Nolan Creek Data Report

May 2014

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The preparation of this report was prepared in cooperation with, and financed through, grants from the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency.

Introduction

Texas Stream Team is a citizen science water quality monitoring program. Citizen scientists collect surface water quality data that may be used in the decision-making process to promote and protect a healthy and safe environment for people and aquatic inhabitants. Citizen scientist water quality monitoring occurs at predetermined monitoring sites, at roughly the same time of day each month. Citizen scientist water quality monitoring data provides a valuable resource of information by supplementing professional data collection efforts where resources are limited. The data may be used by professionals to identify water quality trends, target additional data collection needs, identify potential pollution events and sources of pollution, and to test the effectiveness of water quality management measures.

Texas Stream Team citizen scientists' data are not used by the state to assess whether water bodies are meeting the designated surface water quality standards. Texas Stream Team citizen scientists use different methods than the professional water quality monitoring community. These methods are utilized by Texas Stream Team due to higher equipment costs, training requirements, and stringent laboratory procedures that are required of the professional community. As a result, Texas Stream Team data do not have the same accuracy or precision as professional data, and is not directly comparable. However, the data collected by Texas Stream Team provides valuable records, often collected in portions of a water body that professionals are not able to monitor at all, or monitor as frequently. This long-term data set is available, and may be considered by the surface water quality professional community to facilitate management and protection of Texas water resources. For additional information about water quality monitoring methods and procedures, including the differences between professional and volunteer monitoring, please refer to the following sources:

- Texas Stream Volunteer Water Quality Monitoring Manual
- Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures

The information that Texas Stream Team citizen scientists collect is covered under a TCEQ approved Quality Assurance Project Plan (QAPP) to ensure that a standard set of methods are used. All data used in watershed data reports are screened by the Texas Stream Team for completeness, precision, and accuracy, in addition to being scrutinized for data quality objectives and with data validation techniques.

The purpose of this report is to provide analysis of data collected by Texas Stream Team citizen scientists. The data presented in this report should be considered in conjunction with other relevant water quality reports in order to provide a holistic view of water quality in this water body. Such sources include, but are not limited to, the following potential resources:

- Texas Surface Water Quality Standards
- Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)
- Texas Clean Rivers Program partner reports, such as Basin Summary Reports and Highlight Reports
- TCEQ Total Maximum Daily Load reports
- TCEQ and Texas State Soil and Water Conservation Board Nonpoint Source Program funded reports, including Watershed Protection Plans

Questions regarding this watershed data report should be directed to the Texas Stream Team at (512) 245-1346.

Watershed Location and Physical Description

Location and Climate

Nolan Creek originates in Bell County slightly northwest of Belton (formerly Nolandville until 1851) where North and South Nolan Creek converge and ends at its confluence with Leon River (Texas State Historical Association "Nolan Creek (Bell County)"; Belton Texas "Belton History"). Nolan Creek is located in the Cross Timbers and Prairies ecoregion (Texas Commission on Environmental Quality (TCEQ)). This area is relatively flat with a low drainage density and is predominantly composed of silty clay underlain by limestone (TCEQ). Bell County is a humid subtropical region characterized by hot dry summers with average temperatures of 28.7°C in August and 8.39°C in February and an average annual precipitation of 41.3 inches (TCEQ; USDA Natural Resources Conservation Program).

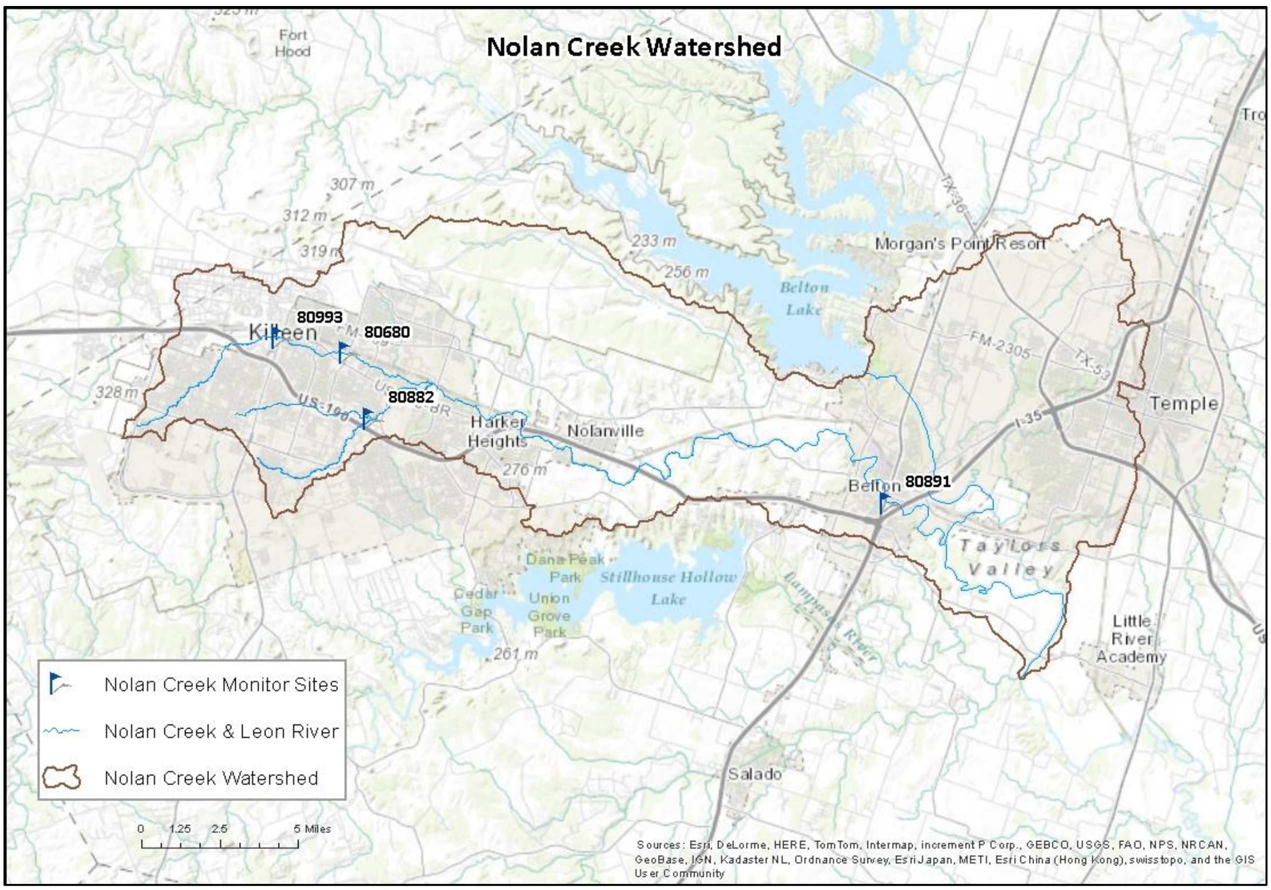

Figure 1: Map of the Nolan Creek Watershed with Texas Stream Team Monitor Sites

Physical Description and Land Use

Nolan Creek is 29 miles long and is surrounded by characteristic grassland vegetation such as little and big bluestem (*Schizachyrium scoparium; Andropogon gerardii*), Indian grass (*Sorghastrum nutans)*, Texas mulberry (*Morus microphylla)*, and American Elm (*Ulmus americana)* (Texas Parks & Wildlife

Department). Nolan Creek is designated for high aquatic life, contact recreation, general, and fish consumption uses (TCEQ). However, the segment is impaired due to elevated bacteria and nutrient levels, possibly due to the numerous On-Site Sewage Facilities (OSSFs) in Bell County (TCEQ). The area surrounding Nolan creek is primarily residential and has experienced a 36% growth in population from 1990 – 2000, largely due to growth at the Fort Hood military base (TCEQ). There are also about 50 confined animal feeding operations (CAFOs) in and around the Nolan Creek and Leon River watershed, runoff from which is also a potential source of the elevated nutrient and bacteria levels (Brazos River Authority).

History

Nolan Creek is named after an adventurer of the 1800s, Philip Nolan, and is most known for its periodic floods (TSHA). Flash floods are so frequent here that the original courthouse in Belton was built on top of tall blocks to protect it from the creek's floodwaters (Belton Texas "Belton History"). In 1913, a flood washed away the Polk family home on the banks of Nolan Creek in Belton, drowning Yettie Polk and her four children (Burnett 2008). Yettie Polk Park was given its name in memory of this tragic event (Burnett 2008). Most recently a major flood occurred in 2010, which inundated downtown Belton and neighborhoods, necessitating water rescues and evacuations (Belton Texas "Municipal Excellence Award"). In 2012 the cities of Belton, Harker Heights, and Killeen established a Nolan Creek Early Flood Warning System that monitors rainfall, stream depth, and flow rate of the creek in order to better prepare for extreme flooding situations (Belton Texas "Municipal Excellence Award").

Water Quality Parameters

Water Temperature

Water temperature influences the physiological processes of aquatic organisms and each species has an optimum temperature for survival. High water temperatures increase oxygen-demand for aquatic communities and can become stressful for fish and aquatic insects. Water temperature variations are most detrimental when they occur rapidly; leaving the aquatic community no time to adjust. Additionally, the ability of water to hold oxygen in solution (solubility) decreases as temperature increases.

Natural sources of warm water are seasonal, as water temperatures tend to increase during summer and decrease in winter in the Northern Hemisphere. Daily (diurnal) water temperature changes occur during normal heating and cooling patterns. Man-made sources of warm water include power plant effluent after it has been used for cooling or hydroelectric plants that release warmer water. Citizen scientist monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases. While citizen scientist data does not show diurnal temperature fluctuations, it may demonstrate the fluctuations over seasons and years.

Dissolved Oxygen

Oxygen is necessary for the survival of organisms like fish and aquatic insects. The amount of oxygen needed for survival and reproduction of aquatic communities varies according to species composition and adaptations to watershed characteristics like stream gradient, habitat, and available stream flow. The TCEQ Water Quality Standards document lists daily minimum Dissolved Oxygen (DO) criteria for specific water bodies and presumes criteria according to flow status (perennial, intermittent with perennial pools, and intermittent), aquatic life attributes, and habitat. These criteria are protective of aquatic life and can be used for general comparison purposes.

The DO concentrations can be influenced by other water quality parameters such as nutrients and temperature. High concentrations of nutrients can lead to excessive surface vegetation growth and algae, which may starve subsurface vegetation of sunlight, and therefore limit the amount of DO in a water body due to reduced photosynthesis. This process, known as eutrophication, is enhanced when the subsurface vegetation and algae die and oxygen is consumed by bacteria during decomposition. Low DO levels may also result from high groundwater inflows due to minimal groundwater aeration, high temperatures that reduce oxygen solubility, or water releases from deeper portions of dams where DO stratification occurs. Supersaturation typically only occurs underneath waterfalls or dams with water flowing over the top.

Specific Conductivity and Total Dissolved Solids

Specific conductivity is a measure of the ability of a body of water to conduct electricity. It is measured in micro Siemens per cubic centimeter ($\mu S/cm^3$). A body of water is more conductive if it has more dissolved solids such as nutrients and salts, which indicates poor water quality if they are overly abundant. High concentrations of nutrients can lower the level of DO, leading to eutrophication. High concentrations of salt can inhibit water absorption and limit root growth for vegetation, leading to an abundance of more drought tolerant plants, and can cause dehydration of fish and amphibians. Sources of Total Dissolved Solids (TDS) can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants. For this report, specific conductivity values have been converted to TDS using a conversion factor of 0.65 and are reported as mg/L.

pH

The pH scale measures the concentration of hydrogen ions on a range of 0 to 14 and is reported in standard units (su). The pH of water can provide useful information regarding acidity or alkalinity. The range is logarithmic; therefore, every 1 unit change is representative of a 10-fold increase or decrease in acidity. Acidic sources, indicated by a low pH level, can include acid rain and runoff from acid-laden soils. Acid rain is mostly caused by coal power plants with minimal contributions from the burning of other fossil fuels and other natural processes, such as volcanic emissions. Soil-acidity can be caused by excessive rainfall leaching alkaline materials out of soils, acidic parent material, crop decomposition creating hydrogen ions, or high-yielding fields that have drained the soil of all alkalinity. Sources of high pH (alkaline) include geologic composition, as in the case of limestone increasing alkalinity and the dissolving of carbon dioxide in water. Carbon dioxide is water soluble, and, as it dissolves it forms carbonic acid. The most suitable pH range for healthy organisms is between 6.5 and 9.

