Kickapoo Creek WPP

A Guidance Document Developed by the Stakeholders of Kickapoo Creek Watershed to Address Water Quality in Kickapoo Creek (Assessment Unit 0605A).

TIAER TR2302

Kickapoo Creek Watershed Protection Plan

A Guidance Document Developed by the Stakeholders of the Kickapoo Creek Watershed to Address the Water Quality in Kickapoo Creek (Assessment Unit 0605A)

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Cover photo: Kickapoo Creek at site 22164 in Henderson County, Texas

ACKNOWLEDGEMENTS

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Background information characterizing the watershed was developed as part of a previous project, *Characterizing the Kickapoo Creek in Henderson County,* also funded by TSSWCB, which the Texas Institute for Applied Environmental Research (TIAER) conducted in partnership with the Angelina-Neches River Authority (ANRA). Reports associated with this characterization project can be accessed from the project website: https://img1.wsimg.com/blobby/go/a8e964db-a942-4185-8025-413095321e29/downloads/Kickapoo.Characterization.Final.Report.pdf?ver=1645118653396

For more information about this document of the Kickapoo Creek WPP, please visit the project website at: https://www.tarleton.edu/tiaer/kickapoo-creek-wpp/.

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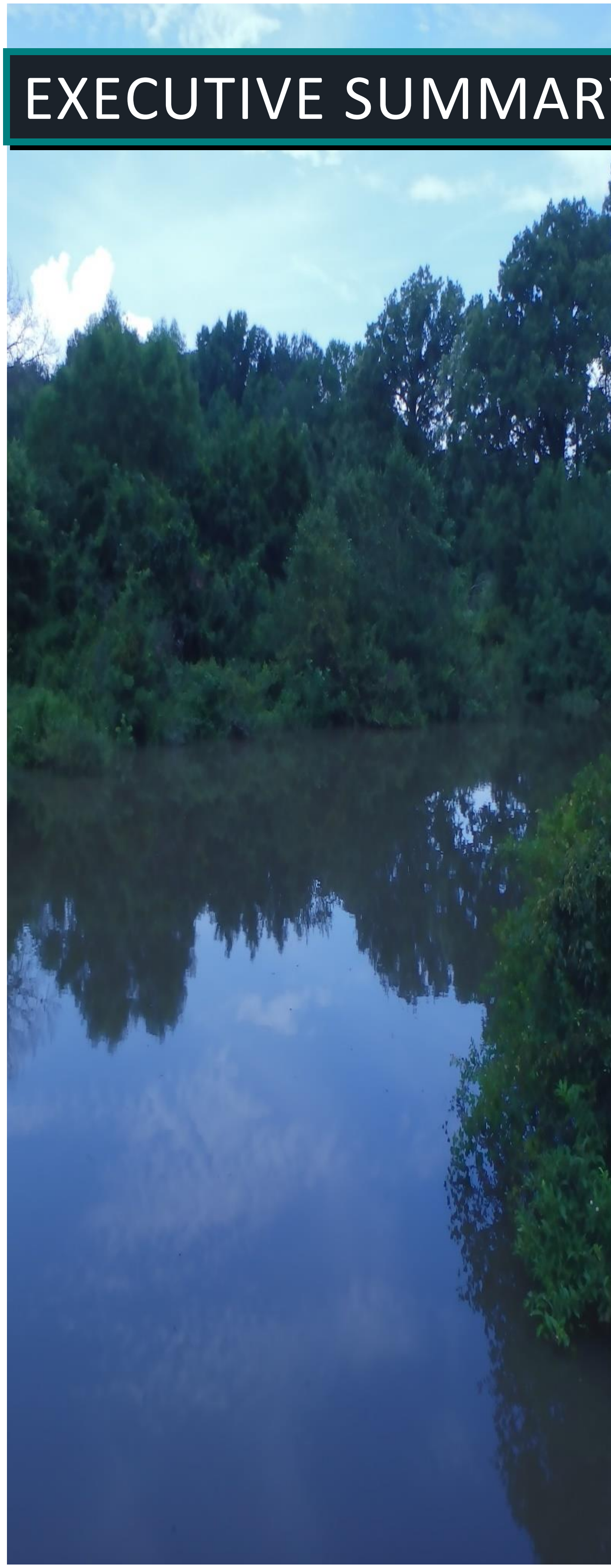
LIST OF ACRONYMS

Acronym	Meaning
ac	Acre
AgriLife Extension	Texas A&M AgriLife Extension Service
AI	Adaptive Implementation
ALU	Aquatic Life Use
AU	Assessment Unit
ANRA	Angelina-Neches River Authority
AnU	Animal Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
CCN	Community Crisis Network
cfu	Colony Forming Unit
cfs	Cubic Feet Per Second
CP	Conservation Plan
CR	County Road
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DAR	Drainage-Area Ratio Method
DO	Dissolved Oxygen
ECHO	Environmental Compliance History Online
E. coli	Escherichia coli
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FDC	Flow Duration Curve
FM	Farm-To-Market
FSA	Farm Service Agency
ft	Feet

GIS	Geographic Information System
hr	Hour
I&I	Inflow and Infiltration
km	Kilometer
LDC	Load Duration Curve
LIP	Landowner Incentive Program
m	meter
mi	Mile
mg/L	Milligram per Liter
mL	Milliliter
MGD	Million Gallons per Day
MPN	Most Probable Number
MS4s	Municipal Separate Storm Sewer Systems
MRLC	Multi-Resolution Land Characteristics Consortium
NASS	National Agricultural Statistics Service
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NPS	Nonpoint Source
NRCS	National Resources Conservation Service
OSSF	On-Site Sewage Facility
PCR	Primary Contact Recreation
RCPP	Regional Conservation Partnership Program
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SSO	Sanitary Sewage Overflows
SWCD	Soil and Water Conservation District
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
Texas Integrated Report	Texas Integrated Report of Surface Water Quality
TCEQ	Texas Commission on Environmental Quality
TDC	Texas Demographic Center
TIAER	Texas Institute for Applied Environmental Research

TMDL	Total Maximum Daily Load
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas State Water Quality Standards
TxDOT	Texas Department of Transportation
USCB	U.S. Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF/P	Waste Water Treatment Facility/Plant

EXECUTIVE SUMMARY



Kickapoo Creek is a rural watershed located in east Texas within Henderson and Van Zandt Counties. The Kickapoo Creek Watershed Partnership was formed to create this guidance document. The goal of the partnership is to improve the overall health of the Kickapoo Creek watershed.

PROBLEM STATEMENT

Kickapoo Creek (0605A) has a history of elevated bacteria concentrations, and since 2000, the Texas Commission on Environmental Control (TCEQ) has listed Water Body 0605A as impaired for bacteria based on the Texas State Water Quality Standards (TSWQS). This impairment means that Kickapoo Creek does not meet the criterion for primary contact recreation (PCR) indicating an increased health risk if participating in activities, such as swimming, which have a high likelihood of water ingestion. The criterion for PCR is 126 colonies per 100 milliliters (mL). The TCEQ assesses support by comparing the geometric mean of *Escherichia coli* (*E. coli)* from samples collected over a set period (generally 7 years) as part of its water quality inventory, which is conducted once every two years. The water quality inventory is presented within the Texas Integrated Surface Water Quality Report. This WPP was based upon the 2020 Texas Integrated Report which indicated bacteria impairments within assessment units (AUs) 0605A_01 and 0605A_02. The 2020 Texas Integrated Report also indicated a depressed dissolved oxygen impairment for AU 0605A_01. Nutrient levels were also elevated, especially chlorophyll-a.

KICKAPOO CREEK WATERSHED PROTECTION PLAN OVERVIEW

A watershed protection plan is a locally, voluntarily driven way to address 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 Kickapoo Creek WPP follows the Environmental Protection Agency's (EPA) nine key elements that are designed to provide guidance for the development of an effective WPP (EPA, 2008).

THE WATERSHED APPROACH

The watershed approach is widely accepted by state and federal water resource management, the watershed approach is used to facilitate water quality management. The 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). One important factor of the watershed approach is that it focuses on hydrologic boundaries to address potential water quality impacts to all stakeholders.

POLLUTANT SOURCES

Backed with credible science, stakeholder input was used to identify potential sources of fecal-derived bacteria pollutants and DO depressing nutrient pollutants. Sources of bacteria loadings identified in the watershed include: cattle, wildlife, and domestic pets/animals, permitted discharges, unauthorized discharges, and failing on-site sewage facilities (OSSFs).

RECOMMENDED ACTIONS

Six primary recommended actions were made to improve water quality in the Kickapoo 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:

1. Water Quality Management Plans or Conservation Plans

To manage bacteria 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.

2. Feral Hog Control

Feral hog management was identified as a big need in the Kickapoo 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.

3. On-Site Sewage Systems

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

4. Sanitary Sewer Overflows (SSOs)

Although infrequent, SSOs and unauthorized Waste Water Facility (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 the proper disposal of fats, oils, grease, and other disposables so they do not cause damage to collection systems.

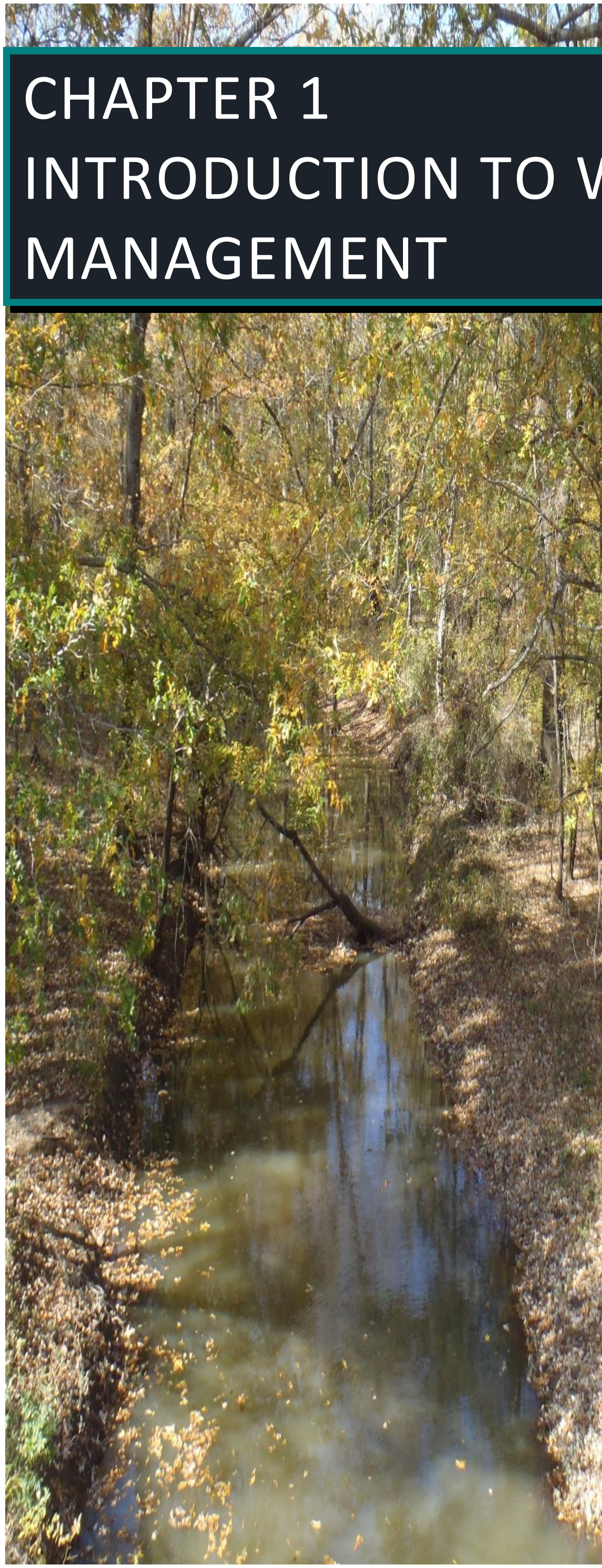
5. Illicit Dumping

Illicit dumping is difficult to quantify in terms of impact on 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.

6. Pet Waste

Pet waste was identified as a contributor to bacteria and nutrient loadings in the watershed. Outreach and education are key components to the proper management of pet waste by owners. Increasing the amount of pet waste stations in apartment complexes and public parks, should one be built in the watershed, will also increase the likelihood of proper waste disposal.

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 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 that are backed by sound science (EPA 2008). One critical aspect of the watershed approach is that it focuses on hydrologic boundaries rather than political boundaries in order 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 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 Kickapoo 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 the implementation
6. Schedule for implementing management measures
7. Milestones for the progress of WPP implementation
8. Criteria for determining success of WPP implementation
9. Water quality monitoring

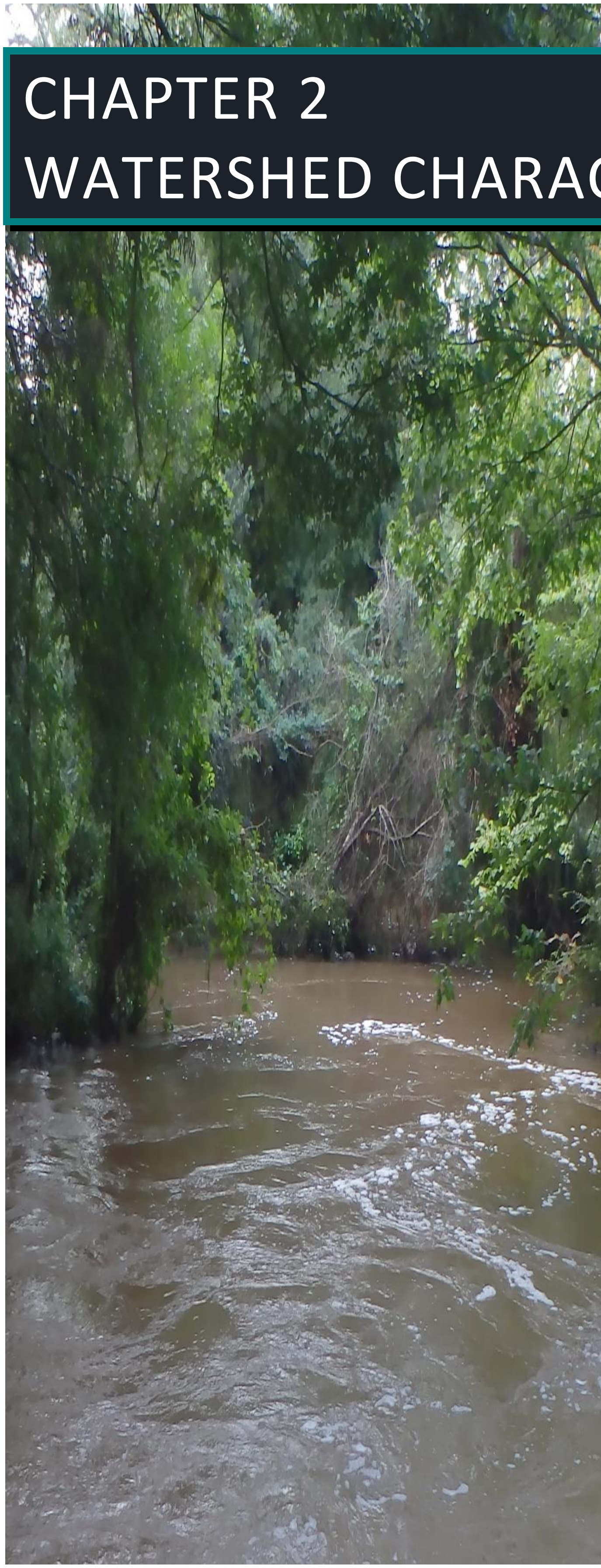
ADAPTIVE MANAGEMENT

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 approach 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 adjust as needed to the implementation strategy. The utilization of an adaptive management process will help to focus effort, implement strategies, and maximize the impact on pollutant loadings throughout the watershed over time.

EDUCATION AND OUTREACH

The development and implementation of a WPP depend 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

KICKAPOO CREEK

The Kickapoo Creek watershed comprises of 176,759 acres and is located almost completely within Henderson County, Texas with a small, northwest portion extending into Van Zandt County (Figure 2.1, Table 2.1). Headwaters for Kickapoo Creek are at the confluence of Lake Palestine outside of the City of Chandler in Henderson County and continues into Van Zandt County. Municipalities within the watershed include Edom, Murchison, and Brownsboro. However, the City of Brownsboro is the only municipality along the water body.

Segment and AUs identified by TCEQ in Figure 2.1 include the following:

- 0605A: Kickapoo Creek in Henderson County from the confluence of Lake Palestine east of Brownsboro in Henderson County to the upstream perennial portion of the stream northeast of Murchison in Henderson County.
- 0605A_01: From the confluence with Lake Palestine (0605) east of Brownsboro in Henderson County to the confluence with Slater Creek (0605E).
- 0605A_02: From the confluence with Slater Creek (0605E) upstream to the confluence with unnamed tributary about 1.62 km north of FM 858 in Van Zandt County at NHD RC 120200010000161.

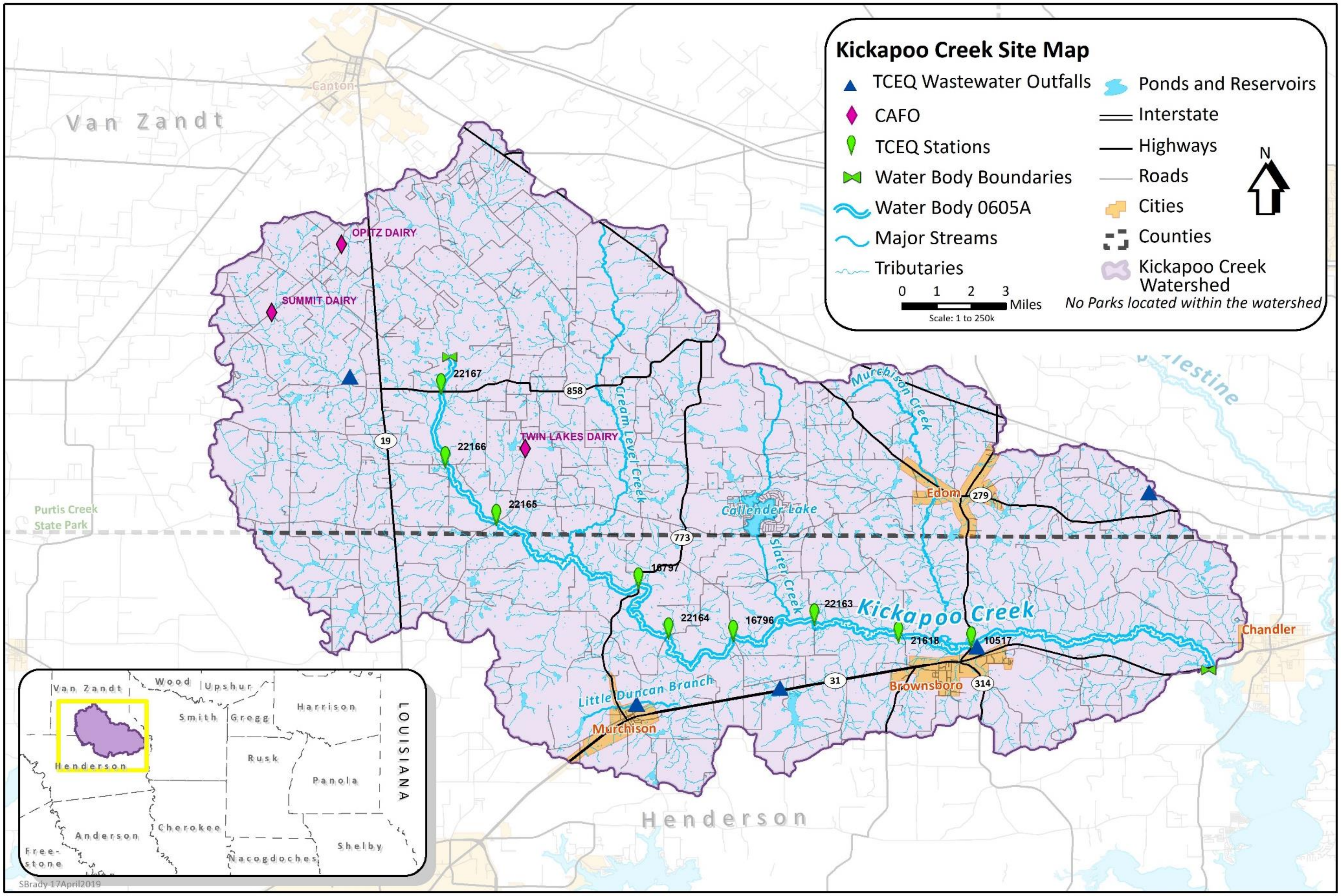

Kickapoo Creek Site Map
TCEQ Wastewater Outfalls
CAFO
TCEQ Stations
Water Body Boundaries
Water Body 0605A
Major Streams
Tributaries
Ponds and Reservoirs
Interstate
Highways
Roads
Cities
Counties
Kickapoo Creek Watershed
0 1 2 3 Miles
Scale: 1 to 250k
No Parks located within the watershed
N
Van Zandt
Canton
OPITZ DAIRY
SUMMIT DAIRY
TWIN LAKES DAIRY
22167
22166
22165
16797
22164
16796
22163
21618
10517
858
19
773
279
31
314
Cream Level Creek
Callender Lake
Slater Creek
Murchison Creek
Kickapoo Creek
Little Duncan Branch
Edom
Brownsboro
Murchison
Chandler
Purtis Creek State Park
Henderson
Wood
Upshur
Smith
Gregg
Harrison
Rusk
Panola
Cherokee
Anderson
Freestone
Nacogdoches
Shelby
LOUISIANA
SBrady 17April2019

Figure 2.1 Watershed and assessment units associated with water body 0605A, Kickapoo Creek

WATERSHED CHARACTERISTICS

This chapter provides geographic, demographic, and water quality overviews of the Kickapoo Creek watershed. Development of the information in this chapter relied heavily on state and federal data resources as well as watershed stakeholder knowledge and insight. Watershed specifics in this chapter are critical to the reliable assessment of potential sources of water quality impairment and the recommendation of beneficial management measures.

WATERSHED DESCRIPTION

Kickapoo Creek is defined as from the confluence of Lake Palestine east of Brownsboro in Henderson County to the upstream perennial portion of the stream northeast of Murchison in Henderson County. Kickapoo Creek is classified by TCEQ as a perennial stream. The watershed is comprised of 176,759 acres. The predominately rural watershed is located almost completely in Henderson County with a small, northwest portion extending into Van Zandt County (Figure 2.2). Headwaters for Kickapoo Creek are at the confluence of Lake Palestine outside the City of Chandler in Henderson County and continues to flow into Van Zandt County. Municipalities within the watershed include Edom, Murchison, and Brownsboro. However, the City of Brownsboro is the only municipality along the water body.

Table 2.1 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 (%)
Henderson County	607,820.63	78,975.06	12.99	44.11
Van Zandt County	550,663.27	100,084.90	18.18	55.89
Entire Watershed		179,059.96		100.00

PHYSICAL CHARACTERISTICS

SOILS AND TOPOGRAPHY

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

Most of the soils (about 62%) in the watershed are well drained with hydrologic soil groups of A and B (Figure 2.3). They include the Pickton, Wolfpen, Nahatche, Freestone, Monco, and Bernaldo soil types. A small proportion (about 17%) of soils are moderately drained with the hydrologic soil group of C. Majority of the moderately drained soil come under Cuthbert soil type. Poorly drained soil is estimated to be about 21% of the watershed. The majority of them are Woodtell and Derlys soil types. The hydrologic soil group map is shown in Figure 2.3, with A representing well-drained soils and D identifying poorly drained soils.

The Kickapoo Creek watershed is a predominately mid-sloping watershed. Approximately 30% of the watershed has less than a 2% slope. Forty-three percent of the watershed has mild slopes ranging from 2% to 5%. Moderate slopes of between 5% - 10% occur in 21% of the watershed area with the remaining 6% area with high slopes. The highest point in the watershed has an elevation of 694 ft and the lowest point 343 ft (Figure 2.4).

ECOREGIONS/LAND USE AND LAND COVER

Ecoregions are land areas with ecosystems that contain similar quality and quantity of natural resources (Griffith et al., 2007). The headwaters of Kickapoo Creek lie within the Northern Post Oak Savanna ecoregion (33a) with the lower portion of the watershed within the Tertiary Uplands ecoregion (35a) (Griffith, et al., 2007). The watershed is primarily rural with only 5% of the watershed comprised of developed land (Figure 2.5). The dominant land use is hay/pasture comprising of 56% of the watershed area largely within the uplands. Riparian areas within Kickapoo Creek watershed are predominately deciduous forest or woody wetlands transitioning to evergreen forest only in the most eastern portion of the watershed. The native deciduous forest is composed mostly of post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and black hickory (*Carya texana*). Some coniferous trees occur, especially among the transitional boundary of Ecoregion 33a and Ecoregion 35a (Griffith et al., 2007). The soils of the watershed are generally well-drained loamy sands or sandy loams in the uplands and frequently flooded loams along the creeks and riparian areas (Stringer, 1998; Hatherly and Mays, 1979). While the riparian areas are largely wooded, frequent flooding and soil wetness severely limits commercial timber production in these areas.

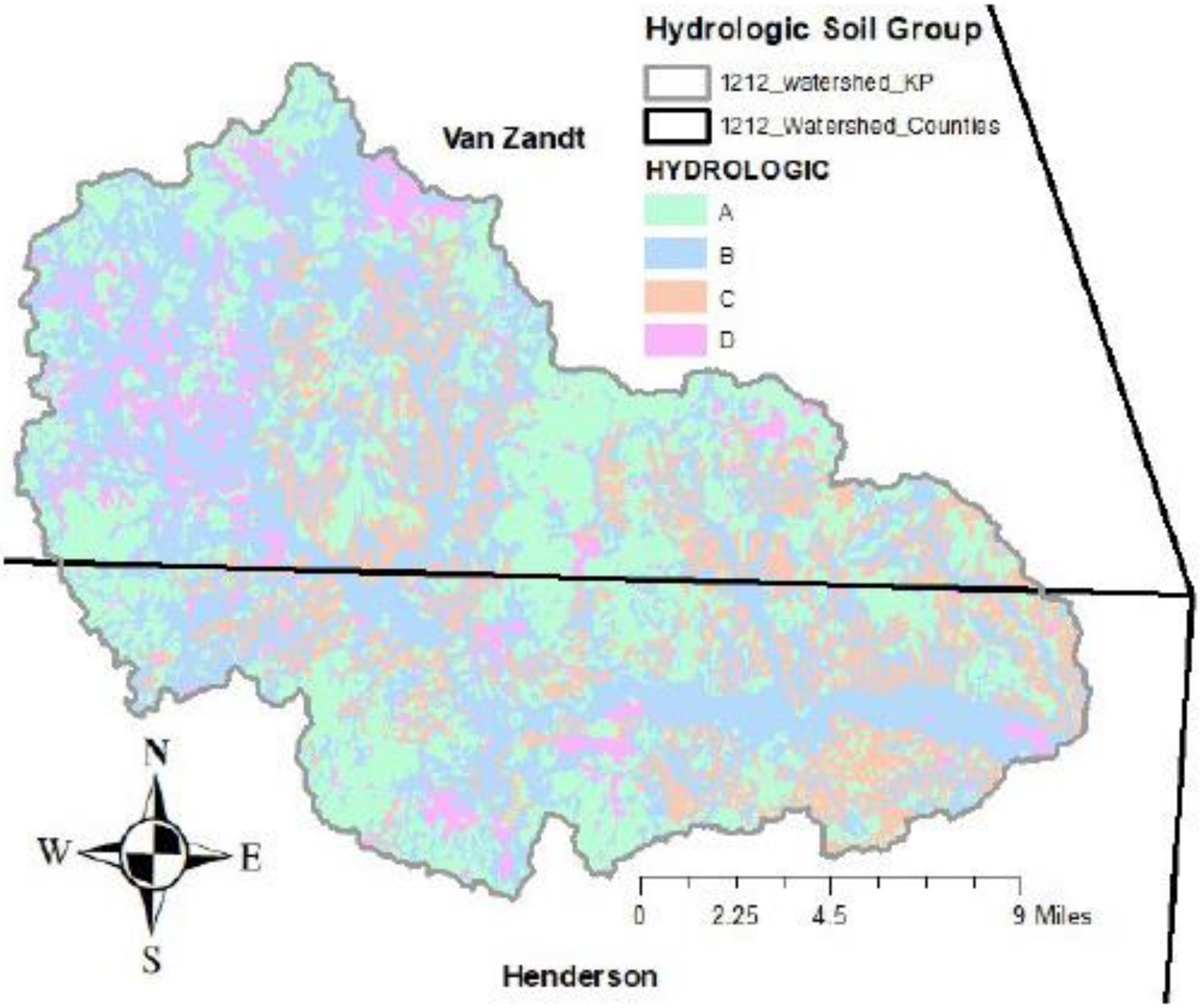


Figure 2.3 **Kickapoo Creek watershed showing drainage characteristics based on the hydrologic soil group**

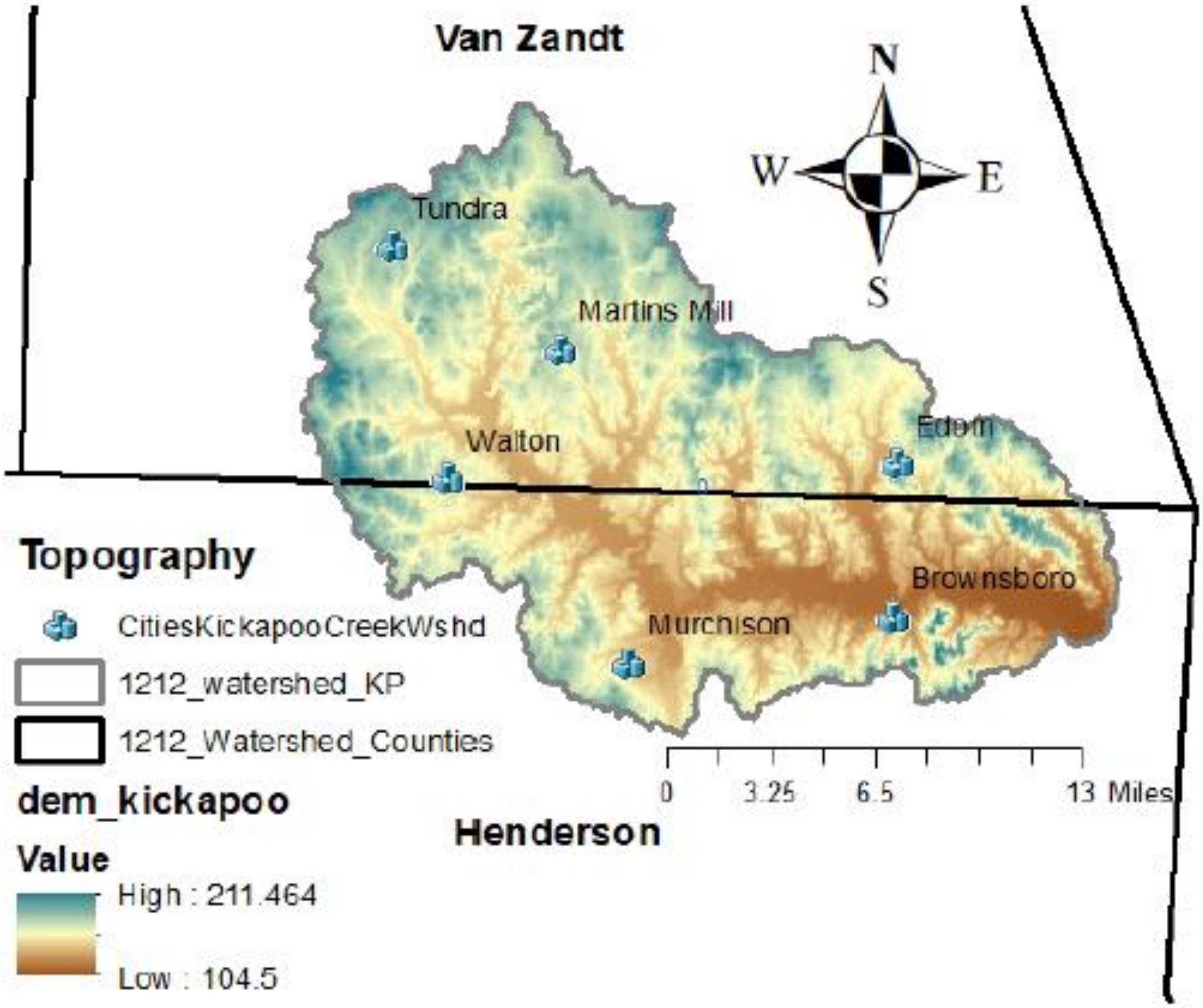

Van Zandt
N
W
E
S
Tundra
Martins Mill
Walton
Edom
Topography
Brownsboro
CitiesKickapooCreekWshd
Murchison
1212_watershed_KP
1212_Watershed_Counties
0
3.25
6.5
13 Miles
dem_kickapoo
Henderson
Value
High : 211.464
Low : 104.5

Figure 2.4 Topography of the Kickapoo Creek watershed

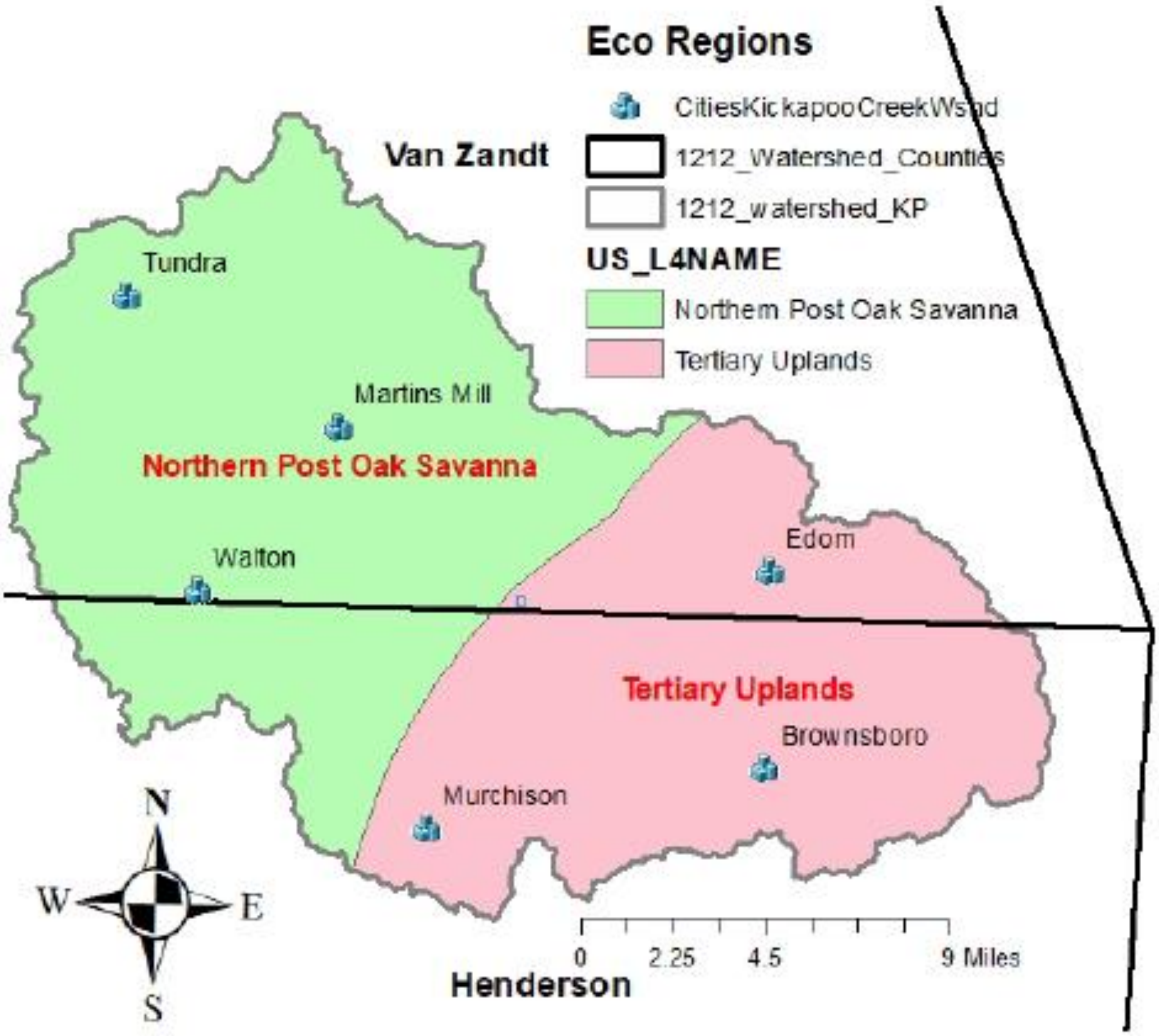


Figure 2.5 Ecoregions of the Kickapoo Creek watershed

Table 2.2 Land use/land cover classes within Kickapoo Creek watershed

Land Cover Category	Area (acres)	Proportion of watershed (%)
Hay/Pasture	99,832	56.5%
Mixed Forest	32,674	18.5%
Woody Wetlands	20,367	11.5%
Evergreen Forest	5,802	3.3%
Developed, Low Intensity	4,133	2.3%
Developed, Open Space	3,966	2.2%
Open Water	2,760	1.6%
Grassland/Herbaceous	2,729	1.5%
Emergent Herbaceous Wetlands	1,607	0.9%
Shrub/Scrub	1,290	0.7%
Deciduous Forest	977	0.6%
Developed, Medium Density	304	0.2%
Barren Land	236	0.1%
Developed, High Intensity	61	0.0%
Cultivated Crops	22	0.0%
Total	176,759	100%

Only 5% of the watershed being comprised of developed land. The dominate land use is hay/pasture comprising of 56% of the watershed area largely within the uplands. Riparian areas within the Kickapoo Creek watershed are predominately deciduous forest or woody wetlands transitioning to evergreen forest only in the most eastern portion of the watershed. The major portion of the Kickapoo Creek watershed is rural with predominant land covers of hay/pasture (56%), forest (22%), and wetlands (12%) (Figure 2.6).

