SURFACE WATER QUALITY ASSESSMENT OF A PROPOSED SOUTHWEST GEORGIA LAKE SITE

by

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(Under the Direction of Jenna Jambeck)

ABSTRACT

Clean and cheap freshwater is an increasingly limited resource and humans continue to engineer systems to utilize available water resources. In some instances, the construction of dams and creation of lakes has caused drastic changes to ecosystems, yet there is limited research documenting some of these changes before, during, and after construction. Many lakes were created before the technology became available to assess water quality. This project assesses a lake development site in southwest Georgia to determine the baseline conditions of the watershed to compare water quality impacts upon lake construction, filling, and equilibration. The water quality within the catchment area was fairly typical, when compared to other water resources within the region. Possible issues for the future include high fecal coliform in some creeks, slightly elevated nutrient loads within some creeks, and slightly depressed dissolved oxygen, which may be compounded by the construction of a shallow lake.

INDEX WORDS: Water Quality, surface waters, reservoirs, GIS, water resource engineering

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

1.0 INTRODUCTION

1.1 Background Information

Freshwater is one of the most important, yet limited natural resources making up about 2-3 percent of total water on earth with a much smaller percentage available in lakes, rivers, or aquifers. Water quality and healthy aquatic ecosystems are critical to the sustainable socio-economic development of an area (Bartram and Balance 1996). Tired Creek Lake is a proposed 960-acre recreational lake located in the agricultural intensive Ochlockonee River Basin and comprises a drainage area of about 16,000 square acres within the watershed. The lake is located a few miles northwest of Cairo, Georgia, above the Floridan Aquifer in the Southeastern Coastal Plains of Georgia. The lake is being developed in hopes of increasing tourism and improving the economy in a poverty stricken South Georgia community. The earthen dam to create the lake is currently under construction and is expected to be complete by the end of 2014. The lake will begin to fill with each precipitation event and take approximately 2-3 years to fill, depending upon rainfall.

A map of the lake's location within Georgia can be seen in **Figure 1.1** and a sketch of the lake can be viewed in **Figure 1.2**. As stated in the Master Plan for the Tired Creek Lake Project, the authorized purpose of the project is to develop a sustainable, high quality public fishing resource that meets the recreational fishing needs of the residents of Grady County. The lake is a rare case in which a dam is being constructed solely for recreational purposes. The lake project was first proposed in the 1930s and has been endeavored ever since. Land availability, permits, and funds were not available until 2012.

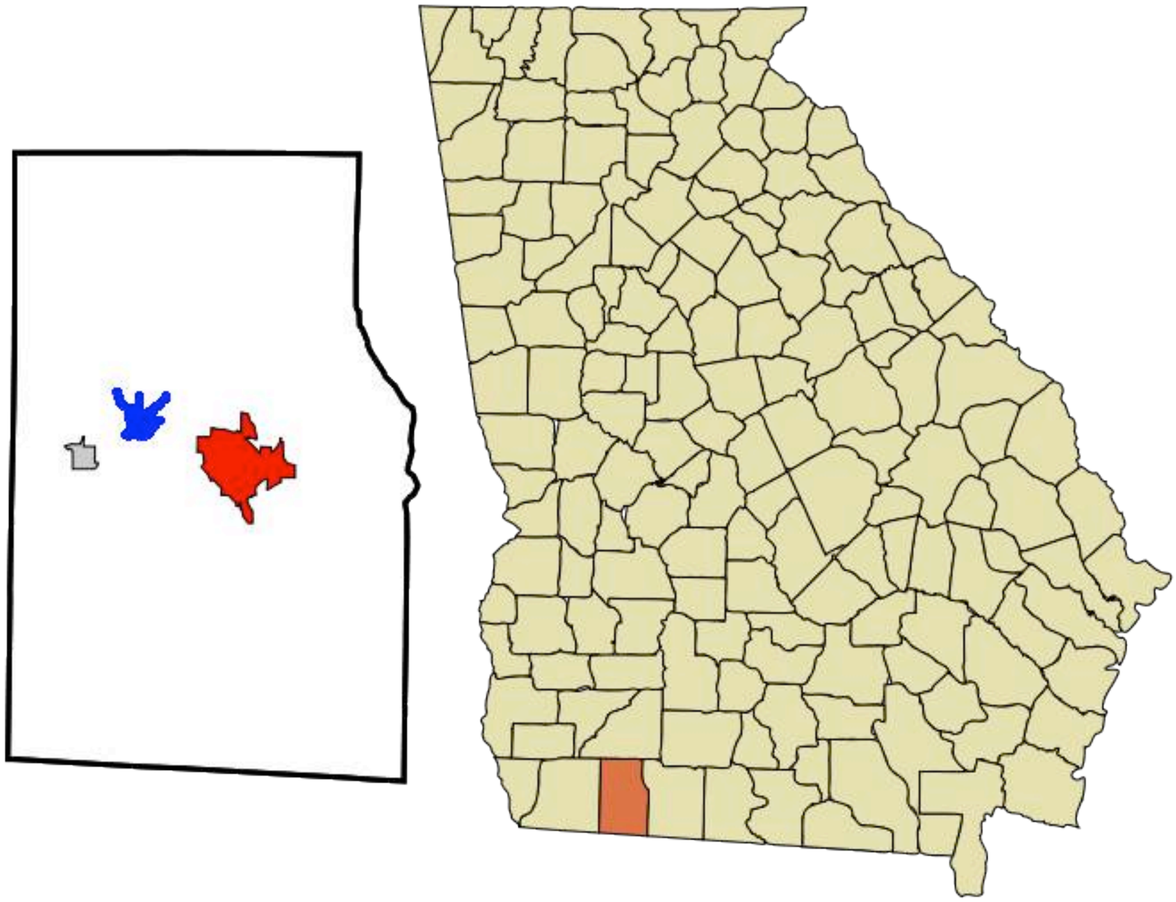

Figure 1.1 Tired Creek Lake location within Grady County, Georgia (Grady County – black outline; Cairo city limits-red; Whigham city limits - grey; Tired Creek Lake (Blue) (Arkyan 2007))

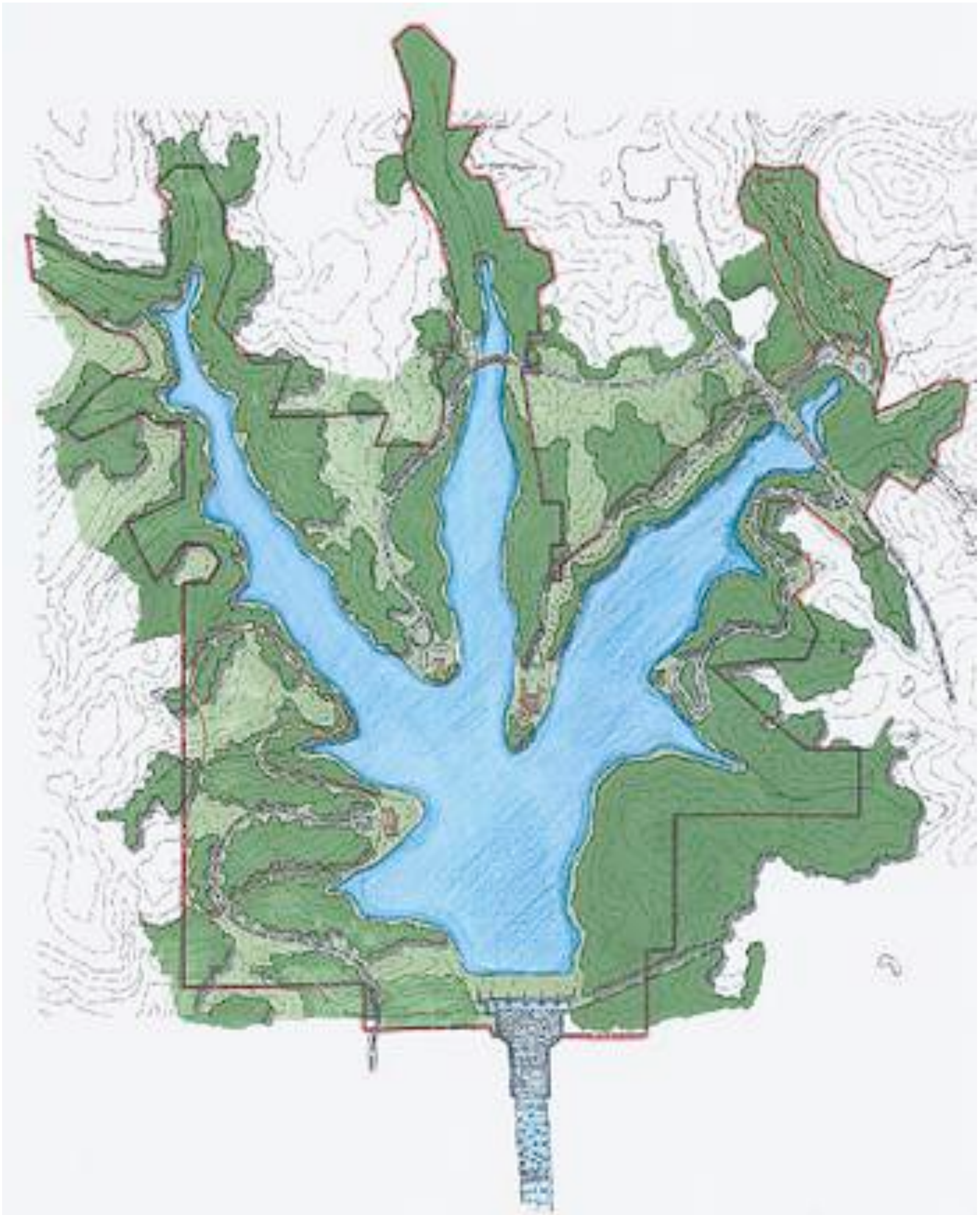

Figure 1.2 Future Tired Creek Lake Sketch

(http://www.timesenterprise.com/mobile/x493360719/Dam-breakthrough).

Water quality research in this geographic region is currently limited and the project provides the opportunity to conduct a full water quality assessment to better understand characteristics of water quality in the area. Natural processes along with anthropogenic activities can degrade our streams, rivers, and lakes. Therefore, it is important to attempt to understand these characteristics and processes through a well-constructed research plan and analysis of data.

The construction of the new lake also provides the opportunity to evaluate water quality changes due to construction and filling of the new lake. These data will be collected over a ten year study of the water quality within the watershed as outlined in the Quality Assurance Project Plan in compliance with the USACE and EPA. The data will be analyzed on a yearly basis, with detailed reports after one, five, and ten years.

There is limited research on water quality changes due to the construction of lakes, because most lakes were constructed before water quality instruments were widely available. Even though dams will not likely be built in developed countries in the future, many dams are yet to be built in developing countries (World Commission on Dams 2000). The pros and cons of building a lake will often be an intense debate, but lakes will continue to be built as countries look to meet electricity, recreation, and drinking water demands. Gaining more knowledge about these processes is important for understanding how to minimize environmental impacts of constructed lakes.

The permanent water quality monitoring network designed for this study includes a total of four monitoring sites: one in each of the three main tributaries feeding into the proposed lake (Black, Sapp, and Buss Tributaries), and one below the proposed dam in Tired Creek, downstream of the confluence of the three upper tributaries. A temporary fifth site called Tired Creek 2 was located just below the confluence of Sapp Creek near the dam location. The five sites were determined by review of lake bathymetry, shoreline maps, aerial photos, and in-field observations.

In accordance with Section 5.3 of the Master Plan for the Tired Creek Lake development plan, Nursery Creek was identified as a direct tributary that may be a potential contributor of sediments or nutrients. To determine whether Nursery Creek should be added to the plan's permanent stations, water quality data was included in the sample plan and a discussion of its contribution to the system is included in this study.

Sampling locations within the Tired Creek Lake Watershed totaled six sites (four permanent plus two temporary sites). The GPS coordinates in decimal degrees of the five continuous monitoring and sampling sites can be found in **Table 1.1**. A map of the monitoring sites is shown in **Figure 1.3**.

Table 1.1 GPS coordinates for monitoring locations.

Site Location	North Latitude	West Longitude
Tired Creek	30.91972	84.26141
Sapp Creek	30.95066	84.24299
Black Creek	30.95486	84.28046
Nursery Creek	30.95439	84.26222
Buss Creek	30.95424	84.26332

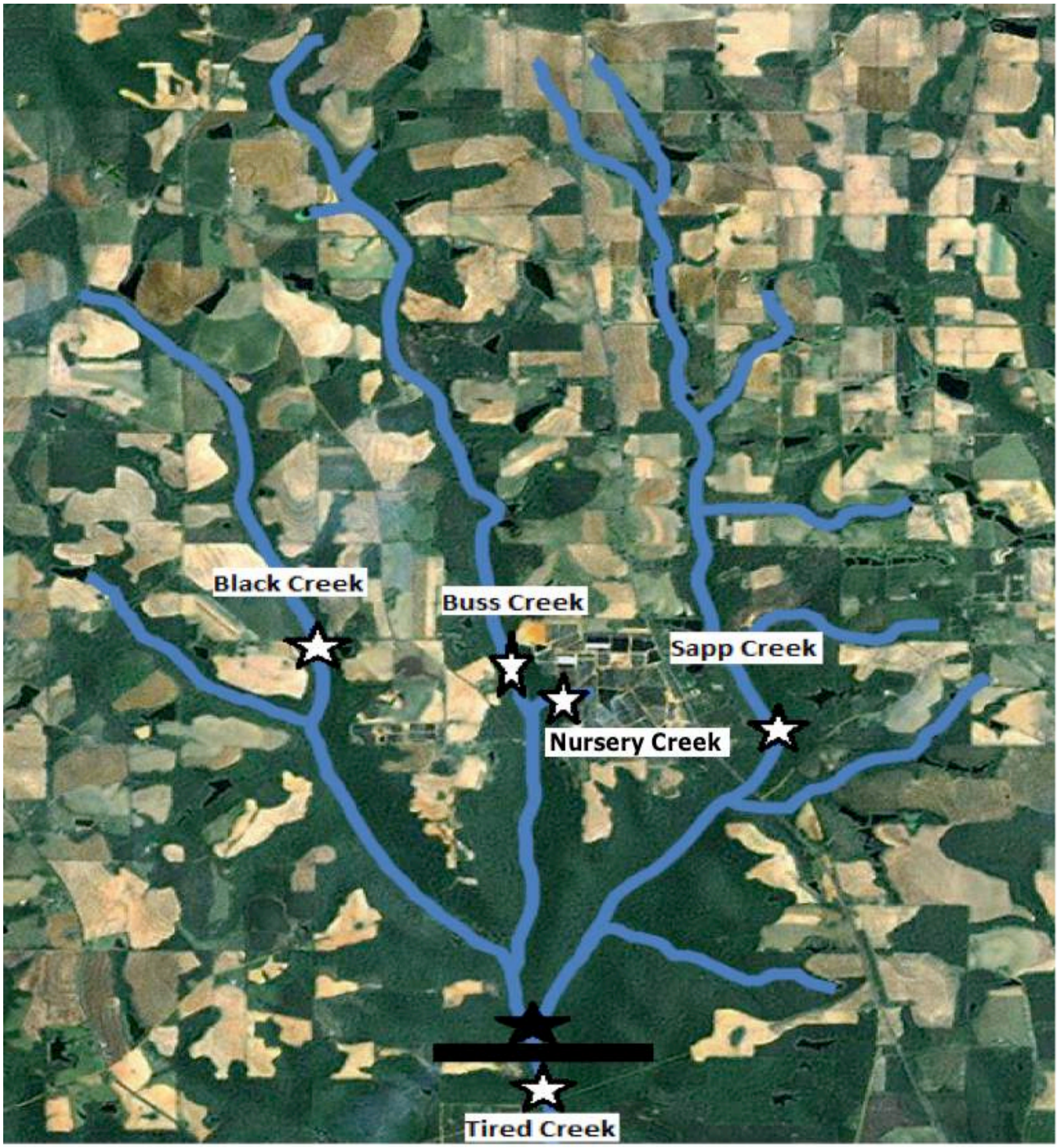

Figure 1.3 Tired Creek Lake water quality monitoring sampling site locations (white star), temporary site location (black star), and dam location (black rectangle).

1.2 Scope and Objectives

The general scope of the project is to provide an overall assessment of the Tired Creek Lake Watershed that will establish baseline conditions for the catchment area. The data will allow for comparison through various stages of construction and filling of the lake in future years. The plan will provide beneficial data to the US EPA, USACE, developing countries, the Grady County Board of Commissioners, and any other interested parties. Below is a list of the specific objectives of the report.

- **Objective 1:** Design, develop and conduct a water quality-monitoring plan to collect data and assess the overall chemical and physical water quality of the catchment area for proposed Tired Creek Lake.

- **Objective 2:** Analyze and synthesize collected data using a combination of GIS, trend analysis, and statistical techniques for environmental analysis.

- **Objective 3:** Assess the health of the current ecosystem through a biological water quality assessment.

- **Objective 4**: Determine the impact of storm events on water quality.

2.0 LITERATURE REVIEW

2.1 Georgia Lakes:

There are a total of about 500,000 large dams globally, which store large amounts of fresh water, provide flood control, and navigation, while providing multiple recreational opportunities (Downing et al., 2006). In Georgia, the EPA identifies 4,435 dams over 6 feet tall, which is the largest quantity in the Southeastern United States and only accounts for about 7% of total dams in Georgia, many of which are smaller (Davis et al 2002). Of the 4,435 dams in Georgia, a total of 48 lakes cover an area greater than 500 acres, in which the Georgia EPD has maintained monitoring programs for many lakes since the 1960s (GA EPD 2008). Each lake in Georgia has characteristics that are specific to its location, land use, and any other parameter effecting water quality. Therefore, specific water quality standards may be different from one lake to another, as with most surface water quality around the world. No water quality monitoring programs are exactly the same, as they all present unique challenges and goals for each program. Eight publically owned major lakes including Hartwell, Seminole, Sidney Lanier, Allatoona, West Point, Walter F. George, Jackson, and Carters Lake all have a standard criteria approved by the legislature by which these lakes are monitored and assessed (GA EPD 2008). Each one of these dams has a profound effect on water quality and the surrounding ecosystem. Sufficient water quality monitoring network design, sampling and analysis allows for the determination of overall water quality in a lake.

The data gathered from monitoring plans informs important decisions regarding water resource management of lakes, while also providing helpful data to stakeholders and other water resource management authorities all around the World. Standard parameters included in typical Georgia lake monitoring programs include depth profiles for dissolved oxygen, temperature, pH, specific conductance, secchi disk transparency, and chemical analyses for chlorophyll *a,* total phosphorus, nitrogen compounds, and turbidity (GA EPD 2008). These samples are collected monthly for a full year once every five years, quarterly for the years in between, and monthly during the growing season April-October (GA EPD 2008). Baseline data is used to assess the current water quality and environmental health, while allowing the ability to predict future impacts of activities within the watershed after dam construction. The first year baseline data of a lake would start the five-year rotation of sampling for Georgia lakes based on normal EPD sampling protocol.

2.2 Water Quality Degradation:

The Clean Water Act was developed by the U.S. Government in 1972 to protect U.S. waters from point source pollution, while also establishing some water quality standards for protection of surface waters. One of the most important regulations within the CWA established the National Pollutant Discharge Elimination System, NPDES, requiring permits for pollutant disposal into surface waters. The CWA was later amended in 1987 with the establishment of Section 319 to address nonpoint source pollution.

Georgia waters are classified for designated uses including drinking water, recreation, fishing, coastal fishing, wild and scenic rivers (GA EPD 2008). All Georgia waters should also be fishable and swimmable by humans. Tired Creek with a designated use of recreation and fishing, located south of Cairo near Reno, GA, is currently impaired due to biota assessments and fecal coliform during the last reporting year of 2010. A section of Tired Creek located just west of Cairo, GA and south of the lake location from Wolf Creek to Parkers Mill Creek has good status. No creeks within the watershed of the lake have been assessed. Of the twenty assessed locations in the Upper Ochlockonee watershed, 16 are impaired due to fecal coliform, dissolved oxygen, benthic macroinvertebrates bioassessments, and/or mercury in fish tissue. Benthic macroinvertebrate assessments provide data beyond the water quality by providing an assessment of ecological quality within aquatic ecosystems.

Tired Creek Lake is being built for the sole purpose of recreational use, in which water quality standards have been developed for in stream recreational use. They specify fecal coliform should not exceed a 30-day geometric mean of 200 CFU/100 mL, daily average dissolved oxygen should be above 5.0 mg/L, a minimum DO of 4.0 mg/L, pH range between 6.0-8.5, a maximum temperature rise of 5°F per day and a maximum temperature of 90°F (GA EPD 2008). Future water quality standards for Tired Creek Lake may vary from in-stream standards for recreational use. A lake built specifically for recreational use may require new standards from the Georgia EPD.

Sources of water quality degradation may be through point source and nonpoint source pollution including anthropogenic activities such as industrial waste, agriculture runoff, nursery runoff, highway runoff, construction and new developments, etc. Agriculture can supply an excess amount of sediment and nutrients to a watershed and lead to the degradation of water quality within the waterbody, having significant negative impacts on water quality and biota (Tian 2011). The catchment area is an intensively cultivated agriculture land including many different crops. In the case of Tired Creek, a large nursery could also pose also some risk to the watershed, along with a second smaller, still active nursery. Large amounts of water possibly containing high nutrient and pesticide concentrations needed to grow a healthy plant may find their way into the streams from nurseries (Schnelle 2011). The nursery does not have a NPDES permit and is not regulated as a point source polluter, even though the main discharge of water is from a single pipe. Best Management Practices or BMP's are used at the nursery, but are not required or evaluated by and outside source. Water not used by plants will be leached into the groundwater or end up in streams, lakes, or ponds by runoff from ditches or storm sewers (Schnelle 2011). Issues related to a nursery would be similar to those of the agricultural land.

Runoff from nearby roads, including Highway 112 could also affect water quality in the watershed. There have been numerous studies summarizing the effects of highway runoff on water quality characteristics in various parts of the world, including similar parameters to this study such as total suspended solids, total organic carbon, hardness, pH, temperature, iron, total nitrogen, and total phosphorus (Kayhanian 2012). Urban development is also a large contributing factor to water degradation in various ways including impermeable surfaces, residential fertilizer runoff, construction sites, etc. (Atasoy 2006). It is important to examine these inputs and identify any other anthropogenic activities possibly causing water quality degradation to the watershed.

There are also natural contributions to water quality in a watershed such as precipitation amounts influencing runoff, aquifer deposition, erosion, or atmospheric deposition. During rainfall events, runoff is generated and carries large amounts of mobilized sediments and nutrients, mainly phosphorous, from the soil into waterbodies (Zeng 2005). Therefore, large precipitation events with high runoff may increase sediment and nutrient concentrations, which have an adverse effect on water quality depending on the input types and loads. Aquifer deposition can enter the water body through natural springs or center pivots used in the irrigation of agricultural lands. The Upper Floridan aquifer yields calcium bicarbonate type water due to influences from limestone, dolomite, and calcareous sand, which make up the aquifer (Clarke 1986). An increase in calcium carbonate may lead to an increase in pH, alkalinity and hardness of the water within the watershed based on characteristics of calcium carbonate. Shoreline deposition of the stream banks may also lead to an increase in sediment and nutrients into the stream. Large storm events with high stream flows may create full bank discharges, which can stimulate channel bed and bank erosion within the stream (Shoonover 2007). Atmospheric deposition, mostly of nitrogen, is typically through precipitation and dry deposition (Peters 2002). All of these natural processes could have an impact on the watershed chemical properties.

Many water quality-monitoring networks of the past have not been effective in sufficiently determining water quality within an area, due to a lack of consistency, logical design strategy, and the nonexistence of a universally accepted methodology (Strobl 2008). With the implementation of sound network design, GIS mapping, and literature reviews, an analysis of the watershed will allow the examination of degradation of water quality and provide data for predicting changes in the lake. Every water quality monitoring design is different, requiring the ability to identify project specific needs and make the changes needed to acquire the most useful data. Parameter specific literature reviews are located in Section 2.2.

2.3 Dissolved Oxygen

Dissolved oxygen is the amount of gaseous oxygen dissolved in water and levels depend on physical, chemical, and biological activities in the water. Oxygen is necessary for most life forms and an important measurement in any water quality research. Oxygen is produced by aquatic plants through photosynthesis such as algae and consumed by aerobic bacteria, while it is also introduced into water through aeration from the atmosphere, most notably during high flows. Chemical processes influenced by DO include redox reactions, dissolution of toxic metals, temperature, movement of water, plants, animals, and organic pollution. If oxygen levels plummet due to various inputs described above, it may cause an entire waterbody “to die”, typically on hot summer days with low flow and calm weather (Swenson and Baldwin 1965). Many fish generally need a DO above 4 mg/L or even higher for trout, if not, they will be stressed to survive. Georgia also has standards for DO described in the previous section and fish kills may occur when levels fall below the standards. There are no maximum levels for dissolved oxygen in Georgia.

2.4 Hydronium

The measure of H^+ concentration in water has the unit pH. Electrodes sense ion activity by creating boundary potential in which it measures ions participating in the reaction with the electrode by reading the voltage. A pH meter is a scaled meter that typically reads high resistance voltage in millivolts (Snoeyink and Jenkins 1980). The measurements only reflect ions reactive and ignore unreactive ions. The pH electrode system is a two-membrane system with a glass membrane. The outer reference electrode is KCl and the inner pH indicator electrode is AgCl. H^+ ions penetrate the glass membrane and create electric potential across the membrane with respect to the AgCl internal electrode to create a voltage that can be transformed into a pH reading based on calibration with standard solutions.

pH meters are typically calibrated using buffered solutions of pH equal to four, seven, and ten. pH naturally ranges between -3.6-12.3, with more acidic solutions on the low end and more alkaline solutions on the high end. Georgia’s water quality standards for pH are described above and range between 6.0-8.5 (GA EPD 2008). Any measurements above and below these thresholds have adverse consequences to the health of the aquatic ecosystem.

2.5 Specific Conductance

Specific conductance is the ability of a solution to transfer electric current and is the reciprocal of resistivity through water. As ion concentrations increase, so does the ability of the water to conduct a current and conductivity increases (Snoeyink and Jenkins 1980). A measurement of the conductivity for a water sample using a sensor also conveys, through conversions, the concentration of total dissolved solids (mg/L) ionized in water and salinity (ppt) (Snoeyink and Jenkins 1980). The unit of measurement for conductivity is recorded as siemens per centimeter (S/cm) and is often micro-siemens (µS/cm) or milli-siemens (mS/cm). It is important to note that temperature affects conductivity as ion activity increases with temperature, but most instruments reference to 25 degrees Celsius. Pure water is a poor conductor because it does not have many dissolved ions resulting in low conductivity and seawater has a large amount of ions and is a good conductor resulting in extremely high conductivity.

2.6 Temperature

Temperature is a highly influential parameter on all other water quality parameters. Temperature in water varies due to atmospheric temperature, changes between night and day, seasonal changes, manmade influences such as electricity generation, or other industrial uses. Higher water temperatures generally lead to negative consequences to other influential water quality parameters and processes. Temperature standards for Georgia are described above. Shade and riparian zones generally decrease water temperature.

2.7 Turbidity

Turbidity is the cloudiness of a liquid sample developed due to the presence of suspended particle matter such as clay, silt, organic matter, and microorganisms in water. There are multiple different causes leading to high turbidity measurements that include, but are not limited to storm events, construction, erosion, runoff, mining, etc. Low turbidity is around 0-5 NTU, whereas, a high measurement may be 4000 NTU, where NTU is used here as nephelometric turbidity units. Drinking water standard is 5 NTU for filtration other than direct filtration and less than 1 NTU for direct filtration or conventional methods, while aquatic life should range from 0-50 NTU (Drinking Water Contaminants 2009). Other turbidity units include Formazin Turbidity Unit (FTU) and the Jackson Turbidity Unit (JTU) used in the Jackson Candle method (Wilde and Gibs 2005).

Turbidity can be determined using a nephelometer, commonly referred to as a turbidimeter, which is a physical test that measures scattered light due to the presence of particles. The more particles present the more light that is reflected or scattered. A sketch of a how a turbidimeter works can be seen in **Figure 2.1**. It cannot be related to suspended particles because dark and white particles scatter different amounts of light and some small particles will reflect more light than equivalent large particles. It is also important to understand brown water may still have low turbidity because it is still clear and lacks suspended matter.

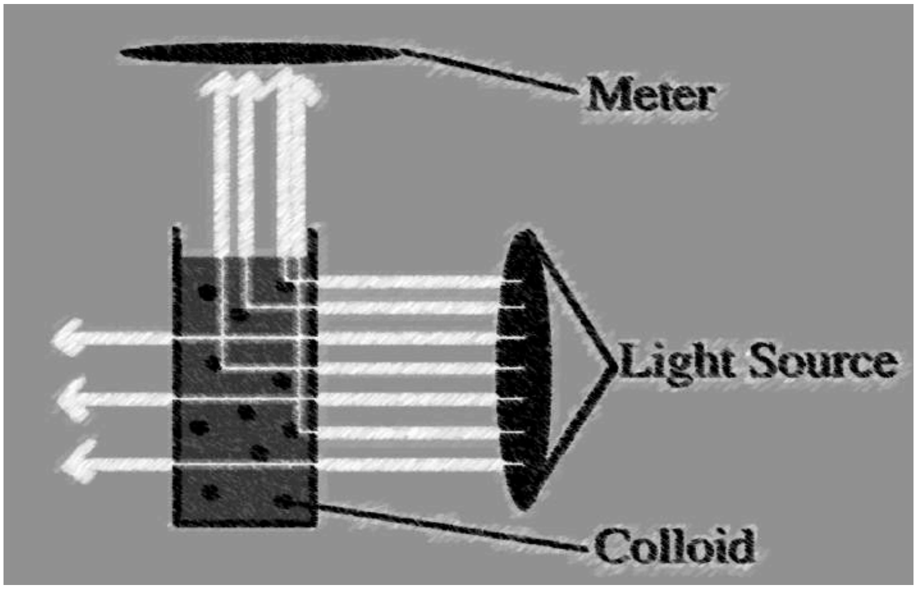

Figure 2.1 Nephelometer (http://water.me.vccs.edu/turbidometer.html)

Turbidity effects many processes in waterbodies such as lakes, rivers, and streams. The processes affected include the photic zone or depths at which light can penetrate through water for aquatic plant growth, habitat quality, recreational values of waterbody, increased bacteria and pollutants, temperature of the waterbody, and even cause a lake to fill up faster (Swenson and Baldwin 1965). Light penetration has an effect on multiple other dependent species connected to aquatic plants by disrupting food chains and decreasing dissolved oxygen availability to fish by producing a low level of oxygen. Turbid waters also increase the absorption of heat into the water bodies due to a darker color of the water, which increase the temperature of the system and leading to negative consequences due to increased temperatures described above.

2.8 Total Suspended Solids

Total Suspended Solids (TSS) is the portion of solids retained from filtering and is used to describe the amount of suspended sediment in a water body. Total suspended solids may include sediment and organic material, such as plants, leaves, insect larvae, eggs, etc. (Smith 2004). TSS relies on a cutoff for particle size determined by the filter size. Results are largely affected by temperature and time of drying due to the effects on weight losses from volatilization of organic matter, mechanically occluded water, water of crystallization, gases from heat-induced chemical decomposition, and weight gained due to oxidation. Therefore, approved methods should be adhered to. High amounts of TSS generally lead a cloudy and distasteful appearance to the body of water, along with increased turbidity (Smith 2004).

2.9 Alkalinity

Alkalinity is measured using sulfuric acid to determine total amounts of carbonate, bicarbonate, and hydroxide ions through a titration method. Alkalinity measures the buffering capacity of water to neutralize acids bringing the pH to 4.2 by combining with H+ ions to produce new compounds (EPA 5.10 2012). Common sources of carbonate and bicarbonate are limestone (CaCO3) when dissolved in water. The Floridan Aquifer, underneath the site, is made of limestone. **Figure 2.2** depicts alkalinity approximations around the Southeastern U.S. based on thousands of lakes in the United States and range from 100-<400 $\mu eq/L$ (5->20 mg/L $CaCO_3$) in the lake location.

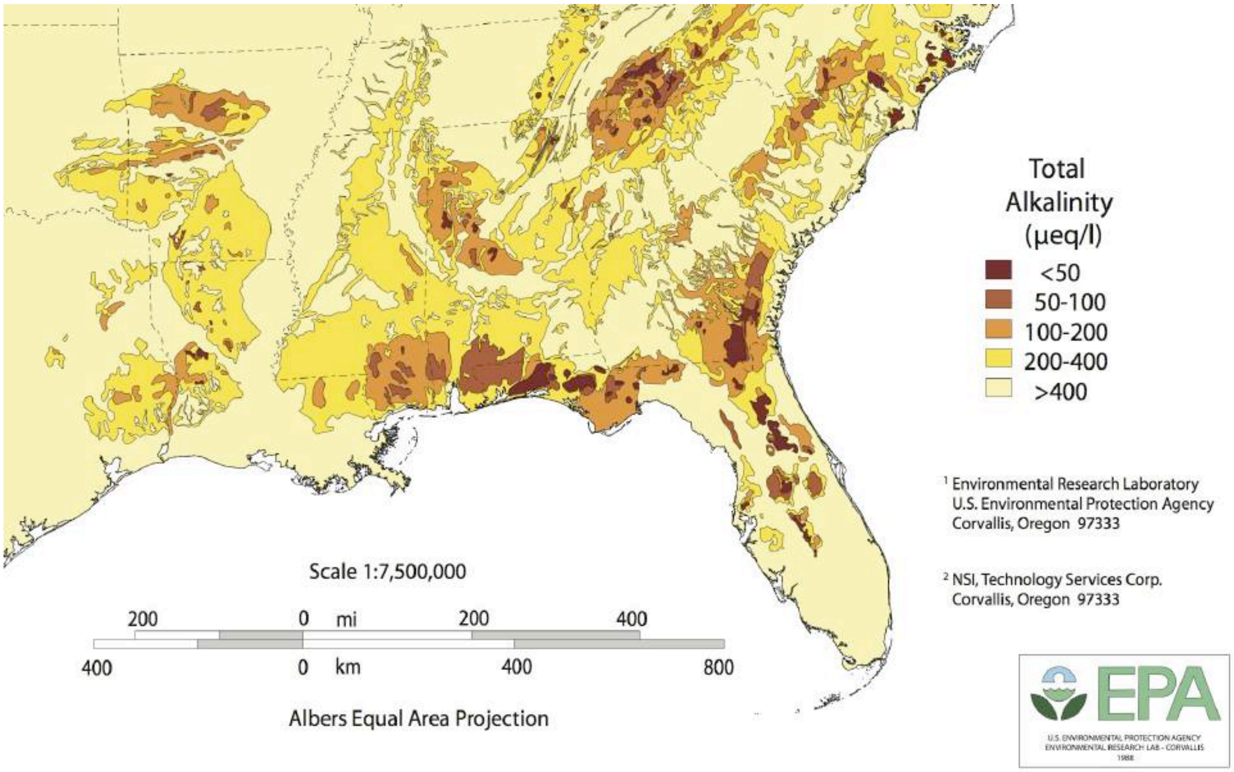

Figure 2.2 Alkalinity map for the Southeastern United States (https://water.usgs.gov/owq/alkus.pdf)

2.10 Hardness

Hardness is similar and often confused with alkalinity due to similarities. Hardness is also dependent on limestone, but is dependent on the calcium instead of the carbonate as for alkalinity. Hardness may also be dependent on magnesium, which has the same charge as calcium as an ion. Hardness arose in an attempt to normalize concentrations of $CaCO_3$ by early sanitation engineers and found that each mole of $CaCO_3$ yields one mole or 2 equivalents of Ca^{2+} (Snoeyink and Jenkins 1980).

Hardness often makes it difficult to produce when soap bubbles for cleaning, hard water leaves white stains on dishware and sinks, and using hard water often requires the addition of a softener. **Figure 2.3** depicts hardness concentrations for the United States on a regional scale in which sites are described as soft, moderately hard, hard, and very hard. Water in the southwest Georgia region is considered soft (purple) or moderately hard (baby blue).

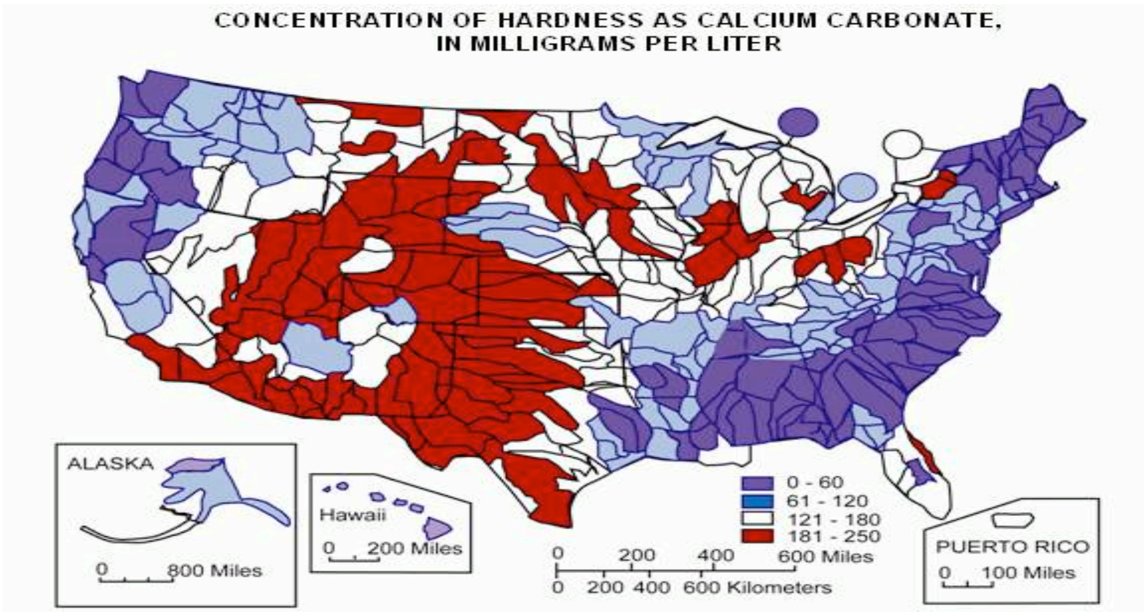

Figure 2.3 **Map of hardness in the United States (edited by USEPA, 2005. Modified from Briggs and others, 1977 (https://water.usgs.gov/owq/hardness-alkalinity.html))**

2.11 Nutrients (Nitrogen and Phosphorous)

The presence of nutrients is important to sustaining life in any stream, but too many nutrients may cause eutrophication in a stream and lead to algal blooms and lower availability of oxygen. There are currently no standards for nutrients in Georgia, but the EPA is working to help determine proper levels for the various regions of the nation. Nutrient concentrations can vary even at the local scale depending on numerous contributing factors. Nutrients are introduced to streams through precipitation, runoff, geologic formations, fertilizer, and multiple types of sewage or feces (Mueller et al 1995). The nutrients of particular interest for this research include total phosphorus and nitrogen compounds.

Nitrogen is an important nutrient to all living things making up multiple different types of amino acids and nucleic acids. Cyanobacteria are aquatic bacteria that are Nitrogen fixers. Nitrogen can take on many forms in natural surface waters that include atmospheric nitrogen, ammonium (NH4+), nitrite (NO2-) and nitrate (NO3-) in order of oxidation state. Total Kjeldahl nitrogen is found during the digestion process used to determine Total Nitrogen. Ammonia concentrations are usually low in streams because they are not stable in most surface water environments and nitrate concentrations were found to be less than 1 mg/L for background sites around the Southeastern United States due to a combination of poor soil drainage, an abundance of soil organic carbon, warm temperatures, forest buffers and high rainfall (Mueller et al 1995). With an increase in pH comes an increase in ammonia toxicity due to the ammonia-ammonium dissociation reaction.

In addition to eutrophication, increased nitrogen can also lead to water acidification and toxicity to animals (Carmango and Alvaro 2006). The EPA recommends total nitrogen from the EPA Region IX to be between 0.07-1.0 mg/L based on ambient conditions of streams in the region (EPA 2000). Although recommended, there are no set standards for surface waters in Georgia.

Phosphorus is also an important nutrient to consider in surface waters, as all living things need it to survive. Two percent phosphorous on a dry weight basis is required for all living protoplasm, which make up living matter in cells (Snoeyink and Jenkins 1980). Most stream samples within the United States were below 0.1 mg/L of total phosphorus, but in freshwaters, phosphorous is often responsible for eutrophication of lakes (Mueller et al 1995). The EPA also recommends .023-0.1 mg/L for total phosphorus when compared to the ambient conditions of other waters in the region (EPA 2000).

2.12 Metals

The metals of particular concern in this experiment were iron and manganese, which are not toxic or known to cause any health problems. Manganese is usually associated with different iron compounds and is not a naturally occurring metal. Manganese is not considered to be a problem in freshwaters where tolerance values range from 1.5 mg/L to 1000 mg/L and concentrations are rarely above 1 mg/L (EPA 1976). Manganese was added to the selected parameters by special request of the EPA.

Iron is an abundant element and generally present in water as ferrous iron (Fe^{2+}) or ferric iron (Fe^{3+}) and may cause water to be reddish or yellowish in color if levels are too high. Iron levels in freshwater aquatic life should not exceed 1.0 mg/L to support a healthy aquatic ecosystem (EPA 1976). This is the case for most freshwater ecosystems, but iron toxicity to freshwater species depends on the type of system. Higher levels of iron concentrations are found in black and brownish waters due to swamps and wetlands, which tend to have lower dissolved oxygen levels and complexed iron (EPA 1976). Complexed iron tends to be inactive chemically and physiologically, which make it non-toxic to freshwater animals (EPA 1976). There are many swamps and wetlands within the lake catchment area, with approximately 120-acres are being flooded after lake construction.

2.13 Indicator Organisms

Indicator organisms are often used to provide insight into pathogenic organism levels in water. Fecal coliform is an indicator organism for possible sewage, animal feces waste, or runoff in a water body. Fecal coliform levels tend to increase when runoff occurs due to storm flow and are lower during dry periods. Fecal coliform are not usually harmful to human health, but provide as an indicator for other harmful bacteria (EPA 5.11 2012).   Georgia uses fecal coliform as the primary indicator organism for bacteria. Beyond the health risks to humans, high levels of fecal bacteria may lead to increases in oxygen demand decreasing availability to the aquatic animals, cloudiness, and foul smells. Other types of indicator bacteria include total coliform, Escherichia coli, enterococci, and fecal streptocci (Meyers et al 2007).

2.14 Biological Assessment

Biological assessments are used to determine the health of aquatic systems and organisms including fish, macroinvertebrates, and plants. Organisms are sensitive to changes in water quality and the impacts to a water body can be studied by determining impacts on aquatic organisms (Chapman 1992). There are numerous methods for assessing the biological health of a water body. Methodology may include, but not limited to physical habitat assessment, benthic macroinvertebrate community assessment, and a fish community assessment.

2.15 Data Analysis:

There are a wide variety of opportunities for analyzing water quality data. Simple analysis of water quality data may be to compare results to standards, regulations or suggestions from state federal organizations. It is also important to identify any trends in the data. Basic water quality statistics often include monthly and yearly total, mean, median, minimum, maximum, geomean, standard deviation, analysis of variance (ANOVA), t-tests, correlation analysis , along with many more depending on the task at hand (Berthouex 2002). These statistics can be used to evaluate and compare trends, parameters, seasonal change, weather events, low flows, high flows, locations, etc.

A correlation matrix is a technique that can be used to compare a specific parameter between locations or for comparing multiple parameters at a specific location. Within the matrix Pearson product moment correlation coefficients or commonly called correlation coefficients ranging from -1 to 1, which relate the two means and standard deviations of the data sets by determining the R-value (Berthouex and Brown 2002). If the variables are positive, then both increase and decrease together and if the levels are negative, then they have an inverse relationship where one decreases as the other increases. Correlations are considered weak, moderate or strong and there are also correlation coefficient critical value tables that can be accessed depending on number of datasets and data points. Correlation coefficients for this research can considered very weak or no relationship (0-0.2), weak (0.2-0.44), moderate (0.45-0.6), strong (0.6-0.8), or very strong (0.8-1), depending on the R-value. A more in depth principle component analysis was not used due to the small number of samples compared to parameters needed for comparison.

Analysis of variance, commonly referred to as AVOVA, is a common statistical method for comparing the means of two or more datasets. A single-factor ANOVA is used to determine if datasets have the same true mean, variances of each dataset are compared to the variance of the whole population; in which the variance of the whole population is inflated if they are different (Berthouex and Brown 2002). If there are two or more datasets different, the ANOVA does not specify which means are different and additional statistical comparisons, such as a t-test between two groups, are needed. Variables included in an ANOVA table include between datasets and within datasets sum of squares, degrees of freedom, mean squares, f-ratio, f-critical, and p-value that describe the whole set. It can be assumed with 95% confidence that if the p-value is less than 0.05 or if f-ratio is larger than f-critical, there is a difference between dataset means (Berthouex and Brown 2002). If an ANOVA results in a difference between means, multiple independent t-tests are needed to determine which datasets are different.

Multiple independent t-test may be used to compare two means, but a Tukey Test is a multiple paired comparison statistical technique for comparing means for multiple datasets through one analysis. The hypothesis of the comparison would be that all the means are equal with 95% confidence. All variances are pooled together by the S^2_{pool}, from which the S_{pool} is the square root and used in conjunction with the *k* means and the *v* degrees of freedom to determine the q-value from a studentized rain statistic table to determine the confidence interval for the two means (Berthouex and Brown 2002). This confidence interval is then used in comparison of the difference between the means of all datasets.

Outliers are data points that do not fit the dataset some distance from other data points. Outliers can lie on the high end or low end of the dataset. There are numerous techniques for determining outliers including the standard deviation methods, Z-score, modified Z-score, Tukey's box plot method, adjusted box plot, MAD method and median rule (Seo 2002). A modified Z-score can be used to determine outliers using the median, which decreases the influence of extreme numbers on the mean as in other methods (Iglewicz and Hoaglin 1993).

2.16 Geographic Information Systems

Geographic Information Systems technology has become widely used software with endless possibilities in just about any field. GIS is designed to help visualize, question, analyze, interpret, and understand data from various sources through the use of multiple map layers at one time to reveals relationships, patterns, and trends to the user through computer modeling (ESRI 2012). GIS applications have proven to be a beneficial tool in assessing many types of water resources for numerous projects since development in the early 1990's, as well in a wide range of other applications (Strager 2010). In order to sustainably manage the various influences to water quality in the watershed, GIS will allow spatial and temporal data to be investigated for various factors and disseminated using the software (Halls 2002). For water resource management, GIS data can be combined with numerical modeling software to characterize water quality in surface water beyond the ability of GIS. The Soil and Water Assessment Tool, or SWAT, is a widely used software in watershed assessments in conjunction with GIS.

2.17 Storm Sampling

Determining water quality during and after rainfall events is also important when assessing a watershed. Techniques developed include manual grab sampling, rising stage samplers, and automatic samplers to accomplish sampling (Hawdon 2007). Manual sampling requires sampling during and immediately following flood events at particular stage heights. This may be troublesome due to safety risks during storms, accessibility, and timing. Rising stage samplers provide a low cost solution for sampling multiple parameters as stage increases during rainfall events, without human presence. Issues with the rising stage samplers are there is no preservation or refrigeration of the samples and a risk of contamination. There are many types of automatic samplers, which collect and refrigerate samples during increased stage events over the whole hydrological event using a pumping system (Gordon 2004). These systems are widely used in for hydrological analysis because they provide sampling with limited human interaction. High cost is the main disadvantage of the automatic samplers, and maintenance of the system is also an issue (Gordon 2004). Rising stage samplers are a low cost alternative to automatic samplers, but more research is needed to determine the viability and variability between sampling techniques for different stages (Graczyk 2000).

3.0 METHODS AND MATERIALS

3.1 Permanent monitoring sites

The water quality assessment included a total of four permanent monitoring sites located in the three tributaries feeding into the lake (Black, Sapp, and Buss Creeks) and a fourth tributary after the confluence of the above creeks located below the dam in Tired Creek. A fifth monitoring site feeding into the lake from a nursery (Nursery Creek) was chosen, along with a sixth site within the lake near the outlet structure in Tired Creek above the permanent monitoring site. The six sites were determined by review of lake bathymetry, shoreline maps, and aerial photos. The future lake appears to have three main tributaries feeding into and one leaving the lake below the dam. The locations of the sites are provided in **Table 3.1**

Table 3.1 Continuous monitoring sites

Location	Elevation (m)	Latitude (N)	Longitude (S)
Black Creek above reservoir	69	¼ mile upstream	¼ mile upstream
Buss Creek above reservoir	69	¼ mile upstream	¼ mile upstream
Sapp Creek Above reservoir	69	¼ mile upstream	¼ mile upstream
Tired Creek 1 below reservoir	57	¼ mile downstream	¼ mile downstream
Nursery Creek above reservoir	69	¼ mile upstream,	¼ mile upstream
Tired Creek 2 near dam outlet	57	Near dam	Near dam

Cross-sectional channel profiles were developed for each tributary to determine changing depth, flow, and size of the channels. The profiles were developed at the start of the yearlong assessment and a year later. Hach Hydromet CTDs (Conductivity, Temperature, and Depth) were set up to collect real-time temperature, specific conductance, and depth at each site. Measurements were recorded every fifteen minutes from all locations. A Hach multi-parameter sonde was used to collect continuous dissolved oxygen concentration, pH, specific conductance, and temperature at the site below the dam. Additional tributaries would be monitored on a quarterly basis if they were observed to be discharging significant inputs of sediments and nutrients directly into the lake, but none were needed.

3.2 Water Stage and Discharge Measurements

Permanent staff gages were installed to record the stage/depth of each monitoring location. Staff gages were referenced using an offset from stage/depth measurements every fifteen minutes from the CTD sensors and used to determine continuous stream stage at each of the five sites. Staff gages were also referenced for each sampling event in the field.

For a wide range of stages, the OTT MF Pro velocity meter, wading rod, and measuring tape were used to calculate discharge through a velocity-area method. The OTT MF Pro uses electromagnetic sensor for determining velocity and is calibrated to zero in a bucket of water. One to three velocity point readings were taken for each depth, with one reading at shallow depths and three velocity readings with weighted averages at deeper depths. Velocity readings were taken every 1-2 feet depending on the width of the stream channel. Data was then stored in the memory of the handheld unit and later uploaded to determine discharge (ft^3/s) at each stage, through the velocity-area method.

A table of stage measurements and their corresponding discharge measurements were then developed for each monitoring location. Using a scatter plot of stream stage vs. discharge, a power curve was applied as a trend line to fit the data. The equation for the line was used to determine continuous discharge measurements for each site.

3.3 Cross-Sectional Profiles

Changes in bed elevation of creeks may occur due to scour or deposition of suspended solids. Each monitoring location was analyzed by comparing cross-sectional profiles completed in October 2012 and November 2013. A reference point was established on each side of the stream using metal stakes driven into the ground. Each stream cross-section was determined using a surveyor level, tape measure, leveling rod, notebook, and pencil. The cross-section extended beyond the bank on each side. The longitudinal profiles could be determined by contour lines from topographic maps.

3.4 Field Measurements and Lab Analysis

Water samples and in situ measurements were collected during monthly sampling and for storm events from six locations described above, to develop baseline data for the watershed assessment. **Table 3.2** lists the parameters for grab sampling, sampling equipment or holding container, preservation technique, and maximum holding time. The sampling locations were the same as the permanent monitoring locations, including laboratory measurements upstream, within and downstream of the lake near the surface. Other grab samples also included QA/QC and storm samples. Wide ranges of parameters were measured to help determine the overall health of the Tired Creek watershed.

Table 3.2 Sampling Method Requirements

Parameter	Sampling Equipment	Sample Holding Container	Preservation	MHT
Specific Conductance	Sensor and Multiprobe	NA	NA	In situ
Temperature	Sensor and Multiprobe	NA	NA	In situ
Depth/Stage	Sensor	NA	NA	In situ
pH	Multiprobe	NA	NA	In situ
Dissolved Oxygen	Multiprobe	NA	NA	In situ
Turbidity	Turbidimeter	NA	NA	In situ
Hardness	Titration Method	NA	NA	In situ
Alkalinity	Titration Method	NA	NA	In situ
Total Nitrogen	Bottle (P)	250 mL clear plastic	4°C, H_2SO_4 to pH <2	28 days
Total Phosphorus	Bottle (P)	250 mL clear plastic	4°C, H_2SO_4 to pH <2	28 days
Fecal Coliform	Bottle (P)	200 mL clear plastic	$Na_2S_2O_3$	8 hours
Iron	Bottle (P)	250 mL clear plastic	HNO_3 to pH<2	6 months
Manganese	Bottle (P)	250 mL clear plastic	HNO_3 to pH<2	6 months
Total Suspended Solids	Bottle (P)	1 L	4°C	7 days

Note: NA-not active; MHT- maximum hold time

Field measurements included dissolved oxygen, water temperature, pH, and specific conductance using a portable MS5 Hach mini-sonde. The instrument received maintenance and calibration before each sampling event and when needed. The sonde was placed in the middle of the stream and allowed a few minutes to equilibrate with the water before recording the measurement in a lab notebook and later transferring to a digital file saved on a hard disk.

Other measurements recorded on-site included turbidity, alkalinity, hardness, and stage. Turbidity, alkalinity, and hardness samples were grabbed from the center of the stream channels. Turbidity was recorded using a turbidimeter, which was calibrated using provided standards before each sampling event. Two turbidity measurements were taken and then averaged to provide the data for each site and event. Sample bottles were rinsed with DI water and sample water between readings. The outside of each bottle was then cleaned with a cloth. Alkalinity and hardness were determined using similar titration methods.

Alkalinity was determined using the Hach Alkalinity Test Kit, Model AL-AP for P and Total MO as $CaCO_3$. A low range test was performed using a Sulfuric acid drop count titration method. The mixing bottle was first rinsed using the sample water. The mixing bottle was then filled to the 23 mL mark with the water sample and a Phenolphthalein Indicator Powder added and mixed to the sample turning it pink. If the sample turned pink a titration method would provide phenolphthalein alkalinity. If the sample did not turn pink and phenolphthalein alkalinity was equal to zero, then a Bromcresol Green-Methyl Red Indicator Powder Pillow was added to the mixing bottle and the following steps were followed to determine methyl orange alkalinity as $CaCO_3$. All samples within the catchment area did not turn pink. A Sulfuric Acid Standard Solution was added one drop at a time to the green sample and swirling the bottle to mix. Each drop equaled five mg/L until the sample turned pink and the measurement was recorded for the methyl orange alkalinity as $CaCO_3$. The measurement was then recorded in the lab notebook and the mixing bottle was cleaned and rinsed using DI water.

Hardness was determined through a similar titration method using the Hach Hardness Test Kit Model 5-EP. The small plastic-tube provided in the test kit and mixing bottle were rinsed using sample water. The small plastic tube was filled with the sample water and added into the mixing bottle. A UniVer 3 Hardness Reagent Powder Pillow was then added to the mixing bottle and swirled to mix turning the sample red. A Hardness 3 Titrant solution was added by the drop, until the sample turned from red to blue. Each drop was equal to 20 mg/L if $CaCO_3$. The measurement was recorded in the lab notebook, with the plastic tube and mixing bottle cleaned and rinsed using DI water.

Laboratory analysis included total suspended solids, iron, manganese, total phosphorus, total nitrogen, ammonia (calculation), TKN (digestion), and nitrate + nitrite (as nitrate), and fecal coliform. All sample bottles were labeled for sample ID, date, time, preservation method, and the individual sampler. A total of four bottles were collected from each site. A 1-liter bottle was collected for TSS, a 250-mL bottle for metals (Fe and Mn), a 250-mL bottle for nutrients (TN, TON, TKN, and TP), and a 200-mL bottle for fecal coliform (FC). Sample locations were approached by wading from downstream of the location and taken on the surface of the water in at least one-half feet deep water. A sample was first taken in the larger TSS bottle and then distributed to other bottles with preservation standards. Preservation for metals included nitric acid to bring the pH below 2, nutrients included sulfuric acid to bring the pH below 2, and preservation for fecal coliform was sodium thiosulfate to prevent chlorine contamination. The TSS bottle was then refilled in the middle of the stream. Once all four bottles were filled, they were immediately transported from the monitoring site and stored in an ice chest to be cooled below 4 degrees Celsius until the courier service picked them up to return to the lab.

Advanced Environmental Laboratories is an EPA approved laboratory and performed the analysis for the parameters described above. A list of EPA approved analytical methods is provided in **Appendix C**. The lab for each sample event conducted QA/QC samples in addition to duplicates submitted from each creek.

Proper chain of custody records were kept for each sampling event and signed by a laboratory representative and myself. Grab samples were then taken on the same day to the laboratory for analysis due to the maximum hold time for fecal coliform. Results were returned via email in a digital copy format.

3.5 Storm Sampling

Precipitation events were measured using a Rainwise Tipping Bucket rain gage measure 0.01 inches for every tip in the bucket. Data was downloaded periodically and stored in minute and daily intervals in an excel file. The rain gage was located at the Tired Creek monitoring location with no impedance from trees.

In addition to monthly sampling, storm samples were also generated over the baseline development period. These samples included rising stage samplers and grab samples for rain events. Rising stage samplers were designed and constructed for storm sampling at each location. Custom rising stage sampler designs attempted to allow first-flush samples to be collected for different stage events and possibly multiple stages for one rain event if the stage increased enough. Composite samples were picked up and preserved within 24 hours of filling. Parameters for these events would include laboratory analysis parameters only due to the inability to collect in situ measurements without a researcher present. Grab samples were also taken for storm samples and included all the parameters sampled during monthly sampling. Grab samples followed the sample protocol outlined for the monthly sampling events.

3.6 Biota Assessment

A biological assessment was performed by a separate organization, CCR Environmental, LLC including habitat assessments, benthic macroinvertebrate assessments, and fish community assessments. Habitat assessments in Buss Creek, Black Creek, Sapp Creek and Tired Creek followed protocol of low gradient streams developed by the GDNR and EPD. Streams were scored based on multiple habitat metrics in the following categories: poor (0-44), marginal (60-100), suboptimal (113-153), and optimal (166-200). The Standard Operating Procedure for Macroinvertibrate Biological Assessment of Wadeable Streams in Georgia, developed by the Georgia DNR, was used for sampling and data collection of macroinvertebrates in Buss Creek, Black Creek, Sapp Creek and Tired Creek. Streams were rated based on a multi-metric index score for stream health from good to poor and A-F. The categories for the indexed score within the region included Tanytarsini Taxa, Shannon-Wiener Index, % Oligochaeta, % Tanytarsini, NCBI, % Predator, and Clinger Taxa. The Standard Operating Procedures for Conducting Biomonitoring on Fish Communities in Wadeable Streams in Georgia were used to monitor fish communities. Tired Creek, located downstream of the dam, was the only monitoring location for fish sampling using electric shock pulses.

3.7 QA/QC

Quality Control samples were developed for 10-15% of total collected samples to provide comparisons and help prevent contamination or error. These QC samples may include a field blank, rinsate blank, split sample, replicate sample, or spiked samples. The laboratory will also run its own QC samples in addition to field QC samples and standards to check for possible contamination. The additional QC samples will be compared to others using statistics during data manipulation once data is received from the lab. Data manipulation may include, but is not limited to standard deviation, coefficient of variation, and relative percent difference, etc.

Field data sheets were reviewed and signed by the project manager for each dataset. If problems occurred, they were noted and corrected. Field and lab data were entered into a spreadsheet format on Microsoft Excel and stored under the file directory on a laptop computer. It was also be backed up on an external hard drive and stored on an online database, such as Dropbox. Hard copies of field data sheets were kept on file for the duration of the project. Laboratory analysis data was stored as a spreadsheet in the same manner. All data was double checked for data entry errors and completeness at each phase of the project by the project manager.

3.8 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Routine inspections and maintenance were conducted to ensure instruments are working properly. Instruments used for water quality monitoring included continuously monitoring specific conductance, temperature, and depth sensors purchased from Hach Hydromet. These sensors were calibrated and serviced based on directions supplied by the manufacturer and observed values. Two Hydrolab datasondes (MS5 and DX5) were used to take DO, pH, turbidity, temperature, and specific conductance at multiple locations around the lake. They were calibrated and serviced based on directions supplied by the manufacturer. The turbidimeter was also calibrated before each sampling event. Individual records were kept for each inspection and calibration of the instruments, which included every sampling trip, to help determine any errors in measurements.

4.0 GEOGRAPHIC INFORMATION SYSTEM (GIS) ANALYSIS

GIS data is used to provide additional data beyond water quality monitoring and sampling data. GIS provides the ability to determine population, stream networks, monitoring locations, watershed delineation, land area, land cover, soil characteristics of each watershed, and critical sources areas. The Tired Creek watershed and the three upper watersheds collectively make the Tired Creek Lake watershed. From the population map, **Figure 4.1**, it was found there are 519 homes located within the Tired Creek Lake watershed with a total 2008 Census data population of 1,308 people. **Figure 4.2** shows the outline of each watershed boundary on a topographic map. The lake will flood zero houses within the catchment area because Grady County and the State of Georgia acquired the land in the 1930's. The location of the land flooded by the lake includes what was previously known as a Georgia State Park. However, flooding of the lake will impact over 120 acres of wetlands and Highway 112.

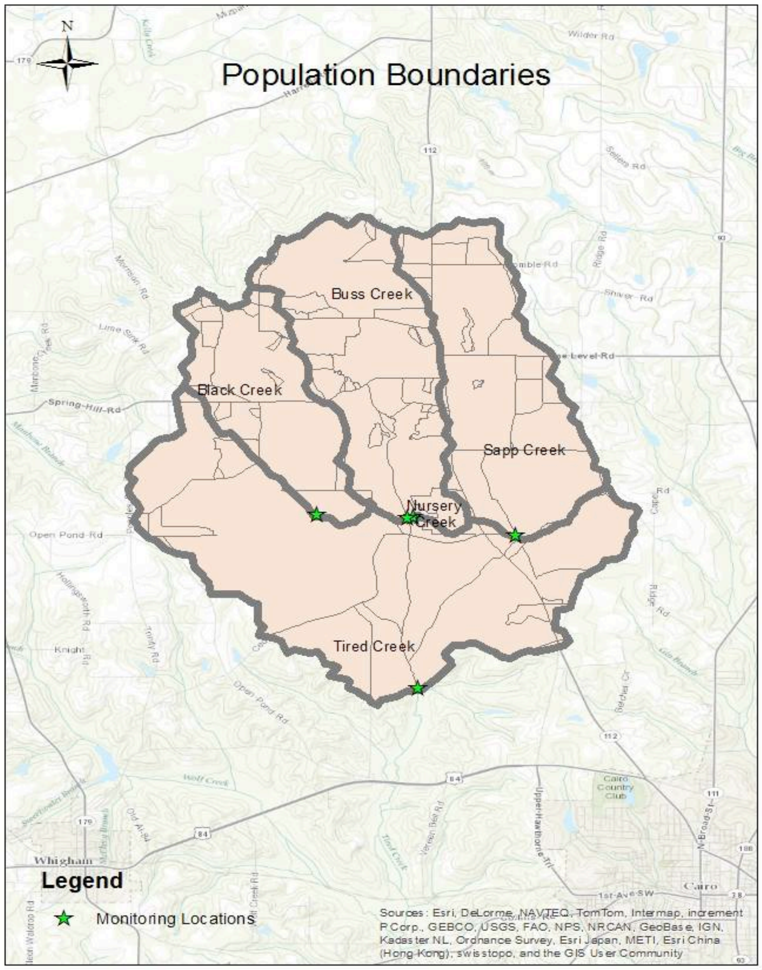

Figure 4.1 Population map with 2008 Census district boundaries

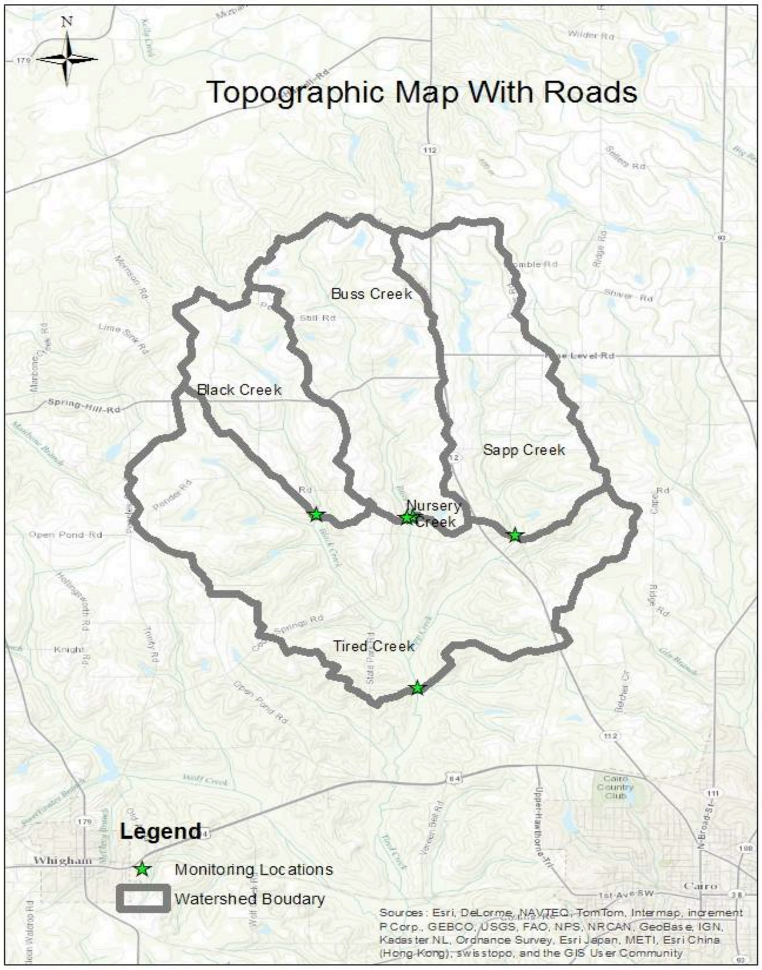

Figure 4.2 Topographic map with watersheds outlined in dark grey

The total watershed for Tired Creek Lake is within the Tired Creek watershed catchment area, which flows into the Ochlockonee River. The Tired Creek Lake watershed comprises 5.5% of 640 square miles of the land area within Grady County **(Figure 4.3).** All creeks within the county feed into the Ochlockonee River, which then flows south into Florida through Lake Talquin. The river then continues south into the Ochlockonee Bay near Panacea, FL and eventually into the Gulf of Mexico.

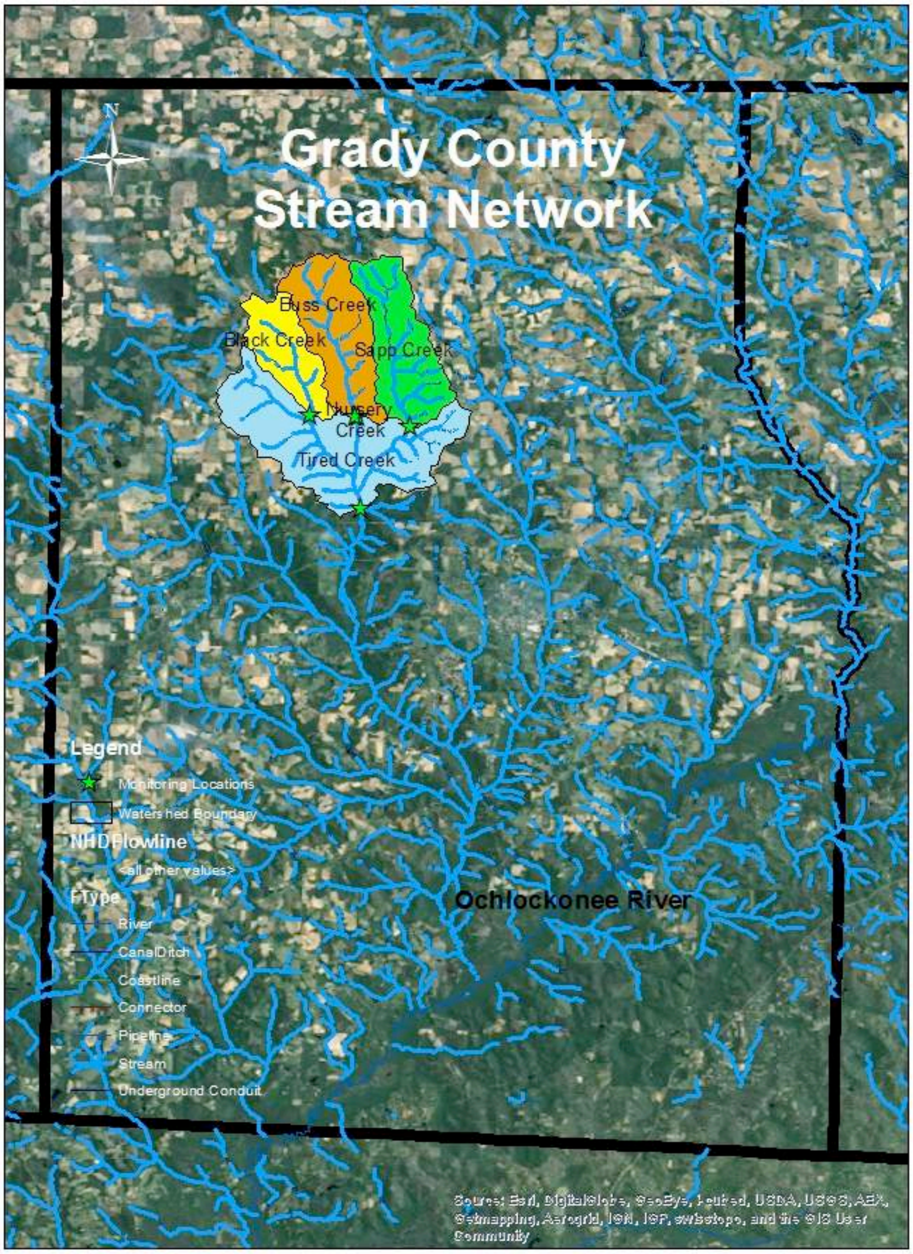

Figure 4.3 Stream network and watershed location within Grady County

A more detailed map of the Tired Creek Lake watershed with each of the upper tributary's watershed boundaries being identified upstream of their respective monitoring locations (Tired Creek (blue), Sapp Creek (green), Buss Creek (orange), and Black Creek (yellow)) is shown in **Figure 4.4**. The Nursery Creek watershed is approximately 400 acres of the southeastern part of the Buss Creek watershed that sticks out, however it was not identified due to the resolution of available data and manmade water diversion. Water bodies including ponds and wetlands are identified in grey.

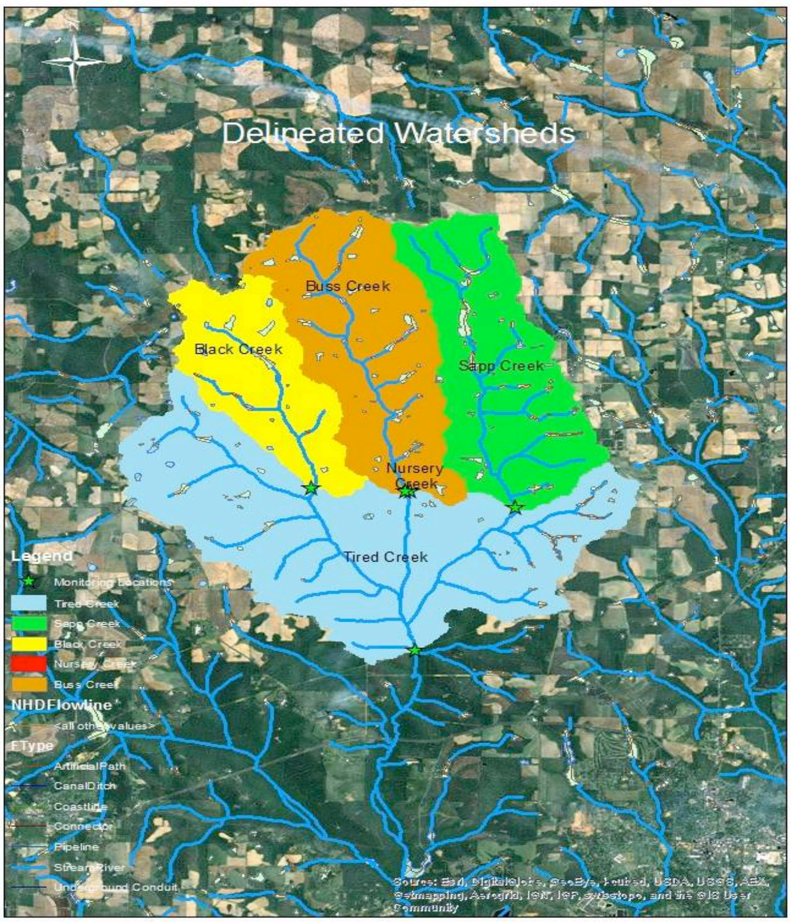

Figure 4.4 Watersheds delineated based on monitoring site location using GIS

Appendix D provides the land use data for each of the identified watersheds within the Tired Creek Lake's 16,126-acre watershed. The watershed is classified as agricultural for approximately 8,272 acres (51.3%) of the land area, which is used for row crop/pasture land. Agriculture crops are not specified within the GIS data file, but based on visual observation and local interviews, typical agriculture in the area includes cotton, peanuts, soybeans, corn, and some dairy farming. Forested lands (deciduous, evergreen, and mixed forests) comprise the second largest land use with 31.1% of the total land cover; followed by wetlands, which make up 10% of the land cover. The remaining land uses within the watershed are low intensity urban (4.28%), open water (1.17%), high intensity urban (0.19%) and dune/mud/beach (0.16%).

As calculated by the monitoring locations, rather than the confluence of creeks, the Tired Creek Lake watershed can be subdivided as follows: Tired Creek 6,705 acres (41.6%); Sapp Creek 3,551 acres (22.0%); Black Creek 2,226 acres (13.8%); and Buss Creek 3,644 acres (22.6%). Land use for each watershed above the monitoring sites can be viewed in **Appendix D**.

The Tired Creek Lake watershed has different soil types varying in composition throughout the watershed. By using the Soil Survey Geographic database (SSURGO), and the USDA's Web Soil Survey, **Figure 4.5** illustrates the various soils within the watershed. **Appendix D** breaks down the SSURGO data into soil types for each watershed. The predominant soils within the entire watershed are Tifton soils (TfA and TfB) making up 39.6% of the total land area**.** Tifton soils are deep, generally well-drained soils established from loamy marine sediments generally found on hill slopes and interfluves with a slope of 0-8%. The soils are predominantly clay as indicated by the taxonomic class of fine loamy, kaolinitic, and thermic Plinthic Kandiudults. Tifton soils, as classified in the soil survey, have moderate to moderately slow permeability with a water table found three to five feet in depth. The soils are strongly acidic to moderately acidic and require lime to neutralize the soils. Other major soils found within the watershed are Nankin (NaB, NcC, NcD) comprising 12.5% of the land area and Oiser and Bibb soils (OsA) 15.2%. Nankin, Oiser and Bibb Soils are frequently flooded and are generally located around the streams and other low-lying areas.

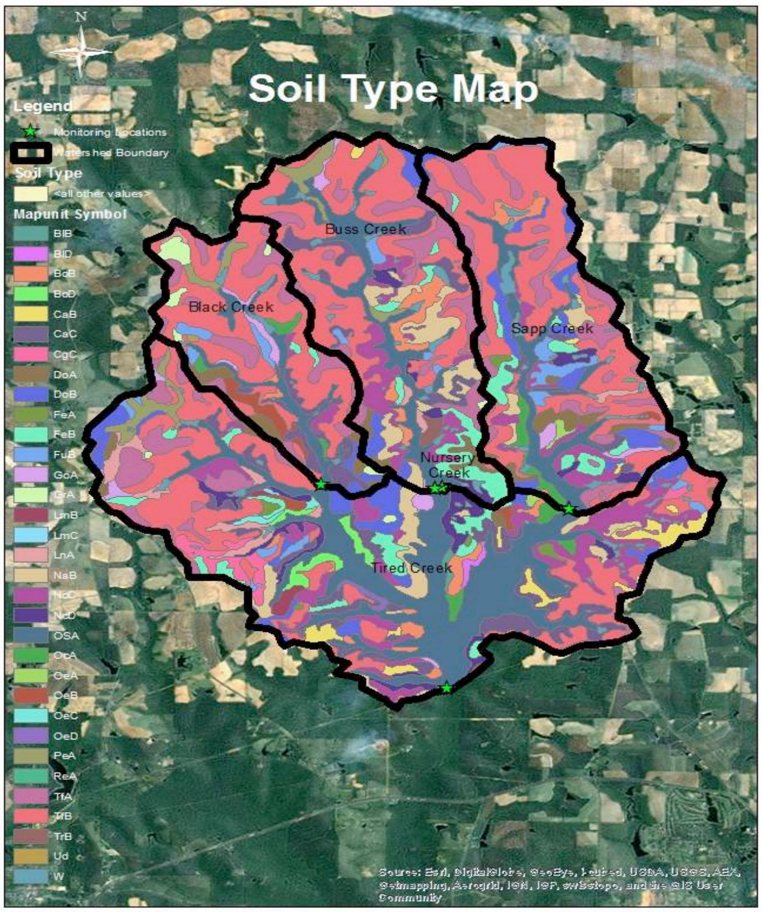

Figure 4.5 Map of soil types from Soil Survey Geographic database (SSURGO)

To determine if soils were susceptible to sheet erosion, a soil erosion risk map was developed in **Figure 4.6** using part of the Universal Soil Loss Equation without management factors included. Without management factors, this can be considered a worst-case scenario for erosion. The map layer takes into account a rainfall and runoff factor, a soil erodibility factor, and a slope length-gradient factor. Highly erodible soils being shown in shades red and low erosion risk soils in shades of blue. This data comes from the SSURGO dataset and hydrologic data. All soils are shown in blue or baby blue, indicating low erosion risks most likely due to the high clay content of the soils, leading to decreased sediment in the water bodies.

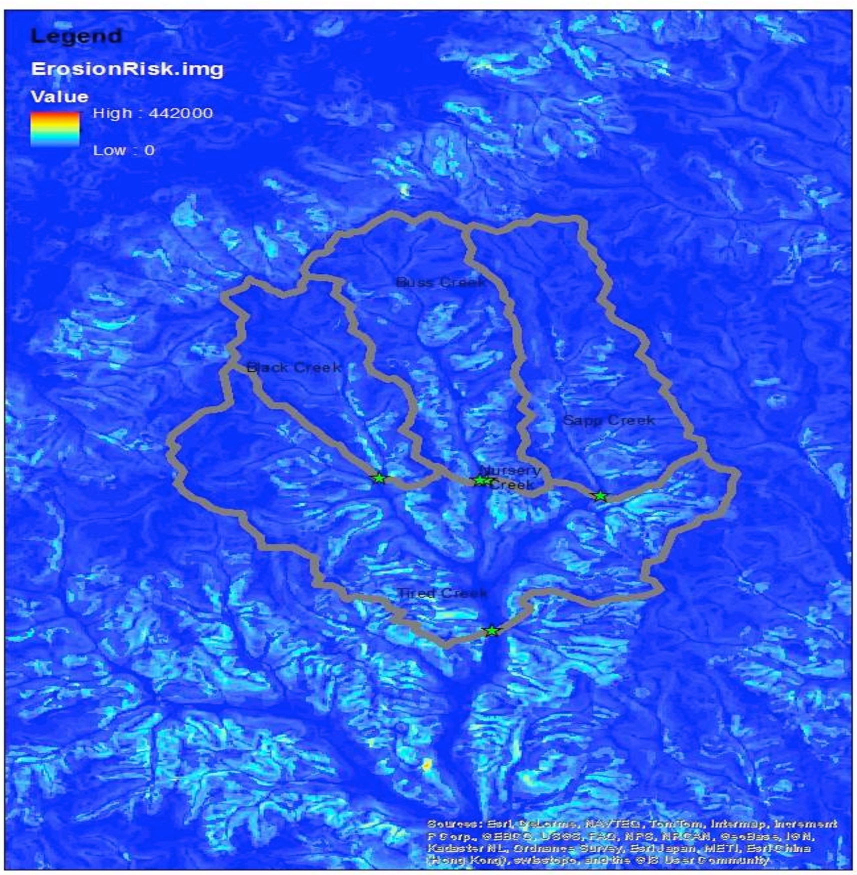

Figure 4.6 Erosion risk map based on SSURGO data

Using satellite imagery and observations in the field, two possible critical sources areas for pollutant sources were identified: Monrovia Nursery and Gainous' Shade Tree, Inc**.** These areas are a small fraction of the watershed that may contribute significantly to pollutant loading for the size of the drainage area into the watershed. These locations are shown on a topographic map in **Figure 4.7.** The monitoring location for Buss Creek is just above the Gainous' Nursery location. Most of the Monrovia Nursery catchment flows through nursery creek, while another portion flows into Buss Creek, just above the monitoring location.

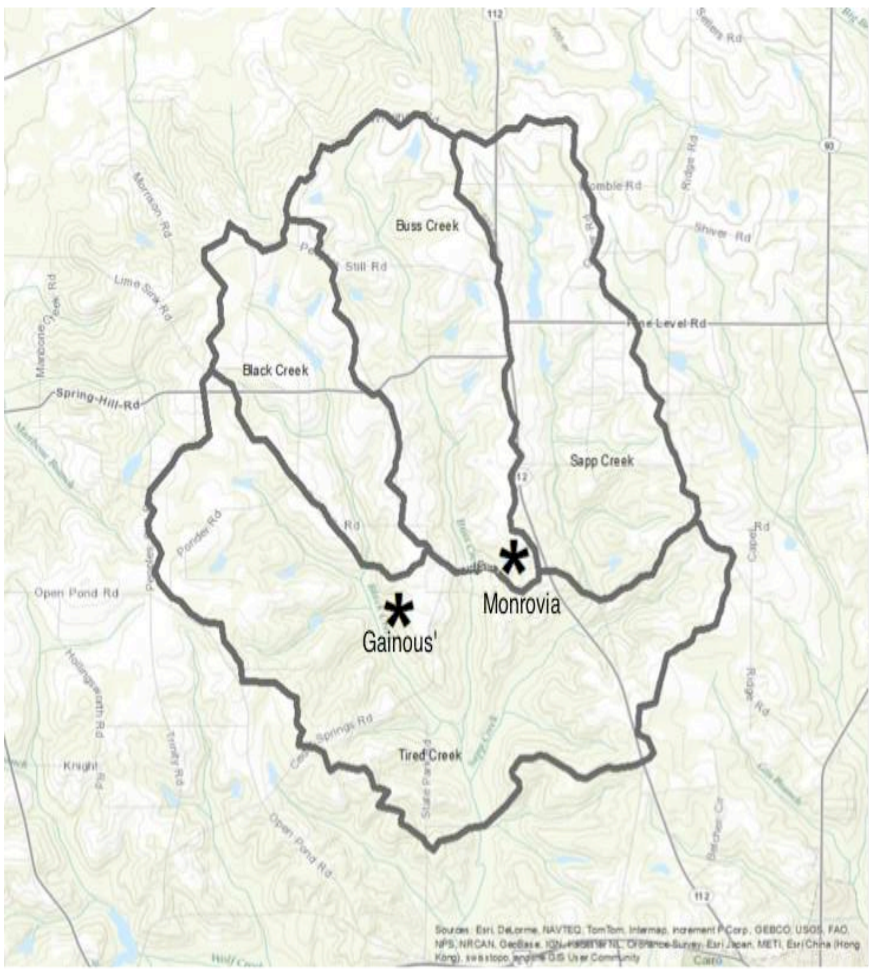

Figure 4.7 Critical Source Area locations within watershed

The Monrovia Nursery North site is currently operating at about 10% or less of its total capacity at the Highway 112 nursery location. The manager of the nursery was contacted for information on the future plans of the property to determine potential impacts to the watershed. The decrease in production was due to the challenging economy, especially for the landscaping industry, and future production of the site is unknown. The second Monrovia site south of Cairo is still operating at full capacity. A satellite image of Monrovia Nursery North is shown in **Figure 4.8.**

The Gainous' Shade Tree nursery, a satellite image in **Figure 4.8,** is operating on 40-acres with surrounding land open to expansion. The research team has not sampled water quality in the area and we do not suspect any major issues, nor have we seen any downstream. The site catchment area is located just below the Black Creek monitoring location, therefore influencing the Tired Creek location. There are no industries or other possible point source discharges within the Tired Creek Lake watershed that have been determined.