Secchi disk and total depth

The Secchi disk is used to determine the clarity of the water, a condition known as turbidity. The disk is lowered into the water until it is no longer visible, and the depth is recorded. Highly turbid waters pose a risk to wildlife by clogging the gills of fish, reducing visibility, and carrying contaminants. Reduced visibility can harm predatory fish or birds that depend on good visibility to find their prey. Turbid waters allow very little light to penetrate deep into the water, which in turn decreases the density of phytoplankton, algae, and other aquatic plants. This reduces the DO in the water due to reduced photosynthesis. Contaminants are most commonly transported in sediment rather than in the water. Turbid waters can results from sediment washing away from construction sites, erosion of farms, or mining operations. Average Secchi disk transparency (a.k.a. Secchi depth) readings that are less than the total depth readings indicate turbid water. Readings that are equal to total depth indicate clear water. Low total depth observations have a potential to concentrate contaminants.

E. coli Bacteria

E. coli bacteria originate in the digestive tract of endothermic organisms. The EPA has determined *E. coli* to be the best indicator of the degree of pathogens in a water body. A pathogen is a biological agent that causes disease. The standard for *E. coli* impairment is based on the geometric mean (geomean) of the *E. coli* measurements taken. A geometric mean is a type of average that incorporates the high variability found in parameters such as *E. coli* which can vary from zero to tens of thousands of CFU/100 mL. The standard for contact recreational use of a water body such as Nolan Creek is a geometric mean of 126 CFU/100 mL.

Texas Surface Water Quality Standards

The Texas Surface Water Quality Standards establish explicit goals for the quality of streams, rivers, lakes, and bays throughout the state. The standards are developed to maintain the quality of surface waters in Texas so that it supports public health and protects aquatic life, consistent with the sustainable economic development of the state.

Water quality standards identify appropriate uses for the state's surface waters, including aquatic life, recreation, and sources of public water supply (or drinking water). The criteria for evaluating support of those uses include DO, temperature, pH, TDS, toxic substances, and bacteria.

The Texas Surface Water Quality Standards also contain narrative criteria (verbal descriptions) that apply to all waters of the state and are used to evaluate support of applicable uses. Narrative criteria include general descriptions, such as the existence of excessive aquatic plant growth, foaming of surface waters, taste- and odor producing substances, sediment build-up, and toxic materials. Narrative criteria are evaluated by using screening levels, if they are available, as well as other information, including water quality studies, existence of fish kills or contaminant spills, photographic evidence, and local knowledge. Screening levels serve as a reference point to indicate when water quality parameters may be approaching levels of concern.

Data Analysis Methodologies

Data Collection

The field sampling procedures are documented in Texas Stream Team Water Quality Monitoring Manual and its appendices, or the TCEQ Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012). Additionally, all data collection adheres to Texas Stream Team's approved Quality Assurance Project Plan (QAPP).

Table 1: Sample Storage, Preservation, and Handling Requirements

Parameter	Matrix	Container	Sample Volume	Preservation	Holding Time
E. coli	Water	Sterile Polystyrene (SPS)	100	Refrigerate at 4ºC*	6 hours
Nitrate/Nitrogen	Water	Plastic Test Tube	10 mL	Refrigerate at 4ºC*	48 hours
Orthophosphate/Phosphorous	Water	Glass Mixing Bottle	25 mL	Refrigerate at 4ºC*	48 hours
Chemical Turbidity	water	Plastic Turbidity Column	50 mL	Refrigerate at 4ºC*	48 hours

*Preservation performed within 15 minutes of collection.

Processes to Prevent Contamination

Procedures documented in Texas Stream Team Water Quality Monitoring Manual and its appendices, or the TCEQ Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012) outline the necessary steps to prevent contamination of samples, including direct collection into sample containers, when possible. Field Quality Control (QC) samples are collected to verify that contamination has not occurred.

Documentation of Field Sampling Activities

Field sampling activities are documented on the field data sheet. For all field sampling events the following items are recorded: station ID, location, sampling time, date, and depth, sample collector's name/signature, group identification number, conductivity meter calibration information, and reagent expiration dates are checked and recorded if expired.

For all *E. coli* sampling events, station ID, location, sampling time, date, depth, sample collector's name/signature, group identification number, incubation temperature, incubation duration, *E. coli* colony counts, dilution aliquot, field blanks, and media expiration dates are checked and recorded if expired. Values for all measured parameters are recorded. If reagents or media are expired, it is noted and communicated to Texas Stream Team.

Sampling is still encouraged with expired reagents and bacteria media; however, the corresponding values will be flagged in the database. Detailed observational data are recorded, including water appearance, weather, field observations (biological activity and stream uses), algae cover, unusual odors, days since last significant rainfall, and flow severity.

Comments related to field measurements, number of participants, total time spent sampling, and total round-trip distance traveled to the sampling site are also recorded for grant and administrative purposes.

Data Entry and Quality Assurance

Data Entry

The citizen monitors collect field data and report the measurement results on Texas Stream Team approved physical or electronic datasheet. The physical data sheet is submitted to the Texas Stream Team and local partner, if applicable. The electronic datasheet is accessible in the online DataViewer and, upon submission and verification, is uploaded directly to the Texas Stream Team Database.

Quality Assurance & Quality Control

All data are reviewed to ensure that they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to specified monitoring procedures and project specifications. The respective field, data management, and Quality Assurance Officer (QAO) data verification responsibilities are listed by task in the Section D1 of the QAPP, available on the Texas Stream Team website.

Data review and verification is performed using a data management checklist and self-assessments, as appropriate to the project task, followed by automated database functions that will validate data as the information is entered into the database. The data are verified and evaluated against project specifications and are checked for errors, especially errors in transcription, calculations, and data input. Potential errors are identified by examination of documentation and by manual and computer-assisted examination of corollary or unreasonable data. Issues that can be corrected are corrected and documented. If there are errors in the calibration log, expired reagents used to generate the sampling data, or any other deviations from the field or *E. coli* data review checklists, the corresponding data is flagged in the database.

When the QAO receives the physical data sheets, they are validated using the data validation checklist, and then entered into the online database. Any errors are noted in an error log and the errors are flagged in the Texas Stream Team database. When a monitor enters data electronically, the system will automatically flag data outside of the data limits and the monitor will be prompted to correct the mistake or the error will be logged in the database records. The certified QAO will further review any flagged errors before selecting to validate the data. After validation the data will be formally entered into the database. Once entered, the data can be accessible through the online DataViewer.

Errors, which may compromise the program's ability to fulfill the completeness criteria prescribed in the QAPP, will be reported to the Texas Stream Team Program Manager. If repeated errors occur, the monitor and/or the group leader will be notified via e-mail or telephone.

Data Analysis Methods

Data are compared to state standards and screening levels, as defined in the Surface Water Quality Monitoring Procedures, to provide readers with a reference point for amounts/levels of parameters that may be of concern. The assessment performed by TCEQ and/or designation of impairment involves more complicated monitoring methods and oversight than used by volunteers and staff in this report. The citizen water quality monitoring data are not used in the assessments mentioned above, but are intended to inform stakeholders about general characteristics and assist professionals in identifying areas of potential concern.

Standards & Exceedances

The TCEQ determines a water body to be impaired if more than 10% of samples, provided by professional monitoring, from the last seven years, exceed the standard for each parameter, except for *E. coli* bacteria. When the observed sample value does not meet the standard, it is referred to as an exceedance. At least ten samples from the last seven years must be collected over at least two years with the same reasonable amount of time between samples for a data set to be considered adequate. The 2012 Texas Surface Water Quality Standards report was used to calculate the exceedances for the Nolan Creek Watershed, as seen below in Table 2.

Table 2: Summary of Surface Water Quality Standards for the Nolan Creek Watershed

Parameter	2012 Texas Surface Water Quality Standards for the Nolan Creek Watershed	
Water Temperature (°C)	33.9° C (Maximum)	
Total Dissolved Solids (mg/L)	500 mg/L (Maximum)	
Dissolved Oxygen (mg/L)	5 mg/L (Minimum)	
pH	6.5-9.0 (Range)	
E. coli (CFU)	399 CFU/100mL	Single Sample
	126 CFU/100mL	Geometric Mean

Methods of Analysis

All data collected from Nolan Creek and its tributaries were exported from the Texas Stream Team database and were then grouped by site. Data were reviewed and, for the sake of data analysis, only one sampling event per month, per site was selected for the entire study duration. If more than one sampling event occurred per month, per site, the most complete, correct, and representative sampling event was selected.

Once compiled, data was sorted and graphed in Microsoft Excel 2010 using standard methods. Upstream to downstream trends and trends over time were analyzed using a linear regression analysis in Minitab v 15. Statistically significant trends were added to Excel to be graphed. The cut off for statistical significance was set to a p-value of ≤ 0.05. A p-value of ≤ 0.05 means that the probability that the observed data matches the actual conditions found in nature is 95%. As the p-value decreases, the confidence that it matches actual conditions in nature increases.

For this report, specific conductivity measurements, gathered by volunteers, were converted to TDS using the TCEQ-recommended conversion formula of specific conductivity 0.65. This conversion was made so that volunteer gathered data could be more readily compared to state gathered data. Geomeans were calculated for *E. coli* data for trends and for each monitoring site.

Nolan Creek Watershed Data Analysis

Nolan Creek Watershed Maps

Numerous maps were prepared to show spatial variation of the parameters. The parameters mapped include DO, pH, TDS, and *E. coli*. There is also a reference map showing the locations of all monitoring sites in the watershed. For added reference points in all maps, layers showing monitoring sites, cities, counties, and major highways were included. All shapefiles were downloaded from reliable federal, state, and local agencies.

Nolan Creek Watershed Trends over Time

Sampling Trends over Time

Sampling along Nolan Creek began in July of 2011 and continues to this day. A total of 48 individual monitoring events from 4 sites were analyzed. The sampling mostly took place in 2013 as more sites were added to the monitoring plan. The time of sampling ranged from 07:00 – 19:00, with 08:00 to 10:00 being the most common time of day to monitor. Nolan Creek is monitored by the Central Texas Master Naturalists and a middle school aquatic science group called "The Creek Freeks".

