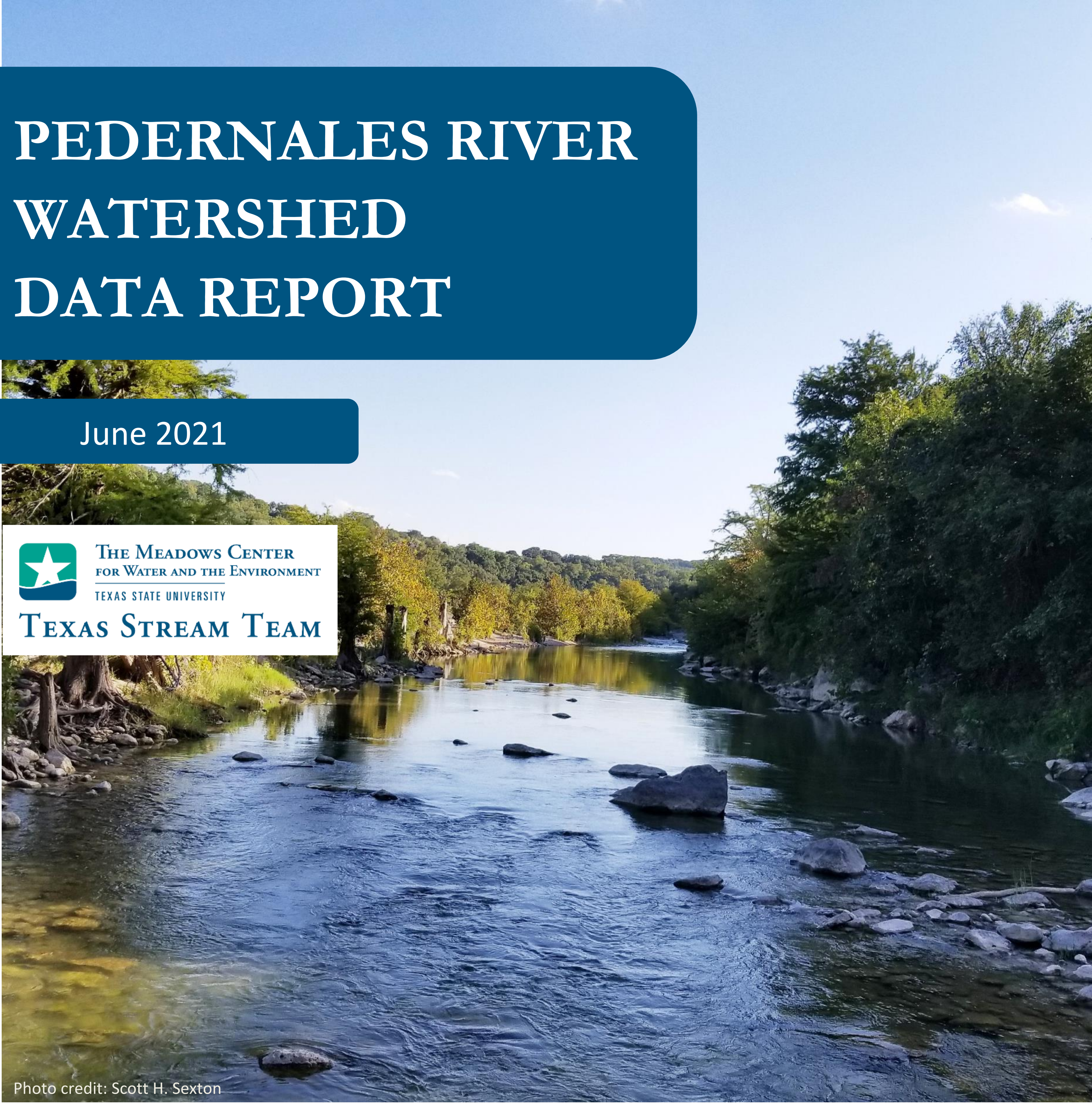
PEDERNALES RIVER WATERSHED DATA REPORT

June 2021



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

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INTRODUCTION

Texas Stream Team

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

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

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

The purpose of this report is to provide a summary of the data collected by Texas Stream Team citizen scientists. The data presented in this report should be considered in conjunction with other relevant water quality reports for a holistic view of water quality in the Pedernales River 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 (CRP) partner reports, such as Basin Summary and Highlight Reports
- TCEQ Total Maximum Daily Load (TMDL) reports
- TCEQ and Texas State Soil and Water Conservation Board Nonpoint Source Program funded reports, including watershed protection plans (WPPs)

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 Pedernales River traverses the central Texas Hill Country for approximately 106 miles from its headwaters in Kimble County until it reaches the Colorado River at Lake Travis. The watershed spans some 1,300 square miles and crosses six counties – Kimble, Kerr, Gillespie, Blanco, Hays, and Travis – and is part of the larger Colorado River Basin (Figure 1).

The Texas Commission on Environmental Quality (TCEQ) classifies freshwater stream segments in the Pedernales River watershed. The Pedernales River is comprised of the classified mainstem (Segment 1414) and five unclassified tributaries including Lick Creek (Segment 1404D), Cypress Creek (Segment 1414B), Miller Creek (Segment 1414D), Barons Creek (Segment 1414A), and Live Oak Creek (Segment 1414C). The Pedernales River and its tributaries provide 23 percent of the inflows to Lake Travis and serves as a drinking water supply for the City of Austin (The Meadows Center for Water and the Environment, 2017).

National Oceanic and Atmospheric Administration (NOAA) climate data from Johnson City, Texas was acquired from the National Data Center (NOAA, 2020). Precipitation averaged 34 inches annually and occurs year-round (Figure 2). Long-term monthly average precipitation has a bimodal distribution with peaks occurring in the summer months of May and June, and in October in the fall. Average rainfall during these months was approximately 4 inches per year. The least amount of rainfall (1.99 inches) occurred in August, which coincided with the warmest time of the year (28.3 °C).

