Draft for Public Comment: November 2023
Adopted: Month Day, Year
AS-477

Two Draft Total Maximum Daily Loads for Indicator Bacteria in Chocolate Bayou

Assessment Units 1107_01 and 1108_01

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Distributed by the
Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087
Email: tmdl@tceq.texas.gov

Total maximum daily load project reports are available on the
Texas Commission on Environmental Quality website at:
www.tceq.texas.gov/waterquality/tmdl.
The preparation of this report was financed in part through grants from
the United States Environmental Protection Agency.

This total maximum daily load report is based in large part on the report titled:
"Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in Chocolate Bayou," TCEQ AS-472
by Steven Johnson, Jessica Casillas, and Thushara Ranatunga of the Houston-Galveston Area Council

Contents

Figures

Tables

Abbreviations

AU	assessment unit
BMP	best management practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
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
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
UA	urbanized area
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 total maximum daily loads (TMDLs) for Chocolate Bayou where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairment to Chocolate Bayou Tidal in the *2010 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report, TCEQ, 2011). The impairment for Chocolate Bayou Above Tidal was later identified in the 2014 Texas Integrated Report (TCEQ, 2015).

This report will consider two bacteria impairments in two assessment units (AUs) of Chocolate Bayou. The impaired water body and identifying AUs are:

- Chocolate Bayou Tidal (AU 1107_01)
- Chocolate Bayou Above Tidal (AU 1108_01)

The Chocolate Bayou watershed lies in southeast Texas within the Houston-The Woodlands-Sugarland Metropolitan Statistical Area. Chocolate Bayou originates in central Brazoria County, with a major tributary beginning in southeast Fort Bend County and travels southeastward in eastern Brazoria County before emptying into Chocolate Bay, an embayment of West Galveston Bay.

Escherichia coli (E. coli) and Enterococci are widely used as indicator bacteria to determine attainment of the contact recreation use in freshwater and saltwater, respectively. 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 freshwater when the geometric mean of all samples for the assessment period exceeds 126 cfu per 100 mL. Similarly, 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.

E. coli and Enterococci data were collected at three TCEQ surface water quality monitoring (SWQM) stations in the impaired AUs over a seven-year period from Dec. 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 non-attainment of the contact recreation standard in AUs 1107_01 and 1108_01.

Within the Chocolate Bayou watershed, probable sources of bacteria include domestic and industrial 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 load duration curve (LDC) analysis (for AU 1108_01) and a modified LDC analysis (for AU 1107_01) was done for the Chocolate Bayou 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 each 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 Chocolate Bayou (Segments 1107 and 1108). This TMDL takes a watershed approach to addressing indicator bacteria impairments. While TMDL allocations were developed only for the impaired AUs 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 Two Total Maximum Daily Loads for Indicator Bacteria in Chocolate Bayou (H-GAC, 2023).[a]

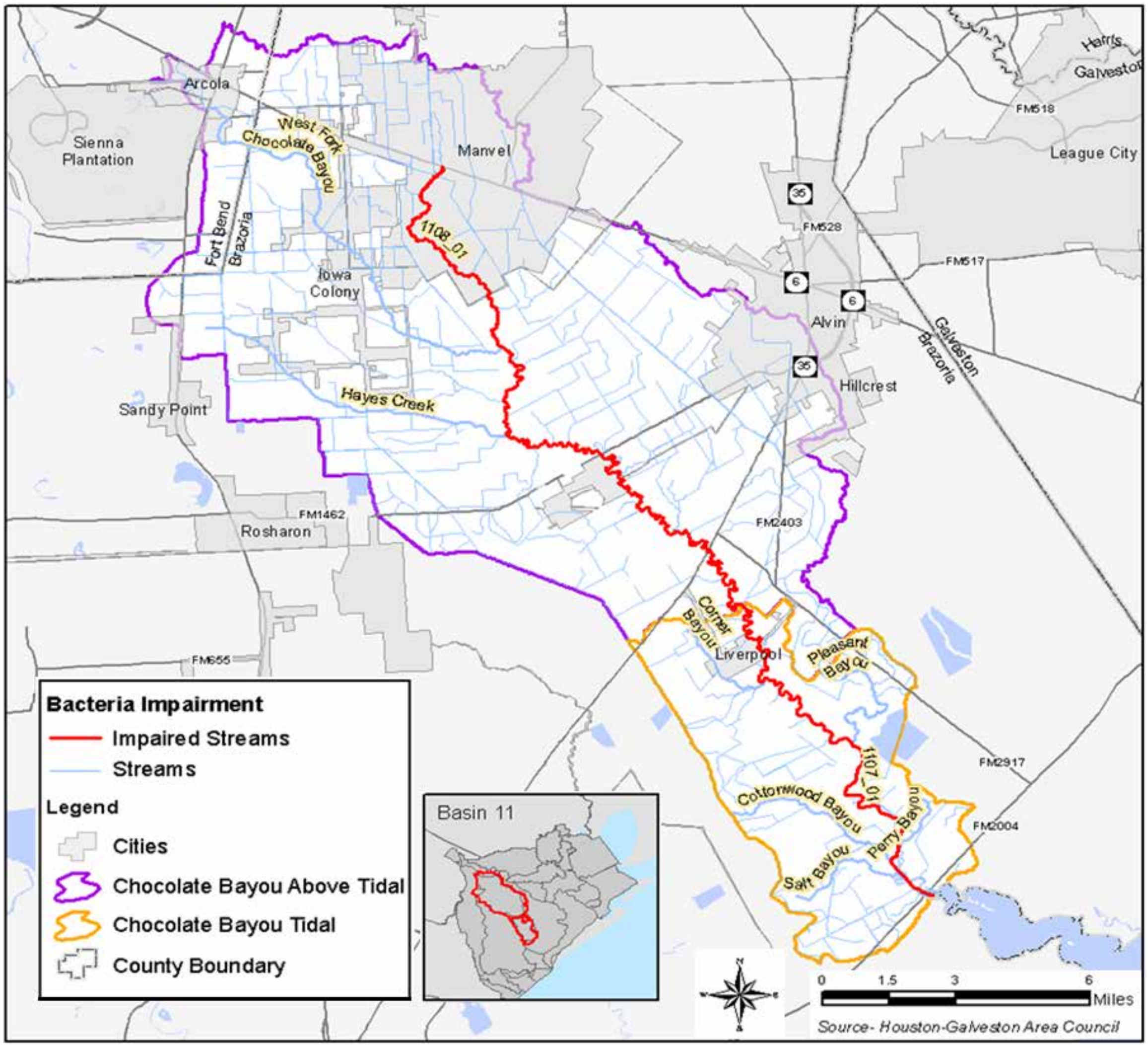

Figure 1. Map of the Chocolate Bayou watershed

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 Part 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.

[a] www.tceq.texas.gov/downloads/water-quality/tmdl/chocolate-bayou-recreational-114/tsd_chocolatebayou_v6.pdf

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

- 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 Chocolate Bayou Tidal in the 2010 Texas Integrated Report (TCEQ, 2011), and again in each subsequent edition through the EPA-approved 2022 Texas Integrated Report (TCEQ, 2022a). The impairment of the primary contact recreation 1 use in Chocolate Bayou Above Tidal was first identified in the 2014 Texas Integrated Report (TCEQ, 2015), and then in each subsequent edition through the EPA-approved 2022 Texas Integrated Report (TCEQ, 2022a).

Recent surface water *E. coli* and Enterococci monitoring within the TMDL watershed has occurred at three TCEQ SWQM stations (Table 1 and Figure 2). The ambient *E. coli* and Enterococci data included in this report were obtained from TCEQ's Surface Water Quality Monitoring Information System between 2004 and 2018 and were used to determine attainment of primary contact recreation 1 use as reported in the 2022 Texas Integrated Report (TCEQ, 2022a). Data assessed indicate non-support of primary contact recreation 1 use because the geometric mean concentrations of available samples exceed the geometric mean criterion of 126 and 35 cfu/100 mL for *E. coli* and Enterococci, respectively, as summarized in Table 1.

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

Water Body	AU	Parameter	TCEQ SWQM Station	Data Range	Number of Samples	Geometric Mean (cfu/100 mL)
Chocolate Bayou Tidal (Segment 1107)	1107_01	Enterococci	21178/ 11478	12/01/2013 – 11/30/2020	66	64.58
Chocolate Bayou Above Tidal (Segment 1108)	1108_01	*E. coli*	11484	12/01/2013 – 11/30/2020	23	212.23

Watershed Overview

The Chocolate Bayou watershed is 173.2 square miles and comprises two segments, Tidal (1107) and Above Tidal (1108) (Figure 1). Each segment is comprised of a single AU. The tidal AU (1107_01) begins approximately 1.5 miles northeast of the City of Liverpool at a saltwater barrier in Brazoria County and traverses 16 miles southeastward to the mouth of Chocolate Bay. The tidal AU has a watershed area of 35.5 square miles and tributaries include Corner, Pleasant, Perry, Cottonwood, and Salt Bayous. The unincorporated communities of Amsterdam, Chocolate Bayou, Chocolate Bayou Springs, and Peterson Landing can also be found in the tidal AU watershed (Damon, 2010).

The above tidal AU (1108_01) begins approximately 1.4 miles west of the City of Manvel in Brazoria County. The headwaters of the West Fork of Chocolate Bayou, a large tributary to Chocolate Bayou, begins near the City of Arcola in extreme southeast Fort Bend County before joining Chocolate Bayou in Brazoria County approximately 2.5 miles south of FM 1128, south of Manvel (Snowden, 1989). Hayes Creek is also a tributary to Chocolate Bayou. AU 1108_01 is 22 miles in length prior to terminating at the tidal segment boundary. Most of AU 1108_01's 137.7 square mile watershed is contained in Brazoria County and includes parts of the cities of Arcola (Fort Bend County), Manvel, Alvin, and the Village of Iowa Colony.

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

- Segment 1107 Chocolate Bayou Tidal – from the confluence with Chocolate Bay 1.4 kilometers (0.9 miles) downstream of Farm to Market Road 2004 in Brazoria County to the saltwater barrier (immediately downstream of the Chocolate Bayou Rice Canal) 5.2 kilometers (3.2 miles) downstream of State Highway 35 in Brazoria County.
    - AU 1107_01 – from the confluence with Chocolate Bay 1.4 kilometers (0.9 miles) downstream of Farm to Market Road

2004 in Brazoria County to the saltwater barrier (immediately downstream of the Chocolate Bayou Rice Canal) 5.2 kilometers (3.2 miles) downstream of State Highway 35 in Brazoria County

- Segment 1108 Chocolate Bayou Above Tidal – from the saltwater barrier (immediately downstream of the Chocolate Bayou Rice Canal) 5.2 kilometers (3.2 miles) downstream of State Highway 35 in Brazoria County to State Highway 6 in Brazoria County.
    - AU 1108_01 – from the saltwater barrier (immediately downstream of the Chocolate Bayou Rice Canal) 5.2 kilometers (3.2 miles) downstream of State Highway 35 in Brazoria County to State Highway 6 in Brazoria County

For the remainder of this report, Chocolate Bayou watershed and TMDL watershed will be used to refer to the entire project area including both AU watersheds.

