Adopted September 15, 2010
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Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries

Segments: 1007B, 1007C, 1007E, and 1007L

Assessment Units:
1007B_01, 1007B_02, 1007C_01, 1007E_01, and 1007L_01

Prepared by the
Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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“Technical Support Document: Indicator Bacteria Total Maximum Daily Loads for the Brays Bayou Watershed, Houston, Texas (1007B_01, 1007C_01, 1007E_01, 1007L_01, 1007B_02)”

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

Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries

Executive Summary

This document describes total maximum daily loads (TMDLs) for Brays Bayou Above Tidal and its tributaries, 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 Texas Water Quality Inventory and 303(d) List*.

The heavily urbanized Brays Bayou Above Tidal watershed encompasses approximately 105 square miles of land located southwest of the City of Houston, Texas. It drains parts of the cities of Houston, Missouri City, Stafford, Bellaire, West University, Southside Place, and Meadows. Approximately 87 percent of the watershed lies within Harris County, while the remaining 13 percent is in Fort Bend County. There are about 121 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 15 select TCEQ water quality monitoring stations in the Brays 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 680 most probable number (MPN)/100mL to 6,293 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 Brays Bayou Above Tidal, Keegans Bayou Above Tidal, Willow Waterhole Bayou Above Tidal, and an Unnamed Non-Tidal Tributary of Brays 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 Brays Bayou Above Tidal (1007B), Keegans Bayou Above Tidal (1007C), Willow Waterhole Bayou Above Tidal (1007E), and an Unnamed Non-Tidal Tributary of Brays Bayou (1007L) in the *2002 Texas Water Quality Inventory and 303(d) List* (2002 Inventory and List). All of these segments (Table 1) are freshwater bodies located in the southern metropolitan Houston area (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
1007B	Brays Bayou Above Tidal	Freshwater	1007B_01, 1007B_02	2002
1007C	Keegans Bayou Above Tidal	Freshwater	1007C_01	2002
1007E	Willow Waterhole Bayou Above Tidal	Freshwater	1007E_01	2002
1007L	Unnamed Non-Tidal Tributary of Brays Bayou	Freshwater	1007L_01	2002

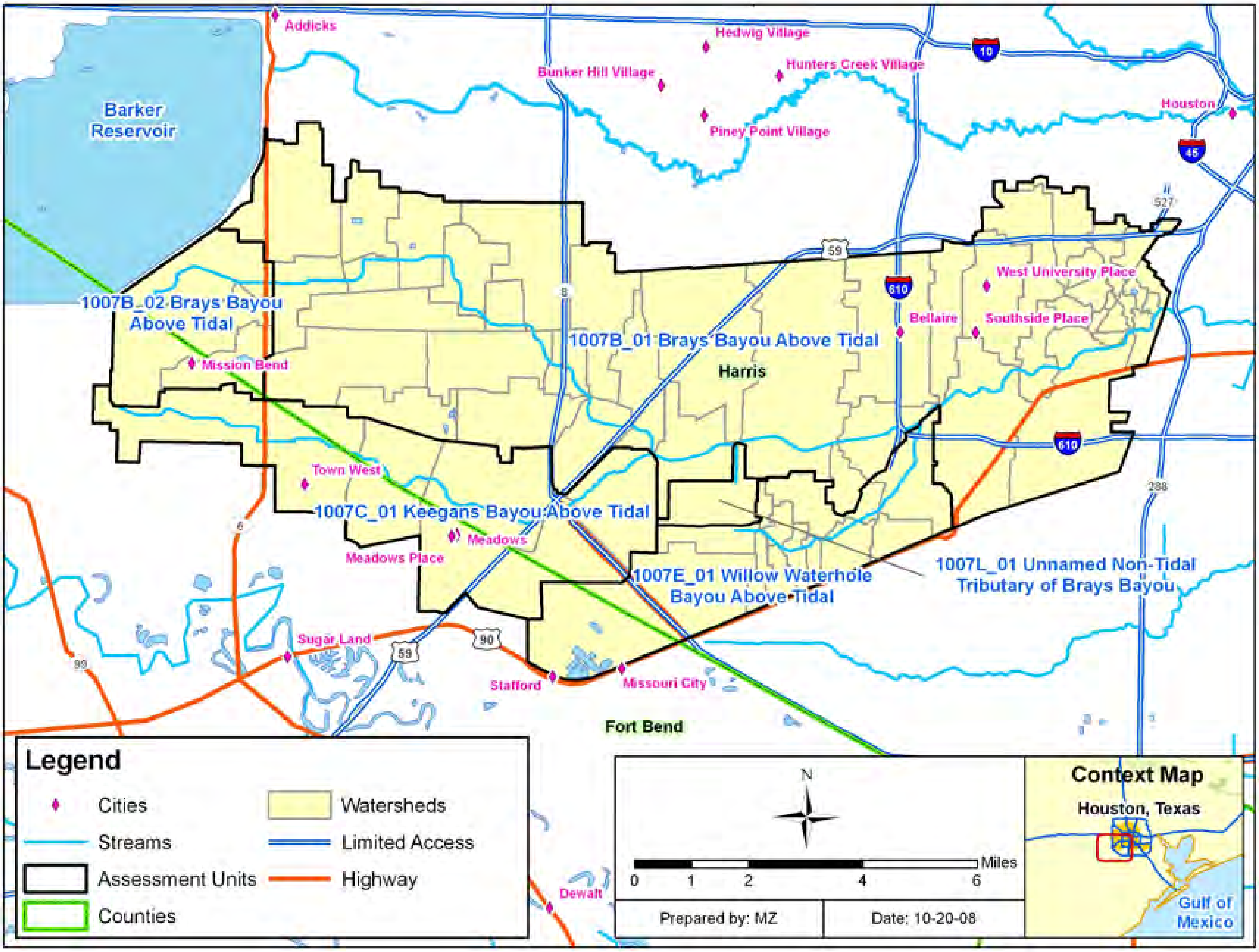

Figure 1. Brays Bayou Above Tidal Watershed

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 15 select TCEQ water quality monitoring stations in the Brays Bayou watershed were examined. Data collected prior to 2001 correspond to fecal coliform concentrations, while data for 2001–2008 are primarily *E. coli* concentrations.

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 bacteria were the preferred indicator prior to 2000.

For this project, *E. coli* data were used for data analysis and modeling to support TMDL development for Brays Bayou Above Tidal and its tributaries. 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 are used, the criteria are expressed as 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 Brays 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.

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

Assessment Unit	Station ID	Indicator Bacteria	Geometric Mean Criteria	Geometric Mean Concentration	Single Sample Criteria	Number of Samples	Number of Samples Exceeding Single Sample Criteria	Percent of Samples Exceeding
1007B_01	11138	EC	126	4,181	394	74	72	97%
		FC	200	10,891	400	35	33	94%
	11139	EC	126	3,129	394	83	80	96%
		FC	200	2,594	400	78	69	88%
	11140	EC	126	4,242	394	58	57	98%
		FC	200	4,546	400	75	69	92%
	15849	EC	126	680	394	58	34	59%
		FC	200	910	400	34	22	65%
	15850	EC	126	1,384	394	58	48	83%
		FC	200	4,268	400	35	30	86%
	15851	EC	126	2,981	394	58	50	86%
		FC	200	3,648	400	35	31	89%
	15852	EC	126	2,845	394	58	56	97%
		FC	200	5,241	400	35	32	91%
	15853	EC	126	5,166	394	56	55	98%
		FC	200	5,670	400	35	34	97%
	15854	EC	126	6,293	394	56	56	100%
		FC	200	6,149	400	35	34	97%
	15855	EC	126	3,201	394	56	55	98%
		FC	200	4,339	400	35	33	94%
	15859	EC	126	3,414	394	55	53	96%
		FC	200	4,176	400	35	33	94%
1007C_01	11169	EC	126	2,589	394	58	58	100%
		FC	200	3,728	400	69	60	87%
1007E_01	16652	EC	126	1,249	394	72	52	72%
		FC	200	2,046	400	70	58	83%
1007L_01	16654	EC	126	854	394	58	42	72%
		FC	200	4,487	400	70	63	90%
1007B_02	15848	EC	126	1,051	394	72	52	72%
		FC	200	1,465	400	35	27	77%

EC: *E. coli* in MPN/100mL

FC: Fecal coliform in cfu/100mL

Watershed Overview

The Brays Bayou Above Tidal watershed, a heavily urbanized watershed, encompasses approximately 105 square miles of land located southwest of the City of Houston, Texas. It drains parts of the cities of Houston, Missouri City, Stafford, Bellaire, West University Place, Southside Place, and Meadows. Approximately 87 percent of the watershed lies within Harris County, while the remaining 13 percent is in Fort Bend County. There are about 121 miles of open streams within the watershed (Harris County Flood Control District [HCFCD], 2008).

The Brays Bayou Above Tidal watershed is fully urbanized, but there are several large parks and regions of open space within the watershed. Table 3 summarizes the acreages and the corresponding percentages of the land use categories for the contributing watershed associated with each respective segment 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 86% and 97%) followed by woody land (between 1.2% and 6%). Open water and bare/transitional land account for less than 2 percent of the subwatersheds.

Table 3. Land Use Summaries

Aggregated Land Use Category	Assessment Unit				
	1007B_01	1007B_02	1007C_01	1007E_01	1007L_01
Percent Developed Land	95.9	93.8	91.1	85.8	96.5
Percent Cultivated Land	0.1	0.1	0.7	0	0
Percent Pasture/Hay	0.3	0.4	1.6	6.2	0
Percent Grassland/Herbaceous Land	0.6	0.5	1.6	0.9	0
Percent Woody Land	2.3	4.1	4.1	6	1.2
Percent Open Water	0.3	0.7	0.1	0.2	0
Percent Wetland	0.4	0.2	0.7	0.7	2.3
Percent Bare/Transitional Land	0.1	0.2	0.1	0.2	0
Acres of Developed Land	40,398	4,114	10,572	6,923	856
Acres Cultivated Land	7.8	0	82	0	0
Acres Pasture/Hay	145	18	189	498	0
Acres Grassland/Herbaceous Land	260	16.9	184	72	0.2
Acres of Woody Land	957	173	467	483	10
Acres of Open Water	118	29	5.6	16	0
Acres of Wetland	164	4.4	86	59	20
Acres of Bare/Transitional Land	43	3.3	15	18	0
Watershed Area (acres)	**42,053**	**4,357**	**11,590**	**8,056**	**888**