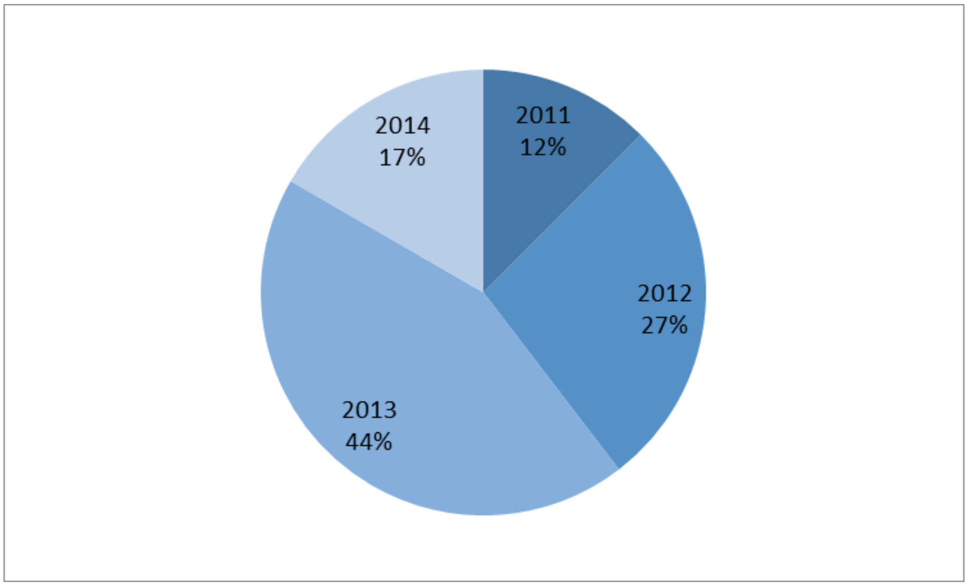

Figure 2: Breakdown of monitoring events by year

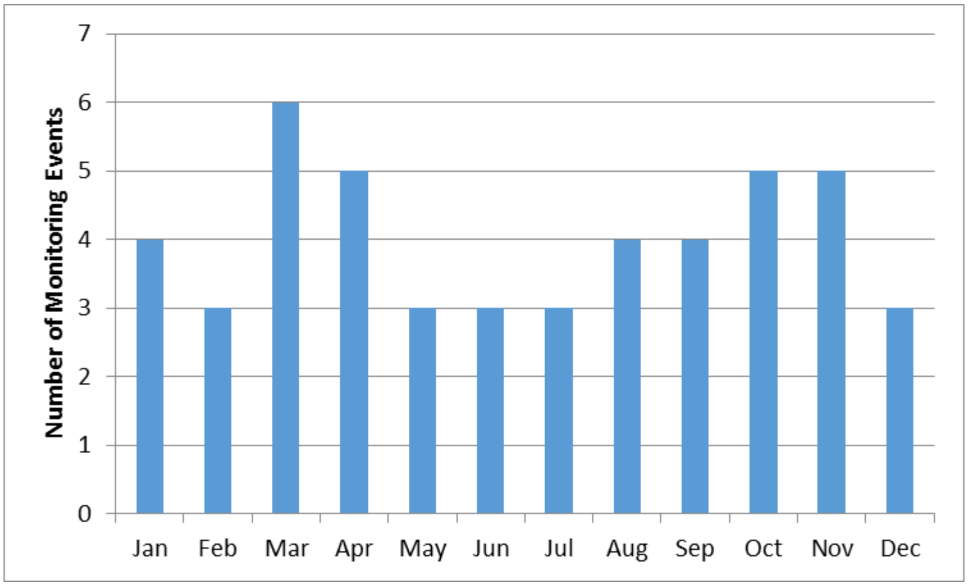

Figure 3: Breakdown of monitoring events by month

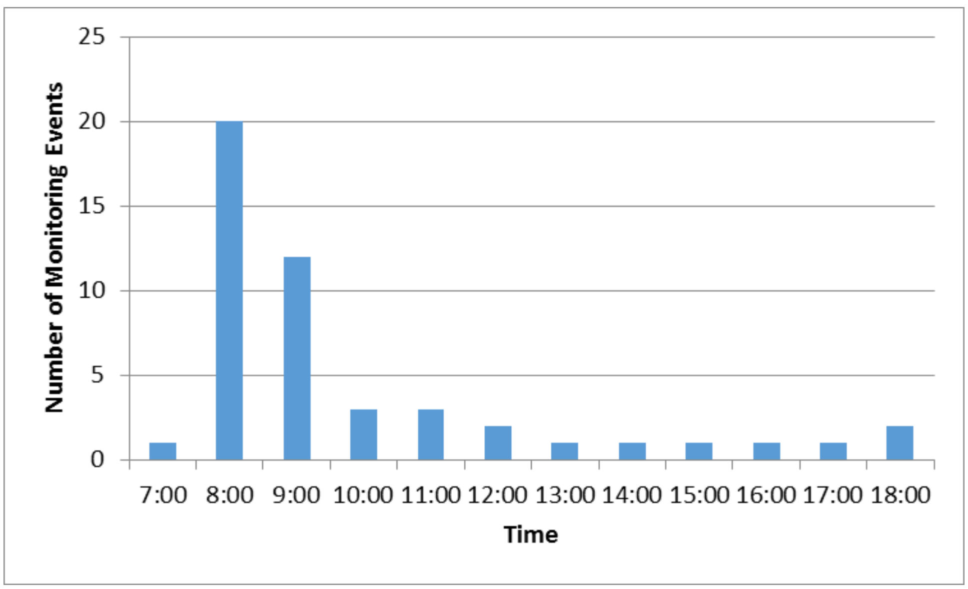

Figure 4: Breakdown of time of monitoring in the Nolan Creek Watershed

Table 3: Descriptive parameters for all sites in the Nolan Creek Watershed

Nolan Creek July 2011 – April 2014				
Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	47	290 ± 56	182	448
Water Temperature (°C)	48	20.5 ± 6.5	5	30.2
Dissolved Oxygen (mg/L)	46	6.36 ± 1.92	2.02	9.9
pH	48	7.26 ± 0.3	6.6	8.0
E. coli Bacteria (CFU/100 mL)	22	167 ± 1698	0	8000

*There were a total of 48 sampling events between 07/2011 and 04/2014. Mean, calculated in Microsoft Excel, is listed for all parameters except E. coli, where a geomean, calculated in Minitab v15, was used.

Trend Analysis over Time

Air and Water Temperature

A total of 48 water temperature values and 47 air temperature values were collected within the Nolan Creek Watershed between 2011 and 2014. Water temperature readings never exceeded the TCEQ optimal temperature of 33.9°C. Air temperature varied between 1 and 32°C.

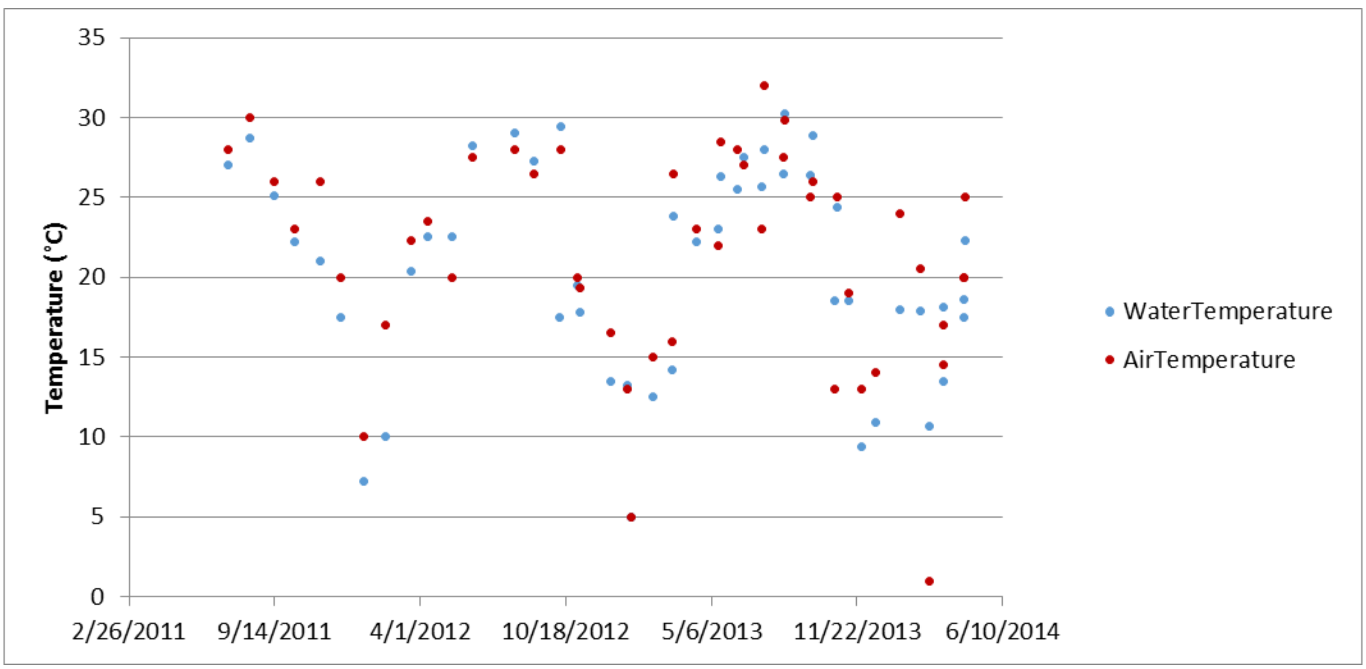

Figure 5: Air and water temperature over time at all sites within the Nolan Creek Watershed

Total Dissolved Solids

Citizen scientists collected 47 TDS measurements within the watershed. The TDS measurement was completed for 97.9% of all monitoring events. The average TDS measurement for all sites was 290 mg/L, and there was a significant increase in TDS values over time ($p = 0.003$).

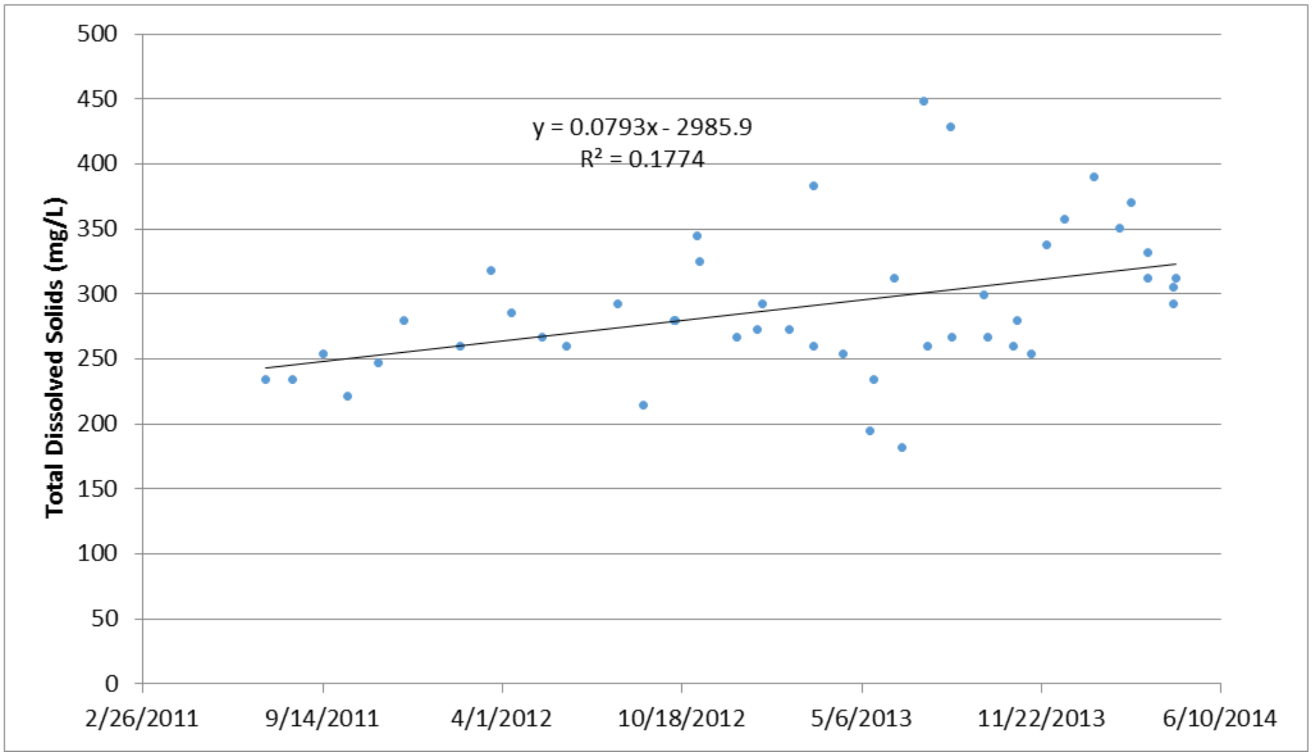

Figure 6: Total Dissolved Solids over time at all sites within the Nolan Creek Watershed

Table 4: Average Total Dissolved Solids (mg/L) by flow for the Nolan Creek Watershed

Flow Level	Average TDS (mg/L)	Standard Deviation
No Flow	N/A	N/A
Low Flow	290	61
Normal Flow	298	53
High	261	47
Flood	N/A	N/A

