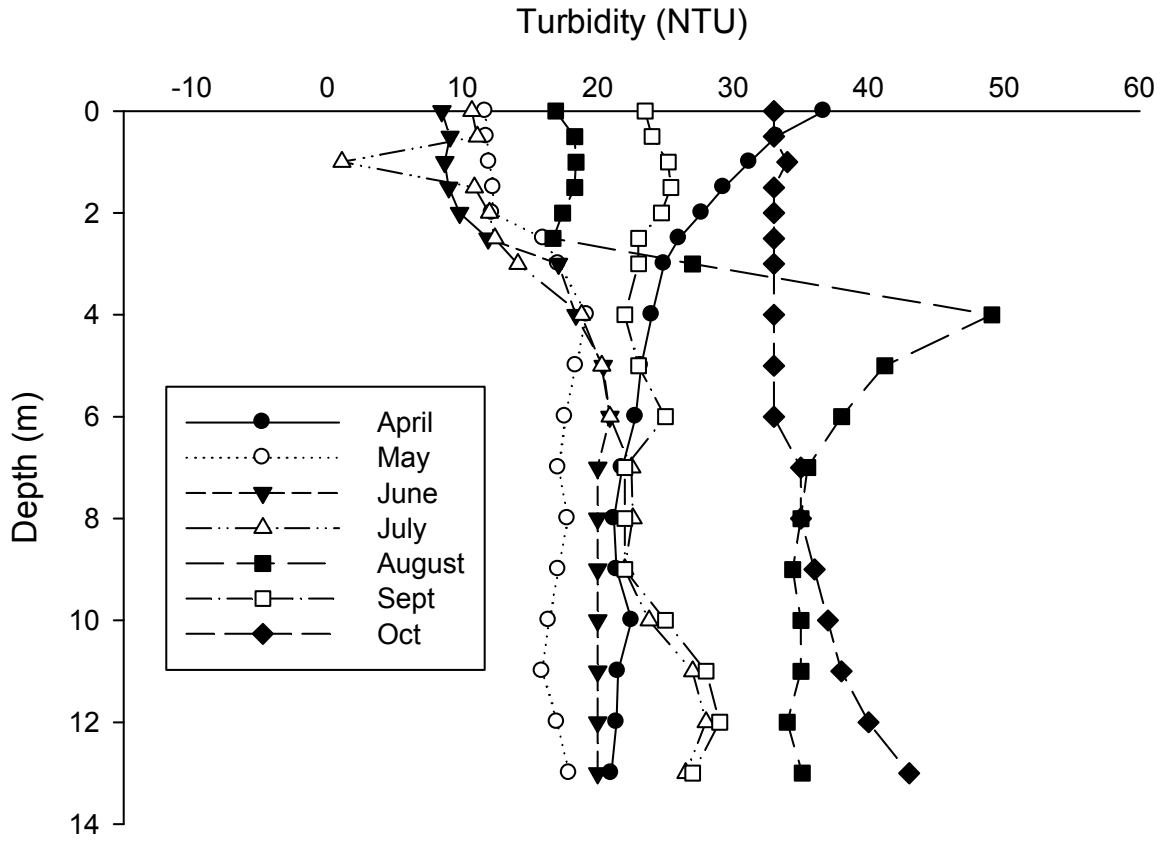

Figure 3.7. Dam (Lacustrine) Turbidity (NTU) measures over study period (2010).

Table 3.8. Dam (Lacustrine) Turbidity (NTU) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	36.7	11.7	8.5	10.7	16.9	23.5	33
0.5	33.2	11.8	9.1	11.1	18.3	24	33
1	31.2	12	8.7	1.1	18.4	25.2	34
1.5	29.3	12.3	9	10.9	18.3	25.4	33
2	27.7	12.2	9.8	12	17.4	24.7	33
2.5	26	16	11.9	12.4	16.7	23	33
3	24.9	17.1	17.1	14.1	27	23	33
4	24	19.2	18.4	18.8	49.1	22	33
5	23.2	18.4	20.4	20.3	41.2	23	33
6	22.8	17.6	20.9	20.9	38	25	33
7	21.8	17.1	20	22.5	35.5	22	35
8	21.2	17.8	20	22.6	35	22	35
9	21.4	17.1	20	22	34.4	22	36
10	22.5	16.4	20	23.8	35	25	37
11	21.5	15.9	20	27	35	28	38
12	21.4	17	20	28	34	29	40
13	21	17.9	20	26.5	35.1	27	43
14	20.9	20.4		27.4	37	28	45

Other parameters (Table 3.9) give us insights into the integration of biology and chemistry operating within the reservoir. The Trophic State Index (TSI) is a good indicator of lake condition. Leesville Lake is still in very good condition with TSI values just slightly eutrophic.

Secchi depth was again good throughout summer months and lower in both the spring and fall. Much of this pattern can be attributed to mixing in the reservoir as the good Secchi depths occurred when the lake was stratified. The increased depths may also reflect grazing by zooplankton populations and lower sediment turbidity during the summer months

Daphnia is a species of zooplankton grazer that can limit the concentrations of phytoplankton and increase Secchi depths. *Daphnia* selects smaller edible phytoplankton cells leaving larger inedible cells to dominate the plankton. The other trend to observe is how chl *a* responds to phosphorus in relation to *Daphnia* abundance. We do see an interesting trend this year during the June bloom of phytoplankton. This bloom did not impact Secchi depth (3.1 meters) and we observed a marked drop in *Daphnia* abundance in June. It is quite probable that this bloom consisted of larger, inedible phytoplankton unavailable to *Daphnia* grazers causing the drop in abundance. This is an important pattern to observe and we will look to quantify phytoplankton populations during bloom conditions to determine this relationship. Currently, other zooplankton did not provide trends for consideration but will be evaluated as other data becomes available. *E. coli* was never elevated at this sight and not a concern here.

Table 3.9. Dam (Lacustrine) Other Parameters measured over study period (2011). Zooplankton are in number per liter.

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12 -Oct
Secchi (M)	1.25 m	2.5 m	3.1 m	3.1 m	2.4 m	2 m	1.3 m
TP Surface (PPM)	0.017	0.036	0.026	0.02	0.026	0.016	0.031
TP 7 Meters (PPM)	0.004	0.092	0.031	0.034	0.013	0.025	
Integrate Chl a (PPB)	25.0	18.2	18.6	17.5		21.0	24.9
TSI Secchi	56.8	46.8	43.7	43.7	47.4	50.0	56.2
TSI TP	44.0	53.2	49.1	45.9	49.1	43.3	51.3
TSI CHL	62.2	59.0	59.3	58.7		60.5	62.1
TSI AVG	54.3	53.0	50.7	49.4	48.3	51.3	56.6
Daphnia	6.47	4.04	0.81	2.02	3.24	4.85	1.21
Bosmina	8.49	2.83	2.02	4.85	8.09	3.24	2.02
Diaptomus	2.43	1.62	2.43	12.13	16.99	8.49	2.02
Cyclops	3.24	2.02	2.43	3.64	3.64	5.26	1.21
Nauplii	2.02	2.02	2.83	6.07	2.83	8.09	0.81
Cerodaphnia	0.40	0.81	1.21	0.00	0.40	4.04	1.21
Diaphanosoma	0.00	0.00	1.21	3.64	7.68	0.00	0.00
Chydorus	0.00	0.00	0.81	1.21	3.64	0.00	0.00
E. coli MPN(cfu/100ml)	4	5.1	1	0	1	0	1

Trends

Looking at a brief comparison of trends (Table 3.10) at the dam during the last two sampling seasons the lake shows very good consistency. Trophic state parameters were elevated in June during 2011 but this is reflective of the phytoplankton bloom we observed. Remaining parameters suggested an improving trophic state condition with the lake remaining in a slightly eutrophic condition.

Table 3.10. Comparisons of key parameters for summers of 2010 and 2011 at the Dam of Leesville Lake.

Parameter	June 10	June 11	July 10	Jul 11	Aug 10	Aug 11	Sept 10	Sept 11
Secchi (M)	2.3	3.1	2.4	3.1	2.7	2.4	3.0	2
TP Surface (PPM)	0.019	0.026	0.053	0.02	0.067	0.026	0.019	0.016
TP 7 Meters (PPM)		0.031		0.034		0.013		0.025
Integrate Chl a (PPB)		18.6	30.2	17.5	18.8		34.6	21.0
TSI Secchi	48.0	43.7	47.4	43.7	45.7	47.4	44.2	50.0
TSI TP	45.5	49.1	58.3	45.9	61.5	49.1	45.3	43.3
TSI CHL		59.3	64.0	58.7	59.4		65.4	60.5
TSI AVG	46.7	50.7	56.6	49.4	55.5	48.3	51.6	51.3
Daphnia	3.2	0.81	1.6	2.02	0.0	3.24	0.4	4.85

3.3.3 Mile Marker 6 (Transition)

Background
In discussing water quality at the transition station, comparisons are made back to Lacustrine and Riverine to compare influence of each. This station behavior is similar to the Dam conditions.

Conductivity (Figure 3.8) showed similar trends to the dam station. We do see strong vertical changes in conductivity in June perhaps contributing to the bloom of phytoplankton.

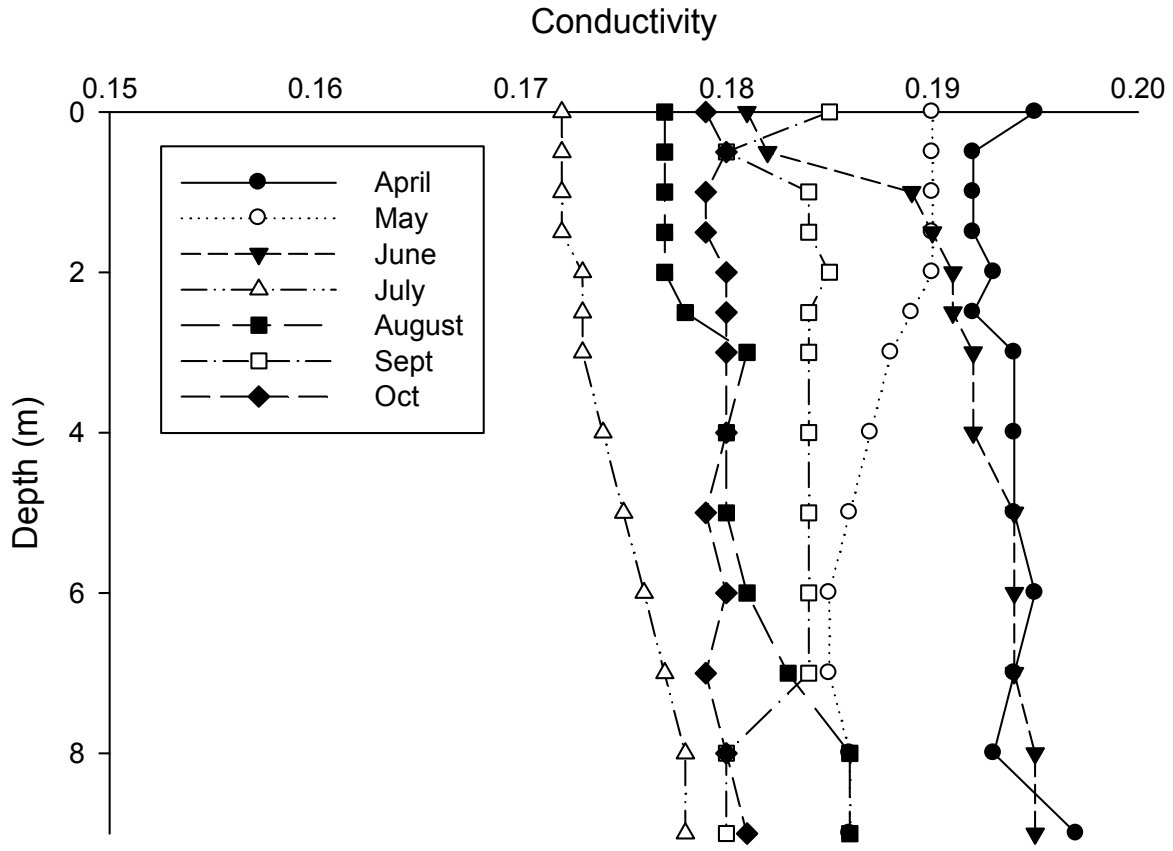

Figure 3.8. Mile Marker 6 (Transition) Conductivity (μs/cm) measures over study period (2011).

Table 3.11. Mile Marker 6 (Transition) Conductivity (μs/cm) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	0.195	0.19	0.181	0.172	0.177	0.185	0.179
0.5	0.192	0.19	0.182	0.172	0.177	0.18	0.18
1	0.192	0.19	0.189	0.172	0.177	0.184	0.179
1.5	0.192	0.19	0.19	0.172	0.177	0.184	0.179
2	0.193	0.19	0.191	0.173	0.177	0.185	0.18
2.5	0.192	0.189	0.191	0.173	0.178	0.184	0.18
3	0.194	0.188	0.192	0.173	0.181	0.184	0.18
4	0.194	0.187	0.192	0.174	0.18	0.184	0.18
5	0.194	0.186	0.194	0.175	0.18	0.184	0.179
6	0.195	0.185	0.194	0.176	0.181	0.184	0.18
7	0.194	0.185	0.194	0.177	0.183	0.184	0.179
8	0.193	0.186	0.195	0.178	0.186	0.18	0.18
9	0.197	0.186	0.195	0.178	0.186	0.18	0.181
10			0.195				

Dissolved oxygen (Figure 3.9) does suggest a similar pattern to the dam station with periods of anoxia over the summer months in the stratified areas. The lake is still well stratified in this area. Coupled with temperature data (Figure 3.10) this stratification was not as pronounced and better predicted with the oxygen data. The lake did not exhibit the same bloom conditions in June as shown at the Dam station. A bloom did exist but chlorophyll *a* concentrations (Figure 3.11) were much lower. This is somewhat unexpected as the transition zone is often the most productive portion of the reservoir. Yet in July, chlorophyll *a* did show a similar pattern with a bloom in the metalimnion.

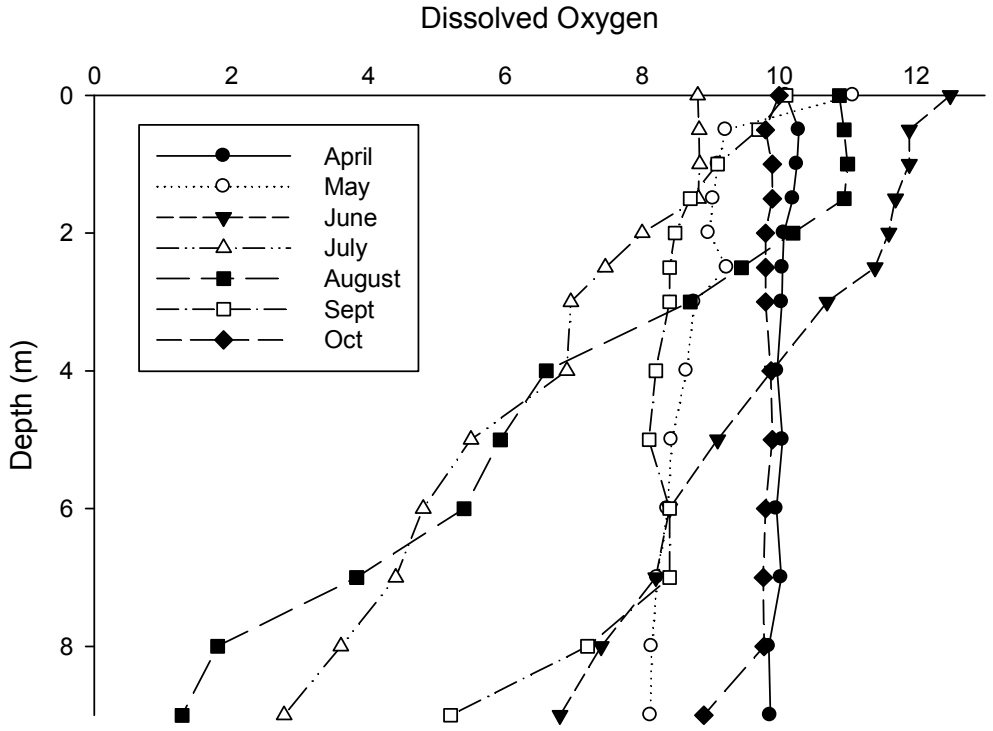

Figure 3.9. Mile Marker 6 (Transition) Dissolved Oxygen (mg/L) measures over study period (2011).

