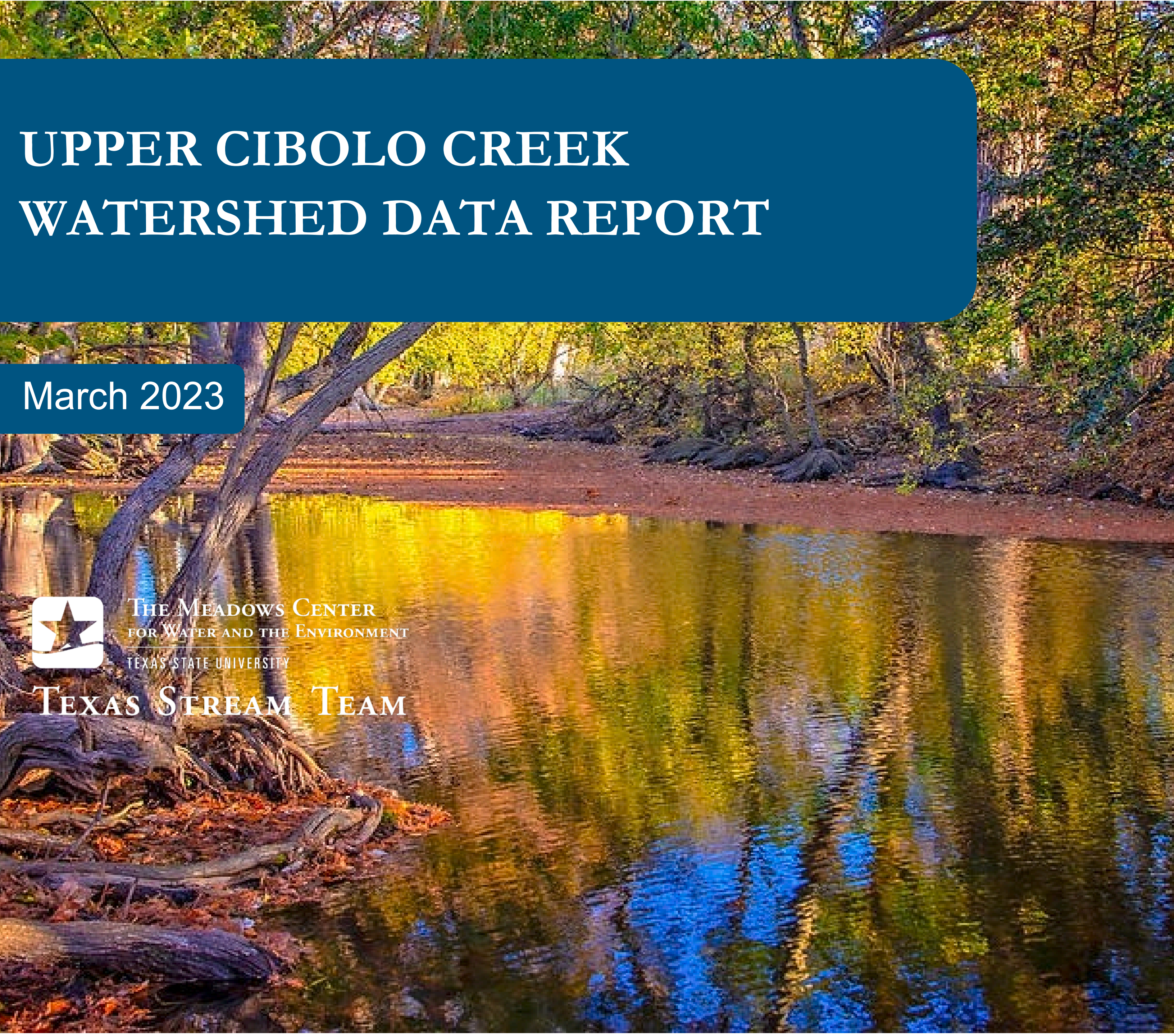
UPPER CIBOLO CREEK WATERSHED DATA REPORT

March 2023



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

United States Environmental Protection Agency

Texas Commission on Environmental Quality

Texas State University
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 community 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 community science water quality monitoring program. Community scientist water quality monitoring occurs at predetermined monitoring sites, at approximately the same time of day each month. Information collected by Texas Stream Team community scientists is covered by a Texas Commission on Environmental Quality-approved Quality Assurance Project Plan to ensure a standard set of methods are used. Community 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 community scientist data are not used by the state to assess whether water bodies are meeting the designated surface water quality uses and standards. Data collected by Texas Stream Team provide valuable information, often collected in water bodies 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 community science monitoring, please refer to the following sources:

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

The purpose of this report is to provide a summary of the data collected by Texas Stream Team community 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 Upper Cibolo Creek Watershed in the San Antonio River Basin. 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
- Texas Commission on Environmental Quality Total Maximum Daily Load reports
- Texas Commission on Environmental Quality 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

The Upper Cibolo Creek Watershed spans 228-square miles, is part of the larger San Antonio River Basin, and is a spring fed stream (Figure 1). The watershed encompasses the city of Boerne, the county seat of Kendall County. This area is important locally for aesthetics, recreation, and for the ecosystem it supports, but it is also historically significant and provides a variety of activities for tourists (City of Boerne, 2023).

Cibolo Creek was called “Xoloton” by the Coahuiltecan Indians and “Bata Coniquiyoqui” by the Tonkawa Indians. The creek would take on several Spanish names before being named “Arroyo del Cibolo” in 1721 by Marqués de San Miguel de Aguayo (Texas State Historical Association, 1994). German immigrants began arriving to the area in the 1840s. Beginning in the mid-19th century, agriculture and ranching were the dominant industries in the area. Sheep ranching would quickly become the principal industry with 8,000+ pounds of wool produced in 1870 and 65,000+ pounds of wool produced in 1880. Over the past few decades, environmental stewardship within the area has increased and protection of Cibolo Creek was largely started by the Cibolo Center for Conservation (Cibolo Center for Conservation, 2023).

The Texas Commission on Environmental Quality designates classifications for stream segments in the Upper Cibolo Creek Watershed and throughout Texas (Table 1). Upper Cibolo Creek (Segment 1908) is the only classified stream segment in the watershed.

The climate in this part of the state is described as subtropical-subhumid with a growing season of 231 average days annually (Smyrl, 2020). National Oceanic and Atmospheric Administration climate data from a weather station at Boerne, Texas was acquired from the National Data Center (National Oceanic and Atmospheric Administration, 2021). Average annual precipitation at Boerne is 37.52 inches and occurs year-round (Figure 2). Long-term monthly average precipitation has a bimodal distribution with peaks occurring in May and September. Average rainfall during these months is 5.28 and 3.9 inches each month, respectively. The least amount of rainfall (2.22 inches) occurs in February. The warmest and coldest months of the year are August (27.9°C) and January (9.4°C), respectively.

Figure 1. Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas.

Table 1. Texas Commission on Environmental Quality segment classifications (Texas Commission on Environmental Quality, 2022).

Segment Number	Segment Name	Segment Description
1908	Upper Cibolo Creek	From the Missouri-Pacific Railroad bridge west of Bracken in Comal County to a point 1.5 km (0.9 mi) upstream of the confluence of Champee Springs in Kendall County.

