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Relationship between Land Use and Surface Water Quality in a Rapidly Developing Watershed in Southeast Louisiana

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Relationship between Land Use and Surface Water Quality in a Rapidly Developing Watershed in Southeast Louisiana

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ABSTRACT

The Tangipahoa River and Natalbany River watersheds (Tangipahoa Parish/County) in the Lake Pontchartrain Basin (southeastern Louisiana) are experiencing rapid urbanization, particularly in the wake of the 2005 hurricane season. To document the impact of land use on water quality, thirty sites were monitored for surface water physiochemical, geochemical, and bacteriological parameters. Water quality data was compared to land use within four sub-watersheds of the Tangipahoa Watershed and three sub-watersheds of the Natalbany Watershed. Urbanization had the most profound impact on water quality of all land uses. In watersheds with little urban land cover (< 7% with the sub-watershed) waterbodies had low dissolved salt, nutrient, and fecal coliform concentrations and high dissolved oxygen levels. Waterbodies within the urban region (> 28% urban land cover within the sub-watershed) of the parish had significantly greater dissolved salt, nutrient, and fecal coliform concentrations and decreased dissolved oxygen concentrations. Specifically, nutrient and fecal coliform concentrations increased as streams flowed through urban areas. The specific conductance, fecal coliform counts, concentrations of sulfate, HCO_3-C, sodium, and nutrients (NO_3-N, NO_2-N, NH_4-N, and PO_4-P), and the ratios of Na:Cl, Cl:Br, and SO_4:Cl were shown to be the parameters most indicative of urban impacts. Many of the geochemical parameters correlated significantly with each other, particularly within the urban streams (the streams with the greatest concentrations). While fecal coliform counts were high within the urban streams, programs to address malfunctioning wastewater treatment plants (WWTP) appear to be working, with fecal coliform counts declining and dissolved oxygen levels rising during the course of the data collection. In contrast, sites undergoing rapid development showed an increase in turbidity levels and a decrease on dissolved oxygen levels (both going from healthy to unhealthy levels) during the 18-month course of the data collection. By understanding the impacts of urbanization on streams of the Gulf Coast, local and regional municipalities may be able to reduce the impacts in already urbanized areas or mitigate the impacts at the outset of development

KEYWORDS

Surface water, water quality, water geochemistry, fecal coliform, urbanization, wastewater

CHAPTER 1: INTRODUCTION

The impacts of different types of land use on water quality have come to the forefront of water quality restoration since the passage of the Clean Water Act in 1972. The need to clean the nations waterways lead to investigations of pollution sources entering the waterways. "Point sources" such as municipal wastewater treatment plants (WWTPs), industrial plants, and other large discharges were targeted first by water quality clean-up efforts. However, after a few decades of addressing pollution inputs into waterways, it became obvious that not all pollution was accounted for within the large sources. While the large dischargers were being corrected, water quality was sill impaired. The so-called "non-point sources" include the cumulative impacts of agriculture, urbanization, and development within a watershed and can account for much if not most pollution within a watershed (EPA, 2008). Non-point sources, however, can be more difficult to track and correct because they include many diffuse land uses that may encompass much of a watershed.

To fulfill requirements of the Clean Water Act, the Louisiana Department of Environmental Quality (LDEQ) releases a list of "impaired waterbodies" for the State of Louisiana, called the Integrated (305b and 303d) Report every two years. The 2006 Integrated Report lists many Louisiana waterways as being impaired for primary contact recreation (29% of rivers) and/or for wildlife and fish propagation (69% of rivers; LDEQ, 2006). Two of the most ubiquitous contaminants are fecal coliform (an indicator for enteric pathogens), which can impair waters for recreational use and contaminate shellfish, and nutrients, which can cause algae blooms, resulting in low dissolved oxygen and fish kills. The need to track down and correct the sources of pollution has become the key to addressing the problem. The use of Geographic Information Systems (GIS) has become an important tool in correlating water quality impairments to the land use within the watershed.

Since 2002 the Lake Pontchartrain Basin Foundation (LPBF), an environmental non-profit organization, has targeted watersheds of the Pontchartrain Basin in southeast Louisiana to track down and correct pollution sources entering the waterways. In 2002 to 2005, the LPBF piloted a program to target the Bogue Falaya and Tchefuncte watershed in St. Tammany Parish for intensive water quality monitoring and assistance to WWTPs. The LPBF assisted approximately 250 WWTPs, ranging in size from small individual plants (500 gallons per day-gpd) to municipal plants (> 1,000,000 gpd). This led to fecal coliform reductions on eight waterways within the watershed (Bourgeois-Calvin et al., 2004). In 2005, the LPBF brought the program to the Tangipahoa and Natalbany watersheds in neighboring Tangipahoa Parish. This study is part of that program.

1.1 The Pontchartrain Basin

The Pontchartrain Basin is a 25,900 km^2 (10,000 mi^2) estuarine ecosystem in southeast Louisiana that encompasses sixteen parishes east of the Mississippi River in Louisiana and four counties in Mississippi. At its center is Lake Pontchartrain, a 1,632 km^2 (630 mi^2) inland bay. Sister lakes Maurepas and Borne flank Lake Pontchartrain to the west and the east, respectively. Six major rivers on Lake Pontchartrain's north shore, twelve municipal storm water canals and bayous on its south shore, and the occasional flood stage diversion of the Mississippi River via the Bonnet Carré Spillway, deliver freshwater to the Lake. Saltwater, from the Gulf of Mexico, is exchanged with the system through two natural inlets, the Chef Menteur and Rigolets passes, and through the artificial Mississippi River Gulf Outlet. The Basin is bordered to the west by artificial levees that hold the Mississippi River, and to the east by the Pearl River watershed, which acts as the Louisiana-Mississippi state line (Houck, 1989). The Basin's topography ranges from rolling woodlands in the north to coastal marshes in the south. Included in the Pontchartrain Basin are the urban areas of the Greater New Orleans Metropolitan Area (GNOMA, on Lake Pontchartrain's south shore) and Baton Rouge Metropolitan Area (BRMA, in the northwestern portion of the basin). Outside of these urban areas, development has been occurring rapidly in St. Tammany Parish north of Lake Pontchartrain (stemming from the GNOMA) and Ascension, Iberville, and Livingston parishes (stemming from the BRMA). Between St. Tammany and Livingston parishes lies Tangipahoa Parish, which is beginning to feel the pressure of development from its neighboring parishes (Figure 1).

Figure 1. The Pontchartrain Basin in Southeast Louisiana consists of sixteen Louisiana parishes (counties) east of the Mississippi River. The Greater New Orleans Metropolitan Area is on Lake Pontchartrain's south shore and the Baton Rouge Metropolitan Area is in the northwestern portion of the basin. Parishes around these urban areas are experiencing rapid growth.

1.2 Tangipahoa and Natalbany Watersheds

Tangipahoa Parish is comprised of two watersheds, the larger Tangipahoa watershed to the east and the smaller Natalbany watershed (a tributary of the Tickfaw watershed) to the west. The Tangipahoa River Watershed is one of the largest watersheds in the Pontchartrain Basin. The Tangipahoa River is 98.1 kilometers long and its 2,010 km^2 watershed covers most of Tangipahoa Parish. The Natalbany River (80.7 km long, watershed is 367.4 km^2) is the largest tributary of the Tickfaw River, adjoining the Tangipahoa watershed to the west (Figure 2). The surface waters in these watersheds are characterized by low dissolved salt contents which increase in the vicinity of Lake Pontchartrain due to mixing with the brackish lake waters and locally in sites contaminated by pollutants (this study).

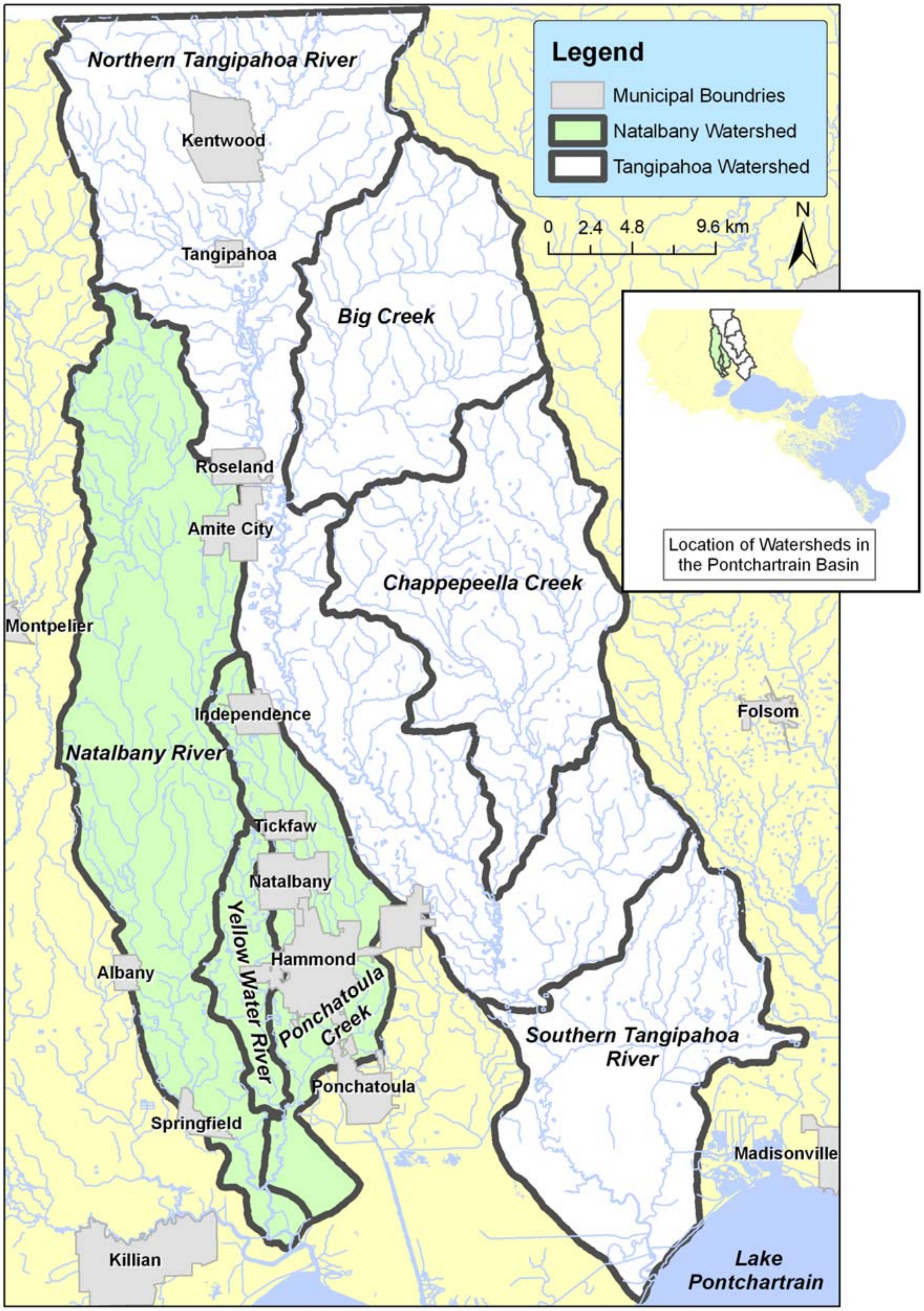


Figure 2. Tangipahoa and Natalbany Watersheds (divided into sub-watersheds with municipalities indicated in gray), located in the Lake Pontchartrain Basin, Southeast Louisiana

The Tangipahoa Watershed is located on the eroded surfaces of the Upper Pleistocene High Terrace and Prairie Terrace Formations (in the upstream ¾ of the watershed) and the Holocene Mississippi alluvium in the downstream watershed (Nymann and Fayard, 1978; Penland et al., 2002; Figure 3).

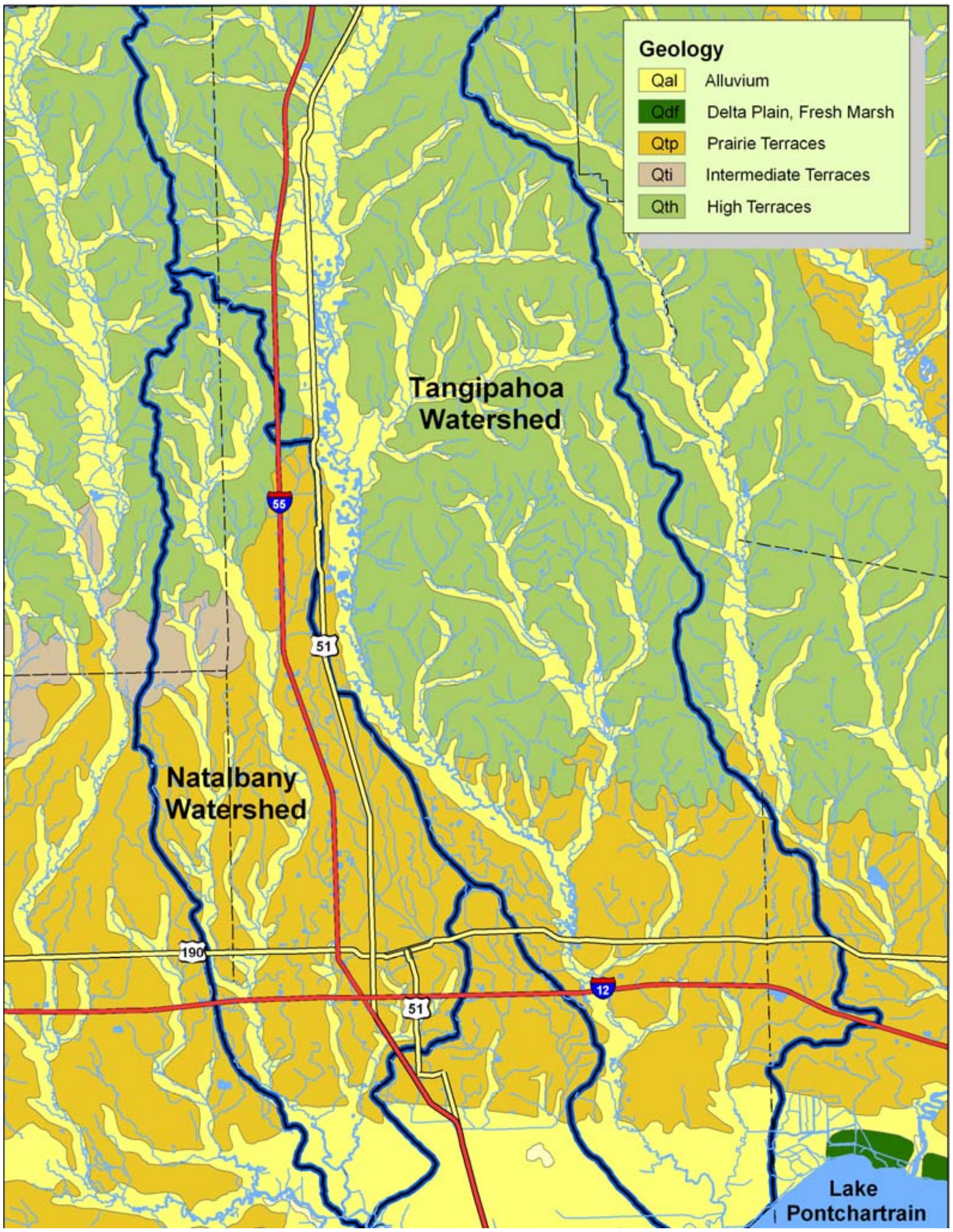


Figure 3. Geology of the Tangipahoa and Natalbany Watersheds- watersheds are predominantly located on Pleistocene-aged terraces with Holocene-aged fill from the Mississippi River in the southern portions of the watersheds.

Upper reaches of the watershed (terraces) are characterized by upland forests and agricultural/grass lands and the lower reaches (alluvium) include wetlands such as bottomland-hardwood forests, swamps, and fresh to brackish water marshes (based on a 2006 land classification obtained from the Pontchartrain Institute of Environmental Studies, PIES). The Parish's more developed/urban areas are located in the southern portion of the watersheds (Figure 4). The Louisiana Department of Wildlife and Fisheries has designated the middle and upper reaches of the Tangipahoa River (north of Interstate 12) as a scenic river through the Louisiana Natural and Scenic Rivers system (as per the "Louisiana Scenic Rivers Act" Acts 1988, No. 947, §1) meaning that the waterway is unique, of ecological significance, and should be preserved for the future.

The mean annual discharge of the Tangipahoa River is 1.2 ± 0.07 km^3, ranging from 0.4 km^3 to 1.9 km^3 and the mean monthly discharge is 0.09 ± 0.005 km^3, ranging from 0.05 km^3 to 0.16 km^3. The monthly discharge is highest in the months January through April, corresponding with the wet season for the area. Lowest discharges are found in the months August through November, corresponding with the dry season (Saksa et al., 2006). The high flow periods discharge about three times more than low flow periods (Saksa et al., 2006).

The Natalbany River is the major tributary of the Tickfaw River, the watershed to the west of the Tangipahoa. The watershed drains the southwestern portion of the parish, occurring in the same geologic setting as the Tangipahoa watershed. Based on 63 years of USGS stream gauge records at Baptist, LA, the median flow of the Natalbany River is 1.2 m^3/sec or 0.04 km^3 annually (USGS, 2007). However, this flow is prior to the inflow of its two largest tributaries, the Yellow Water River and Ponchatoula Creek.

Historically, recreational activity occurred on the Tangipahoa River, including swimming, fishing, boating, and tubing. Water quality on the river became a high-profile issue in 1988 when the Louisiana Department of Health and Hospitals (LDHH) posted swimming advisories along the river due to high fecal coliform counts (LDHH, 2008). Since that time the river has become a model for the importance of cleaning waterways, however it still remains on the Impaired Waterbodies List (Bourgeois-Calvin, 2006).

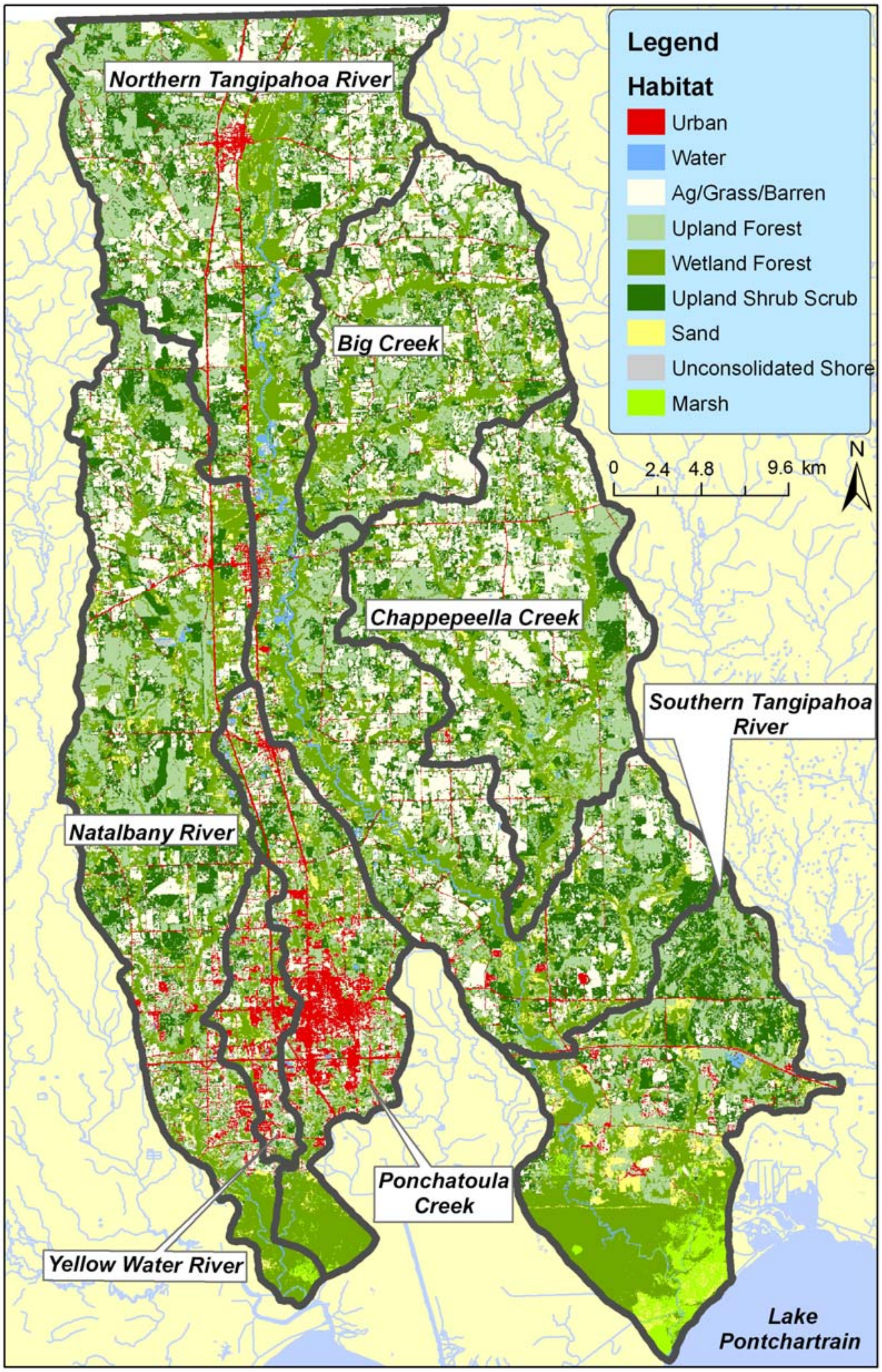


Figure 4. Land Use within the Tangipahoa and Natalbany Watersheds. Land use consists mostly of forests and agriculture with a growing urban footprint in the southern portions of the Natalbany and Tangipahoa watersheds.

The Tangipahoa River and its major tributary Big Creek are included on the 2006 Impaired Waterbodies (303d) List (LDEQ, 2006) for fecal coliform and mercury (Appendix A). These impairments impact “primary contact recreation” (i.e., swimming) and “fish and wildlife propagation” stream uses according to the list. The section of the Tangipahoa River (extending from Interstate 12 north to the state line) listed as impaired is also denoted as a scenic stream and an outstanding natural resource. However, Tangipahoa Parish’s largest population center, the cities of Hammond and Ponchatoula, occur in the Natalbany Watershed (Figure 2- municipal boundaries, Figure 4- “urban” land use on southern end of map) so it has experienced severe pressures of urbanization and development. Consequently, the Natalbany and its two tributaries, the Yellow Water River and Ponchatoula Creek, are also on the 2006 Impaired Waterbodies (303d) List for fecal coliform, mercury, total dissolved solids, lead, and nitrates/nitrites. These impairments impact “primary contact recreation”, “secondary contact recreation” (i.e., boating), and “fish and wildlife propagation” water uses (Appendix A).

According to the Impaired Waterbodies List, the fecal pollution derives from three sources: dairy farms and municipal and individual/on-site WWTPs. Tangipahoa Parish’s nine municipal WWTPs discharge into these watersheds. Outside of the municipalities there are various methods of treating wastewater. Businesses treat their sewage with individual WWTPs or connect to small wastewater plants, subdivisions and trailer parks treat sewage with small community plants, and houses/trailers have individual aerated or septic wastewater systems with discharges running to ditches and eventually to the rivers. The majority of the small, individual WWTPs are not properly operated, releasing fecal bacteria into the environment, due to a lack of knowledge of the owner/operator (Bourgeois-Calvin et al., 2004). In addition, there are approximately 135 dairy farms in the parish, the greatest concentration in Louisiana. More than eighty of those dairies have participated in a joint NRCS and LSU Agriculture Center program to construct and cleanout or decommission waste lagoons (Figure 5).

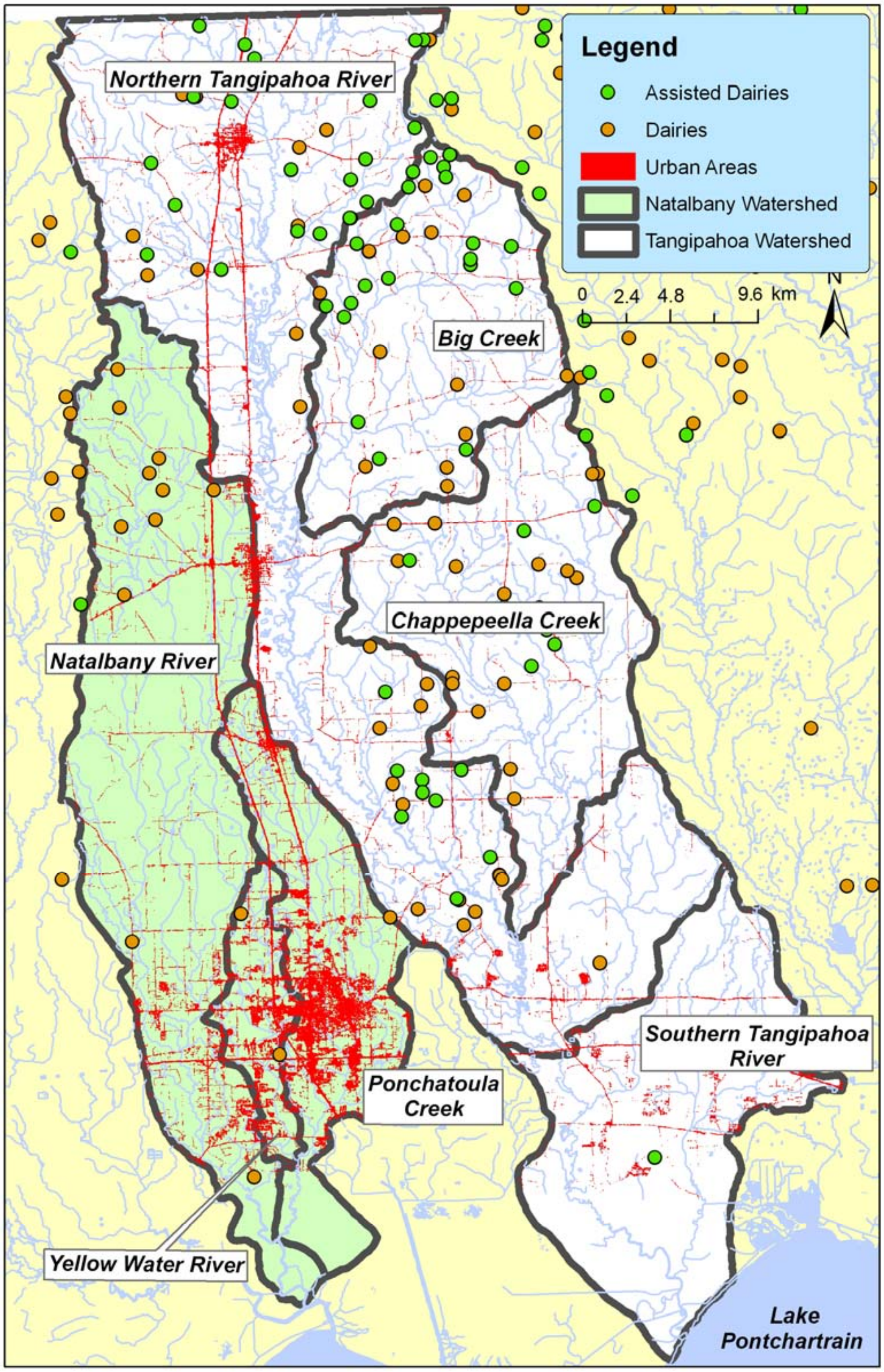


Figure 5. Locations of Urban Areas and Dairies in Tangipahoa and Natalbany Watersheds. The central and northern portions of the watersheds show predominant dairy and agricultural land use. Many of the dairies have been assisted by federal programs to construct and maintain waste lagoons. The southern portions of the watersheds show increasing urban land use.

In addition to the current stresses on the watersheds, Tangipahoa Parish is situated between two of the fastest growing parishes in the state, St. Tammany Parish to the east and Livingston Parish to the west, experiencing sprawl from the GNOMA and the BRMA, respectively. While Tangipahoa is a mostly rural parish with dairy, crop farming, and timber as its economic staples, the parish is beginning to feel the impacts of sprawl, with development spreading from municipalities including Hammond, Ponchatoula, and Amite (Figure 2). According to the 2000 census, Tangipahoa Parish's population grew over 17% in the 1990's (USBC, 2000). People displaced by Hurricane Katrina in 2005 exacerbated the rapid growth, increasing the population 6.6% within one year (from 106,152 prior to Katrina to 113,137 one year following Katrina: US Census Bureau, 2007) and growth is continuing. The rapid development and conversion of land from agricultural to urban usage is very likely to negatively impact the Parish's waterways. Urban waste waters and industrial pollutants are expected to further increase fecal, nutrient, suspended solids, sulfate, heavy metal, and chloride concentrations (Manahan, 1999; Paul, 2001).

Tangipahoa Parish officials have begun to understand the need to mitigate damages to the environment and address rapid development and urban sprawl. The Parish has completed its first land use planning effort. In addition to the rapid growth and land use planning occurring in Tangipahoa Parish, the Pontchartrain Basin is undergoing the TMDL (Total Maximum Daily Loads) program through 2011. In the EPA-driven, federally mandated program, the State of Louisiana must identify all of its impaired waterways (through the Impaired Waterbodies/303d list). Once identified, the streams are sampled for their current conditions and the watershed is modeled to determine the maximum load of a pollutant that a stream can handle to improve or retain its water quality. To reduce the pollutant load, the current dischargers into the stream may have tighter limits imposed on their discharge. And, further development in the stream's watershed may be postponed or halted based on the condition of the stream (EPA-OWOW, 2008).

1.3 Problem Statement

This research is designed to analyze water quality characteristics (physiochemical, bacteriological, and geochemical) to create a water quality "signature" for urbanized areas as compared to rural (dairy-influenced) and developing areas in the Tangipahoa and Natalbany

Watersheds. The signature will differentiate the Tangipahoa and Natalbany watersheds in terms of quality characteristics through analysis of data collected for this research and historic data. Then, the watersheds will be divided into their sub-watersheds and land use will be compared to water quality data, through GIS and statistical correlations. GIS will be used to quantify urbanization, as impervious cover, that will be used to correlate water quality with land use.

A review of previous research on the impacts of land use on water quality reveals that much of the work has been performed along the Atlantic Coast (Correll et al., 1992; Mallin et al., 2000; Roman et al., 2000- Chapter 2 below). Due to the unique geology of the Mississippi Delta region and the rapid development in formerly rural areas of southeast Louisiana, a study of land use impacts of water quality is warranted in the Pontchartrain Basin.

1.4 Research Objectives

The objectives of this research study are listed below:

1) Describe the streams and watersheds:

- Characterize the Tangipahoa and Natalbany watersheds (river and tributaries, land use patterns, etc), using data collected in the project and historic data;
- Obtain average values and long-term trends for the enteric pathogen indicator fecal coliform, dissolved geochemical data (especially nutrients and inorganic constituents), and physiochemical data;
- Compare parameters among sites utilizing statistical analysis (including Wilcoxon / Kruskal-Wallis Rank Sums tests, Spearman's Rho, and linear regression) among physiochemical parameters, geochemical parameters, and enteric pathogen indicators for each site.

2) Analyze water quality parameters in relation to land use:

- Utilize all of the data above plus data on land use to quantify the relationship between land use, particularly percent "urban" land cover, and water quality;
- Develop water quality "signatures" related to percentage of "urban" land cover in these watersheds;
- Test application of 10% rule in these watersheds.

3) Assess improvement, using water quality data, particularly fecal coliform and dissolved oxygen, as a result of LPBF program.

- Analyze bi-weekly water quality data collected since 2005 by LPBF for fecal coliform and other parameters;
- Compare early data to later data (utilizing linear regression), after assistance to WWTPs/dairies for improvements;
- Quantify assistance to WWTPs and water quality improvements.

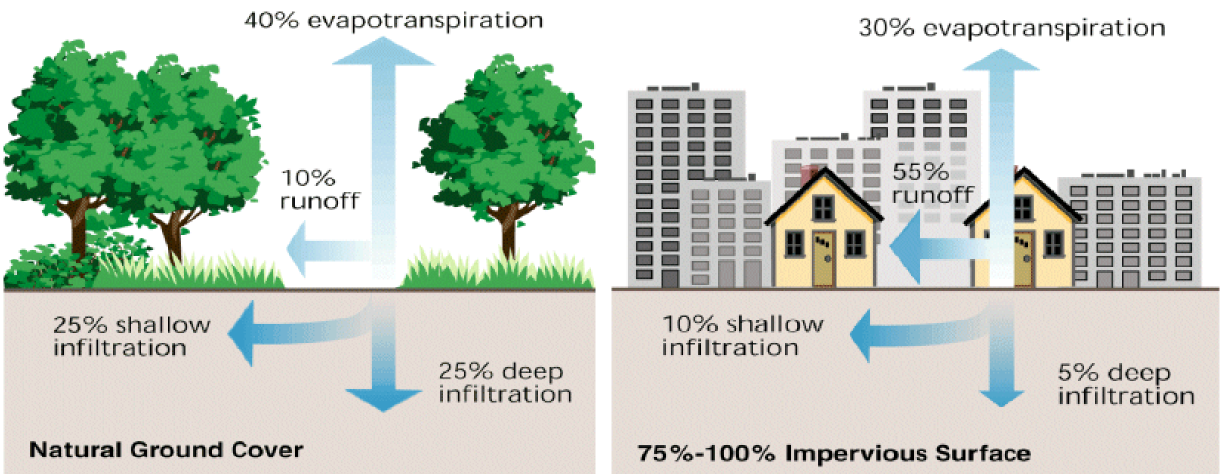
CHAPTER 2: REVIEW OF PREVIOUS RESEARCH

2.1 Urbanization Impacts

In the United States, urbanization is second only to agriculture as a source of stream impairment, yet urbanization has a much smaller footprint (Paul and Meyer, 2001). A strong characteristic of urbanization is impervious surfaces (including cement, roofs, etc) that do not allow rainwater to percolate through the soil. The hard, straight surfaces speed stormwater from the land into the waterbody, resulting in rapid, high volume flows that lead to increased stream bank erosion. In addition, the water commonly contains increased sediments (that wash off the land and into the stream), human fecal pollution (due to failing wastewater treatment and collection systems), metals and hydrocarbons, and nutrients (especially nitrogen and phosphorus, due to fecal pollution and the use of fertilizer) that cause increased algal production and increase oxygen demand (Center for Watershed Protection, 2006; Paul, 2001; Allan, 2004; Hasse et al., 2003). Calcium, sodium, potassium, magnesium, chloride, and sulfate concentrations are generally elevated in urban streams from wastewater pollutants (Manahan, 1999; Paul, 2001).

2.2 Impervious Cover and Stream Degradation

A number of studies throughout the United States focus on water quality degradation through development and urbanization. The 10% rule has become the standard for the relationship between development and water quality. A combination of many studies on different aspects of watershed ecology converge on the fact that if greater than 10% of a watershed is covered by impervious surfaces, the water ecosystem will begin to suffer (Brabec 2000; Beach, 2002; Center for Watershed Protection, 2006). As impervious coverage increases, so does the damage to the waterway. Impervious cover of 10-20% yields a 2-fold increase in runoff, 35-50% impervious cover increases runoff three-fold, and 75-100% impervious cover increases runoff 5 fold over forested areas (Paul et al., 2001; Figure 6). Forests, wetlands, and grassy areas can mitigate the impacts of such flows, but only to a certain point. As impervious surface coverage increases, mitigation becomes less useful and the ecosystem eventually becomes non-functioning (Center for Watersheds Protection, 2006). Brabec et al. (2002) proposed a ranking system where a stream can be characterized as “protected” with less than 10% impervious cover, 10-30% impervious cover characterized as “impacted”- the point at which degradation first occurs, and greater than 30% impervious cover characterized as "degraded"- where stream degradation becomes severe. Such a ranking system can help unify stream impact analysis.



Images: http://www.fairfaxcounty.gov/parks/accotink/impervious.htm

Figure 6. Land Use and Water Flow. As impervious cover increases in a watershed, more surface runoff is funneled straight to waterways and does not infiltrate into groundwater.

2.3 Correlation of Water Quality and Land Use

Much of the research utilizing GIS to relate water quality to land use and demographics in watersheds has been conducted on the Atlantic coast. These studies generally show a consistent theme of greatly increased nutrient and fecal levels with increased urbanization.

Mallin et al. (2000) examined how enteric pathogen indicators related to water quality, demographics, and land use throughout a system of coastal creeks in North Carolina. Water quality was monitored monthly for physiochemical parameters and enteric pathogen indicators (fecal coliform and *Escherichia coli*) on 5 waterways for a period of four years. Yearly geometric means for fecal coliform were utilized in correlations (Pearson correlation) with land use factors. The results showed bacteria counts decreased away from upstream sites (the source) and that both fecal coliform and *E.coli* values were inversely correlated with salinity. Turbidity correlated strongly with enteric pathogen indicators as did nitrate concentrations. Orthophosphate correlated weakly. Of the land use and demographic factors, fecal coliform levels significantly correlated with population and strongly with percent developed land within a watershed. The strongest correlation however was between fecal coliform and the percent impervious surface within a watershed.

Correll et al. (1992) examined the effect of land use on nutrient transport to coastal waters in Maryland. The region was divided into sub-watersheds by dominant land use. Total nitrogen, dissolved ammonium, nitrate, total phosphate, and orthophosphate were measured, and the ratios calculated for total nitrogen to total phosphate. Differences between watersheds were found to be due primarily to differences in land use and topography. The upper estuary acted as a sink for nutrients, retaining most of the ammonium and phosphate entering the system. Correll et al. (1992) hypothesized this was because the upper estuary streams were smaller and had greater contact with the stream bed. Lower in the estuary, where the streams were larger, the cumulative inputs of nutrients coupled with the streams larger size, caused the streams not to attenuate the nutrients and act as a nutrient source. Discharges from all land use types had large seasonal variations due to differences in evapotranspiration rates. Discharges also varied greatly between years due to precipitation.

Roman et al. (2000) found urbanized estuaries in the northeastern United States, including New York/ New Jersey Harbor, yielded an annual total nitrogen load of 1,560 kg/year/km, 3.8 times more than less urbanized estuaries (410 kg/yr/km). About 65% of the nitrogen from the urban areas came from municipal wastewater discharge and agricultural runoff represented less than 10% of the nitrogen load. Phosphorus loading followed similar patterns, in urbanized areas almost 90% of phosphorus loading came from wastewater treatment discharge; whereas, 59% of phosphorus loading came from wastewater treatment in less urbanized areas.

Brett et al. (2005) compared nutrient and sediment concentrations in 17 streams of the Sammamish and Lake Washington watersheds in Washington State with land uses ranging from forest-dominated to urban. They hypothesized that loss of forested cover due to urbanization minimized the uptake and recycling of nutrients, particularly in a humid climate. Monthly grab samples were collected for nutrients and sediment load (irrespective of weather conditions) throughout a ten-year period and analyzed with geometric means. Seven land cover categories (forest, grass/shrub/crop, water, bare soil, urban forest, urban grassy, and urban paved) were classified for land use utilizing a Landsat image. Soluble reactive phosphorus and total phosphorus concentrations and turbidity correlated moderately or strongly positively with percent urban and negatively with forested land cover. Total nitrogen was weakly correlated with land cover and NO_3, NH_4, organic nitrogen, and total suspended solids were not significantly correlated with land use. Regression analyses showed urban streams experienced 95% higher total phosphorus and 122% higher soluble reactive phosphorus than forest-dominated streams. Urban areas generated two to three times more phosphorus than forested areas. The streams also had 71% higher turbidity. Urbanization also increased total nitrogen (44%) in the streams, but increases in NO_3 and NH_4 were not statistically significant. The study supports the 10% rule, showing that a 10% conversion of land to impervious surface will result in increases in phosphorus and nitrogen components and turbidity/suspended solids.

CHAPTER 3: MATERIALS AND METHODS

3.1 Water Monitoring

Thirty sites within the Tangipahoa and Natalbany Watersheds (Figure 7) were sampled in this study. Of the sites, 10 were located along the Tangipahoa River, 10 were located on seven tributaries of the Tangipahoa River, and 10 were located in the Natalbany Watershed (4 on the Natalbany River, 4 on Ponchatoula Creek, and 2 on the Yellow Water River). The sites were each sampled 10 times from June 2006 – June 2007. The sample dates were June 12 (Tangipahoa River only), July 17-18, September 18-19, October 23-24, and November 13-14, 2006 and January 22-23, February 26-27, March 22-23, April 16-24, May 21-22, and June 25-26, 2007. On each date, the sites were generally sampled for all physiochemical, bacteriological, and geochemical parameters.

Physiochemical Parameters: LPBF established 30 test sites along the lengths of the Tangipahoa and Natalbany Rivers and their tributaries (Figure 7). The sites were monitored bi-weekly for the parameters of water temperature (ºC), dissolved oxygen (mg/L), specific conductance (µS/cm), turbidity (NTU), and pH (during part of the study). For this study, monthly measurements of these parameters corresponding to the collection of geochemical data (described below) were utilized. The physiochemical parameters were monitored *in situ* at each site. Beyond these basic measurements a suite of other analytical laboratory methods were employed in this study (Table 1).

Geochemical Parameters and Analysis: Once per month a grab sample of 120 ml volume was collected from each of the monitoring sites (Figure 7). On the day of collection the samples were filtered through Whatman 42 ashless filter paper at the University of New Orleans Geochemical Laboratory for Water Analyses and stored in a refrigerator until analyzed. The analyzed cations included SiO_2-Si, Na, Li, NH_4-N, K, Mg, and Ca, and Sr. The analyzed anions included HCO_3-C, Br, F, Cl, NO_3-N, NO_2-N, PO_4-P and SO_4. SiO_2-Si was measured with a VIS (visible light) spectrophotometer utilizing the Molybdate Blue colorimetric method. Alkalinity was expressed as HCO_3-C and measured with an alkalinity pH titration (Table 1). An ion chromatograph was used to analyze the remaining anions and cations. Typically, the cation analyses were performed the day of collection. If not, those samples were acidified with a drop of reagent hydrochloric acid to lower the pH (to retain the ammonium ion until analyzed). The anion samples were typically run later in the same week. The reported precision for the ion chromatograph analyses were for undiluted samples, i.e., samples with concentrations falling within the range of the standards used in the analyses. The precision of diluted samples can be estimated by multiplying the values given below by the dilution factor used to place the concentrations within the range of the standards. The precision values are the best estimate of accuracies.

The following standard concentrations were utilized in the analysis of cations and anions:

Cation Standards (in mg/l):

Li	0.25	1.25	2.5	
Na	0.8	4	8	
NH_4	0.25	1.25	2.5	
K	1	5	10	
Mg	0.5	2.5	5	
Ca	1	5	10	
Sr	1	5	10	
SiO_2	1	2	3	4

Anion Standards (in mg/l):

F	0.25	1.25	2.5
Cl	0.8	4	8
Br	0.25	1.25	2.5
NO_2	0.25	1.25	2.5
NO_3	1	5	10
PO_4	1	5	10
SO_4	1	5	10

Molecular concentrations were converted from elemental concentrations by multiplying with the following fractions:

NH_4 to NH_4-N	mol wt N (14.007)/mol wt NH_4 (18.039) = 0.7765
NO_2 to NO_2-N	mol wt N (14.007)/mol wt NO_2 (46.005) = 0.3045
NO_3 to NO_3-N	mol wt N (14.007)/mol wt NO_3 (62.004) = 0.2259
PO_4 to PO_4-P	mol wt P (30.974)/mol wt PO_4 (94.9716) = 0.3261
SiO_2 to SiO_2-Si	mol wt Si (28.09)/mol wt SiO_2 (60.0888) = 0.4675

To eliminate zero concentrations in analyzing data, component concentrations reading below detection limits were assigned a value equal to one half the detection limits. The detection limit was one half of the precision, which was 1/10 of the lowest analytical standard for each component. Hence, concentrations below detection were assigned a value of 1/40 of the lowest standard.

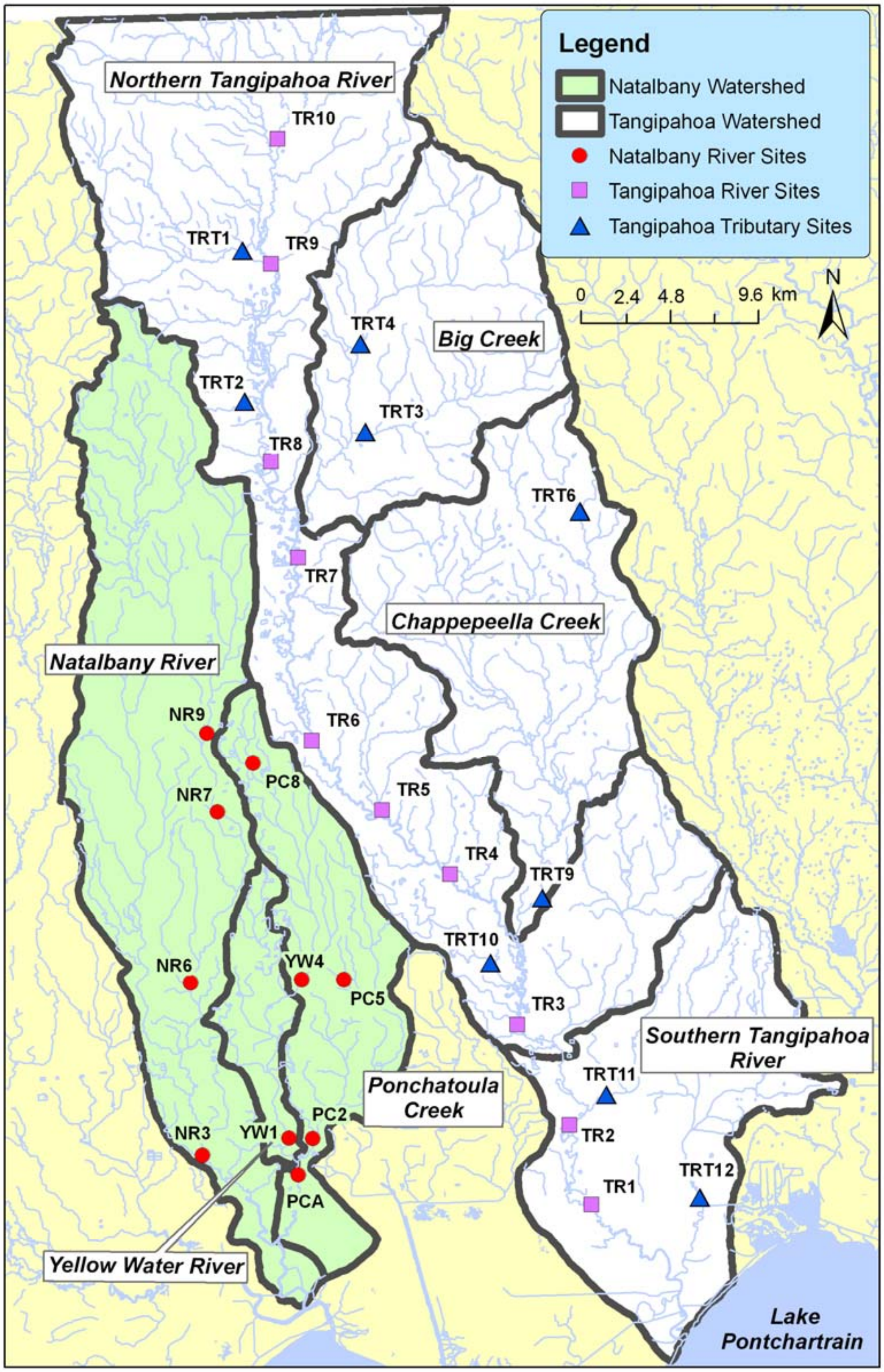


Figure 7. Water Quality Monitoring Sites- sites sampled ten times for physiochemical and geochemical parameters, June 2006-June 2007, and bi-weekly for bacteriological parameters, January 2005-June 2007.

Parameter	Method	Equipment & Precision
Dissolved Oxygen	Standard Methods for Examination of Water and Wastewater, 20th Ed. method 4500-OG	YSI85 S-C-DO-T Meter 0-20mg/L range, 0.3mg/L precision
Temperature	Standard Methods for Examination of Water and Wastewater, 20th Ed. method 2550B	YSI85 S-C-DO-T Meter -5 to +65°C range, 0.1°C precision
Specific Conductance	Standard Methods for Examination of Water and Wastewater, 20th Ed. method 2510B	YSI85 S-C-DO-T Meter 0 to 4999 µS/cm range, ± 0.5% precision
pH	Standard Methods for Examination of Water and Wastewater, 20th Ed. method 4500-H^+B	YSI 60 pH Meter 0 to 14.00 range, 0.1pH precision
Turbidity	Standard Methods for Examination of Water and Wastewater, 20th Ed. method 2130 B	Hach Portable Turbidimeter 0 to 1000 NTU range, 0.01 NTU precision
Alkalinity	Standard Methods for Examination of Water and Wastewater, 20th Ed method 2320 B	pH 4.5 Titration using 0.01N NCl 0.2 mg/l HCO_3-C precision
Anions	Standard Methods for Examination of Water and Wastewater, 20th Ed (1998) method 4110 B	Dionex IC-1000 Ion Chromatograph
		Precision
Nitrate-N		0.02 mg/l as NO3-N within 0.02 - 2.3 mg/l
Nitrite-N		0.01 mg/l as NO2-N within 0.01 - 0.8 mg/l
Phosphate-P		0.03 mg/l as PO4-P within 0.03 - 3.3 mg/l
Fluoride-F		0.02 mg/l F within 0.025 - 2.5 mg/l
Chloride-Cl		0.08 mg/l Cl within 0.08 - 8 mg/l
Bromide-Br		0.02 mg/l Br within 0.02 - 2.5 mg/l
Sulfate-SO4		0.1 mg/l SO4 within 0.1 - 10 mg/lMH4-N
Cations	American Society for Testing and Materials (ASTM) Method D 6919-03 (EPA Approved 3/12/07)	Dionex IC-1000 Ion Chromatograph
		Precision
Ammonium-N		0.02 mg/l NH4-N within 0.02 - 2 mg/l
Lithium		0.02 mg/l Li within 0.02 - 2 mg/l
Sodium		0.08 mg/l Na within 0.08 - 8 mg/l
Potassium		0.1 mg/l K within 0.1 - 10 mg/l
Magnesium		0.05 mg/l Mg within 0.05 - 5 mg/l
Calcium		0.1 mg/l Ca within 0.1 - 10 mg/l
Strontium		0.1 mg/l Sr within 0.1 - 10 mg/l
Silicon	Colorimetric, Molybdate Blue USGS Method I-1700-85 (EPA approved)	Turner 100 UV-VIS spectrograph 0.02 mg/l SiO2-Si precision

Table 1: Description of methods, instruments, and precision for physiochemical and geochemical analyses.

Bacteriological Analysis: Grab samples of 120 ml volume were taken at each site, during monitoring, to be analyzed for the enteric pathogen indicators fecal coliform and *E.coli*. Samples were collected in sterile, single-use vessels and transported to an EPA-approved laboratory within six hours of collection, in accordance with *Standard Methods for the Examination of Water and Wastewater* (1998) Methods 1060C and 9060B. The lab employed the Multiple Tube Fermentation Technique for fecal coliform and *E.coli* analyses in accordance with Standard Methods 9221E (Fecal Coliform Procedure) and 9221 F (*Escherichia coli* Procedure), respectively.

3.2 Statistical Analysis

Distribution analysis of initial results showed the data were not normally distributed; therefore, nonparametric statistics were utilized in the analysis of the water quality data. The Kruskal-Wallis test was used to assess variability among sites ($\alpha = 0.05$) for multiple populations, and the Wicoxon Rank Sum test was utilized for two populations ($\alpha = 0.05$). Spearman's Rho was utilized to assess significance in correlations ($\alpha = 0.05$). These analyses are typically used on surface water data (Gilbert, 1987). To assess the change in parameters from urbanization and over time, linear regression was used.

The data by site was generally presented in quantiles, representing the median (center line), 25% and 75% (box), and maximum and minimum values (bars) (Figure 8). Outliers were sometimes not included with quantiles.

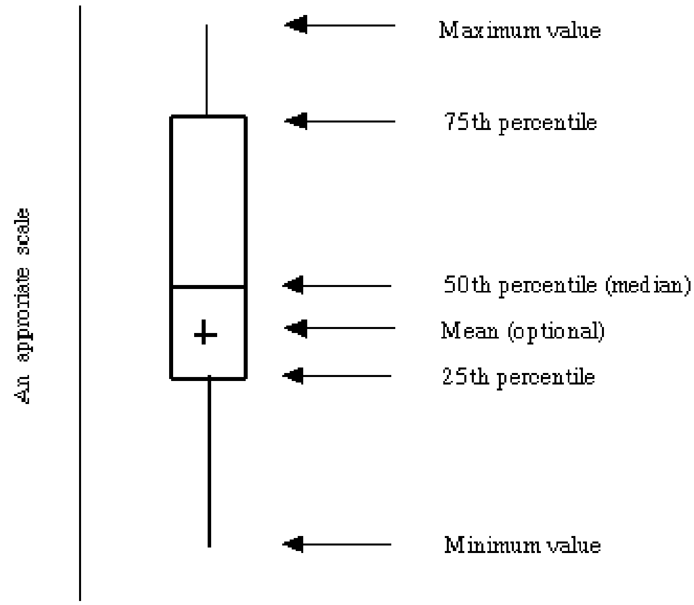


Figure 8. Quantiles were used to represent the data collected at each site. The quantiles show the median (line in box), 75% (upper end of box), 25% (lower end of box), minimum value (lower end of line) and maximum value (upper end of line) data points.

3.3 GIS Mapping/Analysis

The primary program utilized in the viewing and creation of GIS themes was ArcDesktop 9.1 (with Spatial Analysts extension- ESRI, 2006). A land use classification obtained from the University of New Orleans Pontchartrain Institute for Environmental Studies was utilized to determine "urbanization" or developed land (defined as impervious cover and associated vegetation disturbance). Additional data sources were obtained from the Natural Resource Conservation Service and the Louisiana Department of Health and Hospitals (dairy data). Wastewater treatment plant data collected by the Lake Pontchartrain Basin Foundation was utilized in the WWTP analyses.

CHAPTER 4: RESULTS

4.1 Physiochemical Data

The temperature (°C), dissolved oxygen (D.O. in mg/l), specific conductance (µS/cm), and turbidity (NTU) were compared among the sites using the Kruskal-Wallis Nonparametric Test (Appendix C).

Temperature: No significant temperature difference was seen among the sites ($\alpha = 0.5302$, Appendix C). Temperature patterns for all sites followed the typical yearly distributions, indicating that there were no large sources of warm/hot water (as in water used to cool machinery) entering the system. Typical of the region, water temperatures reached lows of around 11°C in January and highs of over 30°C in August. The high summer water temperatures corresponded with low D.O. values (parameter correlations below), especially in the slow moving streams and streams affected by urbanization.

Dissolved Oxygen: Significant differences were seen among the sites ($\alpha = <0.0001$) for dissolved oxygen (D.O.) concentrations. While all Tangipahoa River (TR) and Natalbany River (NR) sites had high dissolved oxygen concentrations, sites on Ponchatoula Creek (PC2 and PCA), Yellow Water River (YW1), and some of Tangipahoa's tributaries (TRT1, TRT2, TRT10, TRT11, TRT12) had low concentrations (Figure 9). The low D.O. values sometimes extended below 5 mg/l (especially in summer), considered the minimum level for healthy water (LDEQ, 2006). Of the low D.O. sites, TRT1, TRT2, YW1, YW4, PC2, and PCA correspond to other indicators of anthropogenic pollution (see below). However, sites YW1, PCA, and PC2 (Figure 7) are also located in a swampy environment (Figure 4) which can have a low D.O. concentration. Sites TRT10, TRT11, and TRT12 are located in the downstream portion of the watershed (Figure 7) in the relatively swampy, anaerobic bottomland-hardwood forests (Figure 4), but this area is also developing rapidly. The low concentrations probably reflect the anaerobic environment but could be affected by development.

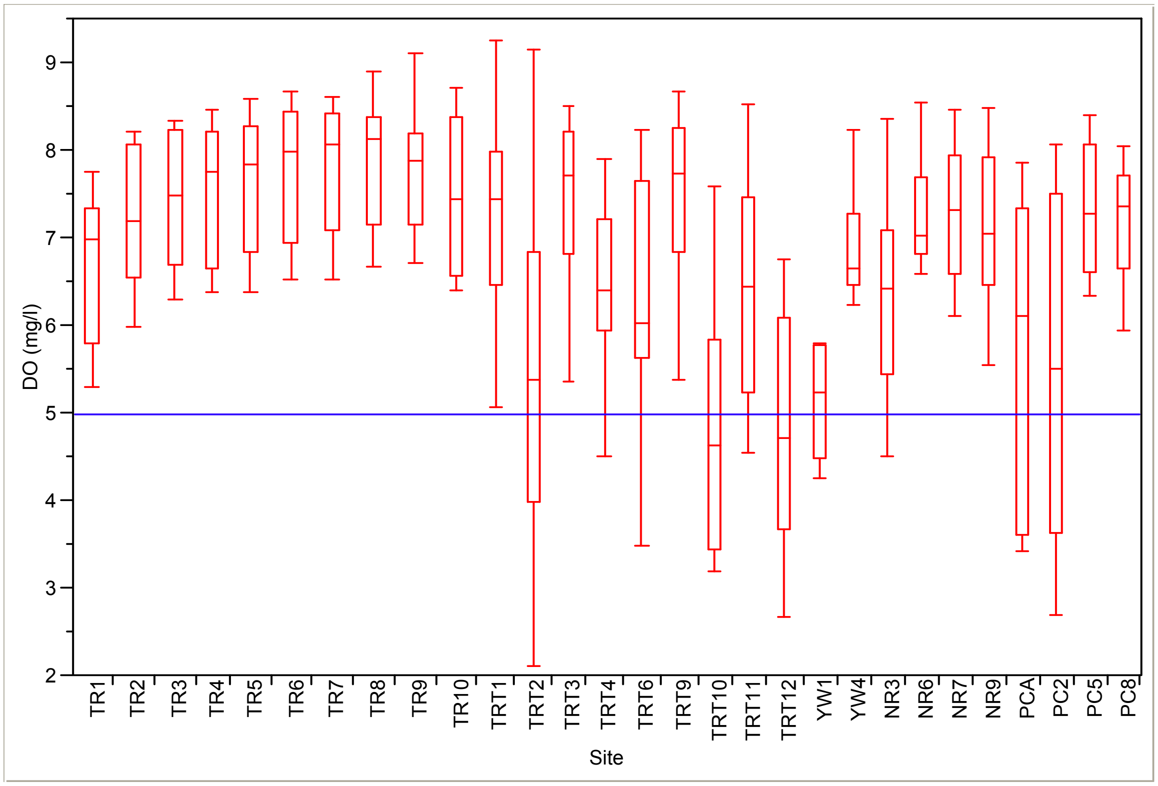


Figure 9. Dissolved Oxygen (mg/l) Quantiles By Site- 10 Samples, June 2006-June 2007. Most sites exceeded the state D.O. limit of 5 mg/l. Sites on Ponchatoula Creek (PCA and PC2), Fluker/ Carpenter Branch (TRT2), Skull's Creek (TRT10), and Bedico Creek (TRT12) had low D.O. and occur in urban or developing areas.

Specific Conductance: Specific conductance varied significantly among the sites ($\alpha = <0.0001$), serving to indicate differences in the "background" source waters of the two watersheds, pollution at some sites, and saltwater influence from the Pontchartrain estuary. The Tangipahoa River (TR) and its northern tributaries (TRT1, TRT3, TRT4, TRT6, and TRT9) had low background specific conductance (Figure 10). At the southernmost Tangipahoa tributary site, TRT12, high specific conductance was due to mixing with the Pontchartrain Estuary. Site TRT2 had exceptionally high specific conductance compared to other TRT sites not influenced by marine water. This site shows both high fecal coliform counts and salt concentrations (tds, Figures 12 and 29 below), indicative of anthropogenic pollution sources. Sites within the Natalbany watershed (NR, PC, and YW sites) had an overall higher specific conductance level, indicative of a different background source water than the Tangipahoa watershed. However, sites YW1, YW4, PCA, and PC2 in the urban area show higher specific conductance (generally increasing the downstream direction, Figure 10) in conjunction with geochemical parameters (see below).

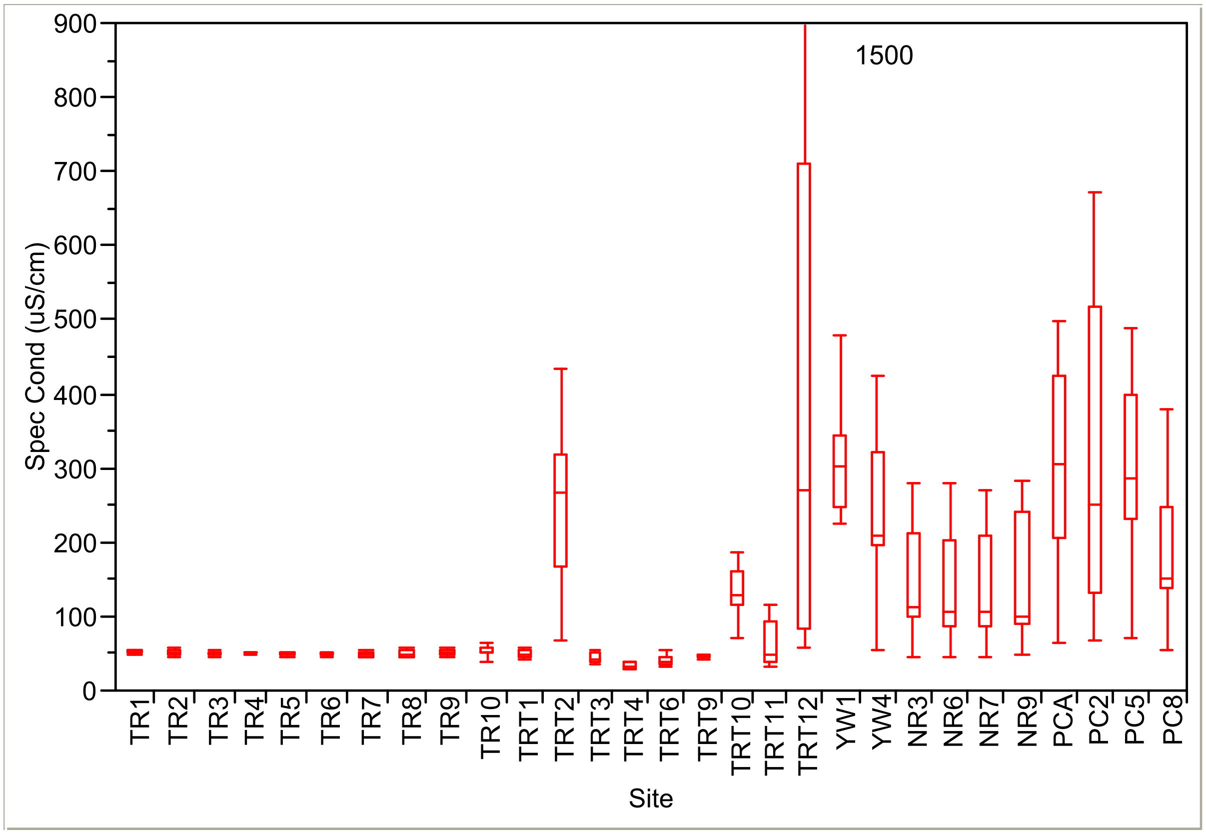


Figure 10. Specific Conductance Quantiles By Site- 10 Samples, June 2006-June 2007. Tangipahoa River (TR sites) and most of its tributaries (TRT sites) had low specific conductance. The Natalbany River (NR sites) had slightly greater specific conductance. The Ponchatoula Creek (PC sites) and Yellow Water River (YW sites) had the highest specific conductance other than Bedico Creek (TRT12); which is influenced by Pontchartrain's brackish water.

