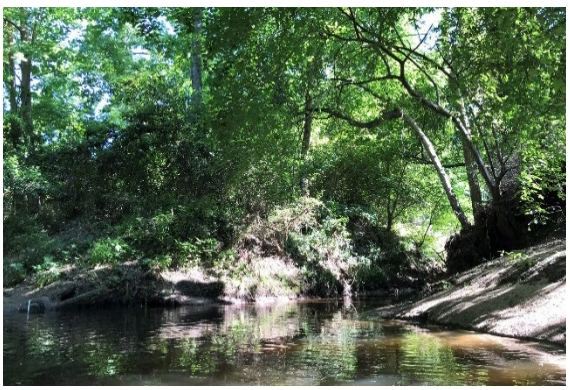
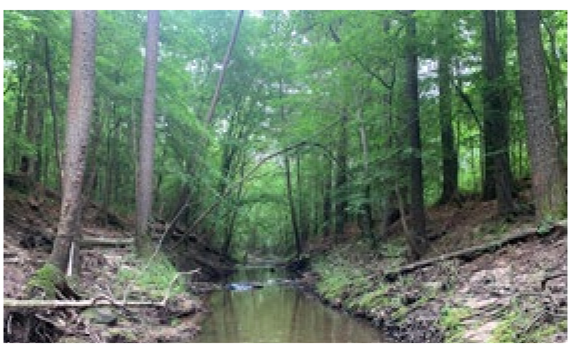
Technical Support Document for Four Total Maximum Daily Loads for Indicator Bacteria in Tributaries of the Neches River below Lake Palestine

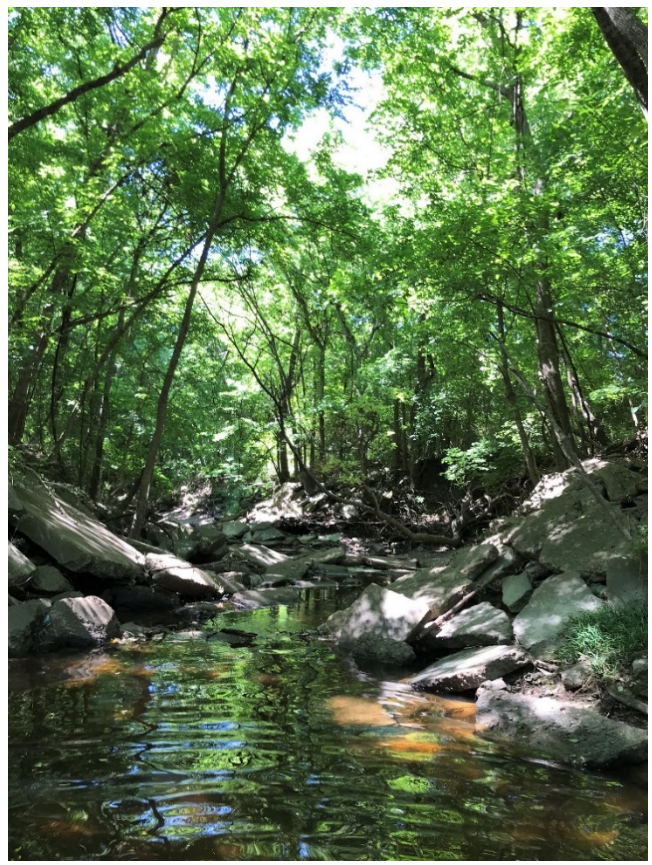
Assessment Units: 0604A_02, 0604B_01, 0604C_01, and 0604M_03



Hurricane Creek at Kiwanis Park in Lufkin, Texas



Biloxi Creek near County Road 216, near Lufkin, Texas



Cedar Creek at Loop 287 in Lufkin, Texas

By Anna Gitter, Luna Yang, and Lucas Gregory,
Texas Water Resources Institute
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P.O. Box 13087
Austin, Texas 78711-3087

By:
Anna Gitter, Luna Yang, and Lucas Gregory
Texas Water Resource Institute
Texas A&M University
College Station, Texas

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Abbreviations

AU	assessment unit
Ave	Avenue
AVMA	American Veterinary Medical Association
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CGP	Construction General Permit
cfs	cubic feet per second
cfu	colony forming unit
DAR	drainage area ratio
DMR	Discharge Monitoring Report
ECHO	Enforcement and Compliance History Online
E. coli	Escherichia coli
EPA	Environmental Protection Agency (United States)
FC	flow category
FDC	flow duration curve
FG	future growth
FM	Farm to Market
GIS	geographic information system
LA	load allocation
LDC	load duration curve
m	meter
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
SH	State Highway
SSURGO	Soil Survey Geographic
SWMP	Stormwater Management Program
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load

TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
U.S.	United States
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
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 its 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 primary objective of the TMDL Program 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 bacteria impairments in tributaries of the Neches River below Lake Palestine (Segment 0604), with Cedar (Segment 0604A), Hurricane (Segment 0604B) and Jack (Segment 0604C) creeks in the *2000 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2002). Biloxi Creek (Segment 0604M) was later identified to be impaired for bacteria on the *2004 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2005). The bacteria impairments have been identified in the *2020 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report) (TCEQ, 2020a).

This document addresses impairments to the primary contact recreation 1 use due to exceedances of the geometric mean criterion for *Escherichia coli (E.coli)* in portions of segments 0604A (Cedar Creek), 0604B (Hurricane Creek), 0604C (Jack Creek) and 0604M (Biloxi Creek). These TMDLs take a watershed approach to addressing bacteria impairments. While TMDL allocations were developed only for the impaired assessment units (AUs), the entire drainage area for each impaired AU is included within the scope of this project. Each segment (with the exception of Jack Creek) consists of multiple AUs. The impaired AUs as well as their upstream unimpaired AUs (0604A_03 for Cedar Creek and 0604B_02 for Hurricane Creek) are considered for this project (Figure 1). The unimpaired downstream AUs of Cedar Creek (0604A_01) and Biloxi Creek (0604M_02) are not included in the project area. According to the 2020 Texas Integrated Report, AU 0604A_03 is listed for a dissolved oxygen impairment.

The dissolved oxygen impairment will not be addressed in these TMDLs. The complete list of water bodies and their identifying AU number considered in this report are:

- Cedar Creek 0604A_02 and 0604A_03
- Hurricane Creek 0604B_01 and 0604B_02
- Jack Creek 0604C_01
- Biloxi Creek 0604M_03

The bacteria impairments considered in the document are for four specific AUs, 0604A_02, 0604B_01, 0604C_01 and 0604M_03. Future references to the project area will be collectively referred to as the Middle Neches project area.

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, 2018). The water quality standards specifically protect appropriate uses for each segment and list appropriate limits for water quality indicators to assure water quality and attainment of uses. TCEQ assesses water bodies based on the water quality standards and publishes the Texas Integrated Report 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, of which the primary uses assigned in the *Texas Surface Water Quality Standards* are:

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

Fecal indicator bacteria are indicators of the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Fecal indicator bacteria 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. *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, 2018) and on May 19, 2020, the United States (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 covers activities that have a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 colony forming units (cfu) per 100 milliliters (mL) and a single sample criterion of 399 cfu per 100 mL.

- Primary contact recreation 2 includes activities that involve a significant risk of ingestion of water (i.e. swimming, diving, wading and whitewater sports), but occurs less frequently than for primary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean for the standard is 206 cfu per 100 mL.

- Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and a geometric mean criterion for *E. coli* of 630 cfu per 100 mL.

- Secondary contact recreation 2 is similar to secondary contact 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 cfu per 100 mL.

- Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for *E. coli* of 2,060 cfu per 100 mL.

Cedar Creek (0604A), Hurricane Creek (0604B), Jack Creek (0604C), and Biloxi Creek (0604M) are freshwater streams and have primary contact recreation 1 use. The associated standard for *E. coli* is a geometric mean of 126 cfu per 100 mL and a single sample of 399 cfu per 100 mL.

1.3. Report Purpose and Organization

TCEQ contracted with the Texas Water Resources Institute (TWRI) for the Middle Neches project area TMDLs. The tasks of this project were to (1) acquire existing (historical) data and information necessary to support assessment activities; (2) perform the appropriate activities necessary to allocate *E. coli* loadings; and (3) assist TCEQ in preparing the TMDLs.

This project used historical bacteria and flow data in order to (1) review the characteristics of the watersheds and explore potential sources of *E. coli* for the impaired AUs; (2) develop an appropriate tool for development of bacteria TMDLs for the impaired AUs; and (3) prepare the draft and final technical support document for the impaired AUs. The purpose of this report is to provide technical documentation

and supporting information for developing the bacteria TMDLs for the Middle Neches project area. This report contains:

- Information on historical data.
- Watershed characteristics.
- Summary of historical bacteria data that confirm the Texas 303(d) listings of impairment due to the presence of indicator bacteria (*E. coli*).
- Development of load duration curves (LDCs).
- Application of the LDC approach for the pollutant load allocation process.

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The Middle Neches project area is located in East Texas and includes portions of four segments draining nearly 59,131 acres in Angelina County (Figure 1). The 2020 Texas Integrated Report provides the following segment and AU descriptions:

- Segment 0604A (Cedar Creek) - From the confluence of the Neches River southwest of Lufkin in Angelina County to the upstream perennial portion of the stream in Lufkin in Angelina County.
    - AU 0604A_02 - From the confluence with Jack Creek (0604C) upstream to confluence with unnamed tributary adjacent to State Loop 287.
    - AU 0604A_03 - From the confluence with unnamed tributary adjacent to State Highway (SH) Loop 287 upstream to headwaters near Hoo Avenue (Ave) in the City of Lufkin.
- Segment 0604B (Hurricane Creek) - From the confluence with Cedar Creek upstream to the headwaters near Groesbeck Ave in the City of Lufkin.
    - AU 0604B_01 - From the confluence with Cedar Creek (0604A) upstream to confluence with unnamed tributary 100 meters (m) above State Loop 287 in Lufkin.
    - AU 0604B_02 - From the confluence with unnamed tributary 100m upstream of SH Loop 287 in the City of Lufkin upstream to headwaters near Groesbeck Ave in Lufkin.
- Segment 0604C (Jack Creek) - From the confluence of Cedar Creek southwest of Lufkin in Angelina County to the upstream perennial portion of the stream in northeast Lufkin in Angelina County.
    - AU 0604C_01 - From the confluence with Cedar Creek (0604A) upstream to confluence with unnamed tributary 1.6 kilometers southwest of U.S. Highway 69 northwest of Lufkin.
- Segment 0604M (Biloxi Creek) - From the confluence with the Neches River southeast of Diboll to Farm to Market (FM) 325 east of Lufkin in Angelina County.
    - AU 0604M_03 - From the confluence with One Eye Creek in Angelina County southeast of Lufkin upstream to FM 325 east of Lufkin.

The Middle Neches project area includes impaired AUs 0604A_02, 0604B_01, 0604C_01, and 0604M_03; and the upstream unimpaired AUs 0604A_03 and 0604B_02. Watersheds were delineated using digital elevation and catchment data from the National Hydrography Dataset Plus version 2 (EPA and USGS 2012). The Middle Neches project area is found in Angelina County, which resides in the East Texas Timberlands region of northeast Texas (TSHA, 2016). The Neches River bounds the southern part of the county, with the largest water body being the Sam Rayburn Reservoir. The Middle Neches project area has numerous farms and a prevalent poultry industry (ANRA, 2015). The Middle Neches project area is within the Level III South Central Plains Ecoregion (35) and includes the Level IV ecoregions designated as Floodplains and Low Terraces (35b) and Southern Tertiary Uplands (35e) (Griffith et al., 2007). Water body and project watershed statistics are provided in Table 1.

Table 1. Segments and AUs included in the Middle Neches project area

Segment ID	Segment Name	AUs	AU Length (miles)	AUs Impaired for Bacteria	Watershed Area (acres)
0604A	Cedar Creek	0604A_02 0604A_03	14.60 2.79	0604A_02	20,191
0604B	Hurricane Creek	0604B_01 0604B_02	3.31 3.10	0604B_01	8,268
0604C	Jack Creek	0604C_01	16.69	0604C_01	18,594
0604M	Biloxi Creek	0604M_03	9.86	0604M_03	12,078
				Total	59,131

2.2. Review of Routine Monitoring Data for TMDL Watersheds

2.2.1. Data Acquisition

All available ambient *E. coli* data records as of January 30, 2020 (for June 2019 to October 2000), were obtained from TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database (TCEQ, 2020b). The data represents all historical *E. coli* data collected in the project area. For Cedar Creek (AU 0604A_02), 148 ambient *E. coli* measurements were available at two TCEQ surface water quality monitoring (SWQM) stations (10478 and 13528). Hurricane Creek (AU 0604B_01) had 104 ambient *E. coli* measurements available from two TCEQ SWQM stations (10487 and 13529). Jack Creek (AU 0604C_01) had 121 ambient *E. coli* measurements available from three TCEQ SWQM stations (10492, 10493 and 10494). Lastly, 0604M_03 had 93 ambient *E. coli* measurements available from two TCEQ SWQM stations (10499 and 22119).

2.2.2. Analysis of Bacteria Data

E. coli data collected at SWQM stations from December 1, 2011 through November 30, 2018, were used to determine attainment of the primary contact recreation 1 use as

reported in the 2020 Texas Integrated Report (TCEQ, 2020a). Data assessed indicate non-support of the primary contact recreation 1 use for four AUs because the geometric mean concentration of available samples exceeds the geometric mean criterion of 126 cfu/100 mL for *E. coli*, as summarized in Table 2.

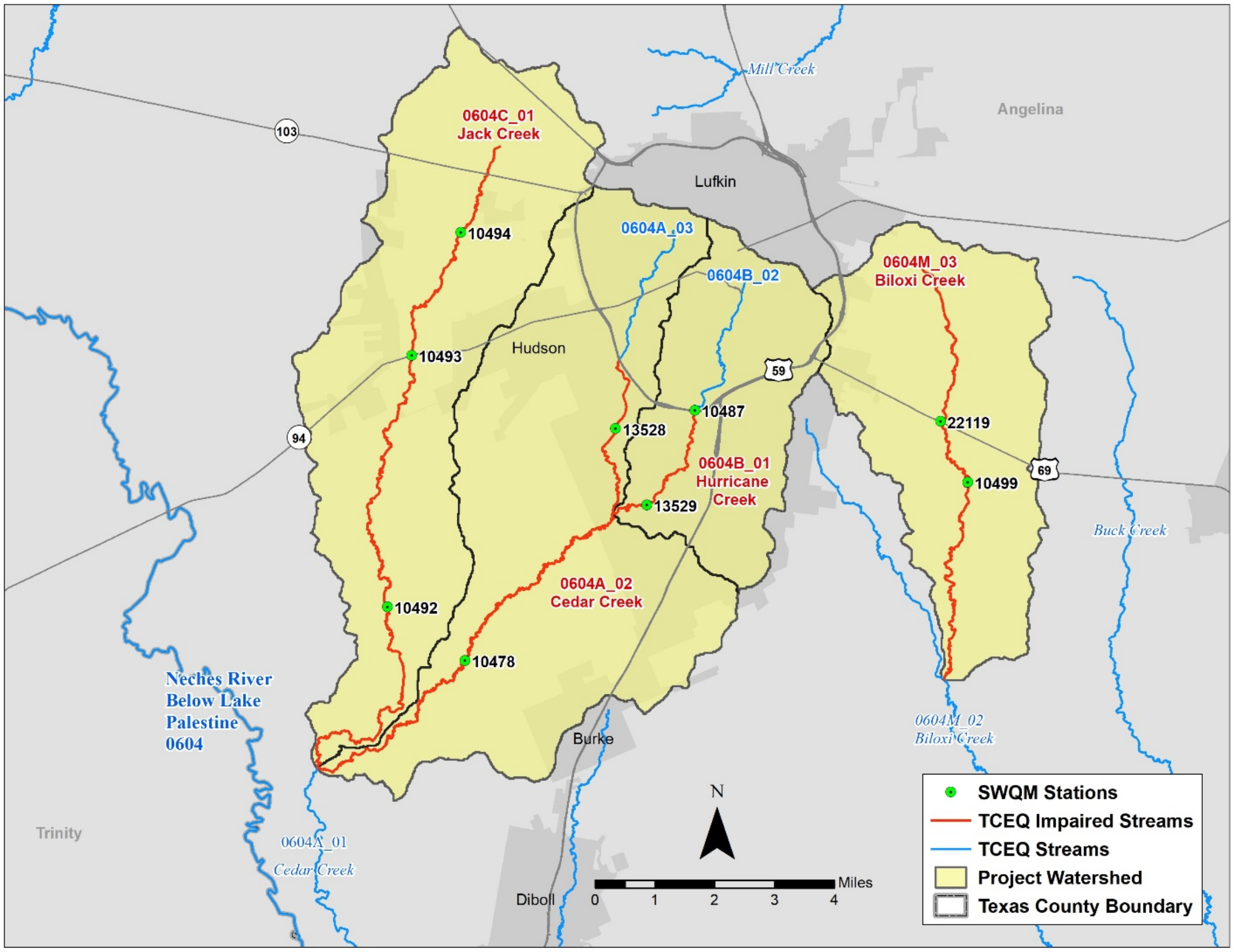


Figure 1. Overview map of the Middle Neches project area

Table 2. 2020 Texas Integrated Report Summary

Water Body	AU	Parameter	Station(s)	Data Range	Number of Samples	Geometric Mean (cfu/100mL)
Cedar Creek	0604A_02	*E. coli*	10478, 13528	12/01/2011-11/30/2018	40	291.49
Hurricane Creek	0604B_01	*E. coli*	10487, 13529	12/01/2011-11/30/2018	43	276.16
Jack Creek	0604C_01	*E. coli*	10492, 10493, 10494	12/01/2011-11/30/2018	61	185.35
Biloxi Creek	0604M_03	*E. coli*	10499	12/01/2011-11/30/2018	33	152.24

2.3. Watershed Climate and Hydrology

The Middle Neches project area is in east Texas which is characterized as a subtropical humid climate. Figure 2 presents the average monthly values for precipitation and temperature as reported by the National Oceanic and Atmospheric Administration (NOAA) at Angelina County Airport station USW00093987 (NOAA, 2020). While the airport is located towards the periphery of the watershed, near Burke, Texas, it was the only location that had consistent data collection from 2005 through 2018. The average monthly low temperatures range from 38.2°F (January) to 73.3°F (August), and the monthly average highs range from 61.5°F (January) to 95.5°F (August). The average monthly precipitation ranges from 2.9 to 4.8 inches, with the greatest precipitation occurring in October and the lowest precipitation occurring in November (Figure 2). From 2005 through 2018, the average annual precipitation was 46 inches, with a low of 28.5 inches occurring in 2010 and high of 68.7 inches occurring in 2018 (Figure 3).