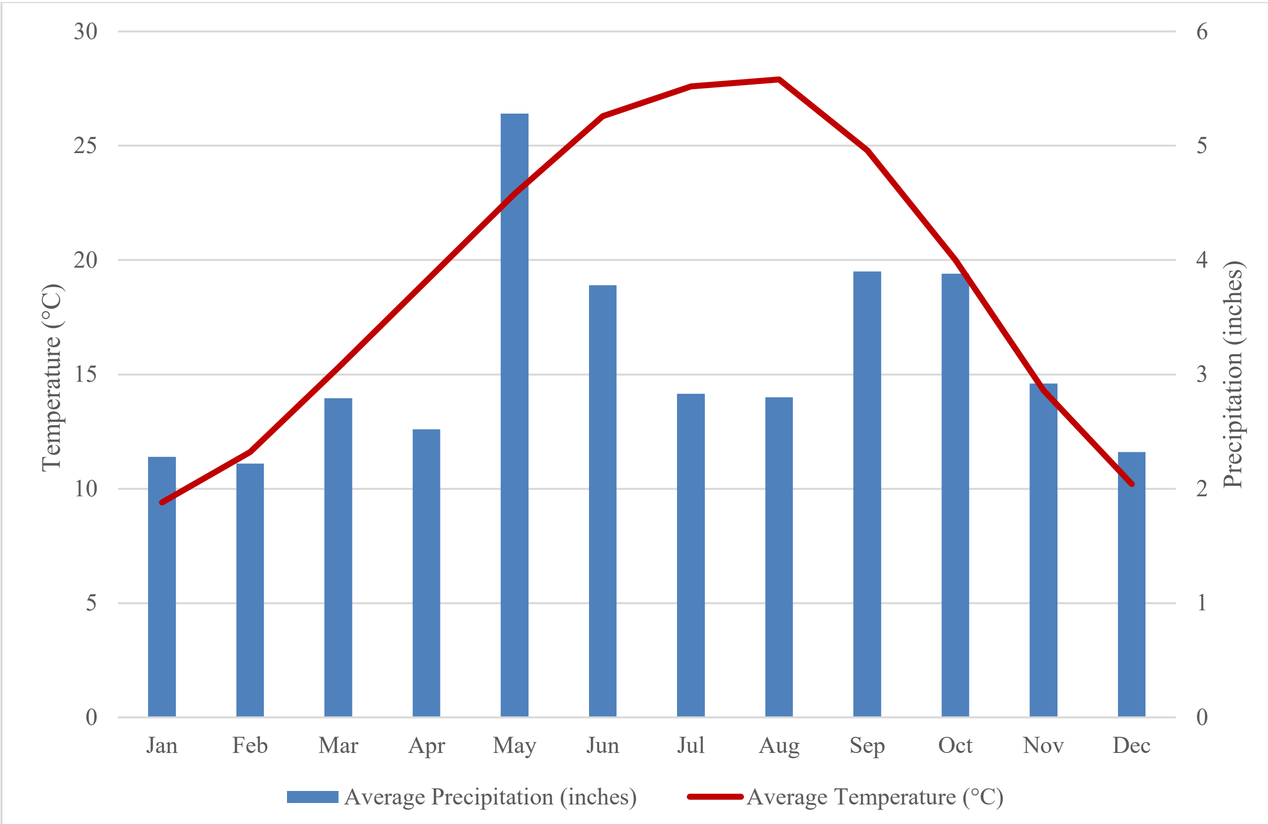

Figure 2. Long-term (1991-2020) monthly average precipitation (inches) and air temperature (°C) from Boerne, Texas (National Oceanic and Atmospheric Administration Climate Data, 2021).

Physical Description

The Upper Cibolo Creek Watershed is contained primarily in Kendall County but also expands into Bandera, Bexar, and Comal counties. Located within the Texas Hill Country, the landscape is described as rolling to hilly terrain. The Edwards Plateau vegetation is comprised of oak, juniper, mesquite, hardwoods, conifers, and grasses. Soils that support the landscape include clay and sandy loams. Mineral resources found in the area include dolomite and limestone (Texas State Historical Association, 1994).

This area supports diverse wildlife including deer, raccoons, squirrels, foxes, coyotes, feral hogs, bobcats, beavers, and badgers (Smyrl, 2020).

Land Use

Land cover types were determined from spatial data sets processed in geographic information systems for the Upper Cibolo Creek Watershed (Figure 3). Ninety-four percent of the land cover in the watershed consists of forest (41%), shrub (39%), and developed land (14%) (Table 2). The remaining land use types, grassland (5%), planted/cultivated (0.4%), bare (0.26%), open water (0.25%), woody wetlands (<0.1%), and emergent herbaceous wetlands (<0.1%) comprise approximately 6% of the watershed by area.

Table 2. Land use in the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas (National Land Cover Data, 2016).

Land Use Type	**Acres (ac)**	**Hectares (ha)**	**Percent (%)**
Forest	59,694.55	24,157.53	40.80%
Shrub	56,829.56	22,998.11	38.84%
Developed	21,003.95	8,500.00	14.36%
Grassland	7,395.28	2,992.76	5.05%
Planted/Cultivated	605.83	245.17	0.41%
Bare	385.23	155.90	0.26%
Open Water	367.45	148.70	0.25%
Woody Wetlands	28.44	11.51	<0.1%
Emergent Herbaceous Wetlands	0.222	0.090	<0.1%
Total	**146,310.51**	**59,209.77**	**100**

