Bathymetry of White Oak Creek, Jordan Lake: Fieldwork and GIS Approaches

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Abstract

Jordan Lake is an artificial reservoir that currently functions as a source of flood control, recreation, wildlife conservation, and water supply. As a part of the Jordan Lake Nutrient Management Study, this research aims to determine the bathymetry and water quality of the White Oak Creek portion of the lake. Bathymetry data was collected continuously using a portable Garmin unit on three trips to White Oak Creek on October 7th, October 14th, and October 28th, 2018. Multiple sample points for water quality were also assessed on these trips. Bathymetric data was interpolated using GIS approaches to create a depth profile of White Oak Creek. Water quality parameters of dissolved oxygen, temperature, and turbidity were statistically analyzed to determine temporal trends. This data will be used by stakeholders of the Jordan Lake study to continue to monitor the lake, particularly in regards to nutrient concentrations.

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1. Introduction

1.1 Background and Development

Jordan Lake is an artificial reservoir located in the Cape Fear River Basin. The lake borders lie in Cary and Pittsboro, North Carolina, among other towns. Since it was constructed, Jordan Lake has been owned and maintained by the US Army Corps of Engineers; therefore, it has been protected from development. However, the lake currently serves multiple functions including public recreation, flood and water quality control, wildlife conservation, and water supply for the surrounding areas (NC P&R, 2018).

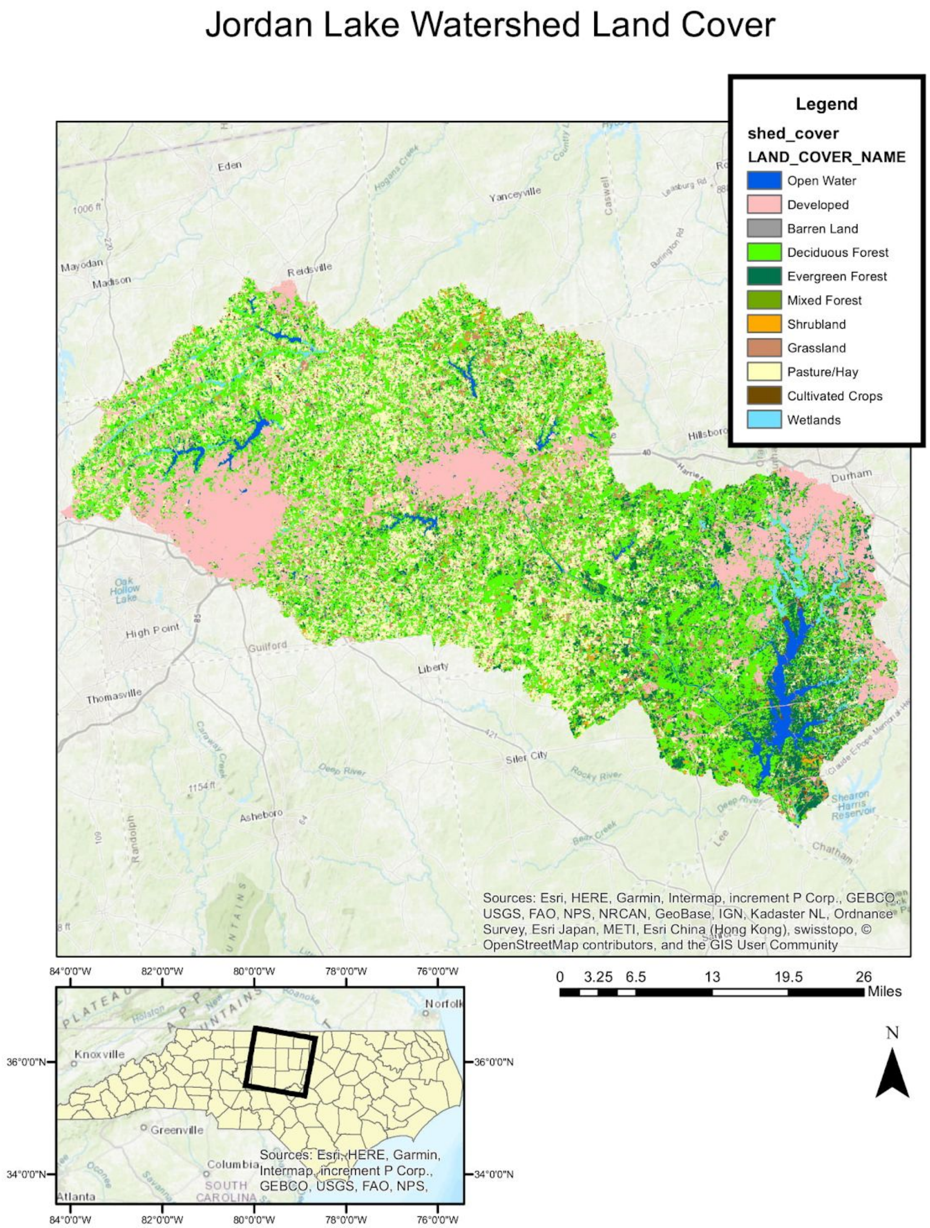
In 1945, a severe hurricane and subsequent flood wreaked havoc on the Cape Fear River Basin, prompting Congress to appoint the US Army Corps of Engineers as the leaders of a comprehensive water resource study of the area. This study lead to the approval of the construction of the Jordan B. Everett Dam and Jordan Lake in 1963, which was initially called New Hope Lake. Although the downstream damage spurred this project as an attempt to control flooding, the reservoir also intended to be a source of recreation and water for a growing region (NC DCR, 2017).