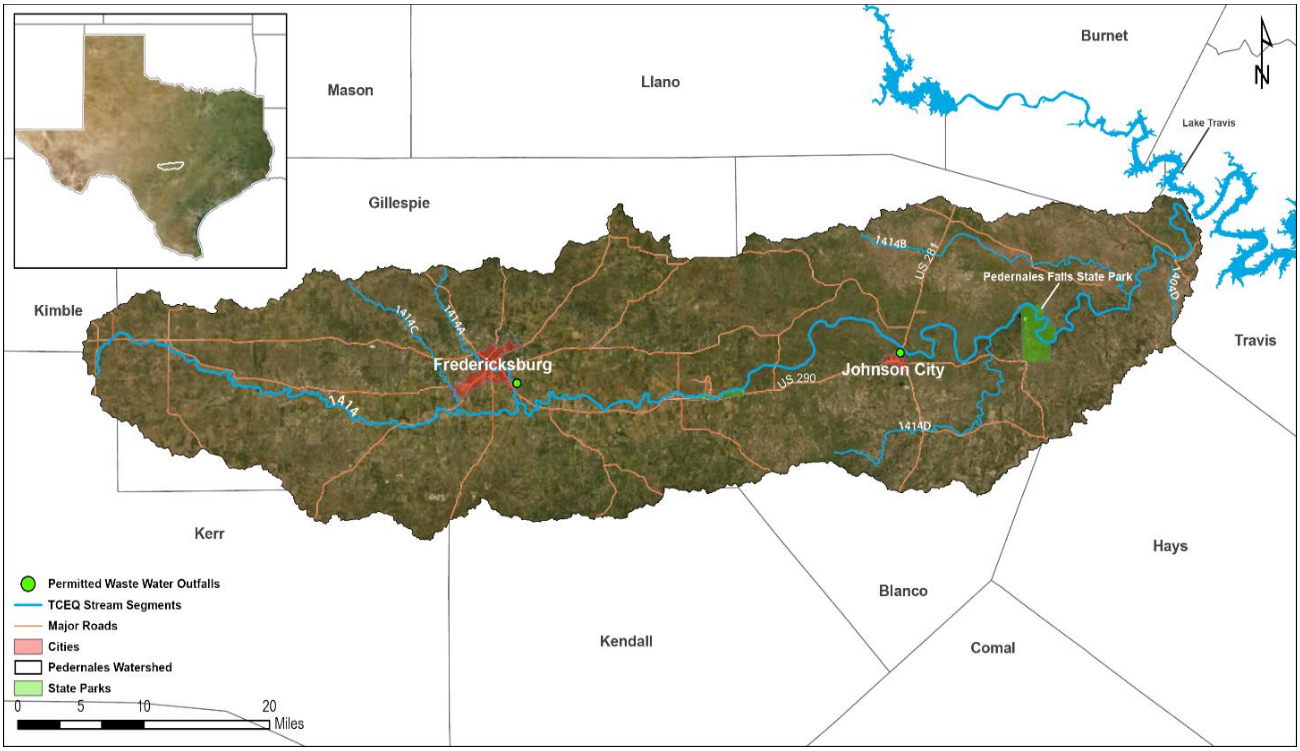

Figure 1. Pedernales River Watershed in the Central Texas Hill Country.

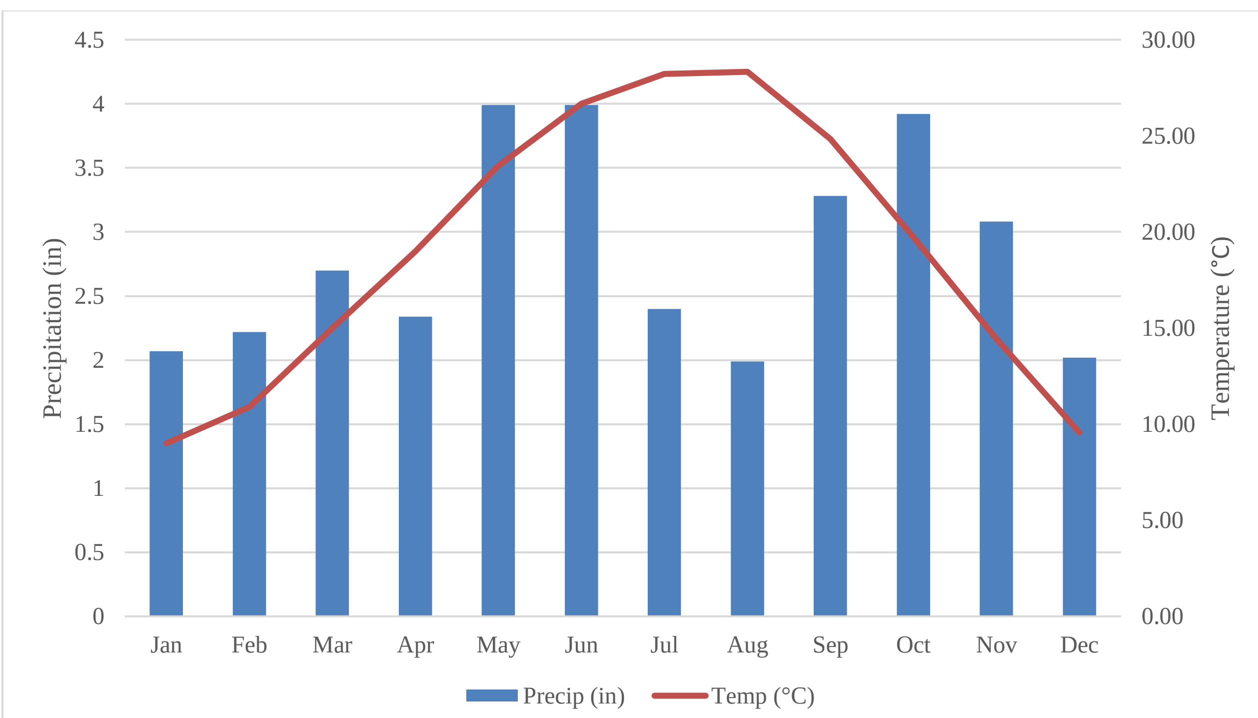

Figure 2. Long-term (1981-2010) monthly average precipitation (in) and air temperature (°C) from Johnson City, Texas (NOAA Climate Data, 2020).

Physical Description

The Pedernales River rises from natural springs originating from the Trinity-Edwards Aquifer and flows eastward through the Edwards Plateau. The Edwards Plateau ecoregion is characterized geomorphologically by a limestone plateau with a network of spring-fed perennial streams that serve as tributaries to the larger river system. The streams are typically cool and clear due to the underlying karst topography and support contact recreation activities such as swimming, kayaking, and fishing. Two parks provide direct access to the river and include the Pedernales Falls State Park and the Lyndon B. Johnson Historical Park.

A major geologic feature of the Pedernales River is the Llano Uplift which is responsible for the Pedernales Falls within Pedernales Falls State Park located in the eastern part of the watershed. In this area, the river changes elevation and drops about 50 feet within about a quarter mile stretch where layered, step-down limestone formations can be observed (Texas Parks and Wildlife Department, 2021). The Pedernales River generally flows through a rocky, rugged terrain where the ground typically rises far above the river valley. Owing to this geomorphology, the Pedernales River is well-known for flash flooding due to the steep sloping drainage. The upper reaches of the Pedernales River are often dry, with most of the water located in the lower reaches (Lower Colorado River Authority, 2000).

