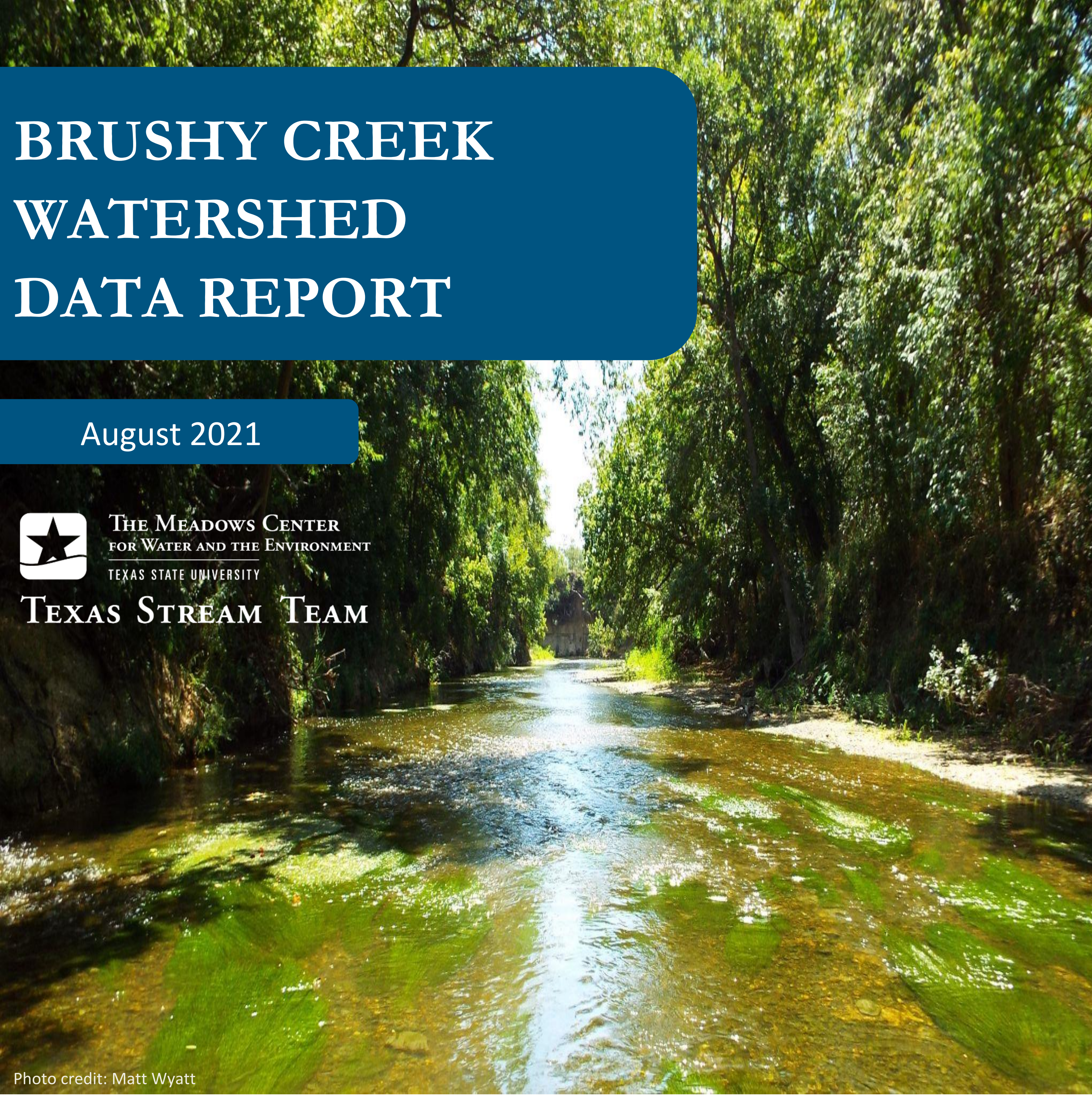
BRUSHY CREEK WATERSHED DATA REPORT

August 2021

The Meadows Center for Water and the Environment
Texas State University

Texas Stream Team



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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:

Sandra S. Arismendez, Water Quality Monitoring Coordinator
Desiree Jackson, Student Research Assistant
Aspen Navarro, Program Coordinator
Laura M. Parchman, GIS and Data Management Associate
Ally Schlandt, Student Research Assistant

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 Brushy 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

Brushy Creek traverses the central Texas Hill Country for approximately 69 miles from its headwaters near Leander in southwestern Williamson County until it reaches the San Gabriel River five miles north of Rockdale in Milam County (Anonymous, 2021). The upper reach of Brushy Creek is intermittent, but at its lower reach the creek is a major tributary of the San Gabriel River (Leatherwood, 2021). Brushy Creek flows through Williamson County, one of the fastest growing areas in the state that has experienced rapid urbanization in the last 25 years (BRA, 2017). The watershed spans some 520 square miles crossing both Williamson and Milam Counties and is part of the larger Brazos River Basin (Figure 1).

The TCEQ classifies freshwater stream segments in the Brushy Creek watershed. Brushy Creek is comprised of the classified mainstem (Segment 1244) and four unclassified tributaries including Brushy Creek above South Brushy Creek (1244A), Lake Creek (1244B), Mustang Creek (1244C), and South Brushy Creek (1244D). Brushy Creek and its tributaries are effluent dominant (BRA, 2017), drain to the San Gabriel River and are important features in flood control for Williamson County (Upper Brushy Creek WCID, 2021).