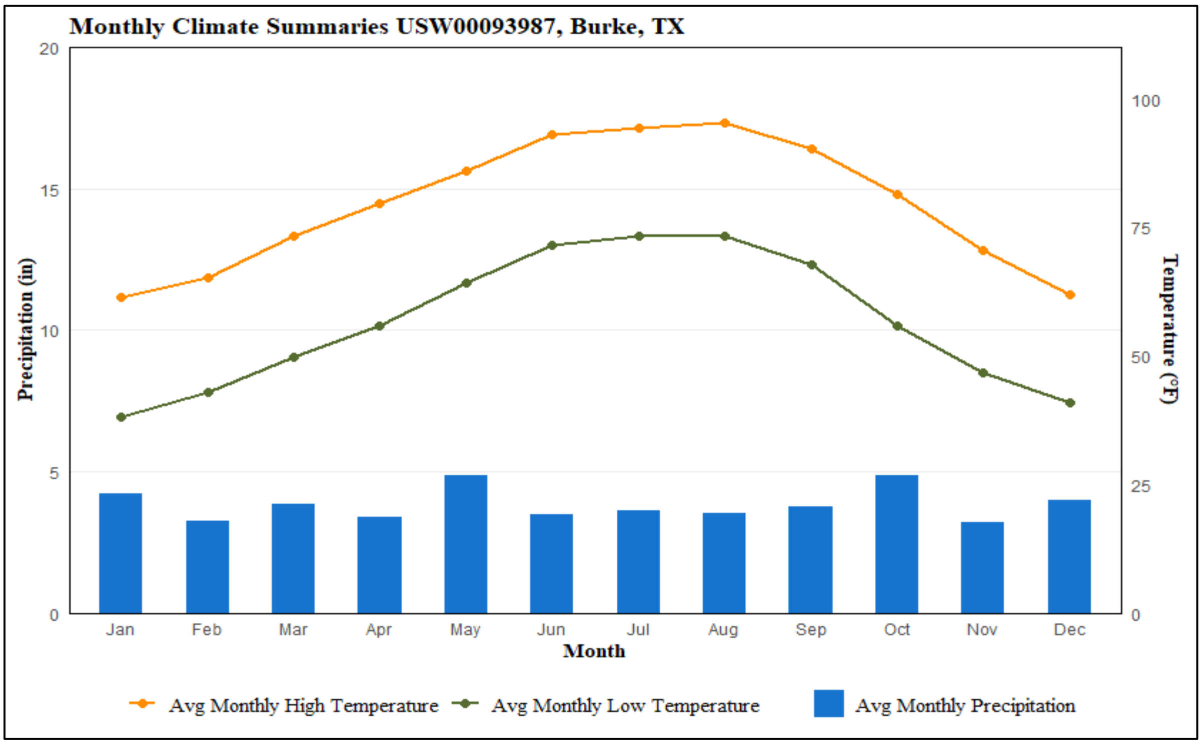


Figure 2. Average monthly temperature and precipitation (2005-2018) at Angelina County Airport

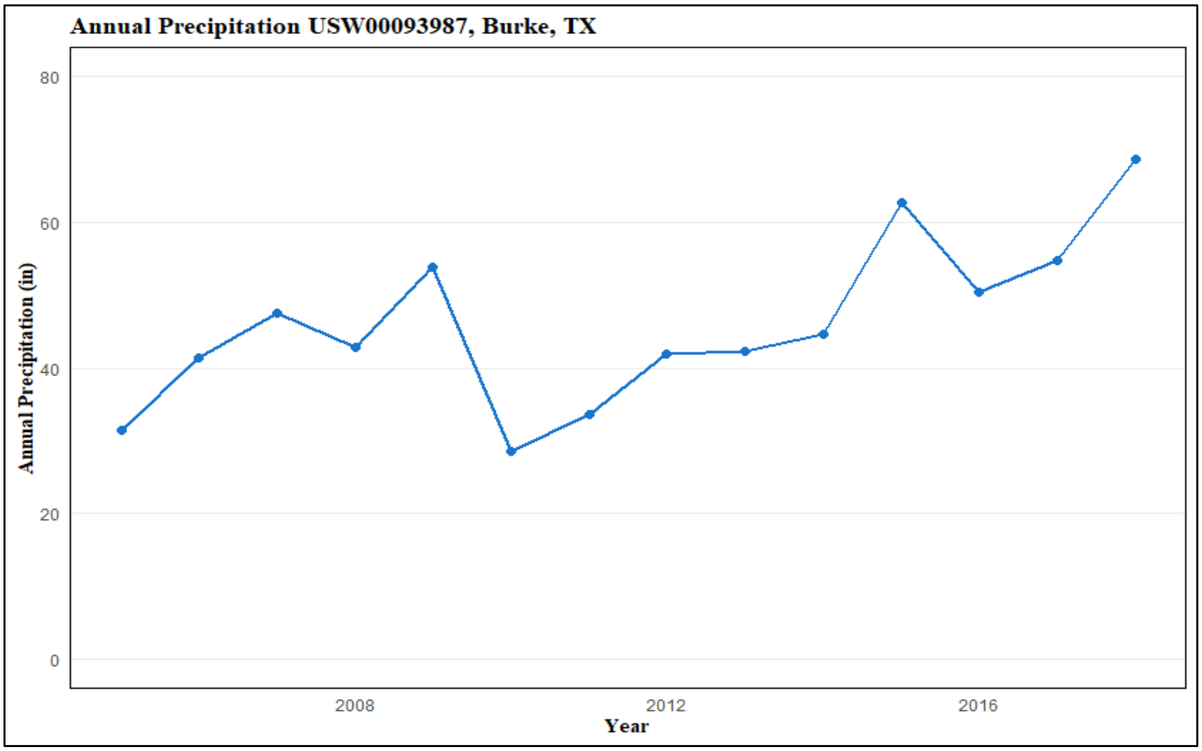


Figure 3. Annual precipitation (2005-2018) at Angelina County Airport

2.4. Watershed Population and Population Projections

Watershed population and projection estimates were developed using 2010 U.S. Census Bureau (USCB) census block geographic units and population data (USCB, 2010) (Figure 4). Census blocks are the smallest geographic units used by USCB to tabulate population data. The Middle Neches project area includes 1,526 census blocks, located entirely or partially in the watershed. The population was estimated for those census blocks partially located in the watershed by multiplying the census block population and the percentage of each block within the watershed. It was assumed for this estimation that population was evenly distributed within a census block. These estimated partial census block populations were then summed with the populations from the census blocks located entirely within the watershed. According to this method, the population for all watershed areas is estimated to be 42,647 (Table 4, Figure 4).

Texas Water Development Board (TWDB) Regional Water Plan Population Projections (Region I Water Planning Group, 2020) were used to estimate population projections (Table 3). The county population projections indicate a 27.3% increase in Angelina County from 2020 to 2070. All watersheds are located within Angelina County; thus, the county population growth rates were presumed to be appropriate for the project watersheds. The 27.3% increase was applied to the estimated 2010 watershed population to estimate 2070 population for each TMDL watershed (Table 4).

Table 3. Population projections in Angelina County

County	2010 Census	2020 Projected	2070 Projected	% Increase (2010-2020)	% Increase (2020-2070)
Angelina	86,771	93,316	118,772	7.5%	27.3%

Table 4. Estimated population increase calculations

AU	2010 Census	2020 Projected	2070 Projected	% Increase (2010-2020)	% Increase (2020-2070)
Cedar Creek (0604A_02)	14,680	15,781	20,089	7.5%	27.3%
Hurricane Creek (0604B_01)	16,067	17,272	21,987	7.5%	27.3%
Jack Creek (0604C_01)	8,272	8,892	11,320	7.5%	27.3%
Biloxi Creek (0604M_03)	3,628	3,900	4,965	7.5%	27.3%
Totals	42,647	45,845	58,361	7.5%	27.3%

2.5. Land Cover

Land cover for the watersheds was obtained from the 2016 National Land Cover Database (NLCD) (USGS, 2019), and is displayed in Figure 5. The following are the land cover categories and definitions represented in the database for in the Middle Neches project area:

- **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.

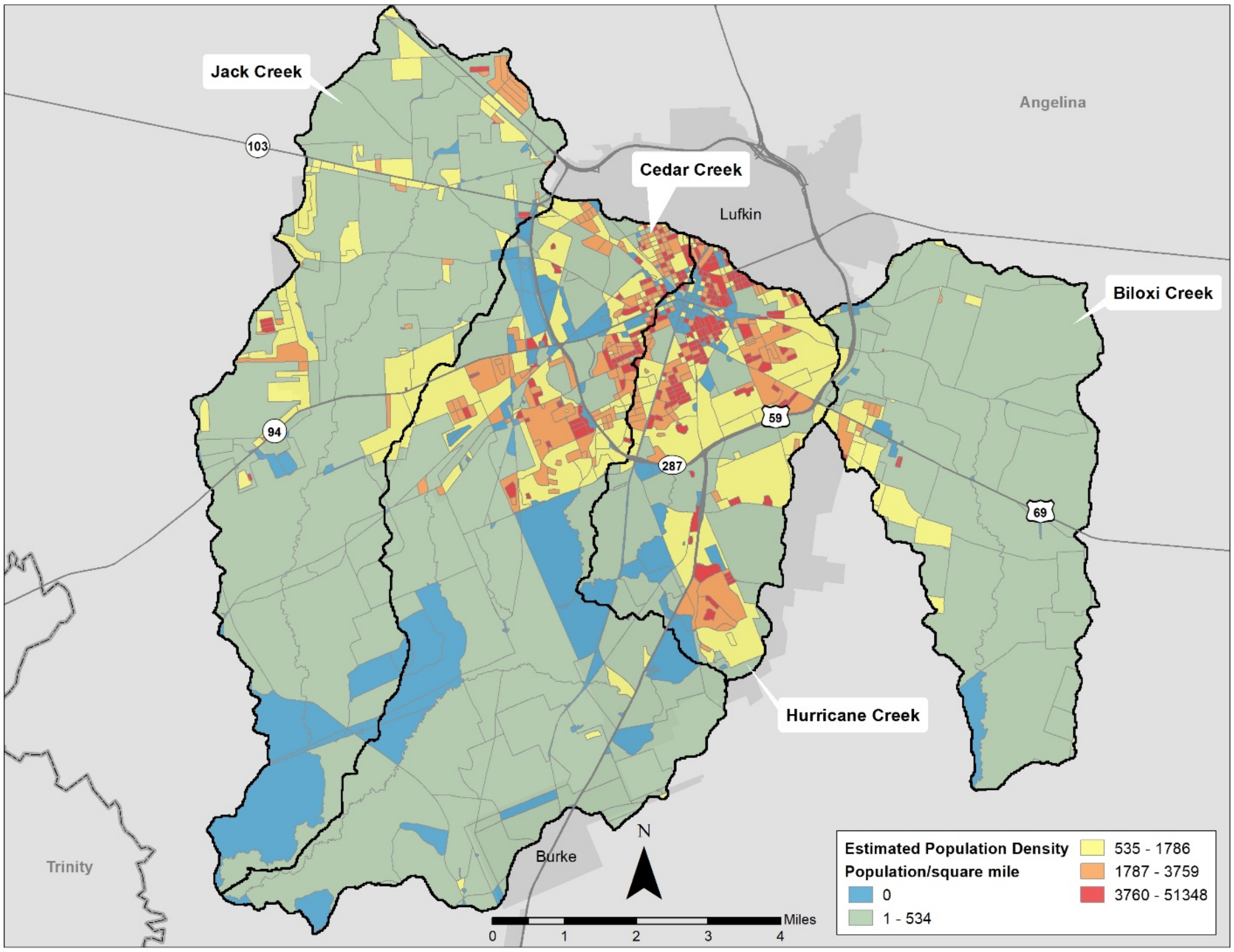


Figure 4. 2010 population density estimates using USCB census block data in the Middle Neches project area

- **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 Middle Neches project area covers 59,131 acres and is predominantly composed of forests (including Evergreen, Deciduous, and Mixed Forest) and Pasture/Hay land cover, with each watershed having various amounts of developed area (Table 5). Pasture/Hay and the forest categories account for 23.78% and 34.58% of the watershed area respectively, which covers over half of the watershed.

The Jack Creek watershed is predominantly Pasture/Hay (33.32%) followed by Evergreen Forest (22.23%) (Table 5). Developed land comprises approximately 13.27% of the watershed, making it the least developed watershed in the Middle Neches project area.

Cedar Creek is the largest watershed and has a greater variety of land cover (Table 5). The primary land cover is developed, covering 25.15% of the watershed's total acreage. Evergreen Forest covers nearly 22.37% of the watershed, followed by Pasture/Hay (18.70%).

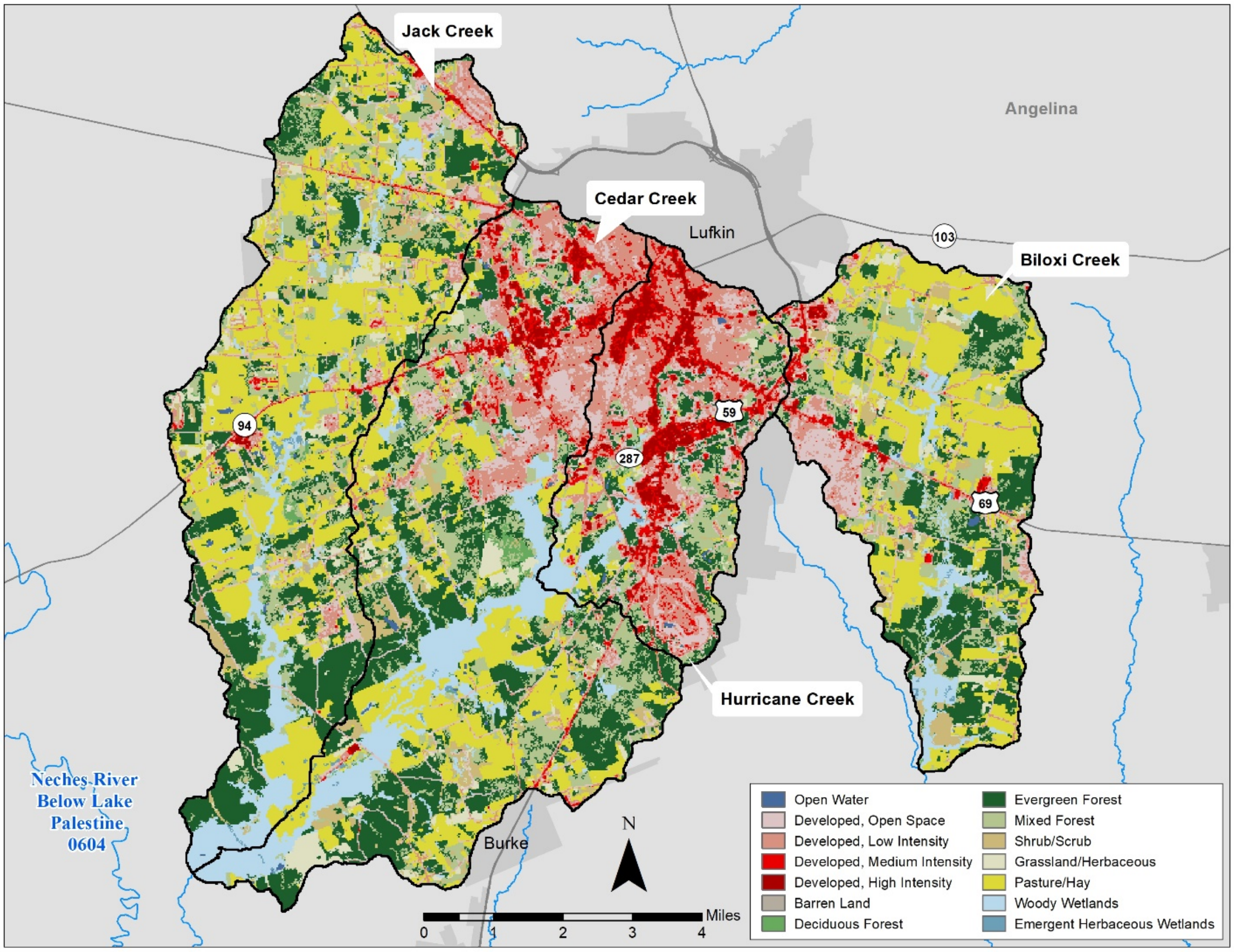


Figure 5. 2016 land cover in the Middle Neches project area

Hurricane Creek has the greatest percentage of development (65.93%) of the four watersheds but is also the smallest watershed within the Middle Neches project area. Evergreen (11.25%) and mixed forest (10.82%) are the second and third greatest land cover classifications in the watershed.

Biloxi Creek is the second smallest watershed and is more rural than Hurricane Creek. Pasture/Hay (31.17%), Evergreen Forest (20.82%) and Mixed Forest (15.34%) are the predominant land covers in the watershed (Table 5). Development only covers approximately 17.43% of the land area.

Table 5. Land cover summary in the Middle Neches project area

NLCD Classification	Cedar Creek (0604A_02)		Hurricane Creek (0604B_01)		Jack Creek (0604C_01)		Biloxi Creek (0604M_03)		Project Area Total	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Open Water	73	0.36	31	0.37	56	0.30	38	0.31	198	0.33
Developed, Open Space	1,713	8.48	1,257	15.14	1,230	6.61	1,097	9.08	5,297	8.95
Developed, Low Intensity	2,370	11.74	2,476	29.83	1,002	5.39	726	6.01	6,574	11.11
Developed, Medium Intensity	651	3.22	986	11.88	191	1.03	200	1.66	2,028	3.43
Developed, High Intensity	345	1.71	754	9.08	45	0.24	82	0.68	1,226	2.07
Barren Land	8	0.04	6	0.07	27	0.15	3	0.02	44	0.07
Deciduous Forest	173	0.86	30	0.36	143	0.77	56	0.46	402	0.68
Evergreen Forest	4,517	22.37	934	11.25	4,135	22.23	2,515	20.82	12,101	20.45
Mixed Forest	2,751	13.62	898	10.82	2,457	13.21	1,853	15.34	7,959	13.45
Shrub/Scrub	822	4.07	63	0.76	811	4.36	616	5.10	2,312	3.91
Grassland/Herbaceous	777	3.85	126	1.52	818	4.40	394	3.26	2,115	3.57
Pasture/Hay	3,776	18.70	335	4.04	6,197	33.32	3,766	31.17	14,074	23.78
Woody Wetlands	2,163	10.71	395	4.76	1,404	7.55	701	5.80	4,663	7.88
Emergent Herbaceous Wetlands	54	0.27	10	0.12	81	0.44	35	0.29	180	0.30
Total Acres	20,193	100.00*	8,301	100.00*	18,597	100.00*	12,082	100.00*	59,173	100.00*

*Total acreage for the watershed differs from 59,131 acres as listed previously in the report due to calculations that included raster data in the geographic information system (GIS) analysis for land cover.

2.6. Soils

Soils influence the hydrology and types of land use and activities possible in a watershed. The U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) provides information about soils through the Soil Survey Geographic (SSURGO) Database (NRCS, 2018). The USDA NRCS 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, and C/D). 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 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 within the Middle Neches project area are primarily categorized as group C (46.22%) and D (42.43%) (Figure 6, Table 6). When wet, group C soils have moderately high runoff potential. Group D soils have a higher runoff potential when wet and water movement is restricted in the soils (NRCS, 2018). In general, soils in the watershed are loamy with sand and clay and predominantly strongly to mildly acidic (ANRA, 2015).

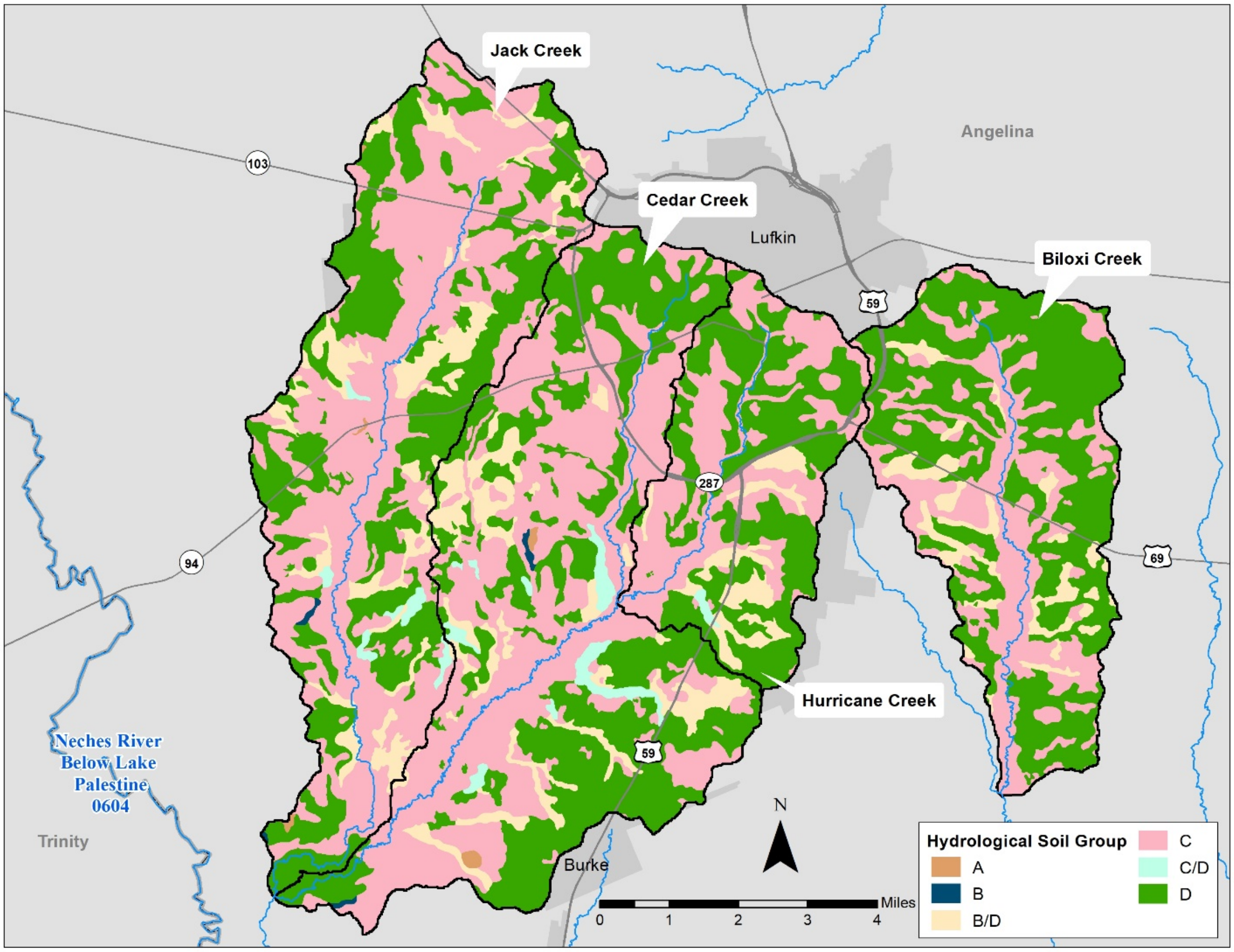


Figure 6. Hydrologic soil groups in the Middle Neches project area

Table 6. Summary of the hydrologic soil groups in the Middle Neches project area

Soil Group	Jack Creek (0604C_01)		Cedar Creek (0604A_02)		Hurricane Creek (0604B_01)		Biloxi Creek (0604M_03)		Project Area Total	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
A	32	0.17	61	0.30	0	0.00	0	0.00	93	0.16
B	30	0.16	49	0.24	0	0.00	0	0.00	79	0.13
B/D	2,022	10.87	1,884	9.33	795	9.62	1,083	8.97	5,784	9.78
C	9,691	52.12	9,842	48.74	3,432	41.51	4,364	36.13	27,328	46.22
C/D	219	1.18	490	2.43	48	0.58	0	0.00	758	1.28
D	6,600	35.50	7,865	38.95	3,993	48.29	6,631	54.90	25,089	42.43
Totals	18,594	100	20,191	100	8,268	100	12,078	100	59,131	100.00

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). Wastewater treatment facilities (WWTFs) and stormwater from industries, construction, and municipal separate storm sewer systems (MS4s) 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 permit.

