SHOAL CREEK WATERSHED DATA REPORT

March 2022

The Meadows Center for Water and the Environment
Texas State University
Texas Stream Team

Photo credit: Shoal Creek Conservancy

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The rising STAR of Texas

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ACKNOWLEDGEMENTS

The Texas Stream Team encourages life-long learning about the environment and people's relationship to the environment through its multidisciplinary citizen science programs. We also provide hands-on opportunities for Texas State University students and inspire future careers and studies in natural resource related fields. Preparation of this report fulfills a contract deliverable for the granting entity, but it also serves as a valuable educational experience for the students that assisted in preparing the report. The Texas Stream Team staff values the student contributions and recognizes each individual for their role. The following staff and student workers assisted in the preparation of this report and are acknowledged for their contributions:

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INTRODUCTION

Texas Stream Team

Texas Stream Team is a volunteer-based citizen science water quality monitoring program. Citizen scientist water quality monitoring occurs at predetermined monitoring sites, at approximately the same time of day each month. Information collected by Texas Stream Team citizen scientists is covered by a TCEQ-approved Quality Assurance Project Plan (QAPP) to ensure that a standard set of methods are used. The citizen scientist data may be used to identify surface 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 scientist data are not used by the state to assess whether water bodies are meeting the designated surface water quality standards. The data collected by Texas Stream Team provide valuable records, often collected in portions of a water body that professionals are not able to monitor frequently or monitor at all.

For additional information about water quality monitoring methods and procedures, including the differences between professional and volunteer citizen science monitoring, please refer to the following sources:

- Texas Stream Team Core Water Quality Citizen Scientist Manual
- Texas Stream Team Advanced Water Quality Citizen Scientist Manual
- Texas Stream Team Program Volunteer Water Quality Monitoring Program Quality Assurance Project Plan
- Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures

The purpose of this report is to provide a summary of the 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 for a holistic view of water quality in the Shoal Creek Watershed. Such sources may include, but are not limited to, the following:

- Texas Surface Water Quality Standards
- Texas Water Quality Inventory and 303(d) List (Integrated Report)
- Texas Clean Rivers Program partner reports, such as Basin Summary 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

To get involved with Texas Stream Team or for questions regarding this watershed data report contact us at TxStreamTeam@txstate.edu or at (512) 245-1346. Visit our website for more information on our programs at www.TexasStreamTeam.org.

WATERSHED DESCRIPTION

Location and Climate

Shoal Creek is an urbanized stream whose 13-square-mile watershed, the Town Lake-Colorado River Watershed, lies within Austin, Texas, in Travis County (Figure 1). The urban stream extends for 11 miles from northwest Austin through the center of the city to its confluence with Lady Bird Lake. This area is important locally for aesthetics, recreation, and for the ecosystem it supports. For the purposes of this report, the Town Lake-Colorado River Watershed will be referred to as the Shoal Creek Watershed throughout.

Shoal Creek provides ecosystem services that include storm drainage, flood control, habitat for native species, and recreational outdoor activities. The hike and bike trails located along its banks are a popular outdoor recreation destination for residents and visitors alike. The Creek is also used for educational purposes by the Shoal Creek Conservancy, a local nonprofit and steward of the natural environment whose goals are to create a healthy and vibrant community.

The TCEQ designates classifications for freshwater stream segments in the Shoal Creek Watershed. Shoal Creek (Segment ID 1429A) is an unclassified freshwater stream that extends from the confluence of Town Lake to the upstream perennial portion of the Creek. Spicewood Tributary (Segment 1403J) is in north Austin west of the MoPac Expressway and is also an unclassified freshwater stream. Another tributary of Shoal Creek is Hancock Branch located in the central part of the watershed, but it does not have a designated classification.

National Oceanic and Atmospheric Administration (NOAA) climate data from a weather station at Camp-Mabry in Austin, Texas, was acquired from the National Data Center (NOAA, 2020). Precipitation at Camp-Mabry averaged 36.25 inches annually and occurred year-round (Figure 2). Long-term monthly average precipitation has a bimodal distribution with peaks occurring in May and October. Average rainfall during these months was 5.0 and 3.9 inches each month, respectively. The least amount of rainfall (1.89 inches) occurred in February. The warmest and coldest months of the year were August (30.3°C) and January (11.2°C), respectively.

Physical Description

Shoal Creek lies above the northern segment of the Edwards Aquifer within the Shoal Creek Watershed and within the larger Colorado River Basin. It is located along the Balcones Escarpment which bisects the Edwards Plateau to the west from the Blackland Prairie to the east and is a sensitive aquifer recharge zone due to its natural karst geology. This area contains numerous springs and natural seeps, but two notable springs are the Seiders Spring and Spicewood Spring. The terrain in this area is generally flat with occasional steep slopes. The banks of Shoal Creek consist of sandy loam soils that are covered with grasses and trees such as pecans, oak trees, and junipers.

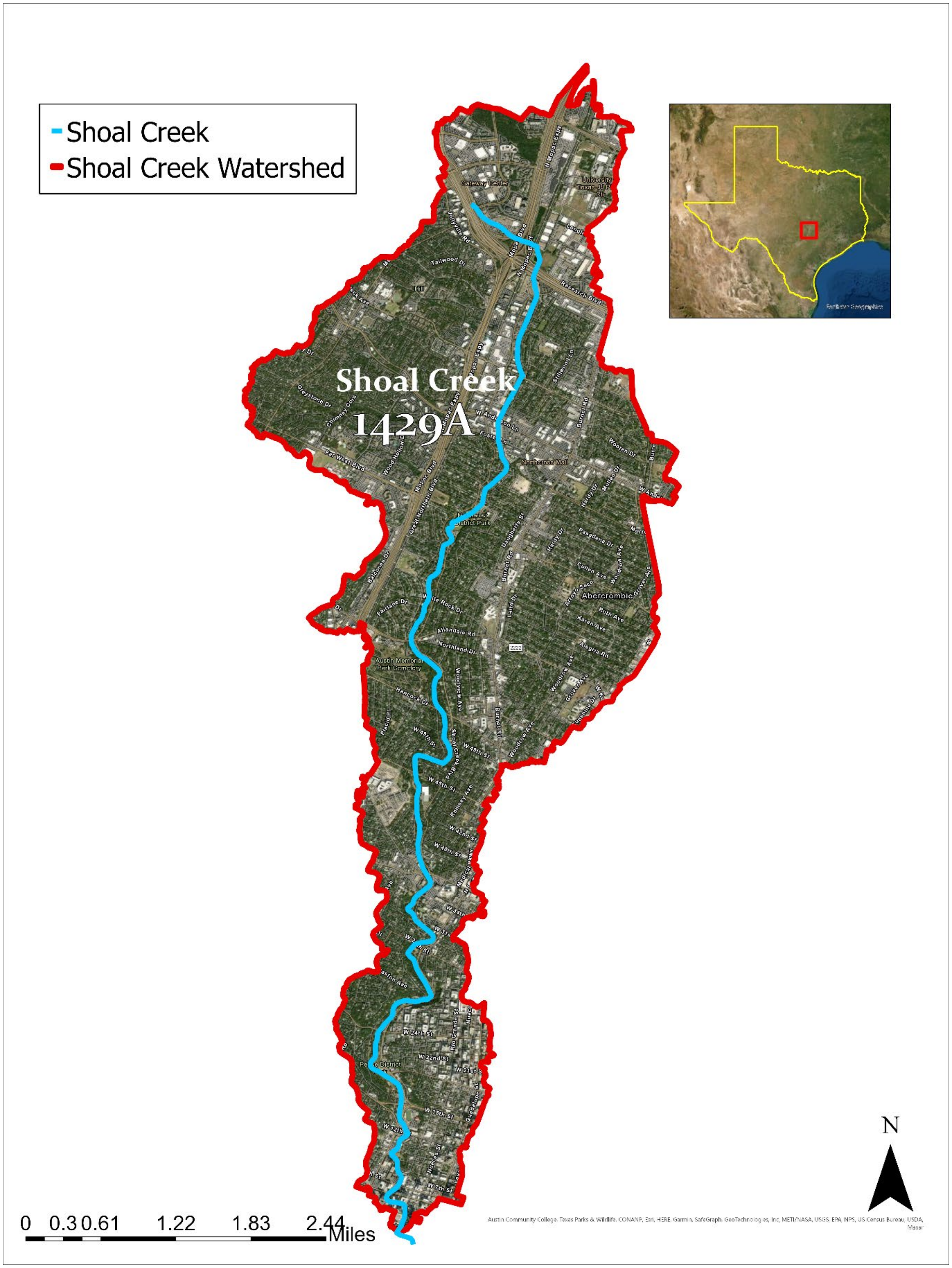

Figure 1. Shoal Creek within the Shoal Creek Watershed in Travis County.