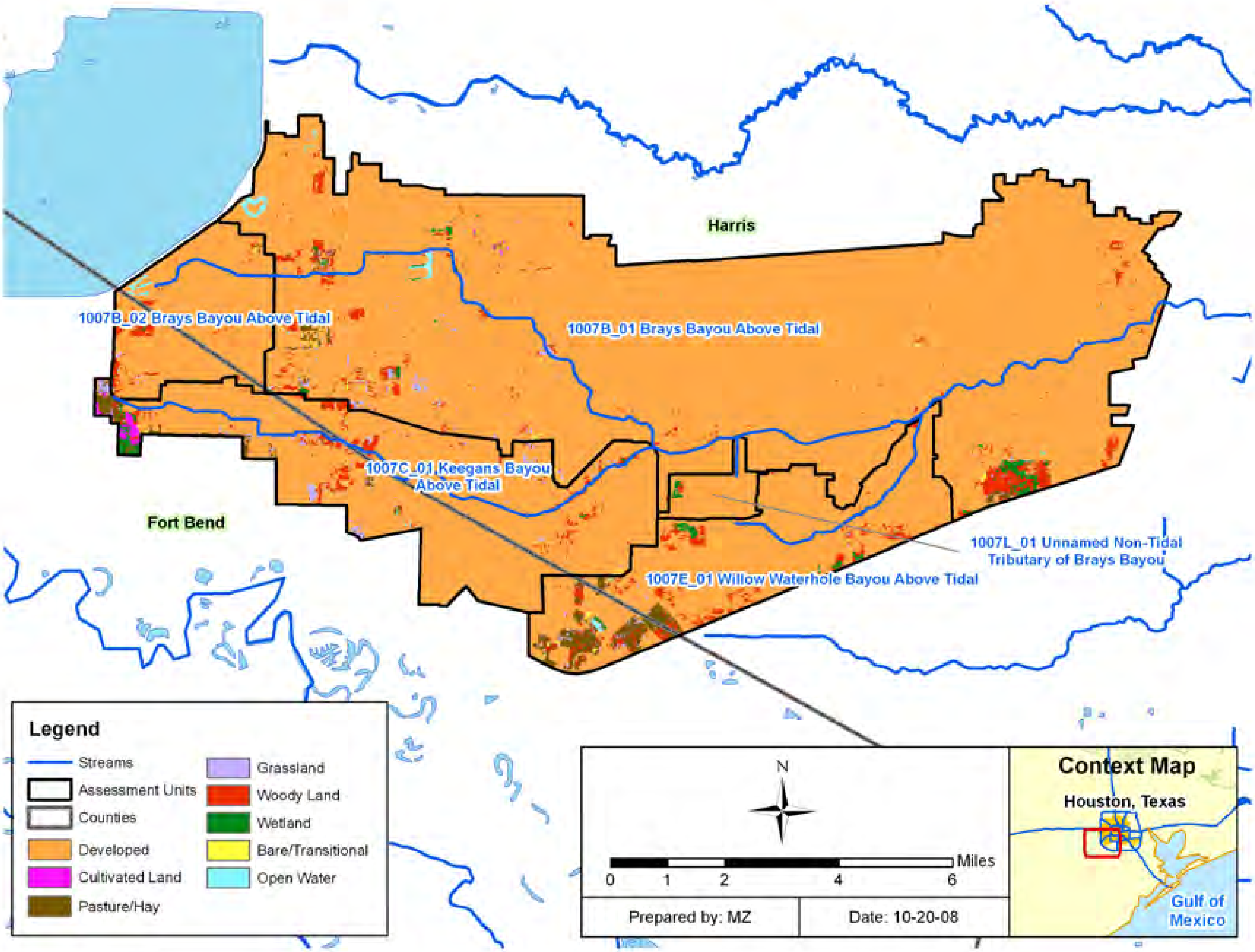

Figure 2. Brays Bayou Above Tidal Watershed Land Use

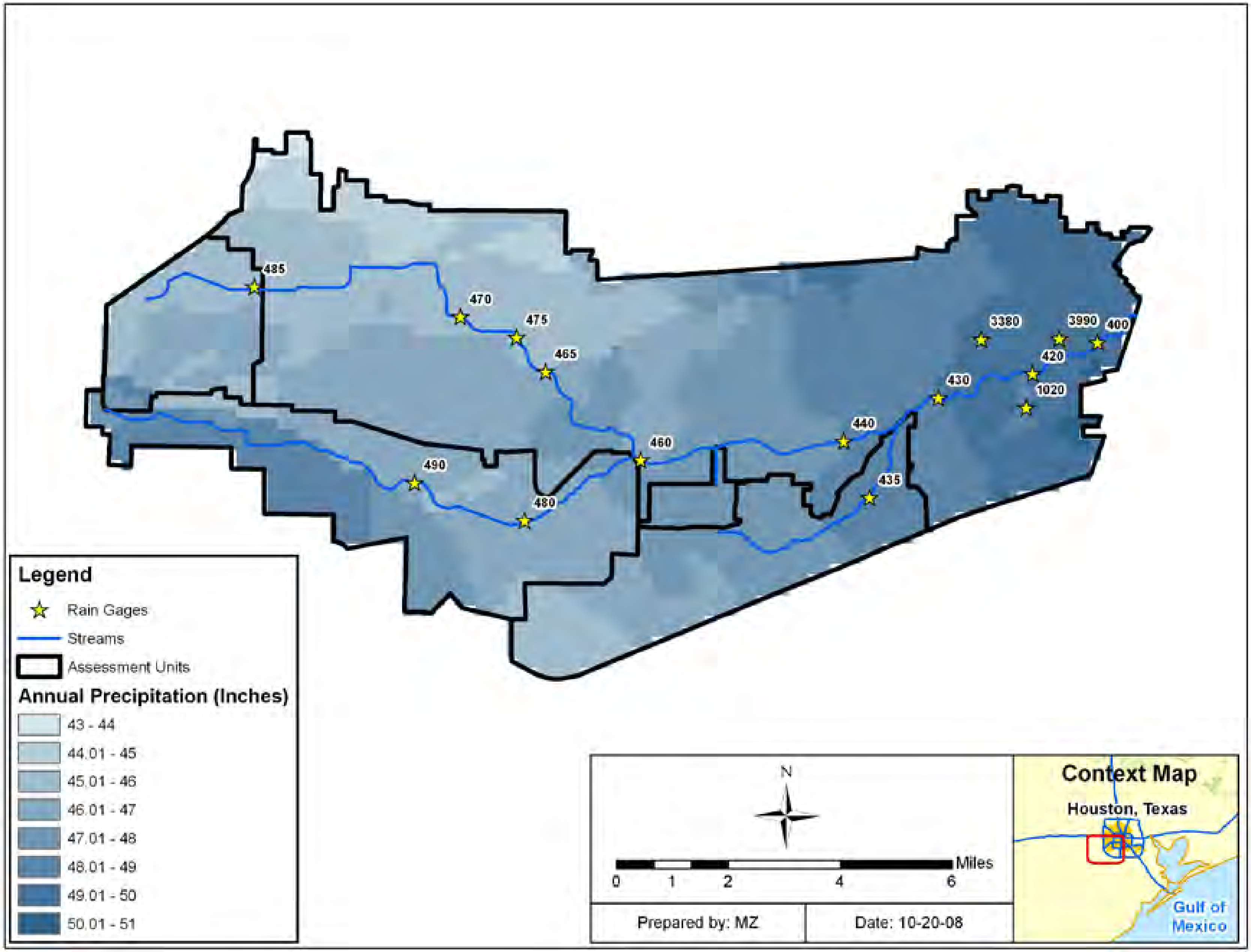

Figure 3. Brays Bayou Above Tidal Watershed Precipitation Map

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 27 percent of the drainage area of the entire watershed, approximately 28 square miles (HCFCD, 2008).

There are 15 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 Brays Bayou Above Tidal watershed experiences frequent rainfall events, with annual precipitation totals of approximately 48 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 water conveyance system has been developed throughout the area. Figure 3 shows average annual rainfall across the Brays Bayou Above Tidal 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.

The State Soil Geographic Database (STATSGO) (National Resources Conservation Service [NRCS] 1994) information was used to characterize soil in the Brays Bayou Above Tidal Watershed. The soil types that dominate the watershed are primarily from the Lake Charles and Edna soil series, with a small portion composed of Katy soil (Figure 4). The distribution and attributes of the three soil series found in the Brays Bayou Above Tidal 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 0.03 percent toward the southeast (USACE 1985). The highest elevations within the watershed are 148 feet above mean sea level.

Table 4. Average Rainfall for Each AU Watershed

Assessment Unit	Annual Average (Inches)
1007B_01	48.4
1007C_01	44.6
1007E_01	52.1
1007L_01	47.0
1007B_02	48.6

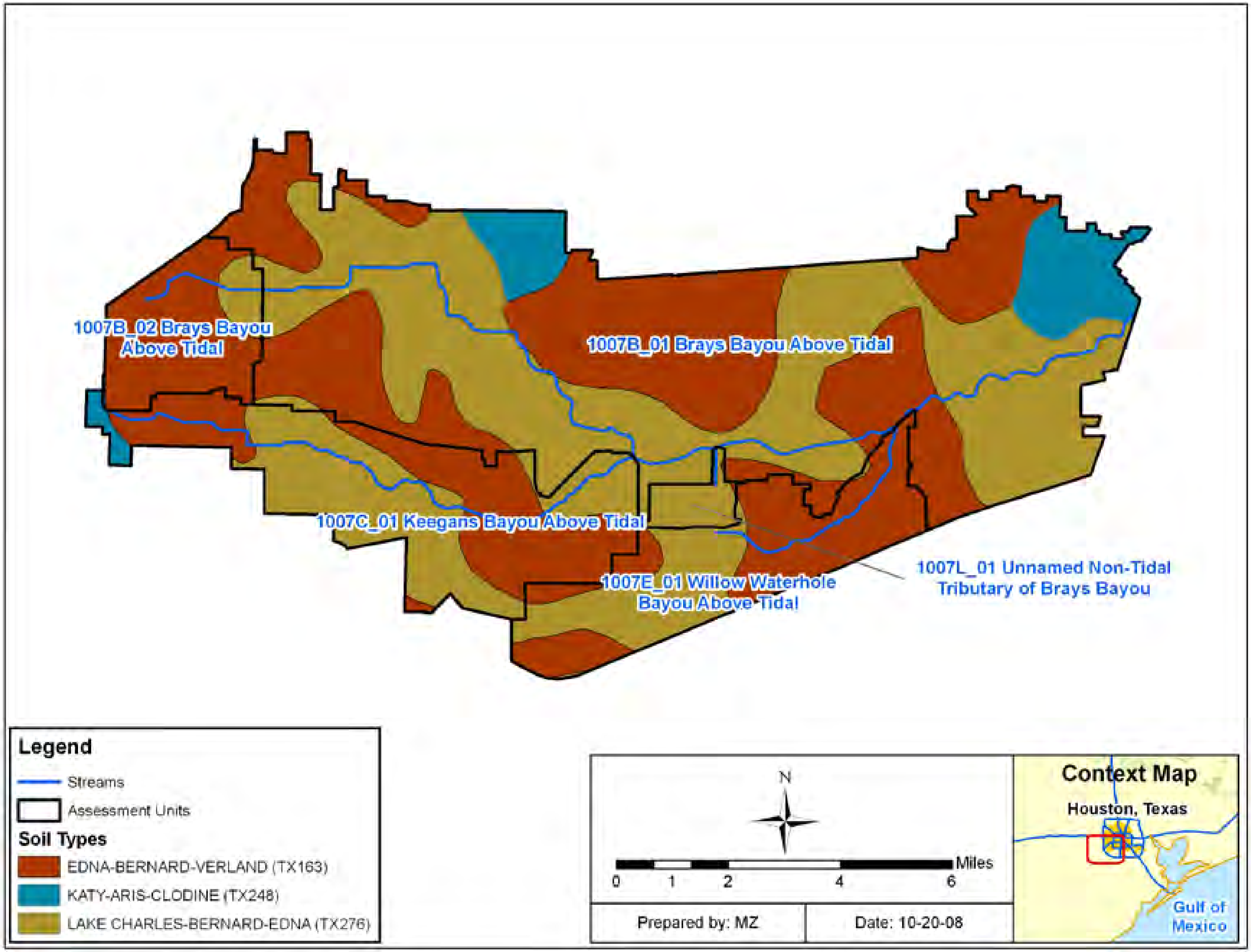

Figure 4. Brays Bayou Above Tidal Watershed Soil Types

Table 5. Characteristics of Soil Types within Brays Bayou Above Tidal 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)
TX163	Edna	46.3%	Fine Sandy Loam	D	Somewhat Poorly Drained	0.10	0.15	1.4
TX248	Katy	6.3%	Fine Sandy Loam	D	Somewhat Poorly Drained	0.15	0.20	1.3
TX276	Lake Charles	47.4%	Clay	D	Somewhat Poorly Drained	0.15	0.20	1.2

Source: All data obtained/calculated from STATSGO database

Stream flow data are key information when conducting water quality assessments. The U.S. Geological Survey (USGS) operates flow gauges at five locations along Brays Bayou and its main tributaries to measure flow and gauge heights. The period of record and type of data collected at these gauges are listed upstream to downstream in Table 6. The locations of these gauge stations and project water quality monitoring (WQM) stations are shown on Figure 5. Four of the five gauges are currently active in the watershed. The historical flow data available from these gauges are summarized as flow exceedance percentiles in constructing flow duration curves.

