Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in Big Creek

Assessment Units: 1202J_01 and 1202J_02

Big Creek at Whaley-Long Point Road

By Justin Bower
Houston-Galveston Area Council
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P.O. Box 13087
Austin, Texas 78711-3087

Prepared by:
Justin Bower
Steven Johnston
Jessica Casillas
Rachel Windham
Thushara Ranatunga
Houston-Galveston Area Council
Houston, TX

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	Construction General Permit
DAR	drainage-area ratio
DMR	discharge monitoring report
E. coli	*Escherichia coli*
EPA	(United States) Environmental Protection Agency
FDC	flow duration curve
FG	future growth
H-GAC	Houston-Galveston Area Council
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	Multi-Sector General Permit
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic Database
SWMP	stormwater management program
SWQM	surface water quality monitoring
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
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WWTF	wastewater treatment facility

Section 1. Introduction

1.1. Background

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

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet 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 in mass per period of time but may be expressed in other ways.

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

TCEQ first identified a bacteria impairment within the Big Creek watershed (1202J) in the *2002 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2002). At the time of the 2002 edition, the report identified waterbodies by their segment identification, but starting with the 2006 edition, impairments were identified using assessment units (AUs) instead. In the 2006 edition, the bacteria impairment within 1202J identified in the 2002 and 2004 editions, was identified as AU 1202J_01 (TCEQ, 2008). AU 1202J_02 within Big Creek was later identified as impaired for bacteria in the *2014 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d) List* (Texas Integrated Report, TCEQ, 2015). The impairments were again identified in the 2022 Texas Integrated Report (TCEQ, 2022a), the latest U.S. Environmental Protection Agency (EPA) approved edition.

This document will consider two bacteria impairments in two AUs of the Big Creek watershed. The impaired AUs and their identifying numbers are:

- Big Creek AU – 1202J_01
- Big Creek AU – 1202J_02

1.2. Water Quality Standards

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

The Standards are rules that do all of the following:

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

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

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

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

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

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

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

- **Secondary contact recreation 1** – Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation 1 or 2 but more than secondary contact recreation 2. It has a geometric mean criterion for *E. coli* of 630 cfu per 100 mL.
- **Secondary contact recreation 2** – Activities with limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 1,030 cfu per 100 mL.
- **Noncontact recreation** – Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic. It has a geometric mean criterion for *E. coli* of 2,060 cfu per 100 mL.

Big Creek is a freshwater stream and has a primary contact recreation 1 use. The associated criteria for *E. coli* is a geometric mean of 126 cfu per 100 mL.

1.3. Report Purpose and Organization

The Big Creek TMDL project was initiated through a contract between TCEQ and the Houston–Galveston Area Council (H-GAC). The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDLs for the impaired AUs. This report contains:

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

Section 2. Historical Data Review and Watershed Properties

2.1. Description of Study Area

The Big Creek watershed (Figure 1) occupies 222 square miles of Fort Bend County in the Houston-Galveston region of southeastern Texas. It falls within the greater Brazos River watershed as part of segment 1202, the Brazos River Below Navasota River, and is within the Houston–The Woodlands–Sugar Land Metropolitan Statistical Area.

The main stem of this freshwater stream is approximately 34 miles long and includes a varied tributary network. The headwaters of the waterway lie in ephemeral drainage and minor streams of the primarily rural areas south and west of the City of Rosenberg. Additional headwaters areas south of the City of Sugar Land area feed tributaries (e.g., Rabbs Bayou) that enter the main channel lower in the system. The official start of the water body is at the confluence of Cottonwood and Coon Creeks and receives flow from a variety of other smaller tributaries. For much of its length, Big Creek is a small to medium sized stream that has been heavily modified in many areas to act as a drainage conveyance or as part of agricultural improvements (e.g., berms in riparian edges of fields). The creek's terminal end is at its confluence with the Brazos River at the eastern edge of Brazos Bend State Park. Unlike the channel upstream, the waterway within the confines of the park is relatively unmodified and has more natural riparian areas.

The historic meanders of the Brazos River have greatly influenced the lands and waterways of the system. Additionally, nearly all the waterways of the system have seen appreciable human modification for drainage and other uses, including a historically prominent role of agriculture in the watershed. The system contains several major impoundments, including Smithers Lake, which serves as a cooling water forebay for the W.A Parish electrical generating station, and Worthington Lake, which impounds water in a recreational lake. A small diversion exists east of the Richmond/Rosenberg area via Middle Creek, and a substantially larger diversion channel is designed to shunt excess flow from the downstream component of the system due north of Brazos Bend State Park directly to the Brazos River corridor.

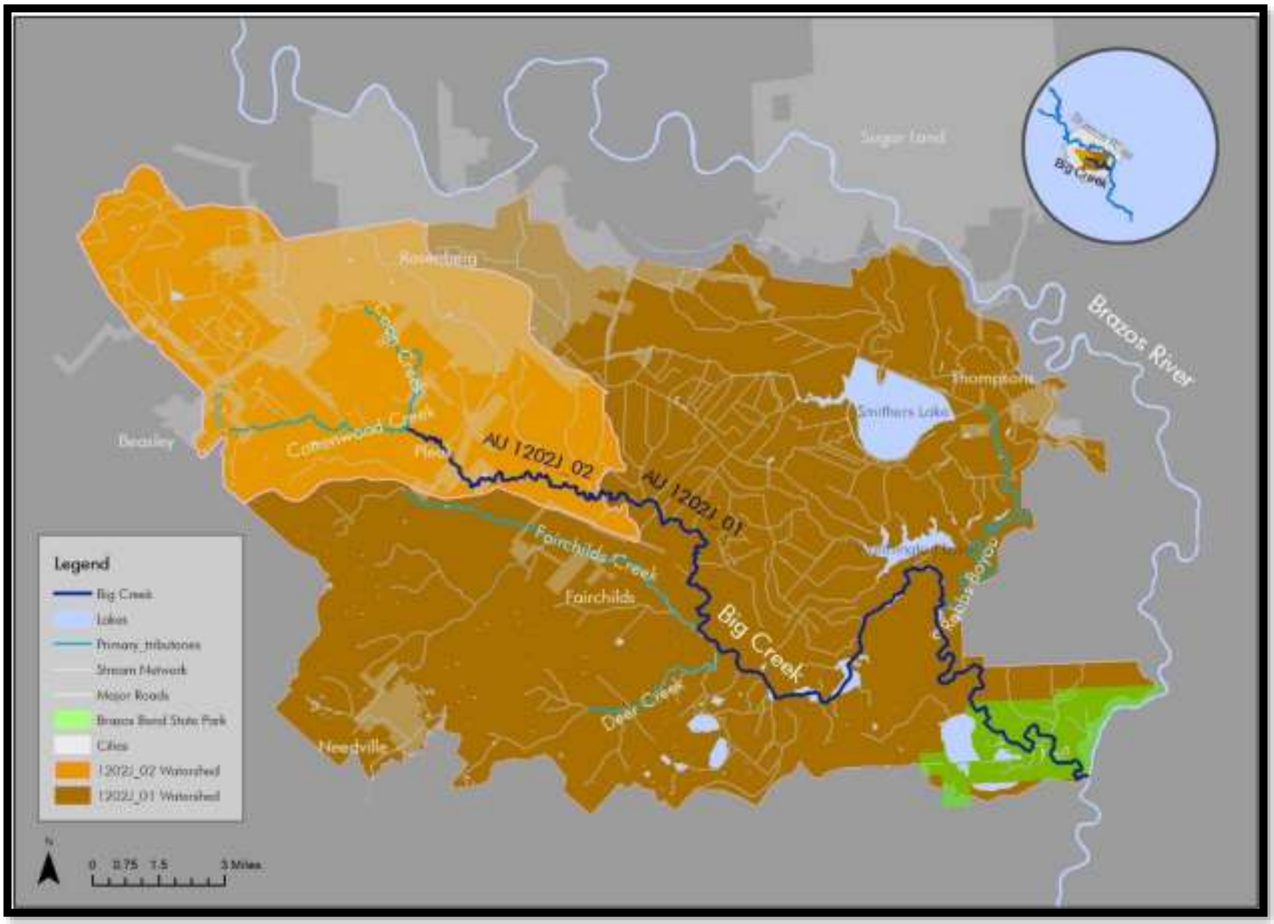

Figure 1. Overview map of the Big Creek watershed

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

- 1202J (Big Creek) – From the confluence of the Brazos River upstream to the confluence of Cottonwood Creek and Coon Creek.
    - AU 1202J_01 – Big Creek from the confluence of the Brazos River upstream to the confluence of an unnamed tributary 2.1 kilometers downstream of Farm-to-Market Road 2977 south of Rosenberg.
    - AU 1202J_02 – Big Creek Appendix D intermittent stream with perennial pools section from the confluence with an unnamed tributary 2.1 kilometers downstream of Farm-to-Market Road 2977 upstream to the confluence of Cottonwood Creek and Coon Creek.

2.2. Review of Routine Monitoring Data

2.2.1. Analysis of Bacteria Data

Assessment data from 2022 Texas Integrated Report (TCEQ, 2022a), are shown in Table 1, and identify AU 1202J_01 as impaired and non-supporting of the primary contact recreation 1 standard with a geometric mean of 282.88 cfu/100 mL, which is above the contact recreation standard of 126 cfu/100 mL.

Table 1. 2022 Texas Integrated Report summary for AUs 1202J_01 and 1202J_02

AU	Texas Integrated Report Year	Parameter	TCEQ SWQM[a] Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
1202J_01	2022	*E. coli*	16353	53	12/1/2013 to 11/30/2020	282.88
1202J_02	2018	*E. coli*	17551	20	11/1/2007 to 11/30/2016	178.05

[a] Surface water quality monitoring

AU 1202J_01 was also listed as impaired in the 2020, 2018, 2016, 2014, 2008, 2006, 2004, and 2002 Texas Integrated Reports, demonstrating a constant impairment. There was no recorded sampling completed for AU 1202J_02 during the 2022 assessment period, therefore, the 2022 Texas Integrated Report lists AU 1202J_02 as a carry forward impairment from the 2018 Texas Integrated Report. AU 1202J_02 has also been listed as impaired in the 2020, 2018, and 2010 Texas Integrated Reports (for fecal coliform, but not *E. coli* in the case of the 2010). Additionally, AU 1202J_02 was also listed as being of concern for contact recreation in the 2012 and 2016 Texas Integrated Reports.

Table 2 presents the historic record for indicator bacteria sample observations. The TCEQ SWQM Station 17932 in AU 1202J_01 was discontinued in 2008, after which TCEQ SWQM Station 16353 began in 2009. TCEQ SWQM Station 17551 was discontinued in 2012 and is the reason no additional data has been reported for AU 1202J_02. Figure 2 provides the monitoring locations for many current and historic stations. Only TCEQ SWQM stations 16353, 17932, and 17551 have fecal indicator bacteria for review.

Table 2. Fecal indicator bacteria results (2004-2020)

AU	Station(s)	Number of *E. coli* Samples	Data Date Range	Maximum Value (cfu/100 mL)	Geometric Mean (cfu/100 mL)
1202J_01	16353 / 17932	91	03/11/2004 - 11/19/2020	14,000	207.36
1202J_02	17551	30	8/18/2004 - 08/22/2012	2,419	110.68

