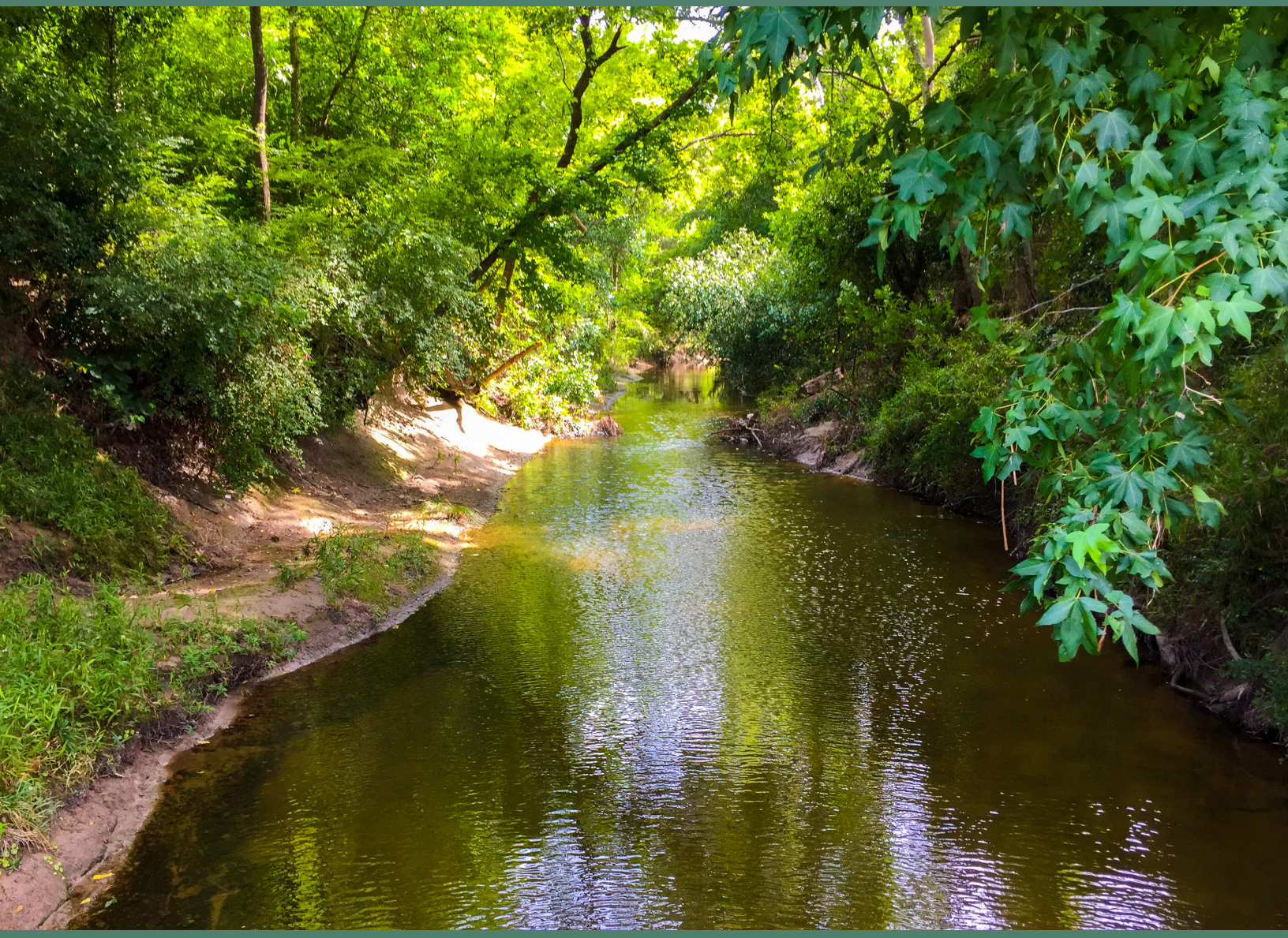
Watershed Characterization of the Tributaries of the Neches River below Lake Palestine: Cedar, Hurricane, Biloxi and Jack Creeks

Texas Water Resources Institute TR-518
August 2019



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Segments: 0604A, 0604B, 0604C and 0604M

TCEQ Contract # 582-18-83550

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List of Acronyms

ANRA	Angelina & Neches River Authority
AU	Assessment Unit
ALU	Aquatic Life-Use
CWA	Clean Water Act
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
EPA	Environmental Protection Agency
HSG	Hydrologic Soil Groups
LULC	Land Use Land Cover
MGD	Million Gallons per Day
MPN	Most Probable Number
MSGP	Multi-Sector General Permit
MSL	Mean Sea Level
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NOAA	National Oceanic Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facilities
PCR	Primary Contact Recreation
RUAA	Recreational Use Attainability Analysis
RMU	Resource Management Unit
SSO	Sanitary Sewer Overflow
SNC	Significant Non-Compliance
SSURGO	Soil Survey Geographic Database
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality

TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United State Geological Survey
WWTF	Wastewater Treatment Facility

Executive Summary

The Neches River below Lake Palestine (TCEQ Segment 0604) flows approximately 231 miles from Blackburn Crossing Dam (Lake Palestine) in Anderson/Cherokee counties to the confluence of Hopson Mill Creek in Jasper/Tyler counties (TWDB, 2019). Four tributaries of the Neches River below Lake Palestine, collectively termed the Middle Neches, are evaluated for this project. Three of the tributaries, including portions of Cedar Creek (0604A_02), Hurricane Creek (0604B_01) and Biloxi Creek (0604M_03), have all been identified to be impaired for elevated concentrations of *Escherichia coli* (*E. coli*) in the *2014 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report) (TCEQ, 2015). The fourth water body, Jack Creek (0604C_01), was listed in the Draft 2018 Texas Integrated Report as impaired for elevated bacteria concentrations (TCEQ, 2019). Of the four tributaries, Cedar Creek (0604A) and Biloxi Creek (0604M) directly discharge into the Neches River below Lake Palestine (0604). Elevated levels of *E. coli* have been identified in the Middle Neches watershed since as early as 2000 (TCEQ, 2015a). The project watershed is entirely located in Angelina County, and encompasses portions of the city of Lufkin and Hudson (Figure 1). This characterization addresses the *E. coli* impairments in the Middle Neches watershed with supplementary water quality monitoring and a review of the current demographic, climatic, physical, and hydrological conditions of the watershed.

Activities for the project have included water quality monitoring, trainings and meetings with local stakeholder individuals to discuss the goals and objectives of addressing the bacteria impairments in the watershed. Educational programs were delivered to stakeholders to inform them of watershed management and to increase their understanding of what factors contribute to bacteria impairments. Existing data for water quality parameters, flow, livestock, wildlife, stormwater permits and number of on-site sewage facilities has been analyzed to develop a better understanding of potential causes and sources of bacteria pollution. Stakeholder engagement will continue in the watershed as the Technical Support Document, a document that provides technical and supporting information for the development of bacteria Total Maximum Daily Loads (TMDL), is developed.

Background Information

Description of Watershed

The Middle Neches watershed, which is composed of four streams, spans nearly 59,130 acres in Angelina County. The Texas Commission on Environmental Quality (TCEQ) describes surface water bodies (called segments) with a specific "identifier" (segment ID) and will further divide segments in hydrologically distinct assessment units (AUs).

Cedar Creek (segment 0604A) is a 27-mile long stream that flows from the confluence of the Neches River southwest of the city of Lufkin up to a perennial stream section in Lufkin. The stream is composed of three AUs, 0604A_01, 0604A_02 and 0604A_03. The watershed being characterized in this report is only for AUs 0604A_02 and 0604A_03. This tributary is required to meet contact recreation, general use and aquatic life use water quality conditions. While Cedar Creek is listed to have an *E. coli* impairment, it also has nutrient concerns for nitrate, ammonia, and total phosphorus. Hurricane Creek (segment 0604B) is a 6-mile segment that is located at the confluence of Cedar Creek south of Lufkin to the upstream confluence of two unnamed tributaries 100m above SH Loop 287 in Lufkin. The creek includes two AUs, 0604B_01 and 0604B_02 and both AUs are reviewed in this watershed. Biloxi Creek (segment 0604M) flows 28.3 miles from the confluence of the Neches River to east of Lufkin. Within Biloxi Creek, two AUs exist, 0604M_02 and 0604M_03, but only the upstream AU 0604M_03 is included in the characterization. Jack Creek (segment 0604C) extends for 16 miles from a confluence with Cedar Creek to an upstream perennial stream portion northeast of Lufkin and consists of only one AU 0604C_01, which is being assessed (TCEQ, 2015a). The Middle Neches watershed neighbors the city of Lufkin (population 35,387) as well as including the town of Hudson (population 4,832) (U.S. Census Bureau, 2019a and 2019b). Within the four different streams, four AUs are listed as impaired for bacteria. The individual streams and their AUs are described in Table 1 (TCEQ, 2015a, 2018a and 2019).

Table 1. Descriptions of segments and AUs included in the Middle Neches watershed (TCEQ, 2015 and 2018).

Segment ID	Name	Description	AUs	AUs Impaired
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.	0604C_01	0604C_01
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.	0604A_01, 0604A_02, 0604A_03	0604A_02
0604B	Hurricane Creek	Perennial stream from the confluence with Cedar Creek to the confluence of two unnamed tributaries 100 meters upstream of SH Loop 287 in Lufkin.	0604B_01, 0604B_02	0604B_01
0604M	Biloxi Creek	From the confluence with the Neches River southeast of Diboll to FM 325 east of Lufkin in Angelina County.	0604M_02, 0604M_03	0604M_03

Water Quality Standards and Monitoring

Water quality monitoring by the TCEQ and its designees is conducted throughout the state of Texas to identify water bodies that are failing to meet or expected to not meet designated water quality uses and their standards, according to sections 303(d) and 305(b) in the Clean Water Act. The Texas Surface Water Quality Standards section of the Texas Administrative Code, Title 30, Chapter 307(30 TAC § 307) and the 2014 Texas Integrated Report: Assessment Results for Basin 6, list the water quality standards for each segment. Water quality standards were initially established by the TCEQ to protect aquatic life and human health. The Texas Surface Water Quality Standards describes the requirements and rationale for water bodies to meet designated uses, of which four of the most common designated uses include contact recreation, domestic water supply, aquatic life use and general use.

Fecal indicator bacteria (FIB) are used to assess the human health risk, described as the risk of contracting a gastrointestinal illness during contact recreation involving ingestion of water. *E. coli* and Enterococcus spp. are two types of FIB used to assess water quality due to their natural presence in the intestinal tracts of warm-blooded organisms, including humans. Detecting FIB,

such as *E. coli*, in a water body indicates the potential presence of associated fecal pathogens and therefore an increased risk for human health. For freshwater bodies, *E. coli* is the FIB standard, while Enterococci is frequently used in tidal or marine environments.

Revisions to the Texas Surface Water Quality Standards that were adopted by TCEQ on June 30, 2010 and by the U.S. Environmental Protection Agency (USEPA) on June 29, 2011, approved the use of different categorical levels and criteria for recreational uses. Criteria are expressed as the number of bacteria per 100 milliliters (ml) of water (in terms of colony forming units, most probable number (MPN), or other appropriate reporting measures). The laboratory method used in this project to enumerate bacteria uses MPN, which is the measurement unit referenced throughout the document. The four recreational uses and their criteria include:

- Primary contact recreation: activities that involve a significant risk of ingestion of water (i.e. swimming, diving, wading and whitewater sports) and has a geometric mean criterion for *E. coli* of 126 MPN/ 100 mL.
- Secondary contact recreation 1: activities that involved limited body contact with water and less significant risk of water ingestion (i.e. fishing, canoeing and boating) and has a geometric mean criterion for *E. coli* of 630 MPN/ 100 mL.
- Secondary contact recreation 2: activities that are similar to secondary contact recreation 1, but activities occur less frequently due to limited public access or physical constraints of the water body. The geometric mean criterion for *E. coli* is 1,030 MPN/ 100 mL.
- Noncontact recreation: a designation that is used when there is no significant risk of ingestion of water, or where contact recreation should not occur due to unsafe conditions. The geometric mean criterion for *E. coli* is 2,060 MPN/ 100 mL (TCEQ, 2010).

A recreational use attainability analysis (RUAA) is conducted to assess the recreational activities occurring in a water body and determine if the appropriate standards have been applied. RUAAs include information concerning historical and current uses as well as important physical characteristics of the water body (TCEQ, 2018b). All water bodies in the Middle Neches are presumed to meet primary contact recreational standards. Segments 0604C (Jack Creek) and 0604M (Biloxi Creek) had RUAAs completed in 2014 and both segments were recommended to retain their PCR use and *E. coli* geometric mean standard of 126 MPN/ 100 mL (TCEQ, 2015b).

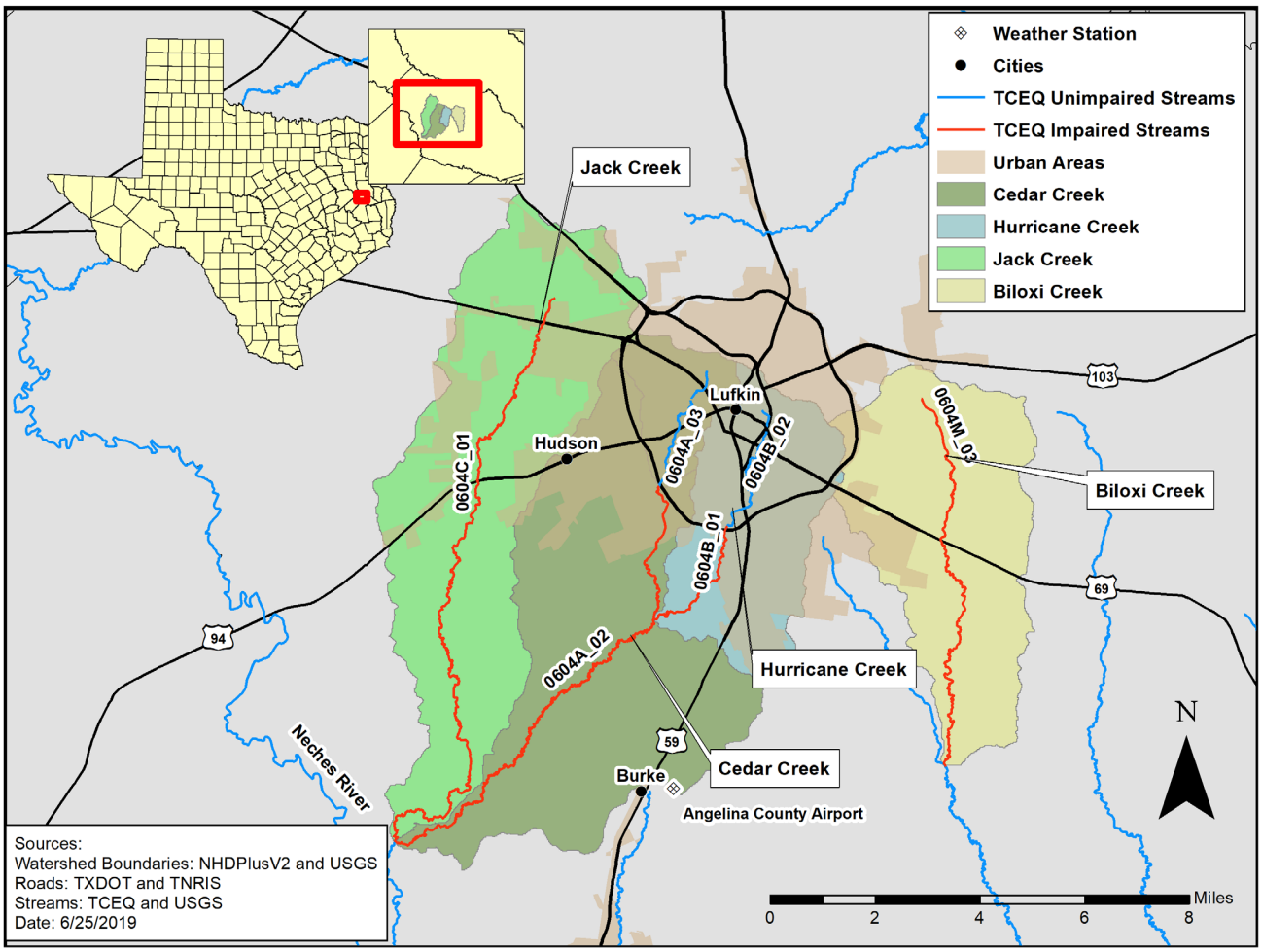

Figure 1. The Middle Neches watershed including Cedar, Hurricane, Jack and Biloxi Creeks.