Table 3.12. Mile Marker 6 (Transition) Dissolved Oxygen (mg/L) Measures Over Study Period (2011).

Depth :	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	10.1	11.08	12.5	8.81	10.88	10.1	10
0.5	10.29	9.22	11.9	8.83	10.95	9.7	9.8
1	10.26	9.11	11.9	8.84	11	9.1	9.9
1.5	10.2	9.04	11.7	8.82	10.95	8.7	9.9
2	10.07	8.97	11.6	8	10.2	8.48	9.8
2.5	10.05	9.24	11.4	7.46	9.45	8.4	9.8
3	10.04	8.76	10.7	6.96	8.7	8.4	9.8
4	9.97	8.65	9.9	6.9	6.6	8.2	9.88
5	10.05	8.43	9.1	5.5	5.93	8.1	9.9
6	9.96	8.37	8.4	4.8	5.4	8.4	9.8
7	10.03	8.22	8.2	4.4	3.83	8.4	9.77
8	9.85	8.14	7.4	3.6	1.8	7.2	9.78
9	9.87	8.12	6.8	2.77	1.28	5.2	8.9
10			5.8				

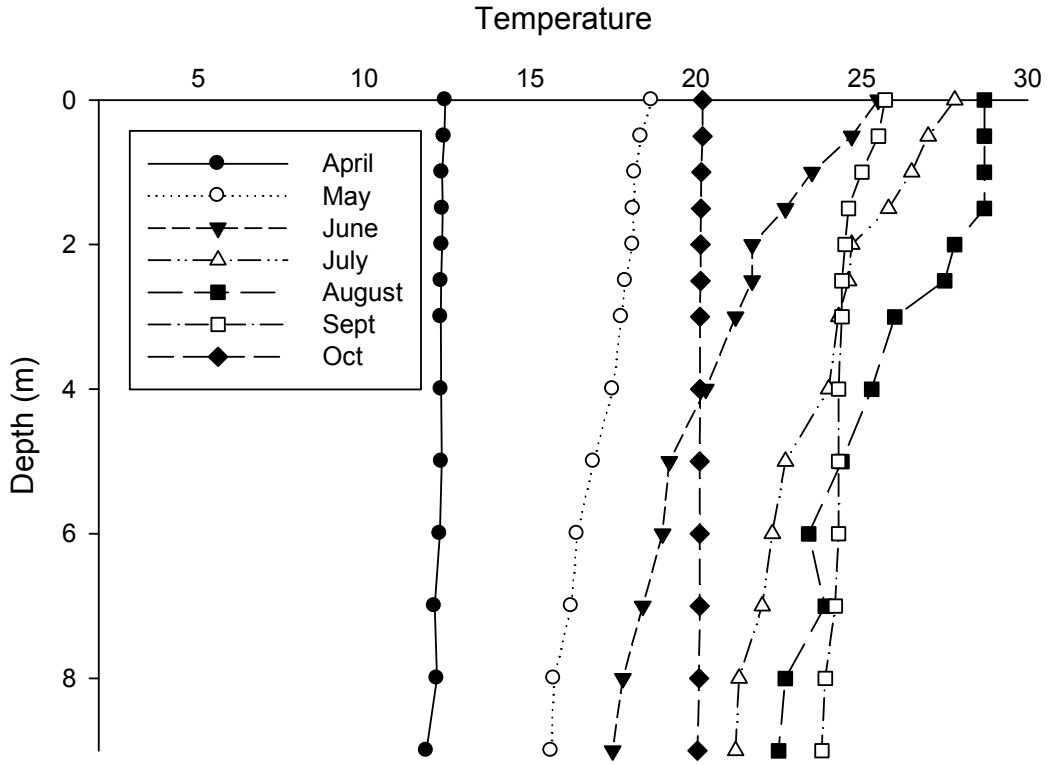

Figure 3.10. Mile Marker 6 (Transition) Temperature (Degrees C) measures over study period (2010).

Table 3.13. Mile Marker 6 (Transition) Temperature (Degrees C) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	12.45	18.67	25.5	27.8	28.7	25.7	20.2
0.5	12.42	18.35	24.7	27	28.7	25.5	20.2
1	12.35	18.16	23.5	26.5	28.7	25	20.17
1.5	12.37	18.12	22.7	25.8	28.7	24.6	20.15
2	12.35	18.1	21.7	24.7	27.8	24.5	20.14
2.5	12.33	17.88	21.7	24.6	27.5	24.4	20.14
3	12.32	17.76	21.2	24.3	26	24.4	20.13
4	12.33	17.5	20.3	24	25.3	24.3	20.13
5	12.34	16.92	19.2	22.7	24.4	24.3	20.12
6	12.29	16.42	19	22.3	23.4	24.3	20.12
7	12.13	16.25	18.4	22	23.9	24.2	20.12
8	12.2	15.72	17.8	21.3	22.7	23.9	20.1
9	11.88	15.64	17.5	21.2	22.5	23.8	20.05
10			17.3				

Chlorophyll a (Figure 3.11) exhibited a similar to the pattern at the dam. Metalimnetic blooms occurred in both June and July. The June bloom was less pronounced peaking at 30 ppb than at the dam but the July bloom was more pronounced with a peak greater than 50 ppb. Remaining months were somewhat consistent with depth and at levels consistent with trophic levels of this reservoir.

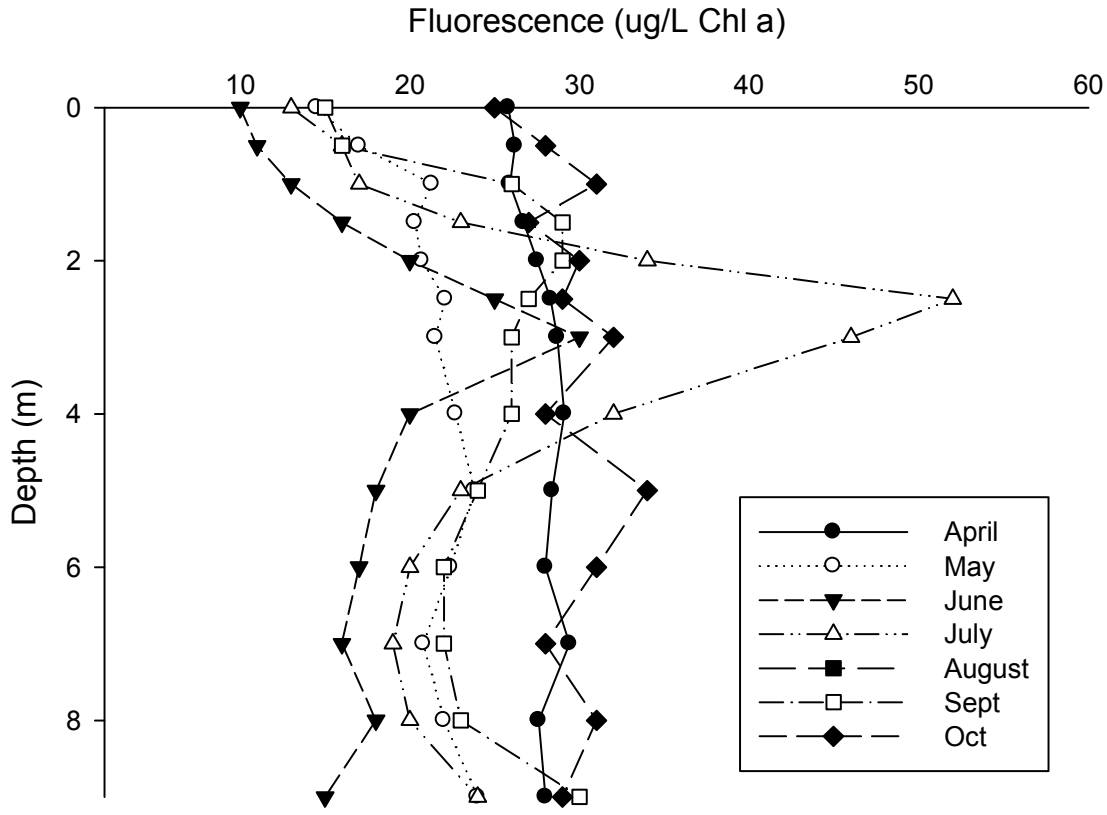

Figure 3.11. Mile Marker 6 (Transition) Fluorometer measured Chlorophyll *a* (ppb) measures over study period (2011).

Table 3.14. Mile Marker 6 (Transition) Fluorometer measured Chlorophyll *a* (ppb) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	25.8	14.5	10	13	n/a	15	25
0.5	26.2	17	11	16	n/a	16	28
1	25.9	21.3	13	17	n/a	26	31
1.5	26.7	20.3	16	23	n/a	29	27
2	27.5	20.7	20	34	n/a	29	30
2.5	28.3	22.1	25	52	n/a	27	29
3	28.7	21.5	30	46	n/a	26	32
4	29.1	22.7	20	32	n/a	26	28
5	28.4	23.8	18	23	n/a	24	34
6	28	22.4	17	20	n/a	22	31
7	29.4	20.8	16	19	n/a	22	28
8	27.6	22	18	20	n/a	23	31
9	28	24	15	24	n/a	30	29
10			17	26	n/a		

pH measures (Figure 3.12) were elevated in response to phytoplankton productivity. August had the most elevated levels for the season with a peak pH of 8.6. While these elevated pH levels further strengthen the evidence for eutrophication they are not high enough to be problematic and did not exceed the state pH standard, which is 9.

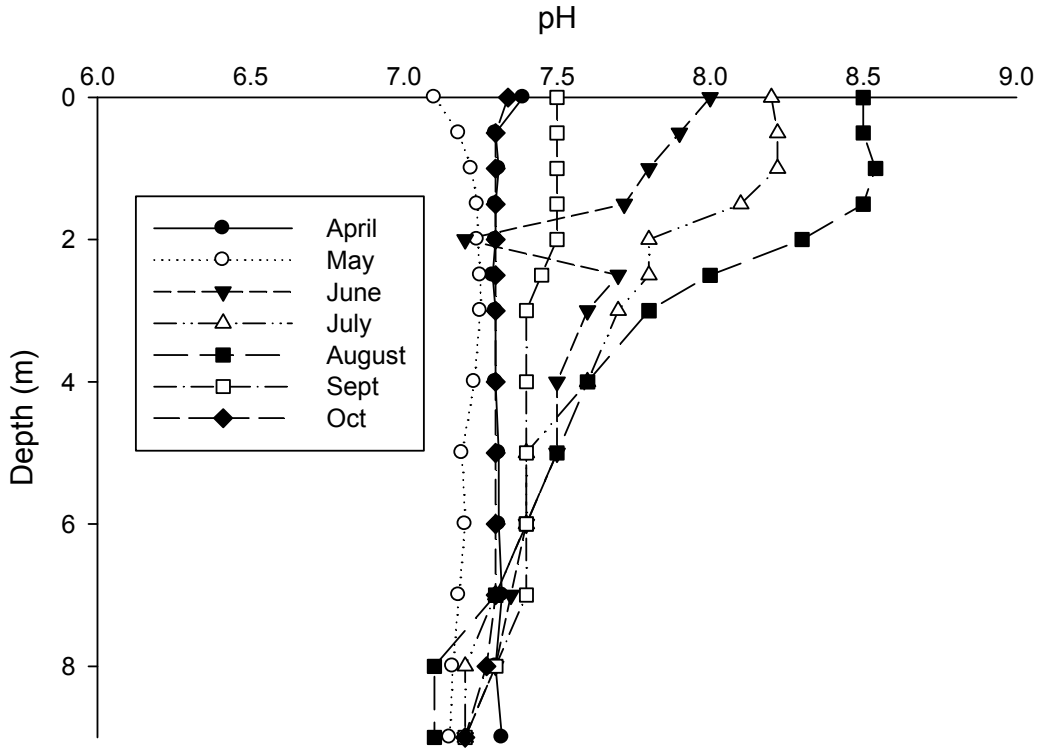

Figure 3.12. Mile Marker 6 (Transition) pH measures over study period (2011).

Table 3.15. Mile Marker 6 (Transition) pH Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	7.39	7.1	8	8.2	8.5	7.5	7.34
0.5	7.3	7.18	7.9	8.22	8.5	7.5	7.3
1	7.31	7.22	7.8	8.22	8.54	7.5	7.3
1.5	7.3	7.24	7.72	8.1	8.5	7.5	7.3
2	7.3	7.24	7.2	7.8	8.3	7.5	7.3
2.5	7.29	7.25	7.7	7.8	8	7.45	7.3
3	7.3	7.25	7.6	7.7	7.8	7.4	7.3
4	7.3	7.23	7.5	7.6	7.6	7.4	7.3
5	7.31	7.19	7.5	7.4	7.5	7.4	7.3
6	7.31	7.2	7.4	7.4	7.4	7.4	7.3
7	7.32	7.18	7.35	7.3	7.3	7.4	7.3
8	7.3	7.16	7.3	7.2	7.1	7.3	7.27
9	7.32	7.15	7.2	7.2	7.1	7.2	7.2
10			7.2				

ORP measures (Figure 3.13) and turbidity (Figure 3.14) were similar in analysis to the dam site.