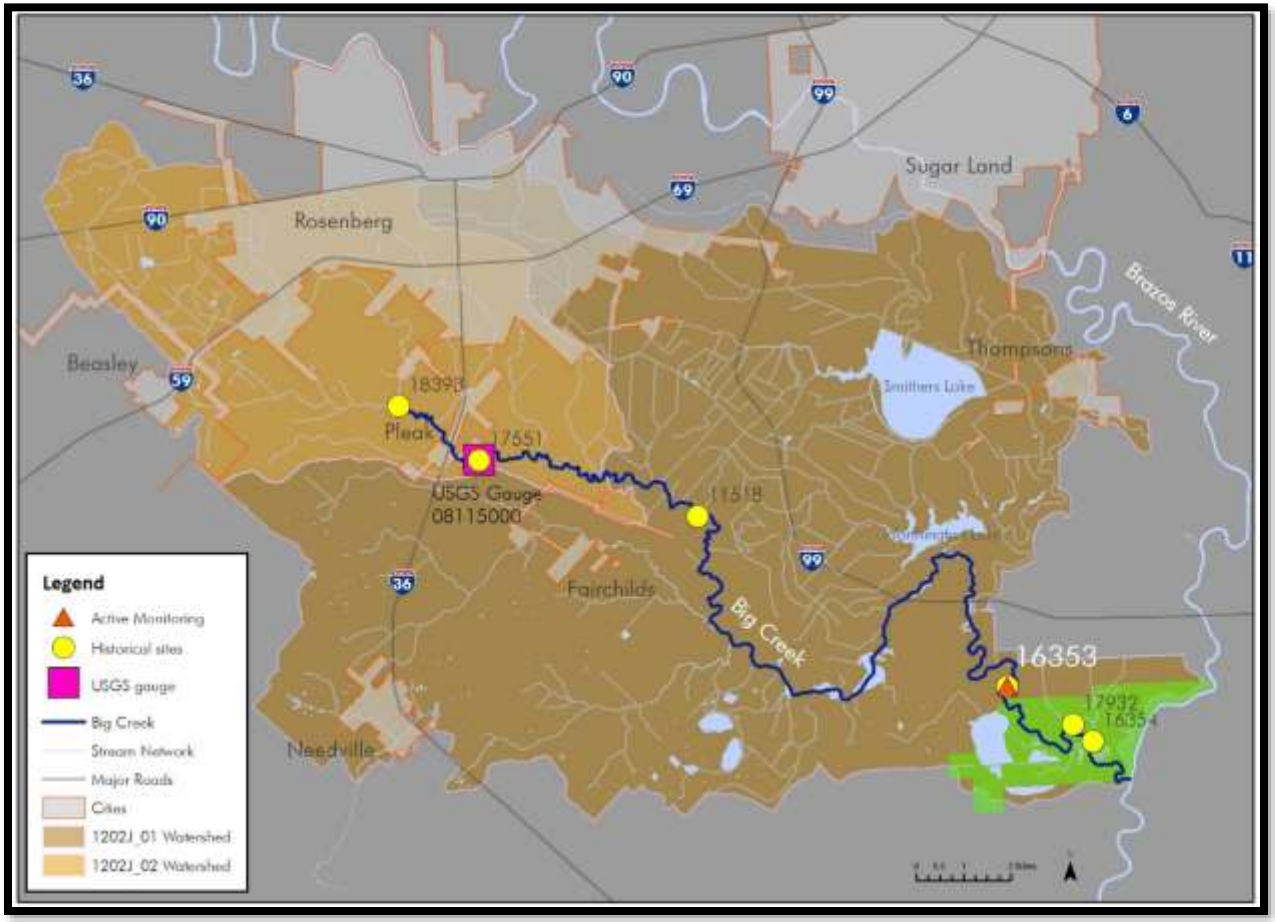

Figure 2. TCEQ SWQM stations and United States Geologic Survey gage

2.3. Climate and Hydrology

The National Oceanic and Atmospheric Administration (NOAA) has consistently operated a weather station in the village of Thompsons within the watershed. From this station (GHCND:USC00418996), daily, monthly, and annual averages for weather parameters including temperature and precipitation have been assessed for the period from 2004 through 2019 (NOAA, 2020).

Average precipitation for the watershed is 45.19 inches per year over the last 15 years (and 49.66 inches over the last five years). Average monthly precipitation over the same timeframe ranges from 2.55 inches to 5.35 inches (Figure 3). This average obscures the impacts of several high rainfall events that broke historical records in recent years and exacerbated flooding issues in the watershed. Rainfall occurs throughout the year, with the winter months receiving lower average rainfall while the summer months typically receive the greatest rainfall due to tropical disturbances. August stands out with the highest average rainfall.

Average monthly air temperature ranges from slightly above 51ºF in January to slightly below 81ºF in August. Figure 3 also demonstrates climatic variation over the course of the 15-year period.

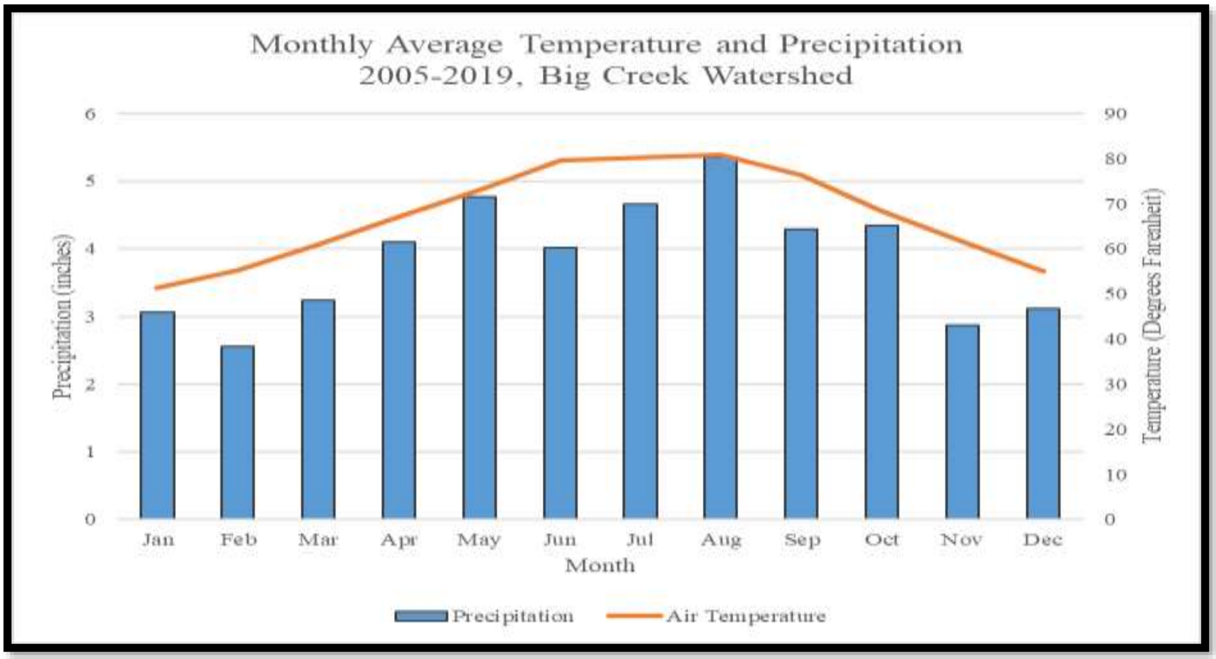

Figure 3. Mean monthly temperature and precipitation, NOAA Station GHCND:USC00418996

2.4. Population and Population Projections

As of 2020, the population of the Big Creek watershed was approximately 66,851 (Table 3), based on H-GAC's Regional Growth Forecast (H-GAC, 2022a) analysis of the United States Census Bureau (USCB) 2020 Decadal Census (USCB, 2020). The area's population is anticipated to grow appreciably over the next thirty years by 486.95%, equal to 392,381. Much of the expected growth will likely take place in the north and northeastern portions of the watershed near and within the cities of Sugar Land, Richmond, and Rosenberg, along the Interstate 69 corridor.

Table 3. 2020 – 2050 population projection

Watershed	2020 U.S Census	2050 Population Projection	Project Population Increase	Percentage Change
1202J_01	48,174	310,120	261,946	543.75%
1202J_02	18,677	82,261	63,584	340.44%
Total	**66,851**	**392,381**	**325,530**	**486.95%**

2.5. Land Cover

As with many urban centers nationwide, areas surrounding the City of Houston have experienced an increase in development associated with urban sprawl, especially along transportation corridors.

In 2018, H-GAC used LANDSAT imagery to categorize the Houston–Galveston region into 10 classes of land cover (H-GAC, 2018). The definitions for the land cover types are as follows:

1. Developed - High Intensity - Contains significant land area that is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies < 20% of the landscape. Constructed materials account for 80% to 100% of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.

2. Developed - Medium Intensity - Contains area with mixture of constructed materials and vegetation or other cover. Constructed materials account for 50% to 79% of the total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.

3. Developed - Low Intensity - Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 20% to 49% of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.

4. Developed - Open Space - Contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20% of total land cover.

5. Cropland - Contains areas intensely managed to produce annual crops. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

6. Pasture/Grassland - This is a composite class that contains both Pasture/Hay lands and Grassland/Herbaceous.

    a. *Pasture/Hay* - Contains 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 and not tilled. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

    b. *Grassland/Herbaceous* - Contains 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.

7. Barren Land - This class contains both barren lands and unconsolidated shore land areas.

    a. *Barren Land* - Contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10% of total cover.

    b. *Unconsolidated Shore* - Includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.

8. Forest/Shrubs - This is a composite class that contains all three forest land types and shrub lands.

    a. *Deciduous Forest* - Contains 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.

    b. *Evergreen Forest* - Contains 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 maintain their leaves all year. Canopy is never without green foliage.

    c. *Mixed Forest* - Contains 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% of total tree cover. Both coniferous and broad-leaved evergreens are included in this category.

    d. *Scrub/Shrubs* - Contains areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

9. Open Water - This is a composite class that contains open water and both palustrine and estuarine aquatic beds.

    a. *Open Water* - Include areas of open water, generally with less than 25% cover of vegetation or soil.

    b. *Palustrine Aquatic Bed* - Includes tidal and non-tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is below 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

c. *Estuarine Aquatic Bed* - Includes tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

10. <u>Wetlands</u> - This is a composite class that contains all the palustrine and estuarine wetland land types.

    a. *Palustrine Forested Wetlands* - Includes tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean derived salts is below 0.5%. Total vegetation coverage is greater than 20%.

    b. *Palustrine Scrub/Shrub Wetlands* - Includes tidal and non-tidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation coverage is greater than 20%. Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.

    c. *Palustrine Emergent Wetlands (Persistent)* - Includes tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses, or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation cover is greater than 80%. Plants generally remain standing until the next growing season.

    d. *Estuarine Forested Wetlands* - Includes tidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

    e. *Estuarine Scrub/Shrub Wetlands* - Includes tidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

    f. *Estuarine Emergent Wetlands* - Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens).

> Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5% and that are present for most of the growing season in most years. Total vegetation cover is greater than 80%. Perennial plants usually dominate these wetlands.

The project area was historically a mix of tallgrass prairies, oak mottes, and low-lying wetlands. Since early settlement of the area, widespread agricultural production has been the dominant land cover (and land use) type. Recent decades have seen a rapid transition to denser urban and suburban development, resulting in a more mixed land cover profile.

Land cover data in the watershed indicates that the most predominant land cover type is still agricultural, with the combination of cropland and pasture/grassland comprising 65.95% in both AUs (Table 4). However, developed areas of varying intensity are common in the watershed (17.44%), especially in high growth areas, and an appreciable acreage of “natural”[1] areas still exist (16.61%). Figure 4 shows the distribution of land cover in the watershed. The balance of land cover types in the watershed is expected to continue to shift toward developed uses in the future, in line with the population projection in Section 2.4.

Table 4. Land cover classifications by area and percentage

		1202J_01		1202_02		Total
Type	**Area (acre)**	**%**	**Area (acre)**	**%**	**Area (acre)**	**%**
Open Water	2,854.60	2.71%	30.03	0.08%	2,884.62	2.03%
Developed – High Intensity	924.25	0.88%	482.44	1.31%	1,406.69	0.99%
Developed - Medium Intensity	3,345.70	3.17%	1,114.35	3.02%	4,460.05	3.13%
Developed - Low Intensity	9,343.92	8.86%	4,827.72	13.07%	14,171.64	9.95%
Developed - Open Space	3,523.58	3.34%	1,265.59	3.43%	4,789.17	3.36%
Barren Land	12.01	0.01%	6.01	0.02%	18.02	0.01%
Forests/Shrubs	10,561.77	10.02%	3,209.36	8.69%	13,771.14	9.67%
Pasture/Grassland	43,379.69	41.13%	16,186.50	43.83%	59,566.20	41.83%
Cropland	24,764.91	23.48%	9,575.38	25.93%	34,340.29	24.12%
Wetlands	6,747.28	6.40%	229.99	0.62%	6,977.27	4.90%
Total	105,457.71	100.00%	36,927.37	100.00%	142,385.09	100.00%

[1] For the purposes of this description, “natural” means areas not in active production or developed uses. This includes open water, second growth forests, barren areas, etc. It does not indicate undisturbed wilderness.

