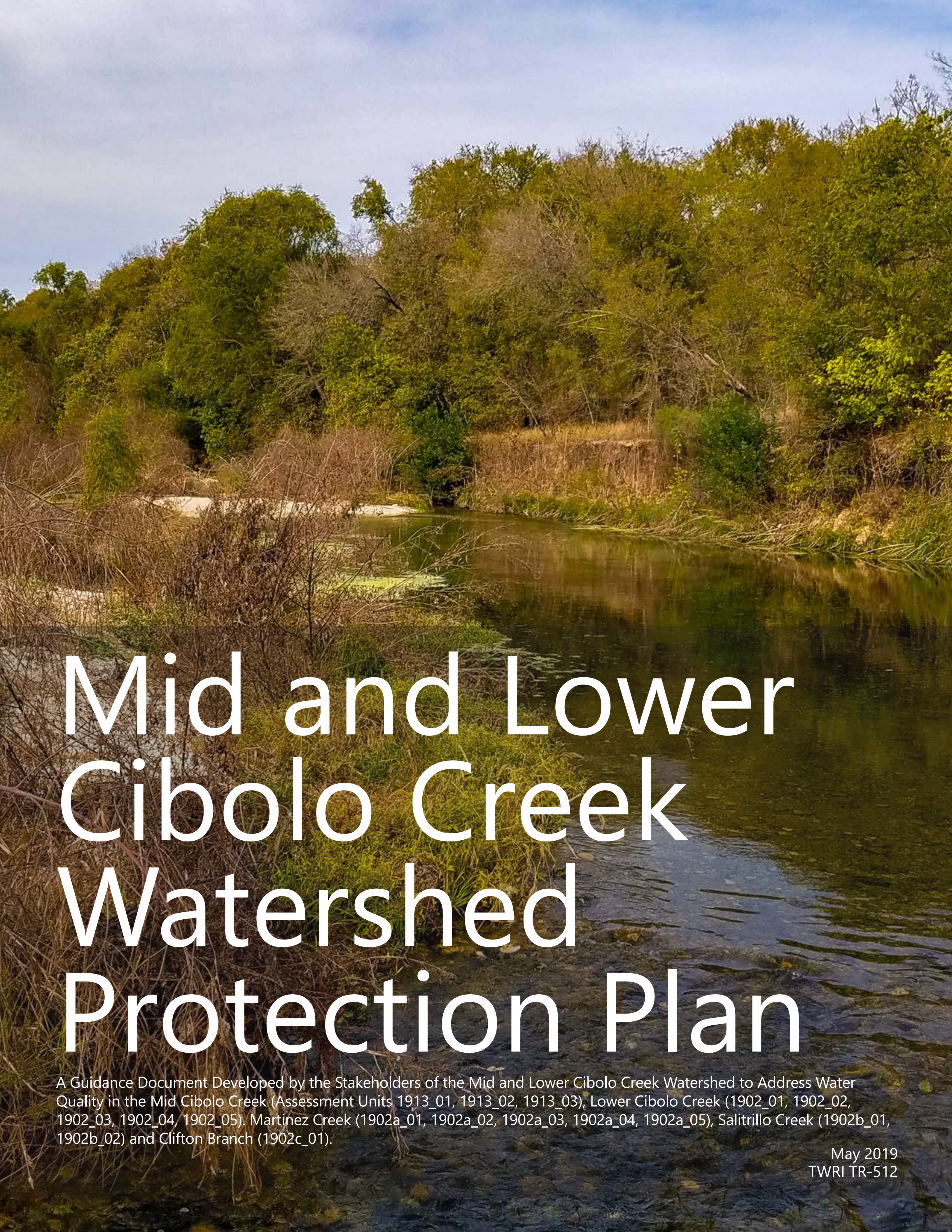

Mid and Lower Cibolo Creek Watershed Protection Plan

A Guidance Document Developed by the Stakeholders of the Mid and Lower Cibolo Creek Watershed to Address Water Quality in the Mid Cibolo Creek (Assessment Units 1913_01, 1913_02, 1913_03), Lower Cibolo Creek (1902_01, 1902_02, 1902_03, 1902_04, 1902_05). Martinez Creek (1902a_01, 1902a_02, 1902a_03, 1902a_04, 1902a_05), Salitrillo Creek (1902b_01, 1902b_02) and Clifton Branch (1902c_01).

May 2019
TWRI TR-512

Mid and Lower Cibolo Creek Watershed Protection Plan

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Texas Water Resources Institute

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Cover photo: Crescent Bend Nature Park in Cibolo, TX, by Clare Entwistle Escamilla, TWRI.

Acknowledgments

The Mid and Lower Cibolo Creek Watershed Protection Plan (WPP) presents the strategy developed by the stakeholders of the Mid and Lower Cibolo Creek watershed to restore water quality in the creek such that it meets applicable water quality standards. The Mid and Lower Cibolo Creek watershed stakeholders dedicated considerable time and effort in discussing the watershed, its influences on water quality, potential means to improve the watershed and water quality, and in selecting management strategies appropriate for inclusion in the watershed plan.

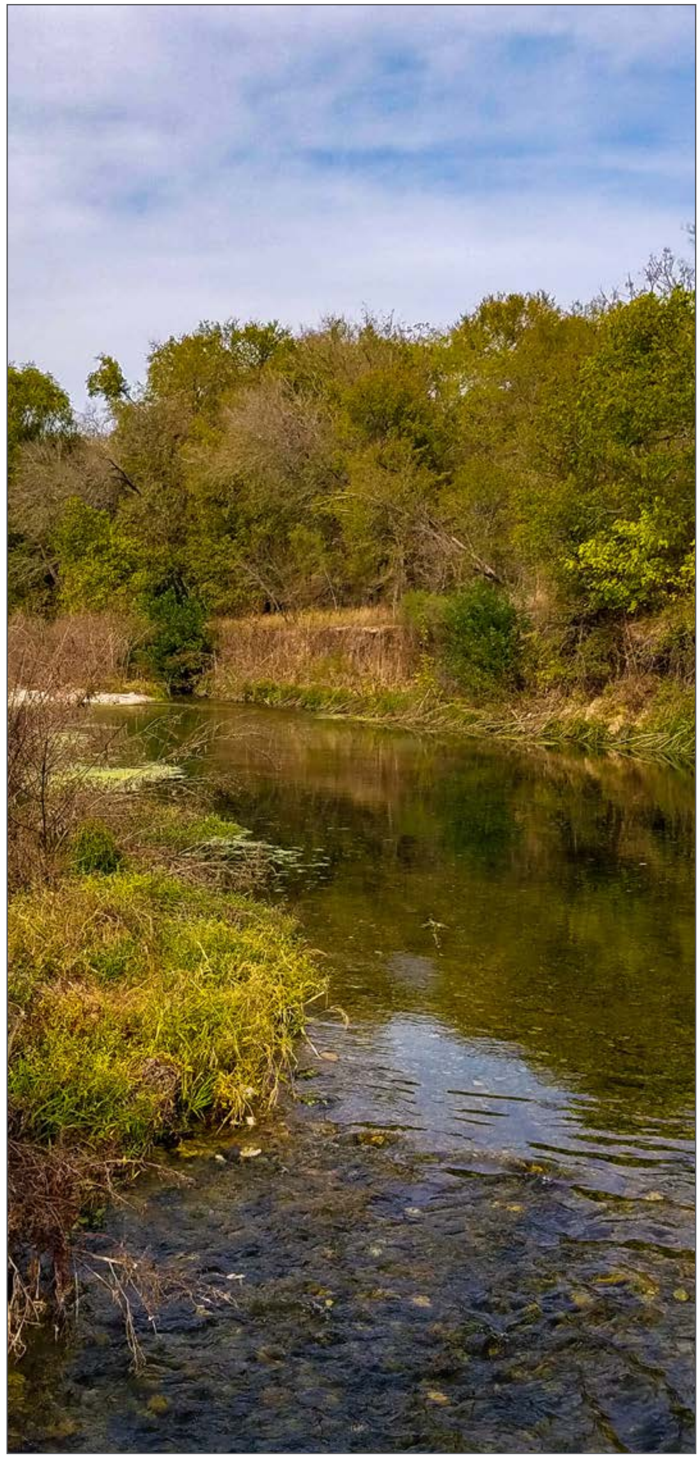
Special appreciation is extended to the many landowners and residents of the watershed who attended stakeholder meetings, workgroups, educational programs, and other events to provide direct input into the plan. Input from all stakeholders was critical to ensure the plan included recommendations that not only address the issues facing the watershed, but that landowners and residents could also feasibly implement the measures. The time and effort of these stakeholders is greatly appreciated and is reflected in the contents of this plan.

Agency support and input was an integral part of the Mid and Lower Cibolo Creek WPP development process. The technical guidance and willingness to provide specialized knowledge of many subjects is very much appreciated. Agencies contributing to the development of the Mid and Lower Cibolo Creek WPP include:

- Texas A&M AgriLife Extension Service
- Texas A&M AgriLife Research
- Texas State Soil & Water Conservation Board
- Texas Commission on Environmental Quality
- Texas Parks & Wildlife Department
- USDA Natural Resources Conservation Service

Local government organization also played a key role in plan development. Representatives provided insight regarding their specific focus areas and ensured inclusion of content in the plan is appropriate for the watershed. These organizations include:

- San Antonio River Authority
- Guadalupe-Blanco River Authority
- AgriLife Extension County Agents
- Cibolo Creek Municipal Authority
- Guadalupe County Farm Bureau
- Wilson County Farm Bureau
- City of Marion
- Guadalupe County
- City of Schertz
- Evergreen UGWCD
- Wilson County SWCD
- Alamo SWCD
- Karnes County SWCD
- City of Stockdale
- City of Cibolo
- City of Universal City



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List of Abbreviations

Acronym	Meaning
ac	Acre
AgriLife Extension	Texas A&M AgriLife Extension Service
AI	Adaptive Implementation
AU	Assessment Units
AnU	Animal Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
cfu	Colony Forming Unit
cfs	Cubic Feet Per Second
CP	Conservation Plan
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
E. coli	Escherichia coli
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FDC	Flow Duration Curve
FSA	Farm Service Agency
ft	Feet
GIS	Geographic Information System
hr	Hour
I&I	Inflow and Infiltration
LDC	Load Duration Curve
LID	Low Impact Development
LIP	Landowner Incentive Program
LULC	Land Use and Land Cover
m	Meter
mi	Mile
mi2	Miles Squared
mg/L	Milligram per Liter
MGD	Million Gallons per Day

Acronym	Meaning
mL	Milliliter
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
MSL	Mean Sea Level
NASS	National Agricultural Statistics Service
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
lbs	Pounds
RCPP	Regional Conservation Partnership Program
RMU	Resource Management Unit
RUAA	Recreational Use Attainability Assessment
SARA	San Antonio River Authority
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring Program
SWQMIS	Surface Water Quality Monitoring Information System
Texas Integrated Report	Texas Integrated Report of Surface Water Quality
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination Systems

Acronym	Meaning
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TWON	Texas Well Owners Network
USCB	U. S. Census Bureau
USDA	U.S. Department of Agriculture
USGS	U. S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF/P	Wastewater Treatment Facility/Plant
yds	Yards

Executive Summary

The Mid and Lower Cibolo Creek is a mixed rural and urban watershed located east of San Antonio. The watershed is predominately rural with a highly developed urban area emerging near the I-35 and I-10 corridors. However, with the increase of residential development and suburbanization, as well as increased hydraulic fracturing activity associated with the Eagle Ford Shale formation, the ecological health of the water body within this region is facing rising potential threat.

Problem Statement

Water quality monitoring conducted by the San Antonio River Authority (SARA) indicated that fecal indicator bacteria levels are often above the state's recreational water quality standard. Furthermore, 24-hour dissolved oxygen (DO) levels fall below water quality standards for minimum DO levels. While there are no specific standards for nutrient levels, water quality monitoring showed nitrate, ammonia and total phosphorus levels were above screening criteria and are listed as a concern as well. With the impairment and concern listings comes a need to plan and implement corrective actions to restore instream water quality.

Action Taken

A detailed analysis of the watershed's land and water resources was conducted, enabling stakeholders to be provided with up-to-date information on watershed characteristics and uses. Potential sources of bacteria pollution were identified and quantified based on data from local, state and federal databases as well as local stakeholder knowledge. Data were integrated into several simplistic watershed models to determine the types and sources of impairment-causing pollutants in the watershed with the highest potential to impact water quality.

Mid and Lower Cibolo Creek Watershed Protection Plan Overview

This document is the result of a two-year stakeholder process to identify sources of pollution in the watershed and develop a plan to reduce loadings through the implementation of voluntary management measures. The plan describes management measures created and supported by stakeholders to address potential sources of pollutants and help decrease loading into the creek. Management measures were selected based on cost effectiveness, stakeholder willingness to adopt measures and success in mitigating pollutant loads.

Pollutant Sources

Stakeholder input, backed by credible science, was used to identify potential sources of fecal-derived bacteria pollutants and DO depressing nutrient pollutants. Sources of bacteria loading identified in the watershed include: cattle and other livestock, household pets, deer, on-site sewage facilities (OSSFs), feral hogs, wastewater treatment facilities (WWTFs) and urban runoff. While other sources of bacteria are likely present in the watershed, available information was insufficient to reliably estimate loadings.

Recommended Actions

Eight primary recommended actions were made to improve water quality in the Mid and Lower Cibolo Creek watershed. Individual recommendations were crafted to deal with bacteria and nutrient pollution but in many cases will have ancillary effects on other pollutants as well. Briefly, these actions are as follows:

Water Quality Management Plans or Conservation Plans

To manage bacteria and nutrient loadings from cattle and other livestock more effectively, voluntary implementation of site-specific water quality management plans and conservation plans are necessary. These plans include technical assistance to help landowners implement best management practices that improve land stewardship and protect water quality. These plans can also help landowners obtain some financial assistance to implement the plans. Each plan is unique to the individual landowner's needs and wants. Some examples of management practices are brush management, alternate water and shade areas for livestock, fencing and buffer strips.

Feral Hog Control

Feral hog management was identified as a big need in the Mid and Lower Cibolo Creek watershed. Active and passive management controls will be implemented throughout the watershed to help control populations and reduce damage to lands and riparian areas. Landowners will be encouraged to continue voluntary trapping and removal of feral hogs with assistance from various agencies. Educational programs will be brought to the watershed to discuss proper management techniques.

On-Site Sewage Systems

Failing OSSFs, in particular those located close to a water body, have been known to contribute to water quality impairments. The strategies to improve OSSF management includes educational programs on how to operate and maintain septic systems. Priority will also be given to identify, repair and replace failing OSSFs as funds are available.

Pet Waste

Pet waste was identified as one of the bigger contributors to bacteria and nutrient loading in the watershed. Outreach and education are key components to proper management of pet waste by owners. Increasing the amount of pet waste stations in public parks and apartment complexes will also increase the likelihood of proper waste disposal.

Urban Stormwater

Urban stormwater is predicted to increase as the watershed continues to develop and grow. Proper management of urban stormwater includes stormwater planning and best management practices implementation to reduce bacteria and nutrient runoff from entering the creek. The plan includes working with cities to identify appropriate areas to implement green stormwater infrastructure, riparian restoration and other practices.

Sanitary Sewer Overflows (SSOs)

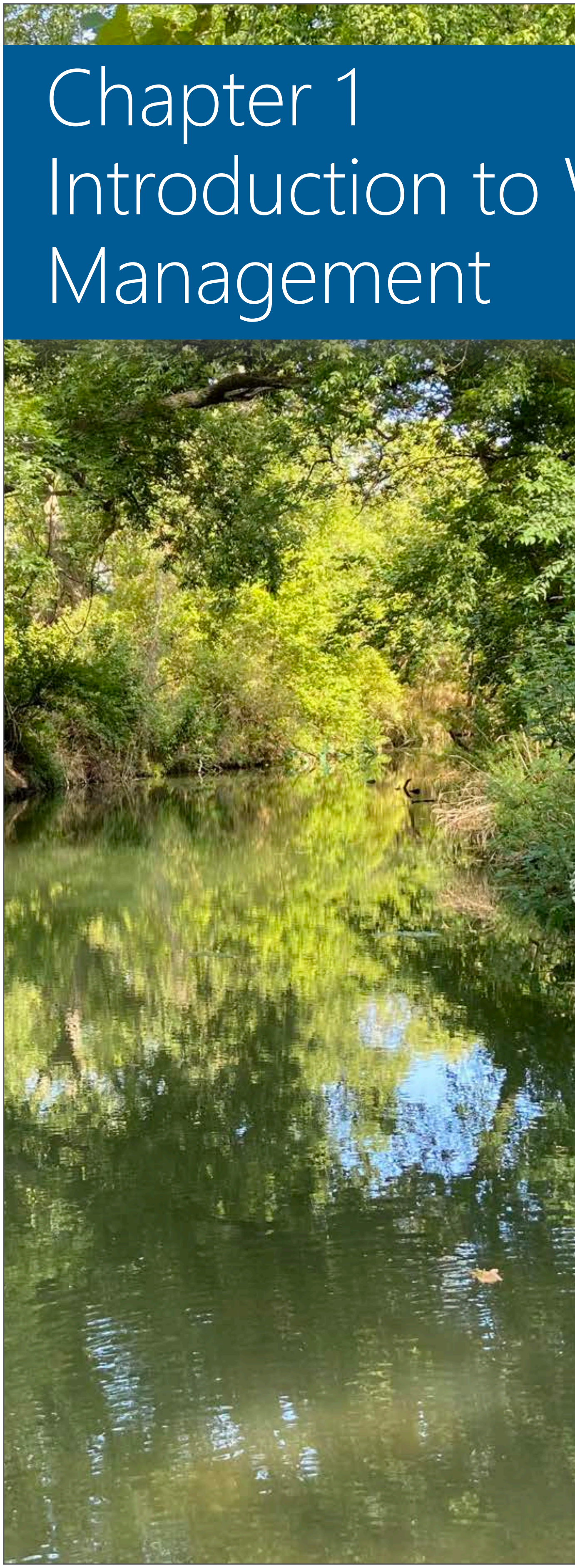
Although infrequent, SSOs and unauthorized WWTF discharges can contribute to bacteria loads. Identifying and replacing failing infrastructure is important to prevent unauthorized discharges. Education and outreach are also important to teach homeowners about proper disposal of fats, oils, grease and other disposables so they do not cause damage to collection systems.

Wastewater Reuse

WWTFs within the watershed have expressed interest in expanding wastewater reuse which can reduce bacteria and nutrient loadings in the watershed by diverting WWTF effluent to non-potable uses such as irrigation or constructed wetlands for enhanced wastewater treatment. The watershed coordinator will work with WWTFs to inventory and identify areas for wastewater reuse.

Illicit Dumping

Illicit dumping is difficult to quantify in terms of impact to bacteria and nutrient loadings but can cause health and safety issues throughout the watershed. Educational signage will be increased at bridges and road crossings to try to reduce dumping at these locations. Hazard waste collection events will also be brought in throughout the watershed to provide an appropriate way to dispose of hazardous materials.



Chapter 1 Introduction to Watershed Management

The Watershed Approach

The watershed approach is widely accepted by state and federal water resource management agencies to facilitate water quality management. The U.S. Environmental Protection Agency (EPA) describes the watershed approach as "a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed" (EPA 2008). The watershed approach requires engaging stakeholders to make management decisions backed by sound science (EPA 2008). One critical aspect of the watershed approach is that it focuses on hydrologic boundaries rather than political boundaries to address potential water quality impacts to all potential stakeholders.

A stakeholder is anyone who lives, works, has interest within the watershed or may be affected by efforts to address water quality issues. Stakeholders may include individuals, groups, organizations or agencies. The continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing and implementing management measures that address water quality throughout the watershed.

Watershed Protection Plan

Watershed protection plans (WPPs) are locally driven mechanisms for voluntarily addressing complex water quality problems that cross political boundaries. A WPP serves as a framework to better leverage and coordinate resources of local, state and federal agencies, in addition to non-governmental organizations.

The Mid and Lower Cibolo Creek WPP follows the EPA's nine key elements, which are designed to provide guidance for the development of an effective WPP (EPA 2008). WPPs will vary in methodology, content and strategy based on local priorities and needs. However, common fundamental elements are included in successful plans and include (see Appendix C – Elements of Successful Watershed Protection Plans):

1. Identification of causes and sources of impairment
2. Expected load reductions from management strategies
3. Proposed management measures
4. Technical and financial assistance needed to implement management measures
5. Information, education and public participation needed to support implementation
6. Schedule for implementing management measures
7. Milestones for progress of WPP implementation
8. Criteria for determining successes of WPP implementation
9. Water quality monitoring

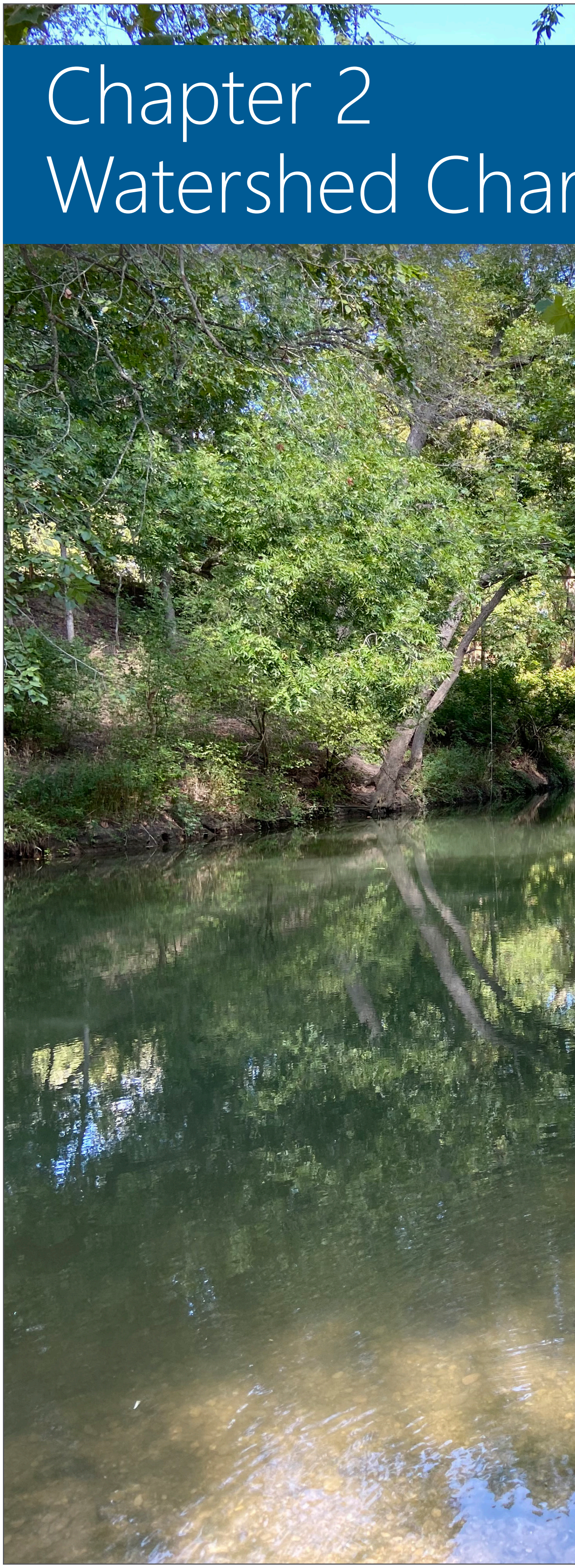
Adaptive Management

Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an ongoing science-based process. Such an approach includes results of continual testing, monitoring, evaluating applied strategies and revising management approaches to incorporate new information, science and societal needs (EPA 2000).

As management measures recommended in a WPP are put into action, water quality and other measures of success will be monitored to make adjustments as needed to the implementation strategy. The use of an adaptive management process will help to focus effort, implement strategies and maximize impact on pollutant loadings throughout the watershed over time.

Education and Outreach

The development and implementation of a WPP depends on effective education, outreach and engagement efforts to inform stakeholders, landowners and residents of the activities and practices associated with the WPP. Education and outreach events provide the platform for the delivery of new and/or improved information to stakeholders through the WPP implementation process. Education and outreach efforts are integrated into many of the management measures that are detailed in this WPP.



Chapter 2 Watershed Characterization

Introduction

This chapter provides geographic, demographic and water quality overviews of the Mid and Lower Cibolo Creek watershed. Development of the information within this chapter relied heavily on state and federal data resources as well as local stakeholder knowledge. The collection of this information was a critical component to the reliable assessment of potential sources of water quality impairment and the recommendation of beneficial management measures.

Watershed Description

Mid Cibolo Creek is defined as from a point 100 meters (m) (110 yards (yds)) downstream of I-10 in Bexar/Guadalupe County to the Missouri-Pacific Railroad Bridge west of Bracken in Comal County. The Lower Cibolo Creek is defined as from the confluence with the San Antonio River in Karnes County to a point 100 meters (110 yds) downstream of I-10 in Bexar/Guadalupe County. The Mid and Lower sections of Cibolo Creek flow south approximately 90 miles (mi) through parts of Comal, Guadalupe, Bexar, Wilson and Karnes counties (Table 1) before its confluence with the Lower San Antonio River. Martinez Creek, Salitrillo Creek and Clifton Branch are tributaries within the watershed.

The watershed is 580 square miles with the headwaters in the I-35 corridor north and east of San Antonio (Figure 1). Lower Cibolo Creek, Martinez Creek, Salitrillo Creek and Clifton Branch are perennial streams. Mid Cibolo Creek is an intermittent stream with perennial pools. The watershed is predominately rural with a highly developed urban area emerging near the I-35 and I-10 corridors. However, with the increase of residential development and suburbanization, as well as increased hydraulic fracturing activity associated with the Eagle Ford Shale formation, the ecological health of the water body within this region is facing rising potential threat. Thus, it is increasingly important to develop a plan to protect the watershed's creeks and streams.

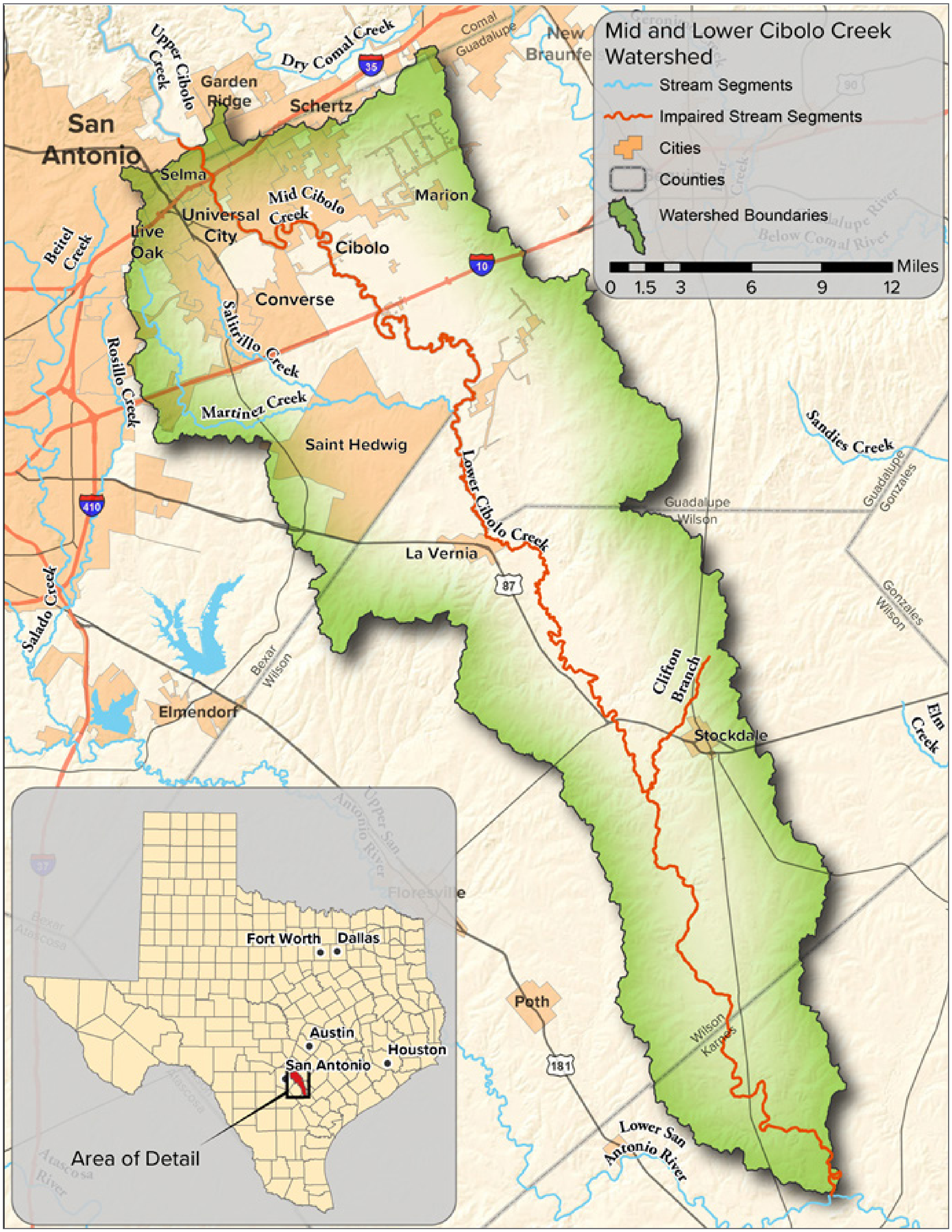


Figure 1. Mid and Lower Cibolo Creek watershed map.

Table 1. County and watershed area summary.

	Area of Total County (Acres)	Area of Watershed Within the County (Acres)	Percent of the Total County Within the Watershed (%)	Percent of the Watershed Within Each County (%)
Bexar	804,048	86,244	10.7	23.2
Wilson	516,500	156,336	30.3	42.1
Guadalupe	458,112	98,624	21.5	26.5
Karnes	480,499	28,970	6.0	7.8
Comal	367,819	1,330	0.4	0.4
Entire Watershed		371,504		100

Physical Characteristics

Soils and Topography

The soils and topography of a watershed are important components of watershed hydrology. Slope and elevation define where water will flow, while elevation and soil properties influence the quantity and speed at which water will infiltrate into the soil, as well as how much water will flow over or through the soil into a water body. Soil properties may also limit the types of development and activities that can occur in certain areas.

The elevation across the watershed ranges significantly from a maximum approximate elevation of 1,033 feet (ft) above mean sea level (MSL) in the northern part of the watershed to a minimum approximate elevation of 221 ft above MSL near the confluence of the Lower Cibolo Creek with the Lower San Antonio River in Karnes County (Figure 2). Elevation was determined using the U.S. Geological Survey (USGS) 10-m national elevation dataset (NED, USGS 2013). Topography of the Mid and Lower Cibolo Creek watershed is comprised of a steep, hilly northern portion and reduces to gradual rolling hills interspersed with flat areas containing woodlands and small pastures in the south (Bass and Burger 2013).

The soils in the Mid and Lower Cibolo Creek watershed are mostly Alfisols (49.1%, 182507.7 acres (ac)), a relatively fertile soil that is well-suited for agriculture and silviculture (Figure 3). Vertisols (27.3%, 101581.1 ac) are more common in the upper part of the watershed. They are clay-rich and exhibit a shrinking and swelling action with changes in moisture that can lead to wide cracks forming during dry periods. Mollisols (18.2%, 67829.2 ac) are characterized by a dark surface layer indicative of high amounts of organic material and are very fertile and productive for agricultural uses, which are mainly distributed around streams and the lower part of the watershed. There are also other soil types, like Entisols (2.7%), Inceptisols (2.2%) and other unclassified order (0.4%).

Hydrologic soil groups are groups of soil that indicate runoff potential and are determined based on the measure of precipitation, runoff and infiltration (NRCS 2009). There are four primary hydrologic soil groups. Group A is composed of sand, loamy sand or sandy loam with low runoff potential and high infiltration. Group B is well drained with silt loam or loam type soils. Group C consists of finer soils and slower infiltration. Group D has high clay content, low infiltration and high runoff potential.

The watershed is characterized by soils with higher runoff potential and low infiltration rates (Figure 4). The predominate soil types in the watershed are Group D (40.6% of watershed soils) and Group C (32.9% of watershed soils). Group A soils comprise 15.3% of the watershed soils followed by Group B at 11.2% of soils.

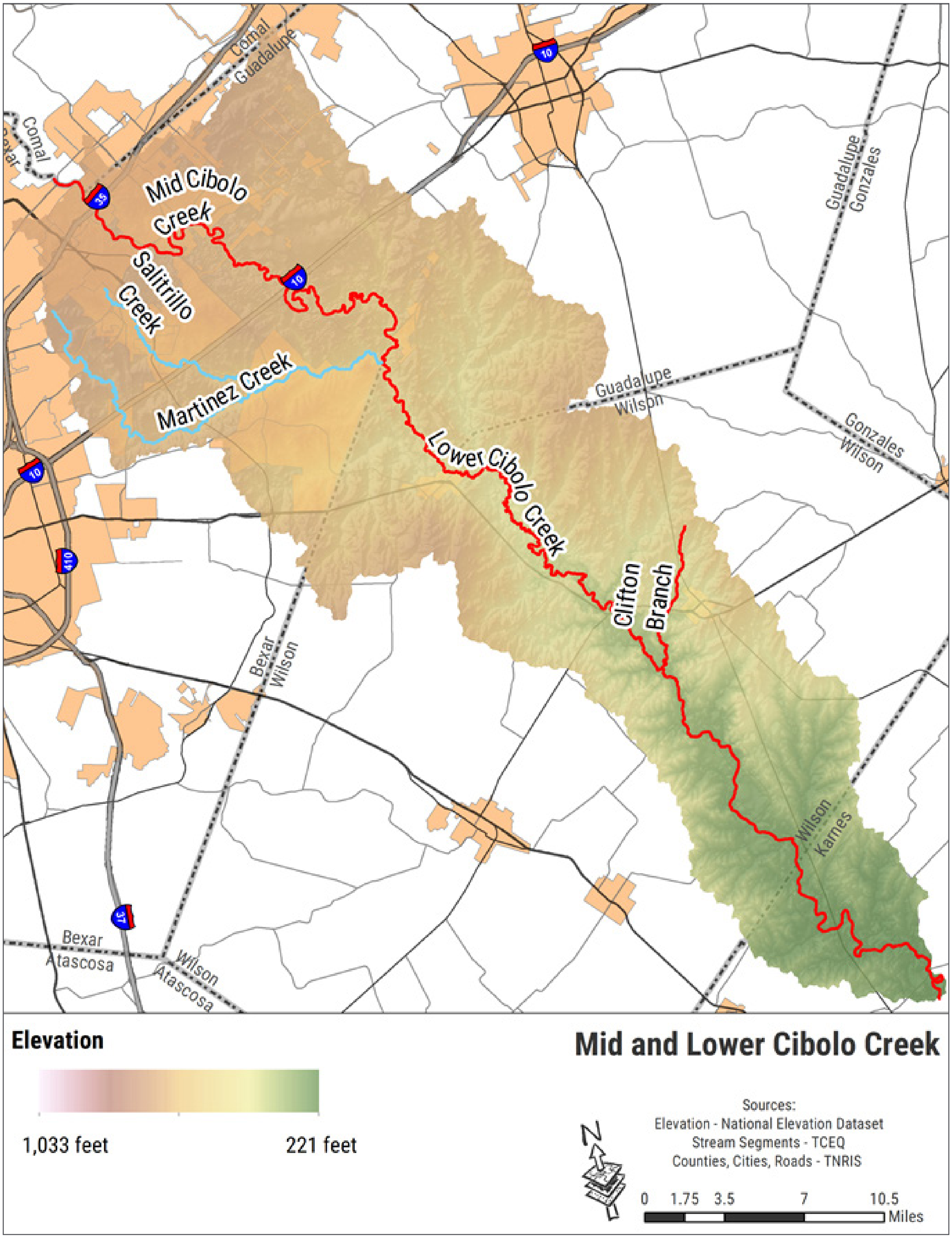


Figure 2. Watershed elevation.

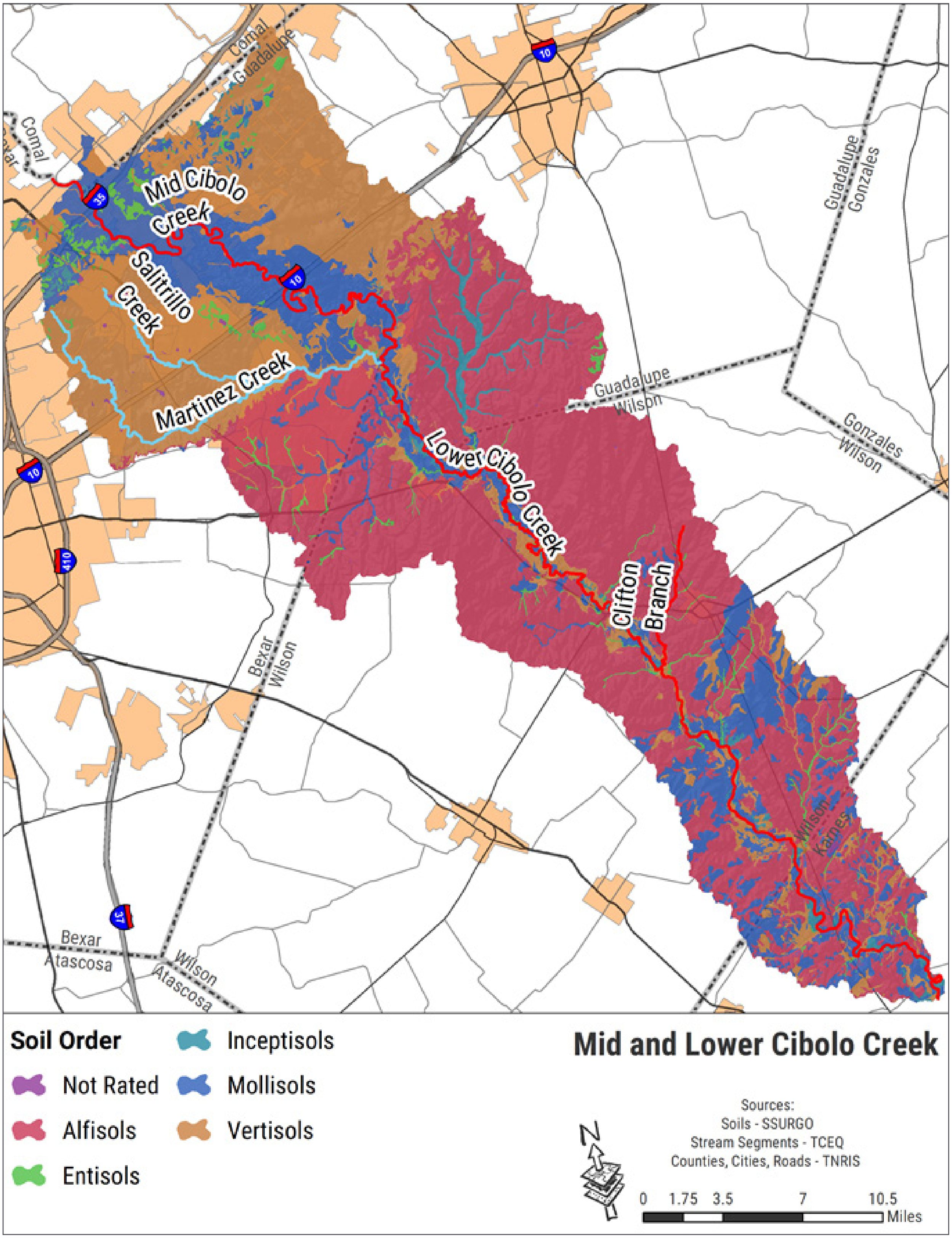


Figure 3. Watershed soil orders.