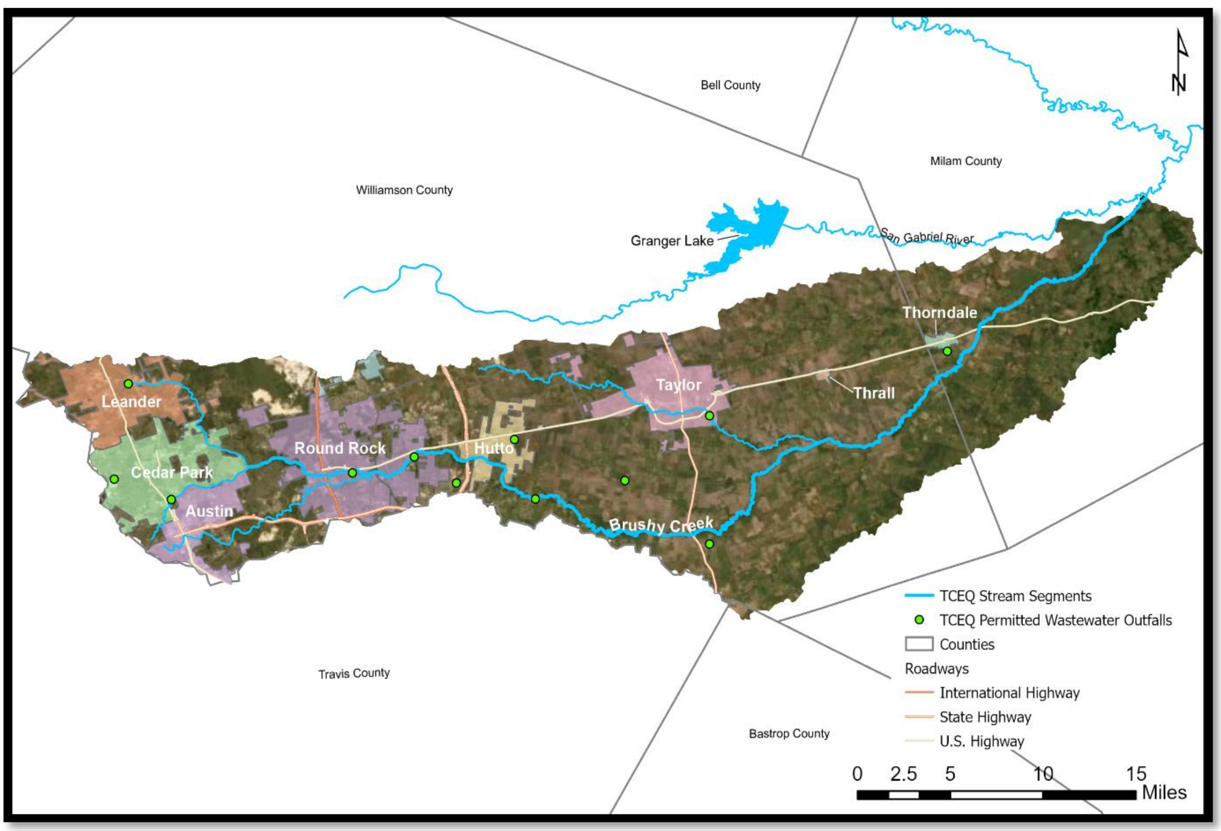


Figure 1. Brushy Creek Watershed in the Central Texas Hill Country.

National Oceanic and Atmospheric Administration (NOAA) climate data from a weather station in nearby Austin, Texas, was acquired from the National Data Center (NOAA, 2020). Precipitation in Austin averaged 37 inches annually and occurred year-round (Figure 2). Long-term monthly average precipitation has a bimodal distribution with peaks occurring in June and October. Average rainfall during these months was 4.4 and 4.6 inches per month, respectively. The least amount of rainfall (2.3 inches) occurred in August, which coincided with the warmest time of the year (29.1 °C).

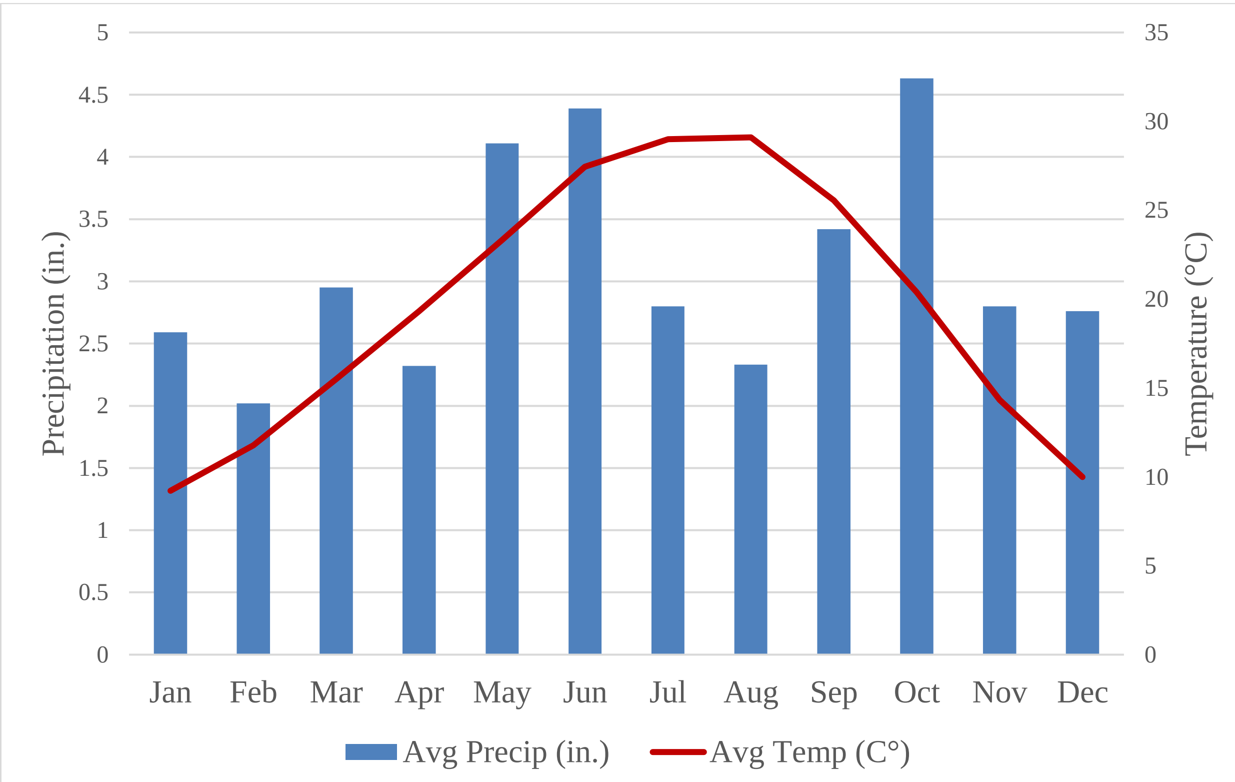


Figure 2. Long-term (1991-2020) monthly average precipitation (in) and air temperature (°C) from Austin, Texas (NOAA Climate Data, 2020).

Physical Description

Brushy Creek lies over the Edwards Aquifer within the Brazos River Basin and traverses the Edwards Backland Prairie and the Edwards Plateau Ecoregions (Guillen and Wrast, 2010). The Edwards Plateau ecoregion is characterized geomorphologically by a limestone plateau with a network of spring-fed streams. In this region of the Central Texas Hill Country, Brushy Creek is described as a predominantly effluent dominated stream due to the large number of permitted discharges into the creek. The climate in the Brushy Creek watershed is typically described as having hot and humid summers with milder winters (Guillen and Wrast, 2010). The stream is typically cool and clear due to the underlying karst topography. There are six parks adjacent to

Brushy Creek where it supports contact recreation activities such as swimming, kayaking, and fishing.

The landscape of this area, including both the land use and the vegetative cover, has been altered as a result of human activities. These activities include road construction, instream sewer lines, conversion of land for agriculture, and commercial and residential urbanization (Guillen and Wrast, 2010). Although predominantly urbanized, the watershed is also susceptible to cattle grazing and on-site septic facilities.

