

# Water quality monitoring and research at Lake Wateree, SC

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**ABSTRACT.** For at least two decades the water quality in Lake Wateree has been the focus of much attention by state and local governments, lake property owners, Duke Energy, and the University of South Carolina (USC). Several locations on or near the lake are on the state 303(d) list for excess nutrients or the consequences of excess nutrients. Most nutrient loading is from sources upstream in the Catawba River watershed. From 1999-2003 the all-volunteer Lake Wateree Water Watch (WW) group conducted monthly sampling for field parameters at 19 locations in the lake. The monitoring effort resumed in 2008 with assistance from faculty, students, and staff at the University of South Carolina. This presentation will provide an overview of the sampling effort and its results. In late 2011 a study was completed that compared sampling data from the 1999-2003 interval to data from 2008-2011. There was some improvement in water clarity between the two intervals. This appears to have resulted in an increase in phytoplankton production as indicated by increased pH at some locations.

Concurrent with the monitoring a research project was conducted during summer 2011. The purpose was to measure fluxes of nutrients (phosphorus and nitrogen) between lake sediment and the overlying water, measure concentrations of nutrients in the sediments, and measure nutrients and field parameters vertically throughout the year. The conceptual justification for the work was based on two prior studies. In 1996 a water quality simulation model of the lake suggested nutrient fluxes may be occurring. Then during summer 2009 special reconnaissance sampling showed the physical conditions develop under which nutrient fluxes could occur. Our findings indicate the exchange of nutrients between the sediment and overlying water occurs in both directions. The direction at any given time depends on other physicochemical characteristics of the lake that are probably related to season and riverine inflow.

## INTRODUCTION

In 1996 the (Lake) Wateree Home Owners Association (WHOA) contracted with the University of South Carolina to conduct a study to assess lake water quality, the then-current monitoring strategies, and to recommend future monitoring needs. One of the main tasks of the study was development of a water quality simulation model of eutrophication kinetics in the lake (Tufford et al. 1999). Among the recommendations from that study were that WHOA initiate a volunteer monitoring program that would incorporate both spatial and temporal scale considerations to ensure a more holistic understanding of water quality in the lake and that short-term intensive studies should be conducted to gain insight into specific physical and biochemical processes (Tufford et al. 1997).

In 1999 WHOA, through its affiliated Water Watch group, initiated sampling of water quality field parameters at nineteen locations in the lake. This effort continued into 2003. The work was restarted in 2008, this time in partnership with researchers at the University of South Carolina (USC), and continues today. There are currently two lake groups: WHOA on the Fairfield County side of the lake and the Lake Wateree Association (LWA) on the Kershaw County side. Concurrent with the monthly monitoring several special projects were initiated, including studies of: a small tributary watershed looking at potential sources of sediment that caused elevated turbidity in the embayment, dissolved oxygen conditions at the sediment/water interface during summer, the flux of nutrients across the sediment/water interface, and details of summer chlorophyll and dissolved inorganic nutrients in two tributary embayments.

This paper provides details of the routine monthly sampling and a comparison of results from the two sampling efforts, 1999-2003 versus 2008-present. We also present and discuss results from the two studies of the sediment/water interface and provide brief summaries of other projects. We conclude with a discussion of the benefits and challenges facing a viable volunteer monitoring effort.

## STUDY AREA

Lake Wateree is in the Piedmont of South Carolina (Fig. 1). It is at the downstream end of a chain of eleven reservoirs along the Catawba River that begins with Lake James in North Carolina. All the dams were built by Duke Energy to provide hydropower. Lake Wateree, completed in 1919, also currently provides municipal water supply along with primary and secondary contact recreational opportunities. The surface area is approximately 5,548 ha (13,710 ac), maximum depth is approximately 24 m (78 ft), and mean hydraulic residence time is 27 d.

## METHODS

Monthly water quality measurements were made with multiparameter sondes. During the 1999-2003 period (hereafter referred to as “past sampling”) monitoring was first accomplished with a YSI 6820 sonde, which was replaced with a Eureka Manta sonde. During the 2008-present period (hereafter referred to as “present sampling”) sampling was conducted with both a YSI 6820 and a Eureka Manta sonde. Each sonde also had an accompanying handheld unit to observed and record measured values.