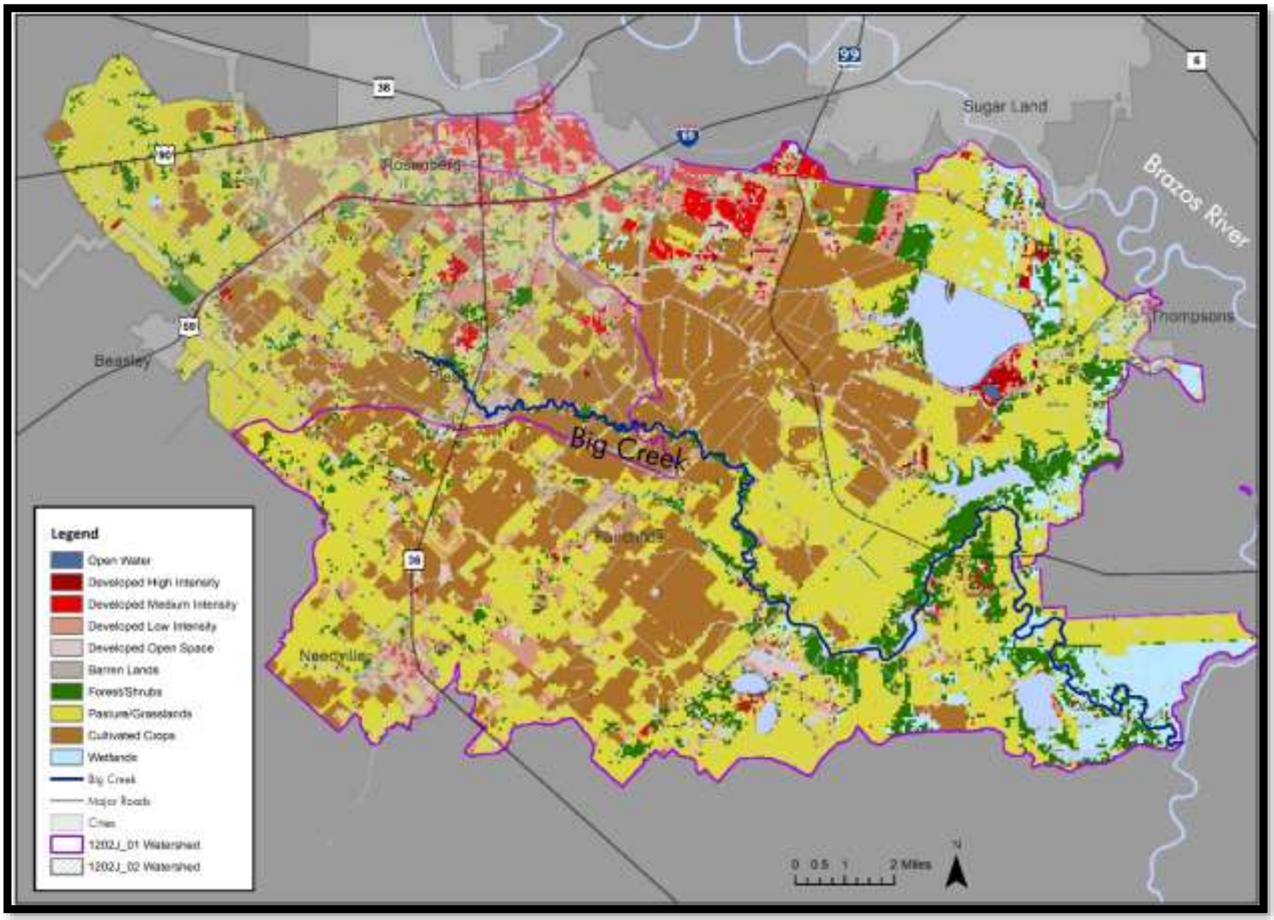

Figure 4. Land cover map showing classifications

2.6. Soils

Soils within the Big Creek watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (USDA NRCS, 2015). The SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The SSURGO database defines the classifications below.

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

- Group B – Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- Group C – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- Group D – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high-water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.
- Soils with dual hydrologic groupings indicate that drained areas are assigned the first letter, and the second letter is assigned to undrained areas. Only soils that are in group D in their natural condition are assigned to dual classes.

Soil data in the watershed were examined to determine their possible runoff potential classifications or hydrological groups. The Group D soil classification represents the majority of the soils in the Big Creek watershed at 97%. The other soils represent less than 3% of the watershed (Table 5, Figure 5). These mostly slow infiltration rate—alluvial clay, silt, and loam soils are consistent with the coastal areas of Texas.

Table 5. Hydrologic soil groups

Hydrologic Soil Group	Area (acres)	Percentage of Area
B	1,759.80	1.24%
C	1,606.86	1.13%
C/D	765.18	0.53%
D	138,251.95	97.10%
Total	**142,383.79**	**100.00%**

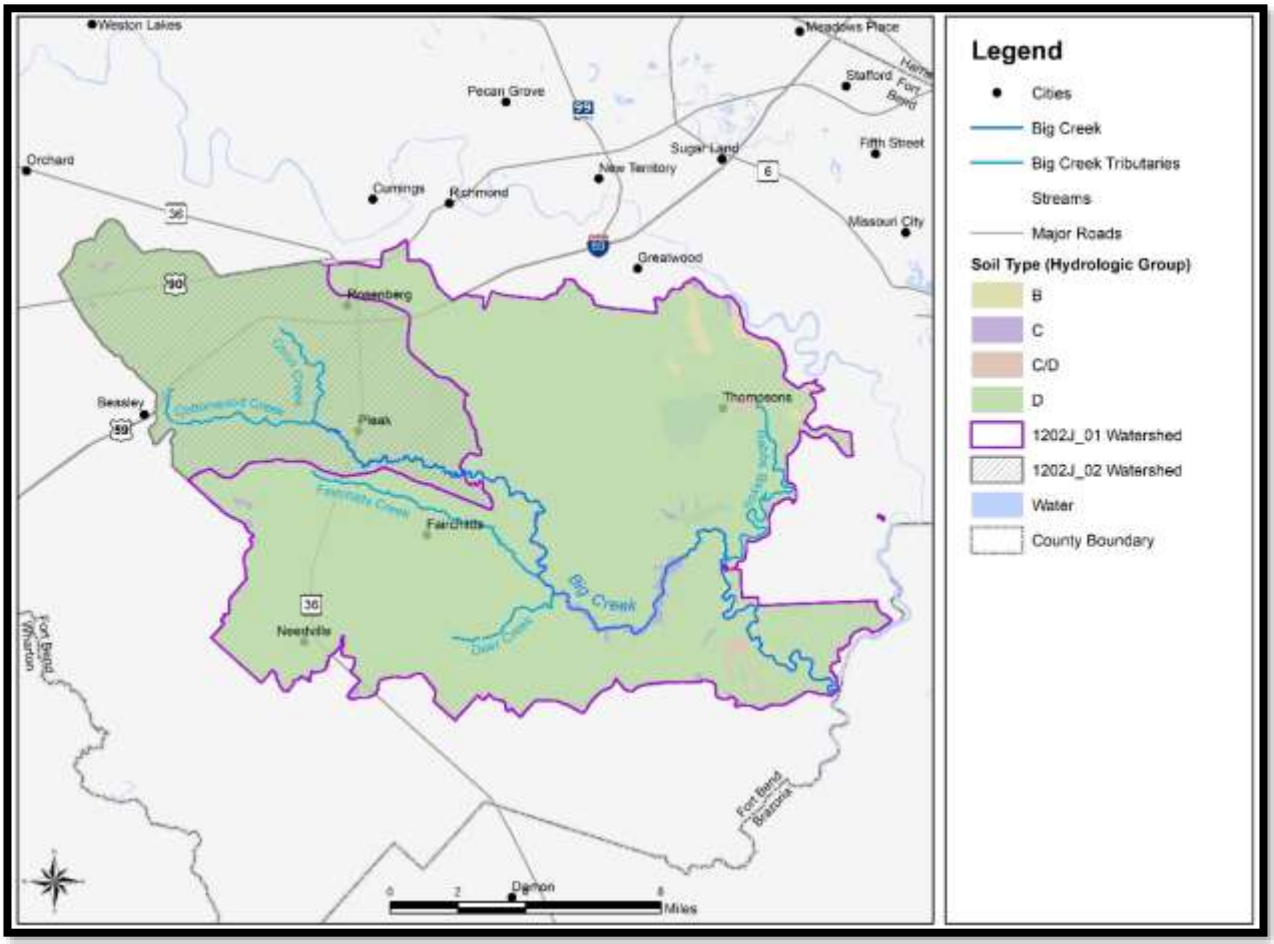

Figure 5. Hydrologic soil groups

2.7. Potential Sources of Fecal Indicator Bacteria

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

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

Except for WWTFs, which receive individual wasteload allocations (WLAs—see the "WLA" section), the regulated and unregulated sources in this section are presented to give a general account of the 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 permit under the TPDES program. The regulated sources in the TMDL watershed include WWTF outfalls, stormwater discharges from regulated construction sites, and municipal separate storm sewer systems (MS4s).

2.7.1.1. Domestic and Industrial Wastewater Treatment Facilities

There are 17 distinct permits in the Big Creek watershed that maintain wastewater discharge permits for 26 wastewater outfalls (Table 6, Figure 6), based on the EPA's Enforcement and Compliance History Online (EPA, 2022), TCEQ's Central Registry, and TCEQ's Outfall Data Layer, last reviewed on Oct. 24, 2022.

Three permittees, (WQ0005142000, WQ0005270000, and WQ0001038000) are industrial users without bacteria limits, which discharge to Smithers Lake and are impounded before entering the Big Creek system. For the purpose of developing the TMDL, these permits are not included in the calculation of WWTFs, but their daily average discharge are considered in determining the daily instream flow for development of the LDCs and in the calculation for area with a stormwater permit.

Additionally, two permitted WWTFs with bacteria limits—River Bend RV Park and Resort WWTF and the City of Needville WWTF—exist in the TMDL boundary. However, they discharge outside of the TMDL watersheds. These permits are also not included in the TMDL calculation but are displayed here for reference, as their service areas include portions of the TMDL boundary and could be a source of sanitary sewer overflows (SSO).

The remaining 12 WWTFs are domestic permits with bacteria limits for their effluent. The final (in the case of interim limits) maximum permitted discharge flows in million gallons per day (MGD) from each facility were recorded for use in development of the TMDL loading calculation.

WWTF permittees are required to sample their effluent for indicator bacteria concentrations and report the results to the state in their Discharge Monitoring Reports (DMRs). The reports are available from the state and EPA for review. Analysis of the permittee's DMRs for a representative period between 2008 and 2018 was conducted to evaluate the WWTFs adherence to their indicator bacteria limit. Three of the permittees reported a total of five violations of the bacteria geometric mean of 126 cfu/100 mL for the reporting period, representing 0.7% of 717 records. Four facilities reported exceeding the maximum value for a total of 26 violations, 20 of which were for one facility (TX0024490), representing 4.6% of all samples in that period.

Table 6. Permitted domestic and industrial WWTFs

AU	TPDES /NPDES[a]	Facility Name	Permittee Name	Primary Discharge Type	Bacteria Limits (cfu/100 mL)	Outfall Number	Daily Average Flow - Permitted Discharge (MGD)	Daily Average Flow - Recent Discharge[b,c] (MGD)
1202J_02	WQ0014757001 / TX0129194	Fort Bend County MUD 5	Fort Bend County MUD 5	Domestic	126	1	0.5	0.1462
1202J_02	WQ0010607002 / TX0024490	City of Rosenberg Plant No. 2	City of Rosenberg	Domestic	126	1	4.5	1.8569
1202J_02	WQ0010607004 / TX0125512	City of Rosenberg WWTF	City of Rosenberg	Domestic	126	1	0.095	0.0025
1202J_01	WQ0014564001 / TX0127138	Koeblen Road WWTF	Fort Bend County MUD 162	Domestic	126	1	0.45	0.1851
1202J_01	WQ0012234002 / TX0084018	Brazos Bend State Park	Texas Parks and Wildlife	Domestic	126	1	0.016	0.0019
1202J_01	WQ0013940001 / TX0116408	Royal Lakes Estates	Royal Valley Utilities, Inc.	Domestic	126	1	0.2	0.0845
1202J_01	WQ0014175001 / TX0122459	Rose Meadows III WWTF	Aqua Texas, Inc.	Domestic	126	1	0.225	0.0730
1202J_01	WQ0014219001 / TX0123595	Needville Manufactured Housing Subdivision WWTF	Aqua Texas, Inc.	Domestic	126	1	0.3	–
1202J_01	WQ0015449001 / TX0136913	Vacek Country Meadows WWTF	Quadvest, L.P.	Domestic	126	1	0.1875	–
1202J_01	WQ0015295001 / TX0135747	Fort Bend County MUD 184	Fort Bend County MUD 184	Domestic	126	1	0.5	0.0297
1202J_01	WQ0014532001 / TX0126829	Fort Bend County MUD 152	Fort Bend County MUD 152	Domestic	126	1	0.98	0.5292

AU	TPDES /NPDES[a]	Facility Name	Permittee Name	Primary Discharge Type	Bacteria Limits (cfu/100 mL)	Outfall Number	Daily Average Flow - Permitted Discharge (MGD)	Daily Average Flow - Recent Discharge[b,c] (MGD)
1202J_01	**WQ0015798002 / TX0139912**	**Austin Bayou WWTF**	**The Signorelli Co.**	**Domestic**	**126**	**1**	**0.9**	**–**
1202J_01	WQ0005142000 / TX0135763	Petra Nova Carbon Capture Plant	Petra Nova CCS I LLC	Industrial	No	1	1.317	0.5024
1202J_01	WQ0005270000 / TX0139190	Braes Bayou Plant	ProEnergy Services, LLC	Industrial	No	1-5	0.189	–
1202J_01	WQ0001038000 / TX0006394	WA Parish Electric Generating Station	NRG TEXAS POWER LLC	Industrial	No	1-6	37	3.4970
1202J_01	WQ0014319001 / TX0124699	River Bend RV Park and Resort WWTF	Elena Sleptsova ODA	Domestic	126	1	0.025	N/A
1202J_01	WQ0010343001 / TX0027634	City of Needville WWTF	City of Needville	Domestic	126	1	0.4	N/A