Land Use

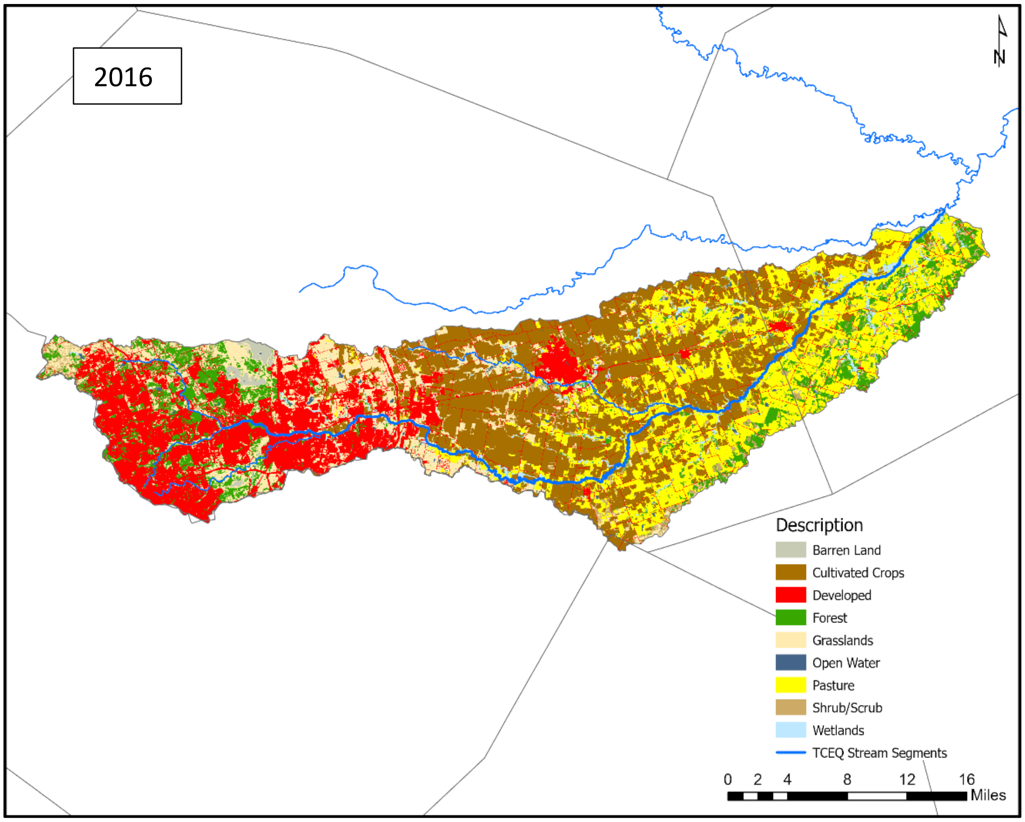
Land cover types were calculated for the Brushy Creek watershed in 2016 and 2019 (Figure 3) (NLCD, 2016 and 2019). The Brushy Creek watershed predominantly consists of cultivated crops, pastures, and developed land use types, with all other land use types, (i.e., open water, barren land, forest, shrub/scrub, grasslands, and wetlands) consisting of just over 10% combined (Table 1). Land cover change analysis resulted in losses of grasslands (-1.25%), cultivated crops (-0.54%), forest (-0.25%) and pastures (-0.20%), and gains in developed (1.85%), barren land (0.16%), shrub/scrub (0.13%), wetlands (0.09%) and open water (0.01%).

History

According to The Handbook of Texas, Brushy Creek was originally named Arroyo de las Animas Benditas, which translates into Creek of the Blessed Souls (Anonymous, 2021). In 1716, Spanish explorers Louis Juchereau de St. Denis and Domingo Ramon named Brushy Creek and since that time it has been known by variations of that name. Brushy Creek was the site of some of the earliest communities in Williamson County and the location of the battle of Brushy Creek in 1839 (Anonymous, 2021).

Table 1. Land use and land cover for Brushy Creek watershed (NLCD, 2016 and 2019).

Land Use (2016-2019)	Acreage 2016	Acreage 2019	Percent Change
Open Water	1,751.2	1,783.3	0.01
Developed	70,895.4	77,069.6	1.85
Barren Land	2,412.3	2,944.2	0.16
Forest	30,108.6	29,271.0	-0.25
Shrub/Scrub	11,184.4	11,611.6	0.13
Grasslands	38,232.0	34,088.7	-1.25
Pastures	74,394.1	73,731.7	-0.20
Cultivated Crops	94,289.4	92,503.5	-0.54
Wetlands	9,356.2	9,648.9	0.09
Total	332,623.6	332,652.5	0.0



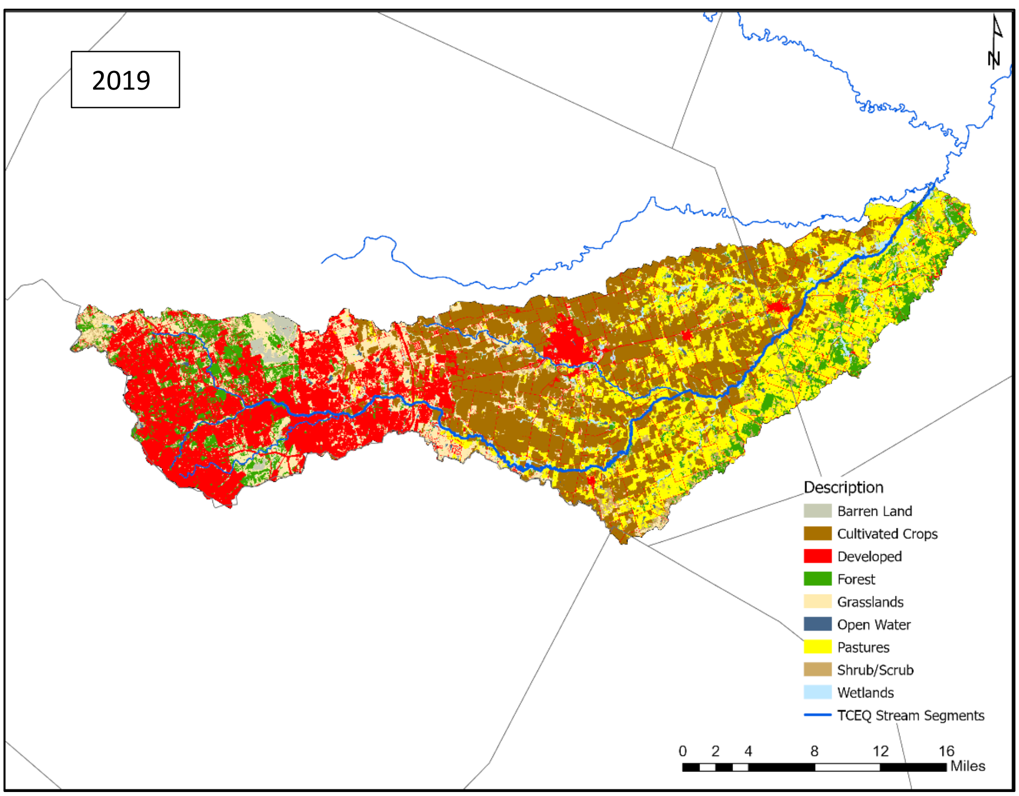


Figure 3. Land cover for the Brushy Creek watershed (NLCD, 2016 and 2019).