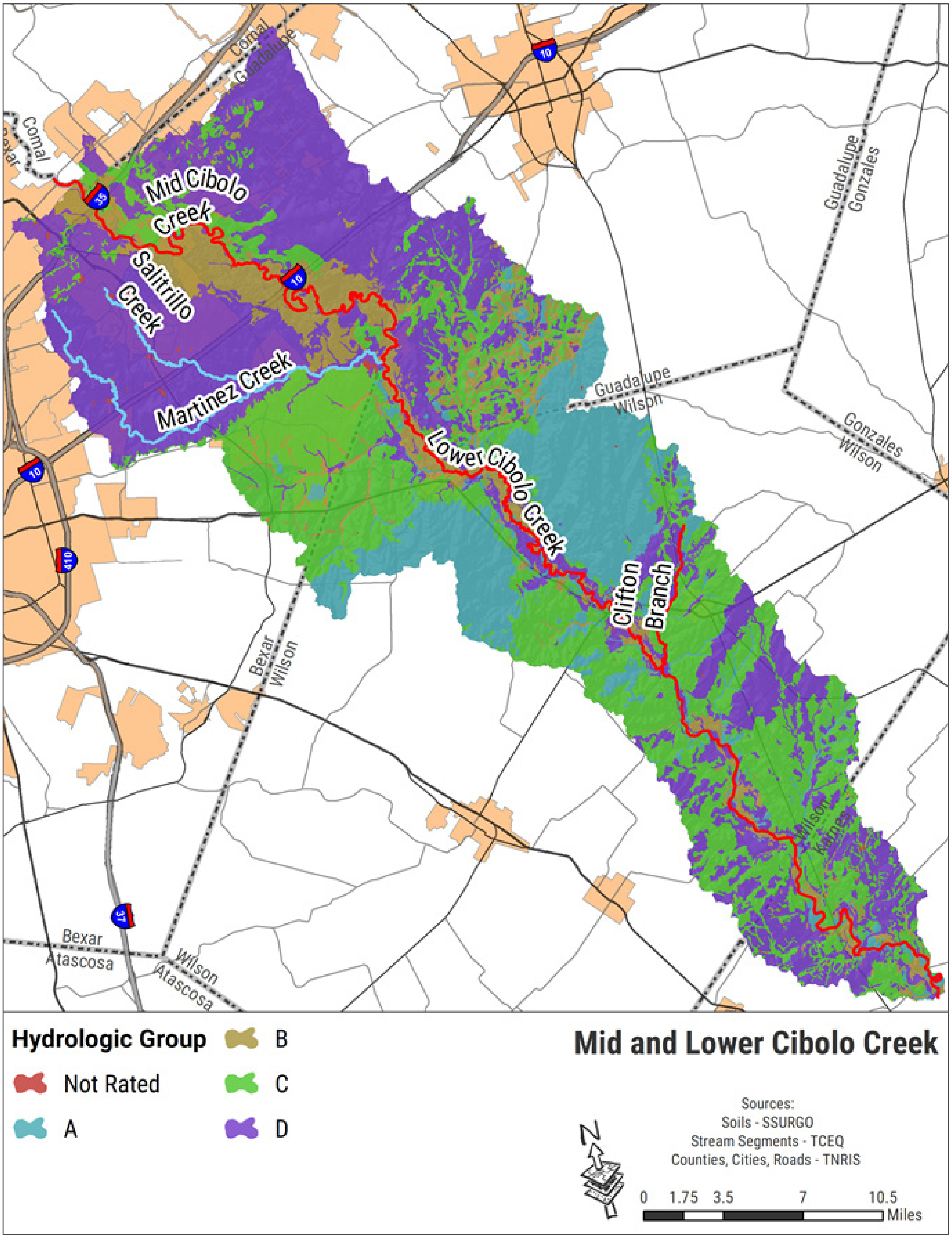


Figure 4. Hydrologic soil groups.

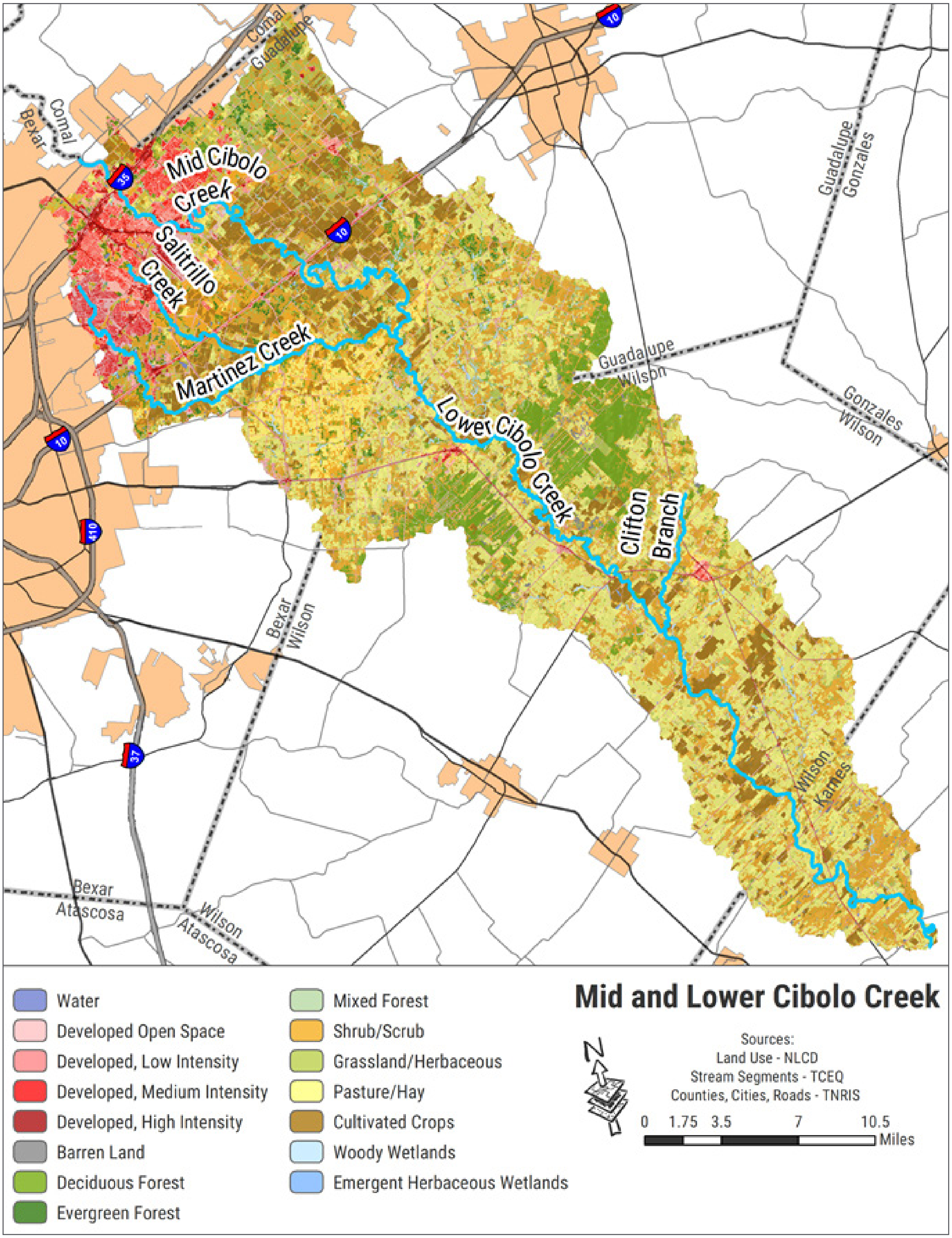


Figure 5. Watershed land use and land cover.

Table 2. LULC summary.

Land Use Class	Acreage	Percentage
Developed Area	51,663	13.9%
Barren Land	2,277	0.6%
Forest	37,954	10.2%
Shrub/Scrub	95,125	25.6%
Grassland/Herbaceous	26,461	7.1%
Pasture/Hay	108,630	29.2%
Cultivated Crop	41,681	11.2%
Wetland	7,279	2.0%
Open Water	660	0.2%

Land Use and Land Cover

According to 2011 National Land Cover Database (NLCD), dominant land use and land cover (LULC) categories are pasture/hay (29.2%, 107,014.4 ac), shrub/scrub (25.6%, 95,942.4 ac) and developed area (13.9%, 51,660 ac) (Figure 5; Table 2). Developed, urban areas are concentrated in the upper watershed, with the remaining portions of the watershed dominated by pasture and shrub.

Ecoregions

Ecoregions are land areas that contain similar quality and quantity of natural resources (Griffith 2004). Ecoregions have been delineated into four separate levels; level I is the most unrefined classification while level IV is the most refined. The watershed flows through two ecoregions (level III ecoregions), including the Texas Blackland Prairies Ecoregion (32) through Bexar and Guadalupe counties and the East Central Texas Plains Ecoregion (33) in Guadalupe, Wilson and Karnes counties (Figure 6). The dominant soil types are fine-textured clay and acidic, sandy or clay loams, respectively. The watershed is further subdivided into two level IV ecoregions identified as Northern Blackland Prairie (32a) and Southern Post Oak Savanna (33b).

The landscape around Northern Blackland Prairie (32a) is mainly underlain by Vertisols with dark, fine-textured and calcareous characters. The main land cover are cropland and non-native pasture, with a small portion of deciduous forests and woodlands. Dominant grasses are eastern gamagrass and switchgrass. The Southern Post Oak Savanna (33b) has more woods and forest than the adjacent prairie ecoregions (32). The land cover is a mix of woods, improved pasture and rangeland.

Climate

The Mid and Lower Cibolo Creek watershed is characterized as a subtropical climate zone, with hot summers and warm or mild winters. The average annual precipitation from 1981 to 2010 ranged from 29.17 inches (in) to 34.10 in (Figure 7). Peak monthly average precipitation occurs in May and October. The driest months are typically January and February. The warmest months on average are July and August; with an average temperature of 95°F (Figure 8). January is the coldest month with average lows around 37°F (NOAA 2018).

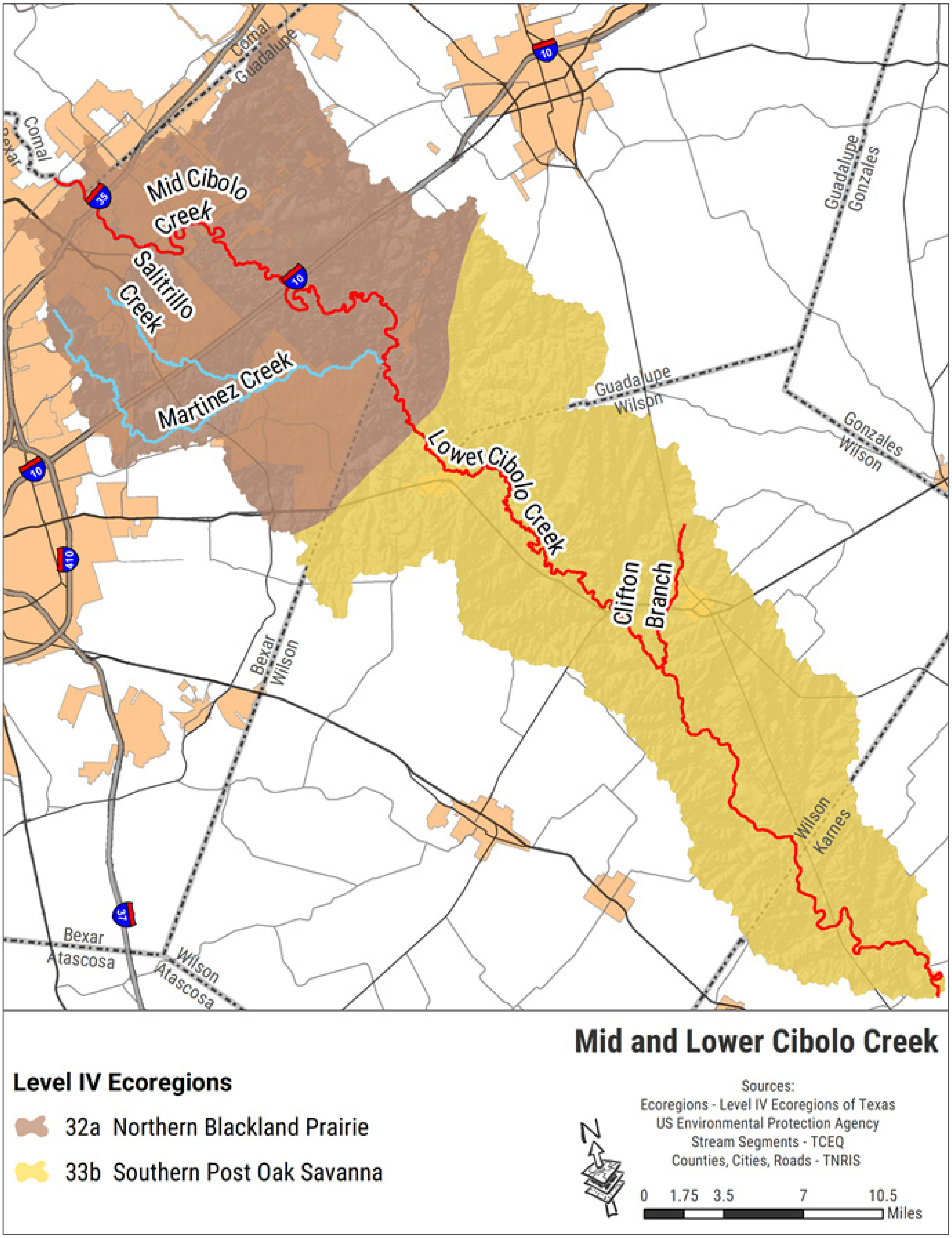


Figure 6. Level IV ecoregions.

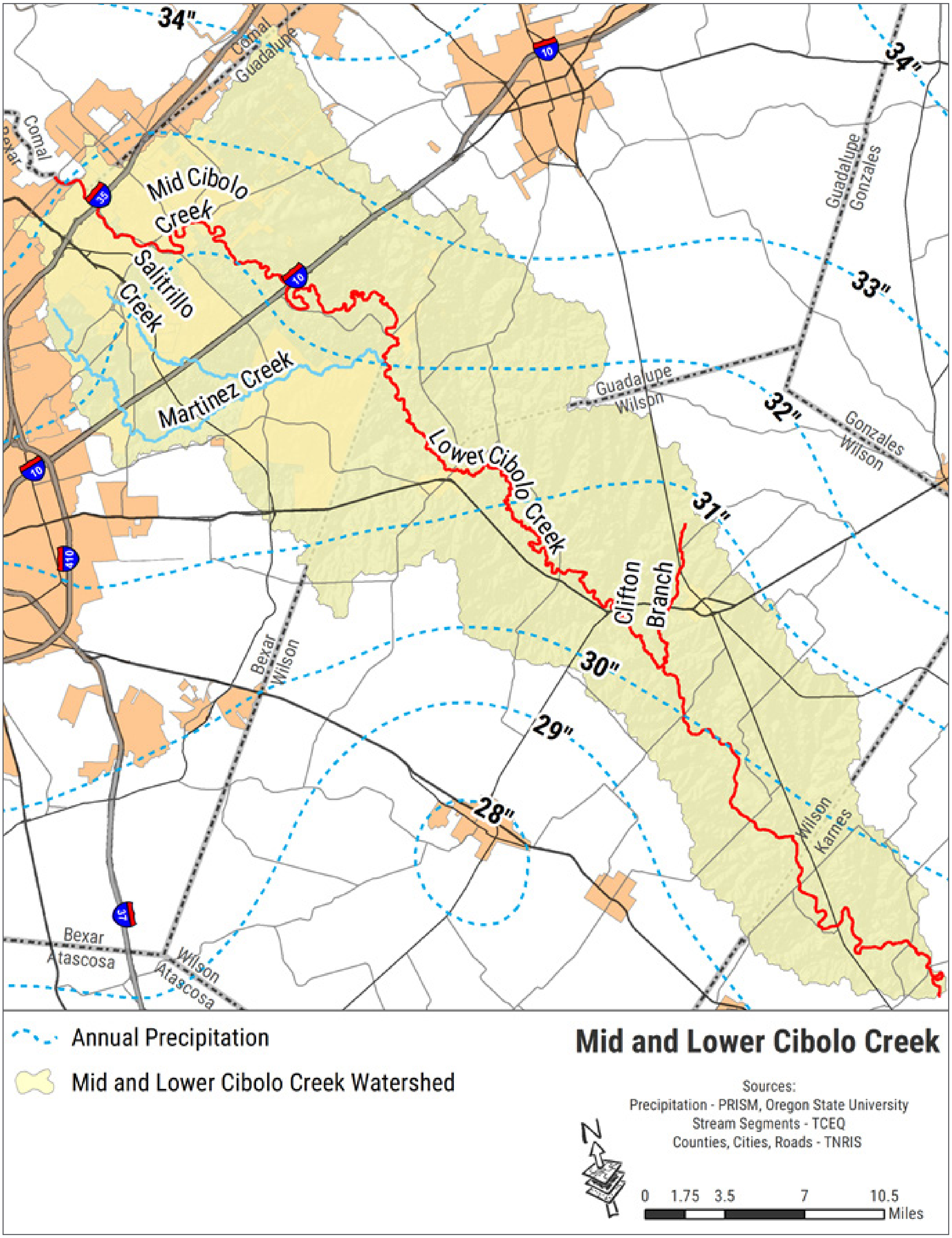


Figure 7. Annual normal precipitation.

Table 3. County population projections through 2070.

City	Population by Year							2070 Increase (from 2010)
	2010	2020	2030	2040	2050	2060	2070	
Bexar	1,714,773	1,974,041	2,231,550	2,468,254	2,695,668	2,904,319	3,094,726	80.5%
Wilson	42,918	54,266	66,837	79,044	90,016	100,411	109,771	155.8%
Guadalupe	131,533	182,693	235,318	276,064	315,934	356,480	396,261	201.3%
Karnes	14,824	15,456	15,938	15,968	15,968	15,968	15,968	7.7%
Comal	108,472	140,825	178,399	216,562	255,092	293,362	330,099	204.3%

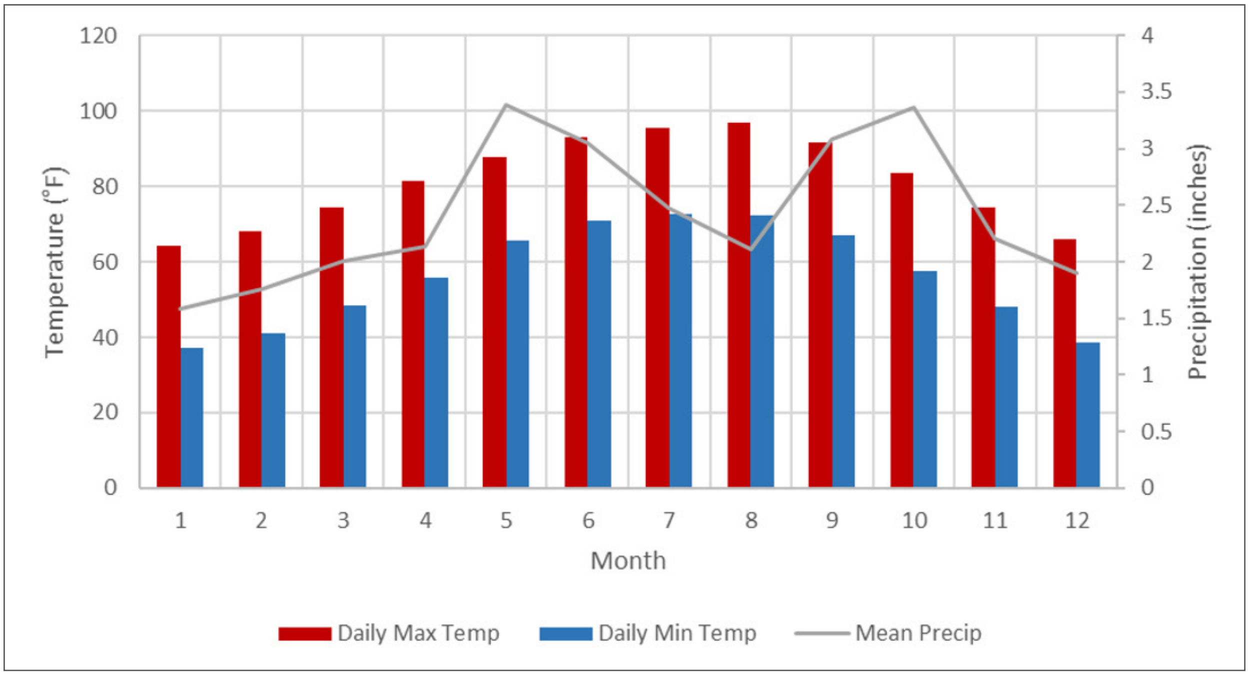


Figure 8. Monthly average air maximum and minimum temperatures (°F) and monthly average rainfall (inches) in Floresville, TX (NOAA, 2018).

Population

According to 2010 Census data, the highest population densities are in the upper portions of the watershed between the I-35 and I-10 highways (Figure 9). These areas include portions of San Antonio, Cibolo, Schertz, Selma, Live Oak, Converse and Universal City. The watershed population was approximately 186,154 based on the 2010 Census data from U.S. Census Bureau (USCB), with all watershed counties projecting population increase over the next 50 years, provided by the Office of the State Demographer and the Texas Water Development Board (TWDB).

Aquifers

Several major and minor aquifers are present within the watershed (Figure 10). Major aquifers include the Carrizo Aquifer, which covers the entire span of the Lower Cibolo Creek watershed. The Edwards, Trinity and Gulf Coast aquifers are the other major aquifers present and are located in the Mid Cibolo Creek watershed and southern tip of the Lower Cibolo watershed. Minor aquifers within the watershed include Queen City, Sparta and Yegua Jackson that are generally used for domestic and livestock purposes. The Yegua-Jackson Aquifer is also used for industrial, irrigation and municipal purposes. Quality ranges from fresh to slightly saline and from hard to soft depending on location.

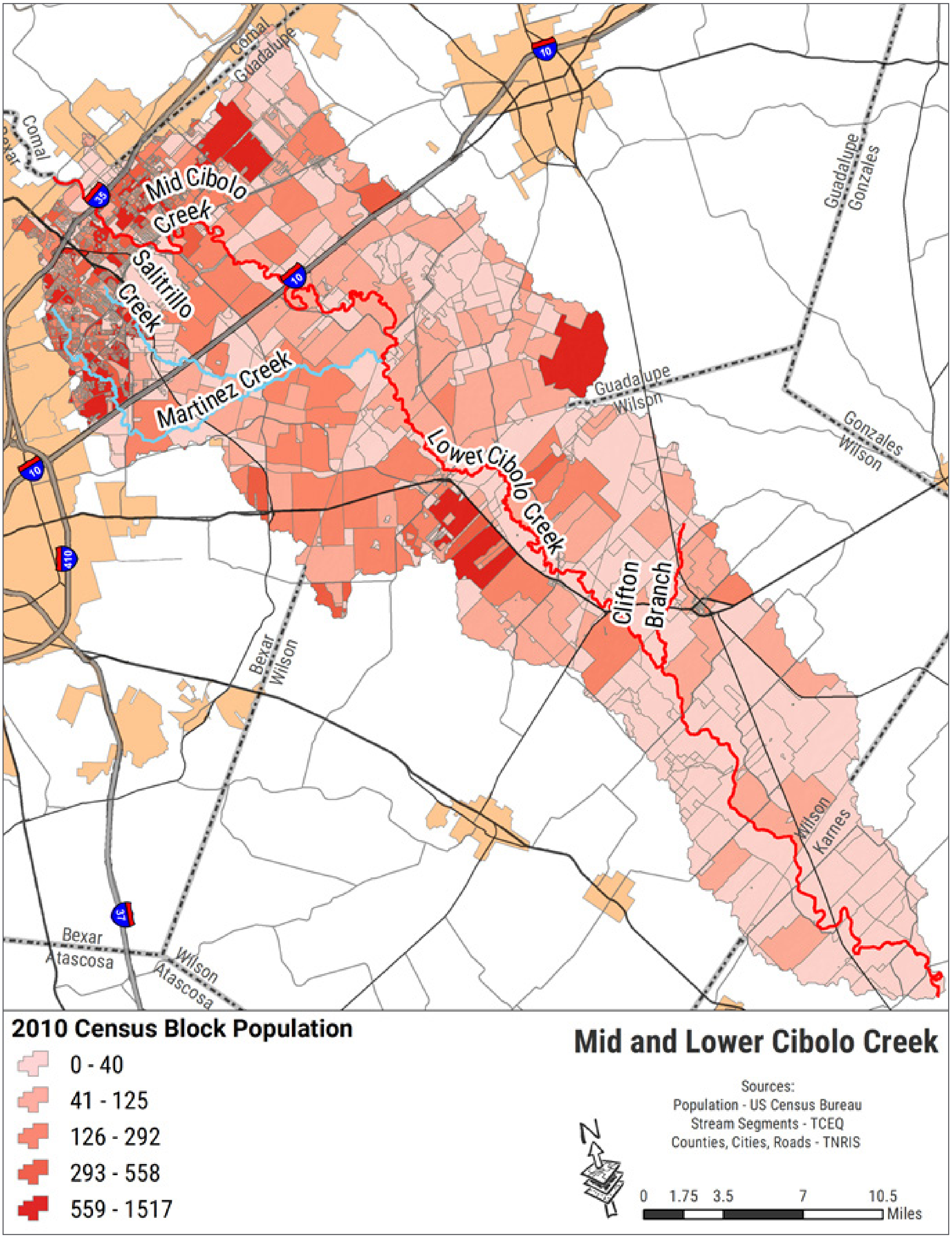


Figure 9. 2010 U.S. Census population estimates.

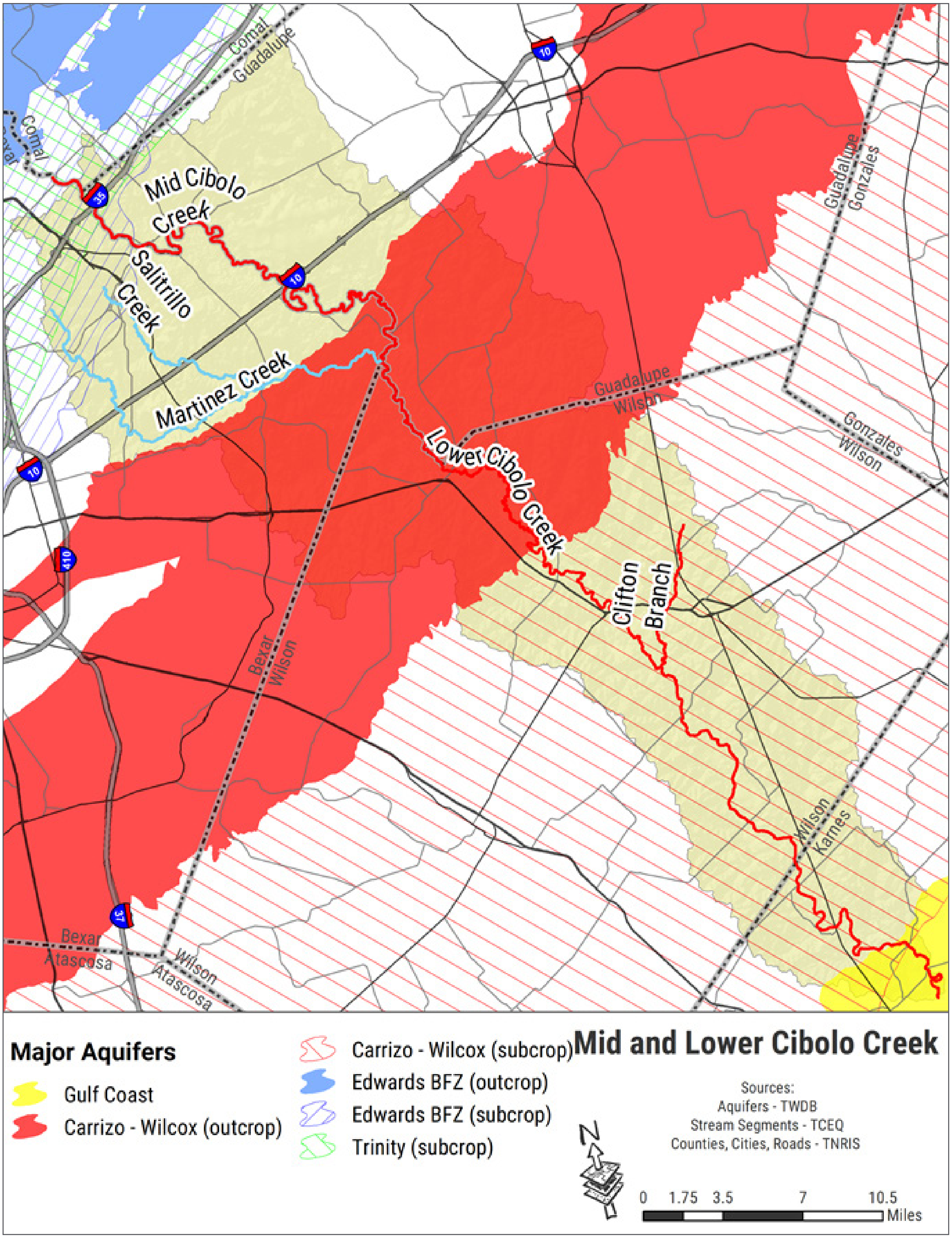


Figure 10. Annual normal precipitation.

Chapter 3 Water Quality

Introduction

Water is monitored in Texas to ensure that its quality supports designated uses defined in the Texas Water Code. Designated uses and associated standards are developed by Texas Commission on Environmental Quality (TCEQ) to fulfill requirements of the Clean Water Act (CWA), which addresses toxins and pollution in waterways and establishes a foundation for water quality standards. It requires states to set standards that: (1) maintain and restore biological integrity in the waters, (2) protect fish, wildlife and recreation in and on the water (must be fishable/swimmable) and (3) consider the use and value of state waters for public supplies, wildlife, recreation, agricultural and industrial purposes.

The CWA (33 USC § 1251.303), administered by the EPA (40 CFR § 130.7), requires states to develop a list that describes all water bodies that are impaired and are not within established water quality standards (commonly called "303(d) list" in reference to Texas Water Quality Inventory and 303(d) List). In addition, states are required to develop total maximum daily loads (TMDLs) or other acceptable strategies to restore water quality of impaired water bodies. A TMDL is a budget that sets the maximum pollutant loading capacity of a water body and the reduction needed for a water body to meet applicable standards. The development of a stakeholder-driven WPP is another potential strategy. By encouraging stakeholders to address possible causes and threats of impairments and giving them decision-making powers to set WPP goals, WPPs can provide a comprehensive, long-term restoration plan with water body assessments and protection strategies.

Table 4. Water quality monitoring station summary from January 1, 2000 to August 1, 2017.

Station	AU	# Samples	Location
12741	1902A_01	38	Martinez Creek on N. Gable Rd
12797	1902_01	50	Cibolo Creek at FM 81
12800	1902_02	18	Cibolo Creek at FM 887
12801	1902_03	18	Cibolo Creek at Plummer Crossing
12802	1902_03	18	Cibolo Creek at Fm 541
12803	1902_03	36	Cibolo Creek at Fm 537
12804	1902_04	18	Cibolo Creek at SH 97
12805	1902_04	34	Cibolo Creek at FM 539
12921	1913_01	24	Cibolo Creek at Weir Rd
12924	1913_02	25	Cibolo Creek at Schaeffer Rd
14197	1902_05	61	Cibolo Creek at Scull Crossing
14202	1902B_01	23	Salitrillo Creek at Autumn Run
14211	1902_02	380	Cibolo Creek at CR 389
14212	1913_03	36	Cibolo Creek Upstream Mun. WWTP
20775	1902C_01	34	Clifton Branch at SH 97
20776	1902C_01	34	Clifton Branch at Old Floresville Rd
20777	1902_01	34	Cibolo Creek at FM 2724

Water Body Assessments

TCEQ conducts a water body assessment on a biennial basis to satisfy requirements of federal Clean Water Act Sections 305(b) and 303(d). The resulting *Texas Integrated Report of Surface Water Quality (Texas Integrated Report)* describes the status of water bodies throughout the state of Texas. The most recent finalized *2014 Texas Integrated Report* includes an assessment of water quality data collected from December 1, 2005 to November 30, 2012. This period is more than two years prior to the start of efforts to develop this WPP.

The *Texas Integrated Report* assesses water bodies at the Assessment Units (AU) level. An AU is a sub-area of a segment, defined as the smallest geographic area of use support reported in the assessment (TCEQ 2016). Each AU is intended to have relatively homogeneous chemical, physical and hydrological characteristics, which allows a way to assign site-specific standards (TCEQ 2016). A segment identification number and AUs are combined and assigned to each water body to divide a segment. For example, The Mid Cibolo Creek is segment 1913 and it has three AUs designated 1913_01, 1913_02 and 1913_03.

In total, there are 16 AUs in the Mid and Lower Cibolo Creek watershed (Figure 11). Monitoring stations are located on most AUs and allow independent water quality analysis for each AU within a segment. At least 10 data points within the most recent seven years of available data are required for all water quality parameters except bacteria, which requires a minimum of 20 samples. During the process of developing this WPP, water quality data from 18 monitoring stations were reviewed within the Mid and Lower Cibolo Creek watershed (Figure 12 and Table 4).

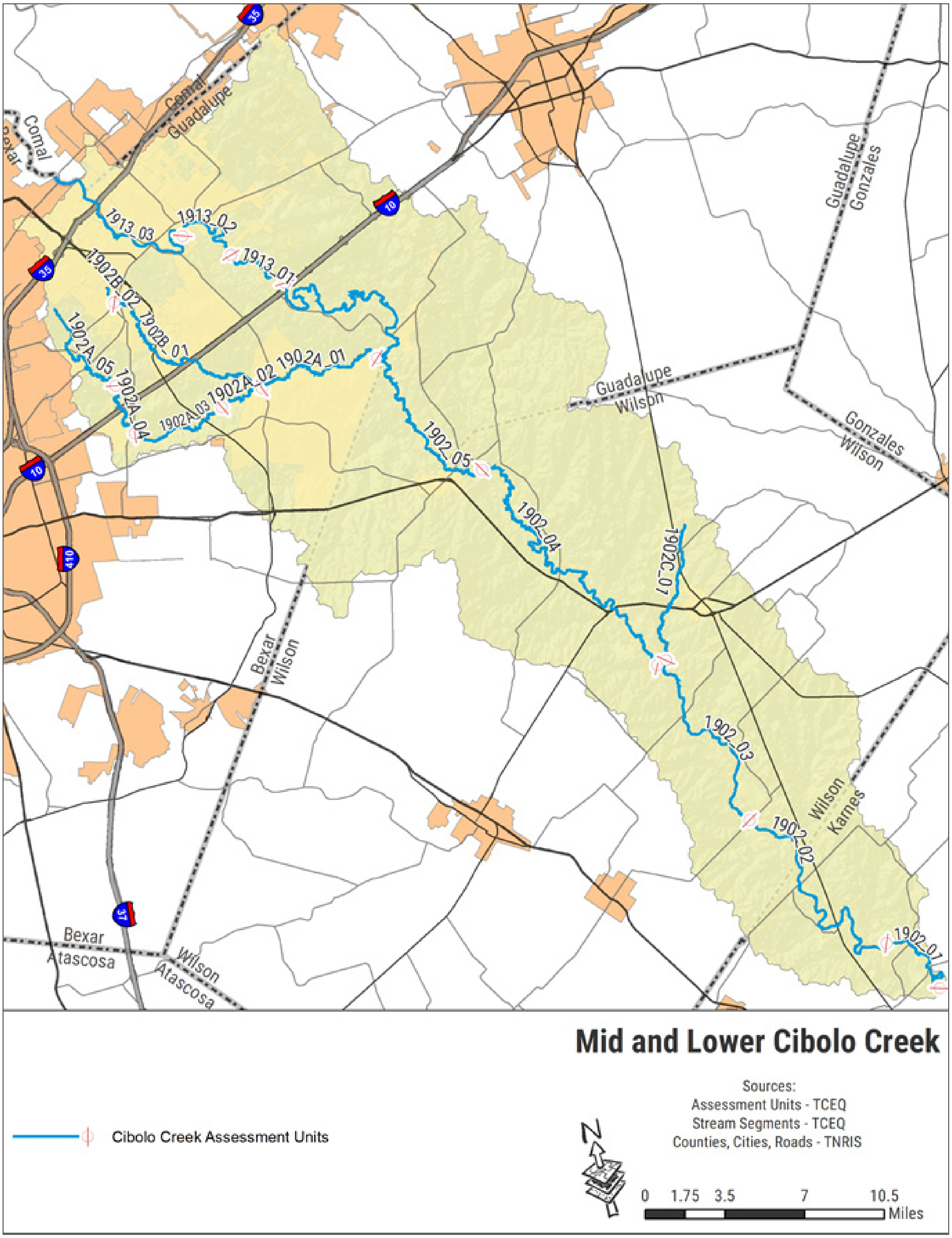


Figure 11. Mid and Lower Cibolo Creek Assessment Units (AU).

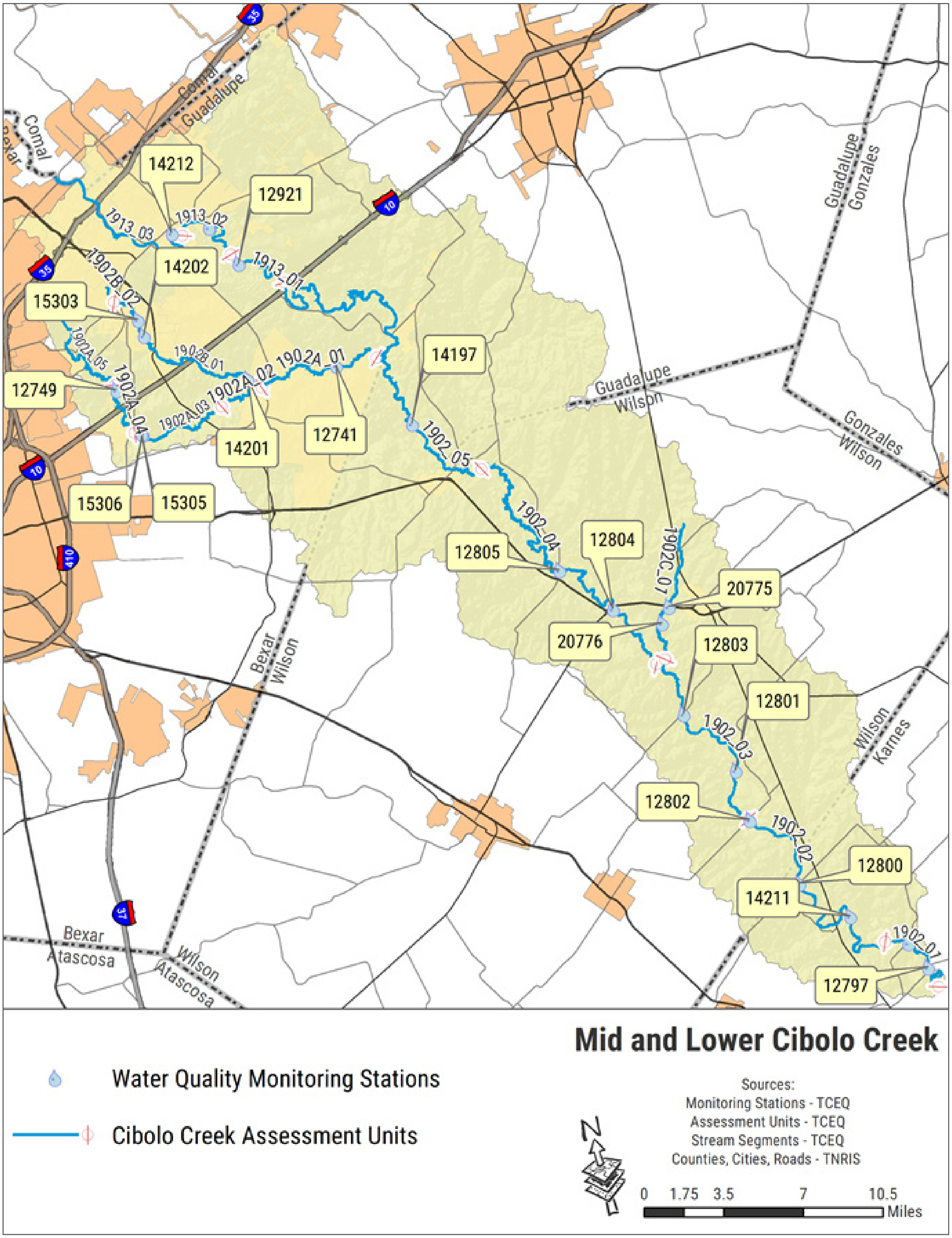


Figure 12. Water quality monitoring stations.

