Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Horsepen Creek

Assessment Unit: 1014C_01

Horsepen Creek at Sunny Ridge Drive, looking upstream

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Prepared for
Total Maximum Daily Load Program
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Abbreviations

AU	assessment unit
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
DAR	drainage area ratio
DMR	discharge monitoring report
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
FDA_{SWP}	fractional proportion of drainage area
FDC	flow duration curve
FIB	fecal indicator bacteria
FG	future growth
H-GAC	Houston-Galveston Area Council
I&I	inflow and infiltration
LA	load allocation
LDC	load duration curve
MCM	minimum control measures
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
MUD	Municipal Utility District
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
PCR1	primary contact recreation 1
PUD	Public Utility District
SSO	sanitary sewer overflow
SWMP	stormwater management program
SWQM	surface water quality monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TWDB	Texas Water Development Board
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
WQMP	Water Quality Management Plan
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 Horsepen Creek in the *2020 Texas Integrated Report of Surface Water Quality*, which in this document will be referred to as the 2020 Integrated Report (TCEQ, 2020a).

This document will consider a bacteria impairment for Horsepen Creek in the downstream assessment unit (AU) 1014C_01.

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 uses. 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 USEPA approved the categorical levels of recreational use and their associated criteria that were first submitted to the USEPA in the 2014 Texas Water Quality Standards (TCEQ, 2014); 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 covers 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).

Horsepen Creek is presumed for PCR1 and has the associated *E. coli* geometric mean criterion of 126 cfu per 100 mL and single sample criterion of 399 cfu per 100 mL.

1.3 Report Purpose and Organization

The Horsepen Creek TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research. This project is considered to be an addendum to the existing bacteria TMDL (*Eighteen Total Maximum Daily Loads for Bacteria in Buffalo and Whiteoak Bayous and Tributaries*) (TCEQ, 2009). The existing TMDL was adopted by the TCEQ on April 8, 2009, and approved by USEPA in June 2009. Addendum One to these 18 TMDLs was completed April 2013 and was approved by USEPA in August 2013 through a Water Quality Management Plan (WQMP) update (TCEQ, 2013). Addendum Two was completed April 2015 and was approved by USEPA in July 2015 through a WQMP update (TCEQ, 2015). Therefore, this will be the third TMDL addendum.

Figure 1 shows the Horsepen Creek watershed within the area of the Buffalo and Whiteoak Bayou watersheds from the original TMDL project. 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 Horsepen Creek.

This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to 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 TMDLs.

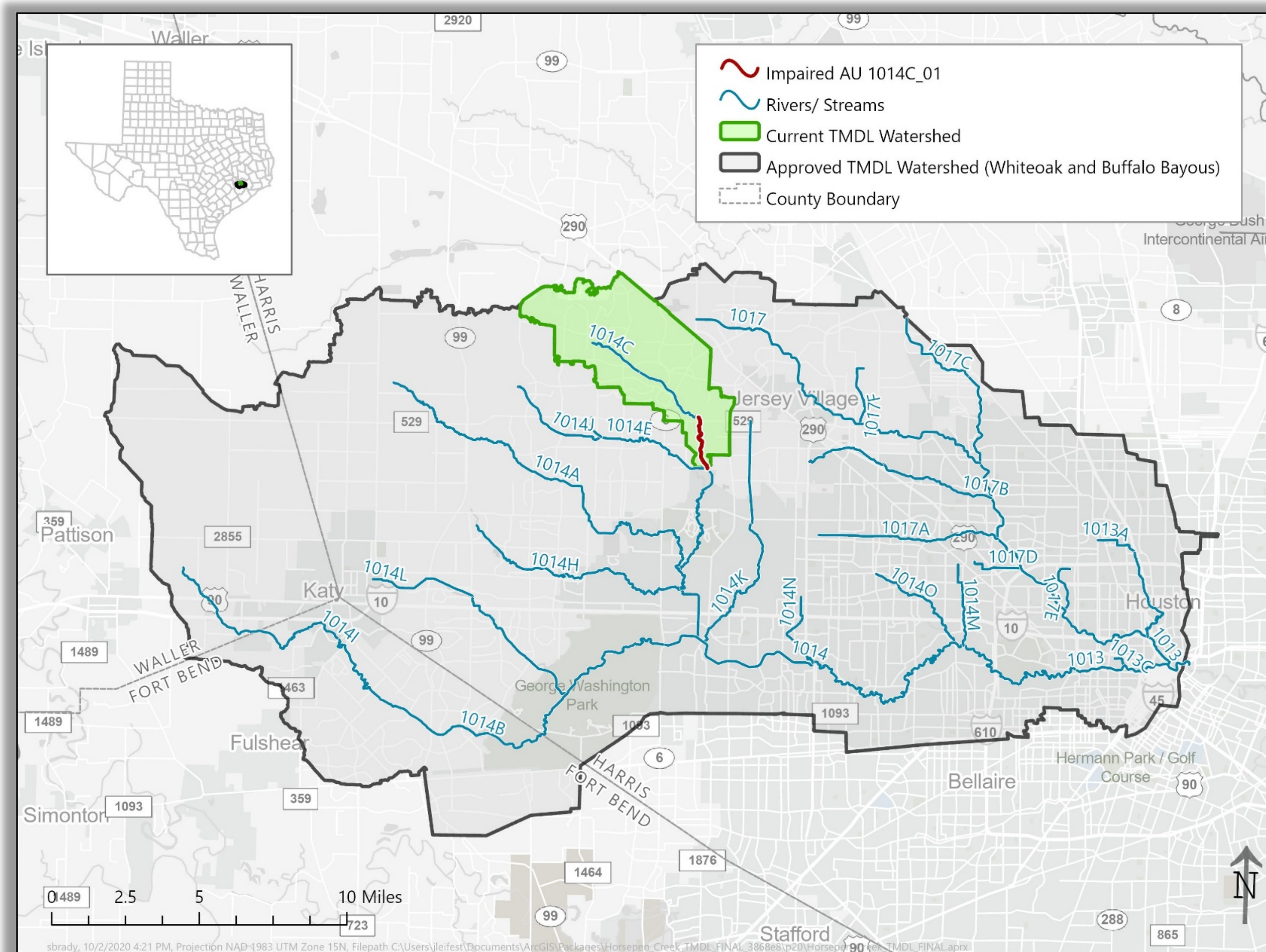

Figure 1. Map showing the previously approved TMDLs and addenda watershed with the current Horsepen Creek watershed considered in this addendum

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

Horsepen Creek (1014C) is a tributary of Buffalo Bayou (Segment 1014) and eventually the San Jacinto River (Segment 1005). Horsepen Creek is an unclassified, freshwater stream composed of three AUs (from downstream to upstream: 1014C_01, 1014C_02, and 1014C_03), all of which have a flow type of “Perennial” (TCEQ, 2020b) (Figure 2). Horsepen Creek (Segment 1014C) is approximately 6.8 miles long and flows into Langham Creek (Segment 1014E). At its mouth Horsepen Creek drains an area of 20.9 square miles, completely within unincorporated Harris County.

The 2020 Texas Integrated Report (TCEQ, 2020b) provides the following segment and AU descriptions for Horsepen Creek:

- 1014C (Horsepen Creek) - From the Langham Creek confluence upstream to a point 0.1 km (0.06 mi) west of Barker Cypress Road
    - AU 1014C_01 - From the Langham Creek confluence upstream to where channelization begins, 0.62 km (0.39 mi) north of FM 529
    - AU 1014C_02 - From 0.62 (0.39 mi) km north of FM 529 upstream to a point 2.4 km (1.5 mi) upstream of SH 6
    - AU 1014C_03 - From a point 2.4 km (1.5 mi) upstream of SH 6 to 0.1 km (0.06 mi) west of Barker Cypress Road

Using a watershed-based approach and because the impaired AU 1014C_01 is downstream of non-impaired AUs 1014C_02 and 1014C_03, the entire watershed of Horsepen Creek will be considered in this report.

2.2 Watershed Climate and Hydrology

The Horsepen Creek watershed is located in the eastern portion of the state of Texas, where the climate is classified as “Subtropical Humid” (Larkin & Bomar, 1983). The region’s subtropical climate is caused by the “predominant onshore flow of tropical maritime air from the Gulf of Mexico,” while the increasing moisture content (from west to east) reflects variations in “intermittent seasonal intrusions of continental air” (Larkin & Bomar, 1983). Occasional anomalous climatic events, including floods and droughts, are a feature of the climate.

Climate data for the full period of available daily records (December 2000 – September 2020) for the Houston Sugar Land Mem weather station (USW00012977) indicate a bimodal precipitation pattern (Figure 3) (Menne et al, 2012). Annual rainfall for the selected weather station averages 47.79 inches. The wettest month is typically August (5.68 inches) while the driest month is typically February (2.67 inches). Average high temperatures generally reach their peak of 94.5° F in August, while the average low temperature reaches a minimum of 43.2° F in January.

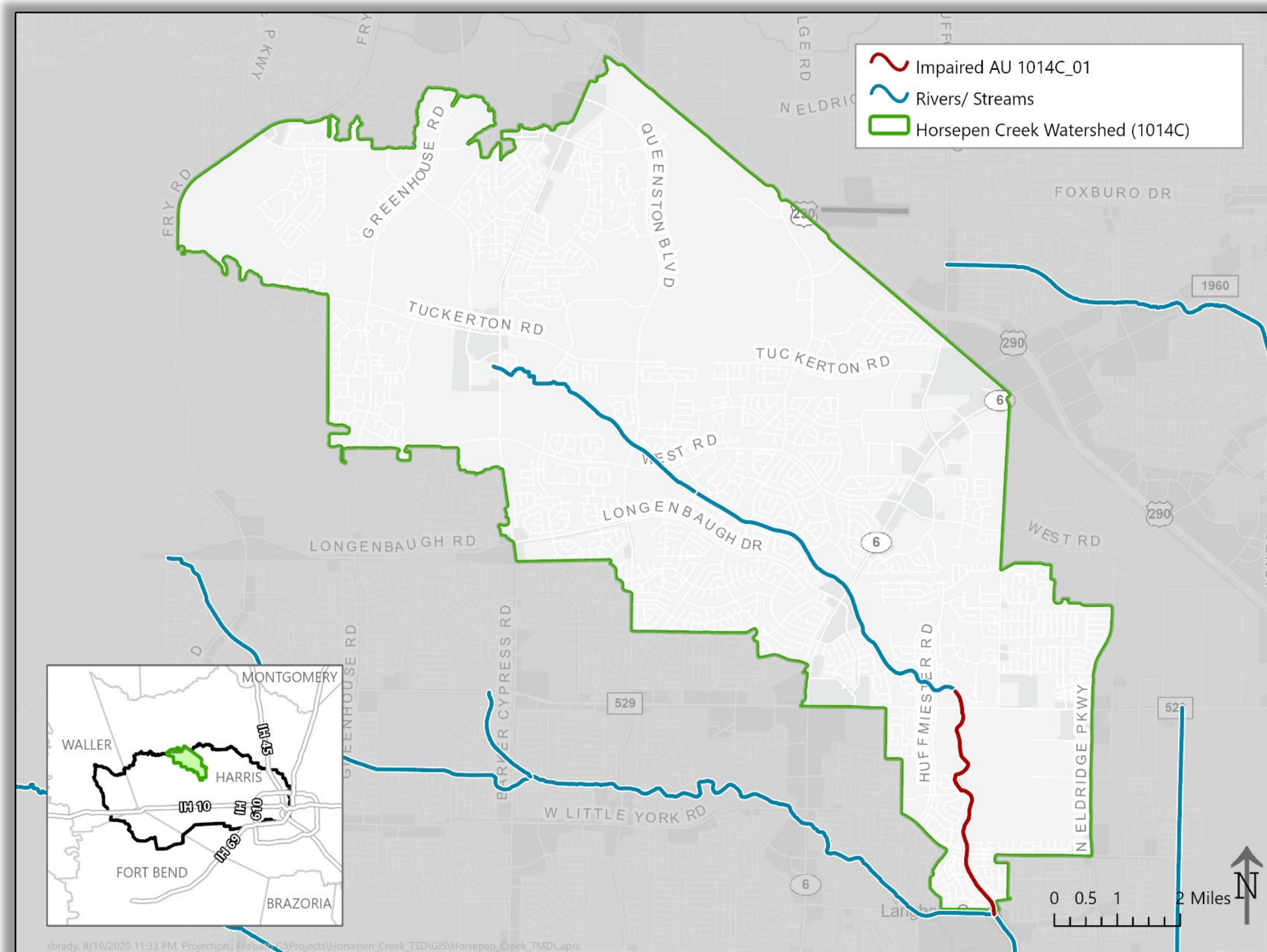

Figure 2. Overview map showing the watershed for Horsepen Creek (1014C_01)