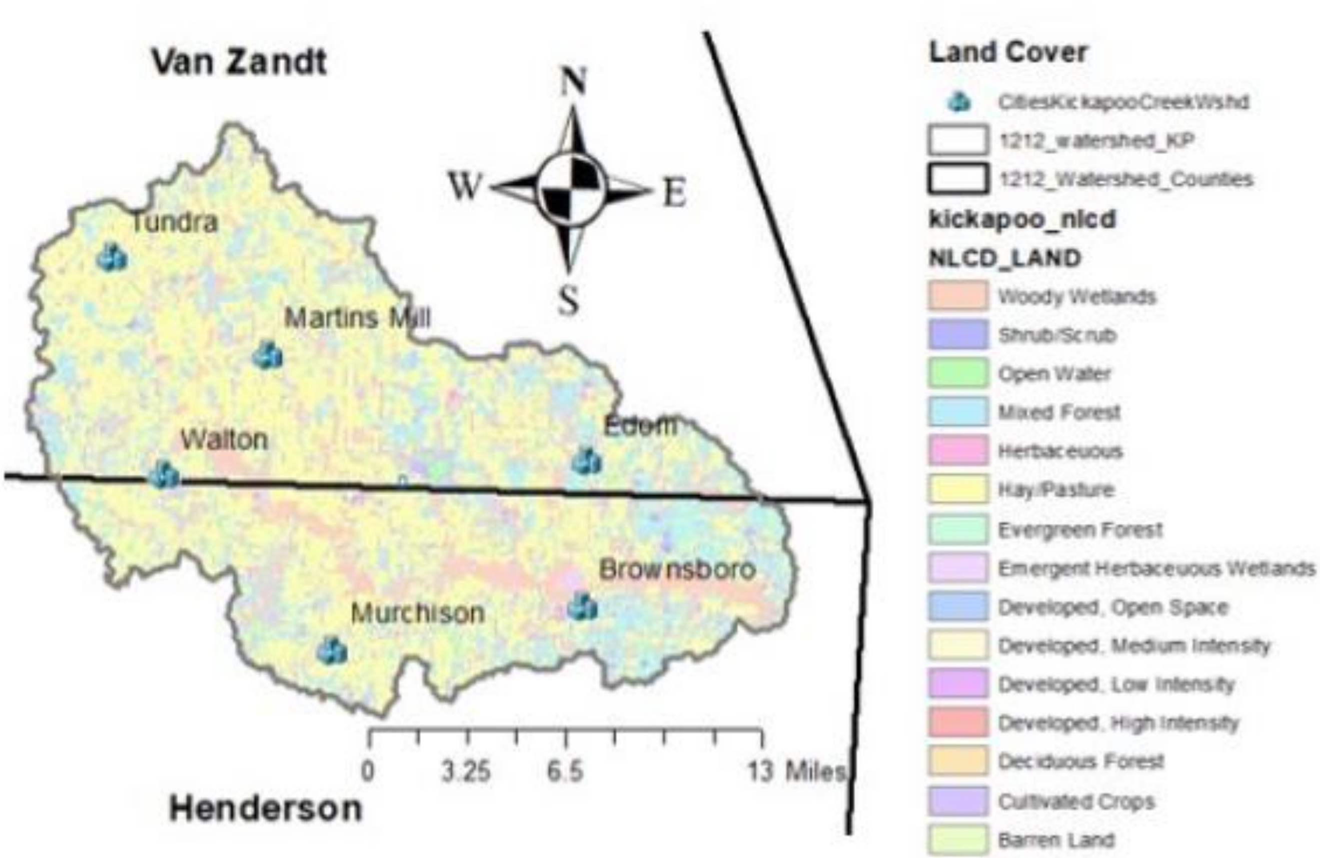


Figure 2.6 Land cover data for the Kickapoo Creek watershed

The land use/land cover categories within the watershed are described as follows from the NLCD legend:

Hay/Pasture: Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Mixed Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous no evergreen species are greater than 75% of total tree cover.

Woody Wetlands: Areas where forest or shrubland vegetation accounts for greater than 20% of vegetation cover and the soil or substrate is periodically saturated with or covered with water.

Evergreen Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

Developed, Low Intensity: Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.

Developed, Open Space: Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas are most commonly including large-lot, single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Open Water: Areas of open water, generally with less than 25% cover of vegetation or soil.

Grassland/Herbaceous: Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Emergent Herbaceous Wetlands: Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Shrub/Scrub: Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Deciduous Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

Developed, Medium Intensity: Areas with mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.

Barren Land (Rock/Sand/Clay): Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthly material. Generally, vegetation accounts for less than 15% of total cover.

Developed, High Intensity: Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial areas. Impervious surfaces account for 80% to 100% of total cover.

Cultivated Crops: Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

CLIMATE

There is no active weather station recording precipitation and temperature data within the Kickapoo Creek watershed. The closest weather stations in proximity to the watershed are located in Tyler, Texas (Tyler Pounds Field GHCND: USW00013972) and Athens, Texas (Athens Municipal Airport: KF44). Both Tyler and Athens stations show more or less similar weather patterns. To show the average climate for the watershed, data from Tyler, population 104,789 based on the U.S. Census Bureau (USCB, 2019), was used in this report. The average annual precipitation is about 48 inches (1,200 mm). The watershed receives some type of precipitation every month, however, June, October and December are the rainiest months and July and August are the least rainy months (Figure 2.7) Summer is usually hot with maximum temperatures in the 90s°F and minimum temperatures in the 70s°F. Spring and fall temperatures range from 60s°F and 70s°F for the maximum and 40s°F and 50s°F for the minimum. Snowfall in the winter is rare to none with maximum temperature in the 50s°F and minimum temperature in the 30s°F.

DEMOGRAPHICS

Population estimates for the Kickapoo Creek watershed were developed using the annual estimates of the resident population for incorporated places (USBC, 2019) and the 911 address database (911.gov; tnris.org) that has the information on the number of households. The estimates shown in Table 2.3 are the most recent in the last 10 years.

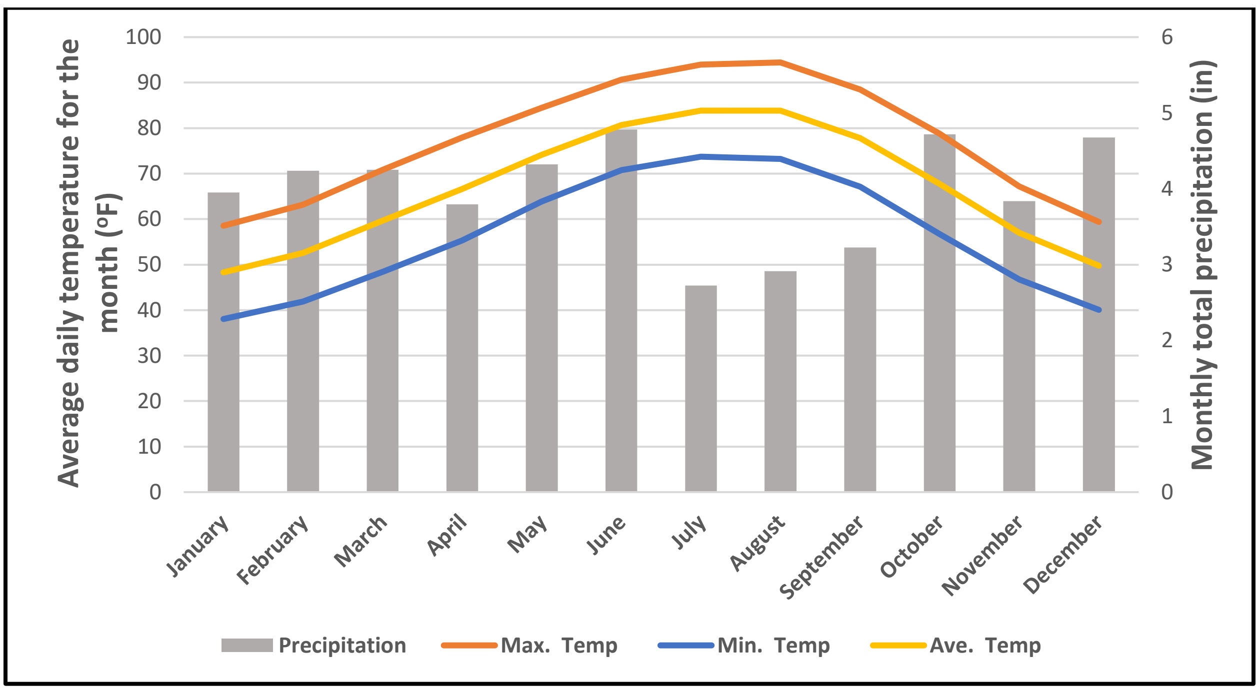


Figure 2.7 Average monthly climate of the watershed including total precipitation, normal average, maximum and minimum air temperatures for Tyler, Texas (average of 1991 to 2020)

Table 2.3 Annual Estimates of the Resident Population for Incorporated Places

(Source: USCB, 2019)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Edom	373	372	369	369	371	373	382	386	389	392
Murchison	592	590	592	585	589	587	591	594	599	599
Brownsboro	1,044	1,044	1,044	1,045	1,063	1,069	1,076	1,227	1,250	1,279
Rural										18,392
Watershed Total										20,662

Edom, Murchison, and Brownsboro are the cities in the watershed for which population estimates are available. Majority of the watershed is rural and the rural population is estimated by clipping the 911 address database of both Van Zandt and Henderson Counties (together) with the Kickapoo Creek watershed boundary. The number of rural households within the watershed obtained in the previous step (6,476) is multiplied by the average population per household (2.84/household for Texas) to estimate the total population within the watershed. The total estimated watershed population is about 20,662.

From Table 2.3, what we can notice immediately is that there is a 14% increase in the estimated population of Brownsboro from 2016 to 2017. Edom and Murchison show more or less a steady population over a period of 10 years from 2010. Table 2.4 shows projected population growth in the watershed from 2020 to 2050. The trend shows a slight increase in population until 2030 and a small decrease thereafter until 2050. Barring a 14% reduction in Brownsboro population in the future there is nothing important to notice from the projected population estimates. The total current population in the watershed is not expected to change dramatically in the next three decades.

Table 2.4 Project Estimates of the Resident Population for Incorporated Places (Estimated based on the projected population growth for counties). Source, Texas Demographic Center (TDC, 2021).

Year	2020	2025	2030	2035	2040	2045	2050
Edom	381	388	393	396	396	398	400
Murchison	594	597	598	595	589	584	578
Brownsboro	1,081	1,088	1,089	1,084	1,073	1,063	1,053

CHAPTER 3
WATER QUALITY

INTRODUCTION

All across Texas, water quality is monitored to support the water body's designated uses as defined in the Texas Water Code. Designated uses and associated standards are developed by the 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, agriculture, 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 the "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 the applicable standards. The development of a stakeholder-driven WPP is another potential strategy. By encouraging stakeholders to address possible causes and

Table 3.1 Water quality monitoring stations

Station	AU	Location
10517	0605A_01	Kickapoo Creek crossing at FM 314 in Henderson County
16796	0605A_02	Kickapoo Creek crossing at FM 1803 in Henderson County
16797	0605A_02	Kickapoo Creek crossing at FM 314 in Henderson County
21618	0605A_01	Kickapoo Creek crossing at Henderson CR 3514 in Henderson County
22163	0605A_01	Kickapoo Creek near the crossing at Henderson CR 3520 in Henderson County
22164	0605A_02	Kickapoo Creek near the crossing at Henderson CR 3806 in Henderson County
22165	0605A_02	Kickapoo Creek crossing at FM 1861 in Van Zandt County
22166	0605A_02	Kickapoo Creek crossing at CR 4206 in Van Zandt County
22167	0605A_02	Kickapoo Creek crossing at FM 858 in Van Zandt County

threats of impairments and giving them decision-making powers to set WPP goals, WPPs can provide comprehensive, long-term restoration plan with water body assessments and protection strategies.

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 *2022 Texas Integrated Report* includes an assessment of water quality data collected from 2011 to 2018. This period is greater than the two years prior to the start of the efforts to develop this WPP. This WPP is based upon data from the *2020 Integrated report.*

The *Texas Integrated Report* assesses water bodies at the Assessment Unit (AU) level. An AU is a sub-area of the segment, defined as the smallest geographic area of use support reported in the assessment (TCEQ, 2020). Each AU is intended to have relatively homogeneous chemical, physical and hydrological characteristics, which allows a way to assign site-specific standards (TCEQ, 2020). A segment identification number and AUs are combined and assigned to each water body to divide a segment. For example, Kickapoo Creek is segment 0605A and has two AUs, 0605A_01 and 0605A_02 (Figure 3.1).

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 nine monitoring stations were reviewed within the Kickapoo Creek watershed (Figure 3.2).

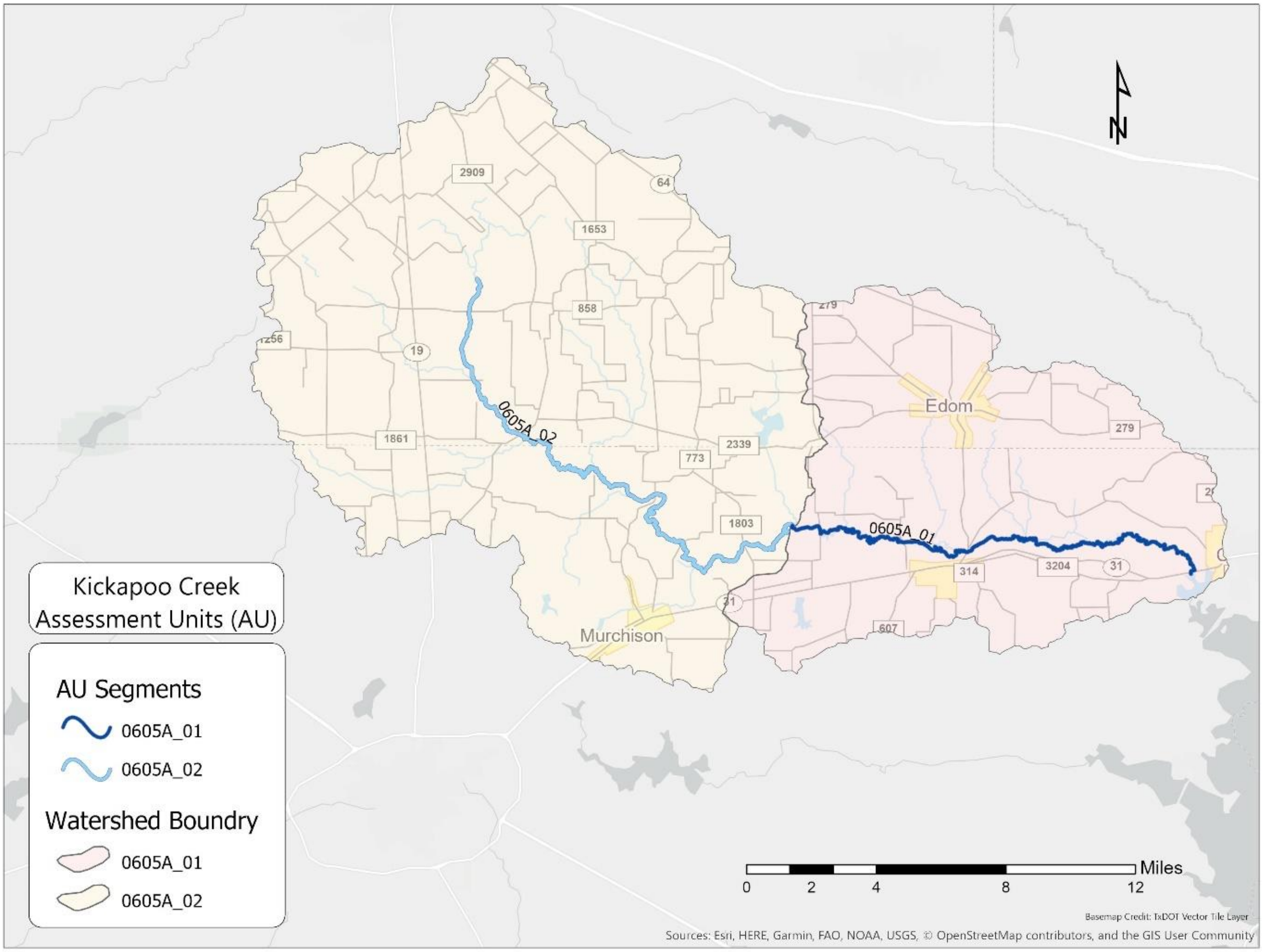


Figure 3.1 Kickapoo Creek Assessment Units (AU)

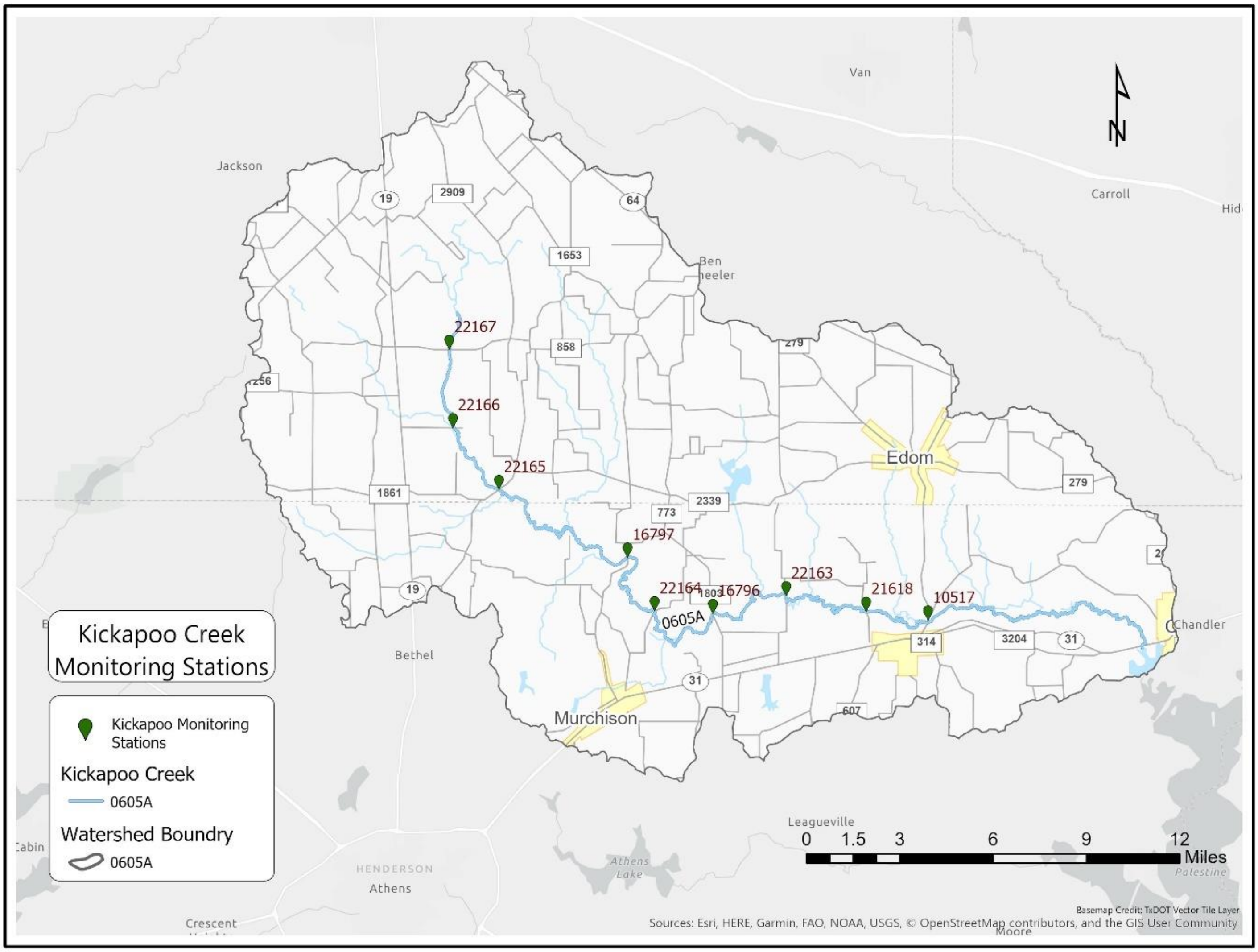


Figure 3.2 Kickapoo Creek monitoring stations (AU)

Table 3.2 Water quality monitoring station IDs in the Kickapoo Creek watershed

Upstream --->Downstream								
Segment 0605A_02						**Segment 0605A_01**		
22167	22166	22165	16797	22164	16796	22163	21618	10517

Table 3.3 History of water quality impairment in the watershed

Integrated Report Year	Bacteria Impairment Category		Dissolved Oxygen Impairment Category	
	0605A_02	0605A_01	0605A_02	0605A_01
2020	5c	5c		5c
2018	5c	5c		5c
2016	5b	5b		5c
2014	5b	5b		5c
2012		5b		5c
2010		5c		5c
2008		5c		5c
2006		5c		5c
2004		5c		
2002		5c		
2000	Not supported for contact recreation	Not supported for contact recreation		

TIAER conducted routine, monthly, ambient water quality monitoring at nine sites in the Kickapoo Creek watershed from 2019 – 2022 (Figure 3.2, Table 3.4). Routine field parameters included water temperature, pH, D.O., conductivity, and flow. Water samples were collected for analysis of *E. coil*, NH_3-N, TSS, VSS, NO_2-N+NO_3-N, TKN, PO_4-P, T.P., BOD, and CHLA. To provide additional data to aid with assessment of the indicated D.O. impairment, TIAER conducted 24-hour D.O. monitoring in conjunction with routine monthly sampling at three location sites (10517, 22164, and 22166). Also, some historic water quality samples available in sites 16796, 16797, and 10517 were also used to support the analysis (Table 3.4).

Table 3.4 Water quality data availability for the Kickapoo Creek watershed

(*Instantaneous Discharge)

Monitoring Station Description	Station ID	Period of data availability						
		Flow*	TSS	Nitro-gen	Phos-phorus	DO	BOD	Bacteria
Kickapoo Creek at FM 858	22167	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020
Kickapoo Creek at Van Zandt CR 4206	22166	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020
Kickapoo Creek at FM 1861	22165	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020
Kickapoo Creek at FM 733 near Murchison	16797	2008-2018 2019-2020	2008-2016 2019-2020	2008-2016 2019-2020	2008-2016 2019-2020	2000-2016 2019-2020	1999-2000 2019-2020	2008-2017 2019-2020
Kickapoo Creek at Henderson CR 3806	22164	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020
Kickapoo Creek at FM 1803	16796	-- 2019-2020	2005-2008 2019-2020	2005-2008 2019-2020	2000-2008 2019-2020	2000-2008 2019-2020	1999-2000 2019-2020	2005-2008 2019-2020
Kickapoo Creek upstream of Henderson CR 3520	22163	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020	2019-2020
Kickapoo Creek at Henderson 3514	21618	--- 2019-2020	--- 2019-2020	2015-2017 2019-2020	2015-2017 2019-2020	--- 2019-2020	--- 2019-2020	--- 2019-2020
Kickapoo Creek at FM 314 near Brownsboro	10517	1978-1986 2019-2020	1997-2010 2019-2020	1997-2010 2019-2020	1999-2010 2019-2020	1997-2010 2019-2020	1998-2000 2019-2020	2000-2010 2019-2020

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), primarily 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 3.7) (TCEQ, 2015).

Table 3.5 Watershed impairments in the *2020 Texas Integrated Report* for Kickapoo Creek

Parameter	Category	AUs	Criteria
Bacteria	5c*	0605A_01	126 cfu/100mL
		0605A_02	
DO 24-hr Average	5c*	0605A_01	3.0 mg/L
DO 24-hr Minimum	5c*	0605A_01	2.0 mg/L

Assessment unit, AU; colony forming unit, cfu; milliliter, mL; dissolved oxygen, DO; milligrams, mg; liter, L; hour, hr *Category 5c – Additional data or information will be collected and/or evaluated for one or more parameters before a management strategy is selected.

Table 3.6 Watershed concerns identified in the *2020 Texas Integrated Report*

Parameter	AUs	River Reach	Criteria
Bacteria	0605A_01	Kickapoo Creek	126 cfu/100mL
	0605A_02		
DO 24 hr Average	0605A_01	Kickapoo Creek	3.0 mg/L
DO 24 hr Minimum	0605A_01	Kickapoo Creek	2.0 mg/L

Table 3.7 Designated water uses for water bodies in the Kickapoo 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	Limited	<10% exceedance based on the binomial method	3.0/2.0 mg/L DO
General Use Standards	The criteria for the general use include aesthetic parameters, radiological substances, toxic substances, temperature (when surface samples are above 5°F and not attained due to permitted thermal discharges) and nutrients (screening standards or site-specific nutrient criteria)		

BACTERIA

Concentrations of fecal indicator bacteria are evaluated to assess illness risk during contact recreation. In freshwater environments, concentrations of *E. coli* bacteria are measured to determine fecal contamination in water bodies from warm-blooded animals and other sources. The presence of fecal indicator bacteria may indicate that associated pathogens from the intestinal tracts of warm-blooded animals could reach water bodies and cause illness in people that recreate in them. Indicator bacteria can originate from numerous sources, including wildlife, livestock, domestic pets, malfunctioning OSSFs, non-point source urban and agricultural runoff, sanitary sewer overflows, and direct discharges from wastewater treatment facilities (WWTFs). Under the primary contact recreation standards, the geometric mean criterion for bacteria is 126 most probable number (MPN) of *E. coli* per 100ml (30 TAC § 307.7).

Kickapoo Creek was evaluated using seven years of monitored data from December 2011 with a geometric mean criterion of 126 MPN/100 mL as the standard (Table 3.5 and 3.6). Both the upstream and downstream segments (AUs 0605A_01 and 0605A_02) have exceeded the geometric mean criteria, and therefore they are declared impaired in the 2020 Texas Integrated Report (Table 3.8).

Table 3.8 Bacterial impairment status of Kickapoo Creek

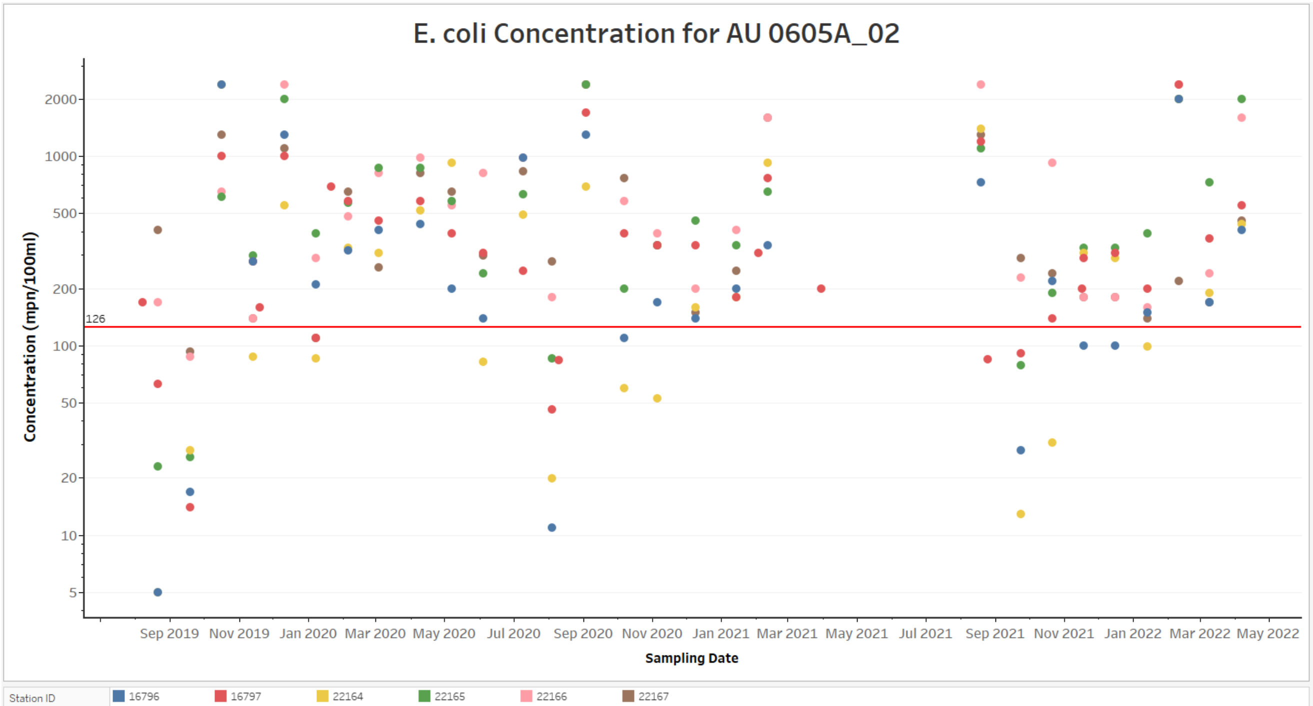
Source: 2020 Texas Integrated Report, Observations used from December 2011 to November 2018 to obtain *E. coli* geometric mean

Assessment Unit	Description	*E. coli*	Support Status
0605A_01	From the confluence with Lake Palestine (0605) east of Brownsboro in Henderson County to the confluence with Slater Creek (0605E).	307.47	Not Supporting
0605A_02	From the confluence with Slater Creek (0605E) upstream to the confluence with unnamed tributary about 1.62 km north of FM 858 in Van Zandt County at NHD RC 12020001000161.	287.89	Not Supporting

E. coli concentrations are currently measured at nine stations throughout the watershed (Table 3.4, Figure 3.2) by the TIAER monitoring team; three stations in AU 0605A_01 and six stations in AU0605A_02. With respect to the water quality criterion of 126 MPN/100 mL, all the stations show *E. coli* concentrations exceeding the criterion with the maximum exceedances (for the total number of samples) in station 22166, the second from the most upstream station, and minimum of exceedances in 22163, on the most downstream stations. Looking at the entire Kickapoo Creek, including data from all nine stations, 77% of the water samples (199 samples/260 total) monitored show *E. coli* exceedances in Kickapoo Creek. Some historic *E. coli* concentrations monitored in the previous years prior to August 2019 are also available in the TCEQ SWQM database for four stations namely 16796, 16797, 21618 and 10517 (Table 3.4, Figure 3.2). Similar to the current data, the historic data also shows significant number of E-coli exceedances in Kickapoo Creek. The entire historic Kickapoo Creek *E. coli* data shows about 72% (90 samples/125 total) of the data samples showing deteriorating water quality when compared to the stipulated water quality criterion. The individual proportions of samples exceeding the *E. coli* criterion in the historic data are 58%, 73% 83% and 73% for the stations 16796, 16797, 21618 and 10517 respectively.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is essential for aquatic organisms to survive and refers to the concentration of oxygen gas incorporated into the water. Dissolved oxygen concentrations fluctuate in the environment, but anthropogenic activities can contribute to excessive organic matter and nutrients, consequently depressing DO concentrations. Every water body assessed by the Texas State Water Quality Standards is assigned to aquatic life-use (ALU) category of either minimal, limited, intermediate, high, or exceptional. To ensure that water bodies protect these ALU categories, DO criterion are implemented. Classified water bodies must meet an average DO criterion from 2.0 to 6.0 mg/L measured over 24 hours and a minimum DO criterion from 1.5 to 4.0 mg/L (TCEQ, 2020). Unclassified streams are assigned an ALU based upon the specific segment's flow-type, categorized as perennial, intermittent with perennial pools, and intermittent without perennial pools. Specific DO criteria are associated with each unclassified stream type unless a site-specific ALU has been assigned to the unclassified water body. The 24-hour average DO criteria are measured over 24 hours, and sampling events occur at various times throughout the year to represent unbiased and seasonally representative data. When 24-hour average DO is not available, grab DO measurements are utilized and include a minimum criterion and screening level criterion (TCEQ, 2020).