Table 5. Watershed impairments in *2014 Texas Integrated Report*.

Parameter	Category	AUs	River Reach	Criteria
Bacteria	5b*	1902_01	Lower Cibolo Creek	126 cfu/100mL
		1902_02	Lower Cibolo Creek	
		1902_03	Lower Cibolo Creek	
	5c**	1902C_01	Clifton Branch	
DO Grab Minimum	5c**	1902C_01	Clifton Branch	3.0 mg/L
DO 24-hr Minimum	4b***	1913_02	Mid Cibolo Creek	2.0 mg/L

Assessment unit, AU; colony forming unit, cfu; milliliter, mL; dissolved oxygen, DO; milligrams, mg; liter, L; hour, hr

*Category 5b – A review of the standards for one or more parameters will be conducted before a management strategy is selected, including a possible revision to the Texas Surface Water Quality Standards (TSWQSs).

**Category 5c – Additional data or information will be collected and/or evaluated for one or more parameters before a management strategy is selected.

***Category 4b – Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.

Table 6. Watershed concerns identified in the *2014 Texas Integrated Report*.

Parameter	AUs	River Reach	Criteria
Bacteria	1902A_01	Martinez Creek	126 cfu/100mL
	1902A_03		
	1902A_04		
Nitrate	1902_04	Lower Cibolo Creek	>20% exceedance (1.95 mg/L Standard Screening Level)
	1902_05		
	1913_01	Mid Cibolo Creek	
	1913_02		
	1902A_03	Martinez Creek	
	1902A_04		
	1902B_01	Salitrillo Creek	
Ammonia	1902B_01	Salitrillo Creek	>20% exceedance (0.33 mg/L Standard Screening Level)
Total Phosphorus	1902_05	Lower Cibolo Creek	>20% exceedance (0.69 mg/L Standard Screening Level)
	1902C_01	Clifton Branch	
	1913_01	Mid Cibolo Creek	
	1913_02		
	1902A_01	Martinez Creek	
	1902A_03		
	1902A_04		
	1902B_01	Salitrillo Creek	

Assessment unit, AU; colony forming unit, cfu; milliliter, mL; milligrams, mg; liter, L

Table 7. Designated water uses for water bodies in the Mid and Lower Cibolo Creek Watershed..

Use	Use Category	Measure	Criteria
Contact Recreation	Primary contact recreation 1	7-year geometric mean	126 cfu/100mL *E. coli*
Aquatic Life Use	High	<10% exceedance based on the bino-mial method	5.0/3.0 mg/L DO
	Intermediate		4.0/3.0 mg/L DO
	Limited		3.0/2.0 mg/L DO
General Use Standards	The criteria for the general use includes aesthetic parameters, radiological substanc-es, toxic substances, temperature (when surface samples are above 5° F and not at-tained due to permitted thermal discharges) and nutrients (screening standards or site-specific nutrient criteria)		

Colony forming unit, cfu; milliliter, mL; milligrams, mg; liter, L; dissolved oxygen, DO; Fahrenheit, F

According to the *2014 Texas Integrated Report* on surface water quality, four AUs in the watershed are impaired due to elevated bacteria (AU 1902_01, 1902_02, 1902_03 and 1902C_01) (Table 5). Two AUs are impaired due to low dissolved oxygen (DO) concentration (AU 1902C_01 and 1913_02). Furthermore, a number of concerns are identified in the *2014 Texas Integrated Report*, including nutrient concerns in seven AUs and a bacteria concern in Martinez Creek (Table 6).

Texas Surface Water Quality Standards

Water quality standards are established by the state and approved by EPA to define a water body's ability to support its designated uses, which may include: aquatic life use (fish, shellfish, and wildlife protection and propagation), primary contact recreation (swimming), public water supply and fish consumption. Water quality indicators for these uses include DO (aquatic life use), *E. coli* (primary contact recreation), pH, temperature, total dissolved solids, sulfate and chloride (general uses) and a variety of toxins (fish consumption and public water supply) (Table 7) (TCEQ 2015).

Bacteria

Concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater environments, concentrations of *E. coli* bacteria are measured to evaluate the presence of fecal contamination in water bodies. The presence of these fecal indicator bacteria may indicate that associated pathogens from the intestinal tracts of warm-blooded animals or other sources could be reaching water bodies and can cause illness in people that recreate in them. The water quality standard for *E.coli* in freshwater for primary contact recreation is a geometric mean of 126 colony forming units (cfu) of *E. coli* per 100 milliliters (mL) of water from at least 20 samples (30 TAC § 307.7). Common sources that indicator bacteria can originate from include wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities (OSSFs), urban and agricultural runoff, sewage system overflows and direct discharges from wastewater treatment facilities (WWTFs).

Currently, four AUs are listed as impaired due to elevated indicator bacteria (TCEQ 2016). This listing is based on the geometric mean value from at least 20 bacteria samples collected at stations in each AU between November 2005 and December 2012. Figure 13 shows the *E. coli* concentration and geometric mean value in those four AUs based on the available data from January 1, 2000 to August 1, 2017. The dataset is acquired from TCEQ's Surface Water Quality Monitoring Information System (SWQMIS).

Dissolved Oxygen

DO is the main parameter used to determine a water body's ability to support and maintain aquatic life uses. If DO levels in a water body drop too low, fish and other aquatic species will not survive. Typically, DO levels fluctuate throughout the day, with the highest levels of DO occurring in mid to late afternoon, due to plant photosynthesis. DO levels are typically lowest just before dawn as both plants and animals in the water consume oxygen through respiration. Furthermore, seasonal fluctuations in DO are common because of decreased oxygen solubility in water as temperature increases; therefore, it is common to see lower DO levels during the summer.

While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Excessive organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO levels as bacteria break down the materials

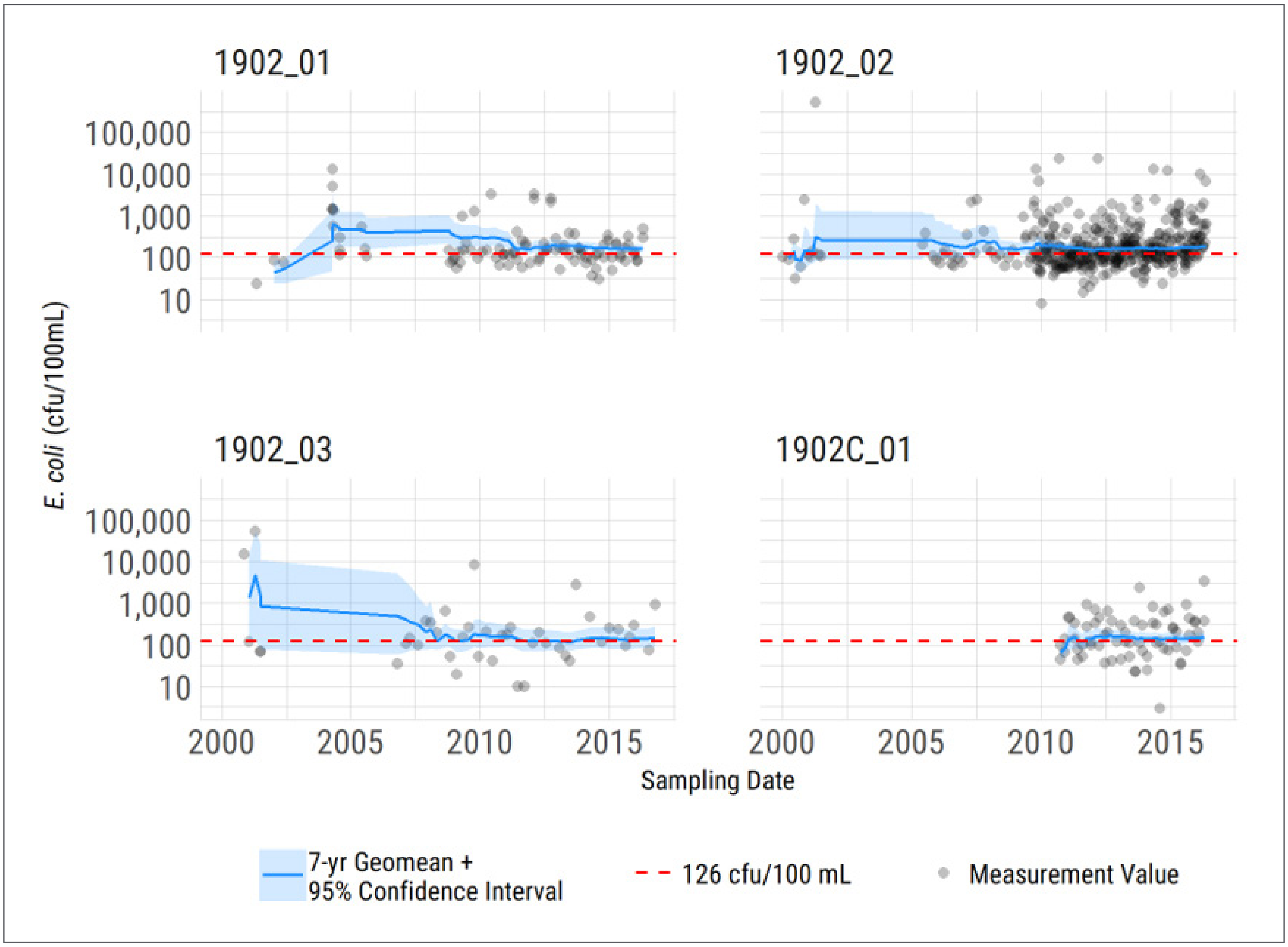


Figure 13. *E. coli* concentrations in impaired assessment units (AUs). The solid line indicates the running 7-year geometric mean.

and subsequently consume oxygen. Excessive nutrients from fertilizers and manures can also depress DO as aquatic plant and algae growth increase in response to nutrients. The increased respiration from plants and decay of organic matter as plants die off can also drive down DO concentrations.

When evaluating DO levels in a water body, TCEQ considers that monitoring events need to be spaced over an index period and a critical period. The index period represents the warm-weather season of the year and spans from March 15th to October 15th. The critical period of the year is July 1st to September 30th and is the portion of the year when minimum streamflow, maximum temperatures and minimum DO levels typically occur across Texas. At least half of the samples used to assess a stream's DO levels should be collected during the critical period with one-fourth to one-third of the samples used coming from the index period. DO measurements collected during the cold months of the year are not considered because flow and DO levels are typically highest during the winter months (TAC §307 2014). Under the *2014 Texas Integrated Report*, AU 1902C_01 was listed impaired for depressed DO because six of 21 assessed DO grab samples were below the 3.0 milligram per liter (mg/L) standard for the segment. AU1913_02 was also listed for depressed DO because four out of four 24-hour (hr) DO minimum values were below the 2.0 mg/L criteria for the segment. However, AU 1913_02 is listed under category 4b because wastewater treatment plant improvements are expected to improve water quality.

Table 8. Watershed nutrient screening levels and criteria.

Parameter	Standard Screening Level	Criteria
Ammonia Nitrogen (NH3-N)	0.33 mg/L	> 20% exceedance
Nitrate Nitrogen (NO3-N)	1.95 mg/L	
Chlorophyll-a	14.1 µg/L	
Total Phosphorus (TP)	0.69 mg/L	

Milligrams, mg; liter, L; microgram, µg

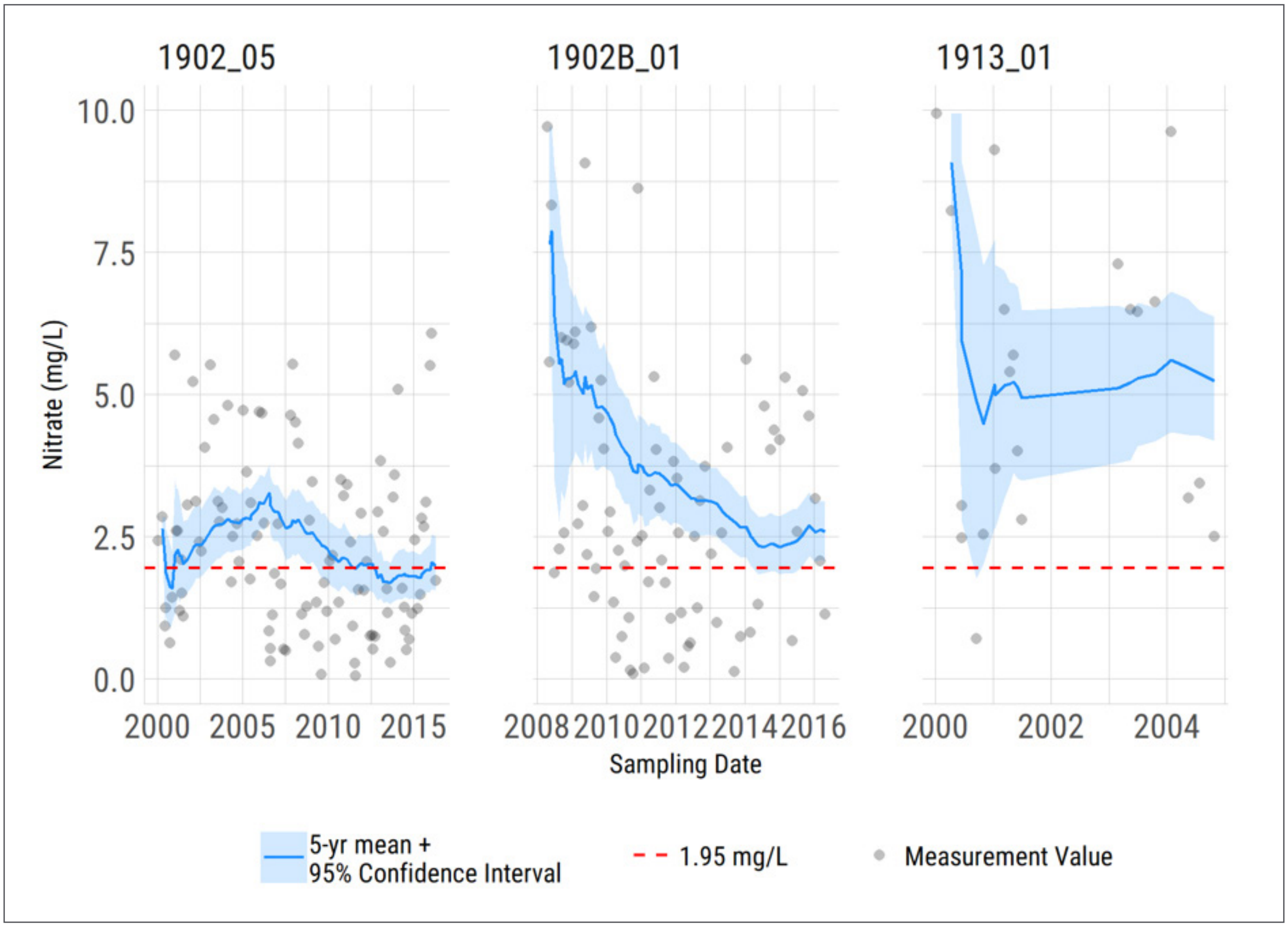


Figure 14. Nitrate concentrations of segment 1902_05, 1913_01 and 1902B_01.

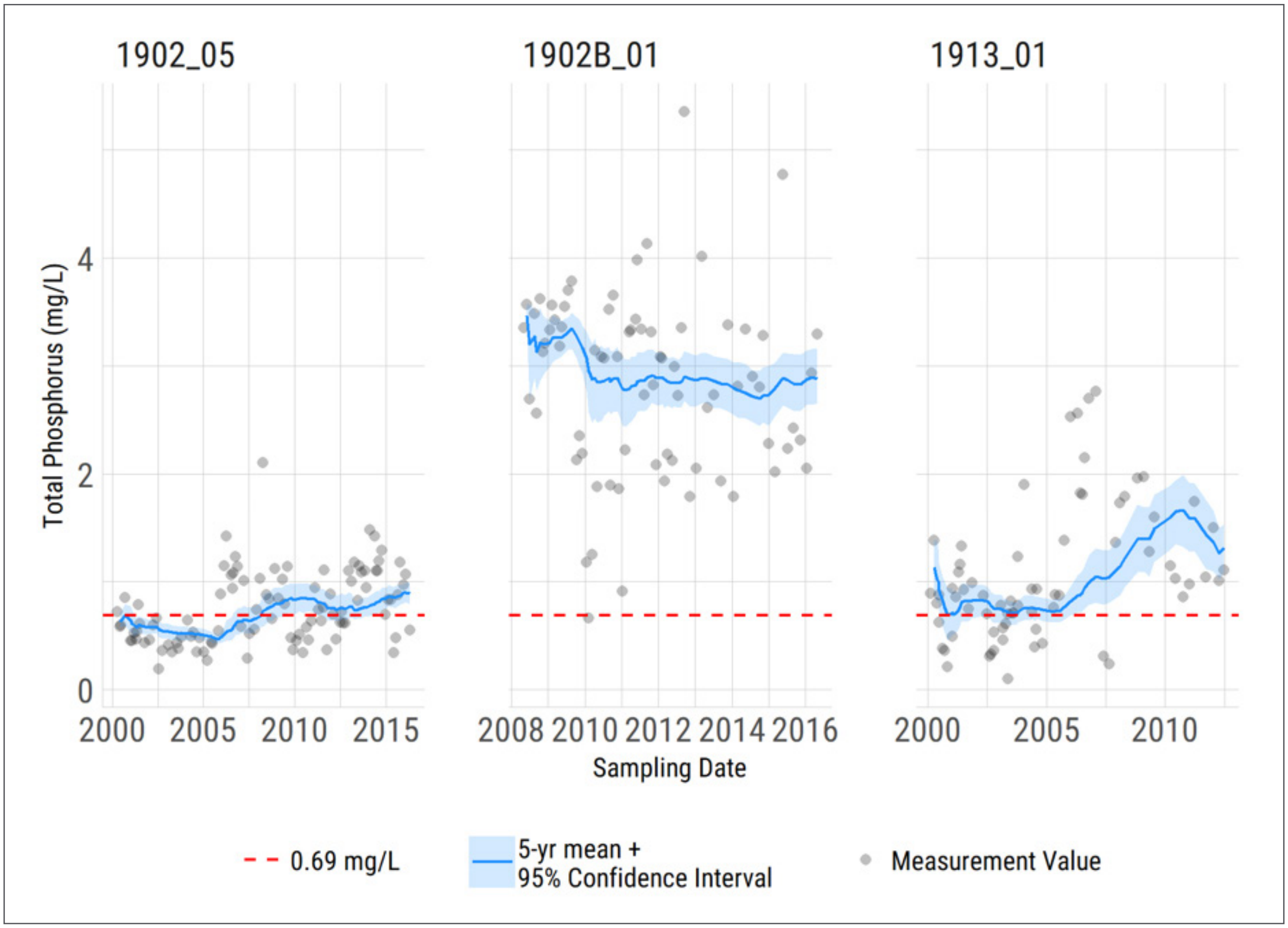


Figure 15. Total Phosphorus concentrations of segment 1902_05, 1913_01 and 1902B_01.

Nutrients

Nutrients, specifically nitrogen and phosphorous, are used by aquatic plants and algae. However, as previously mentioned, excessive nutrients can lead to plant and algal blooms, which will result in reduced DO levels. High levels of nitrates and nitrites can directly affect respiration in fish. Sources of nutrients include effluents from WWTFs and fertilizers that runoff from yards and agricultural fields. Nutrients also bind to soil and sediment particles. Therefore, runoff and erosion events that result in heavy loads of sediment can increase nutrient levels in water bodies as well.

Nutrient standards have not been set in Texas. However, nutrient screening levels developed for statewide use were established to protect water bodies from excessive nutrient loadings. Screening levels are set at the 85th percentile for parameters from similar water bodies. If more than 20% of samples from a water body exceed the screening level, that water body is on average experiencing pollutant concentrations higher than 85% of the streams in Texas and is therefore considered to have an elevated nutrient concentration concern. Screening levels have been designated for ammonia, nitrate, orthophosphorus, total phosphorus and chlorophyll-a. The current nitrate screening level in freshwater streams for nitrate is 1.95 mg/L and 0.69 mg/L for total phosphorous (Table 8). The nutrients levels in several AUs are analyzed and the results are shown in Figure 14 (Nitrate) and Figure 15 (Total Phosphorus).

Flow

Generally, streamflow (the amount of water flowing in a river at a given time) is dynamic and always changing in response to both natural (e.g. precipitation events) and anthropogenic (e.g. changes in land cover) factors. From a water quality perspective, streamflow is important because it influences the ability of a water body to assimilate pollutants.

There are five USGS streamflow gages located within the watershed (Figure 16). Four of the stations provide long-term instantaneous daily streamflow information used in this report. Over the previous 10 years, average monthly streamflows peaked in May and remain relatively stable throughout the rest of the year (USGS 2012, Figure 17).

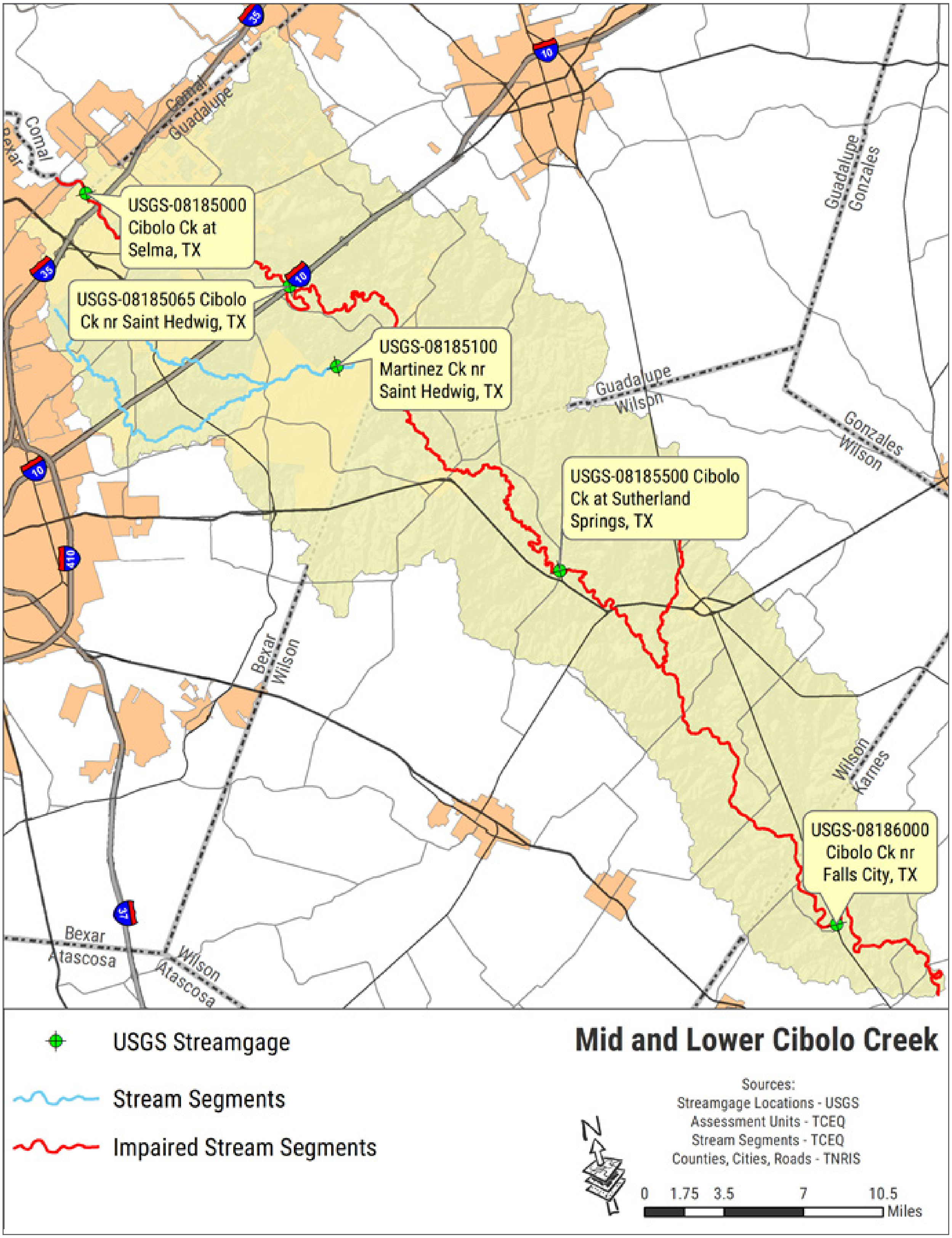


Figure 16. USGS streamflow gages.

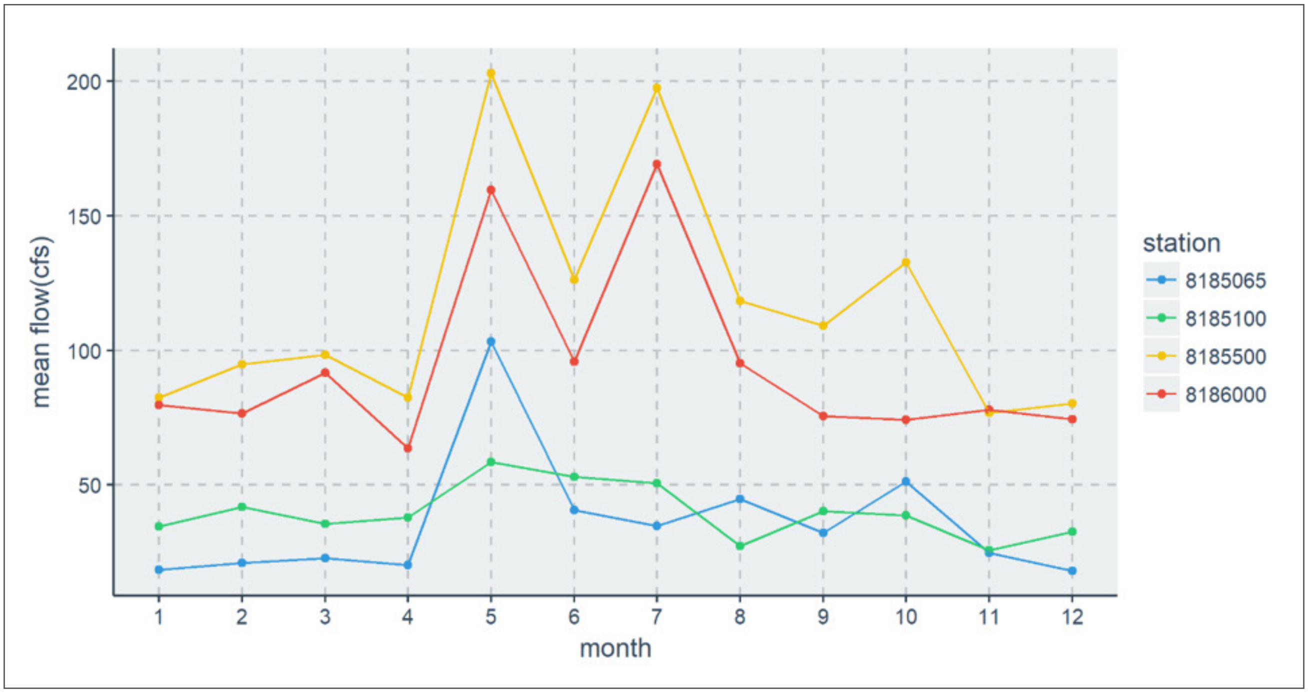


Figure 17. Mean monthly streamflows (cfs), January 2007 through July 2017.

Chapter 4
Potential Sources of Pollution

Introduction

As described in Chapter 3, most water body impairments in the Mid and Lower Cibolo Creek watershed are primarily due to the excessive fecal indicator bacteria. Table 9 includes a summary of potential pollutant sources, causes and impacts.

Pollution sources are categorized as either a point or non-point source. Point sources enter receiving waters at identifiable locations, such as a pipe. Nonpoint sources include anything that is not a point source and enters the water body by runoff moving over and/or through the ground. For cities with Municipal Separate Storm Sewer System (MS4s), certain urban stormwater management practices are required under a MS4 permit and are therefore considered to be point source controls. For example, some urban runoff from the City of San Antonio is considered point source pollution. Potential pollution sources in the watershed were identified through stakeholder input, watershed surveys, project partners and watershed monitoring.

Point Source Pollution

Point source pollution is any type of pollution that can be traced back to a single point of origin, such as a WWTF. Generally, WWTFs discharges are permitted, which means they are regulated by permits under the Texas Pollutant Discharge Elimination System (TPDES). Other permitted discharges include industrial or construction site stormwater discharges, and discharges from MS4s of regulated cities or agencies.

WWTFs

WWTFs treat municipal wastewater before discharging the treated effluent into a water body. WWTFs are required to test and report the levels of indicator bacteria and nutrients as a condition of their discharge permits. Plants that exceed their permitted levels may require infrastructure or process improvements to meet the permitted discharge requirements.

Table 9. Potential pollution source summary.

Pollutant Source	Pollutant Type	Potential Cause	Potential Impact
WWTFs/SSOs/MS4s	Bacteria, nutrients	Inflows & Infiltrations • Overload from large storm events • Conveyance system failures due to age, illicit connections, blockages, etc.	Untreated wastewater may enter watershed or water bodies.
OSSFs	Bacteria, nutrients	• System not properly designed for site specific conditions • Improper function due to age or lack of maintenance / sludge removal • Illegal discharge of untreated wastewater	Improperly treated wastewa-ter reaches soil surface; may runoff into water bodies.
Urban Runoff	Bacteria, nutrients	Stormwater runoff from lawns, parking lots, dog parks, etc. • Improper application of fertilizers • Improper disposal of pet waste	Stormwater drains quickly route water directly to creek or river
Livestock	Bacteria, nutrients	• Manure transport in runoff • Direct fecal deposition to streams • Excessive runoff from pastures due to over grazing • Riparian area disturbance and degradation	Deposited directly into water body or may enter during runoff events
Wildlife	Bacteria, nutrients	• Manure transport in runoff • Direct fecal deposition to streams • Riparian area disturbance and degradation	Deposited directly into water body or enters dur-ing runoff events
Pets	Bacteria, nutrients	• Fecal matter not properly disposed of • Lack of dog owner education regarding effects of improper disposal	Bacteria and nutrients en-ter water body through runoff
Illegal Dumping	Bacteria, nutrients, litter	Disposal of trash and animal carcasses in or near water body	Direct or indirect contamina-tion of water body

Wastewater treatment facility, WWFTs; sanitary sewer overflow, SSOs; municipal separate storm sewer systems, MS4s; on-site sewage facility, OSSFs

There are currently ten facilities operating in the watershed (Figure 18). In the near future, two WWTFs (Woman Hollering Treatment Plant and Martinez III WWTP) will be taken offline with the addition of two new plants (CCMA South WWTP and Martinez IV WWTP). In addition, the designed flow of the Odo J Riedel Regional Water Reclamation Plant will be extended from 6.2 to 10 million gallons per day (MGD). Generally, WWTF discharges are well below the permitted bacteria concentration limits. However, periodic exceedance in permitted bacteria and or flow limits as reported through the EPA Environmental Compliance History Online (ECHO) database are documented (Table 10). Annual nutrient loading reports were not available from this source.

Sanitary Sewer Overflows (SSOs)

SSOs can occur when sewer lines lose capacities due to age, lack of maintenance, inappropriate connections or overload during storm events. Inflow and infiltration are common issues to all sanitary sewer systems. Inflow occurs primarily during large runoff events and can occur through uncapped cleanouts and gutter connections to the sewer system or through cross connections with storm sewers and faulty manhole covers. Infiltration happens slowly as it generally occurs through cracks and breaks in lateral lines on private property or sewer mains, bad connections between laterals and sewer mains, and in deteriorated manholes.

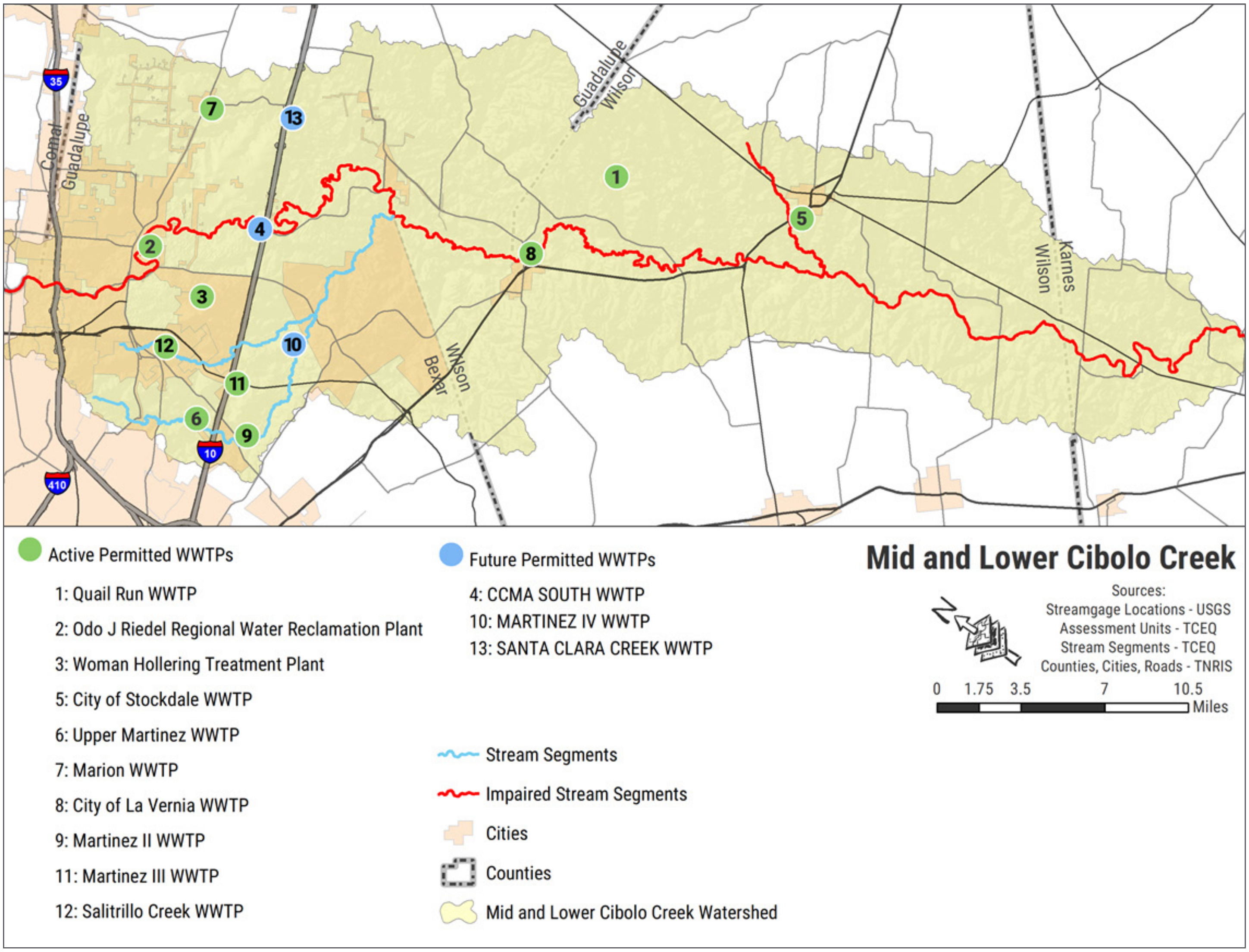


Figure 18. Permitted municipal wastewater treatment facilities.

These overflows and spills can reach water bodies, resulting in substantial periodic bacteria loading. Permit holders are required to report SSOs that occur in their system to TCEQ. According to the TCEQ regional office, 106 SSO events were reported in the region from January 1, 2011 through August 28, 2017 (Table 11, Table 12). Many of the events were blockages caused by material that should not be flushed or poured down drainpipes. Other than SSO event reports, no compliance or pollutant loading data associated with SSOs are available. The pollutant loads associated with individual events are likely to vary widely depending on the amount and makeup of the discharge.

Regulated Stormwater

Regulated stormwater includes any stormwater originating from TPDES-regulated MS4s, industrial facilities and regulated construction activities. Polluted urban stormwater runoff is commonly transported through MS4s. MS4s often have large numbers of discharge points, so permits for such systems are issued covering all the outfalls in a city's MS4. Any failures of MS4s — due to age, illicit connections and blockages, etc. — will lead to the potential pollution of urban stormwater, especially under wet weather with large urban runoff. Currently, there are nine phase II MS4 permits in the watershed (Figure 19).

Table 10. Summary of municipal wastewater treatment facilities/plants (WWTFs/WWTPs) permitted discharges and compliance status.

Name	Received Water Body	Design Flow (MGD)	Recent Average Flow (MGD)	Operation Status	Quarters in NC (5 years) (04/16-07/19)*
Odo J Riedel Regional Water Reclamation Plant	Mid Cibolo Creek	6.2	5.51	Active	7 (2 *E. coli*; 2 Am-monia Nitro-gen; 1 Suspended Solids; 2 Flow)
Marion WWTP	Lower Cibolo Creek	0.2	0.0623	Active	1 TSS
City of La Vernia WWTP	Lower Cibolo Creek	0.25	0.114	Active	0
Quail Run WWTP	Lower Cibolo Creek	0.075	0.0152	Active	2 (1 BOD, 1 *E. coli*)
City of Stockdale WWTP	Lower Cibolo Creek	0.3	0.028	Active	7 (5 *E. Coli*; 7 BOD; 1 TSS)
Salitrillo Creek WWTP	Salitrillo Creek	5.83	4.483	Active	7(4 *E. Coli*; 1 Nitro-gen; 4 Flow)
Woman Hollering Treatment Plant	Woman Hollering Creek	0.046	0.0373	Active (future off-line)	6 (1 Total Ammonia Nitro-gen; 5 Flow)
Upper Martinez Creek WWTP	Martinez Creek	2.21	1.607	Active	0
Martinez III WWTP	Escondido Creek	0.15	0.0484	Active (future off-line)	0
Martinez II WWTP	Martinez Creek	3.5	2.339	Active	0
CCMA South WWTP	Mid Cibolo Creek	0.5		Non-active (future online)	
Martinez IV WWTP	Martinez Creek	2		Non-active (future online)	
Santa Clara Creek WWTP	Lower Cibolo Creek	5		Non-active (future online)	

Million gallons per day, MGD; noncompliance, NC; total suspended solids, TSS; biochemical oxygen demand, BOD
*There can be multiple violations for different parameters within a quarter violation period.

Table 11. Reported sanitary sewer overflow events and discharged volumes (January 1, 2011–August 28, 2017).