Figure 4.8 Satellite image of Monrovia (right) and Gainous Shade Tree, Inc (left)

5.0 RESULTS AND DISCUSSION

5.1 Important Dates/Project Information

Monthly sampling events were conducted over a wide range of stages at each monitoring location between the 20th-24th days of each month from October 2012-November 2013. Important dates and events can be seen in **Table 5.1**. The January 31, 2013 sampling was 12 hours following a ½ inch nighttime rain event, but did not catch the peak of the storm. The February 22nd sampling event was immediately followed the first 1-inch rain event, totaling almost 12 inches over a three-day period and serving as a typical storm event sample. The June 6, 2013 storm event sample was collected using rising stage samplers. A second stage height was sampled one foot above the first sampler at the Buss Creek and Tired Creek locations on the evening of June 24, 2012. A fifth storm sampling event was on November 26, 2013 following approximately 1 inch of rain.

Other notable dates included timbering and dam construction starting August 20, 2013 and the end of baseline on October 22, 2013 with a full year of data. Upon receipt of USACE approval, the County initiated clearing and construction of the dam site on August 20, 2013. Timbering for the normal pool of the lake began at the lower end of the site upon completion of the first year of baseline data as contemplated within the approved water quality monitoring plan. Timbering and construction will not affect the upstream sites including Buss, Sapp, Black, and Nursery Creek, but will influence the Tired Creek site.

Table 5.1 Important dates for baseline development

Date	Type	Description
10/22/12	Monthly	No rain; Continuous monitoring begins
11/20/12	Monthly	No recent rain
12/24/12	Monthly	1.42 inches of rain on 12/20/12
1/21/13	Monthly	.41 inches of rain on 1/17/13
1/31/13	Storm	12 hours following a .47 inch rain event on early morning 1/31/12
2/22/13	Storm	Immediately following a approximately 2 inches of rain
3/21/13	Monthly	.9 inch rain event on 3/19/12
4/22/13	Monthly	.49 inch rain event on 4/20/13
5/23/13	Monthly	No recent Rain
6/6/13	Storm	.49 inch 6/4/13; .96 inch 6/5/13; 1.68 inch 6/6/14; Rising stage
6/24/13	Monthly/Storm	.73 inches 6/22/13; 2nd stage storm sample
7/23/13	Monthly	.1 inch rain 7/21/13; .2 inch rain 7/22/13
8/19/13	Monthly	1.36 inch rain 8/17/13; .16 inch rain 8/18/13
8/20/13	None	Dam Construction and Timbering begins
9/24/13	Monthly	.77 inch rain 9/21/13; .28 inch rain 9/22/13; .08 inch rain 9/23/13
10/22/13	Monthly	No recent rain; end of baseline
11/25/13	Monthly	Tired Creek grab sample only
11/26/13	Storm	Sampled after 1 inch of rain during 1.36 inch rain event

5.2 Rainfall Data

Rainfall measured onsite near the Tired Creek monitoring location was recorded for each rain event over the assessment period using a tipping bucket rain gauge and events are shown in **Figure 5.1**. Each individual rain event recorded ranged from around 0.01 inches to as high as 4.4 inches, with about 130 events during the assessment period. The two largest rain events were 4.39 inches on February 26, 2013 and 4.35 inches on June 30, 2013. Small rain events may be due to fog or condensation causing the gauge to tip only a few times, in which each tip records 0.01 inches. There were 98 rain events larger than 0.1 inches over the assessment period.

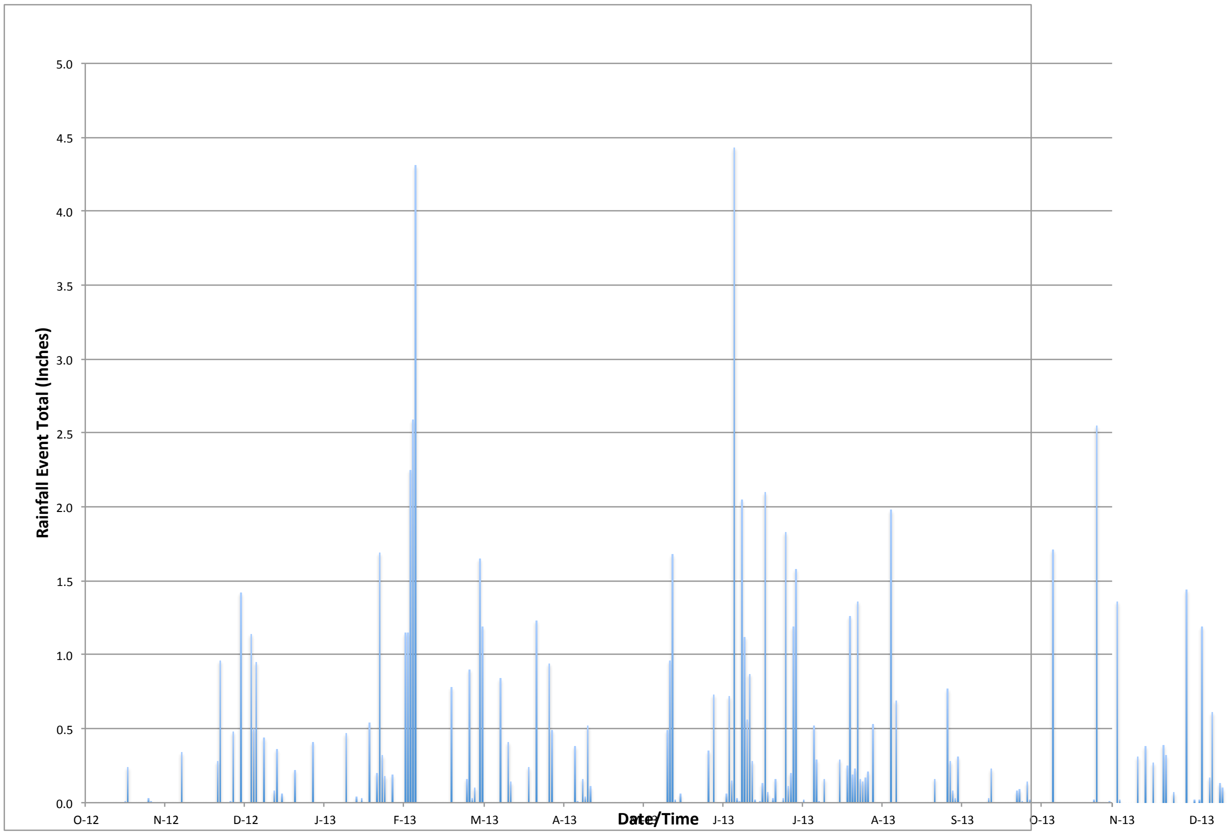

Figure 5.1 Individual rainfall events over the assessment period

A bar graph for monthly totals throughout the watershed assessment period is shown in **Figure 5.2**. The summer and fall leading up to the start of the baseline assessment period were very dry. Dry parts of the baseline development period included fall 2012, January 2013, late spring May 2013, and again in fall of 2013. Large rain events include February 2013 and summer 2013. The February flood event over four days totaled 11.5 inches over four days, in which all creek levels overflowed the stream banks. The baseline development period total 66.09 inches of rain from October 2012-Ocotber 2013, 69.4 inches over the calendar year 2013, and 76.17 inches for the full assessment period. Both yearly totals were well above an average for Cairo of 52.07 inches of rainfall per year.

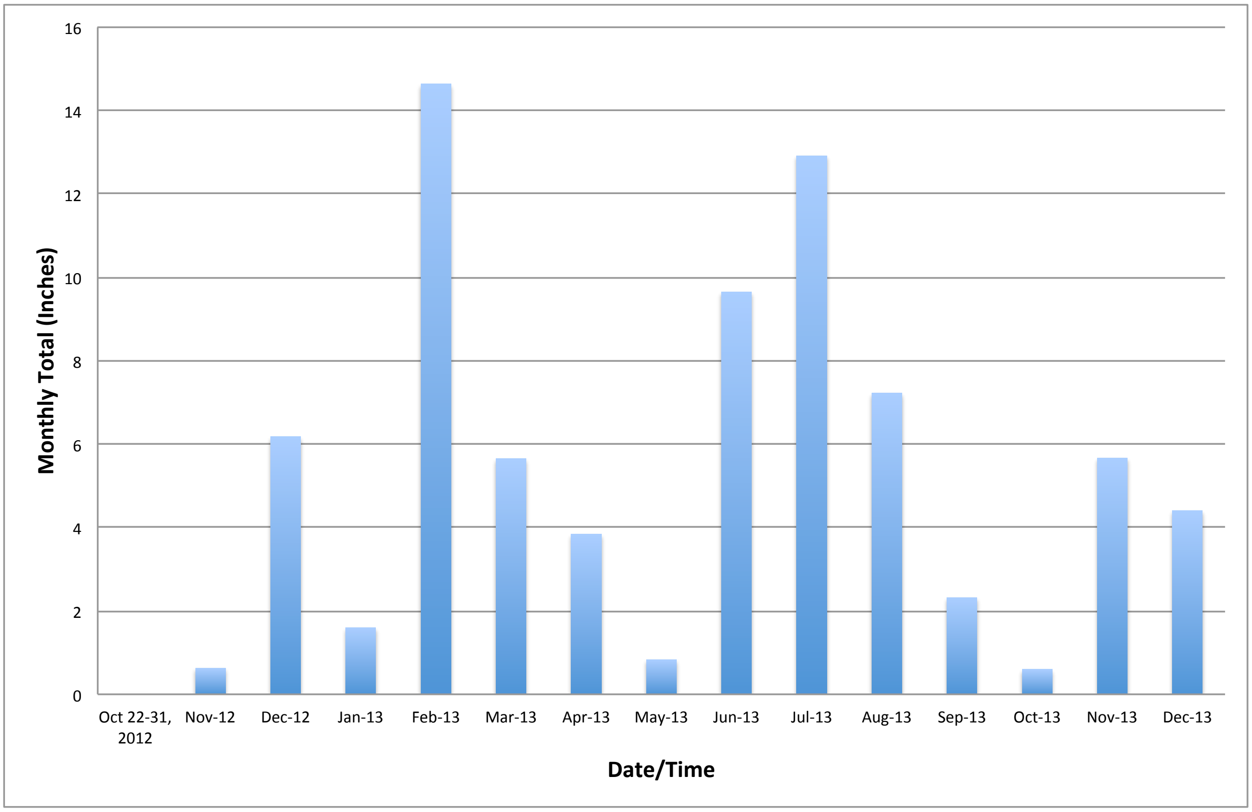

Figure 5.2 Tired Creek Lake Monthly rainfall data

5.3 Sapp Creek

The Sapp Creek watershed is located in the Northeast area of the Tired Creek Lake Watershed and is approximately 3,550-acres above the monitoring location**.** A photo of the sampling site is provided in **Figure 5.3.** Surveyed cross-sections are in **Figure 5.4** and include October 2012 and November 2013 for the annual analysis of channel morphology. The channel filled in 0.12 meters due to sediment on the left side and became a slightly wider on the left side. Noticeable changes creek bed erosion occurred due to large storms, but sediment deposited back over time.

Figure 5.3. Sapp Creek monitoring location photo January 2014 view towards the south

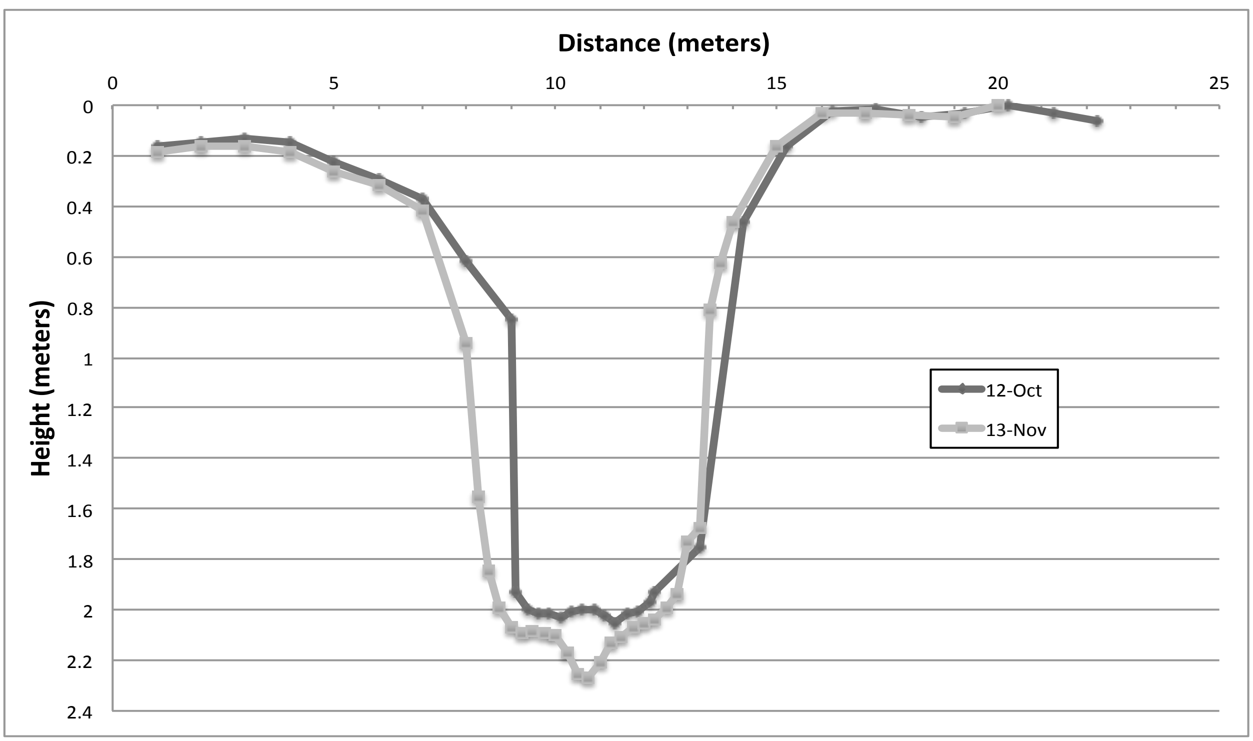

Figure 5.4. Sapp Creek cross-section

As stated above in the Methods section, continuous monitoring at the site included stage, specific conductance, and temperature. **Figure 5.5** depicts the continuous stage measurements over the baseline data collection. The maximum stage recorded was 6.4 feet on February 25, 2013, and the minimum was 0.07 feet on June 20, 2013. The stage was plotted with calculated discharge measurements based on the velocity area method at a range from 0.14-1.4 feet in **Figure 5.6**. A power curve was fit to the data to provide an equation for the relationship between stage and discharge implementing an r^2=0.87:

$$Q_1 = 7.1223\ x_1^{2.0041} \qquad (1)$$

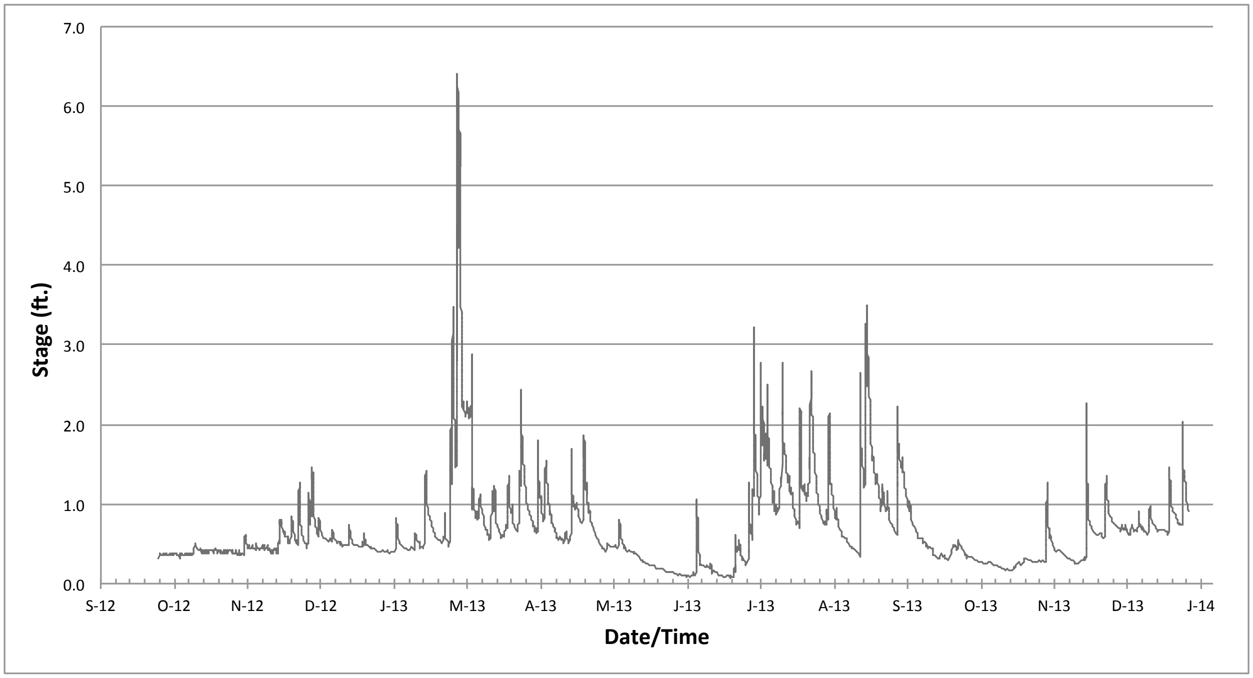

Figure 5.5 Sapp Creek stage vs. time over full baseline period

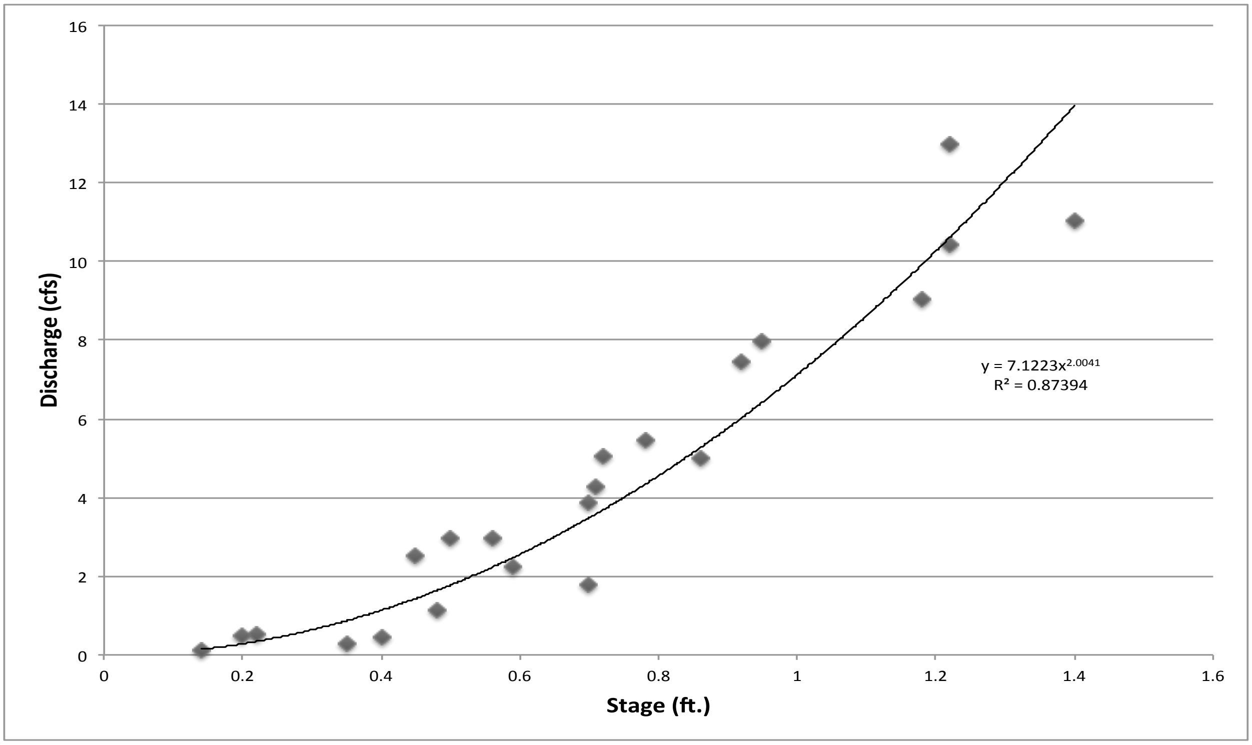

Figure 5.6 Sapp Creek Rating Curve for stage vs. discharge

Using *Equation 1*, Q=discharge and x=stage, the total discharge per month was calculated and provided in **Appendix E.** The highest discharge per month was 45.8 mcf in February 2013, while July and August 2013 also had high discharge. The lowest was 1.25 mcf for October 2013 and also low flows in May and June 2013. Cumulative discharge over the year from October 2012-September 2013 was approximately 178 mcf and 187 mcf for 2013 year.

Monthly grab sampling and monitoring data was obtained at the site, as well as storm grab samples on January 31, 2012, February 22 2013, November 27, 2013 and a rising stage sample on June 6, 2013. Sampling minimums, maximums, averages, medians, variances and standard deviations are provided in **Table 5.2**. All data points can be found in **Appendix E** with the addition of sample time and weather. Sampled stage heights ranged from a minimum of 0.17 feet to a maximum of 3.9 feet.

Although there are no standards set by the State of Georgia or federal agencies for iron and manganese, there are recommendations based upon the literature; iron and manganese freshwater concentrations are should be below 1 mg/L (REFs). Iron concentrations were above these recommendations averaging 2.68 mg/L with a maximum of 5.6 mg/L and a minimum of 1.7 mg/L. However, it is important to note higher iron concentrations are typically found in freshwater influenced by blackwater swamps, such as Sapp Creek. Manganese concentrations fell within the recommendations averaging 0.19 mg/L with a maximum of 1 mg/L and a minimum of 0.05 mg/L.

Georgia Environmental Protection Division's Water Quality Monitoring and Assessment of Water Quality in Georgia, Chapter 3, provides recreational stream water quality standards. The standard articulates a 4-sample geometric mean over a month for fecal coliform and requires monthly baseline analyses with mean values not to exceed 200 CFU/100 mL and maximum not to exceed values of 4,000 CFU/100 mL for recreational waters. Average fecal coliform was a concentration of 1319 CFU/100 mL and a maximum of 9420 CFU/100 mL. It is important to note this number was highly influenced by including storm data in the averages.

Few states have nutrient concentration regulations or standards due to variability between waters and Georgia does not currently have any. However, the EPA has provided recommendations based on a large dataset of regional data. For Sapp Creek, the average total nitrogen levels were 0.61 mg/L and fell within the recommended levels for the catchment area. Total phosphorus levels averaged .09 mg/L and fell on the high end of reference levels, but should not be a concern. Ammonia was usually below the detection limit or near zero as expected. No recommended levels were determined for TON or TKN.

Based on Georgia EPD standards, dissolved oxygen for each month exceeded the 4 mg/L minimum limit for a single sample and the 5.0 mg/L minimum daily average with a yearly average of 7.58 mg/L. All pH measurements fell within the 6-8.5 standard unit range. Temperatures remained within the 5°F change per day and below a maximum of 90°F range, meeting state guidelines. A yearlong graph of temperature vs. time is provided in **Figure 5.7,** with a minimum temperature of 44.19°F and a maximum temperature of 85.03°F. The high temperature may have been due to low flows and an air temperature reading if probe was not submergerd. Air temperature during sampling averaged 68.87 °F.

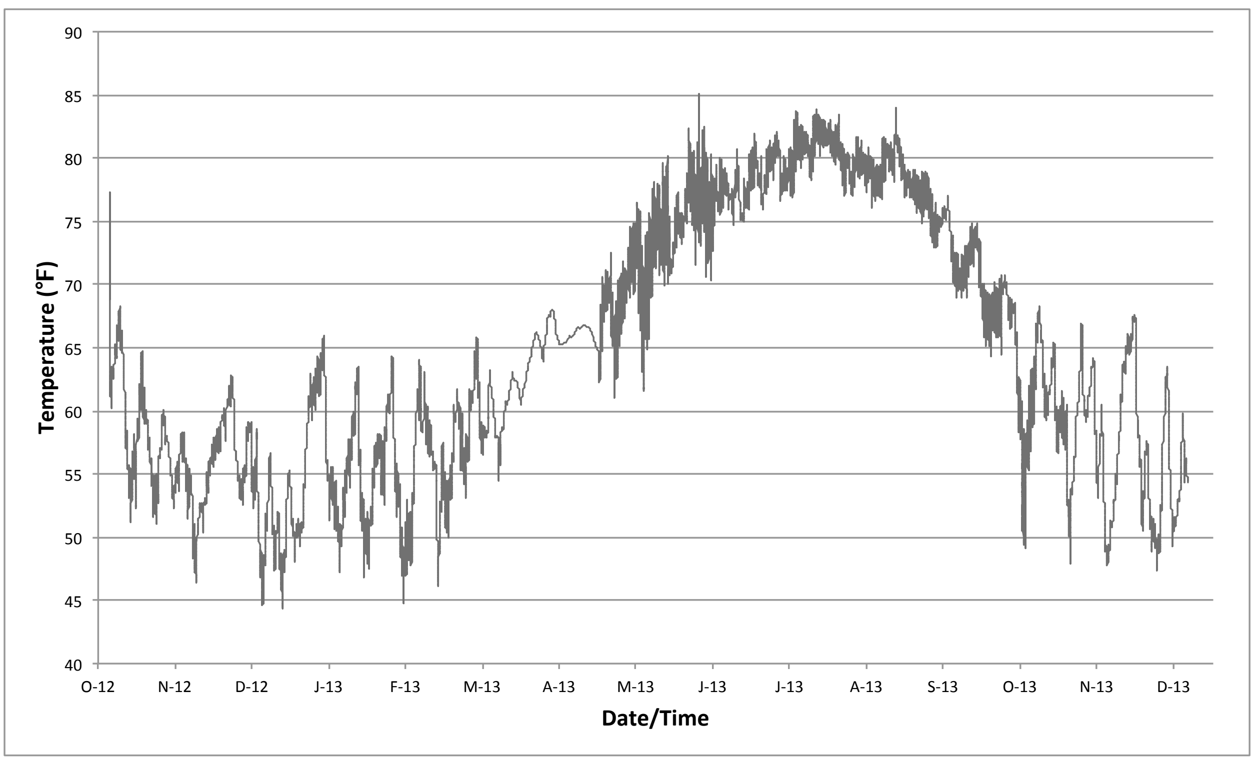

Figure 5.7 Sapp Creek temperature vs. time over full baseline period

Specific conductance for the baseline year is provided in **Figure 5.8**. Specific conductance for Sapp Creek averaged 77.3 μS/cm, with some data gaps (Mar 24-May 8, May

20-June 6, and June 12-23), including excessively high specific conductance measurements due to sediment build up on the instrument or no readings due to extremely low flows. These data gaps were filled in by cross-referencing conductivity with CTD stage measurements.

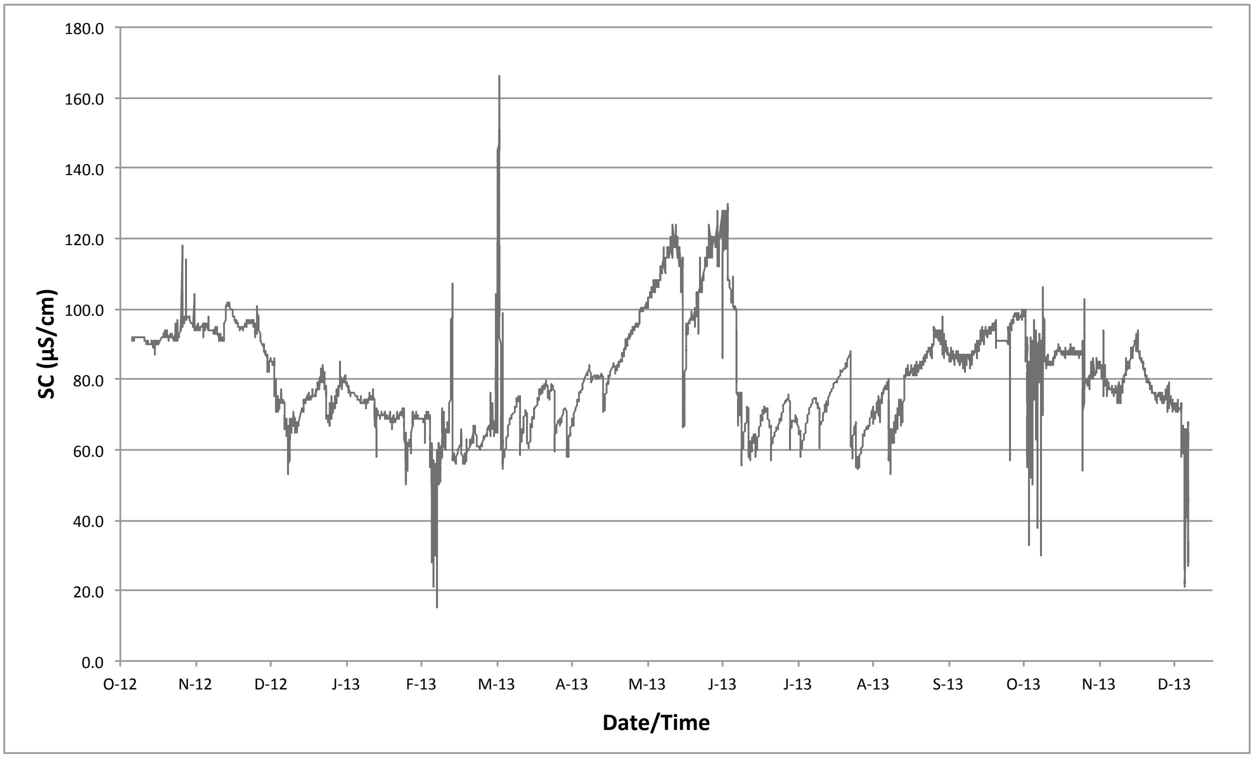

Figure 5.8 Sapp Creek specific conductance vs. time over full baseline period

Particulate matter parameters included turbidity and total suspended solids. There are no standards for these parameters in natural waters other than a 25 mg/Lor NTU increase due to land disturbing activities. Both tend to increase with storm loads. TSS averaged 17.3 mg/L, but was highly influenced due to storm loads with a minimum during low flows in October 2012 of 2.00 mg/L and maximum of 120 mg/L during the February 2013 storm. Turbidity was also influenced by storms with an average of 14.03 NTU, which was well below a maximum of 50

NTU needed to support aquatic life. The minimum turbidity recorded was 4.8 NTU during low flows in October 2012 and a max of 58.7 NTU during the February 2013 storm event.

Hardness and alkalinity were also documented for each sampling event. The data showed hardness averaged 44 mg/L as $CaCO_3$, which was well within the typical 0-60 mg/L range in the Southwestern Georgia region. Alkalinity averaged 28 mg/L during the watershed assessment period, which was 8 mg/L higher than the typical maximum range of the region. It is important to note that many parts of Georgia are above 20 mg/L.

Sapp Creek's physical habitat and benthic macroinvertebrates were assessed in November 2012. Based on the 10 habitat parameters, Sapp Creek scored a 134.5 in the suboptimal range for physical habitat. Ranges are located in the literature review. Based on the pebble count, Sapp Creek is 86% sand, which is typical in the region. The macroinvertebrate assessment multi-metric index score totaled 59, qualifying it for an A stream health rating.

Overall, the water quality within Sapp Creek was in good health meeting almost all the standards and recommendations. One problem is potentially high fecal coliform counts above state standards with a geometric mean of 337 CFU/100 mL. It is important to note the geometric average is skewed due to storm events and would fall below 200 CFU/100 mL when not including storm events with a geometric mean of 190 CFU/100 mL.

Table 5.2 Sapp Creek data for all samples

	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
n	16.0	16.0	15.0	16.0	16.0	16.0	16.0
Minimum	1.70	0.05	44.0	0.30	0.26	0.04	2.00
Maximum	5.60	1.00	9420	1.00	0.93	0.23	120
Average	2.68	0.19	1320	0.61	0.46	0.09	17.3
Median	2.45	0.13	134	0.59	0.44	0.08	5.60
Variance	1.21	0.05	6401110	0.03	0.03	0.00	937
Standard Deviation	1.10	0.23	2530	0.17	0.17	0.06	30.6

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
n	16.0	16.0	15.0	15.0	15.0	15.0	14.0
Minimum	0.02	0.00	6.28	56.4	9.85	49.7	4.17
Maximum	0.54	0.01	7.05	111	26.0	78.9	10.2
Average	0.15	0.00	6.75	77.3	17.9	64.3	7.57
Median	0.14	0.00	6.75	74.1	16.0	60.8	7.98
Variance	0.02	0.00	0.06	281	30.4	98.5	3.09
Standard Deviation	0.13	0.00	0.24	16.8	5.51	9.92	1.76

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)
n	15.0	15.0	15.0	15.0	16.0
Minimum	4.80	40.0	20.0	44.0	0.17
Maximum	58.7	60.0	40.0	88.0	2.91
Average	14.0	44.0	28.0	68.9	0.82
Median	7.90	40.0	25.0	67.0	0.56
Variance	190	68.6	49.3	150.4	0.49
Standard Deviation	13.8	8.28	7.02	12.3	0.70

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

Correlation matrices were developed using the Data Analysis Toolpak for correlation in Microsoft Excel to relate all the parameters within the creek. The correlation coefficient term is a Pearson's R-value, in which a positive value is a positive correlation and a negative value is an inverse correlation between the parameters. The correlation matrix for all samples and samples without storm data are located in **Table 5.3**, with very weak or no relationship (0-0.2), weak

(0.2-0.45), moderate (0.45-0.65), or strong (0.65-0.8) or very strong (0.8-1), depending on the R-value. The strongest correlation coefficient was between turbidity and TSS with 0.95, while both were strongly correlated with TP at 0.88 and 0.84. AT and WT were also very strongly correlated as expected with a correlation coefficient of 0.87. Other strong correlations included DO and WT (-0.74), TN and TKN (0.72), TP and Mn (0.71), AT and DO (-0.71), Alk and SC (0.71), TKN and Fe (0.68), Stage and SC (-0.66), and Alk and DO (-0.65). All moderately correlated parameters are bolded in **Table 5.3.**

Table 5.3 Sapp Creek correlation matrix for all samples

Sapp Creek Correlation Matrix for All Samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.59**	1.00																	
FC	0.22	**0.58**	1.00																
TN	0.41	0.17	**-0.49**	1.00															
TKN	**0.68**	0.30	-0.28	**0.72**	1.00														
TP	**0.62**	**0.71**	0.18	0.28	**0.45**	1.00													
TSS	**0.46**	**0.51**	0.31	-0.02	0.11	**0.84**	1.00												
TON	-0.33	-0.19	-0.35	**0.45**	-0.30	-0.21	-0.18	1.00											
NH4	-0.20	-0.10	-0.17	-0.05	-0.11	-0.29	-0.26	0.04	1.00										
pH	-0.43	-0.03	-0.04	**-0.57**	-0.26	-0.28	-0.18	**-0.45**	**0.45**	1.00									
SC	**0.45**	0.31	-0.04	0.29	0.32	-0.29	-0.34	0.00	0.17	-0.16	1.00								
WT(M)	0.12	-0.09	-0.32	**0.50**	0.39	-0.14	-0.17	0.23	-0.09	-0.26	0.22	1.00							
WT(E)	0.12	-0.09	-0.32	**0.50**	0.39	-0.14	-0.17	0.23	-0.09	-0.26	0.22	1.00	1.00						
DO	-0.16	-0.12	0.24	-0.24	-0.10	0.28	0.24	-0.25	-0.04	0.11	**-0.58**	**-0.74**	**-0.74**	1.00					
Turb	**0.52**	**0.63**	0.42	-0.09	0.07	**0.88**	**0.95**	-0.21	-0.28	-0.28	-0.32	-0.14	-0.14	0.23	1.00				
Hd	-0.21	0.00	-0.24	-0.07	-0.30	-0.20	-0.15	0.29	-0.19	0.21	0.22	-0.12	-0.12	-0.27	-0.20	1.00			
Alk	0.07	0.20	0.16	-0.02	0.01	-0.40	-0.34	-0.04	0.27	0.10	**0.71**	0.28	0.28	**-0.65**	-0.39	0.02	1.00		
AT	0.12	0.01	-0.14	**0.45**	0.31	-0.05	-0.05	0.24	0.00	-0.40	0.26	**0.87**	**0.87**	**-0.71**	-0.04	-0.26	0.38	1.00	
Stage	-0.14	-0.12	0.12	-0.16	-0.26	0.12	0.15	0.14	-0.30	-0.19	**-0.66**	0.16	0.16	0.16	0.28	-0.28	**-0.53**	0.10	1.00

The correlation matrix for parameters without storm samples is shown in **Table 5.4**. The differences between each parameter correlation when including storm data and not including storm data can be seen in **Appendix E**, in which large changes (>0.65) are bolded and boxed and moderate changes (0.45-0.64) are bolded. When storm samples were removed, the most noticeable difference was a stronger correlation between SC and Fe of 0.68 compared to 0.45, SC and Mn of 0.86 compared to 0.31. Mn and FC went from a positive correlation of 0.58 to a negative correlation of -0.19. Mn and TP correlation also decreased to -0.34 from 0.71, while Mn and Turbidity decreased from 0.68 to a -0.11. TSS and TN correlation went from a very weak -0.02 to a strong 0.65, while TSS and TON went from -0.18 to 0.57. Turbidity and TN also became strongly correlated changing from -0.09 to 0.67. The TP and TSS correlation also went down from 0.84 to 0.2. All moderate correlations can also be seen bolded in the table. A more in depth analysis of storm data for each parameter is found in subsequent sections.

Table 5.4 Sapp Creek Correlation Matrix not including storm samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.51**	1.00																	
FC	0.00	-0.19	1.00																
TN	**0.58**	0.03	-0.08	1.00															
TKN	**0.77**	0.17	-0.04	**0.67**	1.00														
TP	**0.46**	-0.34	0.16	**0.54**	**0.64**	1.00													
TSS	0.11	-0.12	-0.32	**0.65**	0.19	0.20	1.00												
TON	-0.24	-0.17	-0.07	0.38	-0.43	-0.15	**0.57**	1.00											
NH4	-0.11	0.22	-0.08	-0.12	-0.12	-0.31	-0.37	-0.05	1.00										
pH	**-0.47**	0.05	-0.10	**-0.68**	-0.30	-0.36	**-0.52**	**-0.47**	**0.48**	1.00									
SC	**0.68**	**0.86**	0.17	0.26	0.36	-0.03	-0.16	-0.13	0.10	-0.17	1.00								
WT(M)	0.30	0.24	-0.25	0.44	0.39	0.08	**0.58**	0.08	-0.18	-0.24	0.11	1.00							
WT(E)	0.30	0.24	-0.25	0.44	0.39	0.08	**0.58**	0.08	-0.18	-0.24	0.11	1.00	1.00						
DO	-0.34	**-0.57**	0.17	-0.14	-0.12	0.20	-0.09	-0.07	0.05	0.00	**-0.51**	**-0.69**	**-0.69**	1.00					
Turb	**0.58**	-0.11	-0.28	**0.67**	**0.49**	**0.66**	**0.58**	0.23	-0.27	**-0.58**	-0.06	0.41	0.41	-0.06	1.00				
Hd	-0.15	0.25	-0.21	-0.21	-0.36	-0.20	0.00	0.21	-0.26	0.26	0.16	-0.25	-0.25	-0.18	-0.11	1.00			
Alk	0.21	**0.57**	**0.47**	-0.06	0.05	-0.30	-0.41	-0.14	0.24	0.12	**0.68**	0.22	0.22	**-0.63**	-0.43	-0.03	1.00		
AT	0.28	0.19	-0.14	**0.50**	0.42	0.04	**0.48**	0.10	-0.06	-0.31	0.17	**0.92**	**0.92**	**-0.67**	0.26	**-0.47**	0.35	1.00	
Stage	-0.21	**-0.59**	-0.08	-0.09	-0.23	0.22	0.40	0.22	-0.28	-0.18	**-0.69**	0.22	0.22	0.15	0.46	-0.26	**-0.56**	0.10	1.00

5.4 Black Creek

Black Creek watershed is located in the Northwest area of the Tired Creek Lake watershed with a drainage area of approximately 2,226-acres above the monitoring location. A photo of the sampling site is provided in **Figure 5.9.** Surveyed cross-sections are in **Figure 5.10** and include October 2012 and November 2013 for the annual analysis of channel morphology.

The channel depth increased at 12.5 meters within the channel by 0.1 meters and both banks decreased a by about 0.1 meters in some spots, most likely due to storm events over the stream bank in February 2012.

Figure 5.9 Black Creek monitoring location photo January 2014 view towards the south

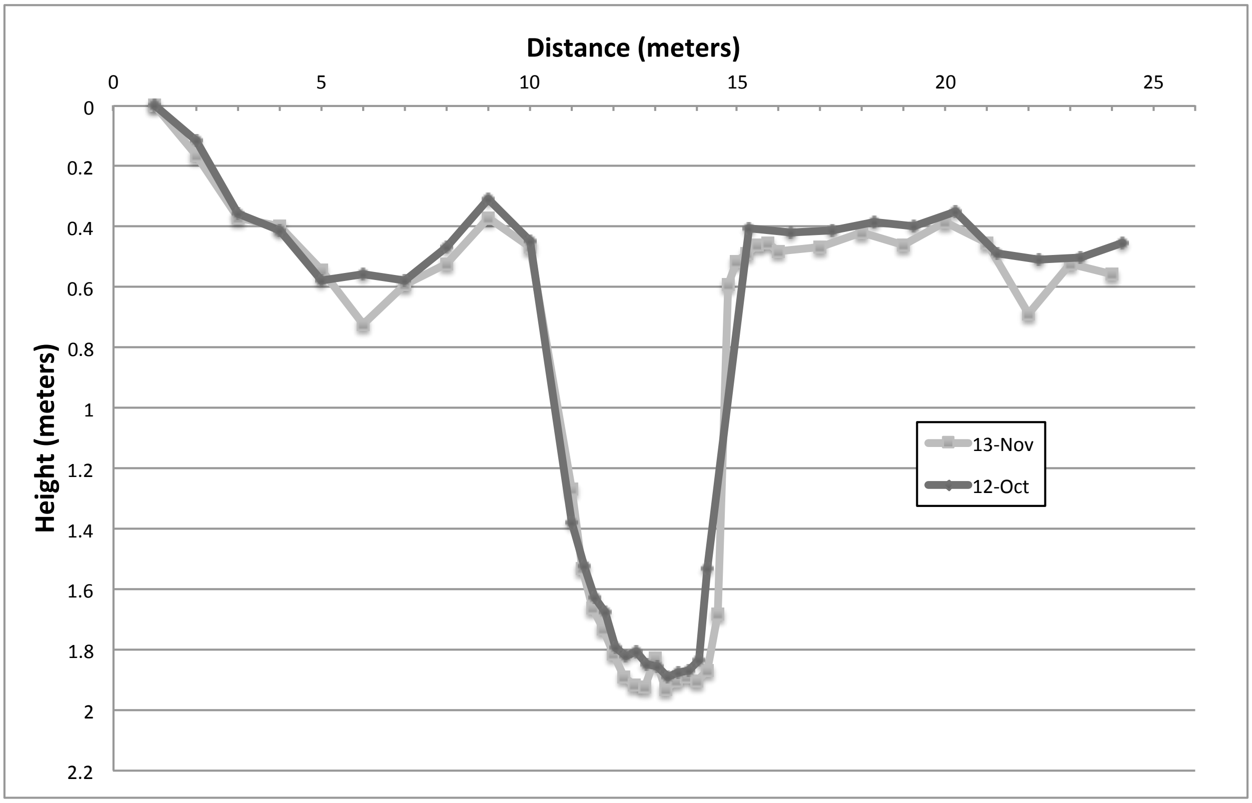

Figure 5.10 Black Creek cross-section

Similar to Sapp Creek, continuous monitoring at the site included stage, specific conductance, and temperature recorded every 15 minutes. **Figure 5.11** depicts the stage measurements over the yearlong baseline data collection with a maximum stage of 5.89 feet on August 17, 2013 and minimum stage of 0.99 feet on October 27, 2012. The stage was plotted with calculated discharge measurements based on the velocity area method at a range of stages from 1.2-3.1 feet in **Figure 5.12**. A power curve was then fit to provide an equation for the relationship between stage and discharge with an r^2=0.79.

$$Q_2 = 0.0104\ x_2^{6.0618} \qquad (2)$$

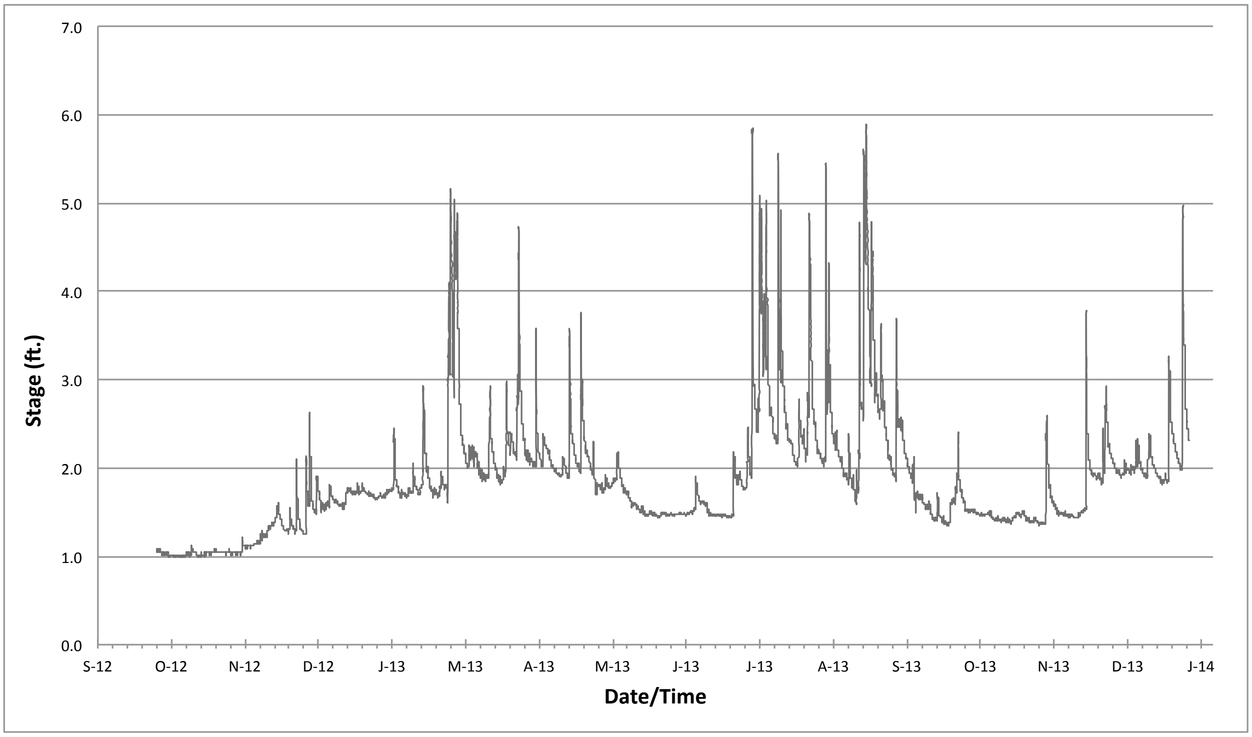

Figure 5.11 Sapp Creek stage vs. time over full baseline period

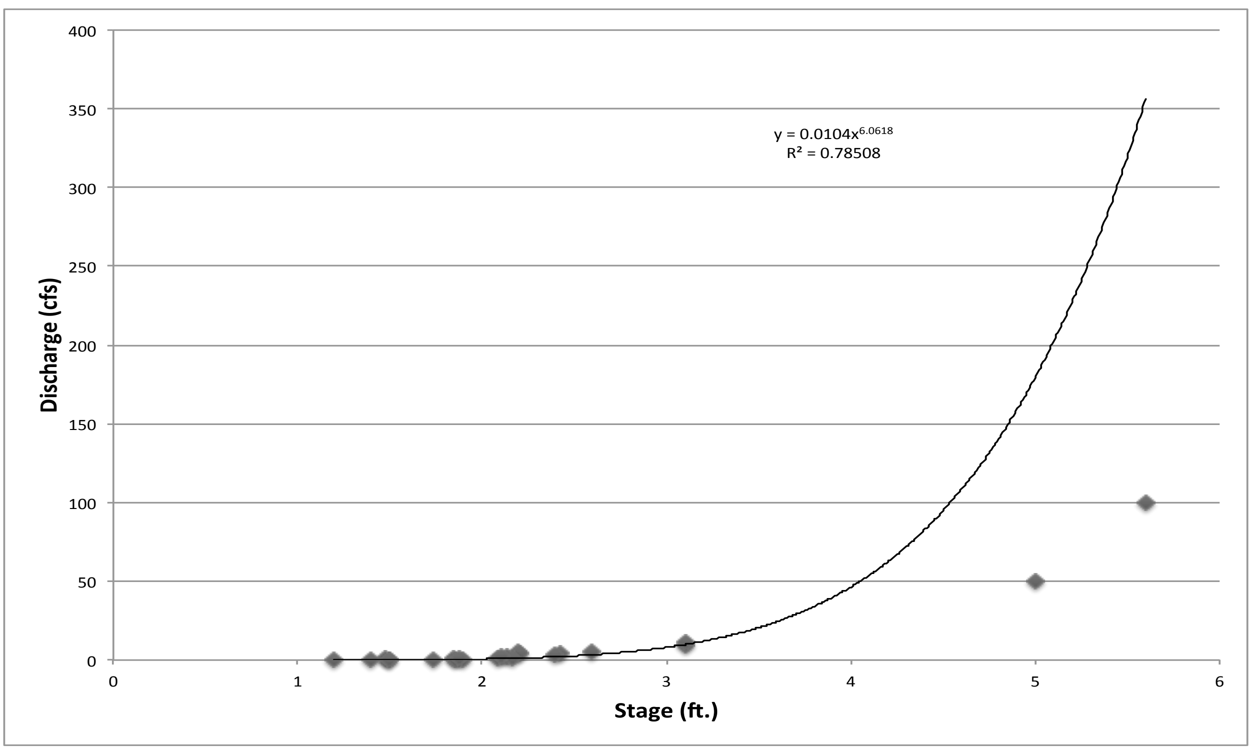

Figure 5.12 Sapp Creek Rating curve for stage vs. discharge

Using *Equation 2*, Q_2=discharge and x_2=stage, the total discharge per month was calculated and is provided in **Appendix E**. The highest monthly discharge was 51.6 mcf during August 2013 and the lowest was 36,000 ft^3 for cumulative October 2013. Cumulative discharge over the whole year October 2012-September 2013 was approximately 140 mcf and for the calendar year of 2013 total discharge was 148.6 mcf.

Monthly grab sampling and monitoring data was obtained at the site, as well as storm grab sampling conducted on January 31, 2013, February 22, 2013, and November 27, 2013. A rising stage sample was not collected on June 6 because stage did not increase enough to fill the sampler. Sampling minimums, maximums, averages, medians, variances and standard deviations are provided in **Table 5.5**. All data points can be found in **Appendix E** with the addition of sample time and weather. Sampled stage heights ranged from a minimum of 1.05 to a maximum of 3.88 feet.

Although there are no standards set by the State of Georgia or federal agencies for iron and manganese, there are recommendations based upon the literature; iron and manganese freshwater concentrations should be below 1 mg/L (REFs). Iron concentrations were above these recommendations, averaging 4.05 mg/L with a maximum of 5.5 mg/L and a minimum of 2.2 mg/L. Again, it is important to note higher iron concentrations are typically found in freshwater influenced by blackwater swamps, which hints the name Black Creek. Manganese concentrations fell within the recommendations averaging 0.3 mg/L with a maximum of 1.2 mg/L and a minimum of 0.06 mg/L.

Water quality parameters were compared to Chapter 3 of Georgia EPD standards for recreational streams. The standards specify a 4-sample geometric mean over a month long period for fecal coliform and monthly baseline analyses with mean values not to exceed 200 CFU/100 mL and maximum not to exceed values of 4,000 CFU/100 mL for recreational waters. Average fecal coliform concentration for the year totaled 719.8 CFU/100 mL with a maximum of 4,900 CFU/100 mL. It is important to note fecal coliform concentrations are highly influenced by including storm data in the averages, which is analyzed further in the subsequent section on fecal coliform.

Few states have nutrient concentration regulations or standards due to variability between waters and Georgia does not currently have any. However, the EPA has provided recommendations based on a large dataset of regional data. For Black Creek, the average total nitrogen levels were 0.97 mg/L and fell within the recommended levels with a maximum of 1 mg/L for the catchment area. Total phosphorus levels averaged .08 mg/L and fell on the high end of reference levels, but should not be a concern. Ammonia was usually below the detection limit or near zero as expected. No recommended levels were determined for TON or TKN.

Based on Georgia EPD standards, dissolved oxygen for each month did not exceed the 4 mg/L minimum limit for a single sample and did exceed the 5.0 mg/L minimum daily average with a yearly average with 5.46 mg/L. Dissolved oxygen results from October 2012, November 2012, May 2013, June 2013, and October 2013 were all below the 4 mg/L minimum standard for recreational streams developed by the Georgia EPD. The lowest reading was 1.52 mg/L in May of 2013. The low DO readings all occurred during the lowest stage readings with minimal flow. It is important to note that low DO levels are typical of a blackwater swamp, which makes up much of the Black Creek stream. Another typical feature of blackwater swamps is lower pH, however most pH measurements fell within the 6-8.5 standard unit range, the average pH being 6.29. The exception was a pH of 5.91 in May. Temperatures remained within the state guidelines less than the 5°F change per day and below a maximum of 90°F, with a minimum temperature of 45.1°F and maximum temperature of 81.8°F.   **Figure 5.13** provides a yearlong graph of temperature vs. time recorded by the CTD. Air temperature during sampling averaged 67.2°F.

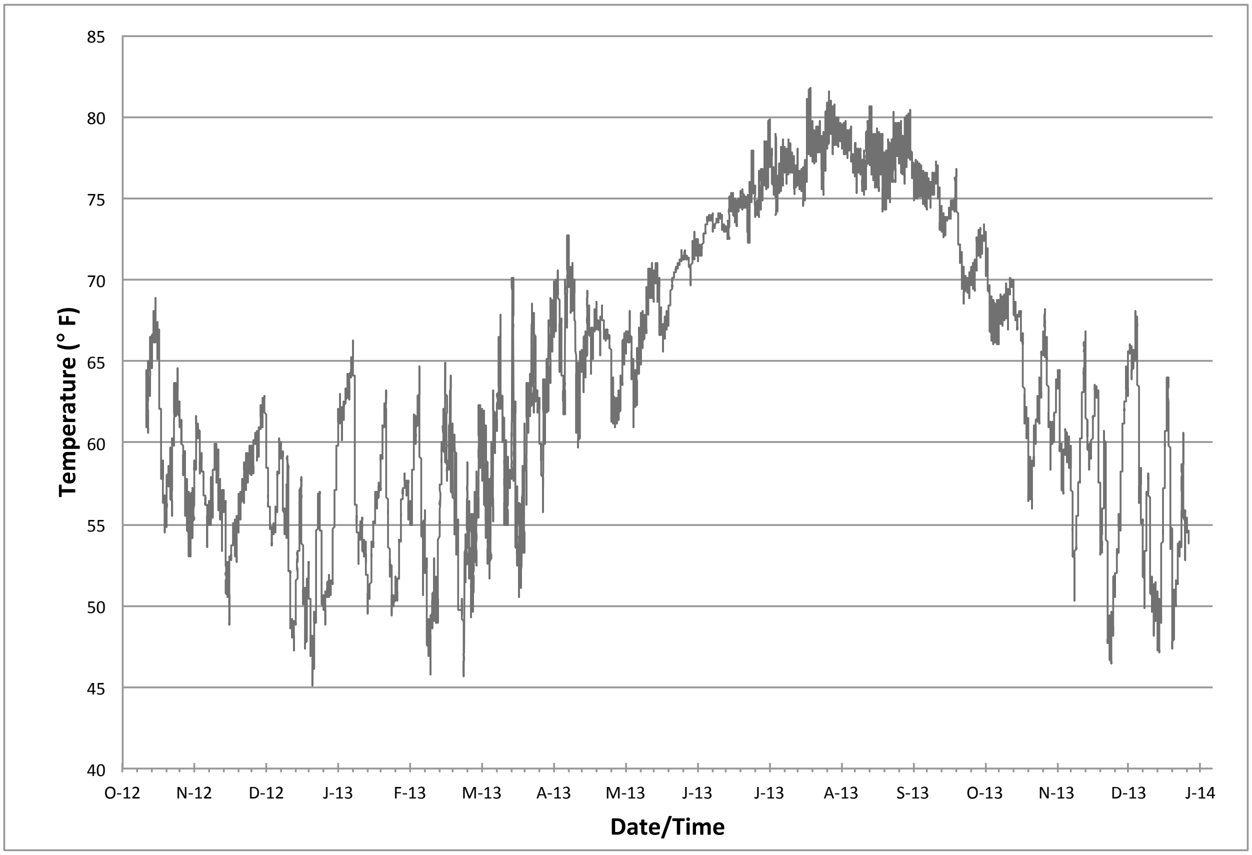

Figure 5.13 Black Creek temperature vs. time over full baseline period

Specific conductance for Black Creek over the baseline year is provided in **Figure 5.14**. Specific conductance for Black Creek averaged 78.7 μS/cm. Sediment build up on the instrument or no reading due to extremely low flows was minimal for this location. The maximum reading was 139 μS/cm during low flows in early June 2013 and a minimum of 39 μS/cm during high flows in early July 2013. The decrease in specific conductance during rain events is due to dilution from rainwater. The entire assessment period averaged 80 μS/cm.

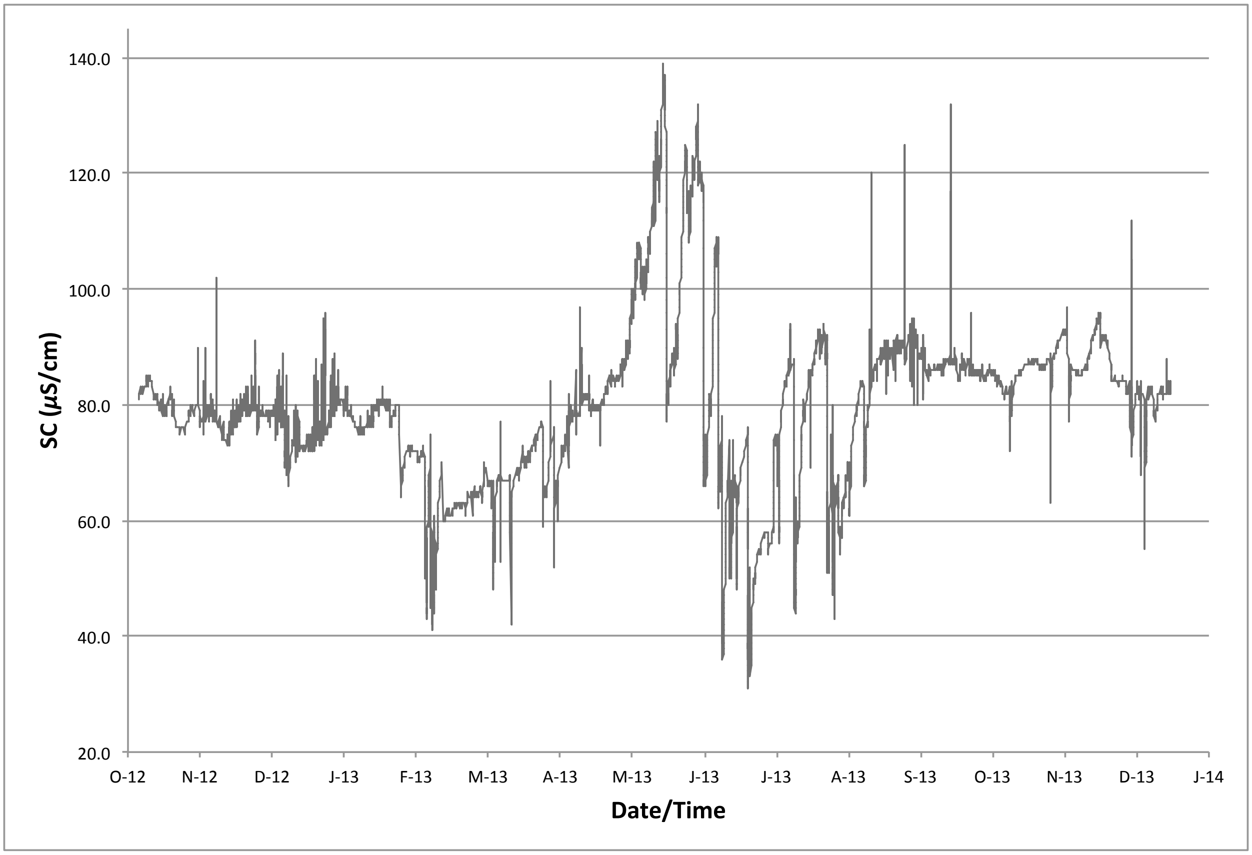

Figure 5.14 Black Creek specific conductance vs. time over full baseline period

Particulate matter parameters included turbidity and total suspended solids. There are no standards for these parameters and both tend to increase with storm events. TSS averaged 9.14 mg/L, but was highly influenced due to storm loads with a minimum during low flows in October 2013 of 2.00 mg/L and maximum of 49 mg/L during the February 2013 storm. Turbidity was also influenced by storms with an average of 13.58 NTU, which was well below a maximum of 50 NTU needed to support aquatic life. The minimum turbidity recorded was 7.01

NTU during low flows in May 2013 and a maximum of 46.1 NTU during the February 2013 storm event.

Hardness and alkalinity were also documented for each sampling event. The data showed no real need for concerns. Hardness averaged 50.67 mg/L as $CaCO_3$, which was well within the typical 0-60 mg/L range in the Southwestern Georgia region. Alkalinity averaged 22 mg/L during the watershed assessment period, which was 2 mg/L higher than the typical maximum range of the region of 20 mg/L.

Black Creek's physical habitat and benthic macroinvertebrates were assessed in November 2012. Based on the 10 habitat parameters, Black Creek scored a 163 in the suboptimal to optimal range for physical habitat, and has the best physical habitat of the sampled creeks. Based on the pebble count data, Black Creek is 93% sand, which is typical in the region. The macroinvertebrate assessment multi-metric index score totaled 42, therefore, which was in fair shape qualifying it for a B stream health rating and the lowest index score for all the creeks sampled. It was interesting that Black Creek had the best physical habitat score and the lowest index score.

Overall, the water quality within Black Creek was in fair health. The foreseeable issues in the future include potentially high fecal coliform counts, although, proper sampling methods for state standards were not performed. It is important to note the geometric mean is skewed due to storm events totaling 249 CFU/100 mL and falls below 200 CFU/100 mL when not including storm events totaling 146 CFU/100 mL. The second issue of concern for Black Creek was the low DO readings below Georgia state standards. This is due to influence from wetlands, which decrease the availability oxygen. It is also important to note the iron concentrations were higher than in other creeks. A more in depth comparison of parameters and creeks is later in the report.

For Black Creek, pH measurements were also on the low end with one not meeting state standards.

Table 5.5 Black Creek data for all samples

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
n	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Minimum	2.20	0.06	34.0	0.40	0.07	0.04	2.00
Maximum	5.50	1.20	4900	1.30	1.20	0.24	49.0
Average	4.05	0.30	720	0.97	0.61	0.08	9.14
Median	4.30	0.20	200	1.00	0.66	0.06	4.60
Variance	0.85	0.08	1875821	0.06	0.09	0.00	138
Standard Deviation	0.92	0.29	1370	0.25	0.30	0.05	11.8

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
n	15.0	15.0	15.0	15.0	15.0	15.0	14.0
Minimum	0.12	0.00	5.91	61.5	10.9	51.5	1.52
Maximum	0.75	0.05	6.92	91.7	24.4	75.9	8.51
Average	0.36	0.01	6.29	74.5	17.5	63.5	5.46
Median	0.30	0.00	6.33	74.3	16.2	61.2	6.22
Variance	0.03	0.00	0.06	90.8	22.8	73.8	4.86
Standard Deviation	0.18	0.02	0.25	9.53	4.77	8.59	2.21

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)
n	15.0	15.0	15.0	15.0	15.0
Minimum	7.01	30.0	15.0	45.0	1.05
Maximum	46.1	80.0	30.0	86.0	3.88
Average	13.6	50.7	22.0	67.2	2.02
Median	9.92	40.0	20.0	65.0	1.88
Variance	96.9	235	27.9	146	0.63
Standard Deviation	9.84	15.3	5.28	12.1	0.79

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

Correlation matrices were developed using the Data Analysis Toolpak for correlation in Microsoft Excel to relate all the parameters within the creek. The correlation coefficient term used is a Pearson's R-value, in which a positive value is a positive correlation and a negative value is an inverse correlation between the parameters. The correlation matrix for all samples and samples without storm data are located in **Table 5.6**, including correlation coefficients considered to be very weak or no relationship (0-0.2), weak (0.2-0.45), moderate (0.45-0.65), or strong (0.65-0.8) or very strong (0.8-1.0), depending on the R-value. The strongest correlation was between turbidity and TSS with a correlation coefficient of 0.98, followed by AT and WT with 0.87. More very strong correlations included TKN and TN (0.81), Alk and SC (0.79), Turbidity and Stage (0.79), Stage and TSS (0.76), and Stage and TON (-0.75). More strong correlations included and DO and Alk (-0.73), Alk and TON (0.68), SC and TP (-0.68), DO and Mn (-0.66), pH and Fe (0.66), TSS and FC (0.65), Alk and Mn (0.65), and TP and Fe (-0.65). All moderately correlated parameters are bolded in the matrix.

Table 5.6 Black Creek correlation matrix for all samples

Black Creek Correlation Matrix for All Samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.10	1.00																	
FC	0.32	0.05	1.00																
TN	-0.03	0.37	-0.39	1.00															
TKN	0.08	-0.02	-0.13	**0.81**	1.00														
TP	**-0.65**	-0.29	-0.17	0.14	0.25	1.00													
TSS	0.18	0.05	**0.65**	0.20	**0.47**	0.18	1.00												
TON	-0.16	**0.52**	-0.29	-0.02	**-0.59**	-0.29	**-0.48**	1.00											
NH4	-0.23	0.37	-0.08	0.32	0.25	0.43	-0.09	-0.10	1.00										
pH	**0.66**	-0.28	0.18	-0.09	0.21	-0.28	0.12	**-0.52**	-0.04	1.00									
SC	0.36	**0.61**	0.02	-0.24	**-0.56**	**-0.68**	**-0.46**	**0.61**	0.04	-0.08	1.00								
WT(M)	-0.41	0.06	-0.27	0.21	0.22	0.23	-0.26	-0.08	0.29	-0.43	0.03	1.00							
WT(E)	-0.41	0.06	-0.27	0.21	0.22	0.23	-0.26	-0.08	0.29	-0.43	0.03	1.00	1.00						
DO	0.10	**-0.66**	0.41	-0.33	0.15	0.12	**0.48**	**-0.69**	-0.39	**0.51**	**-0.62**	**-0.52**	**-0.52**	1.00					
Turb	0.10	-0.04	**0.62**	0.17	0.45	0.21	**0.98**	**-0.49**	-0.15	0.09	**-0.51**	-0.23	-0.23	**0.51**	1.00				
Hd	0.18	0.22	-0.20	0.27	-0.02	-0.12	0.05	**0.46**	-0.17	-0.13	-0.01	**-0.46**	**-0.46**	-0.17	-0.01	1.00			
Alk	0.10	**0.65**	-0.05	0.02	-0.39	**-0.46**	**-0.45**	**0.68**	0.14	-0.34	**0.79**	0.27	0.27	**-0.73**	**-0.51**	0.11	1.00		
AT	-0.44	0.26	-0.09	0.12	0.08	0.11	-0.13	0.03	0.25	**-0.62**	0.17	**0.87**	**0.87**	**-0.49**	-0.12	**-0.49**	0.33	1.00	
Stage	-0.01	-0.26	**0.51**	0.13	**0.58**	0.18	**0.76**	**-0.75**	-0.13	0.13	**-0.61**	0.08	0.08	**0.60**	**0.79**	-0.29	**-0.57**	0.12	1.00

The correlation matrix for parameters not including storm samples in Black Creek is shown in **Table 5.7.** The differences between each parameter correlation for including storm events and not including storm events can be seen in **Appendix E**, in which large changes (>0.65) are bolded and boxed and moderate changes (0.35-0.64) are bolded. After storm samples were removed, the most noticeable difference was a stronger correlation between TSS and TP from 0.18 to 0.76. Other notable changes in correlation included Turbidity and Fe from 0.1 to -0.58, Turbidity and Mn from -0.04 to -0.53, Turbidity and FC decreased from 0.62 to -0.23, FC and TKN increased from -0.13 to -0.56, TSS and FC from 0.18 to -0.57, and TSS and FC from 0.65 to -0.2. All other increases can be seen in the tables below. A more in depth analysis of storm samples is found in subsequent sections.

Table 5.7 Black Creek correlation matrix not including storm samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.15	1.00																	
FC	0.36	-0.15	1.00																
TN	-0.15	**0.50**	**-0.62**	1.00															
TKN	-0.22	-0.07	**-0.56**	**0.71**	1.00														
TP	**-0.72**	-0.32	-0.25	0.04	0.28	1.00													
TSS	**-0.57**	-0.32	-0.20	0.06	0.36	**0.76**	1.00												
TON	0.16	**0.62**	0.12	0.14	**-0.60**	-0.40	**-0.47**	1.00											
NH4	-0.44	**0.48**	-0.42	**0.51**	0.37	**0.52**	0.18	-0.04	1.00										
pH	**0.52**	-0.29	0.12	-0.28	0.05	-0.28	0.13	-0.41	-0.44	1.00									
SC	**0.65**	**0.73**	0.21	0.06	-0.39	**-0.73**	**-0.75**	0.60	0.03	0.02	1.00								
WT(M)	-0.26	0.07	-0.01	0.37	**0.57**	0.21	0.03	-0.36	0.40	-0.34	-0.08	1.00							
WT(E)	-0.26	0.07	-0.01	0.37	**0.57**	0.21	0.03	-0.36	0.40	-0.34	-0.08	1.00	1.00						
DO	-0.15	**-0.78**	0.00	**-0.48**	0.05	0.22	**0.51**	**-0.63**	**-0.49**	**0.57**	**-0.68**	-0.44	-0.44	1.00					
Turb	**-0.58**	**-0.53**	-0.23	-0.06	0.30	**0.66**	**0.87**	**-0.50**	-0.02	0.14	**-0.77**	0.07	0.07	**0.55**	1.00				
Hd	0.16	0.25	0.33	-0.04	**-0.50**	-0.20	-0.12	**0.69**	-0.23	-0.34	0.18	**-0.52**	**-0.52**	-0.17	-0.25	1.00			
Alk	0.31	**0.76**	0.14	0.38	-0.16	**-0.48**	**-0.60**	**0.66**	0.14	-0.40	**0.75**	0.20	0.20	**-0.78**	**-0.71**	0.29	1.00		
AT	-0.26	0.24	-0.10	0.34	**0.46**	0.07	-0.22	-0.25	**0.52**	-0.42	0.10	**0.90**	**0.90**	**-0.51**	-0.21	**-0.53**	0.32	1.00	
Stage	-0.39	**-0.48**	-0.32	0.10	**0.68**	0.28	**0.48**	**-0.78**	-0.06	0.09	**-0.65**	0.43	0.43	**0.50**	**0.59**	**-0.48**	**-0.55**	0.31	

5.5 Buss Creek

Buss Creek watershed is located in the top center of the Tired Creek Lake Watershed and approximately 3,644-acres of the drainage area above the monitoring location. A photo of the monitoring site is provided in **Figure 5.15,** with surveyed cross-sections for October 2012 and November 2013 in **Figure 5.16.** There were minimal changes in channel morphology to both channels at the locations over the year of data collection based on analysis of cross sections.

Figure 5.15 Buss Creek monitoring location January 2014 view towards the south

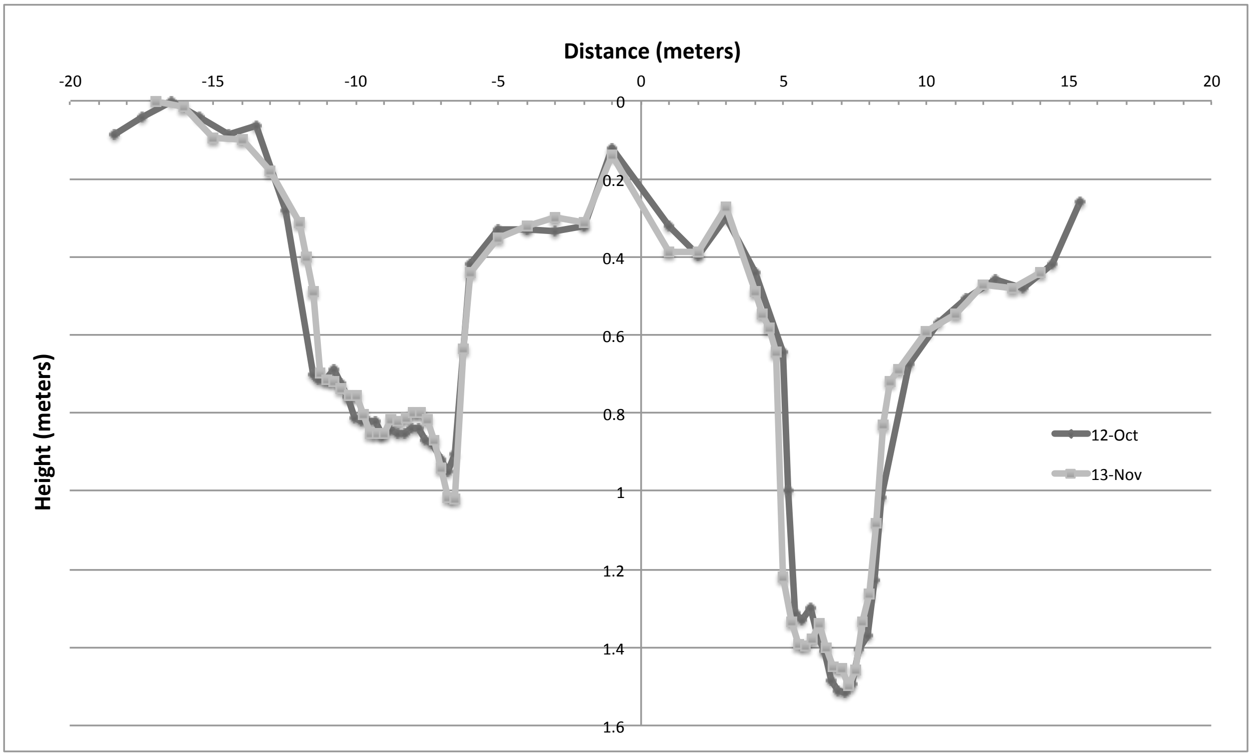

Figure 5.16 Buss Creek cross-section

Just as at the other continuous monitoring sites, monitoring at the site included stage, specific conductance, and temperature every 15 minutes with a CTD sensor. The addition of a second pressure transducer at this location was installed in February 2013 due to the presence of a 2nd channel, which contributed during high flows. A beaver dam restricted significant flow on the 2nd channel but the dam was susceptible to breaking during high flows, and the additional pressure transducer should gather the necessary data if the dam would break. Over time, the additional channel filled with soil, most likely due to the clear cutting of a forest not affiliated with the lake construction. **Figure 5.17** plots the stage over the monitoring period with a maximum stage recorded of 5.33 feet on February 26, 2013 and the minimum stage was recorded on November 2, 2012 of 1.32 feet.

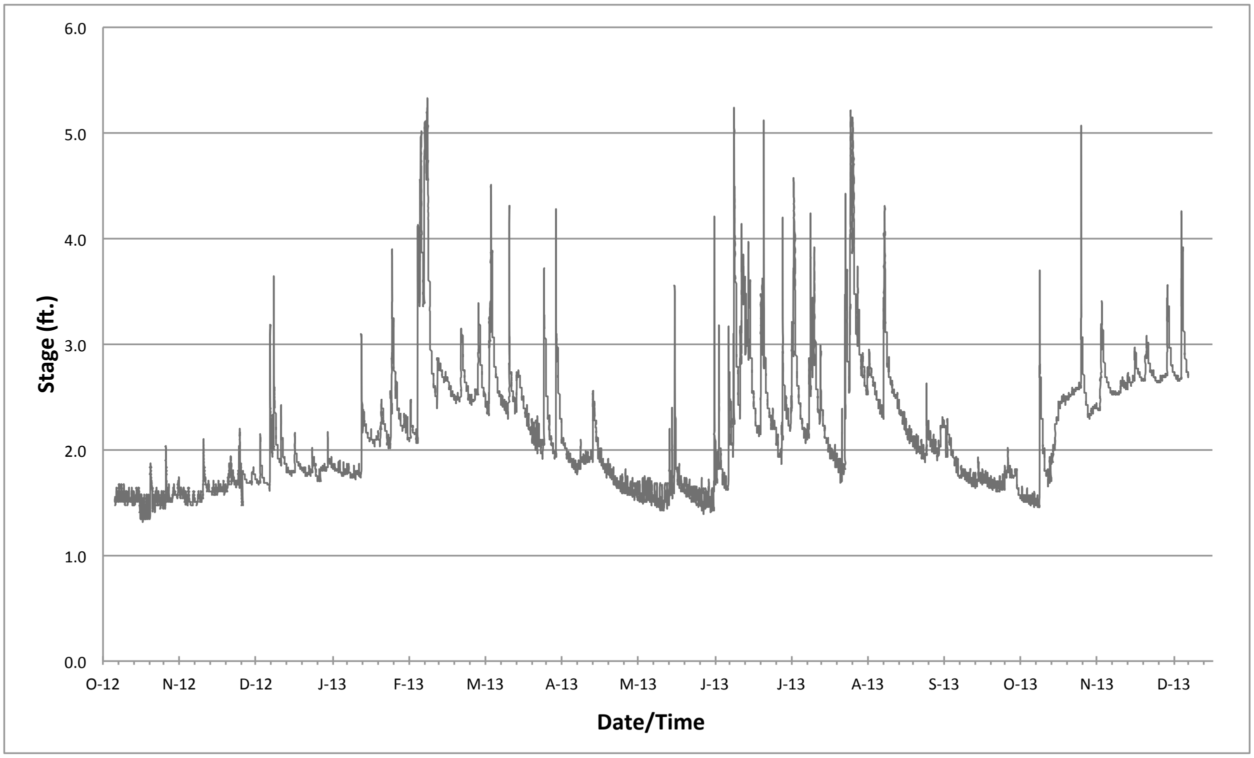

Figure 5.17 Buss Creek stage vs. time over full baseline period

The stage was plotted verses calculated discharge measurements at a range of stages from 1.5-3.4 feet. An addition of 4 and 4.5 feet stage predictions were used to flatten out the power curve for more realistic discharge measurements at higher stages. A rating curve, **Figure 5.18**, was then developed using a power curve to provide an equation for the relationship between stage and discharge with an r^2=0.68:

$$Q_3 = 0.036\ x_3^{5.0274} \qquad (3)$$

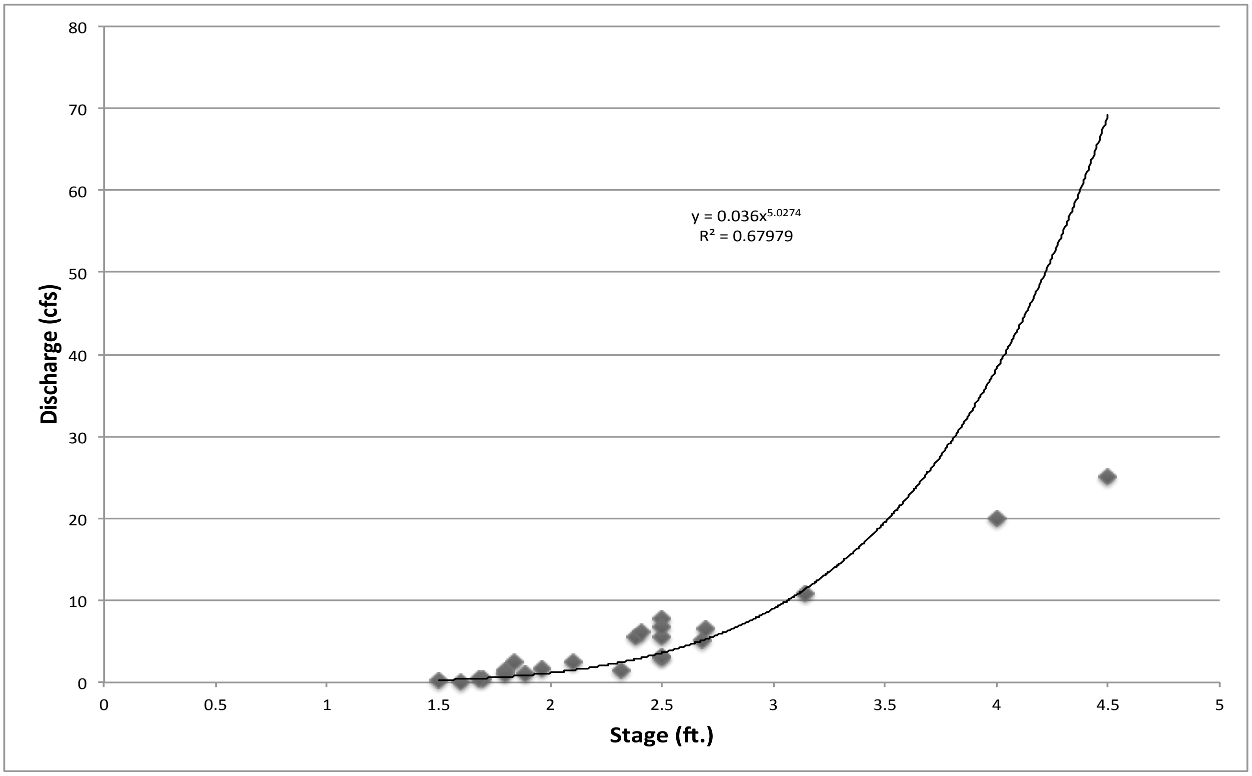

Figure 5.18 Buss Creek Rating Curve

Using *Equation 3*, Q=discharge and x=stage, the total discharge per month was calculated and is provided in **Appendix E**. The highest monthly discharge was 63 mcf in February and summer of 2013 was also a high discharge period. The lowest monthly discharges were 1.2 mcf in November 2012 and 1.3 mcf in October 2013. Cumulative discharge over the baseline period from October 2012-September 2013 was 151 mcf and 178 mcf for the calendar year of 2013.

Monthly sampling was conducted at the location with storm grab samples taken on January 31 and February 22, and November 27, 2013. A rising stage sample was collected on June 6 and a second stage height was collected on June 24th. Results of sampling included minimums, maximums, averages, medians and standard deviations, which are provided in **Table**

5.8. All data points can be found in **Appendix E** with the addition of sample time and weather. Sampled stage heights ranged from 1.51-3.14 feet.