Turbidity: Turbidity showed significant differences among sites (α = <0.0001). The Tangipahoa River (TR sites) and most of its agriculturally influenced northern tributaries (TRT 1-9) had low turbidity while most Natalbany watershed sites (NR, PC, and YW sites) and southern Tangipahoa tributary sites (TRT 10-12) had greater turbidity (Figure 11). Turbidity in Ponchatoula Creek and Yellow Water River generally increased in the downstream direction. The sites having greater turbidity include sites within the most developed and the developing areas of the watersheds and sites located in low-lying bottomland hardwood forests (Figures 5 and 7). Turbidity values at these sites also routinely exceeded the LDEQ limit of 50 NTU for water quality (blue line, Figure 11). This pattern generally mirrored the pattern for specific conductance (Figure 10). However, a continuing increase in dissolved salts from mixing with the Pontchartrain Estuary will increase specific conductance while flocculating particulate matter and lowering turbidity.

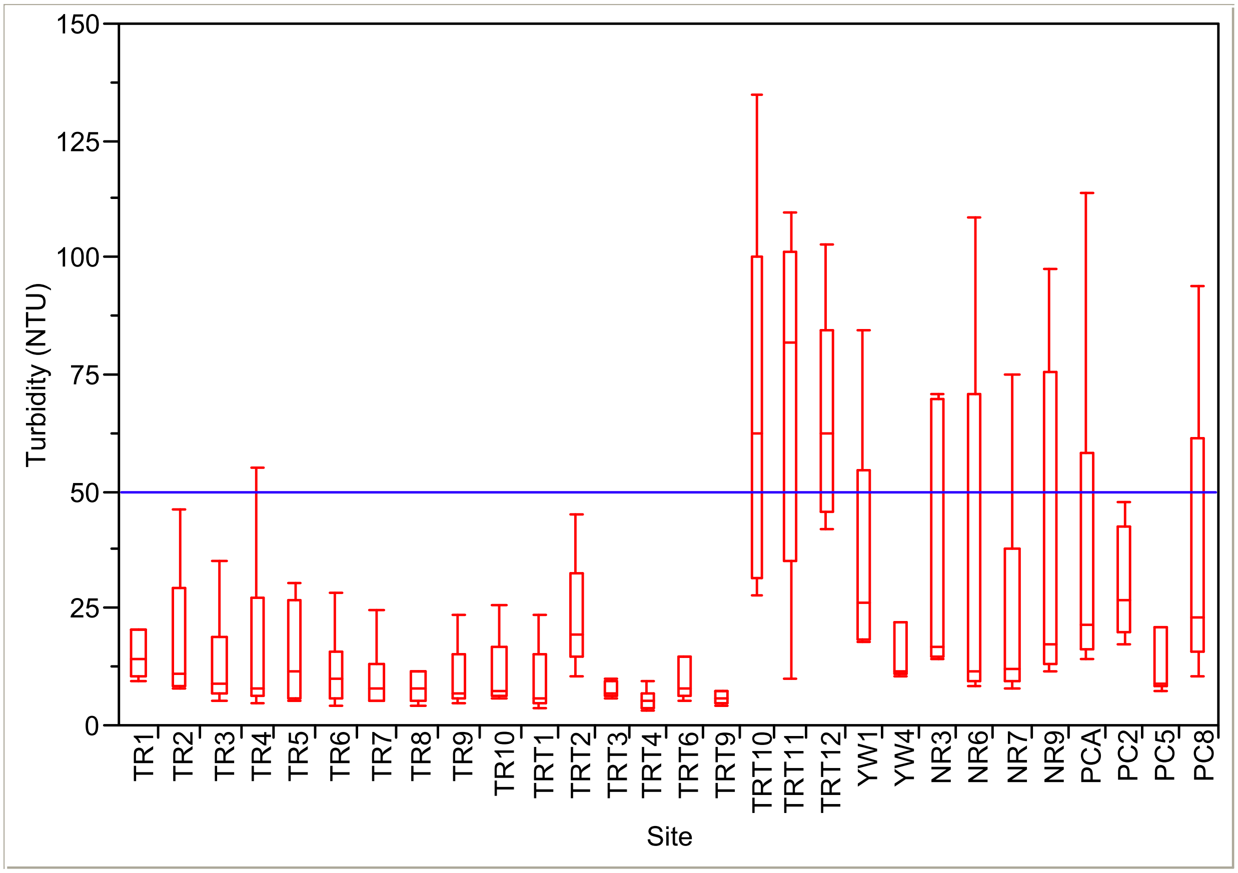


Figure 11. Turbidity Quantiles By Site- 10 Samples, June 2006-June 2007. The Tangipahoa watershed generally had turbidities below the 50 NTU state standard. However, sites in developing areas (TRT10, TRT11, TRT12) had high turbidity. Turbidities in the Natalbany watershed were higher.

In summary, the water monitoring sites generally showed difference among the physiochemical parameters. For temperature, there was no significant difference among all water quality sites. Dissolved oxygen concentrations were high among all sites except PC2 and PCA (Ponchatoula Creek south- of Hammond, the most urbanized area of the parish), TRT12 (Bedico Creek) and TRT10 (Skull's Creek- both located in bottomland hardwood forest experiencing rapid development), and TRT2 (Carpenter Branch- downstream of the Town of Fluker's WWTP discharge). Specific conductance values were high at TRT12 due to mixing with Pontchartrain estuarine waters. Specific conductance was also higher at all PC and YW sites and increases in downstream direction, through the most urbanized areas. Turbidity was high at all NR and YW sites, PC8 and PCA, and TRT10, TRT11, and TRT12 and showed a general increasing trend in the downstream direction on Yellow Water and Ponchatoula Rivers. The high turbidity is likely due to their locations in a swampy area, combined with being in urban or rapidly developing areas.

4.2 Geochemical Data

Total Dissolved Solids (tds): The total dissolved solids (tds) values were calculated by adding all of the dissolved components analyzed for each sampling date at each site. The median values for each site were then calculated and graphed. As shown on Figure 12, the individual sites and the larger Tangipahoa and Natalbany watersheds differ in their tds levels.

The Tangipahoa River (TR1-10) is characterized by low, consistent tds levels of less than 50 mg/l. The tds levels are elevated slightly toward the south (TR1), where the river flows into the brackish Lake Pontchartrain. The data indicates that there are no major inputs that would significantly raise the tds.

Most of the tributaries draining the upper portion of the Tangipahoa watershed, including Big Creek (sites TRT3 and TRT4) and Chappepeela Creek (Sites TRT6 and TRT9), have low median tds levels, around 40 mg/L. This area is dominated by dairies, rural land use, and forests (Figure 4). Site TRT2 (Carpenter Branch in Fluker, LA) has noticeably higher tds concentrations (a median of almost 200 mg/l) than its neighboring tributaries. The sampling site on this creek is directly downstream of the effluent from the Town of Fluker's wastewater treatment plant. The southern portion of the watershed (TRT10-12) is in a wetland/ bottomland hardwood forest with urban/ developing land use and TRT12 is close to the Pontchartrain estuary. All of these factors likely influence the higher tds (100-150 mg/L) levels.

The Natalbany River has a slightly higher median tds level (around 60-70 mg/L compared to 50 mg/L on the Tangipahoa River). This higher tds level has two probable sources: a higher background level in the Natalbany Watershed and/or an increase due to urbanization. Compared to the Tangipahoa Watershed, a greater percentage of the Natalbany watershed is urbanized (around 2-5% in Tangipahoa verses 7->30 % in Natalbany). The Yellow Water River and Ponchatoula Creek are the two sub-watersheds in Tangipahoa Parish with the greatest percent (> 28%) of urbanized land (Table 4, in Land Use Data vs. Water Quality Parameters section below). The median tds values increased dramatically in the downstream direction to a high of 250 mg/l and greater, for both Ponchatoula Creek and Yellow Water River (Figure 12). Urbanization increases in the downstream direction in both of these streams.

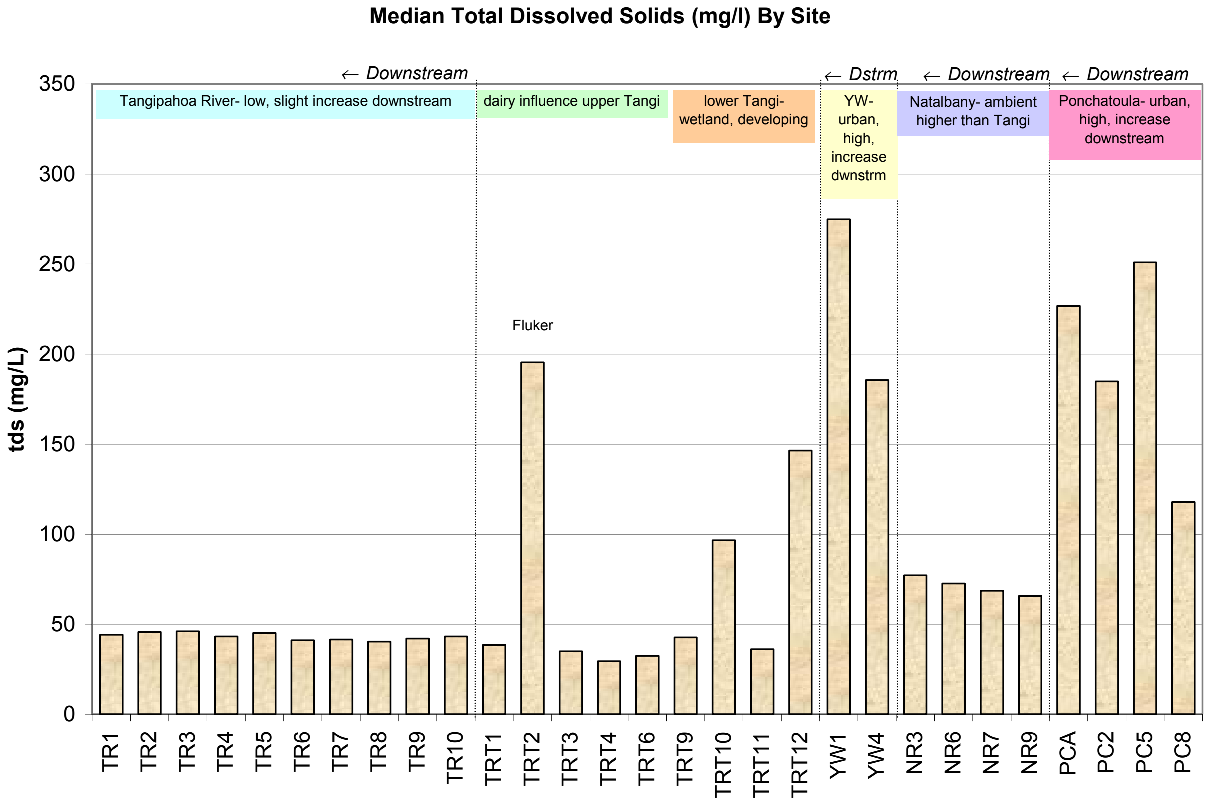


Figure 12. Median Total Dissolved Solids (mg/l) By Site- 10 Samples, June 2006-June 2007, sites with known or suspected anthropogenic sources had highest concentrations.

When the tds values are broken down into the major and minor components, differences become observable. The major components are Na, Cl, SiO_2-Si, HCO_3-C, SO_4, Ca, Mg, and K (Figure 13). Of the major component concentrations, Na (dark blue), Cl (tan), and SiO_2-Si (blue-green) account for the bulk. Alkalinity as HCO_3-C (olive green) and SO_4 (pink) varied significantly (Appendix C) among the sites. The Tangipahoa River sites (TR1-10) and dairy influenced tributaries (TRT3-9), and even the site influenced by saltwater (TRT12) had low median HCO_3-C concentrations. The background sources of HCO_3-C are due to weathering and the low background concentrations reflect surface water input rather than groundwater input where weathering is more significant. While the concentrations on the Natalbany River are higher compared to the Tangipahoa River, the values are low compared to sites with known anthropogenic pollution, including Ponchatoula Creek (PC sites) and Yellow Water River (YW sites) in the urban area and Carpenter Branch (the discharge for the Fluker community sewage plant, site TRT2). Sulfate (pink) also shows this trend, indicating both HCO_3-C and SO_4 could be used as indicators of anthropogenic sources since the medians are not high in the background sites (Figure 13 and Table 2 below).

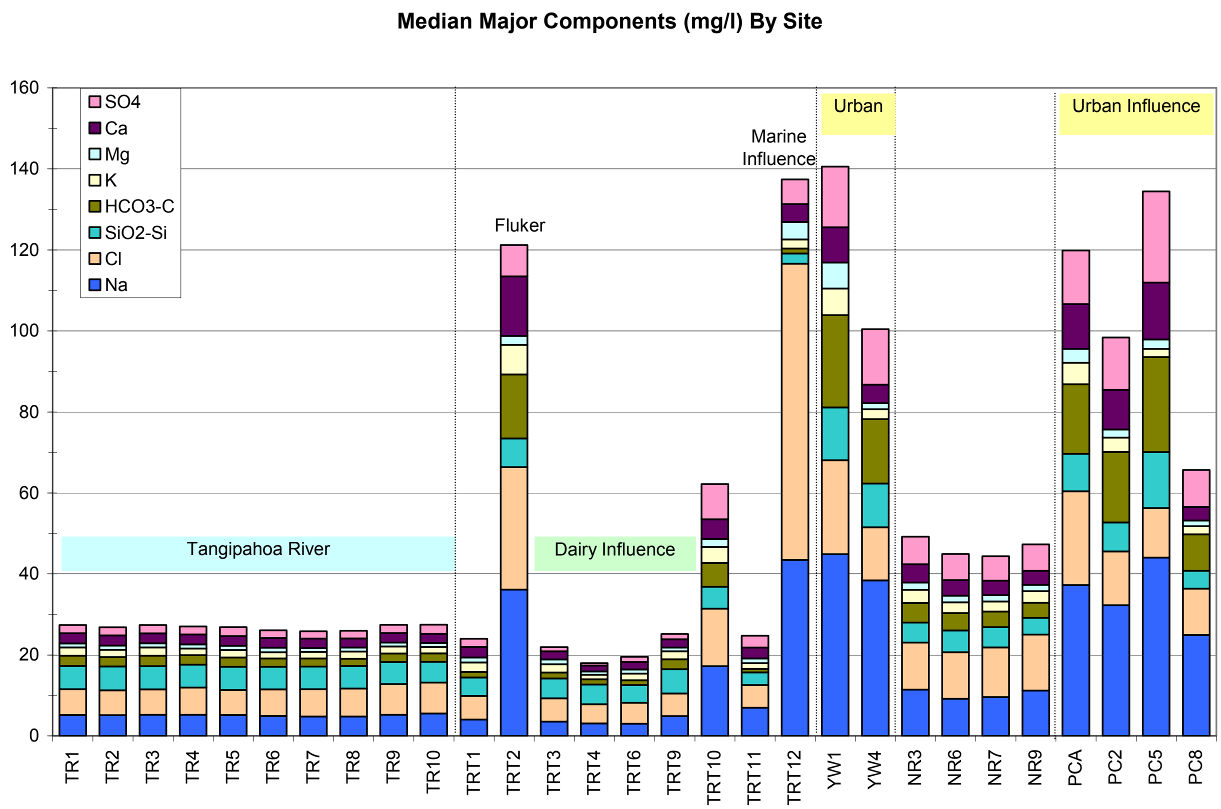


Figure 13. Median Major Components (mg/l) By Site- 10 Samples, June 2006-June 2007, sites with known or suspected anthropogenic sources had highest concentrations. Dissolved salts generally increased in the downstream direction in urban streams. The one marine influenced site (TRT12) shows a difference in salt concentrations as compared to the urban sites.

Of the minor component median concentrations, the nutrients NO_3-N (red) and PO_4-P (bright green) occur in significant amounts in YW1 and PCA (Figure 14). These sites are downstream of the most urbanized area, YW1 flowing into PCA (Figure 2). In Ponchatoula Creek (PCA-PC8) and Yellow Water River (YW1 and YW4) the graph illustrates an obvious increase of NO_3-N, NH_4-N, and PO_4-P in the downstream direction. Traces of NO_2-N also had a corresponding increase in the downstream portion of Ponchatoula Creek and Yellow Water River. Note the median high Br concentration at TRT12 reflecting mixing with marine waters (Figure 14 and Table 2 below).

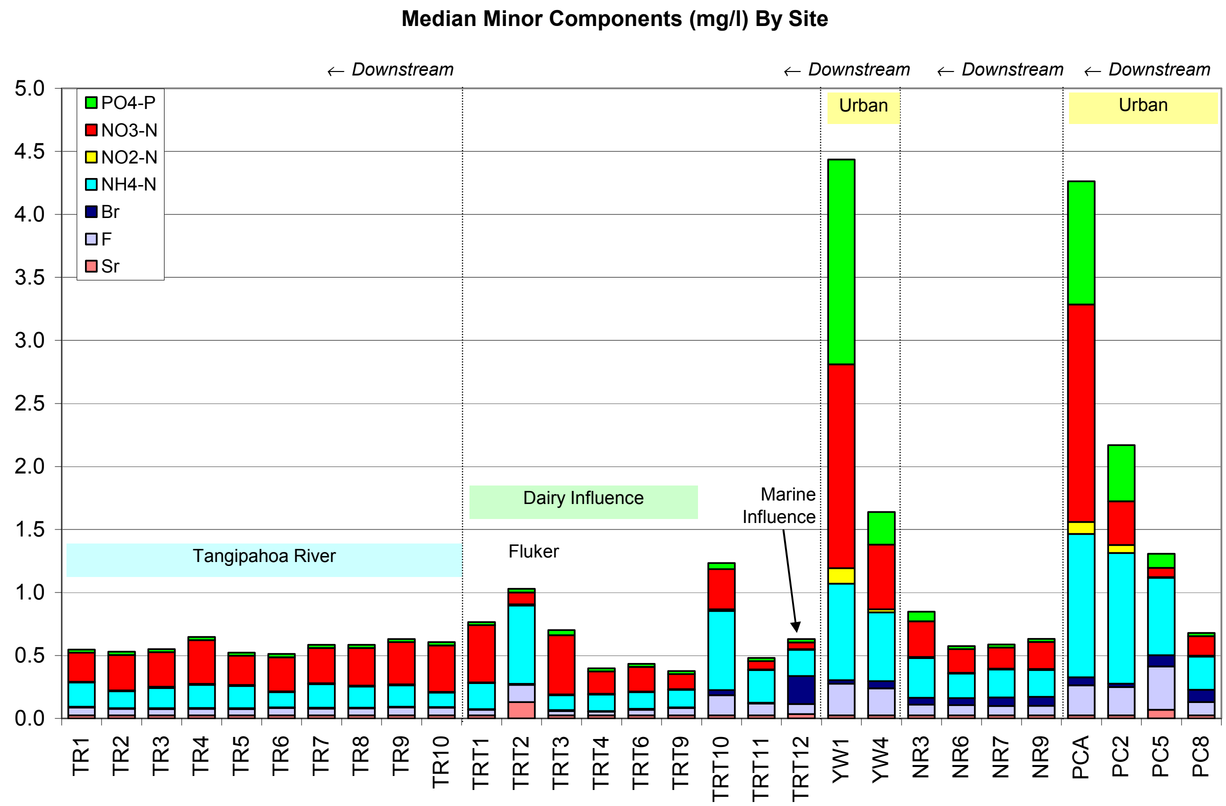


Figure 14. Median Minor Components (mg/l) By Site- 10 Samples, June 2006-June 2007, sites with known or suspected anthropogenic sources had highest concentrations. Nutrients increased dramatically in the downstream direction in urban streams.

To illustrate differences among the watersheds, the median concentrations of each parameter are listed in Table 2 for the watersheds, with "Dairy" and "Urban" land uses noted. The data utilized for each column is stated under the column heading. Of note, the "Dairy" column (being those creeks most influenced by dairy activity) included data from two creeks, Big Branch and Chappepeela Creek. These creeks along with the Tangipahoa River showed low levels of dissolved salts and nutrients, indicating the background levels for the region. In contrast, several dissolved salts and nutrients, including Na, NH_4-N, NO_2-N, PO_4-P, SO_4, HCO_3-C, and tds, had concentrations many times greater than background levels on Ponchatoula Creek and Yellow Water River (the waterways most influenced by urbanization). Particularly, Na, HCO_3-C, and SO_4 median concentrations were up to six times greater on these waterways.

Parameter	Tangipahoa	Dairy	Natalbany	Yellow Water (Urban)	Ponchatoula (Urban)
Data (mg/l)	***TR1-TR10***	***TRT3-TRT9***	***NR3-NR9***	***YW1&YW4***	***PCA-PC8***
Na	5.14	3.33	10.26	39.55	34.07
NH_4-N	0.17	0.14	0.23	0.60	0.63
K	1.75	1.82	2.72	3.57	2.91
Mg	1.00	0.96	1.61	1.61	2.15
Ca	2.42	1.9	3.60	5.59	9.80
Sr	0.03	0.03	0.03	0.03	0.03
SiO_2-Si	5.69	4.89	4.72	10.94	7.41
F	0.05	0.04	0.08	0.23	0.23
Br	0.01	0.01	0.06	0.05	0.06
Cl	6.57	5.35	12.00	13.8	14.7
NO_2-N	0.006	0.006	0.006	0.037	0.018
NO_3-N	0.296	0.200	0.205	0.617	0.246
Inorganic N	0.507	0.361	0.508	1.307	0.896
PO_4-P	0.025	0.025	0.025	0.425	0.206
SO_4	2.02	1.23	6.70	14.17	12.39
HCO_3-C	2.10	1.46	4.14	16.63	16.51
TDS	258.24	210.87	408.74	665.81	665.08

Table 2. Median Parameter Values for Each Watershed, significantly greater values are highlighted.

Sulfates (SO_4): When comparing SO_4 concentrations by site, vast differences emerge (Figure 15). A previous study conducted by Stoessell and Prochaska (2005) showed aquifers and ground water in the adjacent areas east (St. Tammany Parish) and west (East Baton Rouge) have trace to low amounts of SO_4, at or below 0.1 mg/l. While none of the sites examined in this study had concentrations that low, Chappepeela Creek (TRT6 & TRT9) and Big Creek (TRT3 & TRT4) had concentrations around 0.5 to 2 mg/l. Berner and Berner (1987) reported an average SO_4 concentration for freshwater of 6.6 mg/l (world average for unpolluted water, green line in Figure 15) and 14.9 for natural North American rivers (orange line, Figure 15). The Tangipahoa River sites had SO_4 concentrations averaging around 2 mg/l (blue line, Figure 15), which could be considered the background level for this region. The sites on Chappepeela and Big Creeks are within the dairy/agricultural area of the watershed.

High levels of SO_4 (up to 40 mg/l) occurred at TRT12 and PC5. Although the median value was low, occasional high levels of sulfate were seen in TRT 12 (Bedico Creek). This creek is located in the southern portion of the watershed and is affected by the SO_4-rich brackish marine waters of Lake Pontchartrain to varying degrees throughout the year, depending on precipitation and freshwater inputs. Wayland et al. (2003) also found that high sulfate concentrations were associated with barren land. Upstream of TRT12, within much of the Bedico Creek watershed, development has been rapid since Hurricane Katrina in 2005. Most of these developments are not utilizing proper sediment controls (see Discussion) so the SO_4 concentration could also reflect development in the watershed. Sulfate concentrations were exceptionally high at PC5, most likely representing a point-source input of cleaners. Surfactants in cleaners commonly contain sulfates and sulfuric acid (H_2SO_4) is common in household and industrial cleaners (Davis, 1992).

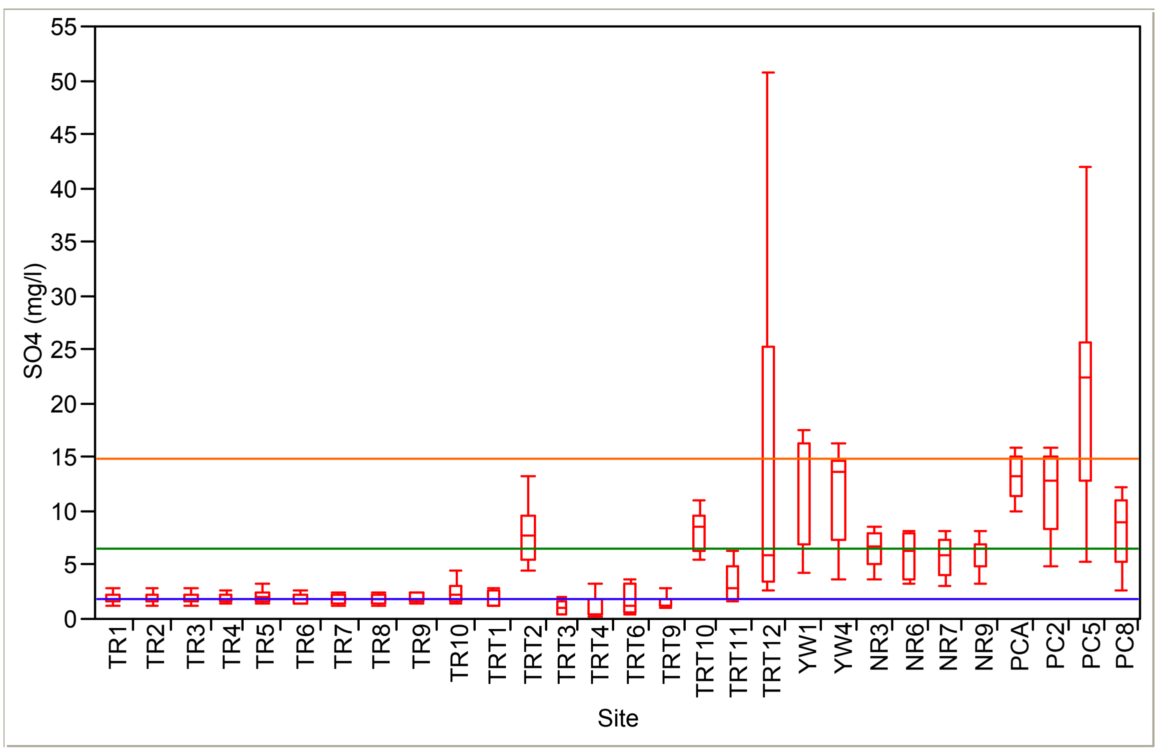


Figure 15. SO_4 (mg/l) Quantiles By Site- 10 Samples, June 2006-June 2007. Background sulfate concentrations were low within the Tangipahoa watershed and only slightly higher in the Natalbany watershed. Sites with known or suspected anthropogenic sources had highest concentrations apart from the marine-influence site (TRT12).

Chloride / Sulfate Comparison: When median chloride concentrations were plotted against median sulfate concentrations for each site a pattern emerges (Figure 16). The Tangipahoa River and most of its tributaries have lower chloride and sulfate concentrations (green box on chart) as compared to the Natalbany River (blue box on chart). The PC, YW, TRT2, and TRT12 sites are outliers from this pattern, having higher chloride levels. Land use analysis of these sites indicates that PC and YW sites are located in the most highly urbanized portion of the parish (Figures 5 & 7). TRT2 is immediately downstream of the Town of Fluker's WWTP. High chloride levels at this site would most likely be from anthropogenic sources and chlorine tablets used for disinfection. The high sulfate levels seen at PC5 may be from a local source (described above). TRT12 (Bedico Creek) is influenced by mixing with marine waters, showing high a chloride concentration and not fitting the pattern of the other sites. In general the sulfate levels are low on the Tangipahoa and Natalbany Rivers and high in urban and developing areas.

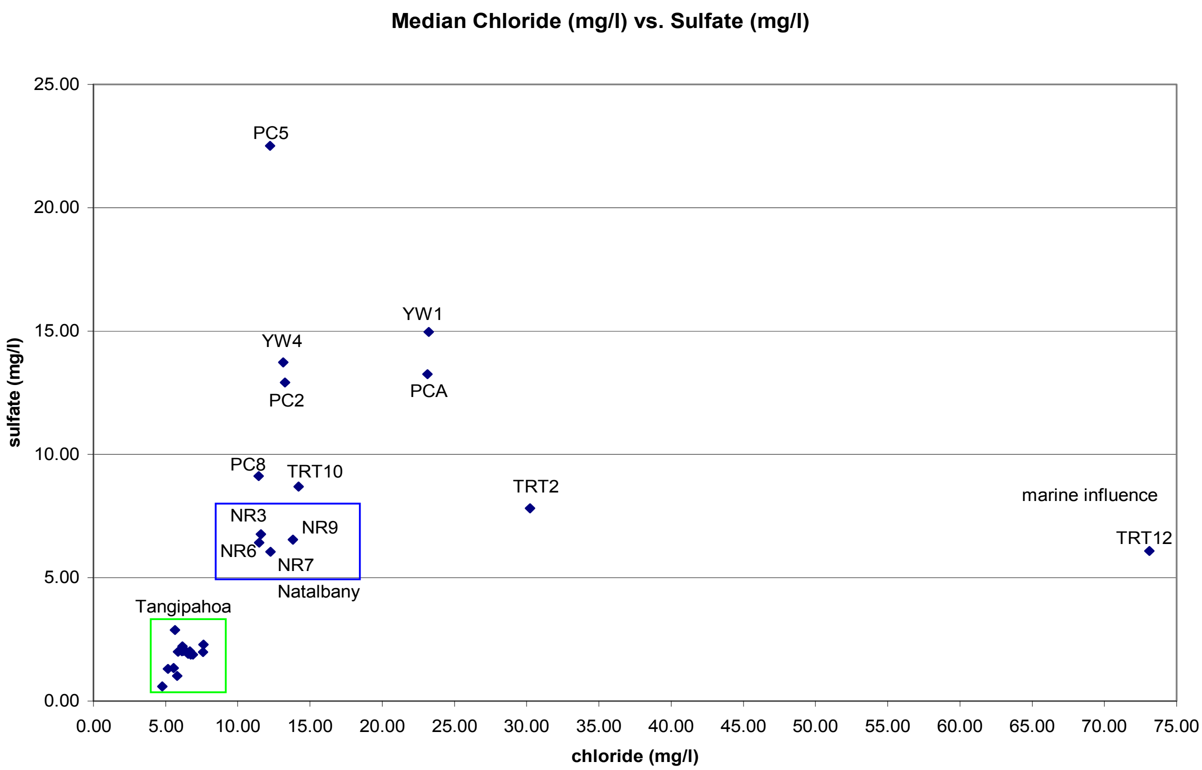


Figure 16. Median Chloride (mg/l) Verses Sulfate (mg/l) - 10 Samples, June 2006-June 2007. Sites within the Tangipahoa watershed had low concentrations of both Cl and SO_4. Concentrations of both were slightly higher in the Natalbany River, yet grouped tightly into a signature pattern. Sites with known or suspected anthropogenic sources had the highest ratios (greater sulfate) and the marine ratio was separate from all others (greater chloride).

Sulfate : Chloride Ratios: The SO_4/Cl molar ratio is 0.0517 for open ocean (Berner and Berner, 1987, blue line, Figure 17). The only site that squarely falls within this range is TRT12 (Bedico Creek), the site containing brackish water from Lake Pontchartrain. TRT2, TRT3, TRT4, and TRT6 have some readings in this range but are too far upstream to contain estuarine water from Lake Pontchartrain (Figure 17). The Tangipahoa River has low, consistent sulfate/chloride ratios around 0.1 (orange line, Figure 17), which is assumed to be the background level for the watershed. In general, the Natalbany watershed is enriched in sulfate compared to the Tangipahoa Watershed, with a molar ratio around 0.22. Yellow Water River and Ponchatoula Creek, both influenced by urbanization, have higher ratios. PC5 is high probably due to a local source. While chloride concentrations did not fluctuate drastically between urbanized and non-urban streams (Figure 13), sulfate does fluctuate, driving up the molar ratio. The molar ratios of the urban streams range is around 0.35 (Figure 17). However, these molar ratios are still considered to be within the "normal" range of 0.431 for unpolluted world rivers (green line, Figure 17) and 0.775 for "natural" North American rivers (Berner and Berner, 1987).

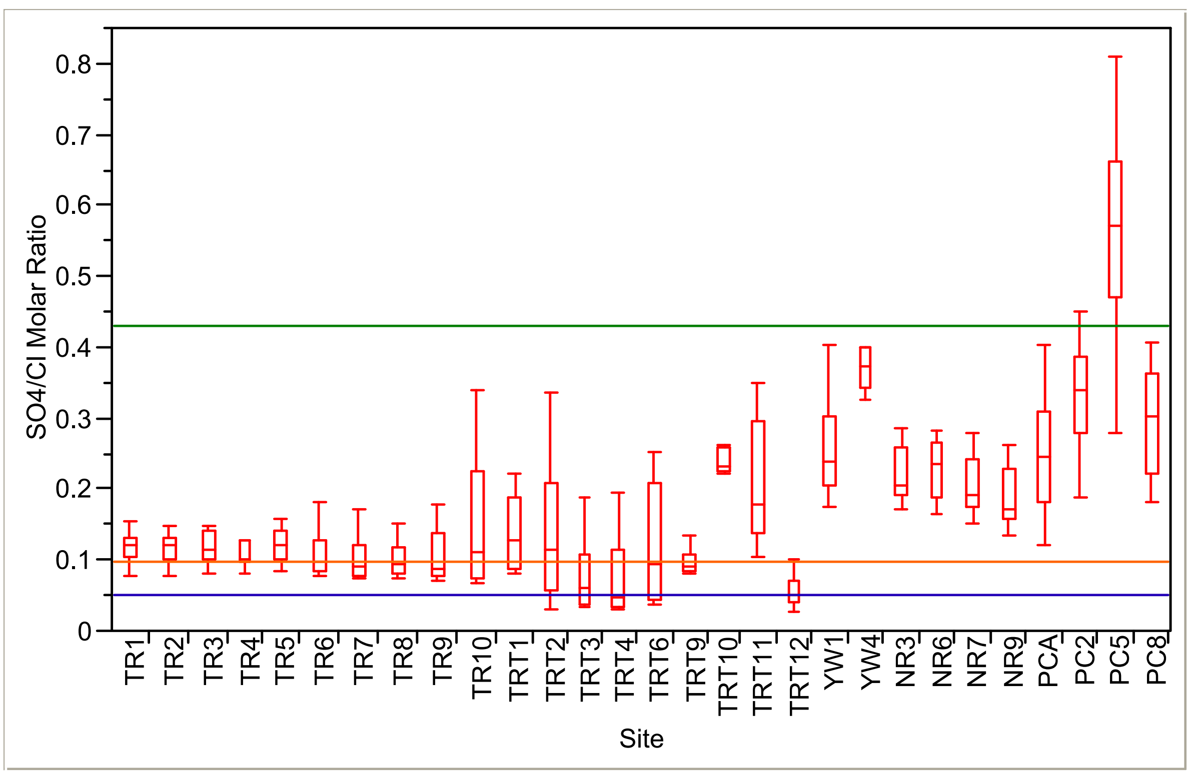


Figure 17. Quantiles- SO_4/Cl Molar Ratios By Site- 10 Samples, June 2006-June 2007. Open ocean SO_4/Cl Molar Ratio = 0.0517, Unpolluted rivers worldwide SO_4/Cl Molar Ratio = 0.431. Most sites had low to normal ratios ranging from 0.1 to 0.4. Site PC5 had anomalous ratios.

Sodium : Chloride Ratios: Previous research in the brackish aquifers of the Pontchartrain Basin (Stoessell and Prochaska, 2005) showed a Na/Cl molar ratio of 0.94 (green line, Figure 18) and a ratio of 0.86 in seawater (blue line in Figure 18, Berner and Berner, 1987). The ratio in the brackish groundwaters is due to the dissolution of halite. However, average natural river water worldwide has a higher ratio of 1.43 (orange line on Figure 18, Berner and Berner 1987), reflecting sodium release weathering chloride-free silicates. As a result of weathering, the Natalbany River (NR sites), Tangipahoa River (TR sites), Big Creek (TRT3 & TRT4), Chappepeela Creek (TRT6 & TRT9), and Black Creek (TRT12) have Na/Cl ratios within these values (Figure 18).

In contrast, Na/Cl molar ratios for Ponchatoula Creek (PC sites), Yellow Water (YW sites), Skull's Creek (TRT10), Sims Creek (TRT11), and Carpenter Branch (TRT2) are significantly higher, with median ratios ranging from 3 to 5. Wastewater is enriched in Na relative to Cl (Wayland et al., 2003) because many common household cleaners utilize sodium as a cation, including sodium bicarbonate (baking soda) and sodium hypochlorite (bleach) (Davis, 1992). Both Yellow Water and Ponchatoula receive wastewater (and the accompanying chlorides of disinfection); however, the chloride levels in the streams are still relatively low so the ratios are high for sodium to chloride.

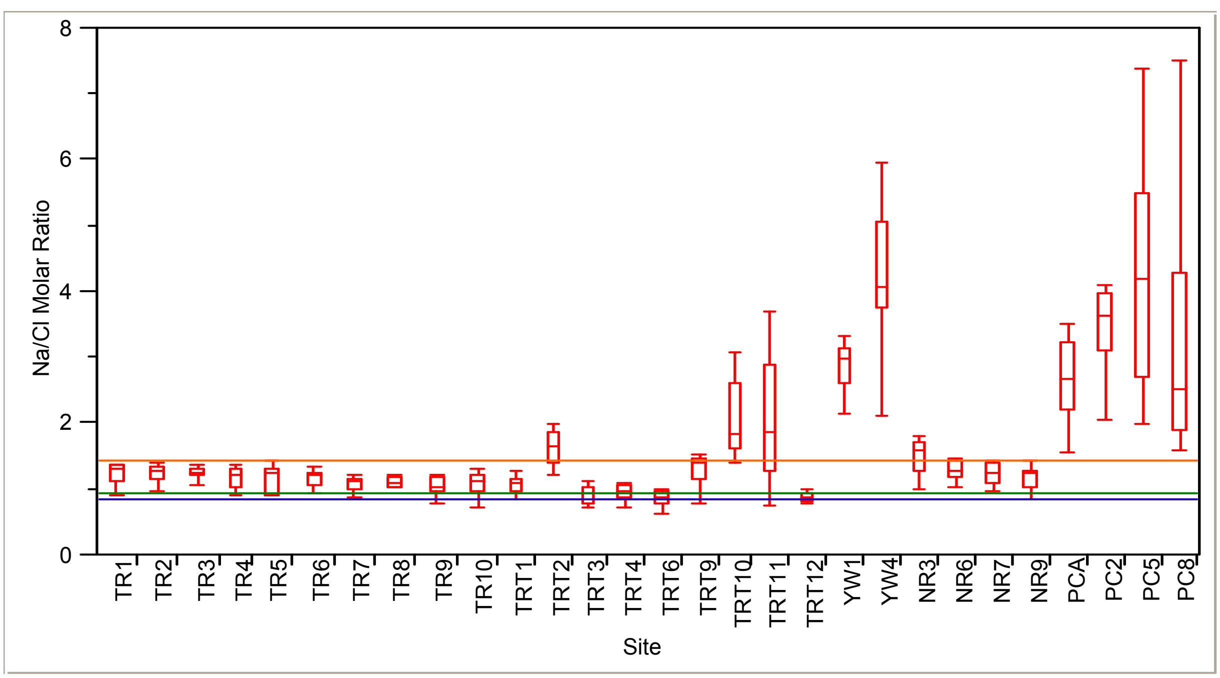


Figure 18. Na/Cl Molar Ratios By Site- 10 Samples, June 2006-June 2007. Sites with known or suspected anthropogenic sources had highest ratios due to the use of cleaning and/or sanitizing products with sodium.

Chloride : Bromide Ratio: The ratio of Cl/Br concentrations has been used to identify or confirm sources of groundwater contamination in south Louisiana (Stoessell and Prochaska, 2005). These constituents can be useful because they are both soluble in water and conservative; that is, they are not prone to adsorption to sediment or redox alteration (Dumouchelle, 2006).

Methodology utilized in USGS groundwater studies (Jagucki and Darner, 2001; Dumouchelle, 2006) was employed for determining the influence of sewer input into groundwater using water geochemistry (Figure 19). A clear pattern of the chloride concentration (mg/L) verses Cl(mg/L)/Br(mg/L) ratio emerges with the data following a predictable path, based on pollution. The USGS studies consider the typical range for Cl:Br ratios in dilute groundwater to be 10 to 85. Groundwater impacted by weathering, precipitation, and natural processes had ratios between 100 and 200 with a theoretical upper limit of 400. Ratios above 400 indicated "probable effects of anthropogenic sources" in these studies.

Utilizing the ratio classification of the USGS studies in the Tangipahoa and Natalbany Watersheds, five sites exhibited Cl/Br ratios >400, including PCA, PC2, PC5, YW1, and TRT2 (Figure 19). These five sites are located in the most urbanized portion of the watershed and/or are known sources of anthropogenic impacts. Bromide was not within the detection limit in any samples from the Tangipahoa River (TR sites) and the agriculture/dairy-influenced sites (TRT3, TRT4, TRT6, and TRT9). This suggests the bromide seen in the urban Natalbany watershed and the developing lower tributaries of the Tangipahoa are the result of anthropogenic impacts. Bedico Creek (TRT12) plots away from the other sites (green box), being the only site containing marine water.

While this method was not found in previous surface water studies, it is shown here to illustrate high Cl:Br relationships and detect sewer input.

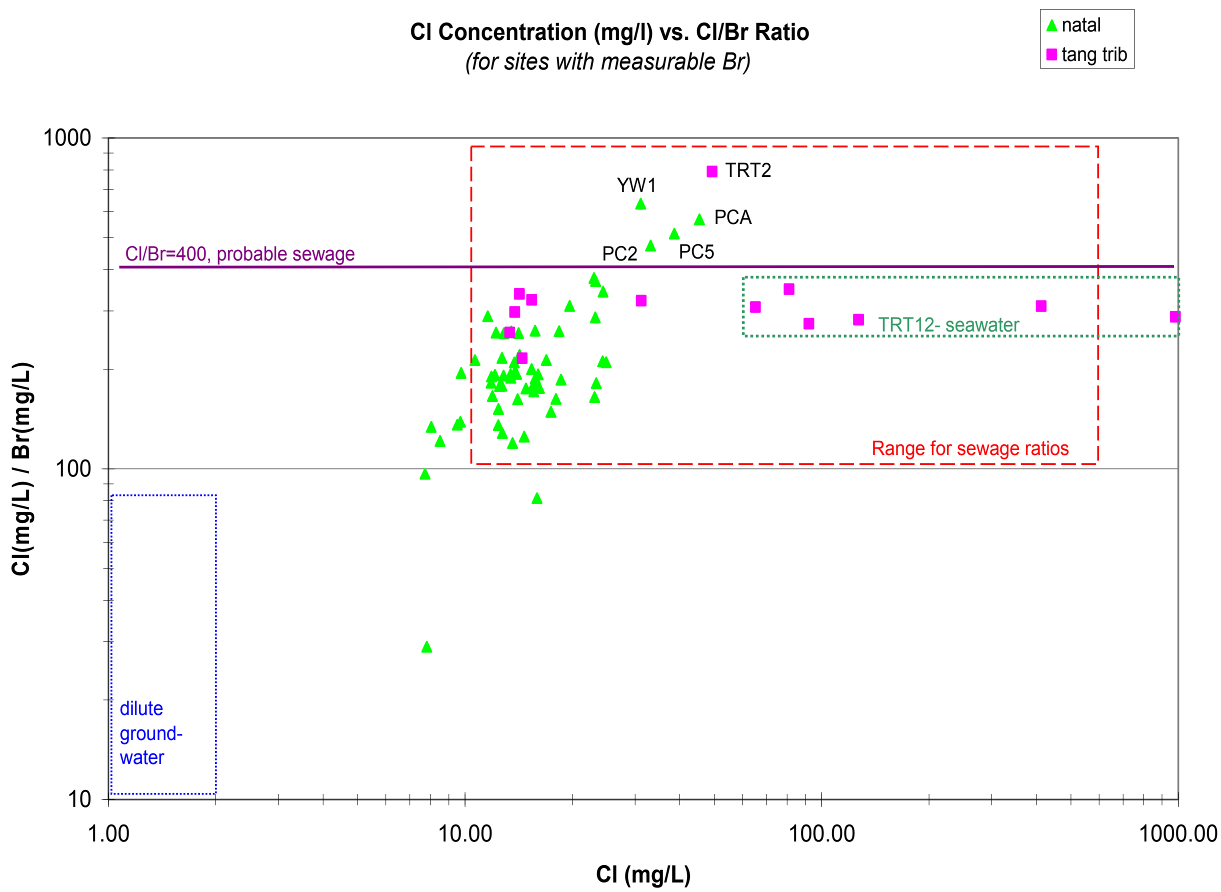


Figure 19. – Cl Concnetration (mg/l) Verses Cl/Br Ratio- 10 Samples, June 2006-June 2007. Sites within Tangipahoa's tributaries and the Natalbany Watershed had Cl/Br ratios up to and greater than 400 (indicating probably sewage input). Seawater had a distinct Cl/Br ratio, below 400. Sites in the Tangipahoa River did not have measurable Br.

In summary, geochemical data of the surface waters provide information about land use. SO_4 concentrations and ratios of SO_4/Cl, Na/Cl, and Cl/Br indicate the presence of anthropogenic sources of pollution. The urban sites on Ponchatoula Creek and Yellow Water River had consistently high levels for these parameters. While graphing Cl:Br ratios is commonly used in groundwater, it is shown here to be an effective surface water indicator of anthropogenic sources.

While significant relationships were presented in the results, each parameter was subjected to the Kruskal-Wallis statistic to assess significant differences among the sites (Appendix C).

4.3 Nutrient Data

All nutrients analyzed (NO_3-N, NO_2-N, NH_4-N, and PO_4-P) have low median concentrations in the Tangipahoa River, the Natalbany River, and the sites influenced by agricultural/dairy land use. In contrast, the nutrient concentrations increase in the downstream direction on Yellow Water River and Ponchatoula Creek (Figure 14). These higher concentrations support the use of nutrients to indicate urbanization and anthropogenic sources.

Nitrates (NO_3-N): In groundwater studies nitrate-nitrogen concentrations of 0.3 mg/l or less have come to be considered representative of background concentrations, 0.3 to 3.0 mg/l as indicating possible anthropogenic impacts, and concentrations of 3.1 to 10 mg/l as being most likely due to human activities" in groundwater (Baker at al, 1989 in Dumouchelle, 2006).

NO_3-N data is plotted in quantiles in Figure 20. Most sites are within the "background" level of 0.3 mg/l (blue line, Figure 20). PCA and YW1 are the only two sites to meet the 3.1 mark for nitrate, considered by Baker et al. (1989) to be "most likely from anthropogenic sources" (green line, Figure 20). As the concentration jumps dramatically between YW4 and YW1, there must be a significant source between the two sites (within the City of Hammond). Land use data in Figures 4 and 5 indicate Yellow Water River and Ponchatoula Creek are the most impacted by urban land use. PCA is the confluence of both the Yellow Water and Ponchatoula rivers and the high nitrate concentration could be due to the additive effect of the two streams.

Ammonia: Although pH was not taken regularly at all sites during the duration of the study, the unionized ammonia (NH_3-N) concentration can be estimated by assuming the activity coefficients for NH_3 and NH_4^+ cancel and using the log equilibrium constant of 9.26 for the disassociation reaction (Manahan, 1999) along with the average stream pH values taken by the LPBF since 2005. At or below a pH of 7.26, NH_3-N is $1/100^{th}$ the concentration of NH_4-N. In the LPBF data, all streams had average pH levels below 7.26 (average pH values ranged from 6.8-7.0), so the NH_3-N value was probably less than 0.01 of the total concentration of the analyzed NH_4-N. Hence, NH_3-N median concentrations were below 10 µg/l, less than the concentrations causing acute or chronic toxicity to macroinvertebrates and fish in streams (20 µg/l- chronic, 100 µg/l- acute; IJCUSC, 1989).

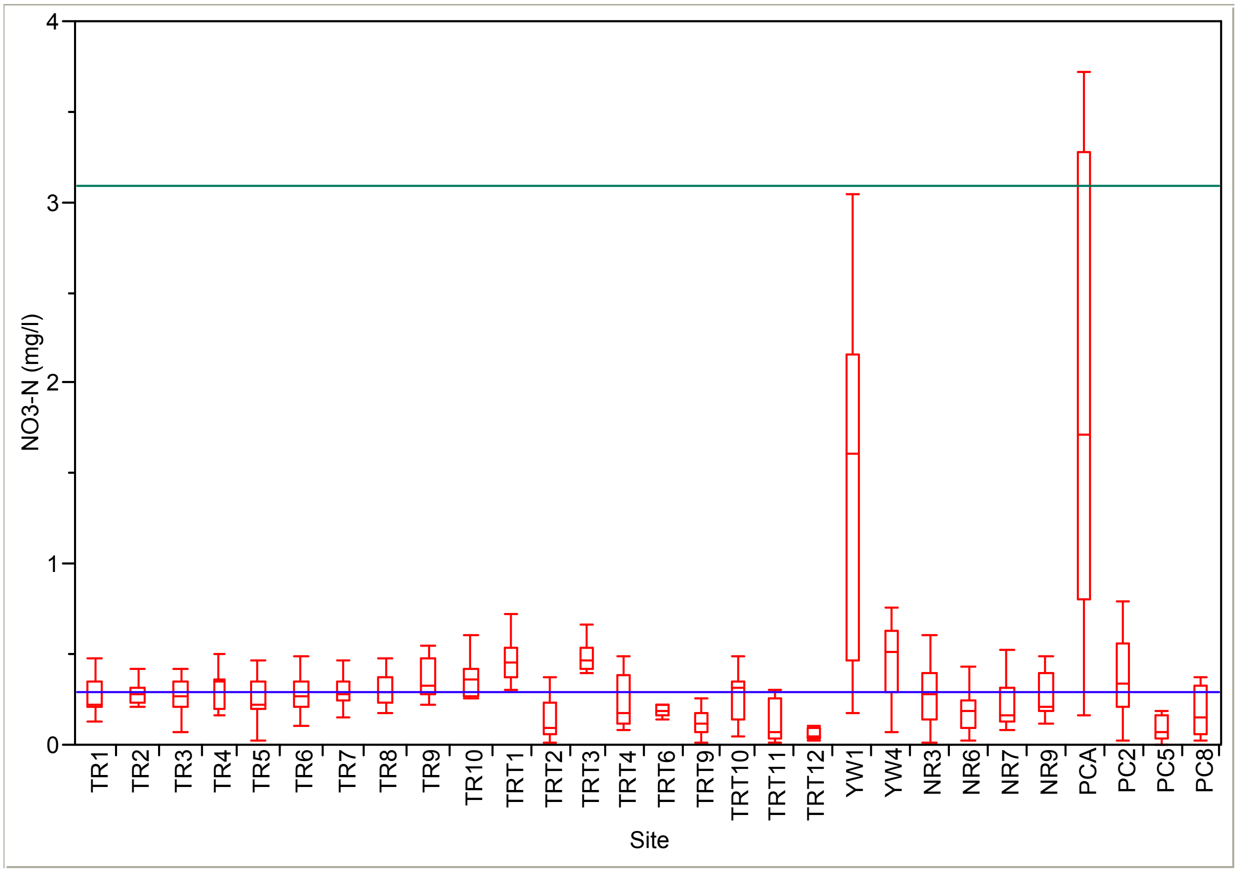


Figure 20. Quantiles- NO3-N (mg/l) By Site- 10 Samples, June 2006-June 2007. Most sites had values similar to groundwater or background values. Sites with known or suspected anthropogenic sources had significantly higher concentrations. The Yellow Water River (YW sites) and Ponchatoula Creek (PC sites) flow together at PCA and account for the additive effect observed at PCA.

Dissolved Inorganic Nitrogen / Phosphate Relationship: Median concentrations of dissolved inorganic nitrogen (DIN- including NO_3-N, NO_2-N, and NH_4-N) were plotted against median phosphate (PO_4-P) concentrations for all sites (Figure 21). The Tangipahoa River and most of its tributaries have low DIN and phosphate concentrations (green box on chart). The sites YW1, PCA, PC2, and YW4 have the greatest DIN and phosphate levels. These sites occur in the most urbanized area of the parish. Median phosphate and DIN concentrations had a robust positive correlation (R^2 = 0.8324, Figure 21).

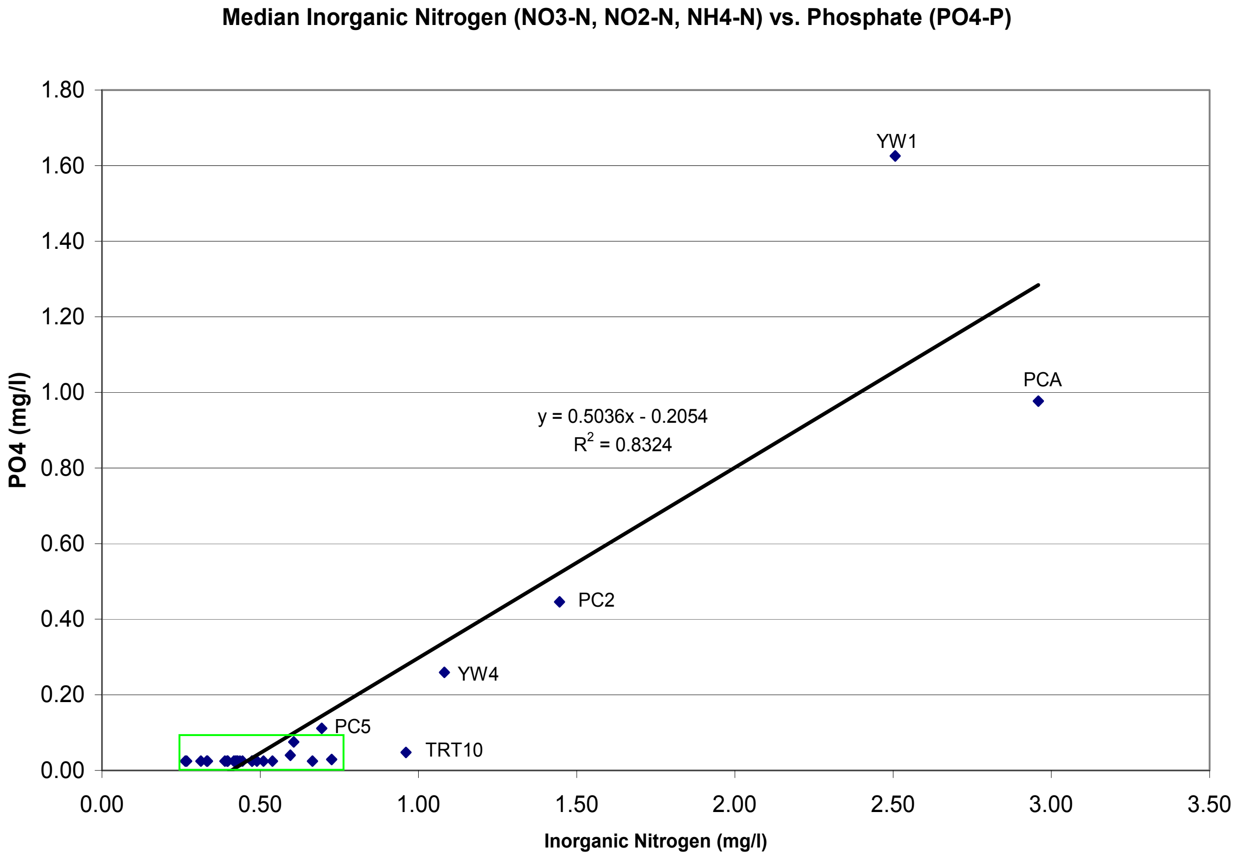


Figure 21. Median Dissolved Inorganic Nitrogen (DIN, including NO_3-N, NO_2-N, NH_4-N) Verses Phosphate (PO_4-P)- 10 Samples, June 2006-June 2007. A strong correlation (R^2=0.8324) was seen between DIN and PO_4 with sites with known or suspected anthropogenic sources having the highest concentrations of both.

Lakes Pontchartrain and Maurepas, into which these waterways flow, are nitrogen limited (Pinkney et al., 2001; Turner, 2002), similar to many coastal estuaries (Berner and Berner, 1987). In contrast, most waterways within the Tangipahoa and Natalbany watersheds were phosphate-limiting, as is common to most rivers (Berner and Berner, 1987). The blue line in Figure 22 represents the marine Redfield Atomic Ratio (0.0625 or 1 P/16N, Berner and Berner, 1987). The Redfield Ratio represents the molecular ratio of nitrogen and phosphorus in marine plankton (Berner and Berner, 1987). Phosphate/nitrate ratios from most sites tested fall below this ratio, indicating these watersheds (particularly the Tangipahoa Watershed) to be phosphate-limiting. Only the urban sites PCA, PC2, YW1, and YW4 had almost all the measured P/N ratios meeting and exceeding the Redfield ratio.

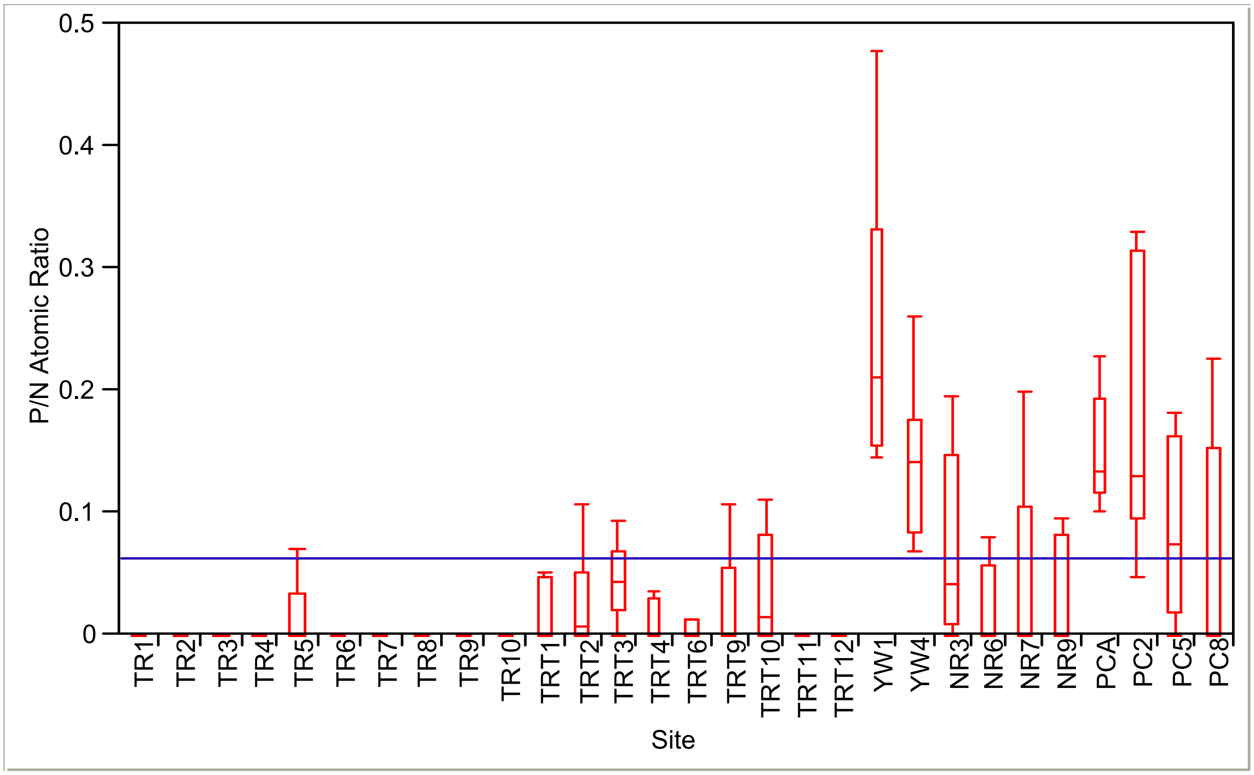


Figure 22. Quantiles of P/N Atomic Ratio By Site- 10 Samples, June 2006-June 2007. While most sites fall below the Redfield Ratio (blue line), indicating the system to be phosphorus limited, sites with known or suspected anthropogenic sources fell above the Redfield Ratio, indicating a nitrogen-limited system.

4.4 Correlations Among Parameters

Spearman's Rho correlations were performed between all parameters (by pair) for all sites and individually by site (Appendix D). Tangipahoa River sites were not found to be significantly different for any parameter analyzed, so were grouped for correlation analyses. Correlations with rho ≥ 0.6500 and significant (chi = 0.05) were recorded as "a+" for positive correlations and "a-" for negative.

When correlations were performed using data from all sites, most of the geochemical parameters correlated positively with other geochemical parameters. For example, SO_4 concentrations correlated well with most anions and cations. Among the individual sites, sites with known anthropogenic sources (including YW1, PC2, and TRT2) showed the most correlations between parameters. Of the parameter pairs, Ca and Mg, Cl and Na, HCO_3-C and Na, and SO_4 and K all showed positive correlations and D.O. and temperature showed negative correlations at ten or more sites.

4.5 Data Comparison to Past Data

Physiochemical and geochemical data collected through this study were compared to similar past data collected by the United States Geologic Survey (USGS). While the USGS collected geochemical data on sixteen sites within these watersheds, the data was sparse (less than 3 samples) on many of the sites. Four USGS sites had enough data to be compared to current data. For comparison to data collected in this study, SiO_2-Si was converted from SiO_2 and HCO_3-C was converted from $CaCO_3$ in the USGS data. The parameters compared (using Wilcoxon Rank Sum Test) among the time periods differed based on USGS data availability at each site. An alpha ≤ 0.05 was considered significant. The data utilized for this comparison included:

1) USGS data from the Tangipahoa River at Robert, LA, collected 1954-1999 (148 analyses). Usable parameters included water temperature, dissolved oxygen, specific conductance, pH, turbidity, fecal coliform counts, and concentrations of Na, NH_4-N, K, Mg, Ca, SiO_2-Si, F, Cl, NO_3-N, PO_4-P, SO_4, and HCO_3-C. The USGS data was compared to data collected on the Tangipahoa River at sites TR2-TR10.
2) USGS data from the Tangipahoa River at Lee's Landing, collected 1963-1964 (55 samples). Usable parameters included specific conductance, pH, and concentrations of Na, K, Mg, Ca, SiO_2-Si, F, Cl, NO_3-N, SO_4, and HCO_3-C. The USGS data was compared to data collected at site TRT1 on Tangipahoa River at Lee's Landing.
3) USGS data from Bedico Creek, Bedico, LA, collected 1965, 1969, and 1974 (3 analyses). Usable parameters included specific conductance, and concentrations of Na, K, Mg, Ca, SiO_2-Si, F, Cl, NO_3-N, SO_4, and HCO_3-C. The USGS data was compared to data collected at TRT12 on Bedico Creek.
4) USGS data from the confluence of Yellow Water River and Ponchatoula Creek, collected 1962-1963 (4 analyses). Usable parameters included specific conductance and concentrations of Na, K, Mg, Ca, SiO_2-Si, F, Cl, NO_3-N, SO_4, and HCO_3-C. The USGS data was compared to data collected at site PCA, the confluence of Yellow Water and Ponchatoula.