Facility	Number of Events	Average Gallons/Event
Martinez II WWTP	2	56,250
Martinez III WWTP	1	6,000
Odo J Riedel Regional Water Reclamation Plant	75	8,175
Salitrillo Creek WWTP	10	3,160
Upper Martinez Creek WWTP	13	6,377

Wastewater treatment plant, WWTP

Table 12. Estimated sanitary sewer overflow receiving volumes.

Water Bodies	Total Received Gallons
Cibolo Creek	308,850
Martinez Creek	131,700
Salitrillo Creek	24,100
Others	36,800
No Water Body Provided	51,805

Nonpoint Source Pollution (NPS)

NPS pollution occurs when precipitation flows off the land, roads, buildings and other landscape features and carries pollutants into drainage ditches, lakes, rivers, wetlands, coastal waters and underground water resources. NPS pollution includes but is not limited to polluted water from leaking or improperly functioning OSSFs, fertilizers, herbicides, pesticides, oil, grease, toxic chemicals, sediment, bacteria, nutrients and many other substances.

OSSFs

OSSFs are common in the watershed and may contribute *E. coli*, nutrients and solids to water bodies if not properly functioning. The number of systems, their locations, ages, types and functional statuses in the watershed are unavailable, making it difficult to determine their real effects on water quality. To estimate the number of systems and approximate their locations, an approach using 911 address points, 2010 census data and recent aerial imagery was used to estimate the number of OSSFs (Gregory et al. 2013). OSSF locations were estimated by validating 911 addresses as household structures (determined by remote imagery) located outside of WWTF service areas. This method of locating potential OSSF sites was utilized since georeferenced OSSF locations were not available from local databases. This method produced an estimate of 17,325 OSSFs within the watershed and 120 OSSFs within 150 yds of water bodies. The highest densities of OSSFs are suburban areas just outside of existing wastewater service boundaries (Figure 20).

Typical OSSF designs include either (1) anaerobic systems composed of septic tank(s) and an associated drainage or distribution field, or (2) aerobic systems with aerated holding tanks and typically an above ground sprinkler system to distribute the effluent. Many factors affect OSSF performance, such as system failure due to age, improper system design for specific site conditions, improper function from lack of maintenance/sludge removal and illegal discharge of untreated wastewater. Adsorption of field soil properties affects the ability of conventional OSSFs to treat wastewater by percolation. Soil suitability rankings were developed by the Natural Resources Conservation Service (NRCS) to evaluate the soil's ability to treat wastewater based on soil characteristics such as topography, saturated hydraulic conductivity, depth to the water table, ponding, flooding effects and more (NRCS 2015). Soil suitability ratings are divided into three categories: not limited, somewhat limited and very limited. Soil suitability dictates the type of OSSFs required to properly treat wastewater. If not properly designed, installed or maintained, OSSFs in somewhat or very limited soils pose an increased risk of failure. Approximately 92.2% of the watershed's soils are considered very limited, 7.5% are somewhat limited and 0.4% are not rated in the Mid and Lower Cibolo Creek watershed.

OSSF density can also affect overall treatment performance. If the systems installed are not appropriately designed, soil treatment capacity may be exceeded and lead to widespread OSSF failure. Several areas, especially the northern part of the watershed, have higher OSSF densities than the surrounding areas and therefore may increase the risk of OSSF failures and subsequent water quality effects (Figure 20). Proximity to streams is important for determining OSSFs' potential impact on water quality. The closer a potentially failing system is to a stream, the more likely it is to impact water quality.

Urban Runoff

Two potential pollution sources of bacteria and nutrients are the improper application of fertilizers and improper disposal of pet waste in the watershed. Stormwater runoff from lawns, parking lots and dog parks will wash fertilizers and wastes into water bodies. Runoff from urban areas is becoming more intensified as infiltration rates decrease with runoff infiltration ability decreasing as a result of the increasing impervious cover in those areas (Figure 21). Increased runoff can adversely affect water quality by carrying more NPS pollution into surrounding water bodies.

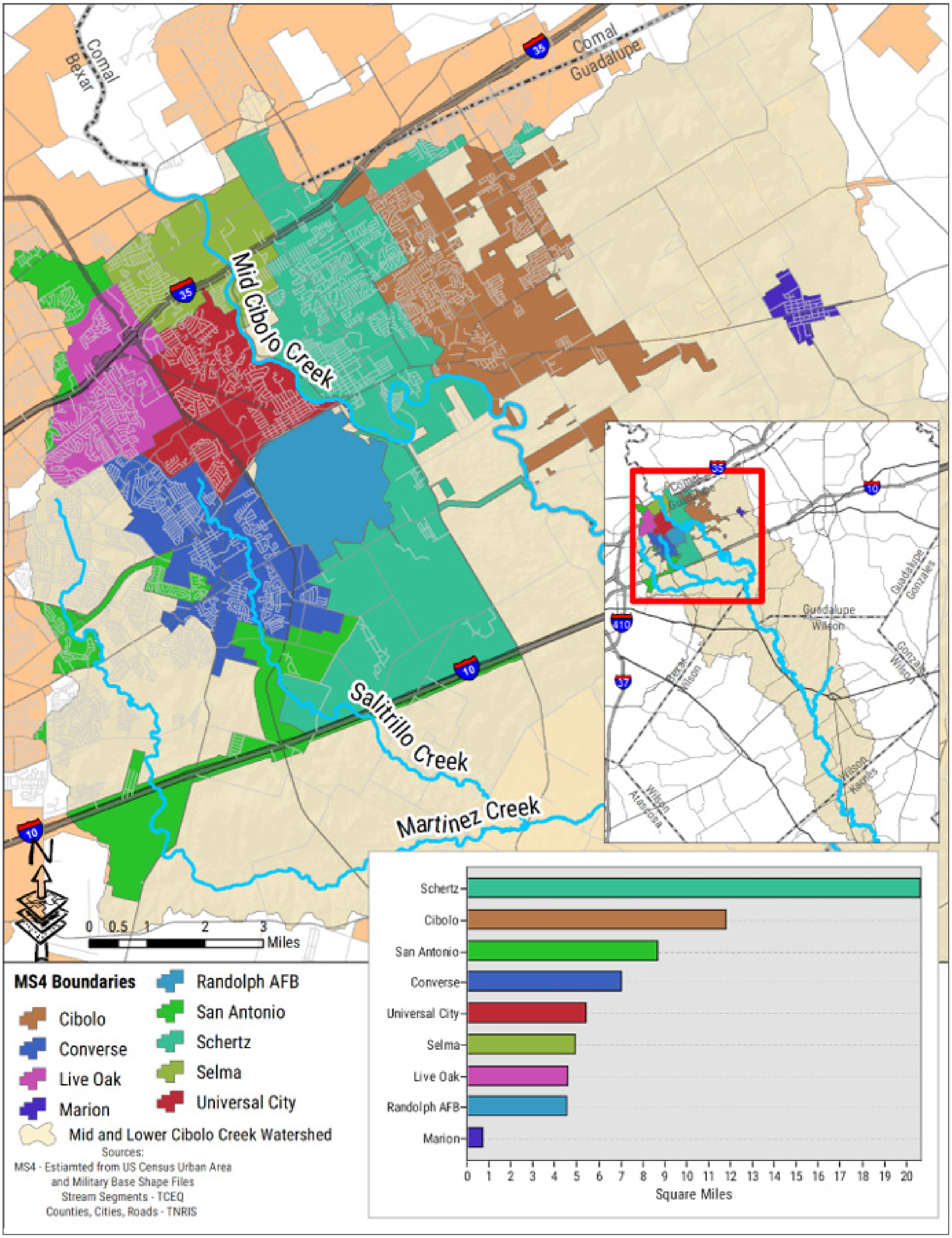


Figure 19. Municipal separate storm sewer systems (MS4) permit boundaries.

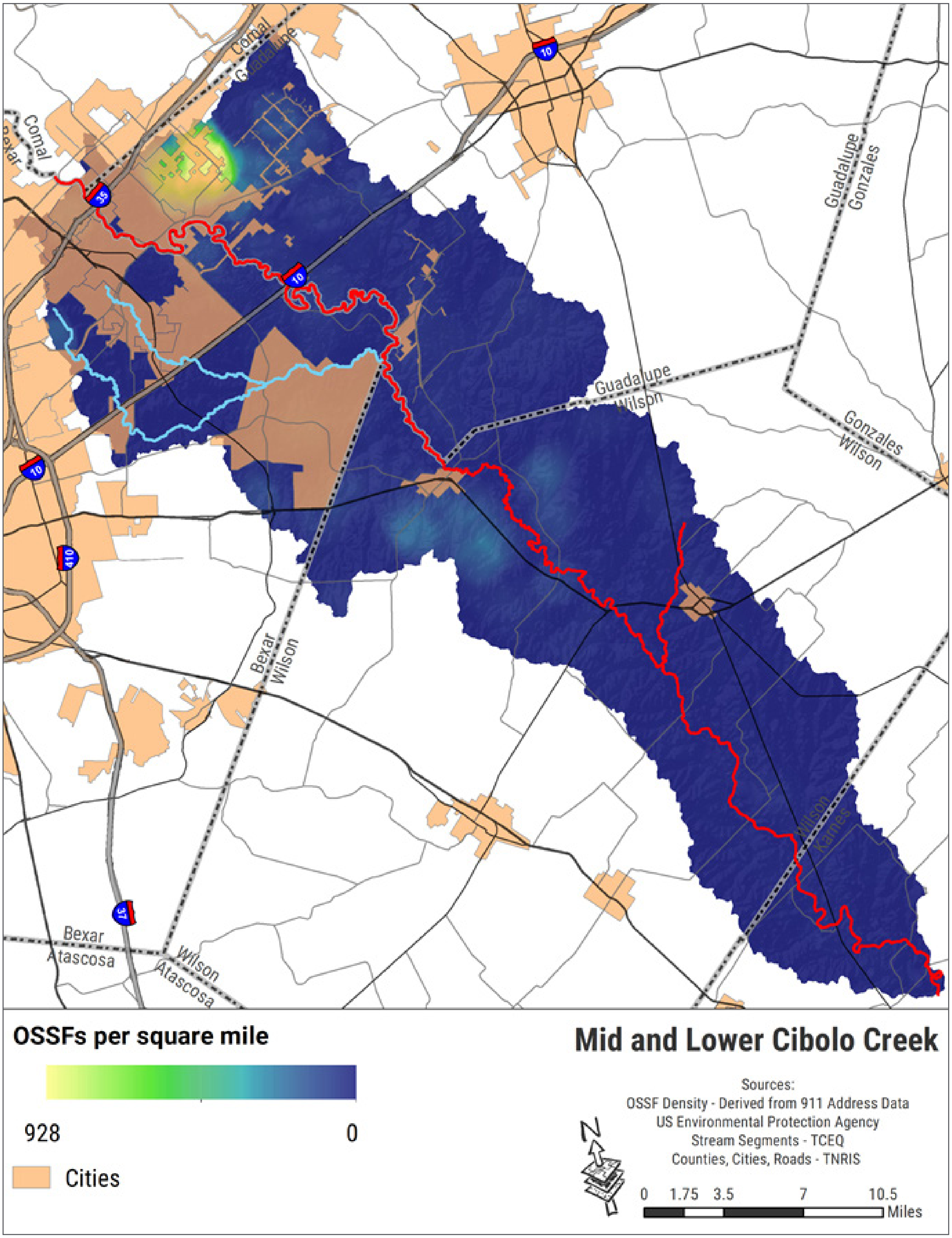


Figure 20. On-site sewage facilities (OSSF) densities.

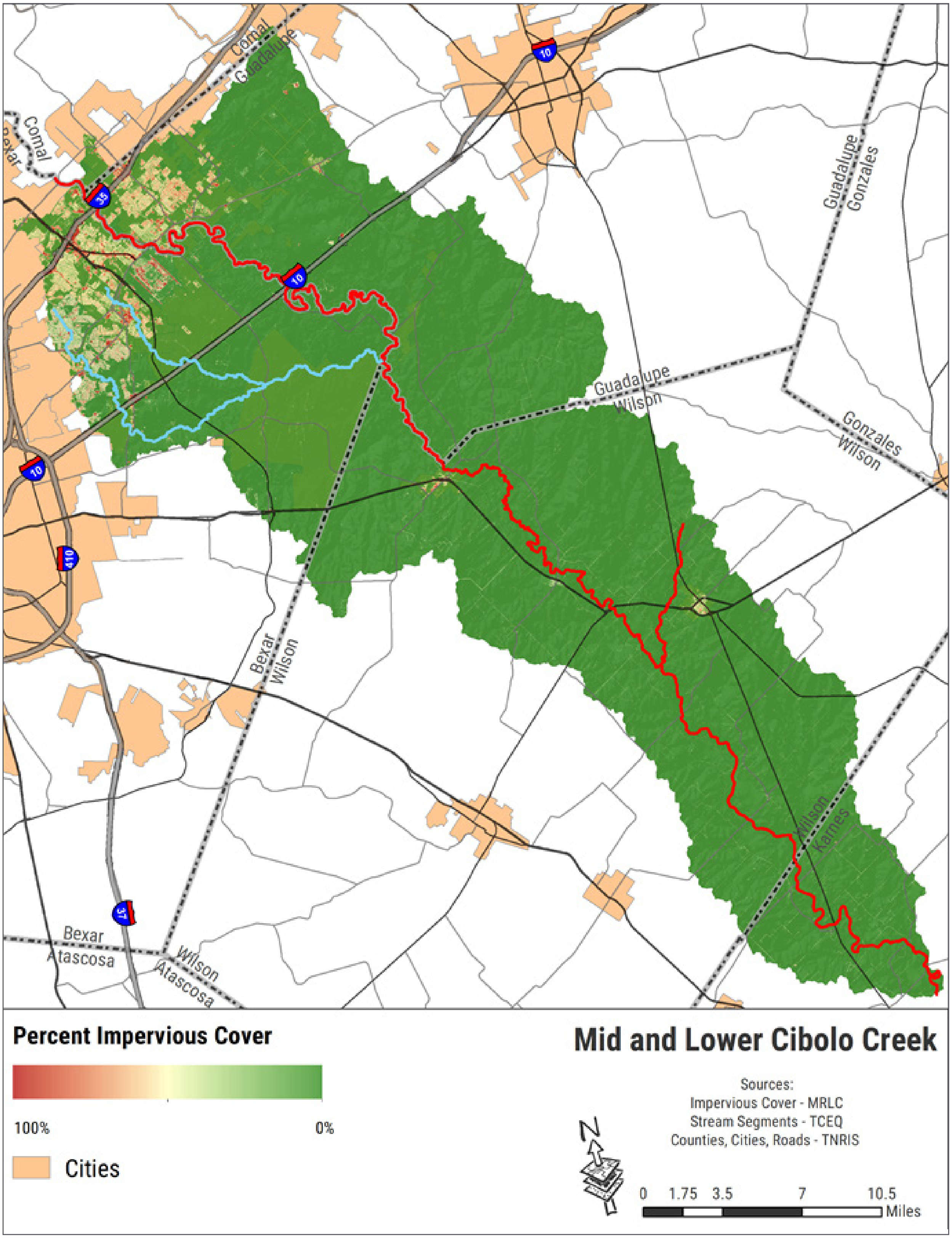


Figure 21. Percent impervious cover.

Table 13. Estimated livestock populations.

County	Livestock				
	Cattle	Hog	Horse	Goat	Sheep
Bexar	4,984	199	482	684	459
Wilson	16,202	192	676	955	430
Guadalupe	6,267	352	564	1,351	559
Karnes	3,300	10	63	54	19
Comal	34	1	3	27	11
Total	30,787	754	1,788	3,071	1,478

Livestock

The grazing of livestock — predominantly cattle, and to a lesser extent goats, horses and sheep — occurs throughout the Mid and Lower Cibolo Creek watershed. These animals also serve as potential sources of NPS pollution. They graze over large tracts of land, rather than being confined, and deposit urine and fecal matter onto the land surface as well as directly into water bodies if accessible. Fecal matter deposited within the watershed is likely to be transported to the creek during runoff events, which contributes to the total bacterial load in the water body.

It is difficult to quantity the exact numbers of these animals within the watershed. However, county level population estimates are available from the National Agricultural Statistics Service (NASS) that help to develop an approximation of the total livestock within the watershed. We estimated cattle populations by applying stakeholder identified average local stocking rates to improved pastures and rangeland identified in NLCD data (Table 13). Estimates for other livestock were derived from NASS county statistics applied to pasture and range land use types.

Wildlife

Wildlife is another contributor to *E. coli* and nutrient loads in the watershed. Riparian areas provide the most suitable wildlife habitat in the watershed, leading most wildlife to spend the majority of their time in these areas. The amount of fecal deposition is directly related to time spent in a given area, thus wildlife feces are considered as a major source in the watershed. Wildlife population density estimated are limited to deer and feral hogs since information regarding other species is not available.

The Texas Parks and Wildlife Department (TPWD) conducts deer population surveys within the state of Texas at the resource management unit (RMU) level. RMUs are developed based on similar ecological characteristics within a defined area. The Mid and Lower Cibolo Creek watershed is situated in parts of Edwards Plateau (RMU 7), South Texas Plains (RMU 8) and Post Oak Savannah (RMU 11). The estimated deer population within RMU 7, 8 and 11 are 7.16 ac/deer, 29.04 ac/deer and 19.40 ac/deer respectively in 2015. Combining with the feedback from stakeholders, the deer densities are estimated as 18.5 ac/deer in Bexar, 20 ac/deer in Wilson, 17 ac/deer in Guadalupe, 23 ac/deer in Karnes and 7.16 ac/deer in Comal. This population estimate was applied to every LULC classes within the watershed except for open water, barren land and developed land. Based on these assumptions, there are an estimated 16,748 deer in the watershed (Table 14).

Feral hogs are a non-native, invasive species rapidly expanding throughout Texas, inhabiting similar areas as white-tailed deer. They are especially fond of places where there is dense cover and food and water are readily available. They are also known to wallow in available water and mud holes. It is obvious that riparian corridors are prime habitat for feral hogs; therefore, they spend much of their time in or near the creek. This preference for riparian areas does not preclude their use of non-riparian areas. Reclusive by nature, feral hogs are something of a nocturnal species. They typically remain in thick cover during the day and venture away from this cover at night into more open areas of the watershed such as cropland, pastures or rangeland. Feral hogs are significant contributors of pollutants to creeks and rivers across the state through direct and indirect fecal loading. In addition, extensive rooting and wallowing in riparian areas by feral hogs cause erosion and soil loss. According Wagner and Moench (2009) and stakeholder input, the density of feral hogs was estimated at 30 ac/hog for non-developed LULC type. In total, an estimated 10,576 feral hogs are in the watershed (Table 14).

Table 14. Estimated wildlife population.

County	Wildlife	
	Feral Hogs	Deer
Bexar	2,029	3,290
Wilson	4,798	7,200
Guadalupe	2,798	4,921
Karnes	917	1,197
Comal	34	140
Total	10,576	16,748

Table 15. Estimated household pet population.

County	Households*	Cat	Dog
Bexar	43,603	27,495	25,289
Wilson	5,595	3,556	3,257
Guadalupe	20,198	12,747	11,707
Karnes	193	125	112
Comal	170	108	102
Total	69,759	44,031	40,467

*The number of occupied households from the 2010 Census was obtained and divided by the county area (miles2) to get the number of households/mile2. The county area in watershed was calculated and multiplied by the previous number of households/mile2 to get the final household number in the table.

Pets

Dogs and cats can contribute to fecal bacteria loading when waste and bacteria runoff from lawns, parks and other areas. This type of loading is easily avoided if pet owners properly dispose of pet waste.

According to the American Veterinary Medical Association (AVMA), the average household in the U.S. is home to 0.58 dogs and 0.63 cats (AVMA 2012). We estimated the number pets in the watershed by multiplying these average densities by the number of households estimated in U.S. Census Block data. Based on these assumptions we estimated 40,467 dogs and 44,031 cats in the watershed (Table 15).

Other Sources

Cropland, improved pasture and native rangeland are potential sources of pollution in the watershed. Fertilizers, herbicides and pesticides are commonly applied to cropland and pastures and may be washed into the Mid and Lower Cibolo Creek watershed during runoff events. These managed lands also provide a source of food and cover for livestock, wildlife and other species that deposit fecal material as they use the land, resulting in potential *E. coli* and nutrient loading to the creek. To date, no watershed specific studies have been conducted to quantify nutrient or bacteria loading contributions from these lands. It is reasonable to conclude that load contributions vary substantially between and within watersheds based on local soil, land cover and management practices based on results from studies conducted elsewhere.

Stakeholders identified illegal dumping as a potential source of bacteria in the watershed. Dumping of animal carcasses in or next to streams can directly contribute bacteria to the watershed. Illegal dumping of residential waste could feasibly contribute bacteria, as well as illegal dumping of septic waste. However, locations and frequency of occurrences is currently unknown.

Chapter 5
Pollutant Source Assessment

Introduction

Multiple approaches were used to assess watershed pollutant loadings to provide a more complete evaluation of potential pollution sources and their impacts on water quality. Each approach provides a piece of information needed to define and address specific pollutant sources. No single method provides a perfect result or a definitive answer as each method analyzes data differently. Methods used included spatial water quality data analysis, load duration curves and spatial analysis of potential *E. coli* sources.

This chapter estimates the load capacity and the current load of E.coli within the watershed. The Spatially Explicit Load Enrichment Calculation Tool, or SELECT, is used to highlight areas of highest potential for bacterial loading from various potential pollutant sources. By estimating the relative potential contribution of different fecal bacteria sources across the watershed, areas can be prioritized as to when and where management measures should occur. The number of management measures needed to reach water quality goals can also be estimated.

Water Quality Monitoring

The *2014 Texas Integrated Report* identified four AUs in the watershed as impaired due to elevated *E. coli* concentration. They are AUs 1902_01, 1902_02, 1902_03 and 1902C_01. Three additional AUs have *E. coli* concerns: AUs 1902A_01, 1902A_03 and 1902A_04. The Mid and Lower Cibolo Creek is being monitored by the San Antonio River Authority (SARA) as part of the Clean Rivers Program. Routine water quality monitoring at these AUs is designed to capture the full range of streamflow conditions (outside of dangerous flood flow conditions). Therefore samples included in the assessement are not biased to high or low flow events.

E. coli *Data Assessment*

Ten years of near-monthly data from 18 stations on the Mid and Lower Cibolo Creek watershed has highlighted that the creek is quite dynamic and that *E. coli* loading across the watershed is both spatially and temporally variable. The presence of streamflow strongly influences the measured

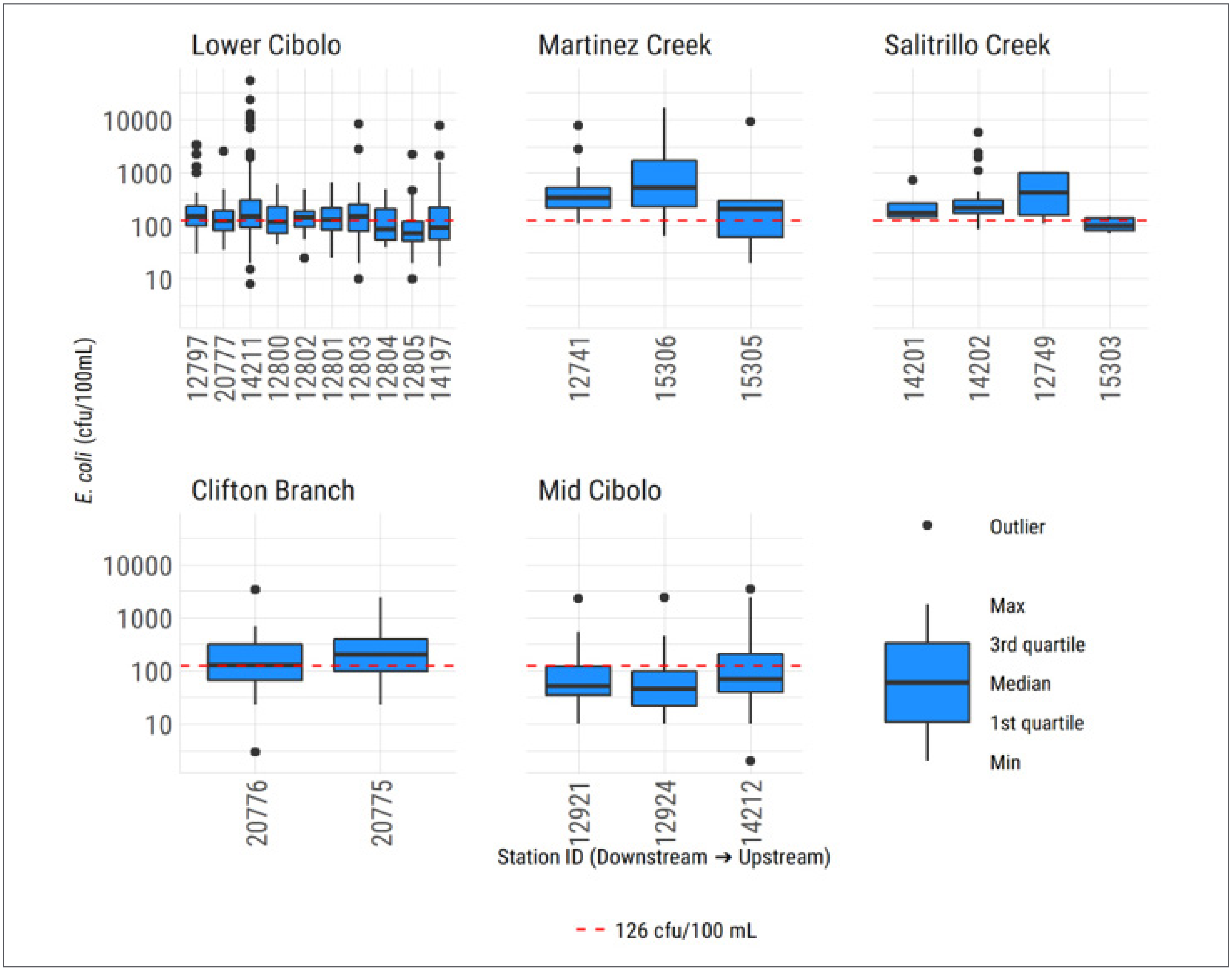


Figure 22. Boxplots of *E. coli* concentrations (January 1, 2007 through August 30, 2016).

E. coli concentrations. Monitoring sites that typically have sustained flow for much of the year tend to have lower geometric means under routine flow conditions.

Figure 22 includes boxplots of measured *E. coli* concentrations at monitoring stations throughout the watershed. These boxplots indicate that the median *E. coli* levels are higher than the water quality standard (red line) at several stations. For station 12741, located in AU segment 1902A_01 (Martinez Creek), most of the sample values exceeded the standard. Higher concentrations of *E. coli* were found downstream in Lower Cibolo Creek or on the tributaries Martinez Creek and Salitrillo Creek. Most of the monitoring stations with a median E.coli concentration over 126 cfu/100 mL are located in the Lower Cibolo Creek. Table 16 provides a tabular summary of *E. coli* values.

Dissolved Oxygen

AU 1902C_01 (Clifton Branch) is impaired due to depressed DO indicated by grab DO samples. Grab DO samples collected from January 2007 through August 2016 confirm this impairment (Figure 23). Based on this data approximately 34% of the samples fell below the 3.0 mg/L minimum criteria.

AU 1913_02 is impaired due to depressed DO indicated by 24-hr monitoring. The AU is categorized as 4b on the Integrated Report since wastewater treatment plant improvements are anticipated to improve water quality. More recent 24-hr monitoring indicate improvements in the minimum DO concentration with all the samples well above the 2.0 mg/L criteria (Figure 24).

Table 16. *E. coli* summary statistics (January 1, 2007 through August 30, 2016).

Station ID	AU	Water Body	Number of Samples	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Geometric Mean (cfu/100 mL)
12797	1902_01	Lower Cibolo	52	30	3400	188.7
20777	1902_01	Lower Cibolo	36	36	2600	138.6
14211	1902_02	Lower Cibolo	393	8	55000	190.8
12800	1902_02	Lower Cibolo	18	44	610	132.1
12802	1902_03	Lower Cibolo	18	25	490	131.5
12801	1902_03	Lower Cibolo	18	25	650	132.3
12803	1902_03	Lower Cibolo	35	10	8300	145.0
12804	1902_04	Lower Cibolo	18	39	490	105.3
12805	1902_04	Lower Cibolo	37	10	2200	76.4
14197	1902_05	Lower Cibolo	63	17	7700	117.8
12921	1913_01	Mid Cibolo	24	10	2300	73.2
12924	1913_02	Mid Cibolo	28	10	2400	50.4
14212	1913_03	Mid Cibolo	39	2	3500	76.7
20776	1902C_01	Clifton Branch	36	3	3400	128.0
20775	1902C_01	Clifton Branch	36	23	2400	191.7
12741	1902A_01	Martinez Creek	40	110	7700	377.7
15306	1902A_03	Martinez Creek	4	65	17000	743.5
15305	1902A_03	Martinez Creek	5	20	9200	234.4
14201	1902B_01	Salitrillo Creek	4	120	720	226.4
14202	1902B_01	Salitrillo Creek	24	86	5800	294.6
12749	1902B_01	Salitrillo Creek	4	110	1000	375.1
15303	1902B_01	Salitrillo Creek	5	72	150	104.4

Assessment unit, AU; colony forming unit, cfu; milliliter, mL

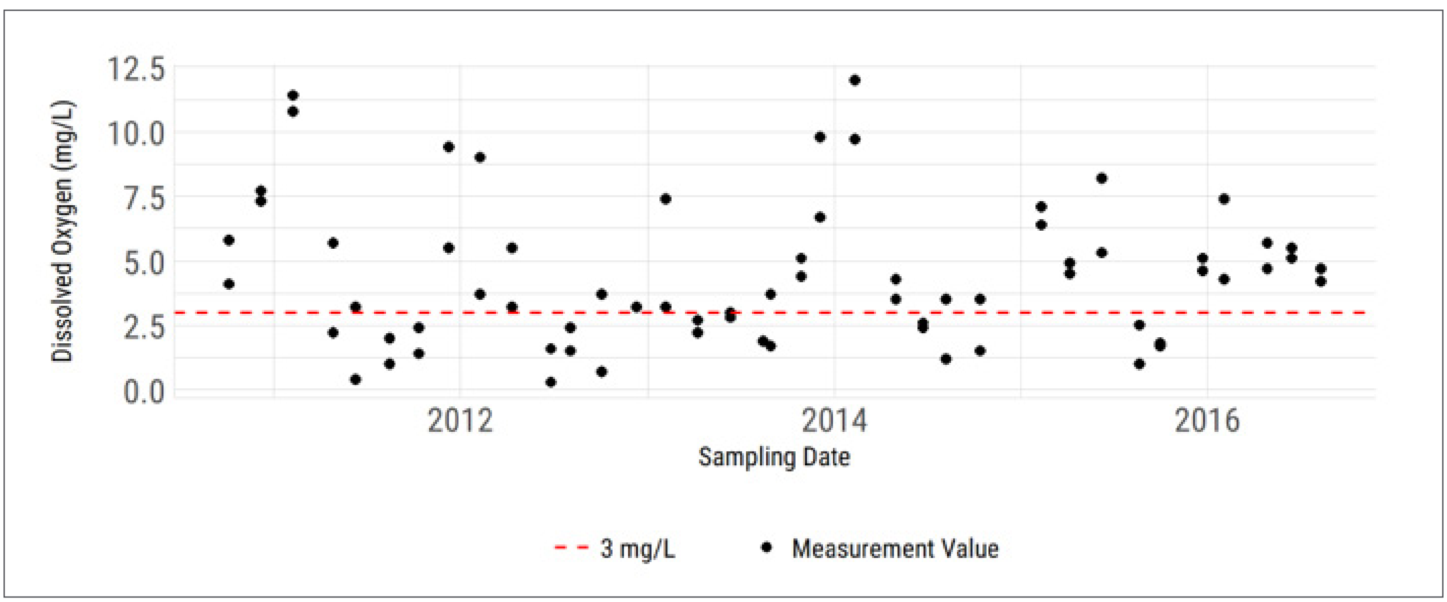


Figure 23. Grab dissolved oxygen (DO) measurements in 1902C_01 (Clifton Branch).

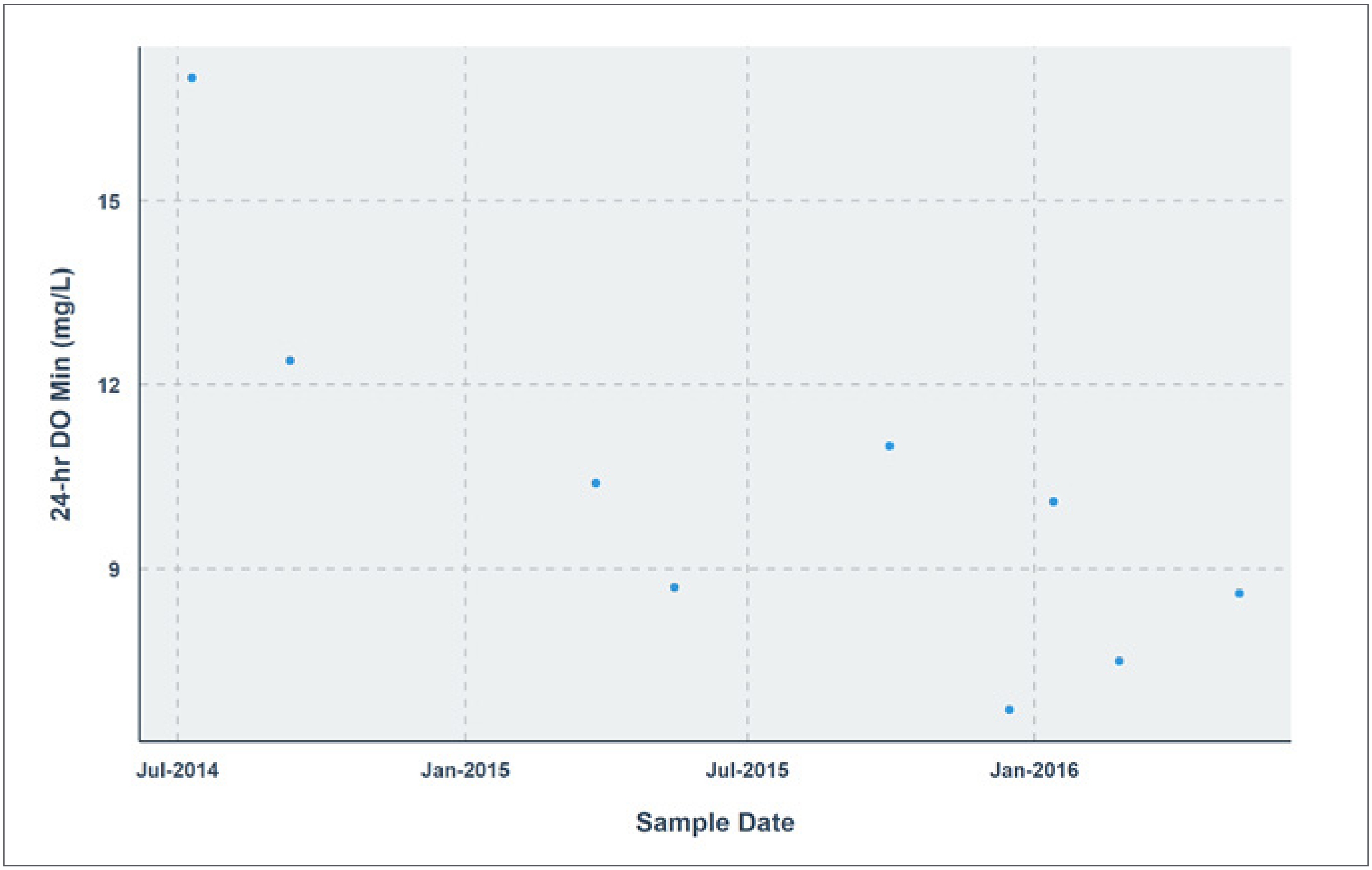


Figure 24. 24-hour (hr) minimum dissolved oxygen (DO) measurements in AU 1913_02.

Nutrients

Several stations in the upstream portions of the watershed have average nutrient concentrations above state screening criteria. Figure 25 and Table 17 show nutrient concentration summaries for stations across the watershed. AUs 1902A_01 (Martinez Creek, Station 12741), 1902B_01 (Salitrillo Creek, Station 14923) and 1913_01 (Mid Cibolo Creek, Station 14202) have higher nitrate and total phosphorus concentrations than expected. AUs 1913_01 and 1913_02 (Mid Cibolo Creek) also have elevated total phosphorus concentrations.

Load Duration Curve (LDC) Analysis

The relationship between flow and pollutant concentration in the watershed was established using LDCs. This approach allows existing pollutant loads to be calculated and compared to allowable loads. It is the basis for estimating needed load reductions of a particular pollutant to achieve the established water quality goal. LDCs also help determine whether point or nonpoint pollutant sources primarily cause stream impairments by identifying flow conditions when impairments occur. Although LDCs cannot identify specific pollutant sources (urban vs. agricultural, etc.), they can identify the likely pollutant type (point vs. nonpoint). For example, if allowable load exceedances primarily occur during high flow or moist conditions, NPS is a contributor. If exceedances occur during low flow conditions, then point sources are the most likely source. Instream disturbances, such as those caused by increased flow velocity (release from a dam) or physical agitation (animal walks in stream), are also known to cause *E. coli* increases under all flow conditions.

Bacteria LDCs were completed at four monitoring sites on the Mid and Lower Cibolo Creek watershed (Stations 12805, 12921, 12741 and 14211) using data collected from January 2007 to August 2016 (Figure 26). The distributions of loads across flow regimes, as well as the needed load reductions at these stations were considered representative of the entire watershed. Nutrient LDCs were not developed since approiate standards for Cibolo Creek are not established. Currently, only statewide nutrient screening criteria exist. Using these values to develop local nutrient reduction goals was deemed inappropriate due to inherent uncertainty associated with application of a statewide value to local water quality management. Despite the lack of nutrient water

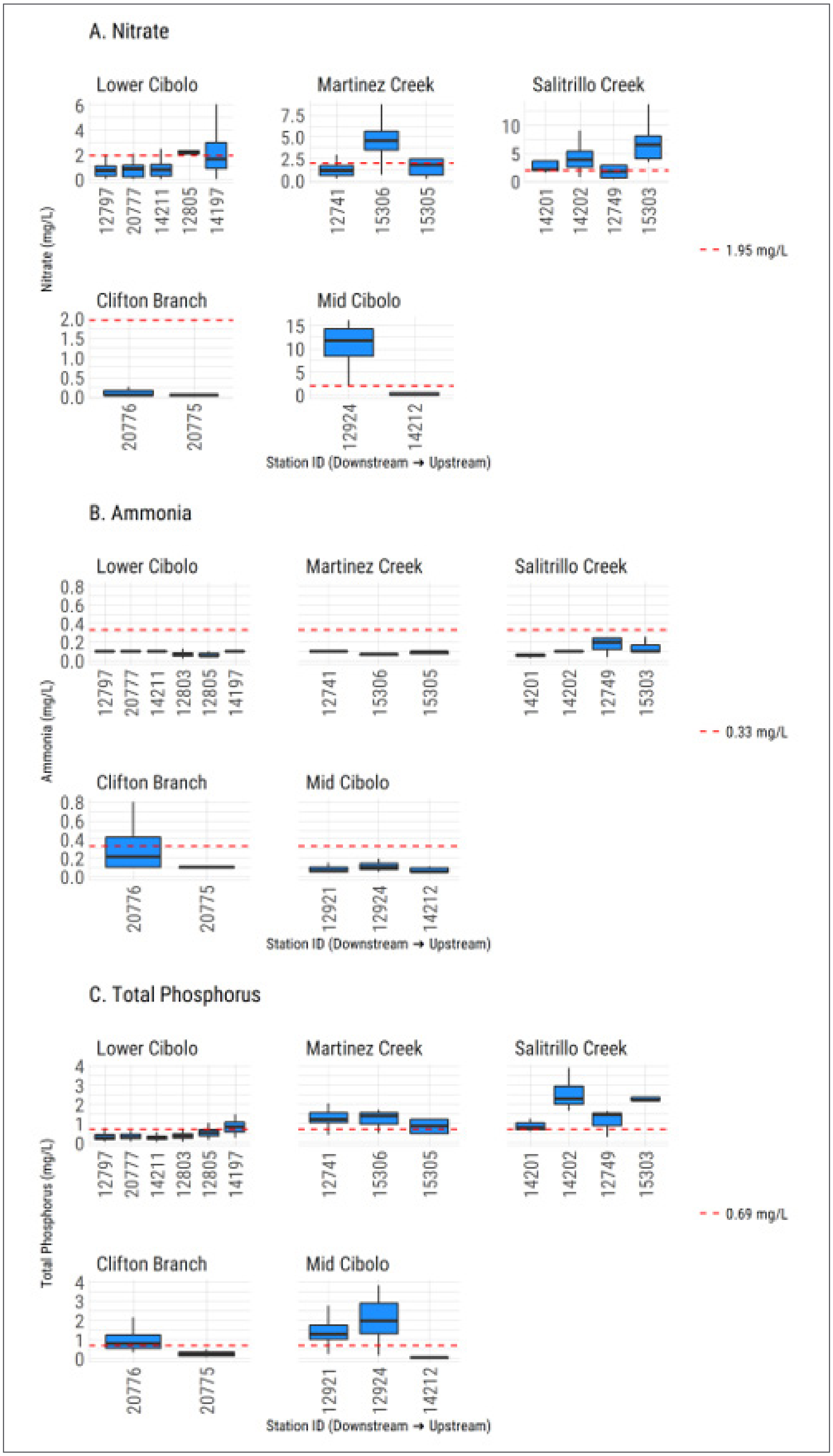


Figure 25. Boxplots of (a) Nitrate, (b) ammonia and (c) total phosphorus at stations with more than five measurement values from January 1, 2007–August 30, 2016.