Land Use and Land Cover

Land use and land cover (LULC) data was obtained from the 2016 National Land Cover Database (NLCD) at a 30m raster resolution. LULC is categorized into 14 different classifications for the Middle Neches watershed and LULC for all four subwatersheds are described in Figure 2 and Tables 2-5. The different land covers are not evenly distributed across all four subwatersheds. Quantitatively describing the land use classifications for each subwatershed is necessary for future planning decisions.

- Open Water: areas of open water that are generally less than 25% vegetation or soil cover.
- Developed, Open Space: areas that have a mixture of constructed materials, but mostly vegetation in the form of lawn grasses exist. Impervious surfaces account for less than 20% of total cover. Such areas typically include large-lot single family housing units,

parks, golf courses and vegetation planted in developed settings for recreation, erosion control or aesthetic purposes.

- Developed, Low Intensity: areas that consist of a mix of constructed materials and vegetation. Impervious surfaces account for 20%-49% of total cover. These areas commonly include single-family housing units.
- Developed, Medium Intensity: areas that consist of a mixture of constructed materials and vegetation. Impervious surfaces account for 50%-79% of the total cover. These areas commonly include single-family housing units.
- Developed, High Intensity: highly developed areas where people reside or work in high numbers. Areas include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
- Barren Land: areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
- Deciduous Forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover. More than 75% of tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% total vegetation cover. More than 75% of the tree species maintain their leaves year round. Canopy is never without green foliage.
- Mixed Forest: areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
- Shrub/Scrub: areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in early successional stage or trees stunted from environmental conditions.
- Herbaceous: areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These types of areas are not subject to intensive management such as tilling, but can be used for grazing.
- Pasture/Hay: areas of grass, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
- Woody Wetlands: areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- Emergent Herbaceous Wetlands: areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

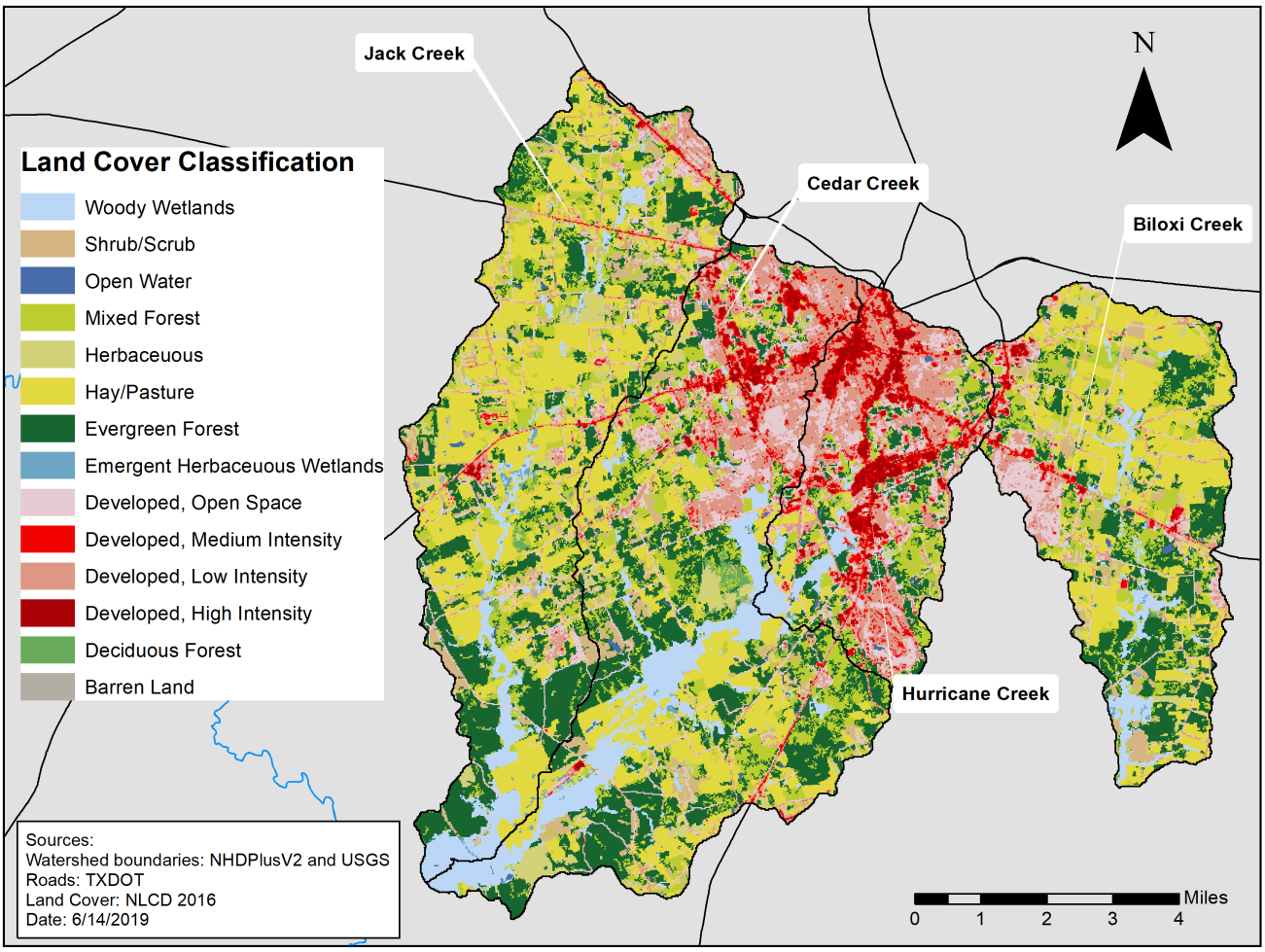

Figure 2. Land use and land cover classifications in the watershed (NLCD, 2016).

Jack Creek

The Jack Creek subwatershed encompasses 18,594 acres and is predominantly hay/pasture (33.32%) followed by evergreen forest (22.23%) (Table 2). Developed land comprises approximately 2,467 acres or 13% of the subwatershed, making it the least developed subwatershed in the Middle Neches. The smallest LULC classification is barren land (28 acres or 0.15%) followed by open water (56 acres or 0.30%).

Table 2. LULC classifications for Jack Creek subwatershed (NLCD, 2016).

NLCD Classification	Acres	Percent (%)
Open Water	56	0.30
Developed, Open Space	1,229	6.61
Developed, Low Intensity	1,002	5.39
Developed, Medium Intensity	191	1.03
Developed, High Intensity	45	0.24
Barren Land	28	0.15
Deciduous Forest	143	0.77
Evergreen Forest	4,133	22.23
Mixed Forest	2,456	13.21
Shrub/Scrub	811	4.36
Herbaceous	818	4.40
Hay/Pasture	6,196	33.32
Woody Wetlands	1,404	7.55
Emergent Herbaceous Wetlands	82	0.44
Total Acres	18,594	100.00

Cedar Creek

Cedar Creek is the largest subwatershed and has a greater variety of different land uses than the Jack or Biloxi Creeks (Table 3). The primary land use is evergreen forest (22.37%), followed by hay/pasture (18.70%). The developed land use classification includes nearly 5,077 acres or 25.15% of the subwatershed's total acreage. The two smallest land use classifications are barren land (8 acres or 0.04%) and emergent herbaceous wetlands (55 acres or 0.27%).

Table 3. LULC classifications for Cedar Creek subwatershed (NLCD, 2016).

NLCD Classification	Acres	Percent (%)
Open Water	73	0.36
Developed, Open Space	1,712	8.48
Developed, Low Intensity	2,370	11.74
Developed, Medium Intensity	650	3.22
Developed, High Intensity	345	1.71
Barren Land	8	0.04
Deciduous Forest	174	0.86
Evergreen Forest	4,517	22.37
Mixed Forest	2,750	13.62
Shrub/Scrub	822	4.07
Herbaceous	777	3.85
Hay/Pasture	3,776	18.70
Woody Wetlands	2,162	10.71
Emergent Herbaceous Wetlands	55	0.27
Total Acres	20,191	100.00

Hurricane Creek

Hurricane Creek has the greatest percentage of development of the four subwatersheds, but is also the smallest subwatershed within the Middle Neches. Nearly 65.93% (5,451 acres) is classified as developed or developed open space (Table 4). Evergreen (11.25%) and mixed forest (10.82%) are the second and third greatest land use classifications in the subwatershed. Similar to the Cedar Creek subwatershed, barren land (0.07% or 6 acres) and emergent herbaceous wetlands (0.12% or 10 acres) are the smallest land use classifications.

Table 4. LULC classifications for Hurricane Creek subwatershed (NLCD, 2016).

NLCD Classification	Acres	Percent (%)
Open Water	30	0.37
Developed, Open Space	1,252	15.14
Developed, Low Intensity	2,466	29.83
Developed, Medium Intensity	982	11.88
Developed, High Intensity	751	9.08
Barren Land	6	0.07
Deciduous Forest	30	0.36
Evergreen Forest	930	11.25
Mixed Forest	894	10.82
Shrub/Scrub	63	0.76
Herbaceous	126	1.52
Hay/Pasture	334	4.04
Woody Wetlands	393	4.76
Emergent Herbaceous Wetlands	10	0.12
Total Acres	8,267	100.00

Biloxi Creek

Biloxi Creek, while the second smallest subwatershed with 12,078 acres, is much more rural than Hurricane Creek. Hay/pasture (31.17%), evergreen forest (20.82%) and mixed forest (15.34%) encompass nearly 8,134 acres or 67.33% of the entire subwatershed (Table 5). Development covers approximately 17.43% or 2,105 acres. Similar to the other subwatersheds, barren land (2 acres or 0.02%) and emergent herbaceous wetlands (35 acres or 0.29%) are the smallest land use classifications.

Table 5. LULC classifications for Biloxi Creek subwatershed (NLCD, 2016).

NLCD Classification	Acres	Percent (%)
Open Water	37	0.31
Developed, Open Space	1,097	9.08
Developed, Low Intensity	726	6.01
Developed, Medium Intensity	200	1.66
Developed, High Intensity	82	0.68
Barren Land	2	0.02
Deciduous Forest	56	0.46
Evergreen Forest	2,515	20.82
Mixed Forest	1,853	15.34
Shrub/Scrub	616	5.10
Herbaceous	394	3.26
Hay/Pasture	3,765	31.17
Woody Wetlands	700	5.80
Emergent Herbaceous Wetlands	35	0.29
Total Acres	12,078	100.00

Climate

The Middle Neches watershed is located in the eastern portion of Texas, characterized as a subtropical humid climate and receiving more rainfall than the rest of the State. Figure 3 presents the average monthly values for precipitation and temperature as reported by the National Oceanic and Atmospheric Administration (NOAA) at Angelina County Airport (NOAA, 2014). From 1981 to 2010, the average annual temperatures in the watershed ranged from a low of 50°F (January) to a high of 82°F (August). Monthly average lows range from 38°F (January) to 72°F (August), and the monthly average highs range from 60°F (January) to 94°F (August). The average monthly precipitation ranges from 3 to 5 inches, with the greatest precipitation occurring in November and the lowest precipitation occurring in July. 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 1981-2010.

The Parameter-elevation Regressions on Independent Slopes Model (PRISM) is an analytical model that is used to assess the annual 30-year (1981-2010) normal precipitation for a watershed. The analytical model distributes singular point measurements for monthly, seasonal and annual precipitation values on a geographic grid. Both vector and raster estimates for precipitation at a 2km by 2km resolution can be determined from the model (PRISM, 2019). The normal precipitation value for the watershed, from the east to the west, decreases from 50.75 inches to 49.38 inches, as depicted in Figure 4. The Biloxi Creek subwatershed appears to have the greatest annual rainfall for the entire watershed, while Jack, Cedar and Hurricane Creek subwatersheds tend to have less precipitation.

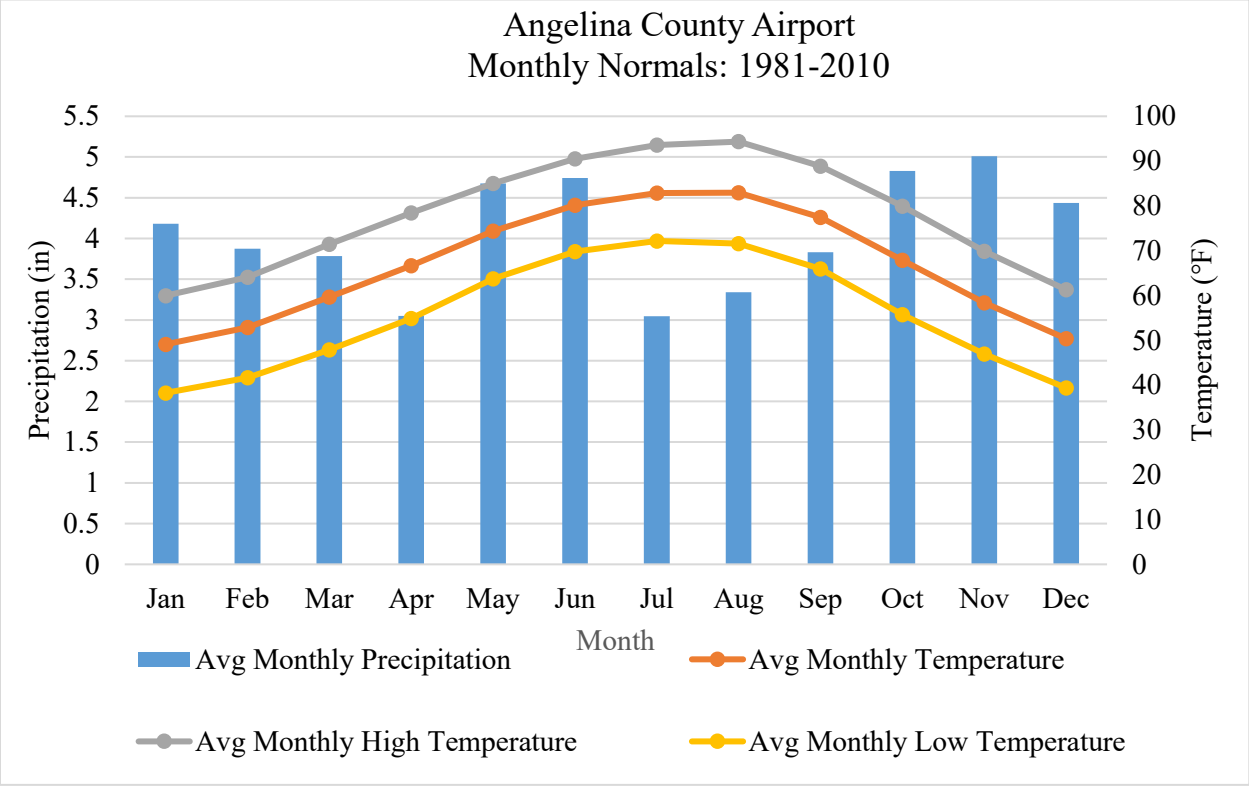

Figure 3. Monthly climate data, including precipitation, normal average, maximum and minimum air temperature, for Angelina County Airport from 1981-2010 (NOAA, 2014).

