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Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston

Segments: 1004E, 1008, 1008H, 1009, 1009C, 1009D, 1009E, 1010, and 1011

Assessment Units: 1004E_02, 1008_02, 1008_03, 1008_04, 1008H_01, 1009_01, 1009_02, 1009_03, 1009_04, 1009C_01, 1009D_01, 1009E_01, 1010_02, 1010_04, and 1011_02

Prepared by the
Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203, P.O. Box 13087
Austin, Texas 78711-3087
TMDL project reports are available on the TCEQ Web site at:
www.tceq.texas.gov/implementation/water/tmdl/

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These TMDLs are based in large part on the report titled
"Technical Support Document for Indicator Bacteria Total Maximum Daily Loads, Lake Houston Watershed, San Jacinto River Basin"
prepared by James Miertschin & Associates, Inc.

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List of Acronyms

ASAE	American Society of Agricultural Engineers
AU	assessment unit
BMP	best management practice
CAFO	concentrated animal feeding operation
CFR	Code of Federal Regulations
CFU	colony-forming units
CFS	cubic feet per second
EPA	Environmental Protection Agency (U.S.)
FDC	flow duration curve
HCFCD	Harris County Flood Control District
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
MRLC	Multi-Resolution Land Characteristics
MS4	municipal separate storm sewer system
MUD	municipal utility district
NEIWPCC	New England Interstate Water Pollution Control Commission
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
OSSF	onsite sewage facility
SSO	sanitary sewer overflow
SWPPP	storm water pollution prevention plan
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSHA	Texas State Historical Association
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	waste load allocation
WQM	water quality monitoring
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston

Executive Summary

This document describes total maximum daily loads (TMDLs) for watersheds upstream of Lake Houston, 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 1996 and 2006 Texas 303(d) lists.

The stream segments addressed by this project are located within the Lake Houston watershed of the San Jacinto River Basin. The southern portion of the watershed includes portions of the City of Houston and its northern suburbs. The Woodlands and the City of Conroe are the largest municipalities located entirely within the watershed. The northern portions of the watershed are relatively rural and include portions of the Sam Houston National Forest. The total drainage area for Lake Houston is 2,850 square miles. The TMDL watersheds are located primarily within Harris and Montgomery Counties, but also include portions of Grimes, Liberty, San Jacinto, Walker, and Waller Counties.

As described in the TCEQ's "2008 Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data" (TCEQ 2008), the TCEQ required 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 ("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 (2000-2007) for 25 select TCEQ water quality monitoring stations in the Lake Houston watersheds were examined, including some stations in unimpaired AUs within the watershed. Almost all of the stations failed to meet water quality standards for *E. coli*. The geometric means for *E. coli* for stations within the impaired AUs ranged from 210 MPN/100mL to 950 MPN/100mL.

The most probable sources of indicator bacteria causing exceedances 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 (LDC) 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 WWTFs 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. In addition, an allowance for future growth is included in the TMDL equation. This includes increased WWTF flow due to projected population increases in the watersheds through 2035.

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.

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 watersheds upstream of Lake Houston.

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

Upon EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan.

Problem Definition

The TCEQ first identified the impairments to the contact recreation use for watersheds upstream of Lake Houston in the 1996 and 2006 versions of the *Texas Water Quality Inventory and 303(d) List* (1996 and 2006 Inventory and List). All of these segments (Table 1) are freshwater bodies located north of the Houston area (Figure 1). In this document, the area that contains all of these segments will also 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	AUs	First Year Listed
1004E	Stewarts Creek	Freshwater	1004E _02	2006
1008	Spring Creek	Freshwater	1008_02, 1008_03, 1008_04	1996
1008H	Willow Creek	Freshwater	1008H _01	2006
1009	Cypress Creek	Freshwater	1009_01, 1009_02, 1009_03, 1009_04	1996
1009C	Faulkey Gully	Freshwater	1009C _01	2006
1009D	Spring Gully	Freshwater	1009D _01	2006
1009E	Little Cypress Creek	Freshwater	1009E _01	2006
1010	Caney Creek	Freshwater	1010_02, 1010_04	2006
1011	Peach Creek	Freshwater	1011_02	2006

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

As described in the TCEQ's "2008 Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data" (TCEQ 2008), the TCEQ required 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 watersheds upstream of Lake Houston. *E. coli* is typically not pathogenic. Its presence in water indicates potential contamination from the feces of warm-blooded animals. The use of indicator bacteria is necessary because it is not currently feasible to directly measure all potential pathogens in water.

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).

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.

Ambient Indicator Bacteria Concentrations

Table 2 summarizes the historical ambient water quality data for indicator bacteria (2000-2007) for select TCEQ water quality monitoring stations in watersheds upstream of Lake Houston. All data in Table 2 correspond to *E. coli* concentrations.

Watershed Overview

The streams addressed by this project are located within the Lake Houston watershed of the San Jacinto River Basin. The southern part of the watershed includes portions of the city of Houston and its northern suburbs. The Woodlands and the city of Conroe are the largest municipalities located entirely within the watershed. Other smaller municipalities located in the watershed include Cut and Shoot, Magnolia, New Waverly, Pinehurst, Splendora, Tomball, and Waller. The northern part of the watershed is relatively rural, and includes portions of the Sam Houston National Forest.

The total drainage area for Lake Houston is 2,850 square miles. The TMDL watersheds are located primarily within Harris and Montgomery Counties, but also include portions of Grimes, Liberty, San Jacinto, Walker, and Waller Counties. Peach Creek forms the boundary between Montgomery County and San Jacinto County. Spring Creek is the boundary between much of Harris County and Montgomery County.

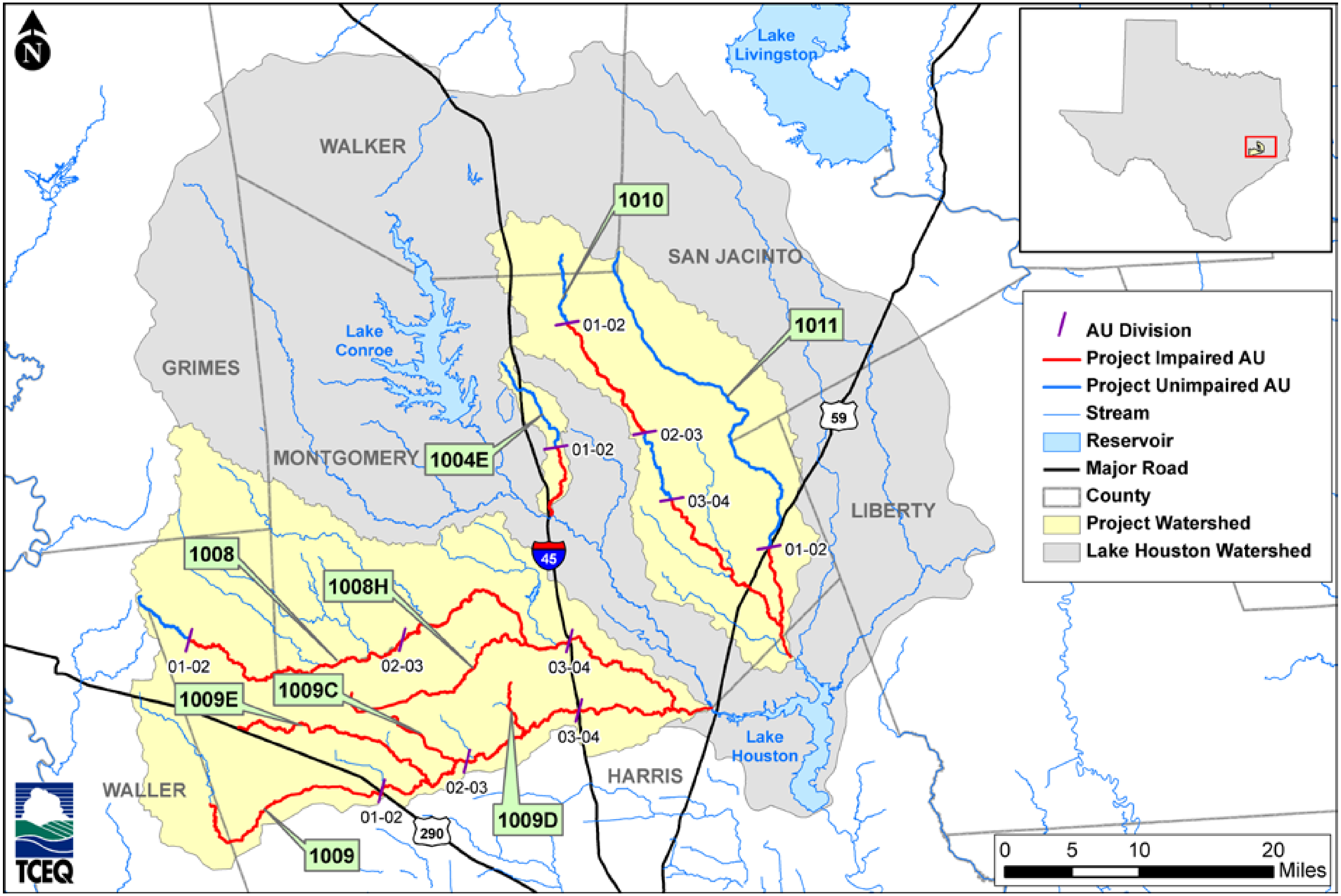


Figure 1. Lake Houston Watershed

Table 2. Historical Water Quality Data – June 2000 to December 2007

(*E. coli* in MPN/100 mL)

AU	Station ID	Geometric Mean Criteria	Geometric Mean Concen-tration	Single Sample Criteria	Number of Samples	Number of Samples Exceeding Single Sample Criteria	Percent of Samples Exceeding
1004E_02	16626	126	236	394	102	41	40%
1008_02	11323	126	345	394	71	26	37%
	11314	126	398	394	53	24	45%
1008_02 Summary		126	367	394	124	50	40%
1008_03	17489	126	414	394	69	27	39%
	11313	126	330	394	56	27	48%
1008_03 Summary		126	374	394	125	54	43%
1008_04	11312	126	538	394	65	33	50%
1008H_01	11185	126	462	394	69	33	48%
1009_01	11333	126	304	394	68	25	37%
1009_02	11332	126	364	394	90	35	39%
	11331	126	628	394	58	31	53%
1009_02 Summary		126	451	394	148	66	45%
1009_03	11330	126	950	394	70	43	61%
	11328	126	692	394	126	80	63%
1009_03 Summary		126	775	394	196	123	63%
1009_04	11324	126	448	394	29	11	38%
1009C_01	17496	126	628	394	69	31	45%
1009D_01	17481	126	687	394	70	44	63%
1009E_01	14159	126	544	394	68	38	56%
1010_02	14241	126	292	394	61	15	25%
1010_03*	11335	126	61	394	5	0	0%
1010_04	11334	126	210	394	143	40	28%
1011_01*	11337	126	164	394	5	1	20%
	11338	126	88	394	5	0	0%
	16625	126	126	394	57	13	23%
1011_01 Summary		126	125	394	67	14	21%
1011_02	11336	126	250	394	130	33	25%
	17746	126	253	394	16	6	38%
1011_02 Summary		126	250	394	146	39	27%

*Not on the 303(d) list, but included as other AUs within the segment are listed

The watershed is located within the Gulf Coastal Plain physiographic region. The southern portion of the watershed is relatively flat, and slopes toward the Gulf of Mexico. The northern portion of the watershed includes gently rolling hills where drainage patterns are more easily defined. The conservation-pool elevation of Lake Houston is 44.1 feet (above sea level); the conservation-pool elevation of Lake Conroe is 201 feet (TPWD 2009).

The watershed is also located entirely within the Gulf Coast Aquifer region. The aquifer consists of layers of clay, silt, sand, and gravel. The maximum total sand thickness of the aquifer is around 1,000 feet in the Houston area. Water extraction by pumping has resulted in significant decreases in aquifer levels and land-surface subsidence of up to nine feet in the Houston area (Ashworth 1995).

The Lake Houston watershed is within the Upper Coast and East Texas climatic divisions. The Gulf of Mexico is the principal source of moisture that drives precipitation in the region. Annual average precipitation generally increases from west to east across the watershed. Annual precipitation data (1997-2006) for key weather stations is provided in Table 3. These data were obtained through the EPA BASINS program (EPA 2007). In 2007, the annual precipitation totals at Tomball, Conroe, and George Bush Intercontinental Airport were 53.2, 50.5, and 65.5 inches, respectively (NWS 2008).

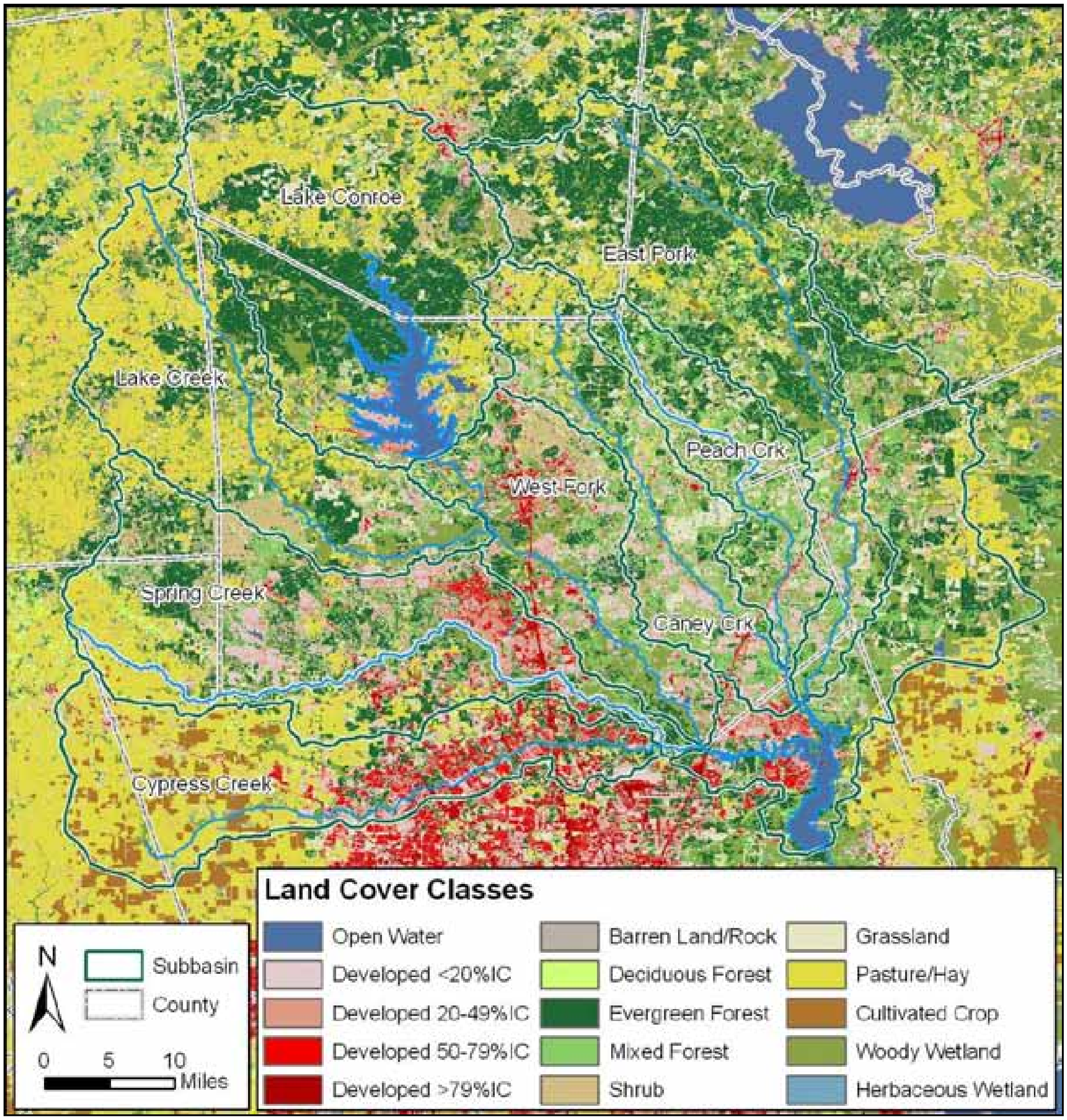
Table 3. Annual Rainfall Totals for Lake Houston Watershed (1997-2006)

Station ID	Location	Average (inches)
TX411810	Cleveland	57.2
TX411956	Conroe	51.1
TX412206	Cypress	50.2
TX414300	George Bush Intercontinental Airport	53.1
TX416024	Montgomery	47.7
TX416280	New Caney	55.4
TX419076	Tomball	51.3
Average		**52.3**

Temperature and precipitation in the study area vary throughout the year, with average temperatures in the low eighties in the summer to the low fifties in the winter. Maximum precipitation occurs in the late spring and autumn. It is not unusual for hurricanes to affect rainfall in the early autumn.

A land cover map of the watershed is provided in Figure 2, based on data from the 2001 National Land Cover Database developed by the USGS and partner agencies (MRLC 2001). Table 4 provides a summary of land cover data in the TMDL subwatersheds. The western portion of the watershed is primarily cropland and pasture. The central and south-central portions of the watershed are more heavily urbanized, while the eastern portion of the watershed is primarily forested.

Soil conditions vary throughout the Lake Houston watershed. In Montgomery County, surface soils are generally light-colored or reddish loams, with clayey and loamy subsoils. The northern portion of Harris County is also characterized by loamy soils (TSHA 2001). Figure 3 shows the soil associations of the Lake Houston watershed (NRCS 2007).



*IC = impervious cover

Figure 2. Lake Houston Watershed Land Use

Stream-flow data is key information when conducting water quality assessments. The U.S. Geological Survey (USGS) operates several flow gauges in the Lake Houston watershed to measure flow and gauge heights (Table 5). The locations of these gauge stations are shown in Figures 4 through 6. The period of flow record used in this study is 1999-2008.

The period of record has been limited to this most recent decade for three reasons. Recent development has altered hydrologic patterns in portions of the watershed, making older data uncharacteristic of current conditions. Second, the period of record for *E. coli* data (2000-2007) falls entirely within the time period. Third, several of the USGS gauging stations were inactive prior to this decade.

Table 4. Land Use Summaries

Aggregated Land Use Category	Seg 1004E	Seg 1008	Seg 1008H	Seg 1009	Seg 1009C	Seg 1009D	Seg 1009E	Seg 1010	Seg 1011
Open water	0%	1%	0%	0%	0%	1%	1%	0%	0%
Developed, Open	12%	11%	13%	11%	16%	22%	8%	12%	9%
Developed, Low	19%	9%	9%	8%	14%	10%	4%	5%	2%
Developed, Medium	6%	3%	3%	7%	14%	11%	3%	1%	0%
Developed, High	3%	1%	1%	2%	1%	1%	0%	0%	0%
Barren Land	0%	0%	0%	1%	2%	3%	0%	0%	0%
Deciduous Forest	0%	2%	4%	3%	3%	8%	5%	0%	1%
Evergreen Forest	13%	20%	23%	8%	18%	17%	7%	13%	22%
Mixed Forest	15%	10%	4%	1%	1%	3%	1%	23%	29%
Shrub/Scrub	17%	11%	3%	3%	1%	1%	3%	7%	9%
Grassland/Herbaceous	3%	5%	4%	2%	4%	8%	2%	14%	14%
Pasture Hay	1%	17%	31%	37%	24%	15%	47%	11%	1%
Cultivated Crops	0%	0%	1%	12%	0%	1%	13%	0%	0%
Woody Wetlands	11%	10%	2%	5%	3%	2%	6%	13%	12%
Herbaceous Wetlands	0%	0%	1%	1%	0%	1%	1%	0%	0%
Open water	43	1,603	102	776	4	23	226	625	167
Developed, Open	1,323	30,625	4,357	22,833	1,153	759	2,751	16,020	9,062
Developed, Low	2,111	26,399	3,084	16,007	991	335	1,382	7,571	2,255
Developed, Medium	660	8,010	1,097	14,787	1,027	371	1,195	1,577	401
Developed, High	301	1,839	378	3,336	45	18	110	313	63
Barren Land	40	1,094	142	1,434	135	90	81	305	133
Deciduous Forest	7	5,374	1,391	5,840	227	282	1,655	116	547
Evergreen Forest	1,463	57,568	7,559	15,810	1,292	612	2,405	17,448	21,764
Mixed Forest	1,729	26,879	1,189	2,557	77	91	305	31,251	29,494
Shrub/Scrub	1,867	30,879	890	5,865	56	19	935	10,015	9,217
Grassland/Herbaceous	369	12,702	1,419	5,123	268	276	887	18,993	14,068
Pasture Hay	140	49,008	10,266	77,456	1,716	517	16,782	14,992	1,317
Cultivated Crops	0	956	395	24,653	0	25	4,672	33	0
Woody Wetlands	1,207	27,910	821	9,786	228	67	2,019	18,369	12,347
Herbaceous Wetlands	3	948	189	2,186	13	36	242	357	156
Watershed Area (acres)	11,264	281,792	33,280	208,448	7,232	3,520	35,648	137,984	100,992

Key	Soil Association
s7158	Ozan-Atasco-Aldine
s7179	Brackett-Bolar-Aledo
s7192	Lake charles-Beaumont
s7198	Morey-Mocarey-Bernard
s7217	Splendora-Segno-Landman-Boy
s7249	Gessner-Clodine-Addicks
s7257	Conroe
s7286	Huntsburg-Fetzer-Depcor-Boy-Annona
s7324	Greenvine-Falba-Burlewash-Arol
s7333	Latium-Frelsburg-Crockett-Carbengle-Brenham-Bosque-Bleiblerville
s7349	Tonkavar-Shiro-Gomery-Elmina
s7351	Nahatche-Kaufman-Gowker
s7364	Nahatche-Hatliff
s7365	Pluck-Kian-Hatliff
s7374	Wockley-Segno-Monaville-Hockley
s7389	Katy-Clodine-Aris
s7392	Tinn-Kaufman-Gladewater

Key	Soil Association
s7398	Sealy-Kenney-Chazos
s7403	Waller-Sorter-Kirbyville
s7520	Waller-Otanya-Kirbyville-Dallardsville
s7551	Pinetucky-Doucette
s7650	Waller-Sorter
s7705	Woodville-Vamont
s7725	Woodville-Wiergate-Burkeville
s7740	Wockley-Hockley-Gessner
s7744	Woodville-Pinetucky

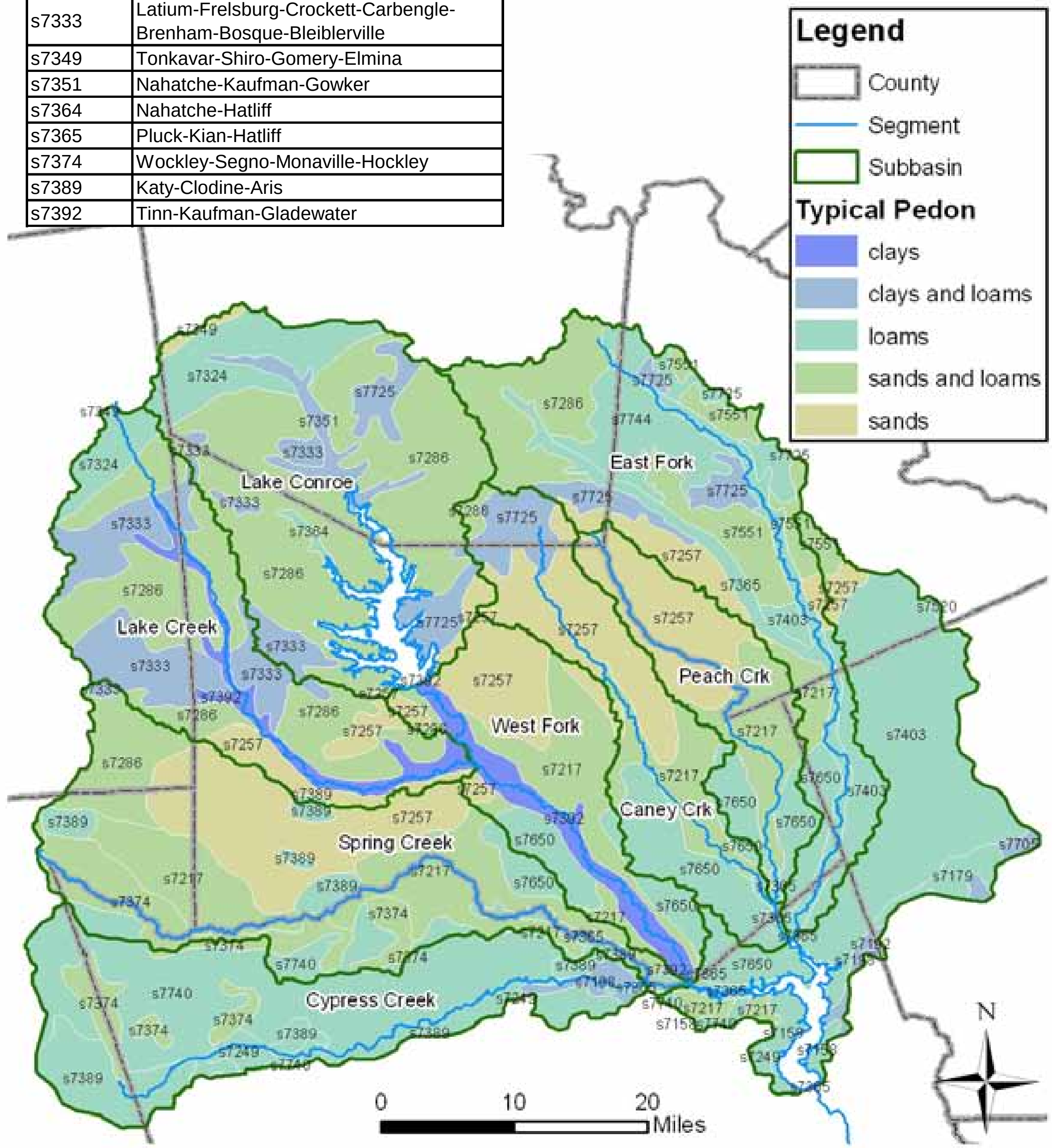


Figure 3. Lake Houston Watershed Soil Associations

Table 5. USGS Gauges in the Lake Houston Watershed

Station	Stream	Location	AU	Flow Records	Drainage Area (sq mi)	Median Flow** (cfs)	Median Flow/Area (cfs/sq mi)
08068275	Spring Creek	near Tomball, TX	Downstream end of 1008_02	1999-2008	186	12.5	0.07
08068325	Willow Creek	near Tomball, TX	Lower portion of 1008H_01	2006-2008	41	6.7	0.17
08068450	Panther Branch	near Spring, TX	Tributary to 1008_03	1972-1976, 1999-2008	33	19	0.57
08068500	Spring Creek	near Spring, TX	Upper portion of 1008_04	1939-2008	404	70	0.17
08068700	Cypress Creek	at Sharp Rd near Hockley, TX	Upper portion of 1009_01	none*	81	-	-
08068720	Cypress Creek	at Katy-Hockley Rd near Hockley, TX	Middle portion of 1009_01	1975-2008	105	1.9	0.02
08068740	Cypress Creek	at House-Hahl Rd near Cypress, TX	Lower portion of 1009_01	1975-2008	138	6.4	0.05
08068780	Little Cypress Creek	near Cypress, TX	Middle portion of 1009E_01	1982-1992, 1997-2008	43	1.3	0.03
08068800	Cypress Creek	at Grant Rd near Cypress, TX	Lower portion of 1009_02	1982-1992, 2001-2008	219	21	0.10
08068900	Cypress Creek	at Stuebner-Airline Rd near Westfield, TX	Middle portion of 1009_03	1987-1989	290	-	-
08069000	Cypress Creek	near Westfield, TX	Downstream end of 1009_03	1944-2008	290	63	0.22
08070500	Caney Creek	near Splendora, TX	Downstream end of 1010_03	1944-2008	105	31	0.30
08071000	Peach Creek	at Splendora, TX	Lower portion of 1011_01	1943-1977, 1999-2008	118	34	0.29