Table 17. Nutrient summary statistics.

Station ID	AU	Water Body	Mean Nitrate (mg/L)	Mean Ammonia (mg/L)	Mean Total Phosphorus (mg/L)
12797	1902_01	Lower Cibolo	0.77	0.1	0.3
20777	1902_01	Lower Cibolo	0.82	0.1	0.32
14211	1902_02	Lower Cibolo	0.93	0.1	0.28
12803	1902_03	Lower Cibolo	N/A	0.07	0.35
12805	1902_04	Lower Cibolo	2.36	0.06	0.52
14197	1902_05	Lower Cibolo	2.1	0.1	0.82
12921	1913_01	Mid Cibolo	N/A	0.53	1.34
12924	1913_02	Mid Cibolo	10.7	0.64	2.04
14212	1913_03	Mid Cibolo	0.92	0.07	0.06
20776	1902C_01	Clifton Branch	0.13	0.35	0.92
20775	1902C_01	Clifton Branch	0.05	0.11	0.29
12741	1902A_01	Martinez Creek	1.28	0.09	1.25
15306	1902A_03	Martinez Creek	4.62	0.07	1.22
15305	1902A_03	Martinez Creek	1.5	0.1	0.84
14201	1902B_01	Salitrillo Creek	3.54	0.06	0.88
14202	1902B_01	Salitrillo Creek	3.99	0.32	2.48
12749	1902B_01	Salitrillo Creek	1.72	0.17	1.14
15303	1902B_01	Salitrillo Creek	7.2	0.14	2.35

Assessment unit, AU; milligrams, mg; liter, L

quality standards and focused efforts to address loading to the stream, the practices aimed at reducing bacteria loads will also yield nutrient load reductions when implemented in the watershed.

Before the development of LDCs, a flow duration curve (FDC) is generated for each monitoring station with continuously measured or instantaneous flow data. At each station, available flow data is sorted from largest to smallest and then ranked from 1 to n. The percent flow exceedance is calculated by dividing the flow's rank by n and then multiplying by 100. The FDC is created by plotting the flow against the percent flow exceedance. The available streamflow gauges in the Mid and Lower Cibolo Creek watershed are Station 8185500, 8285065, 8185100 and 8186000. Multiplying the FDC by the concentration of the pollutant's water quality criterion produces the LDC (Figure 27). This curve shows the maximum pollutant load a stream can receive across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. Percent load reductions are calculated by subtracting the geometric mean of the measured loads from the maximum allowable load within predetermined flow categories.

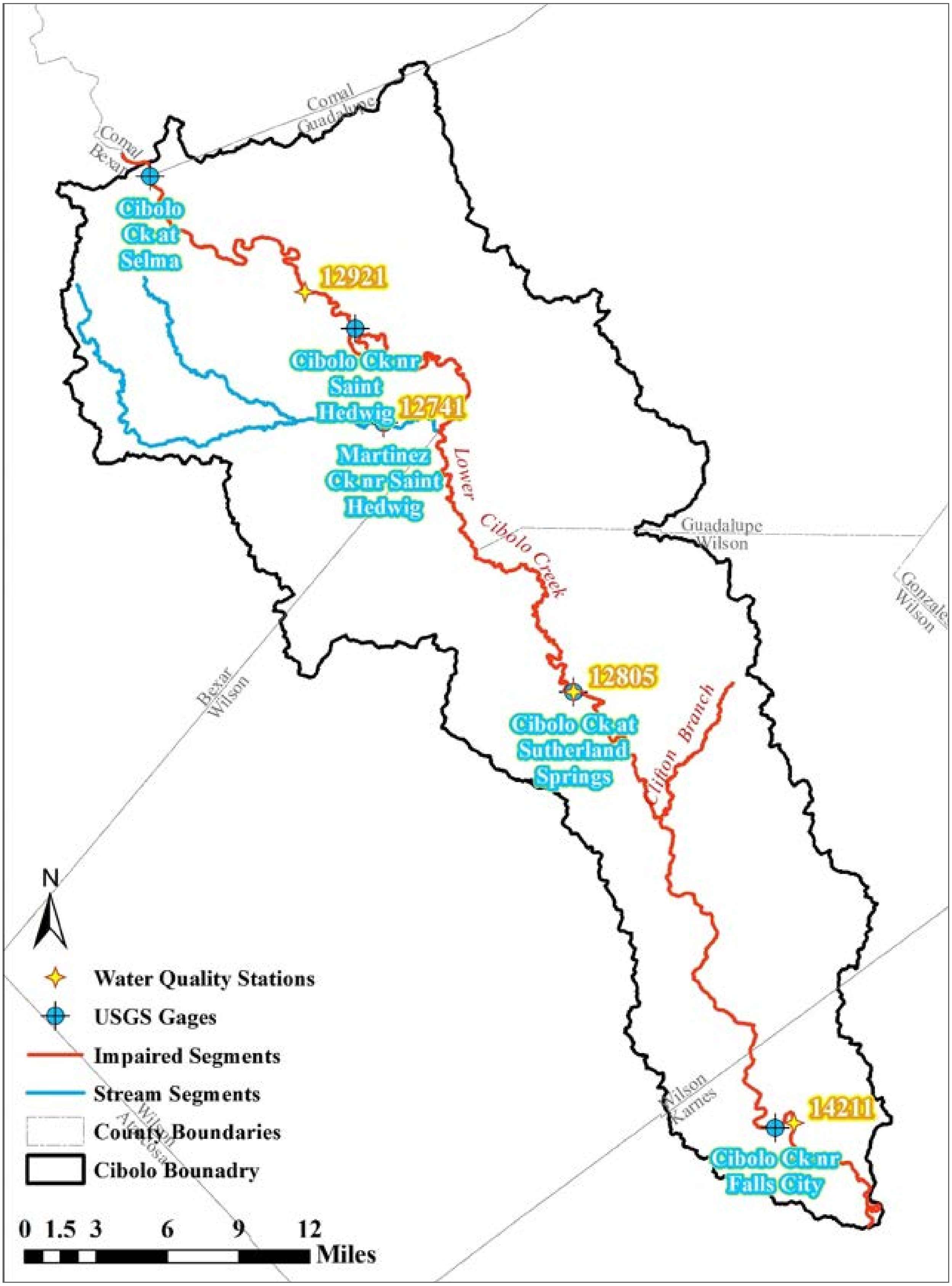


Figure 26. Monitoring station and stream gauge locations used for load duration curve development.

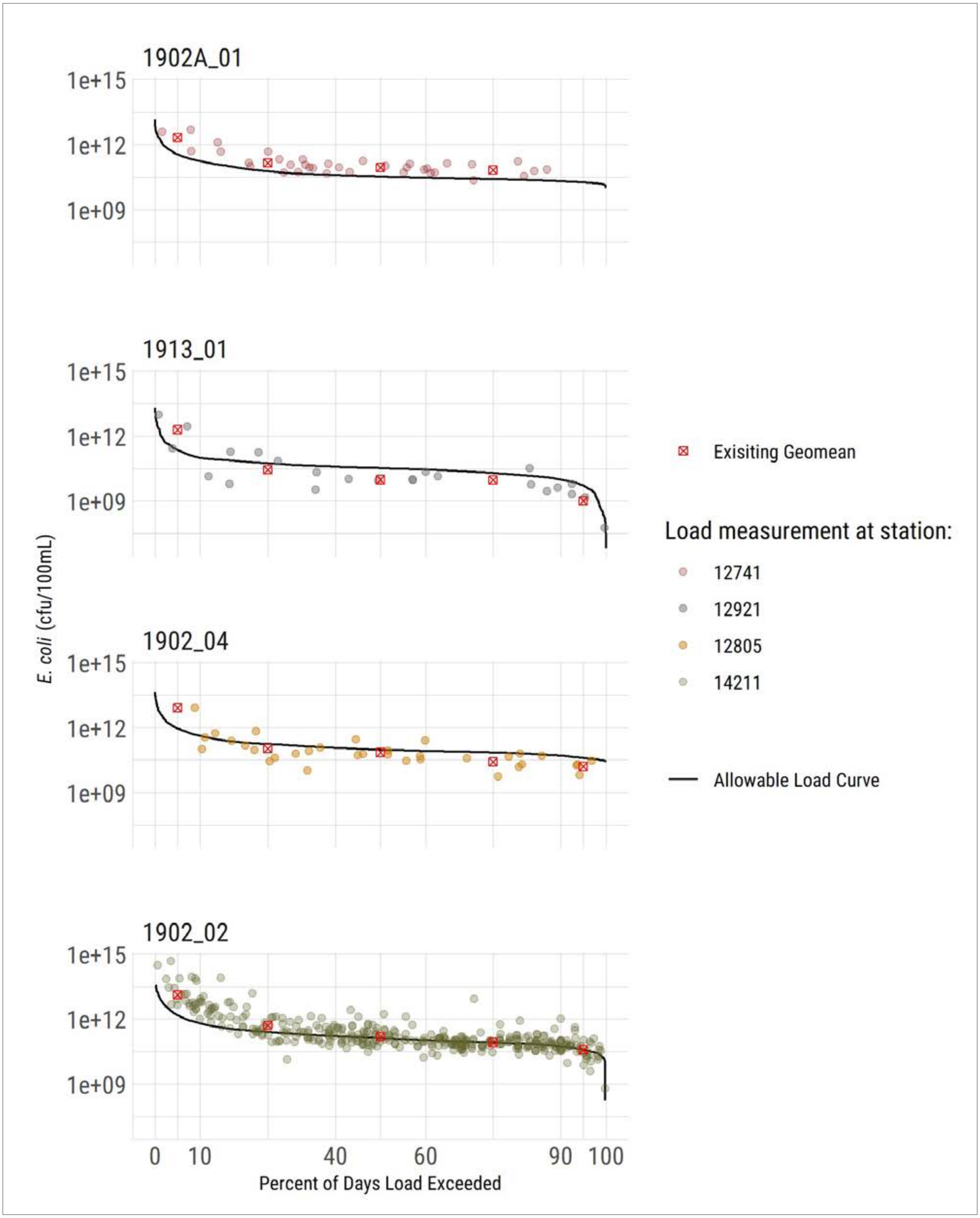


Figure 27. Load duration curves of bacteria load along Mid and Lower Cibolo Creek.

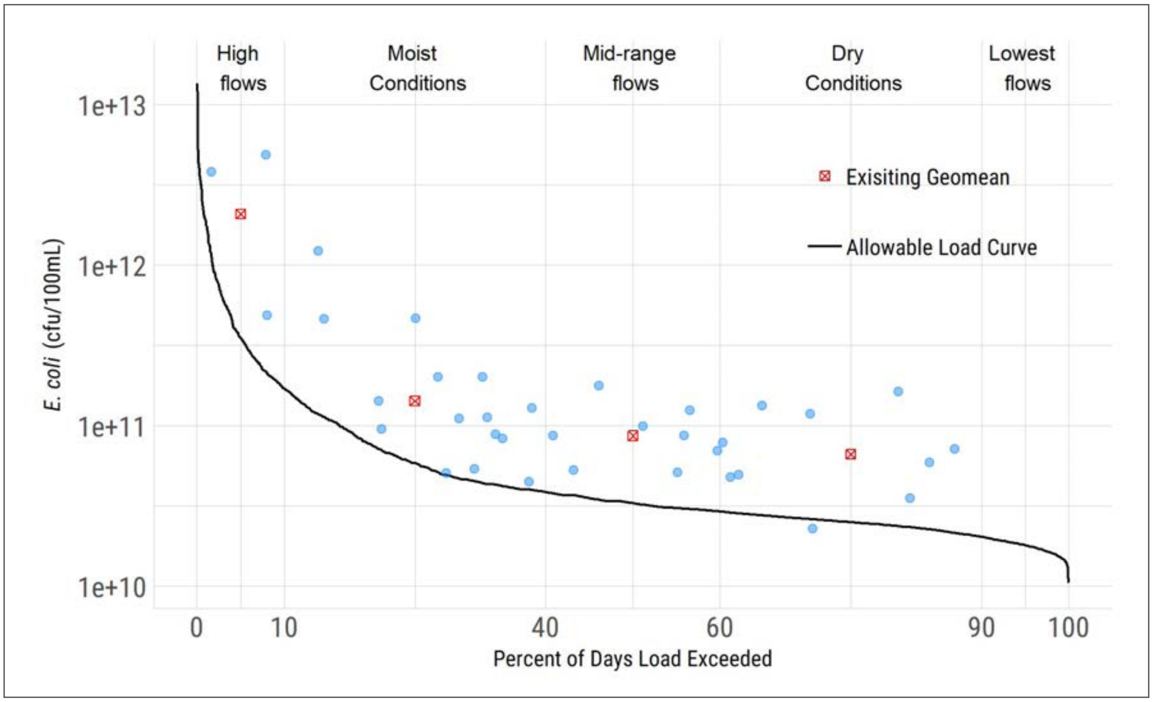


Figure 28. Load duration curve at 12471 (Martinez Creek).

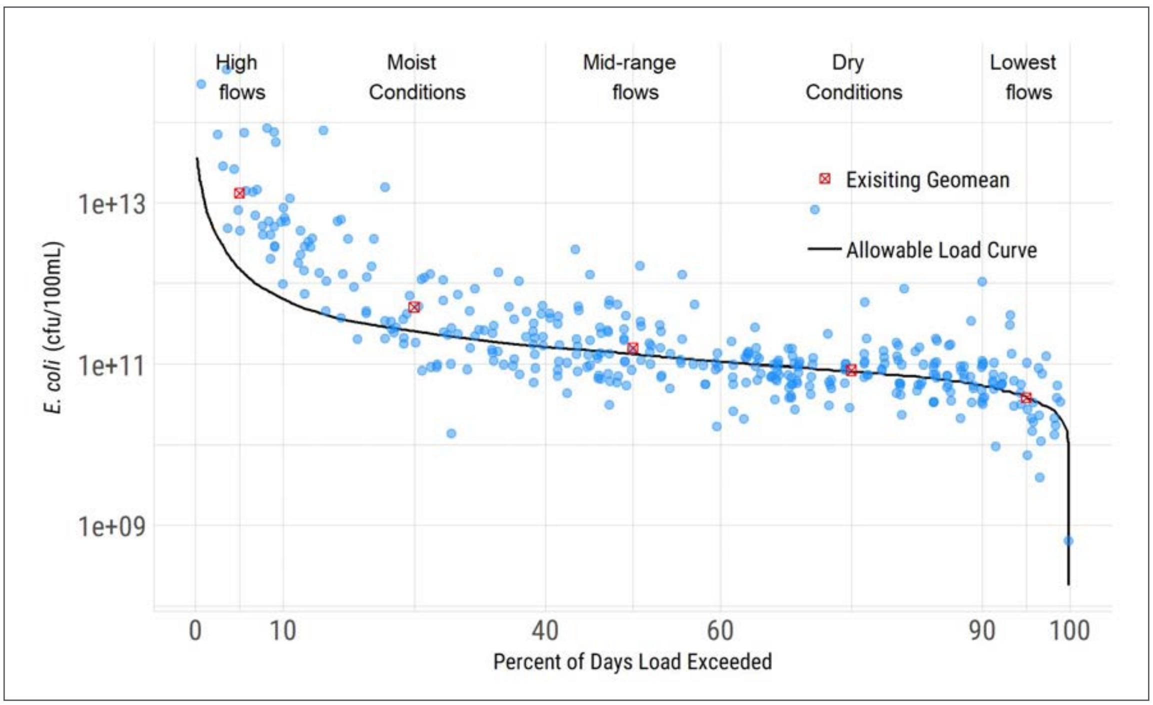


Figure 29. Load duration curve at Station 14211 (Lower Cibolo Creek near St. Hedwig).

Station 12741

Station 12741 is located in the downstream section of Martinez Creek. The LDC shows that nearly all of the *E. coli* loads are above the allowable load curve across all flow conditions indicating that potential sources for bacteria come from both point and nonpoint pollution (Figure 28).

Station 14211

Station 14211 is located in Lower Cibolo Creek near Falls City. It is the most downstream monitoring point in the watershed. The LDC indicates bacteria exceedances in four of the five flow conditions (Figure 29). In the remaining dry condition flow category, geometric mean bacteria loads are very near the allowable load curve. This indicates both point and nonpoint sources potentially contribute to bacteria loadings in the watershed.

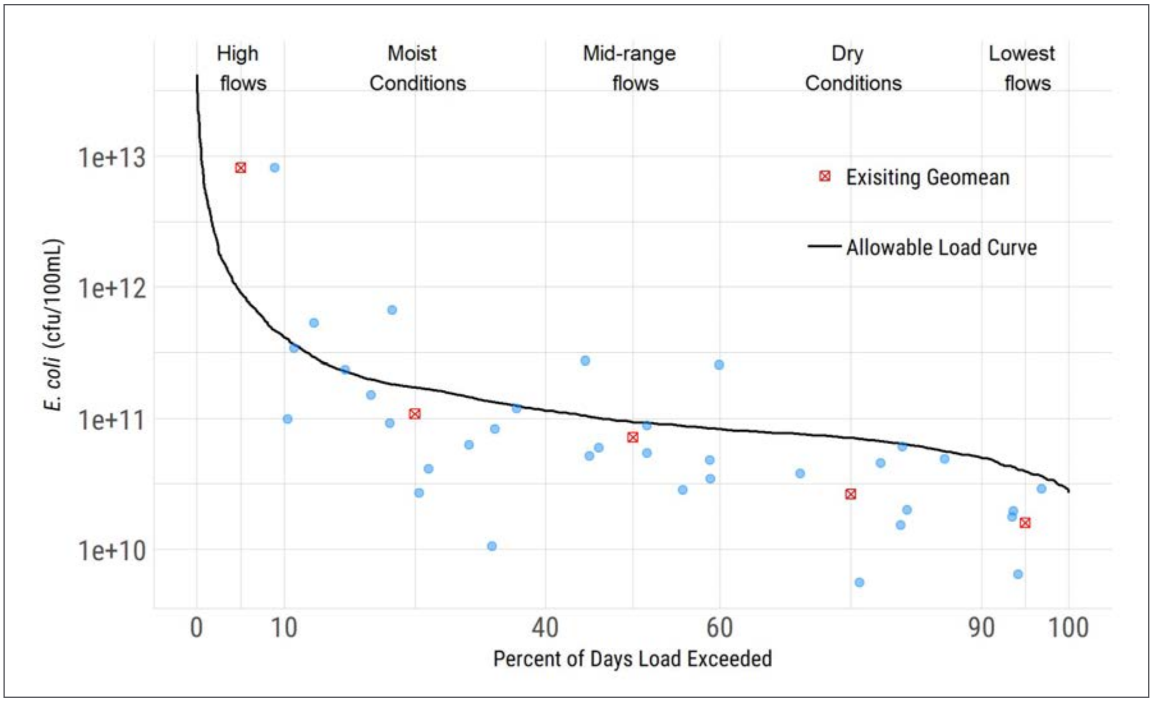


Figure 30. Load duration curve at Station 12805 (Lower Cibolo Creek at Sutherland Springs).

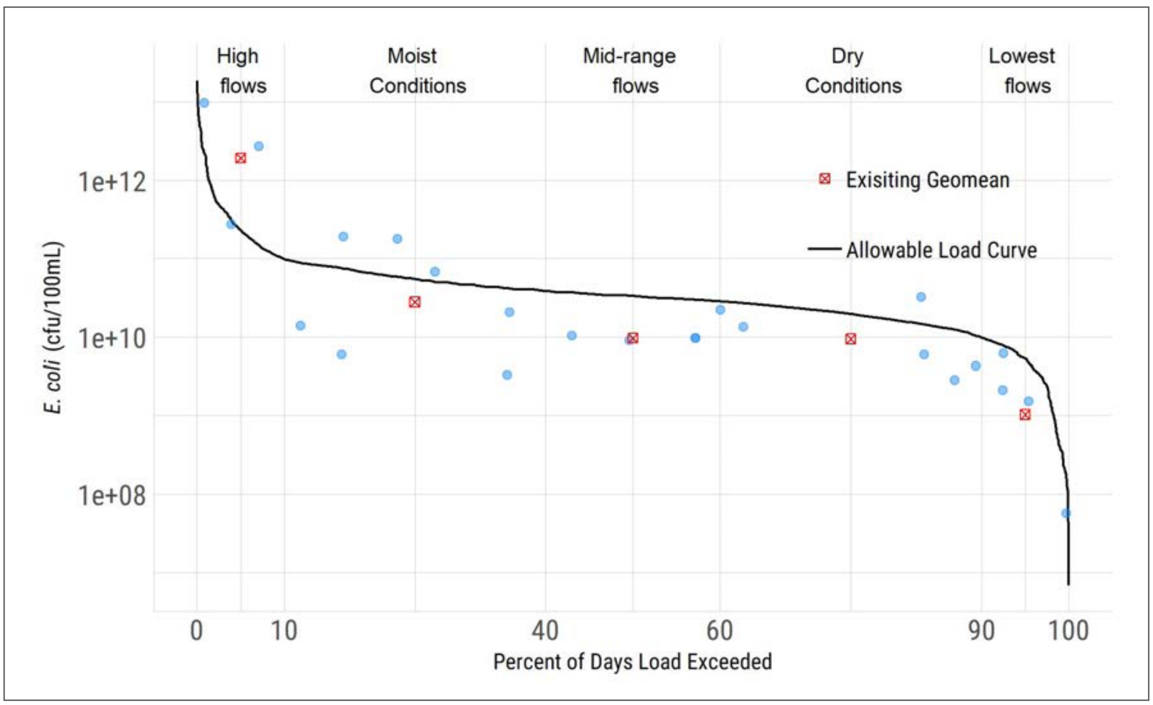


Figure 31. Load duration curve at Station 12921 (Lower Cibolo Creek at St Hedwig).

Station 12805

Station 12805 is in Lower Cibolo Creek at Sutherland Springs. Water quality data indicates that this AU meets water quality standards. The LDC shows that the majority of load measurements are below the allowable load, with occasional exceedances (Figure 30).

Station 12921

Station 12921 is located in the upper reach of Lower Cibolo Creek near St. Hedwig. This station is the most upstream station that LDCs were developed. The LDC suggests that *E. coli* exceedances primarily occur in high flow and moist conditions (Figure 31). This suggests that nonpoint sources and resuspension of *E. coli* from stream sediments are responsible for elevated levels.

Table 18. Estimated E.coli load reductions needed to meet primary contact water quality criteria in Lower Cibolo Creek (based on the 126 colony forming units (cfu) per 100 milliliters (mL) of water standard).

	Flow Conditions				
	High	Moist	Mid-Range	Dry	Low
Days per year	36.5	109.5	73	109.5	36.5
Median Flow (cubic feet per second)	230.4	65.3	39.8	25	12.9
Existing Geomean Concentration (MPN/100 mL)	1267.08	199.87	165.21	126.82	157.89
Allowable Daily Load (Billion MPN)	710.25	201.30	122.69	77.067	39.77
Allowable Annual Load (Billion MPN)	25,924.11	22,042.24	8,956.42	8,438.84	1,451.48
Existing Daily Load (Billion MPN)	6481.10	326.91	159.65	75.78	45.33
Existing Annual Load (Billion MPN)	236,592.67	35,796.27	11,654.23	8,298.10	1,654.64
Annual Load Reduction Needed (Billion MPN)	210,668.57	13,754.03	2,697.80	N/A	203.16
Percent Reduction Needed	89.04%	38.42%	23.14%	N/A	12.28%
Total Annual Load (Billion MPN)	293,995.90				
Total Annual Load Reduction (Billion MPN)	227,323.55				
Total Percent Reduction	77.32%				

Most probable number, MPN

Table 19. Estimated E.coli load reductions needed to meet primary contact water quality criteria in Martinez Creek (based on the 126 colony forming units (cfu) per 100 milliliters (mL) of water standard).

	Flow Conditions				
	High	Moist	Mid-Range	Dry	Low
Days per yr	36.5	109.5	73	109.5	36.5
Median Flow (cubic feet per second)	79.37	20	11.8	6.92	1.661
Existing Geomean Concentration (MPN/100 mL)	517.57	58.80	44.88	70.74	45.28
Allowable Daily Load (Billion MPN)	244.67	61.65	36.38	21.33	5.12
Allowable Annual Load (Billion MPN)	8,930.54	6,751.07	2,655.42	2,335.87	186.89
Existing Daily Load (Billion MPN)	1,106.86	30.29	13.14	11.29	1.03
Existing Annual Load (Billion MPN)	40,400.35	3,316.84	959.36	1,235.71	37.56
Annual Load Reduction Needed (Billion MPN)	31,469.81	N/A	N/A	N/A	N/A
Percent Reduction Needed	77.89%	N/A	N/A	N/A	N/A
Total Annual Load (Billion MPN)	45,949.83				
Total Annual Load Reduction (Billion MPN)	31,469.81				
Total Percent Reduction	68.49%				

Most probable number, MPN

Table 20. Subwatersheds used in Spatially Explicit Load Enrichment Calculation Tool (SELECT).

ID	Subwatershed	HUC12	Area (Acres)
1	Upper Santa Clara Creek	121003040203	28,712.81
2	Dietz Creek-Cibolo Creek	121003040202	28,329.43
3	Lower Santa Clara Creek	121003040204	11,651.41
4	Salitrillo Creek-Martinez Creek	121003040205	37,503.76
5	Martinez Creek-Cibolo Creek	121003040206	22,818.52
6	Elm Creek	121003040303	38,467.3
7	Headwaters Dry Hollow Creek	121003040301	10,721.86
8	Dry Hollow Creek-Cibolo Creek	121003040302	34,315.34
9	Gum Branch-Cibolo Creek	121003040304	31,301.98
10	Alum Creek	121003040305	17,757.15
11	Clifton Branch-Cibolo Creek	121003040401	25,204.68
12	Wallace Branch-Cibolo Creek	121003040302	15,085.46
13	Town of Denhawken-Dry Creek	121003040304	21,775.73
14	Pulashi Creek-Cibolo Creek	121003040303	17,898.78
15	Mulifest Creek-Cibolo Creek	121003040305	29,936.39

Annualized Reductions

Based on LDC analysis, two segments require bacteria load reductions to meet water quality standards. Using the LDCs for station 14211 and 12741 we calculated annual load reductions for Lower Cibolo and Martinez creeks respectively. Based on these estimates, a 77% reduction in fecal bacteria loads is needed in Lower Cibolo Creek (Table 18) and a 68% reduction is needed in Martinez Creek (Table 19) to meet water quality standards.

Spatial Analysis of Potential *E. coli* Loads (SELECT)

To aid in identifying potential areas of *E. coli* contributions within the watershed, a Geographic Information System (GIS) analysis was applied using the methodology employed by SELECT (Borel et al. 2012). The best available information, as well as stakeholder input were utilized to identify likely nonpoint sources of bacteria and to calculate potential loadings.

SELECT was developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University. SELECT estimates the potential *E. coli* loadings from various sources across the watershed. Geographical distributions and pollutant loads were estimated for selected sources within 15 subwatersheds (Table 20, Figures 32-39) based on known pollutant production rates. SELECT output allows us to identify subwatersheds with the largest potential to impact water quality for best management practice (BMP) implementation.

It is necessary to note that the loading estimates for each source are potential loading estimates and do not account for bacteria fate and transport processes that occur between the points where they originate and where they enter the water body, if at all. As such, these analyses represent worst-case scenarios that do not depict the actual *E. coli* loadings expected to enter the creek.

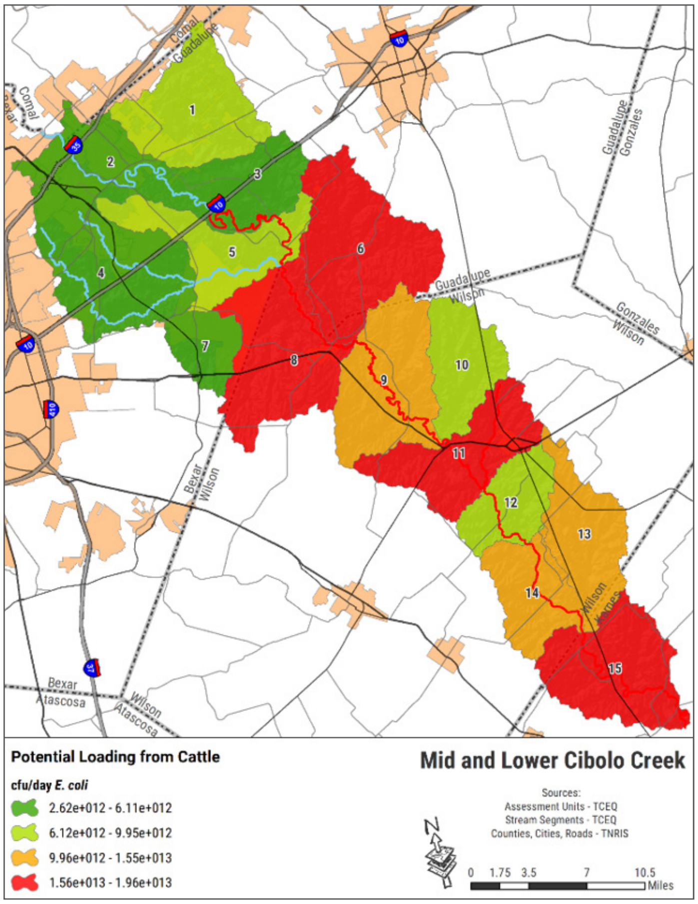


Figure 32. SELECT results for cattle.

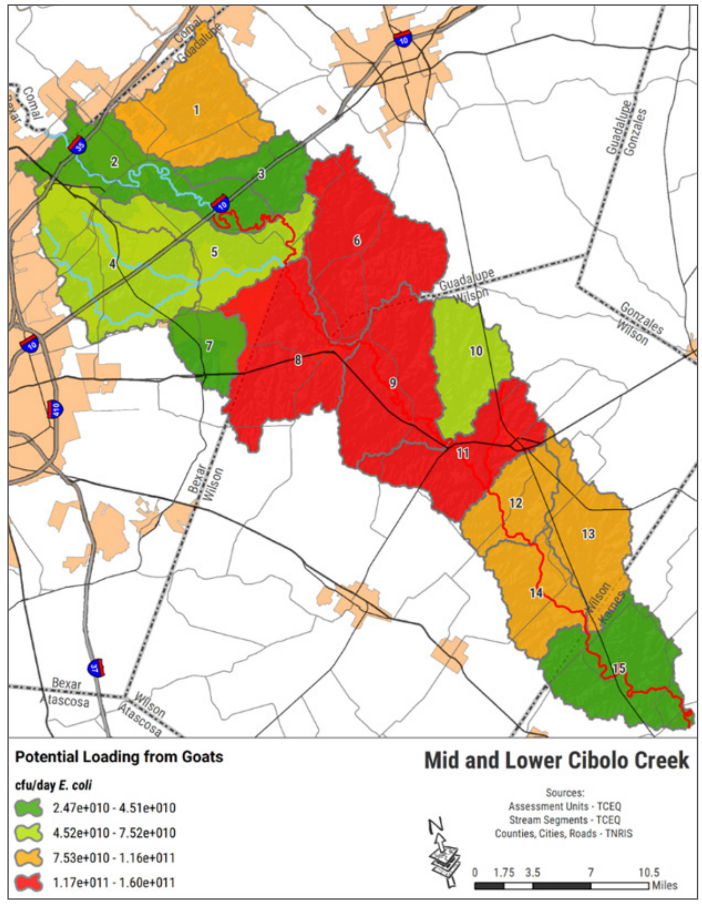


Figure 33a. SELECT results for goats.

Cattle

Cattle can contribute to *E. coli* bacteria loading in two ways. First, they can contribute through the direct deposition of fecal matter into streams while wading. Second, runoff from pasture and rangeland, which can contain elevated levels of *E. coli*, can increase bacteria loads in the stream if the runoff is not intercepted. Improved grazing practices and land stewardship can dramatically reduce bacteria loadings. For example, recent research in Texas watersheds indicate that rotational grazing and grazing livestock in upland pastures during wet seasons result in significant reductions in *E. coli* levels (Wagner et al. 2012). Furthermore, alternative water sources and shade structures located outside of riparian areas significantly reduce the amount of time cattle spend in and near streams, thus resulting in improved water quality (Wagner et al. 2013; Clary et al. 2016).

The commonly used stocking rates and the amount of grazed lands in the area were identified based on stakeholder input and the best available data. This plan estimated approximately 30,787 cattle animal units (AnUs) across the entire watershed. Appendix A describes the assumptions and equations used to estimate potential bacteria loading. The highest potential loadings are in subwatersheds 6, 8, 9, 11, 13 and 14 (Figure 32).

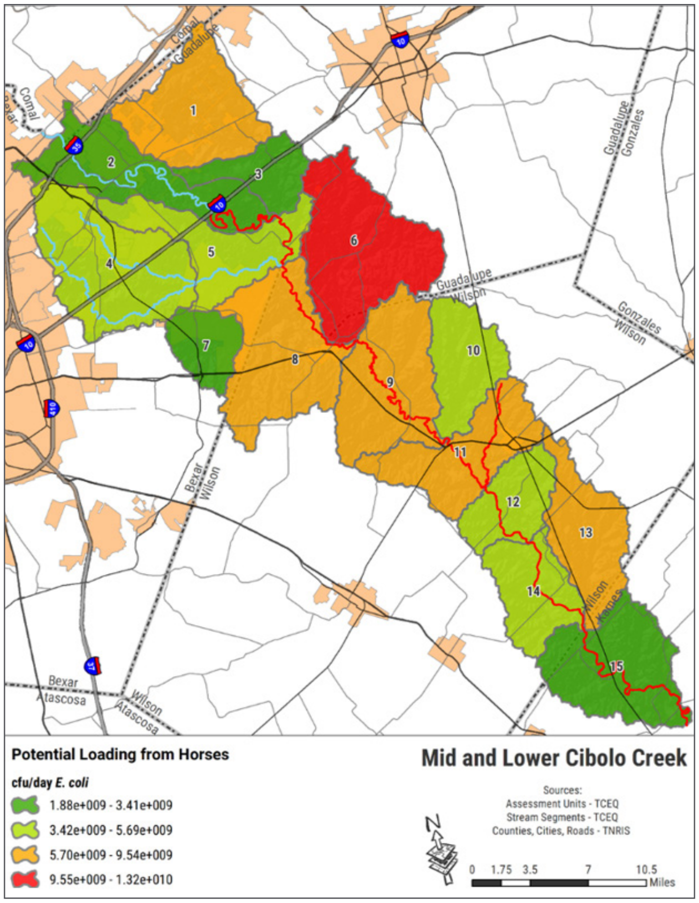


Figure 33b. SELECT results for horses.

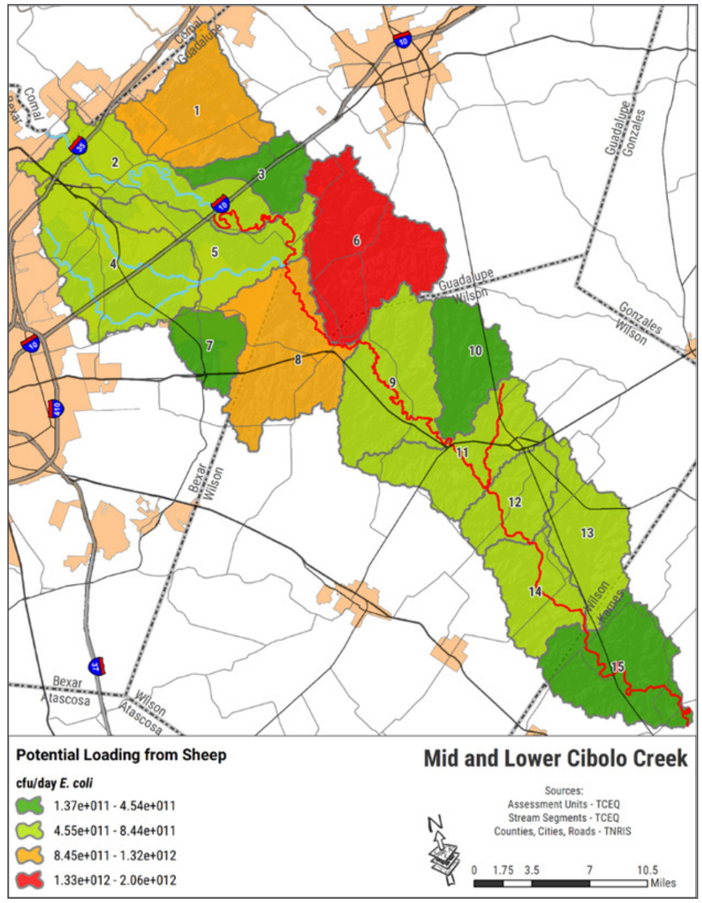


Figure 33c. SELECT results for sheep.

Other Livestock

Besides cattle, other livestock — goats, horses and sheep — can contribute to *E. coli* bacteria loading. Livestock estimates were derived from U.S. Department of Agriculture (USDA) Census of Agriculture (USDA 2012) population estimates for each county. The spatial distribution of relative *E. coli* loading potential for each type of livestock is the same as cattle due to the reliance on land use to distribute potential loads over the entire watershed. Therefore, SELECT prioritizes the same subwatersheds (6, 8, 9, 11, 13 and 14) for potential loads (Figure 33a, 33b and 33c).