The underlying limestone throughout the watershed is part of the Marble Falls formation and is over 300 million years old. During the Cretaceous period between 100 to 120 million years ago, this part of Texas was covered by ocean sea water. For this reason, many marine fossils can be found in the limestone deposits as they become exposed due to erosion.

Ecoregion

The Pedernales River watershed is comprised of the Edwards Plateau Woodland and Llano Uplift Level IV ecoregions (USEPA, 2021). This area is diverse in flora and fauna typical of the Texas Hill Country. Ashe juniper and mesquite brush have prevailed because of fire suppression and grazing pressures, reducing the savanna character historically found in the Edwards Plateau. The Llano Uplift is described as a basin, surrounded by a limestone escarpment (USEPA, 2021). Woody vegetation found in this area depending on aspect and habitat may include live oak, honey mesquite, post oak, blackjack oak cedar elm, and black hickory. This area is known for the exposed granite batholith that has been dated to be one billion years old.

The land use types in the watershed are diverse. A mixture of grass prairieland and wooded areas inhabit the Edwards Plateau, but ranching is the major land use in the Llano Uplift with areas of sandy loam also producing agricultural crops such as wheat, sorghum and peaches.

Land Use

Land cover types were calculated for the Pedernales River watershed (Figure 3) using USGS National Land Cover Data (NLCD,2016). The watershed predominantly consists of shrub/scrub (70%) and forest (19%), with all other land use types, (i.e., open water, developed, barren, forest, grasslands/herbaceous, planted and cultivated, woody wetlands, and emergent herbaceous wetlands) making up just over 10% combined (Table 1) (NLCD, 2016).

Table 1. Land use and land cover for Pedernales River watershed (USGS, 2016).

Land Use	Acres	Hectares	Percent (%)
Open Water	2,741.58	1,109.50	0.33%
Developed	27,444.30	11,106.56	3%
Barren Land	382.44	154.77	0.05%
Forest	157,924.00	63,910.97	19%
Shrub/Scrub	573,203.00	231,972.08	70%
Grasslands/Herbaceous	32,650.50	13,213.48	4%
Planted & Cultivated	24,811.60	10,041.12	3%
Woody Wetlands	201.64	81.60	0.025%
Emergent Herbaceous Wetlands	16.45	6.66	0.002%
Total	819,375.52	331,596.73	100.00%

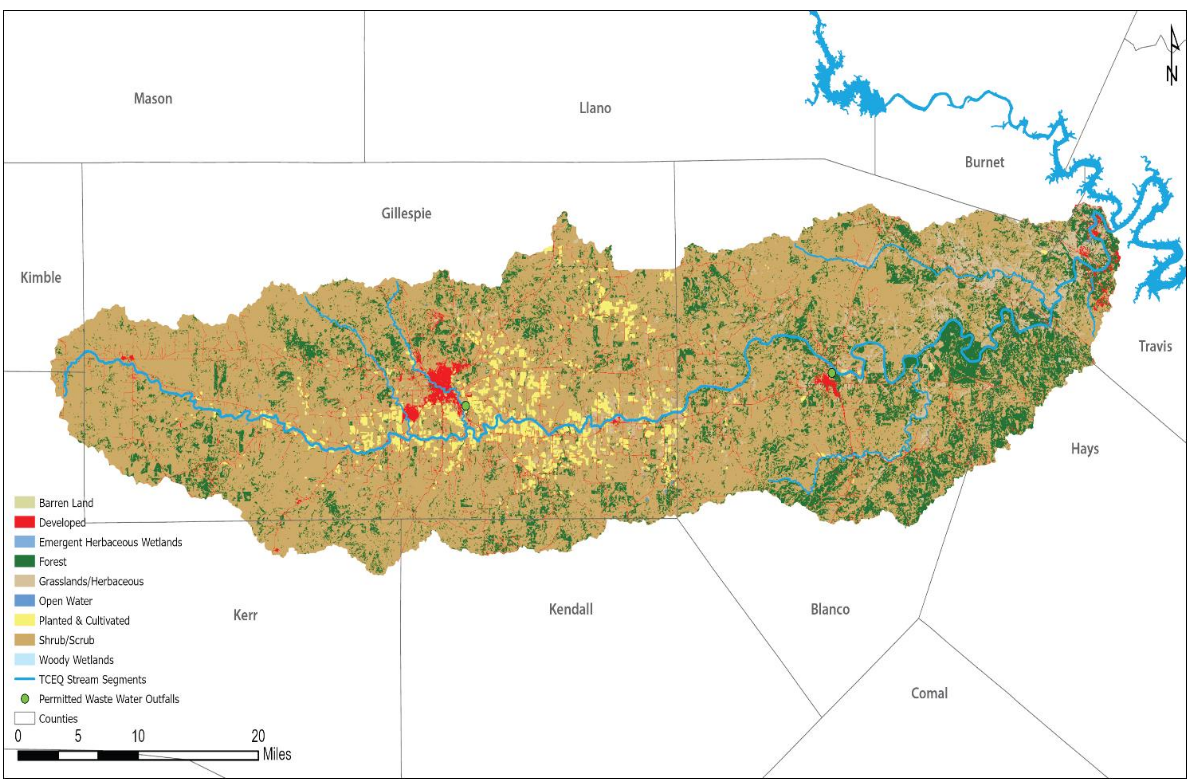

Figure 3. Land cover for the Pedernales River watershed (USGS, 2016).

History

The name Pedernales, pronounced “Perdenales,” is the Spanish term for the flint rocks characteristic of the riverbed (Smyrl, 2021). The Lipan Apache Indians were the first inhabitants of the Pedernales River. The areas of Fredericksburg, Harper, and Johnson City were later colonized by German immigrants in the mid- to late-1800s, once the threat of Indian raids subsided.

Endangered Species and Conservation Needs

The common names of 46 species listed as threatened or endangered (under the authority of Texas state law and/or under the US Endangered Species Act) within the Pedernales River watershed are included in Appendix I at the end of this report. Table 2 provides a summary of the number of species per taxonomic group listed as endangered, threatened, G1 or G2, species of greatest conservation need, and endemic.

Table 2. State and Federally Listed Species in the Pedernales River 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 Count
Amphibians	3	5	7	8	10
Birds	2	7	1	7	15
Fish	3	4	2	7	12
Mammals	0	2	0	6	19
Reptiles	0	3	0	4	12
Insects	4	0	22	22	34
Crustaceans	0	1	9	7	8
Mollusks	0	4	14	15	26
Arachnids	4	0	25	25	15
Plants	1	3	15	22	62
Total Count	17	29	95	123	213

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 so that it supports public health and protects aquatic life, consistent with the sustainable economic development of the state. Water quality standards identify appropriate uses for the state’s surface waters, including aquatic life, recreation, and sources of public water supply (drinking water). The criteria for evaluating support of those uses in the Pedernales River 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 Pedernales River Watershed (TCEQ, 2018).