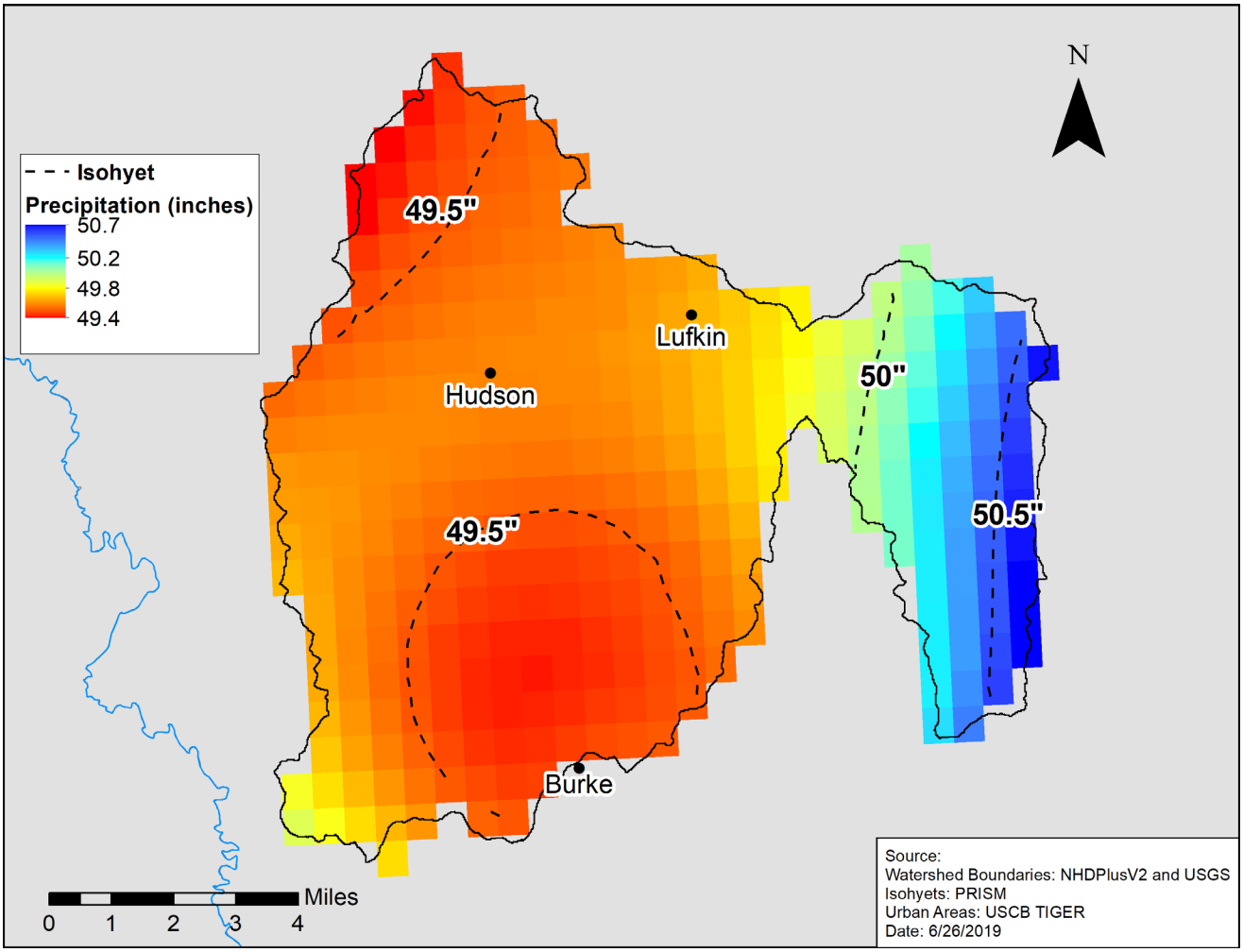

Figure 4. 30-year average precipitation in the Middle Neches watershed (PRISM, 2019).

Ecoregions

Ecoregions are distinct land areas with similar ecosystems and natural resources. Four different ecoregion levels exist, ranging from less defined (level I) to highly refined (level IV) (USEPA, 2013). Of the delineated ecoregions levels, the Middle Neches watershed is located in the Level III Ecoregion 35 of the South Central Plains and more specifically in 35e, described as Southern Tertiary Uplands (Griffith, Bryce, Omernik and Rogers, 2007). The Southern Tertiary Uplands is characterized as a plains region with low, rolling hills and low to moderate gradient streams. Significant portions of the ecoregion are national forests with predominantly pine forest and pastureland in the northern part of the region. Geological characteristics include siltstone, sandstone and calcareous and acidic clays (Griffith, Bryce, Omernik and Rogers, 2007).

Soils and Topography

Soils and topography are key characteristics influencing the hydrology of a watershed and can determine the types of land use and activities possible. The topography of a landscape will dictate the slope and elevation and therefore the direction and speed of runoff. The United States Department of Agriculture (USDA) National Resources Conservation Service (NRCS) provides information about soils through the Soil Survey Geographic Database (SSURGO). Soils are categorized into specific hydrologic soil groups (HSG), based upon similar rainfall, runoff and infiltration characteristics. The HSG ratings are particularly useful when determining runoff potential under consistent precipitation and cover conditions. Soils within the watershed are primarily categorized as group C (46.22%) and D (41.43%) (Figure 5, 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). The varieties of HSGs are fairly uniform between each subwatershed, with Group C and D soils being most common.

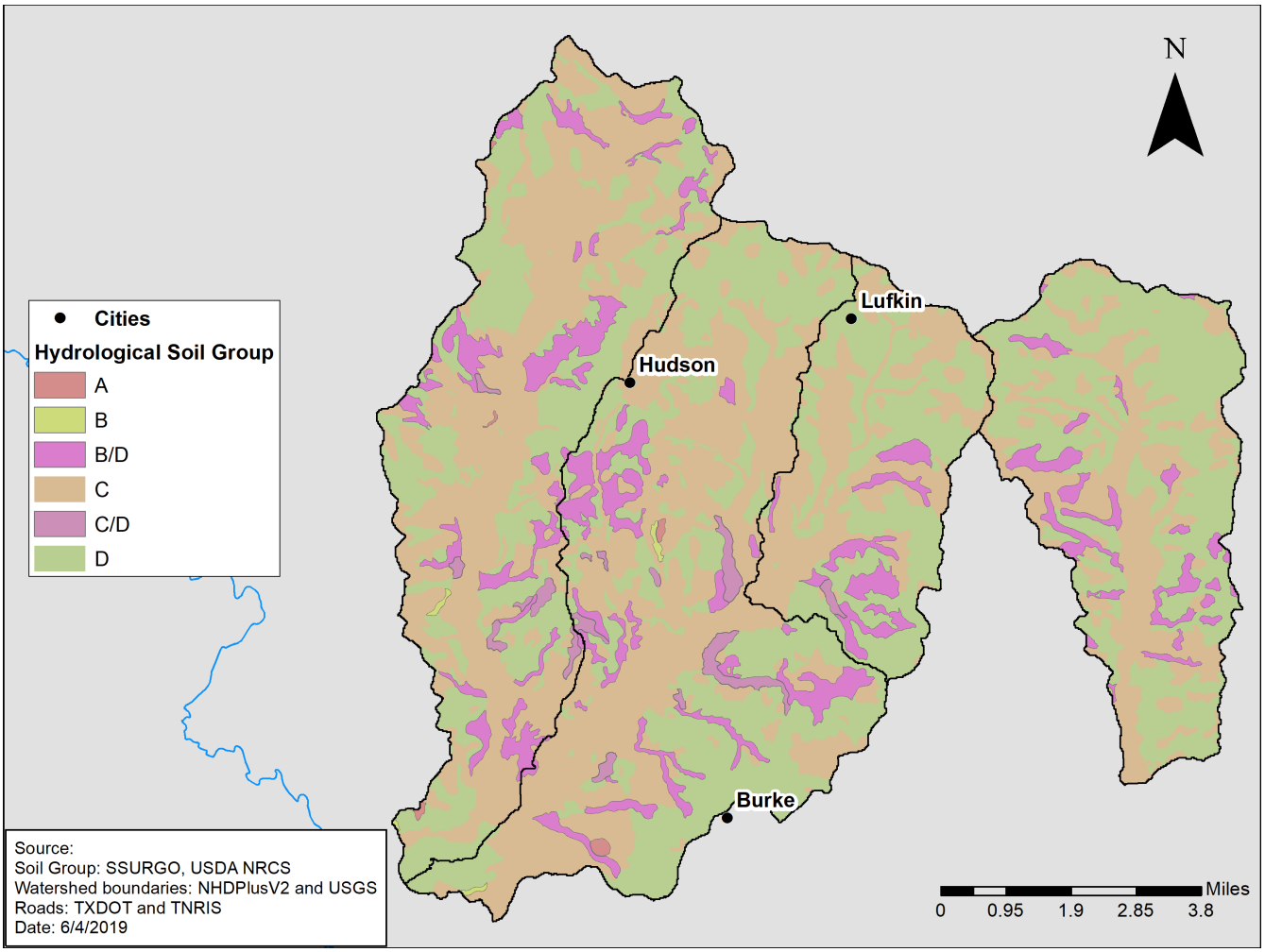

Figure 5. Hydrologic soil groups in the watershed (SSURGO and NRCS, 2018).

Table 6. Descriptions of the hydrologic soil groups in the watershed (NRCS 2018).

Hydrologic Soil Group	Description[1]	Acres	Percentage in Watershed (%)
A	Less than 10% clay, more than 90% sand or gravel. Soils have a high infiltration rate (low runoff potential) when thoroughly wet. These soils consist mainly of deep, well drained to excessively drained sands or gravelly sands.	93	0.16
B	Between 10 and 20% clay, 50 to 90% loam. Soils having a moderate infiltration rate when wet. These consist chiefly 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.	79	0.13
B/D	See below[2]	5,784	9.78
C	Between 20 and 40% clay, less than 50% sand. 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.	27,328	46.22
C/D	See below[2]	758	1.28
D	Greater than 40% clay, less than 50% sand. Soils having a 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 clay layer at or near the surface, and soils that are shallow over a nearly impervious material. These soils have a very slow rate of water transmission.	25,088	42.43

[1] All descriptions are from the USDA NRCS Updated Hydrologic Soils Group

[2] According to NRCS (2018): "Certain wet soils are placed in Group D based solely on the presence of the water table within 60 centimeters [24 inches] of the surface, even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 60 centimeters [24 inches] below the surface in a soil where it would be higher in a natural state."

Across the watershed, the elevation ranges from about 155 feet above mean sea level (MSL) to 409 feet above MSL. The highest elevation is found within the Jack Creek subwatershed while the lowest elevation located towards the southern end of the Cedar Creek subwatershed (Figure 6). The digital elevation model (DEM) was acquired from the United States Geological Survey (USGS) 10-meter seamless DEM dataset (USGS, 2013).

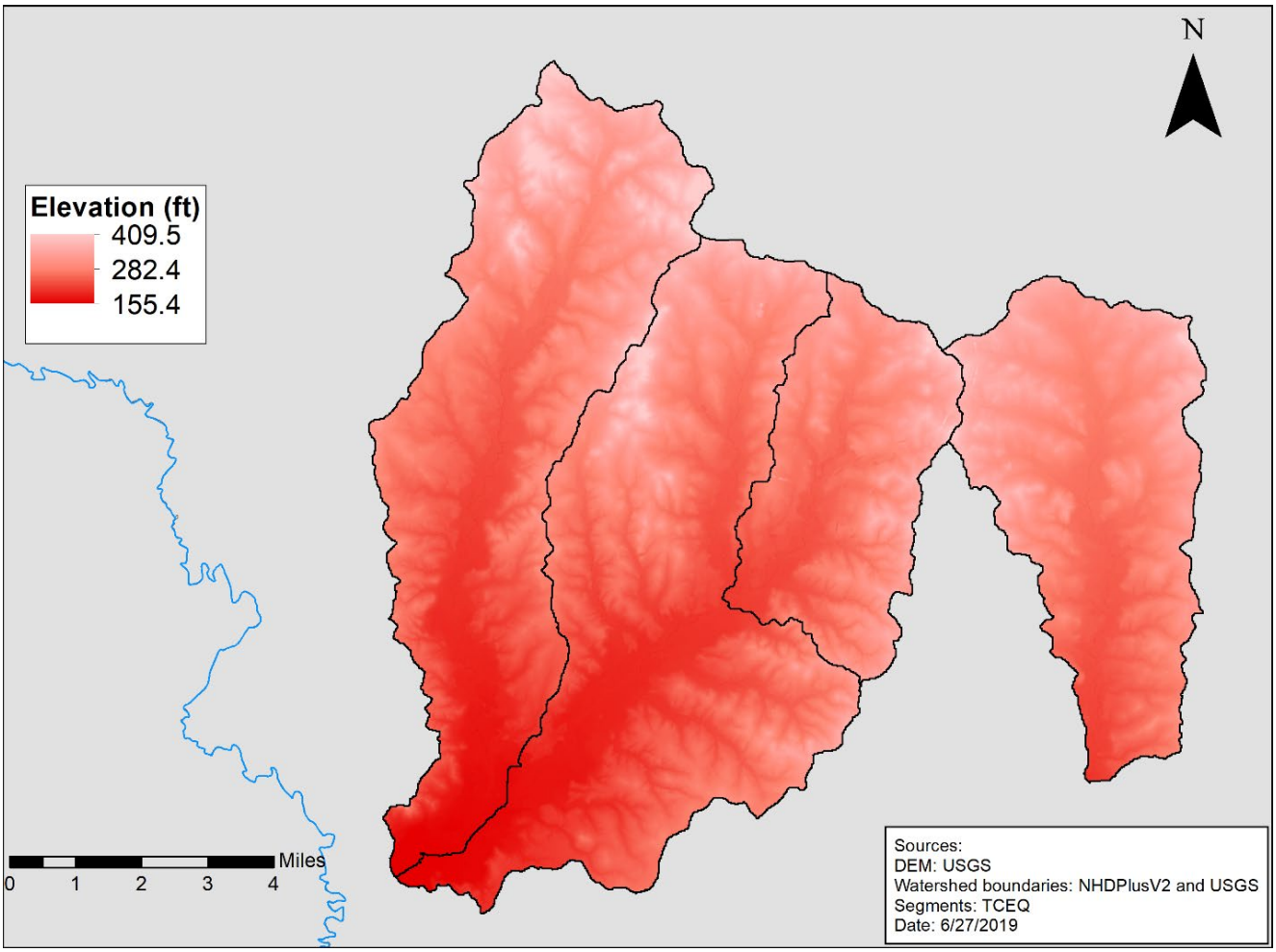

Figure 6. Middle Neches watershed elevation (USGS, 2013).

Populations and Projections

According to the 2010 Census (U.S. Census Bureau, 2012), the population in the Middle Neches watershed is concentrated around the city of Lufkin and more dispersed outside of the city, with an estimated watershed population of 42,647. While Lufkin is the largest city, the city of Hudson is also located within the watershed's boundaries. Figure 7 displays the population by census block in each subwatershed. Population projections are developed by the Texas Water Development Board (TWDB) and are listed in Tables 7 and 8 (TWDB, 2019). Overall for Angelina County, the population is expected to increase by 36.9% from 2010 to 2070.