All statistical analyses of current data verses USGS data are included in Appendix E.

Significant differences were observed (Table 3) between USGS data collected on the Tangipahoa River in Robert, LA and data collected at sites TR2-TR10. The current values for pH, turbidity, NH_4-N, Cl, and NO_3-N were significantly higher than the USGS data and the reverse was true for dissolved oxygen, specific conductance, Na, K, and HCO_3-C. The current NH_4-N and NO_3-N concentrations are higher, indicating increased nutrient enrichment of the watershed.

At the southern end of the Tangipahoa River (at Lees Landing, site TRT1), some significant differences were seen between USGS and current data (Table 3). The pH and concentrations of K, Mg, Cl, and NO_3-N values in this study were significantly higher than the USGS data and the reverse was true for specific conductance and Ca concentrations. The pH and Cl and NO_3-N concentrations were higher for current TR1 and TR2-TR10 data.

On Bedico Creek at TRT12, most parameters show no significant difference, as most of the component salts are derived from the brackish water of the Pontchartrain estuary. However, the current concentrations for SiO_2-Si and Cl were significantly higher than the USGS data with the reverse true for F concentrations (Table 3).

On Ponchatoula Creek, identified as one of the most polluted and impacted by anthropogenic activities through this research, some significant differences are seen among the parameters (Table 3). The current concentrations for K, Mg, Ca, and HCO_3-C were significantly higher than the USGS data with the reverse true for F concentrations.

Parameters	Tangipahoa River Robert vs. TR2-10	Tangipahoa River Lees vs. TR1	Bedico Creek Vs. TRT12	Ponchatoula Cr Vs. PCA
Water Temperature	No diff	----------	----------	----------
Dissolved Oxygen	USGS ↑	----------	----------	----------
Specific Conduct	USGS ↑	USGS ↑	No diff	No diff
pH	TR ↑	TR ↑	----------	----------
Turbidity	TR ↑	----------	----------	----------
Fec Col	USGS ↑	----------	----------	----------
Na	USGS ↑	No diff	No diff	No diff
NH_4-N	TR ↑	----------	----------	----------
K	USGS ↑	TR ↑	No diff	PCA ↑
Mg	No diff	TR ↑	No diff	PCA ↑
Ca	No diff	USGS ↑	No diff	PCA ↑
SiO_2-Si	No diff	No diff	TRT ↑	No diff
F	No diff	No diff	USGS ↑	USGS ↑
Cl	TR ↑	TR ↑	TRT ↑	No diff
NO_3-N	TR ↑	TR ↑	No diff	No diff
PO_4-P	No diff	----------	----------	----------
SO_4	No diff	No diff	No diff	No diff
HCO_3-C	USGS ↑	No diff	USGS ↑	PCA ↑

Table 3. Wilcoxon Analyses- USGS Data vs. Current Data (α = 0.05). No diff = no significant difference, USGS ↑ = USGS data significant greater, TR, TRT, or PCA ↑ = current data significantly greater. Cells with lines through them had no USGS data for analysis

4.6 Bacteriological Data

Fecal coliform data collected in the larger LPBF study on the Tangipahoa and Natalbany watersheds (of which this research is a part) was utilized for bacterial analysis. Included in the larger fecal coliform data set are bi-weekly fecal coliform data collected within the watersheds. The data set contains:

- 60 samples collected at each Tangipahoa River site ("TR" sites) January 2005 through June 2007;
- 32 samples collected at each Tangipahoa Tributary Site ("TRT" sites) January through August 2005 and July 2006 through June 2007;

- 36 samples collected at each site within the Natalbany watershed ("NR", "YW", and "PC" sites October 2005 through June 2007.

Fecal coliform data was used as the indicator of enteric pathogens so that a comparison to past data could be performed (see section "Data Comparison to Past Data" above). However, *Escherichia coli* data was also collected and analyzed. The correlation between the two indicators was extremely robust (> 0.98, Spearman's Rho) so conclusions drawn about fecal coliform in relation other parameters and land use may also be drawn for *E.coli*.

Fecal coliform had significant differences among the sites ($\alpha = <0.0001$, Appendix C). Tangipahoa River had low fecal coliform counts, most counts occurring below the Louisiana State standard for primary contact recreation (< 400 MPN / 100 ml water for a single sample, LDEQ, 2007) (Figure 23). Among the Tangipahoa tributaries, TRT1, TRT2, and TRT3 (Black Creek, Carpenter Branch, and Big Creek, respectively) in the northern portion of the Tangipahoa watershed had high fecal coliform counts (Figure 23). The sources of the counts at TRT1 and TRT2 were found to be from homes and trailers not tied in to the community wastewater systems. TRT3 is located in an area dominated by dairies; the source of the high count has not yet been located. However, TRT4, TRT6, and TRT9 are also located in the dairy region and these sites show low fecal coliform counts, implying a localized source of TRT3's counts (as TRT4 is upstream of TRT3). The lower tributaries (TRT10, TRT11, and TRT12, which are Skull's Creek, Sim's Creek, and Bedico Creek, respectively) are located in the rapidly developing portion of this watershed. Counts were slightly elevated on TRT11, but remain low on TRT10 and TRT12 (Figure 23). TRT 12, Bedico, is the southernmost of all of the tributaries with the most interaction with the Pontchartrain Estuary. The intermixing with the saltier waters serves to kill the bacteria and flush it from the system.

Within the Natalbany watershed, the Natalbany River (NR sites) showed generally higher counts than the Tangipahoa River, with greater than 25% of samples from each site exceeding the LDEQ limit (Figure 23). Sites along Ponchatoula Creek (PC sites) and Yellow Water River (YW sites) have high fecal coliform counts that generally increased in the downstream direction. Counts on Yellow Water River were particularly high. These sites are located in the most urbanized portion of the parish; which includes many small wastewater plants.

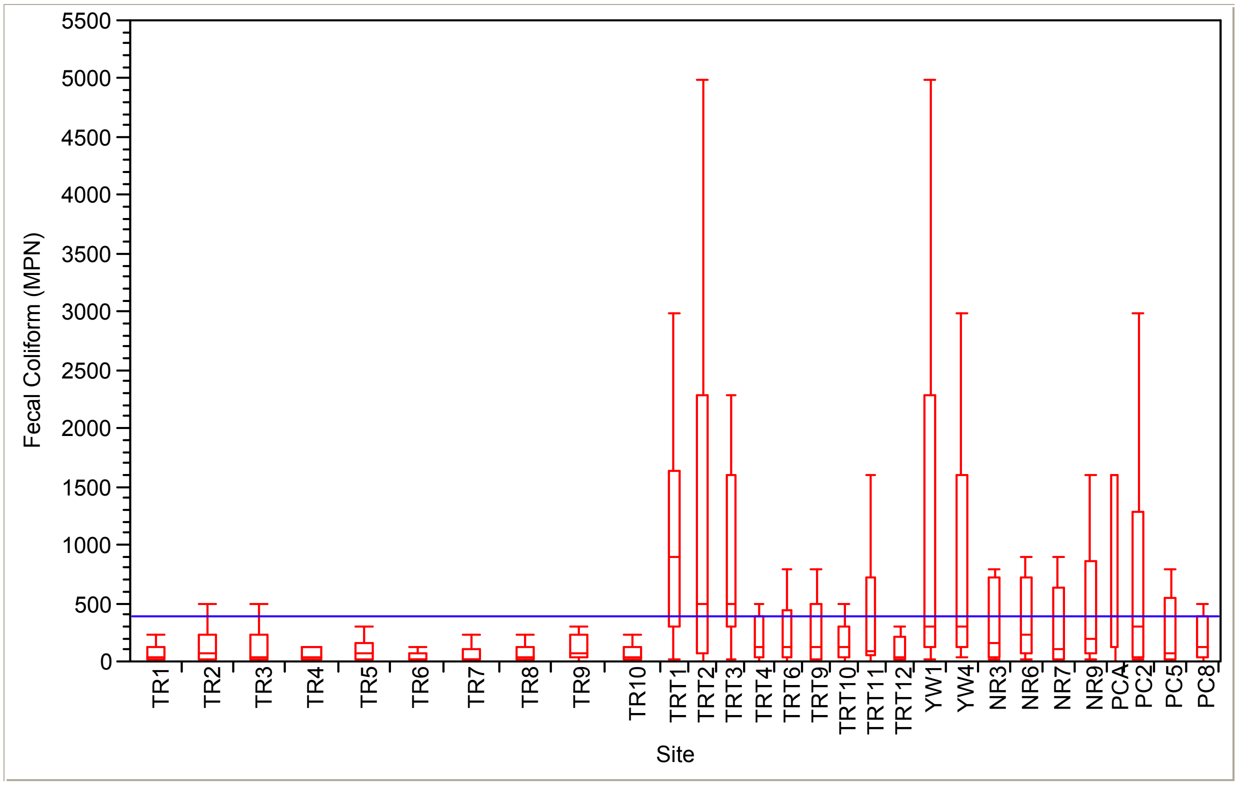


Figure 23. Fecal Coliform Quantiles By Site- bi-weekly samples collected January 2005 – June 2007. Tangipahoa River (TR sites) had low "most probable number" (MPN) values for fecal coliform. The highest fecal coliform counts occurred in streams with known or suspected anthropogenic sources.

Figure 24. Sludge (a bi-product of wastewater treatment) Observed on Ponchatoula Creek (upstream of site PC2) September '06

4.7 Land Use Data vs. Water Quality Parameters

Land use classification data based on digital ortho quarter quad (DOQQ) images captured in 2006 was obtained from PIES UNO and manipulated by LPBF using ArcDesktop Version 9.1. Based on the land classification data, land us in the 2135 km^2 Tangipahoa Parish was:

- 1188 km^2 (55%) water/ marsh/ wetland forest/ scrub shrub/ sand;
- 331 km^2 (16%) upland forest;
- 464 km^2 (22%) agricultural/ grass/ barren;
- 143 km^2 (7%) urban (impervious surfaces/ minimal vegetation).

The data was compared to land use classifications 1982 (obtained from UNO PIES). In 1982 upland forest was the largest habitat class with 767 km^2 (35.9%) followed by agricultural/grass/barren with 592 km^2 (27.0%). By 2006, upland forest decreased to 331 km^2 (less than one half of the 1982 value) and agricultural/grass/barren decreased to 464 km^2 (down nearly one quarter from the 1982 value). In 1982 urban areas accounted for 75 km^2 (3.4%). Urban land use increased to 143 km^2 (nearly double the 1982 value) (Table 4). This is an urbanization increase of nearly 3 km^2 per year.

The urban growth is largely concentrated in the southern portion of the parish while the northern portion remains dominated by dairy and agriculture (Figures 4 & 5). Particularly, the watersheds of Ponchatoula Creek and Yellow Water River show significantly greater urban land use (28% and 34%, respectively) as compared to the other sub-watersheds (2-7%).

Sub-Basin	Water/Marsh/Wet Forest/Scrub	Upland Forest	Ag/Grass/ Barren	Urban
North Tangipahoa	48	20	26	4
Big Creek	45	18	36	2
Chappepeela Creek	46	19	33	2
South Tangipahoa	70	19	6	5
Natalbany River	52	20	21	7
Yellow Water River	35	14	16	34
Ponchatoula Creek	44	14	13	28

Table 4. Percent Land Use Types By Sub-watershed- 2006. Most sub-watersheds are dominated by wetland environments, forests, and agriculture. The Ponchatoula Creek and Yellow Water sub-watersheds had significantly higher percentages of urban land use compared to the other sub-watersheds.

Urbanization and Water Quality Parameters Comparison: The percentage of urbanization within each of the sub-watersheds outlined in Table 4 was compared to the median site values for the physiochemical and geochemical parameters tested. When all parameters were tested against percent urbanization of the watershed, relationships were observed in specific conductance, Na, SO_4, alkalinity (HCO_3-C), and fecal coliform. In all cases, the specific conductance, concentrations, and counts increased as the percent of urbanized land increased. While the watersheds present only a snap shot along the urbanization continuum (as percent urbanization values range 2-7% for most sub-watersheds and 28-34% for urbanized watersheds), this data can be used to anticipate how further urban development within watersheds such as the rapidly developing "South Tangipahoa" sub-watershed (Bedico Creek area) may impact water quality, as seen in the Yellow Water River and Ponchatoula Creek watersheds.

When the outliers TRT2 and TRT12 were removed, median specific conductance exhibited a robust positive correlation with urbanization ($R^2 = 0.8557$), with urbanization clearly linked to greater specific conductance (Figure 25). Specific conductance values increased from a background range of 50-100 µS/cm to a range of 150-300 at 30% urbanization (Figure 25). That equals a gain of at least 7 µS/cm in specific conductance per additional percent urbanization within these watersheds (based on 50 µS/cm at 2% vs. 250 µS/cm at 30%). The two outliers from this pattern have known sources: TRT12 (Pontchartrain marine waters) and TRT2 (Fluker sewage).

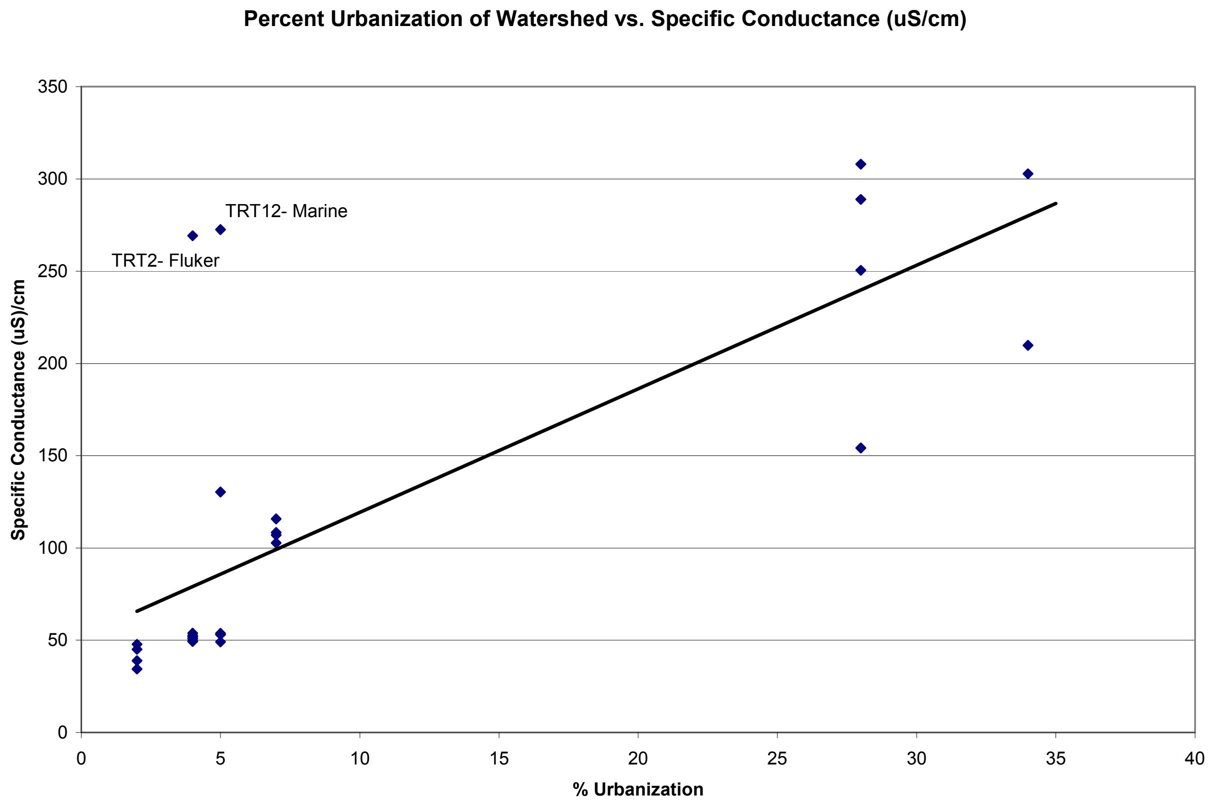


Figure 25. Percent Urbanization Verses Median Specific Conductance. With known outliers (TRT2 and TRT12) removed, a robust correlation of R^2=0.8557 was observed between percent urbanization and median specific conductance values.

Median sodium concentration also exhibited a robust positive correlation with urbanization (R^2 = 0.9285) when the outliers TRT2 and TRT12 removed (Figure 26). Sodium concentrations increased from a background range of 5-10 mg/l (in watersheds with 2-7% urban land cover) to a range of 35-45 mg/l (in watersheds with 30% urban land cover) (Figure 26). That equals a gain of over 1 mg/l sodium per additional percent urbanization within these watersheds (based on 5 mg/l at 2% vs. 40 mg/l at 30%). Again, the two outliers from this pattern have known sources, TRT12 (Pontchartrain marine waters) and TRT2 (Fluker sewage).

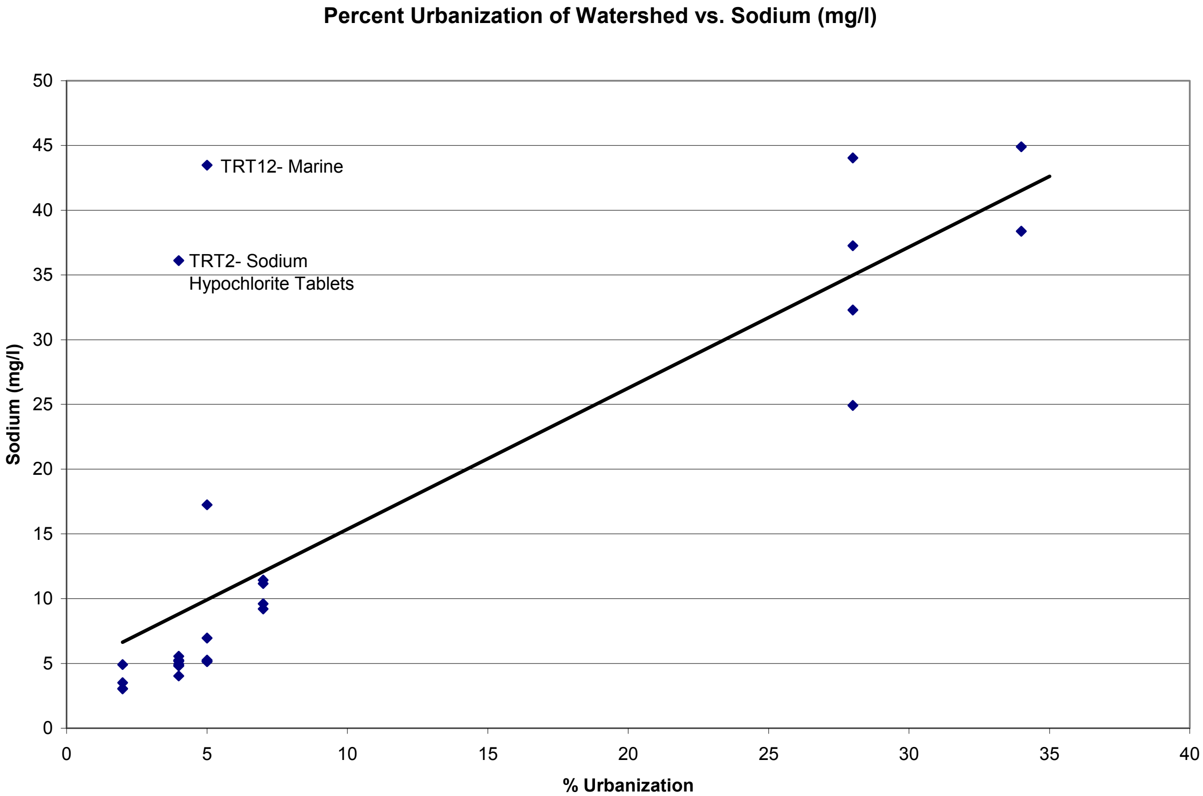


Figure 26. Percent Urbanization Verses Median Sodium Concentrations (mg/l). With known outliers (TRT2 and TRT12) removed, a robust correlation of R^2=0.9285 was observed between percent urbanization and median sodium concentrations.

Median sulfate concentrations also exhibited a fairly robust positive correlation with urbanization (R^2 = 0.7513) (Figure 27). Sulfate concentrations increased from a background range of 2-5 mg/l (in watersheds with 2-7% urban land cover) to a range of around 15 mg/l (in watersheds with 30% urban land cover) (Figure 27). That equals a gain of almost 0.5 mg/l sulfate per additional percent urbanization within these watersheds (based on 2 mg/l at 2% vs. 15 mg/l at 30%). TRT2 and TRT12 were not outliers in this analysis, showing sulfate to be a good predictor of urbanization. However, TRT12 would have been an outlier with more marine input from Lake Pontchartrain.

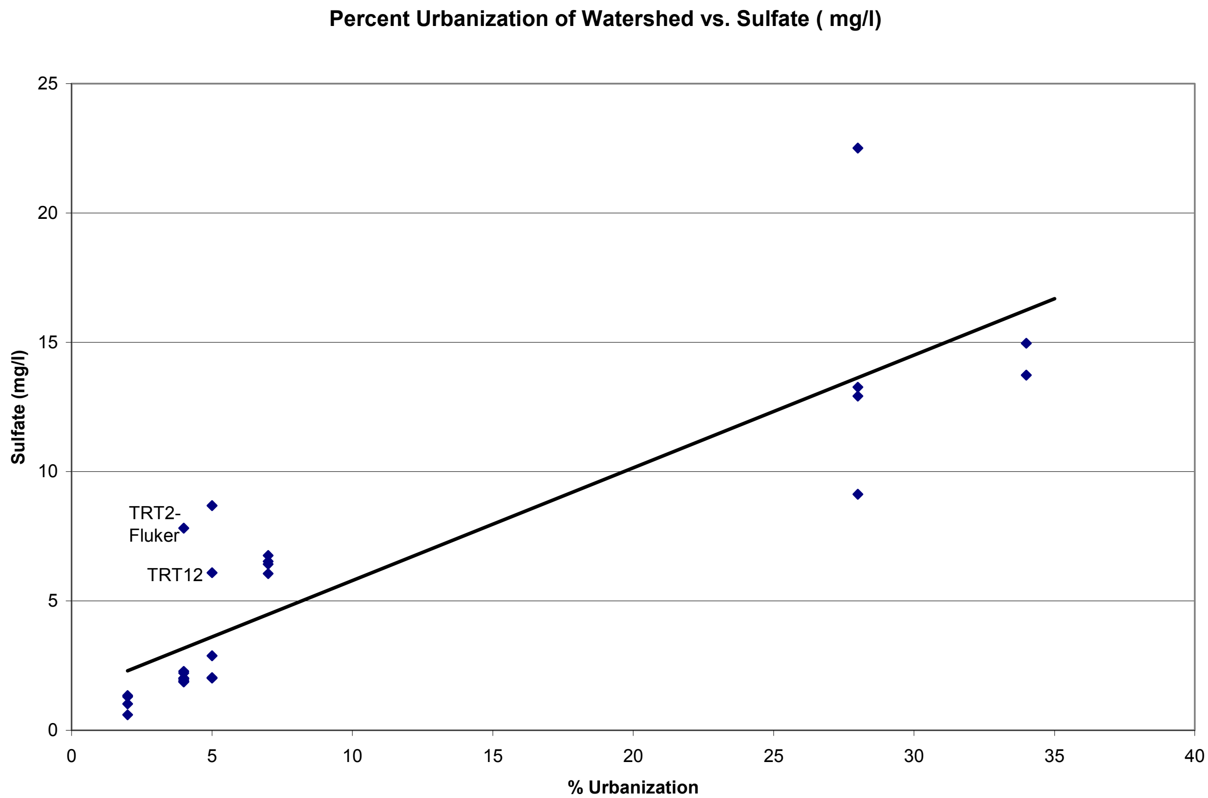


Figure 27. Percent Urbanization Verses Median Sulfate Concentrations (mg/l). A fairly robust correlation of R2=0.7513 was observed between percent urbanization and median sulfate concentrations. TRT2 and TRT12 were not outliers in this analysis.

With the outlier TRT2 removed from analysis, alkalinity (as HCO_3-C) exhibited a robust positive correlation with urbanization ($R^2 = 0.8794$) (Figure 28). HCO_3-C concentrations increased from a background range of 2-5 mg/l (in watersheds with 2-7% urban land cover) to a range of 15-25 mg/l (in watersheds with 30% urban land cover) (Figure 28). That equals a gain of over 0.5 mg/l per additional percent urbanization within these watersheds (based on 2 mg/l at 2% vs. 20 mg/l at 30%). The outlier from this pattern was TRT2, Fluker, a known local source of pollution. TRT12 would have been an outlier with more marine input from Lake Pontchartrain.

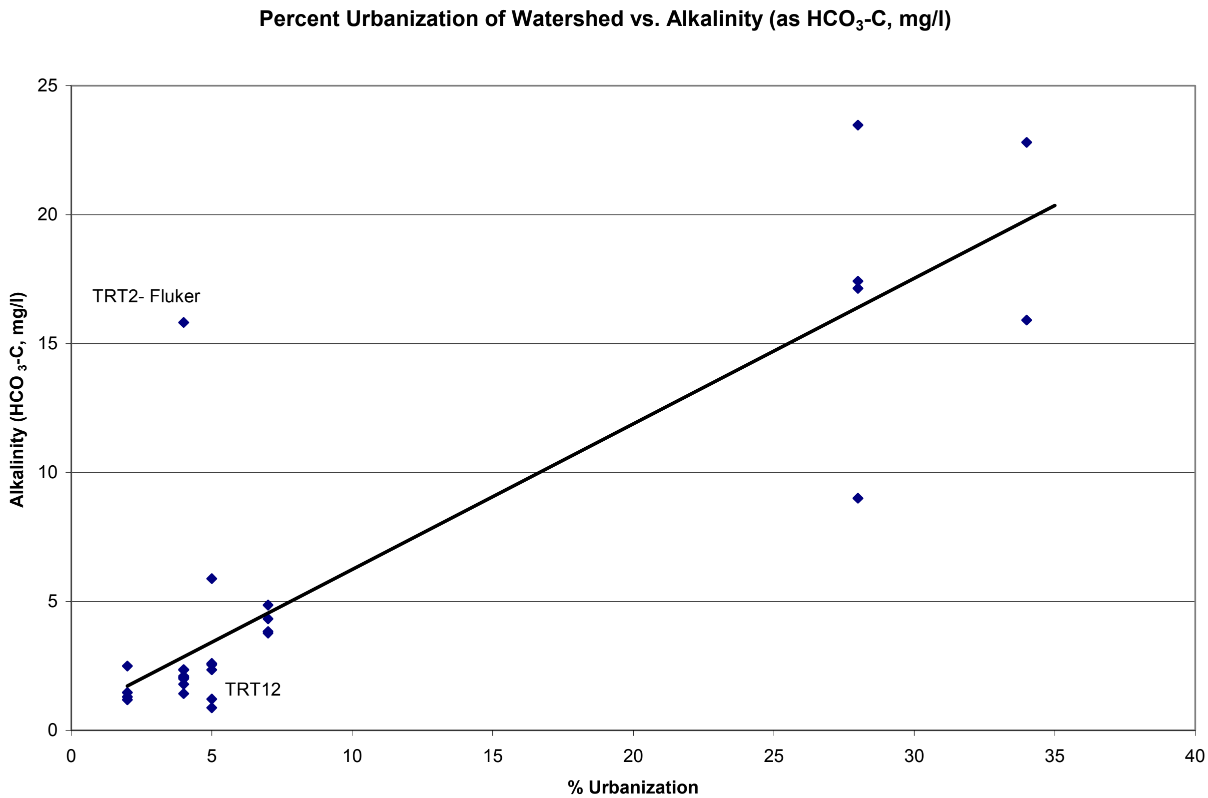


Figure 28. Percent Urbanization Verses Median Alkalinity (as HCO_3-C, mg/l). With known outlier (TRT2) removed, a robust correlation of R^2=0.8794 was observed between percent urbanization and median alkalinity values.

When nutrient concentrations, NO_3-N, NH_4-N, and PO_4-P, were plotted against percent urbanization, increased concentrations occurred on more urbanized streams, but were the highest on the downstream sites. As shown in Figure 14, the nutrient levels increased as a Ponchatoula Creek and Yellow Water River flowed through the urban area. The increased nutrient concentration is a product of many cumulative urban sources, especially wastewater treatment plants. Paul and Meyer (2001) indicate that in an urban setting, the greatest source of nutrients entering a waterway is from wastewater plants (particularly small, individual plants), followed by lawn fertilization.

Dumouchelle (2006) found that NH_4-N concentrations in home sewage treatment units ranged from 1.20 to 25.7 mg/l, PO_4-P concentrations reached a high of 4.37 and 4.39 mg/l, and NO_3-N concentrations ranged from 0.64 to 3.77 mg/l. Nutrient values in this study did not reach the high levels observed in the Dumouchelle study, the median nitrate and phosphate values were less than 1.8 mg/l. However, the sites downstream of the urban areas had NO_3-N concentrations as much as 3 times greater than non-urbanized watersheds (blue diamonds, Figure 29). NH_4-N concentrations were nearly twice as high (pink squares). Also, the linear increases of NO_3-N and NH_4-N with urbanization were nearly identical (dark blue and pink lines, Figure 29). Finally, PO_4-P concentrations (green triangles) were at or below detection limit (0.03 mg/l) in the Tangipahoa River and more than 10 times greater downstream of the urban areas (Figure 29).

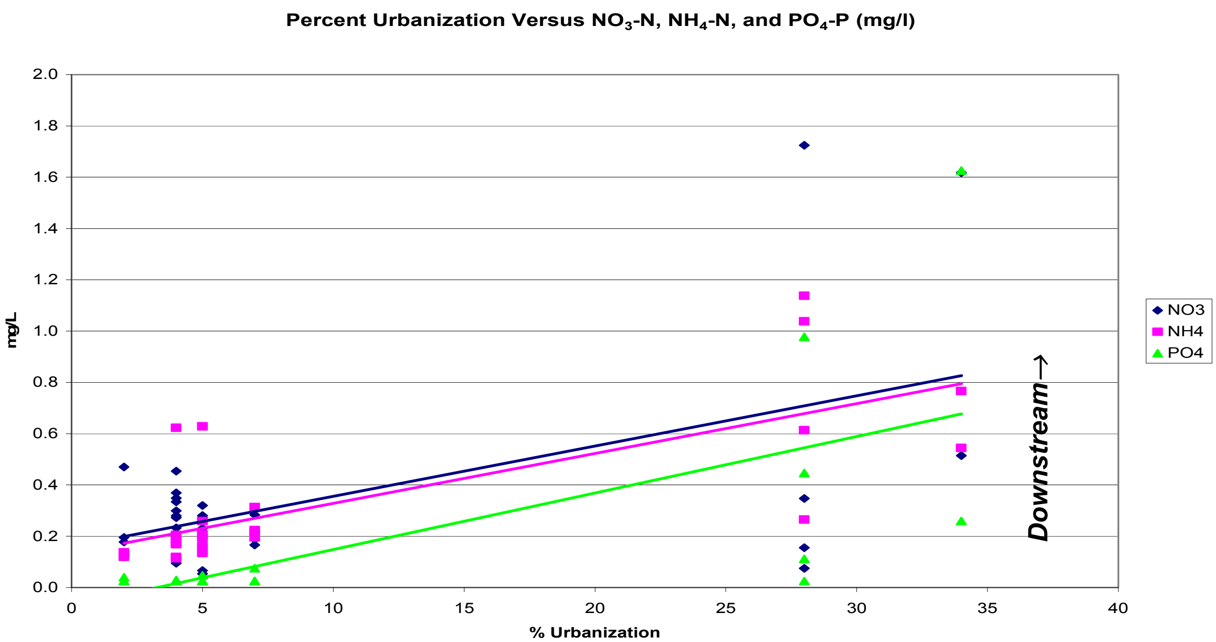


Figure 26. Percent Urbanization Verses Median Nutrient (Nitrate, Ammonia, and Phosphate) Concentrations (mg/l). While watersheds with low percent urbanization had low nutrient values, sites in urbanized watersheds had increasing nutrient concentrations in the downstream direction.

As the Ponchatoula Creek watershed also encompassed the Yellow Water River watershed and represents the most urbanized region of the parish, the progression of nutrient concentration was mapped and plotted against the percent urban development for the area of watershed between the sites monitored (Figure 30). At site PC8 urban land cover was 16% and nutrient levels were above the background levels but relatively low. Between sites PC8 and PC5, urban land cover increased to 18% and nutrients were stable. Between sites PC5 and PC2, urban land cover jumped to 32% and nutrient levels increased. Between sites PC2 and PCA, urban land cover remained steady at 34% but nutrient levels increased significantly. This progression visually shows the increase in nutrient concentrations with the increase in urban land cover.

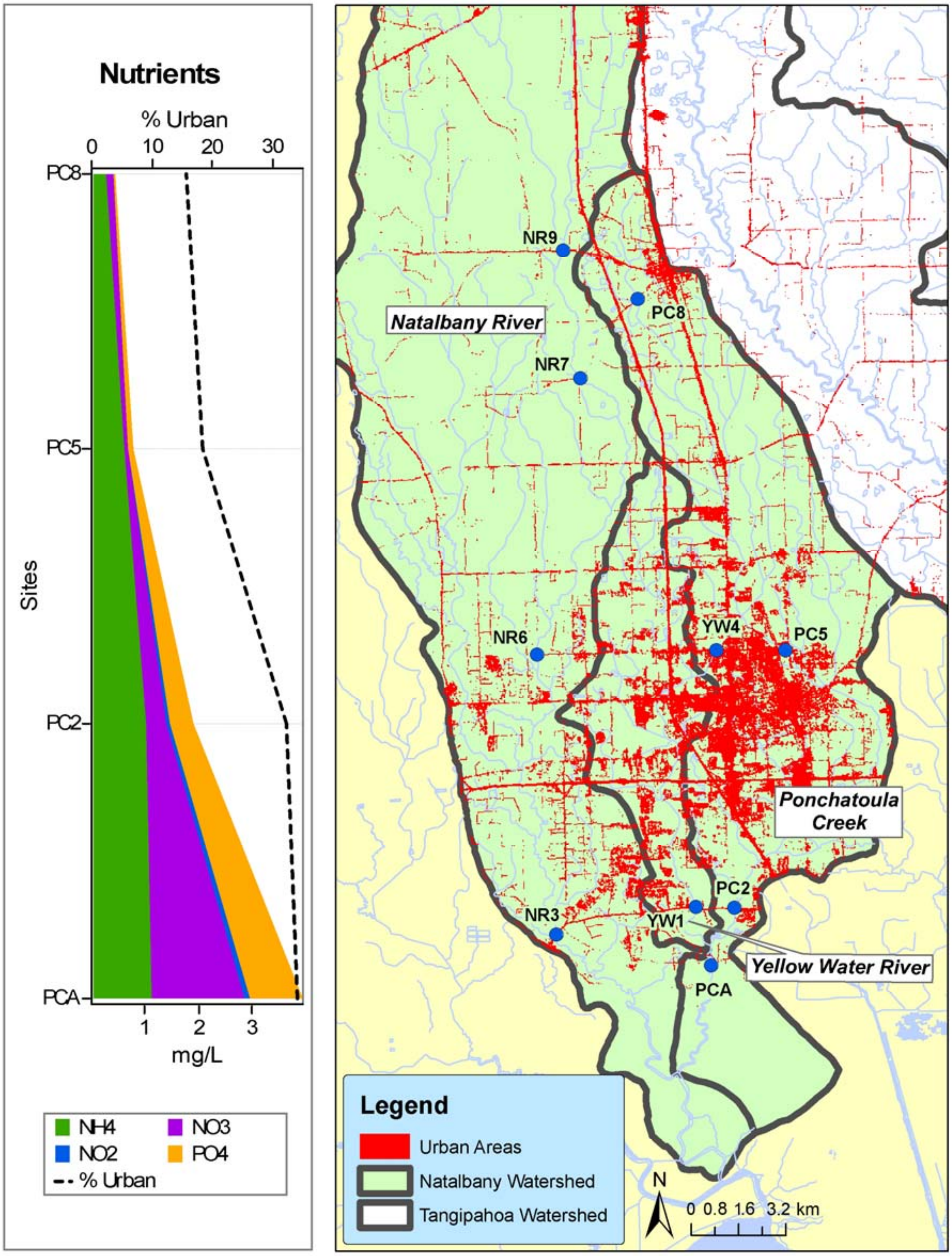


Figure 30. Nutrients Verses Urbanization in the Ponchatoula Creek / Yellow Water River Watershed. As percent urbanization increases within the Ponchatoula Creek/ Yellow Water River Watershed, median concentrations of all nutrients increased with the highest concentrations occurring immediately south of the most urbanized portion of the watershed.

When fecal coliform geometric means were plotted against percent urbanization, a pattern emerged yet local influences were obvious as well (Figure 31). In general, urbanization led to an increase in fecal coliform geometric mean counts, ranging from geomeans around 100 at 2% urbanization, to geomeans around 500 MPN at 34% urbanization (Figure 32). Similar to the nutrient concentrations, the fecal coliform counts generally increased in the downstream direction, with the greatest counts occurring downstream of the urbanized areas. Fecal coliform counts at sites TRT1, TRT2, and TRT3 were all the product of localized sources, yet had a major impact on the stream's water quality (Figures 31 and 32). Removing the localized sources, there was a positive correlation between urbanization and fecal coliform (R^2 = 0.5866).

When fecal coliform counts were charted for Ponchatoula Creek, a general pattern of increasing counts with increased percent impervious cover was observed; however, the influence of localized sources (small, individual WWTP) was also evident with the high counts observed at PC8 (Figure 33).

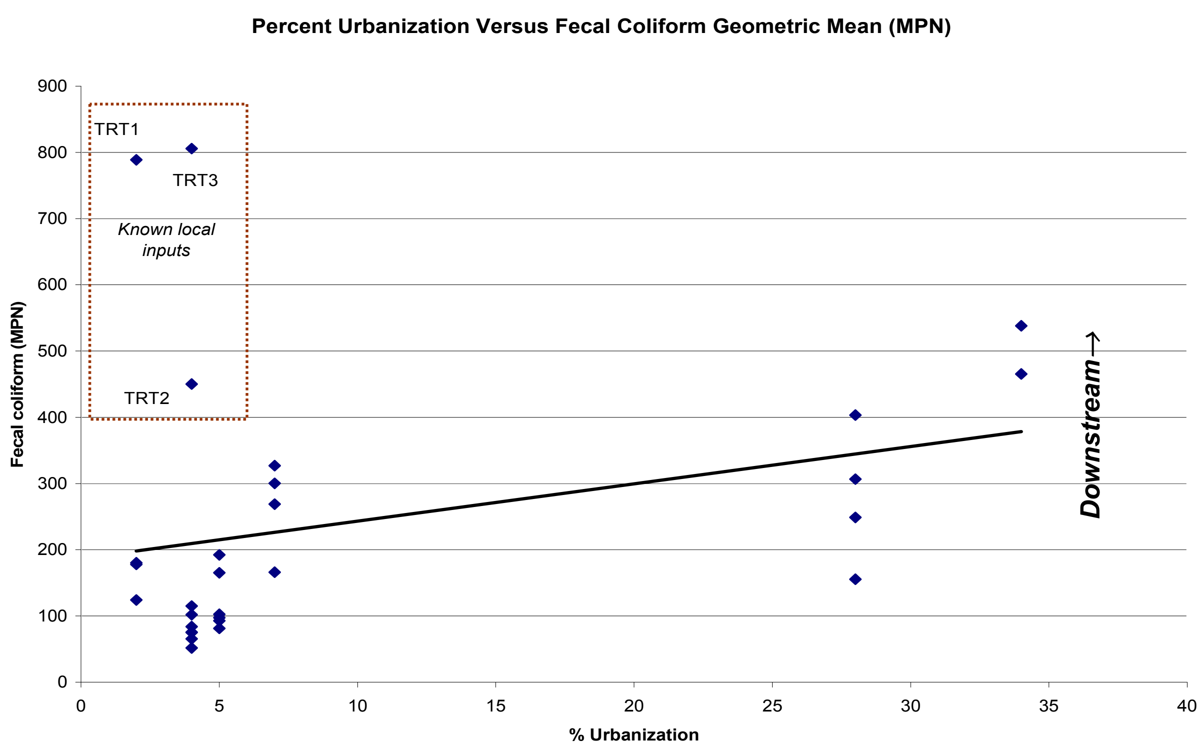


Figure 31. Median Fecal Coliform Geometric Means Verses Urbanization. Sites with known local sources charted away from the general trend of increasing fecal coliform counts with increased urbanization.

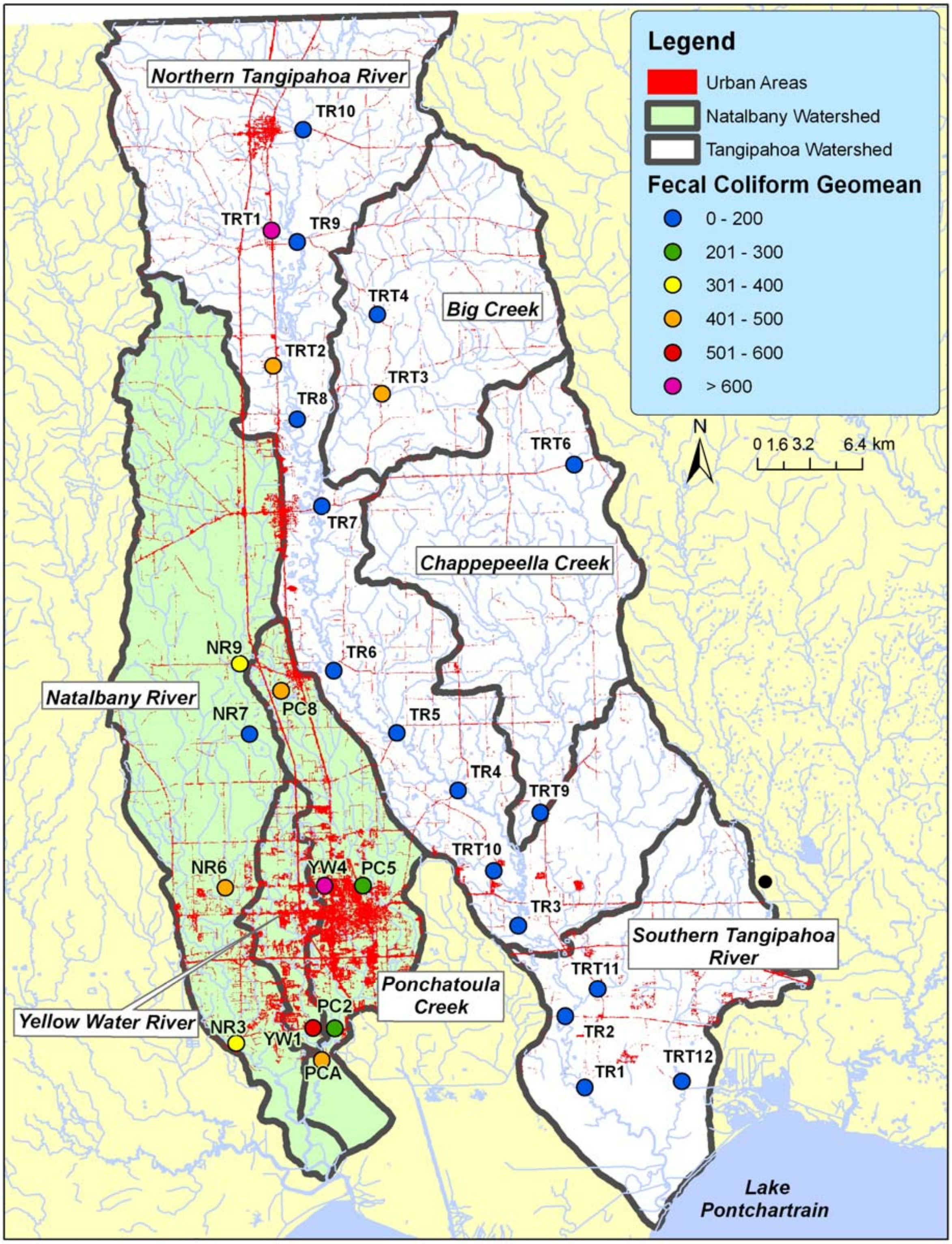


Figure 32. Fecal Coliform Geometric Means and Urbanization in Tangipahoa and Natalbany Watersheds. In general, the highest fecal coliform counts were observed in the most urbanized areas. However, some local inputs were observed in the northern Tangipahoa watershed.

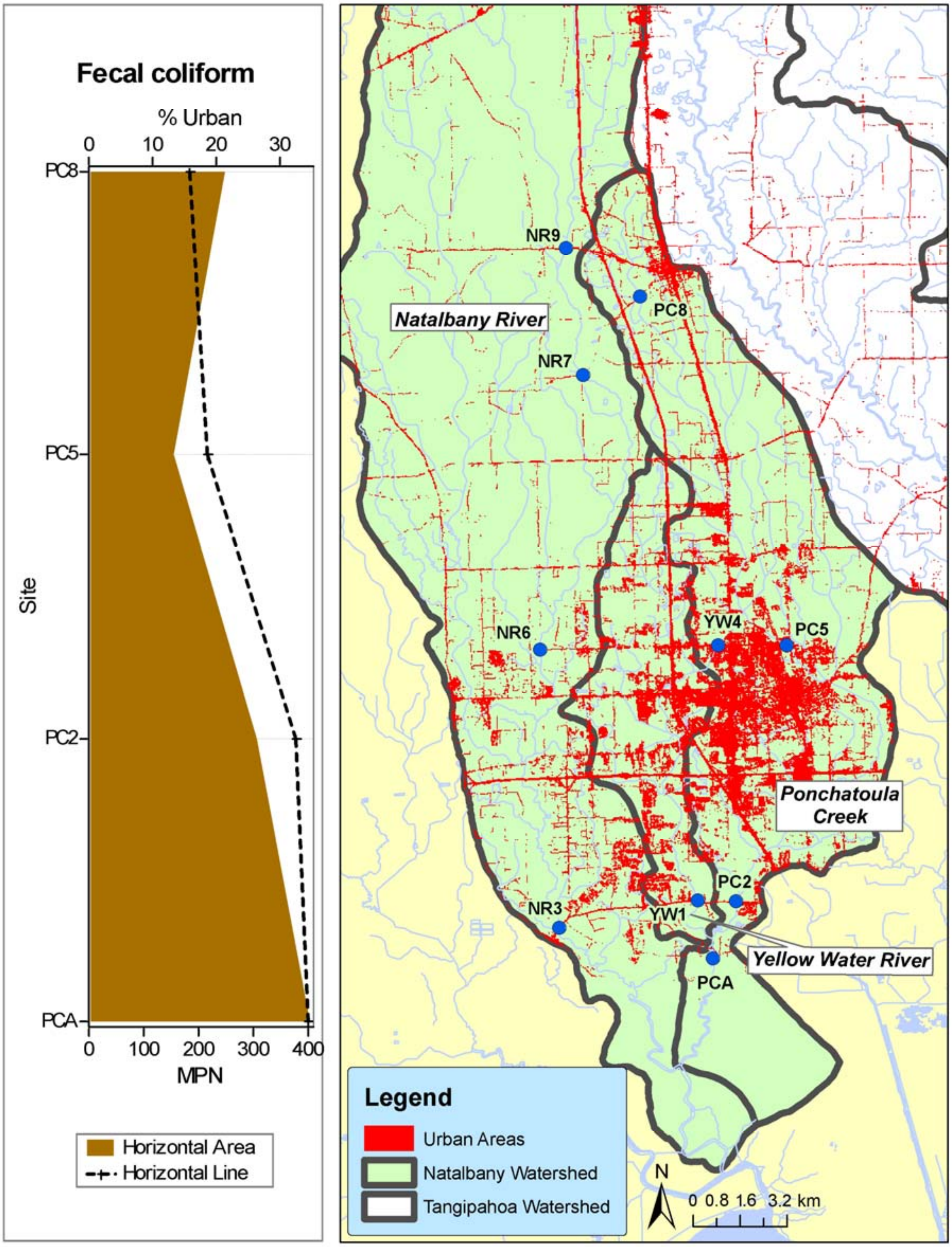


Figure 33. Fecal Coliform and Urbanization in the Ponchatoula Creek/Yellow Water River Watershed. The Ponchatoula Creek and Yellow Water River watersheds followed the general pattern of increased fecal coliform concentrations with increased urbanization. However, the northernmost site, site PC8, also shows local inputs.

In summary, several parameters, including specific conductance, concentrations of sodium, sulfate, alkalinity, and nutrients, and fecal coliform counts, showed significant positive correlations with urbanization. The sites along the Tangipahoa River and in the dairy-influenced portion of the parish (Big Creek and Chappepeela Creek) had low counts and concentrations of the various parameters. In contrast, sites along the heavily urbanized Ponchatoula Creek and Yellow Water River had consistently greater concentrations for most of the parameters examined. The increase in concentrations corresponds to the impacts of urbanization observed in similar environments (see Discussion). Also, sites influenced by seawater (TRT12) and sewage (TRT2) were outside of the trend in most cases (as noted on the graphs). While no watersheds had exactly 10% urbanization, these analyses show water quality degrading as the percentage of urban land cover increased.

Wastewater Treatment Plant Assessment: Previous research into the causes of surface water contamination in urban areas has shown that a dense concentration of WWTPs is common in urban areas and a major contributor to the anthropogenic impacts observed in streams, including high fecal and nutrients levels (Paul and Meyer, 2002). In accordance with the previous research, the concentration of WWTPs was most dense in the urban area of Tangipahoa Parish (Figure 34) and corresponded with increased fecal coliform and nutrients levels.

LBPF and LDEQ examined 117 WWTPs from January 2005 through June 2007. Analysis through this study found that most systems (75%) were not functioning properly and required some kind of assistance (yellow dots, Figure 34), meaning that they were discharging fecal bacteria and nutrients into the watershed. Of the plants inspected, the majority (60%) utilized an aerated treatment process, 21% of the systems were ponds (aerated and non-aerated), 15% of the plants were in transition (being tied in to a larger community system) and only 4% of the plants were non-aerated septic systems. 42% of the plants had discharges exceeding 5000 gallons per day (gpd), with some plants having discharges well over 1 million gpd.

Septic system plants traditionally discharge the treated wastewater into drainage fields. The drainage field allows for filtration of the wastewater through the soil, killing enteric pathogens, oxidizing ammonium to nitrate, removing phosphate by sorption, and reducing nitrate to nitrogen gas in the process. However, drainage fields do not work well in clay-rich soils with a water table near the surface, so an aeration system is often utilized to oxidize ammonium to nitrate but this does not remove nitrate and phosphate nor does it kill pathogenic bacteria associated with the waste. Because of the clay-rich soils in Tangipahoa Parish and the near-surface water table south of Hammond, non-aerated septic systems are not permitted in most areas.

Of 117 plants investigated, 64% were not properly permitted for their discharge. In Louisiana, the Louisiana Department of Health and Hospitals (LDHH) permits WWTPs to be built according to the Louisiana Sanitary Code (2007). The LDEQ permits the plant to discharge into waters of the state, as part of the LPDES (Louisiana Pollutant Discharge Elimination System) program of the Clean Water Act (2007). This has caused a historic disconnect between these two agencies to where plants were routinely permitted to be built but not to discharge. This meant that these plants did not have their effluent tested for years to decades, a provision of the LPDES permit.

The most frequently encountered issue in regard to plant maintenance and functioning was the use of disinfection for the plant effluent. While the treatment process does reduce the fecal bacteria count, it does not bring it to the low levels (< 400 MPN/ 100 ml water for a single sample) required by LDEQ. Of the plants assisted, 66% had the equipment to disinfect the effluent and 44% did not. In the permitting of plants to be built by LDHH, the plants are not required to have disinfection. LDEQ, through the LPDES program, requires disinfection (if needed) to discharge into waters of the state. So, plants that were not permitted by LDEQ most likely did not have disinfection for the wastewater effluent.

Of the plants that could disinfect the effluent, only 61% of the plants were utilizing it correctly. This means that of all the plants inspected, 33% of the plants utilized disinfection for their effluent and 67% did not. All of the waterways tested (with the exception of Chappepeela Creek) are listed on the 2006 Impaired Waterbodies List as impaired for fecal bacteria. Use of disinfection is the single greatest factor in reducing the fecal bacteria levels.

While this data represents only a snapshot of the current wastewater issue, the large percentage of unpermitted plants and plants not utilizing disinfection represent many cumulative sources of pollution. Through correct permitting, many pollution sources could be eliminated.

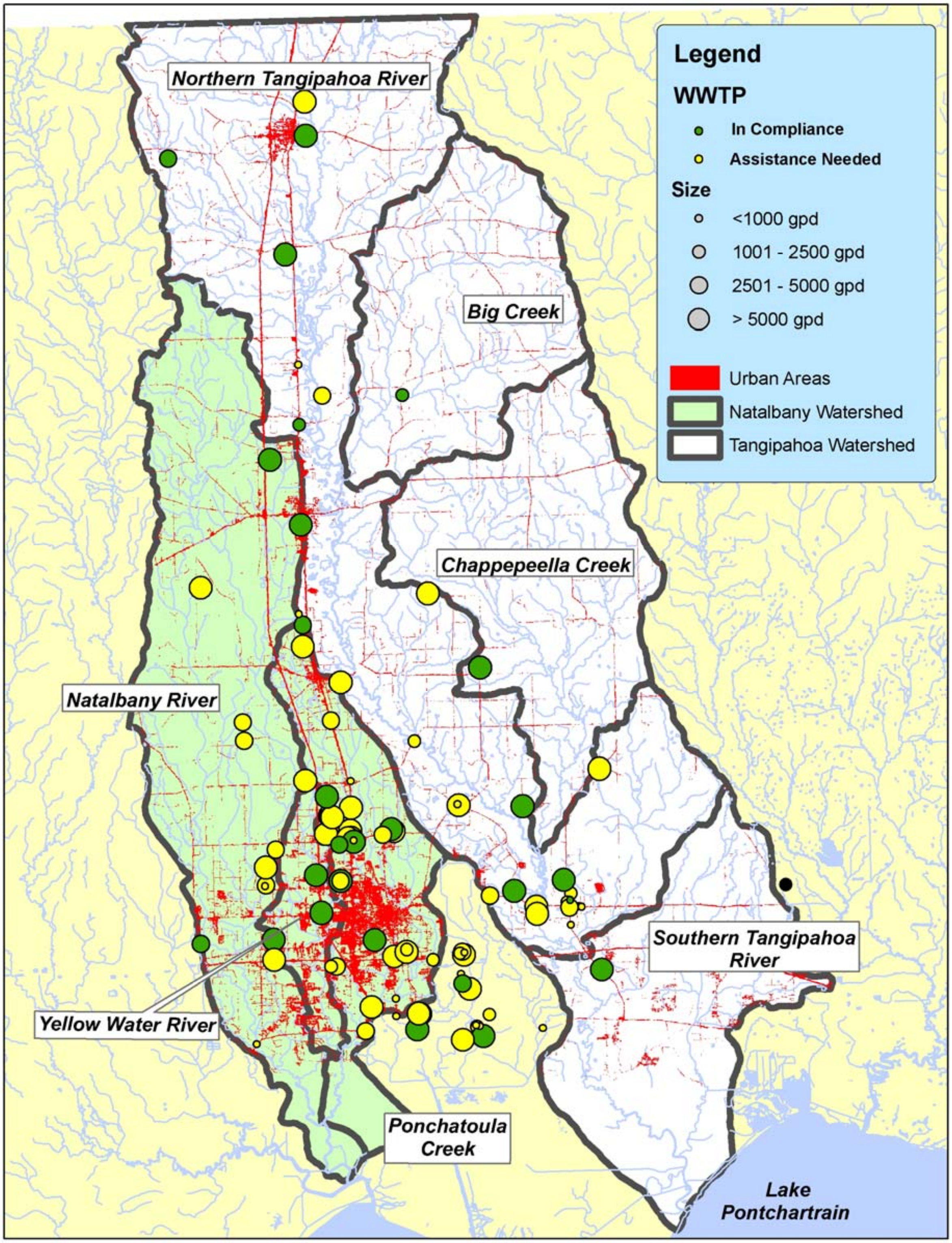


Figure 34. WWTPs By Size and Compliance Status in the Tangipahoa and Natalbany Watersheds. The most dense concentration of WWTPs occurred around the most urbanized areas and the majority of plants required assistance to come into compliance with LPDES permits.

Trends Over Time: With the technical assistance to the WWTPs occurring within the same time period as data collection, fecal coliform and dissolved oxygen data were plotted chronologically for sites within the Tangipahoa and Natalbany watersheds to assess trends over time. A linear regression line (green dotted line) was fit through the data to detect any general increasing or decreasing trends. The state water quality standard (red line) was also included on the graphs. For fecal coliform, the geometric mean of five samples was graphed for each date (each geometric mean including data from the two samples prior to the date listed, the date listed, and two samples after the date listed).

Sites on the Tangipahoa River had relatively consistent fecal coliform geometric means and dissolved oxygen levels throughout the time period. The river had low counts with spikes during rain events observed throughout the river, at the northernmost site (TR10, Figure 35a), the middle of the river (TR6, Figure 36a), and near the mouth (TR1, Figure 37a). All Tangipahoa sites also exhibited consistent dissolved oxygen levels, all above 5 mg/l (the state standard) yet reducing slightly though the time period (Figures 35b, 36b, and 37b).

In contrast, sites on Ponchatoula Creek and Yellow Water River showed decreasing fecal coliform geometric means (Figures 38a, 39a, 40a, 41a, 42a, and 43a) and increasing dissolved oxygen trends (Figures 38b, 39b, 40b, 41b, 42b, and 43b) over time.

Similar decreases in fecal coliform counts were observed on eight waterways within the Bogue Falaya and Tchefuncte watersheds in 2002-2004 due to the location and correction of pollution sources (Bourgeois-Calvin, 2006). Citing the successes in the Bogue Falaya/ Tchefuncte and Tangipahoa/Natalbany watersheds, the Louisiana Department of Environmental Quality's "Louisiana Clean Waters Program" adopted the watershed approach of locating and correcting pollution sources for use statewide in 2007

Turbidity and dissolved oxygen data for Bedico Creek was graphed chronologically with linear trend lines (green dotted line) and state standards (red line). The dissolved oxygen levels show a decline over time (Figure 44b) and the turbidity levels show an increase (Figure 44a). The Bedico Creek watershed has been the site of recent, rapid development, which has negatively impacted the turbidity and dissolved oxygen levels. At the start of the sampling period both parameters met state standards for healthy water (DO > 5mg/l, turbidity < 50 NTU). By the end of the sampling period (18 months) the trends show that both parameters were no longer meeting state standards.

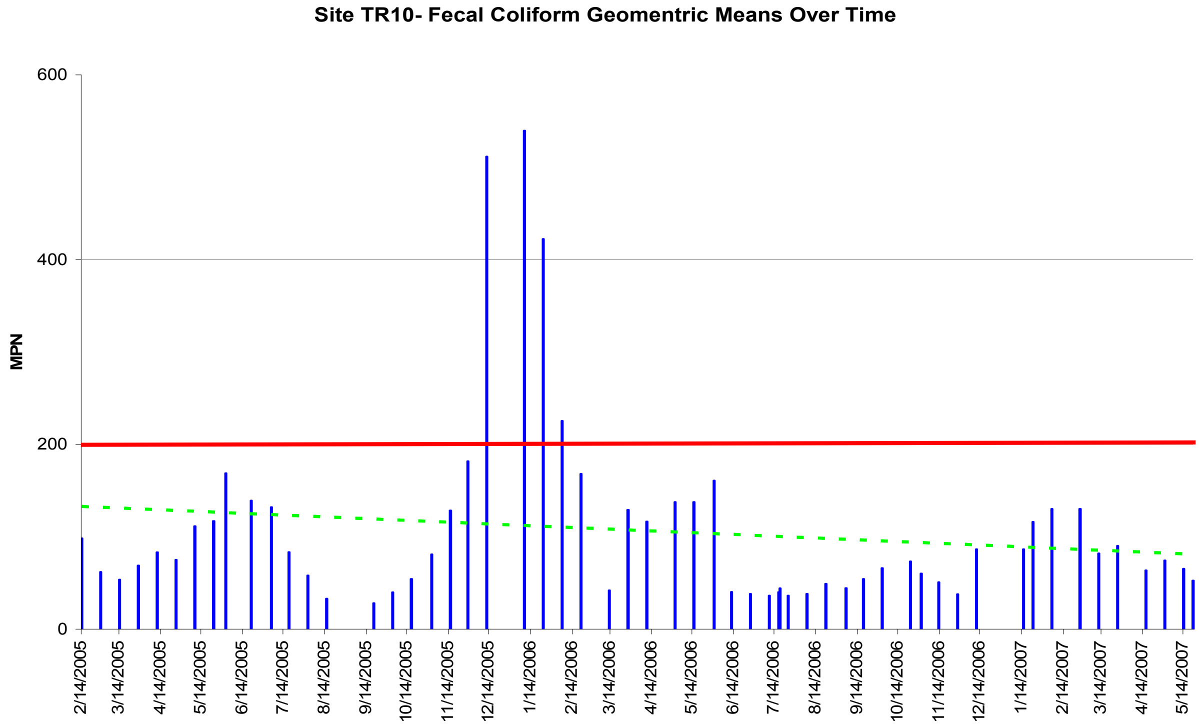


Figure 35a. Northernmost Tangipahoa River Site- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform had low, consistent levels over time only impacted by rain events.

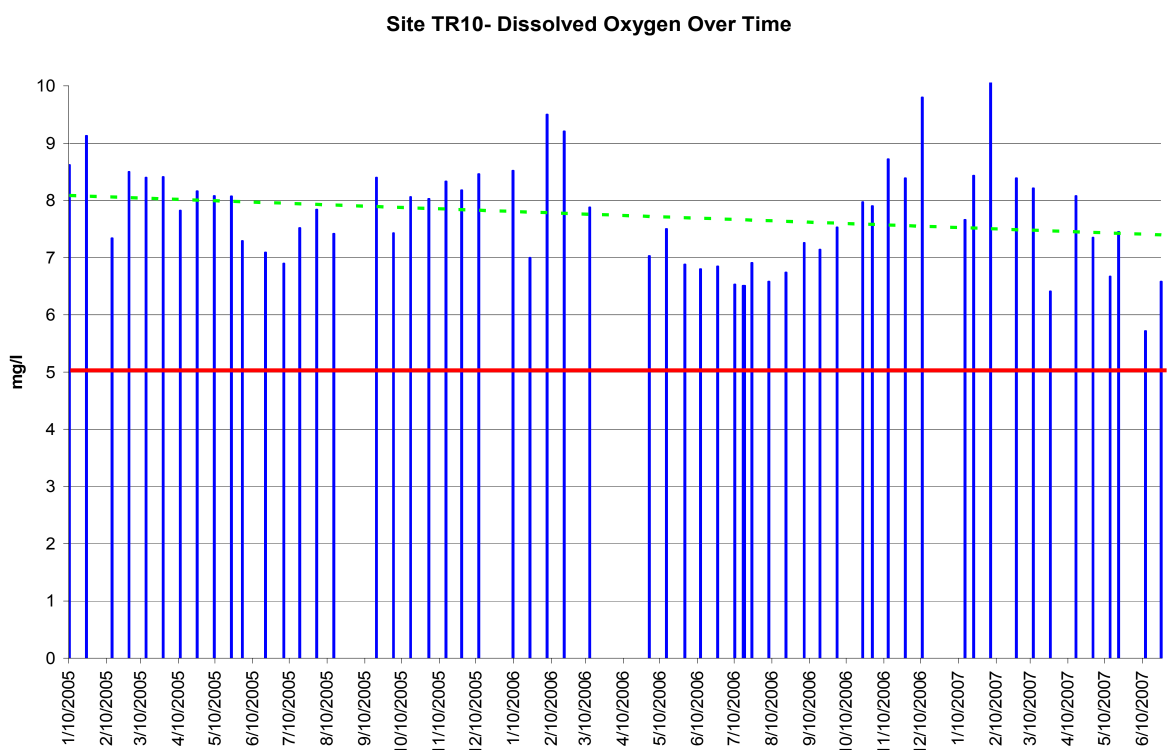


Figure 35b. Northernmost Tangipahoa River Site- Trend Over Time, Dissolved Oxygen (mg/l). DO was consistently high.