*gauge height data only
**For period of record: 1999-2008

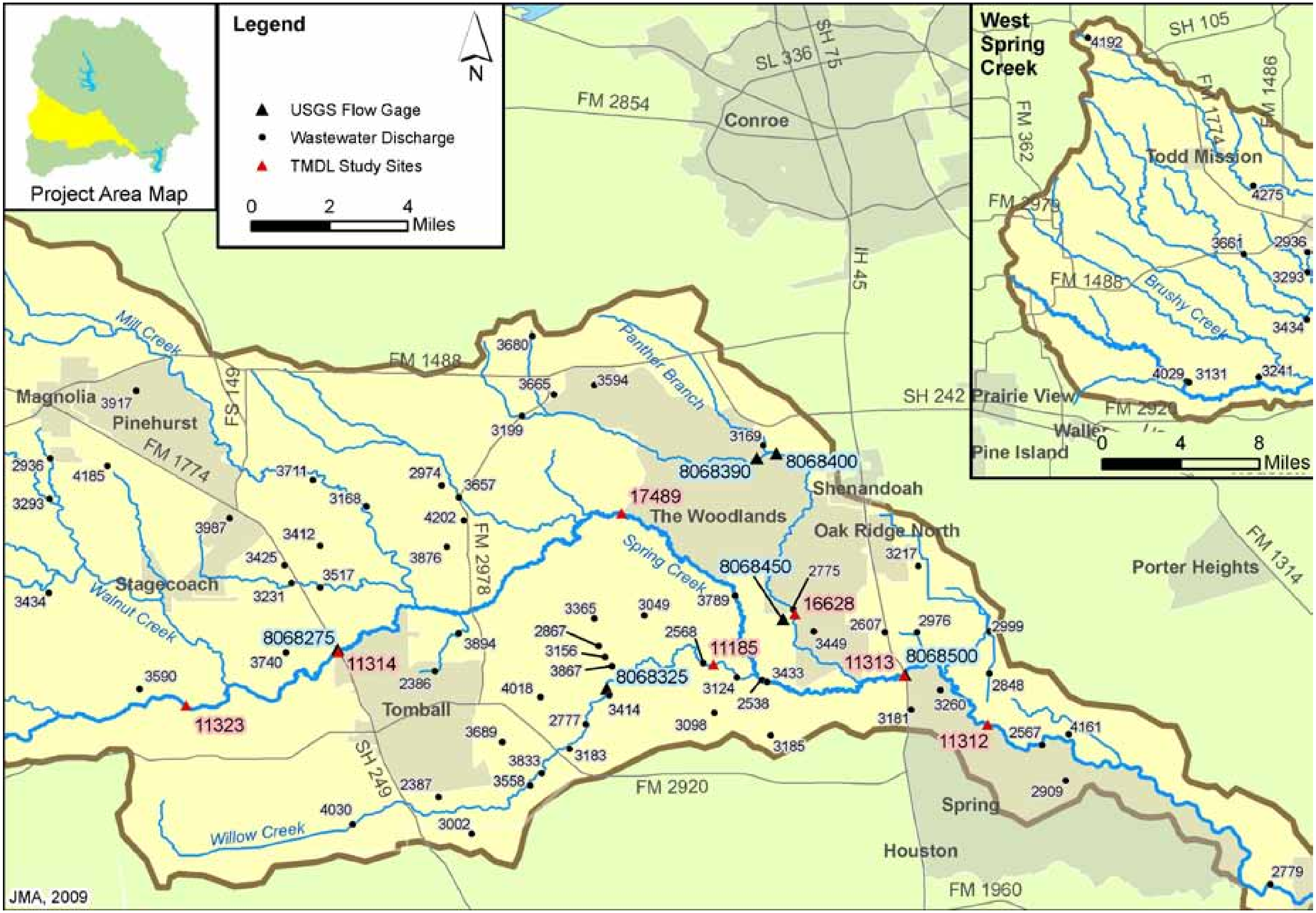


Figure 4. Spring Creek Watershed Sampling Locations, Wastewater Discharges, and USGS Gauge Locations

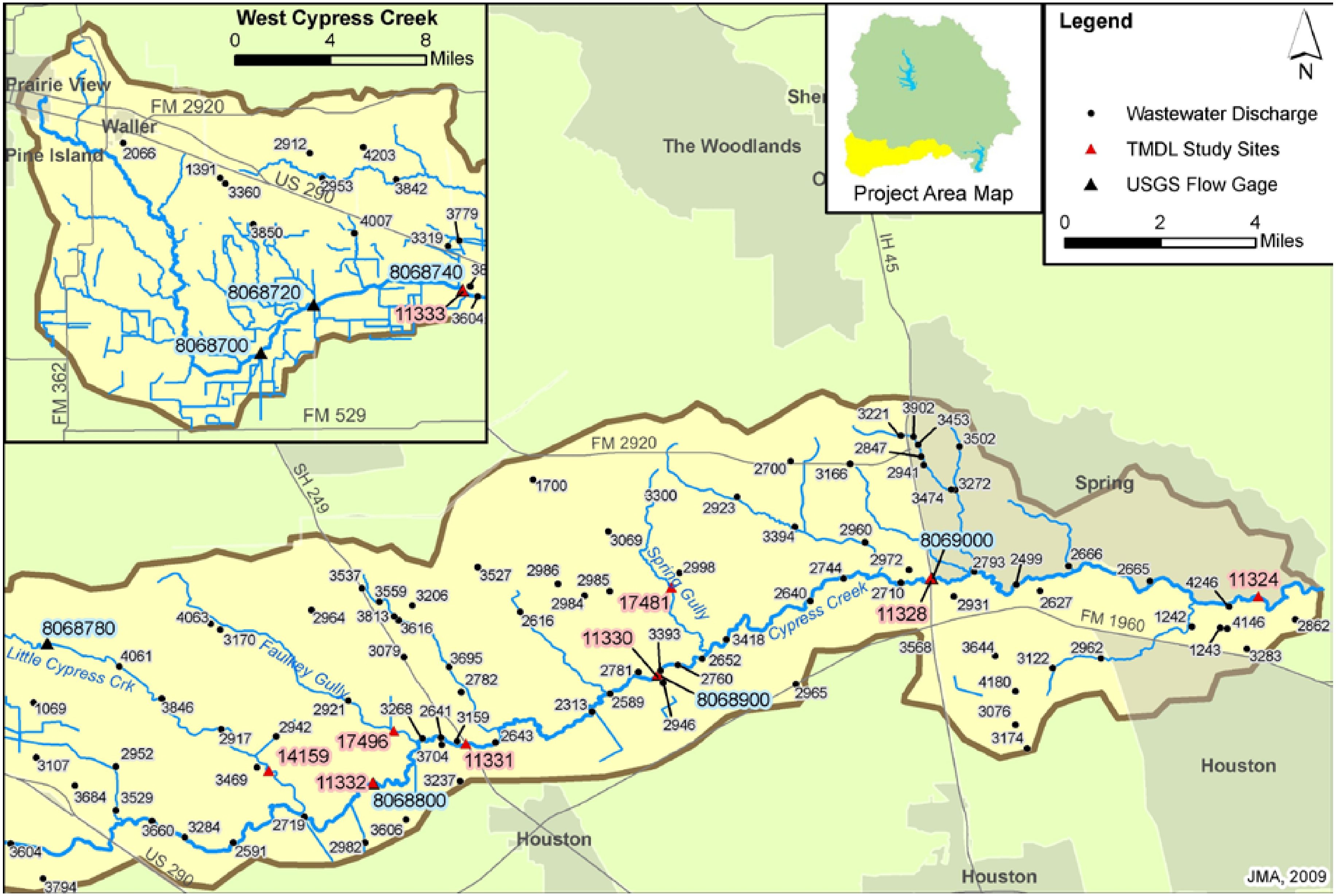


Figure 5. Cypress Creek Watershed Sampling Locations, Wastewater Discharges, and USGS Gauge Locations

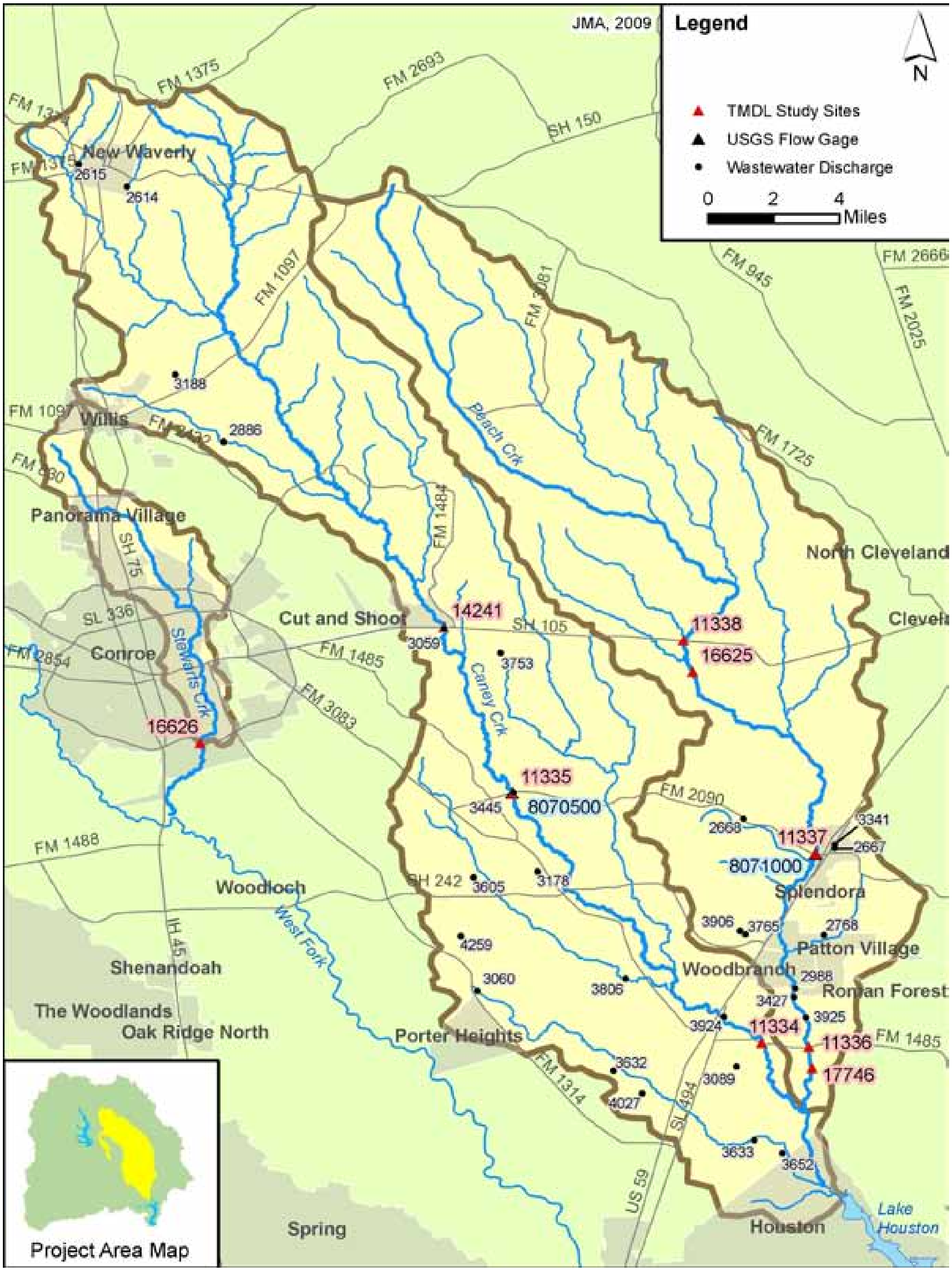


Figure 6. Eastern Creeks Sampling Locations, Wastewater Discharges, and USGS Gauge Locations

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 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 Stewarts Creek (1004E), Spring Creek (1008), Willow Creek (1008H), Cypress Creek (1009), Faulkey Gully (1009C), Spring Gully (1009D), Little Cypress Creek (1009E), Caney Creek (1010), and Peach Creek (1011).

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.

With the exception of WWTFs, which receive individual WLAs (see the “Waste Load Allocation” section), the regulated and unregulated sources in this section are presented to give a general account of the different sources of bacteria expected in the watershed. These are not meant to be interpreted as precise loadings or used for allocating bacteria loads.

Regulated Sources

With the exception of Stewarts Creek (1004E), all the segments in this study have NPDES/TPDES-permitted sources. Approximately 14% of the TMDL area watershed is regulated under two TPDES permits for storm water discharge. One (TPDES Permit No. WQ0004685000) is jointly held by Harris County, Harris County Flood Control District (HCFCD), City of Houston, and Texas Department of Transportation, while the other (TPDES Permit No. TXR040256) is held by The Woodlands. There are no NPDES-permitted concentrated animal feeding operations (CAFOs) within the general Lake Houston watershed.

Wastewater Treatment Facilities

TPDES-permitted facilities that continuously discharge wastewater to surface waters addressed in these TMDLs are listed in Table 6 and displayed in Figures 4-6. As of June 2007, there were 183 permitted outfalls for WWTFs in the TMDL area watershed and Table 6 lists both the NPDES number as well as the TPDES permit number. As shown, Stewarts Creek is the only impaired segment with no WWTF discharges. In contrast, Cypress Creek has over 100 WWTFs (inclusive of Spring Gully, Faulkey Gully, and Little

Table 6. WWTF Dischargers in the TMDL Area Watershed

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1008	Spring Creek	1008_02	11871-001	TX0072702	2936	City of Magnolia	0.65	0.268	C
		1008_02	12402-001	TX0086053	3131	Houston Oaks Golf Management, LP	0.01	0.002	C
		1008_02	12898-001	TX0095125	3241	Aqua Utilities, Inc	0.075	0.027	C
		1008_02	13115-001	TX0097969	3293	Clovercreek MUD	0.12	0.0326	C
		1008_02	13653-001	TX0110663	3434	Magnolia ISD	0.015	0.004	C
		1008_02	14007-001	TX0117846	3590	AquaSource Development Co	0.13	NA	C
		1008_02	14133-001	TX0119857	3661	White Oak Utilities, Inc	0.2	0.0373	C
		1008_02	14266-001	TX0094315	3740	HMV Special Utility District	0.025	0.031	C
		1008_02	14542-001	TX0126934	4185	1774 Utilities, Corp	0.15	0.0076	C
		1008_02	14624-001	TX0127973	4029	Rosehill Utilities, Inc	0.02	NA	C
		1008_03	10616-001	TX0022381	2386	City of Tomball	1.5	0.673	C
		1008_03	10857-001	TX0025399	2538	Montgomery Co WCID #1	0.42	0.24005	C
		1008_03	11968-001	TX0077275	2974	Tecon Water Company, LP	0.052	NA	C
		1008_03	12303-001	TX0085693	3098	Aqua Utilities, Inc	0.015	0.0065	C
		1008_03	12382-001	TX0087475	3124	C&P Utilities, Inc/ J&S Water Company, LLC5	0.12	0.068	C
		1008_03	12587-001	TX0090905	3168	Tecon Water Company, LP	0.46	NA	C
		1008_03	12650-001	TX0092088	3185	Spring Oaks Mobile Home Park, Inc.	0.025	0.0069	C
		1008_03	12851-001	TX0094552	3231	Richard Clark Enterprises, LLC	0.06	NA	C
		1008_03	13614-001	TX0108553	3412	Richfield Investment Corp	0.61	NA	C
		1008_03	13636-001	TX0109622	3425	Richfield Investment Corp	0.405	NA	C
		1008_03	13648-001	TX0042099	3433	Encanto Real UD	0.25	0.077	C
		1008_03	13863-001	TX0115827	3517	H.H.J., Inc	0.8	0	C
		1008_03	14124-001	TX0119598	3657	Magnolia ISD	0.02	0.065	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1008 (cont.)	Spring Creek (cont.)	1008_03	14218-001	TX0123587	3711	Diocese of Galveston-Houston	0.015	0.005	F
		1008_03	14491-001	TX0126306	3876	Is Zen Center	0.035	0.0012	C
		1008_03	14517-001	TX0125547	3894	South Central Water Company	0.038	0	C
		1008_03	14551-001	TX0127035	3917	AUC Group, LP	0.95	NA	C
		1008_03	14592-001	TX0127663	3987	South Central Water Company	0.32	0	C
		1008_03	14662-001	TX0128333	4192	Navasota ISD	0.024	0.001	C
		1008_04	10908-001	TX0020974	2567	Harris County WCID #92	0.7	0.416	C
		1008_04	11001-001	TX0024759	2607	Southern Montgomery County MUD	2	0.972	C
		1008_04	11406-001	TX0056537	2779	Harris Co. MUD #26	1.5	0.5417	C
		1008_04	11574-001	TX0026221	2848	Spring Creek UD	0.93	0.439	C
		1008_04	11799-001	TX0071528	2909	Harris Co. MUD #82	2.2	0.462	C
		1008_04	11970-001	TX0076538	2976	Montgomery Co. MUD #19	0.715	NA	C
		1008_04	12030-001	TX0078263	2999	Rayford Road MUD	0.0015	NA	C
		1008_04	12637-001	TX0091791	3181	Spring Center, Inc	0.006	0.00385	C
		1008_04	12788-001	TX0095621	3217	Eastwood Mobile Home Park LP	0.05	0.0065	C
		1008_04	12979-004	TX0119181	3260	Northgate Crossing MUD #2	0.95	0.19	C
		1008_04	14656-001	TX0128295	4161	Montgomery Co MUD #94	1.08	NA	C
1008C[c]	Lower Panther Branch	1008C_01	11401-001	TX0054186	2775	San Jacinto River Authority	7.8	NA	C
		1008C_01	12597-001	TX0091715	3169	San Jacinto River Authority	7.8	3.275	F
		1008C_01	12703-001	TX0092843	3199	Magnolia ISD	0.048	0.014	C
		1008C_01	13697-001	TX0090000	3449	Cedarstone One Investors, Inc	0.003	0.0004	C
		1008C_01	14013-001	TX0118028	3594	AquaSource Development Co	0.05	NA	C
		1008C_01	14141-001	TX0120073	3665	Aqua Development, Inc	0.45	NA	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1008H	Willow Creek	1008H_01	10616-002	TX0117595	2387	City of Tomball	1.5	0.9	C
		1008H_01	10910-001	TX0058548	2568	Northampton MUD	0.75	0.378	C
		1008H_01	11404-001	TX0026255	2777	Dowdell PUD	0.95	0.234	C
		1008H_01	11630-001	TX0058530	2867	Harris Co. MUD #1	1.5	0.248	C
		1008H_01	12044-001	TX0078433	3002	Harris Co MUD #368	1.6	0.461	C
		1008H_01	12153-001	TX0081264	3049	North Harris Co MUD #19	0.25	0.096	C
		1008H_01	12519-001	TX0089915	3156	Aquasource Utility, Inc	0.1	0.025	C
		1008H_01	12643-001	TX0091987	3183	Pinewood Community LP	0.1	0.062	C
		1008H_01	13487-001	TX0119628	3365	Timbercrest Community Association	0.2	0.067	C
		1008H_01	13619-001	TX0083976	3414	Aqua Utilities, Inc	0.04	0.018	C
		1008H_01	13942-001	TX0117633	3558	Inline Utilities, LLC	0.25	0.101	C
		1008H_01	14181-001	TX0122530	3689	Aqua Development, Inc	0.075	0.0212	C
		1008H_01	14421-001	TX0125687	3833	2920 Venture, LTD/Harris County MUD #4014	0.6	0.0016	C
		1008H_01	14475-001	TX0126152	3867	Northwest Harris Co. MUD #19	0.7	0	C
		1008H_01	14606-001	TX0127795	4018	South Central Water Company	0.08	0	C
		1008H_01	14610-001	TX0127850	4030	501 Maple Ridge, LTD	0.64	0	C
1009	Cypress Creek	1009_01	10310-001	TX0032476	2066	City of Waller	0.9	NA	C
		1009_01	13296-002	TX0105376	3319	Harris Co MUD #358	2	0.785	C
		1009_01	14448-001	TX0125938	3850	Houston Warren Ranch Partners, LLC	0.55	0	C
		1009_01	14576-001	TX0127311	4007	523 Venture, Inc/Becker Road LP[3]	0.2	0	C
		1009_02	02608-000	TX0092258	1069	Center Point Energy Houston Electric LLC	0.02	0.0016	N
		1009_02	10962-001	TX0062049	2591	Harris County WCID #113	0.3	0.11	C
		1009_02	11084-001	TX0046833	2641	Lake Forest Plant Advisory Council	2.76	1.331	C
		1009_02	11267-001	TX0046868	2719	Timberlake ID	0.4	0.257	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1009 (cont.)	Cypress Creek (cont.)	1009_02	11912-002	TX0075159	2952	Northwest Harris Co MUD #10	1.5	0.481	C
		1009_02	11986-001	TX0076791	2982	Tower Oak Bend WSC	0.05	NA	C
		1009_02	12327-001	TX0086011	3107	Cypress Hill MUD #1	0.8	0.381	C
		1009_02	12541-001	TX0090182	3159	Chasewood Utilities, Inc	0.1	0.018	C
		1009_02	12877-001	TX0094706	3237	Harris Co MUD #230	0.76	0.204	C
		1009_02	13020-001	TX0096920	3268	Harris Co MUD #286	0.6	0.207	C
		1009_02	13059-001	TX0098434	3284	Kwik-Kopy Corp	0.015	0.008	C
		1009_02	13881-001	TX0116009	3529	Harris Co MUD #365	1.2	0.528	C
		1009_02	14028-001	TX0117129	3604	Harris Co MUD 371	0.25	0.104	C
		1009_02	14030-001	TX0075221	3606	Northwest Harris Co MUD #9	1.5	0.51	C
		1009_02	14130-001	TX0081272	3660	Northwest Harris Co MUD #10	0.048	0.001	C
		1009_02	14172-001	TX0121126	3684	Utilities Investment Company, Inc	0.183	0.056	C
		1009_02	14209-001	TX0123366	3704	CTP Utilities Inc	0.18	0	C
		1009_02	14327-001	TX0124770	3779	Harris Co. MUD #391	0.95	0.159	C
		1009_02	14354-001	TX0124974	3794	Harris Co. MUD #374	0.65	NA	C
		1009_02	14476-001	TX0126161	3868	Rouse-Houston, LP	0.8	0.031	C
		1009_03	10528-001	TX0026450	2313	Harris Co. FWSD # 52	0.7	0.32	C
		1009_03	10955-001	TX0046710	2589	Harris County WCID #116	1.3	0.652	C
		1009_03	11024-001	TX0021211	2616	Harris Co WCID #119	0.995	0.415	C
		1009_03	11081-001	TX0046761	2640	Ponderosa Joint Powers Agency	4.87	2.897	C
		1009_03	11089-001	TX0046701	2643	Prestonwood Fresh UD	0.95	0.322	C
		1009_03	11105-001	TX0046639	2652	Bammel UD	2.6	1.06	C
		1009_03	11215-001	TX0046663	2700	Meadowhill Regional MUD	2.4	0.519	C
		1009_03	11239-001	TX0055166	2710	CNP UD	2.5	0.856	F