Segment	TDS (mg/L)	Dissolved Oxygen (mg/L)	pH Range (s.u.)	*E. coli* Bacteria (#/100 mL)	Temperature (°C)
1414 - Pedernales River (High Aquatic Life Use)	525	*Mean: 5.0 Minimum: 3.0	6.5-9.0	Primary Contact Recreation1: 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 the Pedernales River (Segment 1414) and found no water quality impairments. Subsequently, no watershed protection plans have been prepared in the Pedernales River 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 conductivity 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 (EPA) 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.

The Pedernales River is designated a primary contact recreation 1 (PCR1) use. This means that recreation activities on the Pedernales River 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 Quality Assurance Project Plan (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 all E. coli sampling events, station ID, location, sampling time, date, depth, sample collector's name/signature, group identification number, incubation temperature, incubation duration, E. coli colony counts, dilution aliquot, field 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 and its tributaries 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 the Pedernales River were acquired for this report (Figure 4). All three sites are on the Pedernales River mainstem (Segment 1414). Between 63 and 65 sampling events occurred at each site, for a total of 192 sampling events (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. Pedernales River watershed Texas Stream Team monitoring sites.

Site ID	Description	Number of Samples (n)	Period of Record
12382	Pedernales River, near SH 16	65	3/23/2012 – 2/20/2015, 2/23/2018 - 1/22/2021
17472	PEDERNALES RIVER @ US 87	64	3/23/2012 – 2/20/2015 2/23/2018 - 1/22/2021
80881	PEDERNALES RIVER @ OLD SAN ANTONIO RD	63	11/15/2012 - 2/20/2015 2/23/2018 – 1/22/2021

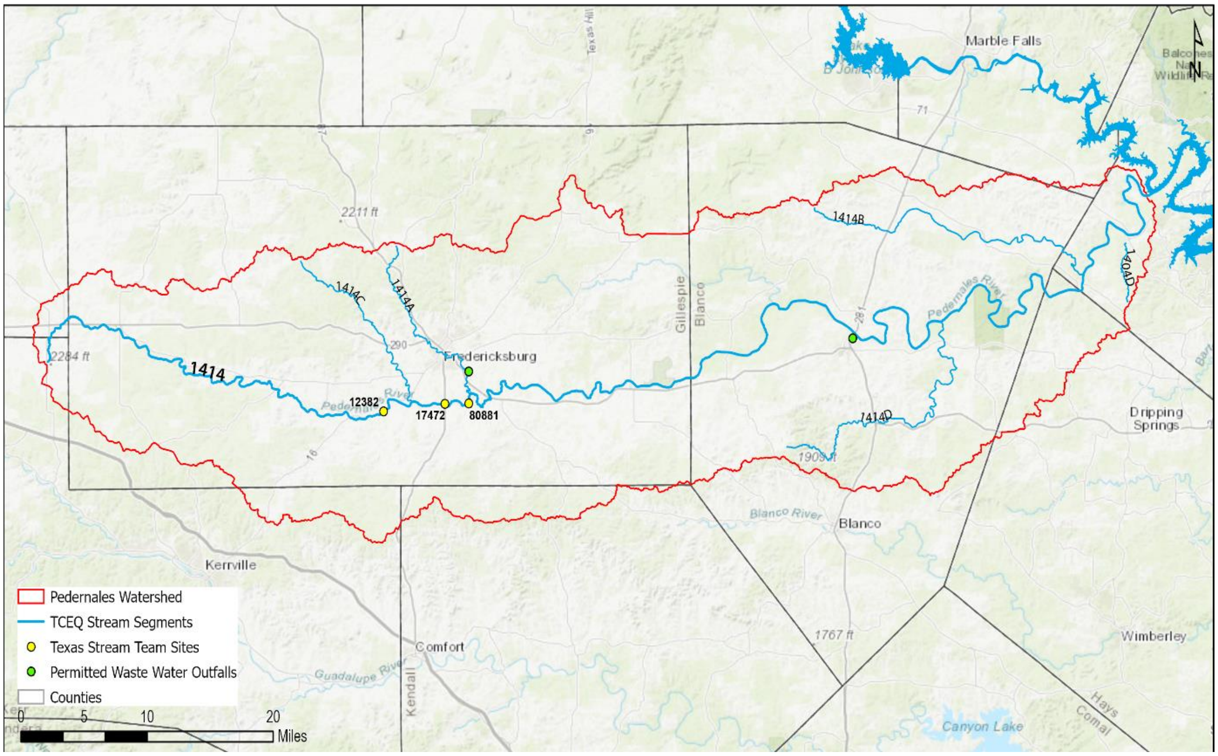

Figure 4. Pedernales River watershed Texas Stream Team citizen scientist monitoring sites.

Site Analysis

The period of record for data analyzed for this report intermittently spanned from March 2012 to January 2021. Data from 192 monitoring events conducted at three sites were acquired from the Waterways Dataviewer (Table 4). Water quality monitoring data for the three sites in the Pedernales River were analyzed and summarized in Table 5 including the number of samples, mean, standard deviation, and range of values. Citizen scientists monitored three sites for standcore and E. coli bacteria water quality monitoring parameters. The total number of sampling events for the Texas Stream Team core and E. coli bacteria water quality monitoring parameters (air and water temperature, conductivity, total dissolved solids (TDS), dissolved oxygen, 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 20.8 to 21.2 °C (Table 5). The lower overall mean air temperature (20.8 °C) was observed at the SH16 site (12382) in the upper reach of the Pedernales River. The higher mean air temperature (21.2 °C) was observed at the Old San Antonio Road site (80881) on the lower Pedernales River. 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 US87 site (17472) and the lowest median temperature reported at Old San Antonio Road (80881).

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 19.9 °C at the US87 site (17472) in the middle reach of the Pedernales River to 20.2 °C at the other two sites (Table 5). The distribution of water temperatures for each site are displayed in Figure 5 from upstream to downstream with all three sites having approximately equal (20.0 °C) median water temperatures.

Specific Conductance

Conductivity measurements were converted to total dissolved solids (TDS) for all sites (Table 5). Average TDS values at all sites were below the WQS of 525 mg/L. Average TDS values for all three sites ranged from 393 to 437 mg/L (Table 5). The distribution of TDS measurements for each site from upstream to downstream are displayed in Figure 6 with the highest median TDS reported at US87 site (17472) in the middle Pedernales River and the lowest median TDS reported at SH16 site (12382) in the upper Pedernales River.