After many years of land acquisition (mostly from small farms in decline due to growing urban pressures), and resolution of legal issues, the lake was filled in 1981 (NC DCR, 2017). It quickly became one of the most popular destinations for recreational activities such as swimming, fishing, water sports, and camping in the state park system.

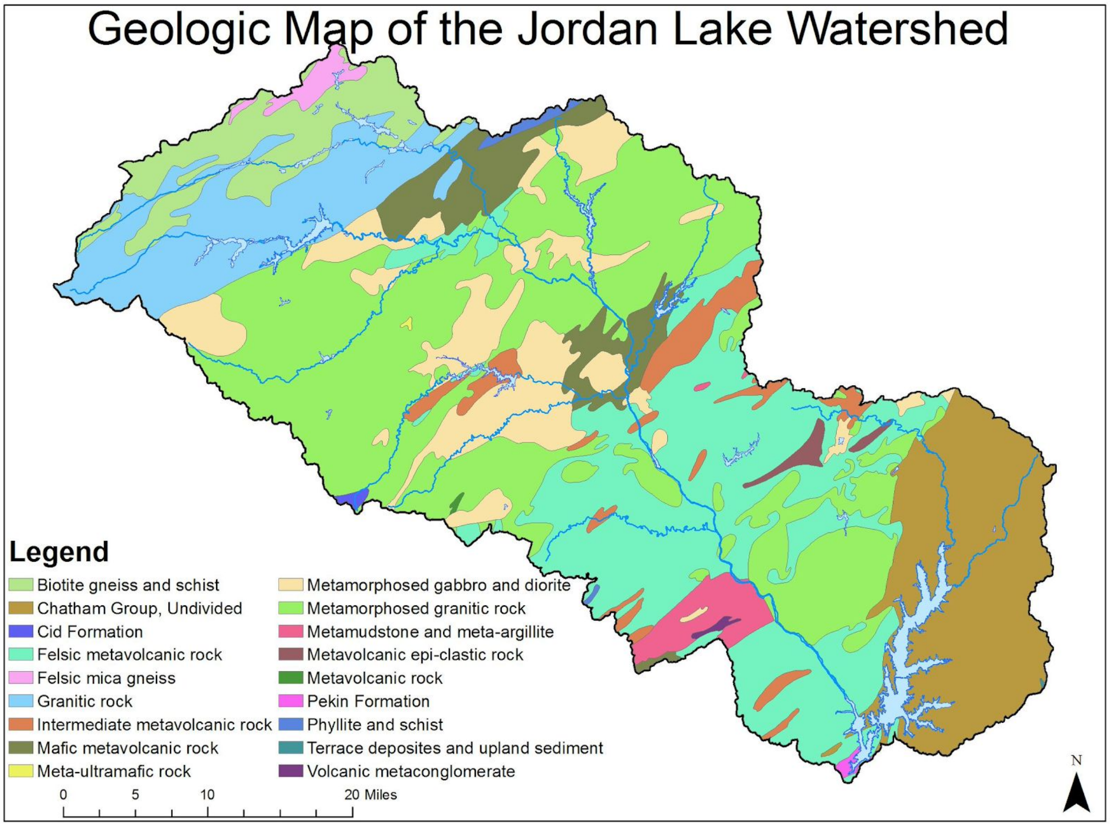
1.2 Ecologic and Geologic Setting

Jordan Lake lies in the North Carolina Piedmont ecoregion of the southeastern United States. This region is typically characterized as having clay soils, mixed deciduous and coniferous forests, rolling topography of low hills, and rocky incised streams. In recent years, this region has seen increased pressure from urban and suburban development as well as the outcome of many years of intensive farming. As such, both naturally occurring and man made natural areas like Jordan Lake are becoming more important as sprawl in the region expands. The land surrounding Jordan Lake is protected by a ring of state parks and the Army Corps of Engineers that owns the lake, but the ecology within the lake is facing pressure as runoff from cities within the watershed continues to degrade the water quality. The existing land cover of the watershed is displayed in **Map 1.**

The geology of the Jordan Lake watershed strongly influences the characteristics of the lake. The vast majority of the lake itself lies in a soft sedimentary region known as the Carolina Triassic Basin as shown in **Map 2**. This soft, flat underlying rock dictates the shape of the lake basin. The Haw river that feeds the lake, as well as the far southern part of the lake, are underlain by much harder metamorphic rock. This dichotomy between hard and soft geology determined the way that the reservoir filled behind the Jordan dam and affects the large sediment flux that is captured by the reservoir on a yearly basis. The bathymetry of