Characterization of Middle Yegua, Davidson, and Deer Creeks Watersheds

Texas Water Resources Institute TR-537
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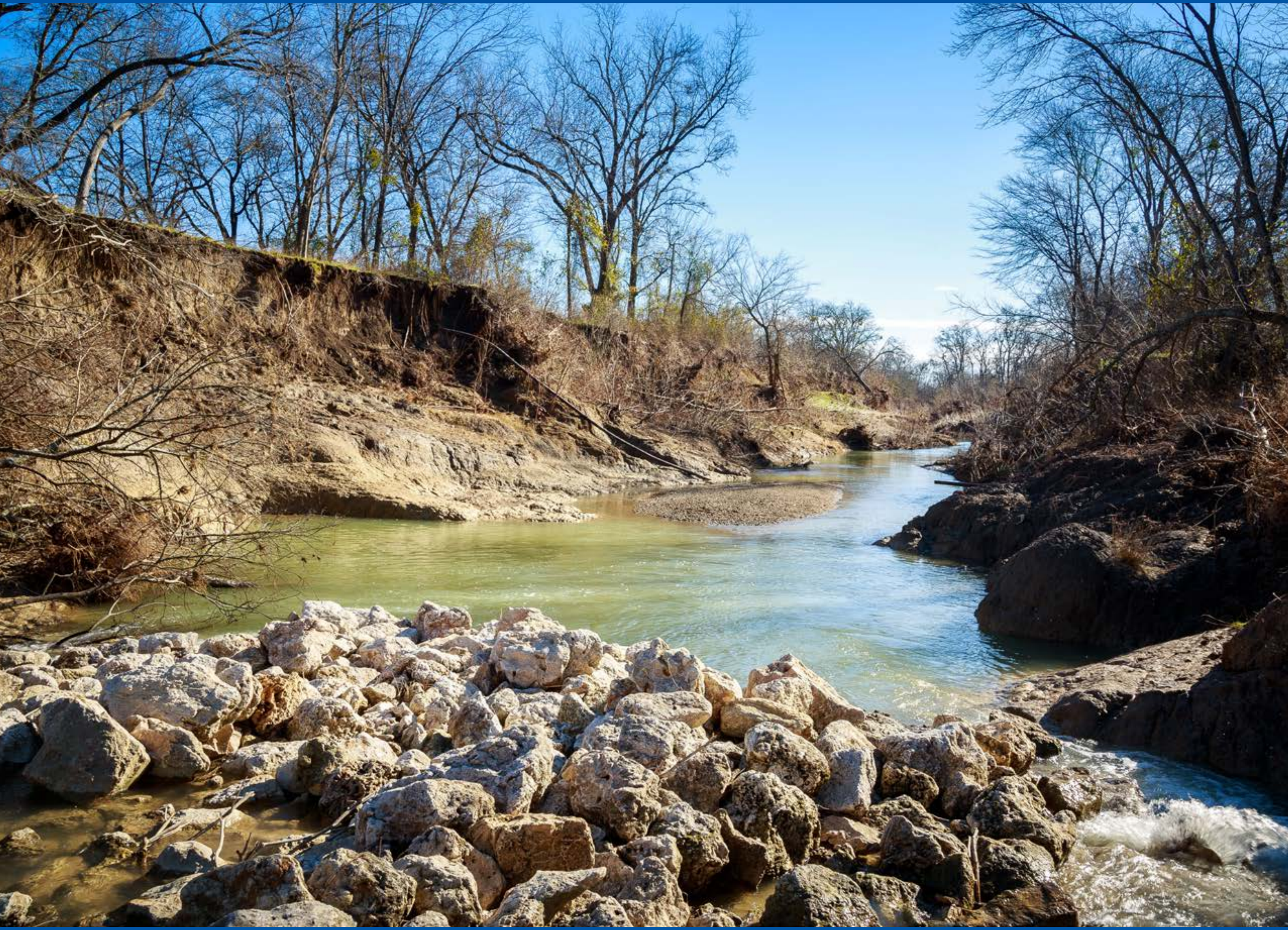

Texas Water
Resources Institute
make every drop count

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Michael Schramm, Allen Berthold
Texas Water Resources Institute

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Cover photo: Deer Creek. Photo by Edward Rhodes[1].

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List of Acronyms

ALU	Aquatic Life Use
AU	Assessment Unit
AVMA	American Veterinary Medical Association
BRA	Brazos River Authority
cfu	Colony Forming Units
CRP	Clean Rivers Program
CWA	Clean Water Act
DAR	Drainage-Area Ratio Method
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
ECHO	Enforcement and Compliance History Online
FDC	Flow Duration Curve
GIS	Geographic Information Systems
HSG	Hydrologic Soil Groups
I&I	Inflow and Infiltration
LDC	Load Duration Curve
LULC	Land Use Land Cover
MGD	Million Gallons per Day
mL	Milliliter
MPN	Most Probable Number
MRLC	Multi-resolution Land Characteristics Consortium
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agricultural Statistics Service
NED	National Elevation Database
NLCD	National Land Cover Database
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facilities
RMU	Resource Management Unit
SELECT	Spatially Explicit Load Enrichment Calculation
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic Database
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute

USDA	United States Department of Agriculture
USGS	United State Geological Survey
WWTF	Wastewater Treatment Facility
yr	Year

Executive Summary

Middle Yegua Creek, Davidson Creek, and Deer Creek have all been identified to be impaired for elevated concentrations of *Escherichia coli* (*E. coli*) in the *2020 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report; TCEQ 2019). Davidson Creek was also listed in the *2020 Texas Integrated Report* as impaired for depressed dissolved oxygen (TCEQ 2019). Elevated levels of *E. coli* have been identified in the Middle Yegua Creek watershed since as early as 2010 (TCEQ 2011). For the Davidson Creek watershed, elevated bacteria levels were first identified in 2002 (TCEQ 2002), and depressed dissolved oxygen were first identified in 2010 (TCEQ 2011). For the Deer Creek watershed, the bacteria impairment was first identified in 2006 (TCEQ 2008). This characterization addresses the *E. coli* impairments in the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds with supplementary water quality monitoring and a review of the current demographic, climatic, physical, and hydrological conditions of the watersheds.

Activities for the project have included water quality monitoring, trainings, and meeting with soil and water conservation districts in each watershed to discuss the goals and objectives of addressing the bacteria impairments. Educational programs were delivered to stakeholders to inform them of watershed management and increase their understanding of what factors contribute to bacteria impairments. Existing data for water quality parameters, flow, livestock, wildlife, stormwater permits, and number of on-site sewage facilities have been analyzed to develop a better understanding of potential causes and sources of bacteria pollution.

Background Information

Description of the Watersheds and Waterbodies

Middle Yegua Creek, Davidson Creek, and Deer Creek are all located in the southern portion of the Brazos River Basin in separate watersheds (Figure 1). Each of the watersheds will be evaluated separately throughout the report to reflect the individual characteristics and water quality issues of the waterbodies.

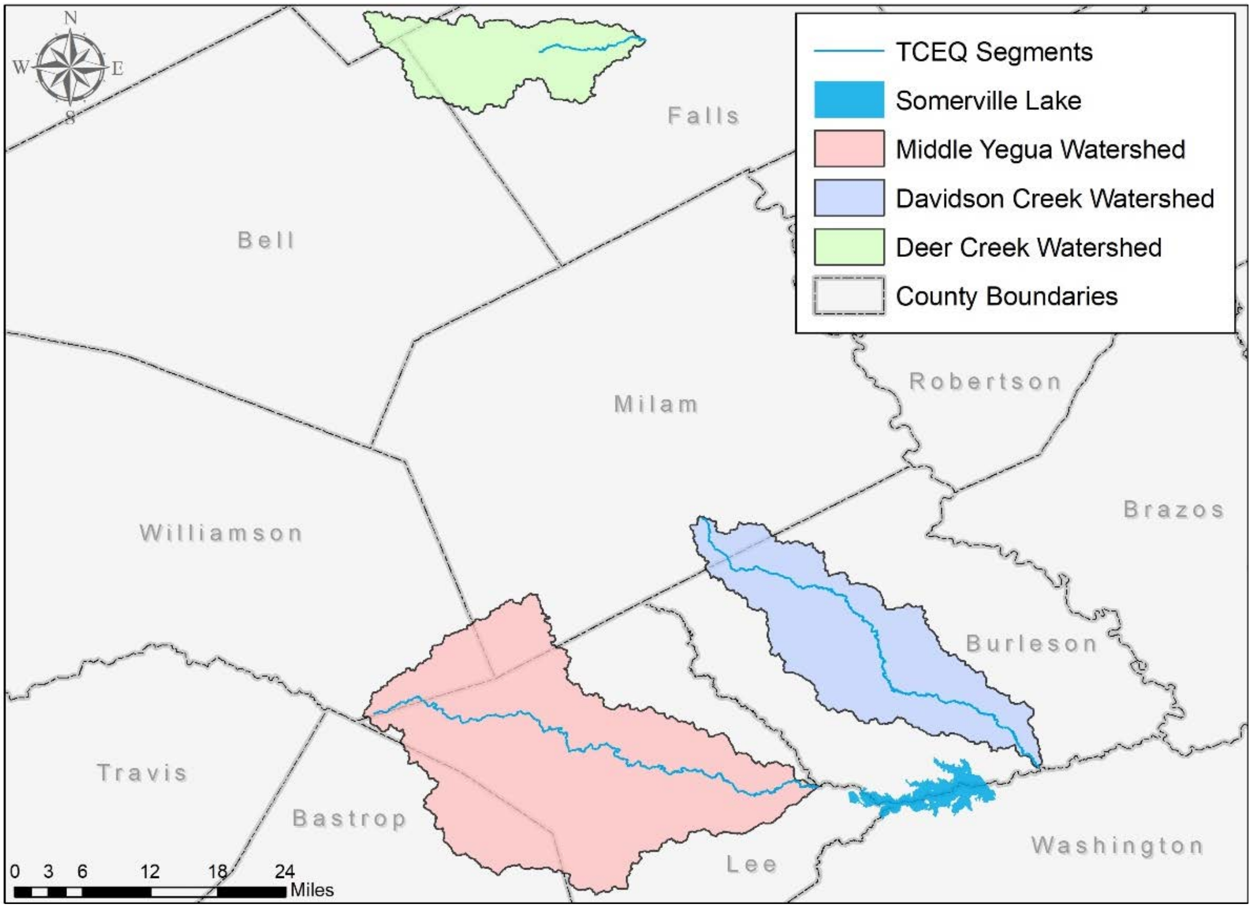

Figure 1. Overview of characterization report watersheds.

Middle Yegua Creek (Segment ID 1212A) begins at the confluence with East Yegua and Yegua creeks in Lee County and flows approximately 62 miles to the Lee County/Williamson County line (Figure 2). Middle Yegua Creek drains an area of approximately 440 square miles in Lee (73%), Bastrop (13%), Williamson (8%), and Milam (6%) counties. The segment is also divided into two assessment units (AU), 1212A_01 and 1212A_02.

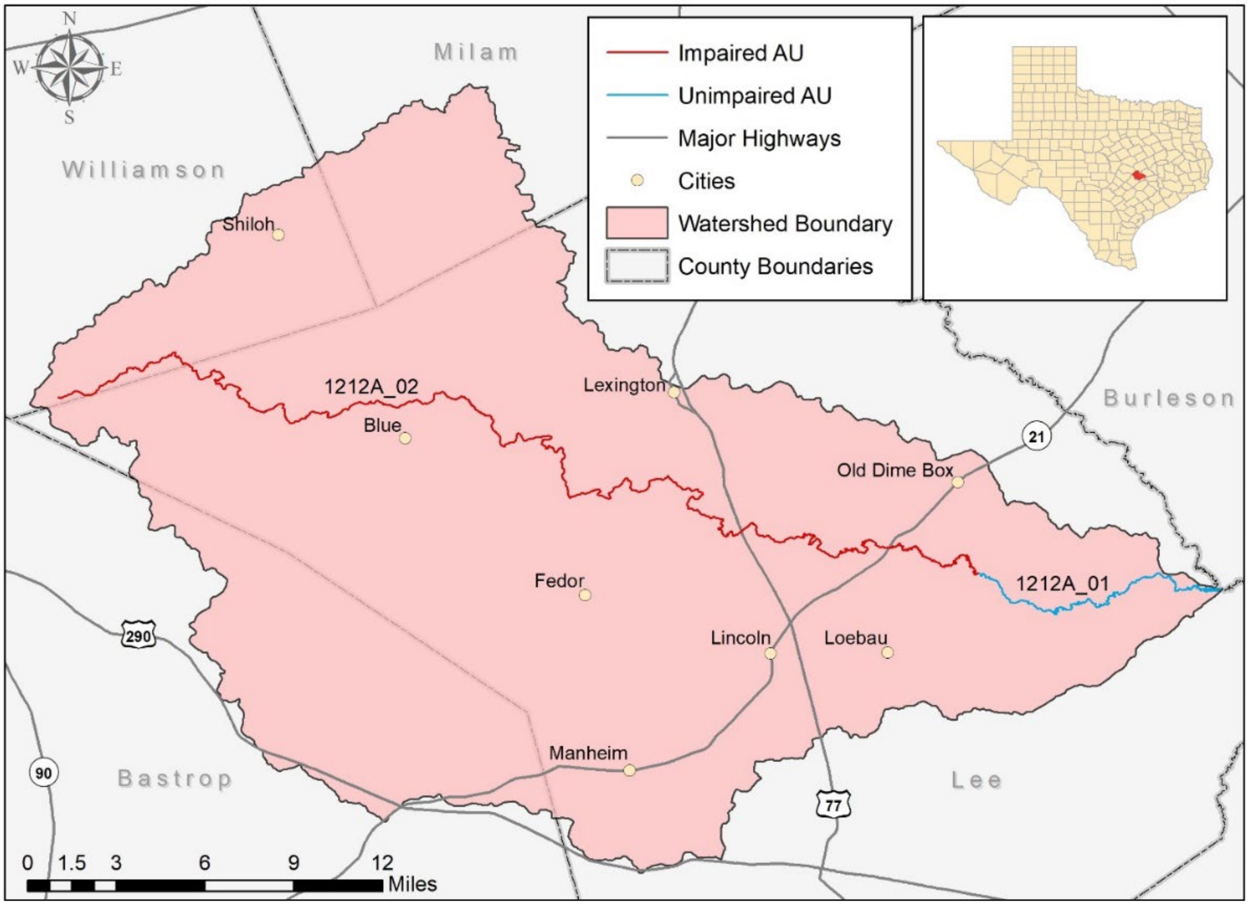

Figure 2. Middle Yegua Creek watershed with assessment units (AUs).

Davidson Creek (Segment ID 1211A) is an intermittent stream with perennial pools that flows approximately 59 miles from the confluence of Yegua Creek to just over 1 mile above CR 322 in Milam County (Figure 3). Davidson Creek drains an area of approximately 218 square miles in Burleson (93%) and Milam (7%) counties. The segment is also divided into two AUs, 1211A_01 and 1211A_02.

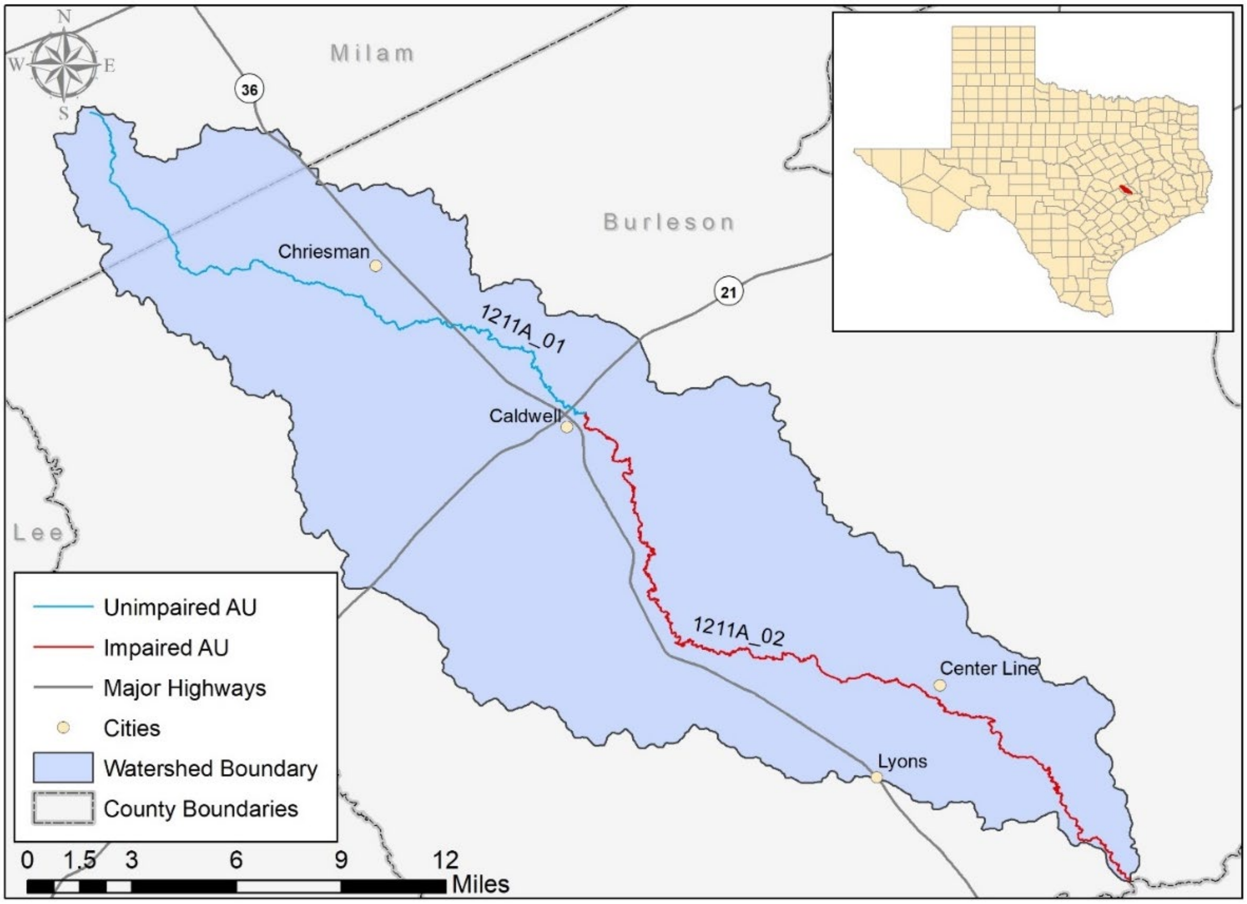

Figure 3. Davidson Creek watershed with assessment units (AUs).

Deer Creek (Segment ID 1242J) is a perennial stream that begins at the confluence of the Brazos River upstream and flows approximately 11 miles to the confluence of Dog Branch northwest of Lott (Figure 4). Deer Creek drains an area of approximately 115 square miles in Falls (87%), McLennan (7%), and Bell (6%) counties. The segment consists of a single AU, 1242J_01.

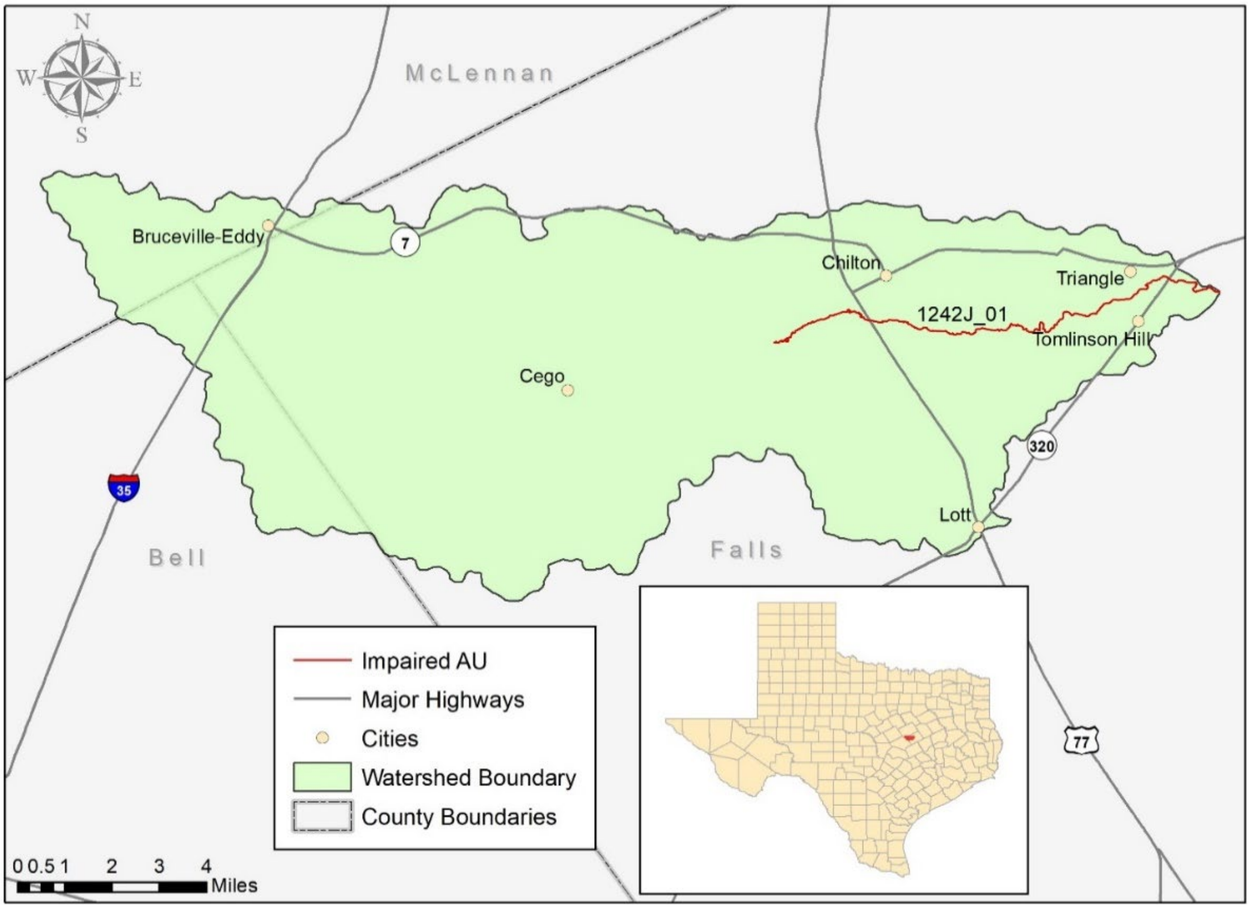

Figure 4. Deer Creek watershed with assessment units (AUs).

Soils and Topography

The soils and topography of a watershed are important components of watershed hydrology. Slope and elevation define where water will flow, while elevation and soil properties influence how much and how fast water will infiltrate into, 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.

All three watersheds are predominantly flat and have moderate drainage. The Middle Yegua Creek watershed has a peak elevation of about 232 feet with the lowest elevation point being approximately 75.5 feet (USGS 2013; Figure 5). The Davidson Creek watershed has a peak elevation of about 194 feet with the lowest elevation point being approximately 59 feet (USGS 2013; Figure 6). The Deer Creek watershed has a peak elevation of about 266 feet with the lowest elevation point being approximately 97 feet (USGS 2013; Figure 7). There is an average of 1° slope across all the watersheds, with more intense slopes restricted to areas such as cut banks near the creek systems.

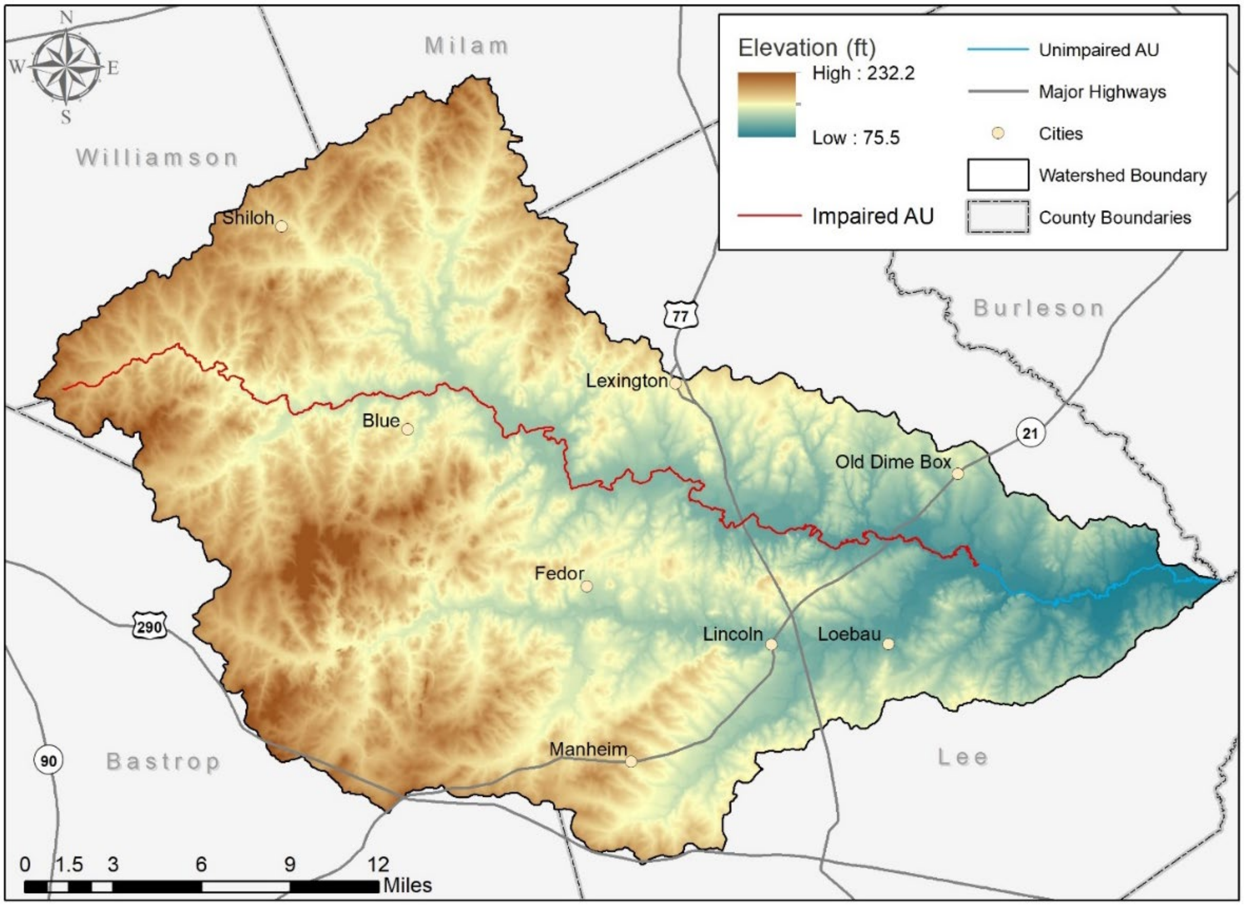

Figure 5. Elevation of the Middle Yegua Creek watershed with assessment units (AUs).

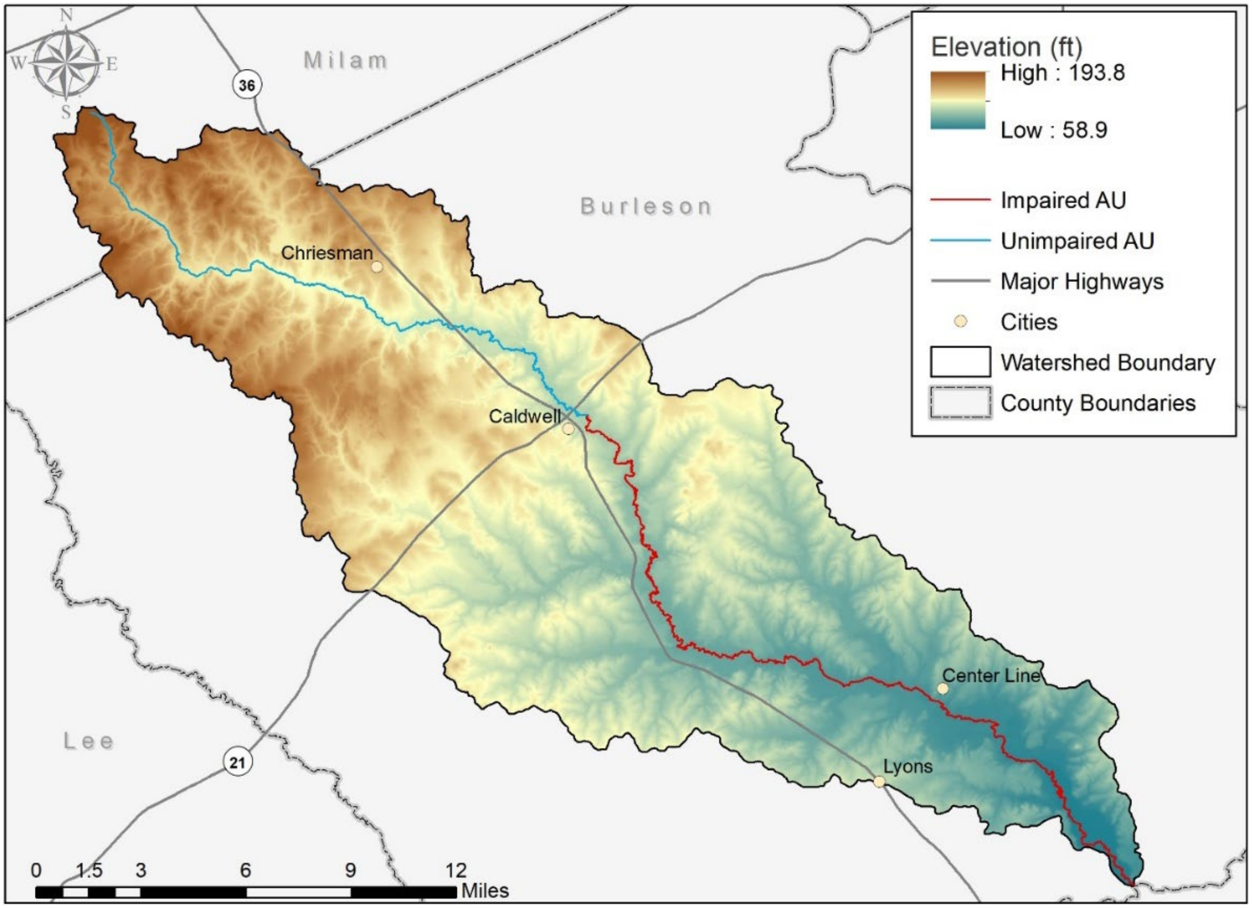

Figure 6. Elevation of the Davidson Creek watershed with assessment units (AUs).

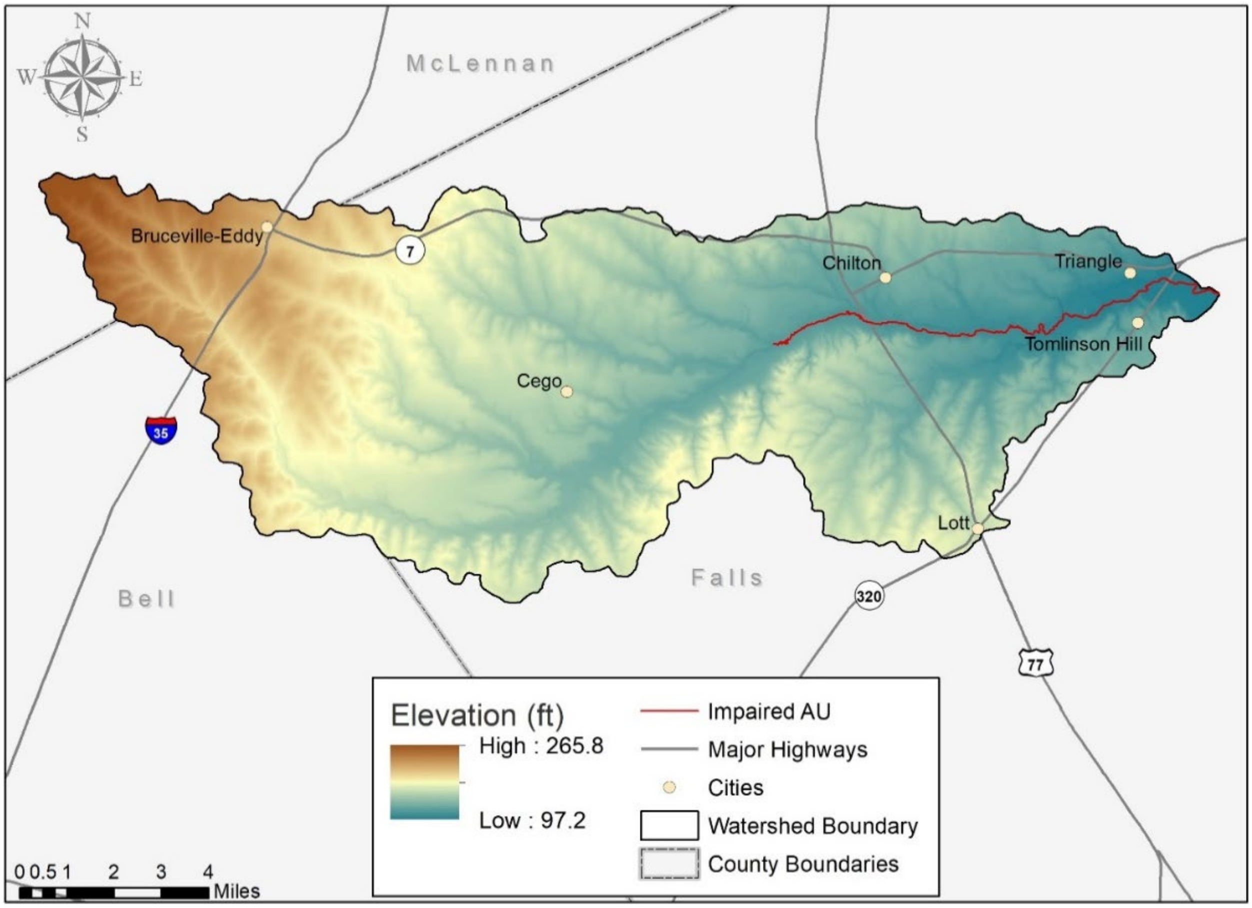

Figure 7. Elevation of the Deer Creek watershed with assessment units (AUs).

Soil data was obtained from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (USDA 2019). The USDA NRCS SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic soil groups (HSGs). These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The null classification identifies areas where data is incomplete or not available. The USDA NRCS SSURGO database defines the other four classifications below:

Group A – Soils have high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B – Soils have a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C – Soils have a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D – Soils have a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Soils with dual hydrologic groupings indicate that drained areas are assigned the first letter, and the second letter is assigned to undrained areas. Only soils that are in group D in their natural condition are assigned to dual classes.

The majority of soils in the Middle Yegua Creek watershed have an HSG of B (37% of the watershed) or D (26%; Figure 8). The remaining six groups are the least dominant HSGs in the watershed (Table 1; USDA 2019).

The majority of soils in the Davidson Creek watershed have an HSG of B (45% of the watershed) or C (21%; Figure 9). The remaining six groups are the least dominant HSGs in the watershed (Table 2; USDA 2019).

The majority of soils in the Deer Creek watershed have an HSG of B (43% of the watershed) or D (24%; Figure 10). The remaining six groups are the least dominant HSGs in the watershed (Table 3; USDA 2019).

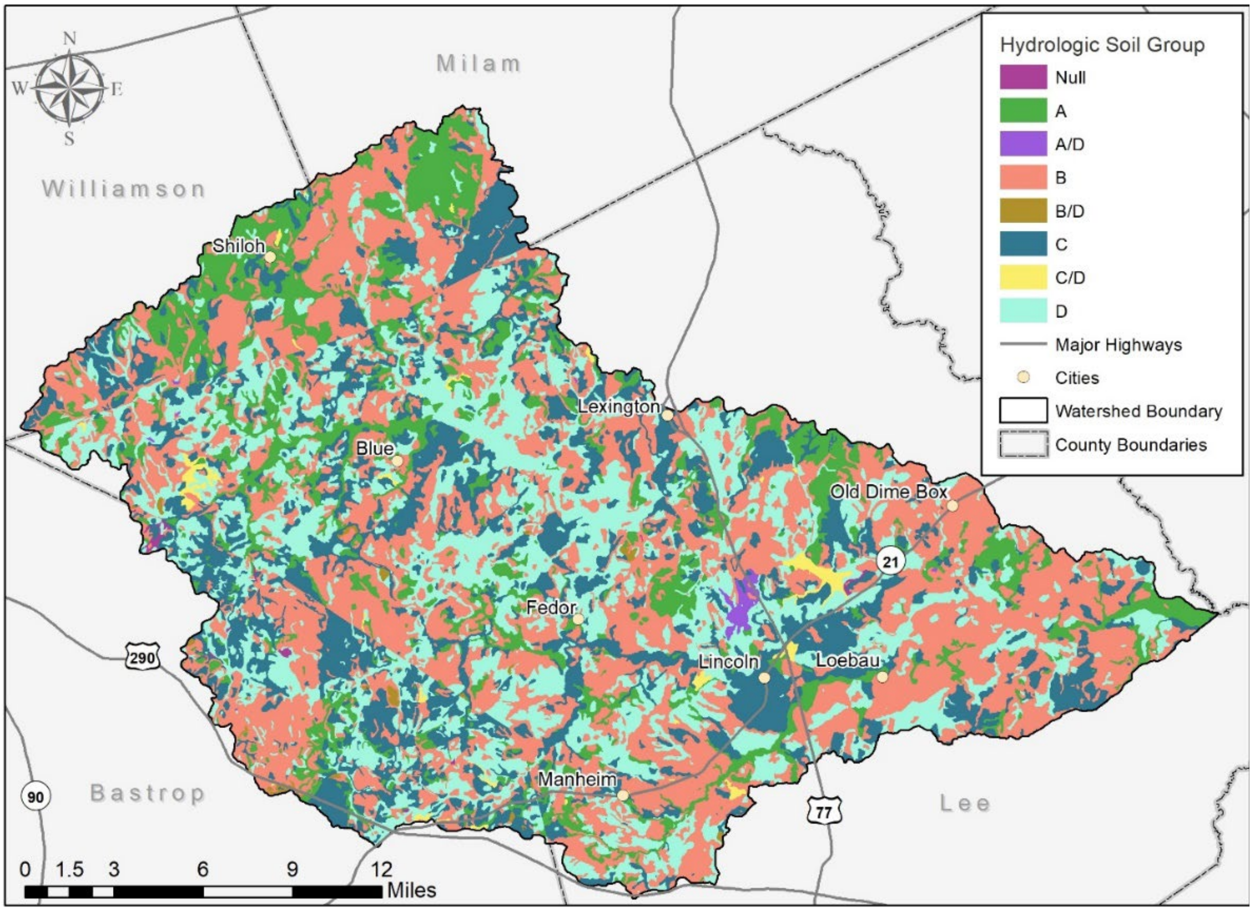

Figure 8. Middle Yegua Creek watershed hydrologic soil groups.

Table 1. Descriptions of the hydrologic soil groups in the Middle Yegua Creek watershed.

Hydrologic soil group	Acres	Percent of total
Null	410	0.1%
A	39,848	14.1%
A/D	781	0.3%
B	104,445	37.1%
B/D	738	0.3%
C	59,172	21.0%
C/D	2,103	0.8%
D	74,300	26.4%
Total	281,798	100%

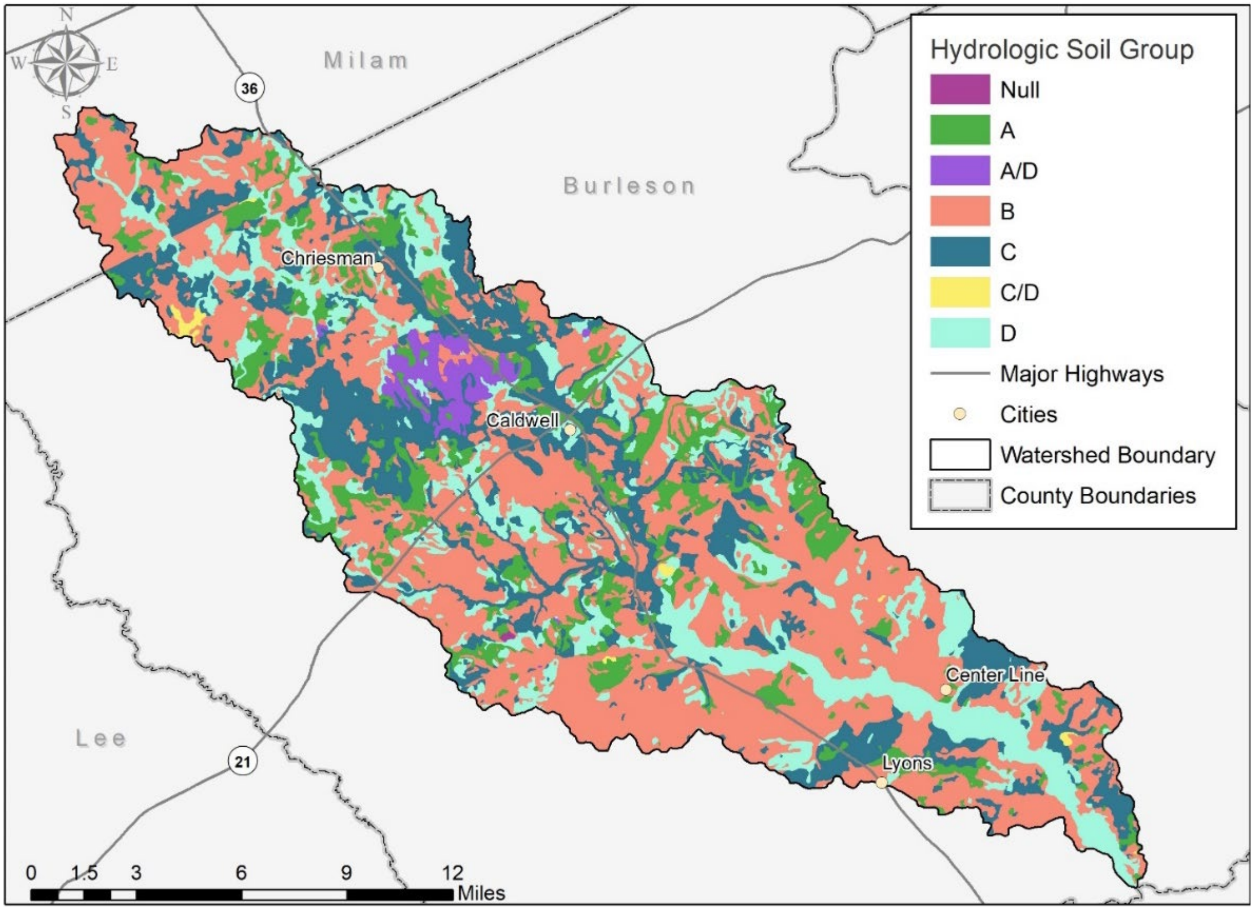

Figure 9. Davidson Creek watershed hydrologic soil groups.

Table 2. Descriptions of the hydrologic soil groups in the Davidson Creek watershed.

Hydrologic soil group	Acres	Percent of total
Null	45	0.03%
A	17,184	12.32%
A/D	2,849	2.04%
B	63,110	45.26%
B/D	0	0.00%
C	29,848	21.40%
C/D	441	0.32%
D	25,890	18.62%
Total	139,447	100%

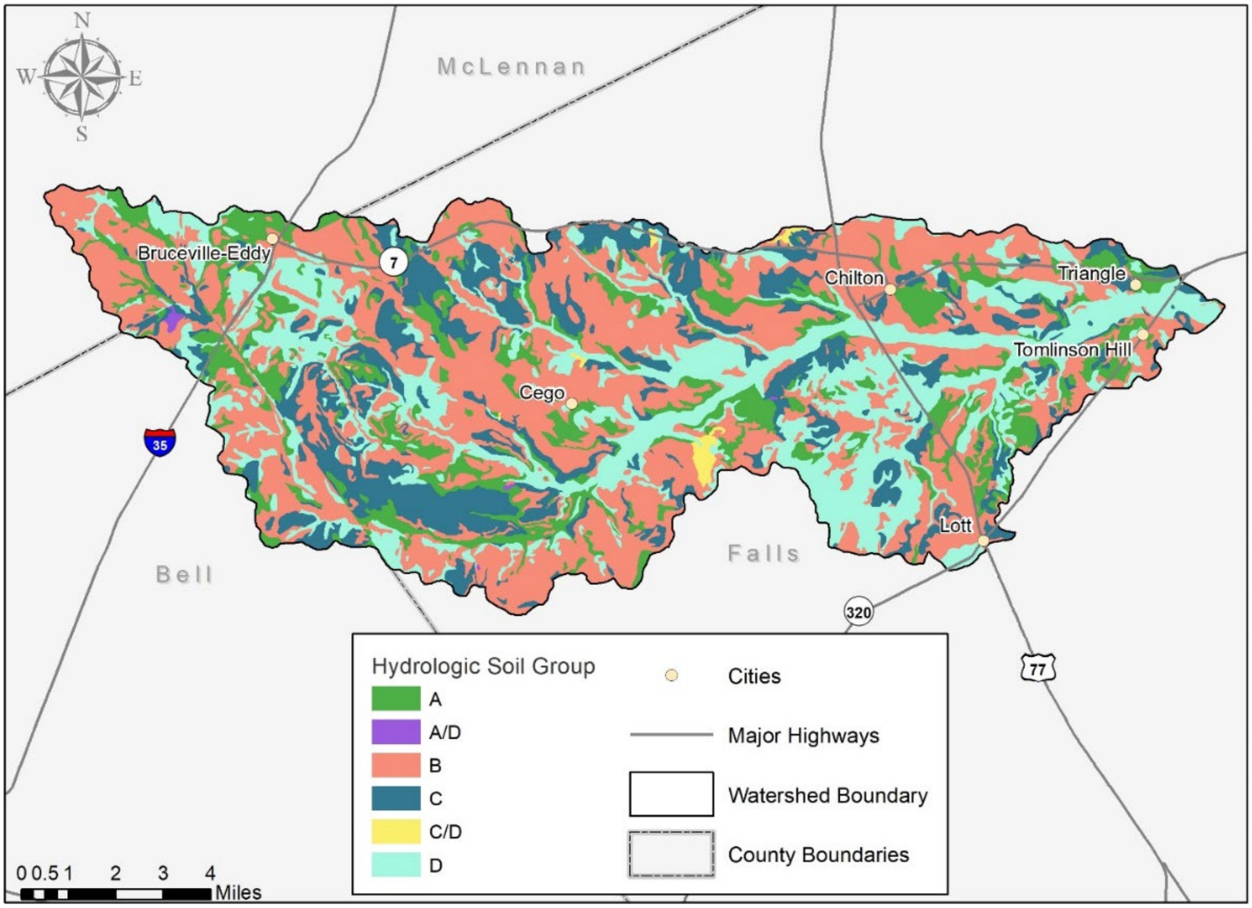

Figure 10. Deer Creek watershed hydrologic soil groups.

Table 3. Descriptions of the hydrologic soil groups in the Deer Creek watershed.

Hydrologic soil group	Acres	Percent of total
Null	0	0.00%
A	11,192	15.23%
A/D	81	0.11%
B	31,407	42.74%
B/D	0	0.00%
C	12,510	17.03%
C/D	337	0.46%
D	17,949	24.43%
Total	73,476	100%

The USDA NRCS provides suitability ratings for septic tank absorption fields based on soil properties, depth to bedrock or groundwater, hydraulic conductivity, and other properties that may affect the absorption of on-site sewage facility (OSSF) effluent, installation, and maintenance. A "Not Limited" rating indicates soils with features favorable to OSSF use. "Somewhat Limited" indicates soils that are moderately favorable, with limitations that can be overcome by design, planning, and installation. "Very Limited" indicates soils that are very unfavorable for OSSF use, with expectation of poor performance and high amounts of maintenance. The majority of the soils in all three watersheds are rated "Very Limited" for OSSF use, followed by smaller areas rated "Somewhat Limited" (Figure 11, Figure 12, Figure 13; USDA 2019).

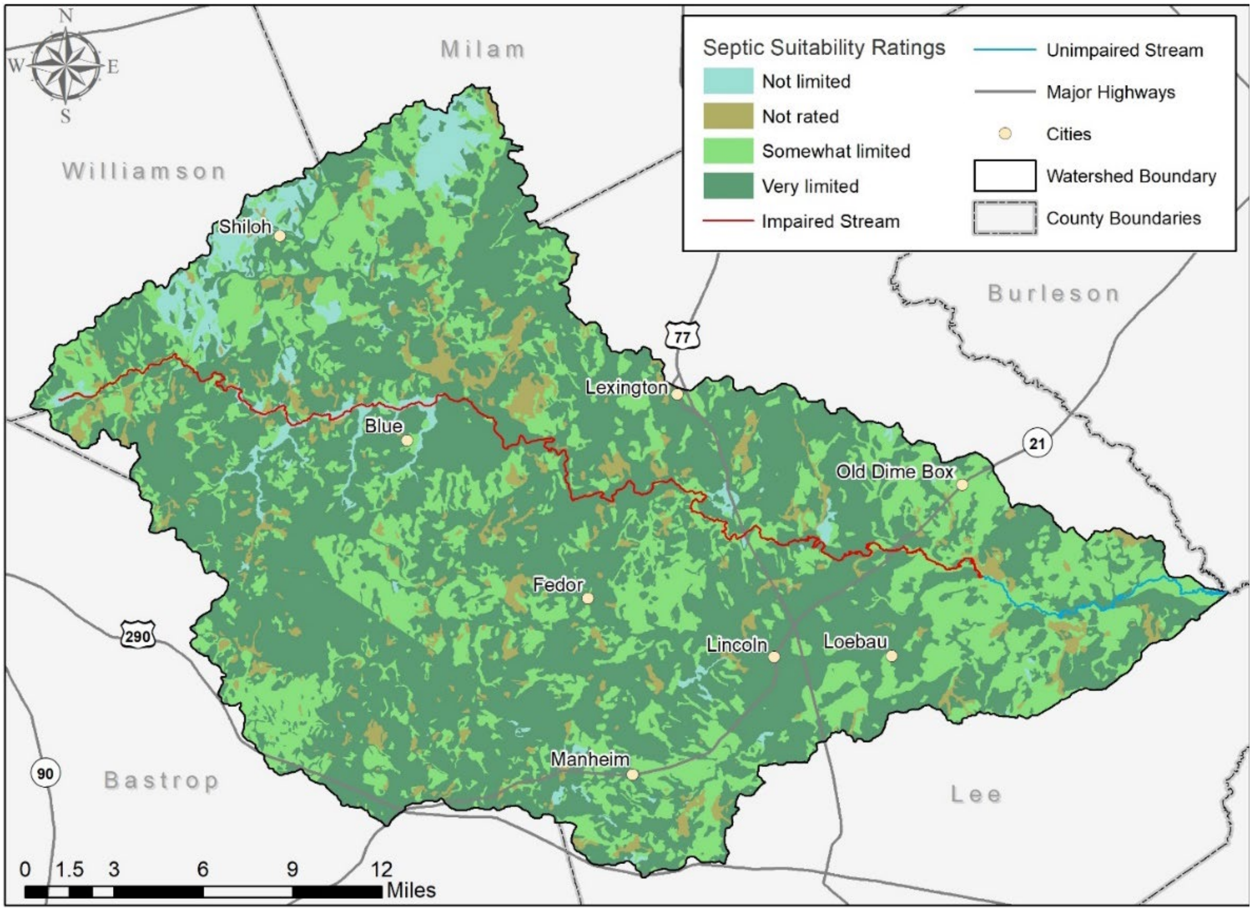

Figure 11. Middle Yegua Creek watershed on-site sewage facility adsorption field ratings.

