Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Lavaca River Above Tidal

Assessment Unit: 1602_02

By Shubham Jain and Michael Schramm,
Texas Water Resources Institute
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Prepared by:
Shubham Jain and Michael Schramm
Texas Water Resources Institute
Texas A&M AgriLife
College Station, Texas

Submitted to TCEQ June 2021

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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
DAR	drainage-area ratio
DMU	Deer Management Unit
E. coli	*Escherichia coli*
FIB	fecal indicator bacteria
FDC	flow duration curve
FG	future growth
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	Minimum Control Measure
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
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic Database
SWMP	stormwater management program
SWQM	surface water quality monitoring
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
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WUG	Water User Group
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 listed water body. 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 in mass per period of time but may be expressed in other ways. Stakeholders develop an implementation plan for the TMDL that describes the regulatory and voluntary measures necessary to improve water quality and attain the contact recreation use.

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 Lavaca River Above Tidal watershed in the *2008 Texas Water Quality Inventory and 303(d) List* (Texas Integrated Report, TCEQ, 2008). The bacteria impairment was identified in each subsequent edition through 2012 and then removed from the 303(d) list in 2014. TCEQ identified the impairment again in the EPA-approved 2020 Texas Integrated Report.

This document will consider one bacteria impairment in one assessment unit (AU) of Lavaca River Above Tidal. The impaired water body and identifying AU number is shown below:

- Lavaca River Above Tidal, AU 1602_02

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

On February 7, 2018, TCEQ adopted revisions to the *Texas Surface Water Quality Standards* (TCEQ, 2018a) and on May 19, 2020, the United States Environmental Protection Agency (USEPA) 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.

Lavaca River Above Tidal AU 1602_02 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

This TMDL project was initiated through a contract between TCEQ and the 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 confirm the State of Texas 303(d) listings of impairment due to presence of indicator bacteria (*E. coli*).
- Development of a load duration curve (LDC).
- Application of the LDC approach for the pollutant load allocation process.

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 (original) TMDLs for Lavaca River Above Tidal and Rocky Creek (TCEQ, 2019).

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The Lavaca River Above Tidal (Segment 1602) is a perennial, classified, freshwater stream located near the Texas Gulf Coast (Figure 1). It consists of two AUs (1602_02 and 1602_03). Segment 1602 flows approximately 67 miles from the confluence of Campbell Branch west of Hallettsville in Lavaca County to Lavaca River Tidal (Segment 1601), 5.3 miles downstream of US 59 in Jackson County. The upstream water bodies include Big Brushy Creek (1602A), Rocky Creek (1602B), and Lavaca River Above Campbell Branch (1602C).

This document addresses the contact recreation use impairment for the upstream AU of Lavaca River Above Tidal (AU 1602_02). Throughout this document, this watershed will be referred to variously as the "Lavaca River Above Tidal AU 1602_02 watershed," the "AU 1602_02 watershed," the "TMDL watershed," and occasionally just "watershed" when the area discussed is clear from context. The total drainage area for the watershed is 587.02 square miles in Gonzales, DeWitt, Fayette, Jackson, and Lavaca counties. Figure 2 shows the TMDL watershed in relation to the two watersheds of the original TMDLs (TCEQ, 2019), which will always be referred to throughout this document as the "original TMDLs."

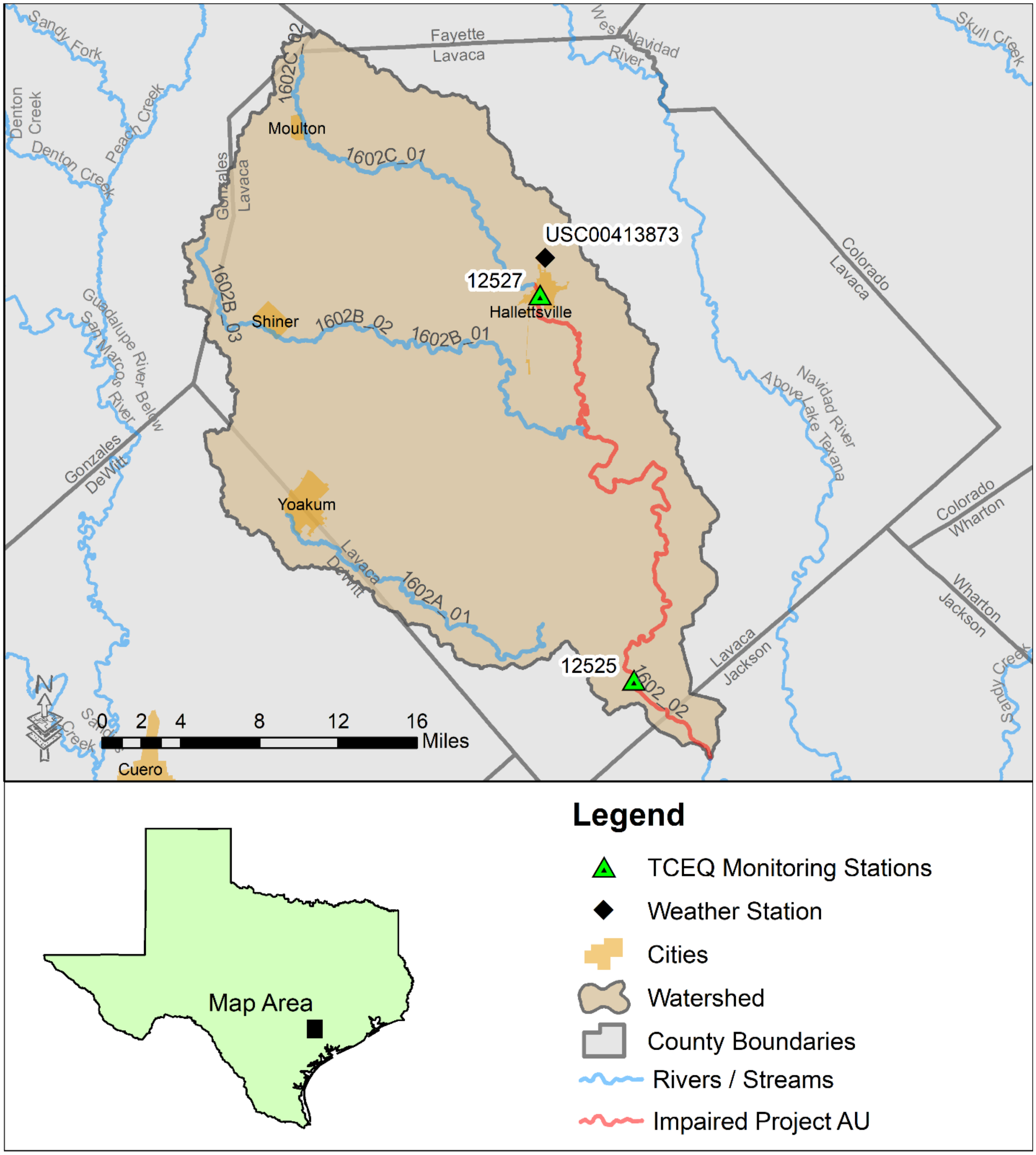
The 2020 Texas Integrated Report (TCEQ, 2020) provides the following water body and AU descriptions:

- Segment 1602 – From a point 8.6 kilometers (5.3 miles) downstream of US 59 in Jackson County to the confluence of Campbell Branch west of Hallettsville in Lavaca County.
    - AU 1602_02 – From the confluence of Beard Branch upstream to the upper end of segment at the confluence of Campbell Branch in Hallettsville.

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Water quality monitoring of AU 1602_02 has been done at two TCEQ surface water quality monitoring (SWQM) stations within that watershed—12525 and 12527 (Figure 1). *E. coli* data collected over the seven-year period between December 1, 2011 to November 30, 2018 were used in assessing attainment of the primary contact recreation 1 use as reported in the 2020 Texas Integrated Report (TCEQ, 2020). The 2020 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the geometric criterion of 126 cfu/100 mL, as summarized in Table 1.


Fayette
Lavaca
West Navidad River
Skull Creek
Sandy Fork
Denton Creek
Denton Creek
Peach Creek
1602C_02
Moulton
1602C_01
Gonzales
Lavaca
USC00413873
12527
Hallettsville
1602B_03
Shiner
1602B_02
1602B_01
Colorado
Lavaca
Guadalupe River Below San Marcos River
Navidad River Above Lake Texana
Gonzales
DeWitt
Colorado
Wharton
Yoakum
Lavaca
DeWitt
1602A_01
Wharton
Jackson
12525
1602_02
Lavaca
Jackson
0 2 4 8 12 16
Miles
N
Cuero
Map Area
Legend
TCEQ Monitoring Stations
Weather Station
Cities
Watershed
County Boundaries
Rivers / Streams
Impaired Project AU