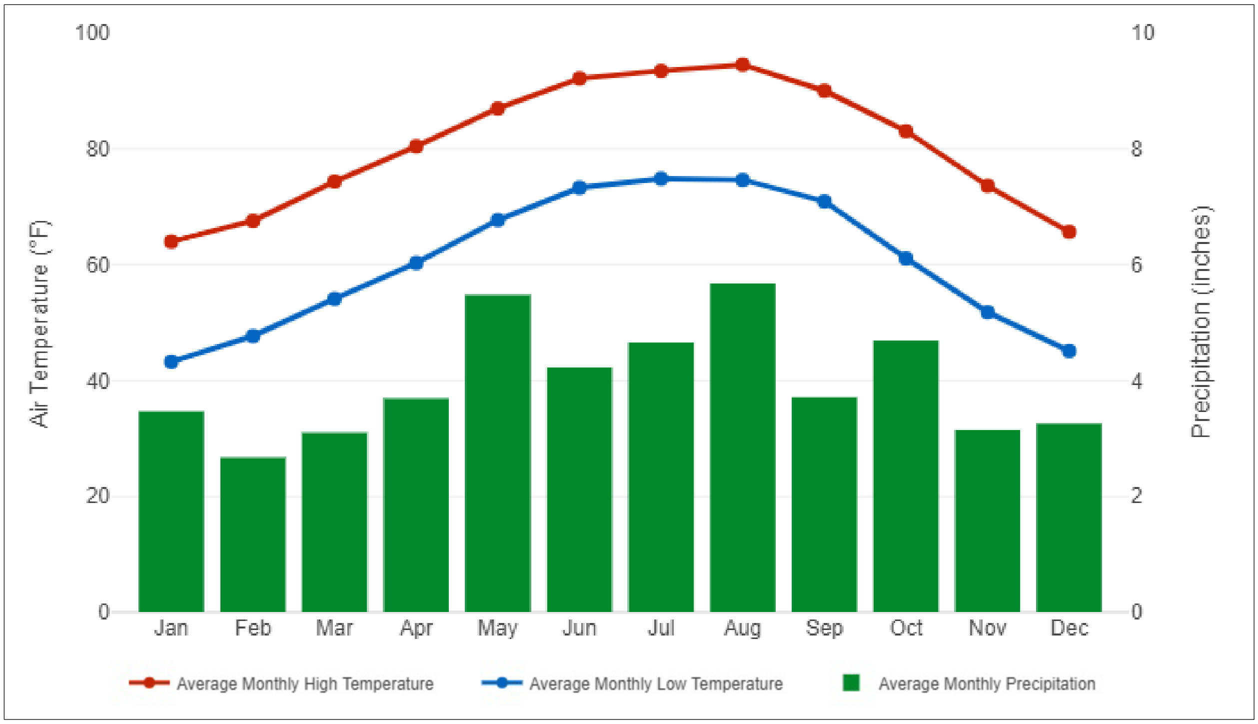

Figure 3. **Average minimum and maximum air temperature and total precipitation by month from 2000 - 2020 for the "Houston Sugar Land Mem" weather station**

2.3 Watershed Population and Population Projections

According to the United States Census Bureau (USCB) 2010 Census (USCB, 2010), there are an estimated 73,514 people in the Horsepen Creek watershed in 2010, indicating an average population density of 3,517.42 people/square mile. The entire population is located in unincorporated Harris County (Figure 4).

Population projection data, available through the state water planning process via the 2016 Region H Regional Water Plan (Region H Water Planning Group, 2015), is based on areas known as Water User Groups. Analysis based on county-level data reveals that populations are predicted to increase 23.9% in the project watershed between 2020 and 2070 (Table 1).

Table 1. 2010 Population and 2020 – 2070 Population Projections for the Horsepen Creek watershed

Location	2010 U. S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	2060 Population Projection	2070 Population Projection	Projected Population Increase (2020-2070)	Percent Change
Horsepen Creek Watershed	73,514	75,892	79,706	84,911	90,160	92,215	94,041	18,149	23.9%

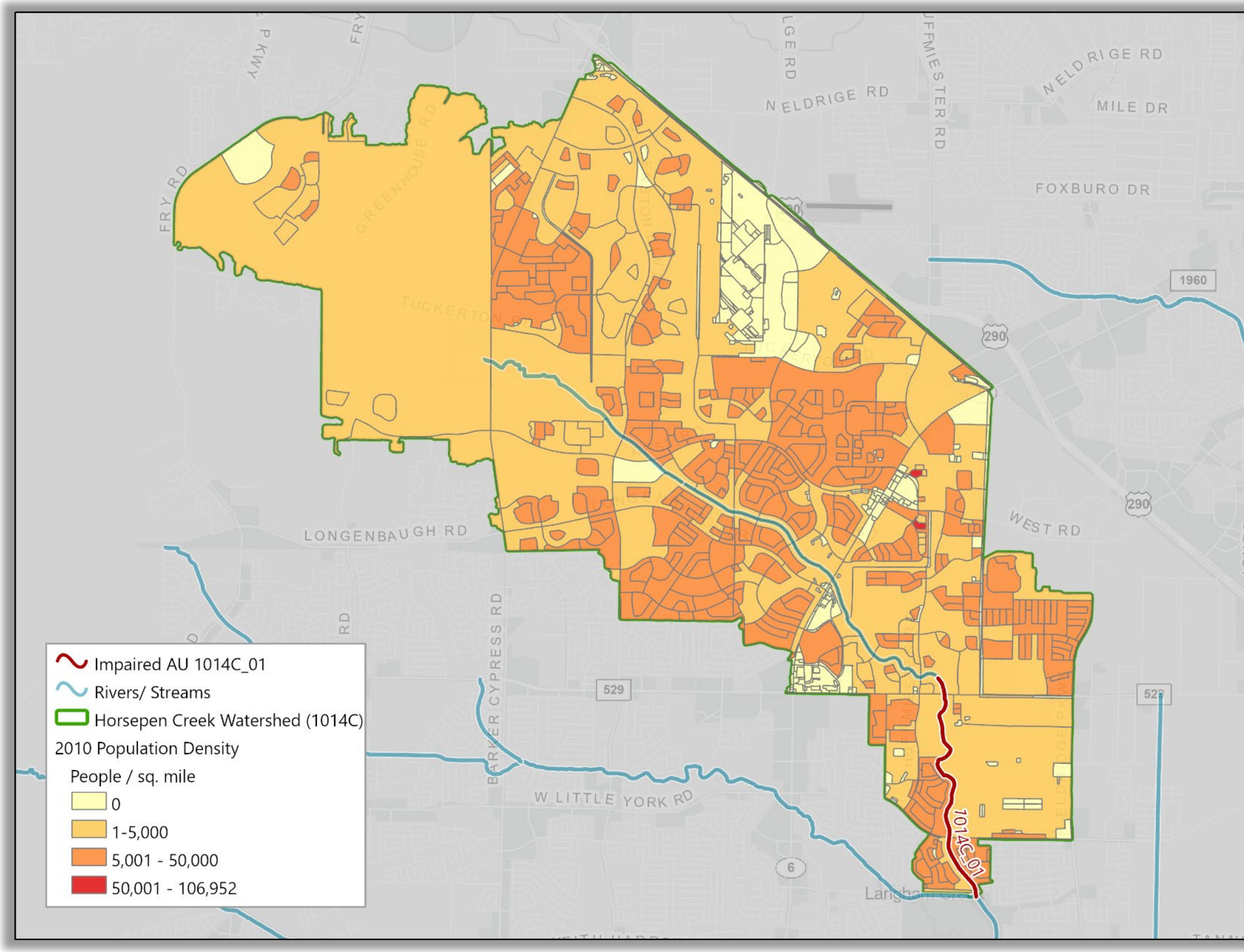

Figure 4. Population density for the Horsepen Creek watershed based on the 2010 U.S. Census blocks

2.4 Land Cover

The land cover data presented in this report were obtained from the United States Geological Survey (USGS) 2016 National Land Cover Database (NLCD) (USGS, 2019) and are displayed in Figure 5. The land cover is represented by the following categories and definitions:

- **Barren Land** – Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
- **Cultivated Crops** – Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
- **Developed, High Intensity** – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80% to 100% 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.
- **Developed, Medium Intensity** – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- **Developed, Open Space** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Deciduous Forest** – 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.
- **Evergreen Forest** – 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.
- **Mixed Forest** – 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.

- **Grassland/Herbaceous** – 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.
- **Pasture/Hay** – 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. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
- **Shrub/Scrub** – Areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Open Water** – Areas of open water, generally with less than 25% cover of vegetation or soil.
- **Emergent Herbaceous Wetlands** – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Woody Wetlands** – Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

As shown in Table 2, the watershed area encompassing the Horsepen Creek watershed is approximately 13,378 acres. The Horsepen Creek watershed is almost completely developed; at 42.48% percent, the dominant classification is "Developed, Medium Intensity".

Table 2. Land cover within the Horsepen Creek watershed

Classification	Area (Acres)	% of Total
Open Water	147.8	1.10%
Developed, Open Space	2,165.6	16.19%
Developed, Low Intensity	3,202.2	23.94%
Developed, Medium Intensity	5,683.2	42.48%
Developed, High Intensity	1,370.1	10.24%
Barren Land	63.7	0.48%
Deciduous Forest	13.6	0.10%
Evergreen Forest	49.0	0.37%
Mixed Forest	3.1	0.02%
Shrub/Scrub	90.6	0.68%
Grassland/Herbaceous	62.1	0.46%
Pasture/Hay	319.2	2.39%
Cultivated Crops	4.0	0.03%
Woody Wetlands	43.2	0.32%
Emergent Herbaceous Wetlands	160.5	1.20%
Total	**13,377.83**	**100%**