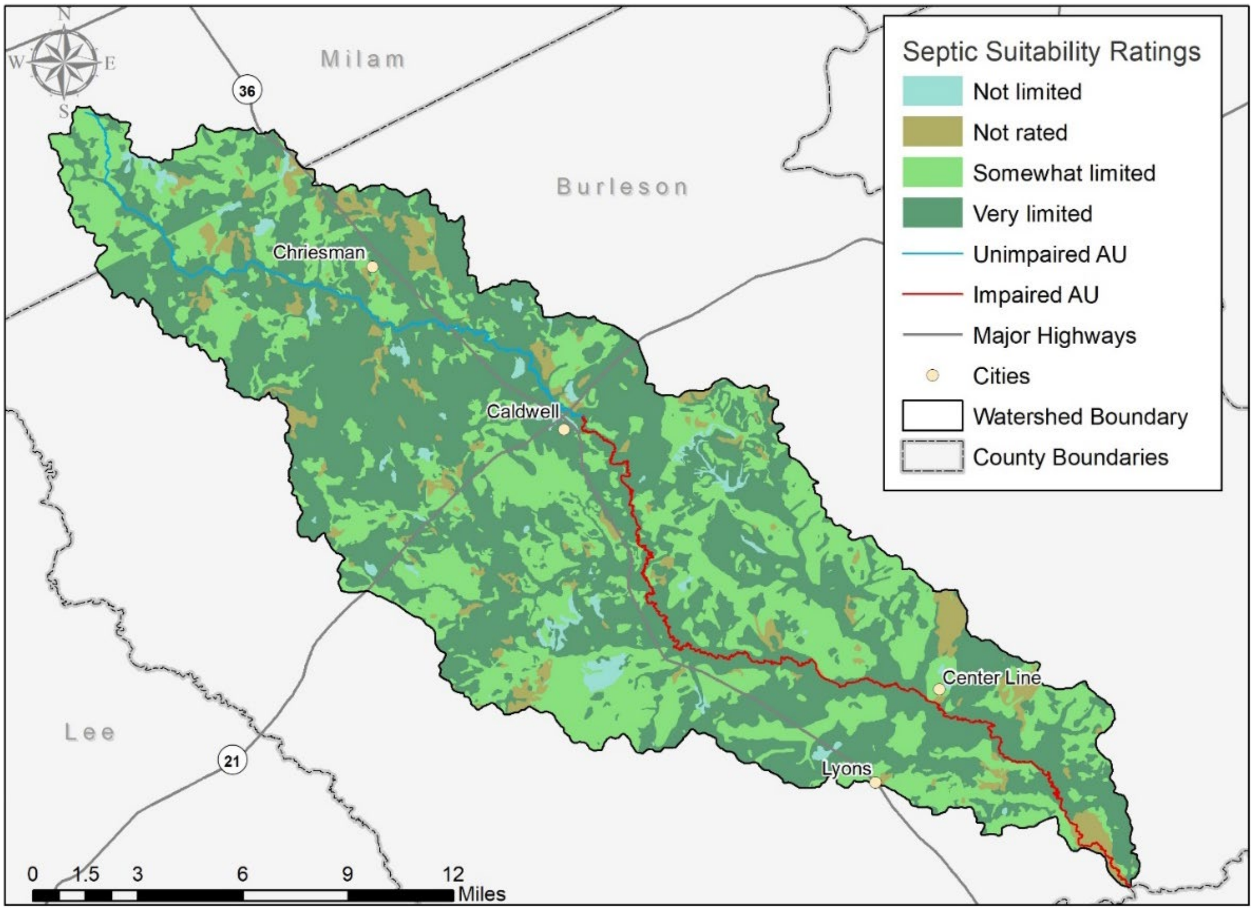

Figure 12. Davidson Creek watershed on-site sewage facility adsorption field ratings with assessment units (AUs).

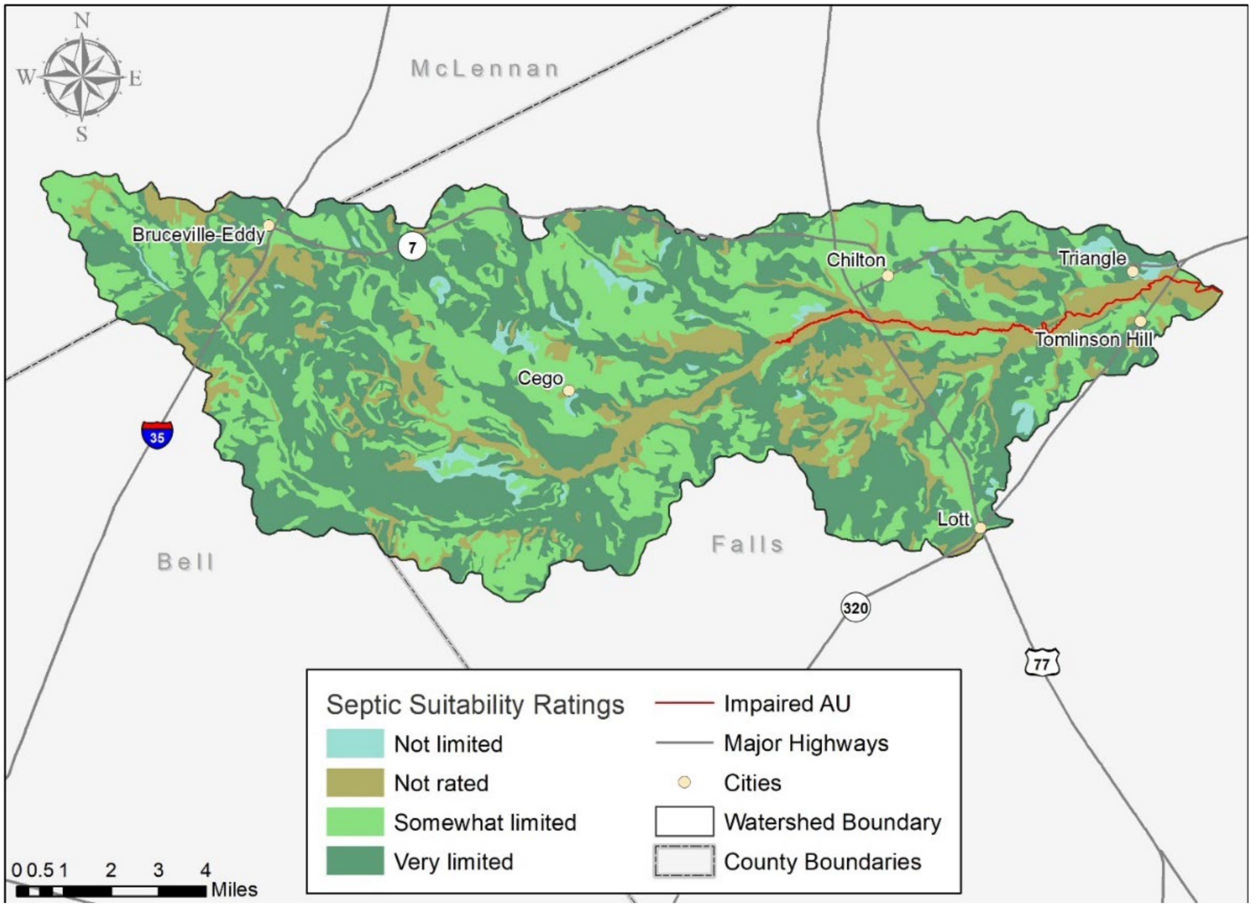

Figure 13. Deer Creek watershed on-site sewage facility adsorption field ratings with assessment units (AUs).

Ecoregions

Ecoregions are land areas with ecosystems that contain similar quality and quantity of natural resources (Griffith et al. 2007). Ecoregions have been delineated into four separate levels: level I is the most unrefined classification, while level IV is the most refined. Middle Yegua Creek watershed is located in two ecoregions (level III ecoregions), including the East Central Texas Plains Ecoregion (33) through Bastrop, Lee, Milam and Williamson counties, and a tiny portion in the Texas Blackland Prairies (32) in Williamson County (Figure 14). Davidson Creek is located in one level III ecoregion, the East Central Texas Plains Ecoregion (33; Figure 15). Deer Creek is also located in one level III ecoregion, the Texas Blackland Prairies Ecoregion (32; Figure 16). The dominant soil types for these ecoregions are fine-textured clay and acidic, sandy or clay loams, respectively. The watersheds are further subdivided into four level IV ecoregions identified as the Northern Blackland Prairie (32a), Floodplains and Low Terraces (32c), Southern Post Oak Savanna (33b), and San Antonio Prairie (33c).

The landscape in the area of Northern Blackland Prairie (32a) is mainly underlain by vertisols with dark, fine-textured, and calcareous charactersistics. The main land cover is cropland and non-native pasture, with a small portion of deciduous forest and woodlands. Dominant grasses are eastern gamagrass and switchgrass. The Floodplains and Low Terraces (32c) landscape includes broad floodplains. A majority of the bottomland forests have been converted to cropland and pasture.

The Southern Post Oak Savanna (33b) has more woods and forest than the adjacent prairie ecoregions (32). The land cover is a mix of woods, improved pasture, and rangeland. The San Antonio Prairies (33c) soils are mostly alfisols, with some vertisols, and mollisols. The upland prairies are dominated by little blue stem and yellow Indiangrass. The land cover is comprised of woodland, improved pasture, rangeland, and some cropland.

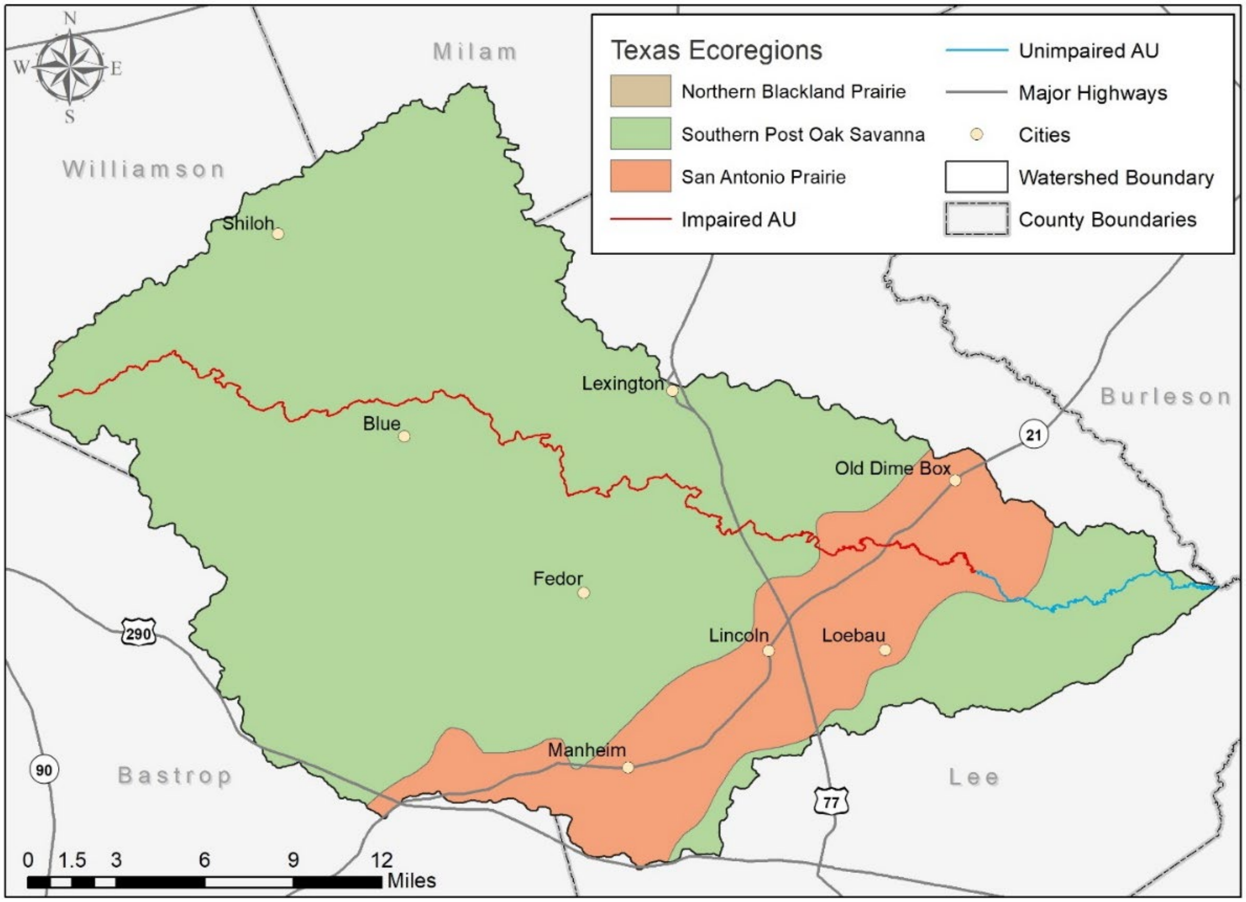

Figure 14. Middle Yegua Creek watershed ecoregions with assessment units (AUs).

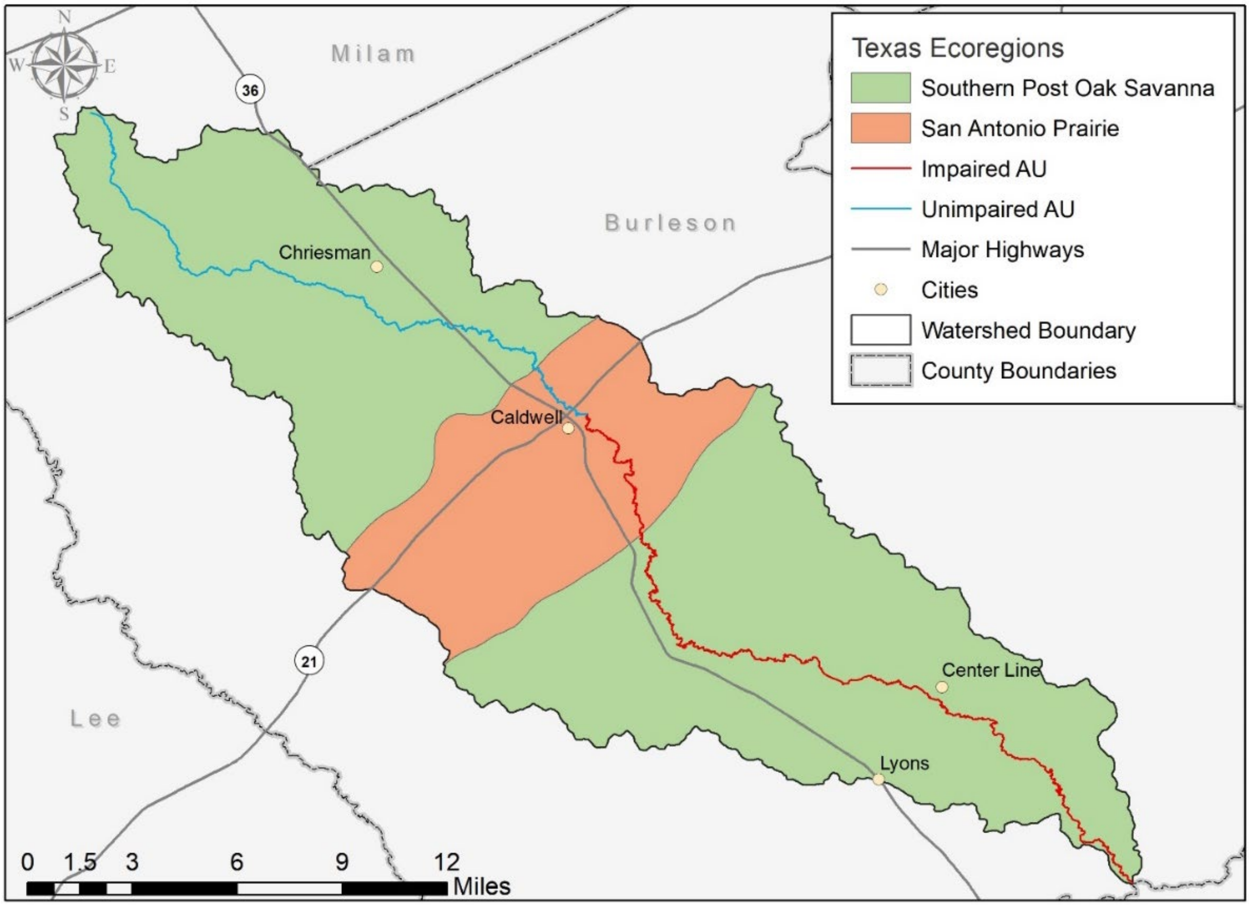

Figure 15. Davidson Creek watershed ecoregions with assessment units (AUs).

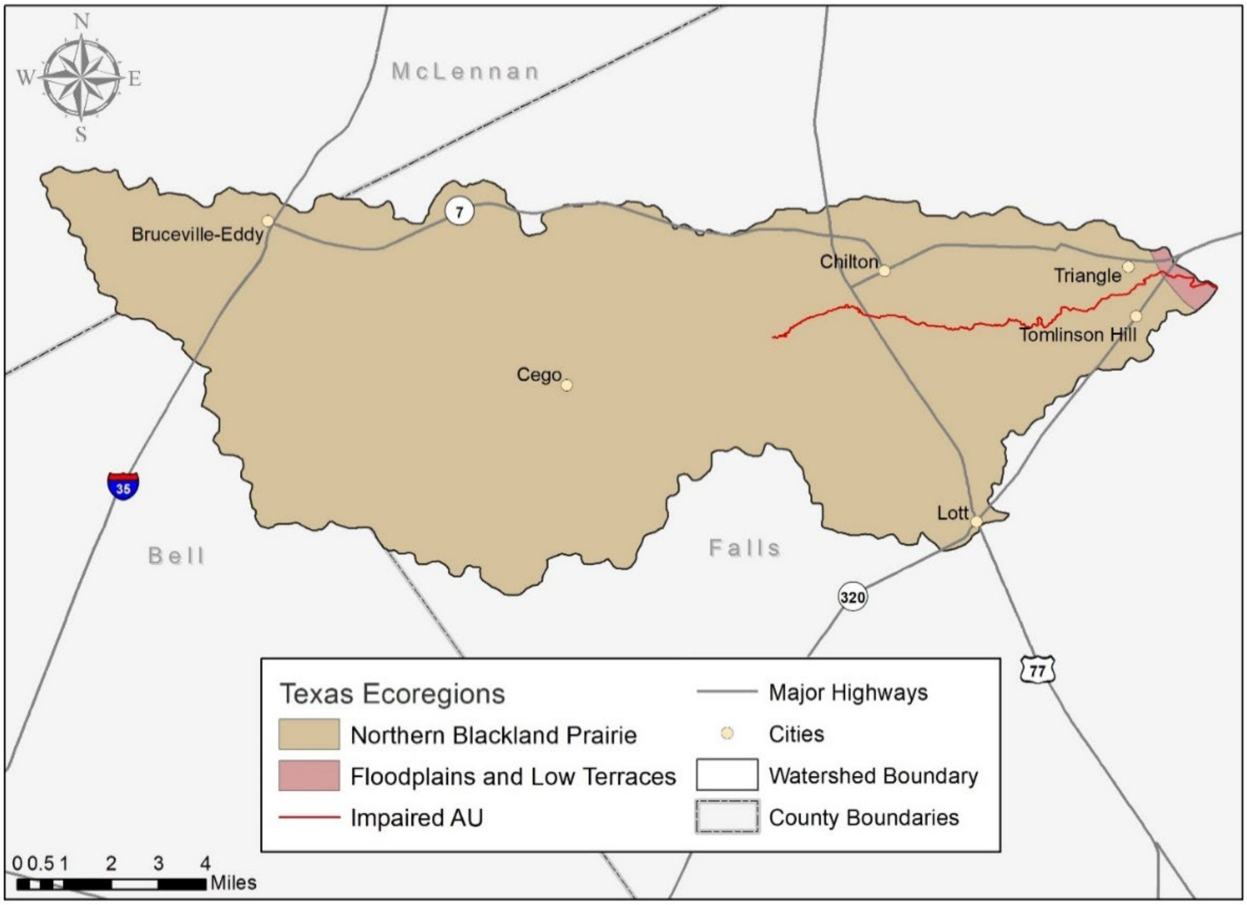

Figure 16. Deer Creek watershed ecoregions with assessment units (AUs).

Land Use and Land Cover

Land use and land cover (LULC) data for each of the watersheds was obtained from the 2019 National Land Cover Database (NLCD) at a 30-meter raster resolution. LULC data is categorized into 15 different classifications and the LULC for all the watersheds are described in Figure 17 through Figure 19 and

Table 4 through Table 6. The different land covers are not evenly distributed across the watersheds. Quantitatively describing the land use classifications for each watershed is necessary for future planning decisions. The following are the LULC classifications:

- Open water: areas of open water that are generally less than 25% vegetation or soil cover.
- Developed, open space: areas that have a mixture of constructed materials, but mostly vegetation in the form of lawn grasses exist. Impervious surfaces account for less than 20% of total cover. Such areas typically include large-lot single family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- Developed, low intensity: areas that consist of a mix of constructed materials and vegetation. Impervious surfaces account for 20%–49% of total cover. These areas commonly include single-family housing units.
- Developed, medium intensity: areas that consist of a mixture of constructed materials and vegetation. Impervious surfaces account for 50%–79% of the total cover. These areas commonly include single-family housing units.
- Developed, high intensity: highly developed areas where people reside or work in high numbers. Areas include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80%–100% of the total cover.
- Barren land: areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
- Deciduous forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover. More than 75% of tree species shed foliage simultaneously in response to seasonal change.
- Evergreen forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% total vegetation cover. More than 75% of the tree species maintain their leaves year-round. Canopy is never without green foliage.
- Mixed forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
- 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 early successional stage, or trees stunted from environmental conditions.
- Herbaceous: areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These types of areas are not subject to intensive management such as tilling but can be used for grazing.
- Pasture/hay: areas of grass, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
- Cultivated crops: areas used to produce annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and perennial woody crops such as orchards and vineyards. Crop

vegetation accounts for greater than 20% of total vegetation. This class includes all land being actively tilled.

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

The Middle Yegua Creek watershed (Figure 17) encompasses 281,798 acres and is predominantly pasture/hay (55.1%) followed by deciduous forest (14.6%;

Table 4). Urban development comprises approximately 12,731 acres or 4.5% of the watershed.

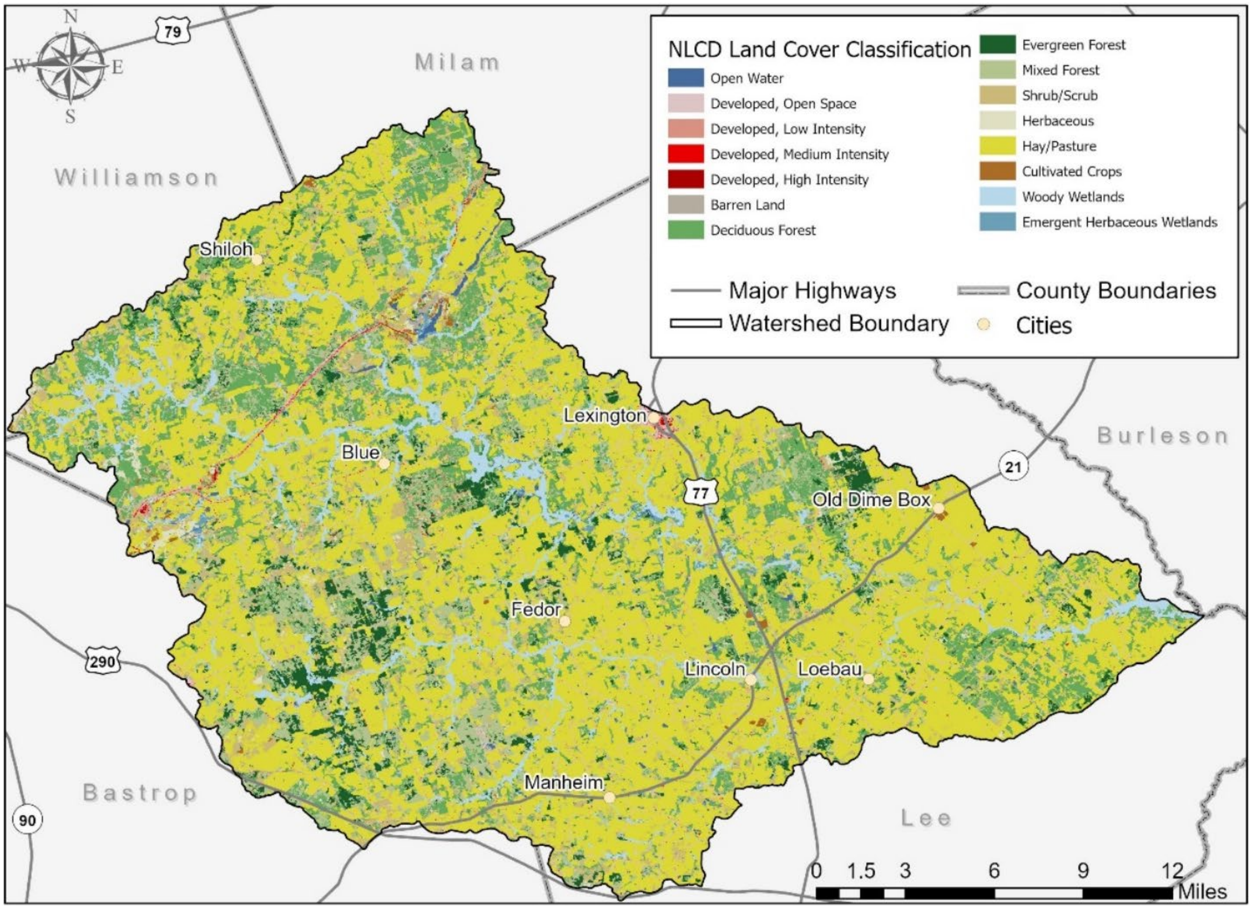

Figure 17. Land use and land cover classifications from the National Land Cover Database (NLCD) in the Middle Yegua Creek watershed (MRLC 2019).

Table 4. Land use and land cover classifications for Middle Yegua Creek watershed (MRLC 2019).

National Land Cover Database classification	Acres	Percent of total
Open water	1,767	0.6%
Developed, open space	9,525	3.4%
Developed, low intensity	2,277	0.8%
Developed, medium intensity	821	0.3%
Developed, high intensity	108	0.0%
Barren land	631	0.2%
Deciduous forest	41,221	14.6%
Evergreen forest	10,880	3.9%
Mixed forest	23,846	8.5%
Shrub/scrub	17,147	6.1%
Grassland/herbaceous	2,810	1.0%
Pasture/hay	155,249	55.1%
Cultivated crops	693	0.2%
Woody wetlands	13,521	4.8%
Emergent herbaceous wetlands	1,302	0.5%
Total	281,798	100%

The Davidson Creek watershed (Figure 18) encompasses 139,447 acres and is predominantly pasture/hay (58.3%) followed by deciduous forest (15.7%;

Table 5). Urban development comprises approximately 8,687 acres or 6% of the watershed.

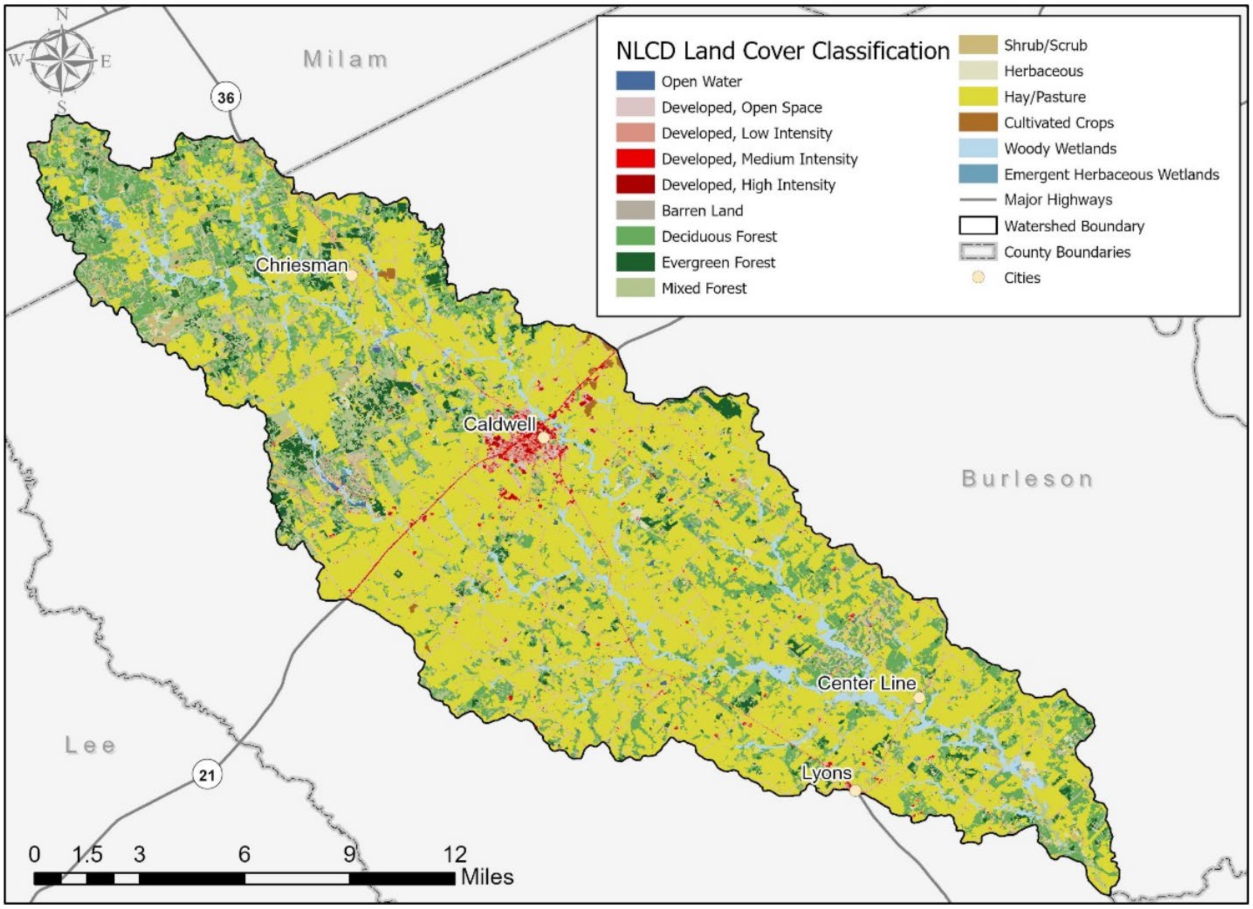

Figure 18. Land use and land cover classifications from the National Land Cover Database (NLCD) in the Davidson Creek watershed (MRLC 2019).

Table 5. Land use and land cover classifications for Davidson Creek watershed (MRLC 2019).

National Land Cover Database classification	Acres	Percent of total
Open Water	522	0.4%
Developed, open space	5,450	3.9%
Developed, low intensity	1,962	1.4%
Developed, medium intensity	997	0.7%
Developed, high intensity	278	0.2%
Barren land	326	0.2%
Deciduous forest	21,858	15.7%
Evergreen forest	5,005	3.6%
Mixed forest	10,789	7.7%
Shrub/scrub	3,106	2.2%
Grassland/herbaceous	989	0.7%
Pasture/hay	81,343	58.3%
Cultivated crops	272	0.2%
Woody wetlands	6,092	4.4%
Emergent herbaceous wetlands	458	0.3%
Total	139,447	100%

The Deer Creek watershed (Figure 19) encompasses 73,476 acres and is predominantly grassland/herbaceous (34.8%) followed closely by cultivated crops (33.8%; Table 6). Urban development comprises approximately 4,247 acres or 6% of the watershed.

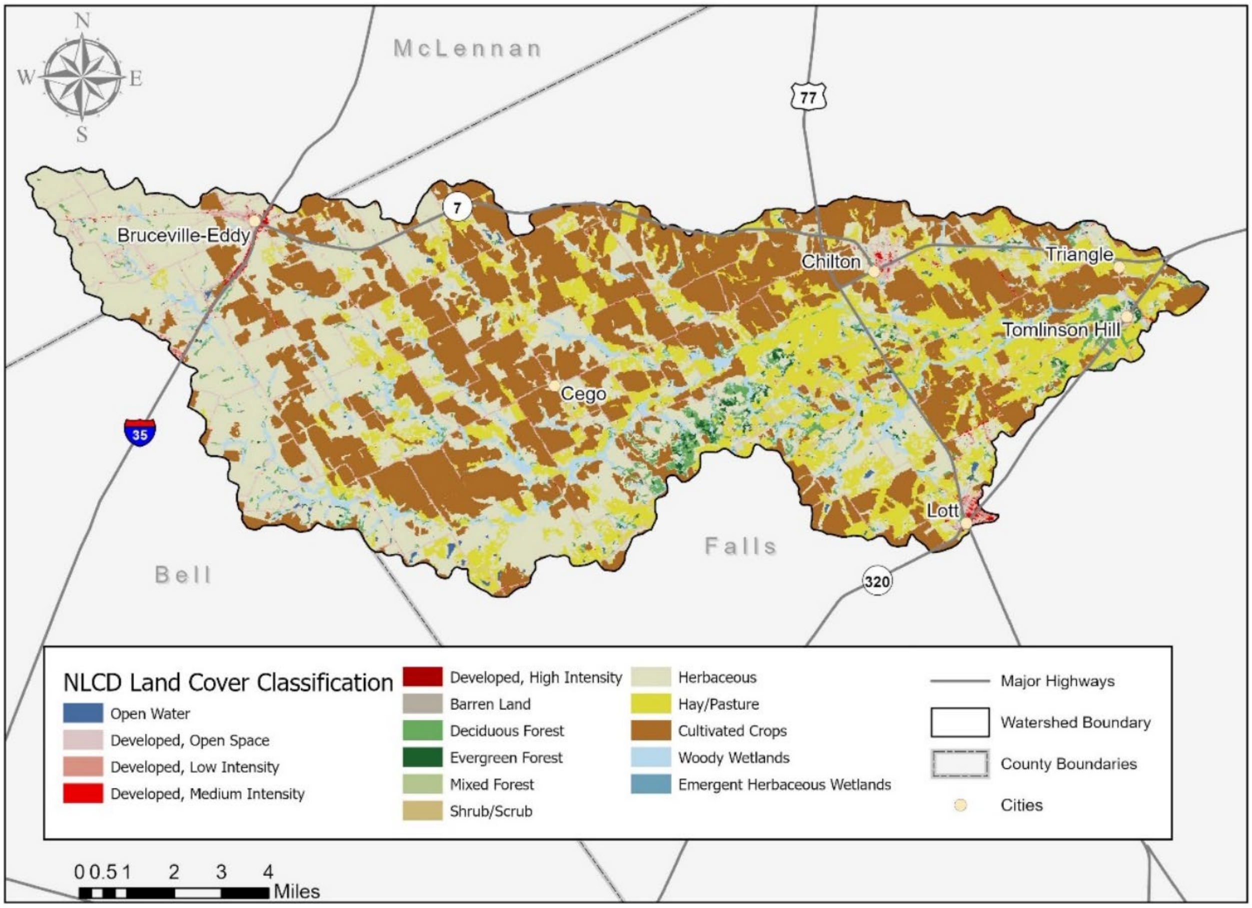

Figure 19. Land use and land cover classifications from the National Land Cover Database (NLCD) in the Deer Creek watershed (MRLC 2019).

Table 6. Land use and land cover classifications for Deer Creek watershed (MRLC 2019).

National Land Cover Database classification	Acres	Percent of total
Open water	232	0.3%
Developed, open space	3,097	4.2%
Developed, low intensity	712	1.0%
Developed, medium intensity	373	0.5%
Developed, high intensity	65	0.1%
Barren land	43	0.1%
Deciduous forest	1,687	2.3%
Evergreen forest	340	0.5%
Mixed forest	143	0.2%
Shrub/scrub	69	0.1%
Grassland/herbaceous	25,589	34.8%
Pasture/hay	12,865	17.5%
Cultivated crops	24,843	33.8%
Woody wetlands	3,293	4.5%
Emergent herbaceous wetlands	125	0.2%
Total	73,476	100%

Climate

There is one active weather station recording precipitation and temperature data in the Middle Yegua Creek watershed. That weather station is the Lexington, TX USC00415193 weather station (NOAA 2021), and it was used to determine the approximate precipitation and temperature data for the watershed (Figure 20). Monthly normal air temperature indicates daily mean air temperature was 66.9°F (NOAA 2021). Minimum average daily temperatures reached a low of 37.2°F in January. The maximum average daily temperature reached a peak of 95.3°F in August. Monthly normal precipitation, from the weather station, indicates that the area had a mean annual rainfall from 1981 to 2010 of 36.6 inches (NOAA 2021). Rainfall normally peaks in October (5.04 inches) with the lowest totals occurring in April (2.05 inches; NOAA 2021). Average annual precipitation values across the study area from the PRISM Climate Group at Oregon State University (2012) indicate average annual rainfall ranges from 34 to 38 inches per year across the watershed, with a clear east-to-west decreasing gradient (Figure 21).

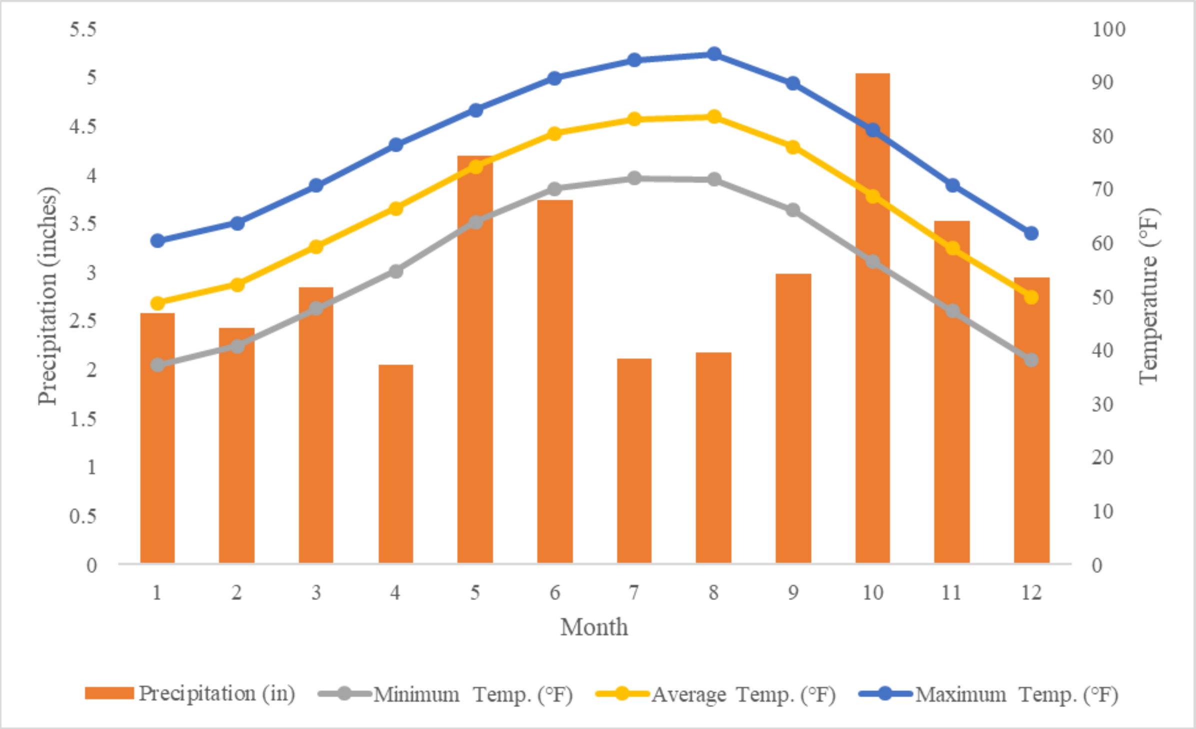

Figure 20. Monthly climate data, including precipitation, normal average, maximum and minimum air temperature, for Lexington, Texas, 1981–2010 (NOAA 2021).

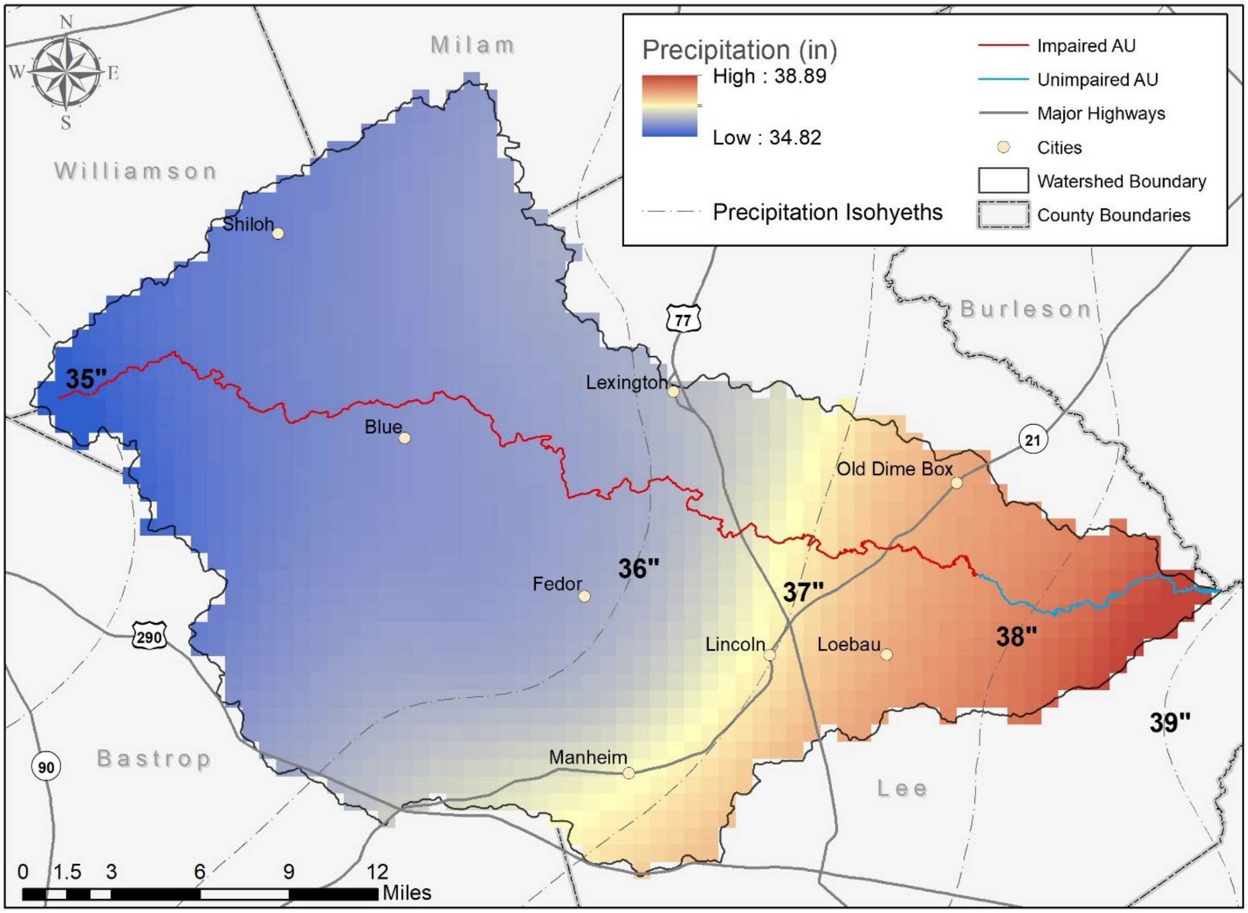

Figure 21. 30-year average precipitation in the Middle Yegua Creek watershed with assessment units (AUs) (PRISM 2012).

There are no active weather stations recording precipitation or temperature data within the boundaries of the Davidson Creek or Deer Creek watersheds. Therefore, nearby weather stations were used to determine the approximate precipitation and temperature data for the watersheds.

The nearby Somerville Dam, TX USC00418446 weather station (NOAA 2021) was used to determine the approximate precipitation and temperature data for the watershed (Figure 22). Monthly normal air temperature indicates daily mean air temperature was 67.4°F (NOAA 2021). Minimum average daily temperatures reached a low of 36.8°F in January. The maximum average daily temperature reached a peak of 96.5°F in August. Monthly normal precipitation, from the weather station, indicates that the area had a mean annual rainfall from 1981 to 2010 of 38.7 inches (NOAA 2021). Rainfall normally peaks in October (4.47 inches) with the lowest totals occurring in July (1.89 inches; NOAA 2021). Average annual precipitation values across the study area from the PRISM Climate Group at Oregon State University (2012) indicate average annual rainfall ranges from 36 to 40 inches per year across the watershed, with a clear east-to-west decreasing gradient (Figure 23).

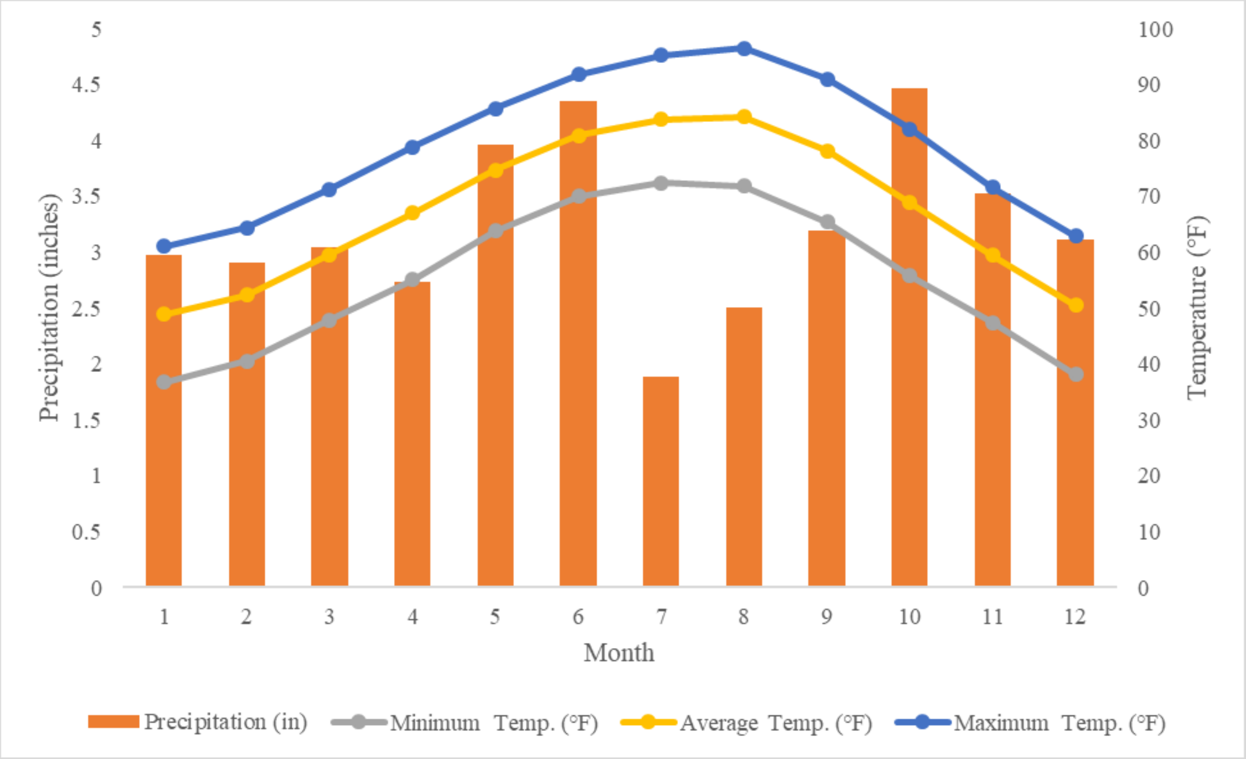

Figure 22. Monthly climate data, including precipitation, normal average, maximum and minimum air temperature, for Somerville Dam, Texas, 1981–2010 (NOAA 2021).

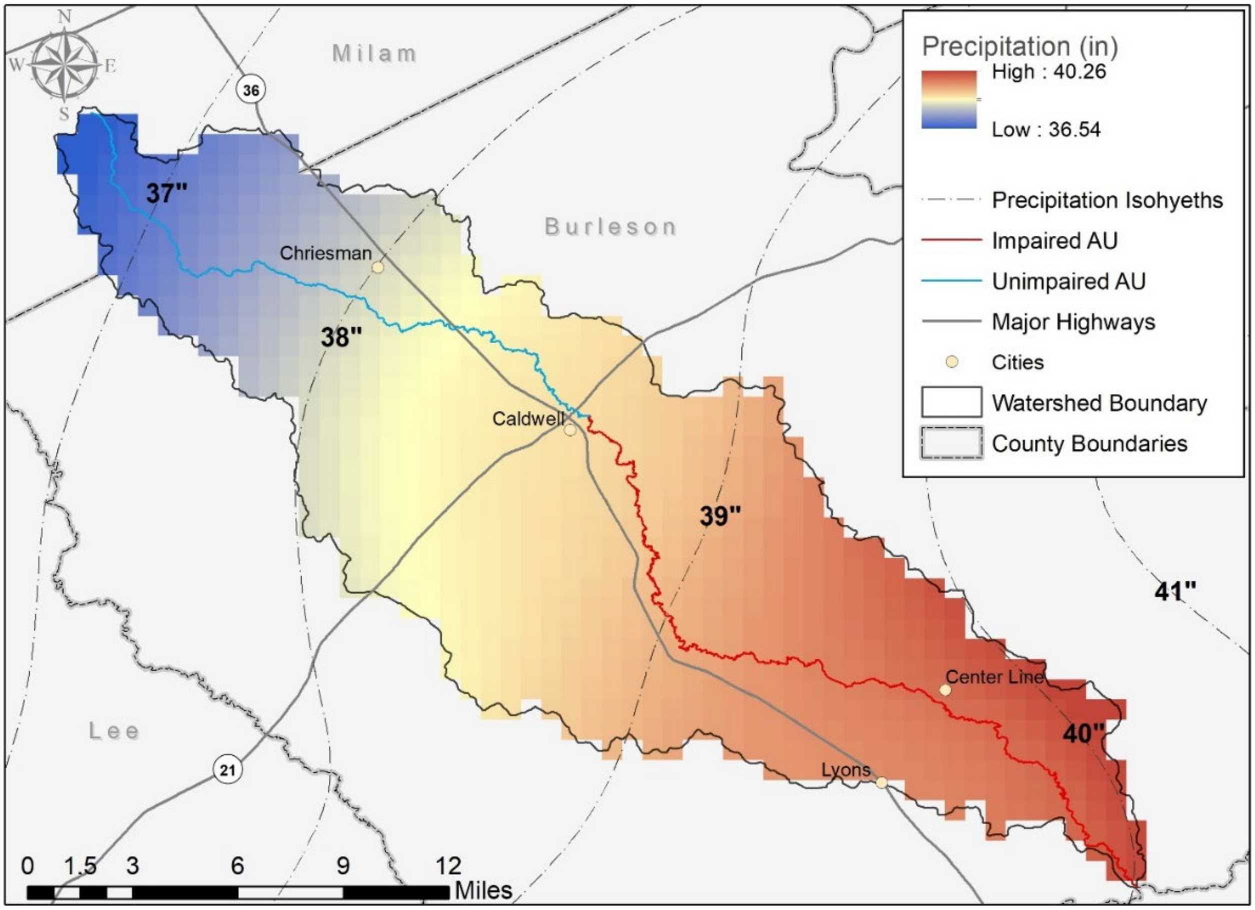

Figure 23. 30-year average precipitation in the Davidson Creek watershed with assessment units (AUs). (PRISM 2012).