[a] NPDES: National Pollutant Discharge Elimination System

[b] Reflects discharges available from January 2017 – May 2022, (EPA, 2022)

[c] WWTFs with no data within the EPA's system, N/A for discharges outside watershed

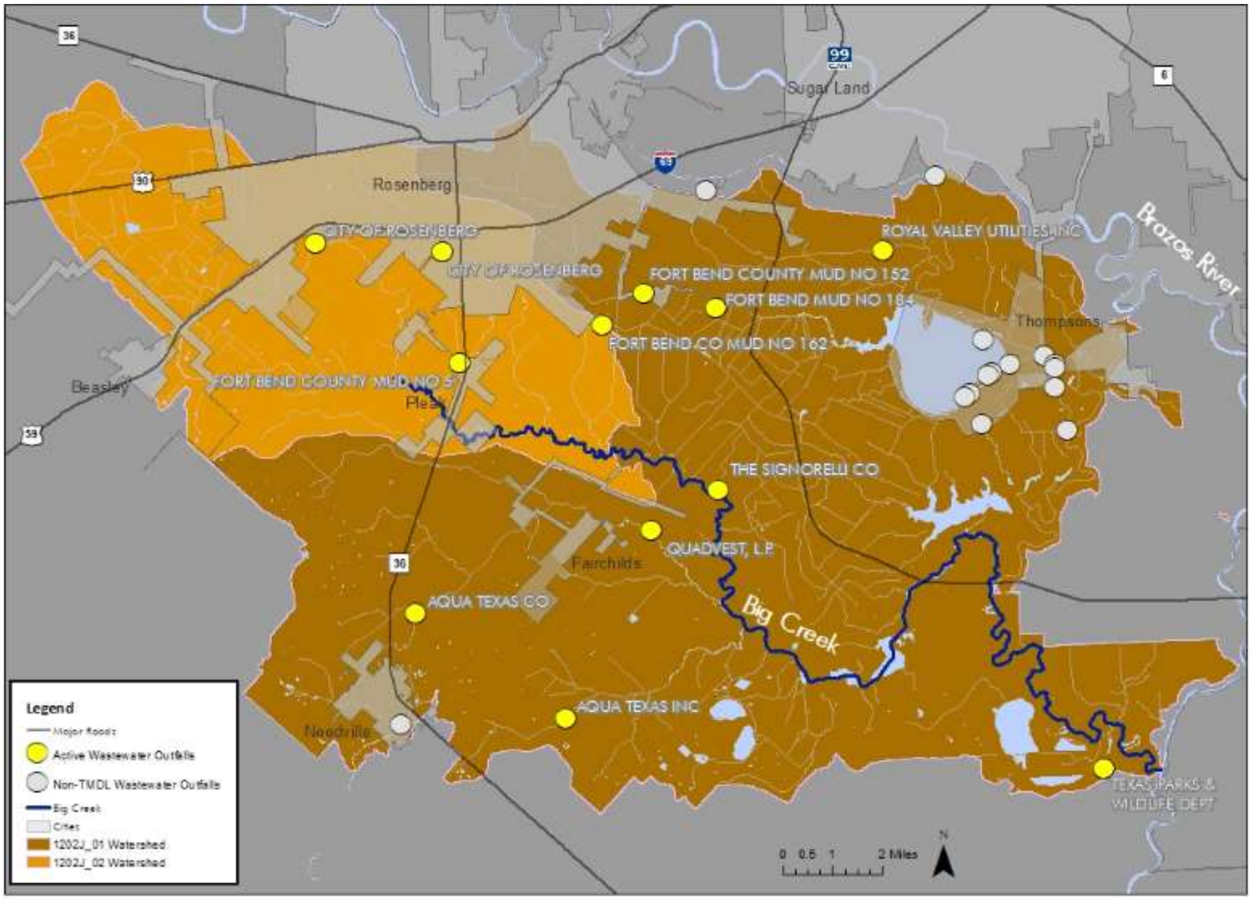

Figure 6. WWTF Outfalls

2.7.1.2 TCEQ/TPDES General Wastewater Permits

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

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

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

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

A review of active general permit coverage via TCEQ's Central Registry (TCEQ, 2022b) for the TMDL watershed as of May 1, 2022, found five general permit authorizations: four concrete production facilities and one aquaculture production facility (Table 7). These facilities do not have bacteria reporting requirements or limits in their permits. They are assumed to contain inconsequential amounts of indicator bacteria in their effluent; therefore, it was unnecessary to allocate bacteria loads to these facilities. No other active wastewater general permit authorizations were found.

Concrete production facilities are required to manage run-off from their property. The areas for each were estimated using county parcel data. The area under permit was found to be 75.71 acres. Three of the facilities were within an urbanized area and were not used to calculate the TMDL to prevent double counting. The area not included within an urbanized area was 9.25 acres.

Table 7. Active general permit coverage

Permit Type	Permit	Permittee	SIC Code
Concrete Production Facilities	TXG113042	717 Construction Services, LLC	3273
Concrete Production Facilities	TXG111575	Williams Brothers Construction Co., Inc.	3273
Concrete Production Facilities	TXG111970	Williams Brothers Construction Co., Inc.	3273
Concrete Production Facilities	TXG113157	Gomez Ready Mix LLC	3273
Aquaculture Production Facilities	TXG130058	Macky's Farm LLC	273

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 entities, stormwater discharges associated with regulated industrial activities, and construction activities.
2. Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities in urbanized areas to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized communities with populations of 100,000 or more based on the 1990 U.S. Census, while the Phase II General Permit regulates other MS4s within a USCB defined urbanized area.

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

- Public education, outreach, and involvement.
- Illicit discharge detection and elimination.
- Construction site stormwater runoff control.
- Post-construction stormwater management in new development and redevelopment.
- Pollution prevention and good housekeeping for municipal operations.
- Industrial stormwater sources.

Phase I MS4 individual permits have their own set of MCMs that are similar to the Phase II MCMs, but Phase I permits have additional requirements to perform water quality monitoring and implement a floatables program.

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

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

A review of active stormwater coverage via TCEQ's Central Registry (TCEQ, 2022b) for the Big Creek watershed was made on May 1, 2022. The review returned 10 Phase II MS4 permit authorizations within the Big Creek watershed (Table 8).

Table 8. MS4 entities

Regulated Entity	Authorization Type	TPDES Permit No.	Location
City of Rosenberg	Phase II	TXR040272	Area within the City of Rosenberg city limits that is within the Houston Urbanized Area
Plantation MUD	Phase II	TXR040226	Area within the City of Sugarland Extraterritorial Jurisdiction that is within the Houston Urbanized Area
Fort Bend County MUD 116	Phase II	TXR040422	Area within the City of Richmond city limits that is within the Houston Urbanized Area
Fort Bend County MUD 155	Phase II	TXR040480	Area within the City of Richmond city limits that is within the Houston Urbanized Area
Fort Bend County MUD 159	Phase II	TXR040481	Area within the Fort Bend County MUD 159 limits that is within the Houston Urbanized Area
Fort Bend County MUD 162	Phase II	TXR040504	Area within the City of Richmond city limits that is within the Houston Urbanized Area
Fort Bend County Drainage District	Phase II	TXR040383	Area within the Drainage District limits that is within the Houston Urbanized Area
Fort Bend County MUD 144	Phase II	TXR040588	Area within the Fort Bend County MUD 144 limits that is within the Houston Urbanized Area
Fort Bend County MUD 147	Phase II	TXR040582	Area within the Fort Bend County MUD 147 limits that is within the Houston Urbanized Area
Fort Bend County MUD 167	Phase II	TXR040551	Area within the Fort Bend County MUD 167 limits that is within the Houston Urbanized Area
TxDOT	Combined Phase I and Phase II MS4	TXS002101	TxDOT rights-of-way within Phase I MS4 area and Phase II MS4 Urbanized Areas

To determine the area of the Big Creek watershed likely under an MS4 Phase II permit, a review of the USCB's census defined urbanized area was made in July 2022 (USCB, 2010). This review determined the total urbanized area for Big Creek was 10.89% or 15,511.76 acres. This area is comprised of 9,541.73 acres and 5,970.03 acres in AU 1202J_01 and AU 1202J_02, respectively (Figure 7).

A review of the TCEQ Central Registry on May 1, 2022, found 13 distinct active MSGPs within the Big Creek watershed (TCEQ, 2022b). The area of these 13 MSGPs was estimated by reviewing Fort Bend County parcel data. The estimated total area was found to be 4,076.49, comprised of 3,606.06 acres and 470.43 acres in AU 1202J_01 and AU 1202J_02, respectively (Table 9). In two instances, two permits referred to the same parcel. To prevent the duplication of acreage, two permits were disregarded. Additionally, some of the MSGPs are found within the estimated census designated urbanized area and were thus disregarded to prevent duplication. Following these permit removals, the total area under a MSGP was estimated to be 3,658.38 acres, comprised of 3,571.40 acres and 86.99 acres in AU 1202J_01 and AU 1202J_02, respectively (Figure 7).

CGP authorizations are required when one acre or more of land is disturbed during construction. Construction activities found in the TMDL watershed change over time and the permit data found via the TCEQ Central Registry is only considered accurate for the date the data was accessed. Within the TCEQ Central Registry, CGP authorizations record disturbed areas as “Area Disturbed” acreages in the permit field. The acres recorded, due to the variable nature of these permits, serve only as a representative estimate, after summing up all disturbed areas, of the watershed area under a stormwater construction permit at any given time.

A review of the TCEQ Central Registry on May 1, 2022, for active, expired, terminated construction permits was made (TCEQ, 2022b). A five-year period of 2017–2021 was used to determine an annual average number of acres under a construction permit. Additionally, construction permits found within the watershed’s urbanized area were removed from the assessment. The annual total disturbed area was estimated to be 1,428.96 acres from 85 permits, 510.27 acres in AU 1202J_01 and 918.69 acres in AU 1202J_02.

The estimated regulated stormwater area was used to calculate the TMDL.

Table 9. MSGPs

AU	TPDES Number	Permittee/ Registrant	Facility Name	City	Estimated Acreage	Acreage Inside Watershed	MSGP Area Within MS4
1202J_01	TXR05R702	Fort Bend Regional Landfill, L.P.	Fort Bend Regional Landfill	Needville	2,596.11	2,596.11	0
1202J_01	TXR05V666	NRG Texas Power LLC	W A Parish Electric Generating Station	Thompsons	975.15	975.15	0
1202J_01	TXR05CL72	Alleyton Resource Company, LLC	Allied Concrete Shop	Rosenberg	0.14	0.14	0
1202J_01	TXR05FG29	Bmc West, LLC	Bison Rosenberg	Rosenberg	34.66	34.66	34.66
				Total	**3,606.06**	**3,606.06**	**34.66**
1202J_02	TXR05AN49	Oldcastle APG West, Inc.	Eagle Cordell Concrete Products	Rosenberg	40.16	40.16	0
1202J_02	TXR05CS25	Williams Brothers Construction Co., Inc.	Beasley Crusher	Rosenberg	46.83	46.83	0
1202J_02	TXR05CT70	Williams Brothers Construction Co., Inc.	Beasley Pug Mill	Rosenberg	46.83	N/A	N/A
1202J_02	TXR05EX19	Martin Marietta Materials Southwest, LLC	Rosenberg Yard	Rosenberg	7.48	7.48	7.48
1202J_02	TXR05CF88	Engelbrecht Manufacturing Inc.	Engelbrecht Manufacturing	Rosenberg	2.36	2.36	2.36
1202J_02	TXR05AO32	City of Rosenberg	City of Rosenberg Wastewater Treatment Plant No 2	Rosenberg	17.14	17.14	17.14
1202J_02	TXR05AV88	Sprint Sand and Clay, LLC	Koeblen Road Sand Pit	Richmond	41.15	41.15	41.15
1202J_02	TXR05CU58	Cherry Crushed Concrete, Inc.	Cherry Crushed Concrete	Richmond	134.24	134.24	134.24
1202J_02	TXR05FN74	Cherry Crushed Concrete, Inc.	Wesson Sand Richmond Pit	Richmond	134.24	N/A	N/A
				Total	**470.43**	**289.36**	**202.37**