Table 6. USGS Gauges in the Brays Bayou Above Tidal Watershed

USGS Gauge Number	Name	Period of Record	Data Type
8075000	Brays Bayou at South Main St.	5/25/1936 - Present	Discharge (cfs)
		6/8/1988 - Present	Gauge Height (ft)
8074810	Brays Bayou at South Gessner Dr.	10/1/2001 - Present	Discharge (cfs)
		5/1/1997 - Present	Gauge Height (ft)
8074800	Keegans Bayou at Roark Rd	9/1/1964 - 2/11/2004	Discharge (cfs)
		8/1/1996 - Present	Gauge Height (ft)
8074780	Keegans Bayou at Keegan Rd	12/10/1964 - 10/28/1984	Discharge (cfs)
		12/10/1964 - 10/28/2002	Gauge Height (ft)
8074760	Brays Bayou at Alief, Texas	10/1/2006 - Present	Discharge (cfs)
		9/27/2006 - Present	Gauge Height (ft)

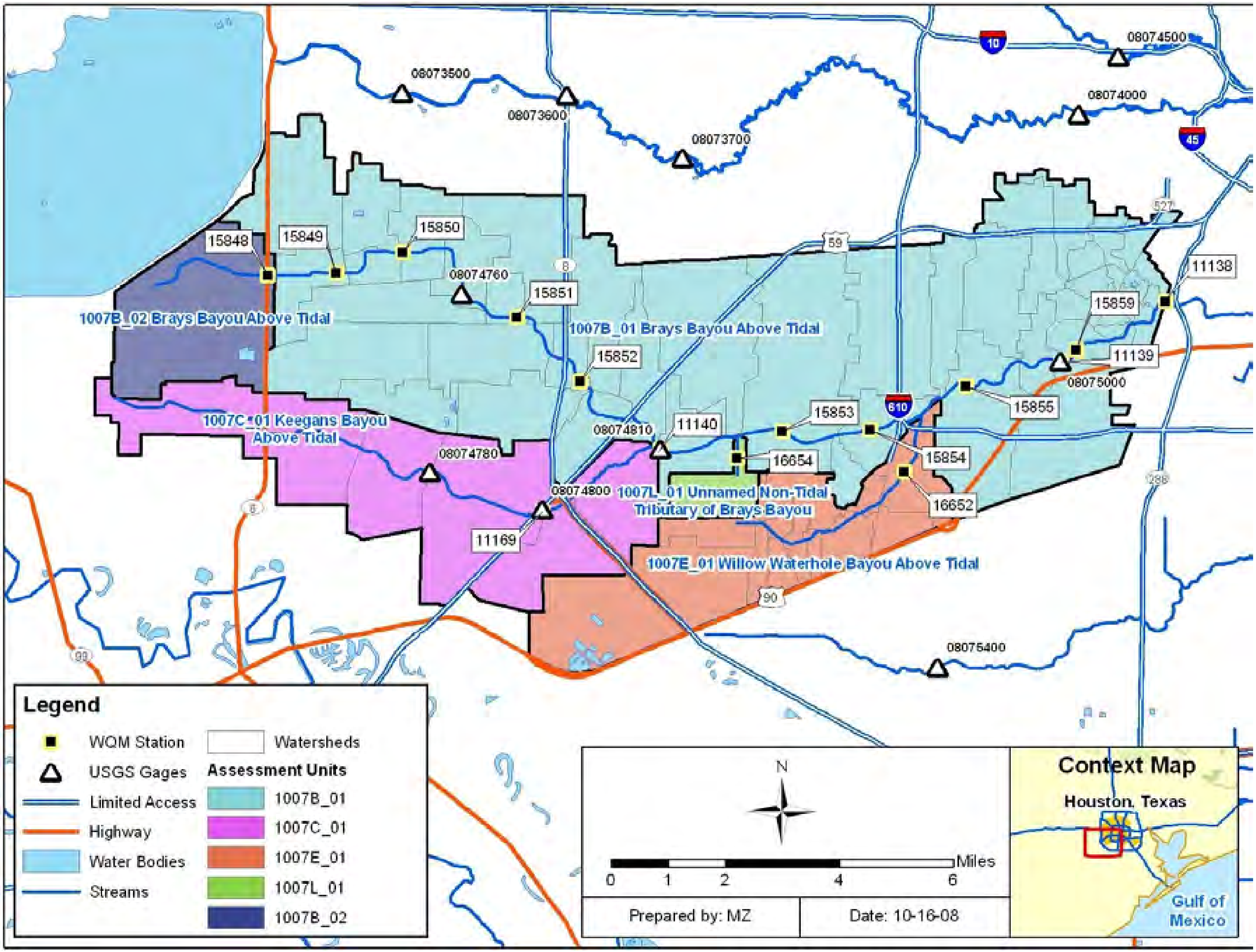

Figure 5. Brays Bayou Above Tidal Watershed Sampling Locations and USGS Gauge Locations

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 in this report is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This is the endpoint in Brays Bayou Above Tidal (1007B), Keegans Bayou Above Tidal (1007C), Willow Waterhole Bayou Above Tidal (1007E), and an Unnamed Non-Tidal Tributary of Brays Bayou (1007L).

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

Within the TMDL area watershed, Brays Bayou Above Tidal (1007B_01), Keegans Bayou above Tidal (1007C_01), Willow Waterhole Bayou Above Tidal (1007E_01) and Brays Bayou Above Tidal (1007B_02) have NPDES/TPDES-permitted sources. There are no NPDES/TPDES-permitted sources located within Unnamed Non-Tidal Tributary of Brays Bayou (1007L_01). 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) or land application sites within the general Brays Bayou Above Tidal 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 October 20, 2008, there were 27 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

Table 7. WWTF Dischargers in the TMDL Area Watershed

Segment	Stream Name	Assessment Unit	TPDES Number	Outfall	NPDES NUMBER	Facility Name[1]	DType	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)
1007B	Brays Bayou Above Tidal	1007B_01	01286-000	001	TX0008851	Texas Medical Center Central Heating & Cooling Services Corp.	W	0.950	0.212
		1007B_01	01853-000	001	TX0052761	Shell Chemical LP & Equilon Enterprises LLC	W	0.475	0.215
		1007B_01	01853-000	002	TX0052761	Shell Chemical LP & Equilon Enterprises LLC	W	0.5000	0.554
		1007B_01	10058-001	001	TX0023841	City of West University Place	W	2.000	1.522
		1007B_01	10495-037	001	TX0062995	City of Houston (Southwest)	W	60.000	32.814
		1007B_01	10495-111	001	TX0065307	City of Houston	W	13.340	7.411
		1007B_01	10495-116	001	TX0088153	City of Houston	W	18.000	9.294
		1007B_01	10550-001	001	TX0020613	City of Bellaire	W	4.500	1.633
		1007B_01	14850-001	001	TX0026972	City of Southside Place	D	0.2650	0.203
		1007B_01	12258-001	001	TX0084425	Beechnut MUD	W	1.380	0.210
		1007B_01	12499-001	001	TX0089621	West Harris County MUD 6	D	0.500	0.214
		1007B_01	13884-001	001	TX0119474	Nguyen, Loc Dac	D	0.025	N/A
		1007B_02	12068-001	001	TX0078751	Fort Bend County MUD 30	D	1.500	0.381
		1007B_02	12119-001	001	TX0079359	West Harris County MUD 4	D	0.280	0.119
		1007B_02	14418-001	001	TX0056481	Chelford City MUD	W	15.500	4.367
1007C	Keegans Bayou Above tidal	1007C_01	01225-000	001	TX0003824	Texas Instruments Inc.	W	1.5[a]	0.866
		1007C_01	01225-000	002	TX0003824	Texas Instruments Inc.	W	1.5[a]	0.200
		1007C_01	10495-095	001	TX0027201	City of Houston	W	7.200	2.159
		1007C_01	10495-119	001	TX0098191	City of Houston	W	23.100	13.121
		1007C_01	11039-001	001	TX0053872	City of Meadows Place	W	1.500	0.854

Segment	Stream Name	Assessment Unit	TPDES Number	Outfall	NPDES NUMBER	Facility Name[1]	DType	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)
		1007C_01	11461-001	001	TX0056952	Bissonnet MUD	D	0.600	0.349
		1007C_01	12078-001	001	TX0078964	Renn Road MUD	W	2.500	0.810
		1007C_01	12379-001	001	TX0087271	North Mission Glen MUD	W	1.180	0.517
1007E	Willow Waterhole Bayou Above Tidal	1007E_01	03060-001	001	TX0104540	Weatherford Farms Inc.	W	0.0360	0.021
		1007E_01	10570-001	001	TX0020052	Harris County WCID - Fondren Road	D	0.600	0.222
		1007E_01	12250-001	001	TX0084484	Harris County MUD 122	D	0.25	0.103
		1007E_01	12641-001	001	TX0091979	Southwest Harris County MUD 1	D	0.400	0.117

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

Source: TCEQ Water Quality Assessment Team, May 2008.

DTYPE: C = Cooling Water; D = Domestic <1 MGD; S = Storm water; W = domestic >=1 MGD or industrial process water, including water treatment plant discharge

[a] The total flow from both outfalls combined cannot exceed 1.5 MGD.