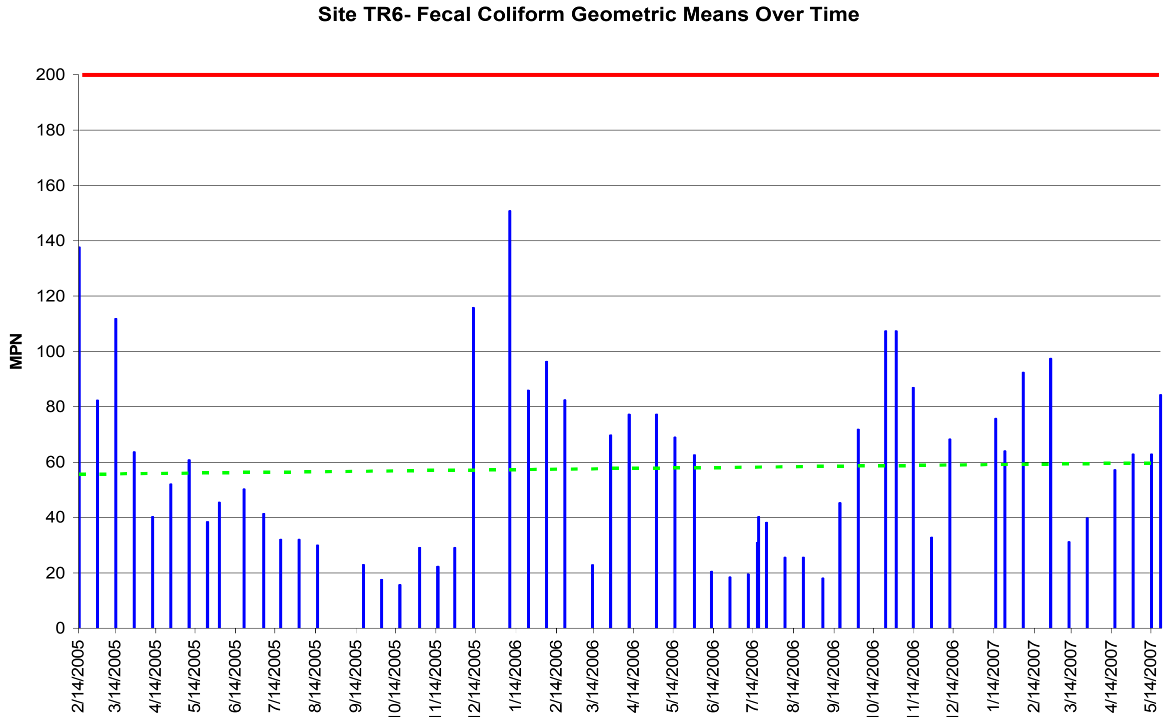


Figure 36a. Middle Tangipahoa River Site- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform had low, consistent levels over time only impacted by rain events.

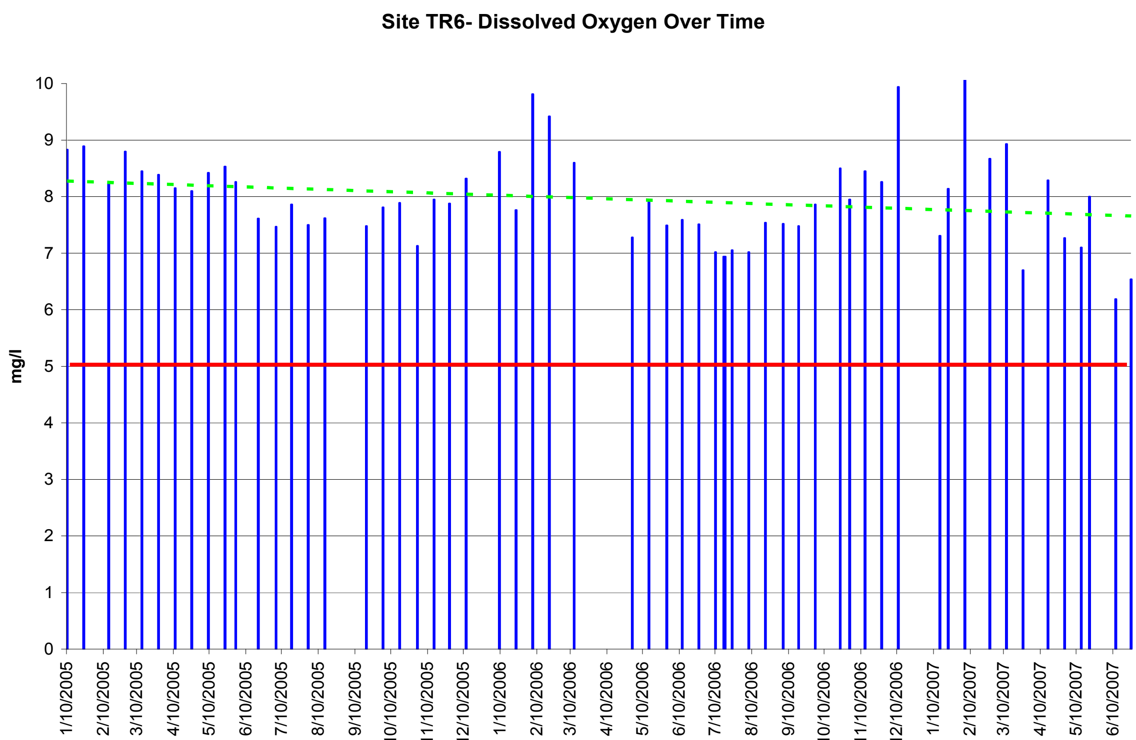


Figure 36b. Middle Tangipahoa River Site- Trend Over Time, Dissolved Oxygen (mg/l). DO was consistently high.

Site TR1- Fecal Coliform Geometric Means Over Time

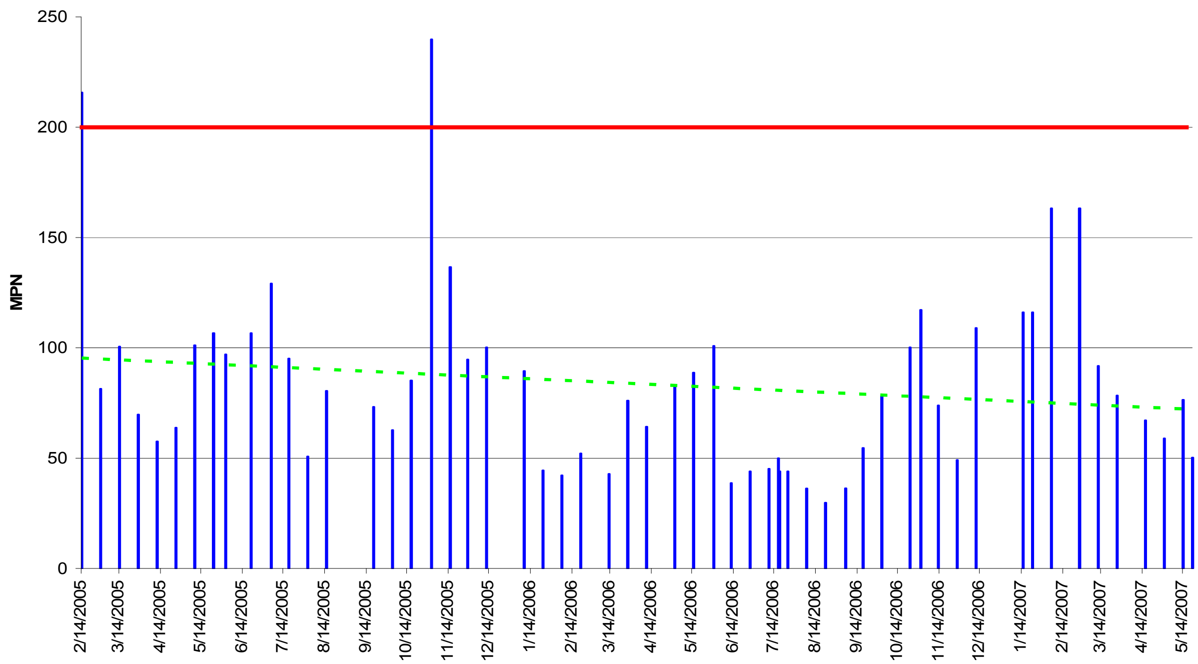


Figure 37a. Southernmost Tangipahoa River Site- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform had low, consistent levels over time only impacted by rain events.

Site TR1- Dissolved Oxygen Over Time

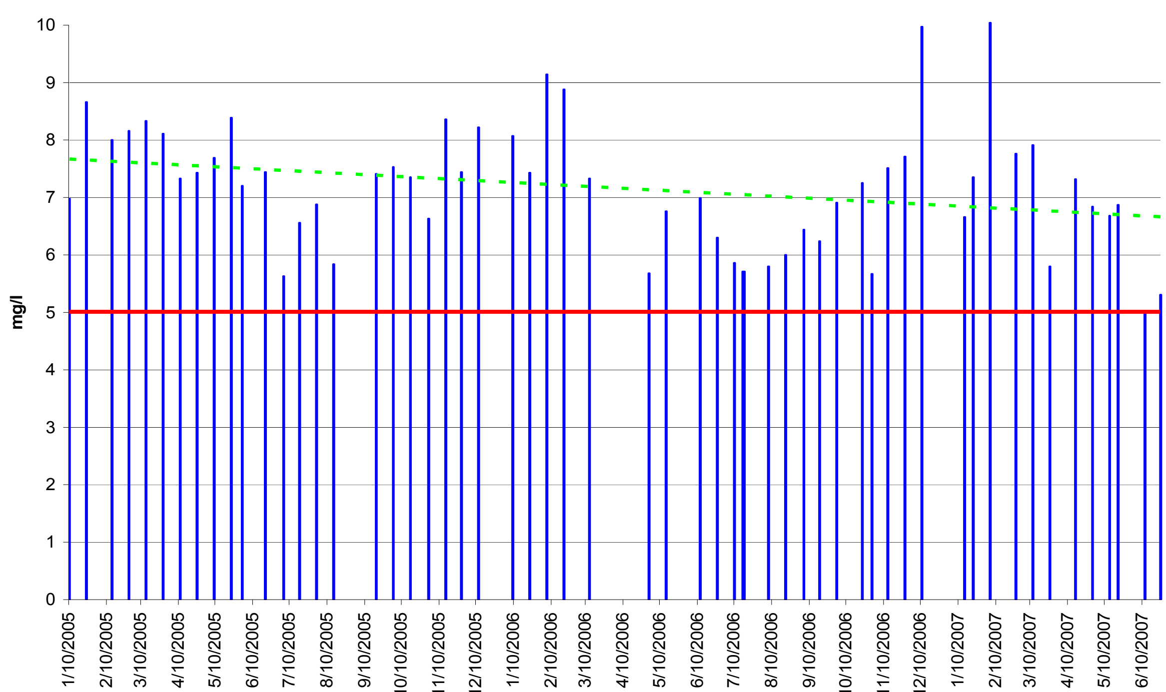


Figure 37b. Southernmost Tangipahoa River Site- Trend Over Time, Dissolved Oxygen (mg/l). DO was consistently high.

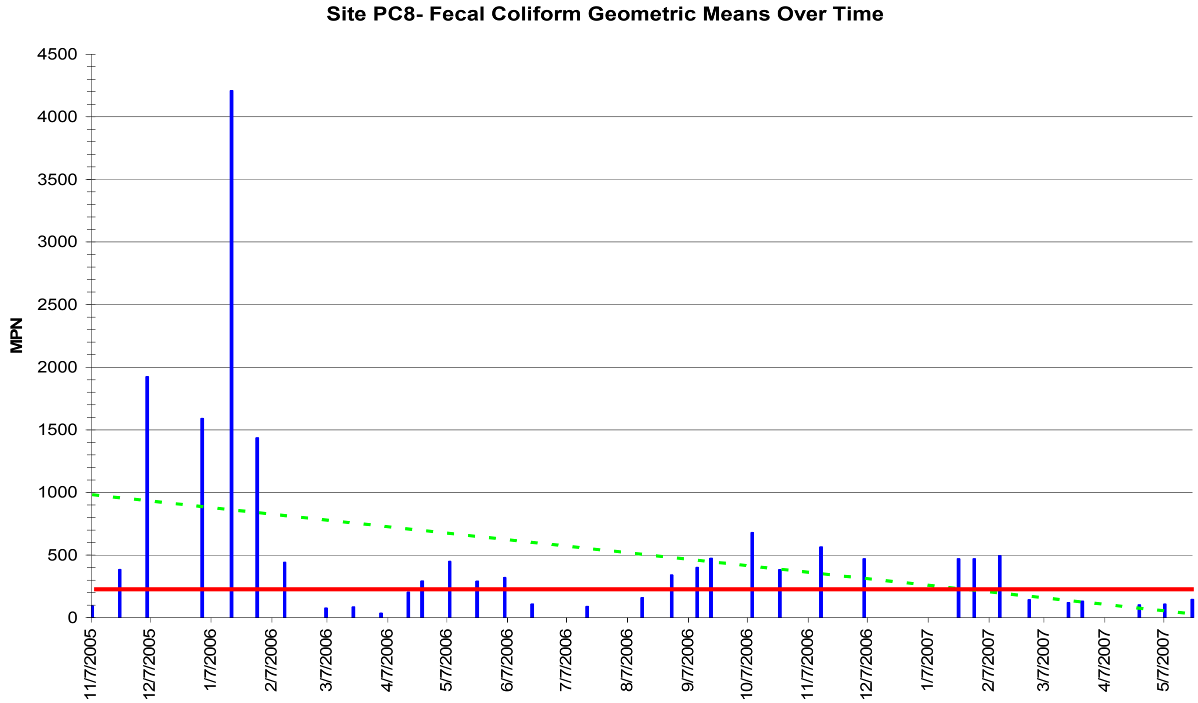


Figure 38a. Northernmost Ponchatoula Creek Site- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform decreased over the period of data collection.

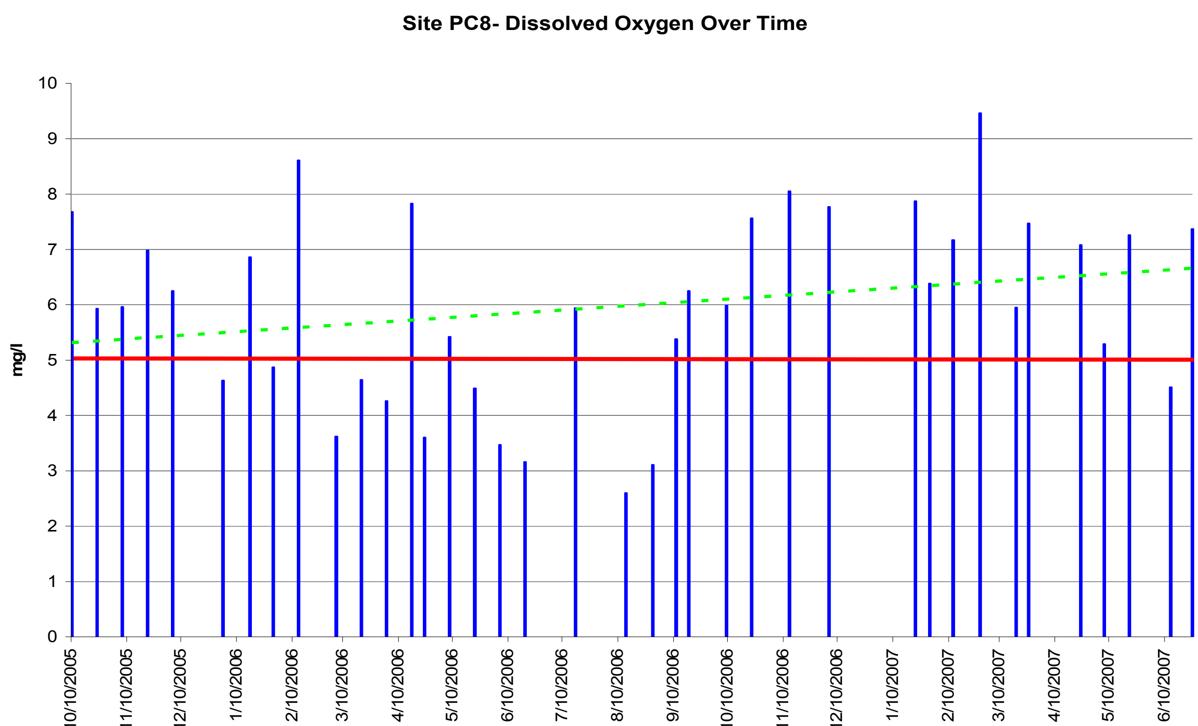


Figure 38b. Northernmost Ponchatoula Creek Site- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

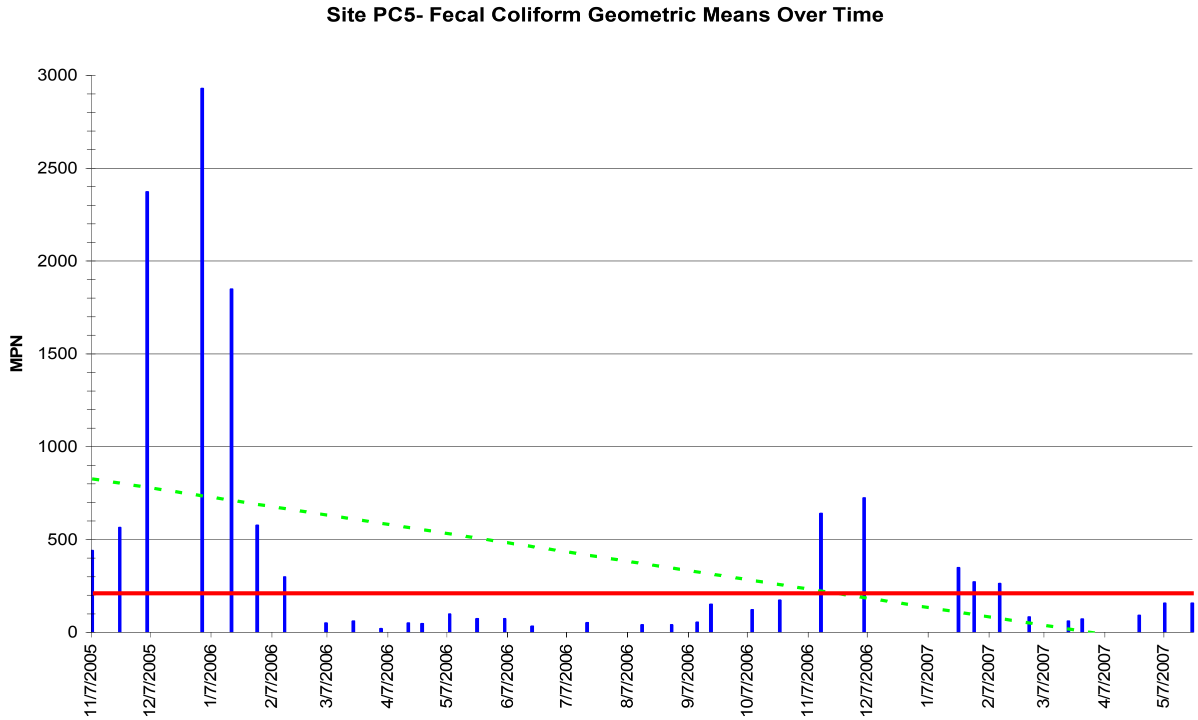


Figure 39a. Ponchatoula Creek, Upstream Hammond- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform decreased over the period of data collection.

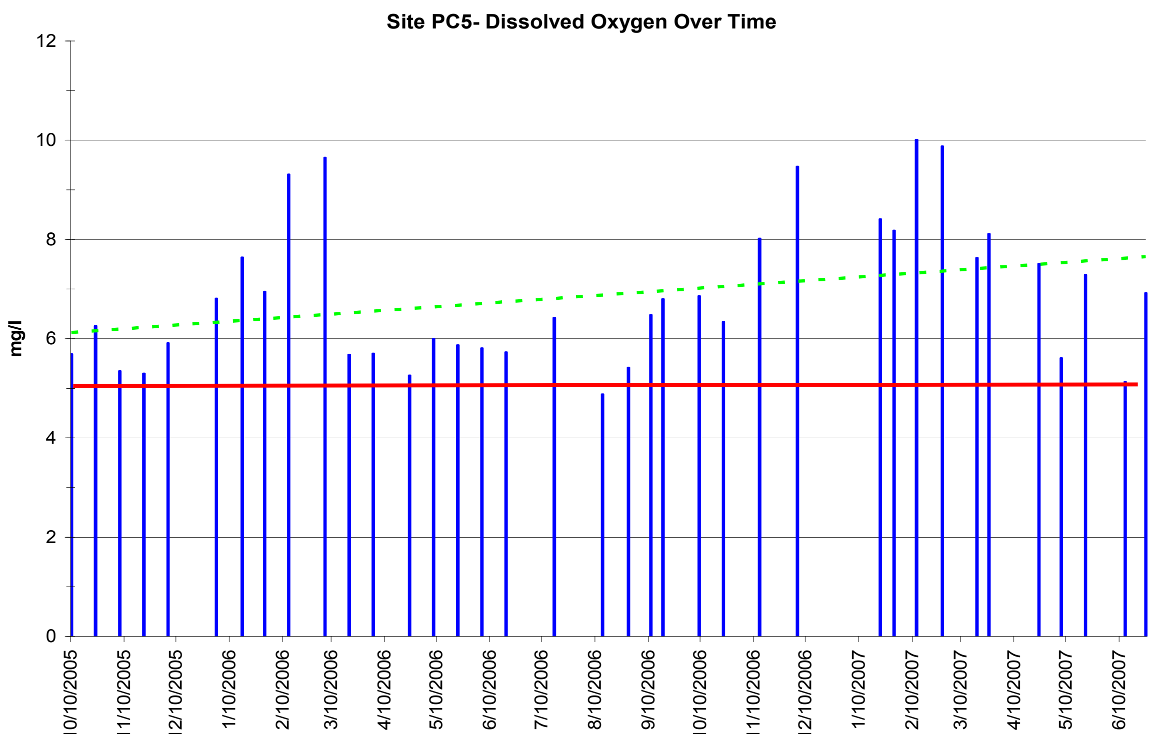


Figure 39b. Ponchatoula Creek, Upstream Hammond- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

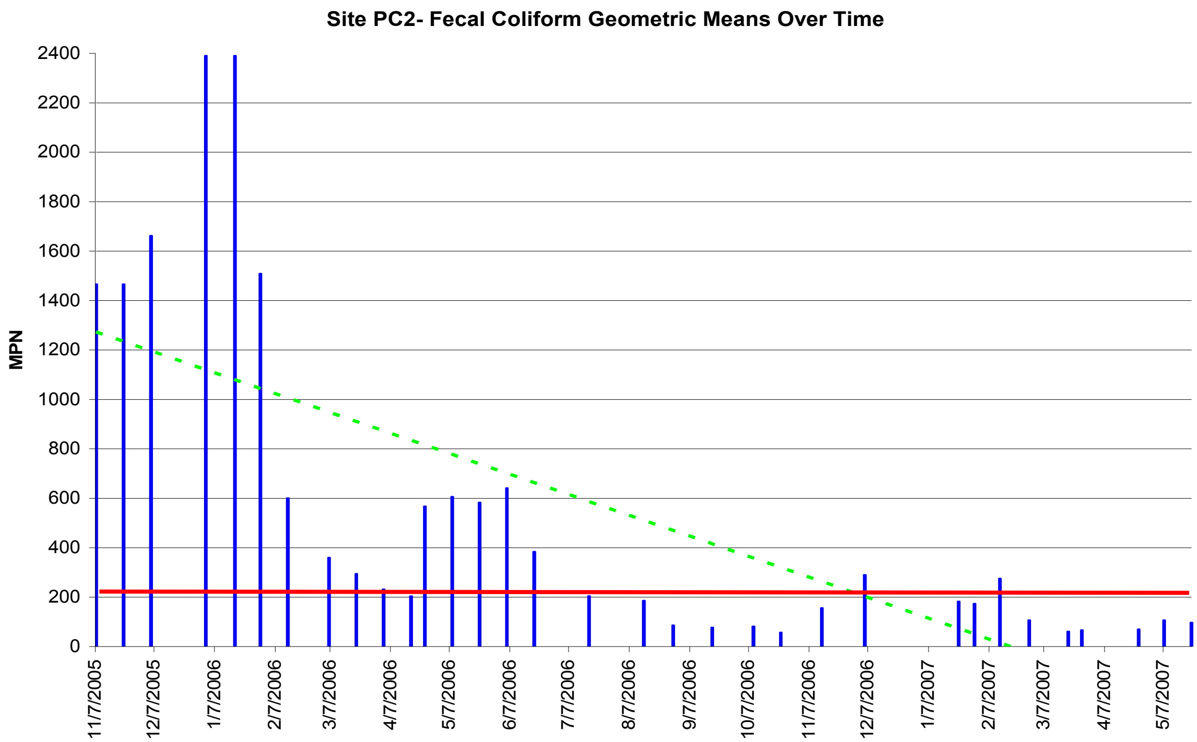


Figure 40a. Ponchatoula Creek, Downstream Hammond- Trend Over Time, Fecal Coliform Geometric Means (mg/l). Fecal coliform decreased over the period of data collection.

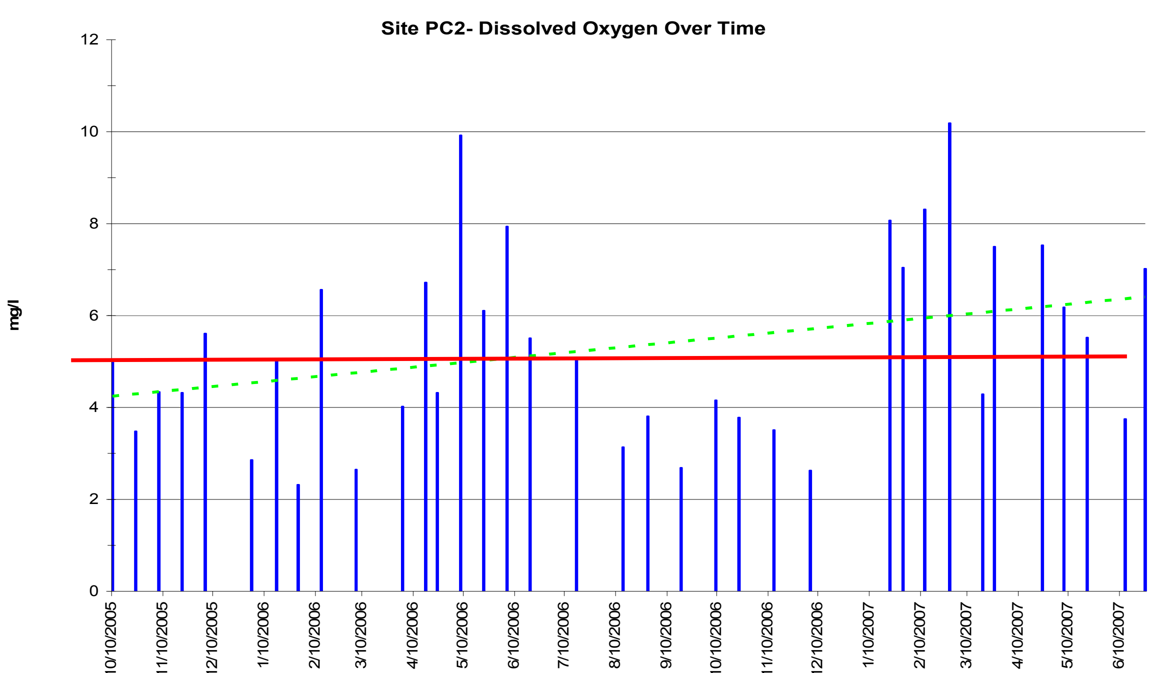


Figure 40b. Ponchatoula Creek, Downstream Hammond- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

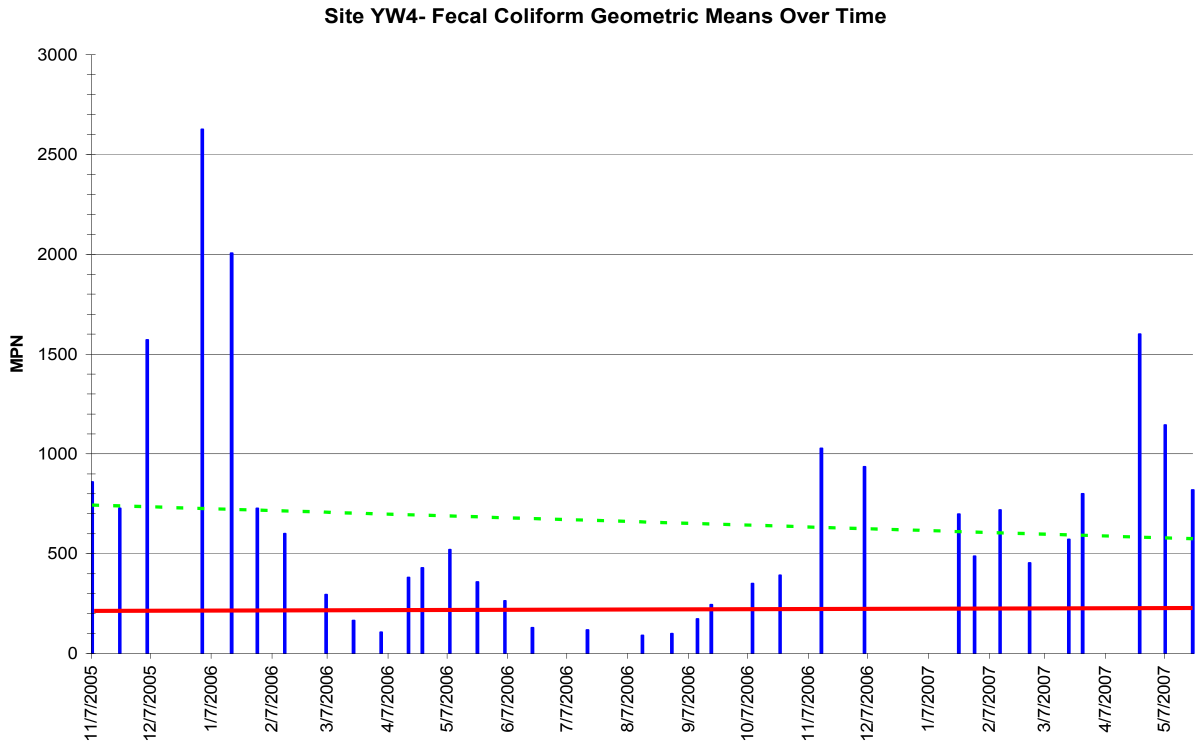


Figure 41a. Yellow Water River, Upstream Hammond- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform decreased over the period of data collection.

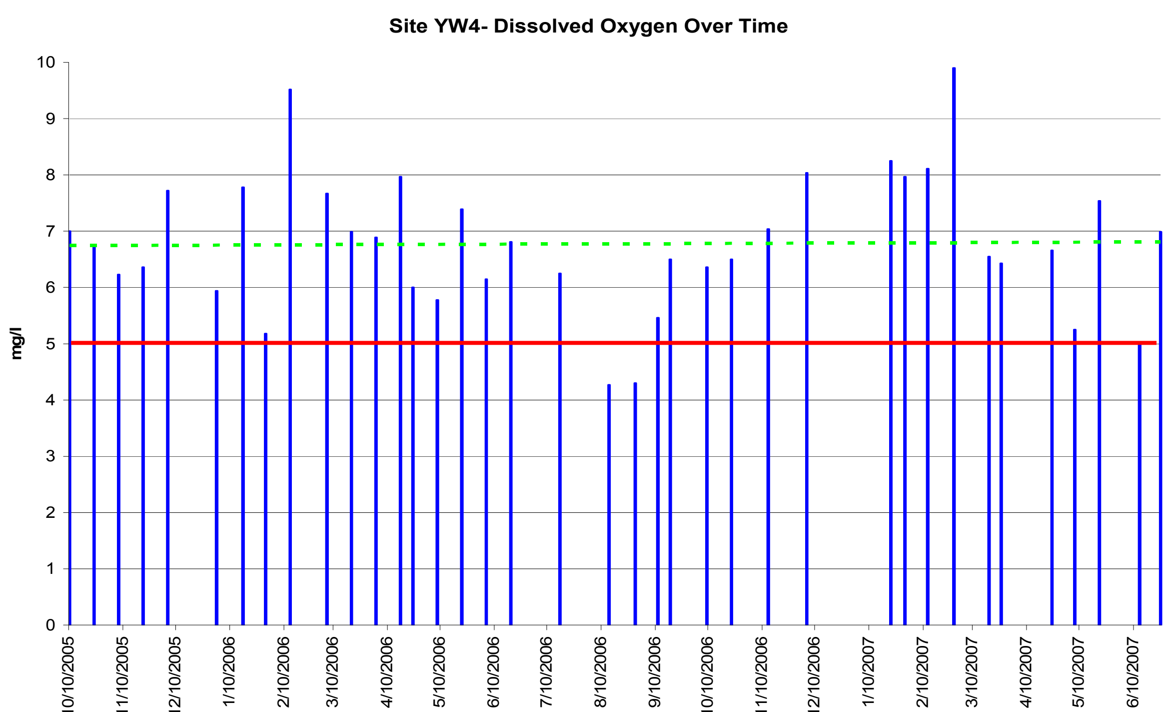


Figure 41b. Yellow Water River, Upstream Hammond- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

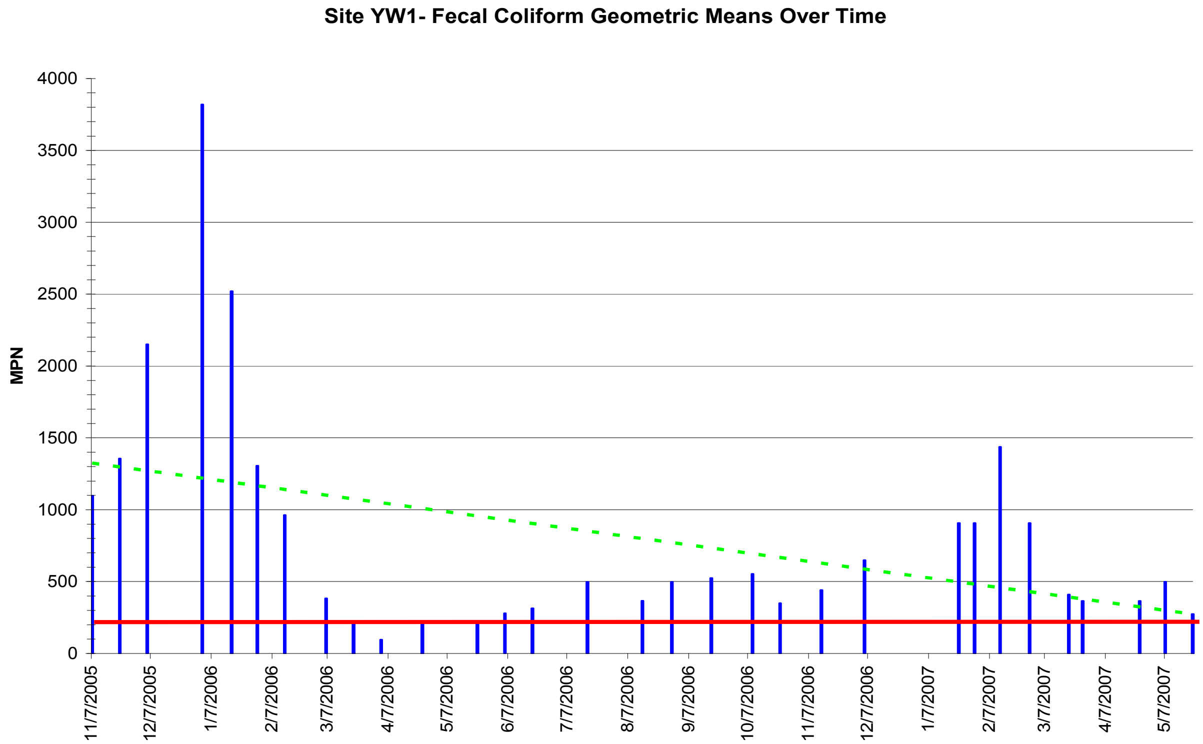


Figure 42a. Yellow Water River, Downstream Hammond- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform decreased over the period of data collection.

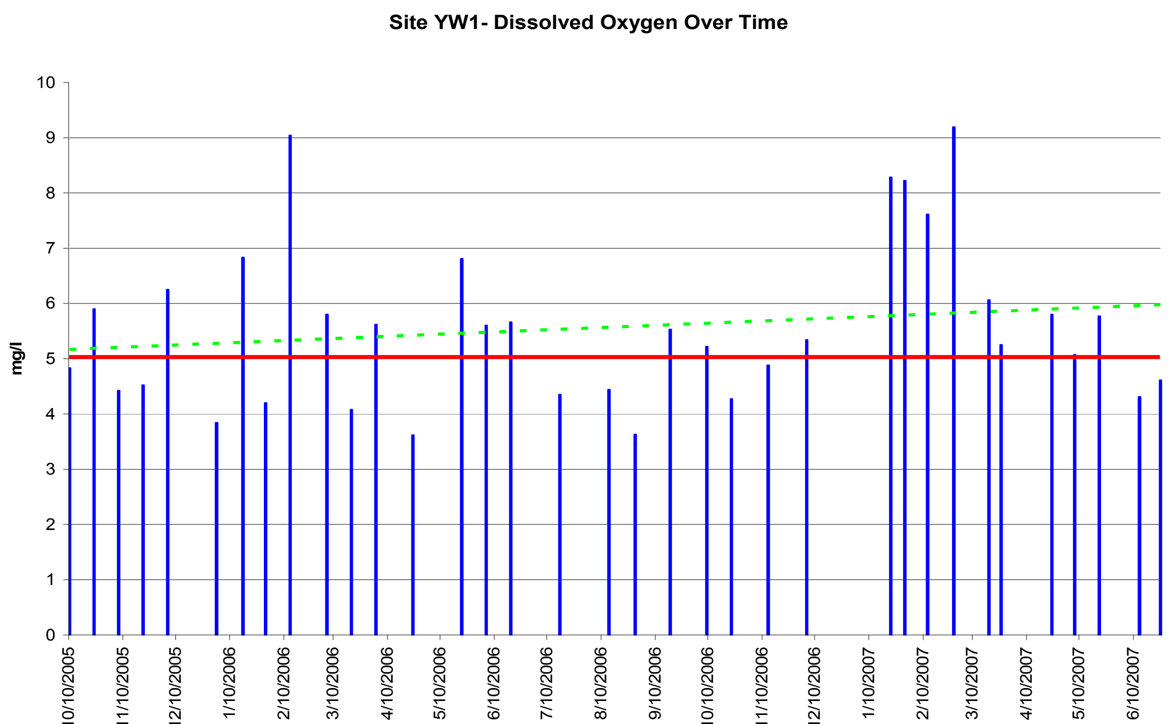


Figure 42b. Yellow Water River, Downstream Hammond- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

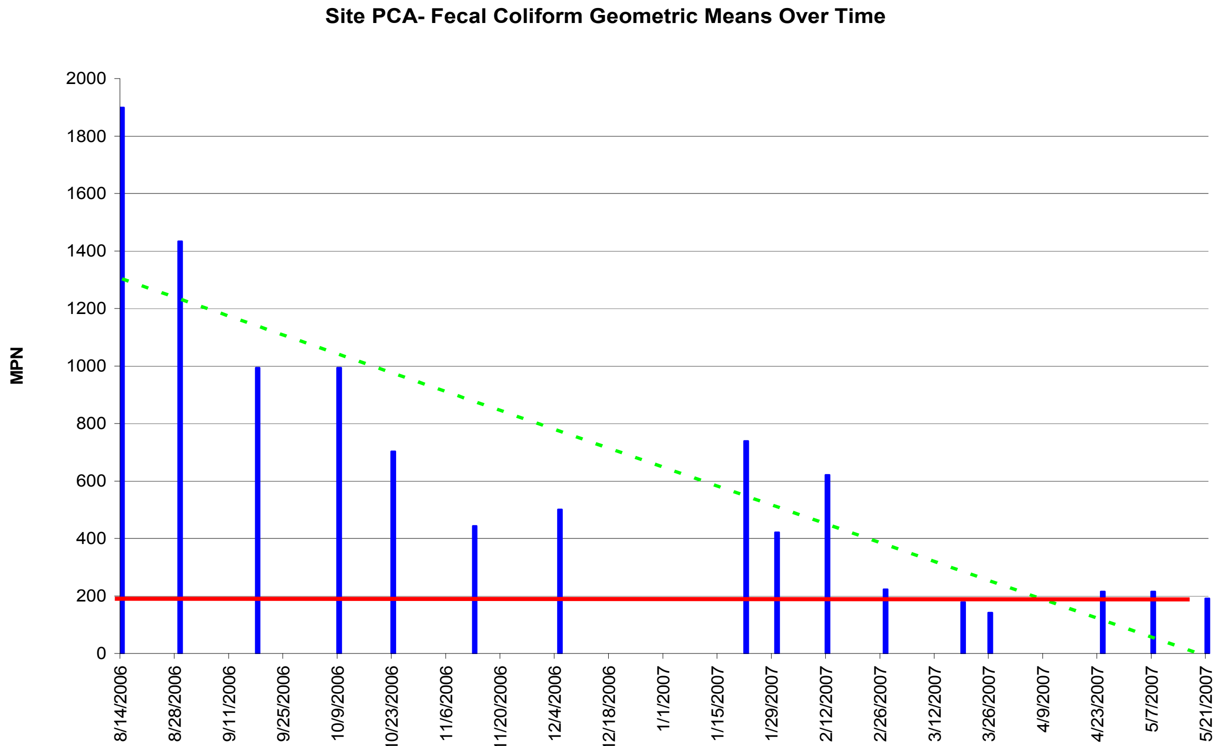


Figure 43a. Ponchatoula Creek, Southernmost Site- Trend Over Time, Fecal Coliform Geometric Means (MPN). Fecal coliform decreased over the period of data collection.

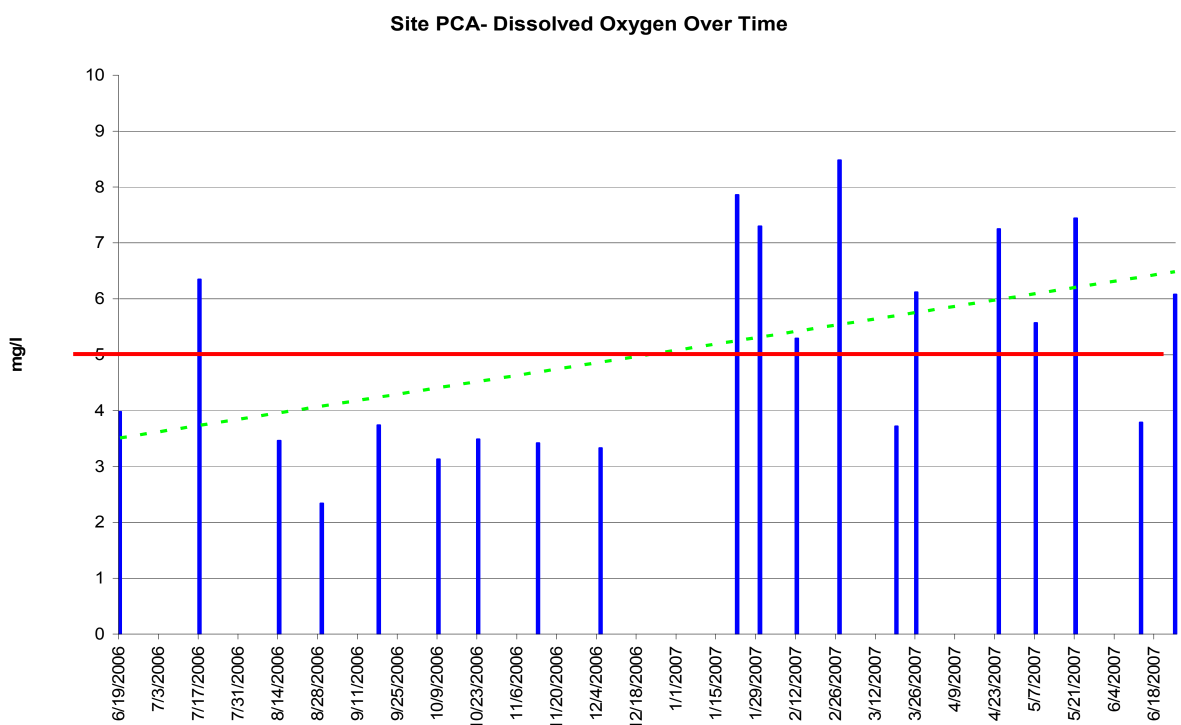


Figure 43b. Ponchatoula Creek, Southernmost Site- Trend Over Time, Dissolved Oxygen (mg/l). DO increased over the period of data collection.

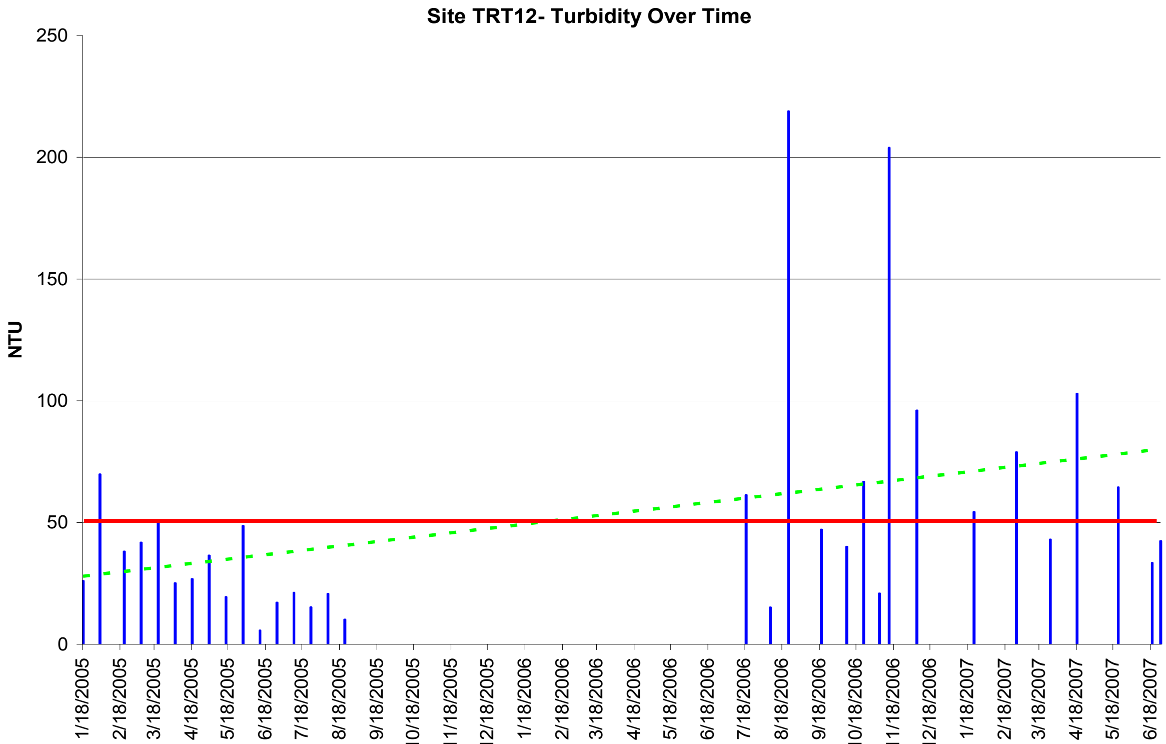


Figure 44a. Bedico Creek- Trend Over Time, Turbidity (NTU). Turbidity increased over the period of data collection.

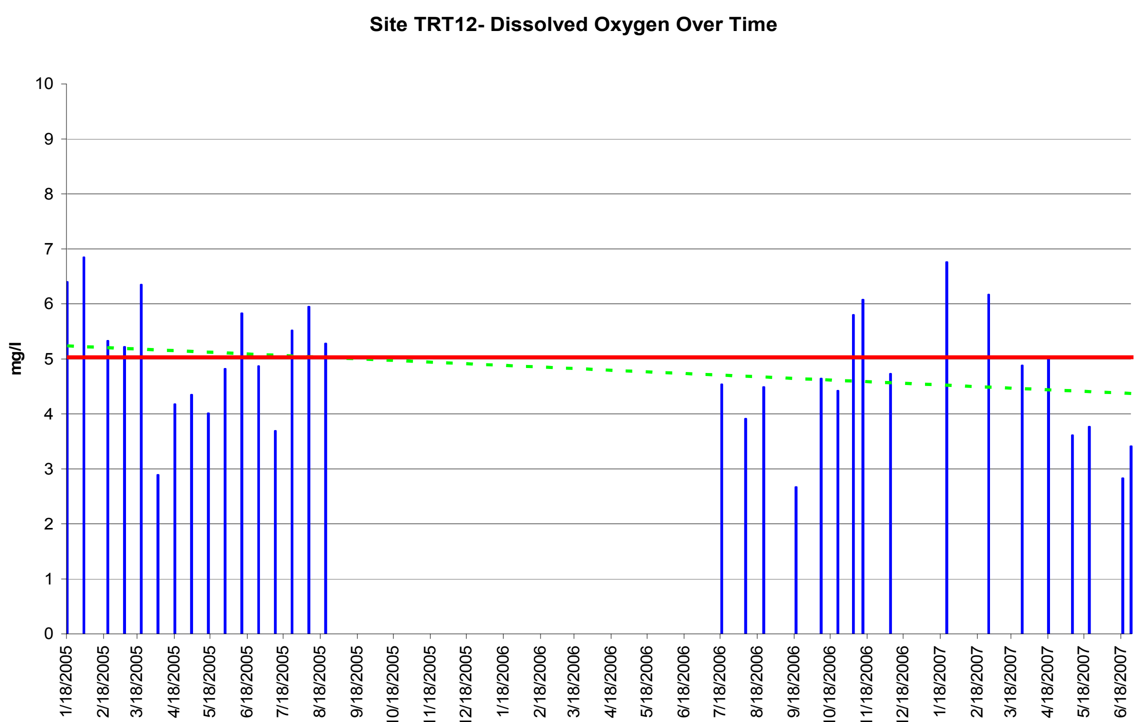


Figure 44b. Bedico Creek- Trend Over Time, Dissolved Oxygen (mg/l). DO decreased over the period of data collection.

Summary of Land Use Analyses

Urban land cover (including impervious surfaces and associated minimal vegetation) is the most rapidly increasing land use within the Tangipahoa and Natalbany watersheds, nearly doubling between 1982 and 2006. Two of the sub-watersheds studied, the Ponchatoula Creek and Yellow Water River in the Natalbany Watershed, had significantly greater percentages of their watersheds urbanized (28 and 34%, respectively) than the other sub-watersheds (2 to 7%). While many parameters studied showed some change in response to urbanization, specific conductance, sodium, sulfate, alkalinity, nutrients, and fecal coliform showed the most defined changes. For each of these parameters there was a definite increase in concentration or count with the increase in urbanization. Using linear regression, the increase could be quantified by each increased percent of urbanization. Nutrient concentrations and fecal coliform counts had increasing trends in the downstream direction for the urbanized streams (Figures 30 and 33).

Previous research shows that the major source of nutrients and fecal coliform in urban areas are numerous, densely packed WWTPs. Utilizing wastewater plant data collected by the LPBF and LDEQ, it was found that the bulk of WWTPs assisted in the region were located in close proximity to the major municipalities, the Cities of Hammond and Ponchatoula. The vast majority of the plants assisted were not functioning properly and/or not permitted properly. This meant that they were discharging fecal bacteria and nutrients into the surface water. As the assistance to the WWTPs was happening concurrent to data collection, fecal coliform and dissolved oxygen concentrations were evaluated over time to see if the WWTP assistance was having an impact on the waterbodies. While Tangipahoa River showed relatively stable trends over time, Ponchatoula Creek and Yellow Water River (specifically targeted for wastewater assistance) showed decreasing fecal coliform counts and increasing dissolved oxygen concentrations over the course of data collection.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.1 Tangipahoa Watershed Water Quality

Water quality within the Tangipahoa and Natalbany Rivers and their tributaries reflect land use within the watersheds. Water quality on the Tangipahoa River is generally good and the river had very consistent results, indicating that there was no wastewater discharge large enough to alter the stream's water quality at any point. Dissolved oxygen levels were within healthy range (> 5 mg/l), turbidity was low (< 50 NTU), and fecal coliform counts generally ranged less than 100 MPN (a geometric mean of 200 MPN/ 100 ml water and a single sample of 400 MPN/100 ml water are the upper limits for primary contact recreation; LDEQ, Title 33). All dissolved salts analyzed had low concentrations throughout the Tangipahoa River. Correspondingly, land use within the Tangipahoa watershed was dominated by forestry and agricultural activities, with only 2-7% of land use classified as urban.

Water quality within the tributaries of the Tangipahoa showed impacts based on local land use. While the upper portion of the Tangipahoa Watershed was characterized by high concentrations of dairy farms, the high fecal bacteria levels on Big Creek (TRT3), Carpenter Branch/Fluker Discharge (TRT2), and Black Creek (TRT1) were due to localized sources. On Black Creek, the source was found to be a trailer park that was not connected to community sewer. The LDEQ is working with the community to connect the outstanding homes.

Most parameters were anomalous on Carpenter Branch (TRT2), the discharge point for the Town of Fluker's wastewater plant. Fecal coliform, specific conductance, and most of the dissolved salts were high. The high concentrations are due to the site being downstream of the town's new wastewater treatment plant, a pond that utilized sodium hypochlorite tablets for disinfection. Also, as the plant is new, not all residences are yet connected. These conditions would lead to the high fecal and nutrient counts. The high salts concentrations (including Na, Mg, and Ca) are most likely due to the tablets used in the chlorination of the wastewater. Other unknown sources may exist in the area. LDEQ has begun to investigate the high fecal counts obtained from the stream. The stream is also in generally poor condition, with the local population dumping trash into it (Figure 45).

Figure 45. Carpenter Branch, the receiving stream for the Village of Fluker's wastewater treatment plant (WWTP) effluent, is also the site of garbage dumping.

The tributaries corresponding to the most dense dairy activity, Big Creek (TRT3 and TRT4) and Chappepeela Creek (TRT6 and TRT9), generally showed the same low concentrations of dissolved salts as the Tangipahoa River, implying the same source water as the river. Surprisingly, most sites on the streams (with the exception of TRT3) exhibited low fecal coliform counts. In the late 1980's the Tangipahoa River was closed to primary contact recreation due to high fecal coliform counts that were attributed to the local dairies. Since that time, most farmers have participated in programs by the Natural Resource Conservation Service (NRCS) and the Louisiana State University Agricultural Center (LSU Ag Center) to install, maintain, and, upon the closure of the dairy, decommission waste retention lagoons. The maintenance of the lagoons involves periodic (approximately every 5 years) re-suspension of the sludge accumulated at the bottom of the lagoon (Figure 46) and application to the land (Figure 47). The sludge acts as a nutrient-rich fertilizer, allowing the farmer to by-pass the use and expense of chemical fertilizers. The LDEQ graphed the Tangipahoa River's yearly average fecal coliform since 1984 (Figure 48). Based on the decreases observed, the program has led to a significant decrease of pollution entering the system.

Figure 46. Dairy Waste Retention Lagoon Clean Out and Agitation of Accumulated Sludge.

Figure 47. Application of Lagoon Sludge to Land to Act as a Fertilizer.

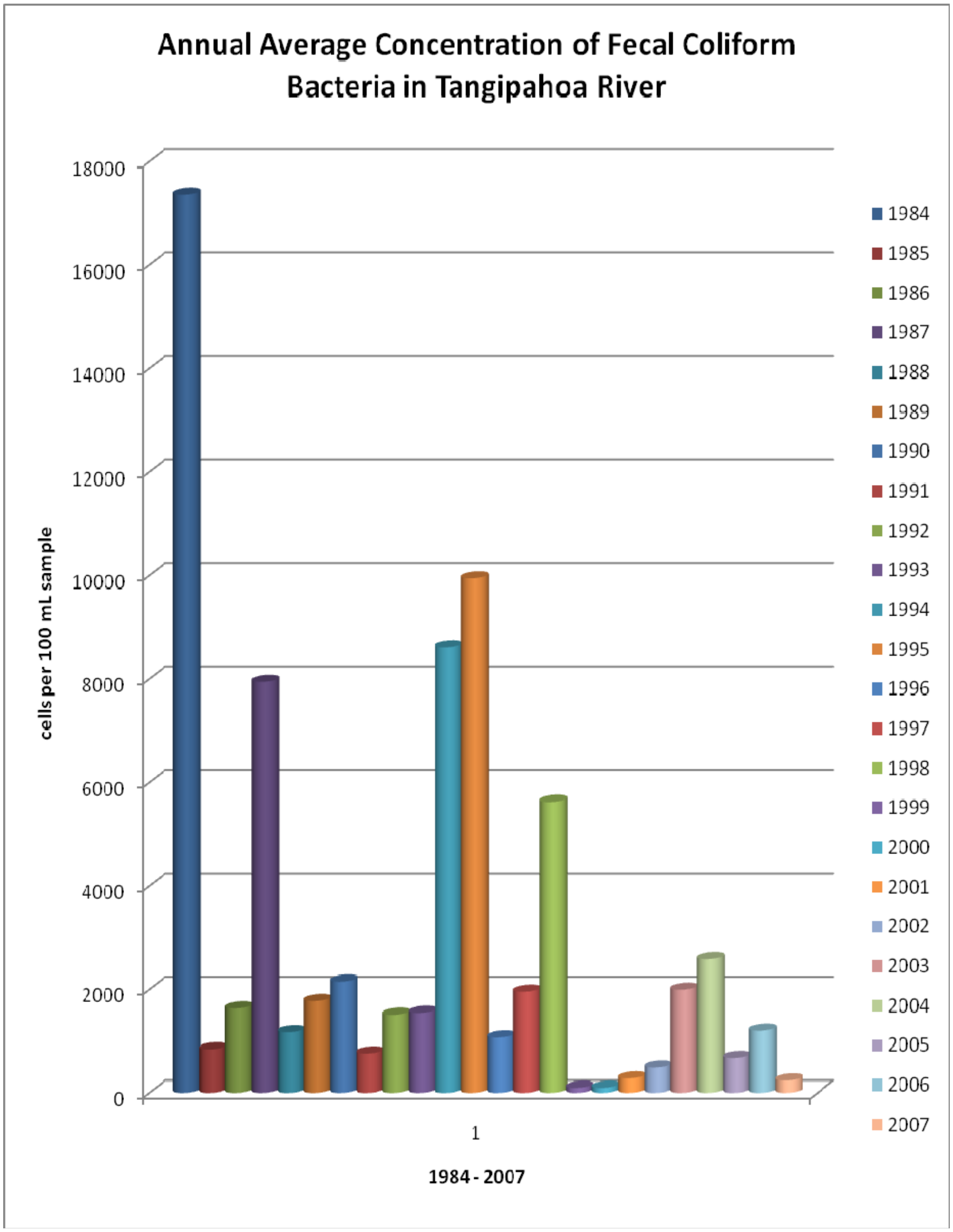


Figure 48. Annual Average Concnetration of Fecal Coliform Bacteria in Tangipahoa River (LDEQ, 2008).

High turbidity was observed on the downstream Tangipahoa tributaries (TRT10, TRT11, and TRT12). High turbidities could be the result of the local environment (a bottomland hardwood, swampy environment) and the rapid development in the area. In particular, turbidity increased and dissolved oxygen decreased on Bedico Creek through the course of the study (Figure 44, Figure 49). Developers do not appear to be following the state laws on sediment and stormwater. During the course of the study, silt fencing, hay bales, and other stormwater best management practices (BMPs) were rarely observed on developing sites (Figure 50), leading to extremely turbid water in Bedico Creek (Figure 49). In the vicinity of Bedico Creek, the LDEQ issued numerous citations to developers for not utilizing stormwater sediment retention devices. Tangipahoa Parish has begun working with LDEQ to better regulate developers to use the stormwater BMPs within the parish.

Figure 49. Bedico Creek- High Turbidity during Heavy Development, Summer 2006.

Figure 50. Development Adjacent to Bedico Creek (notice no stormwater sediment BMPs).

Areas in closer proximity to the estuarine Lake Pontchartrain exhibited greater salt concentration, indicative of seawater influence. In Bedico Creek (TRT 12) concentrations of all of the major components (Na, K, Mg, Ca, Cl, SO_4) were high relative to the other sites. However, the molar ratios of Cl and SO_4 (Figure 17), of Na and Cl (Figure 18), and of Cl and Br (Figure 19), indicated the source to be diluted seawater and not from anthropogenic sources. Even though many of the components are high in both seawater and urban water, the molar ratios could be used to distinguish the source of the water (further discussion below). As is indicative of the estuarine influence, Bedico Creek is dominated by bottomland hardwood and cypress/tupelo swamps (Figure 51).

Figure 51. Camps along Bedico Creek in Wetland (Cypress/Tupelo Swamp) Environment

5.2 Natalbany Water Quality

In contrast to the Tangipahoa watershed, monitoring in the Natalbany watershed indicated that serious water quality issues exist. Land use within the Natalbany watershed ("NR" sites) ranged from 7% urban land cover in the Natalbany River watershed to 34 and 28% urban land cover in the Yellow Water River ("YW" sites) and Ponchatoula Creek ("PC" sites) watersheds, respectively. These watersheds span the largest urban area in the parish, including the cities of Hammond and Ponchatoula (Figure 3). Ponchatoula Creek within the City of Hammond is channelized and the water is gray and turbid (indicative of sewage pollution) with trash in it (Figure 52).


Figure 52. Ponchatoula Creek in Hammond. Creek was channelized and water was gray and turbid (indicating sewage input) and contained household garbage.

Greater than 10% impervious cover within a watershed leads to severe impacts on water quality (Chapter 2). The data collected in these watersheds corroborate this fact. Dissolved oxygen was lowest at sites PC2 and PCA (Ponchatoula Creek south of Hammond and Ponchatoula). Specific conductance was high at all PC and YW sites, rising as the stream flowed through the urban area. Turbidity was also high at all NR and YW sites, and PC8 and PCA, likely due to their location in a swampy area combined with urbanization. Finally, fecal coliform was chronically high at all NR, YW, and PC sites and also generally increased in the downstream direction. As shown in Figure 34, the high counts are due to a dense concentration of small wastewater treatment plants; which are not functioning properly most of the time.