With the exception of WWTFs, which receive individual WLAs (see section 4.7.3), the regulated and unregulated sources in this section are presented to give a general account of the different 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 permits under the TPDES program. The regulated sources in the Middle Neches project area include WWTF outfalls and construction, concrete production, and industrial stormwater discharges.

2.7.1.1. – Domestic and Industrial WWTFs

As of April 2020, there are three facilities with individual TPDES permits that discharge within the Middle Neches project area (TCEQ, 2020c). The Hurricane Creek WWTF (City of Lufkin) and the City of Hudson WWTF treat domestic wastewater with discharge limits of 11.3 million gallons per day (MGD) and 0.98 MGD, respectively. Georgia Pacific Chemicals, LLC discharges stormwater associated with industrial activity (Table 7, Figure 7). Georgia-Pacific Chemicals, LLC discharges stormwater and while it is not considered in the bacteria loading allocations, it is included the regulated stormwater allocation.

Table 7. Permitted point source discharge facilities in the Middle Neches project area

TPDES Permit No./NPDES[a] No.	Facility/ Permittee	Effluent Type	Permitted Discharge (MGD)	Recent Discharges (MGD)[b]	WLA[c]
WQ0010214001/ TX0024309	Hurricane Creek WWTF/ City of Lufkin	Treated domestic wastewater	11.3 (annual average)	6.620	WLA_{WWTF}
WQ0011826001/ TX0068985	City of Hudson WWTF/ City of Hudson	Treated domestic wastewater	0.98 (daily average)	0.456	WLA_{WWTF}
WQ0001737000/ TX0082261	Lufkin Plant/ Georgia-Pacific Chemicals, LLC	Stormwater and occasional once-through non-contact cooling water	Intermittent and flow variable	0.454 daily max	WLA_{SW}[d]

[a] National Pollutant Discharge Elimination System (NPDES).

[b] Based on mean reported discharges in discharge monitoring reports (DMRs) for the reporting periods ending April 1, 2015 through February 29, 2020 (EPA, 2020).

[c] Indicates if an individual allocation is included as part of the WLA for WWTFs (WLA_{WWTF}), or if it is included as part of the regulated stormwater WLA (WLA_{SW}).

[d] The stormwater is also regulated under TXR05V688 permit as described in Table 9.

2.7.1.2. – TCEQ/TPDES Water Quality General Permits

Certain types of activities are required to be covered by one of several TCEQ/TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- 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)

On April 6, 2020, a review of active general permits in the Middle Neches project area indicated one general permit for a concrete production facility (Permit No. TXG110196). The concrete production facility is authorized to discharge stormwater and will be included in the regulated stormwater allocations for AU 0604A_02. The concrete production facility covers approximately 17.90 acres. No other active general wastewater permits were found for the Middle Neches project area.

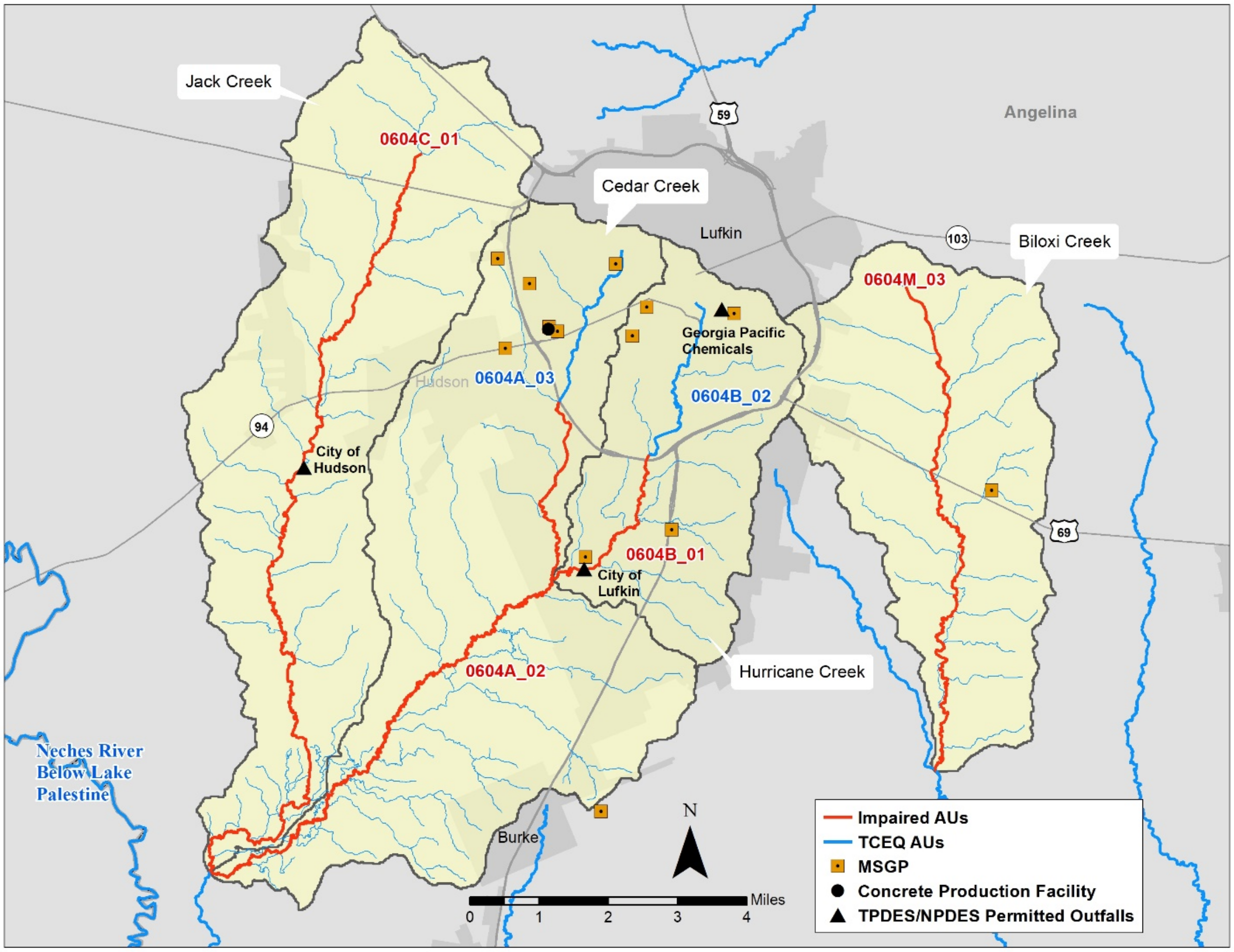


Figure 7. Active regulated sources in the Middle Neches project area

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 MS4, industrial facilities, and regulated construction activities.
2. Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities in urban 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 United States

Census, whereas the Phase II General Permit regulates smaller communities 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 significantly reduce pollutants discharged into receiving water bodies. Phase II MS4 MCMs include:

- 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 monitor water quality and implement a floatables program.

Discharges of stormwater from a Phase II MS4 area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following 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 (CGP) for construction activities disturbing more than one acre.

No Phase II MS4 permits were identified in any of the watersheds. As of March 27, 2020, TCEQ Central Registry indicates there are 14 active stormwater general permits in the Middle Neches project area (1 concrete production, 13 MSGPs) (Figure 7, Table 8) (TCEQ, 2020d). Areas disturbed/covered by the permits were estimated using aerial imagery.

Due to the short-term and economy-driven nature of construction permits, a search of active, terminated, and expired CGPs between March 2003 and December 2020 was conducted. Construction activities can change in the project area and within each watershed and serve as a representative estimate of the acres of land disturbed. As of 2020, Hurricane Creek watershed has the greatest number of acres impacted by construction activities (Table 9). Other construction activities may be occurring in the

watersheds that are not required to have the CGP authorization. Appendix A provides a full list of the CGP permits in the Middle Neches project area. On average, 329 acres were under CGPs annually in the Middle Neches project area. Jack Creek had the greatest number of acres under CGPs, on average, with an annual average of 101 acres. Biloxi Creek has the fewest CGP acres on average, with an annual average of 65 acres.

Table 8. Active stormwater general permits in the Middle Neches project area

Permit No.	Permittee	Facility Name	Permit Type	Watershed	Area of Regulated Stormwater (acres)[a]
TXG110196[b]	Contractor's Supplies, Inc.	Contractor's Supplies Lufkin Plant	Concrete Production	Cedar Creek	17.90
TXR05BW92	Lufkin Industries	Lufkin Industries	MSGP	Hurricane Creek	58.67
TXR05CS74	City of Lufkin	Hurricane Creek WWTF	MSGP	Hurricane Creek	32.19
TXR05CY79	Prince Energy LLC-Lufkin Plant	Prince Energy LLC	MSGP	Cedar Creek	2.08
TXR05DJ51	Jewell Hudgens, Inc.	Jewell Hudgens Machine Plant B	MSGP	Cedar Creek	5.95
TXR05ED54	Pilgrim’s Pride Corporation	Pilgrim's Pride Lufkin Shop and Staging Area	MSGP	Cedar Creek	7.53
TXR05EH01/ TXR05DB06	Pilgrim’s Pride Corporation	Pilgrim's Pride Lufkin Processing Plant	MSGP	Cedar Creek	6.57
TXR05EM92	Stella-Jones Corporation	Stella-Jones	MSGP	Biloxi Creek	45.60
TXR05EN77	Sun Coast Resources, Inc.	Sun Coast Resources	MSGP	Cedar Creek	8.87
TXR05M434	United Parcel Service, Inc.	UPS Lufkin	MSGP	Hurricane Creek	4.82
TXR05V688[c]	Georgia-Pacific Chemicals LLC	Lufkin Plant	MSGP	Hurricane Creek	20.46
TXR05X793	Angelina County	Angelina County Airport	MSGP	Cedar Creek	48.24
TXR05Y085	Texas Metal Casting Co.	Texas Metal Casting	MSGP	Cedar Creek	7.75
TXR05EP27	Southern Newspapers	The Lufkin Daily News	MSGP	Hurricane Creek	1.12
Total Acres					267.75

[a] Acres disturbed for MSGPs were estimated using aerial imagery.

[b] Concrete production facility TXG110000 permit included because it has a stormwater component.

[c] Stormwater is also regulated under WQ0001737000 as described in Table 7.

Table 9. Average CGP areas acres/year in each watershed of the Middle Neches project area

Year	Total	Biloxi Creek Watershed	Cedar Creek Watershed	Hurricane Creek Watershed	Jack Creek Watershed
2003	404	72	257	28	47
2004	792	139	291	62	300
2005	849	139	281	80	349
2006	845	150	209	114	372
2007	963	220	206	165	372
2008	773	229	250	184	110
2009	235	87	22	126	0
2010	191	12	30	149	0
2011	110	12	12	86	0
2012	150	21	23	106	0
2013	188	54	28	106	0
2014	26	21	5	0	0
2015	0	0	0	0	0
2016	47	0	11	0	36
2017	140	0	22	0	118
2018	140	0	22	0	118
2019	9	0	9	0	0
2020	52	18	9	25	0
Average Acres/Year	329	65	94	68	101

2.7.1.4. – Review of Compliance Information on Permitted Sources

The Enforcement and Compliance History Online (ECHO) database was reviewed for non-compliance issues regarding bacteria for individually permitted wastewater dischargers in the watersheds (EPA, 2020) (Table 10). The ECHO database contains DMR data conducted and submitted by the permitted facilities. The City of Lufkin WWTF permit requires weekly (five times per week) and the City of Hudson WWTF requires twice per month effluent monitoring of *E. coli* concentrations. Self-monitoring records were reviewed for both dischargers to evaluate permit compliance from August 2016 to July 2020.

2.7.1.5. – 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. Sewer 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 are typical causes of overflows under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the inflow and infiltration problem. Other causes, such as a collapsed sewer line, may occur under any condition.

TCEQ Central Office in Austin provided statewide data on SSOs from January 2016 through December 2019 and basin-wide data on SSOs from 2014 through 2015 (TCEQ, 2019 and 2020e). Table 11 summarizes the number of overflows that have been reported by regulated entities in the Middle Neches project area from 2014-2019. The City of Hudson WWTF reported 10 SSOs and the City of Lufkin/Hurricane Creek WWTF reported 1 SSO. The SSO that was reported for the Hurricane Creek WWTF did not include a location for the event, but was assumed to have occurred in the Hurricane Creek watershed where the WWTF is located.

Based on limited, available location information, there were no reported overflows in the Biloxi Creek watershed. The City of Diboll WWTF, Briar Village Sewage Utility, and North Angelina County Regional Wastewater Treatment Facility/Idlewood WCID 1 service areas slightly overlap the Middle Neches project area. After reviewing reported SSO events, two occurred in Jack Creek from the North Angelina County Regional Wastewater Treatment Facility/Idlewood WCID 1, but no other overflows with provided locations occurred in the project area.

Table 10. Summary of *E. coli* monitoring compliance history for permitted WWTFs in the Middle Neches project area

AU	TPDES Permit No.	Facility	Min. Monitoring Frequency	Daily Average Limit	Single Grab or Daily Max Limit	% of reported DMR Daily Average Values Exceeding Limit	% of reported DMR Single Grab or Daily Max Values Exceeding Limit
0604B_01	WQ0010214001	City of Lufkin WWTF/ Hurricane Creek WWTF	5/week	126	399	0%[a]	0%[a]
0604C_01	WQ0011826001	City of Hudson WWTF	2/month	126	399	2%[a]	2%[a]

[a]48 monthly *E. coli* records (8/1/2016-7/31/2020).

Table 11. Summary of reported SSO events from 2014 through 2019 in the Middle Neches project area (in gallons)

AU	Incidents	Total Volume	Minimum Volume	Maximum Volume
Cedar Creek (0604A_02)	4	1,200	100	500
Hurricane Creek (0604B_01)	1	50	NA	50
Jack Creek (0604C_01)	8	3,084	1	1000
Biloxi Creek(0604M_03)	0	0	0	0

[a] There was only one spill; therefore, the average volume is the total volume of the one spill.

2.7.1.6. – Illicit Discharges

Pollutant loads can enter streams 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 Number TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer 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* (New England Interstate Water Pollution Control Commission, 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, various agricultural activities, failing on-site sewage facilities (OSSFs), and domestic pets.

2.7.2.1. – Wildlife and Unmanaged Animals

Fecal indicator bacteria, such as *E. coli*, inhabit the intestines of all warm-blooded animals, including wildlife such as mammals and birds. To develop bacteria TMDLs, it is important to identify the potential for bacteria contributions from wildlife. Riparian corridors of water bodies naturally attract wildlife. With direct access to the stream channel, direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where they may be washed into nearby streams by rainfall runoff.

The Texas Parks and Wildlife Department (TPWD) provides deer population-density estimates by Resource Management Unit and Ecoregion in the state. The Middle Neches project area lies in the Resource Management Unit 14 with an average deer density of 45.5 acres per deer over the period 2005 through 2015 (TPWD, 2018). Suitable NLCD classes for deer habitat classified in the 2016 NLCD include Shrub/Scrub, Grassland/Herbaceous, Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, Emergent Herbaceous Wetlands, and Pasture/Hay. Jack Creek had the greatest amount of suitable habitat with 16,046 acres, which corresponds to an estimated 353 deer (Table 12).

Texas A&M AgriLife Extension (2012) estimates one hog per 39 acres as a statewide average density for feral hogs. The density was applied to appropriate NLCD classes for feral hogs in the watershed, which include Pasture/Hay, Shrub/Scrub, Grassland/Herbaceous, Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, and Emergent Herbaceous Wetlands. Jack Creek had the greatest estimated feral hog population with 411 hogs (Table 12).

Table 12. Estimated feral hog and white-tailed deer populations in Middle Neches project area

AU	Feral Hogs		White-Tailed Deer	
	Suitable Habitat (acres)	Estimated Population	Suitable Habitat (acres)	Estimated Population
Cedar Creek (0604A_02)	15,033	385	15,033	330
Hurricane Creek (0604B_01)	2,791	72	2,791	61
Jack Creek (0604C_01)	16,046	411	16,046	353
Biloxi Creek (0604M_03)	9,936	255	9,936	218

2.7.2.2. – Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be sources of fecal bacteria loading. Activities, such as livestock grazing close to water bodies and the use of manure as fertilizer, can contribute *E. coli* to nearby water bodies. Litter produced by commercial poultry operations can be another source of bacteria pollution in the Middle Neches project area if appropriate measures for litter management are not practiced.

Watershed livestock populations were estimated using county-level data available from the 2017 Census of Agriculture (USDA, 2019). The Angelina county-level data was refined to reflect acres of grazeable land within each AU watershed. The refinement was determined by the grazeable area of Angelina County and the grazeable acres of the AU watersheds. The ratio was the grazeable area (defined as an aggregate of Pasture/Hay and Grassland/Herbaceous NLCD classifications) of the AU watershed divided by the total grazeable area of the county. Cattle appear to be the dominant livestock in the watershed and among all AU watersheds (Table 13).

Table 13. Estimated grazing livestock population in Middle Neches project area

AU	Cattle and Calves	Horses	Goats	Sheep	Hogs and Pigs
Cedar Creek (0604A_02)	777	84	68	11	17
Hurricane Creek (0604B_01)	79	8	7	1	2
Jack Creek (0604C_01)	1,197	129	105	17	26
Biloxi Creek (0604M_03)	710	77	62	10	15

Texas State Soil Water Conservation Board (TSSWCB) staff indicates that two poultry operations exist in the Middle Neches project area, specifically in the Biloxi Creek (0604M_03) watershed and contain approximately 243,000 broilers.

Pets can also be a source of fecal indicator bacteria because stormwater runoff carries animal waste into streams. The American Veterinary Medical Association (AVMA) estimates there are 0.614 dogs and 0.457 cats per American household (AVMA, 2018). The number of domestic cats and dogs in the watershed was estimated by applying the AVMA estimates to the number of households in the watersheds. The number of watershed households was estimated using the 2010 USCB Census Block household counts, multiplied by the proportion of the Census Block within each watershed. Table 14 summarizes the estimated number of pets in each watershed.