The sondes had sensors to measure temperature, dissolved oxygen (DO), specific conductance, pH, and turbidity. The sondes were calibrated prior to a sampling trip and data recorded either on paper or in the handheld unit. In the present sampling two boats were used, operated by Water Watch volunteers. In many months another volunteer was in one of the boats to assist with sampling. Back in the office data were transferred to an MS Excel workbook and, during the present sampling, to an MS Access database. In the present sampling a monthly summary report of the results was prepared for Water Watch to load into their web site (<https://sites.google.com/site/watereewaterwatch/>).

During June, July, and August of 2009 we made special trips to the lake to get vertical profiles of field parameters at fifteen locations in the forebay of the lake. The focus of this sampling was to measure change in the redox state in the deeper strata near the sediment. This is a frequent occurrence in temperate lakes during summer due to oxygen depletion (Wetzel 2001). For this sampling a YSI 600XLM was used. It did not have a turbidity sensor but did have an oxidation-reduction potential (ORP) sensor. As with the monthly sampling the sensors were calibrated before each trip and the data placed into MS Excel workbooks upon return. A Water Watch volunteer provided the boat and served as pilot.

In 2010 we received funding from the SC Water Resources Center to conduct detail nutrient and

chlorophyll sampling in the lake, with particular focus on nutrient fluxes across the sediment/water interface. For this work two sediment chambers were constructed and deployed in a manner similar to (Thorbergsdottir et al. 2004). One was deployed at the Colonel Creek embayment site and one at the Channel 4 site. A water sample was taken at the bottom of the lake at the sampling location upon deployment. At intervals water was pumped from the chamber to the surface (Fig. 2). All samples were placed on ice in the boat and analyzed in the lab for soluble reactive phosphorus (SRP) and ammonium (NH<sub>4</sub>). Fluxes were estimated as described by (Thorbergsdottir and Gislason 2004). Water Watch volunteers provided the boats and assisted with deployment and sampling.

## RESULTS AND DISCUSSION

### Monthly sampling

Initial comparison of monthly sampling results from the past and present programs suggest conditions changed in the lake. The type of change tended to be consistent throughout the lake but the magnitude was different among locations. In general lake temperatures were warmer, there was less turbidity, and DO and pH increased.

The clearest example of this occurred in the Big Wateree Creek embayment (Fig. 3). The embayment is at the north end of the lake and has a reputation among samplers and many residents of being an exceptionally turbid location. Our results show that turbidity in the past was, on average, above the SCDHEC standard of 25 NTU. In the present it was below the standard. Temperature in the present was as much as 3-4 degrees (C) warmer, DO is significantly higher and pH in the present was often above the SCDHEC criterion of 8.5.

A second example is Channel 3, which is in the mainstem of the reservoir at about mid-lake (Fig. 4). Here the same general changes occurred as was seen in the Big Wateree Creek embayment but the differences were not as significant. Temperature, DO, and pH tended to be higher in the present. Turbidity tended to be lower in the present but that relationship is less clear. June was a notable month when present DO and pH were especially elevated compared to past mean values.

The two locations shown here (Fig. 4) exemplify both the type of changes and magnitudes seen in the comparison of past to present sampling. Here we show summer conditions because those typically are of greatest interest to recreational users and also tend to be when eutrophic conditions are most obvious. There were past versus present differences in other seasons but there tended to be less obvious patterns. One exception is

water temperature, which in the present tends to be cooler during winter and warmer during summer.

The types of changes seen during summer may be explained by differences in phytoplankton dynamics. Lake Wateree has been on the SCDHEC 303(d) list of impaired waterbodies for many years. The occurrence of excess nutrients, especially phosphorus, was one of the reasons for the listing. Phytoplankton growth models have three factors that drive the relative abundance in freshwater: light, nutrients, and temperature. Our analysis suggests that reduced turbidity permits more light to penetrate the water column. This provides more energy for phytoplankton to utilize the excess nutrients for growth. Warmer water temperature also enhances the environment for growth. More phytoplankton could cause the increase in DO that was measured. An increase in phytoplankton growth also means removing additional inorganic carbon from the water, which alters the carbonic acid equilibrium and increases pH. We cannot know for certain if this is what happened in the lake but the changes we measured fit the established understanding of water chemistry in lakes (Wetzel 2001).