The southernmost Ponchatoula Creek sites are located within (PC2) and downstream of (PCA) the most urbanized portion of the parish and until October 2006 received the treated wastewater effluent from the City of Hammond. The Hammond plant was out of compliance (with its LPDES permit) at the time and high fecal coliform counts, along with deposits of sludge- a bi-product of waste treatment (Figure 24), were observed in the stream. Both sites on the Yellow Water River had high fecal coliform counts as well. The Yellow Water River also runs through the City of Hammond. Investigations into the sources of the high counts indicated only one major discharger, a Sanderson's Farms chicken processing plant. This plant, however, had recently undergone a massive upgrade of its wastewater system. The high counts are thought to come from a number of small wastewater units, including home and small commercial units (Figure 53). While fecal coliform counts on these streams have decreased as a result of assistance to WWTPs, the streams are still highly impaired and are being investigated by LDEQ.

High salt concentrations (including Na, K, Ca, Mg, F, HCO_3-C, SiO_2-Si) were also observed on Ponchatoula Creek and Yellow Water River sites. As seen in Figure 13, the salt concentrations increase in the downstream direction in Ponchatoula and Yellow Water while the adjacent Natalbany River (with only 7% urbanization) has much lower concentrations. Given the sharp rise in the urban areas, the salts concentrations can not solely be a result of artesian source water but also reflect the addition of anthropogenic pollutants into the system. The presence of elevated sodium with respect to chlorine (Figure 17) is indicative of pollutants such as cleaning products entering the system. Many cleaning products utilize Na, Ca, and K as a base for the product (examples include sodium bicarbonate, calcium carbonate, and potassium silicate). Finally, the presence of high nutrient concentrations in Ponchatoula Creek and Yellow Water River (discussed below) suggests that wastewaters are the source of the high salt concentrations.

Nutrient levels increased significantly as Ponchatoula Creek and Yellow Water River flowed through the urban area (Figure 13, Figure 30). The downstream urban sites exhibited NO_3-N concentrations as much as three times greater than non-urbanized watersheds. NH_4-N concentrations were nearly twice as high, and PO_4-P concentrations were increased by more than a factor of 10 downstream of the urban areas. High concentrations of nutrients (known as eutrophication) in the waterway lead to high algae growth. When the algae die, the decomposition bacteria utilize all of the dissolved oxygen in the water, leading to fish kills (Pickney et al., 2001; Turner, 2002; Rabalais, 2002).

High nutrient levels are associated with poorly treated sewage and the use of fertilizers in the urban setting (Paul and Meyer, 2001). The LDEQ and LPBF WWTP assistance map shows a dense concentration of WWTPs around the urban area (Figure 34). Also, a survey of land use within the Yellow Water River watershed indicated many homes outside of the municipalities utilize various home treatment systems. The high nutrient levels are most likely from inefficient wastewater treatment, as the clay soils do not allow for waste drainage fields (as is typical in other parts of the country), so treated wastewater is piped to roadside ditches leading to the streams (Figure 54).

Water quality data collected in the current study was also compared to data collected by the USGS in rivers and streams within the watersheds from the 1960's to the 1990's. The Tangipahoa River exhibited higher levels of turbidity, NO_3-N, NH_4-N, and Cl and lower dissolved oxygen in the current data as compared to old data. While the current data indicated slightly impaired water as compared to the old, the current values are still well within the healthy range for the river. However, fecal coliform, Na, HCO_3-C, and K concentrations were lower in the current data as compared to the old data. On Bedico Creek, SiO_2-Si and Cl were greater in the current data as compared to the older data. Finally, on Ponchatoula Creek K, Mg, and HCO_3-C were greater in the current data compared to the older data. Most significant among the old verses new comparison was the fact that fecal coliform levels were decreased in the newer data, as compared to the older data for the Tangipahoa River. As was stated in the introduction, the Tangipahoa River was the recipient of waste from hundreds of dairy farms for many decades, causing it to be placed on the Impaired Waterbodies list. In the early 1990's NRCS, LSU Ag Center, and dairy farmers began a cost-share program to install, maintain, and eventually decommission waste retention lagoons. Data from this study illustrates significant decreases in fecal coliform levels have been achieved in the Tangipahoa River.

5.3 Land Use vs. Water Quality

The fecal coliform counts, Na:Cl, Cl:Br, and SO_4:Cl ratios, and sulfate, sodium, alkalinity, and nutrient concentrations were the most indicative of urban development in the Tangipahoa and Natalbany watersheds. Urban streams, including Ponchatoula Creek and Yellow Water River in Hammond, exhibited the highest regional fecal coliform levels (Figure 32). Fecal coliform counts in these waterways and in some Tangipahoa tributaries reached geometric means greater than 400 while the Tangipahoa River, Chappepeela Creek and other non-urban waterways ranged closer to 100. Relative to non-urban areas, urban areas also exhibited 1.5 to 6 times greater specific conductance (Figure 24), 3.5 to 9 times greater sodium concentrations (Figure 25), 3 to 7.5 times greater sulfate concentrations (Figure 26), and 3 to12 times greater alkalinities (as HCO_3-C). The nutrient levels increased as Ponchatoula Creek and Yellow Water River flowed through the urban area (Figure 30), implying the increased concentrations are a product of many cumulative urban sources, especially wastewater treatment plants. The downstream urban sites had NO_3-N concentrations as much as 3 times greater than non-urbanized watersheds. NH_4-N concentrations were nearly twice as high, and PO_4-P concentrations were more than 10 times greater downstream of the urban areas (Figure 28). Urban streams had SO_4/Cl molar ratios of around 3.5 compared to 1.2 for the Tangipahoa River. For Na/Cl molar ratios, urban streams had ratios of 3.5 to 4.1 while non-urbanized streams had nearly a 1:1 ratio.

The water quality findings create a set of "local" water quality "signatures" that could be referenced to assess the health of the water. Clean water, as in the Tangipahoa River, had low fecal coliform counts, high dissolved oxygen, low turbidity, low nutrient levels, and low dissolved salts. Polluted streams, as in Ponchatoula Creek and Yellow Water River, had high fecal coliform, low dissolved oxygen, high specific conductance, high dissolved salts (especially Na, SO_4, and HCO_3-C), increasing nutrient loads (including NO_3-N, NH_4-N, and PO_4-P), and increased ratios for Na:Cl, Cl:Br, and Cl:SO_4 downstream (Figures 14, 29, and 30).

These relationships are in line with other studies. For example, a study in southeast Brazil found that alkalinities and sulfate concentrations were greater in urbanized areas (Ometo et al., 2000). They also found that the highest concentrations were observed in the downstream reaches of the stream, indicating a cumulative effect. A New York/New Jersey study (Roman et al., 2000), indicated that urban estuaries contained almost 4 times greater total nitrogen than less urbanized estuaries. Also, a Washington State study found that urbanization increased total nitrogen loading (44%) in the streams, but increases in NO_3 and NH_4 loading were not statistically significant (Brett et al., 2005). A New England study (Rhodes et al., 2001) found that average concentrations of NO_3 and SO_4 correlated with percent catchment area classified for human use (agricultural, residential, commercial, industrial, urban open, and transportation areas). A linear best-fit line demonstrated a positive correlation between concentration of NO_3 and SO_4, and percent human land use ($R = 0.68$). A similar correlation for SO_4 concentrations was found in this study (Figure 27) and increases in NO_3 concentrations with urbanization were observed (Figures 29 and 30).

Data from Yellow Water River and Ponchatoula Creek also show higher specific conductance and higher concentrations of Na, Mg, Ca, SiO_2-Si, NO_3-N, NO_2-N, PO_4-P, SO_4, and HCO_3-C and decreased dissolved oxygen. In a general study of urbanization impacts on streams, Paul et al. (2001) found a consistent pattern between urbanization and water quality. Urban streams generally show increases in oxygen demand (and therefore a decrease in dissolved oxygen), specific conductance, suspended solids, ammonium, hydrocarbons, and metals. The streams also experience higher phosphorus levels from sources such as wastewater and fertilizer. Even more than phosphorus, urbanized streams experience jumps in nitrogen, particularly ammonium and nitrate from sources such as leaky sewer lines, inadequate sewage treatment, illicit sewage discharge, and fertilizer. These trends correspond well to observations made in this study (Figures 14, 29).

Although fecal coliform and dissolved salt concentration were high and dissolved oxygen levels low in Ponchatoula Creek and Yellow Water River due to urbanization and anthropogenic impacts, assistance to improperly functioning WWTPs was shown to reduce fecal coliform counts and increase dissolved oxygen levels in the watersheds (Figures 38-43). Reducing bacterial counts and increasing dissolved oxygen levels will become increasingly important as the Pontchartrain Basin engages in the Total Maximum Daily Load (TMDL) process, designed to increase the health of waterways.

5.4 Groundwater and Weathering Interactions

The surface water geochemical data does not show any significant input from saline groundwater upwelling along the regional east-west trending Baton Rouge Fault System. These saline groundwaters have greater salt content (300 to > 14,000 mg/l) than the "background" conditions observed in the Tangipahoa and Natalbany watersheds (50-70 mg/l), along with lower sulfate and magnesium concentrations and a Na:Cl molar ratio near 1 (Stoessell and Prochaska, 2005; Stoessell Data Compilation at http//www. ronstoessell.org/South_Louisiana_Data.pdf/). The only surface water samples having significant salt contents (other than marine-influenced samples from Bedico Creek) are those from polluted areas. The likely source for these dissolved salts are from pollution because they have higher sulfate and magnesium concentrations and higher Na:Cl ratios.

A similar argument can be made to show the lack of input into the surface waters from the “normal” regional groundwaters that are unaffected by the Baton Rouge Fault System. These groundwaters have much higher alkalinities than the surface waters along with a higher tds range of 200 to 500 mg/l (Stoessell and Prochaska, 2005; Stoessell Data Compilation at http//www.ronstoessell.org/South_Louisiana_Data.pdf/). The low alkalinities of the surface stream waters rule out input from these “normal” regional groundwaters.

The two watersheds are carved predominantly in the Prairie Terrace Formation. This is a heavily weathered formation composed of the clays smectite, kaolinite, illite, and hydroxyl-interlayered vermiculate (10-50% dry weight), sand more than 98% quartz (10-100% dry weight), and silt (10-65% dry weight). The various terrace formations consist of Mississippi River Flood Plain deposits of layered clays and silty sands (Cureau et al., 1991). Further weathering of the minerals in these deposits under earth-surface conditions is a slow process because of sluggish reaction kinetics and the clay minerals are already near equilibrium with dilute surface waters, as indicated by the low alkalinity concentrations in the stream samples. Cation-exchange reactions on clay minerals will occur rapidly but thousands of years of exchange with the flowing surface waters have also produced near equilibrium conditions. Hence, significant “background” chemical trends were not observed in the Tangipahoa and Natalbany Rivers.

5.5 Tangipahoa Growth

Growth in Tangipahoa Parish and all of the “Florida Parishes” north of Lake Pontchartrain has been rapid and generally unplanned. The Florida Parishes experienced accelerated population growth between 1982 and 2006. Most of the development occurred in St. Tammany and Livingston Parishes (Figure 1) along Interstate 12, comprising outgrowths of GNOMA and BRMA, respectively. However, Tangipahoa Parish is situated between these two parishes and is feeling development pressure, particularly following Hurricane Katrina. A land use classification on urbanization in Tangipahoa Parish indicated that between 1982 and 2006, urban areas nearly doubled, much of the growth being concentrated in the southern portion of the parish (near the intersection of Interstate 12 and Hwy 55, Figure 4). This growth is at the expense of the agricultural lands and upland forests. Many small dairy farmers are finding it hard to stay in business and are selling their land to developers, leading to the spotty and sprawled distribution of development in Tangipahoa Parish.

The rapid, sprawled development has led to the increased use of individual treatment systems, aerated treatment units (ATUs), small community wastewater “package plants” (Figure 53), and septic systems (where allowed) that discharge into stormwater drainage ditches and small creeks (Figures 54 and 55, notice gray turbid water- indicative of poorly treated or untreated sewage). Due to the dense concentration of WWTPs discharging into stormwater ditches (especially in urbanized areas), the ditches act as extended waste treatment, providing some nutrient removal and uptake (conditions favor denitrification and algal blooms), settling suspended solids, and killing bacteria (by exposure to ultraviolet light).

A St. Tammany Parish study by Fearnley et al. (2006) tested the quality of wastewater entering the ditches and the assimilative capacity of the ditches. They found that organic nitrogen concentrations in septic tank ditches averaged 0.5 mg/L, more than twice the USGS average organic nitrogen in St. Tammany Parish surface waters (0.24 mg/L). Ammonium-nitrogen concentration in septic tank ditches averaged 21 mg/L, more then 4 times the cutoff concentration of treated wastewater effluent in St. Tammany Parish, which is 5 mg/L. Fecal coliform in septic tank ditches averaged more than 3,900 CFU (colony forming units)/100 ml water and fecal coliform in municipal sewage ditches averaged 1,855 CFU/100 ml water. As St. Tammany Parish borders Tangipahoa, has the same underlying geology, and the same land use issues, the fecal and nutrients figures are most likely similar for Tangipahoa Parish.

Figure 53. Wastewater Package Plant. Small community plant commonly used in subdivisions.

Figure 54. Wastewater Plant Effluent Being Piped into Ditch

Figure 55. Untreated Sewer in Ditch (with Toilet Articles)

With the cumulative inputs of many wastewater sources impacting the waterways, the need for regionalization of the sewage treatment process becomes apparent. Additionally, the Pontchartrain Basin began the TMDL program in 2007, to run through 2011. In this program mandated by the Clean Water Act, waterbodies on the Impaired Waterbodies (Clean Water Act, Section 303d) list are individually assessed for their pollutant loads. Based on the data obtained and watershed modeling, TMDLs of individual pollutants are assigned to each stream. If the stream can not meet the load, the dischargers into that stream will have tighter limits imposed on their effluents and new discharges will not be allowed until the load limit is met. Many small wastewater plants do not have the design capacity to meet the tighter limits, so regionalization of wastewater will become a necessary outcome of the TMDL process. The TMDL process will be a major driver in the handling of wastewater in all rapidly developing areas for years to come.

5.6 Tangipahoa Parish Future

Tangipahoa Parish has completed its first land use planning effort to mitigate damages to the environment and get a handle on rapid development and urban sprawl. The Tangipahoa Land

Use plan, now in draft, is intended to preserve the rural character of the parish. The plan aims to do this by directing growth to the municipalities and outskirts of the municipalities in the southern portion of the parish; creating and utilizing incentives for dairy, agriculture, and silviculture; promoting developments that cluster homes and leave green spaces open within subdivisions; promoting greenways and blueways in the parish's most sensitive environments; and not building in low-lying swampy or floodplain areas (Tangipahoa Parish, 2008).

5.7 Future Research

The analyses performed for this study give a good a starting point from which LDEQ and Tangipahoa Parish can assess future progress. All data from this study will be made available to the parish, the state, and the EPA. The data will give Tangipahoa Parish a better understanding of how water quality can become impaired with urbanization, so that the same mistakes are not made in the now developing regions of the parish. Similar studies are needed in all of Louisiana's rapidly developing parishes.

5.8 Conclusions

Water quality analyses of the Tangipahoa and Natalbany watersheds in southeast Louisiana showed significant differences among streams with urban, rural, or developing land uses within their watersheds.

- Urban streams exhibited the highest regional fecal coliform levels. Fecal coliform counts in these waterways and in some Tangipahoa tributaries reached geometric means greater than 400 while the Tangipahoa River, Chappepeela Creek and other non-urban waterways ranged closer to 100.
- Relative to non-urban areas, urban areas also exhibited 1.5 to 6 times greater specific conductance, 3.5 to 9 times greater sodium concentrations, 3 to 7.5 times greater sulfate concentrations, and 3 to12 times greater alkalinities (as HCO_3-C).
- The nutrient levels increased as Ponchatoula Creek and Yellow Water River flowed through the urban area. The downstream urban sites had NO_3-N concentrations as much as 3 times greater than non-urbanized watersheds. NH_4-N concentrations were nearly twice as high, and PO_4-P concentrations were more than 10 times greater downstream of the urban areas.

- Urban streams had SO_4/Cl molar ratios of around 3.5 compared to 1.2 for the Tangipahoa River. For Na/Cl molar ratios, urban streams had ratios of 3.5 to 4.1 while non-urbanized streams had nearly a 1:1 ratio.

Water Quality Parameter	**Background**	**Urban**
Fecal Coliform	100 MPN	400 MPN
Specific Conductance	50-100 μS/cm	150-300 μS/cm
Dissolved Salts	<50 mg/l	200-250 mg/l
Sodium	5-10 mg/l	35-45 mg/l
Sulfate	2-5 mg/l	15 mg/l
Alkalinity	2-5 mg/l	15-25 mg/l
Nitrate-Nitrogen	0.2 mg/l	0.8 mg/l
Ammonia- Nitrogen	0.2 mg/l	0.8 mg/l
Phosphate- Phosphorus	<0.03 mg/l	0.7 mg/l
Sulfate : Chloride Ratio	1.2	3.5
Sodium : Chloride Ratio	1.1	3.5 - 4.1

Table 5. Background Verses Urban Water Quality Summary

The water quality impacts observed in urban streams can be utilized to predict, and hopefully counteract, issues in other developing watersheds in the Pontchartrain Basin and along the Gulf Coast.

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APPENDIX A: EXCERPT FROM 2006 IMPAIRED WATERBODIES LIST

Subsegment Number	Subsegment Description	Type	Size (Miles)	PCR	SCR	FWP	ONR	Impaired Use for Suspected Cause	Suspected Causes of Impairment	Suspected Sources of Impairment
LA040503_00	Natalbany River-Headwaters to Tickfaw River	R	54	N	F	N		PCR	Fecal Coliform	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
LA040503_00	Natalbany River-Headwaters to Tickfaw River	R	54	N	F	N		FWP	Mercury	Atmospheric Deposition - Toxics
LA040503_00	Natalbany River-Headwaters to Tickfaw River	R	54	N	F	N		FWP	Mercury	Source Unknown
LA040504_00	Yellow Water River-Origin to Ponchatoula Creek	R	12	N	N	N		PCR	Fecal Coliform	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
LA040504_00	Yellow Water River-Origin to Ponchatoula Creek	R	12	N	N	N		SCR	Fecal Coliform	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
LA040504_00	Yellow Water River-Origin to Ponchatoula Creek	R	12	N	N	N		FWP	Total Dissolved Solids	Drought-related Impacts
LA040504_00	Yellow Water River-Origin to Ponchatoula Creek	R	12	N	N	N		FWP	Total Dissolved Solids	Site Clearance (Land Development or Redevelopment)
LA040505_00	Ponchatoula Creek and Ponchatoula River	R	25	N	F	N		PCR	Fecal Coliform	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
LA040505_00	Ponchatoula Creek and Ponchatoula River	R	25	N	F	N		FWP	Lead	Source Unknown
LA040505_00	Ponchatoula Creek and Ponchatoula River	R	25	N	F	N		FWP	Mercury	Atmospheric Deposition - Toxics
LA040505_00	Ponchatoula Creek and Ponchatoula River	R	25	N	F	N		FWP	Mercury	Source Unknown

Subsegment Number	Subsegment Description	Type	Size (Miles)	PCR	SCR	FWP	ONR	Impaired Use for Suspected Cause	Suspected Causes of Impairment	Suspected Sources of Impairment
LA040701_00	Tangipahoa River-Mississippi State Line to I-12 (Scenic)	R	56	N	F	N	F	PCR	Fecal Coliform	Dairies (Outside Milk Parlor Areas)
LA040701_00	Tangipahoa River-Mississippi State Line to I-12 (Scenic)	R	56	N	F	N	F	PCR	Fecal Coliform	Municipal Point Source Discharges
LA040701_00	Tangipahoa River-Mississippi State Line to I-12 (Scenic)	R	56	N	F	N	F	PCR	Fecal Coliform	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
LA040701_00	Tangipahoa River-Mississippi State Line to I-12 (Scenic)	R	56	N	F	N	F	FWP	Mercury	Atmospheric Deposition - Toxics
LA040701_00	Tangipahoa River-Mississippi State Line to I-12 (Scenic)	R	56	N	F	N	F	FWP	Mercury	Source Unknown
LA040702_00	Tangipahoa River- From I-12 to Lake Pontchartrain	R	23	F	F	N		FWP	Mercury	Atmospheric Deposition - Toxics
LA040702_00	Tangipahoa River- From I-12 to Lake Pontchartrain	R	23	F	F	N		FWP	Mercury	Source Unknown
LA040703_00	Big Creek and Tributaries-Headwaters to confluence with Tangipahoa River	R	10	N	N	F		PCR	Fecal Coliform	Dairies (Outside Milk Parlor Areas)
LA040703_00	Big Creek and Tributaries-Headwaters to confluence with Tangipahoa River	R	10	N	N	F		SCR	Fecal Coliform	Dairies (Outside Milk Parlor Areas)
LA040704_00	Chappepeela Creek-From La. Hwy. 1062 to confluence with Tangipahoa River	R	31	F	F	F	X			

PCR = Primary Contact Recreation
SCR = Secondary Contact Rec.
FWP = Fish and Wildlife Prop.
ONR = Outstanding Natural Resource

APPENDIX B: RAW DATA

APPENDIX B1: Physiochemical and Bacteriological Data (n/d – non detect)

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
TR1	6/12/06	29.9	7	49		10.5	30
TR2	6/12/06	29.8	7	49		8.63	23
TR3	6/12/06	30	7	48		7.97	50
TR4	6/12/06	30.2	7.2	49		7.72	23
TR5	6/12/06	28.8	7.5	48		6.22	50
TR6	6/12/06	28.7	7.6	47		6.19	13
TR7	6/12/06	27.9	7.4	46		5.95	13
TR8	6/12/06	26.9	7.8	47		5.43	23
TR9	6/12/06	26.5	7.7	49		6.32	50
TR10	6/12/06	25.9	6.8	52		6.01	30
TR1	7/17/06	31.2	5.7	53		14.2	50
TR2	7/17/06	30.3	6.6	52		10.3	230
TR3	7/17/06	30.5	6.7	51		7.26	230
TR4	7/17/06	29.8	6.8	52		7.22	30
TR5	7/17/06	28.7	6.9	50		6.07	50
TR6	7/17/06	28	6.9	49		5.86	30
TR7	7/17/06	27.6	7.1	49		5.6	30
TR8	7/17/06	26.9	7.2	51		5.73	23
TR9	7/17/06	26.7	7.2	52		5.82	50
TR10	7/17/06	26.4	6.5	58		7.11	23
YW1	7/17/06	29.7	4.4	481		19.4	230
YW4	7/17/06	29	6.3	359		13.2	50
PCA	7/17/06	32	6.4	447		16.4	
PC2	7/17/06	30.6	5	503		20.4	800
PC5	7/17/06	29.9	6.4	490		8.21	30
PC8	7/17/06	29.3	5.9	241		28.6	130
NR3	7/17/06	31.5	4.5	162		14.9	30
NR6	7/17/06	28.7	6.8	191		9.12	50
NR7	7/17/06	28.2	6.1	201		10.2	130
NR9	7/17/06	27.8	5.6	284		14.2	80
TRT1	7/18/06	26	7.1	45		5.4	800
TRT2	7/18/06	28.3	4.7	318		15.5	80
TRT3	7/18/06						
TRT4	7/18/06	26.9	6	33		3.63	80
TRT6	7/18/06	25.6	6.2	38		5.86	80
TRT9	7/18/06	27.9	6.9	48		4.82	23
TRT10	7/18/06	29.2	3.5	189		35.8	50
TRT11	7/18/06	33.4	8.5	116		90.2	80
TRT12	7/18/06	32.1	4.5	357		61.3	50
TR1	9/18/06	27.1	6.3	53		14.6	23
TR2	9/18/06	26.3	7.1	53		11.4	50
TR3	9/18/06	26.1	7.2	55		13.80	3000
TR4	9/18/06						
TR5	9/18/06	24.5	6.9	62		27.1	8000
TR6	9/18/06	25.5	7.5	52		15.9	30
TR7	9/18/06	25.1	7.5	51		6.3	30
TR8	9/18/06	25	7.8	51		8.23	500
TR9	9/18/06	25	7.4	59		10.3	2300

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
TR10	9/18/06	24.5	7.2	61		6.25	80
YW1	9/18/06	25.1	5.5	228		196	5000
YW4	9/18/06	26.6	6.5	219		177	3000
PCA	9/18/06	27.1	3.7	373		88.4	65000
PC2	9/18/06	26.8	2.7	675		41.2	65000
PC5	9/18/06	26.4	6.8	301		41	5000
PC8	9/18/06	26.4	6.3	171		94.1	13000
NR3	9/18/06	26.3	6.2	210		209	13000
NR6	9/18/06	26.7	6.8	199		109	23000
NR7	9/18/06	26.1	6.5	198		26.9	500
NR9	9/18/06	26.1	6.8	216		97.8	3000
TRT1	9/19/06	23	5.1	58		14.1	1700
TRT2	9/19/06	23.4	3.4	302		10.9	5000
TRT3	9/19/06	23.2	6.9	38		6.89	300
TRT4	9/19/06	23.3	5.7	29		4.05	50
TRT6	9/19/06	24	6.2	41		9.65	170
TRT9	9/19/06	24.4	6.7	51		7.24	3000
TRT10	9/19/06	25.5	3.2	170		28.8	140
TRT11	9/19/06	27.1	6.5	77		17.1	30
TRT12	9/19/06	27.7	2.7	465		47.1	1700
TR1	10/23/06	20.2	7.3	59		20.7	230
TR2	10/23/06	19.1	8.1	57		29.7	1300
TR3	10/23/06	19.3	8.2	57		19.30	800
TR4	10/23/06	18.5	8.4	58		16	1300
TR5	10/23/06	18.2	8.4	58		14.3	8000
TR6	10/23/06	17.4	8.5	57		14.2	3000
TR7	10/23/06	17.6	8.4	55		13.2	300
TR8	10/23/06	17.3	8.4	56		11.1	80
TR9	10/23/06	17.2	8.2	59		15.4	50
TR10	10/23/06	17.1	8	67		16.9	230
YW1	10/23/06	22.1	4.3	341		45.1	300
YW4	10/23/06	18.6	6.5	310		11.7	1300
PCA	10/23/06	22.1	3.5	421		48.2	230
PC2	10/23/06	21.8	3.8	346		47.9	500
PC5	10/23/06	19.1	6.3	379		9.42	5000
PC8	10/23/06	19.8	7.6	269		61.8	300
NR3	10/23/06	21.1	7.3	225		69.5	3000
NR6	10/23/06	19.5	7	214		76.2	5000
NR7	10/23/06	19.2	7.5	234		75.1	5000
NR9	10/23/06	19	7.5	229		74.3	13000
TRT1	10/24/06	14.8	7.7	48		6.79	1700
TRT2	10/24/06	14.9	6.3	285		28.5	1300
TRT3	10/24/06	15.1	8.4	56		7.29	500
TRT4	10/24/06	15.5	7.1	41		9.95	1300
TRT6	10/24/06	17.5	7.6	55		50.4	130
TRT9	10/24/06	17.9	8.6	62		7.59	50
TRT10	10/24/06						
TRT11	10/24/06	17.8					1300
TRT12	10/24/06	20	4.4	3196		66.8	50
TR1	11/13/06	16.9	7.5	55		14.6	80
TR2	11/13/06	16.3	8.2	54		11.8	23

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
TR3	11/13/06	16.4	8.4	54		8.61	23
TR4	11/13/06						
TR5	11/13/06	16.2	8.3	52		9.28	80
TR6	11/13/06	16.1	8.5	52		8.32	30
TR7	11/13/06	16	8.4	50		7.91	50
TR8	11/13/06	15.5	8.6	51		8.62	80
TR9	11/13/06	15.3	8.5	52		7.03	50
TR10	11/13/06	14.5	8.7	61		7.39	50
YW1	11/13/06	19.5	4.9	274		17.9	300
YW4	11/13/06	17.7	7	427		12.6	300
PCA	11/13/06	20.1	3.4	501		16.2	500
PC2	11/13/06	18.5	3.5	572		17.7	30
PC5	11/13/06	17.5	8	465		9.26	80
PC8	11/13/06	17.7	8.1	381		31.2	300
NR3	11/13/06	19.3	6.4	282		14.9	80
NR6	11/13/06	16.9	7.4	282		10.6	800
NR7	11/13/06	16.5	8.4	271		10.9	30
NR9	11/13/06	16.7	8.5	279		28.4	300
TRT1	11/14/06	14.7	7.3	58		5.77	300
TRT2	11/14/06	12.6	5	239		25.8	500
TRT3	11/14/06	14	7.9	45		6.33	500
TRT4	11/14/06	14.5	6.8	31		5.06	130
TRT6	11/14/06	14.7	5.9	39		6.95	50
TRT9	11/14/06	15.2	8	46		4.72	500
TRT10	11/14/06	14	4.4	157		135	500
TRT11	11/14/06	14.2	7.8	57		800	1700
TRT12	11/14/06	15.8	6.1	1449		204	1700
TR1	1/22/07	14	7.4	53		37.8	16000
TR2	1/22/07	14.1	7.5	51		46.5	5000
TR3	1/22/07	14.2	7.8	54		46.7	9000
TR4	1/22/07	13.8	8	51		55.1	16000
TR5	1/22/07	13.7	7.8	51		65.1	16000
TR6	1/22/07	13.4	8.1	49		57.5	9000
TR7	1/22/07	13.6	8.1	47		45.6	3000
TR8	1/22/07	13.3	8.1	46		43.4	16000
TR9	1/22/07	13.4	8.1	47		36	9000
TR10	1/22/07	13.2	8.4	54		52.7	5000
YW1	1/22/07	14	8.3	65		84.8	16000
YW4	1/22/07	13.8	8.3	57		50.2	16000
PCA	1/22/07	13.9	7.9	67		114	5000
PC2	1/22/07	14	8.1	69		97.2	9000
PC5	1/22/07	13.7	8.4	71		49.8	16000
PC8	1/22/07	13.3	7.9	55		62	16000
NR3	1/22/07	14.1	8.4	48		70.9	9000
NR6	1/22/07	13.5	8.6	48		69.2	16000
NR7	1/22/07	13.2	8.5	47		71.8	3000
NR9	1/22/07	13.1	8.3	50		80.9	16000
TRT1	1/23/07	11.7	8.8	49		24.1	300
TRT2	1/23/07	10.7	9.2	69		18.7	220
TRT3	1/23/07	12	8	72		34.1	16000
TRT4	1/23/07	12	7.9	57		36.1	3000

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
TRT6	1/23/07	11.6	8.3	46		30.9	500
TRT9	1/23/07	12.6	8.2	50		31	1700
TRT10	1/23/07	11.9	7.6	72		35	300
TRT11	1/23/07	11.6	7.2	34		59	900
TRT12	1/23/07	11.7	6.8	59		54.3	1600
TR1	2/26/07	18.6	7.8	53	6.97	11.8	50
TR2	2/26/07	18.6	8.1	54	7.11	8.75	50
TR3	2/26/07	18.3	8.3	53	7.14	5.52	13
TR4	2/26/07	18.4	8.5	52	6.98	5.49	13
TR5	2/26/07	17.8	8.6	51	6.95	5.33	13
TR6	2/26/07	17.6	8.7	50	7.01	4.8	13
TR7	2/26/07	16.7	8.6	48	6.98	5.28	30
TR8	2/26/07	16.5	8.9	47	7.04	5.66	30
TR9	2/26/07	16.8	9.1	48	7.19	7.11	80
TR10	2/26/07	16	8.4	51	7.22	8.56	130
YW1	2/26/07	18.5		258		24.6	300
YW4	2/26/07	17.4		183		11.2	50
PCA	2/26/07	20.5		254		30.6	30
PC2	2/26/07	19.2		216		26.8	23
PC5	2/26/07	18.8		268		7.41	23
PC8	2/26/07	18.6		138		10.8	300
NR3	2/26/07	19.3		109		21.2	50
NR6	2/26/07	17.9		100		11.4	230
NR7	2/26/07	17.8		95		13.7	50
NR9	2/26/07	17.4		93		15.30	30
TRT1	2/27/07	15.4	9.3	51	6.72	4.64	1600
TRT2	2/27/07	13.8	8.3	193	7.33	13.2	130
TRT3	2/27/07	15.5	8.5	44	6.72	6.63	30
TRT4	2/27/07	15.9	7.5	36	6.28	5.99	50
TRT6	2/27/07	17.4	8	37	6.03	8.78	30
TRT9	2/27/07	18.8	8.7	48	6.73	5.82	30
TRT10	2/27/07	19.2	6.6	130	6.45	28.3	30
TRT11	2/27/07	18.8	6.9	49	5.98	110	80
TRT12	2/27/07	21.7	6.2	88	6.06	78.9	80
TR1	3/26/07	23.4	5.8	55	6.77	10.7	30
TR2	3/26/07	22.8	6.3	54	6.84	9.13	30
TR3	3/26/07	52.9	6.4	53	6.86	9.14	30
TR4	3/26/07	22.5	6.5	53	6.74	8.16	23
TR5	3/26/07	22.2	6.5	52	6.69	12.6	13
TR6	3/26/07	21.6	6.7	51	6.85	10.3	30
TR7	3/26/07	21.2	6.7	49	6.63	9.48	13
TR8	3/26/07	20.5	6.8	50	6.66	7.57	50
TR9	3/26/07	20.7	6.7	53	6.78	6.14	50
TR10	3/26/07	19.9	6.4	53	6.89	6.65	50
YW1	3/26/07	22.5	5.3	304		33.3	1600
YW4	3/26/07	22.2	6.4	201		11.6	1600
PCA	3/26/07	23	6.1	296		20	30
PC2	3/26/07	23.2	7.5	278		38.8	80
PC5	3/26/07	23.2	8.1	278		9.41	50
PC8	3/26/07	22.1	7.5	141		16.9	30
NR3	3/26/07	22.9	5.5	107		16.2	80

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
NR6	3/26/07	22.1	7.8	92		9.84	240
NR7	3/26/07	21.8	7.4	91		10.1	30
NR9	3/26/07	21.6	7.1	95		12.4	130
TRT1	3/27/07	20.2	7.6	51	6.61	5.22	1600
TRT2	3/27/07	20.1	4.2	254	7.08	20.9	500
TRT3	3/27/07	20.2	7.5	41	6.69	8.49	1600
TRT4	3/27/07	20.2	6.3	33	6.18	5.53	11
TRT6	3/27/07	20.5	5.7	37	5.95	8.94	22
TRT9	3/27/07	21.9	7.9	47	6.73	6.2	30
TRT10	3/27/07	21.9	4.8	127	6.38	62.8	130
TRT11	3/27/07	23.9	4.8	115	6.43	10.1	30
TRT12	3/27/07	24.7	4.9	287	6.10	43.1	50
TR1	4/16/07	19.4	7.3	51	6.74	47.8	900
TR2	4/16/07	18.8	7.7	46	6.76	35.8	900
TR3	4/16/07	19.1	7.9	46	6.76	35.5	500
TR4	4/16/07	18.7	8	53	6.70	31.3	1600
TR5	4/16/07	18.7	8	53	6.70	30.7	1600
TR6	4/16/07	17.7	8.3	52	6.86	28.5	30
TR7	4/16/07	18.1	8.2	53	6.72	25.1	1600
TR8	4/16/07	17.7	8.2	58	6.64	24.7	1600
TR9	4/16/07	17.7	8.1	54	6.85	24.1	1600
TR10	4/16/07	16.6	8.1	59	7.34	25.8	500
YW1	4/24/07	23.8	5.8	353		28.40	30
YW4	4/24/07	23.5	6.7	213		10.7	1600
PCA	4/24/07	26.5	7.3	321		20.3	80
PC2	4/24/07	25	7.5	224		19.4	30
PC5	4/24/07	24.4	7.5	298		8.49	50
PC8	4/24/07	24.5	7.1	155		17.8	50
NR3	4/24/07	25.1	6.9	120		16.2	30
NR6	4/24/07	24.7	6.6	110		14.2	80
NR7	4/24/07	23.6	7	108		9.41	13
NR9	4/24/07	23.6	6.9	103		13.9	50
TRT1	4/18/07	17.9	6.9	53	6.54	7.67	1600
TRT2	4/18/07	16.8	6	94	6.87	145	1600
TRT3	4/18/07	17.6	6.8	50	6.70	10.4	900
TRT4	4/18/07	17.6	6.1	35	6.27	5.45	80
TRT6	4/18/07	18.1	5.3	35	5.93	7.76	23
TRT9	4/18/07	20.1	7.2	45	6.84	5.99	8
TRT10	4/18/07	19.9	4.6	124	6.42	66.2	170
TRT11	4/18/07	20.8	5.7	45	6.05	93.1	80
TRT12	4/18/07	21.8	5	132	6.17	103	70
TR1	5/21/07	24.9	6.9	54	6.91	9.5	23
TR2	5/21/07	24.7	7.2	59	6.98	8.15	23
TR3	5/21/07	25.1	7.5	54	7.09	6.47	23
TR4	5/21/07	24.6	7.8	52	7.06	5.12	30
TR5	5/21/07	24.1	7.9	50	6.98	5.37	13
TR6	5/21/07	23.6	8	49	7.13	4.42	80
TR7	5/21/07	23.2	8.1	48	7.10	5.45	130
TR8	5/21/07	22.2	8.4	48	7.15	4.28	80
TR9	5/21/07	22.6	7.9	53	7.14	4.95	170
TR10	5/21/07	21.6	7.5	53	7.58	6.39	50

Site	Date	Temp °C	Dissolved Oxygen mg/l	Specific Conductance µS/cm	pH	Turbidity NTU	Fecal Coliform MPN
YW1	5/21/07	25.2	5.8	301		18.6	300
YW4	5/21/07	23.7	7.5	207		11.3	1600
PCA	5/21/07	27.9	7.4	223		22.8	240
PC2	5/21/07	26.6	5.5	132		23.9	30
PC5	5/21/07	25.6	7.3	126		9.3	80
PC8	5/21/07	24.9	7.3	149		13.6	80
NR3	5/21/07	27	6.7	111		14.3	500
NR6	5/21/07	23.1	7.7	104		8.44	170
NR7	5/21/07	23.7	7.3	109		8.22	22
NR9	5/21/07	24.2	7.1	102		11.6	130
TRT1	5/22/07	21.2	7.7	48	6.51	4.03	900
TRT2	5/22/07	22.4	5.8	324	7.18	45.4	30
TRT3	5/22/07	20.9	7.7	41	6.77	6.28	50
TRT4	5/22/07	20.7	6.5	31	6.16	3.42	2
TRT6	5/22/07	21.8	5.8	39	5.88	5.47	13
TRT9	5/22/07	23.5	7.6	45	6.72	4.96	4
TRT10	5/22/07	23.6	5	109	6.34	693	50
TRT11	5/22/07	25.6	5.7	44	5.90	54	50
TRT12	5/22/07	25.5	3.8	258	6.09	64.5	13
TR1	6/25/07	29	5.3	59	6.57	15	110
TR2	6/25/07	28.6	6	56	6.76	14.4	130
TR3	6/25/07	28.7	6.3	53	6.82	14.9	50
TR4	6/25/07	28.4	6.4	54	6.94	23.4	50
TR5	6/25/07	27.4	6.4	53	6.72	11.7	30
TR6	6/25/07	27	6.5	6	6.84	11.2	130
TR7	6/25/07	26.3	6.5	61	6.71	13.6	1700
TR8	6/25/07	25.8	6.7	59	6.76	11.6	500
TR9	6/25/07	25.4	6.7	55	6.86	6.89	1700
TR10	6/25/07	26.1	6.6	41	7.25	9.03	170
YW1	6/25/07	29.1	4.6	315		18.3	80
YW4	6/25/07	27.4	7	204		11.4	300
PCA	6/25/07	31	6.1	161		14.5	17
PC2	6/25/07	30	7	136		26.7	50
PC5	6/25/07	29	6.9	280		14.6	50
PC8	6/25/07	29.6	7.4	153		16.8	130
NR3	6/25/07	28.7	5.4	81		17.9	130
NR6	6/25/07	26.9	6.9	81		12.6	80
NR7	6/25/07	27.4	6.7	84		13.5	30
NR9	6/25/07	26.8	6.1	86		19.8	80
TRT1	6/26/07	22.9	5.1	54	6.68	19.7	900
TRT2	6/26/07	23.8	2.1	437	7.34	18.6	1700
TRT3	6/26/07	23.4	5.4	46	6.73	7.68	500
TRT4	6/26/07	23.1	4.5	40	6.24	5.31	70
TRT6	6/26/07	24.1	3.5	49	6.03	7.37	130
TRT9	6/26/07	25.9	5.4	50	6.59	7.31	17
TRT10	6/26/07	26.5	3.4	133	6.40	65.3	13
TRT11	6/26/07	26.6	4.6	33	5.91	81.9	500
TRT12	6/26/07	29	3.4	75	6.03	42.4	80

APPENDIX B2: Geochemical Data (n/d – non detect)

		Li	Na	NH_4-N	K	Mg	Ca	Sr	SiO_2-Si	F	Br	Cl	NO_2-N	NO_3-N	PO_4-P	SO_4	HCO_3-C	tds
Site	Date	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
TR1	6/12/06	n/d	5.47	0.92	1.31	0.69	1.09	n/d	5.76	0.08	n/d	6.40	n/d	0.22	n/d	1.38	2.91	45.69
TR2	6/12/06	n/d	5.42	0.71	1.34	0.77	1.23	n/d	5.87	0.07	n/d	6.23	n/d	0.31	n/d	1.34	2.66	44.75
TR3	6/12/06	n/d	5.35	0.76	1.33	0.72	1.15	n/d	5.85	0.05	n/d	6.27	n/d	0.27	n/d	1.38	2.97	46.04
TR4	6/12/06	n/d	5.63	0.85	1.33	0.74	1.13	n/d	5.82	0.07	n/d	6.67	n/d	0.36	n/d	1.46	3.09	47.87
TR5	6/12/06	n/d	5.27	0.73	1.25	0.73	1.24	n/d	6.10	0.05	n/d	6.23	n/d	0.22	n/d	1.46	3.45	48.73
TR6	6/12/06	n/d	5.23	0.76	1.23	0.64	0.99	n/d	5.69	0.05	n/d	6.66	n/d	0.27	n/d	1.43	2.66	44.10
TR7	6/12/06	n/d	4.96	0.70	1.27	0.72	1.13	n/d	5.65	0.05	n/d	6.71	n/d	0.27	n/d	1.38	1.75	39.28
TR8	6/12/06	n/d	5.14	0.67	1.25	0.71	1.15	n/d	5.57	0.05	n/d	6.88	n/d	0.28	n/d	1.40	2.31	42.32
TR9	6/12/06	n/d	5.34	0.70	1.25	0.68	1.17	n/d	5.46	0.08	n/d	7.69	n/d	0.31	n/d	1.49	2.83	46.01
TR10	6/12/06	n/d	5.98	0.63	1.25	0.71	1.19	n/d	5.35	0.06	n/d	8.23	n/d	0.37	n/d	1.68	2.35	44.93
TR1	7/17/06	n/d	5.75	0.53	1.50	0.80	1.42	n/d	6.38	0.05	n/d	6.44	n/d	0.23	n/d	0.05	2.54	44.25
TR2	7/17/06	n/d	5.54	0.34	1.48	0.81	1.43	n/d	6.30	0.05	n/d	6.06	n/d	0.25	n/d	1.83	2.95	47.22
TR3	7/17/06	n/d	5.37	0.26	1.45	0.83	1.51	n/d	6.28	0.04	n/d	6.22	n/d	0.21	n/d	1.72	2.98	46.95
TR4	7/17/06	n/d	5.88	0.59	1.50	0.86	1.49	n/d	6.31	0.05	n/d	6.61	n/d	0.24	n/d	1.79	2.59	46.66
TR5	7/17/06	n/d	5.75	0.36	1.40	0.90	1.65	n/d	6.44	0.05	n/d	6.15	n/d	0.23	n/d	1.72	3.22	49.23
TR6	7/17/06	n/d	5.70	0.32	1.51	0.87	1.53	n/d	6.16	0.04	n/d	6.56	n/d	0.22	n/d	1.74	2.80	46.75
TR7	7/17/06	n/d	5.35	0.67	1.43	0.84	1.54	n/d	6.09	0.05	n/d	6.76	n/d	0.26	n/d	1.70	2.85	47.19
TR8	7/17/06	n/d	5.70	0.71	1.40	0.84	1.61	n/d	6.12	0.04	n/d	7.26	n/d	0.33	n/d	1.88	2.52	47.00
TR9	7/17/06	n/d	5.95	0.77	1.38	0.82	1.66	n/d	6.11	0.07	n/d	7.76	n/d	0.35	n/d	1.89	2.67	48.71
TR10	7/17/06	n/d	6.86	0.69	1.47	0.86	1.75	n/d	6.20	0.06	n/d	8.70	n/d	0.43	n/d	2.28	2.87	52.63
YW1	7/17/06	0.006	58.84	0.90	9.67	2.19	15.46	n/d	15.90	0.31	n/d	31.17	1.05	4.98	2.67	17.25	26.89	340.37
YW4	7/17/06	0.006	50.57	1.02	3.38	1.21	3.37	n/d	12.60	0.27	0.07	13.94	0.04	0.76	0.58	14.31	22.83	236.65
PCA	7/17/06	n/d	52.60	3.31	7.24	2.15	12.73	n/d	12.50	0.46	n/d	22.97	0.28	3.73	2.04	15.92	26.55	303.64
PC2	7/17/06	0.008	66.44	8.02	6.23	1.74	8.94	n/d	14.30	0.85	0.08	30.98	0.10	0.16	2.42	16.06	34.02	353.56
PC5	7/17/06	0.008	56.74	0.95	2.56	3.71	18.08	n/d	16.70	0.34	0.27	38.59	n/d	0.16	0.21	29.39	26.51	322.67
PC8	7/17/06	n/d	71.58	0.69	1.64	0.69	2.84	n/d	6.18	0.30	0.06	7.81	n/d	0.08	0.24	6.78	37.92	299.53
NR3	7/17/06	n/d	14.31	1.00	3.66	1.36	3.10	n/d	5.23	0.13	0.07	12.81	n/d	0.28	0.13	5.97	7.50	93.63
NR6	7/17/06	n/d	11.88	0.95	2.63	1.53	2.72	n/d	5.49	0.09	0.08	12.41	n/d	0.15	n/d	5.56	4.62	74.01
NR7	7/17/06	n/d	11.63	0.71	2.34	1.40	2.51	n/d	5.07	0.07	0.10	12.71	n/d	0.09	n/d	5.24	4.81	72.58
NR9	7/17/06	n/d	13.25	1.57	3.26	1.50	3.52	n/d	4.15	0.08	0.20	15.91	n/d	0.18	n/d	7.02	5.53	84.53
TRT1	7/18/06	n/d	4.21	0.75	1.56	0.72	1.44	n/d	4.69	0.03	n/d	5.79	n/d	0.36	n/d	1.40	2.78	41.84
TRT2	7/18/06	n/d	46.60	1.16	7.76	2.24	16.19	0.14	6.05	0.23	0.06	49.26	n/d	0.07	n/d	4.66	21.88	253.04
TRT3	7/18/06																	

Site	Date	Li mg/l	Na mg/l	NH_4-N mg/l	K mg/l	Mg mg/l	Ca mg/l	Sr mg/l	SiO_2-Si mg/l	F mg/l	Br mg/l	Cl mg/l	NO_2-N mg/l	NO_3-N mg/l	PO_4-P mg/l	SO_4 mg/l	HCO_3-C mg/l	tds mg/l
TRT4	7/18/06	n/d	3.28	0.68	1.10	0.49	1.05	n/d	5.01	0.03	n/d	4.82	n/d	0.16	n/d	0.70	1.98	33.81
TRT6	7/18/06	n/d	3.39	0.76	1.58	0.65	1.07	n/d	4.74	0.03	n/d	5.25	n/d	0.23	n/d	1.64	2.38	37.84
TRT9	7/18/06	n/d	5.34	0.67	2.04	0.69	1.35	n/d	6.06	0.04	n/d	5.50	n/d	0.13	n/d	1.35	3.47	48.35
TRT10	7/18/06	n/d	28.80	1.99	4.87	2.01	4.83	n/d	4.89	0.18	0.07	14.46	0.06	0.16	0.07	5.66	17.52	164.05
TRT11	7/18/06	n/d	18.06	1.77	2.68	1.19	2.78	n/d	3.28	0.25	n/d	8.54	n/d	0.07	n/d	6.44	8.90	94.75
TRT12	7/18/06	n/d	52.82	1.23	2.83	5.22	4.45	n/d	2.38	0.15	0.34	92.12	n/d	0.09	n/d	16.83	3.99	202.12
TR1	9/18/06	n/d	5.01	0.12	2.03	0.99	2.28	0.04	5.95	0.06	n/d	5.72	n/d	0.23	n/d	1.88	2.38	44.00
TR2	9/18/06	n/d	5.26	0.10	1.76	0.92	2.14	n/d	6.19	0.05	n/d	6.20	n/d	0.24	n/d	1.73	2.60	45.70
TR3	9/18/06	n/d	5.45	0.16	2.05	0.94	2.17	n/d	6.06	0.05	n/d	6.23	n/d	0.26	n/d	1.73	2.61	46.20
TR4	9/18/06																	
TR5	9/18/06	n/d	4.70	0.19	4.52	1.19	2.49	n/d	4.84	0.06	n/d	6.00	n/d	0.34	0.04	2.62	2.24	45.19
TR6	9/18/06	n/d	5.14	0.11	1.57	0.92	2.12	n/d	5.84	0.05	n/d	6.34	n/d	0.23	n/d	1.45	1.71	39.93
TR7	9/18/06	n/d	4.90	0.13	1.59	0.98	2.20	n/d	6.23	0.05	n/d	6.78	n/d	0.28	n/d	1.37	2.00	42.76
TR8	9/18/06	n/d	4.72	0.09	1.86	0.90	2.09	n/d	5.81	0.05	n/d	6.49	n/d	0.28	n/d	1.43	1.76	40.26
TR9	9/18/06	n/d	5.02	0.17	2.58	0.98	2.33	n/d	5.77	0.06	n/d	7.49	0.01	0.48	n/d	1.78	2.15	45.88
TR10	9/18/06	n/d	4.17	0.07	0.67	1.08	1.75	n/d	6.30	0.06	n/d	8.62	n/d	0.42	n/d	1.66	2.38	45.53
YW1	9/18/06	n/d	14.20	0.43	3.77	0.69	3.57	n/d	3.62	0.12	n/d	5.20	0.02	0.54	0.51	5.13	6.82	79.64
YW4	9/18/06	n/d	7.91	0.22	3.25	0.76	5.83	n/d	2.86	0.11	n/d	3.13	0.01	0.31	0.23	6.35	5.29	62.73
PCA	9/18/06	0.010	61.30	1.67	9.35	2.17	14.80	n/d	15.89	0.39	0.07	30.90	0.10	3.19	2.50	13.60	29.70	341.72
PC2	9/18/06	0.010	88.00	14.70	8.49	1.66	8.35	n/d	16.97	0.85	0.08	33.10	0.10	0.40	2.66	29.60	44.60	462.20
PC5	9/18/06	n/d	20.10	0.36	1.90	2.02	12.10	n/d	7.27	0.19	n/d	7.72	n/d	0.19	n/d	10.20	14.13	142.87
PC8	9/18/06	n/d	4.14	0.31	2.95	0.62	2.62	n/d	2.23	n/d	n/d	2.41	n/d	0.38	n/d	2.66	2.11	32.97
NR3	9/18/06	n/d	6.88	0.48	4.39	1.03	3.08	n/d	2.93	0.09	n/d	5.84	0.02	0.61	0.32	4.56	2.68	50.12
NR6	9/18/06	n/d	5.08	0.18	3.66	0.87	2.16	n/d	2.66	0.07	n/d	5.52	0.01	0.31	0.21	3.92	2.64	42.66
NR7	9/18/06	n/d	7.81	0.21	2.53	1.12	2.56	n/d	3.08	0.09	0.07	8.50	n/d	0.12	0.13	4.43	3.52	52.78
NR9	9/18/06	n/d	11.20	0.17	2.81	1.20	3.17	n/d	3.68	0.08	0.07	13.80	n/d	0.12	0.05	5.12	3.33	63.14
TRT1	9/19/06	n/d	3.30	0.21	5.07	1.22	2.71	n/d	4.03	0.05	n/d	4.72	0.01	0.49	0.25	2.78	2.41	43.95
TRT2	9/19/06	n/d	39.50	3.60	8.69	2.00	12.60	0.13	9.41	0.18	n/d	37.20	0.06	0.07	0.11	13.30	17.10	226.08
TRT3	9/19/06	n/d	3.06	0.10	1.46	0.90	1.66	n/d	5.01	0.02	n/d	4.92	n/d	0.40	0.06	0.60	1.29	31.97
TRT4	9/19/06	n/d	2.52	0.07	1.04	0.64	1.24	n/d	5.06	n/d	n/d	4.22	n/d	0.09	n/d	0.39	1.40	28.47
TRT6	9/19/06	n/d	2.58	0.10	2.22	0.98	1.90	n/d	5.12	0.04	n/d	4.78	n/d	0.16	n/d	2.54	1.18	32.82
TRT9	9/19/06	n/d	4.42	0.13	3.00	0.90	1.97	n/d	5.54	0.06	n/d	5.48	0.02	0.20	0.07	1.46	2.35	42.41
TRT10	9/19/06	n/d	27.80	0.56	3.93	1.81	4.64	n/d	6.51	0.21	n/d	10.10	n/d	0.05	0.15	6.79	14.34	143.46
TRT11	9/19/06	n/d	8.98	0.10	2.09	1.80	4.67	0.05	5.03	0.11	n/d	4.99	n/d	0.02	n/d	4.76	5.80	67.89
TRT12	9/19/06	n/d	68.60	0.60	4.33	8.97	7.13	0.10	4.02	0.10	0.45	127.00	n/d	0.05	n/d	16.50	2.89	257.45
TR1	10/23/06	n/d	5.31	0.09	2.50	0.91	2.15	n/d	5.71	0.06	n/d	6.64	0.01	0.13	n/d	2.32	0.14	33.55

Site	Date	Li mg/l	Na mg/l	NH_4-N mg/l	K mg/l	Mg mg/l	Ca mg/l	Sr mg/l	SiO_2-Si mg/l	F mg/l	Br mg/l	Cl mg/l	NO_2-N mg/l	NO_3-N mg/l	PO_4-P mg/l	SO_4 mg/l	HCO_3-C mg/l	tds mg/l
TR2	10/23/06	n/d	5.13	0.04	2.68	0.89	2.09	n/d	5.25	0.05	n/d	6.14	0.03	0.03	n/d	2.21	0.13	31.36
TR3	10/23/06	n/d	5.27	0.04	2.55	0.89	2.06	n/d	5.62	0.06	n/d	6.58	0.03	0.07	n/d	2.33	0.13	32.89
TR4	10/23/06	n/d	5.16	0.03	2.62	1.00	2.34	n/d	5.63	0.06	n/d	6.78	0.03	0.17	n/d	2.41	0.13	33.96
TR5	10/23/06	n/d	5.21	n/d	2.58	1.01	2.31	n/d	5.85	0.05	n/d	6.55	0.03	0.03	n/d	2.25	0.14	33.38
TR6	10/23/06	n/d	4.95	n/d	2.61	1.09	2.52	n/d	5.73	0.06	n/d	6.58	0.03	0.18	n/d	2.32	0.07	33.62
TR7	10/23/06	n/d	4.82	n/d	2.32	0.97	2.24	n/d	5.82	0.05	n/d	7.05	n/d	0.16	n/d	2.37	0.15	33.74
TR8	10/23/06	n/d	4.92	n/d	2.17	0.96	2.23	n/d	5.82	0.05	n/d	7.28	n/d	0.23	n/d	2.37	0.14	34.16
TR9	10/23/06	n/d	5.23	n/d	2.33	0.94	2.43	n/d	5.89	0.05	n/d	8.11	n/d	0.30	n/d	2.56	0.15	36.34
TR10	10/23/06	n/d	6.71	n/d	2.24	0.99	2.27	n/d	5.87	0.06	n/d	10.43	n/d	0.26	n/d	3.19	0.15	40.36
YW1	10/23/06	n/d	22.40	0.28	4.07	1.42	7.84	n/d	7.20	0.17	n/d	10.40	0.10	0.28	0.45	7.73	0.26	74.06
YW4	10/23/06	n/d	23.10	0.20	3.85	1.48	5.80	n/d	7.59	0.17	n/d	8.65	0.06	0.26	0.30	7.81	0.29	71.09
PCA	10/23/06	n/d	36.00	2.72	5.09	2.25	10.50	n/d	8.98	0.29	0.07	24.20	0.06	0.49	0.73	12.50	0.26	119.53
PC2	10/23/06	n/d	23.10	1.83	3.91	1.80	11.00	n/d	6.80	0.22	n/d	9.52	0.08	0.63	0.58	10.60	0.39	83.87
PC5	10/23/06	n/d	27.90	0.78	2.32	2.22	15.10	0.14	11.60	0.21	n/d	8.62	0.03	0.11	0.08	13.80	0.28	98.37
PC8	10/23/06	n/d	13.50	0.22	3.28	1.30	5.17	n/d	3.60	0.14	n/d	6.42	n/d	n/d	0.11	5.97	0.13	44.76
NR3	10/23/06	n/d	5.78	0.18	5.26	0.88	2.63	n/d	2.36	0.08	n/d	6.89	0.03	0.02	0.10	3.67	0.14	31.69
NR6	10/23/06	n/d	3.45	n/d	5.54	0.62	1.67	n/d	1.73	0.06	n/d	4.25	n/d	n/d	0.38	3.26	0.14	24.43
NR7	10/23/06	n/d	3.02	0.28	6.26	0.84	2.06	n/d	1.87	0.06	n/d	4.52	0.03	0.53	0.37	3.45	0.13	28.81
NR9	10/23/06	n/d	3.36	0.35	7.96	0.94	2.18	n/d	1.87	0.06	n/d	6.05	0.03	0.49	0.49	4.29	0.13	33.72
TRT1	10/24/06	n/d	3.95	1.87	4.77	1.61	3.28	n/d	5.18	0.04	n/d	6.12	0.02	0.60	0.25	2.07	0.14	39.52
TRT2	10/24/06	n/d	32.80	0.42	9.70	3.04	17.80	0.14	11.48	0.15	n/d	30.20	0.02	0.03	0.11	9.61	0.29	130.51
TRT3	10/24/06	n/d	3.57	0.09	4.00	1.41	2.64	n/d	4.89	0.04	n/d	6.01	n/d	0.47	0.09	2.18	0.13	33.44
TRT4	10/24/06	n/d	2.75	0.08	2.69	0.86	1.62	n/d	4.59	0.03	n/d	4.51	n/d	0.37	0.03	2.20	0.13	26.96
TRT6	10/24/06	n/d	2.98	0.10	3.68	1.35	2.45	n/d	4.48	0.06	n/d	5.09	n/d	0.19	0.03	7.81	0.13	34.73
TRT9	10/24/06	n/d	6.23	0.19	3.34	1.02	2.16	n/d	6.34	0.10	n/d	6.73	n/d	0.26	0.04	1.82	0.13	37.12
TRT10	10/24/06																	
TRT11	10/24/06	n/d	13.50	0.46	2.02	1.16	3.54	n/d	4.44	0.49	n/d	8.70	n/d	0.24	n/d	5.35	n/d	45.91
TRT12	10/24/06	0.008	498.00	n/d	18.70	64.30	31.00	0.77	4.03	0.18	3.41	982.00	n/d	0.06	n/d	118.00	0.14	1725.97
TR1	11/13/06	n/d	4.79	0.12	2.05	1.19	2.94	n/d	6.40	0.03	n/d	5.57	n/d	0.26	n/d	2.37	5.42	61.46
TR2	11/13/06	n/d	4.79	0.10	1.96	1.20	2.85	n/d	6.61	0.03	n/d	5.49	n/d	0.26	n/d	2.25	2.69	47.64
TR3	11/13/06	n/d	4.94	0.12	2.02	1.19	2.79	n/d	6.50	0.04	n/d	5.72	n/d	0.28	n/d	2.32	2.59	47.46
TR4	11/13/06							n/d										
TR5	11/13/06	n/d	4.76	0.12	1.86	1.17	2.66	n/d	6.97	0.04	n/d	5.77	n/d	1.32	n/d	2.21	2.34	51.25
TR6	11/13/06	n/d	4.43	0.11	1.88	1.18	2.69	n/d	6.50	0.03	n/d	5.46	n/d	0.35	n/d	2.21	2.57	46.55
TR7	11/13/06	n/d	4.30	0.20	2.00	1.17	2.65	n/d	6.81	0.02	n/d	5.69	n/d	0.33	n/d	2.51	2.02	44.90
TR8	11/13/06	n/d	4.43	0.16	1.92	1.17	2.68	n/d	6.74	0.03	n/d	5.70	n/d	0.33	n/d	2.38	1.98	44.47