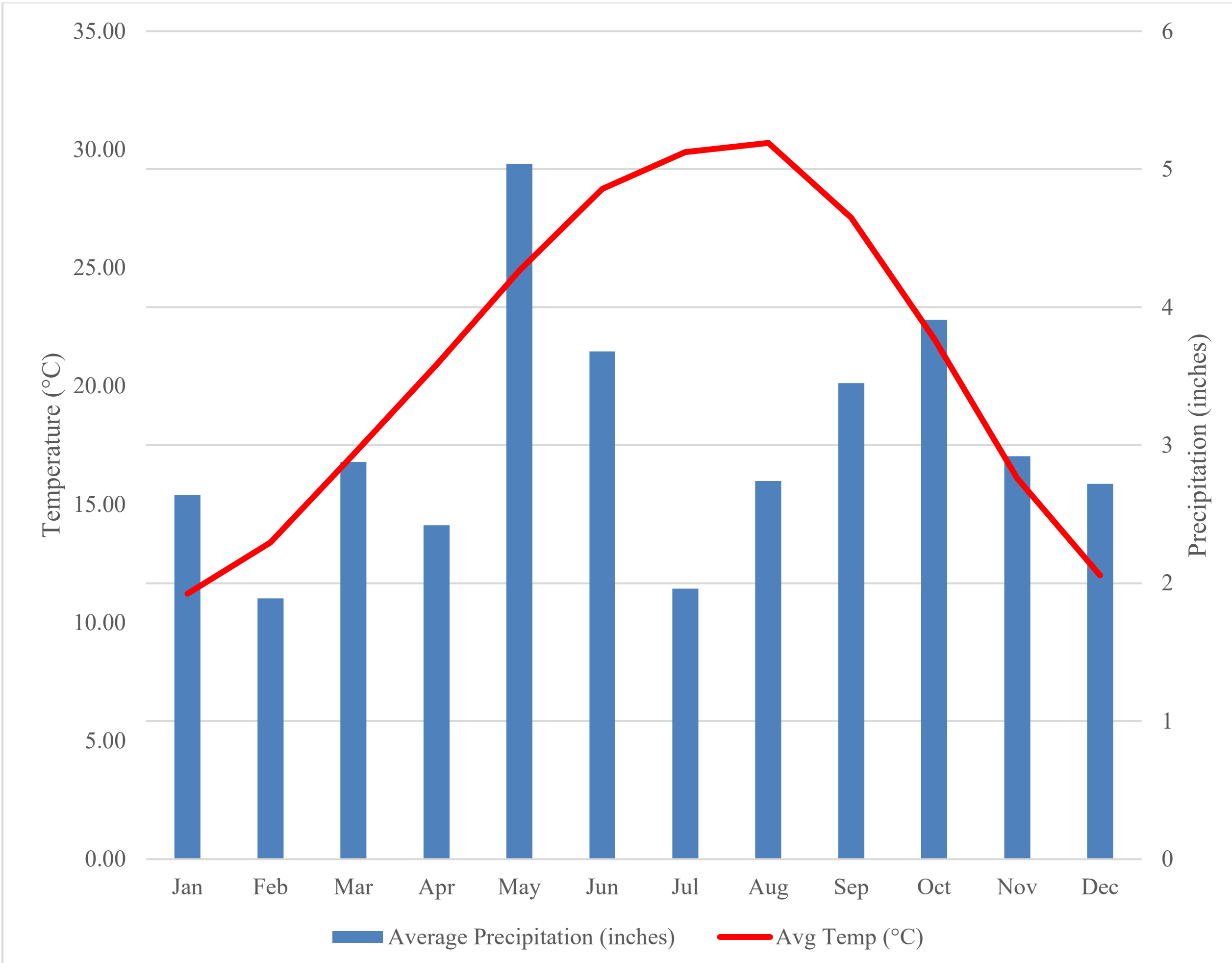

Figure 2. Long-term (1991-2020) monthly average precipitation (in) and air temperature (°C) from Camp -Mabry in Austin, Texas (NOAA Climate Data, 2020).

Land Use

Land cover types were identified and mapped for the Shoal Creek Watershed (Figure 3) (NLCD, 2016). The watershed predominantly consists of developed land cover, therefore supporting the urban nature of this watershed. The Shoal Creek Characterization Report (2019) identified the percent land use types (Table 1). They determined that only 5% of the watershed remains undeveloped/open space, while the remaining 95% is developed (SCC, 2019).

Developed land use is predominantly comprised of single-family dwellings (35%) and commercial businesses (28%) which results in a high percentage of impervious cover or surfaces that prevent infiltration of water into the ground (SCC, 2021). High impervious cover often results in increased flooding and erosion and degraded water quality. Shoal Creek generally has low base flow and no permitted domestic wastewater discharges but is heavily influenced by nonpoint source pollution from stormwater runoff due to the high impervious cover.

History

Shoal Creek has been a significant landmark in the history of Texas for many years. It has been a popular fishing and swimming hole for Austinites going back to as early as 1839 (Anonymous, 2022). In the late 1800s, the Creek served to demarcate the western boundary of the present-day City of Austin (SCC, 2021). It's also been noted that Native Americans inhabited this area some 11,400 years ago and the Comanche defied settlements in the area to retain access to Shoal Creek (SCC, 2021). Today the Shoal Creek Watershed is 95% developed and has been identified as having the 10th highest population density in the City of Austin with a population of 72,000 (SCC, 2021).