Dissolved Oxygen

Average dissolved oxygen values at all sites were above the 5.0 mg/L WQS in the Pedernales River (Table 5). The range of average DO values for all sites spanned from 6.2 to 5.3 mg/L. The distribution of DO measurements for each site from upstream to downstream are displayed in Figure 7. The highest median DO was reported at the US87 site (17472) and the lowest at SH16 (12382) in the Pedernales River.

pH

The pH values at all sites were well within the WQS of 6.5 to 9.0 s.u. (Figure 8). Average pH for all sites ranged from 8.0 to 8.1 s.u. (Table 5). The US87 site (17472) had a slightly higher median pH (8.2 s.u.), while the other two sites, Old San Antonio Road and SH16, had slightly lower values, 8.0 and 8.1 s.u., respectively (Figure 8).

Transparency

Secchi disc transparency was measured and reported at all three sites (Table 5). The average range of Secchi disc transparency values reported was from 0.4 to 0.9 m. The largest median transparency values were reported at US87 and Old San Antonio Road, 0.8 m for both sites, while the smallest was reported at SH16 (12382) at 0.3 m (Figure 9).

Total depth measurements are provided alongside the transparency measurements for a relative comparison (Figure 9). The smallest difference between the two measurements was at SH16, while the greatest difference was at Old San Antonio Road. The bigger the difference the less water transparency, therefore more turbid.

Total Depth

Total depth at each site was also measured and reported (Table 5). The deepest average total depth was reported at the Old San Antonio Road site (1.5 m), while the shallowest average total depth was reported at the SH16 site (0.4 m).

E. coli

E. coli bacteria was measured and reported at all three sites on the Pedernales River (Table 5). The E. coli geometric means for the entire period of record met the WQS (126 cfu/100 mL) at the SH16 site (12382), but not at the other two, US87 (17472) and Old San Antonio Road (80881) (Table 5). The median value at SH16 was below the WQS, but slightly above at US87 and Old San Antonio Road (Figure 10).

Trend analysis was conducted to determine if E. coli bacteria were increasing over time (Figure 11). Although not significant (p-value >0.05) for all sites, an increasing trend was observed for the SH16 site.

Table 5. Texas Stream Team data summary in the Pedernales River watershed (March 2012-January 2021). Mean±SD (range)

Parameter	**Pedernales River @ SH16 ID 12382 n=65**	**Pedernales River @ US87 ID 17472 n=64**	**Pedernales River @ Old SA Rd ID 80881 n=63**
Air Temp. (°C)	20.8±6.6 (30)	20.9±6.9 (29)	21.2±6.7 (31)
Water Temp. (°C)	20.2±6.2 (22)	19.9±6.5 (22.9)	20.2±6.4 (21.1)
Cond. (µS/cm)	604±105 (586)	672±127 (683)	669±112 (620)
***TDS (mg/L)**	393±68 (381)	437±83 (444)	435±73 (403)
Dissolved Oxygen (mg/L)	5.3±2.1 (9.0)	6.2±1.9 (10.1)	5.7±1.9 (9.5)
pH (s.u.)	8.0±0.2 (1.2)	8.1±0.2 (1.1)	8.1±0.2 0.7)
Secchi Disc Transp. (m)	0.4±0.1 (0.6)	0.8±0.5 (3.4)	0.9±0.4 (1.9)
Total Depth (m)	0.4±0.2 (1.3)	1.1±0.8 (4.8)	1.5±0.4 (2.1)
*******E. coli*** **(cfu/100mL)**	87.1 (4,990)	135.3 (5,000)	140.2 (5,000)

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

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

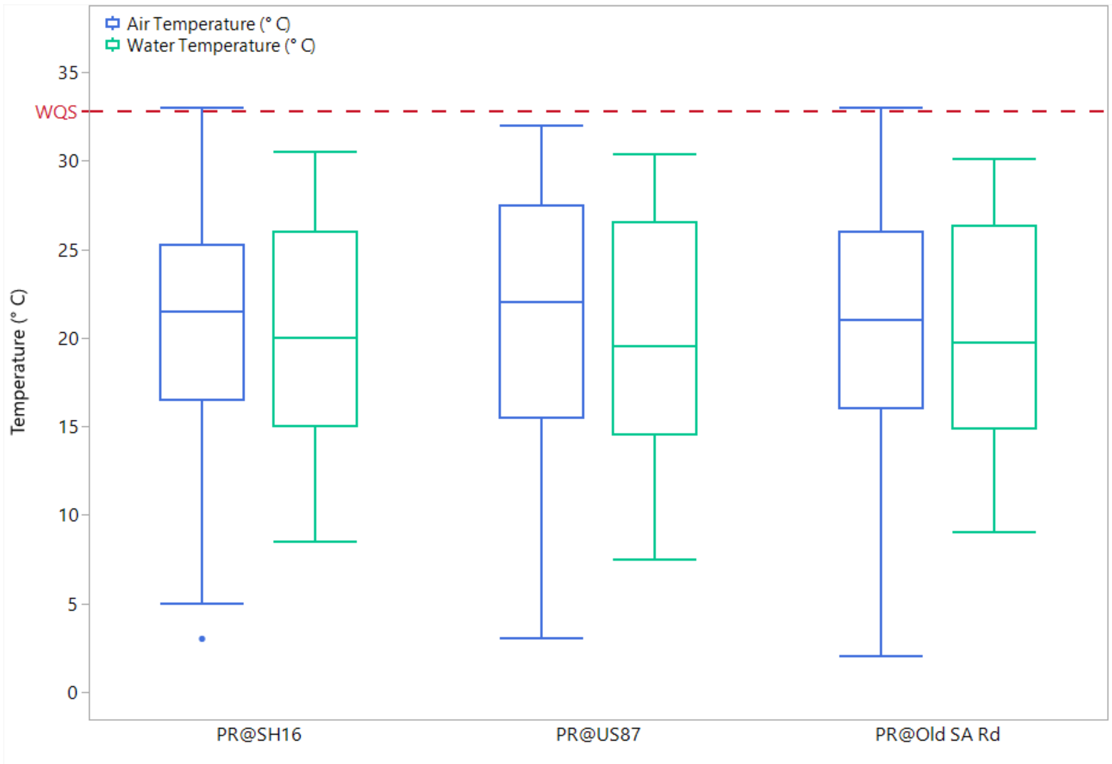

Figure 5. Air and water temperature for sites in the Pedernales River watershed (March 2012 – January 2021).