Jack Creek

The Jack Creek subwatershed has a population of 8,272 individuals and is expected to increase to 11,324 by 2070 (Table 8). Most of the population for the subwatershed is located near the cities of Lufkin and Hudson (Figure 7).

Cedar Creek

Cedar Creek subwatershed has the second largest population within the Middle Neches, with approximately 14,680 individuals (Table 8). The population is expected to increase to 20,097 by 2070. According to the U.S. Census Block (2010) data, most of the population appears to be dispersed near the town of Burke and outside of Hudson and Lufkin (Figure 7).

Hurricane Creek

The largest population within the Middle Neches watershed is located in the Hurricane Creek subwatershed. Approximately 16,067 individuals live in the subwatershed and the population is expected to increase to 21,996 by 2070 (Table 8). The census blocks with the greatest population density are located outside of the city of Lufkin (Figure 7).

Biloxi Creek

Biloxi Creek has the smallest population with only 3,628 individuals and is expected to increase to 4,967 by 2070 (Table 8). The population density appears to be uniformly spread across the subwatershed (Figure 7).

Table 7. Population projections in Angelina County (TWDB, 2019).

Population Projections								
County	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**Percent Increase (2010-2070)**
Angelina	86,771	93,316	99,848	105,329	110,332	114,808	118,772	36.9%

Table 8. Population projections for each subwatershed (U.S. Census Bureau, 2012).

Watershed	2010 Population	2070 Population Projections
Jack Creek	8,272	11,324
Cedar Creek	14,680	20,097
Hurricane Creek	16,067	21,996
Biloxi Creek	3,628	4,967
Total Watershed	42,647	58,384

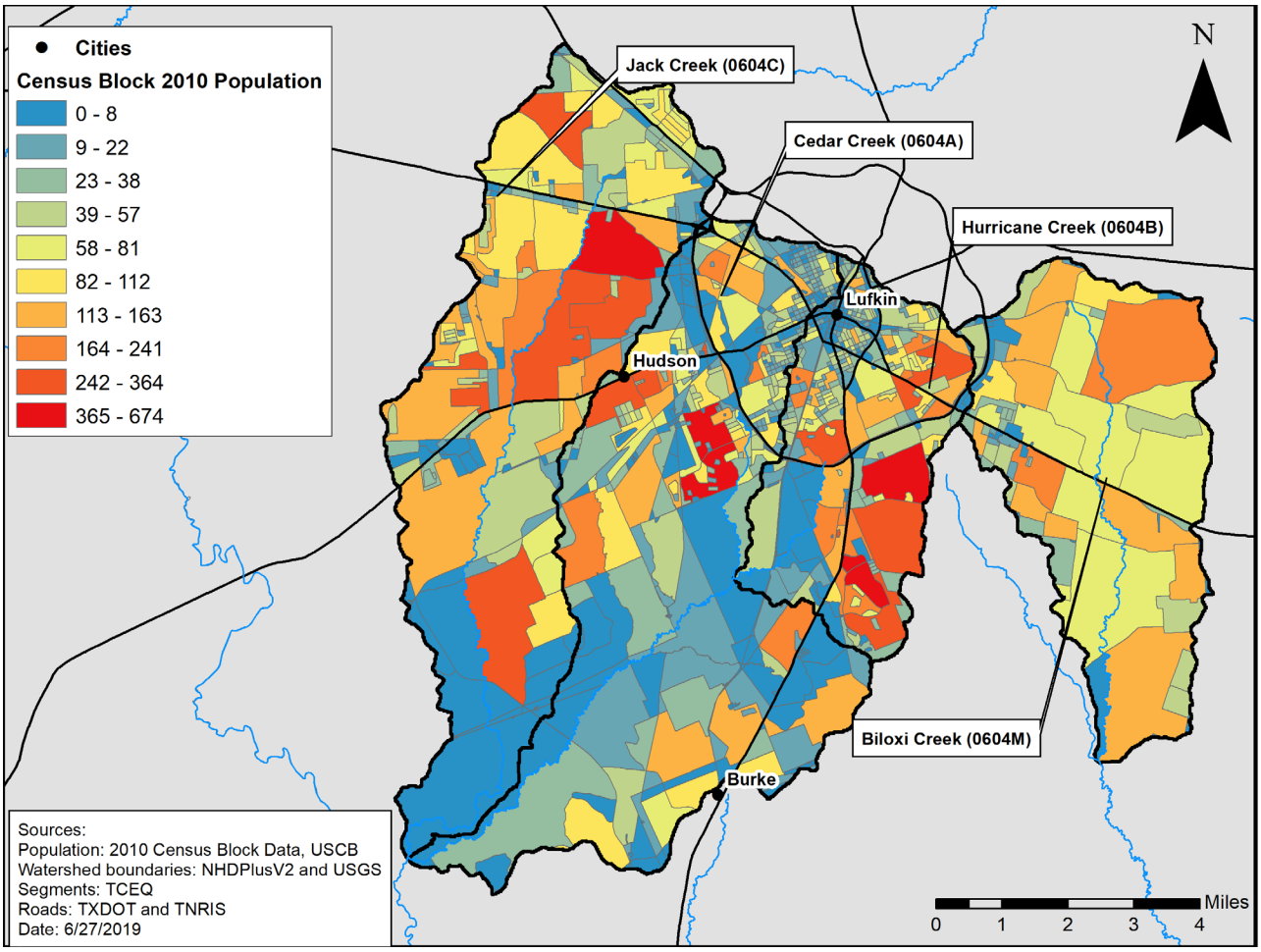

Figure 7. Population census block data for each subwatershed in the Middle Neches (U.S. Census Bureau, 2012).

Water Quality

The state of Texas is required to identify water bodies that do not meet the required water quality standards for their uses, as directed by the CWA, sections 303(d) and 305(b). AUs that do not meet their water quality standards are included on the Texas 303(d) List of the Texas Integrated Report, which is released every two years. All water bodies in the Middle Neches watershed are assessed for general use, contact recreation and aquatic life uses (TCEQ, 2018c). Cedar, Hurricane, and Biloxi creeks do not meet bacteria standards for recreational use. Hurricane Creek is also impaired for depressed dissolved oxygen levels and Jack creek has a concern for elevated bacteria (TCEQ, 2015 and 2018). Both Cedar and Hurricane Creeks were first listed on the Texas 303(d) list in 2000 and Biloxi Creek was listed in 2004 for having bacteria impairments.

Historical Water Quality Data

Historical water quality was retrieved from the Surface Water Quality Monitoring Information System (SWQMIS) for seven different monitoring stations in the watershed (Table 9, Figure 8). Station 22119 on Biloxi Creek (0604M) was not included in the review since no historical water quality data exists. Historical *E.coli* data and all other parameters were reviewed from January 1, 2000 to December 31, 2018. Sampling for most sites occurred quarterly.

Table 9. Monitoring stations and segments reviewed in the Middle Neches watershed.

Segment	Station ID	Description	AU
0604C	10494	Jack Creek at FM 3150 7km west of Lufkin	0604C_01
	10492	Jack Creek at FM 2497 5km southeast of SH 94/FM 2497 intersection 13.3 km southwest of Lufkin	0604C_01
0604A	10478	Cedar Creek at FM 2497 5.55 km northwest of FM 2497/US 59 intersection 7.45 km north northwest of City of Diboll	0604A_02
	13528	Cedar Creek at FM 1336 1.29 km west-southwest of FM 324/FM 1336 intersection in southwest Lufkin	0604A_02
0604B	10487	Hurricane Creek at State Loop 287 in South Lufkin	0604B_01
	13529	Hurricane Creek at FM 324 6.74 km south southwest of Lufkin	0604B_01
0604M	10499	Biloxi Creek at Angelina CR 216 8 km southeast of Lufkin 2.4km downstream of US 69	0604M_03
	22119	Biloxi Creek at East Denman Ave/US 69 near Lufkin	0604M_03

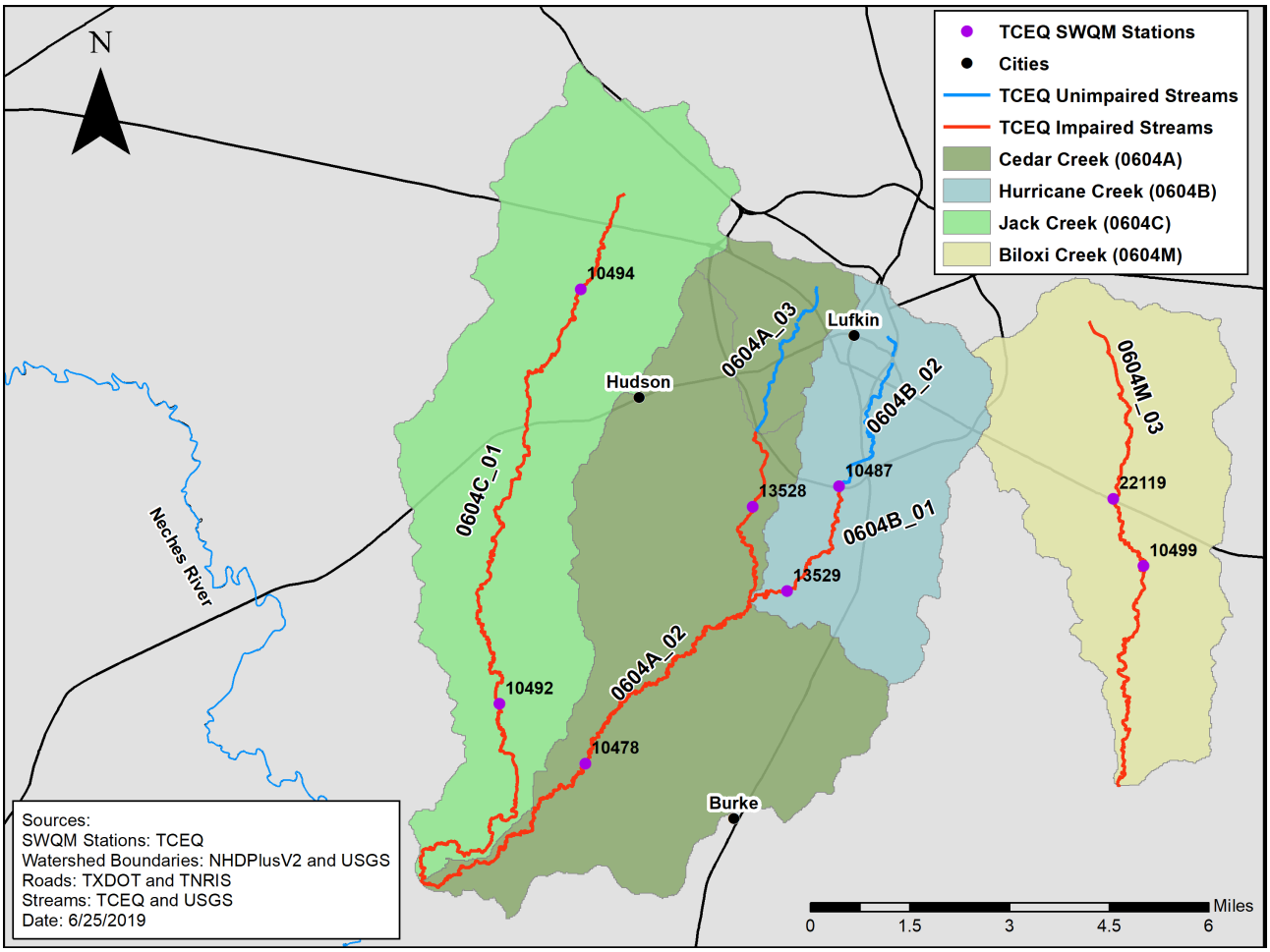

Figure 8. Locations of TCEQ SWQM stations in the Middle Neches watershed.

Bacteria

Concentrations of FIB specifically *E. coli*, are used to assess the risk of illness during contact recreation in a water body. The primary contact recreational standard, in which all water bodies in the watershed are expected to meet, is a geometric mean of 126 MPN/ 100mL for *E. coli*. Currently all water bodies are listed as impaired or to have a concern for elevated concentrations of *E. coli*. All segments have historical *E. coli* concentrations and geometric means exceeding the regulatory standard of 126 MPN/ 100 mL (Table 10 and Figure 9).

Table 10. Geometric means for historical *E. coli* data.

AU	Station ID	Site Description	Number of Samples	Data Range	*E. coli* Geometric Mean (MPN/ 100 mL)
0604C_01	10494	Jack Creek at FM 3150	22	2013-2018	306.28
0604C_01	10492	Jack Creek at FM 2497	74	2000-2018	152.62
0604A_02	13528	Cedar Creek at FM 1336	65	2002-2018	182.15
0604A_02	10478	Cedar Creek at FM 2497	74	2000-2018	232.03
0604B_01	10487	Hurricane Creek at State Loop 287	22	2013-2018	329.18
0604B_01	13529	Hurricane Creek at FM 324	74	2000-2018	278.66
0604M_03	10499	Biloxi Creek at Angelina CR 216	88	2000-2018	211.13

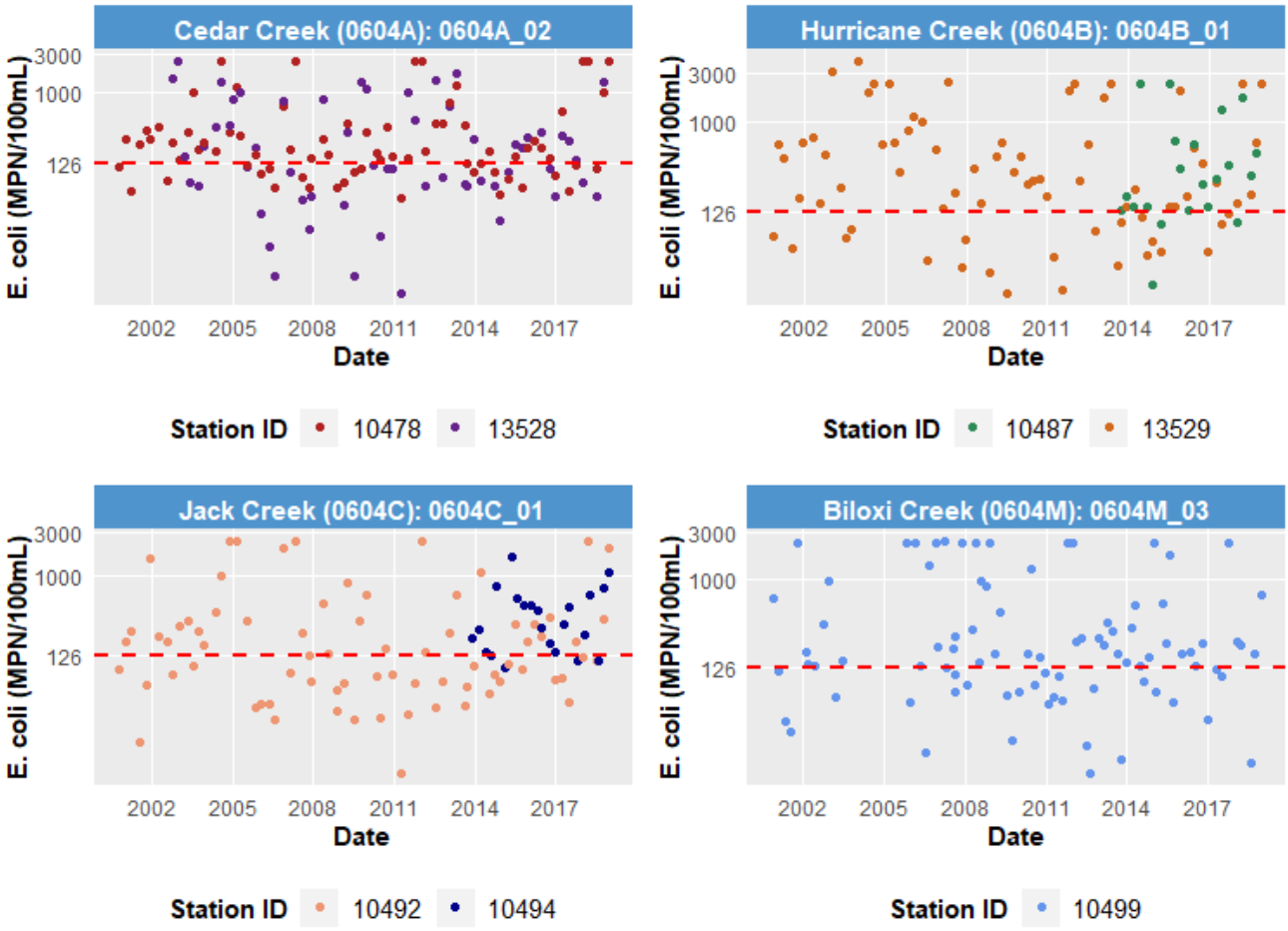

Figure 9. Historical *E. coli* concentrations at monitored segments and stations in the Middle Neches subwatersheds from 2000-2018. The dotted red line indicates the primary contact recreation standard of 126 MPN/100mL for *E. coli.*