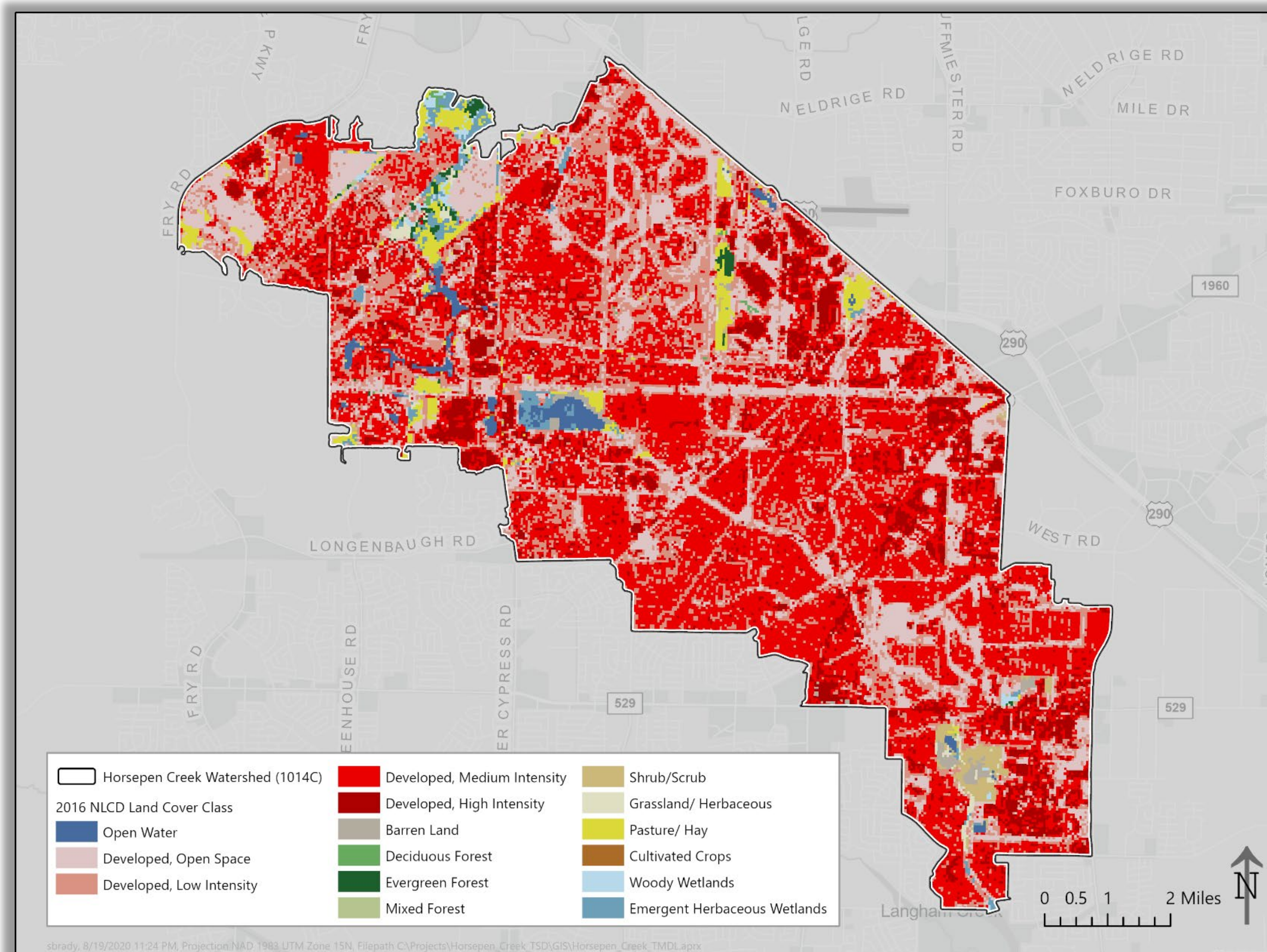

Figure 5. Land cover map showing categories within the Horsepen Creek watershed

2.5 Soils

Soils within the TMDL watershed, categorized by their septic tank absorption field ratings, are shown in Figure 6. These data were obtained through the United States Department of Agriculture Natural Resources Conservation Service (NRCS) Gridded Soil Survey Geographic database (NRCS, 2019).

Soil properties and features such as saturated hydraulic conductivity, flooding, depth to bedrock, depth to cemented pan, ponding, rocks, fractured bedrock, subsidence, and excessive slope can affect septic tank effluent absorption, construction, maintenance and public health (NRCS, 2019). The dominant soil condition within a septic drainage field can be used to identify soils that may prove problematic regarding septic system installation/performance and potentially lead to system failures such as effluent surfacing or downslope seepage.

Soils are rated based on the limiting factors (or conditions) affecting proper effluent drainage and filtering capacity. Soil conditions for septic tank drainage fields are expressed by the following rating terms and definitions (NRCS, 2019):

- *Not Limited – Indicates that the soil has features that are very favorable for the specific use. Good performance and very low maintenance can be expected.*
- *Somewhat Limited – Indicates that the soil has one or more features that are moderately favorable for the specified use. The limitations can be overcome or minimized with special planning, design, and installation procedures. Fair performance and moderate maintenance can be expected.*
- *Very Limited – Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.*
- *Not Rated – Indicates insufficient data exists for soil limitation interpretation.*

The majority of the soils within the Horsepen Creek watershed are categorized as "Very Limited" with a fraction rated "Not Rated" based on the dominant soil condition for septic drainage field installation and operation.

2.6 Review of Routine Monitoring Data

2.6.1 Data Acquisition

Ambient *E. coli* data were obtained from the TCEQ Surface Water Quality Web Reporting Tool on January 21, 2020 (TCEQ, 2020c). The data represented all the historical routine ambient *E. coli* and other water quality data collected in the project area and included routine *E. coli* data collected from October 1, 2007, through April 10, 2019. Ambient *E. coli* data were available for one surface water quality monitoring (SWQM) station in AU 1014C_01 (Table 3, Figure 7; TCEQ, 2020d).

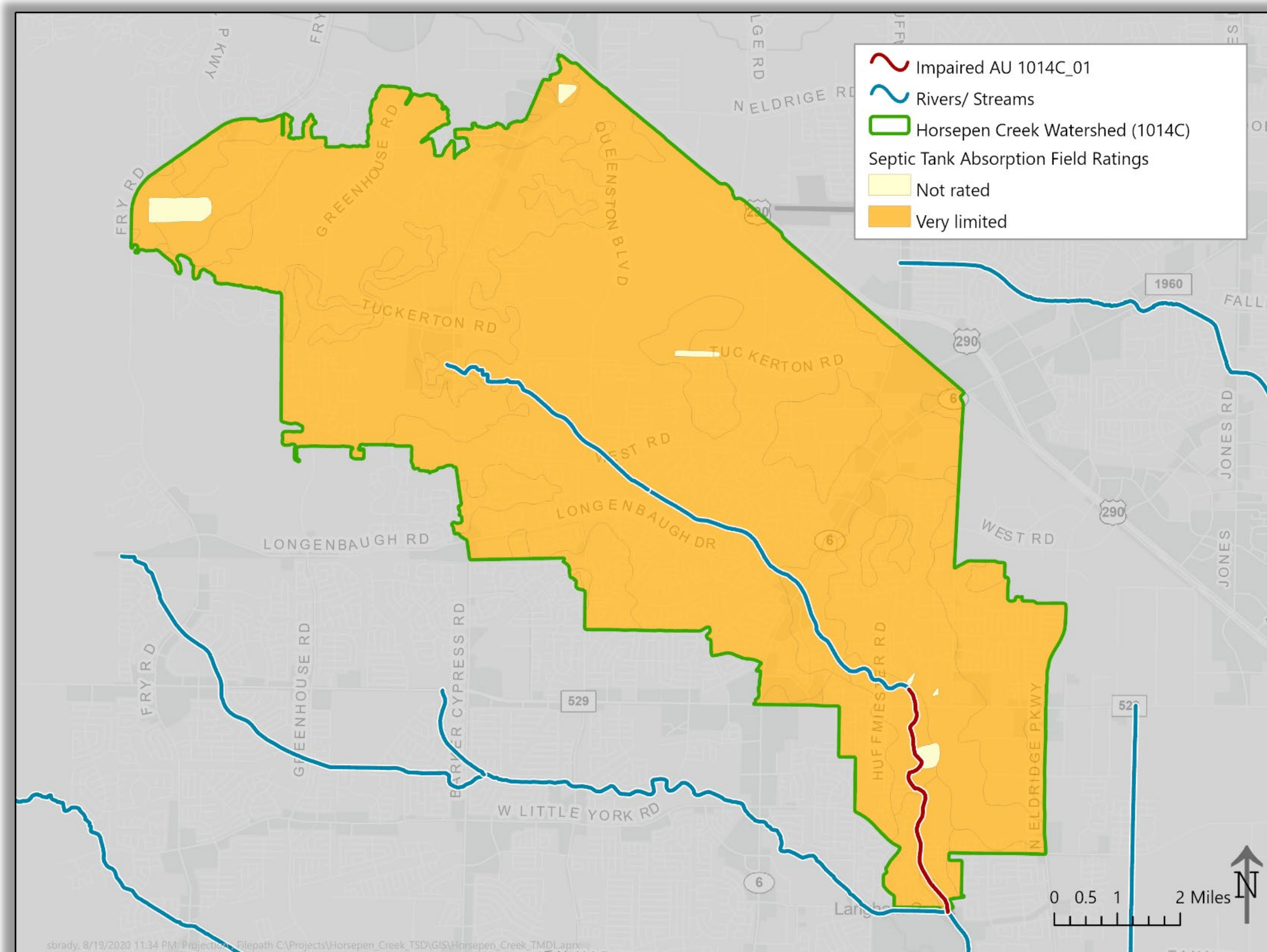

Figure 6. Septic tank absorption field limitation ratings within the Horsepen Creek watershed

Table 3. Summary of historical data set of *E. coli* concentrations from the Surface Water Quality Web Reporting Tool

AU	Station	Station Location	Parameter	No. of Samples	Geometric Mean (cfu/100 mL)	Date Range
1014C_01	20465	Horsepen Creek at FM 529	*E. coli*	46	324.81	2007-2019

2.6.2 Analysis of Bacteria Data

E. coli data collected at station 20465 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 Texas Integrated Report (TCEQ, 2020b) and are summarized in Table 4. The 2020 assessment data for Horsepen Creek watershed indicates non-support of the PCR1 use because the geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 mL.

Table 4. 2020 Integrated Report Summary for Horsepen Creek AU 1014C_01

AU	Station ID	Station Description	Parameter	Number of Samples	Date Range	Station Geometric Mean (cfu/ 100 mL)
1014C_01	20465	Horsepen Creek at FM 529	*E. coli*	28	2011 to 2018	414