Table 14. Estimated dog and cat populations in Middle Neches project area

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
Cedar Creek (0604A_02)	6,049	3,714	2,764
Hurricane Creek (0604B_01)	6,733	4,134	3,077
Jack Creek (0604C_01)	3,128	1,921	1,429
Biloxi Creek (0604M_03)	1,522	935	696

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 soil. 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. However, properly designed and operated OSSFs are expected to contribute virtually no fecal bacteria to surface waters. For example, it has been 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 (Weiskel, 1996). Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The Middle Neches project area is located in Region 5 of the document which has an estimated OSSF failure rate of 19%.

Estimates of the number of OSSFs located in the watersheds were determined using 911 address data to identify residence locations that were visually validated with aerial imagery data. Residential and business addresses that were found to be outside of city boundaries, the area covered by the Certificates of Convenience and Necessity (CCN), and outside of the city's sewer system were assumed to have an OSSF (Public Utilities Commission of Texas, 2017; City of Lufkin, 2003). A regional approach to evaluate the CCNs was undertaken, which included reviewing all wastewater services in Angelina County in the vicinity of the Middle Neches project area. These included CCNs for the City of Lufkin, City of Diboll, Briar Village Sewer Utility, and the North Angelina County Regional Wastewater Treatment Facility/Idlewood WCID 1. CCN information, when available, was gathered from the Public Utility Commission of Texas (2017). The City of Hudson wastewater service area was estimated using the city boundaries (USCB, 2010). The town of Burke does not have a centralized wastewater system and is dependent upon OSSFs for individual wastewater treatment. The Jack Creek and Biloxi Creek watersheds have the greatest number of OSSFs and the Hurricane Creek watershed is estimated to not contain any OSSFs (Table 15, Figure 8).

Table 15. OSSF estimate for the Middle Neches project area

AU	Estimated Number of OSSFs
Cedar Creek (0604A_02)	716
Hurricane Creek (0604B_01)	0
Jack Creek (0604C_01)	1,434
Biloxi Creek (0604M_03)	947

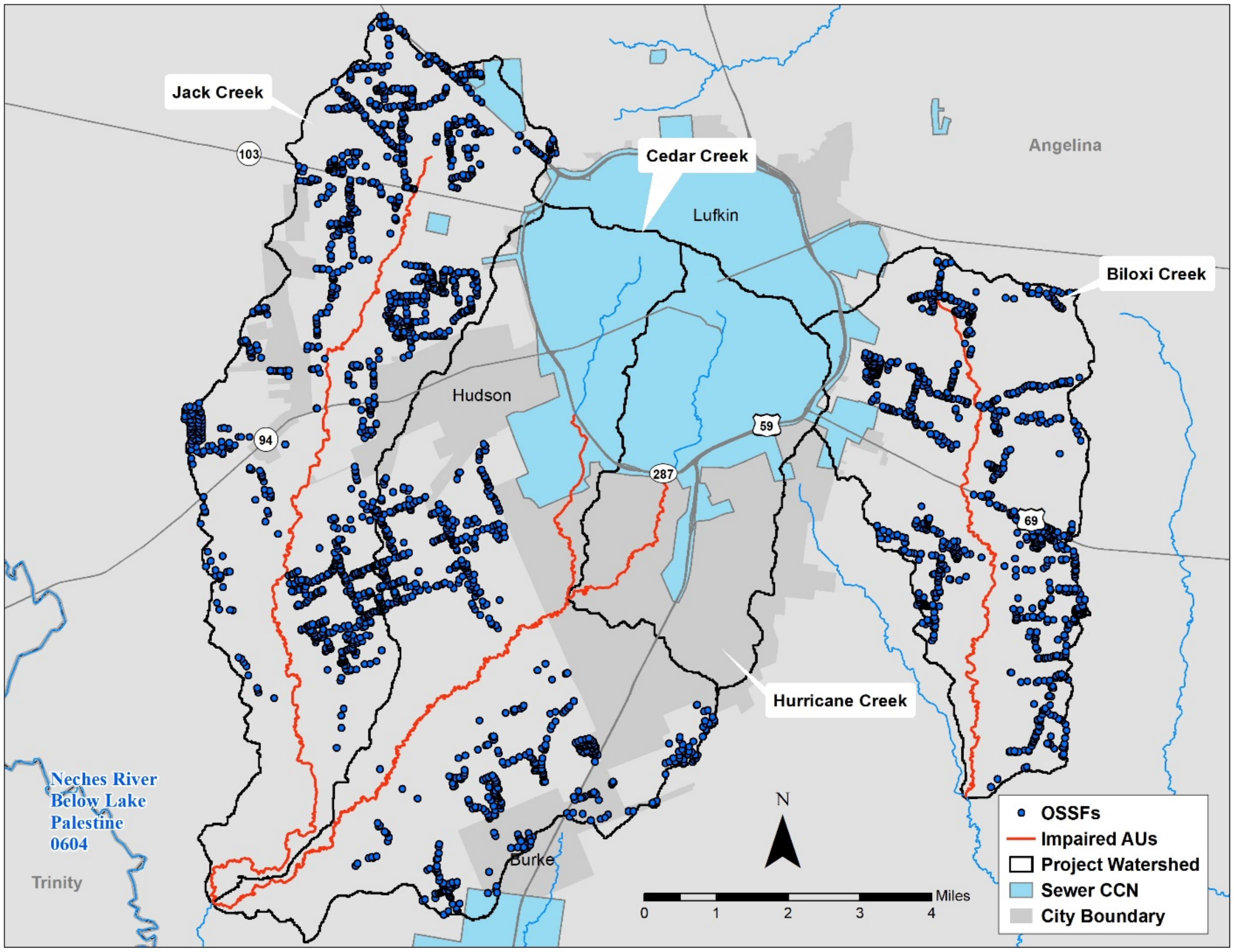


Figure 8. Estimated locations of OSSFs in the Middle Neches project area

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 sludge (or biosolids). While 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 processes (replication and die-off) are instream processes and are not considered in the bacteria source loading estimates of each AU in the TMDL watersheds.

Section 3. Bacteria Tool Development

This section describes the rationale of the bacteria tool selection for each 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. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for the impaired AUs in the Middle Neches project area 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 (TWRI, 2007). Mechanistic models and empirically derived LDCs are the two approaches commonly used for bacteria TMDLs in Texas.

Mechanistic computer models provide analytical abstractions of a real or prototype system. Mechanistic models, also referred to as process models, are based on theoretical principles that provide for representation of governing physical processes that determine the response of certain variables such as streamflow, and bacteria concentration to rainfall and runoff events. 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. (2017) also note that while mechanistic bacteria modeling 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., 2017). 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 allows for estimation of existing and allowable loads by utilizing 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 with the bacteria TMDLs that constrain the use of the more powerful mechanistic models. Further, the Bacteria Task Force appointed by TCEQ and TSSWCB supports 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 be used to 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 criterion and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source.

3.1.1. Data Resources

Data resource availability was sufficient to complete LDCs for the TMDL watersheds. LDCs require streamflow and *E. coli* data.

Daily streamflow data were unavailable in the Middle Neches project area. However, mean daily streamflow records in cfs were available in the nearby Long King Creek watershed. The U.S. Geological Survey (USGS) gauge 08066200 (Long King Creek at Livingston) was used to simulate daily streamflow data for the impaired AUs in the Middle Neches project area using the drainage area ratio (DAR) methodology (Figure 9). The USGS gauge 08066200 streamflow records became available January 1, 1963. The USGS gauge 08066200 was chosen due to similar characteristics to the Middle Neches project area, as well as its proximity. The Euclidean distance between the USGS gauge 08066200 and the downstream SWQM stations in the AU watersheds ranges from 38 miles to 43 miles. The drainage area above the USGS gauge 08066200 is approximately 141.044 square miles. The drainage area above the USGS gauge was delineated using the ArcGIS Spatial Analyst Watershed tool. The input data were flow accumulation and flow direction rasters derived from the National Hydrography Dataset Plus Version 2.1, which can be retrieved from EPA's NHDPlus Texas Data.[1]

The Middle Neches project area and the drainage area above the USGS gauge 08066200 receive similar annual precipitation, 46 inches and 52 inches respectively. General information of the USGS gauge 08066200 is tabulated in Table 16. Further discussion about streamflow development is in Section 3.2.3.

[1] www.epa.gov/waterdata/nhdplus-texas-data-vector-processing-unit-12

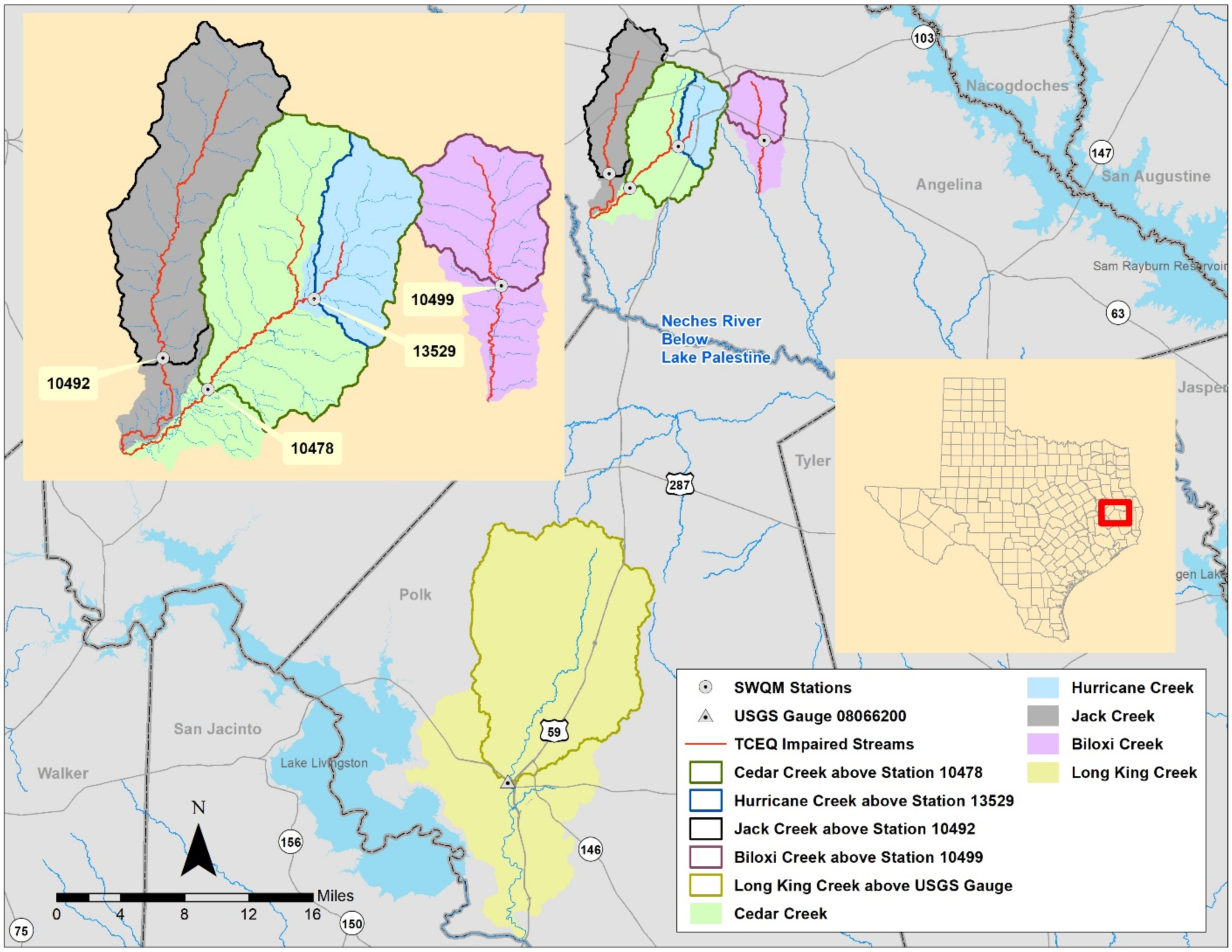


Figure 9. USGS streamflow gauge and SWQM station watersheds used in streamflow development

Table 16. Information on the USGS streamflow gauge (08066200) used for daily streamflow development

Gauge No.	Site Description	Drainage Area (square miles)	Daily Streamflow Record	Mean Daily Streamflow (cfs)	Minimum Daily Streamflow (cfs)	Maximum Daily Streamflow (cfs)
08066200	Long King Creek at Livingston, TX	141.044	01/01/1963 – Present	62	0	2,750

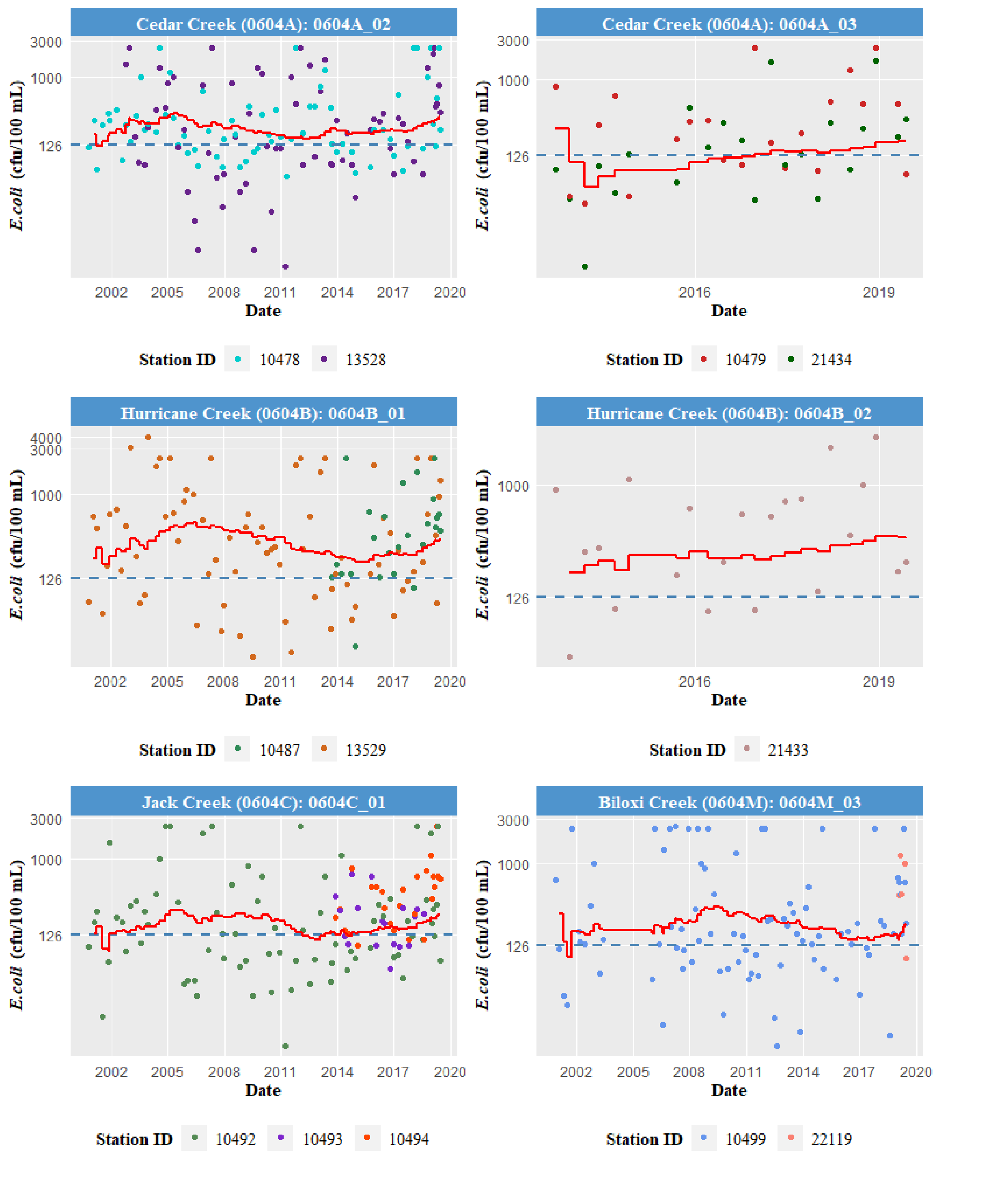
Historical *E. coli* data available for the impaired and upstream AUs were obtained from the TCEQ SWQMIS database (Table 17, Figure 10) (TCEQ, 2020b). Data was obtained August 2020 and includes *E. coli* data available through June 12, 2019. SWQM stations 10478, 13529, 10492 and 10499 were used for the development of LDCs and are shaded in grey in Table 17. These stations are geographically located in the downstream portion of each watershed, therefore accounting for the largest drainage area for each watershed, and each had the greatest amount of historical *E. coli* data.

Table 17. Summary of historical *E. coli* dataset for the Middle Neches project area

Water Body	AU	Station[a]	Station Location	No. of Samples	Date Range	Data Range (cfu/100mL)	Geometric Mean (cfu/100mL)
Cedar Creek	0604A_03	21434	Cedar Creek at Ellis Ave.	22	09/19/2013 -06/12/2019	6 - 1700	134.76
		10479	Cedar Creek at Loop 287	22	09/19/2013 - 06/12/2019	34 - >2400	249.23
	0604A_02	13528	Cedar Creek at FM 1336	70	10/09/2002 - 06/4/2019	3 - >2400	202.25
		10478	Cedar Creek at FM 2497	78	10/12/2000 - 06/04/2019	48 - >2400	251.02
Hurricane Creek	0604B_02	21433	Hurricane Creek below Kiwanis Park Drive	22	09/19/2013 - 06/12/2019	42 - >2400	365.57
	0604B_01	10487	Hurricane Creek at Loop 287	26	09/19/2013 - 06/04/2019	24 - >2400	382.1
		13529	Hurricane Creek at FM 324	78	10/25/2000 - 06/04/2019	19 - >2400	306.45
Jack Creek	0604C_01	10494	Jack Creek at FM 3150	26	12/02/2013 - 06/11/2019	93 - >2400	335.21
		10493	Jack Creek at SH 94	18	12/02/2013 - 08/06/2018	50 - 650	179.01
		10492	Jack Creek at FM 2497	77	10/12/2000 - 06/11/2019	6 - >2400	161.47
Biloxi Creek	0604M_03	22119	Biloxi Creek at US 69	6	01/22/2019 - 06/11/2019	91 - >2400	n/a[b]
		10499	Biloxi Creek at Angelina CR 216	87	11/15/2000 - 06/11/2019	10 - >2400	209.41

[a] Stations are listed in upstream to downstream order for each AU.

[b] n/a (not applicable). Geometric mean only provided if sample size was 10 or greater.



The 126 cfu/100mL criterion is indicated using a dashed blue line. The red line indicates the 7-year rolling geometric mean.

Figure 10. Summary plots of historical bacteria data in Middle Neches project area

3.1.2. Allocation Tool Selection

Based on the review of available *E. coli* data in the project area and nearby streamflow records for the DAR methodology the LDC method was chosen for the Middle Neches project area.

3.2 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 series of sequential steps.

- Step 1: Determine the hydrologic period of record to be used in developing the FDCs.
- Step 2: Determine the SWQM station locations for FDC and LDC development.
- Step 3: Develop daily streamflow records at selected ungauged SWQM station locations using streamflow records from the surrogate gauge and DAR method.
- Step 4: Develop FDCs at the SWQM station locations, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDCs at the SWQM station locations based on the relevant criterion and the data from the FDCs.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDCs.

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

3.2.1. Step 1: Determine Hydrologic Period

Daily hydrologic streamflow records were developed from the USGS gauge 08066200 at Long King Creek in Livingston. USGS gauge 08066200 was selected due to its relatively natural flows with minimal alterations since there are only three permitted dischargers with no active water right diversions (TCEQ, 2020c, 2020d, and 2021a). Optimally, the period of record to develop FDCs should include as much data as possible to capture extremes of high and low flows and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of conditions experienced when the *E. coli* data were collected.

The period of record for available *E. coli* data was October 2000 through June 2019. However, there were only four *E. coli* measurements (one measurement at each of the four SWQM stations) in the year 2000, thus only streamflow records from January 2001 through June 2019 were used.

3.2.2. Step 2: Determine SWQM Station Locations

For the Middle Neches project area, there are four impaired AUs (0604A_02, 0604B_01, 0604C_01, and 0604M_03) with historical *E. coli* measurements at nine TCEQ SWQM stations. The FDCs and LDCs were developed at SWQM station 10478 in Cedar Creek

(0604A_02), SWQM station 13529 in Hurricane Creek (0604B_01), SWQM station 10492 in Jack Creek (0604C_01), and SWQM station 10499 in Biloxi Creek (0604M_03). Those SWQM stations were selected because they are the most downstream SWQM stations for the AUs and had the greatest amount of available data (Table 17) to meet the 24 minimum-sample suggestion for the development of LDCs (TWRI, 2007).