#### Sampling at the sediment-water interface

During the summer of 2009 preliminary data collection took place in Lake Wateree to determine if the physical conditions develop that are necessary for significant sediment nutrient release to occur. Results clearly show hypoxia and reducing conditions develop (Fig. 5). Prior analysis of nutrient inflow-outflow using data from the US Environmental Protection Agency Storage and Retrieval (STORET) system showed that more nutrients enter the lake than leave it on an annual basis (Kloot and Tufford 2009). Prior simulation modeling work of Lake Wateree showed there are not enough nutrients in the lake using surface inflows as the only source. Calibration of phytoplankton concentration required including a substantial internal load (Tufford et al. 1999). In combination these results suggest there is a significant internal stock of nutrients in the sediments, that conditions occur that favor their release, and that current in-lake water quality conditions cannot occur without a significant load other than the Catawba River.

Based on the summer 2009 results we planned field measurements of nutrient flux across the sediment-water interface. The chambers were deployed in August and September 2011. The results show that fluxes of both nutrient species occur but they are variable by location and month (Table 1). During August there was a substantial flux of both NH<sub>4</sub> and SRP from the sediment into the overlying water column. During September the fluxes were less than during August and, in the case of SRP, was from the water column into the sediment. The magnitude of NH<sub>4</sub> flux was larger in the Colonel Creek

embayment than at Channel 4. The opposite relationship occurred with SRP.

The values we measured are within ranges found in the literature at other locations as is the bidirectional characteristic (Wang et al. 2004, Ozkundakci et al. 2011, Haggard et al. 2012). This work suggests that sediment nutrient dynamics are either seasonal or driven by other factor(s), for example temporal variability in hydrodynamics that affect ambient concentrations in the water column immediately above the sediment. Additional field measurements are needed over a longer time period to better quantify the role of sediment fluxes in the overall nutrient budget of the lake.

This information has resource management implications. During periods of flux into the water column the increased quantity of dissolved nutrients are subject to turbulent redistribution into the photic zone. The nutrients are then available for phytoplankton growth. Whether or not this occurs is dependent on the stability of the vertical structure of the water column that would tend to resist full mixing. In Lake Wateree this is probably dependent largely on regional precipitation patterns that drive river and tributary discharge, which often have significant interannual variability.

## Conclusions

From a USC perspective the partnership with Water Watch has been positive and productive. We have had a long-standing interest in Lake Wateree from both limnecological and resource management perspectives. Effective characterization of complex aquatic systems requires long-term monitoring using a sampling strategy that should detect spatial and temporal variability. This can help inform lake users and managers of potential problems or noteworthy changes in water quality conditions.

The partnership provided student research opportunities that led to one Masters degree and was the basis for an undergraduate research scholarship. A graduate course uses the Lake Wateree as an outdoor classroom with the assistance of Water Watch volunteers. Several undergraduate students had the opportunity to participate in field-based research and the transmission of results to stakeholders who have a direct interest in the information. A key element of all this was the availability of volunteers with boats and scheduling flexibility. This removed a frequent constraint to field work in deep water situations.

Water Watch has identified several benefits to the results of the partnership, including:

- 1) The greatest benefit is education of participants as to water quality attributes and measures. This

includes the informal transfer of knowledge to friends/neighbors, i.e., we all become better stewards of a precious resource. Having stakeholders involved in the volunteer team gets people involved in a hands on way that is very important. Team members take pride in their roles.