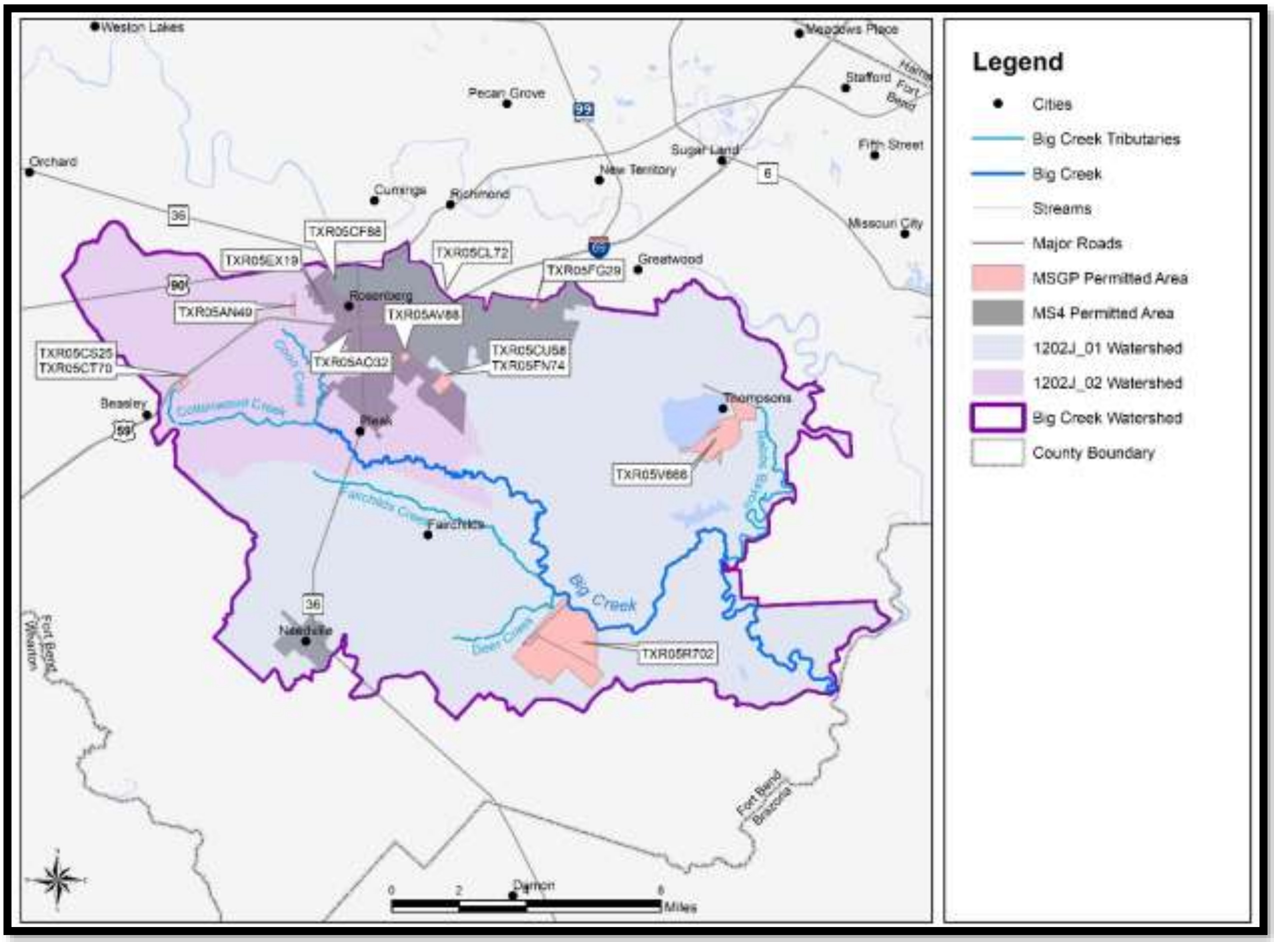

Figure 7. Urbanized areas and MSGPs

2.7.1.4. Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. In dry weather, these overflows most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration (I&I) are typical causes of overflows under conditions of high flow in the WWTF system. Blockages in the line may worsen the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

SSOs reported between 2016 and 2021 were reviewed (TCEQ, 2022c). For the WWTFs identified in Table 6, eight of the facilities reported at least one SSO during the timeframe. There were a total of 38 SSOs that discharged 209,200 gallons of untreated wastewater into the watershed. The number one reported cause was equipment failure (13) followed by blockages (9) and rainfall infiltration (7).

2.7.1.5. Dry Weather Discharges/Illicit Discharges

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

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

Direct Illicit Discharges:

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

Indirect Illicit Discharges:

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

2.7.2. Unregulated Sources

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

2.7.2.1. Wildlife and Unmanaged Animals

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

Most avian and mammalian wildlife, including invasive species, are difficult to estimate, as long-term monitoring data or literature values indicating historical baselines are lacking. However, the White-Tailed Deer Program of the Texas Parks and Wildlife Department (TPWD) estimates deer populations for their Resource Management Units. In the ecoregion surrounding Big Creek for Deer Management Unit 10, TPWD deer population estimates recorded from 2008 through 2019 average one deer for every 25.27 acres (TPWD, 2020). By applying this factor to the acreage of the Big Creek watershed, the white-tailed deer population is estimated at 5,634 (Table 10).

Table 10. Estimated deer population

AU Watershed	Area (acres)	Estimated Deer Population
1202_01	105,457.73	4,173
1202_02	36,927.36	1,461
Total	**142,385.09**	**5,634**

Feral hogs are a non-native, invasive species, which likely impact the watershed with fecal waste contamination. Like deer, factors for estimating feral hog populations based on land area are available. These factors vary depending on land cover types and range between 8.9 and 16.4 hogs per square mile (Timmons et al., 2012). Feral hog population estimates may be weighted more heavily in riparian areas where animals are protected from the stresses associated with development and have more direct access to water resources. Considering these factors, feral hog populations were estimated to be 8.9 per square mile in Developed-Low Intensity, Barren Land, and Cropland ("Low Quality"); 16.4 per square mile in Developed-Open Space, Pasture/Grassland, Forest/Shrubs and Wetlands ("High Quality"); and assuming no hogs in other developed areas or open water. Using these assumptions, the total feral hog population for the Big Creek watershed is estimated to be 2,854 (Table 11).

Table 11. Feral hog estimated population

AU Watershed	Low Quality (acres)	Feral Hogs	High Quality (acres)	Feral Hogs	Total
1202J_01	34,120.84	474	64,212.33	1,645	2,119
1202J_02	14,409.11	200	20,891.44	535	735
Total	**48,529.95**	**674**	**85,103.78**	**2,180**	**2,854**

The *E. coli* contribution from feral hogs and wildlife could not be determined based on existing information.

2.7.2.2. Unregulated Agricultural Activities and Domesticated Animals

Several agricultural activities that do not require permits can be potential sources of fecal bacteria loading.

In Table 12, estimates of livestock in the TMDL watershed are shown. Livestock numbers from the 2017 Census of Agriculture are provided at the county level for Fort Bend County collected by the USDA (USDA, 2022). The county livestock numbers were distributed equally across livestock and farm operations in pasture and grassland land cover types within the county. To determine the number of livestock within each subwatershed, the number of livestock per acre was calculated for Fort Bend County and then that stocking rate was applied to each subwatershed based on the proportion of the county found within each subwatershed. Livestock numbers are not used to develop the TMDL loading allocation.

Table 12. Estimated livestock populations

Area Name	Area (Acres)	Cattle and Calves	Hogs and Pigs	Sheep and Goats	Equine	Poultry
Fort Bend	197,123	31,605	54	983	2,027	2,796
1202J_01	43,380	6,955	12	216	446	615
1202J_02	16,187	2,595	4	81	166	230

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 13 summarizes the estimated number of dogs and cats in the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household according to data from the American Veterinary Medical Association (AVMA) 2017-2018 U.S. Pet Statistics (AVMA, 2018). The number of households in the watershed was based on H-GAC's Regional Forecast analysis of the USCB 2020 Decadal Census (H-GAC, 2022a). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 13. Estimated pet population

AU Watershed	Estimated Households	Dogs	Cats
1202J_01	15,655	9,612	7,154
1202J_02	5,844	3,588	2,671
Total	**21,499**	**13,200**	**9,825**

2.7.2.3. On-Site Sewage Facilities

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

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters if the systems are not properly operating. Properly designed and operated, however, OSSFs contribute virtually no fecal bacteria to surface waters. For example, Weiskel et al. (1996) reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system. Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The TMDL watershed is within the Region IV area, which has a reported failure rate of about 12%, providing insights into expected failure rates for the area.

Some OSSFs in the watershed are operated under permit; however, some units are unregistered or not consistently reported. For the purposes of this report, all OSSFs will be treated as unregulated sources of fecal waste due to the nature of their permits, lack of reported data, and diffuse nature.

Within Big Creek watershed, 4,227 registered OSSFs have been documented (Table 14, (H-GAC, 2022b). Non-registered OSSF locations were estimated using H-GAC's geographic information database of potential OSSF locations (H-GAC, 2022c) in the Houston-Galveston area using known OSSF locations, 911 addresses, and WWTF service boundaries. For the TMDL watershed there is an estimated additional 2,598 non-registered OSSF units. Figure 8 presents the estimated registered and non-registered OSSF locations within the TMDL watershed.

Table 14. Estimated OSSFs

AU	Registered	Non-registered	Total
1202J_01	2,832	2,024	4,856
1202J_02	1,395	574	1,969
Total	**4,227**	**2,598**	**6,825**

OSSFs can be an appreciable source of fecal waste when not sited or functioning properly, especially when they are in close proximity to waterways. Many factors including soil type, design, age, and maintenance can influence the likelihood of an OSSF failure. By applying the estimated 12% failure rate to the 6,825 OSSFs estimated within the TMDL watershed (Table 14), 819 OSSFs are projected to be failing.

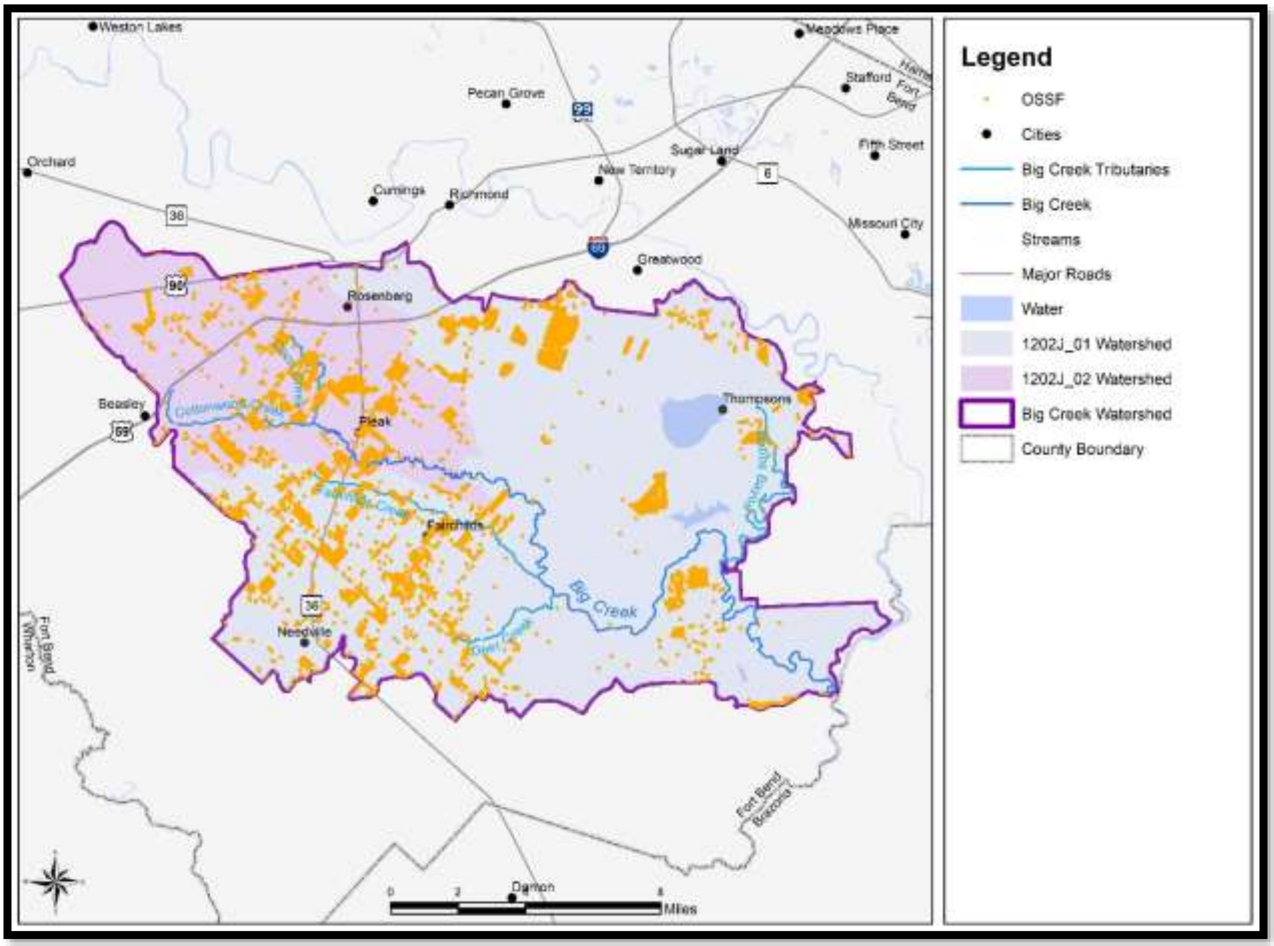

Figure 8. Estimated OSSF locations

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

Section 3. Bacteria Tool Development

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

3.1. Tool Selection

The goal of the TMDL process is to determine an assimilative loading value, i.e., *E. coli* concentration, for a water body such that the value does not exceed the standards criteria developed for that pollutant. The loading value cannot be developed with available environmental watershed data as that data is most likely insufficient or incomplete to fully describe a system like a watershed. A tool or method is usually required to approximate a real-world system. Watershed models "provide an approach, besides monitoring data and export coefficients, for estimating loads, providing source load estimates, and evaluating various management alternatives" (Hauck, 2009). The models can assist by filling in missing data and information by relying on observable or mathematically derived relationships linking physical, chemical, and biological processes.