Although there are no standards set by the State of Georgia or federal agencies for iron and manganese, there are recommendations based upon the literature; iron and manganese freshwater concentrations should be below 1 mg/L (REFs). Iron concentrations were above these recommendations averaging 3.75 mg/L with a maximum of 16 mg/L for the second rising stage storm sample June 24, 2013 and a minimum sample was 0.63 mg/L. Again, it is important to note higher iron concentrations are typically found in freshwater influenced by blackwater swamps. Manganese concentrations fell within the recommendations averaging 0.14 mg/L with a maximum of 0.28 mg/L and a minimum of 0.05 mg/L.

Few states have nutrient concentration regulations or standards due to variability between waters and Georgia does not currently have any. However, the EPA has provided recommendations based on a large dataset of regional data. For Buss Creek, the average total nitrogen levels were 4.1 mg/L, which are 3.1 mg/L above the recommended levels with a reference of 1 mg/L for the catchment area. It is important to note the average may be a bit skewed due to large concentrations in October and November 2012. The TN median was 2.1 mg/L. Total phosphorus levels averaged .26 mg/L and were above reference levels, of 0.023-0.1 mg/L. The average may be influenced by storm samples and the median was only 0.14 mg/L, which is closer to the high end of recommended levels. Ammonia concentrations averaged 0.02, with many samples at or below the detection limit near zero, as expected. No recommended levels were determined for TON or TKN.

Water quality parameters were compared to Georgia EPD standards for recreational streams. The standards specify a 4-sample geometric mean over a month long period for fecal coliform and monthly baseline analyses with the mean not to exceed 200 CFU/100 mL and a maximum value of 4,000 CFU/100 mL for recreational waters. Average fecal coliform for the year totaled 1060 CFU/100 mL with a maximum of 5,500 CFU/100 mL and a geometric mean of 580 CFU/100 mL. Again, it is important to note fecal coliform concentrations are highly influenced by including storm data in the averages, which is analyzed further in the subsequent section on fecal coliform. When storm events were removed, the geometric mean was twice the state standard totaling 401 CFU/100 mL.

Dissolved oxygen for the entire year averaged 6.47 mg/L, exceeding the 5.0 mg/L average. The lowest DO reading was 3.81 mg/L in October 2012 when flow was minimal at low stage levels and fell below the minimum DO for one sample. All pH measurements fell within the 6-8.5 standard unit range. The average pH of the stream was 6.72 during the assessment period. Temperatures remained within the state guideline for less than a 5°F change per day and below a maximum of 90°F, with a minimum temperature of 33°F and maximum temperature of 86.5°F. It is important to note these temperatures may be skewed f the temperature sensor was not fully underwater. A yearlong graph of temperature vs. time is provided in **Figure 5.19.** Water temperatures average 64.2°F during sampling events, while air temperature averaged 68.2°F.

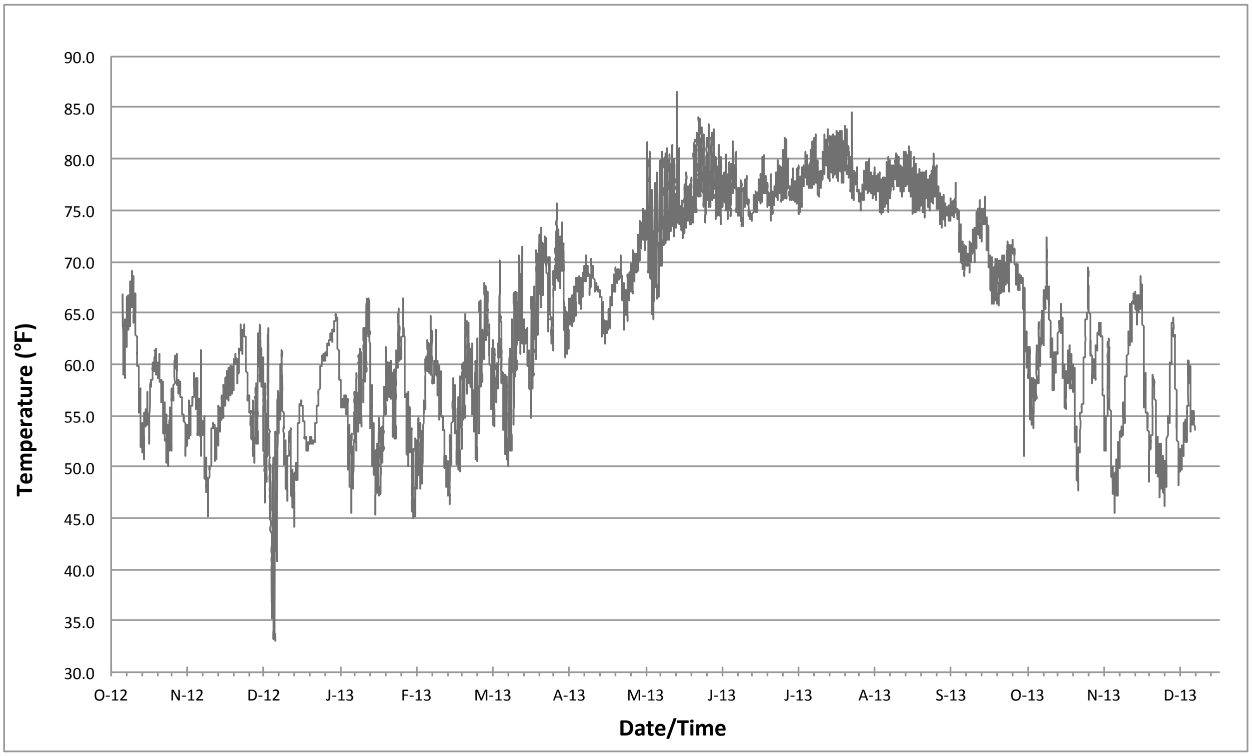

Figure 5.19 Buss Creek temperature vs. time over full baseline period

Specific conductance for the baseline year is provided in **Figure 5.20**. Specific conductance for Buss Creek over the whole monitoring period averaged 146.4 μS/cm and 121.96 μS/cm during sampling events. Data issues were developed due to sediment build up on the instrument Nov. 23-Dec. 17, Jan. 6-Jan. 24, and May 19-June 19, which were resolved by cross-referencing stage and SC. An adaptive management plan to address sediment build up is discussed in detail in the conclusion of the report.

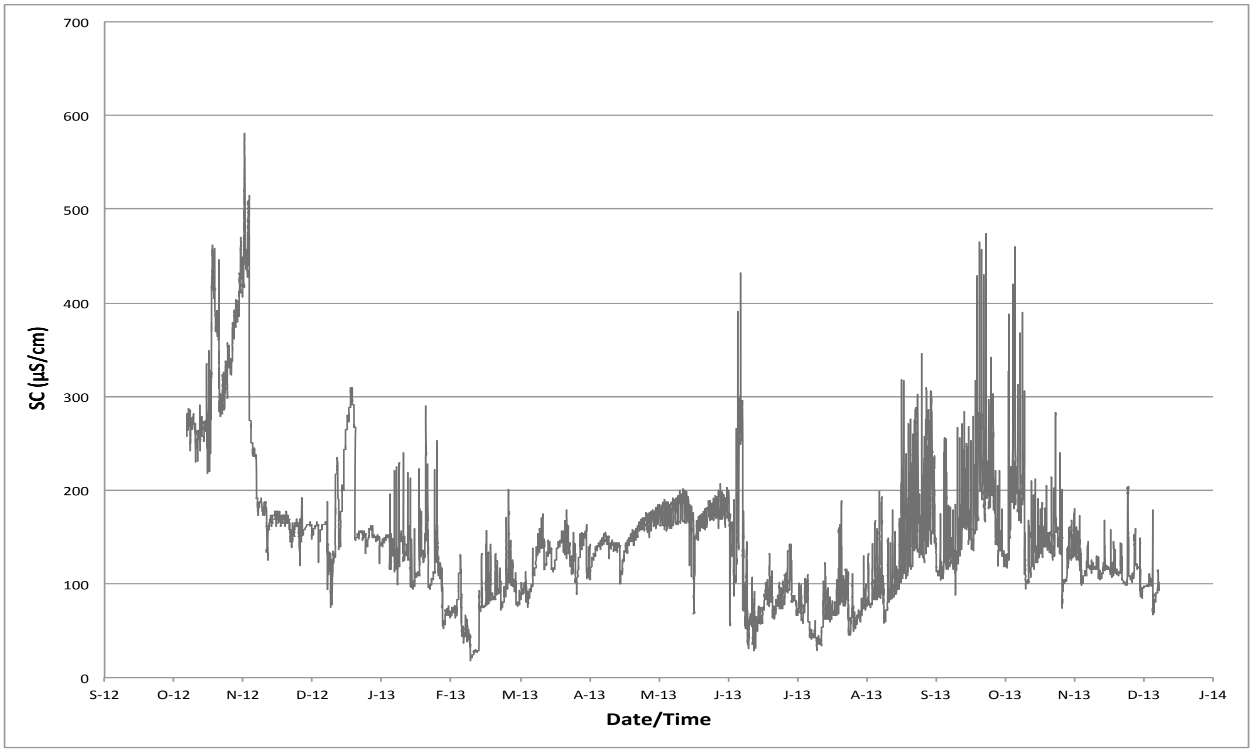

Figure 5.20 Buss Creek specific conductance vs. time over full baseline period

Particulate matter parameters included turbidity and total suspended solids. There are no standards for these parameters and both tend to increase with storm events. TSS averaged 70.32 mg/L with a median of 7.60 mg/L, but was highly influenced due to storm loads with a minimum during low flows in October 2012 of 2.00 mg/L and maximum of 840 mg/L for the June 2013 rising stage storm sample. Turbidity was also influenced by storms with an average of 23.61 NTU, which was well below a maximum of 50 NTU needed to support aquatic life. The minimum turbidity recorded was 3.68 NTU during low flows in November 2013 and a maximum of 163 NTU during the February 2013 storm event.

Hardness and alkalinity were also documented for each sampling event. The data showed no real need for concerns. Hardness averaged 74.67 mg/L as $CaCO_3$, which was just above the typical 0-60 mg/L range in the Southwestern Georgia region. Alkalinity averaged 39.3 mg/L during the monitoring period, which was 2 times than the typical maximum range of the region of 20 mg/L.

Buss Creek's physical habitat and benthic macroinvertebrates were assessed in November 2012. Based on the 10 habitat parameters, Buss Creek scored a 128.5 in the suboptimal range for physical habitat and was the lowest score for all creeks sampled. Based on the pebble count, Buss Creek is 74% sand, which is typical in the region. The macroinvertebrate assessment multi-metric index score totaled 53; therefore, it was in fair shape qualifying it for a B stream health rating.

Overall, the water quality within Buss Creek was in good health meeting almost all the state standards, but not meeting some recommendations. Nutrient levels for both TP and TN were above recommended levels to prevent eutrophication in lakes. High fecal coliform counts will be a possible issue to watch for in the future, but proper sampling methods were not performed and concentration is influenced by storm samples. Alkalinity and hardness were both above reference levels for the area, but still similar to many other areas in nearby regions.

Table 5.8 Buss Creek monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
n	17.0	17.0	15.0	17.0	17.0	17.0	17.0
Minimum	0.63	0.05	181	0.95	0.23	0.09	2.00
Maximum	16.0	0.28	5500	20.0	3.90	1.35	840
Average	3.75	0.14	1060	4.10	1.09	0.26	70.3
Median	2.90	0.14	520	2.10	0.75	0.14	7.60
Variance	12.7	0.00	2376233	25.4	0.88	0.10	40730
Standard Deviation	3.56	0.06	1542	5.04	0.94	0.32	202

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(℃)	WT(℉)	DO (mg/L)
n	17.0	17.0	15.0	15.0	15.0	15.0	14.0
Minimum	0.34	0.00	6.12	51.7	9.91	49.8	3.81
Maximum	16.0	0.10	7.35	310	25.9	78.6	8.55
Average	3.00	0.02	6.72	122	18.1	64.6	6.44
Median	1.70	0.00	6.74	94.8	15.7	60.2	6.23
Variance	17.	0.00	0.09	4835	29.9	96.	2.51
Standard Deviation	4.22	0.03	0.30	69.5	5.46	9.83	1.58

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (℉)	Stage (ft.)
n	15.0	15.0	15.0	15.0	17.0
Minimum	3.68	40.0	15.0	44.0	1.51
Maximum	163.0	140	100.0	88.0	3.14
Average	23.6	74.7	39.3	68.2	2.15
Median	9.97	60.0	30.0	65.0	1.99
Variance	1692	712	453	164	0.31
Standard Deviation	41.1	26.7	21.3	12.8	0.56

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

Correlation matrices were developed using the Data Analysis Toolpak for correlation in Microsoft Excel to relate all the parameters within the creek. The correlation coefficient term used is a Pearson's R-value, in which a positive value is a positive correlation and a negative value is an inverse correlation between the parameters. The correlation matrix for all samples is located in **Table 5.9**, including correlation coefficients considered to be very weak or no relationship (0-0.2), weak (0.2-0.45), moderate (0.45-0.65), or strong (0.65-0.8) or very strong

(0.8-1.0), depending on the R-value. The strongest correlation was between TN and TON of with a correlation coefficient equal to 0.99, closely followed by TSS and Turbidity (0.97), TP and TSS (0.96), and Fe and TP (0.93). AT and WT were also very strongly correlated. Other very strong correlations included TN and TKN (0.88), TON and TKN (0.83), Fe and Turbidity (0.82), SC and TN (0.8), SC and TKN (0.8), and TON and SC (0.79). More strong correlations included turbidity and FC (0.75), TP and FC (0.72), Alk and TON (0.72), pH an FC (0.71), Alk and SC (0.71), Alk and TN (0.69), TSS and FC (0.68), Hd and TN (0.66), Hd and TON (0.66), FC and Fe (0.66), and Hd and NH4 (0.65). All other moderate correlations are bolded in the table.

Table 5.9 Buss Creek Correlation Matrix for All Samples

Buss Creek Correlation Matrix for All Samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.54**	1.00																	
FC	**0.66**	0.26	1.00																
TN	-0.24	-0.02	-0.20	1.00															
TKN	-0.02	0.19	-0.23	**0.88**	1.00														
TP	**0.93**	**0.63**	**0.72**	0.01	0.26	1.00													
TSS	0.16	**0.59**	**0.68**	-0.01	0.31	0.36	1.00												
TON	-0.28	-0.06	-0.18	**0.99**	**0.83**	-0.04	-0.08	1.00											
NH4	-0.31	-0.38	-0.22	**0.46**	0.40	-0.27	-0.23	**0.45**	1.00										
pH	**0.58**	0.32	**0.71**	-0.12	-0.15	**0.58**	**0.46**	-0.11	0.10	1.00									
SC	-0.40	-0.01	-0.16	**0.80**	**0.80**	-0.08	-0.15	**0.79**	**0.50**	-0.14	1.00								
WT(M)	-0.18	-0.23	-0.38	-0.13	-0.07	-0.15	-0.15	-0.13	-0.41	-0.38	-0.40	1.00							
WT(E)	-0.18	-0.23	-0.38	-0.13	-0.07	-0.15	-0.15	-0.13	-0.41	-0.38	-0.40	1.00	1.00						
DO	**0.58**	0.14	**0.57**	-0.39	-0.40	0.41	0.44	-0.38	0.21	**0.54**	-0.37	**-0.63**	**-0.63**	1.00					
Turb	**0.82**	0.09	**0.75**	-0.24	-0.33	**0.96**	**0.97**	-0.21	-0.30	**0.53**	-0.19	-0.15	-0.15	**0.45**	1.00				
Hd	-0.42	0.27	0.03	**0.66**	**0.62**	-0.07	-0.24	**0.66**	**0.65**	0.27	**0.53**	-0.40	-0.40	0.09	-0.25	1.00			
Alk	-0.44	0.26	-0.20	**0.69**	**0.54**	-0.05	-0.06	**0.72**	-0.06	-0.28	**0.71**	-0.11	-0.11	**-0.57**	-0.12	0.30	1.00		
AT	-0.22	-0.22	**-0.47**	-0.03	-0.03	-0.09	-0.10	-0.03	-0.28	**-0.50**	-0.23	**0.91**	**0.91**	**-0.64**	-0.10	-0.29	0.06	1.00	
Stage	**0.61**	0.06	0.21	**-0.48**	-0.34	0.44	0.02	**-0.49**	-0.36	-0.13	**-0.48**	0.06	0.06	0.43	0.41	**-0.63**	**-0.51**	-0.02	1.00

A correlation matrix not including storm samples is shown in **Table 5.10**. The differences between each parameter correlation for including storm data and not including storm data can be seen in **Appendix E**, in which large changes (>0.65) are bolded and boxed and moderate changes (0.35-0.64) are bolded. The largest change after removing storm data was for Fe and TP, which became negatively correlated at -0.15 from a 0.93 correlation before. The Mn and stage coefficient became -0.76, hardness and FC became strongly correlated at 0.68, and the Turbidity and TP decreased to 0.28. Other notable changes included TKN and Fe (-0.68), TP and FC (0.63), Turbidity and FC (-0.15), AT and TSS (0.63), TON and Fe (-.0.83), TN and Fe (-0.81),and FC and Fe (-0.17).

Table 5.10 Buss Creek Correlation Matrix Not Including Storm Samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	-0.03	1.00																	
FC	-0.17	0.36	1.00																
TN	**-0.81**	0.04	0.07	1.00															
TKN	**-0.68**	-0.11	-0.04	**0.96**	1.00														
TP	-0.15	0.23	0.08	0.33	0.39	1.00													
TSS	0.36	-0.12	-0.32	-0.28	-0.12	0.34	1.00												
TON	**-0.83**	0.07	0.08	**1.00**	**0.95**	0.32	-0.31	1.00											
NH4	-0.01	-0.15	0.44	0.44	**0.53**	0.25	-0.10	0.41	1.00										
pH	0.30	0.39	0.31	0.03	0.00	0.32	-0.27	0.03	0.44	1.00									
SC	**-0.51**	0.06	0.11	**0.80**	**0.81**	0.19	-0.21	**0.79**	**0.48**	-0.03	1.00								
WT(M)	0.06	-0.08	**-0.65**	-0.22	-0.17	-0.01	**0.50**	-0.23	**-0.61**	-0.33	**-0.49**	1.00							
WT(E)	0.06	-0.08	**-0.65**	-0.22	-0.17	-0.01	**0.50**	-0.23	**-0.61**	-0.33	**-0.49**	1.00	1.00						
DO	0.34	-0.08	**0.62**	-0.30	-0.30	0.01	-0.20	-0.31	**0.51**	0.38	-0.32	**-0.60**	**-0.60**	1.00					
Turb	**0.48**	-0.26	-0.15	**-0.59**	**-0.50**	0.28	**0.60**	**-0.61**	-0.28	-0.12	**-0.48**	0.17	0.17	0.14	1.00				
Hd	**-0.48**	0.41	**0.68**	**0.66**	**0.60**	0.43	-0.27	**0.67**	**0.65**	**0.47**	**0.53**	**-0.48**	**-0.48**	0.23	**-0.50**	1.00			
Alk	**-0.74**	0.35	0.00	**0.71**	**0.57**	0.06	-0.34	**0.73**	-0.11	-0.20	**0.71**	-0.17	-0.17	**-0.60**	**-0.49**	0.32	1.00		
AT	-0.01	0.05	**-0.52**	-0.17	-0.13	0.01	**0.63**	-0.17	**-0.58**	-0.44	-0.38	**0.94**	**0.94**	**-0.63**	0.19	-0.37	-0.05	1.00	
Stage	0.38	**-0.76**	-0.33	**-0.55**	-0.43	-0.39	0.32	**-0.57**	-0.18	**-0.50**	**-0.54**	0.29	0.29	0.26	**0.45**	**-0.67**	**-0.69**	0.21	1.00

5.6 Nursery Creek

Nursery Creek watershed is located in the Southeast corner of the Buss Creek watershed and was added to the monitoring plan to assess its potential as a critical source area. The data was used to determine whether the site should be permanently added to the plan as a significant contribution towards discharge within the watershed during low flows. The creek drains about part of the 400-acre watershed of the Monrovia Nursery, while the rest drains into Buss Creek, just above the Buss Creek monitoring location. The nursery is currently operating at about five percent capacity or less than 20 acres due to the rough economic times, with no increase in capacity in the foreseeable future. Sources of water from the nursery are back flow from groundwater irrigation, a retention pond, and runoff from overland flow of semi-impervious surfaces including packed clay and black plastic mats. The soil is predominately a faceville sandy loam, which is a fine kaolinitic soil with slope ranging from 1-15%.

A photo of the monitoring site for Nursery Creek is provided in **Figure 5.21** and a surveyed cross-section in **Figure 5.22**. From the cross-sections, it was determined there was considerable channel morphology due to the channel deepening by 0.16 m in the center. In a visual observation there was a lot of channel morphology at the start of the creek coming from the nursery. This channel morphology may be due to the flashiness of the stream or rapid weathering of the soil due to intense fertilizer application.

Figure 5.21 Nursery Creek monitoring location photo January 2014 view towards the south

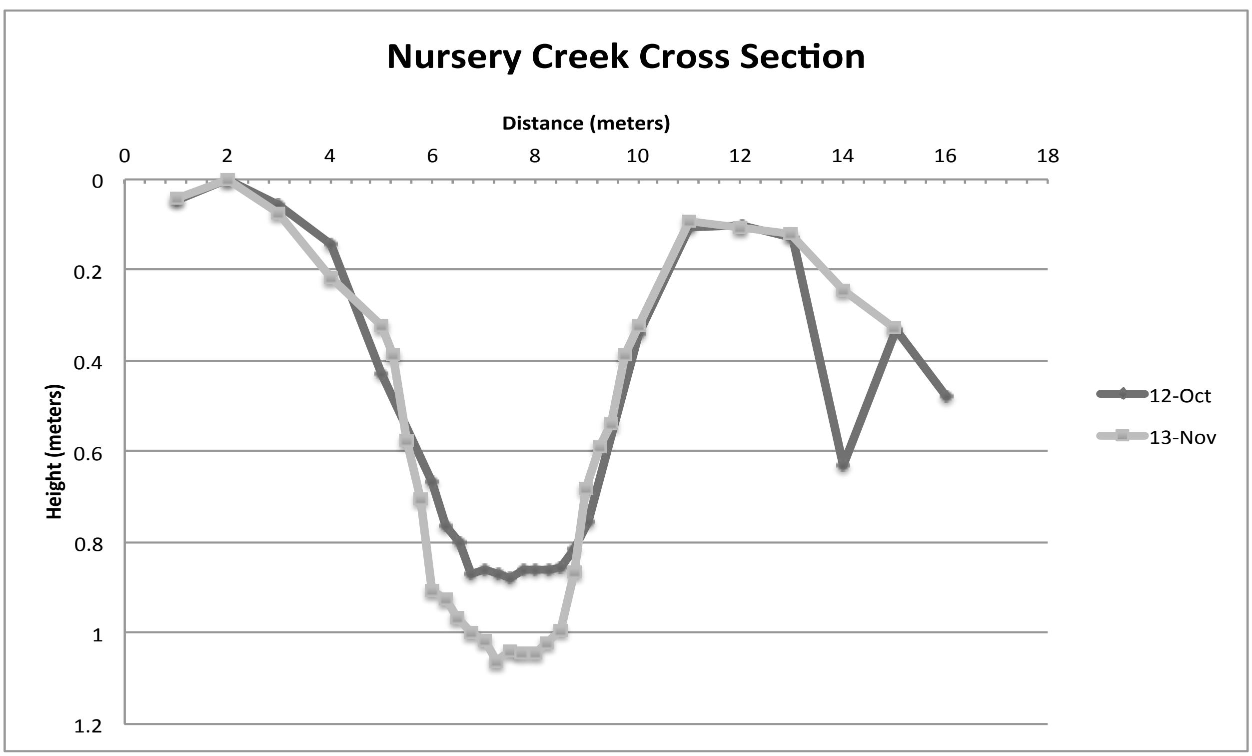

Figure 5.22 Nursery Creek cross-section

Continuous monitoring at the site included stage, specific conductance, and temperature. **Figure 5.23** depicts the stage measurements over the yearlong baseline data collection. The many peaks up and down are due to irrigation schedules. The maximum stage was 2.79 feet on November 18, 2013 and the minimum stage was 0.06 feet on August 13, 2013. The stage was plotted verses calculated discharge measurements at a range of stages from 0.12-1.1 feet. A rating curve, **Figure 5.24**, was developed using a power curve to provide an equation for the relationship between stage and discharge with an r^2=0.76:

$$Q_4 = 4.2242\ x_4^{2.8775} \qquad (4)$$

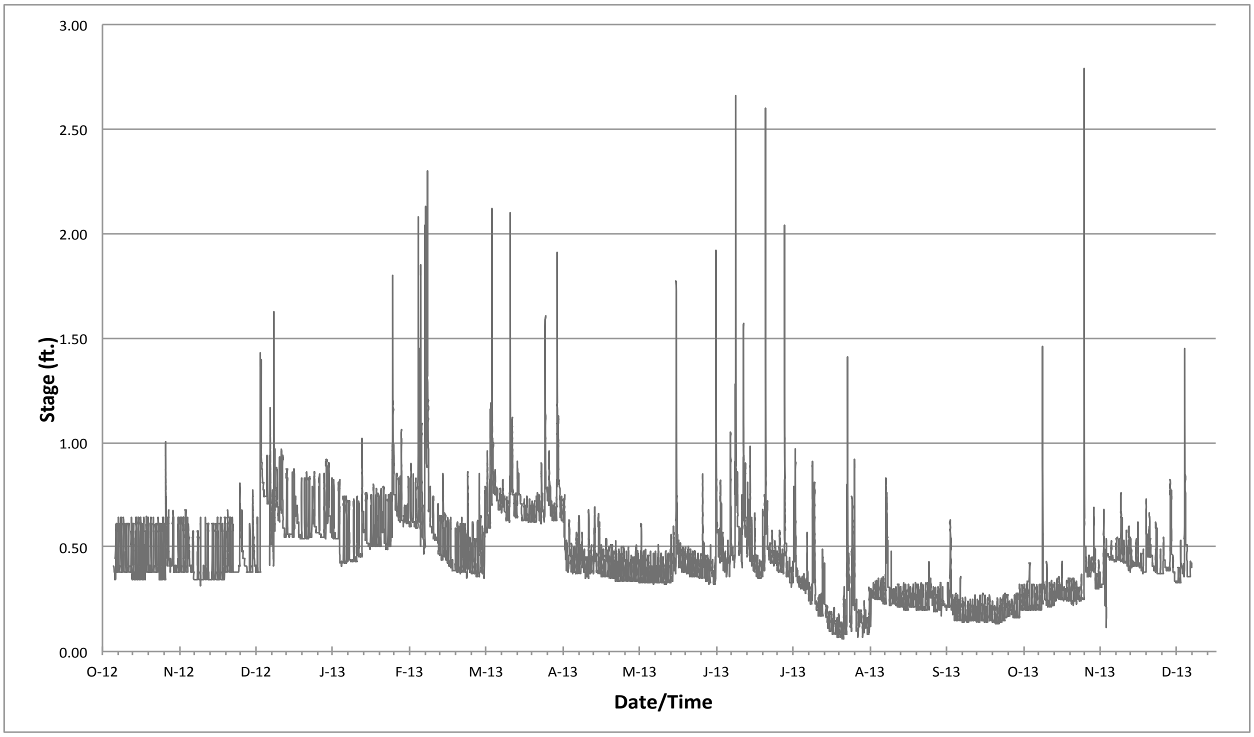

Figure 5.23 Nursery Creek stage over full baseline period

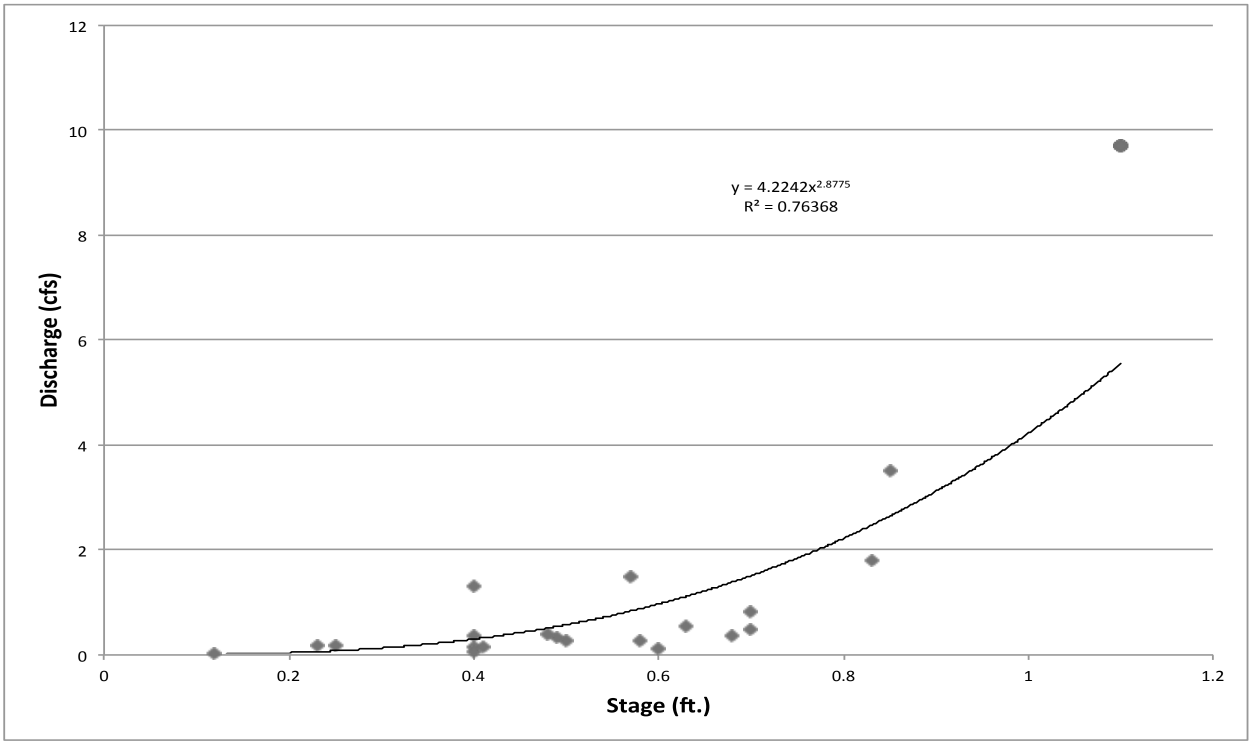

Figure 5.24 Nursery Creek Rating Curve

Using *Equation 4*, Q_4=discharge and x_4=stage, the total discharge per month was calculated and is provided in **Appendix E**. The highest monthly discharge was 6.9 mcf in March and the lowest was 0.1 mcf in October 2013. Cumulative discharge over the baseline period from October 2012-September 2012 was approximately 28.2 mcf and for the 2013 year was 26.3 mcf. It is important to note that decreasing nursery production resulted in a correlated decrease in discharge from the site from the retention pond and back flow from groundwater irrigation. The irrigation schedule impact can be seen in the small oscillations between working hours and night hours during the workweek.

Monthly sampling was conducted at the location, along with storm sampling conducted on January 31, 2013, February 22, 2013, and November 26, 2013 for grab samples and a rising stage sample obtained on June 6. Analysis of the results for all sampling events included minimums, maximums, averages, medians, variances and standard deviations provided in **Table 5.11** below. All data points can be found in **Appendix E** with the addition of sample time and weather.   Sampled stage heights ranged from 0.13-1.78 feet.

Based upon the literature, iron and manganese freshwater concentrations should be below 1 mg/L. Iron concentrations were above these recommendations averaging 1.75 mg/L with a maximum of 8.1 mg/L and a minimum of .07 mg/L. It is important to note the median concentration was 0.49 mg/L, which falls within the limit. There is no blackwater swamp influence on the catchment area. Manganese concentrations fell within the recommendations averaging 0.02 mg/L with a maximum of 0.06 mg/L and a minimum of 0.003 mg/L.

Water quality parameters were compared to Georgia EPD standards for recreational streams. The standards specify a 4-sample geometric mean over a month long period for fecal coliform and monthly baseline analyses with a mean value not to exceed 200 CFU/100 mL and a not to exceed maximum value of 4,000 CFU/100 mL for recreational waters. Average fecal coliform for the year totaled 1551 CFU/100 mL with a maximum of 16,900 CFU/100 mL and a geometric mean of 373.71 CFU/100 mL. It is important to note this number was highly influenced by including storm data in the averages, which is analyzed further in the subsequent section on fecal coliform. After removing storms, the geometric mean total fell to 296 CFU/100 mL and still above state standards.

Few states have nutrient concentration regulations or standards due to variability between waters and Georgia does not currently have any. However, the EPA has provided recommendations based on a large dataset of regional data. For Nursery Creek, the average total nitrogen levels were 3.8 mg/L and were determined to be above the recommended levels with a maximum of 1 mg/L for the catchment area. A measurement of 18 mg/L was determined in

October 2012, which was 13.7 mg/L higher than any other measurement. The median for TN was 3.0 mg/L. Total phosphorus levels averaged .18 mg/L and were above of reference levels of 0.1 mg/L, but should not be a concern with median levels of 0.11 mg/L. Ammonia concentrations averaged 0.03 mg/L, with many measurements below detection limits. No recommended levels were determined for TON or TKN.

Dissolved oxygen for the entire year averaged 8.24 mg/L, above the daily average 5.0 mg/L guidelines set by the Georgia EPD. The lowest DO reading was 4.68 mg/L in October 2013 and therefore above the minimum requirement of a single reading below 4.0 mg/L, while the highest reading came in the January 2013 storm sampling event. All pH measurements fell within the 6-8.5 standard unit range with the average pH of 7.62. Temperatures fell within the 5°F change per day, with a minimum temperature of 39.92°F, however did slightly exceed the maximum guideline of 90°F on August 5, 2013 with 90.12°F. The high temperature is most likely due to an exposed sensor to air during low flows in the shallow creek. A yearlong graph of temperature vs. time is provided in **Figure 5.25**. Air temperature during sampling averaged 68.13 °F.

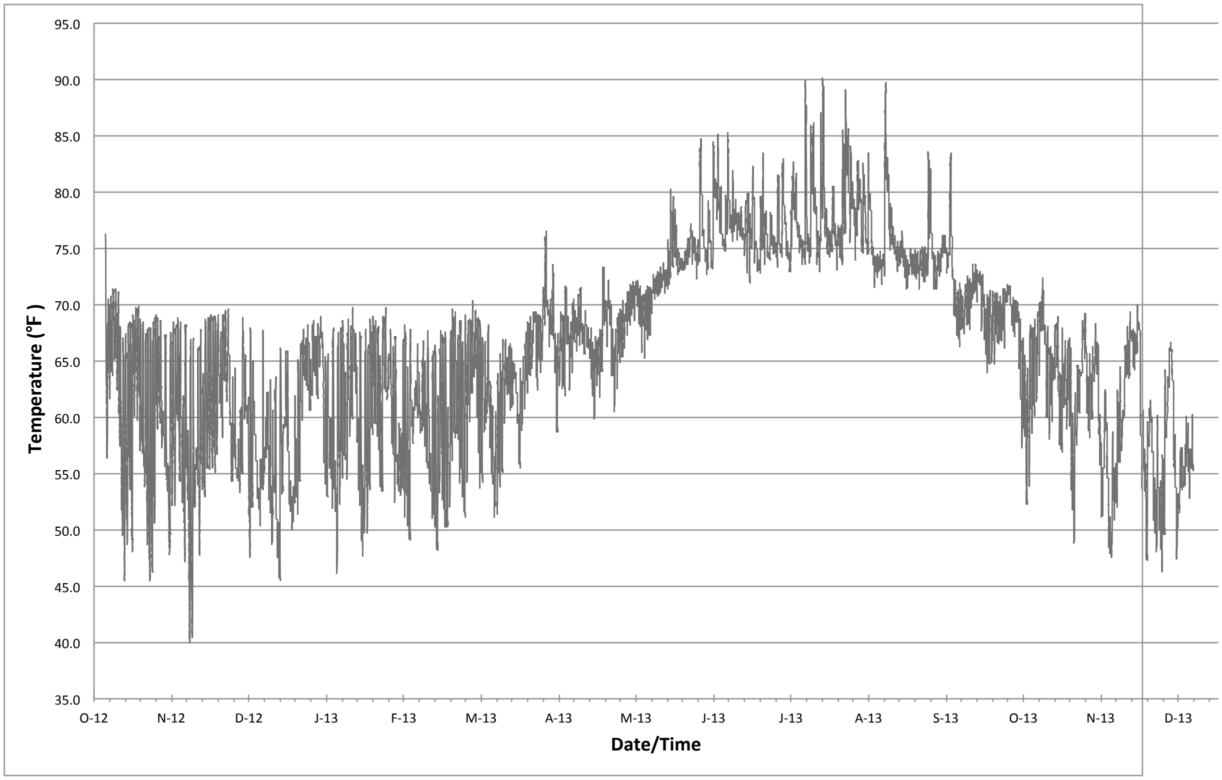

Figure 5.25 Nursery Creek temperature vs. time over full baseline period

The specific conductance for the baseline year is provided in **Figure 5.26.** Specific conductance for Nursery Creek averaged 218.75 μS/cm. Data issues were developed due to sediment build up on the instrument May 23-June 26, Sept. 2-Sept 20, and low flow events resulting in a zero reading, while other dates may be off, there is no way to know for sure. Cross-referencing SC with stage filled in data gaps. The maximum reading was 545 μS/cm and the lowest reading was 14 μS/cm. Grab sample data averaged 256.3 μS/cm with a minimum of 153.3 μS/cm and a maximum of 340.6 μS/cm.

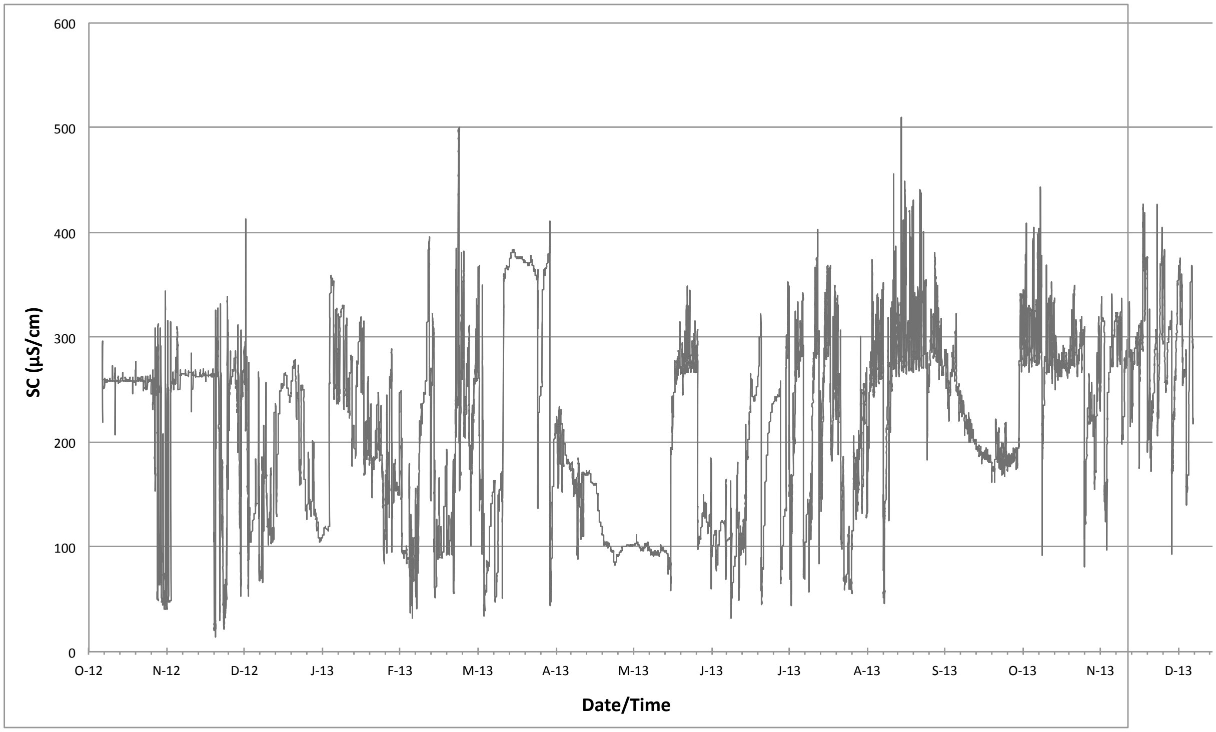

Figure 5.26 Nursery Creek specific conductance vs. time over full baseline period

Particulate matter parameters included turbidity and total suspended solids. There are no standards for these parameters and both tend to increase with storm events. TSS averaged 127.38 mg/L, but was highly influenced due to storm loads with a minimum during in January 2013 of 2.00 mg/L and maximum of 750mg/L during the November 2013 storm. Median concentration was 12.5 mg/L. Turbidity was also influenced by storms with an average of 46.76 NTU and a median of 11.4 NTU, which were both below a maximum of 50 NTU needed to support aquatic life. The minimum turbidity recorded was 5.12 NTU during low flows in May 2013 and a maximum of 251 NTU during the November 2013 storm event.

Hardness and alkalinity were also documented for each sampling event. Hardness averaged 141.33 mg/L as $CaCO_3$, which was well above the typical 0-60 mg/L range in the

Southwestern Georgia region. Alkalinity averaged 116 mg/L during the watershed assessment period, which was also much higher than the typical maximum range of the region of 20 mg/L.

Overall, the water quality within Nursery Creek was not typical of what is found in the region. Nutrient levels for both TP and TN were above recommended levels to prevent eutrophication in lakes. High fecal coliform counts will be issues to watch for in the future, but proper sampling methods were not performed and data is influenced by storm samples. Alkalinity and hardness were both well above reference levels for the area and not typical in the region, most likely due to groundwater irrigation. There is continuous channel morphology within the creek bed and flows are intermittent, having a negative impact on the aquatic system. A physical habitat and benthic macroinvertebrate assessment was not conducted due to the temporary status of the creek.

Table 5.11 Nursery Creek monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
n	16.0	16.0	15.0	16.0	16.0	16.0	16.0
Minimum	0.07	0.003	34.0	1.10	0.07	0.03	2.00
Maximum	8.10	0.06	16900	18.0	2.00	0.62	750
Average	1.75	0.02	1551	3.88	0.58	0.18	127
Median	0.49	0.01	560	3.00	0.44	0.11	12.5
Variance	8.14	0.00	18148561	15.1	0.30	0.03	61883
Standard Deviation	2.85	0.02	4260	3.89	0.55	0.16	249

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT (°C)	WT (°F)	DO (mg/L)
n	16.0	16.0	15.0	15.0	15.0	15.0	14.0
Minimum	0.90	0.00	6.83	152	14.7	58.5	4.68
Maximum	17.0	0.17	8.09	341	26.3	79.4	10.3
Average	3.28	0.03	7.62	240	19.8	67.6	8.24
Median	2.55	0.01	7.70	260	19.5	67.1	8.37
Variance	14.1	0.00	0.16	2880	13.7	44.3	2.55
Standard Deviation	3.76	0.05	0.40	53.7	3.70	6.66	1.60

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
n	15.0	15.0	15.0	15.0	16.0		
Minimum	5.12	80.0	60.0	44.0	0.13		
Maximum	251	180	195	86.0	1.78		
Average	46.8	141	116	68.1	0.63		
Median	11.4	160	120	65.0	0.55		
Variance	6636	1112	1054	158	0.18		
Standard Deviation	81.5	33.4	32.5	12.6	0.42		

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

Correlation matrices were developed using the Data Analysis Toolpak for correlation in Microsoft Excel to relate all the parameters within the creek. The correlation coefficient term used is a Pearson's R-value, in which a positive value is a positive correlation and a negative value is an inverse correlation between the parameters. The correlation matrix for all grab samples collected at Nursery Creek can be viewed in **Table 5.12**, including correlation coefficients considered to be very weak or no relationship (0-0.2), weak (0.2-0.45), moderate (0.45-0.65), or strong (0.65-0.8) or very strong (0.8-1.0), depending on the R-value.

Nursery Creek had a lot of strong correlations. The strongest correlations were turbidity and TSS with a correlation coefficient of 0.99, turbidity and Fe with a coefficient of 0.99, TN and TON with a coefficient of 0.99, Fe and TSS with a coefficient of 0.94, AT and pH with a coefficient of -0.92, SC and Alk with a coefficient of 0.9, and Fe and Mn with a coefficient of 0.9. Other very strong correlations were Hd and Alk (0.86), SC and Hd (0.86), Turbidity and TP (0.86), WT and AT (0.84), Turbidity and Mn (0.83), Stage and TSS (0.81), Turbidity and Stage (0.81), Stage and Fe (0.81), TSS and Mn (0.8), TSS and TP (0.8), TP and Mn (0.79), TP and Fe (0.78), NH4 and TN (0.78), and WT and pH (-0.79). Other strong correlations included TON and NH4 (0.77), TP and SC (-0.77), Hd and TP (0.77), Stage and TP 90.73) TSS and FC (0.72), TON and DO (-0.70), Turb and FC (0.69), pH and DO (0.69), DO and TN (-0.69), Turb and Hd (-0.68), Alk and TON (0.68), Alk and TP (-0.68), Hd and Fe (-0.66), DO and AT (-0.66) SC and Fe (-0.65), Hd and Mn (-0.65), Stage and Mn (0.65), and TKN and TP (0.65). Other moderately correlated parameters are bolded.

Table 5.12 Nursery Creek correlation matrix for all samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.90**	1.00																	
FC	**0.58**	0.44	1.00																
TN	-0.12	0.10	-0.11	1.00															
TKN	0.21	**0.51**	-0.10	0.22	1.00														
TP	**0.78**	**0.79**	0.37	-0.18	**0.65**	1.00													
TSS	**0.94**	**0.80**	**0.72**	-0.15	0.16	**0.80**	1.00												
TON	-0.16	0.03	-0.09	**0.99**	0.09	-0.28	-0.18	1.00											
NH4	-0.22	-0.10	-0.18	**0.78**	0.14	-0.22	-0.26	**0.77**	1.00										
pH	0.12	0.17	-0.10	-0.03	0.06	0.06	0.08	-0.03	**-0.45**	1.00									
SC	**-0.65**	**-0.61**	**-0.45**	**0.47**	-0.38	**-0.77**	**-0.63**	**0.54**	0.42	0.16	1.00								
WT(M)	**-0.51**	**-0.61**	-0.32	-0.16	-0.20	-0.38	**-0.51**	-0.14	0.30	**-0.79**	0.05	1.00							
WT(E)	**-0.51**	**-0.61**	-0.32	-0.16	-0.20	-0.38	**-0.51**	-0.14	0.30	**-0.79**	0.05	1.00	1.00						
DO	0.23	0.19	-0.13	**-0.69**	0.08	0.29	0.16	**-0.70**	**-0.81**	**0.69**	-0.30	-0.44	-0.44	1.00					
Turb	**0.99**	**0.83**	**0.69**	-0.18	0.28	**0.86**	**0.99**	-0.22	-0.26	0.09	**-0.67**	**-0.51**	**-0.51**	0.19	1.00				
Hd	**-0.66**	**-0.65**	**-0.49**	0.30	**-0.50**	**-0.77**	**-0.64**	0.38	0.16	0.30	**0.86**	0.01	0.01	-0.08	**-0.68**	1.00			
Alk	**-0.50**	**-0.49**	-0.29	**0.60**	-0.40	**-0.68**	**-0.46**	**0.68**	0.44	0.28	**0.90**	-0.10	-0.10	-0.33	**-0.51**	**0.86**	1.00		
AT	-0.14	-0.30	-0.06	0.02	-0.19	-0.12	-0.12	0.04	0.42	**-0.92**	-0.05	**0.84**	**0.84**	**-0.66**	-0.14	-0.10	-0.11	1.00	
Stage	**0.81**	**0.65**	0.31	-0.30	0.16	**0.73**	**0.81**	-0.32	-0.39	**0.47**	**-0.50**	**-0.62**	**-0.62**	**0.56**	**0.81**	**-0.45**	-0.36	-0.42	1.00

The correlation for parameters without storm samples is shown in **Table 5.13** below. The differences between each parameter correlation for including storm data and not including storm data can be seen in **Appendix E**, in which large changes (>0.65) are bolded and boxed and moderate changes (0.35-0.64) are bolded. The largest changes were Stage and Mn to -0.56, TP and WT to 0.68, Turbidity and WT to 0.44, TP and Stage to -0.18, Fe and WT to 0.38, and DO and Mn to -0.67. Other large changes included NH4 and Mn to 0.69, DO and TKN to -0.67 Stage and Fe down to 0.07, Hd and WT to -0.77, Alk and WT to -0.77, TSS and MN to 0.16, Turb and Mn to 0.19, WT and SC to -0.64, WT and Mn to 0.08, and AT and TKN to 0.46. Other notable changes are bolded in the table.

Table 5.13 Nursery Creek correlation matrix not including storm samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.32	1.00																	
FC	0.43	0.27	1.00																
TN	-0.19	**0.70**	0.09	1.00															
TKN	**0.62**	**0.67**	0.20	0.41	1.00														
TP	**0.83**	0.40	0.27	-0.15	**0.78**	1.00													
TSS	**0.86**	0.16	**0.67**	-0.16	0.38	**0.61**	1.00												
TON	-0.26	**0.66**	0.07	**1.00**	0.33	-0.23	-0.20	1.00											
NH4	0.15	**0.69**	-0.02	**0.80**	**0.60**	0.20	0.05	**0.77**	1.00										
pH	-0.19	-0.34	0.06	-0.03	**-0.48**	**-0.52**	0.06	0.03	-0.41	1.00									
SC	-0.40	-0.10	-0.01	**0.50**	-0.29	**-0.70**	-0.24	**0.54**	0.29	0.41	1.00								
WT(M)	0.38	0.08	-0.05	-0.33	**0.48**	**0.68**	0.10	-0.39	0.09	**-0.88**	**-0.64**	1.00							
WT(E)	0.38	0.08	-0.05	-0.33	**0.48**	**0.68**	0.10	-0.39	0.09	**-0.88**	**-0.64**	1.00	1.00						
DO	0.04	**-0.67**	0.07	**-0.80**	**-0.67**	-0.20	0.21	**-0.76**	**-0.87**	**0.61**	-0.20	-0.27	-0.27	1.00					
Turb	**0.79**	0.19	0.35	-0.15	**0.55**	**0.81**	**0.80**	-0.22	0.26	-0.29	**-0.49**	0.44	0.44	-0.04	1.00				
Hd	**-0.51**	-0.18	0.09	0.27	**-0.54**	**-0.71**	-0.28	0.34	-0.09	**0.63**	**0.76**	**-0.77**	**-0.77**	0.13	**-0.55**	1.00			
Alk	-0.37	0.09	0.17	**0.64**	-0.18	**-0.62**	-0.14	**0.69**	0.31	**0.56**	**0.89**	**-0.77**	**-0.77**	-0.19	-0.43	**0.81**	1.00		
AT	0.16	0.25	-0.03	0.01	**0.46**	**0.50**	-0.05	-0.04	0.35	**-0.95**	-0.36	**0.88**	**0.88**	**-0.60**	0.27	**-0.50**	**-0.48**	1.00	
Stage	0.07	**-0.56**	-0.03	-0.38	-0.41	-0.18	0.37	-0.35	-0.36	0.66	0.01	-0.43	-0.43	**0.69**	0.27	0.11	0.08	**-0.65**	1.00

5.7 Tired Creek

Tired Creek watershed is approximately 16,126 acres above the monitoring location just below the dam on the power line. All of the upper creeks combine to form Tired Creek. The Tired Creek monitoring location encompasses all 6,705-acres of drainage area within the Tired Creek Lake Watershed beyond what is within the other creek catchments. Photos of the monitoring site are provided in **Figure 5.27** and **Figure 5.28**.

Figure 5.27 Tired Creek monitoring location photo 1 January 2014 view towards the south

Figure 5.28 Tired Creek monitoring location photo 2 January 2014 view towards the south

A surveyed cross section is provided in **Figure 5.29** including October 2012 and November 2013. From the overlap of the cross sections, there is a bit of channel morphology that has taken place over the past year. The channel has widened on the left side by about 0.5 meters and filled in on the left side by approximately 0.24 meters. It was also noticed that the right side above the stream bank has declined by about 0.1 meters. During the February 2013 flood event, the normally 12-15 feet wide channel became approximately 400-500 feet wide and is shown in **Figure 5.30.** It is also important to note a thick clay layer (3-5 inches) that has deposited on top of the normal streambed after the start of dam construction and timbering above the monitoring location.

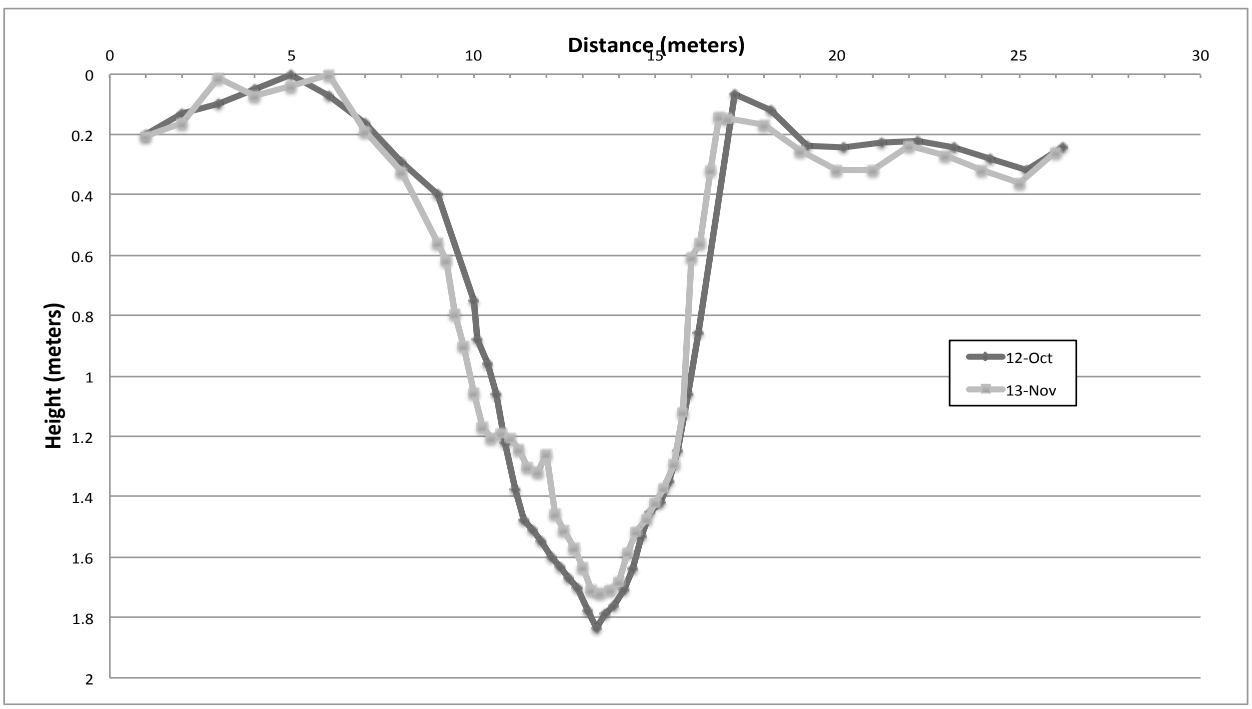

Figure 5.29 Tired Creek cross-section

Figure 5.30 Tired Creek during February flood event on February 24, 2013 view east

Similar to all the other monitoring locations, continuous monitoring at the site included stage, specific conductance, and temperature. A multi-probe for dissolved oxygen, pH, specific conductance, and temperature was also deployed at the site, but experienced multiple instrument failures that have since been attempted to resolve. Data is available upon request.

Continuous stage measurements over the yearlong baseline data collection are provided in **Figure 5.31**. A beaver dam downstream caused the increase in stage for October 2013 and November 2013 with no precipitation. A sharp drop in stage can be seen after a few rain events. The maximum stage recorded was 8.69 feet on February 25, 2013 and the minimum was 1.25 feet on June 19, 2013.

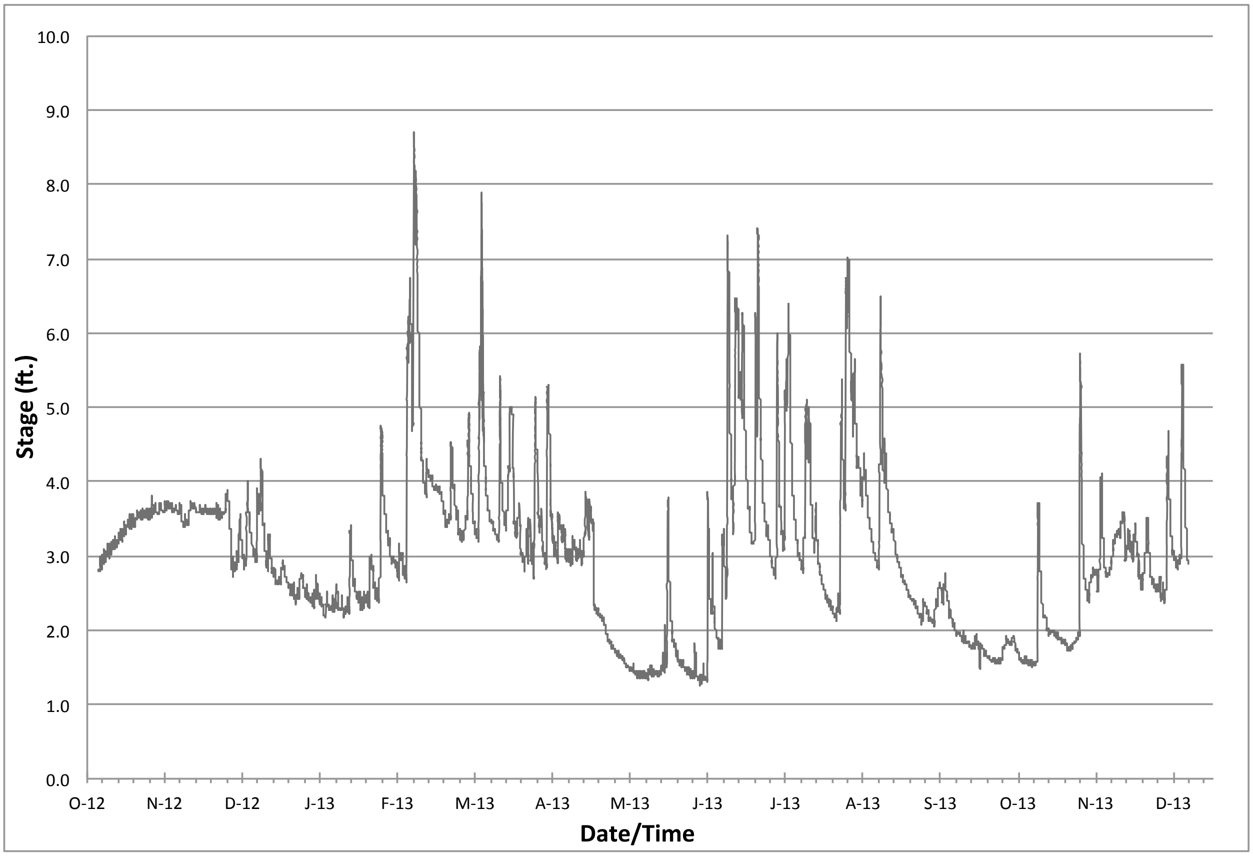

Figure 5.31 Tired Creek stage vs. time over full baseline period

The stage was plotted with calculated discharge measurements at a range of stages from 1.38-4.2 feet. A rating curve, **Figure 5.28**, was then generated to provide an equation for the relationship between stage and discharge with an r^2=0.93:

$$Q_5 = 0.107\ x_5^{4.4765} \qquad (5)$$

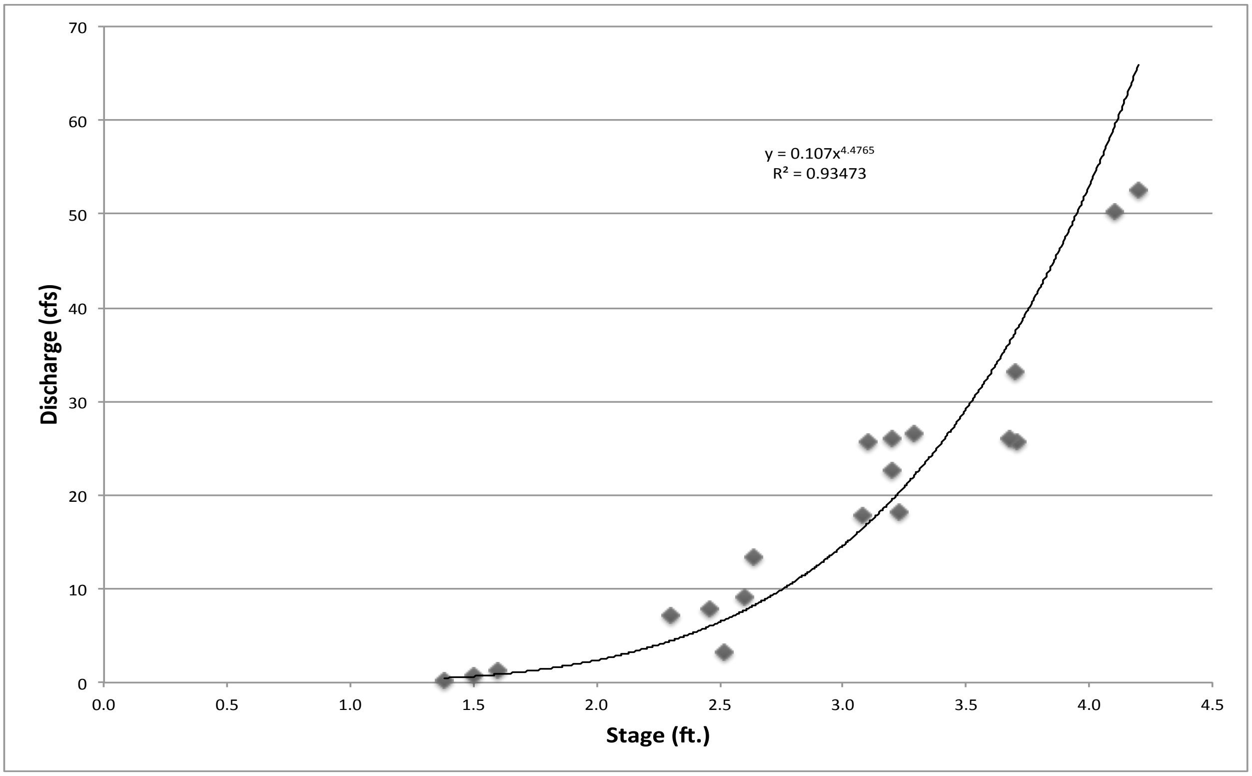

Figure 5.32 Tired Creek Rating Curve for stage vs. discharge

Using *Equation 5*, Q_5=discharge and x_5=stage, the total discharge per month was calculated and is provided in **Appendix E**. Due to drought conditions and beaver dams, October and November 2012 were considered no flow months. The highest monthly discharge was 312 mcf during July 2013 and February 2013 close with 289 mcf. The lowest discharge recorded no flows for October and November 2012. Cumulative discharge over the whole baseline year October 2012 to September 2013 was approximately 1.2 billion ft^3. The calendar year for 2013 totaled 1.22 billion ft^3. The Tired Creek flow is the total flow that will eventually fill the lake. Based on court rulings and permits, only 30% of total flow can be withheld to fill up the lake. This ruling was put in place to help protect needed water resources and aquatic ecosystems downstream.

Monthly grab sampling was conducted at the location with storm grab sampling collected on January 31, 2013, February 22, 2013, and November 26, 2013. A rising stage sample was obtained on June 6 and a second stage height on the evening of June 24. Results of sampling, **Table 5.14**, include minimums, maximums, averages, medians, variances, and standard deviations. All data points can be found in **Appendix E** with the addition of sample time and weather. Sampled stage ranged from 1.48-5.37 feet.

Based upon the literature, iron and manganese freshwater concentrations should be below 1 mg/L. Iron concentrations were above these recommendations averaging 2.89 mg/L with a maximum of 9.3 mg/L and a minimum of 1.0 mg/L. Again, it is important to note higher iron concentrations are typically found in freshwater influenced by blackwater swamps, which hints the name. Manganese concentrations fell within the recommendations averaging 0.1 mg/L with a maximum of .25 mg/L and a minimum of 0.04 mg/L.

Water quality parameters were compared to Georgia EPD standards for recreational streams. The standards specify a 4-sample geometric mean over a month long period for fecal coliform and monthly baseline analyses with a mean not to exceed 200 CFU/100 mL and a maximum value not to exceed 4,000 CFU/100 mL for recreational waters. Average fecal coliform for the year totaled 930 CFU/100 mL with a maximum of 3500 CFU/100 mL and a minimum of 220 CFU/100 mL. FC median was also only 350 CFU/100 mL and a geometric mean of 565 CFU/100 mL. After removing storms, average FC fell to 406 CFU/100 mL and the geometric mean fell to 371 CFU/100 mL. Again, It is important to note fecal coliform concentrations are highly influenced by including storm data in the averages, which is analyzed further in the subsequent section on fecal coliform.

Few states have nutrient concentration regulations or standards due to variability between waters and Georgia does not currently have any. However, the EPA has provided recommendations based on a large dataset of regional data. For Tired Creek, the average total nitrogen levels were 1.86 mg/L and were above the recommended levels with a maximum of 1 mg/L for the catchment area. The median for TN was 1.2 mg/L. Total phosphorus levels averaged .2 mg/L, which was 2 times the recommended concentration for recreational waters in the stream. Ammonia was usually below the detection limit or near zero as expected, with an average of .01 mg/L. No recommended levels were determined for TON or TKN.

Based on Georgia EPD standard, dissolved oxygen for the entire year averaged 6.72mg/L, above the 5.0 mg/L minimum daily average for aquatic life. The lowest DO reading was 4.94 mg/L and above the minimum 4.0 mg/L single sample requirement. All pH measurements fell within the 6-8.5 standard unit range with an average pH of 6.93. Temperatures remained within the state guideline within the 5°F change per day and below a maximum of 90°F, with a minimum temperature of 43.4°F and maximum temperature of 81.4°F. A yearlong graph of temperature vs. time is provided in **Figure 5.33**. Average water temperature during sampling was 63.60 °F, while average air temperature was 66.13°F.

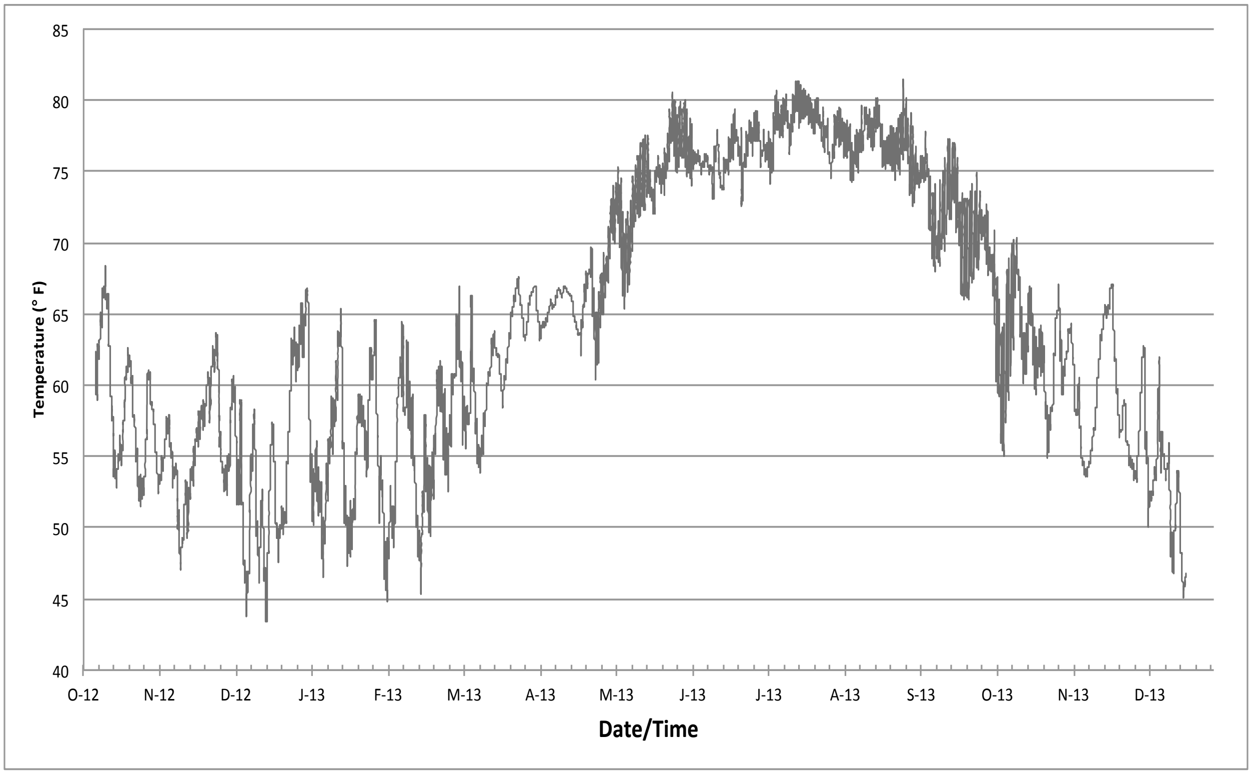

Figure 5.33 Tired Creek temperature vs. time over full baseline period

Specific conductance for the assessment period is provided in **Figure 5.34**. Specific conductance for Tired Creek averaged 122.5 μS/cm over the assessment period. Data issues were developed due to sediment build up on the instrument on a few occasions from mid-March to June. Cross-referencing stage and SC was used to fill data gaps. The maximum SC recorded was 259 μS/cm on November 6, 2012 during low flows and the minimum SC of 31 μS/cm was recorded on August 17, 2013 during high precipitation events.

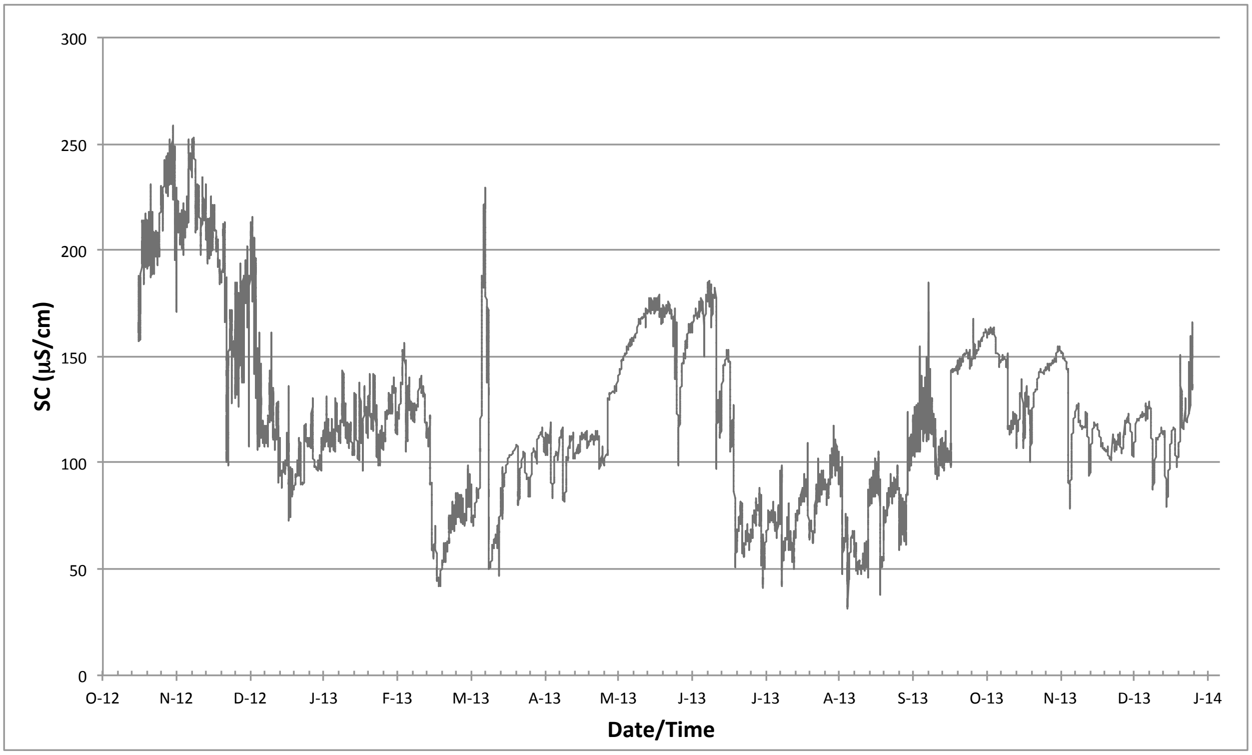

Figure 5.34 Tired Creek specific conductance vs. time over full baseline period

Particulate matter parameters included turbidity and total suspended solids. There are no standards for these parameters and both tend to increase with storm events. TSS averaged 43.38 mg/L, but was highly influenced due to storm loads with a minimum during January 2013 of 2.00 mg/L and maximum of 220 mg/L during the November 26, 2013 storm. A sample the day earlier was only 3.5 mg/L. Turbidity was also influenced by storms with an average of 36.5 NTU, which was well below a maximum of 50 NTU needed to support aquatic life. The minimum turbidity recorded was 6.2 NTU during low flows in October 2012 and a maximum of 275 NTU during the November 2013 storm event.

Hardness and alkalinity were also documented for each sampling event. The data showed no real need for concerns. Hardness averaged 63.13 mg/L as $CaCO_3$, which was just above the typical 0-60 mg/L range in the Southwestern Georgia region. Alkalinity averaged 40.67 mg/L during the watershed assessment period, which was 2 times higher than the typical maximum range of the region of 20 mg/L.

Tired Creek's physical habitat, benthic macroinvertebrates, and a fish community were assessed in November 2012. Based on the 10 habitat parameters, Tired Creek scored a 150.5 in the suboptimal range for physical habitat. Based on the pebble count, Tired Creek is 78% sand, which is typical in the region. The macroinvertebrate assessment multi-metric index score totaled 61. Therefore, it was in good shape qualifying it for an A stream health rating and the best score of the creeks assessed. The fish community survey sampled a total of 49 fish and 10 species (predominately bass), which is a low number of fish and species for the size and location of the stream and is considered poor.

Overall, the water quality within Tired Creek was in good health meeting almost all the state standards, but not meeting some recommendations. Nutrient levels for TN were above recommended levels to prevent eutrophication in lakes. High fecal coliform counts will be issues to watch for in the future, but proper sampling methods were not performed and data is influenced by storm samples. Alkalinity and hardness were both above reference levels for the area, but still similar to many other areas in nearby regions. The fish community within the creek was also poor when compared to other creeks within the region.

Table 5.14 Tired Creek monthly sampling storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
n	18.0	18.0	15.0	18.0	18.0	18.0	18.0
Minimum	1.00	0.04	220	0.70	0.19	0.06	2.00
Maximum	9.30	0.25	3500	4.40	3.00	0.73	220
Average	2.89	0.10	930	1.86	0.82	0.20	43.4
Median	2.55	0.06	350	1.20	0.64	0.12	11.5
Variance	3.57	0.00	1269532	1.72	0.53	0.04	5048
Standard Deviation	1.89	0.07	1127	1.31	0.73	0.20	71.1

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
n	18.0	18.0	16.0	16.0	16.0	16.0	15.0
Minimum	0.21	0.00	6.25	62.3	8.84	47.9	4.94
Maximum	3.60	0.08	7.55	211	24.4	75.8	8.54
Average	1.03	0.01	6.95	110	17.4	63.3	6.77
Median	0.50	0.00	7.02	96.3	15.4	59.7	6.33
Variance	1.31	0.00	0.11	2188	28.0	90.8	1.63
Standard Deviation	1.15	0.02	0.32	46.8	5.29	9.53	1.28

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)
n	16.0	16.0	16.0	16.0	18.0
Minimum	6.20	40.0	25.0	42.0	1.48
Maximum	275.0	120	80.0	81.0	5.37
Average	36.5	63.1	40.0	66.3	2.95
Median	13.7	60.0	35.0	67.50	2.99
Variance	4455	769.6	257	142.2	0.80
Standard Deviation	66.8	27.7	16.0	11.9	0.89

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

Correlation matrices were developed using the Data Analysis Toolpak for correlation in Microsoft Excel to relate all the parameters within the creek. The correlation coefficient term used is a Pearson's R-value, in which a positive value is a positive correlation and a negative value is an inverse correlation between the parameters. The Tired Creek correlation matrix for all samples data is located in **Table 5.15**, including correlation coefficients considered to be very weak or no relationship (0-0.2), weak (0.2-0.45), moderate (0.45-0.65), or strong (0.65-0.8) or very strong (0.8-1.0), depending on the R-value.

The strongest correlations were between TON and SC with a correlation coefficient of 0.98, TSS and Turbidity with a coefficient of 0.96, SC and TN with a coefficient of 0.96, TKN and TP with a coefficient of 0.95, turbidity and Fe with a coefficient of 0.94, Hd and SC with a coefficient of 0.93, Hd and TON with a coefficient of 0.92, and Hd and TN with a coefficient of 0.92. Other very strong correlations included Alk and TON (0.88), Alk and SC (0.87), Alk and Hd (0.86), Alk and TN (0.85), WT and AT (0.84), TSS and Mn (0.84), TON and TN (0.83), Mn and TP (0.81), FC and Fe (0.79), FC and Mn (0.79). More strong correlations included DO and Alk (-0.75), FC and turbidity (0.74), FC and TSS (0.70), TSS and Fe (0.68), turbidity and Mn (0.67), and NH4 and alkalinity (0.66). Other moderate correlations are bolded in the table.

Table 5.15 Tired Creek correlation matrix for all samples

Tired Creek Correlation Matrix for All Samples

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.51**	1.00																	
FC	**0.79**	**0.79**	1.00																
TN	**-0.52**	0.04	-0.25	1.00															
TKN	-0.18	**0.64**	-0.06	**0.48**	1.00														
TP	0.02	**0.81**	0.41	0.35	**0.95**	1.00													
TSS	**0.68**	**0.84**	**0.70**	-0.04	0.38	**0.57**	1.00												
TON	**-0.48**	-0.37	-0.25	**0.83**	-0.09	-0.21	-0.29	1.00											
NH4	-0.23	0.26	-0.12	0.40	0.33	0.38	0.37	0.22	1.00										
pH	-0.05	0.12	0.18	0.20	-0.34	-0.04	0.00	0.26	**0.53**	1.00									
SC	-0.47	-0.36	-0.19	**0.96**	-0.04	-0.35	-0.23	**0.98**	**0.53**	0.32	1.00								
WT(M)	-0.16	-0.18	-0.22	0.12	0.34	-0.23	-0.15	0.05	-0.24	**-0.56**	0.01	1.00							
WT(E)	-0.16	-0.18	-0.22	0.12	0.34	-0.23	-0.15	0.05	-0.24	**-0.56**	0.01	1.00	1.00						
DO	**0.55**	**0.57**	0.41	**-0.51**	0.22	**0.55**	0.41	**-0.57**	-0.36	-0.02	**-0.57**	-0.22	-0.22	1.00					
Turb	**0.94**	**0.67**	**0.74**	-0.27	-0.25	0.28	**0.96**	-0.23	-0.17	-0.02	-0.20	-0.14	-0.14	0.36	1.00				
Hd	**-0.55**	-0.42	-0.28	**0.92**	0.05	-0.36	-0.35	**0.92**	**0.62**	0.37	**0.93**	0.10	0.10	**-0.51**	-0.33	1.00			
Alk	**-0.51**	-0.42	-0.30	**0.85**	-0.08	-0.35	-0.27	**0.88**	**0.66**	0.32	**0.87**	-0.03	-0.03	**-0.75**	-0.26	**0.86**	1.00		
AT	-0.11	-0.13	-0.30	0.29	0.13	-0.25	0.05	0.27	-0.13	-0.44	0.23	**0.84**	**0.84**	**-0.46**	0.01	0.24	0.27	1.00	
Stage	0.26	0.10	0.15	-0.33	-0.12	-0.03	0.14	-0.31	0.08	-0.19	-0.40	-0.08	-0.08	0.12	0.14	-0.33	-0.04	-0.07	1.00

The correlation matrix for Tired Creek not including storm samples is shown in **Table 5.16.** The differences between each parameter correlation for including storm data and not including storm data can be seen in **Appendix E,** in which large changes (>0.65) are bolded and boxed and moderate changes (0.35-0.64) are bolded. The largest changes in correlation were between TSS and Mn changing to 0.08, Mn and TP to -0.08, and turbidity and pH to -0.7. Other notable changes included FC and Fe to -0.17, pH and TSS to -0.61, and turbidity and Mn to 0.08, turbidity and TP to 0.82, TSS and TP to 0.88. Mn and TN became negatively correlated to -0.56, and Fe and TN to -0.91.

Table 5.16 Tired Creek Correlation Matrix not including storm data

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.71**	1.00																	
FC	-0.17	0.37	1.00																
TN	**-0.91**	**-0.56**	0.21	1.00															
TKN	0.08	0.11	-0.05	0.22	1.00														
TP	0.24	-0.08	-0.40	-0.12	**0.64**	1.00													
TSS	0.42	0.08	-0.26	-0.28	**0.62**	**0.88**	1.00												
TON	**-0.94**	**-0.58**	0.22	**0.99**	0.07	-0.23	-0.39	1.00											
NH4	**-0.66**	**-0.69**	-0.04	**0.52**	-0.17	-0.05	-0.20	**0.55**	1.00										
pH	**-0.48**	-0.33	-0.14	0.29	**-0.51**	-0.39	**-0.61**	0.38	**0.60**	1.00									
SC	**-0.95**	**-0.59**	0.18	**0.97**	0.03	-0.28	-0.44	**0.99**	0.52	0.43	1.00								
WT(M)	0.14	0.42	**0.57**	0.05	**0.52**	-0.07	0.22	-0.03	-0.28	**-0.52**	-0.07	1.00							
WT(E)	0.14	0.42	**0.57**	0.05	**0.52**	-0.07	0.22	-0.03	-0.28	**-0.52**	-0.07	1.00	1.00						
DO	**0.63**	**0.48**	-0.10	**-0.47**	0.17	0.39	0.26	**-0.50**	-0.33	-0.14	**-0.52**	-0.11	-0.11	1.00					
Turb	**0.45**	0.08	-0.27	-0.29	**0.63**	**0.82**	**0.98**	-0.40	-0.29	**-0.70**	**-0.45**	0.26	0.26	0.23	1.00				
Hd	**-0.86**	**-0.55**	0.20	**0.92**	0.07	-0.30	-0.43	**0.93**	**0.61**	**0.51**	**0.94**	0.02	0.02	-0.43	**-0.45**	1.00			
Alk	**-0.89**	**-0.75**	-0.03	**0.84**	-0.07	-0.33	-0.43	**0.87**	**0.67**	0.42	**0.87**	-0.13	-0.13	**-0.73**	-0.42	**0.85**	1.00		
AT	-0.14	0.20	0.52	0.28	0.38	-0.27	0.04	0.23	-0.13	-0.39	0.21	**0.90**	**0.90**	**-0.50**	0.09	0.26	0.21	1.00	
Stage	0.24	-0.12	-0.34	-0.23	0.15	0.22	0.20	-0.27	0.10	-0.26	-0.35	-0.01	-0.01	-0.04	0.21	-0.28	0.04	0.00	1.00

5.8 Tired Creek 2

The Tired Creek 2 site is a sample only location with no continuous monitoring. The site was established to compare to the Tired Creek site for QA/QC and provide a sample point above dam construction for comparison below the construction site during construction. After dam construction started, it was determined the site is not sited sufficiently upstream to avoid impacts by dam construction. The site was chosen based on the confluence of major tributaries and any farther North would have caused additional mixing of tributaries possibly changing water quality characteristics below the sampling point. The Tired Creek location will still allow for beneficial comparison to data collected during construction, filling, and equilibrating phases of the project.