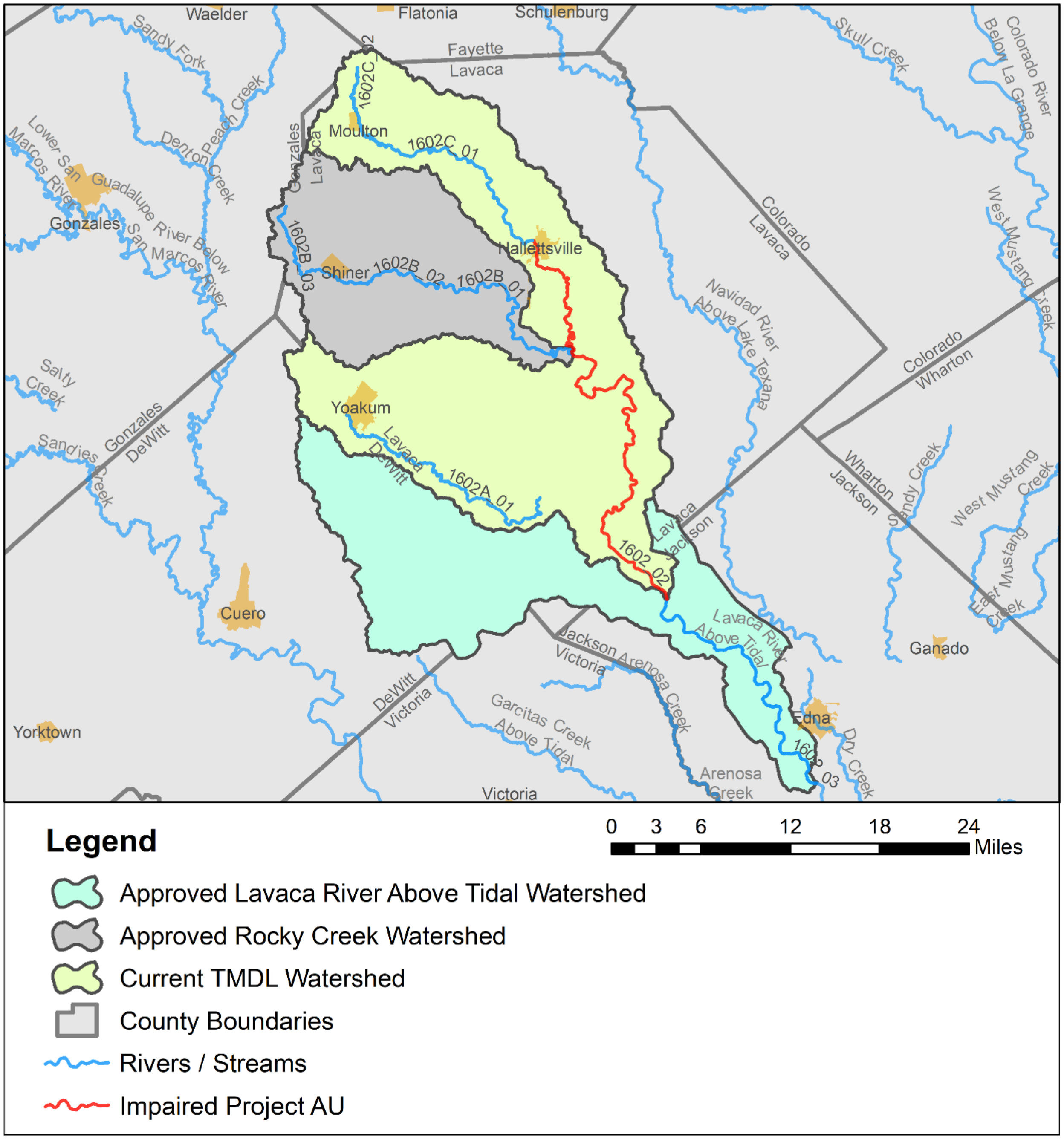

Waelder
Flatonia
Schulenburg
Fayette
Lavaca
Sandy Fork
Peach Creek
Denton Creek
Moulton
1602C_01
1602C_02
Gonzales
Lavaca
Lower San Marcos River
Guadalupe River Below San Marcos River
Gonzales
1602B_03
Shiner
1602B_02
1602B_01
Hallettsville
Colorado
Lavaca
Navidad River Above Lake Texana
Skull Creek
Colorado River Below La Grange
West Mustang Creek
Colorado
Wharton
Salty Creek
Sandies Creek
Gonzales
DeWitt
Yoakum
Lavaca
DeWitt
1602A_01
1602_02
Lavaca
Jackson
Wharton
Jackson
Sandy Creek
West Mustang Creek
East Mustang Creek
Cuero
Lavaca River Above Tidal
Jackson
Victoria
Arenosa Creek
Ganado
DeWitt
Victoria
Garcitas Creek Above Tidal
Edna
Dry Creek
1602_03
Yorktown
Arenosa Creek
Victoria
Legend
0 3 6 12 18 24
Miles
Approved Lavaca River Above Tidal Watershed
Approved Rocky Creek Watershed
Current TMDL Watershed
County Boundaries
Rivers / Streams
Impaired Project AU

Table 1. 2020 Texas Integrated Report Summary for the TMDL watershed

Water Body Name	AU	Parameter	SWQM Stations	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
Lavaca River Above Tidal	1602_02	*E. coli*	12525, 12527	45	12/01/2011–11/30/2018	202.74

2.3. Watershed Climate and Hydrology

The precipitation and temperature data for the study region were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center Database. The City of Hallettsville weather station (USC00413873) located within the watershed area (Figure 1) was used to retrieve the precipitation and temperature data from 2005 through 2020 (NOAA 2020). The watershed receives the highest average monthly precipitation of 3.76 inches in May and the lowest average monthly precipitation of 1.81 inches in the month of February (Figure 3). The average high temperature peaks in August at 97.09 ˚F, while the average low temperature reaches a minimum of 42.94 ˚F in January (Figure 3). From 2005 through 2020, the mean annual precipitation was 35.13 inches with a low of 17.05 inches recorded in 2011, and a high of 50.41 inches recorded in 2015 (Figure 4).

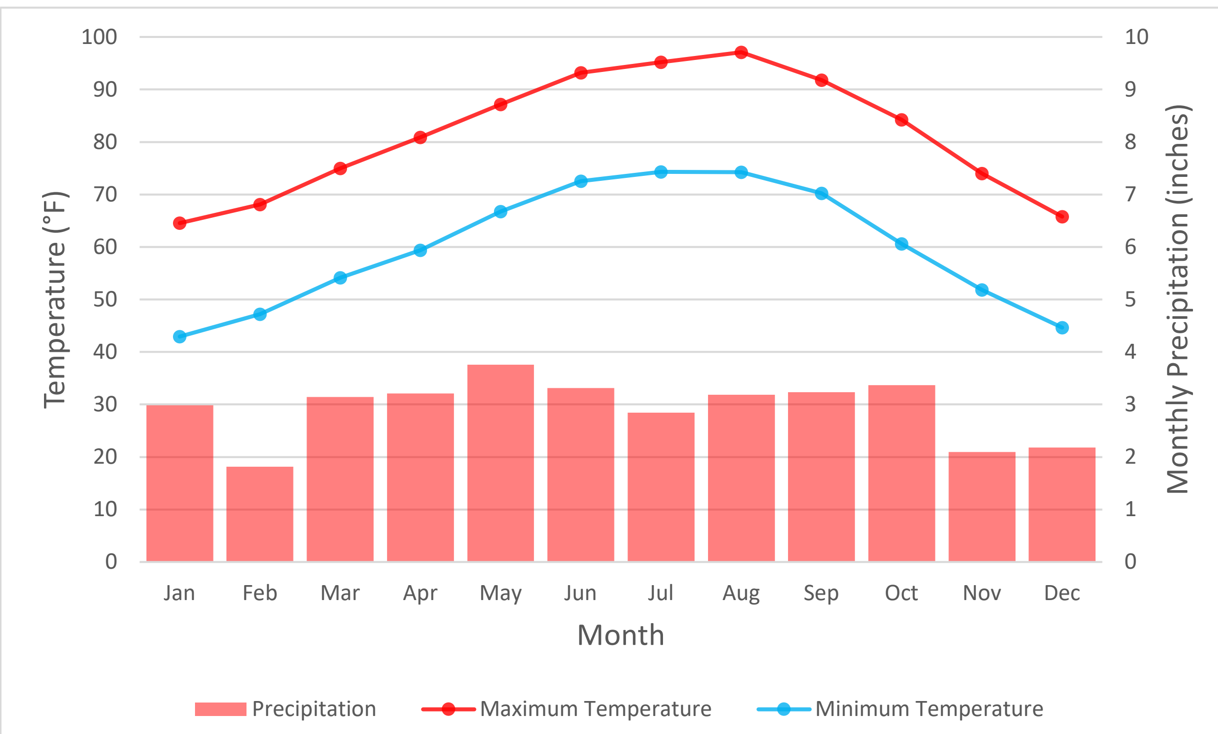


Figure 3. Average monthly temperature and precipitation (2005–2020) at Hallettsville, Texas station (USC00413873)

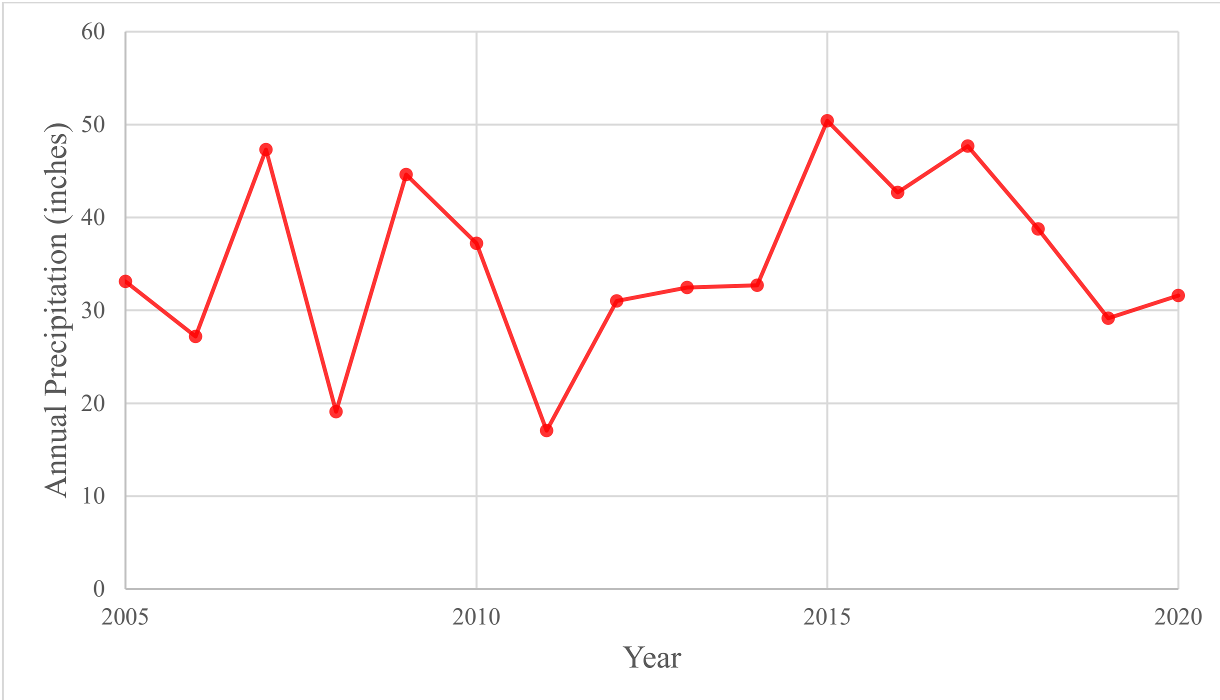


Figure 4. Annual precipitation (2005–2020) at Hallettsville, Texas station (USC00413873)

2.4. Watershed Population and Population Projections

Watershed population estimates were developed using the United States Census Bureau (USCB) 2010 census blocks data (USCB, 2010). Census blocks are the smallest geographic units used by USCB to tabulate the population data. The AU 1602_02 watershed includes 1,929 census blocks, located entirely or partially in its watershed. Population was estimated for those census blocks partially located in the TMDL watershed by multiplying the census block population and the percentage of each block within a census block. These estimated, partial census block populations were then summed with the populations from the census blocks located entirely within the TMDL watershed. Based on this methodology, the AU 1602_02 watershed population is estimated at 19,618 people (Figure 5).

Texas Water Development Board (TWDB) 2021 Region P Regional Water Plan Population and Water Demand Projection data indicate that between 2010 and 2070, the population of Lavaca County, which encompasses the majority of the TMDL watershed, is not expected to increase in population (Region P Water Planning Group, 2019). The 2021 Region P, K, and L Regional Water Plan Population and Water Demand Projection data indicate an increase in population for the City of Yoakum Water User Group (WUG) in DeWitt County and the rural area population in the other four counties in the TMDL watershed (Table 2; Region K Water Planning Group, 2019; Region L Water Planning Group, 2019; Region P Water Planning Group, 2019). The decadal proportional increases from these WUGs were applied to the corresponding estimated 2010 historical WUG populations and added to the AU 1602_02 watershed population to estimate future total population projections (Table 3). The procedure used to determine the watershed population and projections is detailed in Appendix A.