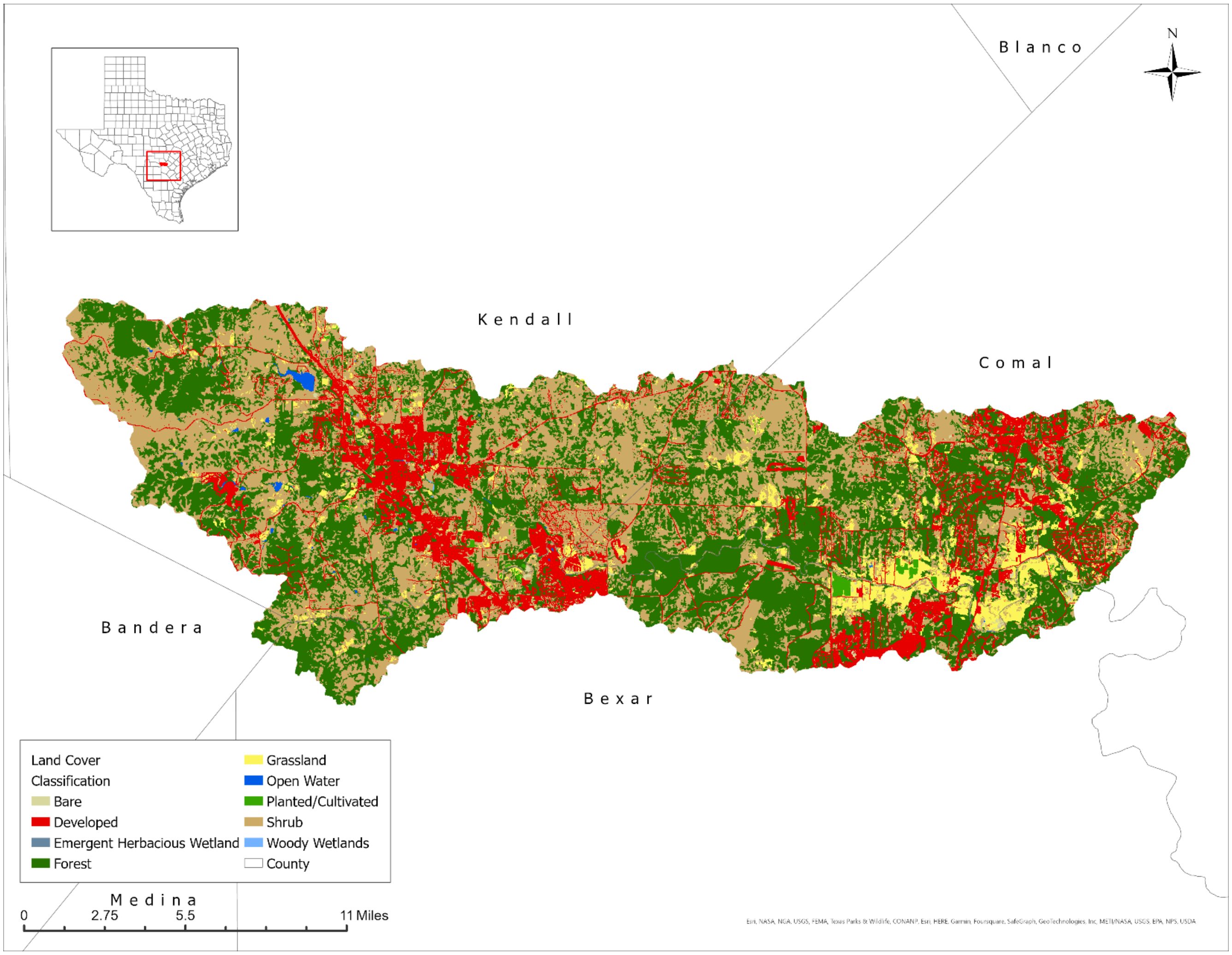

Figure 3. Land cover for the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas (National Land Cover Data, 2016).

History

Bandera, Bexar, Comal, and Kendall counties were established by hunter-gatherer communities more than 10,000 years ago, and were occupied by Coahuiltecans, Comanche, Tonkawa, Lipan Apache, Waco Indians, and Karankawas indigenous peoples (Long, 2020). Spanish explorers arrived between the late 16th and early 18th centuries before establishing missions in the area (Greene, 2020). Farming and ranching communities soon dominated the land.

German colonists began colonizing the area in the 19th century. Because of the low number of slaves, the area did not face as much hardship from the Civil War and Reconstruction. Sheep outnumbered cattle by 1880 and the county became an important source of wool (Long, 2020).

The area experienced population growth and ethnic diversity, primarily because of the prosperous cattle and wool industries. The construction of highways would spark a new period of economic growth, mainly from trade and tourism (Smyrl, 2020).

Endangered Species and Conservation Needs

The common names of 44 species listed as threatened or endangered (under the authority of Texas state law and/or under the United States Endangered Species Act) within the Upper Cibolo Creek Watershed are included in Appendix A. 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 3.

Table 3. State and federally listed species in the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas (Texas Parks and Wildlife Department, 2021).

Taxon	Endangered (Federal or State)	Threatened (Federal or State)	G1 or G2 (Critically imperiled or imperiled)	Species of Greatest Conservation Need (NPWD) (S1 or S2)	Endemic Total Count
Amphibians	1	3	3	4	11
Birds	2	4	2	6	14
Fish	1	7	4	8	20
Mammals	0	2	0	6	8
Reptiles	0	3	0	6	9
Crustaceans	1	0	9	9	19
Insects	5	0	20	20	45
Arachnids	6	0	15	16	37
Mollusks	3	3	10	11	27
Arthropods	0	0	0	2	2
Plants	1	2	15	20	38
Total Count	**20**	**24**	**78**	**108**	**230**

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 as drinking water. The criteria for evaluating support of those uses in the classified segment of Upper Cibolo Creek (Segment 1908) included in this report are provided in

Table 4. The total dissolved solids criteria are for maximum annual averages, the dissolved oxygen criteria are for minimum 24-hour dissolved oxygen means at any site within the segment, the minimum and maximum values for pH apply to any site within the segment, the *E. coli* indicator bacteria for freshwater is a geometric mean, and the temperature criteria is a maximum value at any site within the segment.

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, and other information, including water quality studies, existence of fish kills or contaminant spills, photographic evidence, and local knowledge. Screening levels serve as a reference to indicate when water quality parameters may be approaching levels of concern.

Table 4. State water quality criteria for classified stream segments in the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas (Texas Commission on Environmental Quality, 2018).

Segment	**Total Dissolved Solids (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH Range (s.u.)**	***E. coli* Bacteria (#/100 mL)**	**Temperature (°C)**
1908 – Upper Cibolo Creek	600	Grab screening level and min. 24-hour mean: 5.0 Grab min.: 3.0	6.5-9.0	Primary Contact Recreation 1: 126 geometric mean, 399 single sample	32.2

Water Quality Impairments

The *2022 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (Integrated Report) includes an index of water quality impairments. The classified segment, Upper Cibolo Creek (Segment 1908), has impairments for bacteria in water. This segment is designated as a Category 5C. Additional data and information will be collected or evaluated before a management strategy is selected. Concerns were also identified for nitrate and total phosphorus.

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. Community 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 community 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

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 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. 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 can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants.

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.

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 streamflow.

The dissolved oxygen 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 dissolved oxygen can also result from high groundwater inflows (which have low dissolved oxygen due to minimal aeration), high temperatures, or water releases from deeper portions of dams where dissolved oxygen 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 community 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 until the Secchi 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 dissolved oxygen in the water due to reduced photosynthesis. Contaminants are mostly 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 the Texas Commission on Environmental Quality as an indicator of the potential presence of pathogens in tidally-influenced saltwater along the Texas Gulf Coast.

The segments within the Upper Cibolo Creek Watershed are designated a primary contact recreation 1 use. This means that recreation activities are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, hand fishing 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 currently monitor water quality for enterococci in coastal waters. Instead community scientists can get certified in *E. coli* bacteria monitoring, the indicator used by the Texas Commission on Environmental Quality for freshwater streams which can be used as a first step for coastal monitoring.

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 the Texas Commission on Environmental Quality 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.

Orthophosphate Phosphorus

Phosphorus almost always exists in the natural environment as orthophosphate and continually cycles through the ecosystem as a nutrient necessary for the growth of most organisms. Testing for orthophosphate in the water excludes the phosphate bound up in plant and animal tissue. There are other methods to retrieve orthophosphate from the material to which it is bound, but they are too complicated and expensive to be conducted by community scientists. Testing for orthophosphate provides an idea of the degree of phosphorus 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 phosphorus has on a water body is known as eutrophication and is described above in the "Dissolved Oxygen" section.

DATA COLLECTION, MANAGEMENT AND ANALYSIS

Data Collection

The field sampling procedures implemented by trained community scientists are documented in the Texas Stream Team Core Water Quality Community Scientist Manual and the Texas Stream Team Advanced Water Quality Community Scientist Manual. The sampling protocols in the manuals adhere closely to the Texas Commission on Environmental Quality Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012). Additionally, all data collection adheres to Texas Stream Team's Texas Commission on Environmental Quality-approved Quality Assurance Project Plan.