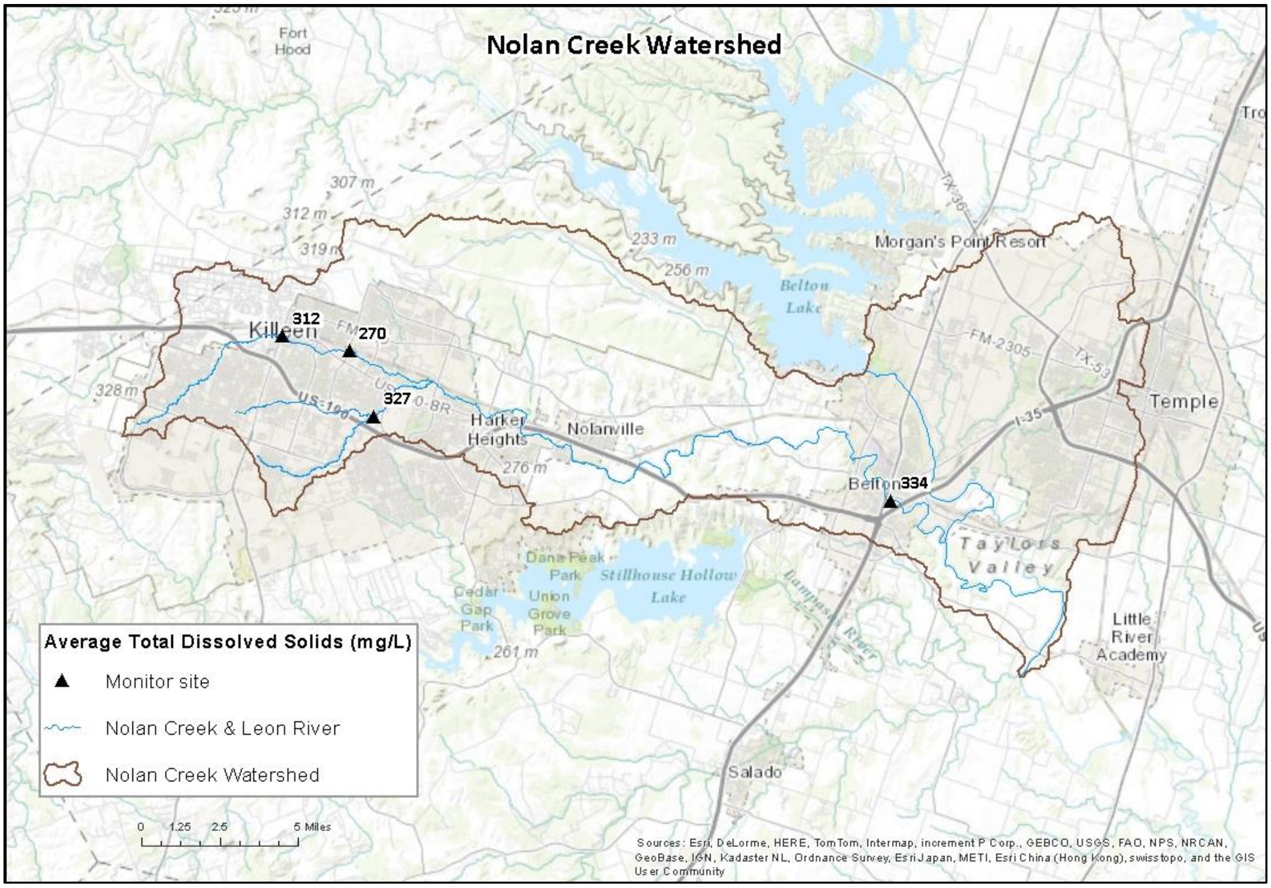

Figure 7: Map of average Total Dissolved Solids on Nolan Creek

Dissolved Oxygen

Citizen scientists collected 46 DO samples on Nolan Creek. Dissolved oxygen fluctuated seasonally with values typically higher in the winter months than the summer months. This is because cold water holds more dissolved gasses than warmer water. The mean DO was 6.36 mg/L and ranged from a low of 2.02 mg/L on June 19, 2013, to 9.90 mg/L on January 16, 2013. Plants and algae add a substantial amount of DO via photosynthesis, resulting in the diurnal trends of high DO levels observed during the daylight hours, peaking in the late afternoon, and then decreasing after dark. This pattern is shown in Table 5.

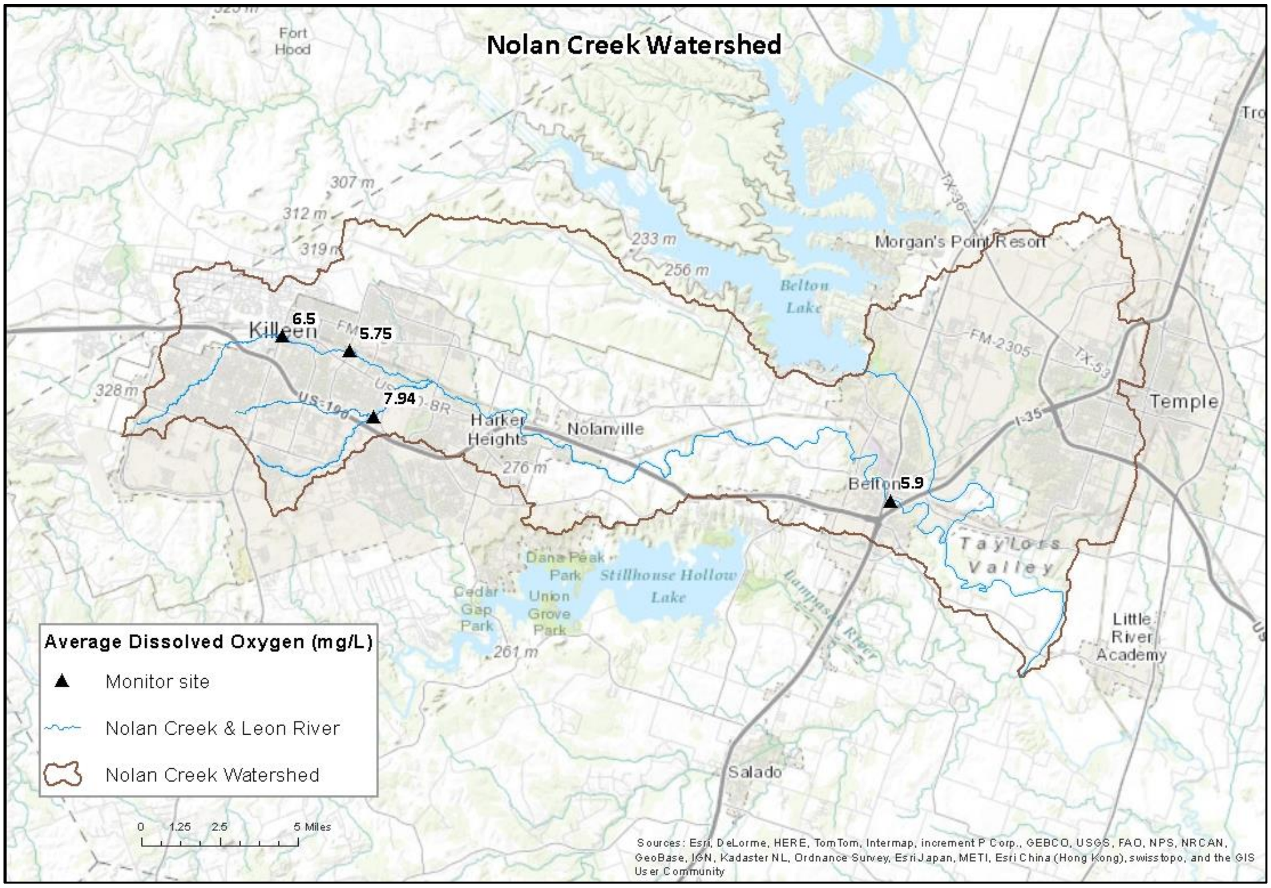

Figure 8: Map of Dissolved Oxygen means for each site in the Nolan Creek Watershed

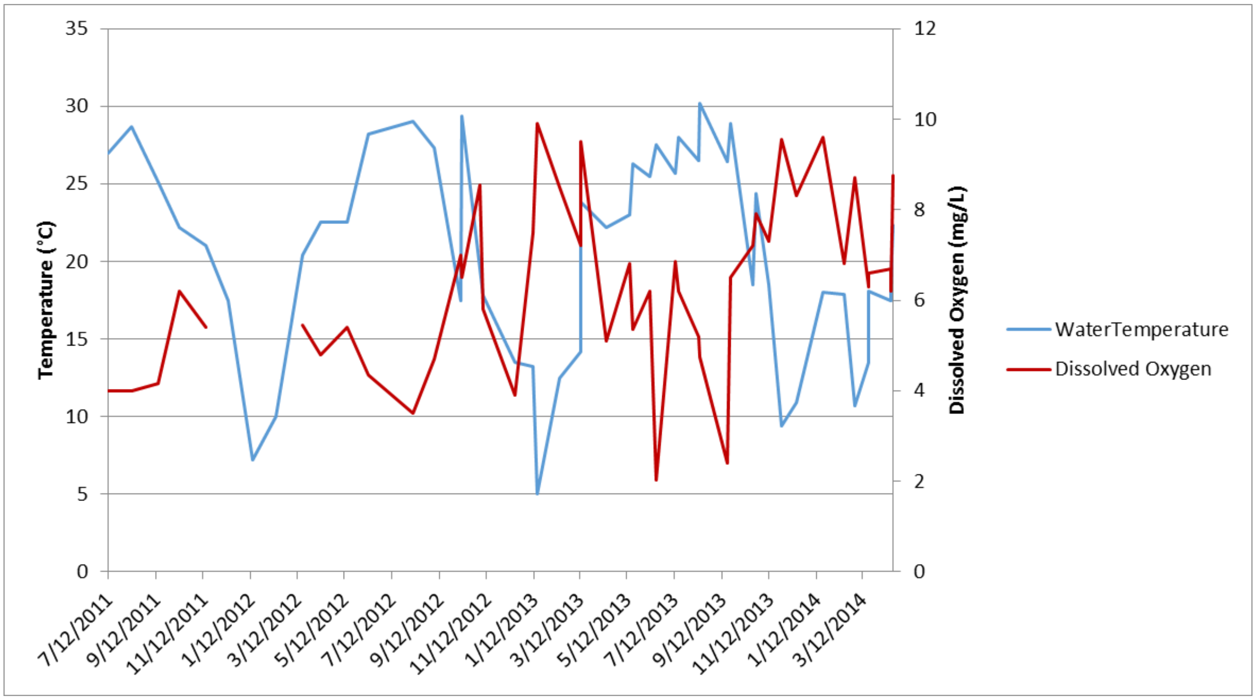

Figure 9: Dissolved Oxygen and Water Temperature at all sites within the Nolan Creek Watershed

Table 5: Average Dissolved Oxygen values by Sampling Time within the Nolan Creek Watershed

Time	Average DO (mg/L)	Standard Deviation
7:00 – 9:00	5.85	2.12
9:00 – 10:00	5.55	1.15
10:00 – 12:00	7.90	1.52
12:00 – 18:00	7.42	1.39

Table 6: Average Dissolved Oxygen at different flow levels for the Nolan Creek Watershed

Flow Level	Average DO (mg/L)	Standard Deviation
No Flow	N/A	N/A
Low Flow	5.71	2.21
Normal Flow	6.84	1.61
High	6.98	1.44
Flood	N/A	N/A

pH

pH was successfully completed for all 48 sampling events. The mean pH was 7.26. The pH for all of the sites ranged from 6.6 to 8.0. There was no significant increase or decrease over time observed in Nolan Creek during the study period.