Monthly sampling was conducted at the location with storm sampling conducted on January 31, 2013 and February 22, 2013. Results of sampling including minimums, maximums, averages, medians, variances and standard deviations are provided in **Table 5.17**. All data points can be found in **Appendix E** with the addition of sample time and weather. When compared to Tired Creek, the site data proved very similar, further strengthening QA/QC. It was also helpful to see there was not a large difference between being in a forested area and in an open area on the power line like the permanent Tired Creek monitoring location.

The mean for fecal coliform should not exceed 200 CFU/100 mL or have a maximum value in excess of 4,000 CFU/100 mL for recreational waters. Average fecal coliform for the year totaled 631.2 CFU/100 mL with a maximum of 2700 CFU/100 mL. Dissolved oxygen for each month was above the 4 mg/L minimum limit for a single sample and 5.0 mg/L daily average with a yearly average of 6.92 mg/L. All pH measurements fell within the 6-8.5 standard unit range. Temperatures never changed more than 5°F per day or were above 90°F, which is within state guidelines. Continuous monitoring for temperature was not conducted at this site, but during monthly sampling the minimum temperature was 46.6°F and the maximum was 75.85°F. The average specific conductance for the site was 109.44 μS/cm.

Collected data at the site was similar to the data collected at the Tired Creek location. This was expected due to only one small tributary feeding into the creek after the Tired Creek 2 location. Once dam construction began, it was soon determined the site would not prove beneficial for comparison due to the size of dam construction and timber removal for the lake. The site was then removed from the plan, but still served as a QA/QC for Tired Creek during baseline development.

Table 5.17 Tired Creek 2 monthly sampling and storm data

	Fe (mg/L)	**Mn (mg/L)**	**FC (CFU/ 100 mL)**	**TN (mg/L)**	**TKN (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
n	13	13	13	13	13	13	13
Minimum	1.10	0.02	106	0.64	0.35	0.07	2.00
Maximum	4.30	0.23	2700	4.10	1.40	2.49	90.0
Average	2.50	0.10	631	1.70	0.60	0.30	17.7
Median	2.50	0.10	250	1.00	0.60	0.10	12.0
Variance	0.70	0.00	633840	1.40	0.10	0.40	523
Standard Deviation	0.80	0.10	796.1	1.20	0.30	0.70	22.9
	TON (mg/L)	**NH4 (mg/L)**	**pH**	**SC (μS/cm)**	**WT(°C)**	**WT(°F)**	**DO (mg/L)**
n	13	13	13	13	13	13	12
Minimum	0.16	BDL	6.27	62.6	8.12	46.6	4.99
Maximum	3.50	0.10	7.25	199	24.4	75.9	9.08
Average	1.02	0.00	6.91	109	17.3	63.1	6.92
Median	0.44	0.00	7.01	97.60	15.9	60.6	6.33
Variance	1.02	0.00	0.10	207	32.6	106	2.41
Standard Deviation	1.01	0.03	0.31	45.6	5.71	10.3	2.43
	Turb (NTU)	**Hd (mg/L)**	**Alk (mg/L)**	**AT (°F)**	**Stage (ft.)**		
n	13	13	13	13	13		
Minimum	6.62	40.0	25.0	44.0	1.48		
Maximum	78.1	120	80.0	82.0	5.37		
Average	21.2	64.6	40.0	67.6	3.18		
Median	14.3	60.0	30.0	65.0	3.30		
Variance	349	677	321	142	0.93		

Note: Fe- iron; Mn- manganese; FC- fecal coliform; TN- total nitrogen; TKN- total kjeldahl nitrogen; TP- total phosphorus; TSS- total suspended solids; TON- nitrate+nitrite; NH4- ammonium; SC- specific conductance; WT- water temperature; DO- Dissolved Oxygen; Turb- turbidity; Hd- hardness; Alk- alkalinity; AT- Air temperature; n- count

5.9 Iron

Iron samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.18** including the minimum, maximum, average, median, variance, and standard deviation. Data for each sample event can be found in **Appendix E.**

Table 5.18 Iron (mg/L) concentration statistics for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	16	16	16	17
Min	2.2	0.63	0.067	1.7	1
Max	5.5	7.1	8.1	5.6	9.3
Average	4.05	2.99	1.75	2.68	2.91
Median	4.30	2.80	0.49	2.45	2.50
Variance	0.85	2.92	8.14	1.21	3.79
Standard Deviation	0.92	1.71	2.85	1.10	1.95

For the same data, a line graph is shown in **Figure 5.35** for all sample dates over the assessment period to provide a visual comparison of the creeks. There are some clear differences between the creeks and peaks come during storm events. Black Creek consistently had the highest concentrations while nursery creek were the lowest when not sampled during a storm event. The black creek average was 1-2 mg/L above the other creeks.

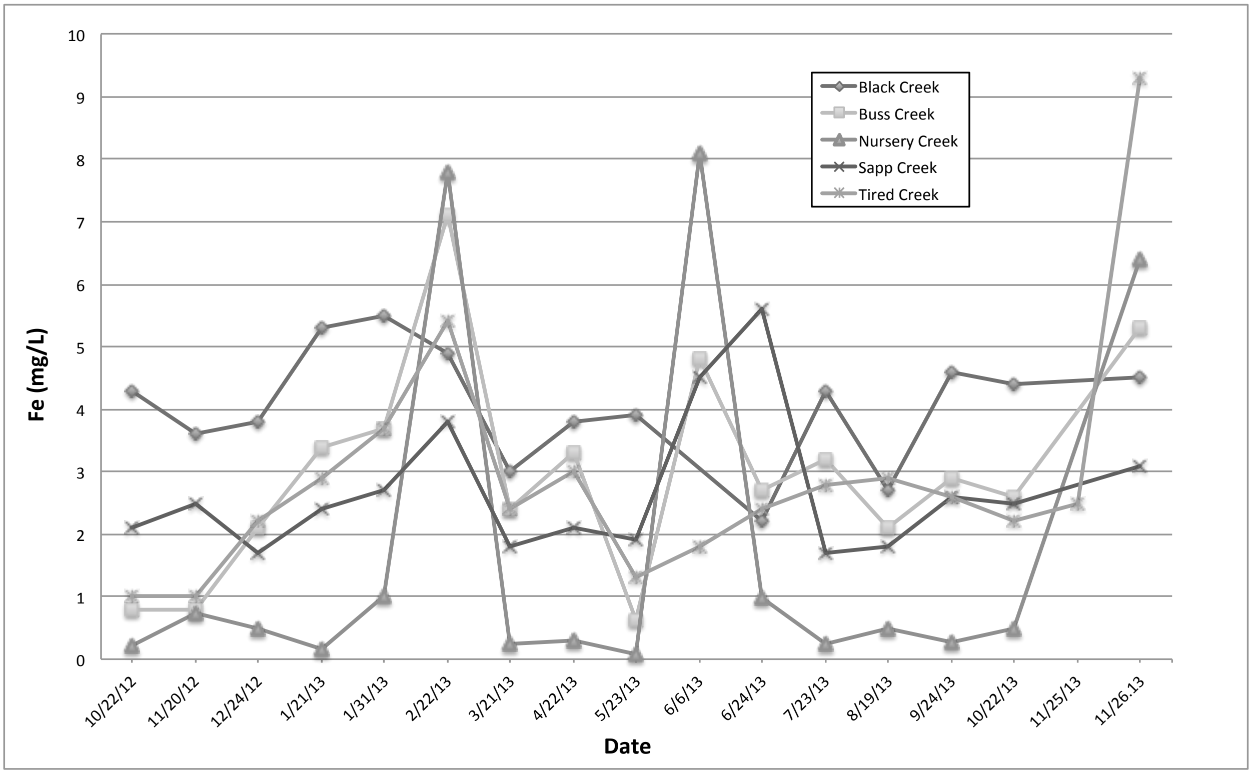

Figure 5.35 Iron concentrations for all grab sample events

A box and whisker plot for iron concentration is shown in **Figure 5.36**. The Nursery Creek median concentration fell within the recommended limit of 1 mg/L for aquatic life. The thicker line represents the recommended maximum concentration based on EPA recommendations. All the other creeks were consistently above this limit, but most likely due to influence from blackwater swamps. There were some large tails, with most in an increasing direction.

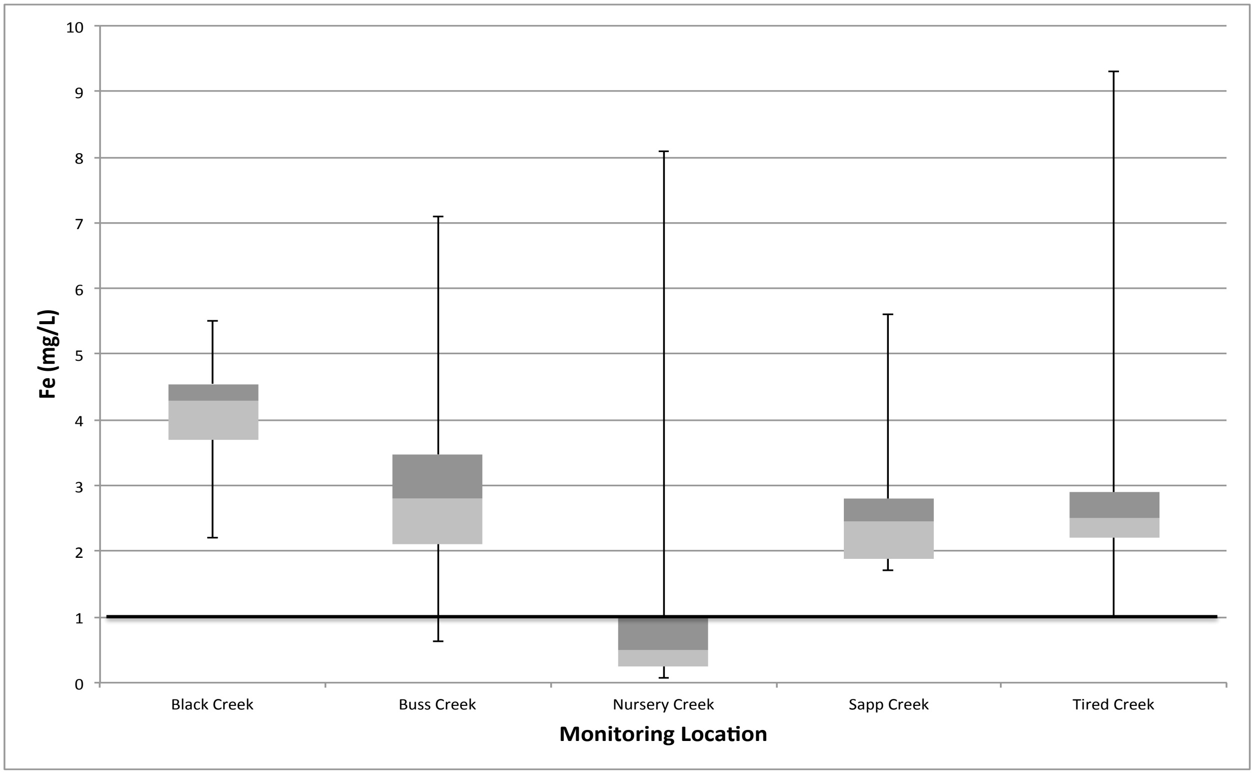

Figure 5.36 Iron box and whisker plot for each location

An ANOVA was performed to see if there were any differences in the creeks (**Appendix E)**. It was hypothesized that all the creeks were the same. Since the F-critical was below F-ratio and the p-value was below 0.05, it was determined there was a difference between the means. A Tukey test (**Appendix E)**, was applied and a 95% confidence interval +/-1.95 was determined. Based on the analysis, a significant difference was determined between Nursery Creek and Black Creek with a difference in means of 2.31 mg/L.

Based on the correlation matrix for Iron in **Table 5.19**, it was determined Nursery Creek and Buss Creek were highly correlated with a correlation coefficient of 0.8. Tired Creek also had a strong correlation with Buss Creek of 0.72. Moderate correlations were Nursery Creek and

Sapp Creek with 0.58 and Nursery Creek and Tired Creek with 0.56. All Black creek correlations were relatively weak.

Table 5.19 Iron correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.42	1.00			
Nursery Creek	0.27	**0.80**	1.00		
Sapp Creek	-0.18	**0.47**	**0.58**	1.00	
Tired Creek	0.30	**0.72**	**0.56**	0.18	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** consists of all the data without storm events including statistical analysis for minimum, maximum, average, median, variance, and standard deviation. **Table 5.20** lists the percent differences after taking storm events out of the data. The minimums did not change for any creeks, but maximums decreased by over 50% for all creeks other than Sapp Creek and the Black Creek change was minimal. Averages also decreased for all the creeks, with Nursery (-78%), Buss (-25%), and Tired Creek (-23%) being the largest declines.

Table 5.20 Iron (mg/L) percent difference not including storm events

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Fe[1]	**Fe[2]**	**%**	**Fe[1]**	**Fe[2]**	**%**	**Fe[1]**	**Fe[2]**	**%**	**Fe[1]**	**Fe[2]**	**%**	**Fe[1]**	**Fe[2]**	**%**
n	15.0	12	-	16.0	12	-	16.0	12	-	16.0	12	-	17.0	13	-
Min	2.2	2.2	**0**	0.6	0.63	**0**	0.1	0.07	**0**	1.7	1.7	**0**	1.0	1	**0**
Max	5.5	5.3	**-4**	7.1	3.4	**-52**	8.1	0.99	**-88**	5.6	5.6	**0**	9.3	3	**-68**
Avg.	4.1	3.83	**-6**	3.0	2.24	**-25**	1.7	0.39	**-78**	2.7	2.39	**-11**	2.9	2.25	**-23**
Med.	4.3	3.85	**-10**	2.8	2.50	**-11**	0.5	0.28	**-44**	2.5	2.10	**-14**	2.5	2.40	**-4**
Var.	0.8	0.75	**-12**	2.9	1.01	**-66**	8.1	0.07	**-99**	1.2	1.13	**-7**	3.8	0.50	**-87**
St. Dev.	0.9	0.86	**-6**	1.7	1.00	**-41**	2.9	0.26	**-91**	1.1	1.06	**-3**	1.9	0.71	**-64**

Note: Fe[1] = all samples; Fe[2] = sample not including storm data; % = percent difference

A second ANOVA, in **Appendix E,** was then conducted for the data not including storm samples. Again, the hypothesis was all the means were the same. The analysis determined F-critical was a much smaller than f-ratio and the p-value was very far below 0.05. This lead to a Tukey test, **Appendix E**, in which, a 95% confidence interval was found to be 1.02. The much smaller confidence interval provided more differences between the creeks than with the storms included. Just as before removing storm samples, the largest difference was between Black Creek and Nursery Creek with a difference of 3.44. Black Creek was determined to be different than all the other creeks, while Nursery Creek was also different than all the other creeks.

A correlation matrix was developed for data not including the storms in **Table 5.21**. The strongest correlation was between Buss Creek and Tired Creek with 0.92. There was also a strong correlation of 0.71 between Nursery Creek and Sapp Creek, which increased from 0.58

after excluding storm samples. Nursery Creek also had a negative correlation of -0.65 with Black Creek, which further proves their differences.

Table 5.21 Iron (mg/L) Correlation not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.17	1.00			
Nursery Creek	**-0.65**	-0.02	1.00		
Sapp Creek	-0.43	0.16	**0.72**	1.00	
Tired Creek	-0.01	**0.92**	-0.05	0.02	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.22.** When compared to non-storm data, there were some noticeable differences. Minimums were all much higher than during storm events with Nursery creek 1393% higher and Buss Creek 487% higher. Maximum concentration for Buss Creek (108%), Nursery Creek (718%), and Tired Creek (210%) were also much higher than non-storm data. Averages for these 3 creeks also increased substantially, along with smaller increases in the other two creeks.

Table 5.22 Iron (mg/L) percent difference non-storm events vs. storm events

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Fe²	**Fe³**	**%**	**Fe²**	**Fe³**	**%**	**Fe²**	**Fe³**	**%**	**Fe²**	**Fe³**	**%**	**Fe²**	**Fe³**	**%**
n	12	3	-	12	4	-	12	4	-	12	4	-	13	4	-
Min.	2.2	4.5	**105**	0.63	3.7	**487**	0.07	1.0	**1393**	1.7	2.7	**59**	1	1.8	**80**
Max.	5.3	5.5	**4**	3.4	7.1	**109**	0.99	8.1	**718**	5.6	4.5	**-20**	3	9.3	**210**
Avg.	3.83	5.0	**30**	2.24	5.2	**133**	0.39	5.8	**1398**	2.39	3.5	**47**	2.25	5.1	**125**
Med.	3.85	4.9	**27**	2.50	5.1	**102**	0.28	7.1	**2482**	2.10	3.5	**64**	2.40	4.6	**90**
Var.	0.75	0.3	**-66**	1.01	2.0	**100**	0.07	10.9	**15477**	1.13	0.6	**-44**	0.50	10.2	**1947**
St. Dev.	0.86	0.5	**-42**	1.00	1.4	**41**	0.26	3.3	**1148**	1.06	0.8	**-25**	0.71	3.2	**352**

Note: Fe^2 = not including storm data; Fe^3 = storm data; % = percent difference

Correlations between creeks for iron concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, iron was strongly correlated to TKN (0.68), moderately strongly correlated to TP (0.62), Mn (0.59), Turb (0.52), and moderately correlated to TSS (0.46), and SC (0.45). For Black Creek, Iron was strongly correlated to pH (0.66) and TP (-0.65). For Buss Creek, iron was strongly correlated to TP (0.93), Turbidity (0.82), FC (0.66), and moderately strongly correlated to Stage (0.61), pH (0.58), DO (0.58), and Mn (0.54). For Nursery Creek, iron was strongly correlated to TSS (0.86), TP (0.83), and Turb (0.79), and moderately correlated to TKN (0.62) and Hd (-0.51). For Tired Creek, iron was strongly correlated to Turbidity (0.94), FC (0.79), and TSS (0.68), moderately correlated to Hd (0.55), DO (0.55), TN (-0.52), Alk (-0.51), TON (-0.48), and SC (-0.47). Based on data from all creeks, iron was correlated with TP at 4 creeks, Turbidity at 4 creeks, and TSS at 3 creeks. For the correlation matrix including all the data from each creek location at the end of **Appendix E,** some correlations resulted. The strongest correlations included Turb (0.66) and moderate inverse correlations with Hd (-0.57), Alk (-0.55) and SC (-0.54).

5.10 Manganese

Manganese samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek and sample event are shown in **Table 5.23** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event can be found in **Appendix E.**

Table 5.23 Manganese (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.00	16.00	16.00	16.00	17.00
Min	0.06	0.05	0.0034	0.05	0.04
Max	1.20	0.28	0.06	1.00	0.24
Average	0.30	0.14	0.02	0.19	0.09
Median	0.20	0.13	0.01	0.13	0.06
Variance	0.08	0.003	0.0003	0.05	0.0003
Standard Deviation	0.29	0.06	0.02	0.23	0.06

For the same data, a line graph is shown in **Figure 5.37** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Black creek had the highest concentrations, while nursery creek had the lowest concentrations, just as with iron. Although, for manganese the Black Creek average was 15 times the Nursery Creek average.

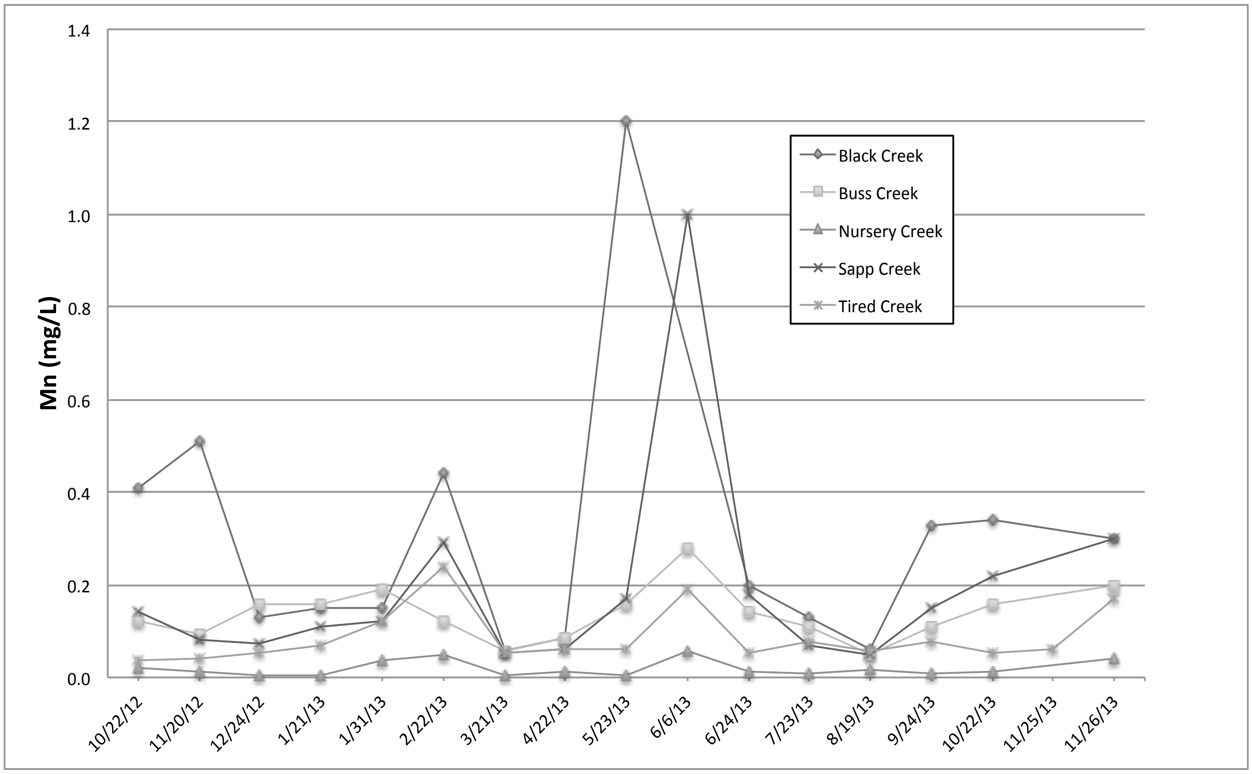

Figure 5.37 Manganese concentration for all grab samples

A box and whisker plot for manganese is provided in **Figure 5.38** including the reference concentration recommended by the EPA represented by a thick black line. The Nursery Creek median is much lower than the rest of the creeks. Black Creek and Sapp Creek have large tails for higher Mn concentrations, while the tails for the other three creeks are much smaller. Though there are noticeable differences, all the creeks were consistently below the 1 mg/L recommended concentration.

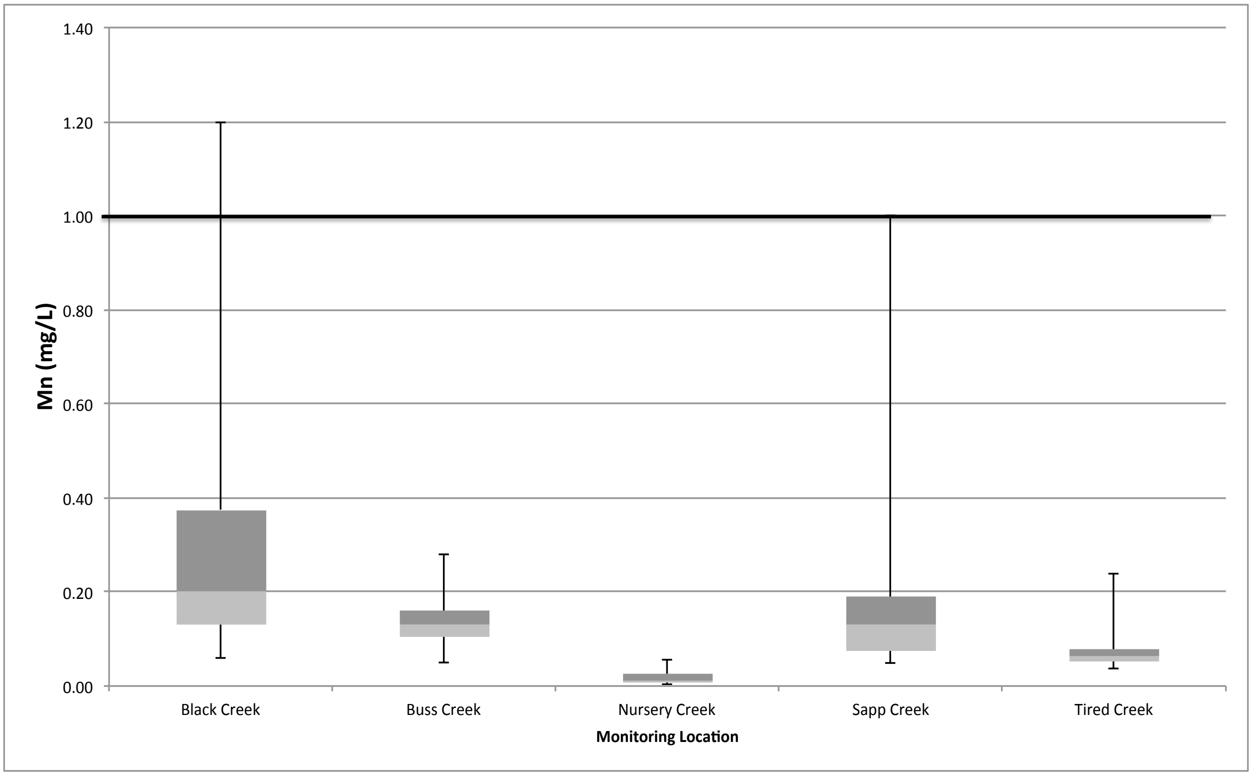

Figure 5.38 Manganese box and whisker plot for each location

An ANOVA (Appendix E) was performed to see if there were any differences for manganese concentrations in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well below F-ratio and the p-value was below 0.05, there was a difference in the creeks. A Tukey test (**Appendix E**) was applied and a 95% confidence interval of +/- 0.174 was determined. Based on the analysis, it was determined a significant difference between Black Creek and Nursery Creek, along with Black Creek and Tired Creek. There was also a difference of -0.17 between Nursery Creek and Sapp Creek, which was close to the confidence interval.

A correlation matrix between the creeks was also developed in **Table 5.24**. The strongest correlation was between Tired Creek and Nursery Creek, with a correlation coefficient of 0.89. Other strong correlations included Sapp Creek and Buss Creek with a 0.77 and Sapp Creek and Nursery Creek, with a 0.73. Moderate correlations included Sapp Creek and Tired Creek with

0.64, Nursery Creek and Buss Creek with 0.58, Tired Creek and Buss Creek with 0.51. All Black Creek correlations were weak.

Table 5.24 Manganese correlation matrix for all samples

	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	0.26	1.00			
Nursery Creek	-0.02	**0.58**	1.00		
Sapp Creek	0.38	**0.77**	**0.73**	1.00	
Tired Creek	0.05	**0.51**	**0.89**	**0.64**	1.00

Storm samples were discarded to determine if they had an influence on the data. Many storm samples were determined by outliers and were bolded in previous tables. All the data without storm events including statistical analysis for minimum, maximum, average, median, variance, and standard deviation is shown in **Appendix E**. **Table 5.25** lists the percentage difference after removing storm events. The minimums did not change for any creeks, but the maximums decreased for all creeks other than Black Creek by more than 30%. Averages also had significant decreases for all the creeks other than Black Creek, with Sapp Creek (-40.5), Nursery Creek (-32.5), Tired Creek (-28.57), and Buss Creek (-12.90).

Table 5.25 Manganese (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Mn^1	**Mn^2**	**%**	**Mn^1**	**Mn^2**	**%**	**Mn^1**	**Mn^2**	**%**	**Mn^1**	**Mn^2**	**%**	**Mn^1**	**Mn^2**	**%**
n	15	12	-	16	12	-	16	12	-	16	12	-	17	13	-
Min	0.06	0.06	**0**	0.05	0.05	**0**	0.00	0.003	**0**	0.05	0.05	**0**	0.04	0.04	**0**
Max	1.20	1.20	**0**	0.28	0.19	**-32**	0.06	0.04	**-33**	1.00	0.22	**-78**	0.24	0.12	**-50**
Avg.	0.30	0.30	**0.2**	0.14	0.12	**-13**	0.02	0.01	**-33**	0.19	0.11	**-40**	0.09	0.06	**-29**
Med.	0.20	0.18	**-13**	0.13	0.12	**-12**	0.01	0.01	**0**	0.13	0.10	**-22**	0.06	0.06	**-6**
Var.	0.08	0.10	**23**	0.00	0.00	**-42**	0.00	0.00	**-71**	0.05	0.00	**-94**	0.00	0.00	**-87**
St. Dev.	0.29	0.32	**11**	0.06	0.04	**-24**	0.02	0.01	**-46**	0.23	0.06	**-75**	0.06	0.02	**-64**

Note: Mn^1 = all samples; Mn^2 = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was much smaller than F-ratio and the p-value was much smaller than 0.05. A Tukey test, **Appendix E**, confirmed the differences between the Creeks with a 95% confidence interval of 0.18. It was determined more differences occurred after removing storm data. All the creeks were different from Black Creek, with the largest difference between Black Creek and Nursery Creek. There was no difference between any creeks other than Black Creek.

A correlation matrix was also developed for the data not including storm events in **Table 5.26**. The strongest correlation was between Sapp Creek and Buss Creek with a correlation coefficient of 0.65. Other moderately correlated creeks included Nursery Creek and Tired Creek with 0.59 and Black Creek and Sapp Creek with 0.5.

Table 5.26 Manganese correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.35	1.00			
Nursery Creek	-0.24	0.33	1.00		
Sapp Creek	**0.50**	**0.65**	0.06	1.00	
Tired Creek	-0.16	0.40	**0.59**	-0.02	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.27**. Minimums were all much higher for the storm events with Nursery Creek 1017% higher, Tired Creek 224.32% higher, Buss Creek 158.62% higher, Sapp Creek 144.9% higher, and Buss Creek 140% higher. Maximums also increased due storm events for all the creeks, except Black Creek, which decreased by 63.3%. The same was seen for averages increasing due to storm events for all the creeks except Black Creek. The Sapp Creek average increased by 274.45%, Nursery Creek increased by 258.53%, Tired Creek increased by 191.04%, and Buss Creek increased 65.5%.

Table 5.27 Manganese (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Mn^2	**Mn^3**	**%**	**Mn^2**	**Mn^3**	**%**	**Mn^2**	**Mn^3**	**%**	**Mn^2**	**Mn^3**	**%**	**Mn^2**	**Mn^3**	**%**
n	12	3	-	12	4	-	12	4	-	12	4	-	13	4	-
Min.	0.06	0.15	**159**	0.05	0.12	**140**	0.003	0.04	**1018**	0.05	0.12	**145**	0.04	0.12	**224**
Max.	1.20	0.44	**-63**	0.19	0.28	**47**	0.04	0.06	**50**	0.22	1.00	**355**	0.12	0.24	**100**
Avg.	0.30	0.30	**-1**	0.12	0.20	**66**	0.01	0.05	**259**	0.11	0.43	**274**	0.06	0.18	**191**
Med.	0.18	0.30	**71**	0.12	0.20	**70**	0.01	0.05	**275**	0.10	0.30	**191**	0.06	0.18	**205**
Var.	0.10	0.02	**-79**	0.00	0.00	**121**	0.00	0.00	**-9**	0.00	0.15	**4559**	0.00	0.00	**456**
St. Dev.	0.32	0.15	**145**	0.04	0.07	**249**	0.01	0.01	**196**	0.06	0.39	**783**	0.02	0.05	**336**

Note: Mn^2 = not including storm data; Mn^3 = storm data; % = percent difference

Correlations between creeks for manganese concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, manganese was strongly correlated to TP (0.71), moderately strongly correlated to Turbidity (0.63), FC (0.58), and TSS (0.51). For Black Creek, manganese was strongly correlated to DO (-0.66) and Alk (0.65), and moderately strongly correlated to SC (0.61) and TON (0.52). For Buss Creek, manganese was moderately strongly correlated to TP (0.63) and TSS (0.59). For Nursery Creek, manganese was strongly correlated to Turbidity (0.83), TSS (0.8), TP (0.79), Stage (0.65), and Hd (-0.65), moderately strongly correlated to SC (-0.61), WT (-0.61), and TKN (0.51), and moderately correlated to Alk (-0.49). For Tired Creek, manganese was strongly correlated to TSS (0.84), TP (0.81), FC (0.79), and Turbidity (0.67), and moderately strongly correlated to TKN (0.64), and DO (0.57). Based on data from all creeks, manganese was correlated to TP in four creeks, TSS in four creeks, turbidity in three creeks, FC in two creeks, DO in two creeks, and TKN in two creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** Mn was weakly correlated to all other parameters.

5.11 Fecal Coliform

Fecal coliform samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses each creek are shown in **Table 5.28** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is provided in **Appendix E.**

Table 5.28 Fecal Coliform (CFU/100 mL) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	15
Min	34	181	34	44	220
Max	4900	5500	16900	9420	3500
Average	719.80	1060.40	1551.00	1319.73	930.20
Median	200.00	520.00	560.00	134.00	350.00
Geometric Mean	248.73	580.82	373.71	337.41	563.17
Variance	579944.64	2552069.82	127698.25	1485729.82	822913.79
Standard Deviation	1335.35	1512.65	4133.89	2466.42	1113.09

For the same data, a line graph is shown in **Figure 5.39** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks represented on a log scale. There was a notable difference in FC concentrations during storm events. All the creeks seemed to follow a similar trend.

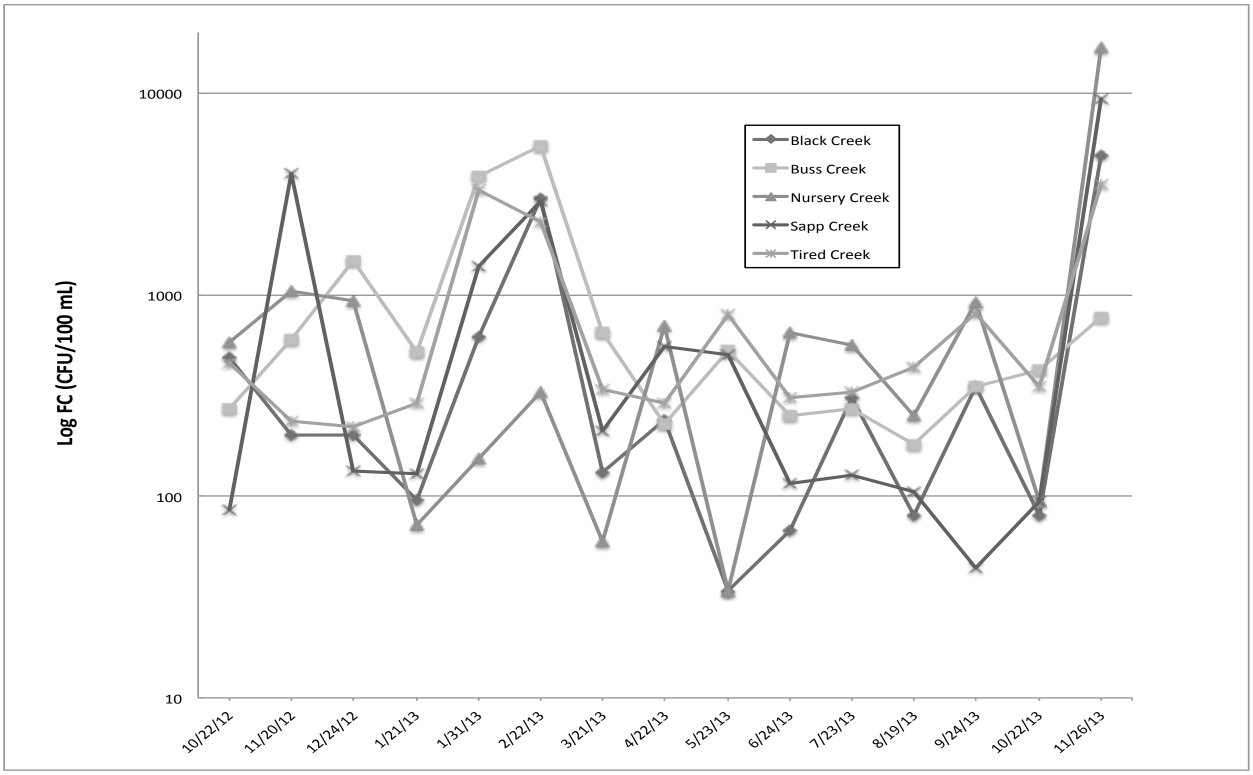

Figure 5.39 Fecal Coliform concentrations for all grab sample events

A box and whisker plot for fecal coliform is shown in **Figure 5.36** on a log scale. The thick black line is the 200 CFU/100 mL level for the geometric mean of four samples determined by GA EPD. All creek geometric means were above the state standard. Nursery Creek had the highest median, while Sapp Creek had the lowest median. Buss Creek and Nursery Creek had similar medians. Black Creek and Nursery Creek were also similar. The longer tails are on the high end, which increased drastically during storm events. These increases had a large impact on averages.

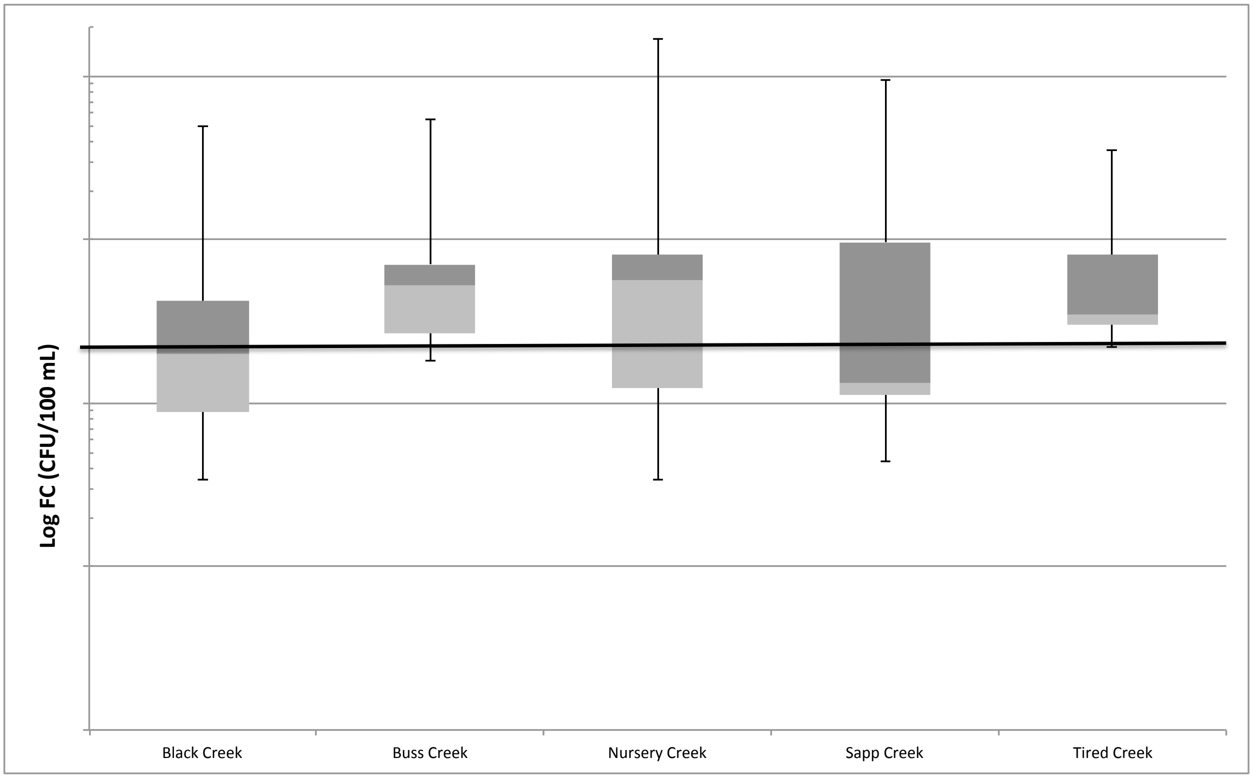

Figure 5.40 Fecal Coliform box and whisker plot for each location

An ANOVA (**Appendix E**) was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well above F-ratio and the p-value was above 0.05, there was no difference between the creeks.

A correlation matrix between the creeks was also developed in **Table 5.29**. The strongest correlation was between Sapp Creek and Nursery Creek, with a correlation coefficient of 0.89. Other very strong correlations included Sapp Creek and Black Creek with 0.88, Nursery Creek and Black Creek with 0.84, and Tired Creek and Black Creek with 0.78, Sapp Creek and Tired Creek with 0.69. Moderately strong correlations included Buss Creek and Tired Creek with 0.63 and Sapp Creek and Tired Creek with 0.61.

Table 5.29 Fecal Coliform correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.41	1.00			
Nursery Creek	**0.84**	-0.07	1.00		
Sapp Creek	**0.88**	0.20	**0.89**	1.00	
Tired Creek	**0.78**	**0.63**	**0.61**	**0.69**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.30** lists the percent differences after taking storm events out of the data. The minimums did not change for any creeks, but the maximums decreased for all creeks other than Black Creek by more than 50%. Averages also had significant decreases for all the creeks: Black Creek (-73.62%), Nursery Creek (-68.41%), Sapp Creek (-61.51%), Tired Creek (-56.34%), and Buss Creek (-54.92%). Geometric means decreased between 21-44%. These decreases caused Black Creek and Sapp Creek to fall below state standards for impaired creeks. Buss Creek, Nursery Creek, and Tired Creek were still above the state standard.

Table 5.30 Fecal Coliform (CFU/100 mL) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	FC 1	FC 2	%	FC¹	FC²	%	FC¹	FC²	%	FC¹	FC²	%	FC¹	FC 2	%
n	15	12	-	15	12	-	15	12	-	15	12	-	15	12	-
Min.	34	34	**0**	181	181	**0**	34	34	**0**	44	44	**0**	220	220	**0**
Max.	4900	490	**-90**	5500	1470	**-73**	17k	1040	**-94**	9420	4000	**-58**	3500	809	**-77**
Avg.	720	190	**-74**	1060	478	**-55**	1551	490	**-68**	1320	508	**-62**	930	406	**-56**
Med.	200	166	**-17**	520	385	**-26**	560	570	**2**	134	128	**-4**	350	335	**-4**
Geo.	249	146	**-41**	581	401	**-31**	374	296	**-21**	337	190	**-44**	563	371	**-34**
Var.	580k	19k	**-97**	2.6m	122k	**-95**	128k	140k	**10**	1.5m	1.2m	**-17**	823k	40k	**-95**
St. Dev.	1335	142	**-89**	1513	359	**-76**	4134	383	**-91**	2466	1074	**-56**	1113	221	**-80**

Note: FC¹ = all samples; FC² = sample not including storm data; % = percent difference; k = thousand; m = million

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was much larger than F-ratio and the p-value was larger than 0.05. Therefore, all the creeks are considered the same.

A correlation matrix was also developed for the data not including storm events in **Table 5.31.** The strongest correlation was between Nursery Creek and Black Creek with a correlation coefficient of 0.55, but still considered moderate. Nursery Creek and Sapp Creek had the next strongest correlation with 0.44.

Table 5.31 Fecal Coliform correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	-0.12	1.00			
Nursery Creek	**0.55**	0.21	1.00		
Sapp Creek	-0.01	0.10	0.44	1.00	
Tired Creek	0.10	-0.27	-0.16	-0.25	1.00

The excluded storm data, **Appendix E**, with statistics including minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences in **Table 5.32**. Minimums were all much higher for the storm events with Sapp Creek 3036% higher Nursery Creek 1017% higher, Black Creek 1717.65% higher, Tired Creek 936.36% higher, and Buss Creek 325.41% higher. Maximums also increased due storm events for all the creeks greater than 100%. The same was seen for averages increasing due to storm events for all the creeks, with Black Creek 1395.04% higher, Nursery Creek 1082.65% higher, Sapp Creek 798.95% higher, Tired Creek 645.33% higher, and Buss Creek 609.21% higher.

Table 5.32 Fecal Coliform (CFU/100 mL) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	FC[2]	**FC[3]**	**%**	**FC[2]**	**FC[3]**	**%**	**FC[2]**	**FC[3]**	**%**	**FC[2]**	**FC[3]**	**%**	**FC[2]**	**FC[3]**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	12	3	-
Min	34	618	**1.7k**	181	770	**325**	34	155	**356**	44	1380	**3k**	220	2.3k	**936**
Max	490	5k	**900**	1.5k	5.5k	**274**	1040	17k	**1.5k**	4k	9.4k	**136**	809	3.5k	**333**
Avg.	190	2.8k	**1.4k**	478	3.4k	**609**	490	5.8k	**1k**	508	4.6k	**799**	406	3k	**645**
Med.	166	190	**15**	385	478	**24**	570	383	**-33**	128	1074	**739**	335	406	**21**
Geo	146	2086	**1328**	401	2547	**534**	296	953	**222**	190	3353	**1664**	371	2975	**701**
Var.	19k	4.6 m	**24k**	122k	5.7m	**4.7k**	140k	92m	**66k**	1.2m	18m	**1.4k**	40k	.4m	**982**
St. Dev.	142	2k	**1.4k**	359	2.4k	**569**	383	9.6k	**2.4**	1k	4.2k	**298**	221	654	**196**

Note: FC[1] = all samples; FC[2] = sample not including storm data; % = percent difference; k = thousand; m = million

Correlations between creeks for FC concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, FC was moderately correlated to Mn (0.58) and TN (0.49). For Black Creek, FC was strongly correlated to TSS (0.65), moderately strongly correlated to Turbidity (0.62), and moderately correlated to Stage (0.51). For Buss Creek, FC was strongly correlated to Turbidity (0.75), TP (0.72), pH (0.71), TSS (0.68), and Fe (0.66) moderately strongly correlated to DO (0.57), and moderately correlated to AT (-0.47). For Nursery Creek, FC was strongly correlated to TSS (0.72) and turbidity (0.69), and moderately correlated to Fe (0.58), Hd (-0.49), and SC (-0.45). For Tired Creek, FC was strongly correlated to Fe (0.79), Mn (0.79), Turbidity (0.74) and TSS (0.70). Based on data from all creeks, FC was strongly correlated to TSS and Turbidity in all creeks except Sapp Creek. It was also correlated to Fe in 3 creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** FC correlated to other parameters. The strongest correlations included moderate correlations with TSS (0.59) and Turb (0.55).

5.12 Total Nitrogen

Total Nitrogen samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.3** included count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.33 Total Nitrogen concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.0	16.0	16.0	16.0	17.0
Min	0.40	0.95	1.10	0.30	0.70
Max	1.30	20.00	18.00	1.00	4.40
Average	0.97	4.07	3.88	0.61	1.81
Median	1.00	1.95	3.00	0.59	1.20
Variance	0.06	27.07	15.14	0.03	1.78
Standard Deviation	0.25	5.20	3.89	0.17	1.33

A line graph is shown in **Figure 5.41** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek had the highest concentrations, while Sapp Creek had the lowest concentrations. There were also some very high concentrations measured in Buss Creek.

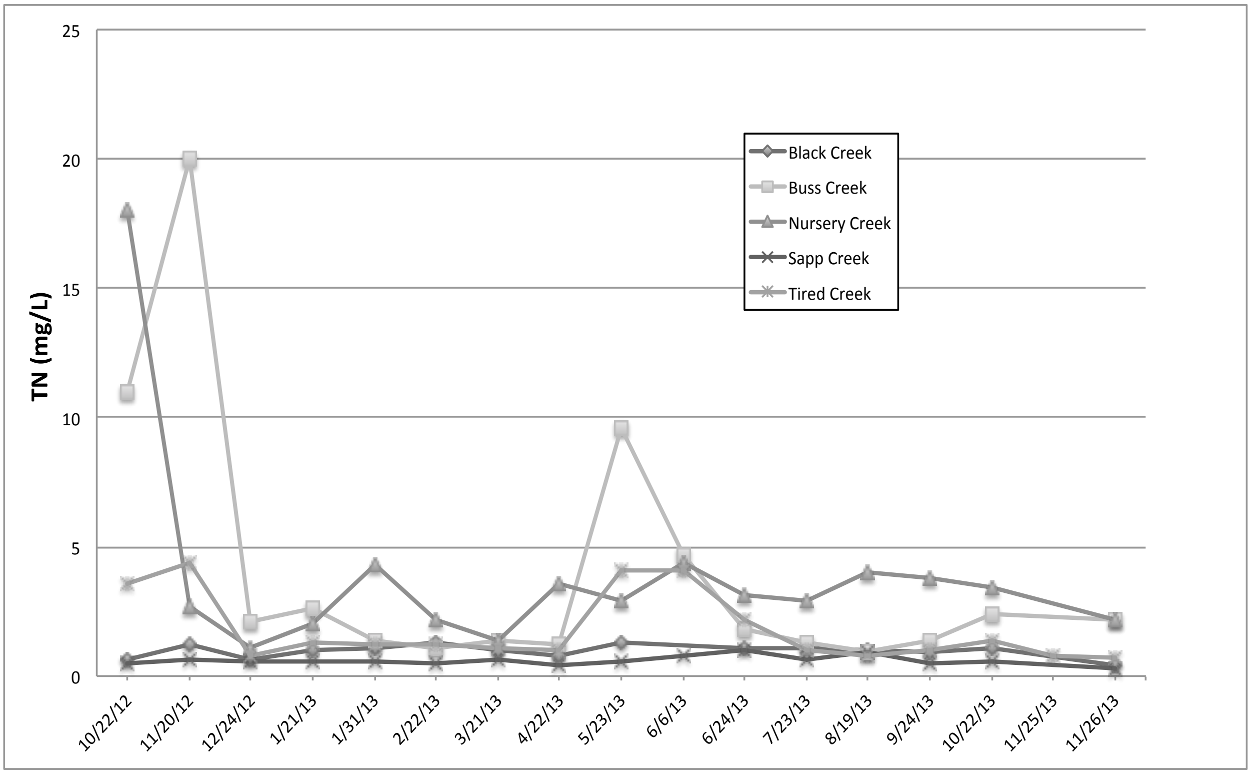

Figure 5.41 Total Nitrogen concentrations for all grab sample events

A box and whisker plot for TN is provided in **Figure 5.42** including the reference level for the Georgia region depicted by the thick black line at 1 mg/L. The Nursery Creek median is higher than the rest of the creeks. Nursery Creek and Buss Creek have large tails for higher TN concentrations, while the tails for the other three creeks are much smaller. All the creeks, except Sapp Creek were above the 1 mg/L recommended concentration for TN to prevent eutrophication.

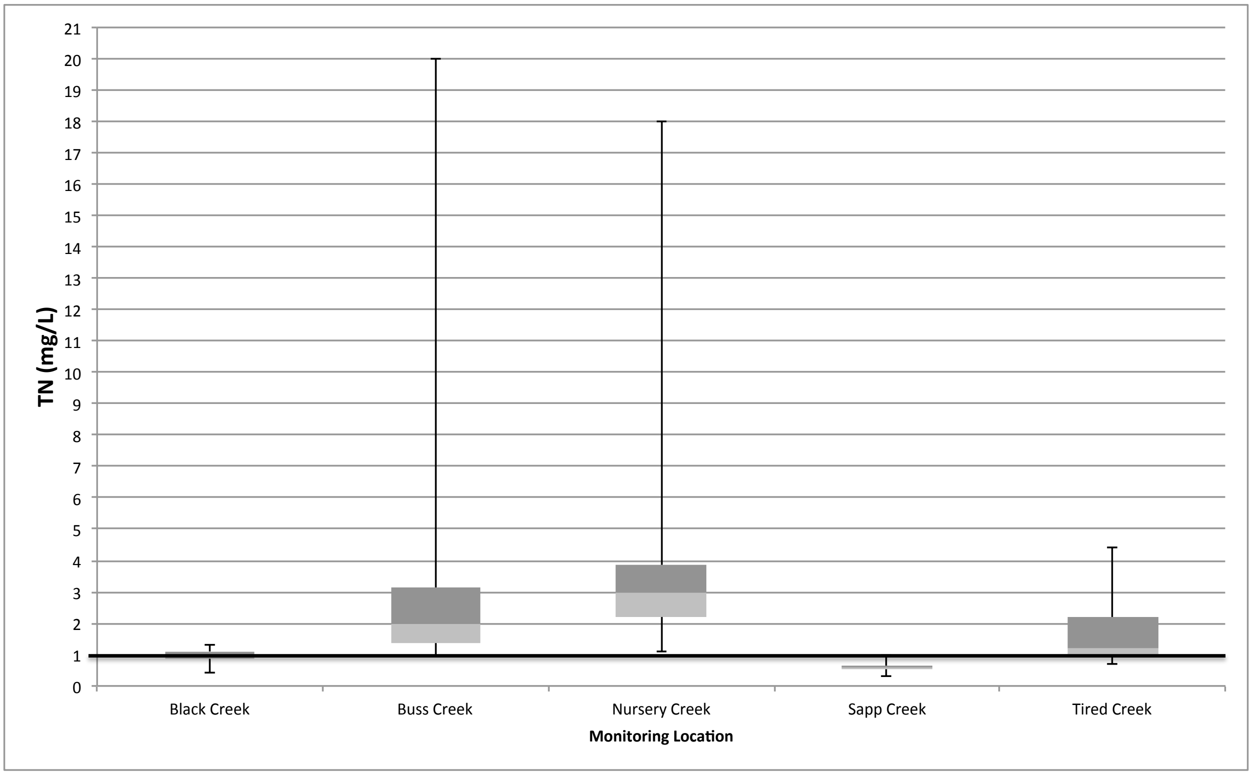

Figure 5.42 Total Nitrogen box and whisker plot for each location

An ANOVA (**Appendix E**) was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well below F-ratio and the p-value was below 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 3.13 was determined. Based on the analysis, it was determined a significant difference between Sapp Creek and Buss Creek, along with Sapp Creek and Nursery Creek. There was also a difference of 3.1 between Buss Creek and Black Creek.

A correlation matrix between the creeks was also developed in **Table 5.34** below. The strongest correlation was between Tired Creek and Buss Creek, with a correlation coefficient of

0.83. A moderate correlation was determined between Sapp Creek and Black Creek with 0.47. Other correlations can be seen in the table.

Table 5.34 Total Nitrogen correlation matrix for all samples

	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	0.17	1.00			
Nursery Creek	-0.30	0.34	1.00		
Sapp Creek	**0.47**	-0.07	-0.14	1.00	
Tired Creek	0.32	**0.83**	0.38	0.19	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.35** lists the percent differences after taking storm events out of the data. The minimum increases included Black Creek (60%) and Sapp Creek (37%). All other changes after removing storm data were minimal.

Table 5.35 Total Nitrogen (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TN[1]	TN[2]	%	TN[1]	TN[2]	%	TN[1]	TN[2]	%	TN[1]	TN[2]	%	TN[1]	TN[2]	%
n	15.0	12.0	-	16.0	12.0	-	16.0	12.0	-	16.0	12.0	-	17.0	13.0	-
Min	0.4	0.64	60	1.0	0.95	0	1.1	1.1	0	0.3	0.41	37	0.7	0.8	14
Max	1.3	1.3	0	20.0	20	0	18.0	18	0	1.0	1	0	4.4	4.4	0
Avg.	1.0	0.98	1	4.1	4.65	14	3.9	4.08	5	0.6	0.63	4	1.8	1.81	0
Med.	1.0	1.00	0	2.0	1.95	0	3.0	3.00	0	0.6	0.59	1	1.2	1.10	-8
Var.	0.1	0.04	-36	27.1	34.75	28	15.1	20.05	32	0.0	0.03	-8	1.8	1.77	-0.5
St. Dev.	0.3	0.20	-20	5.2	5.90	13	3.9	4.48	15	0.2	0.17	-4	1.3	1.33	-0.2

Note: TN[1] = all samples; TN[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was much smaller than F-ratio and the p-value was smaller than 0.05. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 4.12. It was determined no creek was significantly different, but the largest difference was Sapp Creek and Buss Creek with a difference in means of 4.02.

A correlation matrix was also developed for the data not including storm events in **Table 5.36**. The strongest correlation was again between Tired Creek and Buss Creek with a correlation coefficient of 0.91. Other moderately correlated creeks included Nursery Creek and Black Creek with an inverse correlation of -0.48. All other correlations can be found in the table.

Table 5.36 Total Nitrogen correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.26	1.00			
Nursery Creek	**-0.48**	0.32	1.00		
Sapp Creek	0.39	-0.21	-0.27	1.00	
Tired Creek	0.36	**0.91**	0.39	-0.09	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.37**. Minimums for Nursery Creek and Buss Creek increased with Nursery Creek 100% higher and Buss Creek 16% higher. Minimums for the other three creeks decreased. Maximums decreased for all the creeks other than Black Creek, with Buss Creek decreasing -77% and Nursery Creek decreasing -76%. The averages decreased for storm events for all the creeks except Tired Creek. The largest changes being the Buss Creek average decreased by 49% and Nursery creek 20%.

Table 5.37 Total Nitrogen (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TN^2	**TN^3**	**%**	**TN^2**	**TN^3**	**%**	**TN^2**	**TN^3**	**%**	**TN^2**	**TN^3**	**%**	**TN^2**	**TN^3**	**%**
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	-	12.0	4.0	-	13.0	4.0	-
Min.	0.6	0.4	**-38**	1.0	1.1	**16**	1.1	2.2	**100**	0.4	0.3	**-27**	0.8	0.7	**-13**
Max.	1.3	1.3	**0**	20	4.7	**-77**	18	4.4	**-76**	1.0	0.8	**-20**	4.4	4.1	**-7**
Avg.	1.0	0.9	**-5**	4.6	2.4	**-49**	4.1	3.3	**-20**	0.6	0.5	**-14**	1.8	1.8	**0**
Med.	1.0	1.1	**10**	2.0	1.8	**-8**	3.0	3.3	**8**	0.6	0.5	**-10**	1.1	1.2	**9**
Var.	0.04	0.2	**444**	34.8	2.7	**-92**	20.1	1.5	**-92**	0.03	0.04	**51**	1.8	2.4	**36**
St. Dev.	0.2	0.5	**133**	5.9	1.6	**-72**	4.5	1.2	**-72**	0.2	0.2	**23**	1.3	1.6	**17**

Note: TN^2 = not including storm data; TN^3 = storm data; % = percent difference

Correlations between creeks for TN concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, TN was strongly correlated to TKN (0.72), moderately strongly correlated to pH (-0.57), and moderately correlated to WT (0.5), FC (-0.49), AT (0.45), and TON (0.45). For Black Creek, TN was strongly correlated to (TKN). For Buss Creek, TN was strongly correlated to TON (0.99), TKN (0.88), SC (0.8), Alk (0.69), and Hd (0.66), and moderately correlated to stage (-0.48), and NH4 (0.46). For Nursery Creek, TN was strongly correlated to TON (0.99), NH4 (0.78), and DO (-0.69), moderately strongly correlated Alk (0.6), and moderately correlated to SC (0.47). For Tired Creek, TN was strongly correlated to SC (0.96), Hd (0.92), Alk (0.85), and TON (0.83), moderately strongly correlated to TKN (0.58), and moderately correlated to Fe (-0.52), DO (-0.51). Based on data from all creeks, TN was correlated to TKN and TON in four creeks, along with Alk in three creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** TN correlated to other parameters. The strongest correlations included TON (0.98) and moderate correlations with SC (0.61), TKN (0.59), NH4 (0.57), Hd (0.52), and Alk (0.51).

5.13 Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.38** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.38 Total Kjeldahl Nitrogen concentration for all grab samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.00	16.00	16.00	16.00	17.00
Min	0.071	0.23	0.071	0.26	0.19
Max	1.2	3.9	2	0.93	3
Average	0.61	1.05	0.58	0.46	0.73
Median	0.66	0.73	0.44	0.44	0.61
Variance	0.09	0.90	0.30	0.03	0.40
Standard Deviation	0.30	0.95	0.55	0.17	0.63

For the same data, a line graph is shown in **Figure 5.43** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. All creeks followed a similar path rising and falling together. There were no consistent large differences between the creeks.

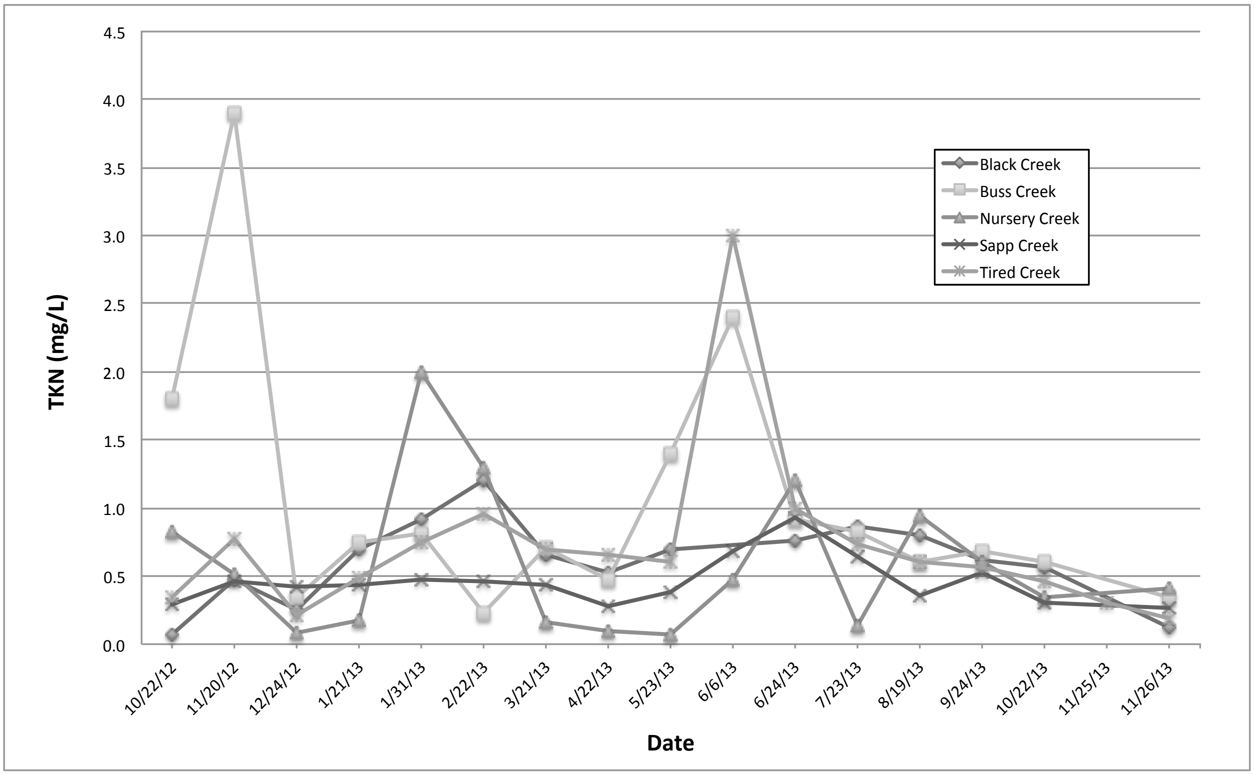

Figure 5.43 Total Kjeldahl Nitrogen concentrations for all samples

A box and whisker plot for TKN is shown in **Figure 5.44**. Buss Creek had the highest median, while Sapp Creek the second highest. Nursery Creek and Sapp Creek had similar medians. The longer tails are on the high end, in which Buss Creek, Tired Creek, and Nursery Creek having the largest tails.

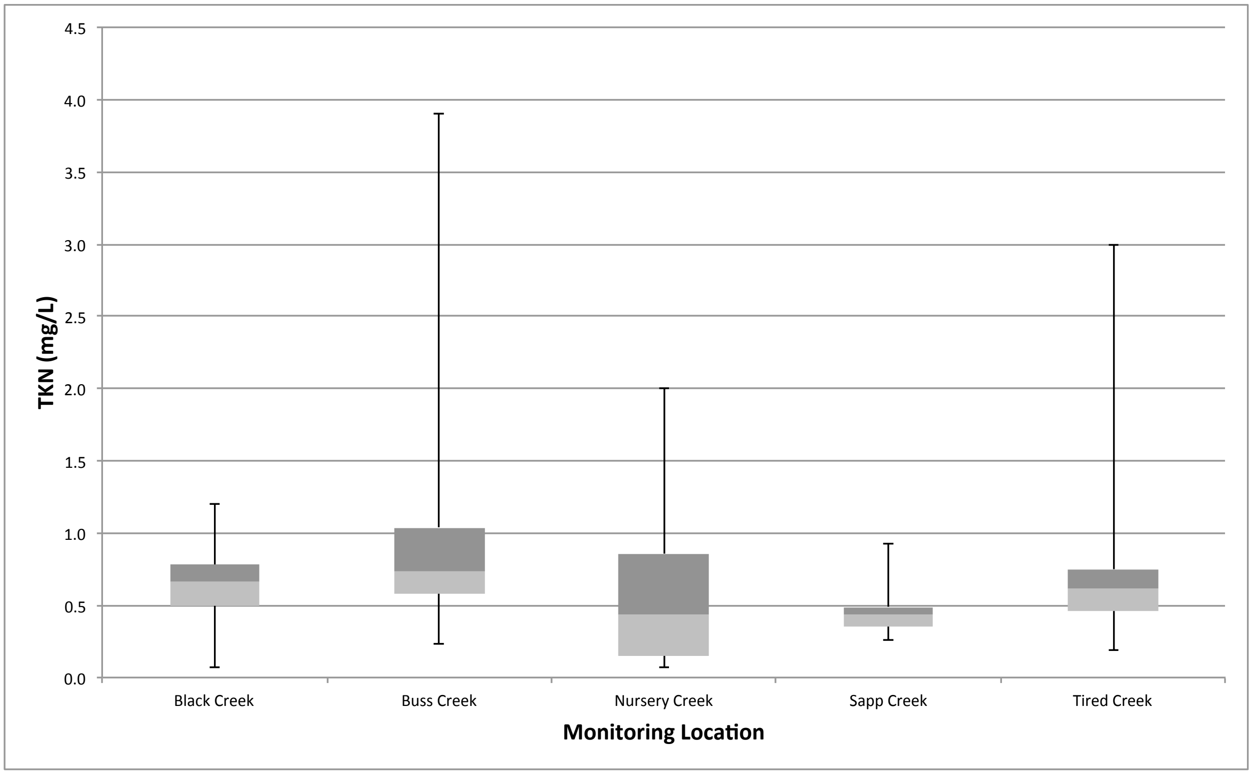

Figure 5.44 Total Kjeldahl Nitrogen box and whisker plot for each location

An ANOVA (Appendix E) was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was above F-ratio and the p-value was above 0.05, there was no difference between the creeks.

A correlation matrix between the creeks was also developed in **Table 5.39**. The strongest correlation was between Tired Creek and Black Creek, with a correlation coefficient of 0.8. Moderate correlations included Sapp Creek and Tired Creek with 0.54 and Sapp Creek and Black Creek with a correlation coefficient of 0.46.

Table 5.39 Total Kjeldahl Nitrogen correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	-0.22	1.00			
Nursery Creek	0.42	-0.04	1.00		
Sapp Creek	**0.46**	0.17	0.26	1.00	
Tired Creek	**0.80**	0.41	0.11	**0.54**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.40** lists the percent differences after taking storm events out of the data. The minimum for TKN increased by 52% for Buss Creek, 16% for Tired Creek, 8% for Sapp Creek and no change in Nursery Creek and Black Creek. The maximums decreased for Tired Creek by 67%, Nursery Creek 40%, and Black Creek 28%. Averages decreased for Tired Creek and Nursery Creek, but stayed very similar for the other creeks.

Table 5.40 Total Kjeldahl Nitrogen (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TKN[1]	**TKN[2]**	**%**	**TKN[1]**	**TKN[2]**	**%**	**TKN[1]**	**TKN[2]**	**%**	**TKN[1]**	**TKN[2]**	**%**	**TKN[1]**	**TKN[2]**	**%**
n	15.0	12.0	-	16.0	12.0	-	16.0	12.0	-	16.0	12.0	-	17.0	13.0	
Min	0.1	0.1	**0**	0.2	0.4	**52**	0.1	0.1	**0**	0.3	0.3	**8**	0.2	0.2	**16**
Max	1.2	0.9	**-28**	3.9	3.9	**0**	2.0	1.2	**-40**	0.9	0.9	**0**	3.0	1.0	**-67**
Avg.	0.6	0.6	**-5**	1.1	1.1	**3**	0.6	0.4	**-26**	0.5	0.5	**-1**	0.7	0.6	**-21**
Med.	0.7	0.6	**-3**	0.7	0.7	**0**	0.4	0.3	**-40**	0.4	0.4	**-2**	0.6	0.6	**-2**
Var.	0.1	0.1	**-42**	0.9	0.9	**5**	0.3	0.1	**-50**	0.0	0.0	**9**	0.4	0.0	**-88**
St. Dev.	0.3	0.2	**-24**	0.9	1.0	**3**	0.5	0.4	**-29**	0.2	0.2	**5**	0.6	0.2	**-66**

Note: TKN[1] = all samples; TKN[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was much smaller than F-ratio and the p-value was less than 0.05. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 0.61 was determined. Based on the analysis, it was determined a significant difference between Nursery Creek and Buss Creek (0.66), along with Sapp Creek and Buss Creek (0.63).

A correlation matrix between the creeks was also developed in **Table 5.41**. The strongest correlations were between Sapp Creek and Tired Creek with a correlation coefficient of 0.68, along with Tired Creek and Black Creek (0.66). A moderate correlation was determined between Sapp Creek and Black Creek with 0.48. Other correlations can be seen in the table below.

Table 5.41 Total Kjeldahl Nitrogen correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	-0.25	1.00			
Nursery Creek	0.00	0.17	1.00		
Sapp Creek	**0.48**	-0.01	0.42	1.00	
Tired Creek	**0.66**	0.25	0.33	**0.68**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.42**. The Nursery Creek minimum rose by 477% and the Black Creek minimum rose by 69%, while Buss Creek decreased by 34%, Tired Creek 14% and Sapp Creek 7%. The maximum for storms data increased in Tired Creek by 200%, Nursery Creek by 67%, and Black Creek 38%, while Buss Creek decreased 38% and Sapp Creek 27%. All of the averages for TKN increased other than Buss creek, which decreased by 13%.

Table 5.42 Total Kjeldahl Nitrogen (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TKN[2]	**TKN[3]**	**%**	**TKN[2]**	**TKN[3]**	**%**	**TKN[2]**	**TKN[3]**	**%**	**TKN[2]**	**TKN[3]**	**%**	**TKN[2]**	**TKN[3]**	**%**
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	-	12.0	4.0	-	13.0	4.0	-
Min	0.1	0.1	69	0.4	0.2	-34	0.1	0.4	477	0.3	0.3	-7	0.2	0.2	-14
Max	0.9	1.2	38	3.9	2.4	-38	1.2	2.0	67	0.9	0.7	-27	1.0	3.0	200
Avg.	0.6	0.7	28	1.1	0.9	-13	0.4	1.0	143	0.5	0.5	3	0.6	1.2	113
Med.	0.6	0.9	44	0.7	0.6	-21	0.3	0.9	234	0.4	0.5	9	0.6	0.9	42
Var.	0.1	0.3	494	0.9	1.0	6	0.1	0.6	283	0.0	0.0	-10	0.0	1.5	3192
St. Dev.	0.2	0.6	144	1.0	1.0	3	0.4	0.8	96	0.2	0.2	-5	0.2	1.2	474

Note: TKN[2] = sample not including storm data; TKN[3] = storm samples; % = percent difference

Correlations between creeks for TKN concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, TKN was strongly correlated to TN (0.72) and Fe (0.68) and moderately correlated to TP (0.45). For Black Creek, TKN was strongly correlated to TN (0.81) and moderately strongly correlated to TON (-0.59), Stage (0.58), and SC (-0.56) and moderately correlated to TSS (0.47). For Buss Creek, TKN was strongly correlated to TN (0.88), TON (0.83), and SC (0.8), moderately strongly correlated to Hd (0.66), and moderately correlated to Alk (-0.54). For Nursery Creek, TKN was strongly correlated to TP (0.65) and moderately correlated to Mn (0.51) and Hd (-0.5). For Tired Creek, TKN was strongly correlated to TP (0.95), moderately strongly correlated to Mn (0.64), and moderately correlated to TN (0.48). Based on data from all creeks, TKN was strongly correlated to TN in three creeks and moderately correlated in a fourth creek. TKN was also strongly correlated to TP in two creeks and moderately correlated in a third creek. For the correlation matrix including all the data from each creek location at the end of **Appendix E,** the only correlation for TKN was a moderate correlation with TN (0.59).

5.14 Nitrate + Nitrite

Nitrate + Nitrite samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.43** including minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.43 Nitrate + Nitrite concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.0	16.0	16.0	16.0	17.0
Min	0.12	0.34	0.9	0.02	0.21
Max	0.75	16.00	17.00	0.54	3.60
Average	0.36	3.01	3.28	0.15	1.08
Median	0.30	1.31	2.55	0.14	0.50
Variance	0.03	19.00	14.13	0.02	1.35
Standard Deviation	0.18	4.36	3.76	0.13	1.16

For the same data, a line graph is shown in **Figure 5.45** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek had a consistently higher concentration of TON than any other creek for most sample dates. Sapp Creek was consistently the lowest concentration when compared to other creeks.

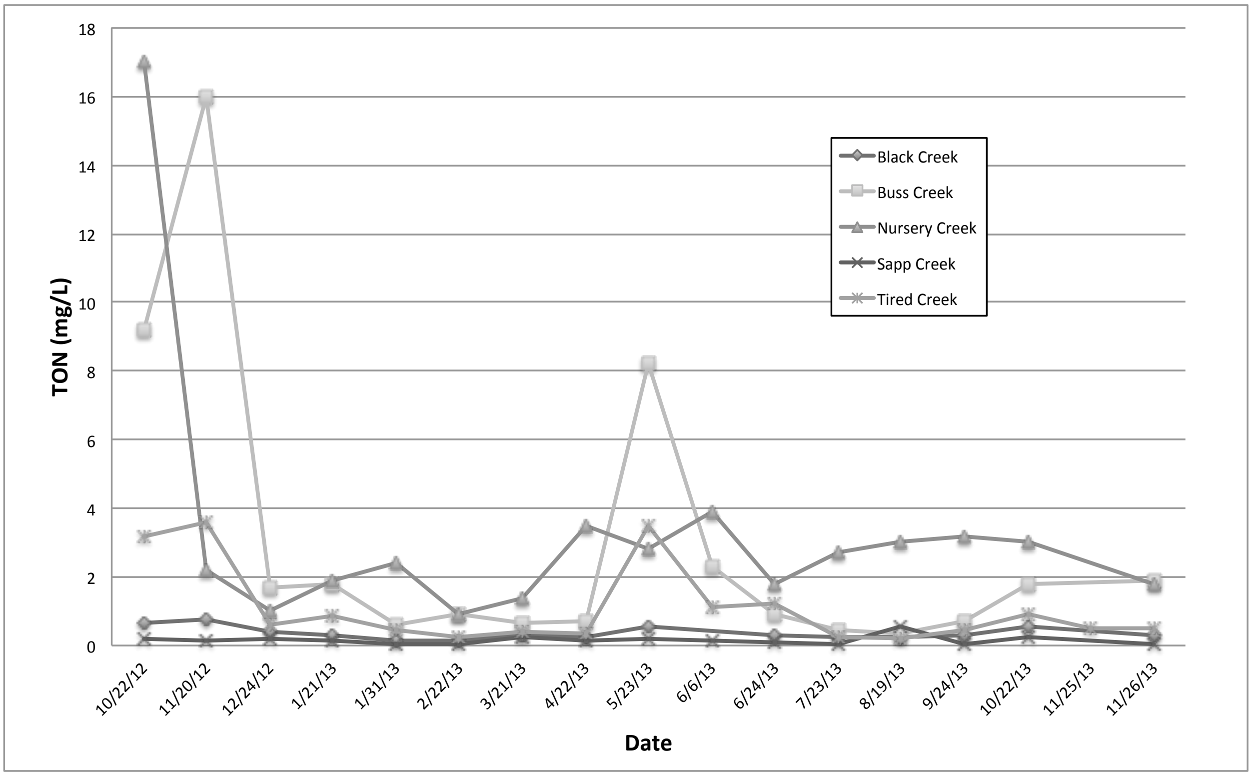

Figure 5.45 Nitrate + Nitrite concentrations for all samples

A box and whisker plot for TON is shown in **Figure 5.46**. Nursery Creek had the highest median, twice the amount of Buss Creek, which was the second highest with 1.31 mg/L. The longer tails are on the high end, in which Buss Creek and Nursery Creek had the highest tails during low flows of October and November 2012.

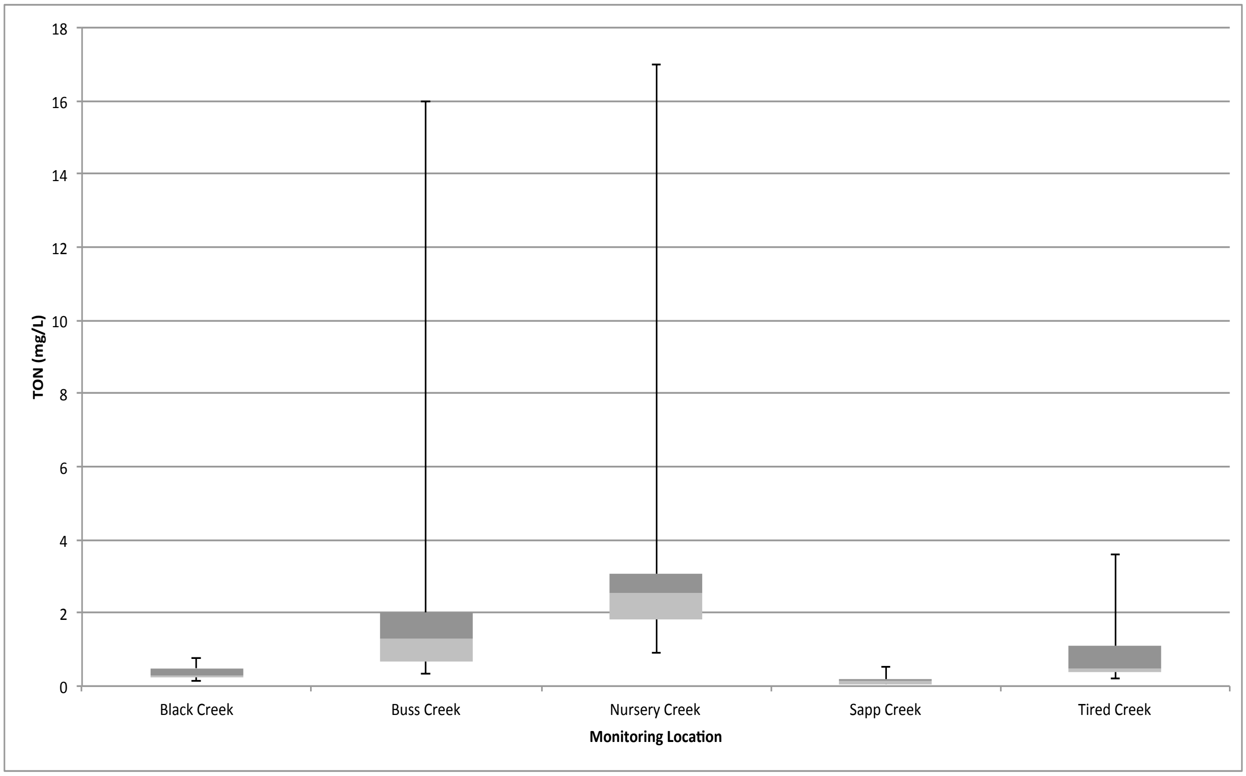

Figure 5.46 Nitrate + Nitrite box and whisker plot for each location

An ANOVA, **Appendix E**, was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well below F-ratio and the p-value was below 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 2.77 was determined. Based on the analysis, it was determined a significant difference between Sapp Creek and Nursery Creek, Nursery Creek and Black Creek, and Sapp Creek and Buss Creek.

A correlation matrix between the creeks was also developed in **Table 5.44**. The strongest correlation was between Buss Creek and Tired Creek with a correlation coefficient of 0.93. There was also strong correlation between Tired Creek and Black Creek (0.85) and Buss Creek and Black Creek (0.85). A moderate correlation was determined between Nursery Creek and Tired Creek (0.47). Other correlations can be seen in the table below.

Table 5.44 Nitrate + Nitrite correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.85**	1.00			
Nursery Creek	0.43	0.37	1.00		
Sapp Creek	0.22	0.05	0.12	1.00	
Tired Creek	**0.86**	**0.93**	**0.47**	0.09	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.45** lists the percent differences after taking storm events out of the data. After removing the storms, there was not a drastic change in the data. The largest change was an 82% increase in the minimum for Black Creek TON. The maximums did not change and all the averages increased from 10-19%.

Table 5.45 Nitrate + Nitrite (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TON[1]	TON[2]	%	TON[1]	TON[2]	%	TON[1]	TON[2]	%	TON[1]	TON[2]	%	TON[1]	TON[2]	%
n	15.0	12.0	-	16.0	12.0	-	16.0	12.0	-	16.0	12.0	-	17.0	13.0	-
Min	0.12	0.22	83	0.34	0.34	0	0.9	1	11	0.02	0.022	10	0.21	0.21	0
Max	0.75	0.75	0	16.00	16.00	0	17.00	17.00	0	0.54	0.54	0	3.60	3.60	0
Avg.	0.36	0.41	12	3.01	3.54	18	3.28	3.63	10	0.15	0.18	19	1.08	1.23	14
Med.	0.30	0.32	5	1.31	1.31	0	2.55	2.75	8	0.14	0.16	19	0.50	0.60	20
Var.	0.03	0.03	-8	19.00	24.52	29	14.13	18.33	30	0.02	0.02	11	1.35	1.66	23
St. Dev.	0.18	0.18	-4	4.36	4.95	14	3.76	4.28	14	0.13	0.13	5	1.16	1.29	11

Note: TON[1] = all samples; TON[2] = sample not including storm data; % = percent difference

A second ANOVA, in **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was much smaller than F-ratio and the p-value was smaller than 0.05. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 3.66. It was determined no creek was significantly different, with the largest difference was Sapp Creek and Buss Creek with a difference in means of 3.36.

A correlation matrix was also developed for the data not including storm events in **Table 5.46**. The strongest correlation was again between Tired Creek and Buss Creek with a correlation coefficient of 0.91. There were also strong correlations between Buss Creek and

Black Creek (0.89) and Tired Creek and Black Creek (0.87). All other correlations can be found in the table.

Table 5.46 Nitrate + Nitrate correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.89**	1.00			
Nursery Creek	0.39	0.35	1.00		
Sapp Creek	0.04	-0.04	0.04	1.00	
Tired Creek	**0.87**	**0.93**	0.44	-0.04	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.47**.

The minimums for Black Creek, Nursery Creek and Sapp Creek decreased, while there was an increase in Buss Creek and Tired Creek for storm events. The maximums for all the creeks decreased in storm data between 60-80%. Averages also decreased between 38-64%, with the largest increase in Sapp Creek and the smallest in Nursery Creek.

