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One Total Maximum Daily Load for Indicator Bacteria in Cotton Bayou Tidal

Assessment Unit 0801C_01

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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"Technical Support Document for One Total Maximum Daily Load for Indicator
Bacteria in Cotton Bayou Tidal," TCEQ AS-473
by Rachel Windham of the Houston-Galveston Area Council.

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Abbreviations

AU	assessment unit
BMP	best management practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming unit
CGP	Construction General Permit
DMU	Deer Management Unit
E. coli	*Escherichia coli*
EPA	(United States) Environmental Protection Agency
FDC	flow duration curve
FG	future growth
H-GAC	Houston-Galveston Area Council
I-Plan	implementation plan
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
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
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TxDOT	Texas Department of Transportation
U.S.	United States
USCB	United States Census Bureau

USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WQBELs	water quality-based effluent limits
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Executive Summary

This report describes a total maximum daily load (TMDL) for Cotton Bayou Tidal, where concentrations of indicator bacteria exceed the criterion used to evaluate attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairments to Cotton Bayou Tidal in the *2010 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ, 2010).

This report will consider one bacteria impairment in one assessment unit (AU) of Cotton Bayou Tidal. The impaired water body and identifying AU are:

- Cotton Bayou Tidal (AU 0801C_01)

The Cotton Bayou watershed is located near the northern border of Galveston Bay. Cotton Bayou comprises two AUs (Cotton Bayou Above Tidal, 0801E_01 and Cotton Bayou Tidal, 0801C_01) and flows for about 5.4 miles to its termination into Cotton Lake, with the last 0.7 miles making up the impaired AU. The Cotton Bayou Tidal watershed covers 16.2 square miles and is located entirely within Chambers County.

Enterococci are widely used as indicator bacteria to determine attainment of the contact recreation use in saltwater. The criterion for determining attainment of the contact recreation use is expressed as the number of bacteria, typically given as colony forming units (cfu) in 100 milliliters (mL) of water. The primary contact recreation 1 use is not supported in saltwater when the geometric mean of all samples for the assessment period exceeds 35 cfu per 100 mL.

Enterococci data were collected at a TCEQ surface water quality monitoring (SWQM) station in the impaired AU over a seven-year period from Oct. 1, 2013 through Nov. 30, 2020. These data were used in assessing attainment of the primary contact recreation 1 use and reported in the *2022 Texas Integrated Report* (TCEQ, 2022a). The assessed data indicate nonattainment of the contact recreation standard in AU 0801C_01.

Within the Cotton Bayou Tidal watershed, probable sources of bacteria include domestic wastewater treatment facilities (WWTFs), regulated stormwater runoff, sanitary sewer overflows (SSOs), illicit discharges, on-site sewage facilities (OSSFs), agricultural activities, and contributions from wildlife and domesticated animals.

A review of the TCEQ Central Registry for active permits found six permitted domestic WWTFs in the Cotton Bayou Tidal watershed. All of them have effluent limits for bacteria. There were also two Phase II Municipal Separate Storm Sewer System (MS4) General Permit authorizations and one combined Phase I and II MS4 individual permit with stormwater discharges, along with numerous

Construction General Permit (CGP) authorizations. Approximately 35.1% (3,634.6 acres) of the watershed was regulated under stormwater permits.

A modified load duration curve (LDC) analysis was done for the TMDL watershed to quantify allowable pollutant loads, as well as allocations for point and nonpoint sources of bacteria. Wasteload allocations (WLAs) were established for WWTFs discharging to the AUs. The WLA was calculated as the full permitted daily-average flow rate multiplied by the geometric mean criterion. Future growth (FG) of existing or new domestic point sources was determined for the watershed using population growth projections.

The TMDL calculations in this report will guide determination of the assimilative capacity of the water body under changing conditions, including FG. WWTFs will be evaluated case by case.

Introduction

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 TMDL for each pollutant that contributes to the impairment of a water body included on a state's 303(d) list of impaired waters. TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

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

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

This TMDL report addresses impairments to the primary contact recreation 1 use due to elevated levels of indicator bacteria in Cotton Bayou Tidal (0801C_01). This TMDL takes a watershed approach to addressing the indicator bacteria impairment. Though Cotton Bayou was considered to be tidally influenced along its full length as recently as 2020, analyses conducted for this project revealed that ambient conditions and biological assessments upstream of a point 0.7 miles from the confluence of Cotton Lake were more characteristic of an above-tidal stream. Therefore, tidal (0801C, AU 0801C_01) and above tidal (0801E, AU 0801E_01) reaches are now recognized in Cotton

Bayou. While TMDL allocations were developed only for the impaired AU identified in this report, the entire project watershed (Figure 1) and all WWTFs that discharge within it are included within the scope of this TMDL. Information in this TMDL report was derived from the *Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Cotton Bayou Tidal* (Windham, 2022).[a]

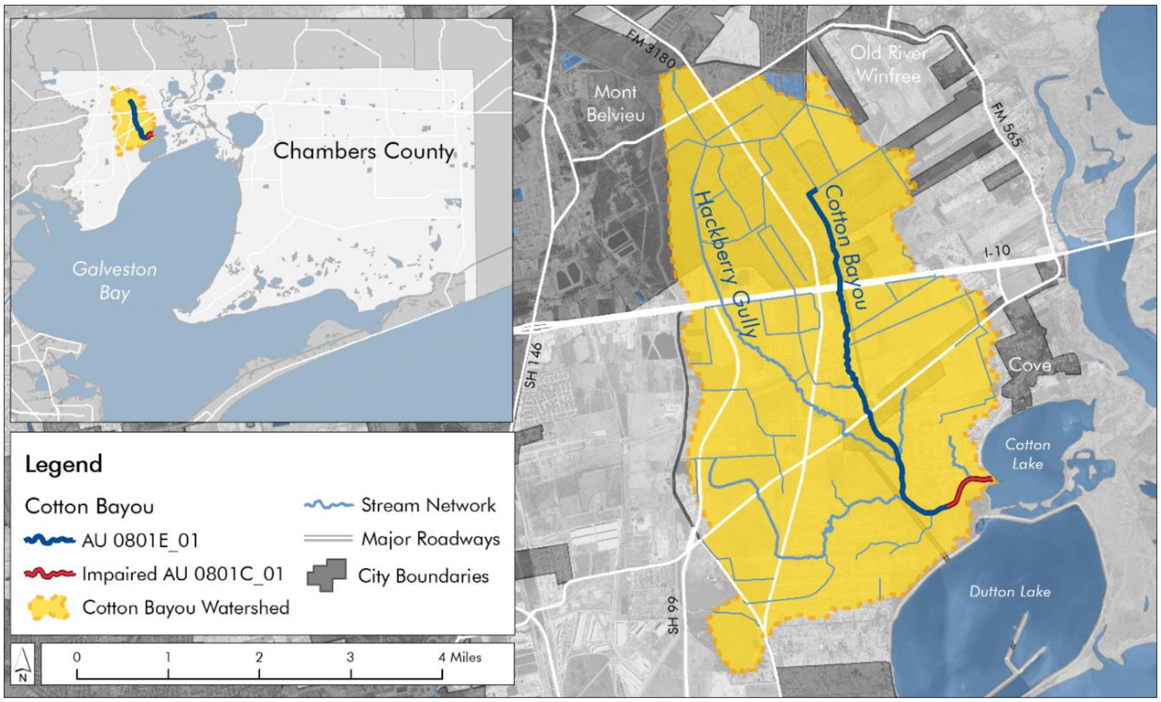

Figure 1. Map of the TMDL watershed

Section 303(d) of the Clean Water Act and the implementing regulations of the United States (U.S.) Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations (CFR), Chapter 1, Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. EPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1991). This TMDL report has been prepared in accordance with those regulations and guidelines.

TCEQ must consider certain elements in developing a TMDL. They are described in the following sections of this report:

[a] www.tceq.texas.gov/downloads/water-quality/tmdl/cotton-bayou-recreational-124/124-as-473-cotton-bayou-bacteria-tsd-2022-sept.pdf

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

Upon adoption of the TMDL report by the commission and subsequent EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan (WQMP).

Problem Definition

TCEQ first identified the impairment of the primary contact recreation 1 use within Cotton Bayou Tidal in the *2010 Texas Integrated Report (*TCEQ, 2010), and again in each subsequent edition through the EPA-approved *2022 Texas Integrated Report* (TCEQ, 2022a).

Recent surface water Enterococci monitoring within the TMDL watershed has occurred at three TCEQ SWQM stations, although only one of those stations is located on the impaired AU (Table 1 and Figure 2). Enterococci data, collected at the station on the impaired AU from Oct. 1, 2013, through Nov. 30, 2020, were used to determine attainment of primary contact recreation use 1 as reported in the *2022 Texas Integrated Report* (TCEQ, 2022a). Data assessed indicate nonsupport of the primary contact recreation 1 use because the geometric mean concentrations of available samples exceed the geometric mean criterion of 35 cfu/100 mL for Enterococci, as summarized in Table 1.