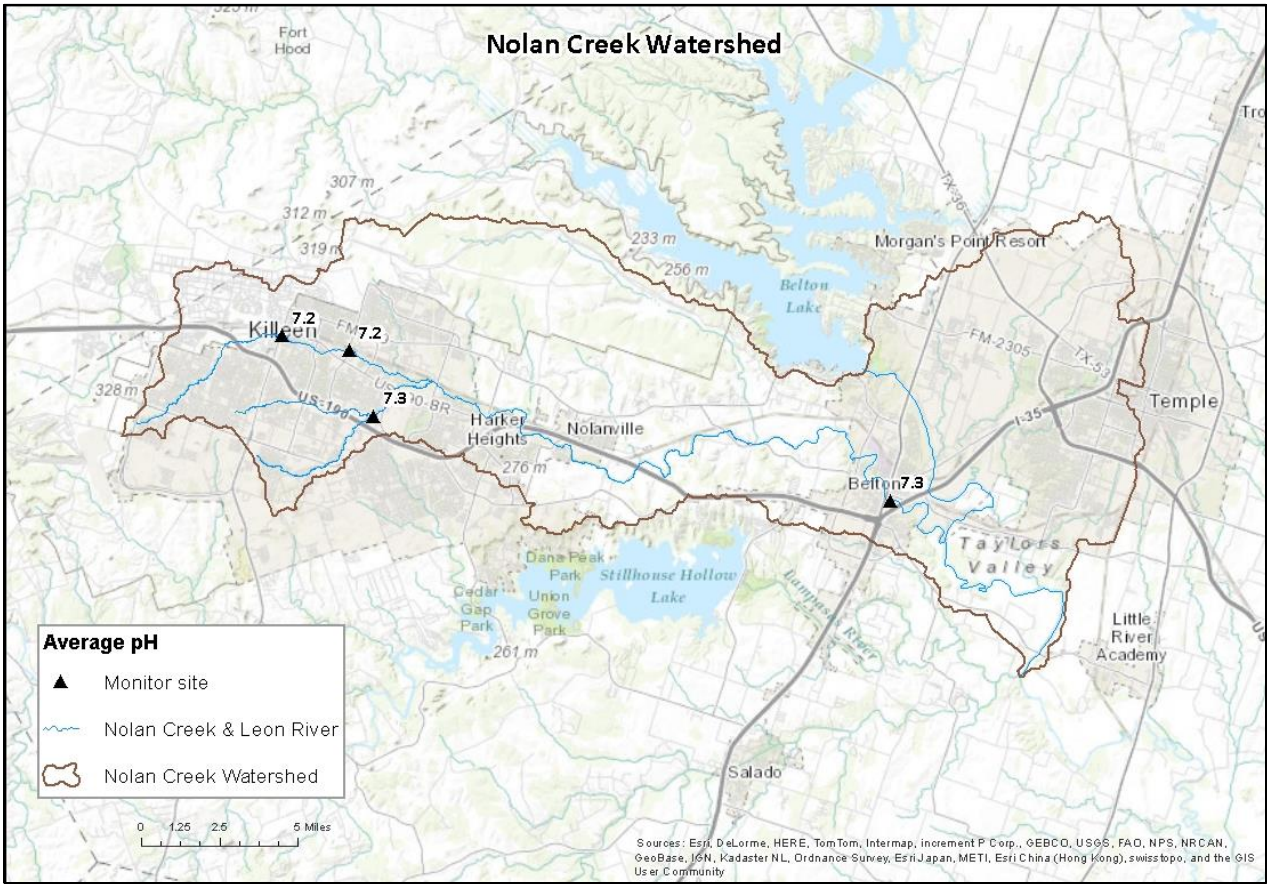

Figure 10: Map of mean pH for each site in the Nolan Creek Watershed

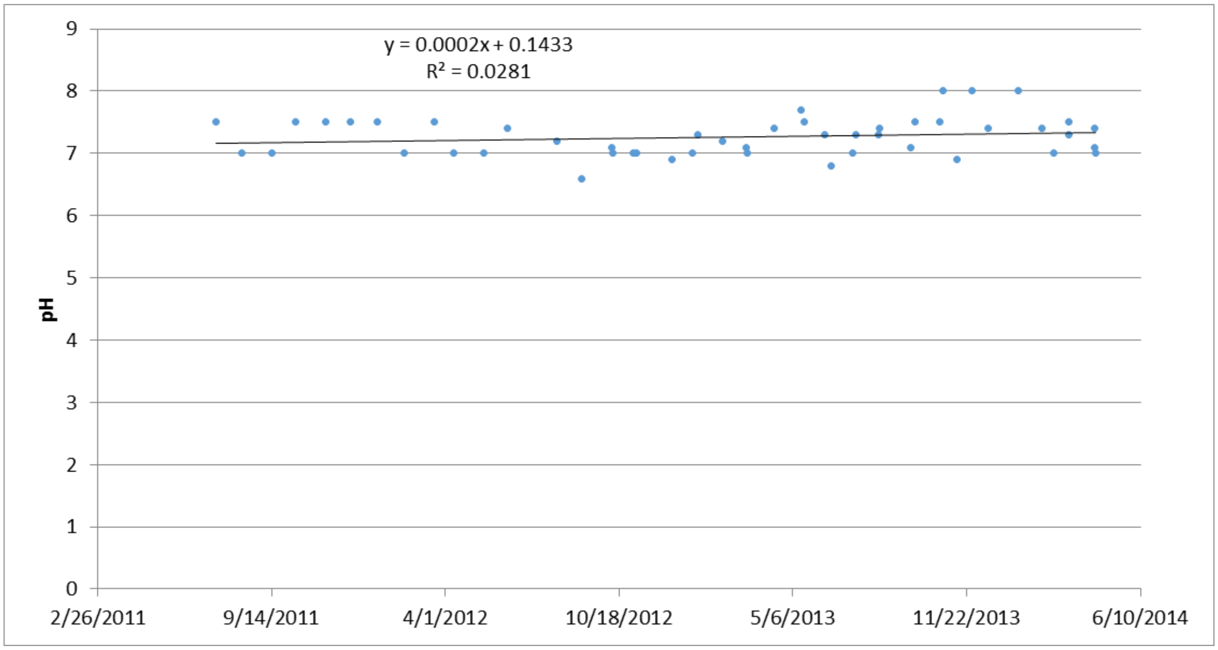

Figure 11: Changes in pH over time at all sites within the Nolan Creek Watershed

E. coli

There were 22 *E. coli* samples taken on Nolan Creek during this study. The geometric mean for *E. coli* was 167 cfu/100 mL, and it ranged from 0 to 8000 cfu/100 mL.

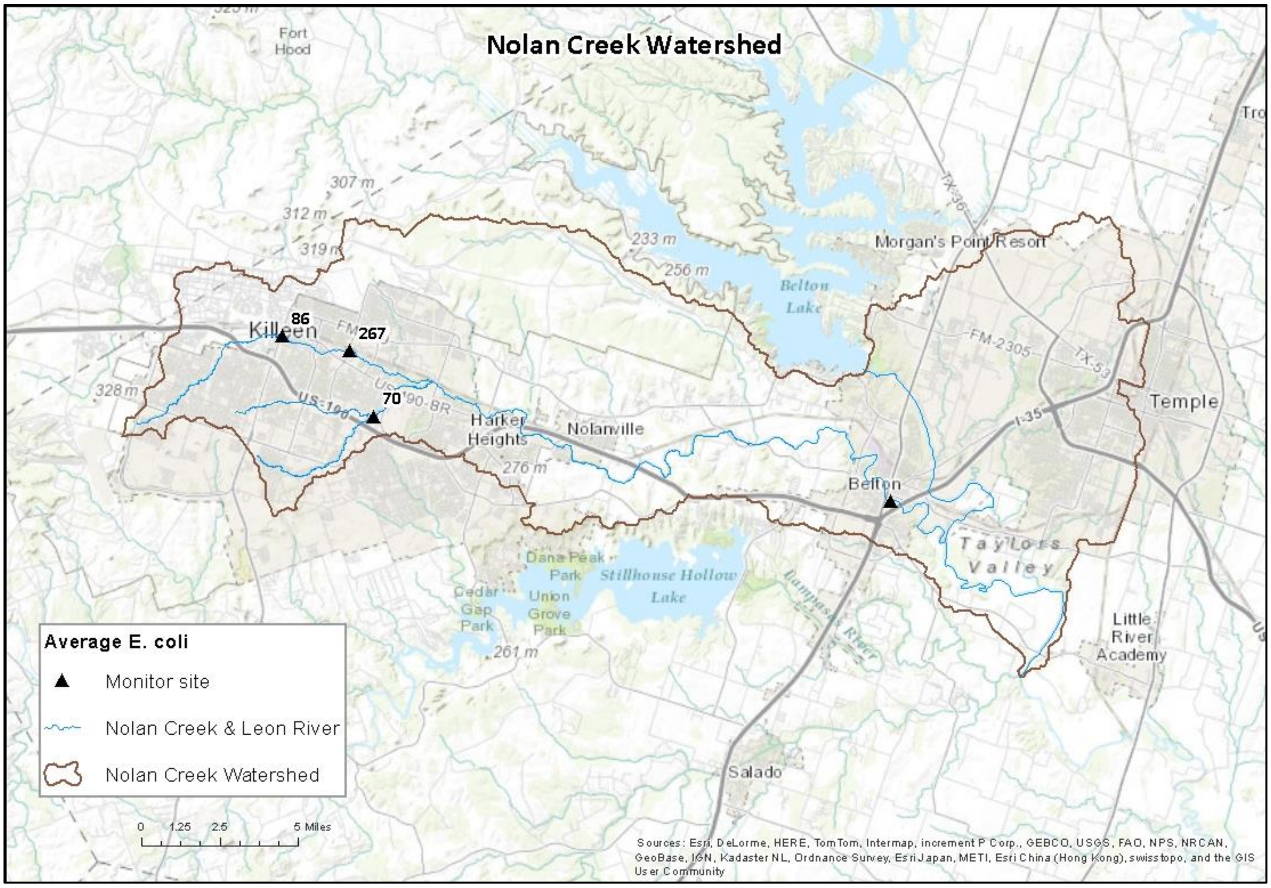

Figure 12: Mean E. coli for each site in the Nolan Creek Watershed

Nolan Creek Watershed Site by Site Analysis

The following sections will provide a brief summarization of analysis, by site. Refer to Figure 1 for the location of each of these sites. The average, minimum, and maximum values are recorded for each site in the watershed. These values are reported in order to provide a quick overview of the watershed. The TDS, DO, and pH values are presented as an average, plus or minus the standard deviation from the average. The *E. coli* is presented as a geomean. Please see Table 7, on the following page, for a quick overview of the average results.

As previously mentioned in the 'Water Quality Parameters' section, TDS is an important indicator of turbidity and specific conductivity. The higher the TDS measurement, the more conductive the water is. A high TDS result can indicate increased nutrients present in the water. Site 80891 had the highest overall average for TDS, with a result of 334 ± 61 mg/L. Site 80680 had the lowest average TDS, with a result of 270 ± 42 mg/L.

The DO measurement can help to understand the overall health of the aquatic community. If there is a large influx of nutrients into the water body than there will be an increase in surface vegetation growth, which can then reduce photosynthesis in the subsurface, thus decreasing the level of DO. Low DO can be dangerous for aquatic inhabitants, which rely upon the dissolved oxygen to breathe. The DO levels can also be impacted by temperature; a high temperature can limit the amount of oxygen solubility, which can also lead to a low DO measurement. Site 80680 had the lowest average DO reading, with a result of 5.75 ± 1.90 mg/L. Site 80882 had the highest average DO reading, with a result of 7.94± 1.34 mg/L.

The pH levels are an important indicator for the overall health of the watershed as well. Aquatic inhabitants typically require a pH range between 6.5 and 9 for the most optimum environment. Anything below 6.5 or above 9 can negatively impact reproduction or can result in fish kills. There were no reported pH levels outside of this widely accepted range. Sites 80882 and 80891 had the highest average pH level, with a result of 7.3 ± 0.4 and 7.3 ± 0.0 respectively. Sites 80993 and 80680 had the lowest average pH level, with a result of 7.2 ± 0.14 and 7.2 ± 0.27 respectively.

E. coli bacteria originate in the digestive tract of endothermic organisms. The EPA has determined *E. coli* to be the best indicator of the degree of pathogens in a water body, which are far too numerous to be tested for directly, considering the amount of water bodies tested. A pathogen is a biological agent that causes disease. The standard for *E. coli* impairment is based on the geometric mean (geomean) of the *E. coli* measurements taken. A geometric mean is a type of average which takes into account the high variability of parameters such as E. coli which can vary from zero to tens of thousands of CFU/100 mL. Site 80680 had the highest average geomean, with a result of 267 CFU/100mL. Site 80882 had the lowest average geomean, with at result of 70 CFU/100mL.