3.2.3. Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and the SWQM station locations were determined, the DAR method was used to develop the daily streamflow record. The mean daily streamflow from USGS gauge 08066200 was multiplied by a factor to simulate flow records at a desired SWQM station (Equation 1). The factor is determined using the drainage area above the ungauged SWQM station, the drainage area above the USGS gauge, and a streamflow percentile exponent factor.

$$Y = X\left(\frac{A_y}{A_x}\right)^{\phi}$$

(Equation 1)

Where:

Y = streamflow for the ungauged location

X = streamflow for the gauged location

A_y = drainage area for the ungauged location

A_x = drainage area for the gauged location

ϕ = exponent based on streamflow percentile (Asquith et al. 2006)

Often, $\phi = 1$ 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 for ϕ are used for different streamflow percentiles (ϕ ranges from 0.7 to 0.935), as suggested by Asquith et al (2006).

Identifying a gauged watershed to develop streamflow for ungauged water bodies requires considering several factors, including separation distance, relative drainage areas, and hydrologic similarity. Furthermore, discharges and diversions in both the gauged watershed and ungauged water bodies may complicate the application of the DAR method.

General understanding about actual streamflow characteristics is relatively uncertain and reliant upon local knowledge. Cedar Creek (AU 0604A_02) and Hurricane Creek (AU 0604B_01) are both described as perennial streams in Appendix D of the Texas Surface Water Quality Standards (TCEQ, 2018). It is assumed that Jack Creek and Biloxi

Creek are also perennial, possibly running dry only during intense drought events. In order to minimize complications from regulated discharges and diversions, a surrogate stream gauge with minimal diversions and discharges was desired. Furthermore, Asquith et al. (2006) suggest a 100-mile maximum separation distance between the source gauge and location for which the streamflow is being developed.

USGS gauge 08066200 at Long King Creek at Livingston, TX was selected since the gauge is located within 100 miles, has no diversions, and minimal upstream discharges (Figure 9). The Long King Creek watershed above the USGS gauge is minimally developed and highly rural which is similar to Jack Creek and Biloxi Creek watersheds, whereas Cedar Creek and Hurricane Creek watersheds are relatively more developed. The USGS gauge records were "naturalized" by correcting the additions of WWTF discharges, and withdrawals of upstream water rights diversions. As used herein, naturalized flow is referring to the flow without the additions of permitted discharges and withdrawals from water rights, i.e., the flow that would occur in response to precipitation, evapotranspiration, near surface geology, soils, land covers of the watershed, and other factors. The naturalized daily streamflow records were developed from extant USGS records.

A search for active TPDES wastewater permits indicated that three permitted entities discharge above the USGS gauge 08066200 in Long King Creek (Table 18). To naturalize the gauged streamflow, DMRs for each permitted entity were retrieved from ECHO (EPA, 2020). Monthly mean daily DMR discharges for each permitted entity were removed from the daily USGS gauged streamflow for the selected period of record (January 2001 to June 2019). The previous month's mean daily DMR discharge was used for any months missing values. The resulting naturalized flow is the streamflow with discharges removed.

In addition to the WWTF discharges, surface water diversions associated with water rights permits have the potential of impacting stream hydrology with regard to the application of the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the Middle Neches project area contains two active water rights permits (TCEQ, 2021a, 2021b, and 2021c). One of the permits is located in the Jack Creek AU 0604C_01 TMDL watershed. A review of the water use data file containing historical, self-reported water diversions indicated that there have been no reported diversions associated with this water rights permit between 2000 and 2014 (TCEQ, 2020g). It can be assumed that the stream hydrology of Jack Creek will not be significantly influenced due to lack of diversions in this watershed. Therefore, diversions associated with water rights permits were not considered in the development of streamflow record for Jack Creek.

The other active water rights permit is located in the Hurricane Creek AU 0604B_01 TMDL watershed. A review of the water use data file containing historical, self-reported water diversions indicated that between 2000 and 2014, this water user diverted an average of approximately 325 acre-feet annually and the monthly average ranged from

2 acre-feet to 54 acre-feet (TCEQ, 2020g). The impact of the diversions on the DAR estimated streamflow was found to have no significant impact on streamflow calculations. Therefore, diversions associated with water rights permits were not considered in the development of streamflow record for Hurricane Creek. No active water right holders or diversions were identified in the Long King Creek watershed either (TCEQ, 2021a and 2021b).

The drainage areas used to develop streamflows for the AU watersheds in the Middle Neches project area are listed in Table 19 and depicted in Figure 9. Drainage areas above the SWQM stations were delineated using the same method described in the subsection 3.1.1.

After applying the DAR to daily naturalized gauged streamflow values (Equation 1), the output is the estimated streamflow at the specific SWQM stations. The estimated streamflow is further adjusted to account for discharges and future growth (FG) flow in each respective AU watershed. For Cedar Creek, the simulated daily streamflow was further adjusted to account for the influence of daily discharge from the City of Lufkin's WWTF. The full permitted discharge plus FG flow were added to the simulated daily flow values for Cedar Creek. The calculation of FG flow is described in 4.7.4. For Hurricane Creek, the outfall of the Lufkin WWTF is located downstream of SWQM station 13529 which was used to develop the TMDL, so it was not added to the streamflow. However, FG flow was added to account for any potential growth upstream of the station. For Jack Creek, the simulated daily streamflow was further adjusted to account for the influence of daily discharge from the City of Hudson WWTF. The full permitted discharge plus FG flow were added to the simulated daily flow values for Jack Creek. For Biloxi Creek, an FG term was added to account for the potential of a future WWTF to serve residents in the area. The calculation of the FG term is described in 4.7.4. Simulated streamflow graphs are included in Appendix B.

Table 18. Upstream discharges in Long King Creek watershed above the USGS gauge 08066200

TPDES Permit No./NPDES No.	Facility/Permittee	Effluent Type	Permitted Discharges (MGD)	Recent Discharges (MGD)[a]
WQ0013388001/ TX0104213	Timberwood Nursing & Rehabilitation Center/ Polk Health Holdings LLC; Livingston Care Associates Inc	Treated domestic wastewater	0.012 (daily average)	0.0037
WQ0011139001/ TX0075701	Moscow WWTF/ Moscow Water Supply Corporation	Treated domestic wastewater	0.040 (daily average)	0.0127
WQ0014796001/ TX0125091	Polk County Safety Rest area WWTF/Texas Department of Transportation	Treated domestic wastewater	0.015 (daily average)	0.0050

[a] Recent discharge period calculated from July 1, 2015 to June 30, 2019

Table 19. Drainage area ratios used at each SWQM station

Location	Drainage Area (square miles)	Drainage Area Ratio
USGS 08066200 (Long King Creek)	141.0440	NA
SWQM Station 10478 (Cedar Creek)	39.4845[a]	0.2799
SWQM Station 13529 (Hurricane Creek)	12.1607	0.0862
SWQM Station 10492 (Jack Creek)	25.5751	0.1813
SWQM Station 10499 (Biloxi Creek)	12.5117	0.0887

[a] Drainage area above SWQM station 10478 includes all of the Hurricane Creek watershed area and the area above the station for the Cedar Creek watershed.

3.2.4. Steps 4 through 6: FDC and LDC

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

1. Order the estimated daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 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 1.
3. 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) and by a conversion factor (28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09 billon), which gives 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 load for each sample by multiplying the measured *E. coli* concentration on a particular day by the corresponding streamflow on that day and the conversion factor (28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09 billon).
- Plot the load for each measurement at the exceedance percentage for its corresponding streamflow on the LDC.

The plots of the LDC display the frequency and magnitude at which measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above the maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below the curve show compliance.

3.3. Flow Duration Curves for TMDL Watersheds

FDCs were developed for the Cedar Creek AU 0604A_02 watershed at SWQM station 10478, Hurricane Creek AU 0604B_01 watershed at SWQM station 13529, Jack Creek AU 0604C_01 watershed at SWQM station 10492, and Biloxi Creek AU 0604M_03 watershed at SWQM station 10499 (Figures 11 to Figures 14). For this report, the FDCs were developed by using naturalized mean daily streamflows obtained from USGS gauge 08066200 and period of record (2001-2019) as described in the previous section.

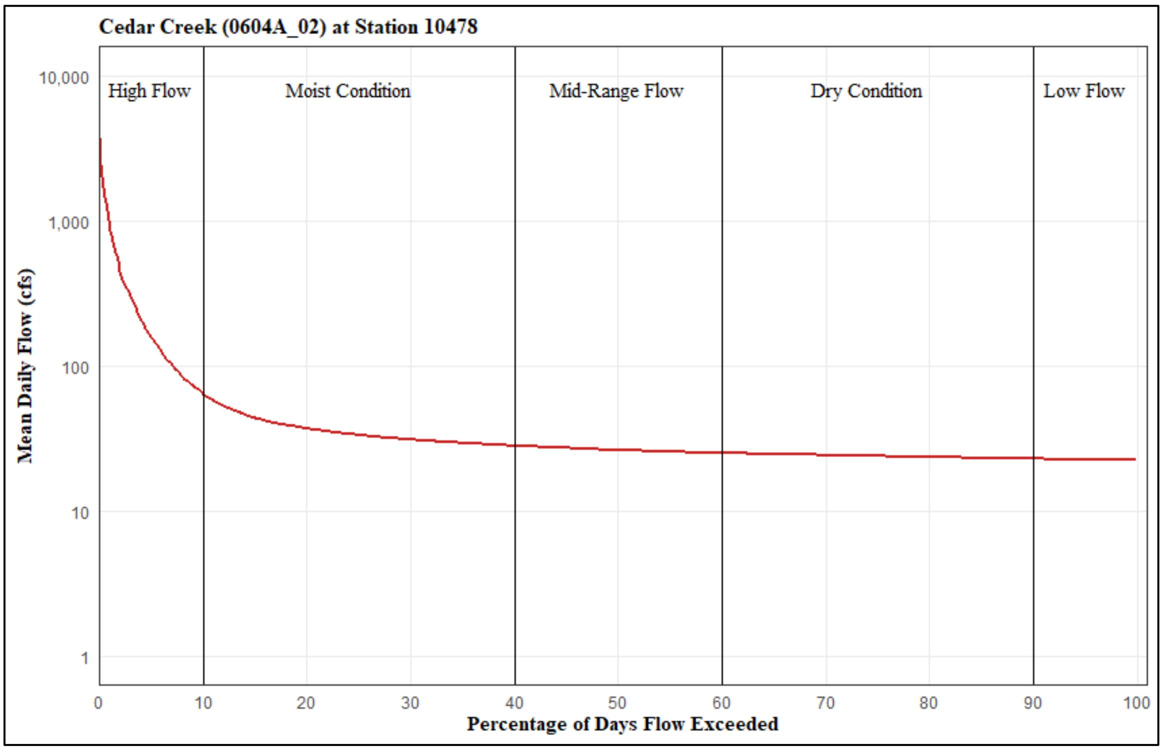


Figure 11. FDC for Cedar Creek AU 0604A_02 at SWQM station 10478

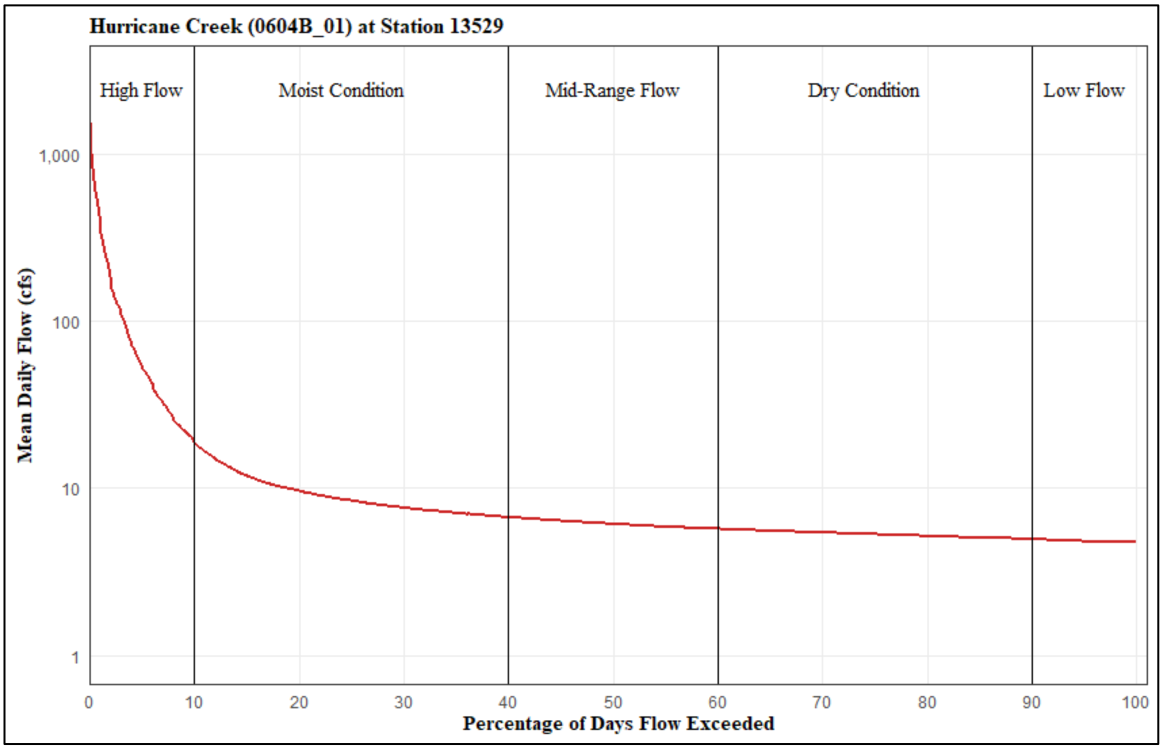


Figure 12. FDC for Hurricane Creek AU 0604B_01 at SWQM station 13529

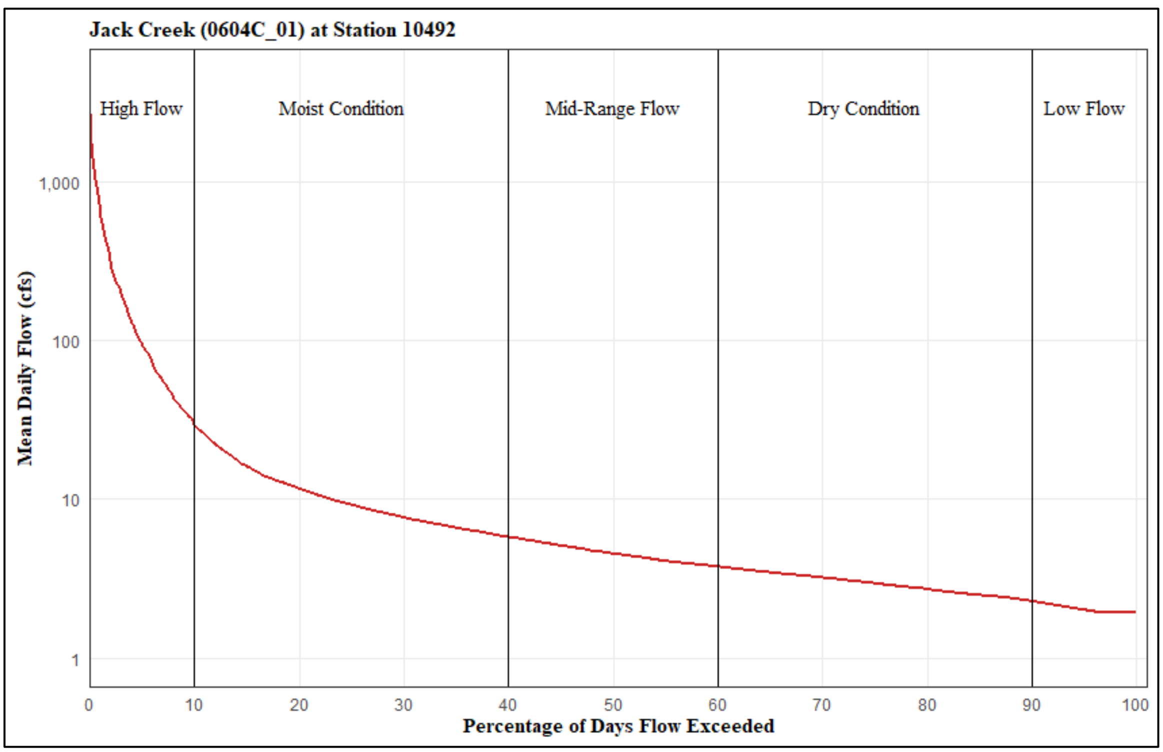


Figure 13. FDC for Jack Creek AU 0604C_01 at SWQM station 10492

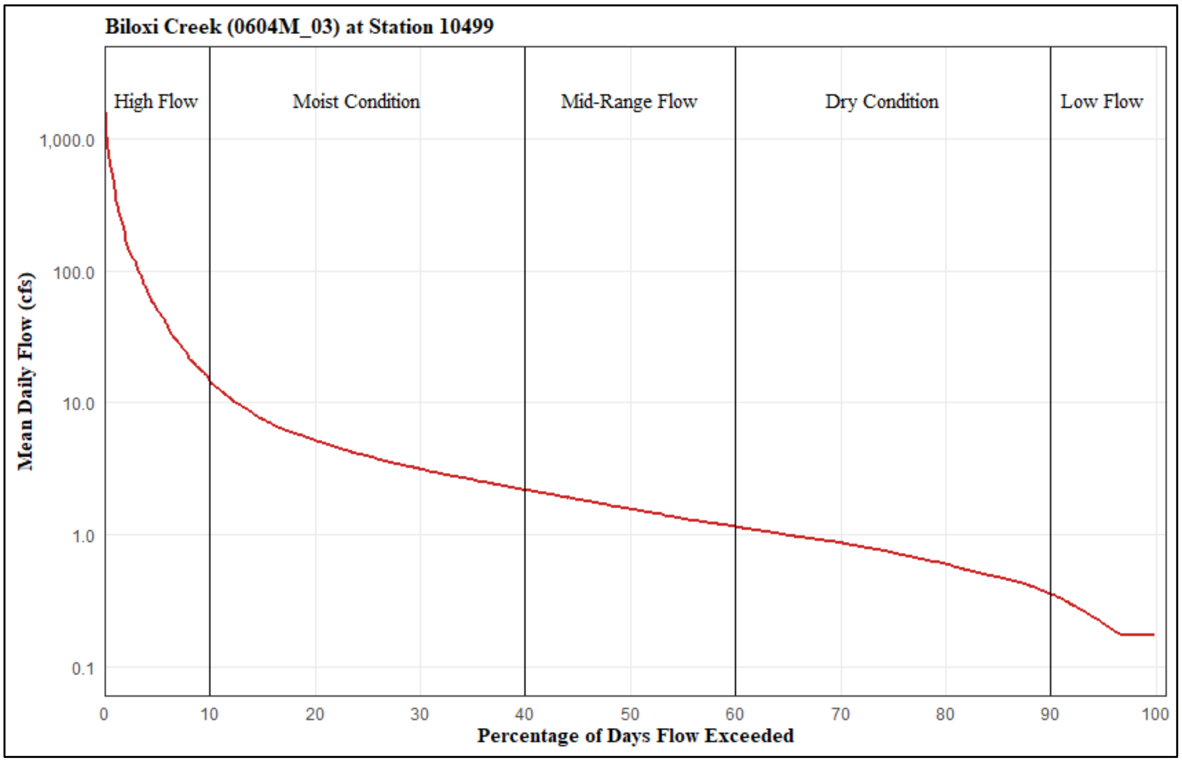


Figure 14. FDC for Biloxi Creek AU 0604M_03 at SWQM station 10499

3.4. Load Duration Curves for TMDL Watersheds

LDCs were developed for four impaired AUs in the Middle Neches project area using *E. coli* data from TCEQ SWQM stations 10478, 13529, 10492 and 10499. 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. A commonly used set of regimes, provided in Cleland (2003), is based on the following five intervals along the x-axis of the FDCs and LDCs: 0-10% (high flows); 10-40% (moist conditions); 40-60% (mid-range flows); 60-90% (dry conditions); and 90-100% (low flows). Figures 15 to 18 depict the LDCs developed for the impaired AUs in the Middle Neches project area.