Endangered Species and Conservation Needs

The common names of 29 species listed as threatened or endangered (under the authority of Texas state law and/or under the US Endangered Species Act) within the Brushy Creek watershed 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 Brushy Creek Watershed (TPWD, 2020).

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
Amphibians	2	3	6	6	6	23
Birds	3	7	2	10	0	22
Fish	2	0	1	2	3	8
Mammals	0	0	1	4	1	6
Reptiles	0	1	0	4	3	8
Crustaceans	0	0	3	2	3	8
Insects	3	0	15	13	12	43
Arachnids	4	0	17	17	16	54
Mollusks	0	4	7	7	7	25
Plants	0	0	6	10	26	42
Total	14	15	58	75	77	239

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 Brushy Creek segments included in this report are provided in Table 3.

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 the Brushy 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)**
1244 - Brushy Creek (High Aquatic Life Use)	800	*Mean: 5.0 Min.: 3.0	6.5-9.0	Primary Contact Recreation: 126 geometric mean, 399 single sample	32.8

*The dissolved oxygen mean is applied as a minimum average over a 24-hour period. The 24-hour minimum is not to extend beyond eight hours per 24-hour day.

Water Quality Impairments

The 2020 Texas Water Quality Inventory and 303(d) List (Integrated Report) assessed Brushy Creek (Segment 1244) and found bacteria water quality impairments for the primary contact recreation use. Subsequently, no watershed protection plans have been prepared in the Brushy Creek watershed.

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 warmer water. Citizen scientist monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases because of the sampling frequency. While citizen scientist data do not show diurnal temperature fluctuations, they may 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 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 cubic centimeter (µS/cm3). 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 lower the level of dissolved oxygen (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 TDS can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants. Specific conductivity values are typically converted to TDS using a conversion factor of 0.65 and are reported as mg/L.

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 only occurs underneath waterfalls or dams with water flowing over the top.

pH

The pH scale measures the concentration of hydrogen ions on a range of 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 mostly 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 scientist 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 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 result from sediment washing away 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 saltwater along the Texas Gulf coast.

Brushy Creek is designated a primary contact recreation 1 (PCR1) use. This means that recreation activities on Brushy 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 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 under 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 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 are documented in the Texas Stream Team Core Water Quality Citizen Scientist Manual and the Texas Stream Team Advanced Water Quality Citizen Scientist Manual. The sampling protocols in both manuals 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 QAPP.

Procedures documented in 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.

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

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 all 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 and 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 and report the measurement results to Texas Stream Team, either by submitting a hard copy of the form or by entering the data directly to the online Waterways Dataviewer. All data are reviewed to ensure they are representative of the samples analyzed and locations where measurements were made, and the data and associated quality control data 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 screening criteria to provide readers with a reference point for parameters that may be of concern. The 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. R-squared is a statistical measure of how close the data are to the fitted regression line. Zero indicates that the model explains none of the variability of the response data around its mean. The p-value is the level of marginal significance within a statistical hypothesis test representing the probability of the occurrence of a given event. 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-precent. As the p-value decreases, the confidence that it simulates actual conditions in nature increases.

DATA RESULTS

Water quality data from three Texas Stream Team monitoring sites on Brushy Creek were acquired for analysis (Figure 4). All three sites are on the Brushy Creek mainstem (Segment 1244). Trained Texas Stream Team citizen scientists conducted between 41 and 13 sampling events at each site, for a total of 92 (Table 4). The period of record for the sampling events ranged from March 2012 to January 2021, with all sites experiencing temporal intermittent sampling.

Table 4. Brushy Creek watershed Texas Stream Team monitoring sites.

Site ID	Description	Number of Samples (n)	Period of Record
80622	Brushy Creek @Chisholm Trail Road	41	3/23/2012 – 2/20/2015, 2/23/2018 - 1/22/2021
12062	BRUSHY CREEK @ CR122	38	3/23/2012 – 2/20/2015 2/23/2018 - 1/22/2021
80771	BRUSHY CREEK @ CR123	13	11/15/2012 - 2/20/2015 2/23/2018 – 1/22/2021