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1009 (cont.)	Cypress Creek (cont.)	1009_03	11314-001	TX0046744	2744	Aqua Texas, Inc	0.4	NA	C
		1009_03	11366-001	TX0046779	2760	Cypress-Klein UD	0.7	0.314	C
		1009_03	11409-001	TX0046817	2781	Kleinwood Joint Powers Board	5	2.162	C
		1009_03	11410-002	TX0046841	2782	Charterwood MUD	1.6	0.282	C
		1009_03	11835-001	TX0072150	2923	Bridgestone MUD	2.5	0.846	C
		1009_03	11900-001	TX0074217	2946	Tina Lee Tilles DBA Turk Brothers Building	0.001	0.0004	C
		1009_03	11925-001	TX0074632	2960	Harris Co MUD #104	0.6	0.198	C
		1009_03	11941-001	TX0074322	2965	Harris Co MUD #58	0.6	0.117	C
		1009_03	11964-001	TX0076481	2972	Harris Co WCID #110	1	0.493	C
		1009_03	11988-001	TX0076856	2984	Harris Co MUD #24	2	0.623	C
		1009_03	11988-002	TX0113123	2985	Harris Co MUD #24	0.06	0.031	N
		1009_03	11988-003	TX0113115	2986	Harris Co MUD #24	0.06	0.062	N
		1009_03	12248-001	TX0084760	3079	UA Holdings 1994-5	0.1	0.029	C
		1009_03	12730-001	TX0090344	3206	Champ's Water Company	0.0154	0.002617	C
		1009_03	13569-001	TX0078930	3393	Samuel Victor Pinter	0.0015	0.0002	C
		1009_03	13573-001	TX0108120	3394	Northwest Harris County MUD #36	0.2	0.113	C
		1009_03	13625-001	TX0081337	3418	Northwest Harris Co MUD #20	0.4	0.601	C
		1009_03	13875-002	TX0115983	3527	Harris Co MUD #383	1.5	0.548	C
		1009_03	13893-001	TX0122211	3537	Dia-Den LTD	0.018	0.002	C
		1009_03	13942-002	TX0125466	3559	Inline Utilities, LLC	0.099	0	C
		1009_03	13963-001	TX0087424	3568	Luther's Bar-B-Q, Inc.	0.005	NA	C
		1009_03	14044-001	TX0092894	3616	149 Enterprises, Inc	0.01	NA	C
		1009_03	14193-001	TX0122963	3695	Kennard Tom Foley	0.035	0.0027	C
		1009_03	14390-001	TX0125181	3813	Huffsmith-Kohrville, Inc	0.053	0	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1009 (cont.)	Cypress Creek (cont.)	1009_04	10783-001	TX0023612	2499	Inverness Forest ID	0.5	0.198	C
		1009_04	11044-001	TX0046671	2627	Memorial Hills UD	0.5	0.188	C
		1009_04	11141-001	TX0046728	2665	Treschwig Joint Powers Board	2	1.201	C
		1009_04	11142-002	TX0046680	2666	Timber Lane UD	2.62	0.929	F
		1009_04	11444-001	TX0046736	2793	Harris County WCID #99	0.225	0.089	C
		1009_04	11572-001	TX0047775	2847	Pilchers Property LP/Northland Joint Venture[1]	0.06	0.025	C
		1009_04	11618-003	TX0118371	2862	Hunter's Glen MUD	1.4	0.356	C
		1009_04	11855-001	TX0072567	2931	North Park PUD	1.31	0.403	C
		1009_04	11886-001	TX0073105	2941	Six Flag Splashtown L.P.	0.06	NA	C
		1009_04	11933-001	TX0075671	2962	Woodcreek MUD	0.6	0.231	C
		1009_04	12239-001	TX0084085	3076	Harris Co MUD #36	0.99	NA	C
		1009_04	12378-002	TX0092967	3122	Richey Rd MUD	0.45	0.319357	C
		1009_04	12470-001	TX0089184	4180	Harris Co MUD #221	1.8	0.688	C, F
		1009_04	12579-001	TX0090824	3166	Spring West MUD	0.762	0.101	C
		1009_04	12614-001	TX0091481	3174	Harris Co MUD #16	0.5	0.147	C
		1009_04	12812-001	TX0093939	3221	Regency 1-45/ Spring Cypress Retal, L.P.	0.06	0.0023	C
		1009_04	13027-001	TX0096865	3272	Harris County	0.01	NA	C
		1009_04	13054-001	TX0097209	3283	CW-MHP Ltd	0.01	0.002	C
		1009_04	13711-001	TX0085910	3453	Spring Cypress WSC	0.035	0.023	C
		1009_04	13765-001	TX0116068	3474	Harris Co MUD #249	0.8	0.2099	C
		1009_04	13819-001	TX0113930	3502	Arthur Edward Bayer	0.06	0	C
		1009_04	14106-001	TX0119270	3644	Aqua Development, Inc	0.08	NA	C
		1009_04	14526-001	TX0031305	3902	Spring ISD	0.03	0.001	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1009C	Faulkey Gully	1009C_01	11824-002	TX0128210	4063	Northwest Harris Co. MUD #5	0.4	0	C
		1009C_01	11832-001	TX0072354	2921	Faulkey Gully MUD	1.42	0.67	C, F
		1009C_01	11939-001	TX0075795	2964	Northwest Harris Co MUD #15	3.12	0.43	C
		1009C_01	12600-001	TX0091171	3170	Elite Computer Consultants, LP	0.008	0.0011	C
1009D	Spring Gully	1009D_01	12025-002	TX0077941	2998	Bilma PUD	0.75	0.294	C
		1009D_01	12224-001	TX0083801	3069	Klein ISD	0.011	0.005	C
		1009D_01	13152-001	TX0098647	3300	Northwest Harris Co MUD #32	0.65	0.356	C
1009E	Little Cypress Creek	1009E_01	11814-001	TX0071609	2912	Boys and Girls Country of Houston	0.1	0.017	C
		1009E_01	11824-001	TX0072346	2917	Northwest Harris County MUD #5	0.8	0.437	C
		1009E_01	11887-001	TX0073393	2942	Grant Rd PUD	0.31	0.165	C
		1009E_01	11913-001	TX0075183	2953	Northwest Freeway MUD	0.45	0.151	C
		1009E_01	13472-001	TX0090841	3360	Hockley Rail Car, Inc	0.006	0.00035	C
		1009E_01	13753-001	TX0113107	3469	Harris Co MUD #360	0.8	0.253	C
		1009E_01	14434-001	TX0125806	3842	Westside Water, LLC	0.1	0.023	C
		1009E_01	14441-001	TX0125881	3846	Harris County MUD #389	0.3	0	C
		1009E_01	14643-001	TX0128180	4061	Northwest Harris Co MUD #10	0.0945	0	C
		1009E_01	14675-001	TX0128457	4203	Quadvest, LP	0.32	0	C
1010	Caney Creek	1010_02	11020-001	TX0056685	2614	City of New Waverly	0.088	NA	C
		1010_02	11715-001	TX0068659	2886	Texas National MUD WWTF	0.075	0.01	C
		1010_02	12670-001	TX0092517	3188	Mountain Man, Inc./ Ranch Utilities, LP[2]	0.175	0.052	C
		1010_03	12204-001	TX0083216	3059	Conroe ISD	0.02	0.0185	C
		1010_04	14597-001	TX0127710	4027	The Signorelli Co.	0.6	0.012375	C
		1010_04	12205-001	TX0083208	3060	Conroe ISD	0.015	0.0071	C

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number[a]	Facility Name	2008 Permitted Flow (MGD)	Average Monthly Flow (MGD)	Monitoring Required[b]
1010 (cont.)	Caney Creek (cont.)	1010_04	12274-001	TX0084638	3089	New Caney MUD	1.06	0.6717	C
		1010_04	12621-001	TX0091677	3178	Martin Realty & Land, Inc	0.15	NA	C
		1010_04	13690-001	TX0111473	3445	Conroe ISD	0.1	0.086	C
		1010_04	14029-001	TX0117145	3605	LGI Housing, LLC/Quadvest, LP6	0.6	0.121	C
		1010_04	14081-001	TX0118311	3632	Martin Realty & Land, Inc.	0.15	0	C
		1010_04	14083-001	TX0118818	3633	White Oak Developers, Inc.	0.2	0	F
		1010_04	14285-001	TX0124281	3753	C&R Water Supply, Inc.	0.3	0.09	C
		1010_04	14379-001	TX0125300	3806	East Montgomery Co MUD #3	0.08	0.039	C
		1010_04	14559-001	TX0127094	3924	Whitestone Houston Land, Ltd.	0.9	NA	C
		1010_04	14694-001	TX0128651	4259	Elan Development, LP	0.18	0	C
1011	Peach Creek	1011_01	11143-001	TX0082511	2667	Splendora ISD	0.04	0.021	C
		1011_01	11143-002	TX0117463	2668	Splendora ISD	0.04	0.009	C
		1011_01	13389-001	TX0102512	3341	City of Splendora	0.3	0.098	C
		1011_02	11386-001	TX0078344	2768	Montgomery Co MUD #16	0.177	0.053	C
		1011_02	11993-001	TX0077241	2988	City of Woodbranch Village	0.133	0.059	C
		1011_02	13638-001	TX0093220	3427	Roman Forest Consolidated MUD	0.322	0.1707	C
		1011_02	14311-001	TX0124583	3765	East Montgomery Co MUD #4	0.75	0	C
		1011_02	14536-001	TX0126853	3906	Flying J Inc.	0.05	0.0025	C
		1011_02	14560-001	TX0127108	3925	Whitestone Houston Land, Ltd.	0.9	NA	C

[a] TCEQ record numbers used to identify locations of permitted facilities on Figures 4-6
[b] C = chlorine residual; F = fecal coliform; N = none (as of June 2007)
[c] Not part of this TMDL project, but a major tributary to impaired segment 1008 (Spring Creek)
NA = Not available at time of TMDL development;
Source: TCEQ Central Records & EPA Envirofacts, June 2007.

Cypress). A few of the WWTFs listed were in the design or construction phase when the list was developed. WWTFs with a current flow value of zero generally fall into this category.

WWTFs can contribute bacteria loads to surface water streams through effluent discharges. There are numerous WWTFs located in the study watershed, and virtually all of them are used to treat domestic sewage. Since raw sewage has high levels of human pathogens, an important part of the treatment process is the elimination of bacteria (including *E. coli*) and other microbes through disinfection. Chlorination is the primary type of disinfection used in the study area, though some WWTFs use ultraviolet radiation. Disinfection is required by TPDES permit for all municipal WWTFs. WWTF effluent accounts for a significant portion of the flow in many of the TMDL study segments (ranging from less than 1% to 59% of the flow).

Sampling was conducted at the outfalls of 31 WWTFs in the watersheds upstream of Lake Houston as part of this project. These results suggest that the disinfection systems of some WWTFs may not adequately handle wet weather events. While most samples were well below the single sample water quality standard (394 MPN/100 mL), a few exceeded the standard (with one count of > 20,000 recorded). Refer to the technical support document (James Miertschin & Associates, Inc. 2009) for specific data related to this effluent sampling. 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.

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 usually occur under conditions of high flow in the WWTF system. Approximately 670 SSOs were reported in the impaired segments of the Lake Houston Watershed between September 2001 and December 2008 (Table 7). The reported SSOs averaged 14,009 gallons per event. Analysis of the specific bacterial input from SSOs was not conducted, but the large number of events indicates these are a likely source of bacteria to these water bodies.

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

Table 7. Sanitary Sewer Overflow Summary for the TMDL Area Watershed

Receiving Water	Number of Occurrences	From	To	Min (gallons)	Max (gallons)	Total Volume
1008	191	9/1/2001	12/29/2008	0	3,972,507	5,779,640
1008H	34	3/2/2002	9/14/2008	0	18,000	80,093
1009	350	9/4/2001	12/29/2008	0	159,000	1,320,169
1009C	13	11/29/2001	9/15/2008	0	12,000	33,085
1009D	24	6/1/2003	9/8/2008	15	5,000	16,305
1009E	21	5/6/2002	12/1/2008	20	70,000	145,952
1010	27	2/7/2002	11/6/2008	0	204,500	551,475
1011	6	9/18/2001	9/18/2008	0	700,000	1,403,000

Portions of the TMDL area watershed are regulated under two TPDES permits for storm water discharge. One (TPDES Permit No. WQ0004685000) is jointly held by Harris County, HCFCD, City of Houston, and Texas Department of Transportation (all designated as co-permittees). The other (TPDES Permit No. TXR040256) is held by The Woodlands. The jurisdictional boundary of these municipal separate storm sewer system (MS4) permits 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>.

Figure 7 displays the portion of the watershed subject to MS4 permits. Table 8 lists the percentage of each watershed covered under MS4 permits. The TMDLs calculated for this project were based on the median flow of the highest range for flow exceedance (see the "Load Duration Curve Analysis" section), which coincides with storm water-influenced high flow events.

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 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 the Lake Houston watershed, 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 Lake Houston 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 as well as unmanaged, introduced species like feral hogs. 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. Currently, insufficient data is available to estimate wildlife populations and spatial distribution in the Lake Houston watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

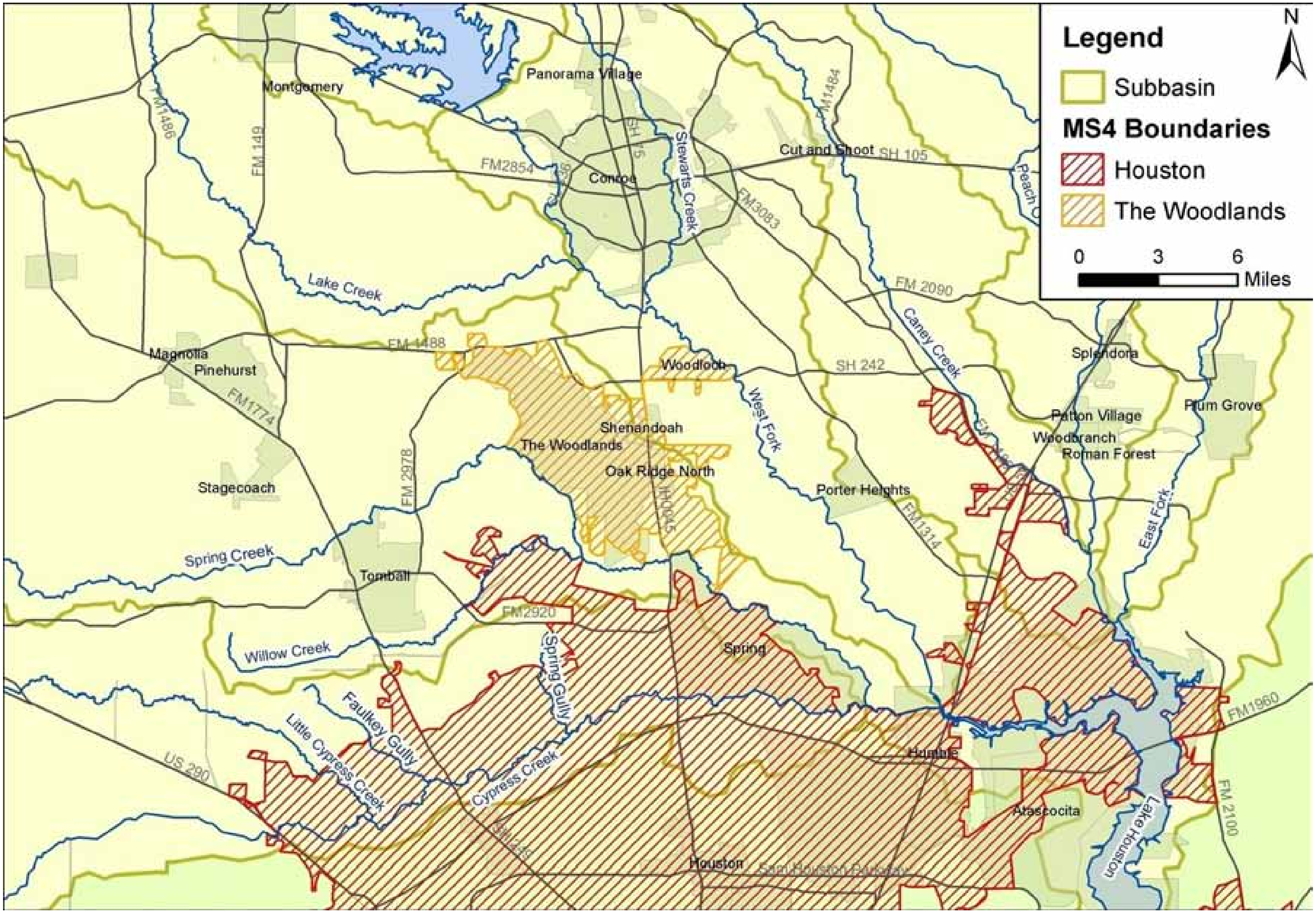


Figure 7. MS4 Areas of the Lake Houston Watershed

Table 8. 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
1004E	Stewarts Creek	WQ0004685000	11,264	0	0%
1008	Spring Creek (Houston)	WQ0004685000	281,792 (combined)	9,718	3%
1008	Spring Creek (The Woodlands)	TXR040256		23,574	8%
1008H	Willow Creek	WQ0004685000	33,280	4,160	12%
1009	Cypress Creek	WQ0004685000	208,448	63,037	30%
1009C	Faulkey Gully	WQ0004685000	7,232	2,582	36%
1009D	Spring Gully	WQ0004685000	3,520	1,172	33%
1009E	Little Cypress Creek	WQ0004685000	35,648	2,852	8%
1010	Caney Creek	WQ0004685000	137,984	8,830	6%
1011	Peach Creek	WQ0004685000	100,992	0	0%

Unregulated Agricultural Activities and Domesticated Animals

Livestock population estimates were based upon the 2007 Census of Agriculture (USDA 2007). The types of livestock explicitly included in the present analysis included cattle, hogs, poultry, horses, sheep, and goats. Animal population estimates are presented in Table 9. Other types of livestock had small populations compared to the major livestock species listed above, and therefore, the fecal loads from these other animal groups were assumed to be negligible.

Fecal coliform bacteria produced by livestock can enter surface waters through several pathways: wash off of waste deposited on the land surface, wash off of concentrated waste from land application sites, direct deposition of waste material in the stream, and potential discharges from animal confinement areas or waste handling systems.

Fecal coliform bacteria production rates for livestock are displayed in Table 10. For the present study, all of the data regarding manure production rates and fecal coliform density were based upon values reported in the literature (ASAE 2003; EPA 2000).

These bacteria generation rates were used to estimate the total potential fecal coliform loading derived from livestock in the study watershed, as shown in Table 11. These estimated loads are potential loads in that some mechanism is needed to deliver the loads to a water source. Comparable *E. coli* generation data was not available in the literature, but it can be expected that the *E. coli* is generally lower than the fecal coliform. The bacteria production numbers from livestock are a rough estimate to demonstrate that this may be a potential source of bacteria in the watershed. These estimates are not used to allocate an allowable loading for livestock.

Table 9. Livestock Population Estimates

Segment	Stream Name	Cattle and Calves	Hogs and Pigs	Chickens	Other Poultry	Horses and Ponies	Sheep and Goats
1004E	Stewarts Creek	343	8	117	39	94	45
1008	Spring Creek	18,627	222	40,344	1,167	2,603	1,393
1008H	Willow Creek	2,064	39	334	112	375	195
1009	Cypress Creek	17,165	221	2,553	756	2,490	1,369
1009C	Faulkey Gully	333	6	54	18	60	31
1009D	Spring Gully	133	3	22	7	24	13
1009E	Little Cypress Creek	3,052	58	493	166	554	288
1010	Caney Creek	6,471	117	1,689	1,275	1,446	705
1011	Peach Creek	4,322	78	820	327	739	455

Table 10. Fecal Coliform Production Rates for Livestock

Animal	Fecal Coliform (Billions/animal/day)
Beef Cow	104
Dairy Cow	101
Swine	10.8
Chicken	0.14
Sheep	12.0
Horse	0.42
Turkey	0.09
Duck	0.02
Geese	49.0

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.

An OSSF failure can occur via two mechanisms, direct and indirect. First, drain field failures, broken pipes, or overloading could result in uncontrolled, direct discharges to the streams. As a second mechanism, an overloaded drain field could experience surfacing of

Table 11. Fecal Coliform Daily Production Rates for Livestock (in Billions)

Segment	Stream Name	Cattle and Calves	Hogs and Pigs	Chickens	Other Poultry	Horses and Ponies	Sheep and Goats
1004E	Stewarts Creek	35,698	90	16	4	39	542
1008	Spring Creek	1,937,204	2,397	5,487	109	1,093	16,711
1008H	Willow Creek	214,684	422	45	10	157	2,337
1009	Cypress Creek	1,785,111	2,388	347	70	1,046	16,428
1009C	Faulkey Gully	34,623	68	7	2	25	377
1009D	Spring Gully	13,872	27	3	1	10	151
1009E	Little Cypress Creek	317,373	623	67	15	233	3,455
1010	Caney Creek	672,935	1,267	230	119	607	8,456
1011	Peach Creek	449,529	842	111	30	310	5,461

effluent, and the pollutants would then be available for surface accumulation and subsequent wash off under runoff conditions.

The number of OSSFs in the study area was estimated using information from the 1990 US Census, which included a question regarding the means of household sewage disposal (US Census 2000). Unfortunately, this question was not posed in the 2000 Census. Based on the 1990 data, the number of OSSFs in the study area was estimated by intersecting the census tracts with the study area watershed. The spatial distribution of OSSFs in 1990 is shown in Figures 8 and 9. Figure 8 shows the density of OSSFs, while Figure 9 shows the percentage of homes served by OSSFs according to the 1990 Census.

Beginning in 1992, county health departments (and other agencies) began registering and recording new OSSF installations. These data were used to determine area growth rates for each county, which were then applied to the study watersheds. Table 12 provides the OSSF estimates for 1990 and 2007 for each TMDL watershed.

OSSF failure rates for different regions of Texas have been estimated in a report by Reed, Stowe, and Yank (2001). According to this report, OSSFs in east-central Texas have a failure rate of about 12 percent and OSSFs in far-east Texas have a failure rate of about 19 percent. Because the study area is intersected by both of these two regions, a failure rate of 15.5 percent could be considered applicable. Table 12 also includes the estimated number of failed septic systems for 1990 and 2007.

Various studies have attempted to quantify the transport and delivery of bacteria in effluent from septic systems. For example, it has been reported that less than 0.01% of fecal coliform originating in the household waste moves farther than 6.5 feet down gradient from the drain field (Weiskel 1996). 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.

Domestic Pets

Domestic pets (dogs and cats) in urban and suburban areas are a potential source of bacteria loading. On average there are 0.632 dogs and 0.713 cats per household (American Veterinary Medical Association 2002). Using U.S. Census data (U.S. Census Bureau 2000), dog and cat populations can be estimated for each segment of the watershed. Table 13 summarizes the estimated number of dogs and cats for the watershed of the study area.

Table 14 provides an estimate of fecal coliform loads from pets. These estimates are based on estimated fecal coliform production rates of $3.3x10^9$ cfu per day for dogs and $5.4x10^8$ cfu per day for cats (Schueler 2000). The portion of these loads that is expected to reach water bodies through wash-off of land surfaces and conveyance in runoff is unknown. These estimates are not used to allocate an allowable loading for pets.

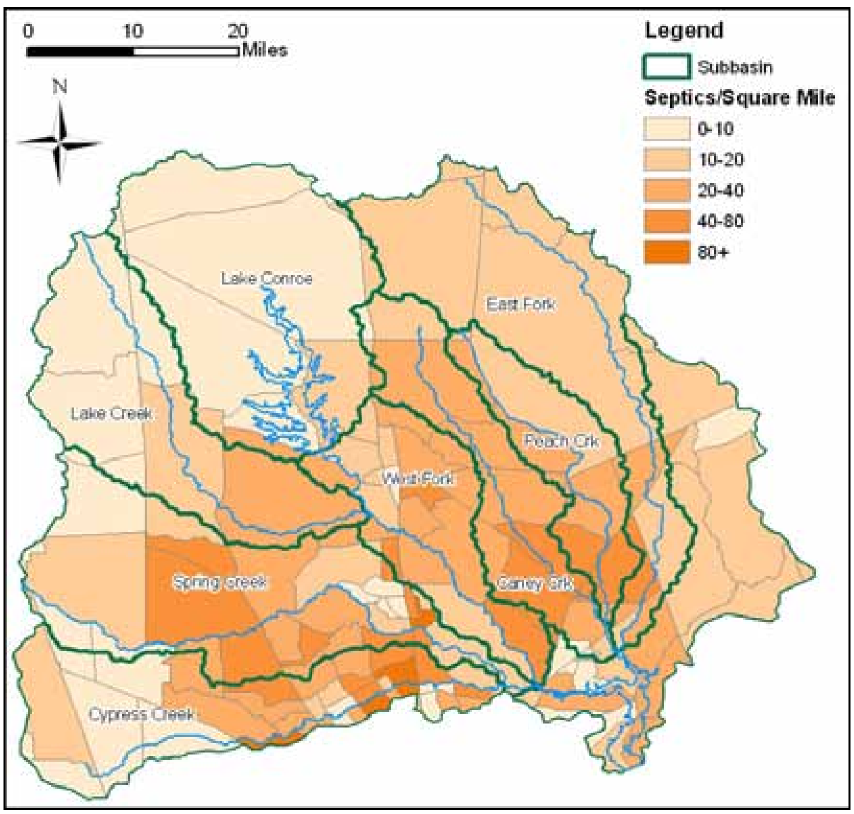


Figure 8. OSSF Density of Lake Houston Watershed (1990)

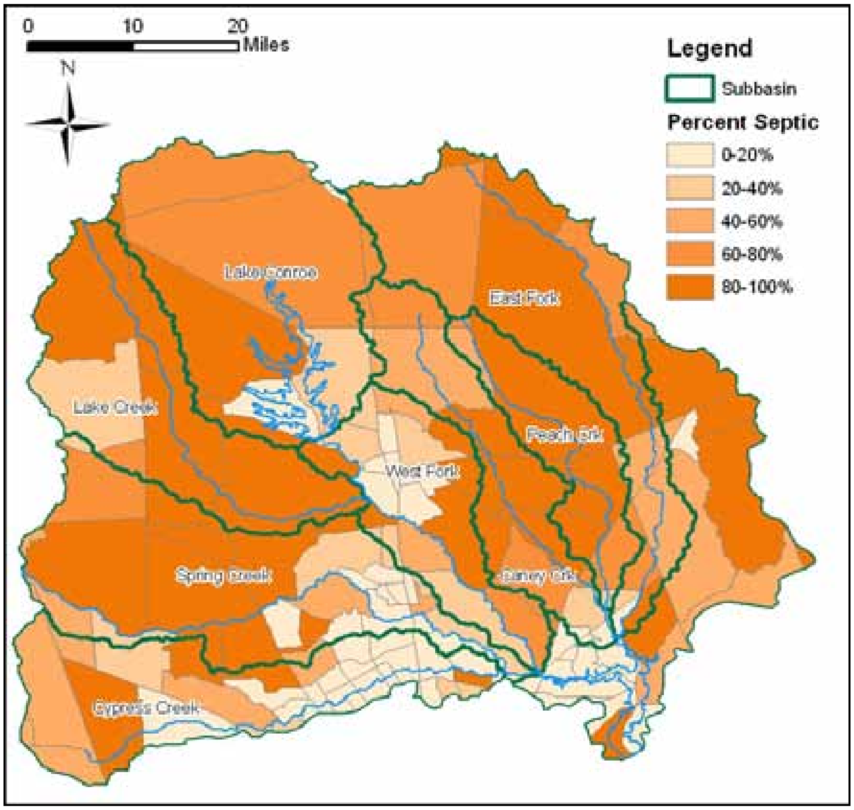


Figure 9. Percent of Households Served by OSSFs (1990)

Table 12. OSSF Estimates for TMDL Watersheds

Segment	Stream Name	1990 OSSFs	2007 OSSFs	Annual Growth Rate 1990-2007	1990 Failed Systems	2007 Failed Systems
1004E	Stewarts Creek	474	957	4.2%	7	15
1008	Spring Creek	11,334	18,926	3.1%	176	293
1008H	Willow Creek	1,843	2,399	1.6%	29	37
1009	Cypress Creek	7,587	10,934	2.2%	118	169
1009C	Faulkey Gully	494	615	1.3%	8	10
1009D	Spring Gully	151	210	2.0%	2	3
1009E	Little Cypress Crk	1,159	1,755	2.5%	18	27
1010	Caney Creek	6,919	12,189	3.4%	107	189
1011	Peach Creek	4,688	7,537	2.8%	73	117

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

Segment	Stream Name	Dogs	Cats
1004E	Stewarts Creek	2,811	3,171
1008	Spring Creek	37,513	42,320
1008H	Willow Creek	4,561	5,145
1009	Cypress Creek	52,411	59,128
1009C	Faulkey Gully	2,640	2,978
1009D	Spring Gully	860	970
1009E	Little Cypress Creek	3,915	4,417
1010	Caney Creek	10,689	12,058
1011	Peach Creek	4,295	4,845

Table 14. Estimated Fecal Coliform Daily Production by Pets

(in Billion cfu)

Segment	Stream Name	Dogs	Cats	Total (counts/day)
1004E	Stewarts Creek	9,276	1,712	10,988
1008	Spring Creek	123,792	22,853	146,645
1008H	Willow Creek	15,050	2,778	17,828
1009	Cypress Creek	172,956	31,929	204,886
1009C	Faulkey Gully	8,710	1,608	10,318
1009D	Spring Gully	2,838	524	3,362
1009E	Little Cypress Creek	12,921	2,385	15,306
1010	Caney Creek	35,272	6,512	41,784
1011	Peach Creek	14,174	2,617	16,790

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 general sources 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 (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. Note that curves for both the single sample and geometric mean criteria are presented. The single samples plotted on the graphs can be compared to the single sample curve, and the geometric means of each flow regime can be compared to the geometric mean curve.