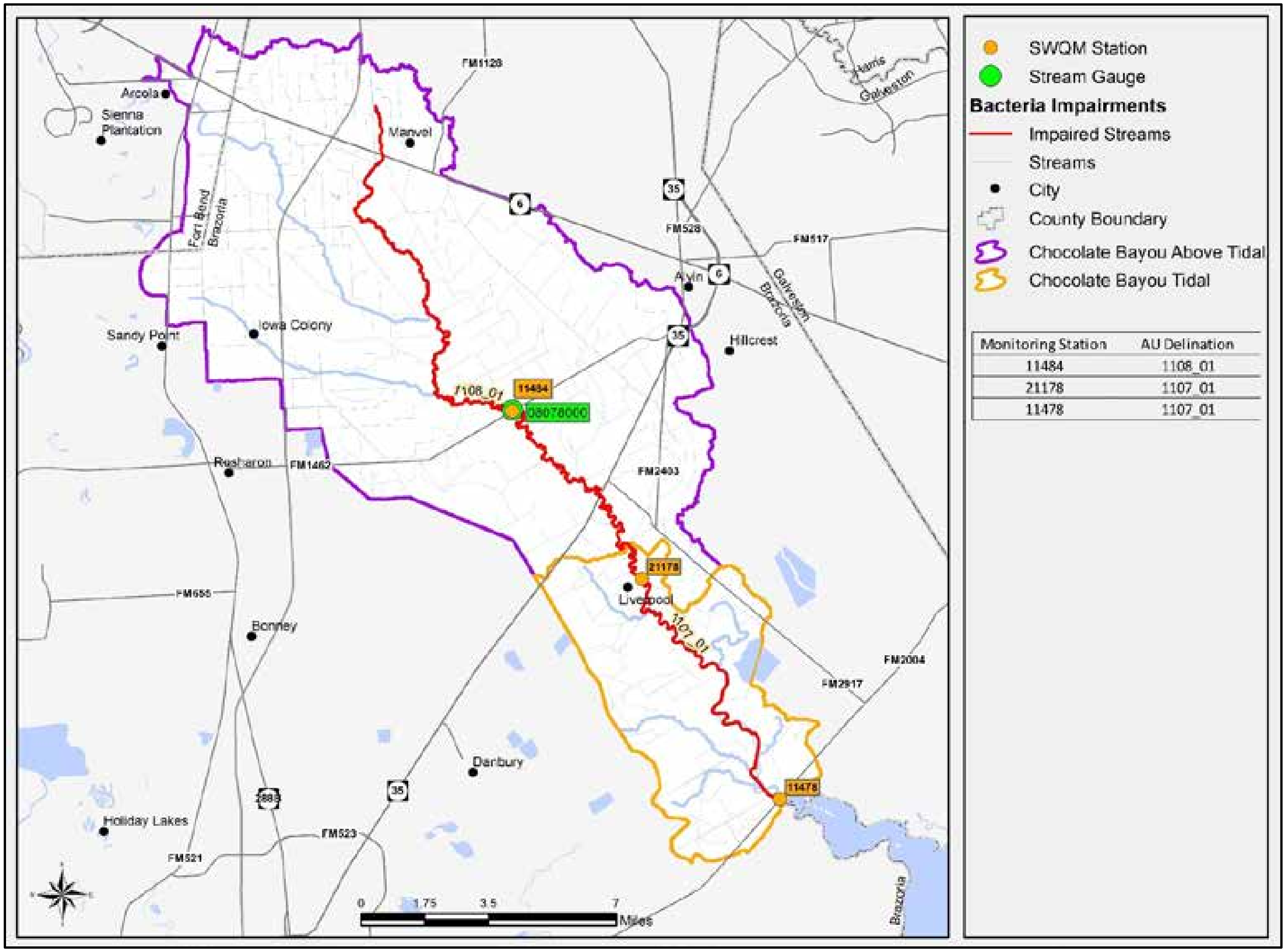

Figure 2. Active TCEQ SWQM and USGS monitoring stations

Climate and Hydrology

Average precipitation recorded between 2000 and 2021 is just over 50 inches per year (Table 2, NOAA, 2022). The highest average monthly precipitation occurs in September, while the lowest average monthly precipitation occurs in February (Figure 3). Average monthly precipitation ranges from just above two inches to slightly over eight inches. Average monthly air temperature ranges from slightly below 50°F in the winter months to slightly above 90°F in the summer months (NOAA, 2022).

Table 2. Average annual rainfall recorded at a gage near the Chocolate Bayou watershed

Station	Station Name	Latitude	Longitude	Average Annual Rainfall (inches)
GHCND: USC00413340	FREEPORT 2 NW TX US	28.9845	-95.3809	50.09

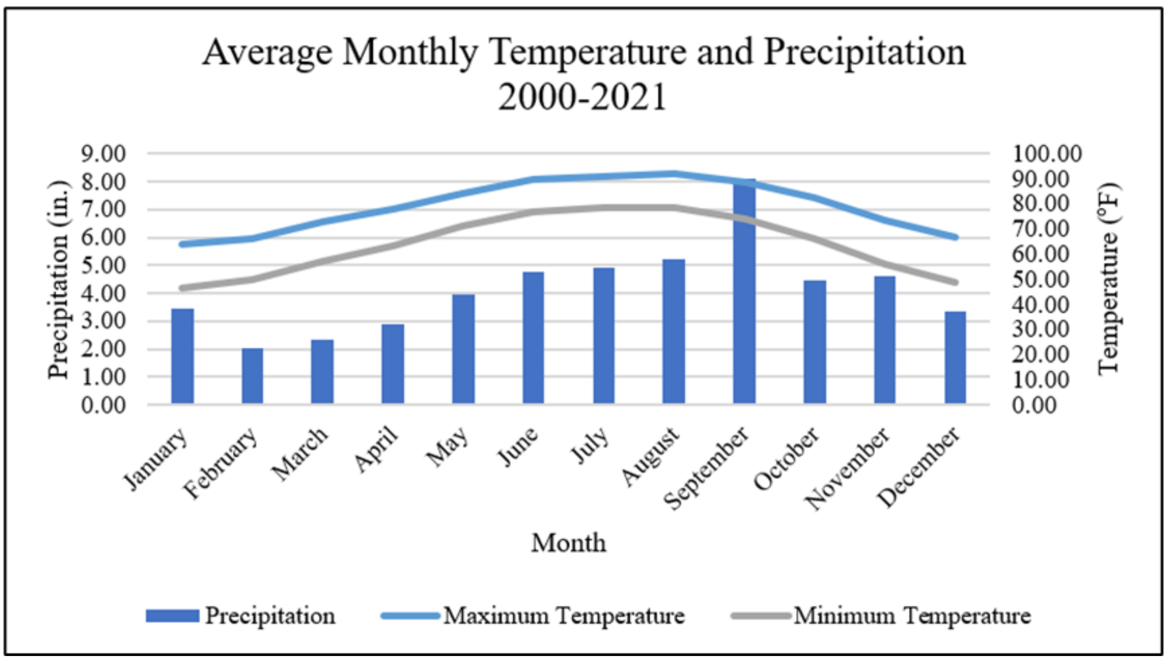

Figure 3. Average monthly temperature and precipitation from 2000 through 2021 at Freeport 2 NW, Texas Station USC00413340

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 2020 population was estimated to be 31,642 people for AU 1108_01 and 2,125 people in AU 1107_01 (H-GAC, 2018a; Table 3)

Regional Growth Forecast methodology (H-GAC, 2017) was used to estimate regional population and household growth out to the year 2045.

Table 3. Population estimates and projections

AU	2020 U.S. Census	2045 Population Projected	Projected Change (2020-2045)	Percentage Increase (2020-2045)
1107_01	2,125	1,228	-897	-42.21
1108_01	31,642	205,151	173,509	548.35

Land Cover

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

- **High Intensity Development** – 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.
- **Medium Intensity Development** – 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.
- **Low Intensity Development** – Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21 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
- **Open Space Development** – 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.

- **Cultivated Crops** – 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/Grasslands** – 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.

- **Barren Lands** – 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.

- **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/Shrub* – 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.

- **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%.

- **Wetlands** – This is a composite class that contains all the palustrine and estuarine wetland land types.

a. *Palustrine Forested Wetland* – 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 Wetland* – 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 Wetland (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 Wetland* – 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 Wetland* – 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 Wetland* – 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.

A summary of the land cover data is provided in Table 4. As depicted in Table 4 and Figure 4, the dominant land uses are Cultivated Crops and Pasture/Grasslands in the AU 1107_01 watershed, at 16.55% and 47.97%, respectively. Pasture/Grasslands is the largest type (42.36%) in the AU 1108_01 watershed, followed by Wetlands (15.23%). Agriculture is the most abundant land use in the Chocolate Bayou watershed.