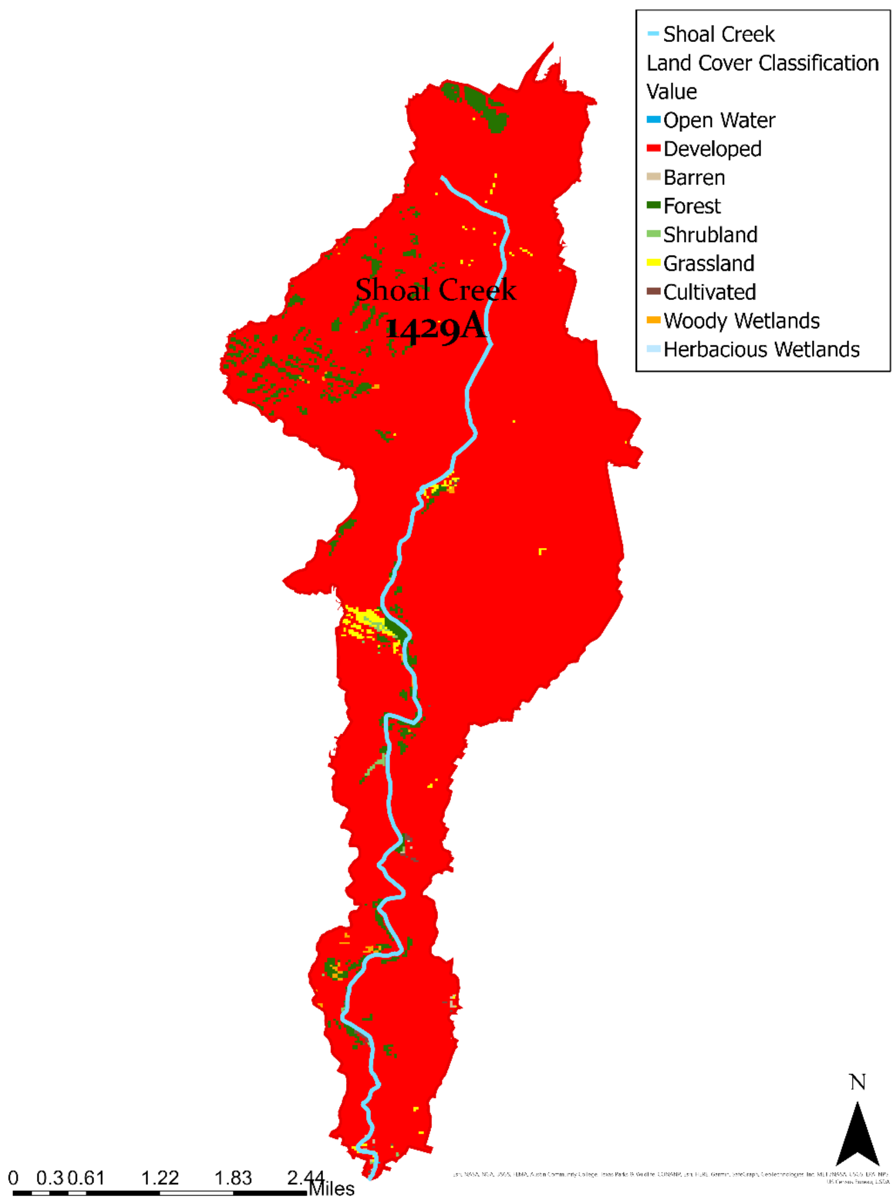

Figure 3. Land cover for the Shoal Creek Watershed in Travis County (NLCD, 2016).

Table 1. Land use in the Shoal Creek Watershed in Travis County (SCC, 2019).

Land Use	Percentage
Undeveloped	1
Open Space	4
Transportation	24
Commercial	28
Multifamily	8
Single Family	35
TOTAL	100

Endangered Species and Conservation Needs

The common names of 21 species listed as threatened or endangered (under the authority of Texas state law and/or under the US Endangered Species Act) within the Shoal Creek area are included in Appendix I at the end of this report. A summary of the number of species per taxonomic group listed as state or federally endangered, threatened, G1 or G2 (critically imperiled or imperiled), species of greatest conservation need, and/or endemic are provided in Table 2.

Table 2. State and Federally Listed Species in the Shoal Creek Watershed in Travis County.

Taxon	Endangered (Federal or State)	Threatened (Federal or State)	G1 or G2 (Critically Imperiled or Imperiled)	Species of Greatest Conservation Need (TPWD) (S1 or S2)	Endemic Total Count
Amphibians	2	1	4	4	4
Birds	2	6	2	10	0
Mammals	0	0	1	5	1
Reptiles	0	1	0	3	3
Crustaceans	0	0	3	2	3
Insects	2	0	9	8	7
Arachnids	4	0	15	15	14
Mollusks	0	3	7	7	6
Plants	0	0	3	9	24
Total Count	10	11	44	63	62

Texas 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 to support public health and protect 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 (drinking water). The criteria for evaluating support of those uses in the unclassified segments of Shoal Creek (Segment ID 1429A) and Spicewood Tributary (Segment 1403J) included in this report are provided in Table 3. The TCEQ Water Quality Standards (2018) state that for unclassified segments, generally "…there is not sufficient data on these waters to develop other conventional criteria and those criteria are the same as for the segment where the water body is located unless further site-specific information is obtained."

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.

Table 3. State water quality criteria in Shoal Creek and Spicewood Tributary within the Shoal Creek Watershed (TCEQ, 2018).

Segment	**Total Dissolved Solids (TDS) (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH Range (s.u.)**	***E. coli* Bacteria (#/100 mL)**	**Temperature (°C)**
1429A – Shoal Creek (General Use)	400	*Grab screening level: 2.0 Grab min.: 1.5	6.5-9.0	Primary Contact Recreation: 126 geometric mean, 399 single sample	32.2
1403J – Spicewood Tributary (General Use)	400	*Grab screening level: 2.0 Grab min.: 1.5	6.5-9.0	Primary Contact Recreation: 126 geometric mean, 399 single sample	32.2

*For intermittent streams where water is present in the streambed, a 24-hour dissolved oxygen mean of at least 2.0 mg/L and 24-hour minimum dissolved oxygen concentration of 1.5 mg/L must be maintained.

Water Quality Impairments

The 2020 Texas Water Quality Inventory and 303(d) List (Integrated Report) assessed the Spicewood Tributary and found bacteria water quality impairments for the primary contact recreation use. In 2015 Total Maximum Daily Loads (TMDL) were developed and adopted for a group of Austin area watersheds that included Spicewood Tributary to address the bacteria impairments. The Implementation Plan (IP) is currently being revised to extend implementation through 2023.

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. This effect is exacerbated in coastal water bodies influenced by tidal, saline waters.

Warm water temperatures occur naturally with seasonal variation, 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 discharge warm water. Citizen scientist monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases because of the monthly sampling frequency. While citizen scientist data may not show diurnal temperature fluctuations, they could demonstrate the fluctuations over seasons and years when collected consistently at predetermined monitoring sites and monthly frequencies.

Specific Conductance and Salinity

Salinity is a measure of the saltiness or the dissolved inorganic salt concentration in water. Salinity is often measured in ocean, estuarine or tidally-influenced waters, but in Texas there are some inland streams that have a high salt content due to the local geology and require salinity measurements. Some common ions measured as salinity include sodium, chloride, magnesium, sulfate, calcium, and potassium. Seawater typically has a salt content of 35 parts per thousand (ppt or ‰). Like other water quality parameters, salinity affects the homeostasis or the balance of water and solutes within both plants and animals. Too much or too little salt can affect plant and animal cell survival and growth, therefore salinity is an important measurement.

Specific conductance is a measure of the ability of a body of water to conduct electricity. It is measured in microsiemens per centimeter (µS/cm). A body of water is more conductive if it has more total dissolved solids (TDS) such as nutrients and salts, which indicates poor water quality if they are overly abundant. High concentrations of nutrients can lead to eutrophication, which results in lower levels of dissolved oxygen (DO). 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 TDS can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants.

Dissolved Oxygen (DO)

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 streamflow.

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 and algae growth, which may starve subsurface vegetation of sunlight and, therefore, reduce the amount of oxygen they produce via photosynthesis. This process is known as eutrophication. Low DO can also result from high groundwater inflows (which have low DO due to minimal aeration), high temperatures, or water releases from deeper portions of dams where DO stratification occurs. Supersaturation typically occurs underneath waterfalls or dams with water flowing over the top where aeration is abundant.

pH

The pH scale measures the concentration of hydrogen ions on a range from zero to 14 and is reported in standard units (s.u.). The pH of water can provide information regarding acidity or alkalinity. The range is logarithmic; therefore, every one-unit change is representative of a 10-fold increase or decrease in acidity or alkalinity. Acidic sources, indicated by a low pH level, can include acid rain and runoff from acid-laden soils. Acid rain is predominantly caused by coal powered 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. A suitable pH range for healthy organisms is between 6.5 and 9.0 s.u.