Procedures documented in Texas Stream Team Water Quality Community Scientist Manuals or the Texas Commission on Environmental Quality 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 Environmental Monitoring Forms. 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 total dissolved solids using a conversion factor of 0.65 and are reported as mg/L.

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 community scientists collect field data and report the measurement results to Texas Stream Team, by submitting a hard copy of the Environmental Monitoring Form, entering the data directly into the online Waterways Dataviewer, or by using the electronic Environmental Monitoring Form. 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 Quality Assurance Project Plan.

Data review and verification is performed using a quality control checklist and self-assessments, as appropriate to the project task, followed by automated database functions that 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 accessed publicly through the online Texas Stream Team Datamap.

Data Analysis

Data were compiled, analyzed, summarized, and compared to state water quality standards and/or criteria to provide readers with a reference point for parameters that may be of concern. The statewide, biennial assessment performed by the Texas Commission on Environmental Quality involves more stringent monitoring methods and oversight than those used by community scientists and staff in this report. The Texas Stream Team community scientist water quality monitoring data are not currently used in the Texas Commission on Environmental Quality assessments mentioned above. However, the Texas Stream Team data 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 community scientists in the study watersheds were exported from the Texas Stream Team database and grouped by site. Sites with 10 or more monitoring events were maintained in the dataset for analysis. Sites with fewer than 10 monitoring events were excluded from the analysis for this report but may be used in future data summary reports. 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. Outlier box or scatter 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 plot 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 eight Texas Stream Team monitoring sites in the Upper Cibolo Creek Watershed were acquired for analysis (Figure 4). The eight sites in the Cibolo Creek Watershed were monitored sporadically beginning on December 1996 through February 2023. Trained community scientists conducted between 17 and 205 sampling events at each site, for a total of 744 monitoring events (Table 5). The period of record for the sampling events ranged from December 1999 to February 2023, with all sites experiencing temporal intermittent sampling.

Site Analysis

Water quality monitoring data from the eight sites were analyzed and summarized including the number of samples, mean/geometric mean, standard deviation, and range of values (Table 6). Community scientists monitored the sites for standard core monitoring parameters, including air and water temperature, conductivity, total dissolved solids, dissolved oxygen, pH, Secchi disc/tube transparency, and total depth. Advanced monitoring was also conducted at select sites and included turbidity, nitrate-nitrogen, and orthophosphate phosphorus.

Air and Water Temperature

Average air temperature for all sites ranged from 17.2 to 28.3°C (Table 6). The lowest mean air temperature (17.2°C) was observed at the Menger Creek Bridge (site 81596), while the highest mean air temperature (28.3°C) was observed Cibolo Creek and Johns Road (site 15108).

Average water temperature for all sites ranged from 16.0 to 25.5°C (Table 6). The lowest mean water temperature (16.0°C) was observed at the Menger Creek Bridge (site 81596), while the highest mean water temperature (25.5°C) was observed at Cibolo Creek and Johns Road (site 15108). All water temperature measurements from all sites monitored for the period of record met the water quality standard (32.2°C) (Figure 5).

Table 5. Texas Stream Team monitoring sites in the Upper Cibolo Creek Watershed within the San Antonio River Basin in Kendall County, Texas.

Site ID	**Description**	**Number of Monitoring Events (n)**	**Period of Record**
80187	Cibolo Creek @ the upper Cibolo Creek Road fifth crossing	109	11/16/2000 – 2/15/2018
80904	Cibolo Creek upstream of Boerne Lake	57	11/15/2012 – 2/16/2023
15108	Cibolo Creek @ Johns Road	17	10/23/1999, 2/23/2001 – 6/16/2005
20823	Upper Cibolo Creek @ River Road Park	104	3/15/2012 – 3/12/2015, 5/17/2018 – 1/23/2023
80966	Currey Creek @ Boerne wastewater treatment plant effluent outfall	99	5/16/2013 – 3/12/2015, 5/17/2018 – 1/23/2023
81596	Menger Creek Bridge @ Herff Road near main street	22	12/13/2019 – 6/20/2022
80186	Cibolo Nature Center Marsh	131	7/16/1999 – 12/16/2021
15126	Cibolo Creek @ Menger Creek	205	12/26/1996, 5/30/2000-1/23/2023
	TOTAL	**744**	

Figure 4. Texas Stream Team monitoring sites in the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas.

Specific Conductance and Total Dissolved Solids

Total dissolved solid values were calculated from specific conductance measurements. Average total dissolved solids ranged from 247 mg/L at the fifth crossing of Upper Cibolo Creek Road (site 80187), to 618 mg/L at Currey Creek near the Boerne wastewater treatment plant effluent outfall (site 80966) (Table 6). The total dissolved solids water quality standard for Cibolo Creek is 600 mg/L. Average total dissolved solids were below the standard at all sites except at Currey Creek near the Boerne wastewater treatment plant effluent outfall (site 80966) (Figure 6). In addition, two sites, both downstream of the Boerne wastewater treatment plant, also periodically exhibited discreet measurements above the water quality standard during the period of record for this study (Figure 6). Those sites included the Cibolo Nature Center Marsh (site 80186) and Menger Creek (site 15126).

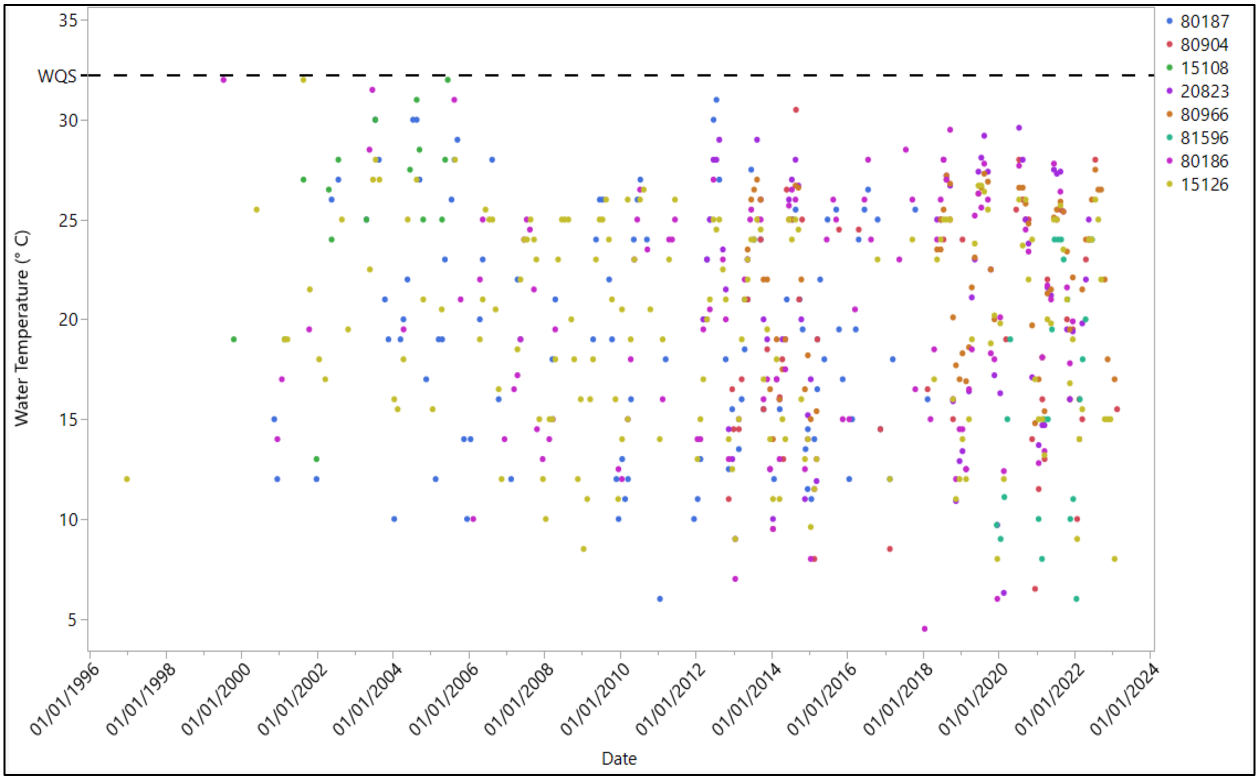

Figure 5. Water temperature for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023). WQS = Water Quality Standard.