Table 4. Land cover percentages

Land Cover Type	1107_01 (Acres)	1107_01 (% Acres)	1108_01 (Acres)	1108_01 (% Acres)	Total (Acres)	Total (% Acres)
Open Water	460.02	2.02	370.94	0.42	830.96	0.75
High Intensity Development	725.09	3.19	1,300.23	1.48	2,025.32	1.83
Medium Intensity Development	660.58	2.91	6,011.76	6.82	6,672.34	6.02
Low Intensity Development	1,645.28	7.24	11,466.73	13.02	13,112.01	11.83
Open Space Development	120.62	0.53	1,019.81	1.16	1,140.43	1.03
Barren Lands	218.91	0.96	538.65	0.61	757.56	0.68
Forest/Shrubs	1,329.39	5.85	4,261.69	4.84	5,591.08	5.04
Pasture/Grasslands	10,905.08	47.97	37,314.70	42.36	48,219.77	43.51
Cultivated Crops	3,763.07	16.55	12,392.38	14.07	16,155.45	14.58
Wetlands	2,903.06	12.77	13,421.68	15.23	16,324.74	14.73
Totals	**22,731.08**	**100**	**88,098.57**	**100**	**110,829.65**	**100**

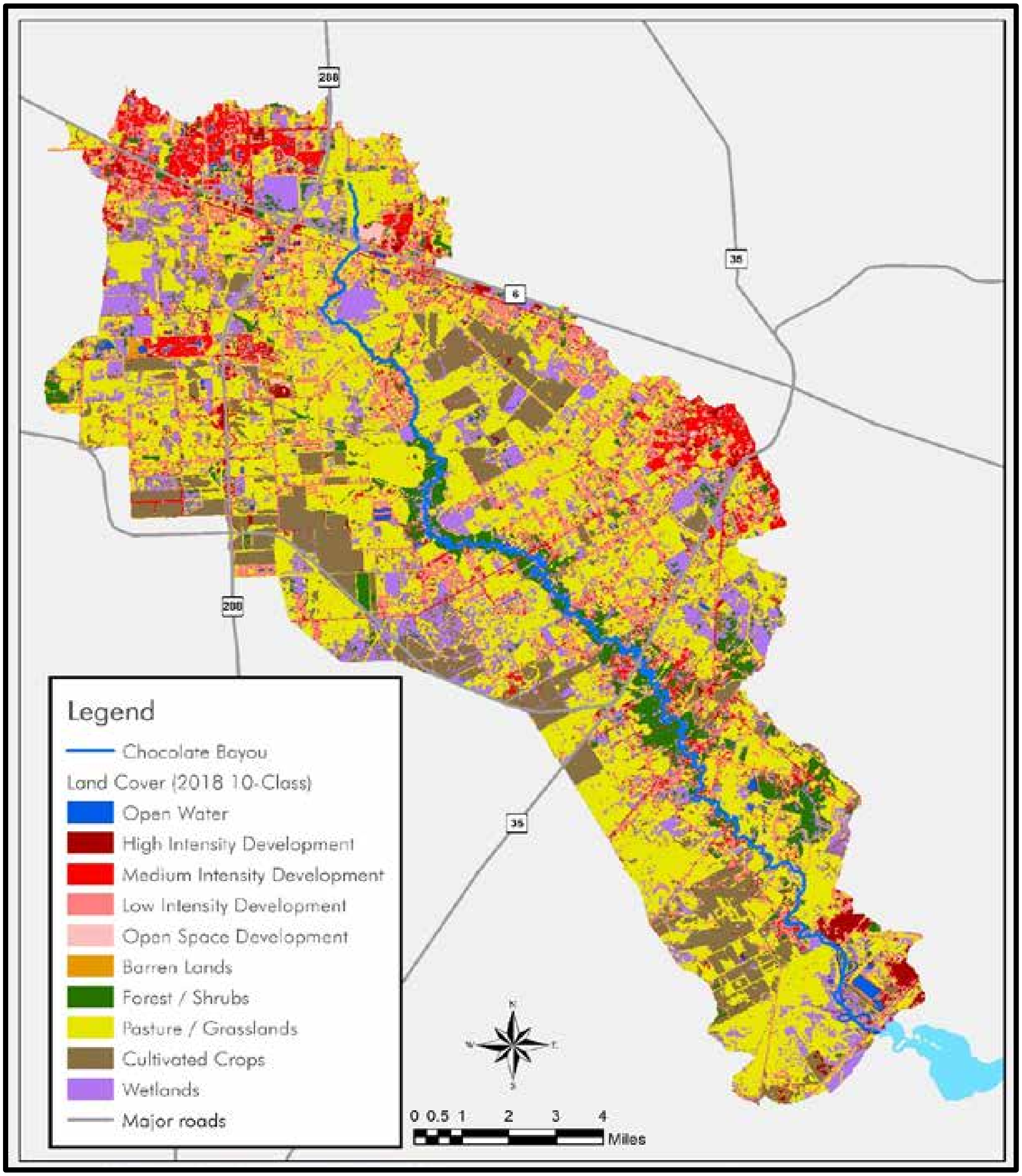

Figure 4. 2018 land cover map

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) (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 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 Chocolate Bayou watershed are made up of clays with a very slow infiltration rates in the Group D hydrologic group at 91.54%, with smaller percentages in the Group C/D and Group C at 4.29% and 4.17%, respectively (Table 5, Figure 5).

Table 5. Hydrologic soil group classifications

Hydrologic Group	**1107_01**		**1108_01**		**Total**	
Type	Area (acres)	Percentage	Area (acres)	Percentage	Area (acres)	Percentage
C	1,182.02	5.20%	3,435.84	3.90%	4,617.86	4.17%
C/D	2,909.58	12.80%	1,850.07	2.10%	4,759.65	4.29%
D	18,639.49	82.00%	82,812.65	94.00%	101,452.14	91.54%
Total	22,731.08	100.00%	88,098.57	100.00%	110,829.65	100.00%

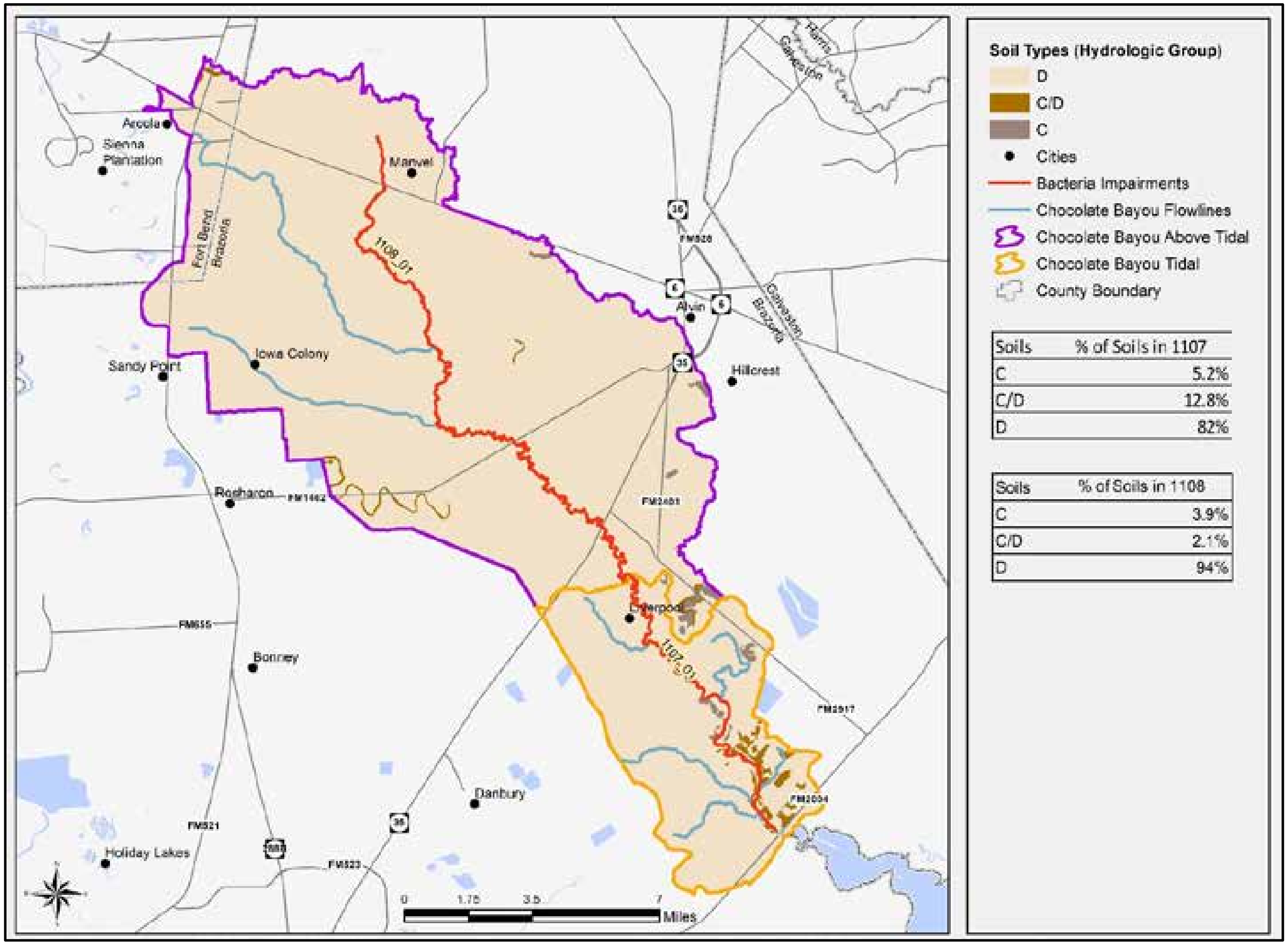

Figure 5. Hydrologic soil groups

Water Rights Review

Surface water rights in Texas are administered and overseen by TCEQ. A search of TCEQ's Texas Water Rights Viewer (TCEQ, 2022b) indicated that there are several water supply canals that deliver water from the Brazos River by the Gulf Coast Water Authority. The bulk of this water is for industrial users found in AU 1107_01 or outside of the Chocolate Bayou watershed. This source was not anticipated to contribute to the flow measured at the U.S. Geological Survey (USGS) gage in AU 1108_01. There were three water rights diversions identified within the catchment area above the USGS station. The withdrawals were found to be minimal and infrequent. It was determined that they had little effect on flow and these diversions were not used to naturalize the flow.

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 is to maintain the concentration of *E. coli* in freshwater and Enterococci in tidal waters below the geometric mean criterion of 126 cfu/100 mL or 35 cfu/100 mL, respectively, which is protective of the primary contact recreation 1 use (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 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 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, industrial sites, and municipal separate storm sewer systems (MS4s).

Domestic and Industrial Wastewater Treatment Facilities

As of June 2020, there are 28 WWTFs with permits that discharge into the Chocolate Bayou watershed (Table 6, Figure 6) (TCEQ, 2022c). There are five industrial wastewater permits and 23 domestic wastewater permits.

Three of the industrial permits, WQ0000001000, WQ0001333000, and WQ0003116000 include a bacteria effluent limit contributed through an internal outfall (101). The internal outfalls for WQ0001333000, and WQ0003116000 are permitted as intermittent and variable. These outfalls are not included in the TMDL calculation. The remaining two industrial facilities, WQ0003903000 and WQ0002068000 lack a bacteria effluent limit and will also not be included in the WWTF wasteload allocation of the TMDL. All industrial facilities include an authorized stormwater component which will be discussed under the Multi-Sector General Permit (MSGP) in the TPDES-Regulated Stormwater section.