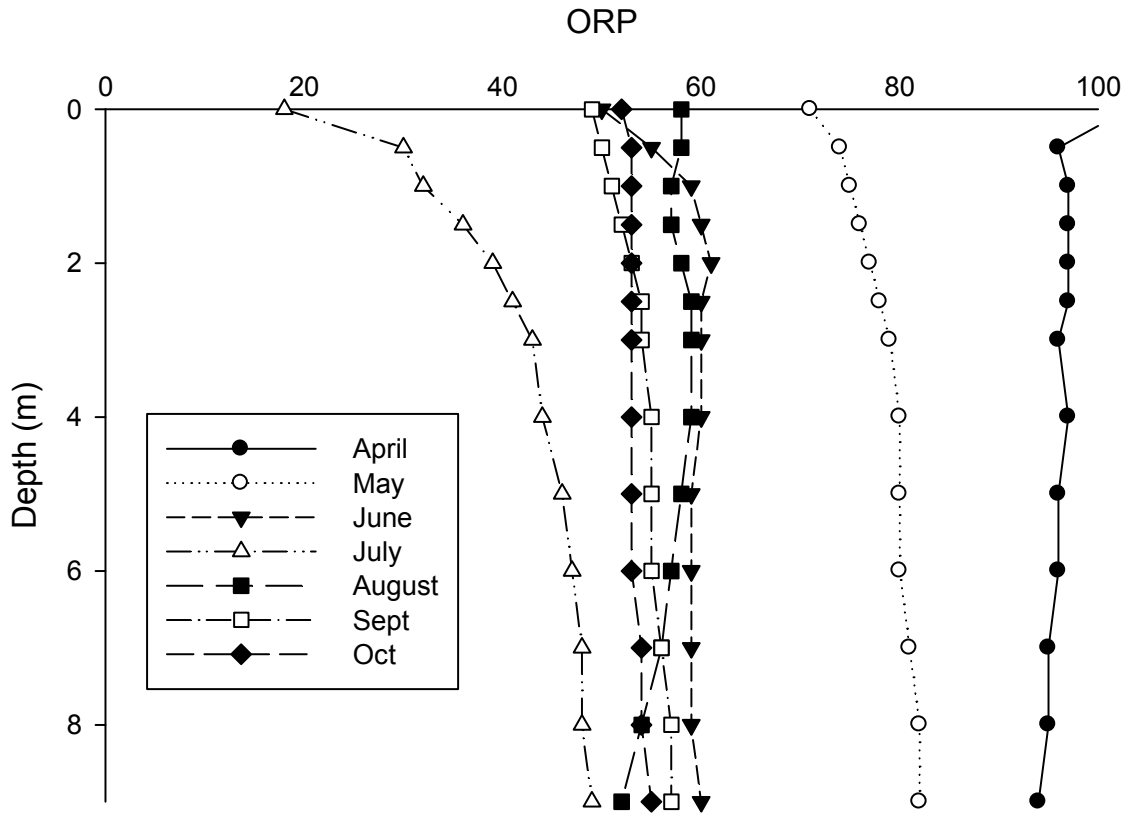

Figure 3.13. Mile Marker 6 (Transition) ORP measures over study period (2011).

Table 3.16. Mile Marker 6 (Transition) ORP Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	103	71	50	18	58	49	52
0.5	96	74	55	30	58	50	53
1	97	75	59	32	57	51	53
1.5	97	76	60	36	57	52	53
2	97	77	61	39	58	53	53
2.5	97	78	60	41	59	54	53
3	96	79	60	43	59	54	53
4	97	80	60	44	59	55	53
5	96	80	59	46	58	55	53
6	96	80	59	47	57	55	53
7	95	81	59	48	56	56	54
8	95	82	59	48	54	57	54
9	94	82	60	49	52	-1	55
10			58				

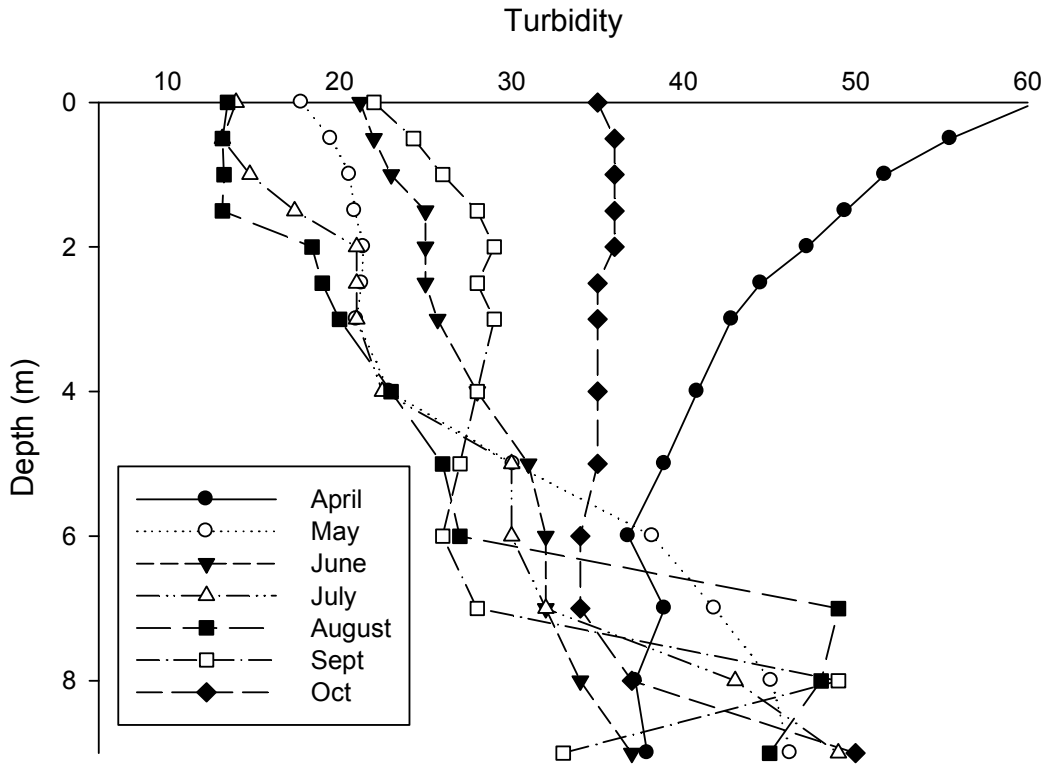

Figure 3.14. Mile Marker 6 (Transition) Turbidity (NTU) measures over study period (2011).

Table 3.17. Mile Marker 6 (Transition) Turbidity (NTU) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	60.5	17.8	21.2	14	13.5	22	35
0.5	55.5	19.5	22	13.2	13.2	24.3	36
1	51.7	20.6	23	14.8	13.3	26	36
1.5	49.4	20.9	25	17.4	13.2	28	36
2	47.2	21.4	25	21	18.4	29	36
2.5	44.5	21.3	25	21	19	28	35
3	42.8	21	25.7	21	20	29	35
4	40.8	22.9	28	22.5	23	28	35
5	38.9	30.1	31	30	26	27	35
6	36.8	38.2	32	30	27	26	34
7	38.9	41.8	32	32	49	28	34
8	37.2	45.1	34	43	48	49	37
9	37.9	46.2	37	49	45	133	50
10			70				

Other parameters (Table 3.18) show similar trends to the dam station (Table 3.9) with some exceptions. Total phosphorus concentrations in the hypolimnion were consistently elevated over concentrations in the epilimnion. This suggests the reservoir is experiencing periods of anoxia in the hypolimnion long enough to release phosphorus from some of the insoluble complexes. It will be important to continue to track this trend over time.

E. coli concentrations were very elevated in April. We observed a turbid plume of water in the area of MM6 in April and it contained the correspondingly high concentrations of bacteria. This demonstrates the importance of hydrology on *E. coli* concentrations in the reservoir.

Zooplankton concentrations were higher at MM6 as expected with very high concentrations of *Bosmina* during several sampling dates throughout the year. It is hard to infer any specific cause for *Bosmina* increases but we will continue to track zooplankton changes over time.

TSI is an additional parameter to that can be compared to the dam site. It trended higher as we would expect at this transition site. This site is typically more productive. Our measures continue to support Mile Marker 6 as a transition area in this reservoir.

Table 3.18. Mile Marker 6 (Transition) Other Parameters measured over study period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12 -Oct
Secchi (M)	0.75	1.5	1.8	1.6	2	1.75	1.5
TP Surface (PPM)	0.01	0.029	0.029	0.029	0.017	0.015	0.031
TP 7 Meters (PPM)	0.01	0.058	0.045	0.05	0.043	0.018	
Integrate Chl a (PPB)	27.7	21.0	17.6	26.1		24.2	29.5
TSI Secchi	64.1	54.2	51.5	53.2	50.0	51.9	54.2
TSI TP	38.2	50.5	50.5	50.5	44.0	42.6	51.3
TSI CHL	63.2	60.5	58.7	62.6		61.9	63.8
TSI AVG	55.2	55.0	53.6	55.4	47.0	52.1	56.4
Daphnia	5.90	5.66	2.83	1.42	2.83	3.30	0.94
Bosmina	19.34	3.30	3.30	3.30	21.23	2.83	0.47
Diaptomus	4.01	3.30	3.77	3.30	15.10	7.08	2.83
Cyclops	3.54	1.42	3.30	2.83	5.66	4.72	2.36
Nauplii	1.89	1.42	3.30	3.30	4.72	3.77	1.89
Cerodaphnia	0.24	1.42	1.42	0.47	1.42	2.36	1.89
Diaphanosoma	0.00	0.00	0.51	3.57	9.17	0.00	0.00
Chydorus	0.00	0.00	2.04	3.06	2.55	0.00	0.00
E. coli MPN(cfu/100ml)	326	24	6.3	0	2	54.1	3.1

3.3.4 Toler Bridge (Riverine)

Background

The station at Toler Bridge is influenced heavily by Riverine conditions and the tail waters of Smith Mountain Lake. We would expect the Pigg River to deliver nutrients and sediment with tail water discharge influencing the hydrology. Comparisons to the remainder of the lake should determine the influence these conditions have until release at Leesville dam.

Conductivity (Figure 3.15) shows the influence of river inputs. Conductivity is much higher at this station than down the lake. This is likely a result of both the Pigg River and the tail waters, with a greater influence from tail water discharge. Unlike the other more lacustrine stations here at Toler Bridge we did not see stratification and much clearer differentiation between season and masses. Early season conductivity was higher than late season reflective of greater rainfall and movement of water through the reservoir from stormwater input earlier in the season.

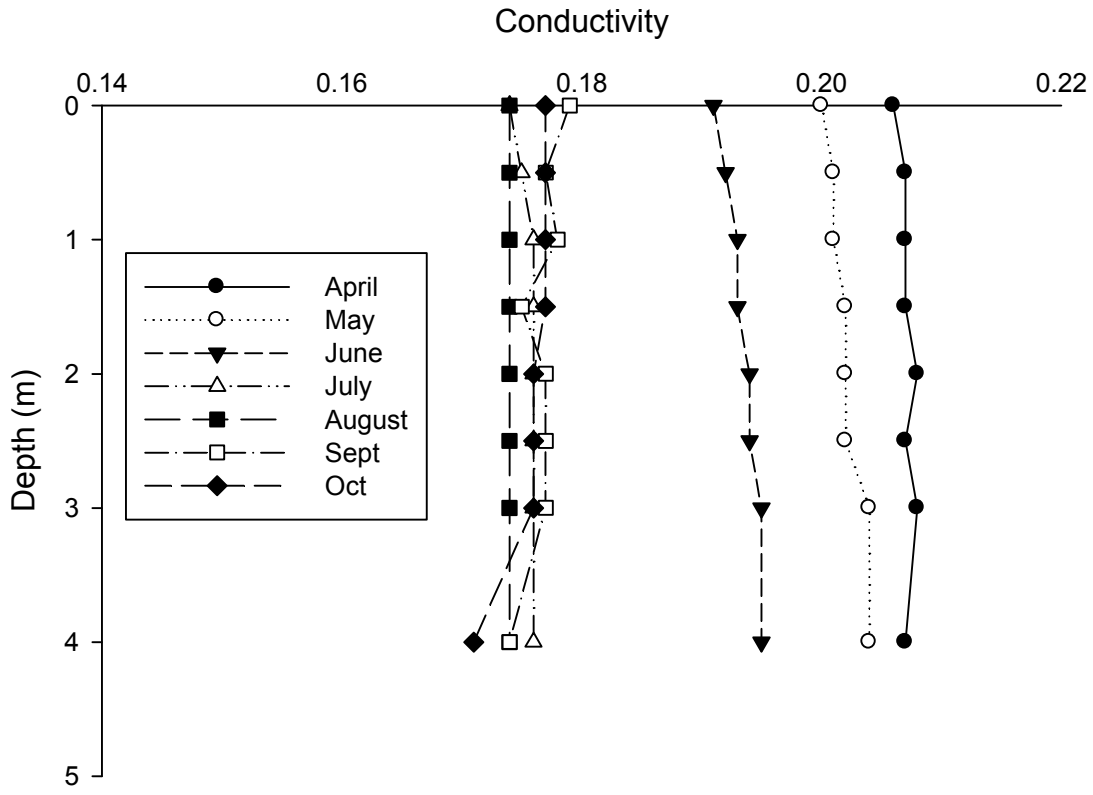

Figure 3.15. Toler Bridge (Riverine) Conductivity (μs/cm) measures over study period (2011).

Table 3.19. Toler Bridge (Riverine) Conductivity (μs/cm) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	0.206	0.2	0.191	0.174	0.174	0.179	0.177
0.5	0.207	0.201	0.192	0.175	0.174	0.177	0.177
1	0.207	0.201	0.193	0.176	0.174	0.178	0.177
1.5	0.207	0.202	0.193	0.176	0.174	0.175	0.177
2	0.208	0.202	0.194	0.176	0.174	0.177	0.176
2.5	0.207	0.202	0.194	0.176	0.174	0.177	0.176
3	0.208	0.204	0.195	0.176	0.174	0.177	0.176
4	0.207	0.204	0.195	0.176	0.174	0.174	0.171
5	0.208	0.204	0.195		0.174	0.174	

Dissolved oxygen measures (Figure 3.16) show that stratification is minimal at this station. A warm surface layer is created but often broken up by rapidly flowing inputs. Temperature measures (Figure 3.17) support this as well. This station is not only typical of a Riverine station on a reservoir but even more exaggerated with the high flows that Leesville Lake experiences.

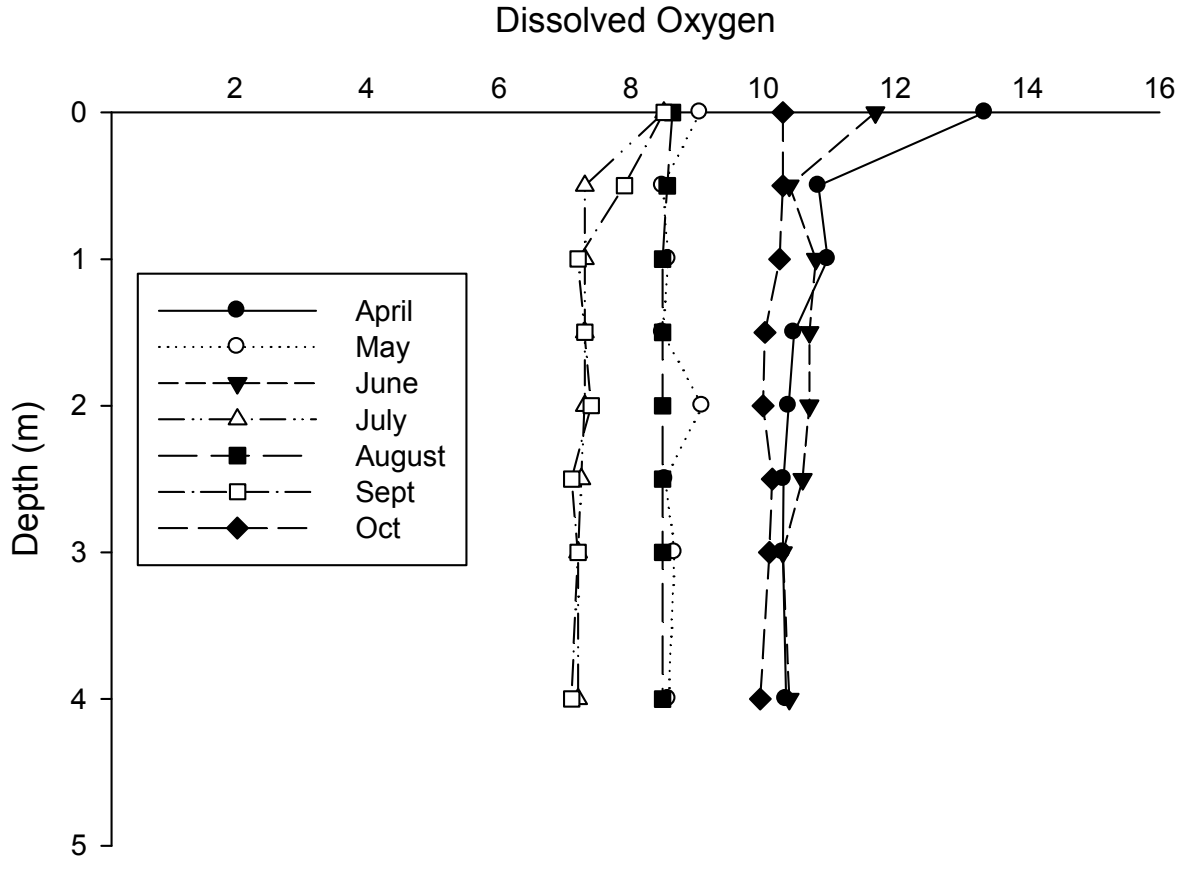

Figure 3.16. Toler Bridge (Riverine) Dissolved Oxygen (mg/L) measures over study period (2011).