		Li	Na	NH_4-N	K	Mg	Ca	Sr	SiO_2-Si	F	Br	Cl	NO_2-N	NO_3-N	PO_4-P	SO_4	HCO_3-C	tds
Site	Date	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
TR9	11/13/06	n/d	4.70	0.12	1.97	1.17	2.72	n/d	6.69	0.03	n/d	5.84	n/d	0.33	n/d	2.46	1.11	40.48
TR10	11/13/06	n/d	5.86	0.10	2.79	1.14	2.73	n/d	6.58	0.04	n/d	6.92	n/d	0.33	n/d	4.59	1.60	47.88
YW1	11/13/06	n/d	55.30	0.64	9.80	10.05	16.00	n/d	17.13	0.29	0.05	31.06	0.03	1.86	2.67	14.96	30.04	344.10
YW4	11/13/06	n/d	49.61	0.49	2.74	1.51	4.88	n/d	14.67	0.23	0.05	12.84	0.01	0.62	0.39	12.67	22.24	233.49
PCA	11/13/06	n/d	46.20	1.56	5.48	5.61	12.44	n/d	9.18	0.22	0.14	45.40	0.05	0.94	1.03	15.05	16.12	241.56
PC2	11/13/06	0.006	60.94	2.52	6.87	2.28	10.12	n/d	13.94	0.63	0.05	23.07	0.04	0.26	2.06	14.09	33.45	328.65
PC5	11/13/06	0.006	51.09	0.42	1.48	2.24	14.68	n/d	19.06	0.40	0.06	10.66	n/d	0.18	0.24	18.57	30.70	297.99
PC8	11/13/06	n/d	39.17	0.37	3.55	1.50	4.32	n/d	4.18	0.17	0.08	8.04	n/d	0.13	0.10	7.67	17.06	161.47
NR3	11/13/06	n/d	9.54	0.32	4.45	1.91	4.65	n/d	5.16	0.05	0.07	9.71	n/d	0.42	0.12	5.29	4.69	73.17
NR6	11/13/06	n/d	8.70	0.21	4.57	2.06	4.36	n/d	5.77	0.07	0.05	9.75	n/d	0.44	0.05	5.85	4.15	71.21
NR7	11/13/06	n/d	8.84	0.17	4.51	1.99	4.11	n/d	5.30	0.07	n/d	10.57	0.01	0.37	0.05	5.45	3.87	68.59
NR9	11/13/06	n/d	10.14	0.23	4.41	1.97	4.18	n/d	5.11	0.07	0.04	11.58	0.01	0.39	0.09	5.55	1.69	59.78
TRT1	11/14/06	n/d	4.96	0.04	2.26	1.37	2.64	n/d	5.55	0.08	n/d	5.96	n/d	0.73	n/d	2.71	1.39	42.20
TRT2	11/14/06	n/d	29.42	n/d	6.41	2.70	14.55	0.15	10.11	0.11	n/d	24.03	n/d	0.10	n/d	7.41	15.78	187.01
TRT3	11/14/06	n/d	3.51	n/d	2.06	1.20	2.23	n/d	5.42	n/d	n/d	5.26	n/d	0.42	0.04	1.02	1.91	38.56
TRT4	11/14/06	n/d	3.05	n/d	1.14	0.74	1.29	n/d	5.96	n/d	n/d	4.25	n/d	0.11	n/d	0.57	1.16	30.17
TRT6	11/14/06	n/d	3.05	n/d	1.62	1.07	1.77	n/d	5.55	0.07	n/d	4.79	n/d	0.20	n/d	0.97	1.16	31.99
TRT9	11/14/06	n/d	4.98	n/d	1.85	0.97	1.95	n/d	7.36	0.08	n/d	4.97	n/d	0.07	n/d	1.31	2.61	45.42
TRT10	11/14/06	n/d	20.37	0.21	7.41	2.50	5.82	n/d	5.29	0.10	n/d	14.27	0.03	0.35	0.11	8.65	8.11	113.90
TRT11	11/14/06	n/d	8.40	0.06	1.90	1.12	2.62	n/d	3.13	0.11	n/d	3.50	n/d	1.19	0.12	3.31	2.13	44.19
TRT12	11/14/06	n/d	227.73	n/d	9.80	29.70	16.33	n/d	2.66	0.08	1.33	412.70	n/d	0.24	0.05	50.85	1.25	761.78
TR1	1/22/07	n/d	4.33	0.35	2.21	0.88	2.61	n/d	5.46	0.07	n/d	5.84	0.00	0.32	0.05	2.84	2.07	43.01
TR2	1/22/07	n/d	4.00	0.23	2.11	0.98	2.74	n/d	n/d	0.06	n/d	5.17	0.01	0.29	0.06	2.90	1.13	25.51
TR3	1/22/07	n/d	4.28	0.23	2.40	1.08	2.71	n/d	4.81	0.05	n/d	5.41	0.01	0.34	0.07	2.99	1.99	41.39
TR4	1/22/07	n/d	4.00	0.23	2.27	1.12	2.66	n/d	4.87	0.05	n/d	5.19	0.01	0.35	0.04	2.79	1.79	39.57
TR5	1/22/07	n/d	3.52	0.18	2.56	1.25	2.48	n/d	3.12	0.04	n/d	6.04	n/d	0.23	0.06	3.38	0.60	30.45
TR6	1/22/07	n/d	3.64	0.24	2.18	1.09	2.54	n/d	4.63	0.06	n/d	5.19	0.01	0.33	0.03	2.59	1.47	36.57
TR7	1/22/07	n/d	3.47	0.26	2.16	1.10	2.44	n/d	4.68	0.06	n/d	5.28	0.01	0.31	0.03	2.49	0.88	33.32
TR8	1/22/07	n/d	3.47	0.18	1.98	1.14	2.44	n/d	5.19	0.06	n/d	5.07	n/d	0.30	0.03	2.47	1.18	35.39
TR9	1/22/07	n/d	3.58	0.20	1.96	1.15	2.49	n/d		0.04	n/d	5.31	0.01	0.29	0.03	2.60	1.44	26.12
TR10	1/22/07	n/d	4.09	0.41	1.88	1.15	2.75	n/d	4.85	0.08	n/d	5.37	0.01	0.39	0.03	3.32	2.33	43.23
YW1	1/22/07	n/d	5.60	0.23	2.09	1.59	5.11	n/d	3.96	0.10	n/d	4.04	0.01	0.18	0.14	4.45	2.95	47.99
YW4	1/22/07	0.016	4.87	0.23	2.09	1.62	4.56	n/d	3.59	0.07	n/d	3.56	n/d	0.08	0.12	3.79	3.24	45.77
PCA	1/22/07	n/d	5.67	0.23	2.09	1.76	5.71	n/d	3.80	0.08	n/d	4.38	0.01	0.17	0.14	4.80	3.78	53.33
PC2	1/22/07	n/d	5.38	0.28	2.06	2.15	6.31	n/d	3.63	0.08	n/d	4.05	n/d	0.23	0.15	4.97	3.56	52.68
PC5	1/22/07	n/d	4.92	0.15	1.90	1.99	6.29	n/d	3.61	0.08	n/d	3.78	n/d	0.07	0.09	5.37	2.09	43.45

		Li	Na	NH_4-N	K	Mg	Ca	Sr	SiO_2-Si	F	Br	Cl	NO_2-N	NO_3-N	PO_4-P	SO_4	HCO_3-C	tds
Site	Date	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
PC8	1/22/07	n/d	4.25	0.16	2.86	1.79	4.11	n/d	2.84	0.08	n/d	3.49	0.01	0.29	0.20	3.79	3.17	44.66
NR3	1/22/07	n/d	3.63	0.22	2.07	1.28	3.10	n/d	3.03	0.05	n/d	4.36	n/d	0.13	0.69	8.63	1.19	38.62
NR6	1/22/07	n/d	3.38	0.30	2.47	1.29	2.89	0.06	3.09	0.05	n/d	4.65	n/d	0.18	0.08	3.26	2.29	37.74
NR7	1/22/07	n/d	3.33	0.27	2.62	1.48	2.90	n/d	3.07	0.05	n/d	4.54	n/d	0.18	0.08	3.24	1.78	35.14
NR9	1/22/07	n/d	3.34	0.30	2.90	1.55	3.14	n/d	3.14	0.06	n/d	4.75	n/d	0.21	0.11	3.39	2.39	39.61
TRT1	1/23/07	n/d	3.00	0.42	2.40	0.63	2.06	n/d	4.20	0.04	n/d	4.84	n/d	0.31	0.08	2.95	1.46	34.49
TRT2	1/23/07	n/d	5.11	0.11	2.28	0.83	4.59	n/d	4.20	0.05	n/d	6.44	0.01	0.24	n/d	5.88	3.26	51.98
TRT3	1/23/07	n/d	3.56	0.66	5.66	1.21	3.01	n/d	4.10	0.04	n/d	7.12	0.02	0.60	0.26	3.68	3.47	55.04
TRT4	1/23/07	n/d	3.02	0.47	4.42	0.87	2.31	n/d	3.54	0.04	n/d	6.51	0.01	0.45	0.19	3.44	1.74	40.23
TRT6	1/23/07	n/d	2.52	0.16	2.95	0.85	2.14	n/d	3.65	0.05	n/d	5.42	n/d	0.23	0.08	3.72	1.50	34.57
TRT9	1/23/07	n/d	3.18	0.14	3.09	0.86	2.26	n/d	3.38	0.04	n/d	6.32	n/d	0.18	0.08	3.05	1.46	34.67
TRT10	1/23/07	n/d	6.50	0.33	2.74	1.62	3.88	n/d	5.24	0.08	n/d	7.05	n/d	0.29	0.11	6.14	3.24	57.73
TRT11	1/23/07	n/d	2.75	0.12	1.17	0.86	2.47	n/d	2.99	0.04	n/d	3.81	n/d	0.03	n/d	1.80	0.29	21.04
TRT12	1/23/07	n/d	6.72	0.11	1.18	1.07	2.30	n/d	2.89	0.07	n/d	10.18	n/d	n/d	n/d	2.82	0.60	33.72
TR1	2/26/07	n/d	5.16	0.16	1.65	1.04	2.54	n/d	4.08	0.07	n/d	5.77	n/d	0.19	n/d	2.06	2.02	38.30
TR2	2/26/07	n/d	5.13	0.11	1.58	1.07	2.55	n/d	4.32	0.03	n/d	5.57	n/d	0.21	n/d	1.98	2.06	38.66
TR3	2/26/07	n/d	5.13	0.12	1.61	1.02	2.47	n/d	4.44	0.07	n/d	5.71	n/d	0.20	n/d	2.03	2.29	40.22
TR4	2/26/07	n/d	4.97	0.11	1.51	1.02	2.44	n/d	4.28	0.05	n/d	5.75	n/d	0.21	n/d	2.02	2.37	40.04
TR5	2/26/07	n/d	5.06	0.09	1.53	1.06	2.49	n/d	4.68	0.05	n/d	5.78	n/d	0.20	n/d	1.98	2.62	42.25
TR6	2/26/07	n/d	4.84	0.11	1.58	1.04	2.46	n/d	4.08	0.06	n/d	5.86	n/d	0.23	n/d	1.91	2.04	37.98
TR7	2/26/07	n/d	4.57	0.10	1.49	0.98	2.29	n/d	3.92	0.07	n/d	5.82	n/d	0.25	n/d	1.88	2.09	37.30
TR8	2/26/07	n/d	4.74	0.08	1.49	0.98	2.28	n/d	3.61	0.07	n/d	6.00	n/d	0.24	n/d	1.88	1.63	34.61
TR9	2/26/07	n/d	5.04	0.12	1.54	0.97	2.32	n/d		0.09	n/d	6.42	n/d	0.27	n/d	1.98	2.06	30.17
TR10	2/26/07	n/d	5.18	0.09	1.43	0.96	2.23	n/d	3.66	0.04	n/d	6.50	n/d	0.37	n/d	2.03	1.80	37.10
YW1	2/26/07	0.007	38.93	0.44	4.91	6.78	8.80	n/d	10.08	0.17	0.06	19.63	0.41	1.53	0.76	15.16	18.10	218.98
YW4	2/26/07	n/d	34.15	0.40	2.40	1.92	5.39	n/d	9.36	0.20	0.07	13.43	0.01	0.32	0.12	14.67	13.54	163.36
PCA	2/26/07	0.006	36.28	1.12	4.75	5.61	11.58	n/d	8.94	0.27	0.05	17.40	0.09	1.30	0.57	15.39	18.17	212.02
PC2	2/26/07	n/d	32.66	0.88	2.67	2.87	14.47	n/d	6.17	0.20	0.05	14.13	0.03	0.54	0.15	14.39	16.90	184.55
PC5	2/26/07	0.104	44.46	1.74	2.55	14.25	0.12	n/d	12.48	0.33	0.08	12.21	n/d	0.04	0.10	21.36	22.90	241.23
PC8	2/26/07	n/d	23.96	n/d	1.80	1.51	3.42	n/d	4.66	0.09	0.12	14.83	n/d	0.15	n/d	11.43	7.40	105.39
NR3	2/26/07	n/d	13.61	0.38	2.27	2.01	5.26	n/d	4.72	0.07	0.06	11.85	n/d	0.17	0.03	7.99	5.24	81.18
NR6	2/26/07	n/d	11.53	0.17	2.58	1.88	4.49	n/d	4.43	0.08	0.06	12.13	n/d	0.11	n/d	8.02	4.81	75.39
NR7	2/26/07	n/d	10.98	0.15	2.39	1.78	4.03	n/d	4.17	0.11	0.06	11.82	n/d	0.14	n/d	7.31	4.01	68.62
NR9	2/26/07	n/d	11.15	0.15	2.33	1.71	3.83	n/d	3.88	0.08	0.07	11.93	n/d	0.19	n/d	6.76	4.12	68.14
TRT1	2/27/07	n/d	4.41	0.09	1.54	1.19	2.56	n/d	4.69	0.03	n/d	5.89	n/d	0.39	n/d	1.50	0.89	33.51
TRT2	2/27/07	n/d	22.93	n/d	4.71	2.15	14.81	n/d	4.84	0.09	n/d	18.80	n/d	0.38	0.03	9.07	11.10	141.09

		Li	Na	NH_4-N	K	Mg	Ca	Sr	SiO_2-Si	F	Br	Cl	NO_2-N	NO_3-N	PO_4-P	SO_4	HCO_3-C	tds
Site	Date	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
TRT3	2/27/07	n/d	3.94	0.14	1.95	1.20	2.14	n/d	4.12	0.02	n/d	5.35	n/d	0.47	0.02	0.61	0.59	29.36
TRT4	2/27/07	n/d	3.07	0.11	1.48	0.90	1.58	n/d		0.02	n/d	4.81	n/d	0.19	0.02	0.61	0.89	18.04
TRT6	2/27/07	n/d	3.41	0.13	1.56	1.07	1.81	n/d	3.40	0.21	n/d	6.42	n/d	0.15	n/d	0.80	0.89	27.92
TRT9	2/27/07	n/d	5.06	0.14	1.82	0.99	2.04	n/d	n/d	0.14	n/d	5.79	n/d	0.07	n/d	1.34	2.37	29.70
TRT10	2/27/07	n/d	17.25	0.72	3.56	2.35	5.36	n/d	5.39	0.14	0.04	14.21	0.02	0.32	n/d	9.89	5.88	96.59
TRT11	2/27/07	n/d	5.51	0.33	1.21	1.21	3.36	n/d	3.10	0.05	n/d	6.17	n/d	0.31	n/d	1.78	0.05	28.00
TRT12	2/27/07	n/d	12.90	0.25	1.30	1.50	2.83	n/d	3.20	0.04	n/d	15.78	n/d	0.11	n/d	3.58	0.06	45.89
TR1	3/26/07	n/d	5.51	0.27	1.75	1.15	2.73	0.07	5.48	0.06	n/d	6.60	n/d	0.35	n/d	1.92	3.10	49.16
TR2	3/26/07	n/d	5.63	0.28	1.80	1.15	2.73	0.05	5.94	0.09	n/d	6.73	n/d	0.40	n/d	2.03	2.97	50.11
TR3	3/26/07	n/d	5.50	0.25	1.75	1.12	2.63	n/d	5.76	0.06	n/d	6.71	n/d	0.36	n/d	1.93	3.60	52.24
TR4	3/26/07	n/d	5.51	0.24	1.68	1.11	2.61	n/d	5.70	0.06	n/d	6.85	n/d	0.37	n/d	1.88	2.16	44.83
TR5	3/26/07	n/d	5.57	0.34	1.74	1.04	2.39	n/d	5.69	0.06	n/d	6.75	n/d	0.35	n/d	1.85	2.36	45.52
TR6	3/26/07	n/d	5.21	0.13	1.58	1.06	2.47	n/d	5.33	0.09	n/d	6.57	n/d	0.36	n/d	1.74	1.79	40.95
TR7	3/26/07	n/d	5.10	0.22	1.65	1.16	2.74	n/d	5.43	0.06	n/d	6.73	n/d	0.35	n/d	1.68	2.05	42.97
TR8	3/26/07	n/d	5.16	0.24	1.67	1.09	2.49	n/d		0.06	n/d	7.14	n/d	0.38	n/d	1.84	1.74	30.25
TR9	3/26/07	n/d	5.37	0.24	1.61	1.06	2.42	n/d	5.16	0.06	n/d	8.55	n/d	0.40	n/d	1.80	1.78	43.05
TR10	3/26/07	n/d	5.66	0.25	1.55	1.01	2.25	n/d	4.74	0.05	n/d	7.81	n/d	0.44	n/d	1.66	2.07	42.92
YW1	3/26/07	0.006	46.53	0.99	6.52	9.29	8.65	n/d	13.25	0.24	0.07	24.38	0.09	3.05	1.43	16.08	22.77	275.25
YW4	3/26/07	0.006	43.95	0.95	2.49	1.96	4.43	0.09	11.27	0.20	0.08	16.89	0.04	0.56	0.23	14.91	15.59	192.86
PCA	3/26/07	0.006	43.99	1.16	6.17	9.69	12.34	0.04	11.67	0.24	0.07	23.31	0.10	3.54	1.28	14.83	20.75	262.49
PC2	3/26/07	0.006	44.84	1.20	3.72	3.26	16.69	0.17	10.07	0.31	0.06	18.33	0.08	0.80	0.46	14.81	23.75	251.12
PC5	3/26/07	0.012	44.86	0.78	2.10	2.40	11.85	0.16	17.76	0.42	0.11	15.72	n/d	0.08	0.16	23.65	25.25	269.40
PC8	3/26/07	n/d	22.17	0.82	1.75	1.59	3.45	n/d	6.14	0.10	0.13	17.97	0.02	0.32	n/d	11.05	8.46	116.85
NR3	3/26/07	n/d	14.54	0.63	2.83	2.16	5.19	0.12	6.45	0.11	0.05	13.48	0.02	0.28	0.03	6.78	5.03	86.82
NR6	3/26/07	n/d	9.70	0.36	2.61	1.88	4.10	0.10	6.38	0.09	0.07	12.51	n/d	0.23	n/d	7.69	4.46	76.53
NR7	3/26/07	n/d	10.39	0.37	2.51	1.71	3.56	0.07	5.48	0.07	0.07	13.40	n/d	0.23	n/d	7.05	3.80	71.35
NR9	3/26/07	n/d	11.59	0.34	2.48	1.69	3.63	0.06		0.07	0.09	15.58	n/d	0.32	n/d	6.92	3.43	61.39
TRT1	3/27/07	n/d	4.58	0.20	1.66	1.23	2.79	n/d	4.78	0.04	n/d	6.04	n/d	0.43	n/d	1.36	0.89	34.59
TRT2	3/27/07	n/d	39.43	0.56	6.84	2.26	14.85	0.18	8.14	0.13	n/d	30.27	n/d	0.25	0.16	9.69	15.85	203.87
TRT3	3/27/07	n/d	3.71	0.15	1.50	1.15	2.01	n/d	4.90	0.04	n/d	5.97	n/d	0.42	0.03	0.57	1.47	35.03
TRT4	3/27/07	n/d	3.33	0.15	1.22	0.88	1.66	n/d	4.64	0.04	n/d	4.81	n/d	0.13	n/d	0.43	1.19	29.09
TRT6	3/27/07	n/d	3.46	0.14	1.35	1.16	2.07	n/d	3.90	0.04	n/d	5.48	n/d	0.17	n/d	0.56	0.90	27.97
TRT9	3/27/07	n/d	5.29	0.17	1.62	1.08	2.32	n/d	5.50	0.05	n/d	5.59	n/d	0.02	n/d	1.26	2.63	42.63
TRT10	3/27/07	n/d	18.32	0.75	3.46	2.38	5.49	0.10	6.52	0.17	0.05	15.38	n/d	0.35	0.04	9.62	4.75	95.69
TRT11	3/27/07	n/d	16.11	0.57	1.54	2.01	4.93	0.08	5.43	0.17	n/d	9.74	n/d	0.07	n/d	4.52	7.09	87.75
TRT12	3/27/07	n/d	47.41	n/d	2.49	4.44	4.72	0.08	2.19	0.08	0.23	81.00	n/d	0.03	n/d	6.07	1.18	157.34

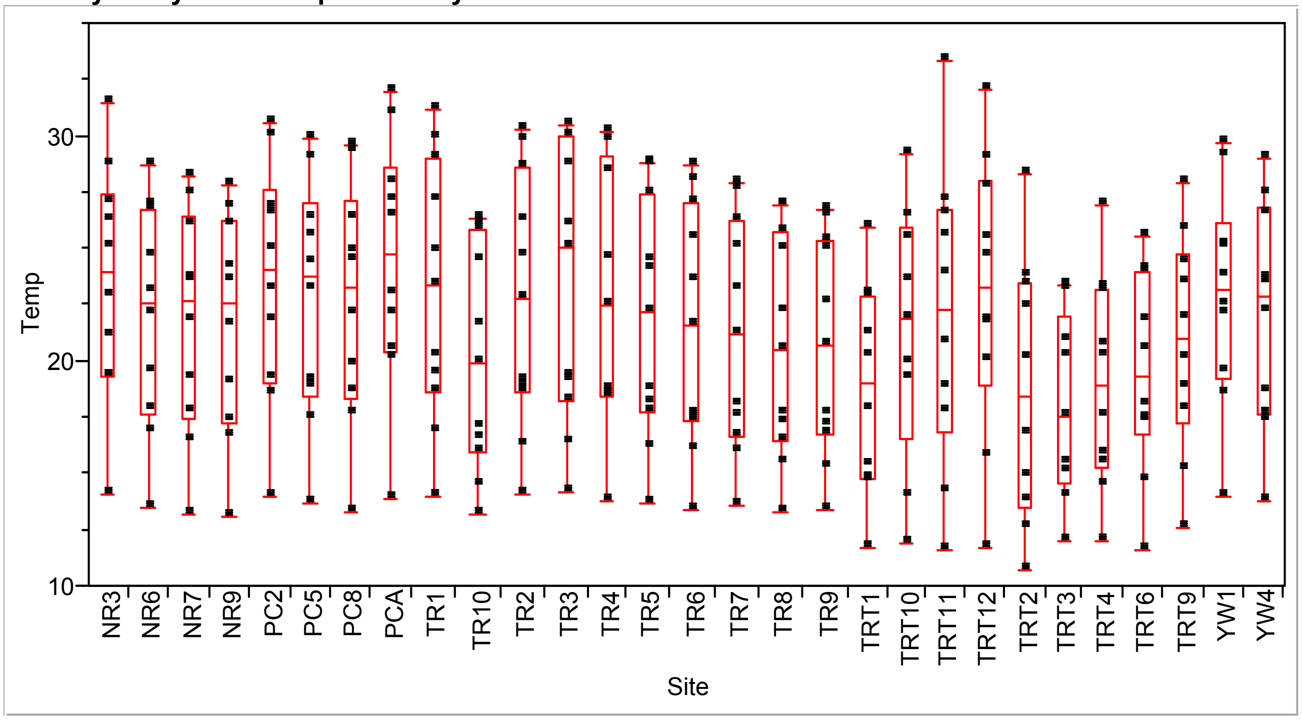
Site	Date	Li mg/l	Na mg/l	NH_4-N mg/l	K mg/l	Mg mg/l	Ca mg/l	Sr mg/l	SiO_2-Si mg/l	F mg/l	Br mg/l	Cl mg/l	NO_2-N mg/l	NO_3-N mg/l	PO_4-P mg/l	SO_4 mg/l	HCO_3-C mg/l	tds mg/l
TR1	4/16/07	n/d	4.40	0.23	2.71	0.81	2.16	0.04	3.83	0.06	n/d	7.06	n/d	0.48	0.03	2.02	0.87	34.38
TR2	4/16/07	n/d	3.80	0.20	2.78	0.78	2.01	n/d	3.33	0.05	n/d	5.70	n/d	0.43	0.04	2.02	0.90	31.12
TR3	4/16/07	n/d	3.74	0.18	2.80	0.80	1.97	n/d	3.51	0.05	n/d	5.39	n/d	0.43	0.03	2.08	0.90	31.15
TR4	4/16/07								3.46	0.05	n/d	7.14	n/d	0.51	n/d	2.33	1.46	26.61
TR5	4/16/07								4.15	0.05	n/d	6.82	n/d	0.47	0.05	2.25	1.48	27.75
TR6	4/16/07	n/d	4.17	0.22	2.80	0.96	2.29	n/d	4.07	0.05	n/d	6.83	n/d	0.49	0.04	2.29	2.04	41.02
TR7	4/16/07	n/d	4.29	0.19	2.43	1.00	2.42	0.03	4.07	0.05	n/d	7.53	n/d	0.47	n/d	2.33	1.48	38.61
TR8	4/16/07								4.08	0.05	n/d	8.86	n/d	0.48	n/d	2.44	1.79	31.29
TR9	4/16/07	n/d	4.46	0.26	2.53	1.00	2.52	0.04	4.27	0.07	n/d	6.80	n/d	0.49	n/d	2.59	1.47	39.14
TR10	4/16/07	n/d	4.76	0.21	2.12	1.01	2.51	0.04	4.31	0.07	n/d	7.03	0.01	0.61	n/d	3.05	1.77	41.81
YW1	4/24/07	0.005	45.93	1.15	6.68	11.46	7.79	0.09	12.73	0.26	0.08	23.19	0.15	1.44	1.82	14.96	28.22	294.98
YW4	4/24/07	0.005	38.28	0.81	2.01	1.50	4.26	0.06	10.87	0.26	0.07	13.75	0.03	0.47	0.28	13.66	16.67	185.85
PCA	4/24/07	n/d	38.24	0.99	5.59	9.46	9.49	0.10	10.61	0.24	0.09	24.28	0.12	2.44	1.02	12.92	24.18	261.50
PC2	4/24/07	n/d	31.91	n/d	3.27	3.09	11.41	0.09	7.55	0.23	n/d	12.39	0.06	0.50	0.39	11.75	17.94	185.04
PC5	4/24/07	0.010	48.62	0.79	1.94	2.15	13.42	0.11	18.27	0.41	0.10	21.26	0.03	0.05	0.12	24.44	24.07	275.56
PC8	4/24/07	n/d	27.98	0.42	1.36	1.26	2.77	n/d	5.41	0.11	0.11	18.58	0.02	0.37	n/d	10.64	9.79	126.39
NR3	4/24/07	n/d	14.10	0.18	2.35	1.88	5.19	0.08	7.77	0.11	0.09	14.04	0.01	0.15	n/d	8.01	5.16	89.57
NR6	4/24/07	n/d	12.72	0.24	2.40	1.77	4.65	n/d	6.87	0.10	0.09	15.84	0.01	0.20	n/d	8.31	5.08	87.59
NR7	4/24/07	n/d	13.05	0.24	2.23	1.61	3.96	0.05	5.72	0.11	0.08	15.74	n/d	0.15	n/d	7.73	4.77	82.01
NR9	4/24/07	n/d	12.70	0.20	1.95	1.45	3.45	n/d	4.84	0.09	0.09	15.47	n/d	0.22	n/d	7.21	4.99	79.34
TRT1	4/18/07	n/d	3.58	0.24	2.72	1.15	2.55	n/d	4.36	0.04	n/d	5.34	n/d	0.52	0.03	1.95	0.90	33.92
TRT2	4/18/07	n/d	7.53	0.68	3.43	1.15	5.72	0.06	3.02	0.11	n/d	7.10	n/d	0.20	n/d	5.82	5.09	64.99
TRT3	4/18/07	n/d	3.08	0.18	4.04	1.04	1.79	n/d	4.34	0.05	n/d	5.80	0.01	0.67	0.12	1.37	1.44	37.39
TRT4	4/18/07	n/d	3.07	0.32	0.96	0.62	1.18	n/d	4.54	0.05	n/d	4.74	n/d	0.21	n/d	0.59	1.17	28.19
TRT6	4/18/07	n/d	2.81	0.13	0.95	0.83	1.37	n/d	4.21	0.04	n/d	4.95	n/d	0.22	n/d	0.59	1.20	27.78
TRT9	4/18/07	n/d	4.85	0.16	1.27	0.77	1.66	n/d	6.00	0.06	n/d	5.46	n/d	0.11	n/d	1.22	2.70	42.51
TRT10	4/18/07	n/d	15.03	0.96	4.15	1.85	4.29	n/d	5.58	0.11	0.05	13.33	0.03	0.50	0.05	9.56	5.67	92.77
TRT11	4/18/07	n/d	4.52	0.29	1.20	0.89	2.52	n/d	2.65	0.06	n/d	5.13	n/d	0.06	n/d	2.06	0.59	25.70
TRT12	4/18/07	n/d	18.06	0.41	1.49	1.92	3.26	0.04	2.43	0.08	0.10	31.20	n/d	0.04	n/d	4.60	1.46	74.05
TR1	5/21/07	n/d	5.44	0.19	1.69	1.11	2.59	0.04	5.98	0.04	n/d	6.05	n/d	0.22	n/d	1.74	3.46	50.31
TR2	5/21/07	n/d	5.94	0.13	1.66	1.15	2.77	0.04	5.88	0.04	n/d	7.93	n/d	0.28	n/d	1.80	2.29	46.96
TR3	5/21/07	n/d	5.26	0.13	1.58	1.08	2.51	0.04	5.67	0.04	n/d	6.50	n/d	0.23	n/d	1.65	2.65	45.43
TR4	5/21/07	n/d	5.15	0.11	1.55	1.01	2.42	0.05	5.75	0.04	n/d	6.11	n/d	0.19	n/d	1.58	2.36	43.18
TR5	5/21/07	n/d	5.15	0.13	1.52	0.99	2.36	0.04	5.74	0.10	n/d	6.00	n/d	0.14	n/d	1.51	2.42	43.03
TR6	5/21/07	n/d	4.93	0.10	1.54	0.99	2.37	0.04	5.56	0.07	n/d	6.22	n/d	0.11	n/d	1.46	2.42	42.41
TR7	5/21/07	n/d	4.49	0.09	1.44	0.96	2.22	0.03	5.54	0.04	n/d	6.02	n/d	0.16	n/d	1.43	2.40	41.51

Site	Date	Li	Na	NH_4-N	K	Mg	Ca	Sr	SiO_2-Si	F	Br	Cl	NO_2-N	NO_3-N	PO_4-P	SO_4	HCO_3-C	tds
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
TR8	5/21/07	n/d	4.67	0.13	1.45	0.95	2.23	0.03	5.61	0.07	n/d	6.62	n/d	0.18	n/d	1.49	2.02	40.76
TR9	5/21/07	n/d	5.22	0.10	1.45	0.97	2.30	0.04	5.20	0.04	n/d	7.59	n/d	0.23	n/d	1.48	2.11	42.08
TR10	5/21/07	n/d	5.56	0.11	1.41	0.96	2.22	0.04	4.93	0.07	n/d	7.61	n/d	0.27	n/d	1.43	2.42	43.46
YW1	5/21/07	0.005	46.69	2.86	8.08	5.95	9.50	0.04	14.63	0.34	0.06	23.23	0.43	1.74	2.10	14.03	22.84	274.45
YW4	5/21/07	0.005	40.16	0.61	2.12	1.54	4.41	0.09	11.00	0.24	0.07	12.67	0.02	0.61	0.24	13.80	16.23	185.39
PCA	5/21/07	n/d	31.74	0.38	4.76	3.90	10.50	0.09	9.38	0.23	n/d	14.66	0.09	2.15	0.80	12.13	15.31	188.60
PC2	5/21/07	n/d	16.52	0.56	3.20	1.76	8.37	0.08	4.19	0.15	n/d	7.39	0.06	0.29	0.31	7.63	9.53	105.66
PC5	5/21/07	0.010	43.60	0.45	2.08	2.54	14.84	0.17	15.19	0.41	0.09	12.28	n/d	0.04	0.17	24.01	24.04	255.94
PC8	5/21/07	n/d	26.66	0.18	1.21	1.18	2.39	n/d	5.14	0.10	0.12	16.17	n/d	0.16	n/d	10.58	9.54	118.79
NR3	5/21/07	n/d	13.34	0.21	2.84	1.91	5.00	0.06	6.82	0.07	0.06	12.69	0.01	0.35	0.05	6.85	5.72	88.50
NR6	5/21/07	n/d	12.05	0.10	2.46	1.63	3.99	0.06	6.22	0.08	0.06	14.22	n/d	0.06	n/d	6.99	4.99	80.58
NR7	5/21/07	n/d	12.22	0.15	2.42	1.45	3.58	0.05	5.50	0.05	0.08	15.35	n/d	0.15	n/d	6.67	4.37	76.66
NR9	5/21/07	0.008	13.15	0.10	2.42	1.37	3.39	0.04	4.71	0.06	0.08	16.04	n/d	0.21	n/d	6.31	4.58	77.26
TRT1	5/22/07	n/d	4.12	0.12	1.52	1.01	2.26	n/d	2.26	0.04	n/d	5.80	n/d	0.44	n/d	1.27	2.86	37.49
TRT2	5/22/07	n/d	51.35	1.06	7.78	2.00	12.20	0.13	3.96	0.14	n/d	46.28	0.04	0.09	n/d	8.22	19.13	235.66
TRT3	5/22/07	n/d	3.38	0.04	1.74	0.95	1.58	n/d	1.24	0.03	n/d	4.99	n/d	0.42	0.04	0.51	1.49	25.42
TRT4	5/22/07	n/d	2.94	0.06	0.97	0.66	1.29	n/d	5.03	0.03	n/d	4.35	n/d	0.17	n/d	0.43	1.46	29.66
TRT6	5/22/07	n/d	3.03	0.08	1.42	0.97	1.77	n/d	4.31	0.04	n/d	4.92	n/d	0.18	n/d	0.69	1.42	30.16
TRT9	5/22/07	n/d	4.82	0.09	1.41	0.83	1.83	0.03	6.51	0.05	n/d	5.03	n/d	0.10	n/d	1.23	2.61	42.96
TRT10	5/22/07	n/d	16.62	0.22	2.02	1.99	4.12	0.06	5.65	0.17	0.05	13.78	0.01	0.12	n/d	8.69	2.78	74.57
TRT11	5/22/07	n/d	4.25	0.09	1.23	1.02	2.65	n/d	2.98	0.04	n/d	4.86	n/d	0.05	n/d	2.46	0.87	27.65
TRT12	5/22/07	n/d	39.54	0.27	2.01	4.16	4.46	0.06	2.39	0.09	0.21	65.22	n/d	0.06	n/d	6.11	1.59	135.68
TR1	6/25/07	n/d	5.11	0.19	2.52	1.15	2.55	0.05	5.50	0.07	n/d	8.44	n/d	0.42	n/d	2.86	2.90	51.34
TR2	6/25/07	n/d	5.09	0.12	2.25	1.18	2.66	0.06	5.78	0.07	n/d	8.09	n/d	0.32	n/d	2.67	2.35	47.94
TR3	6/25/07	n/d	5.21	0.13	2.17	1.05	2.45	0.05	5.86	0.07	n/d	8.61	n/d	0.37	n/d	2.69	2.29	48.27
TR4	6/25/07	n/d	5.34	0.14	1.90	1.07	2.94	0.06	5.95	0.06	n/d	8.99	n/d	0.37	n/d	2.46	2.66	50.85
TR5	6/25/07	n/d	5.27	0.15	1.88	1.08	2.50	0.04	5.81	0.08	n/d	8.87	n/d	0.34	n/d	2.62	1.76	45.42
TR6	6/25/07	n/d	5.26	0.12	1.87	1.08	2.60	0.05	5.27	0.08	n/d	10.61	n/d	0.76	n/d	2.72	1.77	48.05
TR7	6/25/07	n/d	5.59	0.17	1.99	1.16	4.10	0.06	5.30	0.06	n/d	11.18	n/d	1.00	n/d	2.36	1.45	49.87
TR8	6/25/07	n/d	5.33	0.18	2.16	1.06	2.61	0.05	5.19	0.07	n/d	10.29	n/d	0.94	n/d	2.42	2.10	50.12
TR9	6/25/07	n/d	5.38	0.14	1.73	0.94	2.47	0.04	5.15	0.08	n/d	10.32	n/d	0.55	n/d	2.22	2.06	47.28
TR10	6/25/07	n/d	1.24	0.06	1.71	0.90	3.92	0.06	n/d	0.05	n/d	2.60	n/d	n/d	n/d	2.40	2.10	23.62
YW1	6/25/07	0.004	43.87	1.84	8.97	7.07	9.52	0.04	14.09	0.36	n/d	31.02	0.18	1.70	3.30	17.56	24.00	291.07
YW4	6/25/07	0.004	38.47	0.60	2.27	1.49	4.49	0.05	10.78	0.24	n/d	17.39	0.03	0.68	0.40	16.49	16.59	193.34
PCA	6/25/07	n/d	20.55	0.26	4.31	3.08	8.57	0.08	6.32	0.22	n/d	13.58	0.11	0.92	0.94	10.02	11.28	138.87
PC2	6/25/07	n/d	16.28	0.22	3.34	1.86	9.49	0.08	4.24	0.21	n/d	10.12	n/d	n/d	0.44	8.76	10.46	113.94

Site	Date	Li mg/l	Na mg/l	NH_4-N mg/l	K mg/l	Mg mg/l	Ca mg/l	Sr mg/l	SiO_2-Si mg/l	F mg/l	Br mg/l	Cl mg/l	NO_2-N mg/l	NO_3-N mg/l	PO_4-P mg/l	SO_4 mg/l	HCO_3-C mg/l	tds mg/l
PC5	6/25/07	0.005	35.48	0.34	1.66	3.19	20.07	0.18	3.21	0.34	0.12	19.14	n/d	0.01	n/d	42.06	22.90	245.93
PC8	6/25/07	n/d	25.90	0.21	2.22	1.55	3.25	n/d	3.66	0.12	0.11	24.85	n/d	n/d	n/d	12.28	9.73	127.81
NR3	6/25/07	n/d	7.32	0.31	4.02	1.61	4.51	0.06	4.26	0.11	n/d	11.34	0.01	0.39	n/d	6.73	3.77	66.09
NR6	6/25/07	n/d	7.21	0.16	3.43	1.61	3.84	0.06	5.24	0.11	n/d	10.83	n/d	0.20	n/d	8.17	4.18	68.82
NR7	6/25/07	n/d	8.03	0.17	3.19	1.64	3.69	0.05	4.93	0.12	n/d	12.74	n/d	0.30	n/d	8.24	3.57	67.94
NR9	6/25/07	n/d	8.72	0.20	3.07	1.65	3.81	0.05	4.61	0.12	n/d	13.82	n/d	0.44	n/d	8.25	4.38	73.78
TRT1	6/26/07	n/d	3.38	0.12	3.29	1.21	2.73	0.04	3.66	0.05	n/d	6.13	n/d	0.47	n/d	3.03	2.33	41.75
TRT2	6/26/07	n/d	46.66	23.22	9.94	3.01	17.58	0.08	13.18	0.25	n/d	56.53	n/d	0.02	0.72	4.98	33.54	369.80
TRT3	6/26/07	n/d	3.14	0.08	2.41	1.15	2.03	n/d	4.90	0.03	n/d	6.76	n/d	0.48	n/d	1.14	1.48	36.87
TRT4	6/26/07	n/d	3.50	0.15	1.84	0.96	2.88	n/d	4.83	0.04	n/d	7.03	n/d	0.50	n/d	1.82	3.79	50.05
TRT6	6/26/07	n/d	3.20	0.14	2.76	1.36	2.39	n/d	4.47	0.05	n/d	7.66	n/d	0.34	n/d	3.20	4.16	53.00
TRT9	6/26/07	n/d	4.43	0.13	2.57	1.05	2.24	0.04	6.01	0.06	n/d	6.95	n/d	0.17	n/d	2.59	2.35	45.60
TRT10	6/26/07	n/d	17.03	0.63	4.08	2.30	5.79	0.08	5.28	0.16	n/d	17.50	n/d	0.33	n/d	11.11	7.20	108.18
TRT11	6/26/07	n/d	3.53	0.23	1.20	0.69	1.88	n/d	2.02	0.08	n/d	7.10	n/d	0.21	n/d	2.09	0.29	23.57
TRT12	6/26/07	n/d	9.89	0.17	1.19	1.50	2.63	0.03	1.90	0.08	n/d	18.95	n/d	0.05	n/d	3.50	1.18	48.27

APPENDIX C: ONE-WAY ANAYLSES OF PARAMETERS BY SITE

Oneway Analysis of Temperature By Site



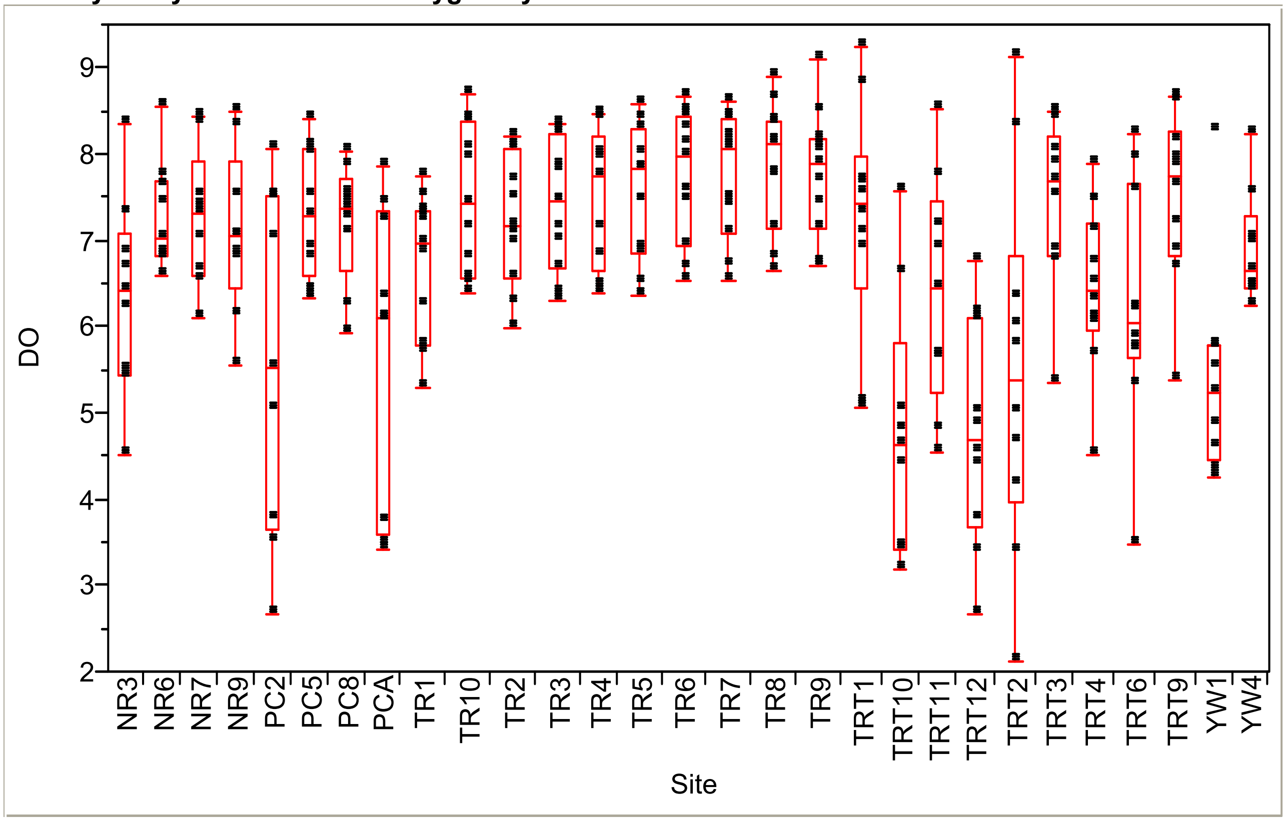
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1803	180.300	1.193
NR6	10	1555	155.500	0.261
NR7	10	1512	151.200	0.100
NR9	10	1480.5	148.050	-0.015
PC2	10	1806	180.600	1.205
PC5	10	1670.5	167.050	0.695
PC8	10	1647	164.700	0.607
PCA	10	1923	192.300	1.644
TR1	11	1907	173.364	0.980
TR10	11	1353	123.000	-1.005
TR2	11	1817	165.182	0.657
TR3	11	1971	179.182	1.210
TR4	9	1498.5	166.500	0.639
TR5	11	1679.5	152.682	0.163
TR6	11	1602.5	145.682	-0.109
TR7	11	1550.5	140.955	-0.296
TR8	11	1461	132.818	-0.618
TR9	11	1449	131.727	-0.661
TRT1	10	1030	103.000	-1.708
TRT10	9	1319.5	146.611	-0.065
TRT11	10	1543.5	154.350	0.218
TRT12	10	1699.5	169.950	0.804
TRT2	10	1040.5	104.050	-1.669
TRT3	9	809	89.889	-2.084
TRT4	10	1060.5	106.050	-1.594
TRT6	10	1143.5	114.350	-1.282
TRT9	10	1365	136.500	-0.449
YW1	10	1710.5	171.050	0.846
YW4	10	1548.5	154.850	0.237

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
26.7815	28	0.5302

Oneway Analysis of Dissolved Oxygen By Site



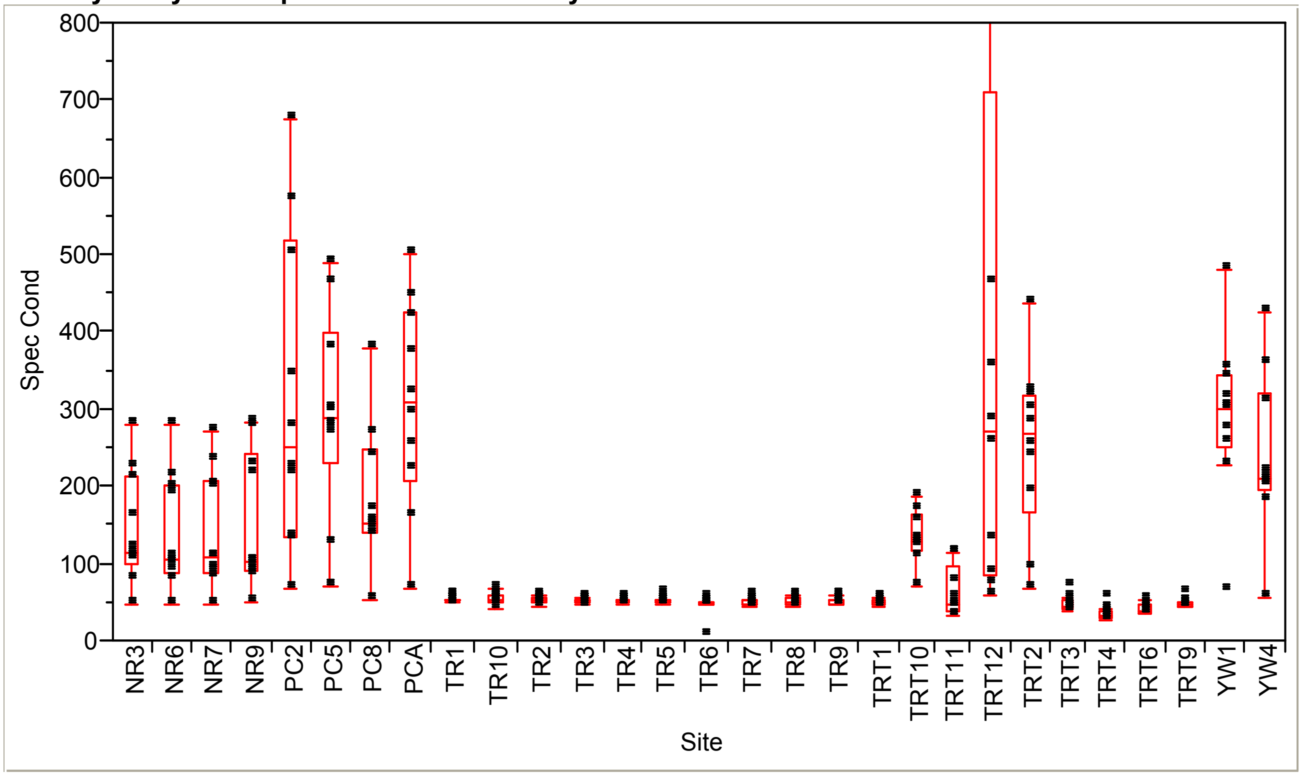
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	9	917	101.889	-1.519
NR6	9	1447	160.778	0.656
NR7	9	1444	160.444	0.643
NR9	9	1354	150.444	0.273
PC2	9	844.5	93.833	-1.817
PC5	9	1475.5	163.944	0.773
PC8	9	1408.5	156.500	0.497
PCA	9	783	87.000	-2.069
TR1	11	1357.5	123.409	-0.802
TR10	11	1968	178.909	1.472
TR2	11	1756	159.636	0.681
TR3	11	1898	172.545	1.211
TR4	9	1617.5	179.722	1.356
TR5	11	2029.5	184.500	1.701
TR6	11	2227	202.455	2.438
TR7	11	2209	200.818	2.371
TR8	11	2328	211.636	2.815
TR9	11	2207.5	200.682	2.366
TRT1	10	1664.5	166.450	0.914
TRT10	9	423	47.000	-3.549
TRT11	9	1000	111.111	-1.178
TRT12	10	375.5	37.550	-4.117
TRT2	10	811	81.100	-2.416
TRT3	9	1638.5	182.056	1.443
TRT4	10	1026.5	102.650	-1.574
TRT6	10	1009	100.900	-1.643
TRT9	10	1848.5	184.850	1.633
YW1	9	530.5	58.944	-3.107
YW4	9	1156.5	128.500	-0.534

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
100.2470	28	<.0001

Oneway Analysis of Specific Conductance By Site



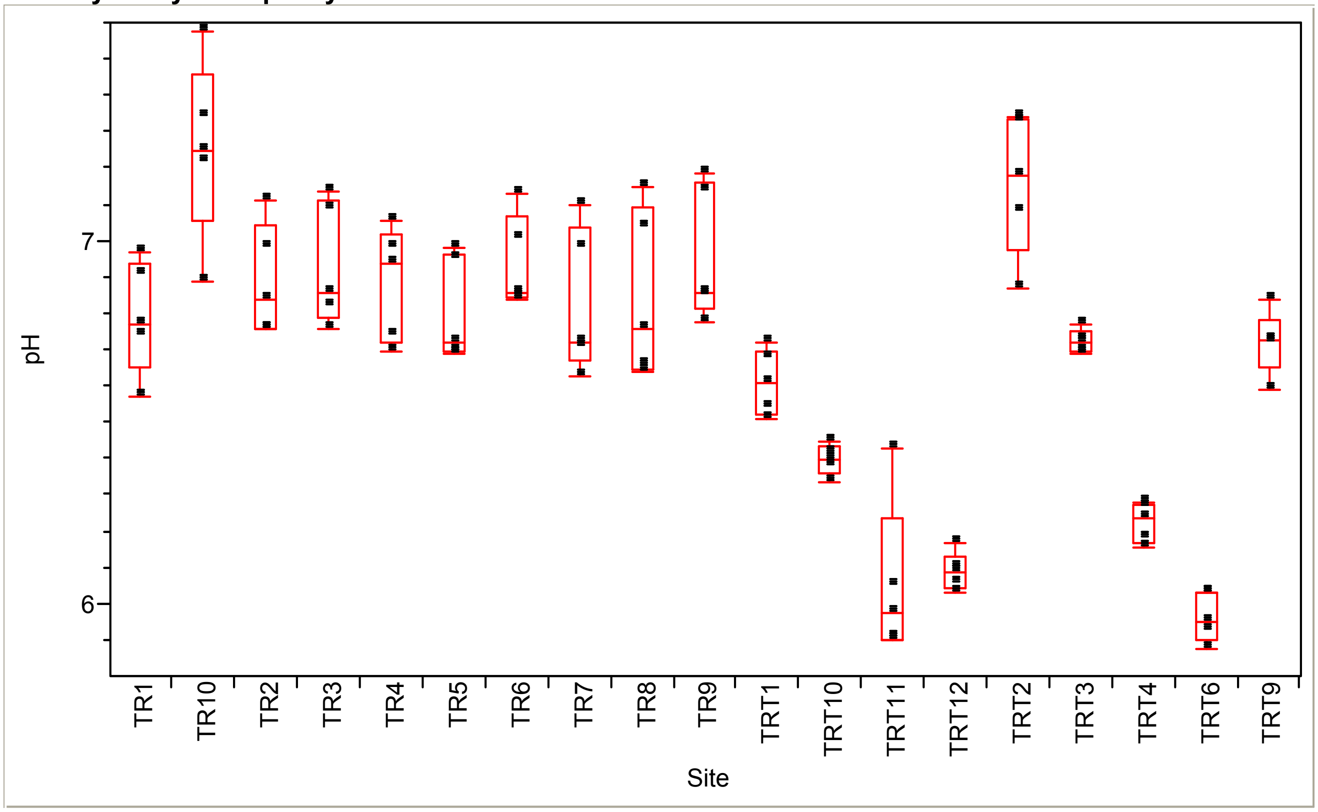
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1973.5	197.350	1.860
NR6	10	1940.5	194.050	1.736
NR7	10	1936	193.600	1.719
NR9	10	2006	200.600	1.983
PC2	10	2472	247.200	3.741
PC5	10	2525.5	252.550	3.943
PC8	10	2205	220.500	2.734
PCA	10	2544	254.400	4.013
TR1	11	1322.5	120.227	-1.099
TR10	11	1372	124.727	-0.921
TR2	11	1225.5	111.409	-1.449
TR3	11	1177.5	107.045	-1.622
TR4	9	950.5	105.611	-1.513
TR5	11	1110.5	100.955	-1.863
TR6	11	829.5	75.409	-2.876
TR7	11	874.5	79.500	-2.714
TR8	11	948.5	86.227	-2.447
TR9	11	1162	105.636	-1.678
TRT1	10	908	90.800	-2.156
TRT10	9	1859.5	206.611	2.092
TRT11	9	856.5	95.167	-1.886
TRT12	10	2391	239.100	3.435
TRT2	10	2431	243.100	3.586
TRT3	9	533.5	59.278	-3.168
TRT4	10	227	22.700	-4.726
TRT6	10	336.5	33.650	-4.312
TRT9	10	630.5	63.050	-3.203
YW1	10	2553	255.300	4.046
YW4	10	2358	235.800	3.311

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
221.7086	28	<.0001

Oneway Analysis of pH By Site



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

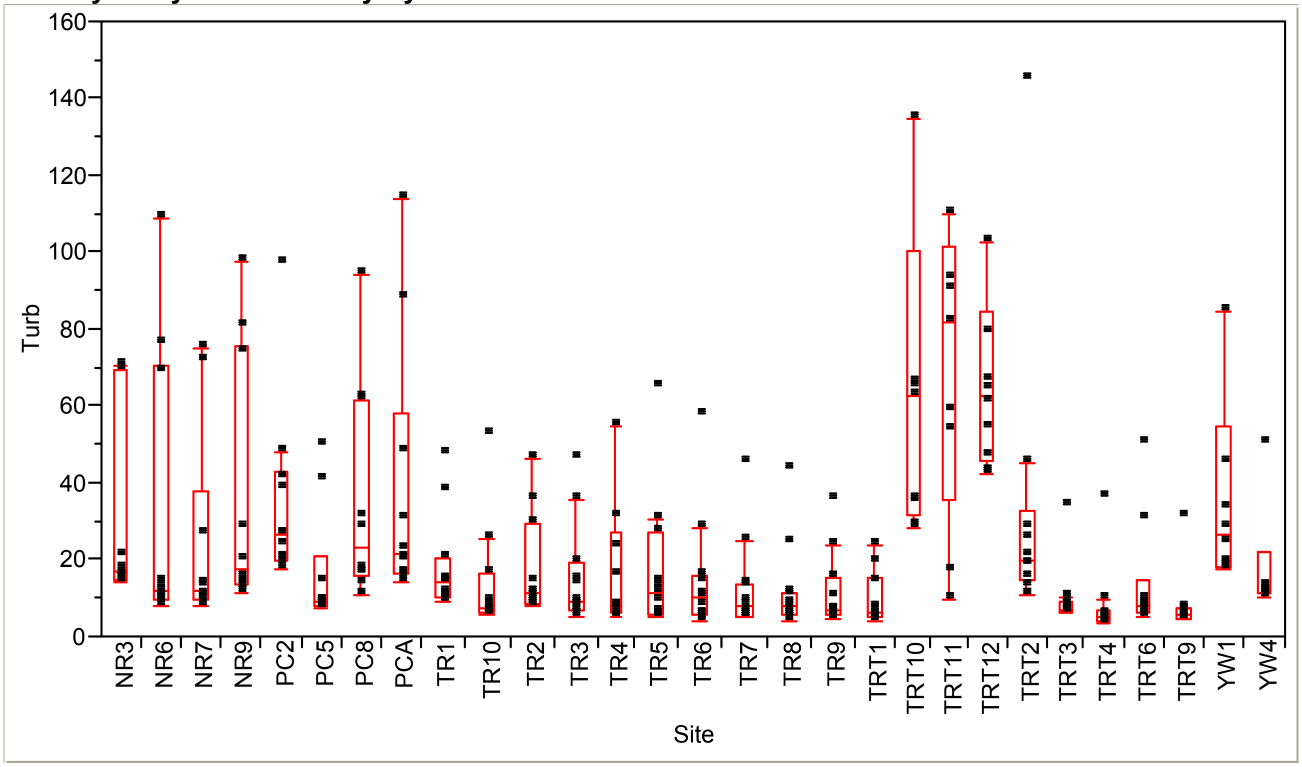
Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	0	0	0.0000	.
NR6	0	0	0.0000	.
NR7	0	0	0.0000	.
NR9	0	0	0.0000	.
PC2	0	0	0.0000	.
PC5	0	0	0.0000	.
PC8	0	0	0.0000	.
PCA	0	0	0.0000	.
TR1	5	274	54.8000	0.558
TR10	5	437.5	87.5000	3.284
TR2	5	322.5	64.5000	1.367
TR3	5	342	68.4000	1.692
TR4	5	311	62.2000	1.175
TR5	5	262	52.4000	0.358
TR6	5	348.5	69.7000	1.800
TR7	5	270.5	54.1000	0.500
TR8	5	282.5	56.5000	0.700
TR9	5	359	71.8000	1.975
TRT1	5	160	32.0000	-1.325
TRT10	5	111	22.2000	-2.142
TRT11	5	45	9.0000	-3.242
TRT12	5	59	11.8000	-3.009
TRT2	5	420.5	84.1000	3.001
TRT3	5	219	43.8000	-0.342
TRT4	5	84	16.8000	-2.592
TRT6	5	26	5.2000	-3.559
TRT9	5	226	45.2000	-0.225
YW1	0	0	0.0000	.
YW4	0	0	0.0000	.