Table 2. WUG historical census population and projections

WUG	2010	2020	2030	2040	2050	2060	2070	Percentage increase (2020–2070)
County-Other, DeWitt	8,777	9,136	9,444	9,594	9,731	9,822	9,887	8.22%
County-Other, Gonzales	1,813	2,277	2,503	2,717	2,965	3,219	3,482	52.92%
County-other, Fayette	9,104	9,532	10,943	11,825	12,511	13,015	13,353	40.09%
County-Other, Jackson	6,534	6,779	7,017	7,118	7,201	7,253	7,286	7.48%
Yoakum, DeWitt County (Region L)	2,165	2,195	2,269	2,305	2,339	2,361	2,376	8.25%
Lavaca County*	19,263	19,263	19,263	19,263	19,263	19,263	19,263	0.00%

*Includes Hallettsville, Moulton, Shiner, Yoakum WUGs within Lavaca County and Lavaca County outside of the WUGs.

Table 3. 2010 population with population projections

Area	2010 (U.S. Census Population, estimated)	2020	2030	2040	2050	2060	2070	Percentage increase (2020 – 2070)
Lavaca River Above Tidal AU 1602_02 watershed	19,618	19,698	19,809	19,870	19,929	19,971	20,006	1.56%

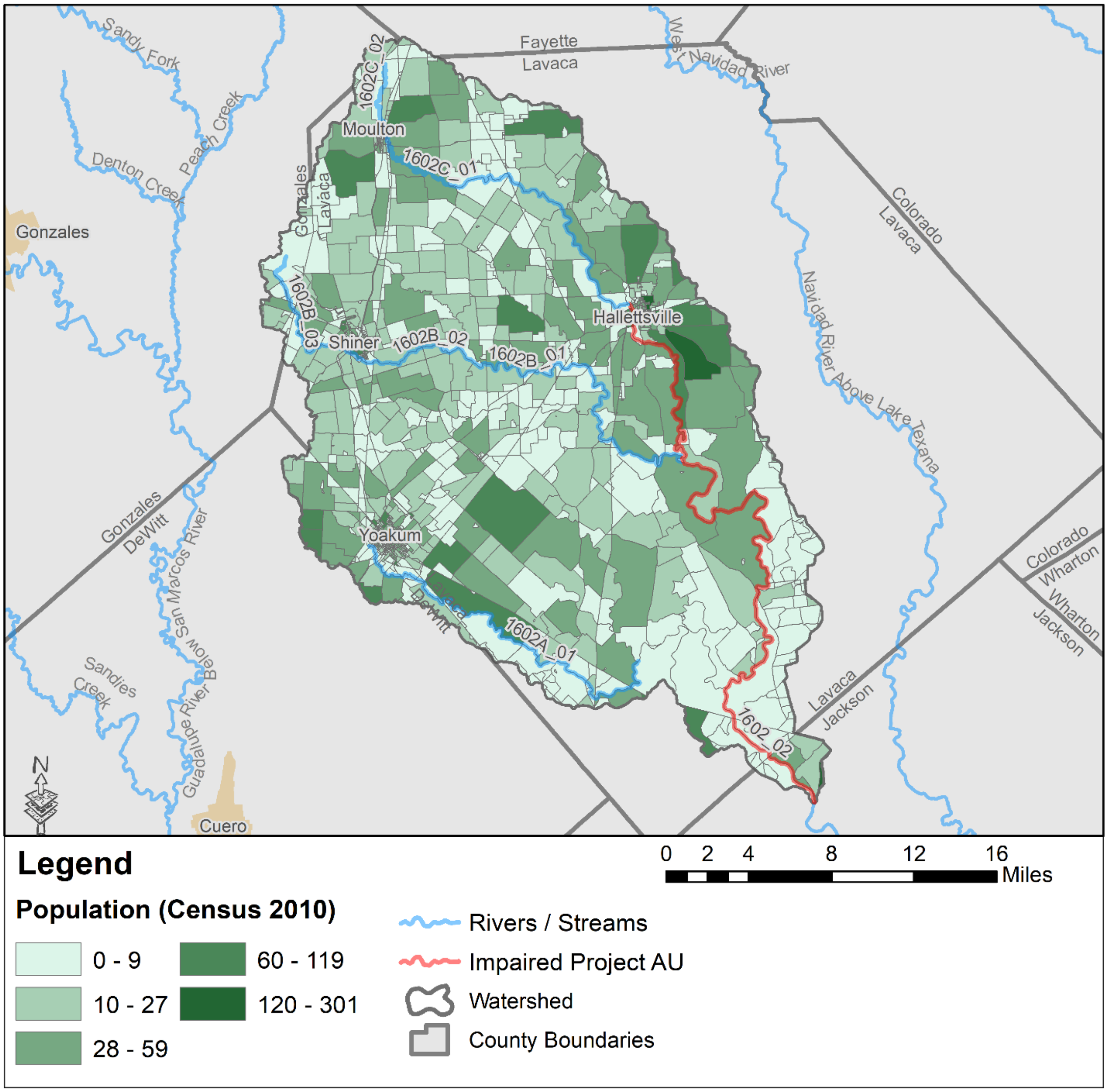


Figure 5. 2010 population estimates by US census blocks

2.5. Land Cover

Land cover data for the TMDL watershed were obtained from the 2016 National Land Cover Database (NLCD) (United States Geological Survey (USGS), 2019) and are displayed in Figure 6. 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.

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

- 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.

The total area of Lavaca River Above Tidal AU 1602_02 watershed is 375,694.64 acres (Table 4). The dominant land covers in the watershed are Hay/Pasture (60.15%), followed by Deciduous Forest (11.31%) and Shrub/Scrub (9.36%). The watershed is predominantly rural in land use, with only about 5% of the total watershed area classified as Developed land cover (Open Space, Low Intensity, Medium Intensity, and High Intensity).

2.6. Soils

Soils within the TMDL watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the United States 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.

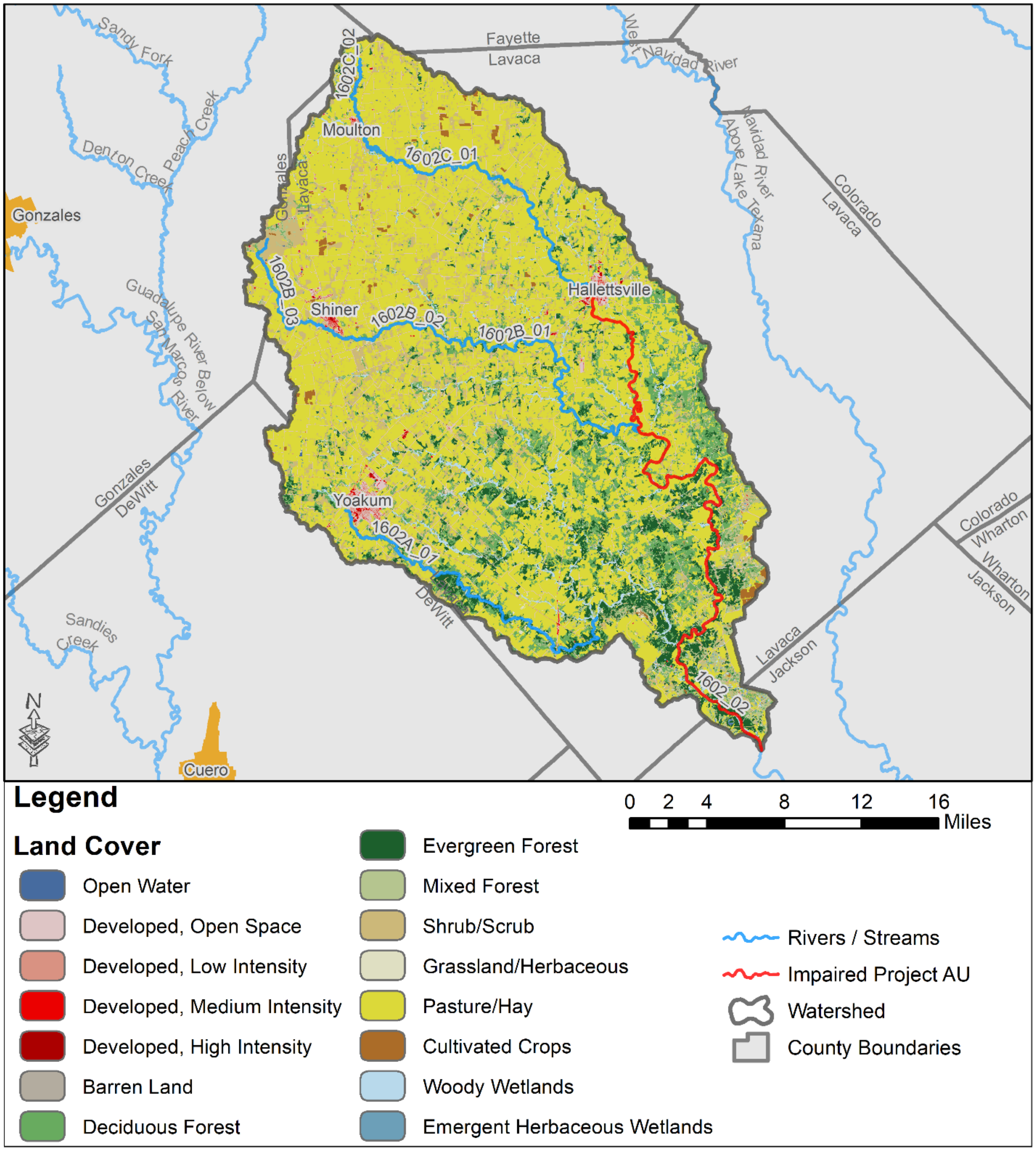


Figure 6. **2016 land cover**

Table 4. Land cover summary

Land cover	Area (Acres)	Percentage
Open Water	813.52	0.22%
Developed, Open Space	14,462.32	3.85%
Developed, Low Intensity	3,016.76	0.80%
Developed, Medium Intensity	955.59	0.25%
Developed, High Intensity	346.69	0.09%
Barren Land	126.14	0.03%
Deciduous Forest	42,488.14	11.31%
Evergreen Forest	23,053.80	6.14%
Mixed Forest	13,811.38	3.68%
Shrub/Scrub	35,147.19	9.36%
Grassland/Herbaceous	1,860.07	0.50%
Pasture/Hay	225,978.32	60.15%
Cultivated Crops	2,635.24	0.70%
Woody Wetlands	10,347.83	2.75%
Emergent Herbaceous Wetlands	651.67	0.17%
Total	375,694.64	100%

- 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.

The TMDL watershed is composed mostly of soils in Hydrologic Soil Group D (52.64%) and Hydrologic Soil Group C (29.51%) (Table 5). Figure 7 shows the spatial distribution of soil hydrologic groups within the watershed.