Table 1. 2022 Texas Integrated Report Summary for the impaired AU

Water Body	AU	Parameter	TCEQ SWQM Station	Data Range	Number of Samples	Geometric Mean (cfu/100 mL)
Cotton Bayou Tidal	0801C_01	Enterococci	18697	10/01/2013 – 11/30/2020	20	81.2

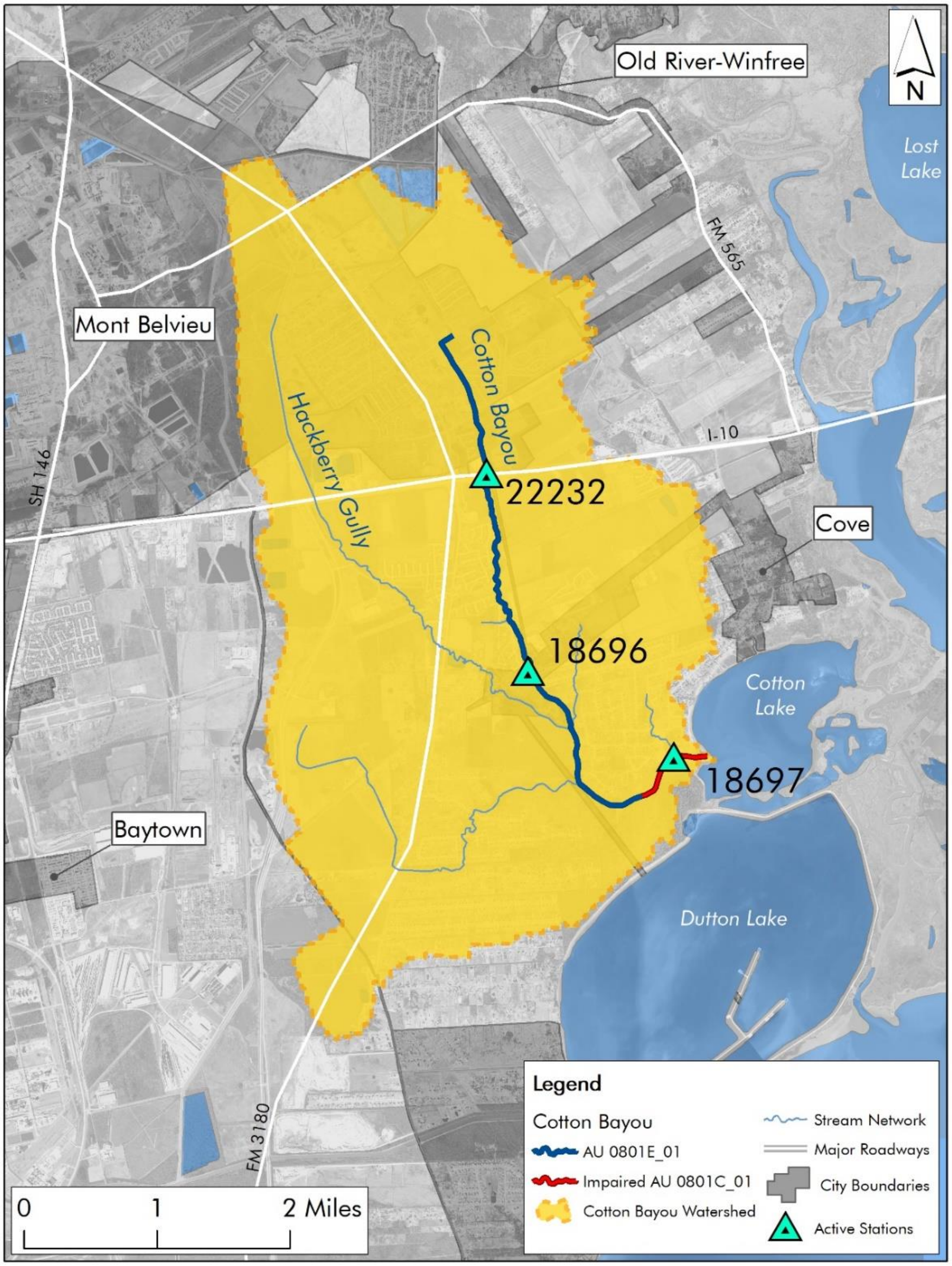

Figure 2. Active TCEQ SWQM stations

Watershed Overview

The Cotton Bayou Tidal watershed is 16.2 square miles and is located near the northern border of Galveston Bay (Figure 1). Cotton Bayou flows approximately 5.4 miles, beginning about 0.74 miles upstream of Interstate Highway 10 and terminating at its confluence with Cotton Lake. Cotton Bayou Tidal makes up the last 0.7 miles of the water body. The entire watershed is in Chambers County.

Most of the land in the watershed is cultivated, grassland, and woody. However, development is increasing near Mont Belvieu and other areas experiencing the effects of urban sprawl. Cotton Bayou Tidal consists of a single AU (0801C_01).

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

- Cotton Bayou Tidal 0801C (AU 0801C_01) – From the confluence of Cotton Lake southeast of Mont Belvieu to a point upstream 1.19 kilometers (0.74 miles) near The Plantation neighborhood in Chambers County.

Climate and Hydrology

Precipitation and temperature data for the period of 2006 through 2020 were retrieved from the National Oceanic and Atmospheric Administration's (NOAA's) Climate Data Online for City of Baytown Station USC00410586 (NOAA, 2018). The highest average monthly maximum temperatures occur in August (92.8° F) and the lowest average monthly minimum temperatures occur in January (42.2° F). The highest average monthly precipitation occurs in August at 8.3 inches and the lowest average monthly precipitation occurs in February at 3.2 inches (Figure 3). The average annual precipitation was 65.5 inches.

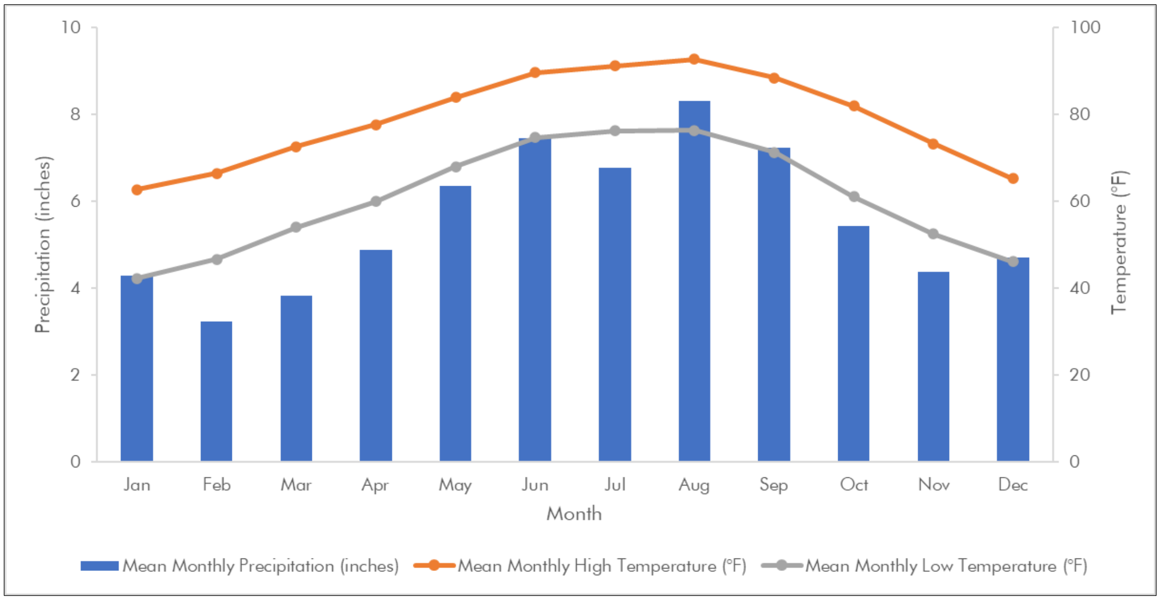

Figure 3. Average monthly temperature and precipitation from 2006 through 2020 at City of Baytown Station USC00410586

Population and Population Projections

Watershed population estimates were developed using the Houston-Galveston Area Council's (H-GAC's) Regional Growth Forecast. Using the methodology outlined in Appendix A, the TMDL watershed's 2018 population was estimated to be 8,598 people (H-GAC, 2018; Table 2). These data were further used to estimate households in the Cotton Bayou watershed at 3,037 in 2018. Regional Growth Forecast methodology (H-GAC, 2017) was used to estimate regional population and household growth out to the year 2045.

Table 2. Population estimates and projections

AU	2018 Population	2045 Population Projection	Projected Increase (2018–2045)	Percentage Increase (2018–2045)
0801C_01	8,598	20,011	11,413	132.74%

Land Cover

In 2018, H-GAC used Landsat satellite imagery to categorize the Houston-Galveston region into 10 classes of land cover (H-GAC, 2019), as displayed in Figure 4.

The following are the land cover categories and definitions found in the TMDL watershed:

- **Developed – High Intensity** – Contains significant land area that is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies less than 20% of the landscape. Constructed materials account for 80–100% 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.
- **Developed – Medium Intensity** – Contains area with a mixture of constructed materials and vegetation or other cover. Constructed materials account for 50–79% 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.
- **Developed – Low Intensity** – Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21–49% of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
- **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.
- **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.
- **Pasture/Grassland** – This is a composite class that contains both Pasture/Hay lands (planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled) and Grassland/Herbaceous (areas are not subject to intensive management such as tilling but can be utilized for grazing).
- **Barren Land** – This class contains both Barren Land (areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material) and Unconsolidated Shore (material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water) areas.
- **Forest/Shrubs** – This is a composite class that contains Deciduous Forest (dominated by tree species that shed foliage simultaneously in response to seasonal change), Evergreen Forest (dominated by tree species that maintain their leaves all year), Mixed Forest (neither deciduous nor

evergreen species are completely dominant), and Scrub/Shrub (tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions).