Dissolved Oxygen

The range of average dissolved oxygen values for all sites spanned from 5.9 to 9.4 mg/L (Table 6). The average 24-hour dissolved oxygen values at all eight sites were above the water quality standard of 5.0 mg/L. The Cibolo Nature Center Marsh site (site 80186) had the lowest average 24-hour dissolved oxygen value (5.9 mg/L) of all the sites assessed in this study. The minimum grab standard for dissolved oxygen (3.0 mg/L) was not met at half of the sites assessed at some point during the period of record for this study (Figure 7). Those sites included the fifth crossing on Upper Cibolo Creek Road (site 80187), River Road Park (site 20823), Menger Creek Bridge at Herff Road near main street (site 82596), and Cibolo Nature Center Marsh (site 80186) (Figure 7).

Table 6. Texas Stream Team data summary for sites within the Upper Cibolo Creek Watershed (Oct 1999 to Feb 2023).

Parameter/Site	80187	80904	15108	20823	80966	81596	80186	15126
Number of events	n =109	n = 57	n = 17	n =104	n =99	n =22	n =131	n =205
Air Temp. (°C)	21.4±6.4 (29)	19.2±5.7 (23)	28.3±5.3 (20)	18.9±6.1 (26)	18.6±6.4 (25)	17.2±6.3 (19)	19.9±6.5 (31)	19.1±6.3 (30)
Water Temp. (°C)	19.6±5.9 (25)	19.2±6.0 (24)	25.5±4.9 (19)	20.7±6.0 (23)	21.9±4.1 (14)	16.0±6.0 (18)	19.8±6.0 (28)	19.4±5.4 (24)
Specific Conductance (µS/cm)	381±36 (180)	396±47 (218)	458±91 (380)	455±110 (700)	951±73 (320)	512±167 (477)	684±113 (540)	731±178 (962)
***Total Dissolved Solids (mg/L)**	247±23 (117)	257±30 (142)	298±59 (247)	296±72 (455)	618±47 (208)	332±108 (310)	444±74 (351)	475±116 (625)
Dissolved Oxygen (mg/L)	7.3±1.2 (9.2)	6.9±2.0 (7.2)	9.4±1.1 (4.5)	6.1±2.1 (8.8)	6.2±0.8 (3.5)	6.2±1.9 (6.9)	5.9±2.5 (13.7)	6.3±1.7 (11.2)
pH (s.u.)	7.9±0.2 (1.5)	8.1±0.3 (1.2)	8.1±0.1 (0.5)	7.5±0.4 (1.7)	7.4±0.4 (1.6)	7.1±0.3 (1.5)	7.6±0.2 (1.2)	7.9±0.3 (1.5)
Secchi Disc Transp. (m)	0.5±0.2 (0.8)	0.8±0.4 (1.4)	1.0±2.3 (7.5)	0.7±0.3 (1.4)	0.3±0.2 (0.6)	0.4±0.3 (0.9)	0.5±0.2 (1.0)	0.3±0.1 (0.8)
Total Depth (m)	0.5±0.1 (0.8)	0.8±0.4 (1.4)	0.6±0.2 (0.7)	0.6±0.4 (1.3)	0.4±0.2 (0.9)	0.3±0.3 (0.9)	0.5±0.2 (0.9)	0.3±0.1 (0.8)
Nitrate-Nitrogen (mg/L)	ND	ND	ND	0.5±0.5 (2)	11.0±6.0 (15)	ND	0.3±0.2 (0.6)	7.1±5.3 (15)
Orthophosphate (mg/L)	ND	ND	ND	0.2±0.3 (1)	7.7±4.6 (19.8)	ND	ND	2.6±2.0 (8.0)

*Total dissolved solids (TDS) were calculated from specific conductance (TDS = specific conductance * 0.65).
ND = no data available.

pH

Average pH values at all sites were within the range of the water quality standards (6.5 to 9.0 s.u.) (Table 6). The average range of values was between 7.1 and 8.1 s.u. at all sites. The Menger Creek Bridge site on Herff Road near main street (site 80596) had one exceedance of the minimum water quality standard during the period of record evaluated (Figure 8).

Transparency and Total Depth

Secchi discs was used for measuring transparency at the sites monitored in the Upper Cibolo Creek Watershed (Table 6). The average Secchi disc values reported at all sites ranged from 0.3 to 1.0 m. (Table 6).

Total depth was measured at all sites monitored (Table 6). The average deepest site (0.8 m) was at Cibolo Creek upstream of Boerne Lake (site 80904), while the sites with the average shallowest depths (0.3 m) were both on Menger Creek (sites 81596 and 15126).

Nitrate-Nitrogen

Average nitrate-nitrogen values at sites where these measurements were collected did not meet the screening criterion (0.69 mg/L) at two (sites 80966 and 15126) of the four sites where this parameter was measured (Table 6). The average range of values was between 0.3 and 11.0 mg/L at all sites. The Currey Creek site at the Boerne wastewater treatment plant effluent outfall (site 80966) had the highest mean value (11.0±6.0 mg/L) of all sites and exceeded the screening criterion (Figure 9). The Cibolo Creek at Menger Creek site (site 15126), located downstream of the Boerne wastewater treatment plant, had the second highest mean value (7.1±5.3 mg/L) and also exceeded the screening criterion. The other two remaining sites with available data were the site on the upper Cibolo Creek at River Road Park (site 20823) and the site at the Cibolo Nature Center Marsh (site 80186) and both mean values for those sites were below the screening criterion.

Orthophosphate Phosphorus

Average orthosphate phosphorus values at two (sites 80966 and 15126) of the three sites where these measurements were collected did not meet the screening criterion (0.69 mg/L) (Table 6). The average range of values was between 0.2 and 7.7 mg/L at all sites. The Currey Creek site at the Boerne wastewater treatment plant effluent outfall (site 80966) had the highest average value (7.7 mg/L) of the three sites with available data and it exceeded the screening criterion (Figure 10). The Cibolo Creek at Menger Creek (site 15126), located downstream of the Boerne wastewater treatment plant, had the second highest mean value (2.6±2.0 mg/L) and also exceeded the screening criterion (Figure 10). The other remaining site with available data was the site on the upper Cibolo Creek at River Road Park (site 20823) and the mean value for that site (0.2±0.3 mg/L) was below the screening criterion (Figure 10).