Mechanistic models traditionally use mathematically or theoretically described relationships to interpret real systems governed by well-known physical process and response variables (e.g., bacterial concentrations and streamflow to precipitation) (Hauck, 2015). There are several mechanistic models available, many capable of handling the needed response and condition values ranging from tidal flow and stream flow, dry to wet weather, land use and rainfall run-off and other hydrologic processes. Other authors suggest that "while the ability of bacteria models has advanced there remain deficiencies in available watershed data to sufficiently fill the physical and biological process identified in the mechanistic models" (Hauck, 2015). With other useful and often simpler tools available to develop TMDL loadings, the more complex and sophisticated mechanistic models may not be the better option.

The LDC method allows for the estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data. Texas and other states have successfully used the LDC method to develop TMDLs which have been accepted by the regulatory community due to the method's simplicity and ability to address information limitations commonly found with bacteria TMDLs. The LDC has become recommended as part of a three-tiered approach by the appointed bacteria task force driven by TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) (TWRI, 2007).

The LDC has limitations, as it will not fully quantify individual source contributions of all point and nonpoint loads, nor is it capable of assessing load reductions provided by specific bacteria reduction management measures. It is recommended here as it provides a simple means for determining the loading value across moisture conditions and can be broadly used to indicate sources of bacteria (e.g., point source and nonpoint source.)

3.2. Data Resources

Both flow data (observed or modeled) and bacteria results are necessary to develop LDCs. U.S. Geological Survey (USGS) flow gages are a typical source of flow data as they represent long-term, continuous flow which is easily adapted to a curve. H-GAC evaluated data for all TCEQ SWQM stations (Figure 2) in the watershed to determine the most representative sites for developing LDCs. One LDC was developed for each AU. In AU 1202J_02, TCEQ SWQM Station 17551 corresponds with a USGS flow gage (08115000), and is the most downstream site in the AU, making it the most representative site with the most sufficient data. Observed bacteria data do not include data after 2012 (Table 2), but there were no other more representative sites in the AU. However, the lack of current data should be taken as a caveat in the applicability of TCEQ SWQM Station 17551's LDC.

In AU 1202J_01 there are no USGS flow gages that correlate to TCEQ SWQM stations. Based on breadth and currency of SWQM data, TCEQ SWQM Station 16353 is the most representative station in the watershed, and is the sole station currently being monitored. While there are stations further downstream, they have less available data, are more likely to be influenced by mixing from the confluence with the Brazos River and are less representative of conditions upstream as they benefit from the more natural areas in and surrounding Brazos Bend State Park.

All the required water quality data (*E. coli* and flow) were adequately available, with the noted exceptions above, through the Surface Water Quality Monitoring Information System (SWQMIS) for the period of 2004–2012 for AU 1202J_02, and 2004–2020 for AU 1202J_01. The extrapolated flow for TCEQ SWQM Station 16353 in AU 1202J_01 was developed for the full period between 2004–2020. SWQMIS is a database that serves as the repository for TCEQ surface water quality data for the state of Texas. All data used for these analyses were collected under a TCEQ-approved Quality Assurance Project Plan. Qualified data (data added to SWQMIS with "qualifier" codes that identify quality, sampling, or other problems that may render the data unsuitable) were excluded from the download. All data for all stations, collected from Jan. 1, 2004, through Dec. 31, 2020, were combined into working datasets for LDC development.

3.3. Method for Developing Flow Duration and Load Duration Curve

To develop the flow duration curve (FDC) and LDC, the previously discussed data resources were used in the following sequential steps.

- Step 1: Determine the hydrologic period of record to be used in developing the FDC.
- Step 2: Determine the stream location for which FDC and LDC development is desired.
- Step 3: Develop daily streamflow record at desired location.

- Step 4: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDC.

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

3.3.1. Step 1: Determine Hydrologic Period

A period of 17 years between January 2004 and December 2020 was observed to cover a timeframe sufficient to encompass both drought and flood years as referenced in Section 2.3.

3.3.2. Step 2: Determine Desired Stream Location

Data from TCEQ SWQM stations 16353 and 17932 will be used to develop the TMDL for AU 1202J_01. Data from TCEQ SWQM Station 17932 will be used to augment the historic data for TCEQ SWQM Station 16353. Data from TCEQ SWQM Station 17551 will be used to develop the TMDL for AU 1202J_02. USGS gage 08115000 located at TCEQ SWQM Station 17551 will be used for daily instream flow.

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

The USGS gage instream flow record was used directly for development of the FDC for TCEQ SWQM Station 17551 due to its co-occurrence with the SWQM station.

For the development of instream flow for TCEQ SWQM Station 16353, the flow records were "naturalized" by subtracting WWTF discharge and adding 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 cover of the watershed, and other factors. The naturalized daily streamflow records were developed from extant USGS records.

Three WWTFs maintain outfall permits to discharge to Big Creek above USGS gage 08115000. The estimated daily DMR reported by the three discharges for the time period of 2016 to 2020 from the WWTF outfall (Table 15) was subtracted from the daily gage streamflow records. This resulted in an adjusted streamflow record with the point source discharge influence removed.

Table 15. Big Creek Permitted Discharges above USGS gage 08115000

TPDES Number	NPDES Number	Permittee	Average Daily Flow (MGD)
WQ0014757001	TX0129194	Fort Bend County MUD 5	0.15
WQ0010607002	TX0024490	City of Rosenberg	1.86
WQ0010607004	TX0125512	City of Rosenberg	0.002

Next, water right consumptions (i.e., the balance between diverted amount and returned flow amount) were researched for the period of 2004 to 2020 (TCEQ, 2022d). No water right diversions were found for the period above the USGS gage station.

The daily, freshwater flow values at TCEQ SWQM Station 16353 were calculated based on the drainage-area ratio (DAR) method. The DAR method involves multiplying a USGS gaging station (08115000) daily streamflow value by a factor to estimate the flow at a desired TCEQ SWQM station location, TCEQ SWQM Station 16353. The factor is determined by dividing the drainage area upstream of the desired monitoring station, TCEQ SWQM Station 16353, by the drainage area upstream of the USGS gage. The calculated DAR, 4.44, is then applied to the daily streamflow measurements for TCEQ SWQM Station 17551 to determine the estimated daily flow value at TCEQ SWQM Station 16353.

Table 16. DAR calculations for USGS Gage 08115000 and TCEQ SWQM Station 16353

Catchment	Area (square miles)	DAR
USGS Gage Station 08115000	46.98	--
SWQM Station 16353	208.49	4.44

Following application of the DAR, the full permitted flows from WWTFs within the TMDL watershed (Table 6) were added to the streamflow record along with future growth (FG) flows (calculated in Section 4.7.4) that account for the probability that additional flows from WWTF discharges may occur as a result of population increases. Additionally, water rights diversions in the catchment area below TCEQ SWQM Station 17551 were removed.

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

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

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

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor (2.44658×10^9), which gives you a loading unit of cfu/day.

- Plot the exceedance percentages, which are identical to the value for the streamflow data points, against the geometric mean criterion for *E. coli*.

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

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

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

3.4. Flow Duration Curve for the TMDL Watersheds

In Figures 9 and 10, the FDCs for TCEQ SWQM stations 16353 and 17551, respectively, are shown. The curves are separated into five flow regimes including high flows (0-10%), moist conditions (10–40%), mid-range flows (40–60%), dry conditions (60–90%), and low flows (90–100%) (Cleland, 2003).

For reference, the *E. coli* geometric mean criterion curve (load at 126 cfu/100 mL) and the *E. coli* single sample criterion curve (load at 399 cfu/100 mL) are also included on the FDCs.

3.5. Load Duration Curve for the TMDL Watersheds

Figures 11 and 12 present the LDCs for TCEQ SWQM stations 17551 and 16353. The figures include the FDC, the *E. coli* geometric mean, and single sample criterion curves (loads at either 126 or 399 cfu/100 mL), the existing load curve, the existing geometric mean load by flow regime (single points), and individual bacteria samples.

