Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria for Harris County Flood Control Ditch D 138

Assessment Unit: 1007W_01

Harris County Flood Control Ditch D 138 at sampling station 21180

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Prepared for
Total Maximum Daily Load Program
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Abbreviations

AU	assessment unit
cfs	cubic feet per second
cfu	colony forming units
DAR	drainage area ratio
DSLP	days since last precipitation
E. coli	*Escherichia coli*
FDA_{SWP}	fractional drainage area stormwater permit
FDC	flow duration curve
FIB	fecal indicator bacteria
FG	future growth
gpcd	gallons per capita per day
HCFC	Harris County Flood Control
H-GAC	Houston-Galveston Area Council
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MGD	million gallons per day
MCM	minimum control measure
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
PCR1	primary contact recreation 1
SSO	sanitary sewer overflow
SWMP	stormwater management program
SWQM	surface water quality monitoring
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
USCB	United States Census Bureau
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation stormwater
WLA_{WWTF}	wasteload allocation wastewater treatment facilities
WWTF	wastewater treatment facility

SECTION 1
INTRODUCTION

1.1 Background

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

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan is developed, which is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

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

The TCEQ identified the bacteria impairment within Harris County Flood Control Ditch D 138 (HCFC Ditch D 138) in the 2020 *Texas Integrated Report of Surface Water Quality* (2020a)*,* which in this document will be referred to as the 2020 Integrated Report.

This document will consider a bacteria impairment in one water body consisting of a single assessment unit (AU): HCFC Ditch D 138 (AU 1007W_01). Because the impaired water body is composed of only one AU that encompasses its entire length, the AU descriptor (_01) is often unnecessarily cumbersome. The impaired water body may be referred to as HCFC Ditch D 138 or AU 1007W_01. The phrase "TMDL watershed" will be used when referring to only the area of the impaired AU addressed in this report.

1.2 Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators that are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards and publishes the Integrated Report list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2018) are rules that:

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

Standards are established to protect uses assigned to water bodies of which the primary uses assigned in the *Texas Surface Water Quality Standards* to water bodies are:

- *aquatic life use;*
- *contact recreation;*
- *domestic water supply; and*
- *general use.*

Fecal indicator bacteria (FIB) are used to assess the risk of illness during contact recreation (*e.g.*, swimming) from ingestion of water. FIB are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *Escherichia coli* (*E. coli)* is a member of the fecal coliform bacteria group and is used in Texas as the FIB in freshwater. *E. coli* is typically expressed as colony forming units (cfu).

On February 7, 2018, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2018) and on May 19, 2020, the United States Environmental Protection Agency (USEPA) approved the categorical levels of recreational use and their associated criteria, thereby confirming the 2018 levels of recreational use and criteria. Recreational use consists of five categories:

- Primary contact recreation 1 (PCR1) is associated with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E.*

coli of 126 cfu per 100 milliliter (mL) and an additional single sample criterion of 399 cfu per 100 mL;

- Primary contact recreation 2 is similar to PCR1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 206 cfu per 100 mL;
- Secondary contact recreation 1 is associated with activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion for *E. coli* of 630 cfu per 100 mL;
- Secondary contact recreation 2 is similar to secondary contact recreation 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 cfu per 100 mL; and
- Noncontact recreation is associated with activities that do not involve significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for *E. coli* of 2,060 cfu per 100 mL (TCEQ, 2018).

HCFC Ditch D 138 has a presumed use for PCR1 and has the associated *E. coli* geometric mean criterion of a 126 cfu per 100 mL and single sample criterion of 399 cfu per 100 mL.

1.3 Report Purpose and Organization

The HCFC Ditch D 138 TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research. The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist the TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired watershed of HCFC Ditch D 138. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listing of impairment due to presence of indicator bacteria (*E. coli*),
- development of a load duration curve (LDC), and
- application of the LDC approach for the pollutant load allocation process.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed *Addendum One*: *Three Total Maximum Daily Loads for Indicator Bacteria in Three Tributaries to Brays Bayou* (TCEQ, 2013) and the original TMDL *Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries* (TCEQ, 2010).

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

The HCFC Ditch D 138 watershed is an urbanized watershed located entirely within Harris County in the southwestern portion of the City of Houston. HCFC Ditch D 138 (1007W) is a tributary of Brays Bayou Above Tidal (1007B) (Figure 1). The HCFC Ditch D 138 watershed drains an area of 0.36 square miles (228 acres). HCFC Ditch D 138 is approximately 0.77 miles long and contains only one AU (1007W_01).

HCFC Ditch D 138 is an unclassified, intermittent stream with perennial pools that flows into Brays Bayou Above Tidal which eventually flows into the Houston Ship Channel/Buffalo Bayou Tidal (Segment 1007).

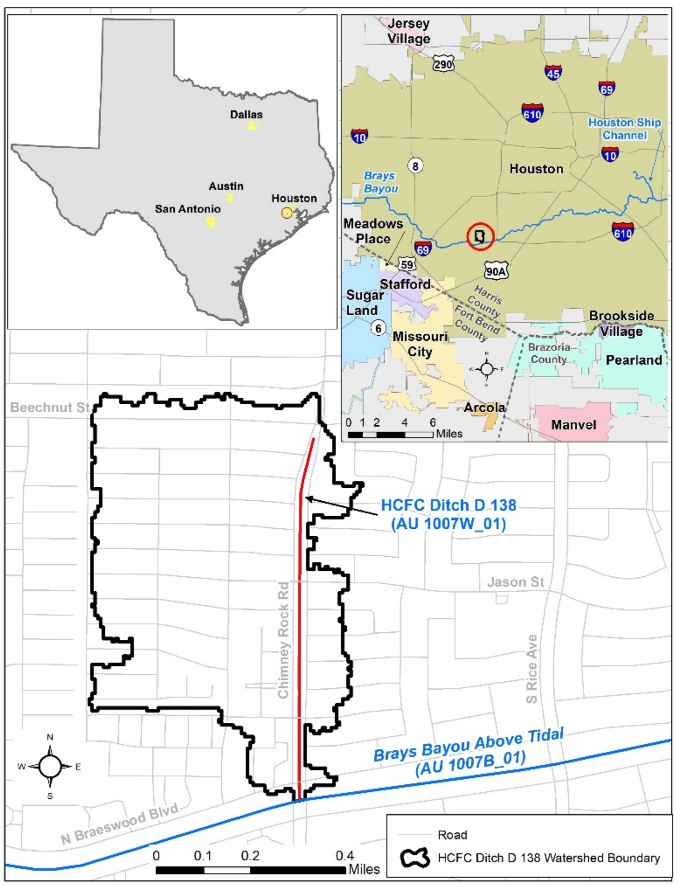

Figure 1. Overview map showing the location and total contributing drainage area for the HCFC Ditch D 138 watershed

The 2020 Integrated Report (TCEQ, 2020a) provides the following water body and AU description for HCFC Ditch D 138:

- 1007W (Harris County Flood Control Ditch D 138; AU 1007W_01) – From the confluence with Brays Bayou to a point immediately south of Beechnut Street in Houston

Using a watershed-based approach, the entire watershed of HCFC Ditch D 138 will be considered in this report. The watersheds of the original TMDL, three addenda, and HCFC Ditch D 138 are presented in Figure 2.