Water Transparency and Total Depth

Two instruments can be used by Texas Stream Team Citizen scientists to measure water transparency, a Secchi disc or a transparency tube. Both instruments are used to measure water transparency or to determine the clarity of the water, a condition known as turbidity. The Secchi disc is lowered into the water until it is no longer visible, then raised until it becomes visible, and the average of the two depth measurements is recorded. A transparency tube is filled with sample water and water is released using the release valve until the black and white pattern at the bottom of the tube can be seen. The tube is marked with two-millimeter increments and is used to measure water transparency. Transparency measurements less than the total depth of the monitoring site are indicative of turbid water. Readings that are equal to total depth indicate clear water. 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 less 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 result from sediment runoff from construction sites, erosion of farms, or mining operations.

E. coli and Enterococci Bacteria

E. coli bacteria originate in the digestive tract of endothermic organisms. The United States Environmental Protection Agency has determined *E. coli* to be the best indicator of the degree of pathogens in a freshwater system. A pathogen is a biological agent that causes disease.

Enterococci bacteria are a subgroup of fecal streptococci bacteria (mainly *Streptococcus faecalis* and *Streptococcus faecium*) that are present in the intestinal tracts and feces of warm-blooded animals. It is used by TCEQ as an indicator of the potential presence of pathogens in tidally-influenced saltwater along the Texas Gulf coast.

Shoal Creek and Spicewood Tributary are designated a primary contact recreation 1 (PCR1) use. This means that recreation activities on Shoal Creek are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, handfishing as defined by Texas Parks and Wildlife Code, §66.115, and the following whitewater activities: kayaking, canoeing, and rafting).

The standard for a bacteria impairment is based on the geometric mean (geomean) of the bacteria measurements collected. A geometric mean is a type of average that incorporates the high variability found in parameters such as *E. coli* and enterococci which can vary from zero to tens of thousands of colony forming units per 100 milliliters (CFU/100 mL). The standard for contact recreational use of a water body is 126 CFU/100 mL for *E. coli* in freshwater or 35

CFU/100 mL for enterococci in saltwater. A water body is considered impaired if the geometric mean is higher than the corresponding water quality standard.

Texas Stream Team does not monitor water quality for enterococci in coastal waters, instead citizen scientists can get certified in *E. coli* bacteria monitoring, the indicator used by TCEQ for freshwater streams.

Orthophosphate

Orthophosphate is the phosphate molecule all by itself. Phosphorus almost always exists in the natural environment as phosphate, which continually cycles through the ecosystem as a nutrient necessary for the growth of most organisms. Testing for orthophosphate detects the amount of phosphate in the water itself, excluding the phosphate bound up in plant and animal tissue. There are other methods to retrieve the phosphate from the material to which it is bound, but they are too complicated and expensive to be conducted by citizen scientists. Testing for orthophosphate provides an idea of the degree of phosphate in a water body. It can be used for problem identification, which can be followed up with more detailed professional monitoring, if necessary. Phosphorus inputs into a water body may be caused by the weathering of soils and rocks, discharge from wastewater treatment plants, excessive fertilizer use, failing septic systems, livestock and pet waste, disturbed land areas, drained wetlands, water treatment, and some commercial cleaning products. The effect excess orthophosphate has on a water body is known as eutrophication and is described above in the “Dissolved Oxygen” section.

Nitrate-Nitrogen

Nitrogen is present in terrestrial or aquatic environments as nitrate-nitrogen, nitrites, and ammonia. Nitrate-nitrogen tests are conducted for maximum data compatibility with TCEQ and other partners. Just like phosphorus, nitrogen is a nutrient necessary for the growth of most living organisms. Nitrogen inputs into a water body may be from livestock and pet waste, excessive fertilizer use, failing septic systems, and industrial discharges that contain corrosion inhibitors. The effect excess nitrogen has on a water body is known as eutrophication and is described previously in the “Dissolved Oxygen” section. Nitrate-nitrogen dissolves more readily than orthophosphate, which tend to be attached to sediment, and, therefore, can serve as a better indicator of possible sewage or manure pollution during dry weather.

DATA COLLECTION, MANAGEMENT AND ANALYSIS

Data Collection

The field sampling procedures implemented by trained citizen scientists in the Shoal Creek Watershed are documented in the Colorado River Watch Network (CRWN) Water Quality Monitoring Manual (Ninth Edition). The CRWN is a partner of the Texas Stream Team and their protocols follow closely the Texas Stream Team Core Water Quality Citizen Scientist Manual and the Texas Stream Team Advanced Water Quality Citizen Scientist Manual. The sampling protocols of both CRWN and Texas Stream Team adhere closely to 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).

Procedures documented in CRWN and Texas Stream Team Water Quality Citizen Scientist Manuals 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 samples are collected and analyzed to detect whether contamination has occurred and to ensure data accuracy and precision.

Field sampling activities are documented on field data sheets. The following items are recorded for each field sampling event: station ID, location, sampling time, date, depth, sample collector's name/signature, group identification number, meter calibration information, and reagent expiration dates. Specific conductance values are converted to TDS using a conversion factor of 0.65 and are reported as mg/L.

For *E. coli* sampling events, station ID, location, sampling time, date, depth, sample collector's name/signature, incubation temperature, incubation duration, *E. coli* colony counts, dilution aliquot, field duplicates and blank, and media expiration dates are recorded.

Values for measured parameters are recorded. If reagents or media are expired, it is noted, and data are flagged and communicated to Texas Stream Team staff. Sampling is not permitted with expired reagents or bacteria media; the corresponding values will be flagged in the database and excluded from data reports. Detailed observational data recorded include 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 reporting and administrative purposes.

Data Management

The citizen scientists collect field data in the Shoal Creek Watershed and report the measurement results to CRWN. The CRWN data get uploaded to the Texas Stream Team Waterways Dataviewer. All data are reviewed to ensure they are representative of the samples analyzed and locations where measurements were made. The measurements and associated quality control data are also reviewed to ensure they conform to specified monitoring procedures and project specifications as stated in the approved QAPP.

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. Once entered, the data can be accessible through the online [Texas Stream Team Datamap.]

Data Analysis

Data were compiled, analyzed, summarized, and compared to state water quality standards and/or screening criteria to provide readers with a reference point for parameters that may be of concern. The state-wide, biennial assessment performed by TCEQ involves more stringent monitoring methods and oversight than those used by citizen scientists and staff in this report. The citizen scientist water quality monitoring data are not currently used in the TCEQ assessments mentioned above but are intended to inform stakeholders about general characteristics and assist professionals in identifying areas of potential concern to plan future monitoring efforts.

All data collected by citizen scientists from the watershed were exported from the Texas Stream Team database and grouped by site. Once compiled, data were sorted, summary statistics were generated and reviewed, and results were graphed in JMP Pro 14.0.0 (SAS Institute Inc., 2018) using standard methods. Best professional judgement was used to verify outliers. Statistically significant trends were analyzed further. Outlier box plots were prepared to provide a compact view of the distribution of the data for each parameter and site(s). The horizontal line within the box represents the median sample value, while the ends of the box represent the 25^{th} and 75^{th} quantiles or the interquartile range. The lines extending from each end of the box, or whiskers, are computed using the 25^{th}/75^{th} quartiles ± 1.5 x (interquartile range). Outliers are plotted as points outside the box plot.

DATA RESULTS

Water quality data from five Texas Stream Team monitoring sites on Shoal Creek were acquired for analysis (Figure 4). Trained citizen scientists conducted between 9 and 155 sampling events at each site, for a total of 268 monitoring events (Table 4). The period of record for the sampling events ranged from August 1995 to August 2021, with all sites experiencing temporal intermittent sampling.

Table 4. Texas Stream Team monitoring sites on Shoal Creek, Austin, Texas.