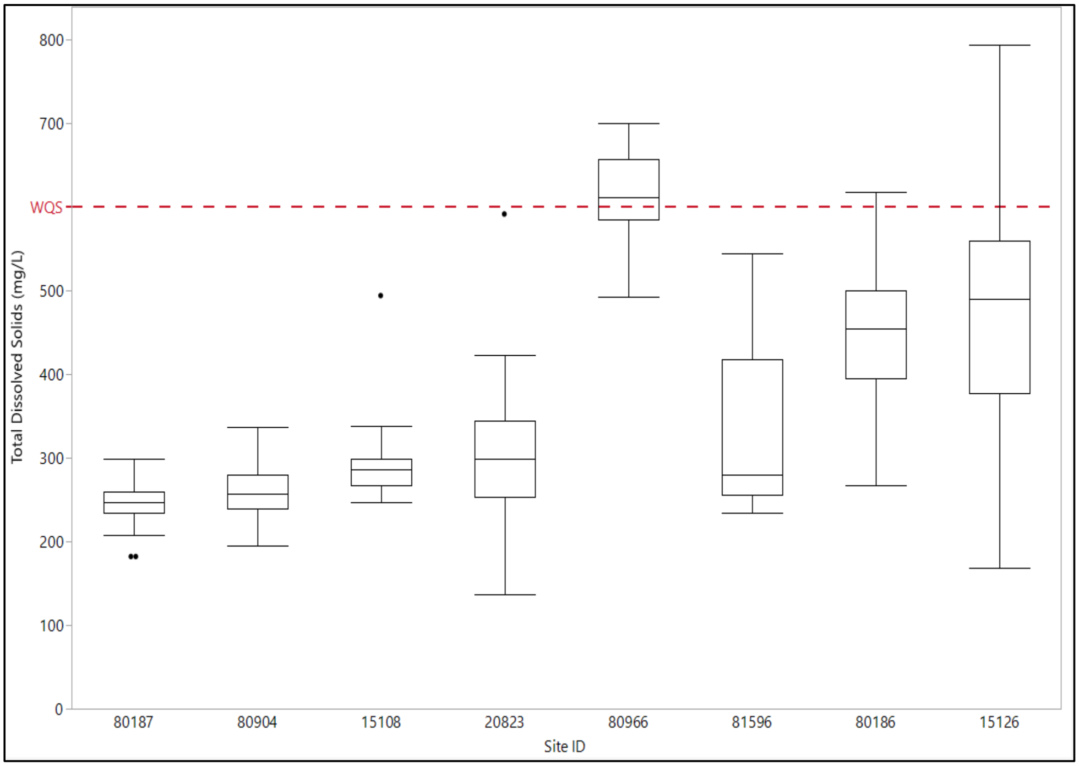

Figure 6. Total dissolved solids (mg/L) for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023). WQS = Water Quality Standard.

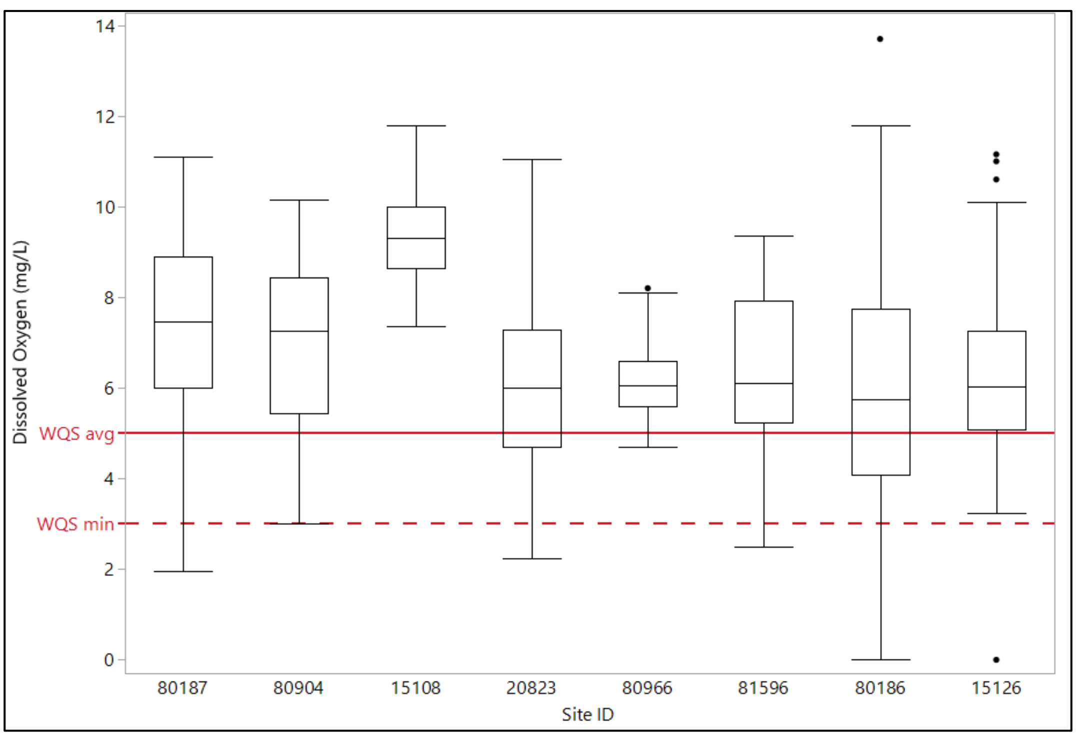

Figure 7. Dissolved oxygen (mg/L) for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023). WQS avg = average 24-hour and WQS min = minimum grab.