Table 5. Hydrologic soil group summary

Hydrologic Soil Group	Acres	Percentage
A	44,239.65	11.78%
A/D	1,923.76	0.51%
B	20,676.80	5.50%
C	110,861.56	29.51%
C/D	234.34	0.06%
D	197,758.54	52.64%
Total	**375,694.64**	**100%**

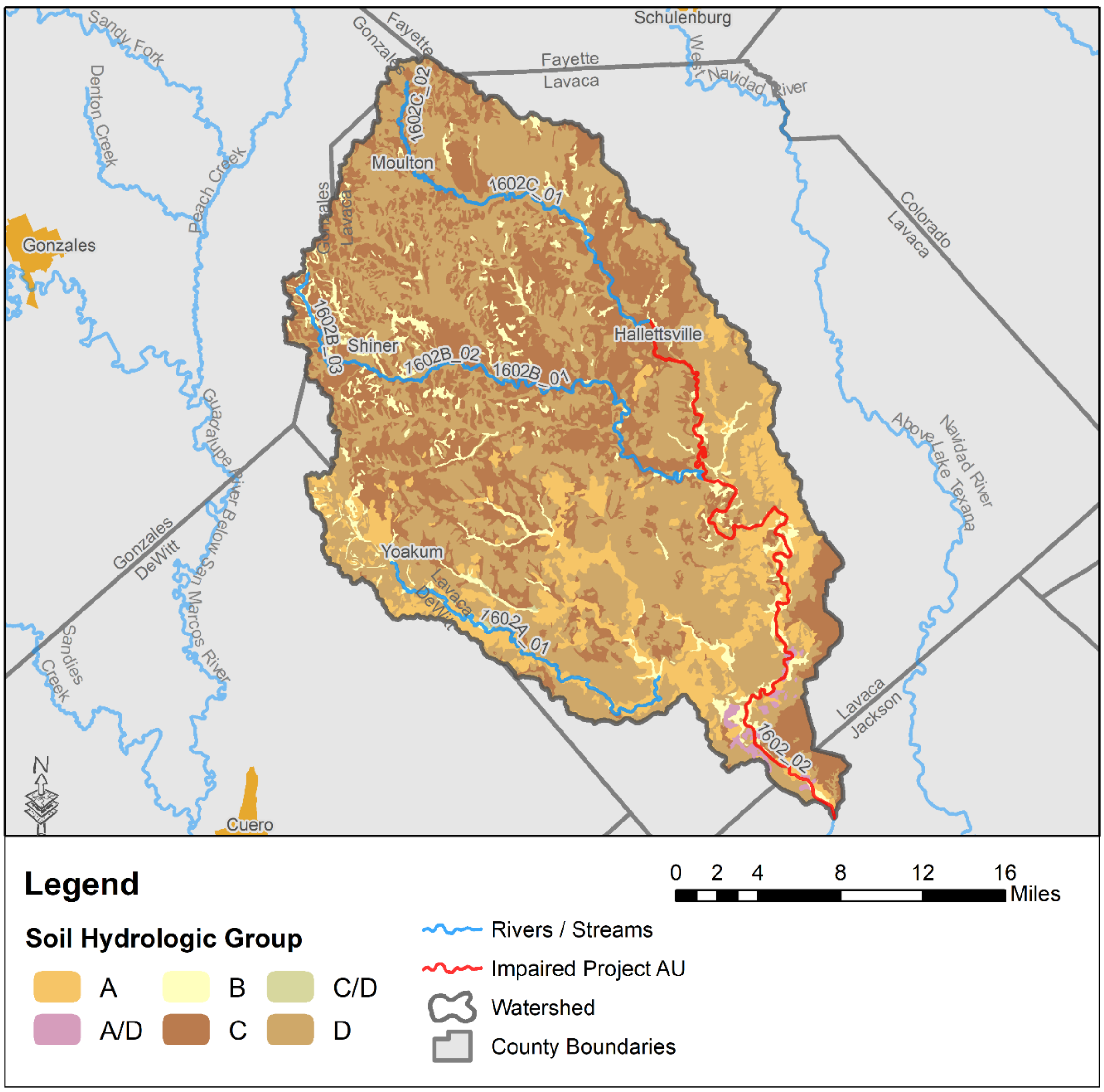


Figure 7. Hydrologic soil groups

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 regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) program. Wastewater treatment facilities (WWTFs) and stormwater discharges from industries, construction, 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.

With the exception of 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 different sources of bacteria expected in the TMDL 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 domestic WWTFs, and stormwater discharges from construction, industrial, and concrete production facilities.

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

As of December 2020, there are four facilities with a TPDES permit that operate within the AU 1602_02 watershed (Table 6, Figure 8; USEPA, 2021). All these facilities treat solely domestic wastewater.

2.7.1.2 TCEQ/TPDES General Wastewater Permits

Certain types of activities must be covered by one of several TCEQ/TPDES 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)

Table 6. Permitted domestic and industrial WWTFs discharging in the TMDL watershed

AU	TPDES/ NPDES[a] Number	Permittee	Outfall Number	Bacteria (*E. coli*) Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD[b])	Daily Average Flow – Recent Discharge (MGD) [c]
1602_02	WQ0010013001 / TX0025232	City of Hallettsville	001	126	Treated domestic wastewater	0.8	0.328
1602C_02	WQ0010227001 / TX0053287	City of Moulton	001	126	Treated domestic wastewater	0.242	0.077
1602B_02	WQ0010280001 / TX0026042	City of Shiner	001	126	Treated domestic wastewater	0.85	0.338
1602A_01	WQ0010463001 / TX0026034	City of Yoakum	001	126	Treated domestic wastewater	0.95	0.584

[a] NPDES: National Pollutant Discharge Elimination System

[b] MGD: million gallons per day

[c] Reflects discharges available from January 01, 2005–December 31, 2020

A review of active general permit coverage (TCEQ, 2021a) in the TMDL watershed, as of December 2020, found two concrete production facilities covered by the general permit. The same review revealed one pesticide permittee covered by the general permit. These facilities and pesticide management area 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 them. There were no other active general wastewater permit facilities or operations in the watershed.

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.

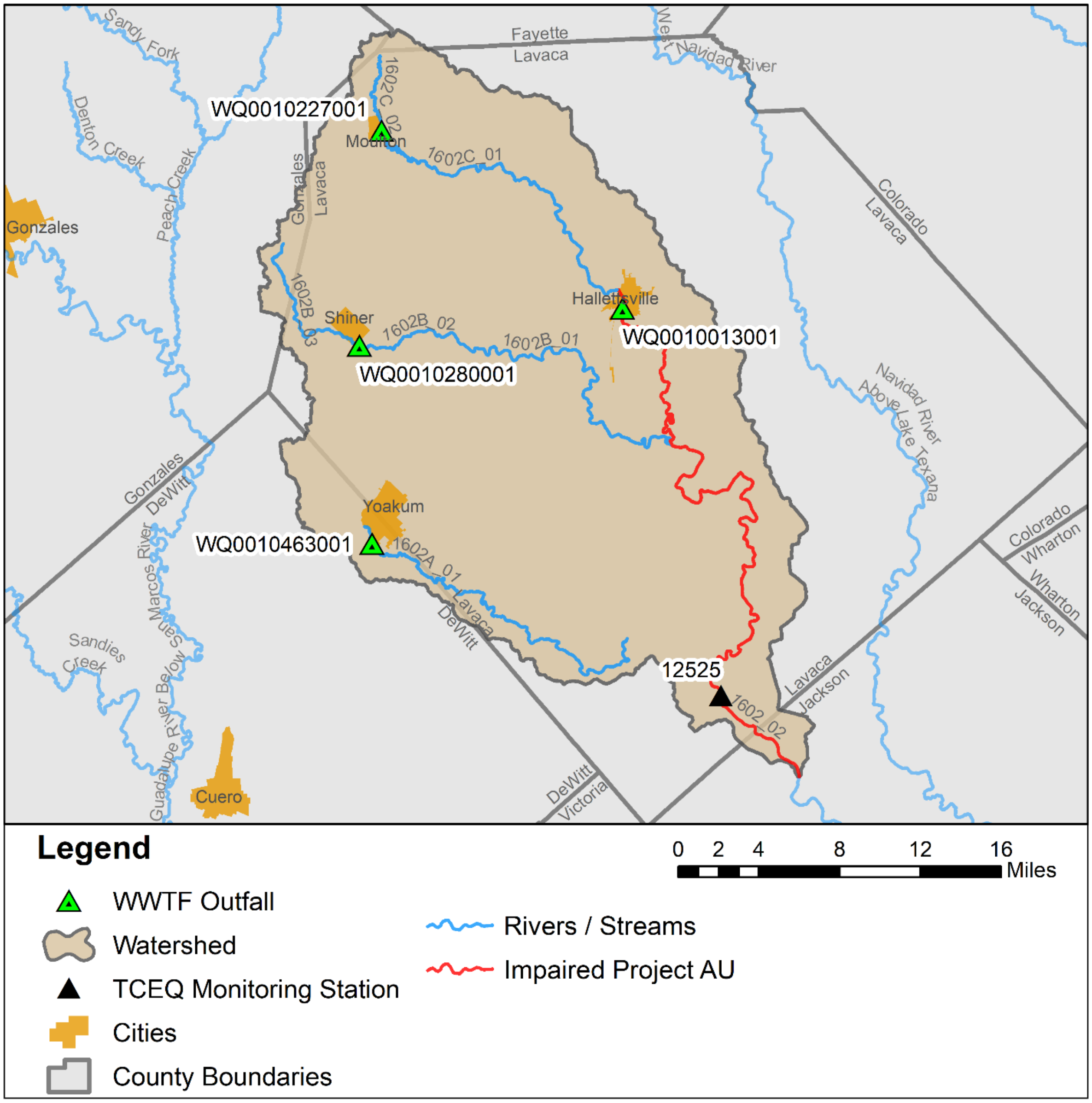


Figure 8. WWTFs in the TMDL watershed

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 MS4s with populations of 100,000 or more based on the 1990 United States Census, whereas the Phase II General Permit regulates small MS4s within an urbanized area as defined by the USCB.

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 will be implemented consistent with permit requirements to minimize the discharge of pollutants from the MS4. The 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.

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 Lavaca River Above Tidal original TMDL watershed does not include any active Phase I MS4 permits, nor does the AU 1602_02 watershed, which lies within the watershed of the original TMDLs.

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

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

The Lavaca River Above Tidal watershed as a whole does not include any active Phase II MS4 permit authorizations. General permit authorizations were obtained from the TCEQ Central Registry. There were nine active MSGP facilities and two concrete production facilities in the TMDL watershed. These authorizations covered approximately 160.21 acres of the Lavaca River Above Tidal TMDL watershed.

