Adopted September 15, 2010
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Four Total Maximum Daily Loads for Indicator Bacteria in Halls Bayou and Tributaries

Segments: 1006D, 1006I, and 1006J

Assessment Units: 1006D_01, 1006D_02, 1006I_01, and 1006J_01

Prepared by the
Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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This TMDL report is based in large part on the report titled "Technical Support Document: Indicator Bacteria Total Maximum Daily Loads for the Halls Bayou Watershed, Houston, Texas (1006D_01, 1006D_02, 1006I_01, 1006J_01)"

prepared by University of Houston and Parsons

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List of Acronyms

AU	assessment unit
BIG	Bacteria Implementation Group
BMP	best management practice
CAFO	concentrated animal feeding operation
C-CAP	coastal change analysis program
CFR	Code of Federal Regulations
cfu	colony-forming units
CFS	cubic feet per second
dL	deciliter
DMR	Discharge Monitoring Report
EC	*Escherichia coli*
EPA	Environmental Protection Agency (U.S.)
FC	fecal coliform
FDC	flow duration curve
FWSD	Fresh Water Supply District
GIS	Geographic Information System
HCFCD	Harris County Flood Control District
HCOEM	Harris County Office of Homeland Security and Emergency Management
H-GAC	Houston-Galveston Area Council
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
mL	milliliter
MGD	million gallons per day
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
MUD	municipal utility district
NEIWPCC	New England Interstate Water Pollution Control Commission
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
OSSF	onsite sewage facility
SSO	sanitary sewer overflow
STATSGO	State Soil Geographic Database

SWPPP	storm water pollution prevention plan
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WLA	waste load allocation
WQM	water quality monitoring
WQMP	Water Quality Management Plan
WWF	wet weather facility
WWTF	wastewater treatment facility

Four Total Maximum Daily Loads for Indicator Bacteria in the Halls Bayou Watershed

Executive Summary

This document describes total maximum daily loads (TMDLs) for the Halls Bayou watershed, where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the contact recreation use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairments in the 2002 and 2004 versions of the *Texas Water Quality Inventory and 303(d) List*.

The heavily urbanized Halls Bayou watershed encompasses approximately 44 square miles of land located in north central Harris County, Texas. There are about 74 miles of open streams within the watershed.

As described in the TCEQ's "2004 Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data" (TCEQ 2004), the TCEQ requires a minimum of 10 samples in order to assess support of the contact recreation use. *Escherichia coli* (*E. coli*) are the preferred indicator bacteria for assessing the contact recreation use in freshwater, and were used for development of the TMDL.

The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of *E. coli* bacteria, typically given as the most probable number (MPN). The contact recreation use is not supported when the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 milliliter (mL), or if individual samples exceed 394 MPN per 100 mL more than 25 percent of the time.

The historical ambient water quality data for indicator bacteria (1992-2008) for eleven selected TCEQ water quality monitoring stations in the Halls Bayou watershed were examined. All of the stations failed to meet water quality standards for *E. coli*. The geometric means of *E. coli* exceeded the standard and ranged from 575 MPN/100mL to 3,139 MPN/100mL.

The most probable sources of indicator bacteria within the entire watershed are non-compliant wastewater treatment facility (WWTF) discharges, storm water runoff from permitted storm sewer sources, sanitary sewer overflows, illicit discharges from storm sewers, failing on-site sewage facilities, and runoff from areas not covered by a permit.

A load duration curve analysis was used to quantify allowable pollutant loads and specific TMDL allocations for point and nonpoint sources of indicator bacteria. The TMDL allocations are discussed in the "TMDL Calculations" section and are presented in Table 19.

The waste load allocation (WLA) for wastewater treatment facilities was established as the permitted flow times one-half the geometric mean criterion for the indicator bacteria.

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites.

Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Consequently, increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

The TMDL calculations in this report will guide determination of the assimilative capacity of each stream under changing conditions, including future growth. New or amended permits for wastewater discharge facilities will be evaluated case by case.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a TMDL for each pollutant that contributes to the impairment of a 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. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

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

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations, Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. The EPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 1991). This TMDL document has been prepared in accordance with those regulations and guidelines. The segments and assessment units (AUs) covered by this document were included in the 2008 303(d) list under category 5a indicating that they are a priority for developing a TMDL.

The TCEQ must consider certain elements in developing a TMDL; they are described in the following sections:

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

The commission adopted this document on September 15, 2010. Upon EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan.

Problem Definition

The TCEQ first identified the impairment to the contact recreation use for Halls Bayou (1006D) and one Unnamed Tributary of Halls Bayou (1006J) in the *2002 Texas Water Quality Inventory and 303(d) List*, and another Unnamed Tributary of Halls Bayou (1006I) on the 2004 version of the list. All of these segments (Table 1) are freshwater bodies located in north central Harris County (Figure 1). In this document, the area that contains all of these segments will be referred to as the TMDL area watershed.

Table 1. TMDL Segments, AUs, and First Year on 303(d) List

Segment Number	Segment Name	Type	Assessment Units	First Year Listed
1006D	Halls Bayou	Freshwater	1006D_01, 1006D_02	2002
1006I	Unnamed Tributary of Halls Bayou	Freshwater	1006I_01	2004
1006J	Unnamed Tributary of Halls Bayou	Freshwater	1006J_01,	2002

The standards for water quality are defined in the *Texas Surface Water Quality Standards* (TCEQ 2000). The specific uses assigned to the five segments included in this report are contact recreation, aquatic life, general, and fish consumption.

The historical ambient water quality data for indicator bacteria (1992-2008) for eleven selected TCEQ water quality monitoring stations in the Halls Bayou watershed were examined for development of these TMDLs. Data collected prior to 2001 correspond to fecal coliform concentrations, while data for 2001–2008 are primarily *E. coli* concentrations.

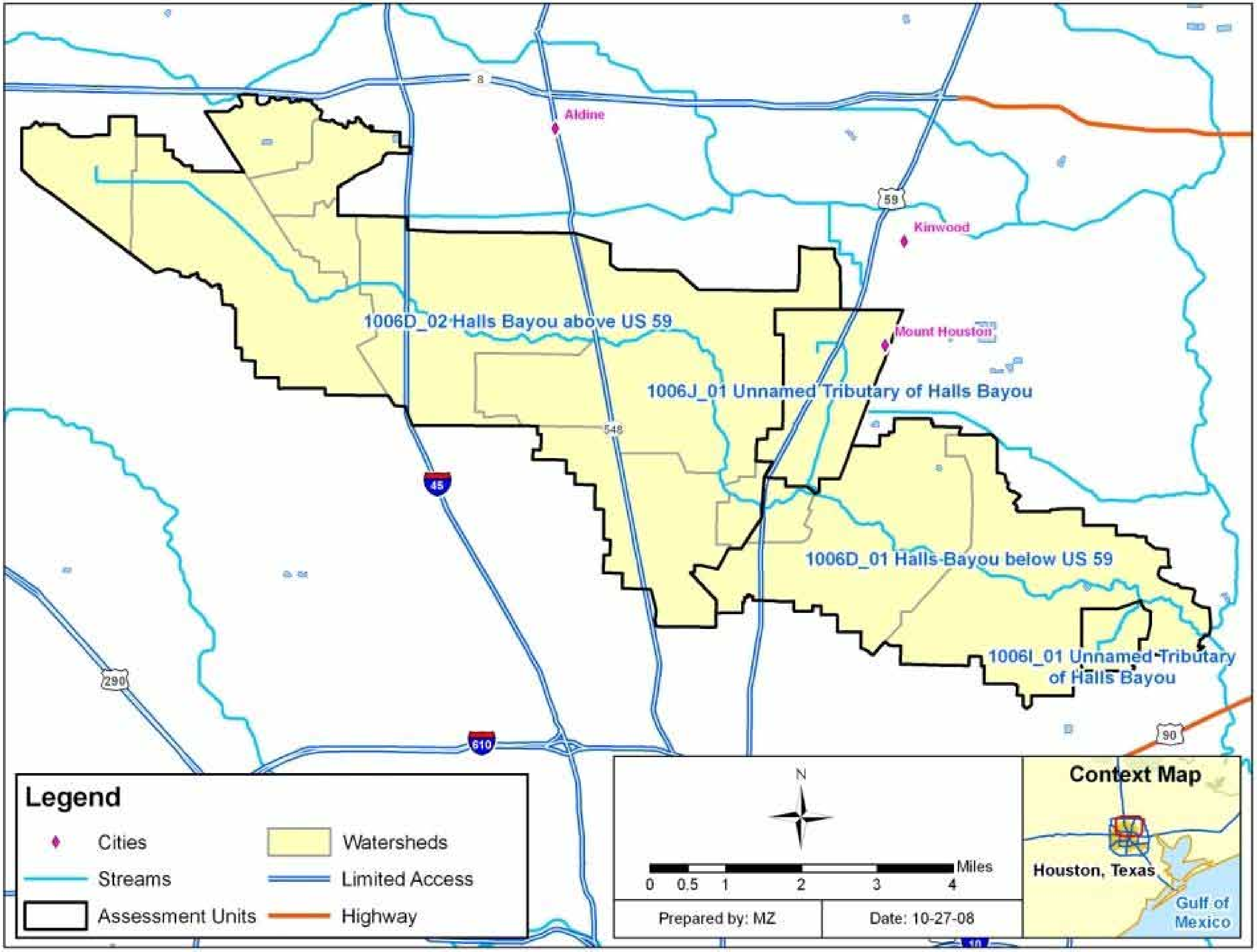

Figure 1. Halls Bayou Watershed

As described in the TCEQ's "2004 Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data" (TCEQ 2004), the TCEQ requires a minimum of 10 samples in order to assess support of the contact recreation use. *E. coli* for freshwater and Enterococci in tidal water are now the preferred indicator bacteria for assessing the contact recreation use. Fecal coliform bacteria may be used when there is insufficient *E. coli* or Enterococci data, since fecal coliform was the preferred indicator prior to 2000.

For this project, *E. coli* data were used for data analysis and modeling to support TMDL development for the Halls Bayou watershed. Fecal coliform data are also presented for some sampling stations.

The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of *E. coli* bacteria, typically given as the most probable number (MPN). When fecal coliform is used, the criteria are expressed as the number of colony-forming units (cfu). These units (MPN and cfu) are considered equivalent.

For the *E. coli* indicator, if the minimum sample requirement is met, the contact recreation use is not supported when:

- the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 mL;
- and/or individual samples exceed 394 MPN per 100 mL more than 25 percent of the time.

For the fecal coliform indicator, if the minimum sample requirement is met, the contact recreation use is not supported when:

- the geometric mean of all fecal coliform samples exceeds 200 cfu per 100 mL;
- and/or individual samples exceed 400 cfu per 100 mL more than 25 percent of the time.

Ambient Indicator Bacteria Concentrations

Table 2 summarizes the historical ambient water quality data for indicator bacteria (1992-2008) for select TCEQ water quality monitoring stations in the Halls Bayou watershed. Data in Table 2 collected prior to 2001 correspond to fecal coliform concentrations, while data for 2001-2008 are primarily *E. coli* concentrations.

Watershed Overview

The Halls Bayou watershed, a heavily urbanized watershed, encompasses approximately 44 square miles of land within the City of Houston and incorporated areas of Harris County. There are about 74 miles of open streams within the watershed (Harris County Flood Control District [HCFCD] 2008). Halls Bayou is a tributary of Greens Bayou.

Most of the Halls Bayou watershed is highly developed. Table 3 summarizes the acreages and the corresponding percentages of the land use categories for the contributing watershed associated with each respective AU in the watershed. The land use/land cover data were derived from the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center. The specific land use/land cover data files were derived from the Coastal

Change Analysis Program (C-CAP), Texas 2005 Land Cover Data (NOAA 2007). The land use categories are displayed in Figure 2. The total acreage of each segment in Table 3 corresponds to the watershed delineation in Figure 2. The predominant land use category in this watershed is developed land (between 73% and 89%) followed by woody land (between 9% and 20%). Open water and bare/transitional land account for less than 2 percent of the subwatersheds.

Table 2. Historical Water Quality Data – November 1992 to March 2008

Assessment Unit	Station ID	Indicator Bacteria1	Geometric Mean Criteria	Geometric Mean Concen-tration	Single Sample Criteria	Number of Samples	Number of Samples Exceeding Single Sample Criteria	% of Samples Exceeding
1006D_01	11127	EC	126	1,356	394	62	45	73%
		FC	200	707	400	82	51	62%
	15862	EC	126	1,258	394	62	43	69%
		FC	200	765	400	40	25	63%
	15863	EC	126	1,265	394	63	49	78%
		FC	200	2,140	400	50	45	90%
	15864	EC	126	903	394	95	65	68%
		FC	200	1,415	400	40	33	83%
	20023	EC	126	916	394	17	10	59%
1006D_02	11126	EC	126	1,519	394	63	51	81%
		FC	200	1,413	400	221	173	78%
	17490	EC	126	3,139	394	59	53	90%
	17491	EC	126	575	394	59	37	63%
1006I_01	16666	EC	126	1,168	394	80	64	80%
		FC	200	2,041	400	80	61	76%
	16667	EC	126	661	394	62	36	58%
		FC	200	829	400	79	52	66%
1006J_01	16665	EC	126	1,818	394	82	72	88%
		FC	200	1,653	400	79	68	86%

[1] EC – *E. coli*, in MPN/100mL; FC – fecal coliform, in cfu/100mL

Table 3. Land Use Summaries

Aggregated Land Use Category	Assessment Unit			
	1006D_01	1006D_02	1006I_01	1006J_01
Percent Developed Land	72.9	80.4	77.5	88.5
Percent Cultivated Land	0	0	0	0
Percent Pasture/Hay	0.2	1.6	0	0
Percent Grassland/Herbaceous Land	0.8	2.9	0.1	0.3
Percent Woody Land	20.2	12.1	12.4	8.6
Percent Open Water	0.0	0.1	0.0	0.0
Percent Wetland	5.8	2.6	10.0	2.5
Percent Bare/Transitional Land	0.1	0.3	0	0.1
Acres of Developed Land	5,959	14,548	348	1,630
Acres Cultivated Land	0	0	0	0
Acres Pasture/Hay	13	284	0	0
Acres Grassland/Herbaceous Land	68	535	0	5
Acres of Woody Land	1,656	2,189	56	157
Acres of Open Water	2	13	0	2
Acres of Wetland	476	465	48	45
Acres of Bare/Transitional Land	9	56	0	0
Watershed Area (acres)	8,182	18,090	452	1,839

The climate of the region is subtropical humid, with hot and humid summers and mild winters (U.S. Army Corps of Engineers [USACE] 1985). The average maximum daytime temperature in the summer is 93 degrees Fahrenheit (°F), while the temperature averages between 39 and 61 °F during the winter. Summer rainfall is dominated by subtropical convection, winter rainfall by frontal storms, and fall and spring by combinations of these two (Burian and Shepherd 2005). The 100-year floodplain encompasses about 20 percent of the drainage area of the entire watershed, approximately 9 square miles (HCFCD 2008).