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

Where:

criterion = 394 MPN/100 mL (*E. coli*) for single sample; 126 MPN/100 ml for geometric mean

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. Stream flow data is essential for determining instream pollutant loads. Fortunately, there are several USGS flow gauging stations in the TMDL study area. Table 5 identified the USGS gauging stations used in this project. Locations of these gauges are previously presented in Figures 4-6. The period of record for flow data used from this station was 1999 through 2008.

Stream flow distribution has been divided into three flow regimes: wet, moderate, and dry conditions. These flow regimes are listed in Table 15 with flow exceedance percentiles and illustrated in all LDC figures. Wet conditions correspond to large storm-induced runoff events. The moderate conditions typically represent periods of medium base flows, but can also represent small runoff events and periods of flow recession following large storm events. The dry conditions represent relatively low flow conditions, resulting from extended periods of little or no rainfall and are maintained primarily by WWTF flows.

Table 15. Hydrologic Classification Scheme

Flow Exceedance Percentile	Hydrologic Condition Class
0-30 %	Wet Conditions (Highest flows)
30-70 %	Moderate Conditions (Mid-range flows)
70-100 %	Dry Conditions (Lowest flows)

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 (cfs) 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. Exceedances in the lowest flow category suggest the likelihood that malfunctioning WWTFs, direct deposition of bacteria, and illicit discharges may be significant sources of bacteria. Exceedances in the highest flow category suggest that storm water and WWTF problems associated with high storm water flows may be significant sources. Exceedances in the mid-range flows suggest a combination of these factors.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the 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

This section presents load duration curves for various water quality sampling stations throughout the study area. The bacterial loads are the product of each grab sample bacteria concentration and the corresponding mean daily streamflow rate. The LDCs are analyzed for compliance with state criteria and for source assessment. Sources are assessed by observing how bacteria levels vary under different flow conditions (flow percentile). Data scatter is also considered, and comparisons are made between LDCs at upstream and downstream locations. LDCs of respective streams are presented in order from most upstream to most downstream location.

AU 1010_02: Station 14241 – Caney Creek at SH 105

The LDC for Station 14241 is shown in Figure 10. Under the moderate and dry flow regimes, there are relatively few exceedances of the grab sample criterion, although the majority of the samples are above the geometric mean criterion. Under wet flow conditions, an increasing number of samples lie above the criteria curve, indicating that state criteria may be exceeded under sustained high flow conditions.

AU 1010_04: Station 11334 – Caney Creek at FM 1485

The LDC for Station 11334 is shown in Figure 11. Criteria exceedances are again most typical under relatively high flow conditions. Fifty-five percent of samples in the wet flow regime exceed the grab sample criteria. Bacteria levels at both moderate and dry conditions generally meet state criteria.

AU 1011_02: Station 11336/17746 – Peach Creek at FM 1485 and Footbridge

The LDC for Stations 11336 and 17746 are shown in Figure 12. As with the previous stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Forty-two percent and 71 percent of samples exceed the grab sample criterion in the wet flow regimes at Station 11336 and 17746 respectively.

AU 1004E_02: Station 16626 – Stewarts Creek

The LDC for Station 16626 is shown in Figure 13. As with the previous stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Sixty-two percent and 43 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. Bacteria levels at dry flows generally meet state criteria.

AU 1008_02: Station 11314 – Spring Creek at SH 249

The LDC for Station 11314 is shown in Figure 14. As with the previous stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Seventy percent and 30 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. 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}.

AU 1008_03: Station 11313 – Spring Creek at IH 45

The LDC for Station 11313 is shown in Figure 15. As with the previous two stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Seventy-four percent and 45 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. Additionally, 25 percent of samples during dry flow conditions exceed the grab sample criteria, although the geometric mean fell slightly below state criteria. 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}.

AU 1008_04: Station 11312 – Spring Creek at Riley Fuzzel Rd

The LDC for Station 11312 is shown in Figure 16. As with the previous stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Ninety-six percent and 32 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. Bacteria levels at dry flow conditions generally meet state criteria. For relatively high flow conditions, bacteria levels at this station appear to be higher than the previous upstream stations. 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}.

AU 1008H_01: Station 11185 – Willow Creek at Gosling Rd

The LDC for Station 11185 is shown in Figure 17. Seventy-seven percent, 30 percent and 40 percent of samples exceed the grab sample criterion in the wet, moderate, and dry flow regimes, respectively. 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}.

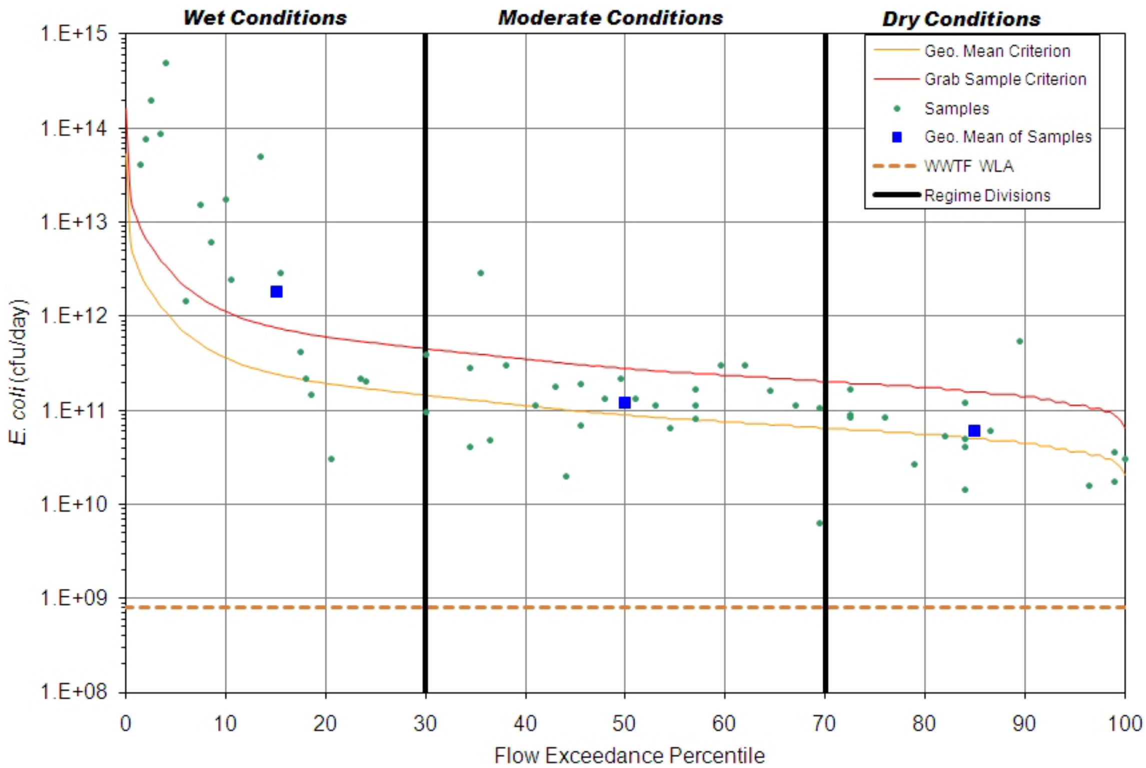


Figure 10. LDC for Station 14241 (Caney Creek at SH 105)

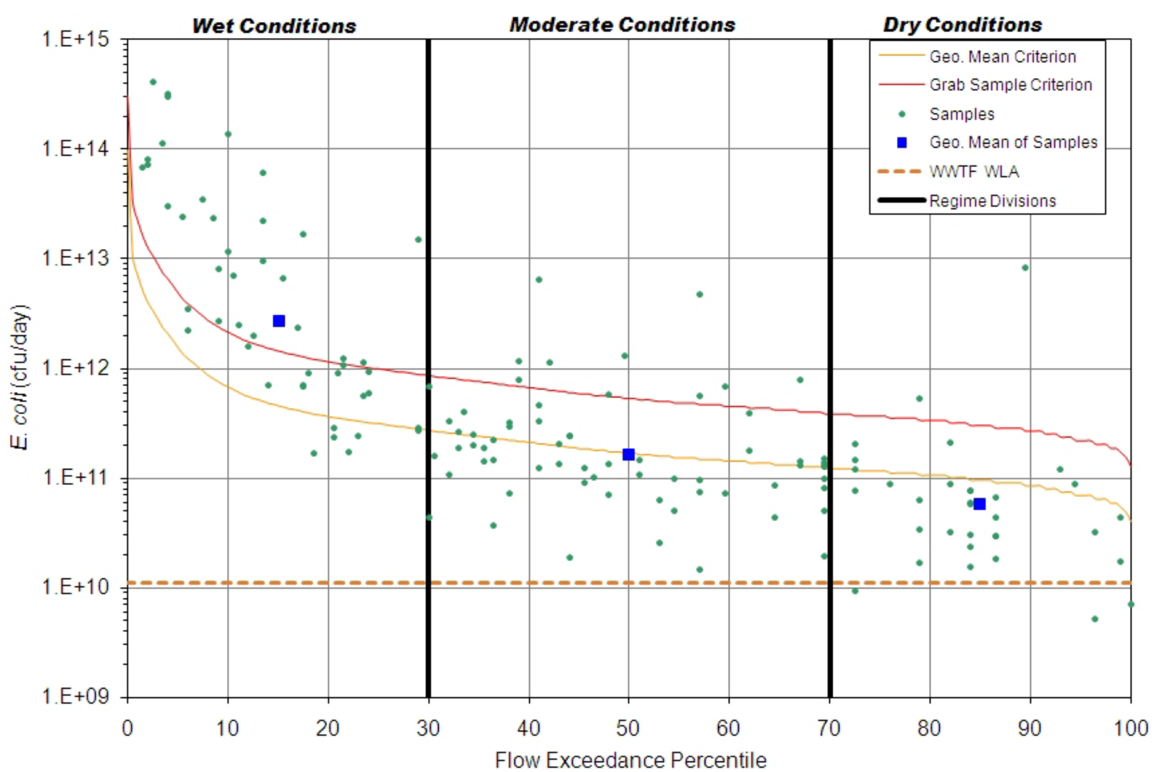


Figure 11. LDC for Station 11334 (Caney Creek at FM 1485)

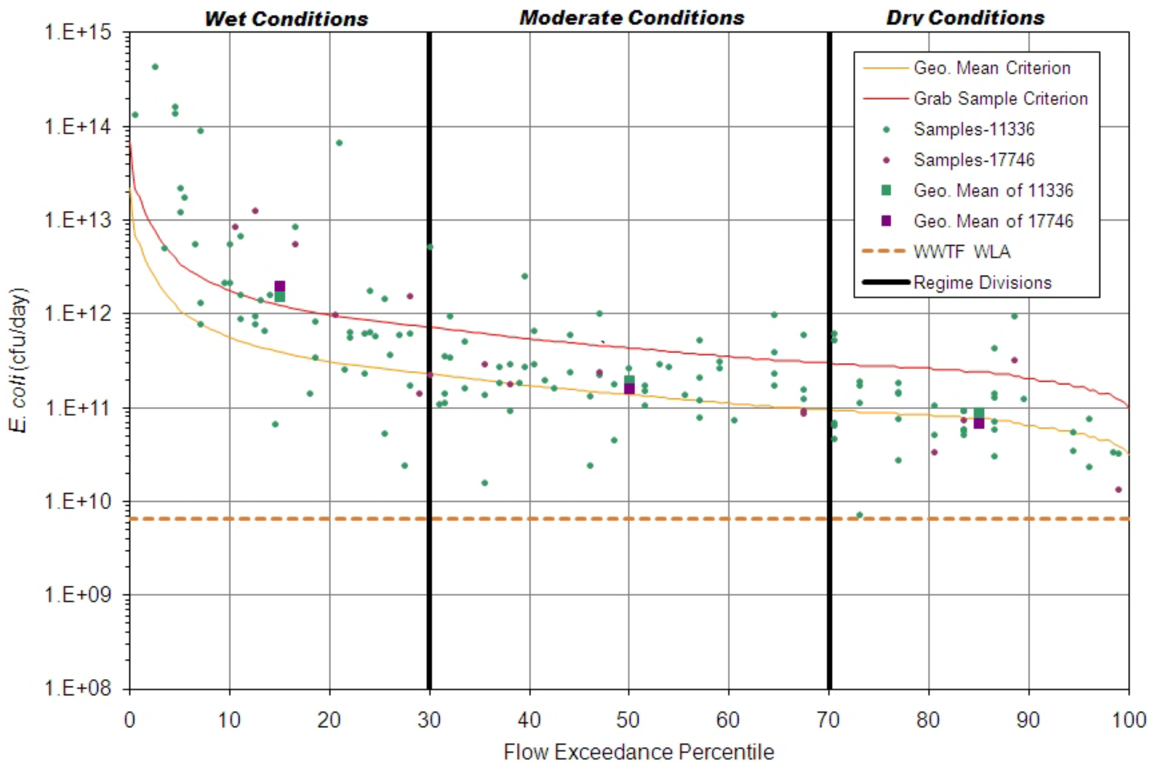


Figure 12. LDC for Station 11336/17746 (Peach Creek at FM 1485 and Footbridge)

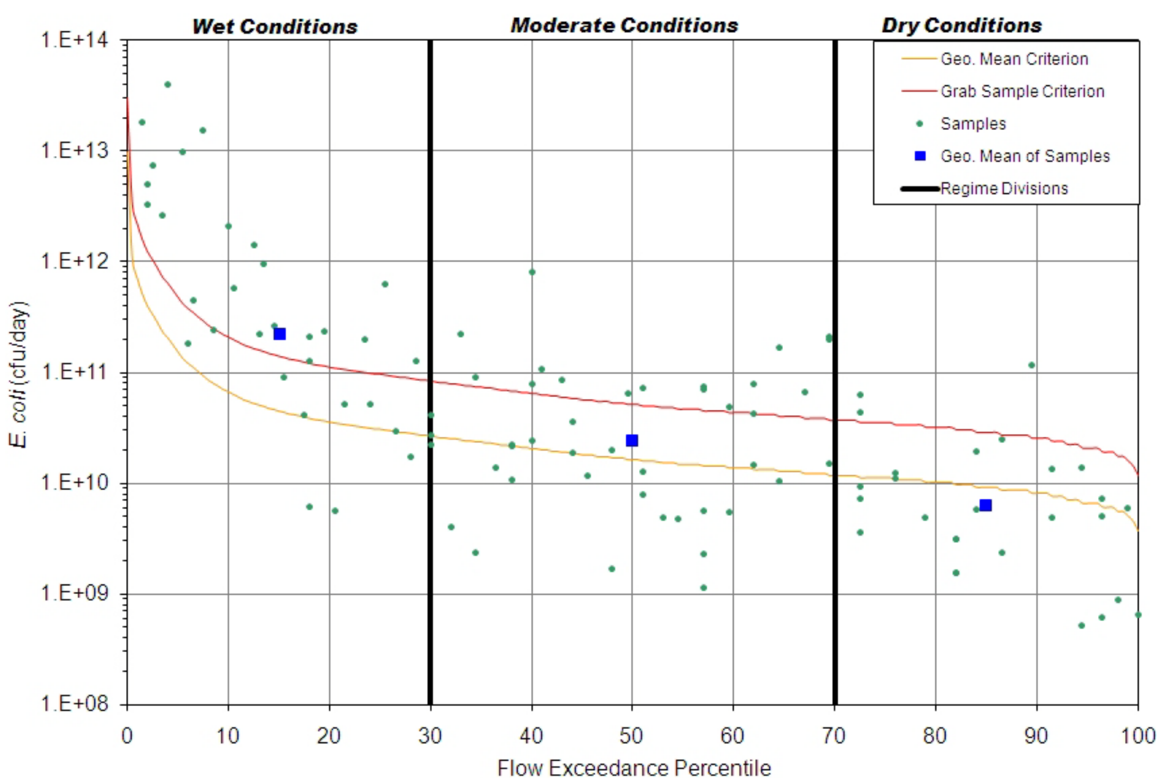


Figure 13. LDC for Station 16626 (Stewarts Creek)

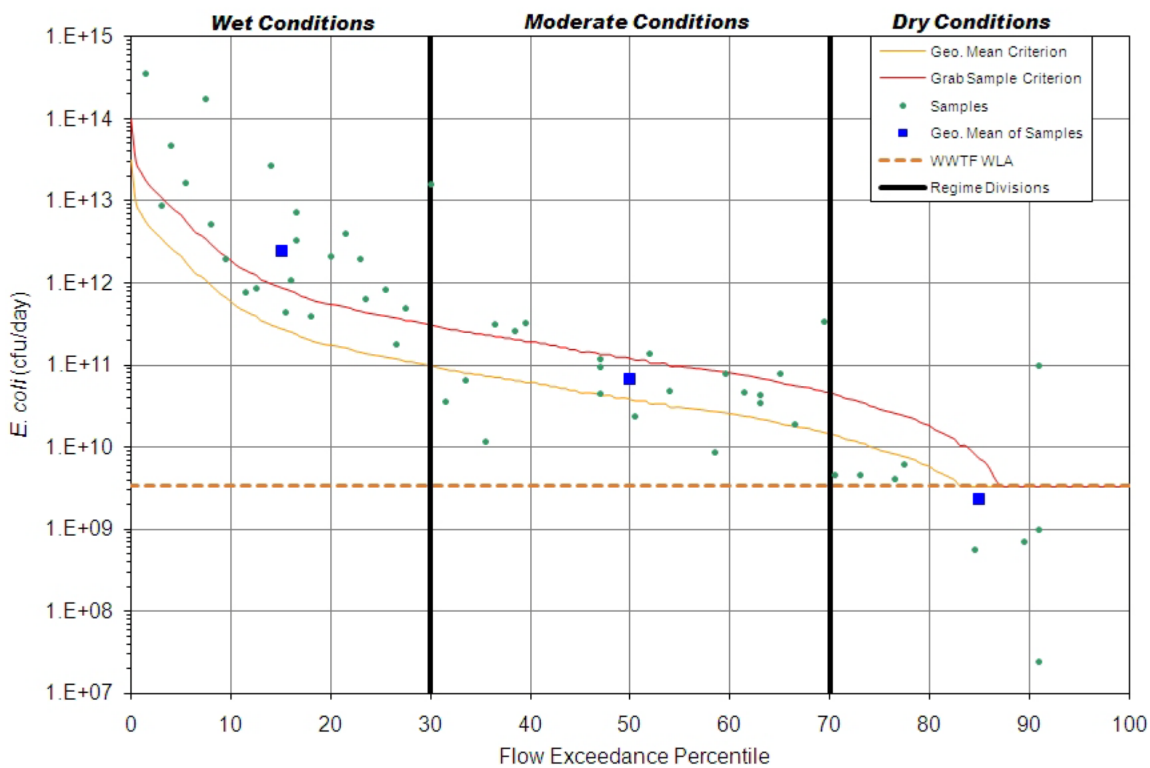


Figure 14. LDC for Station 11314 (Spring Creek at SH 249)

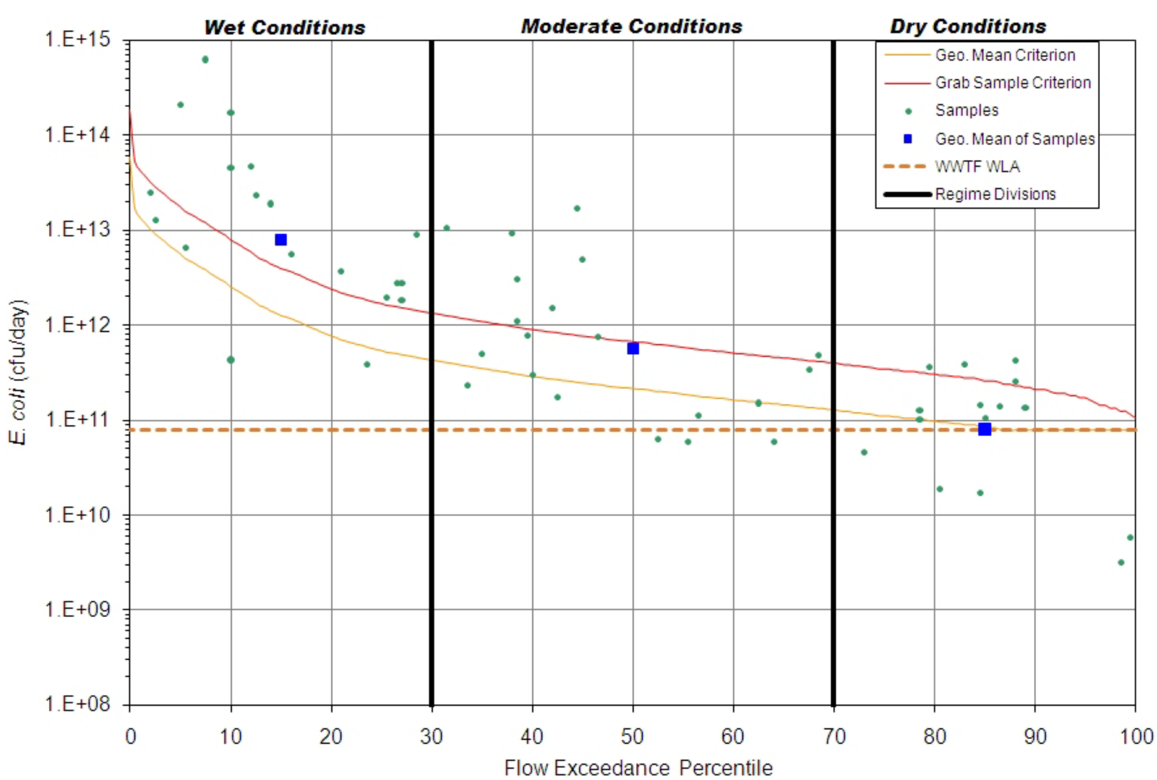


Figure 15. LDC for Station 11313 (Spring Creek at IH 45)

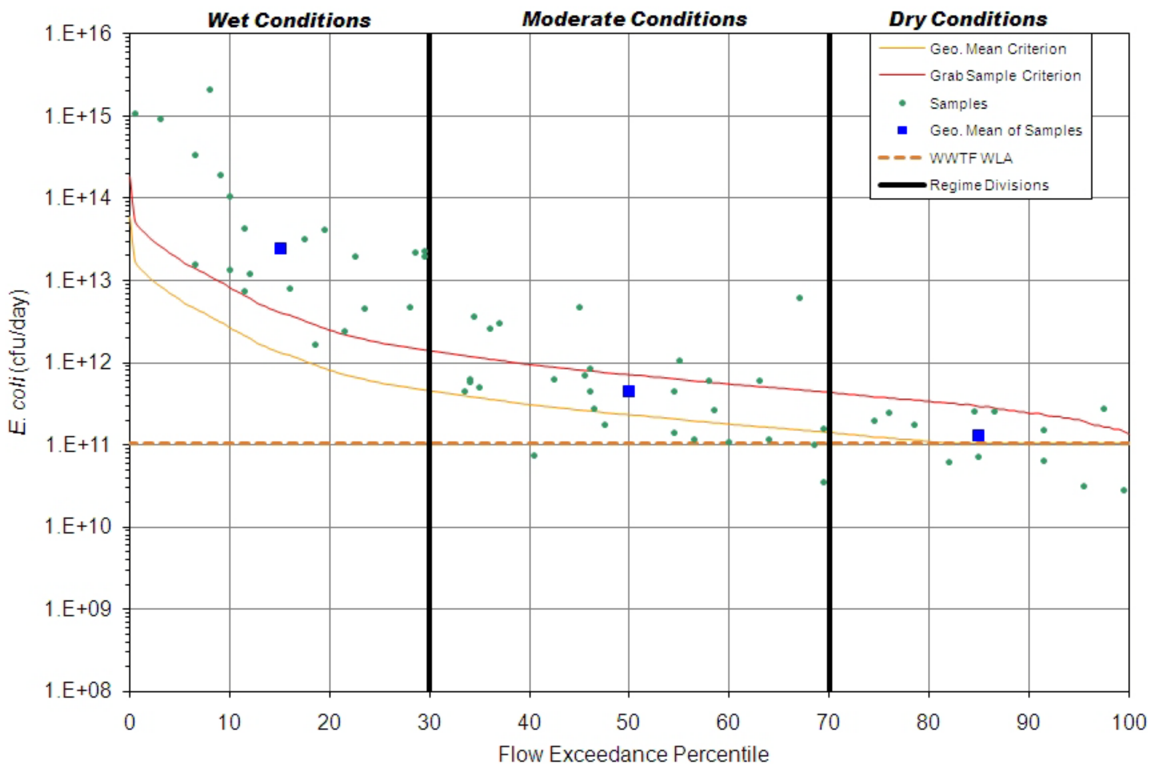


Figure 16. LDC for Station 11312 (Spring Creek at Riley Fuzzel Rd)

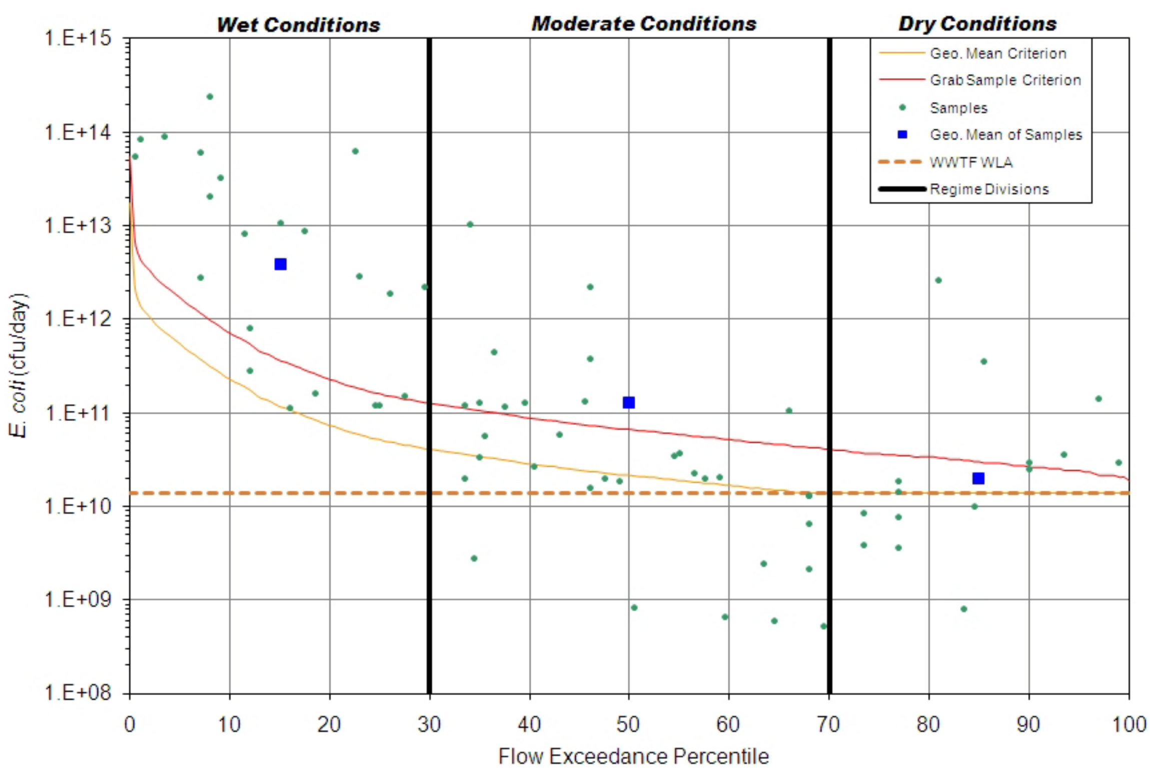


Figure 17. LDC for Station 11185 (Willow Creek at Gosling Rd)

AU 1009_01: Station 11333 – Cypress Creek at Hahl Rd

The LDC for Station 11333 is shown in Figure 18. Exceedances of state criteria appear to be most common under high flow conditions, beginning at approximately the 35 flow exceedance percentile. Eighty percent and 22 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. Samples collected during dry conditions generally meet state criterion. 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}.