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
76.0202	18	<.0001

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of Turbidity By Site



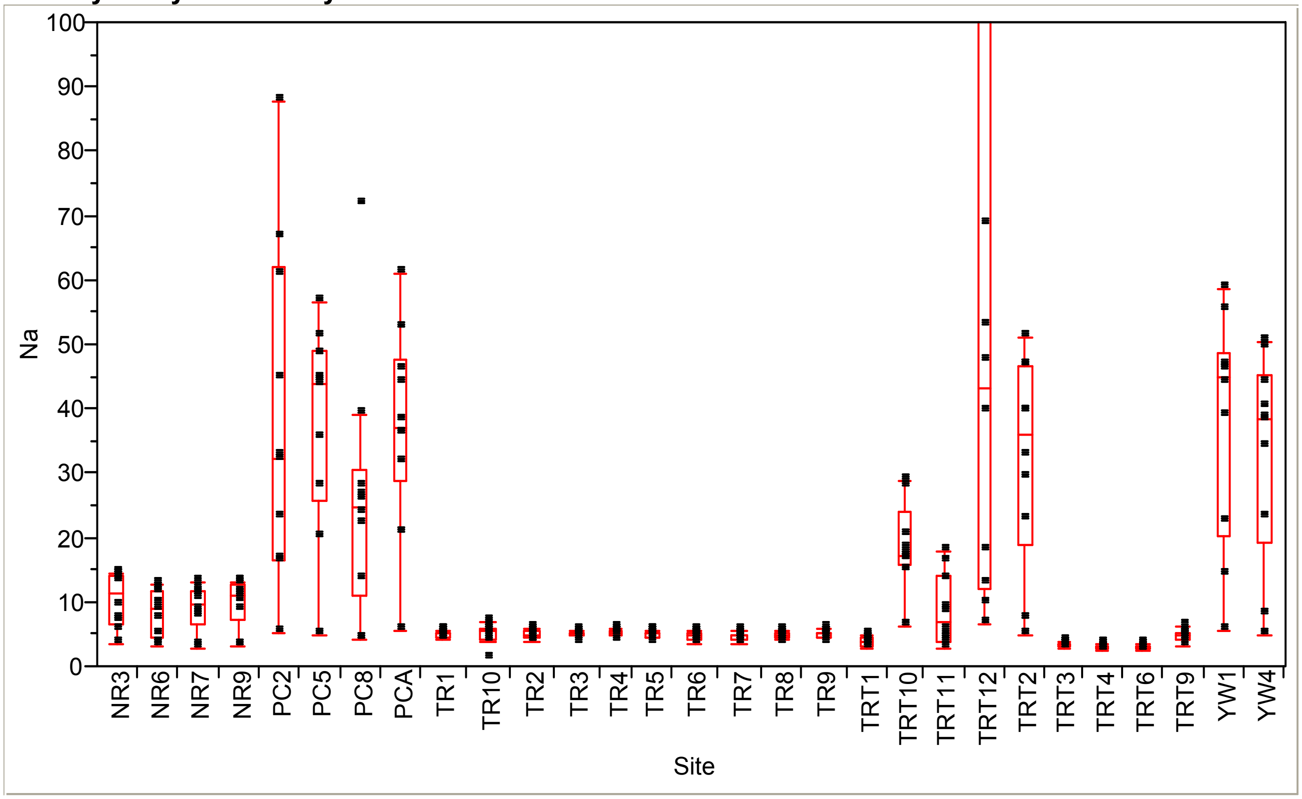
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	2027	202.700	2.061
NR6	10	1640.5	164.050	0.603
NR7	10	1559.5	155.950	0.298
NR9	10	1962	196.200	1.816
PC2	10	2171.5	217.150	2.606
PC5	10	1273	127.300	-0.779
PC8	10	2031	203.100	2.076
PCA	10	2113	211.300	2.386
TR1	11	1777.5	161.591	0.537
TR10	11	1125.5	102.318	-1.808
TR2	11	1571	142.818	-0.204
TR3	11	1366	124.182	-0.942
TR4	9	1097	121.889	-0.931
TR5	11	1337	121.545	-1.046
TR6	11	1199	109.000	-1.544
TR7	11	1059	96.273	-2.048
TR8	11	1017	92.455	-2.199
TR9	11	1015	92.273	-2.206
TRT1	10	739.5	73.950	-2.791
TRT10	9	2256.5	250.722	3.667
TRT11	9	2211.5	245.722	3.488
TRT12	10	2610	261.000	4.260
TRT2	10	1942	194.200	1.741
TRT3	9	763	84.778	-2.256
TRT4	10	463	46.300	-3.834
TRT6	10	1015.5	101.550	-1.750
TRT9	10	562	56.200	-3.460
YW1	10	2181	218.100	2.642
YW4	10	1574.5	157.450	0.355

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
139.9809	28	<.0001

Oneway Analysis of Na By Site



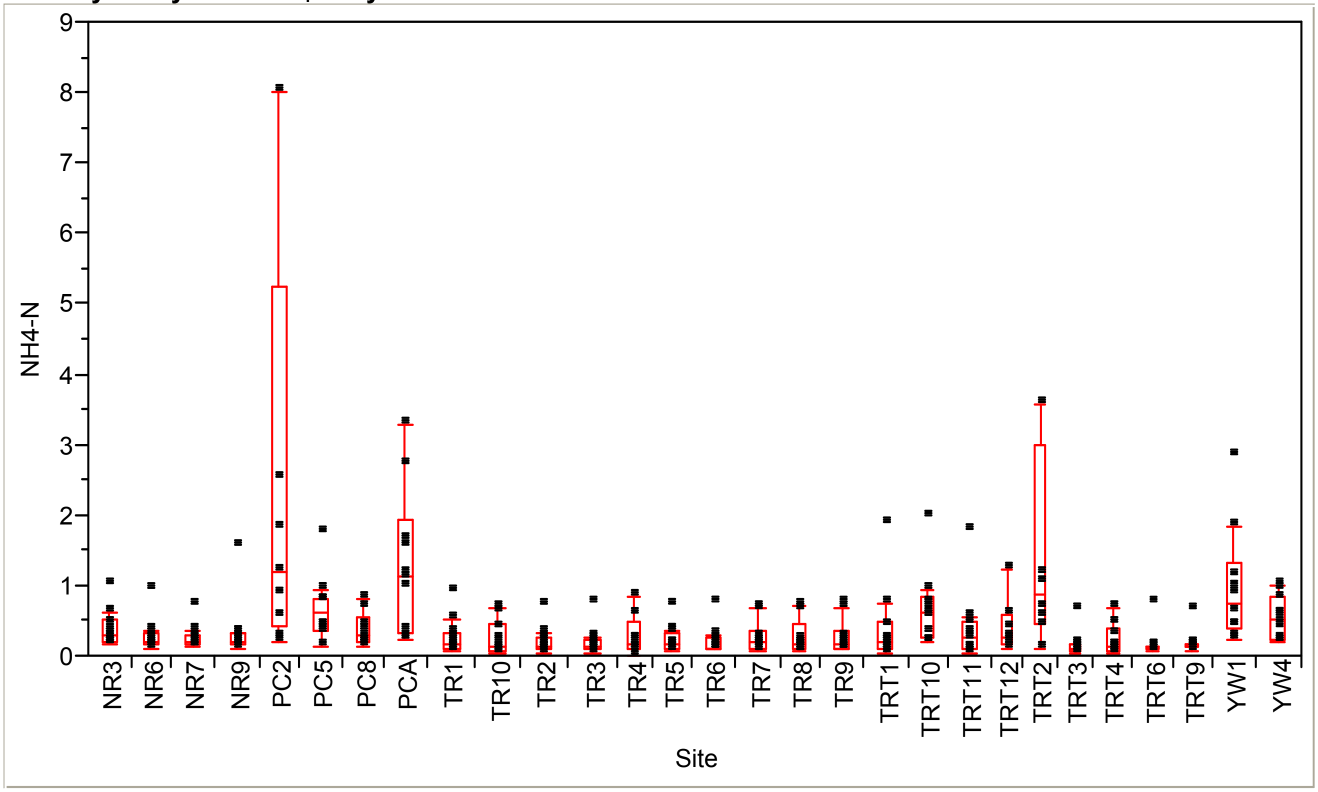
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1840	184.000	1.403
NR6	10	1540	154.000	0.264
NR7	10	1598	159.800	0.484
NR9	10	1656	165.600	0.704
PC2	10	2449	244.900	3.716
PC5	10	2448.5	244.850	3.714
PC8	10	2066	206.600	2.262
PCA	10	2498	249.800	3.902
TR1	11	1304.5	118.591	-1.132
TR10	11	1334	121.273	-1.025
TR2	11	1286.5	116.955	-1.197
TR3	11	1293	117.545	-1.173
TR4	8	1013.5	126.688	-0.685
TR5	10	1139.5	113.950	-1.253
TR6	11	1119	101.727	-1.805
TR7	11	1002	91.091	-2.229
TR8	10	979	97.900	-1.863
TR9	11	1257.5	114.318	-1.302
TRT1	10	520	52.000	-3.606
TRT10	9	2007	223.000	2.731
TRT11	10	1371	137.100	-0.374
TRT12	10	2494.5	249.450	3.889
TRT2	10	2360.5	236.050	3.380
TRT3	9	308	34.222	-4.054
TRT4	10	163.5	16.350	-4.960
TRT6	10	172	17.200	-4.928
TRT9	10	993	99.300	-1.810
YW1	10	2509	250.900	3.944
YW4	10	2348.5	234.850	3.334

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
206.6913	28	<.0001

Oneway Analysis of NH_4-N By Site



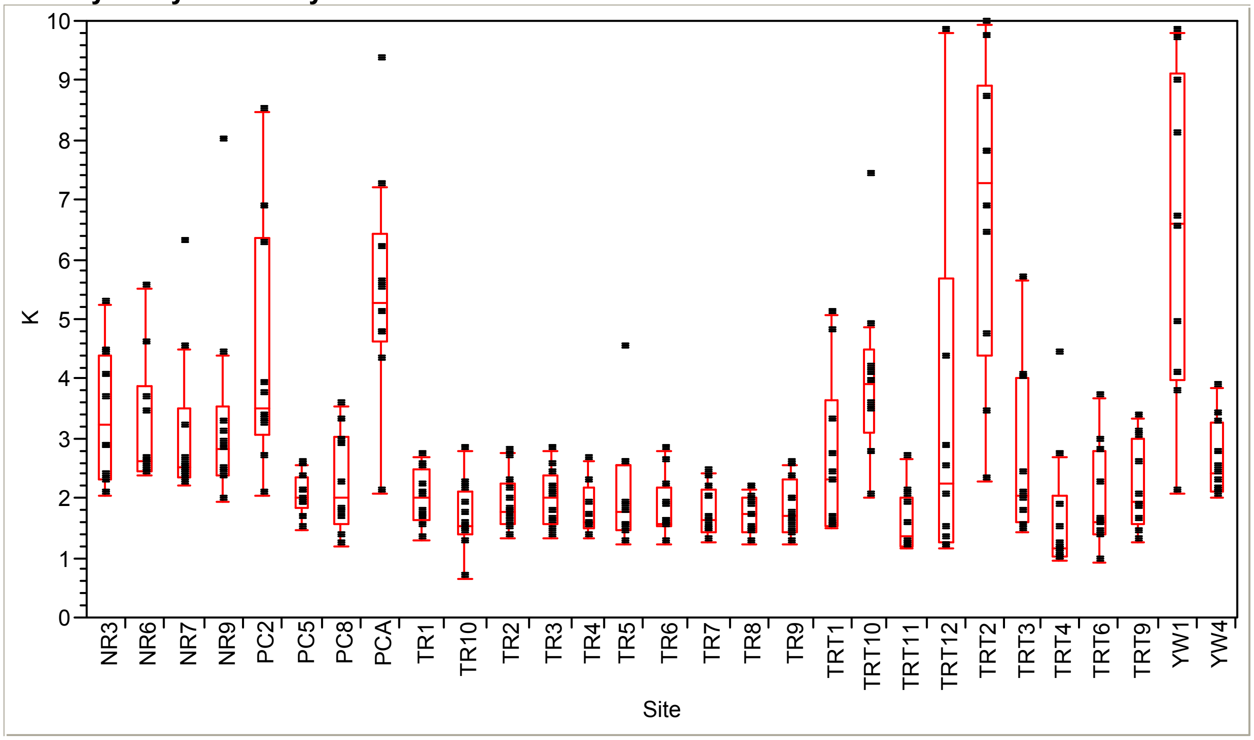
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1642	164.200	1.060
NR6	9	1174.5	130.500	-0.286
NR7	10	1345	134.500	-0.140
NR9	10	1353	135.300	-0.107
PC2	9	2071.5	230.167	3.534
PC5	10	2038.5	203.850	2.666
PC8	9	1445	160.556	0.863
PCA	10	2295	229.500	3.705
TR1	11	1347.5	122.500	-0.658
TR10	10	999.5	99.950	-1.540
TR2	11	1033.5	93.955	-1.873
TR3	11	1098	99.818	-1.624
TR4	8	884	110.500	-0.991
TR5	9	1010.5	112.278	-0.985
TR6	10	943.5	94.350	-1.767
TR7	10	1155	115.500	-0.910
TR8	9	974.5	108.278	-1.138
TR9	10	1172	117.200	-0.841
TRT1	10	1197.5	119.750	-0.737
TRT10	9	1810	201.111	2.419
TRT11	10	1246.5	124.650	-0.539
TRT12	7	1098	156.857	0.633
TRT2	8	1708	213.500	2.724
TRT3	8	533	66.625	-2.575
TRT4	9	815	90.556	-1.818
TRT6	9	660.5	73.389	-2.477
TRT9	9	796.5	88.500	-1.897
YW1	10	2181	218.100	3.243
YW4	10	1921.5	192.150	2.192

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
98.3556	28	<.0001

Oneway Analysis of K By Site



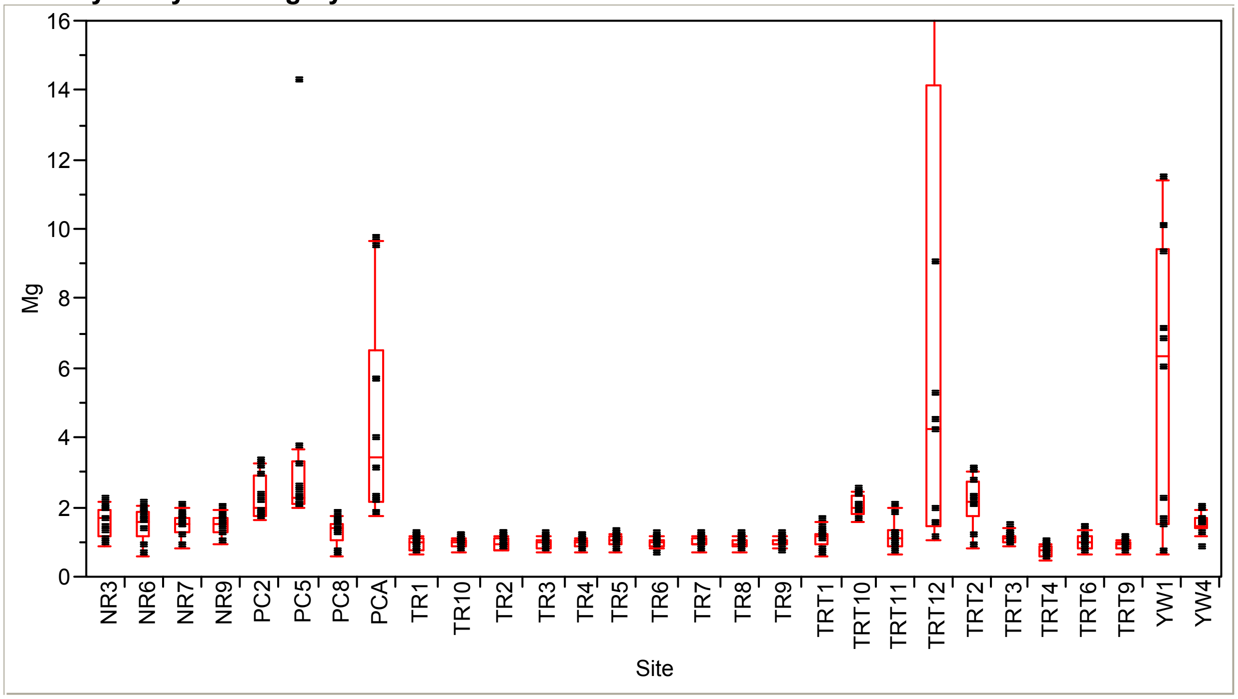
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	2113	211.300	2.440
NR6	10	2070	207.000	2.277
NR7	10	1938.5	193.850	1.777
NR9	10	2008.5	200.850	2.043
PC2	10	2303	230.300	3.162
PC5	10	1247.5	124.750	-0.843
PC8	10	1339	133.900	-0.496
PCA	10	2532.5	253.250	4.033
TR1	11	1288	117.091	-1.192
TR10	11	885.5	80.500	-2.652
TR2	11	1219.5	110.864	-1.440
TR3	11	1252.5	113.864	-1.320
TR4	8	735.5	91.938	-1.862
TR5	10	1088	108.800	-1.449
TR6	11	1086.5	98.773	-1.923
TR7	11	1007.5	91.591	-2.209
TR8	10	838.5	83.850	-2.396
TR9	11	1073	97.545	-1.972
TRT1	10	1530	153.000	0.226
TRT10	9	2062.5	229.167	2.953
TRT11	10	683	68.300	-2.987
TRT12	10	1430	143.000	-0.150
TRT2	10	2618.5	261.850	4.360
TRT3	9	1349.5	149.944	0.104
TRT4	10	634	63.400	-3.173
TRT6	10	1080	108.000	-1.479
TRT9	10	1302	130.200	-0.636
YW1	10	2576	257.600	4.198
YW4	10	1779	177.900	1.172

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
145.1817	28	<.0001

Oneway Analysis of Mg By Site



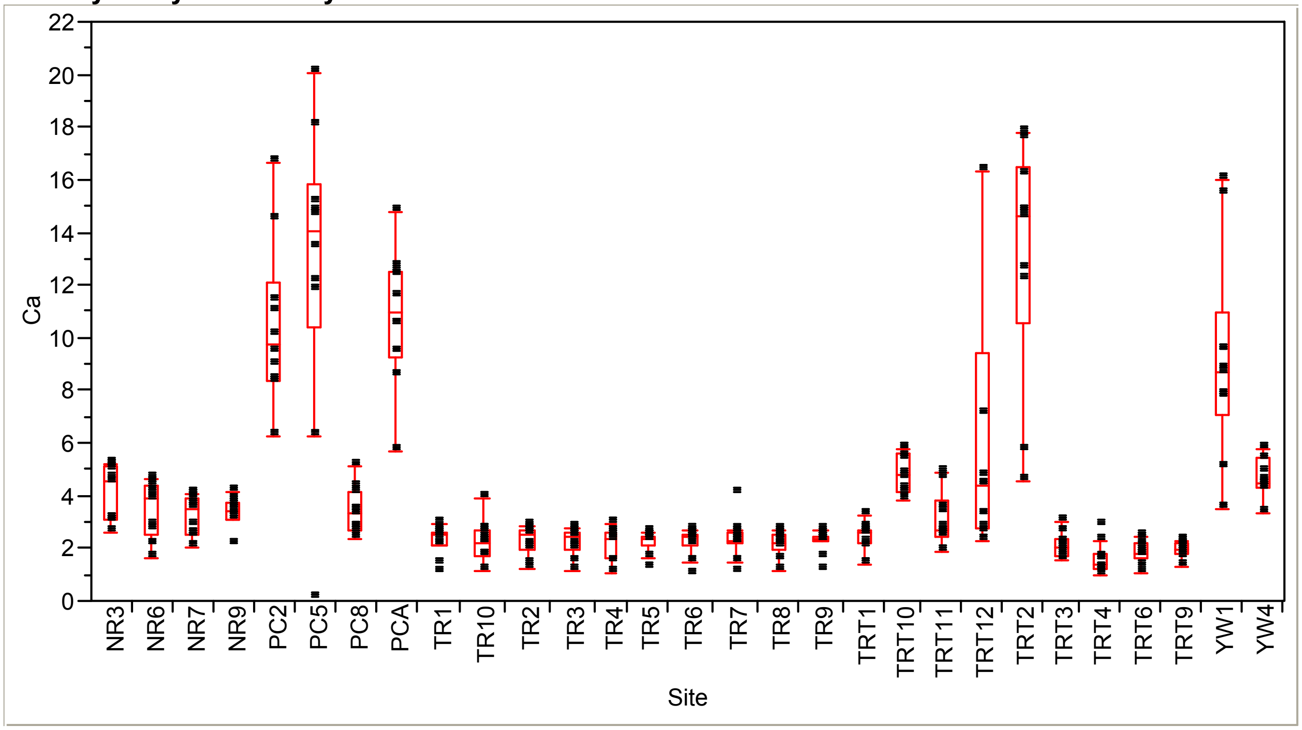
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1908	190.800	1.662
NR6	10	1771.5	177.150	1.143
NR7	10	1828.5	182.850	1.360
NR9	10	1878	187.800	1.548
PC2	10	2427.5	242.750	3.635
PC5	10	2615	261.500	4.347
PC8	10	1545.5	154.550	0.285
PCA	10	2663	266.300	4.529
TR1	11	955	86.818	-2.400
TR10	11	946.5	86.045	-2.431
TR2	11	1006.5	91.500	-2.213
TR3	11	951	86.455	-2.414
TR4	8	738	92.250	-1.851
TR5	10	1094.5	109.450	-1.424
TR6	11	1030	93.636	-2.128
TR7	11	1049	95.364	-2.059
TR8	10	866	86.600	-2.292
TR9	11	914	83.091	-2.548
TRT1	10	1328	132.800	-0.537
TRT10	9	2196.5	244.056	3.489
TRT11	10	1292.5	129.250	-0.672
TRT12	10	2443.5	244.350	3.695
TRT2	10	2231	223.100	2.888
TRT3	9	1203	133.667	-0.478
TRT4	10	312	31.200	-4.396
TRT6	10	987	98.700	-1.833
TRT9	10	674	67.400	-3.021
YW1	10	2370.5	237.050	3.418
YW4	10	1845.5	184.550	1.424

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
183.7325	28	<.0001

Oneway Analysis of Ca By Site



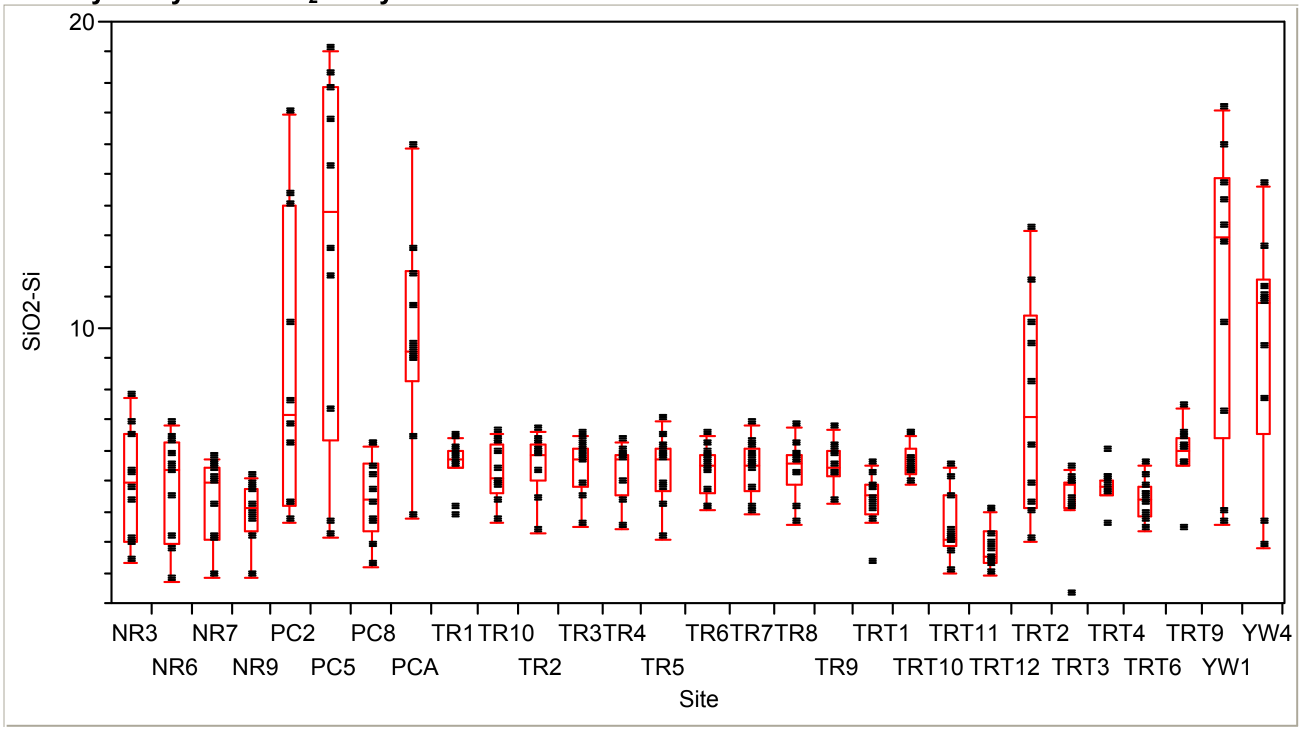
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	2057.5	205.750	2.229
NR6	10	1692	169.200	0.841
NR7	10	1672	167.200	0.765
NR9	10	1791.5	179.150	1.219
PC2	10	2625.5	262.550	4.386
PC5	10	2485	248.500	3.853
PC8	10	1776	177.600	1.160
PCA	10	2643.5	264.350	4.455
TR1	11	1086	98.727	-1.924
TR10	11	1028.5	93.500	-2.133
TR2	11	1124.5	102.227	-1.785
TR3	11	995	90.455	-2.254
TR4	8	782	97.750	-1.665
TR5	10	934	93.400	-2.034
TR6	11	1015.5	92.318	-2.180
TR7	11	1046.5	95.136	-2.068
TR8	10	828	82.800	-2.436
TR9	11	1017	92.455	-2.175
TRT1	10	1213	121.300	-0.974
TRT10	9	2040	226.667	2.863
TRT11	10	1556.5	155.650	0.327
TRT12	10	2067.5	206.750	2.267
TRT2	10	2712	271.200	4.715
TRT3	9	654.5	72.722	-2.669
TRT4	10	411	41.100	-4.020
TRT6	10	509.5	50.950	-3.646
TRT9	10	551.5	55.150	-3.486
YW1	10	2528	252.800	4.016
YW4	10	2227.5	222.750	2.875

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
208.7611	28	<.0001

Oneway Analysis of SiO_2-Si By Site



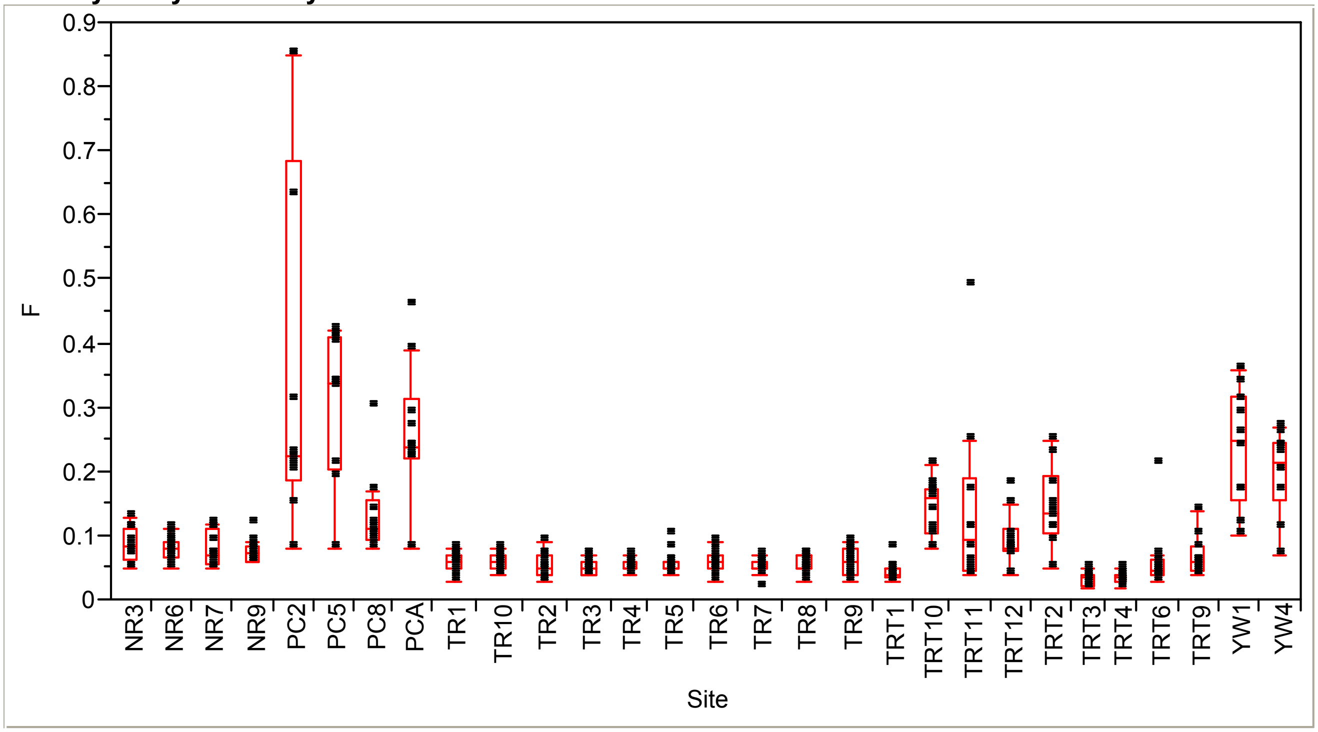
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1220.5	122.050	-0.866
NR6	10	1292	129.200	-0.589
NR7	10	996	99.600	-1.733
NR9	9	637	70.778	-2.696
PC2	10	1992	199.200	2.112
PC5	10	2282.5	228.250	3.235
PC8	10	985	98.500	-1.776
PCA	10	2371	237.100	3.577
TR1	11	1791.5	162.864	0.744
TR10	10	1476.5	147.650	0.120
TR2	10	1703	170.300	0.995
TR3	11	1793.5	163.045	0.751
TR4	9	1361.5	151.278	0.246
TR5	11	1714.5	155.864	0.460
TR6	11	1651.5	150.136	0.227
TR7	11	1693	153.909	0.380
TR8	10	1527	152.700	0.315
TR9	9	1449.5	161.056	0.604
TRT1	10	874.5	87.450	-2.203
TRT10	9	1480	164.444	0.728
TRT11	10	513.5	51.350	-3.598
TRT12	10	234	23.400	-4.678
TRT2	10	1776	177.600	1.277
TRT3	9	832	92.444	-1.903
TRT4	9	990	110.000	-1.261
TRT6	10	866.5	86.650	-2.234
TRT9	9	1671.5	185.722	1.507
YW1	10	2273.5	227.350	3.200
YW4	10	2167	216.700	2.788

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
113.7710	28	<.0001

Oneway Analysis of F By Site



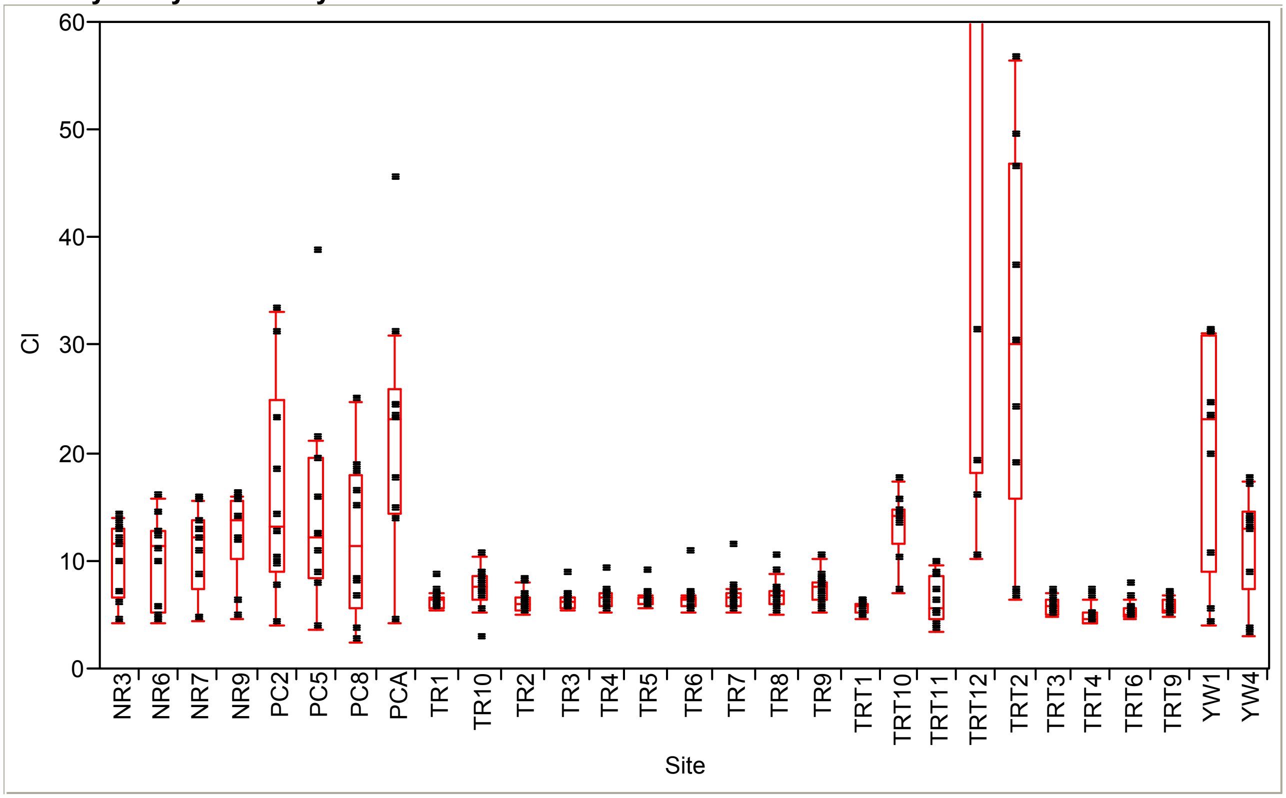
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1709	170.900	0.933
NR6	10	1671.5	167.150	0.789
NR7	10	1583	158.300	0.450
NR9	10	1618.5	161.850	0.586
PC2	10	2579	257.900	4.265
PC5	10	2658	265.800	4.567
PC8	9	1971.5	219.056	2.630
PCA	10	2594	259.400	4.322
TR1	11	1237.5	112.500	-1.366
TR10	11	1187.5	107.955	-1.549
TR2	11	988.5	89.864	-2.277
TR3	11	961	87.364	-2.378
TR4	9	856.5	95.167	-1.860
TR5	11	1082.5	98.409	-1.933
TR6	11	1165	105.909	-1.632
TR7	11	936.5	85.136	-2.467
TR8	11	1052.5	95.682	-2.043
TR9	11	1257	114.273	-1.295
TRT1	10	536.5	53.650	-3.554
TRT10	9	2044	227.111	2.922
TRT11	10	1676	167.600	0.806
TRT12	10	1782.5	178.250	1.214
TRT2	10	2169.5	216.950	2.696
TRT3	8	213.5	26.688	-4.088
TRT4	8	222.5	27.813	-4.049
TRT6	10	834.5	83.450	-2.413
TRT9	10	1200	120.000	-1.013
YW1	10	2555.5	255.550	4.175
YW4	10	2434.5	243.450	3.711

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
198.6975	28	<.0001

Oneway Analysis of CI By Site



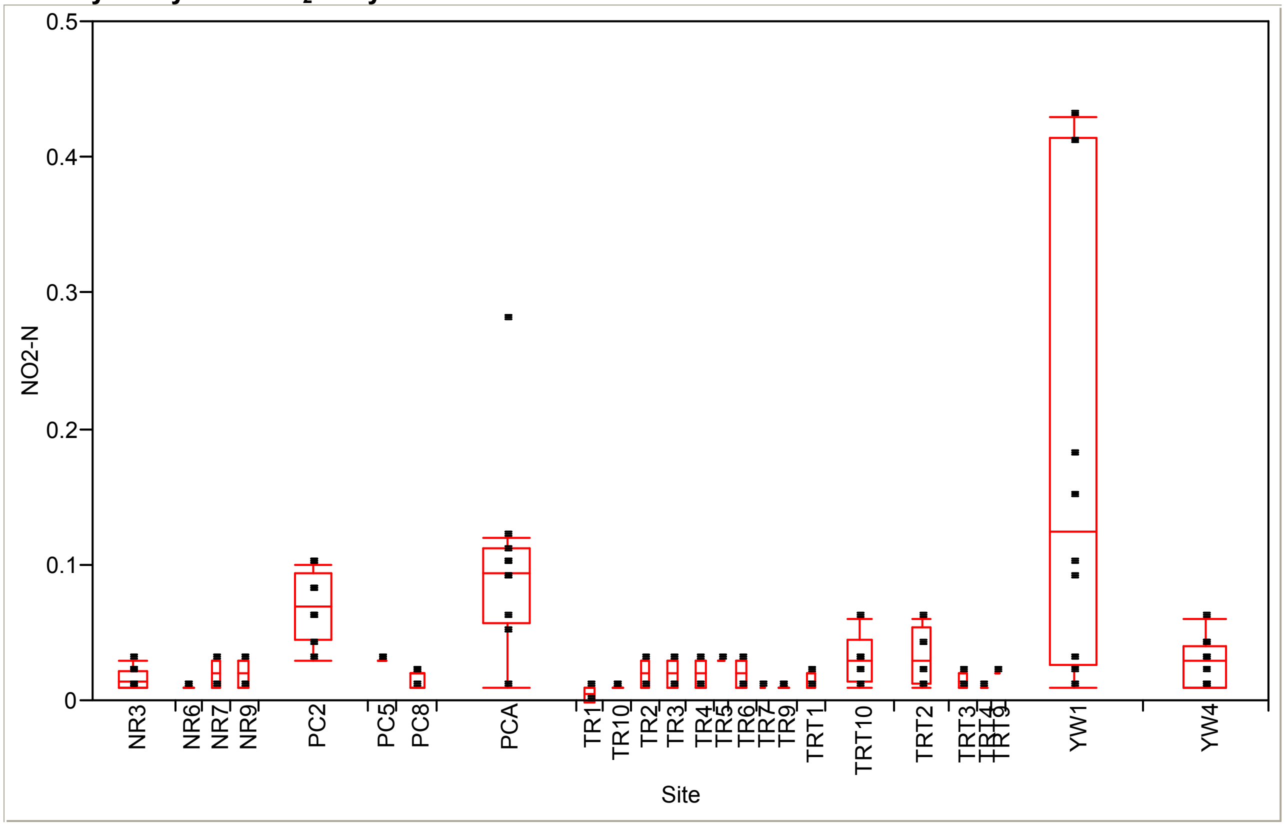
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1762	176.200	1.039
NR6	10	1630.5	163.050	0.545
NR7	10	1790	179.000	1.145
NR9	10	1997.5	199.750	1.924
PC2	10	2103	210.300	2.321
PC5	10	2056.5	205.650	2.146
PC8	10	1754.5	175.450	1.011
PCA	10	2388	238.800	3.392
TR1	11	1199.5	109.045	-1.556
TR10	11	1564.5	142.227	-0.246
TR2	11	1121	101.909	-1.838
TR3	11	1124.5	102.227	-1.826
TR4	9	1108.5	123.167	-0.900
TR5	11	1217	110.636	-1.493
TR6	11	1249	113.545	-1.379
TR7	11	1358	123.455	-0.987
TR8	11	1457	132.455	-0.632
TR9	11	1615	146.818	-0.065
TRT1	10	710.5	71.050	-2.909
TRT10	9	2022.5	224.722	2.711
TRT11	10	939.5	93.950	-2.048
TRT12	10	2753	275.300	4.764
TRT2	10	2510	251.000	3.851
TRT3	9	714	79.333	-2.460
TRT4	10	430	43.000	-3.963
TRT6	10	591	59.100	-3.358
TRT9	10	779.5	77.950	-2.650
YW1	10	2172	217.200	2.580
YW4	10	1838	183.800	1.325

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
145.5572	28	<.0001

Oneway Analysis of NO_2-N By Site



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

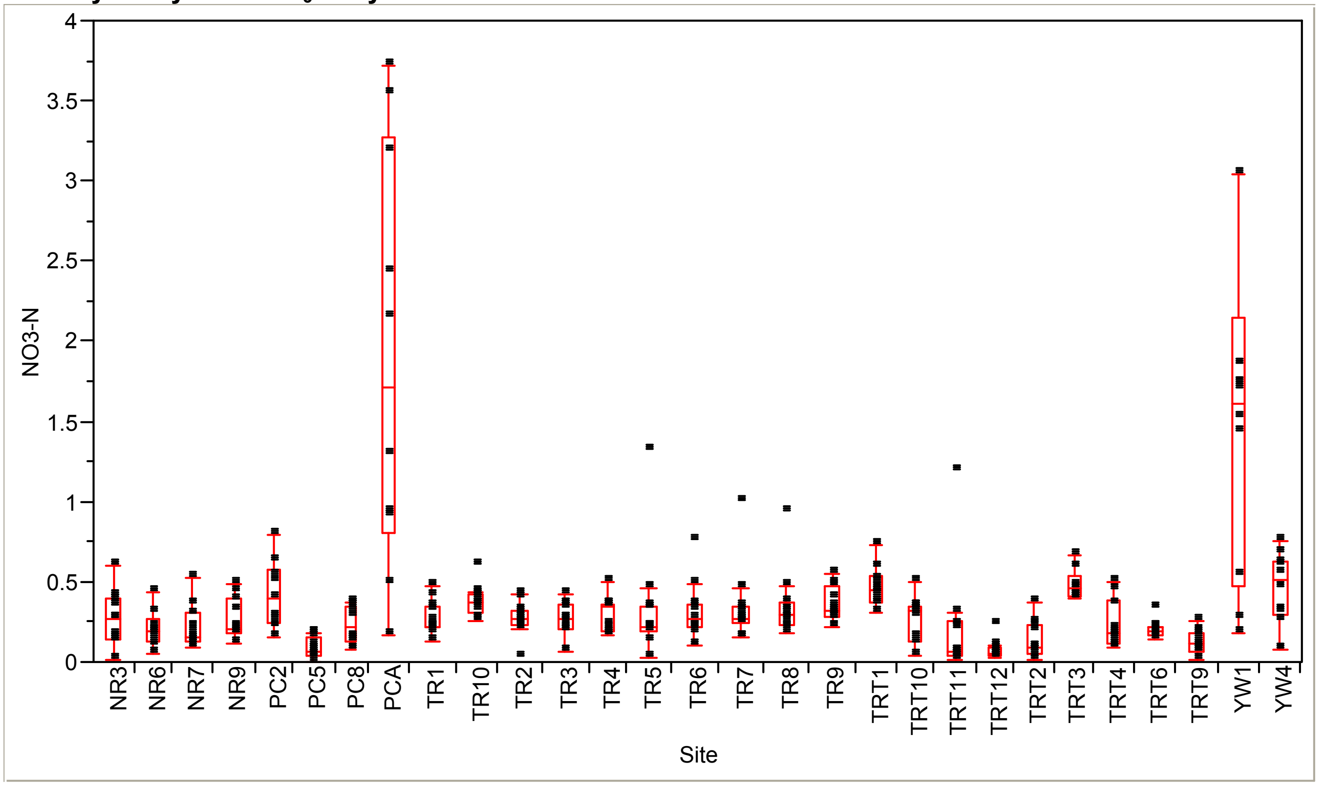
Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	6	165	27.5000	-1.624
NR6	2	31	15.5000	-1.617
NR7	2	64	32.0000	-0.638
NR9	2	64	32.0000	-0.638
PC2	8	523	65.3750	2.749
PC5	2	97	48.5000	0.312
PC8	3	85.5	28.5000	-1.048
PCA	10	672	67.2000	3.371
TR1	2	16.5	8.2500	-2.047
TR10	2	31	15.5000	-1.617
TR2	2	64	32.0000	-0.638
TR3	2	64	32.0000	-0.638
TR4	2	64	32.0000	-0.638
TR5	1	48.5	48.5000	0.209
TR6	2	64	32.0000	-0.638
TR7	1	15.5	15.5000	-1.126
TR8	0	0	0.0000	.
TR9	2	31	15.5000	-1.617
TRT1	2	50.5	25.2500	-1.038
TRT10	5	212	42.4000	-0.048
TRT11	0	0	0.0000	.
TRT12	0	0	0.0000	.
TRT2	4	173.5	43.3750	0.021
TRT3	2	50.5	25.2500	-1.038
TRT4	1	15.5	15.5000	-1.126
TRT6	0	0	0.0000	.
TRT9	1	35	35.0000	-0.313
YW1	10	658	65.8000	3.176
YW4	9	360	40.0000	-0.387

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
49.0811	24	0.0019

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of NO_3-N By Site



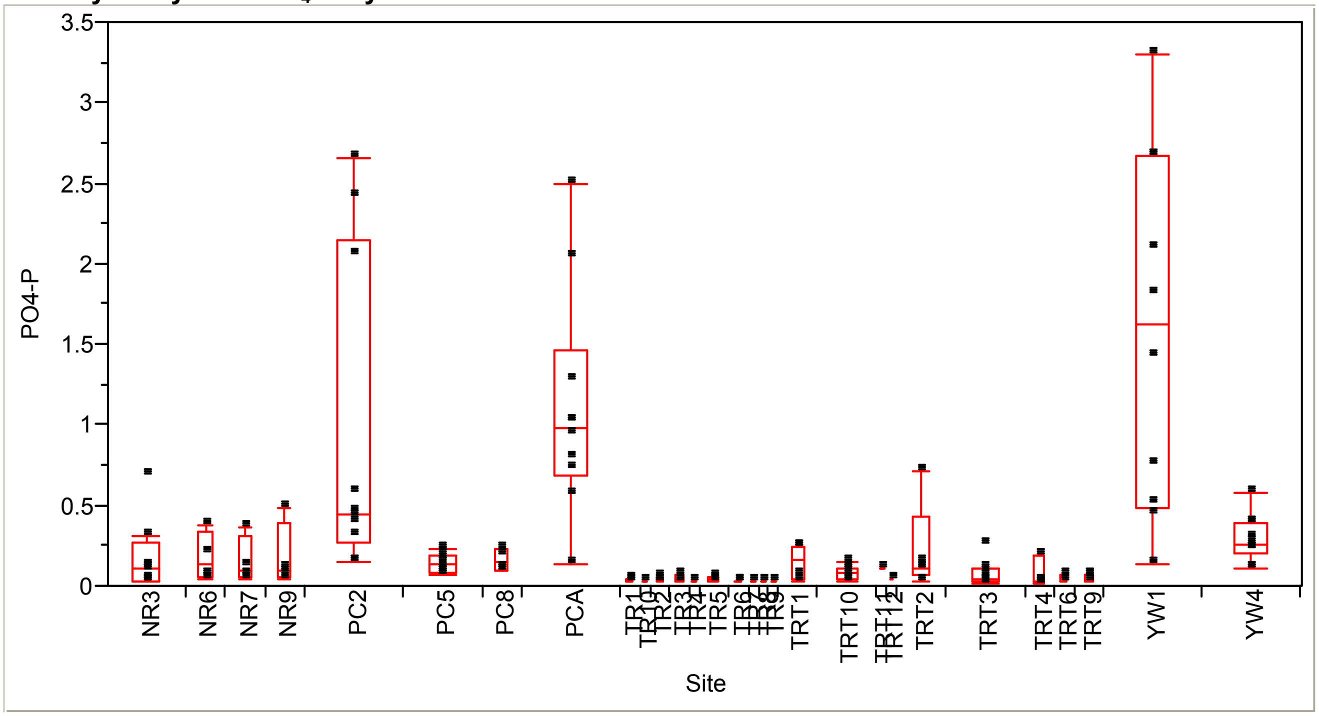
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1373.5	137.350	-0.311
NR6	9	903.5	100.389	-1.638
NR7	10	1070	107.000	-1.476
NR9	10	1385.5	138.550	-0.265
PC2	9	1735.5	192.833	1.719
PC5	10	375	37.500	-4.144
PC8	8	949	118.625	-0.917
PCA	10	2574	257.400	4.293
TR1	11	1552.5	141.136	-0.174
TR10	10	2020.5	202.050	2.169
TR2	11	1595	145.000	-0.018
TR3	11	1583	143.909	-0.062
TR4	9	1436	159.556	0.509
TR5	11	1573.5	143.045	-0.097
TR6	11	1692	153.818	0.334
TR7	11	1742.5	158.409	0.519
TR8	11	1869	169.909	0.983
TR9	11	2076.5	188.773	1.743
TRT1	10	2296	229.600	3.226
TRT10	9	1269	141.000	-0.162
TRT11	10	771.5	77.150	-2.622
TRT12	9	298.5	33.167	-4.081
TRT2	10	701	70.100	-2.892
TRT3	9	2121	235.667	3.276
TRT4	10	1142	114.200	-1.200
TRT6	10	985	98.500	-1.802
TRT9	10	572.5	57.250	-3.386
YW1	10	2467	246.700	3.883
YW4	10	2065	206.500	2.340

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
138.9210	28	<.0001

Oneway Analysis of PO_4-P By Site



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

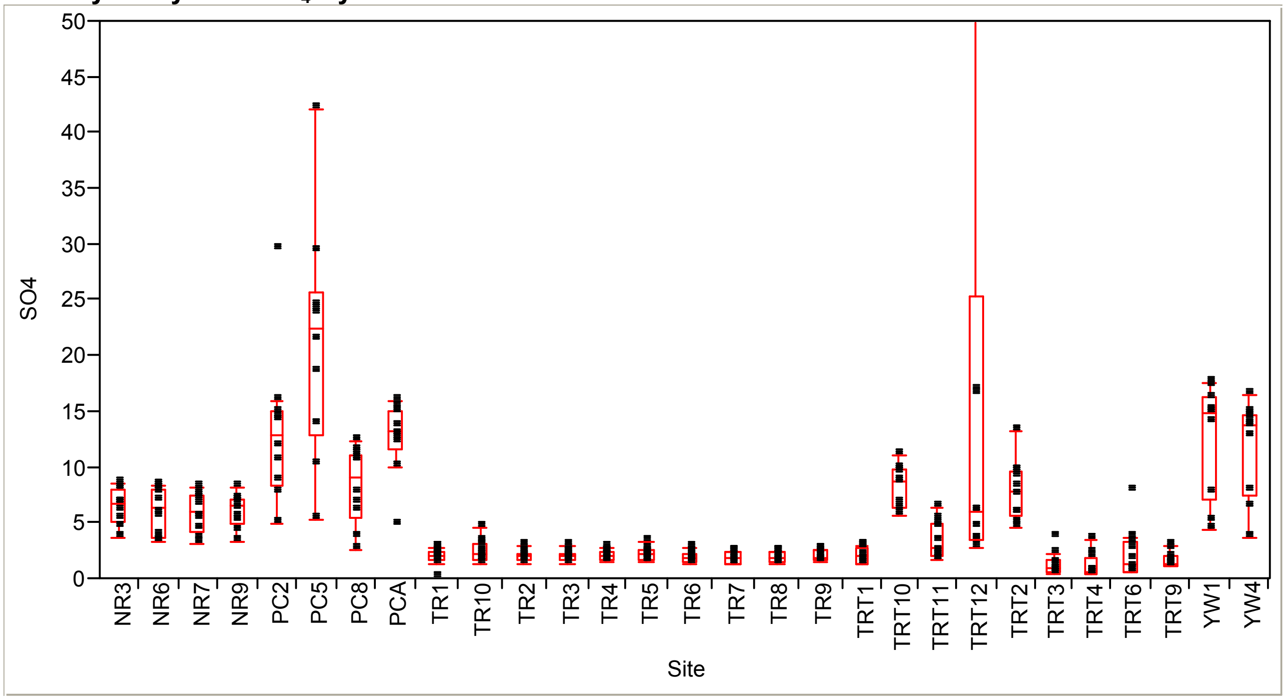
Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	8	409.5	51.188	-0.815
NR6	4	235.5	58.875	-0.116
NR7	4	222.5	55.625	-0.305
NR9	4	225	56.250	-0.269
PC2	10	953	95.300	3.228
PC5	8	494	61.750	0.057
PC8	4	256.5	64.125	0.174
PCA	10	1038.5	103.850	4.034
TR1	2	38	19.000	-1.700
TR10	1	9.5	9.500	-1.462
TR2	2	54.5	27.250	-1.364
TR3	2	46.5	23.250	-1.527
TR4	1	20.5	20.500	-1.147
TR5	3	83	27.667	-1.661
TR6	2	30	15.000	-1.863
TR7	1	9.5	9.500	-1.462
TR8	1	9.5	9.500	-1.462
TR9	1	9.5	9.500	-1.462
TRT1	4	216	54.000	-0.399
TRT10	6	261	43.500	-1.249
TRT11	1	59.5	59.500	-0.029
TRT12	1	28.5	28.500	-0.917
TRT2	5	290	58.000	-0.189
TRT3	8	275.5	34.438	-2.214
TRT4	3	84	28.000	-1.644
TRT6	2	51	25.500	-1.435
TRT9	3	99	33.000	-1.394
YW1	10	1061.5	106.150	4.251
YW4	10	810	81.000	1.880

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
82.2670	28	<.0001

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of SO_4 By Site



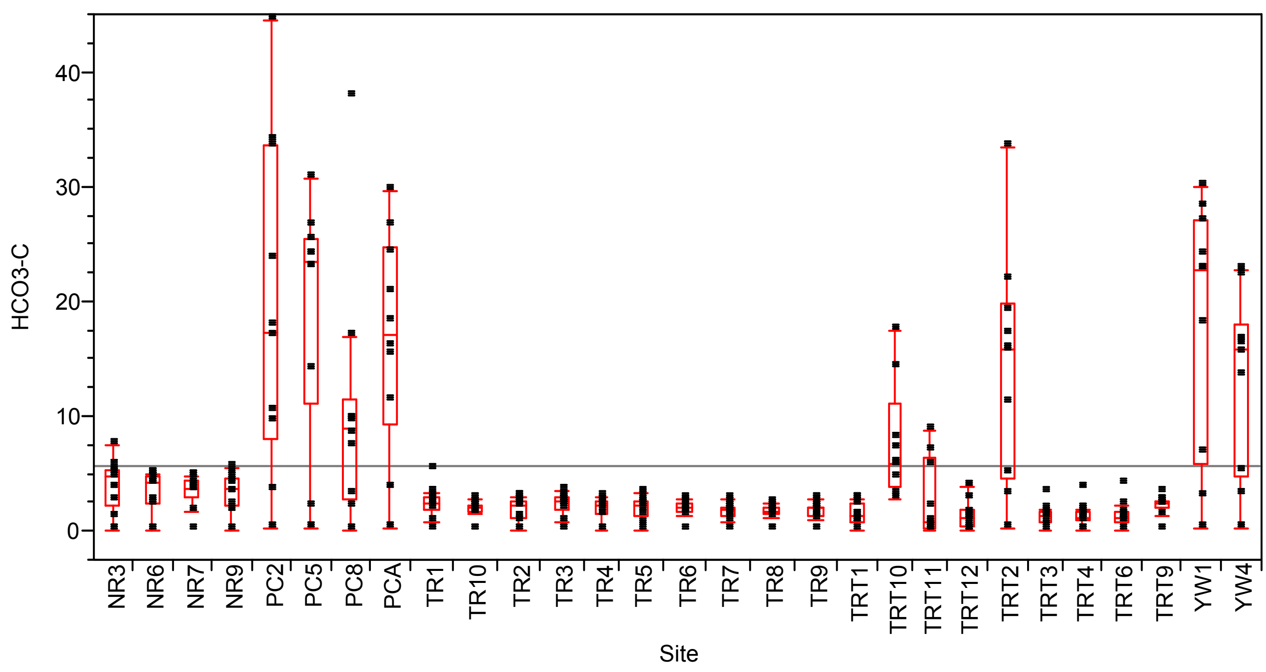
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	2069	206.900	2.193
NR6	10	2025	202.500	2.028
NR7	10	1987.5	198.750	1.887
NR9	10	2021	202.100	2.013
PC2	10	2532	253.200	3.933
PC5	10	2735.5	273.550	4.698
PC8	10	2210.5	221.050	2.725
PCA	10	2572	257.200	4.084
TR1	11	970.5	88.227	-2.378
TR10	11	1176.5	106.955	-1.639
TR2	11	999	90.818	-2.276
TR3	11	999	90.818	-2.276
TR4	9	838.5	93.167	-1.968
TR5	11	1069	97.182	-2.025
TR6	11	932	84.727	-2.517
TR7	11	901.5	81.955	-2.626
TR8	11	966.5	87.864	-2.393
TR9	11	1031	93.727	-2.161
TRT1	10	907.5	90.750	-2.169
TRT10	9	2075	230.556	2.919
TRT11	10	1376	137.600	-0.408
TRT12	10	2226	222.600	2.783
TRT2	10	2208	220.800	2.716
TRT3	9	372.5	41.389	-3.811
TRT4	10	391	39.100	-4.110
TRT6	10	801	80.100	-2.569
TRT9	10	543	54.300	-3.539
YW1	10	2534.5	253.450	3.943
YW4	10	2485.5	248.550	3.759

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
229.4111	28	<.0001

Oneway Analysis of HCO_3-C By Site



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
NR3	10	1809.5	180.950	1.241
NR6	10	1820.5	182.050	1.282
NR7	10	1764.5	176.450	1.071
NR9	10	1707	170.700	0.854
PC2	10	2406	240.600	3.491
PC5	10	2363.5	236.350	3.330
PC8	10	2089	208.900	2.295
PCA	10	2381.5	238.150	3.398
TR1	11	1525	138.636	-0.369
TR10	11	1245.5	113.227	-1.376
TR2	11	1315	119.545	-1.126
TR3	11	1439	130.818	-0.679
TR4	9	1069	118.778	-1.042
TR5	11	1291.5	117.409	-1.210
TR6	11	1190.5	108.227	-1.574
TR7	11	1034.5	94.045	-2.136
TR8	11	1018.5	92.591	-2.194
TR9	11	1095.5	99.591	-1.917
TRT1	10	890.5	89.050	-2.222
TRT10	9	2040	226.667	2.808
TRT11	9	961	106.778	-1.470
TRT12	10	750.5	75.050	-2.750
TRT2	10	2302.5	230.250	3.100
TRT3	9	686	76.222	-2.562
TRT4	10	725	72.500	-2.846
TRT6	10	747.5	74.750	-2.761
TRT9	10	1317.5	131.750	-0.611
YW1	10	2396	239.600	3.453
YW4	10	2278	227.800	3.008

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
138.1374	28	<.0001

APPENDIX D: CORRELATIONS AMONG PARAMETERS

Correlations
(+ or - noted for pos. or neg. signif corrs >0.6500)

Parameters	(all corrs pos.) All Data	Tangi Riv	TRT1	TRT2	TRT3	TRT4	TRT6	TRT9	TRT10	TRT11	TRT12	NR3	NR6	NR7	NR9	PC2	PC5	PC8	PCA	YW1	YW4	(a-)	(a+)	total a
DO-Temp		a-		a-	a-	a-			a-		a-	a-	a-	a-	a-							10	0	**10**
SC-Temp				a+																		0	1	**1**
SC-DO				a-					a-							a-			a-			4	0	**4**
Turb-Temp						a-																1	0	**1**
Turb-DO																						0	0	**0**
Turb-SC						a+																0	1	**1**
FC-Temp										a-												1	0	**1**
FC-DO															a+							0	1	**1**
FC-SC	a+						a+													a-		1	2	**3**
FC-Turb					a+					a-				a+			a+					1	3	**4**
Na-Temp				a+																		0	1	**1**
Na-DO				a-	a+											a-						2	1	**3**
Na-SC				a+					a+	a+						a+			a+			0	5	**5**
Na-Turb			a-										a-	a-	a-		a-			a-		6	0	**6**
Na-FC												a-	a-	a-			a-					4	0	**4**
K-Temp				a+																		0	1	**1**
K-DO																a-						1	0	**1**
K-SC	a+			a+	a+	a+	a+	a+	a+	a+	a+	a+				a+			a+			0	12	**12**
K-Turb		a+	a+			a+														a-		1	3	**4**
K-FC							a+	a+										a+		a-		1	3	**4**
K-Na				a+						a+	a+			a-		a+			a+	a+		1	6	**7**
Mg-Temp					a-																	1	0	**1**
Mg-DO					a+													a+				0	2	**2**
Mg-SC	a+				a+					a+	a+										a-	1	4	**5**
Mg-Turb																						0	0	**0**
Mg-FC																	a-					1	0	**1**
Mg-Na	a+				a+					a+	a+	a+										0	5	**5**
Mg-K						a+				a+	a+											0	3	**3**
Ca-Temp					a-													a-				2	0	**2**
Ca-DO																		a+				0	1	**1**
Ca-SC	a+				a+		a+			a+	a+											0	5	**5**
Ca-Turb							a+	a+												a-		1	2	**3**

Parameters	All Data	Tangi Riv	TRT1	TRT2	TRT3	TRT4	TRT6	TRT9	TRT10	TRT11	TRT12	NR3	NR6	NR7	NR9	PC2	PC5	PC8	PCA	YW1	YW4	(a-)	(a+)	total a
Ca-FC														a-								1	0	**1**
Ca-Na	a+									a+	a+	a+							a+	a+		0	6	**6**
Ca-K				a+		a+	a+			a+	a+							a+	a+	a+		0	8	**8**
Ca-Mg	a+		a+	a+	a+	a+	a+	a+	a+	a+	a+	a+	a+	a+	a+	a+						0	15	**15**
SiO2-Temp																						0	0	**0**
SiO2-DO																						0	0	**0**
SiO2-SC						a-				a+						a+						1	2	**3**
SiO2-Turb						a-						a-	a-	a-						a-		5	0	**5**
SiO2-FC												a-		a-				a-				3	0	**3**
SiO2-Na			a+							a+		a+	a+			a+		a+	a+	a+	a+	0	9	**9**
SiO2-K				a+						a+						a+		a-	a+	a+		1	5	**6**
SiO2-Mg				a+						a+		a+										0	3	**3**
SiO2-Ca				a+						a+		a+			a+				a+	a+		0	6	**6**
F-Temp				a+			a-		a+			a+	a+							a+		1	5	**6**
F-DO				a-							a-	a+			a-							3	1	**4**
F-SC	a+		a+	a+						a+	a+					a+		a+				0	7	**7**
F-Turb					a+															a-		1	1	**2**
F-FC					a+								a-		a-					a-		3	1	**4**
F-Na	a+			a+						a+	a+					a+	a+	a+	a+	a+	a+	0	10	**10**
F-K				a+						a+	a+					a+			a+	a+		0	6	**6**
F-Mg											a+											0	1	**1**
F-Ca	a+										a+								a+	a+	a-	1	4	**5**
F-SiO2										a+						a+			a+	a+	a+	0	5	**5**
Cl-Temp				a+											a+							0	2	**2**
Cl-DO				a-															a-			2	0	**2**
Cl-SC	a+			a+	a+			a+			a+					a+			a+			0	7	**7**
Cl-Turb					a+			a+				a-	a-					a-				3	2	**5**
Cl-FC					a+							a-	a-				a-	a-				4	1	**5**
Cl-Na	a+			a+		a+					a+	a+	a+	a+	a+	a+	a+		a+	a+	a+	0	13	**13**
Cl-K				a+	a+						a+		a-	a-		a+			a+	a+		2	6	**8**
Cl-Mg	a+								a+		a+											0	3	**3**
Cl-Ca					a+			a+			a+	a+	a+							a+		0	6	**6**
Cl-SiO2												a+	a+	a+		a+				a+		0	5	**5**
Cl-F	a+			a+							a+		a+			a+	a+			a+	a+	0	8	**8**
SO4-Temp																	a+					0	1	**1**
SO4-DO															a-							1	0	**1**
SO4-SC	a+				a+	a+	a+	a+			a+	a-				a+			a+			1	8	**9**
SO4-Turb		a+						a+										a-				1	2	**3**

Parameters	All Data	Tangi Riv	TRT1	TRT2	TRT3	TRT4	TRT6	TRT9	TRT10	TRT11	TRT12	NR3	NR6	NR7	NR9	PC2	PC5	PC8	PCA	YW1	YW4	(a-)	(a+)	total a
SO4-FC						a+	a+						a-	a-	a-							3	2	**5**
SO4-Na	a+									a+	a+		a-			a+			a+			1	5	**6**
SO4-K	a+	a+	a+		a+	a+	a+	a+		a+	a+	a-				a+				a+		1	11	**12**
SO4-Mg	a+				a+						a+		a+				a+					0	5	**5**
SO4-Ca	a+				a+						a+		a+	a+					a+	a+		0	7	**7**
SO4-SiO2						a-				a+			a+			a+						1	3	**4**
SO4-F	a+									a+	a+		a+	a+		a+				a+		0	7	**7**
SO4-Cl	a+				a+	a+		a+			a+		a+	a+	a+	a+	a+			a+	a+	0	12	**12**
HCO3-Temp				a+											a+							0	2	**2**
HCO3-DO				a-											a-							2	0	**2**
HCO3-SC				a+				a-	a+	a+						a+						1	4	**5**
HCO3-Turb								a-				a-		a-	a-					a-		5	0	**5**
HCO3-FC												a-	a-	a-	a-					a-		5	0	**5**
HCO3-Na	a+			a+					a+	a+		a+	a+	a+	a+	a+		a+	a+	a+	a+	0	13	**13**
HCO3-K								a-	a+	a+			a-	a-		a+			a+	a+		3	5	**8**
HCO3-Mg																				a+		0	1	**1**
HCO3-Ca													a+						a+	a+	a+	0	4	**4**
HCO3-SiO2			a-							a+		a+	a+	a+		a+		a+	a+	a+	a+	1	9	**10**
HCO3-F				a+						a+			a+			a+				a+	a+	0	6	**6**
HCO3-Cl				a+								a+	a+	a+	a+	a+				a+		0	7	**7**
HCO3-SO4								a-		a+			a+		a+	a+			a+			1	5	**6**
Inorg N-Temp				a+																a+	a+	0	3	**3**
Inorg N-DO				a-								a-				a-						3	0	**3**
Inorg N-SC				a+		a+		a+								a+						0	4	**4**
Inorg N-Turb					a+																	0	1	**1**
Inorg N-FC																						0	0	**0**
Inorg N-Na				a+															a+	a+	a+	0	4	**4**
Inorg N-K				a+				a+								a+	a+		a+	a+		0	6	**6**
Inorg N-Mg																						0	0	**0**
Inorg N-Ca																			a+		a-	1	1	**2**
Inorg N-SiO2						a-										a+			a+		a+	1	3	**4**
Inorg N-F				a+												a+			a+	a+	a+	0	5	**5**
Inorg N-Cl				a+		a+										a+				a+	a+	0	5	**5**
Inorg N-SO4						a+										a+				a+	a+	0	4	**4**
Inorg N-HCO3				a+											a+	a+			a+		a+	0	5	**5**

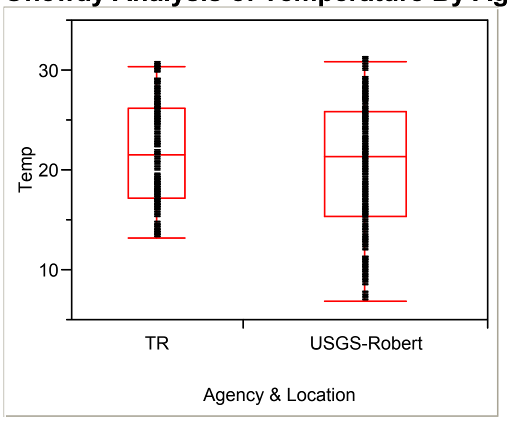
total a+	22	3	5	32	21	14	10	13	8	29	27	15	18	10	11	36	8	9	29	33	17
total a-	0	1	2	7	3	6	1	4	2	2	2	11	12	12	9	4	4	6	2	10	3
Total a	**22**	**4**	**7**	**39**	**24**	**20**	**11**	**17**	**10**	**31**	**29**	**26**	**30**	**22**	**20**	**40**	**12**	**15**	**31**	**43**	**20**

APPENDIX E: ONE-WAY ANAYLSES, CURRENT VS. USGS DATA

Tangiaphoa River:

TR 2-10 vs. Robert (USGS data)

Oneway Analysis of Temperature By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	12156.5	125.325	1.384
USGS-Robert	138	15573.5	112.851	-1.384

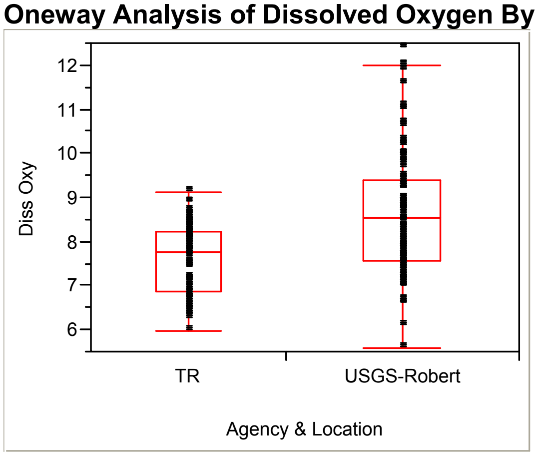
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12156.5	1.38401	0.1664

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.9182	1	0.1661

Oneway Analysis of Dissolved Oxygen By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	7617.5	78.531	-6.028
USGS-Robert	114	14748.5	129.373	6.028