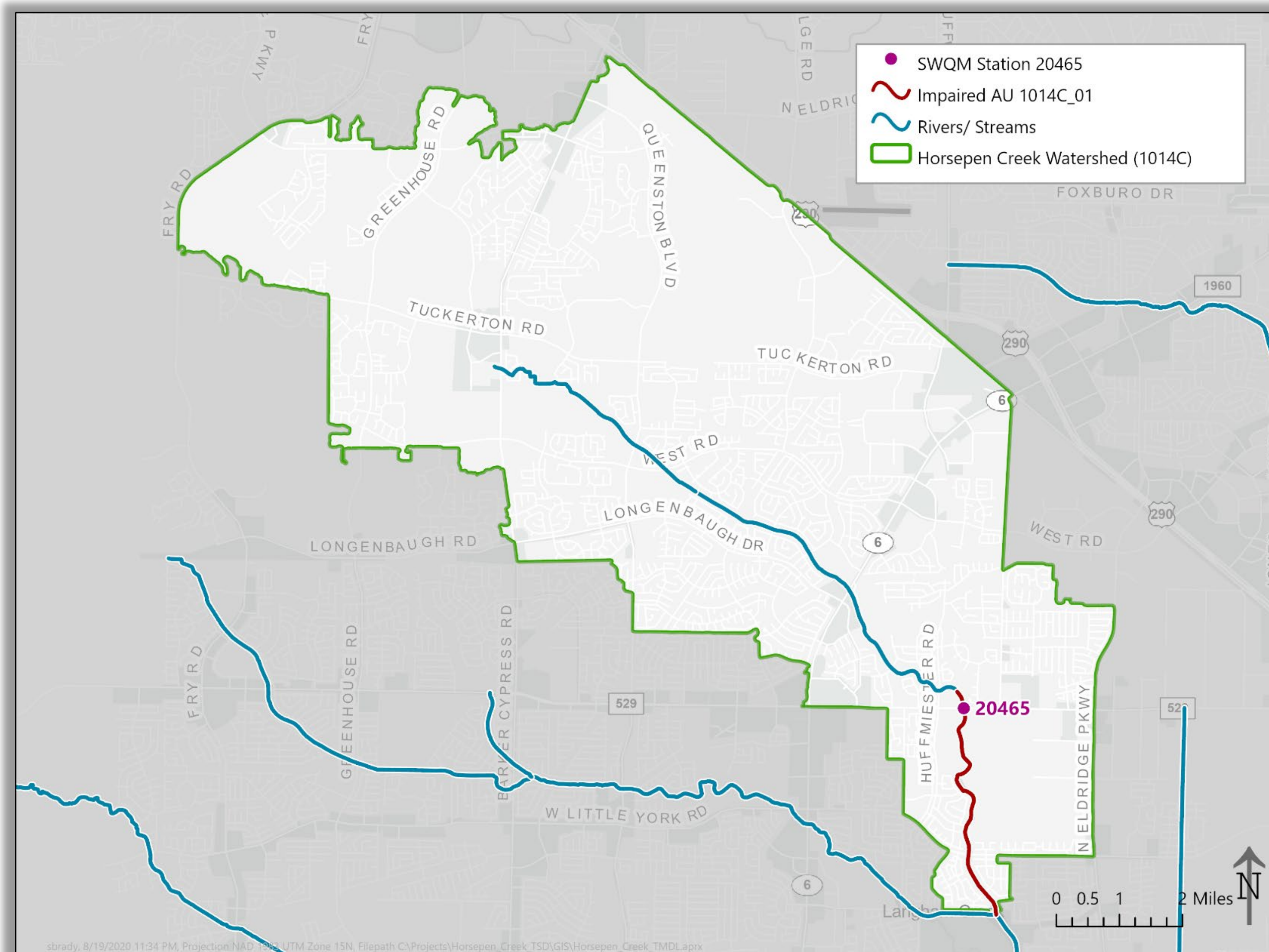

Figure 7. **TCEQ SWQM station within the Horsepen Creek watershed**

2.7 Source Analysis

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.

2.7.1 Regulated Sources

Regulated sources are controlled by permit under the TPDES program. Thirteen WWTFs, and stormwater discharges from one Phase I MS4 permittee and one combined Phase I and Phase II MS4 permittee, as well as one hydrostatic water well discharge permit are the permitted sources in the Horsepen Creek watershed.

2.7.1.1 Domestic WWTF Discharges

As of May 13, 2020, there are 13 WWTFs with TPDES permits (one has two outfalls) within the Horsepen Creek watershed (Table 5 and Figure 8). Recent discharge data are presented in Table 5 and were obtained from discharge monitoring reports (DMRs) made available through the USEPA Enforcement and Compliance History Online (ECHO) website (USEPA, 2020).

Table 5. Permitted WWTFs discharging to the subject AU (1014C_01) or upstream

Permittee	TPDES No.	Outfall No.	NPDES[1] No.	Facility Name	Permitted Discharge (MGD)	Recent[2] Discharge (MGD)[3]
Wyman-Gordon Forgings, Inc.	WQ0001402000	1	TX0042129	Wyman Gordon Forgings Cypress Plant	Intermittent and flow variable[4]	2.27
Wyman-Gordon Forgings, Inc.	WQ0001402000	2	TX0042129	Wyman Gordon Forgings Cypress Plant	0.225	0.15
Spencer Road Public Utility District (PUD)	WQ0011472001	1	TX0026263	Spencer Road WWTF	0.98	0.33
Harris County Municipal Utility District (MUD) No. 208	WQ0011947001	1	TX0075884	Copperfield Plant WWTF	6.7	2.56
West Harris County MUD No. 15	WQ0012223001	1	TX0083496	West Harris County MUD 15 WWTF	0.6	0.51
Chimney Hill MUD	WQ0012304001	1	TX0085588	Chimney Hill MUD WWTF	1.2	0.69
R&K Weiman MHP, L.C.	WQ0012310001	1	TX0085871	Weiman MHP WWTF	0.03	0.02
Harris County MUD No. 196	WQ0012447001	1	TX0088838	Harris County MUD 196 WWTF	1.4	0.85
Harris County MUD No. 155	WQ0012726001	1	TX0100161	Harris County MUD 155 WWTF	1.55	0
Remington MUD No. 1	WQ0013328001	1	TX0101371	Remington Plant 2	1.1	0.77
Dril-Quip, Inc.	WQ0014655001	1	TX0128287	Dril-Quip WWTF	0.075	0.02
Harris Co MUD No. 500	WQ0014740001	1	TX0129071	Horsepen Creek WWTF	0.84	0.21
Harris County MUD No. 250	WQ0014811001	1	TX0093581	Harris County MUD 250 WWTF	0.1	0.07
Eli Gravriel Sasson	WQ0014830001	1	TX0104795	West Houston MHP	0.099	0.04

[1] National Pollutant Discharge Elimination System
[2] Period January 2017 – May 2020
[3] Million gallons per day
[4] Not considered in the TMDL calculations

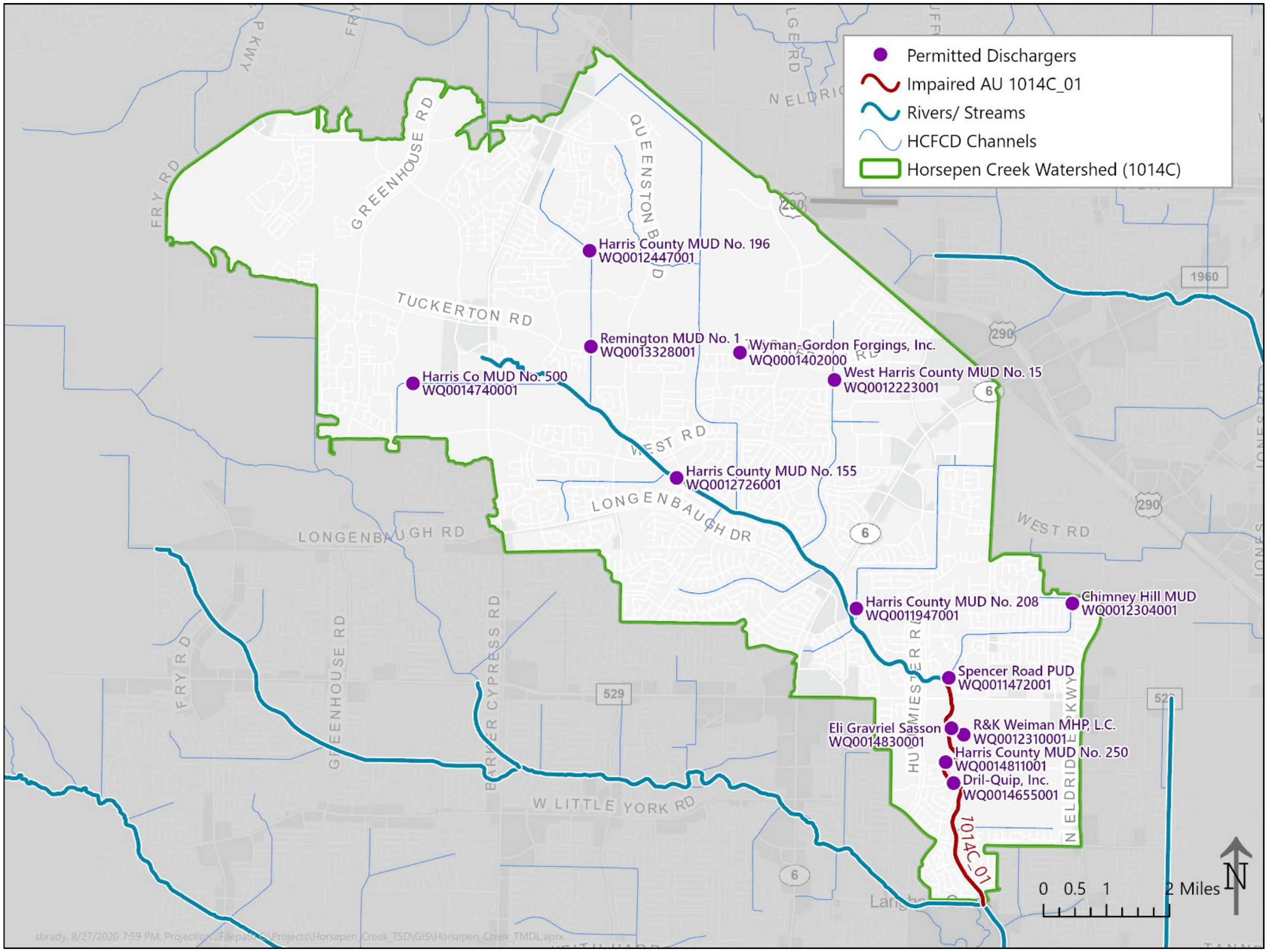

Figure 8. **WWTF outfalls within the Horsepen Creek watershed, labeled by Permittee and TPDES number**

2.7.1.2 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 the reports of SSO events that were determined to have occurred within the Horsepen Creek watershed between 2016 and 2020 is shown in Table 6 and Figure 9. The causes of the SSOs were, from most common to least common: other, line blockage, equipment failure, grease blockage, unknown, line break, power outage, continuous release, and I&I.

Table 6. Summary of SSO incidents reported in the Horsepen Creek watershed from 2016 to 2020

Watershed	Number of Incidents	Total Volume (gallons)	Min Volume (gallons)	Max Volume (gallons)	Avg Volume (gallons)
Horsepen Creek	83	182,836	5	18,000	2,202.84

2.7.1.3 TCEQ/TPDES Water Quality General Permits

In addition to the individual wastewater discharge permits listed in Table 5, discharges of processed wastewater from certain types of facilities must 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)

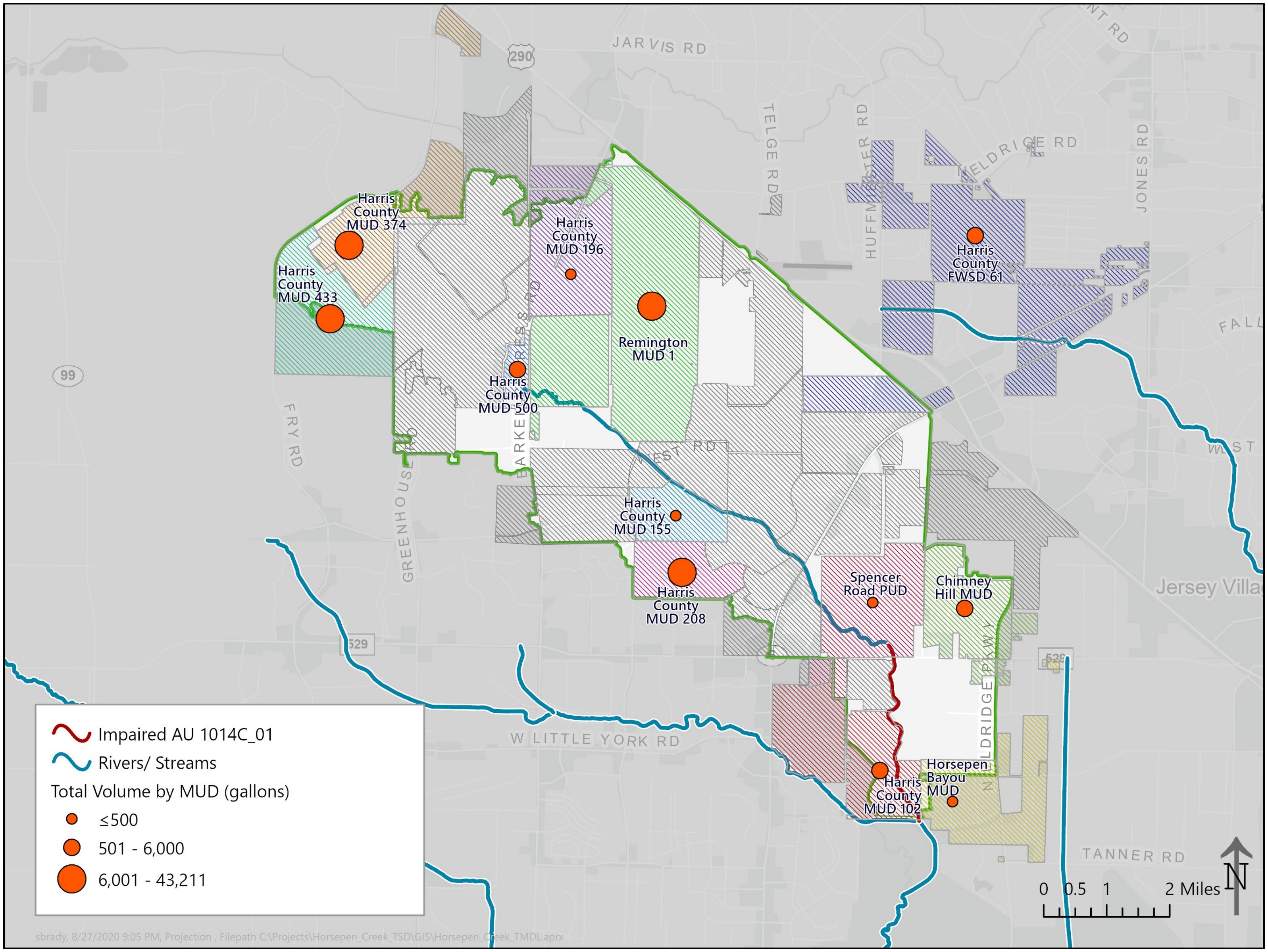

Figure 9. SSO incidents summarized by regulated entity reported in the Horsepen Creek watershed from 2016 to 2020