The weather station chosen to determine the approximate precipitation and temperature data for the Deer Creek watershed was the Marlin, TX USC00415611 station (NOAA 2021; Figure 24). Monthly normal air temperature indicates daily mean air temperature was 66.4°F (NOAA 2021). Minimum average daily temperatures reached a low of 35.4°F in January. The maximum average daily temperature reached of peak of 95.6°F in August. Monthly normal precipitation, from the weather station, indicates that the area had a mean annual rainfall from 1981 to 2010 of 38.5 inches (NOAA 2021). Rainfall normally peaks in May (4.76 inches) with the lowest totals occurring in July (2.07 inches; NOAA 2021). Average annual precipitation values across the study area from the PRISM Climate Group at Oregon State University (2012) indicate average annual rainfall ranges from 35 to 36 inches per year across the watershed (Figure 25).

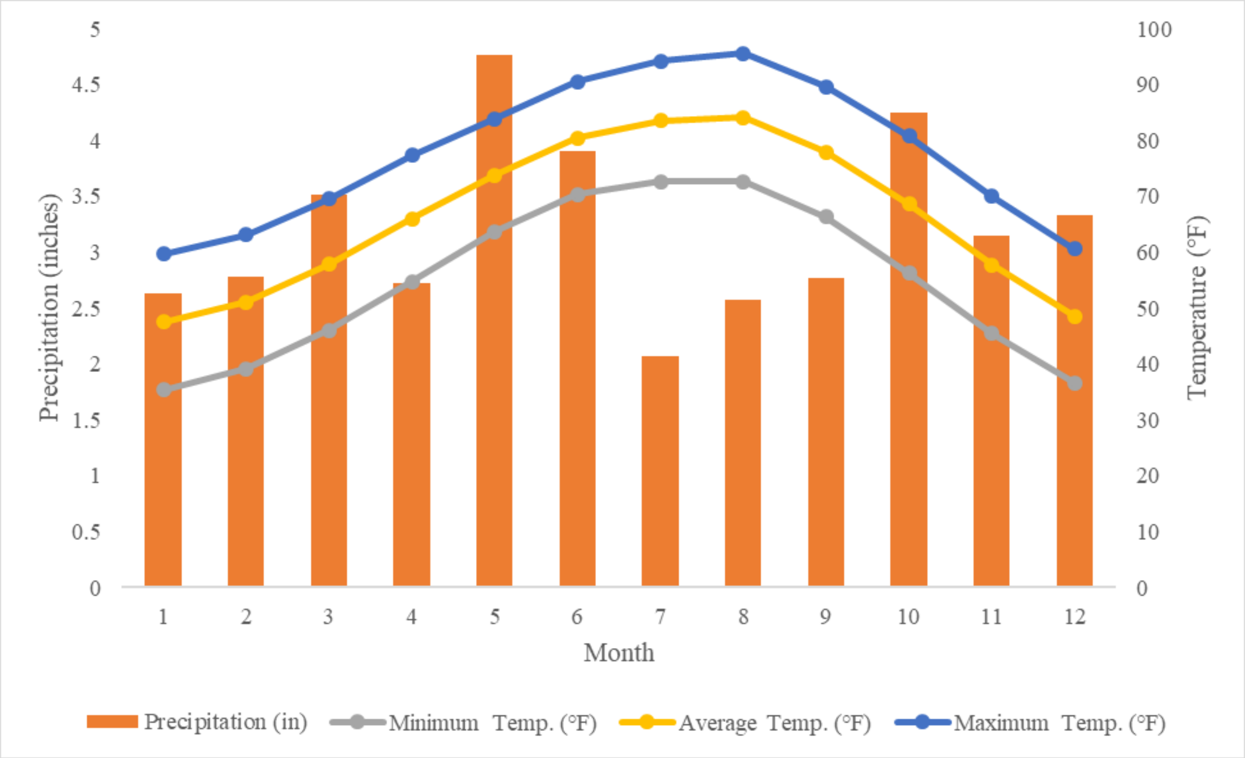

Figure 24. Monthly climate data, including precipitation, normal average, maximum and minimum air temperature, for Marlin, Texas, 1981–2010 (NOAA 2021).

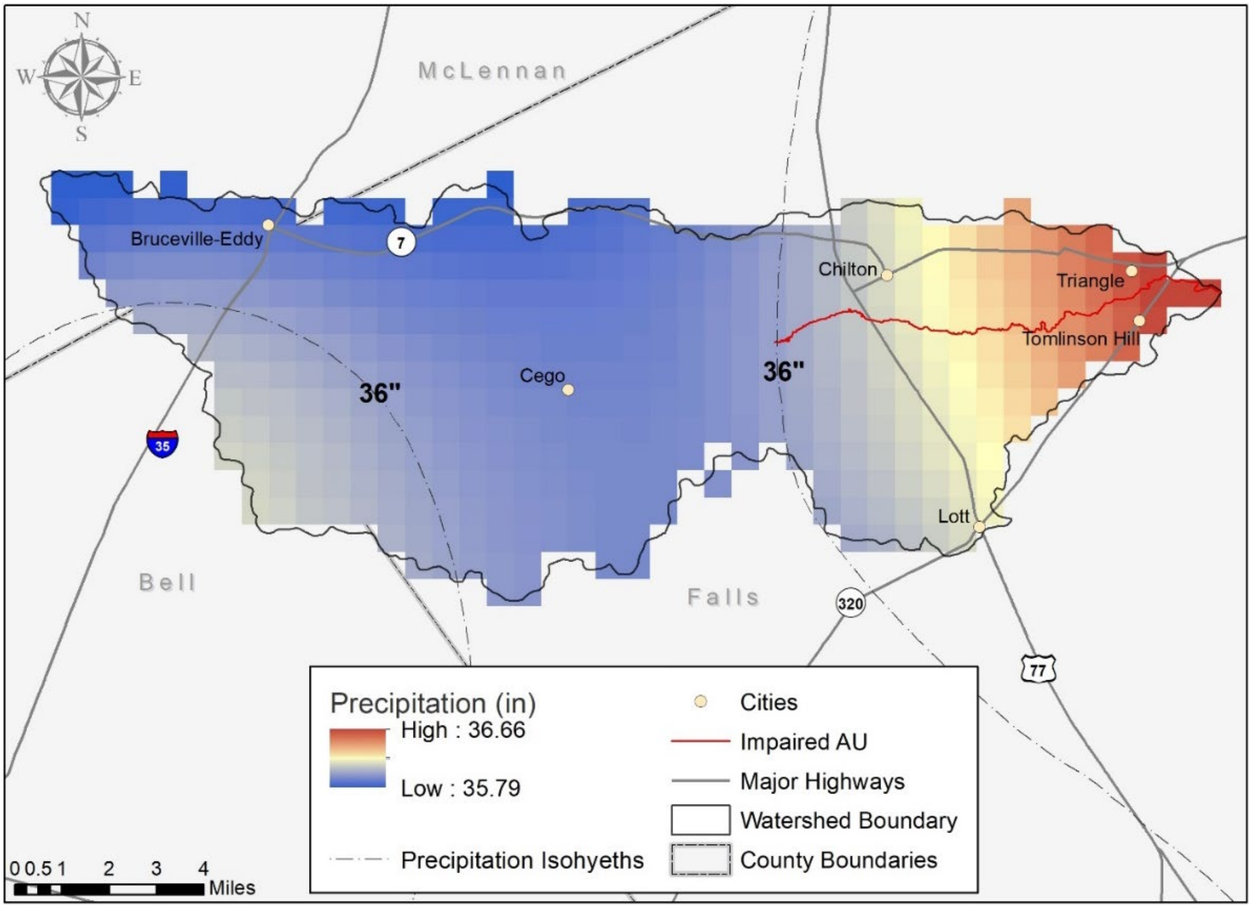

Figure 25. 30-year average precipitation in the Deer Creek watershed with assessment units (AUs) (PRISM 2012).

Demographics

Population estimates for all three watersheds were developed using 2010 U.S. Census block data (USCB 2010). Because U.S. Census block boundaries are not the same as the watersheds boundaries, their populations were estimated by multiplying the census block populations to the percent of each block within the watersheds (Figure 26, Figure 27, Figure 28). The following are the approximate populations of each watershed:

- Middle Yegua Creek watershed: 8,137
- Davidson Creek watershed: 8,666
- Deer Creek watershed: 4,116

Texas Water Development Board (TWDB) regional water plan population and water demand projections (TWDB 2021) were used to estimate population projections for counties within the watersheds (Table 7, Table 8, Table 9). From 2010 to 2070, the population of the Middle Yegua Creek watershed is estimated to increase by 106.3%, the Davidson Creek watershed by 34%, and the Deer Creek watershed by 33.6%. Note that the 2010 population totals in Tables 7–9 are based on county-level population data and differ slightly from the U.S. Census block-based population estimates outlined above.

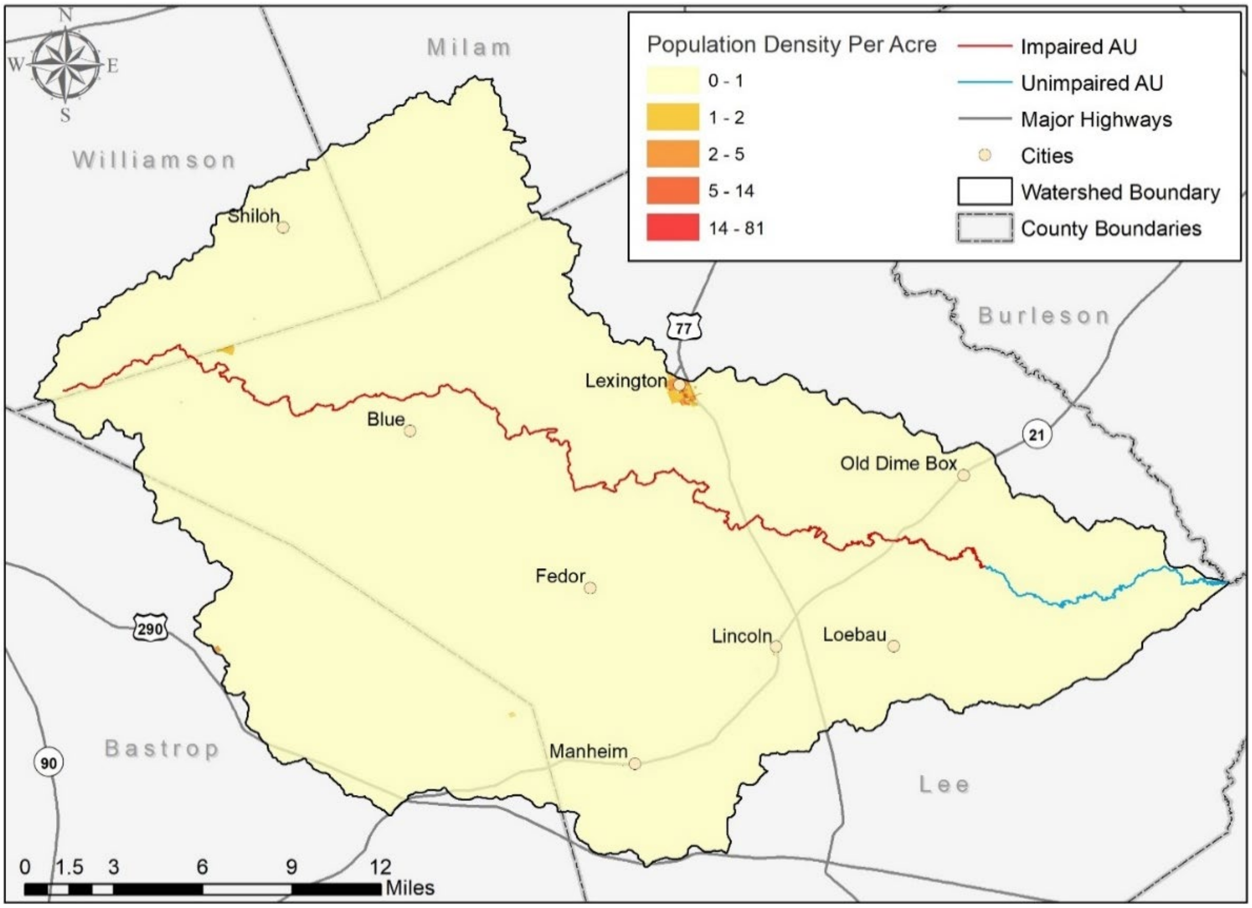

Figure 26. Middle Yegua Creek watershed 2010 population by census block with assessment units (AUs).

Table 7. Population projections by county for the Middle Yegua Creek watershed (TWDB 2021).

County	2010 U.S. Census	Projected population in the watershed by year						Percent increase (2010–2070)
		2020	2030	2040	2050	2060	2070	
Bastrop	971	1,250	1,644	2,156	2,850	3,789	5,031	418.1
Lee	6,033	6,948	7,812	8,308	8,489	8,610	8,675	43.8
Milam	416	441	467	486	510	530	548	31.8
Williamson	717	951	1,159	1,424	1,737	2,138	2,529	252.7
Total	8,137	9,590	11,082	12,374	13,586	15,067	16,783	106.3

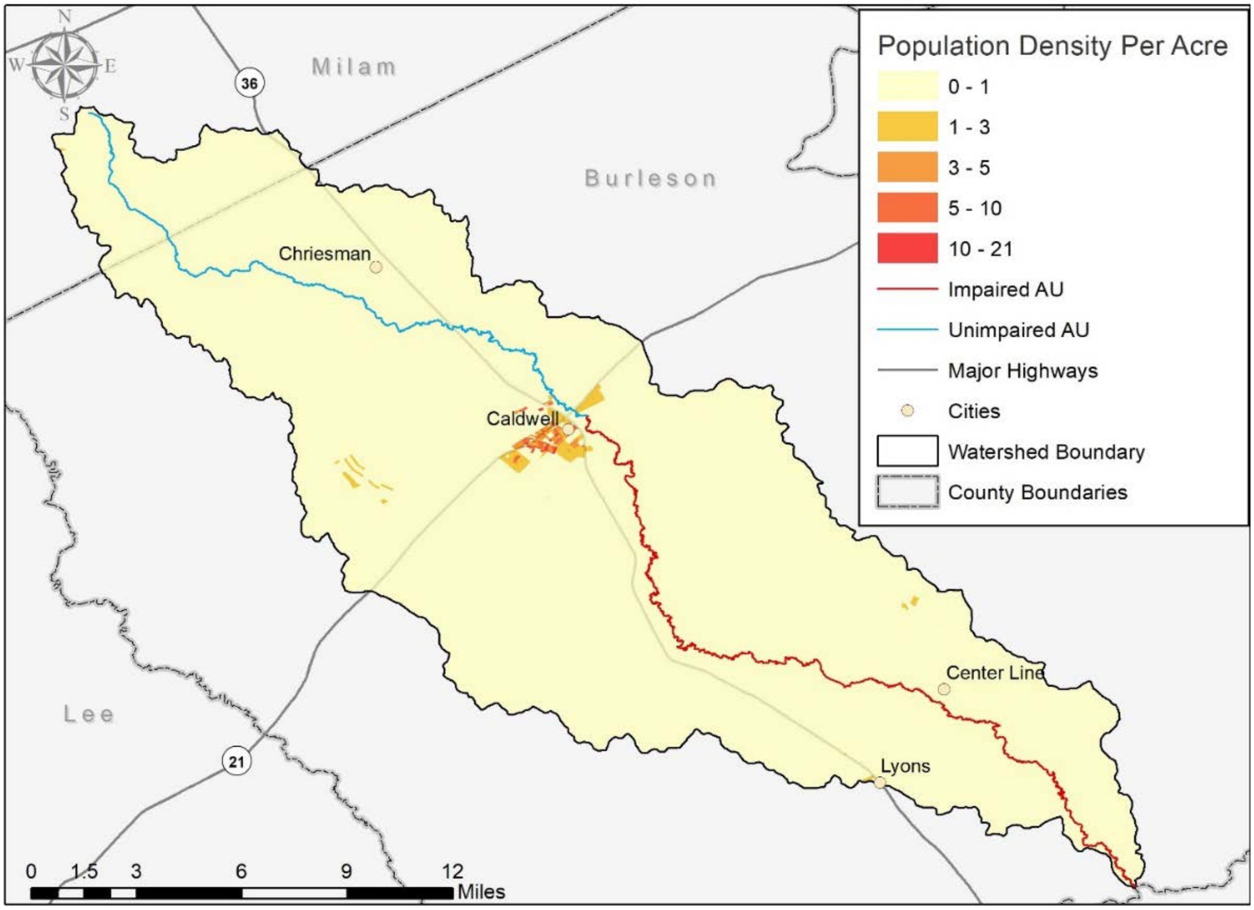

Figure 27. Davidson Creek watershed 2010 population by census block with assessment units (AUs).

Table 8. Population projections by county for the Davidson Creek watershed (TWDB 2021).

County	2010 U.S. Census	Projected population in the watershed by year						Percent increase (2010–2070)
		2020	2030	2040	2050	2060	2070	
Burleson	8,509	9,178	9,875	10,316	10,760	11,110	11,402	34.0
Milam	157	166	176	183	192	200	207	31.8
Total	8,666	9,344	10,051	10,499	10,952	11,310	11,609	34.0

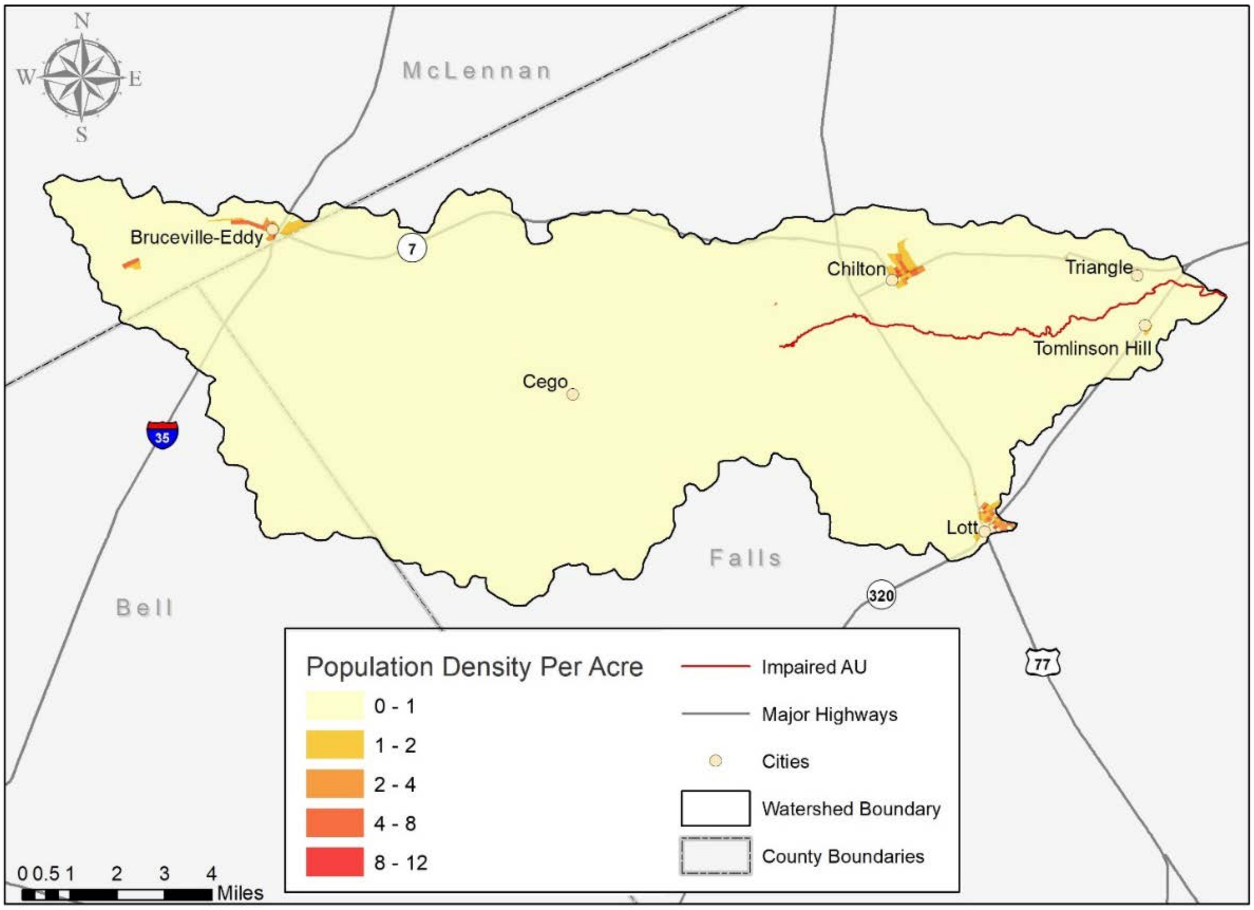

Figure 28. Deer Creek watershed 2010 population by census block with assessment units (AUs).

Table 9. Population projections by county for the Deer Creek watershed (TWDB 2021).

County	**Projected population in the watershed by year**							**Percent increase (2010–2070)**
	2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	
Bell	232	278	324	372	419	467	515	121.8
Falls	2,592	2,816	2,959	2,990	2,920	3,009	3,100	19.6
McLennan	1,292	1,387	1,497	1,594	1,692	1,789	1,885	45.9
Total	4,116	4,481	4,780	4,956	5,031	5,265	5,500	33.6

Water Quality

Introduction

Under the Federal Clean Water Act (CWA) section 303(d) and 305(b), the state of Texas is required to identify water bodies that are unable to meet water quality standards for their designated uses. The Texas Commission on Environmental Quality (TCEQ) assigns unique "segment" identifiers to each water body. Locations within a segment are broken up into hydrologically distinct AUs. The AUs are evaluated every two years to determine if they meet designated water quality standards, and those that are not meeting requirements are listed on the 303(d) List in the Texas Integrated Report.

TCEQ defines the designated uses for all water bodies, which in turn establishes the water quality criteria to which a water body must adhere. Currently, all water bodies in the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds must meet "primary contact recreation" uses and support aquatic life use. The water quality for recreation use is evaluated by measuring concentrations of fecal indicator bacteria in 100 milliliters (mL) of water. Aquatic life use is a measure of a water body's ability to support a healthy aquatic ecosystem. Aquatic life use is evaluated based on the dissolved oxygen (DO) concentration, toxic substance concentrations, ambient water and sediment toxicity, and indices of habitat, benthic macroinvertebrates, and fish communities. General use water quality requirements also include measures of temperature, pH, chloride, sulfate, and total dissolved solids. Currently, water bodies are also screened for levels of concern for nutrients and chlorophyll-a.

According to the *2020 Texas Integrated Report* and *303(d) List* (TCEQ 2020), there is one impaired AU due to elevated levels of bacteria in each watershed: AU 1212A_02 in Middle Yegua Creek, AU 1211A_02 in Davidson Creek, and AU 1242J_01 in Deer Creek (Figure 29, Figure 30, Figure 31). Davidson Creek is impaired for low DO concentrations along with the elevated levels of bacteria. There are also concerns for depressed DO and habitat in Middle Yegua Creek as well as concerns for the macrobenthic community and nitrate in Deer Creek.

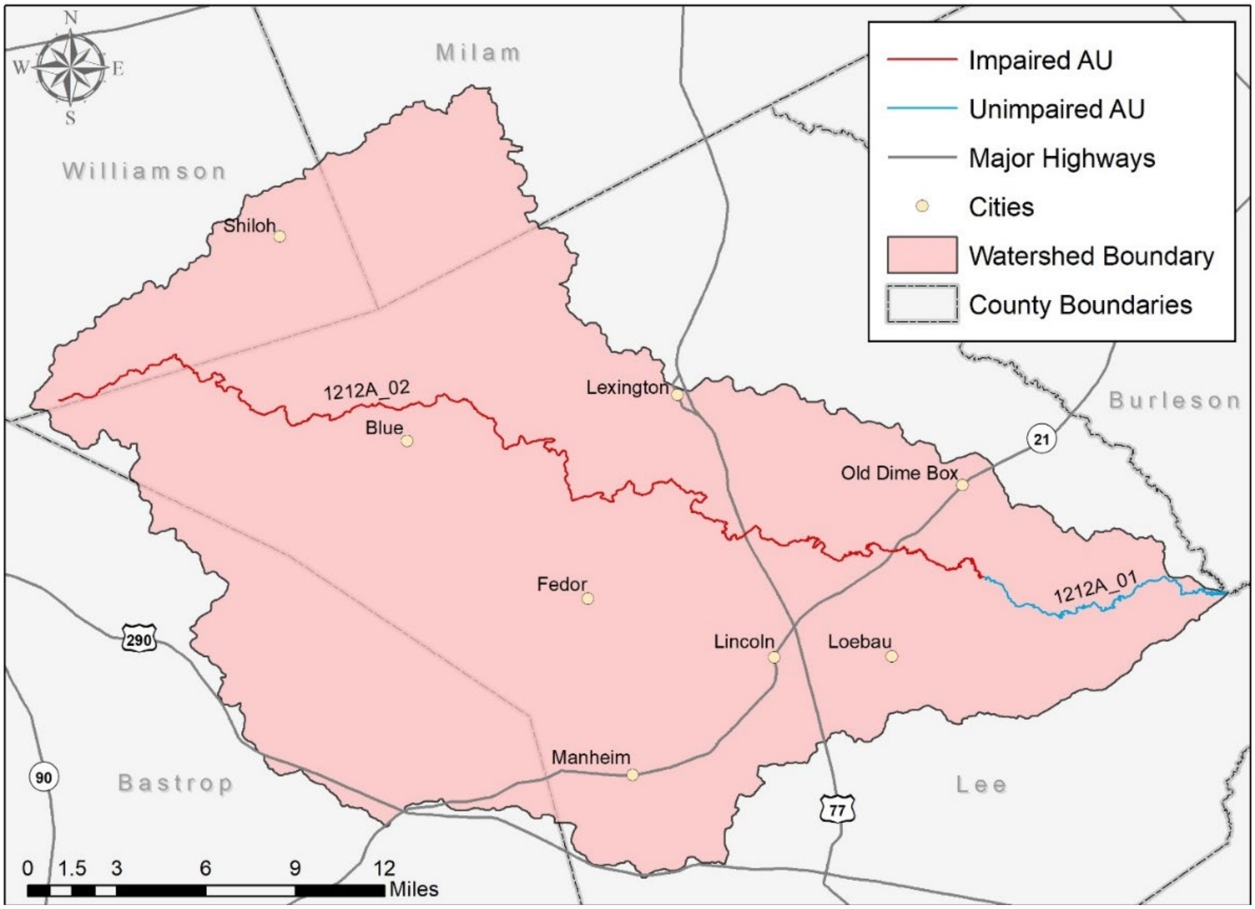

Figure 29. Texas Commission on Environmental Quality assessment units (AUs) and watershed impairments for Middle Yegua Creek watershed.

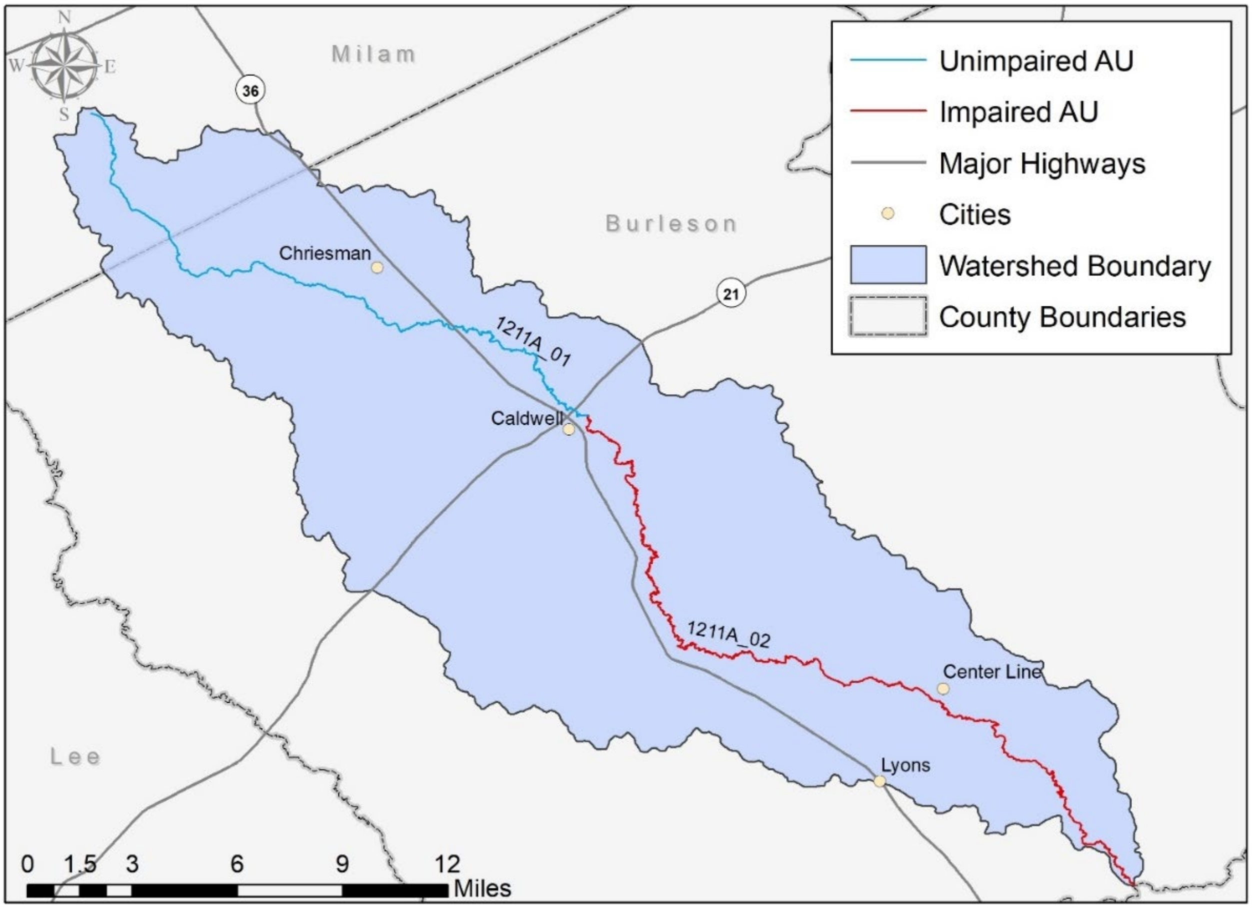

Figure 30. Texas Commission on Environmental Quality assessment units (AUs) and watershed impairments for Davidson Creek watershed.

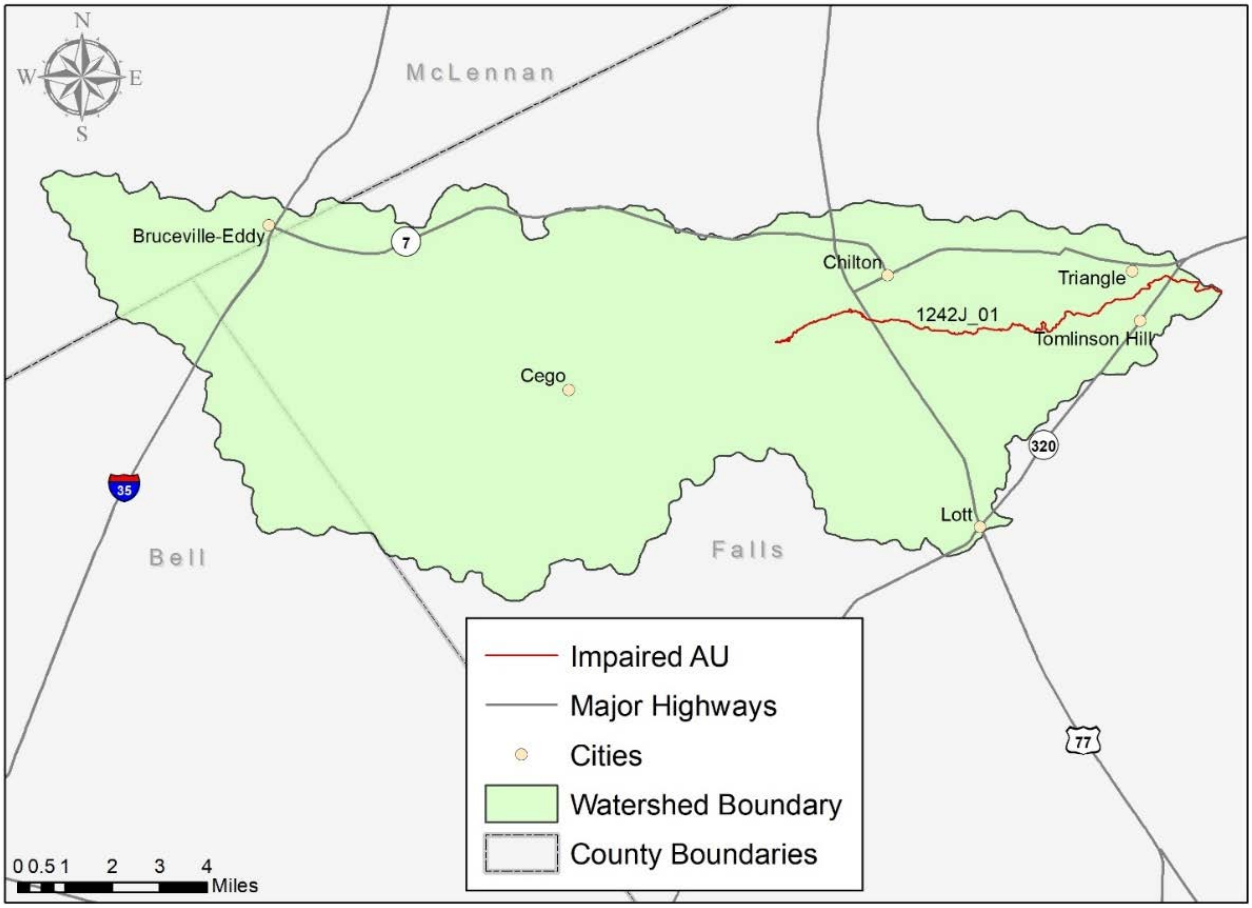

Figure 31. Texas Commission on Environmental Quality assessment unit (AU) and watershed impairment for Deer Creek watershed.

Water quality is monitored at designated sampling sites throughout the watershed. The TCEQ Surface Water Quality Monitoring (SWQM) Program coordinates the collection of water quality samples at specified water quality monitoring sites in the watersheds and the state (Figure 32, Figure 33, Figure 34). Through the TCEQ Clean Rivers Program (CRP), the Brazos River Authority (BRA) conducts quarterly monitoring of field parameters (clarity, temperature, DO, specific conductance, pH, salinity, and flow), conventional parameters (total suspended solids, sulfate, chloride, ammonia, total hardness, nitrate-nitrogen, total phosphorous, alkalinity, total organic carbon, turbidity, and chlorophyll-a), and bacteria. The one site currently being monitored by BRA is detailed in Table 10. The sites monitored by the Texas Water Resources Institute (TWRI) are detailed in Table 11. At these sites, TWRI conducted monthly monitoring of field parameters (clarity, temperature, DO, specific, conductance, pH, and flow) and bacteria from December 2018 to February 2020 and July 2020 to December 2021.

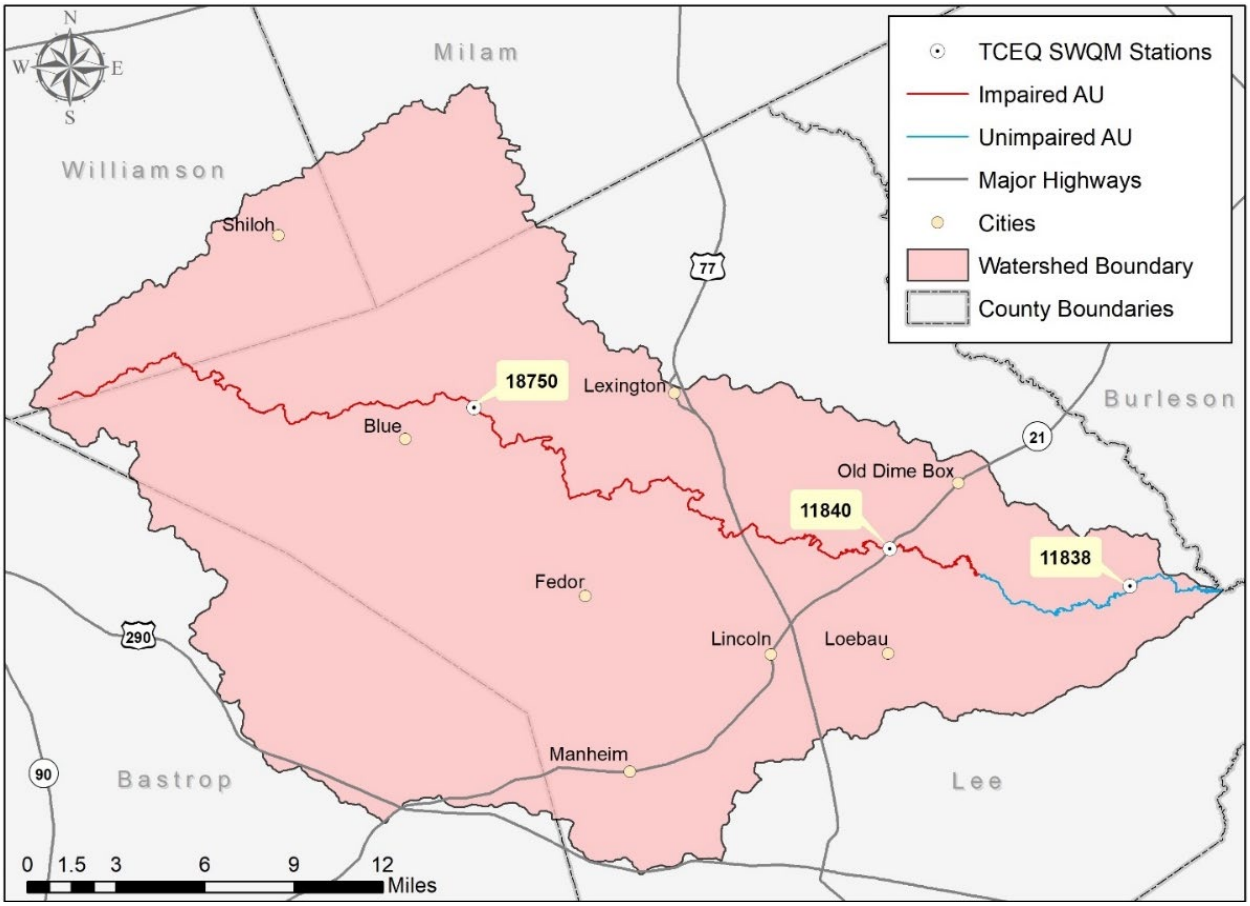

Figure 32. Surface water quality monitoring stations in the Middle Yegua Creek watershed with assessment units (AUs).

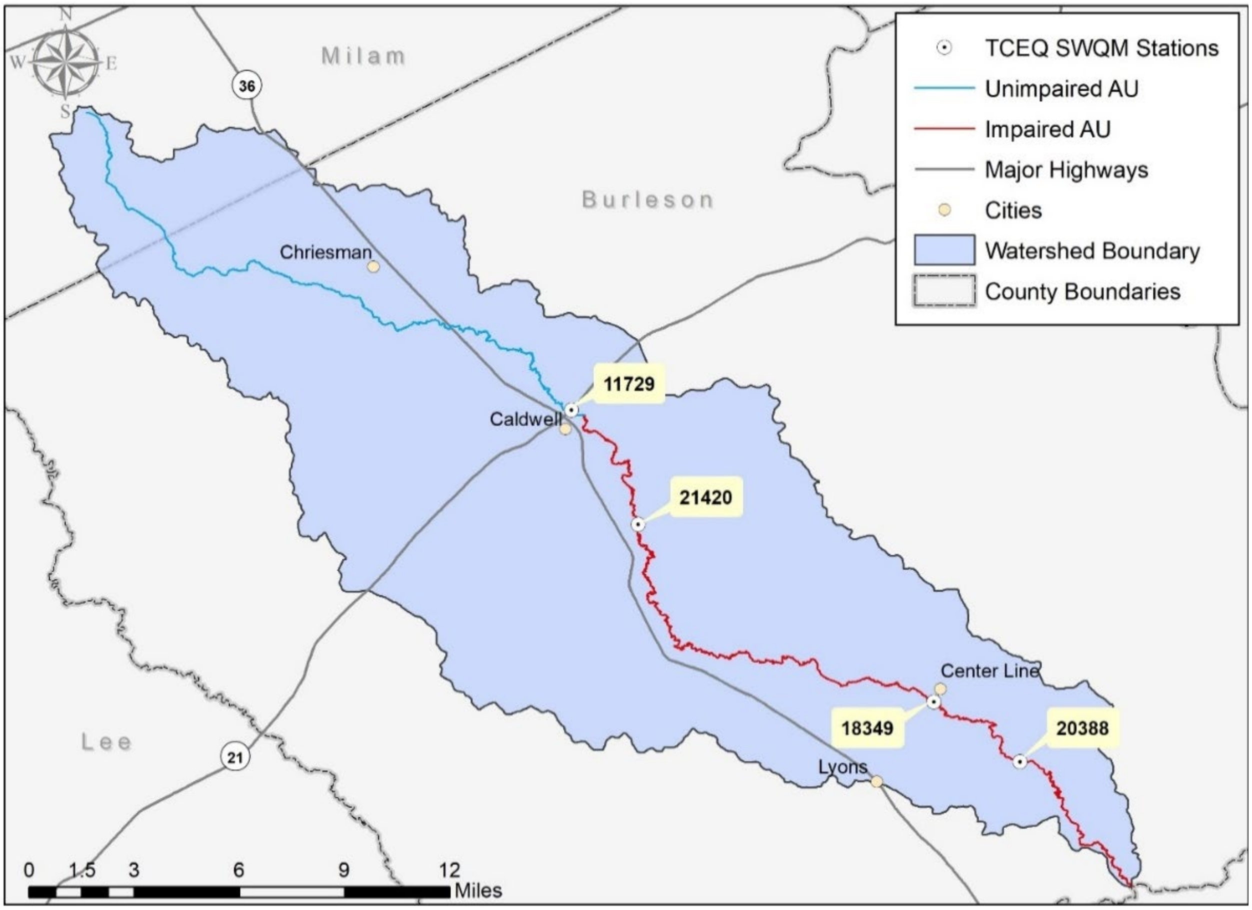

Figure 33. Surface water quality monitoring stations in the Davidson Creek watershed with assessment units (AUs).

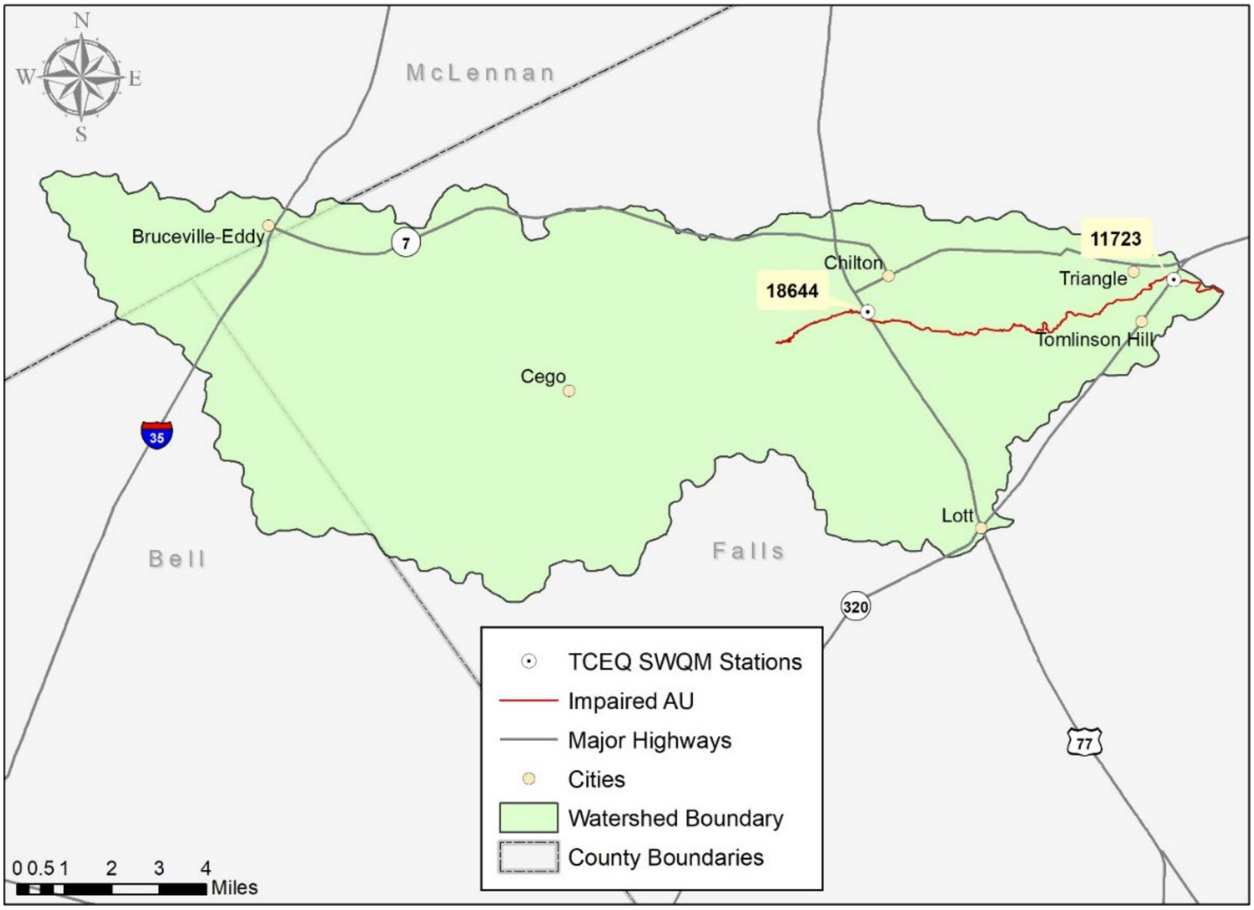

Figure 34. Surface water quality monitoring stations in the Deer Creek watershed with assessment units (AUs).

Table 10. Site currently monitored by the Brazos River Authority.

Station			Number of annual samples collected				
ID	Assessment unit	Description	24-hour dissolved oxygen	Conventional	Field	Flow	Bacteria
11723	1242J_01	Deer Creek immediately downstream of SH 320 west of Marlin		4	4		4

Table 11. Sites currently monitored by Texas Water Resources Institute.

Station			Number of samples collected December 2018–December 2021		
ID	Assessment unit	Description	Field	Flow	Bacteria
18750	1212A_02	Middle Yegua Creek immediately upstream of FM 696	33	33	33
11840	1212A_02	Middle Yegua Creek at SH 21 4.4 miles northeast of Lincoln	33	33	33
11838	1212A_01	Middle Yegua Creek immediately upstream of FM 141 4 miles southeast of Dime Box	33	32*	33
18349	1211A_02	Davidson Creek downstream of FM 60 near Lyons Texas	33	33	33
21420	1211A_02	Davidson Creek at CR 122 in Burleson County	33	33	33
11729	1211A_02	Davidson Creek immediately downstream of SH 21 0.5 miles northeast of Caldwell	33	33	33
18644	1242J_01	Deer Creek downstream of US 77 S of Chilton	33		33
11723	1242J_01	Deer Creek immediately downstream of SH 320 W of Marlin	33		33

*Flow measurement could not be collected for this station in April 2019 due to unsafe conditions.

Bacteria

As mentioned above, concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater environments, concentrations of *E. coli* bacteria are measured to evaluate the presence of fecal contamination in water bodies 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 be reaching water bodies and can cause illness in people that recreate in them. Indicator bacteria can originate from numerous sources including wildlife, domestic livestock, pets, malfunctioning OSSFs, urban and agricultural runoff, sanitary sewer overflows (SSOs), 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 100 mL. Currently, all water bodies in the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds are evaluated under this standard. As previously mentioned, three AUs (1212A_02 [Middle Yegua Cree]), 1211A_02 [Davidson Creek], and 1242J_01 [Deer Creek]) are listed as impaired due to elevated indicator bacteria Table 12.

Table 12. Geometric means for historical *E. coli* data.

Assessment unit	**Description**	**Current standard**	***E. coli* geometric mean (most probable number [MPN]/100 milliliters [mL])**	**Supporting/not supporting**
1212A_02	Middle Yegua Creek – From the confluence with West Yegua Creek upstream to headwaters of water body in Williamson County	126 MPN/100 mL *E. coli*	890[1]	Not supporting
1211A_02	Davidson Creek – Portion of Davidson Creek from confluence with unnamed tributary upstream to headwaters in Milam County	126 MPN/100 mL *E. coli*	2,212.19[2]	Not supporting
1242J_01	Deer Creek – Perennial stream from the confluence of the Brazos River upstream to the confluence of Dog Branch northwest of Lott	126 MPN/100 mL *E. coli*	373.55[1]	Not supporting

[1] *2020 Texas Integrated Report* Assessment Results (TCEQ 2020)

[2] *2014 Texas Integrated Report* Assessment Results (TCEQ 2015a)

Currently, *E. coli* concentrations are measured at eight stations throughout the watersheds by TWRI and at one station by BRA. There are also sites on Middle Yegua Creek AU 1212A_02 (SWQM station 18751) and Deer Creek AU 1242J_01 (SWQM station 16407) that are no longer active, but where *E. coli* samples were collected at historically. *E. coli* measurements for each impaired AU, including historical stations, are shown in Figure 35 through Figure 37.