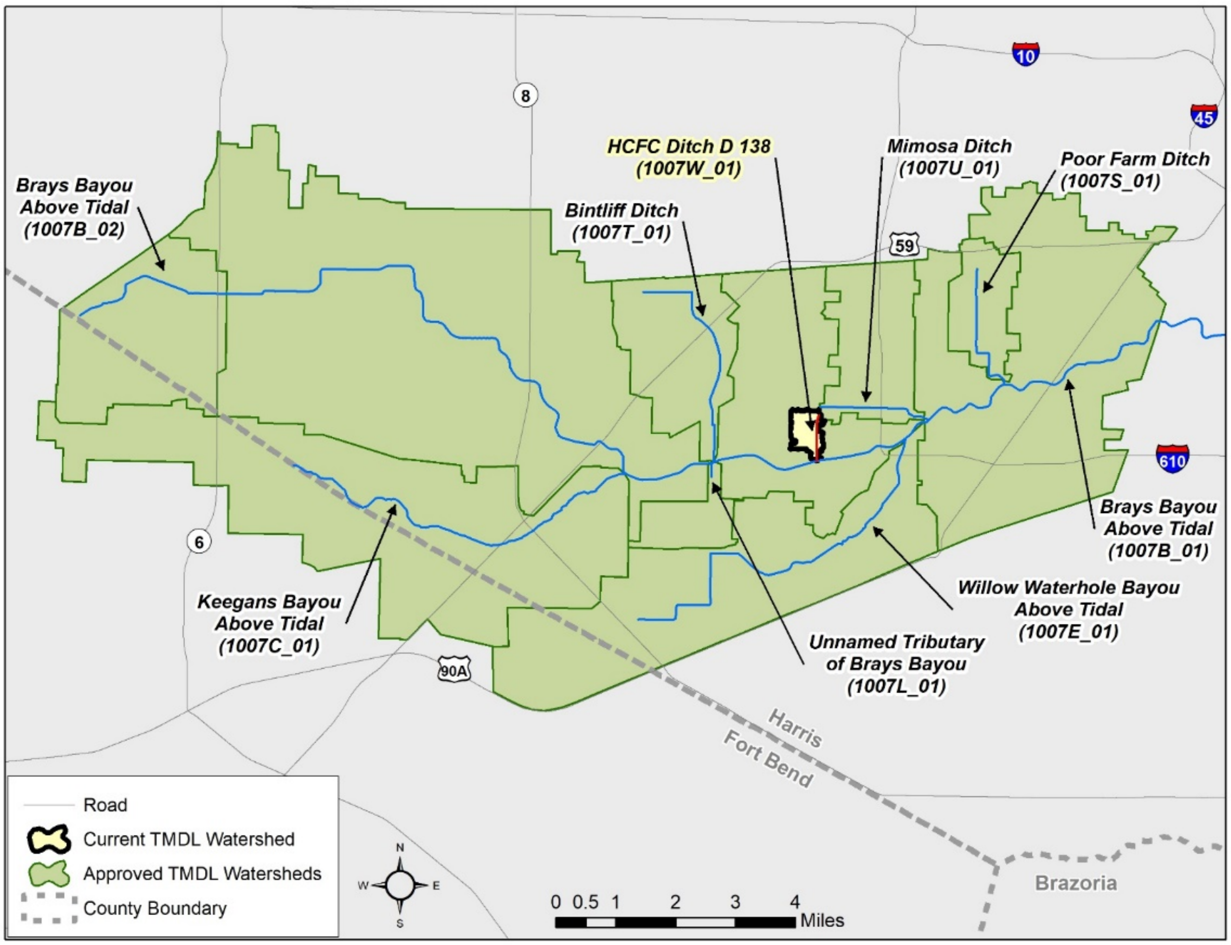

Figure 2. Map showing the previously approved five TMDL watersheds, three addendum watersheds, and the current HCFC Ditch D 138 watershed considered in this addendum

2.2 Watershed Climate and Hydrology

The HCFC Ditch D 138 watershed is within the Upper Coast climatic division categorized as subtropical humid (Larkin & Bomar, 1983). The Gulf of Mexico is the principal source of moisture that drives precipitation in the region. Weather data were obtained for the 15-year period from 2005 – 2019 from the National Climatic Data Center for the William P. Hobby Airport in Houston (NOAA, 2020). Data from this 15-year period indicates that the average high temperatures typically peak in August (94.2 °F). During winter, the average low temperature generally reaches a minimum of 45.2

°F in January (Figure 3). Annual rainfall averages 53.6 inches. The wettest month was August (6.6 inches) while February (2.6 inches) was the driest month, with rainfall occurring throughout the year.

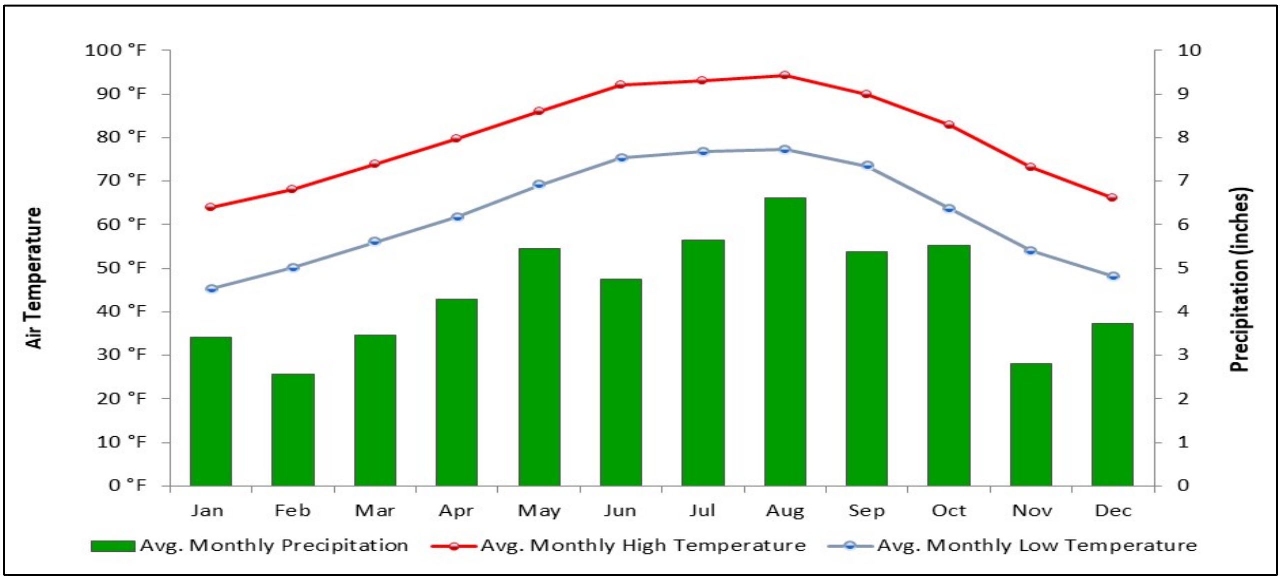

Figure 3. Average minimum and maximum air temperature and total precipitation by month from Jan 2005–Dec 2019 for William P. Hobby Airport, Houston, TX

2.3 Watershed Population and Population Projections

As depicted in Figure 1, the HCFC Ditch D 138 watershed is geographically located within the municipal boundary of the City of Houston. According to the 2020 Houston-Galveston Area Council (H-GAC) population forecast (H-GAC, 2017), the HCFC Ditch D 138 watershed has an estimated population of 3,913 people. Indicative of a developed urban watershed, current predominant population densities for this watershed is seven to ten people per acre (Figure 4).