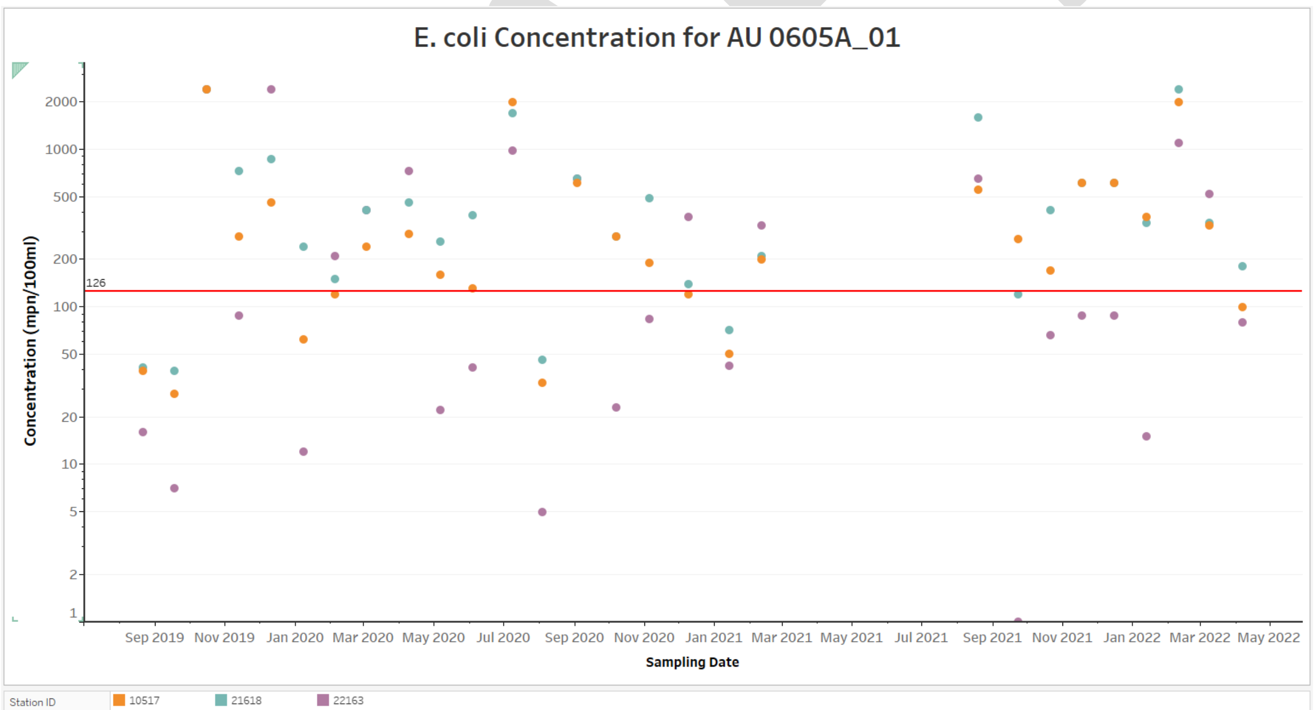


Figure 3.3 a & b **E. coli (MPN/100 mL) concentration in Kickapoo Creek at nine different stations**

Note: Data shown for stations from AU 0605A_01 and AU 0605A_02 for the period August 2019 to May 2022, red line indicates the E. coli water quality criterion of 126 MPN/100 mL, data points above the red line indicate non-compliance, y-axis is plotted in log scale.

The DO status of the Kickapoo Creek watershed was evaluated using the seven years of historical data from December 2011 (Table 3.9) against the DO standards and reported in the 2020 Texas Integrated Report. The downstream segment (AU 0605A_01) had low DO, and therefore it was declared as not supporting. However, the upstream segment (0605A_02) is fully supporting the DO criterion (Table 3.9).

DO concentrations were measured at nine stations throughout the watershed (Table 3.4 and Figure 3.2.) by the TIAER monitoring team; three stations in AU 0605A_01 and six stations in AU 0605A_02. In addition, 24 hours DO is continuously monitored in three out of those nine stations (22166, 22164, and 10517). Some historical DO concentrations monitored in the previous years, 2018 – 2021, are also available for three stations: 16796, 16796, and 10517 (Table 3.4). The grab DO concentrations were converted to dissolved oxygen saturation (DO sat) based on the method outlined in https://projects.ncsu.edu/cals/course/zo419/oxygen.html using water temperature, DO concentrations, and the elevation of the station.

When studying 24 hours DO data, with respect to the average DO criterion of 3 mg/L (Table 3.5 and 3.6), 4% (1/28 samples), 16% (4/25 samples), and 15% (4/26 samples) of water samples are below the criterion for the stations 22166, 22164, and 10517 respectively (Figure 3.4). With reference to the minimum DO criterion of 2 mg/L, 4% (1/28), 12% (3/25), and 19% (5/26) of water samples are below the criterion for the stations 22166, 22164, and 10517 respectively (Figure 3.5). The two downstream stations show some DO concentrations below the criterion with the upstream station 22166 showing no water samples below the DO minimum or average. Looking at the entire Kickapoo Creek including data from all the six stations (Figure 3.4), 11% of the water samples (9 samples/84 total) monitored show DO concentrations below the average criterion and (Figure 3.5) 11% of the water samples (9/84) show DO concentrations below the minimum criterion in the Kickapoo Creek. Historic data on 24 hours DO was not available and therefore they will not be discussed in this report.

Table 3.9 Dissolved oxygen impairment status of Kickapoo Creek

Source: 2020 Texas Integrated Report, data from December 2011 to November 2018 used to obtain DO grab minimum

Assessment Unit	Description	DO grab minimum (mg/L)	Support Status
0605A_01	From the confluence with Lake Palestine (0605) east of Brownsboro in Henderson County to the confluence with Slater Creek (0605E).	1.33 (1/3 exceedances)	Not Supporting
0605A_02	From the confluence with Slater Creek (0605E) upstream to the confluence with unnamed tributary about 1.62 km north of FM 858 in Van Zandt County at NHD RC 12020001000161.	N/A (0/18 exceedances)	Fully Supporting

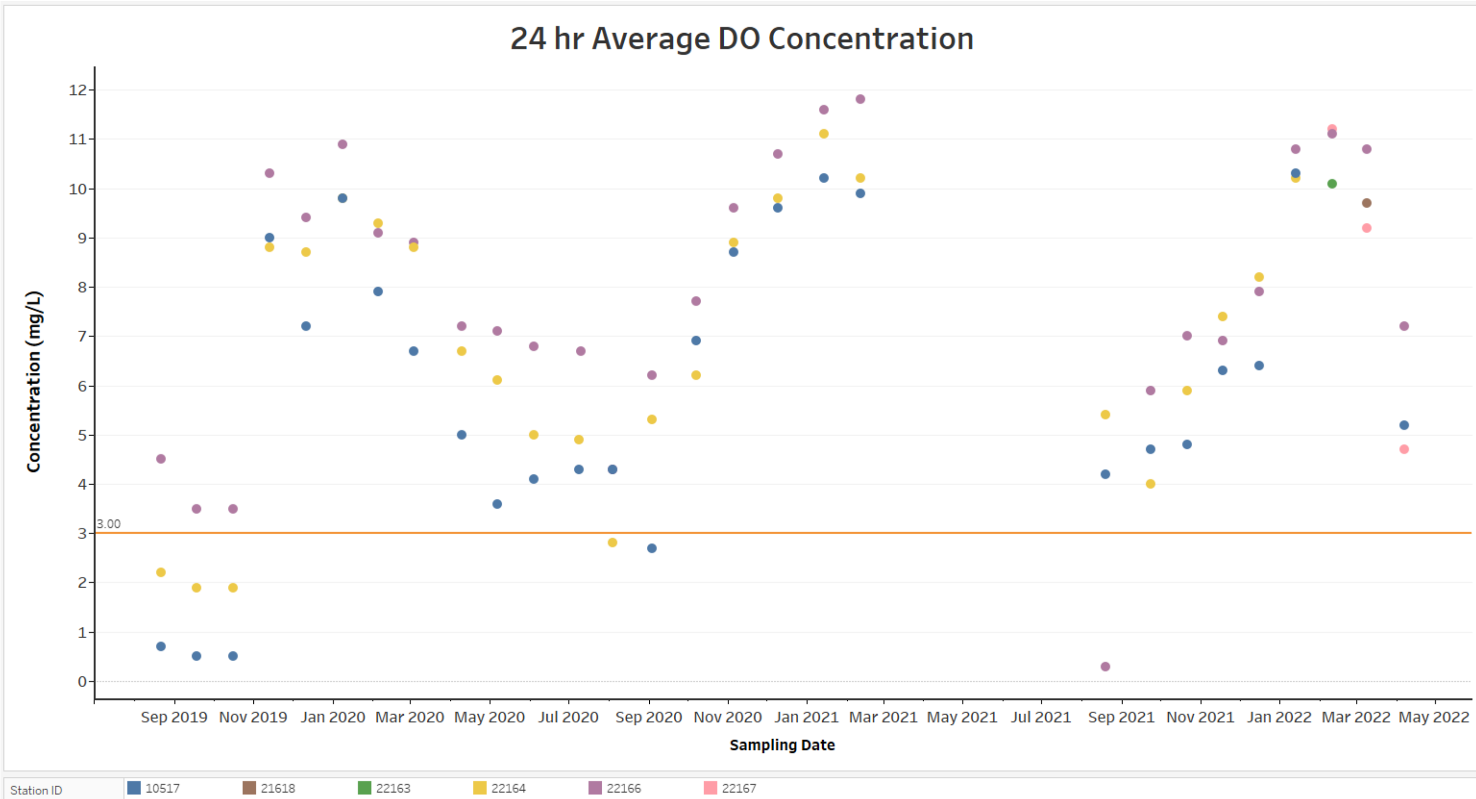


Figure 3.4 **24-hour average dissolved oxygen concentration (mg/L) in Kickapoo Creek from August 2019 to April 2022**

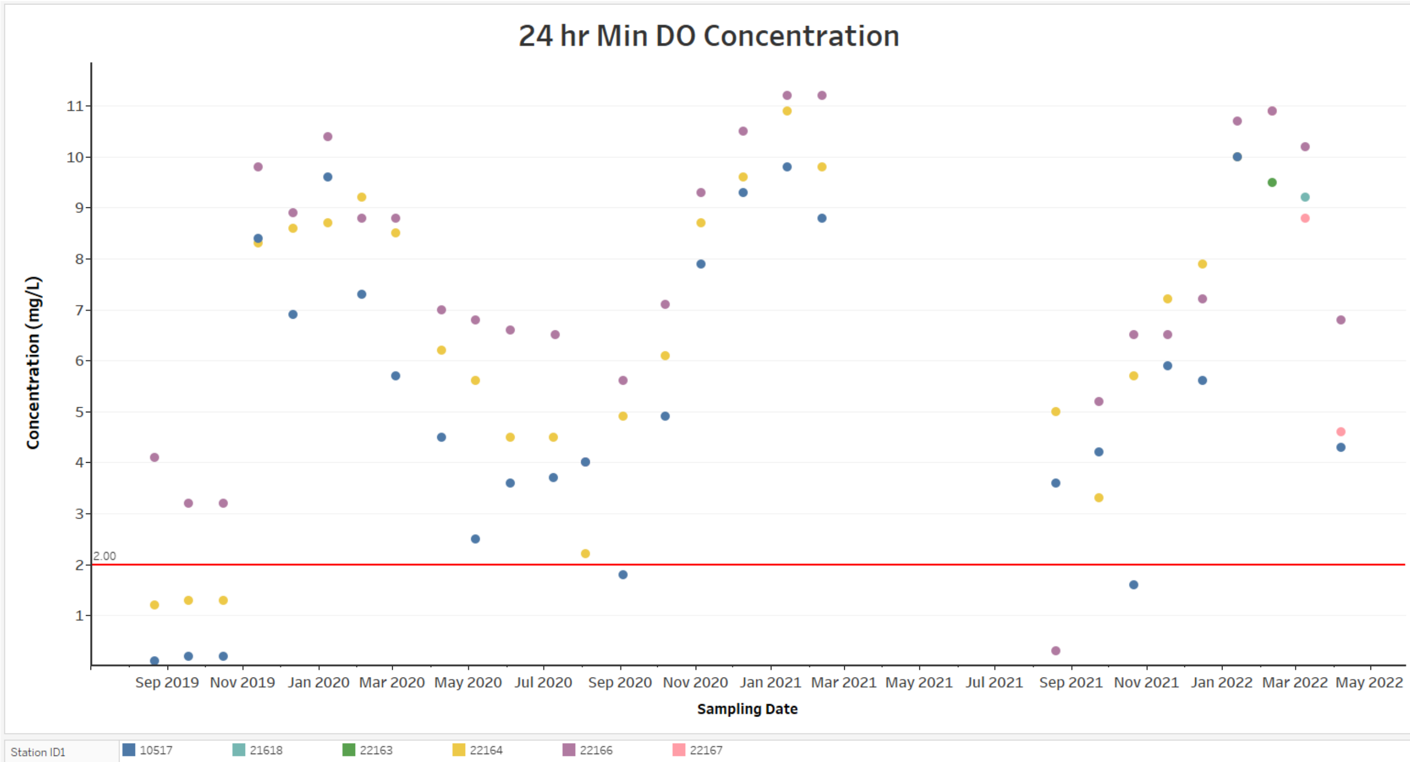


Figure 3.5 Minimum dissolved oxygen concentration (mg/L) (based on the 24-hour data) in Kickapoo Creek from August 2019 to April 2022

Note: Red line indicates the minimum water quality criterion of 2 mg/L and the orange line indicates the mean water quality criterion of 3 mg/L, data points below the red line or orange line indicate non-compliance.

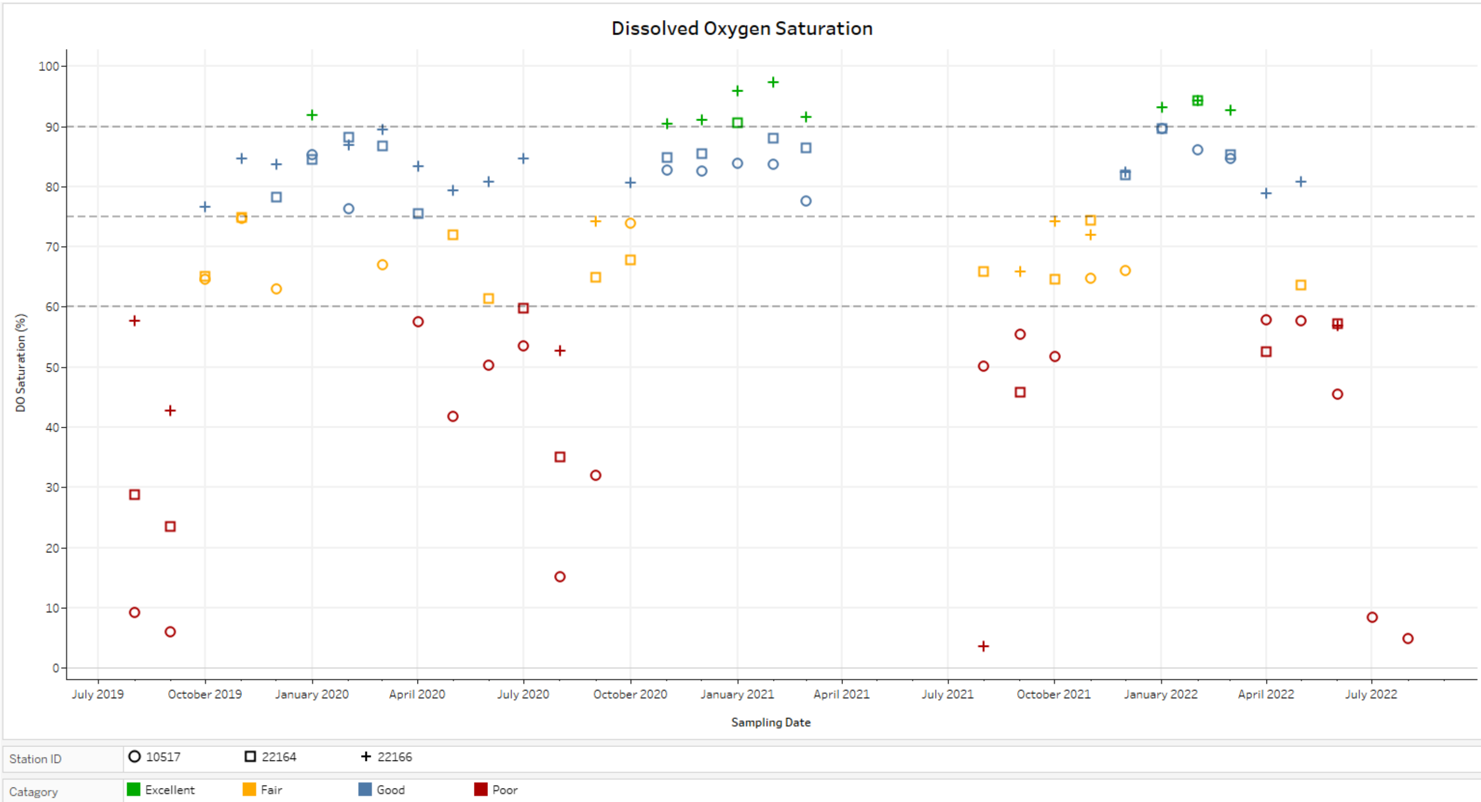


Figure 3.6 Dissolved oxygen saturation (%) in Kickapoo Creek at three stations

Note: Data shown for the three stations currently monitored in the watershed for the period August 2019 to August 2022. Numbers closer to 100 are desirable and closer to 0 are not desirable.

Current data on DO monitored at the three stations are converted to DOsat and classified into four categories as >90% DOsat: excellent; >75 and <90: good; >60 and <75: fair; and <60: poor. This categorization was created for easy interpretation of results and not based on any stipulated standards. The categorization of DOsat results of water samples for the stations is shown in (Figure 3.6). All the stations show samples under all the categories. However, majority of the water samples collected in the three stations fall under the category of good (37%), followed by poor (29%), fair (22%), and excellent (12%). From the three sites Station 10517 has the highest number of samples in poor category and least number of samples in the excellent category, whereas Station 22166 has least number of samples in the poor category and highest number of samples in the excellent category.

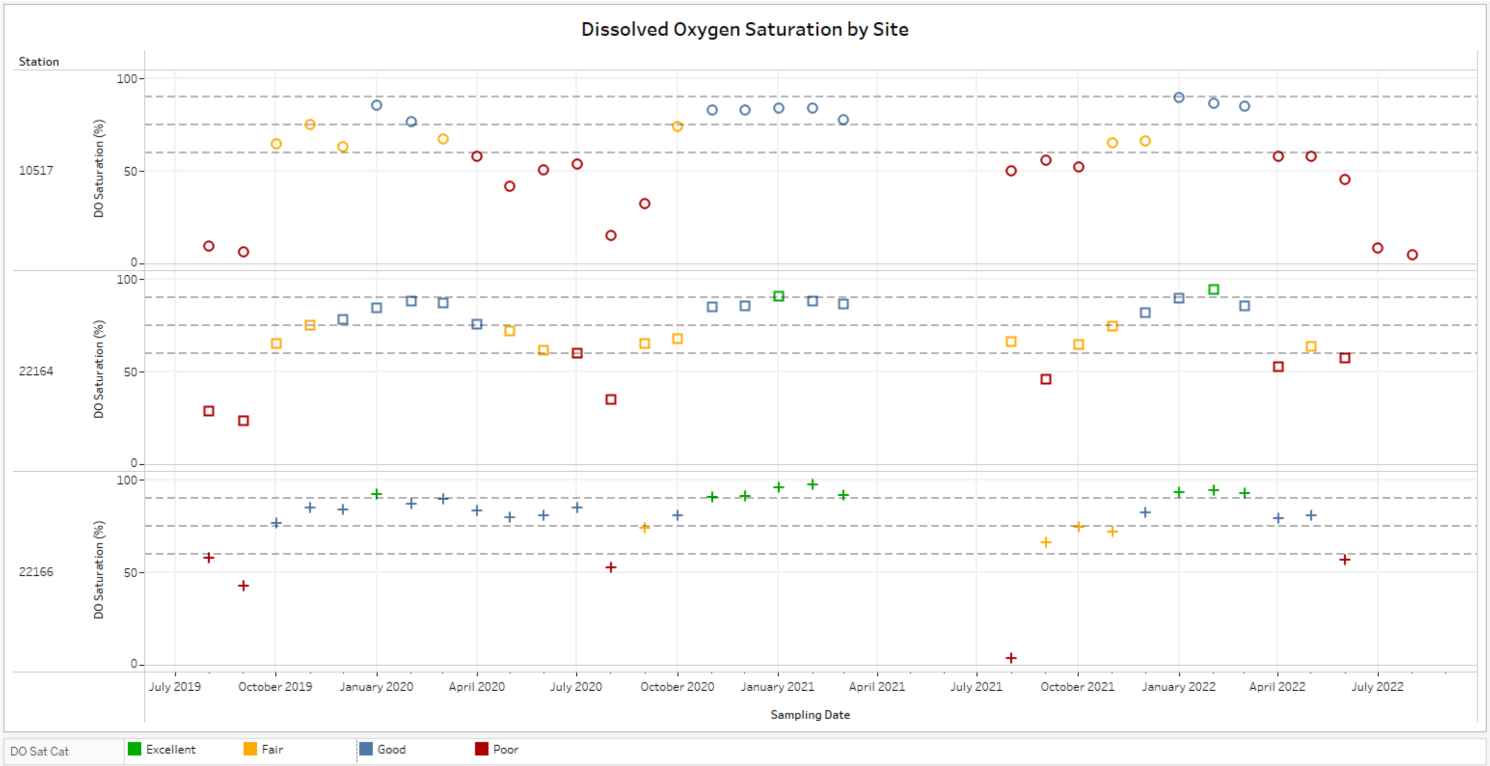


Figure 3.7 Dissolved oxygen saturation (%) in Kickapoo Creek by station

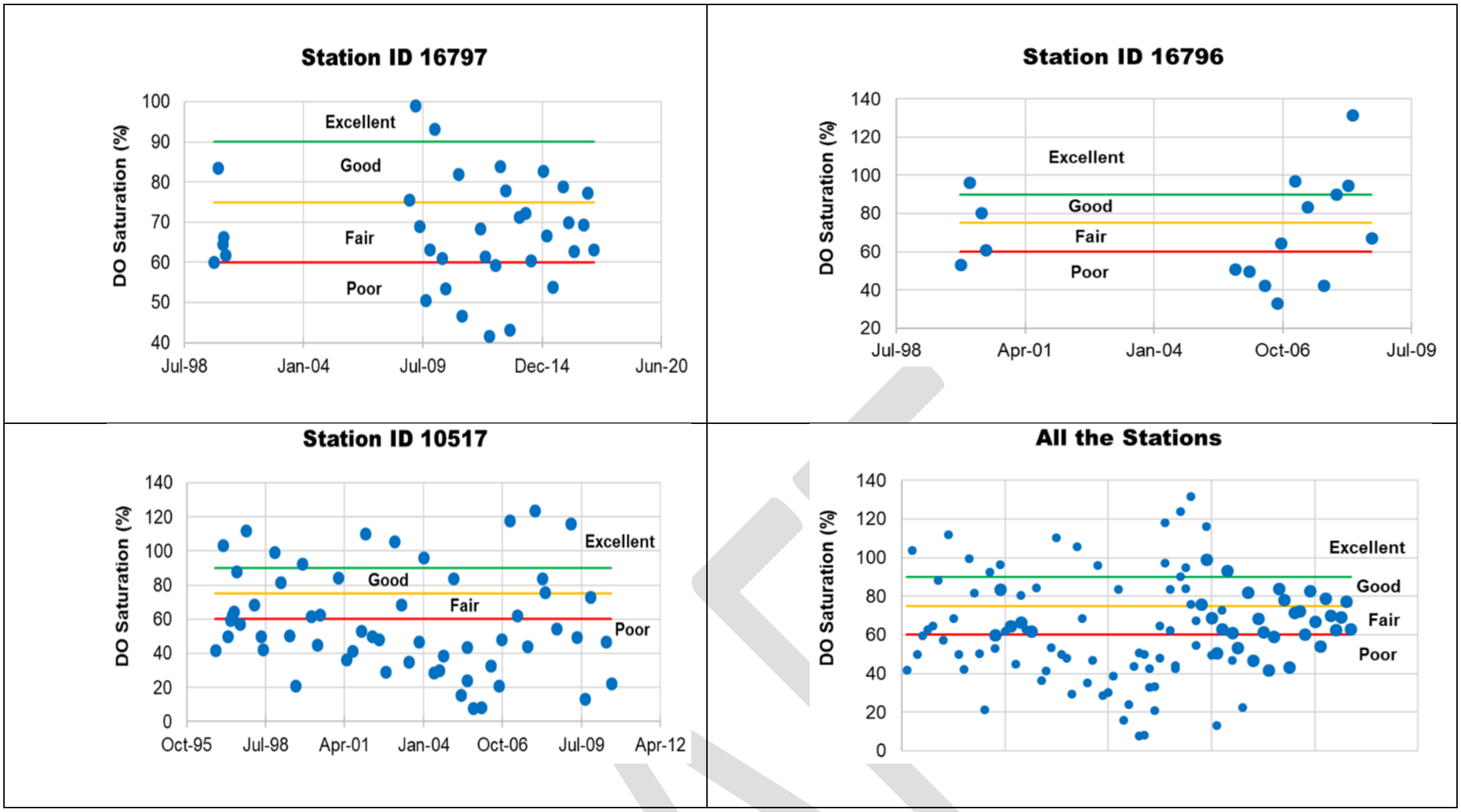


Figure 3.8 Historic data on dissolved oxygen saturation (%) in Kickapoo Creek

Note: The first three graphs show data for the three individual stations in the creek. The fourth graph shows data of all the three stations. Data points below red line indicates poor dissolved oxygen saturation (DOsat) (<60%), data points in between red and yellow lines (60 to 75 % DO saturation) show fair quality, points within yellow and green lines (>75 and <90) mean good DOsat, and those above green (>90% DOsat) indicate excellent DO conditions in the stream. The quality categorization is suggestive for easy interpretation of dissolved oxygen results and not based on any stipulated standards.

Some historic grab DO concentrations monitored in the previous years are also available for three stations, namely 16796, 16796, and 10517. Unlike the current data, the historic data shows significant number of water samples showing poor DO saturation in Kickapoo Creek. The entire historic Kickapoo Creek DO saturation data shows about 43% of the data samples showing poor DO saturation and 26% of the samples show fair DO saturation. About 15% and 16% of the historic water samples show good and excellent categories (Figure 3.7). The maximum number of poor DOsat water samples occur in the most downstream station (10517) of Kickapoo Creek.

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 (for example, precipitation events) and anthropogenic (for example, change in land cover) factors. From a water quality perspective, streamflow is important because it influences the ability of a water body to assimilate pollutants.

A United States Geological Survey (USGS) streamflow gauge (Gauge ID: 08031200) continuously monitored streamflow data from 05/01/1962 until 09/29/1989. The gauge was located near Brownsboro, TX. However, the continuous monitoring was discontinued in 1989, and more recent data on daily streamflow was not available for this watershed. However, instantaneous streamflow information is available for all the nine stations, along with the water quality data. Therefore, continuous streamflow data was estimated for all the nine stations (where the water quality is currently monitored) based on the Drainage-Area Ratio method (DAR).

In the Drainage-Area Ratio Method (DAR), streamflow data from the source station (where continuous flow data is available) will be converted to flow per unit area (ft^3/sec of discharge/mi^2) by dividing each value of the time series with the drainage area corresponding to the source station. The flow per unit area time series from the source station will be used to estimate the flow data for the target location by simply multiplying the drainage area of the target location. When multiple source stations are involved to estimate flow for a single target station, appropriate weights need to be used.

To estimate the streamflow of Kickapoo Creek two nearby stations with similar watershed characteristics (to that of Kickapoo Creek) are available. They are Neches river at Neches, TX and Sabine river at Minneola, TX. Although Kickapoo Creek is a part of the Upper Neches river watershed, it could have been adequate to use the gauge available at Neches river at Neches, TX alone. However, using the flow data from this gauge alone resulted in under-estimation of peaks and completely missing one runoff event. This was verified using limited flow observations monitored for Kickapoo Creek at Brownsboro, TX (Figure 3.9).

Using data from the Sabine River alone came with problems in inadequately reproducing the flow patterns. Majority of the flow peaks were overestimated, while some were under-estimated (Figure 3.10). However, using a combination of the two stations (with equal weights) produced the flow patterns and magnitudes adequately for the Kickapoo Creek watershed (Figure 3.11).

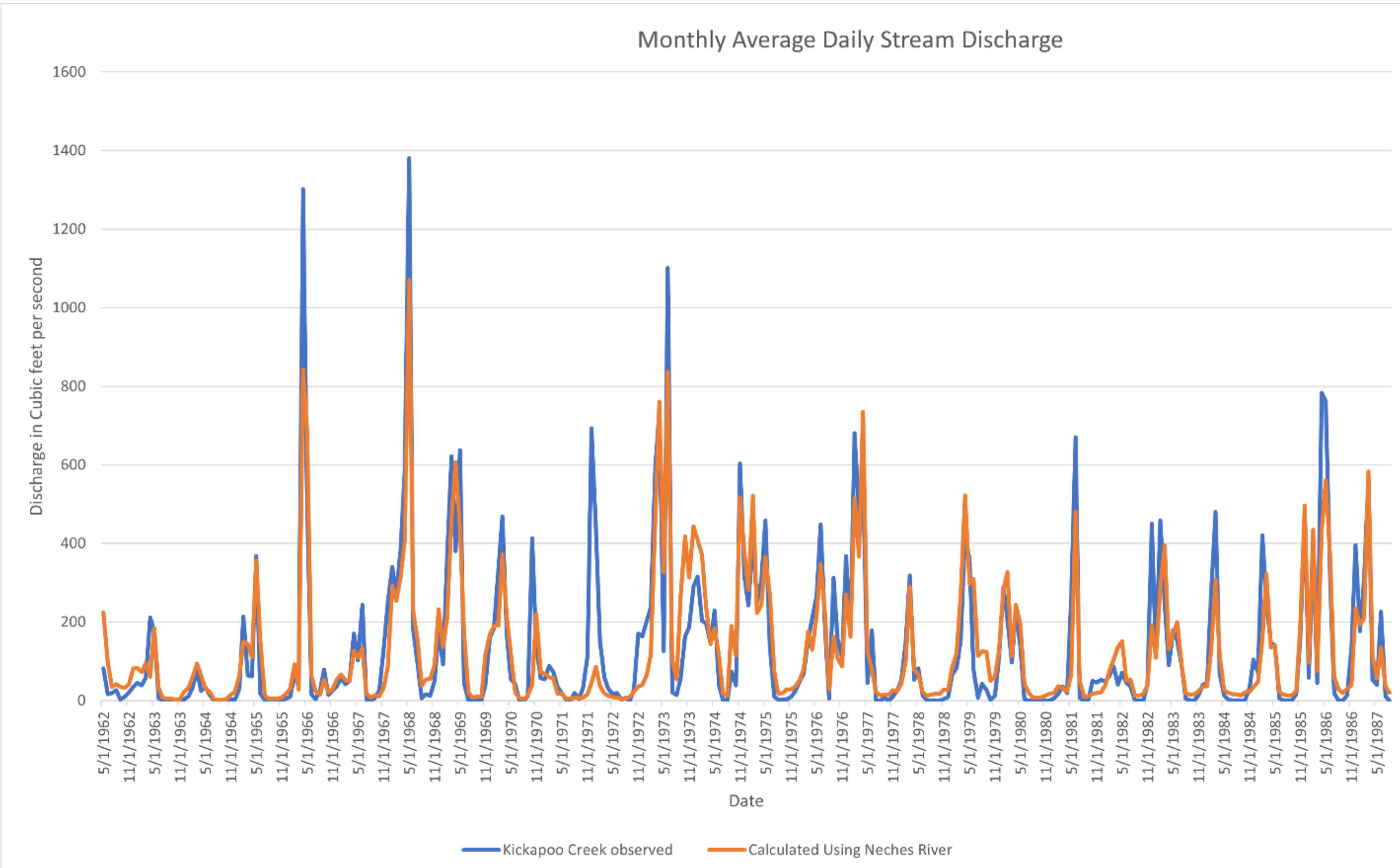


Figure 3.9 Comparison of monthly average streamflow of Kickapoo Creek (estimated using the flow of the Neches River in Neches, Texas) with limited monitored flow at Brownsboro, Texas.