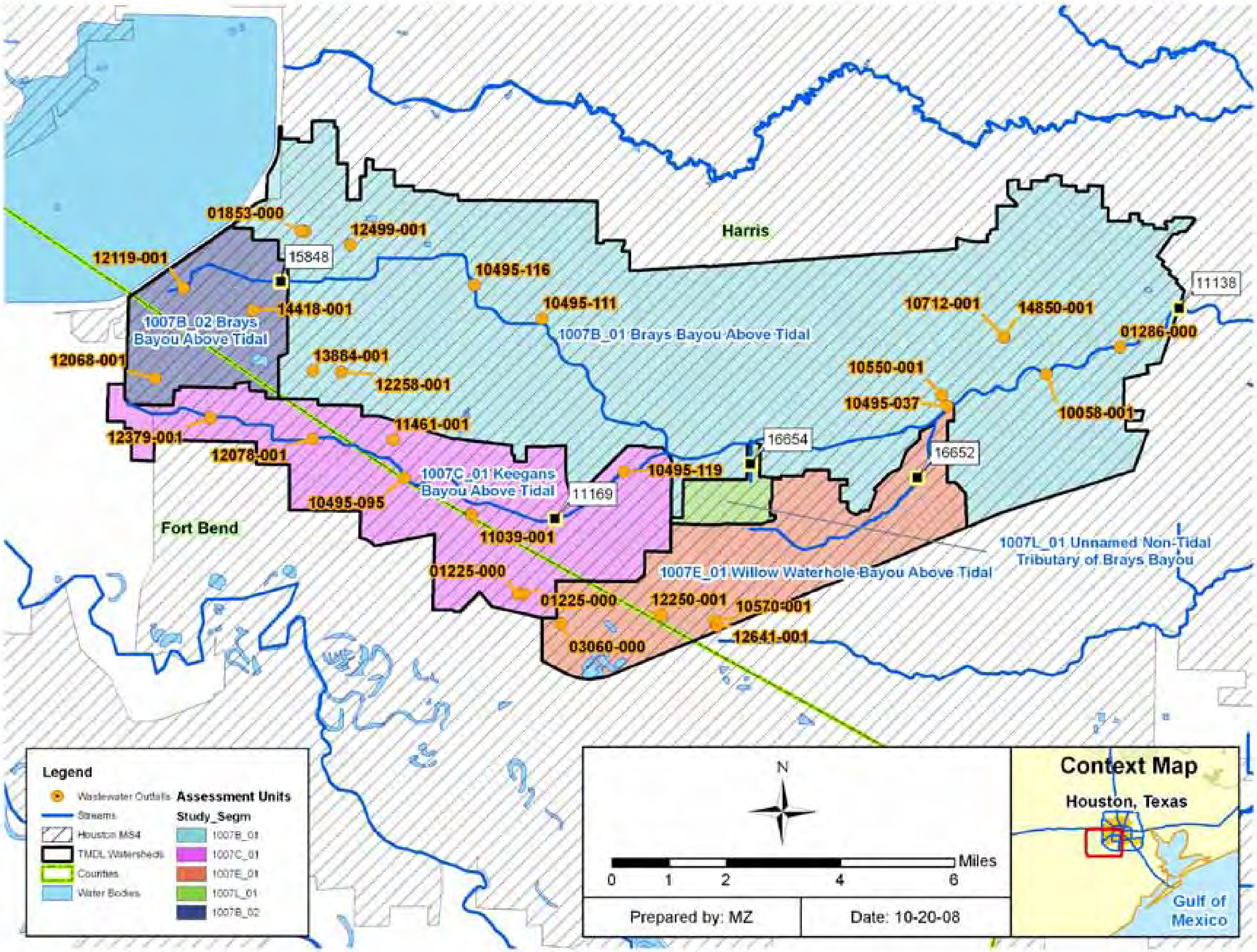

Figure 6. TPDES-Permitted Facilities in the TMDL Area Watershed

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 only available for some of the TPDES permitted dischargers in the general Brays 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 five TPDES WWTFs (as of October 2008) that monitor their discharge for fecal coliform. Discharge Monitoring Reports (DMRs) were used to determine the number of fecal coliform analyses that were performed for the five 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. Only two 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 390 sanitary sewer overflows reported in the general Brays Bayou watershed between February 2001 and December 2003. The reported SSOs averaged 2,106 gallons per event. The locations and magnitudes of the all reported SSOs are displayed in Figure 7 along with the service area boundaries.

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 watershed 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

Table 8. Discharge Monitoring Report Data for Permitted Wastewater Discharges (January 1998-June 2007)

TPDES Number	Facility Name	Segment	Dates Monitored		Number of Records	Number of MCMX Exceedances	Number of MCAV Exceedances	FC Daily Load (Billion cfu)	
			Start	End				90 Percentile Monthly Average	Maximum Monthly Average
14850-001	City of Southside Place	1007B_01	03/31/1998	06/30/1999	5	0	0	0.116	0.143
01853-000	Shell Chemical LP & Equilon Enterprises LLC	1007B_01	01/31/1998	06/30/2007	54	0	0	0.188	3.22
11461-001	Bissonnet MUD	1007C_01	03/31/1998	06/30/1999	2	1	0	0.427	0.473
12068-001	Fort Bend County MUD 30	1007B_02	05/31/2007	06/30/2007	2	1	0	33	36.6
12499-001	West Harris County MUD 6	1007B_01	02/28/1998	05/31/1999	3	0	0	0.297	0.369

Source: TCEQ, September 2007

Notes: FC = Fecal Coliform, cfu = Colony Forming Unit, MCMX = Measurement: Concentration Maximum, MCAV = Measurement: Concentration Average 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 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
10495-002	1007B_01	42	3/1/2001	11/27/2003	23	14,290
10495-003	1007B_01	66	2/20/2001	12/1/2003	30	19,964
10495-037	1007B_01	90	2/25/2001	10/22/2003	22	24,690
10495-090	1007B_01	1	6/27/2001	6/28/2001	11,288	11,288
10495-095	1007B_01	7	3/2/2001	11/12/2003	78	9,000
10495-109	1007B_01	1	10/11/2003	10/11/2003	75	75
10495-111	1007B_01	40	2/22/2001	11/23/2003	32	31,240
10495-116	1007B_01	18	6/19/2001	8/12/2003	55	22,200
10495-119	1007B_01	50	2/16/2001	11/12/2003	11	15,000
14418-001	1007B_01	1	11/5/2002	11/7/2002	9,687	9,687
10495-037	1007C_01	8	4/19/2001	4/10/2003	55	2,664
10495-095	1007C_01	2	6/14/2001	12/24/2001	910	1,658
10495-119	1007C_01	11	2/25/2001	11/18/2003	156	6,496
10495-037	1007E_01	41	3/1/2001	10/28/2003	15	9,787
10495-037	1007L_01	12	4/5/2001	9/1/2003	99	27,200

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:

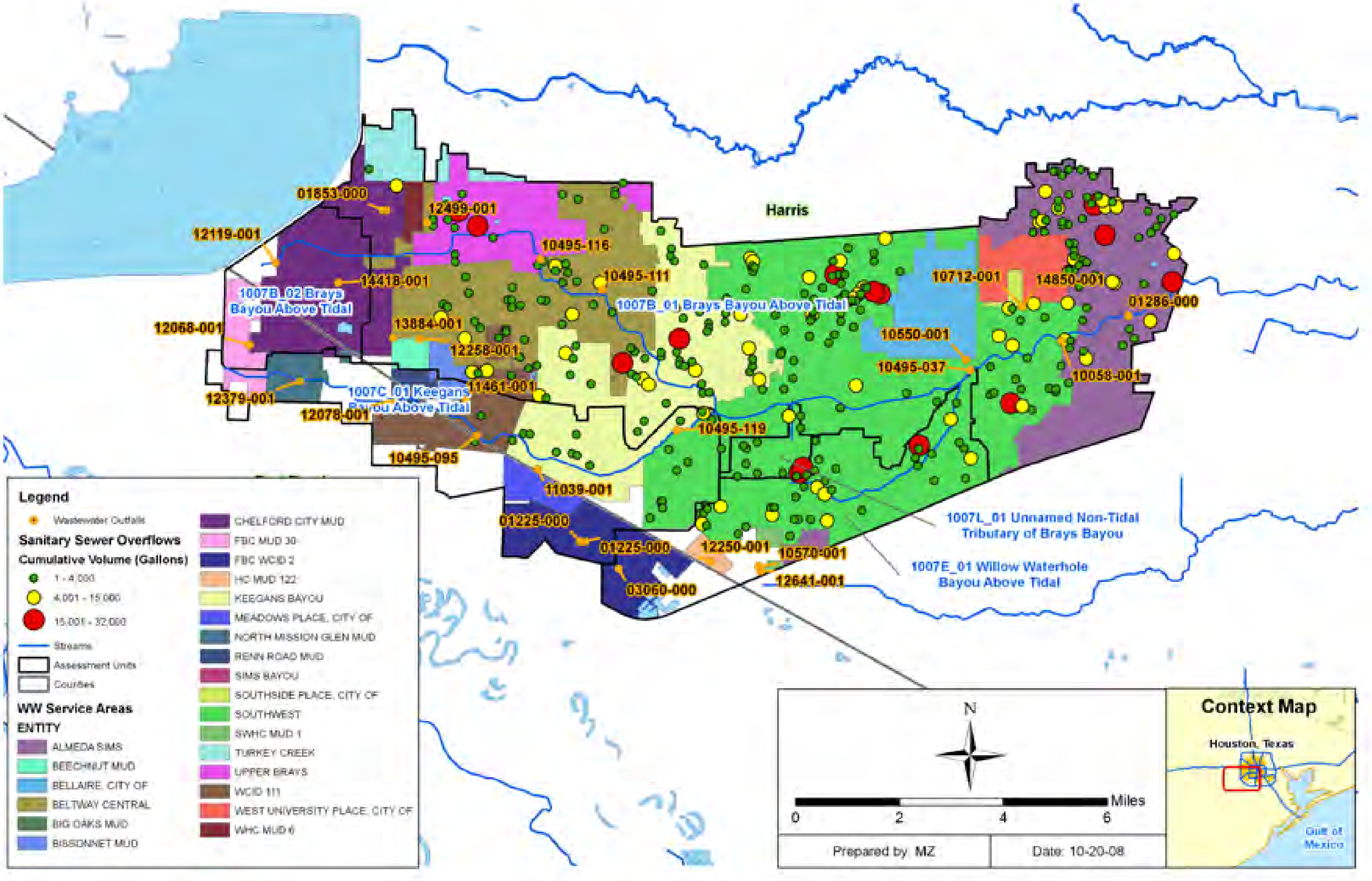

Figure 7. Sanitary Sewer Overflows in the TMDL Area Watershed

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 Assessment Unit under MS4 Jurisdiction
1007B_01	Brays Bayou Above Tidal	WQ0004685000	42,053	42,053	100%
1007B_02	Brays Bayou Above Tidal	WQ0004685000	4,354	4,267	98%
1007C_01	Keegans Bayou Above Tidal	WQ0004685000	11,590	11,196	97%
1007E_01	Willow Waterhole Bayou Above Tidal	WQ0004685000	8,056	8,056	100%
1007L_01	Unnamed Non-Tidal Tributary of Brays Bayou	WQ0004685000	888	888	100%

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 Brays 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 Brays Bayou watershed.

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 riparian corridors in particular. However, for Brays 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 Brays 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 8 displays un-sewered 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 un-sewered area were then totaled by TMDL watershed. This approach gives an estimate of OSSFs in the watershed. Table 11 shows the estimated number of OSSFs calculated using this GIS method. 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):

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

Table 11. Estimated Number of OSSFs and Fecal Coliform Load in the TMDL Area Watershed

Segment	Stream Name	OSSF Estimate using 1990 Census method	Number of Failing Septic Tanks[a]	Potential Violation Database[b]	Estimated Loads from Septic Tanks (Billion cfu/day)[c]
1007B_01	Brays Bayou Above Tidal	5	1	0	5
1007B_02	Brays Bayou Above Tidal	1	0.1	0	1
1007C_01	Keegans Bayou above tidal	120	14	0	72
1007E_01	Willow Waterhole Bayou Above Tidal	19	2	0	10
1007L_01	Unnamed Non-Tidal Tributary of Brays Bayou	0	0	0	0

[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.