Population projections from 2020 – 2045 were developed by utilizing data from the H-GAC regional growth forecast (H-GAC, 2017). The projected 2020 through 2045 populations were allocated based on proportion of the area within the TMDL watershed. According to the growth projections, a population increase of 3.4% is expected in the HCFC Ditch D 138 watershed by 2045. Table 1 provides a summary of the 2020 through 2045 population projections for the HCFC Ditch D 138 watershed.

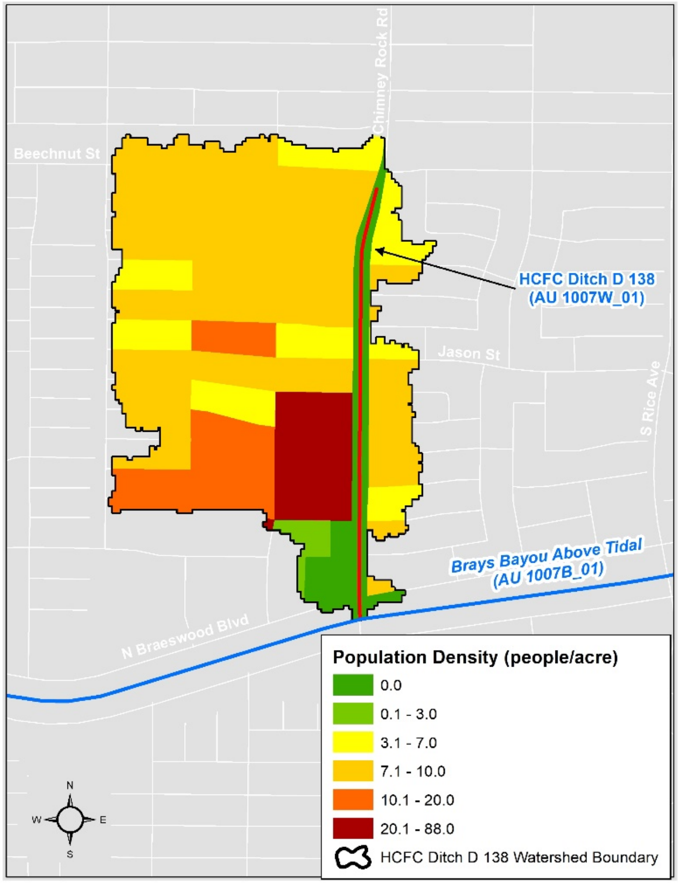

Figure 4. Population density for the HCFC Ditch D 138 watershed

Table 1. Population Projections for the HCFC Ditch D 138 watershed

Location	2020 Population Projection	2030 Population Projection	2040 Population Projection	2045 Population Projection	Projected Population Increase (2020-2045)	Percent Change
HCFC Ditch D 138 Watershed	3,913	3,925	4,233	4,045	132	3.40%

2.4 Review of Routine Monitoring Data

2.4.1 Analysis of Bacteria Data

Environmental monitoring within the HCFC Ditch D 138 watershed has occurred at TCEQ surface water quality monitoring (SWQM) station 21180 (Figure 5). *E. coli* data collected at station 21180 over the seven-year period of December 1, 2011, through November 30, 2018, were used in assessing attainment of the PCR1 use as reported in the 2020 Integrated Report (TCEQ, 2020a) and are summarized in Table 2. The 2020 assessment data for the TMDL watershed indicate non-support of the PCR1 criterion because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 mL.

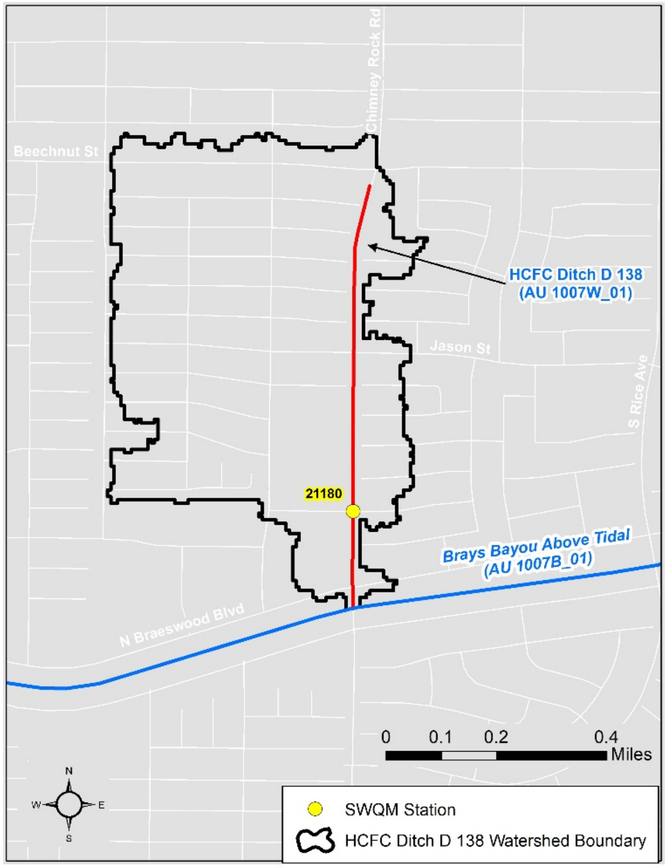

Figure 5. HCFC Ditch D 138 watershed showing TCEQ SWQM station used to assess PCR1

Table 2. 2020 Integrated Report Summary for the HCFC Ditch D 138 watershed

Watershed	AU	Parameter	Station	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
HCFC Ditch D 138	1007W_01	*E. coli*	21180	56	2011-2018	633

2.5 Land Cover

The land cover data presented in this report are from the H-GAC 2018 10 Class Land Cover Data Set (H-GAC, 2017). The land cover is represented by the following categories and definitions:

- **Developed, High Intensity** – High intensity includes heavily built up urban centers and large constructed surfaces in suburban and rural areas. Constructed surfaces account for 80% to 100% of the total cover.
- **Developed, Medium Intensity** – Medium intensity developed areas most commonly include multi- and single-family housing areas. Constructed surfaces account for 50% to 79% of the total cover.
- **Developed, Low Intensity** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. These areas most commonly include single-family housing units. Constructed surfaces account for 21% to 49% of total cover.

The land cover data is provided for the entire HCFC Ditch D 138 watershed in Figure 6. The entire watershed is considered developed, with the categories of Developed, Low Intensity and Developed, Medium Intensity comprising 89% of the land cover and Developed, High Intensity comprising the remaining 11%. A summary of the land cover data for the TMDL watershed is provided in Table 3.