Site ID	Description	Number of Samples (n)	Period of Record
121	Shoal Creek at Northwest Park	66	2000-2012
448	Shoal Creek at Seiders Spring	19	2019-2021
80123	Shoal Creek below 35th Street	9	2001-2003, 2007
237	Shoal Creek below 34th Street	155	1999-2019
43	Shoal Creek at 4th Street	19	1995-1996, 1999-2000
TOTAL		268	

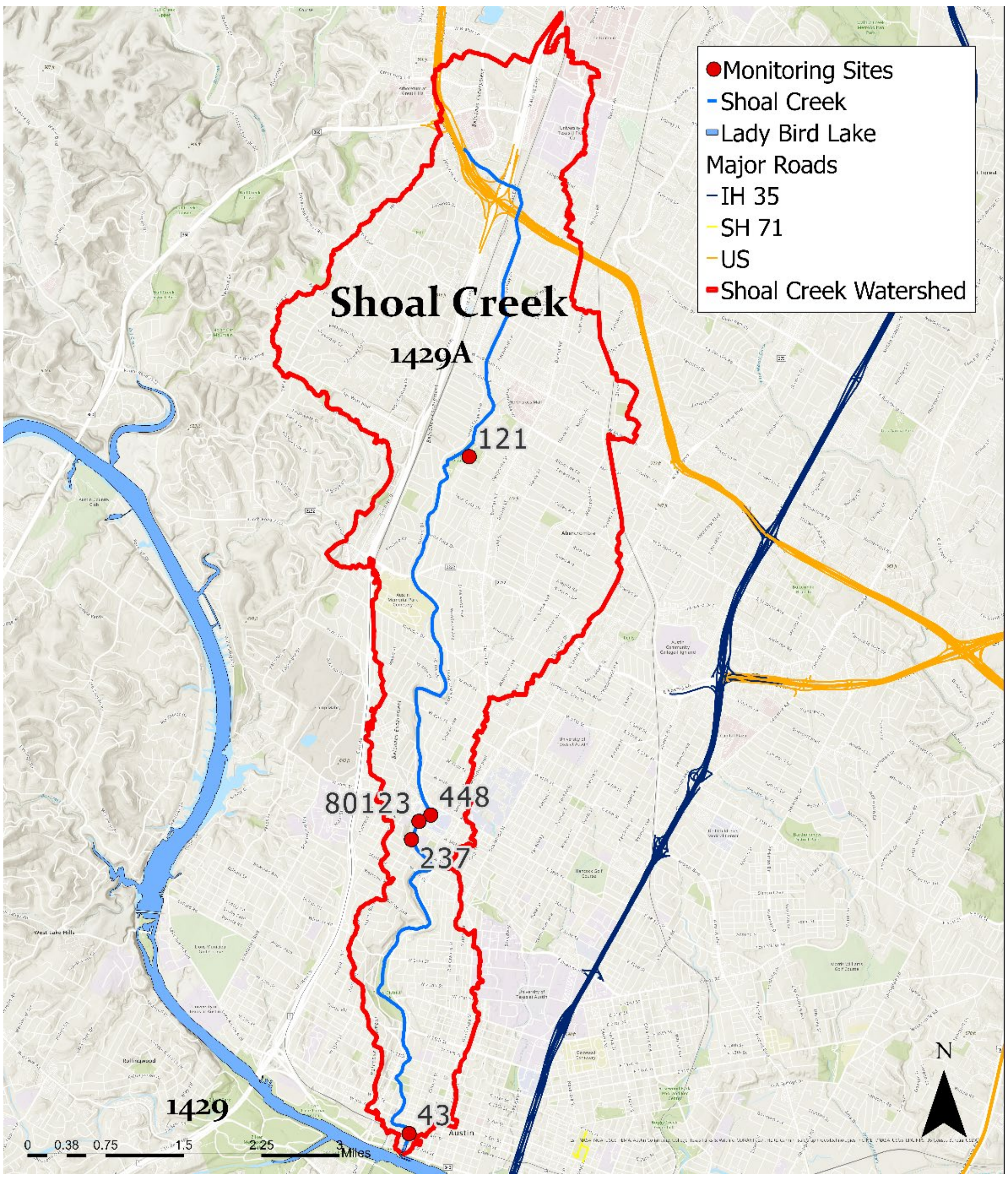

Figure 4. Texas Stream Team monitoring sites on Shoal Creek in the Shoal Creek Watershed.

Site Analysis

The period of record for data from Shoal Creek analyzed for this report intermittently spanned from August 1995 to August 2021. Data from 268 monitoring events conducted at five sites were acquired from the Waterways Dataviewer (Table 4). Water quality monitoring data for the five sites on Shoal Creek were analyzed and summarized including the number of samples, mean, standard deviation, and range of values (Table 5). Citizen scientists monitored the five sites for standard core and *E. coli* bacteria water quality monitoring parameters. The total number of sampling events for the Texas Stream Team standard core and *E. coli* bacteria water quality monitoring parameters (air and water temperature, conductivity, TDS, DO, pH, Secchi disc transparency, total depth, and *E. coli*) were mostly intermittent for the duration of the period of record.

Table 5. Texas Stream Team data summary for sites on Shoal Creek, Austin, Texas (Aug 1995-Aug 2021). Mean±SD (range).

Parameter	**NW Park ID 121 n=67**	**Seiders Spring ID 448 n=19**	**Below 35th St. ID 80123 n=9**	**Below 34th St. ID 237 n=155**	**4th St. ID 43 n=19**
Air Temp. (°C)	24.4±7.3 (35)	21.1±6.8 (23)	16.6±4.7 (15)	23.9±7.6 (39)	26.8±6.9 (25)
Water Temp. (°C)	22.0±6.7 (27)	19.7±5.6 (16)	15.2±4.6 (12.5)	22.2±7.1 (32)	23.6±6.7 (23)
Specific Conductance (µS/cm)	486±154 (740)	555±197 (600)	787±247 (640)	633±213 (960)	ND
***TDS (mg/L)**	316±100 (481)	360±128 (390)	511±161 (416)	412±139 (624)	ND
Dissolved Oxygen (mg/L)	8.3±3.1 (15.9)	4.6±2.2 (7.7)	4.7±2.1 (3.6)	8.3±2.6 (13.5)	4.8±4.4 (11.1)
pH (s.u.)	7.7±0.4 (2.1)	7.1±0.2 (0.5)	7.7±0.4 (1.2)	7.6±0.4 (2.9)	7.8±0.3 (0.9)
Secchi Tube Transp. (m)	1.0±0.3 (1.2)	1.0±0.2 (0.9)	ND	0.9±0.3 (1.2)	ND
Secchi Disc Transp. (m)	0.2±0.1 (0.3)	ND	0.7±ND (ND)	0.3±0.1 (0.3)	ND
Total Depth (m)	0.5±0.6 (3)	0.6±0.4 (1.7)	0.3±0.2 (0.6)	0.3±0.2 (0.9)	ND
*****E. coli* (CFU/100ml)**	97.7±177.2 (582.8)	ND	ND	263.9±1659.7 (7990.5)	541.1±2388.1 (7200)

*TDS was calculated from specific conductance (TDS = specific conductance * 0.65)

**Geometric means were calculated for *E. coli*.

ND = no data available

Air and Water Temperature

Average air temperature for all sites ranged from 16.6 to 26.8 °C (Table 5). The lowest mean air temperature (16.6 °C) was observed at the site located below 35th Street (Site 80123). The highest mean air temperature (26.8 °C) was observed at the 4th Street site (Site 43). The distribution of air and water temperature for each site for the entire period of record are displayed from upstream to downstream in Figure 5.

Water temperatures were predominantly below the water quality standard (WQS) at most sites with an occasional exceedance (Figure 5). Average water temperature for all sites ranged from 15.2 °C at the site below 35th Street (Site 80123) to 23.6 °C at the 4th Street site (Site 43) (Table 5). The distribution of water temperatures for each site from upstream to downstream are displayed in Figure 5.