There are three rain gauges located within the watershed (Figure 3). The gauges are maintained by the Harris County Office of Homeland Security and Emergency Management (HCOEM). The Halls Bayou watershed experiences frequent rainfall events, with annual precipitation totals of approximately 49 inches. Monthly rainfall totals are consistent throughout the year. High intensity rainfall often causes localized street flooding and occasional out-of-bank conditions. The watershed is located near the Gulf coast, and is subject to extreme weather between June 1 and November 30 every year, although the chance of tropical weather declines dramatically in October. As a result, an extensive storm

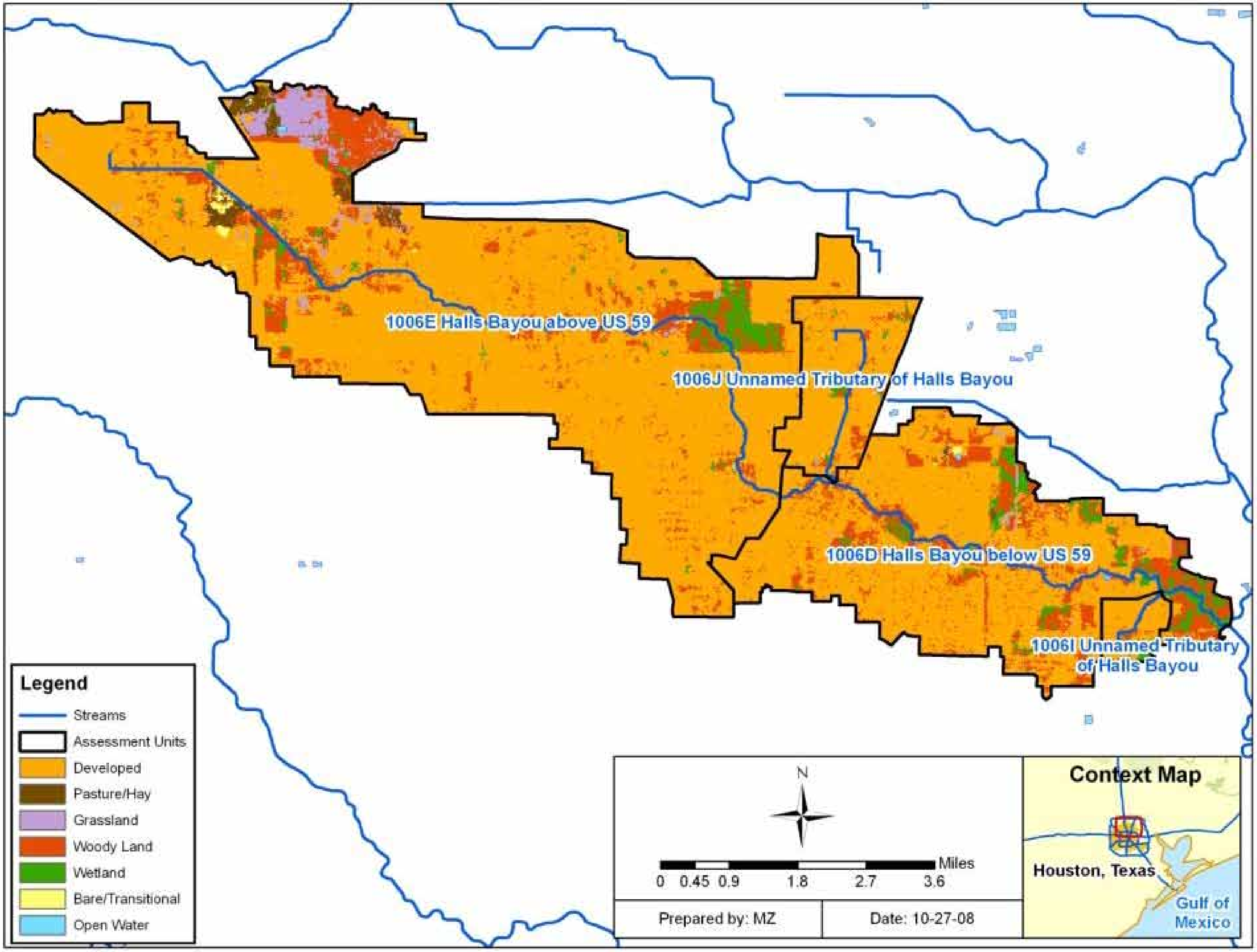

Figure 2. Halls Bayou Watershed Land Use

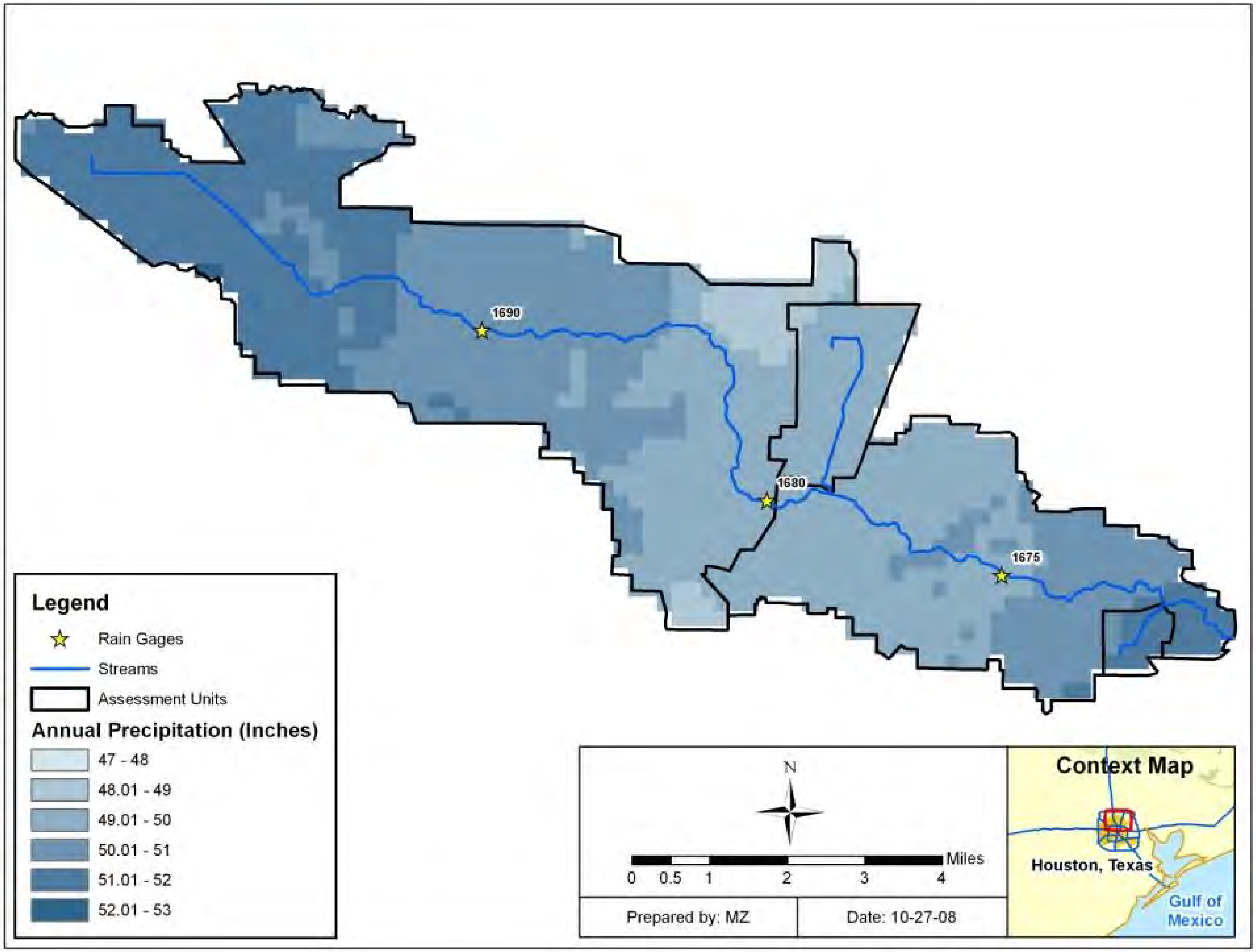

Figure 3. Halls Bayou Watershed Precipitation Map

water conveyance system has been developed throughout the area. Figure 3 shows average annual rainfall across the Halls Bayou watershed. This figure was developed by using data from 148 HCOEM rain gauges located across Harris, Fort Bend, and Galveston Counties to estimate rainfall values at unobserved locations throughout the remainder of the watershed. Average values by subwatershed are summarized in Table 4. These average values were used to support the development of flow duration curves. Average values by subwatershed are summarized in Table 4. These average values were used to support the development of flow duration curves.

Table 4. Average Rainfall for Each AU Watershed

Assessment Unit	Annual Average (Inches)
1006D_01	55.1
1006D_02	45.7
1006I_01	55.1
1006J_01	45.7

The State Soil Geographic Database (STATSGO) (National Resources Conservation Service [NRCS] 1994) information was used to characterize soil in the Halls Bayou watershed. The soil types that dominate the watershed are primarily from the Clodine soil series, with a small portion composed of Aldine soil (Figure 4). The distribution and attributes of the two soil series found in the Halls Bayou watershed are listed in Table 5. All soil types in the watershed are somewhat poorly drained, thus contributing to high runoff rates. The land surface slopes at a slight percent change of only about 0.3 percent (USACE 1985). The highest elevations within the watershed are 111 feet above mean sea level.

Stream flow data are key information when conducting water quality assessments. The U.S. Geological Survey (USGS) operates a flow gauge at one location along Halls Bayou to measure flow and gauge heights. The period of record and type of data collected at these gauges are listed in Table 6. The location of this gauge station and project water quality monitoring (WQM) stations are shown on Figure 5. This gauge is currently active in the watershed. The historical flow data available from this gauge and flow data collected during intensive surveys in 2006 are summarized as flow exceedance percentiles in constructing flow duration curves.