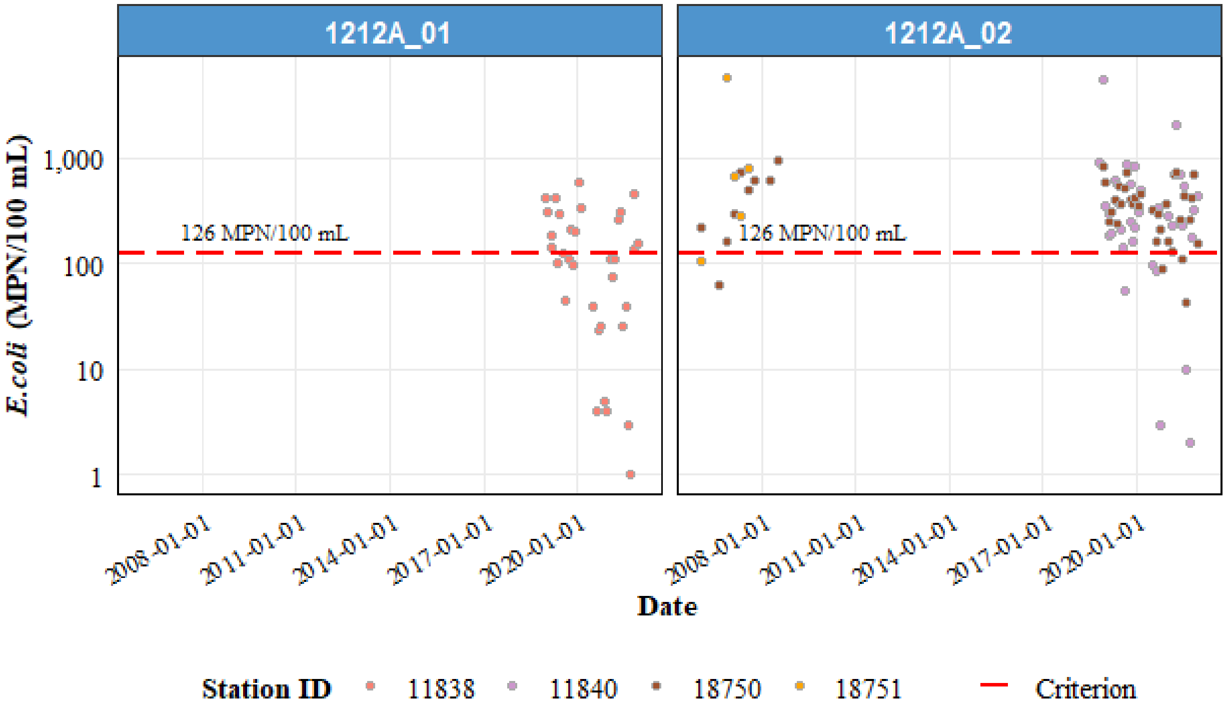

Figure 35. Historical *E. coli* concentrations for the Middle Yegua Creek watershed.

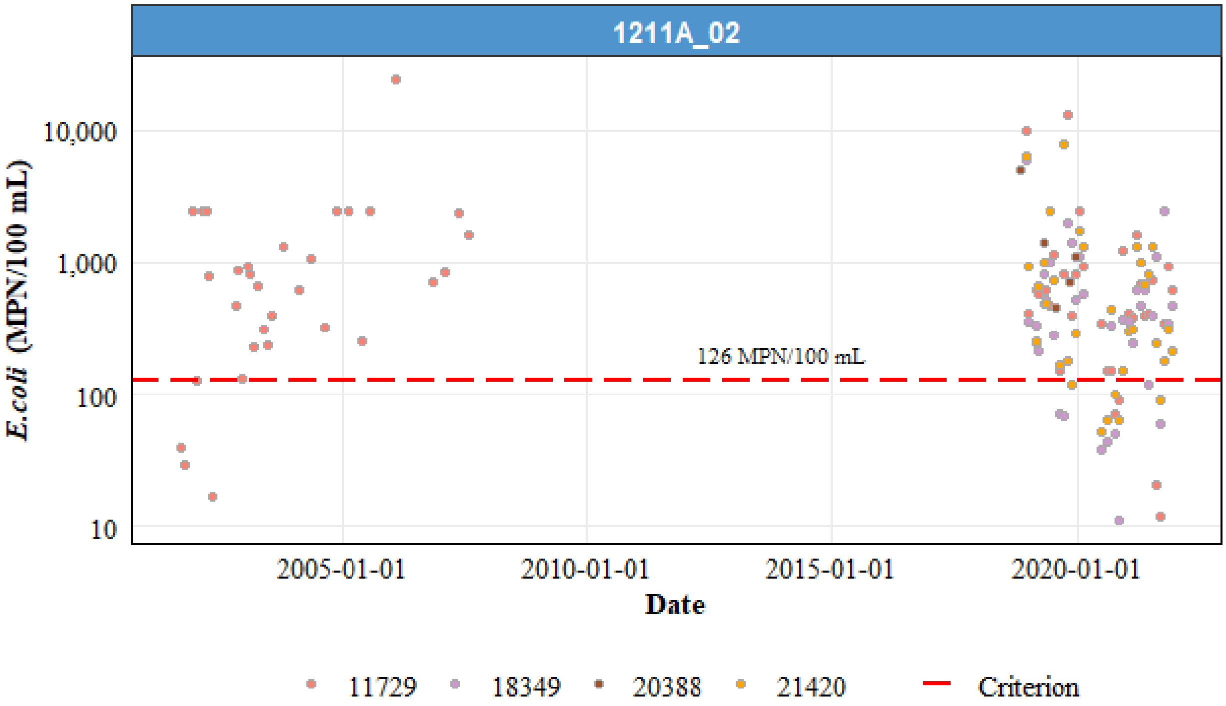

Figure 36. Historical *E. coli* concentrations for the Davidson Creek watershed.

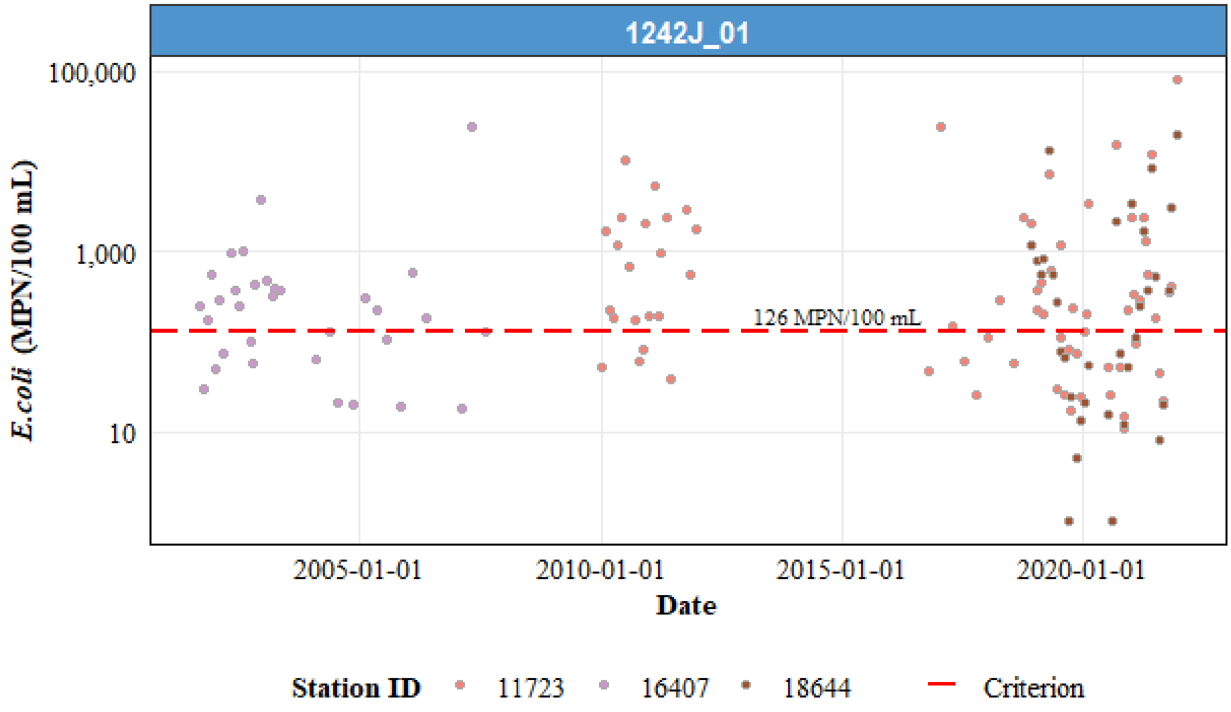

Figure 37. Historical *E. coli* concentrations for the Deer Creek watershed.

Dissolved Oxygen

DO is essential for aquatic organisms to survive and refers to the concentration of oxygen gas incorporated into water. DO concentrations naturally fluctuate in the environment, but anthropogenic activities can contribute 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 are required to meet an average DO criterion measured over 24 hours and a minimum DO criterion (TCEQ 2015b). Unclassified streams are assigned an ALU based upon the flow-type for the specific segment, which are 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 2015b). Limited 24-hour average DO data is available for Davidson Creek AU 1211A_02, with sampling events occurring between 2003 and 2019 (Figures 38–40). All segments in the watersheds are assumed to support a subcategory of aquatic life use. The ALU categories and DO screening levels are listed for each water body in Table

13, and grab samples DO concentrations are plotted in Figure 42–43. Middle Yegua Creek AU 1212A_02 has a concern for depressed DO, while Davidson Creek AU 1211A_02 is listed to not support the DO standards and criteria.

Table 13. Aquatic life use (ALU) and dissolved oxygen (DO) criteria for the Middle Yegua, Davidson, and Deer creeks watersheds.

Segment	Water body	ALU category	DO screening level criteria (milligrams/liter [mg/L])	DO grab minimum (mg/L)	24-hour DO average (mg/L)	24-hour DO minimum (mg/L)
1212A	Middle Yegua Creek	High	5 (CS)[1]	3	-	-
1211A	Davidson Creek	Intermediate	4	3	4 (NS)[2]	3 (NS)[2]
1242J	Deer Creek	High	5	3	-	-

[1] CS: Concern for Screening Level;

[2] NS: Not Supporting

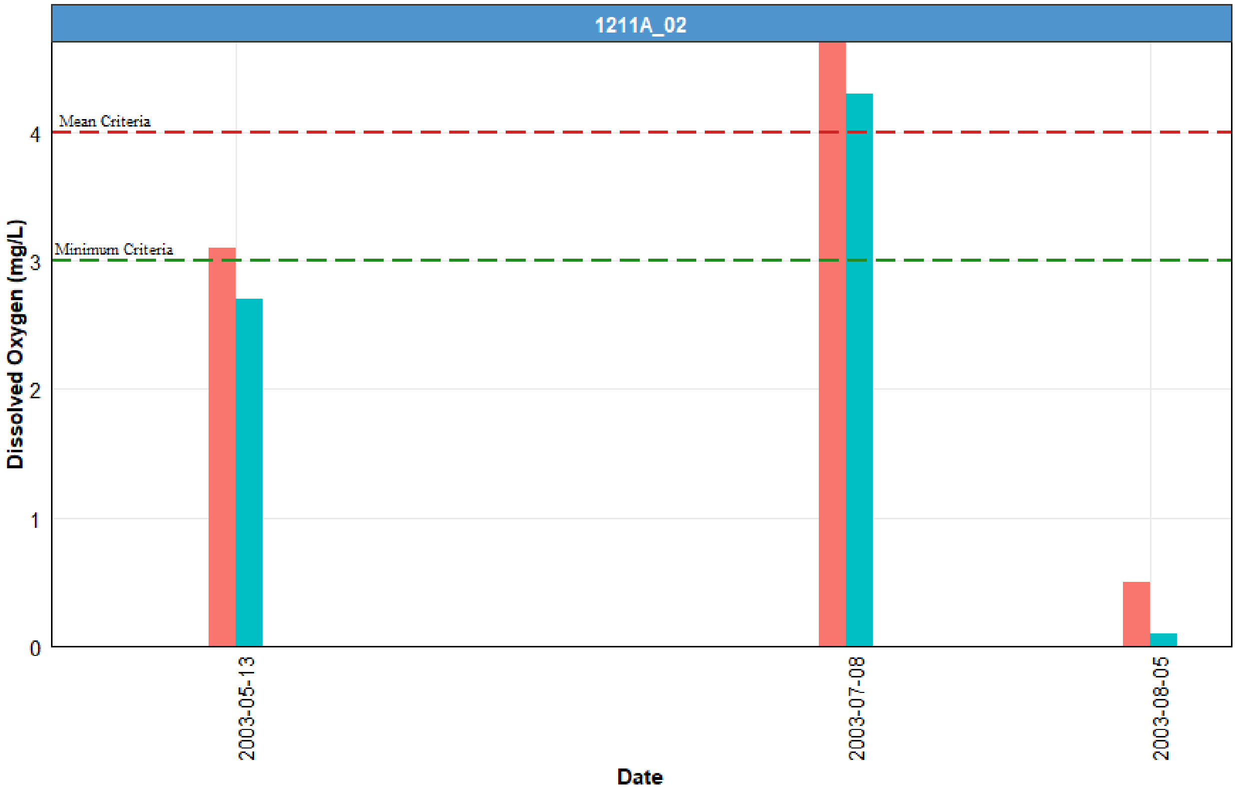

Figure 38. Historical 24-hour dissolved oxygen concentrations for the Davidson Creek watershed station 20388. The orange bar indicates average 24-hour dissolved concentrations, and the blue bar indicates minimum 24-hour dissolved oxygen concentrations.

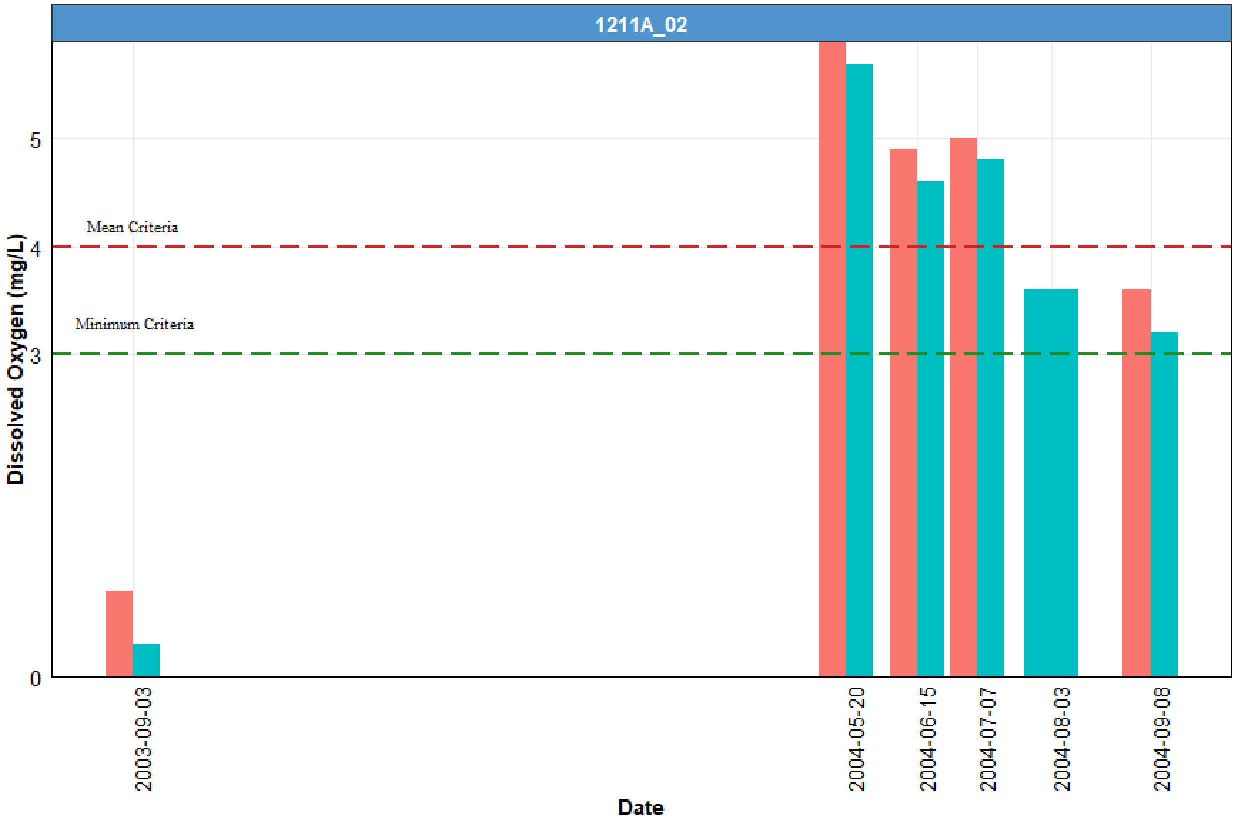

Figure 39. Historical 24-hour dissolved oxygen concentrations for the Davidson Creek watershed station 11729 between 2003 and 2004. The orange bar indicates average 24-hour dissolved concentrations, and the blue bar indicates minimum 24-hour dissolved oxygen concentrations.

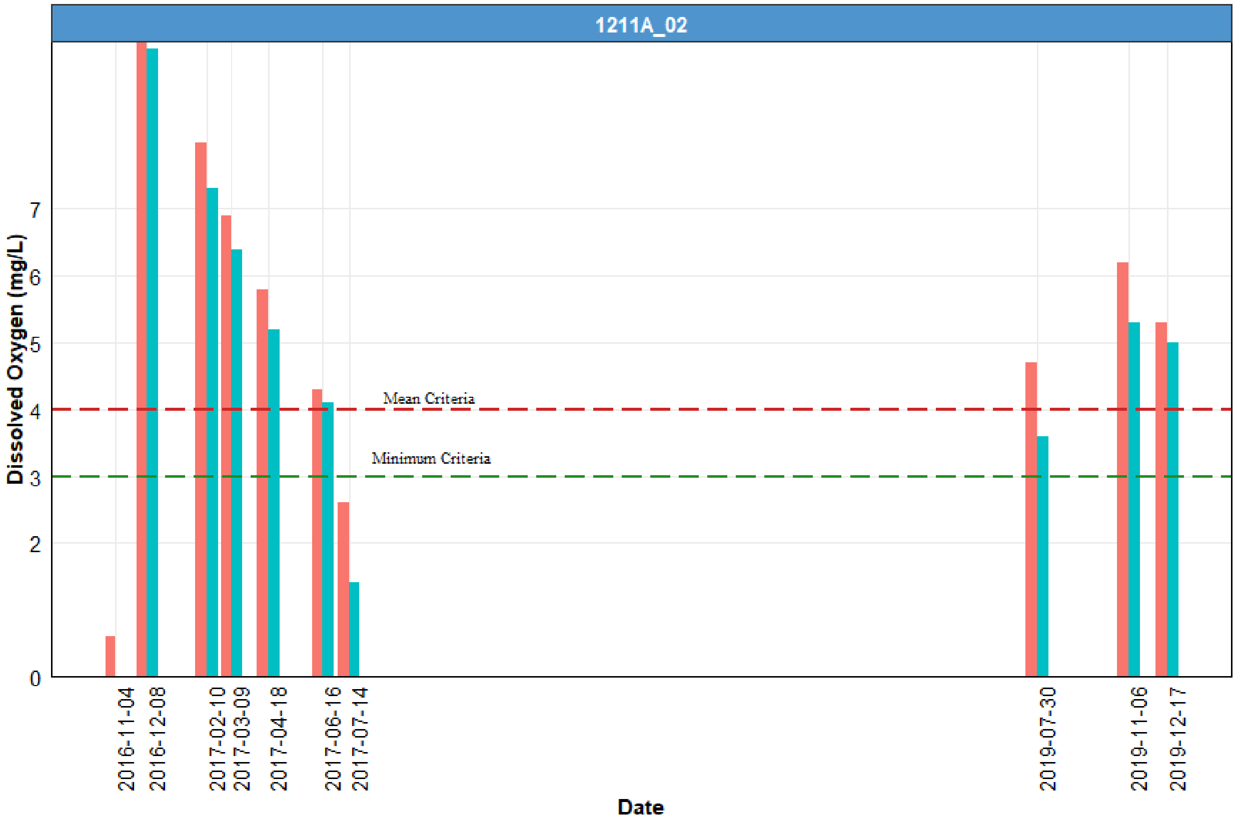

Figure 40. Historical 24-hour dissolved oxygen concentrations for the Davidson Creek watershed station 11729 between 2016 and 2019. The orange bar indicates average 24-hour dissolved concentrations, and the blue bar indicates minimum 24-hour dissolved oxygen concentrations.

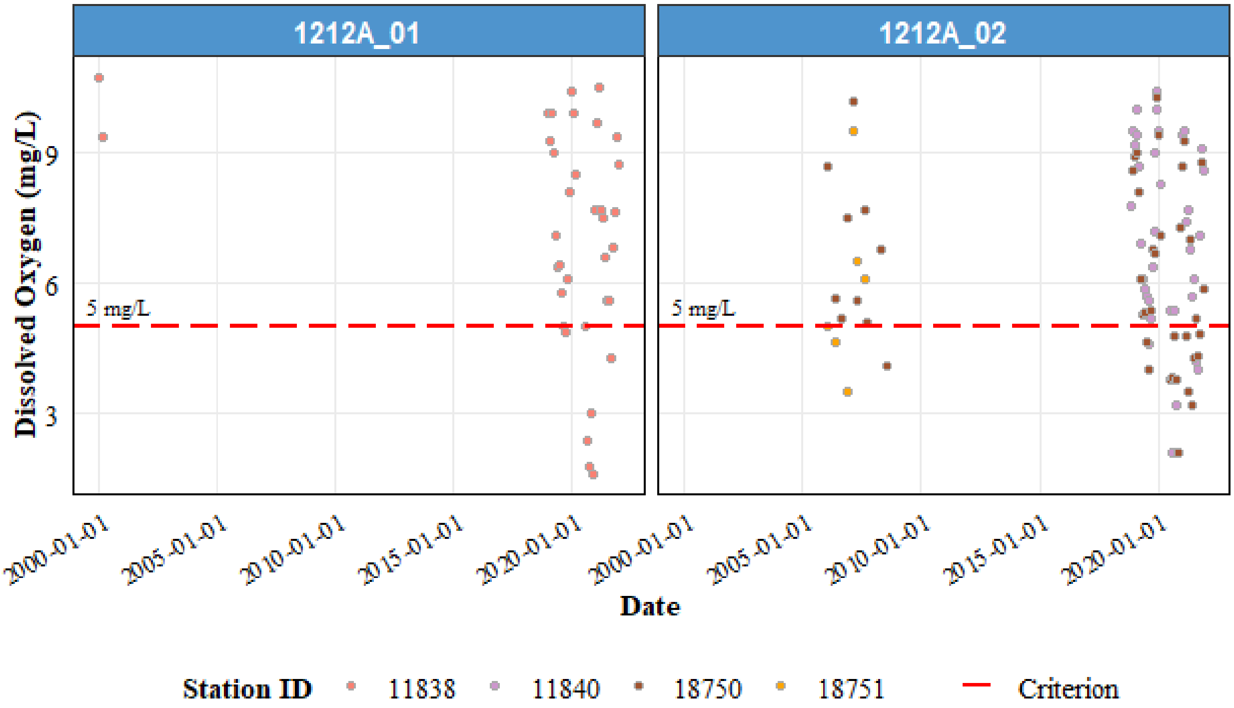

Figure 41. Historical grab sample dissolved oxygen concentrations for the Middle Yegua Creek watershed.

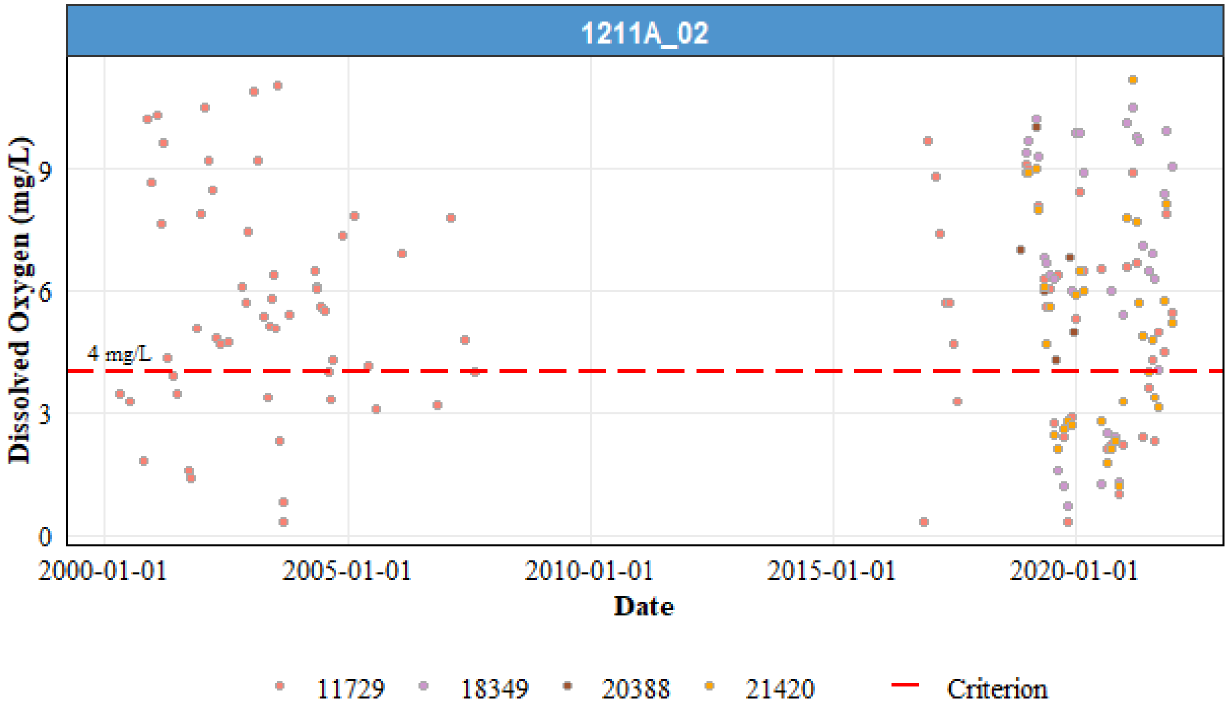

Figure 42. Historical grab sample dissolved oxygen concentrations for the Davidson Creek watershed.

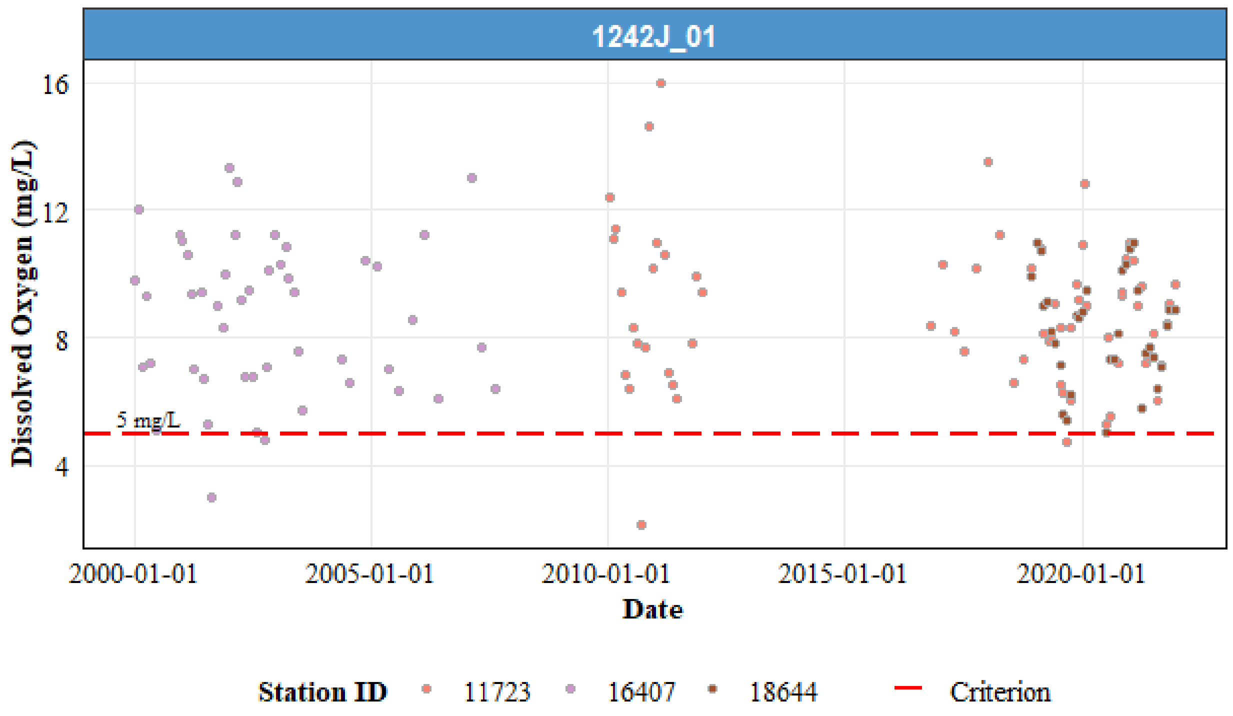

Figure 43. Historical grab sample dissolved oxygen concentrations for the Deer Creek watershed.

Flow

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

There are two U.S. Geological Survey (USGS) streamflow gages in the watersheds. USGS streamflow gage 08109700 is located at SWQM station 11840 in Middle Yegua Creek. Instantaneous streamflow information is available at this station dating back to August 1962. A second streamflow gage (08110100) is located at SWQM station 18349 in the lower portion of the Davidson Creek watershed. This gage has instantaneous streamflow records dating back to October 1962. Instantaneous streamflow data for each gage was used to calculate the monthly aggregated streamflow from January 2009 through December 2021 (Figure 44, Figure 45).

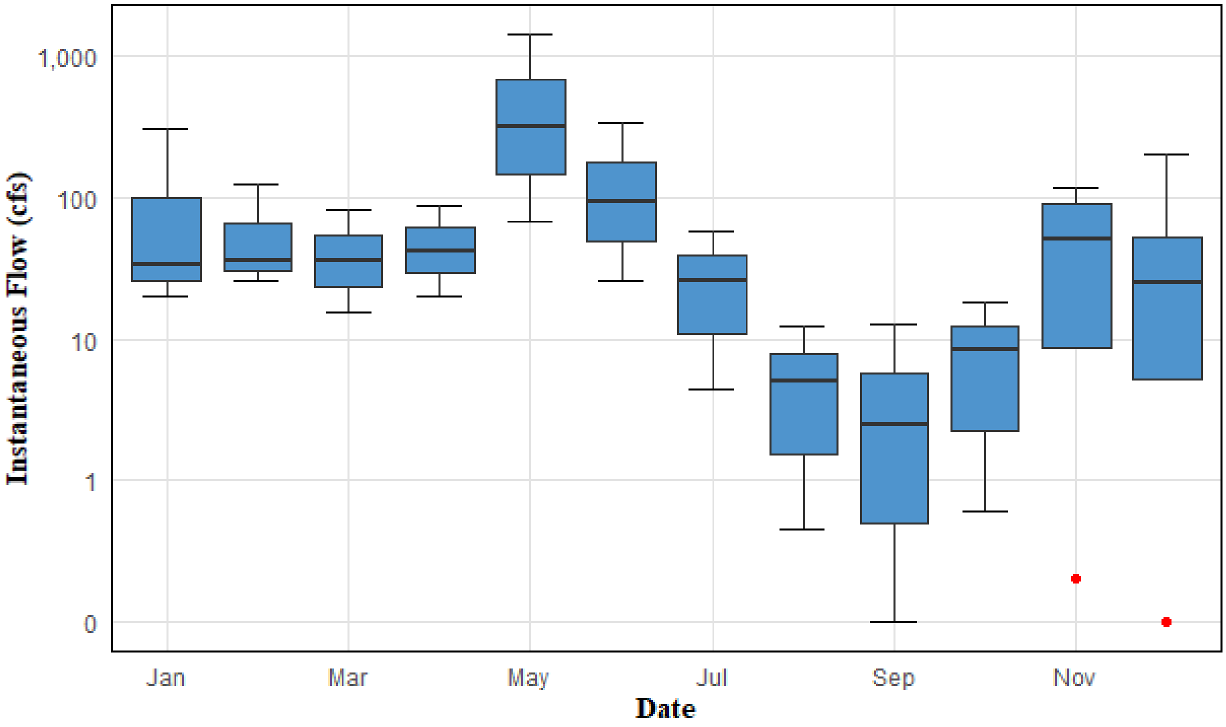

Figure 44. Aggregated monthly streamflow for Middle Yegua Creek from January 2009 through December 2021.

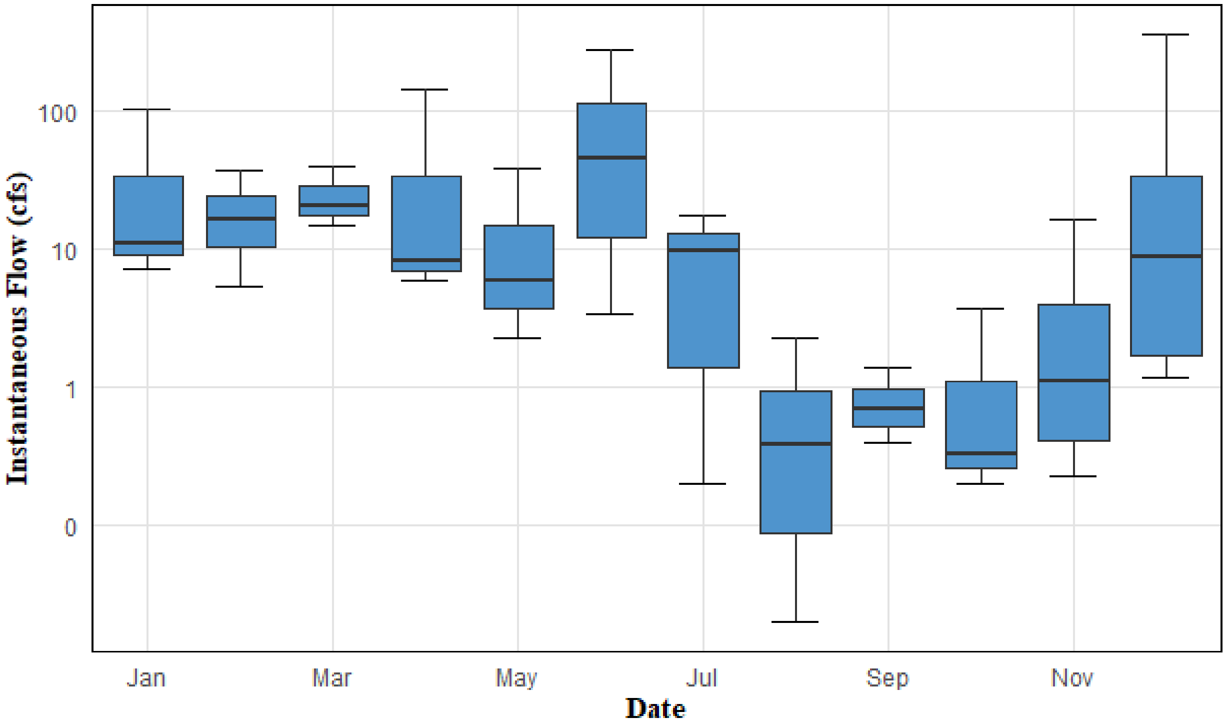

Figure 45. Aggregated monthly streamflow for Davidson Creek from January 2009 through December 2021.

Hydrologic data in the form of daily streamflow records were unavailable in the Deer Creek watershed. However, streamflow records are available in a nearby watershed (Middle Bosque River) with similar characteristics (Figure 46). There is one USGS streamflow gage in the Middle Bosque River watershed (08095300) which has instantaneous streamflow records dating back to October 2007. This gage was used to develop mean daily streamflow for Deer Creek AU 1242J_01 from January 2009 through December 2021 using the Drainage-Area Ratio Method (DAR) described in the Pollutant Source Assessment section of this document (Figure 47).

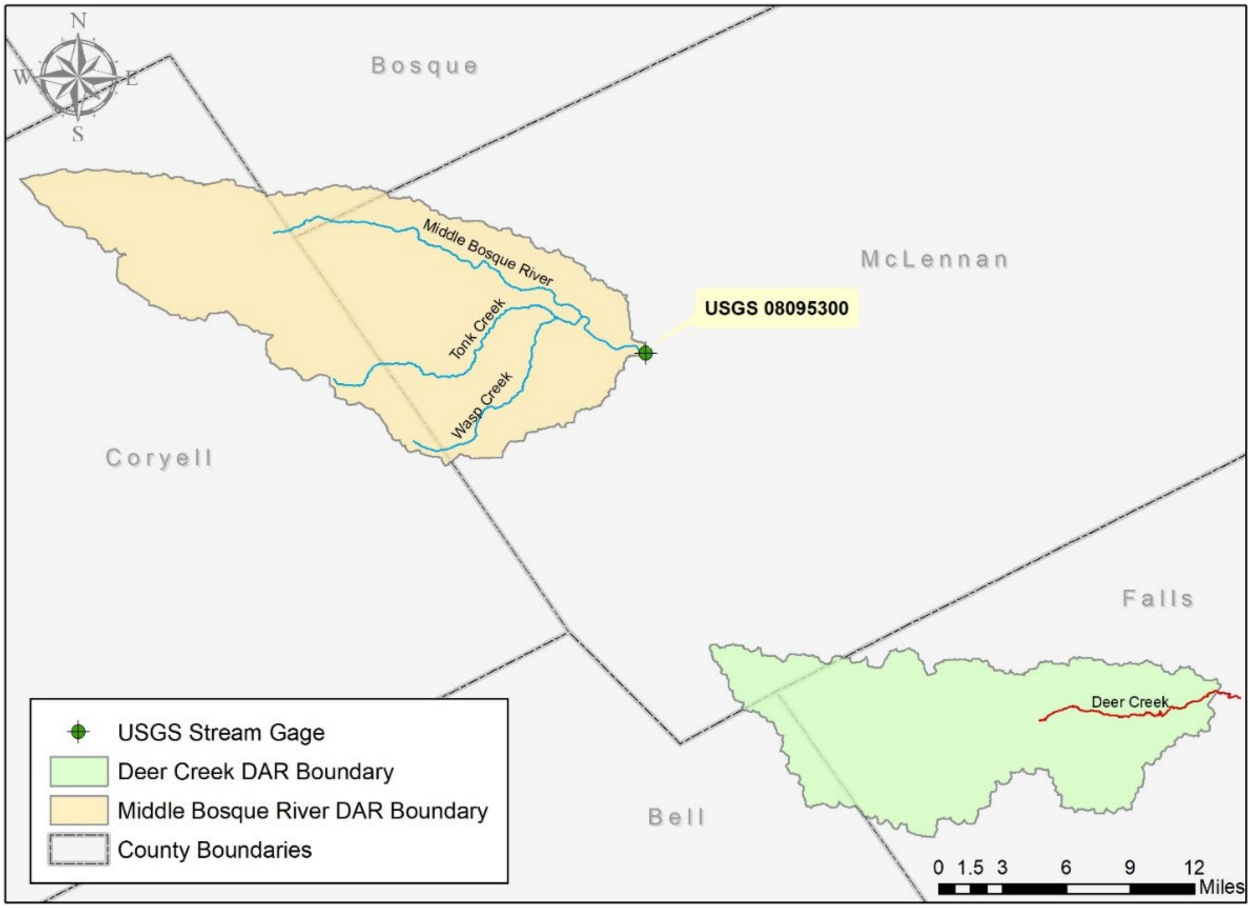

Figure 46. U.S. Geological Survey (USGS) streamflow gage and watershed used in streamflow development for Deer Creek.

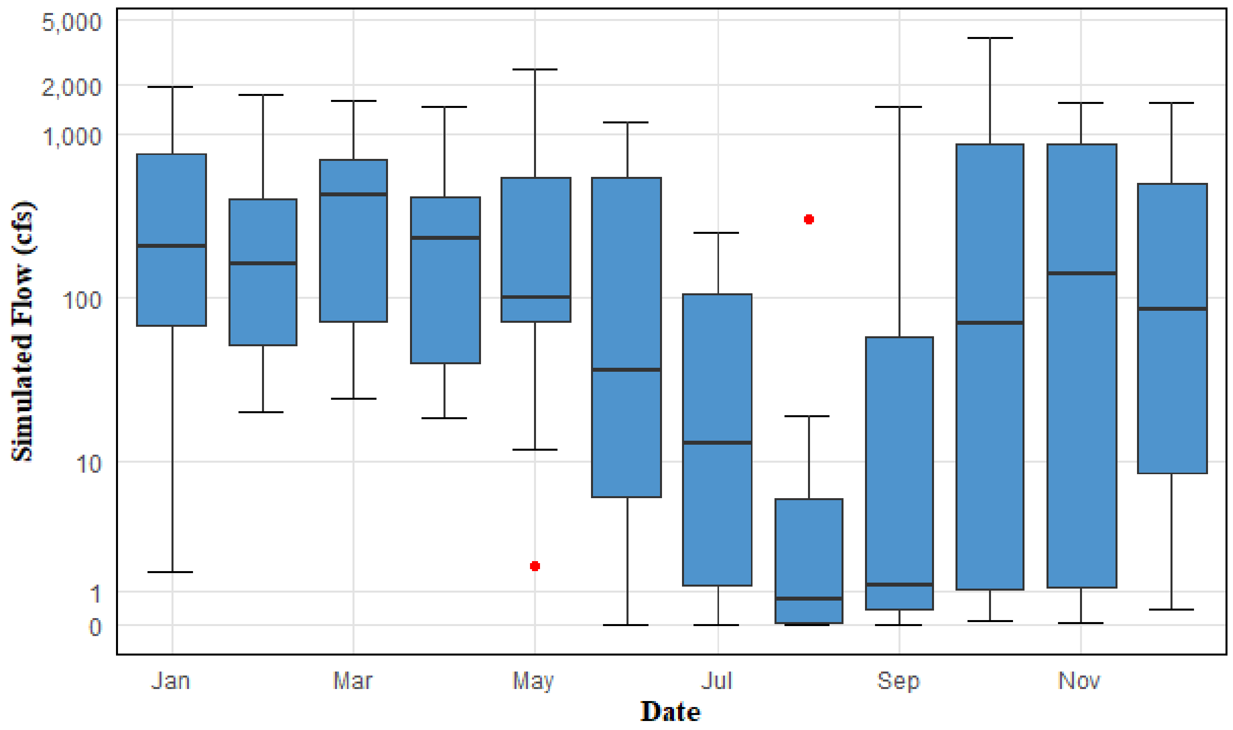

Figure 47. Aggregated monthly streamflow for Deer Creek from January 2009 through December 2021.

Potential Sources of Water Quality Issues

Domestic Livestock

Domestic livestock farms, particularly cattle, are common throughout the rural watersheds. Runoff from rain events can transport fecal matter 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 to the water. Streamside riparian buffers, fencing, and grazing practices that reduce the time livestock spend near streams can reduce livestock impacts on water quality.

Because watershed-level livestock numbers are not available, populations were estimated using the USDA National Agricultural Statistics Services' (NASS) and USGS NLCD datasets. Specifically, the horse, goat, sheep, poultry, and pig/hog populations for each county was obtained using the USDA NASS 2017 dataset. The county-level data were multiplied by a ratio based on the acres of grazeable land, identified with USGS NLCD data, divided by the total number of acres in the county. Then the proportion of grazeable acres in the watersheds within each county was used to estimate the number of livestock from each county that occur in the watersheds (Table 14). Grazeable land for cattle is defined as aggregate of pasture/hay, shrub/scrub, forest, and herbaceous LULC classifications. A stocking rate of 10 acres/animal unit was used for the forest, shrub/scrub, and herbaceous land uses to determine the number of cattle in each watershed. A stocking rate of 3 acres/animal unit was used for the hay/pastureland use.

Table 14. Estimated grazing livestock populations in the watersheds.

Segment	Water body	Cattle	Horses	Goats/sheep	Pigs/hogs	Poultry
1212A	Middle Yegua Creek	53,745	1,149	2,072	663	30,336
1211A	Davidson Creek	27,524	456	709	251	46,804
1242J	Deer Creek	6,854	247	683	37	623

Wildlife and Feral Hogs

Bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. Wildlife are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. While several bird and mammal species are likely to contribute bacteria loads in area waterways, feral hogs and white-tailed deer are the only species with reasonable density and population estimates for significant bacteria load contribution.

A common estimate frequently used in the state of Texas is a density of one hog per 33.3 acres (Wagner and Moench 2009). Appropriate LULC classes for feral hogs in the watersheds include forest, wetland, shrub/scrub, herbaceous, pasture/hay, and cultivated crops. White-tailed deer estimates for the watersheds are not available, therefore estimates from the Texas Parks and Wildlife (TPWD) resource management unit (RMU) 19 for Middle Yegua Creek and Davidson Creek watersheds and RMU cross timbers and prairies for Deer Creek were utilized. The estimated deer population for RMU 19 from 2005 to 2015 is 41.7 acres per deer, and the estimated deer population for RMU CTP from 2005 to 2015 is approximately 26.7 acres per deer. The estimates for feral hogs and white-tailed deer for each watershed can be found in Table 15.

Table 15. Estimated feral hog and white-tailed deer populations in the watersheds.

Segment	Water body	Feral hogs	Deer
1212A	Middle Yegua Creek	8,008	6,403
1211A	Davidson Creek	3,901	3,119
1242J	Deer Creek	2,071	2,584

Domestic 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 Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds, pets often spend most 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 per home across the United States (AVMA 2018). The estimated number of domestic pets in the watersheds can be calculated by multiplying these ratios with the number of households in each watershed (Table 16).

Table 16. Estimated dog and cat populations in the watersheds.

Segment	Water body	Estimated number of households	Estimated number of dogs	Estimated number of cats
1212A	Middle Yegua Creek	3,675	2,256	1,679
1211A	Davidson Creek	3,965	2,435	1,812
1242J	Deer Creek	1,633	1,003	746

OSSFs

Given the rural nature of the watersheds, many homes are not connected to centralized sewage treatment facilities and therefore use OSSFs. Typical OSSF designs include either (a) anaerobic systems composed of septic tank(s) and an associated drainage or distribution field or (b) aerobic systems with aerated holding tanks and typically an above ground sprinkler system to distribute the effluent. Failing or undersized OSSFs will contribute direct bacteria loads as the effluent from the systems move through or over the ground into adjacent water bodies.

Based on visually validated county 911 data and areas of existing wastewater service, estimations of the number of OSSFs that may occur in each watershed were determined (Table 17). Given the extensive occurrence of "Very Limited" soils for OSSF use (Figure 11, Figure 12, Figure 13), the vast majority of these systems occur in areas with expected failure rates of at least 15% (Reed, Stowe, & Yanke 2001). Figure 48 through Figure 50 depict expected distributions of all OSSFs in the watersheds but do not identify failing OSSFs.

Although most well-maintained OSSFs are likely to function properly, failing OSSFs can leak or discharge untreated waste onto distribution fields. Runoff generated during storm events can transport this waste overland and into nearby water bodies. Untreated OSSF effluent can contribute to levels of indicator bacteria, DO, nutrients, and other water quality parameters.

Table 17. Number of estimated on-site sewage facilities (OSSFs) in the watersheds.

Segment	Water body	Estimated OSSFs
1212A	Middle Yegua Creek	3,953
1211A	Davidson Creek	2,408
1242J	Deer Creek	1,685

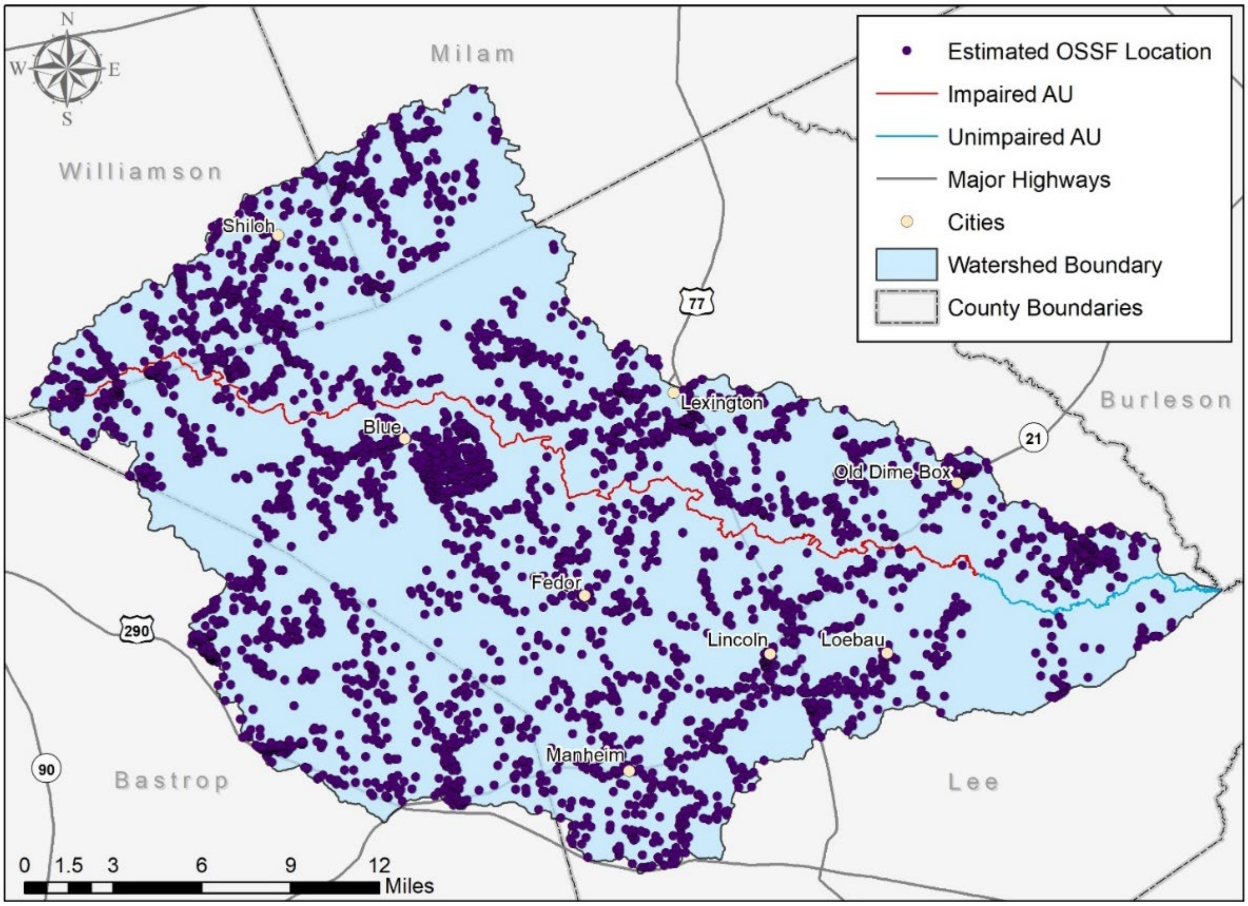

Figure 48. Estimated on-site sewage facility (OSSF) locations in the Middle Yegua Creek watershed with assessment units (AUs).