Specific Conductance and Total Dissolved Solids (TDS)

Specific conductance measurements were converted to TDS for all sites with data (Table 5). Average TDS values at two sites, the site below 35th Street (Site 80123) and the site below 34th Street (Site 237), met and exceeded the water quality standard (400 mg/L), while the other two sites, the NW Park (Site 121) and Seiders Spring (Site 448), did not. The range of TDS values for all sites was from 316 to 511 mg/L (Table 5). The distribution of TDS measurements by site are displayed in Figure 6.

Dissolved Oxygen

Average DO values at all five sites were above the screening water quality standard of 2.0 mg/L (Table 5). The range of average DO values for all sites spanned from 4.6 to 8.3 mg/L. The distribution of DO measurements for each site are displayed in Figure 7. Individual dissolved oxygen values extended below the grab minimum water quality standard (1.5 mg/L) at three sites (Sites 121, 448, and 43) during the period of record evaluated, but all had averages at or above the screening water quality standard (2.0 mg/L).

pH

The pH values at all sites were within the water quality standard of 6.5 to 9.0 s.u. (Figure 8). Average pH for all sites ranged from 7.1 to 7.8 s.u. (Table 5).

Transparency and Total Depth

Secchi tubes and discs were used for measuring transparency at the sites monitored on Shoal Creek (Table 5). The average Secchi tube transparency values reported at three sites (121, 448, and 237) where this parameter was measured ranged from 0.9 to 1.0 m. A 120 cm long transparency tube was used for these measurements; therefore, the average water transparency was less than the total length of the tube.

The average range of Secchi disc transparency values reported was from 0.2 to 0.7 m (Table 5). The largest measurement, or most transparent, was the site below 35th Street (Site 80123). The smallest measurement, or least transparent, was NW Park site (Site 121) (Table 5).

Total depth was measured at four of the five sites monitored (Table 5). The deepest site was at Seiders Spring (Site 448), while the shallowest sites were at the below 34th and 35th Street sites (237 and 80123).

E. coli

E. coli bacteria was measured and reported at three of the five sites included in this report (Table 5). The *E. coli* geometric mean was calculated for the entire period of record for each site. The NW Park site (97.7 cfu/100 ml) was below the WQS (126 cfu/100 ml), while the other two sites, below 34th Street (263.9 cfu/100 ml) and 4th Street (541.1 cfu/100 ml), exceeded the WQS (Table 5). The distribution of *E. coli* values by site are displayed in Figure 10.

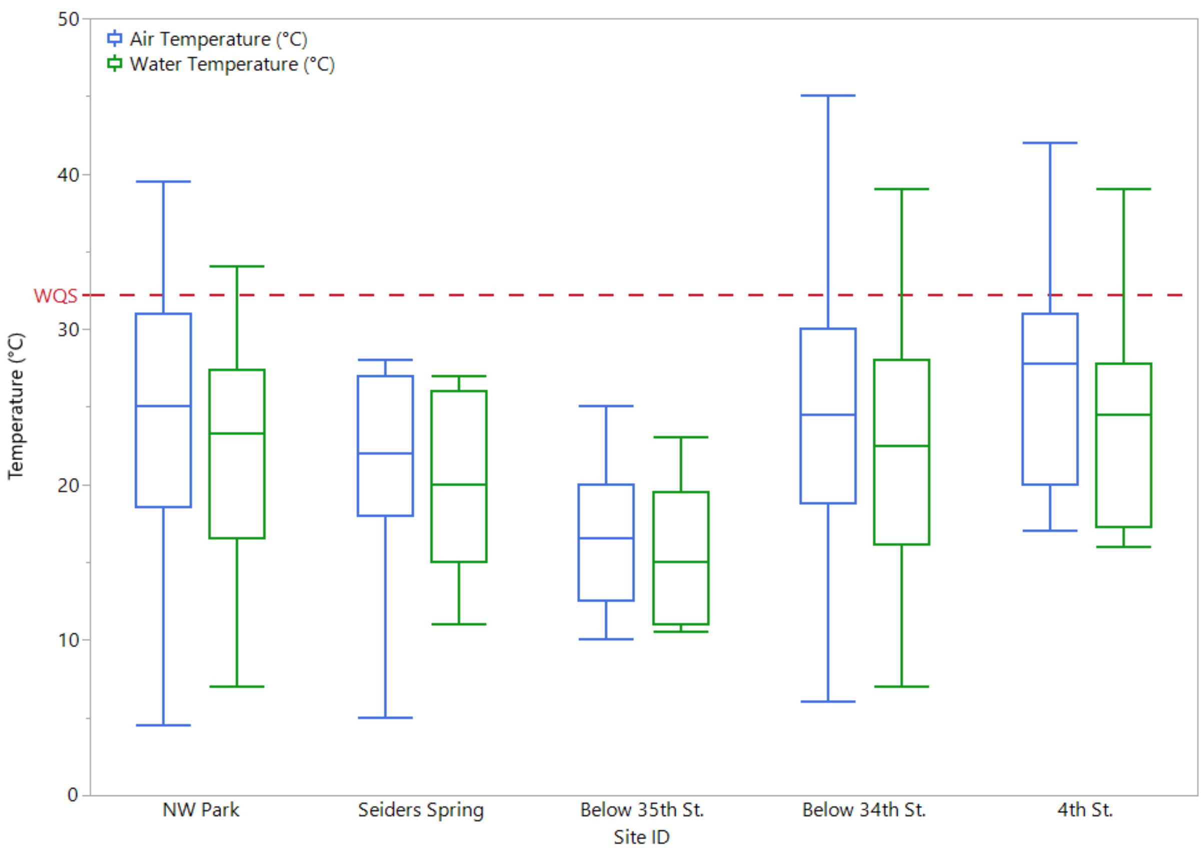

Figure 5. Air and water temperature for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

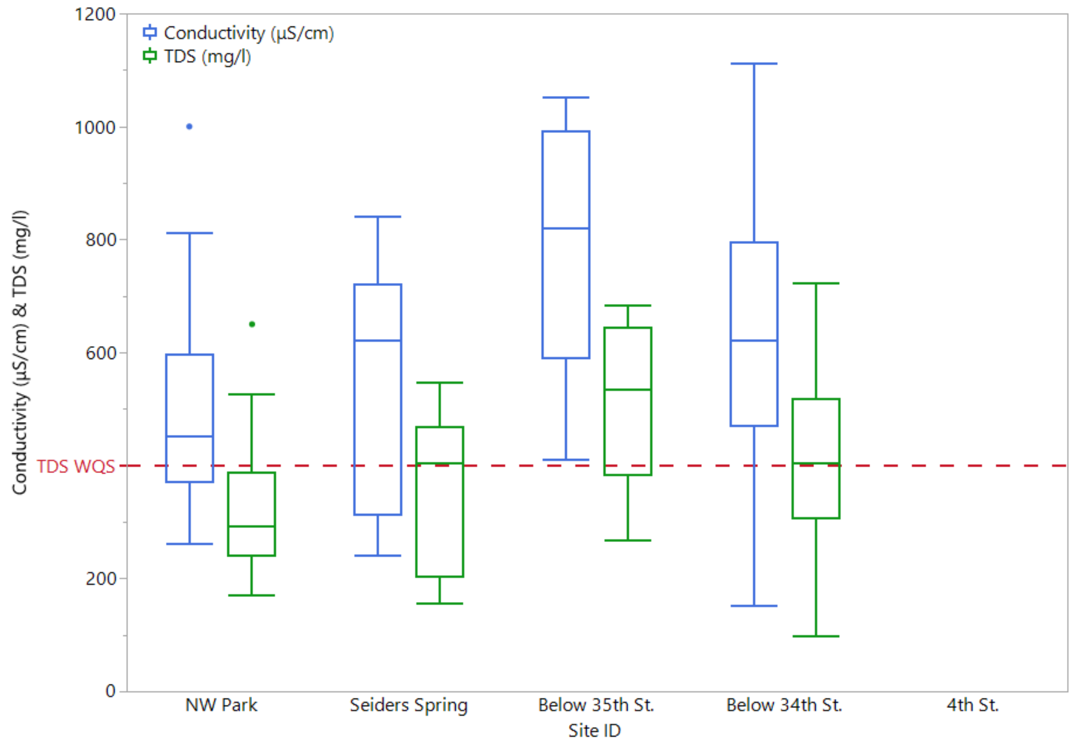

Figure 6. Conductivity (µS/cm) and total dissolved solids (TDS) (mg/L) for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