Table 3.20. Toler Bridge (Riverine) Dissolved Oxygen (mg/L) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	13.36	9.05	11.7	8.5	8.63	8.5	10.3
0.5	10.84	8.48	10.4	7.3	8.55	7.9	10.3
1	10.98	8.57	10.8	7.3	8.48	7.2	10.25
1.5	10.47	8.48	10.7	7.3	8.48	7.3	10.03
2	10.39	9.08	10.7	7.3	8.48	7.4	10
2.5	10.31	8.52	10.6	7.25	8.48	7.1	10.14
3	10.3	8.66	10.3	7.2	8.48	7.2	10.1
4	10.35	8.57	10.4	7.2	8.48	7.1	9.96
5	10.26	8.89	10.4		8.4	7.3	7.25

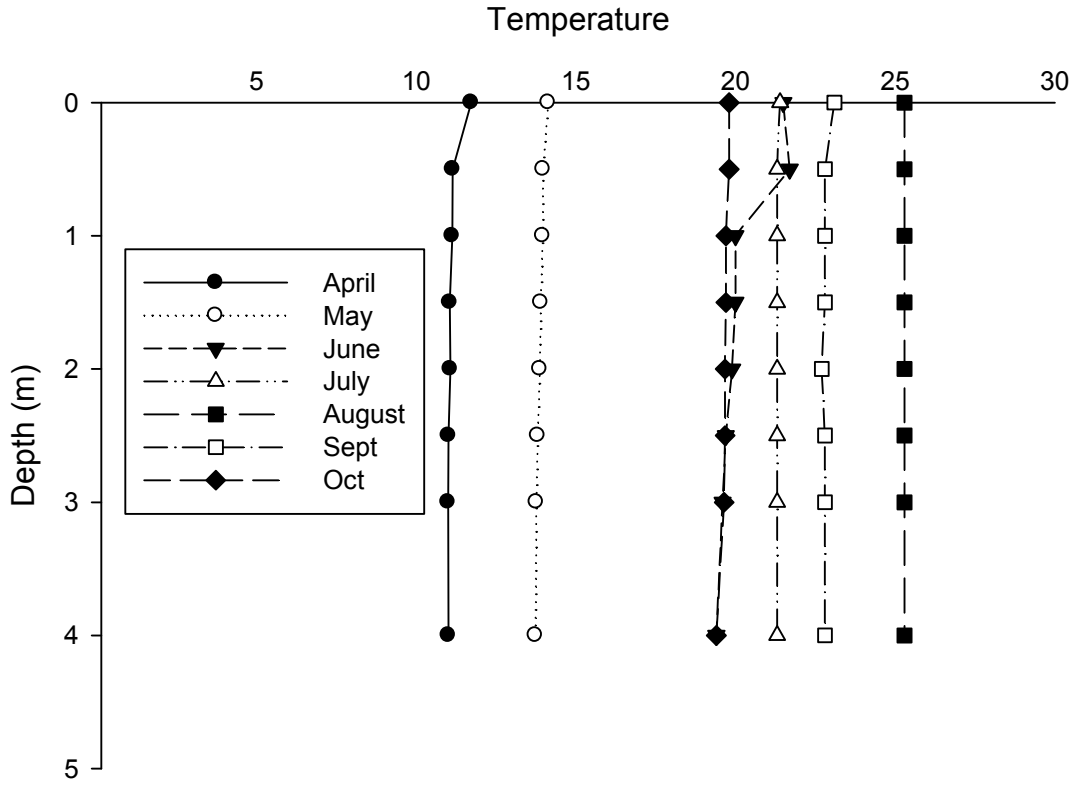

Figure 3.17. Toler Bridge (Riverine) Temperature (Degrees C) measures over study period (2011).

Table 3.21. Toler Bridge (Riverine) Temperature (Degrees C) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	11.73	14.14	21.5	21.4	25.3	23.1	19.8
0.5	11.15	13.98	21.7	21.3	25.3	22.8	19.8
1	11.13	13.97	20	21.3	25.3	22.8	19.7
1.5	11.06	13.91	20	21.3	25.3	22.8	19.7
2	11.07	13.88	19.9	21.3	25.3	22.7	19.68
2.5	11.02	13.81	19.7	21.3	25.3	22.8	19.68
3	11	13.77	19.6	21.3	25.3	22.8	19.65
4	11.01	13.74	19.4	21.3	25.3	22.8	19.4
5	11.2	13.66	19.1		25.3	22.8	19.16

Chlorophyll (Figure 3.18) does develop in this station and interestingly, increases at depth similar to downward stations when flow is not a significant contributor. Concentrations are lower most probably a result of sediment turbidities (Figure 3.21).

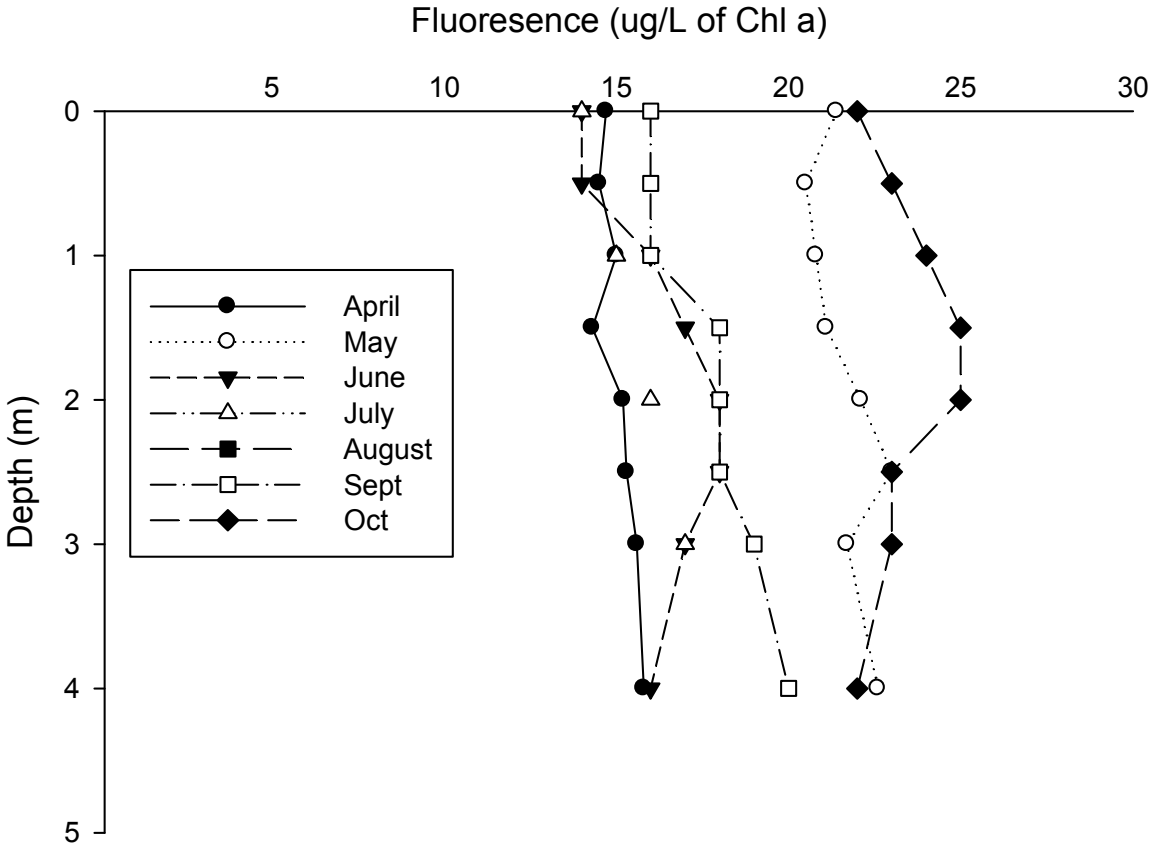

Figure 3.18. Toler Bridge (Riverine) Fluorometric measured Chlorophyll *a* (ppb) measures over study period (2011).

Table 3.22. Toler Bridge (Riverine) Fluorometer measured Chlorophyll *a* (ppb) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	14.7	21.4	14	14	n/a	16	22
0.5	14.5	20.5	14		n/a	16	23
1	15	20.8	16	15	n/a	16	24
1.5	14.3	21.1	17		n/a	18	25
2	15.2	22.1	18	16	n/a	18	25
2.5	15.3	23	18		n/a	18	23
3	15.6	21.7	17	17	n/a	19	23
4	15.8	22.6	16		n/a	20	22
4.5	16.1						
5	16.5	21	16		n/a	18	23
5.5	15.5						

pH (Figure 3.19) is suggestive of slightly elevated river conditions. The slight elevations from a typical river are due to the higher phytoplankton productivity.

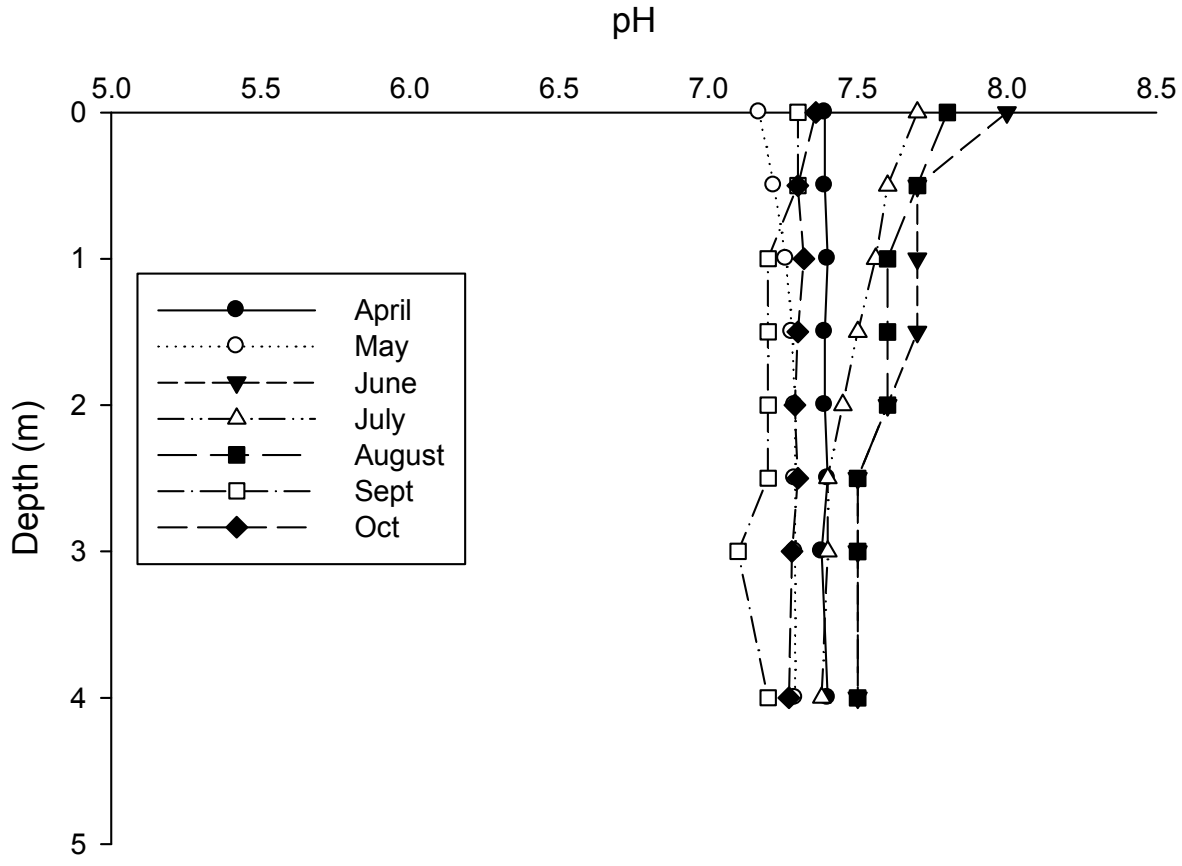

Figure 3.19. Toler Bridge (Riverine) pH measures over study period (2011).

Table 3.23. Toler Bridge (Riverine) pH Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	7.39	7.17	8	7.7	7.8	7.3	7.36
0.5	7.39	7.22	7.7	7.6	7.7	7.3	7.3
1	7.4	7.26	7.7	7.56	7.6	7.2	7.32
1.5	7.39	7.28	7.7	7.5	7.6	7.2	7.3
2	7.39	7.29	7.6	7.45	7.6	7.2	7.29
2.5	7.4	7.29	7.5	7.4	7.5	7.2	7.3
3	7.38	7.29	7.5	7.4	7.5	7.1	7.28
4	7.4	7.29	7.5	7.38	7.5	7.2	7.27
5	7.4	7.28	7.5		7.5	7.1	7.25

ORP (Figure 3.20) is well within the oxygenated range. Readings in July were moving into the reduced stage suggesting high rates of biological decay or influences from tail water operations. Toler Bridge station continually exhibits floating debris containing larger logs and pondweed that may contribute to readings.