Table 5.47 Nitrate + Nitrate (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TON[2]	TON[3]	%	TON[2]	TON[3]	%	TON[2]	TON[3]	%	TON[2]	TON[3]	%	TON[2]	TON[3]	%
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	-	12.0	4.0	-	13.0	4.0	-
Min	0.2	0.1	-45	0.3	0.6	82	1.0	0.9	-10	0.0	0.0	-9	0.2	0.3	24
Max	0.8	0.3	-60	16.0	2.3	-86	17.0	3.9	-77	0.5	0.1	-78	3.6	1.1	-69
Avg.	0.4	0.2	-53	3.5	1.4	-60	3.6	2.3	-38	0.2	0.1	-64	1.2	0.6	-53
Med.	0.3	0.2	-52	1.3	1.4	6	2.8	2.1	-24	0.2	0.1	-63	0.6	0.5	-22
Var.	0.03	0.01	-70	24.5	0.6	-97	18.3	1.6	-91	0.0	0.0	-91	1.7	0.1	-92
St. Dev.	0.2	0.1	-46	5.0	0.8	-84	4.3	1.3	-71	0.1	0.0	-69	1.3	0.4	-72

Note: TON[2] = sample not including storm data; TON[3] = storm samples; % = percent difference

Correlations between creeks for TON concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, TON was moderately strongly correlated to TSS (0.57), and moderately correlated to pH (-0.47)). For Black Creek, TON was strongly correlated to Stage (-0.75), DO (-0.69), and Alk (0.68), moderately strongly correlated to SC (0.61) and TKN (-0.59), and moderately correlated to pH (-0.52), Mn (0.52), Turb (-0.49), TSS (-0.48), and Hd (0.46). For Buss Creek, TON was strongly correlated to TN (0.99), TKN (0.83), SC (0.79), Alk (0.72), and Hd (0.66), and moderately correlated to stage (-0.49), and NH4 (0.45). For Nursery Creek, TON was strongly correlated to TN (0.99), NH4 (0.77), and DO (-0.70), and Alk (0.68), moderately strongly correlated and moderately correlated to SC (0.45). For Tired Creek, TON was strongly correlated to SC (0.98), Hd (0.92), Alk (0.88), and TN (0.83), moderately strongly correlated to DO (-0.57), and moderately correlated to Fe (-0.48). Alkalinity had a strong correlation to TON in all creeks but Sapp Creek. SC had two strong correlations, a moderately strong correlation, and a moderate correlation for a total of four correlations within the five creeks. DO and TN were also correlated in 3 of the 5 creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** TON correlated to other parameters. The strongest correlations included TN (0.98) and SC (0.65) and moderate correlations with Alk (0.57), Hd (0.56), and NH4 (0.56).

5.15 Ammonium

Ammonium samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.48** including count, minimum, maximum, average, median, variance, and standard deviation. Most concentrations were determined to be below the detection limit, which is typical of waters in the region not influenced by industries or water treatment facilities. Data for each sample event is shown in **Appendix E.**

Table 5.48 Ammonium concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	16	16	16	17
Min	BDL	BDL	BDL	BDL	BDL
Max	0.05	0.1	0.17	0.01	0.06
Average	0.01	0.02	0.03	0.00	0.01
Median	0.00	0.00	0.01	0.00	0.00
Variance	0.00	0.00	0.00	0.00	0.00
Standard Deviation	0.02	0.03	0.05	0.00	0.02

A line graph is shown in **Figure 5.47** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek and Buss Creek had the most readings and highest concentrations, while Sapp Creek had the fewest readings and lowest concentrations. Each data point on the zero line was BDL. A box and whisker plot for NH4 was not developed due to all the BDL concentrations.

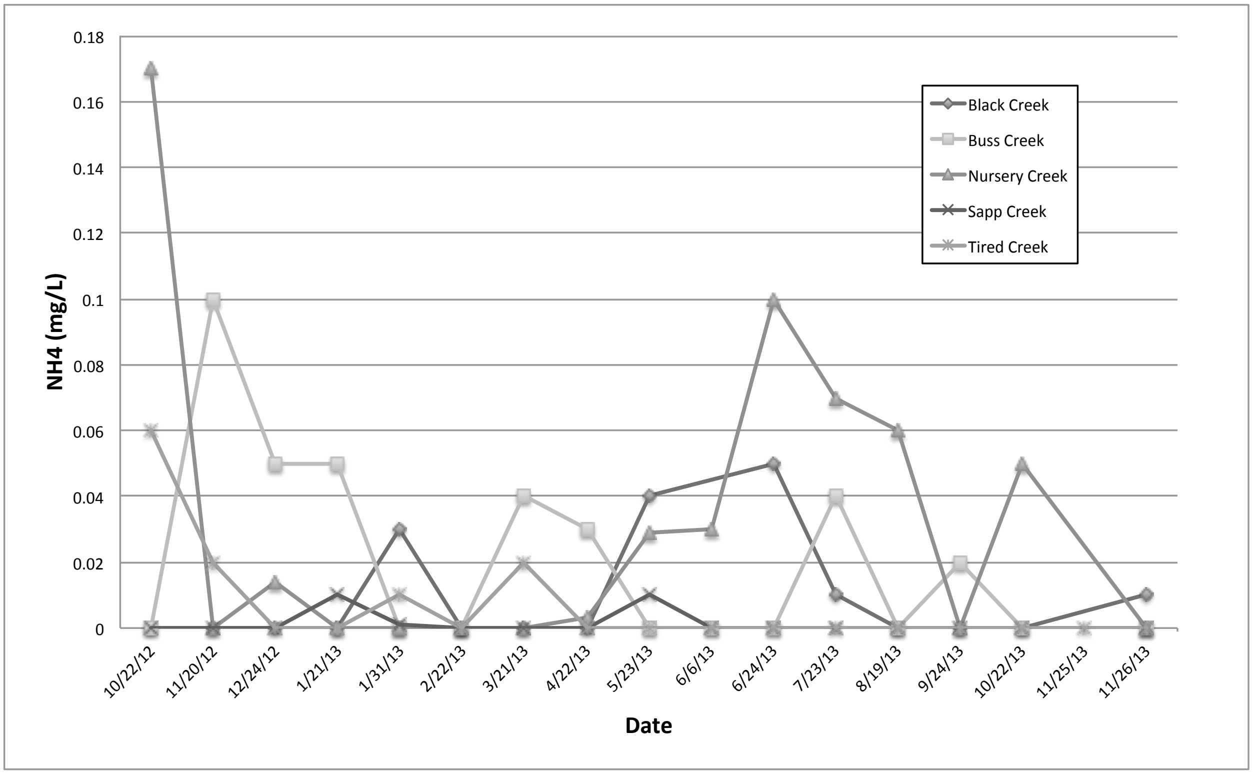

Figure 5.47 Ammonium concentrations for all grab samples

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well below F-ratio and the p-value was below 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- .028 was determined. Based on the analysis, it was determined a significant difference between Sapp Creek and Nursery Creek, along with Tired Creek and Nursery Creek.

A correlation matrix between the creeks was also developed in **Table 5.49** comparing the creeks. The strongest correlation was between Tired Creek and Nursery Creek, with a moderate correlation coefficient of 0.58. All other correlations were weak.

Table 5.49 Ammonium correlation matrix for all samples

	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	-0.39	1.00			
Nursery Creek	0.19	-0.35	1.00		
Sapp Creek	0.29	0.05	-0.16	1.00	
Tired Creek	-0.19	0.08	**0.58**	-0.17	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.50** lists the percent differences after taking storm events out of the data. The minimum and maximums for NH4 in each creek did not change. Black Creek was on the only creek average to decrease by 11%, while all four other creek averages increased by 19-33% after removing the storms. The Nursery Creek median increased 153% after removing storms.

Table 5.50 Ammonium (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	NH4[1]	**NH4[2]**	**%**	**NH4[1]**	**NH4[2]**	**%**	**NH4[1]**	**NH4[2]**	**%**	**NH4[1]**	**NH4[2]**	**%**	**NH4[1]**	**NH4[2]**	**%**
n	15	12	-	16	12	-	16	12	-	16	12	-	17	13	-
Min	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
Max	0.05	0.05	**0**	0.1	0.1	**0**	0.17	0.17	**0**	0.01	0.01	**0**	0.06	0.06	**0**
Avg.	0.01	0.01	**-11**	0.02	0.03	**33**	0.03	0.04	**26**	0.00	0.00	**27**	0.01	0.01	**19**
Med.	0.00	0.00	**0**	0.00	0.03	**0**	0.01	0.02	**153**	0.00	0.00	**0**	0.00	0.00	**0**
Var.	0.00	0.00	**10**	0.00	0.00	**12**	0.00	0.00	**20**	0.00	0.00	**31**	0.00	0.00	**28**
St. Dev.	0.02	0.02	**5**	0.03	0.03	**6**	0.05	0.05	**10**	0.00	0.00	**14**	0.02	0.02	**13**

Note: NH4[1] = all samples; NH4[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was smaller than F-ratio and the p-value was smaller than 0.05. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 0.036. There proved to be a significant difference of means between Nursery Creek and Sapp Creek.

A correlation matrix was also developed for the data not including storm events in **Table 5.51**. The strongest correlation was again between Tired Creek and Nursery Creek with a correlation coefficient of 0.58. There was also an inverse correlation between Nursery Creek and Buss Creek.

Table 5.51 Ammonium correlation matrix not including storm samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	-0.40	1.00			
Nursery Creek	0.27	**-0.56**	1.00		
Sapp Creek	0.31	-0.04	-0.24	1.00	
Tired Creek	-0.24	0.01	**0.58**	-0.22	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.52.** There was no change in the minimums for any creek, but the maximum for Black Creek decreased by 40% and the average increased by 60%. For the other four creeks, maximums decreased by 83-100% and averages decreased 68-100%. Based on the percent difference for including storm data versus not including storm data and non-storm data versus storm data, it was determined storms decrease the concentration of ammonium.

Table 5.52 Ammonium (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	NH4^2	**NH4^3**	**%**	**NH4^2**	**NH4^3**	**%**	**NH4^2**	**NH4^3**	**%**	**NH4^2**	**NH4^3**	**%**	**NH4^2**	**NH4^3**	**%**
n	12	3	-	12	4	-	12	4	-	12	4	-	13	4	-
Min	0	0.0	**0**	0	0.0	**0**	0	0.0	**0**	0	0.0	**0**	0	0.0	**0**
Max	0.05	0.03	**-40**	0.1	0.0	**-100**	0.17	0.03	**-82**	0.01	0.001	**-90**	0.06	0.01	**-83**
Avg.	0.01	0.013	**60**	0.03	0.0	**-100**	0.04	0.01	**-82**	0.00	0.0	**-85**	0.01	0.002	**-68**
Med.	0.00	0.01	**0**	0.03	0.0	**-100**	0.02	0.00	**-100**	0.00	0.0	**0**	0.00	0.0	**0**
Var.	0.00	0.00	**-24**	0.00	0.0	**-100**	0.00	0.00	**-92**	0.00	0.0	**-98**	0.00	0.0	**-92**
St. Dev.	0.02	0.02	**-13**	0.03	0.0	**-100**	0.05	0.02	**-71**	0.00	0.001	**-87**	0.02	0.005	**-71**

Note: NH4^2 = sample not including storm data; NH4^3 = storm data; % = percent difference

Correlations between creeks for ammonium concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, NH4 was moderately correlated to pH (0.45). For Black Creek, NH4 had the strongest correlation to TP (0.43), but was still considered week. For Buss Creek, NH4 was strongly correlated to Hd (0.65) and moderately correlated to SC (0.50), TN (0.46), and TON (0.45). For Nursery Creek, NH4 was strongly correlated to DO (-0.81), TN (0.78), and TON (0.77) and moderately correlated to pH (-0.45). For Tired Creek, NH4 was strongly correlated to Alk (0.66), moderately strongly correlated to Hd (0.62) and moderately correlated to SC (0.53)and pH (0.53). Based on data from all individual creek correlations, NH4 was correlated to pH in three creeks and also correlated to Hd, SC, TN and TON in two creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** NH4 correlated to other parameters. NH4 had a moderate correlation to TN (0.57), TON (0.56), and SC (0.45)

5.16 Total Phosphorus

Total Phosphorus samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.51** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.53 Total Phosphorus concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.0	16.0	16.0	16.0	17.0
Min	0.04	0.09	0.03	0.04	0.06
Max	0.24	0.64	0.62	0.23	0.73
Average	0.08	0.19	0.18	0.09	0.17
Median	0.06	0.13	0.11	0.08	0.12
Variance	0.00	0.02	0.03	0.00	0.03
Standard Deviation	0.05	0.15	0.16	0.05	0.16

A line graph is shown in **Figure 5.48** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. There are noticeable peaks during storm events in February, June, and November.

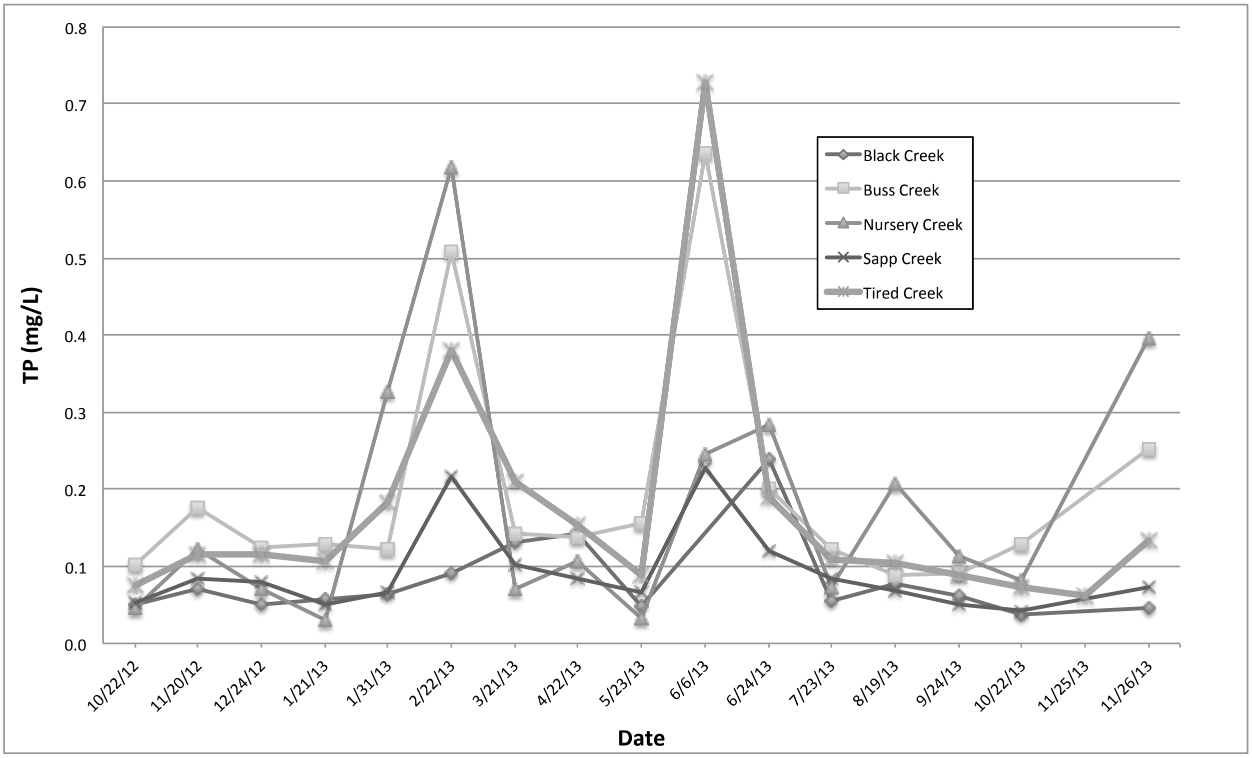

Figure 5.48 Total Phosphorous concentrations for all grab samples

A box and whisker plot for TP is provided in **Figure 5.49,** including a thick black line indicating the maximum recommended level by the EPA to prevent eutrophication in lakes. The Buss Creek median is higher than the rest of the creeks, while Tired Creek and Nursery Creek are a bit smaller. All 3 creeks were above recommended reference levels of 0.1 mg/L to help prevent eutrophication. Black Creek had the lowest median and Sapp Creek was a bit higher. Both of which are below reference levels in the region to prevent eutrophication.

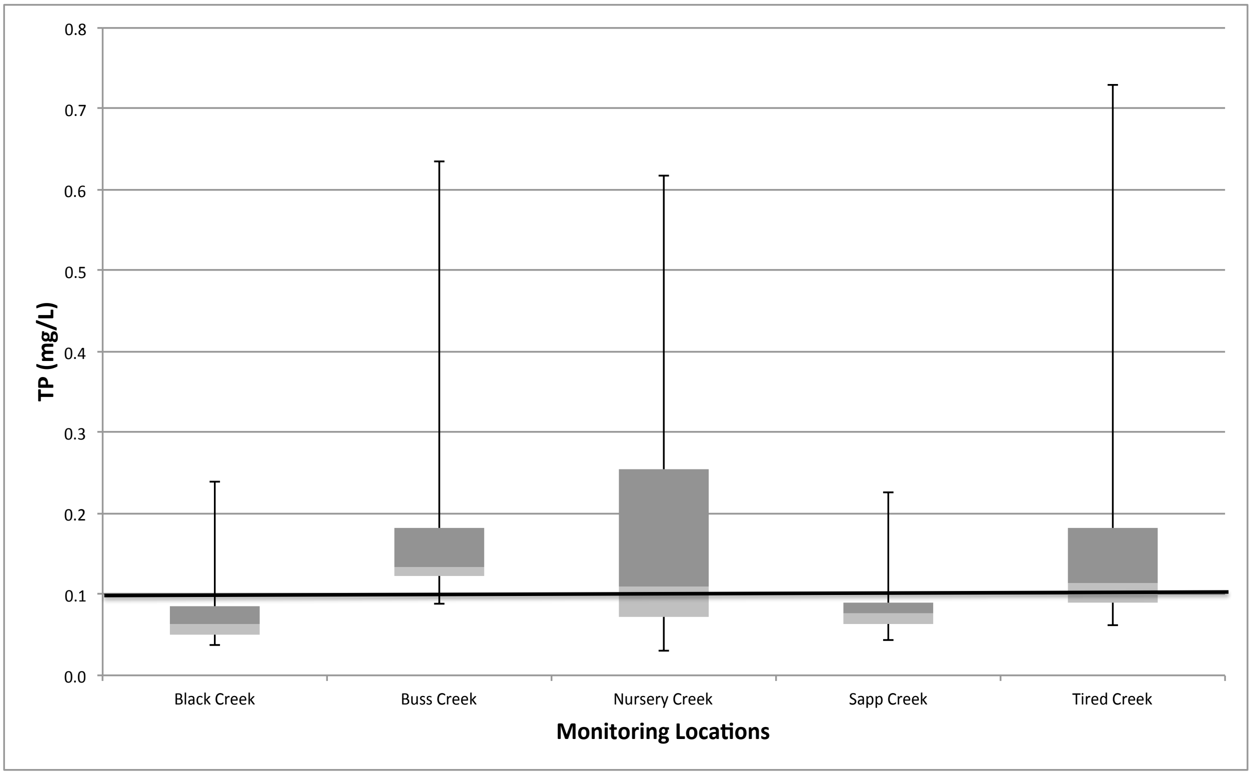

Figure 5.49 Total Phosphorus box and whisker plot for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was just below F-ratio and the p-value was below 0.05, there was a small difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 0.14 was determined. Based on the analysis, it was determined there were no significant differences in the means between creeks. The largest differences included Black Creek and Buss Creek (-0.11) and Buss Creek and Sapp Creek (0.1).

A correlation matrix between the creeks was also developed in **Table 5.54**. The strongest correlations were between Buss Creek and Sapp Creek (0.94), Buss Creek and Tired Creek (0.93) and Sapp Creek and Tired Creek (0.91). Moderately strong correlations included Buss Creek and Nursery Creek (0.62) and Sapp Creek and Nursery Creek (0.62).

Table 5.54 Total Phosphorus correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.16	1.00			
Nursery Creek	0.20	**0.62**	1.00		
Sapp Creek	0.43	**0.94**	**0.62**	1.00	
Tired Creek	0.42	**0.93**	**0.46**	**0.91**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.5** lists the percent differences after taking storm events out of the data. After removing the storm samples, minimums did not change and there were minimal changes in Black Creek. As for the other four creeks, Maximums decreased 47-71% and averages also decreased 20-42%. Variances and standard deviations also decreased.

Table 5.55 Total Phosphorus (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TP1	**TP2**	**%**	**TP1**	**TP2**	**%**	**TP1**	**TP2**	**%**	**TP1**	**TP2**	**%**	**TP1**	**TP2**	**%**
n	15.0	12.00	-	16.0	12.00	-	16.0	12.00	-	16.0	12.00	-	17.0	13.00	-
Min	0.04	0.04	**0**	0.09	0.09	**0**	0.03	0.03	**0**	0.04	0.04	**0**	0.06	0.06	**0**
Max	0.24	0.24	**0**	0.64	0.20	**-69**	0.62	0.28	**-54**	0.23	0.12	**-47**	0.73	0.21	**-71**
Avg.	0.08	0.09	**5**	0.19	0.13	**-32**	0.18	0.10	**-42**	0.09	0.07	**-20**	0.17	0.11	**-33**
Med.	0.06	0.06	**-5**	0.13	0.13	**-3**	0.11	0.08	**-30**	0.08	0.07	**-3**	0.12	0.11	**-8**
Var.	0.00	0.003	**21**	0.02	0.001	**-95**	0.03	0.006	**-79**	0.00	0.001	**-82**	0.03	0.002	**-92**
St. Dev.	0.05	0.06	**10**	0.15	0.03	**-79**	0.16	0.07	**-54**	0.05	0.02	**-58**	0.16	0.04	**-73**

Note: TP1 = all samples; TP2 = sample not including storm data; % = percent difference

A second ANOVA, in **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was a fraction smaller than F-ratio and the p-value was barely smaller than 0.05, just as with storms included. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 0.06. There was a significant difference between Buss Creek and Sapp Creek (0.06).

A correlation matrix was also developed for the data not including storm events in **Table 5.56**. All creeks were somewhat correlated. The strongest correlation was between Tired Creek and Sapp Creek with a correlation coefficient of 0.88. More strong correlations included Black Creek and Tired Creek (0.84), Black Creek and Sapp Creek (0.81), Black Creek and Nursery

Creek (0.73), and Buss Creek and Sapp Creek (0.66). Moderately strong correlated creeks included Buss Creek and Black Creek (0.59) and Nursery Creek and Sapp Creek.

Table 5.56 Total Phosphorus (mg/L) percent difference non-storm data and storm data

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.59**	1.00			
Nursery Creek	**0.73**	0.32	1.00		
Sapp Creek	**0.81**	**0.66**	**0.55**	1.00	
Tired Creek	**0.84**	**0.54**	0.42	**0.88**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.57**.

Non-storm TP concentrations increased for all creeks other than Black Creek, in which the maximum decreased by 62% and the average decreased by 22%. Concentrations of the other four creek minimums increased 38-733%, maximums increased 89-218%, and averages increased 98-285%. There was also a large increase in the variance and standard deviation of storm data. Based on higher concentrations in storm data and lower concentrations after removing storm data, it was determined storm flow increases total phosphorus.

Table 5.57 Total Phosphorus (mg/L) percent difference

non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TP^2	**TP^3**	**%**	**TP^2**	**TP^3**	**%**	**TP^2**	**TP^3**	**%**	**TP^2**	**TP^3**	**%**	**TP^2**	**TP^3**	**%**
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	--	12.0	4.0	-	13.0	4.0	-
Min	0.04	0.05	**23**	0.09	0.12	**38**	0.03	0.25	**733**	0.04	0.07	**54**	0.06	0.13	**116**
Max	0.24	0.09	**-62**	0.20	0.64	**218**	0.28	0.62	**118**	0.12	0.23	**89**	0.21	0.73	**247**
Avg.	0.09	0.07	**-22**	0.13	0.38	**185**	0.10	0.40	**285**	0.07	0.15	**98**	0.11	0.36	**210**
Med.	0.06	0.06	**6**	0.13	0.38	**193**	0.08	0.36	**372**	0.07	0.15	**97**	0.11	0.28	**165**
Var.	0.003	0.00	**-85**	0.001	0.05	**4908**	0.01	0.03	**362**	0.001	0.01	**1363**	0.002	0.07	**3578**
St. Dev.	0.06	0.02	**-61**	0.03	0.23	**608**	0.07	0.16	**115**	0.02	0.09	**283**	0.04	0.27	**506**
Note: TP^2 = sample not including storm data; TP^3 = storm data; % = percent difference															

Correlations between creeks for TP concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, TP was strongly correlated to Turb (0.88), TSS (0.84), and Mn (0.71), moderately strongly correlated to Fe (0.62), and moderately correlated to TKN (0.45). For Black Creek, TP was strongly correlated to SC (-0.68) and Fe (-0.65) and moderately correlated to Alk (-0.46). For Buss Creek, TP was strongly correlated to turbidity (0.96), Fe (0.93), and FC (0.72), moderately strongly correlated to Mn (0.63) and pH (0.58). For Nursery Creek, TP was strongly correlated to Turbidity (0.86), TSS (0.80), Mn (0.79), Fe (0.78), SC (-0.77), Hd (-0.77), Stage (0.73), TSS (0.72) and Alk (-0.68). For Tired Creek, TP was strongly correlated to TKN (0.95) and Mn (0.81), moderately strongly correlated to TSS (0.57) and DO (0.55). Based on data from all the creeks, TP was correlated to Fe in four creeks, Mn in four creeks, turbidity in three creeks, and TSS in three creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** all TP correlations were weak. The strongest correlations included Fe (0.34), TKN (0.29), TSS (0.28), and turbidity (0.25).

5.17 Total Suspended Solids

Total Suspended Solids samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.58** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.58 Total Suspended Solids concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15.0	16.0	16.0	16.0	17.0
Min	2.0	2.0	2.0	2.0	2.0
Max	49.0	840.0	750.0	120.0	220.0
Average	9.1	72.5	127.4	17.3	33.0
Median	4.6	6.8	12.5	5.6	11.0
Geometric Mean	6.0	11.1	22.6	7.4	13.5
Variance	138.4	43362.1	61883.8	936.7	3299.4
Standard Deviation	11.8	208.2	248.8	30.6	57.4

A line graph is shown in **Figure 5.50** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. There are noticeable peaks during storm events in February, June, and November.

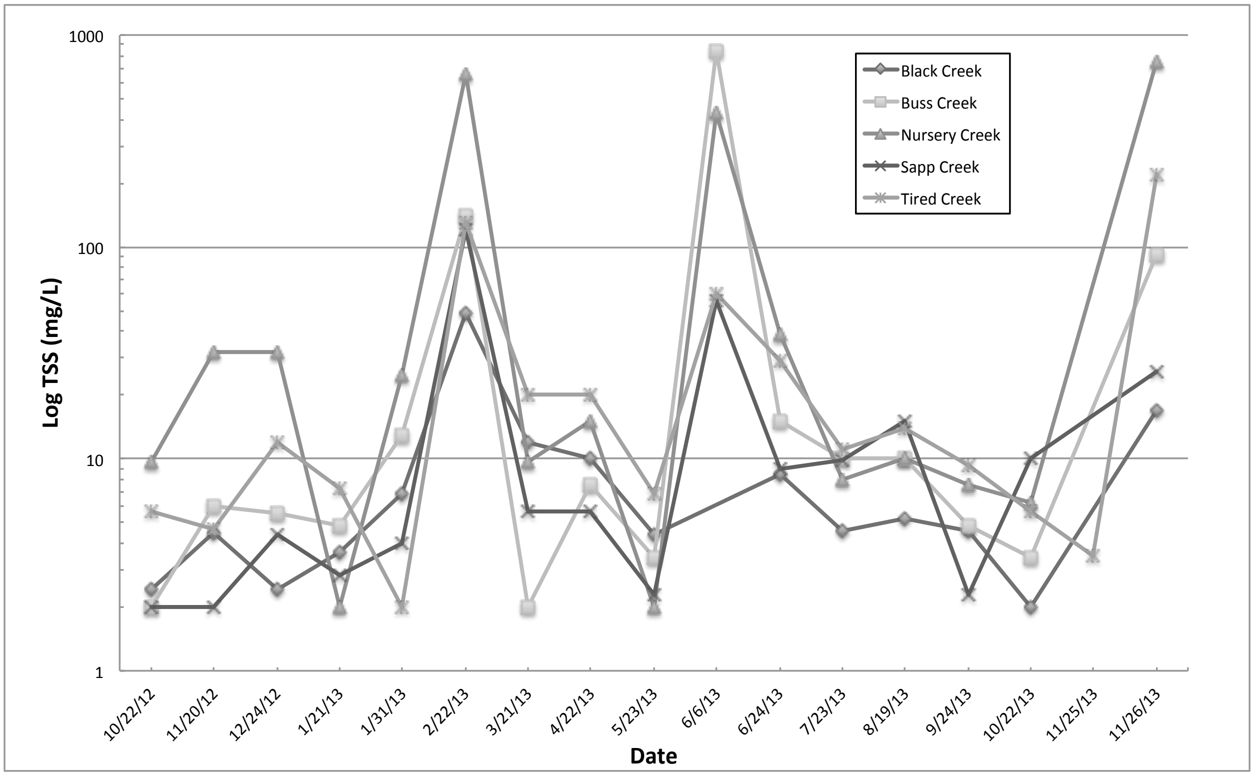

Figure 5.50 Total Suspended Solids concentration for all grab samples

A box and whisker plot for TSS is provided in **Figure 5.51**. The Nursery Creek median is higher than the rest of the creeks, while Tired Creek is the second highest. Black Creek and Sapp Creek had the lowest TSS medians. The longer tails were due to storm events and increases in concentrations.

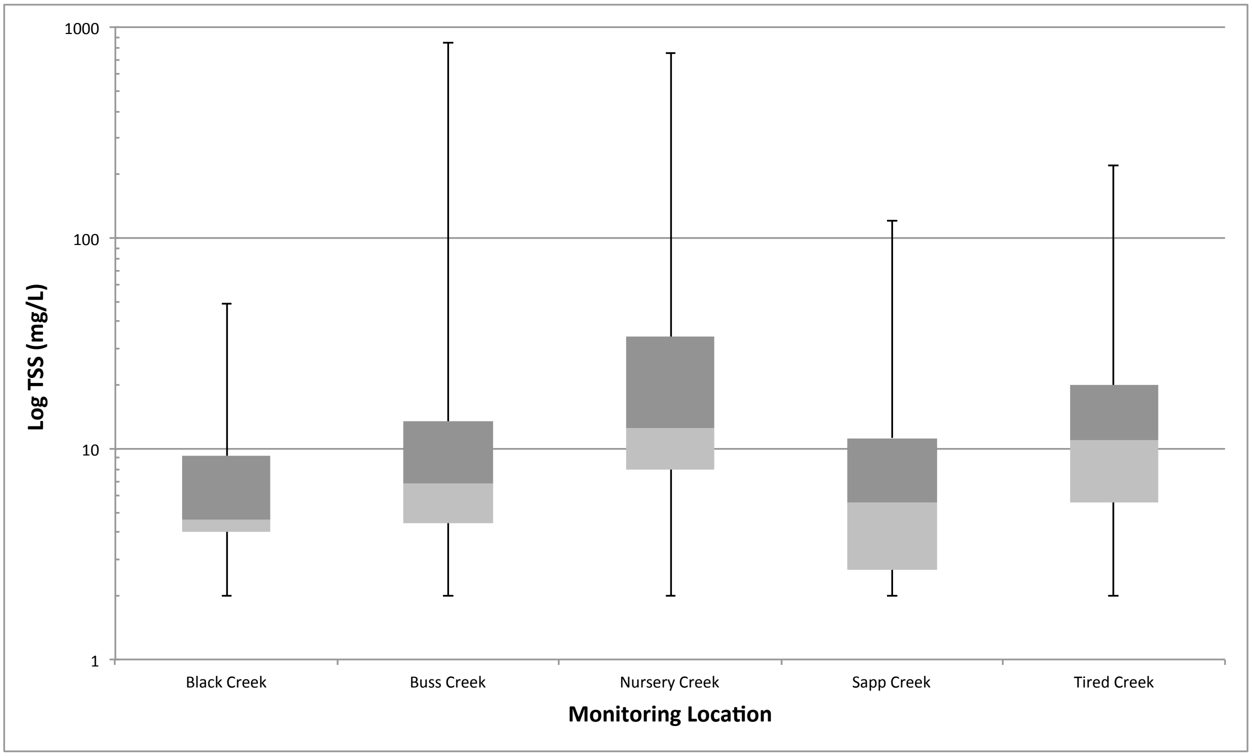

Figure 5.51 Total Suspended Solids box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was larger than F-ratio and the p-value was above 0.05, there were no differences in the creeks. Therefore, a tukey test was not needed.

A correlation matrix between the creeks was also developed in **Table 5.59**. All creeks were correlated with the strongest correlations were between Black Creek and Sapp Creek (0.96) and Nursery Creek and Tired Creek (0.95). Other strong correlations included Buss Creek and Black Creek (0.92), Black Creek and Nursery Creek (0.79), Nursery Creek and Sapp Creek (0.78), and Tired Creek and Black Creek (0.66). Moderate and weak correlations can be found in the correlation matrix.

Table 5.59 Total Suspended Solids correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.92**	1.00			
Nursery Creek	**0.79**	**0.48**	1.00		
Sapp Creek	**0.96**	**0.49**	**0.78**	1.00	
Tired Creek	**0.66**	0.27	**0.95**	**0.59**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.60** lists the percent differences after taking storm events out of the data. After removing the storm samples, minimums stayed similar, but maximums decreased by 76-98%. All the other averages also decreased 41-91% after removing storms for TSS. Variances and standard deviations also decreased substantially.

Table 5.60 Total Suspended Solids (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TSS[1]	TSS[2]	%	TSS[1]	TSS[2]	%	TSS[1]	TSS[2]	%	TSS[1]	TSS[2]	%	TSS[1]	TSS[2]	%
n	15.0	12.0	-	16.0	12.0	-	16.0	12.0	-	16.0	12.0	-	17.0	13.0	-
Min	2.0	2.00	0	2.0	2.00	0	2.0	2.00	0	2.0	2.00	0	2.0	3.50	75
Max	49.0	12.0	-76	840.0	15.0	-98	750	39.0	-95	120	15.0	-88	220.0	29.00	-87
Avg.	9.1	5.35	-41	72.5	6.21	-91	127	14.4	-89	17.3	5.90	-66	33.0	11.45	-65
Med.	4.6	4.55	-1	6.8	5.15	-24	12.5	9.65	-23	5.6	5.00	-11	11.0	9.40	-15
Var.	138	10.0	-93	43k	14.9	-100	62k	159	-100	937	17.5	-98	3299	56.86	-98
St. Dev.	11.8	3.17	-73	208.2	3.86	-98	248	12.6	-95	30.6	4.19	-86	57.4	7.54	-87

Note: TSS[1] = all samples; TSS[2] = sample not including storm data; % = percent difference; k = thousand

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was a smaller than F-ratio and the p-value was smaller than 0.05. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 8.88. There was a significant difference between Black Creek and Nursery Creek (-9.08).

A correlation matrix was also developed for the data not including storm events in **Table 5.61**. The strongest correlation was between Tired Creek and Black Creek with a correlation coefficient of 0.79. Moderately correlated creeks included Buss Creek and Tired Creek (0.64) and Buss Creek and Sapp Creek (0.58). All other correlations can be seen in the table below.

Table 5.61 Total Suspended Solids (mg/L) correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.25	1.00			
Nursery Creek	0.15	**0.53**	1.00		
Sapp Creek	0.13	**0.58**	0.02	1.00	
Tired Creek	**0.79**	**0.64**	**0.46**	0.38	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.62**. Concentrations of TSS increased for all statistical analysis other than a decrease in the minimum for Tired Creek, which was odd considering Turb increased for the storm event in January. Minimums increased from 100% for Sapp Creek to 1150% for Nursery Creek. Maximums also increased from 308% in Black Creek to as much as 5500% in Buss Creek. Averages ranged from a 354% increase in Black Creek to a 4269% increase in Buss Creek. There were also large increases in variance and standard deviation of storm data. Based on higher concentrations in storm data and lower concentrations after removing storm data, it was determined storm flow increases total suspended solids.

Table 5.62 Total Suspended Solids (mg/L) percent difference non-storm data and storm data

	Black Creek			**Buss Creek**			**Nursery Creek**			**Sapp Creek**			**Tired Creek**		
	TSS²	**TSS³**	**%**	**TSS²**	**TSS³**	**%**	**TSS²**	**TSS³**	**%**	**TSS²**	**TSS³**	**%**	**TSS²**	**TSS³**	**%**
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	-	12.0	4.0	-	13.0	4.0	-
Min	2.00	6.90	245	2.00	13.	550	2.00	25.0	1150	2.00	4.00	100	3.50	2.00	-43
Max	12.0	49.0	308	15.0	840	5500	39.0	750	1823	15.00	120	700	29.00	220	659
Avg.	5.35	24.3	354	6.21	271	4269	14.4	466	3132	5.90	51	773	11.45	103	800
Med.	4.6	17.0	274	5.15	116	2152	9.65	545	5548	5.00	41	720	9.40	95	911
Var.	10.0	483	4721	14.9	147K	984448	159	105K	65K	17.53	2539	14K	56.86	882	15K
St. Dev.	3.17	22.0	594	3.86	383	9822	12.6	323	2464	4.19	50	1104	7.54	93.9	1146

Note: TSS² = sample not including storm data; TSS³ = storm data; % = percent difference

Correlations between creeks for TSS concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15**). For Sapp Creek, TSS was strongly correlated to turbidity (0.95) and TP (0.84) and moderately correlated to Mn (0.51) and Fe (0.46). For Black Creek, TSS was strongly correlated to turbidity (0.98), Stage (0.76), and FC (0.65), and moderately correlated to TON (-0.48), DO (0.48), TKN (0.47), SC (-0.46), and Alk (-0.45). For Buss Creek, TSS was strongly correlated to turbidity (0.97) and FC (0.68), moderately strongly correlated to Mn (0.59), and moderately correlated to pH (0.46). For Nursery Creek, TSS was strongly correlated to turbidity (0.99), Fe (0.94), Stage (0.81), Mn (0.8), TP (0.8), and FC (0.72), moderately strongly correlated to Hd (-0.64), SC (-0.63), WT (-0.51), and Alk (-0.46). For Tired Creek, TSS was strongly correlated to turbidity (0.96), Mn (0.84), FC (0.70), and Fe (0.68). Based on data from all the creeks, TSS was correlated to turbidity in all five creeks, Mn in four creeks, Fe in three creeks, and FC in three creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** TSS correlations included turbidity (0.87), FC (0.59), and a weak correlation with Fe (0.41).

5.18 pH

pH measurements for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.63** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.63 pH concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	5.91	6.12	6.83	6.28	6.25
Max	6.92	7.35	8.09	7.05	7.55
Average	6.29	6.72	7.62	6.75	6.95
Median	6.33	6.74	7.70	6.75	7.02
Variance	0.06	0.09	0.16	0.06	0.11
Standard Deviation	1.59	1.70	1.94	1.70	1.72

A line graph is shown in **Figure 5.48** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek consistently had the highest pH, while Black Creek had the lowest readings over the assessment period.

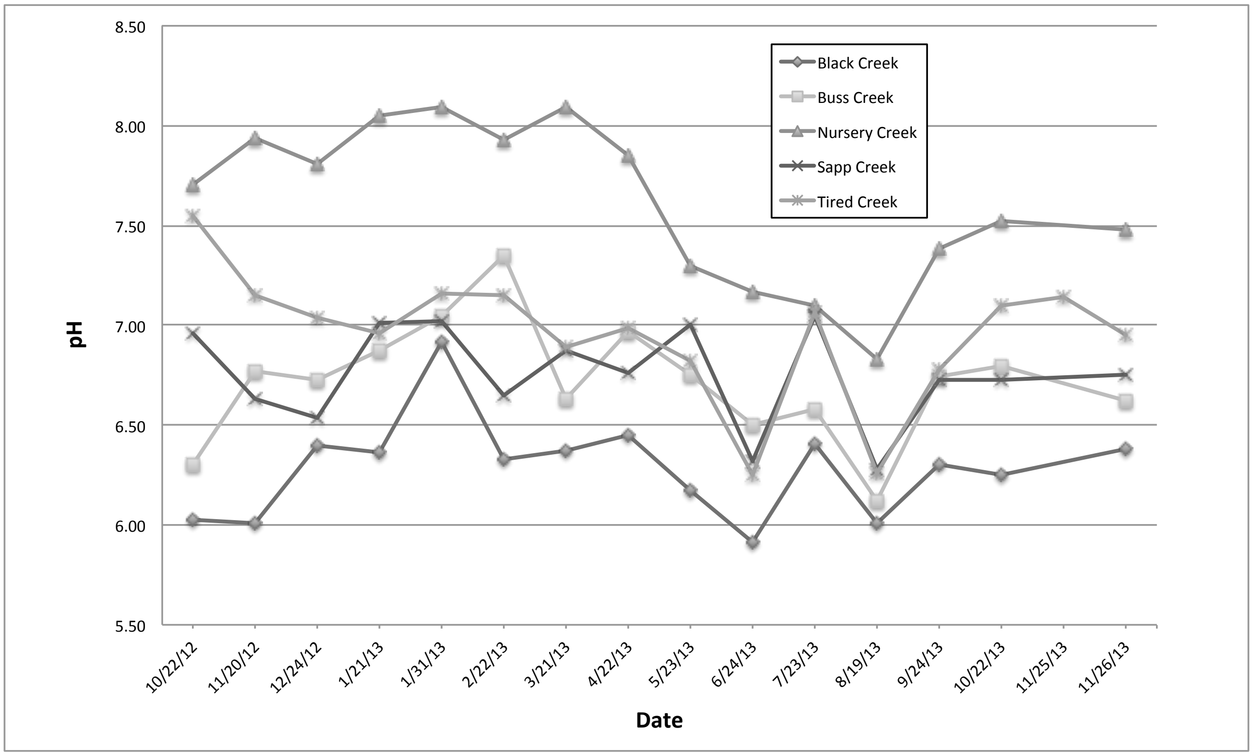

Figure 5.52 pH concentration for all grab samples

A box and whisker plot for pH is provided in **Figure 5.53** with the state standards for pH range between the thick black lines. The Nursery Creek median is higher than the rest of the creeks, while with Black Creek the lowest. All 5 creeks were within GAEPD state standards for recreational waters to support aquatic life. A single Black Creek measurement was below a pH of 6.0, evident by the tails.

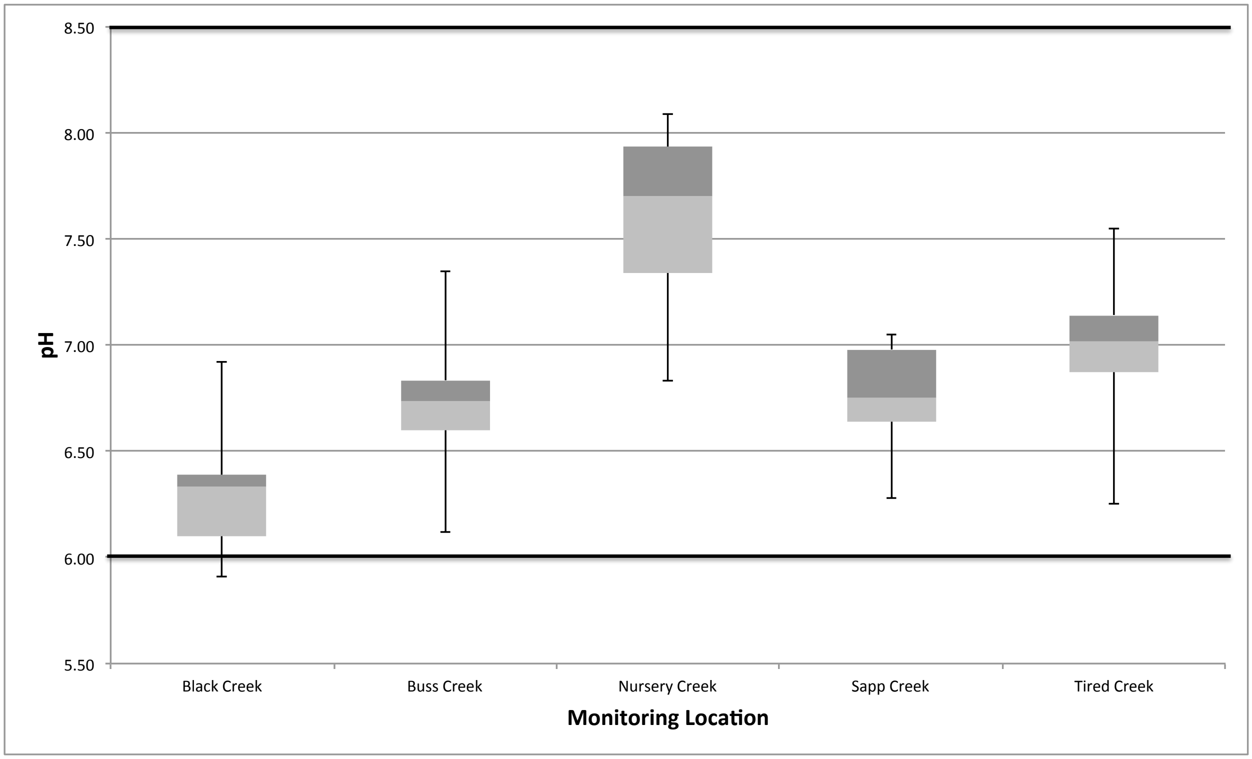

Figure 5.53 pH box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was well below F-ratio and the p-value was below 0.05, there were differences in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 0.33 was determined. Based on the analysis, it was determined there were multiple significant differences in the means between creeks. All the creeks were different from Black Creek and Nursery Creek with Nursery Creek having the largest differences between other creeks, while Tired Creek, Buss Creek, and Sapp Creek were similar. The largest differences included Nursery Creek and Black Creek (-1.33) and Nursery Creek and Buss Creek (-0.90).

A correlation matrix between the creeks was also developed in **Table 5.64**. The strongest correlation was between Tired Creek and Sapp Creek (0.66). Moderately strong correlations

Buss Creek and Nursery Creek (0.64) and Tired Creek and Nursery Creek (0.62) and Buss Creek and Black Creek (0.58). All other correlations can be found in the table below.

Table 5.64 pH correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.58**	1.00			
Nursery Creek	**0.50**	**0.64**	1.00		
Sapp Creek	**0.54**	0.30	0.40	1.00	
Tired Creek	0.37	0.38	**0.62**	**0.66**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.65** lists the percent differences after taking storm events out of the data. Changes after removing storm data were minimal for all statistical analysis.

Table 5.65 pH percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	pH^1	pH^2	%	pH^1	pH^2	%	pH^1	pH^2	%	pH^1	pH^2	%	pH^1	pH^2	%
n	15	12	-	15	12	-	15	12	-	15	12	-	16	13	-
Min	5.91	5.91	**0**	6.12	6.12	**0**	6.83	6.83	**0**	6.28	6.28	**0**	6.25	6.25	**0**
Max	6.92	6.45	**-7**	7.35	6.97	**-5**	8.09	8.09	**0**	7.05	7.05	**0**	7.55	7.55	**0**
Avg.	6.29	6.22	**-1**	6.72	6.65	**-1**	7.62	7.56	**-1**	6.75	6.74	**0**	6.95	6.92	**0**
Med.	6.33	6.28	**-1**	6.74	6.74	**0**	7.70	7.61	**-1**	6.75	6.75	**0**	7.02	6.99	**0**
Var.	0.06	0.04	**-41**	0.09	0.06	**-33**	0.16	0.17	**6**	0.06	0.07	**14**	0.11	0.12	**18**
St. Dev.	1.59	1.74	**9**	1.70	1.86	**9**	1.94	2.13	**10**	1.70	1.89	**11**	1.72	1.88	**10**

Note: pH^1 = all samples; pH^2 = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was significantly smaller than F-ratio and the p-value was much smaller than 0.05, just as with storms included. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 0.37. Differences were very similar to when storms were included. All the creeks were different from Black Creek and Nursery Creek with Nursery Creek having the largest differences between other creeks, while Tired Creek, Buss Creek, and Sapp Creek were similar. The largest differences included Nursery Creek and Black Creek (-1.34) and Nursery Creek and Buss Creek (-0.92).

A correlation matrix was also developed for the data not including storm events in **Table 5.66**. All creeks were somewhat correlated and similar to when storm data was included. The strongest correlation was between Tired Creek and Sapp Creek (0.68). Moderately strong correlations Buss Creek and Black Creek (0.61), Buss Creek and Nursery Creek (0.59) and Tired Creek and Nursery Creek (0.59). All other correlations can be found in the table below.

Table 5.66 pH correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.61**	1.00			
Nursery Creek	0.40	**0.59**	1.00		
Sapp Creek	**0.52**	0.38	0.38	1.00	
Tired Creek	0.32	0.30	**0.59**	**0.68**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.67**. Averages increased from 1-5% for storm data.

Table 5.67 pH percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	pH^2	**pH^3**	**%**	**pH^2**	**pH^3**	**%**	**pH^2**	**pH^3**	**%**	**pH^2**	**pH^3**	**%**	**pH^2**	**pH^3**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	13	3	-
Min	5.91	6.33	**7**	6.12	6.62	**8**	6.83	7.48	**10**	6.28	6.65	**6**	6.25	6.95	**11**
Max	6.45	6.92	**7**	6.97	7.35	**5**	8.09	8.09	**0**	7.05	7.02	**0**	7.55	7.16	**-5**
Avg.	6.22	6.54	**5**	6.65	7.01	**5**	7.56	7.83	**4**	6.74	6.81	**1**	6.92	7.09	**2**
Med.	6.28	6.38	**2**	6.74	7.05	**5**	7.61	7.93	**4**	6.75	6.75	**0**	6.99	7.15	**2**
Var.	0.04	0.11	**199**	0.06	0.13	**130**	0.17	0.10	**-40**	0.07	0.04	**-46**	0.12	0.01	**-89**
St. Dev.	1.74	0.33	**-81**	1.86	0.37	**-80**	2.13	0.32	**-85**	1.89	0.19	**-90**	1.88	0.12	**-94**
Note: pH^2 = sample not including storm data; pH^3 = storm data; % = percent difference															

Correlations between creeks for pH concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, pH was moderately correlated to TN (-0.57), TON (-0.45) and NH4 (-0.45). For Black Creek, pH was strongly correlated to Fe (0.66) and moderately correlated to AT (-0.62), TON (-0.52), and DO (0.51). For Buss Creek, pH was strongly correlated to FC (0.71) and moderately correlated to Fe (0.58), TP (0.58), DO (0.54), Turb (0.53), AT (-0.50), and TSS (0.46). For Nursery Creek, pH was strongly correlated to AT (-0.92), WT (-0.79), and DO (0.69), and moderately correlated to Stage (0.47) and NH4 (-0.45). For Tired Creek, pH was moderately correlated to WT (-0.56) and NH4 (0.53). Based on data from all the creeks, pH was correlated to AT in 3 creeks, NH4 in 3 creeks, and DO in 3 creeks. It is important to note these are positive and negative correlations. In the correlation matrix including all the data from each creek location, end of **Appendix E,** pH correlated to other parameters. The strongest correlations included Alk (0.68) and Hd (0.66) and a moderate correlation with DO (0.49).

5.19 Specific Conductance

Specific Conductance for all grab samples in the creeks was compared to determine any trends, similarities, or differences. Statistical analyses for each creek is shown in **Table 5.68** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.68 Specific Conductance concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	61.5	51.7	152.3	56.4	62.3
Max	91.7	310.0	340.6	111.2	210.6
Average	74.46	121.96	240.46	77.30	111.93
Median	74.30	94.80	260.20	74.10	97.75
Variance	90.83	4835.14	2880.35	280.58	2150.81
Standard Deviation	20.77	73.77	79.39	25.21	52.47

A line graph is shown in **Figure 5.54** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek was consistently higher than the other four creeks, which were relatively similar other than some higher readings in Buss Creek and Tired Creek on occasion.

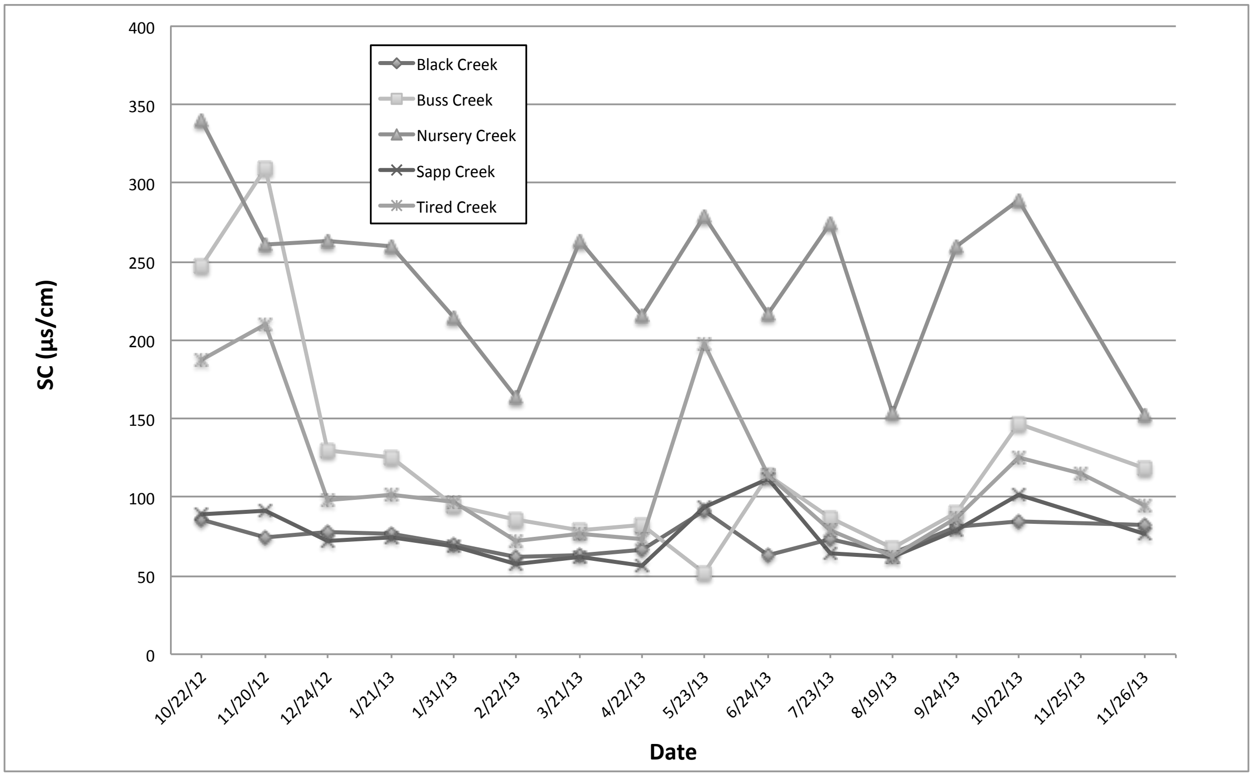

Figure 5.54 Specific Conductance concentration for all grab samples

A box and whisker plot for SC is provided in **Figure 5.51**. The Nursery Creek median is higher than the rest of the creeks, while Tired Creek and Buss Creek were similar and Sapp Creek and Black Creek were similar. The larger tails were in the positive direction. There was more variation in Nursery, Buss, and Tired Creeks when compared to Black and Sapp Creek.

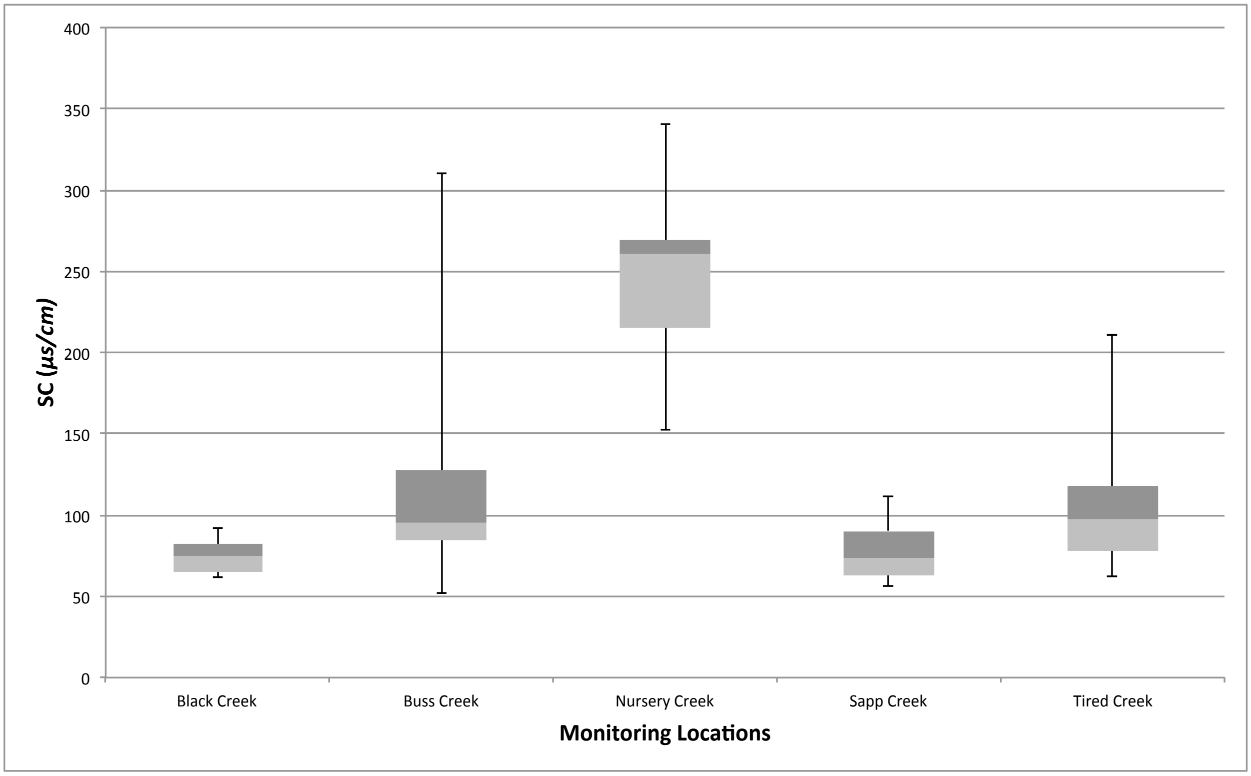

Figure 5.55 Specific Conductance box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was significantly below F-ratio and the p-value was below 0.05, there were differences in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 48.31 was determined. All the creeks other than Nursery Creek were similar, with the largest difference between Nursery Creek and Black Creek (-166) and Nursery Creek and Sapp Creek (163.16).

A correlation matrix between the creeks was also developed in **Table 5.69**. All creeks were correlated to Tired Creek. The strongest correlations were between Buss Creek and Tired Creek (0.68) and Sapp Creek and Tired Creek (0.67). Moderately strong correlations included Tired Creek and Black Creek (0.60) and Tired Creek and Nursery Creek (0.57). All other correlations can be found below.

Table 5.69 Specific Conductance correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.24	1.00			
Nursery Creek	**0.54**	0.42	1.00		
Sapp Creek	**0.48**	0.43	0.41	1.00	
Tired Creek	**0.60**	**0.68**	**0.57**	**0.67**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.70** lists the percent differences after taking storm events out of the data. After removing the storm samples, there were minimal changes, but all averages increased 1-7%.

Table 5.70 Specific Conductance percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	SC^1	SC^2	%	SC^1	SC^2	%	SC^1	SC^2	%	SC^1	SC^2	%	SC^1	SC^2	%
n	15	12	-	15	12	-	15	12	-	15	12	-	16	13	-
Min	61.5	62.6	**2**	51.7	51.7	**0**	152.3	153.3	**1**	56.4	56.4	**0**	62.3	62.3	**0**
Max	91.7	91.7	**0**	310	310	**0**	340.6	340.6	**0**	111.2	111	**0**	211	210.6	**0**
Avg.	74.5	75.1	**1**	122	128	**5**	240.4	256.3	**7**	77.3	79.7	**3**	112	117.4	**5**
Med.	74.3	75.2	**1**	94.8	102	**8**	260.2	261.8	**1**	74.1	76.5	**3**	97.8	102	**4**
Var.	90.8	91.9	**1**	4835	5935	**23**	288	2094	**-27**	2801	310	**11**	2150	2482	**15**
St. Dev.	20.8	22.8	**10**	73.8	81.8	**11**	79.39	83.51	**5**	25.2	27.8	**10**	52.4	57.23	**9**

Note: SC^1 = all samples; SC^2 = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was again much smaller than F-ratio and the p-value was smaller than 0.05, just as with storms included. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 57.73. Just as before, all the creeks other than Nursery Creek were similar, with the largest difference between Nursery Creek and Black Creek (-181) and Nursery Creek and Sapp Creek (176).

A correlation matrix was also developed for the data not including storm events in **Table 5.71**. All creeks were somewhat correlated, with at least moderately strong correlation with Tired Creek. The strongest correlations were between Black Creek and Nursery Creek (0.7) and

Buss Creek and Tired Creek (0.67). Moderately strong correlations included Tired Creek and Sapp Creek (0.64) and Tired Creek and Black Creek (0.61), and Tired Creek and Nursery Creek (0.56). All other correlations can be found below.

Table 5.71 Specific Conductance correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1				
Buss Creek	0.20	1.00			
Nursery Creek	**0.70**	**0.45**	1.00		
Sapp Creek	0.41	0.40	0.34	1.00	
Tired Creek	**0.61**	**0.67**	**0.56**	**0.64**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.72**.
Storm SC concentrations decreased for all creeks, with the smallest differences in Black Creek. Maximums decreased 10-62% and averages decreased 5-31%. There were also decreases in the variance and standard deviation of storm data. Based on lower concentrations in storm data and slightly higher concentrations after removing storm data, it was determined storm flow decreases SC.

Table 5.72 Specific Conductance percent difference non-storm data and storm data

	Black Creek			**Buss Creek**			**Nursery Creek**			**Sapp Creek**			**Tired Creek**		
	SC^2	**SC^3**	**%**	**SC^2**	**SC^3**	**%**	**SC^2**	**SC^3**	**%**	**SC^2**	**SC^3**	**%**	**SC^2**	**SC^3**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	13	3	-
Min	62.6	61.5	**-2**	51.7	86	**67**	153.3	152	**-1**	56	57.9	**3**	62.3	72.0	**16**
Max	91.7	82.8	**-10**	310	118	**-62**	341	214	**-37**	111	76.3	**-31**	210	97.4	**-54**
Avg.	75.1	71.5	**-5**	128	99.8	**-22**	256	177	**-31**	80	67.7	**-15**	117	88.2	**-25**
Med	75.2	70.3	**-7**	101	94.8	**-7**	261.8	164	**-37**	76.5	69.0	**-10**	102	95.1	**-7**
Var.	91.9	114	**25**	5935	281	**-95**	2094	1107	**-47**	310.2	85.8	**-72**	2482	197	**-92**
St. Dev.	22.8	10.7	**-53**	81.8	16.7	**-80**	83.51	33.28	**-60**	27.80	9.27	**-67**	57.	14.0	**-75**

Note: SC^2 = sample not including storm data; SC^3 = storm data; % = percent difference

Correlations between creeks for SC concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, SC was strongly correlated to Alk (0.71) and stage (-0.66), moderately strongly correlated to DO (-0.58), and moderately correlated to Fe (0.45). For Black Creek, SC was strongly correlated to Alk (0.68) and TP (-0.68), moderately strongly correlated to DO (-0.62), Stage (-0.61), TON (0.61), and Mn (0.61), and moderately correlated to TKN(-0.56), Turb (-0.51), and TSS (-0.46). For Buss Creek, SC was strongly correlated to TN (0.8), TKN (0.8), TON (0.79), and Alk (0.71), moderately correlated to Hd (0.53), NH4 (0.5), and Stage (-0.48). For Nursery Creek, SC was strongly correlated to Alk (0.9), Hd (0.86), TP (-0.77), turbidity (-0.67), and Fe (-0.65), moderately strongly correlated to TSS (-0.63) and Mn (-0.61), and moderately correlated to TON (0.54), Stage (-0.5), TN (0.47), and FC (-0.45). For

Tired Creek, SC was strongly correlated to TON (0.98), TN (0.96), Hd (0.93) and Alk (0.87), moderately strongly correlated to DO (-0.57), and moderately correlated to NH4 (0.53). Based on data from all the creeks, SC was correlated to Alk in all five creeks, TON and Stage in four creeks, and DO, TN and Hd in three creeks. It is important to note these are positive and negative correlations. In the correlation matrix including all the data from each creek location, end of **Appendix E,** SC was strongly correlated to other parameters. The strongest correlations included Alk (0.92), Hd (0.89), and TON (0.65), a moderately strong correlation with TN (0.61), and moderate correlations with Fe (-0.54) and NH4 (0.45).

5.20 Water Temperature

Water temperature during grab sampling for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.73** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.73 Water Temperature (°C) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	10.85	9.91	14.72	9.85	8.84
Max	24.41	25.86	26.32	26.03	24.35
Average	17.51	18.11	19.78	17.92	17.40
Median	16.20	15.67	19.50	16.00	15.40
Variance	22.77	29.85	13.68	30.39	28.02
Standard Deviation	6.36	6.95	6.10	6.96	6.64

A line graph is shown in **Figure 5.56** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. As you would expect, all the temperatures were similar, with lower temperature in the fall and winter months and higher temperatures in the spring and summer. Nursery Creek temperature was noticeably higher than the rest at the start of assessment. This may be due to inputs from the irrigation pond, which heats in the sun.

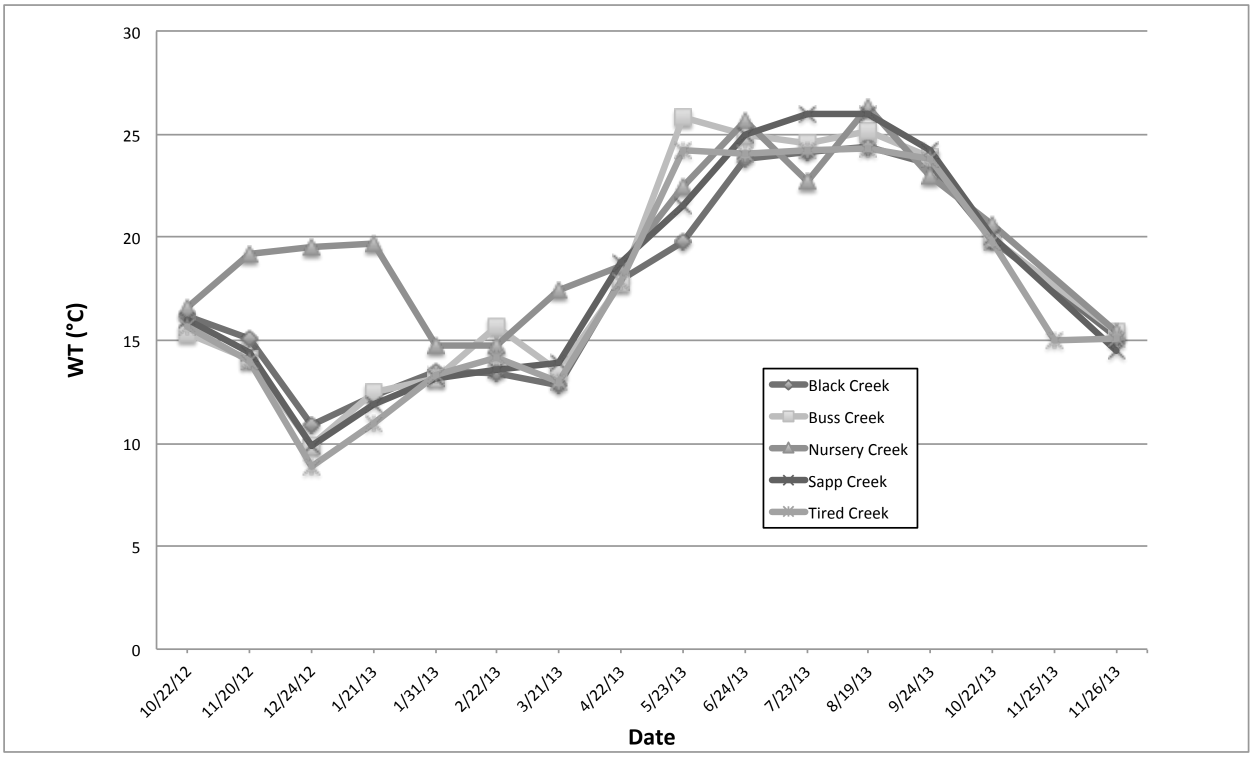

Figure 5.56 Water Temperature for all samples

A box and whisker plot for WT is provided in **Figure 5.57**. The nursery creek temperature was the highest. The tails were fairly evenly distributed. Tired Creek and Buss Creek had similar temperatures, while Black Creek and Sapp Creek medians were a bit higher.

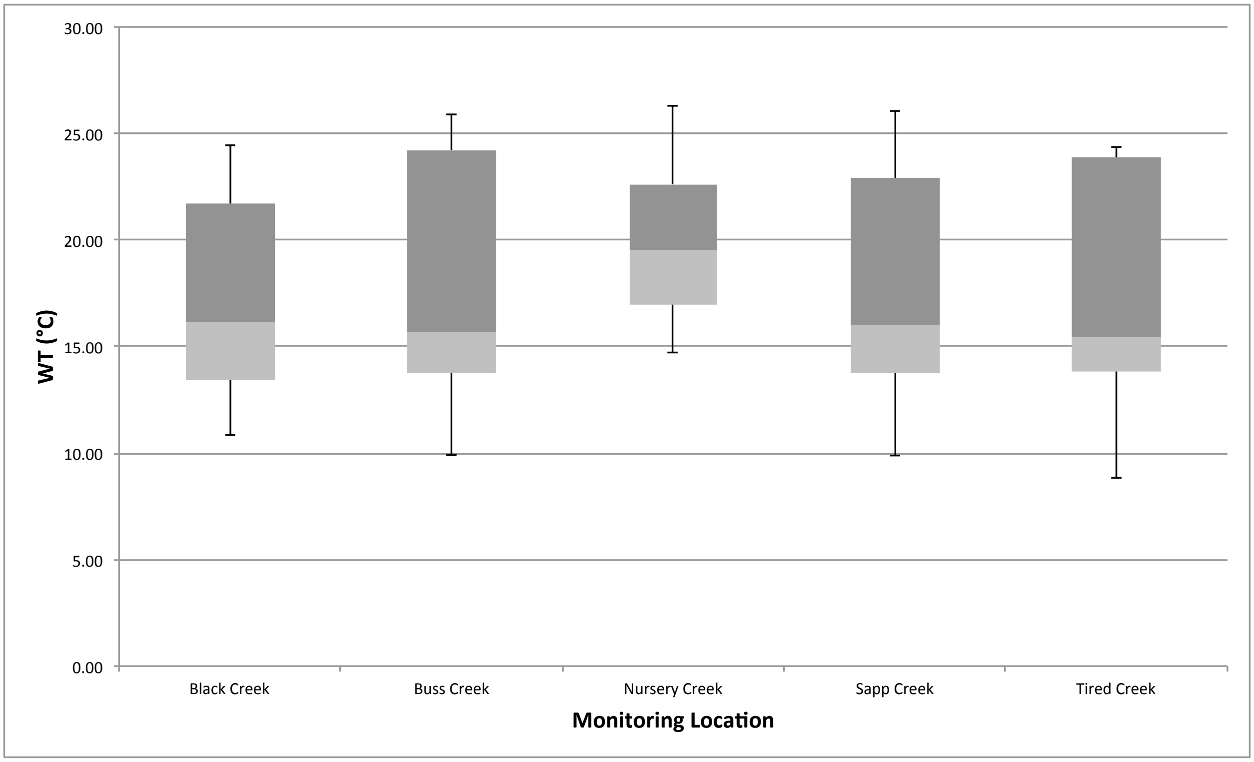

Figure 5.57 Water Temperature box and whisker for all locations

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was larger than F-ratio and the p-value was above 0.05, there was no difference in the creeks.

A correlation matrix between the creeks was also developed in **Table 5.74**. All the creeks had strong correlations, with those correlations to Nursery Creek the weakest. The strongest correlations were between Buss Creek and Tired Creek (0.99), and Sapp Creek and Black Creek (0.99). Storm samples were not removed because they would have no effect on temperature beyond the time of year.

Table 5.74 Water Temperature correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.95**	1.00			
Nursery Creek	**0.81**	**0.78**	1.00		
Sapp Creek	**0.99**	**0.97**	**0.81**	1.00	
Tired Creek	**0.97**	**0.99**	**0.76**	**0.98**	1.00

5.21 Dissolved Oxygen

Dissolved oxygen samples for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.75** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.75 Dissolved Oxygen (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	14	14	14	14	15
Min	1.52	3.81	4.68	4.17	4.94
Max	8.51	8.55	10.34	10.23	8.54
Average	5.46	6.44	8.22	7.57	6.77
Median	6.22	6.23	8.37	7.98	6.33
Variance	4.86	2.51	2.58	3.09	1.63
Standard Deviation	2.21	1.58	1.61	1.76	1.28

A line graph is shown in **Figure 5.58** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. There was a noticeable trend of higher DO during high flows and lower DO during low flows. Nursery Creek was consistently higher than the rest of the creeks, while Black Creek was the lowest of the creeks.

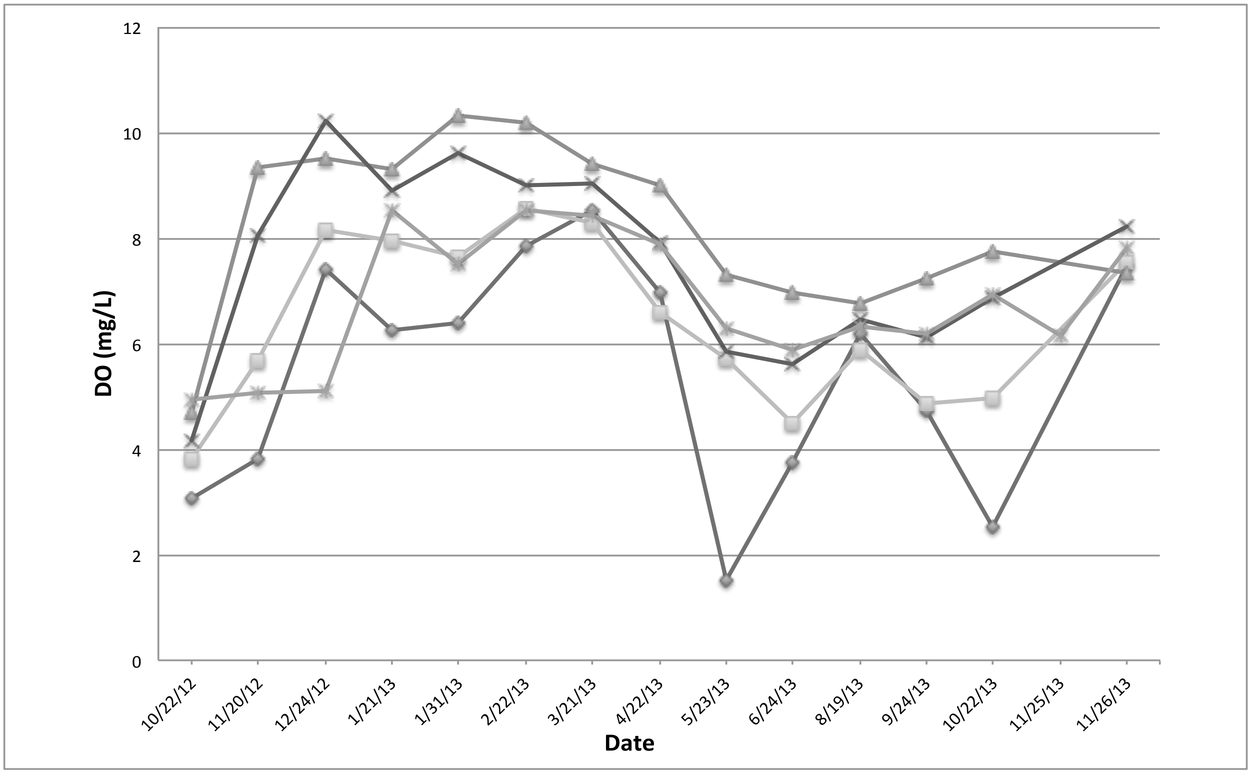

Figure 5.58 Dissolved Oxygen concentration for all grab samples

A box and whisker plot for dissolved oxygen is provided in **Figure 5.59** including the minimum daily limit of 4 mg/L. The Nursery Creek median is higher than the rest of the creeks, with Sapp Creek just below. Black Creek, Buss Creek and Tired Creek were all similar medians, although, Black Creek fell well below all the rest and below 2.0 mg/L on one occasion. The tails were all the largest below the median. All 5 creeks were above recommended reference levels based on GAEPD regulations.

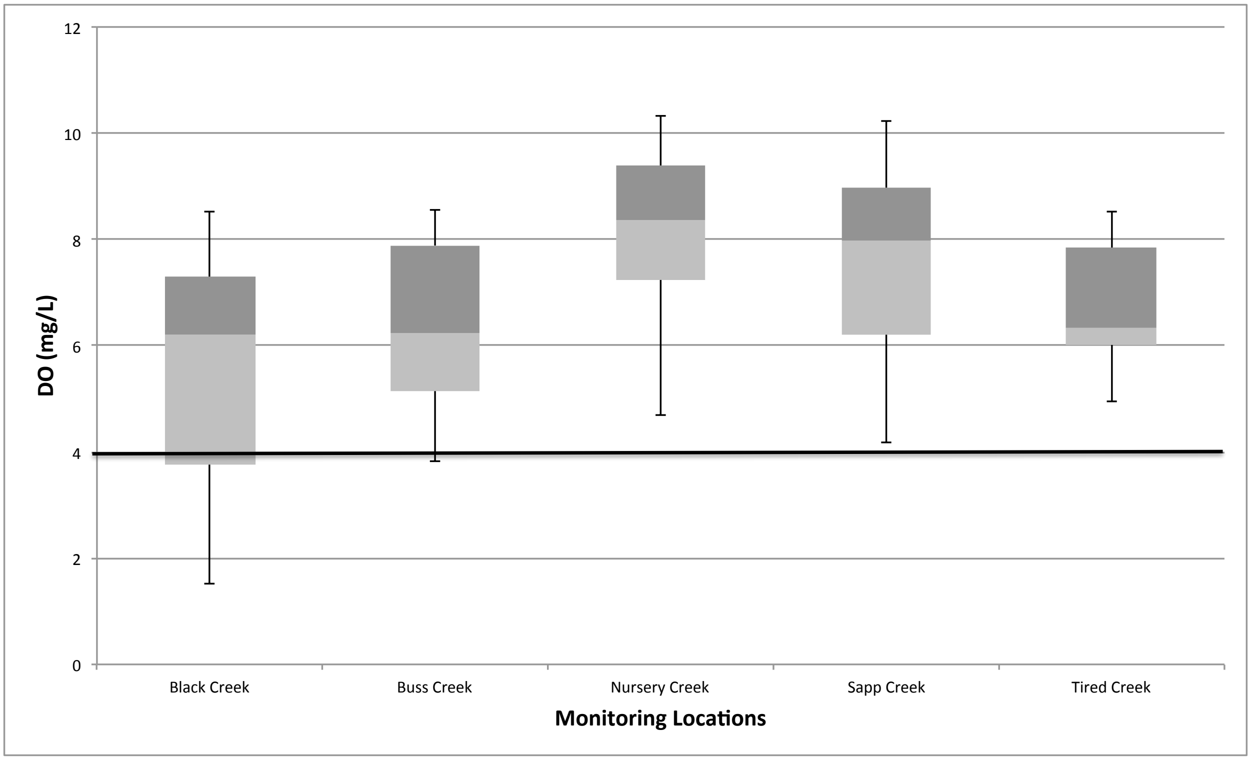

Figure 5.59 Dissolved Oxygen box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was less than F-ratio and the p-value was more than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 1.88 was determined. Based on the analysis, it was determined there was a difference between Nursery Creek and Black Creek and Sapp Creek and Black Creek.

A correlation matrix between the creeks was also developed in **Table 5.76**. All the creeks had moderate or stronger correlation for DO. The strongest correlations were between Sapp Creek and Buss Creek (0.92) and Nursery Creek and Sapp Creek (0.91).

Table 5.76 Dissolved Oxygen correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.83**	1.00			
Nursery Creek	**0.58**	**0.80**	1.00		
Sapp Creek	**0.75**	**0.92**	**0.91**	1.00	
Tired Creek	**0.59**	**0.66**	**0.51**	**0.49**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.77** lists the percent differences after taking storm events out of the data. After removing the storm samples, minimums did not change. Maximums decreased for Buss Creek 3% and Nursery Creek 8%, but did not change for the other creeks. Averages for all creeks decreased 4-9%, along with small decreases in medians. Variances and standard deviations did not change by much also.

Table 5.77 Dissolved Oxygen percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	DO^1	**DO^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**
n	14	11	-	14	11	-	14	11	-	14	11	-	15	12	-
Min	1.5	1.5	**0**	3.8	3.8	**0**	4.7	4.7	**0**	4.2	4.2	**0**	4.9	4.9	**0**
Max	8.5	8.5	**0**	8.6	8.3	**-3**	10.3	9.5	**-8**	10.2	10.2	**0**	8.5	8.5	**0**
Avg.	5.5	5.0	**-9**	6.4	6.0	**-6**	8.2	7.9	**-4**	7.6	7.2	**-5**	6.8	6.5	**-4**
Med.	6.2	4.7	**-24**	6.2	5.7	**-8**	8.4	7.8	**-7**	8.0	6.9	**-14**	6.3	6.2	**-1**
Var.	4.9	5.0	**3**	2.5	2.4	**-6**	2.6	2.3	**-9**	3.1	3.2	**4**	1.6	1.5	**-5**
St. Dev.	2.2	2.2	**1**	1.6	1.5	**-3**	1.6	1.5	**-5**	1.8	1.8	**2**	1.3	1.2	**-3**

Note: DO^1 = all samples; DO^2 = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was less than F-ratio and the p-value was less than 0.05, just as with storms included. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 2.18. Just as when storms were included, there was a difference between Nursery Creek and Black Creek and Sapp Creek and Black Creek.

A correlation matrix was also developed for the data not including storm events in **Table 5.78**. All creeks were somewhat correlated, with the weakest correlation between Sapp Creek and Tired Creek of 0.38. The strongest correlations were again between Nursery Creek and Sapp Creek (0.94) and Sapp Creek and Buss Creek (0.93).

Table 5.78 Dissolved Oxygen correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.79**	1.00			
Nursery Creek	**0.58**	**0.83**	1.00		
Sapp Creek	**0.73**	**0.92**	**0.94**	1.00	
Tired Creek	**0.47**	**0.55**	**0.45**	0.38	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 79**. Non-storm DO minimums all increased from 52-321%. There was a minimal change in maximums. All averages increased for storm data 17-46% There was also a notable decreases in the variance and standard deviation of storm data in al creeks other than Nursery Creek. Based on higher DO in storm data and lower DO after removing storm data, it was determined storm flow increases DO.

Table 5.79 Dissolved Oxygen percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	DO²	**DO³**	**%**	**DO²**	**DO³**	**%**	**DO²**	**DO³**	**%**	**DO²**	**DO³**	**%**	**DO²**	**DO³**	**%**
n	11	3	-	11	3	-	11	3	-	11	3	-	12	3	-
Min	1.5	6.4	321	3.8	7.5	98	4.7	7.3	57	4.2	8.2	97	4.9	7.5	52
Max	8.5	7.9	-8	8.3	8.6	3	9.5	10.3	9	10.2	9.6	-6	8.5	8.5	0
Avg.	5.0	7.2	46	6.0	7.9	31	7.9	9.3	17	7.2	8.9	24	6.5	8.0	23
Med.	4.7	7.5	58	5.7	7.7	34	7.8	10.2	31	6.9	9.0	31	6.2	7.8	25
Var.	5.0	0.6	-89	2.4	0.3	-87	2.3	2.9	22	3.2	0.5	-85	1.5	0.3	-82
St. Dev.	2.2	0.8	-66	1.5	0.6	-64	1.5	1.7	10	1.8	0.7	-62	1.2	0.5	-58

Note: DO^2 = sample not including storm data; DO^3 = storm data; % = percent difference

Correlations between creeks for DO concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, DO was strongly correlated to WT (-0.74), AT (-0.71), and Alk (-0.65), and moderately strongly correlated to SC (-0.58). For Black Creek, DO was strongly correlated to Alk (-0.73) and TON (-0.69) and moderately correlated to Mn (-0.66), moderately strongly correlated to SC (-0.62) and Stage (0.6), and moderately correlated to WT (-0.52), pH (0.51), turbidity (0.51), AT (-0.49), and TSS (0.48). For Buss Creek, DO was moderately strongly correlated to AT (-0.64), WT (-0.63), Fe (0.58), FC (0.57), and Alk (-0.57) and moderately correlated to pH (0.54) and turbidity (0.45). For Nursery Creek, DO was strongly correlated to NH4 (-0.81), TON (-0.7), pH (0.69), TN (-0.69), and AT (-0.66) and moderately strongly correlated to stage (0.56). For Tired Creek, DO was strongly correlated to

Alk (-0.75), moderately strongly correlated to SC (-0.57), TON (-0.57), Mn (0.57), Fe (0.55), and TP (0.55), and moderately correlated to TN (-0.51), Hd (-0.51) and AT (-0.51). Based on data from all the creeks, DO was correlated to AT in all 5 creeks, Alk in four creeks, WT, SC, TON, and pH in 3 creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** there were no strong correlations for DO. DO was moderately correlated to AT (-0.51) and pH (0.49).