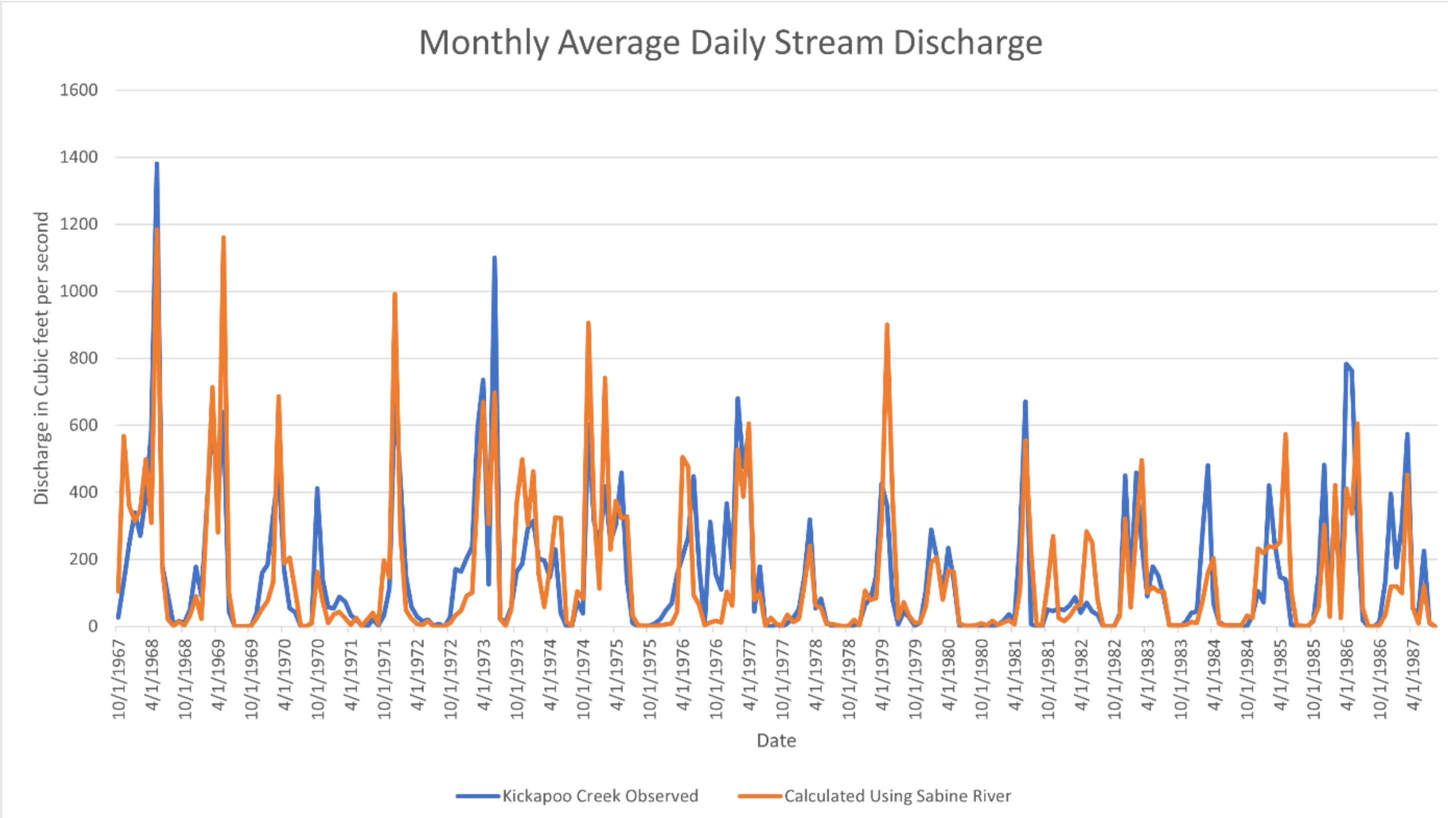


Figure 3.10 Comparison of monthly average streamflow of Kickapoo Creek (estimated using the flow of the Sabine River in Mineola, Texas) with limited monitored flow at Brownsboro, Texas.

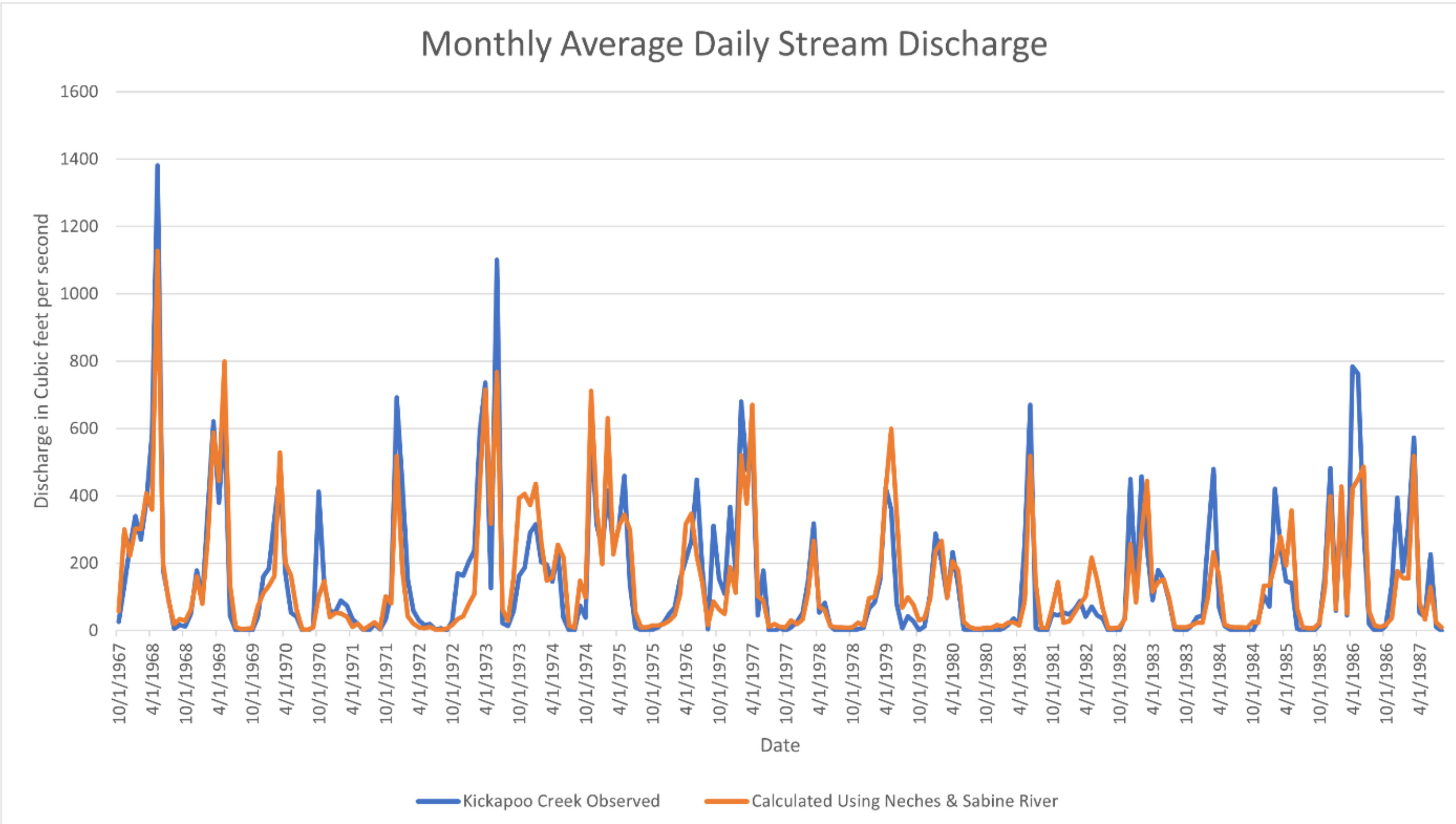


Figure 3.11 Comparison of monthly average streamflow of Kickapoo Creek (estimated using the flow of the Neches and Sabine Rivers) with limited monitored flow at Brownsboro, Texas

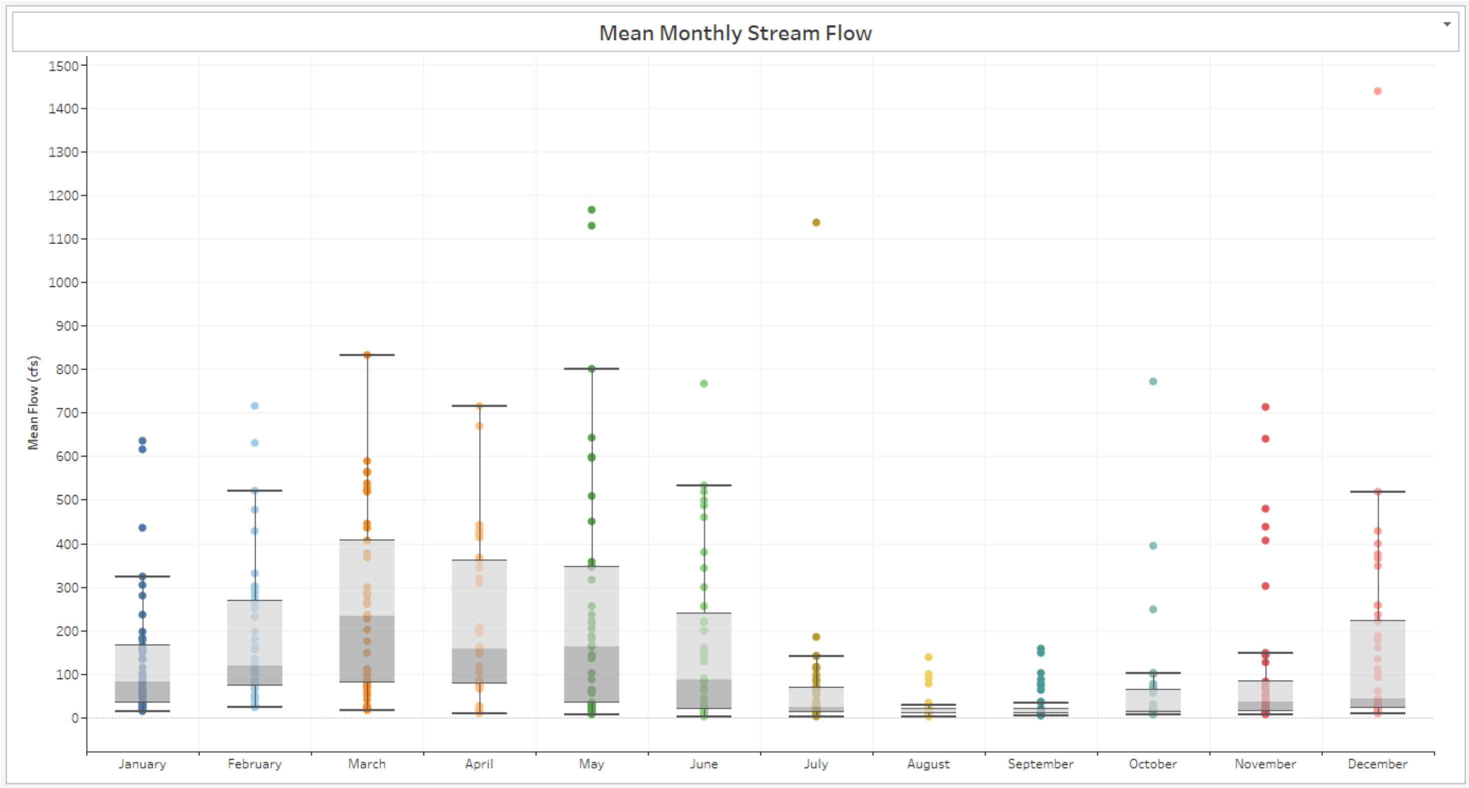
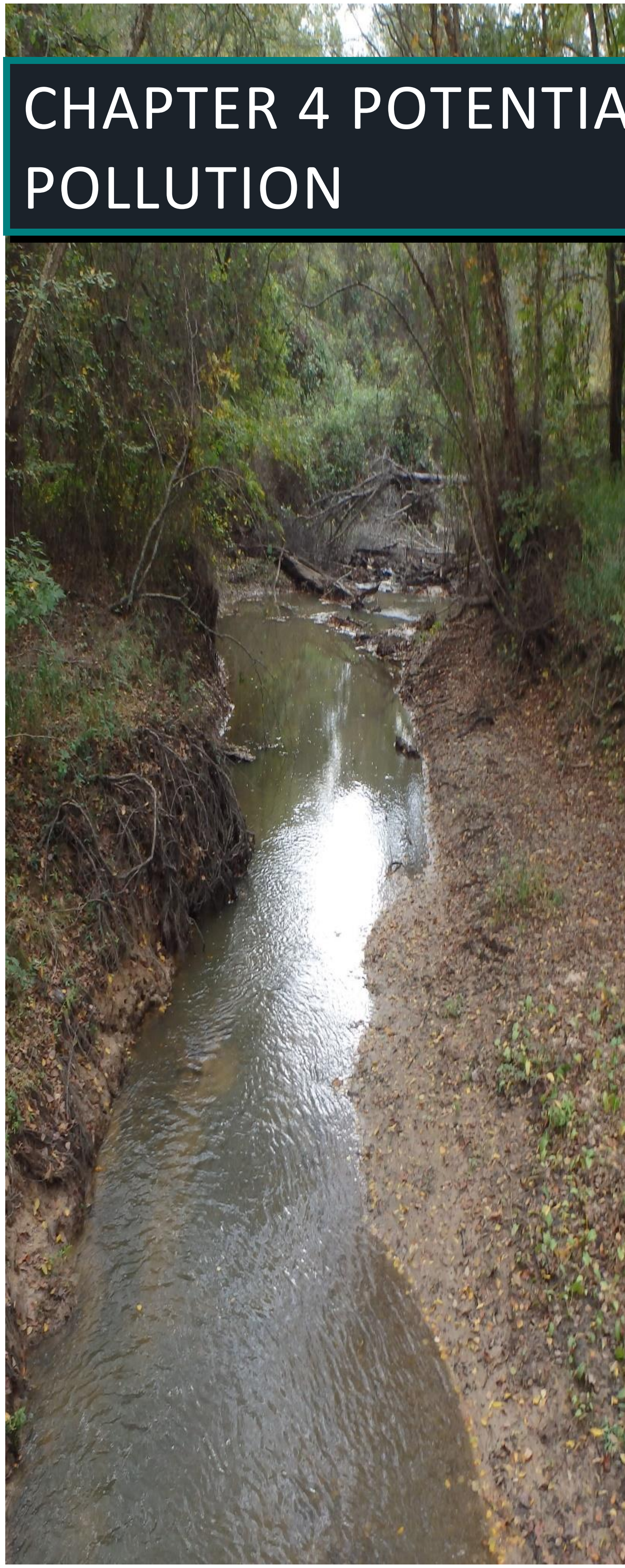


Figure 3.12 Monthly average streamflow trends in the Kickapoo Creek watershed at Station 105017

The monthly stream flows are shown here (Figures 3.12) for better interpretation of the trends, patterns and magnitudes. Although figure 3.12 shows trends only for the station 10517, similar trends were seen in the other eight stations as well because the source of flow data is the same and the only variable changing flow is the drainage area of each water quality station in Kickapoo Creek. With respect to the average flow in the creek, August and September are the driest months and March and May are the wettest months in the watershed.

CHAPTER 4 POTENTIAL SOURCES OF POLLUTION



INTRODUCTION

As laid out in Chapter 3, most of the impairments in the Kickapoo Creek watershed are primarily due to the excessive fecal indicator bacteria. Table 4.1 includes a summary of potential pollutant sources, causes, and impacts.

Pollution sources are categorized as either point sources or nonpoint sources. 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 Systems (MS4s), certain urban stormwater management practices are required under an MS4 permit and are therefore considered to be point source controls 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. WWTFs discharges are 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 as a condition of their discharge permits. Facilities that exceed their permitted levels may require infrastructure or process improvements to meet the permitted discharge requirements.

There are currently five WWTFs in the Kickapoo Creek watershed (Figure 4.1). 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 4.2). Annual nutrient loading reports were not available from this source.

SANITARY SEWER OVERFLOWS (SSOS)

Storm Sewer Overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes, line breaks, defective design, power failures, or vandalism. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. The TCEQ Region 5 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, the responsible entity, and a general location of the spill. The reports of SSO events that occurred within the Kickapoo Creek watershed between January 2015 and December 2019 are shown in two separate incidences and reported for two different facilities. The reports indicate that the SSOs occurred year-round and that both durations were unknown. Overflow volumes for both incidences were one gallon.

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 no MS4 permits in the watershed.

Table 4.1 Potential pollution source summary

Pollutant Source	Pollutant Type	Potential Cause	Potential Impact
WWTFs/SSOs	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 wastewater 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 water body
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 during runoff events
Pets	Bacteria, nutrients	• Fecal matter not properly disposed of • Lack of dog owner education regarding effects of improper disposal	Bacteria and nutrients enter water body through runoff
Illegal Dumping	Bacteria, nutrients, litter	Disposal of trash and animal carcasses in or near water body	Direct or indirect contamination of water body

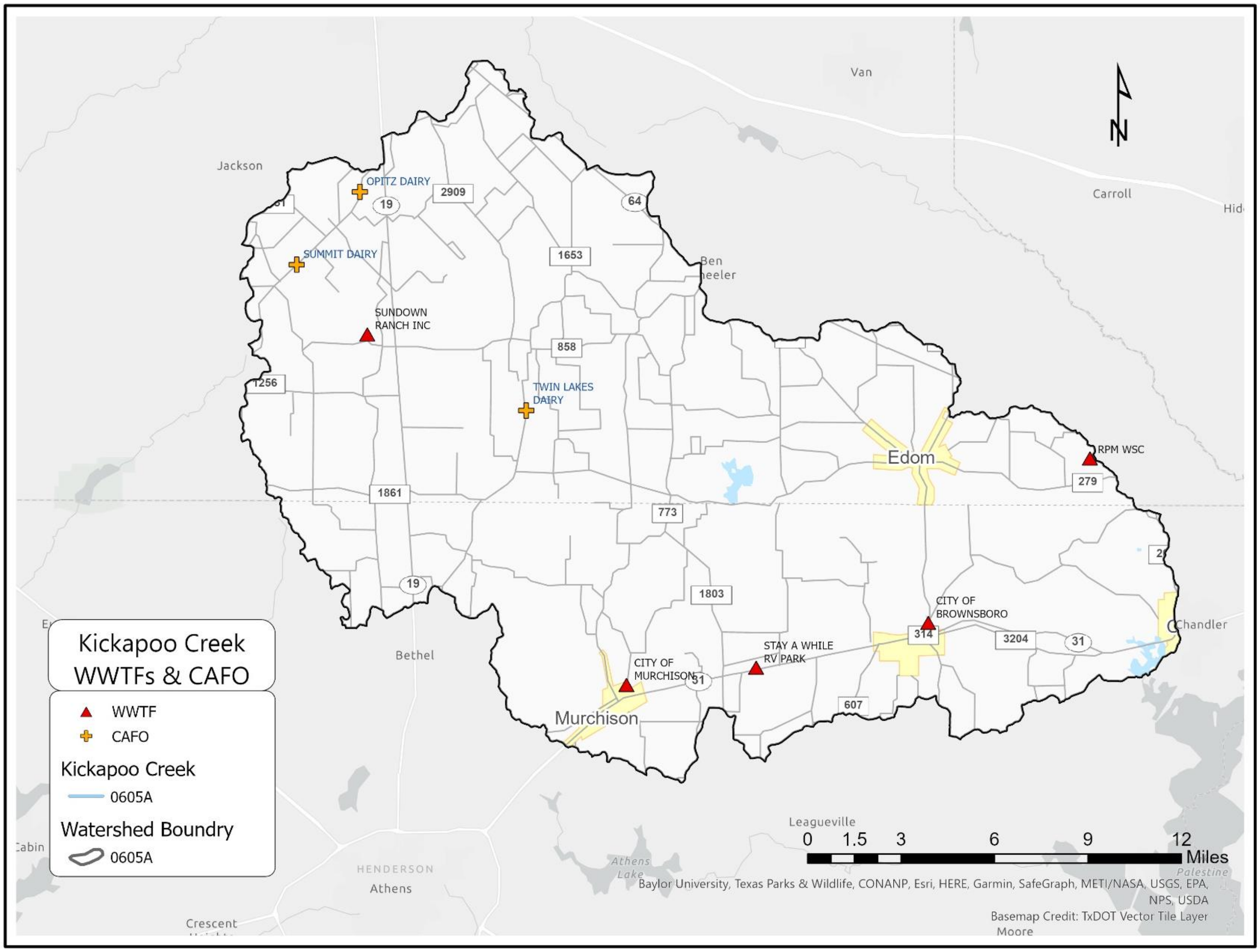


Figure 4.1 Location map for wastewater treatment facilities/plants (WWTFs/WWTPs) and concentrated animal feeding operations (CAFO) in Kickapoo Creek watershed

Table 4.2 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 (3 years)
Sundown Ranch INC TPDES No. WQ0015423001	Kickapoo Creek	0.01	0.001	Active	8
City of Brownsboro TPDES No. WQ0010540001	Kickapoo Creek	0.16	0.064	Active	11
City of Murchison TPDES No. WQ0011816001	Kickapoo Creek	0.08	0.019	Active	12
Stay A While Rv Park TPDES No. WQ0015651001	Kickapoo Creek	0.0075	0.0034	Active	9
RPM WSC TPDES No. WQ0014958001	Kickapoo Creek	0.01	0	Active	6

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, nutrient, and many other substances.

OSSFS

Septic systems or on-site sewage facilities (OSSFs) are often used in rural areas that do not have the ability to connect to a central wastewater collection system. OSSFs may contribute *E. coil*, 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 potential OSSFs in the watershed the number of households is needed.

The number of households was estimated based on the 911 emergency address points (911.gov; https://data.tnris.org/collection/117cf9e1-3b1e-48f2-97a3-47020d871035) outside of city boundaries (TxDOT 2021 (http://gis-txdot.opendata.arcgis.com/datasets/txdot-city-boundaries)). Of the 7,507 households in the Kickapoo Creek watershed, 6,576 (87.6%) were estimated to be outside of municipal areas serviced by WWTFs and, thus, likely on septic systems. The densities of OSSFs for the watershed are classified into five groups and shown (Figure 4.2).

Typical OSSF designs include either (1) anaerobic systems composed of septic tanks and associated drainage or distribution field, or (2) aerobic systems with aerated holding tanks and typically above-ground sprinkler systems 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 filtration. Soil suitability rankings were developed by the Natural Resources Conservation Services

(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.

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. 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.

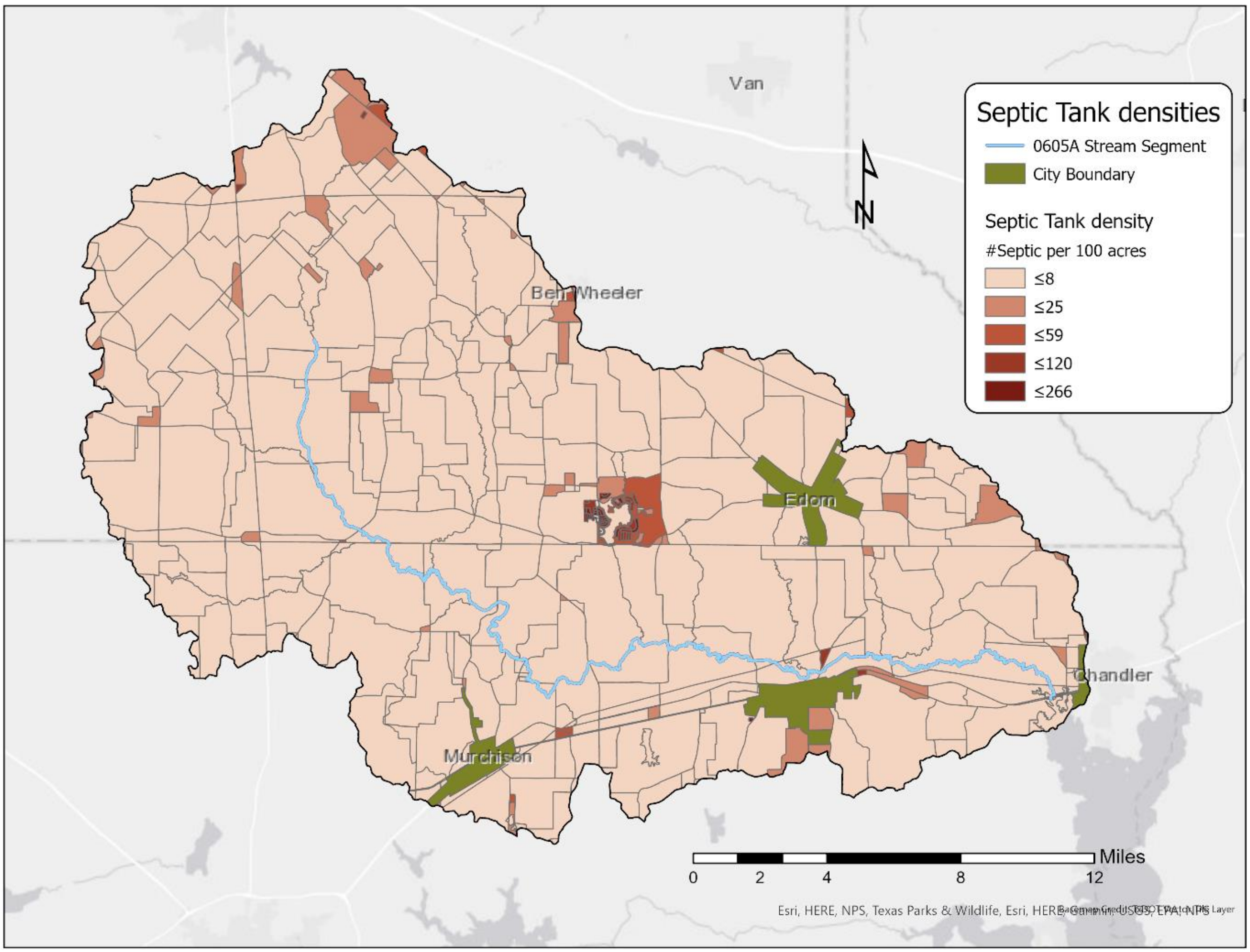


Figure 4.2 On-site sewage facilities (OSSF) densities

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 4.3). Increased runoff can adversely affect water quality by carrying more NPS pollution into surrounding water bodies.

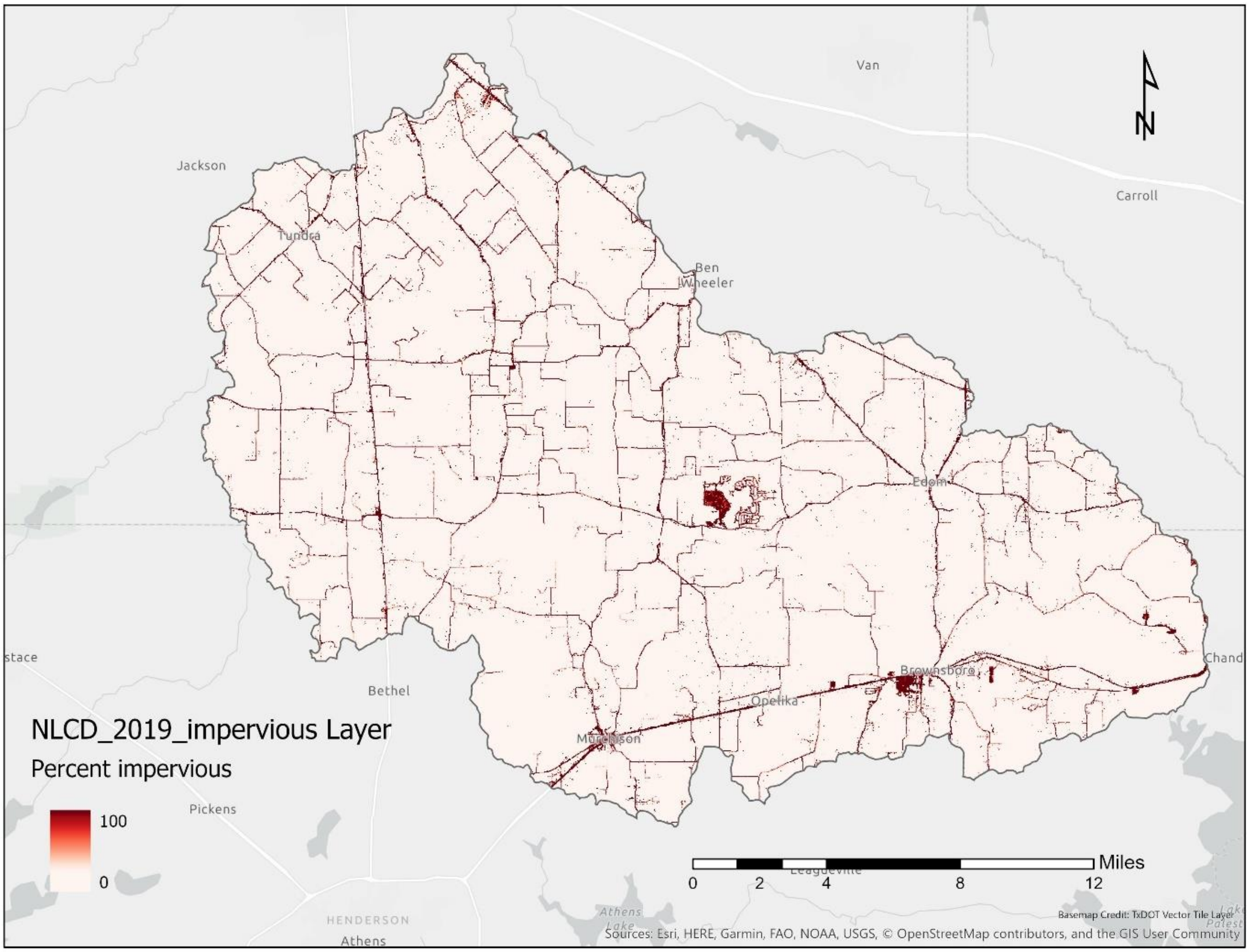


Figure 4.3 Percent impervious cover

Table 4.3 Area ratio calculation for land use

Land use	Henderson County (Acres)	Van Zandt County (Acres)	Watershed from Henderson (Acres)	Watershed from Van Zandt (Acres)
Deciduous Forest	14,219	26,471	327	1,105
Evergreen Forest	18,117	4,942	3,871	1,936
Mixed Forest	93,241	65,638	14,844	17,901
Shrub/Scrub	4,331	2,119	750	546
Herbaceous	19,007	5,594	1,300	1,488
Hay/Pasture	267,378	350,404	37,561	60,523
Total	416,293	455,168	58,653	83,499
Ratio from total county			**0.141**	**0.183**

Table 4.4 Estimated livestock populations

County	Area Ratio	Cattle & Calves	All Goats	Mule, Burros, and Donkeys	Horses & Ponies
Henderson	0.141	59,076	2,083	1,389	3,914
Van Zandt	0.183	89,422	3,917	1,123	4,253
Watershed		**24,694**	**1,011**	**401**	**1,330**

LIVESTOCK

The grazing of livestock, predominately cattle and to a lesser extent horses, goats, and donkeys, occurs throughout the Kickapoo Creek watershed. These animals also serve as potential sources of NPS pollution. Runoff from precipitation events can transport fecal matter, nutrients, and bacteria from pastures and rangeland into nearby creeks and streams. Livestock with direct access to streams can also wade and defecate directly into water bodies resulting in direct contributions of bacteria and nutrients to the water. Streamline riparian buffers, fencing, and grazing practices that reduce the time livestock spend near streams can reduce livestock impacts on water quality.

It is difficult to quantify the exact numbers of livestock within the watershed, especially when watershed-level livestock numbers are not available. Therefore, the populations were estimated using the USDA Agricultural Census dataset (USDA, 2017). Specifically, the cattle and calves, horses and ponies, all goats, mules, burros, and donkey populations for each county were obtained. The county-level data were multiplied by a ratio based on the area of the particular county within the watershed, the area ratio calculation only considered Land use suitable for the livestock (i.e. pasture/hay, rangeland, herbaceous, scrub/shrub, and forest). Therefore, the animal numbers in Van Zandt County were multiplied by 0.183 and Henderson County numbers by 0.141 (Table 4.3) with the assumption that livestock was distributed uniformly in the specified land use throughout the counties.

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 a major source in the watershed. Wildlife population density estimations 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 wildlife management area (WMA) level. WMAs are developed based on similar ecological characteristics within a defined area. The Kickapoo Creek watershed is situated in parts of the Post Oak Savanah Region. The estimated deer population per 1000 acres is 46 for Post Oak Savanah. This population estimate was applied to every Land use/Land cover class within the watershed except for open water, barren land, and developed land. Based on these assumptions, there are an estimated 165,940 X 46 /1,000 = 7,633 deer in the watershed (Table 4.5)

Table 4.5 Estimated deer populations

Total Area of watershed (acres)	Total area minus Open water, Developed and Barren(acres)	# Deer per 1000 acres	Total # of Deer in the watershed
179,251	165,940	46	7,633

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 readily available. They also are known to wallow in available water and mud holes. It is obvious that riparian corridors are prime habitats 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 typically remaining in thick cover during the day and venturing away from this cover and into more open areas of the watershed at night. Feral hogs are significant contributors of pollutants to creeks and rivers across the state through direct and indirect fecal loadings. In addition, extensive rooting and wallowing in riparian areas by feral hogs cause erosion and soil loss. A study conducted by Texas A&M AgriLife and AgriLife Extension (Timmons, et. al, 2012) reported the density of feral Hogs in Texas is 8.9-16.4 hogs/square mile the average being 12.65 hogs/square mile. The Total suitable area in the watershed, which is the total area except for water, barren, and developed land, is 259.28 square miles. This gives a total estimate of 3,280 feral hogs in the watershed (Table 4.6).

Table 4.6 Estimated feral hog populations

Total Area of watershed (sq. mile)	Total area minus Open water, Developed and Barren(sq. mile)	# Hogs per sq. mile	Total # of Hogs in the watershed
280.08	259.28	12.65	3280

PETS

Fecal matter from pets can contribute to bacteria loads in the watersheds when not picked up and disposed of properly. In rural areas, such as the Kickapoo Creek watershed, pets often spend most of their time roaming around outdoors, making proper waste disposal impractical. The American Veterinary Medical Association (AVMA) estimates there are approximately 0.614 dogs and 0.457 cats in homes across the United States (AVMA, 2018).