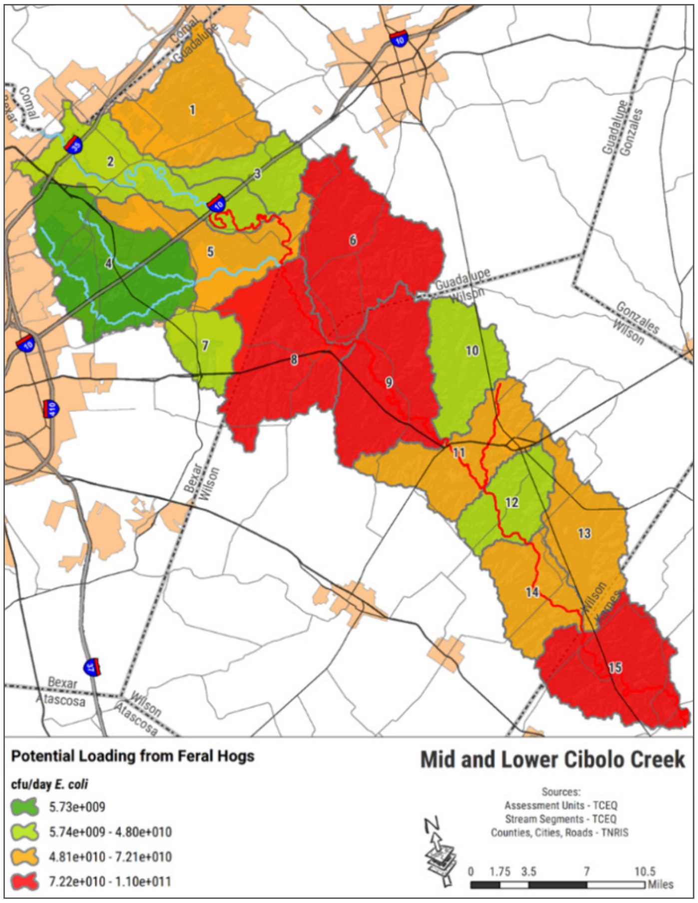


Figure 34. SELECT results for feral hogs.

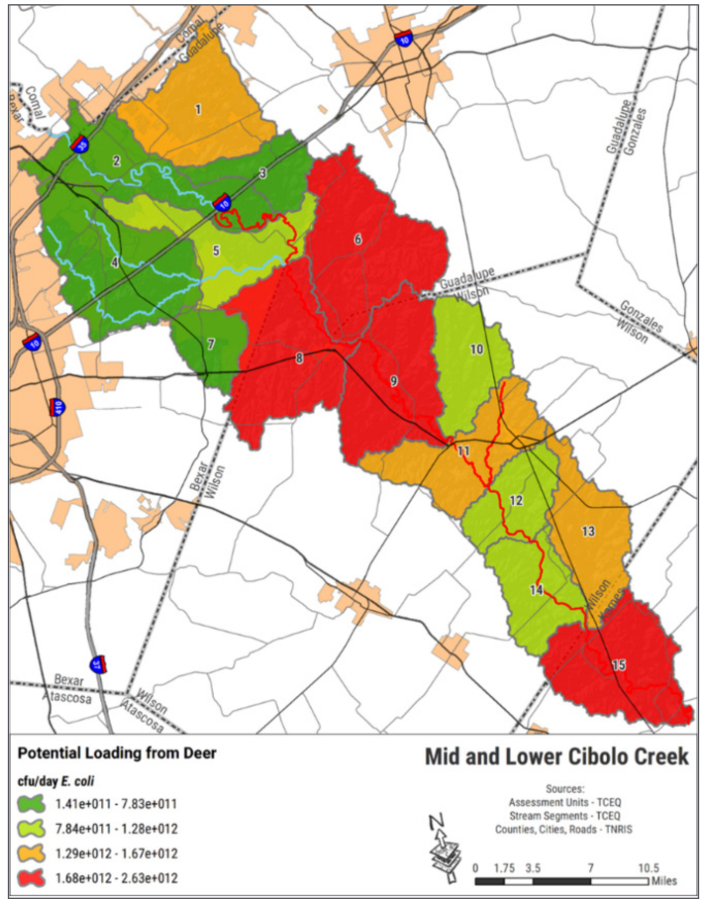


Figure 35. SELECT results for white-tailed deer.

Feral Hog

Current population estimates of feral hogs in Texas alone range from 1 to 3 million individuals (Mayer 2009; Mapston 2010). Feral hogs contribute to *E. coli* bacteria loadings through the direct deposition of fecal matter into streams while wading or wallowing in riparian areas. Riparian areas provide ideal habitats and migratory corridors for feral hogs as they search for food. While complete removal of feral hog populations is unlikely, habitat management and trapping programs can limit populations and associated damage.

The SELECT results indicate the highest potential daily loadings occur in subwatersheds 6, 8, 9 and 15 (Figure 34). Appendix A describes the equations and assumptions used to generate potential annual loads.

Deer

White-tailed deer are the primary wild deer species in the watershed (although game ranches may raise mule deer or exotics such as axis deer). The white-tailed deer is a warm-blooded mammal. Texas has more white-tailed deer than any other state. Population estimates in recent years range from 3 to 4 million. An estimated 430,000-500,000 whitetails are harvested by sportsmen in Texas annually. Deer contribute to *E. coli* bacteria loadings similarly to feral hogs. The highest potential daily *E. coli* loadings from deer occur in subwatersheds 6, 8, 9 and 15 (Figure 35).

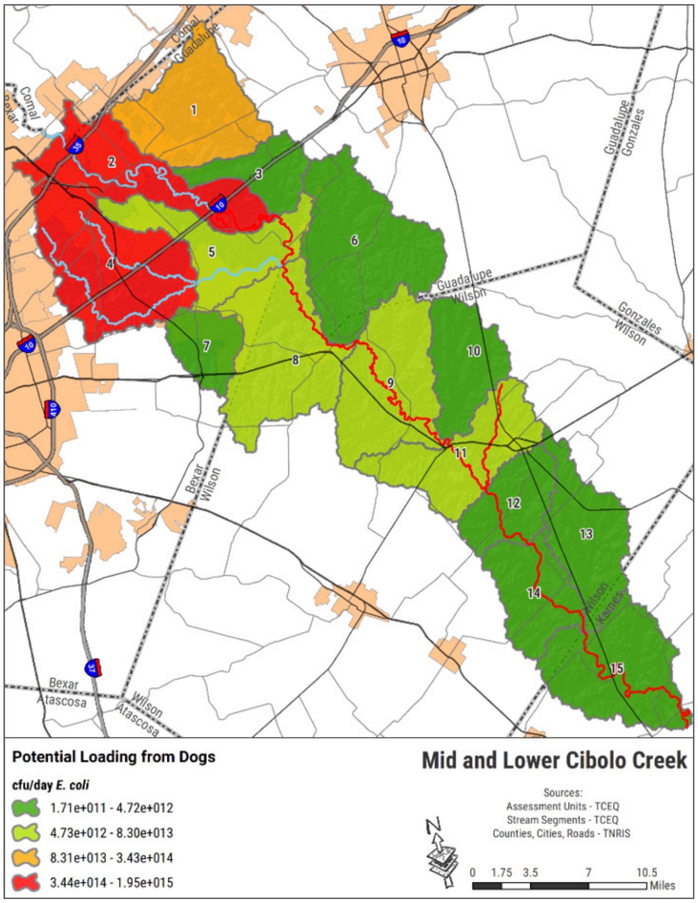


Figure 36. SELECT results for dogs.

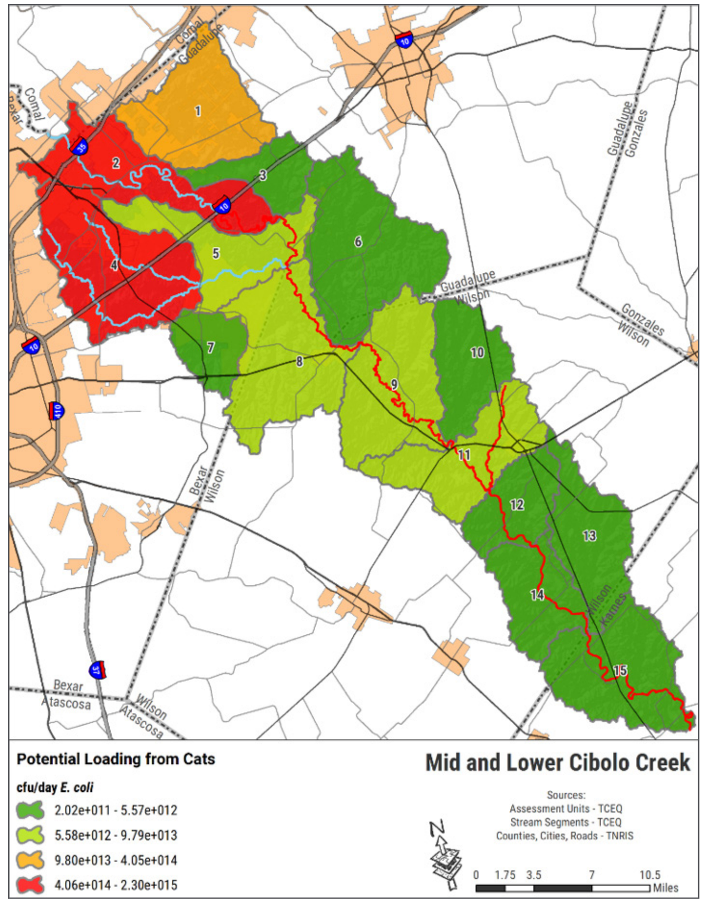


Figure 37. SELECT results for cats.

Domestic Pets

Pet dogs and cats contribute to bacteria loadings when pet waste is not disposed of properly and subsequently washes into nearby water bodies during rain and storm events. The highest potential loads from domestic pets are anticipated to occur in developed and urbanized areas. SELECT results for both dogs and cats indicate relatively high potential loadings occur in subwatersheds 1, 2 and 4 (Figures 36 and 37). Appendix A describes the equations and assumptions used to generate potential annual loads.

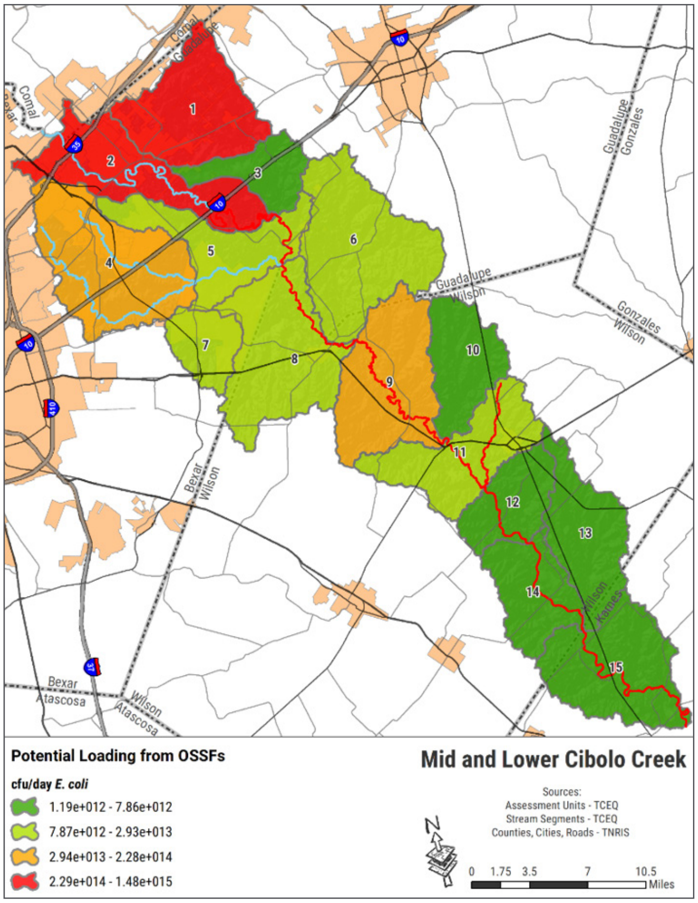


Figure 38. SELECT results for on-site sewage facilities (OSSFs).

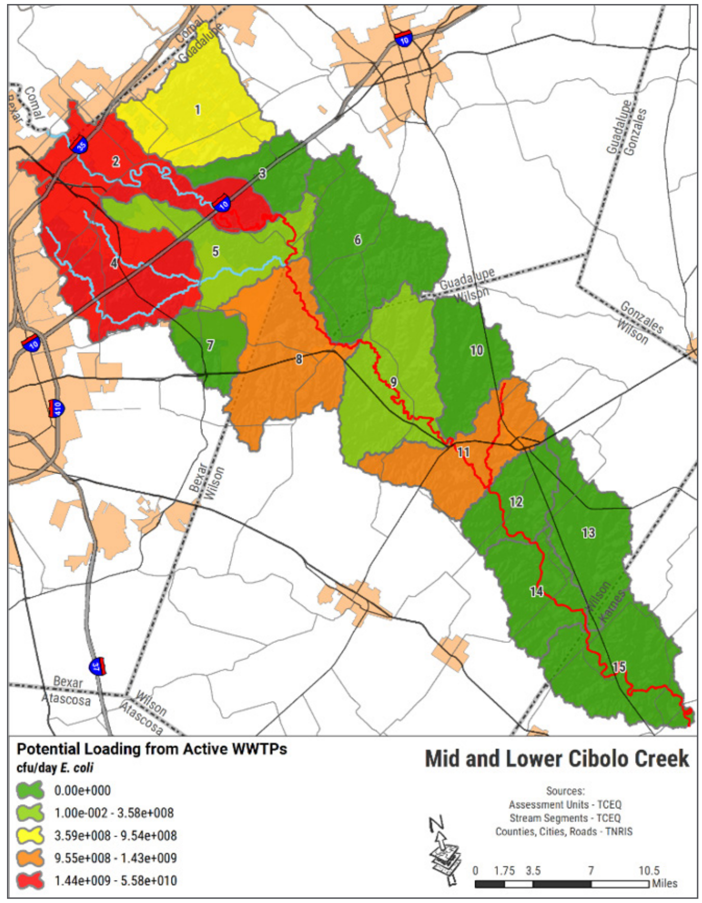


Figure 39. SELECT results for active permitted wastewater treatment plants (WWTPs).

OSSFs

Failing or unmaintained OSSFs can contribute bacteria loads to water bodies, in particular those where effluent is released near the water bodies. Within the Mid and Lower Cibolo Creek watershed, approximately 15% of OSSFs are assumed to fail during a given year. It was estimated that there are approximately 17,325 OSSFs within the watershed based on the most recently available 911 address data. Among them, 2,575 OSSFs are assumed to be failing. SELECT analysis indicates the highest potential loadings occur in subwatersheds 1, 2 and 9 (Figure 38). Appendix A describes the equations and assumptions used to generate potential annual loads.

WWTFs

Currently, there are ten active permitted wastewater dischargers in the watershed. These wastewater discharges are regulated by TCEQ and are required to report average monthly discharges and *E. coli* concentrations. Within the next several years, two WWTFs will go off-line (Woman Hollering Plant and Martinez III WWTP) and two new plants will be added (CCMA South WWTP and Martinez IV WWTP).

Although the permitted discharge volumes and bacteria concentrations are typically below permitted values, potential loading was calculated using the maximum permitted discharges and concentrations to assess the maximum potential load. Potential E.coli loading from WWTFs under current and future scenarios are highest in subwatersheds 2, 4, 8 and 11 (Figure 39 and 40).

Table 21. Spatially Explicit Load Enrichment Calculation Tool (SELECT) calculated total potential loads.

ID	Subwatersheds	Total Annual SELECT load Colony Forming Units/Year
1	Upper Santa Clara Creek	8.19×10^{17}
2	Dietz Creek-Cibolo Creek	1.31×10^{18}
3	Lower Santa Clara Creek	1.61×10^{18}
4	Salitrillo Creek-Martinez Creek	5.16×10^{15}
5	Martinez Creek-Cibolo Creek	5.02×10^{16}
6	Elm Creek	2.14×10^{16}
7	Headwaters Dry Hollow Creek	1.69×10^{16}
8	Dry Hollow Creek-Cibolo Creek	4.40×10^{16}
9	Gum Branch-Cibolo Creek	1.38×10^{17}
10	Alum Creek	4.31×10^{15}
11	Clifton Branch-Cibolo Creek	8.33×10^{16}
12	Wallace Branch-Cibolo Creek	5.90×10^{15}
13	Town of Denhawken-Dry Creek	7.12×10^{15}
14	Pulashi Creek-Cibolo Creek	6.32×10^{15}
15	Mulifest Creek-Cibolo Creek	1.20×10^{16}

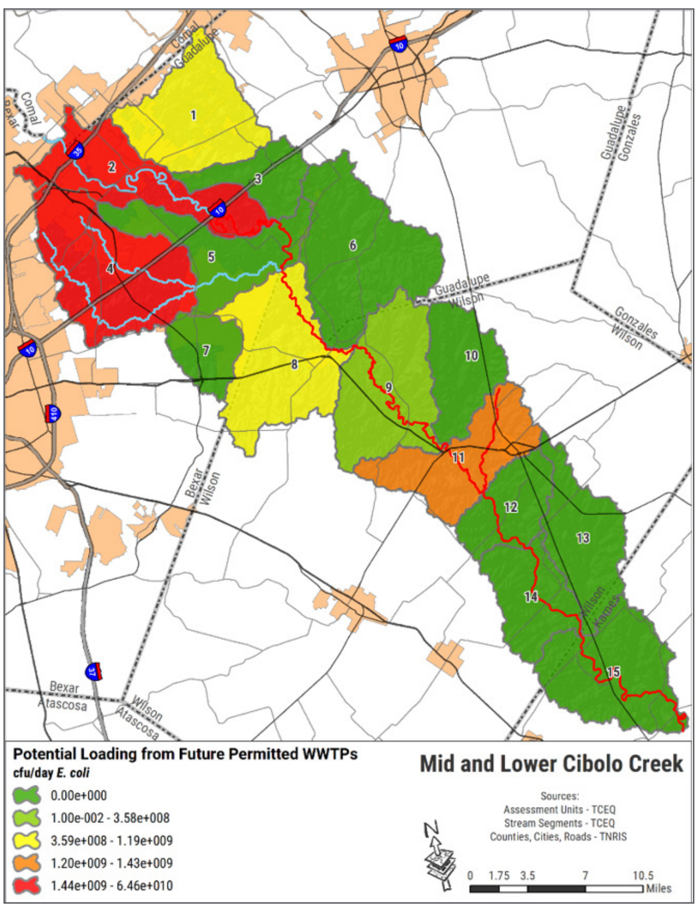


Figure 40. SELECT results for future permitted wastewater treatment plants (WWTPs).

Total Potential E. coli *Load*

Figure 41 and Table 21 show total estimated potential *E. coli* loadings across the watershed based on the combined total potential loadings from sources used in SELECT. Here we see that the highest potential loadings exist in subwatersheds 1, 2, 3, 9 and 11.

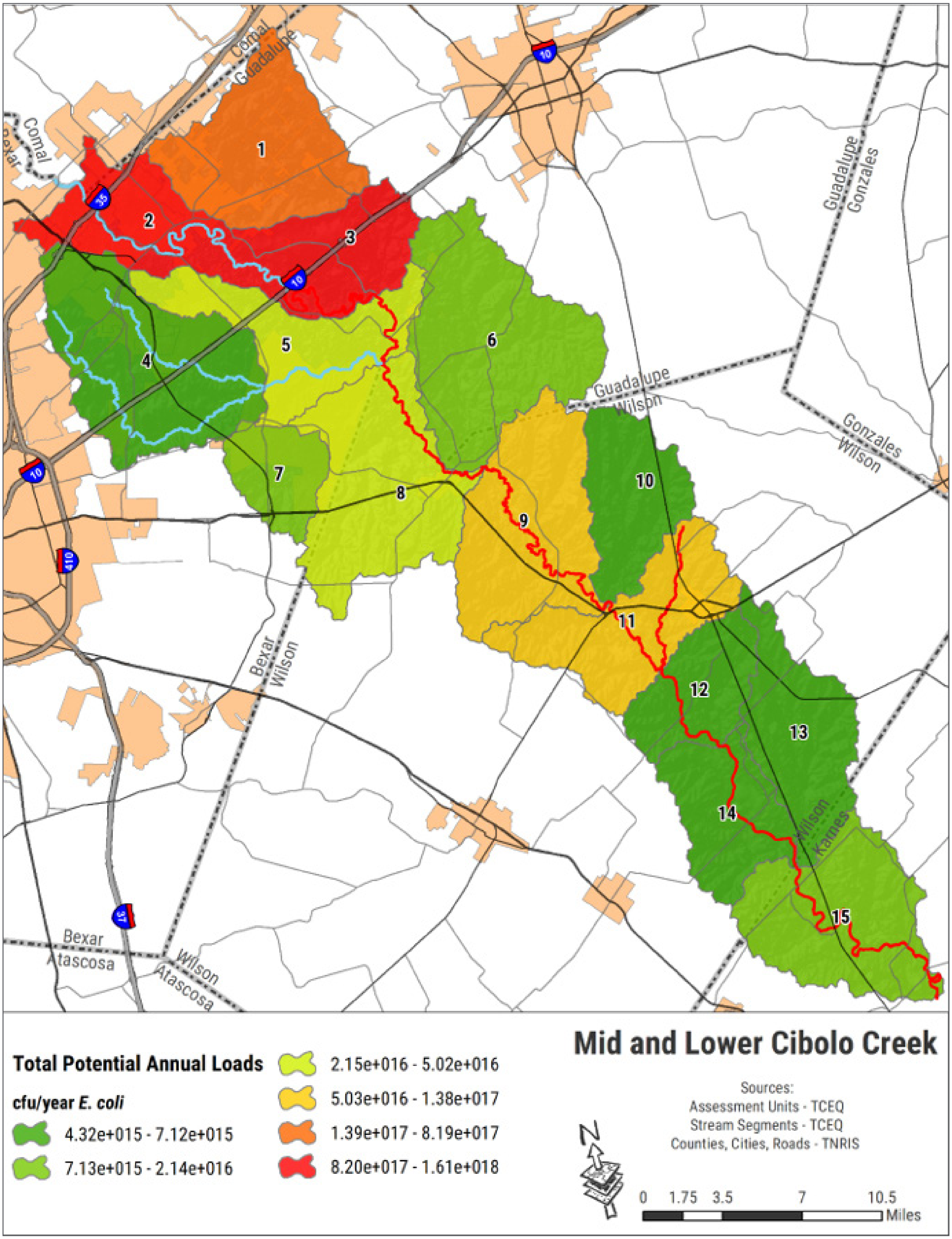


Figure 41. Combined SELECT results.

Chapter 6
Strategies for Watershed Protection Plan Implementation

Introduction

Chapter 4 and 5 illustrate the diverse sources of bacteria and nutrient loading to Mid and Lower Cibolo Creek. No single source of *E. coli* in the watershed is the primary cause of current levels in the watershed. According to SELECT modeling, cattle, pets, deer and OSSFs have the highest potential to contribute *E. coli* to the Creek and its tributaries; however, all potential sources in the watershed contribute at some level. Due to the diverse potential sources, a range of management strategies are recommended to address all potential sources of *E. coli* in the watershed. Recommended management strategies were developed based on stakeholder feedback and management recommendation effectiveness in reducing bacteria loading.

Estimated potential load reductions from each management measure are presented with each recommended action discussed in this chapter. Each loading estimate presented is based on a predicted worst-case scenario loading. As a result, these estimates do not accurately predict real loadings that are occurring or expected load reductions that may be realized in-stream. Actual reductions are dependent on several factors that may trigger the need for adaptive implementation (AI). Potential annual load reductions from management measures are discussed through this chapter and indicate that reducing bacteria loads entering the Mid and Lower Cibolo Creek to levels that support primary contact recreation use is feasible.

Priority implementation areas for each recommended management strategy were identified based on spatial analysis and stakeholder feedback. While management measures can be implemented throughout the watershed, priority locations were selected based on areas where management strategies could be most effective in removing or reducing potential loading.

Stakeholder input was crucial throughout the decision-making process for these suggested management strategies.

Table 22. Available pasture and rangeland practices to improve water quality.

Practice	NRCS Code	Focus Area or Benefit
Brush Management	314	Livestock, water quality, water quantity, wildlife
Fencing	382	Livestock, water quality
Filter Strips	393	Livestock, water quality, wildlife
Grade Stabilization Structures	410	Water quality
Grazing Land Mechanical Treatment	548	Livestock, water quality, wildlife
Heavy Use Area Protection	562	Livestock, water quantity, water quality
Pond	378	Livestock, water quantity, water quality, wildlife
Prescribed Burning	338	Livestock, water quality, wildlife
Prescribed Grazing	528	Livestock, water quality, wildlife
Range/Pasture planting	550/512	Livestock, water quality, wildlife
Shade structure	N/A	Livestock, water quality, wildlife
Stream crossing	578	Livestock, water quality
Supplemental feed location	N/A	Livestock, water quality
Water well	642	Livestock, water quantity, wildlife
Watering facility	614	Livestock, water quantity

Natural Resources Conservation Service, NRCS

Management measures suggested in this chapter are voluntary and will rely on stakeholder adoption for successful implementation. Therefore, receiving stakeholder input on willingness to adopt these practices is important throughout this process. All management measures were discussed with and approved by stakeholders to ensure community support and successful implementation.

Management Measure 1 – Developing and Implementing Water Quality Management Plans or Conservation Plans

Potential bacteria loadings in the Mid and Lower Cibolo Creek watershed from cattle and other livestock are relatively high compared to other evaluated sources. Livestock waste is mostly deposited in upland areas and transported to water bodies during runoff events. Therefore, much of the *E. coli* bacteria in livestock waste dies before reaching a water body. However, livestock may spend significant amounts of time in and around water bodies, thus resulting in more direct impacts on water quality.

Livestock distribution is highly dependent upon availability and distribution of water, food and shelter. This allows livestock to be managed easily compared to non-domesticated species. The time livestock spend in and around riparian areas can be reduced by providing supplemental water, feed, shade and forage around a property. As a result, it can effectively reduce the potential of *E. coli* concentrations from runoff entering nearby water bodies.

A variety of BMPs are available to achieve goals of improving forage quality, diversifying water resource locations and better distributing livestock across a property. Practices commonly implemented to effectively improve forage and water quality are listed in Table 22. However, the actual appropriate practices will vary by operation and should be determined through technical assistance from NRCS, TSSWCB, and local soil and water conservation districts (SWCDs) as appropriate. Currently, seven conservation plans have been developed and implemented across the watershed. Through implementation of this watershed plan we hope to increase the adoption of Conservation Plans (CPs) and Water Quality Management Plans (WQMPs) to 40 total plans over the next 10 years. Load reductions achieved from this measure will vary depending on where and what conservation measures are implemented in various plans. Establishing additional acreage under management practices and additional conservation plans in this watershed is the primary goal of this management measure.

The implementation of CPs and WQMPs is beneficial, regardless of location in the watershed. Although those management measures mainly address and calculate bacteria sources from cattle, the use of CPs and WQMPs can reduce fecal loading from all types of livestock. Research has proven that recommended management measures also reduce nutrient and sediment loading from properties where they are implemented. The overall effectiveness of CPs and WQMPs can be greater on properties with riparian habitat. Therefore, all properties with riparian areas are considered a priority. Meanwhile, properties without riparian habitat are also encouraged to participate in implementation activities. Priority areas will include subwatersheds 6, 8, 9, 10, 11, 12, 13 and 14. Table 23 summarizes management recommendations for cattle and other livestock in the watershed.

Management Measure 2 – Promote Technical and Direct Operational Assistance to Landowners for Feral Hog Control

Potential *E. coli* loading from feral hogs across the watershed represents a considerable potential influence on instream water quality. Feral hogs prefer to shelter in riparian areas due to habitat, food, and water availability. This preference results in more time spent near waterbodies and potentially produces a disproportionate influence on water quality due to the proximity of their fecal deposition to the stream. Common feral hog behavior, such as rooting and wallowing also affect water quality by degrading ground cover, increasing soil/sediment disturbances and decreasing bank stability. Through a combination of agency technical assistance, education and landowner implementation of feral hog management techniques, the goal of this management measure is to reduce and maintain feral hog populations 15% below current populations (Table 24).

Removing hogs physically is the best strategy for reducing their impact on water quality. While the complete eradication of feral hogs from the watershed is not feasible, a variety of methods are available to manage or reduce populations. In the watershed, trapping animals is the most effective method available to landowners. With proper planning and diligence, trapping can successfully remove large numbers of hogs at once. Furthermore, costs of purchasing or building live traps can also be split amongst landowners. Shooting removes comparatively fewer hogs before they begin to move to other parts of the watershed.

Excluding feral hogs from supplemental feed is also an effective management tool. Given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. The construction of exclusion fences around feeder can help reduce the ability of feral hogs to access the food sources (Rattan et al. 2010). Additionally, locating feeders away from riparian areas is another important strategy for minimizing feral hog impacts on water quality.

Education programs and workshops will be used to improve feral hog removal effectiveness. Currently, AgriLife Extension provides a variety of educational resources for landowners: http://feralhogs.tamu.edu. SARA has also hosted feral hog management workshops to landowners in Bexar, Wilson and Karnes counties. Delivering up-to-date information and resources to landowners through workshops and demonstra-tions is critical to maximizing landowner success in remov-ing feral hogs. Meanwhile, developing wildlife management plans designed by landowners to establish goals of land-owners and describe the activities and practices will benefit wildlife, habitat and water quality as well.

Based on spatial analysis, the highest potentials for loadings from feral hogs are in subwatersheds 3, 6, 8, 9 and 15. However, given feral hogs' propensity to travel great distances along riparian corridors in search of suitable food and habitat, priority areas will include all subwatersheds with high importance placed on properties with riparian habitat.

Management Measure 3 – Identify and Repair or Replace Failing On-Site Sewage Systems

OSSFs are used to treat wastewater in areas of the watershed where centralized wastewater treatment facilities are not available. Conventional systems use a septic tank and gravity-fed drain field that separates solids from wastewater prior to distribution of the water into soil where actual treatment takes place. In the Mid and Lower Cibolo Creek watershed, approximately 92.2% of the watershed's soils are considered very limited and 7.5% are somewhat limited. This indicates that conventional septic tank systems are not suitable for the proper treatment of household wastewater.

In these areas, advanced treatment systems, most commonly aerobic treatment units, are suitable alternative options for wastewater treatment. While advanced treatment systems are highly effective, the operation and maintenance needs for these systems are rigorous compared to conventional septic systems. Limited awareness and lack of maintenance can lead to system failures.

Failing or non-existent OSSFs can provide significant bacteria and nutrient loading into the watershed. The exact number of failing systems is unknown, however, it is estimated as many as 2,599 systems may be malfunctioning across the watershed. A number of reasons contribute to OSSF failure, including improper system design or selection, improper maintenance and lack of education and financial resources.

To address these needs, efforts are required to focus on expanding and providing education and workshops to homeowners (Table 25). Additionally, maintenance providers, installers and inspectors should be secured to assist homeowners to repair or replace OSSF systems if issues arise. While OSSFs should be replaced as needed across the entire watershed, priority will be placed on subwatersheds 1, 2, 3, 6, 7, 8, 9 and 11. Additionally, priority will be placed on OSSFs within 150 yds of perennial water bodies.

Table 23. Management measure 1: Cattle and other livestock.

<table>
<tr><th colspan="4">Source: Cattle and Other Livestock</th></tr>
<tr><td colspan="4">Problem: Direct and indirect fecal bacteria loading due to livestock in streams, riparian degradation and overgrazing</td></tr>
<tr><td colspan="4">Objectives:
• Work with landowners to develop property-specific CPs and WQMPs that improve grazing practices and water quality.
• Provide technical and financial support to producers.
• Reduce fecal loadings attributed to livestock.</td></tr>
<tr><td colspan="4">Location: Priority subwatersheds identified below</td></tr>
<tr><td colspan="4">Critical Areas: All properties with riparian habitat throughout the watershed and all properties in subwatersheds 6, 8, 9, 10, 11, 12, 13 and 14</td></tr>
<tr><td colspan="4">Goal: Develop and implement CPs and WQMPs that minimize time spent by livestock in riparian areas and better utilize available grazing resource across the property.</td></tr>
<tr><td colspan="4">Description: CPs and WQMPs will be developed with producers to implement BMPs that reduce water quality impacts from overgrazing, time spent by livestock in and near streams and runoff from grazed lands. Practices will be identified and developed in consultation with NRCS, TSSWCB and local SWCDs as appropriate. Education programs and workshops will support and promote the adoption of these practices.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>TSSWCB, SWCDs</td><td>Develop funding to hire WQMP technician</td><td>2019–2029</td><td>Estimated $75,000 per year</td></tr>
<tr><td>Producers, NRCS, TSSWCB, SWCDs</td><td>Develop, implement and provide financial assistance for 40 livestock CPs and WQMPs over 10 years</td><td>2019–2029</td><td>$600,000 (est. $15,000 per plan)</td></tr>
<tr><td>AgriLife Extension, TWRI</td><td>Deliver education and outreach programs and workshops to landowners</td><td>2019, 2023, 2027</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Prescribed management will reduce loadings associated with livestock by reducing runoff from pastures and rangeland as well as reducing direct deposition by livestock. Implementation of 40 WQMPs and CPs is estimated to reduce annual loads from livestock by 2.21×10^{14} cfu E. coli per year in the Mid and Lower Cibolo Creek watershed. Up to 983 pounds of nitrogen and 511 pounds of phosphorus per plan per year reduction is feasible.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">High: Decreasing the time that livestock spend in riparian areas and reducing runoff through effectively managing vegetative cover will directly reduce NPS contributions of bacteria and other pollutants to creeks.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Landowners acknowledge the importance of good land stewardship practices and management plan objectives; however, financial incentives are often needed to promote the WQMP and CP implementation.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Landowners are willing to implement stewardship practices shown to improve productivity; however, costs are often prohibitive and financial incentives are needed to increase implementation rates.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial costs are a major barrier to promote implementation. Education and outreach are needed to demonstrate benefits of plan development and implementation to producers.</td></tr>
</table>

Conservation plan, CP; water quality management plan, WQMP; best management practices, BMPs; Natural Resources Conservation Service, NRCS; Texas State Soil and Water Conservation Board, TSSWCB; Soil and Water Conservation Districts, SWCDs; Texas Water Resources Institute, TWRI; colony forming unit, cfu; nonpoint source, NPS

Table 24. Management measure 2: Feral hogs.

Source: Feral Hogs			
Problem: Direct and indirect pollutant loading and riparian habitat destruction from feral hogs			
Objectives: • Reduce fecal contamination from feral hogs. • Work with landowners to reduce feral hog populations. • Reduce food availability for feral hogs. • Provide education and outreach to stakeholders.			
Critical Areas: All subwatersheds with high importance placed on riparian properties.			
Goal: Manage the feral hog population through all available means in efforts to reduce the feral hog population by 15% (1,587 hogs) in the watershed and maintain them at this level.			
Description: Voluntary implementation of feral hog population management practices including trapping, reducing food supplies and educating landowners.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Landowners, managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog utilization	2019–2029	$200 per feeder
	Voluntarily trap/remove/shoot feral hogs to reduce numbers	2019–2029	N/A
Landowners, producers, TPWD	Develop and implement wildlife management plans and wildlife management practices	2019–2029	N/A
AgriLife Extension, Texas Wildlife Services, TPWD	Deliver Feral Hog Education Workshop	2020, 2023, 2026	$3,000 each
Estimated Load Reduction			
Removing and maintaining feral hog populations directly reduces fecal loading potential to water bodies, as well as nutrient and sediment loading in the watershed. Reducing the population by 15% in the Mid and Lower Cibolo Creek watershed is estimated to reduce potential annual loads by 5.52×10^{13} cfu *E. coli* annually. .			
Effectiveness:	Moderate: Reduction in feral hog population will result in a direct decrease in bacteria and nutrient loading to the streams. However, removing enough feral hogs to decrease the population is difficult.		
Certainty	Low: Feral hogs are transient, intelligent and adapt to changes in environmental conditions. Population reductions require diligence on the part of landowners. Combined, this causes considerable uncertainty in the ability to remove 15% of the population annually.		
Commitment	Moderate: Many landowners are actively battling feral hog populations and will continue to do so as long as resources remain available. Hogs adversely affect their livelihood.		
Needs	Moderate: Landowners benefit from technical and educational resources to inform them about feral hog management options. Funds are needed to deliver these workshops.		

Texas Parks and Wildlife Department, TPWD; colony forming unit, cfu

Management Measure 4 – Increase Proper Pet Waste Management

Potential pollutant loading from pet waste was identified as one of the largest potential sources of bacteria in the watershed. If not managed properly, pet waste and the *E. coli* it contains are readily transported to local water bodies during runoff events. Properly disposing of pet waste into a trash can is a simple and effective way of reducing *E. coli* loads in the watershed.

Management strategies emphasize reducing the amount of pet waste that can be transferred to streams via overland transport (Table 26). Examples of potential strategies include providing waste bag dispensers and collection stations in areas of higher pet density (parks, neighborhoods). These strategies encourage pet owners to pick up waste before it can be transported to streams. Many public parks in the Mid Cibolo watershed already have pet waste stations available. Apartment complexes and homeowners associations were identified as potential areas to install new stations.

Low cost spay and neuter programs can also help decrease populations of feral cats and dogs and therefore help reduce potential bacteria loading in the creek. Several animal rescues around the watershed offer these programs for pet owners and strays. Work to strengthen these programs and advertise their availability around the watershed are key to reducing populations of stray cats and dogs.

Finally, providing education and outreach materials to pet owners about bacteria and nutrient pollution and pet waste can increase the number of residents who pick up and dispose of pet waste. Recognizing that domestic pets in rural portions of the watershed likely have large areas to roam and that picking up pet waste is likely not feasible for all owners, management measures should target areas of the watershed with high housing and pet densities. The priority areas for this management measure are urbanized and public areas located in subwatersheds 1, 2, 3, 9 and 11.

Management Measure 5 – Implement and Expand Urban and Impervious Surface Stormwater Runoff Management

Stormwater generated from urban and impervious surface is a potentially large source of E.coli entering water bodies, especially in the Mid Cibolo Creek watershed, which is rapidly developing and has a high percentage of impervious cover (Figure 22). Stormwater management is common in the urban cities within the Mid Cibolo Creek watershed, such as the City of San Antonio. Nine entities currently hold MS4 permits. Those permits require development of stormwater management plans to reduce detrimental effects of stormwater on instream water quality.

The objective of this management measure is to work with local municipalities to identify and install demonstration BMPs that manage stormwater runoff as appropriate and as funding permits (Table 27). Urban stormwater BMPs reduce or delay runoff generated by impervious or highly compacted surfaces such as roofs, roads and parking lots. Potential BMPs include, but are not limited to, rain gardens, rain barrels/cisterns, green roofs; permeable pavement, bioretention, swales and tree box filters. These BMPs vary in performance in reducing stormwater runoff quantity and directly or indirectly improve runoff quality based on design and location. Furthermore, volume reductions from BMPs can reduce stormwater entering local sewage collection systems through inflow and infiltration. Well-placed and well-designed stormwater BMPs can substantially decrease and delay runoff as well as bacteria and nutrient loading.

Several projects are being proposed in the City of Cibolo Capital Improvement Plan to reduce stormwater runoff and to improve riparian and stream ecosystems. The Tolle Nature Park is a 60-ac park centered on Town Creek, a tributary to Cibolo Creek that will include constructed wetlands and integrated stormwater BMPs. In addition, there is a proposed Cibolo Valley Ranch Detention pond retrofit which will restore an existing six-acre pond by creating wetlands and a future park. Stream restoration projects as well as construction of a greenway are proposed within the City of Cibolo and inside the Mid and Lower Cibolo Creek watershed to stabilize eroding banks, create a stable bankfull channel and improve aquatic habitat.

The second objective is to deliver education programs in the watershed that educate residents about the impacts of stormwater on riparian areas and water quality. This can include demonstration sites of possible green stormwater infrastructure projects, training for city officials, flyers and other outreach materials.