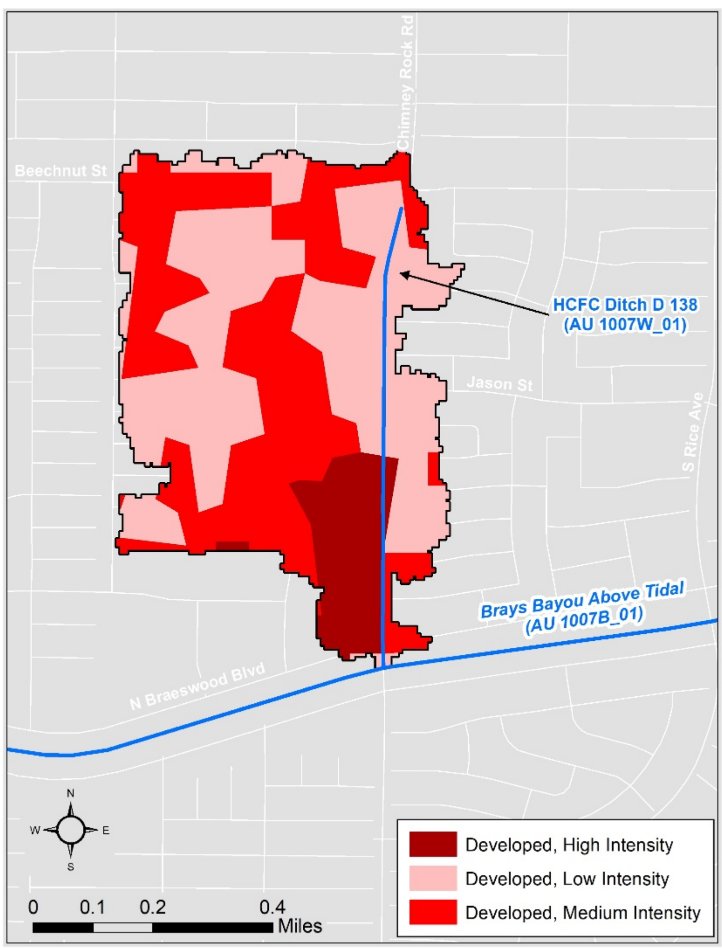

Figure 6. Land cover within the HCFC Ditch D 138 watershed

Table 3. Land Cover within the HCFC Ditch D 138 watershed

Classification	Area (acres)	% of Total
Developed, High Intensity	25.9	11.4%
Developed, Medium Intensity	93.7	41.1%
Developed, Low Intensity	108.4	47.5%
Total	**228.0**	**100%**

2.6 Potential Sources of FIB

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) program. Examples of regulated sources are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities.

Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual wasteload allocations (WLAs) (see report Section 4.7.3, WLA), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.6.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES program. Stormwater discharges from industries, construction, and MS4s represent the potential permitted sources in the TMDL watershed.

2.6.1.1 Domestic WWTF Discharges

No permitted WWTFs exist in the TMDL study area.

2.6.1.2 SSOs

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. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

The TCEQ Region 12 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. A summary of SSO incidents that occurred during a four-year period from 2016-2019 in Harris County was obtained from the TCEQ Central Office in Austin. The summary data indicated eight SSO incidents had been reported within the HCFC Ditch D 138 watershed. All SSO incidents were due to a temporary blockage of the collection system. Four of the SSO incidents had no corresponding estimate of the amount of overflow that had occurred. The remaining four SSO incidents reported an estimated overflow that ranged from 313 to 2,020 gallons per incident.

2.6.1.3 TCEQ/TPDES Water Quality General Permits

Discharges of processed wastewater from certain types of facilities are required to be covered by one of several TCEQ/TPDES general permits:

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

A review of active general permit coverage (TCEQ, 2020b) in the HCFC Ditch D 138 watershed as of June 15, 2020, found three pesticide permittees were covered by the general permit. The pesticide management areas do not have bacteria reporting or limits in their permits. These management areas were assumed to contain inconsequential amounts of indicator bacteria in its effluent; therefore, it was unnecessary to allocate bacteria loads to these facilities. No other active general wastewater permit facilities or operations were found.

2.6.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term “illicit discharge” is defined in TPDES General Permit No. TXR040000 for Phase II (Small) MS4s as “Any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities.” Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (*e.g.*, used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal 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; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.6.1.5 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, industrial facilities, and regulated construction activities; and
2. stormwater runoff not subject to regulation.

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

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

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

Phase I MS4 individual permits have similar MCMs organized a little differently and are further required to perform water quality monitoring.

For Phase I permits the jurisdictional area is defined by the city limits and for Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2010 Census urbanized area.

One Phase I MS4 permit and one combined Phase I and Phase II MS4 permit currently provide 100% MS4 coverage for the TMDL study area (Table 4 and Figure 7).

Table 4. TPDES MS4 permits in the HCFC Ditch D 138 watershed

Watershed	Entity	TPDES Permit	NPDES[a] Permit	Permit Type
HCFC Ditch D 138	City of Houston and Harris County and Harris County Flood Control District	WQ0004685000	TXS001201	Phase I
HCFC Ditch D 138	Texas Department of Transportation	WQ0005011000	TXS002101	Combined Phase I/II

[a] National Pollutant Discharge Elimination System

2.6.1.6 Stormwater General Permits

Discharges of Stormwater from an industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – stormwater from construction activities disturbing more than one acre

A review of active stormwater general permit coverage (TCEQ, 2020b) as of June 15, 2020, found no active MSGPs or construction permits within the HCFC Ditch D 138 watershed.

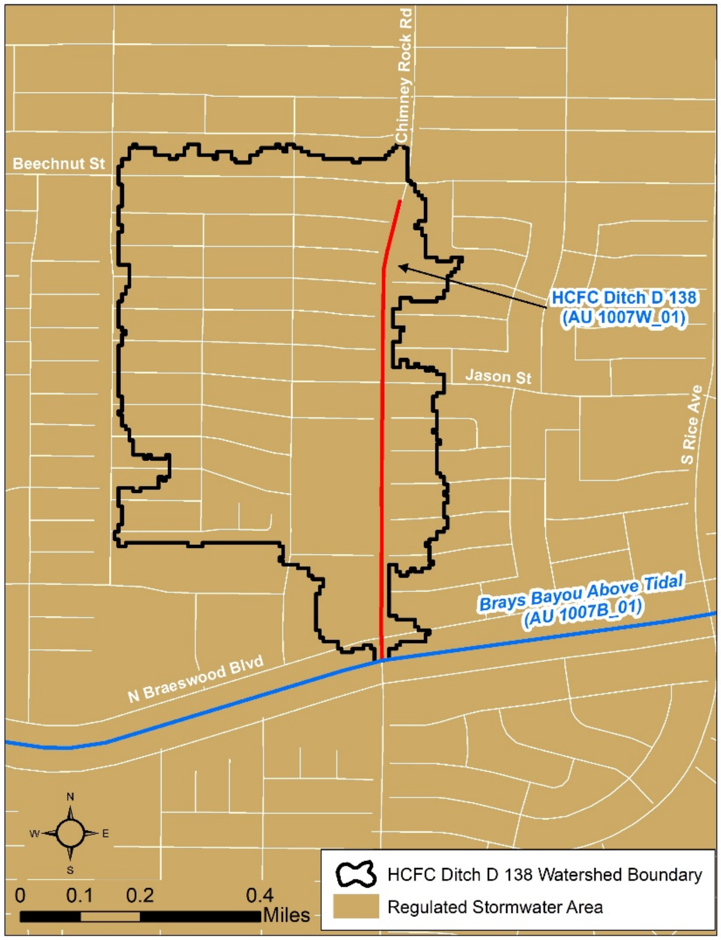

Figure 7. Regulated stormwater areas based on MS4 permits within the HCFC Ditch D 138 watershed

2.6.2 Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife, feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing on-site sewage facilities (OSSFs), and domestic pets.

2.6.2.1 Wildlife and Unmanaged Animals

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

The *E. coli* contribution from feral hogs and wildlife in HCFC Ditch D 138 cannot be determined based on existing information; however, due to the urbanized nature of the watershed it is assumed that the contribution would be minimal.

2.6.2.2 OSSFs

Failing OSSFs were not considered a major source of bacteria loading in the HCFC ditch D 138 watershed, because the entire watershed area is served by a wastewater collection and treatment system. A review of OSSF information received from H-GAC indicates that no OSSFs are known to exist in the TMDL study area.

2.6.2.3 Unregulated Agricultural Activities and Domesticated Animals

Due to the highly urbanized nature of the TMDL study area, livestock were not considered a major source of bacteria loading.