A search of active, terminated, and expired construction authorizations between January 2011 and December 2020 was conducted. Table 7 summarizes the acreages found in that 10-year period. On average, 48.762 acres of land in the TMDL watershed were under construction authorizations each year within the 10-year period.

Table 7. Annual total and average acres under construction authorizations

Year	Construction Authorization Acres
2011	5
2012	17
2013	27
2014	17
2015	17
2016	21.54
2017	26.54
2018	144.04
2019	117.5
2020	95
Annual Average (2011 – 2020)	**48.762**

2.7.1.4. Sanitary Sewer Overflows

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 exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

SSO incidents in the TMDL watershed from January 2009 through December 2020 were obtained from the TCEQ Region 14 Office and Central Office in Austin (TCEQ, 2016; TCEQ, 2021b). Wastewater facilities reported only nine incidents in the watershed between 2009 and 2020. Two incidents had unknown discharge volumes, while the other seven had a total discharge of 12,600 gallons, with a minimum of 100 gallons and a maximum of 5,000 gallons.

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 or small 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 identified 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, agricultural animals, failing on-site sewage facilities (OSSFs), and domestic pets.

2.7.2.1. Wildlife and Unmanaged Animal Contributions

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. Wildlife are naturally attracted to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Wildlife also leave feces on land, where they may be washed into nearby water bodies by rainfall runoff.

The Texas Parks and Wildlife Department (TPWD) provided deer population-density estimates by Deer Management Unit (DMU) and Ecoregion in the state (TPWD, 2020). The AU 1602_02 watershed lies within DMU 11 (Post Oak Savannah), with an average deer density of 21 acres per deer in the suitable land cover over the period 2005-2019. Based on 355,973.63 acres of suitable land in the watershed (land covers classified in the 2016 NLCD as Pasture/Hay, Shrub/Scrub, Grassland/Herbaceous, Cultivated Crops, Forests, Wetlands), there are an estimated 16,951 deer in the watershed (Table 8).

AgriLife Extension (2012) estimates one hog per 39 acres of suitable land cover as a statewide average density of feral hogs. This density was applied to the suitable land in the TMDL watershed (land covers classified in the 2016 NLCD as Pasture/Hay, Shrub/Scrub, Grassland/Herbaceous, Cultivated Crops, Forests, Wetlands), resulting in an estimated 9,128 feral hogs in the watershed (Table 8).

Table 8. Estimated deer and feral hog populations

AU	Estimated Number of Deer	Estimated Number of Feral Hogs
1602_02	16,951	9,128

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 water bodies and farmers' use of manure as fertilizer, can contribute FIB to nearby water bodies. Within the TMDL watershed, dry poultry litter is often used as fertilizer from the many regional poultry operations. Since the dry poultry litter is composted prior to application, it is unlikely to be a source of bacteria. The estimated counts of goats, sheep, and horses were developed using county-level data available from the 2017 Census of Agriculture (USDA, 2019). The county level data were refined to reflect acres of grazeable land (Pasture/Hay, Shrub/Scrub, and Grassland/Herbaceous) within the TMDL watershed. The refinement was determined by the area classified as grazeable land in the watershed divided by the total area of the county classified as grazeable land. The ratio of grazeable acres was multiplied by USDA county level livestock estimates. Cattle and calf populations were determined based on stocking rate feedback from stakeholders. A stocking rate of one animal unit per seven acres of grazeable land was applied to estimate the cattle and calf animal units in the watershed. To convert from animal units to head of cattle, a conversion factor of 1.3 head of cattle per animal unit was multiplied by the resulting animal unit calculation. Table 9 shows the watershed level estimates for livestock.

Table 9. Estimated livestock populations

AU	Cattle and Calves	Goats	Sheep	Horses
1602_02	48,839	717	378	813

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 10 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 2017 – 2018 U.S. Pet Statistics (AVMA, 2018). The number of households in the watershed was estimated using 2010 Census data (USCB, 2010). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 10. Estimated households and pet populations

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
1602_02	9,800	6,017	4,479

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 TMDL watershed is located within the Texas Region 4 area, which has a reported failure rate of about 12%, providing insights into expected failure rates for the area (Reed, Stowe, and Yanke, 2001).

Estimates of the number of OSSFs in the watershed were determined by using the 911 addresses that lie outside of the Certificates of Convenience and Necessity boundaries (Gregory et al., 2014). Residential and business locations were selected from the 911 address points by using aerial imagery data. These sources indicate that there are 4,045 OSSFs located within the AU 1602_02 watershed. Figure 9 shows the OSSF density in the TMDL watershed.

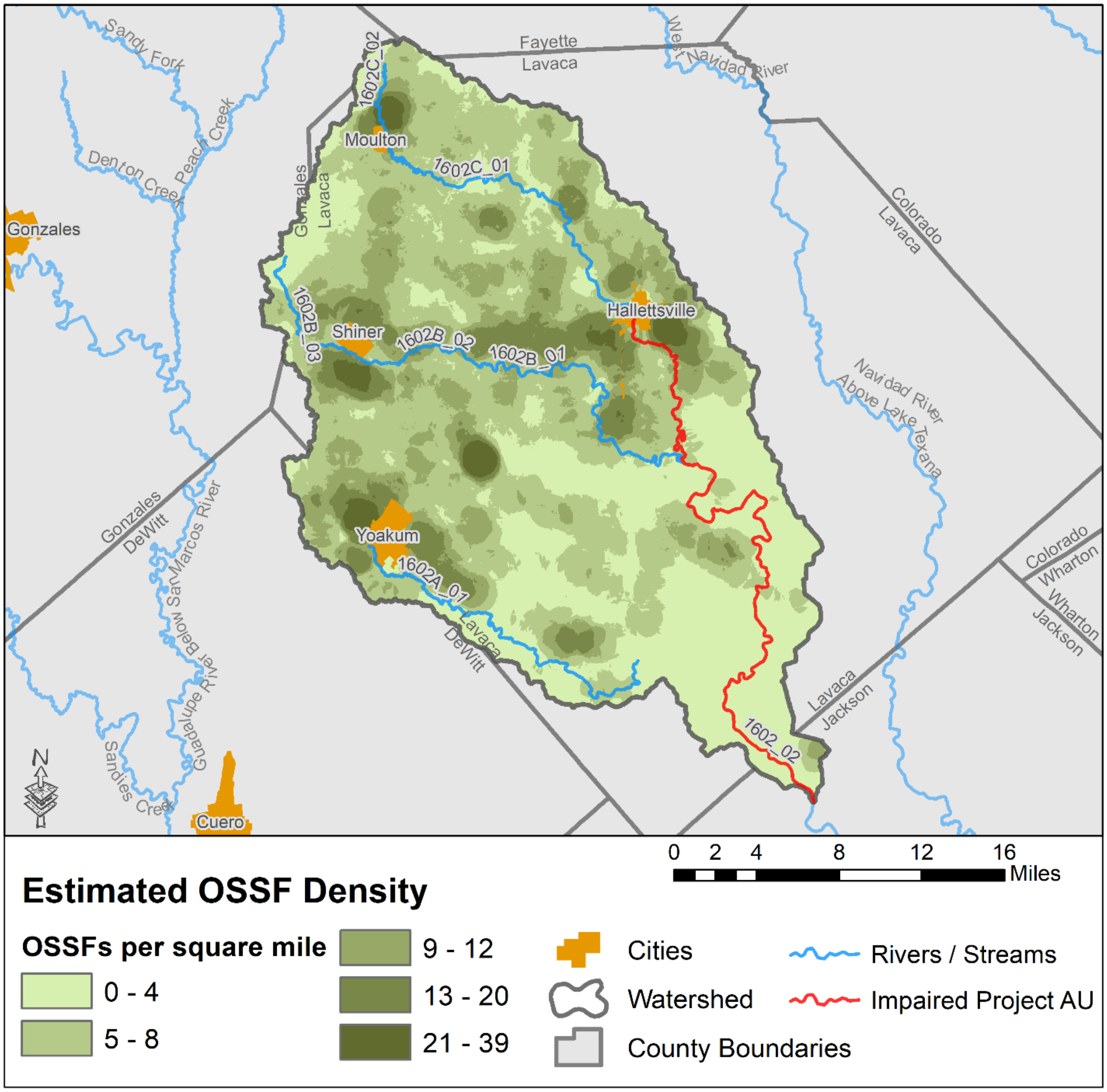


Figure 9. OSSF density

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 appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly treated effluent 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 die-off of 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 of the bacteria tool selection 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, e.g., *E. coli*, loads to their sources such that the total loads do not violate the pertinent numeric criterion protecting contact recreation use. The appropriate bacteria tool was selected for the impaired AU by considering the availability of data and other information necessary to support application of the selected tool and guidance in the Texas bacteria task force report (TWRI, 2007). Mechanistic models and empirically derived LDCs are the two approaches commonly used for bacteria TMDLs in Texas.

Mechanistic models, also referred to as process models, are based on theoretical relationships that numerically describe the physical processes that determine streamflows and bacteria concentrations, in addition to other related response variables. There are mechanistic models that reliably represent streamflow and bacteria response to land use, rainfall, tidal inputs, and other processes. While hydrologic processes integrated within these models are quite robust, the numeric representations of bacteria transport processes are considered less reliable (TWRI, 2007). Painter et al. (2016) also note that while mechanistic bacteria modelling has progressed significantly, the application of these models relies on quite specific watershed information, more than what is required for representation of hydrologic processes. As a result, decisions on input parameters that affect bacteria response must be made by the modeler when the actual numeric values may not be available within an acceptable range of certainty (Painter et al., 2016). However, under circumstances where the governing physical processes are acceptably quantifiable, the mechanistic model provides an understanding of the important biological, chemical, and physical processes of the prototype system and reasonable predictive capabilities to evaluate alternative allocations of pollutant load sources.

The LDC method estimates 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 that frequent information limitations with bacteria TMDLs constrain the use of the more powerful mechanistic models. Further, the bacteria task force appointed by TCEQ and the Texas State Soil and Water Conservation Board supported the application of the LDC method within their three-tiered approach to TMDL development (TWRI, 2007). The LDC method lacks the predictive capabilities to evaluate alternative allocation approaches to reach TMDL goals, and it cannot quantify specific source contributions and instream fate and transport processes. However, the method does provide a means to estimate the difference in bacteria loads and relevant criteria and can give indications of broad sources of the bacteria, that is, point and nonpoint sources.

3.2. Data Resources

Streamflow and *E. coli* data availability were used to guide selection of the allocation tool. The necessary information and data are largely unavailable for the TMDL watershed to allow the adequate definition of many of the physical and biological processes influencing instream bacteria concentrations for mechanistic model application, and these limitations became an important consideration in the allocation tool selection process.

Hydrologic data in the form of daily streamflow records were unavailable in the TMDL watershed. However, streamflow records are available at the downstream AU 1602_03 (USGS, 2021). Streamflow records for the streamflow gauge 08164000 (Lavaca River near Edna, TX) are collected and made available by the USGS (Table 11, Figure 10). This gauge was used to develop estimated, naturalized, mean-daily streamflow for the AU 1602_02 watershed. The steps for estimating streamflow for the TMDL watershed are further discussed in Section 3.3.4. .