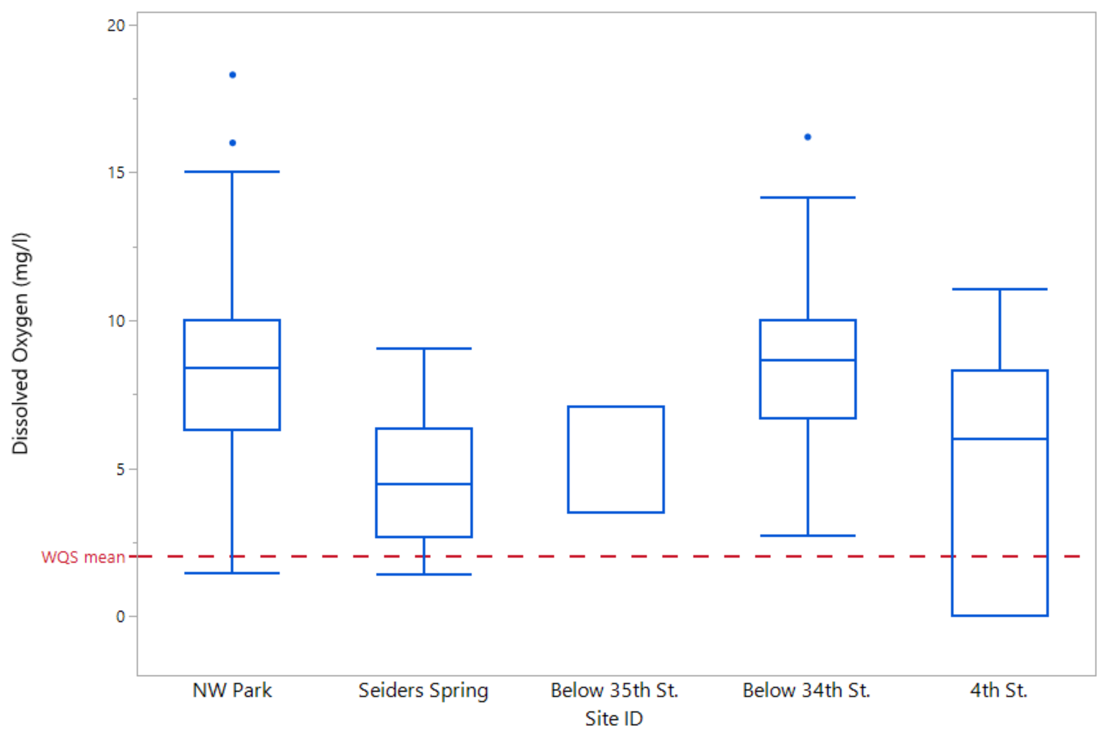

Figure 7. Dissolved oxygen (mg/L) for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

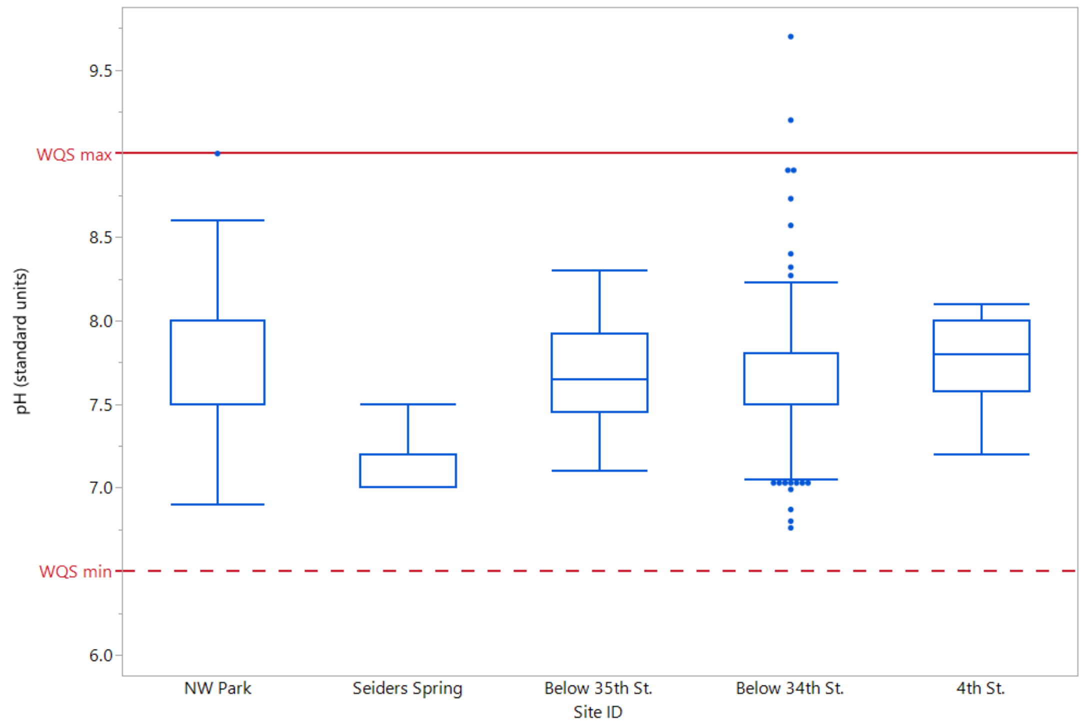

Figure 8. pH (s.u.) for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

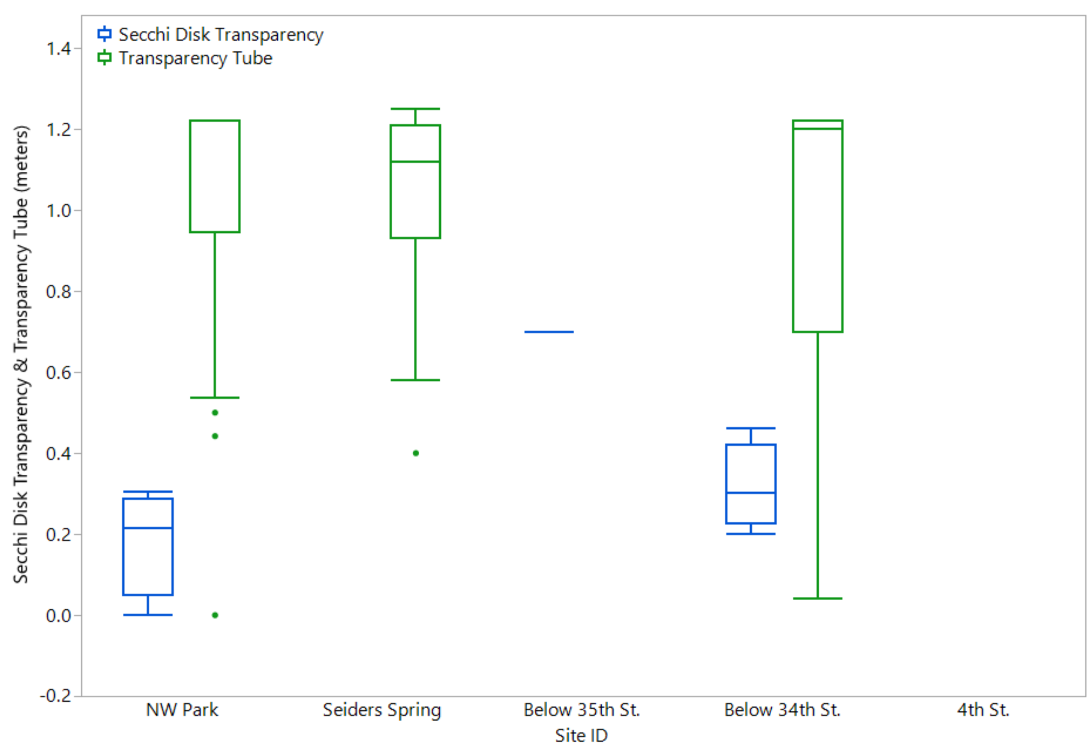

Figure 9. Secchi disc and transparency tube measurements for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

