Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Poesta Creek

Assessment Unit: 2004B_01

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	construction general permit
DAR	drainage area ratio
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (United States)
FC	flow category
ft^3	cubic feet
FDC	flow duration curve
FG	future growth
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	minimum control measures
MGD	million gallons per day
mL	milliliter
MOS	margin of safety

MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic database
SWMP	stormwater management program
SWQM	surface water quality monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
U.S.	Unites States
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WWTF	wastewater treatment facility

Section 1. Introduction

1.1. Background

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a water body included on a state's 303(d) list of impaired waters. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time but may be expressed in other ways.

The TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The program's primary objective is to restore and maintain water quality uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

TCEQ first identified the bacteria impairment within Poesta Creek assessment unit (AU) 2004B_01 in the *2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ, 2022a). TCEQ first identified a bacteria impairment within the Poesta Creek watershed to the upstream Poesta Creek AU (2004B_02) in the 2014 Texas Water Quality Inventory and 303(d) List (TCEQ, 2015).

This document will consider one bacteria impairment in one AU of Poesta Creek. The impaired AU and its identifying number is:

- Poesta Creek AU 2004B_01

1.2. Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, TCEQ established the *Texas Surface Water Quality Standards* (TCEQ, 2018a). The Standards describe the limits for indicators that are monitored to assess the quality of available water for specific uses. TCEQ monitors and assesses water bodies based on these Standards and publishes the Texas Integrated Report list biennially.

The Standards are rules that do all of the following:

- Designate the uses, or purposes, for which the state's water bodies should be suitable.
- Establish numerical and narrative goals for water quality throughout the state.
- Provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.

Standards are established to protect uses assigned to water bodies. The primary uses assigned to water bodies are:

- aquatic life use
- contact recreation
- domestic water supply
- general use

Fecal indicator bacteria are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Fecal indicator bacteria are bacteria that are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from fecal waste may be reaching water bodies because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2018b). The fecal indicator bacteria used for freshwater in Texas is *Escherichia coli* (*E. coli*), a species of fecal coliform bacteria.

On Feb. 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018a) and on May 19, 2020, the U.S. Environmental Protection Agency (EPA) approved the categorical levels of recreational use and their associated criteria. Recreational use consists of several categories:

- **Primary contact recreation 1** – Activities that are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, handfishing, and the following whitewater activities: kayaking, canoeing, and rafting). It has a geometric mean criterion for *E. coli* of 126 colony forming units (cfu) per 100 milliliters (mL) and an additional single sample criterion of 399 cfu per 100 mL.

- **Primary contact recreation 2** – Water recreation activities, such as wading by children, swimming, water skiing, diving, tubing, surfing, handfishing, and whitewater kayaking, canoeing, and rafting, that involve a significant risk of ingestion of water but that occur less frequently than for primary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 206 cfu per 100 mL.

- **Secondary contact recreation 1** – Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation 1 or 2 but more than secondary contact recreation 2. The geometric mean criterion for *E. coli* is 630 cfu per 100 mL.

- **Secondary contact recreation 2** – Activities with limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 1,030 cfu per 100 mL.
- **Noncontact recreation** – Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic. The geometric mean criterion for *E. coli* is 2,060 cfu per 100 mL.

Poesta Creek (AU 2004B_01) is a freshwater stream and has a primary contact recreation 1 use. The associated criterion for *E. coli* is a geometric mean of 126 cfu per 100 mL.

1.3. Report Purpose and Organization

The Poesta Creek TMDL project was initiated through a contract between TCEQ and Texas Water Resources Institute (TWRI). The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired AU. This report contains:

- Information on historical data.
- Watershed properties and characteristics.
- Summary of historical bacteria data that confirms the Texas 303(d) listings of impairment due to concentrations of *E. coli*.
- Development of a load duration curve (LDC).
- Application of the LDC approach for developing the pollutant load allocation.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed *Two Total Maximum Daily Loads for Indicator Bacteria in the Tidal Segments of the Mission and Aransas Rivers* and its addendum, *Addendum One to Two Total Maximum Daily Loads for Indicator Bacteria in the Tidal Segments of the Mission and Aransas Rivers* (TCEQ 2016; TCEQ 2017).

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

Poesta Creek runs from northwest of Beeville and flows approximately 28.73 miles southeast to Aransas River Above Tidal (AU 2004_02) (Figure 1). It consists of a single segment (2004B) and two AUs (2004B_01 and 2004B_02). This document will consider the contact recreation use impairment of the downstream AU of Poesta Creek (2004B_01). The drainage area for AU 2004B_01, including the contributing area from upstream AU 2004B_02, is 123.06 square miles (78,765.53 acres) and is located entirely in Bee County.

The 2022 Texas Integrated Report (TCEQ, 2022a) has the following water body and AU descriptions:

- Poesta Creek (Segment 2004B) – From the confluence with the Aransas River to the headwaters of the stream about 7.5 kilometers upstream of Farm-to-Market Road 673.
  - AU 2004B_01 – From the confluence of the Aransas River to the confluence of Talpacate Creek.
  - AU 2004B_02 – From the confluence with Talpacate Creek to the headwaters of the stream approximately 7.5 kilometers upstream of Farm-to-Market Road 673.

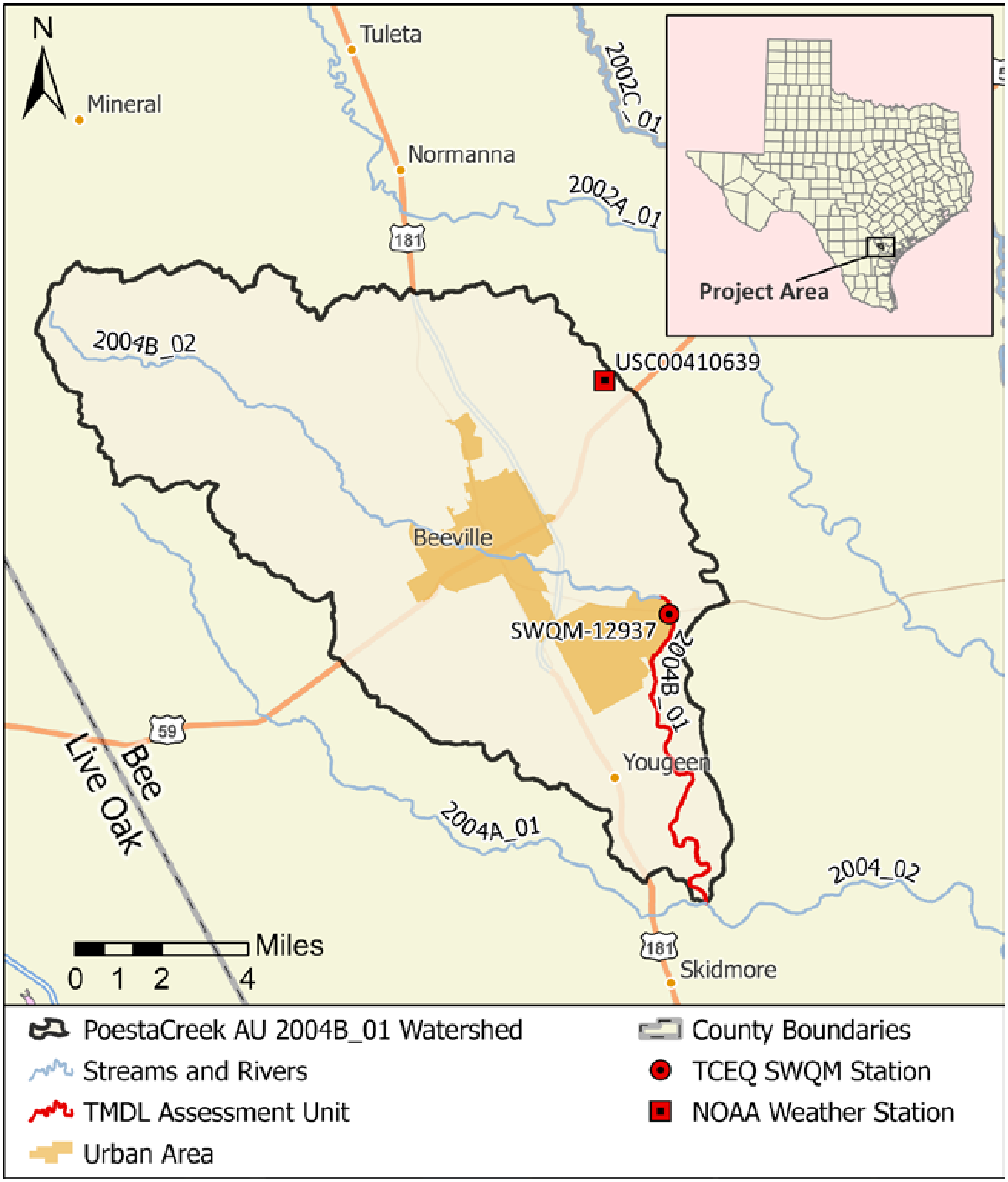

Figure 1. **Map of the project watershed**

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Recent water quality monitoring has occurred at one TCEQ surface water quality monitoring (SWQM) station (12937) within Poesta Creek AU 2004B_01 (Figure 1). *E. coli* data collected at this station over the seven-year period of Dec. 1, 2013, to Nov. 30, 2020, were used in assessing attainment of the primary contact recreation use as reported in the 2022 Texas Integrated Report (TCEQ, 2022a). The 2022 assessment data indicate non-support of the primary contact recreation use because the geometric mean concentrations exceeded the geometric criterion of 126 cfu/100 mL, as summarized in Table 1.

Table 1. 2022 Texas Integrated Report summary for the Poesta Creek watershed

Watershed	AU	Parameter	SWQM Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Poesta Creek	2004B_01	*E. coli*	12937	21	12/01/13 – 11/30/20	269.79

2.3. Climate and Hydrology

Regional precipitation and temperature data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center database. The precipitation and temperature data were obtained from the Beeville 5 NE, TX weather station (USC00410639) for a 15-year period from 2008 through 2022 (NOAA, 2023). The highest average monthly precipitation is observed in September at 4.02 inches and the lowest monthly precipitation is observed in February at 1.17 inches (Figure 2). The highest observed monthly maximum temperatures occur in August (96.52 F) and the lowest average monthly minimum temperatures occur in January (42.59 F). The mean annual recorded precipitation within the 15-year period between 2008 and 2022 was 30.28 inches.