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 5 summarizes the estimated number of dogs and cats within the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household according to data from the American Veterinary Medical Association 2017-2018 U.S Pet Statistics (AVMA, 2018). The number of households in the TMDL watershed was estimated using 2010USCB data (USCB, 2010). Actual contribution and significance of bacteria loads from pets reaching the water body is unknown.

Table 5. Estimated distribution of dog and cat populations within the HCFC Ditch D 138 watershed

Watershed	Households	Dogs	Cats
HCFC Ditch D 138	1,241	762	567

2.6.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die in the environment. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (*e.g.*, warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate in organic rich materials such as compost and sludge. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both processes (replication and die-off) are in-stream processes and are not considered in the bacteria source loading estimates for HCFC Ditch D 138.

SECTION 3
BACTERIA TOOL DEVELOPMENT

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

3.1 Tool Selection

For consistency between the HCFC Ditch D 138 TMDL and the previously completed TMDLs in the Brays Bayou watershed, the pollutant load allocation activities for HCFC Ditch D 138 used the LDC method. The LDC method has been previously used on TCEQ-adopted and USEPA-approved TMDLs for the *TMDL Addendum One*: *Three Total Maximum Daily Loads for Indicator Bacteria in Three Tributaries to Brays Bayou* (TCEQ, 2013) and *Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries* (TCEQ, 2010).

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and the Texas State Soil and Water Conservation Board supports application of the LDC method within their three-tiered approach to TMDL development (Jones *et al*., 2009). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion, and can give indications of broad sources of the bacteria, *i.e.*, point source and nonpoint source.

3.2 HCFC Ditch D 138 Data Resources

Successful application of the LDC method requires two basic types of data: continuous daily streamflow data and historical bacteria data for the relevant indicator bacteria, which in this case is *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the HCFC Ditch D 138 watershed; however, streamflow records were available for the nearby Brays Bayou watershed. Streamflow records for Brays Bayou are collected and made readily available by the United States Geological Survey (USGS; USGS, 2020), which operates the streamflow gauge (Table 6, Figure 8). USGS streamflow gauge 08074760 is located along the mainstem of Brays Bayou and is in close enough proximity to HCFC Ditch D 138 that the same precipitation events would likely impact each watershed.

The determination was made to modify the streamflow records for Brays Bayou by using a drainage area ratio (DAR) approach. This approach is explained in more detail in Section 3.3.3. The modified streamflow records from Brays Bayou serve as the primary source for streamflow records in this document.

Table 6. Basic information on Brays Bayou USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08074760	Brays Bayou at Alief, TX	9,600	Oct. 2006 – present

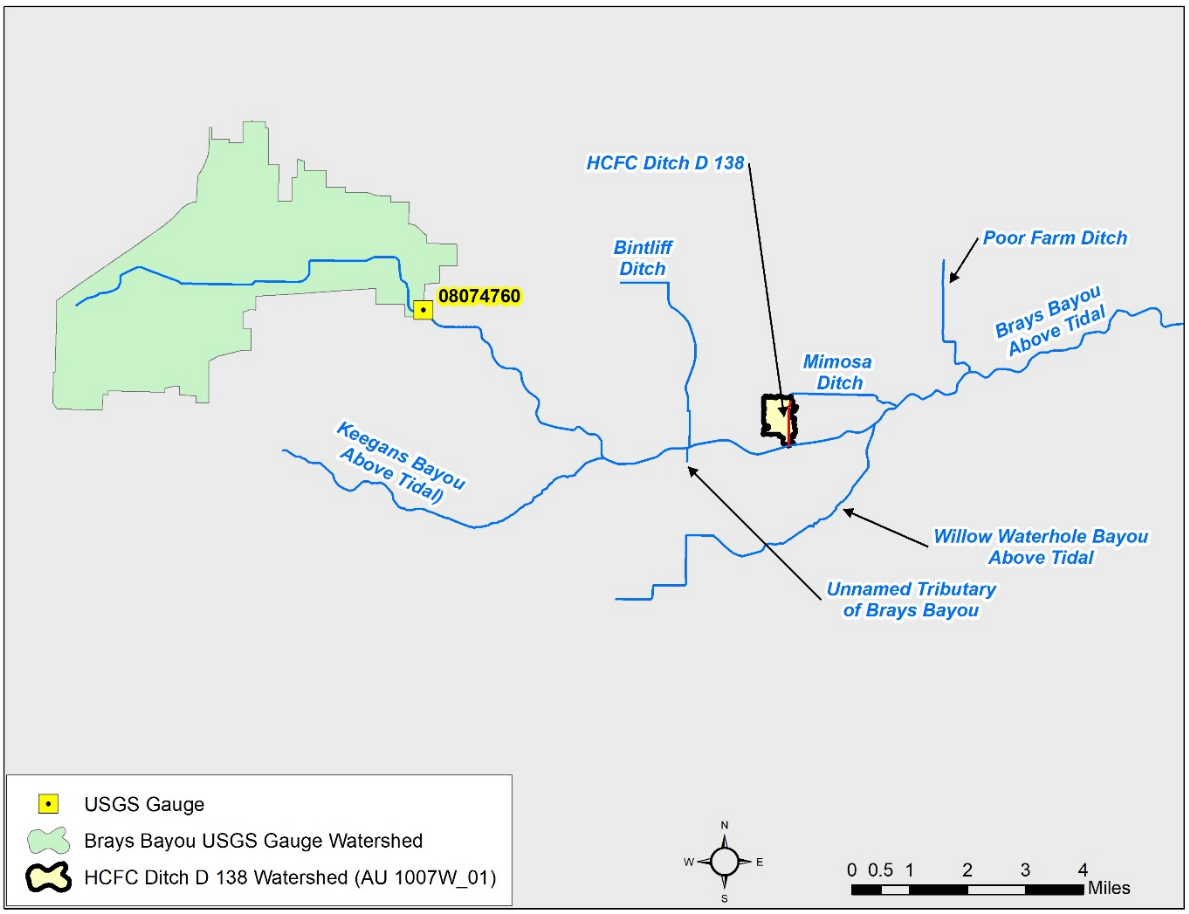

Figure 8. HCFC Ditch D 138 watershed including USGS Station 08074760 watershed

Ambient *E. coli* data were available through the TCEQ Surface Water Quality Monitoring Information System for HCFC Ditch D 138 sampling station 21180, and consisted of 60 *E. coli* sample results with a geometric mean of 569 cfu/100 mL collected over a period from October 2012 to April 2019.

3.3 Methodology for FDC and LDC Development

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

- **Step 1:** Determine the hydrologic period of record to be used in developing the FDC.
- **Step 2:** Determine stream location for which FDC and LDC development is desired.
- **Step 3:** Develop daily streamflow records at the desired stream location using the daily gauged streamflow records and DAR.
- **Step 4:** Develop an FDC at the desired stream location, segmented into discrete flow regimes.
- **Step 5** Develop the allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- **Step 6:** Superpose historical bacteria data on each allowable bacteria LDC.

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

3.3.1 Step 1: Determine Hydrologic Period

A 13-year daily hydrologic (streamflow) record was available for USGS gauge 08074760 located on nearby Brays Bayou (Table 6, Figure 8). Optimally, the period of record to develop FDCs should include as much data as possible in order to capture extremes of high and low streamflow and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions experienced within the watershed and when the *E. coli* data were collected. Therefore, a 10-year record of daily streamflow from January 2010 through December 2019 was selected to develop the FDC at the sampling station location, and this period includes the collection dates of all available *E. coli* data at the time this work effort was undertaken. A 10-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and at the same time is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed. A 10-year hydrologic period was also used in the previously completed *Addendum One*: *Three Total Maximum Daily Loads for Indicator Bacteria in Three Tributaries to Brays Bayou* (TCEQ, 2013) and the original TMDL *Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries* (TCEQ, 2010), which maintains consistency of the HCFC Ditch D 138 TMDL with the previous TMDLs.