- 2) Resource constraints within SCDHEC limit their ability to monitor water quality at the level of intensity desired by Water Watch. It is likely that if there were to be an issue, Water Watch would know it long before any governmental agency.
- 3) Water Watch members know far more about the lake in general, including learning the lake layout, observation of seasonal changes and their effects on the lake, learning animal habits and habitats (especially in headwaters), monitoring shore conditions, and being able to report improper shore management. The process gives us a historical basis to talk about long term trends, both positive and negative. It also provides credibility when we pursue actions to improve or correct situations impacting our river, for we can point to what we are doing on our part to assure water quality. It shows we are serious and that we care about our water.
- 4) A benefit that is also a challenge is that as more is known, more is wanted regarding water quality information. Unfortunately the acquisition of more information requires additional funds. The associations cannot provide this and there are few grants available for such testing unless it is on a scope far too wide for our small group of volunteers to undertake. We would like to see USC take a greater interest in expansion of the testing, as a community benefit, and underwrite that effort.

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Table 1. Results of nutrient flux sampling for ammonium and SRP using benthic chambers during summer 2011. Channel 4 is in the forebay near the dam. Colonel Creek is a small tributary on the west side of the lake near the downstream end (Fig. 1). Positive values indicate flux from the sediment to the water column, negative values indicate the opposite.

Chamber location	Duration (hrs)	2011	NH4 g/m <sup>2</sup> -d	SRP g/m <sup>2</sup> -d
Channel 4	3:50	Aug	0.59	0.091
Channel 4	4:50	Sep	0.22	-0.019
Colonel Creek embayment	6:15	Aug	2.52	0.031
Colonel Creek embayment	6:20	Sep	0.34	-0.024