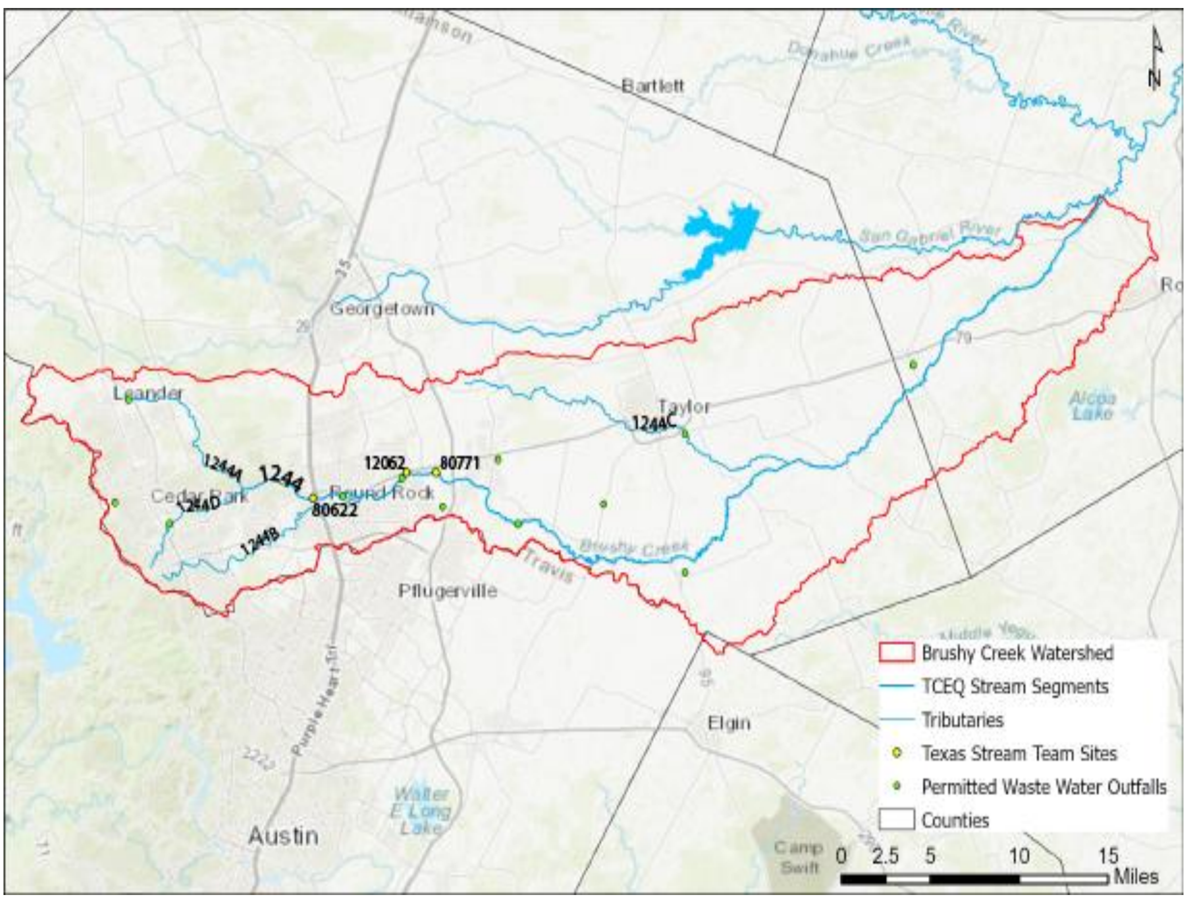


Figure 4. Brushy Creek watershed Texas Stream Team citizen scientist monitoring sites.

Site Analysis

The period of record for data analyzed for this report intermittently spanned from March 2012 to January 2021. Data from 92 monitoring events conducted at three sites were acquired from the Waterways Dataviewer (Table 4). Water quality monitoring data for the three sites in Brushy Creek were analyzed and summarized including the number of samples, mean, standard deviation, and range of values (Table 5). Citizen scientists monitored three 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*) remained somewhat consistent for the period of record.

Air and Water Temperature

Average air temperature for all sites ranged from 18.3 to 22.9 °C (Table 5). The lower overall mean air temperature (18.3 °C) was observed at the Chisholm Trail Rd. site (80622) in the upper reach of Brushy Creek. The higher mean air temperature (22.9 °C) was observed at the most downstream site at CR123 (80771). The distribution of air temperatures for each site are displayed in Figure 5 from upstream to downstream with the highest median temperature reported at the CR123 site (80771) and the lowest median temperature reported at Chisholm Trail Rd. (80622).

Water temperatures at all sites were well below the water quality standard (WQS) of 32.8 °C (Figure 5). Average water temperature for all three sites ranged from 18.9 °C at the Chisholm Trail Rd. site (80622) to 21.4 °C at the CR123 site (80771) (Table 5). The distribution of water temperatures for each site are displayed in Figure 5 from upstream to downstream.

Specific Conductance

Specific conductance measurements were converted to TDS for all sites (Table 5). Average TDS values at all sites were below the water quality standard of 800 mg/L. Average TDS values for all three sites ranged from 396 to 607 mg/L (Table 5). The distribution of TDS measurements for each site from upstream to downstream are displayed in Figure 6 with the lowest median TDS reported at the most upstream Chisholm Trail Rd. (80622) and the highest median TDS reported at the most downstream CR123 site (80771). A gradual increasing pattern of TDS values were observed from upstream to downstream.

Dissolved Oxygen

Average DO values at the CR122 (7.2 mg/L) and Chisholm Trail Rd. (8.0 mg/L) sites were above the 5.0 mg/L water quality standard in Brushy Creek, but not at the CR123 site (4.0) (Table 5). The range of average DO values for all sites spanned one order of magnitude along this urbanized reach of Brushy Creek from 8.0 to 4.0 mg/L. The distribution of DO measurements for each site from upstream to downstream are displayed in Figure 7. A gradual decreasing pattern of dissolved DO values were observed from upstream to downstream.

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 7.8 to 7.9 s.u. (Table 5).

Transparency and Total Depth

Secchi discs and tubes were used for measuring transparency at sites monitored in Brushy Creek (Table 5). The average Secchi tube transparency values reported at the two sites (80622 and 12062) where this parameter was measured was >1.2 m or the maximum reportable value using a 120 cm tube.

The average range of Secchi disc transparency values reported was from 0.3 to 0.8 m. The largest median transparency values measured with a disc were reported at CR123 (0.8 m), while the smallest was reported at Chisholm Trail Rd. (0.3 m) (Figure 9).

Total depth measurements are provided alongside the Secchi disc transparency measurements for relative comparison (Figure 9). No difference between the two measurements was observed at CR122 and CR123 where the water appeared transparent most of the time, while the greatest difference was at Chisholm Trail Rd. where a minimal difference (0.1 m) was recorded. The bigger the difference the less water transparency, therefore more turbid.

E. coli

E. coli bacteria was measured and reported at the Chisholm Trail Rd. and CR122 sites on Brushy Creek (Table 5). The *E. coli* geometric means for the entire period of record met the WQS (126 cfu/100 ml) at both sites (Figure 10).

Table 5. Texas Stream Team data summary in the Brushy Creek watershed (March 2012-January 2021). Mean±SD (range); NA=no data available.

Parameter	Brushy Creek @ Chisholm Trail Rd. ID 80622 n=38	Brushy Creek @ CR122 ID 12062 n=41	Brushy Creek @ CR123 ID 80771 n=13
Air Temp. (°C)	18.3±8.1 (32.0)	19.9±7.4 (30.5)	22.9±6.5 (19.7)
Water Temp. (°C)	18.9±5.5 (22.0)	20.7±5.2 (18.9)	21.4±6.3 (17.6)
Specific Conductance (µS/cm)	610±104 (590)	815±200 (930)	933±103 (394)
***TDS (mg/L)**	396±68 (384)	529±130 (605)	607±67 (256)
Dissolved Oxygen (mg/L)	8.0±1.5 (5.0)	7.2±1.8 (6.6)	4.0±1.8 (6.8)
pH (s.u.)	7.9±0.5 (2.1)	7.8±0.5 (1.7)	7.9±0.3 (1)
Secchi Tube Transp. (m)	1.2±0.4 (1.8)	1.2±0.3 (1.6)	NA
Secchi Disc Transp. (m)	0.3±0.1 (0.5)	0.6±0.2 (0.8)	0.8±0.2 (0.5)
Total Depth (m)	0.4±0.2 (0.9)	0.6±0.2 (1.1)	0.8±0.2 (0.5)
Nitrate-nitrogen (mg/L)	1.5±NA	8.5±NA	4.6±5.4 (14.5)
*******E. coli*** **(CFU/100ml)**	55.4 (172.4)	60.2 (172.4)	NA