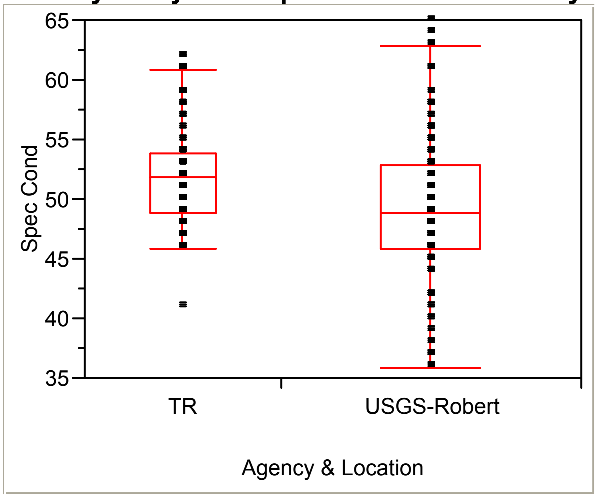
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
7617.5	-6.02793	0.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
36.3496	1	<.0001

Oneway Analysis of Specific Conductance By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	14368	148.124	4.615
USGS-Robert	147	15522	105.592	-4.615

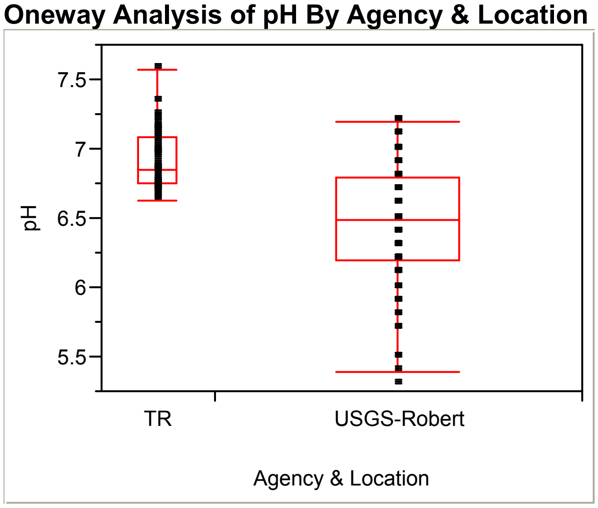
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
14368	4.61548	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
21.3112	1	<.0001

Oneway Analysis of pH By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	45	6269	139.311	6.125
USGS-Robert	145	11876	81.903	-6.125

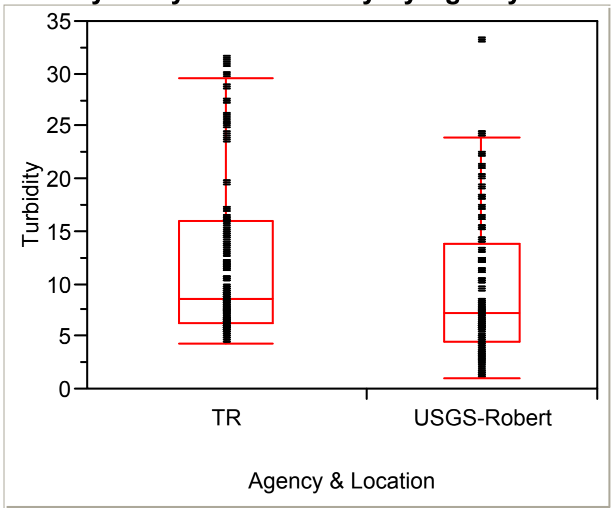
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
6269	6.12505	0.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
37.5353	1	<.0001

Oneway Analysis of Turbidity By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	9481.5	97.7474	2.667
USGS-Robert	79	6094.5	77.1456	-2.667

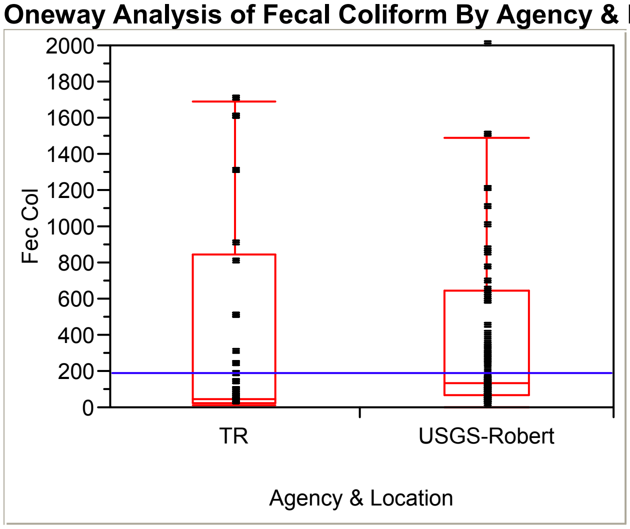
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
6094.5	-2.66666	0.0077

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.1190	1	0.0076

Oneway Analysis of Fecal Coliform By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	8498	87.608	-2.559
USGS-Robert	98	10612	108.286	2.559

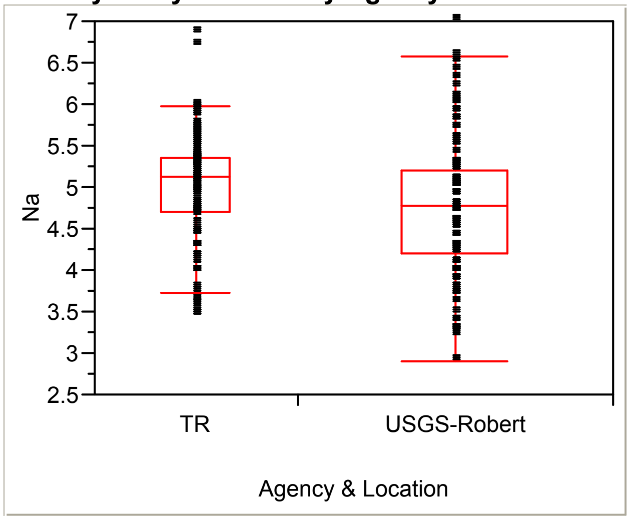
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
8498	-2.55921	0.0105

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.5561	1	0.0105

Oneway Analysis of Na By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	94	12869.5	136.910	3.044
USGS-Robert	145	15810.5	109.038	-3.044

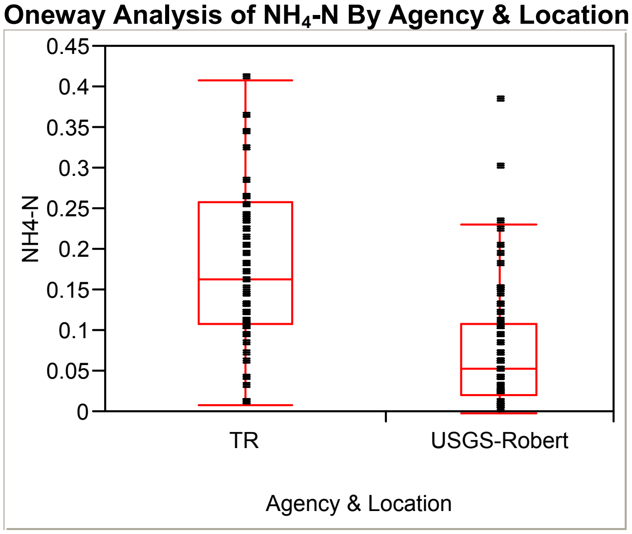
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12869.5	3.04431	0.0023

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
9.2737	1	0.0023

Oneway Analysis of NH_4-N By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	92	9888	107.478	7.171
USGS-Robert	74	3973	53.689	-7.171

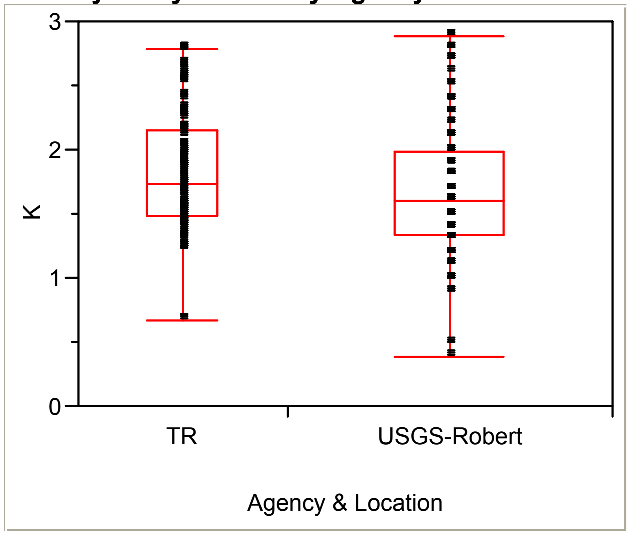
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
3973	-7.17083	0.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
51.4441	1	<.0001

Oneway Analysis of K By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	94	12701.5	135.122	2.724
USGS-Robert	145	15978.5	110.197	-2.724

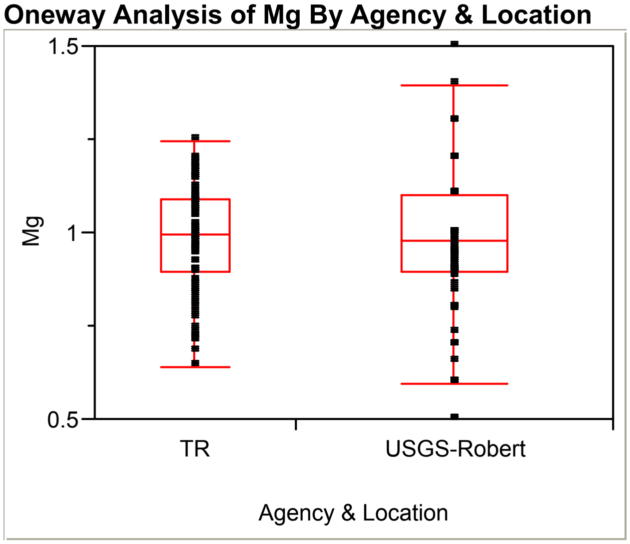
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12701.5	2.72379	0.0065

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.4243	1	0.0064

Oneway Analysis of Mg By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	94	12190	129.681	1.548
USGS-Robert	147	16971	115.449	-1.548

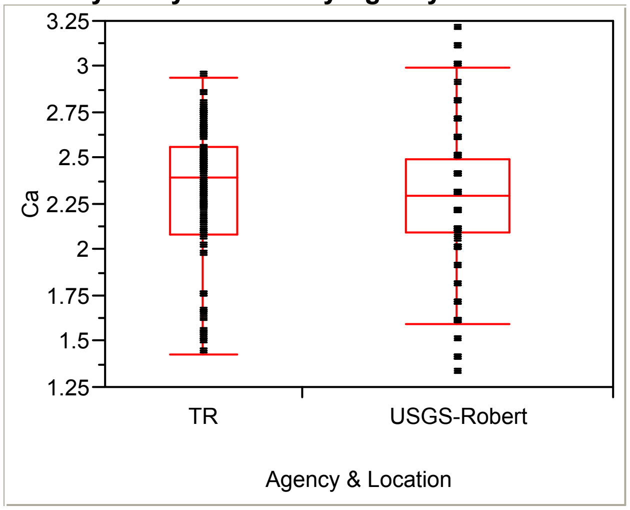
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12190	1.54812	0.1216

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.3996	1	0.1214

Oneway Analysis of Ca By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	94	11684.5	124.303	0.588
USGS-Robert	147	17476.5	118.888	-0.588

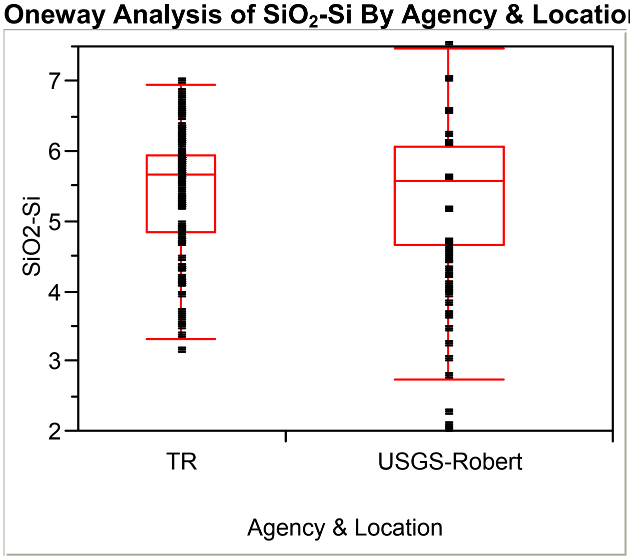
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
11684.5	0.58781	0.5567

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.3466	1	0.5560

Oneway Analysis of SiO_2-Si By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	92	11656.5	126.701	1.381
USGS-Robert	145	16546.5	114.114	-1.381

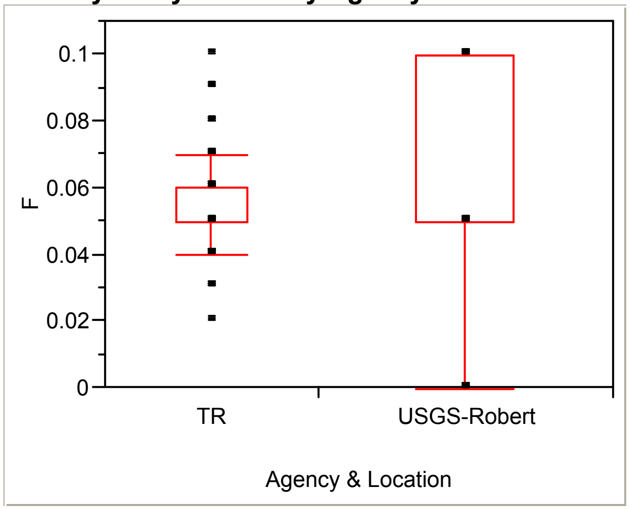
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
11656.5	1.38096	0.1673

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.9097	1	0.1670

Oneway Analysis of F By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	10698.5	110.294	-0.948
USGS-Robert	132	15636.5	118.458	0.948

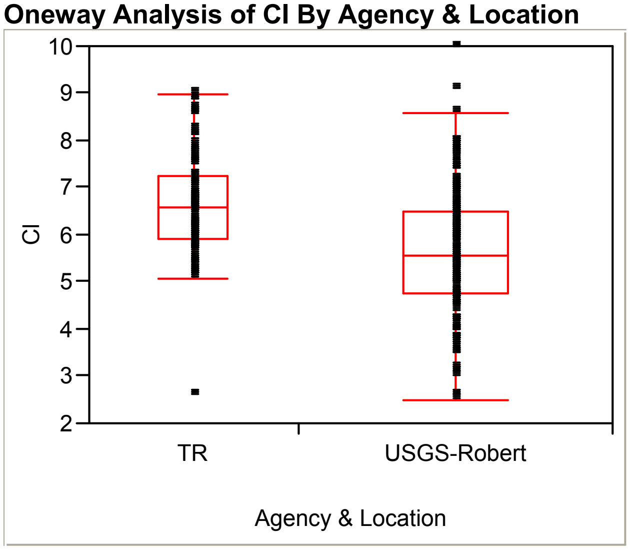
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
10698.5	-0.94847	0.3429

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.9016	1	0.3424

Oneway Analysis of Cl By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	14990	154.536	6.004
USGS-Robert	145	14413	99.400	-6.004

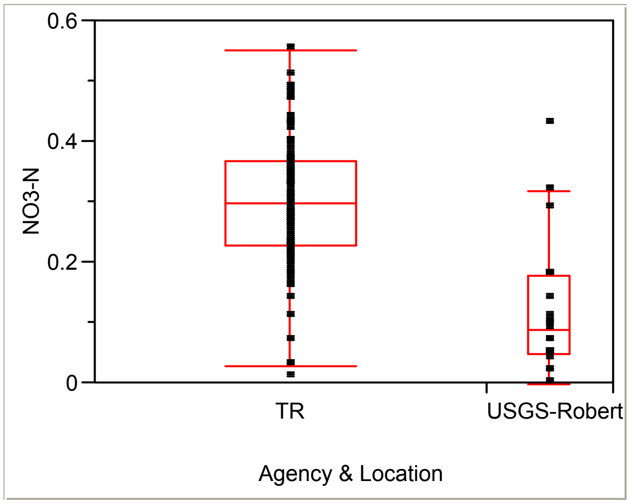
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
14990	6.00446	0.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
36.0648	1	<.0001

Oneway Analysis of NO_3-N By Agency & Location



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
TR	0.01	0.178	0.23	0.3	0.37	0.482	1.32
USGS-Robert	0	0.02	0.05	0.09	0.18	0.314	5

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	7357	75.8454	6.122
USGS-Robert	31	899	29.0000	-6.122

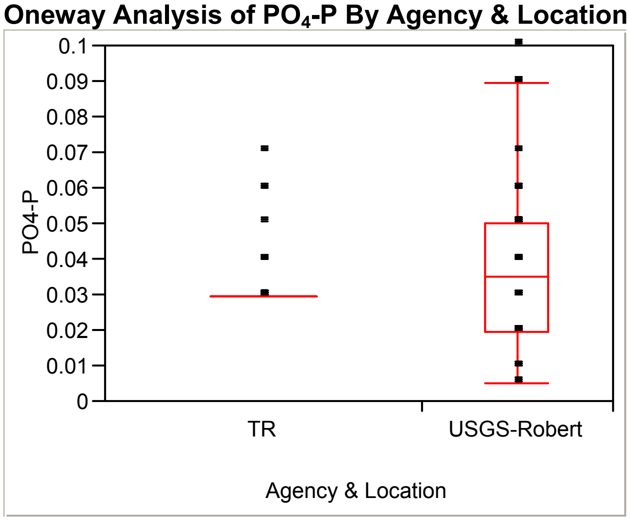
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
899	-6.12180	0.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
37.5105	1	<.0001

Oneway Analysis of PO_4-P By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	7263	74.8763	-1.295
USGS-Robert	58	4827	83.2241	1.295

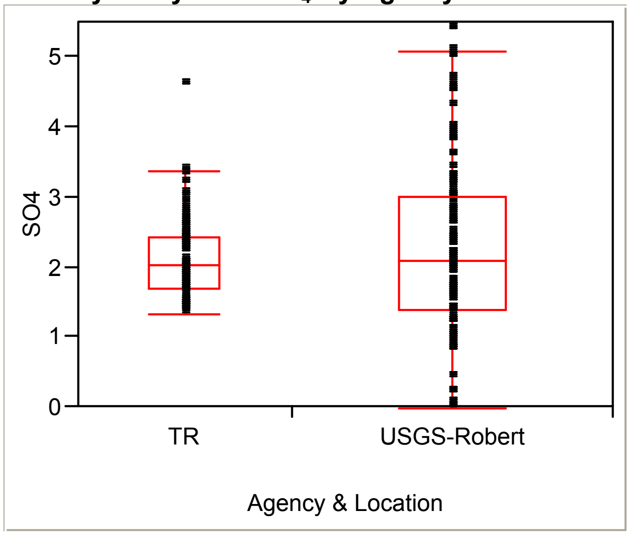
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
4827	1.29546	0.1952

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.6838	1	0.1944

Oneway Analysis of SO_4 By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	11570.5	119.284	-0.402
USGS-Robert	145	17832.5	122.983	0.402

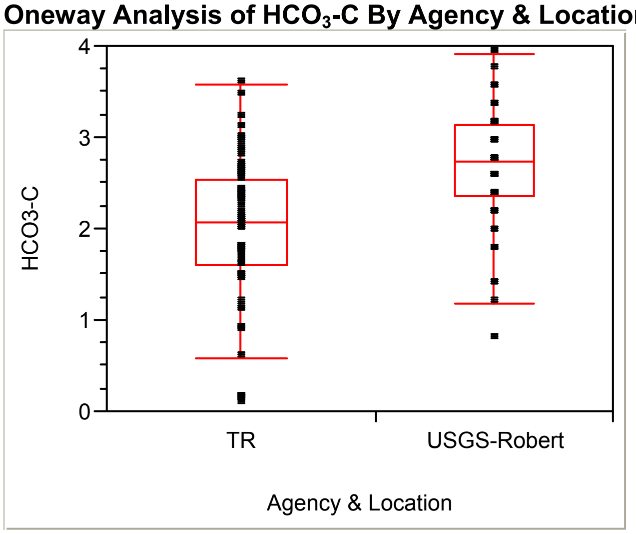
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
11570.5	-0.40201	0.6877

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1624	1	0.6870

Oneway Analysis of HCO_3-C By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR	97	6563	67.660	-6.445
USGS-Robert	84	9908	117.952	6.445

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
9908	6.44494	0.0000

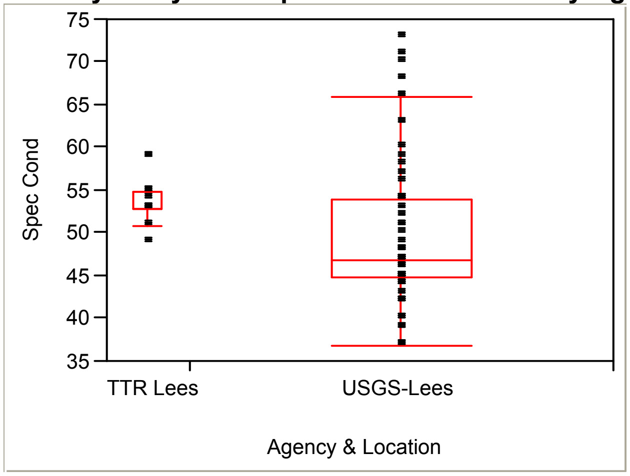
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
41.5556	1	<.0001

Tangipahoa River @ Lee's Landing

TR1 (Lees Landing) vs. USGS Lees Landing Data (1963-1964)

Oneway Analysis of Specific Conductance By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	514	46.7273	2.499
USGS-Lees	55	1697	30.8545	-2.499

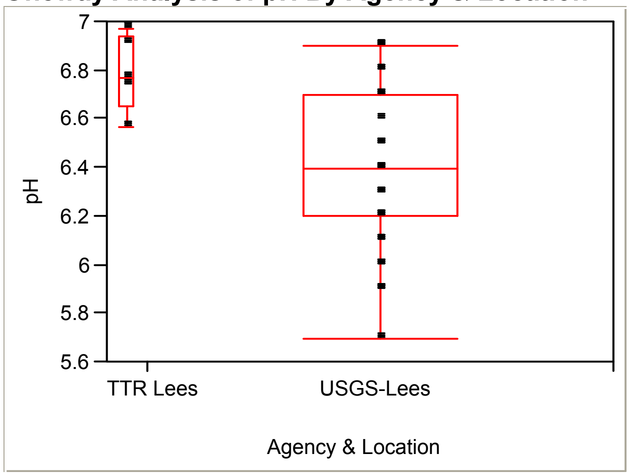
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
514	2.49944	0.0124

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.2904	1	0.0121

Oneway Analysis of pH By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	5	257	51.4000	2.793
USGS-Lees	55	1573	28.6000	-2.793

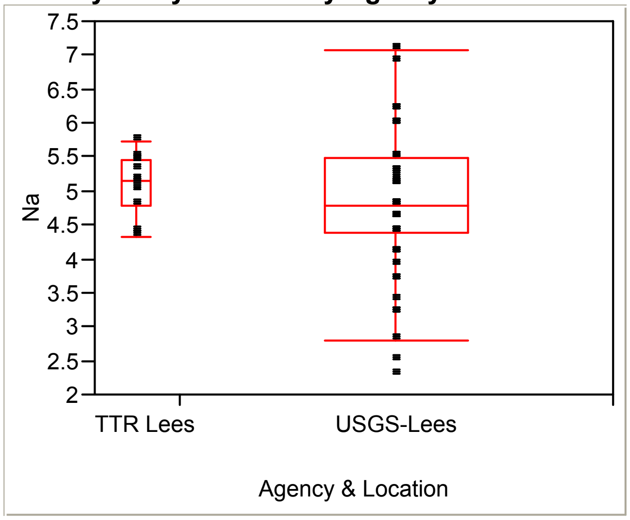
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
257	2.79321	0.0052

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.8772	1	0.0050

Oneway Analysis of Na By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	438	39.8182	1.190
USGS-Lees	55	1773	32.2364	-1.190

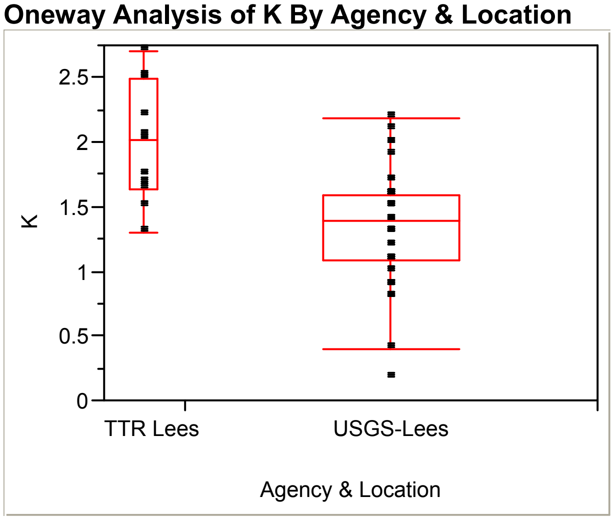
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
438	1.19025	0.2339

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.4373	1	0.2306

Oneway Analysis of K By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	595.5	54.1364	3.921
USGS-Lees	55	1615.5	29.3727	-3.921

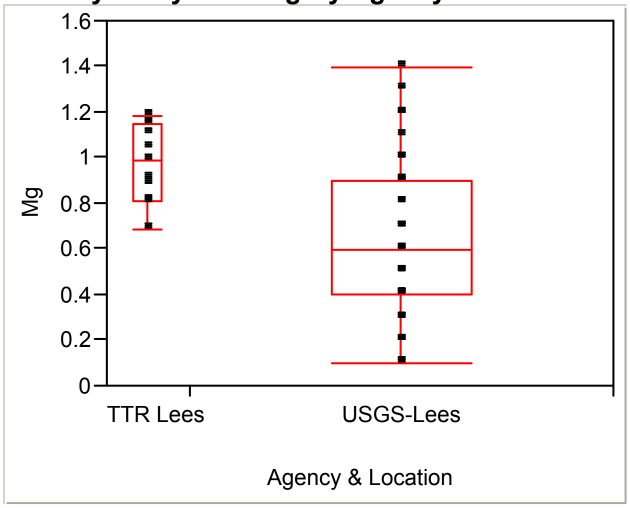
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
595.5	3.92143	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
15.4455	1	<.0001

Oneway Analysis of Mg By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	544	49.4545	3.019
USGS-Lees	55	1667	30.3091	-3.019

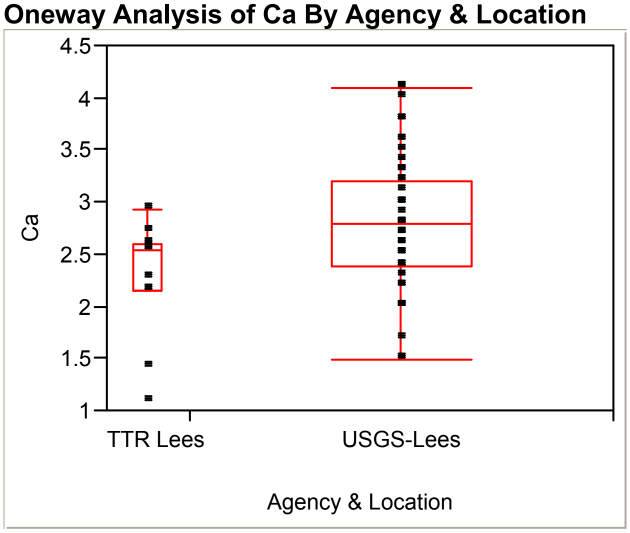
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
544	3.01935	0.0025

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
9.1686	1	0.0025

Oneway Analysis of Ca By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	233	21.1818	-2.326
USGS-Lees	55	1978	35.9636	2.326

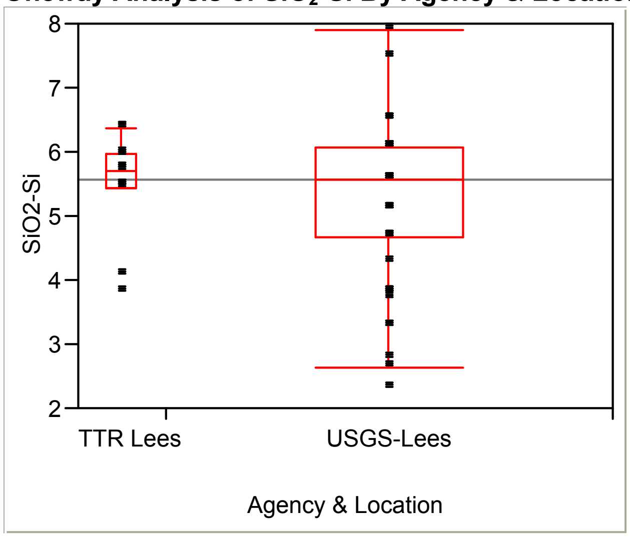
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
233	-2.32633	0.0200

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.4520	1	0.0195

Oneway Analysis of SiO_2-Si By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	378	34.3636	0.156
USGS-Lees	55	1833	33.3273	-0.156

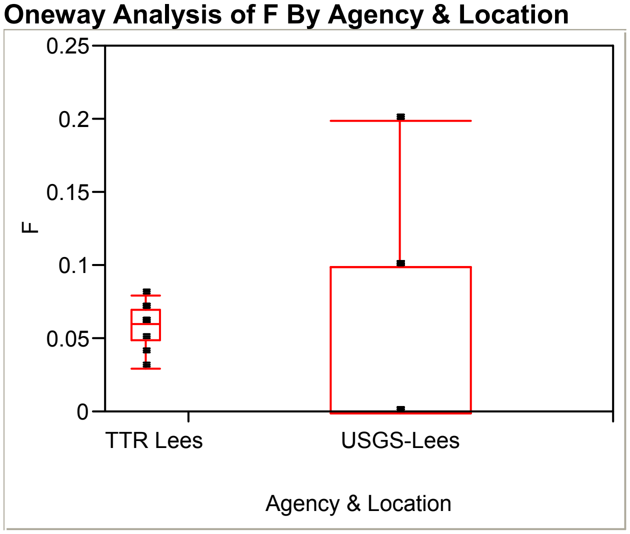
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
378	0.15594	0.8761

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0271	1	0.8693

Oneway Analysis of F By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	330	30.0000	-0.693
USGS-Lees	55	1881	34.2000	0.693

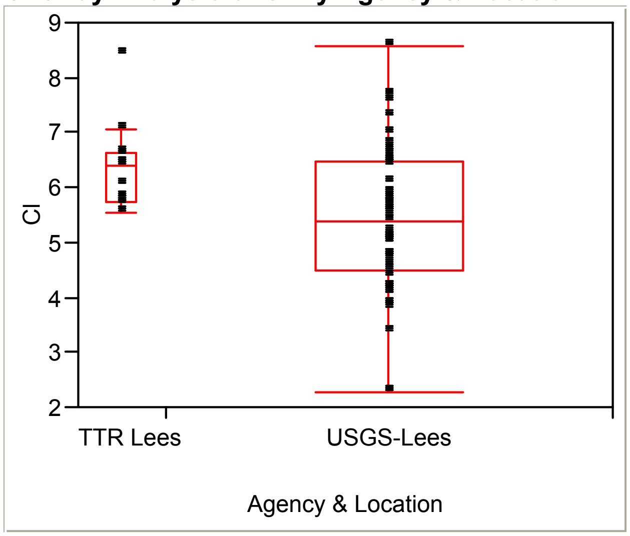
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
330	-0.69288	0.4884

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.4928	1	0.4827

Oneway Analysis of Cl By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	497	45.1818	2.203
USGS-Lees	55	1714	31.1636	-2.203

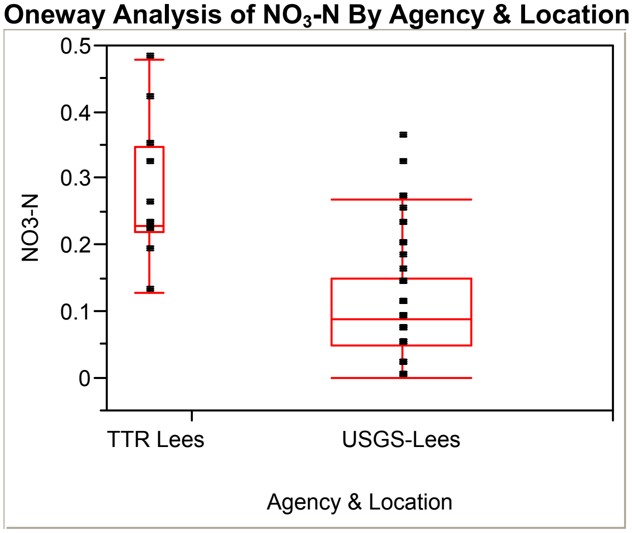
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
497	2.20347	0.0276

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.8933	1	0.0270

Oneway Analysis of NO_3-N By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	583.5	53.0455	4.028
USGS-Lees	53	1496.5	28.2358	-4.028

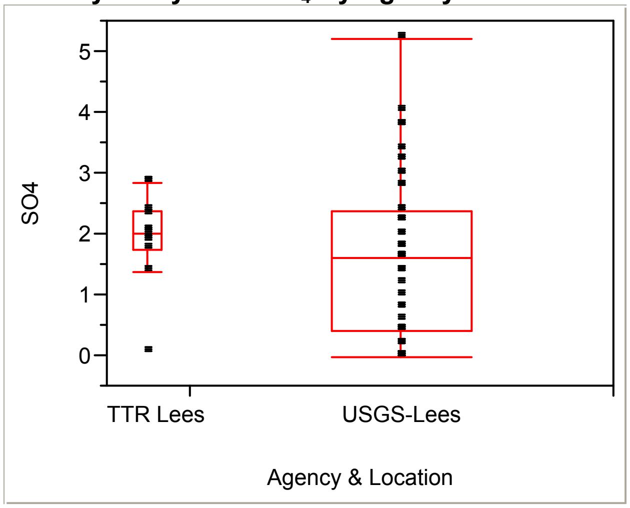
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
583.5	4.02761	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
16.2937	1	<.0001

Oneway Analysis of SO_4 By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	442	40.1818	1.259
USGS-Lees	55	1769	32.1636	-1.259

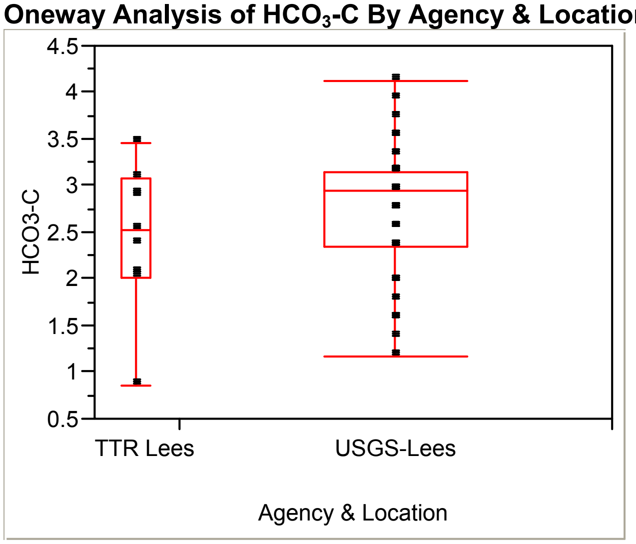
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
442	1.25863	0.2082

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.6059	1	0.2051

Oneway Analysis of HCO_3-C By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TTR Lees	11	306	27.8182	-1.073
USGS-Lees	55	1905	34.6364	1.073

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
306	-1.07322	0.2832

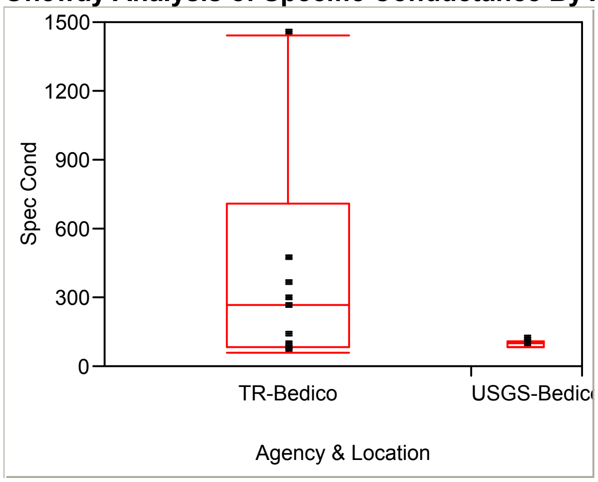
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.1705	1	0.2793

Bedico Creek

Bedico Creek- TRT12 vs. USGS data (only 3 values collected 1965, 1969, 1974)

Oneway Analysis of Specific Conductance By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	76.5	7.65000	1.016
USGS-Bedico	3	14.5	4.83333	-1.016

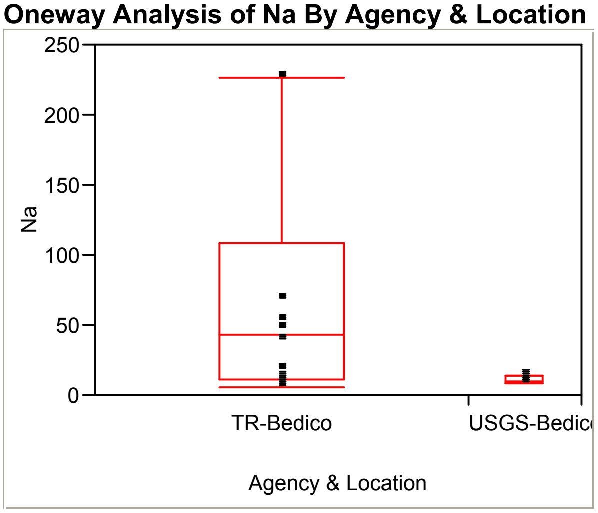
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
14.5	-1.01558	0.3098

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.2105	1	0.2712

Oneway Analysis of Na By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	79	7.90000	1.437
USGS-Bedico	3	12	4.00000	-1.437

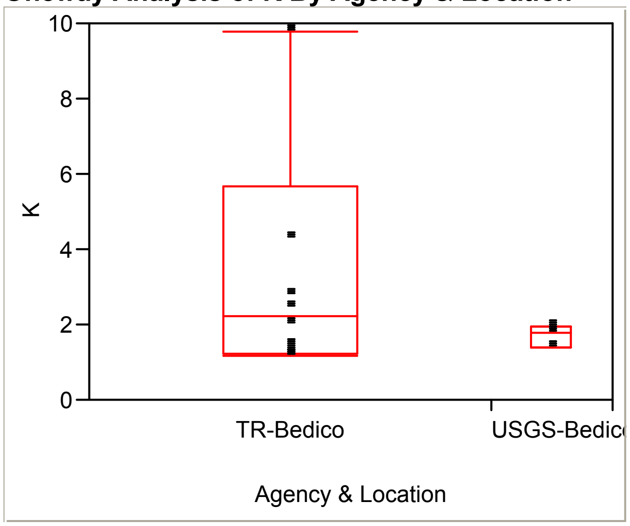
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12	-1.43676	0.1508

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.3143	1	0.1282

Oneway Analysis of K By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	74	7.40000	0.592
USGS-Bedico	3	17	5.66667	-0.592

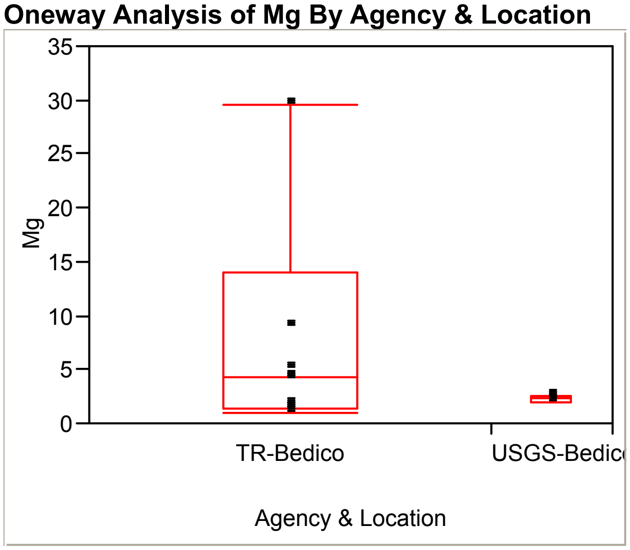
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
17	-0.59161	0.5541

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.4571	1	0.4990

Oneway Analysis of Mg By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	73	7.30000	0.423
USGS-Bedico	3	18	6.00000	-0.423

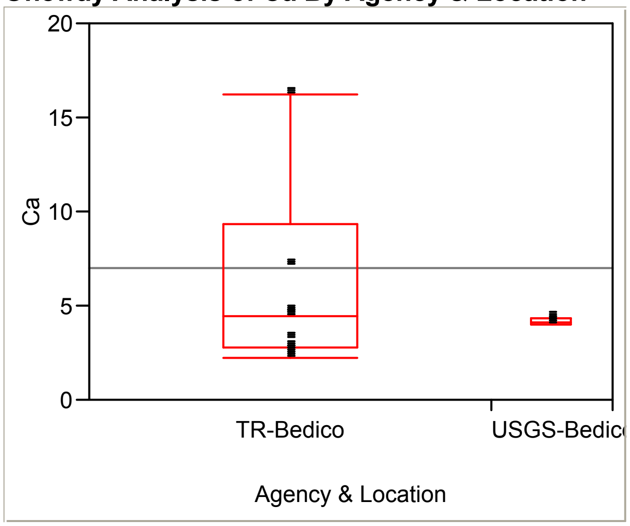
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
18	-0.42316	0.6722

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.2579	1	0.6116

Oneway Analysis of Ca By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	73	7.30000	0.423
USGS-Bedico	3	18	6.00000	-0.423

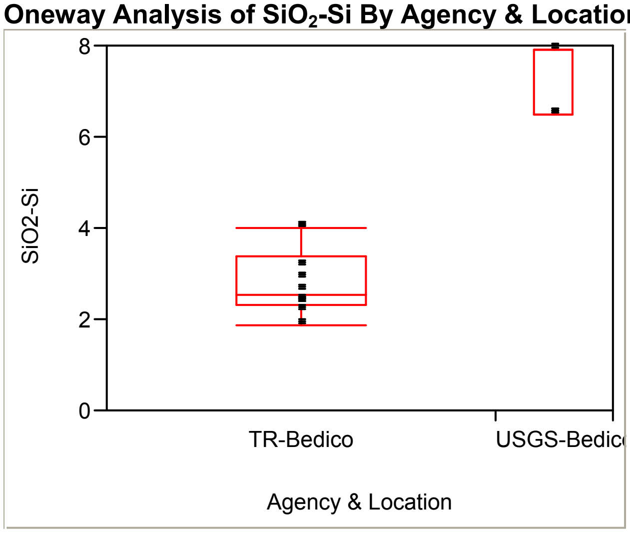
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
18	-0.42258	0.6726

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.2571	1	0.6121

Oneway Analysis of SiO_2-Si By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	55	5.5000	-2.454
USGS-Bedico	3	36	12.0000	2.454

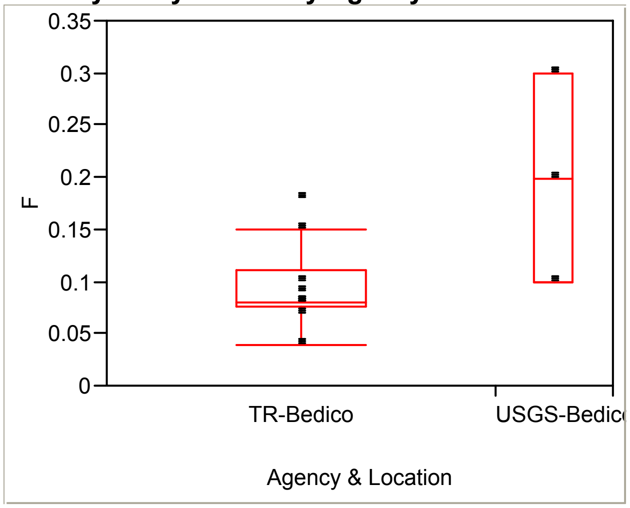
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
36	2.45432	0.0141

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.4463	1	0.0111

Oneway Analysis of F By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	57.5	5.7500	-2.060
USGS-Bedico	3	33.5	11.1667	2.060

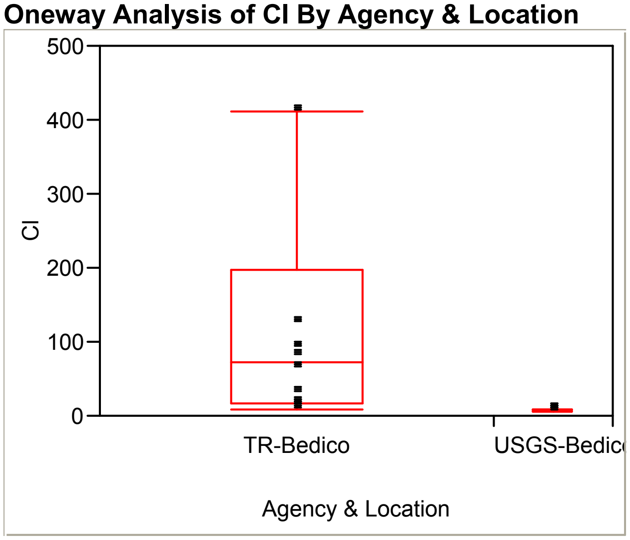
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
33.5	2.05973	0.0394

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.6034	1	0.0319

Oneway Analysis of Cl By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	85	8.50000	2.451
USGS-Bedico	3	6	2.00000	-2.451

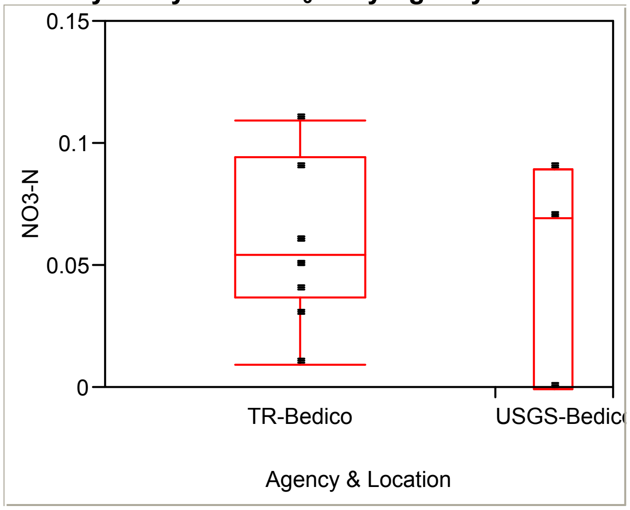
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
6	-2.45095	0.0142

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.4286	1	0.0112

Oneway Analysis of NO_3-N By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	70.5	7.05000	-0.000
USGS-Bedico	3	20.5	6.83333	-0.000

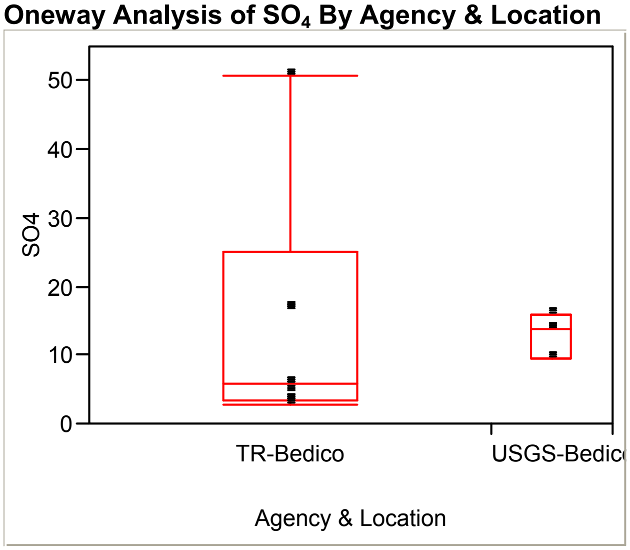
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
20.5	-0.00000	1.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0072	1	0.9324

Oneway Analysis of SO_4 By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	67	6.70000	-0.423
USGS-Bedico	3	24	8.00000	0.423

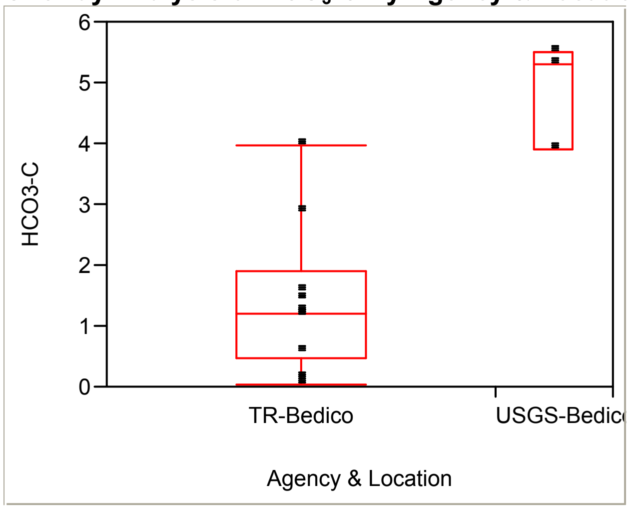
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
24	0.42258	0.6726

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.2571	1	0.6121

Oneway Analysis of HCO_3-C By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Bedico	10	56	5.6000	-2.285
USGS-Bedico	3	35	11.6667	2.285

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
35	2.28506	0.0223

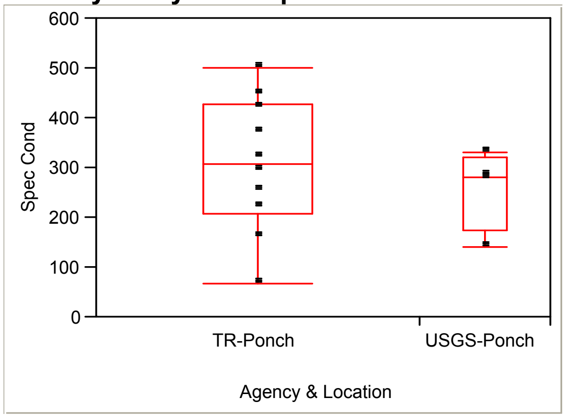
1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.6154	1	0.0178

Ponchatoula Creek

Ponchatoula Creek at Wadesborough- TW data vs USGS data (1962-1963, 4 samples)

Oneway Analysis of Specific Conductance By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	80	8.00000	0.636
USGS-Ponch	4	25	6.25000	-0.636

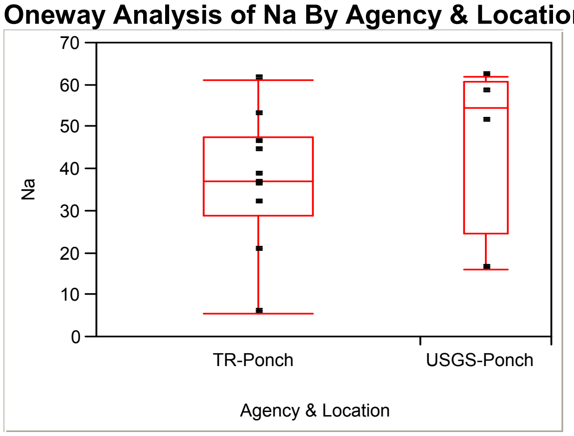
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
25	-0.63640	0.5245

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.5000	1	0.4795

Oneway Analysis of Na By Agency & Location



Quantiles

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	67	6.70000	-1.061
USGS-Ponch	4	38	9.50000	1.061

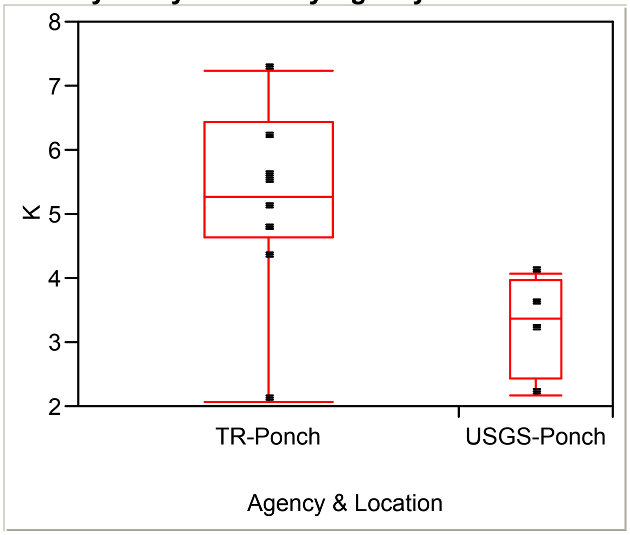
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
38	1.06066	0.2888

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.2800	1	0.2579

Oneway Analysis of K By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	91	9.10000	2.192
USGS-Ponch	4	14	3.50000	-2.192

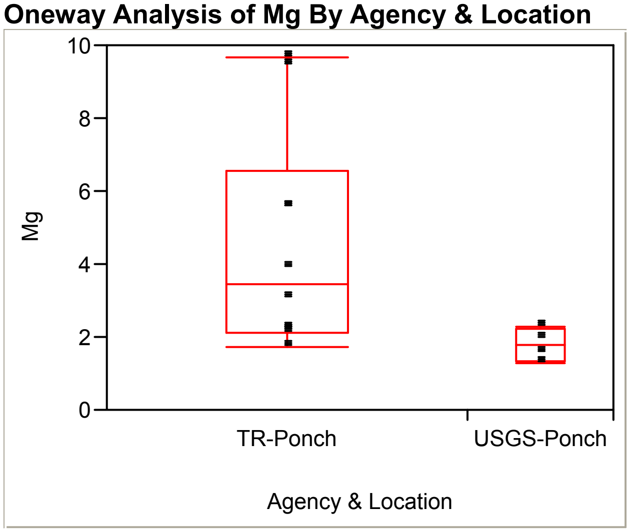
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
14	-2.19203	0.0284

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.1200	1	0.0237

Oneway Analysis of Mg By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	90	9.00000	2.053
USGS-Ponch	4	15	3.75000	-2.053

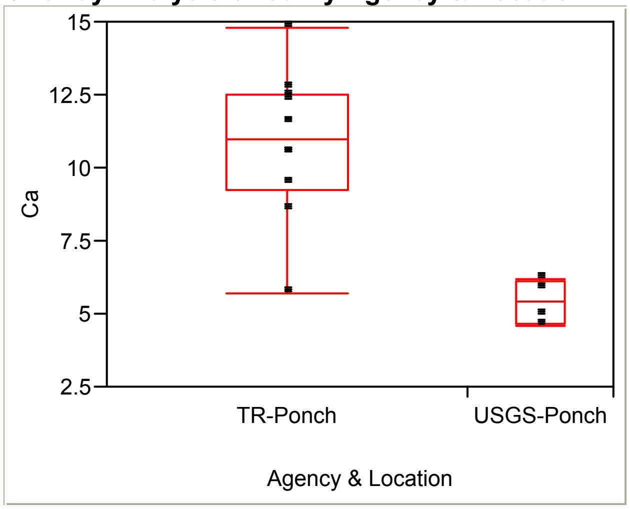
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
15	-2.05287	0.0401

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.5099	1	0.0337

Oneway Analysis of Ca By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	93	9.30000	2.478
USGS-Ponch	4	12	3.00000	-2.478

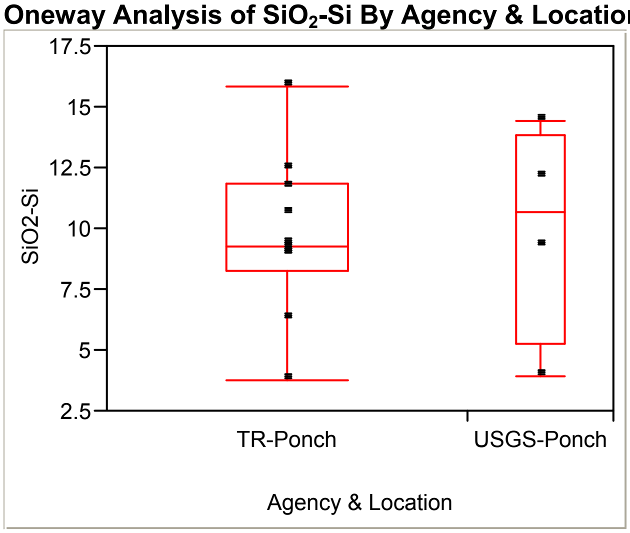
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
12	-2.47760	0.0132

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.4943	1	0.0108

Oneway Analysis of SiO_2-Si By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	72	7.20000	-0.354
USGS-Ponch	4	33	8.25000	0.354

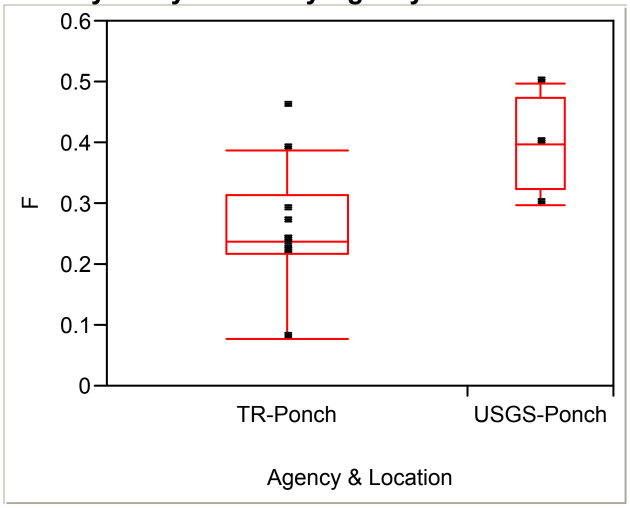
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
33	0.35355	0.7237

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1800	1	0.6714

Oneway Analysis of F By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	59	5.9000	-2.199
USGS-Ponch	4	46	11.5000	2.199

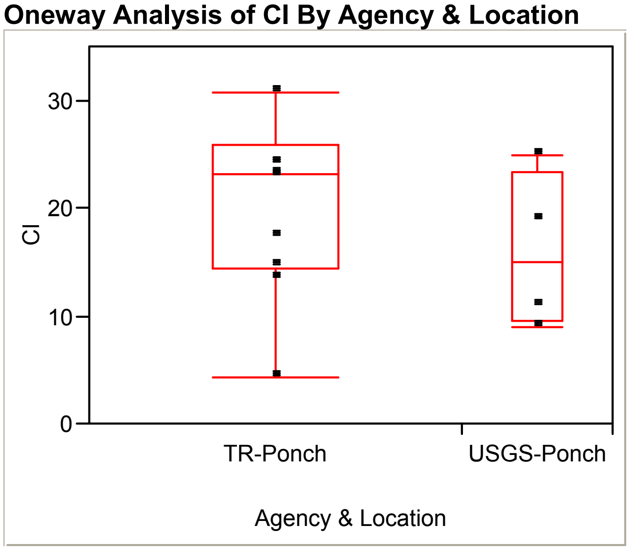
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
46	2.19929	0.0279

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.1540	1	0.0232

Oneway Analysis of Cl By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	81	8.10000	0.778
USGS-Ponch	4	24	6.00000	-0.778

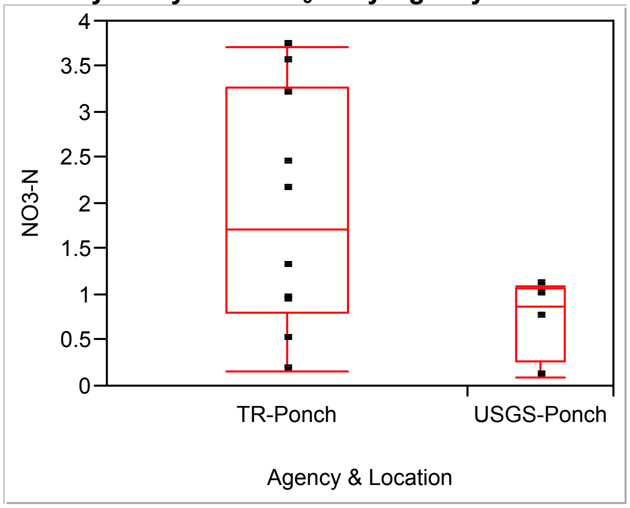
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
24	-0.77782	0.4367

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.7200	1	0.3961

Oneway Analysis of NO_3-N By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	85	8.50000	1.344
USGS-Ponch	4	20	5.00000	-1.344

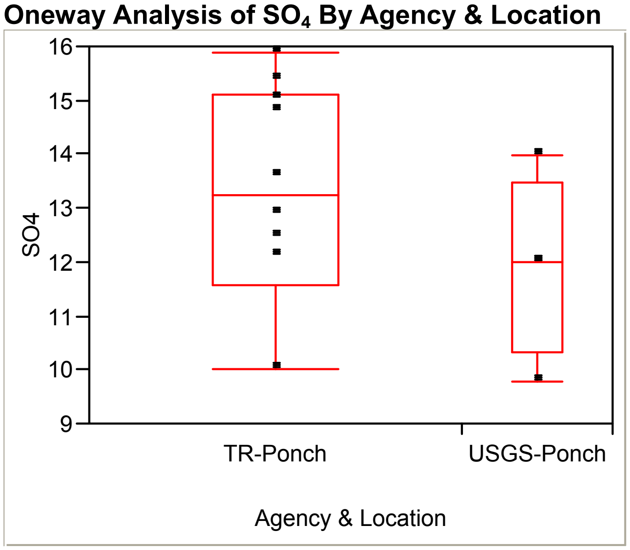
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
20	-1.34350	0.1791

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.0000	1	0.1573

Oneway Analysis of SO_4 By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	84	8.40000	1.203
USGS-Ponch	4	21	5.25000	-1.203

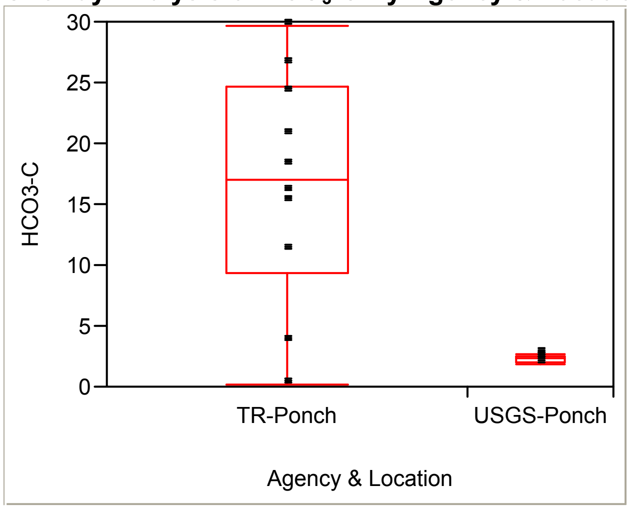
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
21	-1.20340	0.2288

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.6236	1	0.2026

Oneway Analysis of HCO_3-C By Agency & Location



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
TR-Ponch	10	91	9.10000	2.194
USGS-Ponch	4	14	3.50000	-2.194

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
14	-2.19444	0.0282

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.1313	1	0.0235

Vita

Andrea Bourgeois-Calvin is a native of New Orleans, Louisiana where she currently resides with her husband, and fellow environmental scientist, John Calvin. She holds a Bachelor of Science degree in Biological Sciences from Loyola University New Orleans and a Master of Science degree in Biological Sciences from the University of New Orleans. She has worked for the past nine years coordinating water quality programs with the Lake Pontchartrain Basin Foundation, an environmental non-profit organization.