A review of general permits coverage (TCEQ, 2020f) for the project watershed (1014C_01) found one active hydrostatic test water discharge and three pesticide permittees. No other active general wastewater permit facilities or operations were found. The general permits for hydrostatic test water discharges and pesticides do not contain bacteria reporting requirements or limits.

2.7.1.4 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.

2.7.1.5 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 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.

A review of Phase I permits and a review of the TCEQ central registry for Phase II MS4 permit coverage in the Horsepen Creek watershed revealed one Phase I and one combined Phase I and Phase II MS4 permit (Table 7 and Figure 10).

For the Horsepen Creek watershed, the total area under MS4 permits is 10,451.01 acres, or 78.12% of the watershed (USCB, 2012).

Table 7. TPDES MS4 permits in the Horsepen Creek watershed

Entity	TPDES Permit	NPDES Permit	Permit Type
City of Houston/ Harris County/ HCFCD/ TxDOT	WQ0004685000	TXS001201	Phase I
Texas Department of Transportation	WQ0005011000	TXS002101	Combined Phase I/II

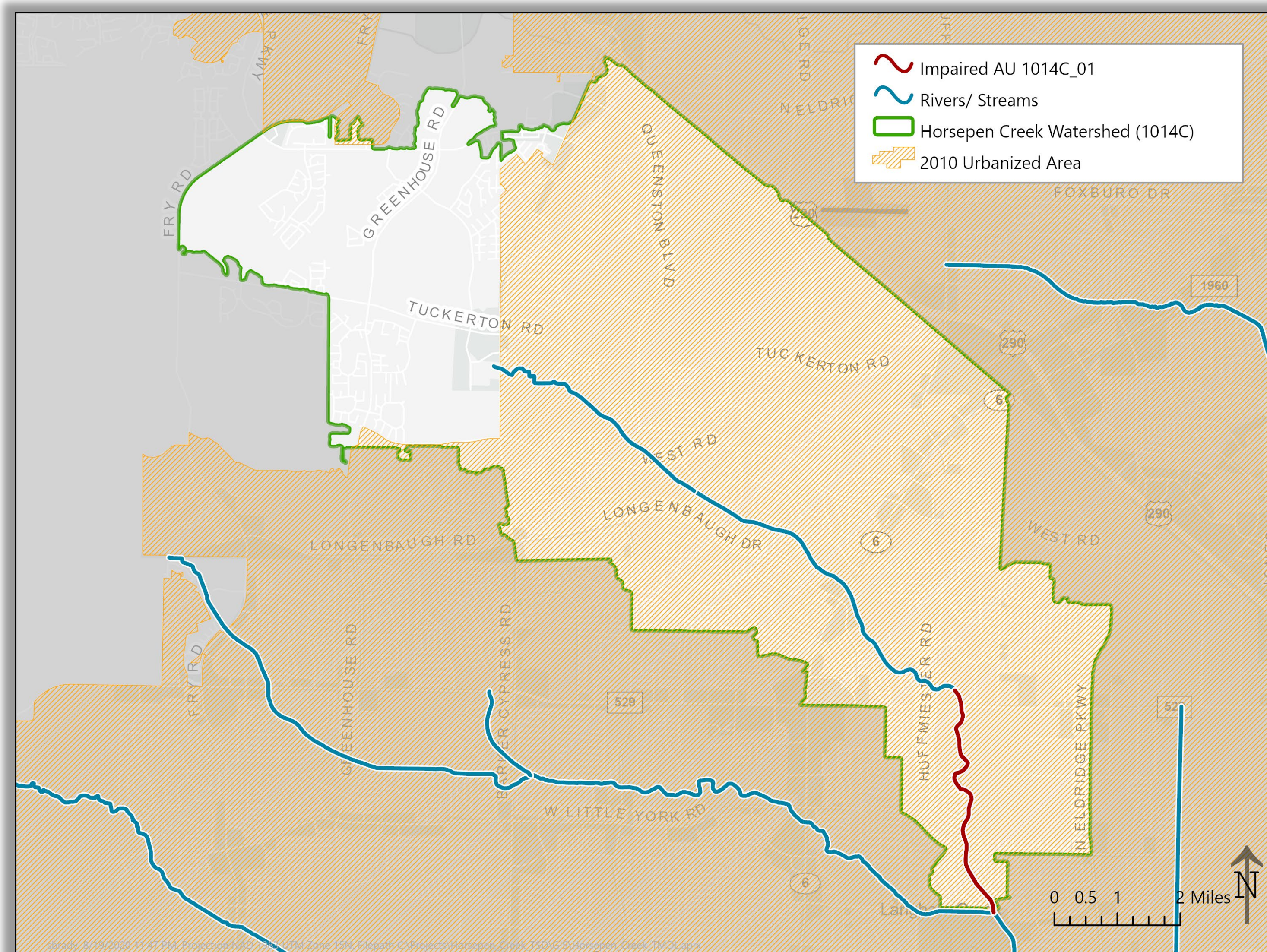

Figure 10. **Regulated stormwater area based on MS4 permits (defined by the urbanized area) within the Horsepen Creek watershed**

2.7.1.6 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:

- TXR040000 – Phase II MS4 general permit for small MS4s located in UAs
- TXR050000 – Multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – Construction General Permit (CGP) for construction activities disturbing more than one acre

No review of MSGP or construction permits was conducted because the urbanized area is being used to account for all stormwater permits in the TMDL allocations for Horsepen Creek. There are no Phase II MS4 permits in the watershed. See Section 4.7.3 for more detailed information.

2.7.1.7 Review of Compliance Information on Permitted Sources

A review of the USEPA ECHO database (USEPA, 2020) was conducted August 21, 2020. The search didn't reveal any non-compliance issues regarding *E. coli* limit violations for WWTFs within the Horsepen Creek watershed.

2.7.2 Unregulated Sources

Unregulated sources of 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.

2.7.2.1 Wildlife and Unmanaged Animal Contributions

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 Horsepen Creek 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.

2.7.2.2 OSSFs

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

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters, if the systems are not properly operating. Properly designed and operated, however, OSSFs would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weiskel et al, 1996).

Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The TMDL watershed is located within Region IV (covering parts of north, central, and coastal Texas), a region having a reported failure rate of about 12%, which provides insights into expected failure rates for the area. Failing OSSFs are a source of fecal pathogens and indicator bacteria loading to streams. Loading from failing OSSFs can be transported to streams in a variety of ways, including runoff from surface discharge or from transport by stormwater runoff.

Estimates of the number of OSSFs in the Horsepen Creek watershed were determined using Houston-Galveston Area Council (H-GAC) supplied spatial data. The H-GAC data indicate that there are a total of 89 OSSFs (H-GAC, personal communication, April 13, 2020) located within the project watershed (Figure 11).

2.7.2.3 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 8 summarizes the estimated number of dogs and cats for 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 number of households in the watershed was estimated using 2010 USCB data (USCB, 2010). The actual contribution and significance of bacteria loads from pets reaching Horsepen Creek is unknown.

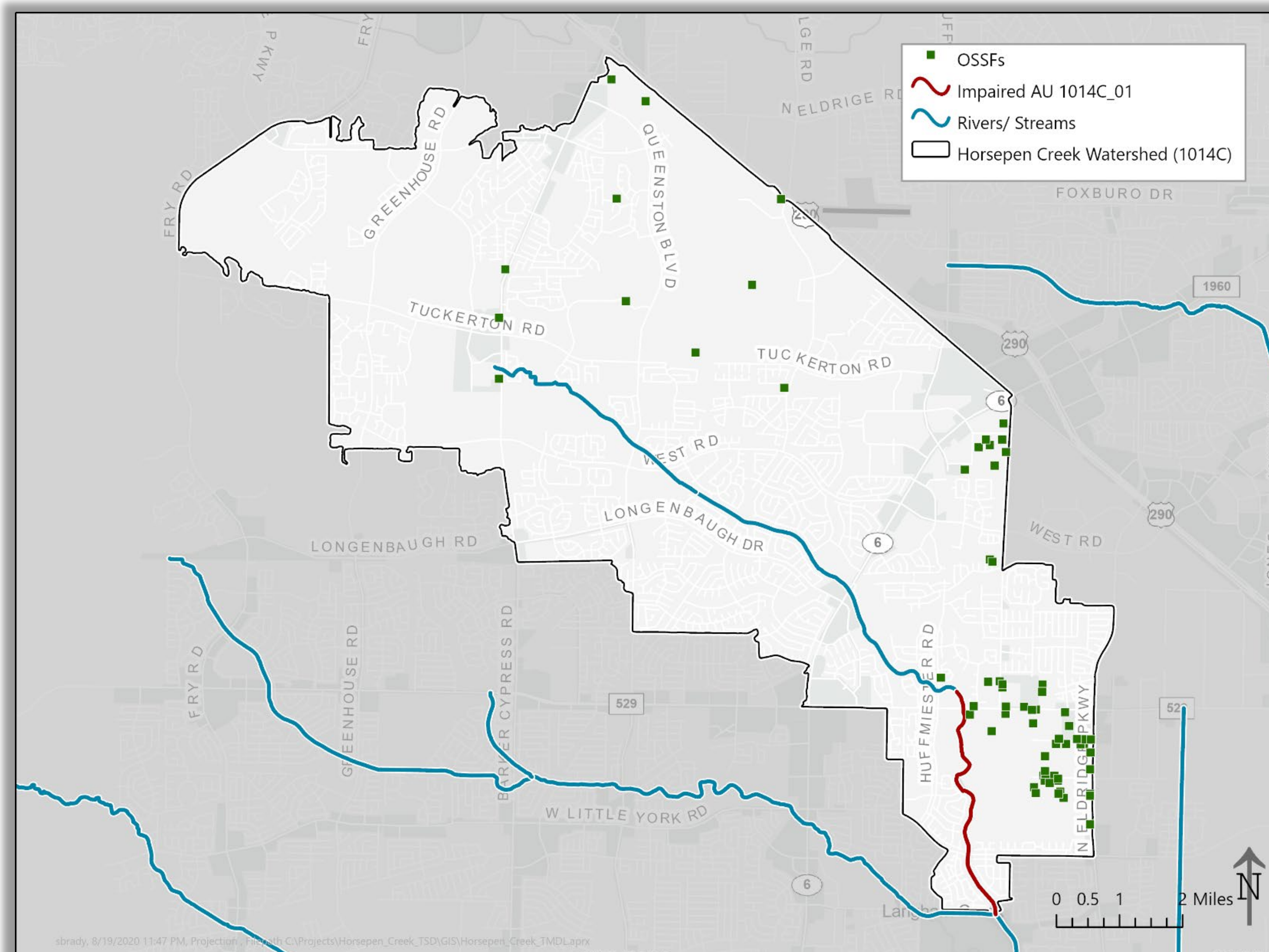

Figure 11. OSSFs located within the Horsepen Creek watershed

Table 8. Estimated households and pet populations for the Horsepen Creek watershed

Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
25,956	15,937	11,862

2.7.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (*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 compost and sludge. While the die-off of 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 in the TMDL watershed.