3.3.2 Step 2: Determine Desired Stream Locations

SWQM station 21180 is the only location within HCFC Ditch D 138 where an adequate number of *E. coli* data have been collected. The 60 *E. coli* sampling results for station 21180 were determined to be adequate to develop pollutant load allocations and exceed the minimum of 24 samples suggested in Jones *et al.* (2009).

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station location were determined, the next step was to develop the 10-year daily streamflow record for the monitoring station. The daily streamflow records were developed from extant USGS records.

The method to develop the necessary streamflow record for the FDC/LDC location (SWQM station location) involved a DAR approach. The DAR approach involves multiplying a USGS gauging station daily streamflow value by a factor to estimate the flow at a desired SWQM station location. The factor is determined by dividing the drainage area upstream of the desired monitoring station by the drainage area upstream of the USGS gauge (Table 7).

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land cover, point source derived flows from within the USGS gauge watershed should first be removed from the flow record prior to application of the ratio. In practice, this complication was addressed by determining the average discharge for each of the five WWTFs located above the Brays Bayou USGS gauge. The average discharge for each WWTF was computed by averaging the data obtained from the USEPA Enforcement and Compliance History Online database (USEPA, 2020). The WWTF discharge averages were summed and then subtracted from the Brays Bayou USGS daily record.

In addition to the WWTF discharges, surface water diversions associated with water rights permits have the potential of impacting stream hydrology with regard to the application of the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the TMDL watershed did not contain any active water rights permits, and only one active water rights permit was located in the Brays Bayou watershed above USGS gauge 08074760 (TCEQ, 2020c). A review of the water use data file containing historical reported water diversions (TCEQ, 2020c) indicated that there have been no reported diversions associated with the water rights permit. It is presumed that water diversions will have an insignificant impact on stream hydrology and pollutant load allocations due to a lack of diversions within the TMDL watershed and the surrogate USGS gauge watershed. Therefore, diversions associated with water rights permits were not considered in the development of the streamflow record. Additionally, water rights permits allow withdrawals of water, as opposed to discharges, and do not need to be assigned loadings in a TMDL.

After removing the average daily WWTF discharge values from the daily streamflow gauge record, each daily flow record was multiplied by the DAR. Following application of the DAR, the future growth (FG) flows (calculated in Section 4.7.4) were added to the streamflow record to account for the probability that additional flows from WWTF discharges may occur as a result of population increases.

Table 7. DAR for the HCFC Ditch D 138 watershed based on the drainage area of the Brays Bayou USGS gauge

Water Body	Gauge/Station	Drainage Area (acres)	DAR
Brays Bayou	USGS Gauge 08074760	9,600	1.0
HCFC Ditch D 138	Station 21180	182	0.019

3.3.4 Steps 4-6: FDC and LDC Method

FDCs and LDCs are graphs indicating the percentage of time during which a certain value of flow or load is equaled or exceeded. To develop a FDC for a location the following steps were undertaken:

- order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 for the second highest flow, and so on);
- compute the percent of days each flow was exceeded by dividing each rank by the total number of data points plus 1; and
- plot the corresponding flow data against exceedance percentages.

Further, when developing a LDC:

- multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor (2.44658×10^7), which gives a loading in units of cfu/day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean criterion of *E. coli*.

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

- using the unique data for the monitoring station, compute the daily loads for each sample by multiplying the measured *E. coli* concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^7), which gives a loading in units of cfu/day; and

- plot on the LDC the load for each measurement at the exceedance percentage for its corresponding streamflow.

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

3.4 FDC for the Monitoring Station within the TMDL Watershed.

The FDC was developed for monitoring station 21180 within the TMDL watershed (Figure 9). For this report, the FDC was developed by applying the DAR method using the Brays Bayou USGS gauge 10-year period of record described in the previous sections. Flow exceedances less than 20% typically represent streamflow influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event, base flow, and no flow conditions.

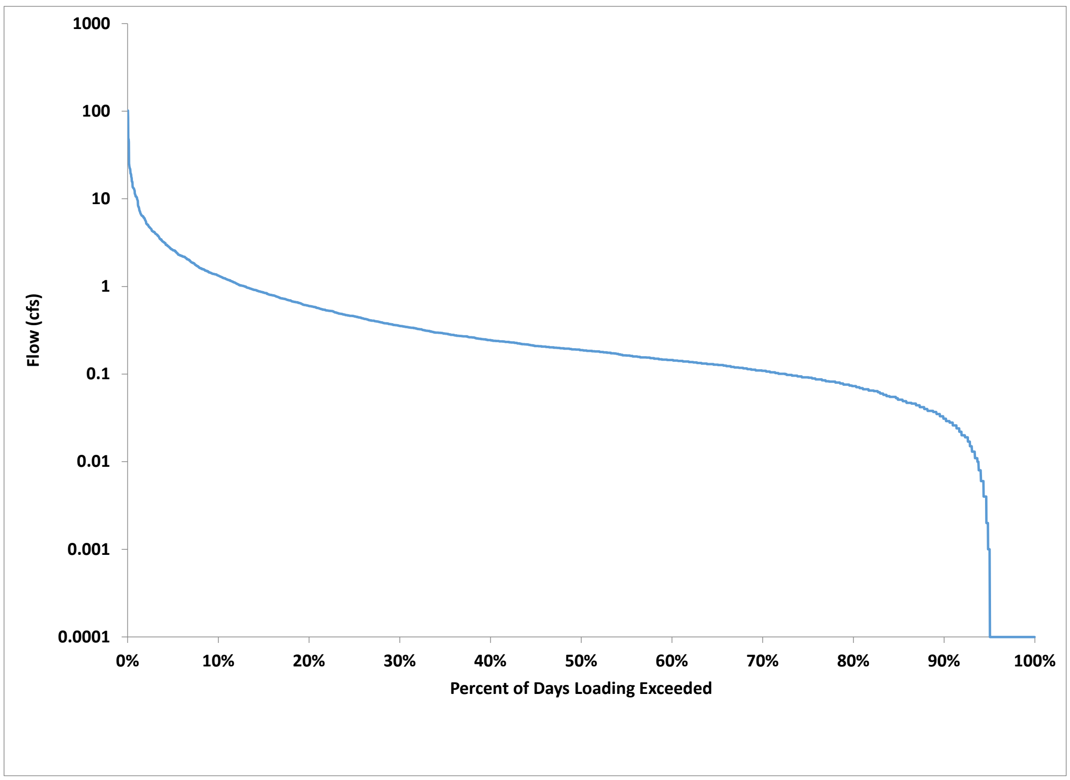

Figure 9. FDC for HCFC Ditch D 138 AU 1007W_01 (Station 21180)

3.5 LDC for the Sampling Station within the TMDL Watershed

A LDC was developed for monitoring station 21180 within the TMDL watershed (Figure 10). A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curve. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10% (high flows); (2) 10-40% (moist conditions); (3) 40-60% (mid-range flows); (4) 60-90% (dry conditions); and (5) 90-100% (low flows).