Table 11. Basic information on the USGS streamflow gauge used for streamflow development

USGS Gauge No.	Site Description	Drainage Area (square miles)	Daily Streamflow Record
08164000	Lavaca River near Edna, TX	819.397	01/01/2005–12/31/2020

Historical ambient *E. coli* data used for the development of LDCs was obtained through the TCEQ Surface Water Quality Monitoring Information System database (TCEQ, 2021c) (Table 12, Figure 11). The TMDL was developed using only the downstream SWQM station 12525, due both to its proximity to the TMDL watershed outlet and having sufficient data needed for analysis.

The TMDL watershed includes two active surface water diversion rights. However, both the water rights owners did not report any surface water diversions, and the maximum allowable diversions were insignificant to impact stream hydrology and pollutant load allocations. Water right permits allow only withdrawals of water, not discharges into a stream and therefore, need not be assigned loadings in a TMDL.

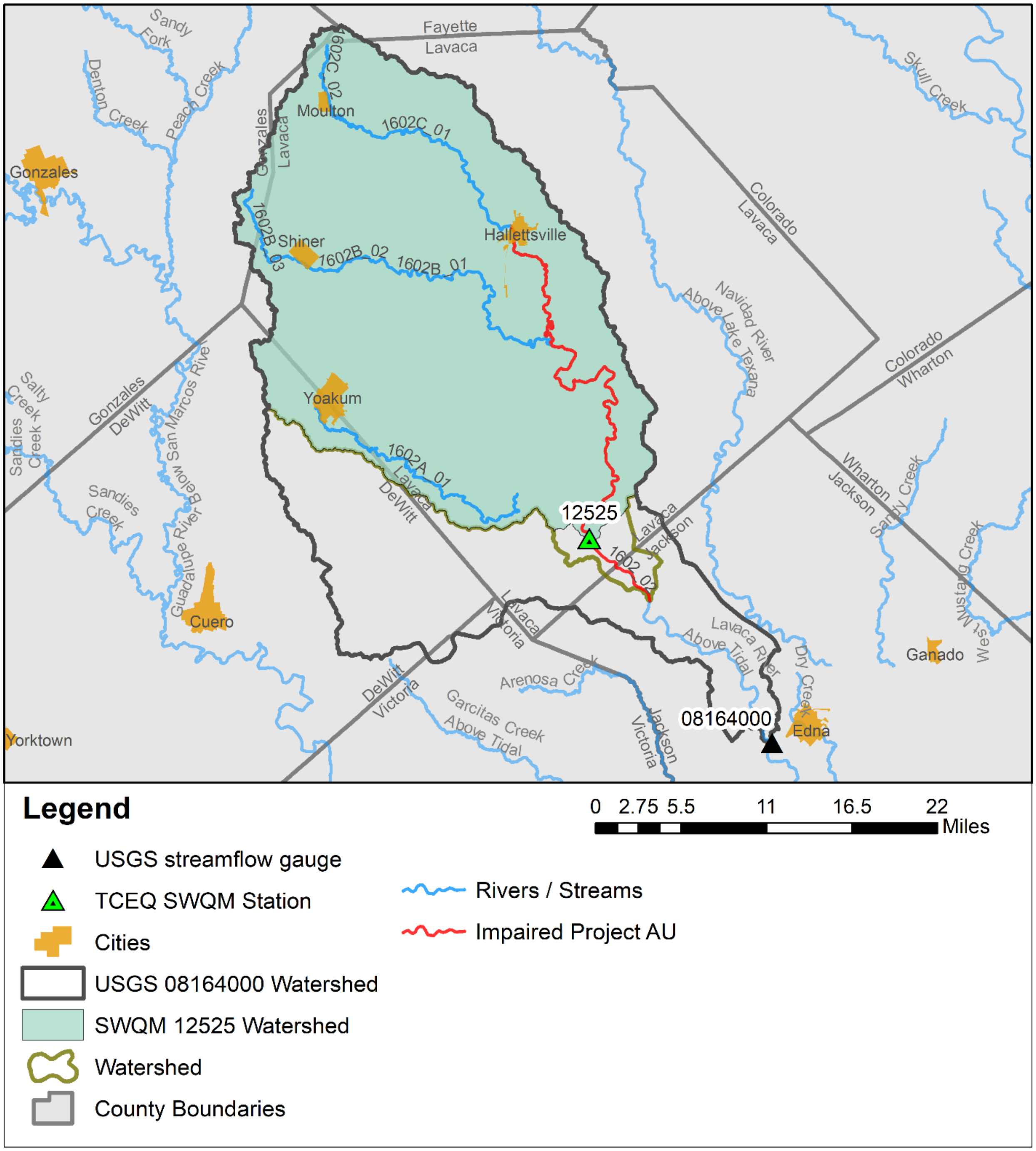


Figure 10. USGS streamflow gauge and watershed used in streamflow development

Table 12. Summary of historical bacteria dataset

Water Body Name	AU	SWQM Station	Station Location	No. of Samples	Data Date Range	Geomean	Percentage exceeding single sample criterion
Lavaca River Above Tidal	1602_02	12525	Lavaca River at SH 111	74	1/11/2005-10/6/2020	200.90	21.62

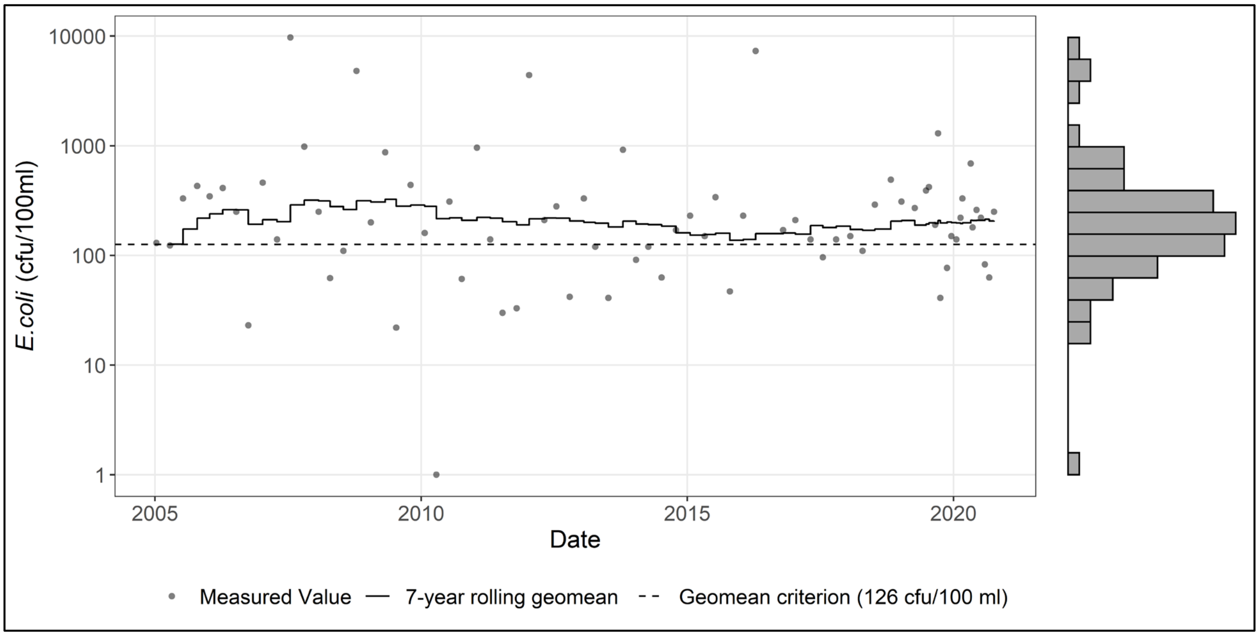


Figure 11. Summary plot of historical bacteria dataset at SWQM station 12525, including seven-year rolling geometric mean and histogram depicting the distribution of measured values

3.3. Methodology for Flow Duration and Load Duration Curve Development

To develop the flow duration curve (FDC) and LDC, 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 desired stream location for which FDC and LDC development is desired.
- Step 3: Develop drainage-area ratio (DAR) parameter estimates.
- Step 4: Develop daily streamflow record at desired location.
- Step 5: Develop FDC at the desired stream location, segmented into discrete flow regimes.

- Step 6: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 7: Superimpose historical bacteria data on the allowable bacteria LDC.

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

3.3.1. Step 1: Determine Hydrologic Period

Daily streamflow records were developed from the USGS gauge 08164000 at Lavaca River near Edna, Texas (Figure 11) (USGS, 2021). The streamflow gauge is located downstream of the AU 1602_02 watershed and its drainage area overlaps that of the TMDL watershed. Thus, the flows per unit drainage area at the USGS gauge are representative of the flows in the AU 1602_02 watershed. Daily mean streamflow data were collected for a 16-year period between January 1, 2005 and December 31, 2020. This period of record was enough to capture a reasonable range of the extreme high and low streamflow events and hydrologic variability from high to low precipitation years. It also represents a period in which most of the *E. coli* data were collected at the SWQM station.

3.3.2. Step 2: Determine Desired Stream Location

Data were available for two SWQM stations located on AU 1602_02, but Station 12525 was located closer to the TMDL watershed outlet and thus was selected for FDC/LDC development (Figure 1). The station had 74 *E. coli* samples within the selected hydrologic period, meeting the 24 minimum-sample suggestion for development of LDCs (TWRI, 2007).

3.3.3. Step 3: Develop Drainage-Area Ratio Parameter Estimates

Once the hydrologic period of record and stream locations are determined, the next step is to develop daily streamflow record for the SWQM station using the streamflow data from the USGS streamflow gauge.

The DAR method was used to transfer the measured streamflow series of the USGS streamflow gauge to the SWQM station location. The daily streamflow at the station (Y) was estimated by multiplying the USGS gauge mean daily streamflow to a factor representing the ratio of their corresponding drainage areas.

$$Y = X(A_y/A_x)^\wedge\varphi \quad \text{(Equation1)}$$

Where:

X = streamflow at the USGS streamflow gauge location

A_y = drainage area for the SWQM station location

A_x = drainage area for the USGS streamflow gauge location

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

Often, φ = 1 is used in the DAR approach. However, empirical analysis of streamflow in Texas indicates that φ = 1 results in substantial bias in streamflow estimates at very low and very high streamflow percentiles (Asquith et al, 2006). Based on these observations, values of φ are used based on suggestions by Asquith et al. (2006). The value of φ varies with streamflow percentiles and lies between 0.7 and 0.935.

3.3.4. Step 4: Develop Daily Streamflow Record at Desired Location

After the DAR parameters were estimated, the DAR method was applied to the 16-year daily record of naturalized flows in the USGS gauge watershed. Here, the naturalized flows refer to the flow without any withdrawals from the water right owners and discharges from any permitted facility.