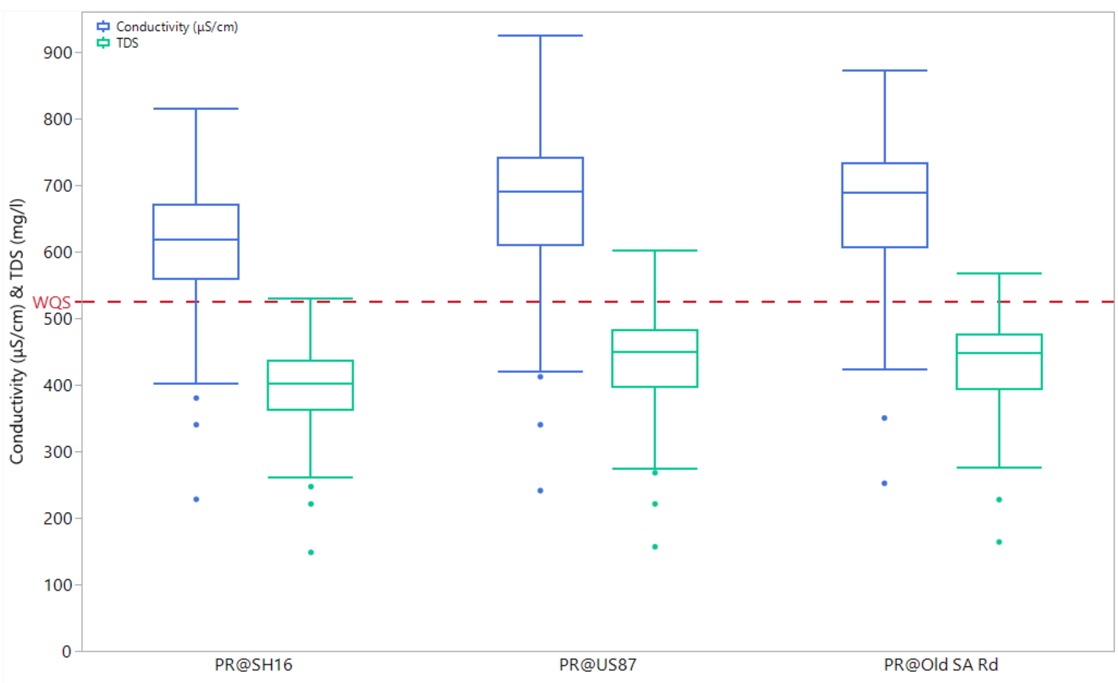

Figure 6. Conductivity (µS/cm) and total dissolved solids (mg/L) for sites in the Pedernales River watershed (March 2012 – January 2021).

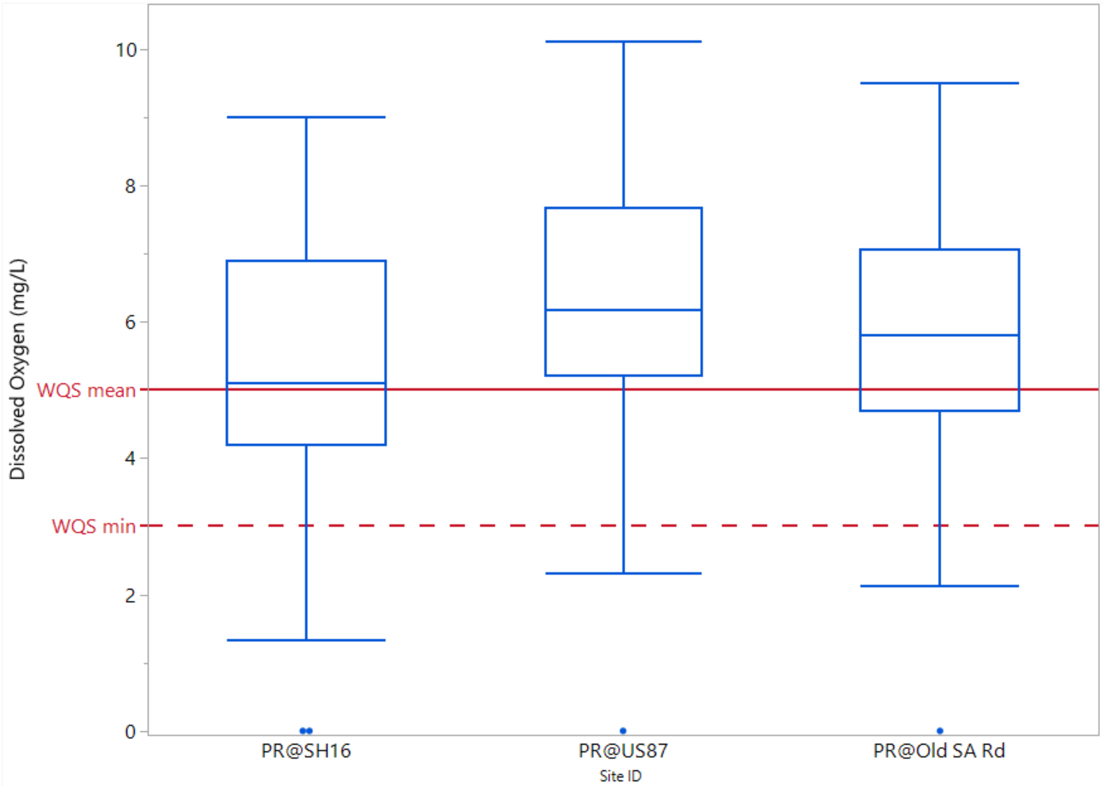

Figure 7. Dissolved oxygen (mg/L) for sites in the Pedernales River watershed (March 2012 – January 2021).