AU 1009_02: Station 11331 – Cypress Creek at SH 249

The LDC for Station 11331 is shown in Figure 19. Seventy-four percent and 55 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. A comparison of the data at this station to the two previous upstream stations suggests that bacteria levels are typically slightly higher at this station. 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}.

AU 1009_03: Station 11328 – Cypress Creek at IH 45

The LDC for Station 11328 is shown in Figure 20. As with the previous station, exceedances of water quality criteria appear common under all flow regimes and most prominently during wet conditions. Eighty-three percent, 56 percent, and 31 percent of samples exceed the grab sample criterion in the wet, moderate, and dry flow regimes, respectively. 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}.

AU 1009_04: Station 11324 – Cypress Creek at Cypresswood Dr

The LDC for Station 11324 is shown in Figure 21. For this station, there are relatively few samples taken under dry flow conditions. Seventy-eight percent and 24 percent of samples exceed the grab sample criterion in the wet and moderate flow regimes, respectively. Bacteria levels collected during dry flow conditions generally meet state criteria, with zero samples that exceed the grab sample criteria. 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}.

AU 1009C_01: Station 17496 – Faulkey Gully at Lakewood Forest Dr

The LDC for Station 17496 is shown in Figure 22. As with the previous stations, exceedances of water quality criteria appear common under all flow regimes and most prominently during wet conditions. Sixty-eight percent, 42 percent, and 25 percent of samples exceed the grab sample criterion in the wet, moderate, and dry flow regimes, respectively. 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}.

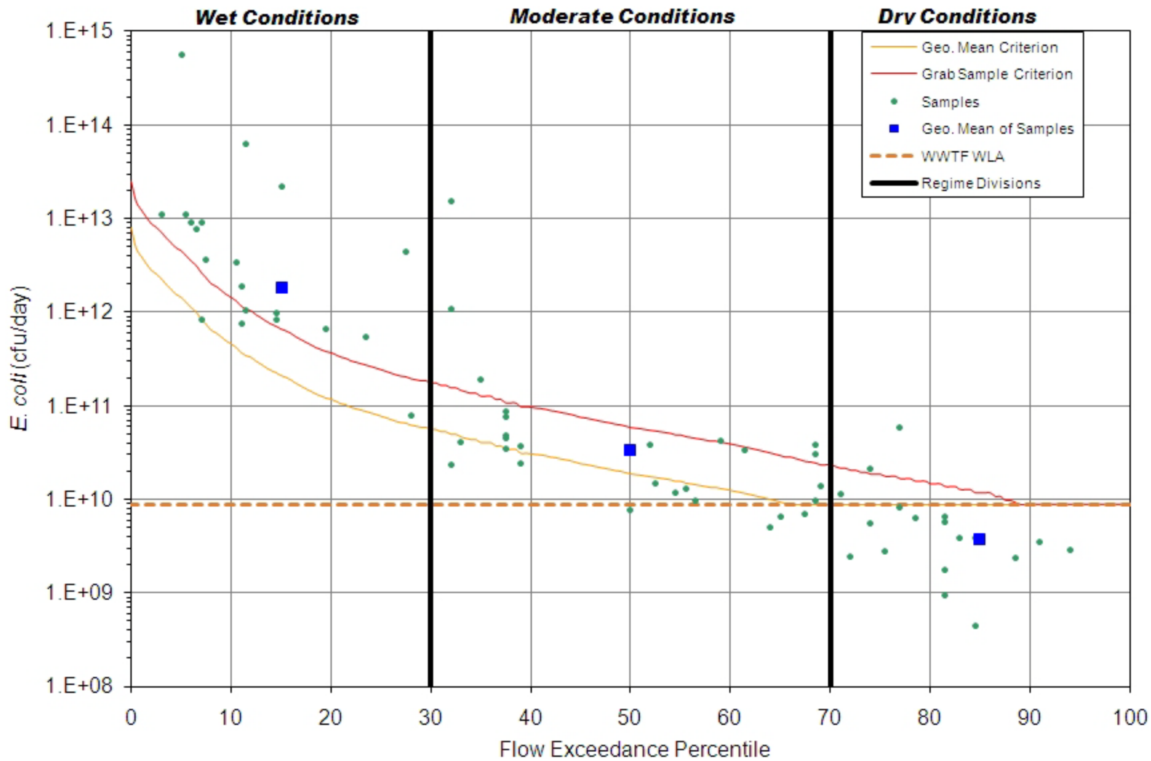


Figure 18. LDC for Station 11333 (Cypress Creek at Hahl Rd)

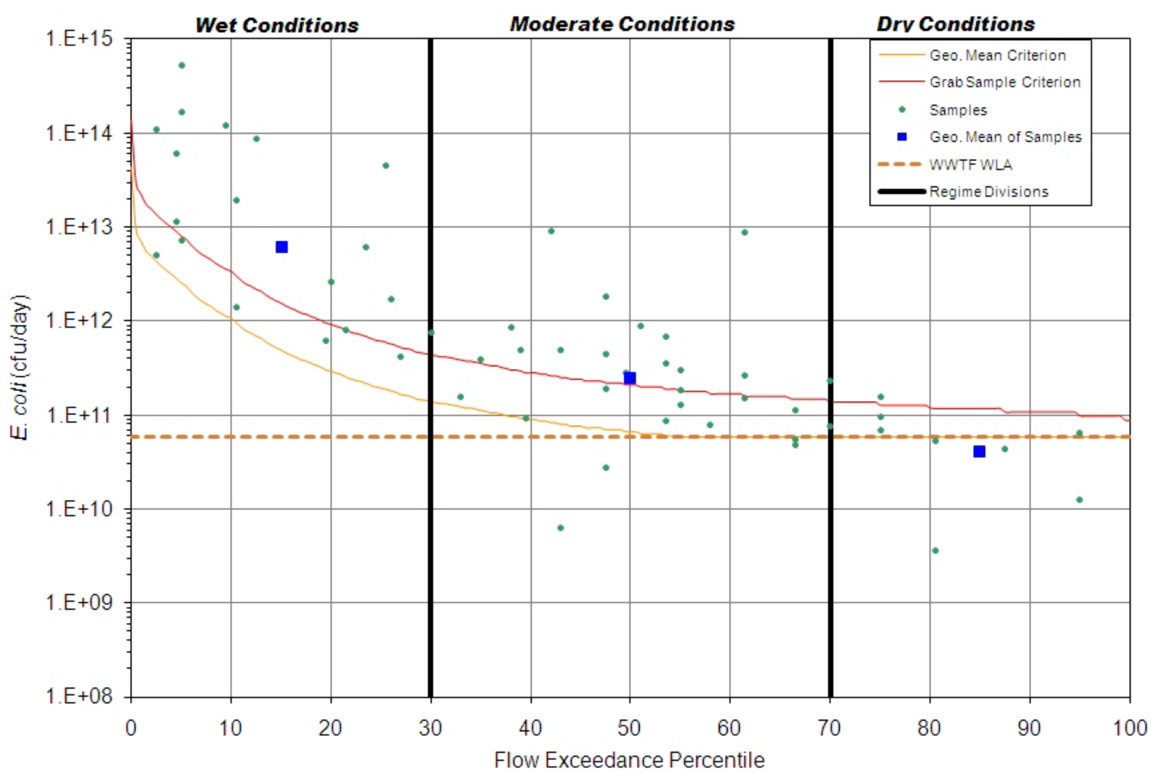


Figure 19. LDC for Station 11331 (Cypress Creek at SH 249)

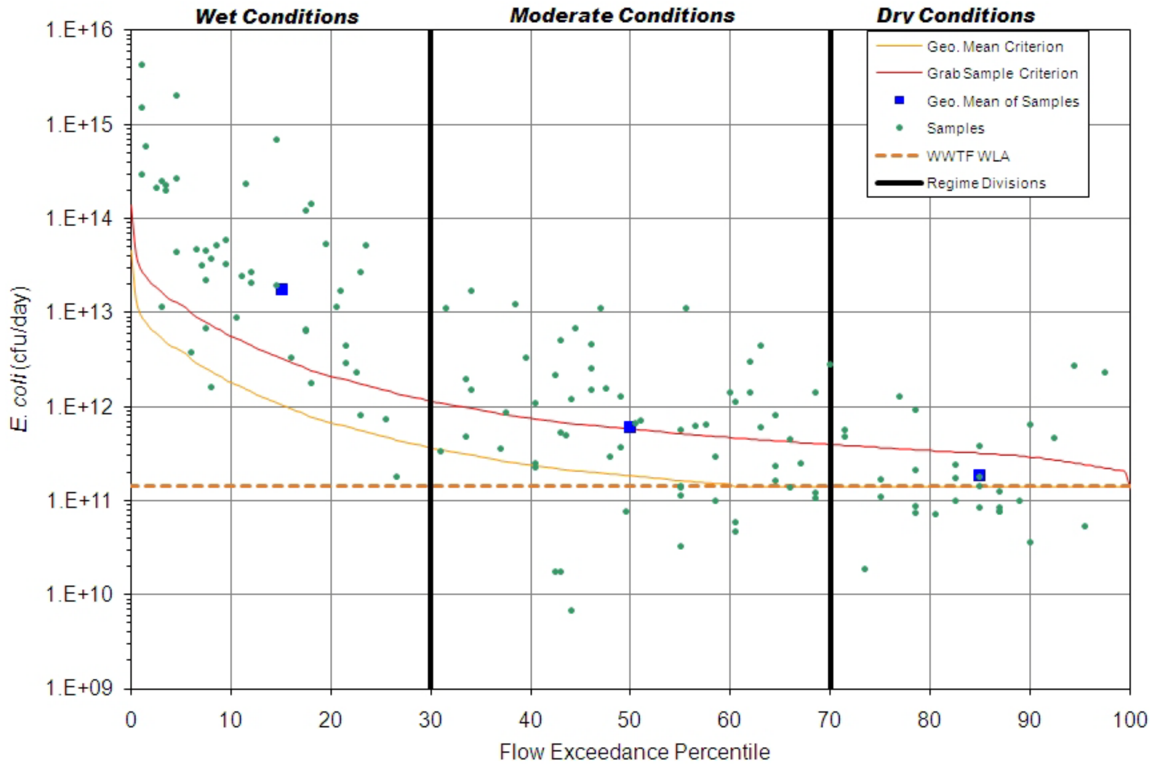


Figure 20. LDC for Station 11328 (Cypress Creek at IH 45)

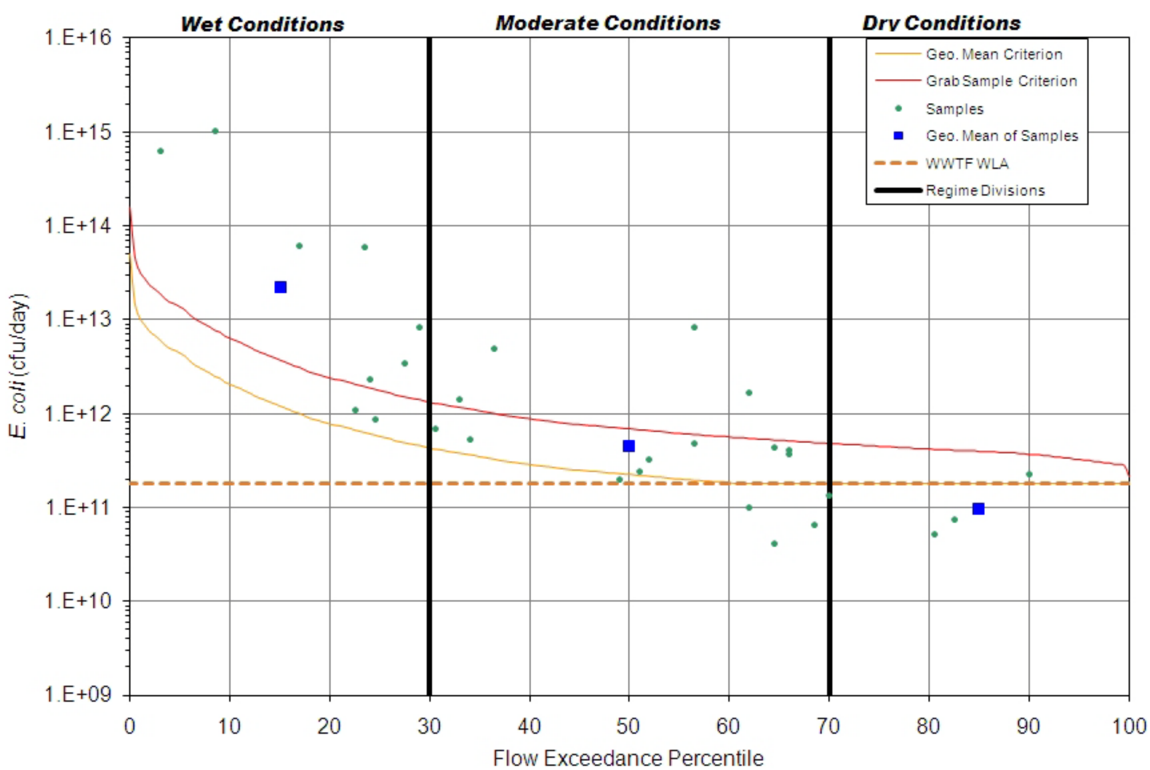


Figure 21. LDC for Station 11324 (Cypress Creek at Cypresswood Dr)

AU 1009D_01: Station 17481 – Spring Gully at Spring Creek Oaks Dr

The LDC for Station 17481 is shown in Figure 23. For this station, exceedances of water quality criteria appear common under all flow regimes. Eight-five percent, 47 percent, and 67 percent of samples exceed the grab sample criterion in the wet, moderate, and dry flow regimes, respectively. 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}.

AU 1009E_01: Station 14159 – Little Cypress Creek at Kluge Rd

The LDC for Station 14159 is shown in Figure 24. As with the previous stations, exceedances of water quality criteria appear common under all flow regimes and most prominently during wet conditions. Eighty-two percent, 40 percent, and 54 percent of samples exceed the grab sample criterion in the wet, moderate, and dry flow regimes, respectively. 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}.

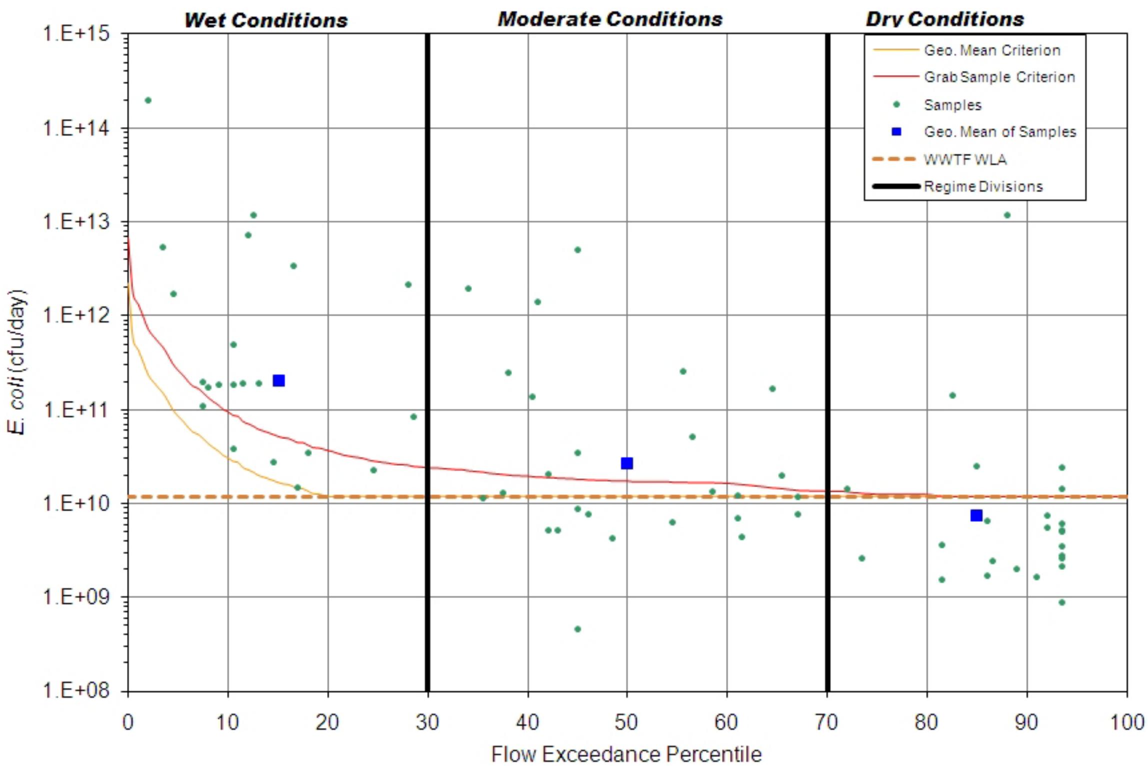


Figure 22. LDC for Station 17496 (Faulkey Gully at Lakewood Forest Dr)

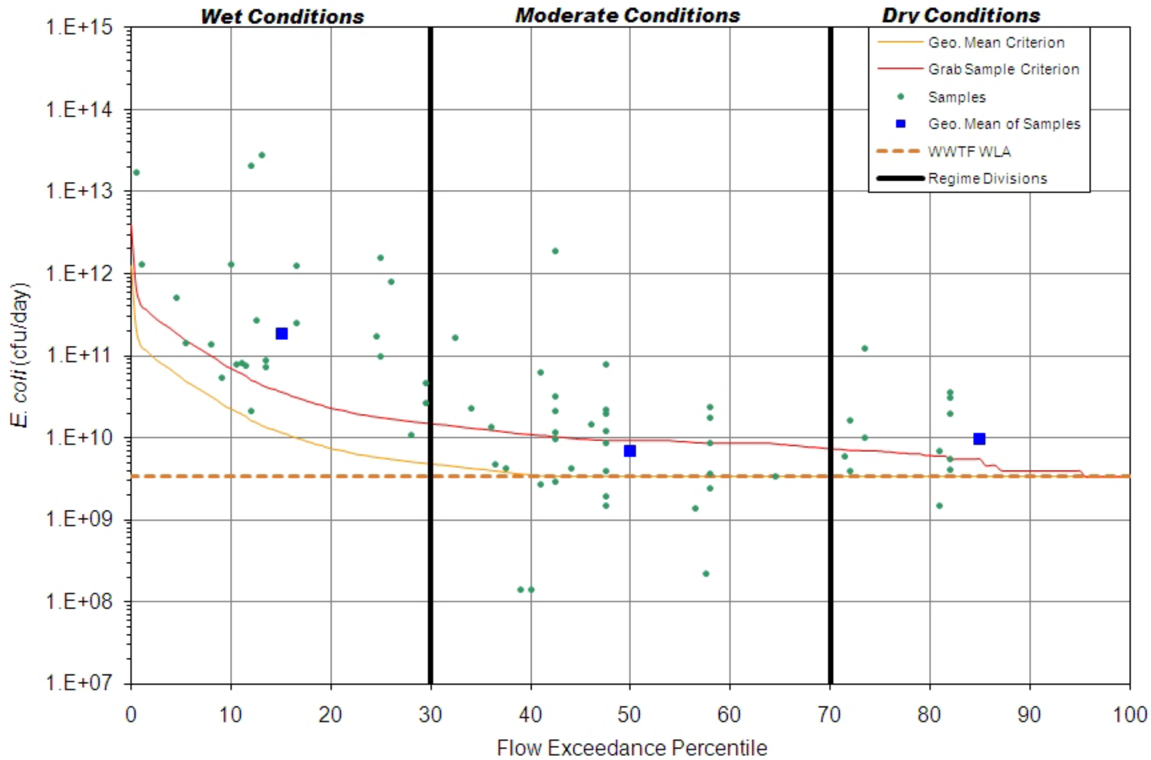


Figure 23. LDC for Station 17481 (Spring Gully at Spring Creek Oaks)

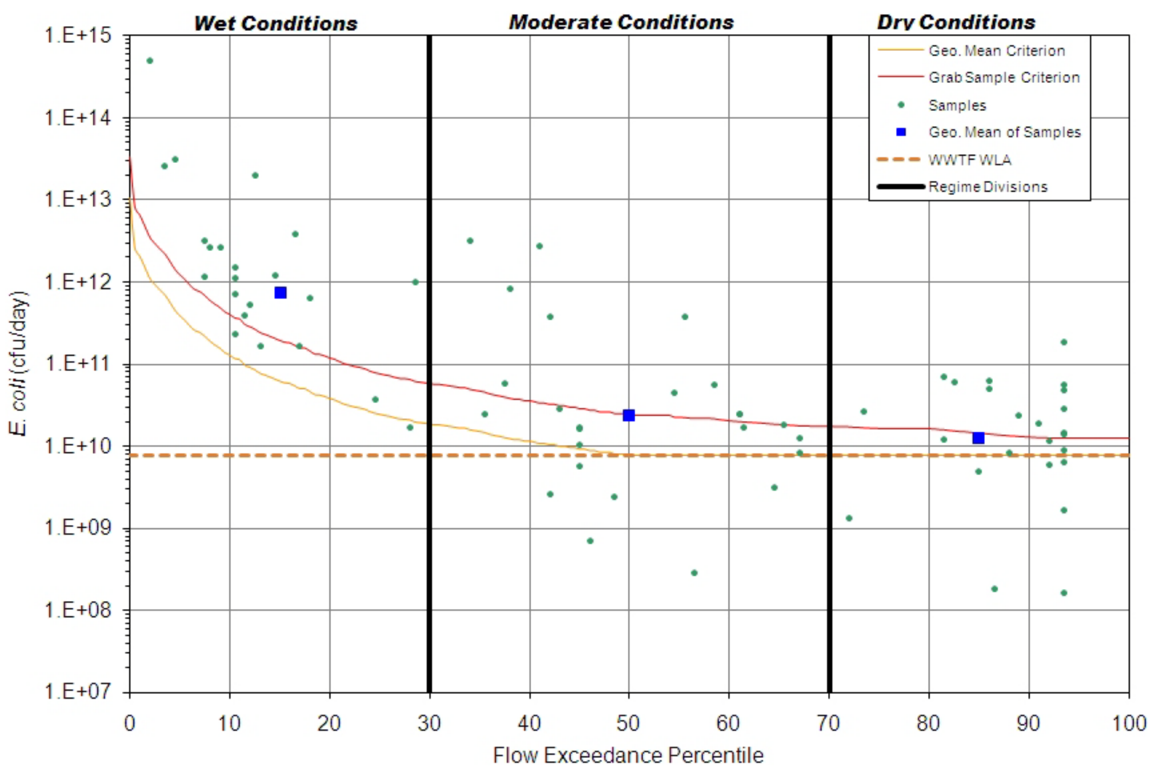


Figure 24. LDC for Station 14159 (Little Cypress Creek at Kluge Rd)

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/100mL of *E. coli*. The net effect of the TMDL with an MOS is that the assimilative capacity is slightly reduced. Furthermore, the critical conditions were defined conservatively, and therefore could be considered an additional implicit MOS.

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 water quality monitoring (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 high flow regime for all stations.