For the TMDL watershed, streamflow distribution was divided into three flow regimes: highest, mid-range, and lowest flows (Table 8), which maintains consistency with the previously completed TMDLs (TCEQ, 2010 and 2013). Highest flows correspond to large storm-induced runoff events. Mid-range flows typically represent periods of medium base flows but can also represent small runoff events and periods of flow recession following large storm events. Conditions within the lowest flows regime represent relatively low flow conditions, resulting from extended periods of little or no rainfall.

Table 8. Flow regime classifications

Flow Regime Classification	Flow Exceedance Percentile
Highest Flows	0 – 20%
Mid-Range Flows	20 – 70%
Lowest Flows	70 – 100%

The LDC with these three flow regimes for monitoring station 21180 are provided in Figure 10, and was constructed for developing the TMDL allocation for the TMDL watershed. Geometric mean loadings for the data points within each flow regime have also been distinguished on the figure to aid interpretation. The LDC for the water quality monitoring station provides a means of identifying the streamflow conditions under which exceedances in *E. coli* concentrations have occurred. The LDC depicts the allowable loading at the station under the geometric mean criterion (126 cfu/100 mL) and shows that existing loadings often exceed the criterion. In addition, the LDC also presents the allowable loading at the station under the single sample criterion (399 cfu/100 mL).

On the graph, the measured *E. coli* data are presented as associated with a "wet weather event" or a "non-wet weather event." A sample was determined to be influenced by a wet weather event based on the reported "days since last precipitation" (DSLP) as noted on field data sheets associated with each sampling event. DSLP (TCEQ water quality parameter code 72053) is a field parameter that may be noted during a sampling event to inform of the general climatic and hydrologic conditions. A sample taken with a DSLP ≤ 3 days was defined as a wet weather event. Note that a wet weather event can be indicated even under low flow conditions as a result of only a small runoff event during a period of very low base flow in the stream.

The *E. coli* event data plotted on the LDC for station 21180 in Figure 10 show exceedances of the geomean criterion have commonly occurred regardless of streamflow conditions. With the exception of two samples, individual results from all wet weather events indicate an exceedance of both sample criterion.

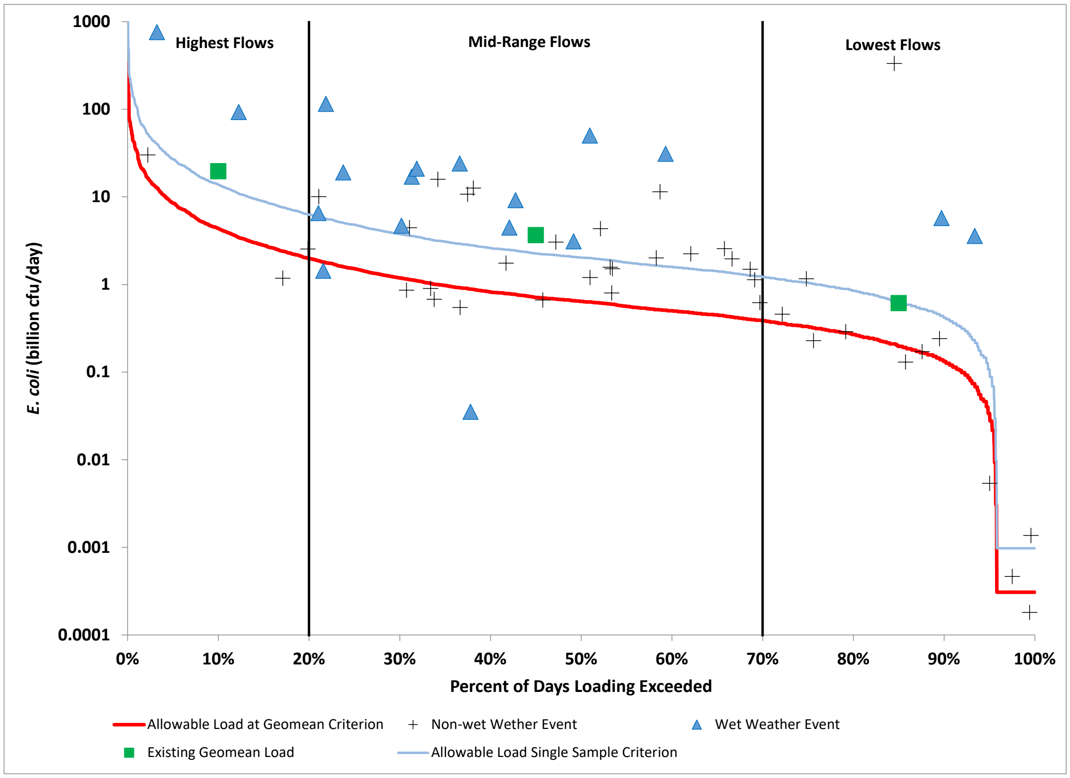

Figure 10. LDC for HCFC Ditch D 138 AU 1007W_01 (Station 21180)

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocations for the HCFC Ditch D 138 watershed. The tool used for developing TMDL allocations was the LDC method previously described in Section 3– Bacteria Tool Development. Endpoint identification, margin of safety (MOS), load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the TMDL watershed. As developed previously in this report, the LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support PCR1.

For the purposes of this TMDL study, the TMDL watershed is considered to be the entire HCFC Ditch D 138 watershed (AU 1007W_01) as shown in the overview map (Figure 1). An adequate amount of data from one SWQM station in the watershed was available for TMDL development; therefore, TMDL calculations are based on the location of the SWQM station 21180 within the TMDL watershed.

Additionally, a DAR approach using historical streamflow records from a nearby USGS gauge on Brays Bayou was employed to estimate the daily flow at the location of the SWQM station.

4.1 Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions. The HCFC Ditch D 138 watershed has a use of PCR1, which is measured against a numeric criterion for the indicator bacteria *E. coli*. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The *E. coli* criterion to protect contact recreation in freshwater streams under the category of PCR1, consists of a geometric mean concentration not to exceed 126 cfu/100 mL (TCEQ, 2018).

The endpoint for this TMDL is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100 mL. This endpoint is identical to the geometric mean criterion in the 2018 Surface Water Quality Standards (TCEQ, 2018).

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from eight years (2012 – 2019) of routine monitoring collected in the warmer months (April – September) against those collected during the cooler months (October – March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log transformed dataset. This analysis of *E. coli* data indicated that there was no significant difference ($\alpha=0.05$) in indicator bacteria between cool and warm weather seasons for HCFC Ditch D 138 ($p=0.271$).

4.3 Linkage Analysis

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

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

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

A LDC was used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one relationship was also inherently assumed when using a LDC to define the TMDL pollutant load allocation (Section 4.7).

4.4 LDC Analysis and Results

A LDC method was used to examine the relationship between instream water quality, and the broad sources of indicator bacteria load, and is the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocation. LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The USEPA supports the use of the basic LDC approach to characterize pollutant sources. In addition, many other states are using this basic method to develop TMDLs. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), the TMDL load was based on the median flow within the Highest Flows regime (or 10% flow).

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

Based on the LDC used in the pollutant load allocation process with historical *E. coli* data added to the graph (Figure 10) and Section 2.6 (Potential Sources of FIB), the following broad linkage statements can be made. For the TMDL watershed, the historical *E. coli* data indicate that elevated bacteria loadings occur under all three flow regimes. On Figure 10, the geometric means of the measured data for each flow regime indicate a slight moderation of the elevated loadings under dry conditions.

4.5 MOS

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

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

The MOS is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a MOS. The TMDL in this report incorporate an explicit MOS of 5%.

4.6 Load Reduction Analysis

While the TMDL for the HCFC Ditch D 138 watershed was developed using an LDC and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical *E. coli* data obtained from the monitoring station within AU 1007W_01.