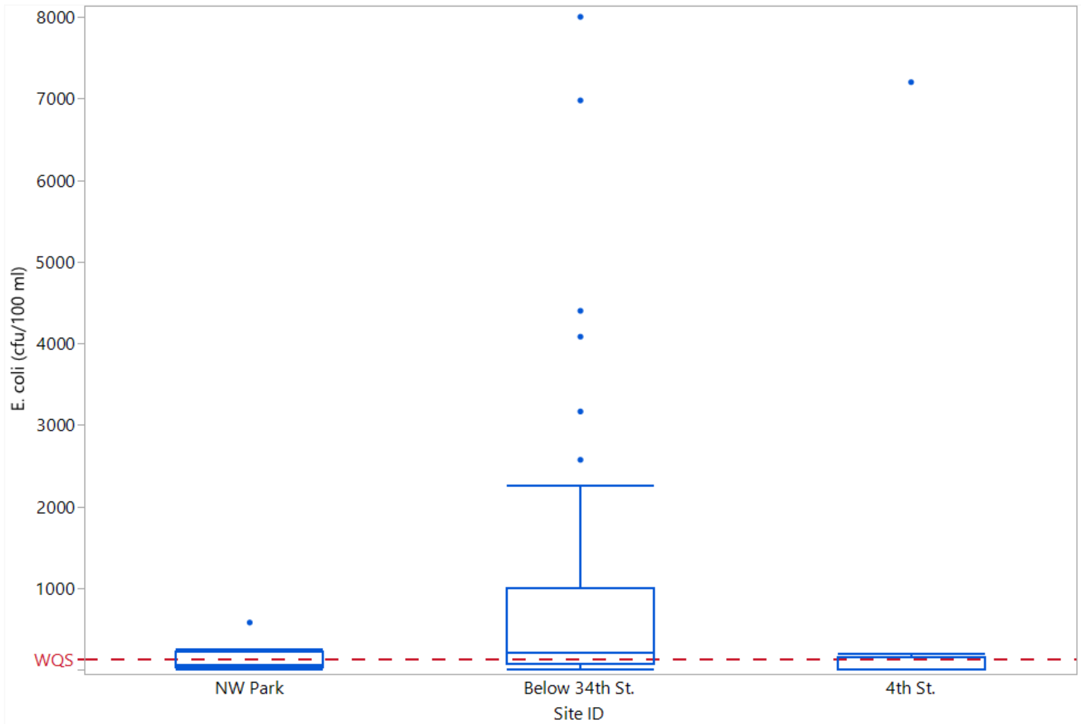

Figure 10. *E. coli* bacteria (CFU/100 ml) for Texas Stream Team sites on Shoal Creek in Austin, Texas (Aug 1995 - Aug 2021).

WATERSHED SUMMARY

Texas Stream Team citizen scientists monitored standard core water quality parameters and *E. coli* bacteria at five sites in the Shoal Creek Watershed from August 1995 to August 2021. All five sites were located on Shoal Creek. Parameters monitored included water and air temperature, specific conductance, total dissolved solids, dissolved oxygen, pH, transparency, total depth, and *E. coli* bacteria. Monitoring for the Advanced Texas Stream Team parameters nitrate-nitrogen and orthophosphate did not take place consistently on Shoal Creek during the period of record. There were eight nitrate-nitrogen measurements in the database ranging from 1 to 8 mg/l, but no orthophosphate measurements. Data from the five monitoring sites were analyzed and summarized in this report.

Water quality standards and criteria for water temperature, DO, and pH were met at all sites monitored on Shoal Creek, while some WQS exceedances were identified for TDS and *E. coli* bacteria. These results coincide with findings in the Shoal Creek Watershed Action Plan (2021) and Characterization Report (2019) and are likely a result of urban runoff, dog and wildlife waste, and City of Austin and private wastewater leakage. Although the WQS for DO was met at all sites, some values exceeded the grab minimum water quality standard.

Although the Spicewood Tributary (Segment 1403J) within the study area is on the 2020 303(d) list of impaired waters for not meeting the *E. coli* bacteria standard for the contact recreation use, unfortunately no Texas Stream Team monitoring occurred on that reach.

The Texas Stream Team citizen scientists monitoring standard core and *E. coli* bacteria water quality parameters on Shoal Creek are encouraged to continue monitoring and consider pursuing the Advanced water quality monitoring trainings and certifications as well as expanding the monitoring to the Spicewood Tributary. Continuation of the ongoing monitoring is crucial due to the results presented here and the potential for increased development in the watershed. There is a need for water quality monitoring to continue for the development of long-term water quality data sets. The information gathered thus far has been useful to describe current water quality conditions. Continuation of this monitoring will allow future trend analysis to capture changes in water quality over time as the area grows. Texas Stream Team will continue to support current citizen scientists as needed by providing technical support, creating new monitoring sites, and re-activating existing sites. We look forward to training new citizen scientists to expand and grow the water quality monitoring efforts in this area and beyond. For more information about Texas Stream Team and upcoming trainings contact us at TxStreamTeam@txstate.edu or visit the calendar of events on our website at www.TexasStreamTeam.org.

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Appendix A.

Table 6. Endangered species located with the Shoal Creek Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	Barton Springs salamander	Federally Listed Endangered/ State Listed Endangered
Amphibians	Austin blind salamander	Federally Listed Endangered/ State Listed Endangered
Birds	Whooping crane	Federally Listed Endangered/ State Listed Endangered
Birds	Golden-cheeked warbler	Federally Listed Endangered/ State Listed Endangered
Insects	Tooth Cave ground beetle	Federally Listed Endangered
Insects	Kretschmarr Cave mold beetle	Federally Listed Endangered
Arachnids	Tooth Cave spider	Federally Listed Endangered
Arachnids	Reddell harvestman	Federally Listed Endangered
Arachnids	Bone Cave harvestman	Federally Listed Endangered
Arachnids	Tooth Cave pseudoscorpion	Federally Listed Endangered

Table 7. Threatened species located within the Shoal Creek Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	Jollyville Plateau salamander	Federally Listed as Threatened, State Listed as Threatened
Birds	White-faced ibis	State Listed as Threatened
Birds	Wood stork	State Listed as Threatened
Birds	Swallow-tailed kite	State Listed as Threatened
Birds	Zone-tailed hawk	State Listed as Threatened
Birds	Black Rail	Federally Listed as Threatened, State Listed as Threatened
Birds	Piping Plover	Federally Listed as Threatened, State Listed as Threatened
Reptiles	Texas horned lizard	State Listed as Threatened
Mollusks	Texas Fatmucket	State Listed as Threatened
Mollusks	Texas Pimpleback	State Listed as Threatened
Mollusks	Texas Fawnsfoot	State Listed as Threatened