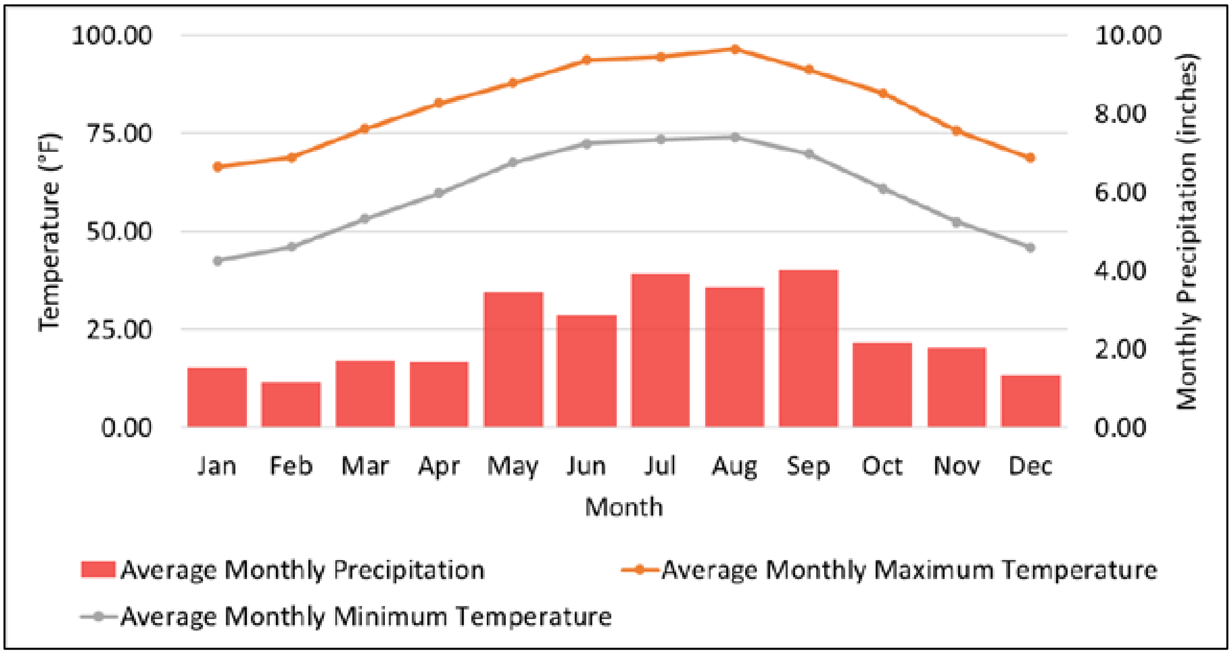

Figure 2. **Average Monthly temperature and precipitation (2008 – 2022) at Beeville 5 NE, TX station USC00410639 (NOAA 2023)**

2.4. Population and Population Projections

Watershed population estimates were developed using the U.S. Census Bureau (USCB) 2020 census blocks (USCB, 2020a) and 2020 decennial population data (USCB, 2020b). The Poesta Creek watershed includes 778 census blocks, located entirely or partially in the watershed. Population was estimated for those census blocks partially located in the watershed by multiplying the census block population and the percent of each block within the AU watershed. It was assumed for this estimation that populations were evenly distributed within the census block. These estimated partial census block populations were then summed with the populations from the census blocks located entirely within the TMDL watershed. Using this methodology, the Poesta Creek watershed population is estimated at 21,357 (Figure 3).

Population projections for Bee County in Table 2 are obtained from the Texas Water Development Board (TWDB) 2021 Regional Water Plan Population and Water Demand Projection data (TWDB, 2019). These population projections indicate a 6.31% increase for the Bee County from 2020 through 2070. The decadal proportional increases from the Bee County estimates were applied to the estimated 2020 watershed population to estimate future total population (Table 3). A step-by-step process for future watershed population is described in Appendix A.

Table 2. Population projections for Bee County

Area	2020 Population	2030 Projected Population	2040 Projected Population	2050 Projected Population	2060 Projected Population	2070 Projected Population
Bee County	33,478	34,879	35,487	35,545	35,579	35,590
Percent Increase	-	4.18%	1.74%	0.16%	0.1%	0.03%

Table 3. Population projection for the Poesta Creek watershed

Area	2020 Population	2030 Projected Population	2040 Projected Population	2050 Projected Population	2060 Projected Population	2070 Projected Population	2020 – 2070 Percent increase
Poesta Creek Watershed	21,357	22,251	22,639	22,676	22,698	22,705	6.31%

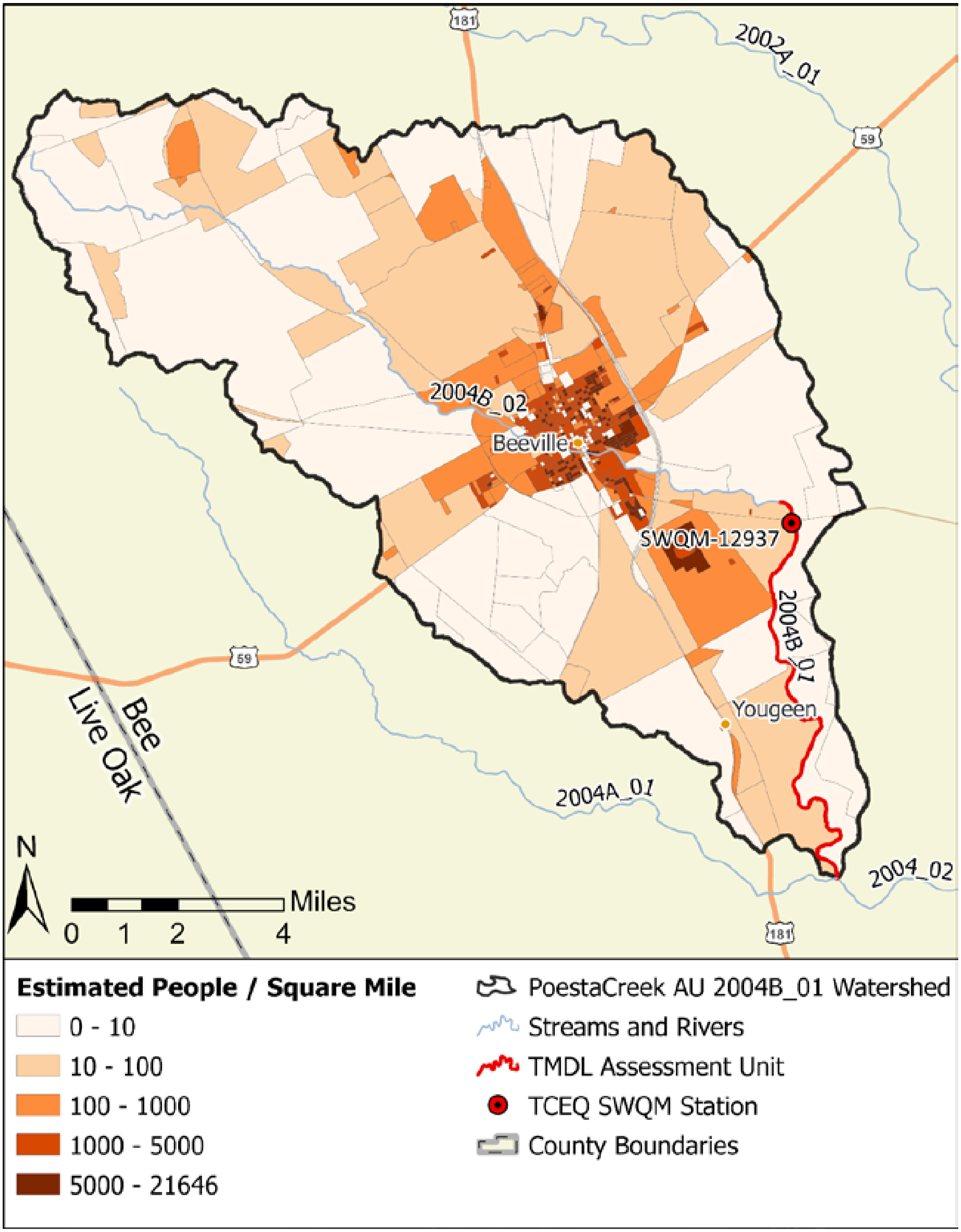

Figure 3. Population density estimate based on 2020 U.S. Census block data in the Poesta Creek watershed

2.5. Land Cover

Land cover data for the TMDL watershed were obtained from the 2019 National Land Cover Database (NLCD) (USGS, 2021), and are displayed in Figure 4. The following categories and definitions represent land cover in the NLCD database:

- **Open Water** – Areas of open water, generally with less than 25% cover of vegetation or soil.
- **Developed, Open Space** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Developed, Low Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
- **Developed, Medium Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of total cover. These areas most commonly include single-family housing units.
- **Developed, High Intensity** – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of total cover.
- **Barren Land (Rock/Sand/Clay)** – Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
- **Deciduous Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- **Evergreen Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. More than 75% of the species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% total tree cover.

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

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

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

- **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 substrate is periodically saturated with or covered with water.

A summary of the land cover data is provided in Table 4. The Poesta Creek watershed encompasses a total of 78,765.53 acres and is predominantly composed of Shrub/Scrub (39.75%) and Pasture/Hay (31.7%). The total developed area accounts for 10.75% of the watershed.

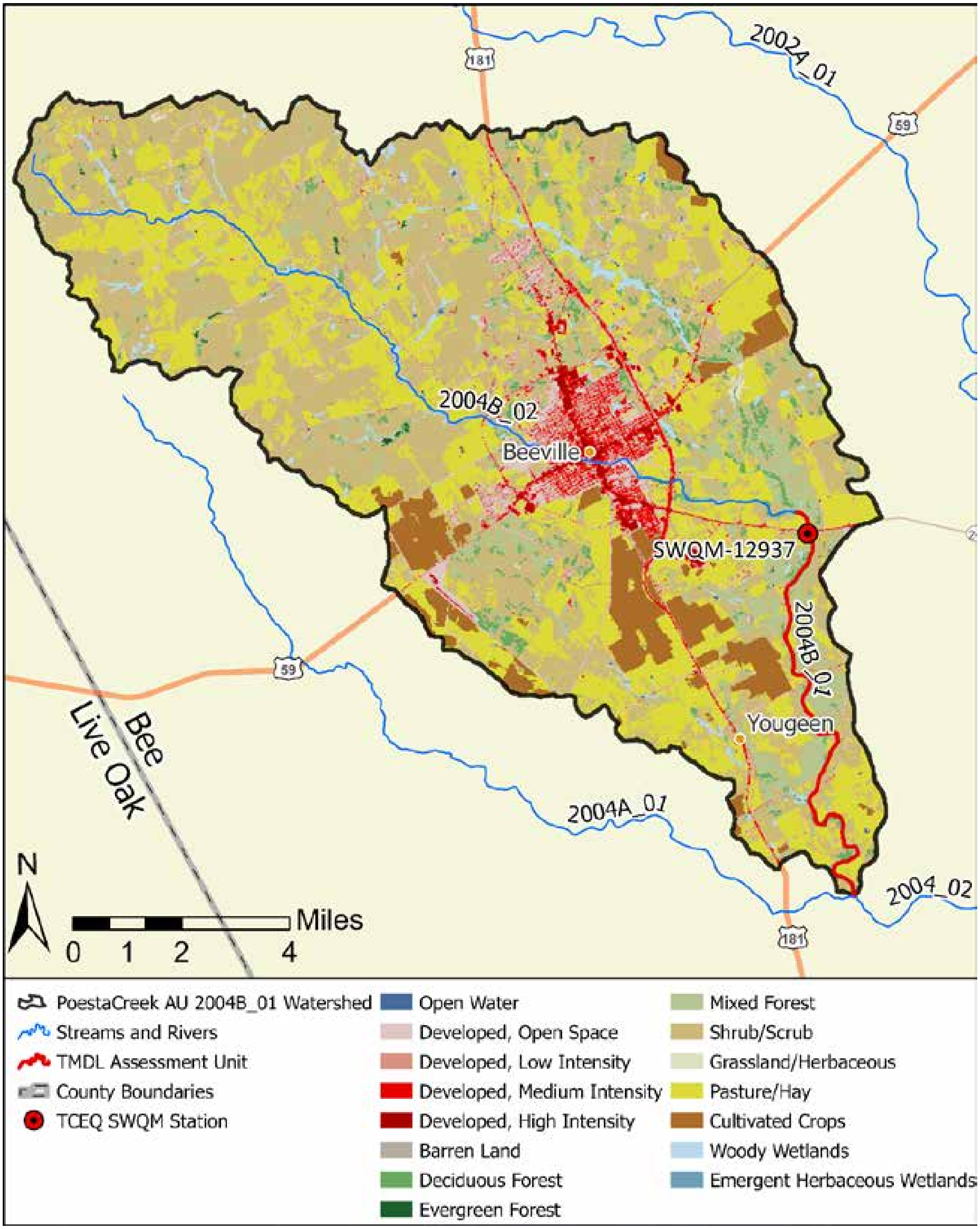

Figure 4. Land cover in the Poesta Creek watershed based on the 2019 NLCD

Table 4. Land cover summary in the Poesta Creek watershed

Land Cover Type	Area (acres)	Percent Total (%)
Open Water	43.14	0.05%
Developed, Open Space	3,369.64	4.28%
Developed, Low Intensity	2,788.46	3.54%
Developed, Medium Intensity	1,741.46	2.21%
Developed, High Intensity	567.76	0.72%
Barren Land	142.96	0.18%
Deciduous Forest	2,142.86	2.72%
Evergreen Forest	75.66	0.10%
Mixed Forest	5,165.63	6.56%
Shrub/Scrub	31,312.97	39.75%
Grassland/Herbaceous	173.18	0.22%
Pasture/Hay	24,967.90	31.70%
Cultivated Crops	4,509.02	5.72%
Woody Wetlands	1,702.57	2.16%
Emergent Herbaceous Wetlands	62.32	0.08%
Total	**78,765.53**	**100%[a]**

[a] Total differs slightly from 100% due to rounding.