Dissolved Oxygen

Dissolved oxygen (DO) is essential for aquatic organisms to survive and refers to the concentration of oxygen gas incorporated into water. DO concentrations naturally fluctuate in the environment, but anthropogenic activities can contribute excessive organic matter and nutrients, consequently depressing DO concentrations. Every water body assessed by the Texas State Water Quality Standards is assigned an aquatic life-use (ALU) category of either minimal, limited, intermediate, high or exceptional. To ensure that water bodies protect these ALU categories, DO criteria are implemented. Classified water bodies are required to meet an average DO criterion measured over 24 hours and a minimum DO criterion (TCEQ, 2015b). Unclassified streams are assigned an ALU based upon the flow-type for the specific segment, which are

categorized as perennial, intermittent with perennial pools and intermittent without perennial pools. Specific DO criteria are associated with each unclassified stream type, unless a site-specific ALU has been assigned to the unclassified water body. The 24-hour average DO criteria are measured over 24 hours and sampling events occur at various times throughout the year to represent unbiased and seasonally representative data. When 24-hour average DO is not available, grab DO measurements are utilized and include a minimum criterion and screening level criterion (TCEQ, 2015b). Limited 24-hour average DO data is available for station 10499 on Biloxi Creek (0604M), with sampling events occurring between 2001 and 2009. All segments in the Middle Neches watershed are assumed to support a subcategory of aquatic life use. The ALU categories and DO screening levels are listed for each water body in Table 11 and plotted in Figure 10. Jack Creek (0604C) has a concern for depressed DO while Biloxi Creek (0604M) is listed to not support its DO standards and criteria.

Table 11. Aquatic life use and dissolved oxygen criteria for Middle Neches watershed (TCEQ, 2015c; ANRA, 2015).

Segment	Water Body	ALU Category	DO Screening Level Criteria (mg/L)	DO Grab Minimum (mg/L)	24 Hour DO Average (mg/L)	24 Hour DO Minimum (mg/L)
0604C	Jack Creek	High	5 (CS)	3	-	-
0604A	Cedar Creek	Intermediate	4	3	-	-
0604B	Hurricane Creek	Intermediate	4	3	-	-
0604M	Biloxi Creek	Limited	3 (CS)	2	3 (NS)	2 (NS)

CS: Concern for Screening Level; NS: Not Supporting

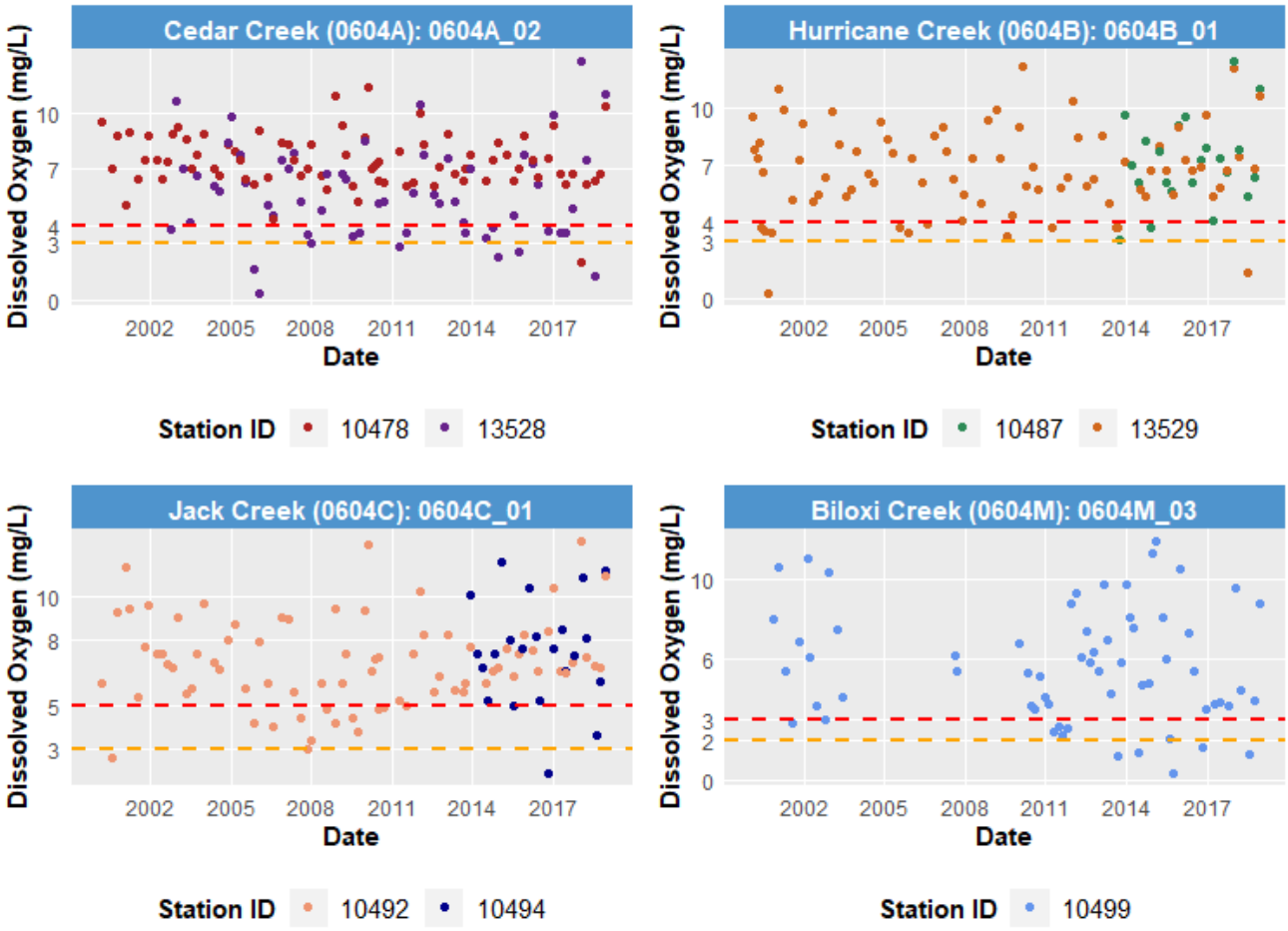

Figure 10. Dissolved oxygen concentrations at each AU in the Middle Neches watershed from 2000-2018. The red dashed line represents the dissolved oxygen screening level (mg/L) for each segment and the yellow dashed line represents the minimum dissolved oxygen grab sample level (mg/L). The points are measured dissolved oxygen grab samples.

Nutrients

Aquatic algae and plants use nutrients, specifically nitrogen and phosphorus, to grow. However, excessive nutrients in a water body can cause plant and algal blooms, which can depress DO levels. Nutrient sources include fertilizers transported by surface runoff, effluent from WWTFs and eroded sediment. A screening level is used for nutrients in water bodies since a numeric criteria is not available. TCEQ applies screening levels of 1.95 mg/L for nitrate and 0.69 mg/L for total phosphorus. Figures 11 and 12 display measured nitrate and phosphorus samples in the watershed. Station 10478 on Cedar Creek is the only station that has exceeded the nitrate screening level between 2014 and 2018. For phosphorus, station 10478 on Cedar Creek, station 10492 on Jack Creek, and station 10499 on Biloxi Creek have also exceeded the screening level

between 2012 and 2018. Station 10499 on Biloxi Creek only had two measured samples for nitrate and phosphorus when reviewing historical data.

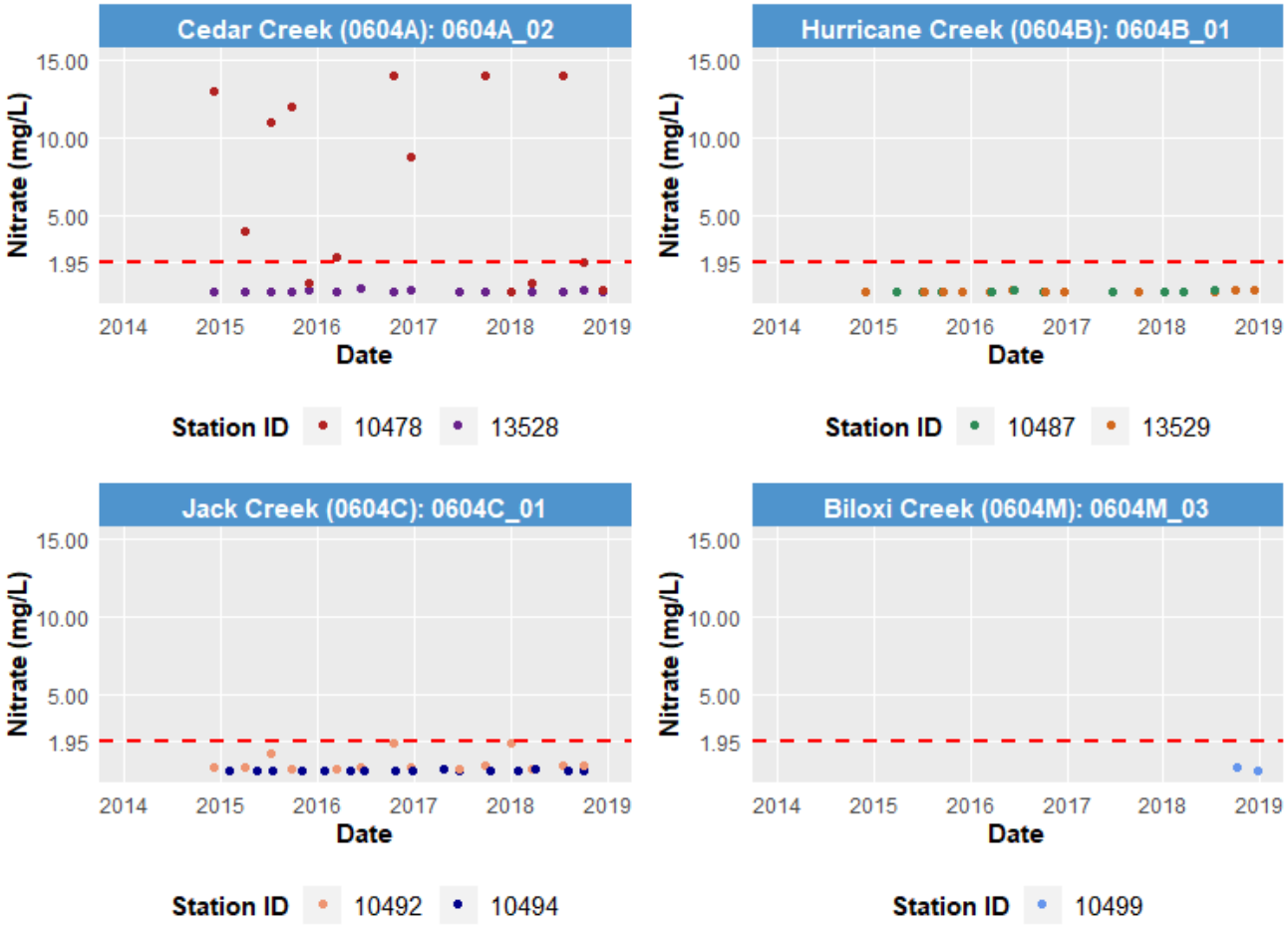

Figure 11. Nitrate concentrations measured in the Middle Neches watershed from 2014-2018. The dotted red line indicates the screening level criteria of 1.95 mg/L.

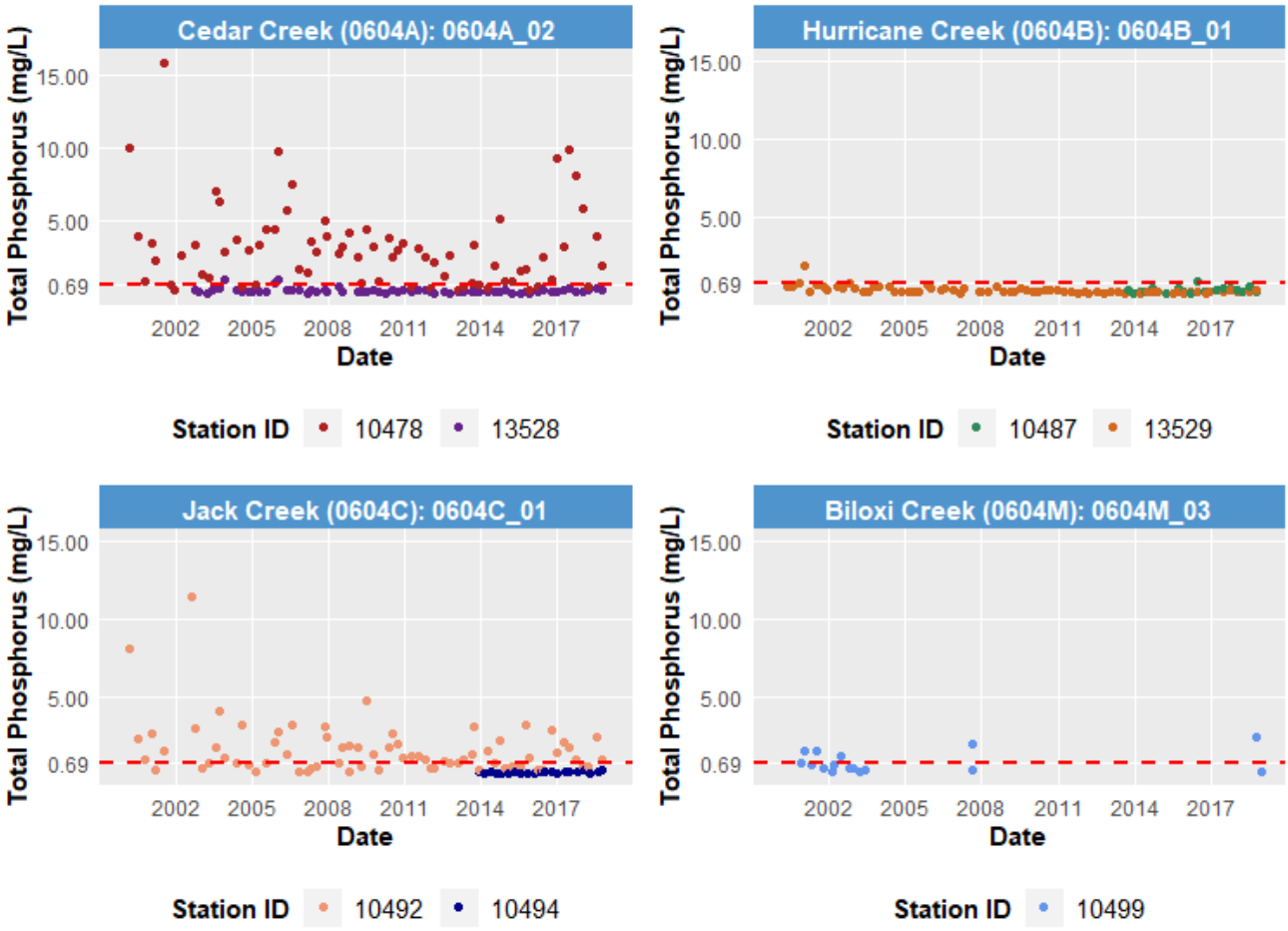

Figure 12. Total phosphorus concentrations measured at stations in the watershed from 2000-2018. The dotted line indicates the screening level criteria of 0.69 mg/L.