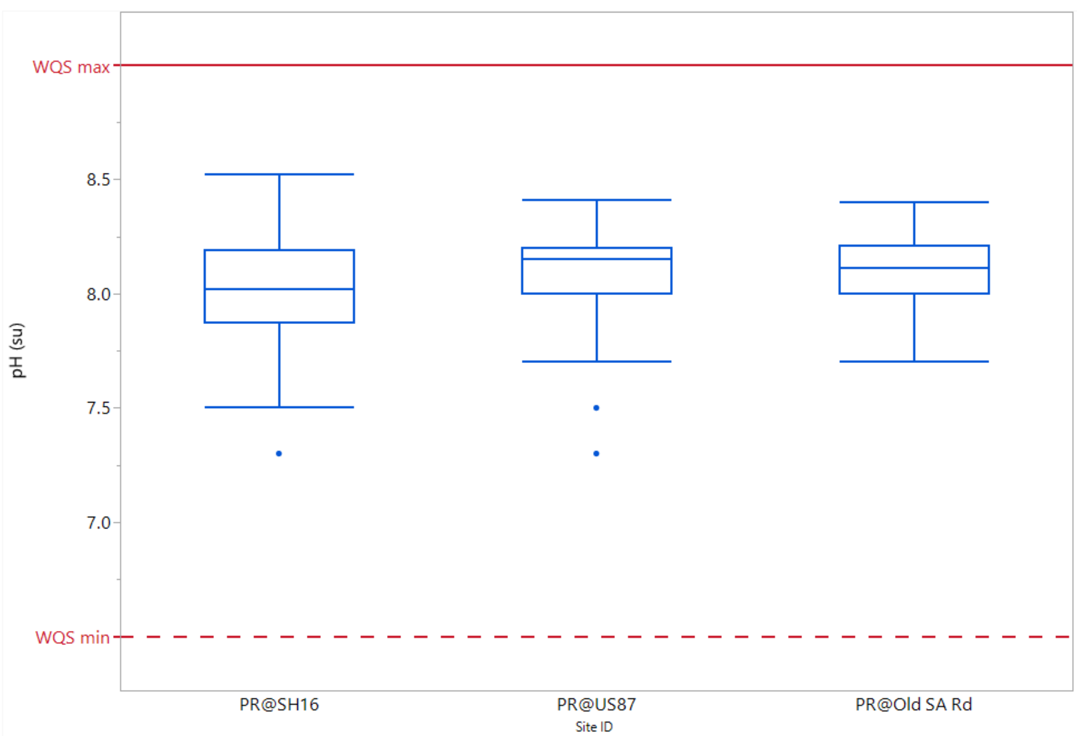

Figure 8. pH (s.u.) for sites in the Pedernales River watershed (March 2012 – January 2021).

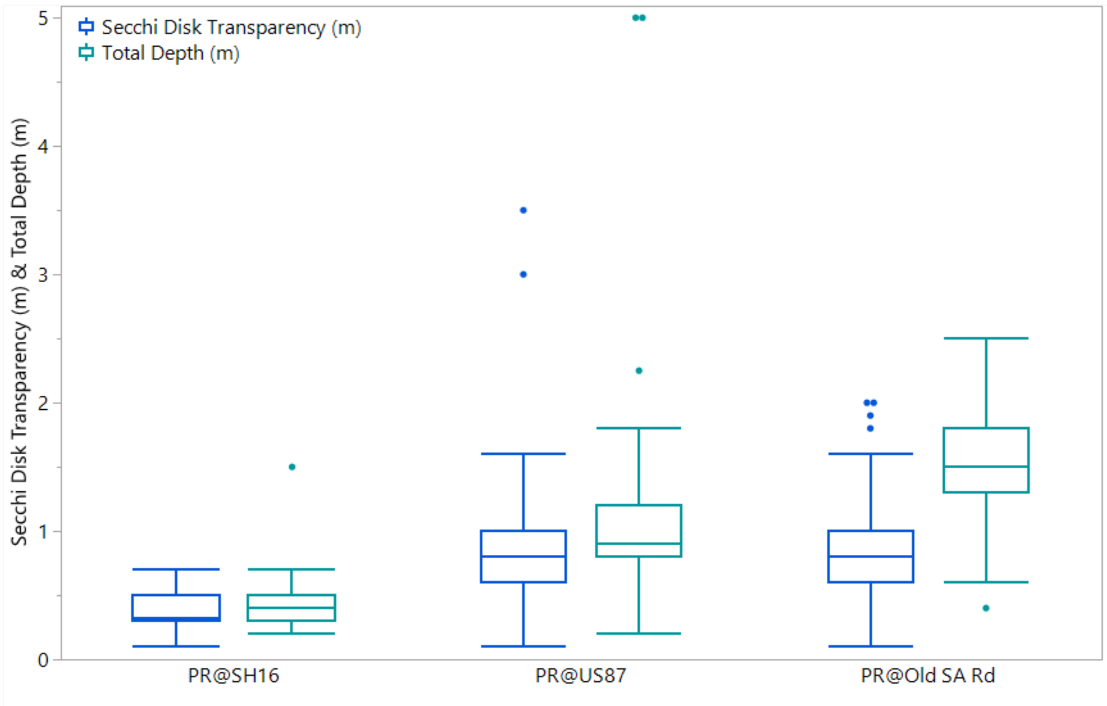

Figure 9. Secchi disc transparency (m) and total depth (m) for sites in the Pedernales River watershed (March 2012 – January 2021).

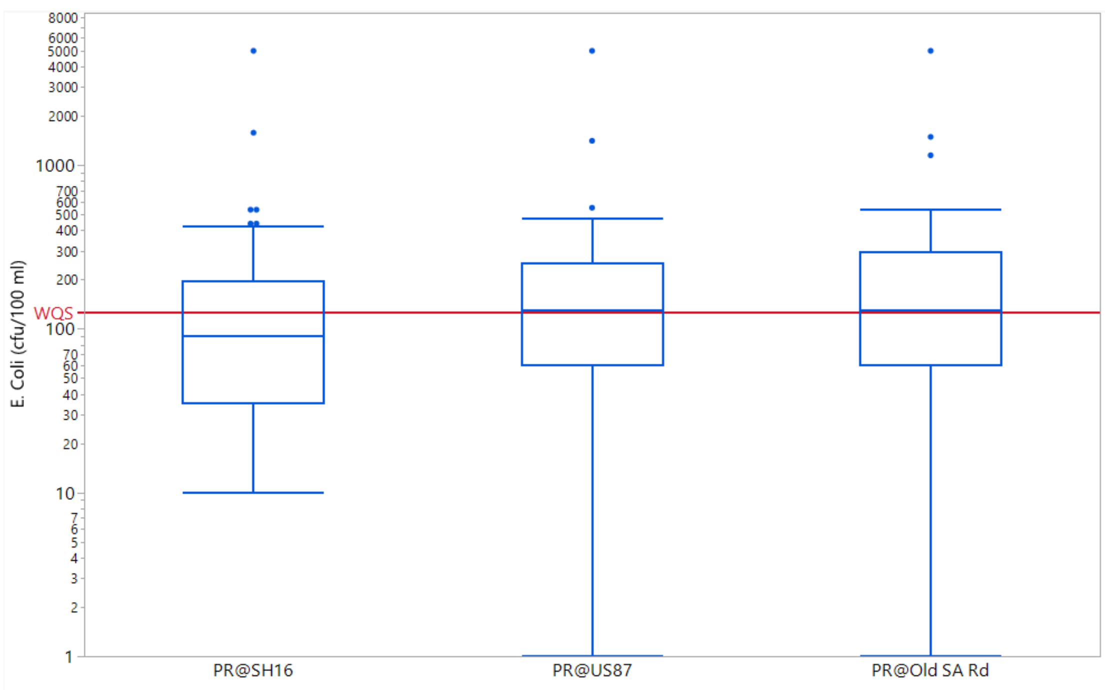

Figure 10. *E. coli* bacteria (cfu/100 ml) for sites in the Pedernales River watershed (March 2012 – January 2021).