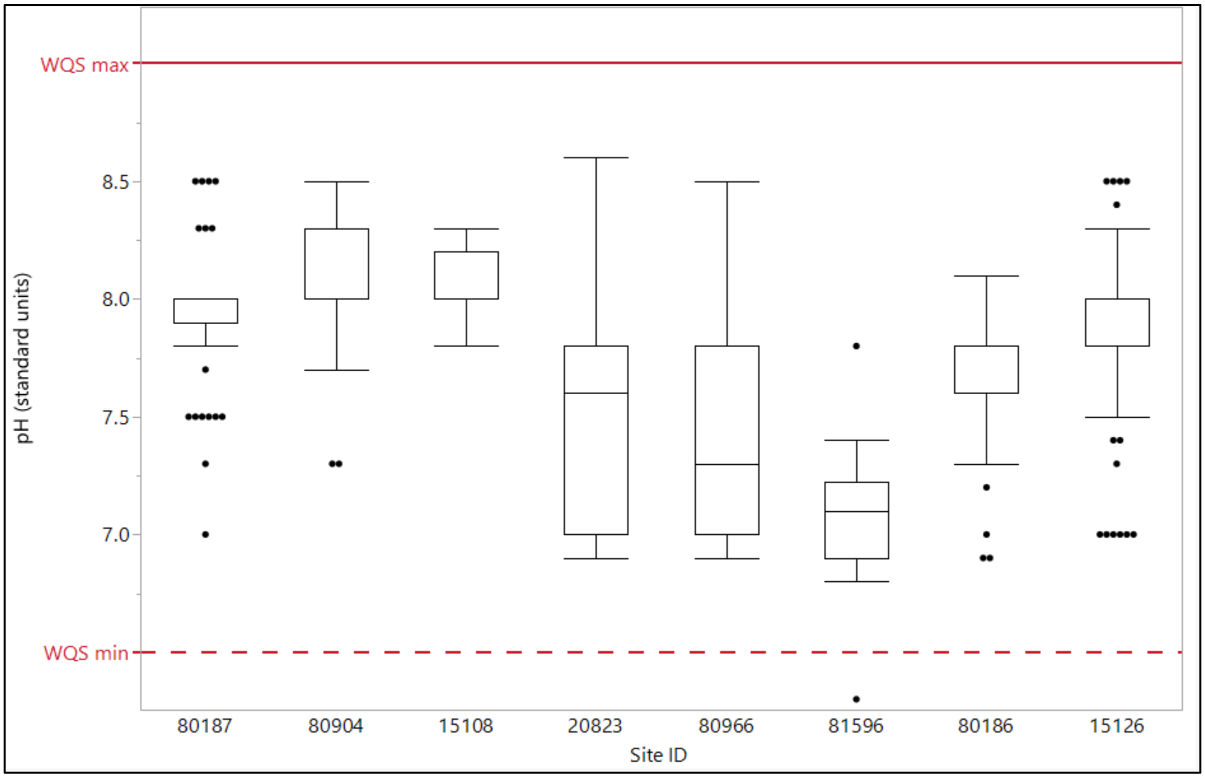

Figure 8. pH (s.u.) for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023). WQS max = maximum range and WQS min = minimum range.

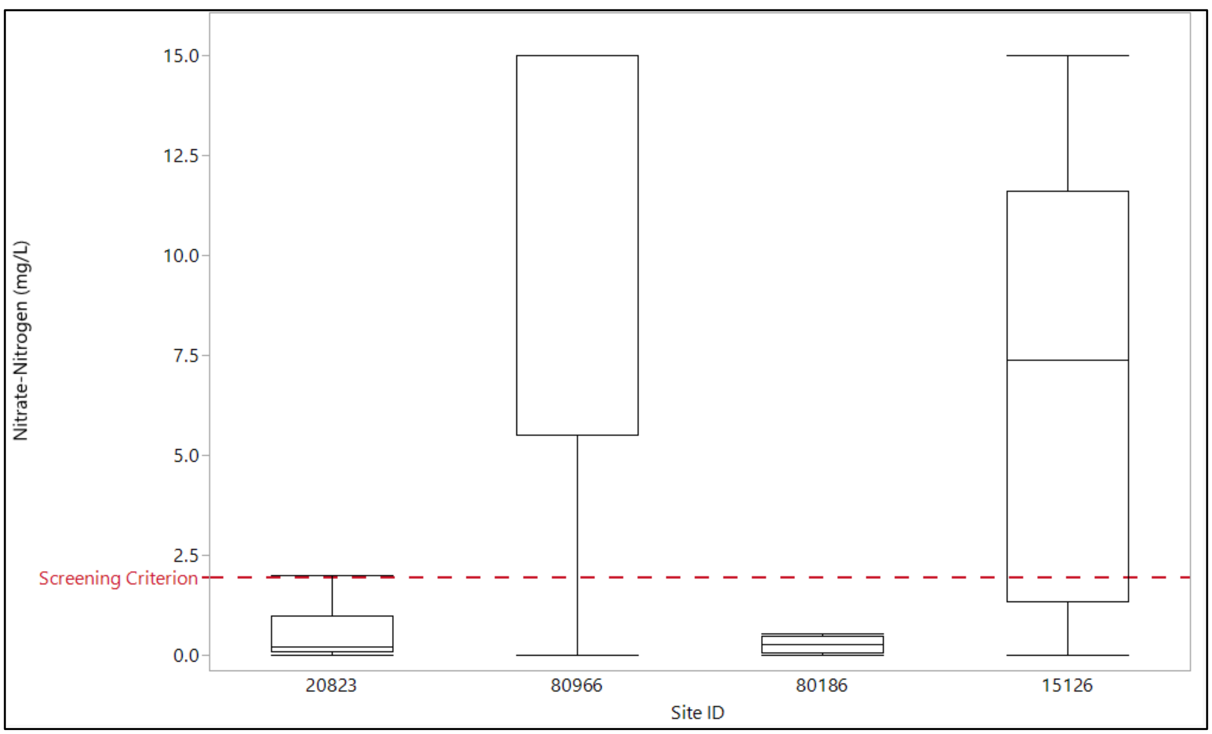

Figure 9. Nitrate-nitrogen (mg/L) for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023).

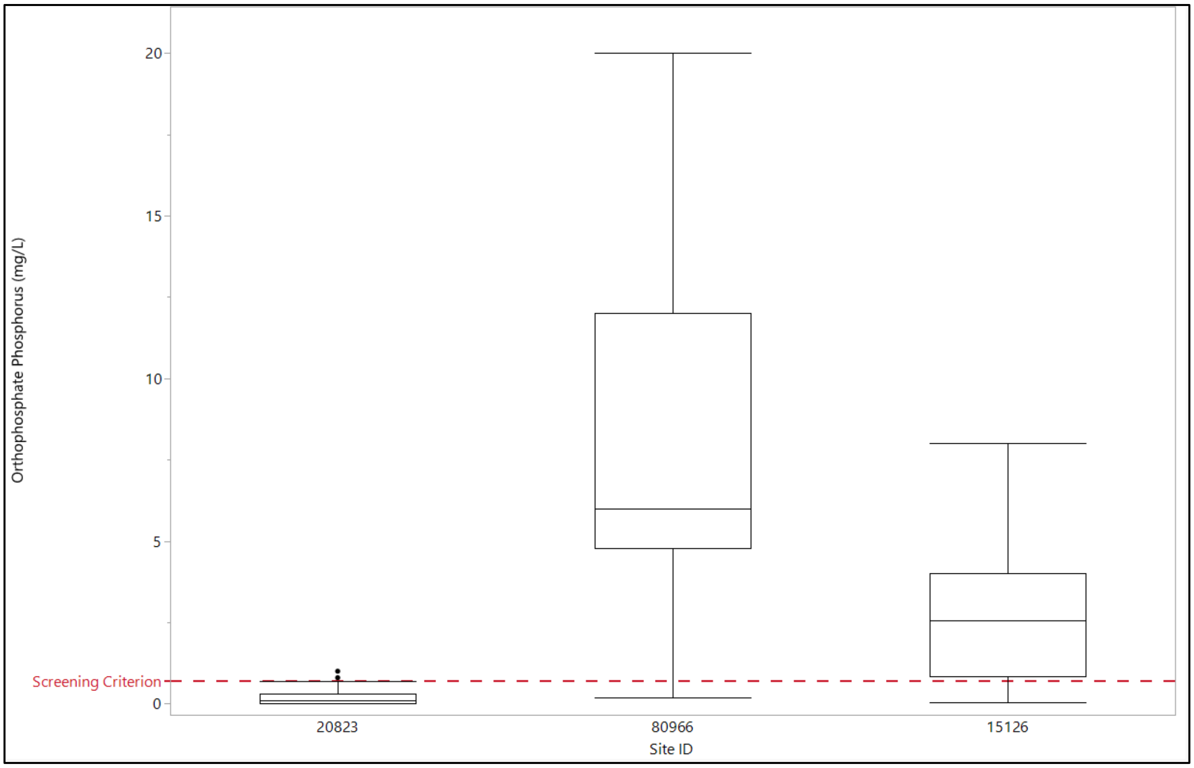

Figure 10. Orthophosphate phosphorus (mg/L) for Texas Stream Team sites within the Upper Cibolo Creek Watershed (Dec 1996 to Feb 2023).