Waste Load Allocation

TPDES-permitted facilities are allocated a daily waste load (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} = criterion/2 * flow * 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 watersheds upstream of Lake Houston 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 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

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1008	Spring Creek	1008_02	11871-001	TX0072702	2936	City of Magnolia	0.65	1.55
		1008_02	12402-001	TX0086053	3131	Houston Oaks Golf Management, LP	0.01	0.02
		1008_02	12898-001	TX0095125	3241	Aqua Utilities, Inc	0.075	0.18
		1008_02	13115-001	TX0097969	3293	Clovercreek MUD	0.12	0.29
		1008_02	13653-001	TX0110663	3434	Magnolia ISD	0.015	0.04
		1008_02	14007-001	TX0117846	3590	AquaSource Development Co	0.13	0.31
		1008_02	14133-001	TX0119857	3661	White Oak Utilities, Inc	0.2	0.48
		1008_02	14266-001	TX0094315	3740	HMV Special Utility District	0.025	0.06
		1008_02	14542-001	TX0126934	4185	1774 Utilities, Corp	0.15	0.36
		1008_02	14624-001	TX0127973	4029	Rosehill Utilities, Inc	0.02	0.05
		1008_03	10616-001	TX0022381	2386	City of Tomball	1.5	3.58
		1008_03	10857-001	TX0025399	2538	Montgomery Co WCID #1	0.42	1.00
		1008_03	11968-001	TX0077275	2974	Tecon Water Company, LP	0.052	0.12
		1008_03	12303-001	TX0085693	3098	Aqua Utilities, Inc	0.015	0.04
		1008_03	12382-001	TX0087475	3124	C&P Utilities, Inc/ J&S Water Company, LLC5	0.12	0.29
		1008_03	12587-001	TX0090905	3168	Tecon Water Company, LP	0.46	1.10
		1008_03	12650-001	TX0092088	3185	Spring Oaks Mobile Home Park, Inc.	0.025	0.06
		1008_03	12851-001	TX0094552	3231	Richard Clark Enterprises, LLC	0.06	0.14
		1008_03	13614-001	TX0108553	3412	Richfield Investment Corp	0.61	1.45
		1008_03	13636-001	TX0109622	3425	Richfield Investment Corp	0.405	0.97
		1008_03	13648-001	TX0042099	3433	Encanto Real UD	0.25	0.60
		1008_03	13863-001	TX0115827	3517	H.H.J., Inc	0.8	1.91
		1008_03	14124-001	TX0119598	3657	Magnolia ISD	0.02	0.05

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1008 (cont.)	Spring Creek (cont.)	1008_03	14218-001	TX0123587	3711	Diocese of Galveston-Houston	0.015	0.04
		1008_03	14491-001	TX0126306	3876	Is Zen Center	0.035	0.08
		1008_03	14517-001	TX0125547	3894	South Central Water Company	0.038	0.09
		1008_03	14551-001	TX0127035	3917	AUC Group, LP	0.95	2.27
		1008_03	14592-001	TX0127663	3987	South Central Water Company	0.32	0.76
		1008_03	14662-001	TX0128333	4192	Navasota ISD	0.024	0.06
		1008_04	10908-001	TX0020974	2567	Harris County WCID #92	0.7	1.67
		1008_04	11001-001	TX0024759	2607	Southern Montgomery County MUD	2	4.77
		1008_04	11406-001	TX0056537	2779	Harris Co. MUD #26	1.5	3.58
		1008_04	11574-001	TX0026221	2848	Spring Creek UD	0.93	2.22
		1008_04	11799-001	TX0071528	2909	Harris Co. MUD #82	2.2	5.25
		1008_04	11970-001	TX0076538	2976	Montgomery Co. MUD #19	0.715	1.71
		1008_04	12030-001	TX0078263	2999	Rayford Road MUD	0.0015	0.004
		1008_04	12637-001	TX0091791	3181	Spring Center, Inc	0.006	0.01
		1008_04	12788-001	TX0095621	3217	Eastwood Mobile Home Park LP	0.05	0.12
		1008_04	12979-004	TX0119181	3260	Northgate Crossing MUD #2	0.95	2.27
		1008_04	14656-001	TX0128295	4161	Montgomery Co MUD #94	1.08	2.58
1008C*	Lower Panther Branch	1008C_01	11401-001	TX0054186	2775	San Jacinto River Authority	7.8	18.60
		1008C_01	12597-001	TX0091715	3169	San Jacinto River Authority	7.8	18.60
		1008C_01	12703-001	TX0092843	3199	Magnolia ISD	0.048	0.11
		1008C_01	13697-001	TX0090000	3449	Cedarstone One Investors, Inc	0.003	0.01
		1008C_01	14013-001	TX0118028	3594	AquaSource Development Co	0.05	0.12
		1008C_01	14141-001	TX0120073	3665	Aqua Development, Inc	0.45	1.07

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1008H	Willow Creek	1008H_01	10616-002	TX0117595	2387	City of Tomball	1.5	3.58
		1008H_01	10910-001	TX0058548	2568	Northampton MUD	0.75	1.79
		1008H_01	11404-001	TX0026255	2777	Dowdell PUD	0.95	2.27
		1008H_01	11630-001	TX0058530	2867	Harris Co. MUD #1	1.5	3.58
		1008H_01	12044-001	TX0078433	3002	Harris Co MUD #368	1.6	3.82
		1008H_01	12153-001	TX0081264	3049	North Harris Co MUD #19	0.25	0.60
		1008H_01	12519-001	TX0089915	3156	Aquasource Utility, Inc	0.1	0.24
		1008H_01	12643-001	TX0091987	3183	Pinewood Community LP	0.1	0.24
		1008H_01	13487-001	TX0119628	3365	Timbercrest Community Association	0.2	0.48
		1008H_01	13619-001	TX0083976	3414	Aqua Utilities, Inc	0.04	0.10
		1008H_01	13942-001	TX0117633	3558	Inline Utilities, LLC	0.25	0.60
		1008H_01	14181-001	TX0122530	3689	Aqua Development, Inc	0.075	0.18
		1008H_01	14421-001	TX0125687	3833	2920 Venture, LTD/ Harris County MUD #4014	0.6	1.43
		1008H_01	14475-001	TX0126152	3867	Northwest Harris Co. MUD #19	0.7	1.67
		1008H_01	14606-001	TX0127795	4018	South Central Water Company	0.08	0.19
		1008H_01	14610-001	TX0127850	4030	501 Maple Ridge, LTD	0.64	1.53
1009	Cypress Creek	1009_01	10310-001	TX0032476	2066	City of Waller	0.9	2.15
		1009_01	13296-002	TX0105376	3319	Harris Co MUD #358	2	4.77
		1009_01	14448-001	TX0125938	3850	Houston Warren Ranch Partners, LLC	0.55	1.31
		1009_01	14576-001	TX0127311	4007	523 Venture, Inc/ Becker Road LP[3]	0.2	0.48
		1009_02	02608-000	TX0092258	1069	Center Point Energy Houston Electric LLC	0.02	0.05
		1009_02	10962-001	TX0062049	2591	Harris County WCID #113	0.3	0.72
		1009_02	11084-001	TX0046833	2641	Lake Forest Plant Advisory Council	2.76	6.58
		1009_02	11267-001	TX0046868	2719	Timberlake ID	0.4	0.95

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1009	Cypress Creek	1009_02	11912-002	TX0075159	2952	Northwest Harris Co MUD #10	1.5	3.58
(cont.)	(cont.)	1009_02	11986-001	TX0076791	2982	Tower Oak Bend WSC	0.05	0.12
		1009_02	12327-001	TX0086011	3107	Cypress Hill MUD #1	0.8	1.91
		1009_02	12541-001	TX0090182	3159	Chasewood Utilities, Inc	0.1	0.24
		1009_02	12877-001	TX0094706	3237	Harris Co MUD #230	0.76	1.81
		1009_02	13020-001	TX0096920	3268	Harris Co MUD #286	0.6	1.43
		1009_02	13059-001	TX0098434	3284	Kwik-Kopy Corp	0.015	0.04
		1009_02	13881-001	TX0116009	3529	Harris Co MUD #365	1.2	2.86
		1009_02	14028-001	TX0117129	3604	Harris Co MUD 371	0.25	0.60
		1009_02	14030-001	TX0075221	3606	Northwest Harris Co MUD #9	1.5	3.58
		1009_02	14130-001	TX0081272	3660	Northwest Harris Co MUD #10	0.048	0.11
		1009_02	14172-001	TX0121126	3684	Utilities Investment Company, Inc	0.183	0.44
		1009_02	14209-001	TX0123366	3704	CTP Utilities Inc	0.18	0.43
		1009_02	14327-001	TX0124770	3779	Harris Co. MUD #391	0.95	2.27
		1009_02	14354-001	TX0124974	3794	Harris Co. MUD #374	0.65	1.55
		1009_02	14476-001	TX0126161	3868	Rouse-Houston, LP	0.8	1.91
		1009_03	10528-001	TX0026450	2313	Harris Co. FWSD # 52	0.7	1.67
		1009_03	10955-001	TX0046710	2589	Harris County WCID #116	1.3	3.10
		1009_03	11024-001	TX0021211	2616	Harris Co WCID #119	0.995	2.37
		1009_03	11081-001	TX0046761	2640	Ponderosa Joint Powers Agency	4.87	11.61
		1009_03	11089-001	TX0046701	2643	Prestonwood Fresh UD	0.95	2.27
		1009_03	11105-001	TX0046639	2652	Bammel UD	2.6	6.20
		1009_03	11215-001	TX0046663	2700	Meadowhill Regional MUD	2.4	5.72
		1009_03	11239-001	TX0055166	2710	CNP UD	2.5	5.96
		1009_03	11314-001	TX0046744	2744	Aqua Texas, Inc	0.4	0.95

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1009	Cypress Creek	1009_03	11366-001	TX0046779	2760	Cypress-Klein UD	0.7	1.67
(cont.)	(cont.)	1009_03	11409-001	TX0046817	2781	Kleinwood Joint Powers Board	5	11.92
		1009_03	11410-002	TX0046841	2782	Charterwood MUD	1.6	3.82
		1009_03	11835-001	TX0072150	2923	Bridgestone MUD	2.5	5.96
		1009_03	11900-001	TX0074217	2946	Tina Lee Tilles DBA Turk Brothers Building	0.001	0.002
		1009_03	11925-001	TX0074632	2960	Harris Co MUD #104	0.6	1.43
		1009_03	11941-001	TX0074322	2965	Harris Co MUD #58	0.6	1.43
		1009_03	11964-001	TX0076481	2972	Harris Co WCID #110	1	2.38
		1009_03	11988-001	TX0076856	2984	Harris Co MUD #24	2	4.77
		1009_03	11988-002	TX0113123	2985	Harris Co MUD #24	0.06	0.14
		1009_03	11988-003	TX0113115	2986	Harris Co MUD #24	0.06	0.14
		1009_03	12248-001	TX0084760	3079	UA Holdings 1994-5	0.1	0.24
		1009_03	12730-001	TX0090344	3206	Champ's Water Company	0.0154	0.04
		1009_03	13569-001	TX0078930	3393	Samuel Victor Pinter	0.0015	0.004
		1009_03	13573-001	TX0108120	3394	Northwest Harris County MUD #36	0.2	0.48
		1009_03	13625-001	TX0081337	3418	Northwest Harris Co MUD #20	0.4	0.95
		1009_03	13875-002	TX0115983	3527	Harris Co MUD #383	1.5	3.58
		1009_03	13893-001	TX0122211	3537	Dia-Den LTD	0.018	0.04
		1009_03	13942-002	TX0125466	3559	Inline Utilities, LLC	0.099	0.24
		1009_03	13963-001	TX0087424	3568	Luther's Bar-B-Q, Inc.	0.005	0.01
		1009_03	14044-001	TX0092894	3616	149 Enterprises, Inc	0.01	0.02
		1009_03	14193-001	TX0122963	3695	Kennard Tom Foley	0.035	0.08
		1009_03	14390-001	TX0125181	3813	Huffsmith-Kohrville, Inc	0.053	0.13
		1009_04	10783-001	TX0023612	2499	Inverness Forest ID	0.5	1.19

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1009 (cont.)	Cypress Creek (cont.)	1009_04	11044-001	TX0046671	2627	Memorial Hills UD	0.5	1.19
		1009_04	11141-001	TX0046728	2665	Treschwig Joint Powers Board	2	4.77
		1009_04	11142-002	TX0046680	2666	Timber Lane UD	2.62	6.25
		1009_04	11444-001	TX0046736	2793	Harris County WCID #99	0.225	0.54
		1009_04	11572-001	TX0047775	2847	Pilchers Property LP/ Northland Joint Venture[1]	0.06	0.14
		1009_04	11618-003	TX0118371	2862	Hunter's Glen MUD	1.4	3.34
		1009_04	11855-001	TX0072567	2931	North Park PUD	1.31	3.12
		1009_04	11886-001	TX0073105	2941	Six Flag Splashtown L.P.	0.06	0.14
		1009_04	11933-001	TX0075671	2962	Woodcreek MUD	0.6	1.43
		1009_04	12239-001	TX0084085	3076	Harris Co MUD #36	0.99	2.36
		1009_04	12378-002	TX0092967	3122	Richey Rd MUD	0.45	1.07
		1009_04	12470-001	TX0089184	4180	Harris Co MUD #221	1.8	4.29
		1009_04	12579-001	TX0090824	3166	Spring West MUD	0.762	1.82
		1009_04	12614-001	TX0091481	3174	Harris Co MUD #16	0.5	1.19
		1009_04	12812-001	TX0093939	3221	Regency 1-45/ Spring Cypress Retal, L.P.	0.06	0.14
		1009_04	13027-001	TX0096865	3272	Harris County	0.01	0.02
		1009_04	13054-001	TX0097209	3283	CW-MHP Ltd	0.01	0.02
		1009_04	13711-001	TX0085910	3453	Spring Cypress WSC	0.035	0.08
		1009_04	13765-001	TX0116068	3474	Harris Co MUD #249	0.8	1.91
		1009_04	13819-001	TX0113930	3502	Arthur Edward Bayer	0.06	0.14
		1009_04	14106-001	TX0119270	3644	Aqua Development, Inc	0.08	0.19
		1009_04	14526-001	TX0031305	3902	Spring ISD	0.03	0.07
1009C	Faulkey Gully	1009C_01	11824-002	TX0128210	4063	Northwest Harris Co. MUD #5	0.4	0.95
		1009C_01	11832-001	TX0072354	2921	Faulkey Gully MUD	1.42	3.39

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1009C	Faulkey Gully	1009C_01	11939-001	TX0075795	2964	Northwest Harris Co MUD #15	3.12	7.44
(cont.)	(cont.)	1009C_01	12600-001	TX0091171	3170	Elite Computer Consultants, LP	0.008	0.02
1009D	Spring Gully	1009D_01	12025-002	TX0077941	2998	Bilma PUD	0.75	1.79
		1009D_01	12224-001	TX0083801	3069	Klein ISD	0.011	0.03
		1009D_01	13152-001	TX0098647	3300	Northwest Harris Co MUD #32	0.65	1.55
1009E	Little Cypress Creek	1009E_01	11814-001	TX0071609	2912	Boys and Girls Country of Houston	0.1	0.24
		1009E_01	11824-001	TX0072346	2917	Northwest Harris County MUD #5	0.8	1.91
		1009E_01	11887-001	TX0073393	2942	Grant Rd PUD	0.31	0.74
		1009E_01	11913-001	TX0075183	2953	Northwest Freeway MUD	0.45	1.07
		1009E_01	13472-001	TX0090841	3360	Hockley Rail Car, Inc	0.006	0.01
		1009E_01	13753-001	TX0113107	3469	Harris Co MUD #360	0.8	1.91
		1009E_01	14434-001	TX0125806	3842	Westside Water, LLC	0.1	0.24
		1009E_01	14441-001	TX0125881	3846	Harris County MUD #389	0.3	0.72
		1009E_01	14643-001	TX0128180	4061	Northwest Harris Co MUD #10	0.0945	0.23
		1009E_01	14675-001	TX0128457	4203	Quadvest, LP	0.32	0.76
1010	Caney Creek	1010_02	11020-001	TX0056685	2614	City of New Waverly	0.088	0.21
		1010_02	11715-001	TX0068659	2886	Texas National MUD WWTF	0.075	0.18
		1010_02	12670-001	TX0092517	3188	Mountain Man, Inc./ Ranch Utilities, LP[2]	0.175	0.42
		1010_03	12204-001	TX0083216	3059	Conroe ISD	0.02	0.05
		1010_04	14597-001	TX0127710	4027	The Signorelli Co.	0.6	1.43
		1010_04	12205-001	TX0083208	3060	Conroe ISD	0.015	0.04
		1010_04	12274-001	TX0084638	3089	New Caney MUD	1.06	2.53
		1010_04	12621-001	TX0091677	3178	Martin Realty & Land, Inc	0.15	0.36
		1010_04	13690-001	TX0111473	3445	Conroe ISD	0.1	0.24

Segment	Stream Name	AU	TPDES Number	NPDES Number	TCEQ Record Number	Facility Name	2008 Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion MPN/day)
1010 (cont.)	Caney Creek (cont.)	1010_04	14029-001	TX0117145	3605	LGI Housing, LLC/ Quadvest, LP6	0.6	1.43
		1010_04	14081-001	TX0118311	3632	Martin Realty & Land, Inc.	0.15	0.36
		1010_04	14083-001	TX0118818	3633	White Oak Developers, Inc.	0.2	0.48
		1010_04	14285-001	TX0124281	3753	C&R Water Supply, Inc.	0.3	0.72
		1010_04	14379-001	TX0125300	3806	East Montgomery Co MUD #3	0.08	0.19
		1010_04	14559-001	TX0127094	3924	Whitestone Houston Land, Ltd.	0.9	2.15
		1010_04	14694-001	TX0128651	4259	Elan Development, LP	0.18	0.43
1011	Peach Creek	1011_01	11143-001	TX0082511	2667	Splendora ISD	0.04	0.10
		1011_01	11143-002	TX0117463	2668	Splendora ISD	0.04	0.10
		1011_01	13389-001	TX0102512	3341	City of Splendora	0.3	0.72
		1011_02	11386-001	TX0078344	2768	Montgomery Co MUD #16	0.177	0.42
		1011_02	11993-001	TX0077241	2988	City of Woodbranch Village	0.133	0.32
		1011_02	13638-001	TX0093220	3427	Roman Forest Consolidated MUD	0.322	0.77
		1011_02	14311-001	TX0124583	3765	East Montgomery Co MUD #4	0.75	1.79
		1011_02	14536-001	TX0126853	3906	Flying J Inc.	0.05	0.12
		1011_02	14560-001	TX0127108	3925	Whitestone Houston Land, Ltd.	0.9	2.15

*Not part of this TMDL project, but a major tributary to impaired segment 1008 (Spring Creek)

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, TPDES permits for domestic WWTFs will require conditions that are consistent with the requirements and assumptions of the WLAs. For TPDES-regulated municipal, construction storm water, and industrial 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 12, 2010, memorandum from EPA relating to establishing WLAs for storm water sources). The EPA memo states that:

> "The CWA provides that storm water permits for MS4 discharges shall contain controls to reduce the discharge of pollutants to the "maximum extent practicable" and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. CWA section 402(p)(3)(8)(iii). Under this provision, the NPDES permitting authority has the discretion to include requirements for reducing pollutants in storm water discharges as necessary for compliance with water quality standards. Defenders of Wildlife v. Browner, 191 F.3d 1159, 1166 (9th Cir. 1999).
>
> The permitting authority's decision as to how to express the WQBEL(s), either as numeric effluent limitations or BMPs, including BMPs accompanied by numeric benchmarks, should be based on an analysis of the specific facts and circumstances surrounding the permit, and/or the underlying WLA, including the nature of the storm water discharge, available data, modeling results or other relevant information. As discussed in the 2002 memorandum, the permit's administrative record needs to provide an adequate demonstration that, where a BMP-based approach to permit limitations is selected, the BMPs required by the permit will be sufficient to implement applicable WLAs. Improved knowledge of BMP effectiveness gained since 2002 should be reflected in the demonstration and supporting rationale that implementation of the BMPs will attain water quality standards and WLAs"

The November 22, 2002, memorandum from EPA relating to establishing WLAs for storm water sources 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 approach to the maximum extent practicable is appropriate to address the storm water component of this TMDL.

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 changing conditions within the watershed. 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 (WQMP). Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

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

The present analysis accounts for future growth through population projections. Current and projected population data was acquired from the Houston-Galveston Area Council (H-GAC). Projected population growth for each watershed was calculated between 2008 and

2035. The projected population percentage increase of each watershed was multiplied with corresponding WLA_{WWTF}, to calculate future WLA_{WWTF}. Population growth percentages are presented in Table 17 with future WWTF loads presented in the subsequent section. The permitted flows were increased by the expected population growth per AU between 2008 and 2035 to determine the estimated future flows.

Future growth also affects nonpoint sources as the watershed land use changes. As future growth occurs, development and the regulated MS4 area will expand. The expansion of MS4 redistributes pollutant load allocation, shifting from current LA to future WLA_{MS4}. However, increases in urban development and re-development lead to increased impervious cover and nonpoint source loads. Storm water best management practices (BMPs) should be used to mitigate nonpoint source load increase attributed to population growth, negating the need for increased future allocation.

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 un-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	Segment	2008 Population	2035 Population	Population Increase	Median Flow for TMDL Calculations (cfs)*
Stewarts Creek	1004E	10,566	22,580	114%	14.6 (1004E_02)
Spring Creek	1008	263,370	521,082	98%	93.1 (1008_02) 460 (1008_03) 491 (1008_04)
Willow Creek	1008H	32,840	90,498	176%	53.7 (1008H_01)
Cypress Creek	1009	289,117	576,108	99%	73.6 (1009_01) 200 (1009_02) 435 (1009_03) 502 (1009_04)
Faulkey Gulley	1009C	13,900	24,871	79%	11.4 (1009C_01)
Spring Gulley	1009D	8,298	17,896	116%	6.65 (1009D_01)
Little Cypress Creek	1009E	25,194	70,950	182%	29.6 (1009E_01)
Caney Creek	1010	58,022	139,977	141%	79.5 (1010_02) 160 (1010_04)
Peach Creek	1011	23,046	61,696	168%	137 (1011_02)

* Median flow of the 0-30% 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 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.

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 15 AUs included in this project are summarized in Table 18. The TMDLs were calculated based on the median flow in the 0-30 flow exceedance percentile range. The WLA_{WWTF} for each AU includes the sum of the WWTF allocations for all upstream AUs. 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 (James Miertschin & Associates, Inc. 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 for recalculating the allocations in Table 19. Figures A-1 through A-15 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-15, 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.

Table 18. *E. coli* TMDL Summary Calculations for Lake Houston Assessment Units

AU	Sampling Location	Stream Name	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billion MPN/day)	$WLA_{STORM\ WATER}$[c] (Billion MPN/day)	LA[d] (Billion MPN/day)	MOS[e] (Billion MPN/day)	Future Growth[f] (Billion MPN/day)
1004E_02	16626	Stewarts Creek	44.9	0.00	0.00	42.6	2.24	0.00
1008_02	11314	Spring Creek	287	3.33	31.4	235	14.4	3.25
1008_03	11313		1420	78.7	141	1050	70.9	77.0
1008_04	11312		1510	103	146	1090	75.7	101
1008H_01	11185	Willow Creek	166	13.9	14.9	104	8.28	24.4
1009_01	11333	Cypress Creek	227	8.70	59.9	138	11.4	8.64
1009_02	11331		615	59.5	141	325	30.8	59.0
1009_03	11328		1340	142	299	690	67.0	141
1009_04	11324		1550	178	338	779	77.4	176
1009C_01	17496	Faulkey Gully	35.3	11.8	4.42	8.00	1.76	9.31
1009D_01	17481	Spring Gully	20.5	3.36	4.09	8.13	1.02	3.89
1009E_01	14159	Little Cypress Creek	91.1	7.82	5.16	59.4	4.56	14.2
1010_02	14241	Caney Creek	245	0.806	14.8	216	12.3	1.14
1010_04	11334		493	11.2	28.2	413	24.7	15.8
1011_02	17746	Peach Creek	422	6.47	0.00	383	21.1	10.9

[a] Maximum allowable load for the median of the high flow range; TMDL= WLA_{WWTF} + $WLA_{STORM\ WATER}$ + LA + MOS + Future Growth
[b] Includes sum of loads from the WWTFs discharging upstream of the TMDL station. Individual loads are calculated as permitted flow*126/2 (*E. coli*) MPN/100mL*conversion factor
[c] $WLA_{StormWater}$ = (TMDL – MOS –WLA_{WWTF})*(percent of drainage area covered by storm water permits)
[d] LA = TMDL – MOS –WLA_{WWTF} –$WLA_{StormWater}$-Future growth
[e] MOS = TMDL x 0.05
[f] Projected increase in WWTF permitted flows*126/2*conversion factor

The strength of this TMDL is the use of the LDC method to determine the overall 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. 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.

Table 19. Final TMDL Allocations

AU	TMDL[a] (Billion MPN/day)	WLA_{WWTF} [b] (Billion MPN/day)	$WLA_{STORM\ WATER}$ (Billion MPN/day)	LA (Billion MPN/day)	MOS (Billion MPN/day)
1004E_02	44.9	0	0	42.6	2.24
1008_02	287	6.58	31.4	235	14.4
1008_03	1,420	156	141	1050	70.9
1008_04	1,510	203	146	1090	75.7
1008H_01	166	38.3	14.9	104	8.28
1009_01	227	17.3	59.9	138	11.4
1009_02	615	119	141	325	30.8
1009_03	1,340	283	299	690	67.0
1009_04	1550	354	338	779	77.4
1009C_01	35.3	21.1	4.42	8.00	1.76
1009D_01	20.5	7.26	4.09	8.13	1.02
1009E_01	91.1	22.0	5.16	59.4	4.56
1010_02	245	1.94	14.8	216	12.3
1010_04	493	27.0	28.2	412	24.7
1011_02	422	17.3	0	383	21.1

[a] $TMDL = WLA_{WWTF} + WLA_{STORM\ WATER} + LA + MOS$
[b] WLA_{WWTF} = Original WLA_{WWTF} + Future Growth

Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. To assess the seasonal variability, *E. coli* data were evaluated based on the season in which they were collected. Two seasons, one warm and one cool, were considered for this analysis. The warm season covers May through September and the cool season includes November through March. (April and October, considered transitional between the warm and cool seasons, were excluded from the seasonal analysis.)

There are no consistent relationships between seasonal conditions and *E. coli* concentrations. Most of the stations exhibit only small variations between summer and winter geometric mean values. Exceptions are the Little Cypress Creek station (14159), which appears to have higher *E. coli* concentrations during the warm season, and the upstream Spring Creek station (11328), which appears to have higher *E. coli* levels during the cool season.

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 TMDL for watersheds upstream of Lake Houston and the implementation phase, a series of five public meetings were held in the area between June 2 and 12, 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. An update about the project was presented by TCEQ staff to the stakeholders on November 17, 2009. Information on past and future meetings for watersheds upstream of Lake Houston bacteria TMDL and related projects in the Houston area can be found on the H-GAC website at <www.h-gac.com/community/water/tmdl/Lake-Houston/default.aspx>.

Implementation and Reasonable Assurances

The issuance of permits consistent with TMDLs through the Texas Pollutant Discharge Elimination System (TPDES) provides reasonable assurance that wasteload allocations in this TMDL report will be achieved. Consistent with federal requirements, each TMDL is a plan element of an update to Texas' WQMP.

The TCEQ's WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations (40

Code of Federal Regulations (CFR) Sec. 130.6(c)). Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, the TCEQ certifies additional elements to the WQMP after the implementation plan (I-Plan) is approved 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.