SARA has funded the Watershed Wise Rebate for the last five years. This program provides funds to design and build permanent stormwater treatment for projects. The budget for this program exceeds $2,000,000 and has provided funds for 26 projects and 15 schools. This program has prompted local developers, engineers, landscape architects and contractors to learn how to design and build low impact development BMPs and increased awareness of stormwater runoff.

Management Measure 6 – Manage SSOs and Unauthorized Discharges

AAlthough infrequent, SSOs and unauthorized WWTF discharges can contribute to bacteria loads, particularly during high runoff events. Inflow is surface runoff that enters the sewer collection system through manhole covers, sewer cleanouts, damaged pipes and faulty connections. Infiltration is groundwater that enters the collection system through compromised infrastructure. As runoff enters the sewer collection system, there is increased potential for overloading the collection system or even the WWTF, resulting in an unauthorized discharge. Furthermore, Inflow and Infiltration (I&I) can have a diluting effect that sometimes decreases treatment efficiency and can increase utility pumping and treatment costs.

The TCEQ SSO Initiative is a voluntary program that initiates an effort to address an increase in SSOs due to aging collection systems throughout the state and encourages corrective action before there is harm to human health and safety or damage to the environment. The two major WWTF entities, SARA and the Cibolo Creek Municipal Authority (CCMA), have SSO Initiatives from TCEQ that can be implemented and updated to support the priorities of the WPP.

Fats, oils, grease, non-flushables and other substances, when disposed of down drains and toilets, can cause damages to collection systems. Several educational programs on proper disposal of fats, oils and grease are available through AgriLife Extension and SARA. Distribution of educational materials and providing online videos on the Cibolo Creek WPP website will help homeowners dispose of fats, oils and grease appropriately. Management measure recommendations for SSOs and unauthorized discharges is listed in Table 28.

Management Measure 7 – Planning and Implementation of Wastewater Reuse

SARA and Cibolo Creek Municipal Authority have expressed interest in expanding wastewater reuse which can reduce potential bacteria and nutrient loadings in the watershed by diverting WWTF effluent to non-potable uses such as irrigation or constructed wetlands for enhanced wastewater treatment. The reuse of wastewater offers an attractive option for irrigation, especially during periods of drought. However, viable options for wastewater in the watershed have not been identified. Working with city staff and officials to identify and secure needed financial and technical resources is required to implement this measure (Table 29).

Management Measure 8 – Reduce Illicit Dumping

Stakeholders indicated that illicit dumping, particularly of animal carcasses, is a problem throughout the watershed. Dumping activities typically occur at or near bridge crossings where individuals may dispose of deer, hogs or small livestock carcasses in addition to other trash. The scope of the problem is not entirely known or quantified but anticipated to be a relatively minor contributor to bacteria loadings in the watershed compared to other sources. However, development and delivery of educational and outreach materials to local residents on proper disposal of carcasses and other trash could help reduce illicit dumping and associated potential bacteria loadings (Table 30).

Hazardous waste collection events happen around the watershed annually. Advertising these events and increasing the events to bi-annually can help increase participation in the collection events and reduce the amount of dumping at crossings and down drains (Figure 42).

Table 25. Management measure 3: OSSF management.

<table>
<tr><th colspan="4">Source: Failing or Non-Existent On-Site Sewage Facilities (OSSFs)</th></tr>
<tr><td colspan="4">Problem: Pollutant loading reaching streams from untreated or insufficiently treated household sewage</td></tr>
<tr><td colspan="4">Objectives:
• Inspect failing OSSFs in the watershed and secure funding to promote OSSF repairs.
• Repair or replace OSSFs by working with counties and communities.
• Educate homeowners on system operations and maintenance.</td></tr>
<tr><td colspan="4">Location: Entire watershed</td></tr>
<tr><td colspan="4">Critical Areas: Primarily subwatersheds 1, 2, 3, 6, 7, 8, 9 and 11 and system within 150 yards of a perennial water body</td></tr>
<tr><td colspan="4">Goal: Identify, inspect and repair or replace 50 failing OSSFs in the watershed, especially within critical areas.</td></tr>
<tr><td colspan="4">Description: Expanded education programs and workshops will be delivered to homeowners on proper maintenance and operation of OSSFs. Failing or non-existent systems will be repaired or replaced as appropriate and as funding allows.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>Counties, contractors</td><td>Identify, inspect and repair or replace OSSFs as funding allows</td><td>2019–2029</td><td>$8,000-$10,000 per system (estimate)</td></tr>
<tr><td>Counties, Municipalities Districts, Homeowners, SARA</td><td>Inspect and identify the possibility in connecting to existing infrastructure</td><td>2019–2029</td><td>N/A</td></tr>
<tr><td>SARA, AgriLife Extension, TWRI</td><td>Operate an OSSF education, outreach, and training program for installer, service providers and homeowners</td><td>2020, 2024, 2028</td><td>N/A</td></tr>
<tr><td>AgriLife Extension, TWRI</td><td>Develop and deliver materials (postcards, websites, handouts, etc.) to educate homeowners</td><td>2019–2029</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">As planned, 50 OSSFs will be repaired or replaced throughout the watershed. It will result in a potential load reduction of 4.04×10^{15} cfu E. coli per year. Nutrients and BOD5 will be reduced as well. Due to the differences of onsite conditions and type of system installed, the reduction rates are not consistent. However, they generally range from 10-40% for nitrogen, 85-95% for phosphorus and 90-98% for BOD5 (EPA 2003).</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">High: Replacement or repair of failing OSSFs yields direct E. coli reductions.</td></tr>
<tr><td>Certainty</td><td colspan="3">Low: The level of funding available to identify, inspect and repair or replace OSSFs is uncertain; however, funding sources are available for assistance.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Watershed stakeholders acknowledge failing OSSFs as a considerable source of bacteria loading. Addressing this source will have the greatest effect on protecting human health and is a top priority.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial resources are needed to identity, repair and replace systems as many homeowners do not have the resources to fund replacement themselves. Education is also critical because many homeowners with failing systems may not even realize their system is failing.</td></tr>
</table>

San Antonio River Authority, SARA; Texas Water Resources Institute, TWRI; colony forming unit, cfu; biochemical oxygen demand, BOD

Table 26. Management measure 4: Pet waste management.

Source: Dog Waste			
Problem: Direct and indirect fecal bacteria loading from household pets			
Objectives: • Expend education and outreach messaging on disposal of pet waste. • Install and maintain pet waste stations in public areas.			
Location: Entire watershed			
Critical Areas: High pet concentration areas, subwatersheds 1, 2, 3, 9 and 11			
Goal: Reduce the amount of pet waste that may wash into water bodies during rainfall and irrigation runoff by providing educational and physical resources to increase stakeholder awareness of water quality and health issues caused by excessive pet waste. Effectively manage *E. coli* loading from 12% of the estimated dog population, or 4,857 dogs.			
Description: Expand education and outreach regarding the need of properly dispose of pet waste in the watershed. Specially target homeowners and the general public. Install and maintain pet waste stations and signage in public areas to facilitate increased collection and proper disposal of pet waste.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
City, local veterinary clinics, pet owners	Allows dog and cat owners to have pets spayed or neutered at little to no cost.	2019–2029	N/A
City officials/police, pet owners, Animal Control Department	Requires pet owners to remove any deposits from public areas. May restrict number of dogs and/or cats in a household.	2019–2029	N/A
Cities, counties, homeowners, homeowner associations	Provide needed maintenance supplies for pet waste stations: est. 50 stations	2019–2029	\$500 per station: \$25,000 total
Cities, Counties, AgriLife Extension, TWRI, HOAs	Develop and provide educational resources to residents	2019–2029	N/A
Estimated Load Reduction			
Load reductions resulting from this management measure are reliant on changes in people's behavior and are therefore uncertain. Assuming 12% of targeted individuals respond by properly disposing of pet waste an annual load reduction of 3.32×10^{15} cfu *E. coli* per year is expected in the Mid and Lower Cibolo Creek watershed.			
Effectiveness:	High: Collecting and properly disposing of dog waste is a direct method of preventing *E. coli* from entering water bodies, directly reducing potential loading in water bodies.		
Certainty	Low: Some pet owners in the watershed likely already collect and properly dispose of dog waste. Those that do not properly dispose of pet waste are likely difficult to reach or convince. The number of additional people that will properly dispose of waste is difficult to anticipate.		
Commitment	Moderate: Most parks currently have pet waste stations installed; however, maintenance is sometimes less frequent than it needs to be. Meanwhile, little to no enforcement occurs to require owners to pick up after their pets.		
Needs	Low: Increasing maintenance on existing pet waste stations is something that could easily occur. Landscapers can easily add this to their list of items when mowing parks if resources are provided.		

Texas Water Resources Institute, TWRI; homeowners associations, HOAs; colony forming unit, cfu

Table 27. Management measure 5: Urban stormwater management.

<table>
<tr><th colspan="4">Source: Urban Stormwater Runoff</th></tr>
<tr><td colspan="4">Problem: Fecal bacteria loading from stormwater runoff in developed and urbanized areas</td></tr>
<tr><td colspan="4">Objectives:
• Educate residents about stormwater BMPs.
• Identify and install stormwater BMP demonstration projects, including identification of appropriate sites and costs.</td></tr>
<tr><td colspan="4">Critical Areas: Urbanized areas in subwatersheds 1, 2, 3, 9 and 11</td></tr>
<tr><td colspan="4">Goal: Reduce E. coli loading associated with urban stormwater runoff through implementation of stormwater BMPs as appropriate and to increase local residents' awareness of stormwater pollution and management.</td></tr>
<tr><td colspan="4">Description: Potential locations and types of stormwater management BMP demonstration projects will be identified in coordination with cities, public works and property owners.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>Cities, property, owners, contractors</td><td>Identify and install stormwater BMPs as funding becomes available</td><td>2019–2029</td><td>$95,288 per acre (estimate)</td></tr>
<tr><td>AgriLife Extension, TWRI</td><td>Deliver education and outreach (Riparian and Stream Ecosystem Education workshop, or others as appropriate) to landowners</td><td>2020, 2025</td><td>N/A</td></tr>
<tr><td>SARA Watershed Wise Rebate Program</td><td>Continue to fund this program</td><td>2020–2025</td><td>$600,000/year</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Installation of stormwater BMPs that reduce runoff or treat bacteria will result in direct reductions in bacteria loadings in the watershed. Potential load reductions were not calculated because the location, type and sizes of projects installed will dictate the potential load reductions</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">Moderate to High: The effectiveness of BMPs at reducing bacteria loadings is dependent on the design, site selection and maintenance of the BMP.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Installation of BMPs requires sustained commitment from city officials or property owners.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate to Low: Urban stormwater management is not a high priority for local municipalities; financial or other incentives will be needed to encourage and secure long-term commitment.</td></tr>
<tr><td>Needs</td><td colspan="3">High: It is unlikely stormwater BMPs will be installed without financial assistance.</td></tr>
</table>

Best management practices, BMP; Texas Water Resources Institute, TWRI; San Antonio River Authority, SARA

Table 28. Management measure 6: Manage sanitary sewer overflows (SSOs) and unauthorized discharges.

<table>
<tr><th colspan="4">Source: Municipal Sanitary Sewer Overflow (SSO) or Unauthorized Discharges</th></tr>
<tr><td colspan="4">Problem: Fecal bacteria loading from unauthorized discharges when excessive water enters the sanitary sewer system through I&I</td></tr>
<tr><td colspan="4">Objectives:
Reduce unauthorized discharges and SSOs.
Replace and repair sewage infrastructure where I&I problems have been identified.
Educate residents and homeowners about the impacts of I&I, the need for infrastructure maintenance and what types of waste can be put in the sewer system.</td></tr>
<tr><td colspan="4">Critical Areas: Urbanized areas in subwatersheds 1, 2, 3, 9 and 11</td></tr>
<tr><td colspan="4">Goal: Work with entities operating WWTFs to continue and expand inspection efforts and identify problematic areas and repair or replace problematic infrastructure to reduce inflow and infiltration issues and minimize WWTF overload occurrences.</td></tr>
<tr><td colspan="4">Description: Identify potential locations within municipal sewer systems where inflow and infiltration occur using available strategies (e.g. smoke tests, camera inspections, etc.). Prioritize system repairs or replacements based on system impacts (largest impact areas addressed first). Complete repairs or replacements to reduce future inflow and infiltration issues and WWTF overloading.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participation</th><th>Recommendations</th><th>Period</th><th>Capital Costs</th></tr>
<tr><td>TWRI, AgriLife Extension, Cities</td><td>Identify potential resources and develop programs to assist homeowners with sewage pipe replacement</td><td>2019–2029</td><td>N/A</td></tr>
<tr><td>Cities, AgriLife Extension, TWRI</td><td>Develop and deliver education material to residents and property owners</td><td>2019–2029</td><td>N/A</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Reduction of SSOs and discharges associated with I&I will result in direct reductions in bacteria loads. However, because the response to education efforts and the development of resources to compel pipe repairs is uncertain, load reductions were not calculated.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">Moderate to High: Although infrequent, reduction in SSOs and unauthorized discharges will result in direct reductions to bacteria loading during the highest flow events.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate to Low: Costs associated with sewer pipe replacement can be expensive to homeowners; homeowners often perceive the issue as a problem for the municipality to resolve.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Municipal public works have incentive to resolve I&I issues to meet discharge requirements. However, lack of funding precludes replacement of sewage pipe.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial needs are likely significant.</td></tr>
</table>

Inflow and infiltration, I&I; wastewater treatment facility, WWTF; Texas Water Resources Institute, TWRI

Table 29. Management measure 7: Planning and implementation of wastewater reuse.

<table>
<tr><td colspan="4">Source: Wastewater Treatment Facilities (WWTFs)</td></tr>
<tr><td colspan="4">Problem: Pollutant loading from WWTF discharges</td></tr>
<tr><td colspan="4">Objectives:
• Identity sites within Mid and Lower Cibolo Creek watershed with high potential for wastewater reuse.
• Encourage and pursue wastewater reuse as funding allows.</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed with focus on larger cities near WWTFs</td></tr>
<tr><td colspan="4">Goal: Encourage the adoption of wastewater reuse as an option to reduce bacteria loadings in the Mid and Lower Cibolo Creek by reducing or eliminating WWTF discharges from several facilities around the watershed (Figure 18)</td></tr>
<tr><td colspan="4">Description: SARA and CCMA have indicated interest in pursuing wastewater reuse to irrigate city properties. However, viable land options have not been identified. Identification of sites with high potential to use wastewater effluent as well as securing funding for project planning and implementation will also be required.</td></tr>
<tr><td colspan="4">Implementation Strategy</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>SARA and CCMA</td><td>Inventory, Identify and prioritize sites within the watershed that could use wastewater reuse</td><td>2019–2029</td><td>N/A</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Wastewater reuse can reduce or eliminate loading to the watershed; the amount depends on how much effluent can be diverted for irrigative purposes.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">High: Reducing or eliminating effluent discharge into the Mid and Lower Cibolo Creek will yield direct reductions in bacteria and nutrient loadings in the watershed.</td></tr>
<tr><td>Certainty</td><td colspan="3">Low: The level of funding available to plan and pursue wastewater reuse is uncertain. The availability of sites that can use treated effluent for irrigation is uncertain.</td></tr>
<tr><td>Commitment</td><td colspan="3">High: City officials and staff have expressed high interest in pursuing this option.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Funding to plan and implement wastewater reuse project is limited as is site availability.</td></tr>
</table>

San Antonio River Authority, SARA; Cibolo Creek Municipal Authority, CCMA

Table 30. Management measure 8: Reduce illicit dumping.

Source: Illicit and Illegal Dumping			
Problem: Illicit and illegal dumping of trash and animal carcasses in and along waterways			
Objectives: • Promote and expand education and outreach efforts in the watershed.			
Critical Areas: Entire watershed with focus at bridge crossing and public access areas			
Goal: Increase awareness of proper disposal techniques and reduce illicit dumping of waste and animal carcasses in water bodies throughout the watershed.			
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on the proper disposal of carcasses and waste materials.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Counties	Develop and deliver educational and outreach materials to residents	2019–2029	N/A
Estimated Load Reduction			
Load reductions are likely minimal from this management measure and were not quantified.			
Effectiveness:	Low: Preventing illicit dumping, especially animal carcasses, is likely to reduce bacteria loads by some amount, although this loading is likely limited to areas with public access.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that illegally dump is likely difficult.		
Commitment	Moderate: Many stakeholders indicate illicit dumping occurs; however, enforcement is difficult in rural areas. The issue is not a high priority and commitment of limited resources will likely remain low.		
Needs	Moderate: Some financial resources will be required to develop educational materials. Information could be incorporated into ongoing watershed related educational and outreach efforts.		

Figure 42. Different types of waste collected during a Household Hazardous Waste event include paint, household chemicals and lawn chemicals. Photo: San Antonio River Authority.

Chapter 7
Education and Outreach

Introduction

An essential element to the implementation of this WPP is an effective education and outreach campaign. Long-term commitments from citizens and landowners will be necessary for achieving comprehensive improvements in the Mid and Lower Cibolo Creek watershed. The education and outreach component of implementation must focus on keeping the public, landowners and agency personnel informed of project activities, provide information about appropriate management practices and assist in identifying and forming partnerships to lead the effort.

Watershed Coordinator

The role of the Watershed Coordinator is to lead efforts to establish and maintain the working partnerships with stakeholders. The Watershed Coordinator also serves as a point of contact for all things related to WPP development, implementation and the WPP itself. A full-time watershed coordinator position is recommended to support WPP implementation.

The future role of the Watershed Coordinator is perhaps most important. The Watershed Coordinator will be tasked with maintaining stakeholder support for years to come, identifying and securing funds to implement the WPP, tracking success of implementation and working to implement adaptive management strategies. Simply put, the Watershed Coordinator is the catalyst to keeping WPP implementation on track.

Public Meetings

Throughout the course of developing the WPP, stakeholder engagement has been critical. Public meetings held to develop the WPP with local stakeholders began in May 2017. Thirteen meetings were held, including general stakeholder meetings and smaller workgroup meetings. Meetings were also held for county officials and local SWCDs to engage stakeholders in the planning process.

Throughout the process, numerous local stakeholders participated in the many public meetings, one-on-one meetings and workshops associated with WPP development. Stakeholders were present from all four counties of the watershed and represented agriculture, urban and environmental interests. Some of the agencies involved in the planning process include: SARA, Guadalupe Blanco River Authority, USDA NRCS, SWCD, city and county officials, landowners, Cibolo Creek Municipal Authority, Evergreen Underground Water Conservation District, TSSWCB, TCEQ, 4-H Water Ambassador and the Farm Bureau.

Future Stakeholder Engagement

Watershed stakeholders will be continually engaged throughout the entire process and following the transition of efforts from development to implementation of the WPP. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events in addition to seeking out and meeting with focused groups of stakeholders to identify and secure implementation funds. The coordinator will also provide content to maintain and update the project website, track WPP implementation progress and participate in local events to promote watershed awareness and stewardship. News articles, newsletters and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress, provide information on new implementation opportunities, inform them on available technical or financial assistance and other items of interest related to the WPP effort.

Education Programs

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared towards providing information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Mid and Lower Cibolo Creek watershed and advertised to watershed stakeholders. An approximate schedule for planned programming is provided in Chapter 6. This schedule will be used as a starting point for planned programming and efforts will be made to abide by this schedule to the extent possible. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate.

Elementary School Watershed Education Programs

The SARA Education Team provides watershed education to students and community members in Wilson and Karnes counties. The team actively works with partners to bring targeted programming to 3rd, 4th and 5th graders as well as high schools and families. Partners include Texas A&M AgriLife Extension Office, Guadalupe-Blanco River Authority, Nueces River Authority, Texas Parks and Wildlife, Evergreen Underground Water Conservation District and more. As of 2017, for the 3rd year in a row, 100% of 5th grade classrooms were provided with inspiring watershed education. In 2017, the River Authority's education team visited 4,180 students in the Southern Basin counties (this also includes Goliad County). Educational programs will continue to be delivered in Bexar, Wilson and Karnes county schools annually.

Low Impact Development Training Program

SARA and Bexar County developed a training program for the construction inspection and maintenance of Low Impact Development (LID) permanent stormwater BMPs. LID is design approach modeled after nature to manage stormwater runoff in a manner that mimics natural hydrologic processes, providing benefits for water quality and mitigating negative impacts of stormwater runoff on downstream resources including streams and rivers. The LID training program is comprised of two courses:

Construction Inspection Registration Course

The Construction Inspection Registration Course focuses on key factors of LID BMP construction inspection to ensure proper functioning at the time of construction. This course was created for design professionals and contractors who construct and perform construction inspections of LID permanent stormwater BMPs including bioretention (e.g. rain gardens and bioswales), permeable pavement, sand filters, green roofs, vegetated swales, vegetated filter strips, stormwater wetlands and cisterns.

Annual Inspection & Maintenance Certification Course

The Annual Inspection and Maintenance Certification Course focuses on post-construction activities to ensure proper functioning into the future. This course was created for inspectors and contractors who perform annual inspection and maintenance services of LID permanent stormwater BMPs including bioretention (e.g. rain gardens and bioswales), permeable pavement, sand filters, green roofs, vegetated swales, vegetated filter strips, stormwater wetlands and cisterns.

Texas Stream Team

The Watershed Coordinator will coordinate with the Meadows Center for Water and the Environment to start a volunteer monitoring program for the Mid and Lower Cibolo Creek Watershed using their existing Texas Stream Team program. The program will help train community members, students, educators and all interested parties to conduct supplemental water quality monitoring around the watershed. There has been some interest to work with the local school districts in the Mid Cibolo watershed to start a volunteer monitoring program.

Healthy Lawns Healthy Waters Workshop

The Healthy Lawns and Healthy Waters Program aims to improve and protect surface water quality by enhancing awareness and knowledge of best management practices for residential landscapes. This program would be beneficial in the more urbanized part of the watershed and can teach homeowners how to care for their lawns appropriately to reduce the risk of NPS pollution entering Cibolo Creek.

Urban Riparian and Stream Restoration Workshop

Stream restoration projects and demonstration sites were discussed in the Urban Stormwater workgroup. The Watershed Coordinator can coordinate with the Texas Water Resources Institute to deliver the Urban Riparian and Stream Restoration Workshop in the watershed. The program discusses natural vs traditional restoration and the unique stressors faced by urban streams.

Feral Hog Management Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods and resources to help them control these pests. Workshop frequency will be approximately every 3-5 years, unless there are significant changes in available means and methods to control feral hogs.

Lone Star Healthy Streams Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program is geared towards expanding stakeholders' knowledge on how beef cattle, horse and poultry producers can improve grazing lands and practices to reduce NPS pollution. They also offer a component of feral hog management. This statewide program promotes the adoption of BMPs that have been proven to effectively reduce bacterial contamination of streams. This program provides educational support for the development of CPs by illustrating the benefits of many practices available for inclusion in a CP to program participants. This program will likely be delivered in the watershed once every 5 years or as needed.

OSSF Operation and Maintenance Workshop

Once OSSFs in the watershed and their owners have been identified, an OSSF rules, regulations, operation and maintenance training will be delivered in the watershed. This training will consist of education and outreach practices to promote the proper management of existing OSSFs and to garner support for efforts to further identify and address failing OSSFs through inspections and remedial actions. AgriLife Extension provides the needed expertise to deliver this training. Additionally, an online training module that provides an overview of septic systems, how they operate and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the partnership website.

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network Program provides needed education and outreach that focuses on private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices. This includes a brief session on proper operation and maintenance of OSSFs as they are commonly used in close proximity to private drinking water wells. Well screenings are conducted through this program and provide useful information to well owners that will assist them in better managing their water supplies.

Riparian and Stream Ecosystem Education Program

Healthy watersheds and good water quality go hand in hand with properly-managed riparian and stream ecosystems. Delivery of the Riparian and Stream Ecosystem Education Program will increase stakeholder awareness, understanding and knowledge about the nature and function of riparian zones. Additionally, the program will educate stakeholders on the benefits of riparian zones and the BMPs that can be implemented to protect them while minimizing NPS pollution. Through this program, riparian landowners will be connected with local technical and financial resources to improve management and promote healthy watersheds and riparian areas on their land.

Wildlife Management Workshops

Periodic wildlife management workshops are warranted to provide information on management strategies and available resources to those interested. The Watershed Coordinator will work with AgriLife Extension Wildlife Specialists and TPWD as appropriate to plan and secure funding to deliver workshops in and near the Mid and Lower Cibolo Creek watershed. Wildlife management workshops will be advertised through newsletters, news releases, the project website and other avenues as appropriate.

Public Meetings

Periodic public stakeholder meetings will be used to achieve several major goals of WPP implementation. Public meetings will provide a platform for the Watershed Coordinator and project personnel as appropriate to provide WPP implementation information including implementation progress, near-term implementation goals and projects, information on how to sign-up or participate in active implementation programs, appropriate contact information for specific implementation programs and other information as appropriate. These meetings will also keep stakeholders engaged in the WPP process and provide a platform to discuss adaptive management in order to keep the WPP relevant to watershed and water quality needs. This will be accomplished by reviewing implementation goals and milestones during at least one public meeting annually and actively discussing how watershed needs can be better served. Feedback will be incorporated into WPP addendums as appropriate.

Newsletters and News Releases

Watershed newsletters will be developed and sent directly to actively engaged stakeholders at least annually or more often if warranted. News releases will be developed and distributed as needed through the mass media outlets in the area and will be used to highlight significant happenings related to WPP implementation and to continue to raise public awareness and support for watershed protection. These means will be used to inform stakeholders of implementation programs, eligibility requirements, when and where to sign up and what the specific program will entail. Lastly, public meetings and other WPP-related activities will be advertised through these outlets.

SARA publishes a quarterly River Reach newsletter, which includes reports on environmental topics and promotes events occurring throughout the basin including all four counties — Bexar, Wilson, Karnes and Goliad. Watershed updates and implementation plans can be announced in these newsletters.

Events

SARA hosts a variety of events in Wilson and Karnes counties that help engage community members with the river and to protect the river and its tributaries. SARA frequently hosts community events at the John William Helton San Antonio River Nature Park such as the Pecan Jubilee and the Planets in the Park events. In addition, SARA operates and maintains multiple parks in Wilson County that offer community members the opportunity to experience the outdoors from paddling to birding to enjoying the playground. The parks and events help develop a connection with and dedication to the river and the surrounding environment.

SARA also organizes two Household Hazardous Waste Collection events each year in both Wilson and Karnes counties, so community members have an opportunity to properly dispose of hazardous waste for free. These events help raise awareness of ways community members can help protect the river and its tributaries.

Watershed Wise

SARA's Watershed Wise program offers a variety of ways community members to learn about the watershed and be involved to help protect local creeks and rivers. Topics covered during these programs include picking up after pets, recycling, reporting illegal dumping, picking up trash, reporting fish kills and spills, or building rain gardens at residences or places of business. SARA also shares ways to learn more about watershed sustainability, stormwater management and LID. A few areas under the program that are particularly related to the Cibolo Creek basin include the Soil and Water Conservation District Partnership and a rebate program for construction of on-site stormwater BMPs and more.

Utilities Outreach

SARA's Utilities department services areas in the eastern part of Bexar County to ensure the highest quality effluent is discharged into Salitrillo and Martinez creeks, which are tributaries to the Cibolo Creek. SARA's Utilities regularly participates in career days at local schools, sends annual mailers to raise awareness about fats, oils and grease and also hosts wastewater treatment plant tours for both schools and military personnel.

Chapter 8
Plan Implementation

Introduction

Implementing the WPP is multi-year commitment that will require active participation from various stakeholders and local entities for a planned 10-year period. Implementation of the management measures described in Chapter 6 will require significant financial and technical assistance, as well as continued water quality education and outreach. The first step to successful implementation is to create a reasonable implementation schedule with interim goals and estimated costs. All management strategies in the WPP are voluntary but have received stakeholder support to help ensure the recommendations will be implemented.

Schedule, Milestones and Estimated Costs

The implementation schedule of the Mid and Lower Cibolo Creek WPP is set over a 10-year period; however, additional management and time may be needed as identified through adaptive management. The schedule, milestones and estimated costs associated with planned implementation were discussed and developed in coordination with watershed stakeholders during the WPP development process. Management measures were selected based on their ability to address *E. coli* loading in the watershed and effectively manage the target source at a reasonable cost.

A complete list of management measures and goals, responsible parties and estimated costs are included in Table 31. Implementation goals are included incrementally to reflect anticipated implementation time frames. In specific cases, funding acquisition, personnel hiring or program initiation may delay the start of implementation. This approach provides incremental implementation targets that can be used as gauges to measure implementation progress. If sufficient progress is not made, adjustments will ensue to increase implementation and meet established goals. Adaptive management may also be used to adjust the planned approach if the original strategy is no longer feasible.

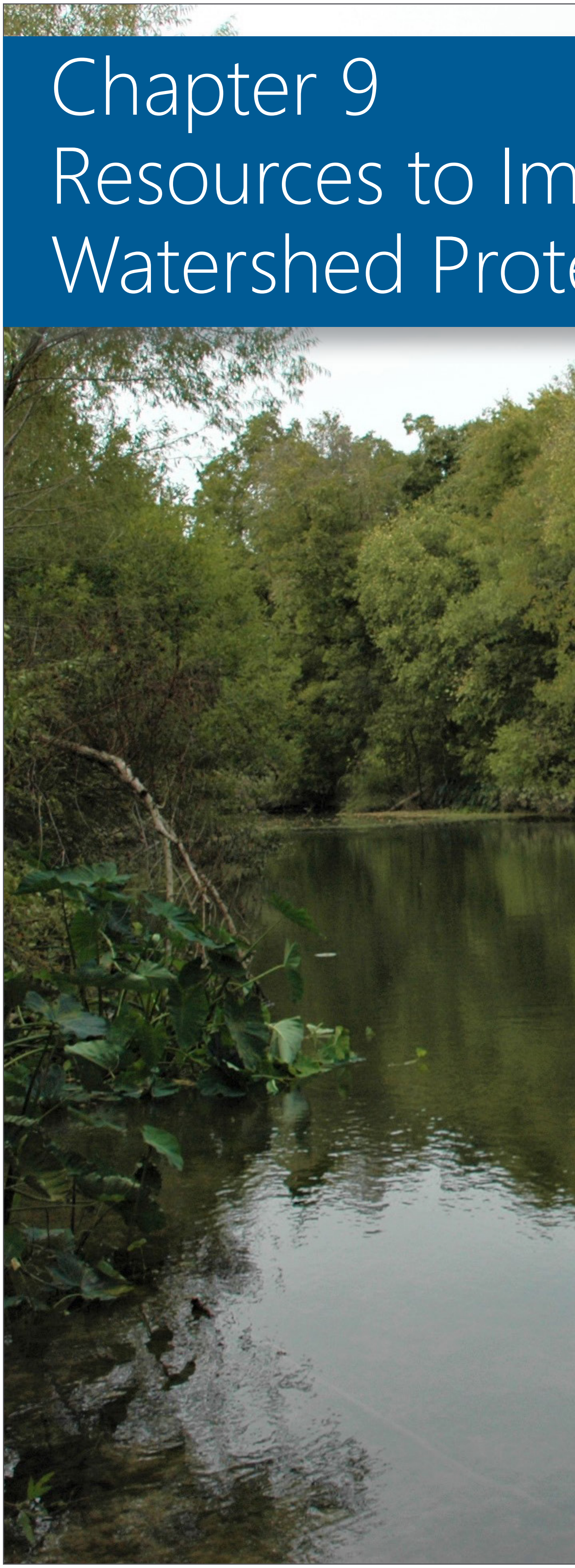
Table 31. Implementation schedule.

Management Measure	Responsible Party	Estimated Unit Cost	Number Implemented Time frame (year) 1–3	Number Implemented Time frame (year) 4–6	Number Implemented Time frame (year) 7–10	Estimated Total Cost
Cattle and other Livestock						
Develop funding to hire WQMP technician	TSSWCB, SWCDs, Watershed Coordinator	$75,000 per year	1			$750,000
Develop, implement and provide financial assistance for CPs and WQMPs	Producers, landowners, NRCS, TSSWCB, SWCDs, Watershed Coordinator	$15,000 per plan	10	10	20	$600,000
Deliver education and outreach programs and workshops to landowners	AgriLife Extension, TWRI, SARA, Watershed Coordinator	N/A	1	1	1	N/A
Feral Hog Management						
Voluntarily construct fencing around deer feeders to prevent feral hog utilization	Landowner, managers, leasees	$200 per feeder	As many as possible			N/A
Voluntarily trap/remove/ shoot feral hogs to reduce numbers	Landowner, managers, leasees	N/A	1,587 hogs per year			N/A
Develop and implement wildlife management plans and wildlife management practices	Landowners, producers, TPWD, Watershed Coordinator	N/A	As many as possible			N/A
Deliver feral hog education workshops	AgriLife Extension, Texas Wildlife Services, TPWD, Watershed Coordinator	$3,000 each	1	1	1	$9,000
OSSF Management						
Identify, inspect and repair or replace OSSFs as funding allows	Counties, contractors	$8,000-$10,000 per system	20	40	40	$800,000-$1,000,000
Operate and OSSF education, outreach and training program for installer, service providers and homeowners	SARA, AgriLife Extension, Watershed Coordinator	$3,500	1	1	1	$10,500
Develop and deliver materials (postcards, websites, handouts, etc.) to educate homeowners	Watershed Coordinator	$1,000	As needed			$1,000

Management Measure	Responsible Party	Estimated Unit Cost	Number Implemented Time frame (year) 1–3	Number Implemented Time frame (year) 4–6	Number Implemented Time frame (year) 7–10	Estimated Total Cost
Pet Waste Management						
Pet waste station establishment and maintenance	Cities, HOAs, counties, Watershed Coordinator	$500 per station	10	20	20	$25,000
Pet waste education materials	SARA, cities, HOAs, counties, Watershed Coordinator	N/A	Annually, in addition to current informational flyers			N/A
Urban Stormwater Management						
Identify and Install Stormwater BMPs	Cities, property owners, contractors, Watershed Coordinator	$95,288 per acre	As many as possible			
Deliver education and outreach programs	SARA, Watershed Coordinator, AgriLife Extension	N/A	1	0	1	N/A
Municipal Sanitary Sewer Overflow or Unauthorized Discharges						
Identify potential resources and develop programs to assist homeowners with sewage pipe replacement	Watershed Coordinator, AgriLife Extension, cities	N/A	As many as possible			N/A
Identify and replace pipes contributing to I&I problems as funding permits	Cities, property owners, contractors	$3,000-$20,000 per site				
Develop and deliver education materials to residents and property owners	Cities, AgriLife Extension, Watershed Coordinator	N/A	1	1	1	N/A
WWTFs Management						
Inventory, identify and prioritize sites within the watershed that could use wastewater reuse	SARA, CCMA	N/A	As needed			N/A

Water Quality Management Plan, WQMP; Texas State Soil and Water Conservation Board, TSSWCB; Soil and Water Conservation Districts, SWCDs; conservation plans, CPs; Natural Resources Conservation Service, NRCS; Texas Water Resources Institute, TWRI; San Antonio River District, SARA; Texas Parks and Wildlife Department, TPWD; on-site sewage facility, OSSF; homeowners associations, HOAs; best management practices, BMPs; inflow and infiltration, I&I; wastewater treatment facilities, WWTF; Cibolo Creek Management Authority, CCMA

Chapter 9
Resources to Implement the Watershed Protection Plan



Introduction

This chapter identifies the potential sources of technical and financial assistance available to maximize the implementation of management measures within the Mid and Lower Cibolo Creek watershed. Grant funding will likely be a substantial source of implementation funding given the availability of resources identified thus far. In addition to funding management measures, it is recommended that funds be identified and developed to hire a local Watershed Coordinator to guide WPP implementation and facilitate long-term success of the plan.

Technical Assistance

Designing, planning and implementing some of the management recommendations in the plan will require technical expertise. In these cases, appropriate support will be sought to provide needed technical guidance. Funds required to secure needed expertise will be included in requests for specific projects and may come from a variety of sources. Table 32 provides a summary of the potential sources of technical assistance for each management measure.

Livestock Management

Developing and implementing practices to improve livestock management will require significant technical assistance from TSSWCB, local SWCDs and local NRCS personnel. Producers requesting planning assistance in the watershed will work with these entities to define operation-specific management goals and objectives and develop a management plan that prescribes effective practices that will achieve stated goals while also improving water quality.

Feral Hog Management

Watershed stakeholders will benefit from technical assistance regarding feral hog control approaches, options, best practices and regulations. AgriLife Extension and TPWD provide educational resources through local programs and public events.

Table 32. Summary of potential sources of technical assistance.

Technical Assistance	
Management Measure (MM)	**Potential Sources**
MM1: Promote and implement WQMPs or CPs	TSSWCB; local SWCDs; NRCS; AgriLife Extension
MM2: Promote technical and direct operational assistance to landowners for feral hog control	AgriLife Extension; TPWD; NRCS; TSSWCB; SARA
MM3: Identify and repair or replace failing on-site sewage systems	Designed technicians from counties; AgriLife Extension
MM4: Increase proper pet waste management	City public works departments; AgriLife Extension; SARA
MM5: Implement and expand urban and impervious surface stormwater runoff management	City public works departments; engineering firms; AgriLife Extension; SARA
MM6: Address inflow and infiltration	City public works departments; engineering firms, TCEQ; SARA; CCMA
MM7: Reduce illicit dumping	AgriLife Extension; county law enforcement; TPWD game wardens

Water Quality Management Plan, WQMP; conservation plans, CPs; Texas State Soil and Water Conservation Board, TSSWCB; Soil and Water Conservation Districts, SWCDs; Natural Resources Conservation Service, NRCS; Texas Parks and Wildlife Department, TPWD; San Antonio River District, SARA; Texas Commission on Environmental Quality, TCEQ; Cibolo Creek Management Authority, CCMA

OSSF Management

Technical support is needed to address failing OSSFs throughout Wilson, Bexar, Guadalupe, Comal and Karnes counties. Technical assistance will be sought from respective county-designated representatives and permitting offices in prospective OSSF program design, funding acquisition, identification of potential participants and publicizing of program availability as funds become available. Technical assistance for education and outreach will be provided through AgriLife Extension.

Pet Waste

Limited technical assistance is available to directly address pet waste. City public works, homeowners associations and parks departments will be relied upon to identify appropriate sites. Technical assistance for educational materials will be provided through AgriLife Extension and SARA.

Urban Stormwater

Several green stormwater projects have been identified in city master plans and outlines in MS4s. City public works staff will be relied upon to identify potential projects and sites. For structural projects, engineering designs may be needed and will be integrated into the costs of the projects. Technical assistance with education and outreach is available through AgriLife Extension and SARA.

Inflow and Infiltration

City public works staff will be relied upon to provide technical expertise on local systems, identify problem areas and work with firms as needed to smoke test or provide other infrastructure assessments. The repair and/or replacement of pipes will require engineering design and assistance from contractors and outside firms. TCEQ also provides technical assistance for municipalities to address SSO issues through the SSO Initiative.

Illicit Dumping

Efforts to reduce illicit dumping will focus on education and outreach. AgriLife Extension will provide technical assistance with education and outreach efforts. County law enforcement and TPWD game wardens are the primary source of enforcement and monitoring activities associated with illicit dumping.

Technical Resource Descriptions

AgriLife Extension

AgriLife Extension is a statewide outreach education agency with offices in every county of the state. AgriLife Extension provides a statewide network of professional educators, volunteers and local county extension agents. AgriLife Extension will be coordinated with to develop and deliver education programs, workshops and materials as needed.

Engineering Firms

Private firms provide consulting, engineering and design services. The technical expertise provided by firms may be required for urban BMP design. Funding for services will be identified and written into project budgets as required.

Counties or Cities Designated Representative

OSSF construction or replacement in Wilson, Karnes and Guadalupe counties requires a permit on file with local counties or cities authorized agents. Permits must be applied for through a TCEQ licensed professional installer. The county or cities designated representative is responsible for approving or denying permits. Site evaluations must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider or licensed professional installer.