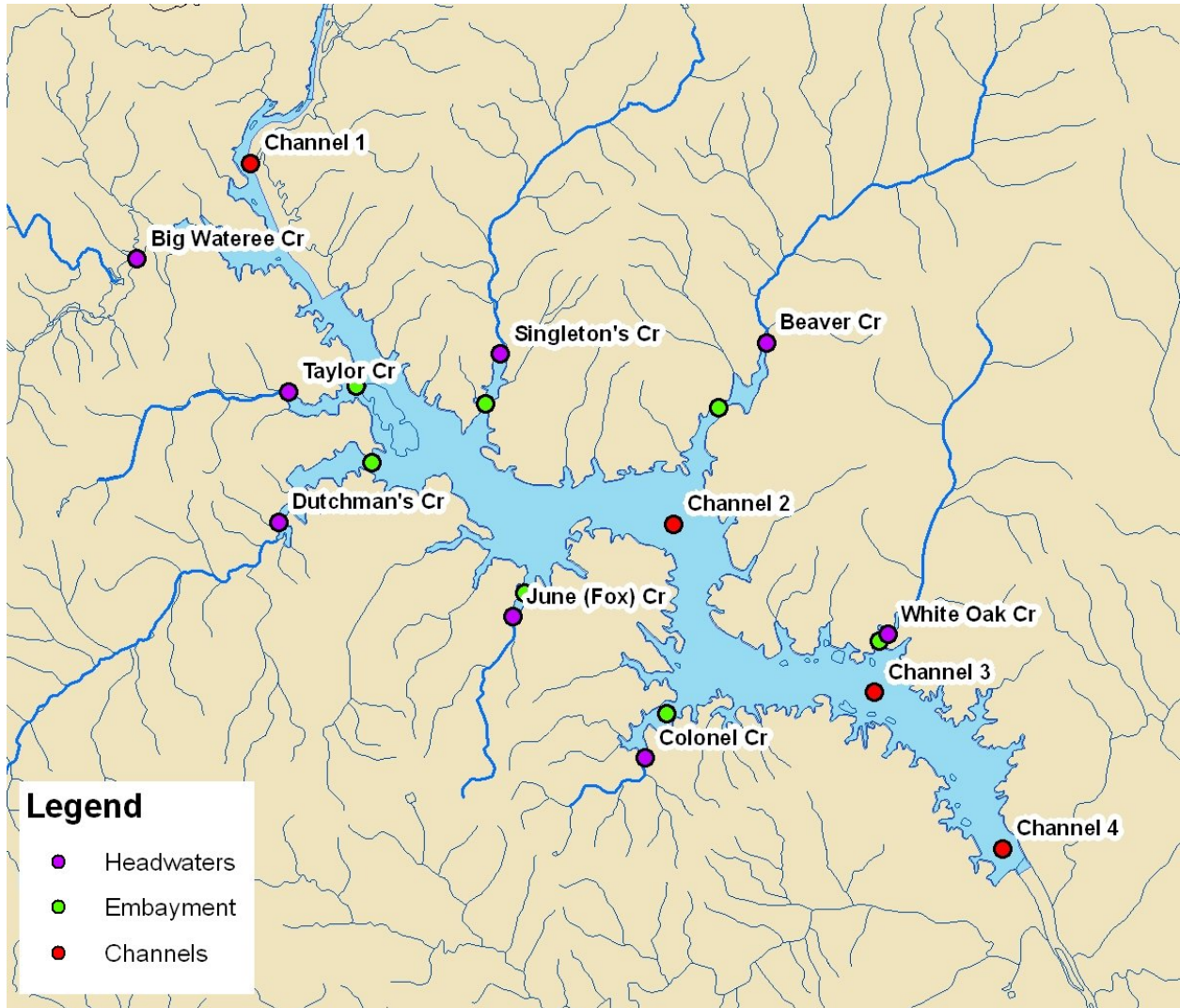


Figure 1. The twenty sites for monthly water quality sampling.



Figure 2. Preparing to deploy one of the sediment chambers (upper) and preparing to take a water sample. The pump first purges non-chamber water from the hose then a sample is taken.