Please see Table 7 for a summary of average results at all sites. It is important to note that not all sites were tested for *E. coli.* Additionally, it is also important to note that there was variation in the number of times each site was tested, the time of day at which each site was tested, and the time of month the sampling occurred. While this is a quick overview of the results, it is important to keep in mind that there is natural diurnal and seasonal variation in these water quality parameters. Texas Stream Team citizen scientist data is not used by the state to assess whether water bodies are meeting the designated surface water quality standards.

Table 7: Average Values for all Nolan Creek Watershed Sites

Site Number	TDS (mg/L)	DO (mg/L)	pH	E. coli (CFU/100 mL)
80993	312 ± 20	6.5 ± 0.2	7.2 ± 0.14	86 ± 50
80680	270 ± 42	5.75 ± 1.90	7.2 ± 0.27	267 ± 2105
80882	327 ± 61	7.94 ± 1.34	7.3 ± 0.4	70 ± 180
80891	334 ± 61	5.9 ± 0.5	7.3 ± 0.0	N/A

Site 80993– South Nolan Creek at Highway 195 and Business 190

Site Description

This site is located on the South Nolan Creek Tributary in Killeen, TX and is in the southeast section of the intersection of US Highway 195 and Business Highway 190. The site is bordered by a commercial development with a parking lot on the North, and a mobile home neighborhood on the South. The site is shallow and has a limestone bedrock creek bottom.

Sampling Information

Routine monitoring at this started in March of 2014, so there are only 2 monitoring events for this study. Both monitoring events took place at around 09:00.

Table 8: Descriptive parameters for Site 80993

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	2	312 ± 20	293	332
Water Temperature (°C)	2	15.5 ± 2.0	13.5	17.5
Dissolved Oxygen (mg/L)	2	6.5 ± 0.2	6.3	6.7
pH	2	7.2 ± 0.14	7.1	7.3
Secchi Disk Transparency (m)	1	0.29 ± 0.0	0.29	0.29
Depth (m)	2	0.28 ± 0.01	0.27	0.29
E. coli Bacteria (CFU/100 mL)	2	86 ± 50	50	150

*Site was sampled 2 times between 3/20/2014 and 4/18/2014.

Air and water temperature

Water temperature fluctuated between 13.5°C and 17.5°C., with a mean of 15.5°C. Air temperature varied between 14.5°C and 20.0°C.

Total Dissolved Solids

Total dissolved solids varied between a minimum of 293 mg/L and 332 mg/L with a mean of 312 mg/L.

Dissolved Oxygen

Mean dissolved oxygen was 6.5 mg/L, with a minimum value of 6.3 mg/L and a maximum value of 6.7.

pH

The mean pH was 7.2 and was tied for the lowest mean pH of the sites analyzed. The minimum pH was 7.1 and the maximum pH was 7.3.

Secchi disk and total depth

Mean total depth was 0.28 m for this site. There was one event where both Secchi disk depth and total depth were taken, and Secchi disk depth was recorded as greater than the total depth, indicating that the water clarity was visible to the bottom of the creek.

Field Observations

The flow was recorded as low for this site. The water had no distinguishable color. The clarity was clear for one event and was recorded as turbid for the monitoring event that took place in March of 2014. Algae cover was recorded as common (26% - 50% coverage).

E. coli Bacteria

The geomean of the two E. coli samples for this site was 86 CFU/100 mL. E. coli ranged from 50 to 150 CFU/100 mL.

Site 80680– South Nolan Creek at South W S Young Drive

Site Description

This site is on the South Nolan Creek tributary in Killeen, TX. The site is on a rocky beach downstream of the South W S Young Bridge and is in the Community Center Park. The north bank of the South Nolan Creek is forested and the south bank has a mowed field.

Sampling Information

This site was sampled 31 times between July 12, 2011 and April 18, 2014. It is still an actively monitored site. The site was sampled between the hours of 08:00 and 11:00 with 09:00 being the typical time when sampling occurred.

Table 9: Descriptive parameters for Site 80680

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	30	270 ± 42	182	358
Water Temperature (°C)	31	20.0 ± 6.5	5.0	30.2
Dissolved Oxygen (mg/L)	29	5.75 ± 1.90	2.0	9.9
pH	31	7.2 ± 0.27	6.6	7.7
Secchi Disk Transparency (m)	28	0.43 ± 0.17	0.15	1.4
Depth (m)	28	0.44 ± 0.27	0.2	1.4
E. coli Bacteria (CFU/100 mL)	14	267 ± 2105	70	8000

Site was sampled 31 times between 7/12/2011 and 4/18/2014.

Air and water temperature

Air temperature was measured 30 times, and water temperature was measured 31 times this period. Air temperature fluctuated in a seasonal pattern with a minimum temperature of 5°C on January 16, 2013, and a maximum temperature of 30°C on August 11, 2011. Water temperature ranged from a minimum of 5 °C on January 16, 2011 to a maximum temperature of 30.2 °C on August 14, 2013.

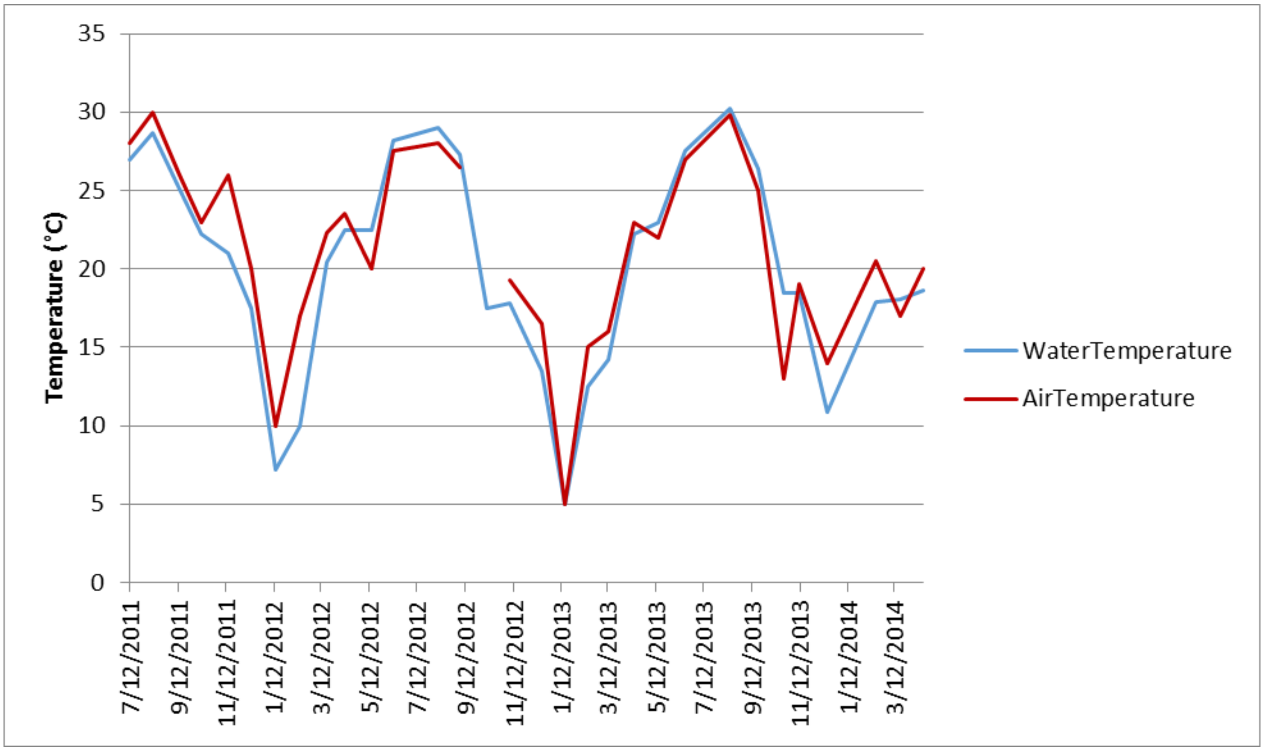

Figure 13: Air and water temperature at Site 80680

Total Dissolved Solids

Citizen scientists collected 30 TDS samples at this site. The minimum value was 182 mg/L and was sampled on June 19, 2013. The maximum value was 357.5 mg/L and was sampled on December 17, 2013. There was a slightly significant increasing trend in TDS values over time for this site ($p = 0.048$). This site had the lowest mean TDS value of all of the sites analyzed in the Nolan Creek Watershed.

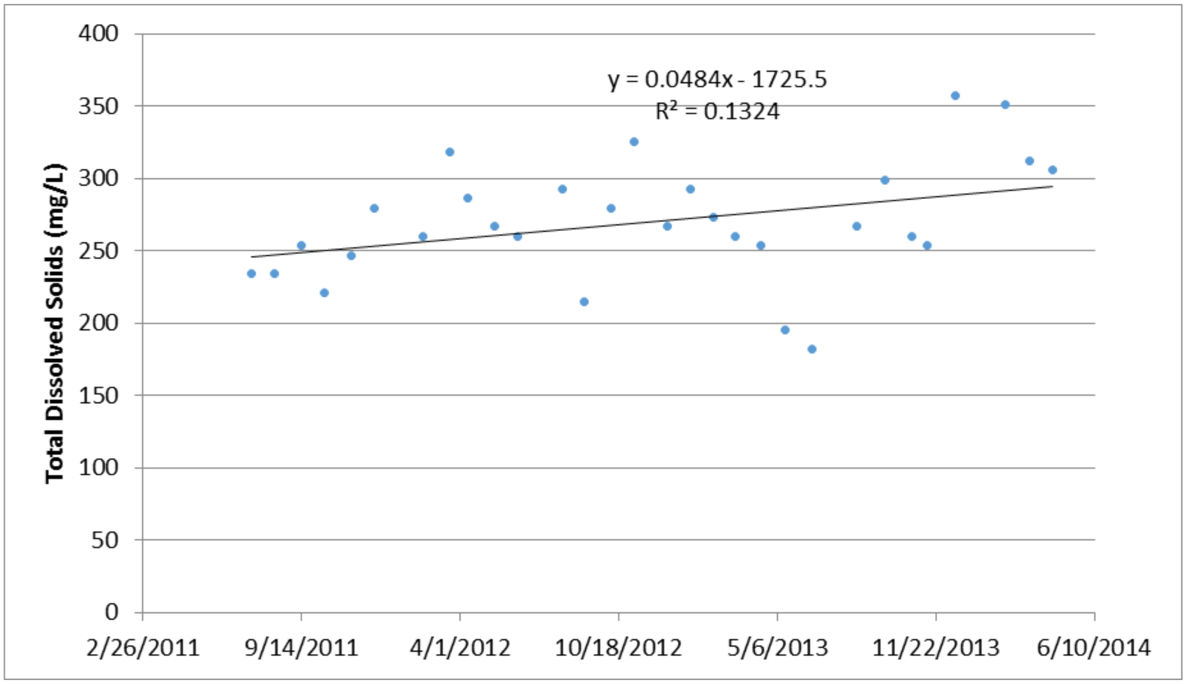

Figure 14: Total Dissolved Solids at Site 80680

Dissolved Oxygen

A total of 29 DO samples were taken at this site. The mean DO concentration was 5.75 and was the lowest mean DO value for all of the sites monitored in the Nolan Creek Watershed. The minimum DO value was 2.02 mg/L and was taken on June 19, 2013. The highest DO value observed was 9.9 mg/L and was taken on January 16, 2013. There was no significant correlation between DO and time observed at this site.