Jordan Lake is driven by this natural change in underlying geology. The surrounding rivers are rocky, deep, and flow through strong natural channels. The former streambeds and alluvial plains that lie under the waters of Jordan Lake are shallowly incised and gradually sloping. This gives the reservoir and flat broad bottom, especially relatively to the relatively steep and rolling terrain in the Piedmont landscape that surrounds Jordan Lake.



Map 1. Land cover classifications of the Jordan Lake watershed.



Map 2. Geologic classifications of the Jordan Lake Watershed.

1.3 Current Concerns and Research

In 2007, after 25 years of recreational and functional use of Jordan Lake, the US Army Corps of Engineers produced an updated master plan for the lake to address water quality and environmental issues associated with excessive use and a rapidly urbanizing surrounding area. The document warns that the pressures of these factors may be negatively affecting water quality in the lake (USACE, 2007).

Due to the wide variety of public service functions provided by Jordan Lake, monitoring changes in bathymetry and water quality are vital. For this reason, the North Carolina General Assembly approved a budget provision in 2016 that tasked the University of North Carolina at Chapel Hill to “oversee a continuing study and analysis of nutrient management strategies and compilation of existing water quality data specifically in the context of Jordan Lake” (UNC, 2018). This study, titled the Jordan Lake Nutrient Management Study, is conducted and analyzed by UNC Chapel Hill in collaboration with the North Carolina Policy Collaboratory, which was also created in 2016 by the NC General Assembly. Ongoing research is being conducted by these groups through the assessment of nutrient concentrations in Jordan Lake, management strategies, and potential outcomes for stakeholders for excessive nutrient loading (UNC, 2018).