2.6. Soils

Soils within the Poesta Creek watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (NRCS, 2018). The SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. 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 SSURGO database defines the classifications below.

- Group A – Soils having 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 having 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 having 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 having 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.

A summary of soil types is provided in Table 5. The Poesta Creek watershed is predominantly split between Group C (35.47%), Group B (29.94%) and Group D (22.94%). Spatial distribution of soil hydrologic groups within the project watershed are shown in Figure 5.

Table 5. Hydrologic soil group summary in the Poesta Creek watershed

Hydrologic Soil Group	Area (acres)	Percent Total (%)
A	1,403.37	1.78%
B	23,582.53	29.94%
C	27,936.52	35.47%
C/D	7,777.4	9.87%
D	18,065.71	22.94%
Total	**78,765.53**	**100%**

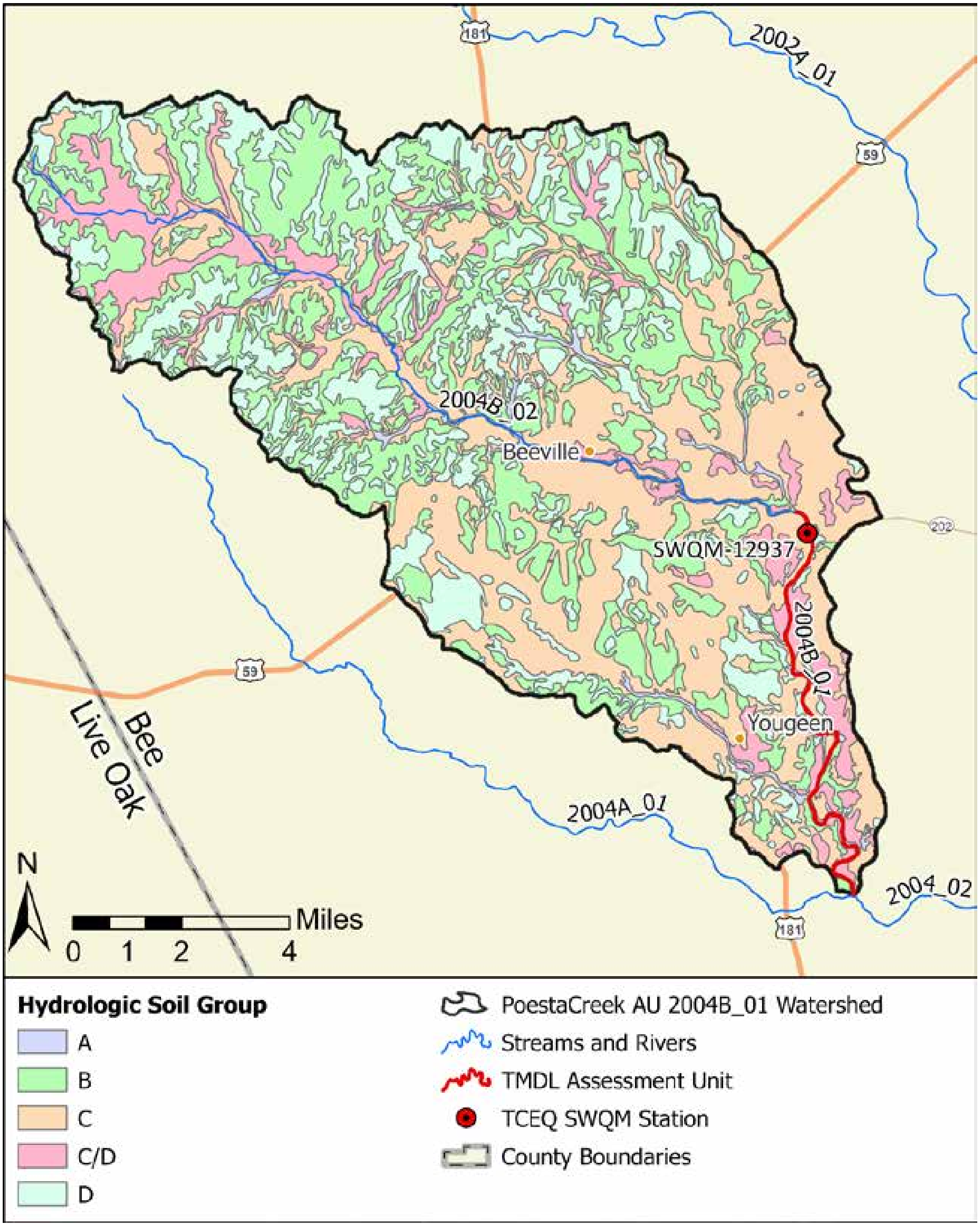

Figure 5. Hydrologic soil groups within the Poesta Creek watershed

2.7. Potential Sources of Fecal Indicator Bacteria

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as “point sources,” come from a single definable point, such as a pipe, and are controlled by permit under the Texas Pollutant Discharge Elimination System (TPDES) program. Wastewater treatment facilities (WWTFs) and stormwater discharges from industrial sites, regulated construction activities, and the separate storm sewer systems of cities are considered point sources of pollution.

Unregulated sources are typically nonpoint source in origin, meaning the pollutants originate from multiple locations and rainfall runoff washes them into surface waters. Nonpoint sources are not regulated by permits.

Except for WWTFs, which receive individual wasteload allocations (WLAs) (see the “WLA” section), the regulated and unregulated sources in this section are presented to give a general account of the various sources of bacteria expected in the watershed. These are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

2.7.1. Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watershed include WWTF outfalls, sanitary sewer overflows (SSOs), stormwater discharges from industrial and regulated construction sites, and other miscellaneous sources.

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

As of December 2022, there is one facility with a TPDES permit that operates within the watershed (TCEQ, 2022b; EPA, 2022; Figure 6). The Moore Street WWTP treats domestic wastewater with a daily average discharge limit of 3.0 million gallons per day (MGD; Table 6).

Table 6. Permitted domestic WWTFs

AU	TPDES/ NPDES Number	Permittee	Outfall Number	Bacteria Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD[b])	Daily Average Flow – Recent Discharge (MGD) [c]
2004B_01	WQ0010124002/ TX0047007	Moore Street WWTP	1	120	Treated domestic wastewater	3.0	1.86

[a] NPDES: National Pollutant Discharge Elimination System

[b] MGD: million gallons per day

[c] Reflects mean of daily discharges between Jan. 1, 2020 and Dec. 31, 2022

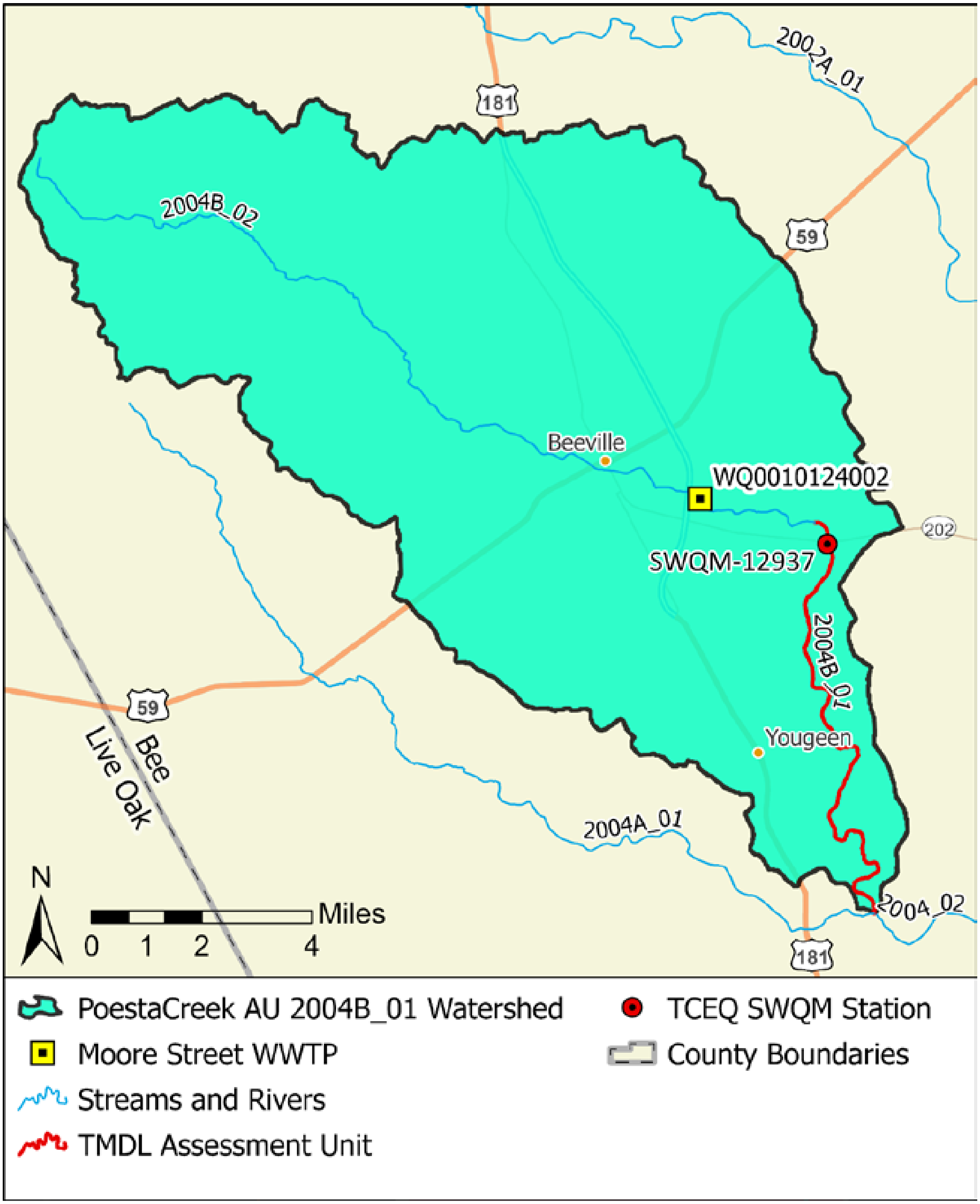

Figure 6. **Active permitted WWTFs in the Poesta Creek watershed**

2.7.1.2 TCEQ/TPDES General Wastewater Permits

Certain types of activities must be covered by one of several TCEQ/TPDES wastewater general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- TXG920000 – concentrated animal feeding operations
- WQG100000 – wastewater evaporation
- WQG200000 – livestock manure compost operations (irrigation only)

The following general permit authorizations are not considered to affect the bacteria loading in the TMDL watershed and were excluded from this investigation:

- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- WQG100000 – wastewater evaporation

A review of active general permits (TCEQ, 2022c) in the Poesta Creek watershed found one general permit authorization for concrete production facilities as of December 2022. These facilities do not have bacteria reporting requirements or limits in their permits. They are assumed to contain inconsequential amounts of indicator bacteria in their effluent; therefore, it was unnecessary to allocate bacteria loads to these facilities. No other active wastewater general permit authorizations were found.