5.22 Turbidity

Turbidity for all the creeks was compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.80** including count, minimum, maximum, average, median, geometric mean, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.80 Turbidity (NTU) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Count	15	15	15	15	16
Min	7.01	3.68	5.12	4.80	6.20
Max	46.10	163.00	251.00	58.70	275.00
Average	13.58	23.61	46.76	14.03	36.50
Median	9.92	9.97	11.40	7.90	13.70
Geometric Mean	11.7	12.3	19.5	10.7	18.5
Variance	96.85	1692.31	6635.97	190.72	4455.32
Standard Deviation	9.84	41.14	81.46	13.81	66.75

A line graph is shown in **Figure 5.60** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. There are noticeable peaks during storm events in February and November. Turbidity for the June storm sample was not available.

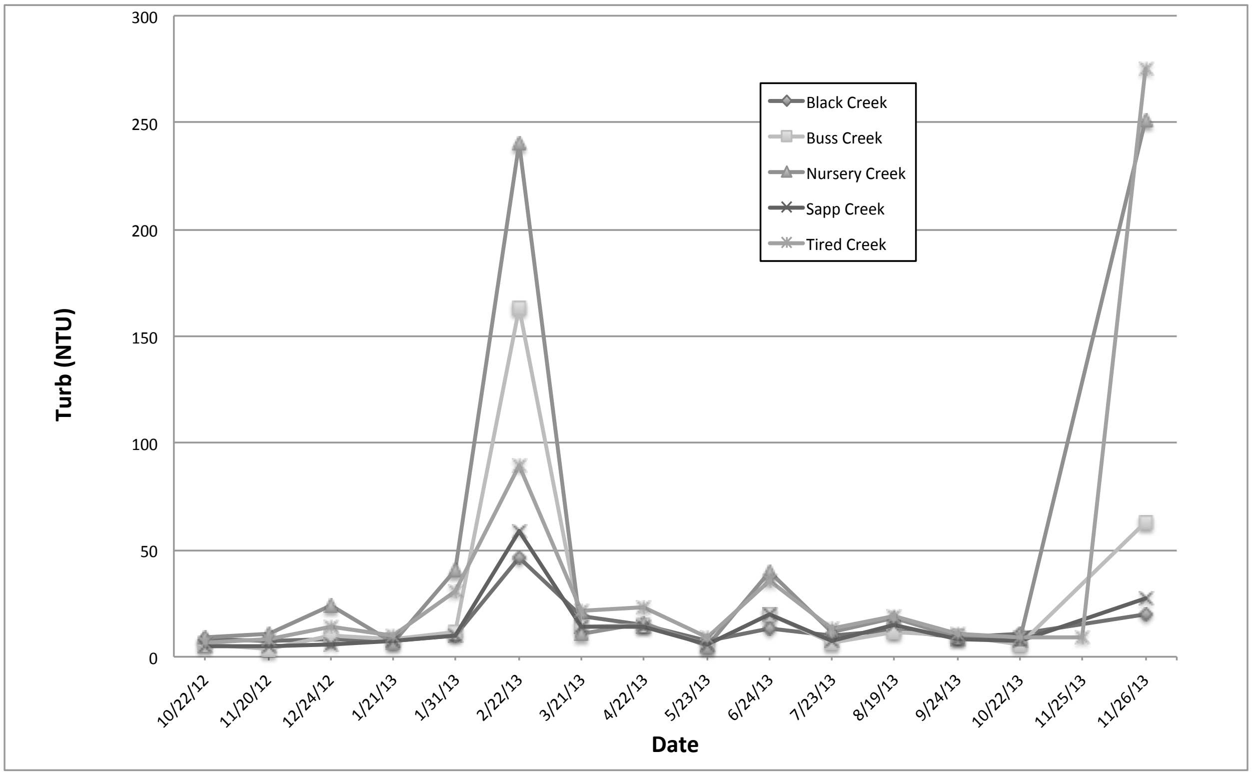

Figure 5.60 Turbidity concentration for all grab samples

A box and whisker plot for turbidity is provided in **Figure 5.61**. All the creeks have similar medians. The longer tails were due to storm events and increases in turbidity. Tired Creek, Nursery Creek, and Buss Creek increases were much larger than those in Sapp and Black Creek.

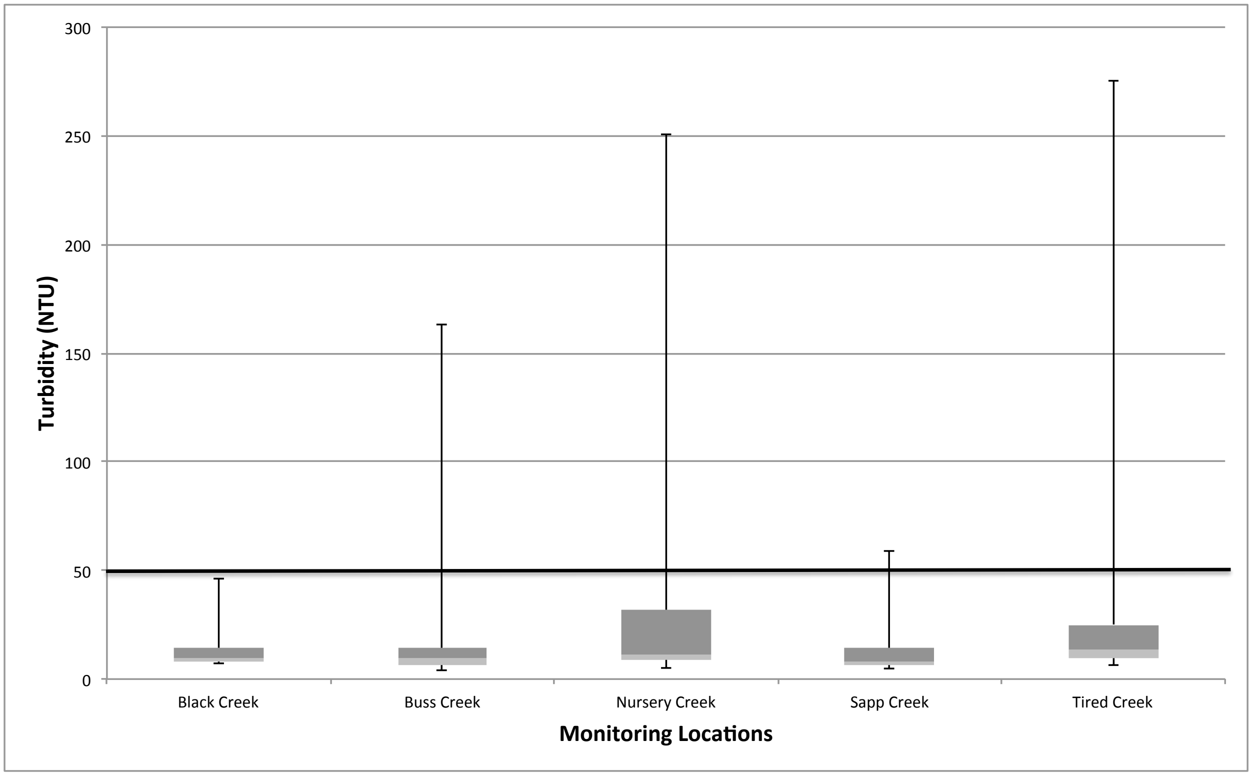

Figure 5.61 Turbidity box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was larger than F-ratio and the p-value was above 0.05, there were no differences in the creeks. Therefore, a Tukey test was not needed.

A correlation matrix between the creeks was also developed in **Table 5.81**. All creeks were correlated with the strongest correlations were between Sapp Creek and Buss Creek (0.98), Black Creek and Sapp Creek (0.95), and Black Creek and Buss Creek (0.96). Other strong correlations included Buss Creek and Nursery Creek (0.87), Tired Creek and Nursery Creek (0.87), Nursery Creek and Sapp Creek (0.85), and Nursery Creek and Black Creek (0.79). Moderate correlations can be found in the correlation matrix.

Table 5.81 Turbidity correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.96**	1.00			
Nursery Creek	**0.79**	**0.87**	1.00		
Sapp Creek	**0.97**	**0.98**	**0.85**	1.00	
Tired Creek	**0.45**	**0.53**	**0.87**	**0.53**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.82** lists the percent differences after taking storm events out of the data. After removing the storm samples, minimums did not change but maximums decreased by 59-88%. All averages also decreased 22-70% after removing storms for turbidity. Variances and standard deviations also decreased substantially.

Table 5.82 Turbidity percent difference not including storm data

	Black Creek			**Buss Creek**			**Nursery Creek**			**Sapp Creek**			**Tired Creek**		
	TU^1	**TU^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**	**DO^1**	**DO^2**	**%**
n	15	12	-	15	12	-	15	12	-	15	12	-	16	13	-
Min	7.0	7.0	**0**	3.7	3.7	**0**	5.1	5.1	**0**	4.8	4.8	**0**	6.2	6.2	**0**
Max	46.1	18.9	**-59**	163.0	20.1	**-88**	251.0	40.1	**-84**	58.7	19.9	**-66**	275.0	35.3	**-87**
Avg.	13.6	10.7	**-22**	23.6	9.7	**-59**	46.8	14.1	**-70**	14.0	9.6	**-32**	36.5	14.5	**-60**
Med.	9.9	9.4	**-5**	10.0	9.0	**-10**	11.4	10.8	**-5**	7.9	7.8	**-2**	13.7	11.0	**-20**
Var.	96.8	13.0	**-87**	1692	22.6	**-99**	6636	93.2	**-99**	191	22.5	**-88**	4455	67.7	**-98**
St. Dev.	9.8	3.6	**-63**	41.1	4.8	**-88**	81.5	9.7	**-88**	13.8	4.7	**-66**	66.7	8.2	**-88**

Note: TU^1 = all samples; TU^2 = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was a greater than F-ratio and the p-value was greater than 0.05. There were no significant differences between any creeks for turbidity.

A correlation matrix was also developed for the data not including storm events in **Table 5.83**. All the creeks were strongly correlated other than Nursery Creek and Black Creek. The strongest correlations were between Tired Creek and Buss Creek (0.96), Sapp Creek and Tired Creek (0.95), and Sapp Creek and Buss Creek (0.93). All other correlations can be seen in the table below.

Table 5.83 Turbidity correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.71**	1.00			
Nursery Creek	0.31	**0.77**	1.00		
Sapp Creek	**0.78**	**0.93**	**0.70**	1.00	
Tired Creek	**0.71**	**0.96**	**0.83**	**0.95**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.84**. Turbidity increased for all statistical analysis in all creeks. Minimums increased 42-701% and maximums also increased 144-711%. Averages also increase dramatically for storm samples 137-1156%. There were also large increases in variance and standard deviation of storm data. Based on higher concentrations in storm data and lower concentrations after removing storm data, it was determined storm flow increases turbidity.

Table 5.84 Turbidity percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	TU²	**TU³**	**%**	**TU²**	**TU³**	**%**	**TU²**	**TU³**	**%**	**TU²**	**TU³**	**%**	**TU²**	**TU³**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	13	3	-
Min	7.0	9.9	**42**	3.7	11.8	**221**	5.1	41.0	**701**	4.8	9.6	**100**	6.2	30.3	**389**
Max	18.9	46.1	**144**	20.1	163	**711**	40.1	251.0	**526**	19.9	58.7	**195**	35.3	275	**679**
Avg.	10.7	25.3	**137**	9.7	79.3	**717**	14.1	177.3	**1156**	9.6	31.8	**232**	14.5	132	**805**
Med	9.4	19.8	**110**	9.0	63.0	**604**	10.8	240.0	**2122**	7.8	27.1	**250**	11.0	89.7	**715**
Var.	13.0	350	**258**	22.6	5.9k	**26k**	93.2	14k	**15k**	22.5	619	**2.7k**	67.7	16k	**24k**
St. Dev.	3.6	18.7	**418**	4.8	76.9	**1516**	9.7	118.2	**1124**	4.7	24.9	**425**	8.2	128	**1452**

Note: TU^2 = sample not including storm data; TU^3 = storm data; % = percent difference; k = thousand

Correlations between creeks for turbidity concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, Turbidity was strongly correlated to TSS (0.95) and TP (0.88), moderately strongly correlated to Mn (0.63) and moderately correlated to Fe (0.52). For Black Creek, turbidity was strongly correlated to TSS (0.98), Stage (0.79), moderately strongly correlated to FC (0.62), and moderately correlated to DO (0.51), SC (-0.51), TON (-0.49), and Alk (-0.51). For Buss Creek, turbidity was strongly correlated to TSS (0.97), TP (0.96), Fe (0.82), and FC (0.75), moderately strongly correlated to pH (0.53), and moderately correlated to DO (0.45). For Nursery Creek, turbidity was strongly correlated to TSS (0.99), TP (0.86), Mn (0.83), St (0.81), FC (0.69), Hd (-0.68), SC (-0.67) and moderately correlated to WT (0.51). For Tired Creek, turbidity was strongly correlated to TSS (0.96), Fe (0.94), FC (0.74), and Mn

(0.67). Based on data from all the creeks, turbidity was correlated to TSS in all five creeks, Fe and FC in four creeks, and Mn and TP in 3 creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** Turb correlated to other parameters. Turbidity correlations included TSS (0.87), Fe (0.66), and FC (0.55).

5.23 Hardness

Hardness for all the creeks was compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.85** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.85 Hardness (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	30	40	80	40	40
Max	80	140	180	60	120
Average	51	75	141	44	63
Median	40	60	160	40	60
Variance	235	712	1112	69	770
Standard Deviation	15	27	33	8	28

A line graph is shown in **Figure 5.62** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek consistently had a higher concentration than all the other creeks, which were similar. There were also noticeable declines in Hardness during storm events.

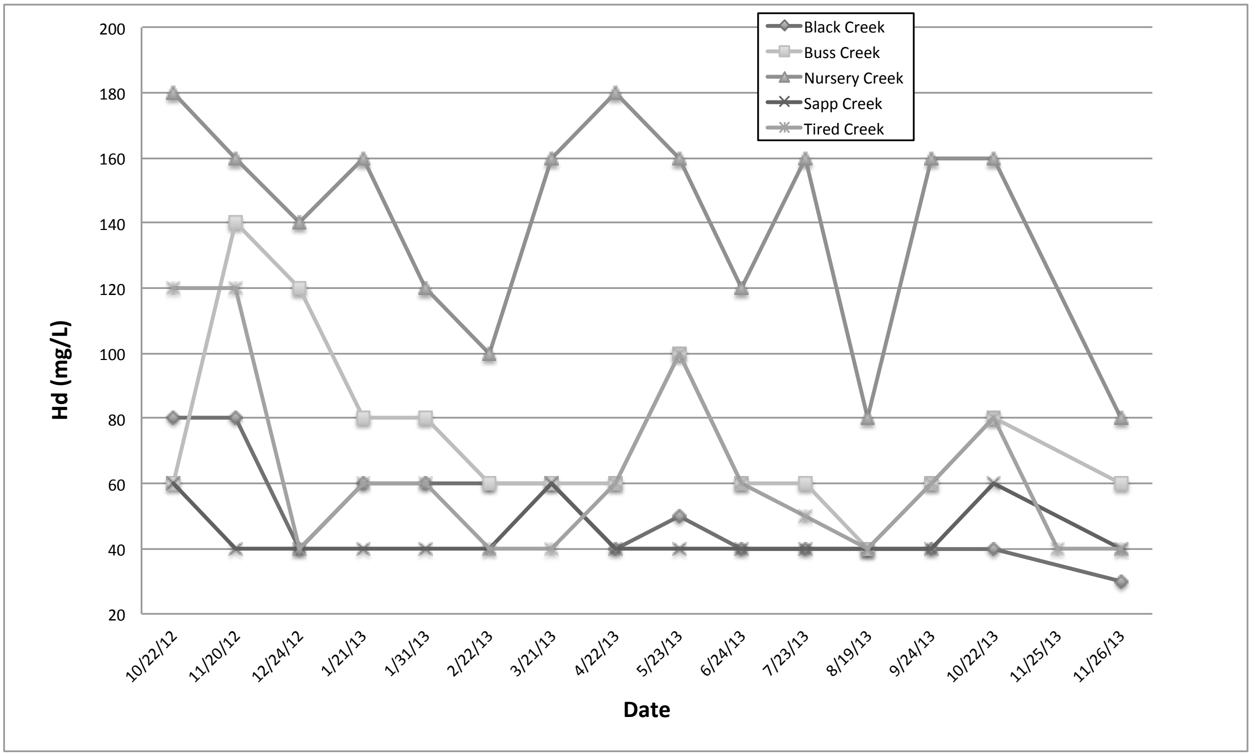

Figure 5.62 Hardness (mg/L) concentration for all grab samples

A box and whisker plot for hardness is provided in **Figure 5.63** below with a thick black line depicting the 120 mg/L reference value for maximum hardness in the region. The box for Sapp Creek does not plot because there are hardness values of 40 and 60 mg/L. The Nursery Creek median is higher than the rest of the creeks and Buss Creek with the second highest median concentrations. All the creeks other than Nursery Creek were close to reference levels within the region, while Nursery Creek was higher than those levels. The higher than normal concentrations in Nursery Creek are most likely due to chemical characteristics of groundwater used for irrigation.

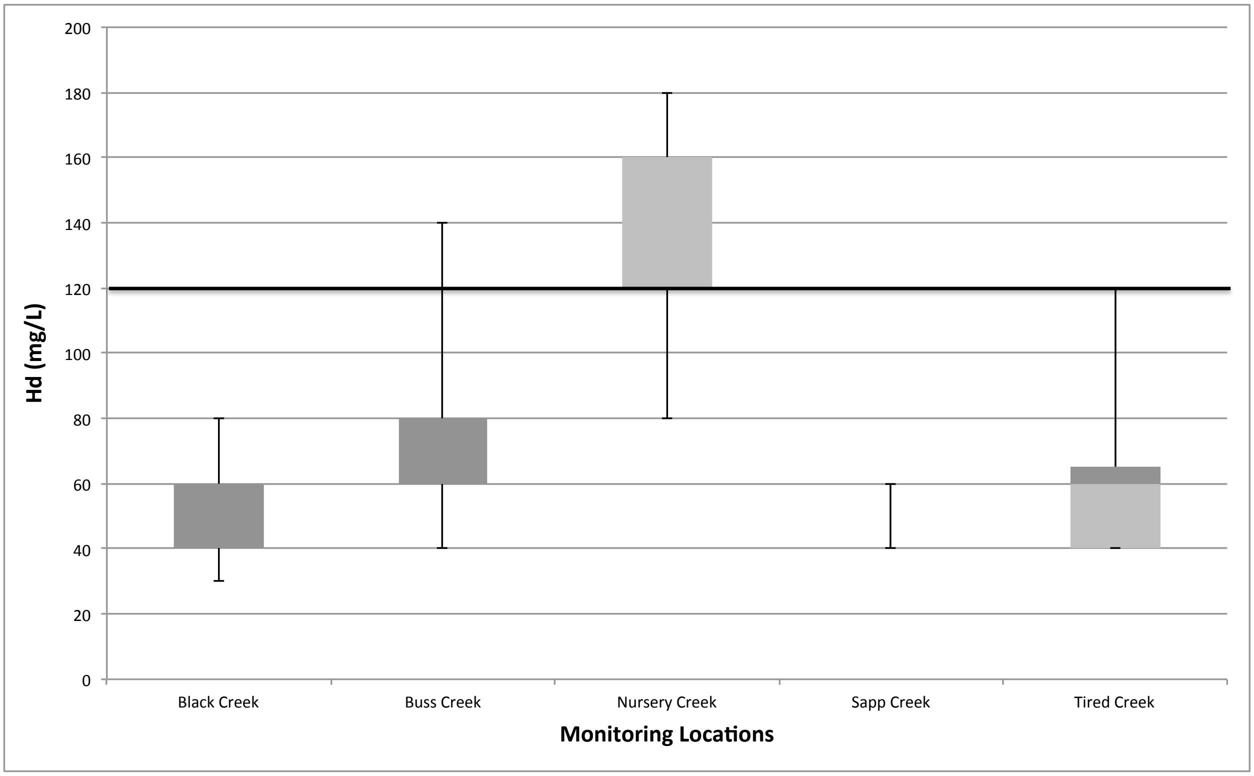

Figure 5.63 Hardness (mg/L) box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was less than F-ratio and the p-value was less than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 25.76 was determined. Based on the analysis, it was determined there was significant differences in the means between Nursery Creek and all the other creeks. There was also a significant difference between Buss Creek and Sapp Creek. All other creeks were found to be similar.

A correlation matrix between the creeks was also developed in **Table 5.86**, in which the strongest correlation were with Tired Creek.. The strongest correlations were moderately strong correlations between Tired Creek and Black Creek (0.64) and Nursery Creek and Tired Creek

(0.56). There was also a moderate correlation between Buss Creek and Tired Creek. Weaker correlations can be found in the table below.

Table 5.86 Hardness correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.36	1.00			
Nursery Creek	0.36	0.30	1.00		
Sapp Creek	0.31	-0.16	0.39	1.00	
Tired Creek	**0.64**	**0.48**	**0.56**	0.28	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.87** lists the percent differences after taking storm events out of the data. After removing the storm samples, only the Black Creek minimum increased 33%, while all the others stayed the same. There were no changes in the maximums and the averages for all the creeks except Black Creek increased slightly 2-7%. Medians did not change, while variance and standard deviation increased for all creeks except Nursery Creek.

Table 5.87 Hardness (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Hd[1]	**Hd[2]**	**%**	**Hd[1]**	**Hd[2]**	**%**	**Hd[1]**	**Hd[2]**	**%**	**Hd[1]**	**Hd[2]**	**%**	**Hd[1]**	**Hd[2]**	**%**
n	15	12	-	15	12	-	15	12	-	15	12	-	16	13	-
Min	30	40	**33**	40	40	**0**	80	80	**0**	40	40	**0**	40	40	**0**
Max	80	80	**0**	140	140	**0**	180	180	**0**	60	60	**0**	120	120	**0**
Avg.	51	51	**0**	75	77	**3**	141	152	**7**	44	45	**2**	63	67	**6**
Med.	40	40	**0**	60	60	**0**	160	160	**0**	40	40	**0**	60	60	**0**
Var.	235	245	**4**	712	861	**21**	1112	761	**-32**	69	82	**19**	770	856	**11**
St. Dev.	15	16	**2**	27	29	**10**	33	28	**-17**	8	9	**9**	28	29	**5**

Note: Hd[1] = all samples; Hd[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. Since F-critical was less than F-ratio and the p-value was less than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 29.36 was determined. Based on the analysis, it was determined there was significant differences in the means between Nursery Creek and all the other creeks. There was also a significant difference between Buss Creek and Sapp Creek, while other creeks were found to be similar.

A correlation matrix was also developed for the data not including storm events in **Table 5.88**. Correlations were similar to including storm data with the strongest correlations with Tired Creek. The strongest correlation was between Black Creek and Tired Creek. There was a moderate correlation between Nursery Creek and Tired Creek and a weak moderate correlation between Buss and Nursery Creek.

Table 5.88 Hardness correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	0.36	1.00			
Nursery Creek	0.40	0.23	1.00		
Sapp Creek	0.35	-0.21	0.33	1.00	
Tired Creek	**0.71**	0.44	**0.46**	0.22	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.89**.

The changes in minimums included a 25% decrease in Black Creek and a 50% increase in Buss Creek, along with no change in the other creeks. All creeks maximums decreased 25-50%, while averages also decreased 2-34%. Variances and standard deviations also decreased in all the creeks other than Black Creek.

Table 5.89 Hardness (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Hd^2	**Hd^3**	**%**	**Hd^2**	**Hd^3**	**%**	**Hd^2**	**Hd^3**	**%**	**Hd^2**	**Hd^3**	**%**	**Hd^2**	**Hd^3**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	13	3	-
Min	40	30	**-25**	40	60	**50**	80	80	**0**	40	40	**0**	40	40	**0**
Max	80	60	**-25**	140	80	**-43**	180	120	**-33**	60	40	**-33**	120	60	**-50**
Avg.	51	50	**-2**	77	67	**-13**	152	100	**-34**	45	40	**-11**	67	47	**-30**
Med.	40	60	**50**	60	60	**0**	160	100	**-38**	40	40	**0**	60	40	**-33**
Var.	245	300	**23**	861	133	**-85**	761	400	**-47**	82	0	**-100**	856	133	**-84**
St. Dev.	16	17	**11**	29	12	**-61**	28	20	**-27**	9	0	**-100**	29	12	**-61**

Note: Hd^2 = sample not including storm data; Hd^3 = storm data; % = percent difference

Correlations between creeks for hardness concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, all Hd correlations were weak. For Black Creek, Hd was moderately correlated to AT (-0.46), TON (0.46), and WT (-0.46). For Buss Creek, Hd was strongly correlated to TN (0.66), TON (0.66), NH4 (0.65), moderately strongly correlated to ST (-0.63) and TKN (0.62), and moderately correlated to SC (0.53). For Nursery Creek, Hd was strongly correlated to Alk (0.86), SC (0.86), TP (-0.77), turbidity (-0.68), Fe (-0.66), and Mn (-0.65), moderately strongly correlated to TSS (-0.64), and moderately correlated to TKN (-0.5), FC (-0.49), and stage (-0.45). For Tired Creek, Hd was strongly correlated to SC (0.93), TN (0.92), TON (0.92) and Alk (0.86), moderately strongly correlated to NH4 (0.62) and moderately correlated to Fe (-0.55), and DO (-0.51). Based on data from all the creeks, Hd was correlated to

SC in three creeks and TON in three creeks, along with multiple correlations in only two creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** Hd correlated to other parameters. The strong correlations with Hd included Alk (0.89), SC (0.89), and pH 0.66, moderately strong correlations between TON (0.56) and Fe (-0.57), and a moderate correlation with TN (0.52).

5.24 Alkalinity

Alkalinity for all the creeks was compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.90** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.90 Alkalinity (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	15	15	60	20	25
Max	30	100	195	40	80
Average	22	39	116	28	40
Median	20	30	120	25	35
Variance	28	453	1054	49	257
Standard Deviation	5	21	32	7	16

A line graph can is shown in **Figure 5.64** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Nursery Creek consistently had a higher concentration than all the other creeks, which were similar.

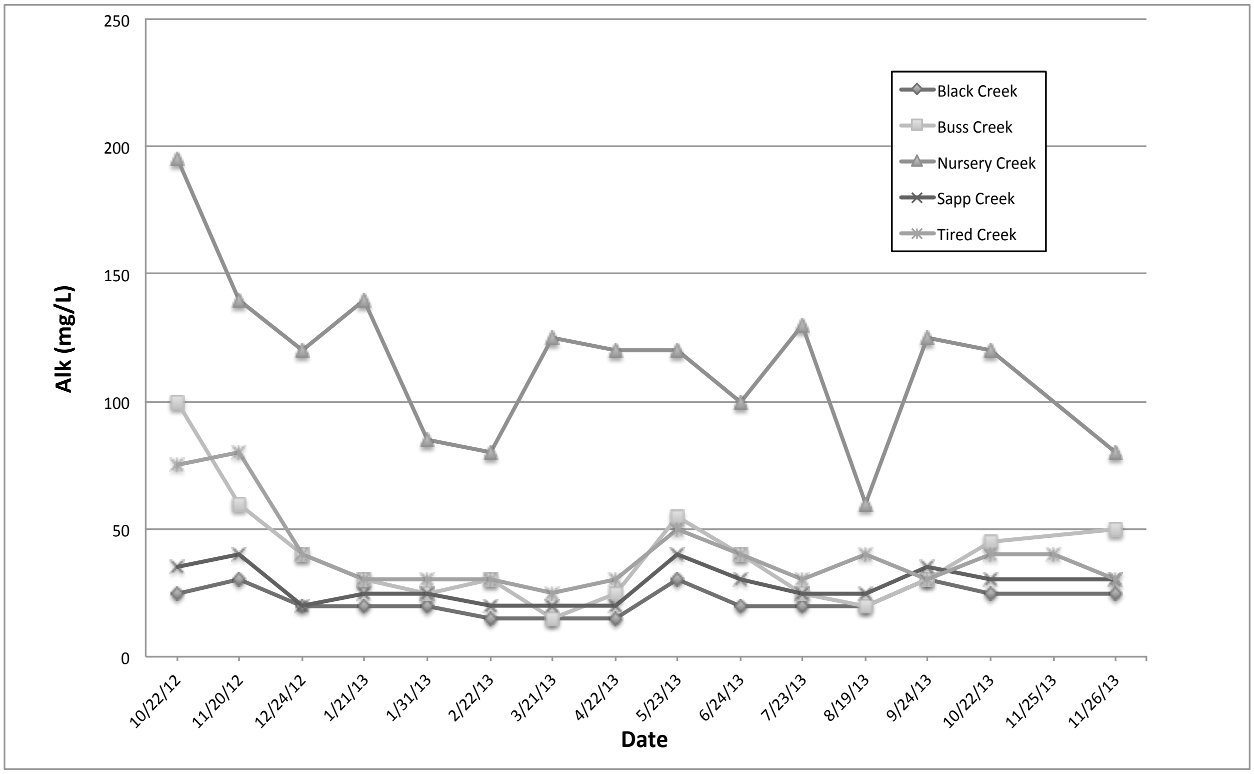

Figure 5.64 Alkalinity (mg/L) concentration for all grab samples

A box and whisker plot for Alkalinity is provided in **Figure 5.65** including a thick black line for the reference alkalinity of 20 mg/L in the region. The Nursery Creek median is higher than the rest of the creeks. All the creeks other than Nursery Creek were close to reference levels within the region, while Nursery Creek was much higher than those levels. The higher than normal concentrations in Nursery Creek are most likely due to chemical characteristics of groundwater used for irrigation.

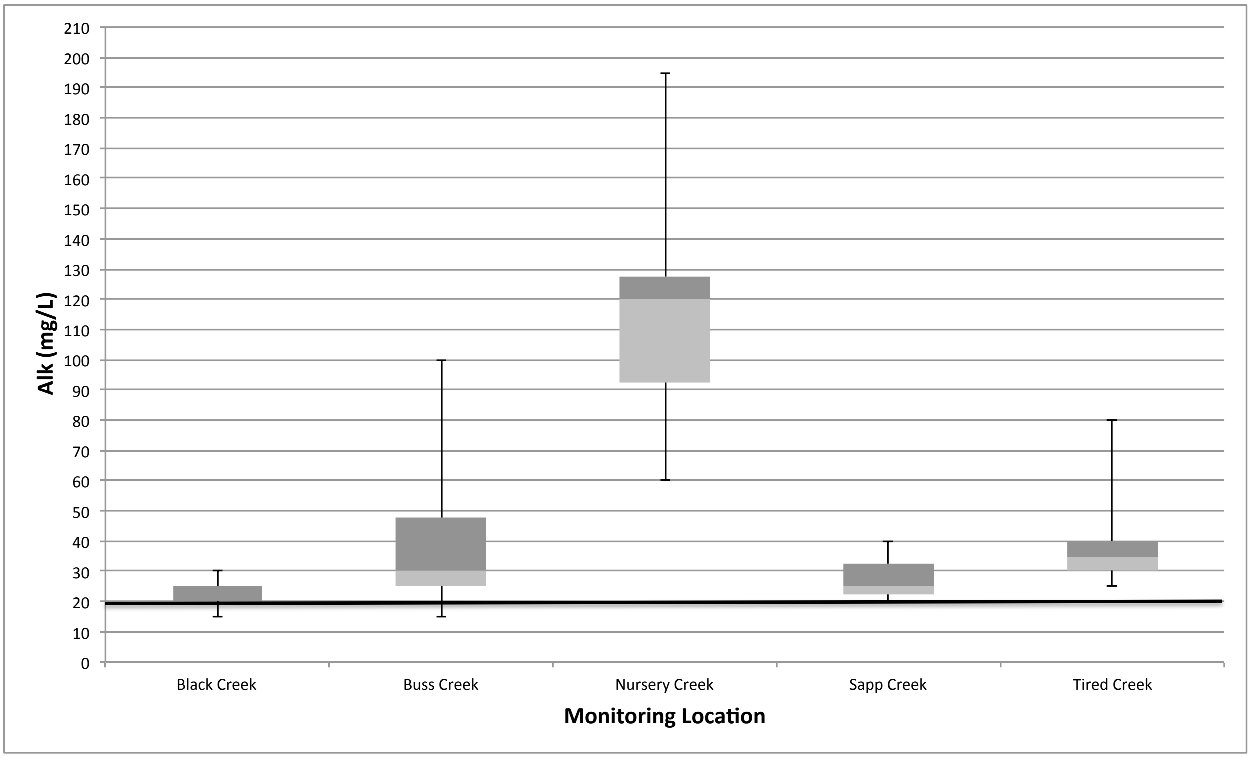

Figure 5.65 Alkalinity (mg/L) box and whisker for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was less than F-ratio and the p-value was less than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 20.44 was determined. Based on the analysis, it was determined there was significant differences in the means between Nursery Creek and all the other creeks, while all the other creeks were found to be similar.

A correlation matrix between the creeks was also developed in **Table 5.91**, including correlations between all the creeks other than weak correlations for Nursery Creek between Sapp Creek and Black Creek. The strongly correlated creeks were Sapp Creek and Black Creek (0.93), Buss Creek and Tired Creek (0.82), Sapp Creek and Tired Creek (0.69), and Buss Creek and Sapp Creek (0.66). Moderately strong correlations can be seen below.

Table 5.91 Alkalinity correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.57**	1.00			
Nursery Creek	0.30	**0.63**	1.00		
Sapp Creek	**0.93**	**0.66**	0.36	1.00	
Tired Creek	**0.57**	**0.82**	**0.55**	**0.69**	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.92** lists the percent differences after taking storm events out of the data. After removing storm data, there was no change in minimums or maximums. Averages in all the creeks increased 2-7%, while medians increased 2-17% in creeks other than Black Creek with no change. Standard deviations and variances can be seen below.

Table 5.92 Alkalinity (mg/L) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Alk[1]	**Alk[2]**	**%**	**Alk[1]**	**Alk[2]**	**%**	**Alk[1]**	**Alk[2]**	**%**	**Alk[1]**	**Alk[2]**	**%**	**Alk[1]**	**Alk[2]**	**%**
n	15	12	-	15	12	-	15	12	-	15	12	-	16	13	-
Min	15	15	**0**	15	15	**0**	60	60	**0**	20	20	**0**	25	25	**0**
Max	30	30	**0**	100	100	**0**	195	195	**0**	40	40	**0**	80	80	**0**
Avg.	22	23	**2**	39	40	**3**	116	125	**7**	28	29	**3**	40	42	**6**
Med.	20	20	**0**	30	35	**17**	120	123	**2**	25	28	**10**	35	40	**14**
Var.	28	30	**6**	453	538	**19**	1054	938	**-11**	49	55	**12**	257	290	**13**
St. Dev.	5	16	**3**	21	23	**9**	32	31	**-6**	7	7	**6**	16	17	**6**

Note: Alk[1] = all samples; Alk[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. Since F-critical was less than F-ratio and the p-value was less than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 23.7 was determined. Based on the analysis, it was determined there was significant differences in the means between Nursery Creek and all the other creeks, with no differences between other creeks.

A correlation matrix was also developed for the data not including storm events in **Table 5.93**. Correlations were similar to including storm data, in which there were weak correlations for Nursery Creek between Sapp Creek and Black Creek. The strongly correlated creeks included Black Creek and Sapp Creek (0.93), Tired Creek and Buss Creek (0.86), Buss Creek and Nursery Creek (0.71), Sapp Creek and Tired Creek (0.70), and Sapp Creek and Buss Creek (0.65). Moderately strong correlations can be seen below.

Table 5.93 Alkalinity correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.55**	1.00			
Nursery Creek	0.25	**0.71**	1.00		
Sapp Creek	**0.93**	**0.65**	0.31	1.00	
Tired Creek	**0.59**	**0.86**	**0.48**	**0.70**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.94**.
The changes included an increase in minimums for Buss Creek, Nursery Creek and Tired Creek by 20-67%. All t maximums decreased 17-63% for storm data. Averages also decreased 11-34% and median decreased in all creeks 9-35%, except for Black Creek, which did not change. There was also a decrease in variances and standard deviations for all creeks.

Table 5.94 Alkalinity (mg/L) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	Alk[2]	**Alk[3]**	**%**	**Alk[2]**	**Alk[3]**	**%**	**Alk[2]**	**Alk[3]**	**%**	**Alk[2]**	**Alk[3]**	**%**	**Alk[2]**	**Alk[3]**	**%**
n	12	3	-	12	3	-	12	3	-	12	3	-	13	3	-
Min	15	15	**0**	15	25	**67**	60	80	**33**	20	20	**0**	25	30	**20**
Max	30	25	**-17**	100	50	**-50**	195	85	**-56**	40	30	**-25**	80	30	**-63**
Avg.	23	20	**-11**	40	35	**-13**	125	82	**-34**	29	25	**-13**	42	30	**-29**
Med.	20	20	**0**	35	30	**-14**	123	80	**-35**	28	25	**-9**	40	30	**-25**
Var.	30	25	**-15**	538	175	**-67**	938	8	**-99**	55	25	**-55**	290	0	**-100**
St. Dev.	5	5	**-8**	23	13	**-43**	31	3	**-91**	7	5	**-33**	17	0	**-100**

Note: Hd[2] = sample not including storm data; Hd[3] = storm data; % = percent difference

Correlations between creeks for Alk concentrations were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, Alk was strongly correlated to SC (0.71) and DO (-0.65) and moderately correlated to St (-0.51). For Black Creek, Alk was strongly correlated to SC (0.79), DO (-0.73), TON (0.68), Mn (0.65), moderately strongly correlated to Stage (-0.57), and moderately correlated to turbidity (-0.51), TP (-0.46), and TSS (-0.45). For Buss Creek, Alk was strongly correlated to TON (0.72), SC (0.71), and TN (0.69), moderately strongly correlated to DO (-0.57), and moderately correlated to TKN (0.54) and Stage (0.51). For Nursery Creek, Alk was strongly correlated to SC (0.9), Hd (0.86), TON (0.68), and TP (-0.68), moderately strongly correlated to TN (0.6), and moderately correlated to turbidity (-0.51), Fe (-0.5), Mn (-0.49), TSS (-0.46), and Stage (-0.48). For Tired Creek, Alk was strongly correlated to TON (0.88), SC

(0.87), Hd (0.86), TN (0.85), DO (-0.75), and NH4 (0.66), and moderately correlated to Fe (-0.51). Based on data from all the creeks, Alk was correlated to SC in five creeks, DO in four creeks, Stage in four creeks, TON in four creeks, and TN in three creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** Alk correlated to other parameters. The strong correlations with Alk included SC (0.92), Hd (0.89), and pH (0.68), moderately strong correlations between TON (0.57) and Fe (-0.55), and a moderate correlation with TN (0.51).

5.25 Air Temperature

Air temperatures during grab sampling for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek is shown in **Table 5.93** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.95 Air Temperature (°F) for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	15	15	15	16
Min	45.0	44.0	44.0	44.0	42.0
Max	86.0	88.0	86.0	88.0	81.0
Average	67.2	68.2	68.1	68.9	66.3
Median	65.0	65.0	65.0	67.0	67.5
Variance	146.2	164	158	150	142
Standard Deviation	12.1	12.8	12.6	12.3	11.9

A line graph is shown in **Figure 5.62** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. As you would expect, all the temperatures were similar, with lower temperature in the fall and winter months and higher temperatures in the spring and summer. Temperatures on sampling dates typically increased between sample locations as temperature warmed over day from morning to afternoon.

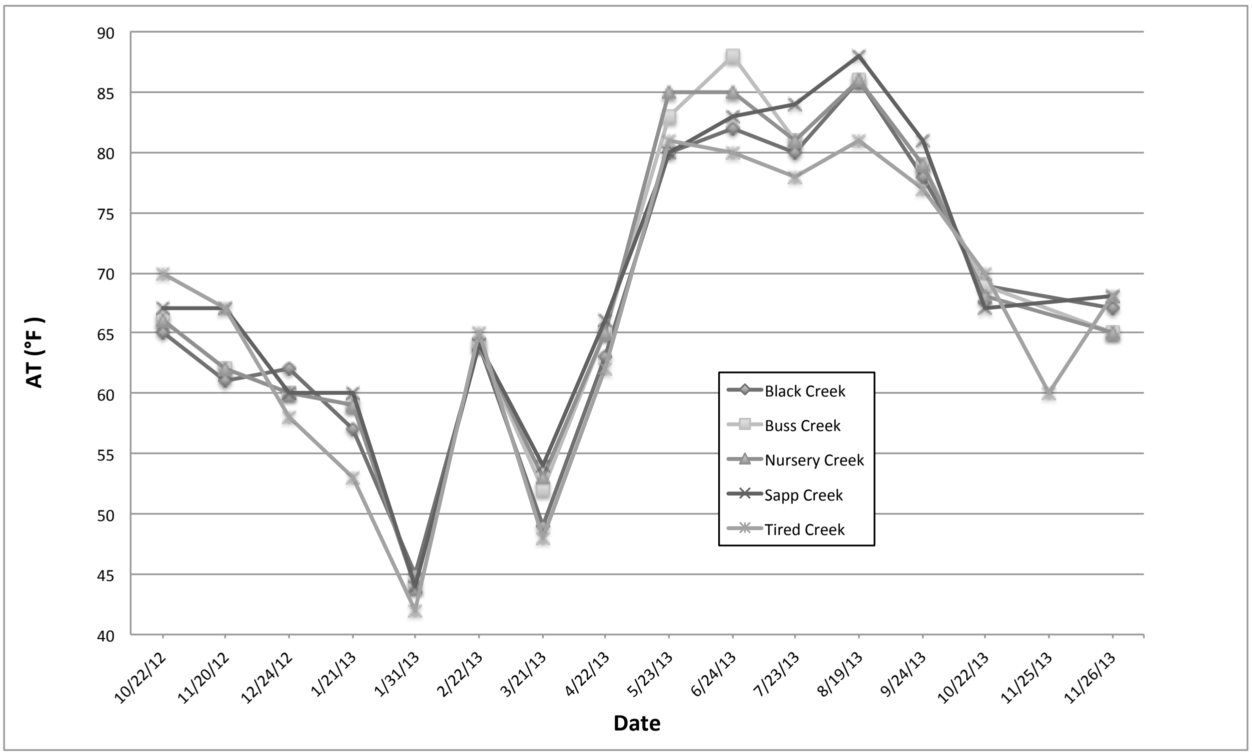

Figure 5.66 Air Temperature for all samples

A box and whisker plot for air temperature is provided in **Figure 5.63** including the maximum temperature standard for Georgia with a thick black line. Air temperature medians ranged from 65-67.5 °F. All the medians were typically the same with similar tails for each location. The lower tails are larger than the upper for lower temperature readings.

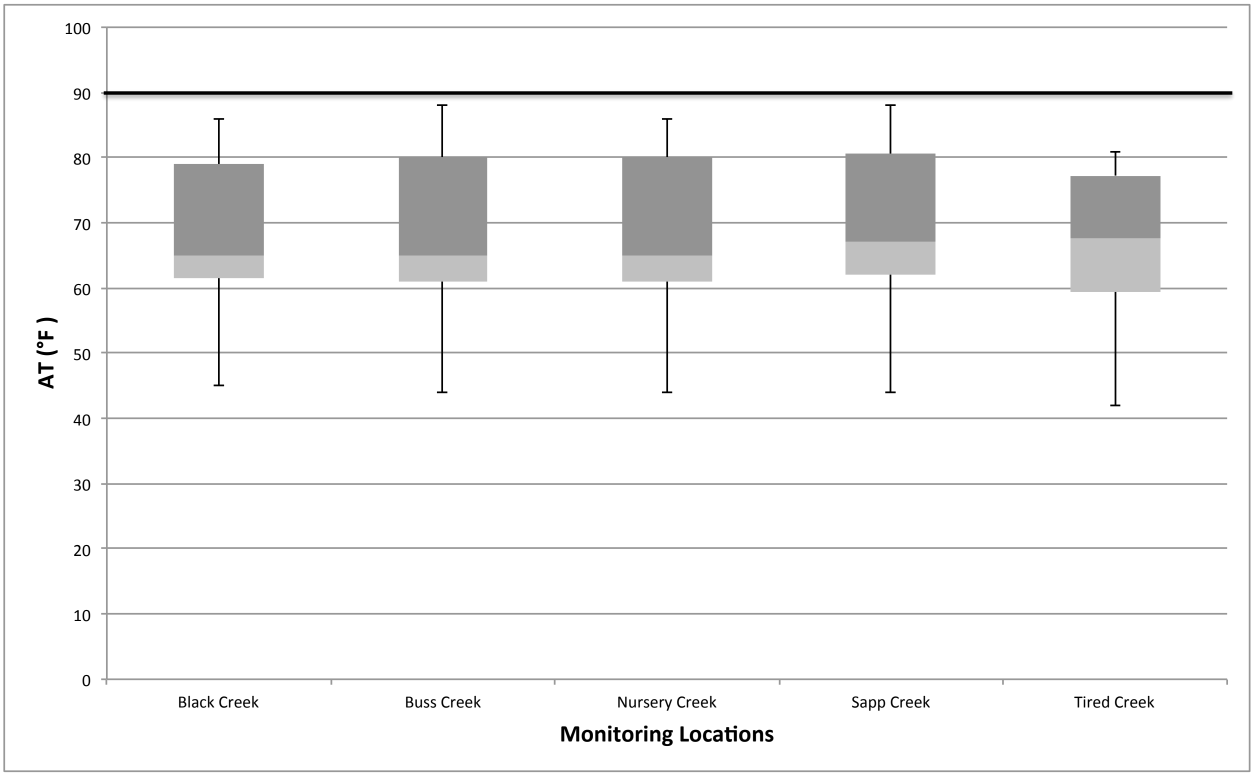

Figure 5.67 Air Temperature box and whisker plots

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was larger than F-ratio and the p-value was above 0.05, there was no difference in the creeks.

A correlation matrix between the creeks was also developed in **Table 5.96**. All the creeks had strong correlations. Storm samples were not removed because they would have no effect on temperature beyond the time of year.

Table 5.96 Air Temperature correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.99**	1.00			
Nursery Creek	**0.99**	**1.00**	1.00		
Sapp Creek	**0.98**	**0.98**	**0.98**	1.00	
Tired Creek	**0.97**	**0.96**	**0.96**	**0.96**	1.00

Correlations between creeks for AT were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, AT was strongly correlated to WT (0.87) and DO (-0.71) and moderately correlated to TN (0.45). For Black Creek, AT was strongly correlated to WT (0.87), moderately strongly correlated to pH (-0.62), and moderately correlated to DO (-0.49) and Hd (-0.49). For Buss Creek, AT was strongly correlated to WT (0.91), moderately strongly correlated to DO (-0.64), and moderately correlated to pH (-0.5) and FC (-0.47). For Nursery Creek, AT was strongly correlated to pH (-0.92), WT (0.84), and DO (-0.66). For Tired Creek, AT was strongly correlated to WT (0.84) and moderately correlated to DO (-0.46). Based on data from all the creeks, AT was correlated to WT in five creeks, DO in five creeks, and pH in three creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** AT correlated to other parameters. The strong correlation with WT was AT (0.85) and a moderate correlation with DO (-0.51).

5.26 Stage and Discharge

Stage recordings for all the creeks were compared to determine any trends, similarities, or differences. Statistical analyses for each creek are shown in **Table 5.97** including count, minimum, maximum, average, median, variance, and standard deviation. Data for each sample event is shown in **Appendix E.**

Table 5.97 Stage (ft.) for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
n	15	16	16	16	17
Min	1.05	1.51	0.13	0.17	1.48
Max	3.88	3.14	1.78	3.90	5.37
Average	2.02	2.09	0.63	0.88	2.94
Median	1.88	1.98	0.55	0.56	2.93
Variance	0.63	0.27	0.18	0.83	0.85
Standard Deviation	0.79	0.52	0.42	0.91	0.92

A line graph is shown in **Figure 5.68** for all the sample dates over the baseline assessment period to provide a visual comparison of the creeks. Tired Creek had the highest stage as expected due to a larger catchment area. Nursery Creek and Sapp Creek had the lowest stage.

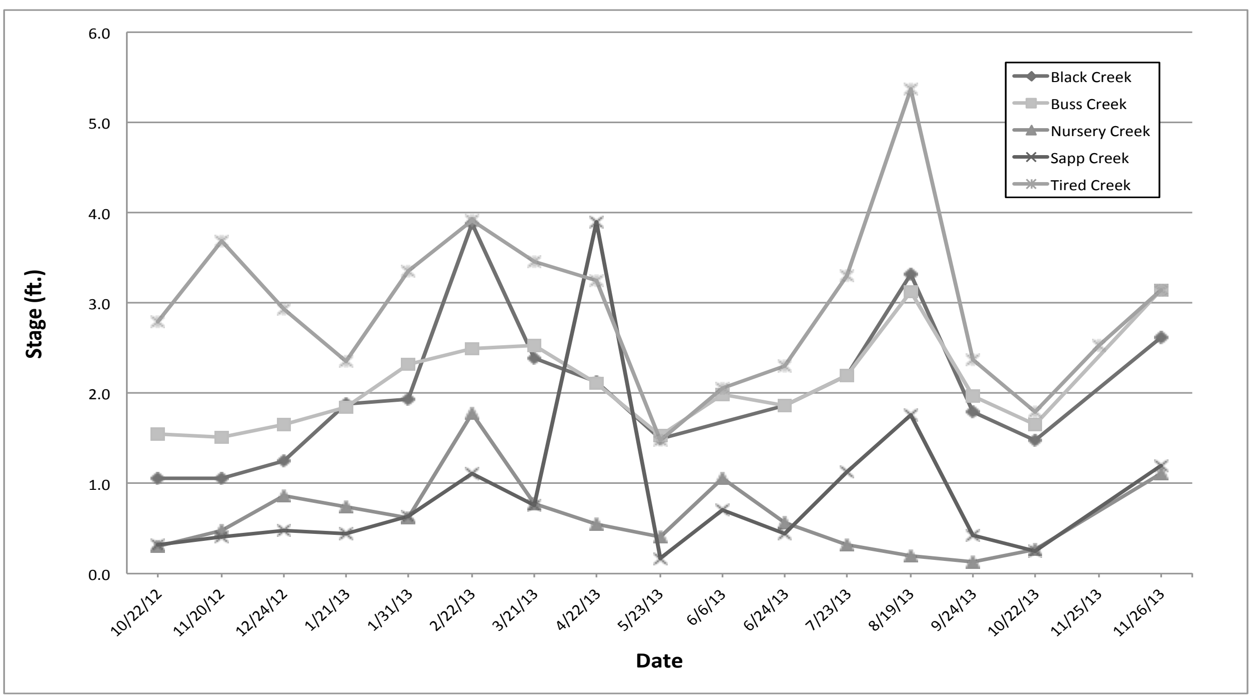

Figure 5.68 Stage for all samples

A box and whisker plot for stage is provided in **Figure 5.69.** The Tired Creek median is higher than the rest of the creeks, with Black Creek and Buss Creek close to 2 feet and Nursery Creek and Sapp Creek near 0.5 feet. The tails were all the largest above the medians.

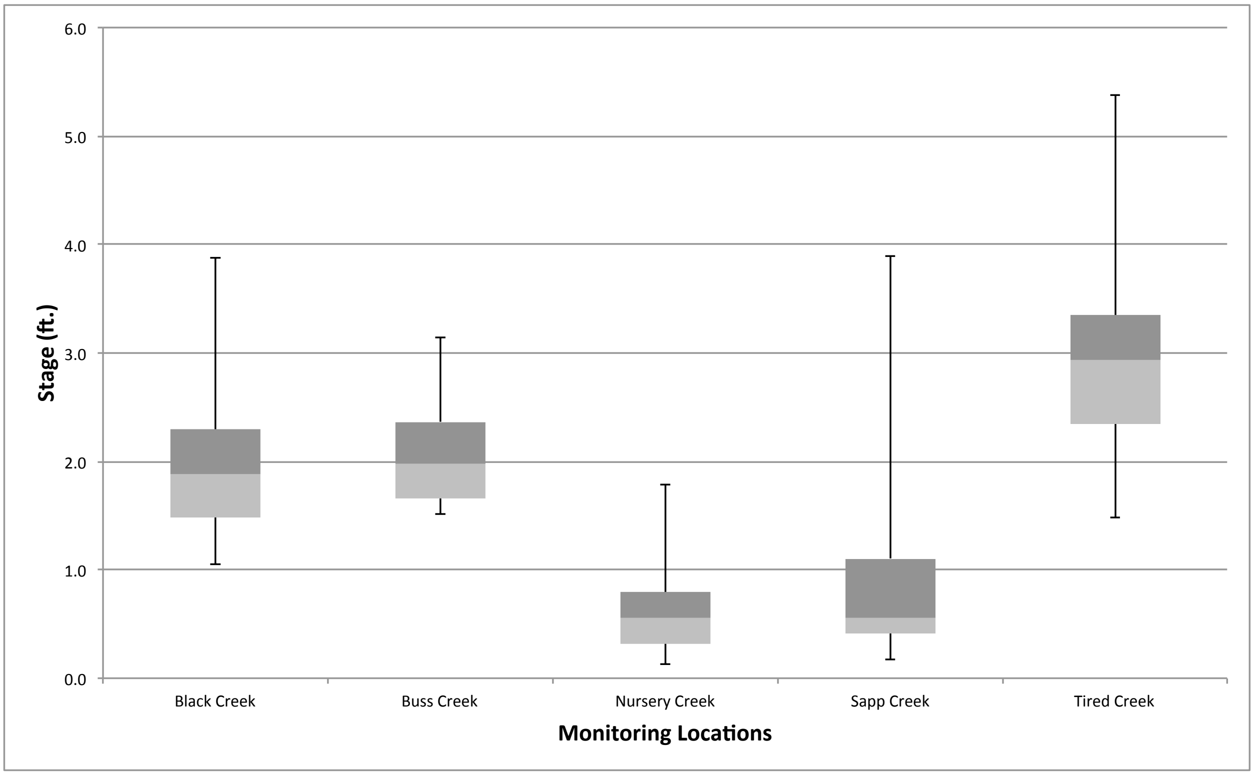

Figure 5.69 Stage box and whisker plot for each location

An ANOVA, **Appendix E,** was performed to see if there were any differences in the creeks. It was hypothesized that all the creeks were the same. Since F-critical was less than F-ratio and the p-value was more than 0.05, there was a difference in the creeks. A Tukey test, **Appendix E**, was applied and a 95% confidence interval of +/- 0.78 was determined. Based on the analysis, it was determined there was a difference between all the combinations of creeks other than Buss Creek and Black Creek and Nursery Creek and Sapp Creek.

A correlation matrix between the creeks was also developed in **Table 5.98**. The strongest correlations were between Buss Creek and Black Creek (0.83) and Buss Creek and Tired Creek

(0.67). Black Creek and Tired Creek and Nursery Creek and Black Creek were also moderately strongly correlated. Weaker correlations can be seen below.

Table 5.98 Stage correlation matrix for all samples

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.83**	1.00			
Nursery Creek	**0.55**	0.30	1.00		
Sapp Creek	0.42	0.42	0.06	1.00	
Tired Creek	**0.61**	**0.67**	0.11	0.44	1.00

Storm samples were then discarded to determine if storm samples had an influence on the data. Many storm samples were determined to be outliers and all outliers were bolded in tables including all the data for each creek. **Appendix E** includes all the data without storm events including statistical analyses for minimum, maximum, average, median, variance, and standard deviation. **Table 5.97** lists the percent differences after taking storm events out of the data. After removing the storm samples, minimums did not change and maximums decreased for Black Creek 14% and Nursery Creek 51%, but did not change for the other creeks. Averages for all creeks decreased 1-26%, along with small decreases in medians 3-20%. Variances and standard deviations decreased in Black Creek, Buss Creek, and Nursery Creek and increased in Sapp Creek and Tired Creek.

Table 5.99 Stage (ft.) percent difference not including storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	ST[1]	**ST[2]**	**%**	**ST[1]**	**ST[2]**	**%**	**ST[1]**	**ST[2]**	**%**	**ST[1]**	**ST[2]**	**%**	**ST[1]**	**ST[2]**	**%**
n	15.0	17.0	-	16.0	12.0	-	16.0	12.0	-	16.0	12.0	-	17.0	13.0	-
Min	1.1	1.5	**0**	1.5	1.51	**0**	0.1	0.13	**0**	0.2	0.17	**0**	1.5	1.48	**0**
Max	3.9	5.4	**-14**	3.1	3.13	**0**	1.8	0.87	**-51**	3.9	3.90	**0**	5.4	5.37	**0**
Avg.	2.0	2.9	**-10**	2.1	1.96	**-6**	0.6	0.47	**-26**	0.9	0.87	**-1**	2.9	2.89	**-2**
Med.	1.9	2.9	**-3**	2.0	1.86	**-6**	0.6	0.44	**-20**	0.6	0.45	**-19**	2.9	2.79	**-5**
Var.	0.6	0.9	**-35**	0.3	0.23	**-15**	0.2	0.06	**-68**	0.8	1.10	**34**	0.9	0.97	**14**
St. Dev.	0.8	0.9	**-19**	0.5	0.48	**-8**	0.4	0.24	**-44**	0.9	1.05	**16**	0.9	0.98	**7**

Note: ST[1] = all samples; ST[2] = sample not including storm data; % = percent difference

A second ANOVA, **Appendix E**, was then conducted for the data not including storm events. Again, the hypothesis was all the means were the same. The analysis determined F-critical was less than F-ratio and the p-value was less than 0.05, just as with storms included. A Tukey test, **Appendix E**, was used to determine the differences between the Creeks with a 95% confidence interval of 0.93. Just as when storms were included, there was a difference between all the combinations of creeks other than Buss Creek and Black Creek and Nursery Creek and Sapp Creek.

A correlation matrix was also developed for the data not including storm events in **Table 5.98.** Similar to when storms were included, the strongest correlations were between Buss Creek and Black Creek (0.97) and Buss Creek and Tired Creek (0.76). Black Creek and Tired

Creek were moderately strongly correlated. Moderate and weaker correlations can be seen below.

Table 5.100 Stage correlation matrix not including storms

	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**0.97**	1.00			
Nursery Creek	-0.15	-0.14	1.00		
Sapp Creek	**0.50**	**0.47**	0.003	1.00	
Tired Creek	**0.63**	**0.76**	-0.08	**0.45**	1.00

The excluded storm data, **Appendix E**, includes each event and statistical analyses for minimum, maximum, average, median, variance, and standard deviation. When compared to non-storm data, there were some noticeable differences shown in **Table 5.99**. Non-storm stage minimums all increased from 32-369%. Changes in maximums differentiated between creeks. All averages increased for storm data 4-144%, while medians also increased similarly. There was also a notable increases in the variance and standard deviation of storm data for Black and Nursery Creek and decreased in Sapp Creek and Tired Creek.

Table 5.101 Stage (ft.) percent difference non-storm data and storm data

	Black Creek			Buss Creek			Nursery Creek			Sapp Creek			Tired Creek		
	ST²	**ST³**	**%**	**ST²**	**ST³**	**%**	**ST²**	**ST³**	**%**	**ST²**	**ST³**	**%**	**ST²**	**ST³**	**%**
n	12.0	3.0	-	12.0	4.0	-	12.0	4.0	-	12.0	4.0	-	13.0	4.0	-
Min	1.1	1.9	**84**	1.5	2.0	**32**	0.1	0.6	**369**	0.2	0.6	**271**	1.5	2.1	**39**
Max	3.3	3.9	**17**	3.1	3.1	**0**	0.9	1.8	**105**	3.9	1.2	**-69**	5.4	3.9	**-27**
Avg.	1.8	2.8	**54**	2.0	2.5	**27**	0.5	1.1	**144**	0.9	0.9	**4**	2.9	3.1	**8**
Med.	1.8	2.6	**44**	1.9	2.4	**30**	0.4	1.1	**144**	0.5	0.9	**100**	2.8	3.3	**16**
Var.	0.4	1.0	**137**	0.2	0.2	**1**	0.1	0.2	**314**	1.1	0.1	**-93**	1.0	0.6	**-37**
St. Dev.	0.6	1.0	**54**	0.5	0.5	**1**	0.2	0.5	**103**	1.1	0.3	**-73**	1.0	0.8	**-21**

Note: ST^2 = sample not including storm data; ST^3 = storm data; % = percent difference

Correlations between creeks for stage were examined (**Tables 5.3, 5.6, 5.9, 5.12, and 5.15)**. For Sapp Creek, stage was strongly correlated to SC (-0.66) and moderately correlated to Alk (-0.53). For Black Creek, stage was strongly correlated to turbidity (0.79), TSS (0.76), and TON (-0.75), moderately strongly correlated to SC (-0.62), DO (0.6), TKN (0.58), Alk (-0.57), and moderately correlated to FC (0.51). For Buss Creek, stage was moderately strongly correlated to Hd (-0.63), Fe (0.61) and moderately correlated to Alk (-0.51), TON (-0.49), SC (-0.48), and TN (-0.48). For Nursery Creek, stage was strongly correlated to turbidity (0.81), TSS (0.81), Fe (0.81), TP (0.73), and Mn (0.65), moderately strongly correlated to WT (-0.62) and DO (0.56), and moderately correlated to SC (-0.5), pH (0.47), and Hd (-0.45). For Tired Creek, all correlations with stage were weak, with the strongest correlation with SC (-0.41). Stage was correlated to SC in all five creeks, alkalinity in 3 creeks, and many others in 2 creeks. In the correlation matrix including all the data from each creek location, end of **Appendix E,** there were no strong or moderate correlations for stage. The strongest correlations included Alk (-0.43) and Hd (-0.42).

Stage measurements were also recorded every fifteen minutes by the CTD devices. **Figure 5.70** shows the stage over the assessment period for all five creeks. The high flow periods and low flows can be seen, along with the differences in stage between creeks. **Figure 5.71** depicts total discharge over the assessment period, in which Tired Creek was the highest and followed by Sapp Creek and Buss Creek. Nursery Creek flow was small in comparison, but had large contributions during low flow periods due to irrigation.

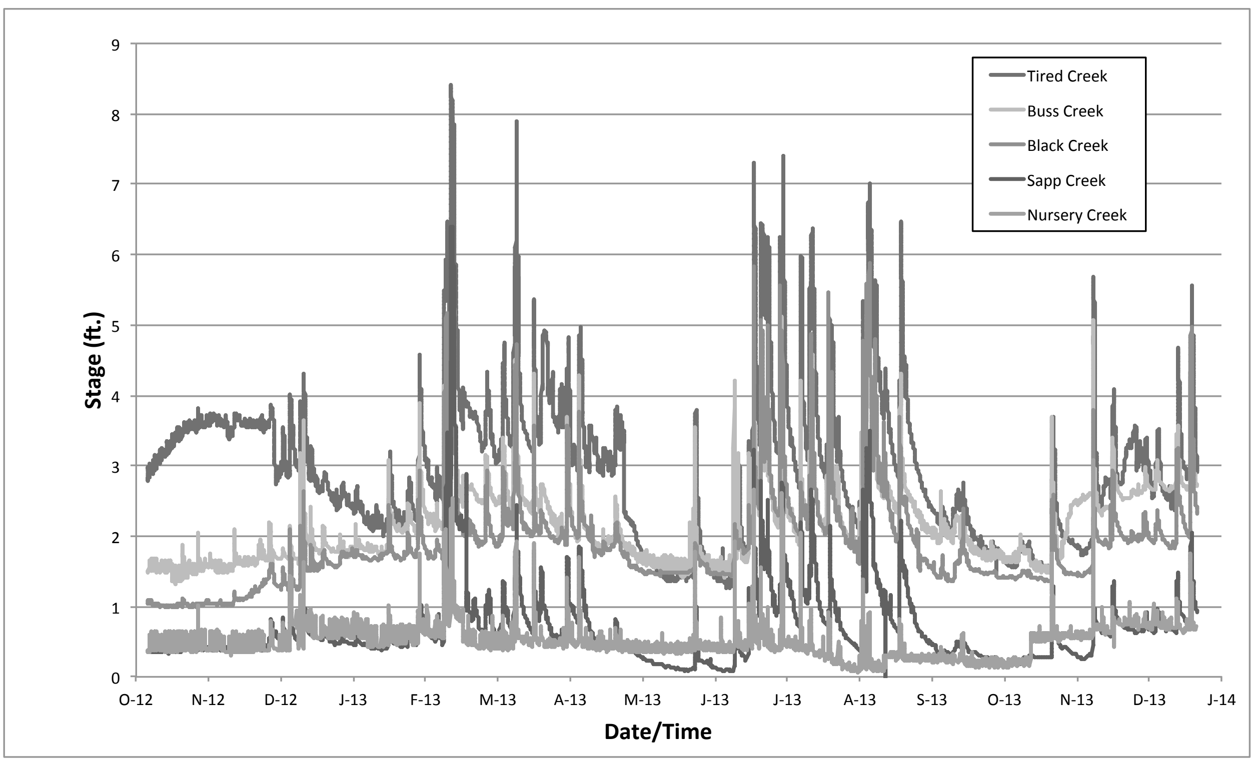

Figure 5.70 Stage for continuous monitoring at all locations

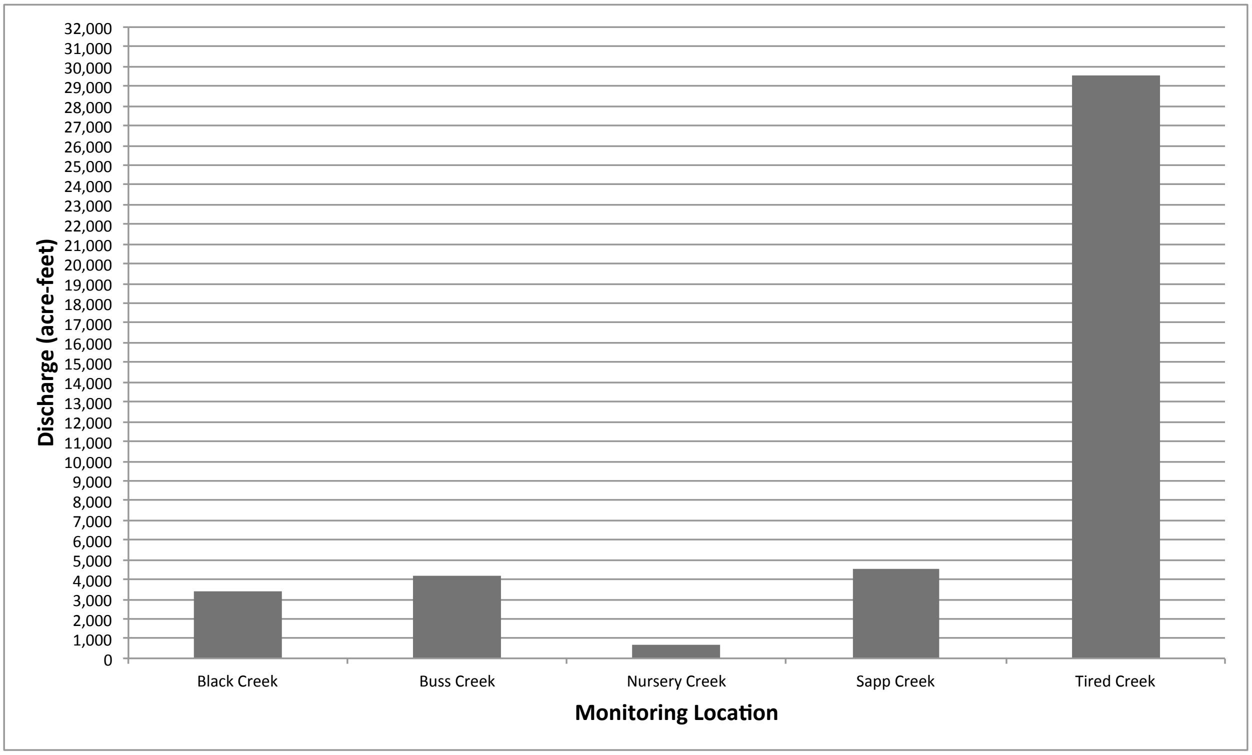

Figure 5.71 Total discharge for each location

6.0 DISCUSSION AND SUMMARY

The Tired Creek Lake project will provide recreational opportunities and economic benefits to the lacking South Georgia community of Cairo, Georgia. This report provided an overall assessment of the Tired Creek Lake water quality by establishing a baseline for Tired Creek and the contributing tributaries. This baseline will then be used to compare during construction, filling, equilibration, and many years into the future. The research will provide meaningful data for water resource management of the lake, while also providing information for new lake developments around the World.

The Tired Creek Lake watershed totals 16,126-acres in northwestern Grady County within the Tired Creek watershed, in which all waters flow into the Ochlockonee River and eventually into the Gulf of Mexico. There are 519 homes within the watershed and 1308 total people. The catchment area is comprised of approximately 50% agriculture land and 31% forested land. The soils are dominated by Tifton series totaling 40%, Oiser and Bibb soils totaling 15%, and Nankin soils totaling about 13%. The whole watershed is a low erosion risk watershed, most likely due to the high clay content. Monrovia Nursery and Gainous' Shade Nursery are two possible critical pollutant source areas, but Monrovia was only sampled because of its large size.

Located in the 16,126-acre catchment area of the Tired Creek Lake Watershed are three main contributing tributaries: Black Creek, Buss Creek, and Sapp Creek, all of which combine to form Tired Creek at the base of the dam. Nursery Creek was identified as a major contributing catchment area within the Buss Creek catchment area, especially during low flows. A total of five permanent monitoring sites were located within these creeks. A sixth site, just for grab sampling, was sampled to determine changes just above the dam and at the Tired Creek location below the dam during construction. Due to the size of the dam construction site, this site was located in the middle of the construction zone and was discarded as a sampling site for future research.

Rainfall totaled 114 rain events from October 2012-October 2013 and 130 events during the full assessment period. The largest monthly rainfall total included February with over 14 inches of rain and a single rain events totaling 4.39 inches, along with high rainfall totals in the Summer of 2013 and the largest rain event of 4.35 inches in June 2013. The lowest precipitation occurred October-November 2012, May 2013, and again October 2013. Of all the rain events, a total of 5 storms were sampled with 3 grab samples and 2 rising stage samples.

The rising stage samples proved to be complicating and were redesigned after failing the first attempt. Grab samples for storms proved to be more beneficial than rising stage samplers with more parameters of data collected and more reliable data. Rising stage samplers are limited to only laboratory data and 24-hour pickup times. The streams were not as flashy as needed to provide sufficient data for rising stage samples on a consistent basis, leading to missing data points for certain streams and possible sample contamination due to preservation and holding times. Although, it is important to note timing of storms for grab sampling, it has proven to be challenging because predicting weather is difficult. More in-depth storm data collection techniques would involve ISCO samplers, which are outside the scope of this study.

A total of twelve monthly samples were taken at each monitoring location, with one additional monthly sample at Tired Creek due to its location below the dam. The samples were analyzed for in situ parameters and laboratory analysis parameters. All sample events followed the same methods outlined earlier in the report.

The Sapp Creek catchment area totaled 3,550-acres and stage ranged from 0.07 feet to 6.4 feet, with a total discharge of 178 mcf from October 2012-October 2013. Sampled stage heights ranged from 0.17 feet to 3.9 feet. Most parameters met the criteria for state standards or recommendations for the region. Possible issues at Sapp Creek included noticeable changes in channel morphology with stream bank and streambed erosion, high Fe concentrations, high FC, and Alk was a small amount higher than other waters in the region.

The Black Creek catchment area totaled 2,226 acres and stage ranged from 0.99 feet to 5.89 feet, with a total discharge of 140 mcf from October 2012-October 2013. Sample stage heights ranged from 1.05 feet to 3.88 feet. Most parameters met the criteria for state standards or recommendations for the region. Possible issues at Black Creek included Fe above recommended levels, high FC, two low dissolved oxygen readings, one pH reading below the state limit, and a macroinvertebrate index score of 42.

The Buss Creek catchment area totaled 3,644 acres and stage ranged from 1.32 feet to 5.33 feet, with a total discharge of 158 mcf from October 2012-September 2013. Sample stage heights ranged from 1.51 feet to 3.14 feet. Most parameters met the criteria for state standards or recommendations for the region. Possible issues at Black Creek included Fe above recommended levels for the region, nutrient levels above recommended levels to prevent eutrophication in lakes, high FC, high Alk, and high Hd.

Nursery Creek catchment area totaled about 400 acres and stage ranged from 0.06 feet to 2.79 feet, with a total discharge of 28.2 mcf from October 2012-September 2013. Sampled stage heights ranged from 0.13 feet to 1.78 feet. Most parameters met the criteria for state standards or recommendations for the region. Possible issues at Nursery Creek included noticeable changes in channel morphology with stream bank and streambed erosion, Fe above recommended levels for the region, nutrient levels above recommended levels to prevent eutrophication in lakes, high FC, high Alk, and high Hd. Based on the health of the stream and the large contributions in volume during the low flow, it is recommended Nursery Creek continue to be monitored.

Tired Creek catchment area totaled 16,126 acres and stage ranged from 1.25 feet to 8.69 feet, with a total discharge of 1.2 billion ft^3 from October 2012-September 2013. Sample stage heights ranged from 1.48 feet to 5.37 feet. Most parameters met the criteria for state standards or recommendations for the region. Possible issues at Tired Creek included noticeable changes in channel morphology with stream bank erosion and sediment deposition, nutrient levels above recommended levels to prevent eutrophication in lakes, high FC, high Alk, high Hd, and a poor fish community.

Black Creek consistently had the highest Fe concentrations. Nursery Creek was the only creek to have concentrations within recommended levels. Black Creek and Nursery Creek had the largest difference in means. Buss Creek was strongly correlated to Nursery Creek and Tired Creek. Nursery Creek was also moderately correlated to Sapp Creek and Tired Creek. It was also determined that storm events caused an increase in Fe concentration in the streams. After removing storm events, Black Creek and Nursery Creek were different than each other, along with all the other creeks. Buss Creek and Tired Creek still had very strong correlation, along with a strong correlation between Nursery Creek and Sapp Creek. The correlation between Black Creek and Nursery Creek became inversely correlated. When comparing the storm data to non-storm data, it further proved an increase in Fe concentrations during storm events. The strongest

Fe correlations to other parameters included TP, turbidity, and TSS. All of which are highly influenced by storm events.

Manganese was similar to Fe concentrations and Black Creek had the highest concentrations, about 15 times that of the Nursery Creek average. All creeks were below the recommended maximum concentrations. Black Creek had a significant difference with Nursery Creek and Tired Creek. Tired Creek and Nursery Creek were very strongly correlated, along with strong correlations for Sapp Creek with Buss Creek and Nursery Creek. Moderate correlations included Sapp Creek and Tired Creek, along with moderate correlations for Buss Creek with Nursery Creek and Tired Creek. It was also determined that storm events caused an increase in Mn concentration in the streams. After removing storm events, all creeks were different than Black Creek and the largest difference was with Nursery Creek. There was no difference between the other creeks. Sapp Creek and Buss Creek became strongly correlated, while Nursery Creek and Tired Creek and Black Creek and Sapp Creek became moderately correlated. When comparing the storm data to non-storm data, it further proved an increase in Mn concentrations during storm events for all creeks other than Black Creek. The strongest Mn correlations to other parameters included TP, turbidity, and TSS. All of which are highly influenced by storm events.

Fecal coliform for all the creeks were above recommended levels by the GA EPD. Nursery Creek was the highest and Sapp Creek the lowest, but no significant difference between any creeks when storm data was included. There were very strong correlations between Black Creek and all creeks except Buss Creek, Nursery Creek and Sapp Creek, and a strong correlation between Sapp Creek and Nursery Creek. It was also determined that storm events caused an increase in FC concentration in the streams. After removing storm events, there was no significant difference between any of the creeks. There was a moderate correlation between Nursery Creek and Black Creek. When comparing the storm data to non-storm data, it further proved an increase in FC concentrations during storm events for all creeks. The strongest FC correlations to other parameters included turbidity and TSS. Both of which are highly influenced by storm events.

Total Nitrogen levels for all creeks other than Sapp Creek were above recommend levels to prevent Eutrophication in lakes with Nursery Creek the highest. There was a significant difference for Sapp Creek with Buss Creek and Nursery Creek. There was a very strong correlation with Buss Creek and Tired Creek, along with a moderate correlation between Black Creek and Sapp Creek. There was no definitive direction in TN concentration changes after removing storm data when looking at all the creeks. After removing storm data, no creek was significantly different. There was still a very strong correlation between Buss Creek and Tired Creek. Changes for TN (Total Nitrogen) concentrations in non-storm data and storm data showed no real definite trends. The strongest correlations to other parameters included TKN, TON (Nitrate + Nitrite) and Alk.

Total Kjeldahl nitrogen is determined during the digestion process to determine TN and no regulations or reference levels were determined. There was no significant difference between the creeks when all sampling data was included. The strongest correlation included Tired Creek and Black Creek, with moderate correlations for Sapp Creek with Tired Creek and Black Creek. There was no definitive direction in TKN concentration changes after removing storm data when looking at all the creeks. After removing the storm data, there were significant differences for Buss Creek with Nursery Creek and Sapp Creek. The strongest correlations included Tired Creek with Sapp Creek and Black Creek, and a moderate correlation between Sapp Creek and

Black Creek. Changes in concentrations when comparing non-storm data to storm data varied, but there was an increase for all creek averages in storm data, except Buss Creek. This leads to the assumption that storms increase TKN concentration. The strongest correlations to other parameters included TN and TP.

Nitrate + Nitrite concentrations were determined for all the creeks, but no regulations or reference levels were determined. Nursery Creek had a higher concentration of TON than other creeks and Sapp Creek the lowest. There was a significant difference for Nursery Creek with Sapp Creek and Black creek, along with a difference between Sapp Creek and Buss Creek. The strongest correlations included Buss Creek and Tired Creek, and Black Creek with Buss Creek and Tired Creek. There was a moderate correlation between Nursery Creek and Tired Creek. There were minimal changes after removing the storm data and no significant differences between the creeks. Correlations between creeks remained the same. When non-storm data was compared to storm data, there were decreases in average concentrations across the board, which show that storm events decrease TON concentrations. The strongest correlations to other parameters included Alk, SC (Specific Conductance), TN, and inversely correlated to DO. Alk [Alkalinity] and SC decrease during storms and DO increases, which further proves the decreases in TON concentrations.

Ammonium concentrations for all the creeks were below detection limit for most sampling events. Nursery Creek and Buss Creek were the highest and had the most measurements above the detection limit. There was a significant difference for Nursery Creek with Tired Creek and Sapp Creek. The only moderate correlation was between Tired Creek and Nursery Creek. It was determine that storm events increased NH4 concentrations due to an increase in four creek averages after removing the storm events. The only significant difference after removing storm events was Nursery Creek and Sapp Creek and the strongest correlation again between Tired Creek and Nursery Creek. After comparing non-storm events to storm events, it was confirmed that storm events decrease the concentrations of ammonium. The strongest correlations with other parameters included pH, Hd, SC, TN, and TON.

Total phosphorus concentrations were similar for all the creeks, with Buss Creek, Nursery Creek, and Tired Creek above recommended levels by the EPA. Black Creek and Sapp Creek were below recommended reference levels. There was no significant difference between any of the creeks. All the creeks were correlated except Black Creek with the strongest correlations for Buss Creek with Sapp Creek and Tired Creek and Sapp Creek and Tired Creek. Due to noticeable peaks during storm events and a decrease in averages, it was determined storm events increased TP concentrations. After removing the storm events, there was a significant difference between Buss Creek and Sapp Creek. Black Creek also became correlated to all the other creeks after not being correlated when storm data was included. The strongest correlations included Tired Creek with Sapp Creek and Black Creek, Black Creek with Sapp Creek and Nursery Creek and Buss Creek with Sapp Creek. When comparing the storm data to non-storm data, it further proved an increase in TP concentrations during storm events for all creeks other than Black Creek. The strongest TP correlations to other parameters included Fe, Mn, Turb, and TSS. All of which are highly influenced by storm events.

Total Suspended Solids were similar for all the creeks with noticeable increases in peaks during storm events. Nursery Creek and Tired Creek had the highest concentrations and Black Creek had the lowest. There was still no significant difference between any of the creeks. Black Creek was strongly correlated to all the other creeks and Nursery Creek was also strongly correlated with Tired Creek and Sapp Creek. After removing storm samples, all the maximums and averages decreased, signifying an increase due to storm events. For the data not including storm events, there was significant difference between Black Creek and Nursery Creek. There was strong correlation between Black Creek and Tired Creek with moderate correlations between Buss Creek and all creeks other than Black Creek, along with Nursery Creek and Tired Creek. When non-storm data was compared to storm data, it was reaffirmed that storm events caused an increase in TSS concentrations. The strongest TSS correlations to other parameters included Turb, Mn, Fe, and FC. All of which are highly influenced by storm events.

pH for all the creeks were determined and all averages were within the GA EPD range. Nursery Creek had the highest pH measurements with one being above the range and Black Creek had the lowest pH measurements with one below the range. There were significant differences between the means of all the creeks with Black Creek and all the creeks with Nursery Creek, while the other three creeks were found to be similar. The strongest correlation was between Sapp Creek and Tired Creek with moderate correlations for Nursery Creek with Buss Creek and Tired Creek, and Black Creek with Buss Creek, Sapp Creek, and Nursery Creek. Changes in pH were minimal after removing storm measurements. Difference after removing storm events were very similar to when storm events were included other than the Nursery Creek and Black Creek correlation becoming weak. Differences in non-storm data when compared to storm data were minimal. The strongest pH correlations included DO, AT, NH4, Alk, and Hd.

Specific conductance was similar for all the creeks, other than a noticeable higher concentration in Nursery Creek. Nursery Creek was significantly different than all the other creeks, while Black Creek and Sapp Creek were the most similar and Buss Creek and Tired Creek were similar. The strong correlations included Tired Creek with Buss Creek and Sapp Creek, with moderate correlations for Tired Creek with Black Creek and Nursery Creek, and

Black Creek with Nursery Creek and Sapp Creek. After removing storm samples, averages increase a small percentage. Nursery Creek remained significantly different than all the other creeks and correlations were similar other than a moderate correlation between Buss Creek and Nursery Creek. When non-storm data was compared to storm data, there was a noticeable decrease in SC for storm during storm event, most likely due to dilution in concentration from the rain. The strongest SC correlations to other parameters included Alk, TON, Stage, Hd, and DO.

Water temperature was sampled continuously using the CTD devices at each monitoring location and sampled during each sampling event. All temperature readings met the state guidelines. At the start of the assessment, Nursery Creek was noticeably higher than the rest of the creeks and then became similar. This may be due to using the pond water for irrigation or overflow from the pond. There was no significant difference over the assessment period for all the creeks and storm samples had no effect on temperature data.