1.4 The Jordan Lake Bathymetry and Water Quality Capstone

To contribute to the research of the Jordan Lake Nutrient Management Study, the University of North Carolina at Chapel Hill selected one of their Capstone courses to collect and analyze bathymetric and water quality data over a semester long study. The Capstone team selected White Oak Creek as their field site and collected this data over three field trips on October 7th, 14th, and 28st, guided by the following research questions:

1. What are the land cover and geology of the Jordan Lake Watershed?
2. What is the bathymetry of White Oak Creek?
3. How do temperature and dissolved oxygen vary between the surface and bottom of the creek? How does this vary over time?
4. What is the turbidity of the creek? How does this vary over time?

Data regarding water depth, locations, temperature, dissolved oxygen, and turbidity were collected at various sample points throughout the field site. The results of this investigation are presented in this paper.

2. Methods

2.1 Data Collection

Spatially referenced bathymetry data was collected using a portable Garmin unit fastened to a small boat. Depth data was corroborated at sample points using a handheld device.

Temperature and dissolved oxygen data were collected by lowering a Niskin bottle into the lake and collecting samples from the top and bottom of the water column. To determine placement of the bottle at the bottom of the water column, a handheld device was used to measure depth, and the Niskin bottle was lowered until it rested approximately one-fourth of a meter from the lake bottom. Water samples collected were then put into a bucket and immediately tested using a YSI temperature and dissolved oxygen meter. Secchi depth data was collected using a Secchi disk lowered at 5 cm intervals.

2.2 Data Correction

Each trip to the field site was preceded by significant rain events. Hurricane Florence made landfall on the southern coast of North Carolina on September 14th and proceeded to release massive quantities of water across the state, leading to near-record breaking levels across Jordan Lake. Hurricane Michael crossed over North Carolina on October 11th as an extratropical cyclone. Though the storm moved quickly, the period of heavy rain significantly raised lake levels once again to 226 ft. Finally, a few days before October 28th prolonged rains supplied yet another increase in lake level. These weather events caused the water level across Jordan Lake to be greatly higher than pool level, which is 216 ft. The water level on October 7th was 7 ft above pool level. The water level on October 14th was 10 ft higher than usual, and it was 3 ft higher on October 28th.

Due to wide inconsistencies in water level of the study area between each trip, the data was corrected in an attempt to create a more representative bathymetric profile of Jordan Lake at full pool level. This was done by averaging depth data collected every ten minutes from a profiler managed by the Collaboratory positioned at the mouth of White Oak Creek (35 44.761N, 79 1.791W) on an arbitrary day (August 28th, 2018). This baseline depth measurement was used to calculate rates of difference between average depth values taken at the profiler on each of the days data was collected (**Table 1**). It was assumed that lake level change over time at the profile was representative of uniform lake level change across the study area. The calculated differences were then removed from the collected data and the three corrected data sets were aggregated.

2.3 Data Analysis

Bathymetric point depth data was interpolated to provide a bathymetric profile of White Oak Creek. Using ArcMap as the platform, an inverse weighted distance and a Kriging interpolation were both performed in order to generate bathymetric profiles of the study area at pool level. The IDW considered ten neighbors and used a weight of inverse distance, as we do not anticipate much variation across the bottom of the study area. Ten neighbors were also considered in the Kriging interpolation and its subsequent variance calculation.