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

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

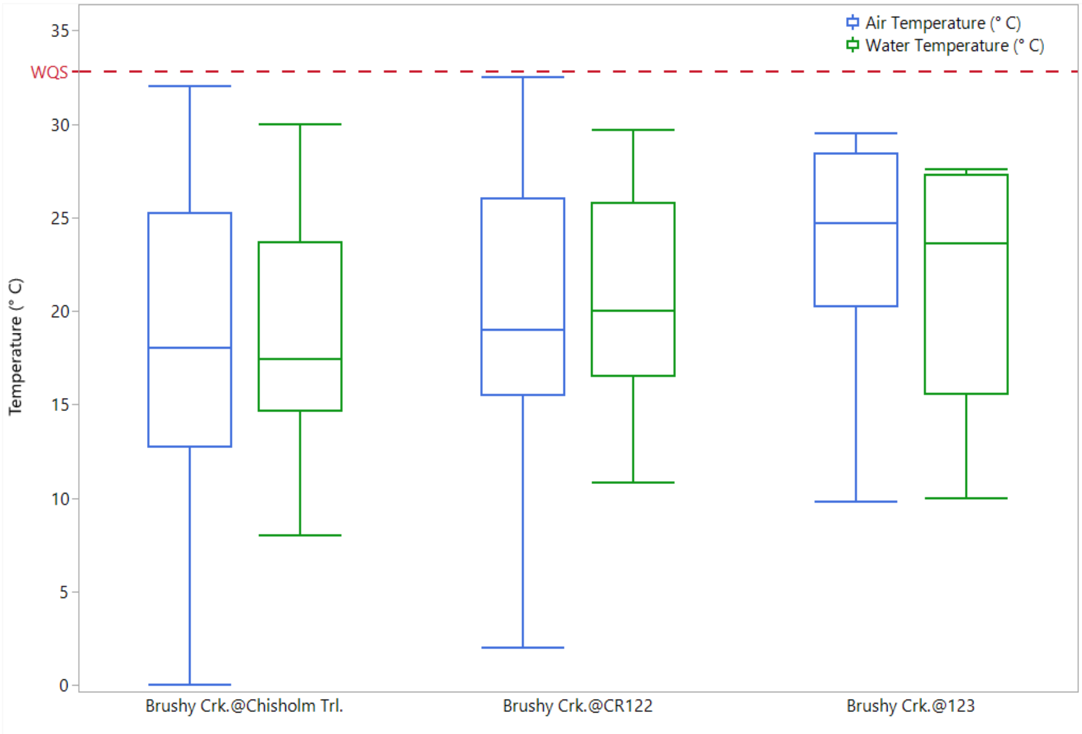


Figure 5. Air and water temperature for sites in the Brushy Creek watershed (March 2012 – January 2021).

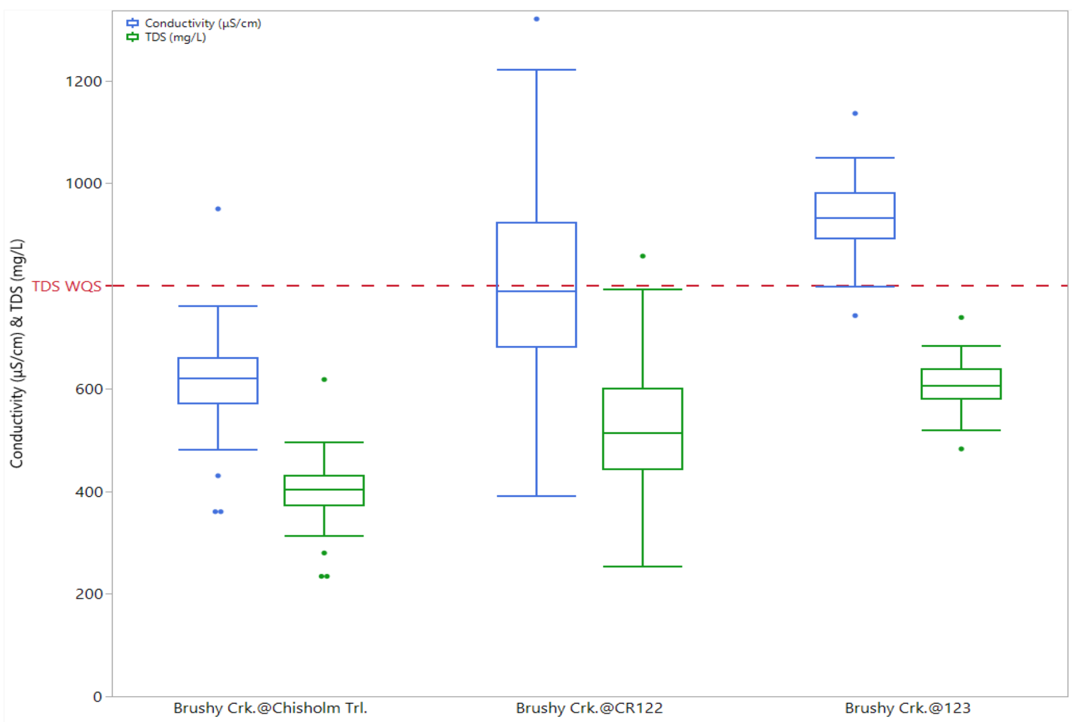


Figure 6. Conductivity (µS/cm) and total dissolved solids (mg/L) for sites in the Brushy Creek watershed (March 2012 – January 2021).