For each flow regime the percent reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 126 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 9).

Table 9. Percent reduction calculations for HCFC Ditch D 138 SWQM station 21180

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cu/100 ML)	Percent Reduction by Flow Regime
Highest Flows (0-20%)	11	566	77.7%
Mid-Range Flows (20-70%)	35	647	80.5%
Lowest Flows (70-100%)	14	391	67.8%

4.7 Pollutant Load Allocation

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

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

Where:

TMDL = total maximum daily load

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

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

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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

4.7.1 AU-Level TMDL Calculations

The bacteria TMDL for AU 1007W_01 was developed as a pollutant load allocation based on information from the LDC for the monitoring station located within the TMDL watershed (Figure 10). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the FDC by the *E. coli* criterion (126 cfu/100 mL) and by the conversion factor used to represent maximum loading in cfu/day. Effectively, the “Allowable Load” displayed in the LDC at 10% exceedance (the median value of the Highest Flows-regime) is the TMDL:

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

Where:

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

Conversion Factor (to billion cfu/day) = (283.1685 100 mL/ft^3 * 86,400 sec/day)/1.0E+9

The allowable loading of *E. coli* that the impaired watershed can receive on a daily basis was determined using Equation 2 based on the median value within the highest flows regime of the FDC (or 10% flow exceedance value) for the SWQM station 21180 (Table 10).

Table 10. Summary of allowable loading calculation for HCFC Ditch D 138

Water Body	AU	10% Exceedance Flow (cfs)	TMDL (Billion cfu/day)
HCFC Ditch D 138	1007W_01	1.419	4.374

4.7.2 MOS

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

MOS = 0.05 * TMDL (Eq. 3)

Where:

MOS = margin of safety load

TMDL = total maximum daily load

Using the values of TMDL for AU 1007W_01 provided in Table 10, the MOS may be readily computed by proper substitution into Equation 3 (Table 11).

Table 11. MOS calculations for HCFC Ditch D 138

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

Water Body	AU	TMDL[a]	MOS
HCFC Ditch D 138	1007W_01	4.374	0.219

[a] TMDL from Table 10.

4.7.3 WLA

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

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

TPDES-permitted WWTFs are allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by one-half the instream geometric criterion. One-half of the water quality criterion (63 cfu/100mL) is used as the WWTF target to provide instream and downstream load capacity, and to be consistent with previously developed TMDLs. Thus, WLA_{WWTF} is expressed in the following equation:

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

Where:

Target= 63 cfu/100 mL

Flow = full permitted flow in million gallons per day (MGD)

Conversion Factor (to billion cfu/day) = 37,854,000 mL/MGD

Due to the absence of any permitted dischargers in the HCFC Ditch D 138 watershed the WLA_{WWTF} component is zero.

Stormwater discharges from MS4, industrial, and construction areas are considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of this TMDL due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in the TMDL watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

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

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

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in Section 2.6.1.5, the HCFC Ditch D 138 watershed is covered 100% by MS4 Phase I permits. However, even in highly urbanized areas such as the HCFC Ditch D 138 watershed, there remain small areas of potential direct deposition of bacteria loadings from unregulated sources such as wildlife. To account for these small unregulated areas, the stream length based on the TCEQ definition of AU 1007W_01 and average channel width as calculated based on recent aerial imagery was used to compute an area of unregulated stormwater contribution (Table 12)

Table 12. Basis of unregulated stormwater area and computation of FDA_{SWP} term

Water Body	AU	Total Area (acres)	Stream Length (feet)	Estimated Average Channel Width (feet)	Estimated Stream Area (acres)	Fraction Unregulated Area	FDA_{SWP}
HCFC Ditch D 138	1007W_01	228	4,058.7	20.23	1.88	0.0082	0.9918

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. In order to calculate the WLA_{SW} (Eq. 6), the FG term must be known. The calculation for the FG term is presented in the next section, but the results will be included here for continuity. Table 13 provides the information needed to compute WLA_{SW}.

Table 13. Regulated stormwater calculations for HCFC Ditch D 138

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

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	FG[c]	MOS[d]	FDA_{SWP}[e]	WLA_{SW}[f]
HCFC Ditch D 138	1007W_01	4.374	0	0.031	0.219	0.9918	4.090

[a] TMDL from Table 10

[b] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[c] FG from Table 14

[d] MOS from Table 11

[e] FDA_{SWP} from Table 12

[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Eq. 6)

4.7.4 FG

The FG component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur because of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases due to FG of permitted discharges. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

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

While the FG allowance is often computed for bacteria TMDLs using information from existing WWTF permits, it is not intended to restrict any future assignments of the allocation solely to expansions at these facilities. Rather, the FG allocation is purposed for any new facilities that may occur and expansions of existing facilities.

According to Rule §217.32 of Texas Administrative Code, new WWTFs are to be designed for a daily wastewater flow of 75-100 gallons per capita per day (gpcd; TAC, 2008). Conservatively taking the higher daily wastewater flow capacity (100 gpcd) and multiplying it by a potential population change would result in a FG permitted flow. Based on the information in Table 1, the projected population change within the HCFC Ditch D 138 watershed for the time period 2020-2045 is 132. Multiplying the projected population growth by the higher daily wastewater flow capacity, yields a value of 0.013 MGD. This value would be considered the full permitted discharge of a potential future WWTF.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * \text{conversion factor} * \text{target} \qquad \text{(Eq. 7)}$$

Where:

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

Conversion factor = (37,854,000 100mL/MGD)/1.0E+9

Target = 63 cfu/100 mL

The calculation results for the impaired TMDL watershed are shown in Table 14.

Table 14. FG calculation for HCFC Ditch D 138

Water Body	AU	Assumed Additional Service Population	FG (MGD)	FG (*E. coli* Billion cfu/Day)[a]
HCFC Ditch D 138	1007W_01	132	0.013	0.031

[a] FG = $WWTF_{FP}$ * conversion factor * target (Eq. 7)

4.7.5 LA

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

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

Where:

LA = allowable loads from unregulated sources within the AU

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 15.

Table 15. LA calculation for HCFC Ditch D 138

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

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	FG[d]	MOS[e]	LA[f]
HCFC Ditch D 138	1007W_01	4.374	0	4.090	0.031	0.219	0.034

[a] TMDL from Table 10

[b] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[c] WLA_{SW} from Table 13

[d] FG from Table 14

[e] MOS from Table 11

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

4.8 Summary of TMDL Calculations

Table 16 summarizes the TMDL calculation for the TMDL watershed. The TMDL was calculated based on the median flow in the 0-20 percentile range (10% exceedance, highest flows regime) for flow exceedance from the LDC developed for SWQM station 21180. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 16. TMDL allocation summary for HCFC Ditch D 138

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

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	LA[d]	FG[e]	MOS[f]
HCFC Ditch D 138	1007W_01	4.374	0	4.090	0.034	0.031	0.219

[a] TMDL = from Table 10

[b] WLA_{WWTF} = 0 due to an absence of any WWTFs in the TMDL watershed

[c] WLA_{SW} = from Table 13

[d] LA = from Table 15

[e] FG = from Table 14

[f] MOS = from Table 11

The final TMDL allocations (Table 17) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 17. Final TMDL allocations for the HCFC Ditch D 138

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

Water Body	AU	TMDL	WLA_{WWTF}[a]	WLA_{SW}	LA	MOS
HCFC Ditch D 138	1007W_01	4.374	0.031	4.090	0.034	0.219

[a] WLA_{WWTF} = WLA_{WWTF} includes the FG component

Section 5
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