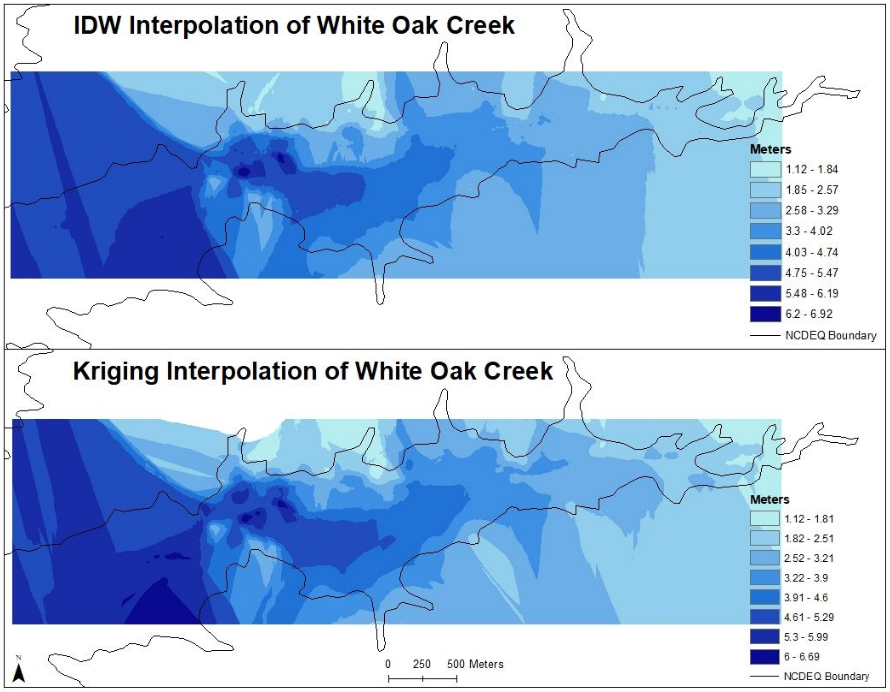
The water quality parameters of temperature and dissolved oxygen were averaged for the surface and bottom water samples on each trip date. A three-day average for surface and bottom water samples was also calculated. Secchi depth measurements were averaged for each trip date, and a three-day average was calculated as well. To obtain turbidity values from Secchi depths, the function [Secchi Depth (ft) = 11.123 x (Turbidity (FNU))^-0.637] was employed (USGS, 2009). This allowed Secchi depths to be converted to Formazin Nephelometric Units. For dissolved oxygen and temperature, a two-sample t-test was conducted for each sampling day and the three-day average.

3. Results

3.1 Bathymetry

Dates	**Profiler Gage Height (m)**	**Rate difference from 8.28.18**
8.28.18	6.708958	0
10.7.18	8.57109	0.277559
10.14.18	9.610583	0.432500
10.28.18	7.440514	0.109042

Table 1. Average measure depth at profiler and rate differences.



Map 3. Bathymetric profiles of White Oak Creek.

The largest rate of difference experienced by White Oak Creek was 0.4325 experienced on October 14. All days samples were taken show significant increases in depth across the creek (**Table 1**). The bathymetric profiles generated by each interpolation are similar in depths and variability across the study area (**Map 3**).

3.2 Water Quality

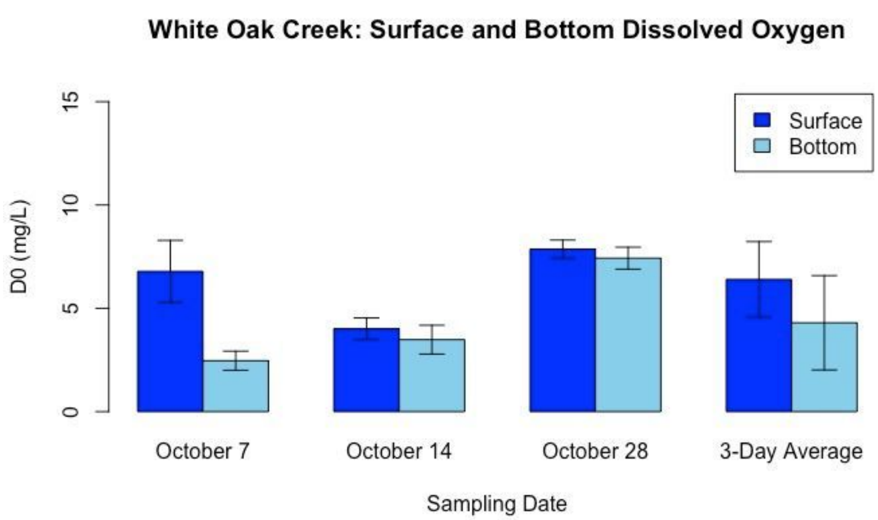


Figure 2. Dissolved oxygen averages for surface and bottom water across all trips.