2.7.1.3. TPDES-Regulated Stormwater

When evaluating stormwater for a TMDL allocation, a distinction must be made between stormwater originating from an area under a TPDES-regulated discharge permit and stormwater originating from areas not under a TPDES-regulated discharge permit. Stormwater discharges fall into two categories:

1. Stormwater subject to regulation, which is any stormwater originating from TPDES-regulated municipal separate storm sewer system (MS4) entities, stormwater discharges associated with regulated industrial activities, and construction activities.
2. Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities in urbanized areas to obtain permit coverage for their stormwater systems. A regulated

MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized communities with populations of 100,000 or more based on the 1990 U.S. Census, while the Phase II General Permit regulates other MS4s within a USCB defined urbanized area.

The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the “maximum extent practicable” by developing and implementing a stormwater management program (SWMP). The SWMP describes the stormwater control practices that the regulated entity will implement, consistent with permit requirements, to minimize the discharge of pollutants. MS4 permits require that SWMPs specify the best management practices to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies. Phase II MS4 MCMs include all of the following:

- Public education, outreach, and involvement.
- Illicit discharge detection and elimination.
- Construction site stormwater runoff control.
- Post-construction stormwater management in new development and redevelopment.
- Pollution prevention and good housekeeping for municipal operations.
- Industrial stormwater sources (only required for MS4s serving a population of 100,000 people or more in the urban area).
- Authorization for construction activities where the small MS4 is the site operator (*optional*).

Phase I MS4 individual permits have their own set of MCMs that are similar to the Phase II MCMs, but Phase I permits have additional requirements to perform water quality monitoring and implement a floatables program. The Poesta Creek watershed contains no Phase I permits.

Discharges of stormwater from a Phase II MS4 area, regulated industrial facility, construction area, or other facility involved in certain activities must be authorized under one of the following general permits:

- TXR040000 – Phase II MS4 General Permit for small MS4s located in urbanized areas (discussed above)
- TXR050000 – Multi-Sector General Permit (MSGP) for industrial facilities
- TXR150000 – Construction General Permit (CGP) for construction activities disturbing more than one acre or are part of a common plan of development disturbing more than one acre

The Poesta Creek TMDL watershed does not include any Phase II MS4 permit authorizations. General permit authorizations were obtained from the TCEQ Central Registry. Table 7 includes a summary of active stormwater general permits in the project watershed as of Dec. 20, 2022 (TCEQ, 2022b). The acreage associated with active stormwater general permits was estimated by importing location information into a Geographic Information System and measuring the estimated disturbed area from available aerial imagery.

Construction permits were summarized by average yearly acreage for permits issued over the entire available period of record. Over that period, 20 construction permits were issued in the Poesta Creek watershed.

Table 7. Summary of land area covered by TPDES-regulated stormwater permits in the Poesta Creek watershed

AU	MSGP (count)	MSGP (acres)	CGP (count)	CGP (average acres)	Total Area of Permits (acres)
2004B_01	6	30.43	20	42.138	72.568

2.7.1.4. Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. These overflows 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 overflows under conditions of high flow in the WWTF system. Blockages in the line may worsen the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

TCEQ Central Office in Austin provided statewide data on SSO incidents from January 2016 through December 2022 (TCEQ 2022d). All SSO incidents were due to a temporary blockage of the collection system. Table 8 summarizes the number of SSO incidents reported by regulated entities operating within the watershed.

Table 8. Summary of reported SSO events (from 2016 through 2022) in the Poesta Creek watershed (in gallons)

AU	Estimated Incidents	Total Volume	Minimum Volume	Maximum Volume
2004B_01	22	249,480	30	93,750

2.7.1.5. Dry Weather Discharges/Illicit Discharges

Pollutant loads can enter water bodies from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry- and wet-weather conditions. The term “illicit discharge” is defined in TPDES General Permit TXR040000 for Phase II MS4s as “Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities."

Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges included in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct Illicit Discharges:

- Sanitary wastewater piping that is directly connected from a home to the storm sewer.
- Materials that have been dumped illegally into a storm drain catch basin.
- A shop floor drain that is connected to the storm sewer.
- A cross-connection between the sanitary sewer and storm sewer systems.

Indirect Illicit Discharges:

- An old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line.
- A failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.7.2. Unregulated Sources

Unregulated sources of bacteria are generally nonpoint. Nonpoint source loading enters the impaired water body through distributed, nonspecific locations, which may include urban runoff not covered by a permit. Potential sources, detailed below, include wildlife, feral hogs, various agricultural activities, agricultural animals, failing on-site sewage facilities (OSSFs), and domestic pets.

2.7.2.1. Wildlife and Unmanaged Animals

Fecal bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are attracted naturally to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Wildlife and feral hogs also leave feces on land, where they may be washed into nearby water bodies by rainfall runoff.

For deer, Texas Parks and Wildlife Department (TPWD) biologists provided estimates for deer management units in Bee County, which included deer management units 8E, 9, 10 and 11 (TPWD, 2021). Based on estimates from 2005 through 2019, an average of one white tail deer per 58.08 acres of habitat was calculated across the watershed. Applying this value to the suitable habitat area of the TMDL watershed returns an estimated 1,207 deer within the watershed. Suitable NLCD (2019) land cover types for both deer and feral hog habitat include the following: Pasture/Hay, Cultivated Crops, Shrub/Scrub, Grassland/Herbaceous, Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, and Emergent Herbaceous Wetlands.

For feral hogs, AgriLife Extension estimates one hog per 33.3 acres as the average density for feral hogs in the TMDL watershed (AgriLife Extension, 2012). Using the same suitable NLCD land cover types, the estimated feral hog density was applied to the area suitable for feral hog habitat which estimated that there are about 2,105 feral hogs in the Poesta Creek watershed.

Both the suitable land cover area and estimated deer and feral hog populations are shown in Table 9 for the Poesta Creek watershed. The *E. coli* contribution from feral hogs and wildlife could not be determined based on existing information.

Table 9. Estimated deer and feral hog populations in the Poesta Creek watershed

AU	Suitable Land Cover (acres)	Estimated White-Tailed Deer	Estimated Feral Hogs
2004B_01	70,112.11	1,207	2,105

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Several agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Activities, such as livestock grazing close to waterbodies and farmers' use of manure as fertilizer, can contribute to nearby water bodies.

Table 10 shows estimated numbers of several livestock counts in the TMDL watershed using county level data available from the 2017 Census of Agriculture (USDA, 2019). The watershed-level livestock numbers were estimated from the county livestock population data based on the ratio of suitable habitat within the watershed and the suitable habitat in Bee County. Suitable habitat is composed of land cover classified as Pasture/Hay, Shrub/Scrub, or Grassland/Herbaceous in the 2019 NLCD. The ratio of suitable habitat (0.139) was multiplied by the county livestock population data to obtain the watershed livestock numbers.

Table 10. Estimated livestock populations

Area	Acres of Suitable Land Cover	Cattle and Calves	Hogs and Pigs	Poultry	Goats and Sheep	Horses
Bee County	406,385.19	30,815	358	4,771	1,560	970
2004B_01	56,454.05	4,281	50	662	217	135

Fecal matter from dogs and cats is transported to water bodies by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 11 summarizes the estimated number of dogs and cats in the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household according to data from the American Veterinary Medical Association

(AVMA) 2017–2018 U.S. Pet Statistics (AVMA, 2018). The number of households in the watershed was estimated using 2020 Census data (USCB, 2020b). The actual contribution and significance of bacteria loads from pets reaching the water bodies is unknown.

Table 11. Estimated households and pet populations

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
2004B_01	8,003	4,914	3,657

2.7.2.3. On-Site Sewage Facilities

Private residential OSSFs, commonly referred to as septic systems, consist of various designs based on physical conditions of the local soils. Typical designs consist of 1) one or more septic tanks and a drainage or distribution field (anaerobic system) and 2) aerobic systems that have an aerated holding tank and often an above ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system, which may consist of buried perforated pipes or an above ground sprinkler system.

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters if the systems are not properly operating. Properly designed and operated, however, OSSFs contribute virtually no fecal bacteria to surface waters. For example, Weiskel et al. (1996) reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system. Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The Poesta Creek watershed is located within the Region 3 area, which has a reported failure rate of about 3%, providing insights into expected failure rates for the area.

Estimates of the number of OSSFs in the Poesta Creek watershed were determined using 911 address points (TNRIS, 2021) to estimate residential locations. OSSFs were estimated to be residential and business addresses that were outside of city boundaries and Certificate of Convenience and Necessity areas (Public Utility Commission of Texas, 2022). Data from these sources indicate that there are 1,102 OSSFs located within the Poesta Creek watershed (Figure 7).

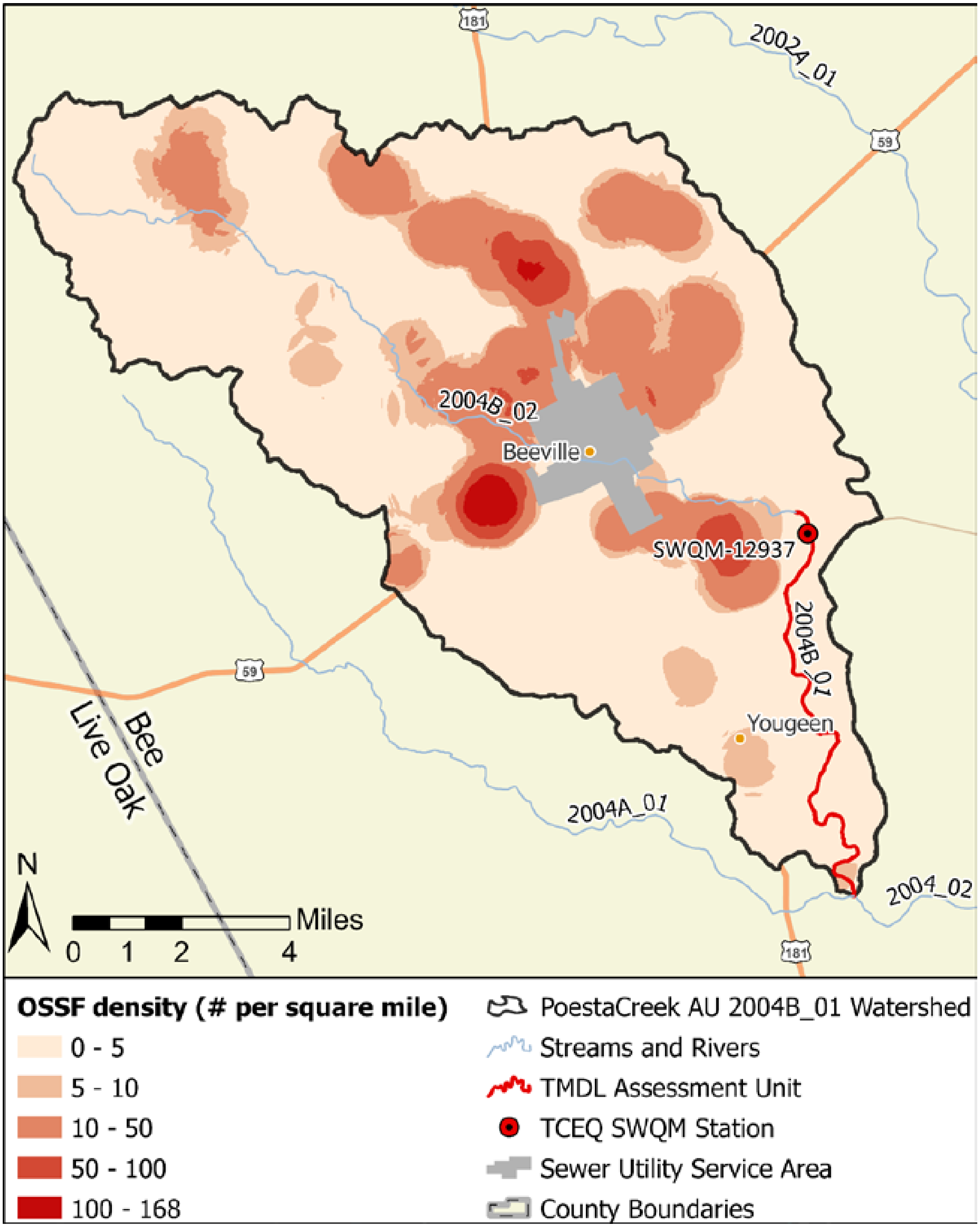

Figure 7. Estimated OSSF density in the Poesta Creek watershed

2.7.2.4. Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if the right conditions prevail (such as warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate in organic-rich materials such as improperly treated compost and sewage sludge (or biosolids). While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both replication and die-off are instream processes and are not considered in the bacteria source loading estimates in the TMDL watershed.