Specific Conductance

Specific conductance reflects the ability of water to carry an electric current and is directly related to the concentration of ions in water. Dissolved salts and other inorganic chemicals conduct an electrical current. A water body tends to have a relatively constant range of specific conductivity and once determined, can be used as a baseline comparison for specific conductance measurements. Changes in the specific conductance may be indicative of discharges or a disturbance that is impairing the health of the water body (USEPA, 2016a). Specific conductance measurements for the watershed are displayed in Figure 13.

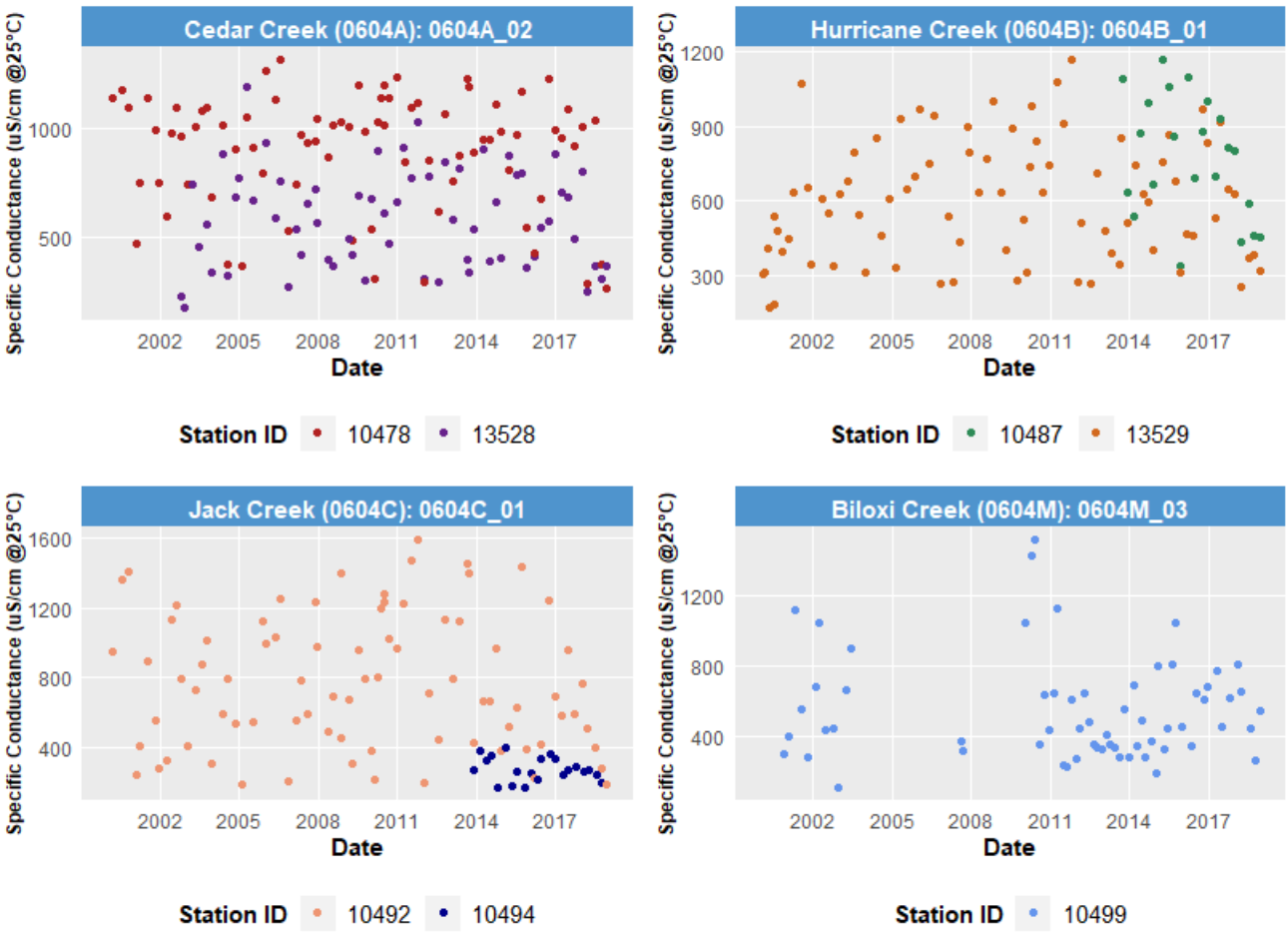

Figure 13. Specific conductance concentrations measured in the Middle Neches watershed from 2000-2018.

Flow

The streamflow for a watershed, which is defined as the volume of water that is moving over a designated point over a period of time, consistently changes due to natural and anthropogenic activities. Weather, seasons, water withdrawals, and land cover changes all affect water flow. Streamflow is critical for assimilating pollutants in a water body to improve water quality conditions. While no USGS streamflow gages exist in the watershed, instantaneous stream flow measurements have been recorded quarterly at most of the monitoring sites. Average, median, minimum and maximum streamflow conditions measured between 2000 and 2018 are listed in Table 12.

Table 12. Instantaneous stream flow (cfs) characteristics in the Middle Neches watershed.

Station	AU	Site Location	# Measurements	Pooled Samples	Average	Median	Minimum	Maximum	Available Data
10494	0604C_01	Jack Creek at FM 3150 7 km west of Lufkin	19	1	1.63	0.5	0	18	2013-2018
10492	0604C_01	Jack Creek at FM 2497 5 km southeast of SH 94/FM 2497 intersection 13.3 km southwest of Lufkin	66	0	4.51	1.6	0.04	31.191	2000-2018
13528	0604A_02	Cedar Creek at FM 1336 1.29 km west-southwest of FM 324/FM 1336 intersection in southwest Lufkin	44	20	0.89	0.225	0	8	2003-2018
10478	0604A_02	Cedar Creek at FM 2497 5.55km northwest of FM 2497/US 59 intersection 7.45km north northwest of City of Diboll	62	0	12.907	11	0.19	55.4	2000-2018
10487	0604B_01	Hurricane Creek at ST Loop 287 in South Lufkin	17	1	0.8	0.5	0	4.9	2014-2018
13529	0604B_01	Hurricane Creek at FM 324 6.74 km south southwest of Lufkin	67	2	2.02	0.85	0	21.8	2000-2018
10499	0604M_03	Biloxi Creek at Angelina CR 216 8 km southeast of Lufkin 2.4km downstream of US 69	65	17	1.11	0.4	0	14	2000-2018

Potential Sources of Pollution

Point source

A "point source" of pollution is defined as any confined, discrete or discernible conveyance, such as a ditch, pipe, tunnel, channel, or conduit, which a pollutant may be discharged (USEPA, 2018). Point sources of pollution include any regulated "end-of-pipe" outfall that is used for wastewater, stormwater or cooling water (TCEQ and TSSWCB, 2013). The National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) regulate point sources of pollution via permits. Within the watershed, permits have been issued for municipal and industrial wastewater treatment facilities (3), construction (1), Multi-Sector general permits for stormwater (11), concrete production (1) and petroleum (1). Sanitary sewer overflow/illicit discharges have also occurred in the watershed. This source of pollution is not regulated, but an unintentional discharge from a permitted system.

Wastewater Treatment Facilities (WWTFs)

Three WWTFs (one industrial wastewater and two sanitary wastewater) exist in the watershed and are permitted to discharge treated wastewater. The Georgia-Pacific Chemicals LLC and the Hurricane Creek (City of Lufkin) WWTFs are located in the Hurricane Creek (0604B) subwatershed, and the City of Hudson WWTF is found within the Jack Creek (0604C) subwatershed. Figure 14 displays the locations of the WWTFs in the watershed. Only Hurricane Creek and the City of Hudson WWTFs are permitted for the discharge of bacteria in effluent. Permit numbers, facility names, description of receiving waters, permitted flow rates and recently measured flow rates (as of March 31, 2019) are listed in Table 13. Recent *E. coli* averages and the number of grab samples exceeding the grab sample bacteria limit from January 2015 to March 2019 is presented in Table 14.

Compliance of WWTFs

A review of the EPA Enforcement & Compliance History Online (ECHO) database from January 2015 to March 2019, revealed non-compliance issues for both Hurricane Creek WWTF and the City of Hudson WWTF. Hurricane Creek WWTF had one exceedance for *E. coli* (exceeding *E. coli* daily max limit). The City of Hudson had a total of 13 exceedances, which included 4 exceedances for total ammonia nitrogen (daily average), 7 exceedances for flow (daily average), and 1 exceedance each for the daily average and daily max of *E. coli*.

The ECHO database was also reviewed for Significant Non-Compliance (SNC) violations, which result from discharges above facilities' permitted limitations and late or missing reports. The City of Hudson has had one SNC violation in the last 12 quarters for failure to submit a discharge monitoring report (DMR). Both facilities are listed to have violations identified in the last 12 quarters as well. No exceedance or violation data was identified in ECHO for the Georgia Pacific, LLC facility.

Table 13. Permitted point source discharge facilities in the Middle Neches watershed.

TPDES Permit No.	NPDES No.	Facility	Receiving Waters	Final Permitted Discharges (MGD)[a]	Recent Discharges (MGD)
WQ0010214001	TX0024309	Hurricane Creek WWTF (City of Lufkin)	to Hurricane Creek; then to Cedar Creek; then to Neches River below Lake Palestine in Segment No. 0604 of the Neches River Basin	11.3	5.2182
WQ0011826001	TX0068985	City of Hudson WWTF	to Jack Creek; then to Long Slough; then to Cedar Creek then to Neches River below Lake Palestine in Segment No. 0604 of the Neches River Basin	0.98	0.414
WQ0001737000	TX0082261	Georgia Pacific Chemicals, LLC	to an unnamed ditch; thence to an unnamed tributary; thence to Hurricane Creek; thence to Cedar Creek; thence to a series of lakes; thence to Cedar Creek; thence to Neches River Below Lake Palestine in Segment No. 0604 of Neches River	*	0.4916

[a] Significant figures represent MGDs as presented in TPDES permits.

* TPDES permit lists flow as intermittent and variable.

Table 14. Bacterial monitoring requirements and compliance status for WWTFs in the Middle Neches watershed from January 2015-March 2019.

TPDES Permit No.	EPA ID	Facility	Receiving Water body	Discharge Type	Min. Self-Monitoring Requirement-Frequency	Permit Limits		Recent Reported Values	
						Daily Average (cfu/100mL)	Daily Max per Sample (cfu/100mL	Daily Average	# of Grab samples exceeding daily max
WQ0010214001	TX0024309	Hurricane Creek WWTF	Hurricane Creek	treated domestic wastewater	5/week	126	399	2	1
WQ0011826001	TX0068985	City of Hudson WWTF	Jack Creek	treated domestic wastewater	2/month	126	399	0.1	1

TPDES General Wastewater Permits

Facilities that discharge processed wastewater, much like wastewater treatment facilities, are also required to have a TPDES permit. TPDES general wastewater permits are issued for an array of different permits:

- TXG110000 - concrete production facilities
- TXG130000 - aquaculture production
- TXG340000 - petroleum bulk stations and terminals
- TXG670000 - hydrostatic test water
- TXG830000 - petroleum fuel or petroleum substances
- TXG870000- pesticides
- TXG920000 - concentrated animal feeding operation
- WQG100000 - wastewater evaporation
- WQG200000 - livestock manure compost operations

A review of active permits in the Middle Neches watershed (March 19, 2019) retrieved two general permits, one concrete production and one petroleum contaminated water (Table 15). The petroleum substances permit is not expected to be a significant risk for bacterial contribution to surrounding water bodies. The concrete production facility is authorized to discharge stormwater and is considered a source of regulated stormwater.

Table 15. Wastewater general permits in Middle Neches watershed.

Permit No.	Permittee	Facility	Permit Type	Receiving Water body	Status
TXG830654	Love's Travel Stops & Country Store	Love's Country Store 290	Petroleum Contaminated Water	Biloxi Creek	Active
TXG111375	TXI Operations, LP	TXI Lufkin Ready Mix	Concrete Production Plant	Unnamed tributary to Cedar Creek	Active

Stormwater General Permits

Stormwater general permits are required for areas or activities that stormwater discharges would originate from, such as industrial facilities, construction sites and Phase II urbanized areas. The following TPDES general permits are required for certain activities that release stormwater:

- TXR040000-MS4 Phase II (NOI & Waiver)
- TXR050000- Multi-Sector (NOI & NEC)
- TXR150000- Construction (NOI & Waiver)

Phase I and Phase II MS4 permits are typically associated with larger urban areas, which are not present in the Middle Neches watershed. After a review of active stormwater permits in the Middle Neches watershed on March 19, 2019, only one active construction permit, with an estimated disturbed area of 8.7 acres, and 11 multi-sector general permits (MSGPs) were retrieved (Table 16). When reviewing expired and terminated construction permits since January 1, 2003, 24 expired and 36 terminated permits were retrieved (Table 17). Approximately 840.07 acres are regulated under MSGPs in the watershed for stormwater.

Table 16. Active stormwater general permits in the Middle Neches watershed.

Permit No.	Permittee	Facility Name	Permit Type	Receiving Water body	Acres Disturbed/Covered	Permit Status
TXR15994V	Ewing Industrial Services, LLC	Providence at Ted Trout Drive	Construction	Cedar Creek	8.7	Active
TXR05BW92	Lufkin Industries	Lufkin Industries	Multi-Sector	Hurricane Creek	58.67	Active
TXR05CS74	City of Lufkin	Hurricane Creek WWTF	Multi-Sector	Hurricane Creek	32.19	Active
TXR05CS85	McFarland Cascade Holdings, Inc.	Lufkin Creosoting	Multi-Sector	Tributary to Biloxi Creek	48.31	Active
TXR05CY79	Prince Energy LLC-Lufkin Plant	Prince Energy LLC	Multi-Sector	Cedar Creek	70.95	Active
TXR05DB06	Pilgrim's Pride Corporation	Lufkin Processing Plant	Multi-Sector	Cedar Creek	6.78	Active
TXR05DJ51	Jewell Hudgens, Inc.	Jewell Hudgens Machine Plant B	Multi-Sector	Cedar Creek	5.95	Active
TXR05ED54	Pilgrim's Pride Corporation	Pilgrim's Pride Lufkin Shop and Staging Area	Multi-Sector	Cedar Creek	7.53	Active
TXR05M434	United Parcel Service, Inc.	UPS Lufkin	Multi-Sector	Hurricane Creek	6.78	Active
TXR05V688	Georgia-Pacific Chemicals LLC	Lufkin Plant	Multi-Sector	Hurricane Creek	20.46	Active
TXR05X793	Angelina County	Angelina County Airport	Multi-Sector	Cedar Creek	574.7	Active
TXR05Y085	Texas Metal Casting Co.	Texas Metal Casting	Multi-Sector	Cedar Creek	7.75	Active

Table 17. Expired and terminated construction permits in the Middle Neches watershed.