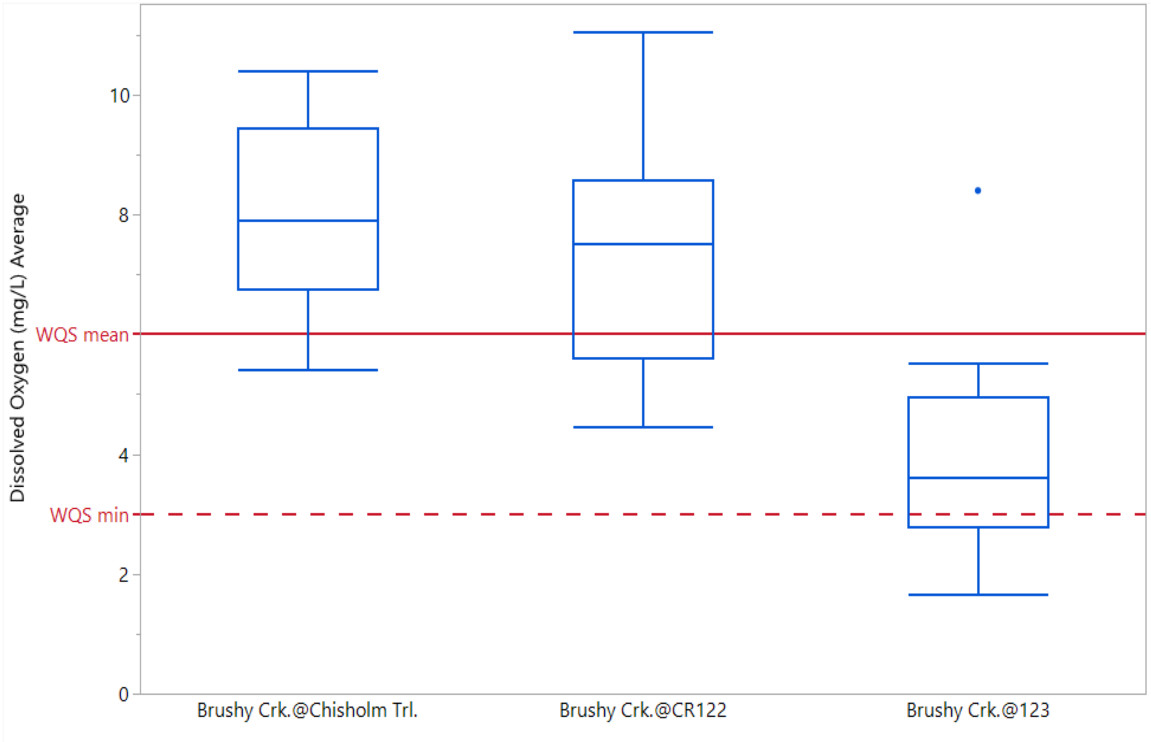


Figure 7. Dissolved oxygen (mg/L) for sites in the Brushy Creek watershed (March 2012 – January 2021).

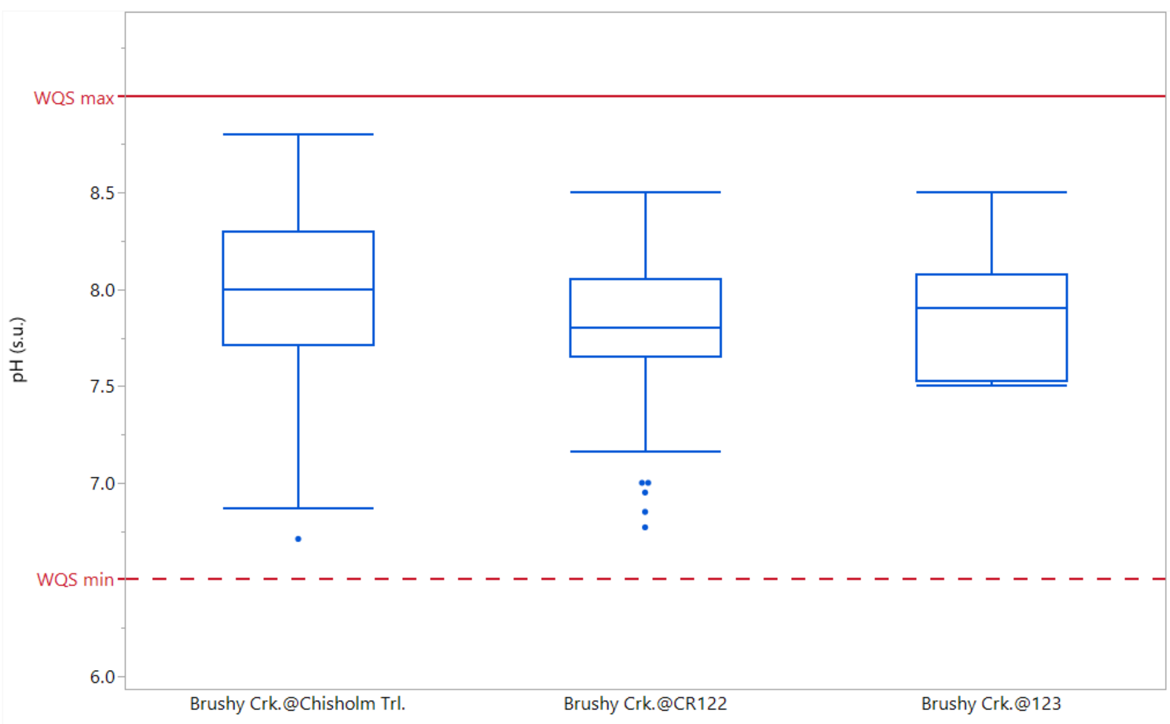


Figure 8. pH (s.u.) for sites in the Brushy Creek watershed (March 2012 – January 2021).

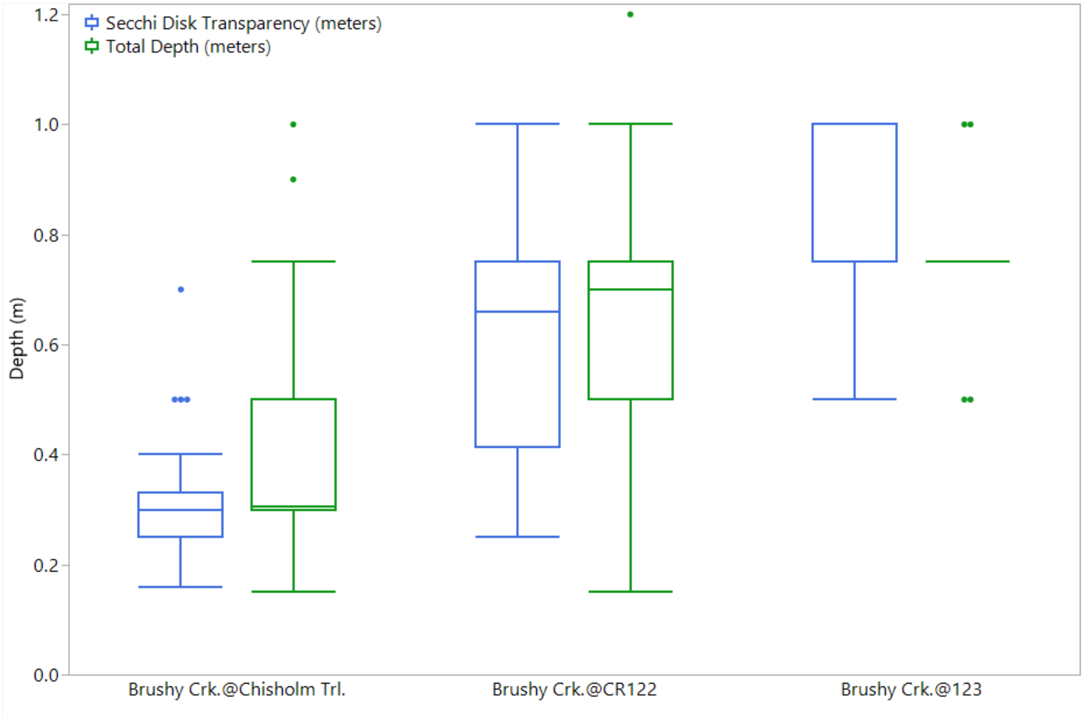


Figure 9. Secchi disc transparency (m) and total depth (m) for sites in the Brushy Creek watershed (March 2012 – January 2021).