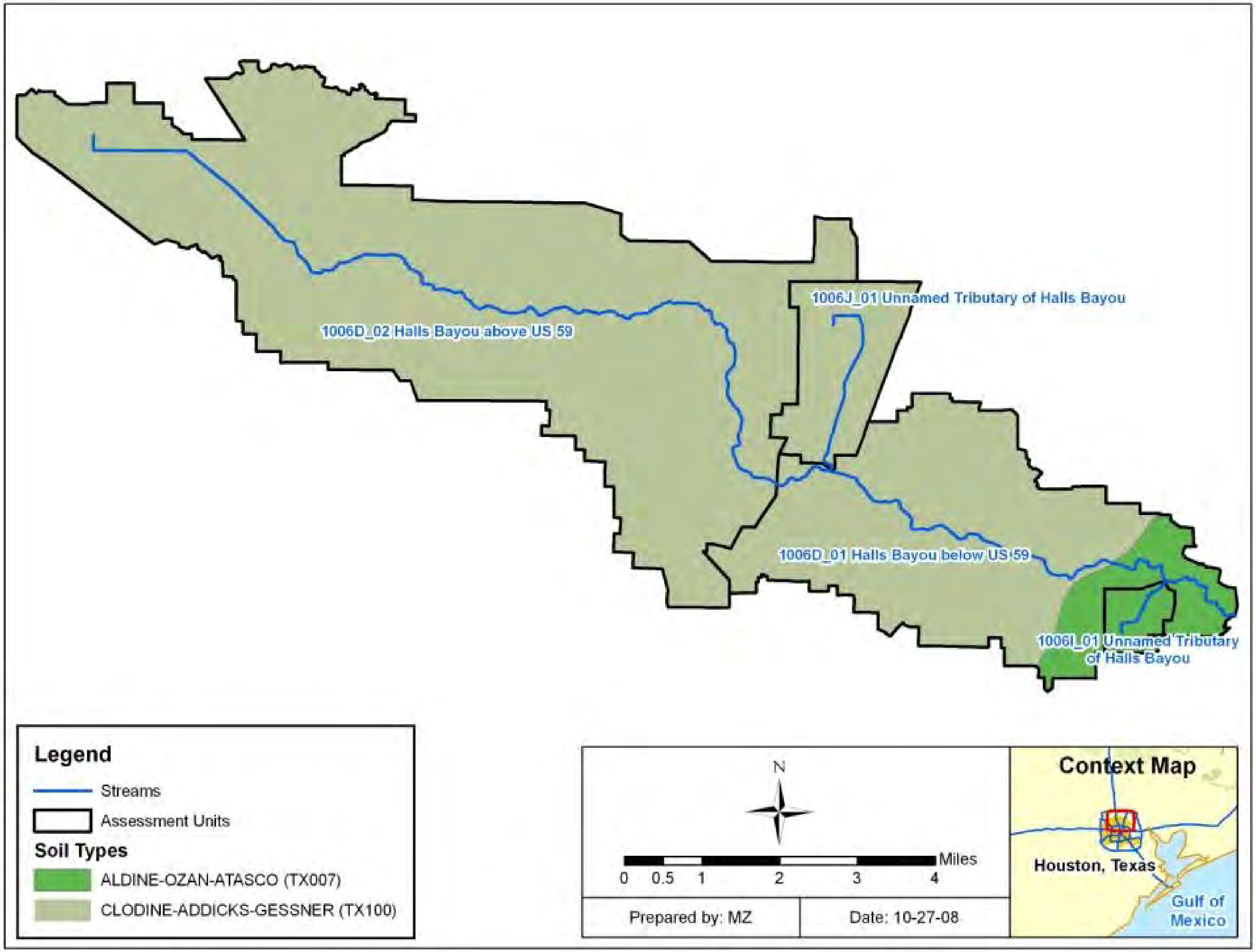

Figure 4. Halls Bayou Watershed Soil Types

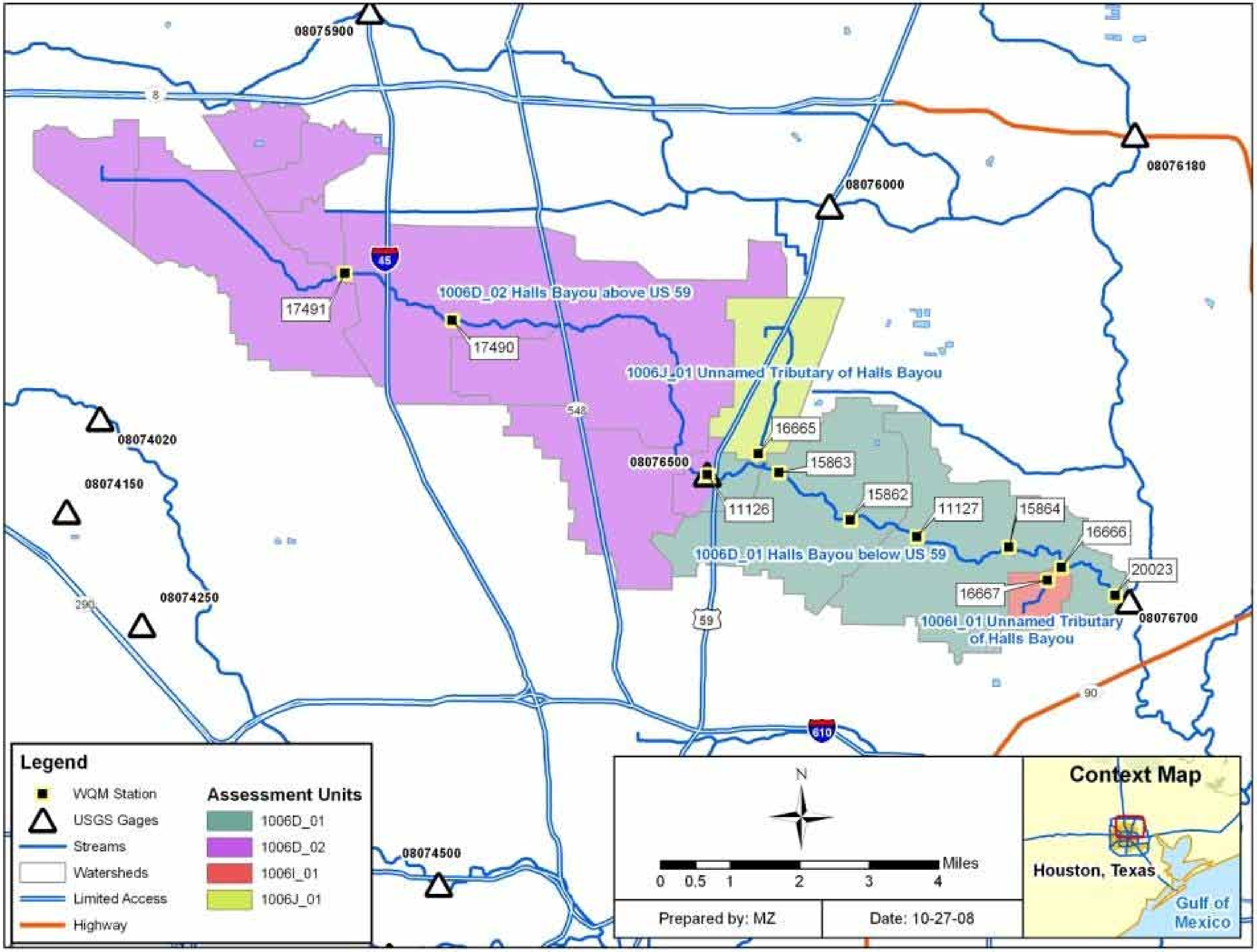

Figure 5. Halls Bayou Watershed Sampling Locations and USGS Gauge Locations

Table 5. Characteristics of Soil Types within Halls Bayou Watershed

NRCS Soil Type	Soil Series Name	Percent of Watershed Area	Surface Texture	Hydrologic Group	Soil Drainage Class	Min Water Capacity (in/in)	Max Water Capacity (in/in)	Min Bulk Density (g/cm3)
TX100	Clodine	93.6%	Loam	D	Poorly Drained	0.15	0.15	1.4
TX007	Aldine	6.4%	Fine Sandy Loam	D	Somewhat Poorly Drained	0.13	0.18	1.45

Source: All data obtained/calculated from STATSGO database

Table 6. USGS Gauges in the Halls Bayou Watershed

USGS Gauge Number	Name	Period of Record	Data Type
8076500	Halls Bayou at Houston, TX	11/1952 – 09/1993 and 10/2000 - Present	Discharge (cfs)
		10/1996 - Present	Gauge Height (ft)

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 serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs for freshwater segments is to maintain the geometric mean of concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This is the endpoint in Halls Bayou (1006D) and two Unnamed Tributaries of Halls Bayou (1006I and 1006J).

Source Analysis

Pollutants may come from several sources, both point and nonpoint. Pollutants referred to as “point sources” come from sources that are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollutant Discharge Elimination System (NPDES). WWTFs, and storm water discharges from industries, construction, and the separate storm sewer systems of cities, are considered point sources of pollution. Nonpoint source pollution originates from multiple locations, usually carried to surface waters by rainfall runoff. It is not regulated by permit under the TPDES or NPDES.

Regulated Sources

Halls Bayou (1006D_01 and 1006D_02), and one Unnamed Tributary of Halls Bayou (1006J_01) have NPDES/TPDES-permitted sources. A significant portion of the TMDL area watershed (approximately 99%) is regulated under the TPDES permit for storm water discharge jointly held by Harris County, HCFCD, City of Houston, and Texas Department of Transportation (TPDES Permit No. WQ0004685000). There are no NPDES-permitted concentrated animal feeding operations (CAFOs) within the general Halls Bayou watershed.

Wastewater Treatment Facilities

The locations of the TPDES-permitted facilities that continuously discharge wastewater to surface waters addressed in these TMDLs are listed in Table 7 and displayed in Figure 6. As of April 1, 2009, there were 49 permitted outfalls for WWTFs in the TMDL area watershed and Table 7 lists both the NPDES number as well as the TPDES permit number.

At the time of the development of the TMDL allocations, not all TPDES-permitted facilities that discharge treated wastewater were required to monitor for fecal bacteria. While current instream water quality criteria are based on *E. coli* bacteria, permit limits were based on levels of fecal coliform, another measure of fecal bacteria of which *E. coli* are often the major constituent. Therefore, data on bacteria loads from WWTF outfalls are not available for all of the TPDES permitted dischargers in the general Halls Bayou Watershed. As of January 1, 2010, a new TCEQ rule requiring *E. coli* monitoring and limits has been established for new and amended WWTF permits statewide. Table 8 lists the three TPDES WWTFs (as of April 2009) that monitor their discharges for fecal coliform. Discharge Monitoring Reports (DMRs) were used to determine the number of fecal coliform analyses that were performed for the three TPDES WWTFs. The 90th percentile of the monthly average load and the maximum monthly average loads are provided to estimate fecal coliform loads. The number of reported monthly exceedances of the geometric mean concentration of 200 cfu/100mL, and the number of reported daily exceedances of the single sample standard of 400 cfu/100mL are shown in Table 8. One of the permitted facilities exceeded fecal coliform permit limits during the monitoring time frame.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are permit violations that must be addressed by the responsible TPDES permittee. SSOs most often result from blockages in the sewer collection pipes caused by tree roots, grease and other debris, and occur under conditions of high flow in the WWTF system. In 2007, the City of Houston provided the project team a database of SSO data. These data are summarized in Table 9. There were approximately 188 sanitary sewer overflows reported in the general Halls Bayou watershed between February 2001 and December 2003. The reported SSOs averaged 3,066 gallons per event. The locations and magnitudes of the all reported SSOs are displayed in Figure 7 along with the service area boundaries.

Table 7. WWTF Dischargers in the TMDL Area Watershed

Segment	Stream Name	AU	TPDES Number	Outfall	NPDES NUMBER	Facility Name[1]	D Type	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)
1006D	Halls Bayou below US 59	1006D_01	12996-001	001	TX0096679	Redwood WWTF	D	0.1	0.041
		1006D_01	10495-016	003	TX0063053	FWSD 23 WWTF	W	7*	3.780
1006D	Halls Bayou below US 59	1006D_02	01536-000	001	TX0007650	Ashbrook Houston Plant	W	0.004	0.002
		1006D_02	10236-001	001	TX0021253	Oakwilde WWTF	D	0.45	0.310
		1006D_02	10419-001	001	TX0070611	Durkee Manor Plant	D	0.25	0.124
		1006D_02	10436-001	001	TX0032093	Western Homes Subdivision	D	0.15	0.086
		1006D_02	10495-151	001	TX0075663	Willow Run WWTF	D	0.75	0.342
		1006D_02	10518-001	001	TX0021261	Sunbelt FWSD WWTF	D	0.45	0.258
		1006D_02	10610-001	001	TX0030988	Hidden Valley WWTF	D	0.475	0.345
		1006D_02	10679-001	001	TX0023825	Harris County WCID 74 WWTF	D	0.95	0.609
		1006D_02	10812-001	001	TX0021270	High Meadows WWTF	D	0.99	0.655
		1006D_02	10825-001	001	TX0032255	Aldine Community Care Center	D	0.023	0.007
		1006D_02	11154-001	001	TX0023515	Mount Houston Road MUD WWTF	D	0.95	0.135
		1006D_02	11231-001	001	TX0021245	Heather Glen WWTF	D	0.5	0.291
		1006D_02	11255-001	001	TX0032034	Greenwood Village WWTF	D	0.393	0.186
		1006D_02	11473-001	001	TX0066478	Blue Bell Manor Utility Com.	D	0.6	0.365
		1006D_02	11673-001	001	TX0063860	Woodloch MHP WWTF	D	0.03	0.009
		1006D_02	11807-001	001	TX0071820	Forest Hills MUD WWTF	D	0.8	0.117
		1006D_02	11821-001	001	TX0072184	The Heavens Mobile Home Park	D	0.05	0.001
		1006D_02	12070-004	001	TX0100323	Aldine ISD Orange Grove WWTF	D	0.015	0.007
		1006D_02	12083-001	001	TX0078883	Hooks MHP WWTF	D	0.06	0.027

Segment	Stream Name	AU	TPDES Number	Outfall	NPDES NUMBER	Facility Name[1]	D Type	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)
1006D (cont.)	Halls Bayou below US 59 (cont.)	1006D_02	12259-001	001	TX0084531	Bayou Forest Village WWTF	D	0.03	0.005
		1006D_02	12261-001	001	TX0084671	Melrose MHP WWTF	D	0.04	0.009
		1006D_02	12261-002	001	TX0119610	Pin Oak MHP WWTF	D	0.03	0.012
		1006D_02	12399-001	001	TX0087785	Sundown MHP WWTF	D	0.05	0.015
		1006D_02	12414-001	001	TX0088102	Woodgate Mobile Home Village	D	0.035	0.016
		1006D_02	12555-001	001	TX0090492	Westfield Mobile Home Park	D	0.1	0.065
		1006D_02	12882-001	001	TX0094986	Rosewood MHP WWTF	D	0.03	0.012
		1006D_02	12917-001	001	TX0095516	Lone Willow MHP West WWTF	D	0.006	0.003
		1006D_02	12918-001	001	TX0095508	Lone Willow MHP	D	0.006	0.002
		1006D_02	13084-001	001	TX0097527	Hartwick Green MHP WWTF	D	0.025	0.011
		1006D_02	14921-001	001	TX0107158	JWR-HO LP	D	0.032	0.008
		1006D_02	14932-001	001	TX0131849	Stripes LLC	D	0.005	NA
		1006D_02	13609-001	001	TX0115797	Aldine ISD Anne Louise Educ.	D	0.042	0.016
		1006D_02	13709-001	001	TX0103071	La Casita Homes II	D	0.01	0.004
		1006D_02	13749-001	001	TX0122521	Balaban Apartments WWTF	D	0.025	0.009
		1006D_02	13767-001	001	TX0095656	Fatima Family Village	D	0.012	0.008
		1006D_02	13770-001	001	TX0090735	Sunset Mobile Home Park	D	0.06	NA
		1006D_02	14156-001	001	TX0122190	West Mount Houston WWTF	D	0.003	0.001
		1006D_02	14217-001	001	TX0123579	Carby Road MHP	D	0.02	0.010
		1006D_02	14277-001	001	TX0124265	Aldine Oaks Mobile Home Com.	D	0.015	0.003
		1006D_02	14620-001	001	TX0127949	Barhram Solhjou WWTF	D	0.07	NA
1006D	Halls Bayou below US 59 (cont.)	1006D_02	10919-001	001	TX0021237	Fallbrook UD WWTF	W	1.3	1.001

Segment	Stream Name	AU	TPDES Number	Outfall	NPDES NUMBER	Facility Name[1]	D Type	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)
(cont.)		1006D_02	12919-001	001	TX0099171	T J Thomas WWTF	D	0.018	0.007
		1006D_02	13211-001	001	TX0099104	Harris County MUD 321 WWTF	D	0.8	NA
1006J	Unnamed Tributary of Halls Bayou	1006J_01	12772-001	001	TX0093572	5510 Acorn LLC	D	0.03	0.013
		1006J_01	14001-001	001	TX0117692	McDonalds WWTF	D	0.004	0.001
		1006J_01	14144-001	001	TX0120189	Mount Houston WWTF	D	0.099	0.009

[1] FWSD – fresh water supply district; MUD – municipal utility district; WWTF – wastewater treatment facility

Source: TCE Water Quality Assessment Team. Personal Communication from Charles Marshall to Randy Palachek, May 28, 2008 (TCEQ 2008).

MGD – millions of gallons per day

NA – data not available

* Outfall 3 is the combined flow from outfalls 001 and 002 for 10495-016, and cannot exceed 7 MGD

Type:

C – cooling water; D – domestic; <1 MGD W = domestic > – 1 MGD or industrial process water, including water treatment plant discharge

Table 8. Discharge Monitoring Report Data for Permitted Wastewater Discharges (June 1998 - June 2004)

TPDES Number	Facility Name	Segment	Dates Monitored		# of Records	Number of MCMX Exceedances	Number of MCAV Exceedances	FC Daily Load (cfu)	
			Start	End				90 Percentile Monthly Average	Maximum Monthly Average
10495-016	City of Houston FWSD No. 23	1006D_01	6/30/2001	6/30/2004	8	8	8	64	106
10495-151	City of Houston	1006D_02	6/30/1998		1	0	0	NA	11.4
12555-001	Westfield MHP Inc.	1006D_02	9/30/1998	3/31/2002	2	0	0	0.029	1.51

Notes: FC = Fecal Coliform, cfu = Colony Forming Unit, MCMX = Measurement: Concentration Maximum, MCAV = Measurement: Concentration Average