WATERSHED SUMMARY

Texas Stream Team community scientists monitored standard core and advanced parameters at eight sites in the Upper Cibolo Creek Watershed from December 1996 to February 2023. All eight sites are either on Cibolo Creek proper or located on tributaries and/or adjacent habitats. One classified segment comprises the Upper Cibolo Creek Watershed (Segment 1908) within the Upper San Antonio River Basin. Collectively these eight sites were monitored for the Texas Stream Team by trained community scientists in the Upper Cibolo Creek Watershed.

Parameters monitored by Texas Stream Team community scientists included water and air temperature, specific conductance, total dissolved solids, dissolved oxygen, pH, transparency, total depth, nitrate-nitrogen, and orthophosphate. Available data from the eight monitoring sites were analyzed and summarized in this report.

The *2022* Integrated Report identified a bacteria impairment on Upper Cibolo Creek (Segment 1908). This segment is designated as Category 5C. Additional data and information will be collected or evaluated before a management strategy is selected. Concerns were also identified for nitrate and total phosphorus.

The Texas Stream Team community scientists did not monitor *E. coli* bacteria, however, they did monitor the advanced nutrient parameters for which there are concerns. Results of the nitrate-nitrogen and orthophosphate phosphorus data analysis supports the concerns identified in the Integrated Report. Two sites, Currey Creek at the Boerne wastewater treatment plant effluent outfall (site 80966) and Cibolo Creek at Menger Creek (site 15126), exceeded the screening criteria for nitrates and total phosphorus. With the growing human population and increased development in the watershed, these findings should be of concern to residents and decision-makers.

Other noteworthy and concerning results presented in this data report include exceedance of the water quality standard for total dissolved solids at Currey Creek at the Boerne wastewater treatment plant effluent outfall (site 80966). Also, the two sites downstream of the Boerne wastewater treatment plant, the Cibolo Nature Center Marsh (site 80186) and Menger Creek (site 15126), periodically exhibited discreet exceedances of the water quality standard during the period of record for this study. In addition, the minimum grab standard for dissolved oxygen (3.0 mg/L) was not met at half of the sites assessed at some point during the period of record for this study. Those sites included the fifth crossing on Upper Cibolo Creek Road (site 80187), River Road Park (site 20823), Menger Creek Bridge at Herff Road near main street (site 82596), and Cibolo Nature Center Marsh (site 80186). And for pH, the Menger Creek Bridge site on Herff Road near main street (site 80596) had one exceedance of the minimum water quality standard during the period of record evaluated.

The Texas Stream Team community scientists monitoring standard core and advanced water quality parameters in the Upper Cibolo Creek Watershed are encouraged to continue monitoring. Continuation of the ongoing monitoring is crucial due to the results presented here and the potential for increased development in the watershed. Continued water quality monitoring is important for the development of long-term data sets that describe current water quality conditions and for historical and future trends to capture changes in water quality as the area grows. Texas Stream Team will continue to support community scientists by providing technical support, creating new monitoring sites, and re-activating existing sites. We look forward to training new community scientists to expand, grow, and sustain 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 7. Endangered species located within the Upper Cibolo Creek Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	Texas Blind Salamander	Federally Listed as Endangered, State Listed as Endangered
Birds	Whooping Crane	Federally Listed as Endangered, State Listed as Endangered
	Golden-cheeked Warbler	Federally Listed as Endangered, State Listed as Endangered
Fish	Fountain Darter	Federally Listed as Endangered, State Listed as Endangered
Crustaceans	Peck's Cave Amphipod	Federally Listed as Endangered, State Listed as Endangered
Insects	Comal Springs Riffle Beetle	Federally Listed as Endangered, State Listed as Endangered
	No accepted common name	Federally Listed as Endangered
	No accepted common name	Federally Listed as Endangered
	Helotes Mold Beetle	Federally Listed as Endangered
	Comal Spring Dryopid Beetle	Federally Listed as Endangered, State Listed as Endangered
Arachnids	Government Canyon Bat Cave Spider	Federally Listed as Endangered
	Cokendolpher Cave Harvestman	Federally Listed as Endangered
	Madla Cave Meshweaver	Federally Listed as Endangered
	Robber Baron Cave Meshweaver	Federally Listed as Endangered
	Braken Bat Cave Meshweaver	Federally Listed as Endangered

	Government Canyon Bat Cave Meshweaver	Federally Listed as Endangered
Mollusks	False Spike	Federally Proposed as Endangered
	Guadalupe Fatmucket	Federally Proposed as Endangered
	Guadalupe Orb	Federally Proposed as Endangered
Plants	Tobusch Fishhook Cactus	State Listed as Endangered

Table 8. Threatened species located within the Upper Cibolo Creek Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	San Marcos Salamander	Federally Listed as Threatened, State Listed as Threatened
	Texas Salamander	State Listed as Threatened
	Cascade Caverns Salamander	State Listed as Threatened
Birds	White-faced Ibis	State Listed as Threatened
	Wood Stork	State Listed as Threatened
	Zone-tailed Hawk	State Listed as Threatened
	Piping Plover	Federally Listed as Threatened, State Listed as Threatened
Fish	Frio Roundnose Minnow	State Listed as Threatened
	Medina Roundnose Minnow	State Listed as Threatened
	Plateau Shiner	State Listed as Threatened
	Headwater Catfish	State Listed as Threatened
	Widemouth Blindcat	State Listed as Threatened
	Toothless Blindcat	State Listed as Threatened
	Guadalupe Darter	State Listed as Threatened
Mammals	Black Bear	State Listed as Threatened
	White-nosed Coati	State Listed as Threatened
Reptiles	Cagle's Map Turtle	State Listed as Threatened
	Texas Tortoise	State Listed as Threatened
	Texas Horned Lizard	State Listed as Threatened
Mollusks	Guadalupe Fatmucket	State Listed as Threatened
	Guadalupe Orb	State Listed as Threatened
	False Spike	State Listed as Threatened
Plants	Bracted Twistflower	Federally Proposed as Threatened

	Tobusch Fishhook Cactus	Federally Listed as Threatened

Table 9. State and federally listed species in the Upper Cibolo Creek Watershed in Bandera, Bexar, Comal, and Kendall Counties, Texas.

Taxon	**Endangered (Federal or State)**	**Threatened (Federal or State)**	**G1 or G2 (Critically imperiled or imperiled)**	**Species of Greatest Conservation Need (NPWD) (S1 or S2)**	**Endemic Total Count**
Amphibians	1	3	3	4	11
Birds	2	4	2	6	14
Fish	1	7	4	8	20
Mammals	0	2	0	6	8
Reptiles	0	3	0	6	9
Crustaceans	1	0	9	9	19
Insects	5	0	20	20	45
Arachnids	6	0	15	16	37
Mollusks	3	3	10	11	27
Arthropods	0	0	0	2	2
Plants	1	2	15	20	38
Total Count	**20**	**24**	**78**	**108**	**230**