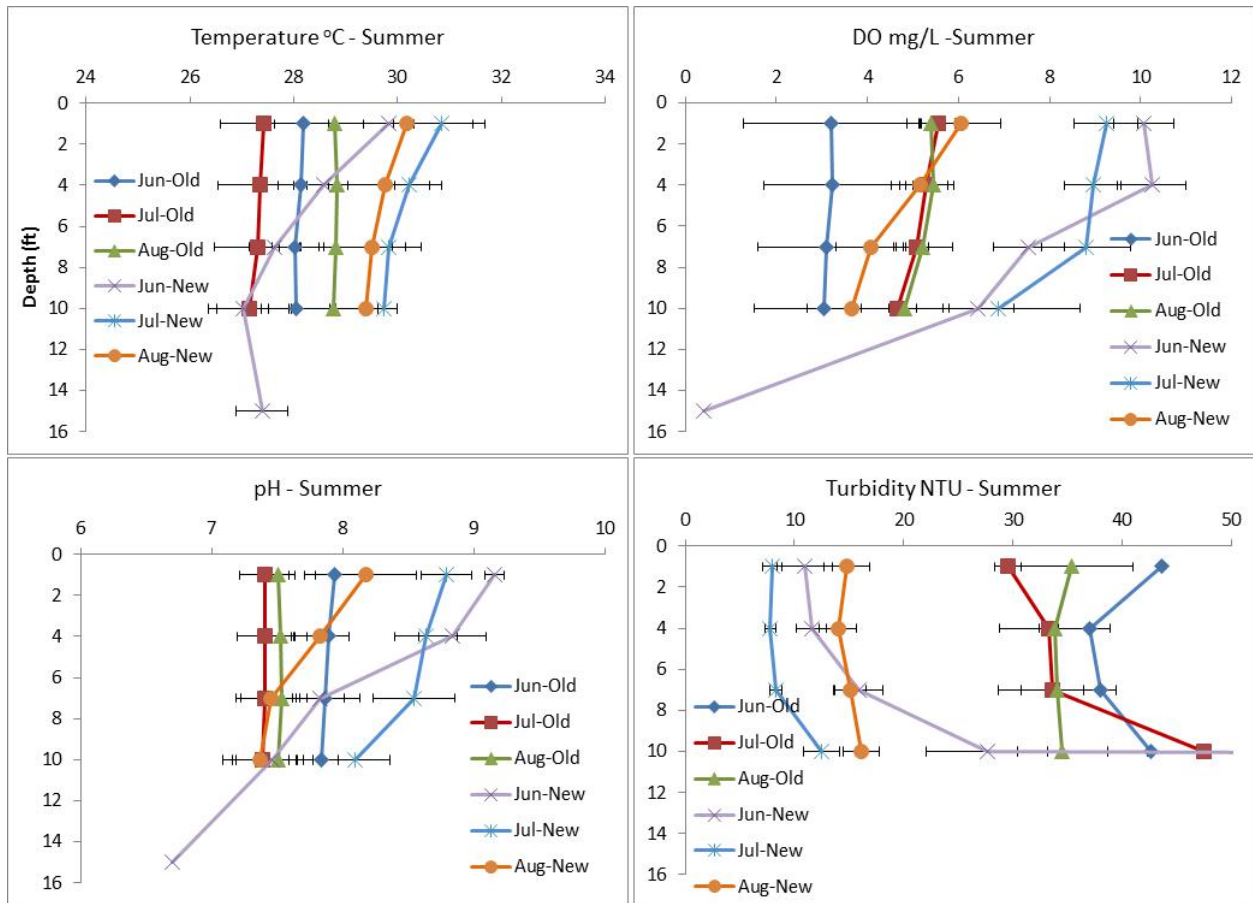


Figure 3. Monthly summer average temperature, DO, pH, and turbidity ( $\pm$  one standard error) at Big Wateree Creek embayment. Values are separated into old (past: 1999-2003) versus new (present: 2008-2012) sampling efforts.