Dissolved oxygen levels for all the creeks averaged above GA EPD minimum values, with Nursery Creek being the highest and Black Creek the lowest. Five Black Creek readings were below 4 mg/L, in which all low readings came during low flows or near baseflow. The low DO is most likely due to blackwater swamp influences. There were significant differences for Black Creek with Nursery Creek and Sapp Creek. Black Creek, Buss Creek, and Nursery Creek were all strongly correlated, along with Buss Creek and Tired Creek. Tired Creek was moderately correlated to the other creeks. After removing storm events, there was a small decrease in maximums and averages for all creeks. The same creeks were still significantly different for non-storm data. Tired Creek and Sapp Creek became weakly correlated and Black Creek and Nursery Creek became moderately correlated. When comparing storm data to non-storm data, averages increased for all creeks and storms were considered to increase DO. This was most likely due to higher flows and oxygenation from the atmosphere. The strongest DO correlations to other parameters included AT, Alk, WT, SC, TON, and pH.

Turbidity was similar for all the creeks with noticeable increases in peaks during storm events. Black Creek, Buss Creek, and Nursery Creek were all strongly correlated. Tired Creek was strongly correlated to Nursery Creek and moderately correlated to the other three creeks. After removing storm samples, all the maximums and averages decreased, signifying an increase due to storm events. For the data not including storm events, still not significant difference between the creeks was determined. There were strong correlation between all the creeks other than Black Creek and Nursery Creek, which became weak. When non-storm data was compared to storm data, it was reaffirmed that storm events caused an increase in Turb concentrations. The strongest Turb correlations to other parameters included TSS, Fe, FC, Mn, and TP. All of which are highly influenced by storm events.

Hardness for all the creeks varied, with Nursery Creek consistently the highest concentration and Sapp Creek the lowest. All creeks were somewhat similar to hardness reference levels within the region, except for Nursery Creek. The Nursery Creek high concentration is due to groundwater irrigation runoff from the Monrovia Nursery. There was a significant difference between Nursery Creek and all the other creeks and also Buss Creek and Sapp Creek. All correlations between creeks were minimal other than moderate correlations in Tired Creek with Black Creek, Nursery Creek, and Buss Creek. After removing the storm data, there was a slight increase in averages for all creeks, but medians did not change. The differences between the creeks remained the same after removing storm data. Correlations between creeks also remained weak, other than a strong correlation between Black Creek and

Tired Creek and a moderate correlation between Tired Creek and Nursery Creek. When non-storm data and storm data were compared, Hd averages decreased for all creeks due to storm events. Therefore, it was determined storm events decreased hardness, most likely due to dilution of the water from rainwater. The strongest Hd correlations to other parameters included SC, TON, Alk, pH, Fe, and TN.

Alkalinity for all the creeks was similar to hardness, with Nursery Creek having the highest concentration, while all the others were similar. Just as hardness, higher Nursery Creek concentrations are due to groundwater irrigation runoff from the Monrovia Nursery. Nursery Creek was significantly different than all the other creeks. There were strong correlations for Sapp Creek with Black Creek, Buss Creek, and Tired Creek and Sapp Creek, and Tired Creek and Buss Creek. All other correlations were moderate other than weak correlations for Nursery Creek with Black Creek and Sapp Creek. After removing storm samples, averages for all the creeks rose slightly, which proves a small decrease in concentration due to storm events. The significant differences between creeks were the same after removing the storm data and correlations very similar. When storm data was compared to non-storm data, all averages decreased similar percentages to hardness, proving the similarities between the two parameters. Based on the decreased averages, storm events decreased the concentration of alkalinity in the streams. The strongest Alk correlations to other parameters included SC, Hd, pH, DO, Stage, TON, TN, and Fe.

Air temperature for all the creeks was similar during the assessment period as expected. The variance in temperature was due to temperature warming up from sampling in the morning to sampling at night. All creeks had a very strong correlation. Changes due to storms were not removed, because they would have no effect beyond time the day and time of the year. The strongest AT correlations to other parameters included WT, DO, and pH.

Stage for each location was recorded continuously by the CTD's and during each sampling event. Tired Creek had the highest stage and the lowest were Nursery and Sapp Creek. There was a significant difference between all the combinations of creeks other than Buss Creek and Black Creek and Nursery Creek and Sapp Creek. The strongest correlations included Buss Creek with Black Creek and Tired Creek, and moderate correlations for Black Creek with Tired Creek and Nursery Creek. Stage was increased for storm samples with an increase in discharge due to storm events. Significant difference were the same after removing storm events. In addition to earlier correlations, Sapp Creek became moderately correlated to Buss Creek and Tired Creek. When compared to non-storm events, storm event stage averages were higher. The strongest correlations for stage between other parameters included SC, Alk, and Hd.

Discharge is related to stage through a power curve developed at each location. Even though stages may be similar, discharges are particular to each creek based on calculated discharges at different stage heights over the assessment period. Tired Creek had the highest discharge followed by Sapp Creek with the second highest, Buss Creek the third largest, Black Creek the fifth largest, and Nursery Creek the least contributing discharge.

All the parameters and assessments were taken into consideration for all creeks. The most differences between creeks included differences with Black Creek and/or Nursery Creek. These two creeks also had the lowest overall stream health grades. Correlations between creeks varied drastically depending on the parameter and the creek.

Nursery creek had a much higher number of strong correlations between parameters when compared to other creeks, while Sapp Creek had the smallest number of correlations. The high number of correlations in Nursery Creek may be due to a smaller number of end members when compared to the larger watersheds for the other creeks. End members into Nursery Creek include groundwater back flow and runoff from irrigation, holding pond water, runoff, fertilizers, pesticides, gas, oils, etc. There are more end members influencing other creeks due to the larger drainage basins and are hard to quantify, especially, with a wide range of agriculture practices and land uses. It is however important to note Tired Creek had many more strong correlations than Sapp Creek, which is a smaller drainage area and therefore less end members.

Timbering and dam construction started on August 20, 2013, but would not have an influence on the upstream sites, only Tired Creek. The baseline assessment provides useful data to eventually use to compare how the water quality changes from before construction, during construction, and after construction. Dam construction and timbering should be completed by the end of the year and the project will move into the filling and equilibrium phase. After which another in depth assessment of the water quality data will be assessed and compared.

7.0 ENGINEERING LESSONS LEARNED

Throughout the project there were multiple lessons learned to provide better data for future and other surface water research projects. Many of the lessons learned are beyond what is typically found in textbooks. These lessons included housing unit design, choosing the correct monitoring location, discharge measurements errors, and instrument failure.

Three types of housing unit designs were originally tested at different monitoring locations for the CTD devices. Design One included a perforated PVC pipe attached to a fence post driven into the ground with a staff gauge attached. The housing unit was two meters tall with a datalogger at the top of the PVC pipe in the water. This design was used at Buss Creek, Sapp Creek, and Black Creek. Design Two included a PVC perforated pipe, which was attached to three fence posts at a 45 degree angle with the datalogger unit at the edge of the creek, where it could be accessed by land. This design was used at Nursery Creek. Because the conductivity sensor was 4 inches above the depth sensor, it was not possible to get conductivity measurements at this monitoring location during low flows. Design Three included a longer cable of ten meters, in which the datalogger was attached to a fence post on land. The cable was strung along two additional fence posts before being submerged in a perforated PVC post and zip tied at the top to prevent sensor movement up and down. This design was used at the downstream Tired Creek location.

Each design was modified to some extent to make data collection easier and more reliable. After the large flood in February 2013, in which multiple housing units fell over or washed away due to high flows and/or floating debris, extra support was needed. With the aid of a metal detector and shovels, all the units were found and repositioned. An additional fence post was added to each unit and driven deeply into the earth to provide stronger support during high flows. The second post, which the PVC housing unit was originally connected to, was attached to the post driven deep into the earth.   All staff gauges were also separated from the housing units and attached to a fence post reinforced by a second post deep into the earth. This decreased the weight of the unit and provided a more permanent support for the staff gauge. Due to sediment buildup inside the perforated PVC pipes, PVC well screened pipes (small slots) were installed to try to limit sediment buildup around the probes inside the PVC. The outcome of this design change is yet to be determined. Design Three at the Tired Creek location proved to be the most beneficial for research. The main reasons include ease of access to download data on the stream bank, a decrease in the top heaviness of the housing unit with datalogger on stream bank, and a decrease in the chances the datalogger would get water damage when located on the stream bank even if fence posts fell over.

Choosing a monitoring location is also important when determining the exact location within the stream. Choosing a proper location helps when calculating discharge measurements. Maps must first be used to determine the general area, but then closer investigation of the site must be done to determine the exact location. If possible, it is recommended to choose a site with the least changes in channel morphology and uniform flow. If determining specific conductance along with stage, it is recommended to choose a spot deep enough, even at low flows, to record specific conductance measurements. Another interesting aspect, especially in South Georgia, is the influence of beaver dams on stream flow. Choosing a location with the least impact from beaver dams will help to provide better discharge approximations.

Total discharge approximations proved to be a difficult task in some creeks, especially in the more shallow creeks or creeks that had significant channel morphology. It was determined there is a trade-off between more accurate calculations and expense. To provide improved discharge measurements, one could survey a cross section each time discharge measurements were calculated and also calculate bed load changes. Both would vary over time depending on high flows and low flows. This is very labor intensive and would require two people in the field, which would increase costs. Another possible solution is to purchase software, which helps with determining discharge. Potential software that may help potentially decrease error includes AQUARIUS (used by USGS), ARC Civil, FLOW3D, or other similar software. Software would also increase costs significantly. A third possible solution is to install a fixed hydraulic structure such as a Parshall flume to provide increased accuracy keeping the area consistent. This would likely increase the budget needed to complete a project the most. The final possible solution is to use ArcSWAT to determine total discharge through modeling, but for the smallest error it would be important to calibrate the model through field measurements. Each method has its pros and cons for providing continuous discharge data and all have potential errors associated with them.

Another important lesson learned throughout the project is to always be prepared for instrument failure when working on research projects. No matter how careful you are, there will always be some things that break or go wrong. To prepare for such events extra instruments can be purchased to have as backup, if funds are available. Some suppliers offer insurance on their instruments, in which they send a replacement on loan during the time of repair. This also helps to decrease the amount of potential data that is lost due to instrument failures, but does increase project cost.

If cost is a concern for a similar project, then these are a few recommendations to cut back on associated costs to water quality monitoring;some data is always better than no data, butone cannot go back and get necessary data. Future water quality monitoring at Tired Creek Lake will not change, but the following arerecommendations for costs savings for similar projects.

Monitoring parameters that have the strongest correlations could be consolidated. Turbidity and total suspended solids were very strongly correlated in all creeks. Turbidity can be calculated in the field with a turbidimeter and the need for total suspended solids calculations in a laboratory are not needed, unless turbidity measurements are very high and TSS can then be taken if deemed necessary. Alkalinity or hardness also correlate and so one could be removed. Metal analyses were added by special request from the EPA every sample event, and these could probably be conducted once a year.

Other ideas to decrease costs include purchasing less expensive sensors that only record depth and not specific conductance on a continuous basis. Specific conductance would still need to be measured during sampling events using a sonde. A less expensive sonde that is not able to be deployed for continuous measurements could decrease costs. In addition, rainfall data could be acquired from a weather station nearby, depending on the accuracy needed for the research, instead of purchasing and monitoring with a rain gauge.

Surface water quality and hydrologic analysis research projects require extensive time and effort to produce accurate and representative data. It is important to always be flexible and learn to adapt, because things will go wrong when working in outdoor environments, but limiting gaps in research should be of the utmost concern.

Appendix A - List of Acronyms and Abbreviations

Symbol	Definition	Unit	Method	MDL
Fe	Iron	mg/L	EPA 200.7	0.038
Mn	Manganese	mg/L	EPA 200.7	0.00024
FC	Fecal Coliform	CFU/100 mL	SM 9222D	1
TN	Total Nitrogen	mg/L	Calculation	0.1
TKN	Total Kjeldahl Nitrogen	mg/L	EPA 351.2	0.071
TP	Total Phosphorus	mg/L	EPA 365.3	0.004
TSS	Total Suspended Solids	mg/L	EPA SM 2540D	2
TON	Nitrate + Nitrite	mg/L	EPA SM 4500NO3-F	0.004
NH4	Ammonium	mg/L	TN-TKN-ON = NH4	0
DO	Dissolved Oxygen	mg/L	Hach MiniSonde 5	-
pH	Hydrogen Ion	pH	Hach MiniSonde 5	-
SC	Specific Conductance	µS/cm	Hach MiniSonde 5	-
WT(E)	Water Temperature	°F	Hach MiniSonde 5	-
WT(M)	Water Temperature	°C	Hach MiniSonde 5	-
AT	Air Temperature	°F	Thermometer	-
Alk	Alkalinity	mg/L	Hach Titration	5
Hd	Hardness	mg/L	Hach Titration	20
Turb	Turbidity	NTU	Turbidimeter	0
Stage	Stage	Ft.	Staff Gage	-
Time	Eastern Standard time	-	Clock	-
V	Total Volume	Feet^3	Power Curve Fit	-
MDL	Minimum Detection Limit	-	-	-
BDL	Below Detection Limit	-	-	-
Mcf	Million cubic feet	-	-	-

APPENDIX C- Methods for Analysis

Table C1. Laboratory Analysis Methods

Parameter	Prep Method	Prep Batch	Analysis Method	Analysis Batch
Fecal Coliform	-	-	SM 9222D	MICs/1067
Metals	EPA 200.7	DGMj/1387	EPA 200.7	ICPj/1233
Total Suspended Solids	-	-	SM2540D	WCAs/1085
Total Phosphorus	EPA 365.3	WCAg/1694	EPA 365.3	WCAg/1695
Nitrate + Nitrite	-	-	SM 4500NO3-F	WCAg/1712
Total Kjeldahl Nitrogen	Copper Sulfate Digestion	WCAg/1739	EPA 351.2	WCAg/1740
Total Nitrogen	Calculation	CLCs/	Calculation	CLCs/
Ammonia	-	-	Calculation	-

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

For the macroinvertebrate biotic indices, Georgia is divided into 23 subecoregions. The tidal sites are also separated into a category, thus giving the state of Georgia twenty-four discrete macroinvertebrate indices. Once you have determined which index to use based on the sample location in the state, an excel spreadsheet has been developed (or will be developed in the future) to calculate the index score which determines the stream ranking, narrative description, and stream health rating of each of the sampling locations.

To calculate the index, fill in the information on the metric calculation sheets (i.e. HBI, %Tolerant taxa, %Predator, EPT taxa, Simpson's Diversity Index) in the excel file for the subecoregion you are working. On the first metric work sheet, fill in the site name or identification number. A different excel file will need to be completed for each sample location. Fill in the numbers of individuals of a particular family, functional feeding group, habit, etc.; as well as taxa numbers, total number of individuals per site, tolerance values, etc. for each of the metric worksheets. There will be 5 to 8 metric worksheets per each index. Once the data has been filled in for each of the metric worksheets then the metrics will be standardized and all calculations will be tabulated. The results can be found in the ranking classification worksheet. Tolerance values, North Carolina tolerance values (for use with the NCBI metric), functional feeding groups, and habit can be found in the GA EPD Macroinvertebrate Taxa List. (Taxa list is formatted for legal size paper.)

GA EPD will continue to refine and calibrate the macroinvertebrate indices. As more data is collected and analyzed, the metrics will be adjusted.

Explanations of the metric equations are below:

When calculating the metrics, each taxa is counted even if it is possible they could be the same genus or species due to not being able to identify the organisms to a lower taxonomic level. This affects metrics that use taxa numbers. For example Perlodidae, *Isoperla sp.,* and *Isoperla clio* are counted as separate taxa.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Metric Calculations

Richness Metrics:

Ephemeroptera, Plecoptera, Trichoptera Taxa (EPT Taxa)

EPT Taxa = **#of Ephemer. taxa + #of Plecoptera taxa + #of Trichoptera taxa**

- The taxonomic level of Order is used to determine if an individual is considered to be Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa or not Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List (This **list can be found on the EPD website www.gaepd.gov).** *Plecoptera Taxa* Plecoptera Taxa = **# of Plecoptera taxa**

- The taxonomic level of Order is used to determine if an individual is considered to be Plecoptera taxa or not Plecoptera taxa.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *Coleoptera Taxa* Coleoptera Taxa = **# of Coleoptera taxa** *(note – do not count adult and larvae as separate taxa)*

- The taxonomic level of Order is used to determine if an individual is considered to be Coleoptera taxa or not Coleoptera taxa.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *Diptera Taxa* Diptera Taxa = **# of Diptera taxa**

- The taxonomic level of Order is used to determine if an individual is considered to be Diptera taxa or not Diptera taxa.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Chironomidae Taxa

Chironomidae Taxa = **# of Chironomidae taxa**

- The taxonomic level of Family is used to determine if an individual is considered to be Chironomidae taxa or not Chironomidae taxa.

- The taxonomic level of Family can be found in the GA EPD Macroinvertebrate Taxa List. *Tanytarsini Taxa* Tanytarsini Taxa = **# of Tanytarsini taxa**

- The taxonomic level of Tribe is used to determine if an individual is considered to be Tanytarsini taxa or not Tanytarsini taxa. Tanytarsini is a tribe in the family of Chironomidae.

- The taxonomic level of Tribe can be found in the GA EPD Macroinvertebrate Taxa List. *Margalef's Index* Dm = **(S-1) LN(N)** Dm = Margalef's Index (Diversity) S = Number of Species in a site N = Total number of Individuals in a sample LN = natural log • Do not count larvae and adult for Coleoptera as separate species. • Species represent any level of taxonomic identification. *Shannon-Wiener Index (base-e)* Shannon-Wiener (base-e) = **- Σ ((pi) * LN(pi))**

- pi = ni/N (relative abundance for each species)

- ni = number of a species

- N = total number of all species

- LN = natural log (base e)

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Simpson's Diversity Index:

D = Σ n(n-1) N(N-1)

n = total number of organisms of a particular species (no matter what level of taxonomic identification)

N = total number of organisms of all species (total # of individuals in sample)

Composition Metrics:

% Ephemeroptera, Plecoptera, Trichoptera (%EPT)

% EPT = **100 * (# of Ephemeroptera + # of Plecoptera + # of Trichoptera) Total Individuals in sample**

- The taxonomic level of Order is used to determine if an individual is considered to be Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa or not Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Amphipoda* %Amp = 100 * **[# Individual Amphipods / Total Individuals in sample]**

- The taxonomic level of Order is used to determine if an individual is considered to be Amphipoda or not Amphipoda.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Chironomidae* %Chir = **100 * [# Individual Chironomidaes / Total Individuals in sample]**

- The taxonomic level of Family is used to determine if an individual is considered to be Chironomidae or not Chironomidae.

- The taxonomic level of Family can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

% Coleoptera

%Coleoptera = 100 * [# Individual Coleoptera / Total Individuals in sample]

- The taxonomic level of Order is used to determine if an individual is considered to be Coleoptera or not Coleoptera.
- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Diptera* %Diptera = **100 * [# Individual Diptera / Total Individuals in sample]**
- The taxonomic level of Order is used to determine if an individual is considered to be Diptera or not Diptera.
- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Gastropoda* % Gastropoda = **100 * [# Individual Gastropoda / Total Individuals in sample]**
- The taxonomic level of Class is used to determine if an individual is considered to be Gastropoda individual or not a Gastropoda individual.
- The taxonomic level of Class can be found in the GA EPD Macroinvertebrate Taxa List. *% Isopoda* **% Isopoda = 100 * [# Individual Isopoda / Total Individuals in sample]**
- The taxonomic level of Order is used to determine if an individual is considered to be Isopoda individual or not an Isopoda individual.
- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

% Non-Insect

%NonIns = **100 * [# Individual Non-Insect / Total Individuals in sample]**

- The taxonomic level of Class is used to determine if an individual is considered to be an Insect or Non-Insect.

- The taxonomic level of Class can be found in the GA EPD Macroinvertebrate Taxa List. *% Odonata* %Odonata = **100 * [# Individual Odonata / Total Individuals in sample]**

- The taxonomic level of Order is used to determine if an individual is considered to be Odonata or not Odonata.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Plecoptera* **%Plec = 100 * [# Individual Plecoptera / Total Individuals in sample]**

- The taxonomic level of Order is used to determine if an individual is considered to be Plecoptera or not Plecoptera.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% Tanytarsini* %Tanytarsini = **100 * [# Individual Tanytarsini / Total Individuals in sample]**

- The taxonomic level of Tribe is used to determine if an individual is considered to be Tanytarsini or not Tanytarsini. Tanytarsini is a tribe in the family of Chironomidae.

- The taxonomic level of Tribe can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

% Oligochaeta

%Oligo = **100 * [# Individual Oligochaeta / Total Individuals in sample]**

- The taxonomic level of Subclass is used to determine if an individual is considered to be Oligochaeta or not Oligochaeta.

- The taxonomic level of Subclass can be found in the GA EPD Macroinvertebrate Taxa List. *% Trichoptera* %Tri = **100 * [# Individual Trichoptera / Total Individuals in sample]**

- The taxonomic level of Order is used to determine if an individual is considered to be Trichoptera or not Trichoptera.

- The taxonomic level of Order can be found in the GA EPD Macroinvertebrate Taxa List. *% (Orthocladiinae / Total Chironomidae)* %(Ortho/TC) = **100 * # Individual Orthocladiinae Total Chironomidae in sample**

- The taxonomic level of Subfamily is used to determine if an individual is considered to be Orthocladiinae or not Orthocladiinae.

- The taxonomic level of Family is used to determine if an individual is considered to be Chironomidae or not Chironomidae.

- The taxonomic level of Family and Subfamily can be found in the GA EPD Macroinvertebrate Taxa List. *% (Tanypodinae / Total Chironomidae)* %(Tany/TC) = **100** * **# Individual Tanypodinae Total Chironomidae in sample**

- The taxonomic level of Subfamily is used to determine if an individual is considered to be Tanypodinae or not Tanypodinae.

- The taxonomic level of Family is used to determine if an individual is considered to be Chironomidae or not Chironomidae.

- The taxonomic level of Family and Subfamily can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

% (Hydropsychidae / Total Trichoptera)

%(Hydro/TT) = **100 * # Individual Hydropsychidae Total Trichoptera**

- The taxonomic level of Family is used to determine if an individual is considered to be Hydropsychidae or not Hydropsychidae.

- The taxonomic level of Order is used to determine if an individual is considered to be Total Trichoptera or not Trichoptera.

- The taxonomic level of Family and Order can be found in the GA EPD Macroinvertebrate Taxa List. *% (Hydropsychidae / Total Ephemeroptera + Plecoptera + Trichoptera)* %(Hydro/(EPT)) = **100 * # Individual Hydropsychidae (# of Epheme. + # of Plecoptera + # of Trichoptera)**

- The taxonomic level of Family is used to determine if an individual is considered to be Hydropsychidae or not Hydropsychidae.

- The taxonomic level of Order is used to determine if an individual is considered to be Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa or not Ephemeroptera taxa, Plecoptera taxa, & Trichoptera taxa.

- The taxonomic level of Order and Family can be found in the GA EPD Macroinvertebrate Taxa List. *% (Chironomus + Cricotopus / Total Chironomidae)* %(Chiro+Crico/TC)= **100 * (# Indiv. Chironomus + # Indiv. Cricotopus) Total Chironomidae in sample**

- The taxonomic level of genus is used to determine if an individual is considered to be Chironomus and Cricotopus or not Chironomus and Cricotopus.

- The taxonomic level of Family is used to determine if an individual is considered to be Chironomidae or not Chironomidae.

- The taxonomic level of Family and genus can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Tolerance/Intolerance Metrics:

Tolerant Taxa

Tolerant Taxa = **# of Tolerant taxa**

- Tolerant Individuals have a tolerance value ≥7

- Tolerance scores can be found in the GA EPD Macroinvertebrate Taxa List. *** Please note it is the number of tolerant taxa not the number of tolerant individuals.** (Do not count adult and larvae for beetles as two separate taxa.) *% Tolerant Individuals* %TolInd = **100 * [# Tolerant Individuals / Total Individuals in sample]**

- Tolerant Individuals have a tolerance value ≥7

- Tolerance scores can be found in the GA EPD Macroinvertebrate Taxa List. *Intolerant Taxa* Intolerant Taxa = **# of Intolerant taxa**

- Intolerant Individuals have tolerance values ≤ 3.

- Tolerance scores can be found in the GA EPD Macroinvertebrate Taxa List.

- Please note it is the number of tolerant taxa not the number of tolerant individuals. (Do not count adult and larvae for beetles as two separate taxa.) *% Intolerant Individuals* %IntolInd = **100 * [# Intolerant Individuals / Total Individuals in sample]**

- Intolerant Individuals have a tolerance value ≤3.

- Tolerance values can be found in the GA EPD Macroinvertebrate Taxa List. *% Dominant Individuals* % Dominant Individuals = **100 * # Individual for Dominant Taxa Total Individuals in sample**

- Determine the dominant taxa (max individuals per taxa) in a site. 9

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Dominant Individuals

Dominant Individuals = **# Individuals in sample for the Dominant taxa** • Determine the dominant taxa (largest number of individuals per taxa) in a site.

Beck's Index

Beck's Index = **[2*(C1 Taxa)] + (C2 Taxa)** • C1 Taxa = # of Taxa with Tolerance values ≤ 1.

• C2Taxa=#ofTaxawithTolerancevalues>1and≥4. *Hilsenhoff Biotic Index*

HBI= Σ ni ai N

N = Number of total organisms ni = number of specimens in each taxonomic group ai = the pollution tolerance score for that taxonomic group

(Tolerance scores can be found in the GA EPD Macroinvertebrate Taxa List.)

North Carolina Biotic Index

NCBI= Σ ni nci N

N = Number of total organisms ni = number of specimens in each taxonomic group nci = the North Carolina pollution tolerance score for that taxonomic group

- To calculate the NCBI only use the individuals that have a North Carolina tolerance value in the GA EPD Macroinvertabrate Taxa List. **Exclude all individuals that do not have a NC tolerance value when calculating this metric.**

- North Carolina tolerance scores can be found in the GA EPD Macroinvertebrate Taxa List under the column heading NCTV.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Functional Feeding Group Metrics:

% Scraper

%Scraper = **100 * [# Individual Scraper / Total Individuals in sample]**

- Scraper is a functional feeding group.
- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.
  Scraper Taxa Scraper Taxa = **# of Scraper taxa**
- The functional feeding group is used to determine if an individual is considered to be a Scraper taxa or not a Scraper taxa.
- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List. *% Collector* %Coll = **100 * [# Individual Collector / Total Individuals in sample]**
- Collector is a functional feeding group.
- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.
  Collector Taxa Collector Taxa = **# of Collector taxa**
- The functional feeding group is used to determine if an individual is considered to be a Collector taxa or not a Collector taxa.
- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

% Predator

%Pred = **100 * [# Individual Predator / Total Individuals in sample]**

- Predator is a functional feeding group.

- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.
  Predator Taxa Predator Taxa = **# of Predator taxa**

- The functional feeding group is used to determine if an individual is considered to be a Predator taxa or not a Predator taxa.

- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List. *% Shredder* %Shed = **100 * [# Individual Shredder / Total Individuals in sample]**

- Shredder is a functional feeding group.

- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.
  Shredder Taxa Shredder Taxa = **# of Shredder taxa**

- The functional feeding group is used to determine if an individual is considered to be a Shredder taxa or not a Shredder taxa.

- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List. *% Filterer* %Filt = **100 * [# Individual Filterer / Total Individuals in sample]**

- Filterer is a functional feeding group.

- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

Filterer Taxa

Filterer Taxa = **# of Filterer taxa**

- The functional feeding group is used to determine if an individual is considered to be a Filterer taxa or not a Filter taxa.

- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List.
  Habit Metrics: *Clinger Taxa* Clinger Taxa = **# of Clinger taxa**

- The functional feeding group is used to determine if an individual is considered to be a Clinger taxa or not a Shredder taxa.

- The functional feeding group can be found in the GA EPD Macroinvertebrate Taxa List. *% Clinger* %Clinger = **100 * [# Individual Clingers / Total Individuals in sample]**

- Clinger is a functional feeding group.

- Functional feeding groups can be found in the GA EPD Macroinvertebrate Taxa List.
  Burrower Taxa Burrower Taxa = **# of Burrower taxa**

- The habit is used to determine if an individual is considered to be a Burrower taxa or not a Burrower taxa.

- The habit can be found in the GA EPD Macroinvertebrate Taxa List.

GADNR/EPD WATERSHED PROTECTION BRANCH Macroinvertebrate Metric Calculation Guidelines

SprawlerTaxa

Sprawler Taxa = **# of Sprawler taxa**

- The habit is used to determine if an individual is considered to be a Sprawler taxa or not a Sprawler taxa.

- The habit can be found in the GA EPD Macroinvertebrate Taxa List. *Swimmer Taxa* Swimmer Taxa = # of Swimmer taxa

- The habit is used to determine if an individual is considered to be a Swimmer taxa or not a Swimmer taxa.

- The habit can be found in the GA EPD Macroinvertebrate Taxa List.

APPENDIX D

Table D1. Land cover (acres and percentages) based on 2008 land cover data.

Stream ID	Dune – Mud	%	Open water	%	Low Int. Urban	%	High Int. Urban	%
Tired Creek	5.34	0.08	63.60	1.0	198.59	2.96	2.89	0.04
Sapp Creek	11.79	0.33	97.63	2.8	250.41	7.05	8.01	0.23
Black Creek	0.89	0.04	23.13	1.0	106.75	4.80	8.45	0.38
Buss Creek	8.01	0.22	90.51	2.5	134.32	3.69	11.56	0.32
Total	26.02	0.16	274.87	1.7	690.07	4.28	30.91	0.19

	Clearcut	%	Deciduous	%	Evergreen	%	Mixed	%
Tired Creek	79.84	1.19	916.46	13.7	1074.13	16.02	827.06	12.33
Sapp Creek	65.83	1.85	185.03	5.2	358.04	10.08	209.27	5.89
Black Creek	25.57	1.15	86.06	3.9	279.32	12.55	145.00	6.51
Buss Creek	56.93	1.56	214.83	5.9	499.70	13.71	226.17	6.21
Total	228.17	1.41	1402.37	8.7	2211.19	13.71	1407.49	8.73

	Row Crop	%	Forested Wetland	%	Open Wetland	%	Total	%
Tired Creek	2628.6	39.2	898.00	13.4	10.90	0.16	6705.41	41.58
Sapp Creek	2131.6	60.0	209.49	5.9	23.80	0.67	3550.85	22.02
Black Creek	1406.2	63.2	131.88	5.9	12.90	0.58	2226.09	13.80
Buss Creek	2105.8	57.8	283.77	7.8	12.45	0.34	3644.03	22.60
Total	8272.1	51.3	1523.13	9.4	60.04	0.37	16126.39	100

Beach/Dune/Mud - Open sand, sandbars, sand dunes, mud - natural environments as well as exposed sand from dredging and other activities.
Open Water - Lakes, rivers, ponds, ocean, industrial water, aquaculture.
Low Intensity Urban - Includes areas with a mixture of some constructed materials, including large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 50 percent of total cover. Areas most commonly include single-family housing units.
High Intensity Urban - Includes areas with a mixture of constructed materials and vegetation including single-family housing units and highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 50-100 percent of the total cover.
Clearcut/Sparse - Recent clearcuts, sparse vegetation, clearcut wetlands.
Quarries/Strip Mines/Rock Outcrop - Exposed rock and soil from industrial uses, gravel pits, landfills. Rock outcrops, mountain tops, barren land.
Deciduous Forest - Forest composed of at least 75% deciduous trees in the canopy, mountain shrub/scrub, deciduous woodland.
Evergreen Forest - Evergreen forest, at least 75% evergreen trees, managed pine plantations, evergreen woodland.
Mixed Forest - Mixed deciduous/coniferous, fall line and coastal plain shrub/scrub, mixed woodland.
Row Crop/Pasture - Row crops, orchards, vineyards, groves, horticultural businesses. Pasture, non-tilled grasses.
Forested Wetland - Cypress gum, evergreen wetland, deciduous wetland, depressional wetlands, and shrub wetlands.

Table D2. Soil map divided into watersheds from 2008 SURGO data

Soil Type	Tired Creek (acres)	Sapp Creek (acres)	Buss Creek (acres)	Black Creek (acres)	Total	
					(acres)	(%)
BiB	18	0	0	0	18	0.1
BiD	23	0	0	0	23	0.1
BoB	110	48	133	12	302	1.9
BoD	101	0	0	0	101	0.6
CaB	217	13	10	0	240	1.5
CaC	465	51	186	154	856	5.3
CgC	135	0	0	0	135	0.8
DoA	99	119	76	107	400	2.5
DoB	364	269	102	54	789	4.9
FeA	33	13	0	0	46	0.3
FeB	232	148	194	15	589	3.7
FuB	81	127	39	58	305	1.9
GoA	55	38	27	46	166	1.0
GrA	9	1	6	83	99	0.6
LmB	40	0	0	0	40	0.2
LmC	4	0	0	0	4	0.0
LnA	138	21	20	9	189	1.2
NaB	238	59	274	0	570	3.5
NcC	617	157	268	32	1074	6.7
NcD	234	59	73	0	366	2.3
OcA	59	71	0	39	169	1.0
OeA	11	19	0	0	30	0.2
OeB	39	8	0	76	124	0.8
OeC	24	0	0	0	24	0.2
OeD	21	0	0	0	21	0.1
OSA	1448	345	458	193	2444	15.2
PeA	106	0	103	47	256	1.6
ReA	0	3	0	0	3	0.0
TfA	406	531	406	349	1692	10.5
TfB	1304	1337	1139	912	4693	29.1
TrB	0	0	31	5	36	0.2
W	74	113	101	35	322	2.0
Total	6705	3550	3644	2226	16125	100.0

BIB (Blanton loamy sand, 0-5% slope), BID (Blanton loamy sand, 5-12% slope), BoB (Bonneau loamy sand, 0-5% slope), BoD (Bonneau loamy sand, 5-12% slope), CaB (Carnegie gravelly sandy loam, 2-5% slope), CaC (Carnegie gravelly sandy loam, 5-8% slope), CgC (Cowarts-Gritney complex, 5-8% slope), DoA (Dothan loamy sand, 0-2% slope), DoB (Dothan loamy sand, 2-5% slope), FeA (Faceville sandy loam, 0-2% slope), FeB (Faceville sandy loam, 2-5% slope), FuB (Fuquay loamy sand, 0-5% slope), GoA (Goldsboro loamy sand, 0-2% slope), GrA (Grady sandy loam, ponded), LmB (Lucy loamy sand, 0-5% slope), LmC (Lucy loamy sand, 5-8% slope), LnA (Lynchburg fine sandy loam, 0-2% slopes), NaB (Nankin loamy fine sand, 2-5% slopes), NcC (Nankin-Cowarts complex, 5-8% slopes), NcD (Nankin-Cowarts complex, 8-12% slope), OcA (Ocilla loamy fine sand, 0-2% slope), OeA (Orangeburg loamy sand, 0-2% slopes), OeB (Orangeburg loamy sand, 2-5% slopes), OeC (Orangeburg loamy sand, 5-8% slope), OeD (Orangeburg loamy sand, 8-12% slope, OsA (Oiser and Bibb soils, frequently flooded), PeA (Pelham loamy fine sand, frequently flooded), TfA (Tifton loamy sand, 0-2% slope), TfB (Tifton loamy sand, 2-5% slope), TrB (Troup loamy sand, 2-5% slope), W (Water)

Appendix E

Table E1. Monthly rainfall totals

Month	Rainfall (Inches)	Cumulative Total (Inches)
Oct 22-31, 2012	0.00	0.00
Nov-12	0.63	0.63
Dec-12	6.18	6.81
Jan-13	1.60	8.41
Feb-13	14.64	23.05
Mar-13	5.65	28.70
Apr-13	3.84	32.54
May-13	0.83	33.37
Jun-13	9.65	43.02
Jul-13	12.92	55.94
Aug-13	7.23	63.17
Sep-13	2.32	65.49
Oct-13	0.60	66.09
Nov-13	5.67	71.76
Dec-13	4.41	76.17

Table E2. Sapp Creek monthly discharge volume

Date	Total Volume Ft^3	Total Volume Acre Feet
Oct 22-31, 2012	774,073.29	17.77
Nov-12	3,077,450.25	70.65
Dec-12	7,219,712.22	165.74
Jan-13	4,611,374.30	105.86
Feb-13	45,753,376.63	1,050.35
Mar-13	23,857,585.38	547.69
Apr-13	13,592,801.95	312.05
May-13	2,192,306.29	50.33
Jun-13	2,866,363.88	65.80
Jul-13	36,113,691.13	829.06
Aug-13	29,685,470.53	681.48
Sep-13	7,362,949.68	169.03
Oct-13	1,246,340.28	28.61
Nov-13	7,153,749.31	164.23
Dec-13	12,477,964.68	286.45
Total	197,985,209.80	4,545.12

Table E3. Sapp Creek data for all samples

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	2.10	0.14	86.00	0.47	**0.29**	0.05	2.00
11/20/12	2.50	0.08	**4000.00**	0.61	0.46	0.08	2.00
12/24/12	1.70	0.07	134.00	0.59	0.42	0.08	4.40
1/21/13	2.40	0.11	129.00	0.58	0.44	0.05	2.80
1/31/13	2.70	0.12	**1380.00**	0.54	0.48	0.07	4.00
2/22/13	3.80	0.29	**2900.00**	0.52	0.46	**0.22**	**120.00**
3/21/13	1.80	0.05	210.00	0.66	0.44	0.10	5.60
4/22/13	2.10	0.06	**550.00**	0.41	**0.28**	0.08	5.60
5/23/13	1.90	0.17	**500.00**	0.59	0.38	0.07	2.30
6/6/13	4.50	**1.00**		0.80	0.68	**0.23**	**56.00**
6/24/13	**5.60**	0.18	116.00	**1.00**	**0.93**	0.12	9.00
7/23/13	1.70	0.07	127.00	0.64	0.64	0.09	9.80
8/19/13	1.80	0.05	106.00	**0.90**	0.36	0.07	15.00
9/24/13	2.60	0.15	44.00	0.52	0.52	0.05	2.30
10/22/13	2.50	0.22	94.00	0.58	**0.31**	0.04	10.00
11/26/13	3.10	0.30	**9420.00**	**0.30**	**0.26**	0.07	**26.00**
Minimum	1.70	0.05	44.00	0.30	0.26	0.04	2.00
Maximum	5.60	1.00	9420.00	1.00	0.93	0.23	120.00
Average	2.68	0.19	1319.73	0.61	0.46	0.09	17.30
Median	2.45	0.13	134.00	0.59	0.44	0.08	5.60
Variance	1.21	0.05	6401110.35	0.03	0.03	0.00	936.66
Standard Deviation	1.10	0.23	2530.04	0.17	0.17	0.06	30.60

Table E3 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
10/22/12	0.19	0.000	6.96	89.50	16.00	60.80	4.17
11/20/12	0.15	0.000	6.63	91.30	14.42	57.96	8.04
12/24/12	0.17	0.000	6.54	72.40	9.85	49.73	10.23
1/21/13	0.13	**0.010**	7.01	74.10	11.90	53.42	8.90
1/31/13	0.06	0.000	7.02	69.00	13.18	55.72	9.60
2/22/13	0.06	0.000	6.65	57.90	13.59	56.46	9.00
3/21/13	0.22	0.000	6.87	62.10	13.88	56.98	9.03
4/22/13	0.14	0.000	6.76	56.40	18.76	65.77	7.91
5/23/13	0.20	**0.010**	7.00	93.10	21.56	70.81	5.85
6/6/13	0.12	0.000					
6/24/13	0.11	0.000	6.32	111.20	24.96	76.93	5.61
7/23/13	0.02	0.000	7.05	63.70	26.03	78.85	
8/19/13	**0.54**	0.000	6.28	61.70	25.99	78.78	6.45
9/24/13	0.02	0.000	6.73	78.90	24.22	75.60	6.11
10/22/13	0.27	0.000	6.73	101.90	20.04	68.07	6.85
11/26/13	0.02	0.000	6.75	76.30	14.46	58.03	8.23
Minimum	0.02	0.00	6.28	56.40	9.85	49.73	4.17
Maximum	0.54	0.01	7.05	111.20	26.03	78.85	10.23
Average	0.15	0.00	6.75	77.30	17.92	64.26	7.57
Median	0.14	0.00	6.75	74.10	16.00	60.80	7.98
Variance	0.02	0.00	0.06	280.58	30.39	98.46	3.09
Standard Deviation	0.13	0.00	0.24	16.75	5.51	9.92	1.76

Table E3 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	4.80	**60.00**	35.00	67.00	0.32	Partly Cloudy	10:30 a.m.
11/20/12	5.20	40.00	40.00	67.00	0.40	Sunny	12:30 p.m.
12/24/12	6.01	40.00	20.00	60.00	0.48	Cloudy	1:30 p.m.
1/21/13	7.61	40.00	25.00	60.00	0.45	Sunny	1:45 p.m.
1/31/13	9.60	40.00	25.00	44.00	0.63	Sunny	10:15 a.m.
2/22/13	**58.70**	40.00	20.00	64.00	1.10	Rain	1:30 p.m.
3/21/13	13.70	**60.00**	20.00	54.00	0.75	Sunny	11:50 a.m.
4/22/13	13.80	40.00	20.00	66.00	**2.91**	Cloudy	12:00 p.m.
5/23/13	6.02	40.00	40.00	80.00	0.17	Partly Cloudy	10:00 a.m.
6/6/13					0.70	Rain	8:00 p.m.
6/24/13	**19.90**	40.00	30.00	83.00	0.45	Sunny	11:20 a.m.
7/23/13	7.80	40.00	25.00	84.00	1.12	Partly Cloudy	12:30 p.m.
8/19/13	14.60	40.00	25.00	88.00	**1.75**	Partly Cloudy	1:30 p.m.
9/24/13	7.90	40.00	35.00	81.00	0.42	Cloudy	2:40 P.M.
10/22/13	7.70	**60.00**	30.00	67.00	0.25	Cloudy	9:00 a.m.
11/26/13	**27.10**	40.00	30.00	68.00	1.20	Rain	1:15 a.m.
Minimum	4.80	40.00	20.00	44.00	0.17		
Maximum	58.70	60.00	40.00	88.00	2.91		
Average	14.03	44.00	28.00	68.87	0.82		
Median	7.90	40.00	25.00	67.00	0.56		
Variance	190.72	68.57	49.29	150.41	0.49		
Standard Deviation	13.81	8.28	7.02	12.26	0.70		

**Minimum Detection Limits:* Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E4. Sapp Creek difference between including storms and not including storms in correlation matrix

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.08	1.00																	
FC	0.22	**0.76**	1.00																
TN	-0.17	0.14	**-0.41**	1.00															
TKN	-0.08	0.13	-0.24	0.05	1.00														
TP	0.17	**1.05**	0.02	-0.25	-0.20	1.00													
TSS	**0.35**	**0.63**	**0.63**	**-0.66**	-0.08	**0.63**	1.00												
TON	-0.09	-0.02	-0.27	0.07	0.13	-0.06	**-0.76**	1.00											
NH4	-0.10	-0.32	-0.09	0.08	0.01	0.02	0.11	0.09	1.00										
pH	0.04	-0.08	0.06	0.11	0.04	0.08	0.34	0.02	-0.03	1.00									
SC	-0.22	**-0.55**	-0.22	0.03	-0.04	-0.26	-0.18	0.13	0.06	0.01	1.00								
WT(M)	-0.17	-0.33	-0.07	0.06	-0.01	-0.22	**-0.75**	0.15	0.09	-0.02	0.11	1.00							
WT(E)	-0.17	-0.33	-0.07	0.06	-0.01	-0.22	**-0.75**	0.15	0.09	-0.02	0.11	0.00	1.00						
DO	0.18	**0.45**	0.07	-0.10	0.02	0.08	0.32	-0.18	-0.09	0.10	-0.07	-0.05	-0.05	1.00					
Turb	-0.06	**0.75**	**0.69**	**-0.76**	**-0.43**	0.22	**0.37**	**-0.44**	-0.01	0.30	-0.26	**-0.55**	**-0.55**	0.30	1.00				
Hd	-0.07	-0.26	-0.04	0.14	0.06	0.00	-0.15	0.08	0.06	-0.05	0.06	0.13	0.13	-0.09	-0.09	1.00			
Alk	-0.14	**-0.37**	-0.31	0.04	-0.04	-0.11	0.07	0.10	0.04	-0.02	0.04	0.06	0.06	-0.02	0.04	0.06	1.00		
AT	-0.16	-0.18	0.00	-0.05	-0.11	-0.09	**-0.53**	0.14	0.06	-0.08	0.09	-0.05	-0.05	-0.05	-0.30	0.21	0.03	1.00	
Stage	0.07	**0.48**	0.20	-0.07	-0.03	-0.10	-0.24	-0.07	-0.02	-0.02	0.03	-0.06	-0.06	0.01	-0.18	-0.01	0.03	0.00	1.00

Table E5. Black Creek monthly discharge volume

Date	Total Volume	
	Ft^3	Acre Feet
Oct 22-31, 2012	9,790.51	0.22
Nov-12	36,420.41	0.84
Dec-12	361,364.87	8.30
Jan-13	717,922.80	16.48
Feb-13	27,305,299.17	626.84
Mar-13	6,130,258.43	140.73
Apr-13	3,237,514.47	74.32
May-13	584,547.10	13.42
Jun-13	8,006,531.95	183.80
Jul-13	41,034,119.84	942.01
Aug-13	51,587,424.80	1,184.28
Sep-13	1,027,016.79	23.58
Oct-13	255,991.55	5.88
Nov-13	1,867,858.07	42.88
Dec-13	6,801,011.26	156.13
Total	148,963,072.03	3,419.72

Table E6. Black Creek data for all sample events

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	4.30	0.41	490.00	**0.64**	0.07	0.05	2.40
11/20/12	3.60	0.51	200.00	1.20	0.48	0.07	4.50
12/24/12	3.80	0.13	200.00	0.67	0.25	0.05	2.40
1/21/13	5.30	0.15	96.00	1.00	0.69	0.06	3.60
1/31/13	5.50	0.15	618.00	1.10	0.92	0.06	6.90
2/22/13	4.90	0.44	**3000.00**	1.30	**1.20**	0.09	**49.00**
3/21/13	3.00	0.06	131.00	0.98	0.66	**0.13**	12.00
4/22/13	3.80	0.08	240.00	0.78	0.52	**0.14**	10.00
5/23/13	3.90	**1.20**	34.00	1.30	0.70	0.05	4.40
6/24/13	**2.20**	0.20	68.00	1.10	0.76	**0.24**	8.50
7/23/13	4.30	0.13	310.00	1.10	0.87	0.06	4.60
8/19/13	2.70	0.06	80.00	1.00	0.80	0.08	5.20
9/24/13	4.60	0.33	350.00	0.91	0.62	0.06	4.60
10/22/13	4.40	0.34	80.00	1.10	0.56	0.04	2.00
11/26/13	4.50	0.30	**4900.00**	**0.40**	**0.12**	0.05	**17.00**
Minimum	2.20	0.06	34.00	0.40	0.07	0.04	2.00
Maximum	5.50	1.20	4900.00	1.30	1.20	0.24	49.00
Average	4.05	0.30	719.80	0.97	0.61	0.08	9.14
Median	4.30	0.20	200.00	1.00	0.66	0.06	4.60
Variance	0.85	0.08	1875821.46	0.06	0.09	0.00	138.44
Standard Deviation	0.92	0.29	1369.61	0.25	0.30	0.05	11.77

Table E6 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
10/22/12	**0.64**	0.00	**6.03**	85.30	16.20	61.16	3.07
11/20/12	**0.75**	0.00	**6.01**	74.30	15.05	59.09	3.81
12/24/12	0.42	0.00	6.40	78.20	10.85	51.53	7.40
1/21/13	0.31	0.00	6.36	76.20	12.31	54.16	6.24
1/31/13	0.15	**0.03**	**6.92**	70.30	13.45	56.21	6.40
2/22/13	0.12	0.00	6.33	61.50	13.41	56.14	7.86
3/21/13	0.32	0.00	6.37	62.60	12.79	55.02	8.51
4/22/13	0.26	0.00	6.45	66.20	17.93	64.27	6.97
5/23/13	0.56	**0.04**	6.17	91.70	19.79	67.62	1.52
6/24/13	0.29	**0.05**	**5.91**	63.40	23.81	74.86	3.74
7/23/13	0.22	**0.01**	6.41	73.30	24.14	75.45	
8/19/13	0.24	0.00	**6.01**	64.70	24.41	75.94	6.20
9/24/13	0.30	0.00	6.30	81.70	23.54	74.37	4.72
10/22/13	0.56	0.00	6.25	84.70	19.86	67.75	2.54
11/26/13	0.30	**0.01**	6.38	82.80	15.16	59.29	7.48
Minimum	0.12	0.00	5.91	61.50	10.85	51.53	1.52
Maximum	0.75	0.05	6.92	91.70	24.41	75.94	8.51
Average	0.36	0.01	6.29	74.46	17.51	63.52	5.46
Median	0.30	0.00	6.33	74.30	16.20	61.16	6.22
Variance	0.03	0.00	0.06	90.83	22.77	73.77	4.86
Standard Deviation	0.18	0.02	0.25	9.53	4.77	8.59	2.21

Table E6 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	7.89	**80.00**	25.00	65.00	1.05	Partly Cloudy	12:09 p.m.
11/20/12	7.76	**80.00**	30.00	61.00	1.05	Sunny	9:45 a.m.
12/24/12	8.03	40.00	20.00	62.00	1.25	Cloudy	11:30 a.m.
1/21/13	7.75	60.00	20.00	57.00	1.88	Sunny	11:55 a.m.
1/31/13	9.92	60.00	20.00	45.00	1.93	Sunny	11:30 a.m.
2/22/13	**46.10**	60.00	15.00	64.00	3.88	Rain	1:10 p.m.
3/21/13	**18.90**	60.00	15.00	49.00	2.39	Sunny	10:00 a.m.
4/22/13	14.70	40.00	15.00	63.00	2.13	Cloudy	10:45 a.m.
5/23/13	7.01	50.00	30.00	80.00	1.50	Partly Cloudy	10:35 a.m..
6/24/13	13.50	40.00	20.00	82.00	1.86	Sunny	10:45 a.m.
7/23/13	9.68	40.00	20.00	80.00	2.19	Partly Cloudy	11:10 a.m.
8/19/13	12.40	40.00	20.00	86.00	3.32	Partly Cloudy	12:10 p.m.
9/24/13	9.20	40.00	30.00	78.00	1.79	Cloudy	1:15 p.m.
10/22/13	11.00	40.00	25.00	69.00	1.48	Drizzle	12:09 p.m.
11/26/13	**19.80**	30.00	25.00	67.00	2.62	Rain	12:45 p.m.
Minimum	7.01	30.00	15.00	45.00	1.05		
Maximum	46.10	80.00	30.00	86.00	3.88		
Average	13.58	50.67	22.00	67.20	2.02		
Median	9.92	40.00	20.00	65.00	1.88		
Variance	96.85	235.24	27.86	146.17	0.63		
Standard Deviation	9.84	15.34	5.28	12.09	0.79		

**Minimum Detection Limits:* Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E7. Black Creek difference between including storms and not including storms in correlation matrix

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	-0.05	1.00																	
FC	-0.05	0.19	1.00																
TN	0.12	-0.13	0.23	1.00															
TKN	0.31	0.05	**0.43**	0.11	1.00														
TP	0.07	0.03	0.08	0.10	-0.02	1.00													
TSS	**0.75**	**0.37**	**0.86**	0.14	0.11	**-0.59**	1.00												
TON	-0.32	-0.10	**-0.41**	-0.16	0.01	0.11	-0.01	1.00											
NH4	0.22	-0.11	0.34	-0.19	-0.13	-0.09	-0.28	-0.05	1.00										
pH	0.14	0.01	0.07	0.18	0.17	0.00	-0.01	-0.12	**0.39**	1.00									
SC	-0.29	-0.12	-0.19	-0.30	-0.18	0.05	0.29	0.01	0.01	-0.10	1.00								
WT(M)	-0.15	0.00	-0.26	-0.15	**-0.36**	0.02	-0.29	0.28	-0.11	-0.09	0.11	1.00							
WT(E)	-0.15	0.00	-0.26	-0.15	**-0.36**	0.02	-0.29	0.28	-0.11	-0.09	0.11	0.00	1.00						
DO	0.25	0.11	**0.41**	0.15	0.09	-0.09	-0.03	-0.06	0.09	-0.06	0.06	-0.08	-0.08	1.00					
Turb	**0.69**	**0.49**	**0.85**	0.23	0.15	**-0.45**	0.11	0.00	-0.13	-0.05	0.26	-0.30	-0.30	-0.04	1.00				
Hd	0.02	-0.03	**-0.53**	0.31	**0.48**	0.08	0.16	-0.23	0.06	0.21	-0.20	0.06	0.06	0.00	0.24	1.00			
Alk	-0.20	-0.11	-0.19	**-0.36**	-0.23	0.02	0.15	0.01	-0.01	0.06	0.04	0.07	0.07	0.04	0.20	-0.18	1.00		
AT	-0.19	0.02	0.01	-0.22	**-0.38**	0.04	0.08	0.28	-0.27	-0.20	0.07	-0.04	-0.04	0.02	0.10	0.03	0.02	1.00	
Stage	**0.38**	0.23	**0.82**	0.03	-0.10	-0.10	0.27	0.02	-0.07	0.04	0.04	-0.35	**-0.35**	0.10	0.20	0.19	-0.02	-0.19	

Table E8. Buss Creek monthly discharge volume

	Total Volume	
Date	Ft^3	Acre Feet
Oct 22-31, 2012	351,870.117	8.078
Nov-12	1,213,985.552	27.869
Dec-12	2,895,977.240	66.482
Jan-13	2,871,801.315	65.927
Feb-13	63,403,619.454	1,455.547
Mar-13	15,639,530.502	359.034
Apr-13	7,114,658.929	163.330
May-13	1,752,949.487	40.242
Jun-13	4,019,114.137	92.266
Jul-13	19,977,572.370	458.622
Aug-13	25,913,269.503	594.887
Sep-13	4,858,813.546	111.543
Oct-13	1,294,542.450	29.719
Nov-13	14,720,722.988	337.941
Dec-13	16,549,024.133	379.913
Total	182,577,451.722	4,191.402

Table E9. Buss Creek monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	0.78	0.12	270.00	**11.00**	**1.80**	0.10	2.00
11/20/12	0.79	0.09	600.00	**20.00**	**3.90**	0.18	6.00
12/24/12	2.10	0.16	**1470.00**	2.10	0.35	0.12	5.50
1/21/13	3.40	0.16	520.00	2.60	0.75	0.13	4.80
1/31/13	3.70	0.19	**3900.00**	1.40	0.81	0.12	13.00
2/22/13	**7.10**	0.12	**5500.00**	1.10	0.23	**0.51**	**140.00**
3/21/13	2.40	0.06	645.00	1.40	0.71	0.14	2.00
4/22/13	3.30	0.08	230.00	1.20	0.48	0.14	7.60
5/23/13	0.63	0.16	530.00	**9.60**	1.40	0.16	3.40
6/6/13	4.80	**0.28**		4.70	**2.40**	**0.64**	**840.00**
6/24/13	2.70	0.14	250.00	1.80	0.92	0.20	15.00
6/24/13	**16.00**	**0.25**		4.60	**1.80**	**1.35**	**36.00**
7/23/13	3.20	0.11	270.00	1.30	0.82	0.12	10.00
8/19/13	2.10	0.05	181.00	0.95	0.61	0.09	10.00
9/24/13	2.90	0.11	350.00	1.40	0.68	0.09	4.80
10/22/13	2.60	0.16	420.00	2.40	0.61	0.13	3.40
11/26/13	5.30	0.20	770.00	2.20	0.34	0.25	**92.00**
Minimum	0.63	0.05	181.00	0.95	0.23	0.09	2.00
Maximum	16.00	0.28	5500.00	20.00	3.90	1.35	840.00
Average	3.75	0.14	1060.40	4.10	1.09	0.26	70.32
Median	2.90	0.14	520.00	2.10	0.75	0.14	7.60
Variance	12.70	0.00	2376233.11	25.40	0.88	0.10	40730.21
Standard Deviation	3.56	0.06	1541.50	5.04	0.94	0.32	201.82

Table E9 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
10/22/12	**9.20**	0.00	6.30	**247.90**	15.30	59.54	3.81
11/20/12	**16.00**	**0.10**	6.77	**310.00**	14.04	57.27	5.68
12/24/12	1.70	**0.05**	6.73	129.70	9.91	49.84	8.16
1/21/13	1.80	**0.05**	6.87	125.00	12.51	54.52	7.96
1/31/13	0.62	0.00	7.05	94.80	13.16	55.69	7.66
2/22/13	0.89	0.00	**7.35**	86.10	15.67	60.21	8.55
3/21/13	0.65	**0.04**	6.63	78.40	13.47	56.25	8.28
4/22/13	0.69	**0.03**	6.97	82.10	17.76	63.97	6.58
5/23/13	**8.20**	0.00	6.75	51.70	25.86	78.55	5.72
6/6/13	2.30	0.00					
6/24/13	0.92	0.00	6.50	113.50	24.98	76.96	4.50
6/24/13	2.80	0.00					
7/23/13	0.44	**0.04**	6.58	86.80	24.58	76.24	
8/19/13	0.34	0.00	6.12	67.20	25.18	77.32	5.88
9/24/13	0.70	**0.02**	6.74	90.40	23.86	74.95	4.86
10/22/13	1.80	0.00	6.80	147.30	19.92	67.86	4.96
11/26/13	1.90	0.00	6.62	118.50	15.40	59.72	7.54
Minimum	0.34	0.00	6.12	51.70	9.91	49.84	3.81
Maximum	16.00	0.10	7.35	310.00	25.86	78.55	8.55
Average	3.00	0.02	6.72	121.96	18.11	64.59	6.44
Median	1.70	0.00	6.74	94.80	15.67	60.21	6.23
Variance	17.81	0.00	0.09	4835.14	29.85	96.71	2.51
Standard Deviation	4.22	0.03	0.30	69.54	5.46	9.83	1.58

Table E9 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	5.83	60.00	**100.00**	66.00	1.55	Partly Cloudy	11:40 a.m.
11/20/12	3.68	**140.00**	60.00	62.00	1.51	Sunny	10:15 a.m.
12/24/12	9.97	120.00	40.00	60.00	1.65	Cloudy	12:45 p.m.
1/21/13	8.40	80.00	30.00	59.00	1.85	Sunny	1:03 p.m.
1/31/13	11.80	80.00	25.00	44.00	2.23	Sunny	12:30 p.m.
2/22/13	**163.00**	60.00	30.00	64.00	2.50	Rain	2:20 p.m.
3/21/13	13.70	60.00	15.00	52.00	2.53	Sunny	10:35 a.m.
4/22/13	15.00	60.00	25.00	65.00	2.11	Cloudy	11:45 a.m.
5/23/13	5.94	100.00	55.00	83.00	1.53	Partly Cloudy	12:30 p.m.
6/6/13					1.99	Rain	3:30 P.M.
6/24/13	20.10	60.00	40.00	88.00	1.87	Sunny	12:30 p.m.
6/24/13					3.09	Rain	5:15 p.m.
7/23/13	6.95	60.00	25.00	81.00	2.20	Cloudy	11:30 A.M.
8/19/13	11.80	40.00	20.00	86.00	3.13	Partly Cloudy	1:00 p.m.
9/24/13	9.50	60.00	30.00	79.00	1.97	Cloudy	2:10 P.M.
10/22/13	5.50	80.00	45.00	69.00	1.65	Cloudy	11:40 a.m.
11/26/13	**63.00**	60.00	50.00	65.00	3.14	Rain	11:00 a.m.
Minimum	3.68	40.00	15.00	44.00	1.51		
Maximum	163.00	140.00	100.00	88.00	3.14		
Average	23.61	74.67	39.33	68.20	2.15		
Median	9.97	60.00	30.00	65.00	1.99		
Variance	1692.31	712.38	453.10	163.60	0.31		
Standard Deviation	41.14	26.69	21.29	12.79	0.56		

**Minimum Detection Limits:* Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E10. Buss Creek difference between including storms and not including storms in correlation matrix

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.57	1.00																	
FC	**0.83**	-0.10	1.00																
TN	**0.57**	-0.06	-0.26	1.00															
TKN	**0.66**	0.29	-0.19	-0.08	1.00														
TP	**1.07**	**0.39**	**0.63**	-0.32	-0.13	1.00													
TSS	-0.20	**0.70**	**1.00**	0.28	**0.43**	0.02	1.00												
TON	**0.55**	-0.13	-0.27	0.00	-0.12	**-0.36**	0.24	1.00											
NH4	-0.29	-0.23	**-0.66**	0.02	-0.13	**-0.53**	-0.13	0.04	1.00										
pH	0.28	-0.07	0.41	-0.15	-0.15	0.26	**0.73**	-0.14	-0.34	1.00									
SC	0.11	-0.07	-0.27	0.01	-0.01	-0.27	0.06	0.01	0.02	-0.12	1.00								
WT(M)	-0.24	-0.15	0.27	0.09	0.10	-0.14	**-0.65**	0.09	0.20	-0.06	0.09	1.00							
WT(E)	-0.24	-0.15	0.27	0.09	0.10	-0.14	**-0.65**	0.09	0.20	-0.06	0.09	0.00	1.00						
DO	0.24	0.22	-0.06	-0.08	-0.10	**0.41**	**0.65**	-0.07	-0.29	0.16	-0.05	-0.03	-0.03	1.00					
Turb	0.34	**0.35**	**0.90**	**0.36**	0.17	**0.68**	**0.36**	**0.39**	-0.02	**0.65**	0.29	-0.32	-0.32	0.31	1.00				
Hd	0.07	-0.15	**-0.65**	0.00	0.02	**-0.50**	0.03	-0.01	-0.01	-0.21	0.00	0.07	0.07	-0.14	0.25	1.00			
Alk	0.30	-0.10	-0.20	-0.01	-0.03	-0.11	0.27	-0.01	0.05	-0.08	0.00	0.06	0.06	0.03	**0.37**	-0.03	1.00		
AT	-0.21	-0.27	0.05	0.14	0.11	-0.10	**-0.73**	0.14	0.30	-0.07	0.15	-0.03	-0.03	-0.01	-0.29	0.08	0.11	1.00	
Stage	0.23	**0.81**	**0.54**	0.08	0.09	**0.82**	-0.31	0.08	-0.18	**0.36**	0.06	-0.22	-0.22	0.17	-0.03	0.04	0.18	-0.22	1.00

Table E11. Nursery Creek monthly discharge volume

Date	Total Volume Ft^3	Total Volume Acre Feet
Oct 22-31, 2012	360,223.70	8.27
Nov-12	1,179,639.51	27.08
Dec-12	2,666,824.40	61.22
Jan-13	2,618,548.90	60.11
Feb-13	5,128,599.35	117.74
Mar-13	6,934,671.50	159.20
Apr-13	3,855,588.67	88.51
May-13	844,532.10	19.39
Jun-13	1,977,765.31	45.40
Jul-13	2,109,314.24	48.42
Aug-13	390,069.32	8.95
Sep-13	188,617.24	4.33
Oct-13	112,305.80	2.58
Nov-13	909,414.38	20.88
Dec-13	1,208,015.24	27.73
Total	30,484,129.65	699.82

Table E12. Nursery Creek monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	0.21	0.02	580.00	**18.00**	0.83	0.05	9.60
11/20/12	0.73	0.01	1040.00	2.70	0.51	0.12	32.00
12/24/12	0.50	0.01	927.00	1.10	**0.09**	0.07	32.00
1/21/13	0.16	0.004	72.00	2.00	**0.18**	0.03	2.00
1/31/13	1.00	**0.04**	155.00	4.30	2.00	0.33	25.00
2/22/13	**7.80**	**0.05**	330.00	2.20	1.30	**0.62**	**660.00**
3/21/13	0.24	0.003	60.00	1.40	**0.16**	0.07	9.70
4/22/13	0.29	0.01	700.00	3.60	**0.10**	0.11	15.00
5/23/13	0.07	0.004	34.00	2.90	**0.07**	0.03	2.00
6/6/13	**8.10**	**0.06**		4.40	0.47	0.25	**430.00**
6/24/13	0.99	0.01	645.00	3.10	1.20	0.28	39.00
7/23/13	0.24	0.01	560.00	2.90	**0.13**	0.07	8.00
8/19/13	0.50	0.02	250.00	4.00	0.94	0.21	10.00
9/24/13	0.26	0.01	918.00	3.80	0.60	0.11	7.60
10/22/13	0.48	0.01	94.00	3.40	0.35	0.08	6.20
11/26/13	**6.40**	**0.04**	**16900.00**	2.20	0.41	**0.40**	**750.00**
Minimum	0.07	0.003	34.00	1.10	0.07	0.03	2.00
Maximum	8.10	0.06	16900.00	18.00	2.00	0.62	750.00
Average	1.75	0.02	1551.00	3.88	0.58	0.18	127.38
Median	0.49	0.01	560.00	3.00	0.44	0.11	12.50
Variance	8.14	0.00	18148561.71	15.14	0.30	0.03	61883.85
Standard Deviation	2.85	0.02	4260.11	3.89	0.55	0.16	248.76

Table E12 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(℃)	WT(℉)	DO (mg/L)
10/22/12	**17.00**	**0.17**	7.70	340.60	16.60	61.88	4.68
11/20/12	2.20	0.00	7.94	260.70	19.16	66.49	9.34
12/24/12	1.00	0.01	7.81	262.90	19.50	67.10	9.52
1/21/13	1.90	0.00	8.05	260.00	19.69	67.44	9.29
1/31/13	2.40	0.00	8.09	214.90	14.72	58.50	10.34
2/22/13	0.90	0.00	7.93	164.00	14.76	58.57	10.19
3/21/13	1.40	0.00	8.09	263.40	17.40	63.32	9.40
4/22/13	3.50	0.00	7.85	215.60	18.64	65.55	8.99
5/23/13	2.80	0.03	7.30	278.50	22.50	72.50	7.29
6/6/13	3.90	0.03					
6/24/13	1.80	**0.10**	7.17	216.40	25.62	78.12	6.98
7/23/13	2.70	**0.07**	7.10	274.50	22.74	72.93	
8/19/13	3.00	**0.06**	6.83	153.30	26.32	79.38	6.75
9/24/13	3.20	0.00	7.38	260.20	22.97	73.35	7.24
10/22/13	3.00	**0.05**	7.52	289.60	20.64	69.15	7.75
11/26/13	1.80	0.00	7.48	152.30	15.40	59.72	7.54
Minimum	0.90	0.00	6.83	152.30	14.72	58.50	4.68
Maximum	17.00	0.17	8.09	340.60	26.32	79.38	10.34
Average	3.28	0.03	7.62	240.46	19.78	67.60	8.24
Median	2.55	0.01	7.70	260.20	19.50	67.10	8.37
Variance	14.13	0.00	0.16	2880.35	13.68	44.31	2.55
Standard Deviation	3.76	0.05	0.40	53.67	3.70	6.66	1.60

Table E12 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	9.36	180.00	**195.00**	66.00	0.31	Partly Cloudy	11:15 a.m.
11/20/12	10.80	160.00	140.00	62.00	0.47	Sunny	10:45 a.m.
12/24/12	23.60	140.00	120.00	60.00	0.87	Drizzle	12:15 p.m.
1/21/13	6.78	160.00	140.00	59.00	0.74	Sunny	12:40 p.m.
1/31/13	**41.00**	120.00	85.00	44.00	0.61	Sunny	12:00 p.m.
2/22/13	**240.00**	100.00	80.00	64.00	**1.78**	Rain	2:00 p.m.
3/21/13	10.80	160.00	125.00	53.00	0.77	Sunny	11:15 a.m.
4/22/13	15.70	180.00	120.00	65.00	0.54	Cloudy	11:30 a.m.
5/23/13	5.12	160.00	120.00	85.00	0.41	Partly Cloudy	12:50 P.M.
6/6/13					1.05	Rain	5:45 p.m.
6/24/13	**40.10**	120.00	100.00	85.00	0.56	Sunny	12:00 p.m.
7/23/13	11.40	160.00	130.00	81.00	0.32	Partly Cloudy	12:00 p.m.
8/19/13	18.00	**80.00**	60.00	86.00	0.20	Partly Cloudy	12:40 p.m.
9/24/13	9.10	160.00	125.00	79.00	0.13	Cloudy	1:50 p.m.
10/22/13	8.60	160.00	120.00	68.00	0.26	Drizzle	9:30 a.m.
11/26/13	**251.00**	**80.00**	80.00	65.00	1.10	Rain	12:00 p.m.
Minimum	5.12	80.00	60.00	44.00	0.13		
Maximum	251.00	180.00	195.00	86.00	1.78		
Average	46.76	141.33	116.00	68.13	0.63		
Median	11.40	160.00	120.00	65.00	0.55		
Variance	6635.97	1112.38	1054.29	157.98	0.18		
Standard Deviation	81.46	33.35	32.47	12.57	0.42		

**Minimum Detection Limits:* Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E13. Nursery Creek difference between including storms and not including storms in correlation matrix

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	**0.58**	1.00																	
FC	0.15	0.17	1.00																
TN	0.06	**-0.60**	-0.19	1.00															
TKN	**-0.41**	-0.16	-0.30	-0.19	1.00														
TP	-0.05	**0.39**	0.09	-0.03	-0.13	1.00													
TSS	0.08	**0.64**	0.06	0.01	-0.22	0.19	1.00												
TON	0.10	**-0.63**	-0.16	-0.01	-0.25	-0.05	0.03	1.00											
NH4	**-0.37**	**-0.79**	-0.16	-0.02	**-0.46**	**-0.42**	-0.31	0.00	1.00										
pH	0.31	**0.51**	-0.16	-0.01	**0.54**	**0.58**	0.02	-0.06	-0.04	1.00									
SC	-0.25	**-0.52**	**-0.44**	-0.03	-0.09	-0.07	**-0.39**	0.00	0.13	-0.24	1.00								
WT(M)	**-0.89**	**-0.69**	-0.27	0.17	**-0.68**	**-1.06**	**-0.62**	0.25	0.20	0.09	**0.69**	1.00							
WT(E)	**-0.89**	**-0.69**	-0.27	0.17	**-0.68**	**-1.06**	**-0.62**	0.25	0.20	0.09	**0.69**	0.00	1.00						
DO	0.19	**0.87**	-0.20	0.11	**0.75**	**0.49**	-0.05	0.05	0.05	0.07	-0.09	-0.17	-0.17	1.00					
Turb	0.19	**0.64**	0.34	-0.02	-0.27	0.05	0.20	-0.01	**-0.52**	**0.38**	-0.19	**-0.96**	**-0.96**	0.23	1.00				
Hd	-0.15	**-0.46**	**-0.58**	0.02	0.04	-0.06	**-0.36**	0.04	0.25	-0.32	0.10	**0.78**	**0.78**	-0.21	-0.14	1.00			
Alk	-0.13	**-0.58**	**-0.46**	-0.04	-0.22	-0.06	-0.31	-0.01	0.12	-0.28	0.02	**0.66**	**0.66**	-0.14	-0.08	0.04	1.00		
AT	-0.30	**-0.55**	-0.03	0.01	**-0.65**	**-0.62**	-0.07	0.08	0.07	0.03	0.32	-0.04	-0.04	-0.06	**-0.41**	**0.40**	**0.37**	1.00	
Stage	**0.73**	**1.21**	**0.35**	0.08	**0.57**	**0.91**	**0.44**	0.02	-0.04	-0.19	**-0.51**	-0.19	-0.19	-0.13	**0.54**	**-0.56**	**-0.44**	0.23	1.00

Table E14. Tired Creek monthly discharge volume

Date	Total Volume Ft^3	Acre Feet
Oct 22-31, 2012	-	-
Nov-12	-	-
Dec-12	70,988,990.43	1629.68
Jan-13	18,262,112.58	419.24
Feb-13	275,494,321.13	6324.48
Mar-13	150,104,934.68	3445.94
Apr-13	98,941,161.35	2271.38
May-13	18,009,395.22	413.44
Jun-13	18,816,313.10	431.96
Jul-13	304,026,937.40	6979.50
Aug-13	209,716,379.74	4814.43
Sep-13	29,555,494.37	678.50
Oct-13	3,385,198.10	77.71
Nov-13	30,466,901.27	699.42
Dec-13	60,994,614.42	1400.24
Total	1,288,762,753.8	29,585.92

Table E15. Tired Creek monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	**1.00**	0.04	460.00	**3.60**	0.34	0.08	5.60
11/20/12	**1.00**	0.04	234.00	**4.40**	0.78	0.12	4.70
12/24/12	2.20	0.05	220.00	0.82	0.22	0.12	12.00
1/21/13	2.90	0.07	290.00	1.30	0.49	0.11	7.20
1/31/13	3.70	**0.12**	**3300.00**	1.20	0.75	0.18	2.00
2/22/13	**5.40**	**0.24**	**2280.00**	1.20	0.95	**0.38**	**130.00**
3/21/13	2.40	0.05	340.00	1.10	0.69	0.21	20.00
4/22/13	3.00	0.06	290.00	1.00	0.66	0.15	20.00
5/23/13	**1.30**	0.06	**800.00**	**4.10**	0.61	0.09	6.80
6/6/13	1.80	**0.19**		**4.10**	**3.00**	**0.73**	**60.00**
6/24/13	2.40	0.05	310.00	2.20	1.00	0.19	29.00
6/24/13	2.70	**0.25**		**2.70**	**2.40**	**0.68**	**220.00**
7/23/13	2.80	0.08	330.00	0.97	0.74	0.11	11.00
8/19/13	2.90	0.06	440.00	0.81	0.60	0.10	14.00
9/24/13	2.60	0.08	**809.00**	0.99	0.57	0.09	9.40
10/22/13	2.20	0.05	350.00	1.40	0.46	0.07	5.60
11/25/13	2.50	0.06		0.80	0.30	0.06	3.50
11/26/13	**9.30**	**0.17**	**3500.00**	0.70	0.19	0.13	**220.00**
Minimum	1.00	0.04	220.00	0.70	0.19	0.06	2.00
Maximum	9.30	0.25	3500.00	4.40	3.00	0.73	220.00
Average	2.89	0.10	930.20	1.86	0.82	0.20	43.38
Median	2.55	0.06	350.00	1.20	0.64	0.12	11.50
Variance	3.57	0.00	1269532.60	1.72	0.53	0.04	5048.24
Standard Deviation	1.89	0.07	1126.74	1.31	0.73	0.20	71.05

Table E15 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(°C)	WT(°F)	DO (mg/L)
10/22/12	**3.20**	**0.06**	**7.55**	**187.70**	15.70	60.26	4.94
11/20/12	**3.60**	**0.02**	7.15	**210.60**	14.01	57.22	5.07
12/24/12	0.60	0.00	7.04	98.10	8.84	47.91	5.10
1/21/13	0.85	0.00	6.96	102.00	10.93	51.67	8.53
1/31/13	0.44	**0.01**	7.16	97.40	13.33	55.99	7.52
2/22/13	0.26	0.00	7.15	72.00	14.17	57.51	8.54
3/21/13	0.39	**0.02**	6.89	76.20	12.99	55.38	8.42
4/22/13	0.36	0.00	6.99	73.30	17.84	64.11	7.87
5/23/13	**3.50**	0.00	6.82	**197.10**	24.23	75.61	6.30
6/6/13	1.10	0.00					
6/24/13	1.20	0.00	6.25	113.60	24.08	75.34	5.88
6/24/13	0.22	**0.08**					
7/23/13	0.24	0.00	7.06	78.90	24.23	75.61	
8/19/13	0.21	0.00	**6.26**	62.30	24.35	75.83	6.33
9/24/13	0.43	0.00	6.78	86.50	23.82	74.88	6.18
10/22/13	0.94	0.00	7.10	125.00	19.80	67.64	6.95
11/25/13	0.50	0.00	7.14	87.00	15.02	59.04	6.14
11/26/13	0.50	0.00	6.95	95.10	15.10	59.18	7.80
Minimum	0.21	0.00	6.25	62.30	8.84	47.91	4.94
Maximum	3.60	0.08	7.55	210.60	24.35	75.83	8.54
Average	1.03	0.01	6.95	110.18	17.40	63.32	6.77
Median	0.50	0.00	7.02	96.25	15.40	59.72	6.33
Variance	1.31	0.00	0.11	2188.33	28.02	90.80	1.63
Standard Deviation	1.15	0.02	0.32	46.78	5.29	9.53	1.28

Table E15 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	6.20	120.00	**75.00**	70.00	2.79	Partly Cloudy	1:05 p.m.
11/20/12	7.93	120.00	**80.00**	67.00	3.68	Sunny	12:00 p.m
12/24/12	14.20	40.00	40.00	58.00	2.93	Cloudy	10:00 a.m.
1/21/13	10.10	60.00	30.00	53.00	2.35	Sunny	10:37 a.m.
1/31/13	30.30	60.00	30.00	42.00	3.35	Sunny	9:15 a.m.
2/22/13	**89.70**	40.00	30.00	65.00	3.91	Rain	3:30 p.m.
3/21/13	21.30	40.00	25.00	48.00	3.46	Sunny	9:00 a.m.
4/22/13	23.40	60.00	30.00	62.00	3.24	Cloudy	9:45 a.m.
5/23/13	9.45	100.00	50.00	81.00	1.48	Partly Cloudy	11:15 a.m.
6/6/13					2.05	Rain	7:00p.m.
6/24/13	35.30	60.00	40.00	80.00	2.30	Sunny	9:15 a.m.
6/24/13					3.05	Rain	10:00 p.m.
7/23/13	13.20	50.00	30.00	78.00	3.30	Partly Cloudy	9:30 a.m.
8/19/13	19.10	40.00	40.00	81.00	5.37	Partly Cloudy	11:00 a.m.
9/24/13	11.00	60.00	30.00	77.00	2.37	Cloudy	12:23 p.m.
10/22/13	8.80	80.00	40.00	70.00	1.80	Drizzle	10:45 a.m.
11/25/13	**9.09**	40.00	40.00	60.00	2.53	Cloudy	3:45 p.m.
11/26/13	275.00	40.00	30.00	68.00	3.15	Partly Cloudy	2:00 p.m.
Minimum	6.20	40.00	25.00	42.00	1.48		
Maximum	275.00	120.00	80.00	81.00	5.37		
Average	36.50	63.13	40.00	66.25	2.95		
Median	13.70	60.00	35.00	67.50	2.99		
Variance	4455.32	769.58	256.67	142.20	0.80		
Standard Deviation	66.75	27.74	16.02	11.92	0.89		

Minimum Detection Limits: Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E16. Tired Creek difference between including storms and not including storms in correlation matrix

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	-0.20	1.00																	
FC	**0.97**	**0.42**	1.00																
TN	**0.38**	**0.60**	**-0.46**	1.00															
TKN	-0.27	**0.53**	-0.01	0.26	1.00														
TP	-0.22	**0.88**	**0.80**	**0.47**	0.31	1.00													
TSS	0.26	**0.76**	**0.96**	0.24	-0.24	-0.30	1.00												
TON	**0.46**	0.21	**-0.47**	-0.16	-0.16	0.02	0.09	1.00											
NH4	**0.43**	**0.95**	-0.08	-0.13	**0.50**	**0.43**	**0.57**	-0.33	1.00										
pH	**0.43**	**0.46**	0.32	-0.10	0.17	**0.35**	**0.61**	-0.12	-0.07	1.00									
SC	**0.48**	0.22	**-0.38**	-0.01	-0.07	-0.06	0.21	0.00	0.01	-0.11	1.00								
WT(M)	-0.30	**-0.60**	**-0.79**	0.07	-0.18	-0.15	**-0.37**	0.09	0.04	-0.04	0.07	1.00							
WT(E)	-0.30	**-0.60**	**-0.79**	0.07	-0.18	-0.15	**-0.37**	0.09	0.04	-0.04	0.07	0.00	1.00						
DO	-0.08	0.08	**0.51**	-0.05	0.05	0.16	0.15	-0.06	-0.03	0.12	-0.05	-0.11	-0.11	1.00					
Turb	**0.49**	**0.59**	**1.01**	0.02	**-0.88**	**-0.54**	-0.02	0.17	0.12	**0.68**	0.25	**-0.40**	**-0.40**	0.13	1.00				
Hd	0.31	0.14	**-0.48**	0.00	-0.02	-0.05	0.07	0.00	0.01	-0.14	0.00	0.08	0.08	-0.09	0.13	1.00			
Alk	**0.38**	0.33	-0.28	0.01	-0.01	-0.02	0.16	0.01	-0.01	-0.11	0.00	0.11	0.11	-0.03	0.16	0.00	1.00		
AT	0.03	-0.32	**-0.82**	0.01	-0.25	0.02	0.00	0.04	0.00	-0.05	0.01	-0.06	-0.06	0.03	-0.08	-0.02	0.06	1.00	
Stage	0.02	0.22	**0.49**	-0.10	-0.26	-0.25	-0.07	-0.05	-0.02	0.07	-0.05	-0.08	-0.08	0.16	-0.07	-0.05	-0.08	-0.07	1.00

Table E17. Tired Creek 2 monthly sampling and storm data

Date	Fe (mg/L)	Mn (mg/L)	FC (CFU/ 100 mL)	TN (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
10/22/12	1.10	0.02	663.00	2.10	0.44	0.07	2.00
11/20/12	1.70	0.04	440.00	3.90	1.40	0.23	10.00
12/24/12	2.20	0.05	200.00	0.99	0.35	0.1	9.2.00
1/21/13	2.90	0.06	280.00	2.00	0.50	0.09	3.2.00
1/31/13	3.10	0.09	2000.00	1.20	0.81	0.15	29.00
2/22/13	4.30	0.23	2700.00	0.64	0.39	0.27	90.00
3/21/13	2.50	0.05	230.00	0.78	0.37	2.49	15.00
4/22/13	3.00	0.063	250.00	0.84	0.47	0.166	12.00
5/23/13	1.30	0.07	690.00	4.10	0.63	0.08	6.00
6/24/13	2.40	0.06	230.00	2.20	1.00	0.21	20.00
7/23/13	2.70	0.07	186.00	0.98	0.69	0.13	13.00
8/19/13	2.20	0.05	230.00	0.78	0.62	0.10	13.00
9/24/13	2.50	0.10	106.00	1.00	0.61	0.065	7.40
Minimum	1.10	0.02	106.00	0.64	0.35	0.07	2.00
Maximum	4.30	0.23	2700.00	4.10	1.40	2.49	90.00
Average	2.50	0.10	631.2	1.70	0.60	0.30	17.70
Median	2.50	0.10	250.0	1.00	0.60	0.10	12.00
Variance	0.70	0.00	633840.3	1.40	0.10	0.40	523.00
Standard Deviation	0.80	0.10	796.1	1.20	0.30	0.70	22.90

Table E17 continued:

Date	TON (mg/L)	NH4 (mg/L)	pH	SC (µS/cm)	WT(℃)	WT(℉)	DO (mg/L)
10/22/12	1.7	BDL	7.06	160	15.9	60.62	4.99
11/20/12	2.4	0.1	7.19	192.8	14.04	57.27	5.38
12/24/12	0.64	BDL	7.11	97.6	8.12	46.62	5.64
1/21/13	1.5	BDL	7.08	101	10.84	51.51	9.08
1/31/13	0.41	BDL	7.25	98.6	12.99	55.38	8.29
2/22/13	0.25	BDL	7.22	78.6	13.99	57.18	8.72
3/21/13	0.42	BDL	7.01	76.8	13	55.4	9.05
4/22/13	0.36	0.01	6.94	73.6	17.84	64.112	7.82
5/23/13	3.50	BDL	6.80	199.10	21.23	70.21	5.64
6/24/13	1.20	BDL	6.33	116.80	24.06	75.31	5.76
7/23/13	0.30	BDL	6.78	78.50	24.21	75.58	-
8/19/13	0.16	BDL	6.27	62.60	24.36	75.85	6.30
9/24/13	0.4	BDL	6.84	86.7	24.04	75.272	6.35
Minimum	0.16	BDL	6.27	62.60	8.12	46.62	4.99
Maximum	3.50	0.10	7.25	199.10	24.36	75.85	9.08
Average	1.02	0.00	6.91	109.44	17.28	63.10	6.92
Median	0.44	0.00	7.01	97.60	15.90	60.62	6.33
Variance	1.02	0.00	0.10	2074.71	32.59	105.59	2.41
Standard Deviation	1.01	0.03	0.31	45.55	5.71	10.28	2.43