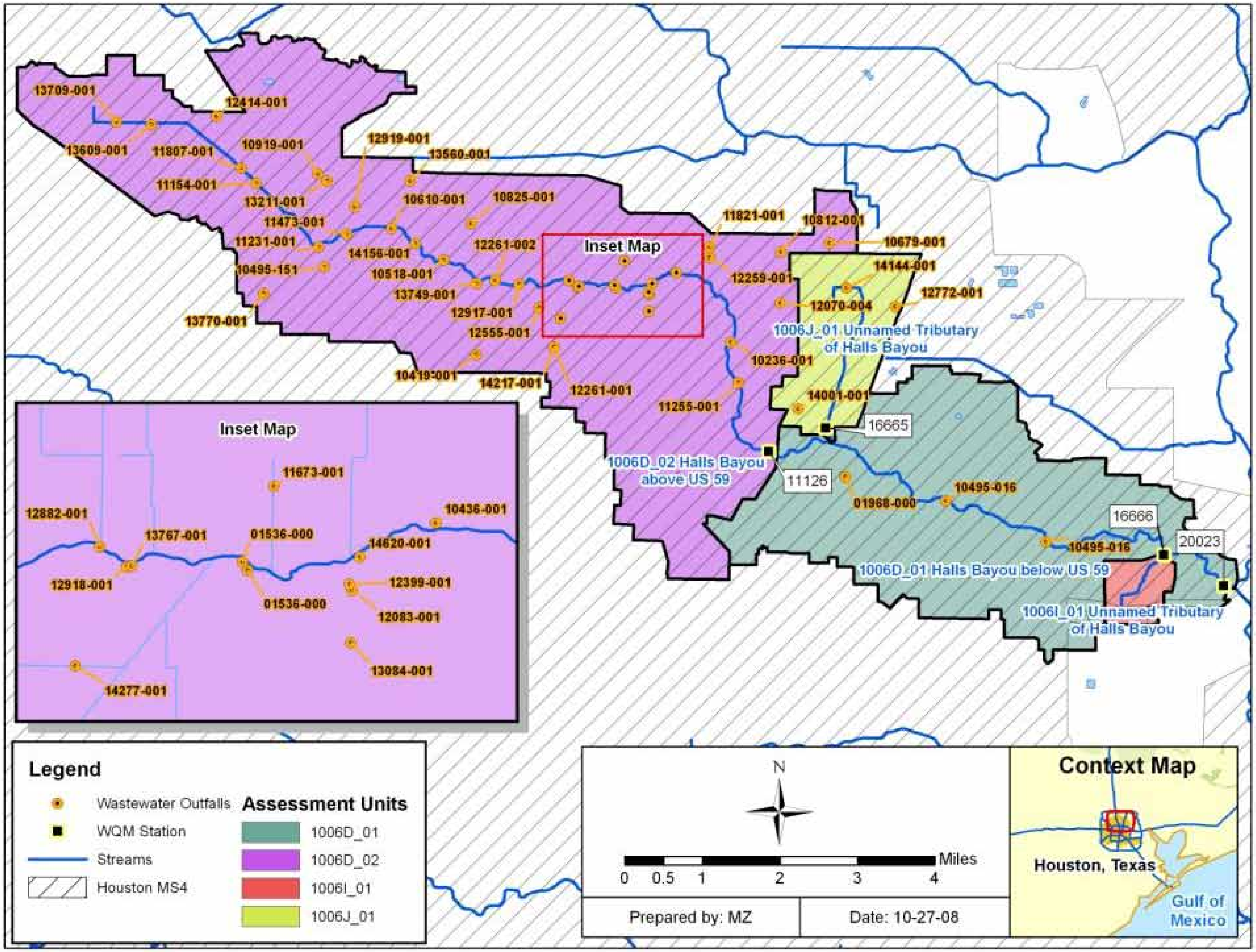

Figure 6. TPDES-Permitted Facilities in the TMDL Area Watershed

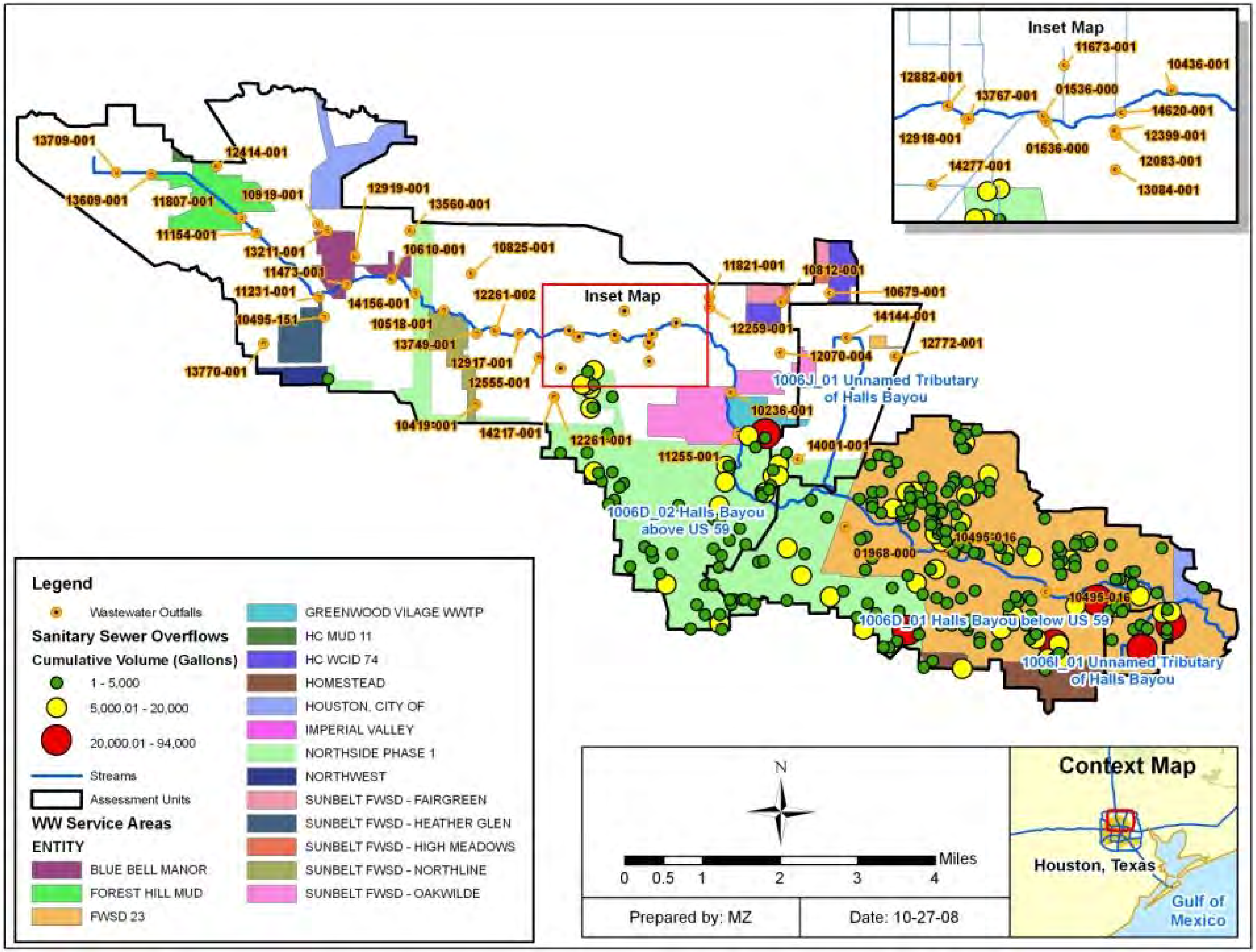

Figure 7. Sanitary Sewer Overflows in the TMDL Area Watershed

Table 9. Sanitary Sewer Overflow Summary for the TMDL Area Watershed

Facility ID	Receiving Water	Number of Occurrences	Date Range		Amount (Gallons)	
			From	To	Min	Max
10495-016	1006D_01	111	02/28/2001	12/04/2003	19	93,420
10495-016	1006I_01	10	04/13/2001	09/18/2003	48	30,792
10495-023	1006D_01	4	07/09/2001	09/26/2002	1	460
10495-090	1006D_01	16	06/12/2001	11/10/2003	44	6,484
10495-090	1006D_02	44	02/22/2001	10/29/2003	45	17,392
10495-090	1006J_01	1	09/24/2002	09/24/2002	280	280
10495-148	1006D_01	2	07/27/2002	08/28/2003	103	145

TPDES Regulated Storm Water

When evaluating WLAs and load allocations (LAs), a distinction must be made between storm water originating from an area under a TPDES regulated discharge permit and storm water originating from areas not under a TPDES regulated discharge permit. Storm water discharges fall into two categories:

1) storm water subject to regulation, which is any storm water originating from a TPDES Phase 1 or Phase 2 permitted-discharge urbanized area; and
2) storm water currently not subject to regulation.

Considerable portions of each subwatershed in the study area are covered under the City of Houston/Harris County discharge permit (TPDES Permit No. WQ0004685000). The jurisdictional boundary of the Houston municipal separate storm sewer system (MS4) permit is derived from Urbanized Area Map Results for Texas, which is based on the 2000 U.S. Census, and can be found at the EPA Web site <http://cfpub.epa.gov/npdes/stormwater/urbanmapresult.cfm?state=TX>.

Under the City of Houston/Harris County permit for storm water discharge, Harris County, Harris County Flood Control District, City of Houston, and Texas Department of Transportation are designated as co-permittees. Figure 6 displays the portion of the watershed that contributes indicator bacteria loads to the receiving waters from permitted and unregulated storm water. Table 10 lists the percentage of each watershed covered under the Houston MS4 permit. The TMDLs calculated for this project were based on the median flow of the highest range for flow exceedance (see the section “Load Duration Curve Analysis”), which coincides with storm water-influenced high-flow events.

Table 10. Percent of MS4 Jurisdiction in the TMDL Area Watershed

Segment	Stream Name	TPDES Number	Total Area (Acres)	Area under MS4 Permit (Acres)	Percent of AU under MS4 Jurisdiction
1006D_01	Halls Bayou (below U.S. 59)	WQ0004685000	8,182	8,007	98%
1006D_02	Halls Bayou (above U.S. 59)	WQ0004685000	18,090	18,090	100%
1006I_01	Unnamed Tributary of Halls Bayou	WQ0004685000	452	376	83%
1006J_01	Unnamed Tributary of Halls Bayou	WQ0004685000	1,839	1,839	100%

Illicit Discharges

Bacteria loads from storm water can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in EPA's Phase II storm water regulations as "any discharge to a municipal separate storm sewer that is not composed entirely of storm water, except discharges pursuant to an NPDES permit and discharges resulting from fire-fighting activities" (NEIWPCC 2003). Dry weather discharges may include allowable discharges such as runoff from lawn watering in addition to illicit discharges. 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.

Various investigations have been conducted in localized areas of Houston. Data from neighboring watersheds (Buffalo and Whiteoak Bayous) demonstrate that illicit discharges are a source of significant indicator bacteria load. While the dry weather flows from the storm sewer network in Buffalo and Whiteoak Bayous were small relative to the other dry weather flows, the *E. coli* concentrations measured during these events were at times high (similar to the levels found in raw sewage). An outfall inventory survey has not been completed for Halls Bayou, and dry weather discharges from the storm sewer network have not been sampled. Therefore, there is insufficient data to adequately quantify the magnitude of indicator bacteria loads from illicit discharges in the Halls Bayou watershed.

Wet Weather Facilities

Wet weather facilities (WWFs) are surge tank facilities in the sanitary sewer system that act to moderate wastewater flow peaks similar to a storm water detention basin. If the surge tank capacity is not exceeded, the tankage is returned to the sewer after the flow subsides. If the capacity is exceeded, the excess is discharged after settling and disinfection.

The City of Houston-Bretshire Plant is the only permitted WWF discharging to Halls Bayou. Permit requirements for the WWFs establish that discharges be monitored and that the receiving water body be monitored both upstream and downstream of the discharge. Relevant monitoring data for the Bretshire WWF, provided by the City of Houston, are presented in Table 11; the geomean is expressed in counts per deciliter (counts/dL). Flows are measured in cubic feet per second (cfs).

The ranges of measured fecal coliform data at the three monitoring locations (discharge, upstream, and downstream) are shown in Figure 8. It can be seen that the fecal coliform levels in the Bretshire WWF are usually very high and the overall geometric mean is about five times those for the stream sampling. However, because the WWF discharge is much lower than the flows measured at the bayou (average flow of 5 cfs compared to approximately 1900 cfs in the bayou), the expected load of fecal coliform from the WWF is not expected to have a substantial impact on the water quality of the bayou. This is confirmed by data in Figure 8, in which the downstream concentrations are within the same order of magnitude as the upstream concentrations. The bacteria allocation for the this WWF is included in the allocation for Outfall 003 for permit 10495-016, which combines Outfall 001 (FWSD 23 WWTF) and Outfall 002 (the Bretshire WWF).

Table 11. Bretshire WWF Monitoring Data

	Flow (cfs)			Fecal Coliform (cfu/100mL)		
Date	Discharge	Upstream	Downstream	Discharge	Upstream	Downstream
9/11/1998	11.84	4,350	4,410	24,000	32,000	38,000
10/18/1998	7.26	1,390	1,390	470,000	44,000	49,000
11/12/1998	3.09	1,850	1,850	990,000	36,000	20,000
11/14/1998	6.54	1,650	1,650	250,000	28,000	25,000
12/11/1998	9.19	1,900	1,970	200	49,000	39,000
5/12/1999	7.26	2,060	2,020	2,300,000	39,000	34,000
7/9/2003	0.64	135	140	930,000	51,000	44,000
11/17/2003	0.02	3,100	3,200	1,900,000	49,000	41,000
5/1/2004	3.05	1,600	1,600	760	55,000	41,000
6/24/2004	4.24	1,880	1,800	690,000	49,000	31,000
6/25/2004	1.4	950	1,005	8,000,000	41,000	38,000
Geomean (count/dL)				186,545	42,165	35,345
Average (cfs)	5	1,896.80	1,912.30			

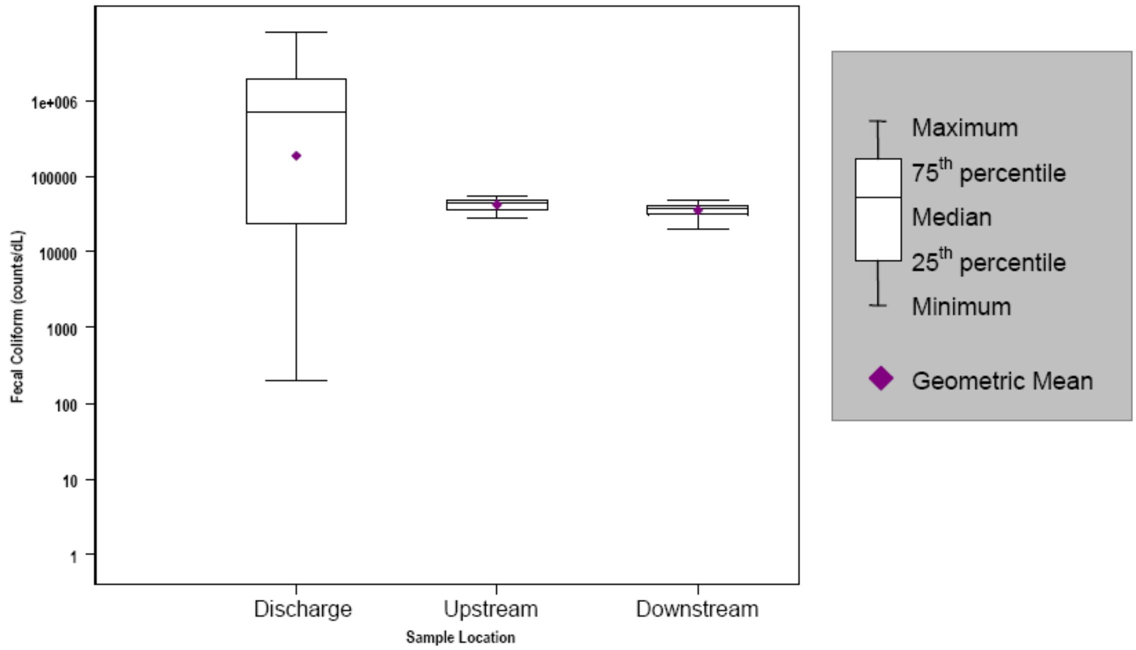

Figure 8. Fecal Coliform Monitoring Data from Bretshire WWF

Unregulated Sources

Nonpoint source (NPS) loading enters the impaired segments through distributed, unspecific locations and is not regulated. Nonpoint sources of indicator bacteria can emanate from wildlife, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities (OSSFs), and domestic pets.

Wildlife and Unmanaged Animal Contributions

Fecal coliform and *E. coli* bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife. Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. Typical of coastal watersheds, there is a significant population of avian species that frequent the watershed, in the riparian corridors in particular. However, for Halls Bayou currently there are insufficient data available to estimate populations and spatial distribution of wildlife and avian species by watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

Unregulated Agricultural Activities and Domesticated Animals

A number of unregulated agricultural activities can also be sources of fecal bacteria loading. Given the fact that the Halls Bayou watershed is highly urbanized, livestock and other domesticated animals are either not found in these watersheds or exist in small numbers. Therefore, livestock and other domesticated animals are not considered as a significant contributor of bacteria loads.