SECTION 3
BACTERIA TOOL DEVELOPMENT

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

3.1 Tool Selection

There have been three TMDL efforts in the area of Buffalo and Whiteoak Bayous prior to this project. The original TMDL (*Eighteen Total Maximum Daily Loads for Bacteria in Buffalo and Whiteoak Bayous and Tributaries*) was adopted by the TCEQ on April 8, 2009, and approved by USEPA in June 2009 (TCEQ, 2009). The original TMDL is described in *Total Maximum Daily Loads for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou* (University of Houston, CDM, 2008). The first addendum to the original TDML (*TMDL Addendum I: One TMDL for Bacteria in Vogel Creek Segment: 1017C*) was approved by the USEPA in August 2013 (TCEQ, 2013), and is described in *Technical Support Document for Bacteria TMDLs for New/Additional Listings in the Houston Metro Area, Houston, Texas (1007T_01, 1007U_01, 1007S_01, 1007V_01, 1017C_01 AND 1007A_01)* (University of Houston, 2012). The second addendum to the original TMDL (*TMDL Addendum II: One TMDL for Bacteria in Rolling Fork Creek Segment: 1017F Assessment Unit: 1017F_01*) was approved by the USEPA in July 2015 (TCEQ, 2015) and is described in *Technical Support Document: Bacteria Total Maximum Daily Loads For Rolling Fork Creek, a Tributary of Whiteoak Bayou, Houston, Texas (1017F_01)* (University of Houston, 2014). Therefore, this will be the third TMDL addendum. For consistency between this TMDL and the previously completed Buffalo and Whiteoak Bayou TMDLs, the pollutant load allocation activities for Horsepen Creek used the LDC method.

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.

3.2 Horsepen Creek 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 Horsepen Creek watershed; however, streamflow records were available for the nearby Langham Creek watershed (Figure 12 and Table 9). Streamflow records for the Langham Creek watershed are collected and made readily available by the USGS, which operates the Langham Creek streamflow gauge (USGS, 2020). USGS streamflow gauge 08072760 is located along the mainstem of Langham Creek and serves as the primary source for streamflow records used in this document. The Langham Creek streamflow gauge served as one source of streamflow records for the original TMDL (University of Houston, CDM, 2008).

Table 9. Basic information on Langham Creek USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (square miles)	Daily Streamflow Record (beginning & end date)
08072760	Langham Creek at West Little York Road near Addicks, TX	25.2	July 1977– present

Ambient *E. coli* data were available through the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) for one station located along Horsepen Creek, as described previously in Table 3.

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 drainage area ratio (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).

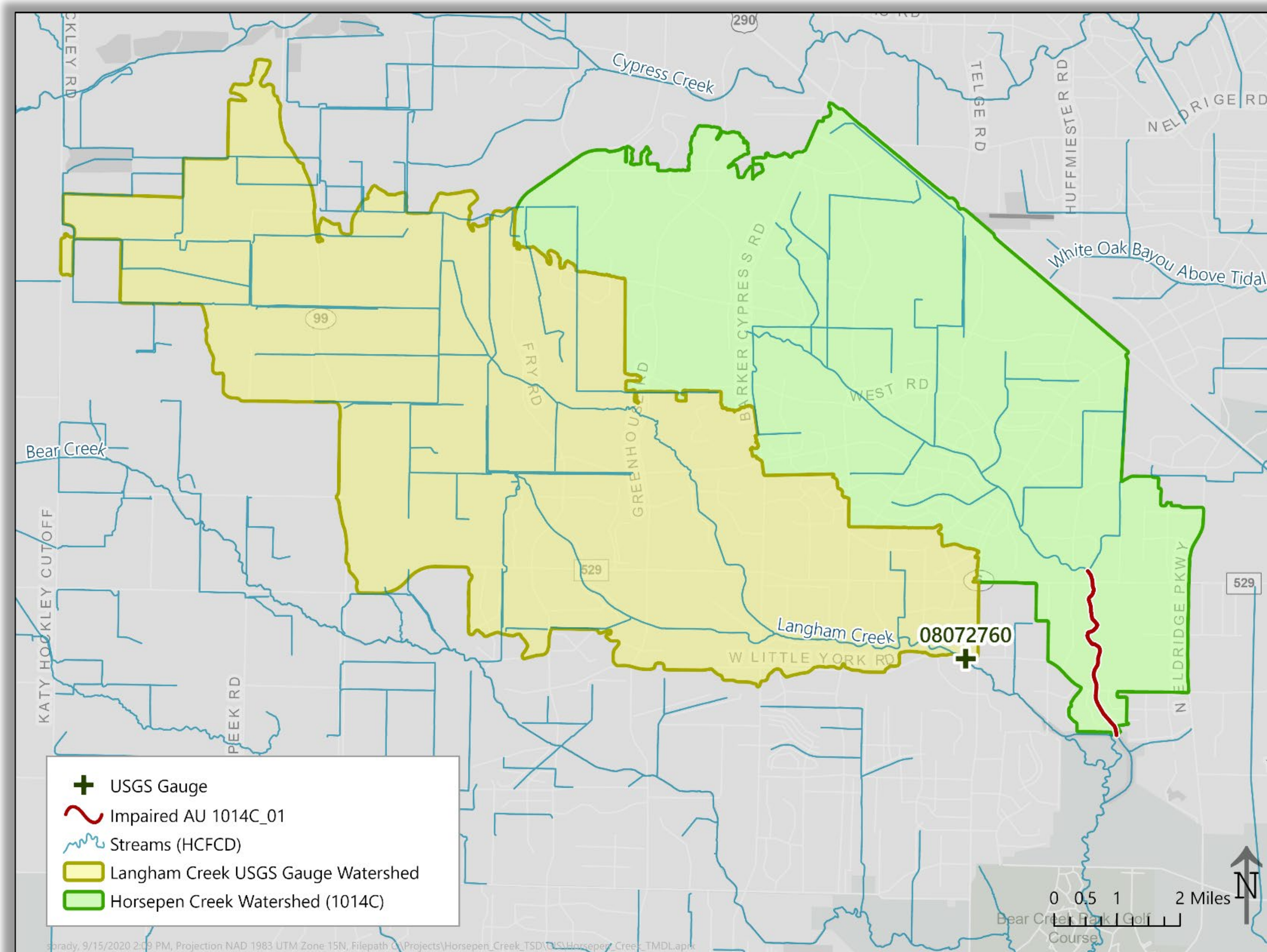

Figure 12. Horsepen Creek watershed, Langham Creek watershed, and USGS Station 08072760 location

3.3.1 Step 1: Determine Hydrologic Period

A 43-year period of continuous daily streamflow was available for USGS gauge 08072760 located on nearby Langham Creek (USGS, 2020). The period of record is more than adequate to capture a reasonable variation in meteorological patterns of high and low rainfall periods. 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. An approximately 11.5-year record of daily streamflow from October 1, 2007, through April 10, 2019, was selected to develop the FDC at the sampling station. A 11.5-year period is of sufficient duration to contain a reasonable variation of dry and wet periods and, at the same time, is short enough in duration to reflect recent and current conditions in the watershed. This time period also corresponds exactly with the available bacteria record for the subject AU.

3.3.2 Step 2: Determine Desired Stream Locations

When using the LDC method, the optimal location for developing the pollutant load allocation is a currently monitored SWQM station located near the outlet of the watershed with an abundance of historical bacteria data. The SWQM station on Horsepen Creek was selected because it was the only station for which *E. coli* data were available. Station 20465 on Horsepen Creek is located near the confluence with Langham Creek (Figure 7) and has an abundance of *E. coli* data that are found in SWQMIS (Table 3). Since Station 20465 is not located downstream of all WWTFs and is not near the outlet of the watershed, an additional LDC was developed at the watershed outlet.

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and locations were determined, the next step was to develop the 11.5-year daily streamflow record for each stream location. The daily streamflow records were developed from extant USGS records (Table 9).

The method to develop the necessary streamflow record for the FDC/LDC locations (i.e., SWQM station location and watershed outlet) 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 FDC/LDC development location. The factor is determined by dividing the drainage area above the desired location by the drainage area above the USGS gauge (Table 10).

Table 10. DARs for the TMDL watershed based on the drainage area of the Langham Creek USGS gauge

Water Body	Segment	Gauge/Station	Drainage Area (acres)	DAR
Langham Creek	1014E	USGS Gauge 08072760	16,111.19	1.00
Horsepen Creek	1014C	Watershed Outlet	13,377.83	0.8303
Horsepen Creek	1014C	SWQM Station 20465	11,606.28	0.7204

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land use/land cover, point source derived flows should first be considered for removal from the flow record of the Langham Creek gauge prior to application of the ratio. A search for TPDES permitted facilities within the Langham Creek watershed returned eight active permits upstream of the gauge (TCEQ, 2020e). Therefore, an adjustment for discharges were made to the Langham Creek USGS gauge record prior to application of the DAR. The DMR data for the WWTFs within the USGS watershed were subtracted from the flow record prior to application of the DAR.

Additionally, a spatial query of water rights features (diversions, withdrawals, return flows) was conducted for the Langham Creek watershed, and one water rights permit was located (TCEQ, 2020g). A review of the available water use data indicated that there were no recent water diversions ("Water Rights and Water Use Data," 2020). A spatial query of water rights features in the Horsepen Creek watershed revealed no water rights. 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.

The DARs for locations within the TMDL study area are presented in Table 10. The computation of the daily streamflow record for Horsepen Creek was performed by first subtracting the recent DMR flows from the daily streamflow record at the USGS Langham Creek gauge, then by multiplying each daily streamflow in the 11.5-year Langham Creek gauged record by the DAR at station 20465. Following application of the DAR, the Horsepen Creek DMR flows were added into the daily streamflow record (Table 5) as well as the future growth (FG) flows (calculated in Section 4.7.4) to account for the probability that additional flows from WWTF discharges may occur as a result of population increases.

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 an 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 point plus one; and
- plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor (2.44658×10^7), 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 FDCs for the TMDL Watershed

For this project, two FDCs were developed. An FDC was developed for monitoring station 20465 within the Horsepen Creek watershed (Figure 13), as well as for the outlet of Horsepen Creek (Figure 14). Both FDCs were developed by applying the DAR method and using the Langham Creek USGS gauge and 11.5-year period (2007-2019) described in the previous sections.

Flow exceedances less than 10% percent typically represent streamflows influenced by storm runoff, while higher flow exceedances represent receding hydrographs after a runoff event and base flow conditions. A feature of both FDCs is the relatively flat nature of the curve at lower flows, indicating that the stream rarely if ever goes dry.