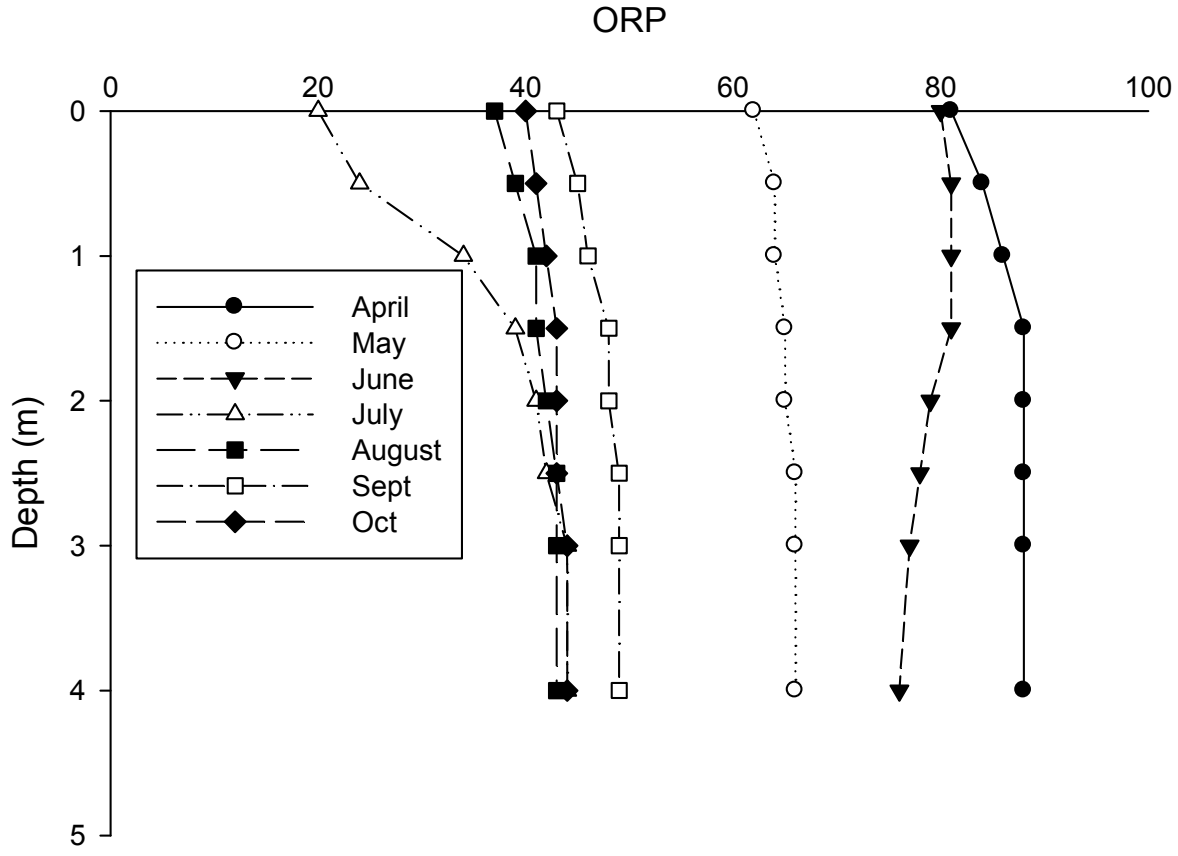

Figure 3.20. ORP measures over study period (2011).

Table 3.24. Toler Bridge (Riverine) ORP Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	81	62	80	20	37	43	40
0.5	84	64	81	24	39	45	41
1	86	64	81	34	41	46	42
1.5	88	65	81	39	41	48	43
2	88	65	79	41	42	48	43
2.5	88	66	78	42	43	49	43
3	88	66	77	44	43	49	44
4	88	66	76	44	43	49	44
5	87	66	74		43	50	44

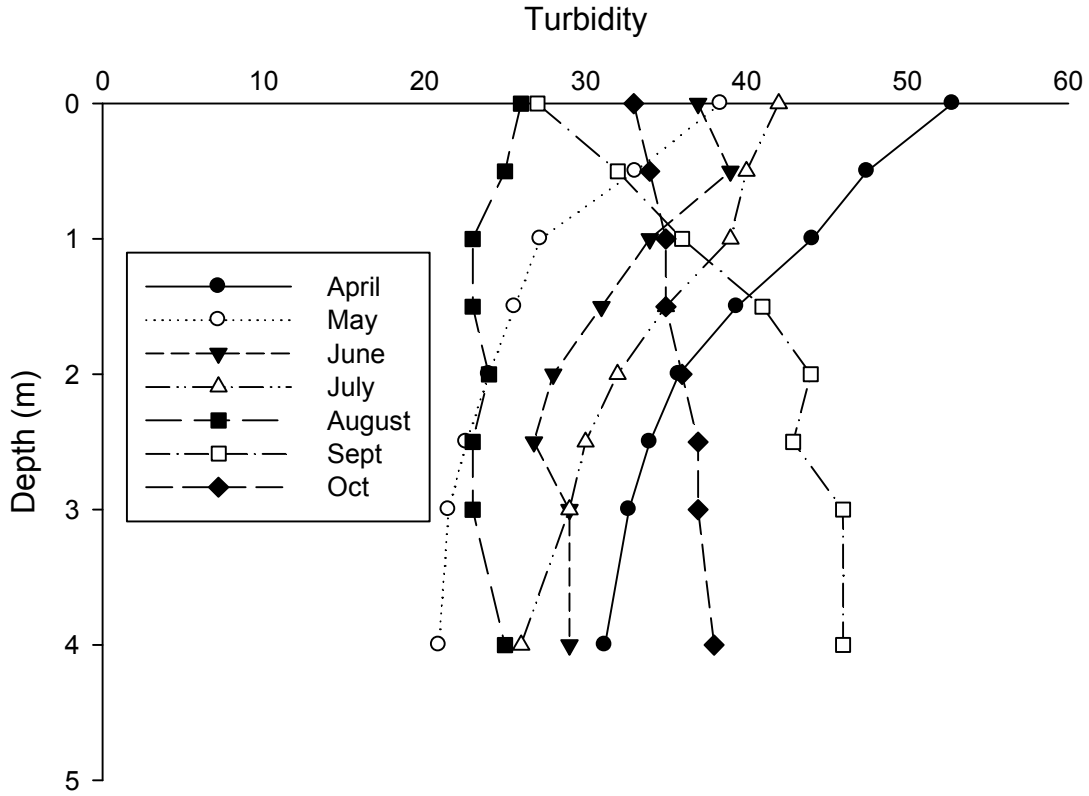

Figure 3.21. Toler Bridge (Riverine) Turbidity (NTU) measures over study period (2011).

Table 3.25. Toler Bridge (Riverine) Turbidity (NTU) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	52.8	38.4	37	42	26	27	33
0.5	47.5	33.1	79	40	25	32	34
1	44.1	27.2	34	39	23	36	35
1.5	39.4	25.6	31	35	23	41	35
2	35.8	24	28	32	24	44	36
2.5	34	22.6	26.8	30	23	42.9	37
3	32.7	21.5	29	29	23	46	37
4	31.2	20.9	29	26	25	46	38
5	30.1	20.7	24		25	49	43

Other parameters (Table 3.26) were as expected for a Riverine station. Zooplankton were not as abundant however the June sample was higher than expected and did contain some *Daphnia*. It is doubtful the zooplankton are influencing chlorophyll at this station. Total phosphorus is generally elevated over other stations. And *E. coli* at this station was well below levels of concern but greater at this station.

Table 3.26. Toler Bridge (Riverine) Other Parameters Measured Over Study Period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12 -Oct
Secchi (M)	2	1.25	1.4	1.2	1.1	0.75	1.4
TP Surface (PPM)	0.048	0.13	0.04	0.038	0.028	0.018	0.038
TP 5 Meters (PPM)	0.018	0.03	0.042		0.025	0.031	
Integrate Chl a (PPB)	15.1	21.7	16.3	15.5		17.6	23.4
TSI Secchi	50.0	56.8	55.2	57.4	58.6	64.1	55.2
TSI TP	57.0	70.6	54.6	53.9	50.0	44.7	53.9
TSI CHL	57.2	60.8	58.0	57.5		58.7	61.5
TSI AVG	54.7	62.7	55.9	56.3	54.3	55.9	56.9
Daphnia	3.06	5.61	2.04	2.55	3.57	3.06	1.53
Bosmina	11.21	2.55	3.06	5.61	11.72	1.02	4.59
Diaptomus	3.06	1.02	5.10	5.10	9.17	9.17	6.11
Cyclops	4.08	1.02	3.57	2.55	4.59	4.08	2.55
Nauplii	2.04	2.55	1.02	3.57	5.61	3.06	1.53
Cerodaphnia	1.02	2.04	2.55	0.51	0.00	2.04	3.06
Diaphanosoma	0.00	0.00	2.04	2.55	3.06	0.00	0.00
Chydorus	0.00	1.02	2.55	1.53	3.57	0.00	0.00
E. coli MPN(cfu/100ml)	44	45	2.8	5.8	9	55.6	2

3.3.5 Other Data

The two marina sites were measured for both Secchi depth and *E. coli* to determine possible contamination from septic systems and possible changes in clarity. Neither site demonstrated data to support the possibility of contamination. The one elevated *E. coli* measure in April at Tri County occurred during a very turbid rain event and was also reflected in measures at MM6. Secchi depths followed the pattern established from the other sites at these positions in the reservoir.

Table 3.27. Pit Stop Marina Other Parameters Measured Over Study Period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
Secchi (M)	1.3	1.75	2.2	2.4	1.9	2.25	1.1
E. coli MPN(cfu/100ml)	8	10	1	1	0	2	4.1

Table 3.28. Tri County Marina Other Parameters Measured Over Study Period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
Secchi (M)	.60	1.5	2.3	2	1.6	1.5	1.4
E. coli MPN(cfu/100ml)	243	22	1	1	1	5.2	1

Two additional sites were analyzed for TP concentrations. Concentrations at MM9 (Table 3.29) were elevated in several instances (April, July and September) and do cause concern. The very elevated reading in July for the tail waters (Table 3.30) is very concerning. The tail water site is highly variable due to differentiated flows from dam release. I am unsure the conditions surrounding this elevated reading.

Table 3.29. Mile Marker 9 Other Parameters Measured Over Study Period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
Secchi (M)	1.2	.75	1.4	1	1.3	.8	.9
TP (mg/L)	0.063	0.036	0.037	0.06	0.022	0.093	0.042
E. coli MPN(cfu/100ml)	76	104	2	3.1	4.1	62	6.3

Table 3.30. Smith Mountain Lake Tail Waters Other Parameters measured over study period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12 -Oct
TP (mg/L)	0.031	0.02	0.039	0.17	0.019	0.021	0.037
E. coli MPN(cfu/100ml)	8	7	13	1	4	24	36

Pigg River site again demonstrated high inputs of phosphorus, E. coli and poor water quality entering the lake (Table 3.31). Surprisingly, this did not impact other measured water quality variables such as oxygen and pH significantly and may be a reflection of diluted waters from Smith Mountain Dam. It appears that high loading may occur during significant storm events. Again, measures of total phosphorus at Toler Bridge (Figure 3.26) are very closely aligned with measures of TP from the tail waters. Pigg River inputs are well elevated suggesting a greater impact from the Pigg River than Smith tail waters.

Table 3.31. Pigg River Other Parameters Measured Over Study Period (2011).

Parameter	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
Secchi (M)	0.6	0.5	0.9	1.05	0.7	0.1	0.3
TP (mg/L)	0.054	0.131	0.07	0.04	0.033	0.165	0.083
E. coli MPN(cfu/100ml)	174	195	33.1	6.9	18.6	1467	309.5

Table 3.32. Pigg River Dissolved Oxygen (mg/L) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	9.89	8.26	12.2	8	10.13	9.8	12.2
0.5	9.79	8.33	10.5	7.7	9	9.6	12.1
1	9.71	8.3	10.5	7.6	9.15	9.56	12

Table 3.33. Pigg River Temperature (Degrees C) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	13.34	17.73	25.6	22.5	27.6	21.8	16.3
0.5	13.19	16.9	25.5	22.5	26.5	21.8	16.3
1	12.59	15.6	25.4	22.5	26.5	21.8	16.3

Table 3.34. Pigg River pH Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	7.26	7.17	7.6	7.6	7.75	7.1	7.3
0.5	7.26	7.22	7.51	7.6	7.7	7	7.1
1	7.29	7.17	7.4	7.5	7.6	6.9	7.05

Table 3.35. Pigg River Conductivity (mg/L) Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	0.168	0.118	0.103	0.171	0.133	0.068	0.084
0.5	0.169	0.142	0.104	0.171	0.159	0.068	0.084
1	0.178	0.166	0.105	0.171	0.159	0.068	0.084

Table 3.36. Pigg River Turbidity Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	64.2	35	20	47	27	124	72
0.5	58	34.7	21	42	29	123	67
1	56	39.9	29	34	49	124	67

Table 3.37. Pigg River ORP Measures Over Study Period (2011).

Depth:	20-Apr	18-May	7-Jun	5-Jul	3-Aug	8-Sep	12-Oct
0	83	60	51	49	37	53	45
0.5	84	59	56	50	40	55	46
1	84	62	58	51	40	56	47

E. coli data collected by volunteers is very helpful for interpreting trends in the lake. The data clearly illustrates the rapidly changing conditions in the reservoir. Pigg River on June 7 had *e. coli* levels of 33.1 CFU/100ml (Table 3.31). Within one week, levels rose to 272 CFU/100ml (Table 3.38). Pitt Stop Marina is another well documented example. The ability to collect this data in increasingly frequent intervals is essential to understanding the dynamics of the lake.

Also, this data demonstrates the need to closely monitor the movement of *e. coli* in the lake. The relationship of July 13 and April 20 data illustrates movement of *e. coli* laden waters further into the reservoir. This is a concern for swimming areas. Increasing frequency of the monitoring of conditions will provide us with good data to predict the nature of the Pigg River and storm events on the elevation of *e. coli* levels. E. coli remains a parameter of concern in Leesville Lake. Frequent continued monitoring is warranted.

Table 3.38. *E. coli* collection by LLA volunteers 2011.

Parameter	Tri-County	MM9	Dam	MM6	Pitt Stop	Pigg	Toler
June 15	3.1	16.1	0	2	0	272	38.4
July 13	18.5	6.3	42.6	5.2	69.5	110	12.2

Section 4: Closing

Our data continues to suggest the lake is eutrophic. Combined with last year's findings we can conclude that while the lake is eutrophic, it is on the lower end of the eutrophic scale or mildly eutrophic. The strongest evidence for this designation is loss of oxygen in the hypolimnion, high pH measures in the epilimnion and our TSI calculations suggesting it is eutrophic.

It continues to exhibit similar conditions as in the past with the Dam site showing more lacustrine results and Toler Bridge very riverine and highly influenced by dam operations at Smith Mountain Lake and Pigg River. Trophic conditions were higher at Toler Bridge and this would be expected in a reservoir. However, it is instructive to look at the influence of Smith Mountain Lake Dam operations and Pigg River inputs. One benefit for trophic conditions in this area is the influence of Smith Mountain Lake tail water. This water is from the lacustrine portion of the lake and water quality does reflect these conditions. Based on the Smith Mountain Lake report, water in this portion of the reservoir averages close to 40 TSI and 10 ppb total phosphorus. Two issues are important here to consider – hypolimnetic withdraw and the Pigg River.

Interpretation of the data is not straightforward. In instances where Dam release is occurring, Smith Mountain tailwater seems to dilute high concentrations of TP from Pigg River. In other instances, pump back from Leesville may pull Pigg River water into Smith Mountain Lake providing a benefit to Leesville Lake. This continues to be an issue to consider in our study of Leesville Lake dynamics. We need to develop a project to look at this issue to gain better clarity.

Moving forward, I suggest further phytoplankton analysis. We were unable to conduct this analysis during 2011 and I still believe it is critical at least once during the summer months to identify the types of phytoplankton that are dominant in the reservoir. We had a considerable phytoplankton bloom over the summer as evidenced in our chlorophyll analysis and we need to determine what species are dominant during these blooms. This will also impact zooplankton populations and fisheries.

Similar to recommendations in the past, an inquiry of data from the Virginia Department of Game and Inland Fisheries should be conducted to determine abundances of shad, alewife or other forage fish in the reservoir. We did see some abundance of *Daphnia* in the reservoir but change over to a *Diaphanosoma* / Copepod dominated population during summer months reduces grazing influence of zooplankton and provides less available forage for planktivores such as shad and alewife. It would be of significance to determine correlations with fisheries data as fish are very significant ecologically.

We greatly improved our detection of *E. coli* during this past sampling season. We will continue to analyze this data but because it is so highly influenced by river flow it is difficult to make broad conclusions at this time.