Failing On-site Sewage Facilities

OSSFs can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSSFs can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater can be discharged to creeks through springs and seeps.

Over time, most OSSFs operating at full capacity will fail (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSSFs experience malfunctions during the year (U.S. Census Bureau 1995). A statewide study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSSFs in Harris County were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSSFs per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1985).

Only permitted OSSF systems are recorded by authorized county or city agents; therefore, it is difficult to estimate the exact number of OSSFs in use in the study area. The estimate of OSSFs was derived by using data from the latest available census data—the 1990 U.S. Census (U.S. Census Bureau 2000)—and a geographic information system (GIS) shape file obtained from the Houston-Galveston Area Council (H-GAC) showing all areas where wastewater service currently exists. Figure 9 displays unsewered areas that did not fall under the wastewater service areas. OSSFs were calculated using spatial GIS queries for areas not covered by wastewater service areas. OSSFs were assigned proportionally based on the percentage of the area falling outside a wastewater service area within each watershed. Finally, the OSSFs for each unsewered area were then totaled by TMDL watershed. This approach gives an estimate of OSSFs in the watershed. Table 12 shows the estimated number of OSSFs calculated using this GIS method.

Table 12. Estimated Number of OSSFs and Fecal Coliform Load in the TMDL Area Watershed

Segment	Stream Name	OSSF Estimate using 1990 Census method	# of Failing Septic Tanks[a]	Potential Violation Database[b]	Estimated Loads from Septic Tanks (Billion cfu/day)[c]
1006D_01	Halls Bayou (below U.S. 59)	0	0	0	0
1006D_02	Halls Bayou (above U.S. 59)	4,042	485	436	3,586
1006I_01	Unnamed Tributary of Halls Bayou	0	0	0	0
1006J_01	Unnamed Tributary of Halls Bayou	1,157	139	175	1,026

[a] A 12% failure rate was multiplied by the estimated number of OSSFs derived from the 1990 census.

[b] The Potential Violation Database was obtained from Harris County (2006-2007).

[c] Load estimate was based on literature values for fecal coliform concentrations since no *E. coli* concentration values were available. This calculation was based on the estimated number of failing septic tanks.

Using the 12 percent failure rate identified by Reed, Stowe & Yanke, LLC (2001), calculations were made to characterize fecal coliform loads in each watershed, because there is little *E. coli* data available. Fecal coliform loads were estimated using the following equation (EPA 2001):

$$\#\frac{counts}{day} = (\#Failing\_systems) \times \left(\frac{10^6\,counts}{100ml}\right) \times \left(\frac{70gal}{personday}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

The average number of people per household was calculated to be 2.79 for counties in the study area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of published reports (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from potential septic system violations within the watersheds was summarized in Table 12. Based on these data, it was determined that the estimated fecal coliform loading reaching the streams from OSSFs in the TMDL area watershed is negligible overall, but may be important locally.

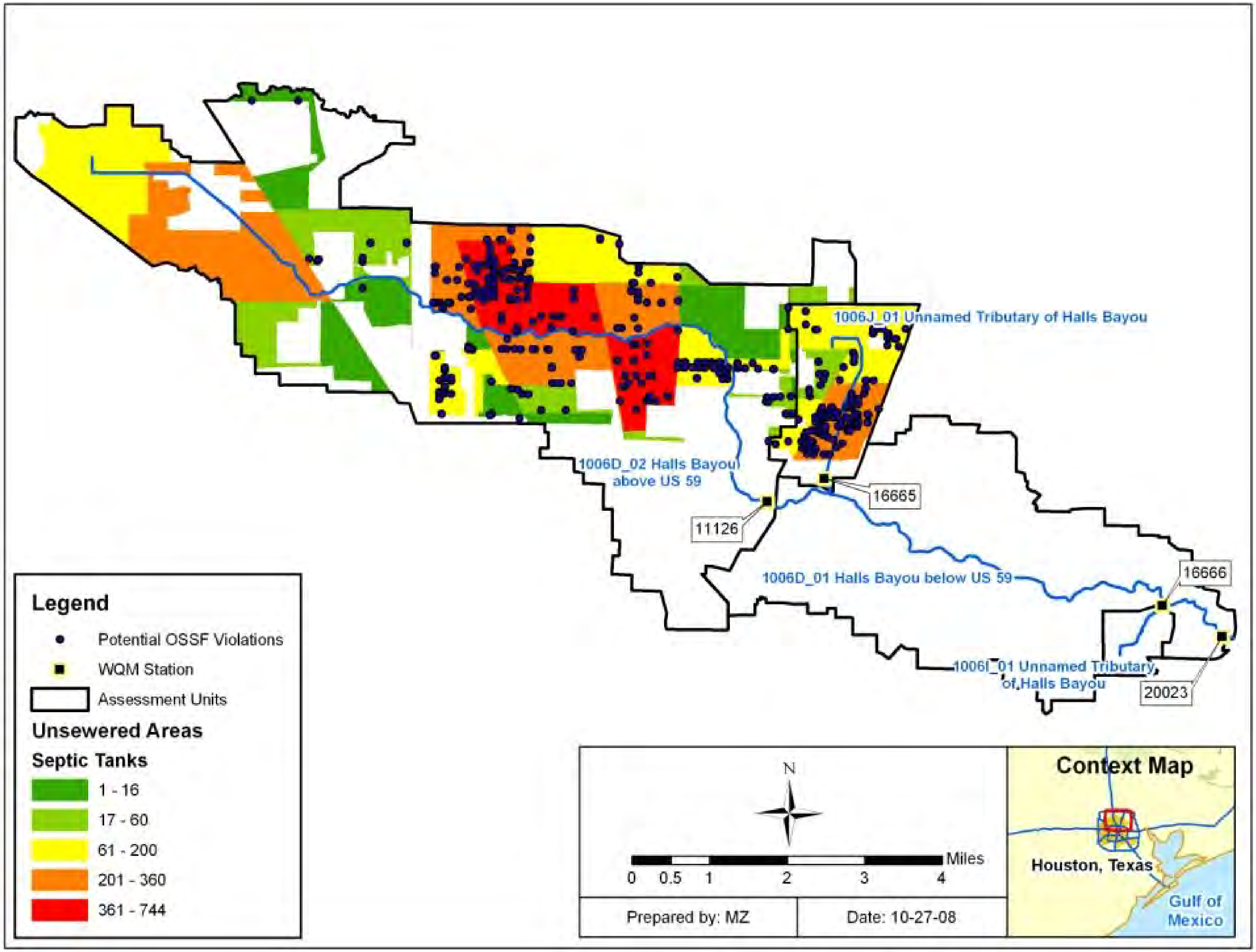

Figure 9. Unsewered Areas and Subdivisions with OSSFs in the TMDL Area Watershed

Domestic Pets

Based on the urban nature of this project and the availability of relevant data, dogs and cats are the only pets considered in calculating loads for domestic pets. Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a potential source of bacteria loading. On average nationally, there are 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association 2002). Using the U.S. Census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 13 summarizes the estimated number of dogs and cats for the watersheds of the TMDL area watershed.

Table 13. Estimated Numbers of Pets in the TMDL Area Watershed

Segment	Stream Name	Dogs	Cats
1006D_01	Halls Bayou (below U.S. 59)	10,956	12,467
1006D_02	Halls Bayou (above U.S. 59)	15,400	17,524
1006I_01	Unnamed Tributary of Halls Bayou	1,220	1,389
1006J_01	Unnamed Tributary of Halls Bayou	3,433	3,907

Table 14 provides an estimate of the fecal coliform load from domestic dogs and cats. These estimates are based on estimated fecal coliform production rates of $5.4\text{x}10^8$ cfu per day for cats and $3.3\text{x}10^9$ cfu per day for dogs (Schueler 2000). Only a small portion of these loads is expected to reach water bodies, through wash-off from land surfaces and conveyance in runoff. This would likely have only a temporary and localized impact on the overall bacteria loading of the watershed.

Table 14. Estimated Fecal Coliform Daily Production by Pets (in Billion cfu)

Segment	Stream Name	Dogs	Cats	Total
1006D_01	Halls Bayou (below U.S. 59)	36,154	6,732	42,886
1006D_02	Halls Bayou (above U.S. 59)	50,819	9,463	60,282
1006I_01	Unnamed Tributary of Halls Bayou	4,027	750	4,777
1006J_01	Unnamed Tributary of Halls Bayou	11,329	2,110	13,438

Bacteria Re-growth and Die-off

Bacteria are living organisms that grow and die. Certain enteric bacteria can re-grow in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can re-grow from improperly treated effluent during their transport in pipe networks, and they can re-grow in organic rich materials such as compost and sludges. 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 (re-growth and die-off) are in-stream processes and are not considered in the bacteria-source loading estimates of each water body in the TMDL area.

Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. This component 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. During ambient flows, these constant 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 is typically diluted and would therefore be a smaller part of the overall concentrations.

Bacteria contributions from permitted and unregulated storm water 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 low concentration 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 reduce because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load duration curve (LDC) analyses were used to examine the relationship between instream water quality and the source of indicator bacteria loads.

Load Duration Curve Analysis

LDCs are similar in appearance to flow duration curves; however, the y-axis is expressed in terms of a bacteria load in MPN/day. The curve represents the single sample criterion for *E. coli* (394 MPN/100 mL), expressed in terms of a load through multiplication by the flows historically observed at this site. Using the single sample criterion to generate the LDC is necessary to display the allowable pollutant load in relation to the existing loads, which are represented by existing ambient water quality samples. The basic steps to generate an LDC involve:

- preparing flow duration curves (FDCs) for gauged and un-gauged sampling locations;
- estimating existing bacteria loading in the receiving water using ambient water quality data;
- using LDCs to identify the critical condition that will define loading reductions necessary to attain the contact recreation standard; and
- interpreting LDCs to derive TMDL elements—WLA, LA, margin of safety (MOS), and overall percent reduction goals.

The result of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve.

Equation 1

TMDL (MPN/day) = criterion * flow in cubic feet per second (cfs) * unit conversion factor

Where:

criterion = 394 MPN/100 mL (*E. coli*)

unit conversion factor = 24,465,755 100 mL/ft^3 * seconds/day

The flow exceedance frequency (x-value of each point) is obtained by determining the percent of historical observations that equal or exceed the measured or estimated flow. While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than five years of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gauging stations operated by the USGS are used.

Because the only USGS gauge in the study area does not have a complete record for the period from 1996-2006, it was necessary to estimate flows using a neighboring gauge. Therefore, USGS gauge 08076000 (Greens Bayou near Houston, Texas) was chosen to conduct flow projections to establish estimated flows for each of these freshwater segments. The period of record for flow data used from this station was 1996 through 2006.

The flow exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of flow and LDCs. The hydrologic classification scheme utilized for the TMDL area watershed is outlined in Table 15.

Table 15. Hydrologic Classification Scheme

Flow Exceedance Percentile	Hydrologic Condition Class
0-20 %	Highest flows
20-80 %	Mid-range flows
80-100 %	Lowest flows

The low-flow category was derived by calculating the percentage of bayou flows contributed by WWTFs using the long-term average reported flows. Some instantaneous flow measurements were available from the intensive surveys collected for this project. These were not combined with the daily average flows or used in calculating flow percentiles but were matched to bacteria grab measurements collected at the same site and time. When available, these instantaneous flow measurements were used in lieu of the daily average flow to calculate instantaneous bacteria loads.

Historical observations of bacteria concentration are paired with flow data and are plotted on the LDC. The indicator bacteria load (or the y-value of each point) is calculated by multiplying the indicator bacteria concentration (counts, or counts/100mL) by the instantaneous flow in cubic feet per second at the same site and time, with appropriate volumetric and time unit conversions. Indicator bacteria loads that exceed the water quality criterion fall above the line that represents the criterion on the graph for each water body.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the single-sample criterion. Using LDCs, a TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition. LDCs do not simulate the fate of contaminants; rather, they calculate allowable loading for a given flow. Since LDCs do not link the loading to specific sources, processes affecting the fate of bacteria are not included.

Load Duration Curve Results

Halls Bayou

The LDC for Halls Bayou AU 1006D_01 (Figure 10) is based on *E. coli* bacteria measurements at sampling location 20023 (Halls Bayou near north end of Banting Street). The LDC indicates that *E. coli* levels exceed both the instantaneous and geometric mean water quality criteria under high and mid-range flow conditions. Wet weather influenced *E. coli* observations are found under high and mid range flow conditions. In the last part of the curve, where permitted WWTF flow makes up nearly all of the base flow, the allowable load becomes equal to the WLA_{WWTF}.

The LDC for Halls Bayou AU 1006D_02 (Figure 11) is based on *E. coli* bacteria measurements at sampling location 11126 (Halls Bayou at Jensen Drive). The LDC indicates that *E. coli* levels exceed both the instantaneous and geometric mean water quality criteria under all flow conditions. In the last part of the curve, where permitted WWTF flow makes up nearly all of the base flow, the allowable load becomes equal to the WLA_{WWTF}.

Unnamed Tributary of Halls Bayou

The LDC for Unnamed Tributary of Halls Bayou AU 1006I_01 (Figure 12) is based on *E. coli* bacteria measurements at sampling location 16666 (Unnamed Tributary of Halls Bayou at Talton Street). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under all flow conditions. Wet weather influenced *E. coli* observations are found under all flow conditions. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry conditions.

Unnamed Tributary of Halls Bayou

The LDC for Unnamed Tributary of Halls Bayou AU 1006J_01 (Figure 13) is based on *E. coli* bacteria measurements at sampling location 16665 (Unnamed Tributary of Halls Bayou downstream of Langley Road). The LDC indicates that *E. coli* levels exceed both the instantaneous and geometric mean water quality criteria under all flow conditions. Wet weather influenced *E. coli* observations are found under high and mid range flow conditions.