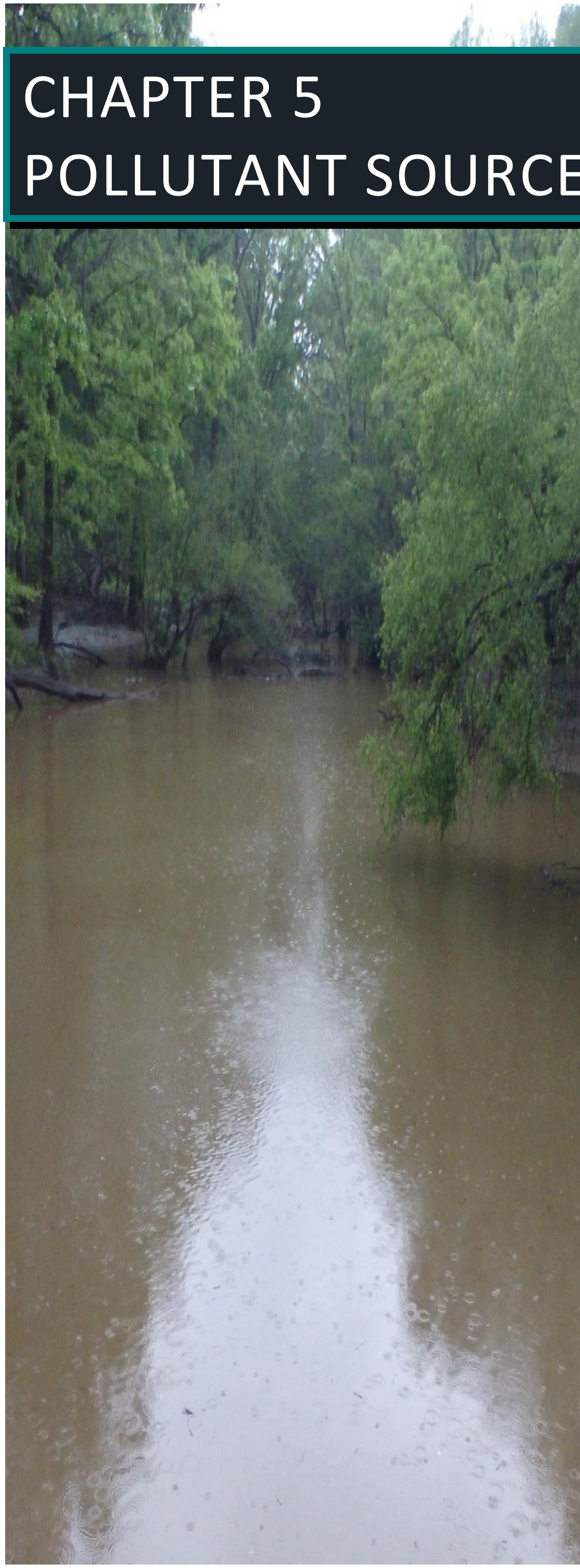
The number of domestic birds per household is insignificant and therefore they are not considered. To estimate the number of domestic pets in the watershed, the above-mentioned ratios were multiplied with the number of households (7,497) in each watershed. The estimates of domestic pets are provided in Table 4.7.

Table 4.7 Estimated domestic pet population

Item	Dogs	Cats
Number of pets per household	0.614	0.457
Number of pets in the watershed	4,603	3,426

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 Kickapoo 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. This results 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 distributions vary substantially between and within watersheds based on local soil, land cover, and management practices based on results from studies conducted elsewhere.



CHAPTER 5
POLLUTANT SOURCE ASSESSMENT

WATER QUALITY MONITORING

The *2020 Texas Integrated Report* identified two AUs in the watershed as impaired due to elevated *E. coli* concentration. They are AUs 0605A_01 and 0605A_02. Kickapoo Creek is being monitored by TIAER at Tarleton State University. 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 assessment are not biased to high or low flow events.

E. COLI DATA ASSESSMENT

As previously mentioned, concentrations of fecal indicator bacteria are evaluated to assess illness risk during contact recreation. In freshwater environments, concentrations of *E. coli* bacteria are measured to determine fecal contamination in water bodies from warm-blooded animals and other sources. The presence of fecal indicator bacteria may indicate that associated pathogens could reach water bodies and cause illness in people. Indicator bacteria can originate from numerous sources, including wildlife, livestock, domestic pets, malfunctioning OSSFs, non-point source urban and agricultural runoff, sanitary sewer overflows, and direct discharges from wastewater treatment facilities (WWTFs). Under the primary contact recreation standards, the geometric mean criterion for bacteria is 126 most probable number (MPN) of *E. coli* per 100mL.

All available data from January 2002 is used for analysis including near monthly current monitoring data by TIAER which started on August 2019 and any available historic data. The data used is summarized in (Table 5.1) below.

DISSOLVED OXYGEN

Dissolved Oxygen (DO) is essential for aquatic organisms to survive and refers to the concentration of oxygen gas incorporated into the water. DO concentrations fluctuate in the environment, but anthropogenic activities can contribute to excessive organic matter and nutrients, consequently depressing DO concentrations. Every water body assessed by the Texas State Water Quality Standards is assigned an aquatic life-use (ALU) category of either minimal, limited, intermediate, high, or exceptional. To ensure that water bodies protect these ALU categories, DO criteria are implemented. Classified water bodies must meet an average DO criterion measured over 24 hours and a minimum DO criterion (TCEQ, 2020). Unclassified streams are assigned an ALU based on the specific segment's flow type, categorized as perennial, intermittent with perennial pools, and intermittent without perennial pools. Specific DO criteria are associated with each unclassified stream type unless a site-specific ALU has been assigned to the unclassified water body. The 24-hour average DO criteria are measured over 24 hours, and sampling events occur at various times throughout the year to represent unbiased and seasonally representative data. When 24-hour average DO is not available, grab DO measurements are utilized and include a minimum criterion and screening level criterion (TCEQ, 2020).

Table 5.1 *E. coli* summary statistics

Station ID	AU	Water Body	Number of samples	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Geometric Mean (cfu/100mL)
10517	0605A_01	Kickapoo Creek	79	14	12000	237
21618	0605A_01	Kickapoo Creek	34	39	2400	317
22163	0605A_01	Kickapoo Creek	28	1	2400	104
16796	0605A_02	Kickapoo Creek	36	5	2400	168
16797	0605A_02	Kickapoo Creek	84	14	24000	306
22164	0605A_02	Kickapoo Creek	28	5	2400	184
22165	0605A_02	Kickapoo Creek	28	23	2400	404
22166	0605A_02	Kickapoo Creek	28	88	2400	505
22167	0605A_02	Kickapoo Creek	28	93	2400	377

LOAD DURATION CURVE (LDC) ANALYSIS

A Load Duration Curve (LDC) is a widely accepted methodology used to characterize water quality data across different flow conditions in a watershed. An LDC provides a visual display of streamflow, load capacity and water quality exceedance. An LDC is first developed by constructing a flow duration curve (FDC) using historical streamflow data. The historical flow measurements used to develop the FDCs for Kickapoo Creek were not available. Therefore, continuous streamflow data was estimated for all the nine stations (where the water quality is currently monitored) based on the Drainage-Area Ratio method (DAR) the details of which are presented in the previous section. An FDC is a summary of the hydrology of the stream, indicating the percentage of time that a given flow is equaled or exceeded. An FDC is constructed by ranking flow measurements from highest to lowest and determining the frequency of different flow measurements at the sampling location. X-axis represents the percent of time that flow was at or above a particular flow value. Y-axis represents the flow value corresponding to the frequency (X-axis) in the dataset. Exceedance values near 100 percent occur during low flow or drought conditions while values approaching 0 percent occur during periods of high flow or flood conditions.

The flow/load exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of the LDC. For this characterization, five flow regimes were identified. These five intervals along the x-axis of the LDCs are (1) 0-10 percent (high flows); (2) 10-40 percent (moist conditions); (3) 40-60 percent (mid-range flows); (4) 60-90 percent (dry conditions); and (5) 90-100 percent (low flows).

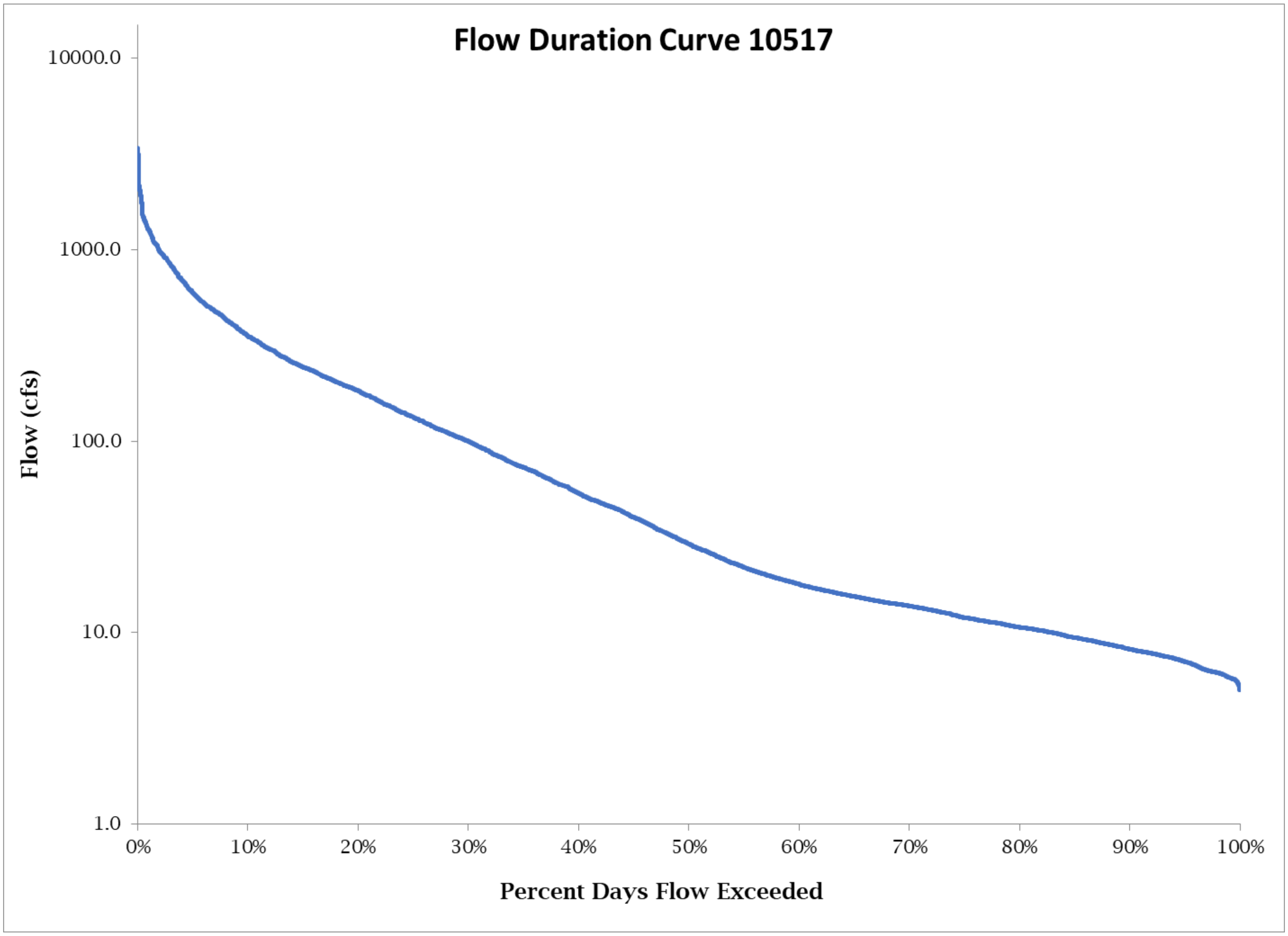


Figure 5.1 Flow duration curve for Station 10517

STATION 10517

Station 10517 Kickapoo Creek crossing at FM 314 in Henderson County is the most downstream monitoring point in the watershed. The LDC indicates most of the *E. coli* load exceeds the allowable load and four out of five flow conditions show exceedances. In the lowest flows condition the geometric mean bacteria load is close to the allowable load curve. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

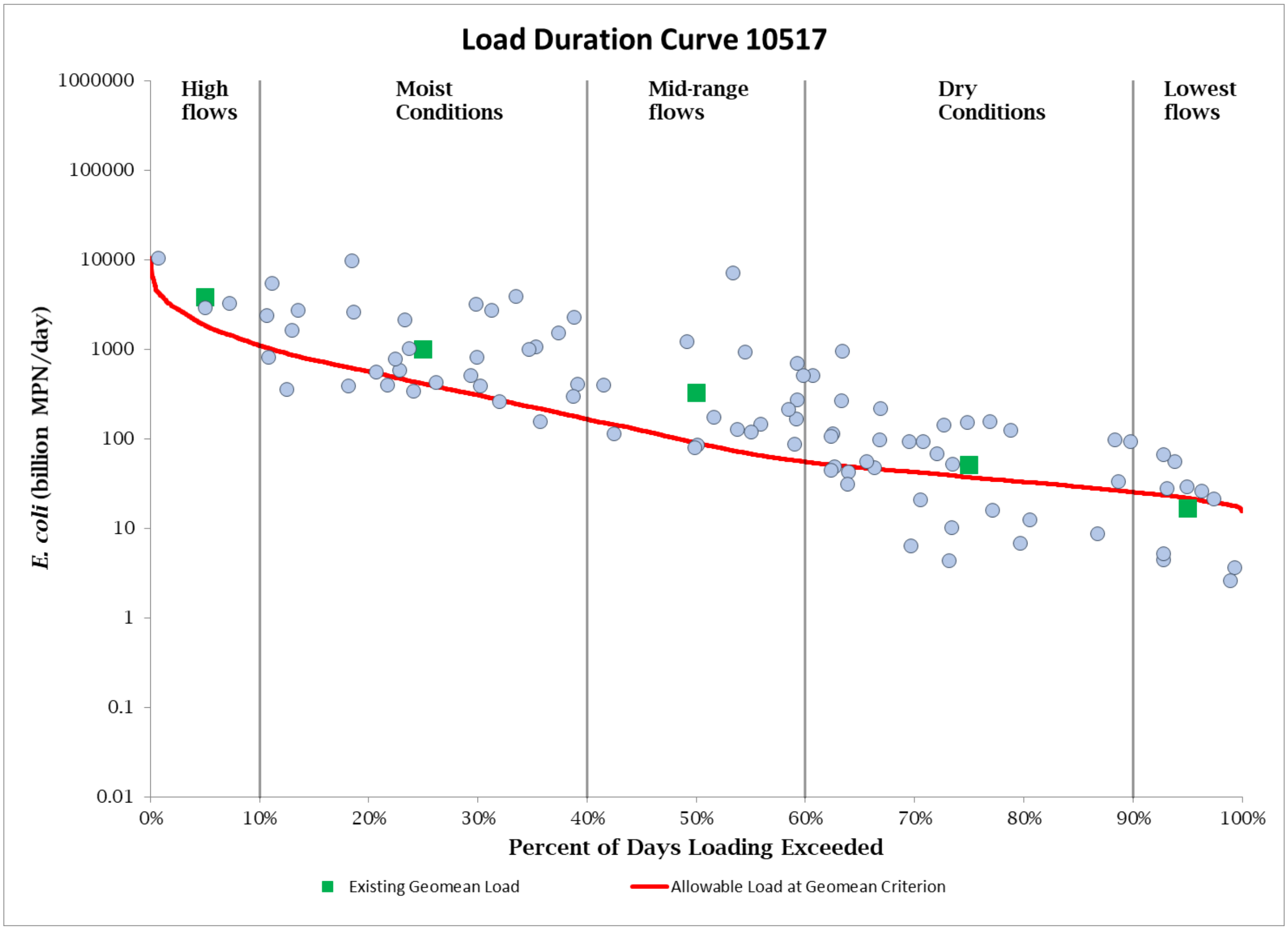


Figure 5.2 Load duration curve for Station 10517

Table 5.2 Percent reduction for Station 10517

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	3806.81	598.5	260	51.5%
25%	995.98	133.9	304	58.6%
50%	326.78	29.0	460	72.6%
75%	50.76	12.0	173	27.2%
95%	16.77	7.1	97	N/A

STATION 21618

Station 21618 Kickapoo Creek crossing at Henderson CR 3514 in Henderson County is second to the most downstream monitoring point in the watershed. The LDC indicates most of the *E.coli* load exceeds the allowable load and all flow conditions show exceedances. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

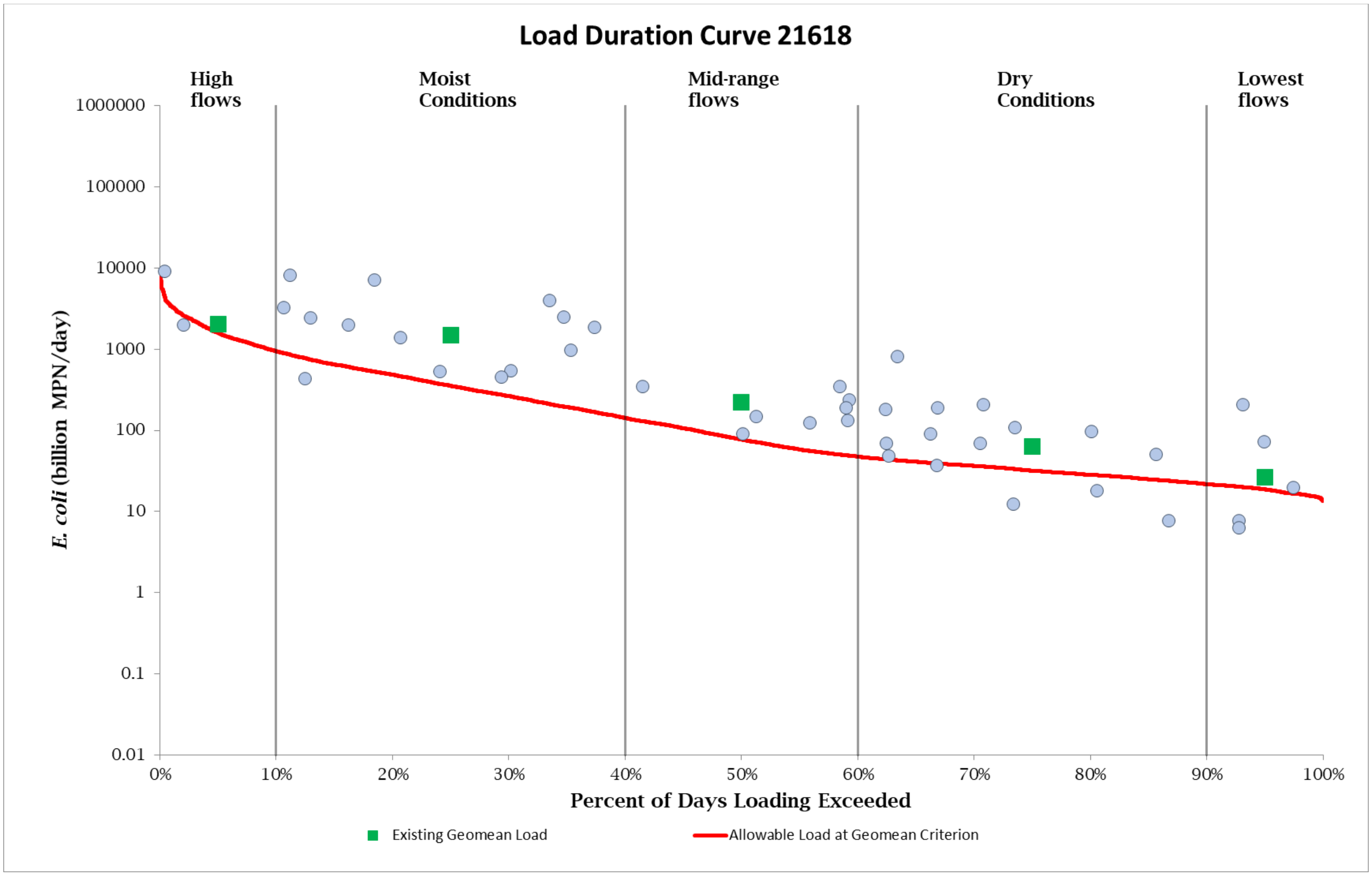


Figure 5.3 Load duration curve for Station 21618

Table 5.3 Percent reduction for Station 21618

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	2012.83	514.2	160	21.3%
25%	1497.58	115.1	532	76.3%
50%	224.01	24.9	367	65.7%
75%	63.03	10.3	250	49.6%
95%	26.45	6.1	178	29.2%

STATION 22163

Station 21613 Kickapoo Creek near the crossing at Henderson CR 3520 in Henderson County is upstream for segment 0605A_01. The LDC indicates the *E. coli* load exceeds only for Mid-range flows and Moist conditions. Whereas most samples in the lowest flows and dry conditions are below the allowable load. This indicates that mostly non-point sources and stormwater flows contribute to bacteria loadings in the watershed.

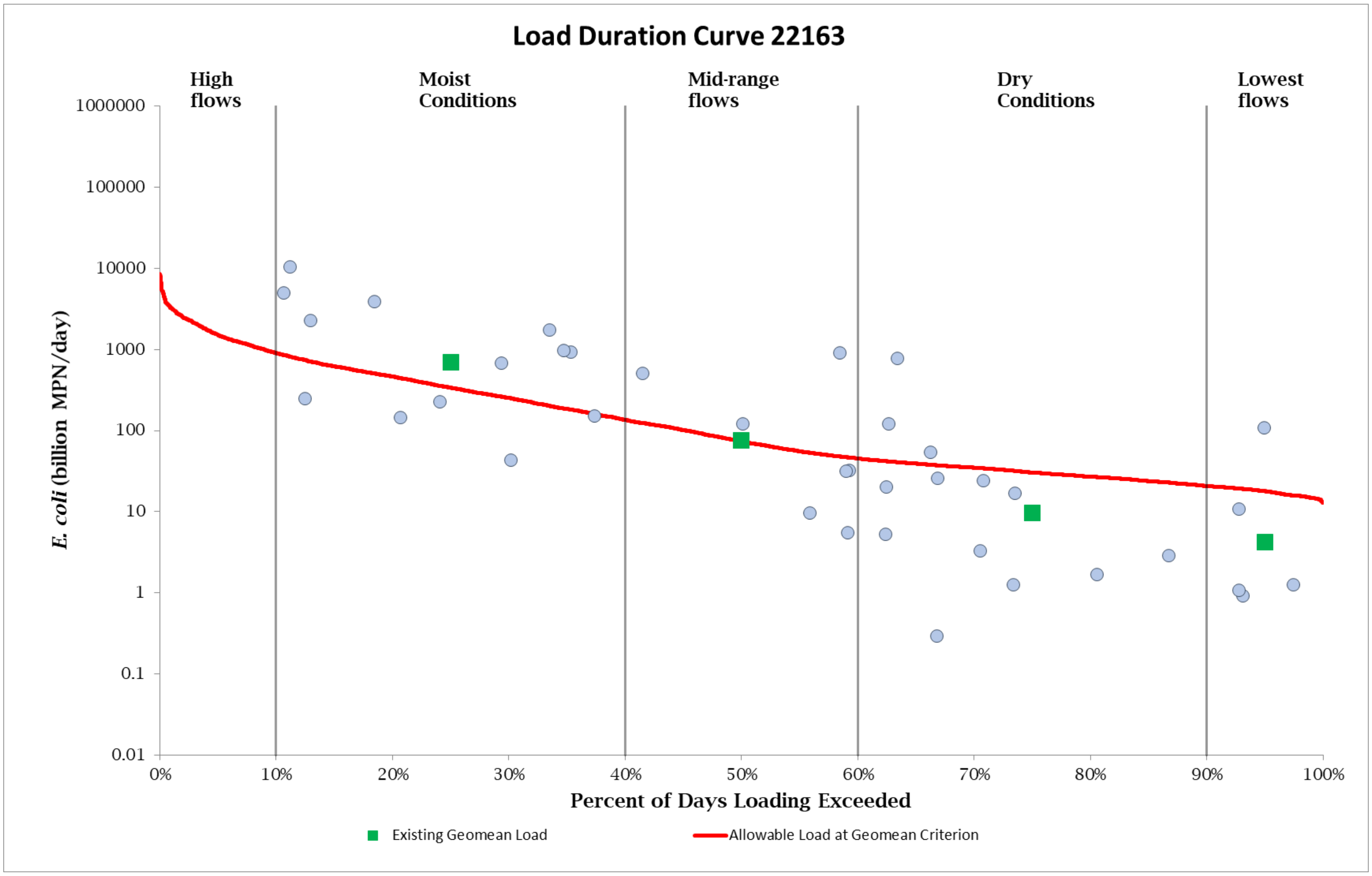


Figure 5.4 Load duration curve for Station 22163

Table 5.4 Percent reduction for Station 22163

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	N/A	491.0	N/A	N/A
25%	701.57	109.9	261	51.7%
50%	76.35	23.8	131	3.8%
75%	9.63	9.8	40	N/A
95%	4.26	5.8	30	N/A

STATION 16796

Station 16796 Kickapoo Creek crossing at FM 1803 in Henderson County is very downstream for segment 0605A_02. The LDC indicates the *E. coli* load exceeds for High flows, Moist conditions and Mid-range flows. Whereas most samples in the lowest flows and dry conditions are below the allowable load. This indicates that mostly non-point sources and stormwater flows contribute to bacteria loadings in the watershed.

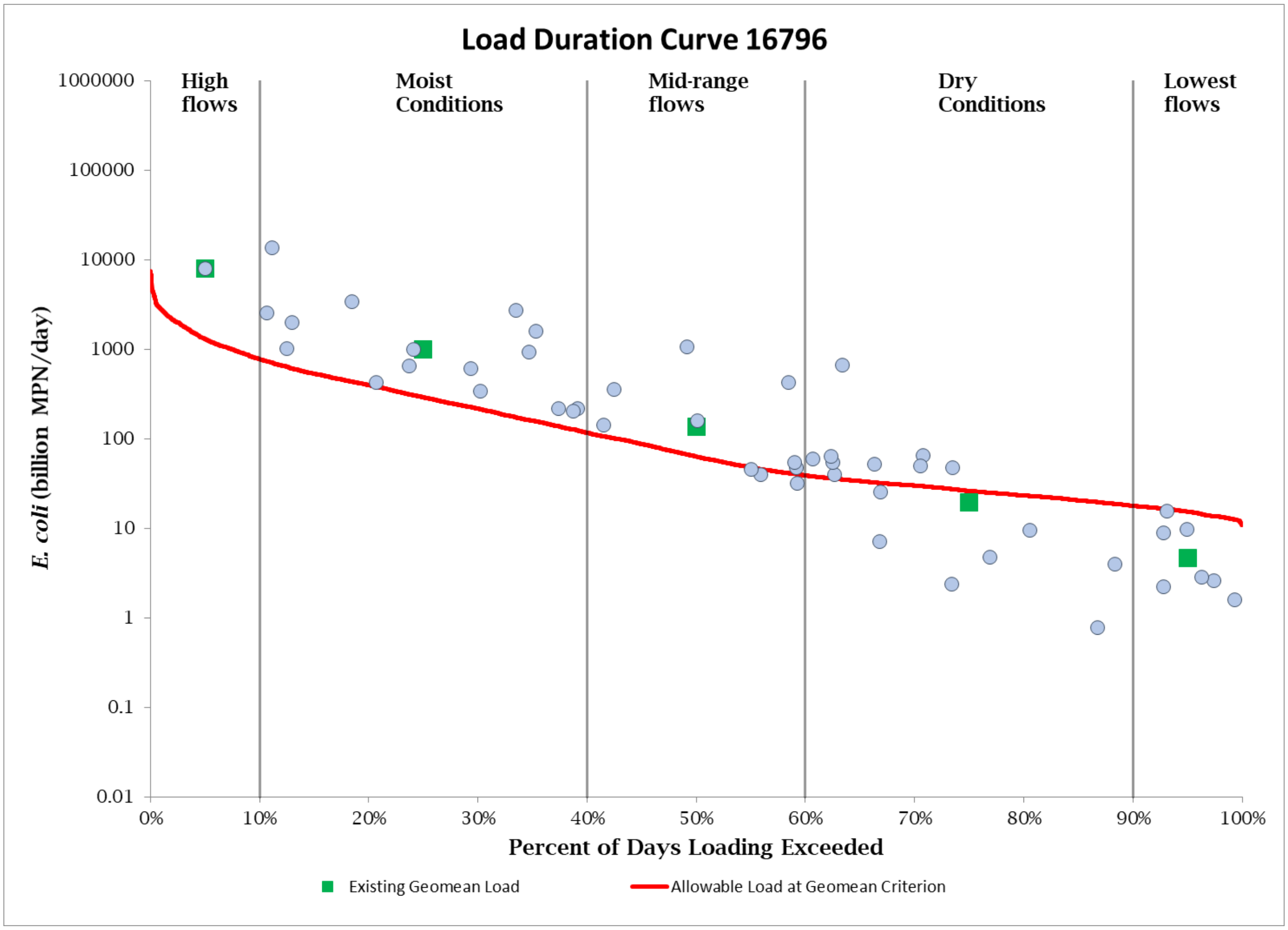


Figure 5.5 Load duration curve for Station 16796

Table 5.5 Percent reduction for Station 16796

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	7960.41	422.6	770	83.6%
25%	997.04	94.6	431	70.8%
50%	135.43	20.5	270	53.3%
75%	19.48	8.5	94	N/A
95%	4.64	5.0	38	N/A

STATION 22164

Station 22164 Kickapoo Creek near the crossing at Henderson CR 3806 in Henderson County is upstream for segment 0605A_01. The LDC indicates the *E. coli* load exceeds only for Mid-range flows and Moist conditions. Whereas most samples in the lowest flows and dry conditions are below the allowable load. This indicates that mostly non-point sources and stormwater flows contribute to bacteria loadings in the watershed

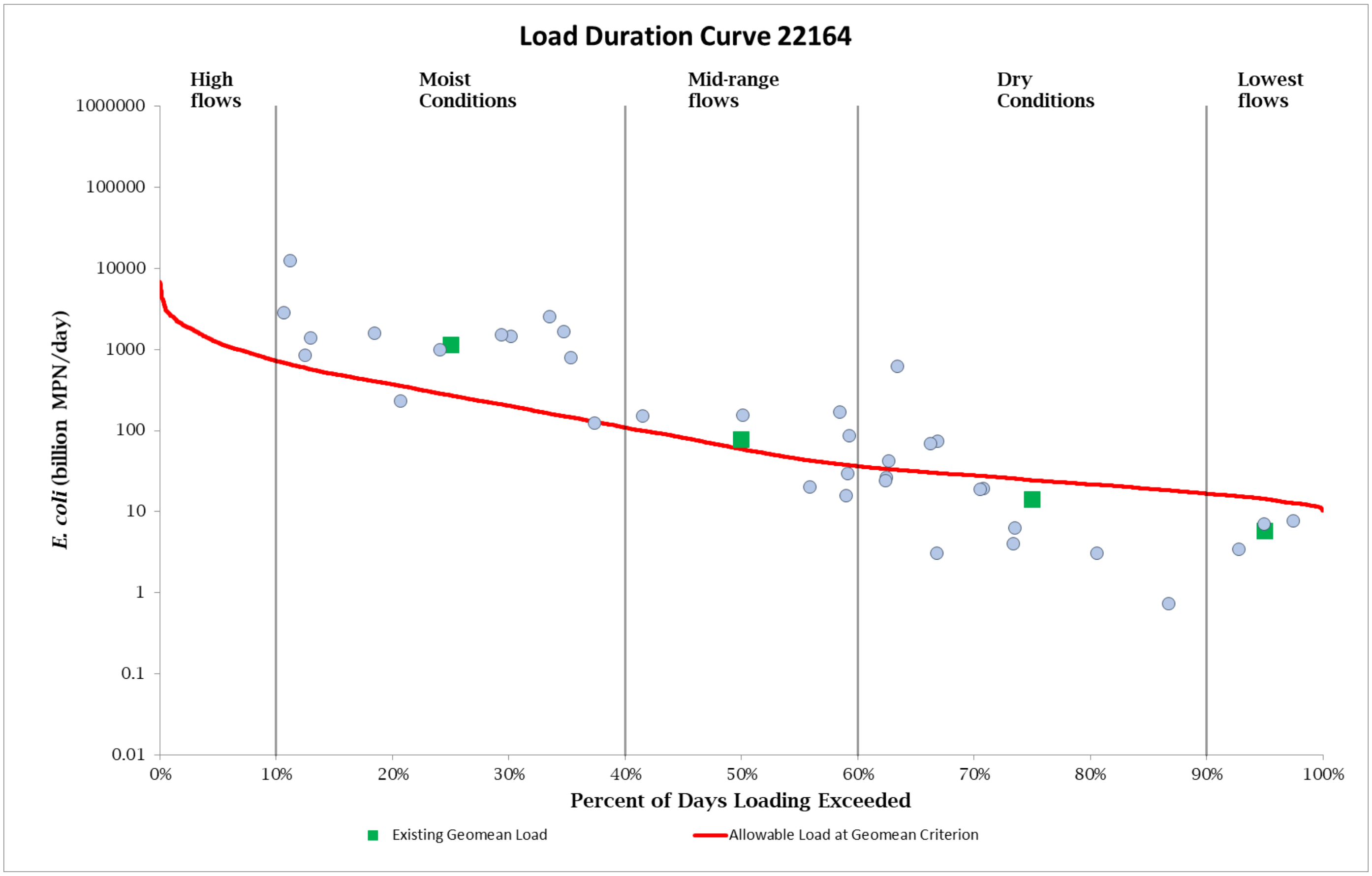


Figure 5.6 Load duration curve for Station 22164

Table 5.6 Percent reduction for Station 22164

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	N/A	394.1	N/A	N/A
25%	1137.09	88.2	527	76.1%
50%	76.73	19.1	164	23.2%
75%	14.11	7.9	73	N/A
95%	5.81	4.7	51	N/A

STATION 16797

Station 16797 Kickapoo Creek crossing at FM 314 in Henderson County, the LDC indicates most of the *E. coli* load exceeds the allowable load, and four out of five flow conditions show exceedances. The only condition in the geometric mean that is below the allowable load is in the lowest flows. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