The average number of people per household was calculated to be 1.94 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 11. 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.

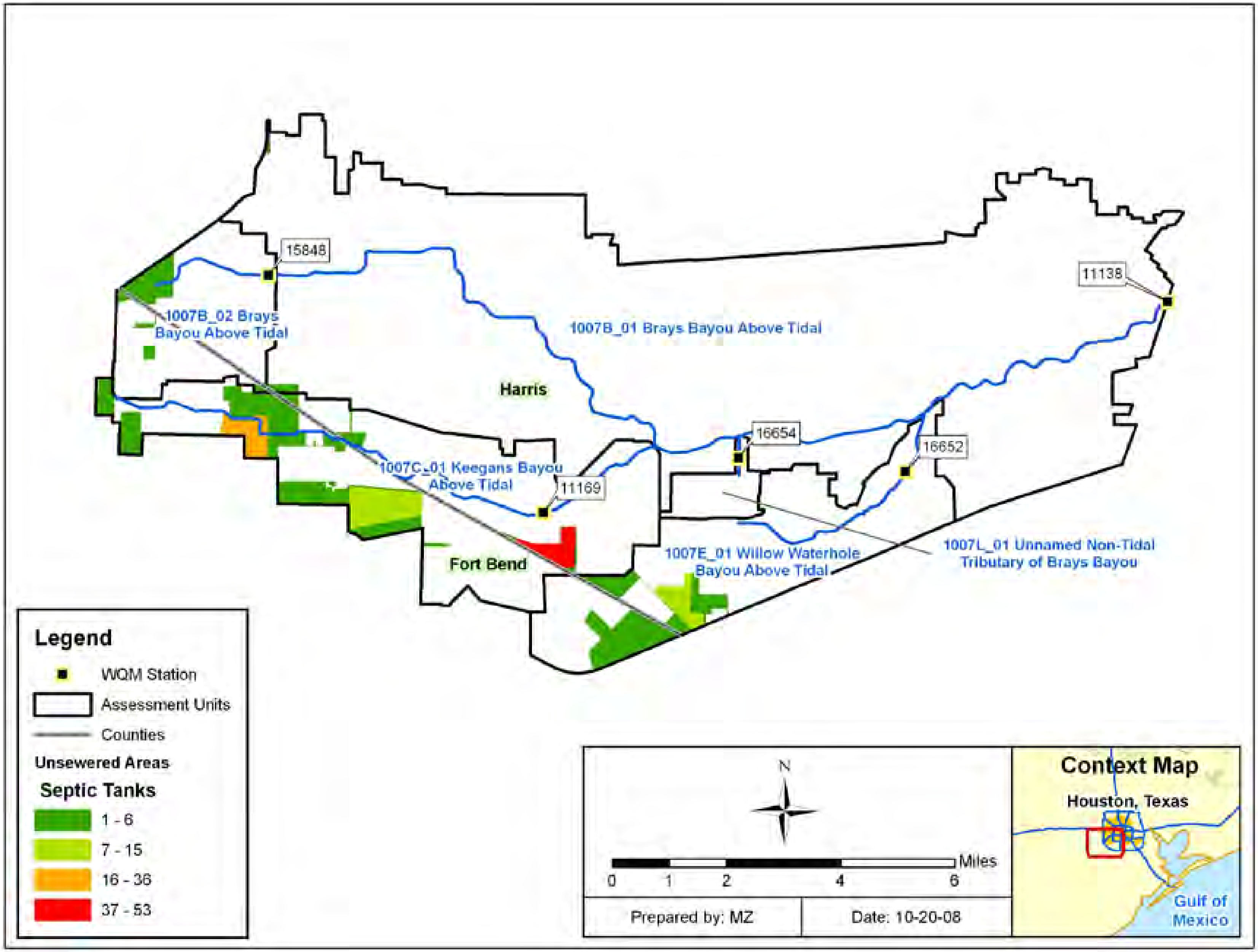

Figure 8. Areas and Subdivisions without Sewers and with OSSF in the TMDL Area Watershed

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 12 summarizes the estimated number of dogs and cats for the watersheds of the TMDL area watershed.

Table 13 provides an estimate of the fecal coliform load from domestic dogs and cats. These estimates are based on estimated fecal coliform production rates of $5.4x10^8$ cfu per day for cats and $3.3x10^9$ 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 12. Estimated Numbers of Pets in the TMDL Area Watershed

Segment	Stream Name	Dogs	Cats
1007B_01	Brays Bayou Above Tidal	120,874	137,546
1007B_02	Brays Bayou Above Tidal	10,753	12,236
1007C_01	Keegans Bayou Above Tidal	24,964	28,407
1007E_01	Willow Waterhole Bayou Above Tidal	17,775	20,227
1007L_01	Unnamed Non-Tidal Tributary of Brays Bayou	7,751	8,820

Table 13. Estimated Fecal Coliform Daily Production by Pets (in Billion cfu)

Segment	Stream Name	Dogs	Cats	Total
1007B_01	Brays Bayou Above Tidal	398,883	74,275	473,158
1007B_02	Brays Bayou Above Tidal	35,484	6,607	42,091
1007C_01	Keegans Bayou Above Tidal	82,380	15,340	97,720
1007E_01	Willow Waterhole Bayou Above Tidal	58,658	10,923	69,581
1007L_01	Unnamed Non-Tidal Tributary of Brays Bayou	25,579	4,763	30,342

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 sludge. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both processes (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 (FDC) 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, 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.

Estimation of flows within the TMDL area watershed is necessary because there is a lack of long-term flow data. Therefore, USGS gauge station 08075000 (Brays Bayou at Houston, Texas), which is located inside the watershed, 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 14.

The low flow category was derived by calculating the percentage of bayou flows contributed by WWTFs using the long-term average reported flows. These percentages varied by AU, resulting in different ranges for the low-flow (and corresponding mid-range flow) categories. 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.

Table 14. Hydrologic Classification Scheme

Assessment Unit	Hydrologic Condition Class		
	Highest Flows (%)	Mid-range Flows (%)	Lowest Flows (%)
1007B_01	0-20	20-50	50-100
1007B_02	0-20	20-70	70-100
1007C_01	0-20	– [a]	20-100
1007E_01	0-20	20-80	80-100
1007L_01	0-20	20-80	80-100

[a] WWTFs provide continuous flows to this AU above the 19th percentile, so there is no mid-range flow condition

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

Brays Bayou Above Tidal

The LDC for Brays Bayou Above Tidal AU1007B_01 (Figure 9) is based on *E. coli* bacteria measurements at sampling location 11138 (Brays Bayou at Alameda Road). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion 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 generally dry conditions. The geometric mean of existing *E. coli* data within each flow range is shown by yellow dots on this LDC and the ones that follow.

The LDC for Brays Bayou Above Tidal AU 1007B_02 (Figure 10) is based on *E. coli* bacteria measurements at sampling location 15848 (Brays Bayou at SH 6). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion under all flow conditions. Wet weather influenced *E. coli* observations are found 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}.

Keegans Bayou Above Tidal

The LDC for Keegans Bayou Above Tidal AU 1007C_01 (Figure 11) is based on *E. coli* bacteria measurements at sampling location 11169 (Keegans Bayou at Roark Road). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion under all conditions. Wet weather influenced *E. coli* observations are found 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}.

Willow Waterhole Bayou Above Tidal

The LDC for Willow Waterhole Bayou Above Tidal AU 1007E_01 (Figure 12) is based on *E. coli* bacteria measurements at sampling location 16652 (Willow Waterhole at McDermed). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion 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 generally dry 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 Non-Tidal Tributary of Brays Bayou

The LDC for Unnamed Non-Tidal Tributary of Brays Bayou AU 1007L_01 (Figure 13) is based on *E. coli* bacteria measurements at sampling location 16654 (Trib Brays Bayou at Dumfries). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion under all flow conditions. Wet weather influenced *E. coli* observations are found under mid-range and high flow conditions.

Margin of Safety

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

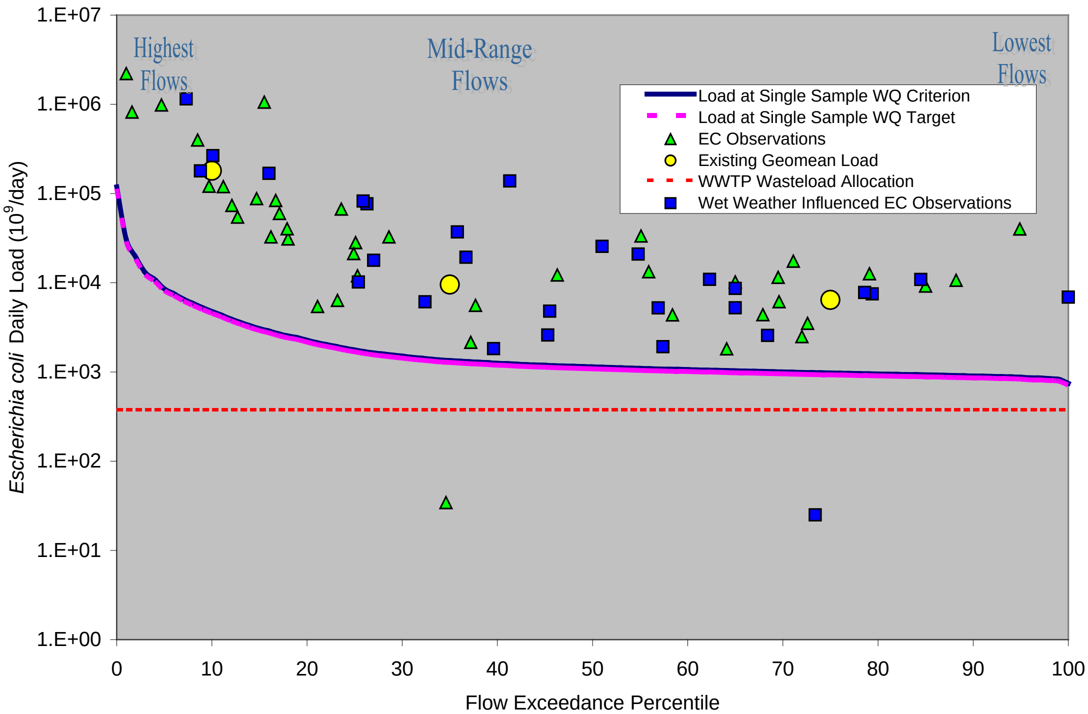

Figure 9. Load Duration Curve for *E. coli* in Brays Bayou Above Tidal (1007B_01)