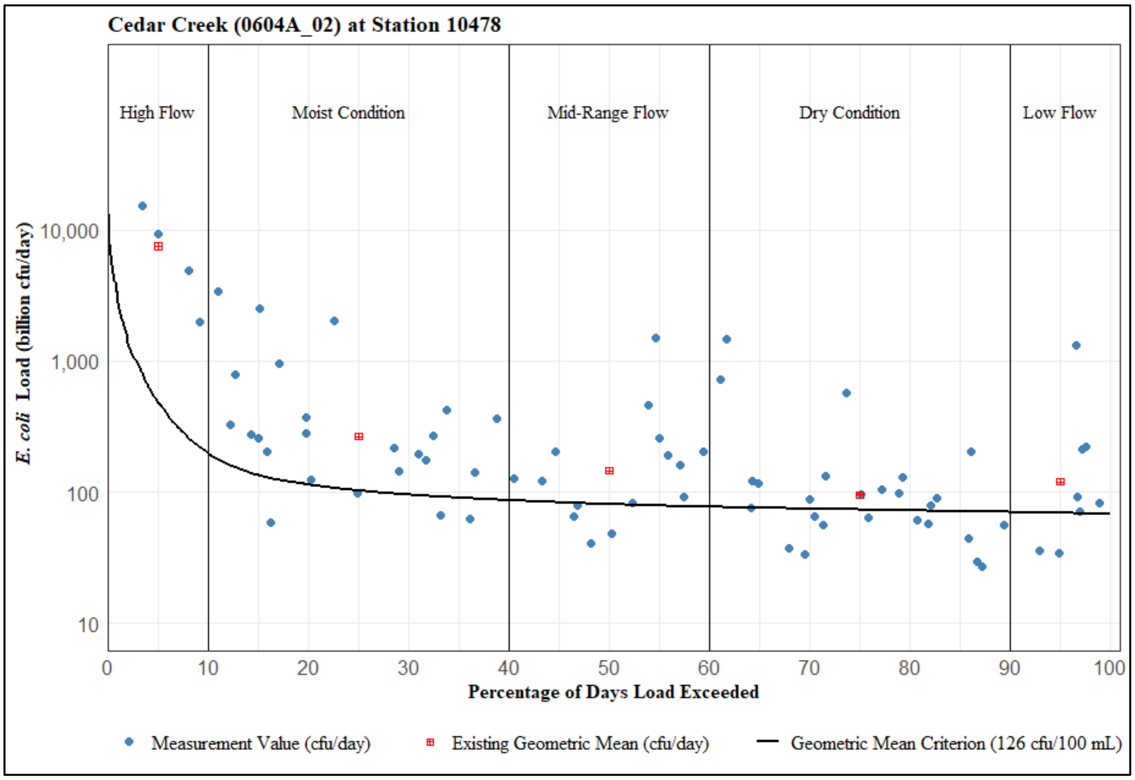


Figure 15. LDC for Cedar Creek AU 0604A_02 at SWQM station 10478

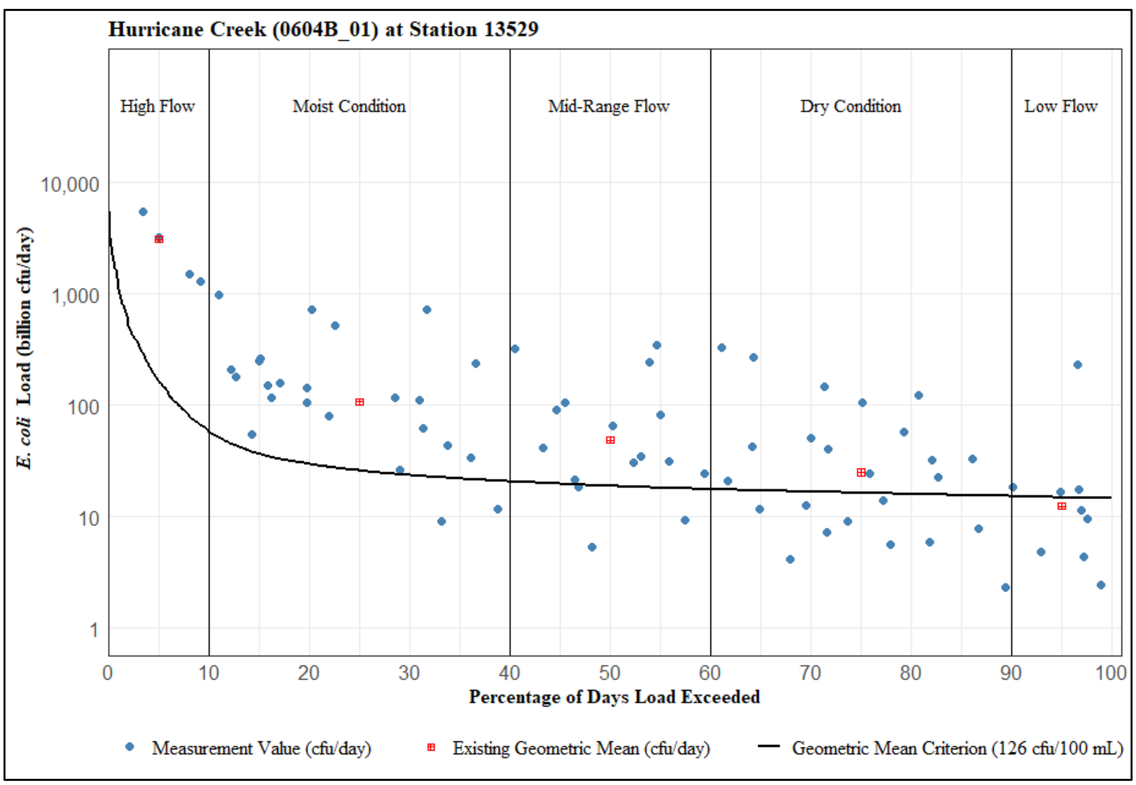


Figure 16. LDC for Hurricane Creek AU 0604B_01 at SWQM station 13529

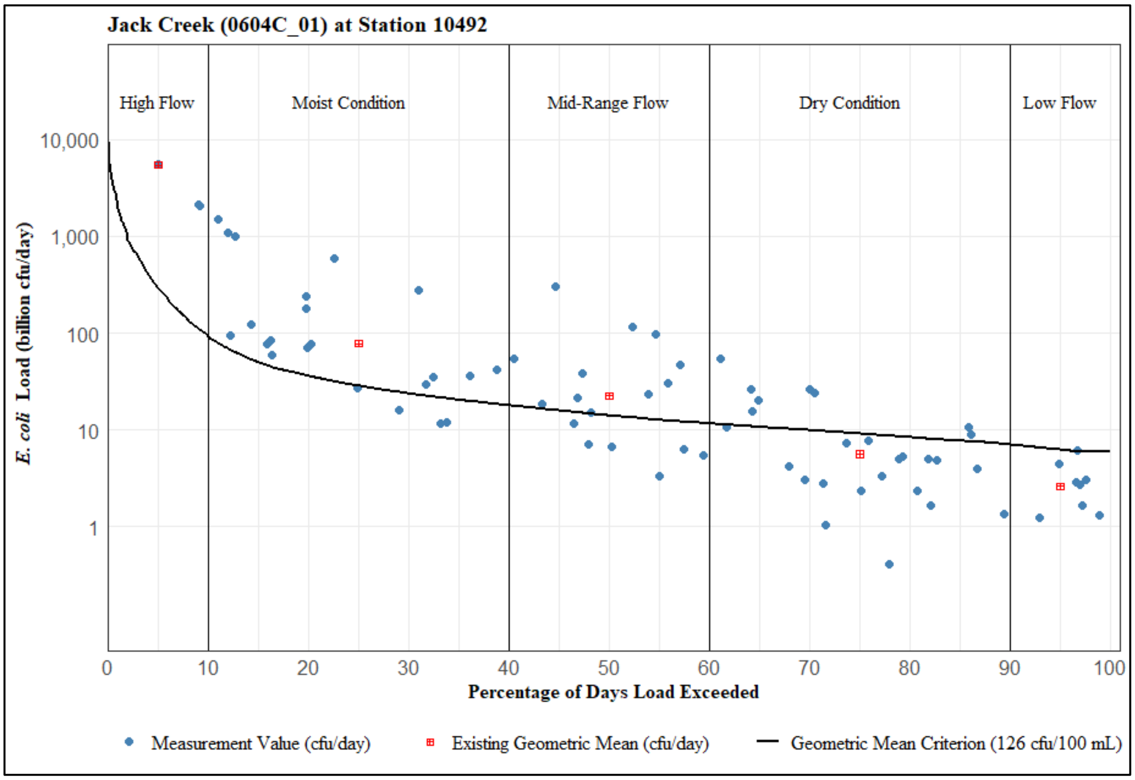


Figure 17. LDC for Jack Creek AU 0604C_01 at SWQM station 10492

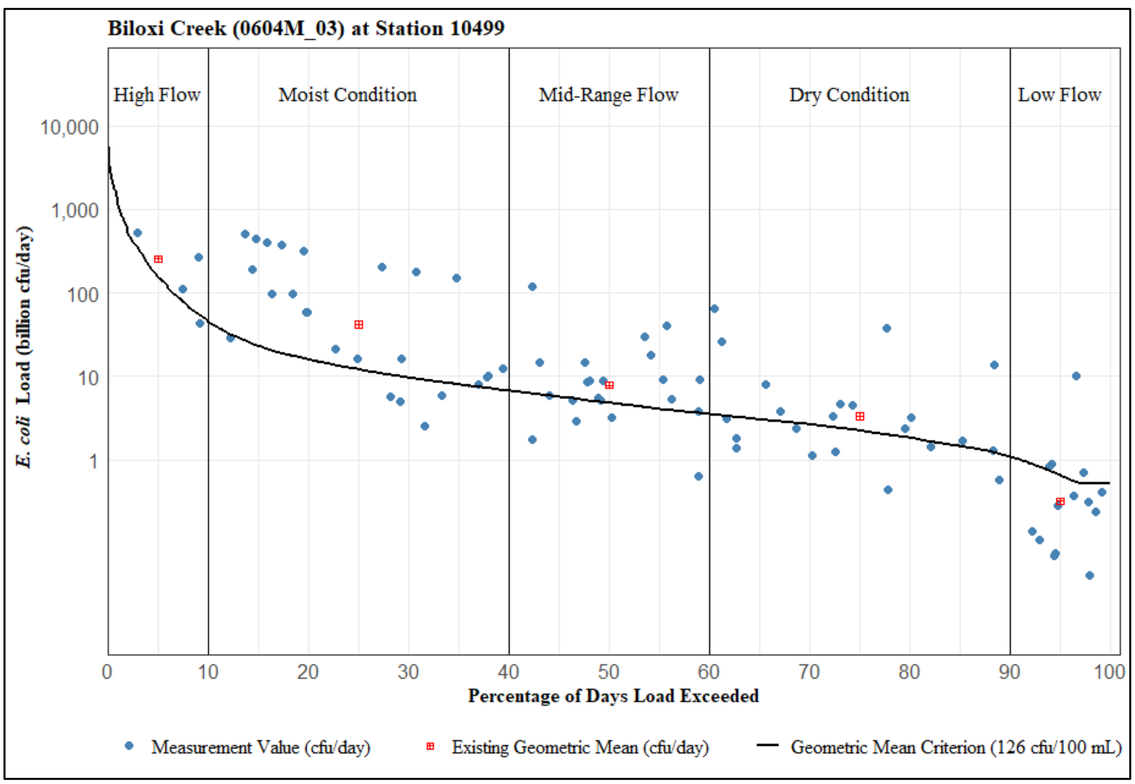


Figure 18. LDC for Biloxi Creek AU 0604M_03 at SWQM station 10499

Section 4. TMDL Allocation Development

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 to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for these TMDLs in this report is to maintain the concentrations 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 (TCEQ, 2018).

4.2. Seasonality

Seasonal variations (or seasonality) occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. The Code of Federal Regulations (CFR) [40 CFR 130.7(c)(1)] requires that TMDLs account for seasonal variation in watershed conditions and pollutant loading.

Seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from routine monitoring samples collected in the 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 test was considered significant at the $\alpha = 0.05$ level.

The Wilcoxon Rank Sum test suggests there is a slight seasonal difference in *E.coli* concentrations for Biloxi Creek AU 0604M_03 ($W=737$, $p=0.0062$; Table 20, Figure 22). The test suggests that there is no significant seasonal difference in *E. coli* concentrations in the other AUs (Table 20, Figures 19-22).

Table 20. Wilcoxon Rank Sum test results

Water Body	AU	SWQM Station	W-statistic	*p*-value
Cedar Creek	0604A_02	10478, 13528	2078	0.2392
Hurricane Creek	0604B_01	10487, 13529	1038	0.1847
Jack Creek	0604C_01	10492, 10493, 10494	1411	0.0500
Biloxi Creek	0604M_03	10499	737	0.0062*

*Indicates a p-value < 0.05

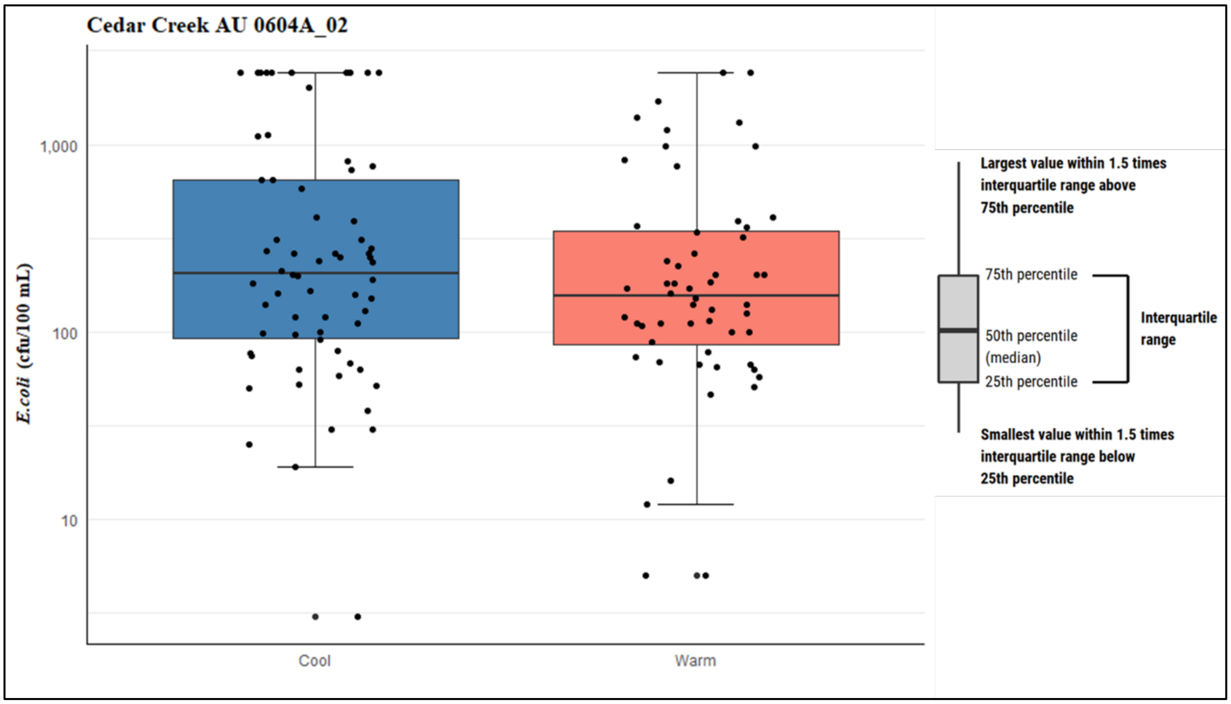


Figure 19. Distribution of *E. coli* concentrations by season in Cedar Creek AU 0604A_02 (SWQM stations 13528 and 10478)

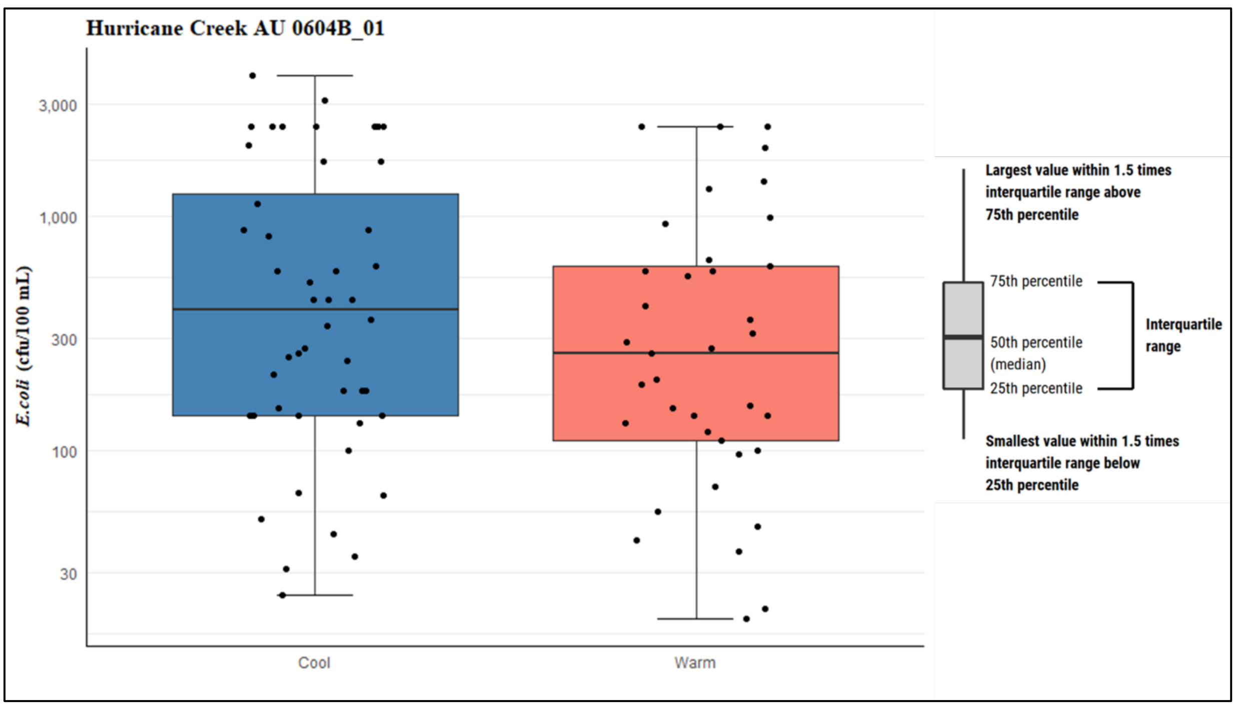


Figure 20. Distribution of *E. coli* concentrations by season in Hurricane Creek AU 0604B_01 (SWQM stations 10487 and 13529)

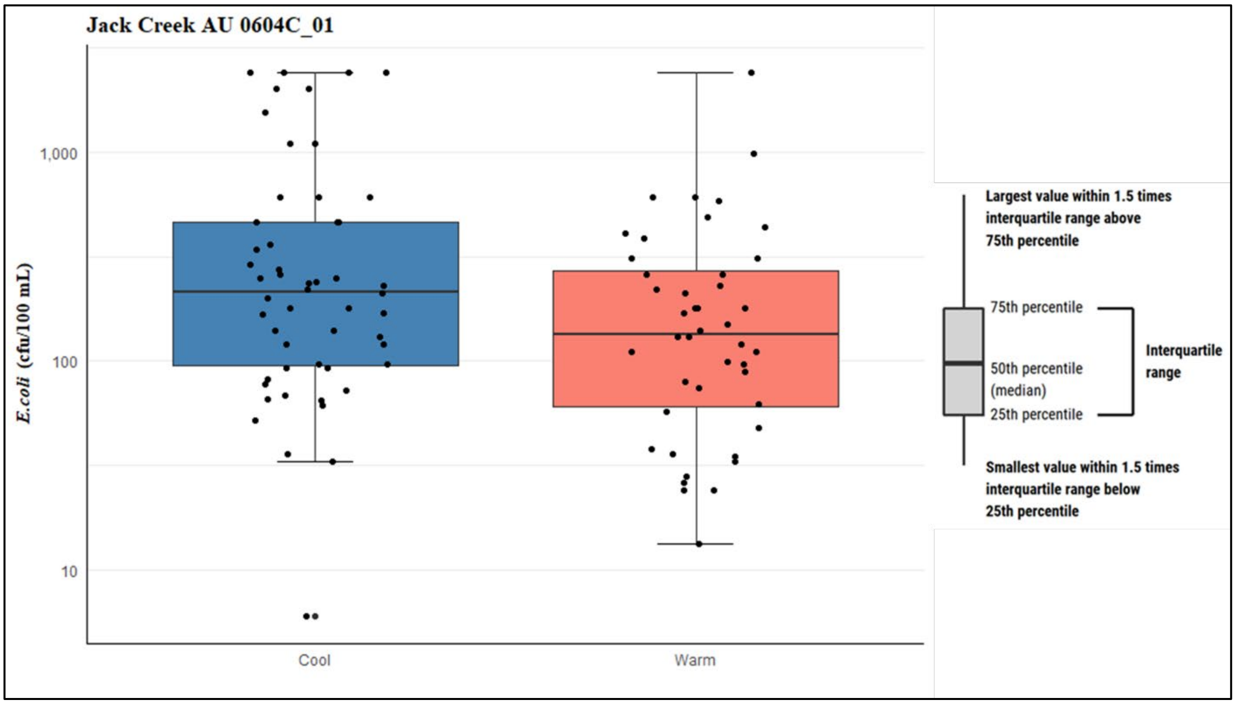


Figure 21. Distribution of *E. coli* concentrations by season in Jack Creek AU 0604C_01 (SWQM stations 10492, 10493, and 10494)