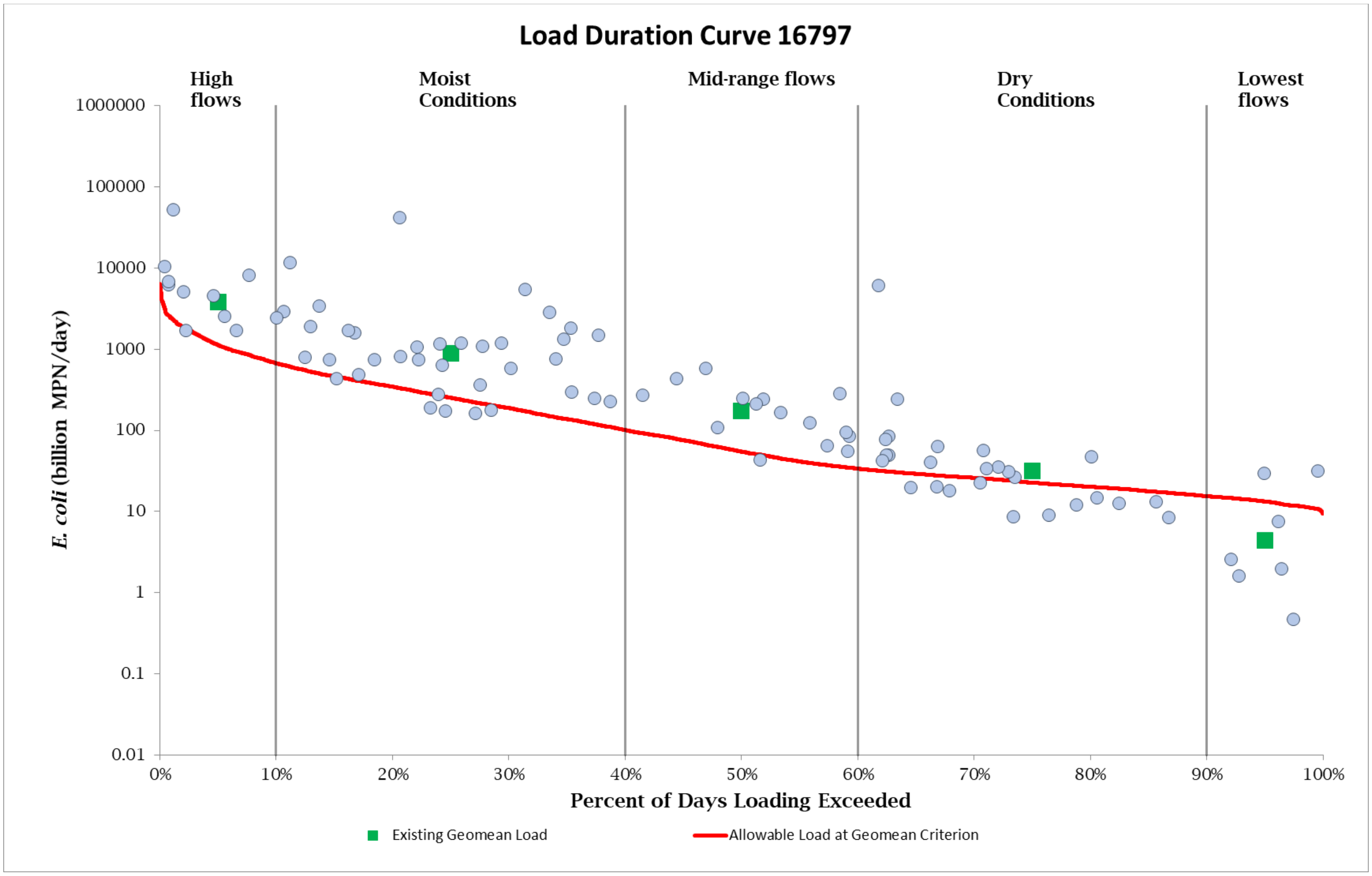


Figure 5.7 Load duration curve for Station 16797

Table 5.7 Percent reduction for Station 16797

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	3820.06	365.7	427	70.5%
25%	892.831	81.8	446	71.7%
50%	173.627	17.7	400	68.5%
75%	31.913	7.3	178	29.2%
95%	4.43782	4.3	42	N/A

STATION 22165

Station 22165 Kickapoo Creek crossing at FM 1861 in Van Zandt County, the LDC indicates most of the *E. coli* load exceeds the allowable load and three out of four flow conditions show exceedances. The only condition the geometric mean is below the allowable load curve is in the lowest flows. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

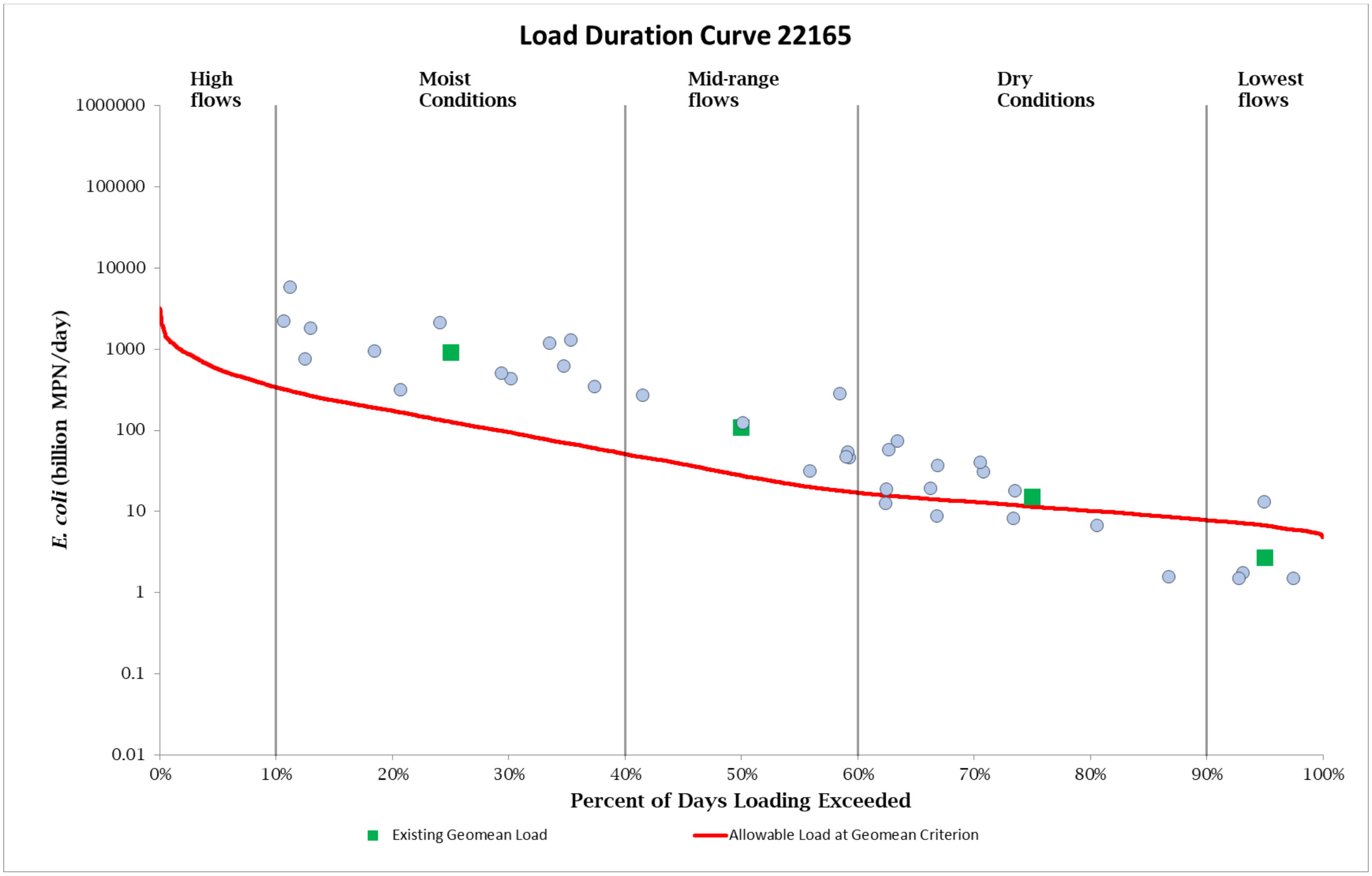


Figure 5.8 Load duration curve for Station 22165

Table 5.8 Percent reduction for Station 22165

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	N/A	184.6	N/A	N/A
25%	914.45	41.3	905	86.1%
50%	108.45	9.0	495	74.5%
75%	14.93	3.7	165	23.6%
95%	2.67	2.2	50	N/A

STATION 22166

Station 22166 Kickapoo Creek crossing at CR 4206 in Van Zandt County is second to the most upstream monitoring point in the watershed. The LDC indicates most of the *E. coli* load exceeds the allowable load and three out of four flow conditions show exceedances. The only condition in the geometric mean is below the allowable load is in the lowest flows. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

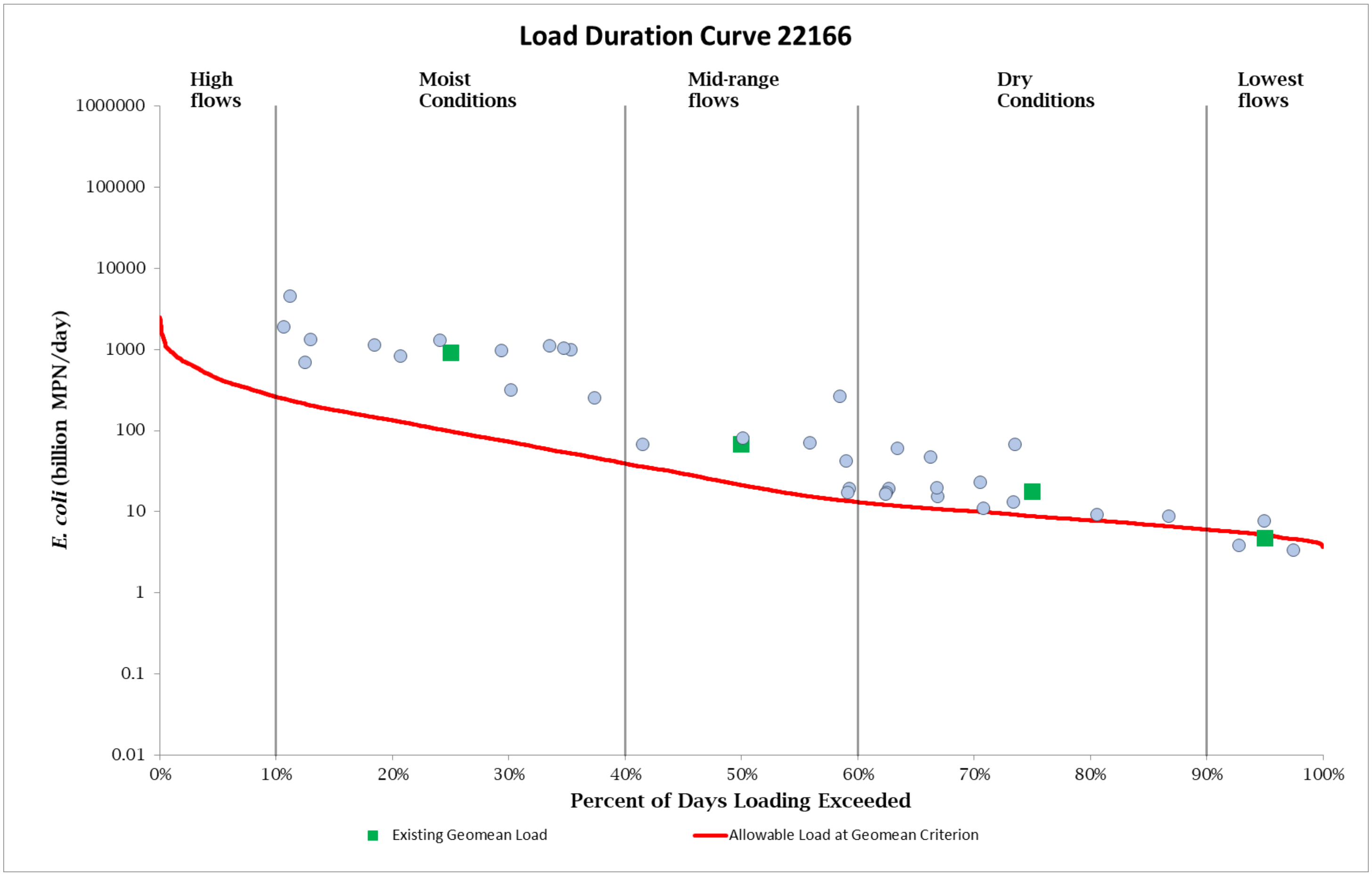


Figure 5.9 Load duration curve for Station 22166

Table 5.9 Percent reduction for Station 22166

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	N/A	142.0	N/A	N/A
25%	916.52	31.8	1179	89.3%
50%	68.27	6.9	405	68.9%
75%	17.47	2.8	251	49.8%
95%	4.76	1.7	116	N/A

STATION 22167

Station 22167 Kickapoo Creek crossing at FM 858 in Van Zandt County is the most upstream monitoring point in the watershed. The LDC indicates most of the *E. coli* load exceeds the allowable load and all four flow conditions show exceedances. This indicates that both point and non-point sources potentially contribute to bacteria loadings in the watershed.

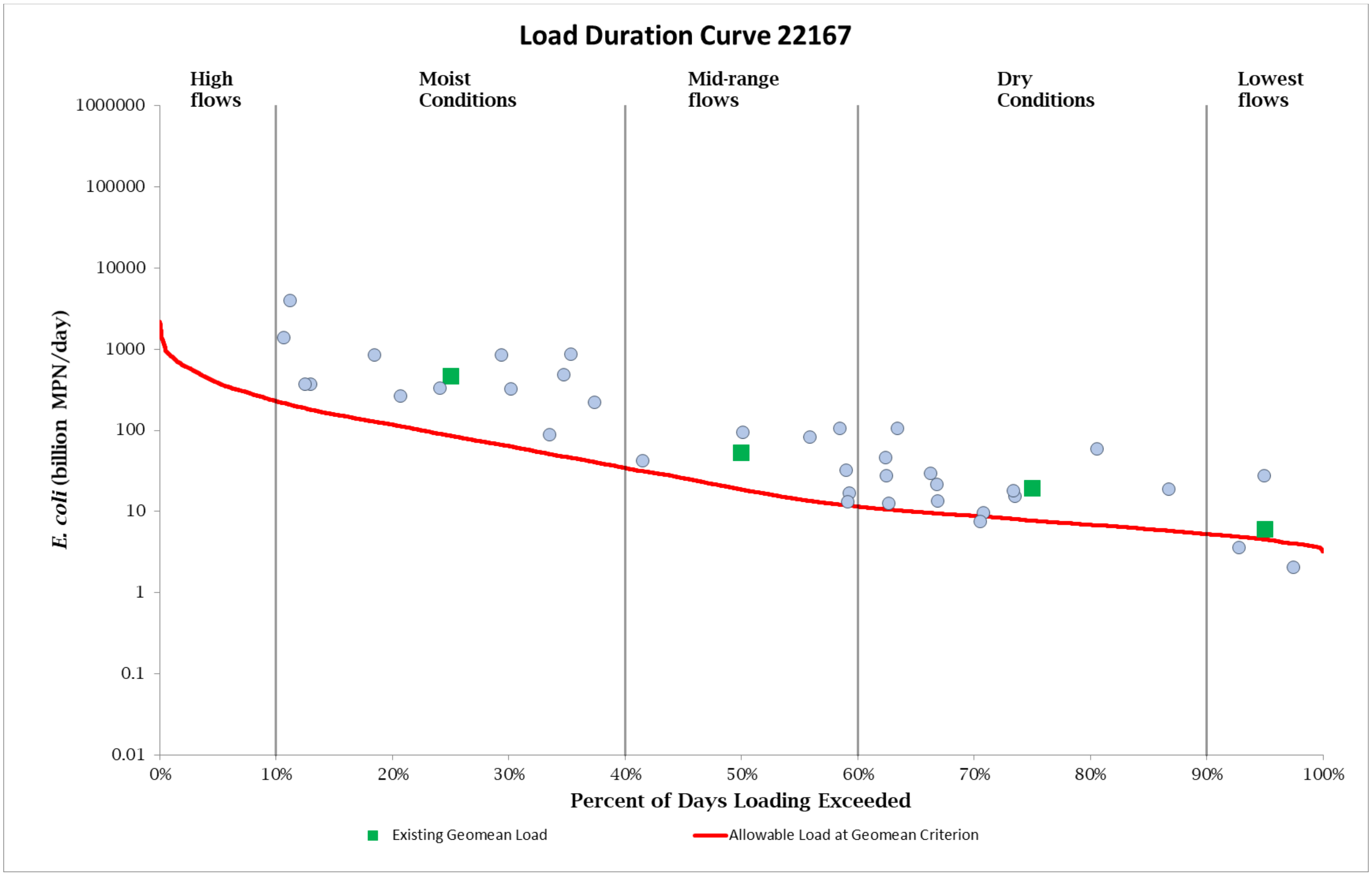


Figure 5.10 Load duration curve for Station 22167

Table 5.10 Percent reduction for Station 22167

	Geomean (billion MPN/day)	Median flow (cfs)	Geometric Mean *E. coli* (MPN/100 mL)	% reduction
5%	N/A	124.4	N/A	N/A
25%	465.85	27.8	684	81.6%
50%	53.31	6.0	361	65.1%
75%	19.40	2.5	318	60.4%
95%	6.00	1.5	167	24.6%

ANNUALIZED REDUCTIONS

Using the LDC for station 10517 this plan calculated annual load reductions for the Kickapoo Creek watershed. Based on this estimate a 44.50% reduction in fecal bacteria load is needed as shown in Table 5.11.

Table 5.11 Summary of load reduction required

		High	Moist	Mid-Range	Dry	Low
Days per Year		36.5	109.5	73	109.5	36.5
Median Flow	(cfs)	598.5	133.9	29.0	12.0	7.1
Existing Geomean Concentration	(MPN/100ML)	260	304	460	173	97
Allowable Daily Load	(Billion MPN)	1844.99	412.78	89.40	36.99	21.89
Allowable Annual Load	(Billion MPN)	67,342.03	45,198.49	6,526.04	4,050.65	798.88
Existing Daily Load	(Billion MPN)	3806.81	995.98	326.78	50.76	16.77
Existing Annual Load	(Billion MPN)	138,948.57	109,059.81	23,854.94	5,558.22	612.11
Annual Load Reduction Needed	(Billion MPN)	71,606.54	63,861.32	17,328.90	1,507.57	N/A
Percent Reduction Needed		51.53%	58.56%	72.64%	27.12%	N/A
Total Annual Load	(Billion MPN)	278,033.64				
Total Annual Load Reduction	(Billion MPN)	154,304.33				
Total Percent Reduction		44.50				

POTENTIAL *E. COLI* LOAD ESTIMATION USING SELECT

In the previous chapters, the potential *E. coli* sources for the Kickapoo watershed are identified. In this section, the potential *E. coli* load will be estimated using the SELECT (Spatial Explicit Load Enrichment Calculation Tool) analysis method with a spatial resolution of 30 m. To estimate the potential *E. coli* load from each source, we first assigned their suitable land use and then the load is calculated using the equation in Table 5.12. The fecal production rates were obtained from the highest range of values from EPA's guideline (USEPA 2001a) for all the sources. A conversion factor of 0.5 was also used to estimate the fecal production rate from fecal coliform to *E. coli*, Doyle and Erikson (2006). The results were aggregated at sub watershed level to identify areas of concern. For this purpose, the watershed was further subdivided into 28 sub watersheds using SWAT (Soil and Water Analysis Tool) as shown in Figure 5.11.

Table 5.12 Calculation of potential *E. coli* loads from various sources

SOURCE	*E. COLI* LOAD CALCULATION
CATTLE	EC = # CATTLE * 10 * 10^{10} CFU/DAY *0.5
HORSES	EC = # HORSES * 4.2 * 10^{8} CFU/DAY *0.5
SHEEP AND GOATS	EC = # GOAT * 1.2 * 10^{10} CFU/DAY *0.5
CAFOS	EC = # PERMITTED HEAD * 10 * 10^{10} CFU/DAY *0.2 * 0.5
POULTRY OPERATIONS	EC = MAX AMOUNT OF LITTER UTILIZED ON-SITE * 44,000 CFU/GRAM
DEER	EC = # DEER * 3.5 * 10^{8} CFU/DAY *0.5
FERAL HOGS	EC = # HOGS * 1.1 * 10^{9} CFU/DAY *0.5
PETS	EC = # HOUSEHOLDS* #PETS/HOUSEHOLD * 5 * 10^{9} CFU/DAY *0.5
OWTSS	EC = # OWTSS *FAILURE RATE * $10 * 10^{6} \frac{\text{CFU}}{\text{100ML}} * 70 \frac{gal}{person\ day} * \frac{Avg\ \#}{Household} * \frac{3758.2\ ml}{gal} * 0.5$
WWTFS	EC = PERMITTED MGD * $\frac{126\ \text{CFU}}{\text{100ML}} * \frac{10^{6}\ gal}{MGD} * \frac{3758.2\ ml}{gal}$

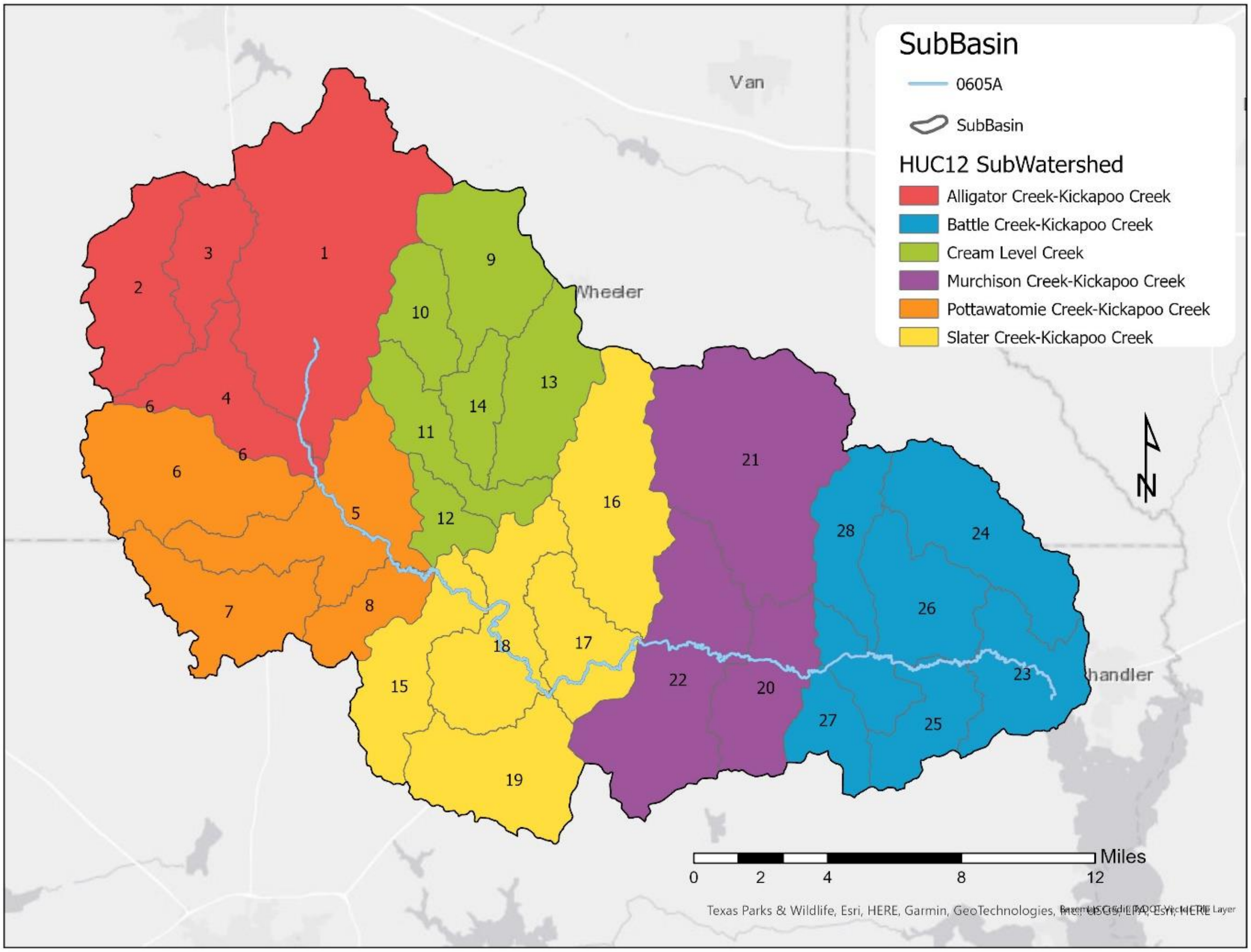


Figure 5.11 Sub watershed map

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 indicates that rotational grazing and grazing livestock in upland pastures during wet seasons result in significant reductions of *E. coli* levels (Wagner et al. 2012). Furthermore, alternative water sources and shade structures located outside of riparian areas significantly reduce the number of time cattle spends 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 land in the area were identified using 2017 Census of Agriculture (USDA-NASS) County level data. This plan estimated approximately 24,694 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 sub watersheds 1, 6, and 21 with a potential *E. coli* load value of more than 6.9 x 1013 cfu/day *E. coli.* Appendix A describes the equations and assumptions used to generate potential annual loads.

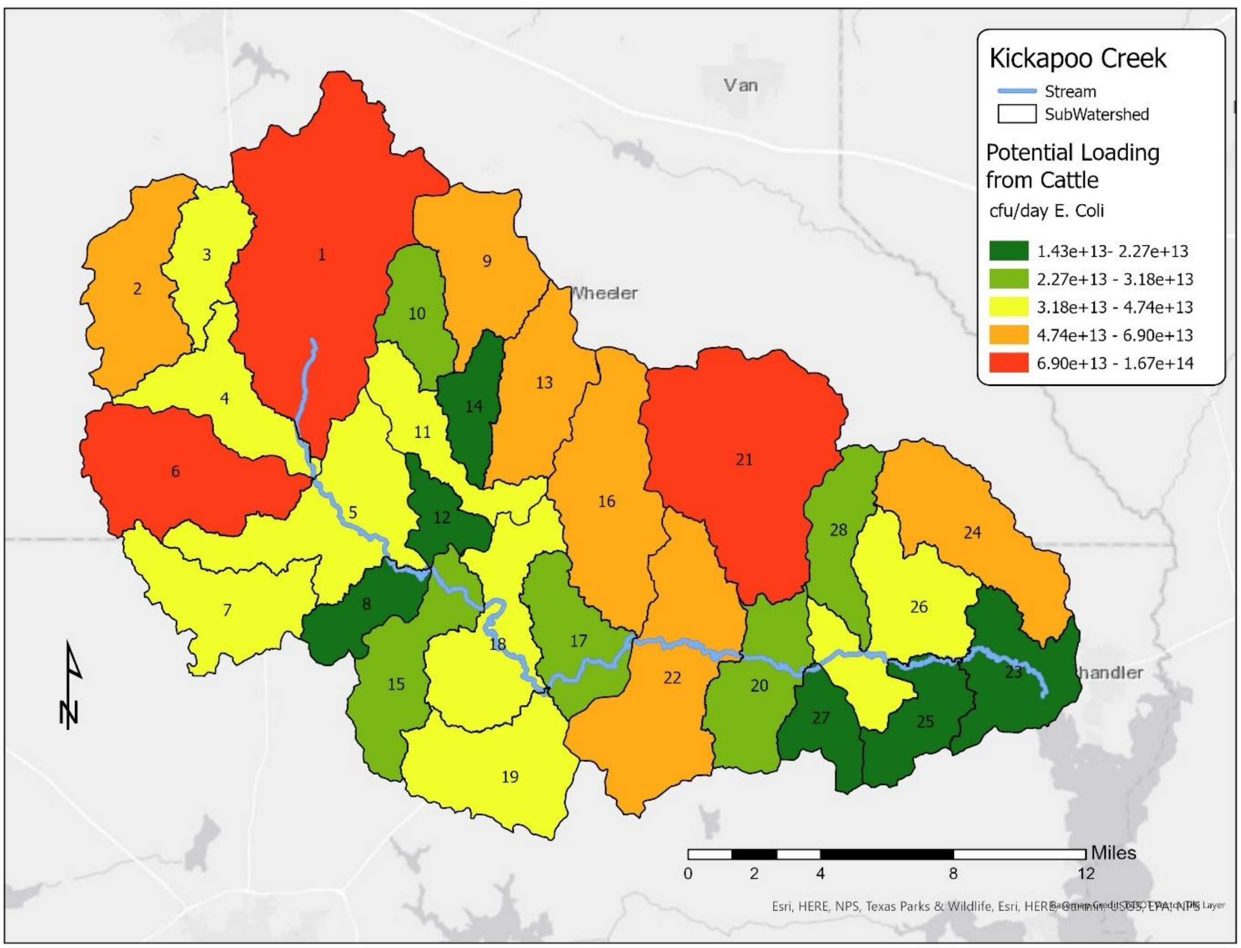


Figure 5.12 Total daily potential *E. coli* load from cattle

OTHER LIVESTOCK

Aside from cattle, other livestock such as goats, horses, and donkeys/mules/burros, can contribute to *E. coli* bacteria loading. Livestock estimates were derived from the 2017 Census of Agriculture (USDA-NASS) County level data. 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. The SELECT model prioritizes the same sub watersheds (1, 6, and 21) for the highest potential *E. coli* load with a value of more than 6.9 x 10^{13} cfu/day *E.coli* for goats only (Table 5.13).

In this plan, mules, burros, and donkeys are combined with the number of horses and ponies. This grouping shows sub watersheds 1, 21, and 22 with the highest potential *E. coli* load with a value of more than 2.12 x 10^{10} cfu/day *E. coli* (Table 5.14). Appendix A describes the equations and assumptions used to generate potential annual loads.

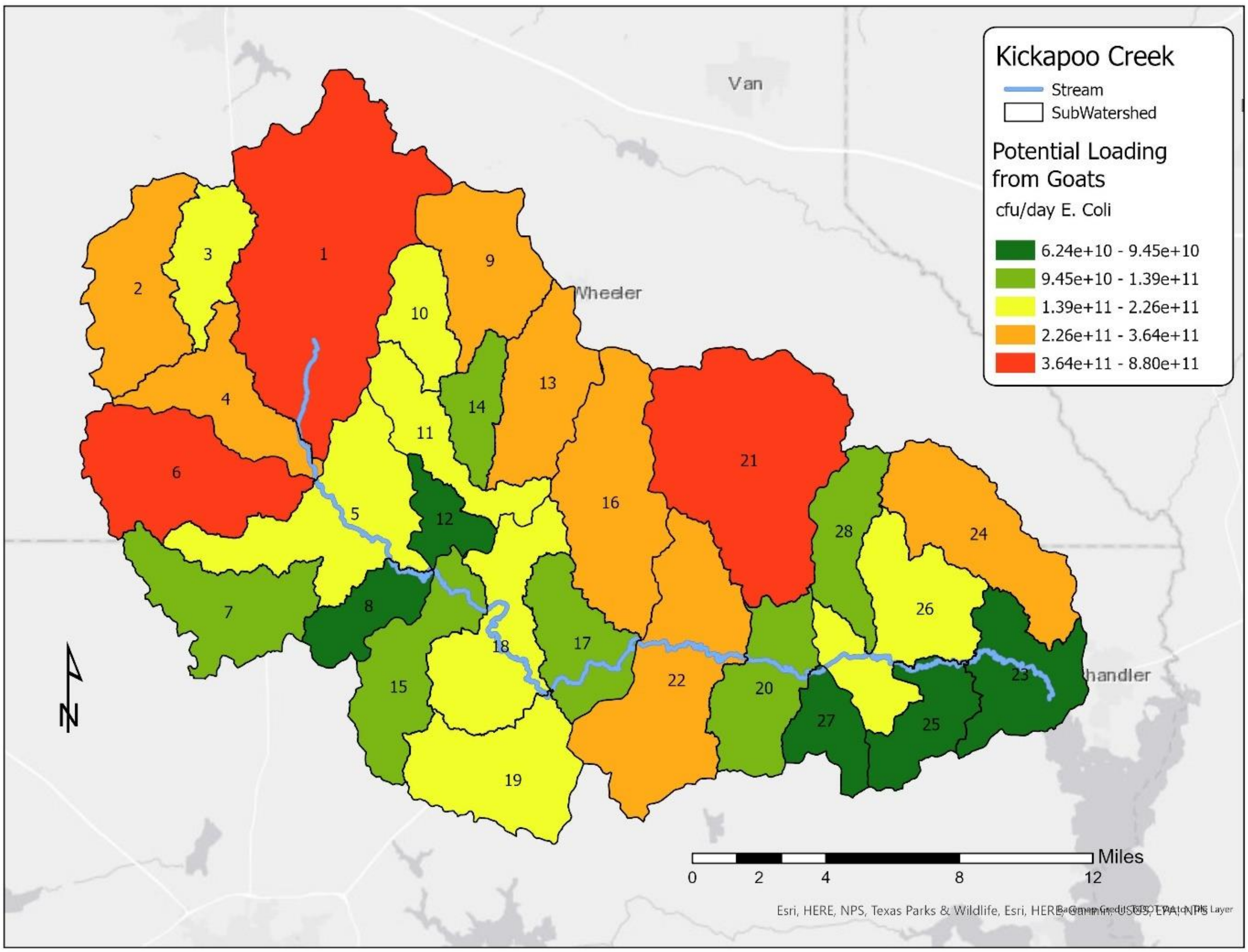


Figure 5.13 Total daily potential *E. coli* load from goats

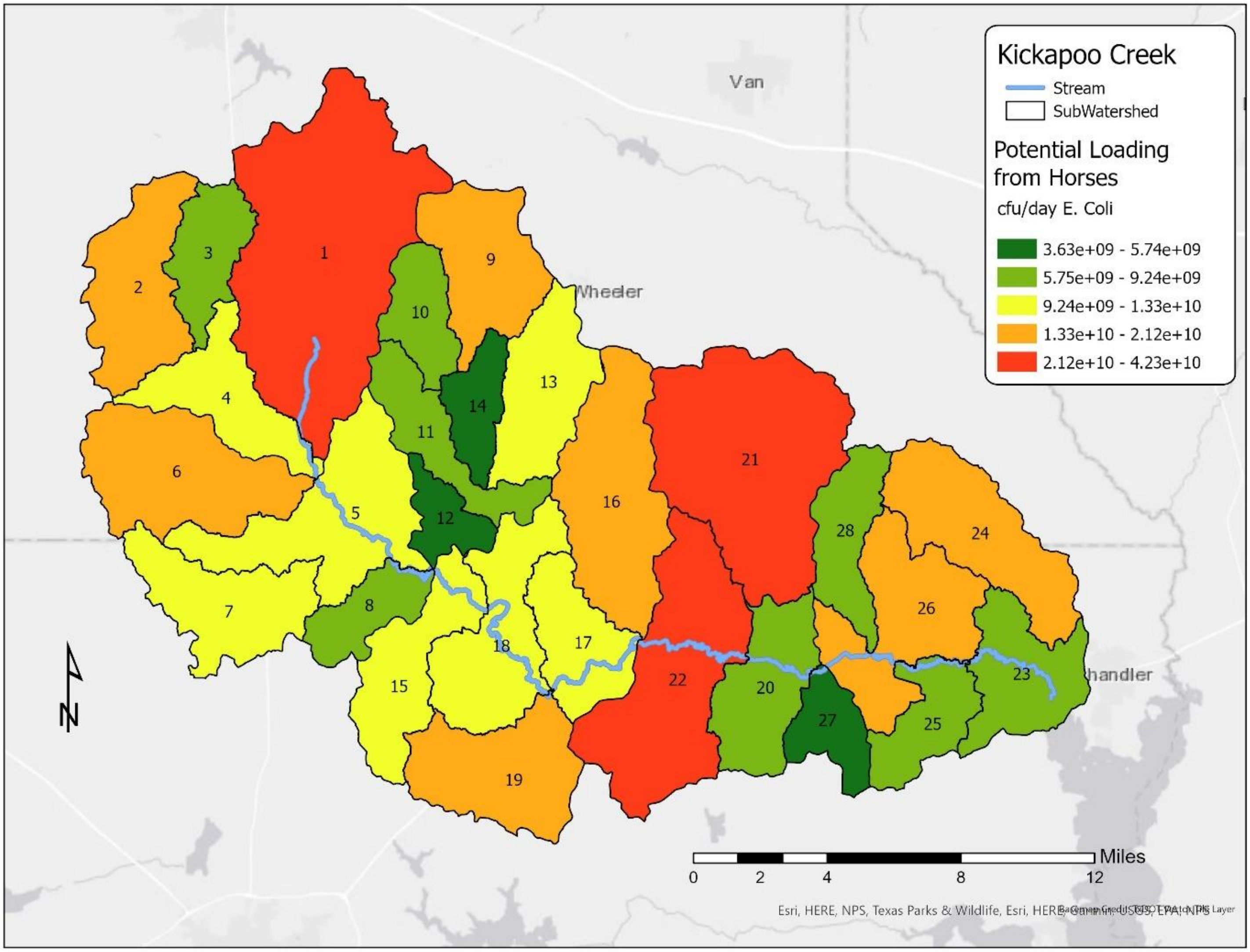


Figure 5.14 Total daily potential *E. coli* load from horses (including mules, burros, and donkeys)

FERAL HOGS

Feral hogs contribute to *E. coli* bacteria loadings through the direct deposition of fecal matter into streams while wading in the channel and/or wallowing in riparian areas. Riparian areas provide ideal habitats and migratory corridors for feral hogs are they search for food. While the complete removal of the feral hog population is unlikely, habitat management and trapping programs can limit populations and associated damage.