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Appendix A

Water Parameter Testing Details

Oxygen
Dissolved oxygen (DO) in Leesville Lake shows a lot about the lake's metabolism. At a certain depth, the concentration of oxygen represents the temporary equilibrium between oxygen-producing processes (such as photosynthesis and aeration) and oxygen-consuming processes (such as decomposition and respiration). The amount of dissolved oxygen that lake water can retain is dependent upon the water's temperature. As temperature increases, the solubility of DO decreases. Because the solubility of gas increases in a liquid as barometric pressure increases, the amount of DO is greater at deeper parts of the lake. Lake eutrophication increases the consumption of dissolved oxygen at the bottom layer of the lake (the hypolimnion), and lowers DO concentrations (Kaulff, 2002, p. 226-236). Dissolved oxygen levels are measured in milligrams per liter (mg/L) or "percent saturation." Percent saturation of dissolved oxygen (DO%) is calculated by taking the amount of oxygen in a liter of water over the total amount of oxygen that the liter can hold.

Large amounts of decaying vegetation lower DO levels in certain areas. In addition to decreasing DO levels, the decomposing material also lowers pH by producing acids. Highly colored acids such as tannic acids, humic acids, and fulvic acids build up and color the water.

DO and percent saturation of dissolved oxygen (DO%) were measured in the field using a hydrolab probe. Prior to sampling at Leesville Lake, the Hydrolab probe was calibrated at Lynchburg College.

DO and DO%, along with other Hydrolab parameters, were measured near the dam, at Mile Mark 6, downstream of Toler Bridge, and near the confluence of Pigg River and the lake. Measurements were taken in milligrams per liter. Starting at the surface, readings were typically taken every half meter for 3 meters. At 3 meters and deeper, readings were taken every meter.

Temperature
Measuring temperatures at various depths indicates if the lake is stratified. Freshwater lakes typically are stratified into three zones—the hypolimnion, the epilimnion, and the metalimnion (typically called the thermocline). The hypolimnion, the deep water zone, has little turbulence and contact with the atmosphere. Its respiratory processes use organic matter from the surface layer for fuel. The uppermost layer is the epilimnion, which is turbulent and provides the energy needs of the biota's animals and microbes. In the metalimnion layer, between the hypolimnion and epilimnion, is the temperature gradient called the thermocline. The temperature difference and resulting density difference of the thermocline disrupts nutrient and gas circulation, resulting in lake stratification (Kaulff, 2002, p. 154).

Temperature was measured at the same test sites as the other Hydrolab parameters by Lynchburg College. The Hydrolab probe measured the temperature of the lake at specific depths in degrees Celsius. Before taking readings out in the field, the temperature probe was calibrated.

pH

pH indicates the alkalinity or acidity of water. For freshwater lakes, this parameter typically lies between 6 and 8. Measuring the pH shows the softness or hardness of water and the biological activities of the water zones. At pH values below 6 and above 8, species diversity and abundance decreases, although the few remaining species can be in high abundance.

A lake's pH can change throughout the day due to photosynthesis. When phytoplankton and other aquatic plants use sunlight to synthesize energy, they remove carbon dioxide from the water and raise pH. Thus, the highest pH levels are typically found in the late afternoon while the lowest levels are found before sunrise.

pH levels can also depend on the amount of decaying vegetation. In a lake's deeper waters, decomposing plants lower pH through the production of tannic acids, humic acids and fulvic acids. These acids are colored and are characteristic of marshes and heavily-vegetated areas.

pH readings were taken by using a Quanta Hydrolab in the field at the same test sites as the other Hydrolab parameters. The process for calibrating the pH probe prior to field sampling is described in the Quality Control and Quality Assurance section.

Conductivity

Conductivity shows the capacity for water to carry electrical currents. Dissolved inorganic solids that carry positive and negative charges influence conductivity. Examples of anions (negatively charged ions) include chloride, nitrate, sulfate, and phosphate; examples of cations (positively charged ions) include sodium, magnesium, calcium, iron, and aluminum. Oil, phenol, alcohol, and sugar are organic solids that remain neutral in water, and thus do not affect conductivity.

Temperature and geology are other factors that influence conductivity. As temperature increases, so does conductivity. The bedrock of the land over which water flows can affect conductivity. In areas with clay soils, conductivity is higher because the dissolved soil ionizes. Areas composed of granite bedrock do not dissolve into ionic materials, and therefore do not affect conductivity as much as areas with clay. The discharge that flows into streams has the ability to raise or lower conductivity. Sewage overflow, which contains chloride, phosphate, and nitrate ions, increases conductivity, while oil leakages lower conductivity. The measurement for conductivity is micromhos per centimeter (μmhos/cm) or microsiemens per centimeter (μs/cm) (http://water.epa.gov/type/rsl/monitoring/).

Once established, a body of water's range of conductivity does not typically fluctuate. Noticeable differences in readings can mean that a source of discharge or pollution has entered the water.

Lynchburg College measured conductivity with Quanta Hydrolab Monitoring Probe at the same test locations as the other Hydrolab parameters. Before sampling, the Hydrolab was calibrated. In the field, readings were taken by applying a voltage between two of the probe's electrodes in the water. The resistance of water creates a drop in voltage that the probe then uses to calculate the conductivity.

Turbidity

Turbidity focuses on levels of sediment pollution in water. Turbidity levels affect the passage of light: soil particles, algae, plankton, and microbes can block light and alter the water color. In addition to reducing light penetration, suspended particles also increase water temperatures due to their absorption of heat.

High turbidity levels also affect aquatic life by reducing photosynthesis, decreasing DO, clogging fish gills, and decreasing fish resistance to disease and growth rates. Once materials settle on the bottom of the lake or river, fish eggs and benthic macro invertebrates can be coated in sediment. According to the Environmental Protection Agency (EPA), high turbidity levels can result from soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders, and excessive algal growth (http://water.epa.gov/type/rsl/monitoring/). It is important to note that turbidity is a measurement often used in coordination with Secchi depth and total dissolved solid (TDS). Secchi depth, which measures a lake's transparency and clarity, is another good indicator of sediment levels. TDS measures sediment in water through filtration.

A turbidity meter was used for this parameter. Consisting of a light and a photoelectric cell, the meter measured the amount of light that was deflected at a 90-degree angle by the particles in the water sample. The units used for turbidity were nephelometric turbidity units, or NTUs.

The Hydrolab probe's transparency tube measured turbidity at the same stops as the other six Hydrolab parameters. Prior to measuring the lake's turbidity, the transparency tube in the probe was calibrated.

Oxidation-Reduction Potential

The oxidation-reduction potential (ORP), also called redox potential, of a lake defines the overall balance between oxidizing and reducing processes (Kaulff, 2002, p. 239). ORP measures the potential electrical energy of a liquid by measuring the specific electrical charges of either oxidizing or reducing agents. In water with a high pH value, there are more reducing agents (a negative ORP value), whereas in water with a low pH value, there are more oxidizing agents resulting in a positive ORP value (http://www.livingspringwaterionizer.com/water-essentials/water-ph-and-orp). Redox reactions are critical for aquatic systems: they lead to organic-matter oxidation, the recycling of nutrients, and the flow of energy from microbes to more complex organisms (Kaulff, 2002, p.246). Lynchburg College and LLA called for the measurement of ORP in the final proposal to further understand chemical activity and developing eutrophication.

ORP is measured in millivolts (mV) by a sensor on the Hydrolab. Within the ORP sensor is a piece of platinum that built up charge without initiating any chemical reactions. This charge was then measured in comparison to the charge in the water. ORP was measured by the Hydrolab probe at three test sites by Lynchburg College. For the lab calibration prior to field sampling, the same steps as the pH calibration were followed.

Total Phosphorus

Total phosphorus (TP) was measured to show nutrient levels in the water. TP levels were compared over time to determine if the lake had current or potential algae problems. Phosphorus is a critical nutrient, often in short supply, for aquatic animals and plants. According to the U.S. Environmental Protection Agency, an increase in phosphorus may accelerate plant growth and algae blooms, lower dissolved oxygen, and contribute to the death of fish, invertebrates, and other aquatic animals. Phosphorus can originate from both natural and human sources such as soil and rocks, sewage, fertilizer, agricultural practices, animal manure, residential and commercial cleaning practices, and water treatment. In bodies of water, phosphorus is either organic or inorganic. Plant or animal tissue contains organic phosphate while inorganic phosphate is required by plants and used by animals (http://water.epa.gov/type/rsl/monitoring/).

Total phosphorus levels measure all forms of phosphorus, which are total orthophosphorus, total hydrolyzable phosphorus, and total organic phosphorus. Ortho phosphorus describes the plain phosphorus molecule, hydrolyzable refers to phosphorus that has undergone hydrolysis, and organic phosphorus is the phosphorus in animal or plant tissue (http://www.uga.edu/sisbl/epa-po4.html).

Lynchburg College conducted total phosphorus testing at each test site. Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were refrigerated until testing. At several test sites, water samples were taken at the surface and at a deeper depth.

The method for determining total phosphorus first involved digesting the sample to change all of the phosphate to orthophosphorus. Samples were then reacted with ascorbic acid to determine concentrations of both dissolved and un-dissolved ortho phosphorus. Lynchburg College used a Systea EasyChem analyzer to test for TP in the samples. Samples were tested within 28 days of collection. Below is the Systea EasyChem method used for detecting total phosphorus.

Systea EasyChem Method

Summary:

Under this method for the determination of total phosphorus, the aqueous sample was mixed with sulfuric acid, ammonium molybdate and antimony potassium tartrate to form antimony-1, 2-phosphorous molybdenum acid. The resulting complex was then reduced by ascorbic acid to get a blue heteropoly acid (molybdenum blue). To determine the concentration of ortho-phosphate, the absorbance of the formed blue complex, was measured at 880nm.

Since only orthophosphorus formed a blue color in this test, polyphosphates (and some organic phosphorus compounds) were converted to the ortho phosphorus form by manual sulfuric acid hydrolysis. Organic phosphorus compounds were converted to the orthophosphorus form by manual persulfate digestion. The developed color was then measured automatically.

List of Chemicals:

- Ammonium Molybdate, (NH4)6Mo7O24•4H2O
- Ammonium Persulfate, (NH4)2S2O8
- Antimony Potassium Tartrate, K(SbO)C4H4O6•3H2O
- Ascorbic Acid, C6H8O6
- Isopropyl Alcohol, (CH3)2CHOH
- Phenolphthalein, C20H14O4
- Potassium Dihydrogen Phosphate, KH2PO4
- Sulfuric Acid conc., H2SO4

Preparation of Reagents and Standards:
Stock Standards:

- 4.0g of ammonium molybdate were dissolved in 75mL DI water, and then the solution was diluted to 100mL with DI. The solution was transferred to a light-resistant polyethylene container and was stable for one month.
- 14.0mL of concentrated sulfuric acid were mixed with 70mL of DI water. The solution was diluted to 100mL with DI water and transferred to a glass container.
- 0.3g of antimony potassium tartrate were dissolved in 75mL DI water, diluted to 100mL with DI water, and transferred to a light-resistant container at 4^{o}C. The solution was stable for approximately 4 weeks.

Reagents:

- For a range up to 20mg/L, a working reagent made up of 50mL sulfuric acid stock, 5mL antimony stock, 15mL molybdate stock, and 50mL of DI water was made and transferred to an EasyChem reagent bottle.
- For the second reagent, 0.9g of ascorbic acid was dissolved in 40mL of DI water. The solution was then diluted to 100mL with DI water and transferred to an EasyChem reagent bottle.

Standards used in the digestion process:

- 15.5mL of sulfuric acid were added to 30mL of DI water. The solution was cooled, diluted to 50mL with DI water, and transferred to a glass container.
- 2.0mL of 11N sulfuric acid solution were added to 50mL of DI water and diluted to 100mL.
- 0.5g phenolphthalein were dissolved in 50mL isopropyl alcohol and 50mL DI water.

Standards:

- A phosphate stock standard of 1000mg/L was prepared by dissolving 4.395g of potassium dihydrogen phosphate in 1000mL of DI water in a 1000mL volumetric flask.
- The 100ppm and 10ppm phosphate stock standard were prepared by subsequently diluting the 1000ppm.

Dissolved Phosphorus

Dissolved phosphorus is the amount of total phosphorus that is in soluble form. This parameter indicates the amount of phosphorus immediately available for aquatic life and, just like one for total phosphate, shows potential algae growth problems.

Dissolved phosphate plays an important role in the aquatic environment. Inorganic dissolved phosphorus is consumed by plants and changed to organic phosphate as it's incorporated into the plant tissue. The organic phosphate then moves to animal tissues when aquatic animals eat the plants. Dissolved phosphate thus ends up in a continual cycle of inorganic phosphorus, organic phosphorus in plant tissue, organic phosphorus in animal tissue, and back to inorganic phosphorus once the animals die and bacteria converts the phosphorus (http://www.uga.edu/sisbl/epa-po4.html). Too much dissolved phosphorus can cause the same problems as increases in total phosphorus.

Dissolved phosphorus testing was completed for all test sites by Lynchburg College. Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were refrigerated until testing. At several test locations, water samples were taken at the surface and at a deeper depth.

The method for determining dissolved phosphate first involved filtering the samples to remove any suspended particles. Samples were then tested for phosphorus using the same method as total phosphorus. Lynchburg College used a Systea EasyChem analyzer to test for dissolved phosphorus in the samples.

Nitrogen:

In addition to phosphorus, nitrogen is also an important element that determines a lake's biota. Inputs of nitrogen include drainage basins and the atmosphere. The largest source of nitrogen comes from atmospheric deposits, which have doubled globally due to fossil fuel emission and other human activities (Kaulff, 2002, p. 270-271).

Excess nitrogen has detrimental effects on lake health. High nutrient levels accelerate eutrophication through algal growth. As the plants grow and decompose, the levels of dissolved oxygen (DO) in water decrease. Reduced DO levels can result in the die-off of fish, foul odors, and reduced recreational and atheistic value.

To determine nitrogen levels, Lynchburg College tested water samples for nitrate (NO_3). Samples were collected in acid-washed, labeled polyethylene bottles, placed in a cooler with ice, and then transferred to a refrigerator upon the return to Lynchburg College. Within 48 hours of collection, the samples were tested for NO_3 using the Systea EasyChem analyzer according to the following method.

Summary of Method:
In this method used to determine nitrate levels, nitrate was reduced to nitrite using Systea's Chemical RI. The resulting stream was treated with sulfanilamide and N-1-naptylethylenediamine dihydrochloride under acidic conditions to form a soluble dye, which was measured colormetrically at 546nm. The product was the sum of the original nitrite ion present plus the nitrite formed from nitrate. Systea has shown that, regardless of the sample matrix used, recovery of NO3 to NO2 is consistently between 95% and 105% recovery.
To determine the nitrate levels, the nitrite alone was subtracted from the total.

List of Chemicals:
Systea (1-Reagent) Nitrate Solution contained:

- Hydrochloric acid, (HCl)
- N-1-naptylethylenediamine dihydrochloride, (NEDD) $C_{12}H_{14}N_2 \bullet 2HCl$
- Sulfanilamide, $C_6H_8N_2O_2S$

Stock Standard contained:

- Potassium Nitrate, KNO_3

Preparation of Reagents and Standards:
Reagents:

- The Systea (1-Reagent) Nitrate Solution was transferred to an EasyChem reagent bottle and placed in the instrument.