Table 6. Permitted domestic and industrial WWTFs

AU	TPDES Number	NPDES[a] Number	Facility Name	Permitted Party	Outfall Number	Bacteria Limits (cfu/100 mL)	Facility Type/ Effluent Type[b]	Daily Average Flow – Permitted Discharge (MGD[c])
1107_01	WQ0000001000	TX0003875	Ascend Performance Materials Chocolate Bayou Plant	Ascend Performance Materials Texas Inc.	001	35	Industrial/PME, IW, SW	7.8
1107_01	WQ0000001000	TX0003875	Ascend Performance Materials Chocolate Bayou Plant	Ascend Performance Materials Texas Inc.	101	35	Industrial/WW	4
1107_01	WQ0000001000	TX0003875	Ascend Performance Materials Chocolate Bayou Plant	Ascend Performance Materials Texas Inc.	002	N/A	Industrial/SW	N/A
1107_01	WQ0000001000	TX0003875	Ascend Performance Materials Chocolate Bayou Plant	Ascend Performance Materials Texas Inc.	003	N/A	Industrial/SW	N/A
1107_01	WQ0001333000	TX0004821	Chocolate Bayou Facility	INEOS USA LLC	001	35	Industrial/IW, PME, SW	8
1107_01	WQ0001333000	TX0004821	Chocolate Bayou Facility	INEOS USA LLC	101	N/A	Industrial/WW	*
1107_01	WQ0001333000	TX0004821	Chocolate Bayou Facility	INEOS USA LLC	002	N/A	Industrial/IW, SW	N/A
1107_01	WQ0001333000	TX0004821	Chocolate Bayou Facility	INEOS USA LLC	003	N/A	Industrial/SW	N/A
1107_01	WQ0001333000	TX0004821	Chocolate Bayou Facility	INEOS USA LLC	004	N/A	Industrial/SW	N/A
1107_01	WQ0003116000	TX0105261	Best Sea-Pack of Texas Facility	Best Sea-Pack of Texas Inc.	001	35	Industrial/IW, PME, SW	0.26
1107_01	WQ0003116000	TX0105261	Best Sea-Pack of Texas Facility	Best Sea-Pack of Texas Inc.	101	N/A	Industrial/WW	*

AU	TPDES Number	NPDES[a] Number	Facility Name	Permitted Party	Outfall Number	Bacteria Limits (cfu/100 mL)	Facility Type/ Effluent Type[b]	Daily Average Flow – Permitted Discharge (MGD[c])
1107_01	WQ0003903000	TX0114995	Allied Petrochemical Plant	Allied Petrochemical, LLC	001	35	Industrial/IW, SW	0.021
1107_01	WQ0014324001	TX0119041	Weybridge WWTF	Aqua Texas, Inc.	001	35	Domestic/WW	0.05
1107_01	WQ0015657001	TX0138321	St. Ives RV Resort LCC	St. Ives RV Resort WWTF	001	35	Domestic/WW	0.015
1108_01	WQ0002068000	TX0072168	HC Manvel	HC Manvel, Inc.	001	126	Industrial/IW, SW	0.033
1108_01	WQ0002068000	TX0072168	HC Manvel	HC Manvel, Inc.	002	N/A	Industrial/IW, SW	N/A
1108_01	WQ0010700001	TX0023337	Oak Manor WWTF	Oak Manor MUD	001	126	Domestic/WW	0.08
1108_01	WQ0012780001	TX0093823	Southwood Estates WWTF	Undine Texas Environmental, LLC	001	126	Domestic/WW	0.4
1108_01	WQ0013367001	TX0102385	City of Arcola WWTF	City of Arcola	001	126	Domestic/WW	0.95
1108_01	WQ0013872001	TX0118397	City of Manvel WWTF	City of Manvel	001	126	Domestic/WW	0.5
1108_01	WQ0014068001	TX0117927	RiceTec WWTF	RiceTec Inc.	001	126	Domestic/WW	0.025
1108_01	WQ0014149001	TX0123994	Savannah Plantation WWTF	SP Utility Co Inc.	001	126	Domestic/WW	0.2
1108_01	WQ0014222001	TX0123633	Brazoria County MUD No. 21 WWTF	Brazoria County MUD No. 21	001	126	Domestic/WW	1.2
1108_01	WQ0014253001	TX0124001	Rodeo Palms WWTF	Brazoria County MUD No. 29	001	126	Domestic/WW	0.45
1108_01	WQ0014279001	TX0119547	Palm Crest WWTF	Aqua Texas Inc.	001	126	Domestic/WW	0.15
1108_01	WQ0014461001	TX0126055	Brazoria County MUD WWTF	Brazoria County MUD No. 30	001	126	Domestic/WW	0.5
1108_01	WQ0014497001	TX0126365	O'Day Investments CR 81 WWTF	O'Day Investments, LP	001	126	Domestic/WW	0.099

AU	TPDES Number	NPDES[a] Number	Facility Name	Permitted Party	Outfall Number	Bacteria Limits (cfu/100 mL)	Facility Type/ Effluent Type[b]	Daily Average Flow – Permitted Discharge (MGD[c])
1108_01	WQ0014546001	TX0126951	Brazoria County MUD No. 31 WWTP	Brazoria County MUD No. 31	001	126	Domestic/WW	2
1108_01	WQ0014724002	TX0129453	Brazoria County MUD 56 WWTF	Rise Communities, LLC	001	126	Domestic/WW	0.995
1108_01	WQ0014724003	TX0129470	Brazoria County MUD No. 55 WWTF	Brazoria County MUD No. 55	001	126	Domestic/WW	0.98
1108_01	WQ0014992001	TX0132896	Glendale Lakes Subdivision WWTF	Fort Bend County MUD No. 141	001	126	Domestic/WW	0.7
1108_01	WQ0015093001	TX0134562	Lacovia Lakes WWTF	AUC Group, L.P.	001	126	Domestic/WW	0.95
1108_01	WQ0015279001	TX0135577	Brazoria County MUD No. 43 WWTF	Brazoria County MUD No. 43	001	126	Domestic/WW	0.3
1108_01	WQ0015486001	TX0137189	Brazoria County MUD No. 42 WWTF	Manvel Town Center, Ltd.	001	126	Domestic/WW	0.615
1108_01	WQ0015582001	TX0137804	Arcola Estates WWTF	Niranjan Shantilal Patel	001	126	Domestic/WW	0.075
1108_01	WQ0015637001	TX0138134	Charleston MUD WWTF	Charleston C.M.I., Ltd	001	126	Domestic/WW	0.245
1108_01	WQ0015714001	TX0138665	Sierra Vista West WWTF	Brazoria County Municipal Utility District No. 53	001	126	Domestic/WW	0.9

* Internal outfall discharge included in permitted discharge through external outfall

[a] NPDES: National Pollutant Discharge Elimination System

[b] Abbreviations as follows: WW (treated domestic wastewater), IW (treated industrial wastewater), SW (stormwater), N/A (No reported effluent discharge) and PME (previously monitored effluent).

[c] MGD: million gallons per day

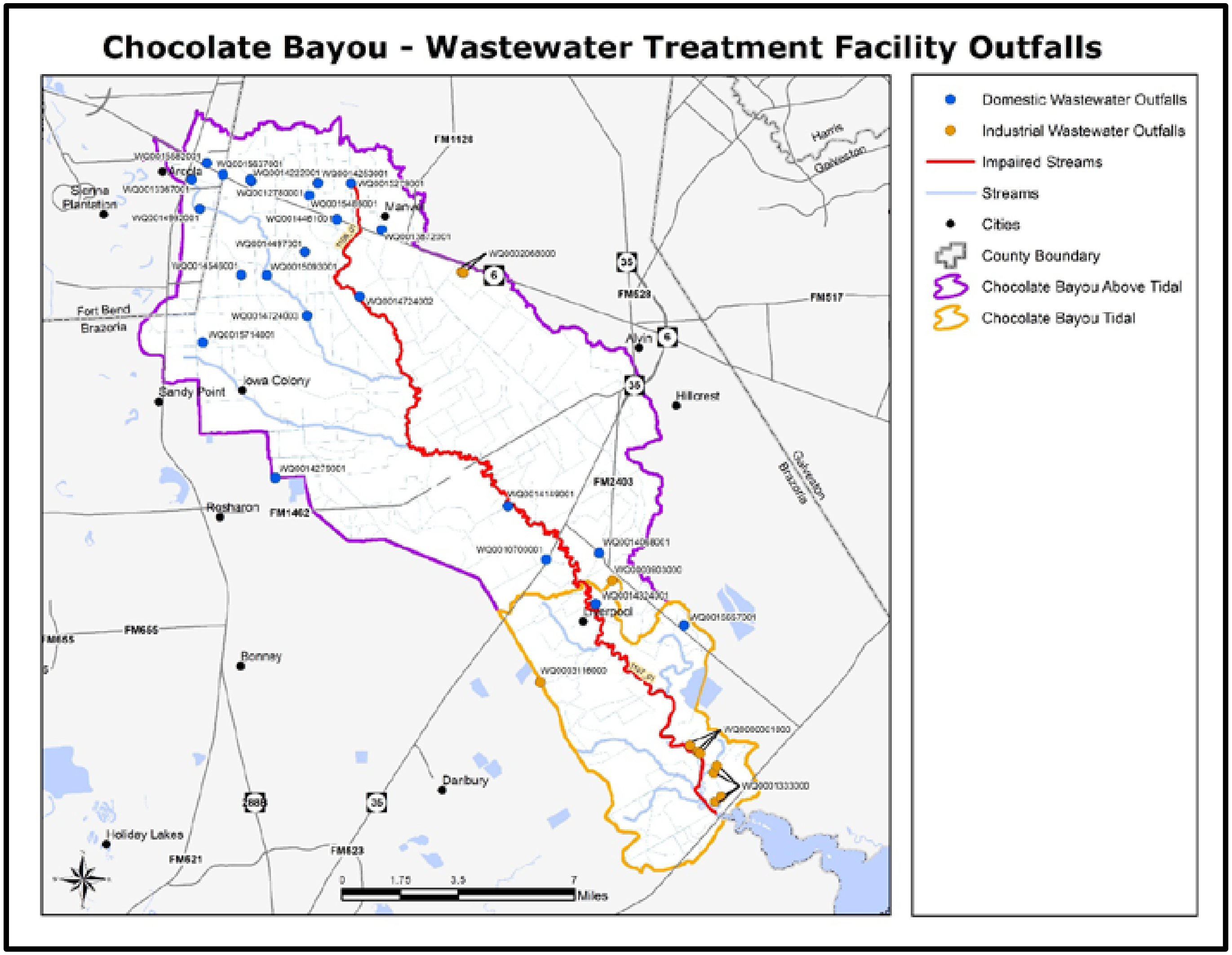

Figure 6. Regulated sources

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, 2022c) in the Chocolate Bayou watershed as of May 1, 2022, found two general permit authorizations for concrete production facilities in the Chocolate Bayou Above Tidal watershed, AU 1108_01. 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.