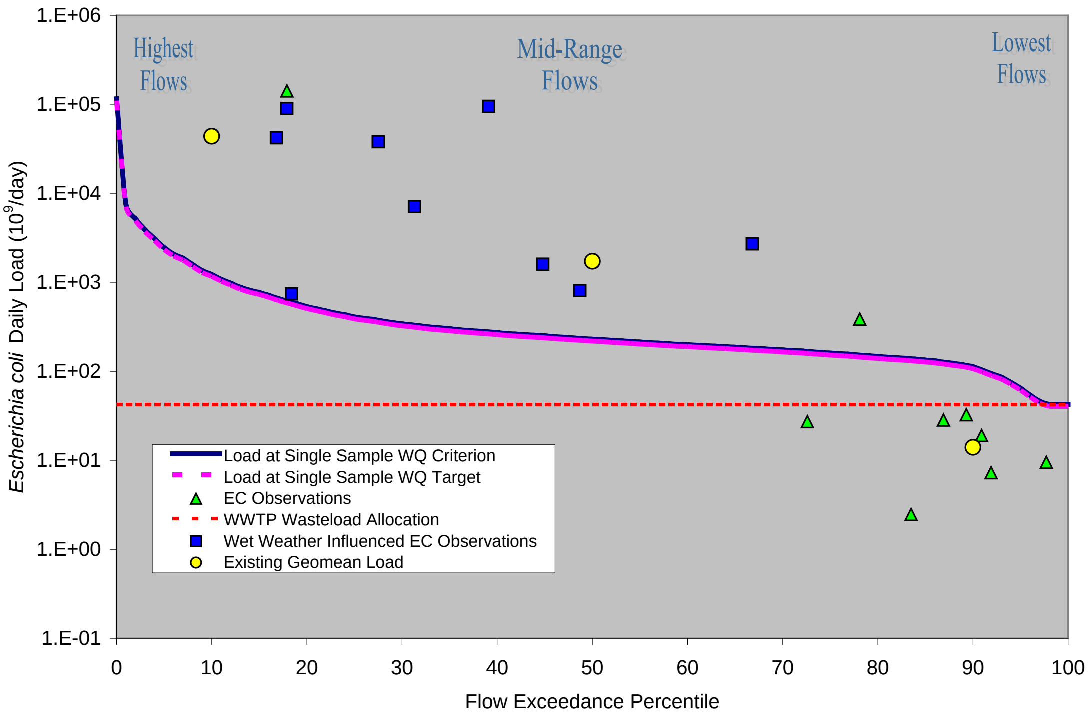

Figure 10. Load Duration Curve for *E. coli* in Halls Bayou (1006D_01)

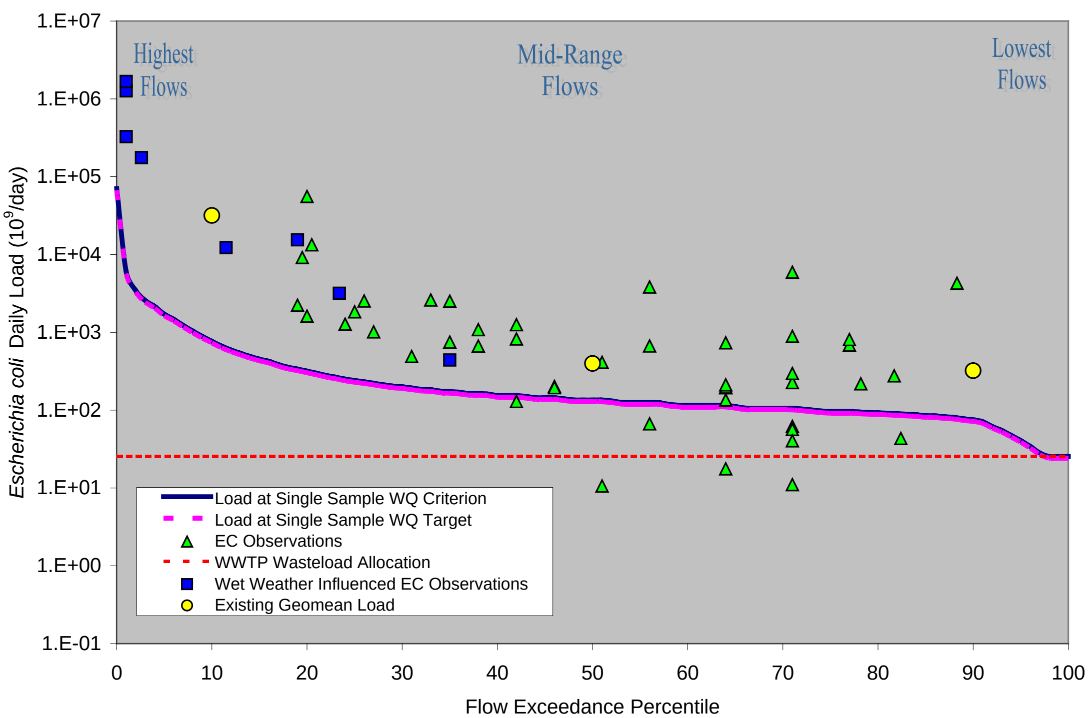

Figure 11. Load Duration Curve for *E. coli* in Halls Bayou (1006D_02)

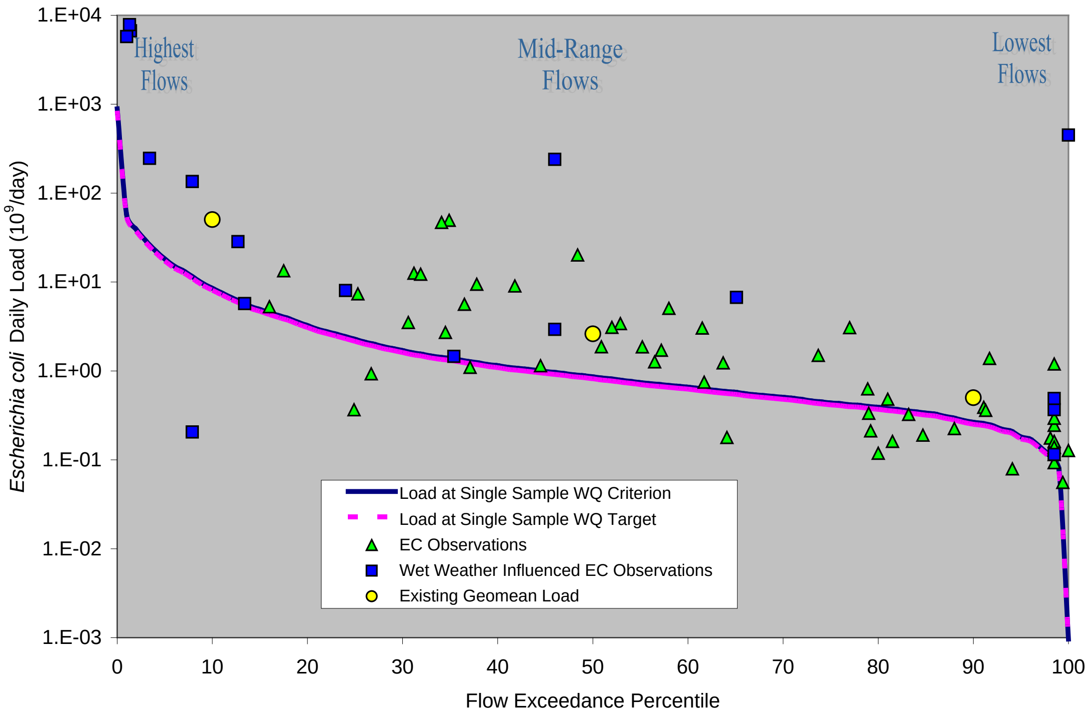

Figure 12. Load Duration Curve for Unnamed Tributary of Halls Bayou (1006I_01)

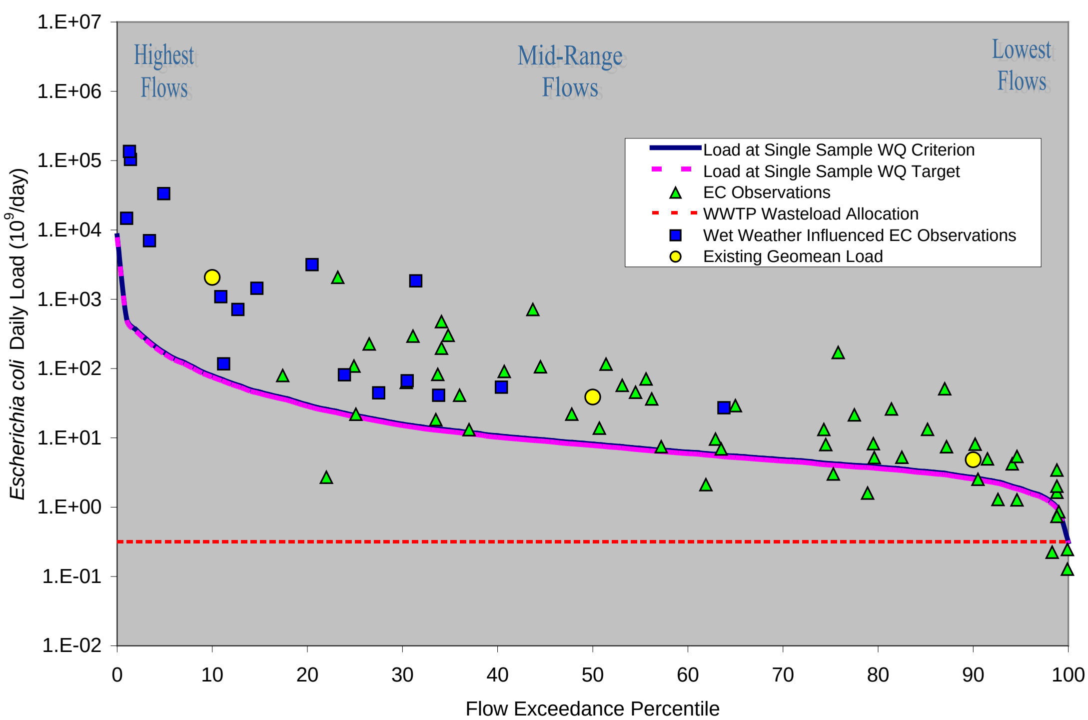

Figure 13. Load Duration Curve for Unnamed Tributary of Halls Bayou (1006J_01)

Margin of Safety

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

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- 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 TMDLs covered by this report incorporate an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For contact recreation, this equates to a geometric mean target of 120 MPN/100 mL of *E. coli*. The net effect of the TMDL with an MOS is that the assimilative capacity is slightly reduced.

Pollutant Load Allocation

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

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

Where:

WLA = waste load allocation (permitted or point source contributions)
LA = load allocation (unregulated or nonpoint source contributions)
MOS = margin of safety

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli*, TMDLs are expressed as MPN/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The bacteria TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. The estimated maximum allowable loads of *E. coli* for each of the AUs was determined as that corresponding to the flow regime requiring the highest load reduction.

Waste Load Allocation

TPDES-permitted facilities are allocated a daily wasteload (WLA_{WWTF}) calculated as their permitted discharge flow rate multiplied by one-half of the instream geometric mean water quality criterion. One-half of the water quality criterion is used as the target to provide instream and downstream load capacity, and to provide consistency with other TMDLs developed in the Houston area. This is expressed in the following equation:

$$WLA_{WWTF} = \text{criterion}/2 * \text{flow} * \text{unit conversion factor (\#/day)}$$

Where:

criterion = 126 MPN/100 mL *E. coli*
flow (10^6 gal/day) = permitted flow
unit conversion factor = 37,854,120 100mL/10^6 gal

Table 16 summarizes the WLA for the TPDES-permitted facilities within the study area. The facilities are required to meet instream criteria at their points of discharge. When multiple TPDES facilities occur within a watershed, loads from individual WWTFs are summed and the total load for continuous point sources is included as part of the WLA_{WWTF} component of the TMDL calculation for the corresponding segment. When no TPDES WWTFs discharge into the contributing watershed of a WQM station, the WLA_{WWTF} is zero. Compliance is achieved when the discharge limits are met. Disinfection is used by facilities to meet the discharge limit.

Individual WLA_{WWTF} values for new or amended TPDES-permitted WWTF dischargers added in the Halls Bayou watershed will be assigned from the future capacity allocation based on the discharge concentration of the water quality standard for indicator bacteria (63 MPN/100mL) and will be subject to the effluent limitations. Any additional flow for these facilities is accounted for in the development of the future capacity allocation.

Storm water discharges from MS4 areas are considered permitted point sources. Therefore, the WLA calculations must also include an allocation for permitted storm water discharges. A simplified approach for estimating the WLA for MS4 areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of storm water loading.

The LDC method was used to determine WLAs for these TMDLs. The percentage of each watershed that is under a TPDES MS4 permit is used to estimate the amount of the overall runoff load that should be allocated as the permitted storm water contribution in the $WLA_{StormWater}$ component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from storm water runoff and the portion allocated to $WLA_{StormWater}$.

Table 16. Waste Load Allocations for TPDES-Permitted Facilities

Receiving Water	Assessment Unit	TPDES Number	NPDES NUMBER	Facility Name	Permitted Flow (MGD)	*E. coli* WLA$_{WWTF}$ (Billion MPN/day)
Halls Bayou below US 59	1006D_01	12996-001	TX0096679	Aqua Utilities, Inc.	0.1	0.238
		10495-016	TX0063053	City of Houston FWSD No. 23	7	16.7*
Halls Bayou above US 59	1006D_02	01536-000	TX0007650	Ashbrook Corp.	0.004	0.00954
		10236-001	TX0021253	Sunbelt FWSD	0.45	1.07
		10419-001	TX0070611	Nitsch & Son Utility Co. Inc.	0.25	0.596
		10436-001	TX0032093	Champs Water Co.	0.15	0.358
		10495-151	TX0075663	City of Houston	0.75	1.79
		10518-001	TX0021261	Sunbelt FWSD	0.45	1.07
		10610-001	TX0030988	Southern Water Corp.	0.475	1.13
		10679-001	TX0023825	Harris County WCID 74	0.95	2.27
		10812-001	TX0021270	Sunbelt FWSD	0.99	2.36
		10825-001	TX0032255	Harvest Communities of Houston Inc.	0.023	0.0548
		11154-001	TX0023515	Mount Houston Road MUD	0.95	2.27
		11231-001	TX0021245	Sunbelt FWSD	0.5	1.19
		11255-001	TX0032034	Southwest Utilities Inc.	0.393	0.937
		11473-001	TX0066478	Blue Bell Manor Utility Co. Inc.	0.6	1.43
		11673-001	TX0063860	Woodloch MHP LLC	0.03	0.0715
		11807-001	TX0071820	Forest Hills MUD	0.8	1.91
		11821-001	TX0072184	Johnson, Ana Araujo	0.05	0.119
		12070-004	TX0100323	Aldine ISD	0.015	0.0358
		12083-001	TX0078883	Hooks Mobile Home Park Ltd.	0.06	0.143
		12259-001	TX0084531	Bayou Forest Village Inc.	0.03	0.0715
		12261-001	TX0084671	Solhjou Houshang	0.04	0.0954
		12261-002	TX0119610	Solhjou Houshang	0.03	0.0715

Receiving Water	Assessment Unit	TPDES Number	NPDES NUMBER	Facility Name	Permitted Flow (MGD)	*E. coli* WLA$_{WWTF}$ (Billion MPN/day)
Halls Bayou above US 59 (cont.)	1006D_02 (cont.)	12399-001	TX0087785	Karbalai, Rita Laura Redow	0.05	0.119
		12414-001	TX0088102	Woodgate Mobile Home Village Inc.	0.035	0.0835
		12555-001	TX0090492	Westfield MHP Inc.	0.1	0.238
		12882-001	TX0094986	Solhjou Bahram	0.03	0.0715
		12917-001	TX0095516	William Emmett Hartzog Jr.	0.006	0.0143
		12918-001	TX0095508	Hartzog, Linda Dianne	0.006	0.0143
		13084-001	TX0097527	Mcculloch, Xiu Hui Li	0.025	0.0596
		14921-001	TX0107158	Lee, Jack Cheng	0.032	0.0763
		14932-001	TX0131849	Stripes LLC	0.005	0.0119
		13609-001	TX0115797	Aldine ISD	0.042	0.1
		13709-001	TX0103071	White Palace LP	0.01	0.0238
		13749-001	TX0122521	AFS Group Inc.	0.025	0.0596
		13767-001	TX0095656	Fatima Family Village Inc.	0.012	0.0286
		13770-001	TX0090735	Smith, William Donald	0.06	0.143
		14156-001	TX0122190	Rex-Temple Inc.	0.003	0.00715
		14217-001	TX0123579	Karbalai, Laura Redow	0.02	0.0477
		14277-001	TX0124265	Ali Mohammad Solhjou	0.015	0.0358
		14620-001	TX0127949	Bahram Solhjou	0.07	0.167
		10919-001	TX0021237	Fallbrook, UD	1.3	3.1
		12919-001	TX0099171	Thomas, Tommy Joe	0.018	0.0429
		13211-001	TX0099104	Harris County MUD 321	0.8	1.91
Unnamed Tributary of Halls Bayou	1006J_01	12772-001	TX0093572	5510 Acorn LLC	0.03	0.0715
		14001-001	TX0117692	Hartman, James William	0.004	0.00954
		14144-001	TX0120189	Ca New Plan Floating Rate Partnership LP	0.099	0.236

* Allocation is for Outfall 003, which includes the combined flow from Outfalls 001 (the WWTF) and 002 (the Bretshire WWF) for 10495-016.