- **Open Water** – This is a composite class that contains Open Water, Palustrine Aquatic Bed (tidal and nontidal 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), and Estuarine Aquatic Bed (similar to Palustrine Wetlands except salinity due to ocean-derived salts is equal to or greater than 0.5%) areas.
- **Wetlands** – This is a composite class that contains all the palustrine (Palustrine Forested Wetland, Palustrine Scrub/Shrub Wetland, and Palustrine Emergent Wetland) and estuarine (Estuarine Forested Wetland, Estuarine Scrub/Shrub Wetland, and Estuarine Emergent Wetland) wetland land types.

A summary of the land cover data is provided in Table 3. As depicted in Table 3 and Figure 4, the dominant land uses are Pasture/Grassland (25.1%), Developed – Low Intensity (23.8%), and Wetlands (15.8%).

Table 3. Land cover area and percentages

2018 Classification	Area (acres)	Percentage Total
Open Water	191.4	1.8%
Developed – High Intensity	218.2	2.1%
Developed – Medium Intensity	320.7	3.1%
Developed – Low Intensity	2,467.5	23.8%
Developed – Open Space	691.9	6.7%
Barren Land	140.6	1.4%
Forest/Shrubs	1,174.7	11.3%
Pasture/Grassland	2,593.3	25.1%
Cropland	919.6	8.9%
Wetlands	1,633.0	15.8%
Totals	**10,350.9**	**100.0%**

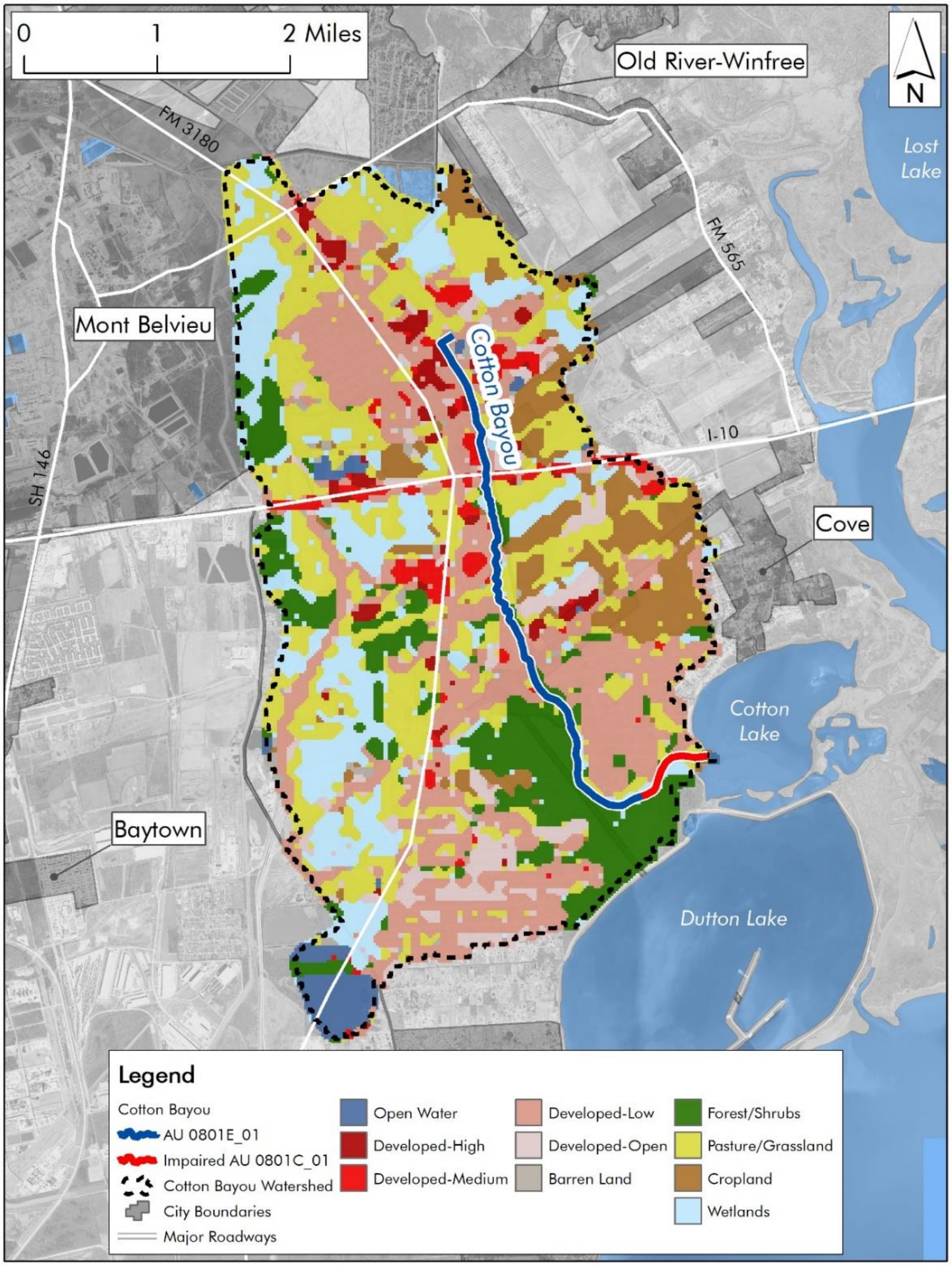

Figure 4. 2018 land cover map

Soils

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

Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (NRCS, 2015). The SSURGO data assign 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 following classifications.

- **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.

Soils in the Cotton Bayou watershed range from fine to fine-silty with most of the watershed area covered by soil with very slow infiltration rates (Figure 5). The soil types are clayey and loamy and transition from acidic-neutral in the northern reaches to neutral-alkaline and saline with increasing proximity to Galveston Bay.

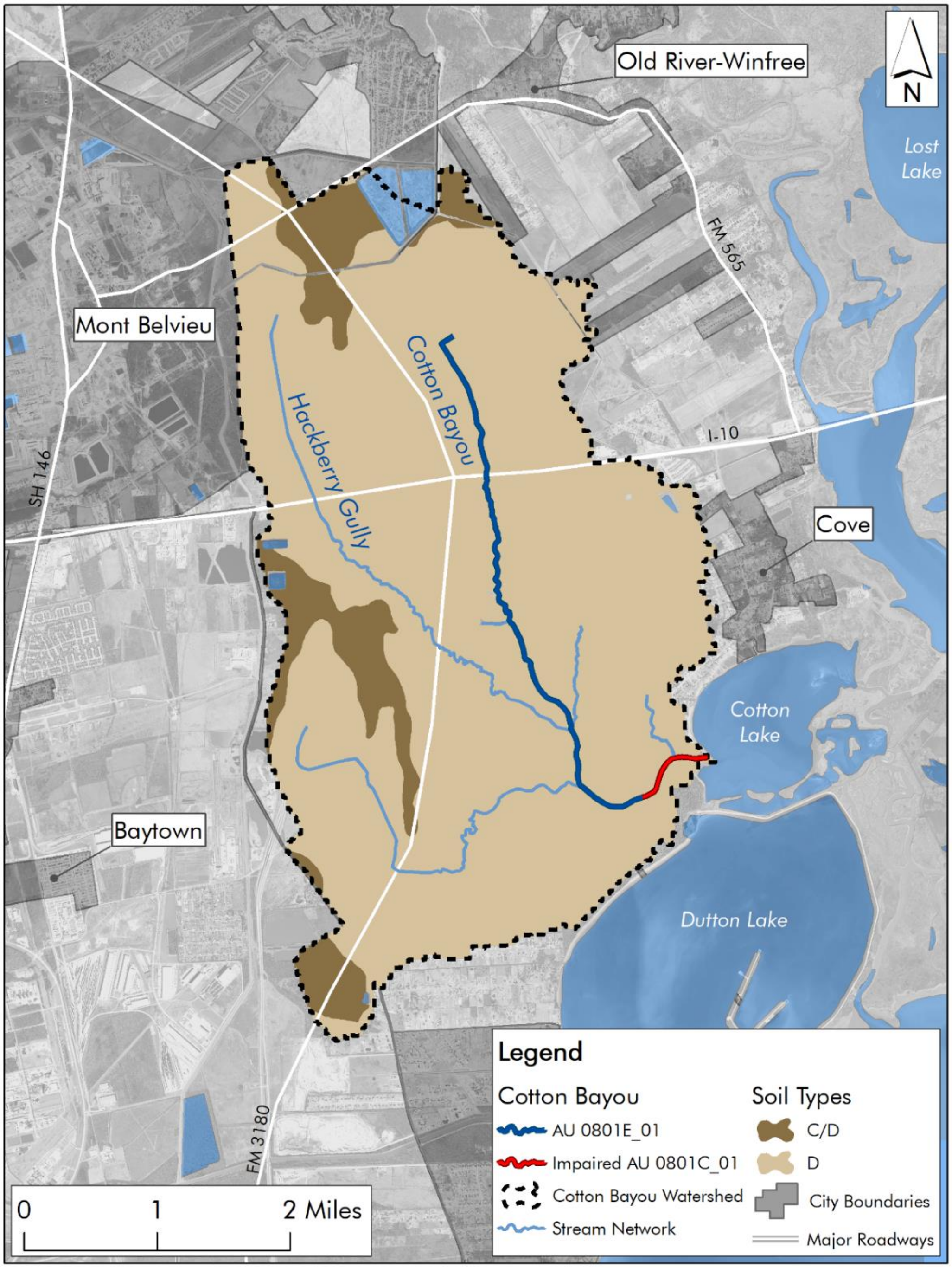

Figure 5. Hydrologic soil groups

Water Rights Review

Surface water rights in Texas are administered and overseen by TCEQ. A search of TCEQ's Texas Water Rights Viewer (TCEQ, 2021a) indicated there are no water rights in the Cotton Bayou watershed.

Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDL in this report is to maintain concentrations of Enterococci below the geometric mean criterion of 35 cfu/100mL, which is protective of the primary contact recreation 1 use in saltwater (TCEQ, 2018).

Source Analysis

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. WWTFs and stormwater discharges from industries, construction activities, and MS4s are considered point sources of pollution.

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

Except for WWTFs, which receive individual 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.

Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watershed include WWTF outfalls and stormwater discharges from regulated construction sites and MS4s.

Domestic and Industrial Wastewater Treatment Facilities

As of March 28, 2022, there were six domestic WWTF permittees in the Cotton Bayou watershed that maintain active wastewater discharge permits, including three facilities that had acquired permits but were not yet actively discharging (Table 4, Figure 6; TCEQ, 2022b). There were no industrial WWTFs in the watershed. All of the permits are located in the drainage area of 0801E_01. No permits were found that discharge to 0801C_01. However, the TMDL takes a watershed approach, so these permits are all relevant to the project.

Table 4. Permitted domestic WWTFs

AU	TPDES Number	EPA ID	Facility Name	Permitted Party	Outfall Number	Bacteria Limits (cfu/100 mL)	Primary Discharge Type	Daily Average Flow – Permitted Discharge (MGD[a])
0801E_01	WQ0011109001	TX0085961	Cotton Bayou Park WWTF	Tiki Leasing Company, Ltd.	001	35 (Enterococci)	Domestic Wastewater	0.032
0801E_01	WQ0011449001	TX0066656	Veranda WWTF	Aqua Texas, Inc.	001	126 (*E. coli*[b])	Domestic Wastewater	0.90
0801E_01	WQ0014807001	TX0053317	Cotton Bayou WWTF	City of Mont Belvieu	001	126 (*E. coli*)	Domestic Wastewater	3.0
0801E_01	WQ0015245001	TX0135348	Rush Gas Station WWTF	3180 Maverick Investments, LLC	001	126 (*E. coli*)	Domestic Wastewater	0.015
0801E_01	WQ0015887001	TX0140333	Chambers County Improvement District No. 3 WWTF	Chambers County Improvement District No. 3	001	126 (*E. coli*)	Domestic Wastewater	0.80
0801E_01	WQ0016031001	TX0141631	Oakville Ranch RV Park and Resort	Parkland Development LLC	001	126 (*E. coli*)	Domestic Wastewater	0.20

[a]MGD: million gallons per day

[b]*E. coli*: *Escherichia coli*

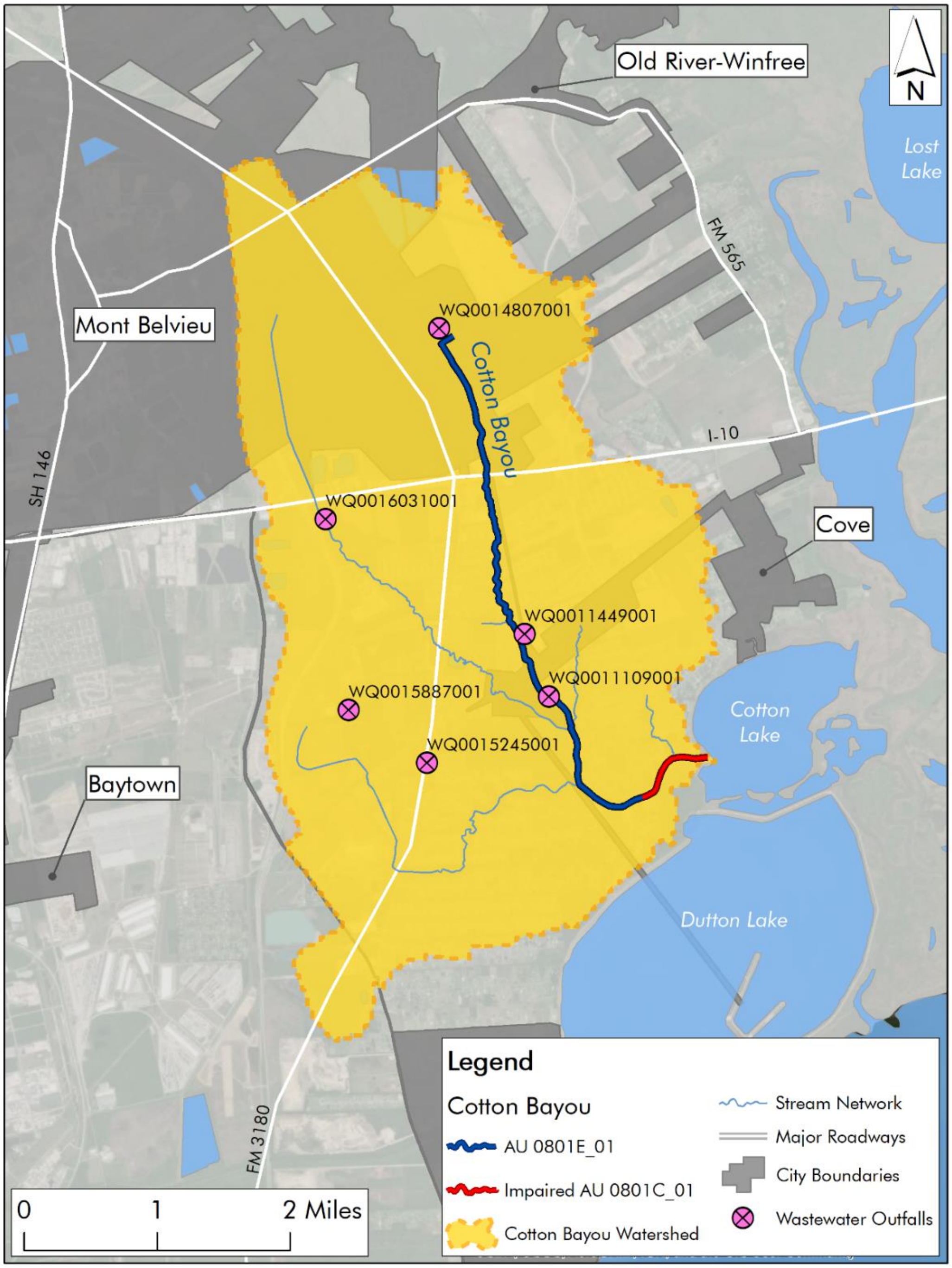

Figure 6. Wastewater outfalls

TCEQ/TPDES Water Quality General Permits

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

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

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

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

A review of active general permit coverage (TCEQ, 2021b) in the Cotton Bayou watershed, as of July 2021, found no active general wastewater permit facilities or operations.

Sanitary Sewer Overflows

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

The TCEQ Office of Compliance and Enforcement provided statewide data on SSOs from 2016 through 2020 (TCEQ, 2021c). Annual SSO volume totaled 1,000 gallons in 2016, 2,943 gallons in 2018, and 1,250 gallons in 2019. No SSOs were reported in 2017 or 2020.

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 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 sanitary wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized MS4s with populations of 100,000 or more based on the 1990 U. S. Census, whereas the Phase II MS4 General Permit (TXR040000) regulates other MS4s within an urbanized area as defined by the U.S. Census Bureau (USCB) in the 2000 and the 2010 Decennial Censuses.

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. The MS4 permits require that SWMPs specify the best management practices (BMPs) 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[b].

[b] MCM only applies to Phase II MS4s which serve a population of 100,000 or more

- Authorization for construction activities where the small MS4 is the site operator (*optional*).

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

- MS4 maintenance activities.
- Post-construction stormwater control measures.
- Detection and elimination of illicit discharges.
- Pollution prevention and good housekeeping for municipal operations.
- Limiting pollutants in industrial and high-risk stormwater runoff.
- Limiting pollutants in stormwater runoff from construction sites.
- Public education, outreach, involvement, and participation.
- Monitoring, evaluating, and reporting.

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

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

TCEQ Central Registry includes a statewide combined Phase I and II MS4 individual permit held by the Texas Department of Transportation (TxDOT) for rights-of-way in USCB urbanized areas and two Phase II MS4 permit authorizations (Figure 7; Table 5) covering 3,355.7 acres.

No MSGP-regulated facilities are within the Cotton Bayou watershed. Numerous CGP authorizations were found in the Cotton Bayou watershed. Areas authorized under the CGP within the Cotton Bayou watershed but outside of the USCB urbanized area covered 278.9 acres. Due to the short-term and economy-driven nature of construction activities, they can change in the watershed area and serve as a representative estimate of the acres of land disturbed. Additionally, other construction activities may be occurring in the watershed that are not required to have a CGP authorization or are not regulated.

The area of regulated stormwater is approximately 3,634.6 acres, or 35.1% of the Cotton Bayou TMDL watershed.