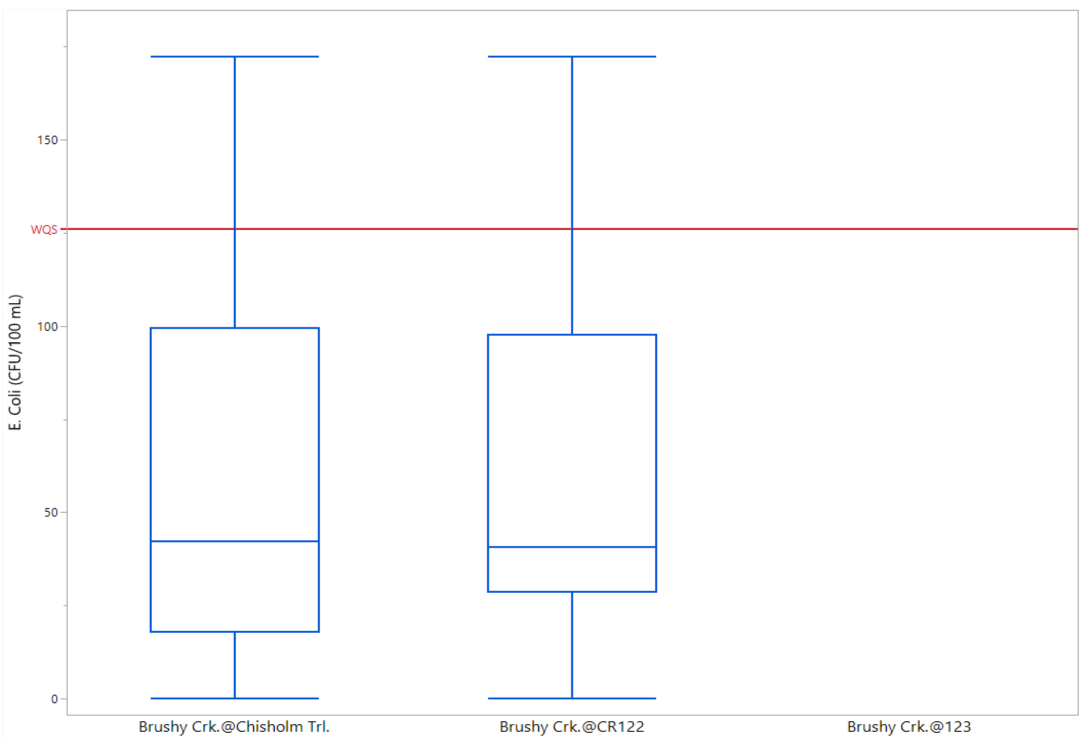


Figure 10. *E. coli* bacteria (CFU/100 ml) for sites in the Brushy Creek watershed (March 2012 – January 2021). No data available for Brushy Creek @ CR123.

WATERSHED SUMMARY

Texas Stream Team citizen scientists monitored standard core water quality parameters and *E. coli* bacteria at three sites in the Brushy Creek watershed from March 2012 to January 2021. 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 in the Brushy Creek watershed during the period of record. Data from the three monitoring sites were analyzed and summarized for this report.

Water quality standards for water temperature, TDS, and pH were met at all sites in the Brushy Creek watershed. However, the water quality standard for mean DO (5.0 mg/L) was not met at the CR123 site (4.0 mg/L). Also noteworthy is the increase in temperature and specific conductance at the CR123 site relative to the remaining two sites in this report, which are both parameters with the potential to affect dissolution of oxygen in water. Although Brushy Creek is not on the State's List of Impaired Waters, there is potential for concern due to the effluent dominant nature of this creek.

The *E. coli* geometric mean at both the Chisholm Trail Rd. and CR122 sites met the primary contact recreation water quality standard (126 CFU/100 mL). However, Brushy Creek (Segment 1244) is on the 2020 Texas Water Quality Inventory and 303(d) List for not meeting the primary contact recreation use due to exceedances of the water quality standard for *E. coli* bacteria. The sites monitored for the present study are representative of a relatively small reach of Brushy Creek and the bacteria impairment is likely representative of a larger number of sites and monitoring events spread over a larger span of time than was conducted for this report.

The Texas Stream Team citizen scientists monitoring standard core and *E. coli* bacteria water quality parameters in the Brushy Creek watershed are encouraged to continue monitoring and consider pursuing the Advanced water quality monitoring trainings. Continuation of the ongoing monitoring is crucial due to the results presented here and the extensive urbanization occurring in this region of Texas. There is a need for this type of 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, and 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 1: Endangered species located within the Brushy Creek Watershed

Species Type	Common Name	Federal/State Listing
Amphibians	Barton Springs salamander	Federally Listed as Endangered, State Listed as Endangered
Amphibians	Austin blind salamander	Federally Listed as Endangered/ State Listed as Endangered
Birds	Whooping crane	Federally Listed as Endangered/ State Listed as Endangered
Birds	Interior least tern	State Listed as Endangered
Birds	Golden-cheeked warbler	Federally Listed as Endangered/ State Listed as Endangered
Fish	Smalleye shiner	Federally Listed as Endangered/ State Listed as Endangered
Fish	Sharpnose shiner	Federally Listed as Endangered/ State Listed as Endangered
Insects	Tooth Cave ground beetle	Federally Listed as Endangered
Insects	Kretschmarr Cave mold beetle	Federally Listed as Endangered
Insects	Coffin Cave mold beetle	Federally Listed as Endangered
Arachnids	Tooth Cave spider	Federally Listed as Endangered
Arachnids	Reddell harvestman	Federally Listed as Endangered
Arachnids	Bone Cave harvestman	Federally Listed as Endangered
Arachnids	Tooth Cave pseudoscorpion	Federally Listed as Endangered

Table 2: Threatened species located within the Brushy Creek Watershed

Species Type	Common Name	Federal/State Listing
Amphibians	Jollyville Plateau salamander	Federally Listed as Threatened/ State Listed as Threatened
Amphibians	Salado Springs salamander	Federally Listed as Threatened/ State Listed as Threatened
Amphibians	Georgetown 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
Birds	Rufa red knot	Federally Listed as Threatened/ State Listed as Threatened
Reptiles	Texas horned lizard	State Listed as Threatened

Mollusks	Texas Fatmucket	State Listed as Threatened
Mollusks	Brazos Heelsplitter	State Listed as Threatened
Mollusks	Texas Pimpleback	State Listed as Threatened
Mollusks	Texas Fawnsfoot	State Listed as Threatened