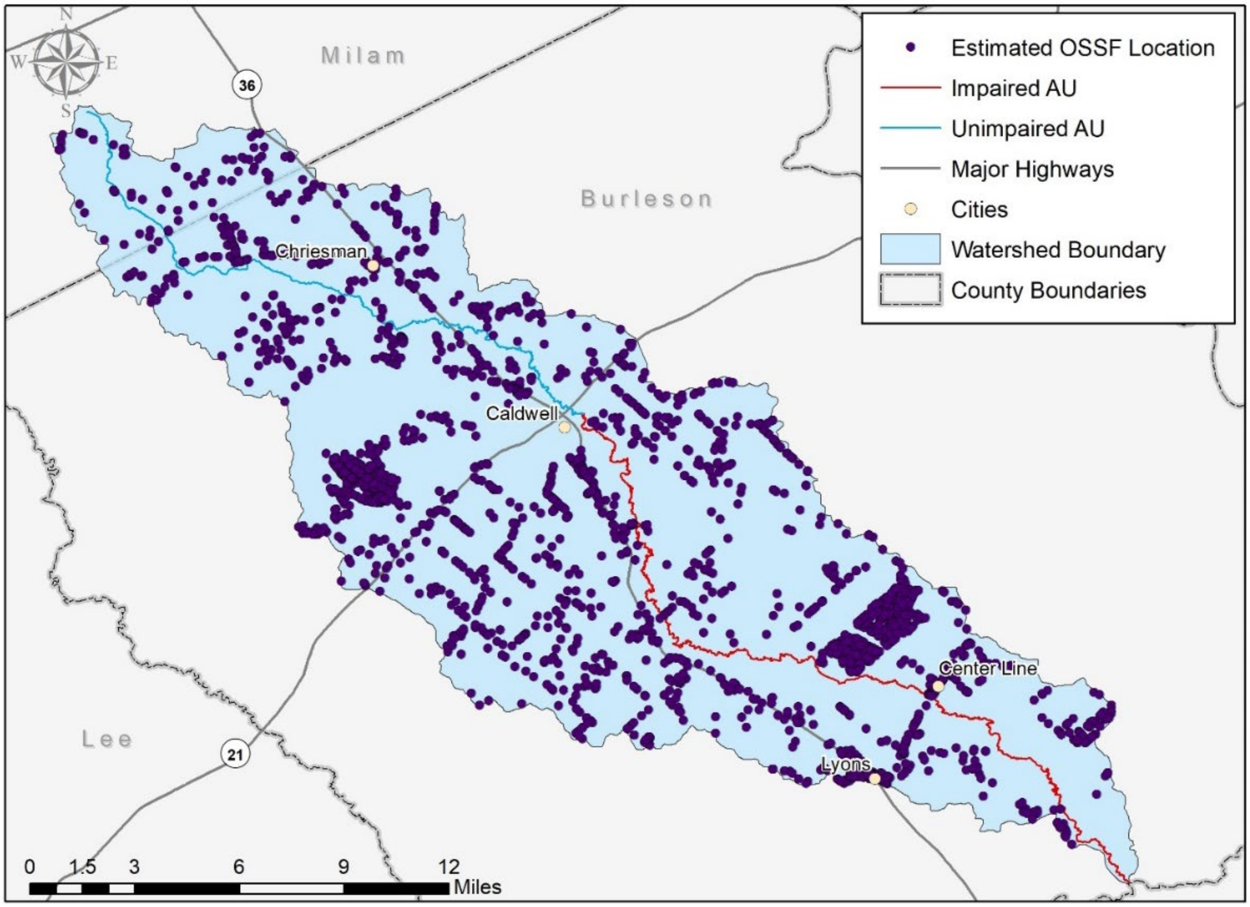

Figure 49. Estimated on-site sewage facility (OSSF) locations in the Davidson Creek watershed with assessment units (AUs).

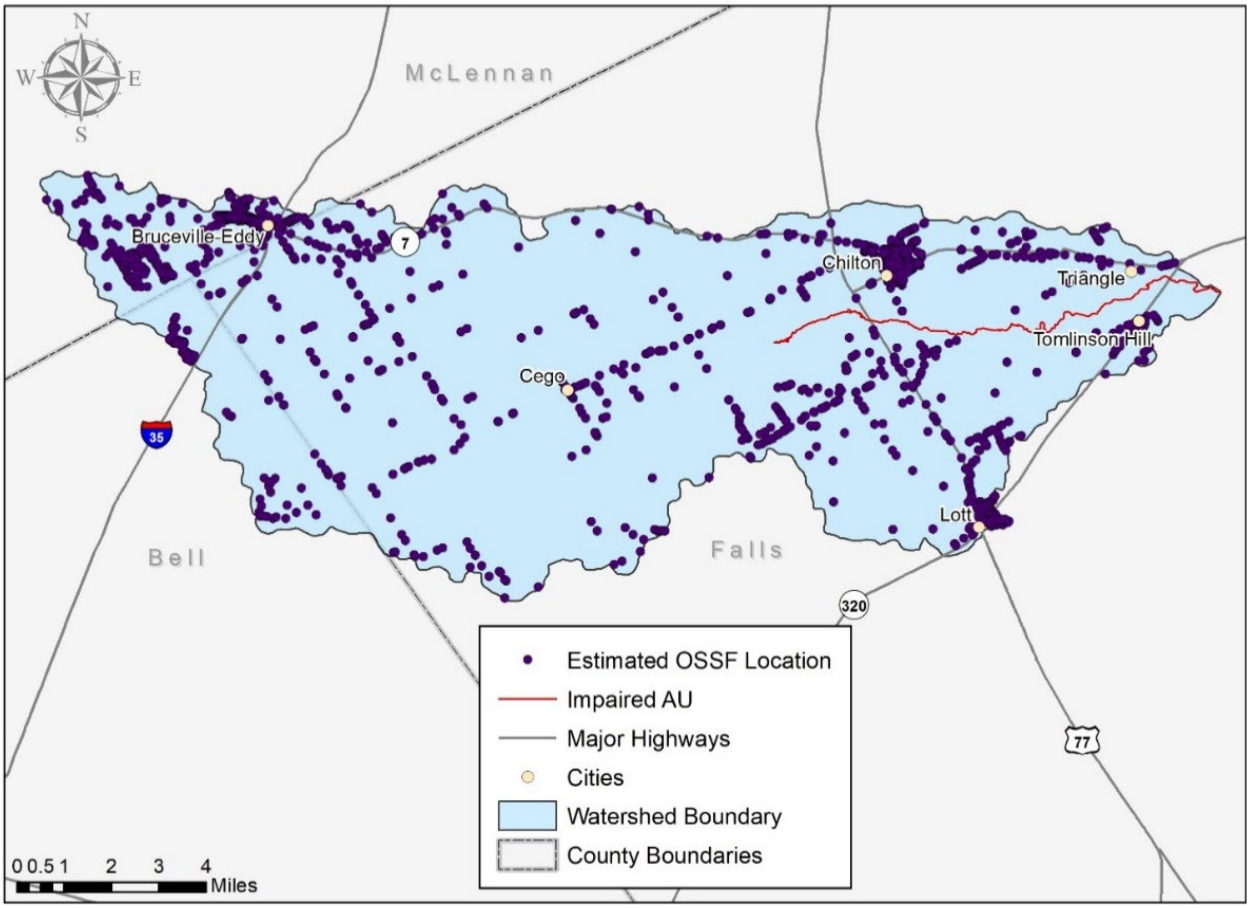

Figure 50. Estimated on-site sewage facility (OSSF) locations in the Deer Creek watershed with assessment units (AUs).

Permitted Discharges

Permitted discharges are sources regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollutant Discharge Elimination System (NPDES) programs. Examples of permitted discharges include WWTF discharges, industrial or construction site stormwater discharges, and discharges from municipal separate storm sewer systems (MS4) of regulated cities or agencies. WWTFs treat municipal wastewater before discharging the treated effluent into a water body. WWTFs are required to test and report the levels of indicator bacteria and nutrients as a condition of their discharge permit. Plants that exceed their permitted levels may require infrastructure or process improvements to meet the permitted discharge requirements.

As of January 2021, five facilities in the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds treat domestic wastewater; one is in the Middle Yegua watershed, two are in the Davidson Creek watershed, and two are in the Deer Creek watershed (Table 18; Figure 51, Figure 52, Figure 53). The city of Caldwell WWTF discharges directly into the impaired Davidson Creek segment, and the Chilton Water Supply and Sewer Service WWTF discharges directly into the impaired Deer Creek segment. Discharge for all five facilities is measured in millions of gallons per day (MGD). All the WWTFs, except the Burleson County WWTF, had a history of non-compliance issues during the 12-quarter period (3 years) from October 1, 2018 through September 30, 2021 (EPA 2021). During this period, the two facilities reported exceedances in bacteria concentration discharge limits, the city of Lexington WWTF and the Chilton Water Supply and Sewer Service WWTF. None of the bacteria effluent violations were reported as "significant" non-compliance effluent violations. Compliance status is based on the period of record available through the EPA's Enforcement and Compliance History online (ECHO) database, which shows history of facility compliance with NPDES and TPDES permit requirements.

Table 18. Permitted wastewater facilities in the watersheds.

Facility Name (TPDES Permit No.)	**Receiving Stream**	**Flow (MGD)**		**Bacteria (MPN/100 mL)**		**Number of Quarters in Violation for Exceedance from 10/2018–9/2021**
		Final Permitted	**Reported (3-year average)**	**Permitted (Daily Average)**	**Reported (3-year average)**	
City of Lexington wastewater treatment facility (WWTF; WQ0010016-001)	Shaw Branch to Middle Yegua Creek (1212A)	0.200	0.0859	126[1]	389	**10** (3 DO monthly min., 9 BOD daily avg., 1 BOD single grab, 9 pH max., 1 pH min., 1 TSS daily avg., 9 *E. coli* daily avg., 10 *E. coli* single grab)
City of Caldwell WWTF (WQ0015306-001)	Davidson Creek (1211A)	0.711	0.386	126[1]	4.69	**7** (1 Ammonia daily avg., 1 Ammonia daily max., 7 BOD daily avg., 2 BOD daily max)
Burleson County WWTF (WQ0010813-002)	Berry Creek to Davidson Creek (1211A)	0.300	N/A[2]	126[1]	N/A[2]	**0**
Chilton Water Supply and Sewer Service WWTF (WQ0010811-001)	Deer Creek (1242J)	0.105	0.042	126[1]	11.7	**3** (1 TSS daily avg., 1 Ammonia daily avg., 1 *E. coli* daily avg.)
City of Lott WWTF (WQ0010017-001)	Bone Branch to Deer Creek (1242J)	0.080	0.050	126[1]	16	**6** (2 DO monthly min., 3 BOD daily avg., 1 pH max., 2 pH min., 3 Flow daily avg., 1 chlorine monthly min.)

[1] MPN/100 mL *E. coli*

[2] Data not available

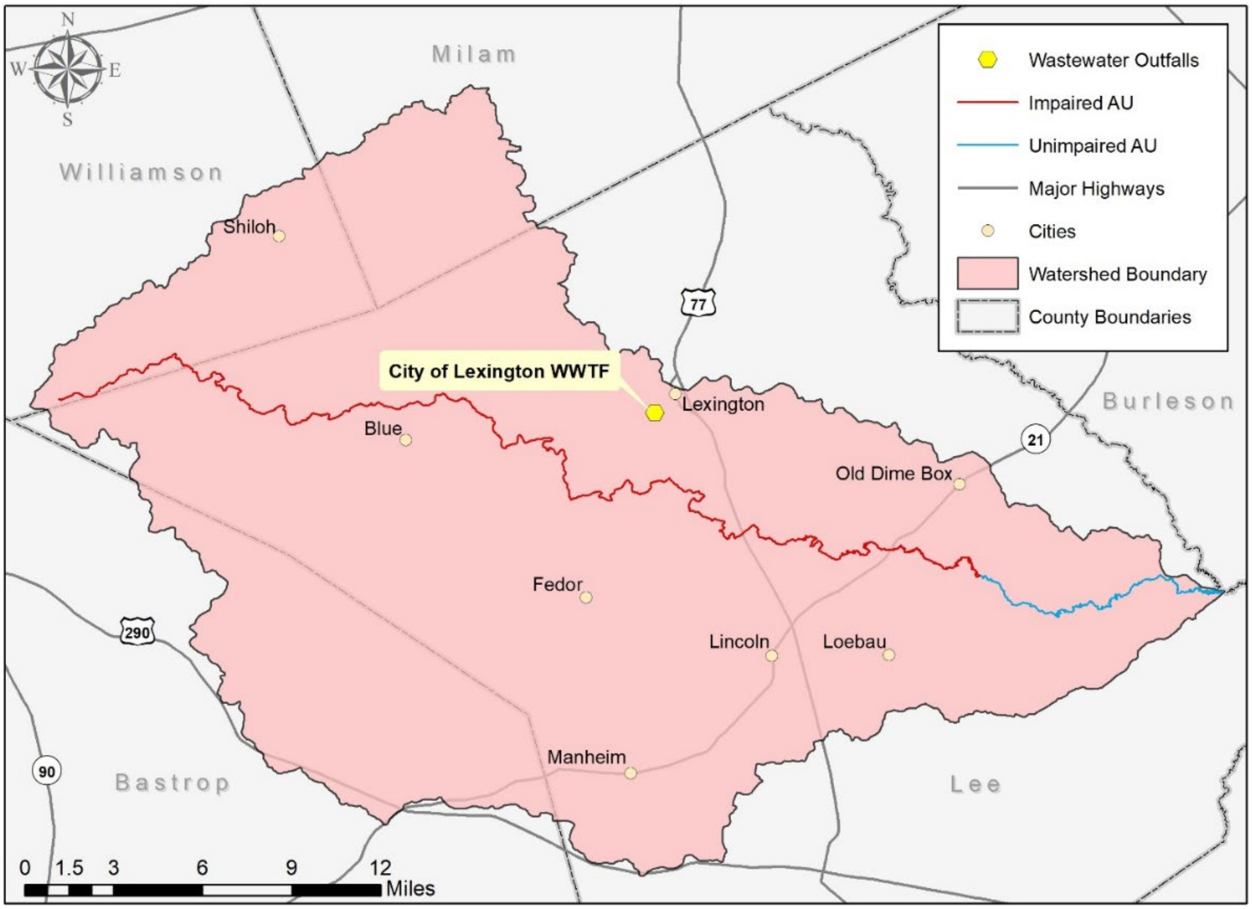

Figure 51. Active permitted wastewater discharge outfall locations for the Middle Yegua Creek watershed with assessment units (AUs).

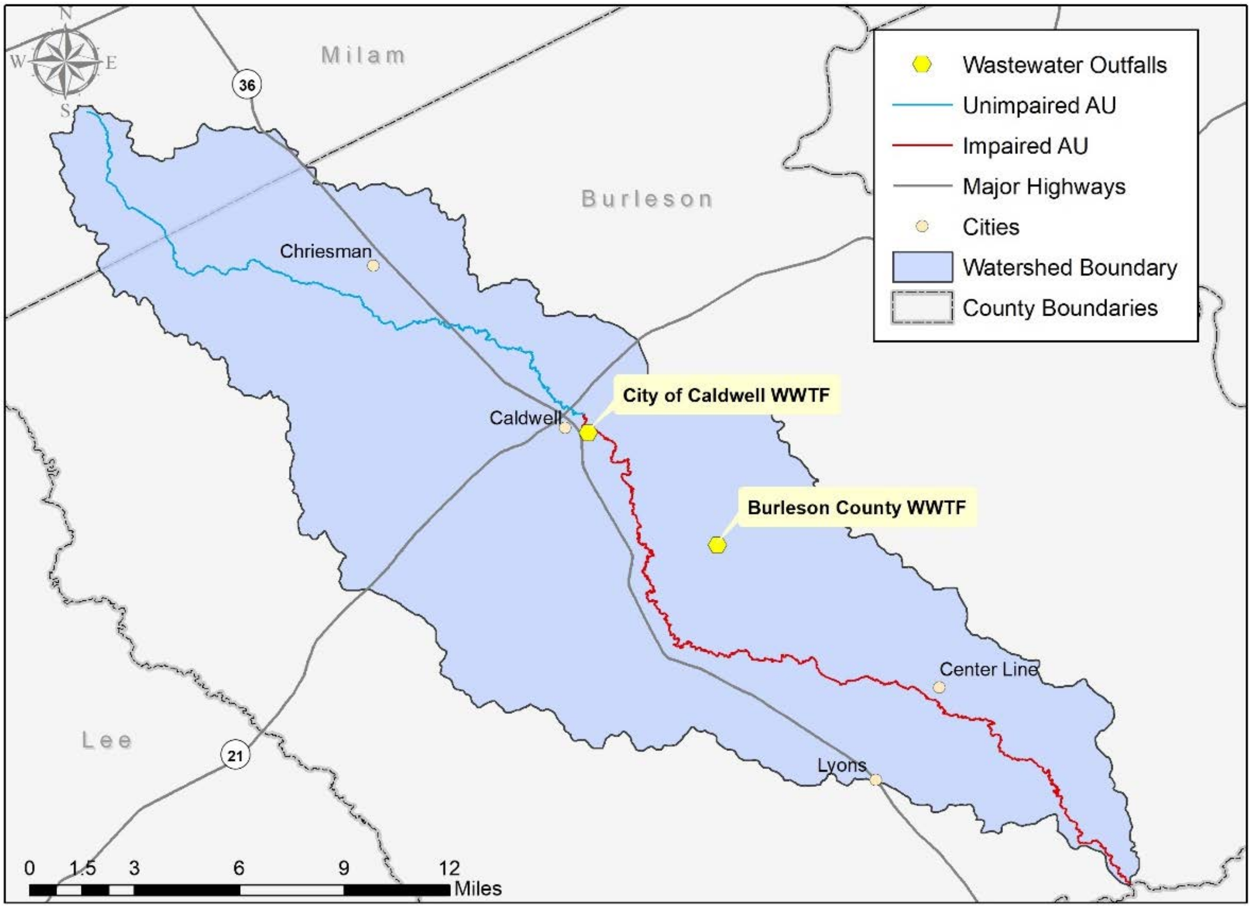

Figure 52. Active permitted wastewater discharge outfall locations for the Davidson Creek watershed with assessment units (AUs).

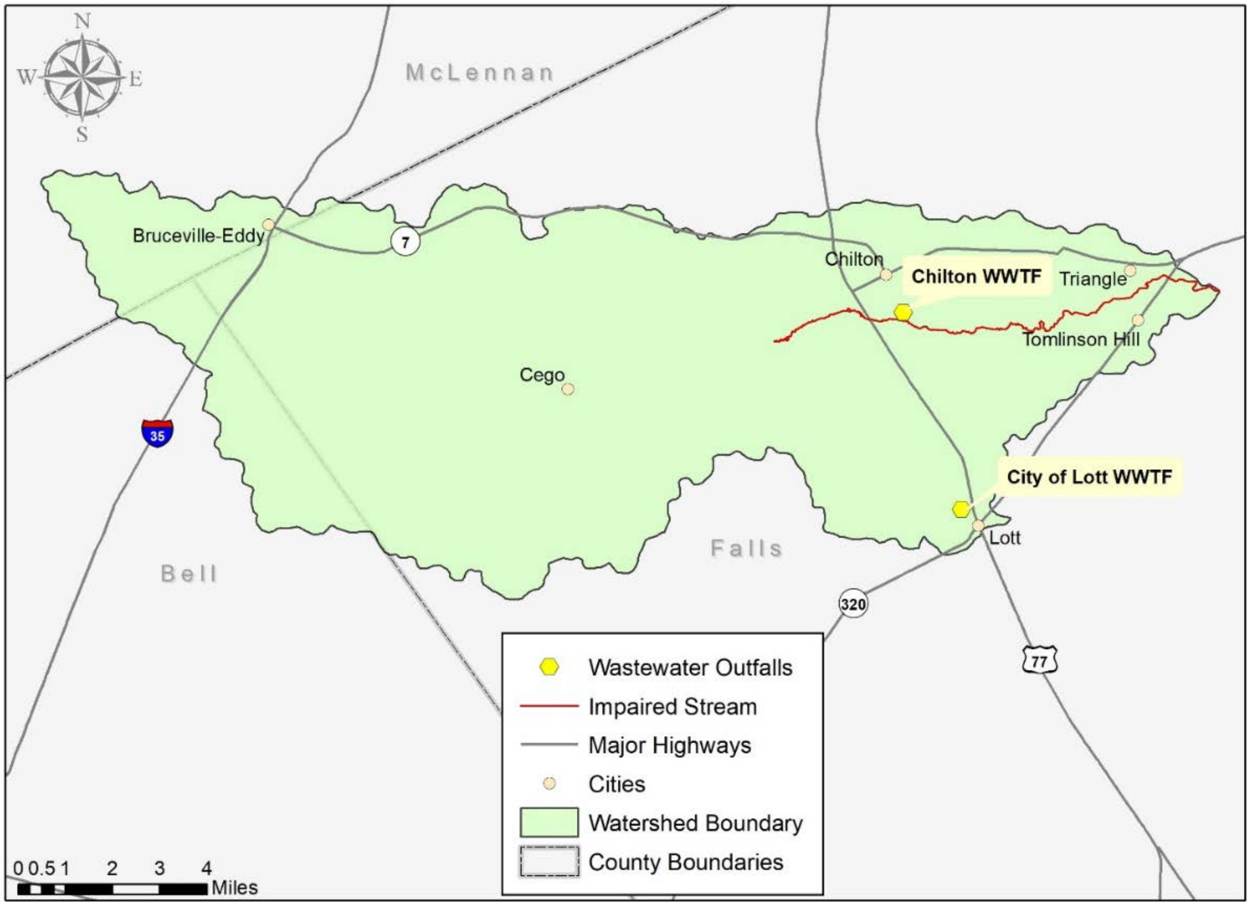

Figure 53. Active permitted wastewater discharge outfall locations for the Deer Creek watershed with assessment units (AUs).

Although stormwater is generally considered a nonpoint source (NPS), stormwater is subject to regulation if it originates from a regulated MS4 or is associated with industrial and/or construction activities. MS4 permits refer to the permitting of municipal stormwater systems that are separate from sanitary sewer systems. Systems are broken down into “large” phase I and “small” phase II permits based on population. Further details on MS4 permitting requirements are available from TCEQ: www.tceq.texas.gov/permitting/stormwater/ms4. TPDES general permits cover stormwater discharges from phase II urbanized areas, industrial facilities, and construction sites over 1 acre. These urban and industrial stormwater sources may contain elevated levels of bacteria or nutrients as they wash accumulated materials from roads, parking lots, buildings, parks, and other developed areas. Potential pollutants can be managed from these sites through stormwater best management practices, including structures such as detention ponds, riparian buffers, pervious pavement, and low impact design.

A review of active stormwater general permits coverage in the Middle Yegua Creek watershed, as of January 2022, found one active industrial facility, one active construction site, and one active concrete production facility. A review of the active stormwater general permits coverage in the

Davidson Creek watershed, as of January 2022, found four active industrial facilities, four active construction sites, and one active concrete production facility. A review of the active stormwater general permits coverage in the Deer Creek watershed, as of January 2022, found no active construction sites, industrial facilities, or concrete production facilities. There are no MS4s or petroleum bulk stations and terminals facilities in any of the watersheds. Based on the 2019 NLCD, only 20 square miles out of the 440 square mile Middle Yegua Creek watershed, 14 square miles out of the 218 square mile Davidson Creek watershed, and 7 square miles out of the 115 square mile Deer Creek watershed are urbanized or developed. Therefore, contributions to surface water impairments from regulated stormwater and urbanized development are assumed to be small based on the relatively low amount of stormwater permits and developed land.

Unauthorized Discharges

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 caused by tree roots, grease, and other debris. 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. Other causes, such as a collapsed sewer line, may occur under any condition. The TCEQ Region 9 and 11 offices maintain 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 watersheds of Middle Yegua Creek, Davidson Creek, and Deer Creek between January 2015 and December 2021 are shown in Table 19. Two separate incidences were reported for two different facilities. The reported data indicate that the SSOs occurred year-round and that both durations were unknown. Overflow volumes for both incidences were 1 gallon.

Table 19. Sanitary sewer overflow events since 2015 for the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds.

Facility	Date	Gallons	Cause
City of Caldwell wastewater treatment facility (WWTF)	03/09/2015	1	Unknown
City of Lexington WWTF	05/15/2015	1	Inflow and infiltration

Water Quality Summary

The Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds are predominantly rural, characterized by vital agricultural communities. Therefore, significant portions of the watersheds have been utilized for cropland, pasture, or grazing. The population of the watersheds are projected to increase by small proportions over the next 50 years.

The primary water quality concern is bacteria impairments in the watersheds. Potential contributors to the bacteria impairments likely include some combination of managed livestock/cattle; unmanaged wildlife/feral hogs; failing OSSFs; stormwater runoff from urban areas and impervious surfaces (including contributions from household pets); and permitted discharges and SSOs (Table 20).

Table 20. Summary of potential bacteria sources contributing to the impairments in the watersheds.

Pollutant source	**Pollutant type**	**Potential cause**	**Potential impact**
Livestock	Bacteria	- Runoff from pastures - Overgrazing - Manure transport to streams - Direct deposition into streams	Fecal material and bacteria directly deposited into stream or through runoff
Wildlife	Bacteria	- Manure transport to streams - Direct deposition into streams - Riparian degradation	Fecal material and bacteria directly deposited into stream or through runoff
On-site sewage facilities	Bacteria	- System failure - Improper design	Insufficiently or untreated water runoff to streams
Urban stormwater and domestic pets	Bacteria	- Increased runoff from impervious surface - Improper disposal of pet waste	Increased velocity and volume of stormwater quickly transport bacteria laden water to streams
Permitted dischargers/sanitary sewer overflows	Bacteria	- Inflow and infiltration - Overloaded or aging infrastructure	Untreated waste enters water body

Pollutant Source Assessment

Introduction

Water quality sampling, described in the previous section, established that the primary water quality concern in the Middle Yegua Creek, Davidson Creek, and Deer Creek watersheds is excessive fecal indicator bacteria. The current water quality standard established by TCEQ for primary contact recreation is 126 MPN/100 mL for *E. coli*. The *2014 Texas Integrated Report* (TCEQ 2015a) lists Davidson Creek as impaired with a geometric mean of 2,212 MPN/100 mL *E. coli*. The *2020 Texas Integrated Report* (TCEQ 2020) lists Middle Yegua Creek as impaired with a geometric mean of 890 MPN/100 mL *E. coli* and Deer Creek as impaired with a geometric mean of 373.55 MPN/100 mL *E. coli*. The *2020 Texas Integrated Report* did not have an *E. coli* geometric mean listed for Davidson Creek, but it is still on the 303(d) list.

To calculate the reductions needed to meet primary contact recreation standards, the bacteria load capacity of Middle Yegua Creek, Davidson Creek, and Deer Creek was calculated. The current bacterial load for all three creeks were also calculated using water quality samples and the load duration curve (LDC) method. By taking the difference between the load capacity and the current load, this characterization estimates the needed reductions to meet water quality standards.

Furthermore, this section estimates the relative load contributions from different potential fecal bacteria sources. A geographic information systems (GIS) analysis, which includes the best available data, provided relative load contribution estimates. By estimating the relative potential contribution of different fecal bacteria sources across the watersheds, areas can be prioritized as to when and where future potential management measures should occur.

Source and Load Determination

Load Duration Curves

LDCs are 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 Middle Yegua Creek and Davidson Creek came from daily streamflow records at USGS gages within the watersheds. The gage used for the Middle Yegua Creek FDC was USGS stream gage 08109700, and the gage used for the Davidson Creek watershed was USGS stream gage 08110100. As previously mentioned, there was no USGS stream gage in the Deer Creek watershed. An alternative method to developing the FDC for this watershed is explained further in this section.

An FDC is a summary of the hydrology of the stream, indicating the percentage of time that a given flow is 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. Exceedance values along the x-axis represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100% occur during low flow or drought conditions, while values approaching 0% occur during periods of high flow or flood conditions.

The red lines on the following LDCs are the allowable load at the water quality criterion for *E. coli* (geometric mean of 126 MPN/100 mL). These lines were created by multiplying the stream flow for each gage in cubic feet per second by the geometric mean of 126 MPN/100 mL for *E. coli* and by a conversion factor (2.44658×10^7), which gives you a loading unit of MPN/day. The grey lines (allowable load at single sample criterion) were developed similarly to the red lines, except instead of multiplying streamflow by 126 MPN/100 mL, the streamflow was multiplied by 399 MPN/100 mL. The exceedance percentages, which are identical to the value for streamflow data points, were then plotted against the geometric mean criterion for *E. coli*. The resulting curves plot each bacteria load value (y-axis) against its exceedance value (x-axis). Exceedance values along the x-axis represent the percent of days that the bacteria load was at or above the allowable load on the y-axis.

For all LDCs, historical bacteria data were superimposed on the allowable bacteria LDCs. Each historical *E. coli* measurement was associated with the streamflow on the day of measurement and converted to a bacteria load. The associated streamflow for each bacteria loading was compared to the FDC data to determine its value for “percent days flow exceeded,” which becomes the “percent of days load exceeded” value for purposes of plotting the *E. coli* loading. Each load was then plotted on the LDCs at their percent exceedance. This process was repeated for each *E. coli* measurement. Points above the LDCs represent exceedances of the bacteria criterion and its associated allowable loadings.

The flow exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of the FDC and LDC. For this characterization, three flow regimes were identified. These three intervals along the x-axis of the LDCs are (1) 0%–25% (high flows), (2) 25%–75% (mid-range conditions), and (3) 75%–100% (lowest flows).

In total, eight LDCs were produced for the three watersheds for each station. For Middle Yegua Creek, one LDC included SWQM stations 18750 (Figure 54). This LDC indicates the *E. coli* loadings exceed allowable loads across all flow conditions. A second LDC was created for SWQM station 11840 in Middle Yegua Creek (Figure 55). This LDC indicates the *E. coli* loadings exceed allowable loads across all flow conditions except low flows. The third LDC for Middle Yegua Creek is for SWQM station 11838 (Figure 56). Although this AU is not currently impaired, a number of samples taken exceed the 126 MPN/100 mL criterion. The LDC also indicates that exceedances are occurring generally near or below the loading criteria at all flow conditions. The three LDCs developed for Davidson Creek SWQM stations 18349, 21420, and 11729 (Figures 57–59) all indicate loads exceeding capacity under all high and mid-range flow conditions. While elevated loadings under high flows are indicative of NPSs of indicator bacteria due to presumed greater amounts of runoff, exceedances during lower flow conditions are generally more indicative of point sources or direct fecal deposition to streams from wildlife or domestic livestock.

The final two LDCs were created for Deer Creek SWQM stations 11723 and 18644 (Figures 60-61). With no USGS stream gages in the Deer Creek watershed, the previously mentioned DAR method (Asquith et al. 2006) was used to create a simulated naturalized streamflow for the watershed over a 10-year period. This method is used to equate the ratio of streamflow of an unknown stream location to that of a nearby drainage area with sufficient data. This method was reviewed jointly by USGS and TCEQ using 7.8 million values of daily streamflow data from 712 USGS streamflow gages in Texas and was found to be a sufficient method in interpolating streamflow measurements. Further information regarding the DAR method used to develop the LDCs for the Deer Creek watershed can be found in Appendix A.

For the Deer Creek DAR, USGS gage 08095300 on the Middle Bosque River was chosen. The Middle Bosque River watershed was ideal, as it is near the Deer Creek watershed, and is comparable in size, land use and land cover. The dataset for the Middle Bosque River included daily streamflow records, dating back to January 2009. Most of the elevated loadings occurred during high and mid-range flow conditions, while lower flow conditions loadings were typically at or below the exceedance line. This is indicative of loadings associated with NPS pollution or from bacteria present within stream sediments that are resuspended under increased flow.

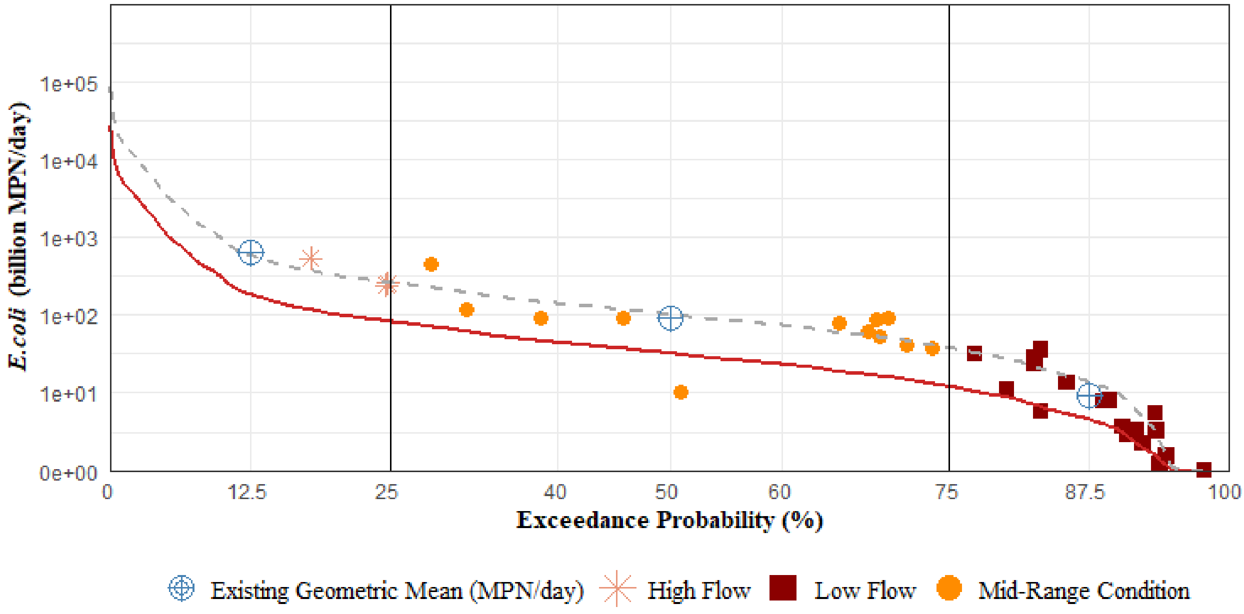

Figure 54. Load duration curve for Middle Yegua Creek surface water quality monitoring station 18750. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

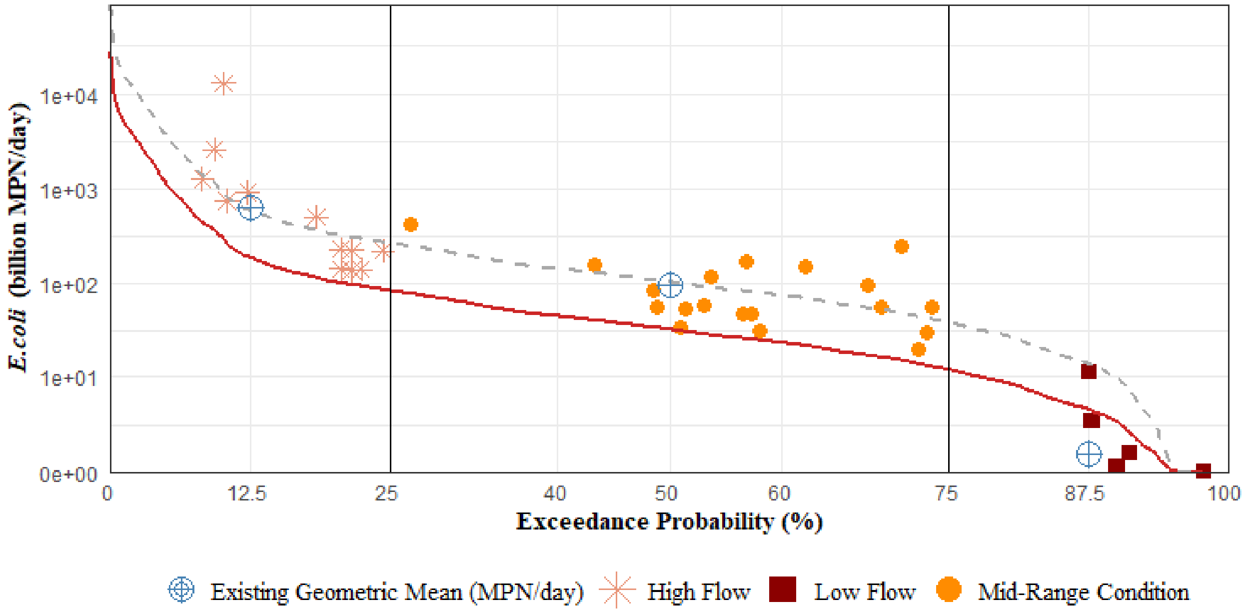

Figure 55. Load duration curve for Middle Yegua Creek surface water quality monitoring station 11840. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

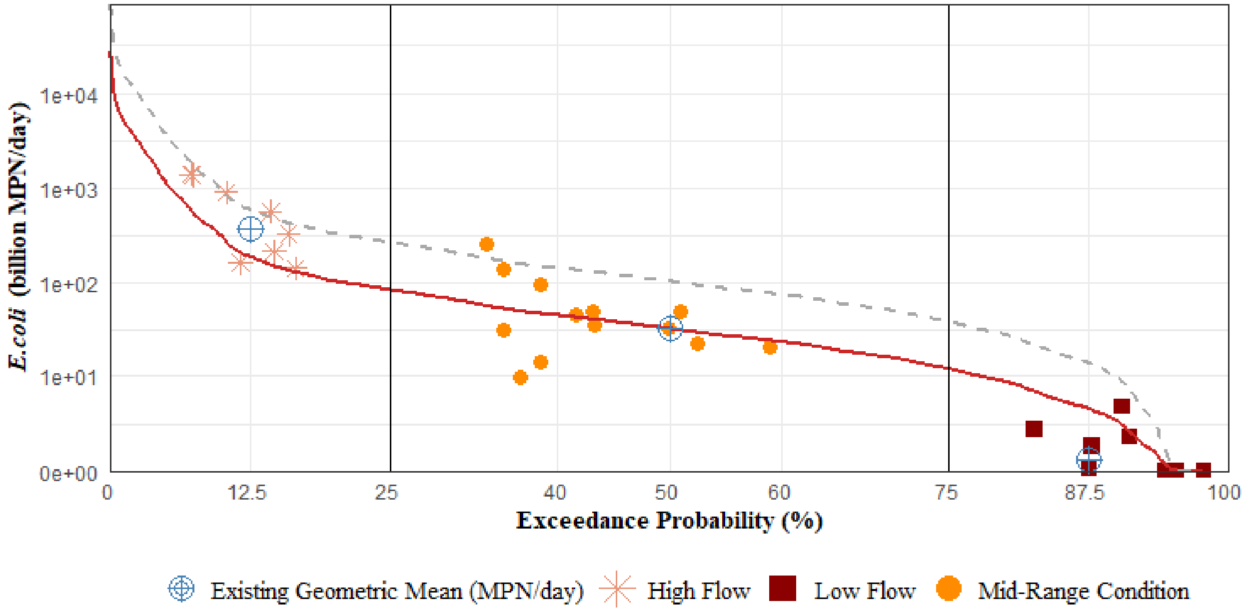

Figure 56. Load duration curve for Middle Yegua Creek surface water quality monitoring station 11838. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

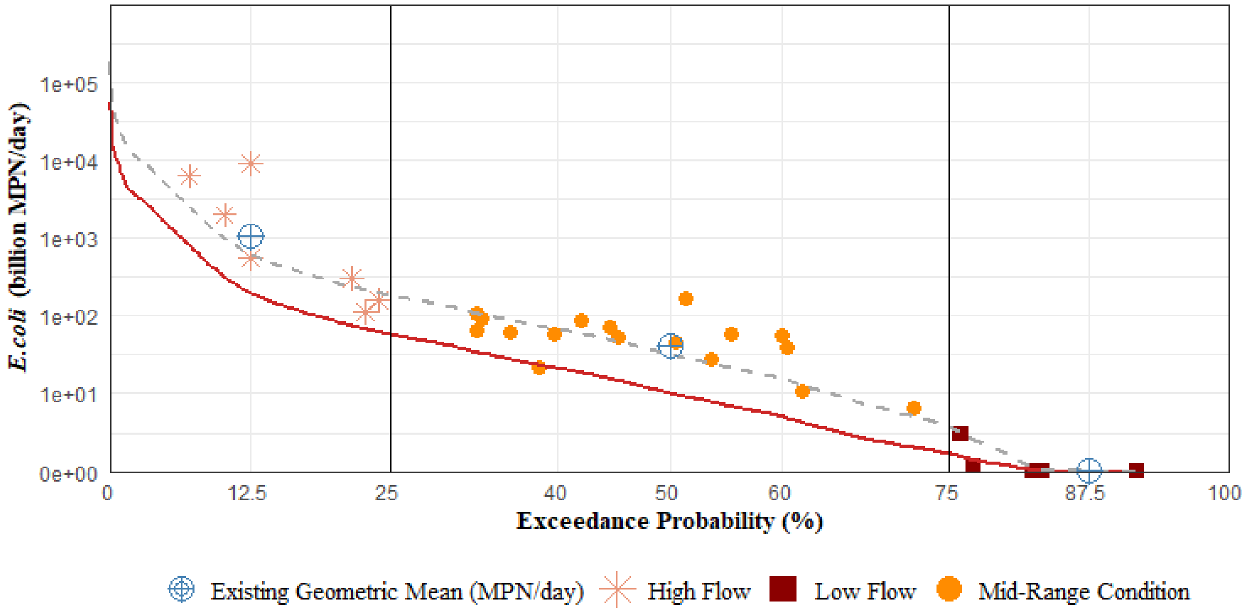

Figure 57. Load duration curve for Davidson Creek surface water quality monitoring station 18349. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

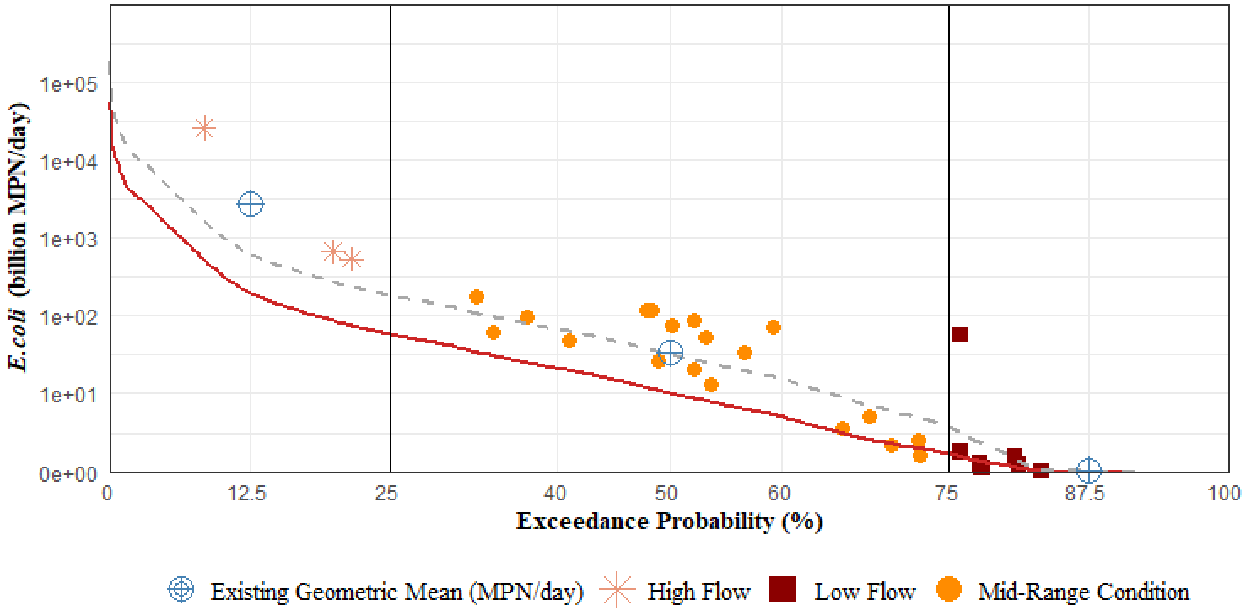

Figure 58. Load duration curve for Davidson Creek surface water quality monitoring station 21420. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

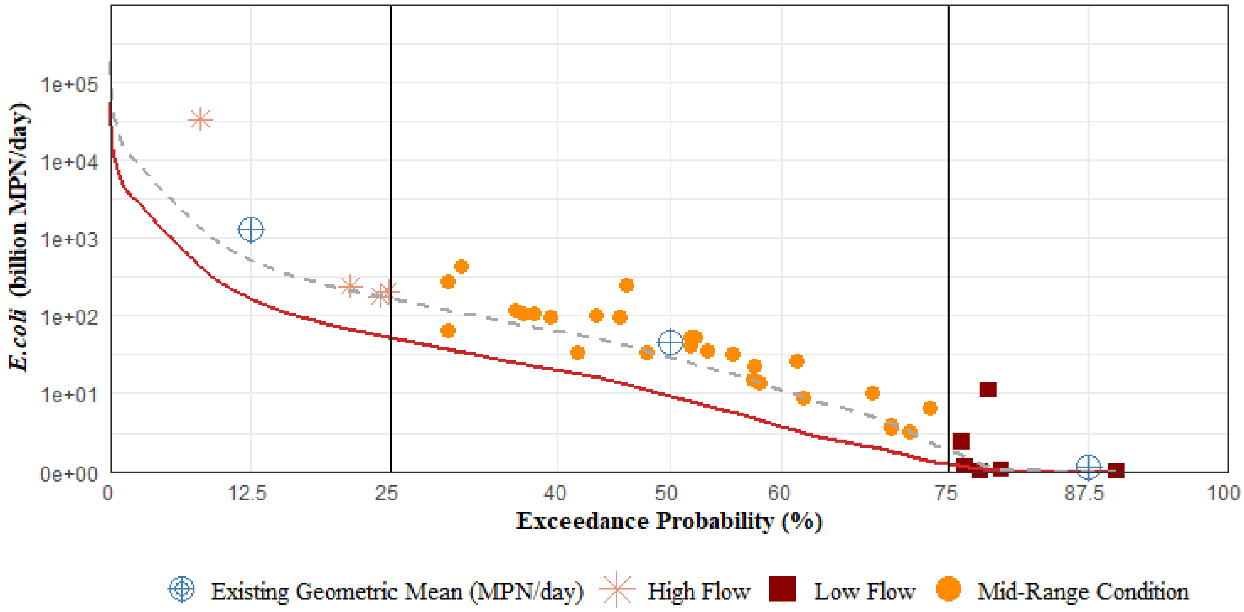

Figure 59. Load duration curve for Davidson Creek surface water quality monitoring station 11729. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

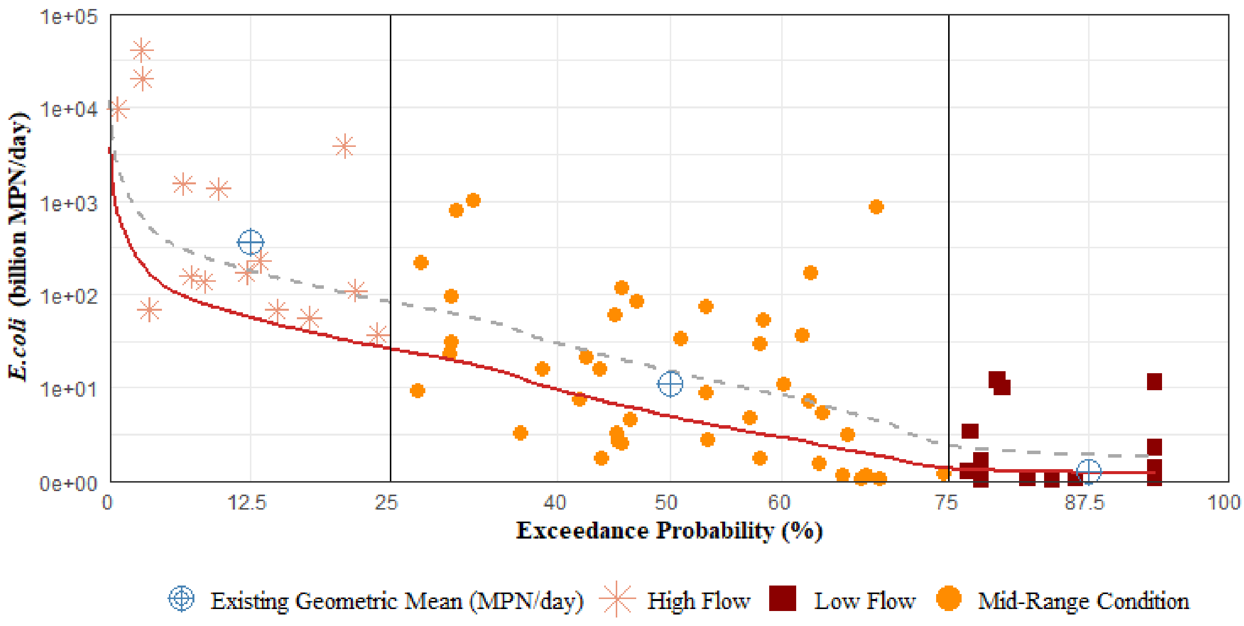

Figure 60. Load duration curve for Deer Creek surface water quality monitoring station 11723. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

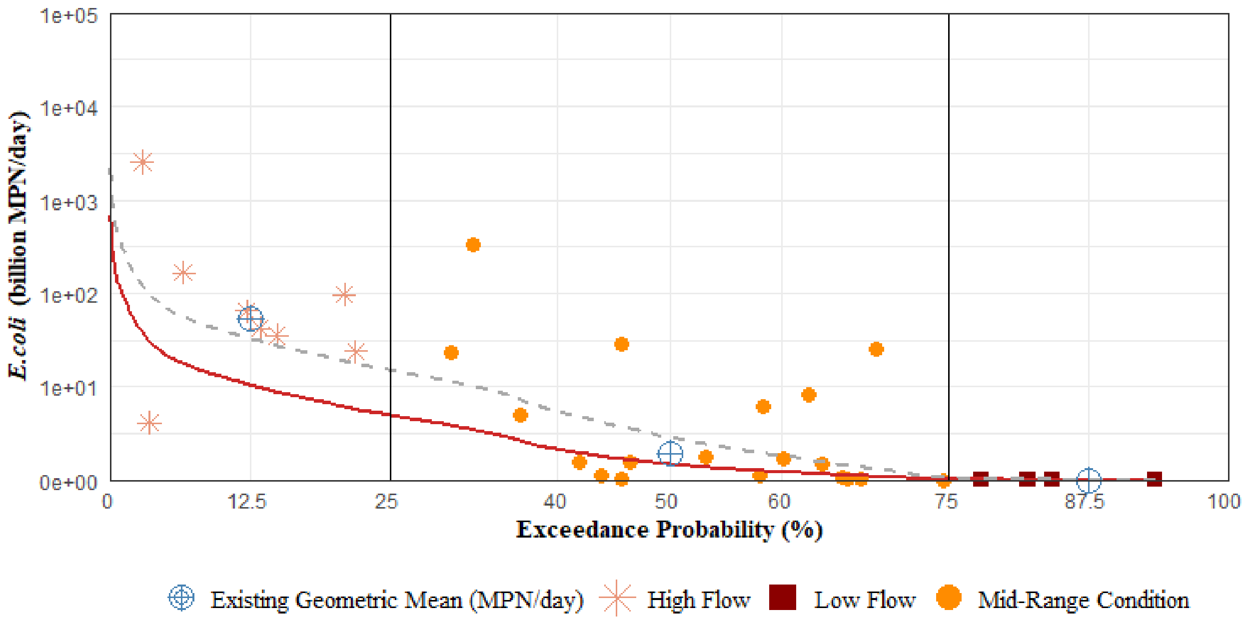

Figure 61. Load duration curve for Deer Creek surface water quality monitoring station 18644. The solid red line indicates the allowable load at geomean criterion (126 most probable number [MPN]/100 milliliters [mL]) and the gray dashed line is allowable load at single sample criterion (399 MPN/100 mL).