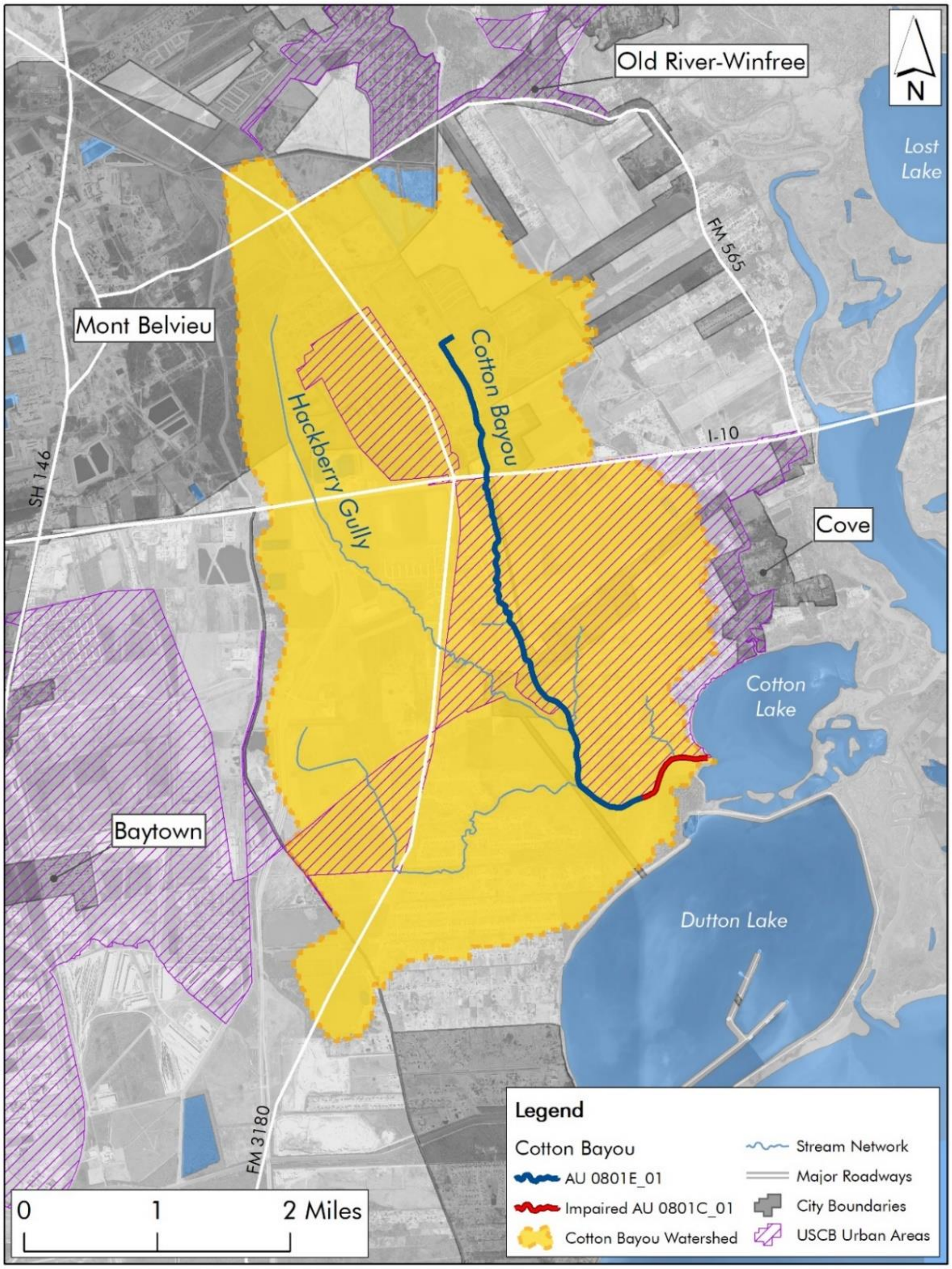

Figure 7. Regulated stormwater areas based on the urbanized area

Table 5. MS4 permit authorizations

Entity	Authorization Type	TPDES Authorization or Permit No./EPA ID	Location
City of Mont Belvieu	Phase II MS4 General Permit TXR040000	TXR040499/Not applicable	Area within the City of Mont Belvieu limits located within the Houston urbanized area
Chambers County	Phase II MS4 General Permit TXR040000	TXR040438/Not applicable	Area within Chambers County that is located within the Houston urbanized area
TxDOT	Combined Phase I and II MS4 Individual Permit	WQ0005011000/ TXS002101	TxDOT rights-of-way located within Phase I MS4 areas and Phase II urbanized areas

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.

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, wildlife, various agricultural activities, agricultural animals, failing OSSFs, unmanaged and feral animals, and domestic pets.

Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Activities, such as livestock grazing close to water bodies and the use of manure as fertilizer, can contribute Enterococci to nearby water bodies. Livestock are present throughout the more rural portions of the project watershed.

Table 6 provides estimated numbers of selected livestock in the TMDL watershed based on the 2017 Census of Agriculture conducted by USDA (USDA NASS, 2019). Those populations were determined based on GIS calculations of suitable habitat in the watershed, which included areas classified as Pasture/ Grassland. The area of suitable habitat within the watershed area (within the corresponding county) was then divided by the total area of the county classified as Pasture/ Grassland. The resulting ratio of suitable habitat was multiplied by USDA county-level livestock estimates. The Texas State Soil and Water Conservation Board (TSSWCB) staff reviewed the watershed estimated livestock numbers. These livestock numbers, however, were not used to develop an allocation of allowable bacteria loading to livestock.

Table 6. Estimated livestock population

AU	Cattle and Calves	Hogs and Pigs	Goats and Sheep	Horses
0801C_01	437	1	19	15

Fecal matter from dogs and cats is transported to water bodies by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 7 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 (AVMA, 2018). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 7. Estimated households and pet population

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
0801C_01	3,037	1,865	1,388

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

For feral hogs, a study by Timmons et al. (2012) estimated a range of feral hog densities within suitable habitat in Texas from 8.9 to 16.4 hogs per square mile. 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, in addition to insights from local stakeholders, feral hog populations were estimated to be 8.9 per square mile in Developed – Low Intensity, 12.7 per square mile in Developed – Open Space, Barren Land, and Cropland, 16.4 per square mile in Pasture/Grassland, Forest/Shrubs, and Wetlands, and no hogs in other developed areas or open water. Using this methodology, the estimated feral hog population is 207 feral hogs in the TMDL watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) has published data showing deer population-density estimates by Deer Management Unit (DMU) and Ecoregion in the state (TPWD, 2020). The TMDL watershed is located entirely within DMU 13. For deer population estimates recorded from 2008 through 2019, the estimated deer population density for the surrounding ecoregion was one deer per 216.7 acres and applies to all habitat types. Applying this value to the entire area of the TMDL watershed returns an estimated 48 deer within the TMDL watershed. The Enterococci contribution from feral hogs and wildlife in the TMDL watershed could not be determined based on existing information.

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 aboveground 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 aboveground sprinkler system.

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

Within the Cotton Bayou watershed, 439 permitted OSSFs have been documented (Figure 8). An additional 350 OSSFs without permits were estimated using H-GAC's geographic information database of potential OSSF locations in the Houston-Galveston area using known OSSF locations, county parcel data, and WWTF service boundaries. An estimated total of 789 OSSFs are located within the TMDL watershed. By applying the estimated 12% failure rate to the number of OSSFs estimated in the watershed area, 95 OSSFs are projected to be failing.