The number of hogs in the watershed was estimated from a study conducted by Texas A&M AgriLife Extension (Timmons, et.al, 2012). In the study, it is reported that the density of feral hogs in Texas is about 12.65 hogs per square mile. The SELECT results indicate the highest potential daily loadings occur in sub watersheds 1 and 21 with a value of more than 1.46 x 10^{11} cfu/day *E. coli* (Figure 5.15). Appendix A describes he equations and assumptions used to generate potential annual loads.

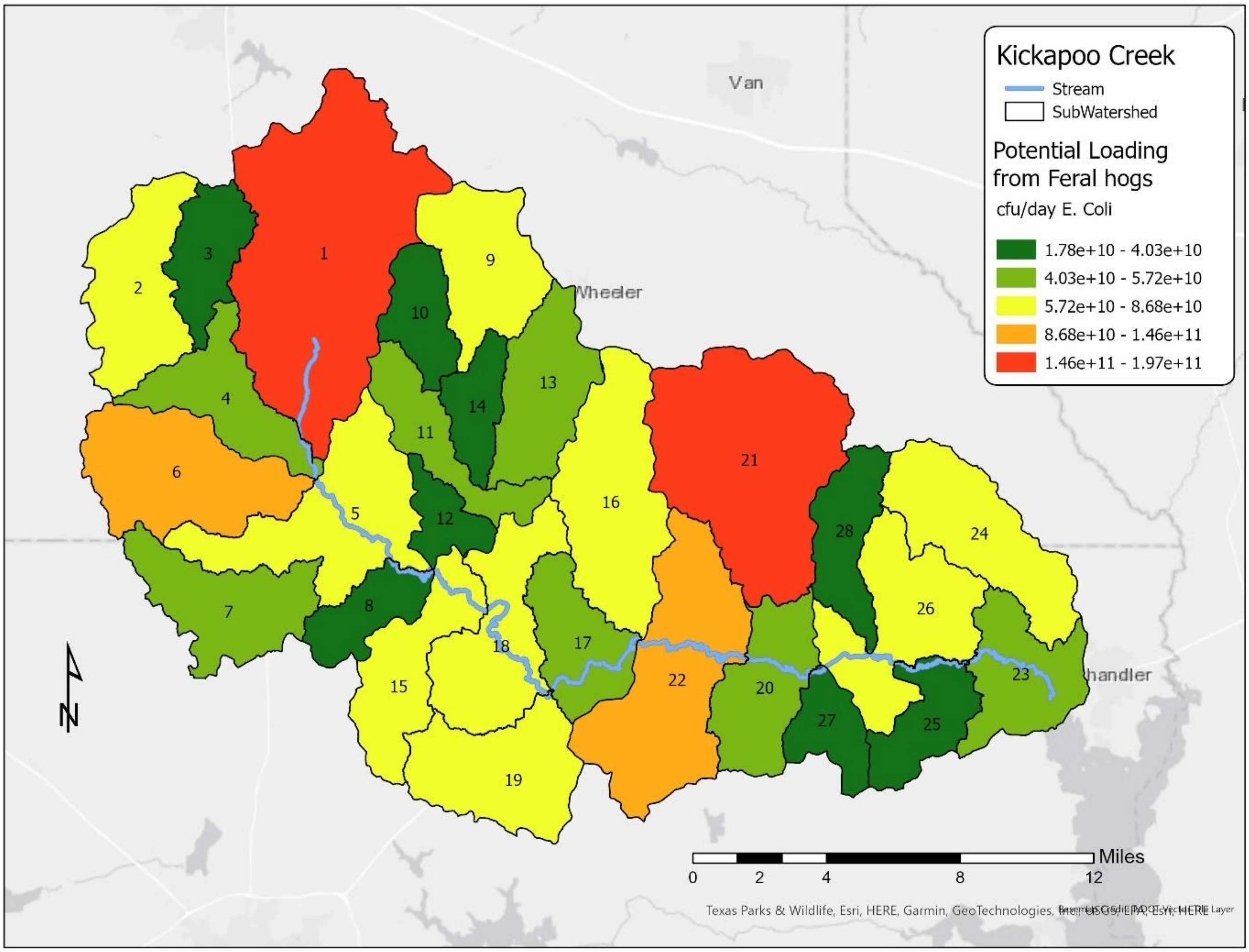


Figure 5.15 Total daily potential *E. coli* load from feral hogs

DEER

White-tailed deer are the primary wild deer species in the watershed. The white-tailed deer population in Texas is higher than that in 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 and women in Texas annually. The deer population was estimated for the Kickapoo Creek watershed by using data from the Texas Parks and Wildlife Department (TPWD) at the wildlife management area level. The white-tailed deer is a warm-blooded mammal and contribute to *E. coli* bacteria loadings similarly to feral hogs. The highest potential *E. coli* load with a value of more than 1.08 x 10^{11} cfu/day *E.coli* is in sub watersheds 1 and 21 (Figure 5.16). Appendix A describes the equations and assumptions used to generate potential annual loads.

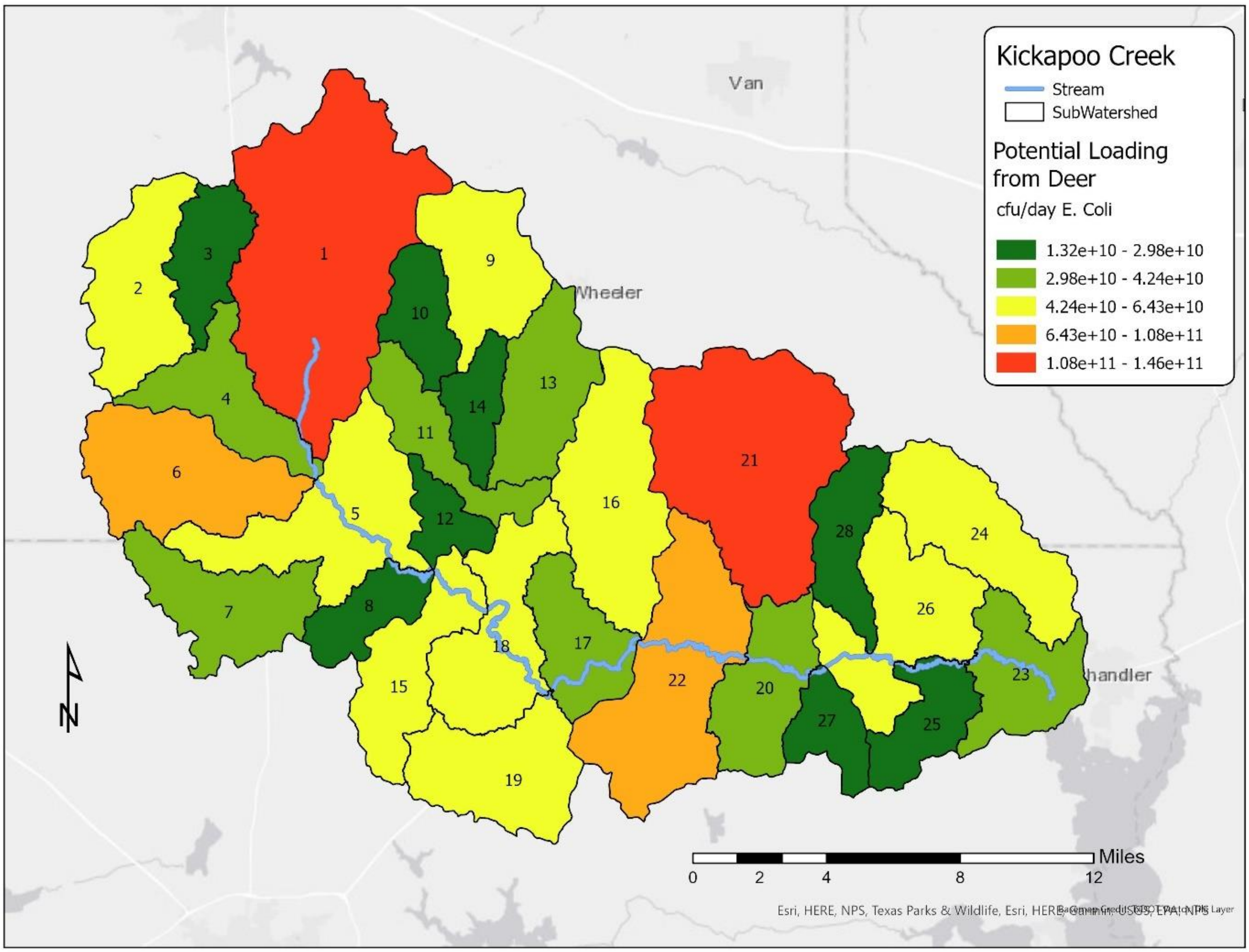


Figure 5.16 Total daily potential *E. coli* load from deer

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 sub watersheds 1 and 16 with a value of more than 1.42×10^{12} cfu/day *E. coli.*

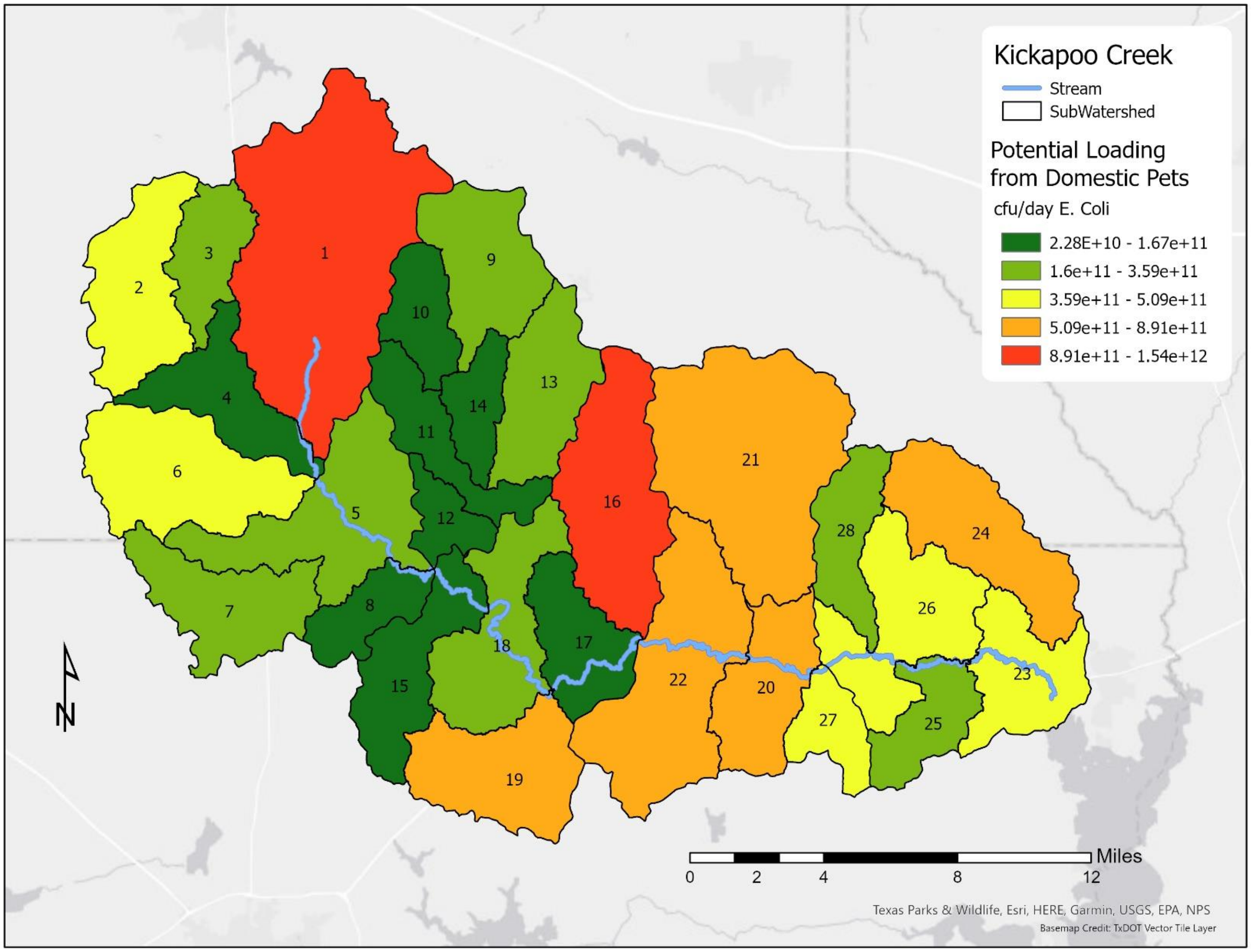


Figure 5.17 Total daily potential *E. coli* load from domestic pets

OSSF

Onsite Sewage Systems (OSSFs) can contribute to bacteria loads in waterbodies, in particular those where effluent is released near the waterbodies. Within the Kickapoo Creek watershed, approximately 15% of OWTFs are assumed to fail during a given year. Using 911 addresses and removing the households within the Community Crisis Network (CCN) areas (areas serviced by WWTFs), it was estimated that there are approximately 6,576 OWTS within the watershed (87.6% of homes in the watershed). Using the 15% failure rate, it is assumed 986 of those are failing systems. The average number of people in the household is derived from 2020 Census block data, a constant sewage discharge of 70 gallons per person per day was also used. The result is shown in Figure 5.18 sub watersheds 1, 16 and 21 show the highest potential *E. coli* load with a value of more than 2.36 x 10^{12} cfu/day *E. coli*.

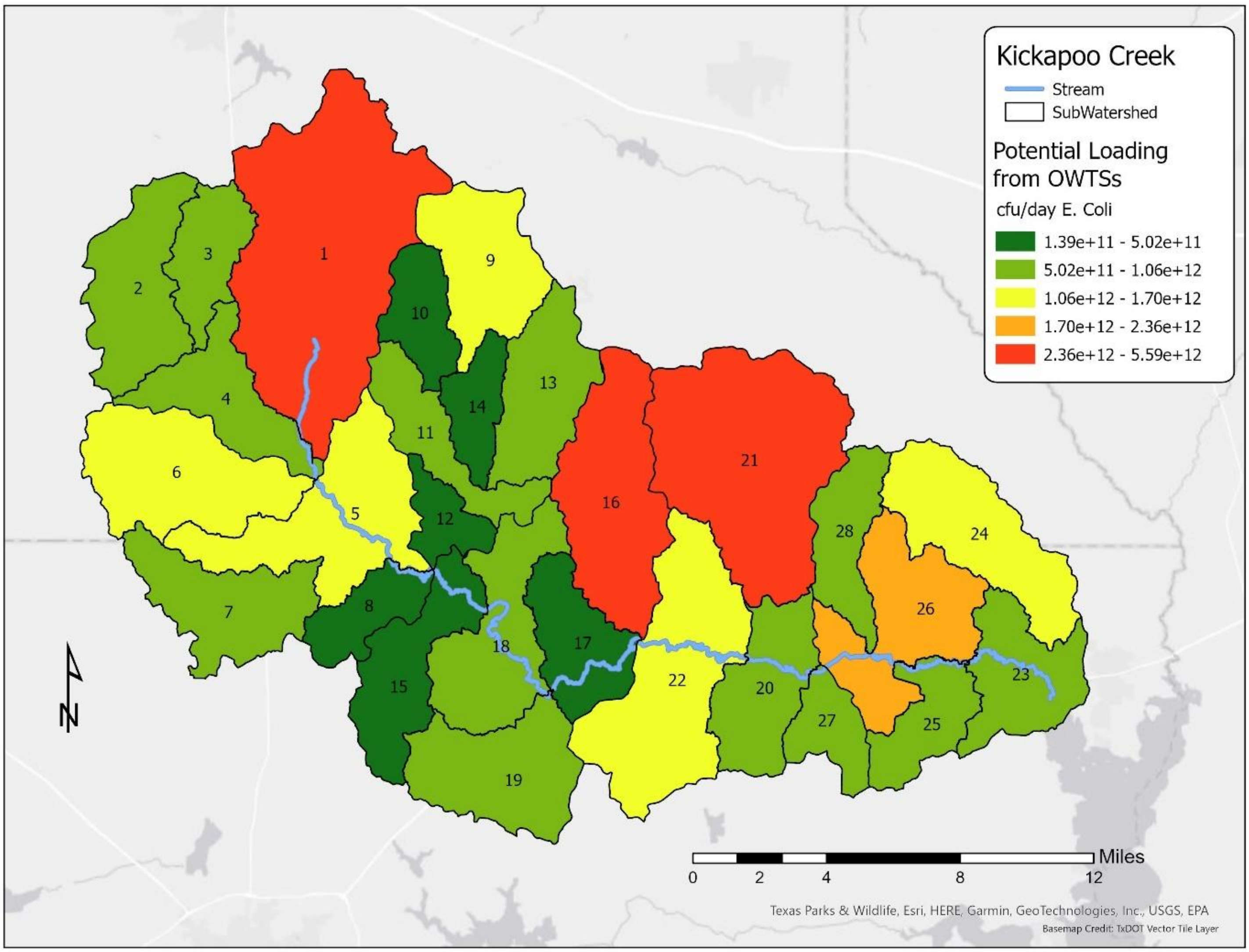


Figure 5.18 Total daily potential *E. coli* load from OSSFs

WWTFS

Currently, there are five active permitted wastewater dischargers in Kickapoo Creek watershed. These wastewater discharges are regulated by TCEQ and are required to report average monthly discharges and *E. coli* concentrations. To estimate potential *E. coli* loads from the WWTFs, the maximum permitted discharge and an *E. coli* concentration of 126 cfu /100 ml is used in the formula in Table 5.12 and applied to the sub watersheds the WWTFs are located. The result is shown in Figure 5.19 and sub watershed 27 has the highest potential with 7.58 x 10^8 cfu/day *E. coli.*

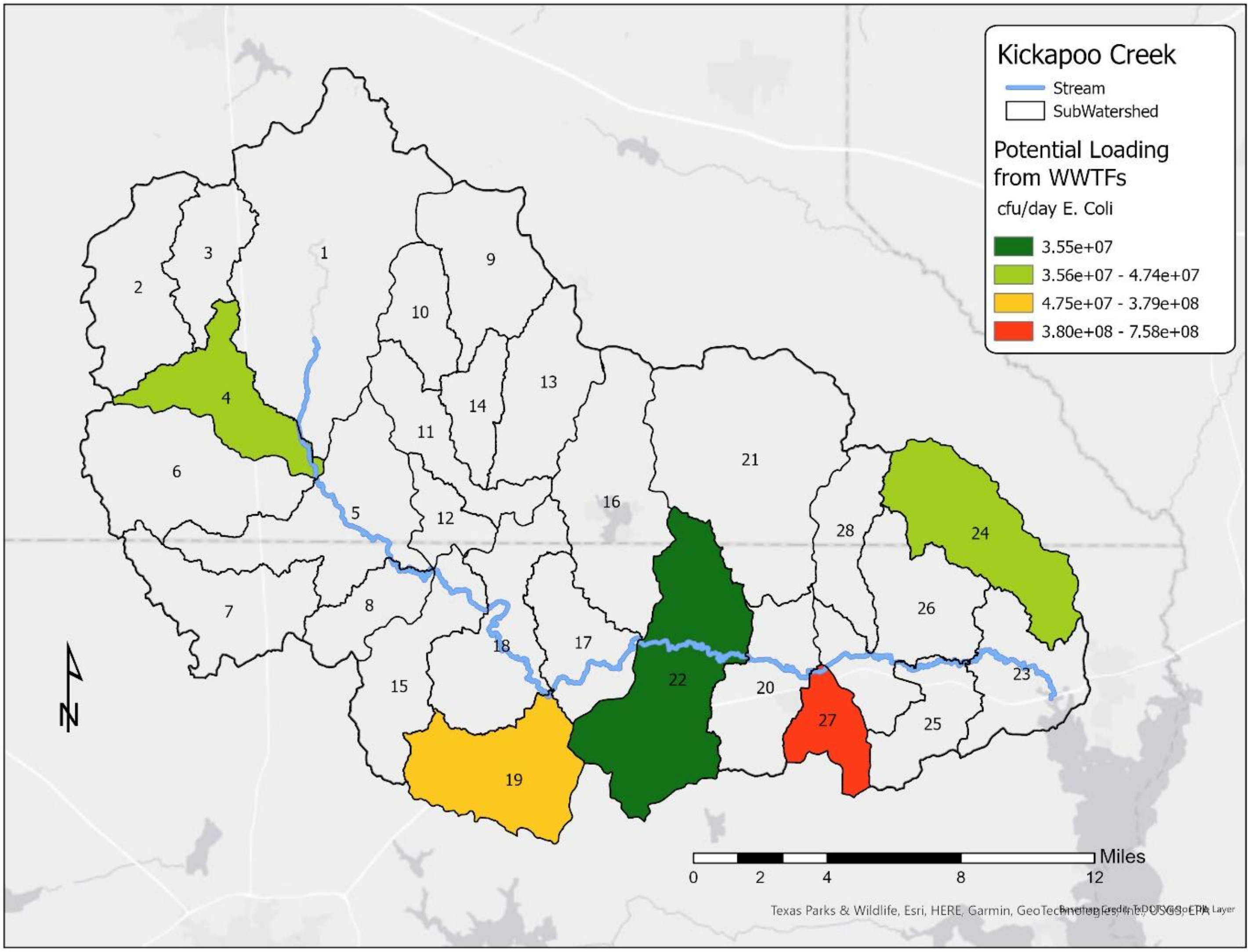


Figure 5.19 Total daily potential *E. coli* load from WWTFs

TOTAL POTENTIAL *E. COLI* LOAD

Figure 5.20 and Table 5.13 show the total estimated potential *E. coli* loadings across the watershed based on the combined total potential loadings from sources used in SELECT. Sub watersheds 1 and 21 show the highest potential *E. coli* load with value more than 7.81 x 10^{13} cfu/day *E. coli*.

Table 5.13 SELECT calculated total potential *E. coli* loads

Sub Watershed	Total Daily Load (cfu/day *E. coli*)	Total Annual Loads (cfu/year *E. coli*)
1	1.74E+14	6.37E+16
2	6.28E+13	2.29E+16
3	3.30E+13	1.20E+16
4	4.46E+13	1.63E+16
5	4.52E+13	1.65E+16
6	7.15E+13	2.61E+16
7	3.32E+13	1.21E+16
8	1.60E+13	5.86E+15
9	5.48E+13	2.00E+16
10	2.74E+13	1.00E+16
11	3.32E+13	1.21E+16
12	1.46E+13	5.33E+15
13	4.95E+13	1.81E+16
14	2.18E+13	7.96E+15
15	2.77E+13	1.01E+16
16	6.66E+13	2.43E+16
17	2.53E+13	9.25E+15
18	3.82E+13	1.39E+16
19	4.46E+13	1.63E+16
20	2.46E+13	8.96E+15
21	1.20E+14	4.39E+16
22	6.01E+13	2.19E+16
23	2.19E+13	8.01E+15
24	5.48E+13	2.00E+16
25	1.98E+13	7.21E+15
26	4.41E+13	1.61E+16
27	1.61E+13	5.87E+15
28	2.74E+13	9.99E+15

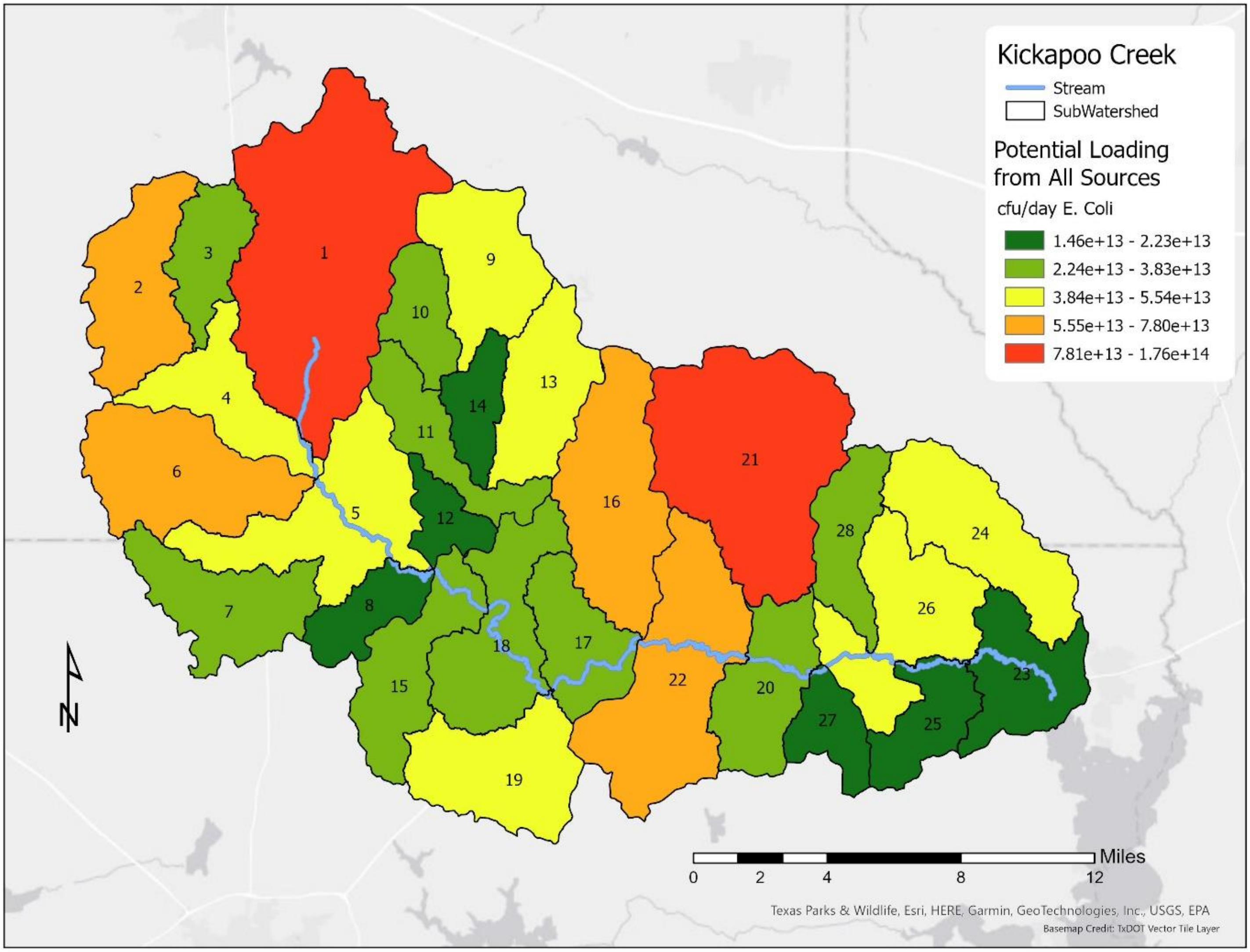


Figure 5.20 Total daily potential *E. coli* load from all sources

CHAPTER 6
STRATEGIES FOR WATERSHED PROTECTION PLAN IMPLEMENTATION

INTRODUCTION

Chapters 4 and 5 illustrate the diverse sources of bacteria and nutrient loading to Kickapoo 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, feral hogs, and OSSFs have the highest potential to contribute *E. coli* to the water body 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 in this chapter and indicate that reducing bacteria loads entering the Kickapoo 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. To note, while Kickapoo Creek watershed is primarily rural, urban areas do comprise of a small amount of the watershed. Opportunities to improve watershed health through improved stormwater management and water conservation does exist but are not included in this plan. Stakeholder input was crucial throughout the decision-making process for these suggested management strategies. 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.

Table 6.1 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 Resource Conservation Service, NRCS

MANAGEMENT MEASURE 1 – DEVELOPING AND IMPLEMENTING WATER QUALITY MANAGEMENT PLANS OR CONSERVATION PLANS

Potential bacteria loadings in the Kickapoo Creek watershed from cattle and other livestock are relatively high 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 die 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 the availability and distribution of water, food, and shelter. This allows livestock to be managed easily compared to non-domesticated species. The time livestock spends 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 best management practices (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 6.1. 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, there are no conservation plans in the watershed. Through the implementation of this watershed plan, we hope to increase the adoption of Conservation Plans (CPs) and Water Quality Management Plans (WQMPs) to 50 total plans over the next 10 years. Load reductions achieved from this measure will vary depending on location 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 habitats. Therefore, all properties with riparian areas are considered a priority. Meanwhile, properties without riparian habitats are also encouraged to participate in implementation activities. Priority areas will include Subwatershed 1, 6, 21, and 22. Table 6.2. 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. While other sources of *E. coli* are potentially larger in volume, due to feral hogs' preference for dense habitats, food resources, and water typically provided in riparian areas enhances the potential effects that they can have on instream water quality. Common feral hog behavior, such as rooting and wallowing also affects 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 6.3).

Physically removing hogs is the best strategy for reducing their impact on water quality. While complete eradication of feral hogs in the watershed is not feasible, a variety of methods are available to manage or reduce populations. Trapping animals is the most effective method available to landowners in the watershed. With proper planning and diligence, trapping can successfully remove large numbers of hogs at once. Furthermore, the 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 the 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 a feeder can help reduce the ability of feral hogs to access 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. Delivering up-to-date information and resources to landowners through workshops and demonstrations is critical to maximizing landowner success in removing feral hogs. Meanwhile, developing wildlife management plans designed by landowners to establish the goals of landowners 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 Subwatershed 1 and 21. 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 a gravity-fed drain field that separates solids from wastewater prior to the distribution of the water into soil where actual treatment takes place. In the Kickapoo Creek watershed, approximately 52.2% of the watershed's soils are considered very limited and 40.4% are considered somewhat limited.

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. 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 6.4). Additionally, maintenance providers, installers, and inspectors should be secured to assist homeowners to repair or replace OSSF systems should an issue arise. While OSSFs should be replaced as needed across the entire watershed, priority will be placed on Subwatersheds 1, 16, and 21. Additionally, priority will be placed on OSSFs within 150 yards of perennial water bodies.

MANAGEMENT MEASURE 4 – MANAGE SSOS AND UNAUTHORIZED DISCHARGES

Although 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 comprised infrastructure.

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 while encouraging corrective action be taken before there is harm to human health and safety or damage to the environment. Sanitary Sewer Overflow Initiatives can be implemented in the Kickapoo Creek WPP.

Fats, oils, grease, non-flushables, and other substances, when disposed of down drains and toilets, can cause damage to collection systems. Several educational programs on the proper disposal of fats, oils, and grease are available through AgriLife Extension. Distribution of educational materials and providing online videos on the Kickapoo 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 6.5.

MANAGEMENT MEASURE 5 – REDUCE ILLICIT DUMPING

Stakeholders have 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 is anticipated to be a relatively minor contributor to bacteria loadings in the watershed compared to other sources. However, the development and delivery of educational and outreach materials to local residents on proper disposal of carcasses and their trash could help reduce illicit dumping and associated potential bacteria loadings (Table 6.6).

Hazardous waste collection events happen around the watershed annually. Advertising the 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.

MANAGEMENT MEASURE 6 – 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 in a trash can is a simple, yet 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 6.7). 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. As there are no parks in the watershed, apartment complexes and homeowners' associations were identified as potential areas to install pet waste 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 is 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 and 16.

Table 6.2 Management measure 1: Cattle and other livestock

Source: Cattle and Other Livestock

Problem: Direct and indirect fecal bacteria loading due to livestock in streams; riparian degradation and overgrazing

Objectives:

- Work with landowners to develop property-specific CPs and WQMPs that improve grazing and water quality.
- Provide technical and financial support to producers.
- Reduce fecal loadings attributed to livestock.

Location: Priority subwatersheds identified below.

Critical Areas: All properties with riparian habitat throughout the watershed and all properties in Subwatersheds 1,6,21 and 22

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

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.

Implementation Strategy

Participation	Recommendations	Period	Capital Costs
TSSWCB, SWCDs	Develop funding to hire WQMP technician	2023-2033	Estimated $60,000 per year
Producers, NRCS, TSSWCB, SWCDs	Develop implementation and provide financial assistance for 50 livestock CPs and WQMPs over 10 years	2023-2033	$1,500,000 (est. $30,000 per plan)
AgriLife Extension, ANRA, SWCDs	Deliver education and outreach programs and workshops to landowners		

Estimated Load Reduction

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 50 WQMPs and CPs is estimated to reduce annual loads from livestock by
1.42×10^{14} cfu *E. coli* per year in the Kickapoo Creek watershed.