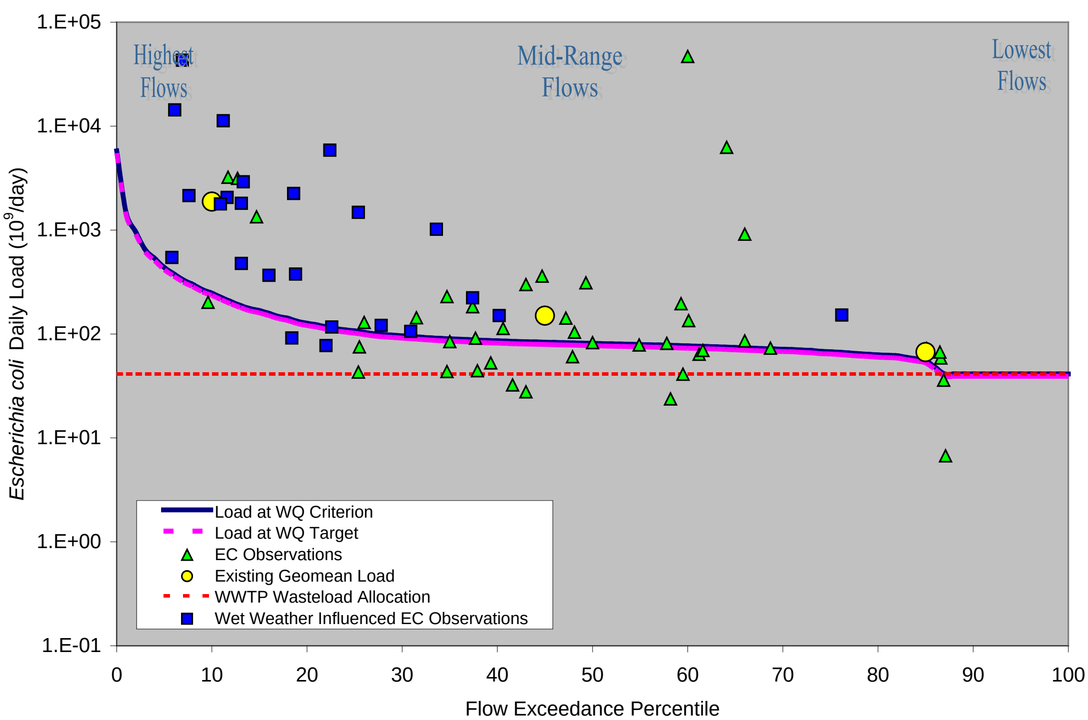

Figure 10. Load Duration Curve for Brays Bayou Above Tidal (1007B_02)

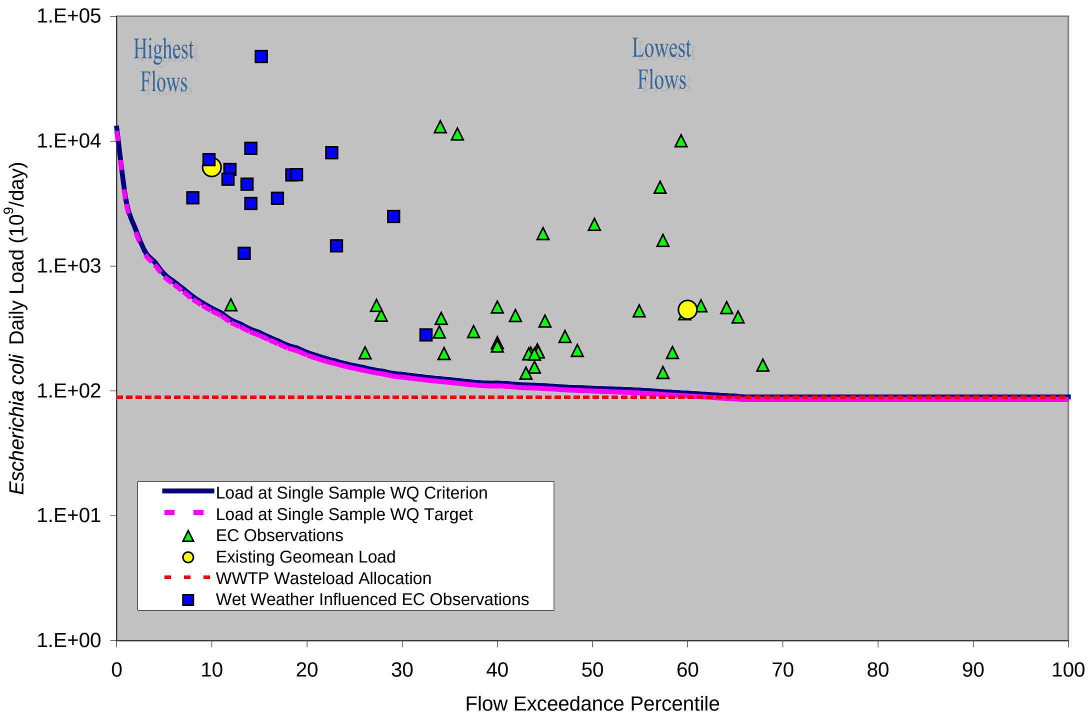

Figure 11. Load Duration Curve for Keegans Bayou Above Tidal (1007C_01)

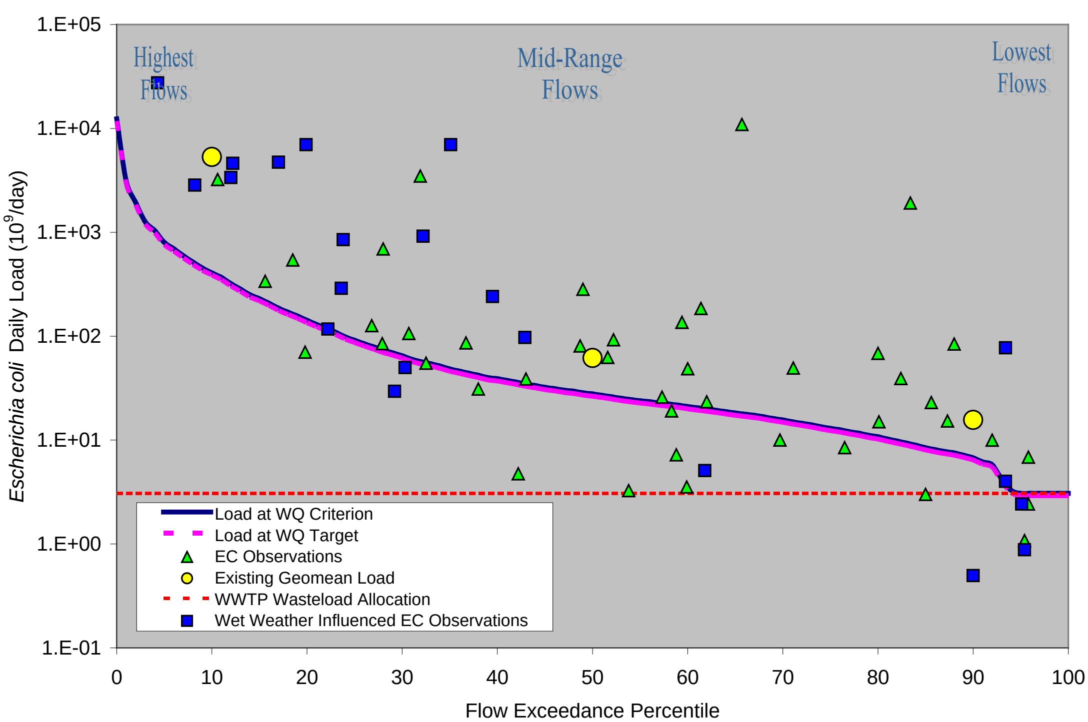

Figure 12. Load Duration Curve for Willow Waterhole Bayou Above Tidal (1007E_01)

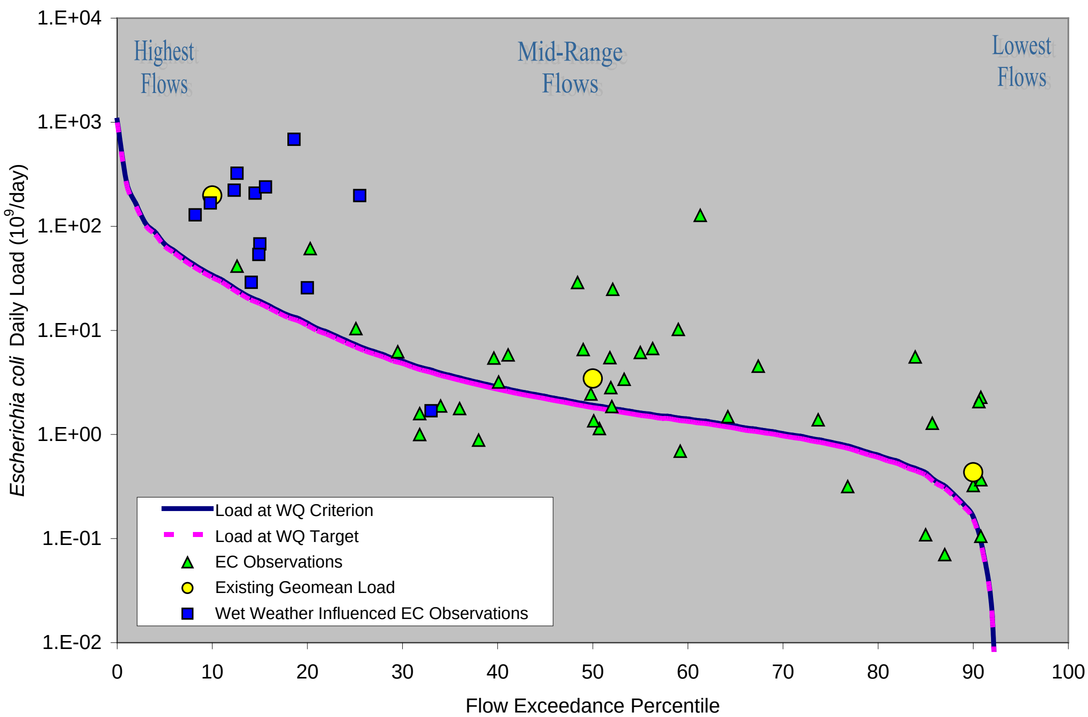

Figure 13. Load Duration Curve for Unnamed Non-Tidal Tributary of Brays Bayou (1007L_01)

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:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

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. The TMDL calculation for AU 1007B_01 was completed using total flows at the end of the AU (i.e. flows from upstream AUs are included).