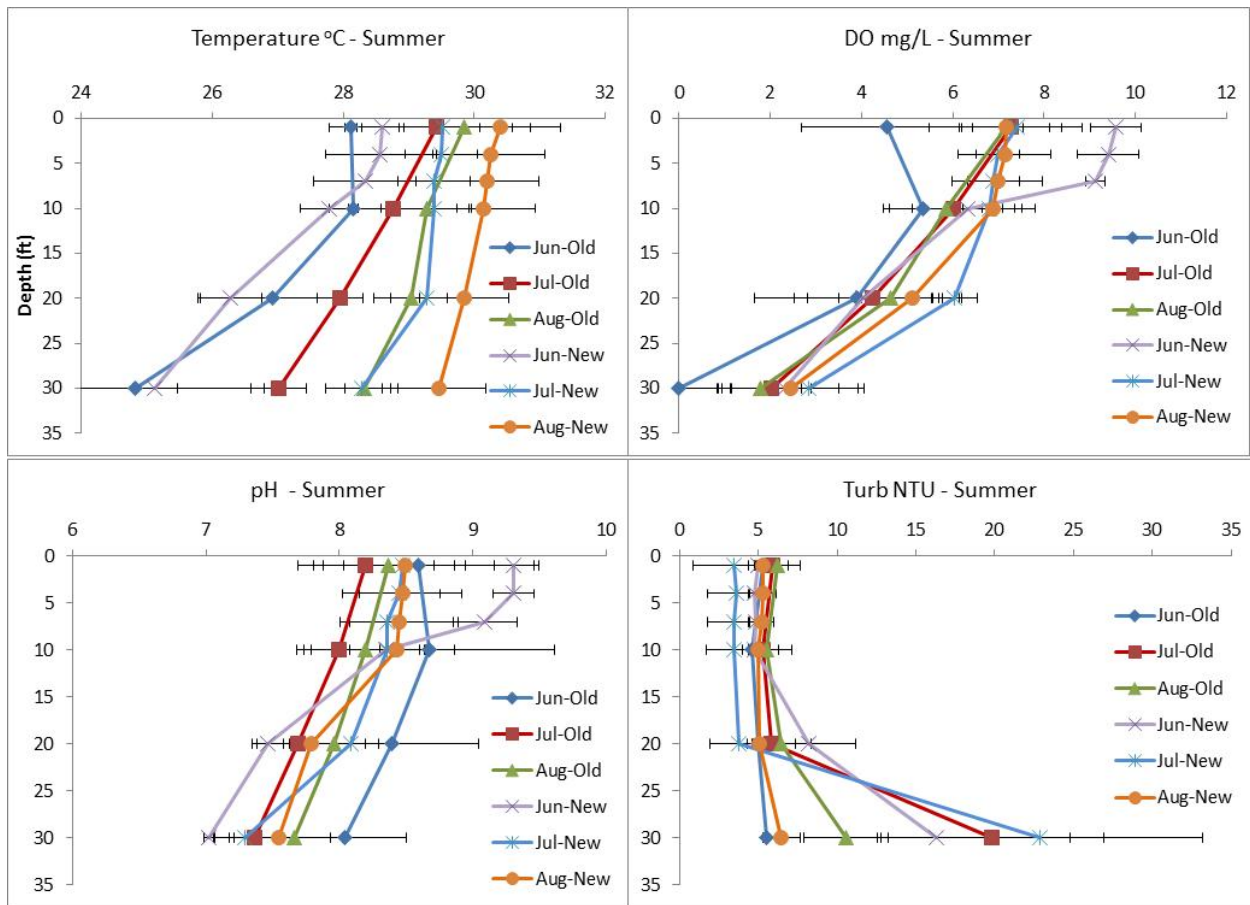


Figure 4. Monthly summer average temperature, DO, pH, and turbidity ( $\pm$  one standard error) at Channel 3. Values are separated into old (past: 1999-2003) versus new (present: 2008-2012) sampling efforts.

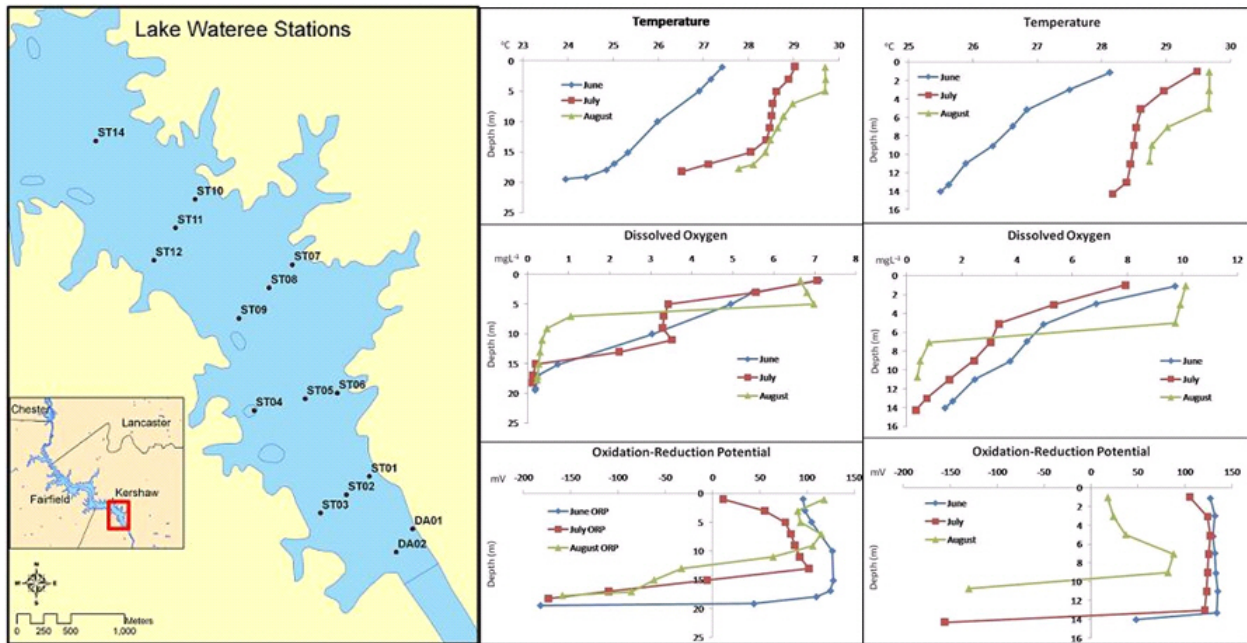


Figure 5. During summer 2009 a network of stations (left panel) was sampled during June, July, and August. Examples of the results for temperature, DO, and ORP are shown for a station near the dam (DA02, center panel) and ST05 (about 2.5 km upstream from DA02, right panel).