Section 3. Bacteria Tool Development

This section describes the rationale for selecting the bacteria tool used for TMDL development and details the procedures and results of LDC development.

3.1. Tool Selection

The TMDL allocation process for bacteria involves assigning bacteria loads to their sources so that the total does not go over the criterion for contact recreation use. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for AU 2004B_01 considered the availability of data and other information necessary for the supportable application of the selected tool and guidance in the Texas Bacteria Task Force report (Jones et al. 2009). Mechanistic models and empirically derived LDCs are the two approaches commonly used for bacteria TMDLs in Texas.

The LDC method allows for estimation of existing and allowable loads by using the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment.

The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by TCEQ, and the Texas State Soil and Water Conservation Board supports application of the LDC method within their three-tiered approach to TMDL development (Jones et al., 2009). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion and can give indications of broad sources of the bacteria.

3.2. Data Resources

The datasets required for the application of the LDC method include daily streamflow records for the TMDL watershed and water quality monitoring data for the indicator bacteria (*E. coli*) within the period of record for which daily streamflow records were obtained. For AU 2004B_01, the only available bacteria data is collected at a SWQM station near the upstream boundary of the AU. An LDC was developed using estimated flows and bacteria concentration measurements at the SWQM station to draw conclusions about linkages between broad sources of loadings and pollutant exceedances (Section 4.3). However, load allocations for the TMDL were developed based on estimated flows at the outlet of the AU to capture hydrologic influences from the entire watershed. This necessitated the development of two LDCs, one using flows estimated at the SWQM station, and one developed using flows estimated at the AU outlet.

Hydrologic data in the form of daily streamflow records were unavailable in the TMDL watershed. However, streamflow records are available in the downstream Aransas River (Segment 2004) watershed. Streamflow records in the watershed were collected and made available by the U.S. Geological Survey (USGS), which operates streamflow gage 08189700 (Aransas River near Skidmore) that was used to develop mean daily streamflow for the Poesta Creek watershed (USGS, 2023; Table 12, Figure 8). The contributing drainage areas for SWQM station 12937 and the AU 2004B_01 watershed outlet in comparison to the USGS gage 08189700 location are shown in Figure 8.

Table 12. USGS streamflow gage information used for streamflow development

Gage No.	Site Description	Drainage Area (square miles)	Daily Streamflow Record available
08189700	Aransas River, near Skidmore	242.58	03/27/1964 – 12/31/2022

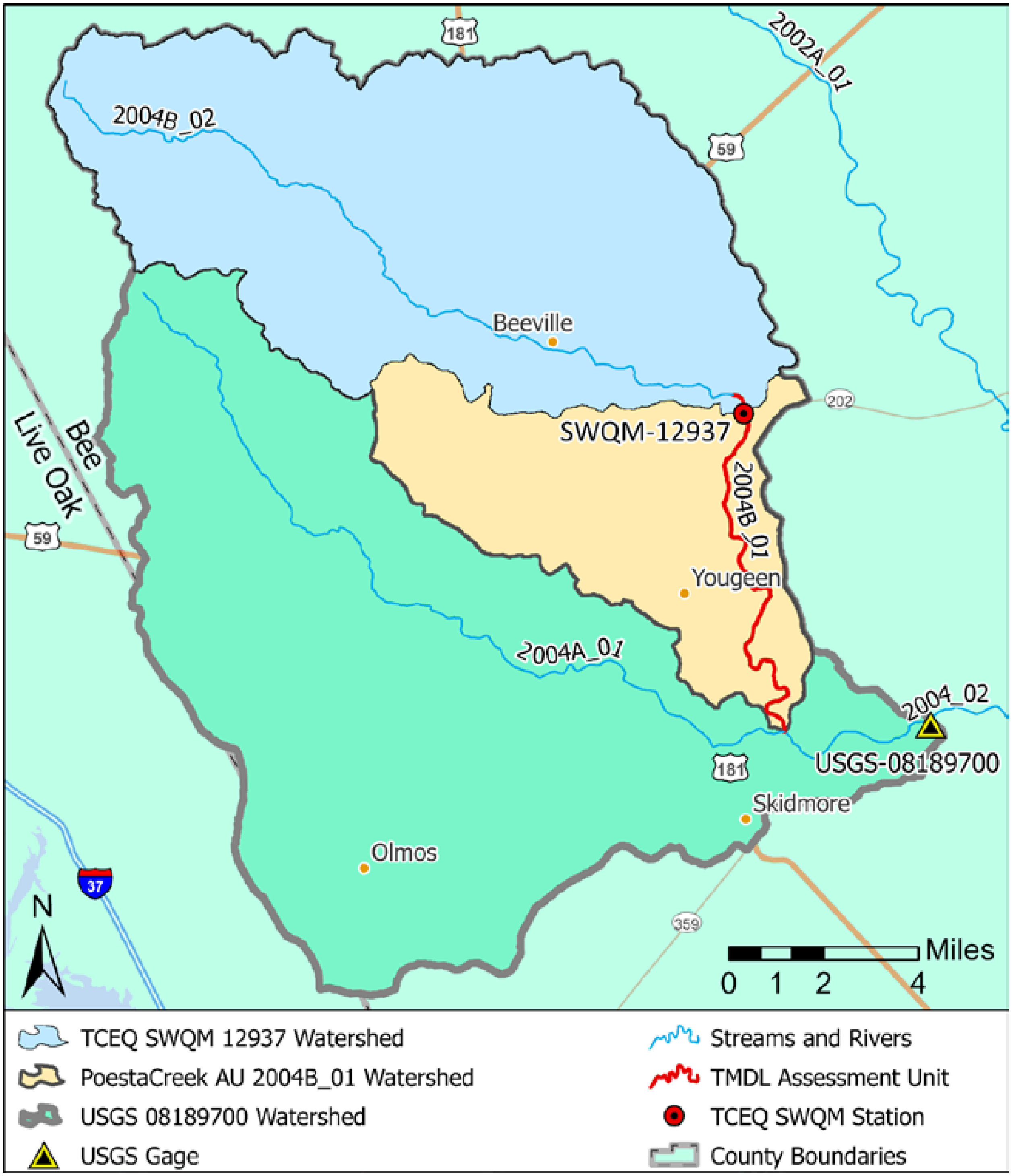

Figure 8. USGS streamflow gage and watersheds used in streamflow development for the Poesta Creek AU 2004B_01 watershed

Historical ambient *E. coli* data used for the development of LDCs was obtained through TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database for TCEQ SWQM Station 12937 (TCEQ, 2023a) (Table 13, Figure 9).

Table 13. Summary of historical bacteria dataset for the Poesta Creek watershed

Water Body Name	AU	Station	Station Location	No. of Samples	Data Date Range	Geomean (cfu/ 100 ml)	Percent Exceeding Single Sample Criterion (%)
Poesta Creek	2004B_01	12937	Poesta Creek at SH 202	24	10/28/2015 – 6/15/2022	282.25	25%

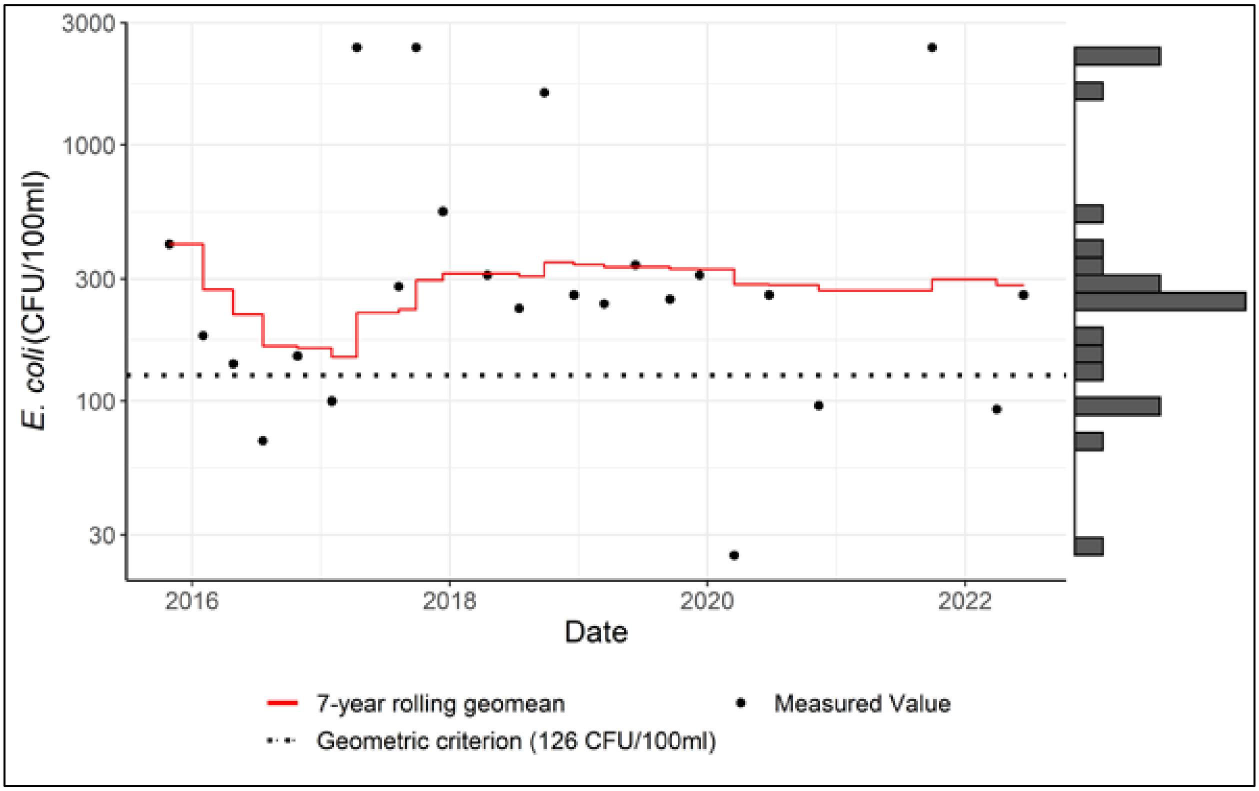

Figure 9. Summary plot of historical bacteria dataset for Poesta Creek at SWQM station 12937

3.3. Methodology for Flow Duration and Load Duration Curve Development

To develop the flow duration curves (FDCs) and LDCs, the previously discussed data resources were used in the following sequential steps.

- Step 1: Determine the hydrologic period of record to be used in developing the FDC.

- Step 2: Determine the stream location for which FDC and LDC development is desired.
- Step 3: Develop daily streamflow record at desired location.
- Step 4: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDC.

More information explaining the LDC method may be found in Cleland (2003) and EPA (2007).

3.3.1. Step 1: Determine Hydrologic Period

Daily streamflow records were obtained from the USGS gage 08189700 at Aransas River near Skidmore (Figure 8; USGS 2023). This streamflow gage was selected because it was the nearest downstream gage to the TMDL watershed. Daily mean streamflow records from Jan. 1, 2003, to Dec. 31, 2022, were obtained for the development of FDCs. This 20-year period of record was selected to capture a reasonable range of extreme high and low streamflow and captures the period in which all the *E. coli* data were collected.