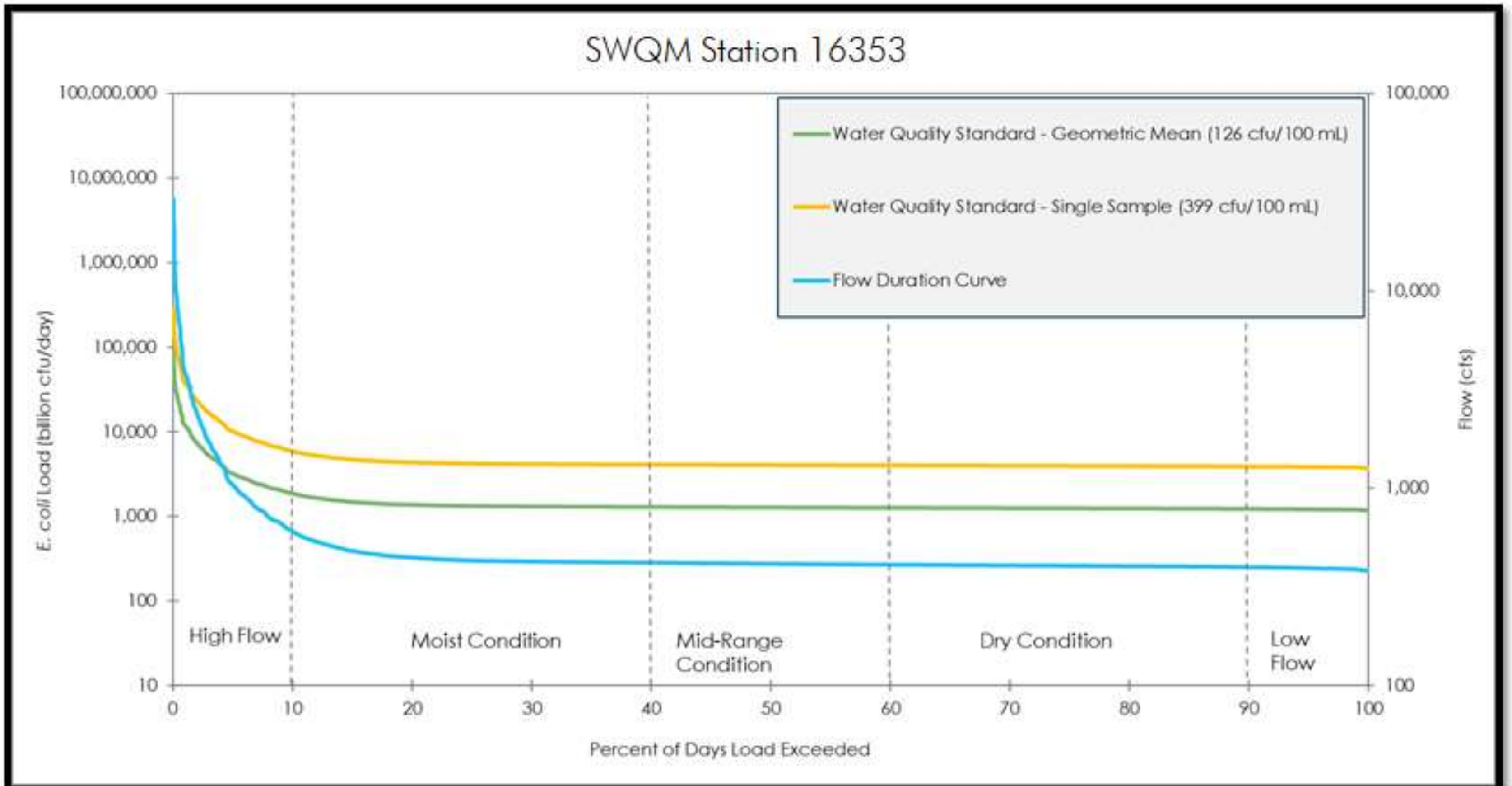

Figure 9. FDC for TCEQ SWQM Station 16353 on AU 1202J_01

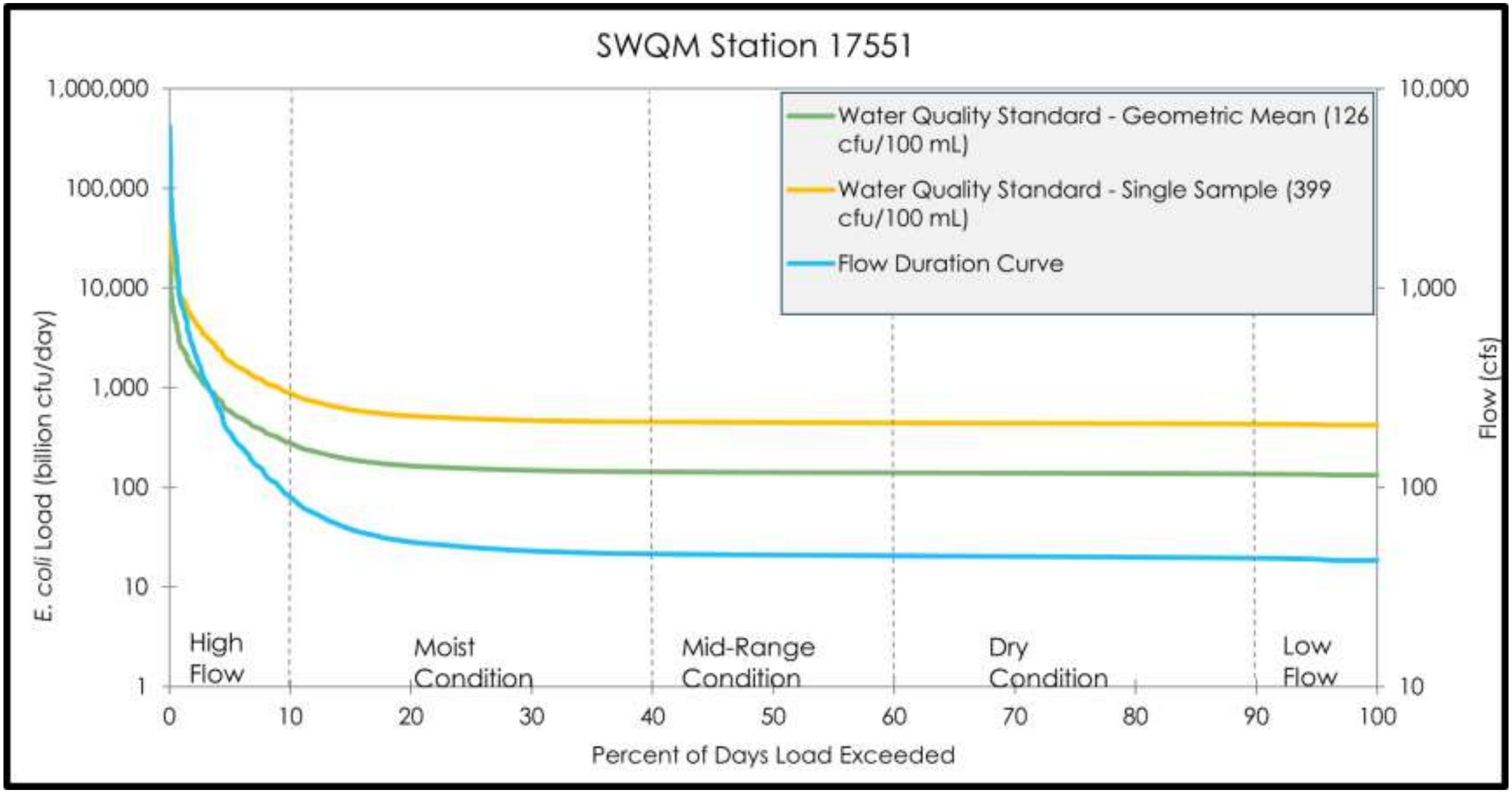

Figure 10. FDC for TCEQ SWQM Station 17551 on AU 1202J_02

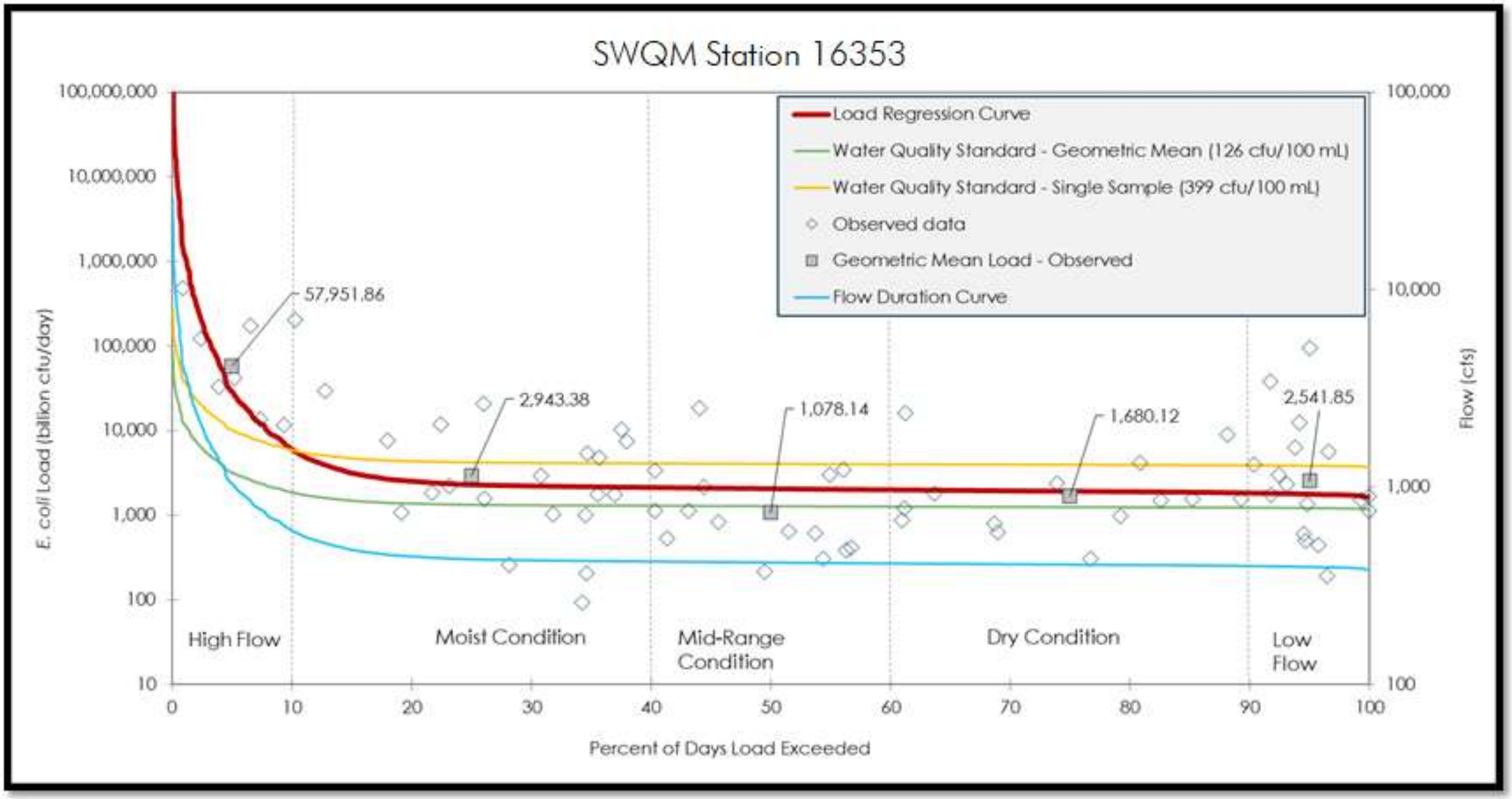

Figure 11. LDC for TCEQ SWQM Station 16353 on AU 1202J_01

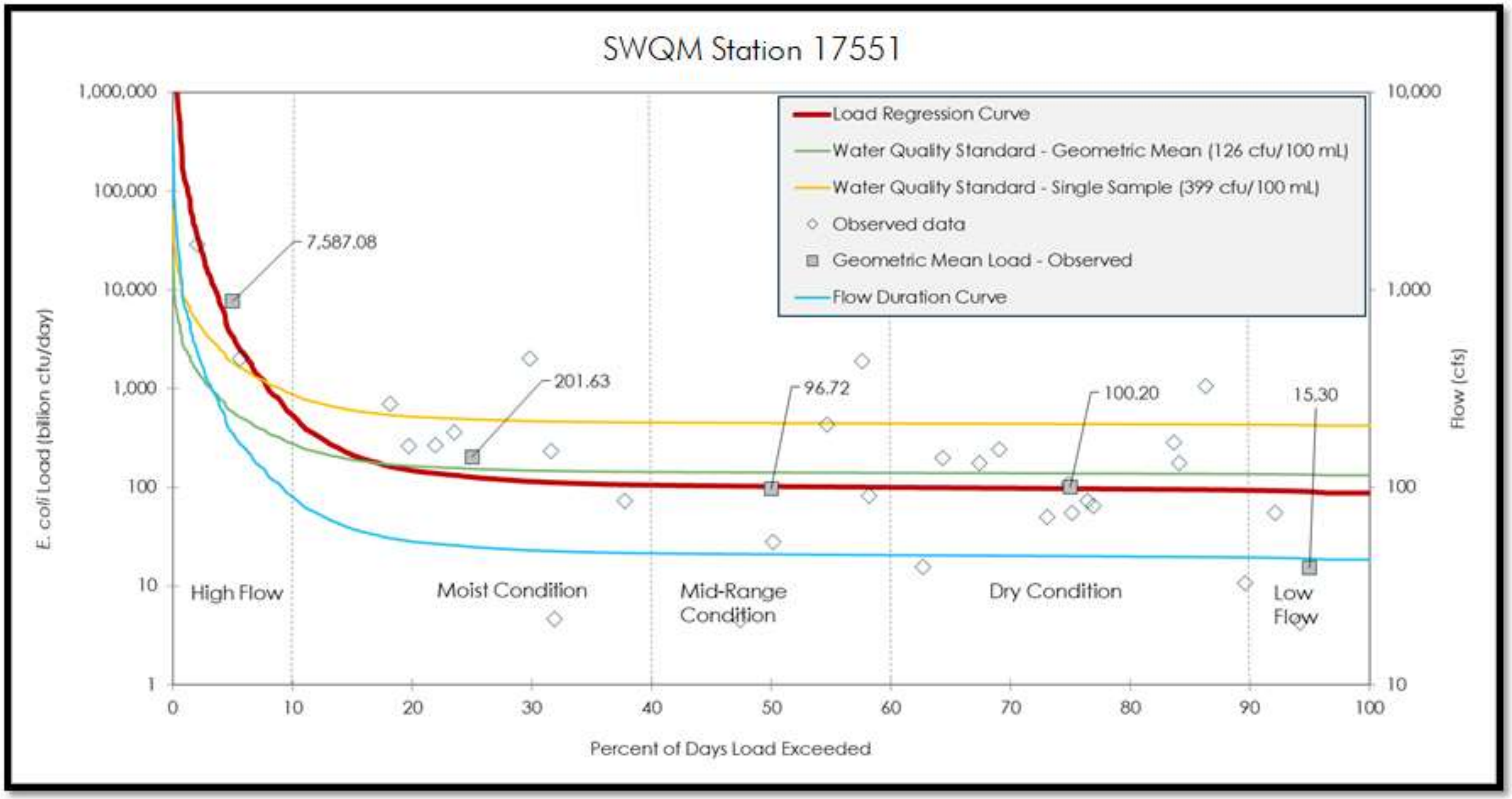

Figure 12. LDC for TCEQ SWQM Station 17551 in AU 1202J_02

Section 4. TMDL Allocation Analysis

4.1. Endpoint Identification

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

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

4.2. Seasonal Variation

Seasonal variations occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. TMDLs must account for seasonal variation in watershed conditions and pollutant loading, as required by federal regulations [Title 40, Code of Federal Regulations, Chapter 1, Part 130, Section 130.7(c)(1) (or 40 CFR 130.7(c)(1))] (EPA, 1991).

To evaluate potential seasonal difference, ambient monitoring data for Big Creek was grouped into a cool season (November–March) and a warm season (May–September). Data collected in April and October was excluded, assuming those months are transitions between the two seasons. There was no discernable difference observed comparing seasons using a Wilcoxon rank-sum analysis of the data.

4.3. Linkage Analysis

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

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

Bacteria load contributions from regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, can carry bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline as runoff washes 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 inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That allocation was based on the flows associated with the watershed areas under stormwater regulation, and the remaining portion was assigned to the unregulated stormwater.

4.4. Load Duration Curve Analysis

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

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

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

At TCEQ SWQM Station 17551, the load regression curve modeled from observed data exceeds the curve representing the geometric mean maximum in only the high and moist flow conditions (Figure 12). This would suggest that nonpoint sources, those sources present in rainfall events, contribute to the elevated levels of indicator bacteria. It should be pointed out again, data was more limited for this portion of the Big Creek watershed, data not being collected since 2012. Changes to the watershed since 2012 could potentially change this relationship.

A review of the LDC for TCEQ SWQM Station 16353 is markedly different from the LDC for TCEQ SWQM Station 17551. While large reductions are needed in higher flow conditions, here we see the curve stay above the standard curve throughout all flow conditions (Figure 11). This would indicate the influence of both nonpoint sources and point sources as contributors to the impairment. While reduction strategies targeting improvement of nonpoint source pollutants may have greater impacts at this site, improvements to both point and nonpoint source loading will positively affect the watershed.