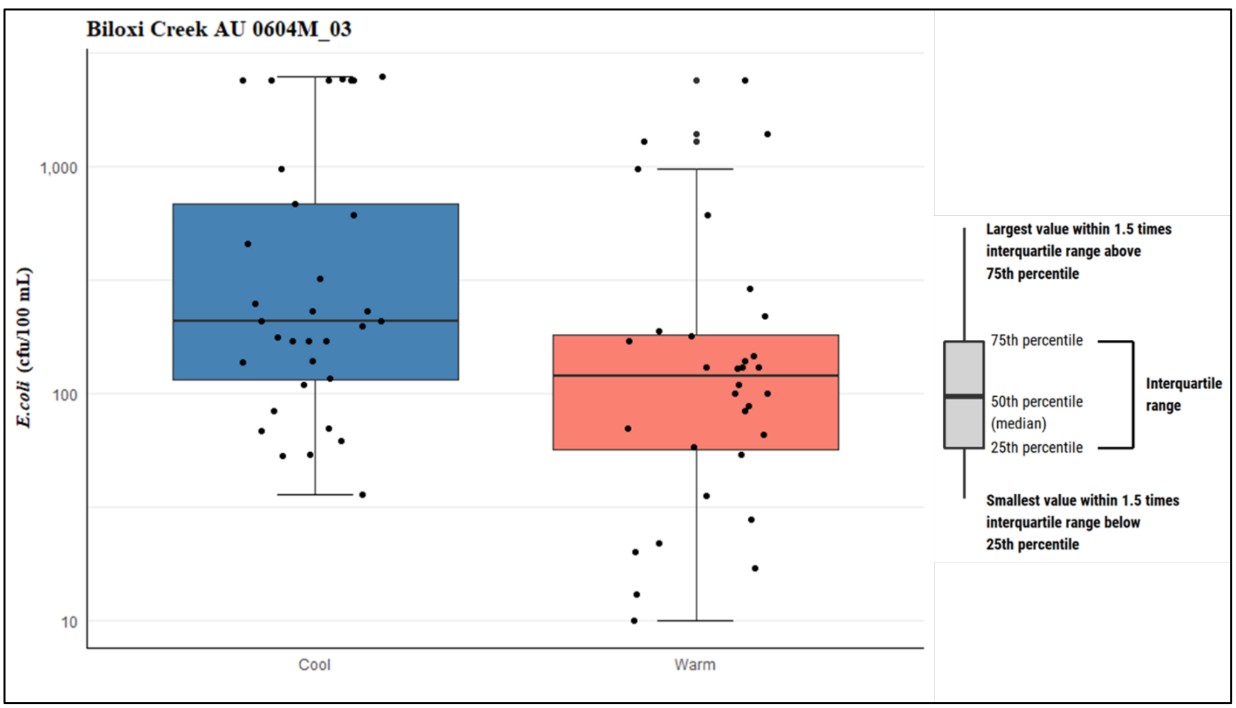


Figure 22. Distribution of *E. coli* concentrations by season in Biloxi Creek AU 0604M_03 (SWQM station 10499)

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. This 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. 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 fecal 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 because the sources of bacteria are attenuated as runoff washes them 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 also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). The stormwater pollutant load 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 are 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. 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 regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. 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 regarding the magnitude or specific origin of the various sources. Only limited information is

gathered regarding point and nonpoint sources in the watershed. The general difficulty in analyzing and characterizing *E. coli* in the environment is another weakness.

The LDC method allows for estimation of existing 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 (point and nonpoint), and provides a means to allocate allowable loadings.

Based on the LDCs to be used in the pollutant load allocation process with historical *E. coli* data added to the graphs (Figures 15-18) and Section 2.7, the following broad linkage statements can be made.

- For the Cedar Creek (AU 0604A_02) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under all flow conditions.
- For the Hurricane Creek (AU 0604B_01) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, mid-range flow, and dry conditions. Under the low flow condition, loadings fall below the geometric mean criterion.
- For the Jack Creek (AU 0604C_01) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, and mid-range flow conditions. Under dry and low flow conditions, loadings fall below the geometric mean criterion.
- For the Biloxi Creek (AU 0604M_03) watershed, historical *E. coli* data indicate that elevated bacteria loading occurs under high flow, moist, mid-range flow, and dry conditions. Under the low flow condition, loadings fall below the geometric mean criterion.

Elevated loadings under high flow and moist condition are likely associated with stormwater and runoff from nonpoint sources. The discharge from the two WWTFs may contribute point source loadings under dry and low flow conditions in AUs 0604A_02 and 0604C_01. SSOs are periodic events that may contribute to bacteria loadings within the watersheds under wet weather conditions. Other sources of bacteria loadings under mid-range, dry, and low flow conditions and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely to contribute bacteria directly to the water. These sources may include direct deposition of fecal material from wildlife, feral hogs, birds, or livestock. OSSFs may contribute to bacteria loadings under any flow conditions. 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 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 a MOS. The TMDLs covered by this report incorporate an explicit MOS of 5%.

4.6 Load Reduction Analysis

While the TMDLs covered by this report will be developed using load allocations, additional insight may be 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 used to develop the LDCs. 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 FC (excluding days with zero flow).

$$\text{Existing Load}_{\text{FC}} = \tilde{\text{Q}}_{\text{FC}} * \text{G}_{\text{FC}} * \text{ Conversion Factor}$$

(Equation 2)

Where:

FC = respective flow category

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

$\tilde{\text{Q}}_{\text{FC}}$ = median flow for FC

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

Conversion Factor (to billion cfu/day) = 28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09

The allowable load (Equation 3) was calculated as:

$$\textbf{Allowable Load}_{\textbf{FC}} = \tilde{\textbf{Q}}_{\textbf{FC}} * \textbf{ Criterion} * \textbf{ Conversion Factor}$$

(Equation 3)

Where:

Allowable Load_{FC} = allowable *E. coli* load at the median flow in each FC

$\widetilde{Q}_{FC}$ = median flow for FC

Criterion = 126 cfu/100 mL

Conversion Factor (to billion cfu/day) = 28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09

Percentage reduction for each flow category (PR_{FC}) (Equation 4) was then calculated as:

$$PR_{FC} = \frac{\text{Existing Load}_{FC} - \text{Allowable Load}_{FC}}{\text{Existing Load}_{FC}}$$

(Equation 4)

4.7. Pollutant Load Allocation

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

TMDL = WLA + LA + FG + MOS

(Equation 5)

Where:

WLA = wasteload allocations, 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

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

The TMDL component for the impaired AUs were derived using the median flow within the high flow regime (or 5% flow) of the LDCs for each impaired AU watershed in the Middle Neches project area. For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component.

Table 21. Percentage daily load reductions needed to meet water quality standards in each flow regime

AU/ SWQM Station	Flow Regime	Median Flow (cfs)	Geometric Mean (cfu/100mL)	Existing Load (Billion cfu/Day)	Allowable Load (Billion cfu/Day)	% Reduction Required
0604A_02/ 10478	High Flows	154.66	1,983.64	7,505.92	476.77	94
	Moist Conditions	33.20	325.24	264.20	102.35	61
	Mid-Range Flows	26.11	227.02	145.03	80.50	44
	Dry Conditions	23.75	163.87	95.21	73.21	23
	Low Flows	22.37	218.57	119.62	68.96	42
0604B_01/ 13529	High Flows	52.61	2,400.00	3,089.09	162.18	95
	Moist Conditions	8.41	525.63	108.18	25.93	76
	Mid-Range Flows	6.10	325.32	48.58	18.82	61
	Dry Conditions	5.30	192.84	24.99	16.33	35
	Low Flows	4.81	105.74	12.45	14.84	NA
0604C_01/ 10492	High Flows	92.89	2,400.00	5,454.38	286.36	95
	Moist Conditions	9.22	342.63	77.31	28.43	63
	Mid-Range Flows	4.53	203.10	22.53	13.98	38
	Dry Conditions	2.94	77.67	5.59	9.07	NA
	Low Flows	2.01	52.82	2.59	6.19	NA
0604M_03/ 10499	High Flows	49.20	213.72	257.26	151.67	41
	Moist Conditions	3.92	438.15	42.00	12.08	71
	Mid-Range Flows	1.35	207.74	6.85	4.16	39
	Dry Conditions	0.72	188.14	3.34	2.23	33
	Low Flows	0.21	61.53	0.32	0.66	NA

4.7.1. AU-Level TMDL Calculations

The TMDLs for the impaired AUs were developed based on information from the LDCs developed for the TCEQ SWQM stations 10478, 13529, 10942, and 10499 (Figures 15 to 18).

As discussed earlier, a bacteria LDC was developed by multiplying the streamflow value along the FDC by the primary contact recreation 1 use geometric mean criterion for *E. coli* (126 cfu/100 mL) and by the conversion factor to convert to loading in cfu per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

$$\text{TMDL} = \text{Criterion} * \text{Flow} * \text{Conversion Factor}$$

(Equation 6)

Where:

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

Flow = 5% exceedance flow from FDC in cfs

Conversion Factor (to billion cfu/day) = 28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09

At the 5% load duration exceedance, the TMDL values are provided in Table 22.

Table 22. Summary of allowable loadings for the Middle Neches project area

AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
0604A_02	154.66	4.768E+11	476.767
0604B_01	52.61	1.622E+11	162.180
0604C_01	92.89	2.864E+11	286.350
0604M_03	49.20	1.517E+11	151.668

4.7.2. Margin of Safety Formula

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)

Where:

MOS = margin of safety load

TMDL = total maximum daily load

The MOS for each AU is presented in Table 23.

Table 23. MOS for the Middle Neches project area

AU	TMDL (Billion cfu/day)	MOS (Billion cfu/day)
0604A_02	476.767	23.838
0604B_01	162.180	8.109
0604C_01	286.350	14.318
0604M_03	151.668	7.583

4.7.3. Wasteload Allocation

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}):

$$WLA = WLA_{WWTF} + WLA_{SW}$$

(Equation 8)

Wastewater (WLA_{WWTF})

TPDES-permitted point source discharge facilities are allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by the instream geometric mean criterion. The *E. coli* primary contact recreation 1 use geometric mean criterion of 126 cfu/100 mL is used as the WWTF target. This is expressed in the following equation:

$$WLA_{WWTF} = \text{Criterion} * \text{Flow} * \text{Conversion Factor}$$

(Equation 9)

Where:

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

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = 1.54723 cfs/MGD * 28,316.8 mL/ft^3 * 86,400 seconds/day × 1.0E-09

The City of Lufkin WWTF is located in the Hurricane Creek AU 0604B_01 watershed, but the WWTF discharges downstream of the SWQM station used to develop the TMDL. This facility is provided as a WLA in the downstream watershed, Cedar Creek AU 0604A_02. The full permitted discharge of the City of Lufkin WWTF is 11.3 MGD (Table 7). The Georgia-Pacific Chemical LLC permit is also found in the Hurricane Creek watershed, however, this permit discharges industrial stormwater, and therefore the discharge was not included in the WLA_{WWTF} calculation but rather in the WLA_{SW} calculation.

The City of Hudson WWTF is found in the Jack Creek AU 0604C_01 watershed with a full permitted discharge of 0.98 MGD (Table 7). Biloxi Creek AU 0604M_03 does not have any TPDES permitted point sources in its watershed, therefore, the daily allowable loading of *E. coli* for the WLA_{WWTF} is zero. The WLA_{WWTF} for each AU is presented in Table 24.

Table 24. WLAs for TPDES-permitted facilities in the Middle Neches project area

AU	TPDES Number	Permittee	Permitted Flow (MGD)	WLA_{WWTF} (Billion cfu/day)
0604A_02	WQ0010214001	City of Lufkin WWTF	11.3[a]	53.897
0604B_01	NA	NA	0.00	0.000
0604C_01	WQ0011826001	City of Hudson WWTF	0.98	4.674
0604M_03	NA	NA	0.00	0.000

[a] Current permitted flow for Cedar Creek based on WWTF located in upstream AU (0604B_01)

Regulated Stormwater (WLA_{SW})

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA_{SW} for the area was used in the development of the 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 land area included in the watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of overall runoff load that should be allocated as the WLA_{SW} component of the TMDL. The load allocation (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}.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$$

(Equation 10)

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of 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

In order to calculate the WLA_{SW} component of the TMDL, the fractional proportion of the drainage under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of 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 results are presented in Table 25.

Table 25. Regulated stormwater area and FDA_{SWP} for the Middle Neches project area

AU	MS4 General Permit (square miles)	MSGP (square miles)	Construction General Permit (square miles)	Concrete Production Facilities (square miles)	Total Area of Permits (square miles)	Watershed Area (square miles)	FDA_{SWP}
0604A_02	0.0000	0.3191	0.2531	0.0280	0.6002	44.4670	0.0135[a]
0604B_01	0.0000	0.1832	0.1063	0.0000	0.2895	12.9190	0.0224
0604C_01	0.0000	0.000	0.1578	0.0000	0.1578	29.0530	0.0054
0604M_03	0.0000	0.0713	0.1016	0.0000	0.1729	18.8720	0.0092

[a] FDA_{SWP} for Cedar Creek includes the permits located in Hurricane Creek watershed

To complete the $WLA_{SW,}$ a value for FG is needed. The calculation for the FG term is presented later in the document, but the results will be included here for continuity. All the needed information to calculate WLA_{SW} is presented in Table 26.

Table 26. Regulated stormwater load for the Middle Neches project area

AU	TMDL	MOS	WLA_{WWTF}	FG	FDA_{SWP}	WLA_{SW}
0604A_02	476.767	23.838	53.897	14.714	0.0135	5.188
0604B_01	162.180	8.109	0.000	14.714	0.0224	3.122
0604C_01	286.350	14.318	4.674	1.276	0.0054	1.437
0604M_03	151.668	7.583	0.000	0.525	0.0092	1.321

Load units expressed as billion cfu/day

With the WLASW and WLA_{WWTF} terms, the total WLA term can be determined by adding the two parts (Table 27).

Table 27. WLA for the Middle Neches project area

AU	WLA_{WWTF}	WLA_{SW}	WLA
0604A_02	53.897	5.188	59.085
0604B_01	0.000	3.122	3.122
0604C_01	4.674	1.437	6.111
0604M_03	0.000	1.321	1.321

Load units expressed as billion cfu/day

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.

To account for the FG component of the impaired AUs, the loadings from WWTFs are included in the FG computations, which is based on the WLA_{WWTF} formula. The FG equation contains an additional term to account for the projected population growth within WWTF service areas between 2010 and 2070, based on TWDB Regional Water Plan Population and Water Demand Projections (Region I Water Planning Group, 2020).

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

(Equation 11)

Where:

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

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

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

Conversion Factor (to billion cfu/day) = 1.54723 cfs/MGD * 28,316.8 mL/ft^3 * 86,400 seconds/day * 1.0E-09 billion

For Hurricane and Biloxi Creeks a slightly different approach was taken.

For Hurricane Creek AU 0604B_01, the outfall of the Lufkin WWTF is located downstream of the SWQM station 13529 which was used to develop the TMDL. Therefore, a WLA_{WWTF} was not included but an FG was calculated to account for the possibility of future WWTF expansion or infrastructure changes. The Lufkin WWTF full permitted discharge was used to calculate the FG using Equation 11.

For Biloxi Creek AU 0604M_03, projecting future growth is hindered by the absence of WWTFs. The Biloxi AU watershed is projected to grow from 3,900 in 2020 to 4,965, a population increase of 1,065 by 2070. To account for this 27.3% increase in population and the potential for future development that may require centralized wastewater, an alternative approach was applied,

Title 30, Texas Administrative Code (30 TAC) Section 217.32 requires a new WWTF to accommodate daily wastewater of 75-100 gallons per capita per day. Using the daily wastewater upper value 100 and multiplying it by the estimated population change would produce a conservative future permitted flow and FG value. Rounding the population increase up to 1,100 individuals and multiplying it by 100 gallons per capita per day results in a potential future WWTF with a permitted capacity of 0.11 MGD.

Table 28. FG calculations for the Middle Neches project area

AU	% Increase	Current Permitted Flow (MGD)	FG Flow (MGD)	FG (Billion cfu/day)
0604A_02	27.30	11.30[a]	3.085	14.714
0604B_01	27.30	0.00	3.085	14.714
0604C_01	27.30	0.98	0.268	1.276
0604M_03	27.30	0.00	0.110[b]	0.525

[a] Current permitted flow for Cedar Creek based on WWTF located in upstream AU (0604B_01)

[b] Hypothetical future, unnamed and without permit, WWTF in 0604M_03 with a projected future full permitted flow of 0.11 MGD.

4.7.5. Load Allocation

The LA is the sum of loads from unregulated sources, and is calculated as:

$$LA = TMDL - WLA - FG - MOS$$

(Equation 12)

Where:

TMDL = total maximum daily load

WLA = sum of all WWTF loads and all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

Table 29 summarizes the LA.

Table 29. LA for Middle Neches project area

AU	TMDL	MOS	WLA	LA	FG
0604A_02	476.767	23.838	59.085	379.130	14.714
0604B_01	162.180	8.109	3.122	136.235	14.714
0604C_01	286.350	14.318	6.111	264.645	1.276
0604M_03	151.668	7.583	1.321	142.239	0.525

Load units expressed as billion cfu/day

4.8. Summary of TMDL Calculations

The TMDL was calculated based on median flow in the 0-10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDCs developed from SWQM stations in the Middle Neches project area. Allocations are based on the current primary contact recreation 1 use geometric mean criterion for *E. coli* of 126 cfu/100mL

for each component of the TMDL. The TMDL allocation summary for the Middle Neches project area is summarized in Table 30.