3.3.2. Step 2: Determine Desired Stream Location

For the project water body, the downstream AU had four SWQM stations (12937, 12938, 12939, 12940). SWQM station 12937 was selected for FDC and LDC development as it was the only station in the AU with available bacteria data. As the station was located near the upstream end of the AU, FDCs and LDCs were also developed for the TMDL watershed outlet for a more appropriate estimate of flows in the watershed.

3.3.3. Step 3: Develop Daily Streamflow Record at Desired Location

Once the hydrologic period of record and the stream locations were determined, the next step was to develop the naturalized daily streamflow record for SWQM station 12937 and watershed outlet. As used herein, naturalized flow is referring to the flow without the withdrawals from water rights and the addition of permitted discharges, i.e., the flows that would occur in response to precipitation, evapotranspiration, near-surface geology, soil, land covers of the watershed, and other factors. The naturalized daily streamflow records were developed from USGS records.

The method to develop the necessary streamflow record involved a flow percentile drainage area ratio (DAR) approach. With this basic approach, each USGS gage’s mean daily streamflow value was multiplied by a factor to estimate flow at the desired SWQM station location (Equation 1).

$$Y = X * (A_y/A_x)^{\phi} \quad \text{(Equation 1)}$$

Where:

Y = streamflow for the ungaged location

X = streamflow for the gaged location

A_y = drainage area for the ungaged location

A_x = drainage area for the gaged location

ϕ = bias correction factor based on streamflow percentile (Asquith et al., 2006)

Conventionally, $\phi = 1$ is used in the DAR approach. However, empirical analysis of streamflows in Texas indicates that $\phi = 1$ results in substantial bias in streamflow estimates at very low and very high streamflow percentiles (Asquith et al, 2006). Based on these observations, a range of values (i.e., 0.7 – 0.935) for ϕ was used for different streamflow percentiles based on suggestions by Asquith et al. (2006). Table 14 provides the DARs used to develop streamflows for the SWQM station and the AU 2004B_01 watershed outlet.

Identifying a gaged watershed, from which streamflow record is extrapolated to an ungaged watershed, requires considering several factors, such as the separation distance, relative drainage area, and hydrologic similarity. Furthermore, discharges and diversions in watersheds may complicate the application of the DAR approach. Asquith et al. (2006) suggested two general criteria for candidate gage selection: (1) the donor streamflow gage be located within 100 miles of the ungaged watershed outlet, and (2) the absolute value of the log (base-10) of the DAR between the gaged and ungaged watershed be less than or equal to 1.5. The USGS gage 08189700 at Aransas River near Skidmore located 7.5 miles southwest of the TCEQ SQWM station 12937, meets both of these criteria. It is also located downstream of the Poesta Creek watershed, making it an even more viable candidate station on the basis of hydrologic similarity.

Daily streamflows at SWQM station 12937 and the AU 2004B_01 watershed outlet were developed using DAR values applied to naturalized mean daily streamflow values for USGS gage 08189700.

Table 14. Drainage area ratios used at SWQM station and watershed outlet

Locations	Drainage area (square miles)	Drainage Area Ratio
SWQM station 12937	86.67	0.357
Poesta Creek AU 2004B_01 watershed outlet	123.07	0.507
Aransas River near Skidmore – USGS 08189700	242.58	-

To properly apply the DAR, the naturalized flows at USGS gage 08189700 were estimated first. WWTF flows in the form of estimated daily reported discharge for all WWTFs upstream of the USGS gage location (based on Discharge Monitoring Reports) were subtracted from the streamflow record of USGS gage 08189700, resulting in an adjusted streamflow record with point source discharge influences removed.

For the surrogate watershed, there are three permitted dischargers upstream of USGS gage 08189700 – WQ0014112001, WQ0010124002, and WQ0010124004. The average daily reported discharge for each WWTF was computed by averaging the most recent 5-year discharge data obtained the EPA ECHO database (EPA, 2022). One permitted diversion was identified above USGS gage 08189700 but did not have any recent reported diversions since 2013 (TCEQ, 2023b). Also, the total reported diversion volume equated to an average outflow less than 0.001 cubic feet per second (cfs) over the 20-year study period, which was not significant to be included in the analysis. Therefore, the only streamflow adjustments made were to subtract the average daily reported discharge by each permitted discharge from the USGS reported streamflow.

After development of the naturalized streamflow in the surrogate watershed, the DAR was calculated using Equation 1 and the individual DARs for SWQM station 12937 and the AU 2004B_01 watershed outlet can be found in Table 14. The resulting streamflow records are the naturalized flows from only the contributing watershed at each station.

After applying the DAR to daily naturalized gaged streamflow values, the output is the estimated naturalized streamflows at SWQM station 12937 and the AU 2004B_01 watershed outlet. For the purposes of TMDL development, a final adjustment to the naturalized streamflow involves adding the full permitted discharge and future growth calculations of any upstream WWTFs. There is only one upstream WWTF (WQ0010124002) whose full permitted discharge flow was added back along with the estimated Future Growth (FG). The FG term was estimated to be 0.1893 MGD (or 0.29 cfs) to account for the growing population. The calculation of FG flows is described in Section 4.7.4. Future Growth.

3.3.4. Steps 4–6: Flow Duration and Load Duration Curves

FDCs and LDCs are graphs that visualize the percentage of time during which a value of flow or load is equaled or exceeded. To develop an FDC for a location, all of the following steps were taken in the order shown:

- Order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (one for the highest flow, two for the second highest flow, and so on).
- Compute the percentage of days each flow was exceeded by dividing each rank by the total number of data points plus one.
- Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cfs by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL or 1.26 cfu/mL) and by a conversion factor (2.44658×10^9), which gives you a loading unit of cfu/day.
- Plot the exceedance percentages, which are identical to the value for the streamflow data points, against the geometric mean criterion for *E. coli*.

The resulting curve represents the maximum daily allowable loadings for the geometric mean criterion. The next step was to plot the measured *E. coli* data on the developed LDC using the following steps:

- Compute the daily loads for each sample by multiplying the measured *E. coli* concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^9).
- Plot on the LDC for each SWQM station the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (*E. coli* concentrations times daily streamflow) display the frequency and magnitude at which measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

3.4. Flow Duration Curves

FDCs were developed for the Poesta Creek watershed at the AU 2004B_01 watershed outlet (Figure 10) and at SWQM station 12937 (Figure 11). For this report, the FDCs were developed by using mean daily streamflow obtained from USGS gage 08189700 and period of record (2003–2022), as described in the previous section. It is worth noting that the mean daily flows within the low flow regime are mostly dominated by wastewater outflows.

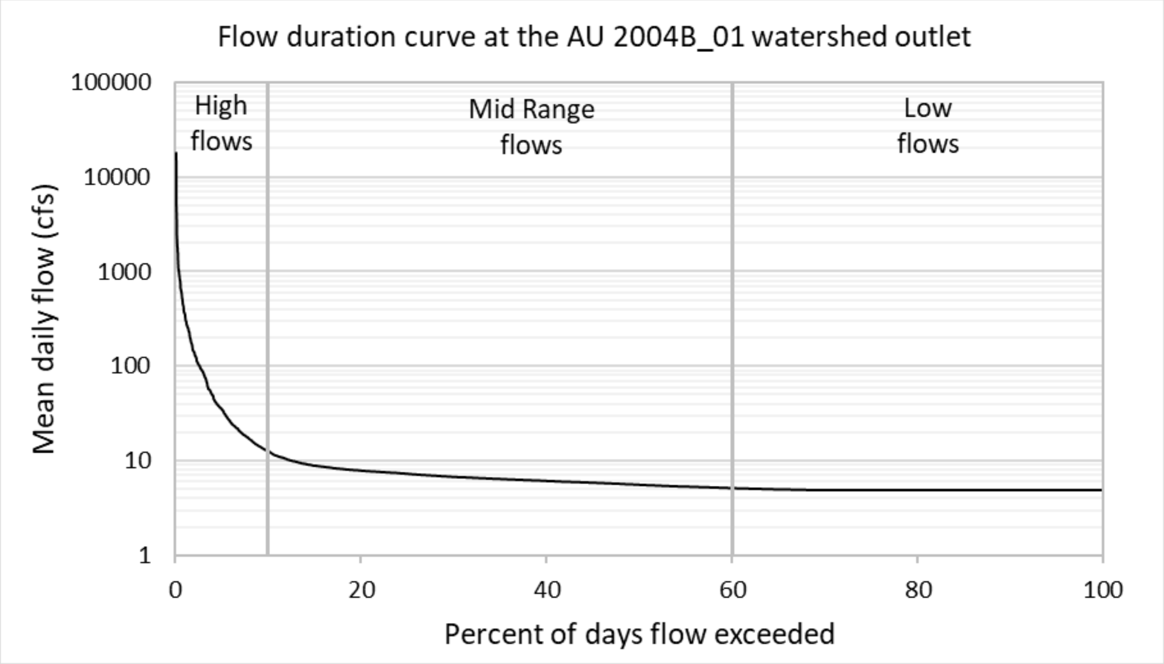

Figure 10. **Flow duration curve at the AU 2004B_01 watershed outlet**

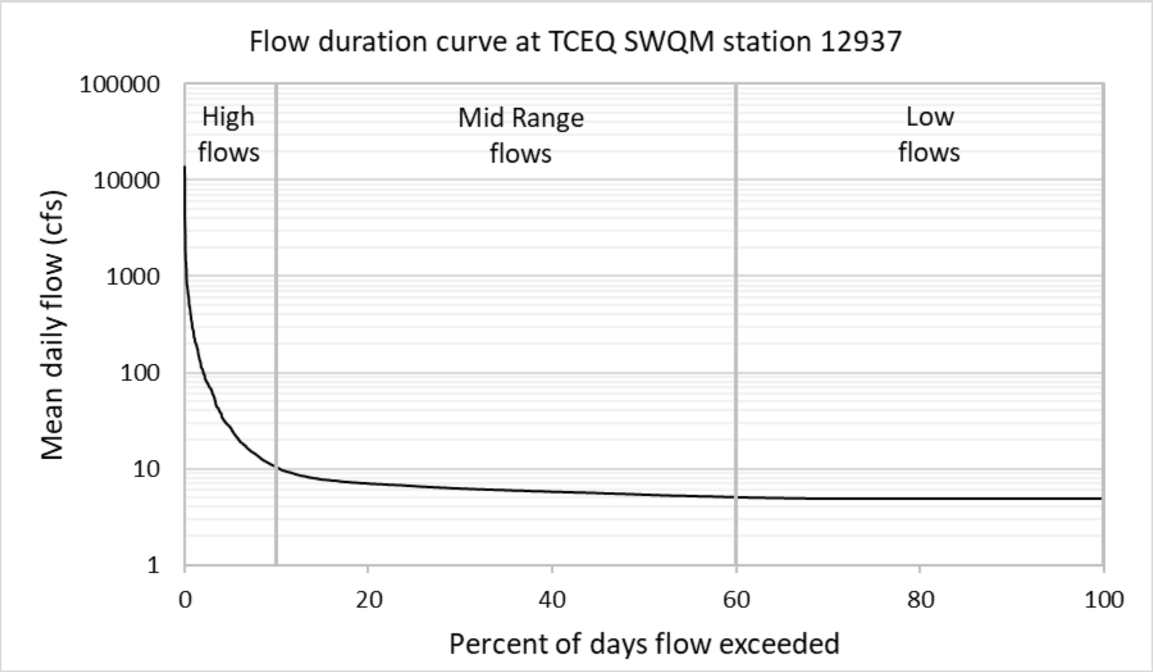

Figure 11. **Flow duration curve at TCEQ SWQM station 12937**

3.5. Load Duration Curves

LDCs were developed for the Poesta Creek watershed at SWQM station 12937 and at the AU 2004B_01 watershed outlet. A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. Exceedances were divided into high flows (0–10%), mid-range flows (10–60%), and low flows (60–100%). The selection of the flow regimes intervals was based on general observation of the developed LDCs, but also on intervals used in the LDCs developed for the Aransas River Tidal (AU 2003_01) and Poesta Creek (AU 2004B_02) in existing TMDLs (TCEQ, 2016; TCEQ, 2017).