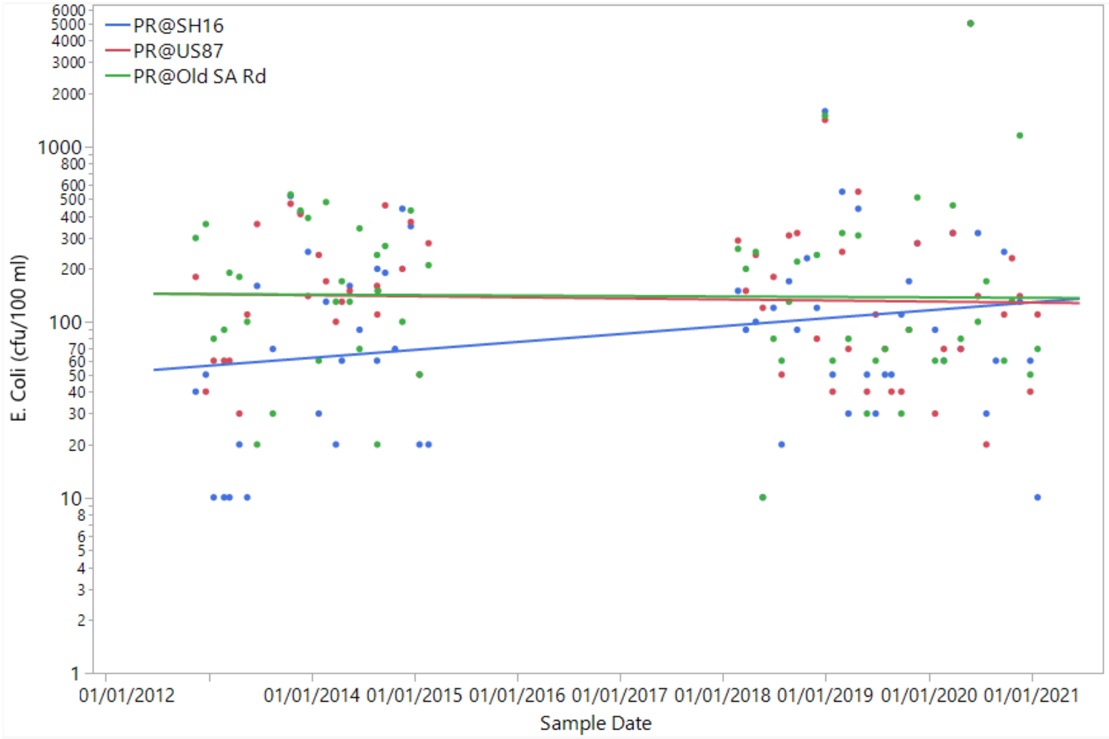

Figure 11. *E. coli* bacteria (cfu/100 m) trend analysis over time for sites in the Pedernales River watershed (March 2012 – January 2021).

WATERSHED SUMMARY

Texas Stream Team citizen scientists monitored standard core water quality parameters and E. coli bacteria at three sites in the Pedernales River watershed from March 2012 to January 2021. Parameters monitored included water and air temperature, specific conductance, total dissolved solids (conductivity), dissolved oxygen, pH, transparency, total depth, and E. coli. Monitoring for the Advanced Texas Stream Team parameters nitrate-nitrogen, orthophosphate, turbidity, and streamflow did not take place in the Pedernales River 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, DO, and pH were met at all sites in the Pedernales River watershed. The E. coli geometric mean at the SH16 site (12382) was higher than the water quality standard, but not at the other two sites, US87 (17472) and Old San Antonio Road (80881). In addition, a trend analysis was conducted to determine if E. coli bacteria was increasing over time. Although not significant (p-value >0.05) for none of the sites, an increasing trend was observed for the SH16 site.

Total depth measurements were provided alongside the transparency measurements for a relative comparison (Figure 9). The smallest difference between the two measurements was at

SH16, while the greatest difference was at Old San Antonio Road. The bigger the difference the less water transparency, therefore more turbid. Bacteria have been documented in high numbers in sediments, therefore highly turbid waters are generally associated with high bacteria counts. This is the case with the SH16 site in the Pedernales River.

The 2020 Texas Integrated Report, prepared biennially by TCEQ, reported no water quality impairments on the Pedernales River. Historically, water quality in the Pedernales River has met the WQS. Findings in this data summary report coincide with the historical account for the most part, however the primary concern for this area involves E. coli bacteria.

The Texas Stream Team citizen scientists monitoring water quality in the Pedernales River watershed are encouraged to continue monitoring and consider pursuing the Advanced water quality monitoring trainings. 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 Pedernales River Watershed

Species Type	Common Name	Federal/State Listing
Amphibian	Barton Springs salamander	Federally Listed as Endangered/State Listed as Endangered
	Texas Blind salamander	Federally Listed as Endangered/State Listed as Endangered
	Austin 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	Smalleye shiner	Federally Listed as Endangered/State Listed as Endangered
	Sharpnose shiner	Federally Listed as Endangered/State Listed as Endangered
	Fountain darter	Federally Listed as Endangered/State Listed as Endangered
Insects	Comal Springs riffle beetle	Federally Listed as Endangered/State Listed as Endangered
	Tooth Cave ground beetle	Federally Listed as Endangered/State Listed as Endangered
	Comal Springs dryopid beetle	Federally Listed as Endangered/State Listed as Endangered
Arachnids	Tooth Cave spider	Federally Listed as Endangered/State Listed as Endangered
	Reddell harvestman	Federally Listed as Endangered/State Listed as Endangered
	Bone Cave harvestman	Federally Listed as Endangered/State Listed as Endangered
	Tooth Cave pseudoscorpion	Federally Listed as Endangered/State Listed as Endangered
Plants	Texas wild-rice	Federally Listed as Endangered/State Listed as Endangered

Table 2: Threatened species located within the Pedernales River Watershed

Species Type	Common Name	Federal/State Listing
Amphibian	San Marcos salamander	State Listed as Threatened
	Jollyville Plateau salamander	State Listed as Threatened
	Texas salamander	State Listed as Threatened
	Blanco blind 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
	Swallow-tailed kite	State Listed as Threatened
	zone-tailed hawk	State Listed as Threatened
	Black Rail	Federally Listed as Threatened/ State Listed as Threatened
	Piping plover	Federally Listed as Threatened/ State Listed as Threatened
	Tropical parula	State Listed as Threatened
Fish	Medina roundnose minnow	State Listed as Threatened
	Plateau shiner	State Listed as Threatened
	Headwater catfish	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 T
	Texas tortoise	State Listed as Threatened
	Texas horned lizard	State Listed as Threatened
Crustacean	Texas troglobitic water slater	State Listed as Threatened
Mollusks	Texas Fatmucket	State Listed as Threatened
	Texas Pimpleback	State Listed as Threatened
	False Spike	State Listed as Threatened
	Texas Fawnsfoot	State Listed as Threatened
Plants	Tobusch fishhook cactus	Federally Listed as Threatened/State Listed as Threatened
	Small-headed pipewort	State Listed as Threatened
	Rock quillwort	State Listed as Threatened