The naturalized flows at the USGS streamflow gauge were estimated by subtracting the recorded mean daily discharges for the four wastewater treatment facilities from the streamflow record of the USGS gauge. As there were no recorded withdrawals by the water right owners during the hydrologic period, no flow had to be added to the USGS gauge streamflow.

Once the naturalized flows were calculated, the next step was to multiply the daily flows with the corresponding DAR factor as discussed in the previous section. The total drainage area of the SWQM station is 569.59 square miles and the DAR between the SWQM station and the USGS gauge watershed is 0.695. The resultant daily flows are the estimated naturalized flows at the station.

The full permitted daily discharges from the four WWTFs and potential future growth flows were added back to the naturalized flows at the SWQM station to obtain the streamflow at the station. The calculations for potential future growth flows are discussed in Section 4.7.4.

3.3.5. Steps 5 through 7: 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 undertaken:

1. 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).
2. Compute the percentage of days each flow was exceeded by dividing each rank by the total number of data points plus one.
3. Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (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 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 Curve for the TMDL Watershed

An FDC was developed for the impaired AU (1602_02) at SWQM station 12525 (Figure 12). For this report, the FDC was developed by applying the DAR method to the USGS gauge streamflow record for the hydrologic period (January 1, 2005–December 31, 2020) described in the previous sections.

3.5. Load Duration Curve for the TMDL Watershed

The LDC was developed for AU 1602_02 using data from SWQM station 12525. It is useful to refine the LDC approach by dividing the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curve. This approach can assist in determining streamflow conditions under which exceedances are occurring. The following five intervals were used along the x-axis of the FDC and LDC: (1) 0-10% (high flows); (2) 10-40% (moist conditions); (3) 40-60% (mid-range flows); (4) 60-90% (dry conditions); and (5) 90-100% (low flows), as recommended by Cleland (2003).

The selection of the flow regime intervals was based on general observation of the developed LDC. Figure 13 depicts the LDC for the AU 1602_02 watershed. The geometric mean loading in each flow regime is also shown to aid interpretation.

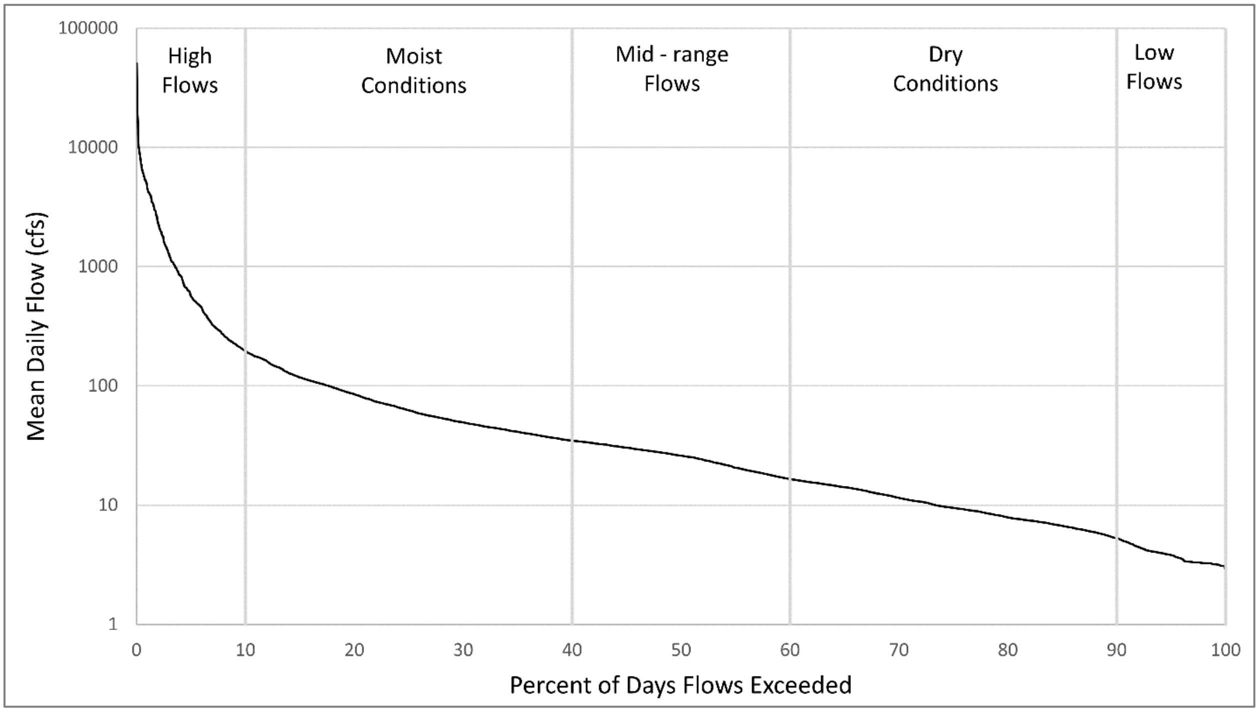


Figure 12. FDC at SWQM station 12525

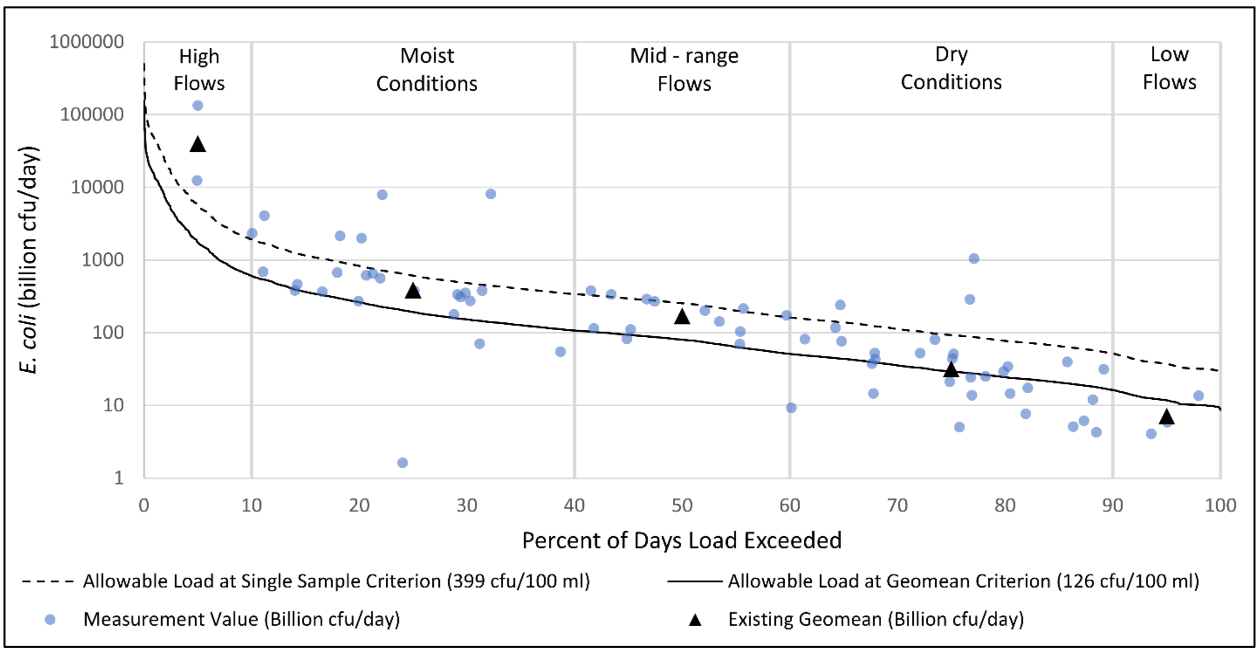


Figure 13. LDC at SWQM station 12525

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.

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

Federal regulations [Title 40, Code of Federal Regulations Title 40, Chapter 1, Part 130, Section 130.7(c)(1) (or 40 CFR 130.7(c)(1))] require that TMDLs account for seasonal variation in watershed conditions and pollutant loading.

Seasonal variations or seasonality occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Analysis of the seasonal differences in indicator bacteria concentrations compared *E. coli* data collected during warmer months (May–September) against those collected during cooler months (November–March). The months of April and October were considered transitional between warm and cool seasons and were excluded from the seasonal analysis. Differences in seasonal concentrations were then evaluated with a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). The Wilcoxon Rank Sum test was chosen for its ability to handle non-normal data without requiring data transformation. The test was considered significant at the $\alpha = 0.05$ level.

The analysis of *E. coli* data for the SWQM station 12525 indicated that there was no significant difference in indicator bacteria between the cool and warm weather seasons ($W = 242.5$, $p = 0.5794$) for AU 1602_02. The distribution of *E. coli* data during cool and warm seasons is shown in Figure 14.

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.

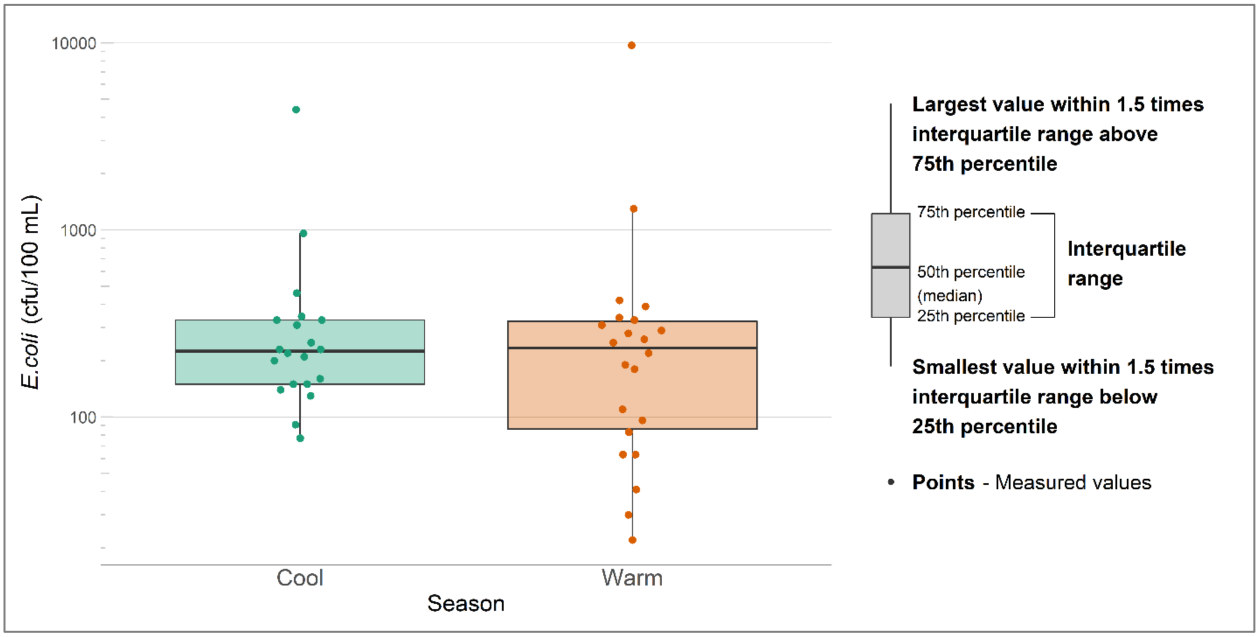


Figure 14. Distribution of *E. coli* concentration by season for SWQM station 12525

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 magnitude, 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, has the capacity to 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.