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 2021 (TCEQ, 2022d). Table 7 summarizes the number of SSO incidents that have been reported by regulated entities in the TMDL watershed.

Table 7. Summary of reported SSO events from 2016 through 2021

Year	Estimated Incidents	Total Volume	Average Volume per SSO[a]
2016	6	12,195.00	2,032.50
2017	3	628.00	209.20
2018	10	3,506.50	350.65
2019	4	14,125.00	3,531.25
2020	8	4,800.00	600.00
2021	10	20,325.00	2,032.50
Total	**41**	**55,579.50**	**1,355.59**

[a] SSO volumes are reported in gallons

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 (UA) as defined by the United States Census Bureau (USCB) in the 2000 and 2010 Decennial Censuses.

The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the “maximum extent practicable or MEP” 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.
- Authorization for construction activities where the small MS4 is the site operator (*optional*)[b].

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 for industrial facilities

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

- 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

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 their MS4 regulated areas and five active Phase II MS4 General Permit authorizations in the Chocolate Bayou watershed (Table 8) (TCEQ, 2022c). When mapped (Figure 7) based on USCB, the census designated UAs are only found in the AU 1108_01 watershed (USCB, 2010). This UA covers approximately 9,138.74 acres.

Table 8. MS4 permit authorizations

Entity	Authorization Type	TPDES Authorization or Permit No./ EPA ID	Location
Brazoria County CRD 3	Phase II MS4 General Permit TXR040000	TXR040148/Not applicable	Area within the Brazoria County CRD 3 limits that is located within the Houston UA
City of Alvin	Phase II MS4 General Permit TXR040000	TXR040138/Not applicable	Area within the City of Alvin limits that is located within the Houston UA
TxDOT	Combined Phase I and Phase II MS4	WQ0005011000/ TXS002101	TXDOT rights-of-way located within Phase I MS4 areas and Phase II MS4 UAs
Brazoria County MUD 29	Phase II MS4 General Permit TXR040000	TXR040527/Not applicable	Area outside of the City of Manvel limits that is located partially within the Houston UA
Brazoria Drainage District 4	Phase II MS4 General Permit TXR040000	TXR040144/Not applicable	Area within the City of Pearland limits that is located within the Houston UA
Brazoria County MUD 21	Phase II MS4 General Permit TXR040000	TXR040528/Not applicable	Area outside of the City of Rosharon limits and located within the City of Houston UA

MSGP authorizations were reviewed on May 1, 2022, through the TCEQ Central Registry (TCEQ, 2022c) for active permit authorizations in the Chocolate Bayou watershed. A total of 16 MSGP authorizations were found (Table 9). To eliminate the possibility of over counting with the stormwater permit area, only the regulated areas located outside or partially outside of the UA was determined (Figure 7).

Five MSGP authorizations were found in the AU 1107_01 watershed with a total area of 2,301.70 acres. Twelve MSGP authorizations were found in the AU 1108_01 watershed. One facility, Allied Petrochemical, LLC, is partially within both AU watersheds and is listed twice in Table 9. Included in this list are the facilities that hold wastewater individual permits and stormwater MSGP authorizations. The total MSGP regulated area in 1108_01, outside of the UA, was found to be 344.16 acres. The MSGP regulated area outside of the UA was used in development of the TMDL.

Table 9. Industrial wastewater permits and stormwater authorizations

AU	TPDES	MSGP Permit Number	Facility Name	City	County	Facility Acreage	Facility Acreage not in UA
1107_01	WQ0000001000	TXR05BQ25 TXR15303N	Ascend Performance Materials Texas Inc.	Alvin	Brazoria	559.3	559.3
1107_01	WQ0001333000	TXR05DG63 TXR15710P	INEOS USA LLC	Alvin	Brazoria	1462	1462
1107_01	WQ0003903000	TXR05AJ66	Allied Petrochemical, LLC	Alvin	Brazoria	48.8	48.8
1107_01	n/a	TXR05DK43	Poly-Coat Systems Inc.	Liverpool	Brazoria	48.9	48.9
1107_01	n/a	TXR05EE81	Gulf Coast Stabilized Materials LLC	Alvin	Brazoria	182.7	182.7
					Total	**2,301.70**	**2,301.70**
1108_01	WQ0003903000	TXR05AJ66	Allied Petrochemical, LLC	Alvin	Brazoria	16.42	16.42
1108_01	WQ0002068000	n/a	HC Manvel, Inc.	Alvin	Brazoria	14	14
1108_01	n/a	TXR05AF97	Living Earth, Letco Group, LLC	Rosharon	Brazoria	10.5	0
1108_01	n/a	TXR05AQ74	Polymer Chemistry Chocolate Bayou, Bernard	Alvin	Brazoria	15.7	15.7
1108_01	n/a	TXR05CT99	Crest Industrial Chemicals, Inc.	Rosharon	Brazoria	19.5	19.5
1108_01	n/a	TXR05CU61	Cherry Crushed Concrete, Inc.	Rosharon	Brazoria	56.4	56.4

AU	TPDES	MSGP Permit Number	Facility Name	City	County	Facility Acreage	Facility Acreage not in UA
1108_01	n/a	TXR05FE89	Lhoist North America of Texas, Ltd.	Arcola	Fort Bend	18.8	0
1108_01	n/a	TXR05DC67, TXR05EZ01	Sand Land, Inc.	Rosharon	Brazoria	46.44	46.44
1108_01	n/a	TXR05EM71	Cherry Crushed Concrete, Inc.	Rosharon	Brazoria	40.3	40.3
1108_01	n/a	TXR05ES71	Cherry Crushed Concrete, Inc.	Alvin	Brazoria	93.6	93.6
1108_01	n/a	TXR05FJ49	Jam Excavating, LLC	Manvel	Brazoria	20.2	20.2
1108_01	n/a	TXR05L089	Texmore, Inc., Cameron Auto Salvage	Manvel	Brazoria	21.6	21.6
					Total	**373.46**	**344.16**

Construction activities found in the Chocolate Bayou watershed are constantly changing due to the short-term nature of most construction activities. The permit data is only considered accurate for the date the data was accessed. A review of the TCEQ Central Registry on May 1, 2022, found 128 active stormwater CGP authorizations (TCEQ, 2022c).

Due to the variable nature of the stormwater construction permits, the acres recorded serve only 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.

For the 128 CGP authorizations found, two were within the AU 1107_01 watershed and 126 were within the AU 1108_01 watershed. The estimated disturbed area was 510 acres within the AU 1107_01 watershed. The estimated disturbed area within the AU 1108_01 watershed was 11,213.77 acres. This amount of construction is reflective of the population growth within AU 1108_01.

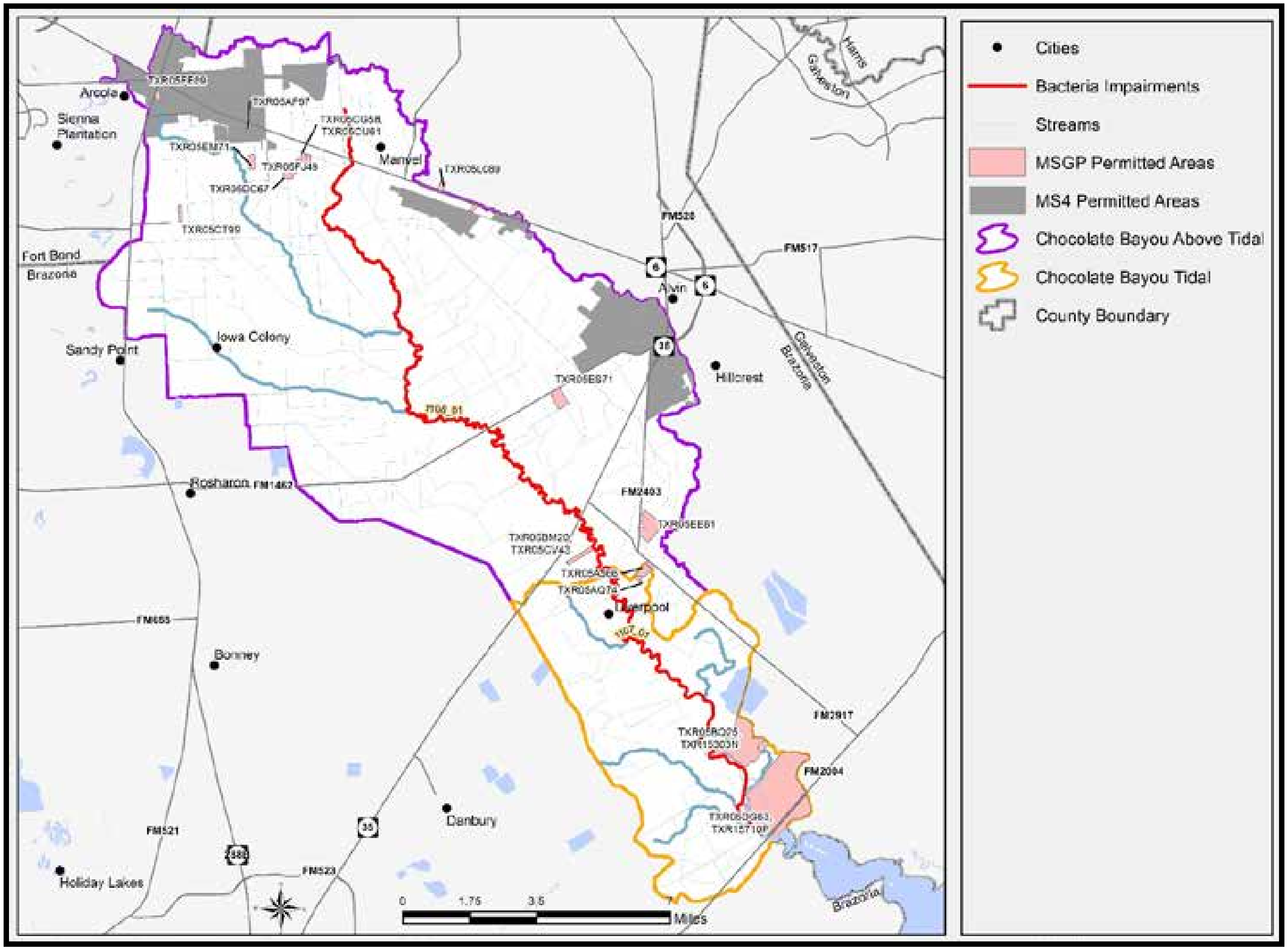

Figure 7. Regulated stormwater area based on MS4s and MSGPs

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, land application fields, 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 *E. coli* and Enterococci to nearby water bodies. Livestock are present throughout the more rural portions of the project watershed.