The TCEQ intends to implement the individual WLAs through the permitting process as either monitoring requirements or effluent limitations. However, there may be a more economical or technically feasible means of improving water quality and circumstances may warrant changes in individual WLAs after this TMDL is completed. Therefore, the individual WLAs, as well as the WLAs for storm water, are non-binding until implemented via a separate TPDES permitting action, which may involve preparation of an update to the state's Water Quality Management Plan. Regardless, all permitting actions will demonstrate compliance with the TMDL.

The executive director or commission may establish interim effluent limits and/or monitoring-only requirements at a permit amendment or permit renewal. These interim limits will allow a permittee time to modify effluent quality in order to attain the final effluent limits necessary to meet the TCEQ and EPA approved TMDL allocations. The duration of any interim effluent limits may not be any longer than three years from the date of permit re-issuance. New permits will not contain interim effluent limits because compliance schedules are not allowed for a new permit.

Where a TMDL has been approved, domestic WWTF TPDES permits will require conditions consistent with the requirements and assumptions of the WLAs. For NPDES/ TPDES-regulated municipal and small-construction storm water discharges, water quality-based effluent limits that implement the WLA for storm water may be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits (November 22, 2002, memorandum from EPA relating to establishing WLAs for storm water sources). The EPA memo also states that:

> "...the Interim Permitting Approach Policy recognizes the need for an iterative approach to control pollutants in storm water discharges...[s]pecifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPS will be tailored in subsequent rounds."

Using this iterative adaptive BMP approach to the maximum extent practicable is appropriate to address the storm water component of this TMDL. The iterative adaptive approach is reflected in the 2008 renewal of TPDES Permit No. WQ0004685000.

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

Load Allocation

The LA is the sum of loading from all nonpoint sources. The LAs for each stream segment are calculated as the difference between the TMDL, MOS, WLA, and WLA for storm water as follows:

$$LA = TMDL - \Sigma WLA_{WWTF} - \Sigma WLA_{StormWater} - MOS$$

Where:

LA = allowable load from unregulated sources
TMDL= total allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
$\Sigma WLA_{StormWater}$ = sum of all storm water loads
MOS = margin of safety

Allowance for Future Growth

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Consequently, increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard. New or amended permits for wastewater discharge facilities will be evaluated case by case. The LDC and the tables in this TMDL will guide determination of the assimilative capacity of the stream under changing conditions, including future growth.

To account for the probability that new additional flows from WWTFs may occur in any of the segments, a provision for future growth was included in the TMDL calculations by estimating permitted flows to year 2035 using population projections completed by H-GAC (H-GAC 2007). Table 17 shows the population increases in each of the four TMDL AUs based on the population projections from the H-GAC report. The population increases range from 27 percent to 42 percent. The permitted flows were increased by the expected population growth per AU between 2005 and 2035 to determine the estimated future flows.

Future WWTF flows were calculated by multiplying the permitted flow by the increase in population estimated for each AU. The future WWTF flows for each AU were added to the flows from runoff to calculate the TMDL. The allocation for future population growth is the difference between the WWTF loads calculated using estimated future flows and permitted flows.

Additional storm water dischargers represent additional flow that is not accounted for in the current allocations. Changes in MS4 jurisdiction or additional development associated with population increases in the watershed can be accommodated by shifting allotments between the WLA and the LA. This can be done without the need to reserve future-capacity WLAs for storm water In non-urbanized areas, growth can be accommodated by shifting loads between the LA and the WLA (for storm water).

Table 17. Population Projection per Subwatershed

Stream Name	AU	2005 Population	2035 Population	Population Increase	Median Flow for TMDL Calculations (cfs)*
Halls Bayou (below U.S. 59)	1006D_01	40,164	51,824	29%	150
Halls Bayou (above U.S. 59)	1006D_02	95,599	121,775	27%	90.7
Unnamed Tributary of Halls Bayou	1006I_01	751	990	32%	0.882
Unnamed Tributary of Halls Bayou	1006J_01	9,256	13,143	42%	8.47

* Median flow of the 0-20% flow-exceedance percentile range, adjusted for future growth.

In urbanized areas currently regulated by an MS4 permit, development and/or re-development of land in urbanized areas must implement the control measures/programs outlined in an approved Storm Water Pollution Prevention Plan (SWPPP). Although additional flow may occur from development or re-development, loading of the pollutant of concern should be controlled and/or reduced through the implementation of best management practices (BMPs) as specified in both the NPDES permit and the SWPPP.

Currently, the iterative, adaptive management, BMP approach is expected to be used in addressing storm water discharges. This approach encourages the implementation of controls (i.e., structural or non-structural), implementation of mechanisms to evaluate the performance of the controls, and finally, allowance to make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality.

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

TMDL Calculations

The final TMDLs for the four AUs included in this project are summarized in Table 18. The TMDLs were calculated based on the median flow in the 0-20 percentile range for flow exceedance. The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 are presented in Table 19. In Table 19, the future capacity for WWTF has been added to the WLA_{WWTF}. The allocations are based on the current criteria for *E. coli* in freshwater. The technical support document (University of Houston and Parsons 2009) contains additional detail on the calculation of the TMDLs.

In the event that the criteria change due to future revisions in the state's surface water quality standards, Appendix A provides guidance in recalculating the allocations in Table 19. Figures A-1 through A-4 of Appendix A were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of hypothetical water quality criteria for *E. coli*. The equations provided, along with Figures A-1 through A-4, allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*. However, one-half the current criterion for *E. coli* will be maintained for WWTFs even if criteria change due to future revisions in the state's surface water quality standards.

The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. LDCs are a simple statistical method that provides a first step in describing the water quality problem. This tool:

- Is easily developed and explained to stakeholders.
- Uses the available water quality and flow data.

Also, the LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed.

The U.S. EPA supports the use of this approach to characterize pollutant sources. The Texas Bacterial Task Force also identifies this method as a tool for TMDL development. In addition, many other states are using this method to develop TMDLs.

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

Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when developing flow exceedance percentiles.

Seasonality analyses of *E. coli* datasets showed that while 70 percent of the stations exhibited higher geometric mean concentrations for the cooler months than the warmer months, there is no statistically significant difference in indicator bacteria between cool and warm weather seasons.

Table 18. *E. coli* TMDL Summary Calculations for Halls Bayou AUs

Assessment Unit	Sampling Location	Stream Name	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billion MPN/day)	WLA_{MS4}[d] (Billion MPN/day)	LA[e] (Billion MPN/day)	MOS[f] (Billion MPN/day)	Future Growth[g] (Billion MPN/day)
1006D_01	20023	Halls Bayou below US 59	463	42.7[c]	382	3.40	23.2	12.0
1006D_02	11126	Halls Bayou above US 59	280	25.4	233	0	14.0	6.94
1006I_01	16666	Unnamed Tributary of Halls Bayou	2.72	0	2.15	0.435	0.136	0
1006J_01	16665	Unnamed Tributary of Halls Bayou	26.1	0.317	24.4	0	1.31	0.133

[a] Maximum allowable load for the flow range requiring the highest percent reduction; TMDL= WLA_{WWTF} + $WLA_{StormWater}$ + LA + MOS + Future Growth

[b] Sum of loads from the WWTF discharging upstream of the TMDL station. Individual loads are calculated as permitted flow * 126/2 (*E. coli*) MPN/100mL*conversion factor

[c] The WLA_{WWTF} for 1006D_01 includes all the facilities discharging upstream of the TMDL station. Thus, this allocation includes WWTF that discharge to other AUs.

[d] $WLA_{StormWater}$ = (TMDL – MOS –WLA_{WWTF})*(percent of drainage area covered by storm water permits)

[e] LA = TMDL – MOS –WLA_{WWTF} –$WLA_{StormWater}$-Future growth

[f] MOS = TMDL x 0.05

[g] Projected increase in WWTF permitted flows*126/2*conversion factor

Table 19. Final TMDL Allocations

Assessment Unit	TMDL [a] (Billion MPN/day)	WLA_{WWTF} [b] (Billion MPN/day)	$WLA_{StormWater}$ (Billion MPN/day)	LA (Billion MPN/day)	MOS (Billion MPN/day)
1006D_01	463	54.6	382	3.40	23.2
1006D_02	280	32.3	233	0	14.0
1006I_01	2.72	0	2.15	0.435	0.136
1006J_01	26.1	0.450	24.4	0	1.31

[a] $TMDL = WLA_{WWTF} + WLA_{StormWater} + LA + MOS$

[b] $WLA_{WWTF} = WLA_{WWTF} + \text{Future Growth}$

Public Participation

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

H-GAC is providing coordination for public participation in this project. To provide public involvement in the Halls Bayou Bacteria TMDL and the implementation phase, public meetings were held on October 19, 2007 and November 10, 2008. These meetings introduced the TMDL process, identified the impaired segments and the reason for the impairment, reviewed historical data, and described potential sources of bacteria within the watershed. In addition, the meetings gave TCEQ the opportunity to solicit input from all interested parties within the study area. Information on past and future meetings for the Halls Bayou Bacteria TMDL and related projects in the Houston area can be found on the H-GAC web site at <www.h-gac.com/community/water/tmdl/houston-metro/default.aspx>.

Implementation and Reasonable Assurances

The TMDL development process involves the preparation of two documents:

1) **a TMDL**, which determines the maximum amount of pollutant a water body can receive within one 24-hour period and still meet applicable water quality standards; and
2) **an Implementation Plan (I-Plan)**, which is a detailed description and schedule of the measures necessary to achieve the pollutant reductions identified in the TMDL.

The TCEQ is committed to developing I-Plans for all TMDLs adopted by the commission and ensuring the plans are implemented. I-Plans are critical to ensure water quality standards are restored and maintained. They are not subject to EPA approval.
In December 2007, stakeholders in the Houston/Harris County area initiated an effort to develop an area-wide I-Plan to address indicator bacteria sources throughout the greater Houston/Harris County area. The effort, known as the Bacteria Implementation Group (BIG), is being lead by the Houston-Galveston Area Council with funding from the TCEQ. This effort will include all of the water bodies that have been listed as impaired for contact recreation because of high indicator bacteria concentrations (Table 20). The draft area-wide I-Plan, which will include the Halls Bayou watershed, is expected to be completed in August 2010.

Table 20. Watersheds Included in Houston/Harris County Implementation Plan

Watershed	Number of Segments	Number of AUs	Counties
Clear Creek	9	18	Harris, Fort Bend, Galveston, Brazoria
Buffalo & Whiteoak Bayous	18	23	Harris, Waller, Fort Bend
Sims Bayou	2	4	Harris, Fort Bend
Brays Bayou	4	5	Harris, Fort Bend
Halls Bayou	3	4	Harris
Greens Bayou	5	8	Harris
Eastern Houston	10	13	Harris
Lake Houston	9	15	Harris, Montgomery, Liberty, San Jacinto, Grimes, Walker, Waller

The TCEQ works with stakeholders to develop the strategies summarized in the I-Plan. I-Plans may use an adaptive management approach that achieves initial loading allocations from a subset of the source categories. Adaptive management allows for development or refinement of methods to achieve the environmental goal of the plan. Additionally, if further research results in revisions to the surface water quality standards, an adaptive management approach affords the TCEQ and stakeholders the opportunity to adjust the implementation in a corresponding manner.

The stakeholder-led BIG will develop the I-Plan for *Four Total Maximum Daily Loads for Indicator Bacteria in the Halls Bayou Watershed* along with all other TMDLs for bacteria in the Houston area. Through the BIG, the excellent resources and expertise of the organizations and individuals involved in the group are available to develop the plan. An adaptive management strategy will be used to develop a plan to set priorities, provide flexibility, and will be appropriate for all stakeholders. Social and economic factors may be considered by the stakeholders during the development of the I-Plan.

Periodic and repeated evaluations of the effectiveness of implementation methods assure that progress is occurring, and may show that the original distribution of loading among sources should be modified to increase efficiency. This adaptive approach provides reasonable assurance that the necessary regulatory and voluntary activities to achieve the pollutant reductions will be implemented.

Implementation of the TMDL

Together, a TMDL and I-Plan direct the correction of water quality conditions not meeting water quality standards in an impaired surface water in the state. A TMDL broadly identifies the pollutant load goal after assessment of existing conditions and the impact on those conditions from probable or known sources. A TMDL identifies a total loading from the combination of point sources and nonpoint sources that would allow attainment of the established water quality standard.

An I-Plan specifically identifies the actions that will be taken to achieve the pollutant loading goals of the TMDL.

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

The TMDL report and the underlying assumptions, model scenarios, and assessment results are not, and should not be, interpreted as required effluent limitations, pollutant load reductions that will be applied to specific permits, or any other regulatory action necessary to achieve attainment of the water quality standard for storm water. The I-Plan developed by stakeholders and approved by the state will direct implementation efforts to certain sources contributing to the impaired water quality.

In determining source reductions, the I-Plan may consider factors such as:

- cost and/or feasibility;
- current availability or likelihood of funding;
- existing or planned pollutant reduction initiatives such as watershed-based protection plans;
- whether a source is subject to an existing regulation;
- the willingness and commitment of a regulated or unregulated source.

Ultimately, the I-Plan will identify the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the I-Plan that is adopted may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment, but with certain exceptions, the I-Plan must nonetheless meet the overall loading goal established by the EPA-approved TMDL.

An exception would include an I-Plan that identifies a phased implementation that takes advantage of an adaptive management approach. It is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, high uncertainty with the TMDL analysis exists, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

Instead, activities contained in the first phase of implementation may be the full scope of the initial I-Plan and include strategies to make substantial progress towards source reduction and elimination, refine the TMDL analysis, conduct site-specific analyses of the appropriateness of an existing use, and monitor in stream water quality to gauge the results of the first phase. Ultimately, the accomplishments of the first phase would lead to development of a phase two or final I-Plan, or revision of TMDL. This adaptive management approach is consistent with established guidance from EPA (see August 2, 2006, memorandum from EPA relating to clarifications on TMDL revisions).