Municipal Public Works Departments

The respective public works departments of San Antonio, Schertz, Cibolo, Selma, Randolph Air Force Base, Live Oak and Universal City are responsible for the management of city streets, utility and open space infrastructure. Implementation of stormwater BMPs and dog waste stations will require coordination and assistance from public works departments from each city.

Natural Resources Conservation Service

The USDA NRCS provides conservation planning and technical assistance to private landowners. For decades, private landowners have voluntarily worked with NRCS specialists to prevent erosion, improve water quality and promote sustainable agriculture. Assistance is available to help land owners (1) maintain and improve private lands, (2) implement improved land management technologies, (3) protect water quality and quantity, (3) improve wildlife and fish habitat and (4) enhance recreational opportunities. Local NRCS service centers in Karnes, Wilson, Bexar and Guadalupe counties are located in Kenedy, Floresville, San Antonio and Seguin respectively.

San Antonio River Authority

SARA provides valuable technical assistance in the Bexar, Wilson, Karnes and Goliad counties. Educational courses are offered in LID training, which include separate courses on proper construction, inspection and maintenance of green stormwater infrastructure. SARA also coordinates hazardous waste pick up events throughout the San Antonio River Basin. SARA will be coordinated with to deliver education programs, workshops and materials as needed.

Soil and Water Conservation Districts

A SWCD, like a county or school district, is a subdivision of the state government. SWCDs are administered by a board of five directors who are elected by their fellow landowners. There are 216 individual SWCDs organized in Texas. It is through this conservation partnership that local SWCDs are able to furnish technical assistance to farmers and ranchers for the preparation of a complete soil and water conservation plan to meet each land unit's specific capabilities and needs. The local SWCDs include Alamo SWCD, Comal-Guadalupe SWCD, Guadalupe County SWCD and Karnes SWCD.

Texas Commission on Environmental Quality

The TCEQ Sanitary Sewer Overflow Initiative is a voluntary program for permitted facilities and municipalities. Through the initiative, an SSO Plan is developed outlining the causes of SSOs, mitigative and corrective actions, as well as a timeline for implementation. Assistance for SSO planning and participation in the SSO Initiative is available through the TCEQ Regional Office (Region 13, San Antonio) and the TCEQ Small Business and Environmental Assistance Division.

Texas Parks and Wildlife Department

The TPWD's Private Land Services is a program to provide landowners with practical information on ways to manage wildlife resources that are also consistent with other land use goals, to ensure plant and animal diversity, to provide aesthetic and economic benefits and to conserve soil, water and related natural resources. To participate, landowners may request assistance by contacting the TPWD district serving their county.

Texas State Soil and Water Conservation Board

The TSSWCB WQMP Program provides technical assistance for developing management and conservation plans at no charge to agricultural producers. A visit with the local SWCD offices is the first step for operators to begin the plan development process.

Financial Resource Descriptions

Successful implementation of the Mid and Lower Cibolo Creek WPP, as written, will require substantial fiscal resources. Diverse funding will be sought to meet these needs. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds.

Grant funds will be relied upon to initiate implementation efforts. Existing state and federal programs will also be expanded or leveraged with acquired funding to further implementation impacts. Grant funds are not a sustainable source of financial assistance, but are necessary to assist in WPP implementation. Other sources of funding will be utilized and creative funding approaches will be sought where appropriate. Sources of funding that are applicable to this WPP and will be sought as appropriate are described in this chapter.

Federal Sources

Clean Water Act §319(h) Nonpoint Source Grant Program

The EPA provides grant funding to the State of Texas to implement projects that reduce NPS pollution through the §319(h) Nonpoint Source Grant Program. These grants are administered by TCEQ and TSSWCB in the State of Texas. WPPs that satisfy the nine key elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures must be included in the accepted WPP and meet other program rules. Some commonly funded items include:

- Development and delivery of educational programs
- Water quality monitoring
- OSSF repairs and replacements, land BMPs, water body clean-up events and others

Further information can be found at: https://www.tceq.texas.gov/waterquality/nonpoint-source/grants/grant-pgm.html and http://www.tsswcb.texas.gov/managementprogram

Conservation Stewardship Program (CSP)

The CSP is a voluntary conservation program administered by USDA NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities as well as improving, maintaining and managing existing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices. Practices may include, but are not limited to, prescribed grazing, nutrient management planning, precision nutrient application, manure application and integrated pest management.

Program information can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/

Conservation Reserve Program

Conservation Reserve Program is a voluntary program for agricultural landowners administered by the USDA Farm Service Agency (FSA). Individuals may receive annual rental payments to establish long-term, resource conserving covers on environmentally sensitive land. The goal of the program is to reduce runoff and sedimentation to protect and improve lakes, rivers, ponds and streams. Financial assistance covering up to 50% of the costs to establish approved conservation practices, enrollment payments and performance payments are available through the program.

Information on the program is available at: http://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index

Environmental Quality Incentives Program (EQIP)

Operated by USDA NRCS, the EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns in addition to opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. Individuals engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Practices selected address natural resource concerns and are subject to the NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local Work Groups are formed to provide recommendations to the USDA NRCS that advise the agency on allocations of EQIP county-based funds and identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local Work Group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP.

Information regarding EQIP can be found at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Regional Conservation Partnership Program (RCPP)

The RCPP is a new, comprehensive and flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through the RCPP and NRCS, state, local and regional partners coordinate resources to help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved.

Information regarding RCPP can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/farmbill/rcpp/

Rural Development Water & Environmental Programs

USDA Rural Development provides grants and low interest loans to rural communities for potable water and wastewater system construction, repair or rehabilitation. Funding options include:

- Rural Repair and Rehabilitation Loans and Grants: provides assistance to make repairs to low-income homeowners' housing to improve or remove health and safety hazards.
- Technical Assistance and Training Grants for Rural Waste Systems: provides grants to non-profit organizations that offer technical assistance and training for water delivery and waste disposal.
- Water and Waste Disposal Direct Loans and Grants: assists in developing water and waste disposal systems in rural communities with populations less than 10,000 individuals.

More Information about the Rural Development Program can be found at:
http://www.rd.usda.gov/programs-services/all-programs/water-environmental-programs

Urban Water Small Grants Program

The objective of the Urban Waters Small Grants Program, administered by the EPA, is to fund projects that will foster a comprehensive understanding of local urban water issues, identify and address these issues at the local level and educate and empower the community. In particular, the Urban Waters Small Grants Program seeks to help restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase their connection to, understanding of and stewardship of local urban waterways.

More information about the Urban Waters Small Grants Program can be found at:
https://www.epa.gov/urbanwaters/urban-waters-small-grants

State Sources

Clean Rivers Program (CRP)

The TCEQ administers the Texas CRP, a state fee-funded program that provides surface water quality monitoring, assessment and public outreach. Allocations are made to 15 partner agencies (primarily river authorities) throughout the state to assist in routine monitoring efforts, special studies and outreach efforts. SARA is the CRP partner for the Mid and Lower Cibolo Creek watershed. The program supports water quality monitoring, annual water quality assessments and engages stakeholders in addressing water quality concerns in the San Antonio River Basin.

More information about the Clean Rivers Program is available at:
http://www.lnra.org/programs/clean-rivers

Clean Water State Revolving Fund (CWSRF)

The CWSRF, authorized through the Clean Water Act and administered by the TWDB, provides low-interest loans to local governments and service providers for infrastructure projects that include stormwater BMPs, WWTFs and collection systems. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects. Through 2016, the program committed over $9.8 billion for projects across Texas.

More information on CWSRF is available at:
http://www.twdb.texas.gov/financial/programs/CWSRF/

Feral Hog Abatement Grant Program

Texas Department of Agriculture (TDA) provides grant funding to governmental agencies (counties, cities, etc.) and Texas higher education institutions for practical and effective projects to develop and implement long-term feral hog abatement strategies. AgriLife Extension and the TPWD currently receive funding through this program. In the past, individual and groups of counties have applied to receive funds for programs to control feral hogs including providing community traps or bounty payments.

More information is available at:
https://www.texasagriculture.gov/GrantsServices/TradeandBusinessDevelopment/FeralHogGrantProgram

Landowner Incentive Program (LIP)

TPWD administers the LIP to work with private landowners to implement conservation practices that benefit healthy aquatic and terrestrial ecosystems and create, restore, protect or enhance habitat for rare or at-risk species. The program provides financial assistance but does require the landowner to contribute through labor, materials or other means.

Further information about this program is available at: http://tpwd.texas.gov/landwater/land/private/lip/

Supplemental Environmental Projects (SEP)

The SEP program, administered by TCEQ, directs fines, fees and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Program dollars may be directed to OSSF repair, trash dump clean up and wildlife habitat restoration or improvement, among other things. Program dollars may be directed to entities for single, one-time projects that require special approval from TCEQ or directed entities (such as Resource Conservation and Development Councils) with pre-approved "umbrella" projects.

Further information about SEP is available at: https://www.tceq.texas.gov/compliance/enforcement/sep/sep-main

Texas Farm and Ranch Lands Conservation Program

The Texas Farm and Ranch Lands Conservation Program was established and is administered by TPWD to conserve high value working lands to protect water, fish, wildlife and agricultural production that are at risk of future development. The program's goal is to educate citizens on land resource stewardship and establish conservation easements to reduce land fragmentation and loss of agricultural production.

Program information is available from TPWD at: http://tpwd.texas.gov/landwater/land/private/farm-and-ranch/

Water Quality Management Plan Program (WQMP)

WQMPs are voluntary, property-specific management plans developed and implemented to improve land and water quality. Technical assistance to develop plans that meet producer and state goals is provided by the TSSWCB and local SWCDs. Once the plan is developed, the TSSWCB may financially assist implementing a portion of prescribed BMPs.

Other Sources

Private foundations, non-profit organizations, land trusts and individuals can potentially assist with implementation funding of some aspects of the WPP. Funding eligibility requirements for each program should be reviewed before applying to ensure applicability. Some groups that may be able to provide funding include but are not limited to:

- Cynthia and George Mitchell Foundation: Provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' land and water resources.
- Dixon Water Foundation: Provides grants to non-profit organizations to assist in improving/maintaining watershed health through sustainable land management.
- Meadows Foundation: Provides grants to non-profit organizations, agencies and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and water availability on private lands.
- Partnerships with local industry in the watershed could also provide in-kind donations or additional funding for implementation projects.
- Texas Agricultural Land Trust: Funding provided by the trust assists in establishing conservation easements for enrolled lands.

Chapter 10
Measuring Success

Introduction

Implementing this WPP requires coordination of many stakeholders over the next 10 years. Implementation will focus on addressing the most readily manageable sources of *E. coli* in the watershed in order to achieve water quality targets. This plan has identified the substantial financial commitments, technical assistance and education required to achieve these targets. The management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

Measuring the impacts of implementing a WPP on water quality is a critical process. Planned water quality monitoring at critical locations will provide data needed to document progress toward water quality goals. While improvements in water quality are the preferred measure of success, documentation of implementation accomplishments can also be used to measure success. The combination of water quality data and implementation accomplishments helps facilitate adaptive management by illustrating which recommended measures are working and which measures need modification.

Water Quality Targets

An established water quality goal defines the target for future water quality and allows the needed bacteria load reductions to be defined. The appropriate goal for water quality in the Cibolo Creek is the existing primary contact recreation standard for *E. coli* of 126 cfu/100mL (Table 33). If there are revisions or adoption of new water quality standards (such as nutrients), these targets may be revised or amended as appropriate.

Additional Data Collection Needs

Continued monitoring of water quality in the Mid and Lower Cibolo Creek watershed is necessary to track changes in water quality resulting from WPP implementation. Currently, water quality monitoring is mainly conducted by SARA on a quarterly basis around the watershed at the stations identified in Figure 12.

Table 33. The water quality targets for impaired water bodies in the Mid and Lower Cibolo Creek watershed.

Station(s)	Segment	Current Concentration†	5 Years After Implementation†	10 Years After Implementation†
12797	1902_01	343.4	234.7	120
14211	1902_02	188.4	157.2	120
12802	1902_03	142.4	134.2	120
20775	1902C_01	199.4	162.7	120

† in units of most probable numbers of *E. coli* per 100 milliliter of water

There are sufficient historical records of water quality measures on the main stem and continued monitoring on each segment and tributaries is suggested throughout implementation to monitor effectiveness. Focused water quality monitoring plans can be assessed and implemented as needed with implementation plans. Monitoring for BMP effectiveness and specialized projects will occur as identified by stakeholders and the watershed coordinator.

Through the adaptive management process and WPP updates, future water quality monitoring recommendations may include targeted water quality monitoring efforts to better track the effects of specific implementation projects on bacteria and nutrient reductions in the watershed. Targeted water quality monitoring may include studies on multiple subwatersheds, paired watershed studies or multiple watershed studies. Targeted monitoring can also include more intensive monitoring along identified stream segments to better identify potential pollutant sources. Any additional monitoring projects will follow quality assurance guidelines.

Data Review

Watershed stakeholders will use two methods to evaluate WPP implementation impacts on instream water quality. First, will be the TCEQ's statewide biennial water quality assessment approach, which uses a moving seven-year geometric mean of *E. coli* data collected through the state's CRP program. This assessment is published in the *Texas Integrated Report* and 303(d) list, which is available online at: https://www.tceq.texas.gov/waterquality/assessment/305_303.html

It is noted that a two-year lag occurs in data reporting and assessment, therefore the 2022 or 2024 report will likely be the first to include water quality data collected during implementation of the WPP.

Water quality improvements are often harder to identify using the seven-year data window utilized for the *Texas Integrated Report*. Therefore, progress toward achieving the established target of 126 cfu/100 mL will also be evaluated using the geometric mean of the most recent three years of water quality data identified within the TCEQ's SWQMIS. Trend analysis and other appropriate statistical analyses will also be used to support data assessment as needed. By reporting statistical trends in concentrations, stakeholders will be made aware of significant progress (or degradation) of instream water quality conditions. Trend analysis of constituent loads (using loads estimated from measured data) can also indicate progress towards instream conditions. Importantly, constituent load analysis can control for changes in flow, so stakeholders can be made aware of impacts of land management on the amount of NPS pollutant reaching water bodies.

The Watershed Coordinator will be responsible for tracking implementation targets and water quality in the watershed to quantify WPP success. Data will be summarized and reported to watershed stakeholders at least annually.

Interim Measurable Milestones

Implementing the Mid and Lower Cibolo Creek WPP will occur over a 10-year period. Milestones are useful for incrementally evaluating the implementation progress of specific management measures recommended in the WPP. Milestones outline a clear tracking method that illustrates progress toward implementation of management measures as scheduled. Responsible parties and estimated costs are also included in the schedule. Milestones associated with each management measure are included in Table 31 In some cases, funding acquisition, personnel hiring or program initiation may delay the start of implementation. This approach provides incremental targets that can be used to measure progress. If sufficient progress is not made, adjustments will ensue to increase implementation and meet established goals. Adaptive management may also be utilized to adjust the planned approach if the original strategy is no longer feasible or effective.

Adaptive Management

Due to the dynamic nature of watersheds and the countless variables governing landscape processes, some uncertainty is to be expected when a WPP is developed and implemented. As the recommended restoration measures of the Mid and Lower Cibolo Creek WPP are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. To provide flexibility and enable such adjustments, adaptive management will be utilized throughout the implementation process.

Adaptive management is often referred to as "learning by doing" (Franklin et al. 2007). It is the ongoing process of accumulating knowledge of the causes of impairment as implementation efforts progress, which results in reduced uncertainty associated with modeled loads. As implementation activities are instituted, water quality is tracked to assess impacts and guide adjustments, if necessary, to future implementation activities. This ongoing, cyclical implementation and evaluation process serves to focus project efforts and optimize impacts. Watersheds in which the impairment is dominated by NPS pollutants are good candidates for adaptive management.

Progress towards achieving the established water quality target will also be used to evaluate the need for adaptive management. Due to the numerous factors that can influence water quality and the time lag that often appears between implementation efforts and resulting water quality improvements, sufficient time should be allowed for implementation to occur fully before triggering adaptive management. In addition to water quality targets, if satisfactory progress towards achieving milestones is determined to be infeasible due to funding, scope of implementation or other reasons that would prevent implementation, adaptive management provides an opportunity to revisit and revise implementation strategy.

The Mid and Lower Cibolo Creek WPP is a living document, intended to be review and revised as needed in order to meet water quality goals. As new data and methods to improve water quality become available, or as we learn what measure are and are not working in the watershed, the number and type of management measures may need to be revised. Stakeholders will continue to give guidance and approval in these situations to make sure the document still has local support.

Stakeholder will also formally review progress of the WPP in meeting goals at least every five years. Progress will be reviewed using the following assessments:

Water Quality – Stakeholders will review water quality assessments of Mid and Lower Cibolo Creek. Additional water quality analysis, as available, will also be used. An increase in pollutant concentrations or percent exceedances will be considered a negative outcome.

Implementation Progress – Stakeholders will review the overall progress of the WPP in meeting anticipated measurable milestones. Substantial delays or lower than expected achievements in milestones will be considered a negative outcome.

External Factors – Stakeholders will evaluate, as appropriate, available data concerning trends in population growth, land use, economic factors, new water quality criteria and other relevant issues to evaluate changes to the amount or number of potential pollutant sources outline in the WPP. Significant increase in potential pollutant sources or hydrologic changes will be considered a negative outcome.

If negative outcomes are identified by two or more of the above assessments during the formal review, stakeholders will make changes based on adaptive management.

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Appendix A: Potential Load Calculations

Estimates for potential loads are based on the best available data (local, state and federal databases; scientific research) and local knowledge developed from stakeholder input (e.g. local livestock stocking practices, wildlife densities, etc.). The developed potential loading rates assume a worst-case scenario and are primarily used to calculate where management measures should be implemented first in order to maximize effectiveness and estimate potential load reductions.

Livestock

The first step to calculate potential bacteria loads from cattle is to develop cattle population estimates. Stakeholder input was critical to develop livestock population estimates across the watershed. Based on input from the stakeholder feedback, we estimated stocking rates for different counties shown in Table 34. Table 35 shows cattle stocking rates and potential pollutant loading per subwatershed to help highlight potential hot spots to target during the implementation phase. This stocking rate likely fluctuates annually based on local conditions but provides a baseline to estimate potential loadings that can be adjusted and fine-tuned if new data becomes available. Other difficulties in developing cattle population estimates include the reliance on the NLCD to identify pasture and rangeland. From this dataset, it is impossible to parse out land that is used for hay production versus grazed pasture. Furthermore, identifying the actual stocking rate used by a particular landowner is not possible with this dataset. Therefore, reliance on local stakeholders was critical to properly estimating cattle populations. Finally, estimates were compared to NASS cattle population estimates for watershed counties to evaluate if the generated estimates compared to USDA census figures. Based on these inputs, there are an estimated 30,787 cattle animal units across the entire watershed.

Table 34. Cattle stocking rates in different counties provided by stakeholders.

County	Improved Pasture Rate		Unimproved Pasture Rate	
	irrigation	dryland	dryland	thick brush
Bexar	5 ac/AnU		12 - 14 ac/AnU	
Wilson	2~3 ac/AnU	5~7 ac/AnU	15 ac/AnU	30 ac/AnU
Guadalupe	5 ~ 7 ac/AnU		12 ~ 15 ac/AnU	
Karnes	Using Wilson			
Comal	Using Guadalupe			

Acre, ac; animal unit, AnU

Using cattle population estimates generated with GIS analysis, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. The annual load from cattle was calculated as:

Where:

PAL_{cattle} = Potential annual *E. coli* loading attributed to cattle

AnU = Animal Units of cattle (~1,000 lbs of cattle)

FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×109 cfu fecal coliform per AnU per day (Wagner and Moench 2009)

Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to cattle is: 6.05×10^{16} cfu *E. coli* per year.

Table 35. Subwatershed loading calculations.

Acres and Percentages of Land Use and Land Cover Categories									Estimated Cattle Fecal Loading	
Subwatershed		Shrub/Scrub	Cattle Estimate per Stocking Rate	Herbaceous	Cattle Estimate per Stocking Rate	Hay/Pasture	Cattle Estimate per Stocking Rate	Total Cattle Estimate per Stocking Rate	Daily	Annual
SELECT ID	**(HUC 12)**	**Acres**		**Acres**		**Acres**				
1	**121003040203**	7737.772	516	7879.437135	638.00	1933.50	322.00	1476.00	7.95E+12	2.90E+15
2	**121003040202**	3513.388	234	2740.567424	222.00	2270.20	378.00	834.00	4.49E+12	1.64E+15
3	**121003040204**	2442.559	163	1150.45	93.00	1382.63	230.00	486.00	2.62E+12	9.56E+14
4	**121003040205**	8833.065	589	1859.44	151.00	2365.39	394.00	1134.00	6.11E+12	2.23E+15
5	**121003040206**	7549.404	503	1190.70	96.00	4863.77	811.00	1410.00	7.59E+12	2.77E+15
6	**121003040303**	11934.8	796	1800.95	146.00	14216.79081	2369.00	3311.00	1.78E+13	6.51E+15
7	**121003040301**	2716.549	181	348.71	28.00	5194.468337	866.00	1075.00	5.79E+12	2.11E+15
8	**121003040302**	9664.375	644	1583.45	128.00	11888.76518	2642.00	3414.00	1.84E+13	6.71E+15
9	**121003040304**	6186.57	412	1981.31	160.00	9344.349707	2077.00	2649.00	1.43E+13	5.21E+15
10	**121003040305**	4257.52	284	1558.99	126.00	4319.790768	960.00	1370.00	7.38E+12	2.69E+15
11	**121003040401**	6334.685	422	1206.93	98.00	11347.90176	2522.00	3042.00	1.64E+13	5.98E+15
12	**121003040402**	4330.688	289	557.54	45.00	6806.383673	1513.00	1847.00	9.95E+12	3.63E+15
13	**121003040404**	5029.452	335	838.87	68.00	11168.87418	2482.00	2885.00	1.55E+13	5.67E+15
14	**121003040403**	3592.561	240	612.47	50.00	8705.855097	1935.00	2225.00	1.20E+13	4.37E+15
15	**121003040405**	10881.54	725	1119.76	91.00	12663.14283	2814.00	3630.00	1.96E+13	7.14E+15
Totals		**95004.93**	**6333**	**26429.58**	**2140**	**108471.81**	**22315**	**30788**	**1.66E+14**	**6.05E+16**

Feral Hogs

Feral hog populations were estimated using an estimated population density of 1 feral hog per 30 ac of suitable habitat. The density estimate was based on estimates developed for the nearby Mission and Aransas watersheds as well as stakeholders feedback (Wagner and Moench 2009). GIS analysis was used to estimate watershed-wide and subwatershed feral hog populations. Based on this analysis, an estimated 10,576 feral hogs exist across the watershed. Like cattle, these numbers provide general estimates that likely change based on annual conditions. Furthermore, feral hogs likely roam across large areas that might be larger than individual subwatersheds; however, these estimates provide initial guidance on where to focus control efforts based on suitable habitats.

Using the feral hog population estimates, we estimated potential *E. coli* loading across the watershed and for individual subwatersheds. The annual load from feral hogs was calculated as:

$$PAL_{fh} = N_{fh} \times ANuC \times FC_{fh} \times Conversion \times 365\frac{days}{year}$$

Where:

PAL_{fh} = Potential annual *E. coli* loading attributed to feral hogs
N_{fh} = Number of feral hogs
$AnUC$ = Animal Unit Conversion; 0.125 animal units/feral hog (Wagner and Moench 2009)
FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

The estimated potential annual loading across all subwatersheds due to feral hogs is: 3.68×10^{14} cfu *E. coli* per year.

Domestic Pets

Dog estimates were generated using an estimated population density of 0.584 dogs per household that was applied to weighted census block household data (AVMA 2012). It was assumed that approximately 40% of dog owners do not pick up dog waste (Swann 1999). Based on these assumptions, there are an estimated 40,467 dogs across the watershed, with about 16,187 dogs whose owners do not pick up after them. Using the resulting dog population estimate, the annual load due to dogs was estimated as:

$$PAL_d = N_d \times FC_d \times Conversion \times 365\frac{days}{year}$$

Where:

PAL_d = Potential annual *E. coli* loading attributed to dogs
N_d = Number of dogs that owners do not pick up after
FC_d = Fecal coliform loading rate of dogs, 5.00×10^9 cfu fecal coliform per dog per day (EPA 2001)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)

Therefore, the estimated potential annual loading attributed to dogs is: 5.55×10^{17} cfu *E. coli* per year.

OSSFs

Using the OSSF estimates, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. Methods to estimate OSSF locations and numbers are described in Chapter 4 of this WPP. The annual load from OSSFs was calculated as:

$$PAL_{ossf} = N_{ossf} \times N_{hh} \times Production \times Fail\ Rate \times FC_s \times Conversion \times 365\frac{days}{year}$$

Where:

PAL_{ossf} = Potential annual *E. coli* loading attributed to OSSFs
N_{ossf} = Number of OSSFs
N_{hh} = Average number of people/household (2.05)
Production = Assumed sewage discharge rate; 70 gallons per person per day (Borel et al. 2015)
Fail Rate = Assumed failure rate; 15% (Reed, Stowe and Yanke 2001)
FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (EPA 2001)
Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner and Moench 2009) and mL to gal (3578.4 mL per gallon)

The estimated potential annual loading across all subwatersheds due to OSSFs is: 1.01×10^{18} cfu *E. coli* per year.

Urban Stormwater Runoff

GIS analysis was used to calculate potential loadings from impervious or urbanized stormwater runoff. Using NLCD data, the acres of developed land cover (assumed impervious) were identified in each subwatershed. Annual runoff and potential annual loading were calculated for each subwatershed using the Simple Method outlined by the Center for Watershed Protection (Collins et al. 2008). Annual runoff is calculated as:

$$R = P \times P_j \times R_v$$

Where:

R = Runoff (inches)
P = Average annual precipitation
P_j = Fraction of annual rain events that produce runoff. Assumed to be 0.9 (Collins, Hirschman and Schueler 2008)
R_v = Runoff coefficient

R_v is the runoff coefficient derived from empirical data and is calculated as:

$$R_v = 0.05 + 0.9 \times I_a$$

Where:

I_a = the fraction of impervious area in the subwatershed

Potential annual load is then calculated as:

$$PAL_{urban} = C \times R \times A \times Conversion$$

Where:

PAL_{urban} = Potential annual *E. coli* loading due to urban and impervious runoff
C = Average *E. coli* concentration for urbanized runoff, assumed to be 4.73×10^3 cfu/100mL (Makepeace, Smith and Stanley 1995)
R = Runoff as calculated above
A = Acres of developed/impervious surface
Conversion = Unit conversion (1.03×10^{-3})

The estimated potential annual loading across all subwatersheds due to urbanized/impervious runoff is:
4.27×10^7 cfu *E. coli* per year.

WWTFs

Potential loadings from WWTFs were calculated for all permitted dischargers with a bacteria monitoring requirement. Potential loads were calculated as the sum of the maximum permitted discharges of all WWTFs multiplied by the maximum permitted *E. coli* concentration:

$$PAL_{wwtf} = Discharge \times Concentration_{max} \times Conversion \times 365\frac{days}{year}$$

Where:

PAL_{wwtf} = Potential annual *E. coli* loading due to wastewater treatment plant discharges
Discharge = Maximum permitted daily discharge
$Concentration_{max}$ = Maximum average permitted concentration of *E. coli* in wastewater discharge (126 cfu/100 mL)
Conversion = Unit conversion (3785.4 mL/gal)

There are two WWTFs operation scenarios: current scenario and future scenario. The estimated potential annual loading of current and future scenarios across all subwatersheds due to WWTF discharges are: 3.27×10^{13} cfu *E. coli* per year and 4.34×10^{13} *E. coli* per year, respectively.

Appendix A. References

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Appendix B: Load Reduction Calculations

Livestock

E. coli loading reductions resulting from implementation of conservation plans and WQMPs involves potential reductions from a variety of livestock. However, since cattle are the dominant livestock in the watershed, cattle were assumed the species managed through livestock-focused management.

According to USDA NASS data, there are approximately 1,383 producers and an estimated 30,787 AnU of cattle in the Mid and Lower Cibolo Creek watershed (see Appendix A). As a result, a broad estimate of 22.3 AnU of cattle per producer was made. This can also be interpreted at 22.3 AnU of cattle addressed by each conservation plan or WQMP. In reality, each WQMP or conservation plan will vary in size and number of animal units addressed. Actual potential load reductions will vary by actual existing land conditions, proximity to water bodies, number of animal units addressed by the management measure and the types of BMPs implemented by the plan.

To estimate expected *E. coli* reductions, efficacy values of likely BMPs were calculated from median literature reported values (Table 36). These BMPs were determined based on feedback from members of the Agriculture Work Group. Because the actual BMPs implemented per WQMP or conservation plan are unknown, an overall median efficacy value of 0.58 (58%) was used to calculate load reductions. The proximity of implemented BMPs to water bodies will influence the effectiveness at reducing loads. A proximity factor of 0.05 (5%) is used for BMPs in upland areas and 0.25 used in riparian areas. Since there is uncertainty in both the specific BMPs and the locations where plans are implemented, an average proximity factor of 0.15 was used.

Table 36. Best management practice effectiveness.

Management Practice	*E. coli* Removal Efficacy		
	Low	High	Median
Exclusionary fencing[1]	30%	94%	62%
Prescribed grazing[2]	42%	66%	54%
Stream crossing[3]	44%	52%	48%
Watering facility[4]	51%	94%	73%

[1]Brenner et al. 1996; Cook 1998; Hagedorn et al. 1999; Line 2002; Line 2003; Lombardo et al. 2000; Meals 2001; Meals 2004; Peterson et al. 2011
[2]Tate et al. 2004; EPA 2010.
[3]Inamdar et al. 2002; Meals 2001
[4]Byers et al. 2005; Hagedorn et al. 1999; Sheffield et al. 1997

Total potential load reductions from WQMPs and conservation plans were calculated with the following equation:

$$LR_{cattle} = N_{plans} \times \frac{AnU}{Plan} \times FC_{cattle} \times Conversion \times 365\frac{days}{year} \times Efficacy \times Proximity\,Factor$$

Where:

LR_{cattle} = Potential annual load reduction of *E. coli*
N_{plans} = Number of WQMPs and conservation plans, 100 are proposed in this WPP
AnU/Plan = Animal Units of cattle (~1,000 lbs of cattle) per management plan, 22.3 AnU
FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^9 cfu fecal coliform per AnU per day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)
Efficacy = Median BMP efficacy value, 0.58
Proximity Factor = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.15

The Agriculture Work Group estimated that on average, approximately 40 producers across the watershed would be willing to implement some type of management measure through WQMPs and conservation plans if assistance was provided.

Based on this estimate, the WPP recommends the implementation of 40 WQMPs or conservation plans across the entire Mid and Lower Cibolo Creek watershed, resulting in a total potential reduction of 2.21×10^{14} cfu *E. coli* per year. Additionally, nutrient reductions can be anticipated with each WQMP or conservation plan. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions ranging from 733 to 983 pounds of nitrogen and 276 to 511 pounds of phosphorus per WQMP or conservation plan depending on presumed size and type of agricultural operation (Schramm et al. 2017; Schramm et al. 2019).

Feral Hogs

Loading reductions for feral hogs assume that existing feral hog populations can be reduced and maintained by a certain amount on an annual basis. Removal of a feral hog from the watershed is assumed to also completely remove the potential bacteria load generated by that feral hog. Therefore, the total potential load reduction is calculated as the population reduction in feral hogs achieved in the watershed. Based on GIS analysis, 10,576 feral hogs were estimated to exist across the Mid and Lower Cibolo Creek watershed (see Appendix A for details). The established goal is to reduce and maintain the feral hog population 15% below current population estimates, thus resulting in a 15% reduction in potential loading that is attributable to feral hogs. Load reductions were calculated based on the following:

$$LR_{fh} = N_{fh} \times FC_{fh} \times Conversion \times Proximity\ Factor\ \times 365 \frac{days}{year}$$

Where:

LR_{fh} = Potential annual load reduction of *E. coli* attributed to feral hog removal
N_{fh} = Number of feral hogs removed
FCfh = Fecal coliform loading rate of feral hogs, 1.00×1010 cfu fecal coliform per AnU per day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench 2009)
Proximity Factor = 0.25

The estimated potential annual loading across the Mid and Lower Cibolo Creek watershed based on reducing and maintaining the population by 15% (1,587 feral hogs) is 5.52×10^{13} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for each feral hog removed. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions 6 pounds of nitrogen and 2 pounds of phosphorus per hog removed (Schramm et al. 2017; Schramm et al. 2019).

Domestic Pets

The Mid and Lower Cibolo Creek watershed contains approximately 40,467 dogs. *E. coli* loading from dogs is based on the assumption that 40% of dog owners do not properly dispose of dog waste. Load reductions are based on the assumption that approximately 12% of pet owners that do not currently dispose of pet waste will respond to the management measure efforts (Swann, 1999). Therefore, the goal is to increase the number of pet owners that dispose of pet waste by 4,857 pet owners in the entire Mid and Lower Cibolo Creek watershed. Since these management measures will be most effective in public areas and places with higher concentrations of dogs, a proximity factor of 0.05 was included to account for the fact that the majority of these areas are upland or further away from riparian areas. The resulting reductions are calculated by:

$$LR_d = N_d \times FC_d \times Conversion \times Effectiveness\ Factor \times 365 \frac{days}{year}$$

Where:

LR_d = Potential annual load reduction of *E. coli* attributed to proper dog waste disposal
N_d = Number of additional dog owners disposing of pet waste
FC_d = Fecal coliform loading rate of dogs, 3.97 ×109 cfu fecal coliform per dog per day (EPA, 2001)
Effectiveness Factor = 0.75
Conversion = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner and Moench, 2009)

The estimated potential load reduction attributed to this management measure in Mid and Lower Cibolo Creek is 3.32×10^{15} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for every additional dog managed. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions between 0.8 and 1.0 pounds of nitrogen and 0.2 pounds of phosphorus per additional dog managed (Schramm et al. 2017; Schramm et al. 2019).

OSSFs

OSSFs are common in the Mid and Lower Cibolo Creek watershed with an estimated 17,325 OSSFs in the watershed, respectively. OSSF failures are factors of system age, soil suitability, system design and maintenance. For this area of the state, a 15% failure rate is typically assumed (Reed, Stowe & Yanke 2001). Load reductions can be calculated as the number of assumed failing OSSFs replaced. The following equation was used to calculate potential load reductions:

$$LR_{ossf} = N_{ossf} \times N_{hh} \times Production \times FC_s \times Conversion \times \ Proximity\ Factor\ \times 365 \frac{days}{year}$$

Where:

LR_{ossf} = Potential annual load reduction of *E. coli* attributed to OSSF repair/replacement
N_{ossf} = Number of OSSFs repaired/replaced
N_{hh} = Average number of people per household (2.65)
Production = Assumed sewage discharge rate; 70 gallon per person per day (Borel et al. 2012)
FC_s = Fecal coliform concentration in sewage; 1.0×106 cfu/100mL (EPA 2001)
Conversion = Conversion rate of 126/200 from fecal coliform to *E. coli* (Wagner and Moench 2009) and mL to gallon (3785.4 mL per gallon)
Proximity Factor = 0.5 for very limited soil suitability

In the Mid and Lower Cibolo Creek watershed, it is assumed that 50 OSSFs to be repaired or replaced. It results in a potential reduction of 4.04×10^{15} cfu *E. coli* annually. Additionally, nutrient reductions can be anticipated for every OSSF replaced. The Tres Palacios Watershed Protection Plan and Carancahua Bay Watershed Protection Plan estimated annual load reductions between 11.6 and 20.5 pounds of nitrogen and 2.9 and 4.8 pounds of phosphorus per additional OSSF repaired or replaced (Schramm et al. 2017; Schramm et al. 2019).

Appendix B. References

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Appendix C: Watershed Protection Plan Review Checklist

EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA 2008) describes the nine elements critical for achieving improvements in water quality that must by sufficiently included in a WPP for it to be eligible for implementation funding through the Clean Water Act Section 319(h) funds. These elements do not preclude additional information from being included in the WPP. This Appendix briefly describes the nine elements and references the chapters and sections that fulfill each element.

Name of Water Body	Mid and Lower Cibolo Creek
Assessment Units	1913_01, 1913_02, 1913_03, 1902_01, 1902_02, 1902_03, 1902_04, 1902_05, 1902a_01, 1902a_02, 1902a_03, 1902a_04, 1902a_05, 1902b_01, 1902b_02, 1902c_01
Impairments Addressed	Bacteria and depressed dissolved oxygen
Concerns Addressed	Impaired fish community, nitrate, total phosphorus

Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources identified, described and mapped	Ch. 3 pgs. 24-29, Ch. 4 pgs. 30-39, Ch.5 pgs. 40-45, Appendix A
2. Subwatershed sources	Ch. 5 pgs. 51-58
3. Data sources are accurate and verifiable	Ch. 5 pgs. 40-45, Appendix A
4. Data gaps identified	Appendix A
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Ch. 5, Appendix B
2. Load reductions linked to sources	Ch. 5 pgs. 51-58
3. Model complexity is appropriate	Appendix B
4. Basis of effectiveness estimates explained	Ch. 6 Tables 23-30, Appendix B
5. Methods and data cited and verifiable	Appendix B
Element C: Management Measures Identified	
1. Specific management measures are identified	Ch. 6 pgs. 60-72
2. Priority areas	Ch. 6 Tables 23-30
3. Measure selection rationale documented	Ch. 6 pgs. 60-72
4. Technically sound	Ch. 6
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Ch. 9 pgs. 80-82
2. Estimate of financial assistance	Ch. 9 pgs. 82-85
Element E: Education/Outreach	
1. Public education/information	Ch. 7 pgs. 74-76
2. All relevant stakeholders are identified in outreach process	Ch. 7 pgs. 73-74
3. Stakeholder outreach	Ch. 7 pgs. 73-76
4. Public participation in plan development	Ch. 7 pgs. 73-74
5. Emphasis on achieving water quality standards	Ch. 7 pgs. 73-74
6. Operation and maintenance of BMPs	Ch. 8 Table 31

Element	Report Section(s) and Page Number(s)
Element F: Implementation Schedule	
1. Includes completion dates	Ch. 8 Table 31
2. Schedule is appropriate	Ch. 8 Table 31
Element G: Milestones	
1. Milestones are measurable and attainable	Ch. 8 Table 31, Ch. 10
2. Milestones include completion dates	Ch. 8 Table 31, Ch. 10
3. Progress evaluation and course correction	Ch. 8 Table 31, Ch. 10
4. Milestones linked to schedule	Ch. 8 Table 31, Ch. 10
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Ch. 6 Tables 23-30
2. Criteria measure progress toward load reduction goal	Ch. 6 Tables 23-30
3. Data and models identified	Ch. 6 Tables 23-30, Appendix B
4. Target achievement dates for reduction	Ch. 10
5. Review of progress toward goals	Ch. 10 pg. 87
6. Criteria for revision	Ch. 10 pgs. 87-88
7. Adaptive management	Ch. 10 pg. 88
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Ch. 10 pgs. 86-87
2. Monitoring measures evaluation criteria	Ch. 10 pgs. 86-87
3. Routine reporting of progress and methods	Ch. 10 pgs. 86-87
4. Parameters are appropriate	Ch. 10 pgs. 86-87
5. Number of sites is adequate	Ch. 10 pgs. 86-87
6. Frequency of sampling is adequate	Ch. 10 pgs. 86-87
7. Monitoring tied to QAPP	Ch. 10 pgs. 86-87
8. Can link implementation to improved water quality	Ch. 10 pgs. 86-87

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