Table 10 provides estimated numbers of selected livestock in the TMDL watershed based on the 2017 Census of Agriculture conducted by USDA (USDA NASS, 2019). These estimations were calculated by applying a ratio of watershed land area compared to county land area times the livestock numbers. 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 10. Estimated livestock population

AU	Cattle and Calves	Goats and Sheep	Horses	Hogs and Pigs	Poultry
1107_01	2,851	159	201	188	5,142
1108_01	9,755	543	688	644	17,595
Total	**12,606**	**702**	**889**	**832**	**22,737**

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 11 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 11. Estimated households and pet population

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
1107_01	784	481	358
1108_01	11,676	7,169	5,336
Total	**12,460**	**7,650**	**5,694**

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.

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. Deer are one of the few wildlife species where population estimates have been routinely made. Texas Parks and Wildlife Department (TPWD) determines deer population-density estimates by Deer Management Units (DMU) and Ecoregion in the state. H-GAC downloaded the DMU data for the Chocolate Bayou watershed for 2006 to 2016 (TPWD, 2019). The population estimates are available in deer per 1000 acres. H-GAC determined an average density of 0.03957 per acre, for the period. This average density is not based on deer preference for suitable habitat. By applying this average density factor to the acreage in the Chocolate Bayou watershed, the white-tail deer population can be estimated at 4,385 (Table 12).

Table 12. Estimated deer population

AU	Area (acres)	Estimated Deer Population
1107_01	22,731.08	899
1108_01	88,098.57	3,486
Total	**110,829.65**	**4,385**

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 available food and water resources. The 8.9 hogs per square mile is applied to Barren, Cropland, and Developed Low Intensity land cover types. The 16.4 hogs per square mile is applied to Open Space Development, Forest/Shrub, Pasture/Grassland and Wetland land cover types. Feral hogs were estimated to have a total population of 2,243 within the Chocolate Bayou watershed (Table 13).

Table 13. Estimated feral hog population

AU	Low Quality Habitat (acres)	Feral Hogs – Low Quality Habitat	High Quality Habitat (acres)	Feral Hogs – High Quality Habitat	Total Estimated Feral Hogs
1107_01	5,627.26	78	15,258.15	391	469
1108_01	24,397.76	339	56,017.88	1,435	1,774
Total	**30,025.02**	**417**	**71,276.03**	**1,826**	**2,243**

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. 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.

Some OSSFs in the TMDL 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 the Chocolate Bayou watershed, 4,620 permitted OSSFs have been documented (Figure 8). Unpermitted OSSF locations were estimated using H-GAC's geographic information database of potential OSSF locations in the Houston-Galveston area using known OSSF locations, 911 addresses, and WWTF service boundaries. An estimated additional 4,551 OSSFs added to the 4,620 permitted systems equal a total of 9,171 units.

OSSFs can be a 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 number of OSSFs estimated in the TMDL watershed area, 1,101 OSSFs are projected to be failing.

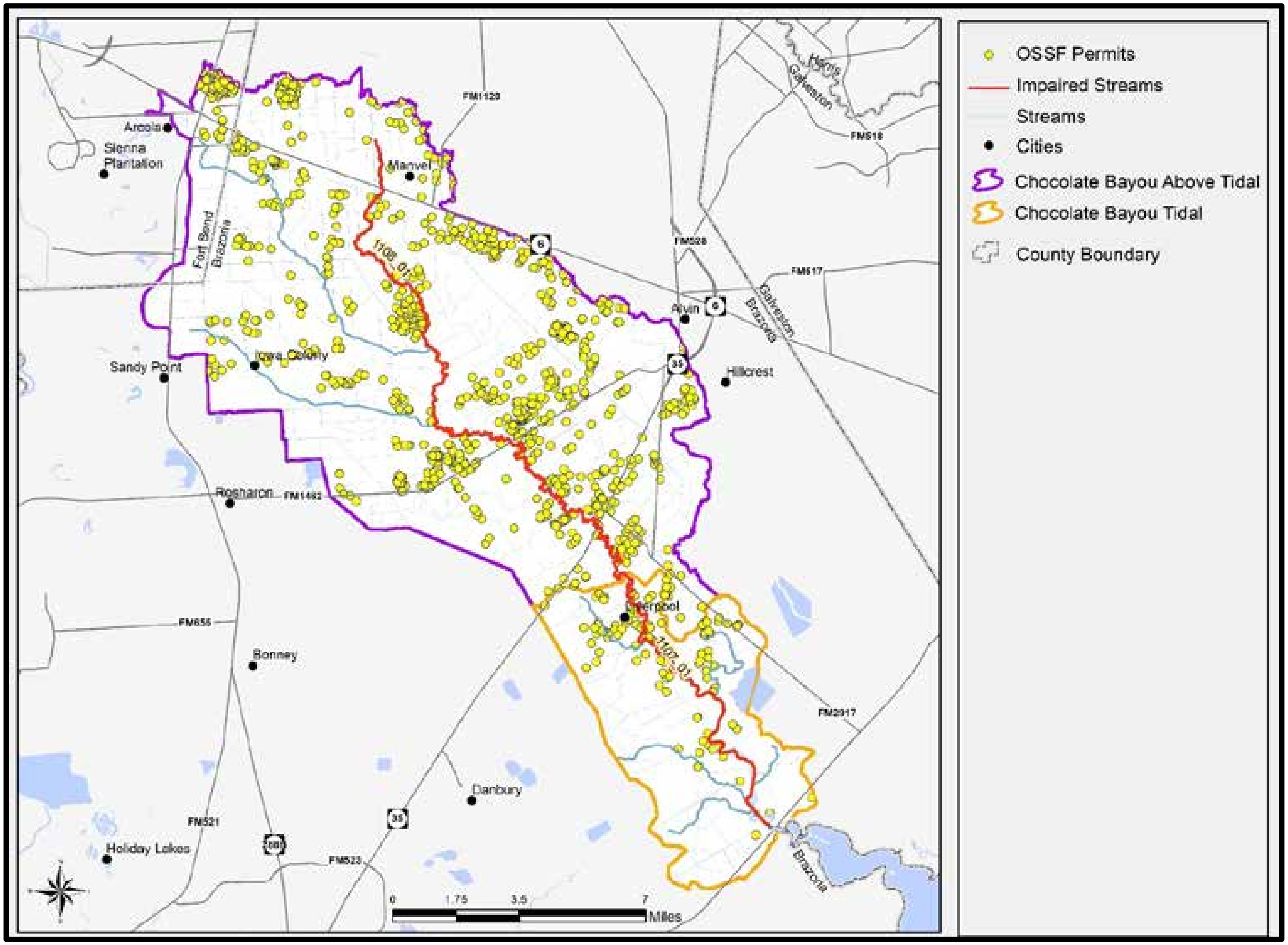

Figure 8. Estimated OSSF density

Bacteria Survival and Die-off

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

Load Duration 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 these TMDLs, the loads shown are of *E. coli* bacteria for AU 1108_01 and Enterococci bacteria for AU 1107_01 in cfu/day.

LDCs and modified LDCs are derived from flow duration curves (FDCs) and modified FDCs. LDCs shown in the following figures represent the maximum acceptable load in the water bodies that will result in achievement of the TMDL water quality targets. The basic steps to generate LDCs involve all of the following:

- Generating a daily flow record – the mean daily streamflow record incorporating full permitted discharges and FG was developed for a TCEQ SWQM station within each TMDL watershed using the drainage area ratio methodology.
- Developing the FDC – the mean daily streamflow is plotted against the exceedance probability of the mean daily streamflow for each day.
- Converting the FDC to an LDC – 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 LDC 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.

The basic steps to generate modified LDCs involve 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 USGS Gage 08078000 on Chocolate Bayou.
- 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 for the tidal AU.
- 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 for the tidal AU.
- Converting the modified FDC to a modified LDC – 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 LDC 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.

More information explaining the modified LDC method may be found in Chapter 2 and Appendix 1 of the Umpqua Basin Total Maximum Daily Loads and supporting documents (ODEQ, 2006).

Load Duration Curve Results

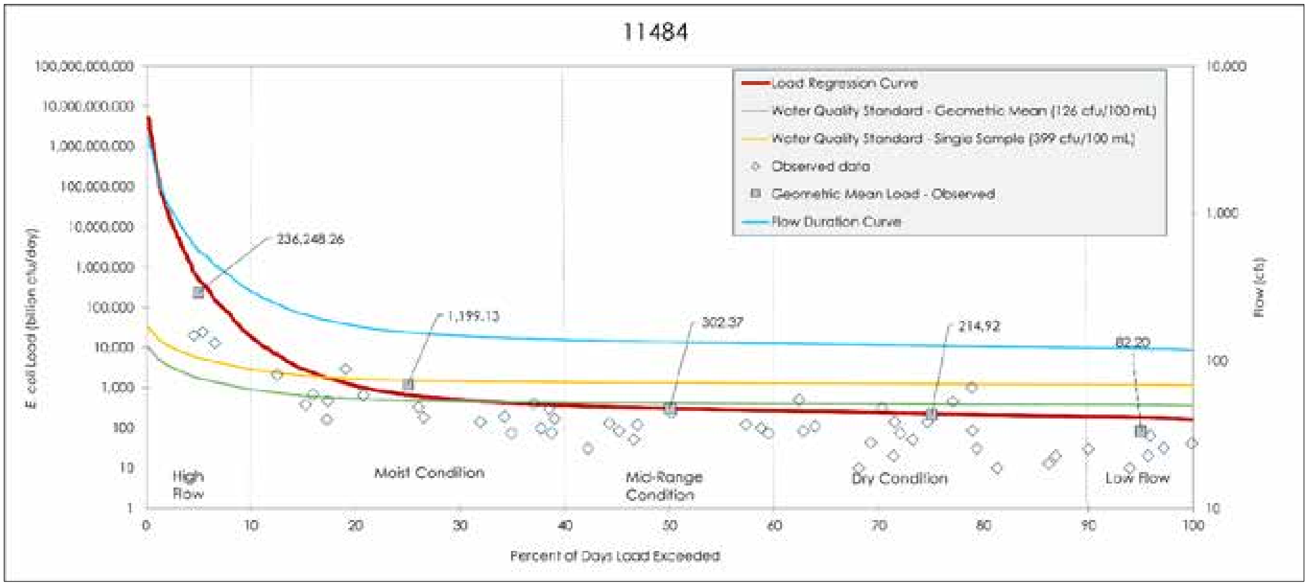

Figure 9. LDC for Chocolate Bayou Above Tidal AU 1108_01 at TCEQ SWQM Station 11484