Permit No.	Permittee	Facility Name	Permit Type	Receiving Water body	Acres Disturbed	Permit Status
TXR15057C	Oncor Electric Delivery, LLC	Lufkin SW STA Lufkin 138KV 16-0055	Construction	Jack Creek	82	Expired (2/16/2017-6/05/2018)
TR150028222	Oncor Electric Delivery Company LLC	Lufkin to Crocket 138KV Line Rebuild 16-008	Construction	Jack Creek	519	Expired (8/24/2016-5/29/2018)
TXR14UQ2	Leyendecker Building Group, Inc.	Shadow Creek II	Construction	Hurricane Creek	6.79	Expired (7/1/2012-6/3/2013)
TXR15UI05	Comanche Contractors LP	Hudson Green Apartments	Construction	Cedar Creek	5	Expired (4/27/2012-6/3/2013)
TXR15SC14	Journeyman Construction Inc.	Lufkin Armed Forces Reserve Center	Construction	Hurricane Creek	15	Expired (2/19/2010-6/3-2013)
TXR15QM46	Watermark Residential II LLC	Lufkin Pioneer Crossing	Construction	Cedar Creek	8	Expired (9/10/2019-6/3-2013)
TXR15PY02	JE Kingham Construction Company LTD	Angelina College Careers Building	Construction	Hurricane Creek	8	Expired (5/6/2010-6/3/2013)
TXR15OF94	Memorial Health System	Cardiovascular and Stroke Center of East Texas	Construction	Cedar Creek	5.5	Expired (5/31/2009-6/3/2013)
TXR15MM14	JE Kingham Construction Company LTD	Lufkin Primary School	Construction	Biloxi Creek	11.5	Expired (9/9/2008-6/3/2013)
TXR15MG36	JE Kingham Construction Company LTD	Angelina College	Construction	Hurricane Creek	8	Expired (8/19/2008-6/3/2013)
TXR15MB02	Zachry Construction Corporation	Angelina County TxDOT Field Office & Yard	Construction	Hurricane Creek	2.52	Expired (8/4/2008-6/3/2013)
TXR15JZ69	JE Kingham Construction Company LTD	Lufkin Memorial Cardiovascular and Stroke Center	Construction	Cedar Creek	6	Expired (2/24/2008-6/3/2013)
TXR15JY15	Don Langston Construction Inc.	VA Clinic	Construction	Cedar Creek	7	Expired (3/4/2008-6/3/2008)
TXR15JV62	Darden SW LLC	Olive Garden Lufkin	Construction	Hurricane Creek	2	Expired (2/9/2008-6/3/2008)
TXR157179	Trans-Texas Homes Corporation	Benton Ridge Subdivision	Construction	Biloxi Creek	72	Expired (5/31/2003-6/3/2008)

TXR157183	Trans-Texas Homes Corporation	Quail Ridge Subdivision	Construction	Jack Creek	38	Expired (5/31/2003-6/3/2008)
TXR15AF05	Woodland Heights Medical Center LP	Woodland Heights Medical Center	Construction	Cedar Creek	1	Expired (9/25/2005-6/3/2008)
TXR15CM22	LG Jumper Inc.	L G Jumper DXP Project	Construction	Cedar Creek	6	Expired (3/28/2006-6/3/2008)
TXR15CP41	Cowpen Properties	Card Crossing	Construction	Hurricane Creek	10	Expired (5/6/2006-6/3/2008)
TXR15DI73	Simon Traylor & Sons Inc.	TxDOT Project STP 2005 280	Construction	Jack Creek	4	Expired (7/29/2006-6/3/2008)
TXR15FX93	Discount Tire Company of Texas, Inc.	Discount Tire Lufkin	Construction	Hurricane Creek	2	Expired (1/19/2007-6/3/2008)
TXR15FY01	Oncor Electric Delivery Company LLC	Oncor Electric Delivery North Herty Lufkin East 138 KV Recon	Construction	Biloxi Creek	70	Expired (1/5/2007-6/3/2008)
TXR15TZ05	JE Kingham Construction Company LTD	Mercer Nissan	Construction	Biloxi Creek	9	Expired (1/27/2012-6/3/2013)
TXR15UU70	Dee Winston	Winston Residence	Construction	Hurricane Creek	5	Expired (8/14/2012-6/3/2013)
TXR15837N	Oncor Electric Delivery Company LLC	Lufkin to Crockett 138KV Line Rebuild 16-008	Construction	Jack Creek	519	Terminated (5/29/2018-12/10/2018)
TXR15CY38	Texas Department of Transportation	TxDOT LFK 0176-08-018 ETC SFT 176-8-18 ETC	Construction	Hurricane Creek	37	Terminated (7/31/2006-8/21/2008)
TXR15GF04	Texas Department of Transportation	TxDOT LFK 1406-01-027 STP 20073330SB	Construction	Cedar Creek	9.7	Terminated (6/4/2007-4/7/2008)
TXR15HF47	Texas Department of Transportation	TxDOT LFK 0176-03-0115 NH 2007584	Construction	Hurricane Creek	53	Terminated (7/16/2007-7/12/2010)
TXR15JA26	Longview Bridge and Road LTD	LBR Angelina County Job McCall Drive and Whitehouse Drive	Construction	Hurricane Creek	5	Terminated (12/3/2007-11/3/2010)
TXR15JD41	JE Kingham Construction Company LTD	TLL Temple Foundation	Construction	Hurricane Creek	5	Terminated (11/21/2007-1/13/2010)

TXR15JK79	Texas Department of Transportation	LFK 3418-01-009 STP 2008242HES	Construction	Hurricane Creek	6.55	Terminated (1/9/2008-9/10/2008)
TXR15K948	Texas Department of Transportation	TXDOT CSJ 020001058	Construction	Cedar Creek	25	Terminated (7/22/2004-5/5/2006)
TXR15KG78	Angelina Excavating Inc.	Crown Colony Section XII	Construction	Hurricane Creek	7.38	Terminated (4/09/2008-12/02/2008)
TXR15MM86	Oncor Electric Delivery Company LLC	Lufkin East Lufkin South Rebuild 08-0037	Construction	Biloxi Creek	75	Terminated (9/5/2008-6/29/2009)
TXR15TJ02	CGI Construction Inc.	CGI Larkspur Transitional Care Center	Construction	Cedar Creek	6	Terminated (1/27/2012-5/3/2013)
TXR15UJ28	Timberline Constructors Inc.	Fuel City Travel Center	Construction	Biloxi Creek	8.36	Terminated (6/12/2012-2/12/2013)
TXR15VW50	Texas Department of Transportation	TxDOT-LFK-0336-04-014-ETC	Construction	Cedar Creek	5.3	Terminated (1/16/2013-4/30/2014)
TXR15W583	Texas Department of Transportation	TxDOT LFK 10801-01-011 STP 2005820 ETC	Construction	Jack Creek	48.6	Terminated (9/20/2005-4/30/2008)
TXR15W765	Texas Department of Transportation	TxDOT LFK 0176-03-0126 C 176-3-126	Construction	Biloxi Creek	29	Terminated (9/30/2005-1/18/2007)
TXR15WN16	Allen Loggins & Son Inc.	69 Project	Construction	Biloxi Creek	12	Terminated (3/21/2013-11/01/2013)
TXR152877	Texas Department of Transportation	TXDOT CSJ031904069	Construction	Jack Creek	10	Terminated (4/09/2003-6/25/2003)
TXR152924	Home Depot USA	The Home Depot Store 513 Lufkin	Construction	Hurricane Creek	12	Terminated (3/22/2003-8/23/2004)
TXR153545	Doughtie Construction Co Inc.	Copeland Street Paving and Drainage Improvements Project	Construction	Cedar Creek	11	Terminated (5/9/2003-11/22/2004)
TXR155601	EMJ Corporation	South Loop Crossing	Construction	Biloxi Creek	16	Terminated (6/7/2003-3/4/2004)
TXR156587	Billy Horton Builders Inc.	Canyon Creek	Construction	Cedar Creek	174	Terminated (7/9/2003-3/14/2008)
TXR1567680	The Card Group Inc.	The Garden District	Construction	Hurricane Creek	117	Terminated (7/19/2003-6/16/2006)
TXR158264	Allen Loggins & Son Inc.	Gaslight Medical Park	Construction	Cedar Creek	9	Terminated (8/22/2003-3/18/2005)

TXR15AO35	M Hanna Construction Co Inc.	Sams Club 6202 Offsite Fill Area Lufkin	Construction	Hurricane Creek	4	Terminated (2/01/2006-3/6/2006)
TXR15B811	JE Kingham Construction Company LTD	Medical Arts Pavilion Memorial Health System of East Texas	Construction	Hurricane Creek	3	Terminated (11/16/2003-9/14/2007)
TXR15BL76	JE Kingham Construction Company LTD	Loving Toyota	Construction	Biloxi Creek	11	Terminated (1/16/2006-9/14/2007)
TXR15C710	B & J Excavating	Gaslight Medical Park	Construction	Hurricane Creek	8	Terminated (11/20/2003-8/25/2004)
TXR15CB93	Texas Department of Transportation	TXDOT LFK 1406-01-026 SFT 1406-1-26 Related to 0737-02-013	Construction	Cedar Creek	16.81	Terminated (5/31/2006-11/02/2007)
TXR15CB94	Texas Department of Transportation	TXDOT LFK 2959-01-006 SFT 2959-1-6 Related to CSJ 0737-02-01	Construction	Jack Creek	10.42	Terminated (05/31/2006-3/27/2008)
TXR15CB95	Texas Department of Transportation	TXDOT LFK 3219-02-005 SFT 3219-2-5 Related to CSJ 0737-02-01	Construction	Jack Creek	8.85	Terminated (5/31/2006-11/26/2007)
TXR15DK13	Angelina Excavating Inc.	Saddle Brook Subdivision	Construction	Hurricane Creek	4	Terminated (7/19/2006-5/29/2007)
TXR15DS52	Texas Department of Transportation	LFK 0336-05-056 C 336-5-56	Construction	Hurricane Creek	12.95	Terminated (9/29/2006-1/22/2008)
TXR15E988	Key Construction Inc.	Southern Colony Shopping Center	Construction	Hurricane Creek	23	Terminated (2/3/2004-4/30/2005)
TXR15EA10	Logans Roadhouse Inc.	Logans Roadhouse Restaurant	Construction	Hurricane Creek	1	Terminated (8/18/2006-1/10/2007)
TXR15EE38	Moore Building Associates LLP	Pinecrest Community Development PH	Construction	Biloxi Creek	10	Terminated (9/2/2006-5/15/2007)
TXR151892	Rockwell Construction Corporation of Texas	The Home Depot Store 513 Lufkin	Construction	Hurricane Creek	11.64	Terminated (5/11/2003-4/27/2004)

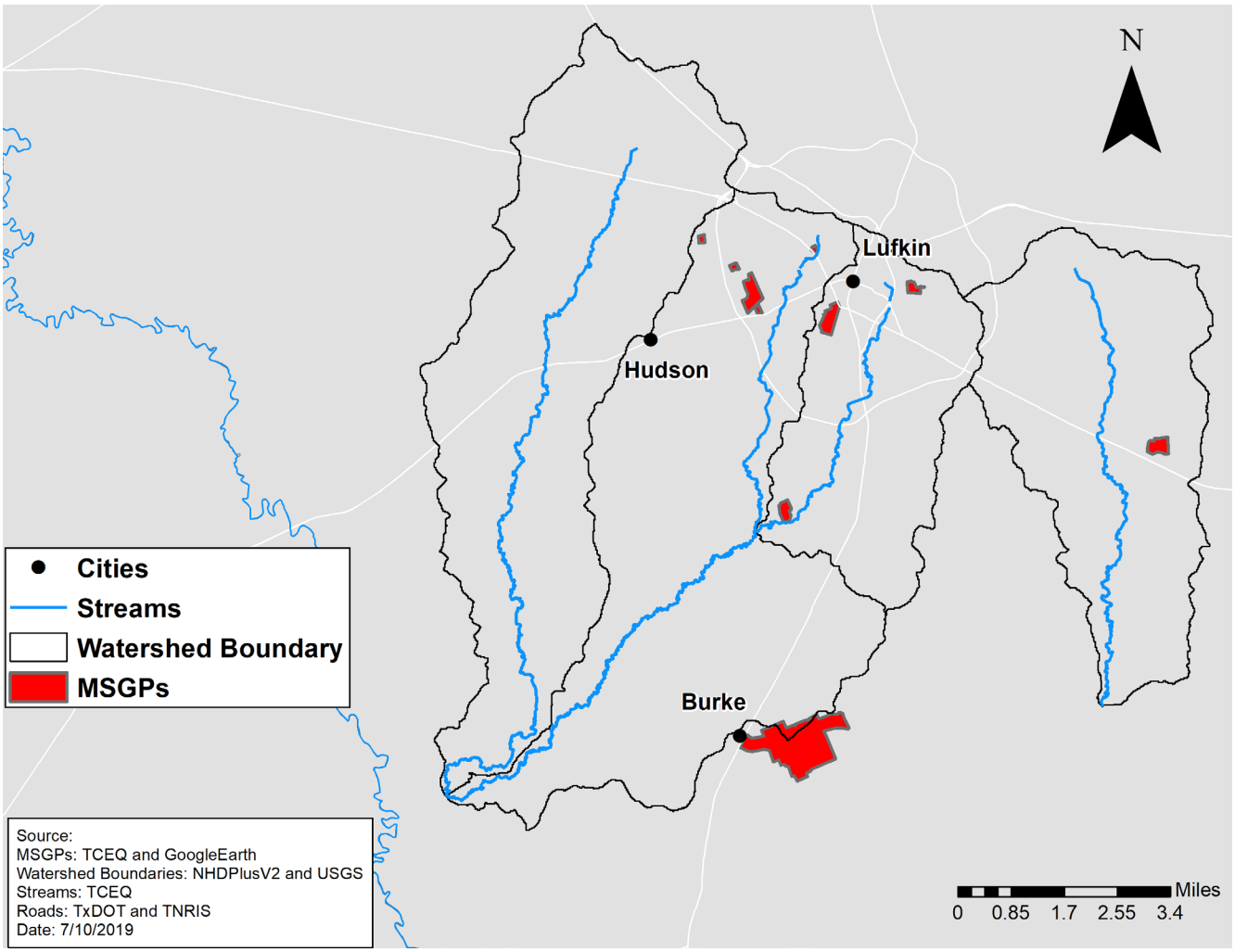

Figure 14. Locations of MSGPs in the Middle Neches watershed.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges from a sewer system that must be addressed by the TPDES permittee or owner of the collection system connected to the permitted system. Under dry weather conditions, SSOs most likely occur from blockages in the sewer collection, resulting from tree roots, grease or other debris. Sewer overflow can also occur during severe storm events, sewer defects, power failures, vandalism and the improper operation and maintenance of the system (USEPA, 2012). Inflow and infiltration events occur in which high water flows from excess water in sewer pipers or storm water overburden the design capacity of wastewater treatment plants, resulting in sewer overflows and water contamination (King County, 2011).

According to the TCEQ Central Office and TCEQ Region 10 office, 11 SSO events were reported, of which 10 events occurred at the City of Hudson WWTF, between January 1, 2014-December 31, 2018. The primary cause for most of the SSO events was from a non-grease related line blockage. Most SSO events occurred on Jack Creek or AU 0604C_01, while one SSO event occurred on Hurricane Creek or AU 0604B_01.