Based on the LDCs developed for Middle Yegua Creek, a total reduction of 5.27×10^{13} MPN/year (yr) is required at SWQM station 18750 (Table 21), 5.19×10^{13} MPN/yr at SWQM station 11840 (Table 22), and 1.63×10^{13} MPN/yr at SWQM station 11838 (Table 21) to reach primary contact recreation standards. Appendix B details the calculations used to develop the annual load reduction estimates.

A total reduction of 8.28×10^{13} MPN/yr is required at the Davidson Creek SWQM station 18349 (Table 23), 2.39×10^{14} MPN/yr at SWQM station 21420 (Table 22), and 1.08×10^{14} MPN/yr at SWQM station 11729 (Table 21) . The largest reductions are needed during higher flows where NPSs of bacteria are a primary concern.

For Deer Creek SWQM station 11723, a total reduction of 2.91×10^{13} MPN/yr is required (Table 24), and a total reduction of 4.14×10^{12} MPN/yr is required at SWQM station 18644 (Table 22). Similar to Middle Yegua Creek and Davidson Creek, the largest reduction is needed during the higher flows.

Table 21. Bacteria load reductions required to meet water quality goals in Middle Yegua Creek for surface water quality monitoring station 18750.

	Flow conditions		
	High	**Mid-range**	**Low**
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	60.03	10.45	1.41
Existing geomean concentration (most probable number [MPN]/100 milliliters)	435	357	267
Allowable daily load (billion MPN)	185	32.3	4.33
Allowable annual load (billion MPN)	16,866.59	5,887.98	395.25
Existing daily load (billion MPN)	639.54	91.44	9.17
Existing annual load (billion MPN)	58,357.94	16,687.20	837.08
Annual load reduction needed (billion MPN)	41,471.35	10,799.21	441.84
Percent reduction needed	71.06%	64.72%	52.78%
Total annual load (billion MPN)	75,882.22		
Total annual load reduction (billion MPN)	52,712.40		
Total percent reduction	69.47%		

Table 22. Bacteria load reductions required to meet water quality goals in Middle Yegua Creek for surface water quality monitoring station 11840.

	Flow conditions		
	High	Mid-range	Low
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	60.03	10.45	1.41
Existing geomean concentration (most probable number [MPN]/100 milliliters)	426	377	26
Allowable daily load (billion MPN)	185	32.3	4.33
Allowable annual load (billion MPN)	16,866.59	5,887.98	395.25
Existing daily load (billion MPN)	625.22	96.55	0.91
Existing annual load (billion MPN)	57,0511.83	17,619.62	82.95
Annual load reduction needed (billion MPN)	40,0164.59	11,731.63	0
Percent reduction needed	70.4%	66.58%	0%
Total annual load (billion MPN)	74,753.75		
Total annual load reduction (billion MPN)	51,896.23		
Total percent reduction	69.42%		

Table 23. Bacteria load reductions required to meet water quality goals in Middle Yegua Creek for surface water quality monitoring station 11838.

	Flow conditions		
	High	**Mid-range**	**Low**
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	60.03	10.45	1.41
Existing geomean concentration (most probable number [MPN]/100 milliliters)	247	126.8	16
Allowable daily load (billion MPN)	185	32.3	4.33
Allowable annual load (billion MPN)	16,866.59	5,887.98	395.25
Existing daily load (billion MPN)	362.86	32.47	0.56
Existing annual load (billion MPN)	33,110.75	5,925.95	51.32
Annual load reduction needed (billion MPN)	16,224.16	37.96	0
Percent reduction needed	49%	0.64%	0%
Total annual load (billion MPN)	39,088.02		
Total annual load reduction (billion MPN)	16,262.12		
Total percent reduction	41.6%		

Table 24. Bacteria load reductions required to meet water quality goals in Davidson Creek for surface water quality monitoring station 18349

	Flow conditions		
	High	Mid-range	Low
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	63.42	3.23	0.02
Existing geomean concentration (most probable number [MPN]/100 milliliters)	671	514	84
Allowable daily load (billion MPN)	195.53	9.96	0.07
Allowable annual load (billion MPN)	17,842.07	1,818.02	6.48
Existing daily load (billion MPN)	1,041.91	40.67	0.05
Existing annual load (billion MPN)	95,074.67	7,421.98	4.30
Annual load reduction needed (billion MPN)	77,232.60	5,603.96	0
Percent reduction needed	81.23%	75.5%	0%
Total annual load (billion MPN)	102,500.95		
Total annual load reduction (billion MPN)	82,836.56		
Total percent reduction	80.82%		

Table 25. Bacteria load reductions required to meet water quality goals in Davidson Creek for surface water quality monitoring station 21420

	Flow conditions		
	High	Mid-range	Low
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	63.42	3.23	0.02
Existing geomean concentration (most probable number [MPN]/100 milliliters)	1,784	424	201
Allowable daily load (billion MPN)	195.53	9.96	0.07
Allowable annual load (billion MPN)	17,842.07	1,818.02	6.48
Existing daily load (billion MPN)	2,768.81	33.53	0.11
Existing annual load (billion MPN)	252,653.99	6,120.12	10.34
Annual load reduction needed (billion MPN)	234,811.93	4,302.11	0.04
Percent reduction needed	92.94%	70.29%	37.35%
Total annual load (billion MPN)	258,784.47		
Total annual load reduction (billion MPN)	239,117.90		
Total percent reduction	92.4%		

Table 26. Bacteria load reductions required to meet water quality goals in Davidson Creek for surface water quality monitoring station 11729

	Flow conditions		
	High	**Mid-range**	**Low**
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	53.19	2.95	0.06
Existing geomean concentration (most probable number [MPN]/100 milliliters)	981	635	174
Allowable daily load (billion MPN)	163.99	9.09	0.18
Allowable annual load (billion MPN)	14,964.70	1,659.83	16.30
Existing daily load (billion MPN)	1,276.83	45.84	0.25
Existing annual load (billion MPN)	116,511.16	8,365.32	22.44
Annual load reduction needed (billion MPN)	101,546.47	6,705.49	6.15
Percent reduction needed	87.16%	80.16%	27.39%
Total annual load (billion MPN)	124,898.92		
Total annual load reduction (billion MPN)	108,258.11		
Total percent reduction	86.68%		

Table 27. Bacteria load reductions required to meet water quality goals in Deer Creek for surface water quality monitoring station 11723

	Flow conditions		
	High	Mid-range	Low
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	18.21	1.53	0.14
Existing geomean concentration (most probable number [MPN]/100 milliliters)	813	289	135
Allowable daily load (billion MPN)	56.14	4.72	0.42
Allowable annual load (billion MPN)	5,122.52	862.21	38.04
Existing daily load (billion MPN)	362.34	10.84	0.45
Existing annual load (billion MPN)	33,063.86	1,978.15	40.74
Annual load reduction needed (billion MPN)	27,941.34	1,115.94	2.70
Percent reduction needed	84.51%	56.41%	6.63%
Total annual load (billion MPN)	35,082.75		
Total annual load reduction (billion MPN)	29,059.98		
Total percent reduction	82.83%		

Table 28. Bacteria load reductions required to meet water quality goals in Deer Creek for surface water quality monitoring station 18644

	Flow conditions		
	High	Mid-range	Low
Days per year	91.25	182.5	91.25
Median flow (cubic feet per second)	3.33	0.26	0
Existing geomean concentration (most probable number [MPN]/100 milliliters)	668	229	8.41
Allowable daily load (billion MPN)	10.26	0.79	0
Allowable annual load (billion MPN)	935.80	144.49	0
Existing daily load (billion MPN)	54.35	1.44	0
Existing annual load (billion MPN)	4,959.62	262.31	0
Annual load reduction needed (billion MPN)	4,023.82	117.82	0
Percent reduction needed	81.13%	44.92%	0%
Total annual load (billion MPN)	5,221.93		
Total annual load reduction (billion MPN)	4,141.64		
Total percent reduction	79.31%		

Pollutant Source Load Estimates

GIS Analysis

To aid in identifying potential areas of *E. coli* contributions within the watersheds, a GIS analysis was applied using the methodology employed by the Spatially Explicit Load Enrichment Calculation Tool (SELECT; Borel et al. 2012). The best available information was used to identify likely NPSs of bacteria and calculate potential loadings.

Using this GIS analysis approach, the relative potential for *E. coli* loading from each source can be compared and used to prioritize management. The loading estimates for each source are potential loading estimates that do not account for bacteria fate and transport processes that occur between the points where they originate and where they enter the water body, if at all. As such, these analyses represent worst case scenarios that do not represent the actual *E. coli* loadings expected to enter the creeks. Potential loads for identified sources are summarized for each of the subwatersheds (Figure 62 62–64) found in all three watersheds.

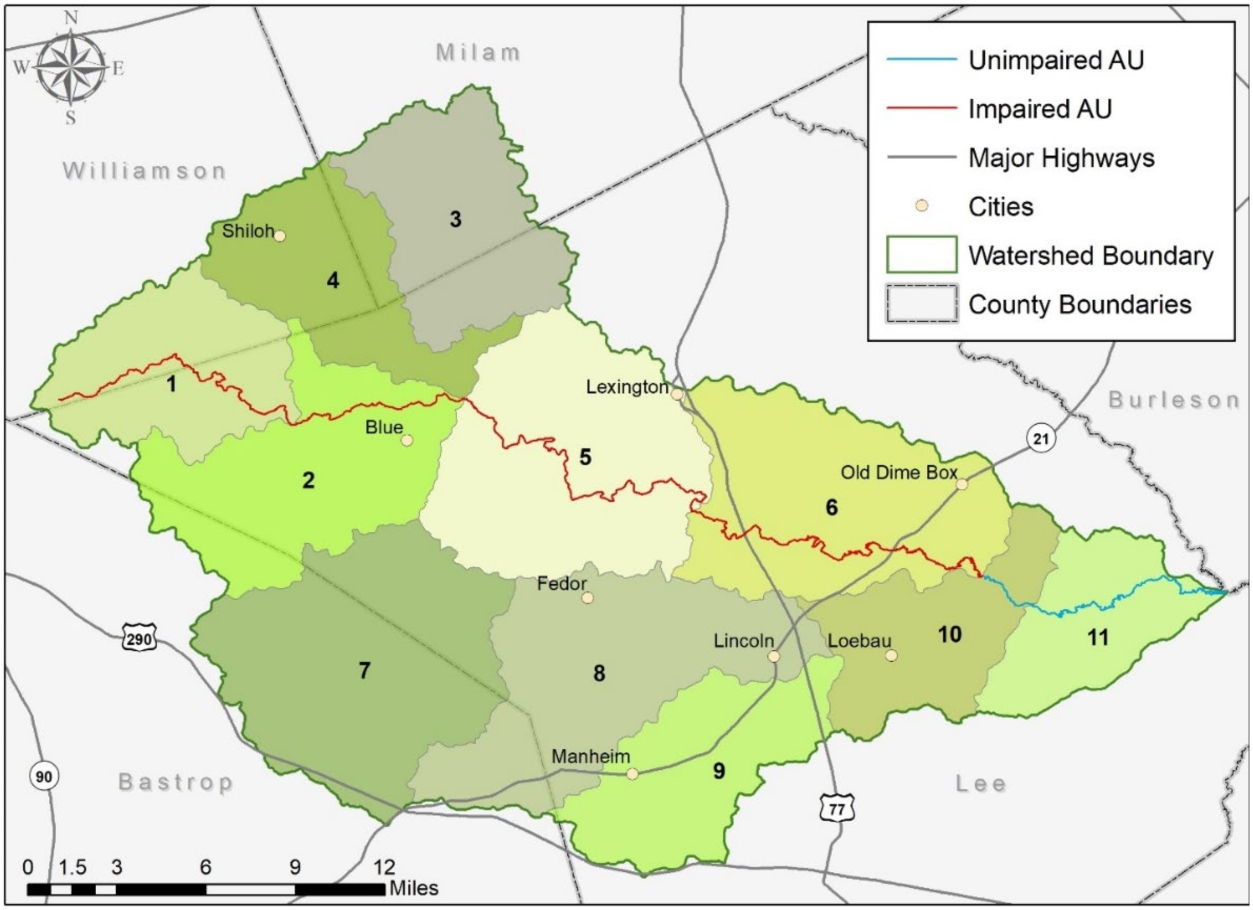

Figure 62. Middle Yegua Creek subwatersheds with assessment units (AUs).

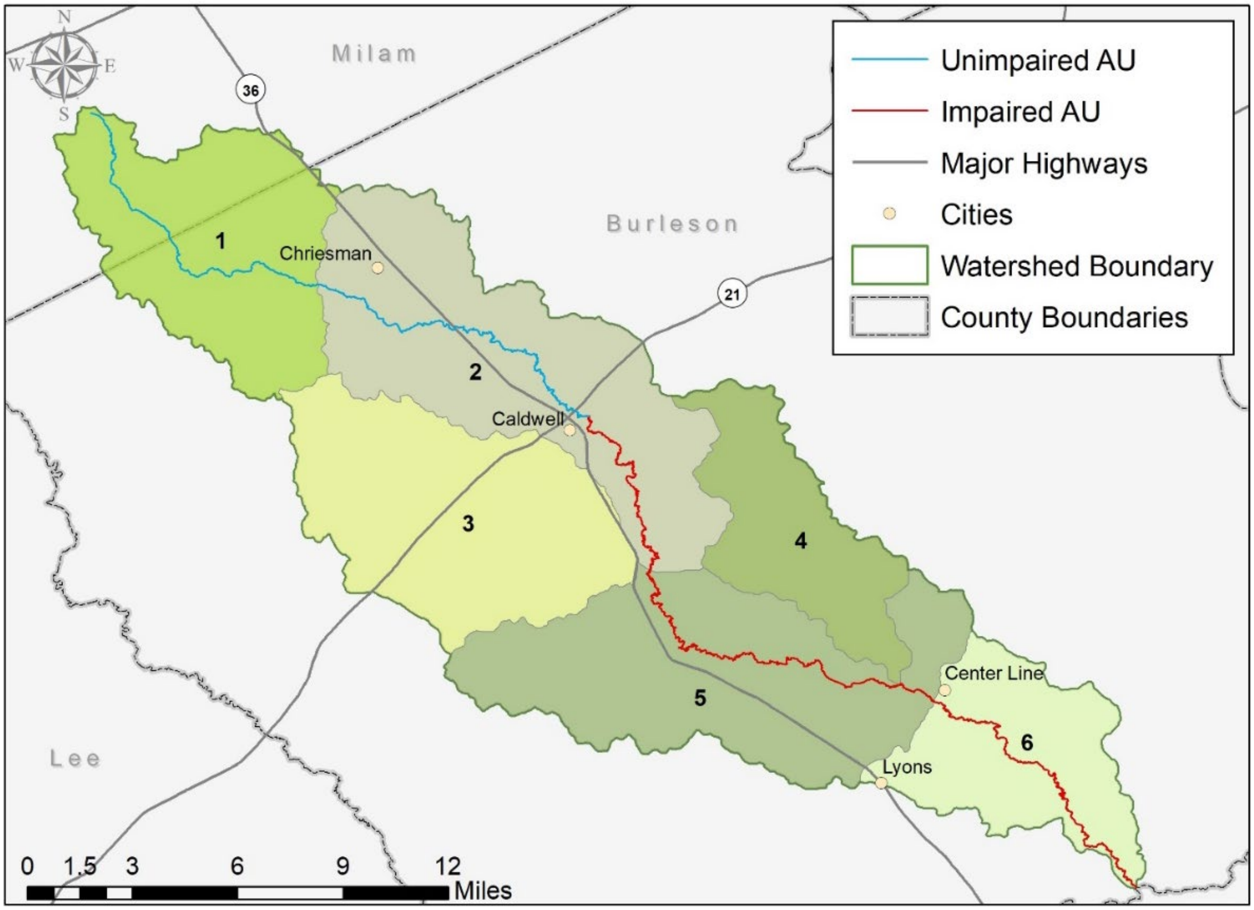

Figure 63. Davidson Creek subwatersheds with assessment units (AUs).

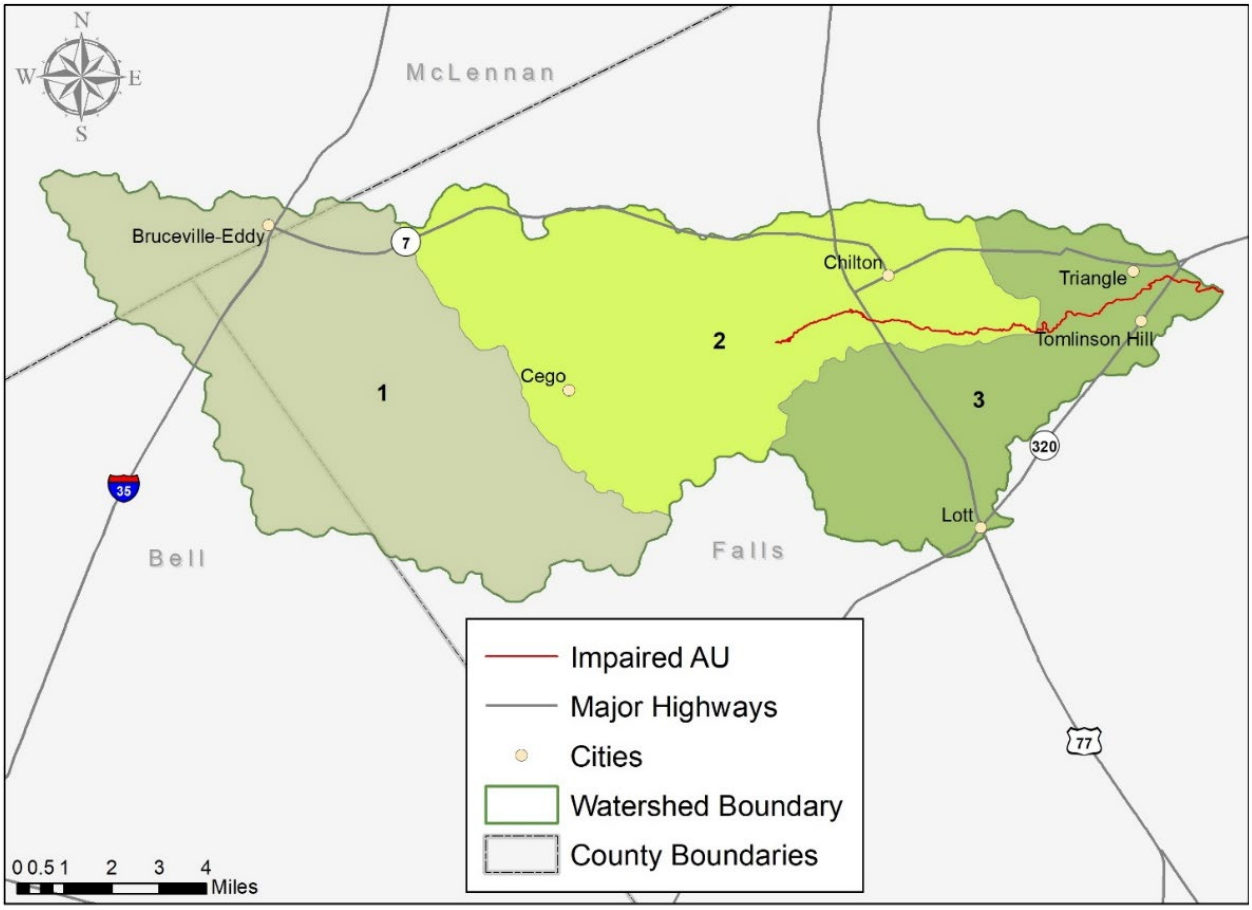

Figure 64. Deer Creek subwatersheds with assessment units (AUs).

Livestock: 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 can contain elevated levels of *E. coli*, which in turn can increase bacteria loads in the stream. Improved grazing practices and land stewardship can dramatically reduce runoff and bacteria loadings. For example, recent research in Texas watersheds indicate that rotational grazing and grazing livestock in upland pastures during wet seasons results in significant reductions in *E. coli* levels (Wagner et al. 2012). Furthermore, alternative water sources and shade structures located outside of riparian areas significantly reduce the amount of time cattle spend in and near streams, thus resulting in improved water quality (Wagner et al. 2013; Clary et al. 2016).

Based on the best available data, it was estimated that there are approximately 54,745 cattle animal units across the entire Middle Yegua Creek watershed. Appendix C describes the assumptions and equations used to estimate potential bacteria loading in all three watersheds. GIS analysis indicated the highest potential annual loading for Middle Yegua Creek occur in subwatersheds 5 and 8 (Figure

65). Across the watershed, the estimated potential annual load due to cattle is 1.06×10^{17} colony forming units (cfu) per year.

For the Davidson Creek watershed, it was estimated that there are approximately 27,524 cattle animal units. GIS analysis indicated the highest potential annual loading occurs in subwatershed 5 (Figure 66). Across the watershed, the estimated potential annual load due to cattle is 5.41×10^{16} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 6,854 cattle animal units. GIS analysis indicated the highest potential annual loading occurs in subwatershed 2 (Figure 67). Across the watershed, the estimated potential annual load due to cattle is 1.35×10^{16} cfu/yr.

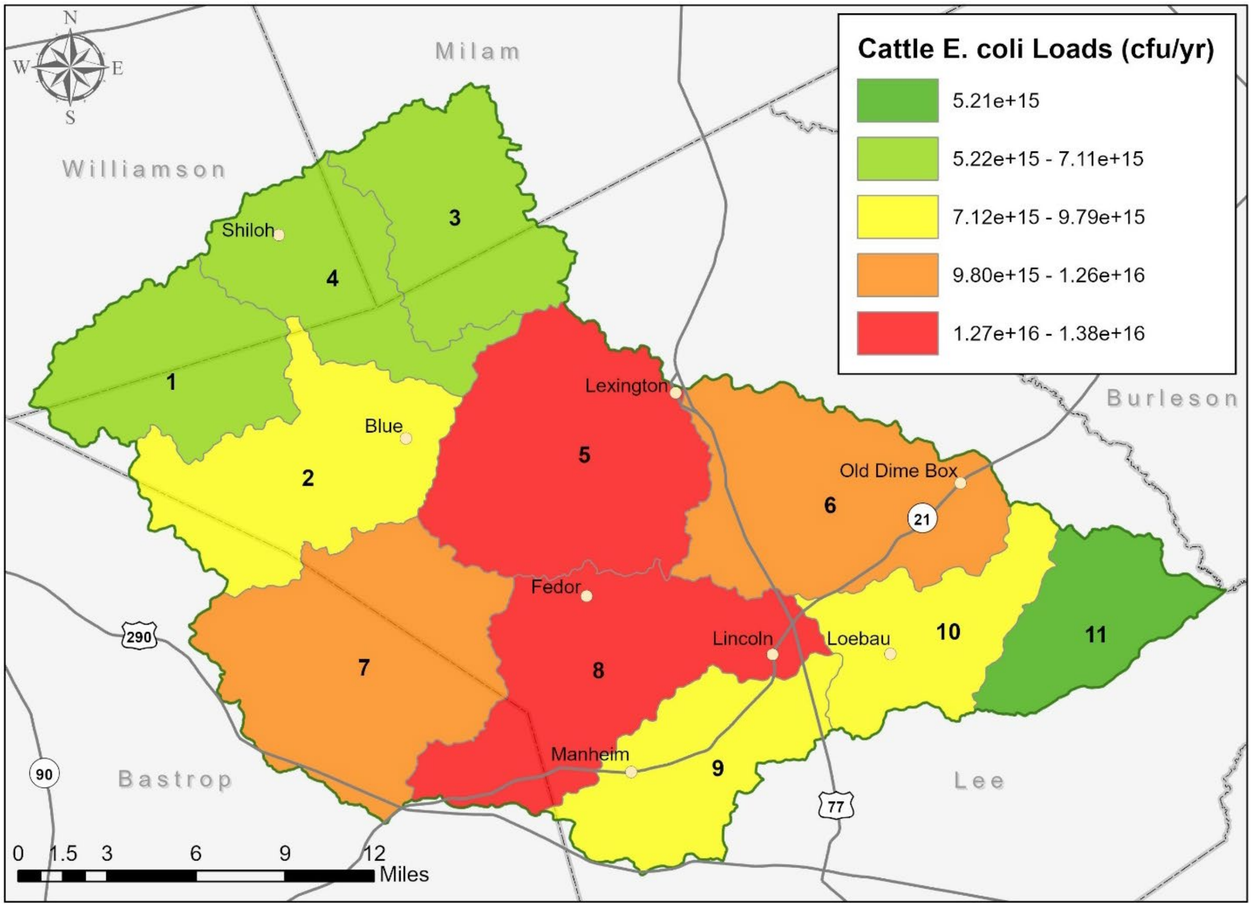

Figure 65. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from cattle in the Middle Yegua Creek watershed.

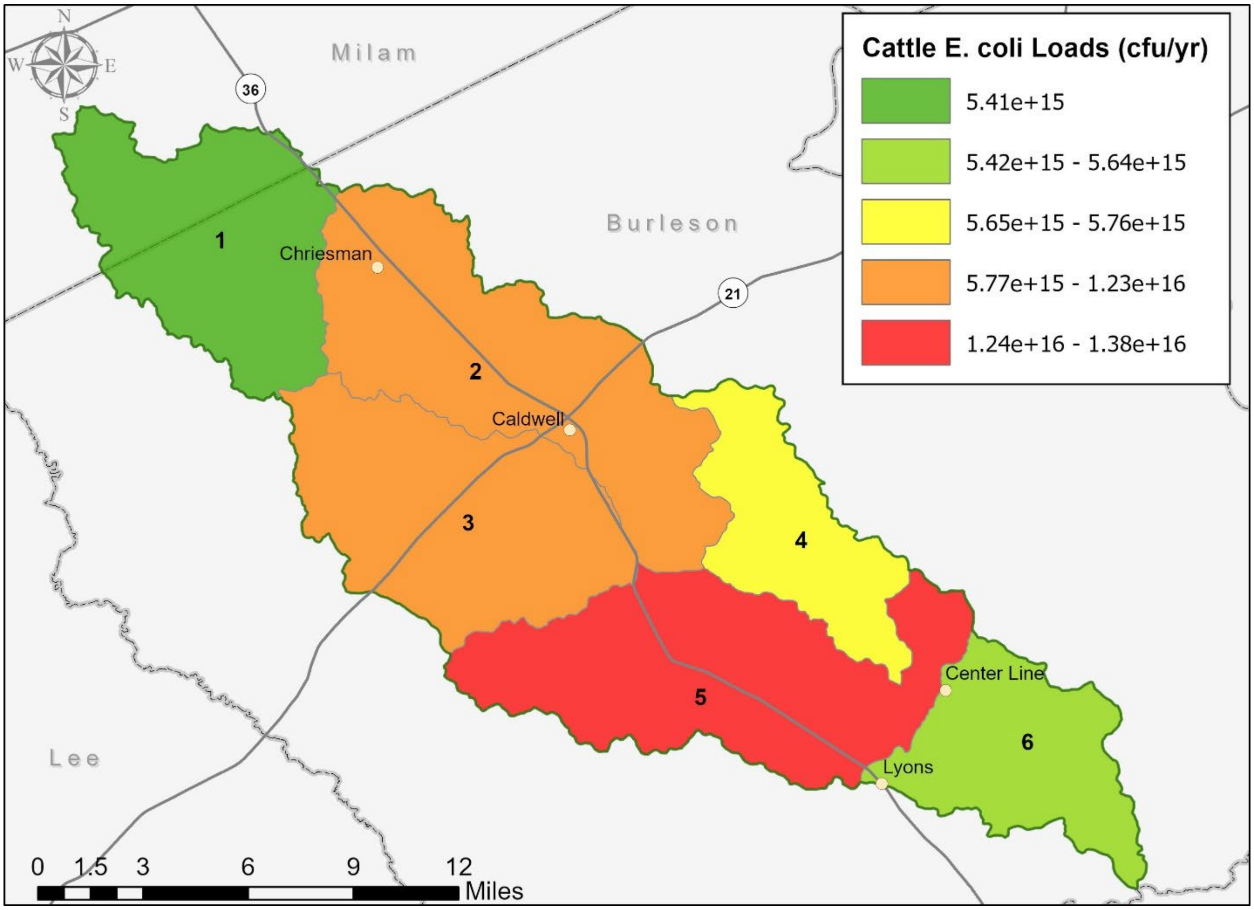

Figure 66. Potential annual bacteria loadings colony forming units (cfu) per year (yr) from cattle in the Davidson Creek watershed.

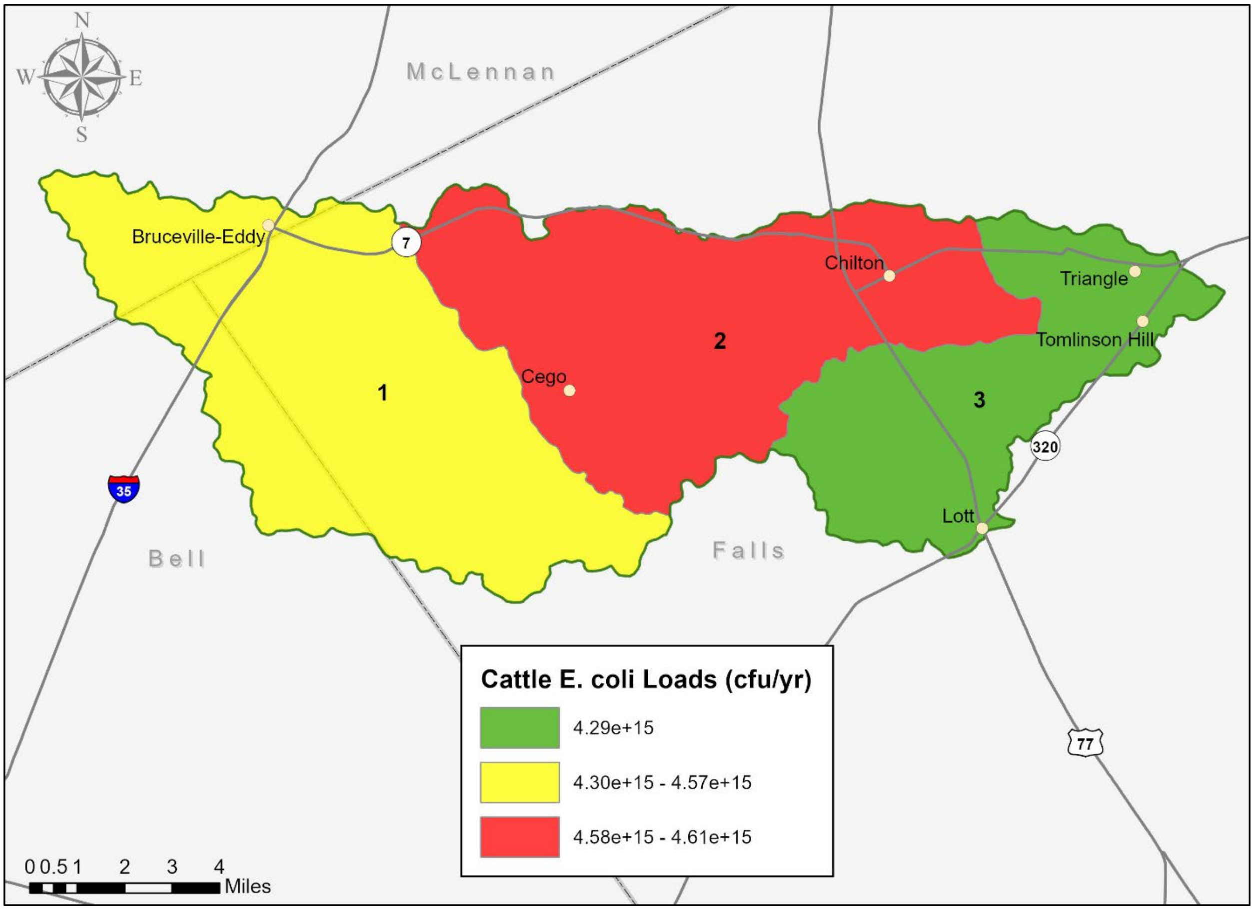

Figure 67. Potential annual bacteria loadings colony forming units (cfu) per year (yr) from cattle in the Deer Creek watershed.

Livestock: Horses

A total of 1,149 animal units of horses in the Middle Yegua Creek watershed were evenly distributed over shrub/scrub, grassland/herbaceous, and pasture/hay. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5 and 8 (Figure 68). Across the watershed, the estimated potential annual load due to horses is 9.61×10^{13} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 456 horse animal units. GIS analysis indicated the highest potential annual loading occurs in subwatersheds 2 and 5 (Figure 69). Across the watershed, the estimated potential annual load due to horses is 3.81×10^{13} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 247 horse animal units. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 70). Across the watershed, the estimated potential annual load due to horses is 2.07×10^{13} cfu/yr.

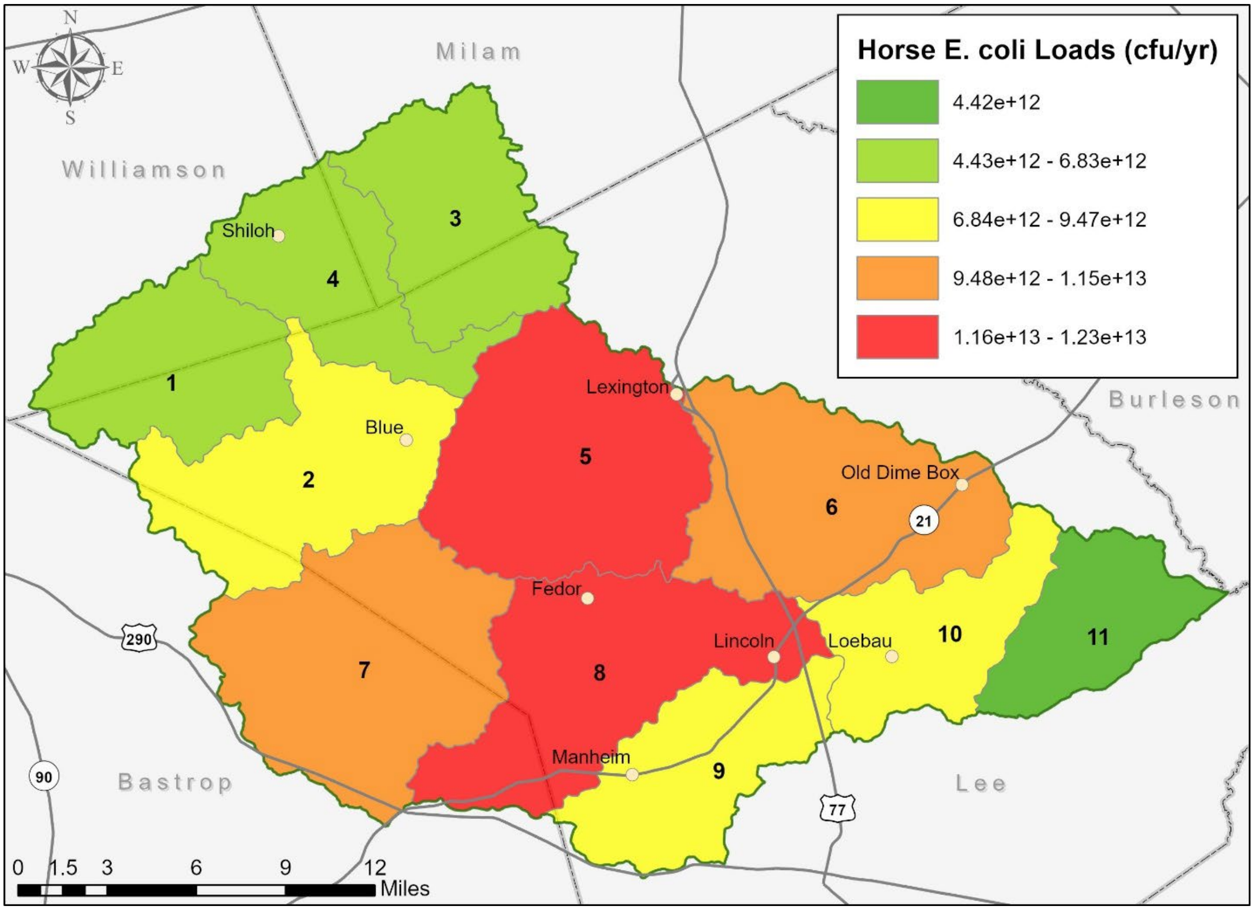

Figure 68. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from horses in the Middle Yegua Creek watershed.

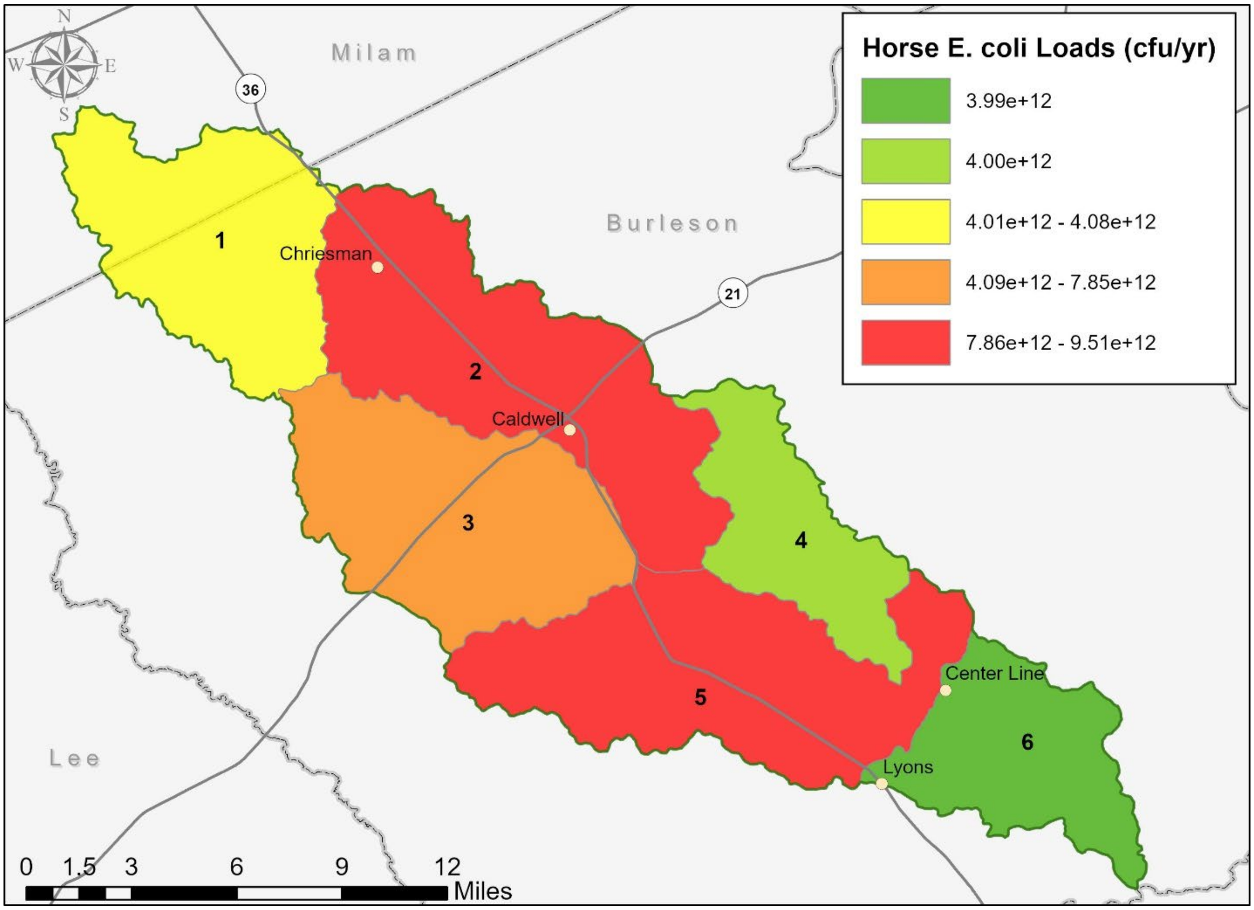

Figure 69. Potential annual bacteria loadings I colony forming units (cfu) per year (yr) from horses in the Davidson Creek watershed.

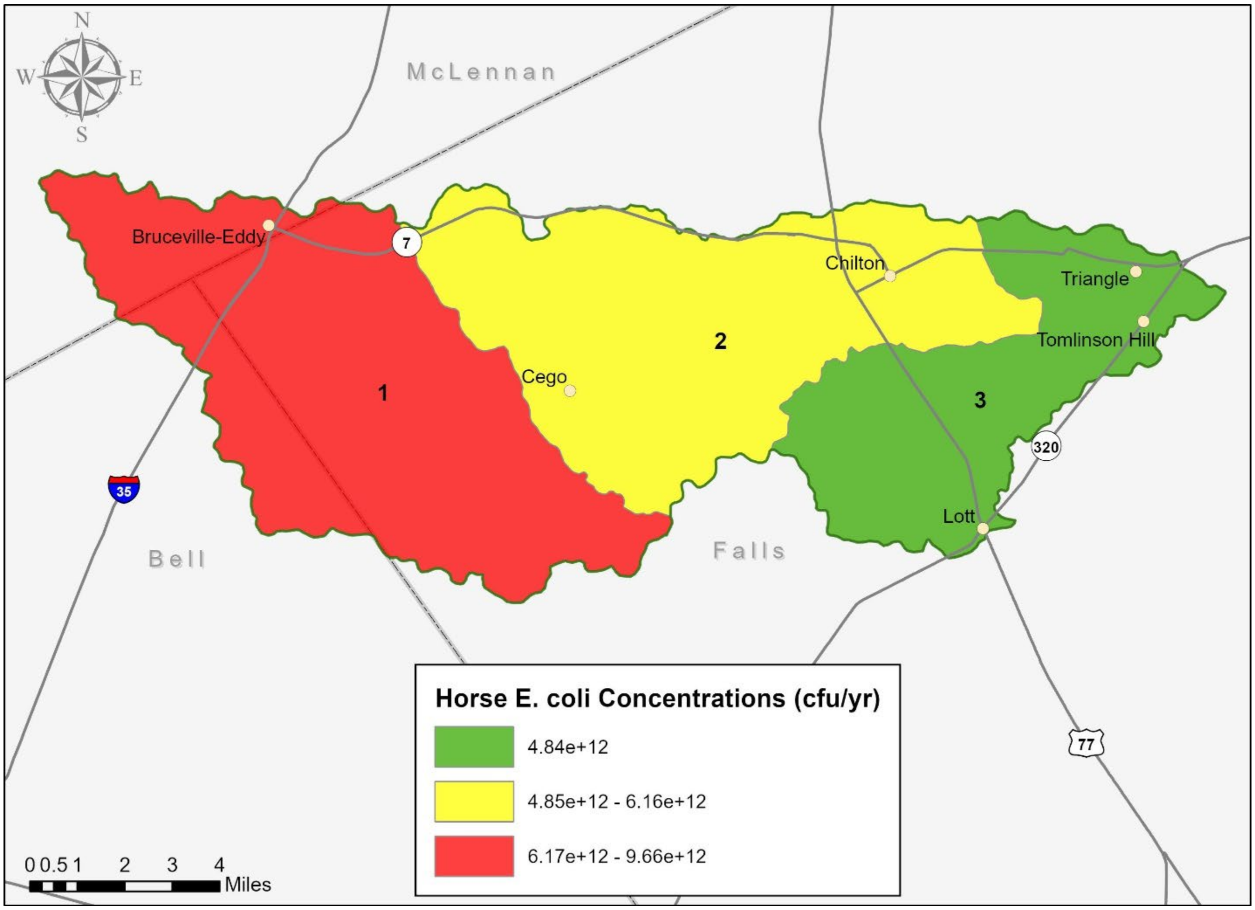

Figure 70. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from horses in the Deer Creek watershed.

Livestock: Goats

A total of 1,268 animal units of goats in the Middle Yegua Creek watershed were evenly distributed over shrub/scrub, grassland/herbaceous, and pasture/hay. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5, 6, 7, and 8 (Figure 71). Across the watershed, the estimated potential annual load due to goats is 1.26×10^{15} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 419 goat animal units. GIS analysis indicated the highest potential annual loading occurs in subwatersheds 2 and 5 (Figure 72). Across the watershed, the estimated potential annual load due to goats is 4.16×10^{14} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 305 goat animal units. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 73). Across the watershed, the estimated potential annual load due to goats is 3.03×10^{14} cfu/yr.

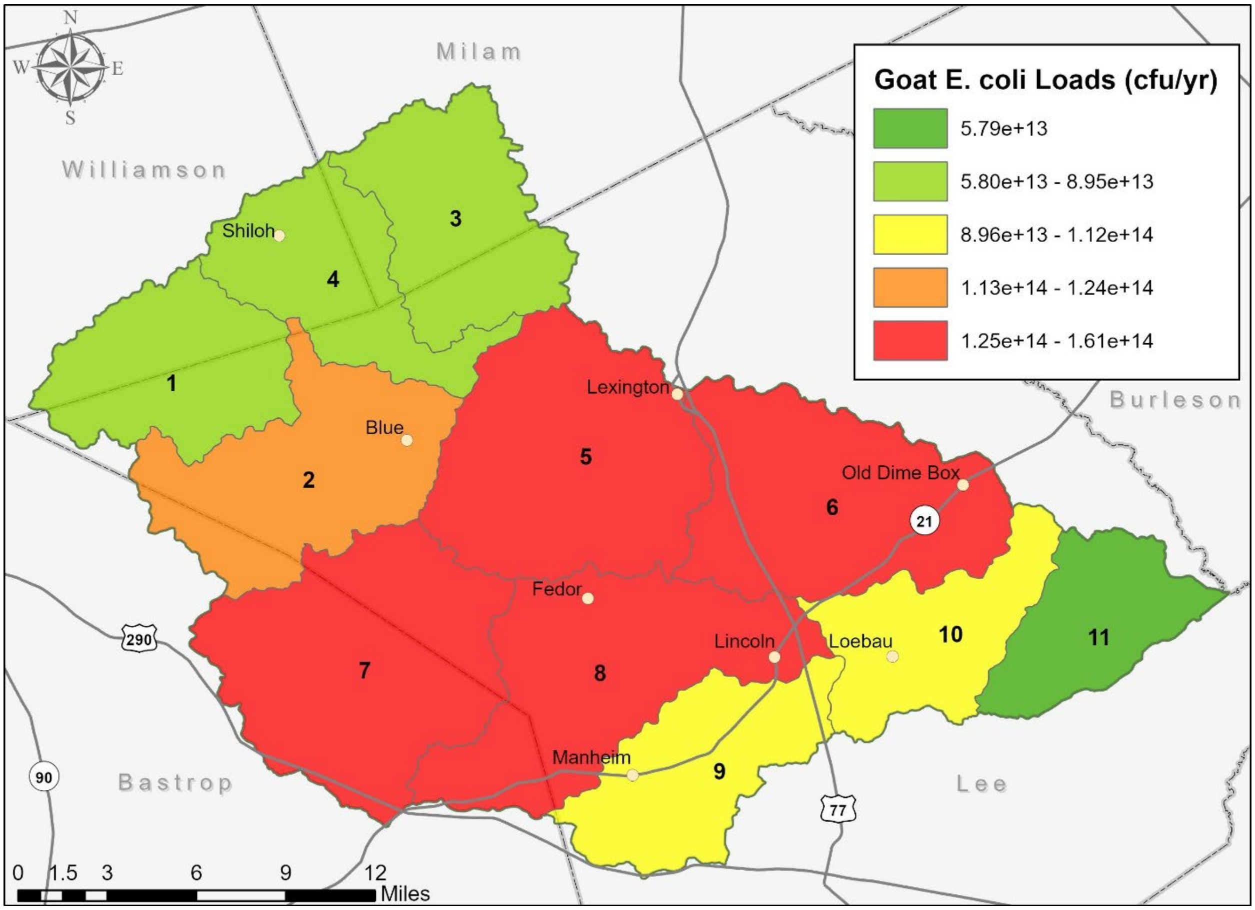

Figure 71. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from goats in the Middle Yegua Creek watershed.