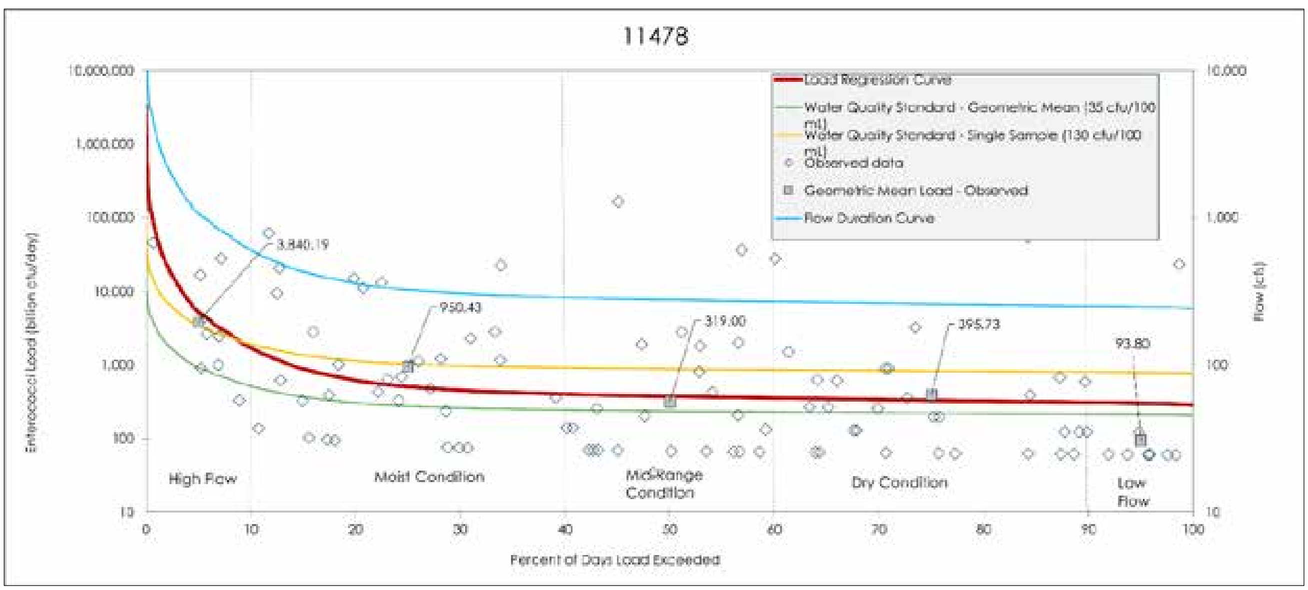

Figure 10. Modified LDC for Chocolate Bayou Tidal AU 1107_01 at TCEQ SWQM Station 11478

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.

These TMDLs incorporate 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 *E. coli* and 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 LDCs developed for each of the TMDL AUs. 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 TMDLs for the impaired AUs were developed as pollutant load allocations based on information from the LDC developed for TCEQ SWQM stations 11484 and 11478 (Figures 9 and 10). The bacteria LDCs were developed by multiplying the streamflow value along the FDC by the primary contact recreation 1 use geometric mean criterion for *E. coli* (126 cfu/100 mL) and Enterococci (35 cfu/100 mL) and by the conversion factor to convert to loading in cfu per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

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

Where:

Criterion = 35 cfu/100 mL for Enterococci or 126 cfu/100 mL for *E. coli*

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 14 shows the TMDL values at the 5% load duration exceedance.

Table 14. Summary of allowable loadings

AU	5% Exceedance Flow (cfs)	TMDL (Billion cfu/day)
1107_01	1,059.388	907.154
1108_01	556.036	1,714.082

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 15.

Table 15. MOS calculations

AU	Parameter	Criterion (cfu/100mL)	TMDL	MOS
1107_01	Enterococci	35	907.154	43.358
1108_01	*E. coli*	126	1,714.082	85.704

All loads are expressed in billion cfu/day.

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:

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

Where:

Criterion = 35 cfu/100 mL for Enterococci or 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 the AU.

Table 16 shows the load allocations for each WWTF and sums the load allocations, providing a total WLA_{WWTF} for the AUs.

Table 16. Wasteload allocations for TPDES-permitted facilities

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	WLA_{WWTF} (billion cfu/day *E. coli*)	WLA_{WWTF} (billion cfu/day Enterococci)
1107_01	WQ0000001000	Ascend Performance Materials Chocolate Bayou Plant	35 (Enterococci)	4.000	-	5.299
1107_01	WQ0014324001	Weybridge WWTF	35 (Enterococci)	0.050	-	0.066
1107_01	WQ0015657001	St. Ives RV Resort LCC	35 (Enterococci)	0.015	-	0.020
		Subtotal for 1107_01		4.065	-	5.386
		Subtotal for 1108_01		12.314	-	16.315
		Total		**16.379**	**-**	**21.700**
1108_01	WQ0010700001	Oak Manor MUD WWTF	126 (*E. coli*)	0.080	0.382	0.106
1108_01	WQ0012780001	Southwood Estates WWTF	126 (*E. coli*)	0.400	1.908	0.530
1108_01	WQ0013367001	City of Arcola WWTF	126 (*E. coli*)	0.950	4.531	1.259
1108_01	WQ0013872001	City of Manvel WWTF	126 (*E. coli*)	0.500	2.385	0.662
1108_01	WQ0014068001	RiceTec WWTF	126 (*E. coli*)	0.025	0.119	0.033
1108_01	WQ0014149001	Savannah Plantation WWTF	126 (*E. coli*)	0.200	0.954	0.265
1108_01	WQ0014222001	Brazoria County MUD 21 WWTF	126 (*E. coli*)	1.200	5.724	1.590
1108_01	WQ0014253001	Rodeo Palms WWTF	126 (*E. coli*)	0.450	2.146	0.596
1108_01	WQ0014279001	Palm Crest WWTF	126 (*E. coli*)	0.150	0.715	0.199
1108_01	WQ0014461001	Brazoria County MUD 30 WWTF	126 (*E. coli*)	0.500	2.385	0.662
1108_01	WQ0014497001	O'Day Investments CR 81	126 (*E. coli*)	0.099	0.472	0.131
1108_01	WQ0014546001	Brazoria County MUD 31 WWTP	126 (*E. coli*)	2.000	9.539	2.650
1108_01	WQ0014724002	Brazoria County MUD 56 WWTP	126 (*E. coli*)	0.995	4.746	1.318
1108_01	WQ0014724003	Brazoria County MUD 55 WWTF	126 (*E. coli*)	0.980	4.674	1.298
1108_01	WQ0014992001	Glendale Lakes Subdivision WWTP	126 (*E. coli*)	0.700	3.339	0.927
1108_01	WQ0015093001	Lacovia Lakes WWTF	126 (*E. coli*)	0.950	4.531	1.259
1108_01	WQ0015279001	Brazoria County MUD 43 WWTF	126 (*E. coli*)	0.300	1.431	0.398

AU	TPDES Number	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD)	WLA_{WWTF} (billion cfu/day *E. coli*)	WLA_{WWTF} (billion cfu/day Enterococci)
1108_01	WQ0015486001	Brazoria County MUD 42 WWTF	126 (*E. coli*)	0.615	2.933	0.815
1108_01	WQ0015582001	Arcola Estates WWTF	126 (*E. coli*)	0.075	0.358	0.099
1108_01	WQ0015637001	Charleston MUD WWTF	126 (*E. coli*)	0.245	1.169	0.325
1108_01	WQ0015714001	Sierra Vista West WWTF	126 (*E. coli*)	0.900	4.293	1.192
Total				**12.314**	**58.733**	**16.315**[a]

[a] The Enterococci values for AU 1108_01 were calculated for use in the WLA_{WWTF} for downstream AU 1107_01

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 these TMDLs 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:

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

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 each AU watershed. To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total watershed area. The estimated areas in Table 17 are cumulative, each AU accounts for the upstream area contribution by adding the total area of regulated stormwater for the AU and that of the upstream AU and then dividing by the watershed area.

Table 17. Regulated stormwater FDA_{SWP} calculations

AU	MS4 Area	MSGP Area	CGP Area	Concrete Production Facilities Area	Total Area of Permits	Watershed Area	FDA_{SWP}
1107_01	0.00	2,301.70	510.00	0.00	23,520.50	110,829.648	21.222%
1108_01	9,138.74	344.16	11,213.77	12.13	20,708.80	88,098.568	23.506%

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 18.

Table 18. Regulated stormwater load calculations

AU	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
1107_01	907.154	21.700	89.534	45.358	21.222%	159.286
1108_01	1,714.082	58.733	322.063	85.704	23.506%	293.261

All loads are expressed in billion cfu/day. With the WLA_{SW} and WLA_{WWTF} terms, the total WLA term can be determined by adding the two parts (Table 19).

Table 19. WLA calculations

AU	Parameter	Criterion (cfu/100mL)	WLA_{WWTF}	WLA_{SW}	WLA
1107_01	Enterococci	35	21.700	159.286	180.986
1108_01	*E. coli*	126	58.733	293.261	351.995

In areas currently regulated by an MS4 permit, development, re-development, 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 non-structural 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 TMDLs 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 these TMDLs are adopted. Therefore, the individual WLAs, as well as the WLAs 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

These TMDLs are, 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 20 summarizes the LA.

Table 20. LA calculations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
1107_01	35	907.154	21.700	159.286	89.534	45.358	591.276
1108_01	126	1,714.082	58.733	293.261	322.063	85.704	954.320

All loads are expressed in billion cfu/day.

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 2020 and 2045 based on H-GAC's Regional Growth Forecast projections (H-GAC, 2018). Table 21 presents the FG calculations.