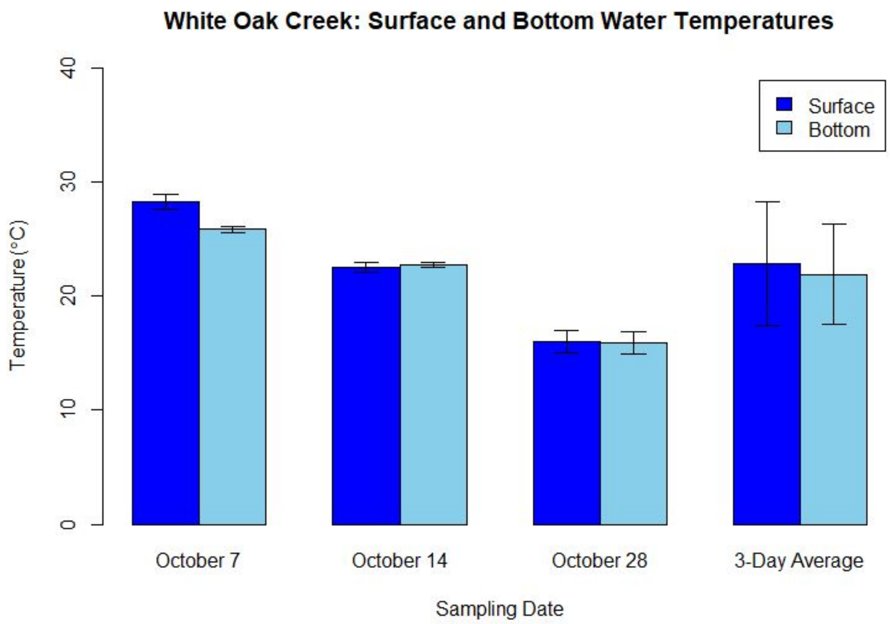


Figure 3. Temperature averages for surface and bottom water across all trips.

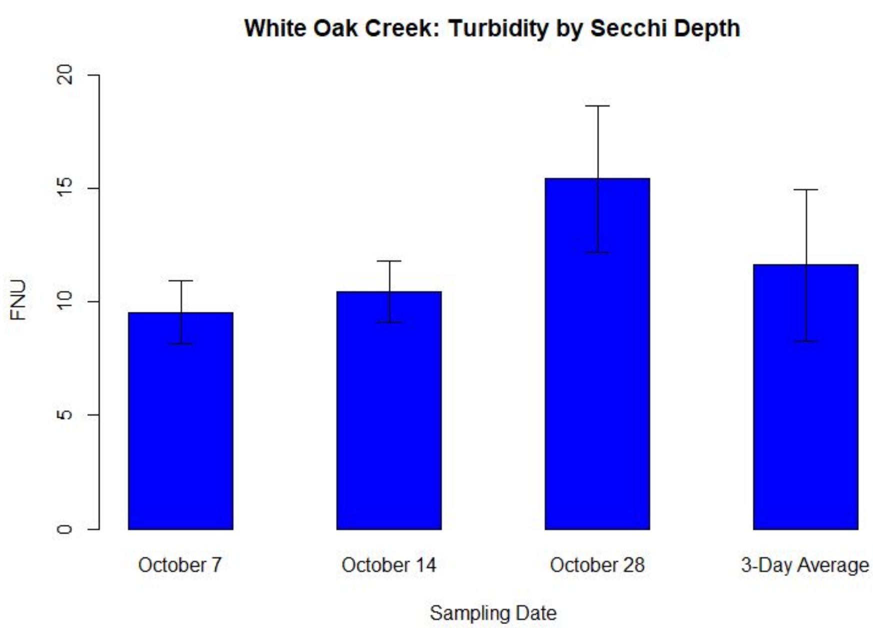


Figure 4. Turbidity averages across all trips.