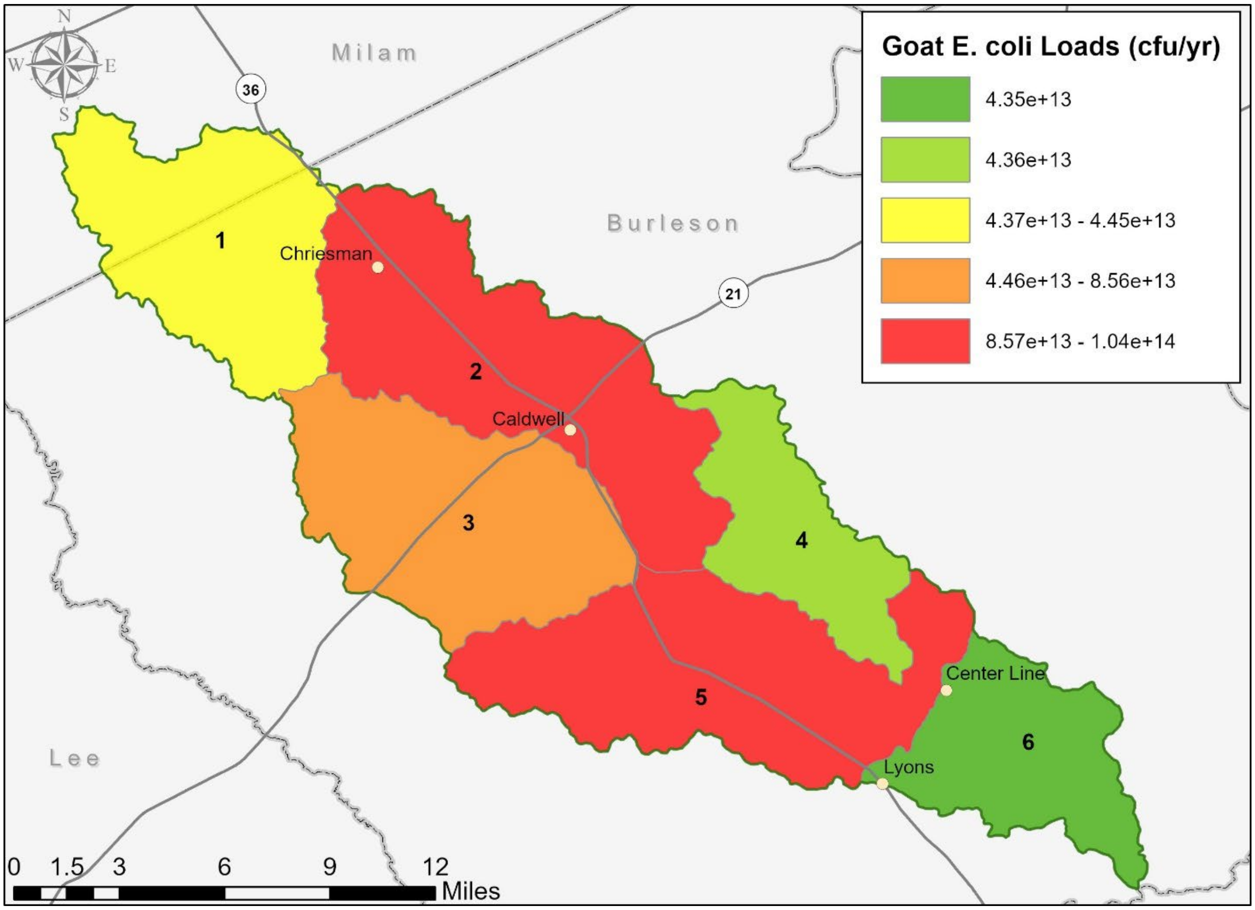

Figure 72. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from goats in the Davidson Creek watershed.

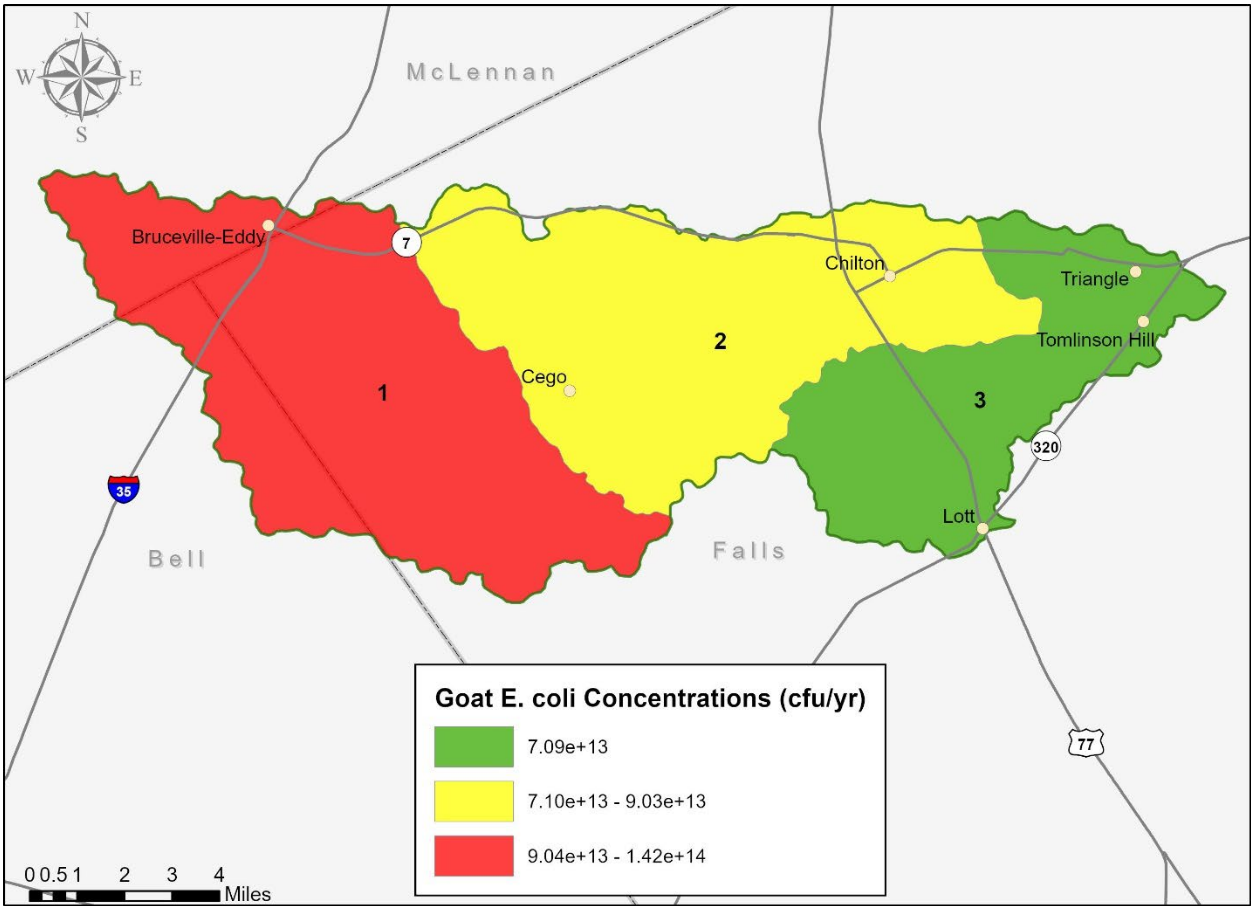

Figure 73. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from goats in the Deer Creek watershed.

Livestock: Sheep

A total of 805 animal units of sheep in the Middle Yegua Creek watershed were evenly distributed over shrub/scrub, grassland/herbaceous, and pasture/hay. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5 and 8 (Figure 74). Across the watershed, the estimated potential annual load due to sheep is 1.07×10^{16} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 290 sheep animal units. GIS analysis indicated the highest potential annual loading occurs in subwatersheds 2 and 5 (Figure 75). Across the watershed, the estimated potential annual load due to sheep is 3.87×10^{15} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 379 sheep animal units. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 76). Across the watershed, the estimated potential annual load due to sheep is 5.05×10^{15} cfu/yr.

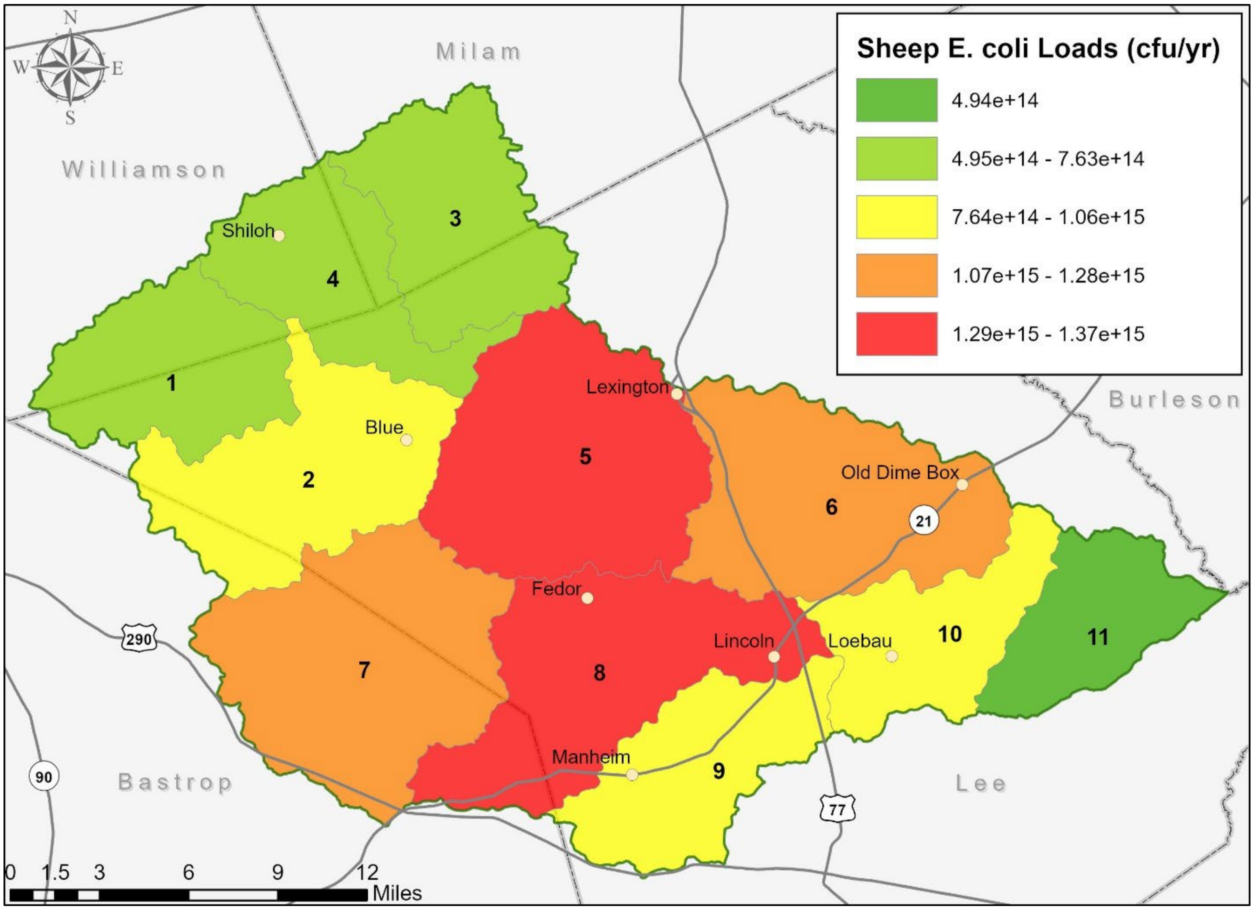

Figure 74. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from sheep in the Middle Yegua Creek watershed.

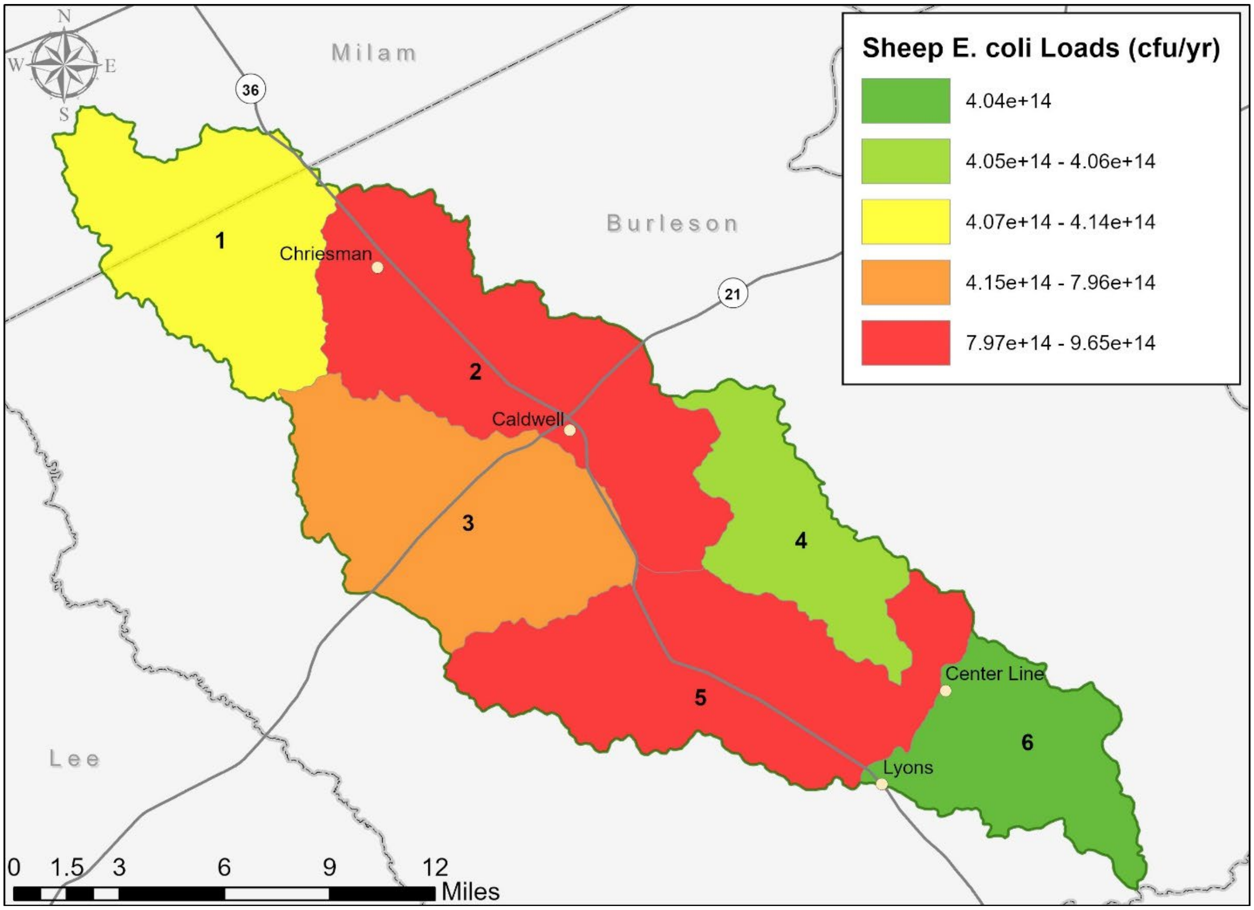

Figure 75. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from sheep in the Davidson Creek watershed.

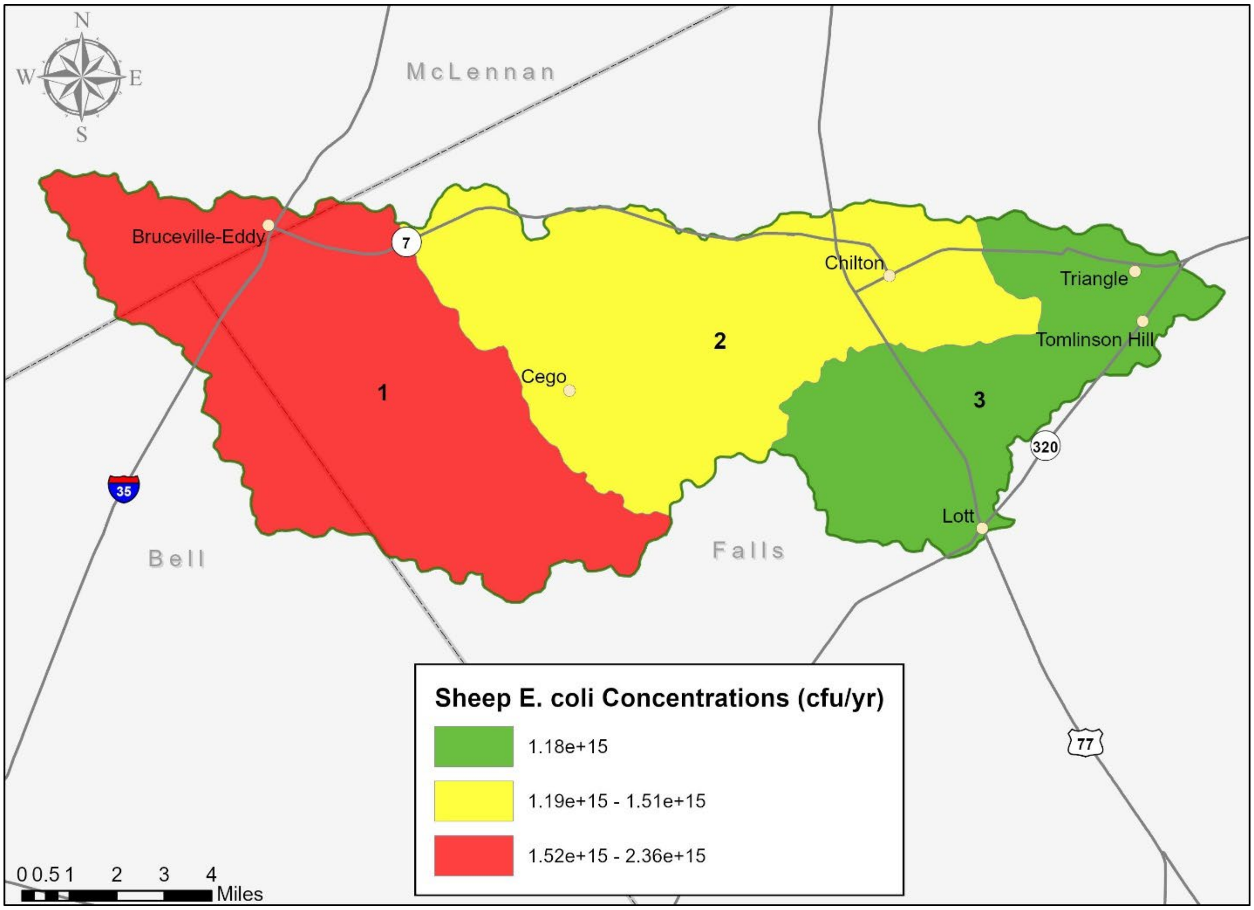

Figure 76. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from sheep in the Deer Creek watershed.

Wildlife: Deer

Wildlife is another *E. coli* and nutrient source 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. Deer populations were estimated using annual deer density estimates from TPWD surveys conducted in and near the watershed.

For the Middle Yegua Creek watershed, a deer population of 6,403 animals was estimated. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5 and 7 (Figure 77). Across the watershed, the estimated potential annual load due to deer is 2.47×10^{15} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 3,119 deer with a density of 41.65 animals per acre. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 2 and 5 (Figure 78). Across the watershed, the estimated potential annual load due to deer is 1.20×10^{15} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 2,584 deer with a density of 26.69 animals per acre. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 79). Across the watershed, the estimated potential annual load due to deer is 9.98×10^{14} cfu/yr.

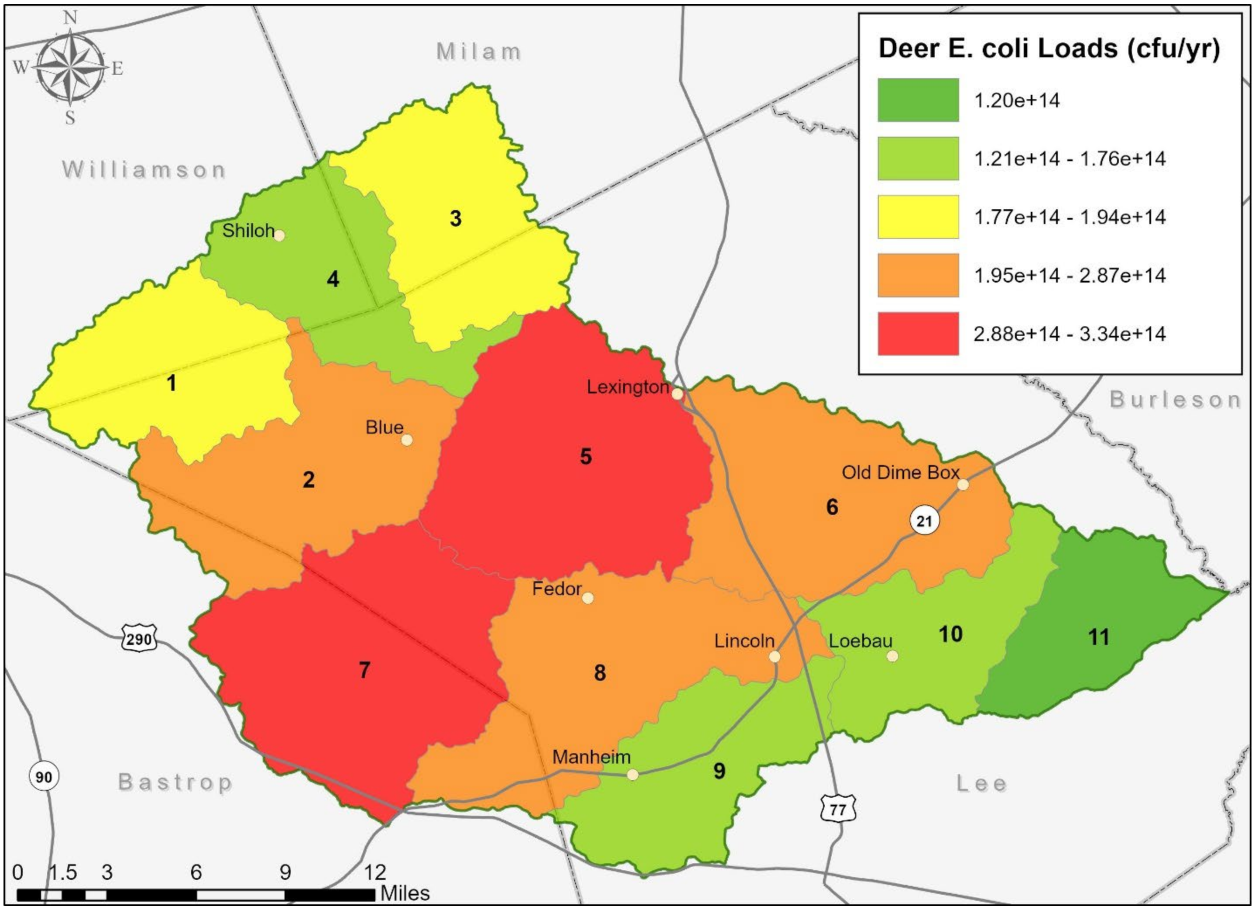

Figure 77. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from deer in the Middle Yegua Creek watershed.

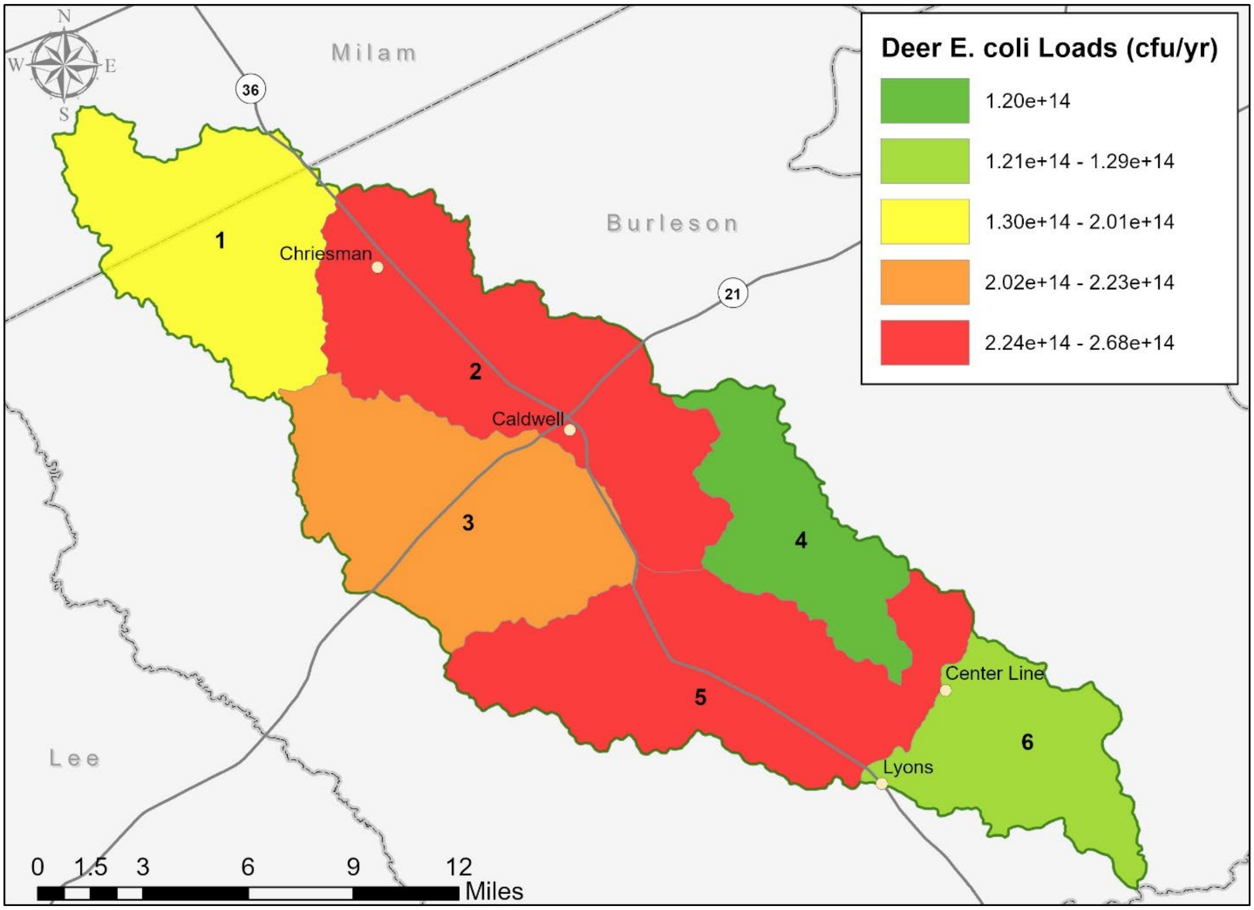

Figure 78. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from deer in the Davidson Creek watershed.

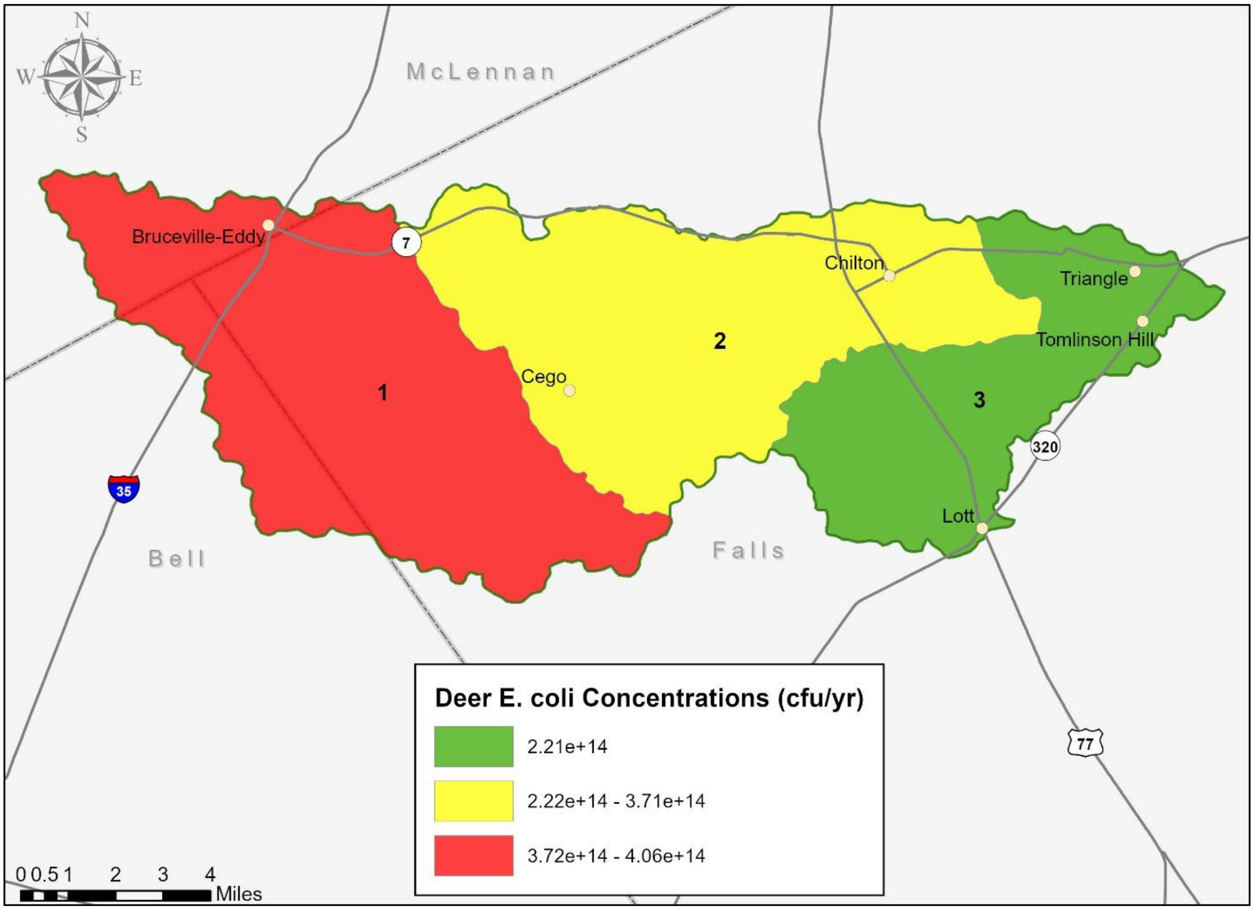

Figure 79. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from deer in the Deer Creek watershed.

Wildlife: Feral Hogs

Feral hogs (*Sus scrofa*) are an introduced, non-native, and invasive species. Early settlers released some of the first domestic hogs in the Texas landscape as early as the 1680s, with many of these hogs becoming feral over time as animals were left to fend for themselves (Mayer 2009; Mapston 2010). Documented introductions of Eurasian wild boar occurred in the early 1920s through the 1940s along the Texas Central Coast, including at the St. Charles Ranch in what is now the nearby Aransas National Wildlife Refuge (Mayer 2009). Current population estimates of feral hogs in Texas alone range from one to three million individuals (Mayer 2009; Mapston 2010).

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

For the Middle Yegua Creek watershed, a watershed-wide estimate of 8,008 hogs was produced. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 5 and 7 (Figure 80). Across the watershed, the estimated potential annual load due to feral hogs is 2.79×10^{14} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 3,901 feral hogs within the watershed. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 2 and 5 (Figure 81). Across the watershed, the estimated potential annual load due to feral hogs is 1.36×10^{14} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 2,071 feral hogs within the watershed. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 82). Across the watershed, the estimated potential annual load due to feral hogs is 7.20×10^{13} cfu/yr.

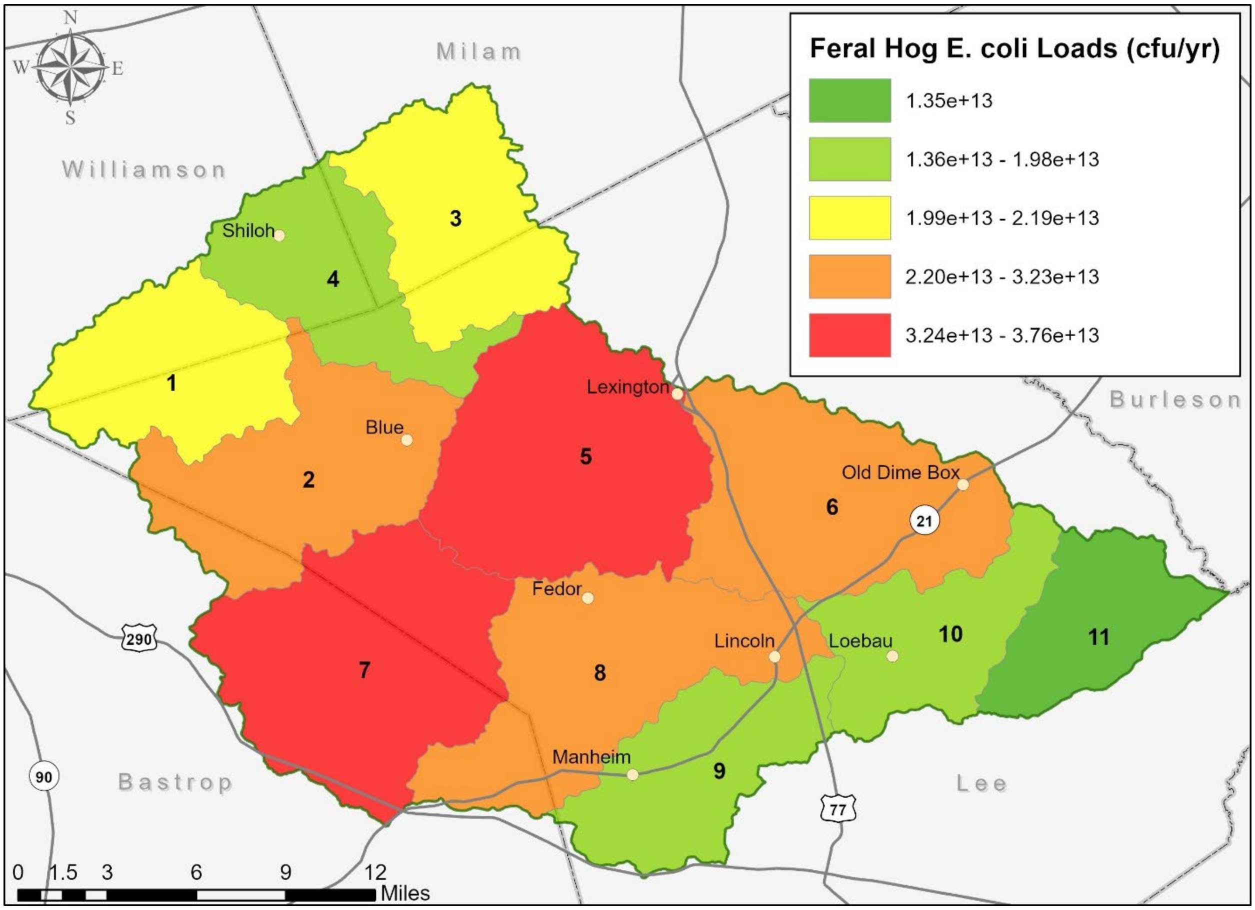

Figure 80. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from feral hogs in the Middle Yegua Creek watershed.

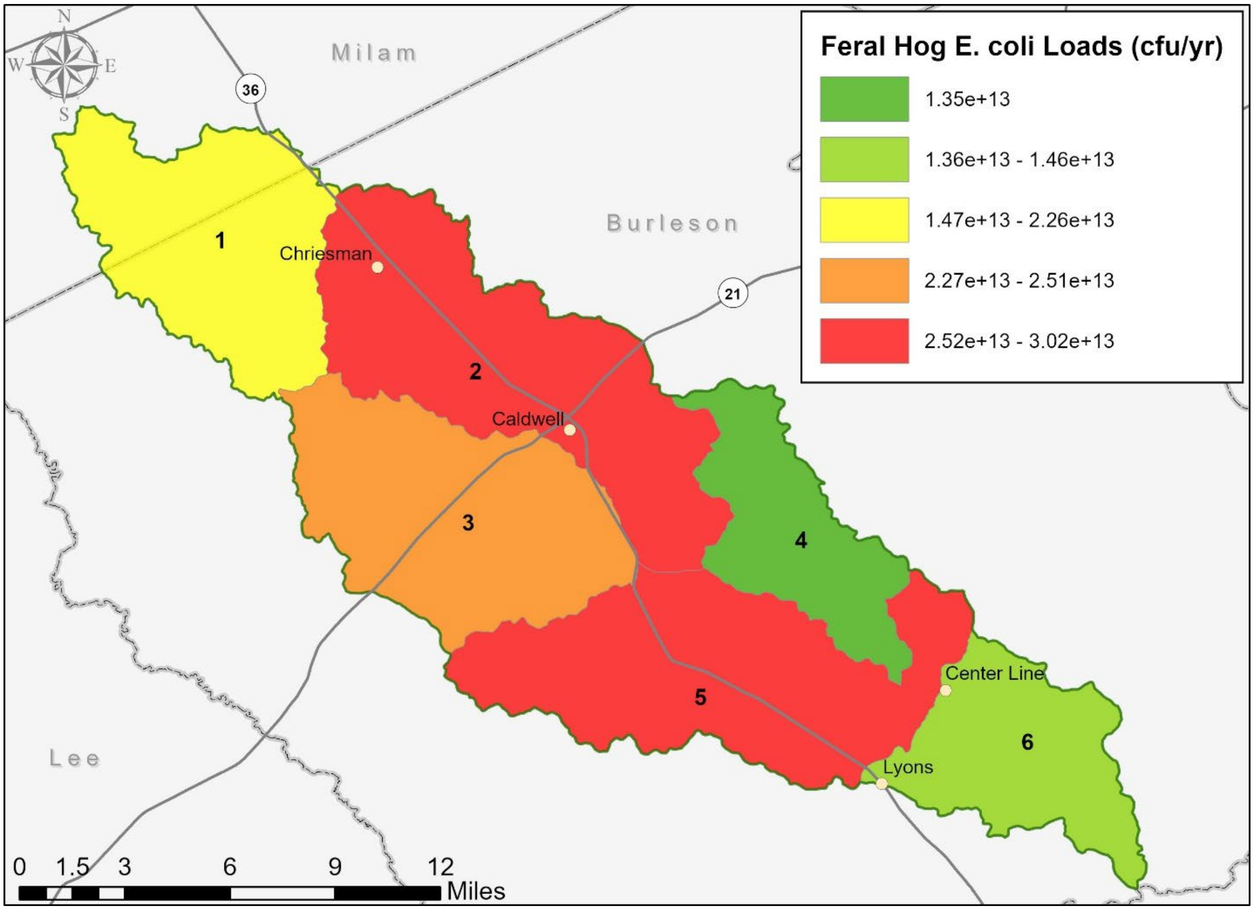

Figure 81. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from feral hogs in the Davidson Creek watershed.

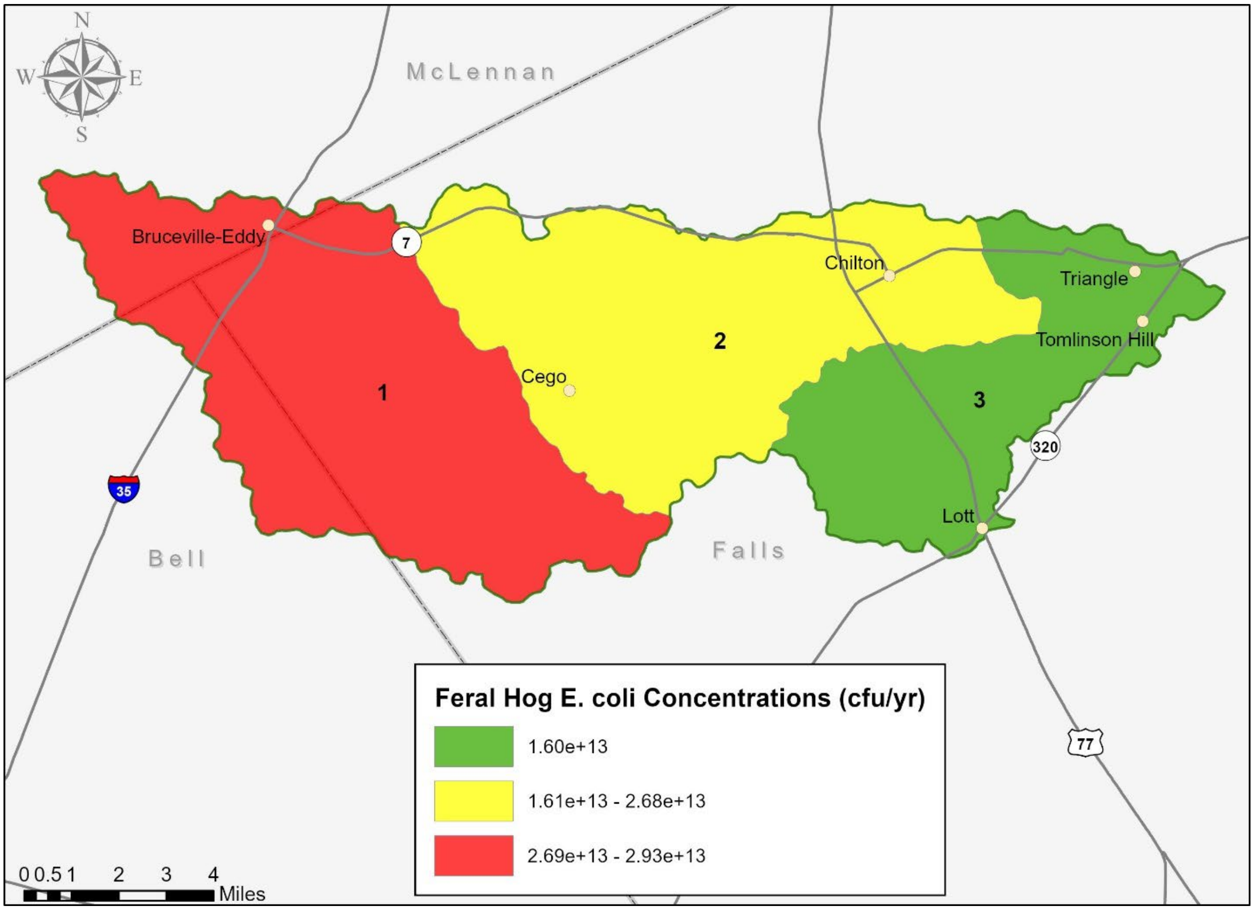

Figure 82. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from feral hogs in the Deer Creek watershed.

OSSFs

Failing or unmaintained OSSFs can contribute to bacteria loads in water bodies, particularly those where effluent is released near the water bodies. Within all three watersheds, approximately 15% of OSSFs are assumed to fail on a given year. For the Middle Yegua Creek watershed, it was estimated that there are approximately 3,953 OSSFs within the watershed based on the most recently available 911 address data. GIS analysis indicated the highest potential annual loading occurs in subwatershed 5 (Figure 83). Across the watershed, the estimated potential annual load due to OSSFs is 7.93×10^{15} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 2,408 OSSFs within the watershed. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 3 and 5 (Figure 84). Across the watershed, the estimated potential annual load due to OSSFs is 4.79×10^{15} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 1,685 OSSFs within the watershed. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 85). Across the watershed, the estimated potential annual load due to OSSFs is 3.85×10^{15} cfu/yr.

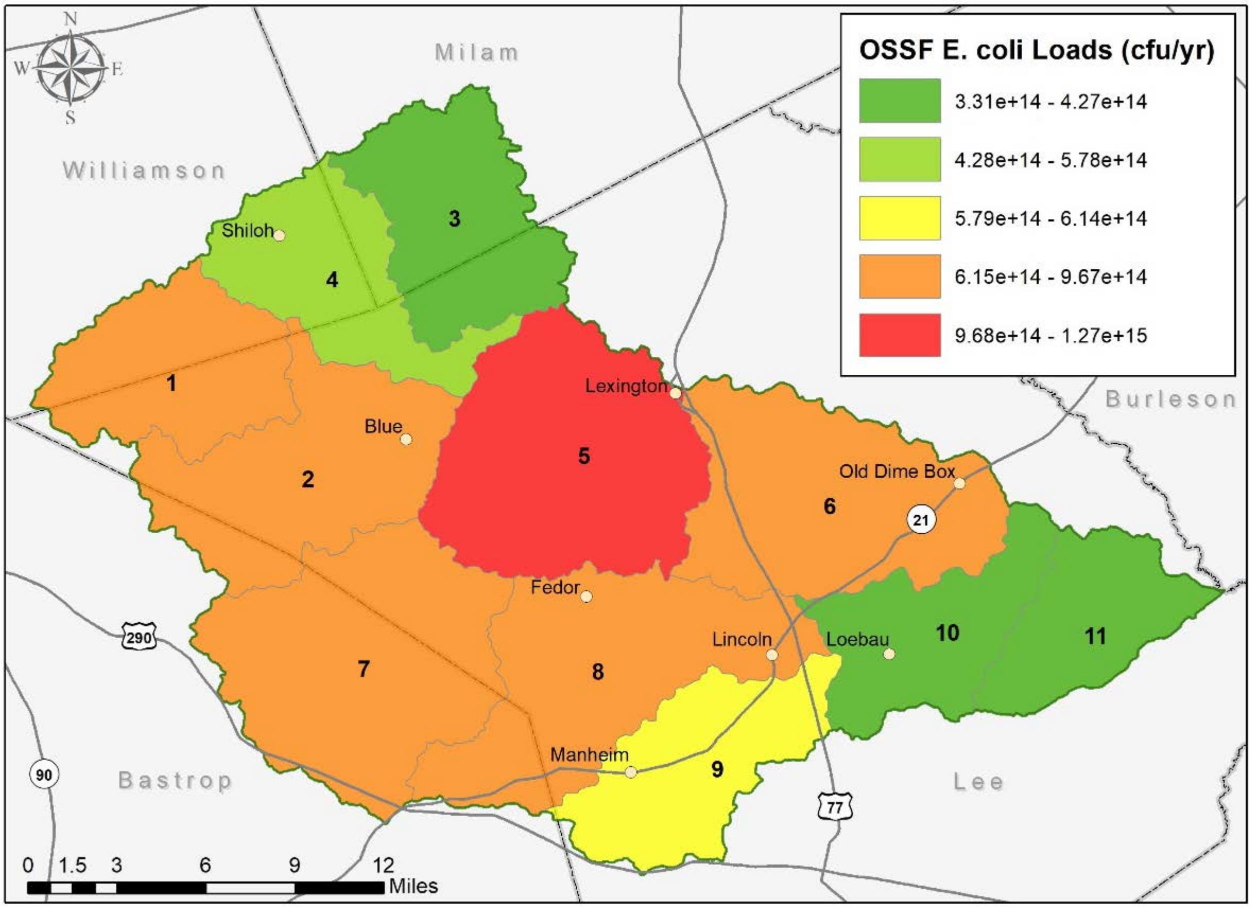

Figure 83. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from on-site sewage facilities (OSSFs) in the Middle Yegua Creek watershed.

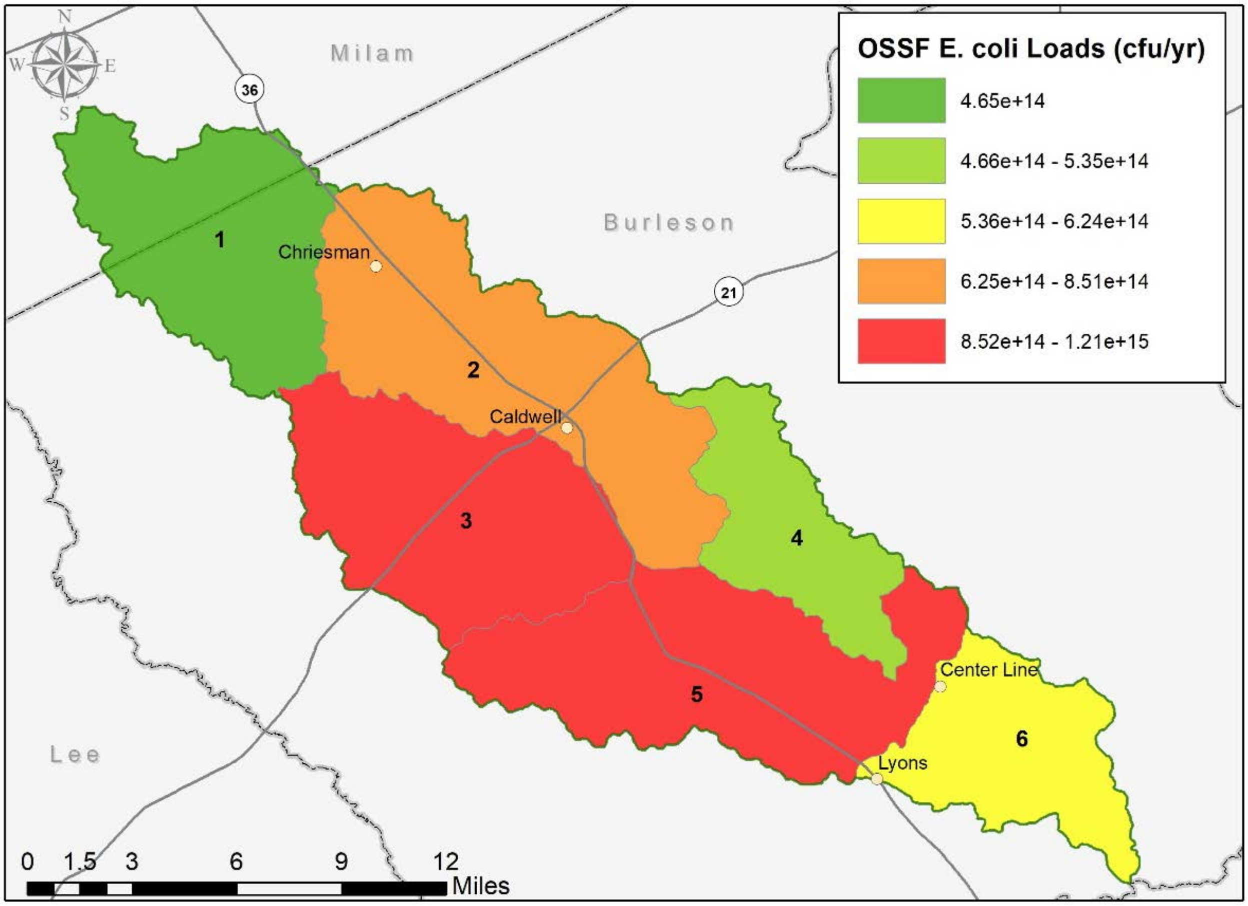

Figure 84. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from on-site sewage facilities (OSSFs) in the Davidson Creek watershed.