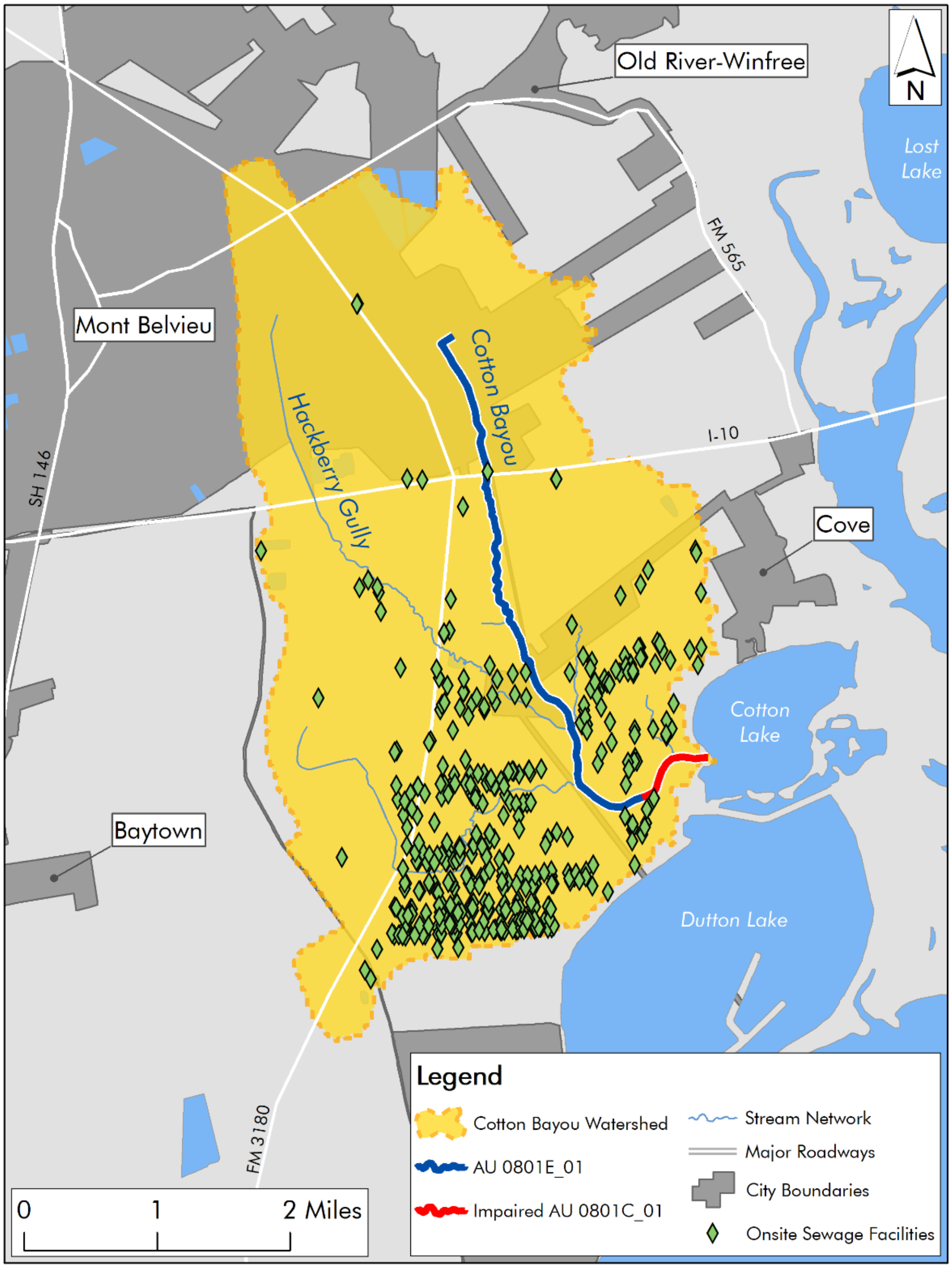

Figure 8. Permitted OSSFs

Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly treated effluent during their transport in pipe networks, and they can survive and replicate in organic-rich materials such as improperly treated compost and sewage sludge (or biosolids). While die-off of bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for regrowth 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.

Linkage Analysis

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

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

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

Modified Load Duration Curve Analysis

LDCs are graphs of the frequency distribution of loads of pollutants in a water body. LDC analyses are used to examine the relationship between instream water quality and broad sources of bacteria loads which are the basis of the TMDL allocations (Cleland, 2003). In the case of this TMDL, the loads shown are of Enterococci bacteria in cfu/day.

In watersheds where there are tidal exchanges along the Texas coast, the flow is adjusted to address tidal influences. The LDC developed through this approach is called a modified LDC. A modified LDC assumes that combining freshwater with seawater increases the loading capacity in the tidal river. Modified LDCs are derived from modified flow duration curves (FDCs). The modified LDC represents the maximum acceptable load in the stream that will result in achievement of the TMDL water quality target. The basic steps to generate modified LDCs include all of the following:

- Generating a daily freshwater flow record – the mean daily freshwater flow record incorporating actual daily average permitted discharges was developed for the most downstream TCEQ SWQM station within the AU using a drainage area ratio methodology and the mean daily streamflow reported at United States Geological Survey (USGS) Gage 08067525 on Goose Creek (Figure 9).
- Generating a daily tidal volume record – the daily tidal seawater volume record was generated using salinity to streamflow regressions and mass-balance equations. The tidal seawater volumes were added to the daily freshwater flow record.
- Accounting for full permitted discharges – the actual daily average permitted discharges are removed from the streamflow and the full permitted daily average discharges and FG discharges are added.
- Developing the modified FDCs – the mean daily streamflow including seawater volume, full permitted discharges, and FG is plotted against the exceedance probability of the mean daily streamflow for each day.
- Converting the modified FDCs to modified LDCs – the mean daily streamflow for each day is multiplied by the primary contact recreation 1 use geometric mean criterion and a conversion factor to produce a graph of the frequency distribution of allowable loads.
- Overlaying the modified LDCs with available indicator bacteria loading measurements to understand under what flow conditions indicator bacteria loading exceeds the primary contact recreation 1 use geometric mean criterion.

Hydrologic data in the form of daily streamflow records were unavailable for the TMDL watershed. However, streamflow records are available in the nearby Goose Creek watershed (Figure 9). USGS collects and shares streamflow records for this watershed. Mean daily streamflow for the TMDL watershed was developed using stream gage 08067525 on Goose Creek. This gage was chosen to develop naturalized streamflow records due to its proximity to the TMDL watershed. The period of record for developing the FDC was from Oct. 1, 2006, through Oct. 31, 2020.

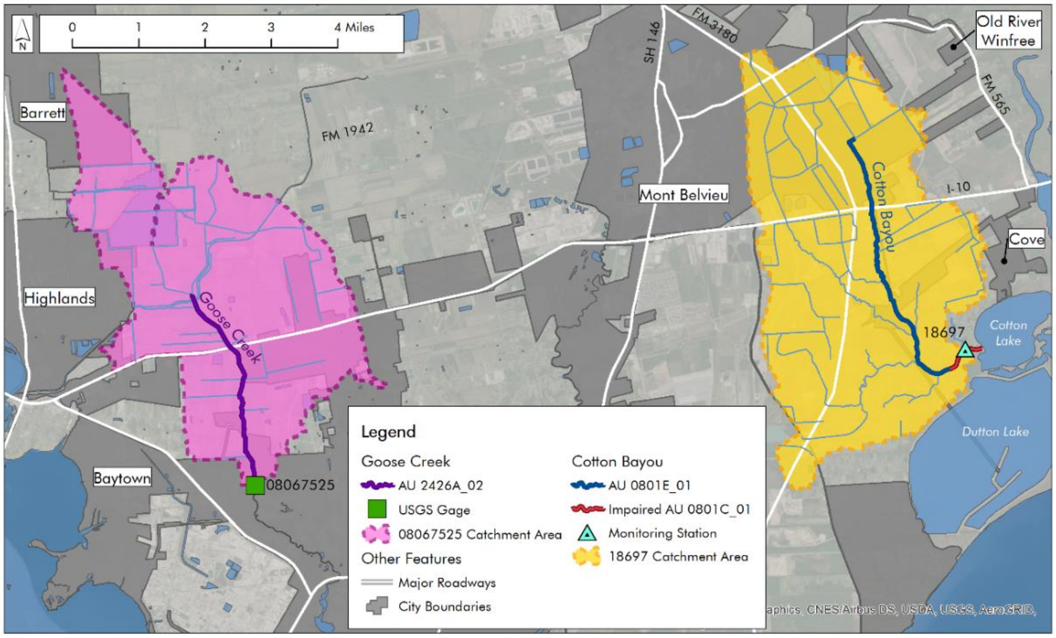

Figure 9. Drainage area comparison for USGS Gage 08067525 and TCEQ SWQM Station 18697

The method used to develop the necessary streamflow records for the modified FDC/LDC location (TCEQ SWQM station location) involved a drainage area ratio approach. Prior to applying the drainage area ratio, mean daily streamflow at Goose Creek was naturalized by subtracting permitted WWTF facility daily discharge volumes as reported in discharge monitoring reports (EPA, 2022). There is no water diversion from Goose Creek recorded, therefore, no water rights adjustments were applied in flow naturalization (TCEQ, 2021a).

The drainage area ratio approach involves multiplying a USGS gaging station daily streamflow value by a factor to estimate the flow at a desired TCEQ SWQM station location. The factor is determined by dividing the drainage area above the desired monitoring station location by the drainage area above the USGS gage (Table 8) and applying a streamflow percentile exponent factor. The resulting streamflow record is the naturalized flow from only the contributing watershed at the SWQM station. Finally, the permitted facility reported discharges in discharge monitoring reports upstream of the TCEQ SWQM station were added to complete the estimated streamflow the TCEQ SWQM station.

Table 8. Drainage area ratios

Station	Drainage Area (acres)	Drainage Area Ratio
USGS Gage 08067525	8,777.25	--
TCEQ SWQM 18697	10,219.38	1.16

As part of the development of the modified FDC/LDC method, it was necessary to estimate the daily tidal exchange at each TCEQ SWQM station and add it to the freshwater streamflow. A regression relationship was developed between estimated daily freshwater streamflow and measured salinity for the TCEQ SWQM station. The resulting predicted salinities were inserted into an equation (ODEQ, 2006) to calculate the volume of seawater that would flow through the SWQM station cross-section over the period of a day. The total modified daily flow volume for Cotton Bayou Tidal was then computed as the daily seawater volume plus the daily freshwater volume.

Flows used in the TMDL must consider the full permitted discharge and FG of permitted WWTFs. First, the actual permitted facility reported discharges used for estimating the volume of seawater were removed. Then the full permitted discharges (Table 4) and calculated FG above the TCEQ SWQM station were added to the calculated daily flows. Detailed information about the daily flow estimation method is available in the *Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Cotton Bayou Tidal* (Windham, 2022).

After development of the daily streamflow record, the modified FDC was generated by calculating the exceedance probability for each daily streamflow record and plotting the mean daily flow against the exceedance probability. Exceedance values along the x axis represent the percentage of days that flow was at or above the associated flow value on the y axis. Exceedance values near 100% occur during low flow or drought conditions while values approaching 0% occur during periods of high flow or flood conditions.

The modified FDC was converted to a modified LDC by multiplying each streamflow value by the primary contact recreation 1 use geometric mean criterion (35 cfu/100 mL) and a conversion factor, resulting in units of cfu/day. The resulting modified LDC plots each bacteria load value (y axis) against its exceedance value (x axis). Exceedance values along the x axis represent the percent of days that the bacteria load was at or above the allowable load on the y axis.

Historical bacteria data from Oct. 1, 2006, through Oct. 31, 2020, were obtained from TCEQ's Surface Water Quality Monitoring Information System for TCEQ SWQM Station 18697. Bacteria concentrations were converted to a daily load by multiplying the measured concentration by the streamflow value on the day the measurement was collected and a conversion factor. The resulting measured daily load points were plotted against the load exceedance for the day the sample was collected.