Effectiveness	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.
Certainty	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.
Commitment:	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.
Needs	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.

Conservation Plan, CP; Water Quality Management Plan, WQMP; Best Management Practice, BMP; National Resource Conservation Service, NRCS; Texas State Soil and Water Conservation Board, TSSWCB; Soil and Water Conservation District, SWCD

Table 6.3 Management measure 2: Feral hogs

Source: Feral Hogs			
Problem: Direct and indirect fecal 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% (492 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	Voluntary construct fencing around deer feeders to prevent feral hog utilization		
	Voluntary trap/remove/shoot feral hogs to reduce numbers		
Landowners, producers, TPWD	Develop and implement wildlife management plans and wildlife management practices		
AgriLife Extension, Texas Wildlife Services, TPWD	Deliver Feral Hog Education Workshop		
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 Kickapoo Creek watershed is estimated to reduce potential annual loads by 2.47×10^{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.

Table 6.4 Management measure 3: OSSF management

Source: Identify and Report or Replace Failing or Non-Existent On-Site Sewage Facilities (OSSFs)			
Problem: Pollutant loading reaching streams from untreated or insufficiently treated household sewage			
Objectives: • Inspect failing OSSFs in the watershed and secure funding to promote OSSF repairs. • Repair or replace OSSFs by working with counites and communities. • Educate homeowners on system operations and maintenance.			
Location: Entire watershed			
Critical Areas: Primarily Subwatershed 1,16 and 21 and system within 150 yards of the perennial water body			
Goal: Identify, inspect, and report or replace 50 failing OSSFs in the watershed, especially within critical areas			
Description: Expanded education programs and workshops will be delivered to homeowners on the proper maintenance and operation of OSSFs. Failing or non-existent systems will be repaired or replaced as appropriate and as funding allows.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Counties, contractors	Identify, inspect, and repair or replace OSSFs as funding allows		
Counties, Municipalities Districts, Homeowners, ANRA	Inspect and identify the possibility in connecting to existing infrastructure		
ANRA, AgriLife Extension, TIAER	Operate an OSSF education, outreach, and training program for installer, service providers and homeowners		
AgriLife Extension, TIAER	Develop and deliver materials (postcards, websites, handouts, etc.) to educate homeowners		
Estimated Load Reduction			
As planned, 50 OSSFs will be repaired or replaced throughout the watershed. It will result in a potential load reduction of 3.2×10^{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).			
Effectiveness	High: Replacement or repair of failing OSSFs yield direct *E. coli* reductions.		
Certainty	Low: The level of funding available to identify, inspect and repair or replace OSSFs is uncertain; however, funding sources are available for assistance		
Commitment:	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.		
Needs	High: Financial resources are needed to identify, 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.		

Table 6.5 Management measure 4: Manage sanitary sewer overflows (SSOs) and unauthorized discharges

Source: Manage Sanitary Sewer Overflow (SSO) or Unauthorized Discharges

Problem: Fecal bacteria loading from unauthorized discharges when excessive water enters the sanitary sewer system through I&I

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.

Critical Areas: Urbanized areas in subwatersheds 16, 19, 20

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 occupancies.

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.

Implementation Strategy

Participation	**Recommendations**	**Period**	**Capital Costs**
TIAER, AgriLife Extension, Cities	Identify potential resources and develop programs to assist homeowners with sewage pipe replacement		
Cities, AgriLife Extension, TIAER	Develop and deliver educational material to residents and property owners		

Estimated Load Reduction

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.

Effectiveness	Moderate to High: Although the infrequent, reduction in SSOs and unauthorized discharges will result in direct reductions to bacteria loading during the highest flow events.
Certainty	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.
Commitment:	Moderate: Municipal public works have incentives to resolve I&I issues to meet discharge requirements. However, lack of funding precludes the replacement of sewage pipes.
Needs	High: Financial needs are likely significant.

Inflow and Infiltration, I&I; wastewater treatment facility, WWTF

Table 6.6 Management measure 5: 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 a focus on 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		
Estimated Load Reduction			
Load reductions are likely minimal from this management measure and were not quantified.			
Effectiveness	Moderate: 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	Low: Anticipating changes in resident behavior due to education and outreach is difficult in rural areas. The issue is not a high priority and commitment to limited resources will likely remain low.		
Commitment:	Moderate: Many stakeholders indicate illicit dumping occurs; however, enforcement is difficult in rural areas. The issue is not a high priority and commitment to 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 outreach efforts.		

Table 6.7 Management measure 6: Increase proper pet waste

Source: Pet Waste

Problem: Direct and indirect fecal bacteria loading from household pets

Objectives:

- Expend education and outreach messaging on the disposal of pet waste.
- Install and maintain pet waste stations in public areas.

Location: Entire Watershed

Critical Areas: High pet concentration areas, subwatersheds 1 and 16.

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 4,603pets

Description: Expand education and outreach regarding the need to properly dispose of pet waste in the watershed. Specifically 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	Allow dog and cat owners to have pets spayed or neutered at little to no cost		
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.		
Cities, Counties, AgriLife Extension, TWRI, HOAs	Develop and provide educational resources to residents		

Estimated Load Reduction

Load reductions resulting from this targeted 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 5.26×10^{14} cfu *E. coli per year.*

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 pet waste. Those that do not properly dispose of pet waste are likely difficult to reach of 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 the resources are provided.

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 Kickapoo 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 the success of implementation and working to carry out 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 January 2022. Five meetings were held, including general stakeholder meetings. Meetings were also held for county officials and local SWCDs to engage stakeholders in the planning process.

Throughout the process, local stakeholders participated in the many public meetings, one-on-one meetings and workshops associated with the WPP development. Stakeholders were present from both counties of the watershed (Henderson and Van Zandt) and represented agriculture and landowners. Some agencies involved in the planning process include: City of Edom, Angelina-Neches River Authority, Trinity-Neches SWCD, TSSWCB, and NRCS.

FUTURE STAKEHOLDER ENGAGEMENT

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, newspapers 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 Kickapoo 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.

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 Kickapoo 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.

HEALTHY LAWNS

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, the City of Brownsboro, and can teach homeowners how to care for their lawns appropriately to reduce the risk of NPS pollution entering Kickapoo Creek.

URBAN RIPARIAN AND STREAM RESTORATION WORKSHOP

Stream restoration projects demonstrating sites were discussed during the stakeholder meetings. The Kickapoo Creek Watershed Coordinator can coordinate with the Texas Water Resources Institute to deliver and host the Urban Riparian and Stream Restoration Workshop in the watershed. The program discussed 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 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 STEAMS WORKSHOP

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program is focused on 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, 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 the 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 better in 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 Kickapoo Creek watershed. Wildlife management workshops will be advertised through newsletters, news releases, the project website, and other avenues as appropriate.

PUBLIC MEETINGS

Stakeholder meetings will be held periodically and 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.

ANRA publishes a yearly basin highlight report which discusses surface water quality in the Angelina-Neches River Basins. Watershed updates and implementation plans can be announced in these newsletters.

CHAPTER 8
PLAN IMPLEMENTATION

INTRODUCTION

Implementing the WPP is a 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 Kickapoo 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 7.1. 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 progress. If sufficient progress is not made, adjustments will ensure increased 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 7.1 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 a WQMP technician	TSSWCB, SWCDs, Watershed Coordinator	$60,000/year		1		$600,000
Develop, implement, and provide financial assistance for CPs and WQMPs	Producers, landowners, NRCS, TSSWCB, SWCDs, Watershed Coordinator	$30,000/plan	10	15	25	$1,500,000
Deliver education and outreach programs and workshops to landowners	AgriLife Extension, ANRA, Watershed Coordinator	N/A	1	1	1	N/A
Feral Hog Management						
Voluntarily construct fencing around deer feeders to prevent feral hog utilization	Landowner, ranch managers, leasees	$200/feeder		As many as possible		N/A
Voluntarily trap/remove/shoot feral hogs to reduce numbers	Landowner, ranch managers, leasees	N/A		As many as possible		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, Lonestar Healthy Streams, TPWD, Watershed Coordinator	$3,000 each workshop	1	1	1	$9,000

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
OSSF Management						
Identify, inspect, and repair or replace OSSFs as funding allows	Counties, contractors	$8,000-$10,000/system	20	40	40	$800,000-$1,000,000
Operate and OSSF education, outreach, and training program for Installer, service providers and homeowners	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
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/site				
Develop and deliver educational materials to residents and property owners	Cities, AgriLife Extension, Watershed Coordinator	N/A	1	1	1	N/A
Illegal Dumping						
Promote and expand education and outreach efforts in the watershed	Cities, AgriLife Extension, Watershed Coordinator	N/A				
Legal action	Local watershed law enforcement			As needed		
Pet Waste Management						

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 station establishment and maintenance	Cities, HOAs, counties, Watershed Coordinator	$150 per station	10	20	20	$7,500
Pet waste education materials	Cities, HOAs, counties, veterinarian hospitals, Watershed Coordinator	N/A	Annually, in addition to current informational flyers			N/A

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 and management measures within Kickapoo Creek. 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 9.1 provides a summary of the potential sources of technical assistance for each management measure.

Table 9.1 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
MM3: Identify and repair or replace failing on-site sewage systems	Designed technicians from counties; AgriLife Extension
MM4: Manage SSOs and Unauthorized Discharges	City public works department; engineering firms; AgriLife Extension
MM5: Reduce Illicit Dumping	AgriLife Extension; county law enforcement; TPWD game wardens
MM6: Increase proper pet waste management	City public works department; AgriLife Extension

LIVESTOCK MANAGEMENT

Designing 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.

OSSF MANAGEMENT

Technical support is needed to address failing OSSFs throughout Henderson and Van Zandt 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.

MANAGE SSOS AND UNAUTHORIZED DISCHARGES

City of 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 sources of enforcement and monitoring activities associated with illicit dumping.

PET WASTE MANAGEMENT

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

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 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 Henderson and Van Zandt Counties requires a permit on file with local counties or the city's authorized agents. Permits must be applied for through a TCEQ-licensed professional installer. The county or city's 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 Brownsboro, Edom, and Murchison 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 RESOURCE CONSERVATION SERVICE

The 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 landowners (1) maintain and improve private lands, (2) implement improved land management technologies, (3) protect water quality and quantity, and (4) enhance recreational opportunities. Local NRCS service centers for Henderson and Van Zandt Counties are located in Athens, Texas.

SOIL AND WATER CONSERVATION DISTRICTS

An 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 water quality management plans to meet each land unit's specific capabilities and needs. The local SWCDs include the Trinity-Neches SWCD and the Kaufman-Van Zandt 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 5, Tyler) 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 consistent with other land use goals, to ensure plant and animal diversity, to provide aesthetic and economic benefits, and to conserve soil, water, and other 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 and financial assistance for developing and implementing water quality management plans. A visit with the local SWCD office is the first step for operators to begin the plan development process.

FINANCIAL RESOURCE DESCRIPTIONS

Successful implementation of the Kickapoo 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 and have been accepted by EPA, 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 for BMP effectiveness
- OSSF repairs and replacements, land BMPs, water body clean-up events

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

Conservation Stewardship Program (CSP)

The CSP is a voluntary conservation program administered by NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional 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. Financial assistance is available to implement the practices.

Program information can be found at: https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program

Conservation Reserve Program (CRP)

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 CRP program is available at: https://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 other 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 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: https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives

Regional Conservation Partnership Program (RCPP)

The RCPP is a 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 the RCPP can be found at: https://www.nrcs.usda.gov/programs-initiatives/rcpp-regional-conservation-partnership-program

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 of less than 10,000 individuals.

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/urbanwaterspartners/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. ANRA is the CRP partner for the Kickapoo Creek watershed. The program supports water quality monitoring, and annual water quality assessments, and engages stakeholders in addressing water quality concerns in the Angelina & Neches River Basin.

More information about the Clean Rivers Program is available at: https://www.anra.org/conservation-recreation/water-quality-activities/clean-rivers-program/

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/

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 assistance but does require landowner to contribute through labor, materials, or other means.

Further information about this program is available at: https://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 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 administrated 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 at TPWD at: https://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 the 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 the 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. 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 Kickapoo Creek is the existing primary contact recreation standard for *E.coli* of 126 cfu/100mL (Table 10.1). 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 Kickapoo Creek watershed is necessary to track changes in water quality resulting from WPP implementation. Currently, water quality monitoring is mainly conducted by TCEQ Region 5 on a quarterly basis around the watershed at the stations identified in Figure 10.1.

There are sufficient historical records of water quality measures on the main stem and continued monitoring of each segment and its tributaries are suggested throughout implementation to monitoring 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 watersheds, 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.

Table 10.1 The water quality targets for impaired water bodies in Kickapoo Creek

Station ID	AU	Current Average Concentation (cfu/100mL)	5 Years After Implementation	10 Years After Implementation
10517	0605A_01	237	181.5	120
21618	0605A_01	317	221.5	120
22163	0605A_01	104	115	120
16796	0605A_02	168	147	120
16797	0605A_02	306	216	120
22164	0605A_02	184	155	120
22165	0605A_02	404	265	120
22166	0605A_02	505	315.5	120
22167	0605A_02	377	251.5	120

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 2024 and 2026 reports will likely be the first to include water quality data collected during the 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 the impacts of land management on the amount of NPS pollutants 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 Kickapoo 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 the 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 10.2. 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 ensure increased 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 Kickapoo 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 implantation 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 toward 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, the scope of implementation, or other reasons that would prevent implementation, adaptive management provides an opportunity to revisit and revise the implementation strategy.

The Kickapoo Creek WPP is a living document, intended to be reviewed 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 measures 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.

Stakeholders will also formally review the 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 Kickapoo 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 outlined in the WPP. A 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 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 population of the livestock was estimated using the 2017 Census of Agriculture (USDA-NASS) County level data. First, the number of livestock is calculated for each county separately and distributed the number to suitable landuse for respective counties. The landuse types that are identified as suitable for livestock are pasture, forests, and shrubs/scrubs. Then, using a (30 x 30 m) grid size, the average number of cattle in each suitable grid is:

$$N_{cattle} = \frac{\mathrm{TC}_{\mathrm{county}}}{\mathrm{TSA}_{county} * \mathrm{A}_{grid}}$$

Where:

N_{county} = Number of cattle in each suitable grid

TC_{county} = Estimated number of cattle in the county

TSA_{county} = Total suitable area in the county

A_{grid} = Area of the grid

CATTLE

Using the above formula, the estimated population of different livestock is calculated. To use the formula for cattle, you would take the total number of Cattle in Henderson county *59,076 cattle* divide by the total area of suitable landuse type in Henderson county *416,293 acres* multiply by *900 sq. meter* multiplied by the conversion factor, from sq. meters to acres *0.00024711 acres / m^2* will give 0.031561 number of cattle in each suitable grid. Similarly, the total number of cattle in Van Zandt county *89,422 cattle* divide by the total area of suitable landuse type in Henderson county *455,168 acres* multiply by *900 sq. meter* multiply by conversion factor from sq. meters to acres *0.00024711 acres / m^2* will give us 0.047773 number of cattle in each suitable grid.

Using cattle population estimates generated with GIS analysis, potential *E. Coli* loading for each Subwatershed was estimated.

The daily load from cattle was calculated as:

$$PDL_{cattle} = \mathrm{N}_{cattle} * \mathrm{FC}_{cattle} * \mathrm{CF}$$

Where:

PDL_{cattle} = Potential Daily *E. coli* Loading attributed to cattle

N_{cattle} = Number of cattle

FC_{cattle} = Fecal coliform loading rate of cattle, 1×10^{10} cfu fecal coliform per cattle per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

GOATS

The population estimate is calculated similarly and the daily load from goats was calculated as:

$$PDL_{goats} = \mathrm{N}_{goats} * \mathrm{FC}_{goats} * \mathrm{CF}$$

Where:

PDL_{goats} = Potential Daily *E. coli* Loading attributed to goats

N_{goats} = Number of goats

FC_{goats} = Fecal coliform loading rate of $1.2 * 10^{10}$ cfu fecal coliform per goats per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

HORSES

The number of mules, burrows and donkeys are combined with number of horses and ponies. The daily load from horses was calculated as:

$$PDL_{horses} = \mathrm{N}_{horses} * \mathrm{FC}_{horses} * \mathrm{CF}$$

Where:

PAL_{horses} = Potential Annual *E. Coli* Loading attributed to horses

N_{horses} = Number of horses

FC_{horses} = Fecal coliform loading rate of 4.2 * 10^8 cfu fecal coliform per horses per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

DEER

The deer population was estimated using data from Texas Parks & Wildlife Department (TPWD) at the wildlife management area level. Since the watershed is located within the Post Oak Savanah region, an estimated deer population of 46 deer per 1,000 acres is used. The land use types that are identified as suitable for deer are all land uses except open water, developed land and barren land.

To estimate the number of deer in each suitable grid:

$$N_{deer} = \frac{\mathrm{D_{deer}}}{\mathrm{A}_{grid} * \mathrm{CF}}$$

Where:

N_{deer} = Number of deer in each suitable grid

D_{deer} = Estimated density of deer in the county (46 deer per 1000 acres)

A_{grid} = Area of the grid (900 m^2)

CF = Conversion factor from m^2 to acres

46 deer divided by 1000 acres multiply by 900 m^2 multiply by a conversion factor from m^2 to acres 0.00024711 will give us <u>0.010230</u> deer per grid of suitable landuse.

Using deer population estimates generated with GIS analysis, potential *E. Coli* loading for each Subwatershed was estimated.

The daily load from deer was calculated as:

$$PDL_{\mathrm{deer}} = \mathrm{N_{deer}} * \mathrm{FC}_{deer} * \mathrm{CF}$$

Where:

PDL_{deer} = Potential Daily *E. Coli* Loading attributed to deer

N_{deer} = Number of deer

FC_{deer} = Fecal coliform loading rate of deer 3.5×10^8 cfu fecal coliform per deer per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

FERAL HOGS

The number of hogs in the watershed was estimated from a study conducted by Texas A&M Agrilife Extension (Timmons, et.al, 2012). In the study it is reported that the density of feral hogs in Texas is about 12.65 hogs per square mile. The land use types that are identified as suitable for hogs are all land uses except open water, developed land and barren land.

To estimate the number of feral hogs in each suitable grid:

$$N_{feral\ hogs} = \frac{\mathrm{D_{feral\ hogs}}}{\mathrm{A}_{grid} * \mathrm{CF}}$$

Where:

$N_{feral\ hogs}$ = Number of feral hogs in each suitable grid

$D_{feral\ hogs}$ = Estimated density of feral hogs in the county (12.65 hogs per sq mile)

A_{grid} = Area of the grid (900 m^2)

CF = Conversion factor from m^2 to sq. miles

Therefore, multiplying the density 12.65 by 900 m^2 and multiply by a conversion factor from m^2 to square miles 3.861×10^{-7} will give us <u>0.004396</u> hogs per grid of suitable landuse.

Using feral hog's population estimates generated with GIS analysis, potential *E. coli* loading for each Subwatershed was estimated.

The daily load from feral hogs was calculated as:

$$PDL_{\mathrm{feral\ hogs}} = \mathrm{N_{feral\ hogs}} * \mathrm{FC_{feral\ hogs}} * \ \mathrm{CF}$$

Where:

$PDL_{\mathrm{feral\ hogs}}$ = Potential Daily *E. Coli* Loading attributed to feral hogs

$N_{\mathrm{feral\ hogs}}$ = Number of feral hogs

$FC_{\mathrm{feral\ hogs}}$ = Fecal coliform loading rate of 1.1×10^9 cfu fecal coliform per feral hogs per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

PETS

The number of pets is calculated using the number of households from 2020 Census data at block level and no of pets per household (0.614)

To estimate the number of pets:

$$N_{pets} = \mathrm{D_{pets}} * \mathrm{N}_{household}$$

Where:

N_{pets} = Number of pets

D_{pets} = Estimated number of pets per household (0.614 pets per household)

Using pet's population estimates generated with GIS analysis, potential *E. coli* loading for each Subwatershed was estimated.

$$PDL_{\mathrm{pets}} = \mathrm{N_{pets}} * \mathrm{FC_{pets}} * \mathrm{CF}$$

Where:

PDL_{pets} = Potential Daily *E. Coli* Loading attributed to pets

N_{pets} = Number of pets

FC_{pets} = Fecal coliform loading rate of 5×10^9 cfu fecal coliform per pets per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

WWTFS

To estimate potential *E. coli* loads from the WWTFs, the maximum permitted discharge and an *E. coli* concentration of 126 cfu /100 ml is used.

$$PDL_{\mathrm{WWTFs}} = PD * \mathrm{Ecoli}_{conc} * \mathrm{CF}$$

Where:

PDL_{WWTFs} = Potential Daily *E. Coli* Loading attributed to WWTFS

PD = Permitted discharge in gallon per day

$Ecoli_{conc}$ = *E. coli* concentration (126 cfu /100 ml)

CF = Conversion factor from gallon to ml (3758.2)

OWTSS

The number and location of the OWTSs in the watershed was estimated using residential 911 addresses and remove the households within the CCN areas (areas serviced by WWTF). The average number of people in the household is derived from 2020 Census block data, a constant sewage discharge of 70 gallon per person per day and a failure rate of 15% was also used.

$$PDL_{\mathrm{OWTSs}} = \mathrm{N}_{OWTSs} * FR * \mathrm{FC}_{\mathrm{OWTSs}} * SD * \mathrm{N}_{household} * \mathrm{CF}_0 * \mathrm{CF}$$

Where:

PDL_{OWTSs} = Potential Daily *E. Coli* Loading attributed to OWTSs

N_{OWTSs} = Number of OWTSs

FR = Failure rate (15%)

$\mathrm{FC}_{\mathrm{OWTSs}}$ = Fecal coliform loading rate of 1×10^6 cfu fecal coliform per 100ml

SD = Average sewage discharge (70 gallon per person per day)

$N_{household}$ = Average number of persons in a household (2.65)

CF_0 = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

CF = Conversion factor from gallon to ml (3758.2)

Table A1.1. Potential *E. Coli* Load

Sub-Watershed	Cattle	Goats	Horses	Deer	Hogs	Pets	WWTF	OWTS	Total Daily
1	1.67E+14	8.80E+11	4.23E+10	1.46E+11	1.97E+11	1.54E+12		4.25E+12	**1.74E+14**
2	6.11E+13	3.21E+11	1.54E+10	5.05E+10	6.81E+10	5.09E+11		7.68E+11	**6.28E+13**
3	3.20E+13	1.68E+11	8.07E+09	2.64E+10	3.56E+10	1.95E+11		5.71E+11	**3.30E+13**
4	4.35E+13	2.29E+11	1.10E+10	3.75E+10	5.07E+10	1.47E+11	4.74E+07	6.15E+11	**4.46E+13**
5	4.35E+13	2.24E+11	1.15E+10	4.93E+10	6.66E+10	2.59E+11		1.15E+12	**4.52E+13**
6	6.93E+13	3.64E+11	1.75E+10	6.46E+10	8.72E+10	4.14E+11		1.27E+12	**7.15E+13**
7	3.19E+13	1.37E+11	1.18E+10	3.90E+10	5.26E+10	2.65E+11		7.76E+11	**3.32E+13**
8	1.56E+13	6.61E+10	5.89E+09	2.18E+10	2.94E+10	9.38E+10		1.98E+11	**1.60E+13**
9	5.30E+13	2.79E+11	1.34E+10	4.64E+10	6.27E+10	3.10E+11		1.06E+12	**5.48E+13**
10	2.66E+13	1.40E+11	6.72E+09	2.29E+10	3.09E+10	1.19E+11		4.96E+11	**2.74E+13**
11	3.21E+13	1.68E+11	8.09E+09	3.04E+10	4.10E+10	1.67E+11		7.28E+11	**3.32E+13**
12	1.43E+13	7.54E+10	3.62E+09	1.31E+10	1.78E+10	2.28E+10		1.39E+11	**1.46E+13**
13	4.78E+13	2.51E+11	1.21E+10	4.18E+10	5.64E+10	3.59E+11		1.01E+12	**4.95E+13**
14	2.14E+13	1.13E+11	5.41E+09	1.97E+10	2.66E+10	4.96E+10		1.83E+11	**2.18E+13**
15	2.70E+13	1.14E+11	1.02E+10	4.27E+10	5.77E+10	1.52E+11		3.19E+11	**2.77E+13**
16	5.93E+13	3.00E+11	1.63E+10	5.91E+10	7.98E+10	1.28E+12		5.59E+12	**6.66E+13**
17	2.47E+13	1.04E+11	9.31E+09	3.39E+10	4.57E+10	8.71E+10		3.73E+11	**2.53E+13**
18	3.70E+13	1.64E+11	1.30E+10	4.84E+10	6.54E+10	2.07E+11		6.93E+11	**3.82E+13**
19	4.26E+13	1.80E+11	1.61E+06	5.02E+10	6.78E+10	7.67E+11	3.79E+08	9.66E+11	**4.46E+13**
20	2.29E+13	9.67E+10	8.62E+09	3.90E+10	5.27E+10	7.15E+11		7.92E+11	**2.46E+13**
21	1.16E+14	6.02E+11	3.04E+10	1.09E+11	1.47E+11	8.91E+11		2.37E+12	**1.20E+14**
22	5.76E+13	2.47E+11	2.13E+10	8.12E+10	1.10E+11	7.03E+11	3.55E+07	1.38E+12	**6.01E+13**
23	2.07E+13	8.74E+10	7.79E+09	3.22E+10	4.34E+10	4.67E+11		6.41E+11	**2.19E+13**
24	5.20E+13	2.57E+11	1.51E+10	5.38E+10	7.27E+10	7.77E+11	4.74E+07	1.64E+12	**5.48E+13**
25	1.83E+13	7.76E+10	6.91E+09	2.67E+10	3.61E+10	2.98E+11		9.83E+11	**1.98E+13**

26	4.17E+13	1.81E+10	1.51E+10	5.86E+10	7.91E+10	5.05E+11		1.71E+12	**4.41E+13**
27	1.47E+13	6.24E+10	5.56E+09	1.92E+10	2.59E+10	4.83E+11	7.58E+08	7.36E+11	**1.61E+13**
28	2.64E+13	1.31E+11	7.63E+09	2.72E+10	3.67E+10	2.43E+11		5.19E+11	**2.74E+13**
Total	**1.22E+15**	**5.86E+12**	**3.40E+11**	**1.29E+12**	**1.74E+12**	**1.20E+13**	**1.27E+09**	**3.19E+13**	**1.27E+15**

APPENDIX B: LOAD REDUCTION CALCULATIONS

LIVESTOCK

E. coli loading reductions resulting from the implementation of conservation plans and WQMPs involve 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 1,490 producers and an estimated 26,589 Animal Units (AnU) of cattle in the Kickapoo Creek watershed (one ANU is equivalent to about 1,000 pounds of cattle).

Table AppB1. Animal Unit Conversion.

County	Cattle & Calves	All Goats	Mule, Burros, and Donkeys	Horses & Ponies	Total
No of Cattle	24,694	1,011	401	1,330	1,330
Animal-unit equivalent	1	0.15	0.2	1.25	4,253
Animal Units	**24,694**	**152**	**80**	**1663**	**26,589**

As a result, a broad estimate of 17.85 AnU of cattle per producer was made. This can also be interpreted at 17.85 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 AppB-1). These BMPs were determined based on feedback from members of the Kickapoo Creek WPP stakeholder 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 of 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 AppB2. 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:

$$LR_{cattle} = N_{plans} * \frac{AnU}{Plan} * FC_{cattle} * CF * 365\ \frac{days}{year} * Eff * PF$$

Where:

LR_{cattle}= Potential annual load reduction of *E. coli*

N_{plans} = Number of WQMPs and conservation plans, 50 are proposed in this WPP

$^{AnU}/_{Plan}$ = Animal Units of cattle (~1,000 lbs of cattle) per management plan, 18.96 AnU

FC_{cattle}= Fecal coliform loading rate of cattle, 1×10^{10} cfu fecal coliform per cattle per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

Eff = Median BMP efficacy value, 0.58

PF = Percentage based factor based on the assumed proximity of the management measure to the water body, 0.15

In the Kickapoo Creek watershed, it is estimated that on average, approximately 50 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 50 WQMPs or conservation plans across the entire Kickapoo watershed, resulting in a total potential reduction of 1.42×10^{14} cfu *E. coli* per year.

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, 3,280 feral hogs were estimated to exist in Kickapoo Creek watershed. 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:

$$LR_{feral\ hogs} = N_{feral\ hogs} * FC_{feral\ hogs} * CF * 365\ \frac{days}{year} * PF$$

Where:

$LR_{feral\ hogs}$= Potential annual load reduction of *E. coli* attributed to feral hog removal

$N_{feral\ hogs}$ = Number of feral hogs removed for this case 492

$FC_{feral\ hogs}$ = Fecal coliform loading rate of $1.1x10^9$ cfu fecal coliform per feral hogs per day

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

PF = 0.25

The estimated potential annual loading across the Kickapoo Creek watershed based on reducing the population by 15% (492 feral hogs) is $2.47x10^{14}$ cfu *E. coli* annually.

DOMESTIC PETS

The Kickapoo Creek watershed contains approximately 4,603dogs. *E. coli* loading from pets is based on the assumption that 40% of pet owners do not properly dispose of dog waste. Load reductions assume 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 553 pet owners in the entire Kickapoo Creek watershed. Since these management measures will be most effective in public areas and places with higher concentrations of pets, 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:

$$LR_{pets} = N_{owners} * FC_{pets} * Eff * CF * 365\ \frac{days}{year}$$

Where:

LR_{pets} = Potential annual load reduction of *E. coli* attributed to proper pet waste disposal

N_{owners} = Number of additional pet owners disposing of pet waste

FC_{pets} = Fecal coliform loading rate of $5x10^9$ cfu fecal coliform per pets per day

Eff = 0.75

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

The estimated potential load reduction attributed to this management measure in Kickapoo Creek is 6.60×10^{14} cfu *E. coli* annually.

OWTSS

OWTSs 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 OWTSs replaced. The following equation was used to calculate potential load reductions:

$$LR_{owtss} = N_{owtss} * N_{hh} * SD * FC_{owtss} * CF * CF_0 * PF * \ 365 \ \frac{days}{year}$$

Where:

$\mathrm{LR_{owtss}}$= Potential annual load reduction of *E. coli* attributed to OWTSs repair/replacement

$\mathrm{N_{owtss}}$ = Number of OWTSs repaired/replaced

$\mathrm{N_{hh}}$ = Average number of people per household (2.65)

SD = Average sewage discharge (70 gallon per person per day)

$\mathrm{FC_{owtss}}$ = Fecal coliform loading rate of $1x10^6$ cfu fecal coliform per 100ml

CF = 0.5 Conversion factor as suggested by Doyle and Erikson (2006)

$\mathrm{CF_0}$ = Conversion factor gallon to ml (3785.4 mL per gallon)

PF = 0.5 for very limited soil suitability

In the Kickapoo Creek watershed, it is assumed that 50 OSSFs to be repaired or replaced. It results in a potential reduction of 3.2×10^{15} cfu *E. coli* annually.

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 be 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. The Appendix briefly describes the nine elements and references the chapters and sections that fulfill each element.

Name of Water Body	Kickapoo Creek
Assessment Units	0605A_01 and 0605A_02
Impairments Addressed	Bacteria and depressed dissolved oxygen
Concerns Addressed	Bacteria and depressed dissolved oxygen

Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources Identified, described, and mapped	Ch.3 pgs. 25-39; Ch.4 pgs. 40-49; Ch.5 pgs. 50-75; Appendix A
2. Subwatershed Sources	Ch.5 pgs. 63-75
3. Data sources are accurate and verifiable	Ch.5 pgs. 50-75; 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. 63-65
3. Model complexity is appropriate	Appendix B
4. Basis of effectiveness estimates explained	Ch.6 Tables 6.2-6.7, Appendix B
5. Methods and data cited and verified	Appendix B
Element C: Management Measures Identified	
1. Specific management measures are identified	Ch.6 pgs. 77-87

Element	Report Section(s) and Page Number(s)
2. Priority areas	Ch.6 Tables 6.2-6.7
3. Measure selection rationale documented	Ch.6 pgs. 77-87
4. Technically sound	Ch.6
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Ch.9 pgs. 97-100
2. Estimate of financial assistance	Ch.9 pgs. 100-103
Element E: Education/Outreach	
1. Public education/information	Ch.7 pgs. 89-92
2. All relevant stakeholders are identified in outreach process	Ch.7 pgs. 88-89
3. Stakeholder outreach	Ch.7 pgs. 88-92
4. Public participation in plan development	Ch.7 pgs. 88-89
5. Emphasis on achieving water quality standards	Ch.7 pgs. 88-89
6. Operation and maintenance of BMPS	Ch. 8 Table 7.1
Element F: Implementation Schedule	
1. Includes completion dates	Ch. 8 Table 7.1
2. Schedule is appropriate	Ch. 8 Table 7.1
Element G: Milestones	
1. Milestones are measurable and attainable	Ch. 8 Table 7.1; Ch.10
2. Milestones include completion dates	Ch. 8 Table 7.1; Ch.10
3. Progress evaluation and course correction	Ch. 8 Table 7.1; Ch.10
4. Milestones linked to schedule	Ch. 8 Table 7.1; Ch.10
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Ch.6 Tables 6.2-6.7
2. Criteria measure progress toward load reduction goal	Ch.6 Tables 6.2-6.7
3. Data and models identified	Ch.6 Tables 6.2-6.7; Appendix B
4. Target achievement dates for reduction	Ch.10
5. Review of progress toward goals	Ch.10 pgs. 105-106
6. Criteria for revision	Ch.10 pgs. 105-107

Element	Report Section(s) and Page Number(s)
7. Adaptive management	Ch.10 pgs. 106-107
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Ch.10 pgs. 104-106
2. Monitoring measures evaluation criteria	Ch.10 pgs. 104-106
3. Routine reporting of progress and methods	Ch.10 pgs. 104-106
4. Parameters are appropriate	Ch.10 pgs. 104-106
5. Number of sites is adequate	Ch.10 pgs. 104-106
6. Frequency of sampling is adequate	Ch.10 pgs. 104-106
7. Monitoring tied to QAPP	Ch.10 pgs. 104-106
8. Can link implementation to improved water quality	Ch.10 pgs. 104-106