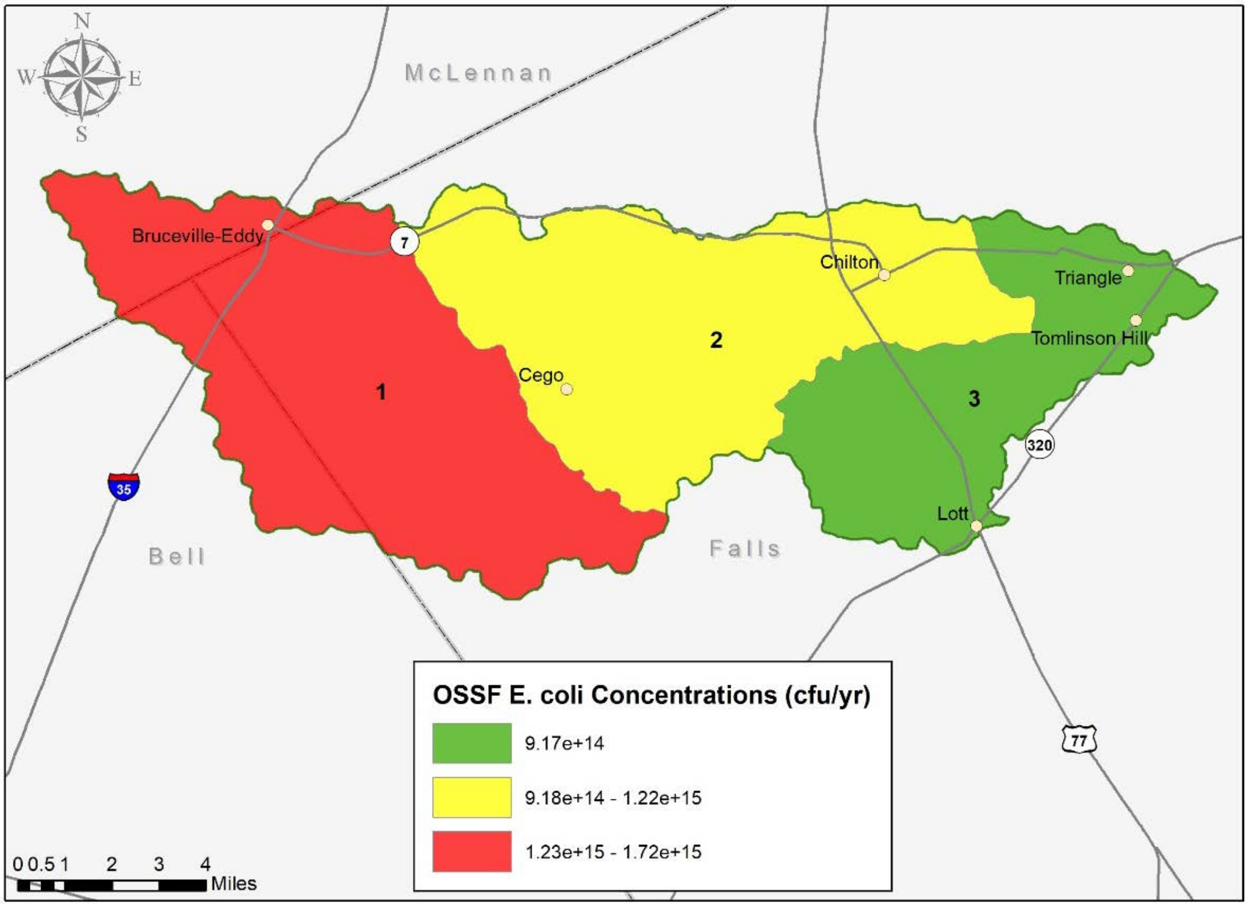

Figure 85. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from on-site sewage facilities (OSSFs) in the Deer Creek watershed.

Domestic Pets: Dogs

Domestic pets, with a particular emphasis on dogs, can contribute to bacteria loadings when pet waste is not disposed of 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. For the Middle Yegua Creek watershed, it was estimated that there are approximately 2,256 dogs within the watershed. GIS analysis indicated the highest potential annual loading occurs in subwatershed 5 (Figure 86). Across the watershed, the estimated potential annual load due to dogs is 2.59×10^{15} cfu/yr. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that there are approximately 2,435 dogs within the watershed. GIS analysis indicated the highest potential annual loadings occur in subwatersheds 2 and 3 (Figure 87). Across the watershed, the estimated potential annual load due to dogs is 2.80×10^{15} cfu/yr.

For the Deer Creek watershed, it was estimated that there are approximately 1,003 dogs within the watershed. GIS analysis indicated the highest potential annual loading occurs in subwatershed 1 (Figure 88). Across the watershed, the estimated potential annual load due to dogs is 1.15×10^{15} cfu/yr.

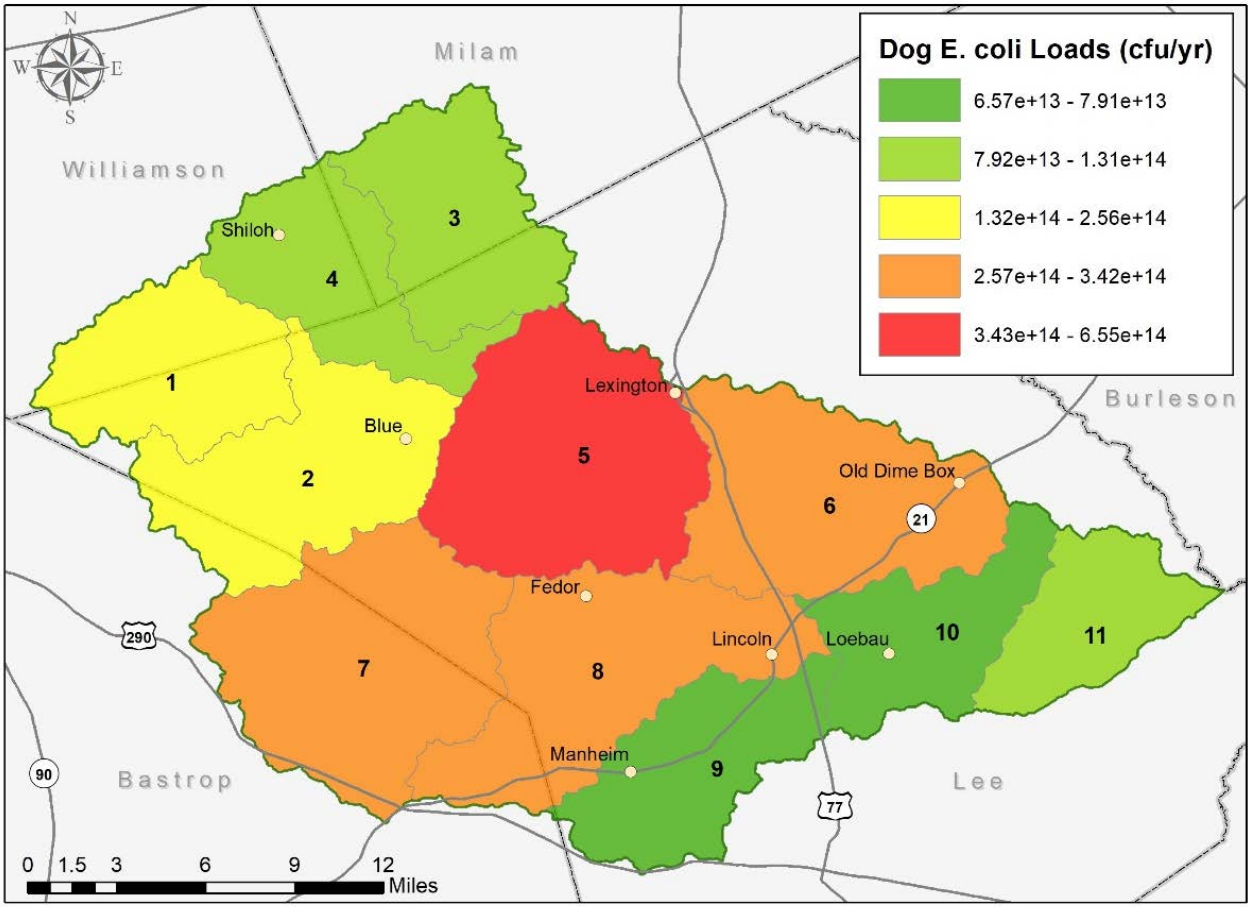

Figure 86. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from dogs in the Middle Yegua Creek watershed.

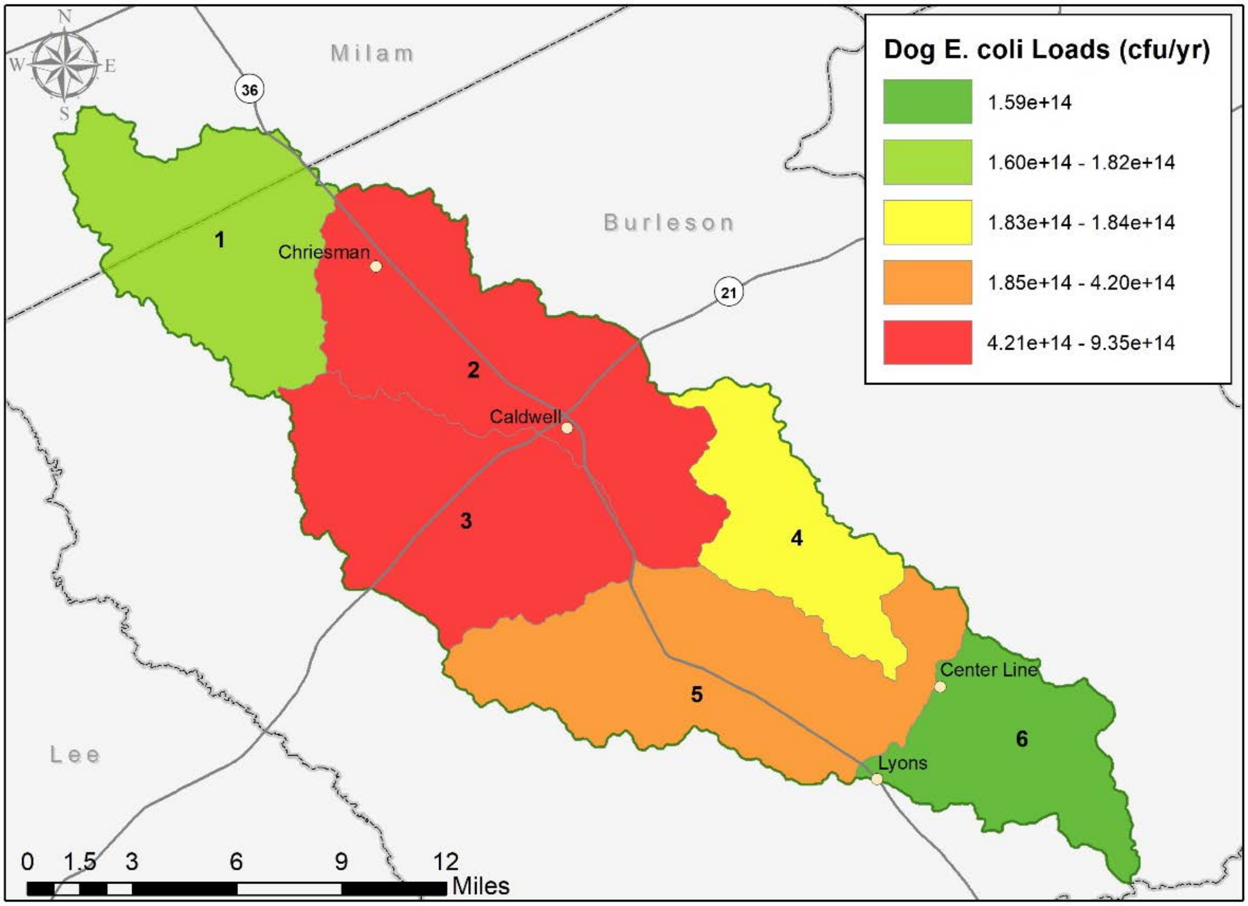

Figure 87. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from dogs in the Davidson Creek watershed.

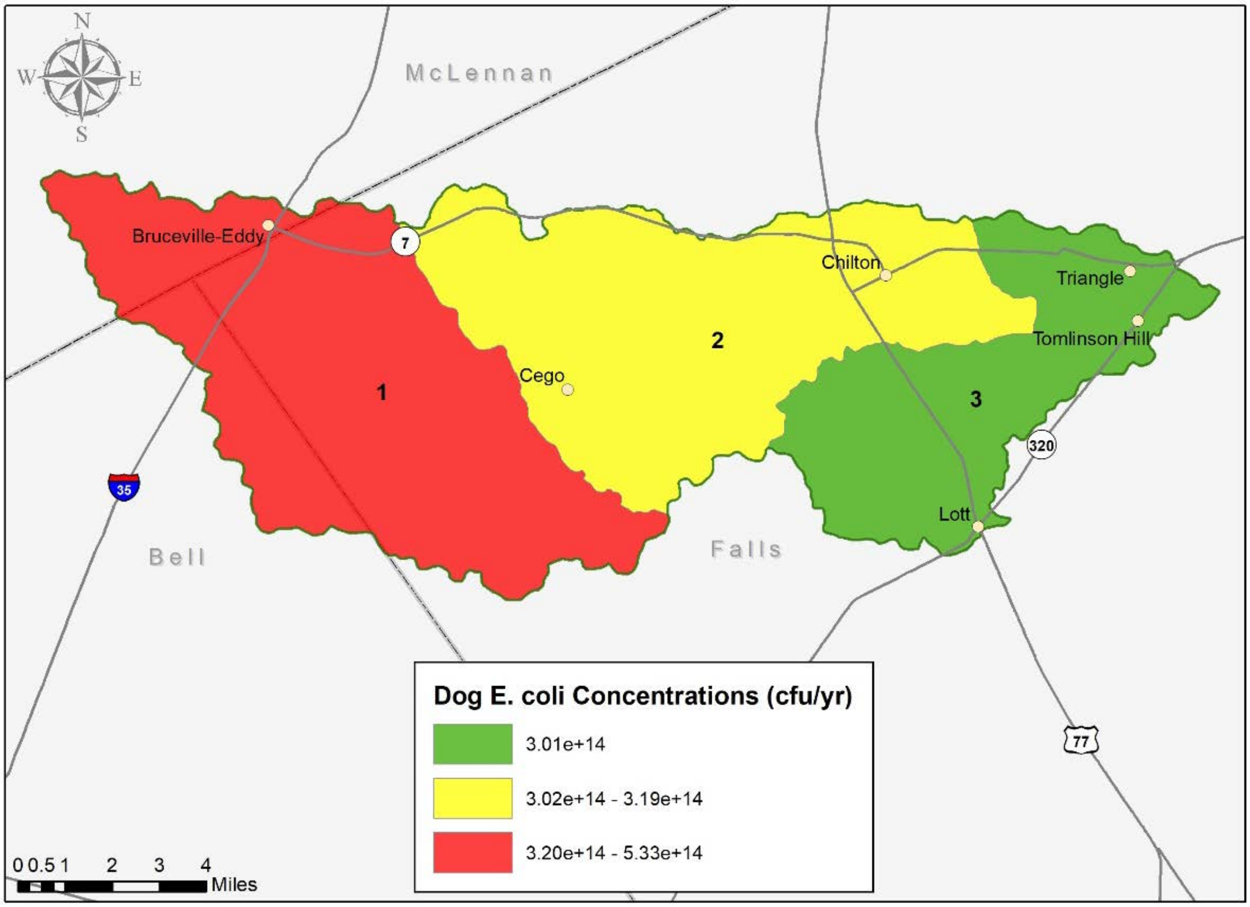

Figure 88. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from dogs in the Deer Creek watershed.

WWTFs

According to TCEQ and NPDES data, there is one permitted wastewater discharger in the Middle Yegua Creek watershed, two in the Davidson Creek watershed, and two in the Deer Creek watershed. These wastewater discharges are regulated by TCEQ and are required to report average monthly discharges and *E. coli* concentrations.

Although the permitted discharge volumes and bacteria concentrations are below permitted values, potential loading was calculated using the maximum permitted discharges and concentrations to assess the maximum potential load. Total potential bacteria loads based on maximum permitted discharges across the Middle Yegua Creek watershed is 3.46×10^{11} cfu/yr (Figure 89), and the highest potential load occurs in subwatershed 6. Appendix C describes the equations and assumptions used to generate potential annual loads.

For the Davidson Creek watershed, it was estimated that the total potential bacteria loads based on maximum permitted discharges is 1.75×10^{12} cfu/yr (Figure 90), and the highest potential load occurs in subwatershed 2.

For the Deer Creek watershed, it was estimated that the total potential bacteria loads based on maximum permitted discharges is 3.20×10^{11} cfu/yr (Figure 91), and the highest potential load occurs in subwatershed 2.

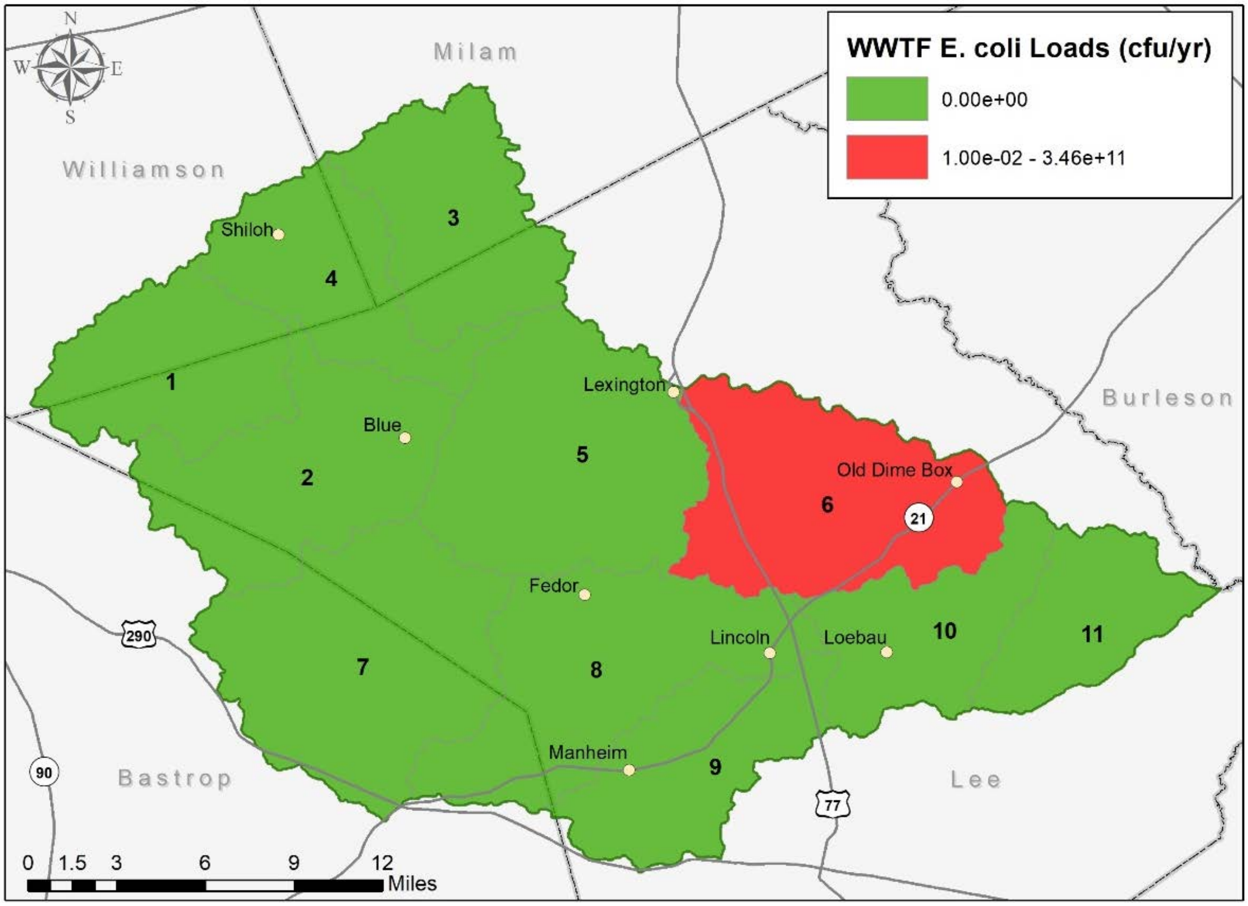

Figure 89. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from wastewater treatment facilities (WWTFs) in the Middle Yegua Creek watershed.

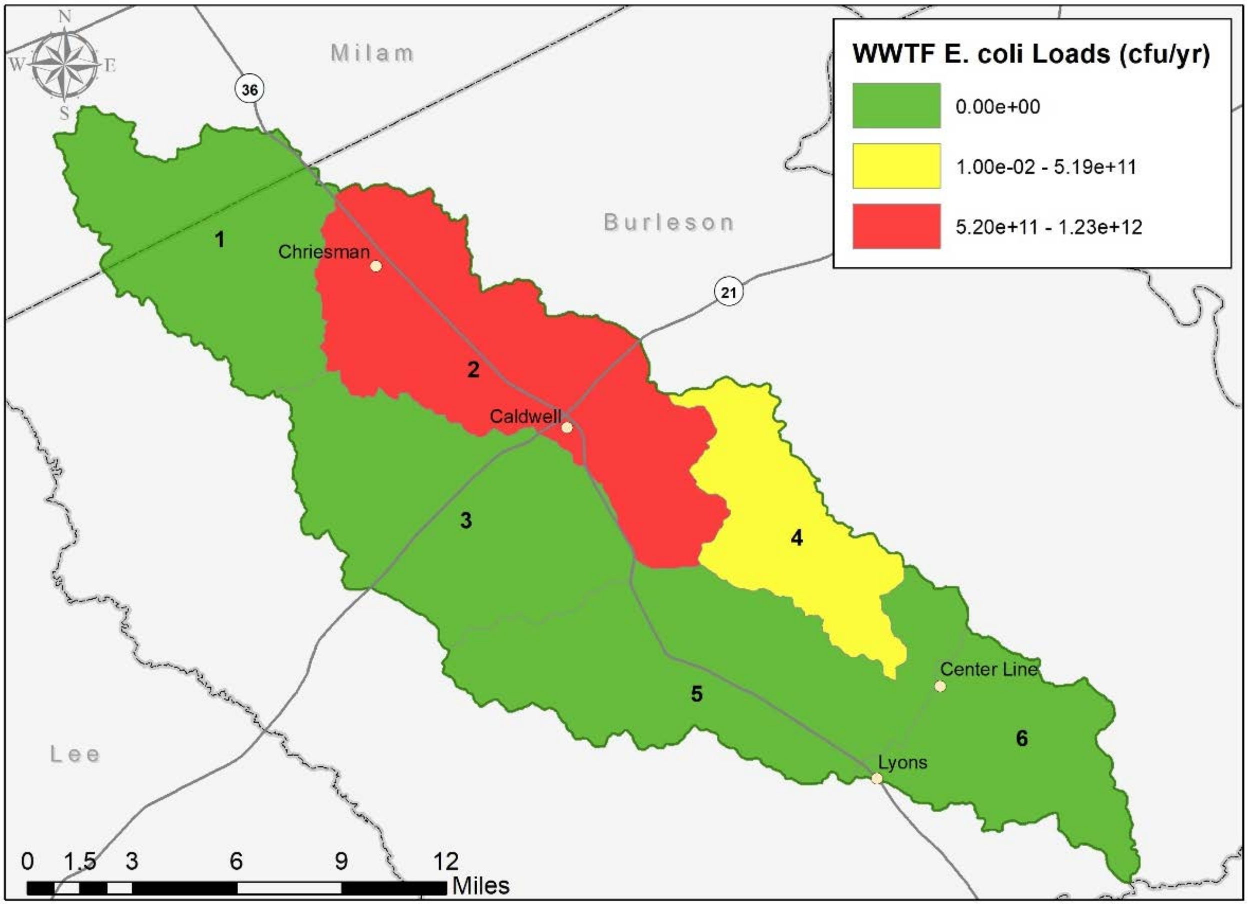

Figure 90. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from wastewater treatment facilities (WWTFs) in the Davidson Creek watershed.

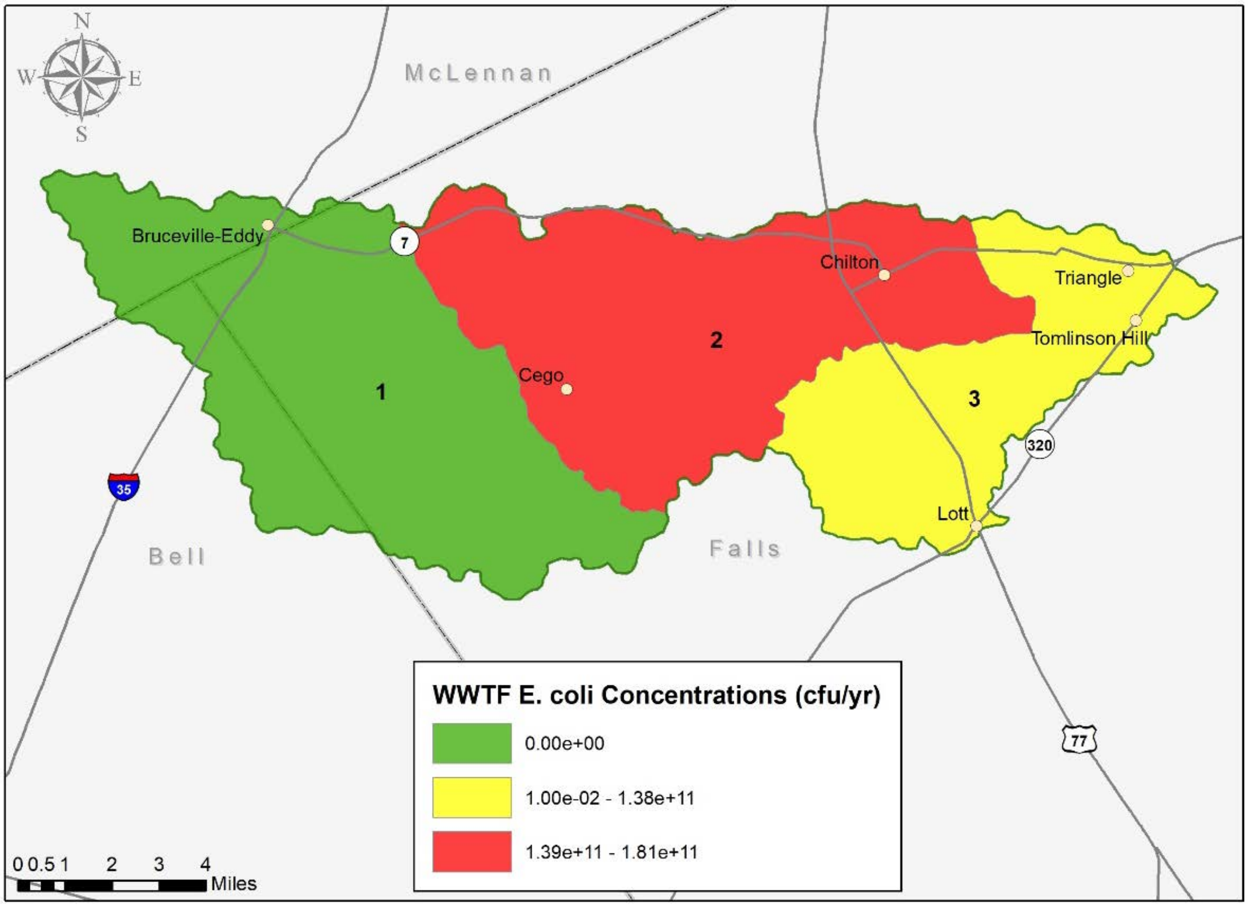

Figure 91. Potential annual bacteria loadings in colony forming units (cfu) per year (yr) from wastewater treatment facilities (WWTFs) in the Deer Creek watershed.

Load Reduction and Sources Summary

The LDCs provided in the first half of this section indicate that the amount of *E. coli* bacteria entering Middle Yegua Creek, Davidson Creek, and Deer Creek exceeds the capacities of those water bodies under all flow conditions except for low flows at SWQM station 11723 in Deer Creek, SWQM station 18349 in Davidson Creek, and SWQM stations 11840 and 11838 in Middle Yegua Creek. Based on these curves, it can be assumed that *E. coli* is entering water bodies under both higher flow and lower flow conditions. Using the LDC approach, a total reduction of 5.27×10^{13} MPN/yr was estimated as needed to meet primary contact recreation standards at the Middle Yegua Creek SWQM station 18750; 5.19×10^{13} MPN/yr at SWQM station 11840; and 1.63×10^{13} MPN/yr at SWQM station 11838. For Davidson Creek, a reduction of 8.28×10^{13} MPN/yr was estimated to meet primary contact recreation standards at SWQM stations 18349; 2.39×10^{14} MPN/yr at SWQM station 21420; and 1.08×10^{14} MPN/yr at SWQM station 11729. For Deer Creek, a reduction of 2.91×10^{13} MPN/yr was estimated to meet primary contact recreation standards at SWQM station 11723, and a reduction of 4.14×10^{12} MPN/yr is needed for SWQM station 18644.

Given the relatively good compliance of permitted dischargers in the watersheds with the exception of the Lexington WWTF in the Middle Yegua Creek watershed, bacteria loading exceedances during low flow conditions are likely attributable to direct deposition from livestock and wildlife in addition to discharges from unregulated failing and faulty OSSFs in riparian zones. Bacteria in runoff are likely to contribute to exceedances during higher flow conditions. Sources of bacteria-laden runoff might include runoff from rangeland and pastures and drainage fields of faulty OSSFs. Although reported SSO events are extremely uncommon in the watersheds, I&I during heavy rainfall events and resulting SSOs or unauthorized discharges may also contribute to elevated loads during some high flow events.

Based on the GIS analysis, bacteria loadings from cattle and livestock are likely to be relatively high compared to other sources (**Error! Not a valid bookmark self-reference.**). Estimated total potential loads are likely conservative because most wildlife sources of fecal bacteria are not included in the analysis.

Identifying where grazed pasture and rangeland in the watersheds are the most concentrated helps to highlight important areas to address and implement potential improvements in pasture and rangeland runoff. GIS analysis suggests relatively high potential for loadings from dogs in subwatersheds that encompass the cities of Lexington, Caldwell, and Bruceville-Eddy; it will be important to address pet waste and stormwater runoff from impervious surfaces in these areas. Deer have moderate potential for *E. coli* loading as compared to other sources. WWTFs and urban stormwater indicated the lowest relative potential for loadings amongst sources assessed.

Table 29. Summary of potential source loads.

Source	Middle Yegua Creek		Davidson Creek		Deer Creek	
	Potential load/year	Highest priority subwatersheds	Potential load/year	Highest priority subwatersheds	Potential load/year	Highest priority subwatersheds
Cattle	1.06×10^{17}	5 & 8	5.41×10^{16}	5	1.35×10^{16}	2
Horses	9.61×10^{13}	5 & 8	3.81×10^{13}	2 & 5	2.07×10^{13}	1
Goats	1.26×10^{15}	5, 6, 7, & 8	4.16×10^{14}	2 & 5	3.03×10^{14}	1
Sheep	1.07×10^{16}	5 & 8	3.87×10^{15}	2 & 5	5.05×10^{15}	1
Deer	2.47×10^{15}	5 & 7	1.20×10^{15}	2 & 5	9.98×10^{14}	1
Feral hogs	2.79×10^{14}	5 & 7	1.36×10^{14}	2 & 5	7.20×10^{13}	1
On-site sewage facilities	7.93×10^{15}	5	4.79×10^{15}	3 & 5	3.85×10^{15}	1
Dogs	2.59×10^{15}	5	2.80×10^{15}	2 & 3	1.15×10^{15}	1
Wastewater treatment facilities	3.46×10^{11}	6	1.75×10^{12}	2	3.20×10^{11}	2
Totals	1.31×10^{17}		6.74×10^{16}		2.49×10^{16}	

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Appendix A: DAR Method Used for LDC Development

Hydrologic data in the form of daily streamflow records were unavailable for the Deer Creek watershed. However, streamflow records were available for the nearby Middle Bosque River watershed of similar land cover characteristics. There were also some instantaneous streamflow records from 2010 to 2011 at SWQM station 11723 in the watershed. Due to the absence of flow records within the impaired watershed, the naturalized flow was constructed using the DAR approach.

Both sets of flow data, instantaneous flows at SWQM station 11723 and USGS gaged daily streamflow in the Middle Bosque River near McGregor, TX (USGS Gage 08095300) were used to estimate the DAR parameters. The watershed boundaries were delineated above both SWQM stations in the Deer Creek watershed and the USGS gage in the Middle Bosque River watershed using 10-meter digital elevation models. The influence of the discharge from the city of Crawford WWTF in the Middle Bosque watershed was removed by subtracting the full permitted flow from the gaged record so that the reference flow is considered to be naturalized flow. Prior to the estimation of DAR parameters, zero flows were removed in order for the log transformation to be applied (Asquith et al. 2006).

A generalized DAR method with two parameters ϕ (exponent) and κ (bias correction factor) was applied to simulate flows on days that instantaneous flows were measured (Asquith et al. 2006). A simulation evaluation coefficient, the Nash-Sutcliffe efficiency, was calculated by comparing simulated flow and observed (instantaneous) flow at each exceedance probability. Table 30 provides the DAR used to develop streamflows at SWQM stations 11723 and 18644. Further information and equations used to calculate the DAR for the Deer Creek watershed can be found in Asquith et al. (2006).

Table 30. Drainage area ratios used to develop daily streamflow records.

Waterbody	Station	Area (square miles)	κ	ϕ
Middle Bosque River	U.S. Geological Survey 08095300	183.372	Not applicable	Not applicable
Deer Creek	Surface water quality monitoring (SWQM) 18644	81.504	1.661	5.190
Deer Creek	SWQM 11723	114.194	1.661	5.190
Nash-Sutcliffe efficiency	0.761	-	-	-

Appendix B: Annual Bacteria Load Reductions

LDCs and measured loads are summarized by range of flows (high, mid-range, and low). The generalized loading capacity for each of the three flow categories was computed by using the median daily loading capacity within that flow regime (12.5%, 50%, and 87.5% load exceedances). The required daily load reduction was calculated as the difference between the median loading capacity and the geometric mean of observed *E. coli* loading within each flow category. To estimate the needed annual bacteria load reductions, the required daily load was multiplied by the number of days per year in each flow condition. Table 31 includes the calculations used to determine annual reductions in each flow condition. The sum of load reductions within each flow condition is the estimated annual load reductions required in the watersheds.

Table 31. Bacteria load reduction calculations by flow condition.

	Flow conditions		
	High	**Mid-range**	**Low**
Days per year	25% × 365	50% × 365	25% × 365
Median flow (cubic feet per second)	Median observed or median estimated flow in each flow category		
Existing geomean concentration (most probable number [MPN]/100 milliliters [mL])	Geometric mean of observed *E. coli* samples in each flow category		
Allowable daily load (billion MPN)	Median Flow × 126 MPN/100 mL × 283.2 100 mL/cubic foot × 86400 seconds/day		
Allowable annual load (billion MPN)	Allowable daily load × days per year		
Existing daily load (billion MPN)	Median flow × existing geomean concentration × 283.2 100 mL/cubic foot × 86,400 seconds/day		
Existing annual load (billion MPN)	Existing daily load × days per year		
Annual load reduction needed (billion MPN)	Existing annual load – allowable annual load		
Percent reduction needed	(Existing annual load – allowable annual load)/existing annual load × 100		
Total annual load (billion MPN)	Sum of existing annual loads		
Total annual load reduction (billion MPN)	Sum of annual load reductions needed		
Total percent reduction	Total annual load reduction/total annual load × 100		

Appendix C: Potential Bacteria Loading Calculations

The SELECT geospatial analysis (Borel et al. 2012) methodology was used to estimate potential bacteria loads in the watersheds and their respective subwatersheds. This approach estimates potential loads by subwatershed. This geospatial approach also provides an easy method to understand relative contributions and spatial distribution across the watersheds without relying on data intense (and expensive) modelling approaches.

This analysis distributes inputs across the watersheds based on land use and land cover attributes. The bacteria loadings are calculated from published bacteria production data. The loadings are then spatially distributed across the watersheds based on appropriate land cover.

Livestock Bacteria Loading Estimates

Cattle populations were estimated across the watershed based on remote-sensed land use data (Homer et al. 2015). The assumptions used in this method are documented in Wagner and Moench (2009) and Borel et al. (2015; Table 32, Table 33, and Table 34).

Table 32. Bacteria loading assumptions for cattle in the Middle Yegua Creek watershed.

Assumptions	
Acres of unimproved rangeland	19,957 acres
Acres of improved pasture	155,249 acres
Cattle stocking density on unimproved pasture	10 acres per animal unit
Cattle stocking density on improved pasture	3 acres per animal unit
Cattle on unimproved range	1,995 animal units
Cattle on improved range	51,750 animal units
Total cattle in the watershed	53,745 animal units
Animal unit conversion factor	1 (Wagner and Moench 2009)
Fecal coliform production rate	8.55×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 33. Bacteria loading assumptions for cattle in the Davidson Creek watershed.

Assumptions	
Acres of unimproved rangeland	4,095 acres
Acres of improved pasture	81,343 acres
Cattle stocking density on unimproved pasture	10 acres per animal unit
Cattle stocking density on improved pasture	3 acres per animal unit
Cattle on unimproved range	410 animal units
Cattle on improved range	27,114 animal units
Total cattle in the watershed	27,524 animal units
Animal unit conversion factor	1 (Borel et al. 2015)
Fecal coliform production rate	8.55×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 34. Bacteria loading assumptions for cattle in the Deer Creek watershed.

Assumptions	
Acres of unimproved rangeland	25,658 acres
Acres of improved pasture	12,865 acres
Cattle stocking density on unimproved pasture	10 acres per animal unit
Cattle stocking density on improved pasture	3 acres per animal unit
Cattle on unimproved range	2,566 animal units
Cattle on improved range	4,288 animal units
Total cattle in the watershed	6,854 animal units
Animal unit conversion factor	1 (Borel et al. 2015)
Fecal coliform production rate	8.55×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

We then calculate potential annual loadings as:

$$\textit{Number of cattle} \times \textit{fecal coliform loading rate} \times \textit{animal unit conversion} \times \textit{factor conversion rate} \times 365 \textit{ days/yr}$$

While cattle are the predominate livestock found throughout the counties, some contributions from horses and goats are expected (other livestock are present in the watersheds, but population estimates assume these to be extremely minor). The numbers of these livestock were estimated using NASS agricultural census counts and the ratio of nonurban county land in the watersheds to the ratio of nonurban land in the counties. Wagner and Moench (2009) and Borel et al. (2015) document the assumptions used in potential daily load calculations for other livestock (Table 35, Table 36, Table 37). Based on these assumptions, potential bacteria load from cattle for the Middle Yegua Creek watershed is 1.06×10^{17} cfu/yr. For the Davidson Creek watershed, the potential bacteria load from cattle is 5.41×10^{16} cfu/yr, and for the Deer Creek watershed, the potential bacteria load from cattle is 1.35×10^{16} cfu/yr.

Table 35. Bacteria loading assumptions for other livestock in the Middle Yegua Creek watershed

Assumptions	
Total number of horses in the watershed	1,149 horses
Total number of goats in the watershed	1,268 goats
Total number of sheep in the watershed	805 sheep
Animal unit conversion factor for horses	1.25 (Borel et al. 2015)
Animal unit conversion factor for goats	0.17 (Borel et al. 2015)
Animal unit conversion factor for sheep	0.2 (Borel et al. 2015)
Fecal coliform production rate for horses	2.91×10^{8} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for goats	2.54×10^{10} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for sheep	2.90×10^{11} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 36. Bacteria loading assumptions for other livestock in the Davidson Creek watershed

Assumptions	
Total number of horses in the watershed	456 horses
Total number of goats in the watershed	419 goats
Total number of sheep in the watershed	290 sheep
Animal unit conversion factor for horses	1.25 (Borel et al. 2015)
Animal unit conversion factor for goats	0.17 (Borel et al. 2015)
Animal unit conversion factor for sheep	0.2 (Borel et al. 2015)
Fecal coliform production rate for horses	2.91×10^{8} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for goats	2.54×10^{10} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for sheep	2.90×10^{11} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 37. Bacteria loading assumptions for other livestock in the Deer Creek watershed

Assumptions	
Total number of horses in the watershed	247 horses
Total number of goats in the watershed	305 goats
Total number of sheep in the watershed	379 sheep
Animal unit conversion factor for horses	1.25 (Borel et al. 2015)
Animal unit conversion factor for goats	0.17 (Borel et al. 2015)
Animal unit conversion factor for sheep	0.2 (Borel et al. 2015)
Fecal coliform production rate for horses	2.91×10^{8} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for goats	2.54×10^{10} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for sheep	2.90×10^{11} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

We then calculate potential annual loadings as:

Number of livestock × fecal coliform loading rate × animal unit conversion × factor conversion rate × 365 days/yr

Based on these assumptions, the annual potential load from horses for the Middle Yegua Creek watershed is 9.61×10^{13} cfu/yr, from goats is 1.26×10^{15} cfu/yr, and from sheep is 1.07×10^{16} cfu/yr. For the Davidson Creek watershed, the annual potential load from horses is 3.81×10^{13} cfu/yr, from goats is 4.16×10^{14} cfu/yr, and from sheep is 3.87×10^{15} cfu/yr. For the Deer Creek watershed, the annual potential load from horses is 2.07×10^{13} cfu/yr, from goats is 3.03×10^{14} cfu/yr, and from sheep is 5.05×10^{15} cfu/yr.

Dog Bacteria Loading Estimates

The dog populations in the watersheds were estimated using AVMA statistics for average number of dogs per household and an estimate of number of households derived from U.S. Census block data (Table 38, Table 39, Table 40). The potential annual bacteria load from household pets is:

Average number of dogs per home × number of homes × dog fecal coliform loading rate × conversion rate × 365 days/yr

Table 38. Bacteria loading assumptions for dogs in the Middle Yegua Creek watershed.

Assumptions	
Average dogs per home	0.614 dogs (AVMA 2018)
Number of homes	3,675 homes
Estimated number of dogs	2,256 dogs
Fecal coliform production rate for dogs	5.0×10^9 colony forming units (cfu)/dog/day (Borel et al. 2015)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 39. Bacteria loading assumptions for dogs in the Davidson Creek watershed.

Assumptions	
Average dogs per home	0.614 dogs (AVMA 2018)
Number of homes	3,965 homes
Estimated number of dogs	2,435 dogs
Fecal coliform production rate for dogs	5.0×10^9 colony forming units (cfu)/dog/day (Borel et al. 2015)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 40. Bacteria loading assumptions for dogs in the Deer Creek watershed.

Assumptions	
Average dogs per home	0.614 dogs (AVMA 2018)
Number of homes	1,633 homes
Estimated number of dogs	746 dogs
Fecal coliform production rate for dogs	5.0×10^9 colony forming units (cfu)/dog/day (Borel et al. 2015)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

The annual potential bacteria load from dogs for the Middle Yegua Creek watershed is 2.59×10^{15} cfu/yr. For the Davidson Creek watershed, the annual potential bacteria load from dogs is 2.80×10^{15} cfu/yr. For the Deer Creek watershed, the annual potential bacteria load from dogs is 1.15×10^{15} cfu/yr.

OSSF Bacteria Loading Estimates

OSSF locations in the watersheds were estimated with visually validated 911 address data. Nearly all the OSSFs occur on soils with an expected failure rate of 15%. Loadings were calculated using the SELECT methodology with the assumptions outlined in Table 41,

Table 42, and Table 43. Different numbers of people per household were assigned to different subwatersheds based on available U.S. Census block data. The potential annual bacteria load from OSSFs is:

$$\textit{Number of OSSFs} \times \textit{failure rate} \times \textit{average people per household} \times \textit{sewage discharge rate} \times \textit{fecal coliform concentration in sewage} \times \textit{mL to gal conversion} \times \textit{conversion rate} \times \textit{365 days/yr}$$

Table 41. Bacteria loading assumptions for on-site sewage facilities (OSSFs) in the Middle Yegua Creek watershed.

Assumptions	
Subwatershed 1 number of on-site sewage facilities (OSSFs)	444
Subwatershed 2 number of OSSFs	389
Subwatershed 3 number of OSSFs	189
Subwatershed 4 number of OSSFs	288
Subwatershed 5 number of OSSFs	632
Subwatershed 6 number of OSSFs	447
Subwatershed 7 number of OSSFs	482
Subwatershed 8 number of OSSFs	398
Subwatershed 9 number of OSSFs	306
Subwatershed 10 number of OSSFs	165
Subwatershed 11 number of OSSFs	213
Failure rate	15% (USDA 2019)
Average number of people per household in the watershed	2.21 (USCB 2010)
Sewage discharge rate	70 gallons (gal)/person/day (Borel et al. 2015)
Fecal coliform concentration in sewage	1.0×10^6 colony forming units (cfu)/100 milliliters (mL; EPA 2001)
Conversion from mL to gal	3,758.2 mL/gal
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 42. Bacteria loading assumptions for on-site sewage facilities (OSSFs) in the Davidson Creek watershed.

Assumptions	
Subwatershed 1 number of on-site sewage facilities (OSSFs)	234
Subwatershed 2 number of OSSFs	428
Subwatershed 3 number of OSSFs	610
Subwatershed 4 number of OSSFs	269
Subwatershed 5 number of OSSFs	553
Subwatershed 6 number of OSSFs	314
Failure rate	15% (USDA 2019)
Average number of people per household in the watershed	2.19 (USCB 2010)
Sewage discharge rate	70 gallons (gal)/person/day (Borel et al. 2015)
Fecal coliform concentration in sewage	10×10^6 colony forming units (cfu)/100 milliliters (mL; EPA 2001)
Conversion from mL to gal	3,758.2 mL/gal
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 43. Bacteria loading assumptions for on-site sewage facilities (OSSFs) in the Deer Creek watershed.

Assumptions	
Subwatershed 1 number of on-site sewage facilities (OSSFs)	752
Subwatershed 2 number of OSSFs	532
Subwatershed 3 number of OSSFs	401
Failure rate	15% (USDA 2019)
Average number of people per household in the watershed	2.52 (USCB 2010)
Sewage discharge rate	70 gallons (gal)/person/day (Borel et al. 2015)
Fecal coliform concentration in sewage	1.0×10^6 colony forming units (cfu)/100 milliliters (mL; EPA 2001)
Conversion from mL to gal	3,758.2 mL/gal
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

The annual potential bacteria load from OSSFs for the Middle Yegua Creek watershed is 7.93×10^{15} cfu/yr. For the Davidson Creek watershed, the annual potential bacteria load from OSSFs is 4.79×10^{15} cfu/yr. For the Deer Creek watershed, the annual potential bacteria load from OSSFs is 3.85×10^{15} cfu/yr.

Feral Hog and Wildlife Bacteria Loading Estimates

Feral hog populations were estimated based on an assumed population density of 33.3 acres/hog (Wagner and Moench 2009) and acres of available habitat identified in the NLCD for each watershed. Potential bacteria loadings from feral hogs were estimated and the assumptions are in Table 44,

Table 45, and Table 46. The potential annual bacteria load from feral hogs is:

Number of feral hogs × animal unit conversion × fecal coliform loading rate × conversion rate × 365 days/yr

Table 44. Bacteria loading assumptions for feral hogs in the Middle Yegua Creek watershed.

Assumptions	
Number of feral hogs in the watershed	8,008
Animal unit conversion factor for feral hogs	0.125
Fecal coliform production rate for feral hogs	1.21×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 45. Bacteria loading assumptions for feral hogs in the Davidson Creek watershed.

Assumptions	
Number of feral hogs in the watershed	3,901
Animal unit conversion factor for feral hogs	0.125
Fecal coliform production rate for feral hogs	1.21×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 46. Bacteria loading assumptions for feral hogs in the Deer Creek watershed.

Assumptions	
Number of feral hogs in the watershed	2,071
Animal unit conversion factor for feral hogs	0.125
Fecal coliform production rate for feral hogs	1.21×10^9 colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

The annual potential bacteria load from feral hogs for the Middle Yegua Creek watershed is 2.79×10^{14} cfu/yr. For the Davidson Creek watershed, the annual potential bacteria load from feral hogs is 1.36×10^{14} cfu/yr. For the Deer Creek watershed, the annual potential bacteria load from feral hogs is 7.20×10^{13} cfu/yr.

White-tailed deer populations were estimated from an assumed population density of 41.65 deer per 1,000 acres of suitable habitat for the Middle Yegua and Davidson Creek watersheds (data provided by TPWD). For the Deer Creek watershed, the assumed population density was 26.69 deer per 1,000 acres of suitable habitat. Potential bacteria loadings were estimated; the assumptions are in Table 47, Table 48, and Table 49. The potential annual bacteria load from white-tailed deer is:

Number of white-tailed deer × animal unit conversion × fecal coliform loading rate × conversion rate × 365 days/yr

Table 47. Bacteria loading assumptions for white-tailed deer in the Middle Yegua Creek watershed.

Assumptions	
Number of white-tailed deer in the watershed	6,403
Animal unit conversion factor for white-tailed deer	0.112
Fecal coliform production rate for white-tailed deer	1.50×10^{10} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 48. Bacteria loading assumptions for white-tailed deer in the Davidson Creek watershed.

Assumptions	
Number of white-tailed deer in the watershed	3,119
Animal unit conversion factor for white-tailed deer	0.112
Fecal coliform production rate for white-tailed deer	1.50×10^{10} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

Table 49. Bacteria loading assumptions for white-tailed deer in the Davidson Creek watershed.

Assumptions	
Number of white-tailed deer in the watershed	2,584
Animal unit conversion factor for white-tailed deer	0.112
Fecal coliform production rate for white-tailed deer	1.50×10^{10} colony forming units (cfu)/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *E. coli* conversion rate	0.63 *E. coli* per cfu fecal coliform (Wagner and Moench 2009)

The annual potential bacteria load from white-tailed deer for the Middle Yegua Creek watershed is 2.47×10^{15} cfu/yr. For the Davidson Creek watershed, the annual potential bacteria load from white-tailed deer is 1.20×10^{15} cfu/yr. For the Deer Creek watershed, the annual potential bacteria load from white-tailed deer is 9.98×10^{14} cfu/yr.

WWTF Bacteria Loading Estimates

Currently, one permitted WWTF operates in the Middle Yegua Creek watershed, two in the Davidson Creek watershed, and two in the Deer Creek watershed. All are permitted to discharge wastewater effluent from treated household sewage and are required to monitor bacteria levels in their discharge. The bacteria loads were estimated at a worst-case scenario of full permitted discharge at 126 cfu/100 mL *E. coli* (**Error! Reference source not found.**, Table 51, Table 52). The potential annual bacteria load from WWTFs is:

Maximum permitted discharge × *bacteria concentration in sewage* × *conversion from mL to gal* × *conversion from gal to MGD* × *365 days/yr*

Table 50. Bacteria loading assumptions for wastewater treatment facilities in the Middle Yegua Creek watershed.

Assumptions	
Subwatershed 6 treated wastewater effluent discharged per day	0.2 million gallons per day (MGD; EPA 2021)
E. coli concentration in sewage	126 colony forming units/100 milliliters (mL)
Conversion from mL to gallons (gal)	3,758.2 mL/gal
Conversion from gal to MGD	10^6 gal/MGD

Table 51. Bacteria loading assumptions for wastewater treatment facilities in the Davidson Creek watershed.

Assumptions	
Subwatershed 2 treated wastewater effluent discharged per day	0.711 million gallons per day (MGD; EPA 2021)
Subwatershed 4 treated wastewater effluent discharged per day	0.3 MGD (EPA 2019)
E. coli concentration in sewage	126 colony forming units/100 milliliters (mL)
Conversion from mL to gallons (gal)	3,758.2 mL/gal
Conversion from gal to MGD	10^6 gal/MGD

Table 52. Bacteria loading assumptions for wastewater treatment facilities in the Deer Creek watershed.

Assumptions	
Subwatershed 2 treated wastewater effluent discharged per day	0.105 million gallons per day (MGD; EPA 2021)
Subwatershed 3 treated wastewater effluent discharged per day	0.08 MGD (EPA 2019)
E. coli concentration in sewage	126 colony forming units/100 milliliters (mL)
Conversion from mL to gallons (gal)	3,758.2 mL/gal
Conversion from gal to MGD	10^6 gal/MGD

The annual potential bacteria load from WWTFs for the Middle Yegua Creek watershed is 3.46×10^{11} cfu/yr. For the Davidson Creek watershed, the annual potential bacteria load from white-tailed deer is 1.75×10^{12} cfu/yr. For the Deer Creek watershed, the annual potential bacteria load from white-tailed deer is 3.20×10^{11} cfu/yr.