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 15 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 Brays 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 15. Waste Load Allocations for TPDES-Permitted Facilities

Receiving Water	Assessment Unit	TPDES Number	Outfall	NPDES NUMBER	Facility Name	Final Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
Brays Bayou Above Tidal	1007B_01	01286-000	001	TX0008851	Texas Medical Center Central Heating & Cooling Services Corp.	0.95	2.27
Brays Bayou Above Tidal	1007B_01	01853-000	001	TX0052761	Shell Chemical LP & Equilon Enterprises LLC	0.475	1.13
Brays Bayou Above Tidal	1007B_01	01853-000	002	TX0052761	Shell Chemical LP & Equilon Enterprises LLC	0.5	1.19
Brays Bayou Above Tidal	1007B_01	10058-001	001	TX0023841	City of West University Place	2	4.77
Brays Bayou Above Tidal	1007B_01	10495-037	001	TX0062995	City of Houston (Southwest)	60	143
Brays Bayou Above Tidal	1007B_01	10495-111	001	TX0065307	City of Houston	13.34	31.8
Brays Bayou Above Tidal	1007B_01	10495-116	001	TX0088153	City of Houston	18	42.9
Brays Bayou Above Tidal	1007B_01	10550-001	001	TX0020613	City of Bellaire	4.5	10.7
Brays Bayou Above Tidal	1007B_01	14850-001	001	TX0026972	City of Southside Place	0.265	0.632
Brays Bayou Above Tidal	1007B_01	12258-001	001	TX0084425	Beechnut MUD	1.38	3.29
Brays Bayou Above Tidal	1007B_01	12499-001	001	TX0089621	West Harris County MUD 6	0.5	1.19
Brays Bayou Above Tidal	1007B_01	13884-001	001	TX0119474	Nguyen, Loc Dac	0.025	0.0596
Brays Bayou Above Tidal	1007B_02	12068-001	001	TX0078751	Fort Bend County MUD 30	1.5	3.58
Brays Bayou Above Tidal	1007B_02	12119-001	001	TX0079359	West Harris County MUD 4	0.28	0.668
Brays Bayou Above Tidal	1007B_02	14418-001	001	TX0056481	Chelford City MUD	15.5	37
Keegans Bayou Above Tidal	1007C_01	01225-000	001	TX0003824	Texas Instruments Inc.	1.5	3.58
Keegans Bayou Above Tidal	1007C_01	01225-000	002	TX0003824	Texas Instruments Inc.	1.5[a]	[b]
Keegans Bayou Above Tidal	1007C_01	10495-095	001	TX0027201	City of Houston	7.2	17.2

Receiving Water	Assessment Unit	TPDES Number	Outfall	NPDES NUMBER	Facility Name	Final Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
Keegans Bayou Above Tidal	1007C_01	10495-119	001	TX0098191	City of Houston	23.1	55.1
Keegans Bayou Above Tidal	1007C_01	11039-001	001	TX0053872	City of Meadows Place	1.5	3.58
Keegans Bayou Above Tidal	1007C_01	11461-001	001	TX0056952	Bissonnet MUD	0.6	1.43
Keegans Bayou Above Tidal	1007C_01	12078-001	001	TX0078964	Renn Road MUD	2.5	5.96
Keegans Bayou Above Tidal	1007C_01	12379-001	001	TX0087271	North Mission Glen MUD	1.18	2.81
Willow Waterhole Bayou Above Tidal	1007E_01	03060-001	001	TX0104540	Weatherford Farms Inc.	0.036	0.0859
Willow Waterhole Bayou Above Tidal	1007E_01	10570-001	001	TX0020052	Harris County WCID - Fondren Road	0.6	1.43
Willow Waterhole Bayou Above Tidal	1007E_01	12250-001	001	TX0084484	Harris County MUD 122	0.25	0.596
Willow Waterhole Bayou Above Tidal	1007E_01	12641-001	001	TX0091979	Southwest Harris County MUD 1	0.4	0.954

[a] The total of both outfalls combined cannot exceed 1.5 MGD

[b] Total allocated load included in outfall 01 (previous row)

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 Update. 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 margin of safety. 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 16 shows the population increases in each of the five TMDL AUs based on the population projections from the H-GAC report. The population increases range from 4 percent to 25 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).

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 to address 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.

Table 16. Population Projection per Subwatershed

Stream Name	Assessment Unit	2005 Population	2035 Population	Population Increase	Median Flow for TMDL Calculations (cfs)*
Brays Bayou Above Tidal	1007B_01	438,120	498,328	14%	776
Brays Bayou Above Tidal	1007B_02	31,557	39,361	25%	52.5
Keegans Bayou above Tidal	1007C_01	85,170	97,237	14%	106
Willow Waterhole Bayou Above Tidal	1007E_01	64,083	71,869	12%	42.2
Unnamed Non-Tidal Tributary of Brays Bayou	1007L_01	12,894	13,380	4%	3.52

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

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 five AUs included in this project are summarized in Table 17. The TMDLs were calculated based on the median flow in the 0-20 flow-exceedance percentile range. The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 are presented in Table 18. In Table 18, 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 18. Figures A-1 through A-5 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-5, 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.

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing historical bacteria concentrations collected in the warmer months against those collected during the cooler months. Overall, this analysis of fecal coliform and *E. coli* data demonstrates that there is no significant difference in indicator bacteria between cool and warm weather seasons.

Table 17. *E. coli* TMDL Summary Calculations for Brays Bayou AUs

Assessment Unit	Sampling Location	Stream Name	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billion MPN/day)	$WLA_{StormWater}$[d] (Billion MPN/day)	LA[e] (Billion MPN/day)	MOS[g] (Billion MPN/day)	Future Growth[h] (Billion MPN/day)
1007B_01	11138	Brays Bayou Above Tidal	2,390	377[c]	1,830	9.06[f]	120	56.7
1007B_02	15848		162	41.2	100	2.05	8.09	10.2
1007C_01	11169	Keegans Bayou above Tidal	325	89.6	200	7.01	16.3	12.7
1007E_01	16652	Willow Waterhole Bayou Above Tidal	130	3.07	120	0	6.49	0.373
1007L_01	16654	Unnamed Non-Tidal Tributary of Brays Bayou	10.8	0	10.3	0	0.542	0

[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 to the segment. Individual loads are calculated as permitted flow * 126/2 (*E. coli*) MPN/100mL*conversion factor

[c] The WLA_{WWTF} for 1007B_01 includes all the facilities discharging upstream of station 11138. 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] Sum of LAs from upstream AUs discharging to this AU (1007B_02, 1007C_01, 1007E_01, and 1007L_01)

[g] MOS = TMDL x 0.05

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

Table 18. 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)
1007B_01	2,390	434	1,830	9.06	120
1007B_02	162	51.4	100	2.05	8.09
1007C_01	325	102	200	7.01	16.3
1007E_01	130	3.44	120	0	6.49
1007L_01	10.8	0	10.3	0	0.542

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

[b] WLA_{WWTF}= WLA_{WWTF} + 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 Brays Bayou Bacteria TMDL and the implementation phase, a public meeting was held on October 16, 2007, at the Sharpstown Community Center. The meeting 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 meeting gave TCEQ the opportunity to solicit input from all interested parties within the study area. A similar meeting was held on November 2, 2007, at the West University City Hall. In addition, an informational open house was held at the Bayland Community Center on November 11, 2008. Information on past and future meetings for the Brays 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 19). The draft area-wide I-Plan, which will include the Brays Bayou watershed, is expected to be completed in August 2010.

Table 19. 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 *Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou Above Tidal and Tributaries* 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 an 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; and

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

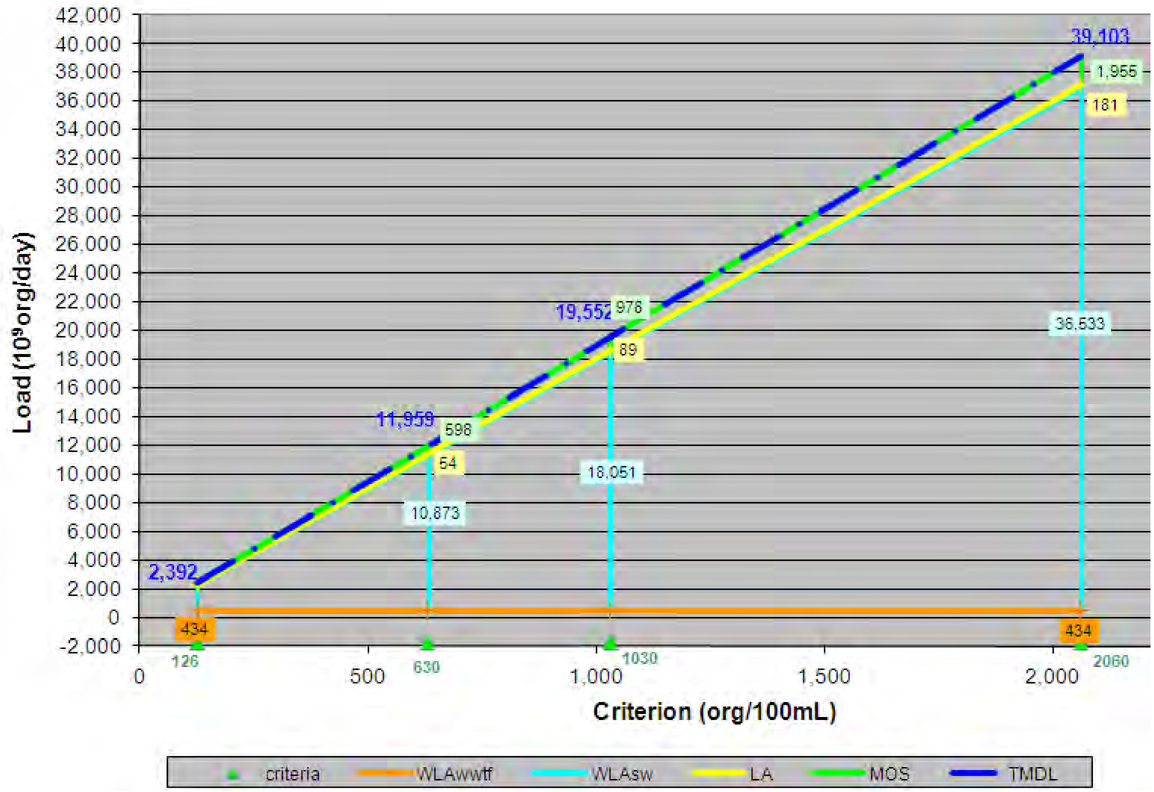

Figure A-1. Allocation Loads for AU 1007B_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 18.982*Std
LA = 0.0888*Std - 2.1362
$WLA_{StormWater}$ = 17.944*Std - 431.53
WLA_{WWTF} = 63*6.884 = 434
MOS = 0.05*TMDL

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

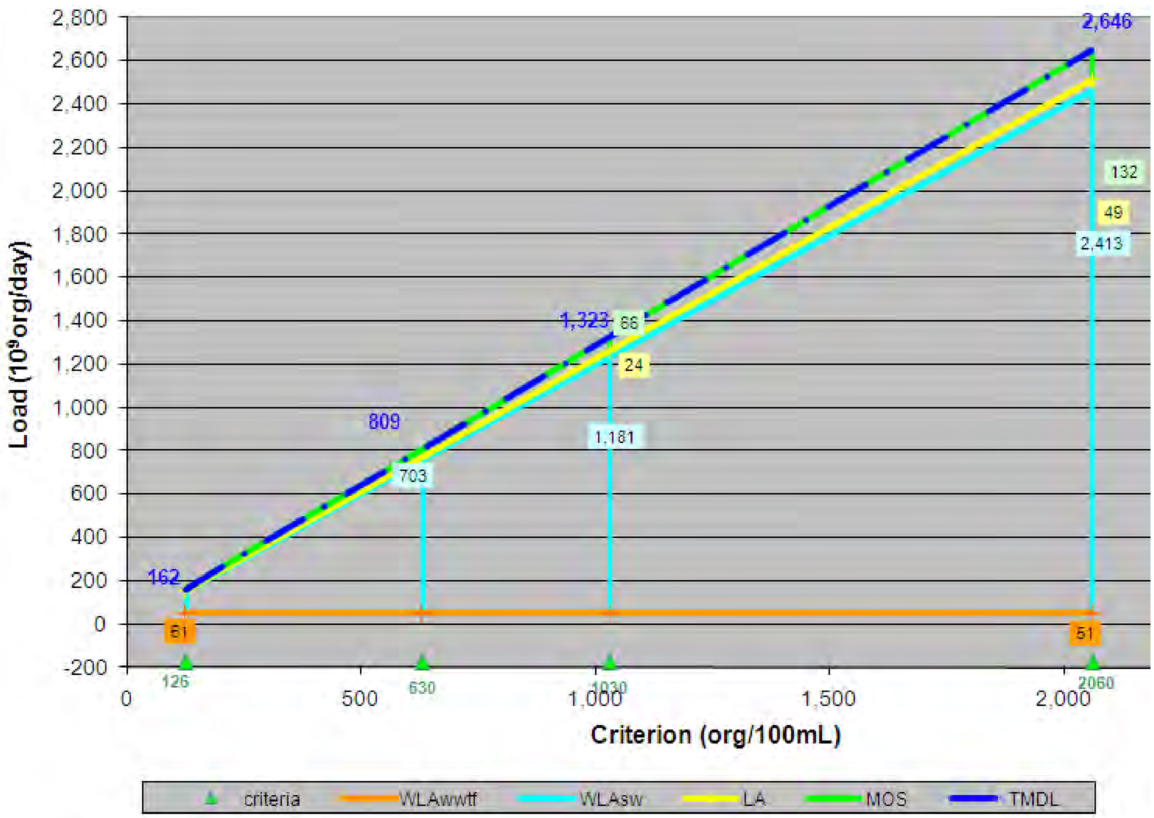

Figure A-2. Allocation Loads for AU 1007B_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 1.2845*Std
LA = 0.0244*Std - 1.028
$WLA_{StormWater}$ = 1.1959*Std - 50.373
WLA_{WWTF} = 63*0.8159 = 51
MOS = 0.05*TMDL