Figure 12 depicts the LDC for Poesta Creek at the AU 2004B_01 watershed outlet. Figure 13 depicts the LDC for Poesta Creek at SWQM station 12937. The geometric mean loading in each flow regime for the LDC at SWQM station 12937 is also shown to aid interpretation.

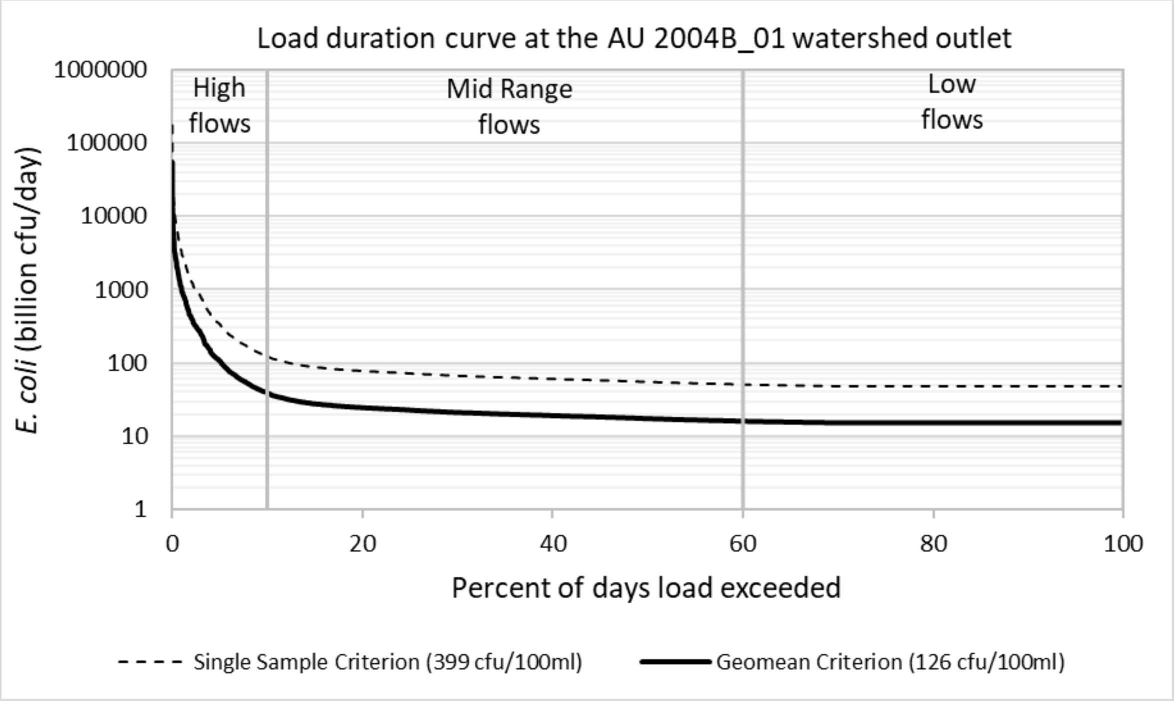

Figure 12. Load duration curve at the AU 2004B_01 watershed outlet

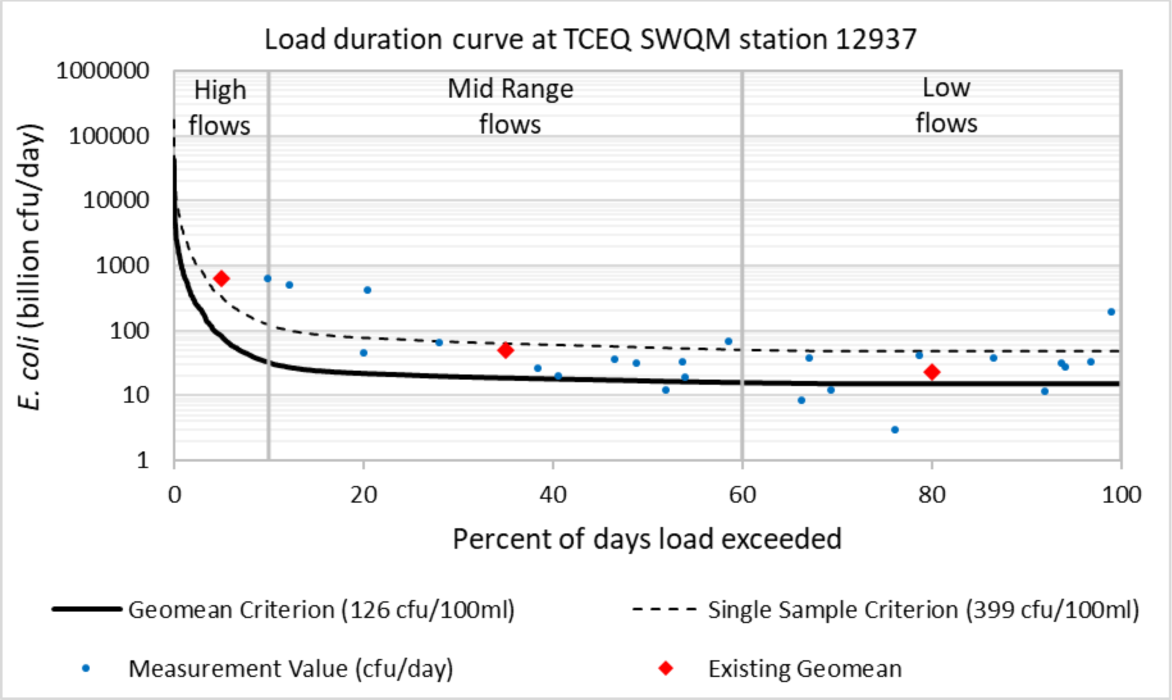

Figure 13. **Load duration curve at TCEQ SWQM station 12937**

Section 4. TMDL Allocation Analysis

4.1. Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work needed and as a criterion against which to evaluate future conditions. Please note that some calculations completed in this section have been rounded and may not lead to the exact final amounts listed in the text, tables, or figures.

The endpoint for the TMDL is to maintain the concentration of *E. coli* below the geometric mean criterion of 126 cfu/100 mL, which is protective of the primary contact recreation 1 use in freshwater.

4.2. Seasonal Variation

Seasonal variations occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. TMDLs must account for seasonal variation in watershed conditions and pollutant loading, as required by federal regulations [Title 40, Code of Federal Regulations, Chapter 1, Part 130, Section 130.7I(1) (or 40 CFR 130.7I(1))].

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing available *E. coli* concentrations obtained from 15 years (2008 through 2022) of routine monitoring at SWQM station 12937. Differences in *E. coli* concentrations were evaluated by performing a Wilcoxon Rank Sum test. *E. coli* concentrations during warmer months (May–September) were compared against those during the cooler months (November–March). April and October are considered transitional periods between warm and cool seasons and therefore were excluded from the analysis. This analysis of *E. coli* data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for the Poesta Creek watershed (W = 23, p-value = 0.07852, Figure 14).

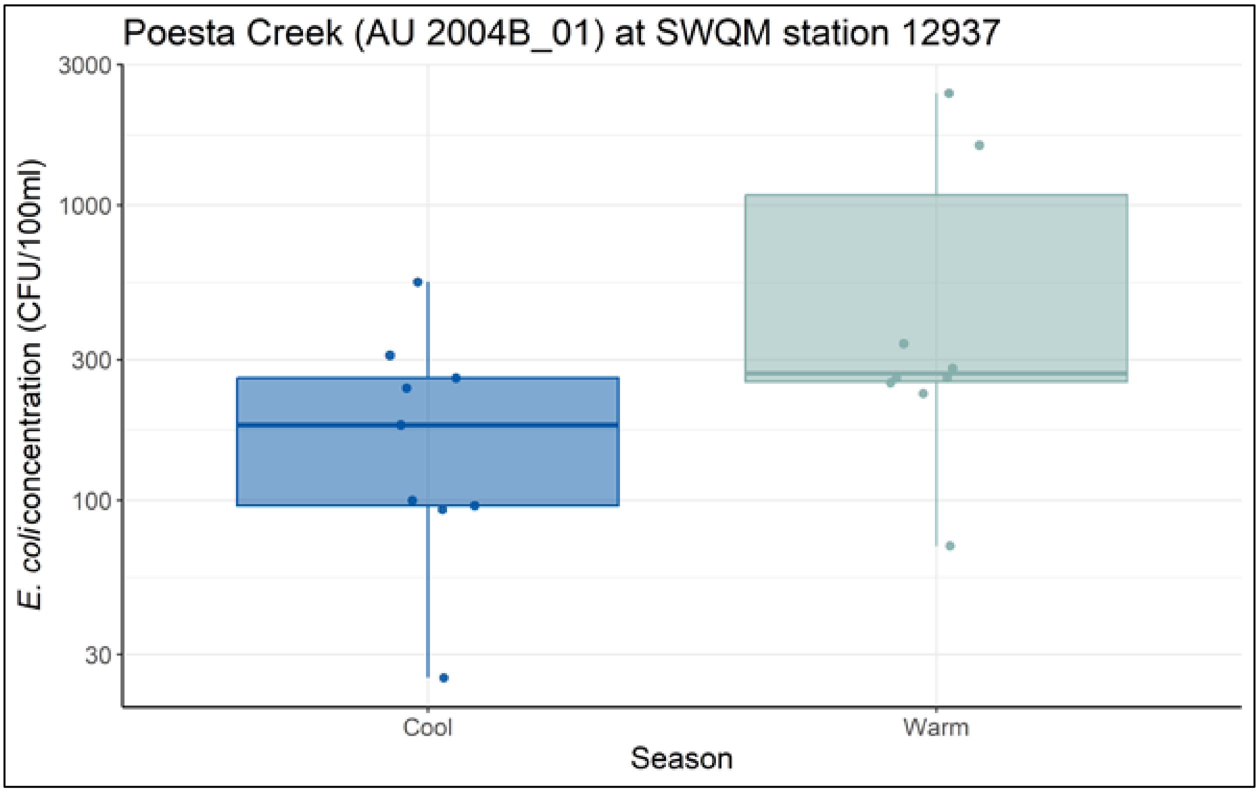

Figure 14. **Distribution of *E. coli* concentration by season in the AU 2004B_01 watershed**

4.3. Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flows in the absence of runoff events, the main contributing sources are likely to be point sources and direct deposition (such as direct fecal deposition into the water body). During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in size, the impact of point sources like direct deposition is typically diluted, and would, therefore, be a smaller part of the overall concentrations.

Bacteria load contributions from regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, can carry bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline as runoff washes fecal bacteria from the land surface and the volume of runoff decreases following the rain event.

LDCs were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a direct relationship between pollutant load sources (regulated and unregulated) and instream loads. Further, this one-to-one relationship was inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That allocation was based on the flows associated with the watershed areas under stormwater regulation, and the remaining portion was assigned to the unregulated stormwater.

4.4. Load Duration Curve Analysis

LDC analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads, and they are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. An LDC is a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders and uses available water quality and flow data. The LDC method does not require any assumptions about loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The EPA supports the use of this approach to characterize pollutant sources. In addition, many other states are using this method to develop TMDLs.

The weaknesses of this method include the limited information it provides about the magnitude or specific origin of the various sources. Information gathered about point and nonpoint sources in the watershed is limited. The general difficulty in analyzing and characterizing *E. coli* in the environment is also a weakness of this method.

The LDC method allows for estimation of existing and TMDL loads by using the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the hydrological conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater), and provides a means to allocate allowable loadings.

For the Poesta Creek (AU 2004B_01) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under all flow regimes. However, bacteria loads are most elevated under high flow conditions.