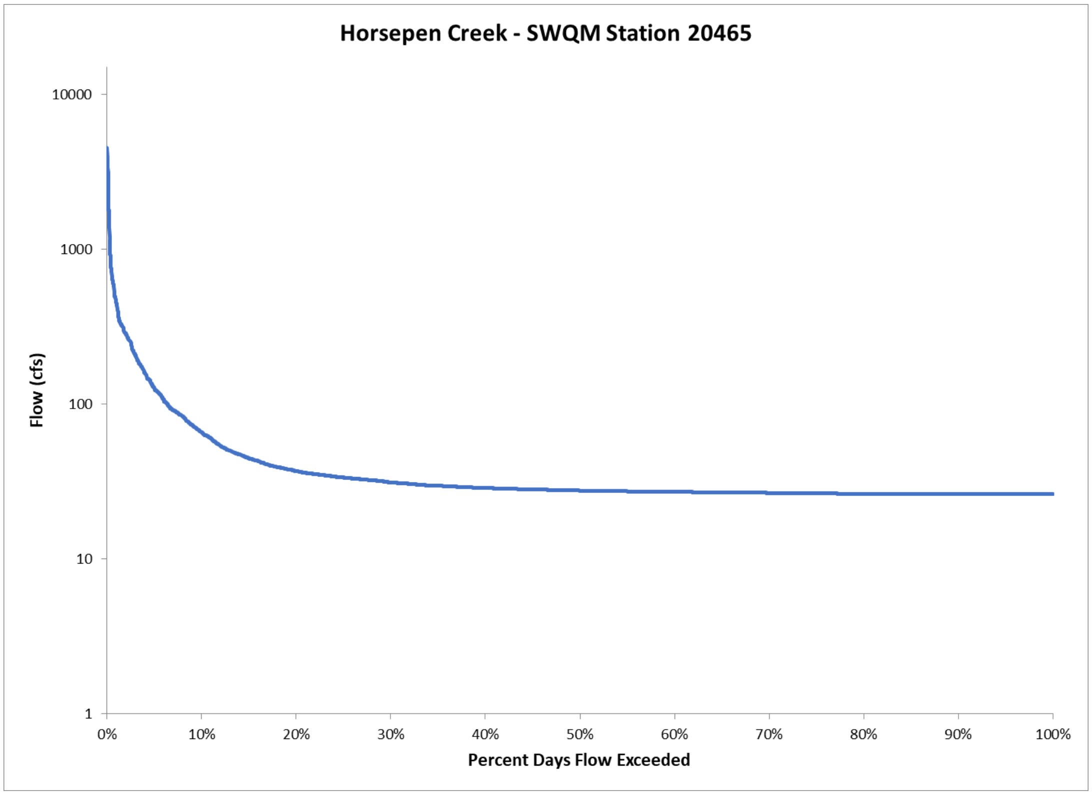

Figure 13. FDC for Horsepen Creek SWQM Station 20465

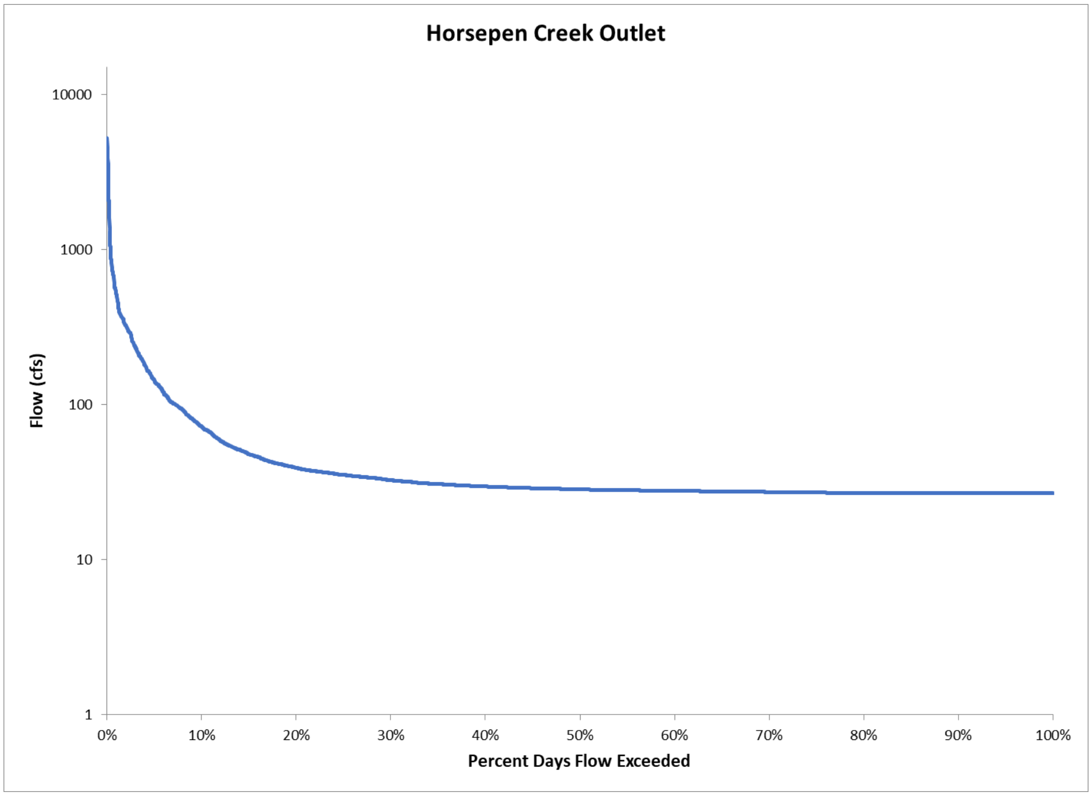

Figure 14. FDC for the outlet of Horsepen Creek (AU 1014C_01)

3.5 LDCs for the TMDL Watershed

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 curves. 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% (upper/mid-range flows); (3) 40-60% (mid-range flows); (4) 60-90% (lower/mid-range conditions); and (5) 90-100% (low flows).

For the Horsepen Creek watershed, a three-interval division was selected:

- Wet: 0-20% range, related to flood conditions and non-point source loading
- Intermediate: 20-80% range, intermediate conditions of receding hydrographs after storm runoff and base line conditions
- Dry: 80-100% range, related to dry conditions

The selection of the flow regime intervals was based on general observations of the monitoring station LDC.

The LDCs for Horsepen Creek, showing the three flow regimes, are provided in Figures 15 and 16. The LDC for SWQM Station 20465 was developed for informational purposes, while the LDC for the watershed outlet was constructed for developing the TMDL allocation for Horsepen Creek. Both LDCs take into account WWTFs that are located upstream of the LDC development location. The SWQM station LDC shows the bacteria data while the "outlet" LDC just displays the allowable loadings and is the basis for TMDL development. Geometric mean loadings for the data points within each flow regime have also been distinguished on Figure 15 to aid interpretation. The LDC depicts the allowable loadings 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 presents the allowable loading at the station under the single sample criterion (399 cfu/100 mL).

Additionally, historical bacteria measurements (*E. coli*) were aligned with the streamflow on the day of measurement. The historical bacteria measurements were then multiplied by the streamflow value and the conversion factor, as described in Section 3.3.4, to calculate a loading associated with each measured bacteria concentration. On each graph the measured *E. coli* data are presented as associated with a "wet weather event" or a "non-wet weather event." Due to the variability in available data, this determination was made based on satisfying one of the following criteria:

- the "days since precipitation event" value (if available) was less than or equal to 3 days (≤ 3);
- the "instantaneous flow" value (if available) was greater than or equal to 10 cfs.

For the Horsepen Creek LDCs, the wet weather data points occurred, as expected, predominately under the higher flow regimes and consistently exceeded the geometric mean criterion. Wet weather data points in the lowest flow regime typically represent bacteria data collected after a small rainfall-runoff event when conditions up to the event were very dry. Often the non-wet weather event data points also exceed the geometric mean criterion for Horsepen Creek. The geometric mean of existing data shown by flow regime further substantiate the elevated *E. coli* levels as they are consistently greater than the geometric mean criterion for the waterbody.