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

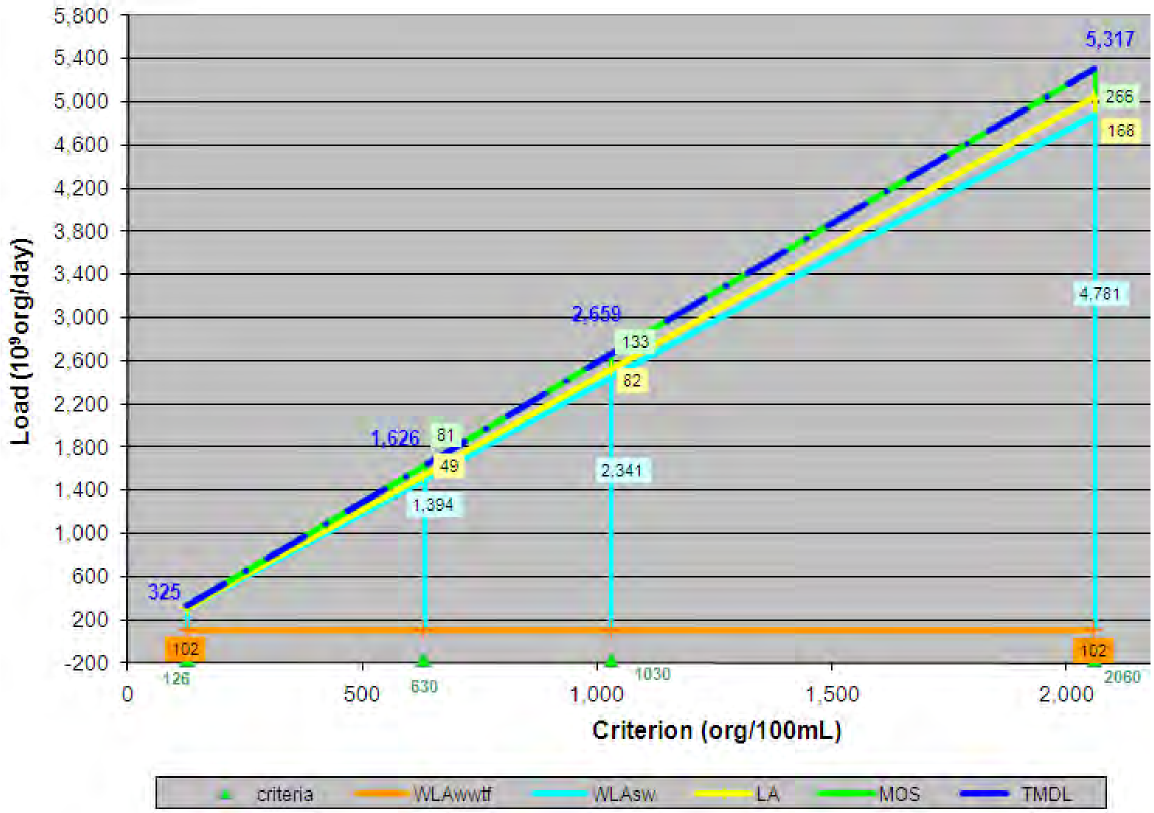

Figure A-3. Allocation Loads for AU 1007C_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 2.5812*Std
LA = 0.0832*Std - 3.417
$WLA_{StormWater}$ = 2.369*Std - 98.848
WLA_{WWTF} = 63* = 102
MOS = 0.05*TMDL

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

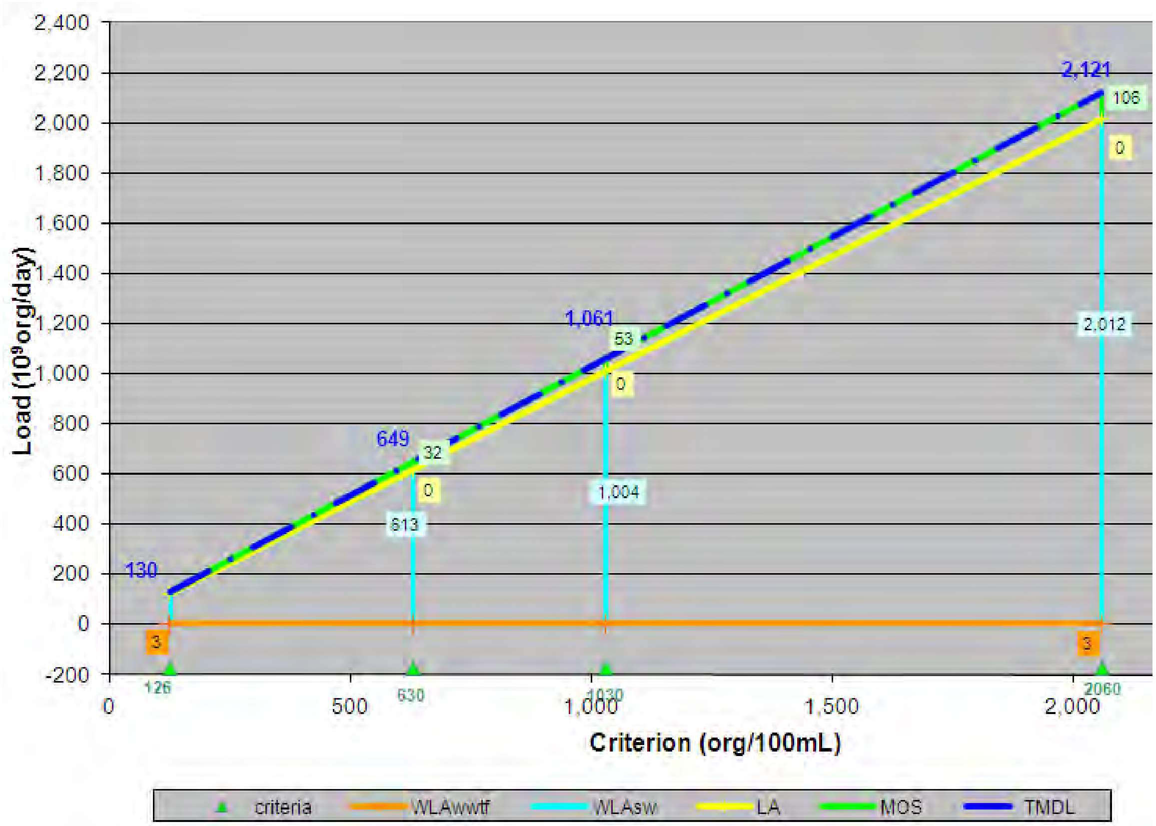

Figure A-4. Allocation Loads for AU 1007E_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 1.0297*Std
LA = 0
$WLA_{StormWater}$ = 0.9782*Std - 3.4395
WLA_{WWTF} = 63*0.0546 = 3
MOS = 0.05*TMDL

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

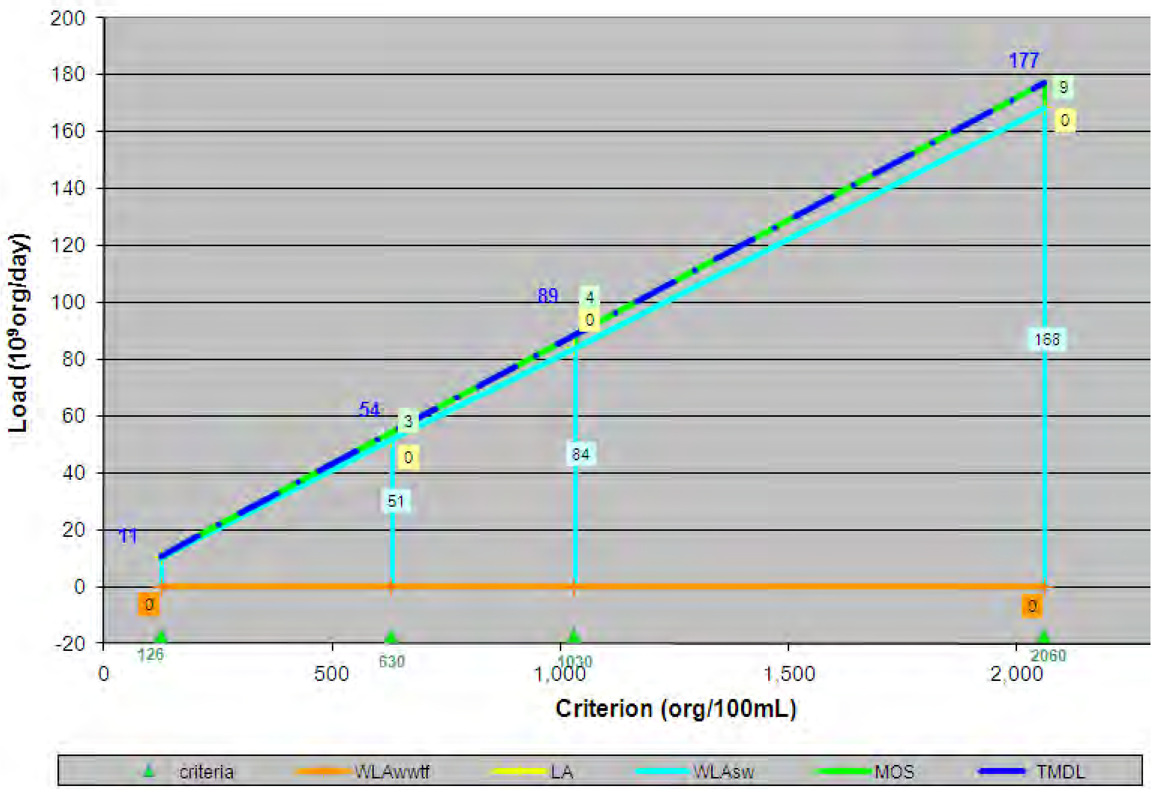

Figure A-5. Allocation Loads for AU 1007L_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.086*Std
LA = 0
$WLA_{StormWater}$ = 0.0817*Std
WLA_{WWTF} = 0
MOS = 0.05*TMDL

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