Nonpoint sources

Nonpoint sources of pollution are defined as any water pollution that does not originate from regulated or point sources (TCEQ and TSSWCB, 2013). Nonpoint source pollution from leaking on-site sewage facilities (OSSFs), urban and agricultural runoffs, domestic pets, wildlife, and livestock would potentially contribute as unregulated sources of FIB.

Failing On-site Sewage Facilities

OSSFs, commonly known as septic systems, can be a potential source of FIB due to inadequate design, inappropriate installation, neglectful operation or age of a system (USEPA, 2016b). The soils of an area or density of septic systems can also influence the likelihood of pollutants from an OSSF reaching a waterway. Estimating the number of OSSFs in a watershed is essential for assessing potential impacts on water quality.

Several limitations exist for OSSF management due to the lack of information about the number of septic systems, their locations, ages, types and functional statuses (USEPA, 2016b). Since comprehensive data is not available, secondary sources of information must be used to approximate the number of OSSFs present. One method utilizes 911 address data points, aerial imagery, 2010 U.S. Census Block house unit data, Convenience and Necessity sewer area, and city boundary data (Gregory et al., 2013). Approximately 3,457 OSSFs are estimated to be located in the Middle Neches watershed. Unfortunately, using this data requires assumptions regarding the presence of OSSFs, therefore carrying a level of uncertainty that can only be removed with on-site inspections. The locations of estimated OSSFs in the watershed are displayed in Figure 15.

Environmental factors, such as soil conditions can also influence the risk for potential failure and pollution from an OSSF. The NRCS developed a soil suitability ranking method, and based on soil characteristics, are categorized into: not limited, somewhat limited, and very limited. OSSFs

in “somewhat limited” or “very limited” soils face greater risks of failure. As tabulated in Table 18, nearly 98% of soil in the watershed are categorized as very limited, 0.22% is somewhat limited, and 2.25% of the soil does not have a rating (Table 18).

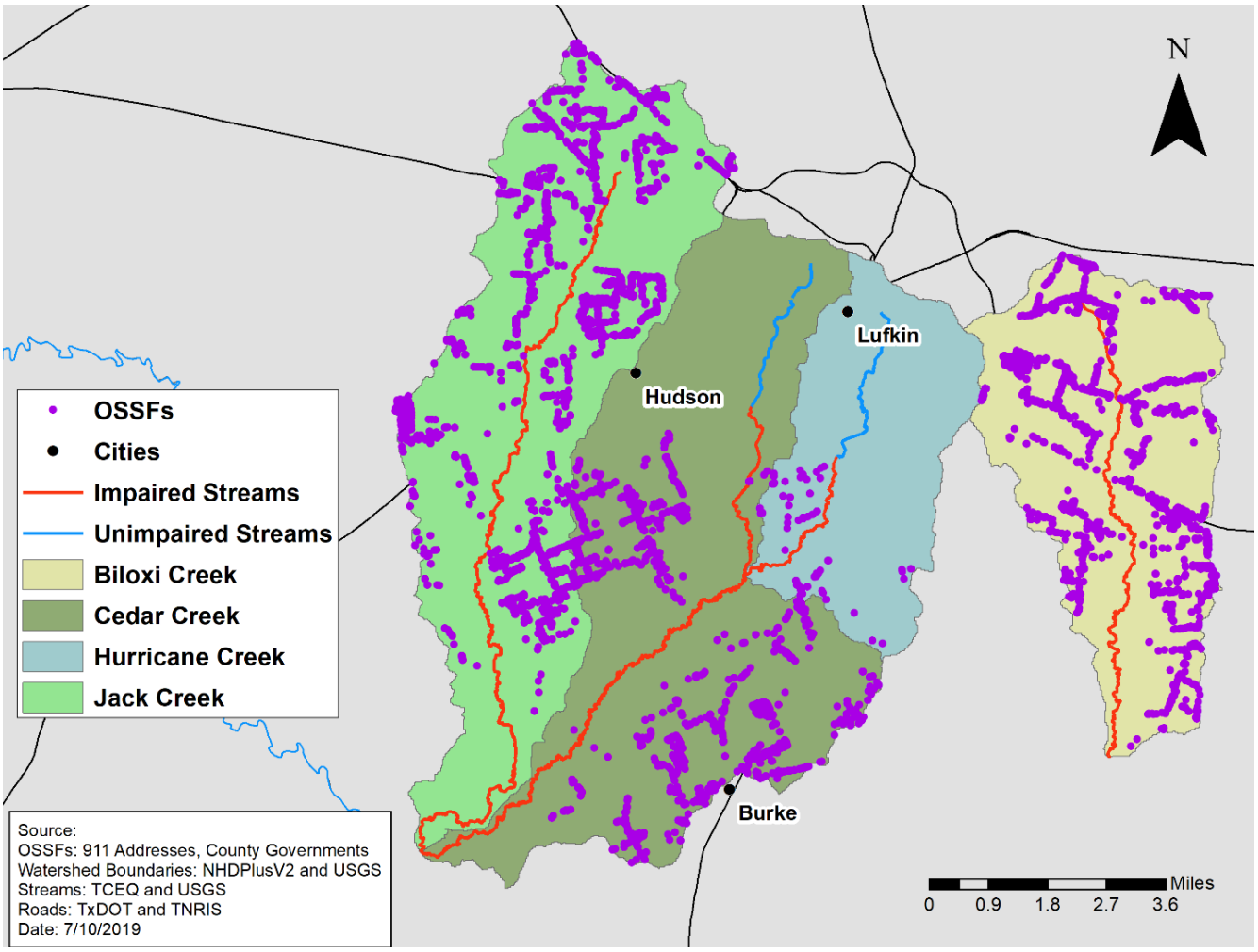

Figure 15. Estimated locations of OSSFs in the Middle Neches watershed.

Table 18. Soil suitability ratings in the watershed.

Soil Condition	Total Acres	Percentage of Watershed (%)
Not Rated	1,330	2.25
Somewhat Limited	131	0.22
Very Limited	57,669	97.53

Grazing livestock

Grazing livestock in a watershed contributes to the overall *E. coli* load due to direct deposition of fecal waste in or near water bodies. The National Agricultural Statistics Service's (NASS) 2017 Census of Agriculture provides livestock populations for each county. This information can be scaled down to the watershed area of interest. For horses, goats, sheep and pigs/hogs, the ratio of acres between the watershed and county was multiplied by the total number of animals in the county, as reported by NASS (2017), to estimate the number of livestock in the watershed. For cattle, the county-level data was multiplied by the area ratio of the grazeable land in the watershed to the grazeable land across the county. Grazeable land for cattle is defined as an aggregate of hay/pasture, shrub/scrub, and herbaceous LULC classifications. Across the watershed, there is estimated to be 2,274 heads of cattle (Table 19).

Table 19. Estimated grazing livestock population in the watershed.

Area	Cattle	Horses	Goats	Sheep	Pigs/Hogs
Angelina County	16,124	1,739	1412	230	344
Middle Neches Watershed	2,274	187	152	17	37

Commercial poultry

Litter produced by commercial poultry can be another source of bacteria pollution in the watershed if inappropriate management measures for litter waste is practiced. Based on NASS (2017) numbers and area suitable for poultry (outside of urban areas), Angelina county has 62,012 layers and 2,298,130 broilers. The watershed-level poultry population was estimated using the county-level population multiplied by the area ratio of non-urban LULC classes within the watershed to the non-urban LULC classes across the county. The estimated results indicate that there are 5,781 layers and 214,255 broilers in the watershed (Table 20). A couple of large broiler operations exist in the Biloxi subwatershed that most likely contains most of the estimated number of broilers.

Table 20. Estimated poultry population in the watershed.

Animal	LULC	Acres in Angelina County	Acres in watershed	Counts in Angelina County	Counts in watershed
Layer	Outside of urban area	527,845	43,831	62,012	5,781
Broiler	Outside of urban area	527,845	43,831	2,298,130	214,255

Pets

Dogs and cats can also be sources of fecal bacteria contamination in water bodies during stormwater runoff. According the American Veterinary Medical Association (AVMA), the estimated number of dogs per household is 0.584 and the estimated number of cats per household is 0.638 (AVMA, 2012). Based on the 2010 census data, there are approximately 17,432 house units located in this watershed, therefore the estimated number of dogs and cats are 10,180 and 11,122 respectively (Table 21).

Table 21. Estimated dog and cat populations in the watershed.

Pet	Household Count	Density (animal/household)	Counts in watershed
Dogs	17,432	0.584	10,180
Cats	17,432	0.638	11,122

Wildlife and Unmanaged Animal Contributions

Wildlife species can contributed a significant proportion of *E. coli* into a watershed due to riparian areas near water bodies providing suitable habitat. As a result, wildlife will spend the majority of their time in these areas and expel fecal waste near or in the water body. Estimating the potential contribution of fecal loading from wildlife is essential for evaluating the overall *E. coli* load; however, data on wildlife numbers is limited. White-tailed deer and feral hogs are two species that reasonable population estimates can be determined.

Feral hog population densities are challenging to estimate and values in the literature vary widely. A common estimate frequently used in the State of Texas is a density of one hog per 33.3 acres (Wagner and Moench, 2009). Appropriate LULC classes for feral hogs in the watershed include forest, wetland, and shrub/scrub, resulting in an overall estimate of 829 feral hogs.

White-tailed deer estimates for the watershed are not available, therefore estimates from the Texas Parks and Wildlife (TPWD) resource management unit (RMU) 15, which is located adjacent to Angelina county (and is in the same Pineywoods ecoregion) was utilized. The estimated deer population for RMU 15 is 45.2 acres per deer (TWRI, 2014). Suitable LULC classes for deer habitat include shrub/scrub, herbaceous, forest, hay/pasture, and wetlands. Table 22 tabulates the estimated feral hog and white-tailed deer populations.

Table 22. Estimated feral hog and White-tailed deer populations in the watershed.

Animal	LULC Classes	Acres in watershed	Density (acre/animal)	Counts in watershed
Feral Hogs	Forest, Wetland, Shrub/Scrub	27,600	33.3	829
Deer	Shrub/scrub, Herbaceous, Forest, Hay/pasture, Cultivated crops, Wetlands	43,787	45.2	969

References

ANRA. 2015. 2015 Basin Summary Report. Angelina and Neches River Authority; [cited 15 Feb 2019]. Available from: https://www.anra.org/divisions/water_quality/crp/pdfs/reports/2015_Summary_Report/ANRA_FY_2015_BHR.pdf.

AVMA. 2012 U.S. Pet Ownership Calculator. American Veterinary Medical Association; [cited 28 Feb 2019]. Available from: https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx.

Gregory L, Blumenthal B, Wagner K, Borel K, Karthikeyan R. 2013. Estimating On-site Sewage Facility Density and Distribution Using Geo-Spatial Analyses. J Nat Environ Sci. 4(1): 14-21.

Griffith, G., Bryce, S., Omernik, J., and A. Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

King County. 2011. Infiltration and Inflow Control. [Internet]. Wastewater Treatment Division, King County, WA; [cited 11 Mar 2019]. Available from: http://www.kingcounty.gov/environment/wastewater/II/What.aspx.

Natural Resources Conservation Service, United States Department of Agriculture. 2019. Web Soil Survey; [cited 15 Feb 2019]. Retrieved from: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

NOAA. 2014. Climate Data Online. National Climatic Data Center; [cited 15 Feb 2019]. Available from: http://www.ncdc.noaa.gov/cdo-web/.

NRCS. 2007. Hydrology National Engineering Handbook: Chapter 7 Hydrologic Soil Groups. 210-VI-NEH. [cited 2019 May 3]. Available from: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba.

PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Group at Oregon State University. 2019. Average Annual Precipitation for Texas (East) (1981-2010). PRISM Products Matrix; [cited 2019 Feb 15]. Available from: http://www.prism.oregonstate.edu/normals/.

TCEQ. 2012. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods. Texas Commission on Environmental Quality; [cited 2 July 2019]. Available from: https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg415/rg-415.pdf.

TCEQ and TSSWB. 2013. Managing nonpoint source pollution in Texas: 2013 annual report. SFR-066/13. Austin: TCEQ and TSSWB.

TCEQ. 2015a. 2014 Texas Integrated Report – Texas 303(d) List (Category 5). Texas Commission on Environmental Quality; [cited 6 May 2019]. Available from: https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/14txir/2014_303d.pdf

TCEQ. 2015b. 2014 Guidance for Assessing and Reporting Surface Water Quality in Texas. Texas Commission on Environmental Quality; [cited 2 July 2019]. Available from: https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/14txir/2014_guidance.pdf.

TCEQ. 2018a. Draft 2016 Texas Integrated Report-Texas 303(d) List (Category 5). Texas Commission on Environmental Quality; [cited 6 May 2019]. Available from: https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/16txir/2016_303d.pdf

TCEQ. 2018b. Recreational Use Attainability Analyses. Texas Commission on Environmental Quality; [cited 25 June 2019]. Available from: https://www.tceq.texas.gov/waterquality/standards/ruaas/index.

TCEQ. 2018c. Texas Surface Water Quality Standards; [cited 25 June 2019]. Available from: https://www.tceq.texas.gov/assets/public/waterquality/standards/tswqs2018/2018swqs_allsections_nopreamble.pdf.

TCEQ. 2019. Draft 2018 Texas Integrated Report-Texas 303(d) List (Category 5). Texas Commission on Environmental Quality; [cited 6 May 2019]. Available from: https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/18txir/2018_303d.pdf

Texas AgriLife Research and Extension. 2015. Preliminary Results of a Recreational Use Attainability Analysis of Ayish Bayou (0610A), East Fork of the Angelina River (0611A), Biloxi Creek (0604M), Jack Creek (0604C0 and Paper Mill Creek (0615A). College Station, TX: Texas AgriLife Research and Extension.

TWRI. 2014. Attoyac Bayou Watershed Protection Plan. Texas Water Resources Institute, TR-458.

U.S. Census Bureau. 2012. American FactFinder; data generated by Luna Yang. United States Census Bureau; [cited 20 Feb 2019]. Available from: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

U.S. Census Bureau. 2019a. Quick Facts: Lufkin City, Texas. United States Census Bureau; [cited 15 Feb 2019]. Available from: https://www.census.gov/quickfacts/fact/table/lufkincitytexas/PST045217.

U.S. Census Bureau. 2019b. ACS Demographic and Housing Estimates: Hudson City, Texas. United States Census Bureau; [cited 15 Feb 2019]. Available from: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF.

U.S. EPA. 2013. Level III ecoregions of the continental United States: Corvallis, Oregon, U.S. EPA – National Health and Environmental Effects Research Laboratory, map scale 1:7,500,000. [cited 1 May 2019]. Available from: https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states.

U.S. EPA. 2016a. Indicators: Conductivity. United States Environmental Protection Agency; [cited 2019 May 10]. Available from https://www.epa.gov/national-aquatic-resource-surveys/indicators-conductivity.

U.S. EPA. 2016b. Sanitary Sewer Overflows and Peak Flows. [Internet]. United States Environmental Protection Agency; [cited 24 April 2019]. Available from: https://www.epa.gov/npdes/sanitary-sewer-overflows-ssos.

U.S. EPA. 2018. Basic Information about Nonpoint Source (NPS) Pollution. United States Environmental Protection Agency; [cited 2019 May 6]. Available from: https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution.

U.S. Geological Survey. 2013. National Elevation Dataset (NED); [cited 2019 Feb 15]. Available from: https://lta.cr.usgs.gov/NED.

Wagner K.L. and Moench E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347.