The TCEQ's WQMP directs the state's efforts to address water quality problems and restore water quality uses throughout Texas. The WQMP is continually updated with new, more specifically focused WQMPs, or "water quality management plan elements" as identified in federal regulations (40 Code of Federal Regulations (CFR) Sec. 130.6(c)). Consistent with federal requirements, each TMDL is a plan element of a WQMP and commission adoption of a TMDL is state certification of the WQMP update.

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

The TCEQ would normally establish best management practices, which are a substitute for effluent limitations in TPDES MS4 permits, as allowed by the federal rules where numeric effluent limitations are infeasible (see November 22, 2002, memorandum from EPA relating to establishing TMDL WLAs for storm water sources). Thus, the TCEQ would not identify specific implementation requirements applicable to a specific TPDES storm water permit through an effluent limitation update. However, the TCEQ would revise a storm water permit, require a revised Storm Water Management Program or Pollution Prevention Plan, or implement other specific revisions affecting storm water dischargers in accordance with an adopted I-Plan.

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Appendix A.
Equations for Calculating TMDL Allocations for Changed Contact Recreation Standards

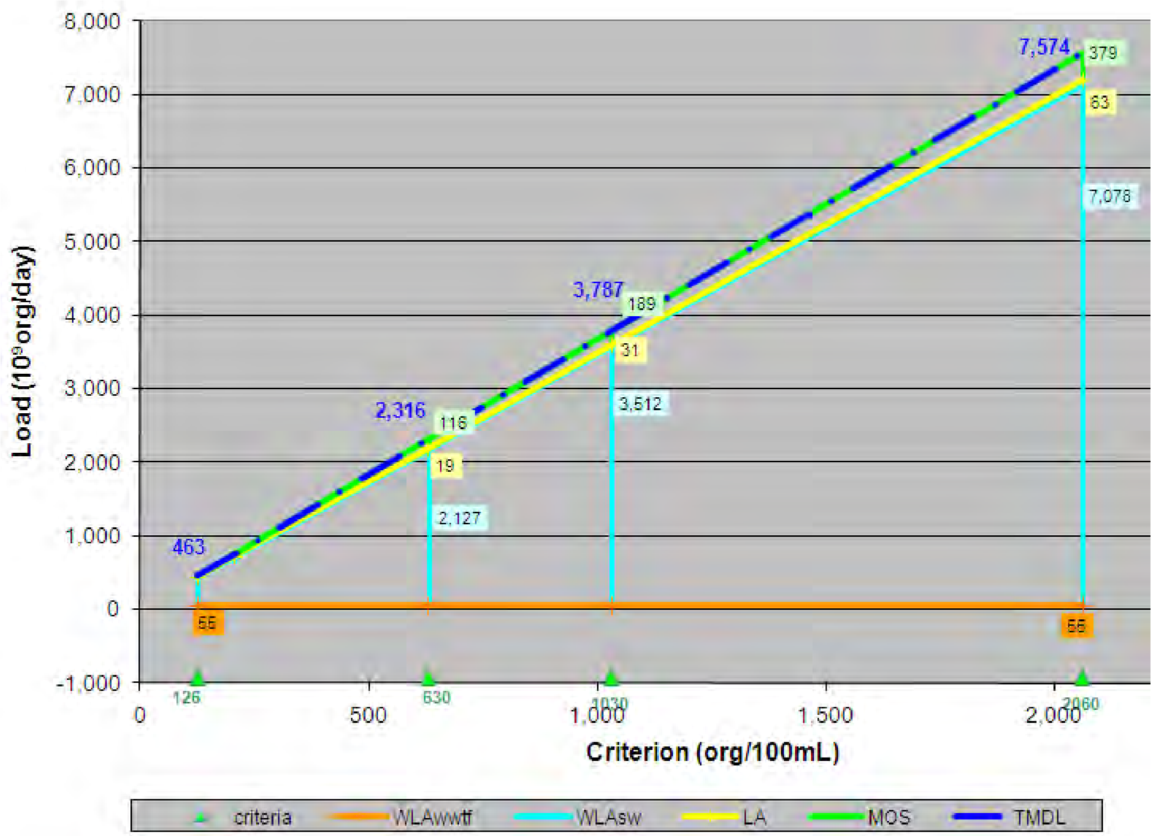

Figure A-1. Allocation Loads for AU 1006D_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 3.6767*Std
LA = 0.0308*Std - 0.4818
WLAStormWater = 3.4621*Std - 54.158
WLAWWTF = 63*0.8673 = 55
MOS = 0.05*TMDL

Where:
WLAWWTF = waste load allocation (permitted WWTF)
WLAStormWater = waste load allocation (permitted storm water)
LA = load allocation (unregulated source contributions)
Std = Revised Contact Recreation Standard
MOS = Margin of Safety

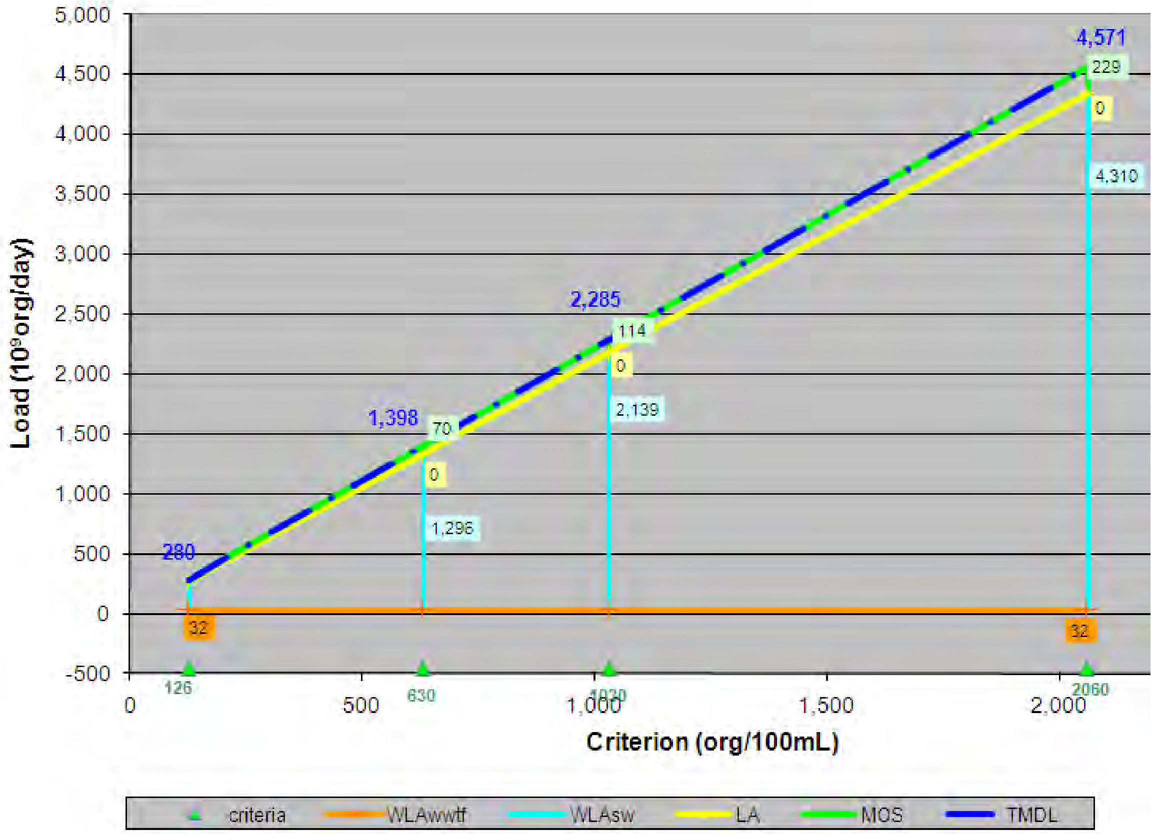

Figure A-2. Allocation Loads for AU 1006D_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 2.2189*Std
LA = 0
WLAStormWater = 2.108*Std - 32.345
WLAWWTF = 63*0.5134 = 32
MOS = 0.05*TMDL

Where:

WLAWWTF = waste load allocation (permitted WWTF)
WLAStormWater = waste load allocation (permitted storm water)
LA = load allocation (unregulated source contributions)
Std = Revised Contact Recreation Standard
MOS = Margin of Safety

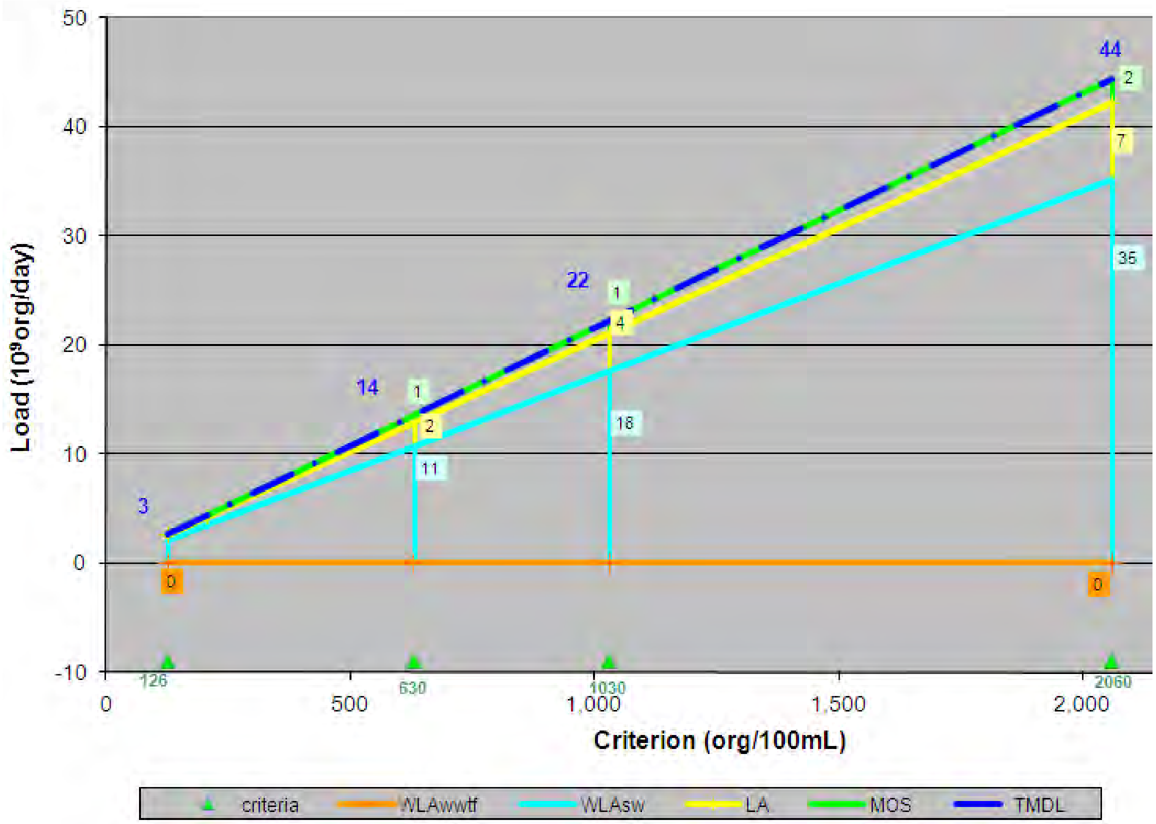

Figure A-3. Allocation Loads for AU 1006I_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.0216*Std
LA = 0.0035*Std
WLAStormWater = 0.017*Std
WLAWWTF = 0
MOS = 0.05*TMDL

Where:

WLA_{WWTF} = waste load allocation (permitted WWTF)
WLAStormWater = waste load allocation (permitted storm water)
LA = load allocation (unregulated source contributions)
Std = Revised Contact Recreation Standard
MOS = Margin of Safety

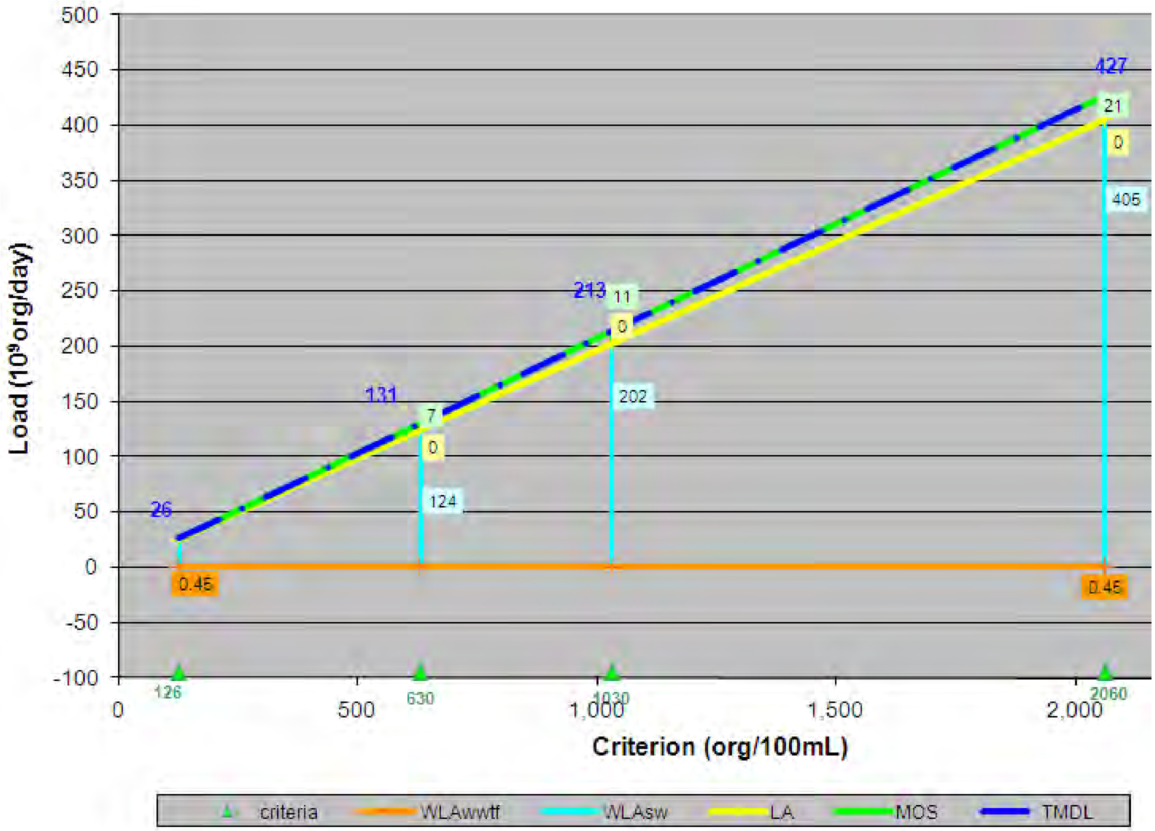

Figure A-4. Allocation Loads for AU 1006J_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.2072*Std
LA = 0
WLAStormWater = 0.1969*Std - 0.4503
WLAWWTF = 63*0.007148 = 0.45
MOS = 0.05*TMDL

Where:

WLA_{WWTF} = waste load allocation (permitted WWTF)
WLAStormWater = waste load allocation (permitted storm water)
LA = load allocation (unregulated source contributions)
Std = Revised Contact Recreation Standard
MOS = Margin of Safety