The majority of high flow and moist condition related loadings are likely attributed to regulated stormwater that comprises a majority of the watershed. Within the watershed, there is one WWTF that could contribute to point source loadings under dry and low flow conditions. Also, SSOs are periodic events that may contribute to bacteria loadings within the watershed under wet weather conditions. Other sources of bacteria loadings under mid-range and low-flow conditions are—in the absence of overland flow contributions (i.e., without stormwater contribution)—most likely to contribute bacteria directly to the water. These sources may include direct deposition of fecal material from sources such as wildlife, feral hogs, birds, livestock, and OSSFs. However, the actual contributions of bacteria loadings directly attributable to these sources cannot be determined using LDCs.

4.5. Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (EPA, 1991), the MOS can be incorporated in the TMDL using either of the following two methods:

1. Implicitly incorporating the MOS using conservative model assumptions to develop allocations.
2. Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning an MOS.

The TMDL in this report incorporates an explicit MOS of 5%.

4.6. Load Reduction Analysis

While the TMDL for the project watershed will be developed using load allocations, additional insight may be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each flow regime was determined using the historical *E. coli* data obtained from the station in the impaired watershed (Table 15). The estimated existing load in each flow regime was calculated with the geometric mean concentration in each flow category (FC) and the median flow in each flow category as estimated in Section 3.3.

$$\text{Existing Load}_{FC} = Q_{FC} * G_{FC} * \text{Conversion Factor} \qquad \text{(Equation 2)}$$

Where:

$\text{Existing Load}_{FC}$ = Existing *E. coli* load at the median flow for FC

FC = Respective flow category

Q_{FC} = Median flow for flow category FC

G_{FC} = Geometric mean of bacteria (cfu *E. coli*/100mL) samples for FC

Conversion Factor (to billion cfu/day) = 28,316.846 mL/cubic feet (ft^3) * 86,400 seconds/day ÷ 1,000,000,000

The allowable load was calculated as:

$\text{Allowable Load}_{FC} = \text{Criterion} * Q_{FC} * \text{Conversion Factor}$ (Equation 3)

Where:

$\text{Allowable Load}_{FC}$ = Allowable load at the median flow for FC

Q_{FC} = Median flow in each FC (cfs)

Criterion = 126 cfu/100 mL (*E. coli*)

Conversion Factor (to billion cfu/day) = 28,316.846 mL/ft^3 * 86,400 seconds/day ÷ 1,000,000,000

Percent reduction for each flow category (PR_{FC}) was then calculated as:

$PR_{FC} = (\text{Existing Load}_{FC} – \text{Allowable Load}_{FC}) ÷ \text{Existing Load}_{FC}$ (Equation 4)

Table 15. Daily load reductions needed to meet *E. coli* standards in AU 2004B_01 by flow category

Flow Category	Flow (cfs)	Geomean Concentration (cfu/100ml)	Existing Load (billion cfu/day)	Allowable Load (billion cfu/day)	Percent Reduction Required (%)
High Flows	26.82	2,400	1,574.81	82.68	94.75%
Mid-Range Flows	6.04	333	49.21	18.62	62.16%
Low Flows	4.93	194	23.40	15.20	35.05%

4.7. Pollutant Load Allocations

A TMDL represents the maximum amount of a pollutant that the water body can receive in a single day without exceeding water quality standards. The pollutant load allocations for the selected scenarios were calculated using the following basic equation:

$\text{TMDL} = \text{WLA} + \text{LA} + \text{FG} + \text{MOS}$ (Equation 5)

Where:

WLA = wasteload allocation, the amount of pollutant allowed by regulated dischargers

LA = load allocation, the amount of pollutant allowed by unregulated sources

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures [40 CFR) 130.2(i)]. For *E. coli*, TMDLs are expressed as billion cfu/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

4.7.1. Assessment Unit-Level TMDL Calculations

The bacteria TMDL for the water body was developed as a pollutant load allocation based on information from the LDC for the AU 2004B_01 watershed outlet (Figure 12). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the FDC by the *E. coli* criterion (126 cfu/100 mL) and by the conversion factor used to represent maximum loading in cfu/day. Effectively, the "Allowable Load" displayed in the LDC at 5% exceedance (the median value of the high flow regime) is the TMDL.

TMDL (cfu/day) = Criterion * Flow (cfs) * Conversion Factor (Equation 6)

Where:

Criterion = 126 cfu/100 mL (*E. coli*)

Conversion Factor (to billion cfu/day) = 28,316.846 mL/cubic feet (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

The allowable loading of *E. coli* that the impaired water body can receive on a daily basis was determined using Equation 6 based on the median value within the high regime of the FDC (or 5% flow exceedance value) for the AU 2004B_01 watershed outlet (Table 16).

Table 16. Summary of allowable loading calculation

Water Body Name	AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/Day)	TMDL (Billion cfu/Day)
Poesta Creek	2004B_01	34.51	106,383,463,592.80	106.383

4.7.2. Margin of Safety Allocation

The MOS is applied only to the allowable loading for a watershed. Therefore, the MOS is expressed mathematically as the following:

MOS = 0.05 * TMDL (Equation 7)

Using the value of TMDL for the AU provided in Table 16, the MOS may be readily computed by proper substitution in Equation 7 (Table 17).

Table 17. MOS calculations

Load units expressed as billion cfu/day *E. coli*

Water Body Name	AU	TMDL[a]	MOS
Poesta Creek	2004B_01	106.383	5.319

[a] TMDL from Table 16.

4.7.3. Wasteload Allocations

The WLA consists of two parts—the wasteload that is allocated to TPDES-regulated WWTFs (WLA_{WWTF}) and the wasteload that is allocated to regulated stormwater dischargers (WLA_{SW}).

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Equation 8)}$$

4.7.3.1. Wastewater

TPDES-permitted WWTFs are allocated a daily wasteload calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion after reductions for the MOS. The water quality criterion (126 cfu/100mL) after reductions for the MOS (F_{MOS}) is used as the WWTF target to provide instream and downstream load capacity. Thus, WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = \text{Criterion} * \text{Flow} * \text{Conversion Factor} * (1 - F_{MOS}) \qquad \text{(Equation 9)}$$

Where:

Criterion = 126 cfu/100mL

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for each AU. The criterion was applied based on the indicator bacteria designated for the segment. Table 18 presents the WLA for each WWTF and the resulting total allocation for the AU within the TMDL watershed.

Table 18. WLAs for TPDES-permitted facilities

Load units expressed as billion cfu/day *E. coli*.

Watershed (AU)	TPDES Permit No.	TPDES Permit No.	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF}
AU 2004B_01	WQ0010124002	TX0047007	Moore Street WWTP	3	13.593

[a] Full Permitted Flow from Table 6.

4.7.3.2. Regulated Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges. A simplified approach for estimating the WLA for these areas was used in the development of this TMDL due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading.

The percentage of the land area that is under the jurisdiction of stormwater permits in the TMDL watershed was used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

Thus, WLA_{SW} is the sum of loads from regulated stormwater sources and was calculated as follows:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Equation 10)}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits, as described in section 2.7.1.3. The results were used to compute an area of regulated stormwater contribution (Table 19).

Table 19. Basis of regulated stormwater area and computation of FDA_{SWP} term

AU	Watershed area (acres)	MSGP (acres)	CGP (acres)	Total area of Permits (acres)	FDA_{SWP}
2004B_01	78,765.53	30.43	42.138	72.568	0.0921%

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. To calculate the WLA_{SW} (Equation 10), the FG term must be known. The calculation for that term is presented in the next section, but the results are included here for continuity. Table 20 provides the information needed to compute WLA_{SW}.

Table 20. Regulated stormwater WLA calculations

Load units expressed as billion cfu/day *E. coli*

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	FG[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Poesta Creek	2004B_01	106.383	5.319	13.593	0.858	0.0921%	0.080

[a] TMDL from Table 16

[b] MOS from Table 17

[c] WLA_{WWTF} from Table 18

[d] FG from Table 21

[e] FDA_{SWP} from Table 19

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Equation 10)

4.7.4. Future Growth

The FG component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component considers the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of water bodies increases as the amount of flow increases.

The allowance for FG will result in protection of existing uses and conform to Texas' antidegradation policy.

The FG component was based on population projections and current permitted wastewater dischargers for the entire TMDL watershed. Recent population and projected population growth between 2020 and 2070 for the TMDL watershed are provided in Table 3. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. Similar to WLA_{WWTF} calculations, the water quality criterion (126 cfu/100 mL) after accounting for the required reductions for MOS (F_{MOS}) is used as the WWTF target. The permitted flows were increased by the expected population growth per AU between 2020 and 2070 to determine the estimated future flows.

Thus, the FG is calculated as follows:

$$FG = Criterion * (\%POP_{2020-2070} * WWTF_{FP}) * Conversion\ Factor * (1 - F_{MOS}) \quad \text{(Equation 11)}$$

Where:

Criterion = 126 cfu/100 mL

$POP_{2020\text{-}2070}$ = estimated percentage increase in population between 2020 and 2070

$WWTF_{FP}$ = full permitted WWTF discharge (MGD)

Conversion factor = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

The calculation results for the TMDL watershed are shown in Table 21.

Table 21. FG calculation

Water Body Name	AU	Full Permitted Flow (MGD)	% Population Increase (2020-2070)	FG (MGD)	FG (*E. coli* Billion cfu/Day)[a]
Poesta Creek	2004B_01	3.0	6.31%	0.1893	0.858

[a] FG = Criterion * (%$POP_{2020\text{-}2070}$ * $WWTF_{FP}$) * Conversion Factor * (1 – F_{MOS}) (Equation 11)

4.7.5. Load Allocations

The LA is the load from unregulated sources, and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \qquad \text{(Equation 12)}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 22.

Table 22. LA calculation

Load units expressed as billion cfu/day *E. coli*

Water Body Name	AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	FG[e]	LA[f]
Poesta Creek	2004B_01	106.383	5.319	13.593	0.080	0.858	86.533

[a] TMDL from Table 16

[b] MOS from Table 17

[c] WLA_{WWTF} from Table 18

[d] WLA_{SW} from Table 20

[e] FG from Table 21

[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Equation 12)

4.8. Summary of TMDL Calculations

Table 23 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0–10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDC developed for the AU 2004B_01 watershed outlet. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL. The TMDL allocation summary for AU 2004B_01 TMDL watershed is summarized in Table 23.

Table 23. TMDL allocation summary

Load units expressed as billion cfu/day *E. coli*

AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
2004B_01	106.383	5.319	13.593	0.080	86.533	0.858

[a] TMDL from Table 16

[b] MOS from Table 17

[c] WLA_{WWTF} from Table 18

[d] WLA_{SW} from Table 20

[e] LA from Table 22

[f] FG from Table 21

The final TMDL allocation (Table 24) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the $\text{WLA}_{\text{WWTF.}}$

Table 24. Final TMDL allocation

Load units expressed as billion cfu/day *E. coli*

AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
2004B_01	106.383	5.319	14.451	0.080	86.533

[a] WLA_{WWTF} includes the FG component

Section 5. References

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Appendix A. Method used to determine population projections.

The following steps were used to estimate the 2020 population and 2020–2070 population projections in the AU 2004B_01 watershed.

1. The 2020 census block level population data was obtained from the Census for Bee County.

2. The 2020 watershed population was estimated by aggregating the population estimated for all the blocks located inside the watershed.

2. For the census blocks partially located in the watershed, block population within watershed was estimated by multiplying the total block population to the proportion of its area in the watershed.

3. Decadal population projections for Bee County between 2020 and 2070 were obtained from the TWDB county population projections dataset (TWDB, 2021).

4. Projected decadal population percentage increases in Bee-county were calculated for each decade between 2020 and 2070.

5. The county level projected population percentage increases calculated in Step 4 were applied to the 2020 watershed population obtained from the census data to obtain population projections for the Poesta Creek watershed.