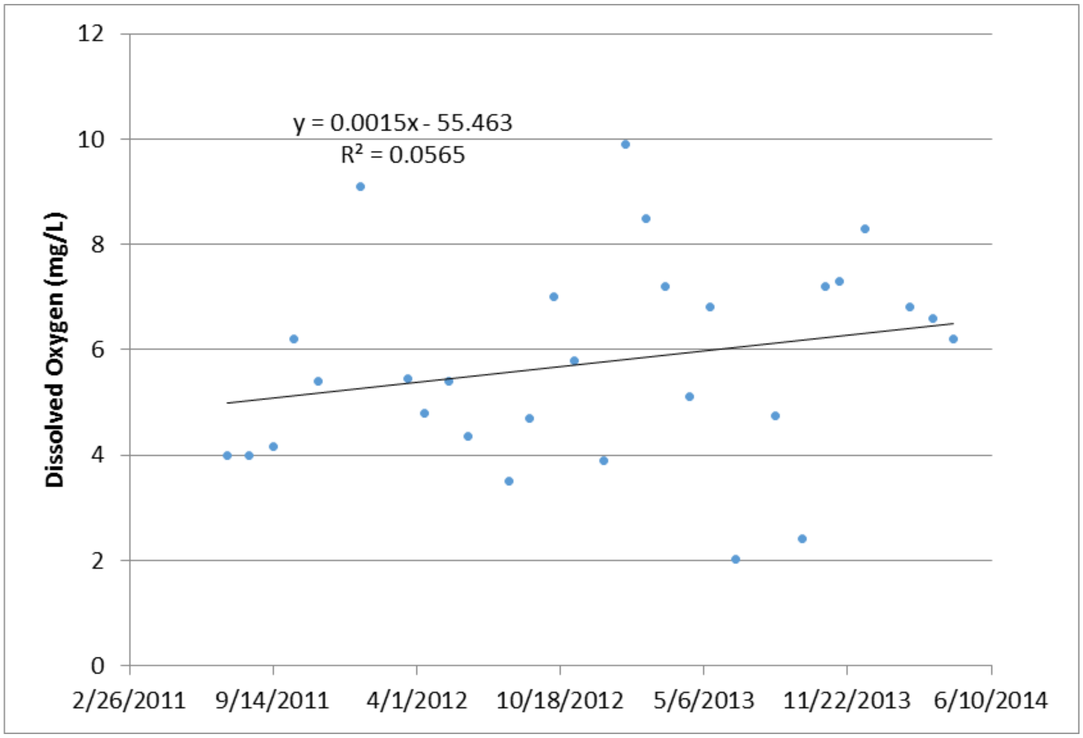

Figure 15: Dissolved Oxygen at Site 80680

pH

A total of 31 pH samples were taken at this site. The mean pH was 7.2 and it was tied for the lowest mean pH in the Nolan Creek Watershed. The lowest pH recorded at this site was 6.6 on September 5, 2012. The highest pH recorded was 7.7 on May 15, 2013.

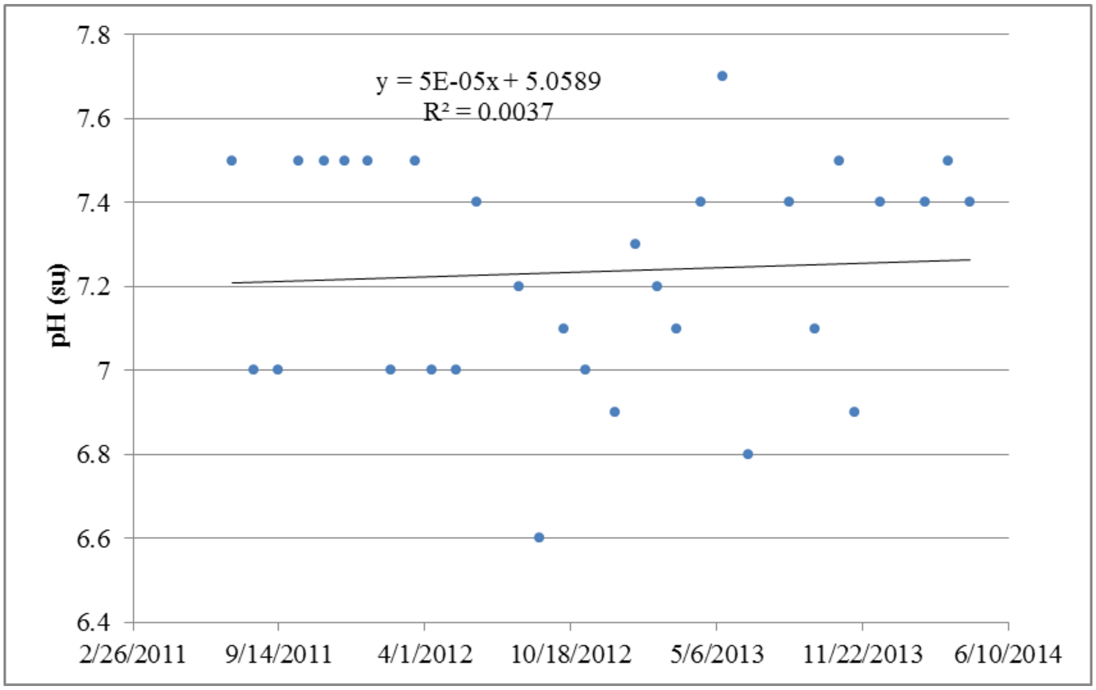

Figure 16: pH at Site 80680

Secchi disk and total depth

Mean Secchi disk depth and total depth were 0.43 and 0.44 m respectively. Secchi disk depth was recorded as greater than total depth in all cases indicating that the water clarity at the site was visible all the way to the creek bottom.

Field Observations

The flow was recorded as either low or normal in all cases except one where it was recorded as high. This event occurred 4 days after a rain event where the watershed received 0.5 inches of precipitation. It was also this event when the highest E. coli sample was recorded (8000 CFU/100 mL). The water was reported to have no color most of the time, but occasionally a tan color was noted. The water was clear except when the creek was reported to be high after the 0.5 inches of precipitation. On that event, the water clarity was recorded as turbid. The water had no distinguishable odor.

E. coli Bacteria

A total of 14 E. coli samples were taken at this site. The geomean for E. coli was 267 CFU/100 mL and was the highest geomean for all of the sites in the Nolan Creek Watershed. The minimum E. coli number was 70 CFU/100 mL and was taken on April 18, 2014. The highest E. coli recorded for this site was 8000 CFU/100 mL on May 15, 2013. This measurement was taken 4 days after a rain event where 0.5 inches of rain fell. The 8000 CFU/100 mL sample was the highest sample of E. coli taken in the watershed.

Site 80882– Nolan Creek Tributary

Site Description

This site is on a small unnamed tributary to Nolan Creek in Killeen, TX. It is located in between two neighborhoods and is downstream of a strip mall. This site is monitored by "The Creek Freeks", a group of students from Gateway Middle School in Killeen.

Sampling Information

This site was monitored 12 times between October 11, 2012 and April 20, 2014. It is currently an actively monitored site. Sampling time varied from 10:00 to 18:00.

Table 10: Descriptive parameters for Site 80882

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	12	327 ± 61	234	449
Water Temperature (°C)	12	30.0 ± 6.6	9.4	29.4
Dissolved Oxygen (mg/L)	12	7.94 ± 1.34	5.35	9.60
pH	12	7.3 ± 0.4	7.0	8.0
Secchi Disk Transparency (m)	0	--	--	--
Depth (m)	7	0.21 0.09	0.01	0.3
E. coli Bacteria (CFU/100 mL)	6	70 ± 180	0	460

Site was sampled 12 times between 10/11/2012 and 4/20/2014.

Air and water temperature

A total of 12 air and 12 water temperatures were taken from this site during this period. The air temperature ranged from a low of 1 °C on March 2, 2014 to a high of 28.5°C on May 19, 2013. The water temperature varied from a low of 9.4°C on November 28, 2013 to a high of 29.4°C on October 11, 2012.

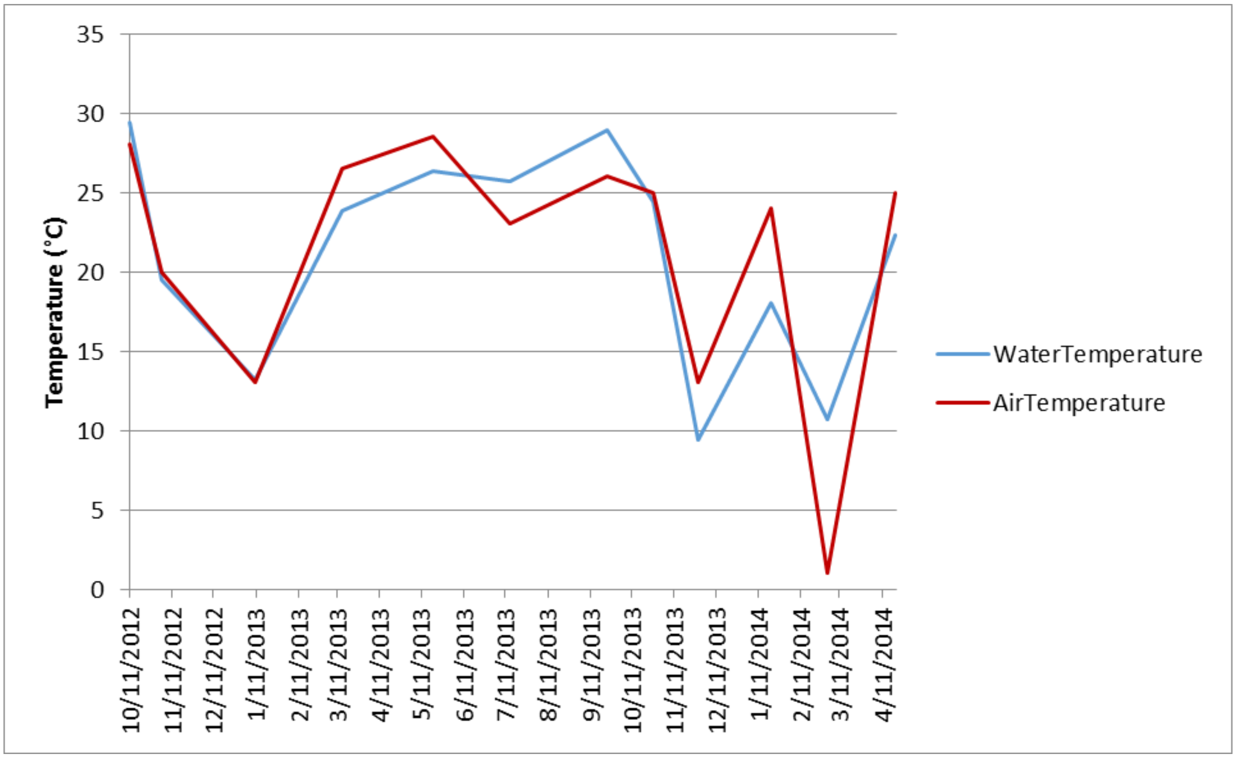

Figure 17: Air and water temperature at Site 80882

Total Dissolved Solids

A total of 12 TDS samples were taken at this site. The mean TDS value was 327 mg/L. The minimum TDS measurement was 234 mg/L and was taken on May 19, 2013. The maximum TDS measurement was 449 mg/L and was taken on July 14, 2013. There was no significant correlation between TDS values and time observed for this site.