For dissolved oxygen, the two-sample t-test resulted in statistical differences between surface and bottom water for October 7th and the three-day average (**Figure 2**). There was no statistical difference for October 14th or October 28th. For temperature, a significant difference was only found for October 7th (**Figure 3**). October 14th and 28th yielded no significant difference between surface and bottom water temperatures. Turbidity measures show a consistent increase throughout the sampling period, with average turbidity increasing from less than 10 FNU on October 7th to greater than 15 FNU on October 28th (**Figure 4**).

4. Discussion

While both bathymetric profiles are similar, the Kriging interpolation is more appropriate for the purposes of mapping the bathymetry of White Oak Creek. Due to the sedimentary nature of the underlying geology, White Oak Creek would exhibit a gradual change in depth with changes in position. Thus, it is not necessary to weight the interpolated values based on distance from their neighbors as the inverse weighted function does.

Given the unique weather events during the study period, the presence of error in the data is more likely than it would have been in less meteorologically variable setting. Therefore, it is important to continue to collect depth data for White Oak Creek in order to lower the influence of error on the dataset.

The variation in dissolved oxygen values at the top and bottom of the lake throughout the sampling dates is likely attributed to seasonality (**Figure 2**). Daily temperatures were steadily decreasing since the first sample date, and the second and third sample dates were chillier. This change in weather possibly contributed to mixing in the water column, which would justify the more uniform dissolved oxygen temperatures at the surface and bottom of the lake. Additionally, the cooling temperatures indicate the the water column can retain more dissolved oxygen overall, as seen on October 28th.

Much of the variation seen in temperature can also likely be attributed to seasonality **(Figure 3)**. Throughout the extent of our sampling dates, the weather was becoming consistently cooler, explaining the overall decreasing trend seen above. The weather surrounding these specific sampling dates may have also played a role in surface and bottom water temperatures being so similar. Considerable mixing likely occurred through the large influx of water and wind associated with the two hurricanes and a severe thunderstorm, all just days before our samples were taken.

A consistent increase in turbidity is seen throughout the progression of sampling dates **(Figure 4)**. This pattern is likely due to the proximity of sampling dates to extreme rain events; hurricane Michael occured on October 11th, and torrential downpours occured the night of October 27th. These disturbances likely increased runoff into the lake which drags sediment, debris, and other clouding agents into the water, thereby increasing turbidity.

5. Conclusion

The bathymetric data we collected and analyzed will be useful for the Jordan Lake Nutrient Management Study. To understand the nutrients of Jordan Lake, we must know how much water the lake actually holds since that influences both inputs and outputs of nutrients. The bathymetric data allows for an understanding of how much water the White Oak Creek portion of Jordan Lake holds. Additionally, our research highlights the importance of factoring in weather events when measuring lake levels and adjusting those measurements so that they are as representative of the true volume as possible.

The temperature, dissolved oxygen, and turbidity data collected and analyzed can also be useful in understanding the quality of the lake in relation to nutrient inputs. We found that seasonality plays a large role in the trends of these parameters in the water column.

Overall, this research highlights that it is important to continuously monitor Jordan Lake so that we can notice when changes occur. This was apparent due to both the changing lake levels and variations in water quality data. As surrounding areas in the Jordan Lake watershed are altered, the lake itself will inevitably face changes as well. Since Jordan Lake is such an important source for the community it supports, this data will help policymakers mitigate risks of any possible changes. Finally, this research and continuations of it will be helpful in understanding who benefits from the lake and who places risks on these benefits. This knowledge will ultimately be useful for deciding what stakeholders will be responsible for quality control of the lake.

6. References

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