Table 30. TMDL allocations for the Middle Neches project area

AU	TMDL	MOS	WLA_{WWTF}	WLA_{SW}	LA	FG
0604A_02	476.767	23.838	53.897	5.188	379.130	14.714
0604B_01	162.180	8.109	0.000	3.122	136.235	14.714
0604C_01	286.350	14.318	4.674	1.437	266.64	1.276
0604M_03	151.667	7.583	0.000	1.321	142.239	0.525

Load units expressed as billion cfu/day

The final TMDL allocations (Table 31) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 31. Final TMDL allocations for the Middle Neches project area

AU	TMDL	MOS	WLA_{WWTF}	WLA_{SW}	LA
0604A_02	476.767	23.838	68.611	5.188	379.130
0604B_01	162.180	8.109	14.714	3.122	136.235
0604C_01	286.350	14.318	5.950	1.437	264.645
0604M_03	151.668	7.583	0.525	1.321	142.239

Load units expressed as billion cfu/day

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Appendix A. CGPs in the Middle Neches Project Area

Table A-1. CGPs in the Middle Neches project area

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR157179	Trans-Texas Homes Corporation	Biloxi Creek	72	Expired (5/31/2003-6/3/2008)
TXR15P819	VM Development LLC	Biloxi Creek	67	Terminated (11/17/2004-4/3/2007)
TXR15BL76	JE Kingham Construction Company LTD	Biloxi Creek	11	Terminated (1/16/2006-9/14/2007)
TXR15FY01	Oncor Electric Delivery Company LLC	Biloxi Creek	70	Expired (1/5/2007-6/3/2008)
TXR15MM86	Oncor Electric Delivery Company LLC	Biloxi Creek	75	Terminated (9/5/2008-6/29/2009)
TXR15MM14	JE Kingham Construction Company LTD	Biloxi Creek	11.5	Expired (9/9/2008-6/3/2013)
TXR15TZ05	JE Kingham Construction Company LTD	Biloxi Creek	9	Expired (1/27/2012-6/3/2013)
TXR15WN16	Allen Loggins and Son Inc	Biloxi Creek	12	Terminated (3/21/2013-11/01/2013)
TXR15XR98	JE Kingham Construction Company LTD	Biloxi Creek	21	Terminated (7/26/2013-9/23/2014)
TXR1582BL	Langston Construction, Inc.	Biloxi Creek	18	Active (2/17/2020)
TXR153545	Doughtie Construction Co Inc	Cedar Creek	11	Terminated (5/9/2003-11/22/2004)
TXR156587	Billy Horton Builders Inc	Cedar Creek	174	Terminated (7/9/2003-3/14/2008)
TXR154900	NA	Cedar Creek	55	Terminated (8/7/2003-8/25/2005)

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR158264	Allen Loggins and Son Inc	Cedar Creek	9	Terminated (8/22/2003-3/18/2005)
TXR15C710	B and J Excavating	Cedar Creek	8	Terminated (11/20/2003-8/25/2004)
TXR15M250	Hoar Construction LLC	Cedar Creek	8	Terminated (08/23/2004-4/4/2005)
TXR15Q056	City of Lufkin	Cedar Creek	13	Terminated (12/2/2004-9/14/2005)
TXR15Y608	NA	Cedar Creek	4	Terminated (8/16/2005-4/12/2007)
TXR15X914	NA	Cedar Creek	4	Terminated (8/28/2005-2/5/2007)
TXR15AF05	Woodland Heights Medical Center LP	Cedar Creek	1	Expired (9/25/2005-6/3/2008)
TXR15CM22	LG Jumper Inc.	Cedar Creek	6	Expired (3/28/2006-6/3/2008)
TXR15DK13	Angelina Excavating Inc	Cedar Creek	4	Terminated (7/19/2006-5/29/2007)
TXR15B811	JE Kingham Construction Company LTD	Cedar Creek	3	Terminated (11/16/2003-9/14/2007)
TXR15GF04	Texas Department of Transportation	Cedar Creek	9.7	Terminated (6/4/2007-4/7/2008)
TXR15JK79	Texas Department of Transportation	Cedar Creek	6.55	Terminated (1/9/2008-9/10/2008)
TXR15JN36	R K Hall Construction Ltd.	Cedar Creek	30	Expired (1/18/2008-6/3/2008)
TXR15JZ69	JE Kingham Construction Company LTD	Cedar Creek	6	Expired (2/24/2008-6/3/2013)
TXR15JY15	Don Langston Construction Inc	Cedar Creek	7	Expired (3/4/2008-6/3/2008)

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR15MP67	R K Hall Construction Ltd.	Cedar Creek	10	Terminated (9/24/2008-11/12/2010)
TXR15OF94	Memorial Health System	Cedar Creek	5.5	Expired (5/31/2009-6/3/2013)
TXR15QM46	Watermark Residential II LLC	Cedar Creek	8	Expired (9/10/2010-6/3/2013)
TXR15TJ02	CGI Construction Inc	Cedar Creek	6	Terminated (1/27/2012-5/3/2013)
TXR15UI05	Comanche Contractors LP	Cedar Creek	5	Expired (4/27/2012-6/3/2013)
TXR15VW50	Texas Department of Transportation	Cedar Creek	5.3	Terminated (1/16/2013-4/30/2014)
TXR150028893	Texas Department of Transportation	Cedar Creek	11	Expired (10/06/2016-6/05/2018)
TXR15010C	Lone Wolf Construction, LLC	Cedar Creek	11	Terminated (2/1/2017-5/17/2018)
TXR15994V	Ewing Industrial Services, LLC	Cedar Creek	8.7	Terminated (3/11/2019-5/12/2020)
TXR15Q059	Ajax Equipment Company Inc.	Cedar Creek	13	Terminated (12/9/2004-3/27/2006)
TXR151892/ TXR152924	Rockwell Construction Corporation of Texas	Hurricane Creek	12	Terminated (5/11/2003-4/27/2004)
TXR155601	EMJ Corporation	Hurricane Creek	16	Terminated (6/7/2003-3/4/2004)
TXR15E988	Key Construction Inc	Hurricane Creek	23	Terminated (2/3/2004-4/30/2005)
TXR15K227	Don Langston Construction Inc	Hurricane Creek	1	Terminated (6/13/2004-4/5/2005)
TXR15L241	Texas J&D Construction Ltd.	Hurricane Creek	4	Terminated (7/25/2004-11/27/2006)

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR15X700	The Whiting-Turner Contracting Co.	Hurricane Creek	6	Terminated (7/17/2005-1/26/2006)
TXR15W424	Wal-Mart Stores Texas LP	Hurricane Creek	20	Terminated (9/9/2005-2/16/2007)
TXR15Z329	Western Builders of Amarillo Inc.	Hurricane Creek	20	Terminated (12/8/2005-2/2/2007)
TXR15AO35	M Hanna Construction Co Inc	Hurricane Creek	4	Terminated (2/01/2006-3/6/2006)
TXR15CP41	Cowpen Properties	Hurricane Creek	10	Expired (5/6/2006-6/3/2008)
TXR15CY38	Texas Department of Transportation	Hurricane Creek	37	Terminated (7/31/2006-8/21/2008)
TXR15EA10	Logans Roadhouse Inc	Hurricane Creek	1	Terminated (8/18/2006-1/10/2007)
TXR15EE38	Moore Building Associates LLP	Hurricane Creek	10	Terminated (9/2/2006-5/15/2007)
TXR15FS40	Brinker Texas LP	Hurricane Creek	2	Terminated (12/31/2006-6/12/2007)
TXR15FX93	Discount Tire Company of Texas, Inc.	Hurricane Creek	2	Expired (1/19/2007-6/3/2008)
TXR15HF47	Texas Department of Transportation	Hurricane Creek	53	Terminated (7/16/2007-7/12/2010)
TXR15JD41	JE Kingham Construction Company LTD	Hurricane Creek	5	Terminated (11/21/2007-1/13/2010)
TXR15JA26	Longview Bridge and Road LTD	Hurricane Creek	5	Terminated (12/3/2007-11/3/2010)
TXR15JV62	Darden SW LLC	Hurricane Creek	2	Expired (2/9/2008-6/3/2008)
TXR15KF80	The Card Group Inc	Hurricane Creek	52	Expired (04/03/2008-06/03/2013)

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR15KG78	Angelina Excavating Inc	Hurricane Creek	7.38	Terminated (4/09/2008-12/02/2008)
TXR15MG36	JE Kingham Construction Company LTD	Hurricane Creek	8	Expired (8/19/2008-6/3/2013)
TXR15SC14	Journeyman Construction Inc	Hurricane Creek	15	Expired (2/19/2010-6/3/2013)
TXR15PY02	JE Kingham Construction Company LTD	Hurricane Creek	8	Expired (5/6/2010-6/3/2013)
TXR15UJ28	Timberline Constructors Inc	Hurricane Creek	8.36	Terminated (6/12/2012-2/12/2013)
TXR15UQ52	Leyendecker Building Group, Inc.	Hurricane Creek	6.79	Expired (7/1/2012-6/3/2013)
TXR15UU70	Dee Winston	Hurricane Creek	5	Expired (8/14/2012-6/3/2013)
TXR15859X	Harmony Hill Baptist Church	Hurricane Creek	7.5	Active (06/03/2019)
TXR1502DT	Teal Construction Company	Hurricane Creek	9	Active (11/13/2020)
TXR1539DE	GVD Construction, LLC	Hurricane Creek	8.8	Active (9/14/2020)
TXR15J438	Allen Loggins and Son Inc	Hurricane Creek	6	Terminated (5/09/2004-3/18/2005)
TXR15MB02	Zachry Construction Corporation	Hurricane Creek	2.52	Expired (8/4/2008-6/3/2013)
TXR157183	Trans-Texas Homes Corporation	Jack Creek	38	Expired (5/31/2003-6/3/2008)
TXR156588	Billy Horton Builders Inc	Jack Creek	9	Terminated (6/10/2003-4/2/2008)
TXR15P602	VM Development LLC	Jack Creek	253	Terminated (11/11/2004-4/3/2007)
TXR15W583	Texas Department of Transportation	Jack Creek	48.6	Terminated (9/20/2005-4/30/2008)

Permit No.	Permittee	Watershed	Acres Disturbed/ Covered	Permit Status
TXR15CB94	Texas Department of Transportation	Jack Creek	10.42	Terminated (05/31/2006-3/27/2008)
TXR15DI73	Simon Traylor and Sons Inc.	Jack Creek	4	Expired (7/29/2006-6/3/2008)
TXR150028222	Oncor Electric Delivery Company LLC	Jack Creek	36[a]	Expired (8/24/2016-5/29/2018)
TXR15057C	Oncor Electric Delivery, LLC	Jack Creek	82	Expired (2/16/2017-6/05/2018)
TXR15837N	Oncor Electric Delivery Company LLC	Jack Creek	36[a]	Terminated (5/29/2018-12/10/2018)
TXR15CB95	Texas Department of Transportation	Jack Creek	8.85	Terminated (5/31/2006-11/26/2007)

[a] 36 of the permit total 519 acres were determined to be within the Jack Creek watershed.

Appendix B. DAR Daily Streamflow Graphs

The resulting daily streamflow estimates for the Middle Neches project area are displayed in Figures B-1 to B-4.

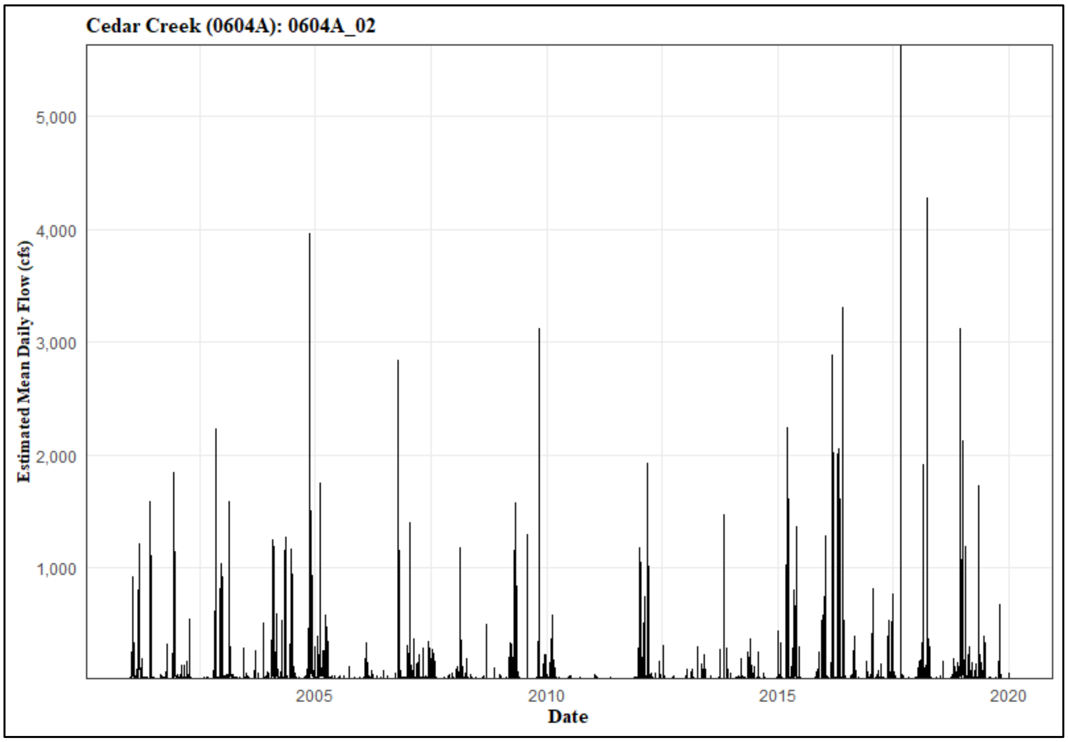

Figure B-1. Resulting estimated mean daily streamflow at station 10478 in AU 0604A_02 from January 2001 through December 2019

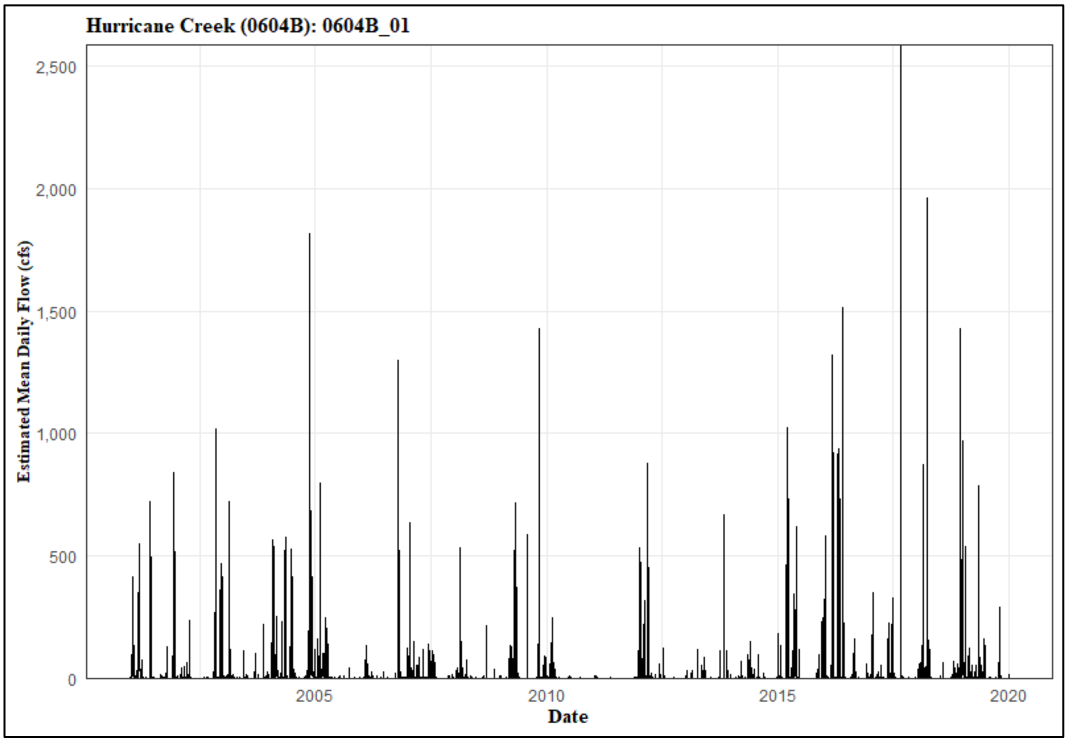

Figure B-2. Resulting estimated mean daily streamflow at station 13529 in AU 0604B_01 from January 2001 through December 2019

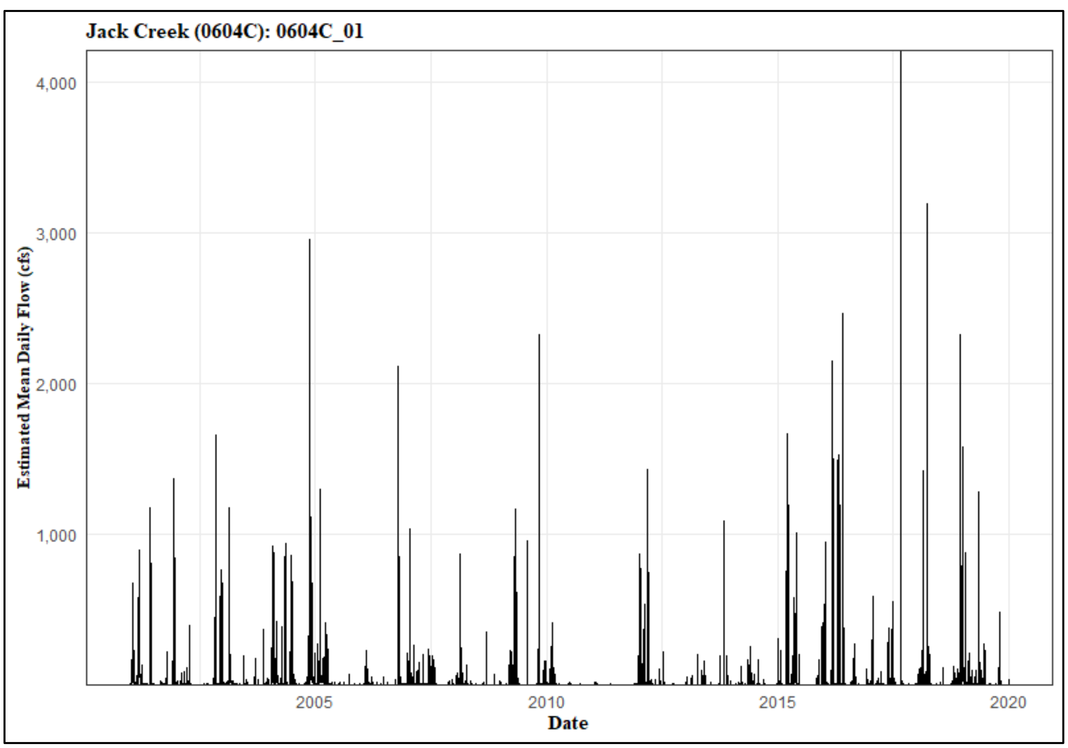

Figure B-3. Resulting estimated mean daily streamflow at station 10492 in AU 0604C_01 from January 2001 through December 2019

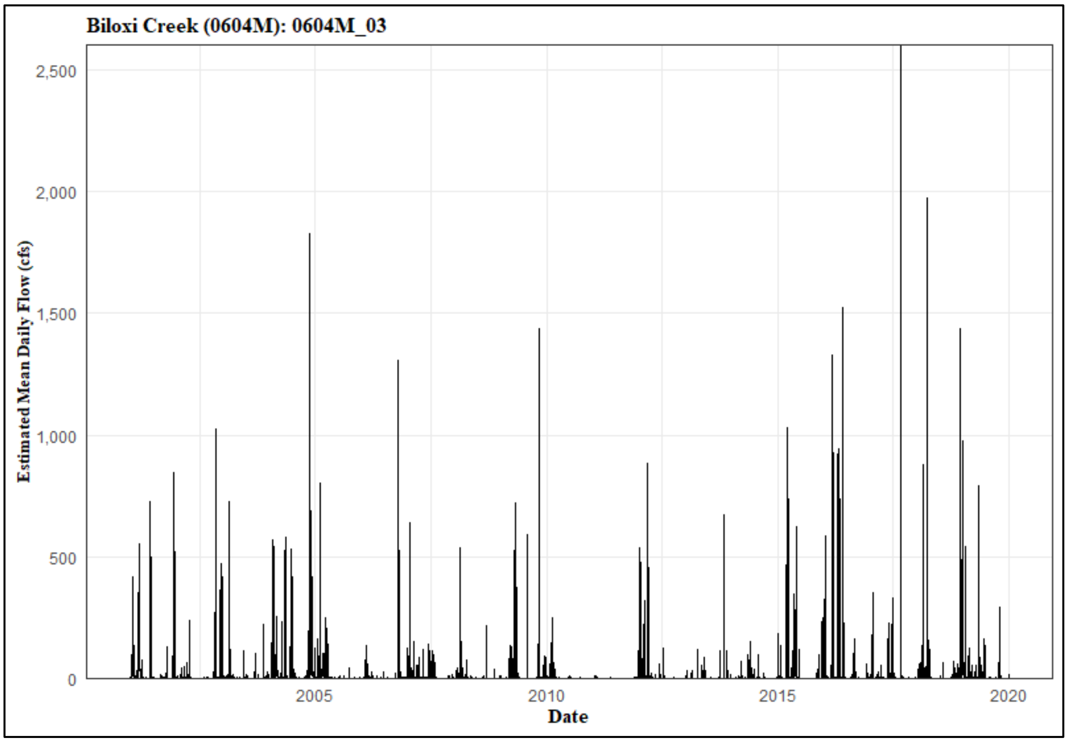

Figure B-4. Resulting estimated mean daily streamflow at station 10499 in AU 0604M_03 from January 2001 through December 2019