Table E17 continued:

Date	Turb (NTU)	Hd (mg/L)	Alk (mg/L)	AT (°F)	Stage (ft.)	Weather	Time
10/22/12	6.62	100	70	69	2.79	Partly Cloudy	12:45 p.m.
11/20/12	10.8	120	80	64	3.68	Sunny	11:25 a.m.
12/24/12	14.3	40	40	61	3.68	Cloudy	10:45 a.m.
1/21/13	10.1	60	30	57	2.35	Sunny	11:15 a.m.
1/31/13	25.5	60	30	44	3.35	Sunny	10:50 a.m.
2/22/13	78.1	40	25	65	3.91	Rain	3:00 p.m.
3/21/13	22.1	40	25	56	3.46	Sunny	12:00 p.m
4/22/13	23.1	60	25	62	3.24	Cloudy	10:15 a.m.
5/23/13	11.30	100.00	55.00	81.00	1.48	Partly Cloudy	11:45 a.m.
6/24/13	32.70	60.00	45.00	81.00	2.30	Sunny	9:45 a.m.
7/23/13	12.60	60.00	30.00	80.00	3.30	Cloudy	10:30 a.m.
8/19/13	18.30	40.00	35.00	82.00	5.37	Partly Cloudy	11:30 a.m.
9/24/13	10	60	30	77	2.37	Cloudy	1:00 p.m.
Minimum	6.62	40.00	25.00	44.00	1.48		
Maximum	78.10	120.00	80.00	82.00	5.37		
Average	21.19	64.62	40.00	67.62	3.18		
Median	14.30	60.00	30.00	65.00	3.30		
Variance	349.18	676.92	320.83	142.42	0.93		
Standard Deviation	18.69	26.02	17.91	11.93	0.96		

**Minimum Detection Limits:* Fe = .038 mg/L; Mn = .00024 mg/L; FC = 1 CFU/100 mL; TN = 0.1 mg/L; TKN = 0.1 mg/L; TP = .004 mg/L; TSS = 2 mg/L; TON = .004 mg/L; NH4 = 0 mg/L; ALk = 5 mg/L; Hd = 20 mg/LU/100 mL

Table E18. Iron concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	4.3	0.78	0.21	2.10	1.00
11/20/12	3.6	0.79	0.73	2.50	1.00
12/24/12	3.8	2.10	0.50	1.70	2.20
1/21/13	5.3	3.40	0.16	2.40	2.90
1/31/13	5.5	3.70	1.00	2.70	3.70
2/22/13	4.9	7.10	7.80	3.80	5.40
3/21/13	3	2.40	0.24	1.80	2.40
4/22/13	3.8	3.30	0.29	2.10	3.00
5/23/13	3.9	0.63	0.07	1.90	1.30
6/6/13		4.80	8.10	4.50	1.80
6/24/13	2.2	2.70	0.99	5.60	2.40
7/23/13	4.3	3.20	0.24	1.70	2.80
8/19/13	2.7	2.10	0.50	1.80	2.90
9/24/13	4.6	2.9	0.26	2.6	2.6
10/22/13	4.4	2.6	0.48	2.5	2.2
11/25/13					2.5
11/26.13	4.5	5.3	6.40	3.1	9.3
Min	2.2	0.63	0.067	1.7	1
Max	5.5	7.1	8.1	5.6	9.3
Average	4.05	2.99	1.75	2.68	2.91
Median	4.30	2.80	0.49	2.45	2.50
Variance	0.85	2.92	8.14	1.21	3.79
Standard Deviation	0.92	1.71	2.85	1.10	1.95

Table E19. Iron ANOVA for all grab samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	60.80	4.05	0.85
Buss Creek	16	47.80	2.99	2.92
Nursery Creek	16	27.97	1.75	8.14
Sapp Creek	16	42.80	2.68	1.21
Tired Creek	17	49.40	2.91	3.79

Iron ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	41.99	4.00	10.50	3.07	2.13E-02	2.49
Within Groups	256.49	75.00	3.42			
Total	298.48	79.00				

Table E20. Iron Tukey Test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	1.07	1			
Nursery Creek	**2.31**	1.24	1		
Sapp Creek	1.38	0.31	-0.93	1	
Tired Creek	1.15	0.08	-1.16	-0.23	1
k	5.00		**95% +/- CL**		
S^2 Pool	3.42		1.95		
S pool	1.85				
V	75.00				
Q	4.20				

Table E21. Iron concentration for not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	4.3	0.78	0.21	2.10	1.00
11/20/12	3.6	0.79	0.73	2.50	1.00
12/24/12	3.8	2.10	0.50	1.70	2.20
1/21/13	5.3	3.40	0.16	2.40	2.90
3/21/13	3	2.40	0.24	1.80	2.40
4/22/13	3.8	3.30	0.29	2.10	3.00
5/23/13	3.9	0.63	0.07	1.90	1.30
6/24/13	2.2	2.70	0.99	5.60	2.40
7/23/13	4.3	3.20	0.24	1.70	2.80
8/19/13	2.7	2.10	0.50	1.80	2.90
9/24/13	4.6	2.9	0.26	2.6	2.6
10/22/13	4.4	2.6	0.48	2.5	2.2
11/25/13					2.5
Min	2.2	0.63	0.067	1.7	1
Max	5.3	3.4	0.99	5.6	3
Average	3.83	2.24	0.39	2.39	2.25
Median	3.85	2.50	0.28	2.10	2.40
Variance	0.75	1.01	0.07	1.13	0.50
Standard Deviation	0.86	1.00	0.26	1.06	0.71

Table E22. Iron ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	45.90	3.83	0.75
Buss Creek	12	26.90	2.24	1.01
Nursery Creek	12	4.67	0.39	0.07
Sapp Creek	12	28.70	2.39	1.13
Tired Creek	13	29.20	2.25	0.50

Iron ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	71.51	4.00	17.88	26.05	3.18E-12	2.54
Within Groups	38.43	56.00	0.69			
Total	109.95	60.00				

Table E23. Iron Tukey test not including storm

Difference in Means					
	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	**1.58**	1.00			
Nursery Creek	**3.44**	**1.85**	1.00		
Sapp Creek	**1.43**	-0.15	**-2.00**	1.00	
Tired Creek	**1.58**	0.00	**-1.86**	0.15	1.00
k	5.00		**95% +/- CL**		
S^2 Pool	0.69		1.02		
S pool	0.83				
V	56.00				
Q	4.36				

Table E24. Iron (mg/L) for storm events

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	5.5	3.70	1.00	2.70	3.70
2/22/13	4.9	7.10	7.80	3.80	5.40
6/6/13		4.80	8.10	4.50	1.80
11/26.13	4.5	5.3	6.40	3.1	9.3
Min.	4.5	3.7	1.0	2.7	1.8
Max.	5.5	7.1	8.1	4.5	9.3
Average	4.97	5.23	5.83	3.53	5.05
Median	4.90	5.05	7.10	3.45	4.55
Variance	0.25	2.01	10.90	0.63	10.19
Standard Deviation	0.50	1.42	3.30	0.79	3.19

Table E25. Manganese (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.41	0.12	0.02	0.14	0.04
11/20/12	0.51	0.09	0.01	0.08	0.04
12/24/12	0.13	0.16	0.01	0.07	0.05
1/21/13	0.15	0.16	0.0040	0.11	0.07
1/31/13	0.15	0.19	0.04	0.12	0.12
2/22/13	0.44	0.12	0.05	0.29	0.24
3/21/13	0.06	0.06	0.0034	0.05	0.05
4/22/13	0.08	0.08	0.01	0.06	0.06
5/23/13	1.20	0.16	0.0043	0.17	0.06
6/6/13		0.28	0.06	1.00	0.19
6/24/13	0.20	0.14	0.01	0.18	0.05
7/23/13	0.13	0.11	0.01	0.07	0.08
8/19/13	0.06	0.05	0.02	0.05	0.06
9/24/13	0.33	0.11	0.01	0.15	0.08
10/22/13	0.34	0.16	0.01	0.22	0.05
11/25/13					0.06
11/26.13	0.30	0.20	0.04	0.30	0.17
Min	0.06	0.05	0.0034	0.05	0.04
Max	1.20	0.28	0.06	1.00	0.24
Average	0.30	0.14	0.02	0.19	0.09
Median	0.20	0.13	0.01	0.13	0.06
Variance	0.08	0.003	0.0003	0.05	0.0003
Standard Deviation	0.29	0.06	0.02	0.23	0.06

Table E26: Manganese ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	4.49	0.30	0.08
Buss Creek	16	2.19	0.14	0.00
Nursery Creek	16	0.31	0.02	0.00
Sapp Creek	16	3.07	0.19	0.05
Tired Creek	17	1.47	0.09	0.00

Manganese ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.71	4.00	0.18	6.41	1.71E-04	2.49
Within Groups	2.06	75.00	0.03			
Total	2.77	79.00				

Table E27: Manganese Tukey Test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	0.16	1			
Nursery Creek	**0.28**	0.12	1		
Sapp Creek	0.11	-0.05	-0.17	1	
Tired Creek	**0.21**	0.05	-0.07	0.11	1
k	5		**95% +/- CL**		
S^2 Pool	0.028		0.174		
S pool	0.17				
V	75				
Q	4.2				

Table E28. Manganese concentration for not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.41	0.12	0.02	0.14	0.04
11/20/12	0.51	0.09	0.01	0.08	0.04
12/24/12	0.13	0.16	0.01	0.07	0.05
1/21/13	0.15	0.19	0.04	0.12	0.12
3/21/13	0.06	0.06	0.0034	0.05	0.05
4/22/13	0.08	0.08	0.01	0.06	0.06
5/23/13	1.20	0.16	0.0043	0.17	0.06
6/24/13	0.20	0.14	0.01	0.18	0.05
7/23/13	0.13	0.11	0.01	0.07	0.08
8/19/13	0.06	0.05	0.02	0.05	0.06
s9/24/13	0.33	0.11	0.01	0.15	0.08
10/22/13	0.34	0.16	0.01	0.22	0.05
11/25/13					0.06
Min	0.06	0.05	0.0034	0.05	0.04
Max	1.20	0.19	0.04	0.22	0.12
Average	0.30	0.12	0.01	0.11	0.06
Median	0.18	0.12	0.01	0.10	0.06
Variance	0.10	0.00	0.00	0.00	0.00
Standard Deviation	0.32	0.04	0.01	0.06	0.02

Table E29. Manganese ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	3.60	0.30	0.10
Buss Creek	12	1.43	0.12	0.00
Nursery Creek	12	0.15	0.01	0.00
Sapp Creek	12	1.37	0.11	0.00
Tired Creek	13	0.80	0.06	0.00

Manganese ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.57	4.00	0.14	6.75	0.00	2.54
Within Groups	1.19	56.00	0.02			
Total	1.76	60.00				

Table E30. Manganese Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	**0.18**	1			
Nursery Creek	**0.29**	0.11	1		
Sapp Creek	**0.19**	0.01	-0.10	1	
Tired Creek	**0.24**	0.06	-0.05	0.05	1
k	5.00		**95% +/- CL**		
S^2 Pool	0.02		0.18		
S pool	0.15				
V	56.00				
Q	4.36				

Table E31. Manganese (mg/L) concentration for storm events

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	5.5	3.70	1.00	2.70	3.70
2/22/13	4.9	7.10	7.80	3.80	5.40
6/6/13		4.80	8.10	4.50	1.80
11/26.13	4.5	5.3	6.40	3.1	9.3
Min	4.5	3.7	1	2.7	1.8
Max	5.5	7.1	8.1	4.5	9.3
Average	4.97	5.23	5.83	3.53	5.05
Median	4.90	5.05	7.10	3.45	4.55
Variance	0.25	2.01	10.90	0.63	10.19
Standard Deviation	0.50	1.42	3.30	0.79	3.19

Table E32. Fecal Coliform (CFU/100 mL) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	490.00	270.00	580.00	86.00	460.00
11/20/12	200.00	600.00	1040.00	4000.00	234.00
12/24/12	200.00	1470.00	927.00	134.00	220.00
1/21/13	96.00	520.00	72.00	129.00	290.00
1/31/13	618.00	3900.00	155.00	1380.00	3300.00
2/22/13	3000.00	5500.00	330.00	2900.00	2280.00
3/21/13	131.00	645.00	60.00	210.00	340.00
4/22/13	240.00	230.00	700.00	550.00	290.00
5/23/13	34.00	530.00	34.00	500.00	800.00
6/24/13	68.00	250.00	645.00	116.00	310.00
7/23/13	310.00	270.00	560.00	127.00	330.00
8/19/13	80.00	181.00	250.00	106.00	440.00
9/24/13	350	350	918	44	809
10/22/13	80	420	94	94	350
11/26.13	4900	770	16900	9420	3500
Min	34	181	34	44	220
Max	4900	5500	16900	9420	3500
Average	719.80	1060.40	1551.00	1319.73	930.20
Median	200.00	520.00	560.00	134.00	350.00
Variance	579944.64	2552069.82	127698.25	1485729.82	822913.79
Standard Deviation	1335.35	1512.65	4133.89	2466.42	1113.09

Table E33. Fecal Coliform ANOVA for all samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15.00	10797	719	1875821
Buss Creek	15.00	15906	1060	2376233
Nursery Creek	15.00	23265	1551	18148561
Sapp Creek	15.00	19796	1319	6401110
Tired Creek	15.00	13953	930	1269532

FC ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6379791	4.00	1594947	0.27	0.90	2.50
Within Groups	420997629	70.00	6014251			
Total	427377421	74.00				

Table E34. Fecal Coliform (CFU/100 mL) concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	490.00	270.00	580.00	86.00	460.00
11/20/12	200.00	600.00	1040.00	4000.00	234.00
12/24/12	200.00	1470.00	927.00	134.00	220.00
1/21/13	96.00	520.00	72.00	129.00	290.00
3/21/13	131.00	645.00	60.00	210.00	340.00
4/22/13	240.00	230.00	700.00	550.00	290.00
5/23/13	34.00	530.00	34.00	500.00	800.00
6/24/13	68.00	250.00	645.00	116.00	310.00
7/23/13	310.00	270.00	560.00	127.00	330.00
8/19/13	80.00	181.00	250.00	106.00	440.00
9/24/13	350.00	350.00	918.00	44.00	809.00
10/22/13	80.00	420.00	94.00	94.00	350.00
Min	34.00	181.00	34.00	44.00	220.00
Max	490.00	1470.00	1040.00	4000.00	809.00
Average	189.92	478.00	490.00	508.00	406.08
Median	165.50	385.00	570.00	128.00	335.00
Variance	18948.81	121752.55	139977.64	1235765.27	39572.08
Standard Deviation	141.93	359.42	383.12	1073.61	221.27

Table E35. Fecal Coliform ANOVA not including storm samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12.00	2279.00	189.92	18948.81
Buss Creek	12.00	5736.00	478.00	121752.55
Nursery Creek	12.00	5880.00	490.00	139977.64
Sapp Creek	12.00	6096.00	508.00	1235765.27
Tired Creek	12.00	4873.00	406.08	39572.08

Fecal Coliform ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	827798.57	4.00	206949.64	0.66	0.62	2.54
Within Groups	17116179.83	55.00	311203.27			
Total	17943978.40	59.00				

Table E36. Fecal Coliform for storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	618.00	3900.00	155.00	1380.00	3300.00
2/22/13	3000.00	5500.00	330.00	2900.00	2280.00
11/26/13	4900	770	16900	9420	3500
Min	618.00	770.00	155.00	1380.00	2280.00
Max	4900.00	5500.00	16900.00	9420.00	3500.00
Average	2839.33	3390.00	5795.00	4566.67	3026.67
Median	339.96	624.00	436.56	1226.80	607.54
Variance	4603241.33	5788300.00	92498425.00	18243733.3	428133.33
Standard Deviation	2145.52	2405.89	9617.61	4271.27	654.32

Table E37. Total Nitrogen (mg/L) concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.64	11.00	18.00	0.47	3.60
11/20/12	1.20	20.00	2.70	0.61	4.40
12/24/12	0.67	2.10	1.10	0.59	0.82
1/21/13	1.00	2.60	2.00	0.58	1.30
1/31/13	1.10	1.40	4.30	0.54	1.20
2/22/13	1.30	1.10	2.20	0.52	1.20
3/21/13	0.98	1.40	1.40	0.66	1.10
4/22/13	0.78	1.20	3.60	0.41	1.00
5/23/13	1.30	9.60	2.90	0.59	4.10
6/6/13		4.70	4.40	0.80	4.10
6/24/13	1.10	1.80	3.10	1.00	2.20
7/23/13	1.10	1.30	2.90	0.64	0.97
8/19/13	1.00	0.95	4.00	0.90	0.81
9/24/13	0.90	1.40	3.80	0.50	1.00
10/22/13	1.10	2.40	3.40	0.60	1.40
11/25/13					0.80
11/26.13	0.40	2.20	2.20	0.30	0.70
Min	0.40	0.95	1.10	0.30	0.70
Max	1.30	20.00	18.00	1.00	4.40
Average	0.97	4.07	3.88	0.61	1.81
Median	1.00	1.95	3.00	0.59	1.20
Variance	0.06	27.07	15.14	0.03	1.78
Standard Deviation	0.25	5.20	3.89	0.17	1.33

Table E38. Total Nitrogen ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	14.58	0.97	0.06
Buss Creek	16	65.15	4.07	27.07
Nursery Creek	16	62	3.88	15.14
Sapp Creek	16	9.71	0.61	0.03
Tired Creek	17	30.69	1.81	1.78

Total Nitrogen ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	166.36	4.00	41.59	4.70	0.002	2.49
Within Groups	663.08	75.00	8.84			
Total	829.44	79.00				

Table E39. Total Nitrogen Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-3.10	1			
Nursery Creek	-2.90	0.20	1		
Sapp Creek	0.37	**3.47**	3.27	1	
Tired Creek	-0.83	2.27	2.07	-1.20	1
k	5.00		**95% +/- CL**		
S^2 Pool	8.84		3.13		
S pool	2.97				
V	75.00				
Q	4.20				

Table E40. Total Nitrogen ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	14.58	0.97	0.06
Buss Creek	16	65.15	4.07	27.07
Nursery Creek	16	62	3.88	15.14
Sapp Creek	16	9.71	0.61	0.03
Tired Creek	17	30.69	1.81	1.78

TN ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	166.36	4.00	41.59	4.70	0.002	2.49
Within Groups	663.08	75.00	8.84			
Total	829.44	79.00				

Table E41. Total Nitrogen Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-3.10	1			
Nursery Creek	-2.90	0.20	1		
Sapp Creek	0.37	**3.47**	3.27	1	
Tired Creek	-0.83	2.27	2.07	-1.20	1
k	5.00		**95% +/- CL**		
S^2 Pool	8.84		3.13		
S pool	2.97				
V	75.00				
Q	4.20				

Table E42. Total Nitrogen concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.64	11.00	18.00	0.47	3.60
11/20/12	1.20	20.00	2.70	0.61	4.40
12/24/12	0.67	2.10	1.10	0.59	0.82
1/21/13	1.00	2.60	2.00	0.58	1.30
3/21/13	0.98	1.40	1.40	0.66	1.10
4/22/13	0.78	1.20	3.60	0.41	1.00
5/23/13	1.30	9.60	2.90	0.59	4.10
6/24/13	1.10	1.80	3.10	1.00	2.20
7/23/13	1.10	1.30	2.90	0.64	0.97
8/19/13	1.00	0.95	4.00	0.90	0.81
9/24/13	0.9	1.4	3.8	0.5	1.0
10/22/13	1.1	2.4	3.4	0.6	1.4
11/25/13					0.8
Min	0.64	0.95	1.1	0.41	0.8
Max	1.3	20	18	1	4.4
Average	0.98	4.65	4.08	0.63	1.81
Median	1.00	1.95	3.00	0.59	1.10
Variance	0.04	34.75	20.05	0.03	1.77
Standard Deviation	0.20	5.90	4.48	0.17	1.33

Table E43. Total Nitrogen ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	11.78	0.98	0.04
Buss Creek	12	55.75	4.65	34.75
Nursery Creek	12	48.9	4.08	20.05
Sapp Creek	12	7.55	0.63	0.03
Tired Creek	13	23.49	1.81	1.77

Total Nitrogen ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	160.52	4.00	40.13	3.60	0.01	2.54
Within Groups	624.89	56.00	11.16			
Total	785.41	60.00				

Table E44. Total Nitrogen Tukey Test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-3.66	1			
Nursery Creek	-3.09	0.57	1		
Sapp Creek	0.35	4.02	3.45	1	
Tired Creek	-0.83	2.84	2.27	-1.18	1
k	5.00		**95% +/- CL**		
S^2 Pool	11.16		4.12		
S pool	3.34				
V	56.00				
Q	4.36				

Table E45. Total Nitrogen storm samples

	Black Creek	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	1.10	1.40	4.30	0.54	1.20
2/22/13	1.30	1.10	2.20	0.52	1.20
6/6/13		4.70	4.40	0.80	4.10
11/26/13	0.4	2.2	2.2	0.3	0.7
n	3.0	4.0	4.0	4.0	4.0
Min	0.40	1.10	2.20	0.30	0.70
Max	1.30	4.70	4.40	0.80	4.10
Average	0.93	2.35	3.28	0.54	1.80
Median	1.10	1.80	3.25	0.53	1.20
Variance	0.22	2.67	1.54	0.04	2.41
St Dev.	0.47	1.63	1.24	0.20	1.55

Table E46. Total Keldahl Nitrogen concentration for all grab samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.07	1.80	0.83	0.29	0.34
11/20/12	0.48	3.90	0.51	0.46	0.78
12/24/12	0.25	0.35	0.09	0.42	0.22
1/21/13	0.69	0.75	0.18	0.44	0.49
1/31/13	0.92	0.81	2.00	0.48	0.75
2/22/13	1.20	0.23	1.30	0.46	0.95
3/21/13	0.66	0.71	0.16	0.44	0.69
4/22/13	0.52	0.48	0.10	0.28	0.66
5/23/13	0.70	1.40	0.07	0.38	0.61
6/6/13		2.40	0.47	0.68	3.00
6/24/13	0.76	0.92	1.20	0.93	1.00
7/23/13	0.87	0.82	0.13	0.64	0.74
8/19/13	0.80	0.61	0.94	0.36	0.60
9/24/13	0.62	0.68	0.60	0.52	0.57
10/22/13	0.56	0.61	0.35	0.31	0.46
11/25/13					0.30
11/26.13	0.12	0.34	0.41	0.26	0.19
Min	0.071	0.23	0.071	0.26	0.19
Max	1.2	3.9	2	0.93	3
Average	0.61	1.05	0.58	0.46	0.73
Median	0.66	0.73	0.44	0.44	0.61
Variance	0.09	0.90	0.30	0.03	0.40
Standard Deviation	0.30	0.95	0.55	0.17	0.63

Table E47. Total Kjeldahl Nitrogen ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	9.22	0.61	0.09
Buss Creek	16	16.81	1.05	0.90
Nursery Creek	16	9.33	0.58	0.30
Sapp Creek	16	7.35	0.46	0.03
Tired Creek	17	12.35	0.73	0.40

Total Kjeldahl Nitrogen ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.22	4.00	0.81	2.32	0.06	2.49
Within Groups	26.05	75.00	0.35			
Total	29.27	79.00				

Table E48. Total Kjeldahl Nitrogen concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.07	1.80	0.83	0.29	0.34
11/20/12	0.48	3.90	0.51	0.46	0.78
12/24/12	0.25	0.35	0.09	0.42	0.22
1/21/13	0.69	0.75	0.18	0.44	0.49
3/21/13	0.66	0.71	0.16	0.44	0.69
4/22/13	0.52	0.48	0.10	0.28	0.66
5/23/13	0.70	1.40	0.07	0.38	0.61
6/24/13	0.76	0.92	1.20	0.93	1.00
7/23/13	0.87	0.82	0.13	0.64	0.74
8/19/13	0.80	0.61	0.94	0.36	0.60
9/24/13	0.62	0.68	0.60	0.52	0.57
10/22/13	0.56	0.61	0.35	0.31	0.46
11/25/13					0.30
Min	0.071	0.35	0.071	0.28	0.22
Max	0.87	3.9	1.2	0.93	1
Average	0.58	1.09	0.43	0.46	0.57
Median	0.64	0.73	0.27	0.43	0.60
Variance	0.05	0.95	0.15	0.03	0.05
Standard Deviation	0.23	0.97	0.39	0.18	0.21

Table E49. TKN ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12.00	6.98	0.58	0.05
Buss Creek	12.00	13.03	1.09	0.95
Nursery Creek	12.00	5.15	0.43	0.15
Sapp Creek	12.00	5.47	0.46	0.03
Tired Creek	13.00	7.46	0.57	0.05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.41	4.00	0.85	3.52	0.01	2.54
Within Groups	13.53	56.00	0.24			
Total	16.94	60.00				

Table E50. TKN Tukey Test not including storm samples

Difference in Means					
	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1.00				
Buss Creek	-0.50	1.00			
Nursery Creek	0.15	**0.66**	1.00		
Sapp Creek	0.13	**0.63**	-0.03	1.00	
Tired Creek	0.01	0.51	-0.14	-0.12	1.00
k	5.00		95% +/- CL		
S^2 Pool	0.24		0.61		
S pool	0.49				
V	56.00				
Q	4.36				

Table E51. TKN storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	0.92	0.81	2.00	0.48	0.75
2/22/13	1.20	0.23	1.30	0.46	0.95
6/6/13		2.40	0.47	0.68	3.00
11/26/13	0.12	0.34	0.41	0.26	0.19
Min	0.12	0.23	0.41	0.26	0.19
Max	1.20	2.40	2.00	0.68	3.00
Average	0.75	0.95	1.05	0.47	1.22
Median	0.92	0.58	0.89	0.47	0.85
Variance	0.31	1.00	0.57	0.03	1.51
Standard Deviation	0.56	1.00	0.76	0.17	1.23

Table E52. Nitrate + Nitrite Concentration for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.64	9.20	17.00	0.19	3.20
11/20/12	0.75	16.00	2.20	0.15	3.60
12/24/12	0.42	1.70	1.00	0.17	0.60
1/21/13	0.31	1.80	1.90	0.13	0.85
1/31/13	0.15	0.62	2.40	0.06	0.44
2/22/13	0.12	0.89	0.90	0.06	0.26
3/21/13	0.32	0.65	1.40	0.22	0.39
4/22/13	0.26	0.69	3.50	0.14	0.36
5/23/13	0.56	8.20	2.80	0.20	3.50
6/6/13		2.30	3.90	0.12	1.10
6/24/13	0.29	0.92	1.80	0.11	1.20
7/23/13	0.22	0.44	2.70	0.02	0.24
8/19/13	0.24	0.34	3.00	0.54	0.21
9/24/13	0.3	0.7	3.2	0.0	0.4
10/22/13	0.6	1.8	3.0	0.3	0.9
11/25/13					0.5
11/26.13	0.3	1.9	1.8	0.0	0.5
Min	0.12	0.34	0.9	0.02	0.21
Max	0.75	16.00	17.00	0.54	3.60
Average	0.36	3.01	3.28	0.15	1.08
Median	0.30	1.31	2.55	0.14	0.50
Variance	0.03	19.00	14.13	0.02	1.35
Standard Deviation	0.18	4.36	3.76	0.13	1.16

Table E53. Nitrate + Nitrite ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15.00	5.44	0.36	0.03
Buss Creek	16.00	48.15	3.01	19.00
Nursery Creek	16.00	52.50	3.28	14.13
Sapp Creek	16.00	2.42	0.15	0.02
Tired Creek	17.00	18.32	1.08	1.35

Nitrate + Nitrite ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	138.16	4.00	34.54	4.99	0.001	2.49
Within Groups	519.37	75.00	6.92			
Total	657.53	79.00				

Table E54. Nitrate + Nitrite Tukey test for all samples

Difference in Means					
	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1				
Buss Creek	-2.65	1			
Nursery Creek	**-2.92**	-0.27	1		
Sapp Creek	0.21	**2.86**	**3.13**	1	
Tired Creek	-0.71	1.93	2.20	-0.93	1
k	5.00		**95% +/- CL**		
S^2 Pool	6.92		2.77		
S pool	2.63				
V	75.00				
Q	4.20				

Table E55. Nitrate + Nitrite concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.64	9.20	17.00	0.19	3.20
11/20/12	0.75	16.00	2.20	0.15	3.60
12/24/12	0.42	1.70	1.00	0.17	0.60
1/21/13	0.31	1.80	1.90	0.13	0.85
3/21/13	0.32	0.65	1.40	0.22	0.39
4/22/13	0.26	0.69	3.50	0.14	0.36
5/23/13	0.56	8.20	2.80	0.20	3.50
6/24/13	0.29	0.92	1.80	0.11	1.20
7/23/13	0.22	0.44	2.70	0.02	0.24
8/19/13	0.24	0.34	3.00	0.54	0.21
9/24/13	0.3	0.7	3.2	0.0	0.4
10/22/13	0.6	1.8	3.0	0.3	0.9
11/25/13					0.5
Min	0.22	0.34	1	0.022	0.21
Max	0.75	16.00	17.00	0.54	3.60
Average	0.41	3.54	3.63	0.18	1.23
Median	0.32	1.31	2.75	0.16	0.60
Variance	0.03	24.52	18.33	0.02	1.66
Standard Deviation	0.18	4.95	4.28	0.13	1.29

Table E56. Nitrate + Nitrite ANOVA not including storm samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12.00	4.87	0.41	0.03
Buss Creek	12.00	42.44	3.54	24.52
Nursery Creek	12.00	43.50	3.63	18.33
Sapp Creek	12.00	2.16	0.18	0.02
Tired Creek	13.00	16.02	1.23	1.66

Nitrate + Nitrite ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	135.14	4.00	33.79	3.85	0.01	2.54
Within Groups	491.76	56.00	8.78			
Total	626.90	60.00				

Table E57. Nitrate + Nitrite Tukey test not including storm sample

Difference in Means					
	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1				
Buss Creek	-3.13	1			
Nursery Creek	-3.22	-0.09	1		
Sapp Creek	0.23	3.36	3.44	1	
Tired Creek	-0.83	2.30	2.39	-1.05	1
k	5		**95% +/- CL**		
S^2 Pool	8.781		3.66		
S pool	2.96				
V	56				
Q	4.36				

Table E58. Nitrate + Nitrite storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	0.15	0.62	2.40	0.06	0.44
2/22/13	0.12	0.89	0.90	0.06	0.26
6/6/13		2.30	3.90	0.12	1.10
11/26/13	0.3	1.9	1.8	0.0	0.5
Min	0.1	0.6	0.9	0.0	0.3
Max	0.3	2.3	3.9	0.1	1.1
Average	0.2	1.4	2.3	0.1	0.6
Median	0.2	1.4	2.1	0.1	0.5
Variance	0.01	0.6	1.6	0.0	0.1
Standard Deviation	0.1	0.8	1.3	0.0	0.4

Table E59. Ammonium Concentration for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	BDL	BDL	0.17	BDL	0.06
11/20/12	BDL	0.1	BDL	BDL	0.02
12/24/12	BDL	0.05	0.014	BDL	BDL
1/21/13	BDL	0.05	BDL	0.01	BDL
1/31/13	0.03	BDL	BDL	0.001	0.01
2/22/13	BDL	BDL	BDL	BDL	BDL
3/21/13	BDL	0.04	BDL	BDL	0.02
4/22/13	BDL	0.03	0.003	BDL	BDL
5/23/13	0.04	BDL	0.029	0.01	BDL
6/6/13		BDL	0.03	BDL	BDL
6/24/13	0.05	BDL	0.1	BDL	BDL
7/23/13	0.01	0.04	0.07	BDL	BDL
8/19/13	BDL	BDL	0.06	BDL	BDL
9/24/13	BDL	0.02	BDL	BDL	BDL
10/22/13	BDL	BDL	0.05	BDL	BDL
11/25/13					BDL
11/26.13	0.01	BDL	BDL	BDL	BDL
Min	0	0	0	0	0
Max	0.05	0.1	0.17	0.01	0.06
Average	0.01	0.02	0.03	0.00	0.01
Median	0.00	0.00	0.01	0.00	0.00
Variance	0.00	0.00	0.00	0.00	0.00
Standard Deviation	0.02	0.03	0.05	0.00	0.02

Table E60. Ammonium ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	0.14000	0.00933	0.00028
Buss Creek	16	0.33000	0.02063	0.00085
Nursery Creek	16	0.52600	0.03288	0.00230
Sapp Creek	16	0.02100	0.00131	0.00001
Tired Creek	17	0.11000	0.00647	0.00024

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.010	4.000	0.003	3.494	0.011	2.494
Within Groups	0.055	75.000	0.001			
Total	0.065	79.000				

Table E61. Ammonium Tukey test for all samples

Difference in Means					
	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
Black Creek	1				
Buss Creek	-0.01	1			
Nursery Creek	-0.02	-0.01	1		
Sapp Creek	0.01	0.02	**0.03**	1	
Tired Creek	0.00	0.01	**0.03**	-0.01	1
k	5		**95% +/- CL**		
S^2 Pool	0.001		0.029		
S pool	0.027				
V	75				
Q	4.2				

Table E62. Ammonium concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	BDL	BDL	0.17	BDL	0.06
11/20/12	BDL	0.1	BDL	BDL	0.02
12/24/12	BDL	0.05	0.014	BDL	BDL
1/21/13	BDL	0.05	BDL	0.01	BDL
3/21/13	BDL	0.04	BDL	BDL	0.02
4/22/13	BDL	0.03	0.003	BDL	BDL
5/23/13	0.04	BDL	0.029	0.01	BDL
6/24/13	0.05	BDL	0.1	BDL	BDL
7/23/13	0.01	0.04	0.07	BDL	BDL
8/19/13	BDL	BDL	0.06	BDL	BDL
9/24/13	BDL	0.02	BDL	BDL	BDL
10/22/13	BDL	BDL	0.05	BDL	BDL
11/25/13					BDL
Min	0	0	0	0	0
Max	0.05	0.1	0.17	0.01	0.06
Average	0.01	0.03	0.04	0.00	0.01
Median	0.00	0.03	0.02	0.00	0.00
Variance	0.00	0.00	0.00	0.00	0.00
Standard Deviation	0.02	0.03	0.05	0.00	0.02

Table E63. Ammonium ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	0.1	0.00833	0.00031
Buss Creek	12	0.33	0.02750	0.00095
Nursery Creek	12	0.496	0.04133	0.00277
Sapp Creek	12	0.02	0.00167	0.00002
Tired Creek	13	0.1	0.00769	0.00030

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.013	4	0.003	3.869	0.008	2.537
Within Groups	0.048	56	0.001			
Total	0.061	60				

Table E64. Ammonium Tukey test not including storm samples

Difference in Means

	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-0.02	1			
Nursery Creek	-0.03	-0.01	1		
Sapp Creek	0.01	0.03	**0.04**	1	
Tired Creek	0.00	0.02	0.03	-0.01	1
k	5		**95% +/- CL**		
S^2 Pool	0.001		0.036		
S pool	0.029				
V	56				
Q	4.36				

Table E65. Ammonium storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	0.03	BDL	BDL	0.001	0.01
2/22/13	BDL	BDL	BDL	BDL	BDL
6/6/13		BDL	0.03	BDL	BDL
11/26/13	0.01	BDL	BDL	BDL	BDL
Min	BDL	BDL	BDL	BDL	BDL
Max	0.03	0.0	0.03	0.001	0.01
Average	0.01	0.0	0.008	0.0003	0.003
Median	0.01	0.0	0.0	0.0	0.0
Variance	0.0002	0.0	0.0002	0.0	0.00002
Standard Deviation	0.015	0.0	0.02	0.0005	0.005

Table E66. Total Phosphorous concentration for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.05	0.10	0.05	0.05	0.08
11/20/12	0.07	0.18	0.12	0.08	0.12
12/24/12	0.05	0.12	0.07	0.08	0.12
1/21/13	0.06	0.13	0.03	0.05	0.11
1/31/13	0.06	0.12	0.33	0.07	0.18
2/22/13	0.09	0.51	0.62	0.22	0.38
3/21/13	0.13	0.14	0.07	0.10	0.21
4/22/13	0.14	0.14	0.11	0.08	0.15
5/23/13	0.05	0.16	0.03	0.07	0.09
6/6/13		0.64	0.25	0.23	0.73
6/24/13	0.24	0.20	0.28	0.12	0.19
7/23/13	0.06	0.12	0.07	0.09	0.11
8/19/13	0.08	0.09	0.21	0.07	0.10
9/24/13	0.063	0.091	0.114	0.050	0.088
10/22/13	0.038	0.130	0.081	0.043	0.074
11/25/13					0.062
11/26.13	0.046	0.253	0.396	0.073	0.134
Min	0.04	0.09	0.03	0.04	0.06
Max	0.24	0.64	0.62	0.23	0.73
Average	0.08	0.19	0.18	0.09	0.17
Median	0.06	0.13	0.11	0.08	0.12
Variance	0.00	0.02	0.03	0.00	0.03
Standard Deviation	0.05	0.15	0.16	0.05	0.16

Table E67. Total Phosphorus ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	1.22	0.08	0.00
Buss Creek	16	3.12	0.19	0.02
Nursery Creek	16	2.82	0.18	0.03
Sapp Creek	16	1.47	0.09	0.00
Tired Creek	17	2.92	0.17	0.03

Total Phosphorus ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.17	4.00	0.04	2.58	0.04	2.49
Within Groups	1.26	75.00	0.02			
Total	1.43	79.00				

Table E68. Total Phosphorus Tukey test for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	1.22	0.08	0.003
Buss Creek	16	3.12	0.19	0.02
Nursery Creek	16	2.82	0.18	0.03
Sapp Creek	16	1.47	0.09	0.003
Tired Creek	17	2.92	0.17	0.03

Total Phosphorus ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.17	4.00	0.04	2.58	0.04	2.49
Within Groups	1.26	75.00	0.02			
Total	1.43	79.00				

Table E69. Total Phosphorus concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	0.05	0.10	0.05	0.05	0.08
11/20/12	0.07	0.18	0.12	0.08	0.12
12/24/12	0.05	0.12	0.07	0.08	0.12
1/21/13	0.06	0.13	0.03	0.05	0.11
3/21/13	0.13	0.14	0.07	0.10	0.21
4/22/13	0.14	0.14	0.11	0.08	0.15
5/23/13	0.05	0.16	0.03	0.07	0.09
6/24/13	0.24	0.20	0.28	0.12	0.19
7/23/13	0.06	0.12	0.07	0.09	0.11
8/19/13	0.08	0.09	0.21	0.07	0.10
9/24/13	0.063	0.091	0.114	0.050	0.088
10/22/13	0.038	0.130	0.081	0.043	0.074
11/25/13					0.062
Min	0.04	0.09	0.03	0.04	0.06
Max	0.24	0.20	0.28	0.12	0.21
Average	0.09	0.13	0.10	0.07	0.11
Median	0.06	0.13	0.08	0.07	0.11
Variance	0.003	0.001	0.006	0.0005	0.002
Standard Deviation	0.06	0.03	0.07	0.02	0.04

Table E70. Total Phosphorus ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	1.02	0.09	0.00
Buss Creek	12	1.60	0.13	0.00
Nursery Creek	12	1.24	0.10	0.01
Sapp Creek	12	0.88	0.07	0.00
Tired Creek	13	1.49	0.11	0.00

Total Phosphorus ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	4.00	0.01	2.68	0.04	2.54
Within Groups	0.14	56.00	0.00			
Total	0.17	60.00				

Table E71. Total Phosphorus Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	-0.05	1.00			
Nursery Creek	-0.02	0.03	1.00		
Sapp Creek	0.01	**0.06**	0.03	1.00	
Tired Creek	-0.03	0.02	-0.01	-0.04	1.00
			95% +/- CL		
k	5.00				
S^2 Pool	0.00		0.06		
S pool	0.05				
V	56.00				
Q	4.36				

Table E72. Total Phosphorus storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	0.06	0.12	0.33	0.07	0.18
2/22/13	0.09	0.51	0.62	0.22	0.38
6/6/13		0.64	0.25	0.23	0.73
11/26/13	0.05	0.25	0.40	0.07	0.13
Min	0.05	0.12	0.25	0.07	0.13
Max	0.09	0.64	0.62	0.23	0.73
Average	0.07	0.38	0.40	0.15	0.36
Median	0.06	0.38	0.36	0.15	0.28
Variance	0.00	0.05	0.03	0.01	0.07
Standard Deviation	0.02	0.23	0.16	0.09	0.27

Table E73. Total Suspended Solids concentration for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	2.4	2.0	9.6	2.0	5.6
11/20/12	4.5	6.0	32.0	2.0	4.7
12/24/12	2.4	5.5	32.0	4.4	12.0
1/21/13	3.6	4.8	2.0	2.8	7.2
1/31/13	6.9	13.0	25.0	4.0	2.0
2/22/13	49.0	140.0	660.0	120.0	130.0
3/21/13	12.0	2.0	9.7	5.6	20.0
4/22/13	10.0	7.6	15.0	5.6	20.0
5/23/13	4.4	3.4	2.0	2.3	6.8
6/6/13		840.0	430.0	56.0	60.0
6/24/13	8.5	15.0	39.0	9.0	29.0
7/23/13	4.6	10.0	8.0	9.8	11.0
8/19/13	5.2	10.0	10.0	15.0	14.0
9/24/13	4.6	4.8	7.6	2.3	9.4
10/22/13	2.0	3.4	6.2	10.0	5.6
11/25/13					3.5
11/26.13	17.0	92.0	750.0	26.0	220.0
Min	2.0	2.0	2.0	2.0	2.0
Max	49.0	840.0	750.0	120.0	220.0
Average	9.1	72.5	127.4	17.3	33.0
Median	4.6	6.8	12.5	5.6	11.0
Variance	138.4	43362.1	61883.8	936.7	3299.4
Standard Deviation	11.8	208.2	248.8	30.6	57.4

Table E74. Total Suspended Solids ANOVA for all samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15.00	137.10	9.14	138.44
Buss Creek	16.00	1159.50	72.47	43362.11
Nursery Creek	16.00	2038.10	127.38	61883.85
Sapp Creek	16.00	276.80	17.30	936.66
Tired Creek	17.00	560.80	32.99	3299.36

Total Suspended Solids ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	150583.69	4.00	37645.92	1.71	0.16	2.49
Within Groups	1647467.23	75.00	21966.23			
Total	1798050.92	79.00				

Table E75. Total Suspended Solids concentration not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	2.40	2.00	9.60	2.00	5.60
11/20/12	4.50	6.00	32.00	2.00	4.70
12/24/12	2.40	5.50	32.00	4.40	12.00
1/21/13	3.60	4.80	2.00	2.80	7.20
3/21/13	12.00	2.00	9.70	5.60	20.00
4/22/13	10.00	7.60	15.00	5.60	20.00
5/23/13	4.40	3.40	2.00	2.30	6.80
6/24/13	8.50	15.00	39.00	9.00	29.00
7/23/13	4.60	10.00	8.00	9.80	11.00
8/19/13	5.20	10.00	10.00	15.00	14.00
9/24/13	4.6	4.8	7.6	2.3	9.4
10/22/13	2.0	3.4	6.2	10.0	5.6
11/25/13					3.5
Min	2.00	2.00	2.00	2.00	3.50
Max	12.00	15.00	39.00	15.00	29.00
Average	5.35	6.21	14.43	5.90	11.45
Median	4.55	5.15	9.65	5.00	9.40
Variance	10.02	14.88	159.23	17.53	56.86
Standard Deviation	3.17	3.86	12.62	4.19	7.54

Table E76. Total Suspended Solids ANOVA not including storm samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12.00	64.20	5.35	10.02
Buss Creek	12.00	74.50	6.21	14.88
Nursery Creek	12.00	173.10	14.43	159.23
Sapp Creek	12.00	70.80	5.90	17.53
Tired Creek	13.00	148.80	11.45	56.86

Total Suspended Solids ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	794.59	4.00	198.65	3.84	0.01	2.54
Within Groups	2900.53	56.00	51.80			
Total	3695.12	60.00				

Table E77. Total Suspended Solids Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-0.86	1			
Nursery Creek	**-9.08**	-8.22	1		
Sapp Creek	-0.55	0.31	8.53	1	
Tired Creek	-6.10	-5.24	2.98	-5.55	1
k	5		**95% +/- CL**		
S^2 Pool	51.80		8.88		
S pool	7.20				
V	56.00				
Q	4.36				

Table E78. Total Suspended Solids storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
1/31/13	6.90	13.00	25.00	4.00	2.00
2/22/13	49.00	140.00	660.00	120.00	130.00
6/6/13		840.00	430.00	56.00	60.00
11/26/13	17.0	92.0	750.0	26.0	220.0
Min	6.90	13.00	25.00	4.00	2.00
Max	49.00	840.00	750.00	120.00	220.00
Average	24.30	271.25	466.25	51.50	103.00
Median	17.00	116.00	545.00	41.00	95.00
Variance	483.07	146508.92	104689.58	2539.67	8822.67
Standard Deviation	21.98	382.76	323.56	50.40	93.93

Table E79. pH for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	6.03	6.30	7.70	6.96	7.55
11/20/12	6.01	6.77	7.94	6.63	7.15
12/24/12	6.40	6.73	7.81	6.54	7.04
1/21/13	6.36	6.87	8.05	7.01	6.96
1/31/13	6.92	7.05	8.09	7.02	7.16
2/22/13	6.33	7.35	7.93	6.65	7.15
3/21/13	6.37	6.63	8.09	6.87	6.89
4/22/13	6.45	6.97	7.85	6.76	6.99
5/23/13	6.17	6.75	7.30	7.00	6.82
6/24/13	5.91	6.50	7.17	6.32	6.25
7/23/13	6.41	6.58	7.10	7.05	7.06
8/19/13	6.01	6.12	6.83	6.28	6.26
9/24/13	6.3	6.74	7.38	6.73	6.78
10/22/13	6.25	6.8	7.52	6.73	7.1
11/25/13					7.14
11/26.13	6.38	6.62	7.48	6.75	6.95
Min	5.91	6.12	6.83	6.28	6.25
Max	6.92	7.35	8.09	7.05	7.55
Average	6.29	6.72	7.62	6.75	6.95
Median	6.33	6.74	7.70	6.75	7.02
Variance	0.06	0.09	0.16	0.06	0.11
Standard Deviation	1.59	1.70	1.94	1.70	1.72

Table E80. pH ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	94.30	6.29	0.06
Buss Creek	15	100.78	6.72	0.09
Nursery Creek	15	114.24	7.62	0.16
Sapp Creek	15	101.30	6.75	0.06
Tired Creek	16	111.25	6.95	0.11

pH ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.11	4.00	3.53	37.43	8.2E-17	2.50
Within Groups	6.69	71.00	0.09			
Total	20.80	75.00				

Table E81. pH Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	**-0.43**	1			
Nursery Creek	**-1.33**	**-0.90**	1		
Sapp Creek	**-0.47**	-0.03	**0.86**	1	
Tired Creek	**-0.67**	-0.23	**0.66**	-0.20	1
k	5		**95% +/- CL**		
S^2 Pool	0.094		0.33		
S pool	0.31				
V	71				
Q	4.2				

Table E82. pH not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	6.03	6.30	7.70	6.96	7.55
11/20/12	6.01	6.77	7.94	6.63	7.15
12/24/12	6.40	6.73	7.81	6.54	7.04
1/21/13	6.36	6.87	8.05	7.01	6.96
3/21/13	6.37	6.63	8.09	6.87	6.89
4/22/13	6.45	6.97	7.85	6.76	6.99
5/23/13	6.17	6.75	7.30	7.00	6.82
6/24/13	5.91	6.50	7.17	6.32	6.25
7/23/13	6.41	6.58	7.10	7.05	7.06
8/19/13	6.01	6.12	6.83	6.28	6.26
9/24/13	6.3	6.74	7.38	6.73	6.78
10/22/13	6.25	6.8	7.52	6.73	7.1
11/25/13					7.14
Min	5.91	6.12	6.83	6.28	6.25
Max	6.45	6.97	8.09	7.05	7.55
Average	6.22	6.65	7.56	6.74	6.92
Median	6.28	6.74	7.61	6.75	6.99
Variance	0.04	0.06	0.17	0.07	0.12
Standard Deviation	1.74	1.86	2.13	1.89	1.88

Table E83. pH ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	74.67	6.22	0.04
Buss Creek	12	79.76	6.65	0.06
Nursery Creek	12	90.74	7.56	0.17
Sapp Creek	12	80.88	6.74	0.07
Tired Creek	13	89.99	6.92	0.12

pH ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.46	4.00	2.86	31.48	9.6E-14	2.54
Within Groups	5.10	56.00	0.09			
Total	16.55	60.00				

Table E84. pH Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	**-0.42**	1.00			
Nursery Creek	**-1.34**	**-0.92**	1.00		
Sapp Creek	**-0.52**	-0.09	**0.82**	1.00	
Tired Creek	**-0.70**	-0.28	**0.64**	-0.18	1.00
k	5.00		**95% +/- CL**		
S^2 Pool	0.09		0.37		
S pool	0.30				
V	56.00				
Q	4.36				

Table E85. pH storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
1/31/13	6.92	7.05	8.09	7.02	7.16
2/22/13	6.33	7.35	7.93	6.65	7.15
11/26/13	6.38	6.62	7.48	6.75	6.95
Min	6.33	6.62	7.48	6.65	6.95
Max	6.92	7.35	8.09	7.02	7.16
Average	6.54	7.01	7.83	6.81	7.09
Median	6.38	7.05	7.93	6.75	7.15
Variance	0.11	0.13	0.10	0.04	0.01
Standard Deviation	0.33	0.37	0.32	0.19	0.12

Table E86. Specific Conductance for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	85.30	247.90	340.60	89.50	187.70
11/20/12	74.30	310.00	260.70	91.30	210.60
12/24/12	78.20	129.70	262.90	72.40	98.10
1/21/13	76.20	125.00	260.00	74.10	102.00
1/31/13	70.30	94.80	214.90	69.00	97.40
2/22/13	61.50	86.10	164.00	57.90	72.00
3/21/13	62.60	78.40	263.40	62.10	76.20
4/22/13	66.20	82.10	215.60	56.40	73.30
5/23/13	91.70	51.70	278.50	93.10	197.10
6/24/13	63.40	113.50	216.40	111.20	113.60
7/23/13	73.30	86.80	274.50	63.70	78.90
8/19/13	64.70	67.20	153.30	61.70	62.30
9/24/13	81.7	90.4	260.2	78.9	86.5
10/22/13	84.7	147.3	289.6	101.9	125
11/25/13					115
11/26.13	82.8	118.5	152.3	76.3	95.1
Min	61.5	51.7	152.3	56.4	62.3
Max	91.7	310	340.6	111.2	210.6
Average	74.46	121.96	240.46	77.30	111.93
Median	74.30	94.80	260.20	74.10	97.75
Variance	90.83	4835.14	2880.35	280.58	2150.81
Standard Deviation	20.77	73.77	79.39	25.21	52.47

Table E87. Specific Conductance ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	1116.90	74.46	90.83
Buss Creek	15	1829.40	121.96	4835.14
Nursery Creek	15	3606.90	240.46	2880.35
Sapp Creek	15	1159.50	77.30	280.58
Tired Creek	16	1790.80	111.93	2150.81

Specific Conductance ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	275282.65	4.00	68820.66	33.59	1.02E-15	2.50
Within Groups	145478.82	71.00	2049.00			
Total	420761.47	75.00				

Table E88. Specific Conductance Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-47.50	1			
Nursery Creek	**-166.00**	**-118.50**	1		
Sapp Creek	-2.84	44.66	**163.16**	1	
Tired Creek	-37.47	10.04	**128.54**	-34.63	1
k	5.00		**95% +/- CL**		
S^2 Pool	2049.00		48.31		
S pool	45.27				
V	71.00				
Q	4.20				

Table E89. Specific Conductance not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	85.30	247.90	340.60	89.50	187.70
11/20/12	74.30	310.00	260.70	91.30	210.60
12/24/12	78.20	129.70	262.90	72.40	98.10
1/21/13	76.20	125.00	260.00	74.10	102.00
3/21/13	62.60	78.40	263.40	62.10	76.20
4/22/13	66.20	82.10	215.60	56.40	73.30
5/23/13	91.70	51.70	278.50	93.10	197.10
6/24/13	63.40	113.50	216.40	111.20	113.60
7/23/13	73.30	86.80	274.50	63.70	78.90
8/19/13	64.70	67.20	153.30	61.70	62.30
9/24/13	81.7	90.4	260.2	78.9	86.5
10/22/13	84.7	147.3	289.6	101.9	125
11/25/13					115
Min	62.6	51.7	153.3	56.4	62.3
Max	91.7	310	340.6	111.2	210.6
Average	75.19	127.50	256.31	79.69	117.41
Median	75.25	101.95	261.80	76.50	102.00
Variance	91.86	5935.29	2094.47	310.29	2481.95
Standard Deviation	22.78	81.80	83.51	27.80	57.23

Table E90. Specific Conductance ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	902.30	75.19	91.86
Buss Creek	12	1530.00	127.50	5935.29
Nursery Creek	12	3075.70	256.31	2094.47
Sapp Creek	12	956.30	79.69	310.29
Tired Creek	13	1526.30	117.41	2481.95

Specific Conductance ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	259940.28	4.00	64985.07	29.70	2.88E-13	2.54
Within Groups	122534.30	56.00	2188.11			
Total	382474.58	60.00				

Table E91. Specific Conductance Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-52.31	1			
Nursery Creek	**-181.12**	**-128.81**	1		
Sapp Creek	-4.50	47.81	**176.62**	1	
Tired Creek	-42.22	10.09	**138.90**	-37.72	1
k	5		**95% +/- CL**		
S^2 Pool	2188.11		57.73		
S pool	46.78				
V	56.00				
Q	4.36				

Table E92. Specific Conductance storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	70.30	94.80	214.90	69.00	97.40
2/22/13	61.50	86.10	164.00	57.90	72.00
11/26/13	82.8	118.5	152.3	76.3	95.1
Min	61.50	86.10	152.30	57.90	72.00
Max	82.80	118.50	214.90	76.30	97.40
Average	71.53	99.80	177.07	67.73	88.17
Median	70.30	94.80	164.00	69.00	95.10
Variance	114.56	281.19	1107.74	85.84	197.34
Standard Deviation	10.70	16.77	33.28	9.27	14.05

Table E93. Water Temperature (°C) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	16.20	15.30	16.60	16.00	15.70
11/20/12	15.05	14.04	19.16	14.42	14.01
12/24/12	10.85	9.91	19.50	9.85	8.84
1/21/13	12.31	12.51	19.69	11.90	10.93
1/31/13	13.45	13.16	14.72	13.18	13.33
2/22/13	13.41	15.67	14.76	13.59	14.17
3/21/13	12.79	13.47	17.40	13.88	12.99
4/22/13	17.93	17.76	18.64	18.76	17.84
5/23/13	19.79	25.86	22.50	21.56	24.23
6/24/13	23.81	24.98	25.62	24.96	24.08
7/23/13	24.14	24.58	22.74	26.03	24.23
8/19/13	24.41	25.18	26.32	25.99	24.35
9/24/13	23.54	23.86	22.97	24.22	23.82
10/22/13	19.86	19.92	20.64	20.04	19.8
11/25/13					15.02
11/26.13	15.16	15.4	15.4	14.46	15.1
Min	10.85	9.91	14.72	9.85	8.84
Max	24.41	25.86	26.32	26.03	24.35
Average	17.51	18.11	19.78	17.92	17.40
Median	16.20	15.67	19.50	16.00	15.40
Variance	22.77	29.85	13.68	30.39	28.02
Standard Deviation	6.36	6.95	6.10	6.96	6.64

Table E94. Water Temperature (°C) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15.00	262.70	17.51	22.77
Buss Creek	15.00	271.60	18.11	29.85
Nursery Creek	15.00	296.66	19.78	13.68
Sapp Creek	15.00	268.84	17.92	30.39
Tired Creek	16.00	278.44	17.40	28.02

Water Temperature ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.53	4.00	13.88	0.56	0.70	2.50
Within Groups	1773.94	71.00	24.99			
Total	1829.47	75.00				

Table E95. Water Temperature (°C) ANOVA not including storm samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12.00	220.68	18.39	24.61
Buss Creek	12.00	227.37	18.95	33.79
Nursery Creek	12.00	251.78	20.98	9.47
Sapp Creek	12.00	227.61	18.97	32.64
Tired Creek	13.00	235.84	18.14	31.74

Water Temperature ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	60.92	4.00	15.23	0.57	0.68	2.54
Within Groups	1486.50	56.00	26.54			
Total	1547.42	60.00				

Table E96. Water Temperature (°C) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	16.20	15.30	16.60	16.00	15.70
11/20/12	15.05	14.04	19.16	14.42	14.01
12/24/12	10.85	9.91	19.50	9.85	8.84
1/21/13	12.31	12.51	19.69	11.90	10.93
3/21/13	12.79	13.47	17.40	13.88	12.99
4/22/13	17.93	17.76	18.64	18.76	17.84
5/23/13	19.79	25.86	22.50	21.56	24.23
6/24/13	23.81	24.98	25.62	24.96	24.08
7/23/13	24.14	24.58	22.74	26.03	24.23
8/19/13	24.41	25.18	26.32	25.99	24.35
9/24/13	23.54	23.86	22.97	24.22	23.82
10/22/13	19.86	19.92	20.64	20.04	19.8
11/25/13					15.02
Min	10.85	9.91	16.6	9.85	8.84
Max	24.41	25.86	26.32	26.03	24.35
Average	18.39	18.95	20.98	18.97	18.14
Median	18.86	18.84	20.17	19.40	17.84
Variance	24.61	33.79	9.47	32.64	31.74
Standard Deviation	6.97	7.65	6.52	7.59	7.27

Table E97. Water Temperature (°C) storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
1/31/13	13.45	13.16	14.72	13.18	13.33
2/22/13	13.41	15.67	14.76	13.59	14.17
11/26/13	15.16	15.4	15.4	14.46	15.1
Min	13.41	13.16	14.72	13.18	13.33
Max	15.16	15.67	15.40	14.46	15.10
Average	14.01	14.74	14.96	13.74	14.20
Median	13.45	15.40	14.76	13.59	14.17
Variance	1.00	1.90	0.15	0.43	0.78
Standard Deviation	1.00	1.38	0.38	0.65	0.89

Table E98. Dissolved Oxygen (mg/L) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	3.07	3.81	4.68	4.17	4.94
11/20/12	3.81	5.68	9.34	8.04	5.07
12/24/12	7.40	8.16	9.52	10.23	5.10
1/21/13	6.24	7.96	9.29	8.90	8.53
1/31/13	6.40	7.66	10.34	9.60	7.52
2/22/13	7.86	8.55	10.19	9.00	8.54
3/21/13	8.51	8.28	9.40	9.03	8.42
4/22/13	6.97	6.58	8.99	7.91	7.87
5/23/13	1.52	5.72	7.29	5.85	6.30
6/24/13	3.74	4.50	6.98	5.61	5.88
8/19/13	6.20	5.88	6.75	6.45	6.33
9/24/13	4.72	4.86	7.24	6.11	6.18
10/22/13	2.54	4.96	7.75	6.85	6.95
11/25/13					6.14
11/26.13	7.48	7.54	7.34	8.23	7.8
Min	1.52	3.81	4.68	4.17	4.94
Max	8.51	8.55	10.34	10.23	8.54
Average	5.46	6.44	8.22	7.57	6.77
Median	6.22	6.23	8.37	7.98	6.33
Variance	4.86	2.51	2.58	3.09	1.63
Standard Deviation	2.21	1.58	1.61	1.76	1.28

Table E99. Dissolved Oxygen (mg/L) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	3.07	3.81	4.68	4.17
Buss Creek	3.81	5.68	9.34	8.04
Nursery Creek	7.40	8.16	9.52	10.23
Sapp Creek	6.24	7.96	9.29	8.90
Tired Creek	6.40	7.66	10.34	9.60

Dissolved Oxygen ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62.93	4.00	15.73	5.40	0.0008	2.51
Within Groups	192.30	66.00	2.91			
Total	255.22	70.00				

Table E100. Dissolved Oxygen (mg/L) Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-0.98	1			
Nursery Creek	**-2.76**	-1.78	1		
Sapp Creek	**-2.11**	-1.13	0.65	1	
Tired Creek	-1.31	-0.33	1.45	0.80	1
k	5.00		**95% +/- CL**		
S^2 Pool	2.91		1.88		
S pool	1.71				
V	66.00				
Q	4.20				

Table E101. Dissolved Oxygen (mg/L) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	3.07	3.81	4.68	4.17	4.94
11/20/12	3.81	5.68	9.34	8.04	5.07
12/24/12	7.40	8.16	9.52	10.23	5.10
1/21/13	6.24	7.96	9.29	8.90	8.53
3/21/13	8.51	8.28	9.40	9.03	8.42
4/22/13	6.97	6.58	8.99	7.91	7.87
5/23/13	1.52	5.72	7.29	5.85	6.30
6/24/13	3.74	4.50	6.98	5.61	5.88
8/19/13	6.20	5.88	6.75	6.45	6.33
9/24/13	4.72	4.86	7.24	6.11	6.18
10/22/13	2.54	4.96	7.75	6.85	6.95
11/25/13					6.14
Min	1.52	3.81	4.68	4.17	4.94
Max	8.51	8.28	9.52	10.23	8.53
Average	4.97	6.04	7.93	7.20	6.48
Median	4.72	5.72	7.75	6.85	6.24
Variance	4.99	2.37	2.34	3.20	1.55
Standard Deviation	2.23	1.54	1.53	1.79	1.24

Table E102. Dissolved Oxygen (mg/L) ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	11	54.72	4.97	4.99
Buss Creek	11	66.39	6.04	2.37
Nursery Creek	11	87.23	7.93	2.34
Sapp Creek	11	79.15	7.20	3.20
Tired Creek	12	77.71	6.48	1.55

Dissolved Oxygen ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.77	4.00	13.94	4.87	0.002	2.55
Within Groups	146.01	51.00	2.86			
Total	201.78	55.00				

Table E103. Dissolved Oxygen (mg/L) Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-1.06	1			
Nursery Creek	**-2.96**	-1.89	1		
Sapp Creek	**-2.22**	-1.16	0.73	1	
Tired Creek	-1.50	-0.44	1.45	0.72	1
k	5.00		**95% +/- CL**		
S^2 Pool	2.86		2.18		
S pool	1.69				
V	51.00				
Q	4.36				

Table E104. Dissolved Oxygen (mg/L) storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	6.40	7.66	10.34	9.60	7.52
2/22/13	7.86	8.55	10.19	9.00	8.54
11/26/13	7.48	7.54	7.34	8.23	7.8
Min	6.40	7.54	7.34	8.23	7.52
Max	7.86	8.55	10.34	9.60	8.54
Average	7.25	7.92	9.29	8.94	7.95
Median	7.48	7.66	10.19	9.00	7.80
Variance	0.57	0.30	2.86	0.47	0.28
Standard Deviation	0.76	0.55	1.69	0.69	0.53

Table E105. Turbidity (NTU) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	7.89	5.83	9.36	4.80	6.20
11/20/12	7.76	3.68	10.80	5.20	7.93
12/24/12	8.03	9.97	23.60	6.01	14.20
1/21/13	7.75	8.40	6.78	7.61	10.10
1/31/13	9.92	11.80	41.00	9.60	30.30
2/22/13	46.10	163.00	240.00	58.70	89.70
3/21/13	18.90	13.70	10.80	13.70	21.30
4/22/13	14.70	15.00	15.70	13.80	23.40
5/23/13	7.01	5.94	5.12	6.02	9.45
6/24/13	13.50	20.10	40.10	19.90	35.30
7/23/13	9.68	6.95	11.40	7.80	13.20
8/19/13	12.40	11.80	18.00	14.60	19.10
9/24/13	9.2	9.5	9.1	7.9	11
10/22/13	11	5.5	8.6	7.7	8.8
11/25/13					9.09
11/26.13	19.8	63	251	27.1	275
Min	7.01	3.68	5.12	4.80	6.20
Max	46.10	163.00	251.00	58.70	275.00
Average	13.58	23.61	46.76	14.03	36.50
Median	9.92	9.97	11.40	7.90	13.70
Variance	96.85	1692.31	6635.97	190.72	4455.32
Standard Deviation	9.84	41.14	81.46	13.81	66.75

Table E106. Turbidity (NTU) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15.00	203.64	13.58	96.85
Buss Creek	15.00	354.17	23.61	1692.31
Nursery Creek	15.00	701.36	46.76	6635.97
Sapp Creek	15.00	210.44	14.03	190.72
Tired Creek	16.00	584.07	36.50	4455.32

Turbidity ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12699.45	4.00	3174.86	1.20	0.32	2.50
Within Groups	187451.64	71.00	2640.16			
Total	200151.09	75.00				

Table E107. Turbidity (NTU) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	7.89	5.83	9.36	4.80	6.20
11/20/12	7.76	3.68	10.80	5.20	7.93
12/24/12	8.03	9.97	23.60	6.01	14.20
1/21/13	7.75	8.40	6.78	7.61	10.10
3/21/13	18.90	13.70	10.80	13.70	21.30
4/22/13	14.70	15.00	15.70	13.80	23.40
5/23/13	7.01	5.94	5.12	6.02	9.45
6/24/13	13.50	20.10	40.10	19.90	35.30
7/23/13	9.68	6.95	11.40	7.80	13.20
8/19/13	12.40	11.80	18.00	14.60	19.10
9/24/13	9.2	9.5	9.1	7.9	11
10/22/13	11	5.5	8.6	7.7	8.8
11/25/13					9.09
Min	7.01	3.68	5.12	4.80	6.20
Max	18.90	20.10	40.10	19.90	35.30
Average	10.65	9.70	14.11	9.59	14.54
Median	9.44	8.95	10.80	7.75	11.00
Variance	13.03	22.64	93.18	22.49	67.66
Standard Deviation	3.61	4.76	9.65	4.74	8.23

Table E108. Turbidity (NTU) ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	127.82	10.65	13.03
Buss Creek	12	116.37	9.70	22.64
Nursery Creek	12	169.36	14.11	93.18
Sapp Creek	12	115.04	9.59	22.49
Tired Creek	13	189.07	14.54	67.66

Turbididty ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	289.67	4.00	72.42	1.64	0.18	2.54
Within Groups	2476.63	56.00	44.23			
Total	2766.30	60.00				

Table E109. Turbidity (NTU) storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	9.92	11.80	41.00	9.60	30.30
2/22/13	46.10	163.00	240.00	58.70	89.70
11/26/13	19.8	63	251	27.1	275
Min	9.92	11.80	41.00	9.60	30.30
Max	46.10	163.00	251.00	58.70	275.00
Average	25.27	79.27	177.33	31.80	131.67
Median	19.80	63.00	240.00	27.10	89.70
Variance	349.72	5913.81	13970.33	619.27	16290.42
Standard Deviation	18.70	76.90	118.20	24.89	127.63

Table E110. Hardness (mg/L) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	80	60	180	60	120
11/20/12	80	140	160	40	120
12/24/12	40	120	140	40	40
1/21/13	60	80	160	40	60
1/31/13	60	80	120	40	60
2/22/13	60	60	100	40	40
3/21/13	60	60	160	60	40
4/22/13	40	60	180	40	60
5/23/13	50	100	160	40	100
6/24/13	40	60	120	40	60
7/23/13	40	60	160	40	50
8/19/13	40	40	80	40	40
9/24/13	40	60	160	40	60
10/22/13	40	80	160	60	80
11/25/13					40
11/26.13	30	60	80	40	40
Min	30	40	80	40	40
Max	80	140	180	60	120
Average	51	75	141	44	63
Median	40	60	160	40	60
Variance	235	712	1112	69	770
Standard Deviation	15	27	33	8	28

Table E111. Hardness (mg/L) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	760.00	50.67	235.24
Buss Creek	15	1120.00	74.67	712.38
Nursery Creek	15	2120.00	141.33	1112.38
Sapp Creek	15	660.00	44.00	68.57
Tired Creek	16	1010.00	63.13	769.58

Hardness ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	91544.41	4.00	22886.10	39.30	2.54E-17	2.50
Within Groups	41343.75	71.00	582.31			
Total	132888.16	75.00				

Table E112. Hardness (mg/L) Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1.00				
Buss Creek	-24.00	1			
Nursery Creek	**-90.67**	**-66.67**	1		
Sapp Creek	6.67	**30.67**	**97.33**	1	
Tired Creek	-12.46	11.54	**78.21**	-19.13	1
k	5.00		**95% +/- CL**		
S^2 Pool	582.31		25.76		
S pool	24.13				
V	71.00				
Q	4.20				

Table E113. Hardness (mg/L) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	80	60	180	60	120
11/20/12	80	140	160	40	120
12/24/12	40	120	140	40	40
1/21/13	60	80	160	40	60
3/21/13	60	60	160	60	40
4/22/13	40	60	180	40	60
5/23/13	50	100	160	40	100
6/24/13	40	60	120	40	60
7/23/13	40	60	160	40	50
8/19/13	40	40	80	40	40
9/24/13	40	60	160	40	60
10/22/13	40	80	160	60	80
11/25/13					40
Min	40	40	80	40	40
Max	80	140	180	60	120
Average	51	77	152	45	67
Median	40	60	160	40	60
Variance	245	861	761	82	856
Standard Deviation	16	29	28	9	29

Table E114. Hardness (mg/L) ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	610.00	50.83	244.70
Buss Creek	12	920.00	76.67	860.61
Nursery Creek	12	1820.00	151.67	760.61
Sapp Creek	12	540.00	45.00	81.82
Tired Creek	13	870.00	66.92	856.41

Hardness ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	88662.01	4.00	22165.50	39.15	1.29E-15	2.54
Within Groups	31701.92	56.00	566.11			
Total	120363.93	60.00				

Table E115. Hardness (mg/L) Tukey test not including storm samples

Difference in Means

	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-25.83	1			
Nursery Creek	**-100.83**	**-75.00**	1		
Sapp Creek	5.83	**31.67**	**106.67**	1	
Tired Creek	-16.09	9.74	**84.74**	-21.92	1
k	5.00		**95% +/- CL**		
S^2 Pool	566.11		29.36		
S pool	23.79				
V	56.00				
Q	4.36				

Table E116. Hardness (mg/L) storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	60	80	120	40	60
2/22/13	60	60	100	40	40
11/26/13	30	60	80	40	40
Min	30	60	80	40	40
Max	60	80	120	40	60
Average	50	67	100	40	47
Median	60	60	100	40	40
Variance	300	133	400	0	133
Standard Deviation	17	12	20	0	12

Table E117. Alkalinity (mg/L) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	25	100	195	35	75
11/20/12	30	60	140	40	80
12/24/12	20	40	120	20	40
1/21/13	20	30	140	25	30
1/31/13	20	25	85	25	30
2/22/13	15	30	80	20	30
3/21/13	15	15	125	20	25
4/22/13	15	25	120	20	30
5/23/13	30	55	120	40	50
6/24/13	20	40	100	30	40
7/23/13	20	25	130	25	30
8/19/13	20	20	60	25	40
9/24/13	30	30	125	35	30
10/22/13	25	45	120	30	40
11/25/13					40
11/26.13	25	50	80	30	30
Min	15	15	60	20	25
Max	30	100	195	40	80
Average	22	39	116	28	40
Median	20	30	120	25	35
Variance	28	453	1054	49	257
Standard Deviation	5	21	32	7	16

Table E118. Alkalinity (mg/L) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	330	22.00	27.86
Buss Creek	15	590	39.33	453.10
Nursery Creek	15	1740	116.00	1054.29
Sapp Creek	15	420	28.00	49.29
Tired Creek	16	640	40.00	256.67

Alkalinity ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	87582.46	4.00	21895.61	59.72	5.45E-22	2.50
Within Groups	26033.33	71.00	366.67			
Total	113615.79	75.00				

Table E119. Alkalinity (mg/L) Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-17.33	1			
Nursery Creek	**-94.00**	**-76.67**	1		
Sapp Creek	-6.00	11.33	**88.00**	1	
Tired Creek	-18.00	-0.67	**76.00**	-12.00	1
k	5.00		**95% +/- CL**		
S^2 Pool	366.67		20.44		
S pool	19.15				
V	71.00				
Q	4.20				

Table E120. Alkalinity (mg/L) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	25	100	195	35	75
11/20/12	30	60	140	40	80
12/24/12	20	40	120	20	40
1/21/13	20	30	140	25	30
3/21/13	15	15	125	20	25
4/22/13	15	25	120	20	30
5/23/13	30	55	120	40	50
6/24/13	20	40	100	30	40
7/23/13	20	25	130	25	30
8/19/13	20	20	60	25	40
9/24/13	30	30	125	35	30
10/22/13	25	45	120	30	40
11/25/13					40
Min	15	15	60	20	25
Max	30	100	195	40	80
Average	23	40	125	29	42
Median	20	35	123	28	40
Variance	30	538	938	55	290
Standard Deviation	5	23	31	7	17

Table E121. Alkalinity (mg/L) ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	270.00	22.50	29.55
Buss Creek	12	485.00	40.42	538.45
Nursery Creek	12	1495.00	124.58	938.45
Sapp Creek	12	345.00	28.75	55.11
Tired Creek	13	550.00	42.31	290.06

Alkalinity ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	82969.20	4.00	20742.30	56.23	5.74E-19	2.54
Within Groups	20657.85	56.00	368.89			
Total	103627.05	60.00				

Table E122. Alkalinity (mg/L) Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-17.92	1			
Nursery Creek	**-102.08**	**-84.17**	1		
Sapp Creek	-6.25	11.67	**95.83**	1	
Tired Creek	-19.81	-1.89	**82.28**	-13.56	1
k	5.00		**95% +/- CL**		
S^2 Pool	368.89		23.70		
S pool	19.21				
V	56.00				
Q	4.36				

Table E123. Alkalinity (mg/L) storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	20	25	85	25	30
2/22/13	15	30	80	20	30
11/26/13	25	50	80	30	30
Min	15	25	80	20	30
Max	25	50	85	30	30
Average	20	35	82	25	30
Median	20	30	80	25	30
Variance	25	175	8	25	0
Standard Deviation	5	13	3	5	0

Table E124. Air Temperature (°F) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	65.00	66.00	66.00	67.00	70.00
11/20/12	61.00	62.00	62.00	67.00	67.00
12/24/12	62.00	60.00	60.00	60.00	58.00
1/21/13	57.00	59.00	59.00	60.00	53.00
1/31/13	45.00	44.00	44.00	44.00	42.00
2/22/13	64.00	64.00	64.00	64.00	65.00
3/21/13	49.00	52.00	53.00	54.00	48.00
4/22/13	63.00	65.00	65.00	66.00	62.00
5/23/13	80.00	83.00	85.00	80.00	81.00
6/24/13	82.00	88.00	85.00	83.00	80.00
7/23/13	80.00	81.00	81.00	84.00	78.00
8/19/13	86.00	86.00	86.00	88.00	81.00
9/24/13	78	79	79	81	77
10/22/13	69	69	68	67	70
11/25/13					60
11/26.13	67	65	65	68	68
Min	45.00	44.00	44.00	44.00	42.00
Max	86.00	88.00	86.00	88.00	81.00
Average	67.20	68.20	68.13	68.87	66.25
Median	65.00	65.00	65.00	67.00	67.50
Variance	146.17	163.60	157.98	150.41	142.20
Standard Deviation	12.09	12.79	12.57	12.26	11.92

Table E125. Air Temperature (°F) ANOVA for all samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	1008.00	67.20	146.17
Buss Creek	15	1023.00	68.20	163.60
Nursery Creek	15	1022.00	68.13	157.98
Sapp Creek	15	1033.00	68.87	150.41
Tired Creek	16	1060.00	66.25	142.20

Air Temperature ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	64.36	4.00	16.09	0.11	0.98	2.50
Within Groups	10787.27	71.00	151.93			
Total	10851.63	75.00				

Table E126. Stage (ft.) for all samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	1.05	1.55	0.31	0.32	2.79
11/20/12	1.05	1.51	0.47	0.40	3.68
12/24/12	1.25	1.65	0.87	0.48	2.93
1/21/13	1.88	1.85	0.74	0.45	2.35
1/31/13	1.93	2.32	0.61	0.63	3.35
2/22/13	3.88	2.50	1.78	1.10	3.91
3/21/13	2.39	2.53	0.77	0.75	3.46
4/22/13	2.13	2.11	0.54	3.90	3.24
5/23/13	1.50	1.53	0.41	0.17	1.48
6/6/13		1.99	1.05	0.70	2.05
6/24/13	1.86	1.87	0.56	0.45	2.30
7/23/13	2.19	2.20	0.32	1.12	3.30
8/19/13	3.32	3.13	0.20	1.75	5.37
9/24/13	1.79	1.97	0.13	0.42	2.37
10/22/13	1.48	1.65	0.26	0.25	1.80
11/25/13					2.53
11/26.13	2.62	3.14	1.10	1.20	3.15
Min	1.05	1.51	0.13	0.17	1.48
Max	3.88	3.14	1.78	3.90	5.37
Average	2.02	2.09	0.63	0.88	2.94
Median	1.88	1.98	0.55	0.56	2.93
Variance	0.63	0.27	0.18	0.83	0.85
Standard Deviation	0.79	0.52	0.42	0.91	0.92

Table E127. Stage (ft.) ANOVA for all samples

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	15	30.32	2.02	0.63
Buss Creek	16	33.50	2.09	0.27
Nursery Creek	16	10.12	0.63	0.18
Sapp Creek	16	14.09	0.88	0.83
Tired Creek	17	50.06	2.94	0.85

Stage ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	59	4.00	14.82	26.74	8.45E-14	2.49
Within Groups	42	75.00	0.55			
Total	101	79.00				

Table E128. Stage (ft.) Tukey test for all samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-0.07	1			
Nursery Creek	**1.39**	**1.46**	1		
Sapp Creek	**1.14**	**1.21**	-0.25	1	
Tired Creek	**-0.92**	**-0.85**	**-2.31**	**-2.06**	1
k	5.00		**95% +/- CL**		
S^2 Pool	0.55		0.78		
S pool	0.74				
V	75.00				
Q	4.20				

Table E129. Stage (ft.) not including storm samples

Date	Black Creek	Buss Creek	Nursery Creek	Sapp Creek	Tired Creek
10/22/12	1.05	1.55	0.31	0.32	2.79
11/20/12	1.05	1.51	0.47	0.40	3.68
12/24/12	1.25	1.65	0.87	0.48	2.93
1/21/13	1.88	1.85	0.74	0.45	2.35
3/21/13	2.39	2.53	0.77	0.75	3.46
4/22/13	2.13	2.11	0.54	3.90	3.24
5/23/13	1.50	1.53	0.41	0.17	1.48
6/24/13	1.86	1.87	0.56	0.45	2.30
7/23/13	2.19	2.20	0.32	1.12	3.30
8/19/13	3.32	3.13	0.20	1.75	5.37
9/24/13	1.79	1.97	0.13	0.42	2.37
10/22/13	1.48	1.65	0.26	0.25	1.80
11/25/13					2.53
Min	1.05	1.51	0.13	0.17	1.48
Max	3.32	3.13	0.87	3.90	5.37
Average	1.82	1.96	0.47	0.87	2.89
Median	1.83	1.86	0.44	0.45	2.79
Variance	0.41	0.23	0.06	1.10	0.97
Standard Deviation	0.64	0.48	0.24	1.05	0.98

Table E130. Stage (ft.) ANOVA not including storm samples

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Black Creek	12	21.89	1.82	0.41
Buss Creek	12	23.55	1.96	0.23
Nursery Creek	12	5.58	0.47	0.06
Sapp Creek	12	10.46	0.87	1.10
Tired Creek	13	37.60	2.89	0.97

Stage ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	45.67	4.00	11.42	20.31	2.21E-10	2.54
Within Groups	31.47	56.00	0.56			
Total	77.14	60.00				

Table E131. Stage (ft.) Tukey test not including storm samples

Difference in Means					
	Black Creek	*Buss Creek*	*Nursery Creek*	*Sapp Creek*	*Tired Creek*
Black Creek	1				
Buss Creek	-0.14	1			
Nursery Creek	**1.36**	**1.50**	1		
Sapp Creek	**0.95**	**1.09**	-0.41	1	
Tired Creek	**-1.07**	**-0.93**	**-2.43**	**-2.02**	1
k	5		**95% +/- CL**		
S^2 Pool	0.56		0.93		
S pool	0.75				
V	56				
Q	4.36				

Table E132. Stage (ft.) storm samples

Date	**Black Creek**	**Buss Creek**	**Nursery Creek**	**Sapp Creek**	**Tired Creek**
1/31/13	1.93	2.32	0.61	0.63	3.35
2/22/13	3.88	2.50	1.78	1.10	3.91
6/6/13		1.99	1.05	0.70	2.05
11/26/13	2.62	3.14	1.10	1.20	3.15
Min	1.93	1.99	0.61	0.63	2.05
Max	3.88	3.14	1.78	1.20	3.91
Average	2.81	2.49	1.14	0.91	3.12
Median	2.62	2.41	1.08	0.90	3.25
Variance	0.98	0.23	0.23	0.08	0.61
Standard Deviation	0.99	0.48	0.48	0.28	0.78

Table E133. Correlation matrix for all creeks and parameters

	Fe	*Mn*	*FC*	*TN*	*TKN*	*TP*	*TSS*	*TON*	*NH4*	*pH*	*SC*	*WT(M)*	*WT(E)*	*DO*	*Turb*	*Hd*	*Alk*	*AT*	*Stage*
Fe	1.00																		
Mn	0.34	1.00																	
FC	0.36	0.10	1.00																
TN	-0.21	-0.13	-0.08	1.00															
TKN	0.06	0.08	-0.10	**0.59**	1.00														
TP	0.34	0.01	0.07	0.04	0.29	1.00													
TSS	0.41	0.04	**0.59**	0.06	0.22	0.28	1.00												
TON	-0.25	-0.16	-0.07	**0.98**	0.43	-0.02	0.01	1.00											
NH4	-0.22	-0.07	-0.12	**0.57**	0.29	0.00	-0.05	**0.56**	1.00										
pH	-0.28	-0.42	0.12	0.19	-0.10	0.10	0.25	0.23	0.12	1.00									
SC	**-0.54**	-0.33	-0.06	**0.61**	0.17	-0.08	0.03	**0.65**	**0.45**	0.62	1.00								
WT(M)	-0.27	-0.09	-0.20	0.00	0.07	-0.15	-0.13	-0.01	0.01	-0.19	0.06	1.00							
WT(E)	-0.27	-0.09	-0.20	0.00	0.07	-0.15	-0.13	-0.01	0.01	-0.19	0.06	1.00	1.00						
DO	0.05	-0.39	0.20	-0.22	-0.16	0.23	0.23	-0.21	-0.21	**0.49**	0.05	-0.37	-0.37	1.00					
Turb	**0.66**	0.01	**0.55**	-0.08	-0.02	0.25	**0.87**	-0.09	-0.12	0.22	-0.04	-0.16	-0.16	0.27	1.00				
Hd	**-0.57**	-0.32	-0.08	**0.52**	0.10	-0.08	0.01	**0.56**	0.41	**0.66**	**0.89**	0.08	0.08	0.10	-0.08	1.00			
Alk	**-0.55**	-0.35	0.00	**0.51**	0.02	-0.07	0.09	**0.57**	0.39	**0.68**	**0.92**	0.14	0.14	0.08	0.01	**0.89**	1.00		
AT	-0.17	0.03	-0.13	0.04	0.03	-0.15	-0.06	0.04	0.06	-0.34	0.01	**0.85**	**0.85**	**-0.51**	-0.08	-0.03	0.06	1.00	
Stage	0.27	-0.03	-0.02	-0.17	0.09	0.21	0.01	-0.22	-0.12	-0.23	-0.43	-0.11	-0.11	-0.04	0.15	-0.42	-0.43	-0.05	1.00

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