For MS4 permits, the TCEQ will normally establish best management practices, which are a substitute for effluent limitations, as allowed by federal rules, where numeric effluent limitations are infeasible (see November 22, 2002, memorandum from EPA relating to establishing TMDL WLAs for storm water sources). When such practices are established in an MS4 permit, the TCEQ will not identify specific implementation requirements applicable to a specific TPDES storm water permit through an effluent limitation update. Rather, the TCEQ might 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.

Strategies for achieving pollutant loads in TMDLs from both point and nonpoint sources are reasonably assured by the state's use of an I-Plan. The TCEQ is committed to supporting implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods ascertain whether progress is occurring, and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect needs identified in evaluations of progress.

Key Elements of the I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures to implement the WLAs and LAs of particular TMDLs within a reasonable time period. I-Plans also identify the organizations responsible for carrying out management measures, and a plan for periodic evaluation of progress. EPA is not required, and is not authorized, to approve or disapprove implementation plans for TMDLs.

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 TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on the I-Plan begins during development of TMDLs, but the plan is not completed until sometime after the EPA approves the TMDLs. The cooperation required to develop the I-Plan will become a cornerstone for the shared responsibility necessary to carry it out.

The stakeholder-led Bacteria Implementation Group (BIG) will develop the I-Plan for *Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* along with other TMDLs for bacteria in the Houston area. The BIG was formed in December 2007 to develop an area-wide plan to address impairments to the contact recreation use throughout the greater Houston/Harris County area. The BIG is led by the H-GAC with funding from the TCEQ.

The BIG's plan will include all the Houston-area water bodies that have been listed as impaired for contact recreation (Table 20), including those identified in this report. The draft I-Plan is scheduled for completion in late 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

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. However, with certain exceptions, the I-Plan must nonetheless meet the overall loading goal established by the EPA-approved TMDL.

The I-Plan for these TMDLs is one of those exceptions because it identifies phased implementation that takes advantage of the adaptive management approach. In many cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

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

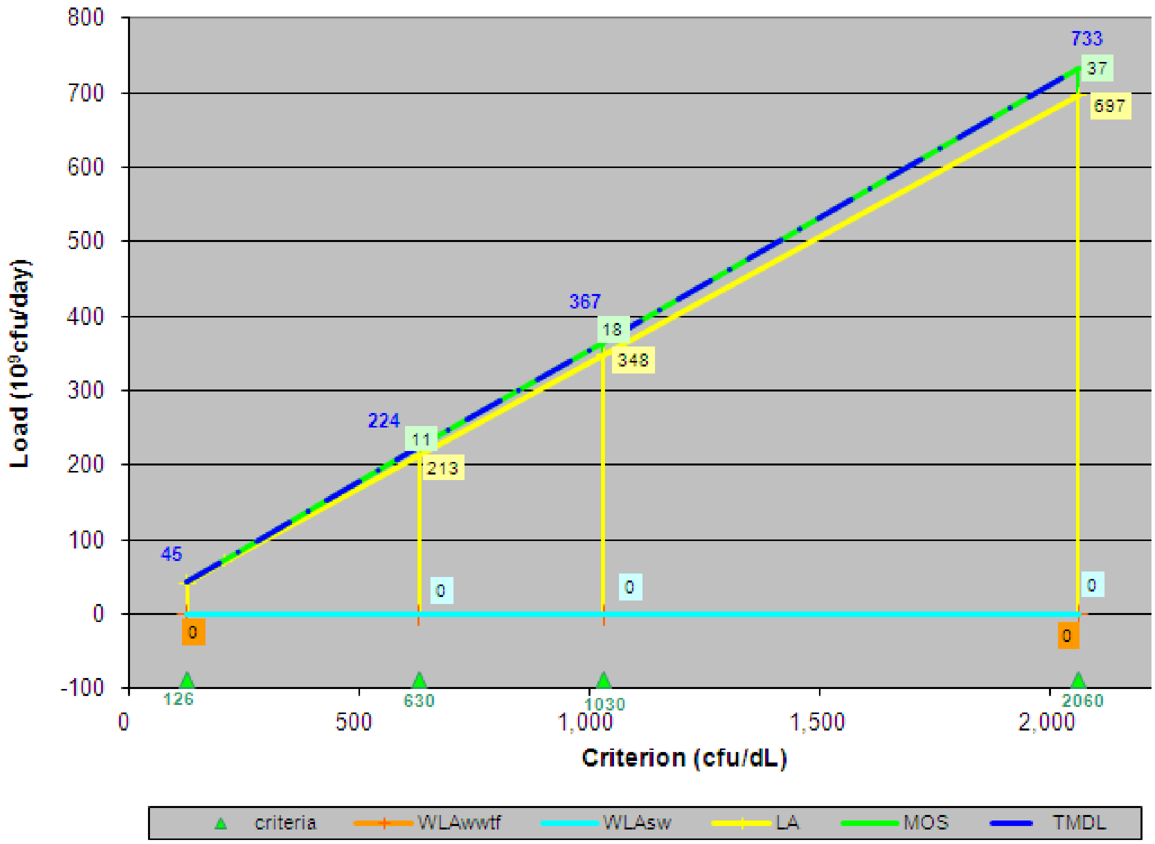

Figure A-1. Allocation Loads for AU 1004E_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.3560*Std
LA = 0.3382*Std
$WLA_{StormWater}$ = 0
WLA_{WWTF} = 63*0 = 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

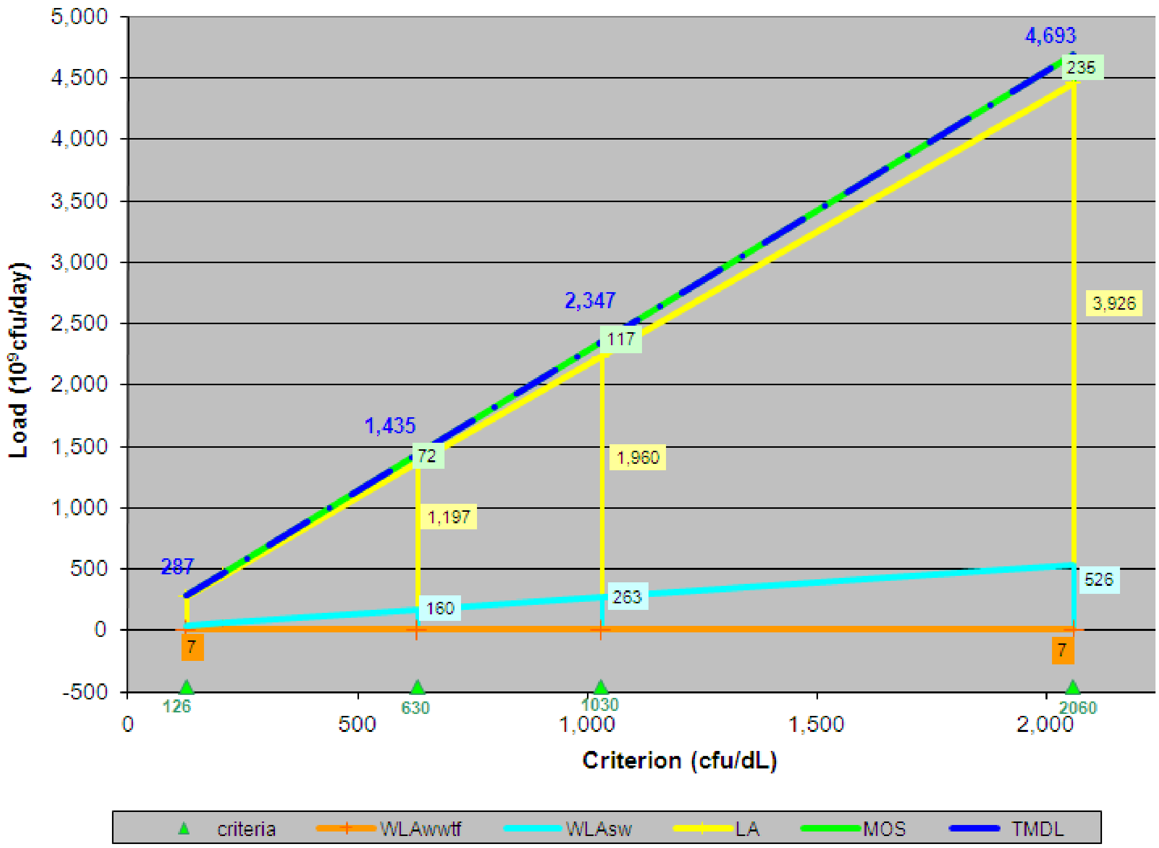

Figure A-2. Allocation Loads for AU 1008_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 2.2783*Std$$
$$LA = 1.9087*Std - 5.804$$
$$WLA_{StormWater} = 0.2557*Std - 0.777$$
$$WLA_{WWTF} = 63*0.1045 = 7$$
$$MOS = 0.05*TMDL$$

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

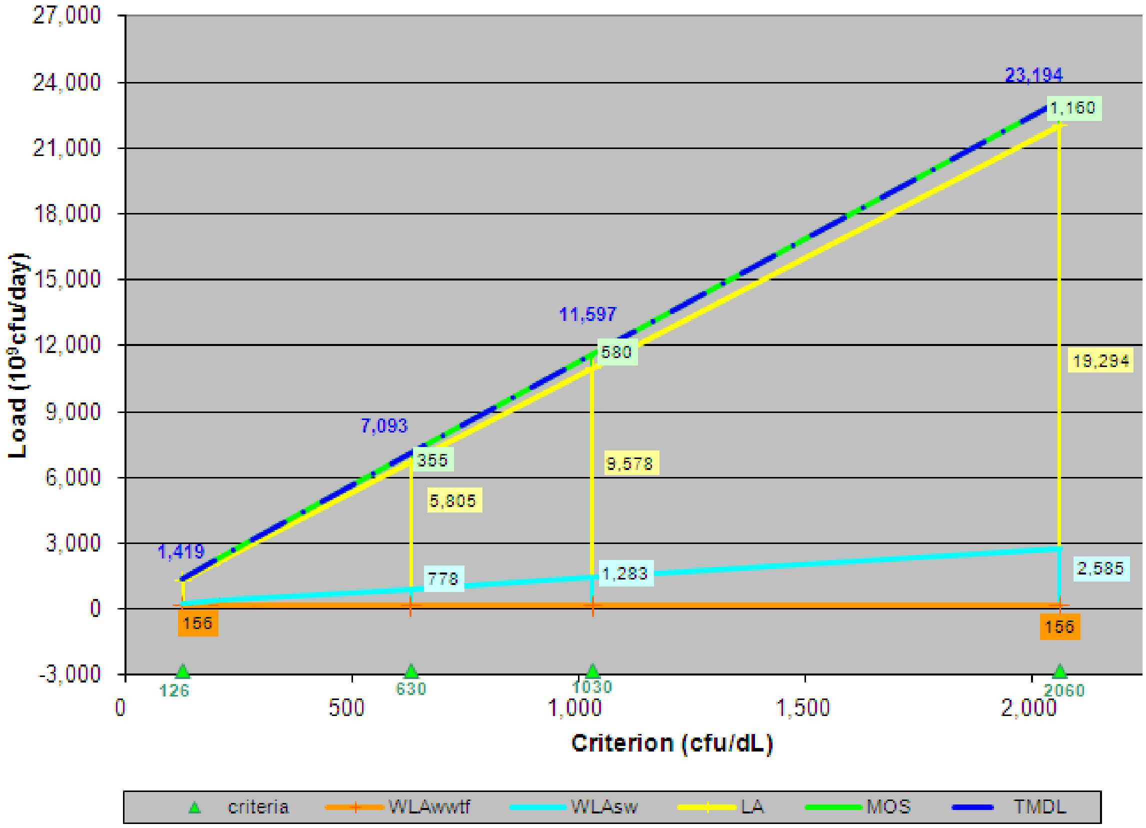

Figure A-3. Allocation Loads for AU 1008_03 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 11.2592*Std
LA = 9.4326*Std - 137.298
$WLA_{StormWater}$ = 1.2636*Std - 18.392
WLA_{WWTF} = 63*2.4713 = 156
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

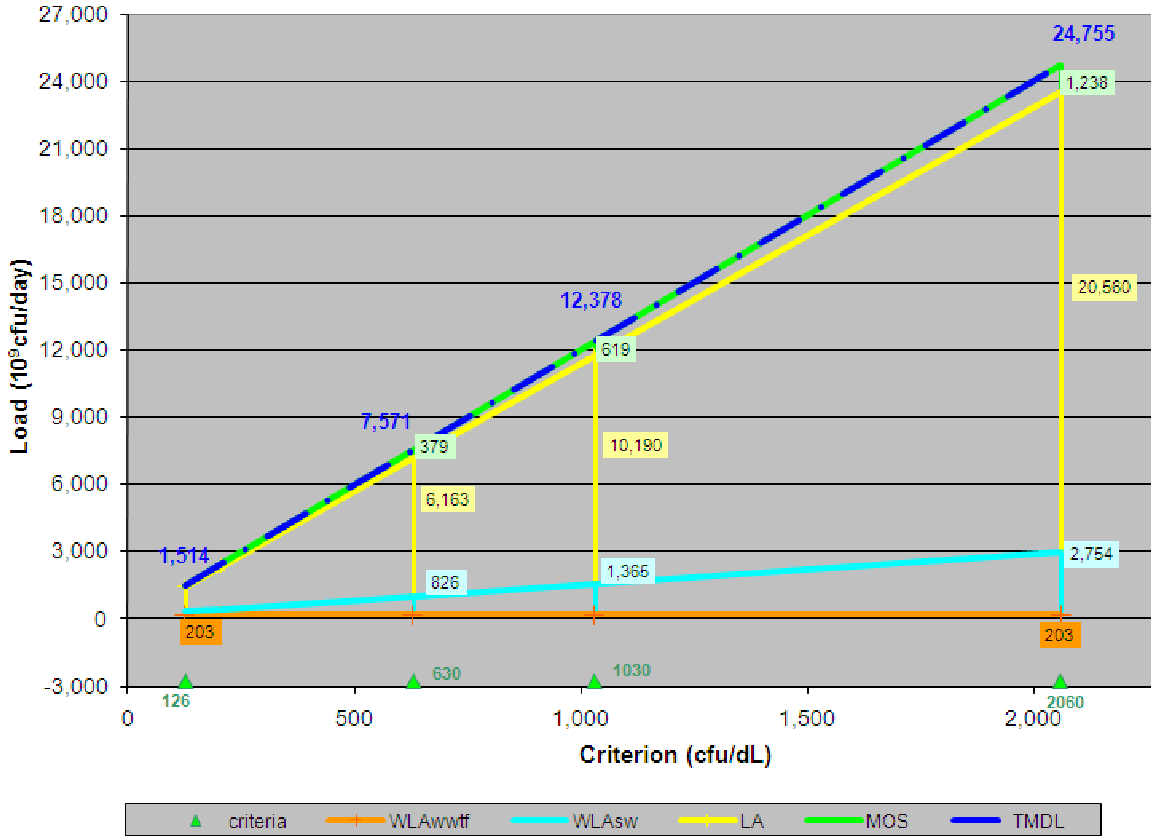

Figure A-4. Allocation Loads for AU 1008_04 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$TMDL = 12.0172 * Std$
$LA = 10.0677*Std - 179.454$
$WLA_{StormWater} = 1.3487*Std - 24.0039$
$WLA_{WWTF} = 63*3.2301 = 203$
$MOS = 0.05*TMDL$

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

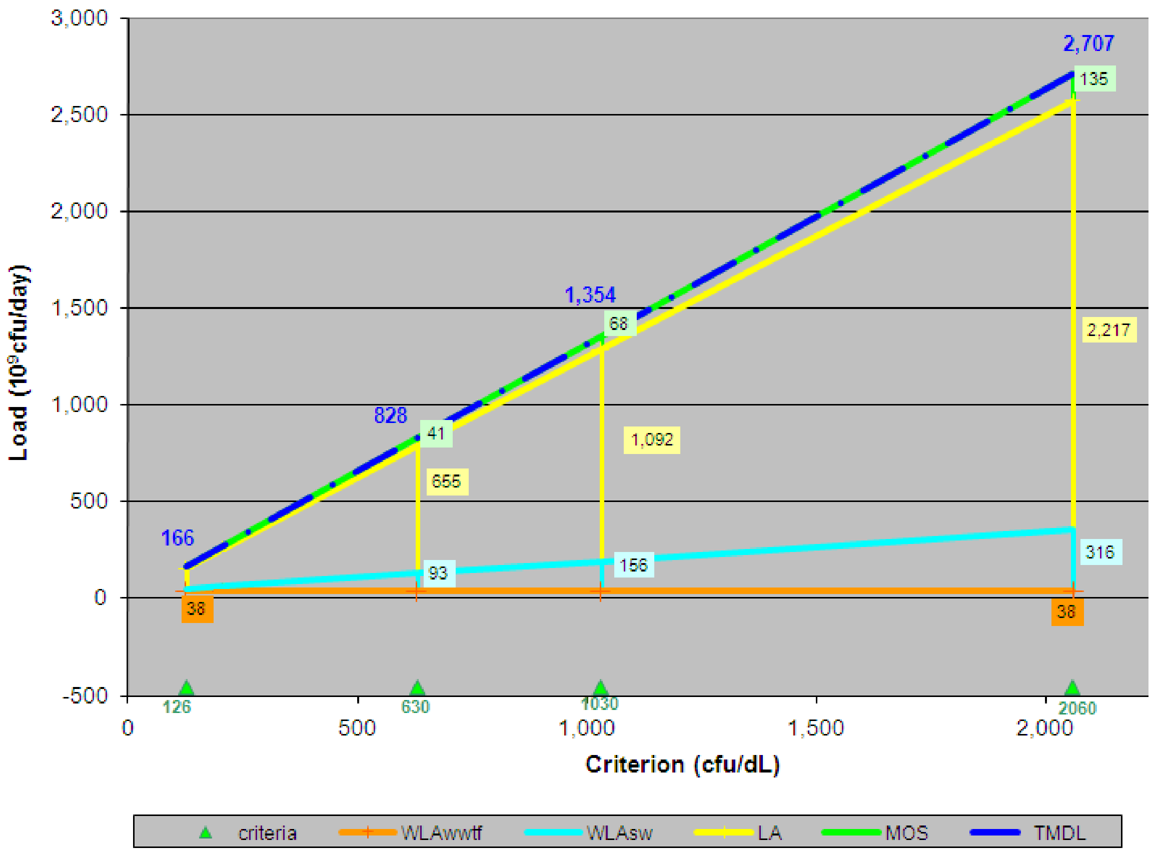

Figure A-5. Allocation Loads for AU 1008H_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 1.3141*Std$$
$$LA = 1.0925*Std - 33.553$$
$$WLA_{StormWater} = 0.1559*Std - 4.789$$
$$WLA_{WWTF} = 63*0.6086 = 38$$
$$MOS = 0.05*TMDL$$

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

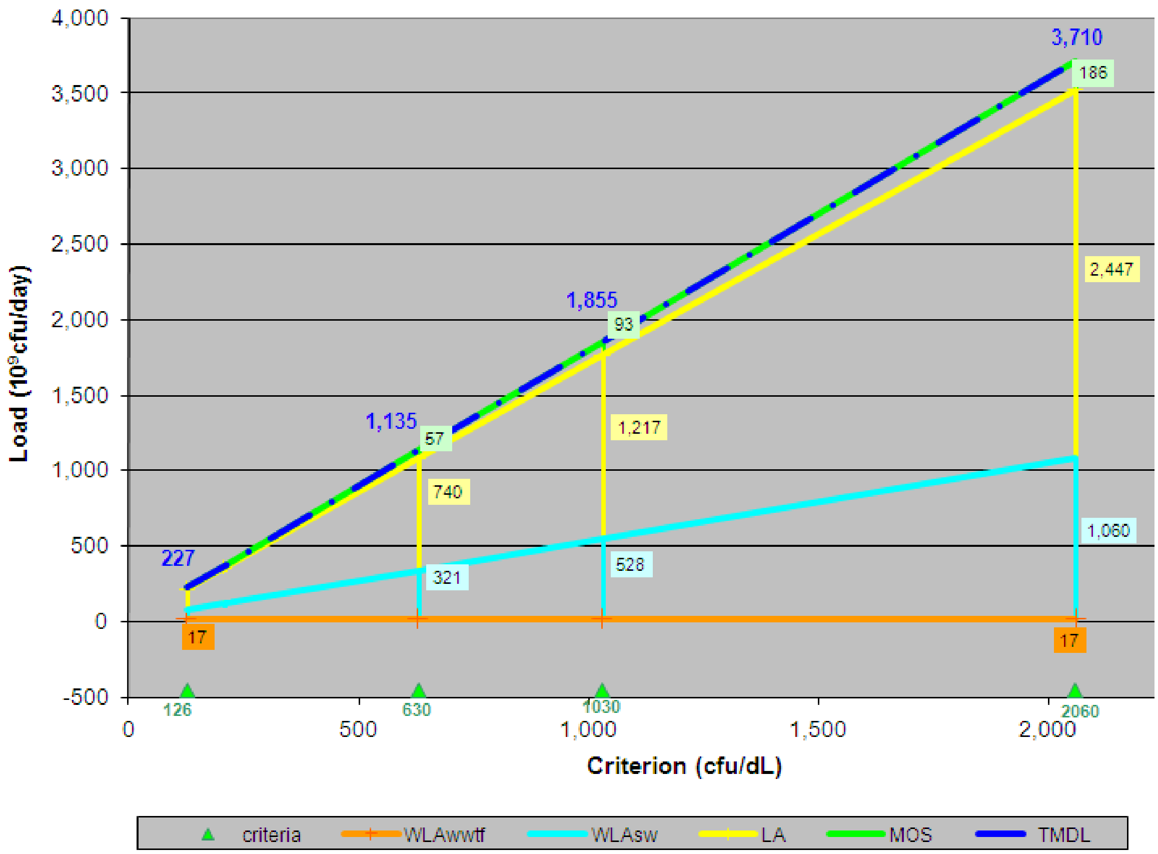

Figure A-6. Allocation Loads for AU 1009_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 1.8010*Std$$
$$LA = 1.1936*Std - 12.100$$
$$WLA_{StormWater} = 0.5173*Std - 5.244$$
$$WLA_{WWTF} = 63*0.2753 = 17$$
$$MOS = 0.05*TMDL$$

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

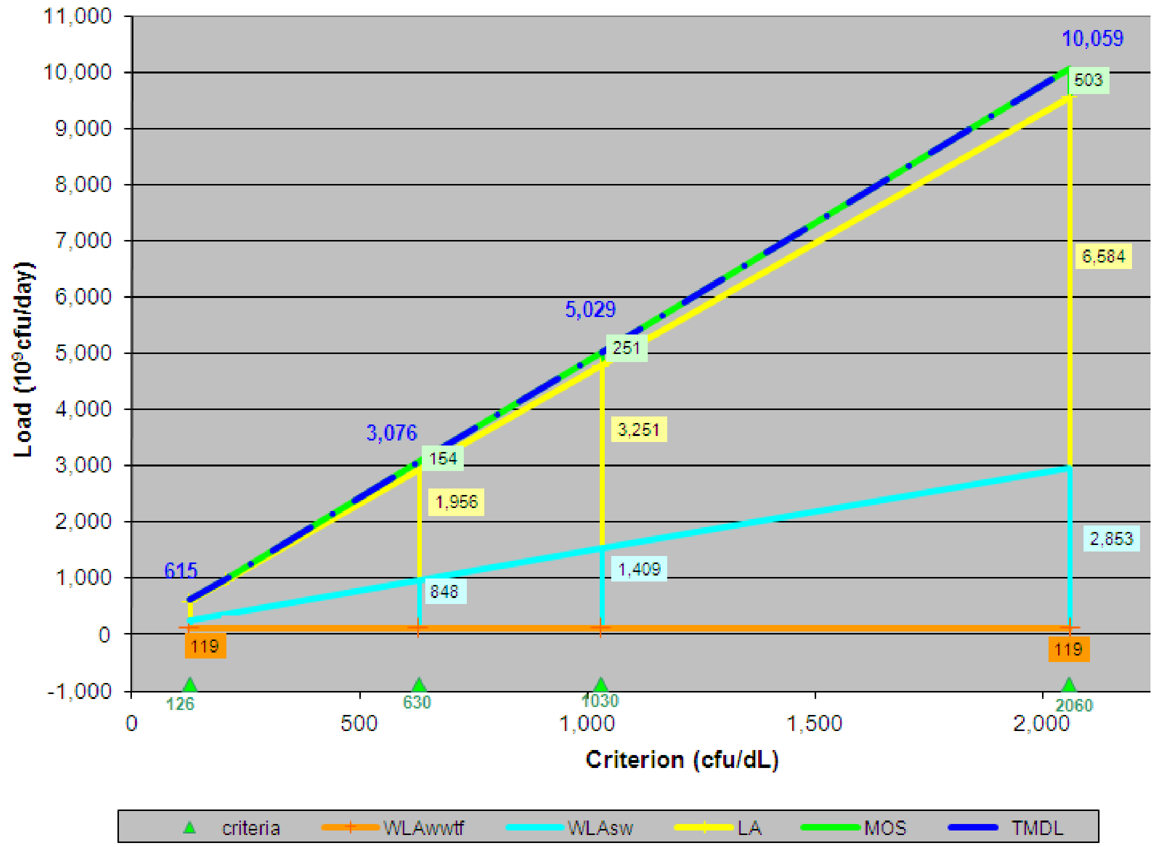

Figure A-7. Allocation Loads for AU 1009_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 4.8828*Std
LA = 3.2362*Std - 82.690
$WLA_{StormWater}$ = 1.4025*Std - 35.836
WLA_{WWTF} = 63*1.8814 = 119
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