An LDC was 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 the LDC to define the TMDL pollutant load allocation (4.7. Pollutant Load Allocations). 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 USEPA 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 utilizing 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.

Based on the LDC to be used in the pollutant load allocation process with historical *E. coli* data added to the graph (Figure 13) the following broad linkage statements can be made.

Historical *E. coli* data for the TMDL watershed indicate that elevated bacteria loading primarily occurs under high flows, moist conditions, mid-range flows, and dry conditions. However, bacteria loads are most elevated under the high flows. Loadings fall below the geometric mean criterion under low flows.

Regulated stormwater only comprises of a small portion of the TMDL watershed; therefore, unregulated stormwater likely contributes to most of the high flow-related loadings. The *E. coli* loadings under low flows cannot reasonably be attributed exclusively to WWTFs because the facilities are located at a significant distance from the SWQM station and have a relatively good compliance record. Therefore, other sources of bacteria loadings under low flows in the absence of stormwater are 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, and livestock. 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 USEPA guidance (USEPA, 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 AU 1602_02 watershed was developed using load allocations, additional insight was gained through a load reduction analysis. A single percentage load reduction required to meet the allowable loading for each flow regime was determined using the historical *E. coli* data obtained from the SWQM stations in the watershed. For each flow regime the percentage reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 126 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 13).

Table 13. Percentage reduction needed to meet water quality standards

Flow Regime	Geomean Concentration (cfu/100 mL)	Percentage Reduction Required
High Flows	2905.00	95.663
Moist Conditions	253.97	50.388
Mid-Range Flows	267.38	52.875
Dry Conditions	136.4	7.626
Low Flows	76.01	NA

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:

$$TMDL = WLA + LA + FG + MOS \qquad \text{(Equation 2)}$$

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 SWQM station located within the watershed (Figure 11). As discussed in more detail in Section 3.5. Load Duration Curve for the TMDL Watershed, 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 flows regime) is the TMDL.

$$TMDL\ (cfu/day) = Criterion * Flow\ (cfs) * Conversion\ Factor \qquad \text{(Equation 3)}$$

Where:

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

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

The allowable loading of *E. coli* that AU 1602_02 can receive on a daily basis was determined using Equation 3 based on the median value within the high-flow regime of the FDC (or 5% flow exceedance value) for the SWQM station (Table 14).

Table 14. Summary of allowable *E. coli* loading calculation

Water Body Name	AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
Lavaca River Above Tidal	1602_02	565.38	1742.889×10^9	1742.889

4.7.2. Margin of Safety Allocation

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

$$MOS = 0.05 * TMDL \qquad \text{(Equation 4)}$$

Where:

TMDL = total maximum daily load

Using the value of TMDL for the AU provided in Table 14, the MOS may be readily computed by proper substitution into Equation 4 (Table 15).

Table 15. MOS calculations

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

Water Body Name	AU	TMDL[a] (billion cfu/day)	MOS (billion cfu/day)
Lavaca River Above Tidal	1602_02	1742.889	87.144

[a] TMDL from Table 14.

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}).

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Equation 5)}$$

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. The *E. coli* primary contact recreation geometric mean criterion (126 cfu/100 mL) was used as the WWTF target to provide instream and downstream load capacity, and to be consistent with other Texas indicator bacteria TMDLs. Thus, the WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \qquad \text{(Equation 6)}$$

Where:

Target= 126 cfu/100 mL

Flow = full permitted flow (MGD)

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

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for the AU. The criterion was applied based on the indicator bacteria designated for the segment. Table 16 presents the WLA for each WWTF and the resulting total allocation for the AU within the TMDL watershed.

Table 16. WLAs for TPDES-permitted facilities

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

Receiving AU	TPDES Permit No.	NPDES Permit No.	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF} (billion cfu/day)
1602C_02	WQ0010227001	TX0053287	City of Moulton	0.242	1.154
1602B_02	WQ0010280001	TX0026042	City of Shiner	0.85	4.054
1602_02	WQ0010013001	TX0025232	City of Hallettsville	0.8	3.816
1602A_01	WQ0010463001	TX0026034	City of Yoakum	0.95	4.531
Total				**2.842**	**13.555**

[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_{SW} 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:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \quad \text{(Equation 7)}$$

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. TPDES Regulated Stormwater, the watershed of the original Lavaca River Above Tidal TMDLs does not contain any MS4 permits. Acreages associated with the MSGP, construction activities and concrete production facilities were calculated using aerial imagery by measuring the estimated disturbed area at each facility location. The results were used to compute an area of regulated stormwater contribution (Table 17).

Table 17. Basis of unregulated stormwater area and computation of the FDA_{SWP} term

Watershed	MSGP (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
Lavaca River Above Tidal AU 1602_02	155.66	48.762	4.55	208.972	375,694.64	0.06%

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 7), 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 18 provides the information needed to compute WLA_{SW}.

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 takes into account 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.

Table 18. 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]
Lavaca River Above Tidal	1602_02	1742.889	87.144	13.555	1.033	0.06%	0.985

[a] TMDL from Table 14

[b] MOS from Table 15

[c] WLA_{WWTF} from Table 16

[d] FG from Table 21

[e] FDA_{SWP} from Table 17

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Eq. 7)

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 three wastewater dischargers serving entirely in the Lavaca County are not projected to have a population growth between 2020 and 2070, while the City of Yoakum is projected to have a population growth in the portion located in the DeWitt County. Therefore, the future growth was estimated at the City of Yoakum WWTF as shown in Table 19. The percentage increase in population served by the WWTF was estimated by using the WUG population projection estimates for the entire City of Yoakum between 2020 and 2070. The 2020 projected Yoakum WUG population is 5,896, and the 2070 projected population is 6,077. The projected population percentage increase within the City of Yoakum was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth in the AU between 2020 and 2070 to determine the estimated future flows.

Table 19. Percentage population increase calculation for Yoakum WUG

Year	Total Population Projection for Yoakum WUG (Region L and Region P)
2020	5,896
2070	6,077
Percentage Increase:	3.07

The *Total Maximum Daily Loads for Indicator Bacteria in Lavaca River Above Tidal and Rocky Creek* (TCEQ, 2019) included estimates for a potential WWTF within the Rocky Creek watershed that is also within the AU 1602_02 watershed. It was estimated to serve half of the population in the Rocky Creek watershed that were not connected to the City of Shiner WWTF. The discharge was approximated by multiplying the estimated population served by 100 gallons per capita per day converted to MGD. This FG estimation procedure is also included here to ensure consistency with the FG term calculated for the upstream AU 1602B_01 in the original TMDLs (TCEQ, 2019). The future growth calculations for the potential WWTF from the original TMDLs are shown in Table 20.

Table 20. FG calculation for potential WWTF in the Rocky Creek original TMDL watershed

Rocky Creek Watershed Population*	City of Shiner Population*	Potential WWTF Service Population*	Potential WWTF Discharge (MGD)	FG (*E. coli* Billion cfu/day)
5,884	2,137	1,874	0.1874	0.894

*TCEQ (2019)

Thus, the FG was calculated as follows:

$$FG = Criterion * (\%POP_{2020\text{-}2070} * WWTF_{FP}) * Conversion\ Factor \qquad \text{(Equation 8)}$$

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

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

Table 21. FG calculation for the AU 1602_02 watershed

Permittee	Receiving AU	Full Permitted Flow (MGD)	% Population Increase (2020-2070)	FG (MGD)	FG (*E. coli* Billion cfu/Day)[a]
City of Moulton	1602C_02	0.242	0.0%	0.0	0.0
City of Shiner	1602B_02	0.85	0.0%	0.0	0.0
City of Hallettsville	1602_02	0.8	0.0%	0.0	0.0
City of Yoakum	1602A_01	0.95	3.07%	0.0292	0.139
Future facility	1602B_02	NA	NA	0.1874	0.894
Total				**0.2166**	**1.033**

[a] $FG = WWTF_{FP} * POP_{2020\text{-}2070}$ * conversion factor * target (Eq. 8)

4.7.5. Load Allocations

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

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \quad \text{(Equation 9)}$$

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 for the AU 1602_02 watershed

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]
Lavaca River Above Tidal	1602_02	1742.889	87.144	13.555	0.985	1.033	1640.172

[a] TMDL from Table 14

[b] MOS from Table 15

[c] WLA_{WWTF} from Table 16

[d] WLA_{SW} from Table 18

[e] FG from Table 21

[f] $LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$ (Eq. 9)

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 flows regime) for flow exceedance from the LDC developed for SWQM station 12525. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 23. TMDL allocation summary for AU 1602_02

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

AU	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
1602_02	1742.889	87.144	13.555	0.985	1640.172	1.033

[a] TMDL from Table 14

[b] MOS from Table 15

[c] WLA_{WWTF} from Table 16

[d] WLA_{SW} from Table 18

[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 $WLA_{WWTF.}$

Table 24. Final TMDL allocation for AU 1602_02

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

AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
1602_02	1742.889	87.144	14.588	0.985	1640.172

[a] WLA_{WWTF} includes the FG component

Section 5. References

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Appendix A. Method Used to Determine Population Projections

The authors used the following steps to estimate the 2010 population and 2020–2070 population projections in the AU 1602_02 watershed.

1. The 2010 Census block population data were obtained for the five counties in the watershed (Gonzales, DeWitt, Fayette, Jackson, and Lavaca).
2. The 2010 watershed population was developed using the block level data for the portion of the five counties in the watershed.
3. For the census blocks that were partially located in the watershed, population was estimated by multiplying the block population to the proportion of its area in the watershed.
4. The population projections for Regions K, L, and P were obtained from the 2021 Regional Water Plans.
5. Lavaca County encompasses most of the watershed area and is expected to have no population growth between 2010–2070 according to the Regional Water Plan.
6. The rural area population in DeWitt, Fayette, Gonzales, and Jackson counties only cover a small portion of the watershed population. The Regional Water Plans provide projections for “County-Other” which were used to determine population projections for the rural areas in these counties.
7. The portion of City of Yoakum WUG in DeWitt County (Region L) has a projected population increase between 2010–2070 and was used to estimate population projections in the City of Yoakum.
8. The 2010 populations for the above mentioned WUGs were obtained from the historical WUG population estimates provided by TWDB.
9. The projected percentage increases for the four “County-Other” areas in the watershed and the City of Yoakum were applied to their 2010 population estimates to obtain the decadal population projections for each of these areas in the watershed.
10. The projected population estimates obtained in Step 9 were summed and added to the static 2010 population of the rest of the Lavaca County in the watershed to obtain population projections for the watershed out to 2070.