Standards:

- A nitrate stock standard of 1000 mg/L was prepared by dissolving 7.218 grams of potassium nitrate in 1000 mL of DI water in a 1000mL volumetric flask.
- The 100 ppm and 10 ppm nitrate stock standard were prepared by subsequently diluting the 1000 ppm.

Summary of Run:

1. Standards and reagents were prepared by the above steps and then placed in the EasyChem instrument.
2. A standard curve for a range of 0.05-10mg/L (check) was created by the following steps:

- A 10ppm nitrate standard was placed in the instrument.
- The instrument made 5, 1, 0.5, 0.10, and 0.05ppm standards through dilutions.
- The instrument read the optical density of the calibrants. O.D. readings of a 0ppm standard and of two blanks (composed of DI water) were taken.
- A standard curve was set. The linear correlation coefficient (r^2) was always greater than 0.995.

3. The optical density of the samples was measured. By comparing the O.D. values to the standard curve set in Step 1, the concentration of nitrate in the lake samples was determined.
4. For every 10 samples, a check standard, spike, and a duplicate were included. Thus, for 40 cups of samples, there were 4 check standards of a known 10ppm nitrate solution, 4 spikes from different samples, and 4 different duplicates of lake samples. The check standards, serving as the Quality Control Samples (QCS), fell within 10% of the QCS true value.
5. The analysis ended with a blank to check the validity of the instrument's readings.

Fluorescence
Using a surface sample, Lynchburg College measured fluorescence. Florescence measurements correlate with the concentration of Chlorophyll in water. Lynchburg College field and lab verified and calibrated the barometer. A fluorescence probe connected to a monitoring screen was lowered into the water at half meter and whole meter intervals by Lynchburg College.

Integrated Chlorophyll *a*

Water samples were measured for integrated chlorophyll *a* to show the amount of productivity throughout the photic zone. Chlorophyll, a green pigment that synthesizes organic elements from sunlight in plants, is required for algal growth. Chlorophyll *a* is the most common type of pigment found in algae. High levels of chlorophyll *a* demonstrate high algal levels (http://www.chesapeakebay.net/chlorophylla.aspx?menuitem=14655).

Lynchburg College took water samples at four test sites for chlorophyll *a* testing. Water samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, 10% HCl, and DI water. Samples were placed in a cooler half-filled with ice at the site of the collection, and then stored in a refrigerator back at Lynchburg College.

To determine chlorophyll *a* levels, Lynchburg College used the chlorophyll *a* filtration method. Within 48 hours, the water samples were filtered through a vacuum pump. First, to prevent photoplankton from licing to the filter, some magnesium carbonate was squirted onto a 0.45 micron 4.25 cm glass fiber filter. Then, about 150 mL or 200 mL of the lake sample was poured and drained through the filter using a vacuum pump. The filter was then folded, placed in aluminum foil, labeled, and refrigerated until it was tested.

Secchi Depth

Measuring secchi depth is one of the simplest ways to determine lake eutrophication and light transparence. The amount of nutrients in lake water determines a lake's cloudiness by accelerating the growth of phytoplankton (microscopic animals) and therefore the growth of zooplankton (microscopic animals). Inorganic solids from fertilizers, soil erosion, and sewage also increase a lake's cloudiness. Secchi disk transparency, chlorophyll *a*, and total phosphorus together define a lake's trophic status (degree of eutrophication).

Typically secchi depth is lowest during the spring and summer months, when water runoff and phytoplankton productivity is most vigorous. Water clarity often increases, sometimes doubling secchi depths, during the fall and winter months. Weather is another factor: a drought will lead to increased water clarity while storms with heavy rain increase runoff and subsequently decrease secchi depth.

A secchi disk, consisting of a 20 cm black and white round disk attached to a line, is used to measure secchi depth. The disk is lowered into the water until the lines separating the black and white sections on the disk are no longer distinguishable. Secchi depth is then recorded at that depth in the water column. Lynchburg College measured secchi depth at all of the eight stops. The rope attached to the disk was marked in meter increments. Measurements were recorded in meters and taken to the tenth decimal place. Volunteers from LLA also took secchi depth readings on or around similar dates as Lynchburg College.

Trophic State

Secchi depth, integrated chlorophyll *a*, and total phosphorus (TP) are used to determine a lake's trophic status. Exposing a lake's health, a trophic state shows the lake's degree of eutrophication. There are 3 main categories under the Trophic State Index (TSI); eutrophic, mesotrophic, and oligotrophic. Eutrophic lakes are highly productive and concentrated in

nutrients; mesotrophic lakes experience temperate productivity and have moderate nutrient levels; oligotrophic lakes have little productivity and low nutrient levels. When the TSI value is greater than 51, lakes are classified as eutrophic. Water has more clarity in oligotrophic lakes rather than in eutrophic lakes due to the lower nutrient levels (http://www.rmbel.info/reports/Static/TSI.aspx).

E. coli

To determine levels of bacteria and look for health hazards, Lynchburg College and LLA took *E. coli* readings at Leesville Lake. Escherichia coli (*E. coli*) is the accepted indicator organism for bacteria levels in Virginia. For the purposes of this report, *E. coli* levels are representative of coliform levels.

High levels of coliform bacteria found in lakes may point to the presence of human or animal excrement. Coliform bacteria are not harmful; however their presence shows that disease-causing bacteria or viruses may be present. Waterborne diseases such as dysentery, giardiasis, typhoid and other gastrointestinal infections can be contracted by swimming or drinking water from a lake containing human sewage. To assure the safety of water from such diseases, the water must meet the state standard for bacteria. In Virginia, the calendar-month geometric mean concentration of *E. coli* cannot exceed 126 cfu/100 mL, and no sample can exceed a concentration of 235 cfu/100mL (Virginia Tech, 2006).

Conducting a fecal coliform test will show if sewage pollution is the problem. Additional tests can distinguish between human and animal sources if necessary. Nonpoint sources are the primary reason for high bacteria levels. Agriculture, land-applied animal waste, and livestock manure are the main nonpoint sources. Cattle and wildlife directly dumping feces into streams cause a large bacteria load. Nonpoint sources from residential areas include straight pipes, failing septic systems, and pet waste (Virginia Tech, 2006).

Prior to 2011, Leesville Lake Association citizen volunteers used Coliscan Easygel® test kits for *E. coli* testing. Beginning in 2011 water samples collected by both LLA volunteers and Lynchburg College were tested for E. coli with the Colilert™ test method. Samples were collected in sterile 125 ml polypropylene bottles and stored according to standard methods. A Colilert™ media packet was added to each water sample; the mixture was poured into a sterile Quanti-Tray, sealed and incubated. A color change from clear to yellow indicates a positive result for total coliform and fluorescence indicates a positive result for E. coli. The number of yellow and fluorescent wells are counted and the values are evaluated using a Most Probable Number (MPN) chart developed by the IDEXX Company, which developed the test method. MPN is used instead of colony forming units (cfus) and is generally considered an equivalent measure of the microbial and bacterial populations. The Colilert™ method has been rated as the "best" in agreement with a reference lab, has the lowest detection limit and the method is EPA approved for ambient water.

Zooplankton

To assess the health and structure of the lake's biological community, water samples were tested for zooplankton levels. Nutrient-rich (eutrophic) lakes, in comparison to nutrient-poor lakes, have more zooplankton. As the levels of phytoplankton increase, zooplankton also increase but at a slower rate (Kaulff, 2002).

Appendix B

Quality Assurance (QA) / Quality Control (QC)

Sample Collection, Preservation, and Storage:

- Leesville Lake samples were collected in labeled polyethylene bottles that had been cleaned and rinsed with tap water, soap, DI water, a 2M HCl (we used 1M HCl) acid wash and finally more DI water. Each label denoted date, location, station, and depth if relevant.
- Samples were refrigerated.
- For detecting nitrate, nitrite, orthophosphate, and ammonia, samples were analyzed within 48 hours of collection. For total phosphorus (TP) and total kjedahl nitrogen (TKN), the samples were analyzed within 28 days.

Hydrolab Calibration:

- The instrument used was a Hydrolab Quanta Water Quality Monitoring System.
- A calibration standard whose value was near that of the field samples was selected
- The sensors were cleaned and prepared for the following parameters:

- Specific Conductance - A calibration standard was poured to within a centimeter of the top of the cup. Any bubbles within the measurement cell of the specific conductance sensor were tapped out. The conductivity of the calibration standard was 1.412.

- Dissolved Oxygen %Saturation and mg/L:

1. Cleaning and Preparation: The o-ring securing the DO membrane was removed, the old electrolyte was shaken out and the DO membrane was rinsed with fresh DO electrolyte. Fresh DO electrolyte was poured into the sensor until a meniscus of electrolyte rose above the entire electrode surface of the sensor. After checking to make sure there were no bubbles in the electrolyte, a new membrane was placed on the top of the DO sensor and secured with the o-ring. There were no wrinkles in the membrane or bubbles in the electrolyte. Excess membrane was trimmed away.
2. Calibration for DO: The Saturated Air-Method was used for the DO calibration. The Calibration cup was filled with DI water until the water was level with the o-ring. No water droplets were on the membrane. The black calibration cup cover, turned upside down, was placed on the top of the Calibration Cup. The barometric pressure, which was 762mmHg, was determined for entry as the calibration standard.

- pH and ORP (Redox):

1. Cleaning and Preparation: The pH sensor was clean with a soft cloth wet with rubbing alcohol and then rinsed with DI water. The platinum band at the tip of the ORP sensor was checked for any discoloration or contamination. Then the reference sleeve was pulled away from the Transmitter and the old electrolyte from the reference sleeve was discarded. Then two KCl salt pellets (or KCl rings) were dropped into the reference sleeve and the sleeve was refilled with reference electrolyte. With the Transmitter sensors pointed toward the floor, the full reference sleeve was pushed back onto its mount until the sleeve had just covered the first o-

ring located on the mount. The Transmitter was then turned so that the sensors pointed towards the ceiling, and the sleeve was pushed the rest of the way onto its mount. The sensors were rinsed with DI water. Next, the Low-Ionic Strength Reference (LISRef) was cleaned and prepared. First the plastic LISRef soaking cap was removed and set aside. The sensor tip was then checked for any visible contamination. Following cleaning, the plastic LISRef soaking cap was filled with reference electrolyte, reinstalled over the LISRef tip, and soaked overnight. The plastic LISRef soaking cap was removed for calibration and field use.

2. Calibration for pH and ORP: A two-point calibration was used, with two pH standards. First, a pH standard of 7 was treated as the zero, and then a pH standard of 4 was treated as the slope. Both pH standards, when calibrated separately, were poured to within a centimeter of the top of the cup.

〈 Turbidity:

1. Cleaning and Preparation: A non-abrasive, lint-free cloth was used to clean the quartz glass tube to remove any scratches that might reduce the sensors accuracy. The sensor was then rinsed with DI water.
2. Calibration for Turbidity: A Quick-Cal Cube was cleaned and dried with a non-abrasive, lint-free cloth. The cube was then placed in the turbidity sensors optical area. Turbidity analyzed and also checked at 0 with DI water.

〈 Depth: Zero was entered for the standard at the water's surface.

〈 After all of the parameters were calibrated, the calibration cup was filled with ¼ of tap water to protect the sensors from damage and drying out during transportation to the lake and storage in Lynchburg College.

〈 The hydrolab was calibrated the morning of each day of lake sampling:

Pre Sampling at Leesville Lake

〈 The bottled were washed according to above procedures, labeled, and placed in a milk crate. 18 bottles were taken: 3 for zooplankton, 12 for nutrients, and 3 for whole water.

〈 The Hydrolab was calibrated and the information was recorded.

〈 An ice chest was half-filled with ice.

〈 Batteries in the Hydrolab were checked.

〈 At the lake, the following parameters were recorded:

- Smith Mountain Lake tailwaters: whole water for TP
- Pigg River near its mouth: Secchi depth, TP, Hydrolab data
- Toler Bridge (after confluence with Pigg River/riverine zone): Secchi depth, TP, no Hydrolab data was taken because the flow of water was too quick
- Mile Mark 9 (mixing zone): Secchi depth, TP?
- Mile Mark 6 (end of mixing zone/beginning of lacustrine): Secchi depth, TP, hydrolab data
- Tri-County Marina: Secchi depth, TP
- Pit Stop Marina: Secchi depth, TP
- Near dam (end point of lacustrine): Secchi depth, TP, Hydrolab data

〈 No data for E. Coli was collected because of a lack of zithromax packs.

Nitrate Method

Summary of Method:

In this method used to determine nitrate levels, nitrate was reduced to nitrite using SysteaÕs Chemical RI. The resulting stream was treated with sulfanilamide and N-1-naptylethylenediamine dihydrochloride under acidic conditions to form a soluble dye, which was measured colormetrically at 546nm. The product was the sum of the original nitrite ion present plus the nitrite formed from nitrate. Systea has shown that, regardless of the sample matrix used, recovery of NO3 to NO2 is consistently between 95% and 105% recovery.
To determine the nitrate levels, the nitrite alone was subtracted from the total.

List of Chemicals:

Systea (1-Reagent) Nitrate Solution contained:

Hydrochloric acid, (HCl)

N-1-naptylethylenediamine dihydrochloride, (NEDD) $C_{12}H_{14}N_2$⟨2HCl

Sulfanilamide, $C_6H_8N_2O_2S$

Stock Standard contained:

Potassium Nitrate, KNO_3

Preparation of Reagents and Standards:

Reagents:

⟨ The Systea (1-Reagent) Nitrate Solution was transferred to an EasyChem reagent bottle and placed in the instrument.

Standards:

⟨ A nitrate stock standard of 1000 mg/L was prepared by dissolving 7.218 grams of potassium nitrate in 1000 mL of DI water in a 1000mL volumetric flask.

⟨ The 100 ppm and 10 ppm nitrate stock standard were prepared by subsequently diluting the 1000 ppm.

Summary of Run:

1. The lake samples were chilled to about 4^0C and analyzed within 48 hours
2. Standards and reagents were prepared by the above steps and then placed in the EasyChem instrument.
3. A standard curve for a range of 0.05-10mg/L (check) was created by the following steps:

⟨ A 10ppm nitrate standard was placed in the instrument.

⟨ The instrument made 5, 1, 0.5, 0.10, and 0.05ppm standards through dilutions.

⟨ The instrument read the optical density of the calibrants. O.D. readings of a 0ppm standard and of two blanks (composed of DI water) were taken.

⟨ A standard curve was set. The linear correlation coefficient (r^2) was always greater than 0.995.

4. The optical density of the samples was measured. By comparing the O.D. values to the standard curve set in Step 1, the concentration of nitrate in the lake samples was determined.
5. For every 10 samples, a check standard, spike, and a duplicate were included. Thus, for 40 cups of samples, there were 4 check standards of a known 10ppm nitrate solution, 4 spikes from different samples, and 4 different duplicates of lake samples. The check standards, serving as the Quality Control Samples (QCS), fell within 10% of the QCS true value.
6. The analysis ended with a blank to check the validity of the instruments readings.

Ortho-Phosphate Method

Summary of Method:
The solution containing phosphate was mixed with sulfuric acid, ammonium molybdate and antimony potassium tartrate to form antimony-1, 2-phosphorous molybdenum acid. To create a blue heteropoly acid (molybdenum blue), the complex was reduced by ascorbic acid. The absorbance of the blue complex was measured at 880nm to determine the concentration of phosphorus.