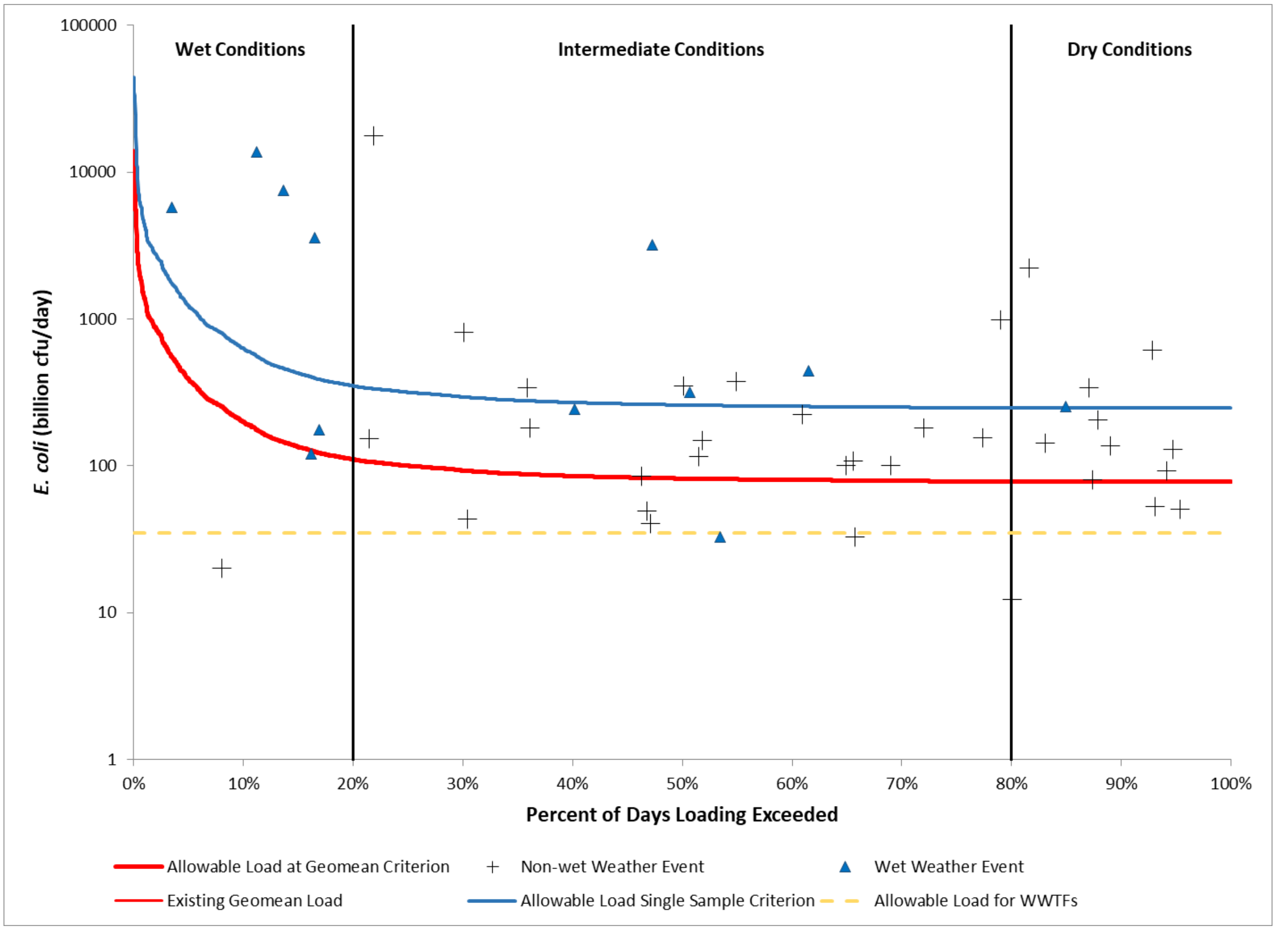

Figure 15. LDC for Horsepen Creek SWQM Station 20465

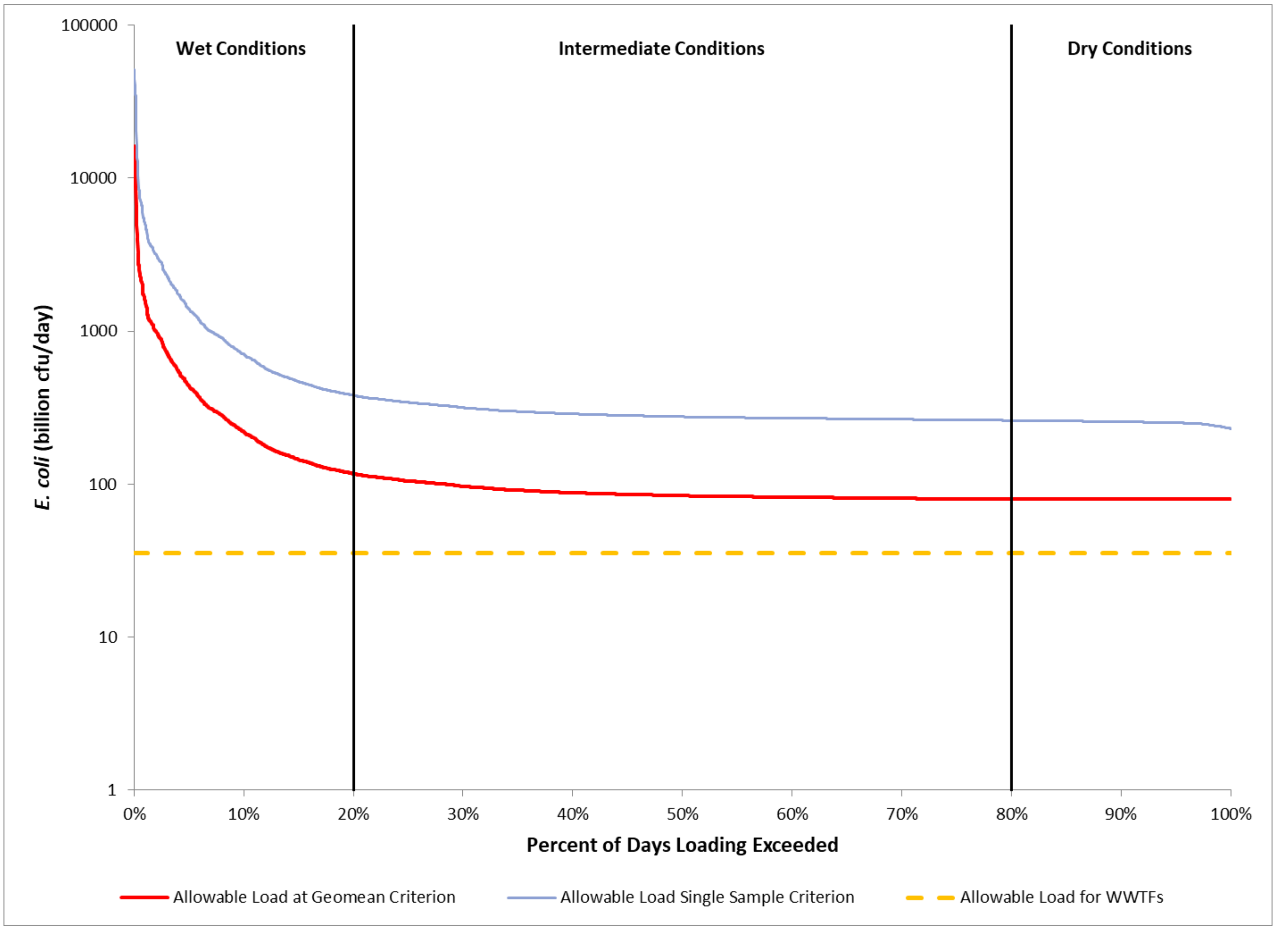

Figure 16. LDC for the outlet of Horsepen Creek (AU 1014C_01)

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocations for the Horsepen Creek 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 of the PCR1 use.

For the purposes of this TMDL study, the TMDL watershed is considered to be the entire Horsepen Creek (AU 1014C_01) watershed as shown in the overview map (Figure 2). TMDL calculations are based on the outlet of the TMDL watershed.

Additionally, a DAR approach using historical streamflow records from a nearby USGS gauge on Langham Creek was employed to estimate the daily flow at the location of the outlet.

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 Horsepen Creek 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 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 Seasonal Variation

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 Code of Federal Regulations (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 11.5 years (2007 – 2019) of routine monitoring collected in the warmer months (May – September) against those collected during the cooler months (October – April). 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 (α=.05) in indicator bacteria between cool and warm weather seasons for Horsepen Creek at station 20465 (P=.1323).

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.

LDCs were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a 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 LDCs to define the TMDL pollutant load allocation (Section 4.7).

4.4 LDC Analysis and Results

An 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 allocation. 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 Wet flow regime (or 10% flow), where exceedances to the PCR1 criteria are most pronounced.

The LDC method allows for estimation of existing and 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 16) and Section 2.7 (Source Analysis), the following broad linkage statements can be made. For the Horsepen Creek watershed, the historical *E. coli* data indicate that elevated bacteria loadings occur under all three flow regimes, especially during high flows. There is some moderation of the elevated loadings under moderate and dry conditions for the TMDL watershed. On Figure 16, the geometric means of the measured data for each flow regime generally support the observation of decreasing concentration with decreasing flow, although the geometric means do consistently exceed the geometric criterion (126 cfu/100 mL).

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 Horsepen Creek 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 the impaired water body.

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 11).

Table 11. Percent reduction calculations for Horsepen Creek (AU 1014C_01) SWQM station 20465

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cfu/100mL)	Required Percent Reduction by Flow
Wet (0-20%)	7	676	81%
Intermediate (20-80%)	26	312	60%
Dry (80-100%)	13	238	47%

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 (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 the TMDL water body was developed as a pollutant load allocation based on information from the LDC for the outlet of the TMDL watershed (Figure 14). 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 Wet conditions-flow 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 Wet regime of the FDC (or 10% flow exceedance value) for the watershed outlet (Table 12).

Table 12. Summary of allowable loadings for Horsepen Creek

Watershed	AU	10% Exceedance Flow (cfs)	Indicator Bacteria	TMDL (Billion cfu/ day)
Horsepen Creek	1014C_01	71.501	*E. coli*	220.415

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:

$$MOS = 0.05 * TMDL \qquad \text{(Eq. 3)}$$

Where:

MOS = margin of safety load

TMDL = total maximum daily load

Using the value of TMDL for the AU provided in Table 12, the MOS may be readily computed by proper substitution into Equation 3 (Table 13).

Table 13. MOS calculations for Horsepen Creek

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

Watershed	AU	TMDL[a]	MOS
Horsepen Creek	1014C_01	220.415	11.021

[a] TMDL from Table 12.

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/100 mL) 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 (MGD)
Conversion Factor (to billion cfu/day) = 37,854,000 mL/MGD

As described in Section 2.7.1.1 and shown in Table 14, there are currently 13 permitted WWTFs within the Horsepen Creek watershed. The daily allowable loading of *E. coli* assigned to WLA_{WWTF} was determined based on the combined full permitted flow of the permitted WWTFs within the TMDL watershed, using equation 5. Table 14 presents the WLA for each WWTF and the resulting total allocation for the AU within the TMDL watershed.

Table 14. WLAs for TPDES-permitted facilities in the Horsepen Creek watershed

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

TPDES Permit No.	NPDES Permit No.	Permittee	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF}
WQ0001402000	TX0042129	Wyman-Gordon Forgings Inc	0.225	0.54
WQ0011472001	TX0026263	Spencer Road PUD	0.98	2.34
WQ0011947001	TX0075884	Harris County MUD 208	6.7	15.98
WQ0012223001	TX0083496	West Harris County MUD 15	0.6	1.43
WQ0012304001	TX0085588	Chimney Hill MUD	1.2	2.86
WQ0012310001	TX0085871	R & K Weiman MHP LC	0.03	0.07
WQ0012447001	TX0088838	Harris County MUD No 196	1.4	3.34
WQ0012726001	TX0100161	Harris County MUD No 155	1.55	3.70
WQ0013328001	TX0101371	Remington MUD No. 1	1.1	2.62
WQ0014655001	TX0128287	Dril-Quip Inc	0.075	0.18
WQ0014740001	TX0129071	Harris Co MUD No. 500	0.84	2.00
WQ0014811001	TX0093581	Harris County MUD No. 250	0.1	0.24
WQ0014830001	TX0104795	Eli Gravriel Sasson	0.099	0.24
		Total	**14.899**	**35.53**

[a] Full Permitted Flow from Table 5

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 Load Allocation (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:

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

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 2.7.1.5 the Horsepen Creek watershed is covered 78.12% by MS4 permits. The results were used to compute an area of regulated stormwater contribution (Table 15).

Table 15. Basis of unregulated stormwater area and computation of FDA_{SWP} term

Watershed	AU	Total Area (acres)	Area Under MS4 (acres)	FDA_{SWP}
Horsepen Creek	1014C_01	13,377.8	10,451.0	0.7812

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 16 provides the information needed to compute WLA_{SW}.

Table 16. Regulated stormwater calculations for Horsepen Creek

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]
Horsepen Creek	1014C_01	220.415	35.531	8.495	11.021	0.7812	129.185

[a] TMDL from Table 12

[b] WLA_{WWTF} from Table 14

[c] FG from Table 17

[d] MOS from Table 13

[e] FDA_{SWP} from Table 15

[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.

The FG component of the TMDL watershed was based on population projections and current permitted wastewater dischargers for the entire TMDL watershed. Recent population and projected population growth between 2020 and 2070 for the TMDL watershed are provided in Table 1. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth per AU between 2020 and 2070 to determine the estimated future flows.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * POP_{2020\text{-}2070} * \text{conversion factor} * \text{target} \qquad \text{(Eq. 7)}$$

Where:

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

$POP_{2020\text{-}2070}$ = estimated percent increase in population between 2020 and 2070

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 17.

Table 17. FG calculation for Horsepen Creek

Water Body	AU	Full Permitted Flow (MGD)	% Population Increase (2020-2070)	FG (MGD)	FG (*E. coli* Billion cfu/Day)[a]
Horsepen Creek	1014C_01	14.899	23.91%	3.562	8.495

[a] FG = $WWTF_{FP}$ * $POP_{2020\text{-}2070}$ * conversion factor * target (Eq. 7)

4.7.5 LA

The 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 18.

Table 18. LA calculation for Horsepen Creek

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]
Horsepen Creek	1014C_01	220.415	35.531	129.185	8.495	11.021	36.183

[a] TMDL from Table 12
[b] WLA_{WWTF} from Table 14
[c] WLA_{SW} from Table 16
[d] FG from Table 17
[e] MOS from Table 13
[f] LA = TMDL – WLA_{WWTF} – WLA_{SW} – FG – MOS (Eq. 8)

4.8 Summary of TMDL Calculations

Table 19 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, Wet Conditions flow regime) for flow exceedance from the LDC developed for the outlet of the Horsepen Creek watershed. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 19. TMDL allocation summary for Horsepen Creek

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]
Horsepen Creek	1014C_01	220.415	35.531	129.185	36.183	8.495	11.021

[a] TMDL from Table 12

[b] WLA_{WWTF} from Table 14

[c] WLA_{SW} from Table 16

[d] LA from Table 18

[e] FG from Table 17

[f] MOS from Table 13

The final TMDL allocation (Table 20) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 20. Final TMDL allocation for Horsepen Creek

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

Water Body	AU	TMDL	WLA_{WWTF}[a]	WLA_{SW}	LA	MOS
Horsepen Creek	1014C_01	220.415	44.026	129.185	36.183	11.021

[a] WLA_{WWTF} includes the FG component

Section 5
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