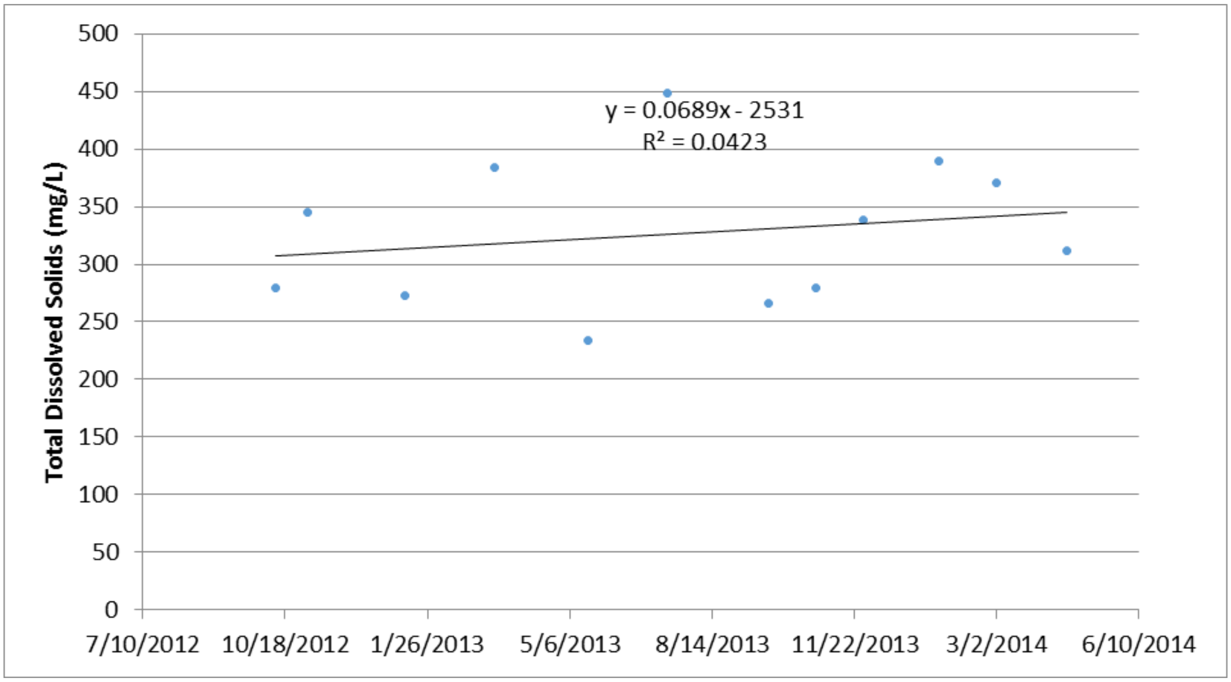

Figure 18: Total Dissolved Solids at Site 80882

Dissolved Oxygen

A total of 12 DO samples were taken at this site. The mean DO was 7.94 mg/L and was the highest mean DO for all of the sites in the watershed. The minimum DO value was 5.35 mg/L and was recorded on May 19, 2013. The maximum DO value was 9.6 mg/L and was recorded on January 20, 2014. There was no significant correlation between DO and time observed for this site.

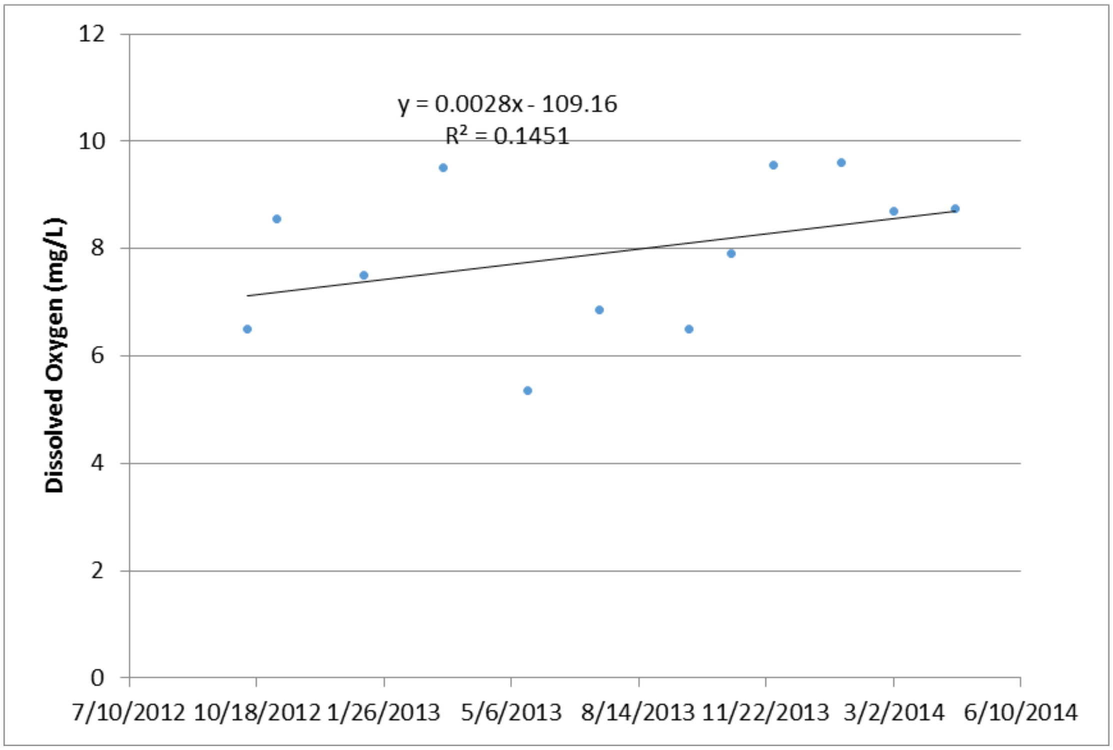

Figure 19: Dissolved Oxygen at Site 80882

pH

A total of 12 pH samples were taken at this site. The mean pH was 7.3 and was tied for the highest mean pH of the sites in the Nolan Creek Watershed. The minimum pH of 7.0 was recorded for 7 of the 12 sampling events, and the maximum pH of 8 was recorded for 3 of the 12 sampling events.

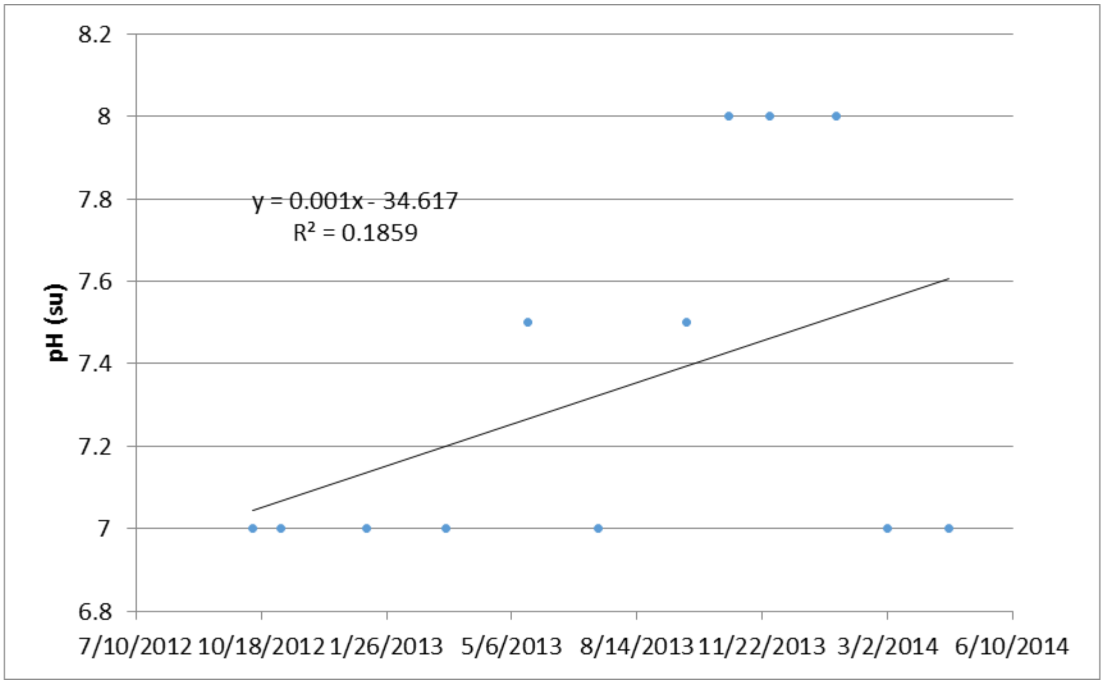

Figure 20: pH at Site 80882

Secchi disk and total depth

Secchi disk depth was not recorded at this site due to its shallowness. The mean total depth was 0.21 m and ranged from 0.01 m to 0.3 m.

Field Observations

Flow was recorded as normal or low for all events except four, when the flow was recorded as high. These high flow events occurred after precipitation fell in the area. Algae was always present in the area, and on several occasions covered more than 75% of the site. The water never had a discernible color, and water clarity was always clear except for one event where it was recorded as cloudy. The water had no detectable odor.

E. coli Bacteria

The geometric mean of E. coli for the site was 70 CFU/100 mL. This was the lowest E. coli geomean of the sites where E. coli was measured. E. coli numbers ranged from a low of 0 on October 26, 2013 to a high of 460 CFU/100 mL on November 28, 2013.

Site 80891– Nolan Creek Wall St. at Ave. C

Site Description

This site is located off of a trail in Confederate Park in Belton, TX.

Sampling Information

This site was sampled 3 times in 2013, from June to August. Sampling time occurred from 07:30 to 13:30.

Table 11: Descriptive parameters for Site 80891

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	3	334 ± 61	260	429
Water Temperature (°C)	3	26.7 ± 1.0	25.5	28.0
Dissolved Oxygen (mg/L)	3	5.9 ± 0.5	5.2	6.2
pH	3	7.3 ± 0.0	7.3	7.3
Secchi Disk Transparency (m)	3	1.0 ± 0.48	0.5	1.5
Depth (m)	3	1.0 ± 0.48	0.5	1.5
E. coli Bacteria (CFU/100 mL)	0	--	--	--

*Site was sampled 3 times between 6/11/2013 and 8/13/2013.

Air and water temperature

Air temperature ranged from 27.5°C to 32°C. The mean water temperature was 26.7 °C, and ranged from 25.5°C to 28.0°C.

Total Dissolved Solids

The mean TDS value of this site was 334 mg/L. This was the highest mean TDS value for all of the sites in the watershed. The minimum TDS value was 260 mg/L and the maximum value was 429 mg/L.

Dissolved Oxygen

The mean DO value was 5.9 mg/L for this site. Dissolved oxygen varied from 5.2 mg/L to 6.2 mg/L.

pH

The mean pH was 7.3 and was tied for the highest mean pH of the sites in the watershed. All 3 sampling events had a pH of 7.3.

Secchi disk and total depth

The mean total depth was 1.0 m for this site. In all 3 sampling events, the Secchi disk depth was recorded as greater than the total depth indicating that the water clarity was visible to the creek bottom.

Field Observations

The flow was reported as normal for 2 events and high for one event which occurred on the day that the area received 4 inches of precipitation. Algae cover was reported as common, meaning that the area had 26 – 50% algae covering. The water color was recorded as no color to a light green color. Water clarity was clear except for the day of the rain event when it was recorded as cloudy. The water had no detectable odor, except for the day of the rain event when it was recorded as having a fishy smell.

Get Involved with Texas Stream Team!

Once trained, citizen monitors can directly participate in monitoring by communicating their data to various stakeholders. Some options include: participating in the Clean Rivers Program (CRP) Steering Committee Process, providing information during "public comment" periods, attending city council and advisory panel meetings, developing relations with local Texas Commission on Environmental Quality (TCEQ) and river authority water specialists, and, if necessary, filing complaints with environmental agencies, contacting elected representatives and media, or starting organized local efforts to address areas of concern.

The Texas Clean Rivers Act established a way for the citizens of Texas to participate in building the foundation for effective statewide watershed planning activities. Each CRP partner agency has established a steering committee to set priorities within its basin. These committees bring together the diverse stakeholder interests in each basin and watershed. Steering committee participants include representatives from the public, government, industry, business, agriculture, and environmental groups. The steering committee is designed to allow local concerns to be addressed and regional solutions to be formulated. For more information about participating in these steering committee meetings, please contact the appropriate CRP partner agency for your river basin at: http://www.tceq.state.tx.us/compliance/monitoring/crp/partners.html.

Currently, Texas Stream Team is working with various public and private organizations to facilitate data and information sharing. One component of this process includes interacting with watershed stakeholders at CRP steering committee meetings. A major function of these meetings is to discuss water quality issues and to obtain input from the general public. While participation in this process may not bring about instantaneous results, it is a great place to begin making institutional connections and to learn how to become involved in the assessment and protection system that Texas agencies use to keep water resources healthy and sustainable.

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Appendix A- List of Maps, Tables, and Figures

Maps

Tables

Figures