4.5. Margin of Safety

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

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

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

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

4.6. Load Reduction Analysis

A review of the LDCs suggest that at high flows, bacteria concentrations at both TCEQ SWQM stations are above the primary contact recreation 1 standard. For TCEQ SWQM Station 17551, the concentration dips below the standard within the moist condition and remains below throughout the rest of the LDC (Figure 12). Figure 11 shows that the overall bacteria concentration remains above the standard for all flow regimes. However, it should be noted that the geometric mean for data within the mid-range condition fell just below the standard curve. There is insufficient information at this time to determine the reason bacteria concentrations are meeting the standard at this flow regime while not at the other regimes.

For determining the TMDL, the highest flow regimes are used. The highest reductions required are found with the high flow regime. The high flows are indicative of nonpoint source load pressures; however, point sources should also be considered as targets for improvement. The LDC results indicated potential point source influence in the watershed on bacteria loads in dry and low flow conditions (Figure 11).

Comparing the geometric mean concentrations within each flow regime to that of the standard can suggest the load reduction necessary to meet the standard. Table 17 presents the results of this comparison, suggesting potential reduction targets for *E. coli* loads at each flow condition.

Table 17. Load reduction calculations for TCEQ SWQM stations 17551 and 16353

AU	Flow Condition	Exceedance Range	Geometric Mean (cfu/100 mL)	Required Percent Reduction
1202J_01	High Flow	(0-10%)	1,893.73	93.35%
	Moist	(10-40%)	274.20	54.05%
	Mid-Range	(40-60%)	106.23	0.00%
	Dry	(60-90%)	169.78	25.79%
	Low Flow	(90-100%)	264.73	52.40%
1202J_02	High Flow	(0-10%)	1,099.77	88.54%
	Moist	(10-40%)	164.97	23.62%
	Mid-Range	(40-60%)	86.73	0.00%
	Dry	(60-90%)	91.54	0.00%
	Low Flow	(90-100%)	14.28	0.00%

4.7. Pollutant Load Allocations

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

$$TMDL = WLA + LA + FG + MOS \qquad \text{(Equation 1)}$$

Where:

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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

4.7.1. Assessment Unit-Level TMDL Calculations

The bacteria TMDL for the water body was developed as a pollutant load allocation based on information from the LDC for the TCEQ SWQM stations within the watershed (Figure 2). As discussed in more detail in Section 3, the bacteria LDCs were developed by multiplying each flow value along the FDC by the *E. coli* criterion (126 cfu/100 mL) and by the conversion factor used to represent maximum loading in cfu/day. Effectively, the "Allowable Load" displayed in the LDC at 5% exceedance (the median value of the high flow regime) is the TMDL.

TMDL (cfu/day) = criterion * flow (cfs) * conversion factor (Equation 2)

Where:

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

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

The allowable loading of *E. coli* that the impaired watershed can receive on a daily basis was determined using Equation 2 based on the median value within the high flow regime of the FDC (or 5% flow exceedance value) for the TCEQ SWQM stations (Table 18).

Table 18. Summary of allowable loading calculation

AU	Criterion (cfu/100 mL)	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (Billion cfu/day)
1202J_01	126	1,038.968	3.203E+12	3,202.806
1202J_02	126	187.971	5.795E+11	579.454

4.7.2. Margin of Safety Allocation

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

MOS = 0.05 * TMDL (Equation 3)

Using the value of TMDL for the AU provided in Table 18, the MOS may be readily computed by proper substitution into Equation 3 (Table 19).

Table 19. MOS calculation

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

AU	TMDL[a]	MOS
1202J_01	3,202.806	160.140
1202J_02	579.454	28.973

[a] TMDL from Table 18

4.7.3. Wasteload Allocations

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

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Equation 4)}$$

4.7.3.1. Wastewater

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

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \qquad \text{(Equation 5)}$$

Where:

Target = 126 cfu/100 mL for *E. coli*

Flow = full permitted flow (MGD)

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

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for each AU. The criterion was applied based on the indicator bacteria designated for that water body. Table 20 presents the WLA for each WWTF and the resulting total allocation for the AU within the TMDL watershed. For AU 1202J_01, WLA_{wwtf} is the sum of WLA for AU 1202J_01 and 1202J_02 from Table 20.

Table 20. WLAs for TPDES-permitted facilities in the TMDL watershed

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

Watershed (AU)	TPDES Permit No.	NPDES Permit No.	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{wwtf}
1202J_02	WQ0014757001	TX0129194	Fort Bend County MUD 5	0.5000	2.3848
1202J_02	WQ0010607002	TX0024490	City of Rosenberg	4.5000	21.4633

Watershed (AU)	TPDES Permit No.	NPDES Permit No.	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{wwtf}
1202J_02	WQ0010607004	TX0125512	City of Rosenberg	0.0950	0.4531
			Total	**5.0950**	**24.3012**
1202J_01	WQ0012234002	TX0084018	Texas Parks and Wildlife	0.0160	0.0763
1202J_01	WQ0013940001	TX0116408	Royal Valley Utilities, Inc.	0.2000	0.9539
1202J_01	WQ0014175001	TX0122459	Aqua Texas, Inc.	0.2250	1.0732
1202J_01	WQ0014564001	TX0127183	Fort Bend County MUD 162	0.4500	2.1463
1202J_01	WQ0014219001	TX0123595	Aqua Texas, Inc.	0.3000	1.4309
1202J_01	WQ0015449001	TX0136913	Quadvest, L.P.	0.1875	0.8943
1202J_01	WQ0015295001	TX0135747	Fort Bend County MUD 184	0.5000	2.3848
1202J_01	WQ0014532001	TX0126829	Fort Bend County MUD 152	0.9800	4.6742
1202J_01	WQ0015798002	TX0139912	The Signorelli Co.	0.9000	4.2927
			Total	**3.759**	**17.9266**

[a] Full Permitted Flow from Table 6.

4.7.3.2. Regulated Stormwater

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

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

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \quad \text{(Equation 6)}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}; Table 21) must be determined to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits, as described in section 2.7.1.3. Additionally, to account for upstream contributions, 1202J_01 FDA_{swp} combines the watershed permit area and drainage area above in 1202J_02 with that of 1202J_01.

Table 21. Basis of regulated stormwater area and computation of FDA_{SWP} term

AU	Total Area (acres)	Concrete Production Facility (acres)	MS4 Area (acres)	MSGP Area (acres)	CGP Area (acres)	Total Area of Permits (acres)	FDA_{swp}
1202J_01	142,385.09	9.25	15,511.76	3,658.38	1,428.96	20,608.35	0.1447
1202J_02	36,927.36	0.00	5,970.03	86.99	918.69	6,975.71	0.1889

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. To calculate the WLA_{SW} (Equation 6), the FG term must be known. The calculation for that term is presented in the next section, but the results will be included here for continuity. Table 22 provides the information needed to compute WLA_{SW}.

Table 22. Regulated stormwater WLA calculation

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

AU	TMDL[a]	MOS[b]	WLA_{wwtf}[c]	FG[d]	FDA_{swp}[f]	WLA_{sw}[g]
1202J_01	3,202.806	160.140	42.228	180.207	0.1447	408.191
1202J_02	579.454	28.973	24.301	82.731	0.1889	83.769

[a] TMDL from Table 18

[b] MOS from Table 19

[c] WLA_{WWTF} from Table 20

[d] FG from Table 23

[f] FDA_{SWP} from Table 21

[g] WLA_{SW} = (TMDL – WLA_{WWTF} – FG - MOS) *FDA_{SWP} (Equation 6)

4.7.4. Future Growth

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

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

The FG component was based on population projections and current permitted wastewater dischargers for the entire TMDL watershed. The rate in recent population and projected population growth between 2020 and 2050 for the TMDL watershed is provided in Table 23. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth per AU watershed between 2020 and 2050 to determine the estimated future flows.

Thus, the FG is calculated as follows:

$$FG = Criterion * (WWTF_{FP} * \%POP_{2020\text{-}2050}) * Conversion\ Factor \qquad \text{(Equation 7)}$$

Where:

Criterion = 126 cfu/100 mL

$\%POP_{2020\text{-}2050}$ = estimated percent increase in population between 2020 and 2050

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

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

The calculation results for the TMDL watershed are shown in Table 23. FG for AU 1202J_01 for calculating the TMDL is a sum of FG AU 1202J_01 and 1202J_02 from Table 23, 180.207 billion cfu/day.

Table 23. FG calculations

AU	Full Permitted Flow (MGD)	% Population Increase (2020-2050)	FG[a] (MGD)	FG[a,b] (*E. coli* Billion cfu/day)
1202J_01	3.759	543.75%	20.437	97.4759
1202J_02	5.095	340.44%	17.345	82.7311
Total	8.854	- %	37.782	180.207

[a]FG in 1202J_01 is not combined with FG in 1202J_02 in this table

[b]FG = Criterion * $WWTF_{FP}$ * $\%POP_{2020\text{-}2070}$ * Conversion Factor (Equation 7)

4.7.5. Load Allocations

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

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \quad \text{(Equation 8)}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 24.

Table 24. LA calculation

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

AU	TMDL[a]	MOS[b]	WLA_{wwtf}[c]	WLA_{sw}[d]	FG[e]	LA[f]
1202J_01	3,202.806	160.140	42.228	408.191	180.207	2,412.04
1202J_02	579.454	28.973	24.301	83.769	82.731	359.68

[a] TMDL from Table 18

[b] MOS from Table 19

[c] WLA_{WWTF} from Table 20

[d] WLA_{SW} from Table 22

[e] FG from Table 23

[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Equation 8)

4.8. Summary of TMDL Calculations

Table 25 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0–10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDCs developed for TCEQ SWQM stations 16353 and 17551 for AUs 1202J_01 and 1202J_02, respectively. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL. The TMDL allocation summary for the Big Creek TMDL watershed is summarized in Table 25.

Table 25. TMDL allocation summary

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

AU	TMDL[a]	MOS[b]	WLA_{wwtf}[c]	WLA_{sw}[d]	LA[e]	FG[f]
1202J_01	3,202.806	160.140	42.228	408.191	2,412.04	180.207
1202J_02	579.454	28.973	24.301	83.769	359.68	82.731

[a] TMDL from Table 18

[b] MOS from Table 19

[c] WLA_{WWTF} from Table 20

[d] WLA_{SW} from Table 22

[e] LA from Table 24

[f] FG from Table 23

The final TMDL allocation (Table 26) needed to comply with the requirements of 40 CFR 130.7 includes the FG component within the $WLA_{WWTF.}$

Table 26. Final TMDL allocation

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

AU	TMDL	MOS	WLA_{wwtf}[a]	WLA_{sw}	LA
1202J_01	3,202.806	160.140	222.435	408.191	2,412.04
1202J_02	579.454	28.973	107.032	83.769	359.68

[a] WLA_{WWTF} includes the FG component

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Appendix A. Method Used to Determine Population Projections

H-GAC, through its Regional Growth Forecast, routinely assesses the region's population and develops population projections. To estimate future population, H-GAC used their Demographic Evolution Model. The model creates a virtual accounting of future people and households within an eight-county area. The model accounts for either the addition or removal of residents due to births, deaths, in-migrants, and out-migrants. The model is a computer simulation which uses a probabilistic approach to imitate both the biologic events and social events that drive the addition and/or removal for the synthesized individuals and households (H-GAC, 2022a).

To accommodate the future households and populations, H-GAC developed a Real Estate Development Model that acts like a real estate developer and generates predictions for Single-Family and Multi-Family units on specific parcels, given the physical availability/suitability of land and economic feasibility.

Once the new residential units are built, H-GAC's Household Location Choice Model allocates future households to new housing units using the grid-level (3-mile grid) location probabilities categorized by age-race-household size and income.

Finally, the household and population data are summarized by various geographies including counties, cities, census tracts, 3-square-mile grids and traffic analysis zone.

The Regional Growth Forecast Methodology, a report that fully discusses the steps H-GAC uses to determine future population growth is available on the H-GAC webpage (H-GAC, 2017). The following steps detail the method used to estimate the 2020 and projected 2050 populations in the TMDL Project watershed.

1. The H-GAC regional forecast team obtained USCB 2020 Decadal Census data from the USCB at the block level.
2. The H-GAC regional forecast team used census block data to develop population estimates for a hexagonal grid of 3 square miles each (H3M) for the H-GAC region.
3. H-GAC staff estimated 2020 watershed populations using the H3M data for the portion of the H3M within the watershed assuming equal distribution.
4. Obtained population projections for the year 2050 from the H-GAC regional forecast based on H3M data.
5. Developed population projections using H-GAC regional forecast data for the portion of the H3M within the watershed assuming equal distribution.
6. Subtracted the 2020 watershed population was from the 2050 population projection to determine the projected population increase. Subsequently, the projected population increase was divided by the 2020 watershed population to determine the percent population increase for the TMDL Project watershed.