List of Chemicals:
Ammonium Molybdate, (NH4)6Mo7O24 4H2O
Antimony Potassium Tartrate, K(SbO)C4H4O6⟨3H2O
Ascorbic Acid, C6H8O6
Potassium Dihydrogen Phosphate, KH2PO4
Sulfuric Acid conc., H2SO4

Preparation of Reagents and Standards:
Stock Solutions:
⟨ 4.0g of ammonium molybdate were dissolved in 100mL of water, then transferred to a light-resistant polyethylene container.
⟨ 14mL of sulfuric acid were added to 70mL of DI water. The solution was cooled, and diluted to 100mL with DI water.
⟨ 0.3g of antimony potassium tartrate were dissolved in 100mL water and the solution was transferred to a light-resistant container.
Reagents:
⟨ The first phosphate reagent depended on the concentration range. For a range of up to 20mg/L, 50mL of (5N) sulfuric acid were mixed with 5mL of antimony stock. 15mL of molybdate stock and 50mL of DI water were added.
⟨ For the second reagent, 0.9g of ascorbic acid were dissolved in 100mL of DI water.
Standards:
⟨ A phosphate stock standard of 1000mg/L was made by dissolving 4.395g of potassium dihydrogen phosphate in 1000mL of DI water.
⟨ The 100 ppm and 10 ppm nitrite stock standard were prepared by subsequently diluting the 1000 ppm standard.

Nitrite Method

Summary of Method:
Under this automated procedure, the nitrite ion reacted with sulfanilamide under acidic conditions to form a diazo compound. This compound then combined with N-1-napthylethylenediamine dihydrochloride to form a reddish-purple azo dye. To determine nitrite concentration, the colored complex was measured at 546nm.

List of Chemicals:
N-1-naptylethylenediamine dihydrochloride, C12H14N2⟨2HCl
Phosphoric Acid, H3PO4
Sodium Nitrite, NaNO2
Sulfanilamide, C6H8N2O2S

Preparation of Reagents and Standards:
Reagents:
⟨ 10mL of concentrate phosphoric acid, 1.0g of sulfanilamide, and 0.1g of N-1-napthylethlyenediamine dihydrochloride were dissolved in approximately 40mL of DI water in a 100mL volumetric flask. The solution was diluted to 100mL with DI water and transferred to a polyethylene bottle.

Standards:
⟨ A nitrite stock standard of 1000 mg/L was made by dissolving 4.9242g of sodium nitrite in one liter of DI water.
⟨ The 100 ppm and 10 ppm nitrite stock standard were prepared by subsequently diluting the 1000 ppm standard.

Total Phosphate Method

Summary of Method:
Under this method for the determination of total phosphate, the aqueous sample was mixed with sulfuric acid, ammonium molybdate and antimony potassium tartrate to form antimony-1, 2-phosphorous molybdenum acid. The resulting complex was then reduced by ascorbic acid to get a blue heteropoly acid (molybdenum blue). To determine the concentration of ortho-phosphate, the absorbance of the formed blue complex, was measured at 880nm.
Since only orthophosphate formed a blue color in this test, polyphosphates (and some organic phosphorus compounds) were converted to the orthophosphate form by manual sulfuric acid hydrolysis. Organic phosphorus compounds were converted to the orthophosphate form by manual persulfate digestion. The developed color was then measured automatically.

List of Chemicals:
Ammonium Molybdate, (NH4)6Mo7O24⟨4H2O
Ammonium Persulfate, (NH4)2S2O8
Antimony Potassium Tartrate, K(SbO)C4H4O6⟨3H2O
Ascorbic Acid, C6H8O6
Isopropyl Alcohol, (CH3)2CHOH
Phenolphthalein, C20H14O4
Potassium Dihydrogen Phosphate, KH2PO4
Sulfuric Acid conc., H2SO4

Preparation of Reagents and Standards:
Stock Standards:
⟨ 4.0g of ammonium molybdate were dissolved in 75mL DI water, and then the solution was diluted to 100mL with DI. The solution was transferred to a light-resistant polyethylene container and was stable for one month.
⟨ 14.0mL of concentrated sulfuric acid were mixed with 70mL of DI water. The solution was diluted to 100mL with DI water and transferred to a glass container.
⟨ 0.3g of antimony potassium tartrate were dissolved in 75mL DI water, diluted to 100mL with DI water, and transferred to a light-resistant container at 4^{o}C. The solution was stable for approximately 4 weeks.
Reagents:
⟨ For a range up to 20mg/L, a working reagent made up of 50mL sulfuric acid stock, 5mL antimony stock, 15mL molybdate stock, and 50mL of DI water was made and transferred to an EasyChem reagent bottle.
⟨ For the second reagent, 0.9g of ascorbic acid was dissolved in 40mL of DI water. The solution was then diluted to 100mL with DI water and transferred to an EasyChem reagent bottle.
Standards used in the digestion process:
⟨ 15.5mL of sulfuric acid were added to 30mL of DI water. The solution was cooled, diluted to 50mL with DI water, and transferred to a glass container.
⟨ 2.0mL of 11N sulfuric acid solution were added to 50mL of DI water and diluted to 100mL.
⟨ 0.5g phenolphthalein were dissolved in 50mL isopropyl alcohol and 50mL DI water.

Standards:

- A phosphate stock standard of 1000mg/L was prepared by dissolving 4.395g of potassium dihydrogen phosphate in 1000mL of DI water in a 1000mL volumetric flask.
- The 100ppm and 10ppm phosphate stock standard were prepared by subsequently diluting the 1000ppm.

Quality Assurance/Quality Control

Initial demonstration of laboratory capability was established through the following methods:

Method Detection Limit (MDL): According to the Code of Federal Regulations, the MDL is the minimum concentration that can be determined with 99% confidence that the true concentration is greater than zero. This method guarantees the ability to detect nutrient concentrations at low levels. In order to proceed with testing, the MDL in reagent water for nutrients had to be less than or equal to the concentrations in the table below. These concentrations were taken from the Ambient Water Quality Monitoring Project Plan for the Department of Environmental Quality:

Nitrate	0.04 mg/L
Nitrite	0.01 mg/L
Orthophosphate	0.01 mg/L
Total Phosphate	0.01 mg/L
Ammonia	0.04 mg/L

Initial Precision and Recovery (IPR): This practice establishes the ability to generate acceptable precision and accuracy. 4 Laboratory Control Samples (LCS) were analyzed and the average percent of recovery (X) along with the standard deviation of the percent recovery (s) for nitrate was determined. Our tested recovery did not exceed the precision limit and X did not fall outside the 90-110% range for recovery. In instances were recover was not accomplished analysis was repeated to achieve the acceptable recover limits.

Matrix spikes (MS) and matrix spike duplicate (MSD) samples were analyzed to demonstrate method accuracy and precision and to monitor matrix interferences.

Out of each set of ten samples, one sample aliquot was analyzed. First, the background concentration (B) of analyte was determined. Then the sample was spiked with the amount of analyte stock solution to produce a concentration in the sample of 1mg/L, or a concentration 1 to 5 times the background concentration. Finally, two additional sample aliquots were spiked with the spiking solution, and the concentrations after spiking (A) were measured.

The percent recovery of analyte in each aliquot was determined using the follow equation:

$$P = [100(A - B)]/T$$

The spike recovery percentage had to lie within the QC acceptance criteria of 90 to 110%. The relative percent difference between the two spiked sample results also had to be less than 20%.

Laboratory reagent water blanks were analyzed with each analytical batch to demonstrate freedom from contamination and that detected nitrate is not at a concentration greater than the MDL.

To demonstrate that the analysis system was in control, the LCS procedure was performed on an ongoing basis, with results lying within +/-10% of the true value.

Records defining the quality of data generated, including LCS data and QC charts, were maintained. A statement of laboratory data quality for each analyte, with the average percent recovery (R) and the standard deviation of the percent recovery (s_r). The accuracy as a recovery interval was expressed as $R - 3s_r$ to $R + 3s_r$.

To demonstrate that the analytical system was in control, the laboratory periodically tested an external reference sample. We have not yet conducted this analysis but will strive to this standard in 2011.

Appendix C

Quality Assurance (QA) / Quality Control (QC) Checklist:

General Procedures:

- Checklist of all routine material and equipment:
  Checklist should include field data sheets showing sampling sites, QA sites if QC samples are collected, containers, preservatives, and labels including QC labels
- Also a topo map, GPS unit, safety gear, and cell phone
- Print field data sheets and labels from CEDS for the run
- Clean equipment, check its condition, and charge batteries

Sampling Requirements:

- For the collection of organic materials, se non-organic or inert materials such as Teflon or stainless steel
- Water matrices: 1. Rope on spool 2. Stainless steel bucket with fitting for bacteria sample bottle 3. Syringe, filter paper, filter holder etc.

Sampling Equipment Preparation and Cleaning:

- Water Sampling Equipment:
- Daily: Rinse buckets at the end of the day with analyte free water and allow to dry; if a pump/hose was used, pump 5 gallons of analyte free water through system and allow to drain; if using Kemmerer or Alpha Bottle sampling devices, follow manufacturer's instructions using analyte free water
- Weekly: Wash buckets with lab grade soap (Liquinox or Alconox) using a brush to remove particulate matter or surface film; rinse with tap water and then analyte free water, allow to dry
- Monthly: pump 5 gallons of a 5% solution (consists of 1 quart of vinegar mixed with 4 ¾ gallons of water) through hose and pump apparatus; pump 5 gallons of anaylte free water through hose and pump apparatus and completely drain
- Annually: replace hoses of pump and hose sampling devices
- Sample container handling and preservation:
- Refer to the DCLS laboratory catalog in CEDS for the appropriate preservation procedures. Samples not preserved properly may be rejected by DCLS.
- make sure the lids were on tight
- Sample containers should be stored with the tops fastened.
- Samples should be iced to 4°C in a cooler immediately after collection. In the cooler, samples shall be placed upright and if possible, covered with ice in such a manner that the container openings are above the level of ice. Chlorophyll a filter pad samples will be placed in appropriately sized Ziploc bags and placed on top of the layer of ice. Ziploc bags containing filters should be oriented so that the sealed opening of the Ziploc bag hangs outside the cooler lid when the lid is closed. Bacteria sample bottles should be stored in mesh bags, placed in coolers and surrounded with wet ice.
- Package glass sample containers in bubble wrap or other waterproof protective materials

- Make sure that every cooler used to ship samples to DCLS contains one temperature bottle to determine sample temp upon arrival at DCLS.
- Regional office should date boxed or packaged sample containers upon receipt and stock on shelves with the oldest dated box/packages used first.

Sample identification:

- Identify each sample by the station description, date, time, depth description, collector initials, parameter group code, sample type, container number, preservation used and volume filtered, if applicable.
- Print sample identification information on an adhesive Avery label and applied to the exterior of the container.
- Print labels for established sampling sites from CEDS

Field Sampling Procedures:

- Use protective gloves: latex or nitrile gloves may be used for common sampling conditions; disposable ones are needed for clean metal sampling
- Rinse sample equipment with sample water before taking actual sample. Dispose of rinse water away from sampling site.
- Take surface water samples facing upstream and in the center of main area of flow
- For bacteria samples, do not rinse bottle before collecting sample and always collect as a grab sample, do not composite

Sampling from a boat:

- Bacteria samples: grab from the water in direction of current, do not use a pump or hose
- Sample away from engine in direction of current (if possible)
- Clear the pump and hose using the air bubble method or calculate the clearing time

Secchi disk:

- Use disk 20 cm in diameter attached to a line/chain marked in 0.1 m increments, check these once a year
- Lower secchi disk on shaded side of boat until black and white quadrants are no longer distinguishable
- Note the above depth, and then depth at which the quadrants are once again distinct
- Secchi depth is the average of the two depths to the closest 0.1 m

Vacuum Filtering Method (In-Line Filtering)

- Nitrogen, phosphorus, and chlorophyll **a**
- conduct filtering as soon as possible after collection but no later than 2 hours after sample collection

Preparation:

- Muffle 25 mm diameter glass fiber filters utilized for PNC (Particulate Nitrogen and Particulate Carbon analysis),
- Acid wash the towers, graduated cylinders and plastic sample bottles
- Rinse the forceps with DI water

- Ensure proper delivery of uncontaminated, dry filter samples to DCLS.

Filtration of samples:

- Rinse acid washed and DI washed container with sample water, then fill container with enough sample water to filter more than one sample
- Rinse filtration towers and base with DI water, connect vacuum power pump to battery
- Place filters on bases, place clean NTNP bottles under PP bases, rinse graduated cylinders with sample, and transfer sample to towers
- Turn pump on
- Add $MgCO_3$ to last 25 ml of Chla sample
- Close valves or turn off pump to remove filtration vacuum
- Bleed excess pressure off and then open vacuum valves of stacks slowly
- Rinse forceps with DI water
- Remove filters from base
- Record volume filtered
- Remove NTNP bottle from PP cylinder and cap tightly
- Label- station, date, time depth, unit code, collector's initials, group code, container #, volume of sample filtered
- Place samples on ice

Collection of samples for chlorophyll a using syringe filtration p. 21

- Field filtration is done with positive pressure and a syringe
- Filter approx 300 ml of site water through a 150cc polypropylene syringe

Field Quality Control Samples

- Equipment Blanks: need to be collected in field between stations, once for each 25 sites sampled, flush/rinse with analyte free water
- Field split samples: collect for each 25 sites sampled, obtain 1 bucket of water and fill 2 identical containers sequentially

Field Testing Procedures (p. 69)

pH/mV/Ion meter

- calibrate meter each day before use with minimum of 2 fresh standard buffer solutions that bracket expected pH
- check calibrations using standard buffer solutions at least once during or end of sampling and record in log sheet, if pH is off by more than 0.2 pH units, flag data collected
- check instrument at least once a month and record in log sheet

Dissolved oxygen and temperature meter

- Calibrate daily when in use, air calibration is the easiest
- Record the % saturated DO in the log sheet
- A DO% saturation confirmation needs to be performed in the middle of run
- Field probe maintenance: average life of membrane is 2-4 weeks, but may vary
- Some gases can contaminate the sensor, evidenced by discoloration of gold cathode
- Check probe performance every month when probe is in daily use
- For the DO meter, make calibration checks daily. Check calibration during sampling and

at conclusion of day's sampling. Record onto log sheet; if check is off ±5%, flag data

- Monthly, place probe into a clean bucket full of analyte free or uncontaminated water, rinse BOD bottle 1 or 2 times with water, determine DO by Winkler method
- If the oxygen concentration of the air calibration disagrees with average results of Winkler value by more than 0.5 mg/l, have the electrode or meter serviced or replaced
- Check temperature probe against another multiprobe instrument's temp. probe semi-annually

DO and conductivity meter calibration checks

- Daily: check calibration during sampling and at conclusion of day's sampling, record and flag data if off by more than 5%
- Monthly: place probe in bucket of analyte free water, rinse BOD bottle with water from bucket, determine the DO by the Winkler method
- If oxygen concentration of air calibration disagrees with results of Winkler value by more than 0.5 mg/l, service or replace electrode

Thermistor Verification

- Check temperature probe against another multiprobe instrument's temperature probe semi-annually
- Check against 3 points such as an ice/water mixture, room water temperature, and warm water temperature
- Do not use thermistor if the difference is more than 0.5 degrees C

Sample Identification and Corrective Action

- Make entries in field data sheet for all field parameters
- Print label from pre-print label file in computer. Include station ID, date collected, time collected, depth, unit code, collector, group code, preservative, lab processing code, blank/dup designation, priority and container number
- Corrective Action: CAR form must be forwarded to QA officer for review and recommendations