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

A useful refinement of the modified LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can support determination of the streamflow conditions under which exceedances are occurring. A commonly used set of regimes, provided in Cleland (2003), is based on the following five intervals along the x axis of the FDCs and LDCs: 0–10% (high flows); 10–40% (moist conditions); 40–60% (mid-range flows); 60–90% (dry conditions); and 90–100% (low flows).

The high flow regime (0–10% exceedance) is used for the TMDL calculations. The median loading of the high flow regime (5% exceedance) is used because it represents a reasonable yet high value for the allowable pollutant load allocation.

Modified Load Duration Curve Results

The modified LDC developed for the TMDL watershed is shown in Figure 10. Based on these modified LDC results, the following broad linkage statements can be made. Bacteria concentrations in the bayou are above the water quality criterion at all levels of flow. The exceedances are highest in the high flow and moist conditions flow regimes, indicating that nonpoint source load pressures are of particular concern in this watershed and should be central to the development of future water quality improvement strategies. However, point sources should also be considered as targets for improvement, as LDC results indicated potential point source influence on bacteria loads in dry and low flow conditions.

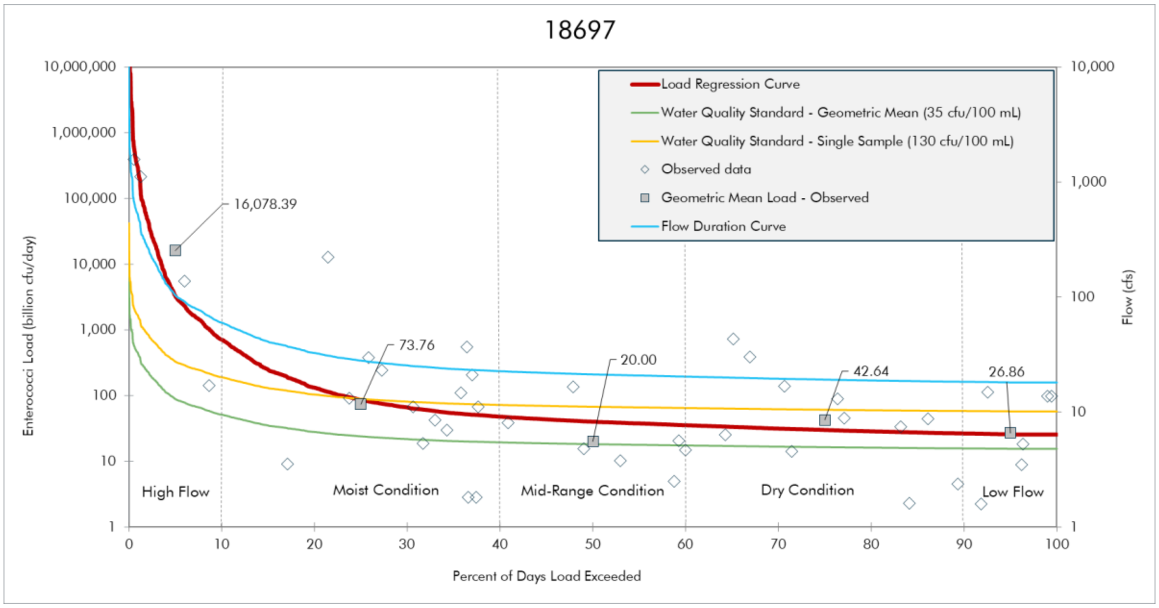

Figure 10. Modified LDC for Cotton Bayou Tidal 0801C_01 at TCEQ SWQM Station 18697

Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis used to develop the TMDL and thus provide a higher level of assurance that the goal of the TMDL will be met. It also accounts 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.

According to EPA guidance (EPA, 1991), the MOS can be incorporated into 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.

This TMDL incorporates an explicit MOS of 5% of the total TMDL allocation.

Pollutant Load Allocation

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

TMDL = WLA + LA + FG + MOS

Where:

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

LA = load allocations, 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 Enterococci, TMDLs are expressed as cfu/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The TMDL components for the impaired AUs are derived using the median flow within the high-flow regime (or 5% flow) of the LDC developed for the TMDL watershed. For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component.

Assessment Unit-Level TMDL Calculations

The TMDL for the impaired AU was developed as pollutant load allocations based on information from the modified LDC developed for TCEQ SWQM Station 18697 (Figure 10). The bacteria modified LDC was developed by multiplying the streamflow value along the modified FDC by the primary contact recreation 1 use geometric mean criterion for Enterococci (35 cfu/100 mL) and by the conversion factor to convert to loading in cfu per day. This effectively displays the modified LDC as the TMDL curve of maximum allowable loading:

TMDL (billion cfu/day) = Criterion * Flow * Conversion Factor

Where:

Criterion = 35 cfu/100 mL Enterococci

Flow = 5% exceedance flow from FDC in cubic feet per second (cfs)

Conversion Factor (to billion cfu/day) = 28,316.8 mL/cubic foot (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

Table 9 shows the TMDL values at the 5% load duration exceedance.

Table 9. Summary of allowable loading

AU	5% Exceedance Flow (cfs)	TMDL (Billion cfu/day Enterococci)
0801C_01	104.133	89.169

Margin of Safety Formula

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

$$MOS = 0.05 * TMDL$$

Where:

TMDL = total maximum daily load

The MOS calculations for each AU are shown in Table 10.

Table 10. MOS calculation

AU	TMDL	MOS
0801C_01	89.169	4.458

All loads are expressed in billion cfu/day Enterococci.

Wasteload Allocation

The WLA is the sum of loads from regulated sources. 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}).

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

Wastewater Treatment Facilities

Determination of the WLA_{WWTF} requires development of a daily WLA for each TPDES-permitted facility. The full permitted daily average flow of each WWTF is multiplied by the instream geometric criterion for the water body and the conversion factor. This calculation is expressed by:

$$WLA_{WWTF} \text{ (billion cfu/day)} = Criterion * Flow * Conversion Factor$$

Where:

Criterion = 35 cfu/100 mL for Enterococci

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. All WWTFs in the Cotton Bayou watershed occur in the above tidal reach, 0801E_01. To account for the contribution of upstream WWTFs for use in calculating TMDLs in the impaired tidal reach, 0801C_01, loadings for 0801E_01 replace 126 cfu/100 mL, the freshwater criterion, with 35 cfu/100mL, the tidal criterion. The individual results were summed for each AU.

Table 11 shows the load allocations for each WWTF and sums the load allocations, providing a total WLA_{WWTF} for the AU.

Table 11. WLAs for TPDES-permitted facilities

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	Enterococci WLA_{WWTF} (billion CFU/day)
0801E_01	WQ0011109001	Tiki Leasing Company, Ltd.	35 (Enterococci)	0.032	0.042
0801E_01	WQ0011449001	Aqua Texas, Inc.	126 (*E. coli*)	0.90	1.192
0801E_01	WQ0014807001	City of Mont Belvieu	126 (*E. coli*)	3.0	3.975
0801E_01	WQ0015245001	3180 Maverick Investments, LLC	126 (*E. coli*)	0.015	0.020
0801E_01	WQ0015887001	Chambers County Improvement District No. 3	126 (*E. coli*)	0.80	1.060
0801E_01	WQ0016031001	Parkland Development LLC	126 (*E. coli*)	0.20	0.265
			Total	**4.947**	**6.554**

Regulated Stormwater

Stormwater discharges from MS4s, industrial facilities, concrete production, and construction activities are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA_{sw} for 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 land area included in the watershed that is under the jurisdiction of stormwater permits was used to estimate the amount of the overall runoff load that should be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL. The load allocation (LA) component of the TMDL corresponds to direct nonpoint source runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

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

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 FDA_{SWP} must be calculated to arrive at the fractional proportion of the drainage area under jurisdiction of stormwater permits. FDA_{SWP} was calculated by first totaling the area of each stormwater permit and authorization. The stormwater sources and area estimates were discussed in the "TPDES-Regulated Stormwater" section. Those area estimates were determined for each category and summed up to determine the total area under stormwater jurisdiction in the TMDL watershed (Table 12). To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total watershed area.

Table 12. Regulated stormwater FDA_{SWP} calculation

AU	MS4 Area	CGP Area (Outside of Urbanized Area)	Total Area of Permits	Watershed Area	FDA_{SWP}
0801C_01	3,355.70	278.90	3,634.60	10,350.90	35.114%

All areas are expressed in acres

A value for FG is necessary to complete the WLA_{SW}. The calculation for FG is presented in the later section "Allowance for Future Growth," but the results will be included here for continuity. The WLA_{SW} calculations are presented in Table 13.

Table 13. Regulated stormwater load calculation

AU	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
0801C_01	89.169	6.554	8.700	4.458	35.114%	24.389

All loads are expressed in billion cfu/day Enterococci.

With the WLA_{SW} and WLA_{WWTF} terms, the total WLA term can be determined by adding the two parts (Table 14).

Table 14. WLA calculation

AU	WLA_{WWTF}	WLA_{SW}	WLA
0801C_01	6.554	24.389	30.943

All loads are expressed in billion cfu/day Enterococci.

In areas currently regulated by an MS4 permit, development, redevelopment, or both, of land must include the implementation of the control measures/programs outlined in an MS4's approved SWMP. Although additional flow may occur from development or redevelopment, loading of the pollutant of concern should be controlled or reduced through the implementation of BMPs as specified in both the TPDES permit and the approved SWMP.