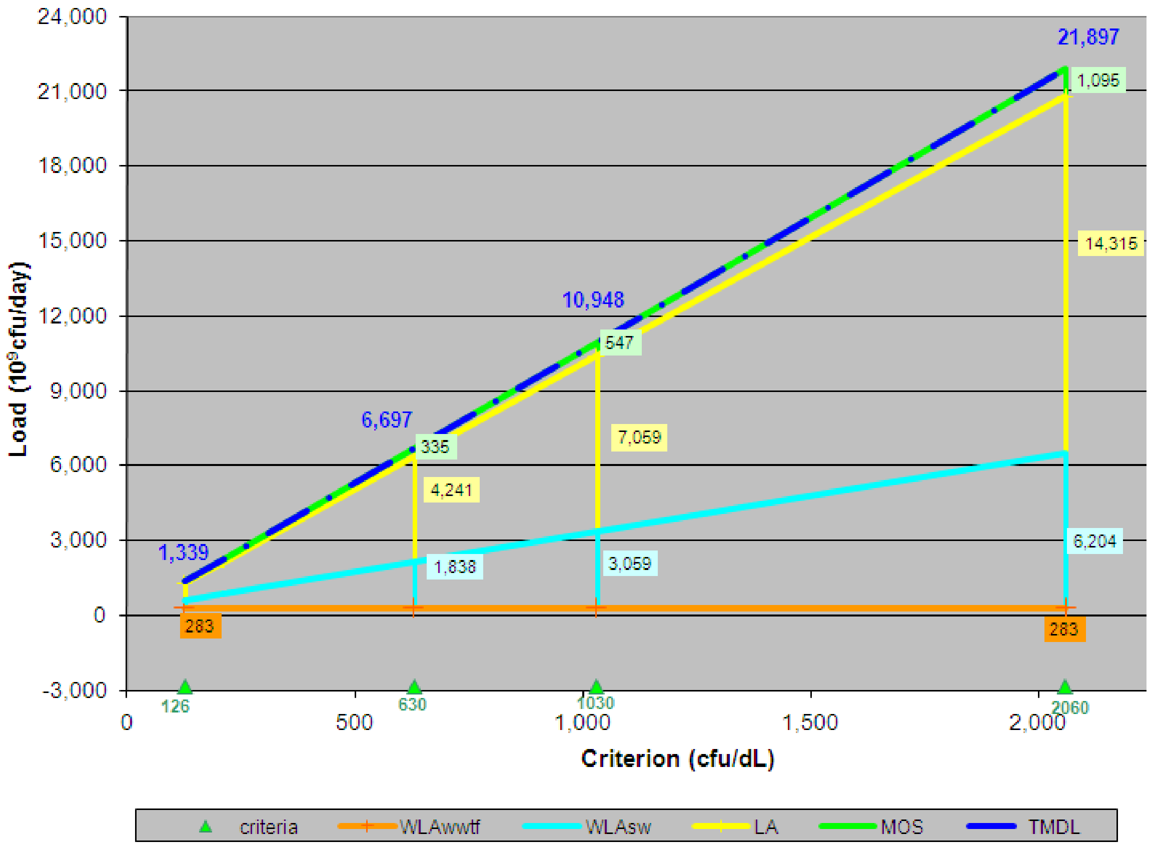

Figure A-8. Allocation Loads for AU 1009_03 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 10.6295*Std
LA = 7.0450*Std - 197.682
$WLA_{StormWater}$ = 3.0531*Std - 85.670
WLA_{WWTF} = 63*4.4977 = 283
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

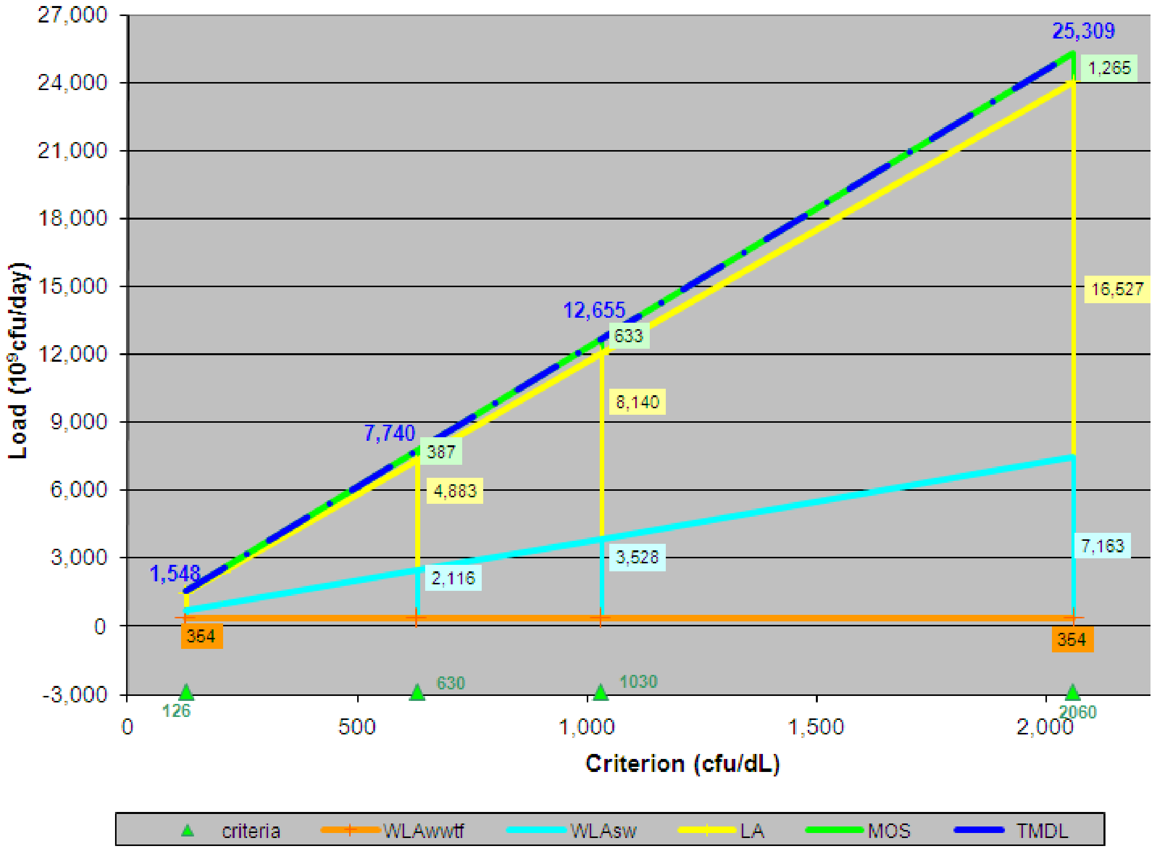

Figure A-9. Allocation Loads for AU 1009_04 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 12.2861*Std
LA = 8.1429*Std - 246.949
$WLA_{StormWater}$ = 3.5289*Std - 107.021
WLA_{WWTF} = 63*5.6186 = 354
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

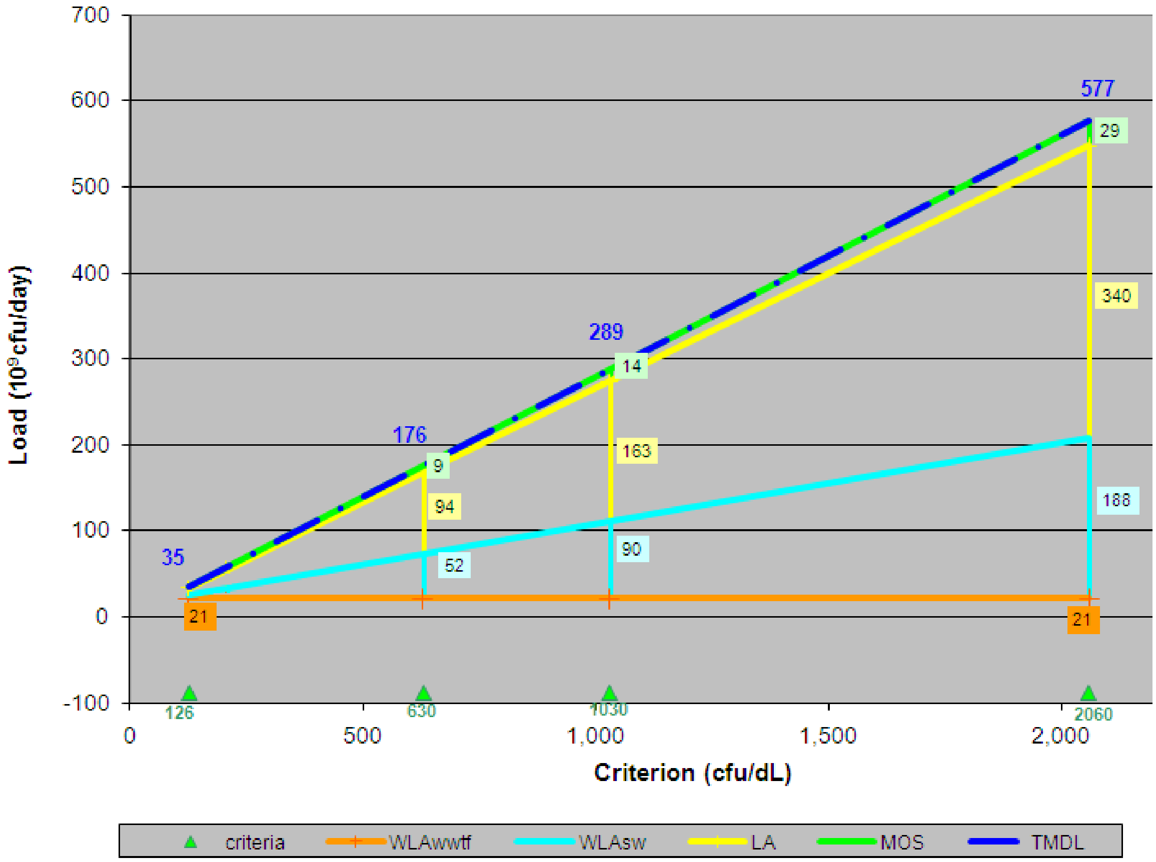

Figure A-10. Allocation Loads for AU 1009C_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.2801*Std
LA = 0.1714*Std - 13.600
$WLA_{StormWater}$ = 0.0947*Std - 7.512
WLA_{WWTF} = 63*0.3351 = 21
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

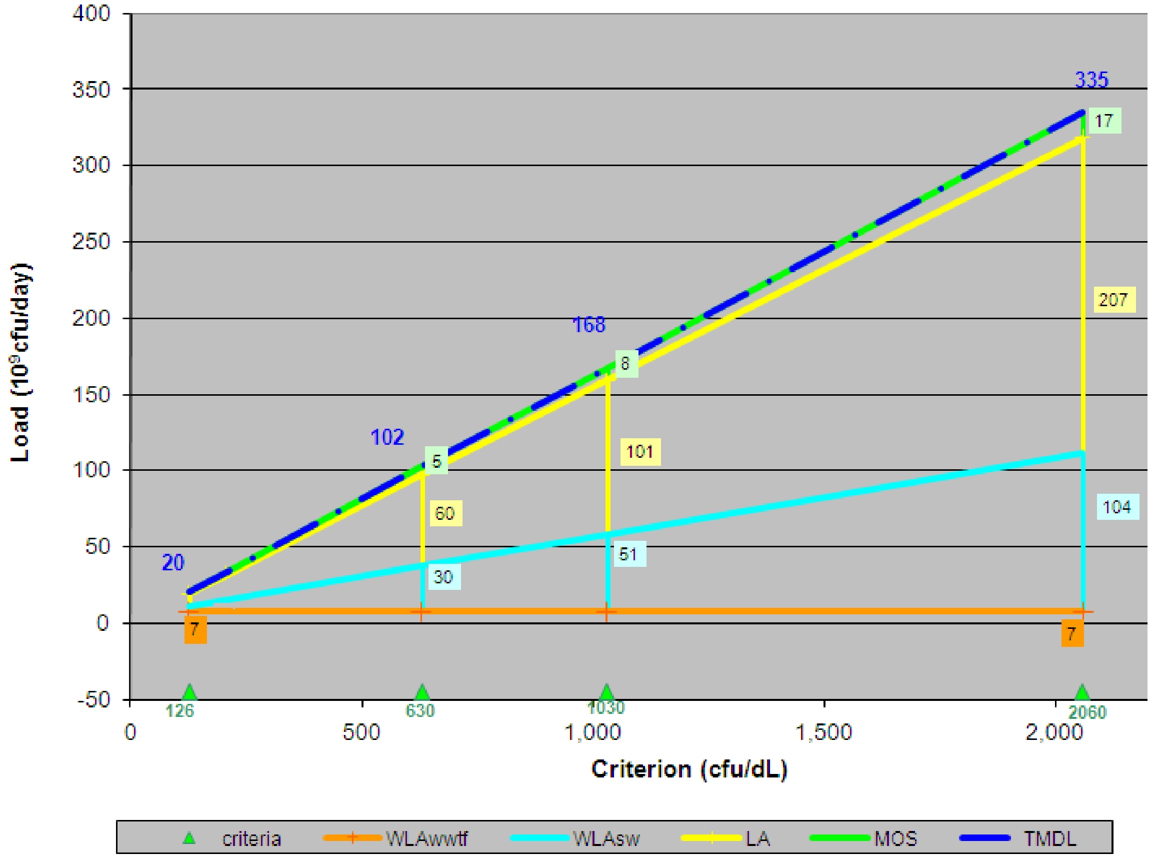

Figure A-11. Allocation Loads for AU 1009D_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 0.1627*Std$$
$$LA = 0.1028*Std - 4.827$$
$$WLA_{StormWater} = 0.0517*Std - 2.429$$
$$WLA_{WWTF} = 63*0.1152 = 7$$
$$MOS = 0.05*TMDL$$

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

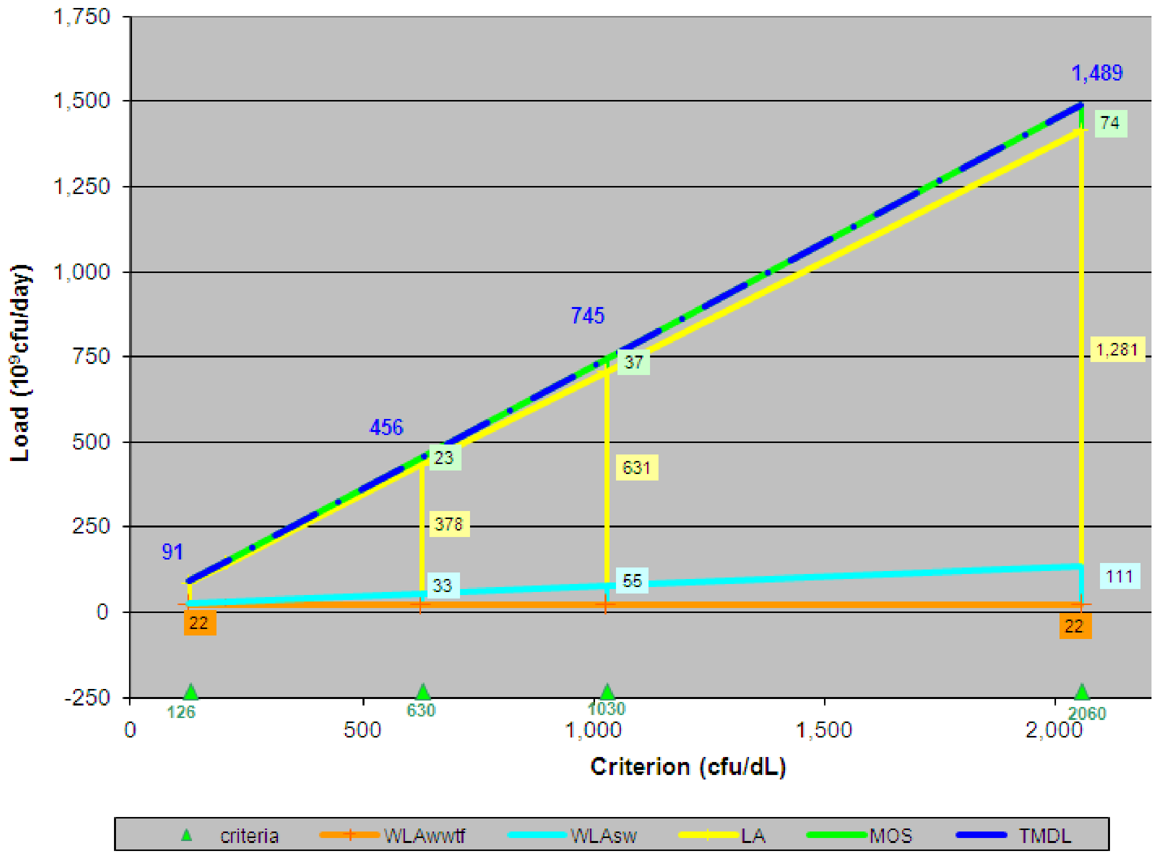

Figure A-12. Allocation Loads for AU 1009E_01 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

TMDL = 0.7230*Std
LA = 0.6319*Std - 20.266
$WLA_{StormWater}$ = 0.0550*Std - 1.763
WLA_{WWTF} = 63*0.3497 = 22
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

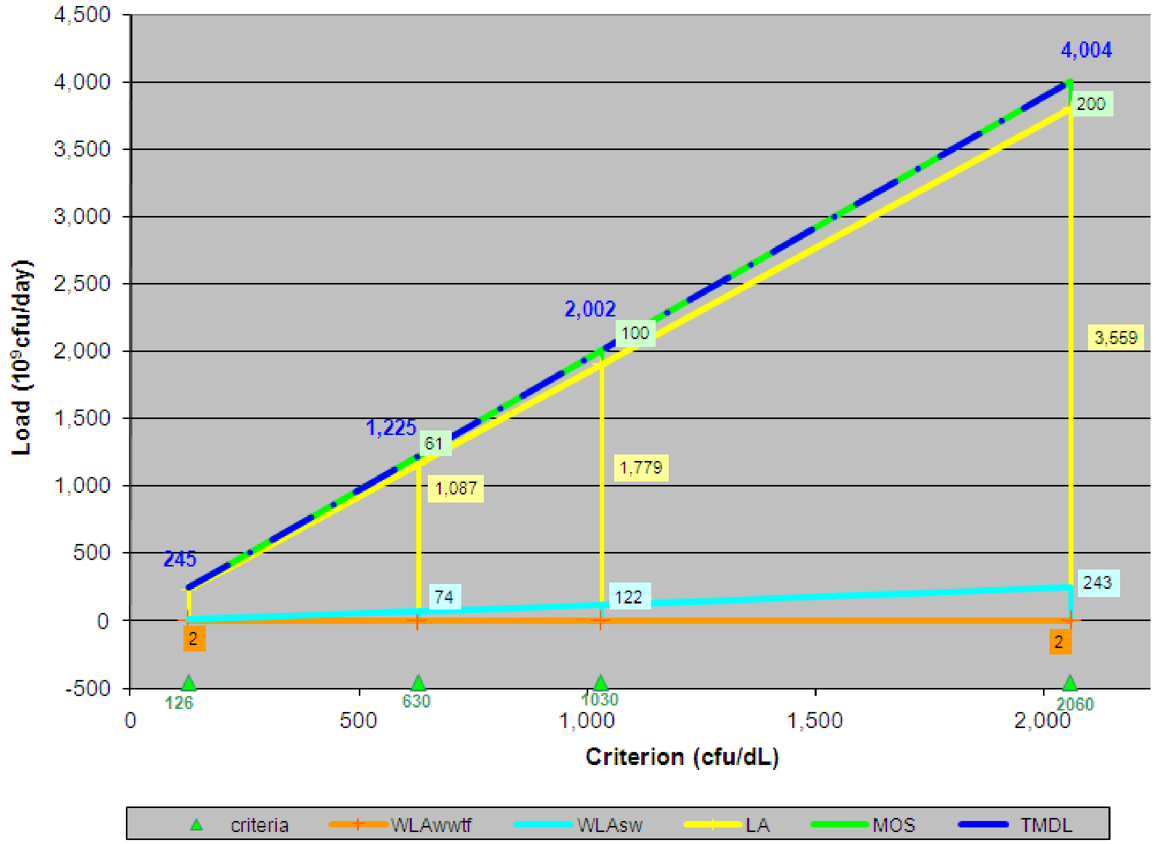

Figure A-13. Allocation Loads for AU 1010_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$TMDL = 1.9438*Std$
$LA = 1.7285*Std - 1.820$
$WLA_{StormWater} = 0.1182*Std - 0.124$
$WLA_{WWTF} = 63*0.0309 = 2$
$MOS = 0.05*TMDL$

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

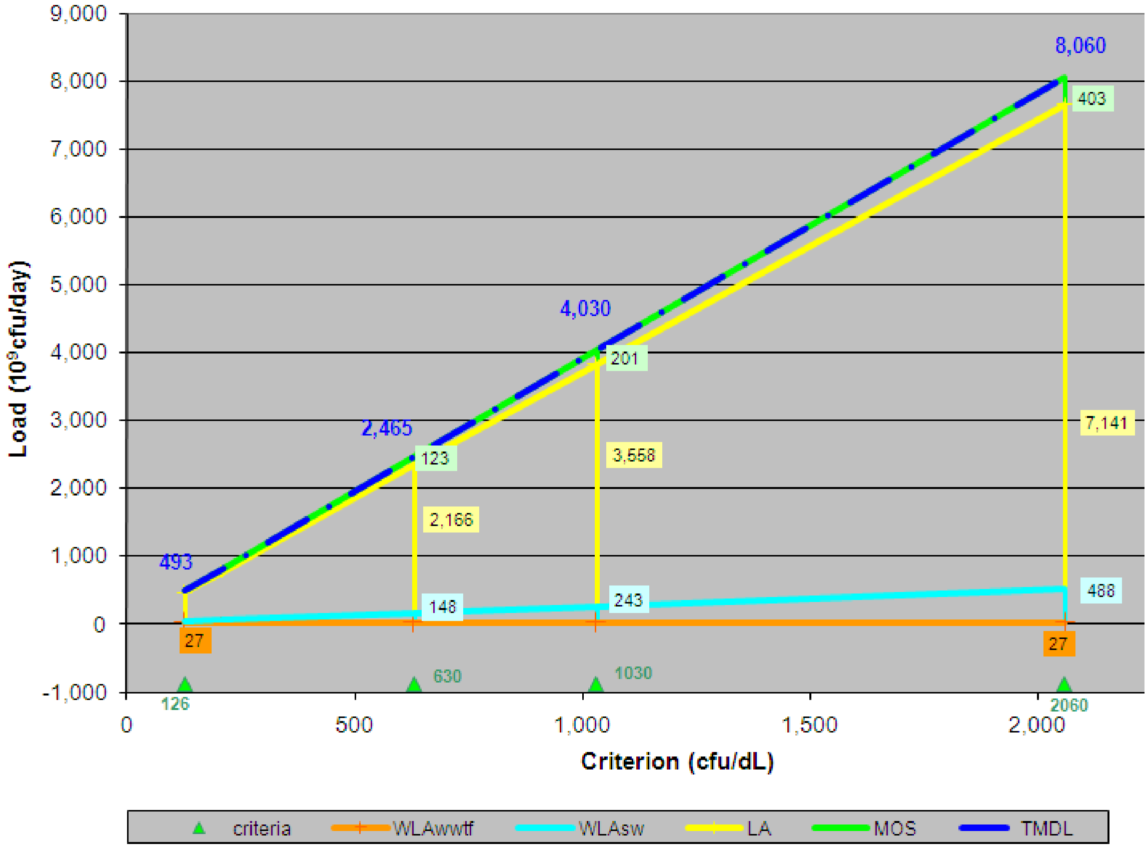

Figure A-14. Allocation Loads for AU 1010_04 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 3.9124*Std$$
$$LA = 3.4789*Std - 25.270$$
$$WLA_{StormWater} = 0.2378*Std - 1.728$$
$$WLA_{WWTF} = 63*0.4285 = 27$$
$$MOS = 0.05*TMDL$$

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

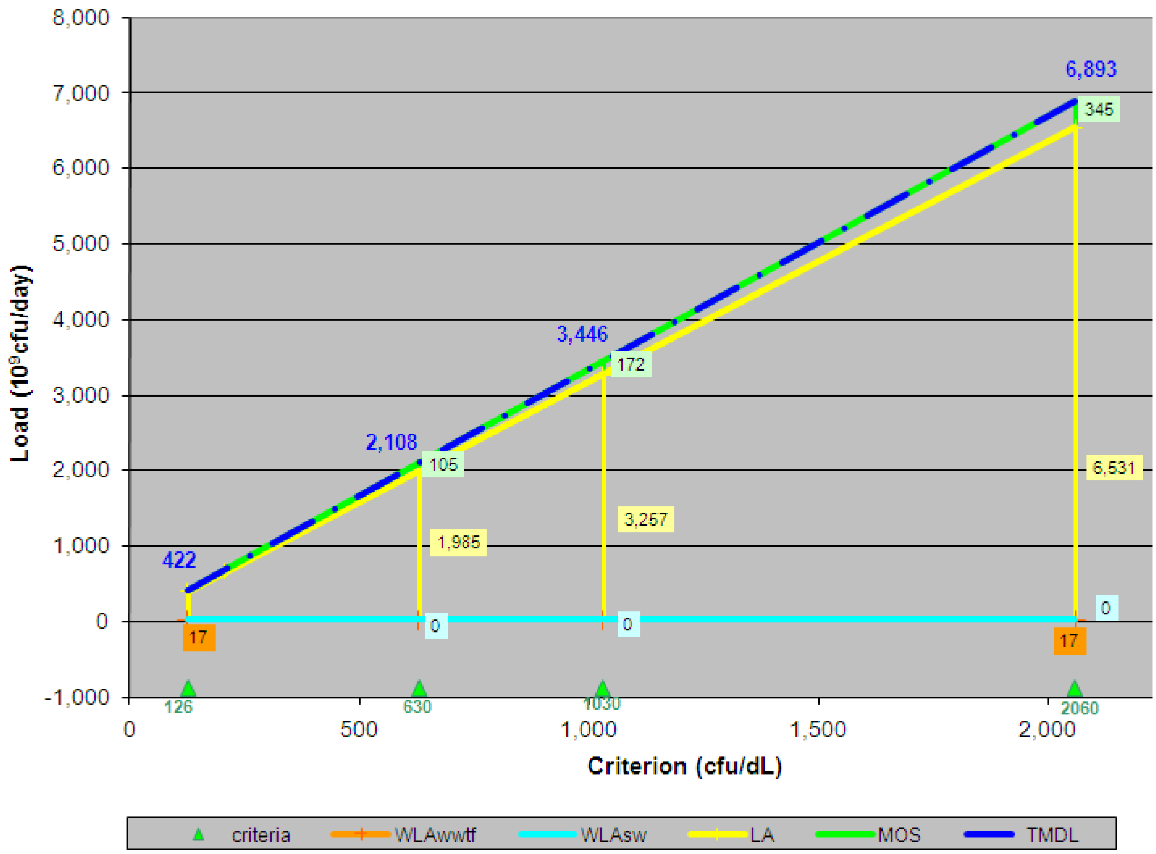

Figure A-15. Allocation Loads for AU 1011_02 as a function of WQ Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 3.3460*Std$$
$$LA = 3.1787*Std - 17.312$$
$$WLA_{StormWater} = 0$$
$$WLA_{WWTF} = 63*0.2748 = 17$$
$$MOS = 0.05*TMDL$$

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