FG (billion cfu/day) = Criterion * ($\%POP_{2020\text{-}2045}$ * $WWTF_{FP}$) * Conversion Factor

Where:

Criterion = 126 cfu/100 mL (*E. coli*) or 35 cfu/100 mL (Enterococci)

$\%POP_{2020\text{-}2045}$ = estimated percentage increase in population between 2020 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

The current population growth projection for the AU 1107_01 watershed is zero through 2045 (Table 21). To account for any possible error or changes in this projection and the potential planning of a future development, FG for a hypothetical WWTF was included. The basis for this hypothetical WWTF was the recent permit for a recreational vehicle (RV) park, St. Ives RV Resort, within the watershed. St. Ives RV Resort's WWTF has a permit to discharge a maximum of 0.015 MGD. This value was used for the hypothetical WWTF (Table 21).

Table 21. FG calculations

AU	Indicator Bacteria	Criterion (cfu/100 mL)	% Population Change (2020-2045)	Full Permitted Discharge (MGD)	FG (MGD)	FG (Billion cfu/day)
1107_01	Enterococci	35	0.0%[a]	4.065	0.015	89.534[b]
1108_01	*E. coli*	126	548.35%	12.314	67.524	322.063

All loads are expressed in billion cfu/day.

[a] Table 3 lists the population change as -42.21%. Using a negative number in the FG calculation would imply decreased capacity at existing WWTFs. Instead, the percent population change was rounded up to 0.0% in the FG calculation for AU 1107_01

[b] FG in AU 1107_01 is the sum of FG values calculated for each WWTF in AU 1108_01 using Enterococci criterion (35 cfu/100mL) FG values for AU 1107_01 from the hypothetical WWTF with a MGD of 0.015

Compliance with these TMDLs 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 these TMDLs 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 TMDLs were calculated based on the median flow in the 0–10 percentile range (5% exceedance, high flow regime) for flow exceedance based on the LDCs developed at TCEQ SWQM stations 11478 and 11484.

Allocations are based on the current geometric mean criterion for *E. coli* or Enterococci of 126 cfu/100 mL or 35 cfu/100 mL, respectively, for each component of the TMDLs. The TMDL allocation summary for Chocolate Bayou TMDL watershed is summarized in Table 22.

Table 22. TMDL allocations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
1107_01	35	907.154	21.700	159.286	591.276	89.534	45.358
1108_01	126	1,714.082	58.733	293.261	954.320	322.063	85.704

All loads are expressed in billion cfu/day.

The final TMDL allocations (Table 23) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 23. Final TMDL allocations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
1107_01	35	907.154	111.234	159.286	591.276	45.358
1108_01	126	1,714.082	380.796	293.261	954.320	85.704

All loads are expressed in billion cfu/day.

WLA_{WWTF} includes the FG component.

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 *E. coli* and Enterococci concentrations obtained from 14 years (2004 through 2018) 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 *E. coli* and 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 *E. coli* and Enterococci data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Chocolate Bayou. Seasonal variation was also addressed by using all available flow and indicator bacteria 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.

A variety of stakeholder engagement methods were employed to generate and maintain stakeholder interest since 2016. Direct e-mail, letters, and phone calls were made with identified stakeholders to provide information and encourage participation in future meetings. Press releases and general e-mails were created by H-GAC to cast a broad net using listservs and news outlets. Project webpages and informational brochures were developed to provide information, meeting notifications, and project updates. Stakeholders that could potentially be impacted by the TMDL and future implementation plan (I-Plan) were contacted, and one-on-one meetings were held with some to foster interest, build support, and generate trust.

TCEQ and H-GAC held a series of fifteen meetings between 2016 and 2022 to make the public, local governments, businesses, non-profits, agriculture producers, and others, aware of the TMDLs, initiate I-Plan development, and develop management measures to include in the I-Plan. Notices of meetings were posted on the TCEQ and H-GAC project webpages and on the TMDL program's online calendar. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the H-GAC project webpage[c] provides meeting summaries, presentations, ground rules, and documents produced for review.

Public meetings were convened early in the project: Dec. 6, 2016, Aug. 10, 2017, and Nov. 14, 2017. All three meetings were held within the Chocolate Bayou watershed at the Brazoria County Public Library in Alvin, TX. These initial public meeting were used to:

- introduce the TCEQ's basin approach to improving water quality;
- review that status of water quality impairments in Basin 11;
- discuss potential watershed management tools to improve water quality;
- highlight water bodies, e.g., Chocolate Bayou, to employ watershed management tools; and
- to form TMDL coordination committees.

The Chocolate Bayou Coordination Committee was formed in 2018 to review and discuss the developing TMDL and begin I-Plan development. The committee formed three work groups, Nonpoint Source, Point Source, and Outreach, to steer management measure development. In 2019, local governments and

[c] www.h-gac.com/watershed-based-plans/san-jacinto-brazos-coastal-basin-tmdl-and-implementation-plan

business leaders were engaged to highlight the developing TMDLs in Basin 11 and center expectations on future I-Plans. Beginning in 2020, the public was invited to the Chocolate Bay Public meeting. The meeting would kick off future meetings which would focus on the TMDLs being prepared for Chocolate Bayou, Mustang Bayou, and Halls Bayou watersheds. The meetings would also focus on development of a single I-Plan, Chocolate Bay I-Plan, that will cover all three watersheds due to their adjacency and common stakeholders.

Since 2020, the group has met six times and are committed to additional meetings in 2023 and 2024 to complete development of the Chocolate Bay I-Plan and the selection of management measures to reduce sources of fecal bacteria.

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 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 these TMDLs address 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.

References

AVMA (American Veterinary Medical Association). 2018. 2017-2018 U.S. Pet Ownership Statistics. www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics.

Cleland, B. 2003. TMDL Development From the "Bottom Up" - Part III: Duration Curves and Wet-Weather Assessments. www.researchgate.net/publication/228822472_TMDL_Development_from_the_Bottom_Up-_PART_III_Durations_Curves_and_Wet-Weather_Assessments.

Damon, Chris. 2010. "Chocolate Bayou, TX," In the Handbook of Texas Online. Texas State Historical Association. Retrieved May 5, 2018, from: www.tshaonline.org/handbook/entries/chocolate-bayou-tx.

EPA. 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. EPA 440/4-91-001. www.epa.gov/sites/default/files/2018-10/documents/guidance-water-tmdl-process.pdf

H-GAC. 2017. A Brief Overview of H-GAC's Regional Growth Forecast Methodology. Houston-Galveston Area Council. www.h-gac.com/getmedia/6f706efb-9c6d-4b6a-b3aa-7dc7ad10bd26/read-documentation.pdf.

H-GAC. 2018a. H-GAC 2018 Regional Growth Forecast. Houston-Galveston Area Council. www.h-gac.com/regional-growth-forecast.

H-GAC. 2018b. Land Use & Land Cover 2018. www.h-gac.com/land-use-and-land-cover-data/default.aspx.

H-GAC. 2023. Technical Support Document for Two Total Maximum Daily Load for Indicator Bacteria in Chocolate Bayou. AS-477. www.tceq.texas.gov/downloads/water-quality/tmdl/chocolate-bayou-recreational-114/as-472-chocolate-bayou-bacteria-tsd.pdf.

NEIWPCC (New England Interstate Water Pollution Control Commission). 2003. Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities. Online. neiwpcc.org/neiwpcc_docs/iddmanual.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2022. National Climate Data Center Climate Data Online. Accessed on May 1, 2022, from: www.ncdc.noaa.gov/cdo-web/.

NRCS. 2015. SSURGO/STATSGO2 Structural Metadata and Documentation. www.nrcs.usda.gov/resources/data-and-reports/ssurgo/stats2go-metadata.

ODEQ. 2006. [Oregon Department of Environmental Quality]. Chapter 2 - Umpqua Basin TMDL. www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Umpqua-Basin.aspx.

Reed, Stowe & Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-site Sewage Facility Systems in Texas. Texas On-site Wastewater Treatment Council. www.tceq.texas.gov/downloads/water-quality/tmdl/study-to-determine-malfunctioning-ossf.pdf.

Snowden Engineering Inc., 1989. Master Drainage Plan Report on Mustang Bayou, Chocolate Bayou, Ditch C-1, Ditch M-1, New Bayou, Halls Bayou, Chigger Creek, Ditch D-4, and Dickinson Bayou Watersheds. Prepared for Brazoria County Conservation and Reclamation District No. 3 and Texas Water Development Board. June 1989.

TCEQ. 2011. 2010 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d). Online. www.tceq.texas.gov/waterquality/assessment/10twqi/10twqi.

TCEQ. 2015. 2014 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d). Online. www.tceq.texas.gov/waterquality/assessment/14twqi.

TCEQ. 2018. Texas Surface Water Quality Standards, 2018, 30 TAC 307. Online. texreg.sos.state.tx.us/public/readtac%24ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y.

TCEQ. 2022a. 2022 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d). Online. www.tceq.texas.gov/waterquality/assessment/22twqi/22txir.

TCEQ. 2022b. Texas Water Rights Viewer. Retrieved May 2022, from: tceq.maps.arcgis.com/home/item.html?id=44adc80d90b749cb85cf39e04027dbdc.

TCEQ. 2022c. TCEQ Central Registry. www2.tceq.texas.gov/wq_dpa/index.cfm. Accessed on May 1, 2022.

TCEQ. 2022d. Personal written communication with Jason Leifester regarding sanitary sewer overflows within the H-GAC region. March 16, 2022.

Timmons J., Higginbotham B., Lopez R., Cathey J., Mellish J., Griffin J, Sumrall A., Skow, K. 2012. Feral Hog Population Growth, Density, and Harvest in Texas. August 2012. agrilife.org/feralhogs/files/2010/04/FeralHogPopulationGrwothDensityandHervestinTexasedited.pdf.

TPWD. 2019. White-tailed deer Management Unit Map Server. TPWD Wildlife Division. Retrieved Oct. 10, 2019, from: tpwd.texas.gov/arcgis/rest/services/Wildlife/TPWD_WL_WTDMU/MapServer.

USCB. 2010. 2010 Census Urban and Rural Classification and Urban Area Criteria. U.S. Department of Commerce Economics and Statistics Administration. Online: www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html.

USDA NASS. (National Agricultural Statistics Service). 2019. State and County Data, Volume 1, Part43A, Inventory and Sales (2017 Census). www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Census_by_State/index.php.

Weiskel, P.K., B.L. Howes, and G.R. Heufelder. 1996. Coliform Contamination of Coastal Embayment: Sources and Transport Pathways. Environmental Science and Technology, 30, 1872-1881. pubs.acs.org/doi/pdf/10.1021/es950466v.

Appendix A.
Population and Population Projections

The following steps detail the method used to estimate the 2020 and projected 2045 populations in the TMDL watershed:

1. Obtained 2020 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 2020 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 2045 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 2020 watershed population from the 2045 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 Chocolate Bayou watershed.