An iterative, adaptive management approach will be used to address stormwater discharges. This approach encourages the implementation of structural or nonstructural controls, implementation of mechanisms to evaluate the performance of the controls, and finally, allowance to adjust (e.g., more stringent controls or specific BMPs) as necessary to protect water quality.

Implementation of Wasteload Allocations

The TMDL in this document will result in protection of existing uses and conform to Texas' antidegradation policy. The three-tiered antidegradation policy in the Texas Surface Water Quality Standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to point source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality.

TCEQ intends to implement the individual WLAs through the permitting process as monitoring requirements, effluent limitations, or both as required by the amendment of Title 30, Texas Administrative Code (TAC) Chapter 319, which became effective Nov. 26, 2009. WWTFs discharging to TMDL water bodies will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in 30 TAC Section 319.9.

Permit requirements are implemented during the routine permit renewal process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality, and circumstances may warrant changes in individual WLAs after this TMDL is adopted. Therefore, the individual WLAs, as well as the WLA for stormwater, are nonbinding until implemented via a separate TPDES permitting action, which may involve preparation of an update to the state's WQMP. Regardless, all permitting actions will comply with the TMDL.

The executive director or commission may establish interim effluent limits, monitoring-only requirements, or both during amendment or renewal of a permit. These interim limits will allow a permittee time to modify effluent quality to attain the final effluent limits necessary to meet TCEQ- and EPA-approved TMDL allocations. The duration of any interim effluent limits may not be any longer than three years from the date of permit reissuance. Compliance schedules are not allowed for new permits.

Where a TMDL has been approved, domestic WWTF TPDES permits will require conditions consistent with the requirements and assumptions of the WLAs. For TPDES-regulated MS4s, construction stormwater, and industrial stormwater discharges, water quality-based effluent limits (WQBELs) that implement the WLA for stormwater may be expressed as BMPs or other similar requirements, rather than as numeric effluent limits.

The Nov. 26, 2014, memorandum from EPA relating to establishing WLAs for stormwater sources states:

> Incorporating greater specificity and clarity echoes the approach first advanced by EPA in the 1996 Interim Permitting Policy, which anticipated that where necessary to address water quality concerns, permits would be modified in subsequent terms to include "more specific conditions or limitations [which] may include an integrated suite of BMPs, performance objectives, narrative standards, monitoring triggers, numeric WQBELs, action levels, etc."

Using this iterative, adaptive BMP approach to the maximum extent practicable is appropriate to address the stormwater component of this TMDL.

Updates to Wasteload Allocations

This TMDL is, by definition, the total of the sum of the WLA (including FG), the sum of the LA, and the MOS. Changes to individual WLAs may be necessary in the future to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the TMDL report; instead, changes will be made through updates to the state's WQMP. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

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

LA = TMDL – WLA – FG – MOS

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

Table 15 summarizes the LA.

Table 15. LA calculation

AU	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
0801C_01	89.169	6.554	24.389	8.700	4.458	45.068

All loads are expressed in billion cfu/day Enterococci.

Allowance for 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.

To account for the FG, the loadings from WWTFs are included in the FG computation, which is based on the WLA_{WWTF} formula. The FG equation includes an additional term to account for project population growth within WWTF service areas between 2018 and 2045, based on H-GAC's Regional Growth Forecast projections (H-GAC, 2018). Table 16 presents the FG calculations.

FG (billion cfu/day) = Criterion * (%$POP_{2018\text{-}2045}$ * $WWTF_{FP}$) * Conversion Factor

Where:

Criterion = 35 cfu/100 mL (Enterococci)

%$POP_{2018\text{-}2045}$ = estimated percentage increase in population between 2018 and 2045

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

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

Table 16. FG calculation

AU	Full Permitted Flow (MGD)	Percentage Population Increase (2018-2045)	FG Flow (MGD)	FG
0801C_01	4.947	132.740	6.567	8.700

All loads are expressed in billion cfu/day Enterococci.

Compliance with this TMDL is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. FGs of existing or new point sources are not limited by this TMDL if the sources do not cause bacteria to exceed the limits. The assimilative capacity of water bodies increases as the amount of flow increases; consequently, increases in flow allow for increased loadings. The LDC and tables in this TMDL report will guide determination of the assimilative capacity of the water body under changing conditions, including FG.

Summary of TMDL Calculations

The TMDL was calculated based on the median flow in the 0–10 percentile range (5% exceedance, high flow regime) for flow exceedance based on the LDC developed at TCEQ SWQM Station 18697.

Allocations are based on the current geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDL. The TMDL allocation summary for the Cotton Bayou Tidal TMDL watershed is summarized in Table 17.

Table 17. TMDL allocation

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
0801C_01	89.169	6.554	24.389	45.068	8.700	4.458

All loads are expressed in billion cfu/day Enterococci.

The final TMDL allocations (Table 18) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 18. Final TMDL allocation

AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
0801C_01	89.169	15.254	24.389	45.068	4.458

All loads are expressed in billion cfu/day Enterococci.

Seasonal Variation

Federal regulations require that TMDLs account for seasonal variation in watershed conditions and pollutant loading [40 CFR 130.7(c)(1)].

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing Enterococci concentrations obtained from 14 years (2006 through 2020) of routine monitoring data collected in the warmer months (May through September) against those collected during the cooler months (November through March). The months of April and October were considered transitional between warm and cool seasons and were excluded from the seasonal analysis.

Differences in Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). This analysis of Enterococci data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Cotton Bayou Tidal. Seasonal variation was also addressed by using all available flow and Enterococci records (covering all seasons) from the period of record used in LDC development for this project.

Public Participation

TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

TCEQ and H-GAC are jointly coordinating public participation in development of both the TMDL and implementation plan (I-Plan). The first of a series of public meetings to engage stakeholders was held online on April 28, 2020, to discuss the project and make the public aware of the TMDL. Additional online meetings were held on July 13, 2020, Aug. 20, 2020, and Aug. 26, 2021 to discuss progress in developing the TMDL. A meeting was held in Mont Belvieu on May 31, 2022 to present the final TMDL allocations. An online meeting was held in on Aug. 23, 2022 to begin developing specific management measures to include in the I-Plan.

Notices of meetings were posted on the project webpages for both TCEQ and H-GAC. At least two weeks prior to scheduled meetings, H-GAC issued media releases and formally invited stakeholders to attend. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the H-GAC project webpage[c] provided agendas, presentations, and meeting summaries for stakeholder review.

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that WLAs in this TMDL report will be achieved. Per federal requirements, each TMDL is included in an update to the Texas WQMP as a plan element.

The WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations [40 CFR 130.6(c)]. Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDL and I-Plan, TCEQ will propose and certify WQMP updates to establish required WQBELs for specific TPDES wastewater discharge permits.

For MS4 entities, where numeric effluent limitations are infeasible, the permits require that the MS4 develop and implement BMPs under each MCM, which are a substitute for effluent limitations, as allowed by federal rules. How a regulated MS4 meets each MCM is not prescribed in detail in the MS4 permits but is included in the permittee's SWMP. During the permit renewal process, TCEQ revises its MS4 permits as needed to require a revised SMWP or to require the

[c] www.h-gac.com/watershed-based-plans/cotton-bayou-tmdl

implementation of other specific BMPs or controls consistent with an approved TMDL and I-Plan.

Strategies for achieving pollutant loads in TMDLs from both point and nonpoint sources are reasonably assured by the state's use of an I-Plan. TCEQ is committed to supporting implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods ascertain whether progress is occurring and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect needs identified in evaluations of progress.

Key Elements of an I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures to implement the WLAs and LAs of particular TMDLs within a reasonable time. I-Plans also identify the organizations responsible for carrying out management measures, and a plan for periodic evaluation of progress.

Strategies to optimize compliance and oversight are identified in an I-Plan when necessary. Such strategies may include additional monitoring and reporting of effluent discharge quality to evaluate and verify loading trends, adjustment of an inspection frequency or a response protocol to public complaints, and escalation of an enforcement remedy to require corrective action of a regulated entity contributing to an impairment.

TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on the I-Plan begins during development of TMDLs. Because this TMDL addresses agricultural sources of pollution, TCEQ will also work in close partnership with TSSWCB when developing the I-Plan. TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural nonpoint sources of water pollution. The cooperation required to develop an I-Plan will become a cornerstone for the shared responsibility necessary to carry it out.

Ultimately, the I-Plan identifies the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the approved I-Plan may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment. The I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

In most cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

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Appendix A.
Population and Population Projections

The following steps detail the method used to estimate the 2018 and projected 2045 populations in the TMDL watershed:

1. Obtained 2018 American Community Survey data from the USCB at the block level.

2. Used U.S. Census block data to develop population estimates for a hexagonal grid of three square miles each (H3M) for the H-GAC region.

3. Determined the population for H3Ms that do not lie entirely in the watershed by multiplying the H3M population by the portion of the H3M located within the watershed assuming equal distribution.

4. Obtained population projections for the year 2045 from the H-GAC regional forecast based on H3M data.

5. Determined the population projections for H3Ms that do not lie entirely in the watershed by multiplying the H3M population by the portion of the H3M located within the watershed assuming equal distribution.

6. Subtracted the 2018 watershed population from the 2045 population projection to determine the projected population increase. Subsequently, the projected population increase was divided by the 2018 watershed population to determine the percent population increase for the Cotton Bayou watershed.